2019 Fall Meeting of the APS Division of Nuclear Physics
Crystal City, Virginia
https://www.aps.org/meetings/meeting.cfm?name=DNP19
underestimates the error, particularly for the higher confidence levels. We also explore different avenues with the aim of reducing the uncertainties.

Michigan State University — Nuclear reactions are one of the most versatile probes to study nuclei from which an array of properties can be extracted, as well as astrophysical information. Reaction models needed in the interpretation of the data often rely on nucleon-nucleus effective interactions that depend on a number of parameters, typically constrained by elastic scattering data. It is important to quantify the uncertainties associated with the observables produced by these models. In this presentation, we discuss a systematic comparative analysis explicit, which enhances both reproducibility and clarity. I will discuss how Bayesian statistics can be used in nuclear physics for parameter estimation (fitting), quantitative model comparison, and for UQ. I will also discuss the advantages of being able to perform validation of statistical analyses, e.g., uncertainties should neither be over- nor under-estimated and how to test that statistically.

1DOE grant number DE-SC0016286

Monday, October 14, 2019 9:00AM - 10:30AM – Session 1WA Physics Opportunities with EIC I Salon 1 - William Briscoe, GWU

9:00AM 1WA.00001 Overview of the Electron-Ion Collider, RICHARD MILNER, Massachusetts Institute of Technology — An overview of the scientific motivation for the U.S.-based Electron-Ion Collider will be presented. This drives a set of EIC accelerator specifications that will be described. The current status of EIC accelerator designs will be presented. Finally, a plausible path to realization will be outlined.

9:30AM 1WA.00002 Exploring Meson Structure with Tagged Structure Functions, CYNTHIA KEPPBEL, Thomas Jefferson National Accelerator Facility — Experimental knowledge of the partonic structure of light mesons is very limited due to the lack of stable mesonic targets. New experimental techniques are being developed to create effective pion, kaon, and other targets from tagged nucleon and nuclear targets and beams. The effective tagged meson targets in particular open the opportunity to uniquely probe the structure and composition of the nucleon sea. Measurements of the light mesons’ partonic structure, moreover, offer fundamental insights into questions of how mass and structure arise in hadronic systems. A description of tagged deep inelastic structure function experiments driving an anticipated program for the Electron-Ion Collider will be presented.

10:00AM 1WA.00003 Nuclear femtography as a bridge from protons and neutrons to the core of neutron stars, SIMONETTA LIUTI, University of Virginia — In this talk I will address how the science of Nuclear Femtography, probed by deeply virtual exclusive electron nucleon scattering, has revolutionized our approach to exploring the internal structure of the nucleon. Current and planned experiments at the future EIC could in principle allow us to use all the information from data and phenomenology, on one side, to form tomographic images of the nucleon’s quark and gluon distributions and, on the other, to reveal the nucleus’s internal structure by measuring mechanical properties such as the quark angular momentum, energy density and pressure distributions. While this information is critical for ultimately understanding the working of the color forces, it also defines a new area of research where the fundamental gravitational properties of protons, neutrons and nuclei can be tested through recent astronomical observations constraining the neutron stars equation of state.

Monday, October 14, 2019 9:00AM - 10:30AM – Session 1WB New Data Analysis Methods I Salon 2 - Michael Doring, GWU

9:00AM 1WB.00001 Introduction to Bayesian methods and uncertainty quantification, SARAH WESOLOWSKI, Salisbury University — The nuclear physics community has largely embraced Bayesian statistical methods in the past decade, due to an increasing need for uncertainty quantification (UQ) on predictions and measurements and the availability of computational power. The Bayesian interpretation of probability allows for an expanded view of what can be treated as a random variable, and also facilitates the inclusion of physical knowledge quantitatively in the form of prior probabilities. Priors make the assumptions in a statistical analysis explicit, which enhances both reproducibility and clarity. I will discuss how Bayesian statistics can be used in nuclear physics for parameter estimation (fitting), quantitative model comparison, and for UQ. I will also discuss the advantages of being able to perform validation of statistical analyses, e.g., uncertainties should neither be over- nor under-estimated and how to test that statistically.

9:30AM 1WB.00002 Application of Bayesian methods in effective field theory, RICHARD FURNSTAHL, Ohio State University — The use of effective field theory (EFT) methods to describe nuclear systems holds the promise of model independence and order-by-order convergence for the calculation of observables. We will describe why Bayesian statistics is an ideal framework to quantify uncertainties from estimating EFT low-energy constants, guided by theoretical expectations about EFT truncation that are explicitly specified through prior probability densities. These uncertainties can then be combined with other sources of error and propagated to observables. Bayesian model selection identifies how many EFT orders can be extracted from given data and offers the possibility of distinguishing between alternative EFT formulations. Bayesian model-checking diagnostics are powerful tools for EFT validation. These statistical methods provide more than just theoretical error bars but can serve as catalysts for physics discovery.

1Supported in part by the NSF and the DOE SciDAC program.

10:00AM 1WB.00003 Uncertainty quantification in Nuclear Reactions, F. M. NUNES, Michigan State University — Nuclear reactions are one of the most versatile probes to study nuclei from which an array of properties can be extracted, as well as astrophysical information. Reaction models needed in the interpretation of the data often rely on nucleon-nucleus effective interactions that depend on a number of parameters, typically constrained by elastic scattering data. It is important to quantify the uncertainties associated with the observables produced by these models. In this presentation, we discuss a systematic comparative study made between the standard frequentist approach and the Bayesian approach when applied to nuclear reactions [1]. We find that the Bayesian approach produces larger confidence intervals than the standard chi2 minimization approach and that the standard method underestimates the error, particularly for the higher confidence levels. We also explore different avenues with the aim of reducing the uncertainties.


Monday, October 14, 2019 9:00AM - 10:30AM – Session 1WE Workshop: Nucleons, Nuclei and Neutron Stars in the Era of Gravitational Waves I Salon 5 - Harald W. Griesshammer, GWU
9:00AM 1WE.00001 Learning about Dense Neutron-rich Matter with Gravitational Waves

JOCelyn READ, California State University, Fullerton — Astronomical observations of neutron stars inform our understanding of dense matter at the highest densities. In 2017, the first gravitational-wave signal from a neutron-star coalescence was observed by LIGO and Virgo. I will describe how we have used its gravitational-wave data to constrain the equation of state of dense matter in neutron stars, by exploring the effect of tidal interactions on the neutron-star coalescence and then translating tidal information from the signal into other properties of the component stars. A new observing run began in April 2019, and LIGO and Virgo have already sent public alerts for new neutron-star merger candidates. I will discuss prospects for learning about matter with gravitational waves in the current Advanced-detector era and outline how next-generation observatories can map the phase diagram of dense neutron-rich matter.

9:30AM 1WE.00002 Probing the Neutron Star Radius with Gravitational Wave Events

CAROLYN RAHTEL, University of Arizona — Observations of neutron stars provide one of the best ways of probing the ultra-dense matter equation of state (EOS). While X-ray measurements of the neutron star radius have provided some promising constraints on the EOS, uncertainties remain at high densities. Detections of gravitational waves from a binary neutron star merger offer an exciting, complementary approach to constraining the EOS. In this talk, I will discuss how we can directly extract stellar radii from gravitational wave events. In particular, I will explore the surprising relationship between the binary tidal deformability and the radius. I will compare the radius constraints from GW170817 to existing radii measurements from X-ray observations and discuss the implications for the EOS. Finally, I will discuss how we can also use gravitational wave events to constrain the properties of the nuclear symmetry energy, motivated by the well-established connection between the stellar radius and the slope of the symmetry energy, L.

10:00AM 1WE.00003 Nuclear Equation of State: Combining Neutron-Star Merger and Laboratory Constraints

BETTY TSANG, Michigan State University — The ground-breaking detection of the binary neutron-star merger event, GW170817 ushers in the era of Multi-Messenger Astrophysics. In addition to the tremendous contributions from astronomy where telescopes from four corners of the world provide observation of the kilonova and the emission spectroscopy of the neutron star merger event, knowledge in nuclear physics is one of the keys to unlock many facets of the neutron star. The nuclear Equation of State (EOS) is central to the understanding of the matter found in neutron stars and in explosive stellar environments, including the dynamics in neutron star mergers and core collapse supernovae in which many of the heavy elements are formed. Such environments are often very neutron-rich and their description requires extrapolating the properties of neutron-rich matter from that of symmetric matter containing equal numbers of neutrons and protons, more similar to the nuclei. This extrapolation is governed by the nuclear symmetry energy, which can be defined to be the difference in energy between the EOS of neutron matter and that of symmetric matter. This difference is particularly relevant to the internal structure of neutron stars and their cooling by neutrino emission. In this talk, I will discuss the latest results from experimental probes using heavy ion collisions with different isospin reactions to explore the symmetry energy from sub-normal to supra-normal density and its implication to the tidal deformability obtained in the neutron star merger.

Monday, October 14, 2019 11:00AM - 12:30PM –
Session 2WA Physics Opportunities with EIC II

11:00AM 2WA.00001 Jet energy loss in hot and cold nuclear matter

YACINE MEHTARTANI, Brookhaven National Laboratory — Jet quenching, observed in heavy ion collisions at RHIC and LHC, is a result of substantial final state interactions that cause high energy jets to lose a sizable fraction of their energy to the deconfined matter formed in such collisions. Understanding how jets interact with this QCD matter is crucial in order to quantitatively probe it and is currently an active field of research. In addition to providing a tool to investigate nuclear structure, the study of jet fragmentation in electron-ion collisions may shed light on the mechanisms of jet energy loss and transport properties of cold nuclear matter. I will review in this talk the recent developments in the theory of jet quenching and discuss physics opportunities at a future EIC.

11:30AM 2WA.00002 Next-generation nuclear physics with polarized light ions at EIC

CHRISTIAN WEISS, Jefferson Lab — The EIC will enable a program of high-energy electron/photon scattering on light ions with polarized beams (deuterium, 3He) and forward detection of the nuclear breakup state (spectator tagging, coherent processes). Physics objectives include the precise determination of the spin structure, studies of the QCD origin of neutron interactions (nuclear modification of partonic structure, short-range correlations), and the quark/gluon imaging of light nuclei (nuclear generalized parton distributions). The detected nuclear breakup state can be used to infer the nuclear configuration during the high-energy process and provides essential new information for physics analyses. Such reactions explore the intersection of high-energy scattering and low-energy nuclear structure and pose many interesting questions in theory, analysis, and simulation. The talk will give an introduction to the light-ion physics program with EIC, including the physics concepts and objectives, examples of simulated measurements, the forward detection capabilities of the EIC designs, and available resources for further study (simulation tools). The presentation will be aimed at a general nuclear/hadronic physics audience.

12:00PM 2WA.00003 Collective Effects in Nucleons and Nuclei

ADRIAN DUMITRU, Baruch College, The City University of New York — In the first part of the talk I describe high-energy coherent scattering from a nucleus. Here, a colored probe scatters from the color field generated collectively by many sources whose low transverse momentum modes have large occupation numbers. I provide examples for how this regime of non-linear color fields could be probed at the EIC. In the second part of the talk I address color charge correlators in the proton and how these relate to Generalized Parton Distributions (GPDs) for exclusive processes. Using photon diffraction into charmonium as an example, I discuss the importance of multi-particle GPDs in J/ψ and ηc production.

I gratefully acknowledge support from DOE, Office of Nuclear Physics

Monday, October 14, 2019 11:00AM - 12:30PM –
Session 2WB New Data Analysis Methods II

Table 1

<table>
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1I gratefully acknowledge support from DOE, Office of Nuclear Physics
of isolated neutron stars and of those that undergo periodic accretion. While several puzzles await solutions, the need for updates of LIGO masses and radii with dynamical observables that include tidal deformations, rotational periods and their time derivatives, surface temperatures of a neutron star at all layers from the surface to the core. The time is ripe now to achieve consistency between the global properties such as (hyperons, quarks, etc.) in understanding the many observable facets of a neutron star. Special emphasis will be placed on the composition stars, and accumulating data on the cooling of neutron star crusts have all given much impetus to ongoing theoretical investigations of the dense

detection of electromagnetic radiation from the binary neutron star merger GW170787, recent reports of additional mergers involving neutron

MADAPPA PRAKASH, Ohio University — The discovery of 2 solar mass neutron stars, detection of gravitational waves with the concomitant

We will discuss a model of high density matter based on the speed of sound, and discuss the effect of various constraints to the

clear predictions for the relation between the isospin-asymmetry energy of nuclear matter and its density dependence, and the mass and radius for

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in neutron star observations yield important new insights on the equation of state of neutron matter at nuclear densities. In this regime the

problems. We will discuss a model of high density matter based on the speed of sound, and discuss the effect of various constraints to the

bs. We are at the threshold of imaging the nucleons three-dimensional structure through its quark and

gluon quantum probability distributions. Extracting the quantum distributions from the experimental data is very challenging, however, because

of the inverse problem: the measured cross sections are given by convolutions of the quantum probability distributions with process-dependent

hard coefficients that are perturbatively calculable from Quantum Chromodynamics. While most previous analyses have been based on the

maximum likelihood approach, it has become evident that Bayesian likelihood methods are needed, using Monte Carlo sampling techniques to

thoroughly explore the parameter space associated with the quantum probability distributions. I this talk I will review recent developments in
tackling the inverse problem for extracting quantum distributions from experimental measurements.

Monday, October 14, 2019 11:00AM - 12:30PM —
Session 2WE Workshop: Nucleons, Nuclei and Neutron Stars in the Era of Gravitational Waves II — Salon 5 - Harald W. Griesshammer, GWU

11:00AM 2WE.00001 The Equation of State of neutron matter and neutron stars

, STEFANO GANDOLFI, Los Alamos National Laboratory — Recent advances in experiments of the symmetry energy of nuclear matter and

in neutron star observations yield important new insights on the equation of state of neutron matter at nuclear densities. In this regime the

equation of state of neutron matter plays a critical role in determining the mass-radius relationship for neutron stars. We show how microscopic

calculations of neutron matter, based on realistic two- and three-nucleon forces that reproduce very accurately properties of light nuclei, make

clear predictions for the relation between the isospin-asymmetry energy of nuclear matter and its density dependence, and the mass and radius for

a neutron star. At densities higher than nuclear density the situation is more complicated, as there is still no clear evidence on the composition of

matter. We will discuss a model of high density matter based on the speed of sound, and discuss the effect of various constraints to the

maximum mass of neutron stars.

11:30AM 2WE.00002 Chiral effective field theory for the nuclear equation of state

, INGO TEWS, Los Alamos National Laboratory — Neutron stars are astrophysical objects of extremes. They contain the largest reservoirs of
degenerate fermions, reaching the highest densities we can observe in the cosmos, and probe matter under conditions that cannot be recreated in

terrestrial experiments. In August 2017, the first neutron-star merger has been observed, which provided compelling evidence that these

events are an important site for the production of elements heavier than iron in the universe. Furthermore, the gravitational-wave signal of such

events might shed light upon the nature of strongly interacting matter in the core of neutron stars. To understand these remarkable events, reliable nuclear physics input is essential. In this talk, I will explain how to use Chiral effective field theory and advanced many-body methods to provide a consistent and systematic approach to strongly interacting systems from nuclei to neutron stars and allow precision studies with controlled theoretical uncertainties. I will present recent results for the equation of state relevant for the nuclear astrophysics of neutron stars and neutron-star mergers, and will discuss future directions and opportunities.

1This work was supported in part by the U.S. DOE under Grant No. DE-AC52-06NA25396 and by the LANL LDRD program.

12:00PM 2WE.00003 The significance of a neutron star's interior composition

, MADAPPA PRAKASH, Ohio University — The discovery of 2 solar mass neutron stars, detection of gravitational waves with the concomitant
detection of electromagnetic radiation from the binary neutron star merger GW170787, recent reports of additional mergers involving neutron

stars, and accumulating data on the cooling of neutron star crusts have all given much impetus to ongoing theoretical investigations of the dense

matter equation of state. In this talk, I will highlight recent work on the role played by nuclei, nucleons and nonnucleonic degrees of freedom

(hyperons, quarks, etc.) in understanding the many observable facets of a neutron star. Special emphasis will be placed on the composition

of a neutron star at all layers from the surface to the core. The time is ripe now to achieve consistency between the global properties such as

masses and radii with dynamical observables that include tidal deformations, rotational periods and their time derivatives, surface temperatures

of isolated neutron stars and of those that undergo periodic accretion. While several puzzles await solutions, the need for updates of LIGO

detectors to detect gravitational radiation from the remnants of post merger events will be emphasized.

1Research supported by DOE grant No. DE-FG02-93ER-40756.
1 This work is supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics under contract DE-AC05-06OR23177, within the framework of the TMD Collaboration.

3:00PM AC.00001 Critical Tests of QCD at the EIC1. JIANWEI QIU. Jefferson Lab — Nuclear Physics community recommended a high-energy high-luminosity polarized EIC as the highest priority for new facility construction following the completion of FRIB in its 2015 Long-Range Plan. National Academy of Sciences provided “An Assessment of U.S.-Based Electron-Ion Collider Science” in 2018, finding the science that EIC will achieve is unique and world-leading and will ensure global U.S. leadership in nuclear science, as well as in accelerator science and the technology of colliders. In this talk, I will briefly review specific measurements at the EIC that provide critical tests of our understanding of mass, spin, hadron structure, and emergent properties of dense systems in QCD.

3:45PM AC.00002 Quantum Information and Nuclear Physics. JOHN PRESKILL, Caltech — I’ll discuss the current status and future potential of quantum information science and technology, emphasizing the prospects for addressing Grand Challenges in Nuclear Physics using quantum computers, quantum simulators, and quantum sensors. Eventually, quantum computers and simulators will be able to explore properties of nuclear matter and features of hadronic dynamics that are beyond the reach of foreseeable classical computers. However, this big physics payoff may still be many years away. Realistically, the goal of the NP community in the near term should be to light the way toward future progress by developing new tools, methods, and insights. Today’s research can hasten the arrival of a new era in which quantum technology fuels remarkable advances in NP research.

Monday, October 14, 2019 5:00PM - 6:30PM — Session BC Plenary II Salon 3/4 - Robert Janssens, University of North Carolina

5:00PM BC.00001 Present Status and Future Prospects of EDM Measurements1. CHEN-YU LIU, Indiana University Bloomington — Searches for a permanent electric dipole moment (EDM) began in 1951 with the neutron. Up to the present, many systems, including nuclei, atoms and molecules, have been explored and no evidence for an EDM has been found. The search for the EDM is currently driven by the desire to explain the over-abundance of matter relative to anti-matter in the universe. The dynamical origin of this imbalance, or baryogenesis, is thought to have occurred a few picoseconds after the Big Bang, driven by combined Charge Conjugation-Parity (CP) symmetry violating processes beyond those predicted by the Standard Model (SM) of particle physics. The same CP-violating process at high energies would generate EDM signals many orders of magnitude above the SM prediction. In many scenarios, successful baryogenesis leads to strict lower bounds on the nEDM on the order of our target sensitivity of $3 \times 10^{-27}$ e-cm. In this talk, I will review the history of EDM measurements and describe the present experimental techniques and physics reaches.

I gratefully acknowledge the support from the LANSCE Rosen scholarship and the NSF via grants PHY-1614545 and PHY-1828512.

5:45PM BC.00002 Short-Range Correlations And The Quarks Within1. OR HEN, Massachusetts Institute of Technology — Short-range correlations (SRC) are pairs of strongly interacting nucleons at close proximity. Due to their large spatial overlap and high relative-momentum, the study of SRC pairs is an appealing gateway for probing the strong nuclear interaction at high-densities (i.e. short-distances) and its relation to the underlying quark-gluon substructure of nuclei. In this talk I will present new results from high-energy electron scattering experiments that probe SRC pairs via measurements of exclusive hard breakup reactions. Special emphasis will be given to the effect of SRCs on the behavior of protons in neutron-rich nuclear systems and how it can impact properties of dense nuclear systems such as neutron stars. Pursuing a more fundamental understanding of short-distance interactions, I will present new measurements of the internal quark-gluon sub-structure of nucleons and show how its modification in the nuclear medium relates to SRC pairs and short-ranged nuclear interactions. Last, I will also discuss the development of new effective theories for describing short-ranged correlations, the way in which they relate to experimental observables, and the emerging universality of short-distance and high-momentum physics in nuclear systems.

1 DOE Office of Science

Monday, October 14, 2019 6:30PM - 8:00PM — Session CA Welcome Reception (6:30pm-8:00pm) Sky View -

6:30PM CA.00001 Welcome Reception (6:30pm-8:00pm) —

Tuesday, October 15, 2019 8:30AM - 10:18AM — Session EA Structure of Proton-Rich Nuclei Salon 1 - Corina Andreoiu, Simon Fraser University

8:30AM EA.00001 In-beam gamma-ray spectroscopy of neutron-deficient nuclei - News from the proton-rich side1. ALEXANDRA GADE, Michigan State University — Nuclei on the neutron-deficient side of the nuclear chart have attracted attention in recent years. The proximity of the N=Z line and the proton dripline offers a unique laboratory for nuclear structure studies with relevance to nuclear astrophysics. This presentation will highlight recent results from the National Superconducting Cyclotron Laboratory obtained using the powerful experimental approach of in-beam gamma-ray spectroscopy.

1 This work was supported by U.S. National Science Foundation under Grant No. PHY-1565546 and by the DOE-SC Office of Nuclear Physics under Grant No. DESC0014537.
Recent studies of exotic nuclei near the self-conjugate doubly-magic $^{100}$Sn nucleus.

DARIUSZ SEWERYNIAK, Argonne National Laboratory — The exotic proton-rich self-conjugate doubly-magic nucleus $^{100}$Sn is one of the corner stones of nuclear structure. The $^{100}$Sn region provides a stringent test for the shell model far away from the line of stability. The $^{11}$Sn nucleus is the fastest known Gamow-Teller $\alpha$ emitter. Its large binding energy is signaled by the existence of an island of proton and $\alpha$ emitters decaying towards the N=Z=50 closed shells. Also, the astrophysical rp-process was proposed to terminate with $\alpha$ decays of light Te isotopes. Despite prohibitively small production cross sections, several exotic nuclei near 100Sn have been studied recently using various probes at the ATLAS facility at the Argonne National Laboratory. 1) First evidence for the $\alpha$-decay chain $^{108}$Xe-$^{104}$Te into $^{100}$Sn was observed. This is only the second case of $\alpha$ decay into a doubly-magic nucleus besides $^{212}$Po, which has been a benchmark of microscopic models of $\alpha$ decay. The reduced $\alpha$-decay widths deduced for $^{108}$Xe and $^{104}$Te are larger than that for $^{212}$Po supporting the expectation that the enhanced interaction between protons and neutrons, which occupy the same orbitals, leads to a larger $\alpha$-particle preformation, which results in the so-called superallowed $\alpha$ decay. 2) A small proton-decay branch was found in $^{108}$Sn, supporting the expectation that the rp-process does not form a Sn-Sb-Te cycle at $^{100}$Sn which is delayed until heavier Sn isotopes. 3) Excited states in the fast $^{105}$Te $\alpha$ emitter were studied for the first time using in-beam $\gamma$-ray spectroscopy to shed light on the long standing issue of the ordering of the $d_{5/2}$ and $g_{7/2}$ single-neutron orbitals in $^{101}$Sn.

This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under Contract number DE-AC02-06CH11357. This research used resources of ANL's ATLAS facility, which is a DOE Office of Science User Facility.
9:30AM EB.00004 Fabrication and Characterization of HPGe Detectors Using Crystals Grown at USD$^{1}$, KYLER KOOL, University of South Dakota, PIRE-GEMADARC COLLABORATION — High purity germanium (HPGe) detectors are widely used in dark matter and neutrino experiments such as CDEX, TEXONO, CoGeNT, COHERENT, GERDA, Majorana, etc. In order to understand and improve the performance of HPGe detectors at various environmental and system configurations in a convenient and economic way, we are in the process of fabricating mini-PPC and planar detectors from HPGe that has been purified with zone refining and grown into HPGe crystals at USD. This way we avoid risking expensive commercial detectors in unconventional operating environments. We take advantage of resources, facilities, and equipment at both USD and Lawrence-Berkeley National Lab. In this presentation, we will describe the process of the fabrication and report our current status and progress.

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1This project is possible because of the support from LBNL for use of their facilities, as well as NSF OIA-1738695 and OISE-1743790.

9:42AM EB.00005 Amorphous Germanium Planar Detectors Directly Immersed in LN/LAr for Study of Contact Properties$^{1}$, RAJENDRA PANTH, WENZHAO WEI, HAO MEI, GUOJIAN WANG, JING LIU, DONGMING MEI, University of South Dakota, PIRE-GEMADARC COLLABORATION — The stability of an electrical contact when directly immersed in liquid nitrogen (LN) and liquid argon (LAr) is important for the rare event searches including neutrinoless double-beta decay using germanium (Ge) detectors. Utilizing the USD-grown crystals, we fabricated several planar Ge detectors to study electrical contact properties. The fabricated planar Ge detectors were directly immersed in LN and LAr in a test facility at the Max-Planck-Institut fuer physik (MPI) in Munich, Germany. We report that amorphous Ge contacts can survive when the detector is directly immersed. We performed several thermal cycle measurements to study the stability of the contacts. Measurements show that leakage current and energy resolution of the detectors are stable.

1We would like to thank Max-Planck-Institut fuer physik (MPI) in Munich, Germany for the test facility. Dr. Iris and her group members for valuable suggestions. This work is supported by NSF OISE-1743790.

9:54AM EB.00006 Point Contact Germanium Detector Response to Low-Energy Surface Events, MATTHEW STORTINI, JASON DETWILER, CLINT WISEMAN, WALTER PETTUS, University of Washington, THE MAJORANA COLLABORATION COLLABORATION$^{1}$ — Point contact germanium detectors lead the field in the search for neutrinoless double beta decay, and they have been used to achieve the greatest half-life sensitivity to date. These detectors have excellent energy resolution, low noise, and low-energy threshold. This makes them a great candidate for rare event searches beyond neutrinoless double beta decay as well. One aspect of germanium detectors that is difficult to characterize is their passivated surface. Charge collection near the passivated surface is sensitive to near-surface impurities / defects as well as surface charge buildup. This impacts these detectors’ efficiency and resolution, especially in the lower energy range. At the University of Washington’s Center for Experimental Nuclear Physics and Astrophysics we have set out to study this problem. In the investigation reported here, we use a Kr83m source, which has multiple low-energy X-rays below 15 keV, and a number of conversion electrons below approximately 30 keV. We will show first data from this study, and compare it to expectations for different charge collection models. The ultimate goal of this study is to build a model that allows us to characterize the response of a point contact germanium detector to low-energy surface events.

1The Majorana Collaboration uses an array of high-purity point contact germanium detectors to search for neutrinoless double beta decay.

10:06AM EB.00007 Level lifetimes determined with the DSAM after fast neutron scattering and relevance to neutrinoless double-beta decay$^{1}$, S.W. YATES, S. MUKHOPADHYAY, E.E. PETERS, A.P.D. RAMIREZ, University of Kentucky Depts. of Chemistry and Physics & Astronomy, B.P. CRIDER, Mississippi State University Dept. of Physics & Astronomy — Neutrinoless double-beta decay (0$^{\nu}\beta\beta$) has not been observed but is being sought in several large-scale experiments. The nuclear matrix elements for 0$^{\nu}\beta\beta$ cannot be determined experimentally and must be calculated from nuclear structure models. Our recent measurements have focused on providing detailed nuclear structure data to guide these model calculations. At the University of Kentucky Accelerator Laboratory (UKAL), we have performed spectroscopic studies with the (n,$n'$) reaction on $^{76}$Ge, which is widely regarded as one of the best candidates for the observation of 0$^{\nu}\beta\beta$, and $^{76}$Se, its double-$\beta$ decay daughter. While $^{76}$Ge can be well understood from shell model calculations, $^{76}$Se cannot. To better characterize this transitional region of triaxiality, studies of the lighter stable Ge nuclei, such as $^{74}$Ge, have been initiated. From these measurements, new excited states were identified, level lifetimes were measured with the Doppler-shift attenuation method, multipole mixing ratios were established, and transition probabilities were determined. In the case of $^{74}$Ge, a great deal of information is now available, and shell model calculations explain the low-lying, low-spin structure very well.

1This material is based upon work supported by the U.S. National Science Foundation under grant no. PHY-1913028.

10:18AM EB.00008 Muon Simulations for LEGEND 1000 Using a GEANT4 Framework$^{1}$, CLAY BARTON, University of South Dakota, LEGEND COLLABORATION — Neutrinoless double beta decay is a proposed rare decay which, if discovered, would confirm the Majorana nature of the neutrino. The LEGEND (Large Enriched Germanium Experiment for Neutrinoless Double-beta decay) collaboration aims to develop a phased, Ge-76 based double-beta decay experimental program with discovery potential at a half-life beyond 10$^{28}$ years, using existing resources as appropriate to expedite physics results. LEGEND 1000 will be the second phase, and is in the early stages of development. One of the major concerns is the site selection for the experiment. LEGEND 1000 must be built in a deep underground laboratory to escape the bulk of the cosmic rays. A depth requirement analysis is being performed, using the GEANT4 particle simulation toolkit to simulate cosmic ray muons in a few proposed experiment designs. This talk will discuss this ongoing simulation effort.

1This material is based upon work supported by the U.S. NSF, DOE-NP, NERSCC and through the LANL LDRD program, and the Oak Ridge Leadership Computing Facility; the Russian RFBR, the Canadian NSERC and CF; the German BMBF, DFG and MPG; the Italian INFN; the Polish NCN and Foundation for Polish Science; and the Swiss SNF; the Sanford Underground Research Facility, and the Laboratori Nazionali del Gran Sasso.

Tuesday, October 15, 2019 8:30AM - 10:18AM — Session EE Mini-Symposium: Towards a US Electron Ion Collider: Physics, Accelerator, and Detectors Salon 5 - Ernst Sichtermann, Lawrence Berkeley National Laboratory
8:30AM EE.00001 Status of Electron Ion Collider designs and RD. ANDREI A. SERYI, Jefferson Laboratory — A U.S.-based Electron Ion Collider (EIC) has recently been endorsed by the U.S. National Academies of Sciences, Engineering, and Medicine (NAS). This brings the realization of such a collider another step closer, after its earlier recommendation in the 2015 Long-Range Plan for U.S. nuclear science of the Nuclear Science Advisory Committee “as the highest priority for new facility construction following the completion of FRIB.” Moreover a C00 is expected to be announced by DOE in 2019. An EIC will be an unprecedented collider that will need to maintain high luminosity (1E33-1E34 cm⁻² s⁻¹) over a very wide range of Center-of-Mass energies (20 GeV to 100 GeV, upgradable to 140 GeV), while accommodating highly polarized beams and many different ion species. A multi-laboratory collaboration is presently working on two site-specific EIC designs - eRHIC led by Brookhaven National Laboratory and JLEIC led by Jefferson Lab. The present talk will summarize the status of Electron Ion Collider designs and RD.

9:06AM EE.00002 Tagged Short-Range Correlations for Medium to Heavy Ions. DOUGLAS HIGINBOTHAM, Jefferson Lab — Understanding short-range correlations between pairs of nucleons in the nucleus (SRC) is an important nuclear physics topic that can address longstanding mysteries in nuclear physics such as the behavior of dense nuclear systems and the modification of parton distributions. As a collider and with a large acceptance detector, the EIC has unique capabilities that are complementary to previous SRC studies, most notably the ability to more fully reconstruct the final state. Making use of the BeAGLE (Benchmark eA Generator for LEptoproduction) simulation code as well as recent advances in SRC phenomenological parameterizations, we are exploring this potential and determine the optimal machine energies for much studies.

9:18AM EE.00003 ABSTRACT WITHDRAWN —

9:30AM EE.00004 Measuring Tensor Spin Observables with the EIC. KARL SLUFER, ELENA LONG, University of New Hampshire — Several experiments at Jefferson Lab are planned which will explore the tensor structure of spin-1 systems. Conventional nuclear mechanisms cannot explain the existing data measured for the tensor structure function b1. E12-13-011 will measure b1 using a solid polarized target, probe the tensor-polarized quark and antiquark distribution functions, and potentially provide a unique and unambiguous signature of hidden color. E12-15-005 will measure the tensor asymmetry Azz in the x > 1 region, to explore the nature of short-range correlations in nuclei. This provides a unique tool to experimentally constrain the ratio of the S- and D-state wavefunctions at large momentum, which has been an ongoing theoretical issue for decades. The Electron Ion Collider is a natural facility to extend and improve these measurements. We will discuss the feasibility of measuring tensor spin observables at the EIC and compare the potential EIC measurements to world data and the planned Jefferson Lab experiments.

9:42AM EE.00005 Jets at the Electron-Ion Collider. MIGUEL ARRAATIA, University of California, Berkeley — The EIC will be the first e-A collider and will produce the first jets in nuclear DIS. Jets will enable new type of studies of nuclei that extend beyond traditional single-hadron measurements. These studies may help us understand the structure and behavior of nuclei in terms of quarks and gluons as key goals of modern nuclear physics. In particular, jets from nuclear DIS will shed light on quark-matter interactions, the quark-to-hadron transition, and the quark structure of nuclei. DIS offers us the ultimate arena for these studies with controlled quark kinematics and flavor as well as medium length and density. In this talk, I will discuss the prospects of measurements such as lepton-jet correlations, flavor-tagged jets, and jet substructure variables that could exploit the unprecedented combination of hermetic tracking, PID and calorimetry of the EIC detectors.

9:54AM EE.00006 Exploring Jet Observables at an EIC with the JETSCAPE Framework. KOLJA KAUDER, Brookhaven National Laboratory — The JETSCAPE collaboration recently version 2.0 of an innovative modular event generator and simulation framework with a unified interface and a comprehensive suite of model implementations for all stages of ultra-relativistic heavy ion collisions. The framework’s modularity and agnosticism regarding the underlying physics assumptions make it a promising platform for developing Monte Carlo models of electron-ion collisions specifically because it allows to concentrate on one aspect at a time, such as medium interaction or hadronization, while leaving other modules unchanged. An overview of necessary modifications and baseline performance for electron+proton collisions will be presented, as well as a first look at possible jet modification observables in e+ nucleus collisions.

10:06AM EE.00007 Full Acceptance Interaction Region Design of JLEIC. V.S. MOROZOV, R. ENT, Y. FURLETOVA, B. GAMAGE, F. LIN, T. MICHALSKII, R. RAJPUT-GHOSHAL, M. WISEMAN, R. YOSHIDA, Y. ZHANG, Jefferson Lab, Newport News, VA 23606, Y. CAI, Y. NOSOCHKOV, M. SULLIVAN, SLAC, Menlo Park, CA, G.-L. SABB, LBNL, Berkeley, CA — Nuclear physics experiments envisioned at a proposed future Electron-Ion Collider (EIC) require high luminosity of 10^{33}-10^{34} cm⁻² s⁻¹ and a full-acceptance detector capable of reconstruction of a whole electron-ion collision event. The particles associated with the initial ion tend to go at very small angles and have small rigidity offsets with respect to the initial ion beam. They are detected after they pass through large apertures of the final focusing quadrupoles. To maximize the luminosity, the final focusing quadrupoles must be placed as close to the interaction point as possible. Together these requirements present serious detection, optics and engineering design challenges. We present a design of a full-acceptance interaction region of Jefferson Lab Electron-Ion Collider (JLEIC). The talk presents how this design addresses the above requirements up to an ion momentum of 200 GeV/c. We summarize the magnet parameters, which are kept consistent with the Nb-Ti superconducting magnet technology.

1Supported by the U.S. DoE under Contracts No. DE-AC05-06OR23177, DE-AC02-76SF00515, and DE-AC03-76SF00098.
8:30AM EG.00001 Extracting the scattering parameters from $^3\text{He}-^4\text{He}$ elastic scattering using Effective Field Theory, MAHESHWAR POUDEL, DANIEL PHILLIPS, Ohio University — The $^3\text{He}(\alpha,\gamma)^7\text{Be}$ reaction is one of the prime reaction in Big Bang nucleosynthesis as well as in solar-fusion pp chain. Accurate input for solar-fusion models requires extrapolation of experimental data on this reaction to energies; roughly between 20 to few hundred keV. Also, the scattering parameters for this reaction affect the shape of exoplanet S(E)[1]. We study the elastic scattering of $^3\text{He}$ by $^4\text{He}$ in the lab energy range 1.0-5.7 MeV to constrain these parameters. We take $^7\text{Be}$ as cluster of $^3\text{He}$ and $^4\text{He}$ as degrees of freedom. We employ Effective Field Theory(EFT) up to next-to-leading order(NLO) to study s- and p-waves with strong interaction included. The relevant scattering amplitudes are the same as those of the modified effective range expansion up to $O(k^2)(O(k^4))$ in the s(p)-waves. We generate s- and p-wave phase shifts and also fit the cross section to study the impacts of imposing constraints available from $^3\text{He}$ bound states and extract s(p) wave effective scattering length(volume) and effective range. [1]Zhang et. al, S-factor and Scattering parameters from $^3\text{He}+^4\text{He} \rightarrow^7\text{Be} + \gamma$ data. arXIV:1811.07611v1 [nucl-th] [2]Mohr et.al, Phys. Rev. C 48 3 (1993) [3]Barnard et.al, Nucl. Phys. 50 (1984) 640

8:42AM EG.00002 Elastic scattering of $^3\text{He}+\alpha$ with SONIK, S.N. PANERU, C.R. BRUNE, R. GRIJ, Ohio U., D. CONNOLLY, B. DAVIDS, C. RUIZ, A. LENNARZ, M. ALCORTA, M. BOWRY, M. DELGADO, N. ESKER, A. GARNSWORTHY, D. HUTCHEON, C. PEARSON, C. SEEAM, P. MACHUI, TRIUMF, U. GREIFE, J. KARPESKY, M. LOVELY, Colorado Sch. of Mines, J. FALLIS, North Island College, A. CHEN, McMaster U., F. LADADAN, U. of British Columbia, A. FIRMINO, U. of Victoria — Elastic scattering of $^3\text{He}+\alpha$ is essential for a theoretical and phenomenological understanding of $^3\text{He}(\alpha,\gamma)^7\text{Be}$, a key reaction in big bang nucleosynthesis and solar neutrino physics. Elastic scattering data for $^3\text{He}+\alpha$ can be used in a phenomenological R-matrix analysis to extrapolate the $^3\text{He}(\alpha,\gamma)^7\text{Be}$ astrophysical S-factor ($S_{1/2}$) to solar energies. The flux predictions for $^7\text{Be}$ and $^8\text{B}$ solar neutrinos depend critically on $S_{1/2}$. Thus, it is important to improve the accuracy and precision of $S_{1/2}$ at solar energies. The existing $\alpha(^3\text{He},^7\text{Be})\alpha$ data do not extend to low energies and lack the precision required to constrain the extrapolation of $S_{1/2}$ to solar energies. A new measurement of $\alpha(^3\text{He},^7\text{Be})\alpha$ was performed using Scattering of Nuclei in Inverse Kinematics (SONIK) scattering chamber, a windowless, extended gas target surrounded by an array of 30 doubly-collimated silicon charged particle detectors situated at TRIUMF, ISAC-1. The measurement was performed at 9 energies with 0.873 ≤ $E(\text{He})$ ≤ 5.462 MeV covering an angular range of 22.5° ≤ $\theta_{\text{lab}}$ ≤ 135°. Experimental techniques and preliminary results from the experiment will be discussed.

This work was supported in part by the U. S. Department of Energy, under grant Nos. DE-NA-0003883 and DE-FG02-88ER40387.

8:54AM EG.00003 ABSTRACT WITHDRAWN —

9:06AM EG.00004 Measurements of the Astrophysical S Factor of $^{12}\text{C}(\alpha,\gamma)^{16}\text{O}$ Reaction, EVGENI TSENTALOVICH, mit — E. TSENTALOVICH MIT-Bates Laboratory, E-mail: tsentalovich@bates.mit.edu A measurement of the astrophysical S factor of $^{12}\text{C}(\alpha,\gamma)^{16}\text{O}$ reaction is proposed using the inverse $^{16}\text{O}(\gamma,\alpha)^{12}\text{C}$ reaction. The proposed experiment uses electron beam to produce Bremsstrahlung photons and allows an extension of the range of measurements down to $E_{\gamma} = 0.6$ - 0.7 MeV.

9:18AM EG.00005 Constraining Sodium Production in Globular Clusters Using the $^{23}\text{Na}(^3\text{He},d)^{24}\text{Mg}$ Reaction, CALEB MARSHALL, North Carolina State University, TUNL, KIANA SETOODEHNIA, University X-ray Free Electron Laser GmbH, FEDERICO PORTILLO, RICHARD LONGLAND, North Carolina State University, TUNL — Globular clusters consist of hundreds of thousands of stars gravitationally bound in a relatively small radius (~10 pc). Over the last few decades, intense observational study has revealed that globular clusters are comprised of multiple stellar populations each with distinct chemical signatures. The star-to-star Na-O anticorrelation is the most pervasive of these so called abundance anomalies, and is theorized to be the result of stellar material undergoing hydrogen burning at 50–100 MK. Unfortunately, many thermonuclear reaction rates suffer from large uncertainties at these temperatures, thereby limiting our understanding of nucleosynthesis in globular clusters. Among these rates one of the most critical is the sodium destroying reaction $^{23}\text{Na}(p,\gamma)^{24}\text{Mg}$. Using the Enge Split-pole Spectrograph at Triangle Universities Nuclear Laboratory (TUNL), we have measured the transfer reaction $^{23}\text{Na}(^3\text{He},d)^{24}\text{Mg}$. Excitation energies, spin-parities, and spectroscopic factors were extracted for states of interest improving our estimates of the $^{23}\text{Na}(p,\gamma)$ reaction rate, and thus constraining sodium destruction in stellar material.

This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under Award Numbers DE-SC0017799 and under Contract No. DE-FG02-97ER41041.

9:30AM EG.00006 Investigation of High-Lying (Alpha, Gamma) Resonances in $^{22}\text{Ne}$ through One-Neutron Transfer in Inverse Kinematics at TIGRESS, BEAU GREAVES, University of Guelph, TIGRESS COLLABORATION — In asymptotic giant branch (AGB) stars, $^{22}\text{Ne}$ plays an important role in several nucleosynthesis processes, with its production competing with the synthesis of $^{19}\text{F}$ through the so called ‘poisoning reaction’, and the following transfer into $^{25}\text{Mg}$ acting as the main neutron sources for the heavy element s-process, affecting the reaction rates of numerous isotopes. In this contribution, we discuss a recent neutron transfer experiment done at TRIUMF in November 2018, directly populating $^{22}\text{Ne}$, allowing for high resolution measurements of the resonance energies with the SHARC silicon detector, coupled to the HPGe detector array TIGRESS for accurate measurement of the characteristic gamma rays. We will then present the method of using the angular distribution of these newly measured gamma rays and protons to determine the spins of the resonance states, allowing for further constraint on the reaction cross-section.
9:42AM EG.00007 Alpha-capture reaction rates for $^{22}\text{Ne}(\alpha,n)$ and $^{22}\text{Ne}(\alpha,\gamma)$ via sub-Coulomb $\alpha$-transfer and its effect on final abundances of s-process isotopes. HESHANI JAYATISSA, GRIGORY ROGACHEV, VLADILEN GOLDBERG, EUGENY KOSHCHIY, OSCAR TRIPPELLA, JOSHUA HOOKER, CURTIS HUNT, SRITEJA UPADHYAVULA, ETHAN UBERSEDER, BRIAN ROEDER, ANNTI SAASTAMOINEN, Cyclotron Institute / Texas A&M University — The $^{22}\text{Ne}(\alpha,n)$ reaction is a very important neutron source reaction for the slow neutron capture process (s-process) in asymptotic giant branch stars. Direct measurements are extremely difficult to carry out at Gamow energies due to the extremely small reaction cross section. The large uncertainties introduced when extrapolating direct measurements at high energies down to the Gamow energies can be overcome by determining the partial width of the relevant states in indirect measurements. This can be done using $\alpha$-transfer reactions at sub-Coulomb energies to reduce the dependence on optical model parameters. The $\alpha$-transfer reaction of $^{22}\text{Ne}(^{6}\text{Li},d)^{26}\text{Mg}$ was carried out at the Cyclotron Institute at Texas A&M University to study this reaction. It appears that the widths of the near $\alpha$-threshold resonances of $^{26}\text{Mg}$ are quite different for similar $^{22}\text{Ne}(^{6}\text{Li},d)^{26}\text{Mg}$ reactions carried out previously using different higher energies. This discrepancy affects the final reaction rate of the $^{22}\text{Ne}(\alpha,n)$ reaction, and the rate of the competing $^{22}\text{Ne}(\alpha,\gamma)$ reaction, thus affecting the final abundances of the s-process isotopes.

9:54AM EG.00008 Experimental Challenges for Measuring $^{14}\text{N}(\alpha,\gamma)^{18}\text{F}$ in Inverse Kinematics. SHANE MOYLAN, CHRIS SEYMOUR, MANOEL COUDER, ALEXANDER DOMBOS, LUIS MORALES, GWENAELLE GILARDY, University of Notre Dame, JERRY HINNEFELD, Indiana University South Bend, PATRICIA HUESTIS, MICHAEL KURKOWSKI, DANIEL ROBERTSON, EDWARD STECH, MICHAEL SKULSKI, HAOBO YAN, GEORG BERG, MICHAEL WIESCHER, University of Notre Dame — Recoils from the $^{14}\text{N}(\alpha,\gamma)^{18}\text{F}$ reaction were recently detected for the first time using the St. George recoil mass separator. This reaction is the first in the $^{14}\text{N}(\alpha,\gamma)^{18}\text{F}(\beta^{-}\nu)^{18}\text{O}(\alpha,\gamma)^{22}\text{Ne}(\alpha,n)$ chain which produces s-process neutrons in TP-AGB, massive helium burning, and carbon burning stars. Recoil mass separation is a technique to study such reactions in inverse kinematics by detection of the recoil nuclei from these reactions. This is effectively done using a helium gas-jet target (HIPPO), an ion optics transport line which includes a Wien filter velocity selector (St. George), and a time-of-flight vs. energy detection system. The recent characterization of the ion optics and reconstruction of the HIPPO helium gas-jet target have allowed for the first detection of $^{18}\text{F}$ recoils. The preliminary results of this commissioning experiment and the experimental challenges of using the recoil separator will be presented, along with the ongoing and proposed improvements to HIPPO that will allow future measurements with St. George.

10:06AM EG.00009 First detection of $^{18}\text{F}$ from the $^{14}\text{N}(\alpha,\gamma)^{18}\text{F}$ reaction with the St. George recoil mass separator. L. MORALES, C. SEYMOUR, M. COUDER, A. DOMBOS, S. MOYLAN, G. GILARDY, University of Notre Dame, J. HINNEFELD, Indiana University South Bend, P. HUESTIS, D. ROBERTSON, E. STECH, M. SKULSKI, G. P. A. BERG, M. WIESCHER, University of Notre Dame — The St. George recoil mass separator at the University of Notre Dame has successfully observed its first recoil from the reaction $^{14}\text{N}(\alpha,\gamma)^{18}\text{F}$ studied in inverse kinematics. The cross section of this reaction contributes to the abundance of $^{22}\text{Ne}$ which is a neutron source for the s-process in TP-AGB, massive helium burning and carbon burning stars via the $^{22}\text{Ne}(\alpha,n)^{26}\text{Mg}$ reaction. The kinematics and cross section of $^{14}\text{N}(\alpha,\gamma)^{18}\text{F}$ at low energies make it an ideal candidate for commissioning experiments of St. George and the characterization of the focal plane detector. The St. George ion optics separates the $^{14}\text{N}$ beam and sends the $^{18}\text{F}$ recoils into a particle identification detection system. The identification uses the time-of-flight versus residual energy approach. The particle identification system was developed for the St. George recoil mass separator, in collaboration with Indiana University South Bend. Preliminary results of the first nuclear reaction measured with St. George will be presented.

1NSF grant (PHY-0959816 & PHY-1062819 & PHY-1430152)

Tuesday, October 15, 2019 8:30AM - 10:18AM — Session EH Mini-Symposium: New Results from CLAS12 — Saloon B - Latifa Elouadrhiri, Jefferson Laboratory

8:30AM EH.00001 The CLAS12 Experiment at Jefferson Lab. RAFFAELLA DE VITA, JLab — The CLAS12 spectrometer in Hall B at Jefferson Lab has been designed to support an extensive program in hadronic and nuclear physics making use of the high intensity and high polarization electron beam provided by the CEBAF accelerator. The physics program of the experiment is built around three main pillars, the study of the structure and multi-dimensional imaging of the nucleon, hadron spectroscopy in the light quark sector with the search for exotic baryons and mesons, and the study of hadronization in the nuclear medium, color transparency and short range correlations. After a first commissioning run in 2017, CLAS12 completed the engineering run in 2018 and entered the production phase, with the first data taking periods on hydrogen and deuterium target at 10.2-10.6 GeV. This presentation will provide an overview of the status of the experiment and the first results from the ongoing data analysis, toward the realization of the CLAS12 program.

9:06AM EH.00002 Deeply virtual $\pi^0$ electroproduction measurements with CLAS12 at Jefferson Lab. ANDREY KIM, University of Connecticut, CLAS COLLABORATION — The recently upgraded Continuous Electron Beam Accelerator Facility (CEBAF) at Jefferson Lab combined with CEBAF Large Acceptance Spectrometer (CLAS12) provides rich opportunities to measure deeply virtual exclusive reactions such as hard electroproduction of photons and mesons. This presentation will focus on the measurements of deeply virtual $\pi^0$ production (DV$\pi^0$DP) with CLAS12 and the planned analysis in terms of underlying Generalized Parton Distributions (GPD). The experimental measurements of $\pi^0$ electroproduction allow us to constrain largely unknown chiral-odd GPDs $E_7$ and $H_7$ which contain information on quark transverse spin densities in unpolarized and polarized nucleons. The first data collected during 2018 and 2019 using 10.6 GeV polarized electron beam on liquid hydrogen target provide unique access to a large kinematic range with photon virtuality $Q^2$ up to 8 GeV$^2$. In this talk we will report the current status of the DV$\pi^0$DP analysis and present preliminary results from CLAS12 data.
9:18AM EH.00003 SIDIS Single Pion Beam Spin Asymmetry measurements with CLAS12

KYUNGSEON JOO, University of Connecticut, STEFAN DIEHL, Justus Liebig University Giessen and University of Connecticut, CLAS COLLABORATION — The CLAS12 detector at Jefferson Laboratory (JLab) started data taking with a polarized 10.6 GeV electron beam, interacting with an unpolarized liquid hydrogen target in February 2018. The collected statistics enable a high precision study of the moment $A_{LL}^{\pi}(\theta)$ corresponding to the polarized electron beam spin asymmetry in semi-inclusive deep inelastic scattering. $A_{LL}^{\pi}(\theta)$ is a twist-3 quantity which provides information about the quark gluon correlations in the nucleon. Based on the available statistics, a multidimensional analysis becomes possible. This contribution will present a simultaneous study of all three pion channels ($\pi^+, \pi^0$ and $\pi^-$) over a large kinematic range of $z, x_F, P_t$ and $Q$ with virtualities $Q^2$ ranging from 1 GeV to 8 GeV.

1This work is supported by DOE grant no: DE-FG02-04ER41309.

9:30AM EH.00004 Deeply Virtual Compton Scattering with CLAS12 at Jefferson Laboratory

GUILLAUME CHRISTIAENS, University of Glasgow, JOSHUA ARTEM TAN, Kyungpook National University, CLAS COLLABORATION — Generalized Parton Distributions (GPDs) provide the opportunity to obtain a 3-dimensional, tomographic picture of the nucleon. GPDs are related to total angular momentum, mass, and charge distributions inside the nucleon via QCD-based sum rules. These distribution functions are experimentally accessible via Deeply Virtual Compton Scattering (DVCS), the reaction in which a high virtual photon interacts with the proton, emitting a high-energy photon in the final state. At Jefferson Lab, the new CLAS12 spectrometer has been commissioned and collected the first DVCS data with a 10.6 GeV electron beam in 2018. Data calibrations are well advanced and the DVCS final state has been cleanly identified from first analysis. In this contribution, the current status of the analysis will be reviewed and initial results on the DVCS beam spin asymmetry will be presented.

9:42AM EH.00005 Deeply Virtual Compton Scattering at CLAS12 with Multi-Energy Polarized Electron Beams

JOSHUA ARTEM TAN, Kyungpook National University and Jefferson Lab, LATIFA ELOUADRHIRI, Jefferson Lab, FRANCOIS-XAVIER GIROD, University of Connecticut — Deeply Virtual Compton Scattering (DVCS) provides the cleanest access to the 3D imaging of nucleon structure encoded in the Generalized Parton Distributions. In the DVCS process, the interaction of a quark inside the nucleon with the virtual photon from the scattered electron results in the nucleons emission of a high-energy real photon. DVCS naturally occurs with Bethe-Heitler (BH) process where a photon is instead emitted by the scattered electron, resulting in the same final-stated particles. The DVCS amplitude can be separated from DVCS-BH interference amplitude by performing experiments at different beam energies, allowing the extraction of the gravitational $D(t)$ form factor, which may shed light on nucleons confinement mechanism. High luminosity and high polarization of Jefferson Labs electron beam together with the large acceptance of the CLAS12 detector in Hall B provide the ideal environment for multi-energy experiments requiring efficient particle detection in broad kinematic ranges. DVCS data were collected with CLAS12 in 2018 at 6.5 GeV, 7.5 GeV and 10.6 GeV electron beam energies on hydrogen target. We will present preliminary results of experiments at different energies, focusing on the Beam-Spin Asymmetry which is particularly sensitive to $D(t)$.

9:54AM EH.00006 Hadronization of quarks and correlated di-hadron production in DIS

HARUT AVAKIAN, Jefferson Lab, CLAS COLLABORATION — The production of two hadrons in Deep Inelastic Scattering (DIS) provides access to partonic dynamics and correlations between orbiting partons not accessible in the single-hadron inclusive DIS (SIDIS). The interpretation of di-hadron production, as well as interpretation of single-hadron production is intimately related to contributions to those samples from correlated di-hadrons in general, and vector mesons, in particular. Single hadron production, being part of correlated di-hadron production, could be described in the factorized approach, as a convolution of set of different spin-dependent and independent distribution and fragmentation functions. However, there are certain applications where the simple fragmentation functions, depending on the fraction of the virtual photon energy carried by the hadron and transverse momentum generated in the fragmentation, may not be enough for precision description of the hadronization process. The list of these applications, some of them critical for interpretation of the data, includes modeling of hadronization of polarized quarks, procedures for accessing transverse momentum of quarks, fraction of secondary lepton pairs produced in electroproduction, and even the procedure for radiative corrections in SIDIS. In this talk, we present latest results on di-hadron multiplicities from CLAS12 detector at Jefferson Lab, indicating that most of the pions in SIDIS at relatively small transverse momentum come from decays of vector mesons.

1JSA/DOE Contract - DE-AC05-06OR23177

10:06AM EH.00007 Charged dihadron beam-spin asymmetries from CLAS12

TIMOTHY HAYWARD, The College of William and Mary, THE CLAS COLLABORATION COLLABORATION — Azimuthal correlations in the production of hadron pairs in semi-inclusive deep-inelastic scattering provide rich information on nuclear structure. The additional degree of freedom present in the two hadron final state allows for studies of correlations in the hadronization process, which can access novel fragmentation functions not accessible in single hadron production. Consequently, several PDFs such as the higher-twist collinear PDF $e(x)$ can be extracted. We present preliminary charged pion beam-spin asymmetries sensitive to $e(x)$ from a subset of the data taken in 2018 with the CLAS12 detector at Jefferson Lab. The data were taken with a 10.6 GeV polarized electron beam and an unpolarized liquid-hydrogen target. The large kinematic acceptance and sample size allows for a multidimensional analysis in Bjorken $x, Q^2, z$ and the invariant mass of the hadron pair.

1This research was supported by DOE grant DE-FG02-96ER41003.

Tuesday, October 15, 2019 8:30AM - 10:30AM — Session EJ Mini-symposium: Quantitative Understanding of QGP Properties I — Salon C - Rainer Fries, Texas AM
8:30AM EJ.00001 Extracting medium properties from comparisons of collision models to data\textsuperscript{1}. STEFFEN BASS, Duke University — A primary goal of heavy-ion physics is the measurement of the fundamental properties of the quark-gluon plasma (QGP), notably its transport coefficients and initial state properties. Since these properties are not directly measurable, one relies on a comparison of experimental data to computational models of the time-evolution of the collision to connect measured observables to the properties of the transient QGP state. These model-to-data comparisons are non-trivial due to the large number of model parameters and the non-factorizing sensitivity of measured observables to multiple parameters. Over the last few years techniques based on Bayesian statistics have been developed to perform a large number of model parameters and the precision extraction of QGP properties including their quantified uncertainties. The computational models can take many forms, but need to be governed by parameters that codify the physical properties we wish to extract, for example the temperature and/or momentum dependent transport coefficients. The Bayesian analysis then evaluates the model at a small set of points in the multidimensional parameter space, varying all parameters simultaneously. Gaussian process emulators are used to non-parametrically interpolate the parameter space, providing fast predictions at any point in parameter space with quantitative uncertainty. Finally, the parameter space is systematically explored using a Markov chain Monte Carlo (MCMC) to obtain rigorous constraints on all parameters simultaneously, including all correlations among the parameters. In this talk I will review the basic components of the Bayesian analysis and discuss recent progress in the determination of QGP initial conditions and transport coefficients, including the QGP shear and bulk viscosities and heavy quark transport coefficient.

\textsuperscript{1}This work has been supported by DOE grant DE-FG02-05ER41367, NSF grant ACI-1550225 as well as computing resources provided by NERSC and OSG.

9:06AM EJ.00002 ABSTRACT WITHDRAWN

9:18AM EJ.00003 Jet Trigger and Jet Reconstruction Performance in Pb+Pb Collisions at ATLAS\textsuperscript{1}, WENKAI ZOU, Columbia University, ATLAS COLLABORATION — Jets in heavy-ion collisions provide a powerful tool to probe the hot and dense QCD medium created in these collisions. In the ATLAS experiment a set of dedicated heavy ion jet triggers are designed to record the events containing jets in a wide range of transverse energies. Further, a jet reconstruction algorithm optimized to correct for the large event-by-event dependent underlying event produced in heavy ion collisions is used in the offline reconstruction of the data. This talk presents the performance of the jet trigger and offline jet reconstruction used by ATLAS experiment in the 2018 heavy ion run where ATLAS recorded Pb+Pb collisions at the center of mass energy of 5.02 TeV. Trigger and reconstruction efficiencies, jet energy and angular scales and resolutions are presented. The study is performed for both small \( R = 0.4 \) and large \( R = 1.0 \) jets. This study might point to possible improvements for the upcoming heavy ion runs.

\textsuperscript{1}DOE-FG02-86ER-40281

9:30AM EJ.00004 First measurements of the jet mass in p+p collisions at \( \sqrt{s} = 200 \) GeV at STAR\textsuperscript{1}, ISAAC MOONEY, Wayne State University, STAR COLLABORATION — Partonic energy loss in a hot, dense QCD medium may be dependent on the parton’s virtuality. In this talk, we present the first measurements of a related observable called the jet invariant mass, \( M_{\text{g}} \), in p+p collisions at \( \sqrt{s} = 200 \) GeV at STAR. We also present the SoftDrop groomed mass, \( M_{\text{SD}} \), for which the contribution of wide-angle non-perturbative radiation is suppressed, facilitating comparisons with Monte Carlo simulations. The measurements are differential in both the jet transverse momentum, \( p_T \), and jet radius parameter, \( R \). After fully correcting for detector effects, we compare our jet mass and groomed mass results to leading-order Monte Carlo event generators PYTHIA and HERWIG, which differ both in parton shower and hadronization mechanisms. We find that PYTHIA6 tuned to RHIC kinematics agrees well with the measurement, while the corresponding LHC tunes for PYTHIA8 and HERWIG7 have significant disagreement with the data. Such a comparison presents an opportunity for further tuning of Monte Carlo event generators. Study of the jet mass in p+p collisions will serve as a baseline for future work in p+A and A+A collisions to explore cold and hot nuclear matter effects.

\textsuperscript{1}This material is based upon work supported by the U.S. Department of Energy Office of Science, Office of Nuclear Physics under Award Number DE-FG02-92ER-40713.

9:42AM EJ.00005 Jet quenching in a multi-stage approach\textsuperscript{1}, AMIT KUMAR, Wayne State University, JETSCAPE COLLABORATION — In this talk, we present a comprehensive study by performing a model-to-data comparison for leading hadrons, inclusive jets, and jet substructure observables. Using the JETSCAPE framework, we succeed in providing a simultaneous description of the nuclear modification factor for single hadrons and jets, jet shape, and jet fragmentation function within a unified multi-stage framework which spans multiple centralities, energies and jet radii. This multi-scale approach includes a high virtuality (radiation dominated) generator (MATTER), followed by an on-shell energy loss generator (LBT/MARTINI) or a strongly coupled drag energy loss (AdS/CFT) stage. Each stage transitions to the next at a parton-by-parton level, depending on local quantities such as the partons energy, virtuality, and the local density. Measurements of jet and single hadron \( R_{AA} \) set strong constraints on the phase-space available for each stage of the energy-loss. We also incorporate jet-medium response through a weakly-coupled transport description with recoil particles excited from the QCD medium. We highlight the central role played by recoil in the description of both integrated jet observables and the sub-structure of the jet.

\textsuperscript{1}This work was supported by the National Science Foundation (NSF) within the framework of the JETSCAPE collaboration.

9:54AM EJ.00006 Bayesian extraction of \( q \) with correlated experimental errors\textsuperscript{1}, RON SOLTZ, Lawrence Livermore Natl Lab, JETSCAPE COLLABORATION — We use Bayesian inference to constrain four- and five- component parameterized dependence of the jet transport coefficient \( q \) on the local temperature and the energy and virtuality of a parton scattering off a thermal medium. These parameters differentiate between different types of energy loss mechanisms; their evolution in energy and virtuality of partons propagating through a 2+1D viscous fluid dynamical medium we explore a high virtuality shower simulator (MATTER), an on-shell transport simulator (LBT), and a combination of the two. All simulations are carried out within the multi-stage JETSCAPE framework. To minimize sensitivity to recoil effects, we focus on single hadron suppression at multiple collision energies and centralities. Previous analyses of relativistic heavy-ion data have neglected correlations among the experimental errors because typically the full error covariance matrix is not available. In this work we introduce as part of the experimental error treatment a correlation length for the systematic errors, for which we explore different ansatze. Our finding underscores the importance of reporting full error covariance matrices for the experimental data.

\textsuperscript{1}This work was supported in part by the National Science Foundation (NSF) within the framework of the JETSCAPE Collaboration.
and experimentally, in light of the new large-N expansion in QCD. I will discuss recent developments in the understanding of parity-violating nucleon-nucleon interactions both theoretically and experimentally. We also show the dependence of the mass reach on coupling strength, highlighting a few examples of the limits set for specific new physics.

After establishing a model-independent EFT description for these processes, I will review progress in the first-principle calculations of the hadronic and nuclear electric dipole moments (EDMs) and neutrinoless double beta decays. Effective Field Theories (EFTs) techniques can lead to a unified description of high- and low-energy probes of new physics, allowing for detailed comparisons between their sensitivities, and to improved predictions for low-energy experiments, with controlled theoretical uncertainties.

The interpretation of low-energy precision experiments and their connection with models of BSM physics relies on controlling the theoretical uncertainties induced by the nonperturbative nature of QCD at low energy and of the nuclear interactions. In this talk I will discuss how Effective Field Theories (EFTs) can lead to a unified description of high- and low-energy probes of new physics, allowing for detailed comparisons between their sensitivities, and to improved predictions for low-energy experiments, with controlled theoretical uncertainties.

I will discuss in details the examples of hadronic and nuclear electric dipole moments (EDMs) and neutrinoless double beta decays. After establishing a model-independent EFT description for these processes, I will review progress in the first-principle calculations of the nucleon EDM and of the time-reversal-violating and lepton-number-violating chiral potentials, the key one- and two-nucleon input for few-body calculations. I will then discuss recent few-body results and the phenomenological implications for BSM physics.

This work was supported in part by funding from the Division of Nuclear Physics of the U.S. Department of Energy under Grant No. DE-FG02-90ER40182.

1 Work supported by the Department of Energy under grant number DE-SC004168.

Tuesday, October 15, 2019 8:30AM - 10:30AM — Session EL Mini-Symposium on Fundamental Symmetries: Theory and Experiment

10:06AM EL.00007 Machine Learning Based Jet $p_T$ Reconstruction with Full Jets in ALICE$^1$, HANNAH BOSSI, Yale University, ALICE COLLABORATION — Reconstructing the jet transverse momentum ($p_T$) is a challenging task, particularly in heavy ion collisions due to the large fluctuating background from the underlying event. One common treatment of this background is to subtract the event-averaged momentum density (excluding the two leading jets) multiplied by the jet area from the original jet transverse momentum. While this method effectively corrects for the average background, it does not account for region-to-region fluctuations. A novel method to correct the jet transverse momentum on a jet-by-jet basis to reduce these fluctuations will be presented. We utilize machine learning techniques to predict the background-free detector-level jet $p_T$ from jet parameters, including the constituents of the jet. The performance of this approach is evaluated using jets from PYTHIA simulations embedded into ALICE Pb-Pb data. In comparison to the standard area-based method, these machine learning based estimators show a significantly improved performance, which could allow for measurements of jets to lower transverse momenta and larger jet radii.

10:18AM EL.00008 Soft and Collective Particle Generator for a Better Understanding of Heavy Ion Background in Jet Studies$^1$, CHARLES HUGHES, ALEX AUKERMAN, THOMAS KROBATSCH, University of Tennessee, ADAM MATYJA, The Henryk Niewodniczanski Institute of Nuclear Physics (IFJ PAN), CHRISTINE NATTRASS, JAMES NEUHAUS, WILLIAM WITT, University of Tennessee — Collisions of atomic nuclei moving near the speed of light at the Large Hadron Collider (LHC) generate the Quark-Gluon Plasma (QGP), a novel phase of nuclear matter. Jets generated early in the nuclear collision, when internal quarks and gluons scatter with high momentum transfer, provide a tool for studying the properties of the QGP. These quarks and gluons traverse the QGP as it forms, lose energy, and become collimated streams of hadrons. The main difficulty in measurements of jet properties is the large background of hadrons due to the multiplicity of soft collisions from the expansion and cooling of the short-lived QGP. We generate a data-driven background for jets based on measurements of hadron transverse momentum spectra and hadron azimuthal flow at the LHC. We use this data-driven background in concert with Monte-Carlo parton shower generators and jet-finding algorithms to better understand how lower momentum jets are modified. We present the current status of these studies.

1 This work was supported in part by funding from the Division of Nuclear Physics of the U.S. Department of Energy under Grant No. DE-FG02-90ER40182.

9:06AM EL.00002 Parity- and Time-Reversal-Violation in Nuclear Systems and the Large-$N_C$ Expansion, JARED VANASSE, Stetson University — At low energies ($E < m_N^2/M_N$) parity-violating and parity and time-reversal-violating nucleon-nucleon interactions are each characterized by five separate low energy constants. These low energy constants must be determined from experiment or very difficult lattice QCD calculations. Given the challenging nature of these experiments, any framework to discern the relative size of these low energy constants would be of great utility. Such a framework is provided by the large-$N_C$ expansion in QCD. I will discuss recent developments in the understanding of parity-violating nucleon-nucleon interactions both theoretically and experimentally, in light of the new large-$N_C$ analysis, as well as future prospects. In addition I will discuss what large-$N_C$ has to say about parity and time reversal violating nucleon-nucleon interactions.

9:18AM EL.00003 ABSTRACT WITHDRAWN —

9:30AM EL.00004 Update on Tests of the Standard Model from the Qweak Experiment$^1$, GREGORY SMITH, ROGER CARLINI, Jefferson Lab, WILLEM VAN OERS, Univ. of Manitoba, Manitoba, Canada and TRIUMF, Vancouver, Canada, MARK PITT, Virginia Tech, Blacksburg, VA — The final results of the Qweak collaboration were published last year (Androic, et al., Nature 557, 207 (2018)). That work describes how the proton’s weak charge was extracted from the parity-violating asymmetry measured in ep scattering at $Q^2 = 0.0248$ (GeV/c)$^2$. Here we describe a new fitting technique which has the advantage that the extrapolation is linear in $Q^2$. The weak charge obtained in this new procedure is consistent with that obtained in the recent publication. We provide some new and interesting comparisons of the Qweak sin$^2θ_W$ result with the predicted running and Z-pole results. We explore the flavor dependence of the mass reach from the Qweak experiment in the context of potential new weak-charge experiments on the proton and in atomic nuclei. We also show the dependence of the mass reach on coupling strength, highlighting a few examples of the limits set for specific new physics.

1 This work was supported by DOE Contract No. DEAC05-06OR23177, under which Jefferson Science Associates, LLC operates Thomas Jefferson National Accelerator Facility.
9:42AM EL.00005 In search for BSM physics in the beta decay of 45Ca
NOAH BIRGE, University of Tennessee — The Standard Model (SM) has become one of the most complete theories encapsulating fundamental particle interactions. Despite its far ranging success, neutrino flavor oscillations, the observed baryon asymmetry, the dark matter puzzle, and complete absence of gravity from the theory makes it clear that there must exist interactions and particles beyond the standard model (BSM). A nonzero Fierz interference term in beta decay is one such candidate to test BSM physics. The Fierz term results from scalar and tensor interactions not included in the SM. The strength of the coupling manifests in the form of a distortion of the beta decay electron energy spectrum. A set of beta-spectrum measurements for 45Ca was completed at the Los Alamos Neutron Science Center in 2017 and I will present details of analysis along with preliminary results.

9:54AM EL.00006 A Search for Exotic Spin-Gravity Couplings Through Polarized Neutron Interferometry
KYLE STEFFEN, IU Bloomington, ROBERT DALGLIESH, ISIS-RAL, NIELS GEERITS, TU Wien, STEVEN PARNELL, JEROEN PLOMP, TU Delft, ROGER PYNN, W. MICHAEL SNOW, IU Bloomington, NINA-JULIANE STEINKE, ISIS-RAL, AD VAN WELLE, TU Delft, VICTOR DE HAAN, BonPhysics — In 1975 Collella, Overhauser, and Werner demonstrated the accessibility of gravitationally-induced phase shifts in quantum systems using perfect silicon crystal neutron interferometry. [1] Recently, further measurement of this effect has been made using the OffSpec instrument (ISIS-RAL) in spin-echo mode to act as a polarized neutron interferometer. [2] The ability to interfere neutrons of various polarization orientations to measure gravitationally-induced phase shifts provides an opportunity to search for spin-dependent gravitational effects. [3] I will describe a direct search for Lorentz violating spin-gravity couplings in the fermion sector of the Standard Model Extension. [4] An overview of the experimental system will be presented, as well as the status of data collection and analysis.


1This work is supported by NSF grant PHY-1614545

10:06AM EL.00007 ABSTRACT WITHDRAWN –

10:18AM EL.00008 New constraints on exotic spin- and velocity-dependent interactions of polarized electrons with an atomic magnetometer.1, YOUNG JIN KIM, PINGHAN CHU, IGOR SAVUKOV, SHAUN NEWMAN, Los Alamos National Laboratory — Many theoretical extensions of the Standard Model of particle physics predicted exotic spin-dependent interactions between fermions mediated by new fundamental spin-0 or spin-1 bosons such as the axion and axionlike particles. The new bosonic particles may explain several important unsolved mysteries in physics, e.g., matter-antimatter asymmetry and the existence of the dark matter. Recently, we conducted a search for exotic spin- and velocity-dependent interactions for polarized electrons. The experiment is based on a high-sensitivity atomic magnetometer containing an optically polarized atomic vapor, which serves as both a source of polarized electrons and a magnetic-field detector. This approach aims to detect magnetic-fieldlike effects from the exotic interactions between the polarized electrons in an atomic magnetometer vapor cell and unpolarized nucleons of a closely located solid-state mass. In this talk, we report new experimental constraints on the exotic interactions.

1We acknowledge the support of the U.S. Department of Energy through the LANL Laboratory Directed Research Development program for this work.

Tuesday, October 15, 2019 8:30AM - 10:18AM –
Session EM Nuclear Theory I – Salon J - Harald W. Griemhammer, George Washington University

8:30AM EM.00001 Electromagnetic response functions for open-shell nuclei from an ab initio symmetry-adapted framework1, ROBERT BAKER, Ohio University, KRISTINA LAUNEY, Louisiana State University, NIR NEVO DINUR, TRIUMF, SONIA BACCA, Johannes Gutenberg-Universität Mainz, JERRY DRAAYER, Louisiana State University, TOMAS DYTRYCH, Academy of Sciences of the Czech Republic — We will discuss work with the ab initio symmetry-adapted no-core shell model (SA-NCSM) and the Lanczos response function method to examine intermediate-mass, open-shell nuclei from a first-principle perspective. Using realistic interactions, the SA-NCSM can handle nuclei in ultra-large model spaces by employing symmetries previously shown to dominate the nuclear dynamics. The Lanczos response function method, when combined with the SA-NCSM, allows us to calculate response functions for nuclei and to study their intrinsic dynamics. With a focus on clustering and collectivity, we will present recent results for electromagnetic response functions, including for the open-shell nucleus 20Ne, discuss the relevant physics, and briefly point to applications for nuclear compressibility.

1This work was supported by the U.S. NSF (OIA-1738287, ACI-1713690), SURA, and the Czech SF (16-16772S), and benefitted from computing resources provided by Blue Waters, LSU (www.hpc.lsu.edu), and the National Energy Research Scientific Computing Center (NERSC).

8:42AM EM.00002 Chiral-EFT corrections to Gamow-Teller transitions in light nuclei1, SOHAM PAL, SHIPLU SARKER, ROBERT BASILI, PIETER MARIS, JAMES P. VARY, Iowa State University, PATRICK J. FASANO, MARK A. CAPRIO, University of Notre Dame — Chiral effective field theory (χEFT) is a framework to systematically derive inter-nucleon interactions, like the LENPIC interaction, and electroweak currents. We have constructed the Gamow-Teller (GT) transition operator from the one-body and two-body weak axial currents. The operator is consistent with the LENPIC interaction up to N2LO. We have applied this operator within the no-core shell model (NCSM) approach to light nuclei. We present preliminary results for the GT transition matrix elements calculated in a harmonic oscillator basis. We also discuss the convergence of the transition matrix elements at each chiral order as function of the basis expansion, and the impact of the χEFT regulator on the operator.

1Supported by US DOE under Award Nos. DE-FG02-87ER40371, DE-SC0018223 (SciDAC-4/NUCLEI), DE-FG02-95ER-40934, and DE-SC0015376. Computational resources provided by NERSC (US DOE Contract No. DE-AC02-05CH11231).
8:54AM EM.00003 Consistent chiral-EFT improved M1 operators for ab initio calculations\textsuperscript{1}, SHIPLU SARKER, SOHAM PAL, ROBERT BASILI, PIETER MARIS, JAMES P. VARY, Iowa State University, PATRICK J. FASANO, MARK A. CAPRIO, University of Notre Dame — Over the past two decades chiral Effective Field Theory (χEFT) has been successfully applied to model the internucleon interaction, such as the LENPIC interactions, and nuclear electroweak currents to study few nucleon systems. Here we construct the effective M1 operator up to N3LO in a harmonic oscillator (HO) basis consistent with the LENPIC interaction from one-body and two-body χEFT electromagnetic current operators, and apply that to light nuclei within the framework of the no-core shell model (NCSM). We present preliminary results for the deuteron, 3H and 3He magnetic moments, and study their convergence at each chiral order as a function of the basis expansion. We also estimate the chiral truncation uncertainties of these magnetic moments and discuss the role of the χEFT regulator.

\textsuperscript{1}Supported by US DOE under Award Nos. DE-FG02-87ER40371, DE-FG02-95ER-40934, DE-SC0018223 (SciDAC-4/NUCLEI), and DE-SC0015376. Computational resources provided by NERSC (US DOE Contract No. DE-AC02-05CH11231.

9:06AM EM.00004 Ab initio M1 observables in the p-shell with consistent χEFT-improved operators\textsuperscript{1}, PATRICK J. FASANO, MARK A. CAPRIO, University of Notre Dame, SHIPLU SARKER, SOHAM PAL, ROBERT BASILI, PIETER MARIS, JAMES P. VARY, Iowa State University — Ab initio methods in nuclear theory strive to make quantitative predictions of nuclear observables, starting with the internucleon interaction. Modern interactions, such as the LENPIC interaction, are derived systematically from chiral effective field theory (χEFT). However, the same χEFT treatment used for deriving the potential can be used to derive consistent effective operators for electromagnetic moments and transitions. We have derived the effective M1 operator, consistent with the LENPIC interaction up to N2LO in the chiral expansion, and apply it within the no-core configuration interaction (NCCI) approach for a variety of nuclei in the p-shell. We present preliminary results for magnetic moments and M1 transition matrix elements, and explore convergence behavior of the χEFT corrections.

\textsuperscript{1}Supported by the US DOE under Award Nos. DE-FG02-95ER-40934, DE-SC0018223 (SciDAC/NUCLEI), and DE-FG02-87ER40371. Computational resources provided by NERSC (US DOE Contract DE-AC02-05CH11231.

9:18AM EM.00005 Ab initio NCSM One-Body Densities as Input to Effective Potentials for Nucleon-Nucleus Elastic Scattering\textsuperscript{1}, MATTHEW BURROWES, CHARLOTTE ELSTER, GABRIELA POPA, Ohio University, KRISTINA LAUNEY, Louisiana State University, PIETER MARIS, Iowa State University, STEPHEN WEPPNER, Eckerd College — Effective interactions (‘optical potentials’) are needed as input to nuclear reaction calculations. Deriving them ab initio is a current topic of interest. In a multiple scattering expansion for nucleon-nucleus elastic scattering the lowest order term requires integrating over nonlocal, translationally invariant one-body densities and off-shell nucleon-nucleon (NN) scattering amplitudes. The one-body densities contain a scalar and a vector part when taking into account the spin of the nucleons in the nucleus. However, up to now only the scalar density has been employed when calculating the first order effective potential. In this talk, proton-nucleus elastic scattering observables calculated with effective ab initio folding potentials based on NCSM scalar and vector one-body densities together with NN amplitudes derived from the same NN interaction will be shown. We will focus on elastic scattering off light nuclei (up to $^{16}$O) in the energy regime between 100 and 200 MeV laboratory kinetic energy.

\textsuperscript{1}Supported in part by U.S. DoE DE-FG02-93ER40756, DE-SC0008485, DE-SC0018223, DE-AC02- 05CH11231, and U.S. NSF ACI-1516338 and ACI-1713690.

9:30AM EM.00006 Quantum Monte Carlo calculation of scattering in $A=4$ and $A=5$ systems\textsuperscript{1}, KENNETH NOLLETT, ABRAHAM FLORES, San Diego State University — Variational Monte Carlo and Green’s function Monte Carlo methods have been applied very successfully to compute energies and other properties of states in light nuclei from quantitatively accurate nucleon-nucleon interactions. However, these calculations have nearly all involved either bound states or else unbound resonance states narrow enough to be approximated as confined systems. The most straightforward application of these methods to nonresonant scattering and reactions is to impose boundary conditions at a spherical surface with fixed separation of the scattering nuclei, and to compute the discrete states inside the confining boundary just like ordinary bound states; the boundary conditions then allow exact continuation of the wave functions into the exterior region, yielding elements of the $S$-matrix. We will describe the application of these methods to neutron scattering from $^4$He and $^3$H nuclei. Spin and orbital angular momentum quantum numbers can change in the latter process, so we are using it as an initial test case to develop coupled-channel calculations. Since the $A=4$ systems are already accurately computed with Faddeev and hyperspherical methods, it will also allow a useful benchmark of our methods before we move on to systems of more nucleons.

\textsuperscript{1}This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under Award Number DE-SC0001925.

9:42AM EM.00007 New ab initio approach for nuclear reactions\textsuperscript{1}, ALEXIS MERCENNE, KRISTINA LAUNEY, Louisiana State University, TOMAS DYTRYCH, Academy of Sciences of the Czech Republic, JUTTA ESCHER, Lawrence Livermore National Laboratory, JERRY DRAAYER, Louisiana State University — I will discuss a new ab initio approach for nuclear reactions involving nuclei up to the medium-mass region. This approach is based on the ab initio symmetry-adapted framework combined with the resonating group method (RGM). It follows the same concept that has been successfully applied to ab initio reactions of light nuclei, but now we take advantage of the SU(3) symmetry. This new feature enables a reorganization of the large-scale model space into physically relevant basis states and paves the way to ab initio reactions involving heavier and more exotic nuclei of astrophysical interest. In particular, the nuclear structure of the target is described with the ab initio symmetry-adapted no-core shell model, and the target-projectile composite system is described within an SU(3) RGM framework. I will discuss the underlying formalism, which involves the expressions of the norm and Hamiltonian kernels in an SU(3) basis, along with the first applications of the model to one-nucleon projectile reactions. The computational efficacy of the reaction model will be illustrated for a $^{20}$Ne target.

\textsuperscript{1}This work was supported by the U.S. National Science Foundation (OIA-1738287, ACI -1713690), the Czech Science Foundation (16-16772S) and under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344, with support from LDRD project 19- ERD-017.
9:54AM EM.00008 Improved Inelastic Scattering Descriptions for Nuclear Data Evaluations, Nuclear Structure and Reaction Studies1, MANUEL CHIMANSKI, JUTA ESCHER, LLNL, BRETT CARLSON, ITA, ROBERTO CAPOTE, ARJAN KONING, IAEA — Inelastic scattering reactions play a crucial role for data evaluations. Also, they can potentially be used in surrogate reaction applications, which aim at indirectly determining cross sections for reactions on unstable nuclei, e.g. for nuclear astrophysics simulations. This work aims at improving quantum models for pre-equilibrium reactions. Standard descriptions are based on projectile-target interactions with the reaction inducing a wide energy range of target excitations. The quantum models developed so far are limited to a single particle emission process. We studied various properties of RPA excited states of nuclei. We find the strength functions to be dominated by well-localized particle-hole states. This allows us to determine the proper weight for the p-â transition amplitudes for cross section calculations. We obtained expressions for up to two particles in the continuum for one-step amplitudes, and up to three particles in the continuum for two-step amplitudes. We find simple expressions that allow for a systematic implementation of multiple-particle emission. We present results and discuss the limits of one-step amplitudes. Planned extensions using QRPA structure information for both spherical and deformed nuclei will be considered.

1This work performed in part under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344, with support from LDRD 19-ERD-017.

10:06AM EM.00009 Nucleon-induced cross-section predictions for deformed nuclei off-stability1, GUSTAVO NOBRE, Brookhaven National Laboratory, MARC DUPUIS, STEPHANE HILAIRE, CEA/DAM, France, DAVID BROWN, Brookhaven National Laboratory, KAYLA CLEMENTS, University of Florida — Many applications such as astrophysics, nuclear waste management and reactor physics require cross sections and reaction rates that are either unknown or have a scarce availability of experimental data. Therefore, a more predictive approach is needed, encompassing the adoption of more fundamental structure models in the reaction calculations. The strong static deformations of such nuclei off stability limits the reliability of extrapolated global optical model potentials. In this work we address these issues for neutron-induced reactions by extending an adiabatic model that has already been successfully applied to stable deformed rare-earth nuclei to all of their known isotopes off stability. To obtain reliable values for quadrupole and hexadecapole deformation parameters in the cases where such measurements are impractical (or even impossible) we use microscopic Hartree-Fock-Bogoliubov calculations of nuclear densities using the Gogny D1S force, from which observables such as transition probabilities and deformation parameters can be extracted. With this method we were able to obtain reliable cross-section predictions for the whole rare-earth region, from neutron to proton driplines. We also investigate the consistent applicability of this approach to proton-induced reactions.

1Contract No. DE-AC02-98CH10886

Tuesday, October 15, 2019 8:30AM - 9:42AM — Session EN Gluon Spin in proton-proton Collisions — Salon K - Jinlong Zhang

8:30AM EN.00001 Direct photon cross section and double helicity asymmetry at mid-rapidity in \( p^+p^- \) collisions at \( \sqrt{s} = 510 \text{ GeV} \), ZHONGLING JI, Stony Brook University, PHENIX COLLABORATION — Double helicity asymmetries \( A_{LL} \) in hadron, jet and direct photon production in \( p^+p^- \) collisions at the Relativistic Heavy Ion Collider (RHIC) are sensitive to the gluon helicity contribution to the proton’s spin. Unlike hadrons and jet, direct photon production provides clean access to the polarized gluon distribution since there is no hadronization. However, the small direct photon production cross section compared to that of \( pp \) and jet production has so far limited its utility in extracting the polarized gluon distribution. With recent increases in RHIC luminosity, we expect this limitation to be partially overcome and try to revisit this “golden” measurement of polarized gluons based on RHIC data from 2013. This analysis measures the direct photon cross section and \( A_{LL} \) from the data collected employing the PHENIX detector at mid-rapidity \( (|y| < 0.35) \). This will be the first direct photon cross section and \( A_{LL} \) measurement in \( p^+p^- \) at \( \sqrt{s} = 510 \text{ GeV} \) with this detector. In this talk I will present the status of direct photon cross section and \( A_{LL} \) analysis.

8:42AM EN.00002 Longitudinal Double-Spin Asymmetry for Inclusive and Di-Jet Production in Polarized Proton Collisions at \( \sqrt{s} = 200 \text{ GeV} \), NICHOLAS LUKOW, Temple University, STAR COLLABORATION — The contribution of the gluon helicity to the spin of the proton is being studied through the use of the unique capability of the Relativistic Heavy Ion Collider (RHIC) to collide polarized protons at \( \sqrt{s} = 200 \text{ GeV} \) and \( \sqrt{s} = 510 \text{ GeV} \). The kinematic coverage of the Solenoidal Tracker At RHIC (STAR) allows access to gluons through quark-gluon and gluon-gluon scattering processes which dominate jet production at low and medium transverse momentum. The polarized gluon distribution function, \( \Delta g(x) \), can be constrained through a global analysis by measuring the longitudinal double-spin asymmetry \( (A_{LL}) \) of inclusive jet and di-jet production. Inclusive jet \( A_{LL} \) results published by STAR at mid-rapidity \( (|y| < 1) \) at \( \sqrt{s} = 200 \text{ GeV} \) have been used in global analyses and show a non-zero truncated first moment of \( \Delta g(x) \) for momentum fraction, \( x \), greater than 0.05. An additional data sample of 43 pb\(^{-1}\) has been collected in 2015. This new data sample is 115% larger than the previous sample and will improve the precision of \( \Delta g(x) \) for \( x > 0.05 \). The status of this new inclusive jet analysis will be presented along with the status of a di-jet analysis using the same data.

1DOE NP contract: DE-SC0003405

8:54AM EN.00003 Probing Gluon Polarization in the Proton with Jets at STAR1, CARL GAGLIARDI, Texas A&M University, STAR COLLABORATION — The STAR Collaboration at RHIC is exploring the gluon polarization in the proton with a broad range of inclusive jet and dijet measurements in polarized \( pp \) collisions. STAR measurements of the longitudinal double-spin asymmetry, \( A_{LL} \), for inclusive jet production in \( pp \) collisions at 200 GeV provided the first clear evidence that the gluons in the proton with momentum fraction \( x > 0.05 \) are polarized. Recently, STAR completed the analysis of \( A_{LL} \) for inclusive jets and dijets in 510 GeV \( pp \) collisions, based on data that were recorded during 2012. The high statistical precision of the 2012 data required the development of new analysis procedures to minimize systematic uncertainties. Together, the measurements provide important new constraints on both the magnitude and \( x \) dependence of the gluon polarization. The results are consistent with the previous measurements at 200 GeV in the overlapping kinematic region, \( x > 0.05 \), and extend the sensitivity down to \( x \approx 0.015 \). The final 2012 inclusive jet and dijet \( A_{LL} \) analysis and results will be discussed, as well as the first ever measurement of \( A_{LL} \) for the underlying event. A status report will also be given regarding other recent STAR gluon polarization measurements.

1This work was supported in part by the US DOE.
9:06AM EN.00004 Understanding the Gluon’s Contribution to the Spin of the Proton using a $\pi^0 A_{LL}$ Measurement with the STAR Experiment at RHIC, ADAM GIBSON, Valparaiso University, STAR COLLABORATION — The origin of the proton’s intrinsic spin has remained a puzzle for 30 years. The STAR experiment at Brookhaven National Laboratory’s Relativistic Heavy Ion Collider (RHIC) has played a major role in showing that the spins of gluons with at least a moderate fraction ($x$) of the proton’s momentum play a role at least as important as the spins of quarks. But, a significant fraction of the proton’s spin remains unaccounted for. So, a major goal in nuclear physics is to constrain the gluon polarization distribution $\Delta g(x)$ at low $x$ and thus understand the spin contribution from low-$x$ gluons. At STAR, strategies toward this end include analyzing larger datasets, using higher center-of-mass energy proton collisions, and forward detectors. Building on a published result from a 2006 dataset, our measurement of the inclusive $A_{LL}$ with the intermediate pseudorapidity Endcap Electromagnetic Calorimeter (EEMC, $1.00 < \eta < 2.00$) in a large dataset (82pb$^{-1}$ collected by STAR in 2012) utilizes these strategies and is complementary to other measurements at STAR. The status of the measurement will be presented including recent efforts at a data-driven approach.

9:18AM EN.00005 RD for the Forward Silicon Tracker at STAR, TE-CHUAN HUANG, National Cheng Kung university, STAR COLLABORATION — The STAR experiment at the Relativistic Heavy Ion Collider is planning to extend its capability to the forward pseudorapidity region ($2.5 < \eta < 4.0$). A set of detector upgrades, including a silicon tracker and small thin gap chambers as the Forward Tracking System (FTS), an electromagnetic and hadronic calorimeter as the Forward Calorimeter System (FCS), are currently designed and will be constructed and installed after the phase II of the Beam Energy Scan program. These upgrades will help STAR to open new opportunities for QCD physics, examples are, nucleon spin structure, parton saturation, and transport properties of matter in relativistic heavy ion collisions. In this presentation, I will focus on the hardware RD of the silicon tracker in the FTS, as well as the results from simulations on the performance of the tracking system.

9:30AM EN.00006 The STAR Forward Calorimeter Upgrade: Performance and Prototype, DAVID KAPUKCHYAN, University of California, Riverside, STAR COLLABORATION — The STAR experiment at the Relativistic Heavy Ion Collider, RHIC, is installing an upgrade consisting of tracking (small thin gap chambers and silicon) and electromagnetic and hadronic calorimetry at forward pseudorapidity, $2.5 < \eta < 4.0$, for pp, pA and AA running after the beam-energy-scan II. The new detectors will utilize the unique capabilities of RHIC to collide polarized protons and heavy ions to explore novel measurements in cold QCD such as the nucleon spin structure, parton saturation, and transport properties of matter in relativistic heavy ion collisions. The new calorimeter system consists of a hodoscope preshower and both electromagnetic and hadron calorimeters have been tested at the Fermilab test beam. The full system prototype has been installed and successfully ran during the 2019 RHIC run. This talk will discuss the results of the tests, integration, and performance of the prototype in heavy ion collisions.

1Supported by DOE DE-FG02-04ER41325
10:30AM FB.00001 The Neutrino Landscape: Neutrinos and the Nucleus , PHIL BARBEAU, Duke University — Over the last 40 years, only the neutrino has challenged the firmness of the Standard Model. Ongoing and planned searches for new physics in the neutrino sector will require dramatically increased sensitivity that stretch current capabilities. Efforts to make possible a judicious choice of an atomic nucleus to interact with the neutrino. I will summarize a range of neutrino-nucleus interaction experiments of interest to the nuclear physics community.

11:06AM FB.00002 Results from the PROSPECT Neutrino Experiment at HFIR1. JIM NAPOLITANO, Temple University, PROSPECT COLLABORATION — The Precision Oscillation and Spectrum (PROSPECT) experiment measures $\bar{\nu}_e$ emitted by the highly enriched $^{235}$U core of the High Flux Isotope Reactor (HFIR) at Oak Ridge National Lab. The two-ton detector has 154 independent liquid scintillator modules, doped with $^6$Li for detection of the delayed neutron from the inverse beta decay reaction $p + \bar{\nu}_e \rightarrow e^- + n$. PROSPECT sits at the Earth’s surface and close to the reactor, yet achieves better than a 1:1 signal-to-background ratio. We have measured the shape of the $\bar{\nu}_e$ spectrum, and have analyzed it both for sterile neutrino oscillations and for comparison to predictions of the cumulative fission $\beta$ spectrum. Results based on more than six month’s running, including reactor on and off comparisons, will be presented.

11:18AM FB.00003 Characterization of Aboveground Backgrounds for Reactor Antineutrino Detection with the PROSPECT Experiment1, NATHANIEL BOWDEN, Lawrence Livermore National Laboratory, PROSPECT COLLABORATION — PROSPECT is a reactor antineutrino experiment whose primary goals are to search for short-baseline neutrino oscillations and perform a precise measurement of the U-235 reactor antineutrino energy spectrum using a 4 ton anode-liquid scintillator detector at the 85MW High Flux Isotope Reactor (HFIR) at the Oak Ridge National Laboratory. Operating in this environment with limited overburden to attenuate cosmic ray backgrounds is a significant technical challenge. The PROSPECT detector uses optical segmentation and a Li-6 doped liquid scintillator to achieve excellent background rejection in a compact, space efficient system. Initial results have demonstrated the ability to detect 100s of antineutrino events per day with good signal-to-background. Here we discuss how the particle identification and event localization capabilities of PROSPECT enable these results and provide the opportunity to characterize background generation mechanisms in environments with little-to-no overburden.

11:30AM FB.00004 Results of a CEvNS Search with the CENNS-10 Liquid Argon Detector1, JACOB ZETTLEMOYER, Indiana University Bloomington, COHERENT COLLABORATION — The first observation of coherent elastic neutrino-nucleus scattering (CEvNS) was made by the COHERENT collaboration at the Oak Ridge National Laboratory (ORNL) Spallation Neutron Source (SNS) in August 2017 with a 14.6 kg CsI(Na) detector. One of the physics goals of the COHERENT experiment is to test the $N_2$ dependence of the CEvNS cross section predicted in the Standard Model by observing CEvNS in multiple low-threshold detectors. To that end, the ∼24 kg CENNS-10 liquid argon detector was deployed at the low-background Neutrino Alley at the SNS. An observation of CEvNS with CENNS-10 would provide a low $N$ measurement to begin to map out the CEvNS cross section. CENNS-10 was deployed in December 2016 for an initial Engineering Run ending in May 2017 and subsequently upgraded for a Production Run beginning in July 2017. In this talk, I will present the latest results from a CEvNS search with the CENNS-10 liquid argon detector.

11:42AM FB.00005 A tonne-scale liquid argon scintillation detector for precision CEvNS studies, DANIEL SALVAT, Indiana University Bloomington, COHERENT COLLABORATION — Large-scale, low-threshold detectors offer the possibility to measure coherent elastic neutrino-nucleus scattering (CEvNS) cross-sections with high statistical precision. These measurements permit a broad collection of physics studies, such as placing improved constraints upon non-standard neutrino interactions and probing neutron distributions within nuclei. Further, a large-scale detector at a spallation target provides a highly sensitive probe of accelerator-produced dark-matter. The COHERENT collaboration has designed a ∼750 kg liquid argon (LAr) scintillation detector to be deployed at the spallation neutron source at Oak Ridge National Laboratory with a ∼610 kg fiducial volume viewed by an array of 3-inch photo-multiplier tubes. The detector is designed to achieve the required ∼20 keVnr threshold needed for efficient and robust detection of nuclear recoils. In this talk, we will discuss the physics sensitivity of the detector, present the experimental design, and outline ongoing RD&D to further improve scintillation light collection for future CEvNS studies with LAr.

11:54AM FB.00006 NuDot: Double-Beta Decay with Direction Reconstruction in Liquid Scintillator1, JULIETA GRUSZKO, Massachusetts Institute of Technology, THE NUDOT COLLABORATION COLLABORATION — As neutrinoless double-beta decay searches seek to reach into and beyond the inverted hierarchy regime, new strategies are needed to reject background events in kiloton-scale detectors. In monolithic liquid-scintillator-based detectors, otherwise-irreducible backgrounds like $^8$B solar neutrino scattering could be identified by their event topology using Cherenkov light signals. NuDot is a 1-ton prototype that aims to demonstrate this technique with 1 to 2 MeV beta particles. Following a successful demonstration of the separation technique in the FlatDot test-stand, the NuDot detector was built at MIT. Preliminary results from the commissioning phase of the experiment will be shown. In the coming months, we will conduct surface measurements demonstrating direction reconstruction of calibration source beta events, followed by an underground measurement of two-neutrino double-beta decay with direction reconstruction.

1This material is based upon work supported by the National Science Foundation under Grant Numbers 1554875 and 1806440. J. Gruszko is supported by a Pappalardo Fellowship in Physics at MIT.
techniques created for electron-proton scattering to the case of electron-nucleus scattering. These simulations reconstruct the products of e-A Monte Carlo generators using possible EIC detectors with various acceptance. The event kinematics is vital at a future electron-ion collider. Various methods for reconstructing the event kinematics have been developed for neutrinoless double beta decay. By making a simultaneous differential CEvNS measurement with Ge detectors of different Ge composition many systematic errors would cancel. We will present the experimental strategy for this proposal and an estimate of the sensitivity of the detection system to changes in the form factor.

Tuesday, October 15, 2019 10:30AM - 12:18PM —
Session FE Mini-Symposium: Towards a US Electron Ion Collider: Physics, Accelerator, and Detectors II

10:30AM FE.00001 The gluonic radii of light nuclei; A threshold coherent electro-production measurement of upsilon at and EIC. Zein-Eddine Meziani, Whitney Armstrong, Ian Cloet, Adam Freese, Sylvester Joosten, Tsung-Shung Lee, Argonne National Laboratory — The fully exclusive elastic electro-production of $\Upsilon$ on the proton, deuteron, $^3$He and $^4$He at an EIC is a powerful tool to extract their gluonic radii and examine the contribution of the trace anomaly to their mass. Only at energies and luminosity planned for a future US-based EIC that one can contemplate these challenging measurements to reach these goals. The full exclusivity of the process as well as the access of large $Q^2$ and low $t$ in the threshold region should allow to address both the reaction mechanism of electroproduction of $\Upsilon$ as well as the multiple gluonic exchange between the probe and the target in a region of virtual-photon target invariant mass ranging from a perturbative to a non-perturbative regime. We will discuss the motivation of such measurements and show projections of achievable precision in the determination of these gluonic radii using the TOPSIDE detector concept.

10:42AM FE.00002 Imaging quarks and gluons at an Electron-Ion Collider. Markus Dieffenbacher, Jefferson Lab — Transverse momentum dependent (TMD) distributions are a novel QCD tool that allow the mapping of the motion of quarks and gluons in nuclear matter. The Electron-Ion Collider will allow for a high-precision study of TMDs at the scale of sea quarks and gluons. In my presentation, I will discuss the requirements on theory as well as on accelerator, detector, and computer technology for the TMD program.

10:54AM FE.00003 Detailed Study of Event Reconstruction for electron-nucleus Collisions at an EIC. Barak Schmoolker, Stony Brook University — The electron-nucleus (and electron-proton) inclusive scattering cross section is a function of the center-of-mass energy, $\sqrt{s}$, and of two kinematic variables. Therefore, an accurate reconstruction of the event kinematics is vital at a future electron-ion collider. Various methods for reconstructing the event kinematics have been developed for electron-proton collisions. For neutral-current processes, the kinematics can be reconstructed using either the scattered electron, the final-state hadronic system, or a combination of both. For charged-current scattering, reconstruction relies on the hadronic system. The accuracy of a given reconstruction method depends non-trivially on the kinematic regime under study, detector acceptance and resolution effects, and the size of radiative processes. In this talk, we will show new detailed simulation studies of kinematic reconstruction for electron-nucleus collisions at an EIC. These simulations reconstruct the products of e-A Monte Carlo generators using possible EIC detectors with various acceptance and resolution characteristics. Furthermore, we will describe novel methods that we have developed to extend the kinematic reconstruction techniques created for electron-proton scattering to the case of electron-nucleus scattering.
11:06AM FE.00004 Machine learning methods for predictions in the future Electron-Ion Collider\textsuperscript{1}, M.P. KUCHERA, Davidson College, Y. ALANAZI, M. ALMAEEN, Old Dominion University, M. HOUCK, Davidson College, T. LIU, E. MCCLELLAN, W. MELNITCHOUK, Jefferson Laboratory, E. PRITCHARD, R. RAMANUJAN, M. ROBERTSON, Davidson College, N. SATO, R. R. STRAUSS, Jefferson Laboratory, E. TSITINIDI, Davidson College, L. VELASCO, University of Dallas, Y. LI, Old Dominion University — We report on the development of machine learning tools to allow fast and accurate predictions for phenomena at the femtometer scale. There are two primary goals of this work: (1) Build a universal Monte Carlo event generator (MCEG). For this we implement generative adversarial networks (GANs). We train on experimental data to develop a model-independent event generator that mimics the final state for a given reaction. In the first stage, we have trained on synthetic data on electron-proton scattering created by the Pythia MCEG, and have developed a one- and two-stage GAN that provides realistic deep-inelastic scattering spectra. (2) Map between experimental observables and theoretical parameters. For this we use a mixture density network (MDN) that allows us to create faithful mappings between experimental data and the underlying quantum probability distributions that describe nucleon structure. This approach represents a new paradigm for QCD global analysis, which will provide valuable tools for theorists as well as for experimentalists in the design of future experiments.

\textsuperscript{1}This work was supported partly by the Jefferson Lab LDRD19-13 and the Center for Nuclear Fentography project CNF19-07.

11:18AM FE.00005 Rare isotopes at the EIC\textsuperscript{1}, PAWEL NADEL-TURONSKI, Stony Brook University — Electron scattering on light- and heavy nuclei to measure is a cornerstone of the Electron-Ion Collider (EIC). However, Deep-Inelastic Scattering (DIS) on a nucleus also produces a wide range of nuclear fragments - some of which are, for instance, close to the neutron drip line. With the appropriate near-beam detection capabilities, an EIC can thus support a program complementary to planned for the Facility for Rare Isotope Beams (FRIB). In addition to providing a cross check using a very different technique, the lifetime of short-lived isotopes produced at the EIC would be longer in the lab frame (by a factor of 100), which could facilitate some measurements. A rare isotope program at the EIC could be carried out in parallel with other measurements, and the ion detection would also benefit key EIC measurements, such as probing the nuclear glue through coherent diffractive processes. This talk will give a first look at the opportunities and requirements for rare isotopes at the EIC.

\textsuperscript{1}This work is supported partly by the Jefferson Lab LDRD19-13 and the Center for Nuclear Fentography project CNF19-07.

11:30AM FE.00006 New heavy flavor program for the future Electron Ion Collider\textsuperscript{1}, XUAN LI, Los Alamos National Laboratory — The proposed high luminosity high energy Electron Ion Collider (EIC) will explore the proton/nucleon structure, search for gluon saturation and precisely determine the nuclear parton distribution functions (nPDFs) in a wide $x$-$Q^2$ phase space. Heavy flavor measurements at the future EIC will allow us to directly study the nPDFs, the quark gluon fragmentation processes, and energy loss in the nuclear medium within the poorly constrained high Bjorken-$x$ region. We propose to develop a new physics program to study the flavor tagged hadrons/jets, heavy flavor hadron-jet correlations and flavor dependent jet fragmentation processes in the nucleon/nucleus going direction (forward region) at the EIC. The proposed measurements will provide a unique path to explore the flavor dependent fragmentation functions and energy loss in heavy nuclei, which can constrain the initial state effects for previous and ongoing heavy ion measurements at the Relativistic Heavy Ion Collider (RHIC) and the Large Hadron Collider (LHC). To realize these measurements, detector R&D and detector design are needed. Details of the proposed physics program and progress on the simulation studies will be discussed in this presentation.

11:42AM FE.00007 Heavy-quark energy-loss measurements at the Electron-Ion Collider\textsuperscript{1}, YUE SHI LAI, Lawrence Berkeley National Laboratory — Electron-nucleus collisions at the Electron-Ion Collider (EIC) will provide a new mean to precisely measure the space-time evolution of energetic quarks as they traverse the nuclear medium. Such measurements will complement results from RHIC and the LHC on energetic quarks passing through a hot quark-gluon plasma. Heavy-quark energy-loss measurements will require the ability to observe the decay vertex of the hadrons containing the heavy-quarks, and to distinguish it from the collision vertex. The performance for several candidate EIC detector designs is presented, including one with an all-silicon particle tracker. The potential of using deep neural networks for these measurements is discussed.

11:54AM FE.00008 Prospects for EIC-driven advances in HEP phenomenology and Lattice QCD\textsuperscript{1}, TIMOTHY HOBBS, Southern Methodist University and EIC Center at Jefferson Lab, BO-TING WANG, PAVEL NADOLSKY, FREDRICK OLNESS, Southern Methodist University — As typified by the recent report of the National Academies, the goal of constructing a high-luminosity electron-ion collider (EIC) is crucial to the future of nuclear and hadronic physics. This machine will dramatically enhance our knowledge of a wide array of phenomena at work in QCD bound states by providing a comprehensive mapping of the internal tomography of hadrons, including the proton and lighter mesons. While these explorations of hadron structure will extend to transverse momentum-dependent observables, in this talk I focus on the prospects for an EIC to sharpen our understanding of the proton’s unpolarized parton distribution functions (PDFs) and the resulting implications for high-energy phenomenology. Modern information on nucleon PDFs arise from many experiments covering vast reaches of kinematical parameter space; I will place the EIC within this larger context and illustrate its ability to provide durable constraints. In addition, I will also highlight the potential of the future EIC program to serve as the basis for a powerful synergy between studies of hadron tomography and lattice QCD calculations.

\textsuperscript{1}This work is supported by the U.S. Department of Energy under Grant No. DE-SC0010129 and an EIC Center@JLab Fellowship.

12:06PM FE.00009 Search for Charged Lepton Flavor Violation at the US Electron-Ion Collider\textsuperscript{1}, JIN HUANG, Brookhaven National Laboratory, ABHAY DESHPANDE, JINLONG ZHANG, Stony Brook University, KRISHNA KUMAR, University of Massachusetts, YUXIANG ZHAO, INFN Sezione Di Trieste — Discovery of neutrino oscillations (demonstrating lepton-flavor violation in neutral leptons) begs a question of profound importance: is there flavor violation in charged leptons as well? Within the Standard Model, conservation laws are typically associated with certain symmetries. No such symmetries are identified for charged lepton (or charged lepton-flavor violation in neutral leptons) thereby violating the Standard Model leading to CLFV possible in future facilities is hence of fundamental importance and high interest. The proposed high-energy Electron-Ion Collider (EIC) with its unprecedented high luminosity will provide a unique opportunity for such a search. We will present results from an ongoing study of sensitivities possible for $\ell \rightarrow \tau$ conversion in e-p scattering with the luminosities and center-of-mass energies being proposed at the future US EIC.

\textsuperscript{1}This work is supported partly by the Jefferson Lab LDRD19-13 and the Center for Nuclear Fentography project CNF19-07.
10:30AM FG.00001 Electrodisintegration of $^{16}\text{O}$: Measurement and Astrophysical Implication$^1$, IVICA FRISCIC, Massachusetts Institute of Technology — Radiative capture reactions play an essential role in stellar nucleosynthesis, but for some of them, the precise determination of their reaction rates at astrophysical energies proved to be extremely challenging. The most prominent example is the $^{12}\text{C}(\alpha, \gamma)^{16}\text{O}$ reaction, for which even after five decades of experimental effort the uncertainty of the reaction rate at stellar energies still did not reach a goal of $\sim 10\%$. By using the state-of-the-art gas jet target and the new generation of energy-recovery linear accelerators (ERLs) to achieve high luminosity, the measurement of the electrodisintegration of $^{16}\text{O}$ close to threshold can be utilized to determine the $^{12}\text{C}(\alpha, \gamma)^{16}\text{O}$ reaction rate with significantly increased precision. We present the formalism, which relates real- and virtual-photon-disintegration reactions and discuss some aspects of designing an optimal experiment. After the new ERLs come online, the presented approach needs to be validated experimentally, but if successful, the same procedure can be used to improve the precision of other astrophysically-important radiative capture reactions.

$^1$This research was supported by the U.S. Department of Energy Office of Nuclear Physics under grant No. FG02-94ER40818.

11:06AM FG.00002 Impact of $^{16}\text{O}(e, e'\alpha)^{12}\text{C}$ and $^{16}\text{O}(\gamma, \alpha)^{12}\text{C}$ measurements on the $^{12}\text{C}(\alpha, \gamma)^{16}\text{O}$ astrophysical reaction rate$^1$, ROY HOLT, Argonne National Laboratory, California Institute of Technology, BRADLEY FILIPPONE, California Institute of Technology, STEVEN PIEPER, Argonne National Laboratory — The $^{12}\text{C}(\alpha, \gamma)^{16}\text{O}$ reaction, an important component of stellar helium burning, plays a key role in nuclear astrophysics. Providing a reliable estimate for the energy dependence of this reaction at stellar helium burning temperatures has been a major goal for the field. In this work, we study the role of potential new measurements of the inverse reactions, $^{16}\text{O}(e, e'\alpha)^{12}\text{C}$ and $^{16}\text{O}(\gamma, \alpha)^{12}\text{C}$, in reducing the overall uncertainty. A multilevel $R$-matrix analysis is used to make extrapolations of the astrophysical $S$ factor for this reaction to the stellar energy of 300 keV. The statistical precision of the $S$-factor extrapolation is determined by performing multiple fits to existing $E1$ and $E2$ ground state capture data, including the impact of possible future measurements of the $^{16}\text{O}(e, e'\alpha)^{12}\text{C}$ and $^{16}\text{O}(\gamma, \alpha)^{12}\text{C}$ reactions. In particular, we consider a proposed MIT experiment that will make use of a high-intensity low-energy electron beam that impinges on a windowless oxygen gas target and a proposed Jefferson Lab experiment that will make use of bremsstrahlung and a bubble chamber in order to measure the total cross section for the inverse reaction.

$^1$Supported by the U.S. National Science Foundation under grant 1812340 and the U.S. Department of Energy, Office of Nuclear Physics under contract No. DE-AC02-06CH11357

11:18AM FG.00003 Extrapolating the $^{12}\text{C}(\alpha, \gamma)^{16}\text{O}$ cross section to astrophysical energies using phenomenological $R$-matrix$^1$, RICHARD DEBOER, University of Notre Dame, CARL BRUNE, Ohio University, MICHAEL WIESCHER, University of Notre Dame — The $^{12}\text{C}(\alpha, \gamma)^{16}\text{O}$ reaction plays a lead role in the energy production and nucleosynthesis in many astrophysical environments. At the representative energy of 0.3 MeV, the cross section is estimated to be only $2 \times 10^{-17}$ barns. Compared to the lowest energy measurements at about 1 MeV, where the cross section is about $2 \times 10^{-12}$ barns (similar to Higgs boson production), it is easy to see why it is such a struggle to measure this reaction directly. The underlying nuclear structure of $^{16}\text{O}$ produces broad resonances in the $^{12}\text{C}(\alpha, \gamma)^{16}\text{O}$ cross section. As it happens, the region of interest lies right in an off-resonance area where interference dominates. This is the main reason why extrapolating the cross section below the region of experimental data is so challenging. In this talk, I will discuss the underlying reaction components from which we can gain further insight into experimental measurements that can be made to better constrain the model and thus improve the extrapolation. As it turns out, this can be achieved not only by pushing measurements to lower energy, but also through targeted measurements at higher energies. An emphasis will be placed on upcoming inverse $^{16}\text{O}(\gamma, \alpha)^{12}\text{C}$ measurements.

$^1$This research was supported in part by the ND CRC and funded by the NSF through Grant No. Phys-0758100, and JINA through Grant No. Phys-0822648. The work of CRB was supported in part by the DOE, Grant Nos. DE-FG02-88ER40387 and DE-NA0002905.

11:30AM FG.00004 Studies of the $^{16}\text{O}(\gamma^*, \alpha)^{12}\text{C}$ reaction for astrophysical relevance at MAGIX/MESA, STEFAN LUNKENHEIMER, Johannes Gutenberg University Mainz, MAGIX COLLABORATION — MAGIX is a versatile fixed-target experiment and will be operated at the new electron accelerator MESA (Mainz Energy-Recovering Superconducting Accelerator) in Mainz. The accelerator will deliver (un)polarized electron beams with currents up to 1 mA at 105 MeV. Using its internal gas-target, MAGIX will reach a luminosity of $O(10^{35} \text{cm}^{-2}\text{s}^{-1})$. This allows to study processes with very low cross section at small momentum transfer in a rich physical program.

The nucleosynthesis process $^{12}\text{C}(\alpha, \gamma)^{16}\text{O}$ has a high astrophysical relevance. At MAGIX, an experiment is planned to determine the S-Factor of this reaction by measuring the inverse reaction $^{16}\text{O}(\gamma^*, \alpha)^{12}\text{C}$. Therefore electrons will be scattered inelastically on oxygen atoms, the scattered electrons and the produced $\alpha$-particles are detected in coincidence. The cross section will be determined as a function of the outgoing center of mass energy of the carbon-$\alpha$-system for the calculation of the S-Factor. In this talk the experimental setup and the results of the current simulations are discussed. Furthermore, the accessible parameter range at MAGIX is specified.

11:42AM FG.00005 Design and Operation of a Windowless Gas Target Internal to a Solenoidal Magnet for Use with a Megawatt Electron Beam$^1$, SANGBAEK LEE, Massachusetts Institute of Technology, DARKLIGHT COLLABORATION — A windowless gas target has been designed, assembled, and tested, which is driven by the DarkLight experiment to search for a new force mediator beyond the standard model. The target is an essential component of the experiment that runs with the 100 MeV scale megawatt electron beam at the Energy Recovery Linac (ERL). After the target system was commissioned run in 2016 at Low Energy Recirculator Facility (LERF) at Jefferson Lab, it was further improved and calibrated at MIT Bates in 2017. The windowless gas target was verified to maintain sufficiently high density and desired pressure gradient as required for experiments in an ERL environment including the DarkLight.

$^1$This research is supported by the NSF MRI Program (Award No. 1437402), the U.S. Department of Energy Office of Nuclear Physics (Grant No. DE-FG02-94ER40818 and DE-AC05-06OR23177), and the U.S. Department of Energy Office of High Energy Physics (Grant No.DE-SC0011970).
11:54AM FG.00006 Precision absolute polarimeter development for the 3He++ ion beam at 5.0-6.0 MeV energy. GRIGOR ATOIAN, ANDREI POBLAGUEV, ANATOLI ZELENSKI, Brookhaven National Lab. — There is opportunity for precision measurements of the absolute 3He++ polarization at beam energies 5.0-6.0 MeV after the EBIS Linac. The analyzing power for the elastic scattering of spin-1/2 particles (3He) on spin-0 particles (3He) can reach the maximum theoretical value $A_N =1$ at some point ($E_N$, $\theta_{CM}$). The main effort of this R&D will be development of precision absolute polarimeter for the measurements of the 3He++ beam polarization produced in the EBIS as a reference for the further polarization measurements along accelerator chain. The polarimeter vacuum system is integrated in the spin-rotator transport line. The 3He++ ion beam will enter the scattering chamber through the thin window to minimize beam energy losses. The scattering chamber is filled with 4He gas at ~5 torr pressure. The silicon strip detectors will be used for energy and TOF measurements of the scattered 4He and recoil 4He nuclei (in coincidence) for the identification of the scattering kinematics.

12:06PM FG.00007 A single fluid bubble chamber for measuring radiative capture reactions.1 D. NETO, University of Illinois at Chicago, M. AVILA, K. BAILEY, Argonne National Laboratory, J.F. BENESCH, B. CADE, Jefferson Lab, B. DIGIOVINE, Argonne National Laboratory, J.M. GRAMES, A. HOFLER, Jefferson Lab, P. HOLT, Caltech, R. KAZIMI, Argonne National Laboratory, D. MEEKINS, M. MCCAUIGHAN, D. MOser, M. POELKER, Jefferson Lab, T. O’CONNOR, K.E. REHM, S.P. RIORDAN, Argonne National Laboratory, R.S. SULEIMAN, Jefferson Lab, R. TALWAR, Argonne National Laboratory, C. UGAELDE, University of Illinois at Chicago — Radiative capture reactions play a critical role in nucleosynthesis. Direct studies by detecting the outgoing γ-rays are often performed at facilities deep underground to reduce the cosmic ray background. We have developed a new method to measure the time-inverse photo-dissociation reactions using a single-fluid bubble chamber. The large range of the γ-radiation allows for thicker targets, increasing the luminosity by several orders of magnitude, in addition to a factor of 10-100 gain in luminosity from the reciprocity theorem. We will describe the operational principle of the bubble chamber and discuss first results of test measurements at JLAB where we have measured the cross section of the photodisintegration process $^{19}$F($\gamma,\alpha$)$^{15}$N by bombarding a superheated fluid of C$_6$F$_6$ with Brem γ rays reaching cross sections of the time-reversed $^{15}$N($\gamma,\alpha$)$^{19}$F reaction of about 80 picobarn. Results of the $^{14}$N($\gamma,p$)$^{15}$C reaction will also be presented.

1This work supported by the US DOE Nuclear Physics Contracts No. DE-AC02-06CH11357 (ANL) and DE-AC05-06OR23177 (JLAB).

12:18PM FG.00008 Gas-Jet-, Cluster-Jet- and Droplet-Targets: Multi-purpose Tools for Nuclear Physics. PHILIPP BRAND, ALFONS KHOUKAZ, Institut für Kernphysik, Westfälische Wilhelms-Universität Münster, 48149 Münster, Germany — Many experiments in nuclear physics and astrophysics demand for windowless jet targets delivering well-defined target beams of highest purity from various gases. Depending on the concrete experimental design, these requirements can be fulfilled by different target types. One possibility is a pure gas-jet target, providing supersonic jet streams with target thicknesses of, e.g., $10^{18}$ atoms/cm$^2$ directly behind the nozzle. A further development of such gas targets are cluster-jet-targets. By using fine Laval-type nozzles in combination with cryogenic gases, the production of nm-sized clusters is possible, leading to well-defined cluster-jet beams with high thicknesses up to $10^{15}$ atoms/cm$^2$ in a distance of even more than 2 m behind the nozzle. Therefore, such targets are well suited for $\gamma$-ray experiments. Even larger thicknesses can be achieved with more macroscopic objects like µm-sized, liquid or frozen droplets generated with a droplet target. High demands on all of these target types by recent experiments led to a boost with respect to new technological developments, resulting in an enormous improvement in performance. The properties of these target types, some prominent examples, and recent achievements will be presented and discussed.

Tuesday, October 15, 2019 10:30AM - 12:18PM — Session FH Mini-Symposium: New Results from CLAS12 II — Salon B - Volker Burkert, Jefferson Laboratory

10:30AM FH.00001 First Measurements of the Inclusive Electron Scattering off Protons with CLAS12, NIKOLAY MARKOV, Jefferson Lab, CLAS COLLABORATION COLLABORATION — Electron scattering data off protons from the CLAS12 detector has recently become available and covers a wide kinematic range in $W$ up to 4 GeV and $Q^2$ up to 10 GeV$^2$, offering new opportunities to explore inclusive, semi-inclusive, and fully exclusive reactions. A study that aims to extract the inclusive electroproduction cross sections from the CLAS12 fall 2018 data collected at a beam energy of 10.6 GeV from an unpolarized liquid-hydrogen target is now in progress. Preliminary results will be presented and future work plans discussed. The data on inclusive electron scattering cross sections in the resonance region at high photon virtualities, $Q^2 >5.0$ GeV$^2$, will become available. In combination with the existing CLAS results on N* electrocouplings, they will shed light on the behavior of the parton distributions in the resonance region of large $x_F$ and offer valuable input for quark-hadron duality studies. The comparison of inclusive electron scattering data from CLAS12 with the available world data is essential for the understanding and validation of the CLAS12 performance in terms of the electron identification and efficiency evaluation.

10:42AM FH.00002 MesonEx:mesons spectroscopy with quasi-real photons in CLAS12 . KENNETH HICKS, Ohio University, MARCO BATTAGLIERI, RAFFAELLA DEVITA, Istituto Nazionale di Fisica Nucleare, DEREK GLAZIER, University of Glasgow, CLAS COLLABORATION COLLABORATION — A broad program to study meson spectroscopy in the light quark sector with the CLAS12 experiment in Hall B at Jefferson Laboratory has been proposed with the goal of searching for exotic mesons and studying poorly known and rare states, such as scalars and strange mesons. For this purpose, the experiment uses quasi-real photons produced by 10.6 GeV electrons scattering off a proton target and detected at small angles (2.5-4.5 deg) in the CLAS12 Forward Tagger. In these kinematics the virtual photon that is produced has very low four-momentum transfer, Q2, and can be considered as quasi-real. This photon has a significant degree of linear polarization that can be determined event-by-event from the electron scattering kinematics and exploited in the study of the hadronic final states via Partial Wave Analyses (PWA) to extract the contribution of individual resonances. After completing the commissioning in February 2018, the experiment started the production phase, completing an extensive period of data taking between 2018 and 2019, collecting about 300 mC of charge corresponding to an integrated luminosity of 0.4/pb. In this talk first results from a selection of final states will be presented.
10:54AM FH.00003 Excited Nucleon Spectrum and Structure Studies with CLAS12

- DANIEL CARMAN, Jefferson Lab, CLAS COLLABORATION

The N* program in Hall B at Jefferson Laboratory studies the spectrum and structure of excited nucleon states employing exclusive electroproduction reactions. This effort is an important avenue to explore strongly interacting systems of QCD. The CLAS detector has provided the dominant part of the available world data on πN, ηN, ππN, and K+Y electroproduction in the nucleon resonance region for Q^2 up to 5 GeV^2. These data have yielded the only results available on the Q^2 evolution of the electrocoupling amplitudes for most N* states up to W=1.8 GeV to explore their internal structure. Starting in early 2018, the N* program using the new CLAS12 spectrometer began. These studies will probe N* states in the mass range up to W of 3 GeV and Q^2 from 0.1 GeV^2 to 12 GeV^2, thus providing a means to access N* structure information spanning a broad range of distance scales. Quasi-real photoproduction studies are also planned to search for additional hybrid baryon states, for which the gluon serves as an active structural component. In this talk the results of the ongoing analysis of the data collected from CLAS12 associated with the N* program will be reviewed to highlight the current status and future plans.

1U.S. Department of Energy contract DE-AC05-06OR23177

11:06AM FH.00004 Exclusive φ Meson Electroproduction with CLAS12

- BRANDON CLARY, University of Connecticut, CLAS12 COLLABORATION

The Continuous Electron Accelerator Facility Large Angle Spectrometer (CLAS) at Jefferson Lab in Virginia has completed a successful period of data acquisition starting in early 2018 of a longitudinally polarized 10.6 GeV electron beam on a 5 cm unpolarized liquid hydrogen target. A program to study exclusive φ meson electroproduction is now underway as this is an ideal channel for quantifying the gluonic properties of the nucleon. This analysis focuses on the exclusive reaction ep → eφK^+K^−. The analysis strategy consists of two steps: first to establish the approach to the small-size regime by testing model-independent features of the reaction mechanism, such as the Q^2-independence of the t-slopes; then in a second step, extracting the gluonic size in the valence region as a function of x_B. This talk will focus on reviewing the current state of the analysis and future plans for the exclusive φ meson channel with CLAS12.

11:18AM FH.00005 Study of Kaon Identification for Hyperon Photoproduction in JLab’s Hall B CLAS12

- ISABELLA ILLARI, WILLIAM PHELPS, George Washington University, CLAS COLLABORATION

The CLAS12 physics program is involved in the study of baryon spectroscopy in quasi-real photoproduction of a large variety of final states, and includes the photoproduction of singly, doubly and triply strange hyperons. The photoproduction of the very strange hyperon, the Ω^−, is of particular interest. Its photoproduction cross section is unknown. Furthermore, the dynamics of the Ω^− photoproduction is unclear, as there are no strange quarks in the initial state while there are three in the final state. The available theoretical predictions for the Ω^− hyperon photoproduction cross section vary from 1 to 300 pb. We will discuss our study of kaon identification in CLAS12 based on Monte Carlo simulations and real data collected by Run Group A, which used a ~11 GeV beam incident on a liquid hydrogen target.

1This work was performed with partial support from US DOE DE-SC001658, The George Washington University, the CLAS Collaboration, and Thomas Jefferson National Accelerator Facility.

11:30AM FH.00006 ABSTRACT WITHDRAWN

11:42AM FH.00007 Deeply virtual Compton scattering with CLAS12

- ANGELA BISELLI, Fairfield University, CLAS COLLABORATION

The CLAS12 physics program is involved in the study of baryon spectroscopy in quasi-real photoproduction of a large variety of final states, and includes the photoproduction of singly, doubly and triply strange hyperons. The photoproduction of the very strange hyperon, the Ω^−, is of particular interest. Its photoproduction cross section is unknown. Furthermore, the dynamics of the Ω^− photoproduction is unclear, as there are no strange quarks in the initial state while there are three in the final state. The available theoretical predictions for the Ω^− hyperon photoproduction cross section vary from 1 to 300 pb. We will discuss our study of kaon identification in CLAS12 based on Monte Carlo simulations and real data collected by Run Group A, which used a ~11 GeV beam incident on a liquid hydrogen target.

1NSF Award Search: Award1812151

11:54AM FH.00008 Measuring Deeply Virtual Compton Scattering on the Neutron with CLAS12 at Jefferson Lab

- KATHERYNE PRICE, Jefferson Lab, CLAS COLLABORATION

A key step towards understanding nucleon structure in terms of generalized parton distributions (GPDs) is the measurement of deeply virtual Compton scattering on the neutron (nDVCS). This talk will report on a new experiment, currently ongoing at Jefferson Lab, utilizing the upgraded 11 GeV CEBAF polarized electron beam, the CLAS12 detector, and a liquid deuterium target. We aim to measure beam-spin asymmetries for nDVCS. This beam-spin asymmetry measurement, when taken with complementary pDVCS measurements, gives us access to quark total angular momentum. As quark GPDs are only accessible in linear combinations within proton and neutron GPDs, measurement of E via nDVCS will also allow us to perform quark flavor separation of GPDs, resulting in a more complete GPD picture of nucleon structure.

1Institut de Physique Nuclaire (Orsay), Jefferson Lab

12:06PM FH.00009 Experimental Determination of the Free Neutron F_2 at Large Bjorken-x: The BONuS12 Proton Recoil Detector

- SOORIYAARACHCHILEGE NADEESHANI, Hampton University, CLAS COLLABORATION

While the proton F_2 structure function has been studied extensively through inelastic electron-proton scattering, much less is known about neutron structure due to the unavailability of high density, free neutron targets. The BONuS12 experiment was proposed to measure the neutron F_2 on a nearly free neutron within a weakly bound deuteron target via the spectator tagging method. The status of the data taking and of the nDVCS analysis, as well as the performances of the detectors and the quality of the data will be presented. This beam-spin asymmetry measurement, when taken with complementary pDVCS measurements, gives us access to quark total angular momentum. As quark GPDs are only accessible in linear combinations within proton and neutron GPDs, measurement of E via nDVCS will also allow us to perform quark flavor separation of GPDs, resulting in a more complete GPD picture of nucleon structure.

1This work is supported by National Science Foundation grant number NSF HRD-1649870
Photons associated with jets in p-p and A-A collisions\textsuperscript{1}.

**CHATHURANGA SIRIMANNA, ABHIJIT MAJUMDER, Wayne State University, JETSCAPE COLLABORATION —** Jet modification is now understood to be a multistage effect: a parton produced in a high virtuality initial state, radiates a multitude of partons, giving way to a variety of lower virtuality stages. Hadrons produced in the fragmentation from these partons are clustered within jets. Modeling of these multistage effects involves several parameters. We consider a set of these parameters which have been tuned to successfully describe a variety of jet-based data. Quarks inside jets can radiate photons along with gluons. Photons are also produced in the hard scattering, via the quark-gluon Compton scattering process. In this work, we study the correlation of photons with jets in p-p and A-A collisions. Photon radiation from the hard scattering, along with radiation from a PYTHIA based hadronization model are included in this analysis. We focus on the photon jet transverse momentum and angular balance. The calculations of photon production from each stage are calculated in close analogy to gluon radiation, with the exact same approximations, i.e., no new parameters are introduced or tuned either in the p-p or A-A collisions. The level of agreement with experimental data provides independent verification of the multi-stage theory of jet modification.

\textsuperscript{1}This work was supported by the National Science Foundation (NSF) within the framework of the JETSCAPE collaboration.

Measurement of $\pi^0$-Hadron Correlations in Pb-Pb Collisions at $\sqrt{s_{\text{NN}}} = 5.02$ TeV with ALICE\textsuperscript{1}.

**MICHAEL OLIVER, Yale University, ALICE COLLABORATION —** In heavy ion collisions at sufficiently high energies, it has been observed that jets (collimated sprays of mostly hadronic particles originating from a quark or gluon) appear to interact with a quark-gluon plasma, losing energy and transferring momentum to the medium. Such jets are typically created back-to-back, an arrangement called a dijet, but are sometimes created opposite a high energy photon, which can pass through a quark-gluon plasma unhindered. Measuring correlations between high momentum neutral pions and associated hadrons allows measurements of the dijet arrangement with high statistical precision and also can be used to calculate a background for measurements of the photon-jet arrangement. In ALICE, we can measure both high energy photons and high momentum $\pi^0$'s with the Electromagnetic Calorimeter and correlate them with charged hadrons measured with ALICE’s Inner Tracking System and Time Projection Chamber. The environment of the heavy ion collision produces unique challenges to such an analysis, particularly for identifying the $\pi^0$'s and disentangling the component of jet-like correlations from the effects of collective flow. We present progress towards and results from a measurement of $\pi^0$-hadron correlations in this collision system.

\textsuperscript{1}This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics under Award Number DE-SC004168.

Measurement of Jets Recalling from Direct-photon and $\pi^0$ Triggers in Au+Au Collisions at $\sqrt{s_{\text{NN}}} = 200$ GeV in the STAR Experiment\textsuperscript{1}.

**JUSTIN EWIGLEBEN, Lehigh University, STAR COLLABORATION —** Jets recalling from a direct photon have long been seen as a golden probe of the quark gluon Plasma created in relativistic heavy ion collisions, due to the ability to tightly constrain the initial hard scattering kinematics and the partonic flavor bias. Until recently, the ability to measure this channel and the ensuing observables at RHIC were largely statistics-limited, owing to the small cross-section of direct photon production compared to for example the most abundant di-jet cross-section. In this talk, we will present measurements of semi-inclusive recoil jets for both direct-photon and $\pi^0$ triggers, using the 13 nb$^{-1}$ of data recorded in 2014 by the STAR experiment. An outlook towards future direct-photon measurements from STAR, including the transverse momentum imbalance $(x_{fj} = p_{T,jet}/p_{T,\gamma})$ as previously measured by the ATLAS and CMS experiments will also be discussed.

\textsuperscript{1}This material is based upon work supported the National Science Foundation under Grant Nos. 1614474 and 1913696.

Neutral Pion $v_2$ in Central d+Au Collisions Measured with PHENIX.

**CARLOS PEREZ LARA, Stony Brook University, PHENIX COLLABORATION —** The observation of multiparticle correlations in Heavy Ion collisions have long been related to collective behavior in the formed medium. Recent results at RHIC provide strong arguments for QGP formation in smaller systems. In this talk, I present the status of the Neutral Pion second harmonic coefficient $v_2$ as a function of transverse momentum for very central d+Au collisions at 200 GeV. The data was recorded during the 2016 operational period in PHENIX. The analysis makes use of the central rapidity electromagnetic calorimeter. The results provides strong insight into the dynamics of the produced hadrons at such scales.

Recent results on correlations and fluctuations in pp, p+Pb, and Pb+Pb collisions from the ATLAS Experiment at the LHC\textsuperscript{1}.

**SOUMYA MOHAPATRA, Columbia University, ATLAS COLLABORATION COLLABORATION —** The azimuthal anisotropies of particle yields observed in relativistic heavy-ion collisions are traditionally considered as a strong evidence of the formation of a deconfined quark-gluon plasma. However multiple recent measurements in pp and p+Pb systems show similar features as those observed in heavy-ion collisions, indicating the possibility of the production of such a deconfined medium in smaller systems. This talk presents a summary of recent ATLAS measurements in pp and p+Pb collisions. It includes measurements of two-particle hadron-hadron and muon-hadron correlations in pp and p+Pb collisions, with a template fitting procedure used to subtract the dijet contributions. Measurements of multi-particle cumulants $c_{n,2-8}$ are also presented. The standard cumulant measurements confirm presence of collective phenomena in p+Pb collisions, but are biased by non-flow correlations and are not able to provide evidence for collectivity in pp collisions. To address this, measurements from a new sub-event cumulant method that suppresses the contribution of non-flow effects are presented. Recent studies of longitudinal flow decorrelations, and higher-order cumulants in Pb+Pb collisions are also presented, and provide insight into the details of the geometry of the initial state.

\textsuperscript{1}DOE-FG02-86ER-40281.
11:30AM FJ.00006 Transport coefficients in the linear sigma model with massive particles\(^1\), MATTHEW HEFFERNAN, SANGYONG JEON, CHARLES GALE, McGill University — The remarkable achievements of the RHIC and LHC programs have raised the hope that transport coefficients of QCD can be extracted from heavy-ion data. Now that simulations have shown that the value of shear and bulk viscosity influence measured spectra, we must study the transport coefficients quantitatively and restrict the parameter space. We present an extended framework for calculating transport coefficients in the linear sigma model, which incorporates vacuum masses and thermal masses arising from mean field effects and showcases many features of strongly interacting systems. We calculate the electrical conductivity and the shear and bulk viscosity of strongly interacting matter in the relaxation time approximation, and the shear viscosity and electrical conductivity using a variational expansion. Our calculations with vacuum sigma masses consistent with the that of f0(500) correspond well to the results and behavior of previous pion gas calculations obtained via completely different techniques, and with expectations from pQCD. We discuss subtleties arising in exact calculations of the bulk viscosity within our framework. Finally, we present a review of existing results and point out avenues of future research.

\(^1\)This work was supported in part by the Natural Sciences and Engineering Research Council of Canada. Computations were made on Beluga, managed by Calcul Quebec and Compute Canada and funded by the Canada Foundation for Innovation (CFI), Ministere de l’Economie, des Sciences et de l’Innovation du Quebec (MESI) and FRQ-NT.

11:42AM FJ.00007 Measurement of the Azimuthal Anisotropy of Charged Particle Production in Xe+Xe Collisions at 5.44 TeV with the ATLAS Detector\(^1\), PENGQI YIN, Columbia University, ATLAS COLLABORATION — ATLAS measurements of flow harmonics \(v_\text{n}\) and their fluctuations in Pb+Pb and Xe+Xe collisions covering a wide range of transverse momenta, pseudorapidity and collision centrality are presented. The \(v_\text{n}\) are measured up to \(n = 7\) using the two-particle correlations, multi-particle cumulants and scalar product methods. The measurements are also performed using non-flow subtraction techniques — recently developed for measurements in proton-nucleus and proton-proton collisions — to improve the understanding of flow in peripheral Pb+Pb and Xe+Xe collisions. The effects of geometric fluctuations and of viscous effects, both of which are stronger in the smaller Xe+Xe system are demonstrated. A universal scaling in the transverse-momentum dependence of the \(v_\text{n}\) is observed for both systems.

\(^1\)DOE-FG02-86ER-40281

11:54AM FJ.00008 Shear Viscosity over Entropy Ratio of Hot Hadronic Matter, RAINER FRIES, ZHIDONG YANG, Texas A&M University — The ratio of shear viscosity to entropy density \(\eta/s\) typically exhibits a minimum at phase transitions, which is prominent in the case of true phase transitions and is smooth if the transition is a crossover \([1]\). For quark gluon plasma both lattice QCD and extractions from data hint at a very small value of \(\eta/s\), close to the conjectured lower bound 1/4\(\pi\). At temperature approaches \(T_c\) from above. On the other hand, hadronic transport is predicting \(\eta/s\) to be as large as 10/4\(\pi\) when the temperature approaches \(T_c\) from below \([2]\). This discrepancy is uncomfortably large. In this talk we review the current results for \(\eta/s\) from the literature and discuss the importance of a reliable estimate of \(\eta/s\) for hot hadronic matter. We introduce the idea of extracting \(\eta/s\) from data through an analysis of the freeze-out process using a Navier-Stokes approximation \([3]\). We quantify uncertainties from this extraction and correct for known biases. This method suggests a smooth minimum of \(\eta/s\) at \(T_c\) and a gradual rise below \(T_c\). We discuss possible consequences of this scenario. \([1]\) L.P. Csernai, J.I. Kapusta, L.D. McLerran, PRL 97, 152303 (2006) \([2]\) J.-B. Rose et al., PRC97, 055204 (2018) \([3]\) Z. Yang, R.J. Fries, arXiv:1807.03410

12:06PM FJ.00009 PHENIX measurement of system size dependence of low pT photon production, ROLI ESHA, Stony Brook University, PHENIX COLLABORATION — Relativistic heavy ion collisions lead to the formation of a deconfined system of quarks and gluons, called the Quark Gluon Plasma. This thermalized medium emits photons as all the other stages of the collisions do. Photons, as opposed to partons, are color blind and do not interact strongly with the medium, thereby, carrying out the information about the partonic and hadronic phases including the dynamic evolution of the QGP. PHENIX has shown a large excess of direct photons at low transverse momentum compared to the \(N_{\text{coll}}\)-scaled pQCD expectations which is interpreted as thermal radiation of the system. The measurements of the integrated yield of low momentum direct photons through different collision species (Au+Au and Cu+Cu) have shown a universal scaling as a function of charged particle multiplicity. Data from small systems (p/d/\(^3\)He+Au) suggests a rapid turn on of the scaling behavior. This may imply that the bulk of the thermal photons are produced near the transition from QGP to hadron gas combined with an onset of QGP formation at low \(dN_\text{ch}/dy\).

Tuesday, October 15, 2019 10:30AM - 12:18PM — Session FL Mini-Symposium on Fundamental Symmetries: Theory and Experiment

10:30AM FL.00001 A Precision Measurement of the Parity Violation Present in the 0.734 eV p-wave Resonance in \(^{139}\)La Using the ‘Double Lanthanum’ Technique: Preliminary Results and Analysis\(^1\), DANIELLE SCHAPER, University of Kentucky, Los Alamos National Laboratory, NOPTREX COLLABORATION — The Neutron Optics Time Reversal Experiment (NOPTREX) Collaboration aims to measure potential time-reversal (T) violating processes in neutron-nucleon forward scattering interactions in parity (P) violating nuclear resonances. Because the proposed theoretical T-violating cross-section is directly proportional to a \(\bar{P}\)-violating cross-section, precision spectroscopy of these resonances is of critical importance. In particular, the 0.734 eV p-wave resonance in \(^{139}\)La exhibits a well known 10% P-violation effect, making it an outstanding candidate for the NOPTREX experiment. We aim to measure this effect in \(^{139}\)La to 1% precision, improving upon previous (room temperature) measurements by using cryogenic targets (15K) to reduce Doppler broadening effects as well as running for a longer period of time to reduce statistical uncertainty. This experiment was conducted at Los Alamos National Laboratory in 2017-2019. This talk will briefly cover the experimental setup, the efforts to constrain systematic uncertainties, the data analysis process, and preliminary results.

\(^1\)This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under Award Number DE-SC-0014622. We would also like to acknowledge support by the NSF GRFP under Grant Number 1247392.
of the Neutron from Exotic Vector Boson Exchange $V \phi$ momentum \[1\]. The resulting rotation performed on FP12 at LANSCE (LANL) by sending transversely polarized slow neutrons through a series of open parallel slots bounded by flat exchange of spin-1 bosons has been predicted in some extensions of the Standard Model. An experiment in search of this interaction was NSR COLLABORATION — An exotic axial vector interaction in the mm-$\mu$2 Hyperpolarized ZI, Pavlovskaya GE, Meersmann T, Resonance parameters and analyzing powers of neutron resonances in natural Xenon $^{131}$Xe, where a previous experiment observed a large P-odd asymmetry in the 3.2 eV p-wave resonance of $^{131}$Xe[1,2]. We present the design for a cryogenic, solid Xe target to be used in a remeasurement of the P-odd asymmetry in the 3.2 eV resonance to higher precision. We will use a polarized $^3$He neutron spin filter to polarize the 3.2 eV asymmetry in the 3.2eV p-wave resonance of $^{131}$Xe and other heavy nuclei, with the help of extensive n-A resonance data from National Nuclear Data Center (NNDC).

This work is supported by NSF grant PHY-1614545.

10:54AM FL.00003 Spin Dependent Components of Slow Neutron-Nucleus Scattering in $^{131}$Xe and other Heavy Nuclei: Pseudomagnetic Precession Measurement and Calculation$^1$. HAO LU, KYLIE DICKERSON, WILLIAM SNOW. Indiana University Bloomington, BOYD GOODSON, Southern Illinois University, EARL BABCOCK, Forschungszentrum Jülich GmbH, NOPTREX COLLABORATION$^2$ — Neutron OPtics Time Reversal Experiment (NOPTREX) collaboration’s searches for new time reversal sources, spin dependent components of slow neutron-nucleus scattering introduce a significant source of systematic error in forward scattering amplitude. We plan to measure for the first time the pseudomagnetic precession effect caused by spin dependent scattering in neutron transmission through polarized $^{131}$Xe and $^{129}$Xe. This experiment takes place at FRM II in Germany where we use a Neutron Spin Echo (NSE) device to measure pseudomagnetic precession and a Spin Exchange Optical Pumping (SEOP) system to polarize Xe isotopes. Furthermore, as the mechanism which gives rise to the pseudomagnetic precession has never been calculated before, we will theoretically evaluate the incoherent scattering length produced by the difference of $a_+ - a_-$ which are the two neutron-nucleus scattering amplitudes corresponding to the two total angular momentum scattering channels $J = f \pm 1/2$. Here we will present our calculation of the contribution from both potential scattering and resonance scattering, as well as our predictions of a potential $\phi$ effect caused by spin dependent scattering in neutron transmission through polarized $^{131}$Xe and $^{129}$Xe.

This work is supported by NSF grant PHY-1614545.

10:42AM FL.00002 Polarized $^3$He Neutron Spin Filter for Parity-Odd Asymmetry Measurement on 0.88-eV p-Wave Resonance of $^{81}$Br$^3$. CLAYTON AUTON, WILLIAM SNOW, JOHNATHAN CUROLE, HAO LU, BEN SHORT, Indiana University Bloomington, SEPPPO PENTTILA, PETER JIANG, Oak Ridge National Laboratory, NOPTREX COLLABORATION — The Neutron OPtics Time Reversal Experiment (NOPTREX) collaboration plans to conduct a sensitive search for time reversal invariance violation in polarized neutron transmission through polarized nuclei by taking advantage of the very large amplification of symmetry-violating effects in p-wave resonances of certain heavy nuclei. As a step toward this experiment we are remeasuring parity violation in selected nuclei to greater precision at LANSCE. One such candidate is $^{81}$Br with a longitudinal asymmetry of $A = 0.024 \pm 0.004$ at the 0.88-eV resonance. We aim to measure this asymmetry to 5% accuracy. This requires an intense source of polarized neutrons at eV energies. We plan to use a polarized $^3$He neutron spin filter based on the very large spin dependent neutron absorption cross-section of neutrons on $^3$He. In the $^3$He system under construction at Indiana University, $^3$He gas is polarized by spin-exchange optical pumping (SEOP). Key components include a $\mu$-metal shielded solenoid and $^3$He gas cell both generously provided by ORNL. This talk will describe the proposed $^{81}$Br experiment, motivation for choice of $^3$He SEOP for NOPTREX, and projected performance of the $^{3}$He spin filter.

This work is supported by NSF grant PHY-1614545.

11:06AM FL.00004 Parity Violation in the 3.2 eV p-wave Neutron Resonance in $^{131}$Xe$^1$. GABRIEL OTERO MUNOZ, WILLIAM SNOW, JONATHAN CUROLE, Indiana University Bloomington, DANIELLE SCHAPER, University Of Kentucky, BOYD GOODSON, Southern Illinois University, KYLIE DICKERSON, Indiana University Bloomington, NOPTREX COLLABORATION$^2$ — Time reversal (TR) violation in polarized neutron transmission through polarized nuclei can be used to search for beyond the Standard Model physics. A few heavy nuclei including $^{139}$La, $^{81}$Br, and $^{131}$Xe can amplify both parity-odd and parity-odd/time-reversal odd effects due to their mixing of s-wave and p-wave resonances[1]. We focus on $^{131}$Xe, where a previous experiment observed a large P-odd asymmetry in the 3.2eV p-wave resonance of $^{131}$Xe[1,2]. We present the design for a cryogenic, solid Xe target to be used in a remeasurement of the P-odd asymmetry in the 3.2 eV resonance to higher precision. We will use a polarized $^3$He neutron spin filter to polarize the 3.2 eV neutrons. It has also been shown that $^{131}$Xe is polarizable using spin exchange optical pumping techniques[1,3], which will be important for future tests measuring TR asymmetry. [1] J.J. Szymanski, W. M. Snow, et al., Phys. Rev. C53, R2576 (1996). [2] A. Komives, J. D. Bowman, et al., Resonance parameters and analysing powers of neutron resonances in natural Xenon, unpublished (1999). [3] Stupic KF, Cleveland Zl, Pavlovskaya GE, Meersmann T, Hyperpolarized $^{131}$Xe NMR spectroscopy, Nucl. Phys. A401, Journal of Magnetic Resonance. 208: 5869 (2011).

11:18AM FL.00005 A Search for Possible Long Range Spin-Dependent Interactions of the Neutron from Exotic Vector Boson Exchange$^1$, KRYSSTYNA LOPEZ, Indiana University Bloomington, NSR COLLABORATION — An exotic axial vector interaction in the mm-$\mu$m range using spin-dependent neutron-atom interactions though exchange of spin-1 bosons has been predicted in some extensions of the Standard Model. An experiment in search of this interaction was performed on FP12 at LANSCE (LANL) by sending transversely polarized slow neutrons through a series of open parallel slots bounded by flat rectangular plates of copper and glass so that the possible exotic interaction would tilt the plane of polarization along the neutron momentum [1]. The resulting rotation $\varphi = \left[2.8 \pm 4.6 (\text{stat.}) \pm 4.0 (\text{sys.})\right] \times 10^{-5}$ rad/m was consistent with zero [2]. For the potential $V_\phi = \frac{g_\phi}{2m} e^{-m r^2} \left(\frac{1}{1 + \frac{r}{\xi}} \right)$ the upper bound on the coupling constant $g_\phi$ was improved by about three orders of magnitude in the mm-$\mu$m range [3]. We discuss this result along with plans to further improve the sensitivity of our search by at least 2 orders of magnitude at the NIST NG-C beam using tungsten and glass plates as the target.


This work is supported by NSF grant PHY-1614545.
11:30AM FL.00006 Status of an Apparatus to Measure the Parity-odd Neutron Spin Rotation in $^4\text{He}$, JERALD BALTA, Indiana University Bloomington, NSR COLLABORATION — The weak interaction between nucleons is sensitive to quark-quark correlations in the nucleon and provides an opportunity to test the Standard Model in the low energy strongly interacting limit. Recent advances in theory [1] [2] coupled to the measurement of the weak pion exchange component of the NN weak interaction imply predictions for parity-odd neutron spin rotation in $^4\text{He}$ of $d\theta/df = 9 \pm 3 \times 10^{-7}$ rad/m. The previous measurement of $d\theta/df = 2.1 \pm 0.3\text{(stat.)} \pm 2.0\text{(sys.)}$ $\times 10^{-7}$ rad/m [3] lies just outside the theoretical value. A new non-magnetic pump and target system and other upgrades to the NSR apparatus can enable an experimental sensitivity approaching $<9\text{(stat.)} \pm 1.0\text{(sys.)}$ $\times 10^{-7}$ rad/m [4] on the NG-C beam at NIST. This would constitute the first Standard Model test of strangeness-conserving nonleptonic weak interactions. The status of the NSR apparatus will be presented.


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1This work is supported by NSF grant PHY-1614545.

11:42AM FL.00007 Precision Half-life Measurement of $^{29}\text{P}$, JACOB LONG, MAXIME BRODEUR, University of Notre Dame, TWINSOL COLLABORATION COLLABORATION — In recent years, precision measurements have led to considerable advances in several areas of physics, including fundamental symmetry. Precise determination of $t_1$ values for superallowed mixed transitions between mirror nuclides could provide an avenue to test the theoretical corrections used to extract the $V_{ud}$ matrix element from superallowed pure Fermi transitions. Calculation of the $t_1$ value requires the half-life, branching ratio, and Q value. The $^{29}\text{P}$ decay half-life is derived from a series of measurements of which all are over 35 years old. The life-time was determined by the $\beta$ counting of implanted $^{29}\text{P}$ on a Ta foil that was removed from the beam for counting. The $^{29}\text{P}$ beam was produced by a transfer reaction and separated by the TwinSol facility of the Nuclear Science Laboratory of the University of Notre Dame. The progress on the $^{29}\text{P}$ analysis will be presented.

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1National Science Foundation

11:54AM FL.00008 ABSTRACT WITHDRAWN —

12:06PM FL.00009 Precise half-life measurement of the superallowed mixed-miror decaying $^{15}\text{O}$, DANIEL P. BURDETT, MAXIME BRODEUR, SEBASTIAN AGUILAR, TAN AHN, DANIEL W. BARDAYAN, University of Notre Dame, FREDERICK D. BECCETTI, University of Michigan, DREW BLANKSTEIN, CHEVELLE BOOMERSHINE, LOUIS CAVES, SAMUEL HENDERSON, JAMES J. KELLY, JAMES KOLATA, BIYING LIU, JACOB LONG, PATRICK D. O’MALLEY, SABRINA Y. STRAUSS, University of Notre Dame — The Standard Model encapsulates our current understanding of matter and interactions in the universe, however there are some known shortcomings which provide a strong incentive to probe explicit experimental evidence of new physics. One such test lies in investigating the unitarity of the CKM matrix. The current limit is provided by a determination of the $V_{ud}$ matrix element, which relies on measurements of half-lives, branching ratios, and Q-values for the ensemble of $0^{-} \rightarrow 0^{-}$ decays in order to extract $F_1$ values. This calculation, however, also requires knowledge of theoretical corrections, so it is ambitious to confirm the result with another ensemble such as $T=1/2$ mixed-miror decays. Aligning with these interests, the half-life of $^{15}\text{O}$ was measured using the $\beta$-Counting Station at the Nuclear Science Laboratory of the University of Notre Dame. Prior to this measurement the uncertainty of the $F_1$ value was dominated by the lifetime. The measurement, along with its impact of the $F_1$ value will be presented.

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1This work was supported in part by the National Science Foundation under Grants No. PHY-1713857, No. PHY-1401343, and No. PHY-1401242.

Tuesday, October 15, 2019 10:30AM - 12:06PM — Session FM Nuclear Theory II — Salon J - James Vary, Iowa State University

10:30AM FM.00001 Unitarity for Two Nucleons with Pions, HARALD GRIESSHAMMER, George Washington University, MARIO SNCHEZ SNCHEZ, CNRS/IP2N Bordeaux, France — One can understand nuclei at the physical point by an expansion about the unitarity limit of infinite scattering length, with all other effective-range parameters zero. The $NN$ S-wave binding energies are then zero, and there is no scale at leading order. Nuclear Physics resides in a sweet spot: bound weakly enough to be insensitive to the details of the nuclear force; but dense enough that the $NN$ scattering lengths are perturbatively close to the unitarity limit. In this contribution, we study how new scales, namely the pion mass and decay constant change the picture in the $NN$ system. We find that when one imposes unitarity at zero energy, phase shifts do not significantly stray from unitarity at low energies in the $S_1$-$D_1$ and in the $S_0$ waves. Wigner’s SU(4) symmetry of combined spin and isospin transformations emerges then quite naturally. At a “magic” effective range $r_{NN} \approx 1.4$ fm, the effects of these new scales are minimal in both channels. We observe that the physical values are close to it, provide further insight into unitarity with pions, and motivate a converging, perturbative expansion around the unitarity limit, with controlled corrections in the inverse scattering lengths, pion-nucleon interaction, ranges and isospin breaking.

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1Supported in part by US DOE.

10:42AM FM.00002 An anomalous structure in S=1 meson-baryon scattering in the resonance region, DANIEL SADASIVAN, MAXIM MAI, MICHAEL DOERING, George Washington University — We present a simultaneous analysis of s- and p-waves of the $S=1$ meson-baryon scattering amplitude using low-energy experimental data. For the first time we study how new scales, namely the pion mass and decay constant change the picture in the $NN$ system. We find that when one imposes unitarity at zero energy, phase shifts do not significantly stray from unitarity at low energies in the $S_1$-$D_1$ and in the $S_0$ waves. Wigner’s SU(4) symmetry of combined spin and isospin transformations emerges then quite naturally. At a “magic” effective range $r_{NN} \approx 1.4$ fm, the effects of these new scales are minimal in both channels. We observe that the physical values are close to it, provide further insight into unitarity with pions, and motivate a converging, perturbative expansion around the unitarity limit, with controlled corrections in the inverse scattering lengths, pion-nucleon interaction, ranges and isospin breaking.

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1Supported in part by US DOE.
10:54AM FM.00003 Bridging phenomenology & lattice QCD in the 3-body sector. MAXIM MAI, MICHAEL DORING, The George Washington University — The interacting three-particle states are populated via an interacting two-particle sub-system (resonant or non-resonant), and a spectator. Using this formulation, we derive the relativistic isobar-spectator amplitude such that the three-body Unitarity is ensured exactly (Eur.Phys.J. A53 (2017) no.9, 177). Unitarity constrains the imaginary parts of such an amplitude in infinite volume. In the finite volume this determines the leading power-law finite-volume effects allowing for a derivation of a highly desired 3-body quantization condition. Short derivation of the latter in the present formalism (Eur.Phys.J. A53 (2017) no.12, 240) as well as a subsequent application to the physical system for which lattice results exist (Phys.Rev.Lett. 122 (2019) no.6, 062503) will be presented in this talk.

1DGF, DOE, NSF

11:06AM FM.00004 Renormalization in the Three-Body Sector with Singular Potentials. DANIEL ODELL, University of Tennessee, Ohio University, ARNOLDAS DELTUVA, Institute of Theoretical Physics and Astronomy, Vilnius University, JOSE BONILLA, University of Tennessee, LUCAS PLATTER, University of Tennessee, Oak Ridge National Laboratory — Despite the success of chiral effective field theory (EFT) in describing the nuclear interaction, there remains a significant debate over the power-counting scheme used to systematize the contributions. One-pion exchange (OPE) is part of the leading-order chiral EFT nucleon-nucleon potential, so we study the case of the attractive, inverse-cube potential, whose wave functions should have the same short-distance behavior. In principle, the renormalization at large cutoffs of two- and three-body observables found with this potential should not be a cutoff dependence of those same observables calculated with OPE. I will present results that demonstrate the sufficiency of a two-body contact term to renormalize three-body binding energies and scattering observables. I will also discuss a rigorous analysis of the higher-order corrections that finds two-body corrections subleading to three-body corrections, suggesting that a two-body counterterm may be required at next-to-leading order.

11:18AM FM.00005 Fitting Nuclear Potentials with TensorFlow & Gaussian Processes. JORDAN MELENDEZ, Ohio State University — A nuclear potential with quantified uncertainties is crucial for meaningful predictions across the nuclear chart. I will discuss how classical optimization methods and neural networks can help us find better potentials more easily. A Bayesian model discrepancy term is shown to both incorporate uncertainty from higher order terms in chiral effective field theory and also regularize the fitting procedure. Information about model correlations can be rigorously incorporated for the first time using Gaussian processes. Combined with TensorFlow, new codes can more effectively sample the posteriors of low-energy constants for full uncertainty quantification. Potential applications are discussed.

11:30AM FM.00006 Exploring the Magnus expansion and the similarity renormalization group. ANTHONY TROPIANO, Ohio State University — We test the Magnus expansion implementation of the similarity renormalization group (SRG) on chiral NN potentials at high cutoffs. At leading order and high cutoffs, chiral potentials feature spurious bound states in spin triplet channels. We explore how bound states decouple with two band-diagonal transformations. Furthermore, we study operator evolution and calculate consistently evolved observables.

11:42AM FM.00007 Applications of Nonequilibrium Greens Function Approach to Nuclear Systems in One Dimension. HAO LIN, PAWEL DANIELEWICZ, NSCL, Michigan State University — While semiclassical transport theories and time-dependent Hartree-Fock method have been extensively applied to describe many-body systems, they fail to take into account the effects of quantum correlations, which can be crucial for strongly interacting quantum systems. The nonequilibrium Greens function approach allows for a systematic way to incorporate correlations. For the time being, we consider only short-ranged two-body correlations. In this talk, I will discuss applications in the description of nuclear systems in 1D, such as the spectral function for the ground state, the isoscalar monopole mode and the isovector dipole mode, and the collision of slabs in 1D. Calculations will be compared with and without correlations.

1This work is supported by NSF PHY-1510971 and DOE DE-SC0019209

11:54AM FM.00008 The iS3D particlization module for heavy-ion collision simulations. MICHAEL MCNELIS, DEREK EVERETT, MATTHEW GOLDEN, ULRICH HEINZ, Ohio State University, JETSCAPE-SIMS COLLABORATION — The iS3D particlization module simulates the emission of hadrons from heavy-ion collisions via Monte-Carlo sampling. The code package includes multiple choices for the non-equilibrium correction to the hadronic distribution function in the Cooper-Frye formula: the 14-moment approximation, Chapman-Enskog expansion, and two types of modified equilibrium distributions. This makes it possible to explore, using Bayesian analysis, whether heavy-ion experimental data prefers one of these models for the 14-moment approximation, Chapman-Enskog expansion, and two types of modified equilibrium distributions. This work is supported by NSF PHY-1510971 and DOE DE-SC0019209

Tuesday, October 15, 2019 10:30AM - 12:30PM
Session FN Nuclear Structure I  Salon K - Lee Sobotka, Washington University in Saint Louis

10:30AM FN.00001 Studying Low-Lying States of $^9$B with a Super-Enge Split-Pole Spectrograph (SE-SPS). RACHEL MALECEK, Louisiana State University — We used the single-particle transfer reaction, $^{10}$B($^{3}$He, $\alpha$), to investigate the structure of the light, neutron-deficient nucleus $^9$B. We are interested in $^9$B specifically because years of previous efforts have yet to agree on definitive results for the energy, width, and spin-parity of its first-excited state. Over the years, there have been many attempts to measure the energy and width of this state of $^9$B, which is thought to be the mirror of the first-excited state of $^{10}$Be. However, because this is a difficult state to populate, the experimental results vary between 0.7 to 1.8 MeV for the energy and 0.3 to 1.5 MeV for the width. We performed the $^{10}$B($^{3}$He,$\alpha$) reaction with the tandem accelerator at Florida State University. A 24-MeV $^3$He beam was incident on an isotopically enriched self-supporting $^{10}$B target. Alpha particles were momentum-analyzed by the new SE-SPS and detected at the focal plane while protons were detected by Double-Sided Silicon Strip Detectors at backward angles. Data was taken every 5 degrees between 5 degrees and 35 degrees in the laboratory frame. Preliminary results will be presented.
10:42AM FN.00002 Nuclear Charge Radii of $^{10,11}$B, PETER MUELLER, ALESSANDRO LOVATO, R.B. WIRINGA, Physics Division, Argonne National Laboratory, BERNHARD MAASS, THOMAS HUETHER, KRISTIAN KOENIG, JOERG KRAEMER, JAN KRAUSE, WILFRIED NOERTERSHAEUSER, ROBERT ROTH, FELIX SOMMER, IKP, TU Darmstadt, RODOLFO SANCHEZ, GSI, Darmstadt, KRZYSZTOF PACHUCKI, Faculty of Physics, University of Warsaw, MARIUSZ PUCHALSKI, Faculty of Chemistry, Adam Mickiewicz University — We present the first laser spectroscopic determination of the change in the nuclear charge radius in boron isotopes. This is achieved by combining high-accuracy ab initio mass-shift calculations and a high-resolution measurement of the isotope shift in the transition frequency from the ground state to the respective excited state in boron atoms. Accuracy is increased by orders of magnitude for the stable isotopes $^{10,11}$B compared to previous measurements. The results are used to extract the difference in the mean-square charge radius $\langle r^2 \rangle_{11} - \langle r^2 \rangle_{10} = -0.49(12) \text{fm}^2$. This value serves as a benchmark for new ab initio nuclear structure calculations using the no-core shell model and Green's function Monte Carlo approaches. In addition, this work is the foundation for a laser spectroscopic determination of the charge radius of the proton-rich, short-lived $^{11}$B in preparation at Argonne's ATLAS facility.

1This work is supported by the Deutsche Forschungsgemeinschaft under grant 27938 4907-SFB 1245, and by the U.S. DOE, Office of Science, Office of Nuclear Physics, under contract DE-AC02-06CH11357.

10:54AM FN.00003 Weak Decays of Halo Nuclei in Effective Field Theor...1, ZICHAO YANG, Department of Physics and Astronomy, University of Tennessee, Knoxville, WAEL ELKAMHAWY, HANS-WERNER HAMMER, Institut fur Kernphysik, Technische Universitat Darmstadt, LUCAS PLATTER, Department of Physics and Astronomy, University of Tennessee, Knoxville — Halo nuclei display a large separation scales, which can be used to treat halo systems using an effective field theory called Halo EFT. We consider the weak decay of valence neutron in one-neutron halo nuclei within this framework for the first time. We calculate the decay strength and the partial decay rate of selected halo nuclei, especially $^{10}$Be and $^{11}$Ne. We describe thereby the process of beta-delayed proton emission. These systems have been considered previously by Baye and Tursunov, but we use updated experimental input parameters. Furthermore, we discuss the uncertainties resulting from these input parameters but also those arising from the effective field theory approach to this process. We discuss the recoil effect of weak decay and resonance in the final state as well.

1This work has been funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation), the National Science Foundation, and the Office of Nuclear Physics, U.S. Department of Energy.

11:06AM FN.00004 Probing single-particle $^{11}$C levels produced via the $^{10}$C(d,p) reaction, MATTHEW BAINES, DAN BARDAYAN, PATRICK O'MALLEY, SEBASTIAN AGUILAR, SAMUEL HENDERSON, SCOTT CARMICHAEL, LAUREN CALLAHAN, CHEVELLE BOOMERSHINE, JACOB LONG, DREW BLANKSTEIN, LOUIS CAVES, TAN AHN, MAXIME BRODEUR, JAMES KOLATA, University of Notre Dame, GAVIN LOTAY, PAUL STEVENSON, University of Surrey, UNIVERSITY OF NOTRE DAME ISNAP TEAM, UNIVERSITY OF SURREY TEAM — There has been tremendous progress in recent years using no-core shell-model approaches to calculate the low-lying level structures of light nuclei. Important constraints to such calculations come from the spectra of single-particle and single-hole states of nuclei near strongly bound spherical nuclei such as Carbon-12. While Carbon-11 has been studied by neutron removal from Carbon-12 and proton addition to Boron-10, the single-neutron states have never been directly probed. The (d,p) reaction on Carbon-10 was studied at the Notre Dame Nuclear Science Laboratory to probe these single-particle states. The experiment and preliminary data will be presented.

1This work was supported by the National Science Foundation.

11:18AM FN.00005 Ab initio predictions for $^{12}$C$, ANNA MCCOY, PETR NAVRATIL, TRIUMF — Obtaining accurate predictions of nuclear structure starting from the interaction between constituent protons and neutrons is a complex, computationally demanding problem, particularly for resonances and continuum states. The ab initio no-core shell model with continuum (NCSMC) explicitly builds in both short-range correlations as well as long-range clustering and collective dynamics necessary for accurately describing resonances and continuum states. We present predictions of, e.g., energies, phase shifts and capture cross sections, relevant for the $p + ^{11}$B → $^{12}$C reaction obtained using the NCSMC with interactions from chiral effective field theory as the only input.

1This work was supported by the NSERC Grant No. SAPIN-2016-00033. TRIUMF receives federal funding via a contribution agreement with the National Research Council of Canada. Computing support came from an INCITE Award on the Titan supercomputer of the Oak Ridge Leadership Computing Facility (OLCF) at ORNL, and from Westgrid Compute Canada.

11:30AM FN.00006 Measurement of the $B(E2; 2^+ \rightarrow 1^+)$ of $^8$Li and comparisons to ab initio calculations, S. L. HENDERSON, T. AHN, M. A. CAPRIO, P. J. FASANO, P. D. O’MALLEY, A. SIMON, S. AGUILAR, J. J. KOLATA, S. JIN, University of Notre Dame, TWINSOL COLLABORATION COLLABORATION — Precise measurements of electromagnetic transition strengths in light nuclei can provide stringent tests of nuclear ab initio calculations. In the $A=7$ isotopes, specifically $^7$Li and $^8$Be, the $B(E2)$ transition strengths have been used to benchmark different ab initio calculations [S. L. Henderson et al., Phys. Rev. C 99, 064320 (2019)]. We will continue testing by extending these measurements into the $A=8$ region and measure the first excited state in $^8$Li, in order to provide additional constraints to these ab initio models. These models can give us insight into the structural changes from $^7$Li to $^8$Li due to the addition of a neutron. We have performed a Coulomb excitation experiment to measure the $B(E2; 2^+ \rightarrow 1^+)$ transition strength in $^8$Li. The $^7$Li was produced and separated with TwinSol and the Coulomb excitation cross section was measured using particle-gamma coincidences. The preliminary $B(E2)$ value will be presented and compared to ab initio calculations for $^7$Li, highlighting the structural evolution in Li isotopes due to lighter neutron excess. The results of this experiment will also provide a test of the accuracy of available ab initio calculations in this light mass region.

1This work has been supported by US NSF grant no. PHY 14-19765 and no. PHY1401343 and DOE grant number DE-FG02-95ER-40934.
11:42AM FN.00007 Investigating a possible positive value of $K_\tau$, and implications for the symmetry energy\textsuperscript{1}. KEVIN HOWARD, UMESH GARG, SIERRA WERYLMILLER, University of Notre Dame, HIDEYOSHI AKIMUNE, KYOKO NOSAKA, Konan University, SOUMYA BACCHI, Saint Marys University, TAKANOBU DOI, YUKI FUJIKAWA, SHINTARO OKAMOTO, Kyoto University, MAMORU FUJIIWARA, TATSUYA FURUNO, KENTO INABA, NOBU KOYABASHI, SHOKEN NAKAMURA, ZAIHONG YANG, TAKAHIRO KAWABATA, Osaka University, NASSER KALANTAR-NAYESTANAKI, MUHIN HAKRAKEH, University of Groningen, MASATOSHI ITOH, YOHEI MATSUDA, Tohoku University, SHINSUKE OTA, University of Tokyo — The isoscalar giant monopole resonances (ISGMR) in isotopic chains with large neutron-excess provide excellent constraints for $K_\tau$, the asymmetry term in the nuclear incompressibility. $K_\tau$ has been extracted from the ISGMR in tin and cadmium to be $-550 \pm 100$ MeV, and is critical input to the symmetry energy of nuclear matter. Recent reports on the ISGMR in $^{40,44,48}$Ca contradict the prior studies, concluding that $K_\tau > +500$ MeV. A simultaneous study of the ISGMR in $^{40,42,44,48}$Ca was thus completed at the Research Center for Nuclear Physics. The spectrograph, Grand Raiden, allowed for measurements of background-free angular distributions for inelastic scattering of $386$ MeV $\alpha$-particles. Multipole decomposition analyses isolated the ISGMR strength, and the energies of the compressional mode were extracted. The results and implications will be discussed.

\textsuperscript{1}Supported by NSF Grant No. PHY-1713857, the Liu Institute, and the College of Science at the University of Notre Dame

11:54AM FN.00008 The Puzzle of the $^{13}$Be\textsuperscript{1}. JEROME MATHEW KOVOOR, MARIJA VOSTINAR, KATHERINE JONES, University of Tennessee, Knoxville, RITUJARNAH NADEGUNDO, Saint Marys University, SEAN BURCHER, University of Tennessee, Knoxville, MATTHIAS HOLL, TRIUMF, JOSHUA HOOKER, University of Tennessee, Knoxville, STEVEN D. PAIN, Oak Ridge National Lab, ORRY WORKMAN, TRIUMF, IRIS S1506 COLLABORATION COLLABORATION — A considerable number of experiments have been performed to study the unbound nucleus $^{13}$Be, however the energy and the ordering of its low-lying states remain unknown. Clarifying the low-lying structure of $^{13}$Be will help in understanding the evolution of the N=8 shell gap and the nature of the nuclei near, or at, the neutron drip line. Additionally, the continuum structures of $^{13}$Be are important for understanding the Borromean structure of the halo nucleus $^{14}$Be. We performed the $^{12}$Be(d,p)$^{13}$Be transfer reaction in inverse kinematics at ISAC II, TRIUMF. The $^{12}$Be beam at 9.5 MeV/u interacted with the IRIS solid D$_2$ target, and recoils and ejectiles were detected in an annular silicon detector array. Preliminary analysis and results will be presented here.

\textsuperscript{1}This research was supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics under Contract No. DE-FG02-96ER40963, DE-AC05-00OR22725, and NSERC, Canada Foundation for Innovation and Nova Scotia Research and Innovation Trust: RCNP, grant-in-aid program of the Japanese government. TRIUMF is supported by a contribution through the National Research Council, Canada.

12:06PM FN.00009 Search for the $^{15}$Be ground state, ANTHONY KUCHERA, RIDA SHAHID, Davidson College, NATHAN FRANK, HAYDEN KARRICK, Augustana College, MONA COLLABORATION COLLABORATION — The ground state of the unbound nucleus $^{15}$Be remains an open question. The MoNA collaboration has performed two experiments to study the structure of $^{15}$Be at the NSCL. In a first attempt to populate $^{15}$Be, a two-proton removal reaction from a $^{17}$C beam was used and decays were searched for in the $^{14}$Be+1 channel. This led to a non-observation due to a lack of $^{14}$Be fragments detected. A follow-up experiment made the first observation of a $^{15}$Be state through the use of a neutron-pickup reaction with a $^{14}$Be beam impinging on a deuterated plastic target. Because of the observed states relatively high decay energy, the existence of a $^{15}$Be state lower in energy decaying sequentially through the first excited state in $^{14}$Be resulting in $^{12}$Be+3n is possible. A first attempt to search for this state in the two-proton removal data set yielded low statistics and the data did not indicate the presence of a lower state. The neutron-pickup data are now being reanalyzed to search for the ground state in $^{15}$Be by simultaneously fitting 2-, 3-, 4-body decay energies. Preliminary results indicate evidence for a state in $^{15}$Be decaying by three neutrons that is lower in energy than the previously measured state.

12:18PM FN.00010 Study of the $^{28}$Mg(\textit{t},$^{30}$Mg)p reaction to investigate nuclear shell evolution at the boundary of the N=20 Island of Inversion, TAMMY ZIDAR, University of Guelph — Some nuclei far from the valley of stability have been found to have ground state properties that are different than those naively expected from the nuclear shell model. The term island of inversion is used to refer to regions of the nuclear landscape in which deformed intruder configurations dominate nuclear ground, e.g. centered on neutron-rich $^{32}$Mg. The ratio of $^{30}$Mg on the border of this region can be used to determine the amount of mixing that occurs moving into the island of inversion. $^{28}$Mg was delivered by the high-intensity and energy accelerator at the isotope mass separator on-line (HIE-ISOLDE) facility at CERN. The high-purity beam of $1.8\times10^6$ pps was impinged on a radioactive tritium target resulting in the desired reaction of $^{28}$Mg(\textit{t},$^{30}$Mg)p. In terms of the experimental setup to study the reaction, two complimentary systems were used: the silicon detector array T-REX, in order to detect and identify the transfer particles, and the MINIBALL -ray spectrometer\textsuperscript{[2]}. The data from these two detectors were used to determine the ratio of the cross-sections of the excited to the ground 0\textsuperscript{+} states. Preliminary results and their interpretations will be presented.\textsuperscript{1} K. Wimmer et al., Phys. Rev. Lett. 105, 252501 (2010), pard\textsuperscript{[2]} N. Warr et al., Eur. Phys. J. A 49, 40 (2013)

Tuesday, October 15, 2019 2:00PM - 3:48PM – Session GA Alternative Career Paths for a Nuclear Physicist – Salon 1 - Evie Downie, GWU
2:00PM GA.00001 Achieving the extraordinary: Careers in Nuclear Physics at the NNSA Laboratories. NANCY JO NICHOLAS, LANL — The broad and diverse National Security mission given to the National Nuclear Security Administrations laboratories requires strategic investments in maintaining and growing its core expertise and technologies in the area of nuclear physics. Nancy Jo Nicholas, Associate Laboratory Director for Global Security at Los Alamos National Laboratory, will discuss the breadth of opportunities for nuclear physicists at the NNSA Laboratories. Nicholas holds a Masters Degree in Experimental Nuclear Physics.

The mission of Los Alamos National Laboratory is to solve the most complex national security challenges through scientific excellence. The Laboratory maintains an agile, responsive, and innovative workforce dedicated to multidisciplinary science, technology, and engineering capabilities. In addition, LANL maintains unique experimental and computational facilities, eleven of them nuclear. Lab personnel with degrees in nuclear physics work in a wide range of basic and applied research fields, technology development, as well as numerous non-traditional technical fields. The NNSA Labs support diverse programs that include scientists of many nationalities, participation in experiments worldwide, sponsorship of workshops and conferences, and classified experiments and analysis. Areas of research at Los Alamos include nuclear science, plasma physics, quantum information science, weapon stockpile modernization, weapons physics, semiconductor irradiations, detector development, neutron radiography, advanced imaging, weapons data analysis, biosecurity, image analysis, signal processing, neural computation, experimental and computational neuroscience, and more. In the Global Security Directorate, nuclear physicists work on multidisciplinary teams in the physics of arms controls, space, nuclear safeguards, and intelligence. Researchers use nuclear material in a variety of forms to pioneer nuclear safeguards concepts, develop instruments and techniques to monitor and measure nuclear materials, operate the Nations only capability for nuclear criticality experiments, and lead the development of unique and innovative special-purpose nuclear reactor concepts.

Nicholas will also touch on the national laboratories significant investments in Laboratory Directed Research and Development, career development, internships, and a wide range of summer schools.

2:36PM GA.00002 From Physics to Data Science: Contemplating Careers Outside of Mainstream Academia. CLAIR J. SULLIVAN, GitHub — Academia and traditional research settings have long been the venue employing the majority of students graduating with degrees in physics, particularly at the doctoral level. At all degree levels the total number of degrees awarded in physics has increased dramatically over the past ten years. However, this same increase in the number of degrees awarded does not correlate with a similar increase in the number of tenure-track academic positions available for those graduates. Physics degree graduates then, by interest or necessity, may need to consider alternative employment options to the traditional academic path. In this talk, we will discuss the recent boom in industrial need for data scientists. The training that physics students receive at all degree levels uniquely positions them to fill the job that has been labeled by many business analysts to be The Best Job in the US. We will discuss what skills are necessary to develop as a viable applicant and how to best prepare for this exciting field. Most importantly, we will explore how a degree in physics makes a graduate uniquely suited to work in this fast-paced and rapidly-growing discipline.

3:12PM GA.00003 From the Navy to Congress: Progressing from Physics to Policy Making. ELAINE LURIA, United States House of Representatives — U.S. Rep. Elaine Luria represents Virginia’s Second Congressional District. Prior to her election in 2018, Rep. Luria served two decades in the Navy, retiring at the rank of Commander. Rep. Luria served at sea on six ships as a nuclear-trained Surface Warfare Officer, deployed to the Middle-East and Western Pacific, and culminated her Navy career by commanding a combat-ready unit of 400 sailors. A member of the House Armed Services Committee and the House Committee on Veterans Affairs, Rep. Luria was one of the first women in the Navys nuclear power program and among the first women to serve the entirety of her career in combatant ships. She leads the House Veterans’ Affairs Subcommittee on Disability Assistance and Memorial Affairs, and is Vice Chair of the House Armed Services Subcommittee on Seapower and Projection Forces. Of all members in the House Democratic Caucus, she served the longest on active duty, having completed 20 years of active military service with the U.S. Navy. Rep. Luria graduated from the U.S. Naval Academy with an undergraduate degree in physics, and received a masters in engineering management from Old Dominion University.

She will share her career path, how her physics training has influenced that path, and give some tips for other physicists contemplating a path to policy making or elected office.

Tuesday, October 15, 2019 2:00PM - 3:36PM — Session GB Mini-Symposium: Neutrino Properties and Interactions: Results, Challenges, and Implications III Salon 2 - Phil Barbeau, Duke University

2:00PM GB.00001 ABSTRACT WITHDRAWN —

2:12PM GB.00002 Weak Neutral-Current Axial-Vector Form Factor and Neutrino-Nucleon Scattering. DAVID RICHARDS, RAZA SUFIAN, Jefferson Lab, KEN-FEI LIU, University of Kentucky — We perform a phenomenological analysis, where we combine a calculation of the strange quark electromagnetic form factor from lattice QCD with (anti)neutrino-nucleon scattering differential cross section data from MiniBooNE experiments to determine the weak axial-vector form factor $g_{A2}^{(0)}(Q^2)$. We show that the precise value of $g_{A2}^{(0)}$ obtained from the lattice calculation greatly improves the precision of the form factor extraction. Finally, we show that a consistent determination of the form factor from neutrino and anti-neutrino scattering data requires a non-zero contribution from the strange quark EM form factor in the neutral current scattering process.

2:24PM GB.00003 New cold matter effects in neutrino oscillations experiments1. MIHAI HOROI, ADAM ZETTEL, Central Michigan University — Recently (arXiv:180306332) we showed that the electron density in cold matter exhibits large spikes close to the atomic nuclei sites. We showed that these spikes in the electron densities, 3-4 orders of magnitude larger that those inside the Sun’s core, have no effect on the neutrino emission and absorption probabilities or on the neutrinoless double beta decay probability. However, it was not clear if the effect of these density spikes is consistent with an average constant electron density in condensed matter.

We now investigated these effects by a direct integration of the coupled equation of motion describing the propagation of neutrinos through cold matter, and we found significant differences between the two approaches for a baseline similar to that from Fermilab to Gran Sasso. These results will be reported, including the effects of cold matter electron densities on the evolution of the mixing amplitudes for the vacuum mass eigenstates.

1Travel support from U.S. DOE grant DE-SC0015376 is acknowledged.
2:36PM GB.00004 Improving the Sensitivity of nEXO to Neutrinoless Double Beta Decay¹. SAMUELE SANGIORGIO, Lawrence Livermore Natl Lab, NEXO COLLABORATION — The nEXO Collaboration has conceived a 5000kg liquid-xenon time projection chamber (TPC) that will enable two orders of magnitude greater sensitivity on the neutrinoless double-beta decay ($\nu_{\beta\beta}$) half-life over present experiments. Such sensitivity arises from the TPC’s capability to simultaneously measure multiple event characteristics. Combined with the use of a large homogenous detector volume, this allows to precisely assess the backgrounds while exploiting the signal from the entire liquid xenon volume. The sensitivity reach is also made possible by a strong radioassay program that carefully screens candidate detectors and by a combination of active and passive shielding in ultra-low-background detector design. In this talk, I will review the elements behind nEXO’s sensitivity, including a background model from new radioassay results, and a more detailed modeling that incorporates reconstruction of time-correlated events and interactions in the liquid xenon outside of the central TPC region. These developments, combined with others, suggest nEXOs sensitivity will exceed $10^{30}$ years for the $\nu_{\beta\beta}$ decay half-life of $^{136}$Xe.

¹This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. LLNL-ABS-779967

2:48PM GB.00005 Simulation of charge readout with segmented charge tiles in nEXO. ZEPENG LI, Yale University, NEXO COLLABORATION — nEXO is a proposed experiment to search for $\nu_{\beta\beta}$ decays of $^{136}$Xe in a single phase liquid xenon time projection chamber (TPC) with 5 tonnes of liquid xenon. The nEXO TPC is designed to use segmented charge tiles as the anode to read out ionization electrons. A dedicated simulation package is developed to study the performance of this anode design. A multivariate method and a deep neural network are developed to distinguish $\nu_{\beta\beta}$ decays and background events arising from radioactivity in the detector materials using the simulated charge signals. The nEXO TPC with charge tiles forming the anode shows promising capability to distinguish signal and backgrounds in the study. A half-life sensitivity for $\nu_{\beta\beta}$ decays is estimated with the discriminators, which suggests the potential for $\sim 32 \%$ employing the multi-variate (deep neural network) methods considered here, relative to the sensitivity estimated in the nEXO pre-conceptual design report.

3:00PM GB.00006 RD on Ba-Tagging for nEXO Using Electron Microscopy, MICKEY CHIU, Brookhaven National Laboratory, NEXO COLLABORATION — nEXO is a proposed 5 ton LXe neutrino-less double beta decay ($\nu_{\beta\beta}$) experiment to discover whether neutrinos are Majorana particles. nEXO is one of the most sensitive proposed ton-scale $\nu_{\beta\beta}$ experiments. With a projected half-life sensitivity of about $10^{30}$ years, it can cover the entire $r$ inverted mass hierarchy. This limit is partly due to radioactive backgrounds that are present in the ton-scale $\nu_{\beta\beta}$-decay region of interest. Additionally, Ba ions from Ba atoms entering the LXe volume naturally decay, emitting $\alpha$ and $\beta$ particles. Our Ba-Tagging technique aims to remove the Ba atoms, and thus Ba ions, from the LXe volume. We will present results using Scanning Transmission Electron Microscopes (STEM) to image and robustly identify single Ba atoms using Energy-Dispersive X-ray Spectroscopy (EDXS) and Electron Energy Loss Spectroscopy (EELS). This technique could provide a path for Ba-tagging in nEXO. We’ll discuss the challenges that remain in developing the entire Ba-tagging chain, from extraction of the single Ba ion out of the 5 tons of LXe to the end-stage identification. We’ll also provide a survey of the other promising Ba-tagging techniques being developed for nEXO.

3:12PM GB.00007 Current Status and Results of CUORE in the Search for Neutrinoless Double Beta Decay¹. BRADFORD WELLIVER, Lawrence Berkeley National Laboratory, CUORE COLLABORATION — The Cryogenic Underground Observatory for Rare Events (CUORE) is the largest bolometric experiment searching for neutrinoless double beta ($0\nu_{\beta\beta}$) decay. If observed $0\nu_{\beta\beta}$ could answer fundamental questions that remain about the nature of the neutrino such as the mass hierarchy, whether they are Majorana fermions, and would present new physics beyond the standard model via lepton number violation. CUORE is comprised of 988 TeO$_2$ crystals (742 kg) arranged into 19 towers, with each crystal operated as a cryogenic bolometer and began taking data in the spring of 2017. This talk will briefly describe the CUORE experiment and summarize the efforts made to improve detector performance, with an emphasis on improving the energy resolution and suppression of backgrounds in the $^{130}$Te $0\nu_{\beta\beta}$ decay region of interest. Additionally the current status of the ongoing $0\nu_{\beta\beta}$ search will be discussed as well as the present state of the CUORE experiment.

¹US Department of Energy, Office of Science, Nuclear Physics

3:24PM GB.00008 The next-phase search for $0\nu_{\beta\beta}$ decay with CUPID. GIOVANNI BENATO, University of California, Berkeley, CUPID COLLABORATION — Neutrinoless double beta ($0\nu_{\beta\beta}$) decay is a matter-creating process that violates lepton number conservation. Its discovery would prove the existence of physics beyond the Standard Model. The CUPID Upgrade with Particle IDentification (CUPID) is a proposed next-phase $0\nu_{\beta\beta}$ decay bolometric experiment aiming at a sensitivity that covers the allowed parameter space for the inverted ordering of neutrino masses. CUPID will deploy $\sim 250$ kg of $^{100}$Mo embedded in scintillating Li$_2$MoO$_4$ crystals simultaneously acting as source and detector for $0\nu_{\beta\beta}$ decay, and will actively distinguish between $\alpha$ and $\beta$ particles thanks to the readout of both the heat and scintillation light channels. In this talk, the design of CUPID, its active background rejection techniques, and expected background budget are presented.

Tuesday, October 15, 2019 2:00PM - 3:48PM –
Session GÊ Mini-Symposium: Short Range Correlations and Bound Nucleon Structure Across Scales I – 
Salon 5 - Misak Sargsian, Florida International University

2:00PM GE.00001 High-momentum nucleons in low-momentum theories. SCOTT BOGNER, Michigan State University — Ab-initio calculations of nuclei have seen explosive progress in recent years, thanks in part to simplifications that result from “low resolution” inter-nucleon interactions with minimal high-momentum components, such as those from chiral effective field theory. The low resolution picture is advantageous for structure calculations since wave functions are dominated by low momenta and are less correlated, calculations are more amenable to perturbative treatments, and mean-field approaches give a reasonable starting point. In recent years there has been impressive and rapid progress in probing the short distance/high-momentum structure of nuclei using hard electron scattering, where a high resolution picture appears to be more natural. An important question to ask is, how do we reconcile the low resolution picture that is so prevalent in microscopic nuclear structure calculations, with the high resolution picture utilized in short-range correlation studies? To address this question, I use the simplest knock-out reaction, deuterons, to illustrate how high-momentum operators (and physical interpretations!) evolve as the resolution is varied using the renormalization group.
2:36PM GE.00002 Role of Short Range Correlations in the Neutron Skin\textsuperscript{1}, GERALD A. MILLER, University of Washington — Recent experiments and many-body calculations indicate that approximately 20\% of the nucleons in medium and heavy nuclei $A \geq 12$ are part of short-range correlated (SRC) primarily neutron-proton. Previous work found that using chiral dynamics to account for the formation of np pairs due to the effects of iterated and irreducible two-pion exchange leads to values consistent with the 20\% level. Here chiral dynamics is applied to study how these correlations influence the calculations of neutron radii of nuclei.

\textsuperscript{1}US Department of Energy Office of Science, Office of Nuclear Physics under Grant No. DE-FG02-97ER-41014.

2:48PM GE.00003 ABSTRACT WITHDRAWN —

3:00PM GE.00004 Scale and Scheme Independence and Position-Momentum Equivalence of Nuclear Short-Range Correlations, REYNIER CRUZ TORRES, Massachusetts Institute of Technology — The study of Two-Nucleon Short-Range Correlations (SRCs) is an important topic in nuclear physics, and has significant implications to other fields. Obtaining a physical interpretation from Quantum Monte Carlo (QMC) calculations is very challenging, especially at small inter-nucleon distances (small-$r$) and high momenta (high-$k$). The Generalized Contact Formalism, which describes SRCs in nuclei, was used in this work to study the small-$r$ and high-$k$ behavior of nuclear \textit{(2 $\leq A \leq 40$)} QMC calculations obtained using four NN potentials that differ significantly at small-$r$ and identify which properties of SRCs are scale and scheme dependent and which are independent. We find that, while absolute abundance of SRCs (contacts) depend on the specific potential used, their ratios to $d$ or $^3\text{He}$ do not. This implies that the SRC abundance is a Mean-Property, and inclusive $(e,e')$ scattering experiments are insensitive to the small-$r$ structure of the NN interaction. We demonstrate that exclusive experiments, on the other hand, can discriminate among these different NN models. We also explore the high-$k$, small-$r$ equivalence of SRCs by comparing contacts extracted independently in these two regimes, and find that pn, spin-1 pair abundances are consistently the same.

3:12PM GE.00005 First Constraints on the Nuclear Force at Neutron Star Densities, JACKSON PYBUS, MIT, CLAS COLLABORATION — The strong nuclear interaction between nucleons is the fundamental quantity of nuclear physics. As it cannot easily be calculated directly from QCD, it is traditionally described using parameterized effective models. While these models are well-constrained at large distances by nucleon-nucleon (NN) scattering data, its short-distance behavior is largely unconstrained, limiting our ability to theoretically describe high-density nuclear systems such as neutron stars. In this talk I will present new measurements of Short-range correlated (SRC) nucleon pairs using exclusive $(e,e'NN)$ reactions done using the CLAS spectrometer at the Thomas Jefferson National accelerator Facility (JLab). The new data covers nucleon momenta range of 400 to 1000 MeV/c and is analyzed using the new theoretical framework of the Generalized Contact Formalism (GCF). We find that the GCF provides good kinematic agreement with data of such SRC breakup events and shows high sensitivity to the short-distance behavior of the nucleon-nucleon (NN) interaction. The data is well described by the phenomenological AV18 interaction up to 1000 MeV/c. Local Chiral interactions are also observed to provide a good description of the data up to their momentum- or position-cutoffs.

3:24PM GE.00006 Studies of Proton Momentum Distribution in $^4\text{He}$, FATIHA BEN-MOKHTAR, Duquesne University — Experimental cross sections for the $^4\text{He}(e,e'p)X$ reaction up to a missing momentum of 0.632 GeV/c at $x_F = 1.24$ and $Q^2 = 2$ (GeV/c)$^2$ will be presented. The data are compared to Relativistic Distorted Wave Impulse Approximation (RDWIA) calculations for $^4\text{He}(e,e'p)^3\text{H}$ channel. Significantly more events in the triton mass region are measured for $p_{\text{min}} > 0.45$ GeV/c than are predicted by the theoretical model, suggesting that the effects of initial-state multi-nucleon correlations are stronger than expected by the RDWIA model.

3:36PM GE.00007 Probing SRC in Inverse Kinematics, GORAN JOHANSSON, Tel Aviv University, SRC@BMN COLLABORATION — Short Range Correlated (SRC) pairs are two close nucleons in the atomic nucleus. The SRC pairs are usually composed of a proton and a neutron, and have high individual and relative momentum but low common center of mass momentum. Low and high are in comparison with the nuclear Fermi momentum. The SRC pairs dominates the high tail of the nucleon momentum distribution. In the last decade the experimental SRC research was done using high energy electrons and protons to search for the pairs and study the properties of the nucleons in the pair. We present here an experiment with a new approach to study SRC in inverse kinematics using a $^{12}\text{C}$ beam of 4 GeV/c/u aiming at a liquid $^3\text{He}$ target. This allows a fully-exclusive measurement including the detection and studying of the residual A-2 nuclear system, after the 2N-SRC knockout. First measurement was done during spring 2018 in the BM@N nucleotron at the Joint Institute of Nuclear Research (JINR), Dubna, Russia. In this talk we will present some new preliminary results from that measurement.

Tuesday, October 15, 2019 2:00PM - 3:36PM –
Session GG Nucleon Structure at Colliders Salon A - Sanghwa Park

2:00PM GG.00001 Investigating Nucleon Structure and Hadronization with Hadrons in Jets at STAR\textsuperscript{1}, JAMES DRACHENBERG, Abilene Christian University, STAR COLLABORATION — The STAR collaboration at RHIC provides insight into the spin structure of the nucleon through collisions of longitudinally and transversely polarized beams of protons. Spin-dependent azimuthal distributions of hadrons within jets from transversely polarized proton collisions provide access to the transverse spin structure of the nucleon. Spin asymmetries from STAR data collected in 2011 at $\sqrt{s} = 500$ GeV and in 2012 at 200 GeV give the first experimental hints that the universality of this “Collins mechanism” may extend to proton-proton collisions, as it does in SIDIS and $e^+e^-$. The STAR data also provide unique insight to the in-jet transverse momentum dependence of the Collins asymmetry, crucial for a deeper understanding of the Collins fragmentation function. The final 2011 and preliminary 2012 STAR hadron-in-jet data will be presented and discussed in context with recent global transversity analyses and model calculations.

\textsuperscript{1}Supported under US Department of Energy Grant DE–FG02–03ER41243.
dependent (TMD) formalisms. Status of the measurement of Collins asymmetry from 2015 proton+proton collisions at scattering (SIDIS, \(Q\)) of its proton, moving in the longitudinal (\(\hat{z}\)) direction. Experimentally, the Sivers function can be accessed through channels that couple to another chiral-odd distribution like the Collins fragmentation function or the transverse spin \(\vec{S}\) direction. Experimentally, the Sivers function can be accessed through channels that couple to another chiral-odd distribution like the Collins fragmentation function or the transverse spin \(\vec{S}\). The measured cross sections of electroweak charm production, although not statistically significant, are consistent with expectations.
From this, preliminary results for the $\Lambda$ elastically with a second proton in the target. The $K$ beam to be created inside the target. We look at the reaction $\gamma p \rightarrow \Lambda$ run of the CLAS detector in Hall B of Jefferson Lab. A high luminosity photon beam incident on a 40 cm liquid hydrogen target allows for a limited compared to other elastic scattering processes, such as $\pi N$ and $\pi N$. The richness of other relevant distributions. Progress on the beam spin asymmetry measurements in dihadron production from electron-proton scattering at Photon Factory, KEK, are presented. The work is supported by DOE grant no: DE-FG02-04ER41309.

The dihadron fragmentation function $F_{2}^{h}$ is measured in SIDIS at CLAS and assumes a longitudinally polarized fragmentation quark recoils and acquires nonzero transverse polarization via a wormgear-type splitting. Measuring beam spin asymmetry modulations in various production channels, including charged and neutral pions as well as kaons, will probe the flavor dependence of $G_{1}^{h}$ and other relevant distributions. Progress on the beam spin asymmetry measurements in dihadron production from electron-proton scattering at CLAS will be shown, and their potential impact on $G_{1}^{h}$ extractions will be discussed.

The data was measured using the CLAS detector at JLAB and EIC. GARY GOLDBEIN, Tufts University — Heavy quark pairs can be produced in e−p collisions at JLAB and the nucleon DAs and the hard interaction amplitude from pQCD. For the first time, we have measured single beam spin asymmetries to extract the potentially applicable collinear factorized description in terms of a convolution of the non-perturbative nucleon to-pion transitions (TDAs), and the quark-gluon distributions leave imprints on the momentum and spin correlations of the quark pairs. These correlations are distinguishable from the quark distribution mechanism. Decays of such spin entangled heavy quark pairs produce a variety of correlations among pairs of the 3-momenta of the decay products. The different angular correlations will be presented and related to measurable distributions of decay products. Some models for spin dependent gluon transverse momentum distributions and generalized transverse momentum distributions will be used to simulate the spin correlations, illustrating how to measure the gluon polarizations in electroproduction.

Tuesday, October 15, 2019 2:00PM - 3:36PM –
Session GH Electromagnetic Interactions 1 | Salon B - Daniel Carman, Jefferson Laboratory

2:00PM GH.00001 Helicity Asymmetry $E$ for $\gamma p \rightarrow \pi^{0}p$ from JLAB CLAS g9a/FROST dataset with application of Machine Learning1, CHAN WOOK KIM, The George Washington University, CLAS COLLABORATION — In pursuit of resolving the problem of missing baryon resonances, the measurement of the double polarization observable $E$ for $\gamma p \rightarrow \pi^{0}p$ was performed using a circularly polarized photon beam on longitudinally polarized proton target (FRozen Spin Target experiment) at $W$ energies between 1450 MeV and 2050 MeV. The final state particles were detected with CEBAF Large Acceptance Spectrometer (CLAS) in Hall B at the Thomas Jefferson National Accelerator Facility. During analysis of the CLAS g9a/FROST data, various types of deep neural networks were tested and employed to control the effects of hydrogen contamination on carbon targets which emerged while polarizing nearby butanol targets via Dynamic Nuclear Polarization technique. The extracted data of helicity asymmetry $E$ will be compared to the SAID, MAID and BnGa partial wave analysis predictions and included to GW SAID database to further investigate missing resonances.

In this talk, preliminary results of extracted helicity asymmetry $E$ for $\gamma p \rightarrow \pi^{0}p$ and applications of machine learning techniques will be presented.

1 This work was performed with support from US DOE DE-SC001658, The George Washington University.

2:12PM GH.00002 TDA measurements based on hard exclusive pion electroproduction with CLAS at JLAB1, STEFAN DIEHL, Justus Liebig University Giessen and University of Connecticut, CLAS COLLABORATION — Many experiments showed the QCD factorisation mechanism in the “nearly forward region” (large $Q$ and small $t$) can be divided into a hard part, described by perturbative QCD ($pQCD$) and in two general structure functions, the GPDs for the nucleon and the pion distribution amplitudes (DAs). The recent measurement from CLAS in the “nearly backward” kinematic region (large $Q$ and small $t$) provided the potentially applicable collinear factorized description in terms of a convolution of the non-perturbative nucleon to-pion transitions (TDAs), the nuclear DAs and the hard interaction amplitude from pQCD. For the first time, we have measured single beam spin asymmetries to extract $A_{1}^{\text{int}(\perp)}$ moments from the hard exclusive $\pi^{+}$ channel off the unpolarized hydrogen target in a wide range of kinematics from forward to backward angles in CMS frame. The measured moment in forward angles is known to be sensitive to generalized parton distributions (GPDs), while in backward angles, it is known to be sensitive to transition distribution amplitudes (TDAs). Our results clearly show that the sign of forward beam spin asymmetry measurements is positive whereas that of backward BSA measurements is negative, with the sign transition taking place around 90. By performing accurate measurements over a wide range of $Q$, $x_{B}$ and $-t$, we can explore the transition from hadronic to partonic reaction mechanisms. As an Outlook, first results on the exclusive pion electroproduction with CLAS12 will be presented.

The work is supported by DOE grant no: DE-FG02-04ER41309.

2:24PM GH.00003 Dihadron Beam Spin Asymmetries and Helicity-Dependent Fragmentation in SIDIS at CLAS, CHRISTOPHER DILKS, Duke University — Dihadron production in Semi-Inclusive Deep Inelastic Scattering (SIDIS) provides unprecedented access to hadron structure and to spin-orbit correlations in hadronization. Beam spin asymmetry measurements in dihadron production are sensitive to twist-3 collinear PDFs as well as dihadron fragmentation functions. In particular, the dihadron fragmentation function $G_{1}^{h}$ has not yet been experimentally constrained, and describes the correlation of the fragmenting quark helicity with azimuthal angles of the hadron pair. The quark-jet hadronization model predicts a sizeable $G_{1}^{h}$ and assumes a longitudinally polarized fragmenting quark recoils and acquires nonzero transverse polarization via a wormgear-type splitting. Measuring beam spin asymmetry modulations in various production channels, including charged and neutral pions as well as kaons, will probe the flavor dependence of $G_{1}^{h}$ and other relevant distributions. Progress on the beam spin asymmetry measurements in dihadron production from electron-proton scattering at CLAS will be shown, and their potential impact on $G_{1}^{h}$ extractions will be discussed.

2:36PM GH.00004 Photoproduction of $\Lambda^{*}$ at CLAS, UTSAV SHRESTHA, KENNETH HICKS, Ohio University, CLAS COLLABORATION — Much is known about the photoproduction of the hyperon resonances $\Lambda(1405) 1/2^{-}$ and $\Lambda(1520) 3/2^{-}$, but little is known about photoproduction to the higher-mass resonances $\Lambda(1670) 1/2^{-}$ and $\Lambda(1690) 3/2^{-}$. Both pairs of resonances are spin-orbit partners and are rated as 4-star (well-known) by the Particle Data Group. In the quark model, the $\Lambda(1405)$ and $\Lambda(1520)$ resonances are assigned to the SU(3) singlet, where the $\Lambda(1670)$ and $\Lambda(1690)$ are assigned to the octet. In this presentation, we will present differential cross sections for $\Lambda(1520) 3/2^{-}$ and preliminary look at the two hyperon octet resonances using the photoproduction data from the CLAS detector at Jefferson Lab. Future plans for a partial wave analysis, which will be necessary to resolve the individual cross sections for these two resonances, will be outlined.

2:48PM GH.00005 A Study of Lambda-Nucleon scattering using the CLAS detector, JOSEPH ROWLEY, KEN HICKS, Ohio University, CLAS COLLABORATION — Elastic scattering of Lambda baryons with protons is important to know, in part because these reactions might take place in the center of a neutron stars. Current $\Lambda N$ elastic scattering data comes primarily from bubble chamber experiments. The richness of $\Lambda$ production in modern day accelerators has thus never been realized. $\Lambda N$ data is very limited compared to other elastic scattering processes, such as $NN$, $KN$ and $\pi N$. Data was mined from existing experiments from the g12 run of the CLAS detector in Hall B of Jefferson Lab. A high luminosity photon beam incident on a 40 cm liquid hydrogen target allows for a $\Lambda$ beam to be created inside the target. We look at the reaction $\gamma p \rightarrow K^{+}\Lambda$ to generate the $\Lambda$ beam. The created $\Lambda$ then proceeded to scatter elastically with a second proton in the target. The $K^{+}\Lambda$ cross section is well known, which allows us to determine the flux of the $\Lambda$ beam. From this, preliminary results for the $\Lambda N$ cross section will be presented along with new data for its angular distribution.

This work was performed with support from US DOE DE-SC001658, The George Washington University.
3:00PM GH.00006 Study of $\Lambda$ Hyperon Fragmentation in Current and Target Regions using CLAS\textsuperscript{1} , TAYA CHETRY, LAMIAA EL FASSI, Mississippi State University, CLAS COLLABORATION — The color propagation and hadron production from hard interactions in nuclei have been extensively studied over the last few decades. These studies are related to one of the basic phenomena of quantum chromodynamics (QCD) dubbed as hadronization or fragmentation. In this process, an energetic struck quark transforms to color-neutral hadrons making it an effective probe of the confinement dynamics as well as the characteristic time-scales involved. This talk will report the first ever analysis of the semi-inclusive deep inelastic scattering of hadrons at intermediate beam energies. Furthermore, the results will lay a strong foundation for the hadronization studies using the upgraded CLAS12 spectrometer and the 11 GeV Jefferson Lab electron beam.

\textsuperscript{1}This work is supported in part by the US DOE contract # DE-FG02-07ER41528.

3:12PM GH.00007 Exclusive electroproduction of pions at Hall A, Jefferson Lab\textsuperscript{2} , BISHNU KARKI, Ohio University, DVCS COLLABORATION — Generalized Parton Distributions (GPDs) provide simultaneous spatial and momentum distribution of quarks and gluons inside the nucleons. GPDs can be accessed experimentally through hard exclusive processes like Deeply Virtual Compton Scattering (DVCS) or Deeply Virtual Meson Production (DVMP). Experiment E12-06-114 completed its data taking at the end of 2016 in Hall A at JLab. Main goal of this experiment is to measure the DVCS and exclusive $\pi^0$ electroproduction cross-sections at various $Q^2$ for three Bjorken-$x$ in valence regime. These result will provide stringent test of QCD factorization in hard exclusive processes over a wide range of $Q^2$ achieved with upgraded CEBAF to 12 GeV. I will show the most recent results for exclusive $\pi^0$ electroproduction at high Bjorken-$x$ (0.60).

\textsuperscript{2}For A2 Collaboration at MAMI

3:24PM GH.00008 Cross Section for $\gamma^* p \to \pi^0 n$ Measured at Mainz\textsuperscript{1}, IGOR STRAKOVSKY, George Washington University, WILLIAM BRISCOE\textsuperscript{2}, The George Washington University — The $\gamma^* p \to \pi^0 n$ differential cross sections were evaluated for 27 energy bins and the full range of pion production angles, making use of model-dependent nuclear corrections to extract $\gamma^* p \to \pi^0 n$ production data on the neutron from measurements on the deuteron target. Additionally, the total photoabsorption cross section was measured. The tagged photon beam produced by the 883-MeV electron beam of the Mainz Microtron MAMI was used for the $\gamma^* p \to \pi^0 n$ meson production. Our accumulation of $3.6 \times 10^{18}$ $\gamma^* p \to \pi^0 n$ events allowed a detailed study of the reaction dynamics. Our data are in reasonable agreement with previous A2 measurements and extend them to lower energies. The data are compared to predictions of previous SAID, MAID, and BnGa partial-wave analyses and to the latest SAID fit, MA19, that included our data. Selected photon decay amplitudes $N^i_{\text{ast}}(\gamma^* n)\gamma$ at the resonance poles are determined for the first time.

\textsuperscript{1}This work was performed with partial support from US DOE DE-SC0016583.

Tuesday, October 15, 2019 2:00PM - 4:00PM – Session GJ Mini-symposium: Quantitative Understanding of QGP Properties III Salon C - Nathan Grau, Augustana University

2:00PM GJ.00001 Towards a quantitative understanding of the QGP: experimental perspectives , RON BELMONT, University of North Carolina at Greensboro — Heavy ion physics is rapidly becoming a quantitative field. While the field is rich and varied with many important subfields, all these can be divided into roughly two main categories: hard probes and bulk quantities. Both are essential to understanding the inner workings of the QGP and developing a full quantitative picture. In this talk we will address both categories, what measurements are needed, and what future facilities will help accomplish these goals.

2:36PM GJ.00002 Nuclear modification factor of neutral pions in p+A, d+Au and 3He+Au collisions in PHENIX , NIVEDITHA RAM, Stony Brook University, PHENIX COLLABORATION — The suppression of neutral pion production in Au+Au collisions at RHIC, and lack of suppression in d+Au collisions are evidence a QGP was formed (in Au-Au collisions) in which hard scattered partons-in a final state effect-lose energy. Initial state, or "cold nuclear matter" effects, including the Cronin-effect, were expected to dominate very asymmetric (small on large) collisions. Recently, however, collectivity has been observed in p/d/He+A collisions, consistent with the formation of QGP droplets. While this does not necessarily imply hadron suppression, as in central Au+Au collisions, earlier d+Au results suggested exactly that, along with a surprising enhancement in peripheral d+Au. In this talk we will present the results of a systematic study of the neutral pion nuclear modification factor in p+Al, p+Au, 3He+Au along with a re-analysis of the d+Au data and compare them to previously published data and theoretical calculations.

2:48PM GJ.00003 Charm quark directed, elliptic flows and diffusion coefficient from a multiphase transport model , XINYUE JU, University of Science and Technology of China — Open charm meson directed flow ($v_1$) and elliptic flow ($v_2$) is studied in relativistic heavy-ion collisions based on a multiphase transport model (AMPT) framework with partonic interactions. The key physics questions we would like to address are how charm quark $v_1$ and $v_2$ are developed in the parton cascade and how they are sensitive to the initial condition and charm quark spacial diffusion coefficient. We study the time evolution of charm quark $v_1$ and $v_2$ in the partonic phase and compare them with those of light flavor quarks. We find that the charm quark with initial $p_T > 0$ ($p_T < 0$) can preserve the large positive (negative) $v_1$ through the partonic cascade, suggesting charm quarks can retain the momentum kick caused by initial electro-magnetic field. Charm quark spacial diffusion coefficient is calculated and its dependence on partonic scattering cross section as well as its time evolution are studied to help understand how they get manifested in the $v_1$ and $v_2$ observables. These findings are expected to guide us on how to better constrain the initial tilt of the fireball and the temperature dependence of charm quark diffusion coefficient in ultra-relativistic heavy-ion collisions.
3:12PM GJ.00005 Measurement of the suppression and azimuthal anisotropy of heavy flavor muons in lead-lead collisions at 2.76 TeV and proton-lead collisions at 5.02 TeV with the ATLAS detector\(^1\). LUKE KRAUTH, Columbia University, ATLAS COLLABORATION — ATLAS measurements are presented on the production of muons from heavy-flavor decays in pp and Pb+Pb collisions at 2.76 TeV and in p+Pb collisions at 5.02 TeV. The measurements are performed over the transverse momentum range \(4 < p_T < 14\) GeV. Backgrounds arising from in-flight pion and kaon decays, hadronic showers, and mis-reconstructed muons are removed using a template-fit procedure. The heavy-flavor muon differential cross-sections and per-event yields are measured in pp and Pb+Pb collisions, respectively. The nuclear modification factor \(R_{AA}\) is observed to be independent of \(p_T\) within uncertainties and to be less than unity, which indicates suppressed production of heavy flavor muons in Pb+Pb collisions. The flow harmonics \(v_n\) for such heavy-flavor muons are also measured in Pb+Pb and p+Pb collisions as a function of \(p_T\) and centrality or event-multiplicity. These measurements provide insight into the energy loss mechanism of heavy quarks as they propagate through the hot, dense medium produced in heavy ion collisions, and can help determine if such a medium is produced in p+Pb collisions.

\(^1\)DOE-FG02-86ER-40281

3:24PM GJ.00006 Non-UPC production of dimuons from two-photon scattering in Pb+Pb collisions with the ATLAS detector\(^1\). BENJAMIN GILBERT, Columbia University, ATLAS COLLABORATION — In relativistic heavy-ion collisions the intense electromagnetic fields of the nuclei provide a large flux of equivalent photons. This flux leads to photon-photon and photon-nucleon reactions at high center-of-mass energies. In ultra-peripheral collisions, the nuclei have large impact parameter, and the dominant interaction mechanism is through these photon-induced processes. These photon-induced processes may also occur in events with smaller impact parameter, resulting in dimuons produced in the same events in which a hot nuclear medium is formed. This talk presents ATLAS measurements of \(\gamma + \gamma \rightarrow \mu\mu\) in non-UPC collisions. The dimuons exhibit a centrality-dependent broadening of their azimuthal angle correlations suggesting that such muons provide a new probe of the medium.

\(^1\)DOE-FG02-86ER-40281

3:36PM GJ.00007 Study of the semileptonic decay of \(D^-\) and \(B^-\) mesons into muons at \(\sqrt{s_{NN}} = 200\) GeV with the PHENIX detector. AJEEA KHATIWADA, CESAR DA SILVA, XUAN LI, Los Alamos National Laboratory, PHENIX COLLABORATION — We study yields of muons from the semileptonic decay of \(D^-\) and \(B^-\) mesons at \(\sqrt{s_{NN}} = 200\) GeV with the data collected by the PHENIX experiment at RHIC. \(D^-\) and \(B^-\) mesons are expected to leave signatures of displaced vertices in the tracking detectors that can be used to measure the relative contribution from charm and bottom hadrons to the muons in the Au+Au collision. Using p+p as control, this measurement will be carried out in the forward rapidity region, exploiting the excellent displaced vertices in the tracking detectors that can be used to measure the relative contribution from charm and bottom hadrons to the muons in Pb+Pb collisions. The flow harmonics \(v_n\) for such heavy-flavor muons are also measured in Pb+Pb and p+Pb collisions as a function of \(p_T\) and centrality or event-multiplicity. These measurements provide insight into the energy loss mechanism of heavy quarks as they propagate through the hot, dense medium produced in heavy ion collisions, and can help determine if such a medium is produced in p+Pb collisions.

3:48PM GJ.00008 Multiparticle correlations from the direct calculation of cumulants using particle azimuthal angles. SHENGQUAN TUO, Vanderbilt University — Instead of using the generating function or Q-cumulant methods for multiparticle correlation studies in heavy ion collisions, we calculate the cumulants directly looping over particle azimuthal angles. It is shown that this method is not possible for central and mid-central AA collisions due to the required computing resource, but possible for smaller collision systems and peripheral AA collisions. With this method we are able to study the correlations as a function of particle pseudorapidity gap between each particle in the multiparticle correlations. The method is tested with PYTHIA and HIJING models and it provides better statistical precision than the three subevent cumulant method with a pseudorapidity gap using the same amount of data.

Tuesday, October 15, 2019 2:00PM - 4:00PM –
Session GL Instrumentation: Detectors for Heavy Ion Collisions

2:00PM GL.00001 The STAR iTPC Upgrade. IRAKLII CHAKABERIA, Kent State University, STAR COLLABORATION — Run-19 of the Relativistic Heavy Ion Collider marked the beginning of the Beam Energy Scan phase II (BES-II). The BES-II program has been inspired by the success of the first phase of the beam energy scan (BES-I). The goal of the BES-II is to accumulate a larger data set to obtain experimental measurements with higher statistical precision and thus turn trends and features found during the BES-I into definitive conclusions and new understanding. With this goal in mind, STAR has undergone several substantial upgrades in preparation for the BES-II. One of the major upgrades is the installation of the new inner TPC sectors (iTPC). The iTPC brings wider pseudorapidity coverage \(|\eta| < 1.5\) and increased reach to lower \(p_T\) down to 60 MeV/c. In addition, it provides improved \(dE/dx\) and \(p_T\) resolution, and therefore better particle identification capabilities. In this talk I will report the results of the iTPC upgrade and its successful commissioning with the cosmic ray data-taking ahead of the Run-19. I will conclude by showing its status and performance during the low energy Au+Au collisions in the Run-19.
2:12PM GL.00002 Development of the readout electronics for the sPHENIX Time Projection Chamber. KLAUS DEHMELT, Stony Brook University, SPHENIX COLLABORATION — The sPHENIX experiment at RHIC is the repurposed experiment of the PHENIX experiment that ended data taking in 2016. The sPHENIX is aiming for measuring Jets and Quarkonia at RHIC energy where the strongly coupled Quark Gluon Plasma (QGP) is formed. In order to separate Upsilon states, a tracking device that can handle a few hundreds kHz collisions and keep a 100MeV mass resolution. Therefore, we have decided to build a time projection chamber without gating grid. The signal charge has to be readout continuously which required a new readout electronics. In the new readout scheme, the signal is readout by 624 Frontend cards that have 8 SAMPA v5 chips, the new version of the one employed for ALICE TPC, and sent to a backend electronics, FELIX PCI card, designed for ATLAS experiment. The data rate from the whole TPC may reach as much as 1.4Tbps. We will show the readout scheme for the TPC and the performance from the prototype boards.

2:24PM GL.00003 Upgrade of the ALICE Time Projection Chamber. AUSTIN SCHMIER, University of Tennessee, ALICE COLLABORATION — The ALICE Time Projection Chamber (TPC) is a gaseous drift chamber used to study proton-proton and heavy ion collisions at the large hadron collider (LHC). The LHC is currently undergoing a major upgrade that will increase the event rate from 1 kHz to 50 kHz and the TPC is therefore being upgraded to handle the increased event rate. The current ALICE TPC uses multi-wire proportional chambers in conjunction with a gated grid to reduce ion backflow, which limits readout to ~3 kHz. There is a readout deadtime of roughly 400 μs. The new design will use gaseous electron multiplier (GEM) foils, allowing for reduced ion backflow and a continuous readout, meeting the 50 kHz requirement. The TPC upgrade will also require 3,600 new front end cards (FECs), each with 128 channels, in order to read the signal from the GEM foils. The FECs amplify, shape, digitize, process, and buffer the signals from the TPC. The physics motivations for the upgrade and the current progress of the construction and testing of the upgraded TPC will be discussed.

2:36PM GL.00004 ABSTRACT WITHDRAWN —

2:48PM GL.00005 Measurement Results for Micropattern Gain Structures for Use in High Rate TPCs. CAITLIN BEATTIE, JOHN HARRIS, RICHARD MAJKA, NIKOLAI SMIRNOV, Yale University, SPHENIX TPC COLLABORATION COLLABORATION — Time Projection Chambers (TPC) are often the preferred choice for central tracking and particle identification in high luminosity colliding beam experiments. A major consideration in such an environment is minimization of back flow of positive ions from the gain element into the main drift volume. This ion back flow (IBF) can lead to space charge build up in the main drift volume that will distort the drift field and the resulting measured tracks. The traditional method of controlling IBF using a grid as a gate necessitates triggering the TPC which is inconsistent with modern physics goals requiring very large data sets. We present our investigation of IBF measurements for a variety of gas mixtures, electric fields, and micropattern structures (four gas electron multipliers (GEMs), and two GEMS plus microgamas) used as the amplification region.

3:00PM GL.00006 Passive Gating Grid Studies for a Time Projection Chamber. PRAKHAR GARG, Stony Brook University — A Time Projection Chamber (TPC) is often the main tracking device in many experiments. A TPC measures space points of charged tracks to provide momentum resolution and particle identification for a variety of measurements. In high multiplicity environments, a TPC has to cope with the build-up of space charge in the drift volume from two main sources: primary ionization and Ion Back Flow (IBF) from an amplification device. One can only concentrate on combating IBF, which can be accomplished with appropriate voltages briefly grid to absorb all charges. However, this limits the operation to low readout rates. To overcome this problem, Micro-Pattern Gas Detectors (MPGD) will be implemented in future TPCs. MPGDs are inherently capable to reduce IBF, yet not to an optimum level. A passive or statically powered gating grid might enhance the IBF reduction. We have simulated woven wire meshes, different patterns of etched meshes, hexagonal micro-pattern meshes and static bi-polar wire gating grids. We have studied several options to achieve good electron transparency for the primary electrons and high blocking for the ions coming from the amplification stage. In this presentation, we will discuss our results and provide techniques for overcoming IBF.

3:12PM GL.00007 Test Beam Campaign with the sPHENIX TPC Prototype. HENRY KLEST, Stony Brook University, SPHENIX COLLABORATION — The sPHENIX experiment will utilize a Time Projection Chamber (TPC) as the central tracker. The goal of the TPC is to perform precise upsilon spectroscopy and jet measurements, both of which require high tracking efficiency and excellent momentum resolution. The sPHENIX collaboration produced a small-scale prototype TPC that features a full-sized version of the readout module and the nearly final readout electronics. This prototype was tested at Fermilab using a beam of 120 GeV protons. The results of this test-beam campaign will be discussed in this presentation.

3:24PM GL.00008 Studies of a Central Membrane for the sPHENIX TPC. SOURAV TARAFDAR, Vanderbilt University, SPHENIX COLLABORATION — sPHENIX is a future experiment at RHIC to measure jets and Upsilon for investigating the properties of the quark-gluon plasma formed in heavy ion collisions. As the central tracker it will feature a Time Projection Chamber (TPC) that is used to measure charged particle tracks. The TPC is sandwiched in between inner tracking detectors and electromagnetic and hadronic calorimeters and also a 1.4 Tesla superconducting solenoid magnet. The TPC will be equipped with micropattern gas detectors for providing the space point resolution and reducing the space charge problem inherent to a TPC. The TPC will also depend on a central membrane which is substantial for supplying a uniform drift field amongst others. A variety of simulations with different designs of the membrane have been performed ranging from the investigation of the tracking performance to jet fragmentation. In this presentation we will discuss these extensive studies.
3:36PM GL.00009 RD studies of a small-strip thin gap chamber as a STAR forward tracker

PRASHANTH SHANMUGANATHAN, Brookhaven National Laboratory, STAR COLLABORATION — The STAR experiment at the Relativistic Heavy Ion Collider is en route on a forward upgrade to address open questions in the QCD physics in very low and very high Bjorken-\(x\), during \(p+p\) and \(p+\text{Au}\) collisions planned in the years 2021 and beyond. Measurements from \(\text{Au}+\text{Au}\) collisions will enable to probe the longitudinal structure of the nuclear initial state as well as transport properties. The detector upgrades, the Forward Calorimeter System and the Forward Tracking System, provide precise identification of pions, photons, electrons, jets and as well as hadrons in the pseudorapidity region 2.5 to 4. The forward tracking system is a combination of silicon mini-strip detectors and small-strip thin gap chambers (STGC), which provide charge sign discrimination, and excellent photon and electron identification. STGCs are the variant of Multi-Wire Proportional Counters, which provides better spatial resolution at high particle flux regions. In between collision point and forward calorimeters four planes of STGC chambers are planned to be installed, and each plane contains two chambers to measure \(x-y\) diagonal position for tracking. Two prototype chambers, each \((30\text{ cm})^2 \times 0.28\text{ cm}\) was built. In this talk, we will present the test results from the R&D studies.

3:48PM GL.00010 Test Beam Results for a Spectator Reaction Plane Detector for Use at the CERN LHC

S. LASCIO, D. MIGNEREY, University of Maryland, College Park, JZCAP TEAM — The ability to determine the reaction plane of a heavy ion collision using spectator neutrons is key to the study of directed flow and the chiral magnetic effect (CME) in these reactions. A shower max detector, the Spectator Reaction Plane Detector (SRPD) has been developed to map spectator neutron positions at zero degrees. The SRPD is comprised of a \(4 \times 4\) array of \(2 \times 2 \times 1\) cm quartz elements. In this specific design the SRPD is positioned between two elements of a Zero Degree Calorimeter (ZDC). The detector performance was evaluated using a Pb beam at the SPS test beam facility at CERN. The results will be compared to a GEANT simulation of the detector for the specific test beam parameters, with implications for the design of a second generation detector for incorporation into a new ZDC for the CERN LHC Run 3.

Tuesday, October 15, 2019 2:00PM - 3:12PM — Session GM QCD Theory

2:00PM GM.00001 Electric Polarizability of Hadrons from Lattice QCD

HOSSEIN Niyazi, ANDREI ALEXANDRU, FRANK LEE, George Washington University — Electric and magnetic polarizabilities are two of the fundamental properties of hadrons which help us understand the distribution of charge and currents inside hadrons and how they respond to external electromagnetic fields. For nucleons, these values are determined experimentally from Compton scattering. For charged pions, the experiments are more challenging since no free pion is available and the results are less precise, but a number of experiments are planned that will improve the accuracy. Lattice QCD can be used to compute hadron properties as determined by quark and gluon dynamics, providing results that are complementary to other theoretical approaches. In this talk I will review the lattice QCD methods used to compute hadron polarizabilities, focusing on electric polarizability, and present our results.

2:12PM GM.00002 More Gluons in the Pion

PATRICK BARRY, North Carolina State University, NOBU SATO, Old Dominion University, WALLY MELNITCHOUK, Jeffrey Lab, CHUENG JI, North Carolina State University — Looking at the QCD-motivated picture of the pion, we can use parton distribution functions (PDFs) to describe the probability of finding a quark, antiquark, or gluon in the pion at a certain momentum fraction, \(x\), and energy scale, \(Q^2\). Because PDFs are universal in observables in which factorization occurs, we may use data from multiple QCD processes to shape them. In the case of pions, people have traditionally used Drell-Yan (DY) data to fit pion PDFs, but DY data only exist at large-\(x\). In this region, the valence quark distributions are known to dominate. Any PDFs determined from DY data alone in the small-\(x\) region are mere extrapolations and cannot be trusted. More recently, we have used Leading Neutron (LN) data to shape the PDFs at small-\(x\). The determinations of these PDFs using both DY and LN datasets show that gluons contribute to 30% of the total momentum of the pion at the input scale compared with 10% from determinations using strictly DY data. Current work includes soft gluon resummation, which improves perturbative calculations in the DY process. Soft gluon radiation from quark lines contribute nontrivially to the cross-section at large-\(x\), which helps to constrain the valence quark distribution as \(x\) goes to 1.

2:24PM GM.00003 Collinear Factorization in Wide-Angle Hadron Pair Production

ERIC MOFFAT, Old Dominion University, TED ROGERS, Old Dominion University/Jeffrey Lab, ANDREA SIGNORI, Argonne National Lab, NOBU SATO, Old Dominion University/Jeffrey Lab — We compute the inclusive unpolarized dihadron production cross section in the far from back-to-back region of \(ee^-\) annihilation within leading order pQCD and using standard collinear factorization. We compare with event generator predictions from PYTHIA, and examine how the degree of agreement varies with the center-of-mass energy. While we find reasonable agreement at large center-of-mass energies, at moderate energies (~12 GeV) we find order-of-magnitude or larger disagreement, which is shown to yield the same leading nonanalytic behaviors in the chiral limit, as expected in QCD. Using the same chiral effective theory framework, we also compute the pseudoscalar meson loop contributions to flavor asymmetries in parton distributions, such as the \(d-u\) and \(s-\bar{s}\) quark asymmetries in the proton.

2:36PM GM.00004 Baryon self-energies in relativistic chiral SU(3) effective theory

MARSTON COPELAND, Department of Physics and Astronomy, Clemson University, Clemson, SC 29634, USA, CHUENG-RYONG JI, Department of Physics, North Carolina State University, Raleigh, North Carolina 27695, USA, WALLY MELNITCHOUK, Jeffrey Lab, Newport News, Virginia 23606, USA — We calculate the self-energies of the flavor SU(3) octet and decuplet baryons, using a relativistic chiral effective theory framework consistent with Lorentz and gauge invariance. The results are compared using several different regularization prescriptions, including finite-range regularization, Pauli-Villars, and dimensional regularization, which are shown to yield the same leading nonanalytic behaviors in the chiral limit, as expected in QCD. Using the same chiral effective theory framework, we also compute the pseudoscalar meson loop contributions to flavor asymmetries in parton distributions, such as the \(d-u\) and \(s-\bar{s}\) quark asymmetries in the proton.
2:24PM GN.00005 Fermion-mass and charge renormalization using relativistic, time-dependent quantum mechanics. TIMOTHY KUTNICK, ATHANASIOS PETRIDIS, Drake University — The time-dependent electromagnetically self-coupled Dirac equation is solved numerically by means of the staggered-leap-frog algorithm with reflecting boundary conditions. The stability region of the method versus the interaction strength and the spatial-grid size over time-step ratio is established. The expectation values of several dynamic operators are then evaluated as functions of time. These include the fermion and electromagnetic energies and the fermion dynamic mass. There is a characteristic time-dependence leading to asymptotic constants of these expectation values. In the case of the fermion mass and charge this amounts to renormalization. The dependence of the expectation values on the spatial-grid size is evaluated in detail and result in finite mass and charge. The contribution of positive and negative energy states to the asymptotic values and the gauge fields is analyzed. A statistical method, employing a canonical ensemble whose temperature is the inverse of the spatial-grid size, is used to remove the momentum-dependence and produce a finite result for each spatial-grid size value. The continuum limit is then taken to calculate both the fermion mass and charge. The renormalization mass correction is about 10% while the charge correction is about 30%.

3:00PM GN.00006 Phenomenological modeling of first-order phase transition in QCD1. THOMAS WELLE, University of Minnesota, CHRISTOPHER PLUMBERG, Lund University, JOSEPH KAPUSTA, University of Minnesota — We present a method for parametrizing the equation of state of QCD in multiple phases. This method involves the use of a switching function, taking values between 0 and 1, which interpolates between the equations of state for two phases as a function of temperature T and baryon chemical potential. As per the conjectured QCD phase structure, this function is constructed to be smooth for all T and except along a line of first-order phase transition which extends from some critical point to the T=0 axis. We use this method to model the transition between the hadron resonance gas and quark-gluon plasma phases of nuclear matter. These results are compared to results of lattice calculations for the case of 3 colors and 3 flavors.

1This work was supported by the U.S. Department of Energy (DOE) Grant No. DE-FG02-87ER40328.

Tuesday, October 15, 2019 2:00PM - 3:48PM — Session GN Nuclear Structure II — Salon K — Elizabeth McCutchan, Brookhaven National Laboratory

2:00PM GN.00001 Study of nuclear structure of 32Mg to probe the island of inversion1. YONGCHI XIAO, BEN CRIDER, Mississippi State University, SEAN LIDDICK, KAITE CHILDEERS, Michigan State University, PARTHA CHOWDHURY, EDWARD LAMERE, UMass Lowell, REBECCA LEWIS, BRENDEN LONGFELLOW, Michigan State University, STEPHANIE LYONS, NSCL, SHREE NEUPANE, DAVID PEREZ-LOUREIRO, UTK, TIMILEHIN OGUNBEKU, Mississippi State University, CHRIS PROKOP, LANL, ANDREA RICHARD, NSCL, UMESH SILWAL, DURGA SIWAKOT, DYLAN SMITH, Mississippi State University, MALLORY SMITH, NSCL — At the limits of the nuclear landscape, nuclei may exhibit different ground state properties as the result of shell evolution. At the center of the N=20 island of inversion in Mg, a recently identified shape coexistent excited 0+ state was found with potentially large mixing with the ground state. Exploring the nature of these 0+-states, and the states that are built on top of them, is important for understanding shape coexistence and configuration mixing in this region. An experiment was performed at NSCL to study Mg via the decay of Na and Na (3n) which utilized a CeBrimplantation-decay detector along with ancillary detection arrays for energy and timing characterization. Preliminary results and a tentative level scheme produced from this work will be presented.

1This work was supported in part by the National Science Foundation (NSF) under Grant No. PHY-184177 (CAREER), and DOE National Nuclear Security Administration through the Nuclear Science and Security Consortium, under Award No. DE-NA0003180.

2:12PM GN.00002 Ground-state magnetic-dipole moment of 37Ca*. K. MINAMISONO, A. J. MILLER, B. A. BROWN, J. WATKINS, NSCL/Department of Physics and Astronomy, MSU, A. KLOSE, Department of Chemistry, Augustana University, D. GARAND, C. SUMITHRARACHCHI, NSCL, MSU, J. D. HOLT, A. TEIGELHÖFER, TRIUMF, J. D. LANTIS, S. V. PINEDA, NSCL/Department of Chemistry, MSU, Y. LIU, Physics Division, ORNL, B. MAA, W. NÖRTERSHUSS, D. M. ROSSI, F. SOMMER, Institut für Kernphysik, Technische Universität Darmstadt, A. SCHWENK, Institut für Kernphysik, Technische Universität Darmstadt/GSI/Max-Plank-Institute für Kernphysik — The ground-state magnetic-dipole moment of 37Ca, which has one neutron add to 36Ca with the neutron number N = 16, was determined to probe the closed-shell nature of the 36Ca nucleus. The hyperfine spectrum of the D2 transition in 37Ca ion was measured using collinear laser spectroscopy technique at BECOLA at NSCL/MSU. The resulting magnetic moment was compared with the shell model and in-medium similarity renormalization group calculations. The details of experiment and results will be discussed.

*This work was supported in part by the NSF, Grants No. PHY-15-65546 and No. PHY-18-11855; the U.S. DOE, NNSA, Grant No. DE-NA000924; the U.S. DOE, Office of NP, Office of Nuclear Physics, Grant No. DE-AC05-00OR22725 with UTBattelle, LLC; NSREC of Canada, Grant No. SAPPJ-2017-00039; and the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) - Projektnummer 279384907 - SFB 1245.

2:24PM GN.00003 Cross-shell configurations in 38Cl structure and the quest for a new shell model interaction. REBEKA SULTANA LUBNA, KONSTANTINOS CRAVARIUS, SAMUEL TABOR, VANDANA TRIPATHI, ALEXANDER VOLYA, ELIZABETH RUBINO, Florida State University, JAMES ALLMOND, Oak Ridge National Laboratory, BRITTANY ABROMEIT, LACY BABY, THAXTER HENSLEY, Florida State University — 38Cl with Z = 17 and N = 21 has long been recognized as providing a window into the interactions between r1d5/2 and r2f7/2 nucleons. The availability of a 14C beam to occur a fusion evaporation reaction in conjunction with the γ-detector array at the John. D. Fox laboratory has allowed further exploration of the higher-spin structure of 38Cl to elucidate the role of excitations across the N = 20 shell gap. Comparison with microscopic structure models has proved very fruitful in the past in interpreting level schemes, but were limited by the need to adjust the N = 20 shell gap for cross-shell excitations for different nuclei. Therefore, we developed a microscopic effective interaction based on fitting the shell model cross-shell interaction matrix elements over a wide range of particle-hole states in nuclei across the sd shell and beyond. The main focus was to tune the monopole terms across the shell gaps, N = 8 and N = 20. The valence space of the new FSU interaction comprises the spsdpf model space, compatible to the normal and intruder states of the sd shell isotopes. The shell model calculations using FSU interaction have been performed in this work to better understand the structure of 38Cl and some nearby even A Cl isotopes.
2:36PM GN.00004 Probing Spin-Isospin Excitations in Proton-Rich Nuclei via the (p,n) Reaction\textsuperscript{1}, JACLYN SCHMITT, REMCO ZEGERS, DANIEL BAZIN, ALEX CARLS, NSCL/MSU, ALYSSA DAVIS, Swarthmore College, MILES DENDERT, NSCL/MSU, BINGSHUI GAO, Institute of Modern Physics, CHARLES HULTQUIST, SHUMPEI NOJI, JORGE PEREIRA, RACHEL TITUS, NSCL/MSU, JUAN ZAMORA, Universidade de São Paulo — Tracking the evolution of nuclear properties away from stability serves as a valuable test for nuclear models. The proton-rich nuclei \( ^{12}\text{O} \) and \( ^{11}\text{N} \) were studied via the (p,n) reaction in inverse kinematics using \( ^{12}\text{N} \) and \( ^{11}\text{C} \) beams, respectively, at 100 MeV/A at the National Superconducting Cyclotron Laboratory (NSCL). The differential cross sections can be calculated from the energy and angle of the recoil neutrons, measured by the Low Energy Neutron Detector Array (LENDA). Then the Gamow-Teller transition strength can be extracted from the cross section and compared to predictions of theoretical models. In the case of \( ^{12}\text{O} \), the resulting structure information can also be compared to the mirror nucleus \( ^{12}\text{Be} \) to explore possible mirror symmetry breaking for extreme proton-to-neutron ratios. This experiment will also establish the (p,n) reaction as a probe to extract Gamow-Teller strengths from proton-rich nuclei, which can be used to study isotopes up to the \( ^{100}\text{Sn} \) region during the FRIB era. Progress of the analysis for this experiment will be presented.

\textsuperscript{1}This work is supported by the U.S. National Science Foundation PHY-1430152 (Joint Institute for Nuclear Astrophysics Center for the Evolution of the Elements) and PHY-1565546.

2:48PM GN.00005 Inverse-kinematics proton scattering from \(^{42,44}\text{S}^\text{41,43}\text{P}\), L. A. RILEY, S. D. GREGORY, E. B. HALDEMAN, B. R. KLYBOR, M. A. LIGGETT, L. M. SKILES, Ursinus College, P.D. COTTLE, K. W. KEMP, VOLYA, Florida State University, D. BAZIN, J. BELARGE\textsuperscript{2}, P. C. BENDER, B. A. BROWN, B. ELMAN, A. GADE, S. LIPSCHUTZ, B. LONGFELLOW, E. LUNDERBERG, T. MIJATOVIC, J. PEREIRA, R. TITUS, D. WEISSHAAR, J. C. ZAMORA, R. G. T. ZEGERS, NSCL, Michigan State University — Excited states of \(^{42,44}\text{S}^\text{41,43}\text{P}\) have been studied via inverse-kinematics proton scattering from a liquid hydrogen target, using the GREITINA \( \gamma \)-ray tracking array. Proton-scattering deformation lengths of the \( ^2_1^+ \) excitations in \(^{42,44}\text{S}^\text{42,43}\text{P}\) have been combined with electromagnetic deformation lengths to yield the ratio of neutron-to-proton matrix elements \( M_n/M_p \). The status of the \( N = 28 \) major shell gap approaching \(^{42}\text{Si}\) is discussed in light of the systematic behavior of \( M_n/M_p \) in even-even nuclei, and the \(^{41,43}\text{P}(p,p')\) results are used to compare the SDPF-U and SDPF-MU shell-model interactions.

\textsuperscript{2}This work was supported by the NSF under Grant PHY-1617250, PHY-1064819, PHY-1565546, and 1401574, and by the DOE Office of Science. Operation at NSCL was supported by the DOE under Grant DE-SC0014537 (NSCL) and DE-AC02-05CH11231 (LBNL).

3:00PM GN.00006 (CEU) Study of excited neutron-rich \(^{44,45}\text{Ca}\) isotopes populated through fusion-evaporation\textsuperscript{1}, ANDREW MACGREGOR, PETER BENDER, University of Massachusetts Lowell — The search for high-spin states with a clear n-particle-hole configurations are key to unraveling the mysteries of evolving nuclear structure. Such states are often high spin in nature and naturally populated via the fusion-evaporation reaction mechanism. Through careful gamma spectroscopy, these states can be unambiguously identified and used as rigorous tests to state of the art nuclear theory. A recent experiment at the John D. Fox superconducting Laboratory at FSU was preformed to examine such states. Here, a \(^{12}\text{C}\) beam was imponed on a \(^{36}\text{S}\) target at 34-Mev. The experimental setup included an array of HPGe detectors as well as a Si telescope for identification of evaporated charged particles. In this work, the alpha evaporation channel will be presented and the detailed gamma-ray spectroscopy results for \(^{44,45}\text{Ca}\) will be presented. Aspects of the experimental approach and data analysis will be presented. Final results will be discussed and compared to recent shell model calculations.

\textsuperscript{1}This material is based upon work supported by the U.S. Department of Energy, Office of Science and Office of Nuclear Physics under contract number DE-FG02-94ER40848.

3:12PM GN.00007 High-spin States and Cross-shell Excitations in \(^{46}\text{Ca}\), JOHN ASH, HIROMONI IWASAKI, NSCL, Michigan State Univ, TEA MIJATOVIC, Ruder Boskovic Institute, ROBERT ELMAN, MARA GRINDER, NSCL, Michigan State Univ, YUTAKA UTSUNO, Advanced Science Research Center, Japan Atomic Energy Agency, CHING-YEN WU, JACK HENDERSON, Lawrence Livermore National Laboratory, DIRK WEISSHAAR, ALEXANDRA GADE, MARK-CHRISTOPH SPIEKER, NSCL, BRANDON ELMAN, BRENDEN LONGFELLOW, DANIEL RHODES, NSCL, Michigan State Univ — Investigation into the evolution of shell structure often necessitates probing far from stability, near the neutron dripline. However, in the case of the calcium isotopes, previously inaccessible high-spin states in stable nuclei offer a new direction to examine structure near doubly-magic \(^{48}\text{Ca}\). These state energies can inform shell model interactions and improve our understanding of cross-shell excitations in the region. To achieve this end, previously unknown states in \(^{46}\text{Ca}\) were populated using the first fusion evaporation reaction at the reaccelerated beam facility (ReA3) of the National Superconducting Cyclotron Laboratory. Using particle and gamma coincidence techniques, several new transitions were observed and compared to large-scale shell model calculations.

\textsuperscript{1}This work was supported by the Department of Energy National Nuclear Security Administration through the Nuclear Science and Security Consortium under Award Number(s) DE-NA0003180.
Electroweak transitions in intermediate mass nuclei

3:24PM GN.00008

GREGOR SARGSYAN, KRISTINA LAUNEY, Louisiana State University, TOMAS DYTRYCH, Nuclear Physics Institute, 250 68 Rez, Czech Republic, JERRY DRAAYER, Louisiana State University — We present beta decay rates and B(E2) strengths calculated using the \textit{ab initio} symmetry-adapted no-core shell model (SA-NCSM). The SA-NCSM utilizes emergent symmetries in nuclei in order to reduce the dimensionality of the model space. This, in turn, allows one to reproduce the low-energy nuclear dynamics with only a small fraction of the model space, and hence making solutions to heavier nuclei feasible. The symmetry-adapted basis of the SA-NCSM is well suited for describing electromagnetic and beta-decay transitions enabling us to use the full capability of the model and perform calculations for sd-shell as well as pf-shell nuclei. This work discusses the reproduction of B(E2) strengths in intermediate-mass nuclei from first principles and without effective charges. It also focuses on a study of the $g_4$ quenching problem for bare interactions (no renormalization involved) and with collective correlations that are well described within the model, as well as on a study of $^{48}$Ca and $^{49}$Ti of interest to neutrinoless double beta decays.

1Supported by the U.S. NSF (ACI-1713690, OIA-1738287) and the Czech Science Foundation (16-16772S). This work benefited from computing resources provided by Blue Waters, LSU (www.hpc.lsu.edu), and the National Energy Research Scientific Computing Center (NERSC).

Detailed spectroscopy following the $^{14}$C on $^{36}$S fusion-evaporation reaction

3:36PM GN.00009

PETER BENDER, PETER DEROSA, DANIEL FOULDS-HOLT, ANDREW MACGREGOR, University of Massachusetts Lowell, SAMUAL TABOR, VANDANA TRIPATHI, REBEKA LUBNA, ELIZABETH RUBINO, Florida State University, JAMES ALLMOND, Oakridge National Laboratory — High-spin state in neutron-rich Sc isotopes were produced using the $^{36}$S($^{14}$C, $p_{3\nu}$) reaction at 34-MeV at Florida State University(FSU). The FSU $\gamma$-array, which is a mix of both signal crystal and clover-style HPGe detectors, was used to detect the prompt $\gamma$-radiation. A silicon telescope placed at $0^\circ$ was used to detect and clearly identify charged particles released from the reaction. The level scheme for $^{47}$Sc has been extended, approaching the neutron separation energy. Natural alignment following the reaction has allowed angular distributions to be extracted. States with clear particle-hole configurations have been identified from proton-$\gamma - \gamma$ coincidences. The experimental results will be presented and discussed in light of recent shell-model calculations.

1This material is based upon work supported by the U.S. Department of Energy, Office of Science and Office of Nuclear Physics under contract number DE-FG02-94ER40848.

Tuesday, October 15, 2019 4:00PM – 6:00pm
Salon 4 - Shelly Lesher, University of Wisconsin, La Crosse

HA.00001 Optimizing Performance of a Charge-Sensitive Amplifier for the LEGEND-200 Experiment

GANNON LAWELEY, University of Oklahoma, Lawrence Berkeley National Laboratory, LEGEND COLLABORATION — The observation of neutrinoless double-beta decay would provide evidence for the proposition that neutrinos are their own antiparticle, a property that is not prescribed in the Standard Model. The proposed Large Enriched Germanium Experiment for Neutrinoless double beta Decay (LEGEND) will search for this decay mode in $^{76}$Ge by deploying high-purity germanium (HPGe) detectors enriched in this isotope. The signal from two hundred kilograms of HPGe detectors will be fed to low-radioactivity, charge-sensing amplifiers (CSA) deployed in the first phase of the LEGEND experiment: LEGEND-200. We optimized the performance of the CSA in different test conditions by varying the operating parameters (including voltages supplied to the active components of the CSA) and measured the properties of the amplified waveforms, such as rise time, dynamic range, and electronic noise. The optimized parameters lead to waveforms with the following characteristics: 90 ns rise time, a dynamic range from 0 - 10 MeV, and noise of 620 keV (FWHM) at a total power consumption of 156 mW in liquid nitrogen. The optimization process will continue as the circuit is integrated with other components of the experiment.

1This work was prepared in partial fulfillment of the requirements of the Berkeley Lab Undergraduate Research (BLUR) Program, Managed by Workforce Development & Education at Berkeley Lab. This material is based upon work supported by the U.S. NSF, DOE-NSF, and NERSC.

HA.00002 Selected Configuration Interaction using Reinforcement Learning

LIHAO YAN, University of Notre Dame, LI ZHOU, Fudan University, CHAO YANG, Lawrence Berkeley National Laboratory, MARK A. CAPRIO, University of Notre Dame — Configuration interaction (CI) is a widely used method for solving quantum many-body problems. The challenge of CI is to solve a large sparse eigenvalue problem. The dimension of the eigenvalue problem grows rapidly as the number of particles and the size of the Slater determinant basis increases. For many problems, the low-lying and ground state eigenfunctions exhibit localization, i.e., most of the CI coefficients are negligibly small. One approach, often referred to as the selected CI method, selects many-body basis functions, i.e., Slater determinants, that have large coefficients to construct a finite dimensional accurate approximation of the many-body Hamiltonian. However, we can only select a small subset of the important basis functions using physical intuition. Typical selected CI algorithms use perturbation theory, but they are not globally optimal. In this work, we use a reinforcement learning (RL) strategy to refine the algorithm. Each state of the RL algorithm corresponds to a particular set of many-body basis. Each action removes some basis and adds new basis into that set. A better set of basis functions is obtained after multiple training episodes. We test the performance of our algorithm against several other selected CI algorithms.

1This work was supported in part by the Department of Energy under Grants No. DESC000018223 (SciDAC-4/NUCLEI) and supported in part by the US DOE under Award No. DE-FG02-95ER-40934
HA.00003 Measurement of Optical Properties of Tetraphenyl Butadiene. SAMUEL NAUGLE, GABRIEL D. OREBI GANN, MICHINARI SAKAI, University of California, Berkeley / LBNL, SCOTT KRavitZ, LBNL, DAN MCKINSEY, University of California, Berkeley / LBNL, RYAN SMITH, University of California, Berkeley — Liquid argon is a popular detection medium for both neutrino and dark matter experiments, due to the high light yield and potential for high-resolution pulse shape discrimination. A wavelength shifter, such as tetraphenyl butadiene (TPB), is required in order to detect the extreme UV photons produced in particle interactions. This poster presents updates on ongoing work to characterize the microphysical optical properties of TPB. By shining UV light on thin-film TPB samples of varying thickness, both in vacuum and submerged in liquid argon, and then looking at the angular reemission distribution using a PMT, we can measure properties of the TPB, such as UV absorption length and photon reemission quantum efficiency. We have constructed a detailed, high-precision Monte Carlo model of our apparatus. A mirror is used to calibrate the Monte Carlo simulation, as well as discern to which systematic effects our experiment is most sensitive. By comparing the Monte Carlo simulation with data, this study will yield refined measurements of the microphysical properties of TPB, allowing for more control and confidence in any model of this material for next-generation detector design. This poster will present the most recent results from this work, including model predictions and vacuum data.

HA.00004 Understanding quantum phase behavior through gamma-ray spectroscopy of 154Gd. ZOE RECHAV, Department of Physics, Truman State University, Kirksville, MO 63501, USA, E. A. MCCUTCHEON, National Nuclear Data Center. Brookhaven National Laboratory. Upton, New York 11973, USA, S. ZHU, C. J. LISTER, J. P. GREENE, M. P. CARPENTER, R. V. F. JANSSENS, T. L. KHOO, T. LAURITSEN, D. SEWEYNIK, Physics Division, Argonne National Laboratory, Argonne, Illinois 60439, USA — Nuclei that undergo rapid transitions from spherical to deformed states can be modeled using quantum phase transitions. At N= 90, discontinuous binding-energies indicate the simultaneous existence of spherical and deformed structures. To expand upon our knowledge of quantum phase transitional behavior at N= 90, the decay of 154Eu to 154Gd was studied with the Gammasphere array at Argonne National Laboratory. The ultra high statistics data set allowed for precise determination of transition intensities between low-lying states in 154Gd important for interpretation of its structure. The new intensities will be used to re-evaluate the efficiency of various theoretical models to describe the phase and shape transition of 154Gd. This work was supported by the DOE Office of Nuclear Physics under contract DE-AC02-06CH11357 and DE-AC02-98CH10946.

HA.00005 19F(d,p)20F measurements using the Super-Enge Split-Pole Spectrograph with implications to Type-I X-ray bursts. ALEX CONLEY, RAFFY TRAAS, SHELLY LESHER, UW. La Crosse, GORDON MCCAIN, KEN HANSELMAN, LAGY BABY, PAUL COTTLE, CHRIS ESPARZA, KIRBY KEMPER, FSU, ANTHONY KUCHERA, GRAY SELBY, Davidson, JESSICA NEBEL-CROSSON, LEW RILEY, Ursinus, INGO WIEDENHOEVER, FSU — Accreting neutron binary systems generate frequent x-ray bursts upon breaking out from the hot Carbon-Nitrogen-Oxygen (CNO) cycle to the rapid proton-capture process (p) by the 19O(a,γ)19Ne(p,γ)20Na reaction chain. Previous studies investigated the 19Ne(p,γ)20Na reaction rate by using the 19Ne(d,n)20Na mirror reaction, relying on experimental data from the isospin-mirror reaction 19F(d,p)20F and shell model calculations to determine which states will populate with significant cross sections. We investigate the 19F(d,p)20F reaction as an indirect study of the 19Ne(d,n)20Na to obtain reliable data and lessen existing uncertainty of the thermal reaction rate. This work was performed using the Super-Enge Split-Pole Spectrograph at FSUs John D. Fox Accelerator Laboratory to measure high-resolution spectra of high-lying states in 20F. Absolute cross sections and spectroscopic factors are determined for proton resonances in 20F at 0.66, 2.04, 2.19, 2.97, 3.49, and 3.53 MeV energies which contribute to the level structure of 20F.

1This work was partially supported by the NSF under grant No. Phy-1712953, 1429019, 1713816 and by FSU.

HA.00006 Single-Neutron Transfer to 50Ti. J. M. NEBEL-CROSSON, L. RILEY, Ursinus College, L. T. BABY, P. COTTLE, J. C. ESPARZA, K. HANSELMAN, K. KEMPER, G. MCCAIN, I. WIEDENHOEVER, Florida State University. A. CONLEY, S. LESHER, R. TRAAS, University of Wisconsin-La Crosse, A. KUCHERA, G. SELBY, Davidson College — Single-neutron states of 51Ti have been studied using the reaction 50Ti(d,p)51Ti with a deuteron energy of 16 MeV at the John D. Fox Laboratory at Florida State University using the Super-Enge Split-Pole Spectrograph. Proton momentum spectra were measured at a scattering angle range of 15-50 degrees at five deuteron energies. This work is motivated by discrepancies between recent inelastic proton-scattering measurements of collective octupole states of neutron-rich calcium and titanium isotopes and Random Phase Approximation predictions, which depend on empirically-determined single-neutron structure beyond 48Ca. Preliminary results and plans of future analysis will be discussed.

1This work was supported by the National Science Foundation under Grant Nos. PHY-1617250 and PHY-1712953 and partially by PHY-1429019 and Florida State University.

HA.00007 10B(d,p)11B and 25Mg(d,p)26Mg measurements using the Super-Enge Split-Pole Spectrograph. GRAY SELBY, ANTHONY KUCHERA, Davidson, GORDON MCCAIN, KEN HANSELMAN, LAGY BABY, PAUL COTTLE, CHRIS ESPARZA, KIRBY KEMPER, FSU, ALEX CONLEY, RAFFY TRAAS, SHELLY LESHER, UW. JESSICA NEBEL-CROSSON, LEW RILEY, Ursinus, INGO WIEDENHOEVER, FSU — Two experiments were performed using the Super-Enge Split-Pole Spectrograph at Florida State Universitys John D. Fox Accelerator Laboratory to measure high-resolution spectra of states in 26Mg and 11B through the use of (d,p) single-particle transfer reactions. Spin assignment confirmation of five states above the proton threshold of 26Si are necessary for assessing the astrophysical impact of the 25Al(p,γ) reaction rate on the 26Al cosmic abundance. We investigate 25Mg(d,p)26Mg as a mirror to 26Al to assign spin to the mirrors to the states of interest. A previous study observed beta-delayed proton emission in the neutron-rich nucleus 11Be with an unexpectedly high decay mode strength that can only be understood if the decay proceeds through a new single-particle resonance in 11B strongly fed by beta-decay. A recent pre-print corroborates the study, providing the expected excitation energy. While the resonance in 11B was not found, spin assignments of 11B states were assigned, one of which was previously unassigned.

1This work was supported by FSU.
HA.00008 Calculation and Normalization of Selected 26Mg (alpha, n) Cross Sections.

KRISTIN RINGHAN, CECILIA FASANO, University of Notre Dame, MEIKO VOLKNANDT, BENJAMIN BRUECKNER, RENE REIFARTH, Goethe University Frankfurt, MICHAEL WIESCHER, University of Notre Dame — An evaporated 26Mg target on tantalum backing was exposed to alpha-particle beam using the 2-MeV Van de Graaff accelerator at Goethe University Frankfurt, and the 26Mg (alpha, n) cross section calculations for five beam energies between 1830 and 2000 keV. The use of a 3He spectrometer at zero degrees relative to the target allowed separation of neutrons in the region of interest from thermal neutrons. Cross sections were normalized with respect to 11B(alpha, n) cross sections for the corresponding energies, which were also measured using the 2-MeV Van de Graaff. While both targets showed evidence of deterioration throughout the process, this was more obviously evident for the 26Mg target. As this measurement follows prior target development and characterization, investigating appropriate target backings and thicknesses for this measurement, the significant deterioration observed provides additional information about 26Mg target stability under beam. When considered in combination with complications when using thinner targets, these observations suggest a need for thick targets and further characterization of target deterioration in order to increase the accuracy of further cross section measurements.

HA.00009 26Mg(alpha,n) and Br(n, gamma) Cross Section Measurements.

CECILIA FASANO, KRISTIN RINGHAN, University of Notre Dame, MEIKO VOLKNANDT, BENJAMIN BRUECKNER, RENE REIFARTH, Goethe University, Frankfurt, MICHAEL WIESCHER, University of Notre Dame — The cross sections of two different reactions were measured using the 2.5 MeV Van de Graaff accelerator at Goethe University, Frankfurt to parameterize varying stellar processes associated with understanding the origin of elements in the universe. 26Mg (alpha, n) was measured using a proton beam over a beam energy range of 1.8-2.0MeV. A 3He spectrometer counted neutrons between the thermal region and reaction region from which yields and cross sections were calculated. Cross sections from this reaction will provide a constraint on neutron flux in stellar environments. To provide a constraint on stellar processes which occur in environments with lower neutron density, Br(n, gamma) activation and decay rates were similarly investigated. The number of activated nuclei as a function of energy was determined using gamma spectroscopy and germanium detectors. Ten minute activations of natural bromine led to cross section measurements of Bromine isotopes with most focus on 82Br which has a half life of minutes and requires sensitive detectors to measure. A more rigorous understanding of this cross section will help constrain the stellar s-process especially in our own sun. Together these two reactions provide better context for current astrophysical models and theories.

HA.00010

Half-life measurements of isotopes relevant to the astrophysical p-process carried out via photoactivation at the Madison Accelerator Laboratory (MAL)

, TYLER HAIN, ADRIANA BANU, James Madison University — One of the projects underway at MAL is related to measurement of photodisintegration reaction rates for the nucleosynthesis of the p-nuclei. Due to the low isotopic abundances of the p-nuclei, the half-lives of isotopes with fewer neutrons than the p-nuclei tend to be measured with large uncertainties. Our goal was to improve the uncertainty on existing data for the half-lives of 73Se, 69Ge, 83Sr, and 83Zn. These isotopes were produced at MAL via photoactivation, gamma-spectroscopy was used to measure the activity of the samples over time and determine the half-life of each isotope using three data analysis methods. To confirm that they gave accurate results, we first tested these methods on a well-known isotope; an isomer of indium (116m1In) with a half-life of 54.29(17) min. A weighted mean of 8 separate measurements yielded a measured half-life for 116m1In of 54.35(02) min, which agrees with the accepted value and is more precise. The final results and uncertainties obtained for the half-lives of 73Se, 69Ge, 83Sr, and 83Zn will be presented by comparing the three data analysis methods that were applied.

HA.00011 Temperature Dependence Measurement of the Light Yield in Stilbene

, ISAIAH COX, East Tennessee State University, ZHAOWEN TANG, MELISSA BOSWELL, STEVEN CLAYTON, JOHN GOETT, ELENA GUARDINCERRI, NGUYEN PHAN, JASON LASHLEY, TAKEYASU ITO, Los Alamos National Laboratory — Dark matter particle masses have been well constrained in the > 10 GeV/c² range due to current direct detection efforts. To probe lower masses, it is necessary to use low Z elements in detectors, which produce higher nuclear recoil energies. We plan to explore the possibility of using hydrocarbon crystals as material for scintillation/phonon detection. Here, we present the temperature dependence of light yield for a stilbene crystal (C₁₂H₂₆) down to 4 Kelvin which will help determine the energy threshold for photon detection.

HA.00012 Development of the Position Sensitive Scintillator Detector (PSSD) for ANASEN

, P. HEDLESKY, University of Dallas, S. MARLEY, J. BLACKMON, C. DEIBEL, A. HOOD, R. MALECEK, A. RYAN, G. GUZIK, M. NAUMAN, B. ELLISON, LSU — The Array for Nuclear Astrophysics and Structure with Exotic Nuclei (ANASEN) will be used to study reactions that are important to the formation of elements using beams of radioactive nuclei at the Tri-University Meson Facility (TRIUMF). This program will focus on the cosmological lithium problem and X-ray burst nucleosynthesis. We will describe the development of an upgrade to ANASEN and testing at Louisiana State University. The detector system uses two different types of detectors to measure reaction products and reconstruct the excitation function. Two rings of silicon detectors will measure the trajectory and energy of the reaction products. The Position Sensitive Scintillator Detector (PSSD) is being developed to measure the x-y position and intensity of the radioactive ion beam. The PSSD uses an array of 4x4 silicon photomultipliers (SIPM’s) to accomplish these measurements. Preliminary results from testing will be presented and performance of the PSSD discussed.
HA.00013 New Insights into Backbending from the Symmetry-adapted Shell Model  
NICK HELLER, Harvey Mudd College, GRIGOR SARGSYAN, KRISTINA LAUNEY, Louisiana State University — We provide new insights into the backbending phenomenon from first principles and intrinsic deformation. Backbending refers to an abrupt increase of moment of inertia at high spins along the yrast band, as observed from the nuclear spectroscopy. Here, we use the ab initio symmetry-adapted no core shell model (SA-NCSM) [1] with chiral potentials, now applicable to heavy nuclei in its valence-shell version, to investigate backbending and moment of inertia from a microscopic perspective. For two traditional isotopes, 32Ne and 48Cr, the microscopic calculations confirm the important role of spin alignment and configuration mixing, but surprisingly unveil no anomalous increase in moment of inertia. Furthermore, for 48Cr, we are able to reconcile contradictions between earlier mean-field and SU(3) shell models [2] while we confirm a spherical high-spin nucleus, we find a close interplay of prolate and oblate deformed configurations with an overall spherical shape. The outcome opens the path toward further understanding heavier nuclei systems, their rotations and moments of inertia. [1] K. D. Launey, et al., PPNP 89, 101 (2016). [2] R. A. Herrera and C. W. Johnson, PRC 95, 024303 (2017).

HA.00014 Characterizing gravitational wave signals from core-collapse supernovae  
NOAH WOLFE, SANJANA CURTIS, SOMDUTTA GHOSH, North Carolina State University, KEVIN EBINGER, GSI Helmholtzzentrum fuer Schwerionenforschung, CARLA FROHLICH, North Carolina State University — Core-collapse supernovae (CCSNe) are the explosive deaths of massive stars, and multi-messenger events which produce signals including gravitational waves, neutrinos, isotope abundances, and light in a multitude of wavelengths. With the next-generation of gravitational wave telescopes (Advanced LIGO/VIRGO), it may soon become possible to detect gravitational waves originating from CCSNe. Here, we compute the gravitational wave eigenfrequencies for a set of CCSNe models based on the PUSH method. The models span a range of progenitor zero-age main sequence masses and two different nuclear equations of state (DD2 and SFHo). We will discuss the influence of the progenitor properties and the equation of state on the gravitational wave signal.

HA.00015 Predicting Cosmogenically Activated Isotopes in Ge-76 Detectors in the MAJORANA DEMONSTRATOR Neutrinoless Double-Beta Decay Experiment  
RILEY FERGUSON, North Carolina State University, MAJORANA COLLABORATION — The Majorana Demonstrator is an array of point-contact Ge detectors fabricated from Ge isotopically enriched in 76Ge to search for neutrinoless double beta decay, an as yet unobserved form of nuclear decay requiring neutrinos to be Majorana particles (their own antiparticles). Extending half-life limits beyond those already demonstrated requires careful control of radioactive contaminants that contribute backgrounds to 0νββ searches. Cosmogenic activation of germanium, the production of radioisotopes through exposure to cosmic-rays, is a potential source of background in the Demonstrator, and for this reason efforts were taken to limit the exposure of germanium material and detectors (through shielding and underground storage) to cosmic rays throughout the construction process. Exposure was tracked throughout this process and recorded in a database; we have developed a database parser and activation calculation toolkit based in python, and are using it to calculate expected levels of cosmogenic activation based on these database records. An overview of the software suite, our calculations of expected activation rates, and preliminary background estimates will be presented. Impacts for the next-generation LEGEND experiment will also be considered.

HA.00016 2-Proton Decay from Exotic Nuclei  
MIRA GHAZALI, Michigan State University — A recent experiment at the National Superconducting Cyclotron Laboratory measured the two-proton decay of 39Ar in order to better understand this decay mode into the sd-shell. The experiment couples the S800 spectrograph to a small silicon-cesium iodide (Si-CsI) array, along with a 2D scintillating fiber array. The Si detector is used to determine the angle of the two protons, and combining the Si and CsI allows one to distinguish between different charged particles and measure their total energy. The fiber array records the angle of the heavy residue emitted from the decay. The S800 spectrograph measures the total energy and identifies the 28S decay residue. A proper energy calibration is needed to accurately analyze data from the experiment. Each detector (along with the fiber array) in the experimental setup requires its own calibration. The ancillary detectors, which include the Si and CsI detectors, call for a linear calibration; this is unlike the S800 spectrograph, which is composed of several different detection systems and consist of different techniques of calibration.

HA.00017 Effects of columnar recombination using a gas-ionization chamber for heavy, high-energy beams  
ANDREW PYPE, MSU NSCL, HIRA TEAM — The HiRA group at the National Superconducting Cyclotron Laboratory (NSCL) set out to test a new system for identifying isotopes in heavy (Z > 82) radioactive beams. The energy and velocity of each beam particle are used to establish its charge and mass. Gamma rays emitted by short-lived isotopes are measured in coincidence. These characteristic gammas are then used to identify specific isotopes in an energy loss vs time-of-flight plot. In order to measure the energy loss of the beam, a gas ionization chamber collects electrons ionized by the beam passing through its gas volume. The electrons drift towards the anode along a constant electric field parallel to the beam, where the signal is amplified and digitized. A common problem faced with ionizing gas detectors is columnar recombination, where a liberated electron recombines with a positive ion. Because this is a stochastic process, it can adversely effects the energy resolution. The effect is explored for beams in the Pb region at high energy, up to 85 MeV/A.

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This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, the Particle Astrophysics and Nuclear Physics Programs of the National Science Foundation, and the Sanford Underground Research Facility.
HA.00018 Neutron Interactions in GRETINA. C. HULTQUIST, D. WEISSHAAR, J. BELARGE, E. KIWN, T. MIJATOVIĆ, National Superconducting Cyclotron Laboratory (NSCL), R. TITUS, R.G.T ZEGER, B.A. BROWN, A. GADE, S. LIPSCHEUTZ, J. SCHMITT, C. SULLIVAN, NSCL, Joint Institute for Nuclear Astrophysics (JINA), Department of Physics and Astronomy, Michigan State University, E.M. NEY, J. ENGEL, Department of Physics and Astronomy, The University of North Carolina at Chapel Hill, D. BAZIN, B. ELMAN, B. LONGFELLOW, E. LUNDERBERG, NSCL, Department of Physics and Astronomy, Michigan State University, P.C. BENDER, Department of Physics, University of Massachusetts Lowell, C.M. CAMPBELL, Lawrence Berkeley National Laboratory, B. GAO, Institute of Modern Physics, Chinese Academy of Sciences, S. NOJI, J. PEREIRA, NSCL, JINA, J.C. ZAMORA, Instituto de Física, Universidade de Sao Paulo — GRETINA is a high-resolution γ-ray spectrometer consisting of segmented germanium crystal detectors that are subject to high-energy neutron damage via the destruction of the crystal lattice structure. Recently, GRETINA was used in a (t, He+) probe of the 86Kr nucleus, where a triton beam was accelerated towards Krypton gas cell, contained within two Kapton foils (C22H18N2O5). t(p,n)3He events from interactions with Hydrogen in the Kapton foil were isolated to study the interactions of neutrons in GRETINA. Neutron-induced peaks and other phenomena were identified in the measured spectra from neutron events in the germanium crystals. These experimental results will be compared to Geant4 simulations to study the efficacy of simulations to replicate neutron interactions in GRETINA.

HA.00019 Neutron Unbound States in the N=20 Island of Inversion. ROBBIE SEATON-TODD, ANTHONY KUCHERA, Davidson College, NATHAN FRANK, JOHN MCDONALD, Augusta College, PAUL DEYOUNG, WILLIAM VON SEEGER, Hope College, THOMAS BAUMANN, DAYAH CHRISMAN, PAUL GUEYE, Michigan State University, MONA COLLABORATION — Radioactive beams are used to study the properties of neutron-rich nuclei out to the neutron drip line, particularly where the N=20 shell gap disappears, known as the “island of inversion.” This region is of interest because the mechanisms driving these changes in nuclear shell structure are not fully understood. An experiment at the National Superconducting Cyclotron Laboratory was conducted, using a 511Mg secondary beam, to better characterize the structure of these exotic nuclei, by populating neutron-unbound excited states in this region. Experimental reaction targets in which rare nuclei and their decay are observed are made thicker for more reactions to occur or thinner for better energy resolution. To observe both good resolution and more reactions a segmented target comprised of alternating Be reaction targets and Si detectors was used. Additionally, the Modular Neutron Array, the large multi-Institutional Scintillator Array (MoNa-LISA), and the Sweeper Magnet were used to perform invariant mass spectroscopy to reconstruct the decay energies of populated unbound states. Results, including decay energies of select nuclei, will be discussed.

†The operation of the National Superconducting Cyclotron Laboratory at Michigan State University is supported by the NSF under grant PHY-1565546

HA.00020 Uncertainty Estimates for Bound States, Resonances, and Scattering of Light Ions†. BENJAMIN LUNA, Tennessee Technological University, THOMAS PAPENBROCK, University of Tennessee — The low-energy structure of neutron halo nuclei is well understood using effective field theories with zero-range interactions. However, this approach yields inaccurate results at leading order for charged-particle halos. We propose instead to describe the low-energy structure of charged-particle halos through a finite-range interaction potential. We use a two parameter delta-shell potential plus the Coulomb potential and compute charge radii, asymptotic normalization coefficients, scattering lengths, effective ranges, and scattering phase shifts for 6Li, 7Li, 7Be, 8Be, and 17F. We also make an attempt to estimate uncertainties due to the adjustment of parameters to data and systematic model uncertainties. Our results agree with data within uncertainties, and we make several predictions. This opens the way to compute S factors of astrophysically relevant reactions with uncertainties.

†This work has been supported by the Joint Institute of Nuclear Physics and Applications at Oak Ridge National Laboratory, the U.S. Department of Energy under grant No. DE-FG02-96ER40963, and contract DE-AC05-00OR22725 with UT-Battelle, LLC (Oak Ridge National Laboratory). B.K. Luna was also partially supported by the U.S. Department of Energy under grant No. DE-SC0016988

HA.00021 Study of Vibrations in the Nab Magnetic Spectrometer. HUNTER PRESLEY, Undergraduate - University of Tennessee, Knoxville, ORNL NAB COLLABORATION COLLABORATION — The Nab experiment intends to precisely measure the beta decay correlation parameters “a” and “b” for the free neutron. The experiment is in the process of being commissioned on the Fundamental Neutron Physics Beamline at the Spallation Neutron Source of the Oak Ridge National Laboratory. The focal point of the experiment is the seven meter, superconducting, magnetic spectrometer which is used to measure electron energy and proton time-of-flight. The magnet is cooled to 4 kelvin by four mechanical cryocoolers positioned on the upper and lower half of the magnet. Each cold head contains a moving valve operating at about one hertz. The motion of these valves is coupled to the magnet and small amplitude vibrations can be felt by hand. If large enough, the vibrations will cause the detectors to move in the magnetic field, which gives rise to an additional source of noise. The detectors are located at the upper and lower end of the spectrometer. To evaluate the potential impact of the vibrations, an accelerometer was used to measure vibration spectrum for each cryocooler cold head and as well for both ends of the spectrometer. I’ll describe the measurements where I used an Endevco model 2228B accelerometer read by a Hewlett Packard Spectrum Analyzer. I’ll give results including reference measurement of floor vibration.

HA.00022 Measuring the Properties of a Supersonic Gas Jet Target. MIA GRACE CANTRELL, University of Tennessee Knoxville, KELLY CHIPPS, MATTHEW HALL, Oak Ridge National Laboratory, KATE JONES, University of Tennessee Knoxville — Stellar explosions are the result of runaway nuclear reactions, but testing these reactions in the laboratory can be difficult. Supersonic gas jet targets can help us study some of these astronomical processes, because many of the nuclear reactions involve isotopes that only exist as gasses. The SOLenoid and Supersonic Target in Structure Experiments (SOLSTISE) experimental system at Oak Ridge National Laboratory has been made to test the implementation of a supersonic gas jet target inside a solenoidal spectrometer, like the Helical Orbit Spectrometer at Argonne National Laboratory. The design of a gas jet target system inside a solenoidal spectrometer is a difficult task, because shadowing of the reaction particles by the jet infrastructure must be minimized, and the vacuum pumps must be placed far away from the magnetic field. Tests are currently being conducted to minimize shadowing by testing different gas receiver cones, and measurements of the energy loss of alpha particles through the jet allow for the determination of jet density profiles for each cone. These preliminary jet density profiles and cone designs will be presented.
HA.00023 Characterizations for a Mirror Neutron Search\textsuperscript{1}. TAYLOR DENNIS, East Tennessee State University, NN’ COLLABORATION — To date, there has been no conclusive evidence as to what kinds of particles make up dark matter. The nn’ Collaboration has developed an experiment at the Spallation Neutron Source (SNS) to search for a possible dark matter candidate, mirror matter, by using a cold neutron beam. Using strong magnetic fields with high gradients, through a hypothetical transition magnetic moment, it is possible that a neutron may oscillate into its mirror neutron counterpart. After initial production, any mirror (sterile) neutrons will pass through a strong neutron absorber and then into another strong magnetic field where some may oscillate back and be detectable. Thus, the regeneration of neutrons from the mirror state, if the process exists in nature, can be discovered. I will present neutron beam characterizations, background analyses, and implications for statistical sensitivity limits for this beyond Standard Model search.

\textsuperscript{1}This work was supported in part by the U.S. Department of Energy, Office of Science, Office of Workforce Development for Teachers and Scientists (WDTS) under the Science Undergraduate Laboratory Internship (SULI) program. This research used resources at the Spallation Neutron Source, a DOE Office of Science User Facility operated by the Oak Ridge National Laboratory.

HA.00024 Analysis of $\gamma\, p \rightarrow p\, \pi^0\pi^0$ Reaction at CLAS\textsuperscript{1}. MIRANDA CARVER, Ohio University, CLAS COLLABORATION — Hall B of Jefferson Lab used the CEBAF Large Acceptance Spectrometer (CLAS) detector to study different properties of nuclear matter. One goal of studying nuclear matter is to understand the basis of the quark-quark interaction. Studying different particle reactions helps further this understanding, and adds to the overall knowledge of the field. The $\gamma\, p \rightarrow p\, \pi^0\pi^0$ photoproduction reaction was measured using the CLAS detector at Jefferson Lab, where all the particles were detected. The aim of this study is to investigate $\gamma\, p \rightarrow p\, f_2$ (1270) signal. The branching ratio of the $f_2$ (1270) to $\pi^0\pi^0$ is 28%. The $f_2$ (1270) meson has been studied before but never via the $\pi^0\pi^0$ channel. This channel is unique because it does not have a dominant $\rho$ meson background which allows for the extraction of the $f_2$ (1270) signal easily. Data for photoproduction of the $f_2$ (1270) can be compared with theoretical calculations that include multi-gluon exchange between the incident photon and the proton target. By comparing data and theory, we will learn more about the role of gluons in the quark-quark interaction. In addition, the $t$ distribution will be computed for photoproduction of the $f_2$ (1270) meson, over incident photon energies from 3.5 to 5.5 GeV.

\textsuperscript{1}Support from the NSF is gratefully acknowledged.

HA.00025 Lifetime Measurements in $^{74}$As\textsuperscript{1}. COLIN HAWES, R. A. HARING-KAYE, K. D. JONES, K. Q. LE, Ohio Wesleyan University, J. DÖRING, Bundesamt für Strahlenschutz, B. ABROMEIT, R. DUNGAN, R. LUBNA, S. L. TABOR, P. L. TAI, VANDANA TRIPATHI, J. M. VONMOSS, Florida State University, S. I. MORROW, Houghton College — The irregular signature-splitting pattern in the positive-parity band in $^{74}$As has recently been suggested to result from an underlying triaxial shape. Lifetime measurements could be used as a way to test this assertion, but so far they are unavailable for high-spin states. Thus the goal of this work was to measure as many lifetimes as possible in $^{74}$As using the Doppler-shift attenuation method in order to test the existing interpretation of its positive-parity structure. High-spin states in $^{74}$As were populated using the $^{14}$C($^{62}$Ni, $\beta\beta\gamma$) reaction at 50 MeV performed at Florida State University. Γ decay decays were measured in coincidence using a Compton-suppressed array of 10 Ge detectors. Three lifetimes were measured within the positive-parity band and used to infer the quadrupole deformation parameter $\beta_2$ as a function of spin. The experimental $\beta_2$ values were then compared with theoretical ones extracted from total Routhian surface calculations. Although the experimental trend in the $\beta_2$ values are not reproduced by the calculations, the magnitudes of two experimental values are in agreement and triaxial shapes appear to be favored.

\textsuperscript{1}This project was funded by the National Science Foundation under Grant No. 1658998 (OWU REU) and 14-01574 (FSU).

HA.00026 Lifetimes Within the 73Se Nucleus\textsuperscript{1}. DEXTER ALLEN, R. HARING-KAYE, K. JONES, K. LE, Ohio Wesleyan University, J. DRING, Bundesamt für Strahlenschutz (Germany), B. ABROMEIT, R. DUNGAN, R. LUBNA, S. TABOR, P.-L. TAI, VANDANA TRIPATHI, J. M. VONMOSS, Florida State University, S. I. MORROW, Houghton College — There is considerable uncertainty in the literature regarding the cascade intensities of the decay sequences in $^{73}$Se. In particular, the degree to which each state is populated by side feeding can vary considerably. The goal of this work was to measure as many lifetimes as possible in $^{73}$Se by gating from above the transition of interest in order to eliminate the effects of uncertainties in side feeding intensities. This was made possible by the excellent γ-ray counting statistics for $^{73}$Se provided by the $^{14}$C($^{62}$Ni, 3$n$) reaction performed at Florida State University using a beam energy of 50 MeV and with a Compton-suppressed Ge detector array consisting of 3 Clover detectors and 7 single-crystal detectors. The Doppler-shift attenuation method was used to measure all lifetimes. Seven lifetimes were measured, four within the strongest positive-parity band and three within the favored negative-parity band. From these lifetimes the quadrupole deformation parameter $\beta_2$ could be inferred and compared with those predicted for these states as a function of spin. In general, the experimental trends were not reproduced in the calculations.

\textsuperscript{1}This project was funded by the Ohio Wesleyan University Summer Science Research Program and National Science Foundation under Grant No. 14-01574 (FSU).

HA.00027 Production of Nuclei on the Proton Dripline using MARS at Texas AM University\textsuperscript{1}. ISAIAH RICHARDSON, Old Dominion University, Norfolk, Virginia — Proton-rich nuclei at the proton dripline have been produced at beam energies of >77MeV/u at facilities such as GANIL and NSCL at Michigan State University. At Texas A&M, our goal is to produce these proton-rich nuclei at energies around 40 MeV/u with beam from the K500 cyclotron, and separate these nuclei using the Momentum Achromat Recoil Spectrometer (MARS). We used a spectrometer simulator, LISE++, to devise an experiment with a $^{40}$Ca beam at 40 MeV/u on Be, Al, and Ni targets to determine how to optimally produce $^{55,56}$Ca. We tuned MARS to the parameters LISE++ predicted to see how much of these exotic nuclei we could produce in experiment. The products were detected with a $\Delta E$ vs. E Si telescope to determine the yield of each isotope. It was concluded that at this energy, the Ni target had the highest production rate for the nuclei close to the proton dripline. The comparison between the experimental production rates and the production rates LISE++ predicted will be presented.

\textsuperscript{1}National Science Foundation REU Grant (PHY-1659847)
HA.00028 Machine Learning: Potential Application for Particle Identification\textsuperscript{1}, PARKER ADAMSON, Angelo State University, MIKE YOUNGS, Blinn College — In this project we examined the potential use of machine learning to significantly decrease the time required to analyze FAUST (Forward Array Using Silicon Technology) data without sacrificing the quality and confidence of the results. Networks of varying structure were first trained using SRIM which simulated perfect, 2\%, and 5\% detector resolution FAUST data. Each trained network was then tested on data disjoint from its training set of each resolution. Under the same procedure we trained and tested neural networks on real experimental data which had been identified using the traditional linearization method. This project establishes the validity and some constraints to the ultimate goal of this research, which is applying one network trained on data from a detector and then applying the network to further data from both that detector and other detectors, through the use of transfer learning, to expedite the analysis process.

\textsuperscript{1}This work was supported by the NSF REU Grant PHY-1659847 and the Welch Foundation Grant A-1266.

HA.00029 Production of X(3872) in Ultra Relativistic Heavy Ion Collisions\textsuperscript{1}, MATTHEW SIBILA, Ohio Northern University, RALF RAPF, XIAOJIAN DU, Texas A and M — The X(3872) particle, discovered in 2003 by the Belle collaboration, is of particular interest due to its structure being either a tetra-quark bound state or a molecular state. Its structure can be understood via an investigation of its production yields and spectra in Ultra Relativistic Heavy Ion Collisions (URHICs). We calculate the yields with a statistical hadronization model evaluating at either chemical freeze-out or kinetic freeze-out. The calculation is further extended with a rate-equation approach with its temperature-dependent hadronic width, accounting for its off-equilibrium production. Furthermore, the transverse-momentum spectra can be evaluated from a blastwave description.

\textsuperscript{1}NSF REU Grant PHY-1659847

HA.00030 Extraction of bismuth from nitric acid media using 1-octanol and hydrophobic liquid binary mixtures, AMY L. VONDER HAAR, Cyclotron Institute, Texas AM University; Department of Chemistry and Biochemistry, Montclair State University, EVGENY E. TERESHATOV, CHARLES M. FOLDEN III, Cyclotron Institute, Texas AM University —\textsuperscript{211}At is a promising nuclide for cancer treatment with a 7.2 h half-life and 5.9 MeV $\alpha$-emission. It is produced in a cyclotron by irradiation of metallic bismuth in the reaction $^{209}$Bi($\alpha$, 2n)$^{211}$At. However, prior to radiotherapy, astatine must be separated from the target. In order to perform this separation, bismuth behavior under astatine separation conditions must be understood and therefore is of medical relevance. To address this issue, the extraction of the radioactive tracer isotope $^{207}$Bi (T\textsubscript{1/2} = 32.2 y) from varying nitric acid concentrations into an array of organic solvents is examined in this work. $^{207}$Bi is used in place of $^{209}$Bi due to the increased sensitivity the radioactivity of $^{207}$Bi provides while maintaining the same behaviors in solution. The organic solvents used include 1-octanol and hydrophobic liquid binary mixtures consisting of combinations of DL-menthol, methyl anthranilate, ibuprofen, lidocaine, and Proton Sponge\textsuperscript{TM}. For each solvent, the partition of $^{207}$Bi between aqueous and organic phases has been measured and summarized in distribution ratio curves as a function of initial nitric acid concentration. The shape of these curves provides insight into the mechanism and efficacy of extraction. The results of this work will be presented.

\textsuperscript{2}This work was supported in part by NSF grant number PHY-1659847 and the U.S. DOE (NNSA) through grant number DE-NA0003841.

HA.00031 Measurement of proton quenching factors in p-terphenyl\textsuperscript{1}, MIRIAM MATNEY, Rice University, CODY PARKER, SHUYA OTA, Cyclotron Institute, Texas A&M University, GREGORY CHRISTIAN, DUSTIN SCRIVEN, STEFANIA DEDE, MICHAEL ROOSA, Cyclotron Institute and Department of Physics and Astronomy, Texas A&M University — The organic scintillator p-terphenyl (C\textsubscript{15}H\textsubscript{12}) is fast, bright, and provides excellent pulse-shape discrimination (PSD). These properties make p-terphenyl a versatile scintillator for use in neutron detectors. In order to characterize the scintillation efficiency of p-terphenyl for more accurate data collection, it is important to understand the amount of quenching as a function of particle energy. Quenching accounts for molecular de-excitation that does not result in the production of light in the scintillator. In this work, quenching factors were measured via a monoenergetic proton beam from the K150 cyclotron at the Texas A&M University Cyclotron Institute at several energies from 3 MeV to 15 MeV. A 15-mm x 15-mm x 25-mm crystal of p-terphenyl was coupled to a photomultiplier tube and irradiated with a proton beam under vacuum. The quenching factor was determined by the relationship between the incident proton energy and the measured proton energy.

\textsuperscript{1}This work was supported by the NSF under REU grant #PHY-1659847 and the US DOE (NNSA) through grant number DE-NA0003841.

HA.00032 Improved waveform analysis techniques for gamma ray spectroscopy\textsuperscript{1}, ERIC LESTER, Cyclotron Institute, Texas A&M University — The evolution of Population III stars has never been directly observed. Indirect techniques may provide crucial constraints on the proposed models of these stars. A planned experiment will study the $^7$Be($^6$Li, d)$^{11}$C reaction to investigate the $^7$Be($\alpha$, $\gamma$)$^{12}$C reaction rate for its contribution to the hot pp-chain. An important facet of this experiment will be the detection of gamma rays from the decay of states around the alpha threshold in $^{11}$C. The Texas CsI Array for Astrophysical Measurements (TexCAAM) has been created for this purpose, and this work concerns the testing of the device. Offline processing tools for digitized waveforms were developed and tested for potential energy resolution improvements over conventional ADC electronics. Other programs were created to determine angular correlations between successively emitted gamma rays and with an external deuteron signal. This software can be used in future experiments to not only to confirm the population of astrophysically important excited states in the $^7$Be($^6$Li, d)$^{11}$C reaction, but also to constrain the spin and parities of other nuclei of interest. Developing results are presented, including a comparison of the methods developed in this work and conventional ADC techniques.

\textsuperscript{1}This work was supported by the NSF under REU grant #PHY-1659847; the US DOE, Office of Science under grant #DE-FG02-93ER40773; and by the NNSA through the CENTAUR under grant #DE-NA0003841.
HA.00033 Geometric analysis of three-body nuclei using Efimov physics\textsuperscript{1}. AUDREY FARRELL, Stony Brook University, ALDO BONASERA, Texas AM University Cyclotron Institute, HUA ZHENG, Shaanxi Normal University — The Thomas theorem describes loosely bound two-body quantum systems that become strongly bound as three-body systems, with a series of excited levels known as Efimov states. Using hyper-spherical geometries to describe two- and three-particle nuclei, we performed fits of total energy to known binding energies in order to determine the weighting of short-range potentials in a given interaction. When applying the appropriate scattering lengths and ranges to the system, we were able to replicate the binding energies of these nuclei with few fitted parameters. With this method, we tested various models for different light nuclei and compared which geometries reproduced the binding energy most accurately. Once we had performed enough fits to have estimates of the two-body potentials for systems of neutrons and protons, we extended our model by treating these systems as point particles in order to reproduce binding energies for heavier isotopes. Using this method we can make predictions of which experimentally measured binding energies correspond to Thomas and Efimov states.

\textsuperscript{1}This work was supported by NSF grant number PHY-1659847 and NNSA grant number DE-NA0003841 (CENTAUR).

HA.00034 Dual-Axis Duo-Lateral Detector Signal Recreation Events. MOLLY ASLIN, Mount Holyoke College, MIKE YOUNGS, ANDY HANNAMAN, SHERRY YENNELLO, Texas AM University Cyclotron Institute — The dual-axis duo-lateral (DADL) silicon detector, used in the Forward Array Using Silicon Technology (FAUST), displays a particularly high position resolution and has previously been seen to minimize a pin cushion effect often seen in similar silicon detectors. However, it is estimated that 5% of incident protons and 1% of incident alpha particles are not picked up by the DADL detector and must be recreated manually. Using proton and alpha beams from the K150 cyclotron, we look to see how position on the detector affects signal resolution. We have isolated some extrema of a DADL detector using a brass mask, which will shield off most of the detector with the exception of selected edges and corners. By analyzing the full waveform for each incident particle, we are able to examine the locations where these contacts prove unreliable and verify how accurate our methods of signal recreation actually are. We have produced maps of position resolution for the DADL and as such, we are able to further characterize the position resolution on the detector.

HA.00035 Radiation Damage Recovery of PbWO\textsubscript{4} Crystals with Optical Bleaching. SEAN OH, University of Connecticut — Deeply Virtual Compton Scattering (DVCS) is the easiest way to study Generalized Parton Distributions, revealing correlations between spatial and momentum distributions of partons within a nucleon. An electromagnetic calorimeter is currently being designed for DVCS experiments in Hall C at Jefferson Lab in Virginia, USA. The calorimeter will consist of an array of 1080 PbWO\textsubscript{4} (CENTAUR) crystals, known to be radiation-hard with good light yield, still undergo damage during radiation exposure; the crystal's light transmittance is reduced as a result, consequently lowering the energy resolution of the calorimeter. However, the radiation damage can be recovered by injecting blue light into the PbWO\textsubscript{4} crystal, a method known as optical bleaching. The calorimeter will adopt this method to endure a high radiation environment in Hall C using crystal optical fibers and blue LEDs, which will also be used for detector calibration. I will present the performance of the optical bleaching system for the electromagnetic calorimeter, as well as the extent of radiation damage sustained by the optical fibers and LEDs. This work was conducted at the Institut de Physique Nucléaire d’Orsay, France during summer 2019 and supported by the National Science Foundation IRES Award No. 1658713.

HA.00036 Efficiency Measurements for HPGe Detectors. MEGAN STURM, GABRIEL CHARLES, NOURREDINE HAMMOUDI, The Institut de Physique Nucléaire Orsay — High Purity Germanium (HPGe) detectors are used for high-resolution gamma spectroscopy in nuclear physics. HPGe can be combined to construct full 4\textpi gamma-ray tracking detectors. For example, the GRETA (Gamma-Ray Energy Tracking Array) project in the USA will consist of 30 HPGe detectors for a total of 120 germanium crystals. Since each detector costs more than $100,000, these detectors are typically bought through collaborations that maintain and repair them. When required, the detectors are moved to the experiment site for data collection and afterwards are returned to their home institution. The Institut de Physique Nucléaire d’Orsay (IPNO), France is in charge of a pool of about 20 coaxial HPGe detectors. For each loan, several characteristics must be provided to users to create accurate simulations of their experiments. Previously, only the detector’s resolution was provided. I will present an independent method I developed to measure the efficiency, peak-to-Compton ratio, resolution and corresponding uncertainties for each of the pool detectors. Additionally, this method can be used in the repair of detectors through redefining their nominal voltage. This work was conducted at IPNO in the summer 2019 and supported by National Science Foundation IRES Award No. 1658713.

HA.00037 Development of a System to Screen for PFAS Chemicals Using PIGE at Union College\textsuperscript{1}. COLIN M. LANGTON, JACOB E. FEINSTEIN, MIA E. VILLENEUVE, SCOTT M. LABRAKE, MICHAEL F. VINEYARD, Union College — Per- and polyfluoroalkyl substances (PFAS) are man-made chemicals that have become a major environmental concern. They can be found in a broad range of products including food packaging, stain- and water-repellent fabrics, nonstick products, makeup, fire-fighting foams, and electronics. These chemicals do not break down easily in the environment, can bioaccumulate, and some can lead to adverse health effects. We are working on a system to screen for these chemicals using proton-induced gamma-ray emission (PIGE) in the Union College Ion-Beam Analysis Laboratory. Samples are bombarded with 1.8-MeV protons from the external beam facility on our 1.1-MV Pelletron tandem accelerator. The emitted gamma-rays are detected with a high-purity Ge detector. Currently samples are screened for the presence of PFAS chemicals within 3-5 minutes by looking for the characteristic fluorine gamma-rays at energies of 110 and 197 keV. Future work includes the development of a standards-based method to measure the concentration of fluorine in soil, water, and paper samples. We will describe our system and present preliminary results.

\textsuperscript{1}NASA NY Space Grant

HA.00038 Development of a Positron-Electron Annihilation Spectrometer to Characterize Defects in Crystalline Materials at Union College. JACOB E. FEINSTEIN, COLIN M. LANGTON, MIA E. VILLENEUVE, SCOTT M. LABRAKE, MICHAEL F. VINEYARD, HEATHER C. WATSON, Union College — Positron-electron annihilation spectrometry is an analytical method for characterizing near-surface defects on the atomic scale in crystalline materials of materials. Using a thin $^{22}$Na source sandwiched between two samples, we will measure the lifetime of the positron and thus be able to characterize the number of defects in a sample from this lifetime. The lifetime of the positron (on the order of 0.4-2.0 nanoseconds) is determined from the time interval between the 1274-keV prompt gamma ray emission from the beta-plus decay of $^{22}$Na into an excited state of $^{22}$Ne and the subsequent annihilation of the electron and positron in the crystalline sample of interest by detecting the coincident 511-keV gamma rays. In the Union College Ion-Beam Analysis Laboratory (UCIBAL), we are currently constructing a system that will be used to measure the lifetime of the positron. We have successfully built, tested, and detected the coincident 511-keV gamma rays from the annihilation of electrons with positrons from the beta-plus decay of $^{22}$Na. Preliminary results will be presented and future modifications to this setup will be discussed which will include the implementation and testing of faster electronics for the timing circuit that will be used to determine the lifetime of the positron.
HA.00039 PIXE Analysis of Heavy Metals in Soil Along East River

JACOB E. FEINSTEIN, COLIN M. LANGTON, SCOTT M. LABRAKE, MICHAEL F. VINEYARD, HEATHER C. WATSON, Union College — We have performed a proton-induced X-ray emission (PIXE) analysis of soil samples collected along the East River in Queens, NY, at the Union College Ion Beam Analysis Laboratory (UCIBAL). Previous results for samples collected over a 5-km distance between Astoria Park and Gantry State Park show a spike in the Pb concentration to about 1500 ppm near the Hell Gate Bridge with a rapid decrease to <500 ppm on either side of the bridge. We suspected that this spike is due to Pb-based paint used on the bridge when it was constructed in 1916. To investigate this, we collected samples at smaller distance intervals around the bridge, which were then dried, sifted into a fine powder and mechanically shaken for 24 hours to ensure a uniform mixture. Pellets were created by hydraulically pressing 0.5 grams of soil with a few drops of polyvinyl alcohol, then coated with a thin layer of Al and used as targets for the PIXE measurements. The samples were bombarded with 2.2-MeV proton beams from the Union College 1.1-MV Pelletron accelerator. X-ray spectra were measured with an SDD detector and analyzed with GUPIX software to determine the concentrations of heavy metals in the soil samples. We will discuss the sample collection and the analysis procedure and present the results.

1NSF Summer Research Fellowship

HA.00040 RADIOACTIVE BETA-DECAY OF 133 INDIUM FOR NUCLEAR STRUCTURE STUDIES

COREY HALVERSON, MIGUEL MADURGA, University of Tennessee, LOW ENERGY NUCLEAR SCIENCE GROUP TEAM, UNIVERSITY OF WARSAW COLLABORATION — THE RAPID NEUTRON CAPTURE (R-) PROCESS FINAL YIELDS ARE DETERMINED BY WAITING POINT NUCLEI WHERE NEUTRON-CAPTURE AND PHOTODISINTEGRATION ARE IN EQUILIBRIUM. THE DECAY PROPERTIES OF THESE NUCLEI, HALF-LIVES AND NEUTRON BRANCHING RATIOS DETERMINE THE PATH OUT OF THESE WAITING POINTS. IN THIS WORK WE STUDY THE NUCLEAR STRUCTURE OF 133SN POPULATED IN THE BETA-DECAY OF 133IN. INDIUM 133 WAS CREATED IN INDUCED FISSILE COLIC 252Cf AT THE ISOLDE FACILITY CERN. ITS DELAYED GAMMA AND NEUTRON EMISSION WAS OBSERVED AT THE ISOLDE DECAY STATION. PRELIMINARY RESULTS OF GAMMA AND NEUTRON EMISSION FROM UNBOUND STATES IN 133SN WILL BE PRESENTED.

1Research reported in this presentation was supported by the University of Tennessee, Knoxville and Oak Ridge National Laboratories.

HA.00041 Using the Glauber Monte Carlo Approach to Determine the Multiplicity and Eccentricity of Pb+Pb Collisions at the LHC

ANYA WOLTERMAN, Macalester College — Glauber models provide insight into the initial state of nuclear collisions by treating them in terms of the interactions of their constituent nucleons, in accordance with theories about the scattering of composite particles. These phenomenological techniques are commonly used to determine various geometric quantities associated with such feitoscopic many-body systems. The Glauber Monte Carlo approach uses a random impact parameter and measured nuclear densities to investigate quantifiable properties such as the particle multiplicity and the average geometric eccentricity for heavy ion collisions. The former involves the incorporation of a particle production model to plot the sum of the transverse accordence with theories about the scattering of composite particles. These phenomenological techniques are commonly used to determine various geometric quantities associated with such feitoscopic many-body systems. The Glauber Monte Carlo approach uses a random impact parameter and measured nuclear densities to investigate quantifiable properties such as the particle multiplicity and the average geometric eccentricity for heavy ion collisions. The former involves the incorporation of a particle production model to plot the sum of the transverse

1Work completed with Professor Manuel Calderon of the University of California Davis as an advisor/mentor.

HA.00042 A Study of Time Dependent Noise in the Majorana Demonstrator Waveforms

THOMAS MARSHALL, ANNA REINE, JOHN WILKERSON, University of North Carolina at Chapel Hill, MAJORANA COLLABORATION — The Majorana Demonstrator is an array of high purity germanium detectors searching for neutrinoless double-beta decay in 76Ge and performing searches for beyond standard model (BSM) physics. The BSM searches are possible because of the Demonstrator’s low trigger threshold, below 1 keV. Such low thresholds can be sensitive to changing noise conditions. Understanding the nature of this noise is critical to our ability to perform BSM searches. An analysis of the RMS of waveform baselines in Demonstrator data helps provide better understanding of the electronic noise conditions present in the experiment so that potential issues can be identified and resolved. I present a comparison of the baseline RMS distributions in individual detectors before and after changes in noise, including an investigation of how changing noise conditions are correlated between different detectors.

1This material is supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, the Particle Astrophysics and Nuclear Physics Programs of the National Science Foundation, and the Sanford Underground Research Facility.

HA.00043 Determining the astrophysical 20Ne(α,p)23Na reaction rate using the Notre Dame 5U accelerator

ALYSSA DAVIS, Swarthmore College, AUSTIN MITCHELL, University of Southern Indiana, DAN BARDEYAN, PATRICK O’MALLEY, University of Notre Dame — In binary star systems including at least one white dwarf, the companion star may accrete mass onto the white dwarf until electron degeneracy pressure can no longer support the additional mass. A threshold is surpassed at high accretion rates, causing a stellar explosion categorized as a type Ia supernova. The system undergoes nucleosynthesis throughout the mass transfer and supernova process, producing heavier elements. Uncertainties in the 20Ne(α,p)23Na reaction rate have been shown to significantly affect the final abundances of a number of nuclei produced in type Ia supernovae. Although previous inverse kinematic measurements have been conducted to model this reaction rate, the explored beam energies were not of astrophysical significance. Utilizing the 5U vertical pelletron accelerator and the Rhinoceros extended gas target at the University of Notre Dame, new direct kinematic cross section measurements were conducted using beam energies as low as 3.5 MeV. Experimental methods and results will be discussed.

1This work is supported by the US National Science Foundation PHY-1713857.
HA.00044 Extraction of optical model parameters for $^{90}$Zr($^6$Li,$^6$Li) at 60 MeV/u using a Markov Chain Monte Carlo algorithm\textsuperscript{1}, AUSTIN SMITH, Point Loma Nazarene University, KEVIN HOWARD, UMESH GARG, University of Notre Dame — The nuclear incompressibility is a fundamental property of nuclear matter which is critical for modeling astrophysical processes. The isoscalar giant monopole resonance (ISGMR) is the most direct means to extract the incompressibility from finite nuclei. $^6$Li can be used in studies of the ISGMR with radioactive ion beams. However, before measurements with radioactive ion beams may begin, the optical model parameters for $^6$Li scattering need to be determined. To determine the optical model parameters, the elastic angular distributions of the $^{90}$Zr($^6$Li,$^6$Li) reaction were measured using the Grand Raiden spectrometer at the Research Center for Nuclear Physics at Osaka University. Experimental density distributions were used for the projectile and target nuclei to generate realistic volume potentials for the DWBA calculations. The optical model code, ECIS, and a Markov Chain Monte Carlo (MCMC) algorithm were employed to constrain the remaining optical model parameters for the reaction. The MCMC algorithm sampled from the 11-dimensional parameter space to visualize parameter probability distributions, from which the ideal optical model parameters were extracted. The results and implications for future work will be presented.

\textsuperscript{1}Supported in part by the National Science Foundation (Grant No. PHY-1559848).

HA.00045 A Method to Account for Hydroxide Contamination in Characterizing the Giant Monopole Resonance to Determine an Accurate $K_\tau$\textsuperscript{1}. SIERRA WEYHMILLER, KEVIN HOWARD, UMESH GARG, JOE ARROYO, University of Notre Dame, HIDETOSHI AKIMUNE, KYOKO NOSAKA, Konan University, SOUMYA BAGCHI, Saint Mary’s College, TAKANOBU DOI, YUKI FUJIKAWA, SHINTARO OKAMOTO, Kyoto University, MAMORU FUJIWARA, Tohoku University, SHINICHE OTA, University of Tokio — Measurements on the isoscalar giant monopole resonance (ISGMR) in finite nuclei over a range of isotope permit the extraction of $K_\tau$, the nuclear incompressibility asymmetry term. $K_\tau$ is critical to understanding proton/neutron asymmetric systems. A recent study has claimed that the energy of the ISGMR is higher in heavier calcium isotopes than lighter ones, indicating a positive $K_\tau$. This is surprising when compared to most previous studies extracting finite nuclear incompressibilities from giant resonances. To independently verify the claim, a simultaneous study of the GMR of $^{40,42,44}$Ca was conducted. However, contributions from hydroxide contamination were found in the $^{40}$Ca foil used in the experiment. The methodology for accounting for the contribution of $^{16}$O to the experimental spectra will be presented, and the implications will be discussed.

\textsuperscript{1}Supported by NSF Grant No. PHY-1559848 and the Gunn Family.

HA.00046 The High Efficiency Total Absorption Spectrometer (HECTOR) and Correcting for Inconsistencies in $^{27}$Al($p, \gamma$)$^{28}$Si\textsuperscript{1}. SEAN KELLY, ANNA SIMON, REBEKA KELMAR, ORLANDO OLIVAS-GÓMEZ, CRAIG REINGOLD, ALEX DOMBOS, PATRICK MILICAN, JACK WURZER, TESSA KLEIN, Nuclear Science Lab, University of Notre Dame — The processes responsible for producing heavy nuclei in stellar environments, such as the p-process and s-process, depend on nuclear reactions among heavy isotopes. In many cases, the measurements of these reaction rates are limited due to the low yield of the reactions under astrophysical conditions. The High Efficiency Total Absorption Spectrometer (HECTOR) is a tool for measuring these small cross sections using the $\gamma$-summing technique. In order to study the efficiency of HECTOR, resonance strengths of the $^{27}$Al($p, \gamma$)$^{28}$Si reaction measured with HECTOR were compared to results from previous literature. HECTOR’s results yield higher resonance strengths than previous works, which may be due to incomplete cascade and branching information used in their calculations. Using a simulation of HECTOR in Geant4, it is possible to quickly calculate and edit cascades for $^{28}$Si at different resonances. By editing the cascade inputs of the simulation to agree with HECTOR’s experimental data, it may become clear where and why previous literature underestimated $^{27}$Al($p, \gamma$)$^{28}$Si resonance strengths.

\textsuperscript{1}University of Notre Dame, Nuclear Science Laboratory and College of Science

HA.00047 Characterization of clover detectors for use in fIREBAll project\textsuperscript{1}, ZARIF RAHMAN, University of Wisconsin La Crosse, KEVIN LEE, WANPENG TAN, ANI APRAHAMIAN, University of Notre Dame, SHELLY LESHER, University of Wisconsin-La Crosse — Measurement of conversion electrons is an important aspect of nuclear structure studies. A new fIREBAll (fInternal conversion Electron Ball Array) array is being constructed by building on the existing “ICEBall” mini-orange array of SiLi detectors. fIREBAll will come into existence from the replacement of the current array of six mini-orange Si(Li) detectors of ICEBall with twelve Si(Li) detectors to broaden the energy range of the detected electrons. fIREBAll will be used in conjunction with two Compton suppressed Ge detectors. Compton suppression shields of Bismuth Germanate (BGO) will be used on two clover detectors for coincidence measurements of gamma-rays and conversion electrons. I have studied the clover detectors in order to characterize their efficiencies and resolutions. They were calibrated using $^{60}$Co and $^{252}$Eu sources and a digital DAQ system. Each of the four crystals for each clover detector were evaluated separately and in summing of all four quadrants. This work is based on the full characterization of the energy resolution and the detection efficiency of the two clover detectors envisioned for use with fIREBAll.

\textsuperscript{1}This work was partially supported by the National Science Foundation under grant No. Phy-1713816

HA.00048 Lifetime measurement of the 6.79 MeV state in $^{15}$O. LEXANNE WEGHORN, University of Wisconsin - La Crosse, BRYCE FRENTZ, ANI APRAHAMIAN, WANPENG TAN, University of Notre Dame, ZARIF RAHMAN, University of Wisconsin-La Crosse, JACK ENRIGHT, University College Cork, KEVIN LEE, CHRISTINA DULAL, MICHAEL WIESCHER, JOACHIM GOERRES, KEVIN HOWARD, SAMUEL HENDERSON, SHANE MOYLAN, BEKA KELMAR, University of Notre Dame — The $^{14}$N($p, \gamma$)$^{15}$O reaction is one of the time-limiting reactions in stellar evolution and the burning of protons to heavier elements known as the CNO cycle. This rate is in turn dependent on the lifetime of the 6.79 MeV state in $^{15}$O. In preparation for a lifetime measurement of the 6.79 MeV state in $^{15}$O, targets were prepared by implanting different doses of $^{14}$N into tantalum, tungsten, and molybdenum backings at beam energies of 350 keV. The targets were produced, and subsequently studied using the 5 MV Sta. Ana accelerator at the University of Notre Dame Nuclear Science Laboratory. The characteristics of the targets were determined using the 1056 keV resonance in $^{14}$N($p, \gamma$)$^{15}$O, which also served as a feasibility test for the lifetime measurement. Varying the backing material and implanted dose of the targets will allow the identification of systematic trends. The lifetime measurement will be performed using the Doppler-Shift Attenuation Method. There have been several former attempts to measure this lifetime with limited determination of upper limits. Information about the production and the properties of the targets will be presented, as well as preliminary results from the lifetime measurement.
HA.00049 St. George detector simulation to identify source of contaminant nuclides\textsuperscript{1}.

ANGEL GARCIA-SIMENTAL, JERRY HINNEFELD, Indiana University South Bend, SHANE MOYLAN, MANOEL COUNDER, University of Notre Dame — The St. George recoil mass separator at the University of Notre Dame is used to measure cross sections of astrophysically important alpha-capture reactions. The St. George detection system, which uses measurements of energy and time-of-flight to identify reaction products and residual beam particles reaching the end of St. George, also detects other nuclides. Possible sources of these nuclides are contamination in the recirculated helium used as a gas jet target or contaminant beams from the accelerator ion source itself. A GEANT4 simulation of the St. George detector system is being used to determine the source of the detected contaminants, as well as other artifacts in the time-of-flight vs. energy plots.

\textsuperscript{1}supported by NSF Awards HRD-1618408 and PHY-1713857

HA.00050 Characterization of CeBr$_3$ Scintillation Detectors for use in Coincidence Measurements\textsuperscript{1}.

JACK ENRIGHT, WANPENG TAN, ANI APRAHAMIAN, University of Notre Dame — Coincidence measurements play an important role in nuclear experiments. The advantages of CeBr$_3$ scintillation detectors over the more commonly used LaBr$_3$ and HPGe detectors in the detection of gamma-rays such as in $^{12}$C+$^{12}$C measurements are shown. The coincidence technique is required for the carbon fusion reaction in order to measure its cross section at energies well below the Coulomb barrier. The usefulness of CeBr$_3$ scintillation detectors for the most important energies of astrophysical $^{12}$C+$^{12}$C fusion processes (1-3 MeV in the center of mass) is discussed. The results of a gamma-gamma coincidence experiment for $^{252}$Cf using the aforementioned CeBr$_3$ detectors alongside lithium glass and liquid scintillators are shown also.

\textsuperscript{1}Naughton Foundation

HA.00051 Improving the efficiency of the St. George detector system by recovering anomalous events\textsuperscript{1}.

GUSTAVO DURAN, JERRY HINNEFELD, Indiana University South Bend, LUIS MORALES, MANOEL COUNDER, University of Notre Dame — The St. George recoil mass separator at the University of Notre Dame is used to study the process of nucleosynthesis in the course of stellar helium burning by measuring cross sections for low energy $(\alpha,\gamma)$ reactions induced by heavy ions in inverse kinematics. The use of inverse kinematics ensures the reaction products are at far forward angles, where they can be efficiently detected. St. George separates the reaction products from the unreacted beam particles that exit the target in the same direction at a rate orders of magnitude higher than the product of interest. Some unreacted beam particles do reach the end of St. George, where ions are identified by measuring their energy and their time-of-flight over a known distance. Time-of-flight is measured with a pair of transmission detectors utilizing microchannel plates and the energy is measured in a silicon strip detector. A fraction of particle detections suffer from too-low energy signals in the silicon detector. These events are being studied using the ROOT data analysis framework, with the hope that the corresponding particle can still be unambiguously identified.

\textsuperscript{1}supported by NSF Award PHY-1713857

HA.00052 Improving LANCE, the ETACHA user interface for the St. George recoil mass separator\textsuperscript{1}.

STEPHANIE TALLMAN, JERRY HINNEFELD, Indiana University South Bend, MICHAEL KURKOWSKI, CHRIS SEYMOUR, MANOEL COUNDER, University of Notre Dame — The St. George recoil mass separator at the University of Notre Dame, used to study nucleosynthetic $(\alpha,\gamma)$ reactions induced by low energy, low Z heavy ions, delivers reaction products in a single charge state to the detection system at its end. The distribution of charge states of reaction products emerging from the helium gas jet target must be known in order to extract the total reaction yield from the yields of the one or two most abundant charge states, which are in practice all that can be measured when the cross section is low. The program ETACHA is used for charge state calculations, and its predictions are compared here to measured distributions for nitrogen and fluorine. LANCE, a code written in python, serves as a front-end that simplifies and automates use of the ETACHA program. Further development of LANCE ensures the viability of ETACHA, particularly in cases where gathering experimental data on charge state distribution is difficult or impossible.

\textsuperscript{1}supported by NSF Award PHY-1713857 and IUSB SMART program

HA.00053 Impact of Neutron Induced Fission on r-process Nucleosynthesis Calculations.

LAUREN WARD, NICOLE VASSH, TREVOR SPROUSE, REBECCA SURMAN, University of Notre Dame — Recent evidence indicates that the r process, which is responsible for the creation of the heaviest elements in the universe, occurs at the site of a neutron star merger. Within such merger environments fission has the potential to be greatly influential on abundance yields of nucleosynthesis calculations. We perform sensitivity studies that look at how changing individual neutron induced fission rates and yields affect the abundances of such calculations. We do this for two distinct sets of theoretical nuclear data (based on FRDM 2012 and HFB-17 masses, respectively) and then relate the result to the fission barrier predictions for both models. Additionally, we perform Monte Carlo variations of all of the fission rates to determine the potential uncertainty range in these nucleosynthesis calculations given two distinct fission yield prescriptions (simple symmetric split and GEF). We find that varying the properties of neutron induced fission have a dramatic impact on r-processes nucleosynthesis yields and require further study.

HA.00054 Exotic Triaxial Shape and Wobbling Rotational Motion in 189Au\textsuperscript{1}.

JOSEPH COZZI, NIRUPAMA SENSHARMA, UMESH GARG, KEVIN HOWARD, University of Notre Dame — While most nuclei are symmetrically shaped, exotic asymmetric shapes have been observed in the excited nuclear states of heavy mass nuclei. One such asymmetric shape, the triaxial shape, is characterized by three different lengths for each of the three primary axes. Due to the asymmetry in its shape, an excited triaxial nucleus spins irregularly. This non-uniform rotational motion is known as ‘wobble’ and results in the emission of highly mixed electric and magnetic gamma rays as the nucleus transitions from higher to lower rotational energy states. Excited 189Au nuclei were created through a dehdyration fusion reaction performed at Argonne National Laboratory. Gammashpere, an array of 110 high purity germanium detectors housed at Argonne, was used to capture the gamma ray decay spectrum from the excited 189Au. This spectrum is being analyzed in order to confirm and expand upon previously published level schemes of 189Au. Directed coefficients of orientated nuclei and angular distributions will be calculated and used to identify the polarity and electromagnetic characteristics of key transitions in the 189Au gamma ray decay spectrum. The level scheme and analysis results from this study on the nuclear shape and rotational motion of 189Au will be presented.

\textsuperscript{1}University of Notre Dame Nuclear Science Laboratory
HA.00055 Superallowed alpha decays near 100Sn - detector development for measurement of the 104Te lifetime\(^1\), JAN COX, ROBERT GRZYWACZ, THOMAS KING, University of Tennessee, Knoxville, KRZYSZTOF RYKACZEWSKI, Oak Ridge National Laboratory, JOE HEIDEMAN, RIN YOKOYAMA, CORY THORNSBERRY, MANINDER SINGH, University of Tennessee, Knoxville — An experiment using a YSO implant detector, along with LaBr\(_3\), HAGRID detectors, is planned to measure the alpha decay chain of \(^{108}\)Xe to doubly magic, \(^{100}\)Sn. Previous attempts to measure the half-life of \(^{104}\)Te resulted in an upper limit of 20ns. The fast scintillation response of the YSO detector will aim for an accurate measurement of the half-lives of both \(^{108}\)Xe and \(^{104}\)Te. The result will enable determination of the alpha particle pre-formation factor. Development of the new segmented YSO detector designed for this experiment will be presented.

\(^1\)This research was funded through DOE Office of Science under Award No. DE-FG02-96ER40983.

HA.00056 Developing all-in-one SiPM package arrays for Nuclear Instrumentation, DONNIE HOSKINS, ZHENGYU XU, MIGUEL MADURGA FLORES, University of Tennessee — The rapid development of Silicon Photo-Multipliers (SiPM) has made them a very attractive solution to read out scintillator materials. Moreover, SiPM are by nature very resistant to extreme environments at low temperatures, low pressures, or high magnetic fields. Most commercial solutions simply integrate arrays of several small SiPM with common cathode and individual anodes readouts. They require external preamplifiers solutions, with dedicated connections that will be prone to electronic pickup and noise. We have developed highly integrated SiPM package, including on-board preamplifiers, for a variety of nuclear instrumentation needs. Here we will present the first results of the board performance using EJ-200 plastic scintillators and LaBr(Ce) Brilliance. Using a compact 4x4, 24x24 mm\(^2\) array with LaBr(Ce), we obtain a 4.5% energy resolution at 667 keV, remarkably similar to the larger 36x36 mm\(^2\) array developed for the apollo array at HELIOS [1]. [1] J.C. Lighthall et al, Nucl. Instr. Methods A622, 97 (2010) ; https://www.phy.anl.gov/atlas/workshop14/APOLLO.pdf

HA.00057 Effects of Radiation on FR4 Printed Circuit Boards, KEVIN SCHEUER, Arizona State University, Radiation Detection and Imaging, RICARDO ALARCON, Arizona State University, JASON HOLMES, Arizona State University, Radiation Detection and Imaging, EVGENY GALYAEV, DAVID BLYTH, Radiation Detection and Imaging, RADIATION DETECTION AND IMAGING COLLABORATION, ARIZONA STATE UNIVERSITY COLLABORATION\(^1\) — Printed Circuit Board applications in high dose rate environments are becoming more common, and considerable research exists on how electrical devices attached to the PCB respond to varying degrees of radiation. An understanding of how the PCB substrate itself reacts is lacking though, particularly for FR4, one of the most common substrates used. The following study presents measurements of electrical and physical parameters for a variety of FR4 substrates, and the respective changes following exposure to a \(3.38 \times 10^{16}\, n/cm^2\) total neutron fluence, in The Ohio State’s Nuclear Reactor Laboratory Auxiliary Irradiation Facility (AIF) vertical dry tube. Consequently, selection of a PCB substrate is shown to be of consideration beyond the typical frequency dependent parameters, especially for environments where high physical stress or flammability are of concern.

\(^1\)Utilized ASU facilities

HA.00058 Study of Neutron-rich Nuclides of Z = 13, 12\(^1\), JOHN MCDONAUGH, NATHAN FRANK, Augustana College, ROBBIE SEATON-TODD, ANTHONY KUCHERA, Davidson College, PAUL GUEYE, MSU/NSCL, PAUL DEYOUNG, Hope College, MONA COLLABORATION COLLABORATION — Neutron-rich nuclides show features not observed in stable nuclides indicating changes in nuclear structure. Certain regions of the chart of nuclides are of particular interest such as the “islands of inversion.” An experiment to produce nuclides in highly excited states was performed at the National Superconducting Cyclotron Laboratory. A \(^{48}\)Ca beam collided with a beryllium production target, which produced multiple secondary beams such as \(^{34}\)Al and \(^{36}\)Si. These beam nuclides impinged on a segmented target consisting of alternating Si-PIN detectors (4 total) and beryllium targets (3 total) producing many nuclides in highly excited states that resulted in a charged fragment and one or more neutrons being emitted. Using a superconducting dipole magnet, the charged fragments were swept into several charged particle detectors while the neutrons were measured as they interacted with arrays of scintillating plastic bars called the MoNa-LISA. The fragments and the emitted neutrons are detected in coincidence and their detected properties may be pieced together by invariant mass analysis to determine the energy of the neutron-unbound nuclide prior to decay. The results of the analysis for neutron detection, isotope separation, and the energy reconstruction of the decayed nuclides will be presented.

\(^1\)This work is supported by NSF Grant 1713522.

HA.00059 Characterizing a Charged Particle Detector Telescope\(^1\), GEORGIA VOTTA, NATHAN FRANK, Augustana College, THOMAS BAUMANN, MSU/NSCL, JAMES BROWN, Wabash College, PAUL DEYOUNG, Hope College, MONA COLLABORATION COLLABORATION — Performing experiments on neutron-unbound nuclei requires the detection of a neutron, a charged particle, and in some instances, gamma rays. The development of a charged particle detector telescope will facilitate the detection of these particles for future experiments performed at the National Superconducting Cyclotron Laboratory at Michigan State University. This system will allow charged particle detection along with efficient detection of gamma-rays by a device like the CAESium-iodide scintillator ARray (CAESAR) and neutrons with the Modular Neutron Array (MoNA). In order to construct this system, each charged particle detector (Si-PIN, position sensitive Si, or CsI(Tl)) needs to be tested to ensure each detector’s response along its area is uniform and to verify the manufacturers’ specifications. The construction of a raster scanner facilitates the process of the position-dependent testing inside a grounded metal box. The raster scanner consists of two stepper motors controlled by Arduino software that allow a \(^{210}\)Po source to be reproducibly transported across the surface of each detector and a mask that collimates the direction of the alpha particles. Results of detector characterizations will be presented.

\(^1\)This work is supported by NSF Grants 1713522 and 1827840.
HA.00060 Design and construction of an MR-TOF-MS for the CHIP-TRAP Penning trap mass spectrometer at Central Michigan University 1, PHILIP SNOAD, RAMESH BHANDARI, NADEESHA GAMAGE, MADHAWA HORANA GAMAGE, MATTHEW REDSHAW, Central Michigan University — High precision mass measurements are vitally important in a wide range of fields, such as nuclear structure, nuclear astrophysics, neutrino physics, metrology, and tests of fundamental physics. At Central Michigan University we are developing a Penning trap mass spectrometer (CHIP-TRAP) for high-precision mass measurements with stable and long-lived isotopes e.g. for a measurement of the $^{163}$Ho EC Q-value to aid direct neutrino mass determination experiments, and the $^{36}$Cl neutron separation energy that, in combination with precise γ-ray spectroscopy measurements will enable a test of $E = mc^2$. To aid in the efficient preparation and transport of ions from radioactive and low abundance isotopes, we are designing a multi-reflection time-of-flight massseparator (MR-TOF-MS) to increase the path length of ions as they travel from our ion sources to the Penning trap. In this presentation, I will show results from simulations of ion transport through our MR-TOF-MS that indicate our design goal of a resolving power $R > 20,000$ is achievable. I will describe the design of the MR-TOF-MS and report on the status of the fabrication, assembly, and commissioning of the apparatus.

1This material is based upon work supported by the US Department of Energy, Office of Science, Office of Nuclear Physics under Award No. DE-SC0015927 and by the National Science Foundation under Grant No. 1607429

HA.00061 Magneto-Ionization spacecraft Shield for Interplanetary Travel: Conceptual Design 1, LORIEN MACENULTY, DAVID ATRI, SEAN CUSICK, DOUG DRAKE, KEEGAN FINGER, LUKE HOFMANN, TRACE JOHNSON, JULIE LAFRANZZO, AURORA LYON, DANIEL MADISON, MOLLY MCCORD, ATHANASIOS PETRIDIS 2, GAVIN MENNING, MELANIE SCHNURR, WILL THOMAS, Drake University, MAGNETO-IONIZATION SPACECRAFT SHIELD FOR INTERPLANETARY TRAVEL TEAM 2. A central issue facing manned interplanetary travel is intense radiation exposure to solar wind and cosmic rays. MISSFIT is dedicated to conceptually developing a shield that combines passive and active shielding similar to Earth’s magnetic field and ionosphere. The system will focus and absorb low-energy particles and deflect high-energy particles. Subgroups are assigned tasks to investigate multiple components of the system, including the motion of charged particles in complex magnetic fields, preferable structures of magnetic fields, energy loss in ionization of gases, and the composition of solar wind and cosmic rays. We will present results pertaining to various shapes and intensities of magnetic field coupled with the effects of those fields on particle trajectory calculations. Furthermore, we will expand on our experimental analysis of gamma ray attenuation in Demron and Vectran, fabrics that claim high radiation protection properties. Upon completion of a conceptual design, funding from NASA to proceed with a technical design will be pursued.

1Iowa Space Grant Consortium
2Advisor
3MISSFIT

HA.00062 Magneto-Ionization Spacecraft Shield For Interplanetary Travel: Radiation Absorption Experiments 1, TRACE JOHNSON, LORIEN MACENULTY, SEAN CUSICK, WILLIAM THOMAS, DAVID ATRI-SCHULLER, MELANIE SCHNURR, JULIE LAFRANZZO, ATHANASIOS PETRIDIS, DOUG DRAKE, KEEGAN FINGER, DANIEL MADISON, GAVIN MENNING, MOLLY MCCORD, LUKE HOFMANN, Drake University, MISSFIT TEAM — An important consideration when humans make the journey to Mars is exposure to high radiation levels. Our conceptual design for a spacecraft radiation shield consists of two parts. The active shield is a magnetic field capable of deflecting or funnelling the charged particles to areas of strong field. The passive shield consists of gas-filled bubbles placed at strong-field regions that absorb energy from funneled particles by ionization and scattering. An important feature of our groups work are experiments conducted to determine the ability of various materials to block radiation. We tested the materials Demron and Vectran which will hold the ionization gases. Our experiments consisted of capturing a radiation absorption spectrum at various material thicknesses. Materials were exposed to radiation from several sources at varying energies. Each X-ray and gamma-ray peak from the spectrum of charged particles was fit with a Gaussian and the attenuation length was determined. The materials showed promise for blocking X-rays, but had difficulty stopping Gamma-rays.

1This research is supported by the NASA Iowa Space Grant under Award No. NNX16AL88H

HA.00063 Quantifying Liquid Argon Neutrino Detector Sensitivity to Supernova Burst Neutrinos 1, CRYSTAL BURGOS, Duke University, KATE SCHOLBERG, Department of Physics, Duke University — We produced figures of merit that show how many neutrinos can be detected for supernovae as a function of distance and compactness. Compactness is the ratio of the mass contained within the radius of the progenitor at the time of core bounce as defined by O’Connor and Ott (2011). This was used to quantify the sensitivity of a 40-kiloton liquid argon detector to core-collapse supernovae. We calculated neutrino event rates for a range of compactnesses. Compiling the results of the neutrino fluxes with a probability distribution of supernovae with respect to compactness and a probability distribution of supernovae with respect to distance allows the generation of useful data visualizations. Specifically, it produces a histogram that shows the number of neutrinos likely to be detected as well as the probability of seeing core-collapse supernovae as a function of core compactness and distance. With the use of these histograms, we are able to determine how many models can be observed given a neutrino event threshold for this type of detector. These methods can be repeated for other types of detectors in the future.

HA.00064 Mixture density networks as a machine learning technique for QCD analysis 1, MEG HOLUCK, ELENI TSITSTINDI, Davidson College, MANAL ALMAEEN, YASIR AWADH ALANAZI, Old Dominion University, MICHELLE KUCHERA, Davidson College, YQHANG LI, Old Dominion University, WALLY MELNITCHOUK, Jefferson Lab, RAGHU RAMANUJAN, Davidson College, NOBUO SATO, Jefferson Lab, CENTER FOR NUCLEAR FEMTOGRAPHY COLLABORATION — The use of machine learning in QCD analysis is an example of how learning techniques can facilitate the interaction between experimental data and QCD theory. In this project a mixture density network (MDN) was developed as a tool for QCD data analysis, providing one solution to the inverse problem using machine learning. The MDN is used to generate maps between experimental observables and theoretical parameters, taking experimental cross sections as inputs and generating parameters that describe the data in terms of the underlying parton distribution functions. To accommodate the possibility of multiple solutions in the theoretical parameter space when experimental data have large uncertainties, the MDN predicts a probability distribution function representing the multiple solutions and their likelihood. The results for the “up” and “down” quark distributions for the case of a 10-dimensional toy problem will be presented.

1This work was supported partly by the Center for Nuclear Femtography project CNF19-07.
HA.00065 Using a mixture density network to interface between experimental observables and QCD theory\textsuperscript{1}, ELENI TSITINIDI, MEG HOUCK, Davidson College, YASIR ALANAZI, MANAL ALMAEEN, Old Dominion University, MICHELLE KUCHERA, Davidson College, YAOHANG LI, Old Dominion University, WALLY MELNITCHOUK, Jefferson Lab, RAGHU RAMANUJAN, Davidson College, NOBUO SATO, Jefferson Lab, CENTER FOR NUCLEAR FEMTOGRAPHY COLLABORATION — We map experimental high-energy scattering data to quantum probability distributions that characterize nucleon structure and the emergence of hadrons in terms of the quark and gluon degrees of freedom of QCD. We train a mixture density network (MDN) to address the inverse problem of transforming observable space into theoretical parameter space. The output of the network provides a mixture of Gaussians that is processed through a mode-finding algorithm to produce multiple points in parameter space with their probabilities. This approach has been used to accurately predict collinear parton distribution functions, and can be straightforwardly extended to other probability distributions, such as generalized parton distributions and Wigner functions. It will thus allow us to build a new generation of QCD analysis tools that will provide a new paradigm for the analysis of high-energy data and the design of future experiments.

\textsuperscript{1}This work was supported partly by the Center for Nuclear Femtography project CNF19-07.

HA.00066 Using Adversarial Networks for Data Processing in the Hall B Drift Chamber\textsuperscript{1}, ANDREW HOYLE, Davidson College, JOSE CRUZ, Central Piedmont Community College, GAGIK GAVLIAN, Jefferson Lab, MICHELLE KUCHERA, RAGHU RAMANUJAN, Davidson College — The image to image translation software Pix2Pix was used to format track data produced by the drift chamber at Hall B at Jefferson Lab. This track data came in the form of images containing particle trajectories from different drift chamber channels. While Pix2Pix is typically used to generate realistic images of objects based on sketches, we trained the model to eliminate unwanted noise data from within each event. This was done using a training dataset containing pairs of track images, one containing all data recorded by the detector in one event, and one containing only the desired track. We explore the most effective architecture and tuning parameters to give the desired results. Results will be presented alongside metrics showing how accurate generated images are to the desired output.

\textsuperscript{1}This work was supported by Davidson College’s Faculty Study and Research Grant

HA.00067 Track Selection In Drift Chambers Using Convolutional Neural Networks\textsuperscript{1}, JOSE CRUZ, Central Piedmont Community College, ANDREW HOYLE, Davidson College, GAGIK GAVLIAN, Jefferson Labs, MICHELLE KUCHERA, RAGHU RAMANUJAN, Davidson College — Particle tracks of interest were selected from Hall B data at Jefferson Lab using machine learning methods. This research uses convolutional neural networks (CNNs) to classify which signals within an event belongs to the particle of interest. Using CNN architectures common in image analysis, we trained our model using data where the track are known. We tested VGG16, VGG9, Xception, InceptionV3, MobileNetV2 and InceptionResNetv2, the CNN architectures starting with pre trained weights to determine which model will provide the best results. The goal is to find the model and setting that provides the most efficient and accurate results with analyzing images at a speed of 3 milliseconds per image or lower. Results will be presented with comparisons between different models in terms of speed, loss, and accuracy.

\textsuperscript{1}This work is supported by the Davidson Research Initiative Branch

HA.00068 Using Deep Learning to Aid Track Reconstruction in the Active-Target Time Projection Chamber\textsuperscript{1}, JOHN BLUE, Davidson College, DULCE PACHECO, Johnson C. Smith University, MICHELLE KUCHERA, RAGHU RAMANUJAN, Davidson College, YASSID AYYAD, DANIEL BAZIN, WOLFGANG MITTIG, JASPREET RANDHAWA, National Superconducting Cyclotron Laboratory (NSCL), ROBERT SOLL, University of Oslo — Machine learning methods were used to aid track reconstruction in the Active-Target Time Projection Chamber (AT-TPC) at the National Superconducting Cyclotron Laboratory in Michigan State University. The AT-TPC is a gas-filled detector where the gas is both the scattering target and detection medium, allowing for three-dimensional reconstruction of reaction target tracks. During the recently run $^{232}\text{Mg}(\alpha,p)$ experiment, $45\%$ of the pads comprising the AT-TPCs sensor plane were overbiased, resulting in particle tracks with significant discontinuities. In an effort to make these broken tracks suitable for event classification and analysis, we used deep learning techniques, including fully-connected neural networks and an implementation of a context encoder neural network architecture developed by Pathak et al. for image inpainting. Preliminary results have shown the context encoder to be successful at inpainting simulated particle tracks in the AT-TPC. A comparison of methods as well as reconstructed tracks in two and three dimensions generated by the networks will be presented.

HA.00069 Automated Histogram Comparison Improvements for the NIFFTE FissionTPC\textsuperscript{1}, CHRISTINE CASE, Abilene Christian University, NEUTRON INDUCED FISSION FRAGMENT TRACKING EXPERIMENT-COLLABORATION — The Neutron Induced Fission Fragment Tracking Experiment (NIFFTE) collaboration aims to make high-precision $^{239}\text{Pu}(n,f)/^{6}\text{Li}(n,t)$ cross section ratio measurements with quantified systematic uncertainties at Los Alamos National Laboratory. The experiment incorporates fixed targets surrounded by a fission Time Projection Chamber (TPC). This fissionTPC enables 3D reconstruction of tracks from charged particles that ionize the TPC gas. During data collection, shifters inspect dozens of histograms visually to monitor detector performance and data quality. Currently, the Kolmogorov-Smirnov (KS) statistic quantifies histogram similarity. One challenge for applying KS to fissionTPC data is comparing histograms that include spontaneous alpha decay background and beam induced events that depend on beam intensity. Thus, the NIFFTE software is being updated with additional automated histogram comparisons. This presentation will include updates and modifications to the previous KS statistic and the new automatic histogram comparison program.

\textsuperscript{1}This research was supported by DOE-NNSA Stewardship Science Academic Alliances Program, under Award Number DE-NA0002921 and through subcontracts from LLNL.
HA.00070 Designing an Integrated Data Acquisition System for a Modular Cosmic Ray Test Stand\(^1\), KOLBY KIESLING, Abilene Christian University — The modular cosmic ray test stand (CRTS) is an array of plastic scintillators with photo-multiplier tubes (PMTs) used to determine efficiencies of prototype detectors using cosmic-ray muons. The CRTS is a fully adjustable detector array using 80/20 with two shelves of four scintillators, each one 20 cm by 180 cm in size, with PMTs attached to both ends. Development of a VME-based data acquisition system (DAQ) has started with goals to benchmark prototype detectors at Abilene Christian University for use at national laboratories. The VME DAQ is composed of a NIM constant fraction discriminator, MCFD-16, which splits ECL out signals to a VME time to digital converter, MTDC-32, and VME charge density integrator, MQDC-32. The Wiener VM-USB is used for event execution and readout on the VME bus. Additionally, a Wiener MPDC is used to control the voltage supply to the PMTs. To monitor the behavior of the equipment as well as quality of data that is collected, MIDAS software has been utilized. This presentation will describe the design process of developing the MIDAS-based DAQ and its early implementation.

\(^1\)This research was supported by US DOE MENP Grant DE-FG02-03ER41243

HA.00071 Manufacturing Scintillator Tiles for the STAR Forward Upgrade\(^1\), LILIAN MCINTOSH, Abilene Christian University, STAR COLLABORATION — Over the last 20 years, Relativistic Heavy Ion Collider (RHIC) experiments at Brookhaven National Laboratory (BNL) have studied the strong interaction through collisions between subatomic particles and nuclei. The Solenoidal Tracker at RHIC (STAR) plays a leading role in providing information regarding the proton structure, properties of the constituents, and their interactions. The STAR Forward Upgrade will enhance its capabilities by creating new low-angle subsystems, including a forward hadronic calorimeter system (HCAl). The HCAl, as well as a new forward tracker and electromagnetic calorimeter, will enable new low-angle measurements at STAR, including forward jet, dijet, and hadron-in-jet production. Abilene Christian University’s (ACU) contribution to the construction of the HCAl entails cutting and polishing 6,300 plastic scintillator tiles to the specifications of the upgrade. In recent years, ACU has invested in new facilities that allow this large-scale production to be completed on campus for the first time. A manufacturing process tailored to these facilities was developed to obtain optimal production efficiency and meet the specifications required for the upgrade. The specific process will be presented, including the scintillator cutting and polishing techniques.

\(^1\)Supported under US Department of Energy Grant DE-FG02-03ER41243

HA.00072 The E1039 drift chamber Cosmic Ray Commissioning\(^1\), YVES NGENZI, Abilene Christian University, SPINQUEST COLLABORATION — SpinQuest/E1039 is a fixed-target Drell-Yan experiment using the Main Injector beam at Fermilab, in the NM4 hall. It follows up on the work of the Nusea/E866 and SeaQuest/E906 experiments at Fermilab that sought to measure the $\frac{d}{u}$ ratio on the nucleon as a function of Bjorken-$x$. By using transversely polarized targets of NH$_3$ and ND$_3$, SpinQuest seeks to measure the Sivers asymmetry of $u$ bar and $d$ bar quarks in the nucleon; a novel measurement aimed at discovering if the light sea quarks contribute to the intrinsic spin of the nucleon via orbital angular momentum. The E1039 Drift Chamber Cosmic Ray Commissioning will be discussed. Cosmic ray datasets were used to understand noise issues and to set nominal HV settings and thresholds for later beam runs. In addition to that, noise was a problem in drift chamber. Therefore, to reduce readout noise we studied the effect of adding ferrite cores to different readout cables; the result of adding ferrite will also be discussed.

\(^1\)This research was supported by US DOE MENP Grant DE-FG02-03ER41243

HA.00073 Improving Function of Wire Chambers for E1039\(^1\), ELIZABETH JENNINGS, Abilene Christian University — E1039 at Fermi National Laboratory is seeking to better understand the contribution of quark-antiquark pairs to nucleon spin. E1039 will utilize a 120GeV unpolarized proton beam and collide it with an 80% transversely polarized target to probe sea quarks in the nucleon; a novel measurement aimed at discovering if the light sea quarks contribute to the intrinsic spin of the nucleon via orbital angular momentum. The E1039 Drift Chamber Cosmic Ray Commissioning will be discussed. Cosmic ray datasets were used to understand noise issues and to set nominal HV settings and thresholds for later beam runs. In addition to that, noise was a problem in drift chamber. Therefore, to reduce readout noise we studied the effect of adding ferrite cores to different readout cables; the result of adding ferrite will also be discussed.

\(^1\)Work is supported in part by the U.S. Department of Energy, NP Medium Energy Division under Awards Number DE-FG02-03ER41243

HA.00074 Analysis of Hodoscope Efficiencies for E1039/SpinQuest Spectrometer using Cosmic Rays\(^1\), NATE ROWLANDS, Abilene Christian University, SPINQUEST COLLABORATION — SpinQuest (E1039) at Fermi National Accelerator Laboratory is trying to help understand the spin structure of the nucleon sea using the 120 GeV proton beam and polarized NH$_3$ and ND$_3$ (ammonia) solid targets to provide the polarized hydrogen and deuterium. It uses the Drell-Yan process to access the nucleon sea via quark-antiquark pairs annihilating into a virtual photon, which decays into a $\mu^+\mu^-$ pair. Scintillator hodoscope planes provide the primary trigger, so understanding their efficiency is critical for the science goals of SpinQuest. This is achieved by counting the number of single track events that hit all eight planes vs the events with hits in seven or fewer planes. The goal is to have 99% efficiency for every hodoscope plane. Initial studies of this technique are being done using cosmic rays. This analysis will measure efficiencies for single muon events. Thus a verified technique of measuring hodoscope efficiencies will be in place when SpinQuest begins engineering runs by November, 2019 and data taking by early 2020.

\(^1\)Work is supported in part by the U.S. Department of Energy, NP Medium Energy Division under Awards Number DE-FG02-03ER41243.
HA.00075 CLAS12 Drift Chamber Reconstruction Code Validation1, MICHAEL ARMSTRONG, University of Surrey, GERARD GILFOYLE, University of Richmond, VERONIQUE ZIEGLER, Jefferson Lab — Jefferson Lab’s upgraded CLAS12 detector studies the quark-gluon structure of hadrons with electron scattering experiments. The CLAS12 software reconstructs particle events collected by CLAS12 or simulated. Upgrades to its more than 84,000 lines of executable code are validated on a nightly basis with unit tests that apply it to a standard data set. Scattered electrons bend in the CLAS12 magnetic field leaving tracks in drift chambers (DC). The reconstructed trajectory is used to determine momentum and vertex position. The raw data (e.g. ADCs) for a single event are stored in the code, reconstructed, and compared to standard values. As the software evolved the previous DC test would signal a failure when the reconstruction was done properly. Recent improvements had changed the momentum reconstruction so it was outside the acceptable range. We also discovered a large discrepancy with the vertex position. To fix the test we simulated momentum and vertex distributions using the CLAS12 Common Tools and extracted the reconstruction resolution. We generated new, simulated raw data for a single event, redefined the acceptable momentum ranges, and added a new requirement on the vertex. The results have been tested and incorporated into the Common Tools.

1Supported by the US Department of Energy.

HA.00076 Improving the Particle Multiplicity Generator Model for the Empirically Trained Hadronic Event Regenerator1, LUISA VELASCO, University of Dallas, RANDALL MCCLELLAN, WALLY MELNITCHOUK, NOBUO SATO, Jefferson Lab, YAOHANG LI, YASIR ALANZI, Old Dominion University, MICHELLE KUCHERA, MICHAEL ROBERTSON, EVAN PRITCHARD, Davidson College, TIANBO LIU, Jefferson Lab — Particle collision event generators are extremely useful, providing synthetic data quickly and to the user’s specifications. At present, all such event generators function via underlying theory that provides rules by which particle multiplicities and momenta are generated. To remove theory dependence, the Empirically Trained Hadronic Event Regenerator (ETHER) at Jefferson Lab implements machine learning models to be trained on experimental data. The focus of this study is to improve the performance of the particle multiplicity generator and develop the implementation of a non-trivial conditional feature. An ensemble training, but it struggles to learn the shifts in the underlying data distribution necessary for the successful implementation of a meta-algorithm is implemented to refine the model's learning ability. The base model is altered to accept a conditional label is to improve the performance of the particle multiplicity generator and develop the implementation of a non-trivial conditional feature. An ensemble training, but it struggles to learn the shifts in the underlying data distribution necessary for the successful implementation of a conditional feature. Preliminary results suggest that many more training steps are required to implement a conditional feature in the generator model.

1Improving the Particle Multiplicity Generator Model for the Empirically Trained Hadronic Event Regenerator

HA.00077 The Upgraded Hall A BigBite Spectrometer, JOSH MCMULLEN, Northern Michigan University, ERIC FUCHEY, University of Connecticut, DOUGLAS HIGINBOTHAM, Jefferson Lab — The recent 12 GeV upgrade to the Continuous Electron Beam Accelerator Facility (CEBAF) will allow for experiments in Thomas Jefferson National Accelerator Facilities (JLAB) Hall A probe deeper into the structure of the nucleon. The increased CEBAF beam energy expands the kinematic range in which high-precision measurements of the electro-magnetic form factor can be recorded. Crucial to these experiments is the use of Hall As BigBite Spectrometer to detect scattered electrons. While the BigBite detector package will be utilized in various configurations, an electromagnetic calorimeters will always serve as the primary trigger mechanism for these experiments. A detailed diagram of the trigger logic scheme will be shown along with brief summaries of the modules and timing information. The layout of the entire BigBite spectrometer package will also be shown along with descriptions of the various detectors.

HA.00078 HF-Free Bipolar Pulsed Electropolishing of SRF Cavities1, HANNAH HU, Cornell University, HUI TIAN, Thomas Jefferson National Accelerator Facility, OLGA TROFIMOVA, Thomas Jefferson National Accelerator Facility, The College of William & Mary — Surface roughness is one of the factors limiting the performance of superconducting radio frequency (SRF) accelerators. Bipolar Pulsed Electropolishing (BPEP) uses a HF-free electrolyte, thus reducing the costs and hazards associated with HF while still yielding a comparable surface finish to that of traditional etching techniques. This project focuses on understanding how polishing parameters affect the etching processes of Nb as well as conducting initial testing on Nb, N2 doped and Nb,Sn samples. Nb samples were polished at varying anodic voltage and pulse repetition frequencies (PRF). N2 doped and Nb,Sn samples were repeatedly etched with 1 µm and 200 nm removal respectively. Before and after each treatment, samples were studied under an Atomic Force Microscope and Scanning Electron Microscope for surface roughness and morphology. Etch rate stays constant with anodic voltage and is directly proportional to PRF. For Nb,Sn, BPEP selectively etches Nb, changing the chemical composition of Nb,Sn. Understanding the effects of these polishing parameters enables us to apply BPEP more efficiently to single and multi-cell Nb, N2 doped, and Nb,Sn SRF cavities.

1this work is made possible through support from NSF award 1659177 to Old Dominion University and US DOE Office of Science, Office of Nuclear Physics under contract no. DEAC0506OR23177.

HA.00079 Scattering in a Finite, Minkowski 1+1D Lattice, ALEXANDRU STURZU, New College of Florida, RAUL BRICENO, Thomas Jefferson National Accelerator Facility, Department of Physics; Old Dominion University, MAXWELL HANSEN, Theoretical Physics Department; CERN — There has been recent developments to allow lattice calculations in Minkowski space-time in order to determine real-time observables. These still require the use of finite volumes, where scattering observables may not be accessed directly. Furthermore, it is not obvious how one can recover infinite-volume scattering amplitudes from finite-volume Minkowski observables. To address this issue, we introduce a physical quantity that can be accessed from finite-volume Minkowski correlates and smoothly recovers the two-particle amplitude in the infinite volume limit. We test the convergence of this idea by considering a strongly interacting 1+1D toy model.

HA.00080 A New Frequency Modulation Function for High Energy Compton Scattering, JEFFREY MCKAIG, Christopher Newport University, BALA TERZI, Old Dominion University, GEOFFREY KRAFFT, Old Dominion University and Thomas Jefferson National Accelerator Facility — When a relativistic electron beam and a low energy laser pulse interact, narrow bandwidth back scattered radiation is produced through Compton Scattering. It has been shown that when the frequency of the laser pulse is modulated, a narrow bandwidth spectrum can be produced in the regime of high laser energies. However, this modulation function only corrects the spectrum for on axis scattering. Here a new frequency modulation function was developed to compensate for on and off axis scattering. This new function was derived using the method of stationary phase on the Fourier transform of the electron velocity in the x direction. In this treatment the scattering angle was kept arbitrary in order to account for off axis scattering. It is shown that this function does indeed recover the narrow bandwidth spectrum on and off axis. Unlike the previous modulation function, this function is shown to depend on the speed, and thus energy, of the electron beam. It is also shown that when electron energies are low, this modulation corrects the spectrum for all aperture placements. The findings of this study will allow for wider applications of the resulting spectrum as well as further development of the theoretical background of high energy Compton Scattering.
HA.00081 Testing and Analyzing the BonSU12 RPTC at Jefferson Lab, RAEMAAAD WRIGHT, Virginia Union University — The BonSU12 (Barely Off-shell Neutron Structure) group intends to measure the fundamental structure of the neutron in the valence quark region. In order to accomplish this, electron beam would scatter off a deuteron target. To ensure scattering is off the neutron, slow, backward moving spectator protons would be tagged with a Radial Time Projection Chamber (RTPC). A gas panel has been built to distribute and control gas flow through the RTPC as well as a Drift Monitoring System (DMS). An RTPC is currently being tested using Helium-Carbon Dioxide (HeCO₂) and is under high voltage, with cosmos and a radiologically controlled source (Sr-90) to see if a signal was generated on the oscilloscope. Once signals begin to show, we will start to take data from the Data Acquisition System. This presentation will focus on the progress and results of this testing.

HA.00082 Studies of the Gain of a Small-Pore Size Microchannel Plate Photomultiplier in High Magnetic Fields, ALAN ROWLAND, University of South Carolina, EIC PID COLLABORATION — Microchannel plate photomultipliers (MCP PMTs) are small devices that convert light into an electric signal. These devices have many applications, but most notably in physics they are used to readout Cherenkov detectors. In the current designs of the central detector of a future Electron Ion Collider, MCP PMTs will readout several Cherenkov detectors located in a magnetic field of ~1.5 T. Work has been done to see how the functionality of MCP PMTs is affected by high magnetic fields and our research furthers these studies. We studied a Planar MCP PMT, which has a pore size of 10 m, inside a variable magnetic field. While one can simply determine the gain of the device outside of a field by means of fits to pulse height distributions, in high magnetic fields (>1.5 T), where the signals become small, this method to determine the gain cannot be applied. Due to the linearity of the relationship between several variables that are proportional to the gain, we have developed a method to determine the gain even when the PMT signals are very small and the standard method is not usable. This helps to extend the range of settings for which the sensor can be evaluated and provides support for this sensor to be used in the EIC.

1This work is supported by the U.S. DOE via the EIC RD Program.

HA.00083 Intrabeam Stripping of H- Ions in the JLEIC Ion Linac with PyORBIT, MADELINE CLYBURN, Berry College, TODD SATOGATA, Thomas Jefferson National Accelerator Facility / Old Dominion University, AMY SY, Thomas Jefferson National Accelerator Facility — Jefferson Lab is designing an electron-ion collider (JLEIC) to meet the experimental needs of the nuclear physics community. In JLEIC, a potential mechanism for beam loss is intrabeam stripping of the H- ions in the linear accelerator (linac). As the ions interact with each other, there is a chance that electrons will be stripped from the ions. This creates neutral particles that are unaffected by the electromagnetic fields and are thus lost. This project determined whether intrabeam stripping is a relevant form of beam loss for JLEIC. The pyORBIT code was modified to simulate the beam dynamics of the JLEIC linac. Then plots were created of relativistic velocity to determine the likelihood of intrabeam stripping. From these plots, the relativistic velocity values of the ion beam were found to be similar to values from previous studies on other linacs; our calculated average power of JLEIC is significantly lower than the powers of other linacs. Previous predictions have shown that intrabeam stripping is negligible below a certain average power value. Our value for average power was many orders of magnitude below this average power value and thus confirmed that intrabeam stripping of the H- ions will have negligible effects on the amount of beam loss in JLEIC ion linac.

HA.00084 Quasielastic Scattering Simulation off Mean Field Nucleons, SAMUEL SOLOMON, JACKSON PYBUS, ANDREW DENNISTON, EFRAIN SEGARRA, AXEL SCHMIDT, OR HEN, Massachusetts Institute of Technology, REYNIER CRUZ TORRES, Thomas Jefferson National Accelerator Facility — Quasielastic (QE) electron-nucleus scattering is a powerful probe for nuclear structure, revealing a distinction between nucleons in mean-field orbitals and those in high-momentum, short-range correlated (SRC) states. Despite being difficult to calculate using ab initio methods, QE cross sections can be estimated from nuclear spectral functions using Plane-Wave Impulse Approximations (PWIA). Recently, a novel approach called Generalized Contact Formalism has been successful in describing the limiting case of QE scattering from a nucleon in an SRC pair. To extend this method, I developed software to simulate QE scattering from a mean field nucleus based on ab initio generator calculations. This allows for independent comparison of scattering events between SRC and mean field nucleons, which are difficult to distinguish experimentally. I plan on using these comparisons to test if the observed missing mass offset in SRC pair break-up reactions can be understood from conventional nuclear physics or is a signature of a previously unobserved 30 MeV force-carrying boson.

1We thank the support from the Undergraduate Research Opportunity Program (UROP) at MIT for funding during this project.

HA.00085 Probing 2N-SRC via (e,e'N) Reactions off 3,4He (12C), PENINAH LEVINE, AXEL SCHMIDT, REYNIER CRUZ TORRES, Massachusetts Institute of Technology, EREZ COHEN, Tel Aviv University, OR HEN, Massachusetts Institute of Technology, ELIEZER PIASETZKY, Tel Aviv University — Quasielastic electron-nucleus scattering suggests that 5–20% of nucleons form short-range correlated (SRC) pairs with very small separation distances and very high relative momenta. Previously, coincidence measurements have provided the most complete picture of SRCs, but few coincidence measurements have been made on light nuclei. Here, we examine SRC-pair break-up from Jefferson Lab data from He-3 and He-4 for the first time. We study the effect of asymmetry and nuclear size on SRC pairing by probing (e,e') event ratios for ³He/⁴He and ¹²C/¹³C respectively. The results of this study find scaling in (e,e') ratios as a function of Pmiss, which matches what we find using (e,e) events. The fact that both channels independently produce the same abundances indicates that inclusive measurements are correctly probing nucleon pair abundances in nuclei. This analysis paves the way for tests of np-dominance and other investigations of pairing in light nuclei.

1This work was supported by the MIT Undergraduate Research Opportunities Program

HA.00086 Simulations of Water-Cherenkov Events with a Sr90 Source for the Calibration of NuDot Experiment, JUNIOR PENA, University of Southern California, NUDOT COLLABORATION — In searching for neutrinoless double-beta decay, it is crucial to understand backgrounds in liquid scintillator detectors for these rare events before the next generation of experiments at the kiloton-scale. With sufficient timing resolution to separate scintillation light from Cherenkov radiation, it is feasible to use directionality from Cherenkov light for identifying backgrounds like ⁸B solar neutrino scattering, which are otherwise irreducible. NuDot is a preliminary 1-ton experiment aiming to demonstrate this technique of separation and event reconstruction with 1 to 2 MeV beta particles. Simulations for NuDot are important for determining the calibration conditions, the amount of source positions needed, and the duration of runs at each position in order to obtain the precise timing calibration for Cherenkov separation. For calibrating, we use water-Cherenkov events from a Sr90 source, and the difficulty lies in simulating the model for how Cherenkov light is produced, how the PMTs behave, and how light propagates through the detector. To aid this issue we use RAT to simulate our experimental setup and calibration runs as closely as possible. A simulation of a timing calibration and how it compares to data collected when running in the same conditions will be shown.

1This work was funded by the MIT Summer Research Program.
HA.00087 Data Acquisition and Triggering for the NuDot Experiment. MANUEL MORALES, Massachusetts Institute of Technology, NU DOT COLLABORATION — In the search for neutrinoless double-beta decay, progress is being made towards kiloton-scale detectors with lower backgrounds. NuDot is a 1-ton liquid scintillator detector prototype designed to identify previously irreducible backgrounds like $^8$B solar neutrino scattering. Using Cherenkov light signals for path reconstruction of 1 to 2 MeV beta particles, NuDot aims to demonstrate this background reduction technique. NuDots DAQ system is complex in how it merges faster and slower signals. For high light-collection efficiency, 59 PMTs are split across 4 slow boards operating at 250 MS/s. To ensure fast timing, 152 PMTs are divided across 5 fast digitizer boards operating at 5 GS/s. When an event is detected by any of the 8” PMTs, a trigger is sent to all the boards housing 2” PMTs. Due to the limited waveform storage of the fast boards, triggers have to be sent in less than 200 ns to record the high-frequency data before it is overwritten. A variety of tests were performed to ensure this and other aspects of DAQ performance. Furthermore, all 9 boards are chained together in order to synchronize start time and utilize a shared clock timestamp. These processes facilitate the stitching together of event waveforms and further data analysis.

HA.00088 The NuDot Calibration System. JESUS HERRERA, Massachusetts Institute of Technology, NU DOT COLLABORATION — To reach greater sensitivity, the search for neutrinoless double beta decay will require new techniques for rejecting background events. NuDot seeks to answer these problems by demonstrating Cherenkov/Scintillation separation in betas with energies of 1–2 MeV. This separation will be used to distinguish between single electron scatter events and double beta decay events, and provides ground to perform direction reconstruction of such events. Demonstrating the direction reconstruction of beta events in NuDot requires a calibration system capable of performing multi–directional movements independent of each other. This calibration system must be capable of controlling the height, azimuthal angle, and inclination angle of a Sr90 source and collimator. Utilizing three integrated stepper motors, independent motion can be achieved. With this setup, we can program such motors to point at any position on the sphere from any point along the sphere radius, and relay their exact positions to us. Given this capability, we can test our direction reconstruction and verify that the values from reconstruction match the position and orientation of the collimator on the calibration system.

HA.00089 Transverse Distributions of the Pion Cloud in a Chiral Light Cone Perturbation Theory Model. MACQUARRIE THOMSON, ETHAN PURCELL PURCELL, ENRIQUE SANCHEZ, Seattle University — Because of the Heisenberg uncertainty principle, protons are allowed to briefly fluctuate into a pion and a nucleon or a pion and a delta. Our goal is to calculate the splitting of the proton into these separate particles while the proton is moving at relativistic speeds, where its spatial extent becomes nearly two-dimensional, a disk of pion cloud. We use a pion 2D momentum distribution function $f_{\pi N} (y, t)$, derived from chiral light cone perturbation theory, in which $y$ is the fraction of proton momentum carried by the pion and the momentum transfer $t$ depends on $y$ and $k_\perp$, the transverse momentum of the pion. To find transverse momentum distributions we calculate $f_{\pi N}$ as a function of $y$ and $k_\perp$ for a range of physically reasonable values of the form factors and coupling constants on which it depends. We then use a 2D Bessel transform of $f_{\pi N}$ to calculate the transverse momentum distribution probability $p_{\pi N} (b, y)$ with $b$ the transverse position coordinate. We compare our results to the expected spatial extent of the cloud, $\sim 1/m_\pi$, and to other theoretical transverse spatial distributions.

1This work is supported by NSF Grant No. 1516105 and by the M. J. Murdock Charitable Trust.

HA.00090 Transverse Distributions of the Strange Cloud of the Proton. ETHAN PURCELL, MACQUARRIE THOMSON, Seattle University — Due to the Heisenberg uncertainty principle, a proton can generate a cloud of strange particles as it splits into a strange meson/baryon pair: a $K$ or $K^*$ meson and a $\Lambda$ or $\Sigma$ baryon. At relativistic speeds the proton is contracted into a disk transverse to its momentum. Our goal is to calculate the transverse momentum distributions and determine the transverse spatial distributions of the strange mesons. We use a light cone model for the two-body wave function $\psi (y, k_\perp)$ that describes the probability that a proton will split into a meson/baryon pair in which the meson has longitudinal momentum fraction $y$ and transverse momentum $k_\perp$. We analytically integrate $\psi (y, k_\perp)$ to determine $f (y)$, the probability of the meson-baryon fluctuation for a given $y$. We numerically integrate $f (y)$ and compare to total fluctuation probabilities, and use this to normalize our distributions. $\psi (y, k_\perp)$ depends upon a parameter $\alpha$ which describes the shape of the fluctuation function. We study the dependence of the transverse momentum distributions on $\alpha$. We then use a Bessel function transformation of $\psi (y, k_\perp)$ to determine the transverse spatial extent of the kaon cloud, and compare it to the expected scale of $1/m_K$.

1This work is supported by the M. J. Murdock Charitable Trust and by NSF Grant No. 1516105.

HA.00091 Light Cone Model of the Transverse Distributions of the Pion Cloud. ENRIQUE SANCHEZ, MACQUARRIE THOMSON, ETHAN PURCELL, Seattle University — The Heisenberg time-energy uncertainty principle allows a proton to briefly fluctuate into a $\pi N$ or a $\pi \Delta$ state. This fluctuation phenomenon creates a cloud of pions, which we investigate for protons moving at relativistic speeds. We describe the pion cloud in a Fock state expansion, in which we use two-body Gaussian wave functions in a Light Cone model to determine the probabilities of each proton fluctuation. The wave functions $\Psi_{\pi N} (y, k_\perp)$, with $B = N, \Delta$, depend on $y$, the pion momentum fraction, and $k_\perp$, the transverse momentum, in which we are interested. We normalize these wave functions we first calculated the probability that the proton will fluctuate into a $\pi N$ or $\pi \Delta$ state by integration over $k_\perp$ and $y$, and set our results equal to values determined by experiment. Our normalization constants depended on a parameter $\alpha$ in the wave functions, related to the width of the distribution in momentum space. We made 3D plots to study the dependence on $y$ of the transverse distributions in $k_\perp$. We then used a 2D Bessel transform to determine the transverse spatial distributions of the pions, which we expect to be $\sim 1/m_\pi$. We compare our results to other theoretical calculations.

1This work is supported by NSF Grant No. 1516105 and by the M. J. Murdock Charitable Trust.

HA.00092 Time-Reversal-Violating Interactions in the Neutron Deuteron System. ANNA DAVID, JARED VANASSE, Stetson University — Time reversal violating interactions within the Standard Model occurs between quarks and at low energies manifests itself in nucleon-nucleon interactions. Time reversal and parity violating nucleon-nucleon interactions, at low energies $E < m_t^2/(2M_N)$ are characterized by five low energy constants. Our calculation of the neutron deuteron system used pionless effective field theory that describes nucleon-nucleon interactions at low energies through contact interactions. We considered two observables, the spin rotation of the incoming neutrons on a polarized deuteron target and the asymmetry of polarized neutrons scattering off a polarized deuteron target. These two observables depend on different linear combinations of the five low energy constants. This work is part of an effort to characterize various possible experiments in terms of the five low energy constants in order to determine which experiments are better suited to measuring different low energy constants.
HA.00093 Collinearity criteria for transverse momentum dependent distributions in SIDIS\textsuperscript{1}, SCOTT DOLAN, Penn State University Berks, MASON ALBRIGHT, Penn State University, LEONARD GAMBERG, Penn State University Berks, WALLA MELNITCHOUK, Jefferson Lab, DANIEL PITONYAK, Lebanon Valley College, ALEXEY PROKUDIN, Penn State University Berks and Jefferson Lab, NOBUO SATO, Jefferson Lab, ZACHARY SCALYER, Villanova University — We present the impact of data selection on the determination of nonperturbative transverse momentum dependence in semi-inclusive deep-inelastic scattering (SIDIS). In particular, we implement for the first time the recently introduced collinearity criteria\textsuperscript{1} that allow selection of data predominantly in the current fragmentation region, and apply this framework to pion and kaon multiplicity data from HERMES. We use a simple analytical approximation for the solutions of the TMD evolution equations that is valid in the nonperturbative region\textsuperscript{2}, and extract the transverse momentum dependence of TMDs and the flavor dependence of their widths. We compare the resulting unpolarized TMD PDFs with previous extractions, and discuss the potential impact of the data selection criteria for future experiments. We summarize our findings and discuss the impact of this analysis for ongoing and future experiments of SIDIS, \textsuperscript{[1]} M. Boglione, J. Collins, L. Gamberg, J. O. Gonzalez-Hernandez T. C. Rogers, N. Sato, Phys.Lett.B766,245(2017), \textsuperscript{[2]} J.C Collins and T. R. Rogers, Phys. Rev. D 91, 074020 (2015).

\textsuperscript{1}DOE Nuclear Physics, DE-FG02-07ER41460, NSF No. PHY-1516088, the TMD Topical Collaboration.

HA.00094 Improvements in Fiber Harp Signal Integrity in the Muon g-2 Experiment\textsuperscript{1}, JADE MEURER, FREDERICK GRAY, Regis University, MUON G-2 COLLABORATION — The Muon g-2 experiment at Fermi National Accelerator Laboratory will test fundamental symmetries of the Standard Model by measuring the anomalous magnetic moment of the muon with improved precision. We measure motion of the beam profile through a system of "fiber harps," consisting of scintillating fibers and Silicon Photomultipliers (SiPMs). Signals from previous versions of the SiPM amplifier circuits show long time constants in the recovery to the baseline voltage, resulting in a need for precise baseline corrections and/or new electronics. We attempt to improve the analysis of previous data by applying mathematical deconvolution methods. We also develop new DC coupled amplifiers to fix the baseline shift introduced by AC coupling for future data collection. This poster will present the success of these methods and future improvements.

\textsuperscript{1}This material is based upon work supported by the National Science Foundation under Grant number PHY-1811832.

HA.00095 A Jet Shape Study with the STAR Experiment\textsuperscript{1}, THOMAS GOSART, Rutgers University, Department of Physics and Astronomy, STAR COLLABORATION\textsuperscript{2} — In relativistic heavy ion physics, jets are a collection of particles that are emitted from hard scattered partons. They are known to interact strongly within quark-gluon plasma (QGP) produced in heavy ion collisions, which is known as jet quenching. It has been observed at the LHC that jets' energy deposition and radiation patterns change when they interact with QGP compared to their vacuum baseline. Jet shape is an observable that is sensitive to the changes within a jet and its lateral energy distribution. In this study, we utilize data collected by the STAR experiment at RHIC to compare the evolution of the jet shape observable in proton+proton and $^{\overline{A}}_{\overline{A}}$ = 200 GeV Au+Au collisions. Such measurements allow us to have a better understanding of the jet quenching phenomenon in heavy ion collisions at RHIC.

\textsuperscript{1}I would like to thank the Rutgers Relativistic Heavy Ion Group for their help and support.

\textsuperscript{2}Project conducted under direction of Professor Sevil Salur and Dr. Joel Mazer.

HA.00096 Control Improvements on the UCN\textsubscript{τ} Magnetic Mapper\textsuperscript{1}, RYAN COLON, Tennessee Technological University, UCN\textsubscript{τ} COLLABORATION — The UCN\textsubscript{τ} experiment utilizes a 670-liter magnetic array designed for the purpose of trapping ultracold neutrons (UCN) with minimal sources of loss. The array uses over 5000 NdFeB magnets to achieve this purpose. Understanding the magnetic field generated by these magnets is key to the experiment, and so it is necessary to have a practical method of mapping the magnetic fields in the trap. This information is useful for ensuring the magnetic field is large enough everywhere to prevent UCNs from escaping and provides empirical inputs into spin dynamics simulations of the experiment. To efficiently collect the magnetic field information, a magnetic field mapping robotic arm was manufactured and implemented, and the efficiency of the arm continues to be improved upon. Control code was improved to allow for the automatic handling of critical errors during mapping runs. Specifically, code allowing for the arm to try and re-find a missed surface point and skip points that it fails to find was implemented; Additionally, code that allows the arm to continue an aborted mapping run with minimal user input after critical errors was developed. The control code additions and their effects on the running of the arm, as well as future control code improvements will be presented.

\textsuperscript{1}This work was supported by the National Science Foundation, no. PHYS-1553861.

HA.00097 Development of a sCMOS Position-Sensitive UCN Detector\textsuperscript{1}, DARSH DINGER, ADAM HOLLEY, Tennessee Technological University, UCN\textsubscript{τ} COLLABORATION — Position-Sensitive Detection (PSD) of particles on a two-dimensional detection plane can be useful in experiments that require characterization of free-moving particles. PSD can aid in the study of systematic effects such as depolarization and phase space evolution in trapping experiments such as the ultracold neutron (UCN) free neutron lifetime experiment UCN\textsubscript{τ}. PSD is demonstrated using a relatively inexpensive scientific complementary-symmetry metal-oxide-semiconductor (sCMOS) camera from PCO to image an Ag enriched ZnS scintillator coated in $^{10}$B from a distance of 1.2 meters away. This scintillator was excited using an $^{241}$Am source which emits alpha particles at 5.48 MeV. The optical design of this PSD system will be discussed, along with details of signal characterization.

\textsuperscript{1}This work was supported by the National Science Foundation, no. PHYS-1553861.
**HA.00098** Monte Carlo study of $\Upsilon(1S)$ production in jets in the forward region\(^1\), YUJIN GUO, Mount Holyoke College — The Large Hadron Collider beauty (LHCb) experiment primarily studies the production and decay of beauty and charm hadrons. Different from ATLAS and CMS, which mainly cover the mid-rapidity region, the LHCb detector uniquely covers the forward region ($2 < \eta < 5$) with precise tracking and particle identification capabilities. A recent study of $J/\psi$ production in jets presents the first measurement of transverse momentum fraction, $z(J/\psi) = p_T(J/\psi)/p_T(jet)$, in the forward region. Despite the consistency between theoretical predictions and measurements of $z(J/\psi)$ from b-hadron decays, a disagreement is found for prompt $J/\psi$ production. It inspires parallel studies of the production of prompt upshits in jets, to compare charm in jets to heavier bottomonium particles. Here, an analysis of ground state upshits ($\Upsilon(1S)$) in jets in the forward region with Monte Carlo events generated at a center-of-mass energy of 8 TeV will be presented. The energy and transverse momentum ($p_T$) distributions for inclusive $\Upsilon(1S)$ will be shown, and the calculations including $z(\Upsilon)$, longitudinal momentum fraction ($z$), radial distance ($r$) and momentum transverse ($j_T$) to jet axis will be performed for $\Upsilon(1S)$ in jets.

\(^1\)National Science Foundation

**HA.00099** Clustering of Mini-jets in High-Energy Proton-+Proton Collisions\(^1\), NANNXI YAO, University of California, Los Angeles, Department of Physics and Astronomy — The jets, narrow bundles of hadrons, manifest the properties of quarks and gluons in high-energy p+p and heavy-ion collisions. Observation of jets helps to investigate the quark gluon plasma (QGP) created in these collisions. Quantum Chromodynamics (QCD) mini-jets are usually distinguished with high-momentum hadrons, mini-jets and mini-dijets will clarify multiple parton interactions in the low transverse-momentum region. In this poster, an algorithm of finding mini-jets is presented, based on K-means clustering method [1]. We partition particles from p+p collisions at 200 GeV simulated by PYTHIA8.1 into clusters by minimizing a potential of the system, and determine the center of the clusters. To further evaluate the cluster-finding algorithm, we analyze differential correlations between cluster centers in the pseudorapidity and azimuthal angle space. This study will pave the road for future application with heavy-ion collisions. [1] C. Wong, L. Wetz and Z. Huang. "On the Clustering Properties of Mini-Jet and Mini-Dijet in High-Energy pp Collisions", 2018, [http://arxiv.org/abs/1801.00759 arXiv:1801.00759].

\(^1\)This work is supported by the US Department of Energy under Grant No. DE-FG02-88ER40424

**HA.00100** Photon Reconstruction and Identification in sPHENIX , FRANCESCO VASSALLI, University of Colorado Boulder, SPHENIX COLLABORATION — The super Pioneering High Energy Nuclear interaction eXperiment (sPHENIX) at the Relativistic Heavy Ion Collider (RHIC) will perform high precision measurements of photon-jet production to study the strongly coupled quark-gluon plasma. Comparison of the color neutral photon with the strongly-interacting jet provides a natural control-experiment channel. In sPHENIX Photon kinematics are reconstructed using calorimeter data. To obtain a high purity sample of prompt photons the hadronic background, especially $n_0$ decay, must be reduced. This can be done by analyzing the calorimeter cluster shape. The methods of event reconstruction for sPHENIX are currently being developed and tested in simulation. The results will serve as a benchmark for the capabilities of the detector. Furthermore, the photon identification efficiency can be increased through converted photon recovery. Photon conversion recovery is performed by analyzing electron, positron track pairs. Photon conversion recovery can also be used to make material maps of the inner detector in simulation. Comparing these maps allows for detailed in situ verification of detector geometry. This presents sPHENIX’s ability to reconstruct and identify photons using GEANT4 simulation.

**HA.00101** ZDC prototypes for test beam measurements at CERN and FNAL , TIANSU ZHANG, University of Illinois at Urbana-Champaign, ATLAS COLLABORATION — The High Luminosity upgrade of the Large Hadron Collider at CERN places significant demands on the radiation hardness of the Zero-Degree Calorimeter (ZDC) of the ATLAS experiment. This detector plays a key role in the heavy ion physics program, in particular in the measurement of the impact parameter and of the number of spectators nucleons in the collision. The Nuclear Physics Laboratory at the University of Illinois (NPL) collaborates on the development of a radiation-hard ZDC for ATLAS. As part of this upgrade effort, prototype hadronic and electromagnetic detector modules along with a single layered reaction plane detector (RPD) have been built. In November 2018, a dedicated beam-test has been performed at the ATLAS hadron beam-line at CERN. Two hadronic detector modules have been tested, together with an RPD prototype. The detector was illuminated with both heavy ion and fragment beams, to study its properties. In my contribution, I will discuss the 2018 test-beam effort, with particular attention to the alignment of the setup, its simulation in Geant4 and the data analysis.

**HA.00102** Development of a Fused Silica Polishing Method , ANDI MANKOLLI, University of Illinois at Urbana-Champaign, JCAP COLLABORATION — The Large Hadron Collider at CERN is being upgraded for high luminosity operations. Protons and heavy ions in the accelerator will collide with unprecedented rates, giving rise to an extremely high-radiation environment. Operating under this high-radiation exposure will be a significant challenge for detector instrumentation, especially for detector modules with thin active layers. Fused silica is a radiation-hard material that can be polished to high optical quality and is a critical component of the Xenon Enriched Neutron Detector (nEXO) Observatory. A new method for polishing fused silica using a combination of mechanical polishing and laser ablation is presented. This method uses a fused silica master and a diamond-based polishing wheel to polish the fused silica. The laser ablation process is used to remove the remaining material after the polishing wheel is removed. The method is effective for polishing fused silica to a high optical quality. The results will serve as a benchmark for the capabilities of the detector. Furthermore, the photon identification efficiency can be increased through converted photon recovery. Photon conversion recovery is performed by analyzing electron, positron track pairs. Photon conversion recovery can also be used to make material maps of the inner detector in simulation. Comparing these maps allows for detailed in situ verification of detector geometry. This presents sPHENIX’s ability to reconstruct and identify photons using GEANT4 simulation.

**HA.00103** Characterizations of UV-sensitive large area SiPMs and its readout for nEXO , JIZHAO LIN, Rensselaer Polytechnic Institute, JONATHAN ECHEVERS , LIANG YANG, University of Illinois at Urbana-Champaign — Silicon Photomultiplier (SiPM) has emerged as a new light sensor for noble liquid detectors. The next-generation Enriched Xenon Observatory (nEXO), a proposed experiment to search for neutrino-less double beta decay, will use SiPMs for detecting Xenon scintillation light. Detailed analysis on the performances of SiPMs under cryogenic experimental conditions is required for future nEXO experiment. In the poster, we will describe the experimental setups and present the results of characterization of SiPMs from FBK. In particular, we present the large-area readout analysis for the resolution, gain and dark noise rate of SiPM under cryogenic condition.

\(^1\)This material is based upon work supported by the National Science Foundation under Grant PHY-1659508. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.
HA.00104 Single Particle Simulation Studies of a Proposed Forward Calorimeter for the sPHENIX Experiment. YUXI XIE, University of Michigan — The sPHENIX experiment is designed to study the quark-gluon plasma, a state of hot nuclear matter created in heavy-ion collisions. A forward upgrade including tracking and calorimetry is proposed for sPHENIX to extend the range for cold nuclear matter measurements, in particular with direct photon and quarkonia, which can be used to constrain the gluon nuclear parton distribution function. The implementation of the plans on re-using the existing E864 hadronic calorimeter modules for the forward electromagnetic calorimeter requires a non-uniform tower structure. The calorimeter performance was studied with single-photon and single $\pi^0$ simulations, showing that the energy responses over pseudorapidity and azimuthal angle in the forward EMCal are uniform despite the nonuniformity of the tower size. Results on the fraction of $\pi^0$s that can be successfully reconstructed as a function of momentum will be presented. The single-particle simulation studies indicate that the proposed forward electromagnetic calorimeter upgrade has promising potential for use in extending the physics program of sPHENIX. Further studies involving full-event simulations will be performed to study the detector performance for distinguishing direct photons from photons decayed from $\pi^0$s.

1Department of Energy

HA.00105 Determining analysis efficiency for Project 8's neutrino mass studies. SIERRA WILDE, University of Washington, PROJECT 8 COLLABORATION — The Project 8 experiment is developing a way to study neutrino mass called Cyclotron Radiation Emission Spectroscopy (CRES). In CRES, an electron's energy is measured by observing the cyclotron radiation emitted by the electron as it accelerates in a magnetic field; because of a special relativistic effect, this frequency depends on the electron's kinetic energy. A radiofrequency detection system collects, measures, and digitizes information about the radiation, and Project 8 analysis software processes the data to distinguish electron signals from noise. However, many electron signals are comparable in power to the noise, which can lead to missed signals and errors in cyclotron frequency reconstruction. This work aims to quantify the systematic effects of variations in signal properties on measured cyclotron frequencies. We use a Project 8 software package to create simulated electron signals and noise. We vary parameters of the simulated signals, and then measure how these variations affect the analysis efficiency in finding signals and its accuracy in determining their frequency. These calibrations will make it possible to quantify uncertainties in Project 8's ongoing experimental observation of the spectrum of electrons emitted in the beta decay of tritium.

1This work was supported by the US DOE Office of Nuclear Physics, the US National Science Foundation, and internal investments at all Project 8 collaborating institutions.

HA.00106 An Internal Scanning Cryostat for High Purity Germanium Detectors. TIM MATHEW, University of Washington, LEGEND COLLABORATION — LEGEND is a next-generation search for neutrinoless double-beta decay ($0\nu\beta\beta$) in $^{76}$Ge incorporating successful technologies from current experiments including the MAJORANA DEMONSTRATOR and GERDA. The $^{76}$Ge high purity germanium (HPGe) detectors use a P-type Point Contact (PPC) geometry. The passivated surfaces on these PPCs make the detectors susceptible to surface backgrounds, such as alpha and beta particles. This can contaminate the $0\nu\beta\beta$ region of interest at 2039 keV. The Collimated Alphas, Gammas, and Electrons (CAGE) test stand is an internal-source scanning cryostat, using vacuum-side motors to control the position of various radioactive sources above an HPGe detector. CAGE is currently taking data at the University of Washington to understand and characterize detector response to surface background events. The data from CAGE will be essential in identifying characteristics of surface event pulse shapes that can be used for event rejection in both current-generation experiments and LEGEND. This poster will present the current status of the CAGE test stand, as well as preliminary data.

1This work is supported by U.S.A: NSF, DOE-NP, LBNL-NERSC, SURF, LANL LDRD program, and ORNL-OLCF; Russia: RFBR; Canada: NSERC and CFI; Germany: BMBF, DFG and MPG; Italy: INFN and LNGS; Poland: NCN and FNP; and Switzerland: SNF.

HA.00107 Event selection in electron scattering from an unpolarized deuterium target. XIAODI HU, MATTHEW HEYRICH, GERARD GILFOYLE, University of Richmond — We are using Jefferson Lab's 11-GeV electron beam incident on a deuterium target and the CLAS12 detector to measure the electromagnetic form factor of the neutron. We developed and tested code to extract kinematic quantities for quasielastic(QE) event selection. A full simulation chain has been developed and is managed by shell and perl scripts on the Richmond Computing Cluster. Quasi-elastic events are generated with QUEEG and inelastic ones with Pythia. Both sets go through gemc, a CLAS12-standard, physics-based Monte Carlo built on geant4. The simulated events are reconstructed with the CLAS12 Common Tools. We wrote the post-reconstruction analysis code in Apache Groovy, a JAVA-like scripting language. To select electrons we apply fiducial cuts to define the electromagnetic calorimeter (EC) active volume and constrain the sampling fraction (ratio of electron energy deposited in the EC to measured electron momentum). We isolated QE events from inelastic background using cuts on $\theta_{pq}$ (angle between 3-momentum transfer and the nucleon), and the hermiticity (number of final-state particles). Initial results on extracting the QE component are consistent with the experimental specifications.

1Supported by the US Department of Energy.

2Joint Poster for CEU

HA.00108 Calculations of Transverse Energy from Single Particle Spectra Measured in Relativistic Heavy Ion Collisions. TANNER MENGEL, BENJAMIN SMITH, BISWAS SHARMA, NATHAN WEBB, SOREN SORENSEN, CHRISTINE NATTRASS, University of Tennessee, Knoxville — During relativistic collisions of heavy nuclei, such as gold, a hot dense medium known as Quark Gluon Plasma (QGP) is formed. As a consequence of such collisions, particles are ejected transverse to the beam axis. The transverse momentum distributions, measured by the STAR and PHENIX experiments at the Relativistic Heavy Ion Collider (RHIC) in Brookhaven National Laboratory, are used to calculate the transverse energy of ejected particles. These momentum distributions correspond to nine centralities for eight identified particles, $\pi^\pm$, $K^\pm$, $\Lambda$, $\bar{\Lambda}$, $p$, and $\bar{p}$, at eight different center-of-mass energies per nucleon. Comparing the estimated transverse energy shows the systematic biases of the different methods used to measure ejected particles during heavy ion collisions. We describe methods used in calculating the transverse energy contributions from each of the identified particles in published momentum spectra, as well as assumptions made for calculating energy contributions from unmeasured particles, such as, $\eta$, $n$, $\pi^0$ and $K^0$. The results of this comparison will be presented.
HA.00109 Heavy Ion Collision Analyses Using RIVET\textsuperscript{1} , CHRISTAL MARTIN, CHRISTINE NAT-Trass, University of Tennessee, Knoxville — When heavy ions collide at ultra-relativistic speeds, a hot, dense state of nuclear matter known as Quark-Gluon Plasma (QGP) is formed. To study the properties of the QGP, data are collected from heavy ion collisions at the Large Hadron Collider (LHC) in Switzerland and the Relativistic Heavy Ion Collider (RHIC) in New York. Experimental analyses using this collected data can be studied using a Monte Carlo (MC) validation software called Robust Independent Validation of Experiment and Theory (RIVET) to make comparisons between experimental data and MC models. Heavy ion analyses are being developed for use by the JETSCAPE collaboration. We discuss procedures to create heavy ion collision analyses using RIVET. We also demonstrate how to incorporate these procedures and analyses into an academic research course.

\textsuperscript{1}We thank JETSCAPE and the NSF for support.

HA.00110 Determining $\pi^0 A_{LL}$ from STAR 2012 Endcap Calorimeter Data , CLAIRE KOVARIK, Valparaiso University, STAR COLLABORATION — The Solenoidal Tracker at RHIC (STAR) located at Brookhaven National Laboratory in New York uses longitudinally polarized proton-proton collisions to determine the gluon contribution to the spin of the proton. One analysis of the 2012 data set, at a proton-proton center of mass energy of 510 GeV, studies the production of neutral pions ($\pi^0$) which immediately (~ $10^{-16}$s) decay into two photons. The neutral pion asymmetry, $A_{LL}$, can be determined through data collected by the Endcap Electromagnetic Calorimeter (EEMC). The EEMC, positioned in an intermediate pseudorapidity range of 1 $<$ $\eta$ $<$ 2, is able to measure the energy and position of each photons electromagnetic shower. By using this information as well as the angle between the photons, the two-photon invariant mass can be reconstructed. The invariant mass spectra are fitted using a skewed Gaussian plus a background function to determine the total number of $\pi^0$s present. The $\pi^0$ asymmetry is calculated from the number of $\pi^0$s in collisions with different polarization directions of the colliding proton beams. The status of the measurement of $A_{LL}$ of the $\pi^0$s as a function of the transverse momentum, $p_T$, of the $\pi^0$ will be presented.

HA.00111 Automation and Machine-Learning can help you do more physics sooner , SPENCER SHANK, WILLIAM LILLIS, Wabash College, MONA COLLABORATION COLLABORATION — Detector calibration is a task that is critical, mundane, and time consuming. As detector arrays have grown in scale, the tasks required have grown as well. For experiments with the MoNA/LISA neutron detectors it is critical to calibrate the arrays’ 576 timing and energy response in order to extract accurate physics data. We will report on methods leveraging automation and machine intelligence to determine calibration parameters, and identify detector elements that require additional attention and/or adjustment from experimenters. We will report on methods using a large number of cosmic-ray tracks to determine relative time offsets of the 288 detector bars, based on a truncated travelling salesman-like approach. Additionally, two methods of determining positions will be explored, one based on the ratio of the scintillation light reaching the two ends of a detector bar, and one using the time difference between the ends. These two methods will be compared, showing that light difference can be used as backup to time difference in some cases, and that specific types of two-neutron events can be distinguished using these parameters and machine learning. These methods can reduce the time taken to calibrate and help one move from calibrations to physics sooner.

HA.00112 Determining Scintillator Nonlinearity using the Wide Angle Compton Coincidence Technique\textsuperscript{1} , ANNA BEGGS, ELIZABETH GEORGE, PAUL VOYTAS, Wittenberg University — At some level, scintillator materials have an energy response that can be nonlinear. The Wide Angle Compton Coincidence (WACC) technique provides some advantages to finding the nonlinearity of a detector by using Compton scattering from this detector into another detector known to be linear, in this case a High Purity Germanium (HPGe) detector. The detectors are in a close geometry and so the Compton scattering that happens in the tested detector over many angles gives an energy response over a range of energies. From the known gamma ray energy and the HPGe photon energy detected, the analysis of a 2D histogram of the scattering detector response vs. the HPGe response provides a means of measuring the scattering detector’s nonlinearity. I will describe our implementation of the WACC technique to measure the nonlinearity of scintillators used for a precision measurement of the $^{20}$F beta spectrum shape as a search for physics beyond the standard model.

\textsuperscript{1}This work is supported by the National Science Foundation under grant numbers PHY-1531763 and PHY-1506084

HA.00113 An Empirical Model of Electronegative Impurities for nEXO , SAMUEL BORDEN, Yale University , NEXO COLLABORATION COLLABORATION — Neutrinoless double beta-decay is a hypothesized radioactive decay, that if observed, would prove that the neutrino is a Majorana particle. nEXO is a future tonne-scale liquid xenon (LXe) time projection chamber (TPC) designed to search for the neutrinoless double-beta decay of Xe-136. Future tonne-scale LXe TPCs such as nEXO will require electrons to be drifted over meter long distances while minimizing loss of charge during drift due to the capture of electrons by electron-negative impurities within the LXe. We will present an empirical model for predicting the level of electronegative impurities in nEXO, based on measurements of outgassing of atmospheric gases from plastics and other detector materials. The model is validated using electron lifetime measurements from EXO-200 and dedicated small-scale setups.

HA.00114 Optimizing the Region of Interest in the KATRIN detector system\textsuperscript{1} , VICTORIA KUBYSHKO, Carnegie Mellon University, KATRIN COLLABORATION — The KATRIN experiment is currently obtaining data to determine the effective electron neutrino mass with a sensitivity of 0.2 eV/c\textsuperscript{2} by precision electron spectroscopy near the endpoint of the $^3\text{He}$-decay of tritium. The neutrino mass is determined by an integrated spectrum which currently uses a fixed wide region of interest (ROI) cut from the detector’s energy spectrum, from 14keV to 32 keV. We expect an energy peak around 28keV, accounting for a 10keV shift from the endpoint energy of 18.6keV. This method discards data from some noisy pixels and shadowed pixels. The goals of this project were to determine the resulting sensitivity of the spectrum when changing the ROI, recommend a method to obtain the best suited ROI, and salvage the data from unused pixels using data from the first tritium runs. Some factors we have considered are background noise, shifting of the peak due to changing potentials, and nonuniformities among pixels. This resulted in the comparison of various ROI cuts to the one currently used.

\textsuperscript{1}DOE Award No. DE-SC0019304
HA.00115 Software Updates for the Main Detector Controls Webpage at the STAR Experiment at Brookhaven National Laboratory1, EMMA DUFRESNE, Creighton University — STAR (Solenoidal Tracker at RHIC), the high-energy physics experiment at Brookhaven National Laboratory, analyzes collisions of heavy ions traveling at relativistic speeds using various detectors. For safety reasons, remote computers are programmed to retrieve data from these detectors. A controls system is set in place to manage the various computers that allow STAR to function. STAR’s control system uses EPICS (Experimental Physics and Industrial Control System), a set of open-source software tools that enable communication with the computers. The largest part of the controls system involves the operation of power supplies and monitoring their voltage values. Detector operators and the shift leader can monitor safety information about the detectors from a single webpage. Information about water and gas alarms, operating status of the sub-detectors, and environmental conditions are seen at a glance. The detector controls framework is being gradually updated to include PC-based rather than embedded computers and to incorporate PyEpics, an interface that allows EPICS to interact with the Python Programming language. These changes will allow for easier maintenance and updates in the future. This project was to re-write the code that gathers and fills the main detector controls webpage with information, remove outdated values and eliminate the need for frequent rebooting. In alignment with the overall trend for detector controls, it was written using PyEpics and HTML formatting. This new code was successfully implemented before the end of the 2019 run.

1Creighton University’s Clare Boothe Luce Scholarship

HA.00116 Determining the Reconstruction Efficiency of $\Lambda^0$ Hyperons in CLAS12 at Jefferson Lab1, MATTHEW MCENEANEY, William & Mary, ANSELM VOSSEN, Duke University — $\Lambda^0$ hyperons may be inferred from their self-analyzing weak decay. Thus, such polarized probes allow one to analyze the polarization of quarks in the proton and test fundamental aspects of QCD. The CLAS12 experiment at Jefferson Lab uses an 11 GeV electron beam incident on a polarized or unpolarized target to study the behavior of the strong force within the proton. In this study, we generated SIDIS events using a Lund Monte Carlo and simulated the response of the CLAS12 detector using GEANT4 with different toroidal magnet field strengths and configurations (either inbending or outbending). We then processed events using the CLAS12 reconstruction framework to find the optimal configuration and maximize our reconstruction efficiency from the $\Lambda^0 \rightarrow \pi^- + p^+$ decay channel. For $\Lambda^0$ hyperons coming from a struck quark ($\not{E_F}_{\text{quark}} > 0$), we obtained our best reconstruction efficiency in the outbending toroidal configuration. We will present the results of this study along with the implications on the statistical precision of a potential measurement of $\Lambda^0$ polarization using the data to be collected by CLAS12.

1NSF REU Program (US National Science Foundation Grant No. NSF-PHY-1757783), US DOE Office of Science

HA.00117 Finding a Material with a Low Energy Threshold for Charged–Current Neutrino Interactions1, THOMAS RICHARDS2, University of Alabama, KATE SCHOLBERG, Duke University — We calculated the thresholds for charged–current electron neutrino and antineutrino interactions for most of the stable isotopes. Looking at the isotopes with the lowest thresholds, we found that tantalum–181 ($^{181}\text{Ta}$) and gadolinium–160 ($^{160}\text{Gd}$) are reasonable candidates for low–threshold neutrino detectors, with thresholds at 0.188 MeV and 0.105 MeV respectively. These materials are both metals, have relatively high natural abundance, and are not frequently found in conjunction with radioactive substances, making them potentially viable for this task. Using the SNOWGLOBES software library, we computed estimated cross sections and event rates for supernova fluxes in these two materials.

1NSF Grant No. NSF-PHY-1757783
2also at Duke University

HA.00118 Measurements of the $^{124}\text{Sn}(\gamma,n)$ and $^{169}\text{Tm}(\gamma,n)$ cross sections at $E_\gamma = 13$ MeV1, KAYLISA WOLSEY, Brigham Young University - Idaho, SEAN FINCH, K. KRISHICHAYAN, Duke University and TUNL, JACK SILANO, Lawrence Livermore National Laboratory, WERNER TORNOW, Duke University and TUNL, ANTON TONCHEV, Lawrence Livermore National Laboratory, INNOCENT TXORSE, Duke University and TUNL — Nuclear data for photo–nuclear reactions is scarce. By using the activation technique, $(\gamma,n)$ cross sections can be measured to a high precision. $^{169}\text{Tm}(n,2n)$ is a common neutron monitor reaction, but there is no available data on its photo–nuclear counterpart, the $^{169}(\gamma,n)$ reaction. Measurement of this reaction would allow use of thulium as a standard $\gamma$–ray monitor. The samples in this experiment were irradiated by monoenergetic $\gamma$–rays provided by the High Intensity $\gamma$–ray Source (HI–S) located at Duke University. The resultant activity was quantified using $\gamma$–ray spectroscopy with high purity germanium detectors. The data confirmed the literature half–lives of $^{196}\text{Au}$, $^{123}\text{Sn}$, and $^{169}\text{Tm}$ as 6.16 d, 40.1 m, and 93.1 d, respectively. The first successful cross-section measurements of $^{124}\text{Sn}(\gamma,n)^{125}\text{Sn}$ and $^{169}\text{Tm}(\gamma,n)^{170}\text{Tm}$ reactions were performed.

1NSF-PHY-1757783

HA.00119 Scrubbing system Supporting tritium gas target for research at HI$_{\text{L}}$S1, TALISI MEYER, Simmons University, COLLIN MALONE, CALVIN HOWELL, Duke University, TUNL — Tritium, a radioactive isotope of hydrogen, will be the basis of study of P-02-13 at HIGS. This study will use a tritium gas target to obtain cross-section measurements of two- and three-body photodisintegration of the triton in order to further understand nuclear structure and reactions, specifically three nucleon interactions (3NI). Tritium scrubber systems are necessary in order to safely handle the tritium inventory. These systems use a Copper–Zinc catalyst to convert elemental T$_3$ into T$_2$O or HTO, allowing the titrated water to be collected in a molecular sieve bed and safely disposed of. Reactions catalyzed by the CuZn bed were examined using a Residual Gas Analyzer at temperatures ranging from 23C to 190C. Isotope concentrations and compositions of the various gas streams that will flow through the scrubbing system during normal operation were monitored over time to characterize the catalyst’s behavior. Primary gases include Helium (5 LPM), 1% Oxygen in Helium (5 LPM), Hydrogen (50-100 sccm), and H$_2$O formed from the catalytic reaction. Through this research, the use of a CuZn bed as a catalyst in this scrubbing system was verified and found to work optimally at higher temperatures.

1Research supported by DOE Grant No. DE-FG02-97ER41033 & funded by the National Science Foundation Grant No. NSF-PHY-1757783
HA.00120 Sensitivity Study to Identify Important Nuclear Reactions in X-ray Burst Nucleosynthesis\(^1\), BRITTNEY CONTRERAS, University of Tennessee, Knoxville — When neutron stars (NS) in a low mass x-ray binary system collect matter from their H or He rich companion star, nuclear burning can occur on the NS’s surface. If a critical accretion rate is reached, nuclear reactions can runaway, resulting in X-Ray Bursts (XRBs). By studying the sensitivity of XRB models to different nuclear reactions, we can help identify which are key in the burst process. The stellar model used for this study was of an XRB in Modules for Experiments with Stellar Astrophysics (MESA). Python scripts were made to analyze the output data and compare it to the baseline model. Those with the greatest change identify key reactions to XRB nucleosynthesis. Preliminary results already indicate five reactions of significance. Additional dominant reactions will be identified with further runs. While in its early stage, the study has emphasized reactions that majorly affect XRB properties. Future work will expand on these current methods to calculate the primary metric “integrated burst variation” and compare it to baseline. As stellar modeling capabilities have improved, this work will be a crucial contribution to sensitivity studies performed in the past.

\(^1\)Grant No. NSF - PHY - 1757783

HA.00121 Development of Pelletron Accelerator for High Precision Calibration of Silicon Detectors, EMMANUEL ANEKE, Georgia Institute of Technology, CLAY FOGLEMAN, ALBERT YOUNG, North Carolina State University — Neutron beta decay (NBD) is the decay of a neutron into a proton by the emission of an electron and electron antineutrino. When we measure the emitted electron, it can have any energy from 0 keV to 783 keV. The emitted electron energies are difficult to precisely measure because of bremsstrahlung, the emission of electromagnetic radiation produced by the deceleration of an electron hitting an atomic nucleus. For the next generation of beta decay measurements, the precision of current bremsstrahlung simulations are not sufficiently precise, motivating direct measurement of the bremsstrahlung loss to calibrate NBD electron energy measurements. We are developing a pulsed and tunable Pelletron accelerator (mostly from spare parts) to provide these measurements. The development of our Pelletron system is the first concern before any bremsstrahlung measurements are made. Our project is to improve the performance of an N \(_2\) \(_0\) purge and implement a suppressor electrode to reduce arcing, understand possible sources of coronal discharge loss, make a first detection of the electron beam, and start to develop a test beamline. These first steps were successful, greatly reducing charge loss and arcing, and confirming the production of over 200 keV electron beams.

HA.00122 Tagging \(c\bar{c}\) events via hadronic decay modes of \(J/\psi\) at ATLAS\(^1\), SERGI CASTELLS, University of Illinois at Urbana-Champaign, NICOLO DE GROOT, Radboud University — Searches for \(c\bar{c}\) from Higgs/Z decays have been done exclusively for the ground \(J/\psi\) state for leptonic decay modes while we aim to tag excited \(c\bar{c}\) states via hadronic decay modes. The study of \(c\bar{c}\) is relevant to Higgs coupling with the charm quark. Excited states such as \(\psi(2S)\) and \(\chi_{c0,1,2}\) are of interest as we can follow their decays into \(J/\psi\gamma\). The production of excited states of \(c\bar{c}\) is via the standard Higgs/Z production chain \(gg\rightarrow H\rightarrow c\bar{c}\gamma\) process. The purpose of creating this tagging algorithm is to apply it to ATLAS data. The tagging is done using machine learning. Training data for the machine learning algorithm comes from Monte Carlo simulations of particle decays and simulations of interactions in ATLAS. Other Monte Carlo simulations are being tested to verify the stability of the algorithm. The accuracy for the fully-connected neural network trained on \(J/\psi\), \(\psi(2S)\), and quark/gluon background is 93.

\(^1\)Funding was provided by the NSF through the Duke/TUNL REU Program

HA.00123 The CLAS12 Forward Tagger Calorimeter\(^1\), ROBERT BEHARY, Duquesne University, FATIMA BENMOHTAR, Duquesne University, RAFFAELLA DE VITA, MARCO BATTAGLIERI, INFN Genova — Lead tungstate (PbWO\(_4\)) crystals have been extensively studied and used in high energy physics calorimetry including the Forward Tagger Calorimeter in Hall B at Jefferson Lab. This detector consists of a matrix of 1.5x1.5x20 cm\(^3\) crystals have been extensively studied and used in high energy physics calorimetry including the Forward Tagger Calorimeter in Hall B at Jefferson Lab. This detector consists of a matrix of 1.5x1.5x20 cm\(^3\) crystals arranged around the beamline to detect electrons and photons scattered at small angles. Due to the proximity to the beamline, the calorimeter is exposed to high radiation dose from electromagnetic background during data taking and can suffer from progressive degradation of the crystal light transmission. This can be monitored using the LED system that is part of the calorimeter equipment and is designed to inject a known amount of light in each crystal. The effects of radiation damage as a function of the crystal distance from the beamline have been studied analyzing the response to LEDs and cosmic rays, confirming the expected behavior as well as the spontaneous recovery due to thermal annealing when exposure to radiation is suspended.

\(^1\)NSF F. Benmokhtar 1615067 and DoE/INFN

HA.00124 Proton Simulation Studies of Neutron Lifetime Measurement at NIST\(^1\), JOSE NEGRON, Gettysburg College, BL2 COLLABORATION — Precise knowledge of the neutron lifetime is crucial to understanding one of the four fundamental forces in the universe, the weak force, and understanding the ratio of hydrogen to helium formed in the early universe. Several major projects have been conducted in order to find the neutron lifetime using two different methods: The Bottle and The Beam methods. The neutron beam experiment underway at NIST shoots a beam of neutrons through an electrostatic trap where protons that decay from the free neutrons are trapped and then directed by a magnetic field to a proton detector and counted. Through Geant4 simulations, the neutron beam apparatus is reproduced, and proton interactions within the apparatus are simulated. Recent focus has been directed at studying proton arrival time at the detector, the effect of different electrostatic fields in the trap, and the proton count rate as a function of trap length. The end goal is to understand the size of systematic errors to ensure they contribute less than 2 seconds to the uncertainty in the neutron lifetime.

\(^1\)This work was supported, in part, by the Cross-Disciplinary Science Institute at Gettysburg College (X-SIG).
the relationship can be well described with a linear to exhibit a nonlinear hydrodynamic response to the initial geometry, characterized by eccentricity cumulants. Previous work has identified that formation of a quark-gluon plasma, which evolves as a strongly coupled liquid. The flow harmonics produced after the QGP freeze-out are known SKANDAPRASAD RAO, Rutgers University, New Brunswick — Jet suppression in heavy-ion collisions provided evidence in the 2000s of the +vNN, and Au NN= 27 GeV. In particular direct and elliptical flow comparisons of kaons determined by the Time Projection Chamber (TPC) and the Even Plane Detector (EPD) found at the Solenoid Tracker at RHIC (STAR).

This work was supported, in part, by the Cross-Disciplinary Science Institute at Gettysburg College (X-SIG).

HA.00126 3-Dimensional Hadronic Structure from Transverse-Spin Observables in High-Energy Collisions JOSHUA MILLER, Lebanon Valley College, JUSTIN CAMMAROTA, Lebanon Valley College/College of William and Mary, LEONARD GAMBERG, Penn State Berks, ZHONGBO KANG, UCLA, DANIEL PITONYAK, Lebanon Valley College, ALEXEI PROKUDIN, Penn State Berks/ Jefferson Lab, NOBUO SATO, Jefferson Lab/Old Dominion University — Quarks and gluons interacting inside of a hadron remains a complex system that needs to be analyzed. To probe inside of hadrons, they have to be collimated at high energies, and protons or protons in a strong magnetic field. The properties of the nearly perfect liquid that permeated the early universe. QGP created in heavy-ion collisions at the Relativistic Heavy Ion Collider (RHIC) has enabled researchers to comprehend the QGP through theoretical models. We present the analysis of anisotropic flow of the quark gluon plasma produced by Gold-Gold ion collisions at √sNN = 27 GeV. In particular direct and elliptical flow comparisons of kaons determined by the Time Projection Chamber (TPC) and the Even Plane Detector (EPD) found at the Solenoid Tracker at RHIC (STAR).

This material is based upon work supported by the National Science Foundation under Grant Nos. 1614474 and 1852010.

HA.00127 Direct and Elliptical Flow Comparison at √sNN = 27 GeV. MANUEL ROSALES, Lehigh University — Understanding the appearance and flow development of Quark Gluon Plasma (QGP) is crucial in improving our comprehension of the nearly perfect liquid that permeated the early universe. QGP created in heavy-ion collisions at the Relativistic Heavy Ion Collider (RHIC) has enabled researchers to comprehend the QGP through theoretical models. We present the analysis of anisotropic flow of the quark gluon plasma produced by Gold-Gold ion collisions at √sNN = 27 GeV. In particular direct and elliptical flow comparisons of kaons determined by the Time Projection Chamber (TPC) and the Even Plane Detector (EPD) found at the Solenoid Tracker at RHIC (STAR).

This material is based upon work supported by the National Science Foundation under Grant Nos. 1614474 and 1852010.

HA.00128 Z boson Measurements in pp Collisions at RHIC THOMAS LIMOGES, Lehigh University — At the Relativistic Heavy Ion Collider (RHIC), pp collisions at center of mass energy 500 GeV often produce Z bosons. We will show results of the momentum balance between the Z boson and the away side jet (X-SIG) using PYTHIA 8 simulations. Using experimental data, muon and electron decay channels are used by STAR to find the Z boson and jet momenta ratio as well as the Z boson production cross section. We will show how the 3-dimensional (3D) structure, a particle with its spin transverse to its momentum must be involved. Such collisions can occur in semi-inclusive deep inelastic scattering (SIDIS), semi-inclusive e+e− annihilation (SIA) and proton-proton collisions. Since the same fragmentation functions (FFs) and parton distribution functions (PDFs) enter these reactions, a global analysis can be performed that fits these functions. In this poster, I will present results from such a fit, where a replica/Monte Carlo method was used, give some computational details, and discuss the insight we can gain about quark-gluon correlations in hadrons and their 3D structure.

This material is based upon work supported by the National Science Foundation under Grant Nos. 1614474 and 1913696.

HA.00129 Constraining theoretical initial conditions models of heavy-ion collisions with Au+Au collision data at √sNN =27 GeV from the STAR detector at RHIC SKANDAPRASAD RAO, Rutgers University, New Brunswick — Jet suppression in heavy-ion collisions provided evidence in the 2000s of the formation of a quark-gluon plasma, which evolves as a strongly coupled liquid. The flow harmonics produced after the QGP freeze-out are known to exhibit a nonlinear hydrodynamic response to the initial geometry, characterized by eccentricity cumulants. Previous work has identified that the relationship can be well described with a linear to exhibit a nonlinear hydrodynamic response to the initial geometry, characterized by eccentricity cumulants. Previous results support the prediction by the standard model. This poster summarises updates done to nSpinSim, a fortran program that simulates the neutron polarimeter apparatus to be implemented in NIST in the updated version of the experiment. nSpinSim is a Monte-Carlo transport code aiming to help researchers understand the resolution in the high-precision measurements by studying systematic errors. Modifications include incorporation of realistic magnetic field maps, updating beam line components, and changing the implementation of how the code chooses neutron parameters from phase-space distributions.

This work was supported, in part, by the Cross-Disciplinary Science Institute at Gettysburg College (X-SIG).

Tuesday, October 15, 2019 4:00PM - 6:00PM — Session HB Meet the Physical Review Editors (4:00pm - 6:00pm) Salon 4 - 4:00PM HB.00001 Meet the Physical Review Editors (4:00pm - 6:00pm) — Wednesday, October 16, 2019 8:30AM - 10:18AM — Session KA Nuclear Probes of Fundamental Symmetries Salon 1 - Vincenzo Cirigliana, LANL
8:30AM KA.00001 Theoretical approaches to neutrinoless double beta decay from the ground up. AMY NICHOLSON, University of North Carolina at Chapel Hill — While the discovery of non-zero neutrino masses is among the most important accomplishments by physicists in the past century, it is still unknown how and in what form these masses arise. Lepton number-violating neutrinoless double beta decay is a natural consequence of Majorana neutrinos and many BSM theories, and, if observed, could potentially explain the matter/anti-matter asymmetry in the universe. Several experimental searches for these processes using nuclear sources are planned and/or underway worldwide, and understanding quantitatively how neutrinoless double beta decay would manifest in nuclear environments is key for interpreting any observed signals. In this talk I will give a brief overview of current theoretical approaches to understanding neutrinoless double beta decay from the microscopic BSM mechanisms, to the combined efforts of effective field theory and lattice QCD on quantifying few-hadron processes, to the many-body approaches necessary for calculating observables for experimentally relevant nuclei.

9:06AM KA.00002 Calculations of nucleon EDMs on a lattice. SERGEY SYRITSYN, Stony Brook University — Electric dipole moments of the nucleons would be evidence of CP violation due to the QCD theta term or effective quark-gluon interactions induced by symmetry-breaking physics beyond the Standard Model. Upcoming experiments will improve precision of neutron EDM measurements by 1-2 orders of magnitude within the next decade. Corresponding improvements on (and eventual observation of) nucleon EDMs will have to be traced back to the quark-gluon level to be used as constraints on new particles and interactions. While low-energy theories and nucleon models provide ballpark estimates of nEDMs that can be produced by different kinds of CP violation in quark-gluon interactions, nonperturbative QCD calculations on a lattice are necessary to find precise and model-independent relations between them. Lattice QCD has reached a respectable level of statistical and systematic precision for hadron spectrum and simple nucleon structure observables with physical quark masses, and on the verge of producing reliable results for nucleon EDMs induced by quark-gluon operators starting from the lowest-order operators. In this talk, I will overview the current status of such calculations as well as show some recent results.

9:42AM KA.00003 Short-lived radioactive molecules: A sensitive laboratory for the study of fundamental symmetries. RONALD G. GARCIA RUIZ, CERN — Molecules containing heavy and deformed radioactive nuclei are predicted to provide enhanced sensitivity to explore the nuclear electroweak structure as well as to test the violation of fundamental symmetries. However, experimental measurements of such radioactive systems are scarce, and in most of the cases, quantum-chemistry calculations constitute the only source of available information. This contribution will expose recent achievements in laser spectroscopy of radioactive molecules at CRIS, ISOLDE-CERN. Laser spectroscopy measurements of short-lived radium fluoride molecules (RaF) will be presented. The impact of these results in EDM searches and symmetry-violating measurements will be discussed.

Wednesday, October 16, 2019 8:30AM - 10:18AM - Session KB Neutrino Physics Salon 2 - Jim Napolitano, Temple University

8:30AM KB.00001 νe - 16O Interactions in Super-Kamiokande With Low Energy Atmospheric Neutrinos. BARAN BODUR, KATE SCHOLBERG, Duke University, SUPER KAMIOKANDE COLLABORATION — Charged current quasi-elastic scattering of electron neutrinos below 100 MeV from 16O nucleus is not yet observed, despite being a major component of the atmospheric neutrino signal at low energies. This channel is an important background for diffuse supernova neutrino background searches (DSNB) with inverse beta decay process in water Cherenkov detectors, an additional νe detection channel in case of a supernova burst, and a possible way to probe atmospheric neutrinos at low energies that will be a background for the future WIMP dark matter searches. A study for the first observation of this interaction with 20 years of Super-Kamiokande data is currently underway. We estimate about 60 signal events in the fiducial volume of Super-Kamiokande experiment and identify νe - 16O and inverse beta decay interactions from atmospheric and DSNB neutrinos as major backgrounds. We will present estimated signal and background rates, methodology and current progress of the search.

8:42AM KB.00002 Neutrino Fast Flavor Conversions in 1D Supernova Simulations. SAMUEL FLYNN, SHERWOOD RICHERS, JAMES KNELLER, GAIL MCLAUGHLIN, North Carolina State University — Until recently the neutrinos emitted from the proto-neutron star created in a core-collapse supernova explosion were not expected to undergo flavor oscillations until significantly outside of the neutrinosphere. That expectation was later challenged when non-isotropic angular distributions of the neutrinos was considered. It was found, that under certain conditions, so-called ‘fast flavor transformation’ could occur at radii which were much closer to the core thus potentially altering the dynamics of the explosion. However, previous analysis of 1D supernova simulations did not find any instances when these conditions are prevalent. In this talk, I will first give an overview of fast flavor conversions by examining toy models which simplify the conditions for conversions to occur. I will then introduce linear stability analysis as a tool for examining more complex cases which more closely resemble supernovae, and our method of reconstructing the neutrino distribution function. Finally, I will present results indicating that fast oscillations can indeed occur in 1D supernova simulations, and suggest an explanation for why other analyses saw no such oscillations.

8:54AM KB.00003 Investigation of Neutron-Induced Backgrounds on 134, 136Xe at En = 5 - 8 MeV for Neutrinoless Double Beta Decay Searches. MARY KIDD, Tennessee Technological University, WERNER TORNOW, SEAN FINCH, FNU KRISHICHAYAN, TUNL/Duke University — Neutrinoless double-beta decay (0νββ) studies are both the best way to determine the Majorana nature of the neutrino and determine its effective mass. The two main experiments searching for 0νββ-decay of 136Xe (Q value = 2457.8 keV) are Kamland-Zen and EXO-200. Though both experiments have enriched 136Xe targets, these targets still contain significant quantities of 134Xe. A new nuclear level was reported in 134Xe that decays to the ground state emitting a 2485.7 keV gamma ray [1]. For incident neutron energies of 2.5 - 4.5 MeV, the γ-ray production cross section for this branch was found to be on the order of 10 mb. Here, we further explore the potential neutron-induced backgrounds on both 134Xe and 136Xe for extended neutron energies from 5 to 8 MeV. We will report our preliminary results for neutron inelastic scattering on 134,136Xe in applications to 0νββ decay searches. [1] E.E. Peters, et al., EPJ Web of Conferences, 93, 01027 (2015).

1NSF PHY-1614348, DE-FG02-97ER41033
9:06AM KB.00004 Neutron-induced background on natural tellurium relevant to 130Te $0\nu\beta\beta$ decay searches at CUORE and SNO+. WERNER TORNOW, SEAN FINCH, Duke University, MARY KIDD, Tennessee Tech University — Gamma-ray production cross-section data have been obtained for the reactions $^{126,128,130}\text{Te}(n,n'\gamma)$ at five mean neutron energies between 3.5 and 10 MeV. We report data for the $\gamma$-ray energy region relevant to $0\nu\beta\beta$ decay of $^{130}\text{Te}$ with $Q_{\beta\beta}$-value of 2527.515 keV. For CUORE only the $\gamma$-ray transitions of excited states of $^{130}\text{Te}$ at 2527.06 keV and of $^{126}\text{Te}$ at 2533.85 keV are of interest. For SNO+ with its inferior energy resolution, additional excited state decays of $^{130}\text{Te}$ levels at 2575.2, 2581.15, and 2607.33 keV, of $^{126}\text{Te}$ levels at 2494.20, 2508.06, 2516.64, 2550.52, 2571.17, 2587.14, 2598.99, and 2630.14 keV, and of $^{128}\text{Te}$ levels at 2496.83, 2503.55, 2577.02, and 2585.462 keV are important. The highest cross-section values were found for cascade $\gamma$-ray transitions to the ground state, while direct transitions to the ground state are very weak and have been observed only for $^{130}\text{Te}$ at 2527.06 keV and of $^{126}\text{Te}$ at 2533.85 keV are of interest. For SNO+ with its inferior energy resolution, additional excited state decays of $^{130}\text{Te}$ levels at 2575.2, 2581.15, and 2607.33 keV, of $^{126}\text{Te}$ levels at 2494.20, 2508.06, 2516.64, 2550.52, 2571.17, 2587.14, 2598.99, and 2630.14 keV, and of $^{128}\text{Te}$ levels at 2496.83, 2503.55, 2577.02, and 2585.462 keV are important. The highest cross-section values were found for cascade $\gamma$-ray transitions to the ground state, while direct transitions to the ground state are very weak and have been observed only for $^{130}\text{Te}$ at 2527.06 keV, for $^{128}\text{Te}$ at 2508.04 keV, and for $^{126}\text{Te}$ at 2533.32 keV. However, both the CUORE and SNO+ detectors may not be able to distinguish between cascade transitions to the ground state and direct transitions, making especially the neutron-induced excitation of the 2527.06 keV state of $^{130}\text{Te}$ a potential problem for $0\nu\beta\beta$ decay searches of $^{130}\text{Te}$.

9:18AM KB.00005 Investigation of the QRPA method for the neutrinoless double beta decay candidate $^{136}\text{Xe}$ using two-nucleon transfer. REBECCA TOOMEY, DAVID WALTER, Rutgers University, MICHAEL FEBBRARO, STEVEN PAIN, KELLY CHIPS, CAROLINE NESARAJA, WILLIAM PETERS, MICHAEL SMITH, Oak Ridge National Laboratory, DANIEL BARDAYAN, JAMES KOLATA, PATRICK O’MALLEY, University of Notre Dame, FREDERICK BECHETTI, University of Michigan, KATE JONES, CORY THORNSBERRY, University of Tennessee, BENJAMIN KAY, Argonne National Laboratory, RAYMOND KOZUB, Tennessee Technological University — The observation of neutrino oscillations implies that the neutrino has a finite rest mass and, as such, may possibly allow decay via the hitherto unobserved neutrinoless double beta decay. There are many major experimental efforts focused on observing this decay mode. Were the decay to be observed, its rate and calculated nuclear matrix elements would provide information on the effective neutrino mass. However, calculations of the required nuclear matrix elements are inherently difficult and often exhibit large uncertainties. Often, quasiparticle random phase approximation (QRPA) methods are used, which rely on the assumption that the initial and final states can be described as a BCS condensate. This can be tested experimentally using two-nucleon transfer, where a breakdown of the BCS assumption could manifest as a pairing vibration, or pair-correlated excited states. The proposed measurement of $^{136}\text{Xe}(^6\text{He},n)^{136}\text{Ba}$ to investigate the $0\nu\beta\beta$ decay candidate $^{136}\text{Xe}$, and the potential implications of the results will be discussed.

1This work has been supported in part by the U.S. D.O.E and the NSF.

9:30AM KB.00006 Neutrino-Induced Neutron Detectors at the Spallation Neutron Source. SAMUEL HEDGES, Duke University, COHERENT COLLABORATION — Neutrino-nucleus interactions can produce excited nuclear states that can de-excite by emitting particles, including neutrons. Neutrino-induced neutrons (NINs) produced in common gamma shielding material, such as lead or iron, can pose a background for neutrino and dark matter experiments. Additionally, NIN production in lead and iron nuclei has the capability to generate both scintillation and charge signals to readout simultaneously. This enables the readout of not only the energy deposition but also the spatial information of interactions. It would be beneficial if hydrogen could be introduced into the LAr medium. This additional proton target could potentially improve sensitivity for neutron detection, limit the number of final state interactions for neutrino physics, and improve background neutron vetoing capability for neutrinoless double-beta decay and other low-energy physics searches. Historically, the introduction of hydrogen into LAr as a hydrocarbon has failed due to the absorption of LAr scintillation by the introduced dopants. A promising novel detection scheme based on using the radiationless transfer of excitation energy is being investigated in a 10% methane loaded liquid argon detector. The apparatus and experiment status will be presented.

9:42AM KB.00007 ABSTRACT WITHDRAWN — 

9:54AM KB.00008 Characterizing Perovskite Nanoplatelets for Liquid Scintillator Nanodetectors1. ELEANOR GRAHAM, Massachusetts Institute of Technology, NUDOT COLLABORATION — The next generation of liquid scintillator neutrinoless double beta decay experiments will require stable loading of candidate isotopes on the kiloton scale, representing a significant chemical challenge. Nanoparticles containing the candidate isotopes provide a promising method for this loading. Additionally, the unique optical properties of nanoparticles can also enhance detection and background discrimination. Perovskite nanoplatelets are particularly attractive due to the reliability of their crystal structure and their easily-scalable synthesis. We investigate the latest generation of perovskite nanoplatelets, targeting properties relevant to detector applications: emission, light yield, maximum loading, and stability. Informed by these results, we present a plan for future development of perovskite nanoplatelets for use in particle detectors.

1Work Supported By U.S. DOE, Office of Science, Office of Nuclear Physics DE-AC05-00OR22725

Wednesday, October 16, 2019 8:30AM - 10:18AM – Session KE Mini-Symposium: Short Range Correlations and Bound Nucleon Structure Across Scales II • Salon 5 - Doug Higinbotham, JLab
relations effects in a phenomenological model. Bardayan, University of Notre Dame


reduced proton occupancies for states below or near the Fermi level as a function of (N-Z)/A. In this contribution we extend the model to examine the role of short- and long-range correlations and their evolution in asymmetric systems [3]. Our approach for the quenching of spectroscopic factors observed in (e,ep), (p,2p) and transfer reactions [1]. Inspired by the results of Ref. [2], we proposed a framework to explain many nuclear properties. Residual interactions between nucleons, both short- and long-range, modify the mean-field approximation and the pure independent-particle picture in the form of quasi-particles. Notably, these correlations are thought to be the reason for the quenching of spectroscopic factors observed in heavy asymmetric nuclei have been a very useful tool for measuring Short Range Correlated (SRC) pairs. While these types of studies have provided interesting results, many body nuclear systems cannot easily be related to theory. On the other hand, a study of light nuclei such as Helium-4 and Helium-3 would allow for a more accurate comparison between experiment and ab initio calculations. In this talk I will present new studies of single nucleon knockout measurements in Helium isotopes that can be calculated exactly.

short-range Correlation Measurement with 3H and 3He at JLab. SHUJIE LI, University of New Hampshire, DOUGLAS HIGINBOTHAM, Thomas Jefferson National Accelerator Facility, JEFFERSON LAB HALL A COLLABORATION — The nucleon-nucleon potential has a strong repulsive core. When a two-nucleon (sub)system falls into this range, they will interact strongly and move away from each other with large momentum. In electron Quasi-elastic(QE) scattering, these so-called short-range correlation(SRC) pairs in nucleon produce events with nucleon initial momentum above the Fermi level. Previous experiments reported a neutron-proton pair (isosinglet) dominance in high-momentum nucleons. This n-p dominance is believed to cause a scaling behavior of nuclei inclusive cross section ratios at Bjorken x between 1.4 and 3 where the high-momentum nucleons dominate. At Jefferson Lab Hall A we checked this n-p dominance of SRC via the electron scattering on A=3 nuclei system. The 3H to 3He inclusive cross section at \( 1 < x < 3 \) were measured in two experiments (E12-11-112 and E12-14-011) with a wide Q2 range (0.4 < Q^2 < 3 GeV^2). In this talk the preliminary results of 3H/3He ratio at \( 1 < x < 2 \) will be released at various Q^2.

Quantum Monte Carlo calculations of lepton-nucleus interactions, ALESSANDRO LOVATO, Argonne National Laboratory — One of the challenges in quantum many-body physics is calculating the electroweak response of a nucleus by fully accounting for the dynamics of its constituent nucleons. Electron-scattering experiments have been pivotal to expose the role of nuclear correlations and in particular their spin-isospin dependence in the initial target state. Besides, accurate calculations of lepton-nucleus scattering are of paramount importance to the accelerator-neutrino experimental program. Greens function Monte Carlo (GFMC), using as inputs realistic Hamiltonian and consistent electroweak currents, enables first-principles calculations of nuclear electroweak responses in the quasi-elastic region. I will present our GFMC results for electron and neutrino scattering on \(^{12}\text{C}\) induced by electromagnetic-, neutral-, and charged-current transitions. I will argue how the strength and energy-dependence of two-nucleon processes associated with correlation effects and interaction currents are crucial in providing the most accurate description of lepton-nucleus scattering in the quasi-elastic regime.

Inclusive lepton-nucleus scattering from Quantum Monte Carlo, SAORI PASTORE, Washington University, St. Louis — In this talk, I will present recent results of Quantum Monte Carlo calculations of lepton-nucleus interactions, including lepton-nucleus scattering and electroweak decays in light nuclei.

Inclusive lepton-nucleus scattering from Quantum Monte Carlo, ALESSANDRO LOVATO, Argonne National Laboratory — One of the challenges in quantum many-body physics is calculating the electroweak response of a nucleus by fully accounting for the dynamics of its constituent nucleons. Electron-scattering experiments have been pivotal to expose the role of nuclear correlations and in particular their spin-isospin dependence in the initial target state. Besides, accurate calculations of lepton-nucleus scattering are of paramount importance to the accelerator-neutrino experimental program. Greens function Monte Carlo (GFMC), using as inputs realistic Hamiltonian and consistent electroweak currents, enables first-principles calculations of nuclear electroweak responses in the quasi-elastic region. I will present our GFMC results for electron and neutrino scattering on \(^{12}\text{C}\) induced by electromagnetic-, neutral-, and charged-current transitions. I will argue how the strength and energy-dependence of two-nucleon processes associated with correlation effects and interaction currents are crucial in providing the most accurate description of lepton-nucleus scattering in the quasi-elastic regime.

Quantum Monte Carlo calculations of lepton-nucleus interactions, SAORI PASTORE, Washington University, St. Louis — In this talk, I will present recent results of Quantum Monte Carlo calculations of lepton-nucleus interactions, including lepton-nucleus scattering and electroweak decays in light nuclei.

Quenching of Spectroscopic Factors: Short- and long-range correlations effects in a phenomenological model, STEFANOS PASCHALIS, MARINA PETRI, University of York, AUGUSTO MACCHIAVELLI, Lawrence Berkeley National Laboratory — The independent-particle model of the nucleus has provided a solid framework to explain many nuclear properties. Residual interactions between nucleons, both short- and long-range, modify the mean-field approximation and the pure independent-particle picture in the form of quasi-particles. Notably, these correlations are thought to be the reason for the quenching of spectroscopic factors observed in (e,ep), (p,2p) and transfer reactions [1]. Inspired by the results of Ref. [2], we proposed a phenomenological model to examine the role of short- and long-range correlations and their evolution in asymmetric systems [3]. Our approach correlates the observed [2] increase of the high-momentum component of the proton momentum density in a neutron-rich nucleus with the reduced proton occupancies for states below or near the Fermi level as a function of (N-Z)/A. In this contribution we extend the model to capture effects of weak binding that may play a role in reactions with exotic beams. Furthermore, we discuss the implications of our SRC results on the symmetry energy and potential changes in charge radii. [1] W. Dickhoff and C. Barbieri, PPNP 52 (2004) 377 [2] M. Duer et al., Nature, 560 (2018) 617 [3] S. Paschalis, et al. arXiv:1812.08051v2 [nucl-ex]
8:30AM KG.00001 Constraining the $^{30}\text{P}(p,\gamma)^{31}\text{S}$ reaction using $^{30}\text{P}(d,\gamma)^{31}\text{P}$ with GODDESS$^1$. RAJESH GHIMIRE, University of Tennessee + Oak Ridge National Laboratory, STEVEN PAIN, Oak Ridge National Laboratory, KATE JONES, University of Tennessee, ANDREW RATKIEWICZ, Lawrence Livermore National Laboratory, JOLIE CZIEWSKI, CHAD UMMEL, HARRISON SIMS, GWENAILLE SEYMOUR, Rutgers University, GODDESS COLLABORATION — In classical nova nucleosynthesis, the $^{30}\text{P}(p,\gamma)^{31}\text{S}$ reaction rate critically affects the mass flow into the A=30-40 range, impacting the abundances of isotopes of phosphorus, sulfur and silicon. However, currently available $^{30}\text{P}$ beam intensities are insufficient to measure the $(p,\gamma)$ reaction directly. The rate of this reaction depends on undetermined spectroscopic strengths of low-lying resonances in $^{31}\text{S}$, located between 6 and 7 MeV in excitation. However, it is experimentally difficult to measure proton spectroscopic factors on unstable nuclei. We performed a $^{30}\text{P}(d,\gamma)^{31}\text{P}$ neutron transfer reaction measurement using the newly commissioned GODDESS (Gretina-ORRUBA: Dual Detectors for Experimental Structure Studies) system with an 8 MeV/u $^{30}\text{P}$ beam, from RAISOR at ATLAS, in order to provide constraints on the spectroscopic strengths for $^{31}\text{S}$ levels via mirror symmetry. Details of the experiment and initial data analysis will be presented.

$^1$This work is supported by the U.S. Dept. of Energy, Office of Science, Office of Nuclear Physics, the NNSA SSAA Program, and the National Science Foundation.

8:42AM KG.00002 GADGET: a Gaseous Detector with Germanium Tagging$^1$. CHRISTOPHER WREDE, MOSHE FRIEDMAN, Michigan State University, DAVID PREZ-LOUREIRO, Michigan State University and University of Tennessee, TAMAS BUDNER, Michigan State University, EMANUEL POLLACCO, IRFU, CEA, Universit Paris-Saclay, MARCO CORTESI, CATHLEEN FRY, BRENT GLASSMAN, MADISON HARRIS, Michigan State University, JOE HEIDEMAN, University of Tennessee, MOLLY JANASIK, Michigan State University, BRIAN ROEDER, Texas AM University, MICHAEL ROOSA, Michigan State University, ANTTI SAASTAMOINEN, Texas AM University, JORDAN STOMPS, JASON SURBROOK, PRANJAL TIWARI, JOHN YURKON, Michigan State University — Nuclear synthesis and energy generation in classical novae and type I x-ray bursts depend on the thermonuclear rates of radiative proton capture reactions. Many of these rates are dominated by contributions from narrow isolated resonances. Each resonance strength can be constructed from the proton branching ratio and lifetime. A new detection system, the Gaseous Detector with Germanium Tagging (GADGET), has been designed and constructed at the National Superconducting Cyclotron Laboratory (NSCL) to measure proton branching ratios. GADGET consists of a gaseous proportional counter to measure the spectrum of low-energy beta-delayed protons and the Segmented Germanium Array (SeGA) of high-purity germanium detectors to measure beta-delayed gamma rays. GADGET has been commissioned at NSCL using a rare-isotope beam of $^{25}\text{Si}$.

$^1$This work was supported by NSF awards PHY-1102511 and PHY-1565546 and DOE award DE-SC0016052.

8:54AM KG.00003 Proton Capture on 34S in the Astrophysical Energy Regime$^1$. MATTHEW LOVELY, Colorado Sch of Mines, DEVIN CONNOLLY, Los Alamos National Lab, JONATHAN KARPESKY, Colorado Sch of Mines, STEPHEN GILLESPIE, TRIUMF National Lab, PATRICK O’MALLEY, University of Notre Dame, ALEN CHEN, McMaster University, BARRY DAVIDS, ANNIKA LENNARZ, TRIUMF National Lab, ALISON LAIRD, University of York, CHRIS RUIZ, DAVE HUTCHIEON, TRIUMF National Lab, UWE GREIFE, Colorado Sch of Mines, DRAGON COLLABORATION — Novae are explosive astrophysical events which provide a unique environment for nucleosynthesis. Oxygen-Neon(O-Ne) novae caused by the thermonuclear runaway of accreted material on the white dwarf of a close binary system can reach peak temperatures of 0.1-0.4 GK. These novae are particularly important for the production of higher mass nuclides through complex reaction networks. Many of the resonance strengths in these networks have been theoretically calculated and lead to a large degree of uncertainty in the final production of the nuclei. One reaction of particular importance for these processes is the proton capture on 34S at energies relevant to nova nucleosynthesis. Previously, this reaction has been measured above $E_{cm}=495$ keV but here we will discuss the recent direct measurement conducted at DRAGON in inverse kinematics from $E_{cm}=272$ keV to 495 keV.

$^1$The research presented was funded through the U.S. Department of Energy Office of Science.

9:06AM KG.00004 Studying the Energy Levels of $^{39}\text{Ca}$ for the $^{38}\text{K}(p,\gamma)^{39}\text{Ca}$ Reaction Rate$^1$. MATTHEW HALL, Oak Ridge National Laboratory, DANIEL BARDAYAN, University of Notre Dame, TRAVIS BAUGHER, ALEX LEPAILLEUR, Rutgers University, STEVEN PAIN, Oak Ridge National Laboratory, ANDREW RATKIEWICZ, Lawrence Livermore National Laboratory, GODDESS COLLABORATION — It has been established that nuclei up to $A=40$ are produced in nova explosions, but there exist discrepancies between theory and observation regarding their abundances. The $^{38}\text{K}(p,\gamma)^{39}\text{Ca}$ reaction rate has been identified as a large source of uncertainty at the endpoint of nova nucleosynthesis and could be key in understanding this discrepancy. To reduce its uncertainty, the $^{40}\text{Ca}(^{4}{	ext{He}},\alpha)^{39}\text{Ca}$ reaction was measured at Argonne National Laboratory using GODDESS (Gammashpere ORRUBA Dual Detectors for Experimental Structure Studies) to study the energy levels in $^{39}\text{Ca}$. $\gamma$ rays from the decay of excited states in $^{39}\text{Ca}$ were measured in coincidence with alpha particles from the reaction. In total, 23 new $\gamma$-ray transitions were found in $^{39}\text{Ca}$, including new $\gamma$-decay information for three $J^e=3/2^+$ excited states that are important in the calculation of the reaction rate. These decay results, as well as how these results affect the reaction rate, will be presented.

$^1$This research was supported in part by the NSF (PHY-1419765 and PHY-1404218), the NNSA under the SSAA program through DOE Cooperative Agreement DE-NA000232, DOE Office of Science, Office of Nuclear Physics, contract nos. DE-AC05-00OR22725 and DE-FG02-96ER40963, and ANL contract no. DE-AC02-06CH11357.
Transfer Reactions on $^{15}$N. C. DEIBEL, G. WILSON, E. GOOD, Louisiana State University, A. LAUER, Duke University, A. CHEN, McMaster University, B. BACK, C. HOFFMAN, B. KAY, R. PARDO, D. SANTIAGO-GONZALEZ, TSE LEUNG TANG, Argonne National Laboratory, A. WUOSMAA, University of Connecticut — The $^{15}(\alpha,\gamma)^{19}$Ne reaction is well known to be an important breakout from the hot CNO cycle into the thermonuclear runaway that drives Type I X-Ray Bursts. This reaction rate is dominated by resonant $\alpha$ capture into a state at $E_x = 4.033$ MeV in $^{19}$Ne. While there have been a variety of experimental studies aimed at determining this reaction rate, the $\alpha$ width of this resonance remains the dominant uncertainty. Currently, $^{15}$O beams of sufficient intensity to study this reaction directly are not available and indirect techniques must be used in order to study the 4.033-MeV state in $^{19}$Ne. Measurements of the $(^6$Li,d) and $(^7$Li,t) $\alpha$-particle transfer reactions on beams of $^{15}$N have been performed at the Argonne Tandem LINAC Accelerator System facility at Argonne National Laboratory using the HELical Orbit Spectrometer (HELIOS) in order to study the mirror to the 4.033-MeV state, located at 3.908 MeV in $^{19}$F. Preliminary results will be shown and implications for the $^{15}(\alpha,\gamma)^{19}$Ne reaction rate discussed.

This work was partially supported by the U.S. Department Of Energy, Office of Nuclear Physics under Contract numbers DE-FG02-96ER40978 and DE-AC02-06CH11357. This research used resources of ANL’s ATLAS facility, which is a DOE Office of Science User Facility.

9:30AM KG.00006 Study of proton-resonances in the $^{19}$Ne(d,n)$^{20}$Na reaction using RESONEUT detector system. MEENU THAKUR, L.T. BABY, I. WIEDENHÖVER, E. TEMANSON, K. HANSELMAN, G. MCCANN, J. BLACKMON, Department of Physics, Florida State University, Tallahassee, FL 32306, USA — Studies of nucleosynthesis in stellar explosions reveal that obtaining relevant information on the lowest lying resonances is crucial step to determine reaction rates in the astrophysical rp-process. In previous experiments at the RESOLUT facility, (d,n) reaction in inverse kinematics has been used to populate these resonances of astrophysical interest [1]. For such measurements, a compact neutron detector array RESONEUT has been developed which can efficiently detect low energy neutrons from (d,n) reaction [1]. In the present paper, results from our recently performed radioactive-beam experiment studying $^{19}$Ne(d,n)$^{20}$Na reaction using RESONEUT will be presented. This reaction is comparable to direct proton capture $^{19}$Ne(p,γ)$^{20}$Na which is of astrophysical significance. Results from previous studies indicate the contradictions in spin and parity assignments of the first proton resonance in $^{20}$Na. So, we study the population of the lowest lying proton resonances in $^{20}$Na using neutron time of flight spectroscopy in an attempt to resolve these contradictions and determine accurate information of reaction rate. [1] S. Kuvin et al, PRC 96, 045812 (2017)

This work is supported by U.S. DOE under grant No. DE-FG02-02ER41220 and the NSF under grant No. PHY-1712953.

9:42AM KG.00007 Measurement of the $^{18}$Ne($\alpha,p)^{21}$Na reaction with ANASEN between 2 and 4 MeV in the center of mass. M. ANASTASIOU, I. WIEDENHÖVER, L. BAGH, Florida State University, N. RUJAL, National Superconducting Cyclotron Laboratory, J. PARKER IV, Florida State University, J. BLACKMON, C. DEIBEL, A. HOOD, J. LIGHTHALL, K. MACON, Louisiana State University, D. SANTIAGO-GONZALEZ, Argonne National Laboratory, Y. KOSHCYI, G. ROGACHEV, Texas AM University — The $^{18}$Ne($\alpha,p)^{21}$Na reaction is one of the reactions providing a pathway for breakout from the hot CNO cycles to the rp-process in Type I X-ray bursts. The actual conditions under which the breakout occurs depend critically on the thermonuclear reaction rate. This rate has not yet been sufficiently determined under X-ray burst conditions. We study the direct $^{18}$Ne($\alpha,p)^{21}$Na reaction with the Array for Nuclear Astrophysics and Structure with Exotic Nuclei (ANASEN), using a helium gas target and an $^{18}$Ne radioactive beam from RESOLUT facility at the FSU accelerator lab. The results are consistent with the time-reverse measurements [1] and provide a total cross section between 2 and 4 MeV in the center of mass. [1] Salter et al., Measurement of the $^{18}$Ne(α,p)$^{21}$Na Reaction Cross Section in the Burning Energy Region for X-Ray Bursts, Phys.Rev.Lett. 108 (242701), 2012

Supported by the US NSF MRI program Grant no. PHY-0820941, NSF Grant no. PHY-1712953.

9:54AM KG.00008 Cross section measurements and R-Matrix analyses of the $^{24}$Mg($\alpha,\gamma)^{27}$Al and $^{27}$Al($p,\alpha)^{24}$Mg reactions with HAGRID. S. AGUILAR, T. AHN, A. BOELTZIG, University of Notre Dame, C. BRUNE, Ohio University, R. DEBOER, University of Notre Dame, K. JONES, University of Tennessee, K. MACON, University of Notre Dame — Alpha-induced reactions have been identified as playing an important role in various astrophysical phenomena. Sensitivity studies have indicated the $^{24}$Mg($\alpha,p)^{27}$Al reaction is important in understanding the energy generation in Type Ia X-ray bursts; therefore precise cross section measurements are needed. The $^{24}$Mg($\alpha,p)^{27}$Al reaction is one of the reactions providing a pathway for breakout from the hot CNO cycles to the rp-process in Type I X-ray bursts; therefore precise cross section measurements are needed. The $^{24}$Mg($\alpha,p)^{27}$Al cross section has not been measured directly, and no data is available for the inelastic channels which may contribute to its reaction rate. Present $^{24}$Mg($\alpha,p)^{27}$Al reaction rates rely exclusively on the inverse $^{27}$Al($p,\alpha)^{24}$Mg cross section. The direct ($\alpha,p$) and inverse ($p,\alpha$) reactions have been performed at the University of Notre Dame’s Nuclear Science Laboratory using the 5U. ANA accelerator to produce a high-intensity beam with high energy resolution, providing new precision cross section measurements. The LaBr3 Hybrid Array of Gamma Ray Detectors (HAGRID) was utilized to span seven unique angles to detect the secondary $\gamma$ rays in the inelastic channels. R-Matrix analyses of the cross sections using secondary $\gamma$ rays and the inelastic channels effect on reaction rates will be presented.

This work was supported by NSF Grant No. PHY-1713857, and JINA-CEE through PHY-0822648, PHY-1430152; and DOE through Grant DE-FG02-96ER40983, and the NNSA Grant Nos. DE-NA0002132, DE-NA0003883.

Wednesday, October 16, 2019 8:30AM - 10:06AM
Session KH Nucleon Structure I Salon B - David Armstrong
8:30AM KH.00001 Nucleon structure functions at large Bjorken x from 12 GeV commissioning experiment E12-10-002 in Hall C. DEBADITYA BISWAS, Hampton University — Ex extractions of F2 structure function from inclusive inelastic electron-proton scattering cross sections is important for the study of nucleon structure. Most existing data have large statistical uncertainties in the region of large Bjorken x. After the successful 12 GeV upgrade of Jefferson Lab, E12-10-002 is one of the first commissioning experiments ran in Hall C to measure the inclusive inelastic electron-proton scattering cross sections in the Q^2 region of 4 to 14 GeV^2. In this talk an overview of experiment E12-10-002 and first results will be presented.

This work is supported by National Science Foundation grant PHY-1508272 and Jefferson Science Associates.

8:42AM KH.00002 Preliminary cross section and F2 structure function results from E12-10-002 in 12 GeV era at Jefferson Lab. ABEL SUN, Carnegie Mellon University — Measurements of H(e,e') and D(e,e') cross sections were done at Jefferson Lab in experimental Hall C in Spring 2018. As part of the 12 GeV early running, we took data to explore a wide range in Bjorken x and to reach a four-momentum transfer Q^2 of up to 17 GeV^2. In this talk, I will show the preliminary cross section and F2 structure function results of our analysis and I will discuss the upcoming physics output.

This work is supported by U.S. DOE grant DE-FG02-87ER40315.

8:54AM KH.00003 Studies on Nuclear dependence of Anti-Quarks in Nuclei at the SeaQuest experiment, ARUN TADEPALLI, Jefferson Lab — The Fermilab E906/SeaQuest is an experiment aimed at studying the anti-quark distributions in nucleons and nuclei. The experiment uses a 120 GeV proton beam extracted from the Main Injector at Fermilab to collide with liquid deuterium, carbon, iron and tungsten targets to study the nuclear dependence of anti-quarks in nuclei. The experiment takes advantage of the Drell-Yan process and the acceptance is tuned to probe specifically the anti-quark structure in nucleons and nuclei. In the Drell-Yan process, a quark from one hadron annihilates with an anti-quark from another hadron, producing a virtual photon which eventually decays into a dilepton. The ratio of cross sections of these three targets relative to deuterium are studied to extract the relevant nuclear dependence and the physics implications. Recent progress on the nuclear dependence analysis at SeaQuest will be reported in this talk.

9:06AM KH.00004 ABSTRACT WITHDRAWN

9:18AM KH.00005 The SpinQuest Polarized Drell-Yan Experiment at Fermilab, MINJUNG KIM, University of Michigan, SPINQUEST COLLABORATION — The E1039/SpinQuest experiment at Fermilab aims to measure azimuthal asymmetries in the Drell-Yan production of dimuon pairs from 120 GeV/c unpolarized protons scattering off polarized nucleons to extract the Sivers functions for u and d quarks at 0.1<x<0.5. Measuring a non-zero Sivers asymmetry would be a significant discovery and present strong evidence for non-zero quark orbital angular momentum of sea quarks. First data taking is scheduled for fall 2019. In this talk we will present an experimental overview and current plans for the SpinQuest experiment.

9:30AM KH.00006 Constraining the Sea Quark Distributions Through W and Z Cross Sections and Cross Section Ratios Measurements at STAR, MATTHEW POSIK, Temple University, STAR COLLABORATION — Over the past several years, parton distribution functions (PDFs) have become more precise. However, there are still kinematic regions where more data are needed to help constrain global PDF extractions, such as the ratio of the sea quark distributions d/u near the valence region. Current measurements appear to suggest different high-x behaviors of this ratio. The STAR experiment at RHIC is well equipped to measure the leptonic decays for W and Z bosons in proton-nucleon collisions at √s = 500/510 GeV. These cross sections and their ratios are sensitive to quark and anti-quark distributions. In particular, the W^+/W^- cross section ratio is sensitive to the d/u ratio. RHIC runs from 2011 through 2013 have collected about 350 pb^-1 of integrated luminosity. This talk will present preliminary results of the 2011-2013 W^+/W^- and W/Z cross section ratios, as well as W and Z differential and total cross sections.

DOE NP contract: DE-SC0013405

9:42AM KH.00007 Constraining the glue in the pion through Drell-Yan lepton pair production, NINA CAO, Harvard University, NOBUO SATO, WALLY MELNITCHOUK, Jefferson Lab, JEFFERSON LAB ANGULAR MOMENTUM (JAM) COLLABORATION — Recently, a new global Monte Carlo analysis of parton distribution functions (PDFs) of the pion determined its valence quark distribution using Drell-Yan data from Fermilab and its sea quark and gluon PDFs from leading neutron electroproduction data from HERA [1]. While that analysis provided greater constraints at small parton momentum fractions x, the pion’s gluon PDF remains poorly known at large values of x. In the present study, we explore to-extent to which transverse momentum (p_T)-dependent Drell-Yan cross section can provide for greater sensitivity to the pion’s gluon PDF at large x. We present preliminary results of a combined QCD analysis of all available p_T-integrated and p_T-dependent pion data, which will provide the most complete imaging of the PDFs in the pion to date across all momentum fractions. [1] P. Barry et al., Phys. Rev. Lett. 121, 152001 (2018)

9:54AM KH.00008 Simultaneous Monte Carlo analysis of parton distributions: a new paradigm in global QCD studies, W. MELNITCHOUK, CARLOTA ANDRES, Jefferson Lab, JACOB ETHIER, Nikhef, NOBUO SATO, Jefferson Lab, YIYU ZHOU, College of William and Mary, JEFFERSON LAB ANGULAR MOMENTUM (JAM) COLLABORATION — We report the results of the first simultaneous extraction of unpolarized and polarized parton distributions and parton-to-hadron fragmentation functions from a Monte Carlo analysis of global high energy lepton and hadron scattering data. We use data resampling techniques to thoroughly explore the Bayesian posterior distribution of the extracted functions, and use k-means clustering on the parameter samples to identify the configurations that give the best description across all reactions. Inclusion of semi-inclusive deep-inelastic scattering data reveals a strong suppression of the strange quark distribution in the proton, in contrast with recent results from W^± and Z production at the LHC. The analysis is the first to include jet production data in both unpolarized and polarized proton-proton collisions, which provides the best constraints to date on the momentum and spin carried by gluons in the proton.
described by the model with remarkable accuracy with a chemical freeze-out temperature of $156.5 \pm 1$ MeV. Recent measurements of yields of hadrons and light nuclei from the ALICE collaboration at the LHC were consistent with a nearly ideal gas of hadrons and nuclei with masses given by their free space values at chemical freeze-out temperature, are in thermal equilibrium and are sufficiently dilute as to have particle distributions accurately described statistically by a nearly ideal gas of hadrons and nuclei with masses given by their free space values at chemical freeze-out temperature output by the model, at least for these weakly-bound light nuclei.

FERNANDO FLOR, University of Houston — The Statistical Hadronization Model (SHM) has been tested to adequately reproduce hadronic particle abundances over nine orders of magnitude in high energy collisions of heavy ions. Experimental particle yields at RHIC and the LHC are used to determine freeze-out parameters obtained using different sets of particles in the thermal fit, differences in the chemical freeze-out temperature arise between various treatments of strangeness conservation under different freeze-out conditions. With the same approach applied to pp and pPb collisions, a flavor-dependent freeze-out in the QCD crossover region and compare to lattice calculations. Lastly, I will compare the quality of fits across different freeze-out parameterizations, and to give guidance to the experimental search for the QCD critical point.

9:42AM KJ.00005 System size and flavor dependence of chemical freeze-out in relativistic particle collisions from RHIC-BES to LHC energies. GABRIELLE OLINGER, RENE BELLWIED, FERNANDO FLOR, University of Houston — The Statistical Hadronization Model (SHM) has been tested to adequately reproduce hadronic particle abundances over nine orders of magnitude in high energy collisions of heavy ions. Experimental particle yields at RHIC and the LHC are used in determining freeze-out parameters of the QCD phase diagram via thermal fits in the SHM framework. When comparing extracted freeze-out parameters obtained using different sets of particles in the thermal fit, differences in the chemical freeze-out temperature arise between light and strange hadrons. In this talk, I will show recent calculations of freeze-out parameters using particle yields from STAR and ALICE collisions at $\sqrt{s_{NN}} = 7$ GeV - $7$ TeV. Using the Grand Canonical approach within the Thermal FIST HRG model, I will show evidence for a flavor-dependent freeze-out in the QCD crossover region and compare to lattice calculations. Lastly, I will compare the quality of fits across various treatments of strangeness conservation under different freeze-out conditions. With the same approach applied to pp and pPb collisions, I will show that the SHM is applicable to small systems and that flavor dependencies in the freeze-out parameters lead to a natural explanation of strangeness enhancement from small to large systems.

9:54AM KJ.00006 Yields of weakly-bound light nuclei as a probe of the statistical hadronization model. YUKARI YAMAUCHI, YIMING CAI, THOMAS COHEN, University of Maryland, College Park, BORIS GELMAN, New York City College of Technology, The City University of New York — The statistical hadronization model is a simple and efficient phenomenological framework in which the relative yields for very high energy heavy ion collisions are essentially determined by the chemical freeze-out temperature. Recent measurements of yields of hadrons and light nuclei from the ALICE collaboration at the LHC were described by the model with remarkable accuracy with a chemical freeze-out temperature of $156.5 \pm 1$ MeV. A key physical question is whether the freeze-out temperature can be understood at the temperature at which the various species of an equilibrated gas of hadrons (including resonances) and nuclei chemically freeze out as the model assumes, or whether it successfully parametrizes the yield data for a different reason. The analysis of the yields of weakly-bound light nuclei indicates that a key assumption underlying the model—that hadrons (and nuclei), just prior to chemical freeze-out temperature, are in thermal equilibrium and are sufficiently dilute as to have particle distributions accurately described statistically by a nearly ideal gas of hadrons and nuclei with masses given by their free space values — appears to be inconsistent with the chemical freeze-out temperature output by the model, at least for these weakly-bound light nuclei.
10:06AM KJ.00007 Charged Particle Distributions in Central Au+Au Collisions at √s_{NN} = 3.0 GeV at STAR², BENJAMIN KIMELMAN, University of California, Davis, STAR COLLABORATION — The RHIC Beam Energy Scan phase I (BES-I) program provided a detailed study of nuclear matter over a wide range of energies. Below √s_{NN} < 19.6 GeV, interesting results were shown in hadron azimuthal anisotropies, particle ratios, and net-proton higher moments. These results motivate the Beam Energy Scan phase II (BES-II). Compared to BES-I, BES-II will have improvements including increased statistics by a factor of 10 to 20 for each energy, improved acceptance from upgrades to the STAR experiment, and an extension of the energy reach from √s_{NN} = 7.7 GeV to √s_{NN} = 3.0 GeV with the STAR fixed-target program. This talk will present results from the lowest fixed target energy to be studied in BES-II including transverse mass spectra, rapidity density distributions, particle ratios, and centrality dependence for charged hadrons. These results are analyzed with a chemical equilibrium model to determine the chemical temperature and potential at freeze-out. The pion ratio and Coulomb potential will also be presented. At low energy, produced particles are sensitive to a Coulomb potential from a net positive source at low momenta which modifies the transverse mass spectra. These new data are compared to previously published results from experiments at the AGS.

²NSF Grant No. 1812398

10:18AM KJ.00008 Charged Particle Spectra from Au+Au √s_{NN} = 27 GeV Collisions at STAR¹, MATTHEW HARASTY, University of California, Davis, STAR COLLABORATION — The RHIC beam energy scan I (BES-I) ran from 2010 to 2014 and covered a range of energies from √s_{NN} = 62.4 to 7.7 GeV. Midrapidity spectra for π, K, and p have been published from those data. Those and other results have justified a new beam energy scan (BES-II), with high statistics and a series of detector upgrades. The first collider energy from BES-II, 27 GeV, was run in 2018. For this run a single sector of the inner time projection chamber (iTPC) upgrade was available. This detector upgrade extended the coverage of the STAR detector to lower p_T and higher η. This talk will report the spectra and yields of π, K, and p as a function of rapidity and centrality from the 27 GeV Au+Au collisions from 2018 at the Relativistic Heavy Ion Collider. The relative yields of the various particle species allows one to measure the chemical freeze-out temperature and baryon chemical potential. The extended coverage provided by the iTPC upgrade will improve estimates of the full 4π yields. The parameters extracted from the 4π yields in the current analysis are compared to previous experimental results extracted from midrapidity particle yields to address the evolution of the baryon chemical potential as a function of rapidity.

¹NSF Grant No. 1812398

Wednesday, October 16, 2019 8:30AM - 10:30AM — Session KL Mini-Symposium on Fundamental Symmetries: Theory and Experiment III — Salon H - Nadia Fomin, University of Tennessee

8:30AM KL.00001 The Search for Electric Dipole Moments in the FRIB Era, JAIDEEP SINGH, Michigan State University — Experimental tests of fundamental symmetries using nuclei and other particles subject to the strong nuclear force have led to the discovery of parity (P) violation and the discovery of charge-parity (CP) violation. It is believed that additional sources of CP-violation may be necessary to explain the apparent scarcity of antimatter in the observable universe. A particularly sensitive and unambiguous signature of both time-reversal- (T) and CP-violation would be the existence of an electric dipole moment (EDM). The current generation of EDM searches in a variety of complimentary systems have unprecedented sensitivity to physics beyond the Standard Model. My talk will focus on diamagnetic systems such as Xe-129 and Hg-199 as well as certain rare diamagnetic atoms such as Ra-225 which have pear-shaped nuclei. This uncommon nuclear structure significantly amplifies the observable effect of T, P, & CP-violation originating within the nuclear medium on diamagnetic systems such as Xe-129 and Hg-199 as well as certain rare diamagnetic atoms such as Ra-225 which have pear-shaped nuclei. Certain isotopes of Radium (Ra), Protactinium (Pa), and Radon (Rn) are all expected to have enhanced atomic EDMs and will be produced in abundance at the Facility for Rare Isotope Beams currently under construction at Michigan State University. I will describe the present status of ongoing EDM searches in Xe-129, Hg-199, and Ra-225 as well as the prospects for next generation searches for time-reversal violation in both atomic and molecular systems in the FRIB-era.

9:06AM KL.00002 Status of the neutron Electric Dipole Moment Search at Los Alamos National Laboratory¹, AUSTIN REID, Indiana University Bloomington, NEDM@LANL COLLABORATION — A permanent neutron EDM presents an experimentally accessible measurement of beyond Standard Model physics. Further improvements on the more than a decade old nEDM upper bound have been hindered by insufficient ultracold neutron (UCN) density. The recently upgraded solid deuterium UCN source at Los Alamos National Laboratory (LANL) generates sufficient densities of stored UCN to measure nEDM at 3 × 10⁻²⁷ e·cm with established technologies. This talk will present the status of the experiment and its projected timeline.

¹The author thanks and acknowledges the support of Los Alamos National Laboratory LDRD and the National Science Foundation, grants PHY-1828512 and PHY-1614545

9:18AM KL.00003 Magnetic Field Monitoring in the SNS Neutron EDM Experiment¹, ALINA ALEKSANDROVA, University of Kentucky, SNS NEDM COLLABORATION — One of the most sensitive probes of charge-conjugation and parity (CP) violation is the neutron electric dipole moment, for which the current upper limit is d_n < 3.0 × 10⁻²⁶ e·cm (90% CL). The Spallation Neutron Source neutron EDM experiment aims to reduce this limit by two orders of magnitude. Targeting a sensitivity of 10⁻²⁹ e·cm, it is important to suppress systematic effects in the experiment caused by magnetic field nonuniformities. Thus, it is important to be able to precisely control and monitor the magnetic field gradients inside of the experimental volume. However, it is not always possible to measure the field within the region of interest directly. To remedy this issue in the SNS nEDM experiment, we have designed a field monitoring system that will allow us to reconstruct the field gradients inside of the fiducial volume using noninvasive measurements of the field components at discrete locations external to this volume. The field monitor array consists of 32 cryogenic-compatible, single-axis fluxgate magnetometer probes that are controlled by an automated switching system. This talk will present the design and studies of this field monitor along with studies performed to characterize the properties of these sensors at cryogenic temperatures.

¹This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under Award Number DE-SC0014622.
9:30AM KL.00004 Design and Testing of a Magnetic Shielding Enclosure for Testing Spin Transport Magnets for the SNS nEDM Experiment. MARRIOTT MCCREA, University of Kentucky, SNS NEDM COLLABORATION — The SNS nEDM Experiment aims to measure the neutron electric dipole moment to a sensitivity of order $10^{-28}\text{e}\cdot\text{cm}$. A series of magnets are being developed to transport polarized helium-3 from an atomic beam source outside the external magnetic shielding to its interior which has a uniform 30 mG magnetic field created by a rectangular solenoid. A pair of modified cosine theta coils are being developed to maintain the internal magnetic field uniformity through the 62 cm diameter opening in the magnetic shielding the polarized He-3 passes through. Once inside the shielding the polarized He-3 will be accumulated in a storage volume before being moved into the measurement cell where it will be used as a comagnetometer during the nEDM measurement. To aid in the magnet development a two layer magnetic shielding enclosure composed of high permeability metal alloys has been designed that will provide a similar magnetic environment to the full scale apparatus. I will describe the simulation, design and testing of this shielding enclosure.

This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under Award Number DE-SC0014622.

9:42AM KL.00005 Measurement of Neutron Polarization and Transport for the SNS nEDM Experiment. KAVISH IMAM, University of Tennessee, SNS NEDM COLLABORATION — The existence and size of a neutron electric dipole moment (nEDM) remains an important question in particle and cosmological physics. The SNS nEDM experiment proposes a new limit for nEDM search by using ultra-cold neutrons (UCN) in a bath of superfluid helium. The experiment uses polarized 8.9 Å neutrons to create polarized UCN in situ in superfluid helium via superthermal downscattering. This process requires the 8.9Å neutrons to retain their polarization as they pass through the magnetic shielding and nEDM cryostat windows. This talk will describe a setup to measure the neutron polarization loss from the magnetic shielding and cryostat windows.

This work was supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under contract DE-FG02-03ER41258

9:54AM KL.00006 Laser Assisted Electric Field Monitoring in a Cryogenic Environment. MARK BROERING, University of Kentucky, JOSH ABNEY, Argonne National Lab, MURCHHANWA ROY, MARK MCCREA, University of Kentucky, CHRISTOPHER SWANK, BRAD FILIPPONE, California Institute of Technology, WEIJUN YAO, Oak Ridge National Lab, WOLFGANG KORSCH, University of Kentucky, SNS NEDM COLLABORATION COLLABORATION — The neutron EDM collaboration at the Spallation Neutron Source (ORNL) plans to use ultra-cold neutrons (UCN) in a bath of superfluid helium. The experiment uses polarized 8.9Å neutrons to create polarized UCN in situ in superfluid helium via superthermal downscattering. This process requires the 8.9Å neutrons to retain their polarization as they pass through the magnetic shielding and nEDM cryostat windows. This talk will describe a setup to measure the neutron polarization loss from the magnetic shielding and cryostat windows.

SNS nEDM Collaboration
For the SNS nEDM collaboration
Formerly University of Kentucky

10:06AM KL.00007 Systematics and Operational Studies for the SNS nEDM Experiment. ROBERT DIPERT, Arizona State University, SNS NEDM COLLABORATION COLLABORATION — The Systematic and Operational Studies (SOS) apparatus, being designed for the PULSTAR reactor at NC State University, is a test bed for the Neutron Electric Dipole Moment (nEDM) experiment at the Spallation Neutron Source (SNS) at Oak Ridge National Laboratory. The PULSTAR-SOS apparatus and SNS-nEDM experiment will have many physically similar conditions, including (a) temperature near 400 mK, (b) the same measurement cell design, size, and wavelength shifter, (c) use of a Superconducting QUantum Interference Device (SQUID) magnetic detection system, and (d) the use of helium-3 as a co-magnetometer, polarization analyzer, and detector. The major difference is that the PULSTAR-SOS apparatus will not have an electric field. However, it is possible to study the major false edm effect by means of relaxation and frequency shift measurements. Construction of the PULSTAR-SOS cryostat has begun at the Triangle Universities Nuclear Laboratory (TUNL). I will report on the systems which have been installed and tested.

This work was supported in part by the US National Science Foundation under Grant No. PHY-0314114 and the US Department of Energy under Grants No. DE-SC0019309 and DE-FG02-99ER41101, DE-AC05-00OR22725, DE-SC0014622

10:18AM KL.00008 Simulation of time dependent magnetic field variations in the SNS nEDM experiment. MOJTABA BEHZADIPOUR, University of Kentucky, SNS NEDM COLLABORATION — The Spallation Neutron Source (SNS) neutron electric dipole moment experiment (nEDM) requires precise control of the magnetic field. Time-dependent variations in the magnetic field will be monitored with the polarized 3He co-magnetometer via detection of the precessing 3He precession frequency difference. We have carried out simulations of the response of the SQUID 3He co-magnetometer to time-dependent variations in the magnetic field and have explored various schemes for corrections to the measured neutron precession frequency due to these time-dependent magnetic field variations. Preliminary results showing the sensitivity of the extracted neutron precession frequency to magnetic field variations will be discussed.

This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under Award Number DE-SC0014622

Wednesday, October 16, 2019 8:30AM - 10:18AM — Session KM Electromagnetic Interactions II — Salon J - Ken Hicks, Ohio University
8:42AM KM.00002 Exclusive Eta and Eta Photoproduction and Beam Asymmetries at GlueXlish will present results of the photon beam
at GlueX, Virginia. GlueX is capable of making beam asymmetry (∆) measurements using a tagged, linearly-polarized 9 GeV photon beam incident
on a hydrogen target. Measurements of the beam asymmetry for the exclusive reactions, γ+p → ηη and γ+p → η′ρ, will provide insight into
the meson production mechanisms. GlueX measurements are the first beam asymmetry results for the η and η′ in this energy range and are
expected to further constrain Regge theory models for photoproduced pseudoscalar mesons. This talk will present results of the photon beam
asymmetries as a function of the Mandelstam variable, t, for multiple η decay modes and the η′ → π⁺π⁻η decay mode.

1NSERC grant SAPPJ-2018-00021, DOE Grant No. DE-FG0287ER40315
9:54AM KM.00008 PrimEx-Eta: A Precision Measurement of the Eta Meson Radiative Decay Width¹, ANDREW SMITH, Duke University, GLUEX COLLABORATION — The $\eta$ meson is a unique probe of QCD symmetry breaking. Of particular importance is the $\eta \rightarrow \gamma \gamma$ decay, as it proceeds via the chiral anomaly. In the chiral limit, the amplitude for the two-photon decay of the pure SU(3) states, $\eta_8$ and $\eta_8$, is exactly calculable, and therefore a precision measurement of the $\eta$ radiative decay width provides both a precision test of this chiral anomaly prediction as well as information about the $\eta\eta$ mixing angle. In the past, this $\gamma \gamma$ decay width has been measured both in a fixed target experiment utilizing the Primakoff effect and in $e^+e^-$ collider experiments. However, the large discrepancy between the results of the two types of experiments remains unresolved. The PrimEx-$\eta$ experiment in Hall D at Jefferson Lab will perform a precision measurement of $\Gamma_{\gamma\gamma}$, via the Primakoff method to address this discrepancy, and to reduce the overall uncertainty. Additionally, it will allow to significantly reduce uncertainties on partial widths for all other $\eta$ decays. In this talk the motivation and experimental techniques will be discussed along with a presentation of data from the experiment’s first phase which was completed in the Spring of 2019.

¹This work is supported in part by the U.S. Department of Energy under Contract No. DE-FG02-03ER41231, Thomas Jefferson National Accelerator Facility and Duke University. Spokespersons: A. Gasparian, L. Gan

10:06AM KM.00009 Search for the onset of Color Transparency in Protons, DEEPAK BHETUVAL, MSU — Color transparency (CT) is a a unique prediction of Quantum Chromodynamics (QCD) where the final (and/or initial) state interactions of hadrons with the nuclear medium are suppressed for exclusive processes at high momentum transfers. During the spring of 2018, the experiment E1206107 to measure the Proton Transparency was the first to run in Hall C at Jefferson Lab using the upgraded 12 GeV electron beam. Our experiment used the High Momentum Spectrometer (HMS) and new Super High Momentum Spectrometer (SHMS) in coincidence to measure $^{12}\text{C}(e,e\text{p})$ proton knockout to extract the proton nuclear transparency with additional 1H measurements to determine the elementary process, over the range $Q^2 = 8 - 14.3 (\text{GeV}/c)^2$. A rise in the proton transparency as a function of $Q^2$ is predicted to be a signature of the onset of Color Transparency. This talk will summarize the status of the experiment since the completion of data taking and show some preliminary results.

Wednesday, October 16, 2019 8:30AM - 10:30AM — Session KN Nuclear Structure III — Salon K — Calem Hoffman, Argonne National Laboratory

8:30AM KN.00001 Investigating shape coexistence in $^{50,52,54}\text{Cr}$ with E0 transitions and pair conversion spectroscopy, JACKSON DOWIE, TIBOR KIBEDI, Australian Natl Univ, HA HOANG, KUMAR RAJU, EIJI IDEGUCHI, RCNP, University of Osaka, ABRAHAM AVAA, iThemba LABS, and University of Witwatersrand, VERNON CHISAPI, iThemba LABS, and University of Stellenbosch, PETE JONES, iThemba LABS, AQUEL AKBER, BEN COOMBES, TOMAS ERIKSEN, MATTHEW GERATHY, TIMOTHY GRAY, GREG LANE, BRENDAN MCCORMICK, A.J. MITCHELL, ANDREW STUCHBERY, Australian Natl Univ — The phenomenon of shape coexistence, whereby excited states of an atomic nucleus exhibit shapes that deviate dramatically from their ground states, appears to be ubiquitous across the nuclear landscape. Electric multipole (E0) transitions, the only possible decay paths between $J^\pi = 0^+$ states, provide a unique probe into nuclear shape coexistence. The E0 strength is large when there is a large change in the nuclear mean-square charge radius, and when there is strong mixing between states of different deformation. The region between $^{40}\text{Ca}$ and $^{56}\text{Ni}$ is virtually unexplored from the perspective of E0 transitions. Only the $^{40,42,44}\text{Ca}$, $^{46,50,52,54}\text{Ni}$ and $^{40}\text{Ca}$ have been investigated; no work has been done on the Cr isotopes to date. The $0^+$ states and E0 transitions in $^{50,52,54}\text{Cr}$ were investigated with the Super-e pair spectrometer at the ANU using beams from the 14UD tandem accelerator. We will present the first pair spectra for $^{50,52,54}\text{Cr}$ and the E0 transition strengths for these nuclei.

8:42AM KN.00002 Microscopic Calculations of Nuclear Level Densities with the Extrapolated Lanczos Method¹, WILLIAM ORMAND, Lawrence Livermore National Laboratory, ALEX BROWN, Michigan State University — A new method for computing the density of states in nuclei making use of an extrapolated form of the tri-diagonal matrix algorithm obtained from the Lanczos method is presented. It will be shown that the global, average properties of the entire Lanczos matrix can be predicted from just four Lanczos iterations. The extrapolated Lanczos matrix (ELM) approach provides for an accurate computation of the density of states described within the configuration space. In many cases, this is sufficient to accurately calculate the density of states at, or near, the neutron separation energy, which is the region needed for Hauser-Feshbach calculations of radiative capture reactions. We will outline a procedure to analytically continue the extrapolated Lanczos matrix to the ground-state region. Validation with exact shell-model calculations will be shown and applications of the method will be demonstrated for $^{57}\text{Fe}$ and $^{76}\text{Ge}$ where comparison with experiment will be shown. We also demonstrate the $J$-dependence of the level density with the method and outline a procedure to extract the spin cutoff parameter.

¹This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344 and Office of Nuclear Physics FWP SCW0498 and the National Science Foundation by Michigan State University under NSF grant PHY-1811855.

8:54AM KN.00003 On the nature of $0^+$ states in $^{64}\text{Ni}$ from Coulomb excitation¹, DAVID LITTLE, ROBERT JANSENS, MICHAEL JONES, University of North Carolina at Chapel Hill, DANIEL AYANGÆKAA, United States Naval Academy, THE UNC/TUNL, USNA, UMD, ANL, LLNL, LBNL, MSU COLLABORATION — Recent experimental work on the $^{64}\text{Ni}$ nucleus has shown that shape coexistence occurs despite its rigidly spherical ground state [1]. Several low-lying $0^+$ states have previously been observed in $^{64}\text{Ni}$, but additional information beyond their excitation energy and spin is needed in order to investigate their properties. A high-statistics Coulomb excitation experiment was performed at the ATLAS facility at ANL, where a $^{208}\text{pb}$ target was bombarded by a $^{64}\text{Ni}$ beam at an energy of 272 MeV. The experimental setup involved the new GRETA tracking array in conjunction with the Compact Heavy Ion Counter, CHICO2. Thirteen transitions were observed in $^{64}\text{Ni}$, including the 1521- and 1680-keV $\gamma$-rays associated with the de-excitation of the $0^+$ and $0^+$ states, respectively. B(E2) reduced transition probabilities were obtained for all observed states. [1] S. Leoni et al., PRL 118, 162502 (2017).

¹This work is supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under Grant Numbers DE-FG02-97ER41041 (UNC) and DE-FG02-97ER41033 (TUNL).
9:06AM KN.00004 The structure of 72Ni via beta-delayed neutron spectroscopy of 72Co$^\dagger$. ANDREW KEELER, ROBERT GRZYWACZ, S GO, T T KING, M MADURGA, S V PAULAUSKAS, S Z TAYLOR, University of Tennessee, B CRIDER, S LIDDICK, R LEWIS, Michigan State University, J H HAMILTON, C ZACHARY, E H WANG, Vanderbilt University, N T BREWER, Oak Ridge National Laboratory, A FIALKOWSKA, Rutgers University, P D O'MALLEY, M HALL, Notre Dame University, M M RAJABALI, Tennessee Technical University, S ILLYUSHKIN, Colorado School of Mines — Studies of beta decays and beta-delayed neutrons of 72Co produced at MSU's National Superconducting Cyclotron Laboratory using the Versatile Array of Neutron Detectors at Low Energy. To carry out this experiment, a novel position-sensitive scintillating detector was developed to enable the sub-nanosecond timing resolution that VANDLE requires, which silicon-based position-sensitive detectors would be unable to provide. A gamma spectroscopy setup including an HPGe Clover and LaBr3 HAGRiD detectors provides the necessary spectroscopic information for a full reconstruction of the 72Co decay strength.

$^\dagger$Funded by the National Nuclear Security Administration under the Stewardship Science Academic Alliances program through DOE Award No. DE-NA0002132 and by the Office of Nuclear Physics, U.S. Department of Energy under Awards No. DE-FG02-96ER40983 (UTK).

9:18AM KN.00005 Nature of triaxial deformation in 76Ge: A model-independent analysis$^\dagger$. A. D. AYANGEAKAA, USNA, R. V. F. JANSSENS, DAVID LITTLE, UNC/TUNL, D. J. HARTLEY, USNA, ANL TEAM, UMD TEAM, LLNL TEAM, MSU/NSCL TEAM, LBNL TEAM — The low-lying structure of 76Ge has become a subject of intense scrutiny ever since it was first suggested as a possible example of rigid triaxiality at low spin [1]. For decades, the experimental observation of such rigid structures has remained elusive and indeed, there has been a longstanding issue associated with whether axially asymmetric nuclei retain rigid-triaxial deformation in their ground-state configuration. In this study, an extensive, model-independent analysis of the nature of triaxial deformation in 76Ge has been performed following a high-statistics Coulomb excitation measurement with GRETINA and CHICO2. Shape parameters deduced on the basis of a rotational-invariant sum-rule analysis provided considerable insight into the underlying collectivity of the ground-state and γ bands. Compelling evidence for low-spin, rigid-triaxial deformation in 76Ge based on the analysis of the statistical variance of the quadrupole asymmetry deduced from the measured E2 matrix elements will be presented. The relevance of these results for calculations aimed at providing, with suitable accuracy, the nuclear matrix elements relevant to neutrinoless double-beta decay will also be highlighted. [1] Y. Toh et al., Phys. Rev. C97, 041304 (2013).

$^\dagger$This work is supported in part by the Office of Naval Research (ONR), the NSF under grant number PHY-1502092 (USNA), and the U.S. DOE, Office of Science, Office of Nuclear Physics, under Grant Numbers DE-FG02-97ER41041 (UNC) and DE-FG02-97ER41033 (TUNL).


$^\dagger$U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under contract Nos. DE-AC02-06CH11357 (ANL) and DE-AC02-98CH10886 (BNL), and grants No. DE-FG02-94ER40834 (Maryland). This research used resources of ANLs ATLAS facility, which is a DOE Office of Science User Facility.

9:42AM KN.00007 Possible particle-hole intruder sequence in 83Se$^{19}$.$^\dagger$. WALTERS, ANNE MARIE FORNEY, University of Marylands, College Park — A new sequence of higher-spin levels at 1266 (7/2$^+$), 2407 (11/2$^+$), 3689 (15/2$^+$), and 4673 (19/2$^+$) has been identified in the single-neutron-hole 83Se$^{19}$ nucleus. This sequence feeds into the 5/2$^+$ level at 583 keV that is strongly populated in (d,p) reaction studies and considered as a 1-particle-2-hole state connected to the known $\Delta J=2$ ground state of 85Se$^{19}$. The data were taken using Gammasphere at the ATLAS accelerator complex at Argonne National Laboratory following the interaction of a 630-MeV 82Se beam with 209Pb and 238U targets. These and previously identified levels in 83Se will be compared to shell-model calculations.


$^\dagger$This work is supported by the U.S. Department of Energy, Office of Nuclear Physics under Contract DE-AC02-06CH11357 and under Grant DE-FG02-94ER40834. This research used resources of ANL's ATLAS facility, which is a DOE Office of Science User Facility.
10:06AM KN.00009 Decays of neutron rich rubidium isotopes studied with Modular Total Absorption Spectrometer (MTAS) 1, DARREN MCKINNON, ROBERT GRZYWACZ, University of Tennessee, BERTIS RASCO, NATHAN BREWER, KRZYSZTOF RYKACZEWSKI, Oak Ridge National Laboratory, ALEKSANDRA FIJALKOWSKA, MARZENA WOLINSKA-CICHOCKA, MAREK KARNY, University of Warsaw, KATHLEEN GOETZ, University of Tennessee, CARL GROSS, DANIEL MCKINNON, Oak Ridge National Laboratory, JON SATCHELDER, Berkeley National Laboratory, JEFF BLACKMON, Louisiana State University, THOMAS KING, University of Tennessee, KRZYSZTOF MIERNIK, University of Warsaw, STAN PAULAUSKAS, University of Tennessee, MUSTAFI RAJABALI, Tennessee Technological University, JEFF WINGER, Mississippi State University — Total absorption spectroscopy is a highly efficient method for detecting gamma radiation from beta decay. The Modular Total Absorption Spectrometer (MTAS) consists of nearly one ton of NaI(Tl) and allows for the determination of beta-feeding distributions over the entire decay window. These studies provide unique insight into nuclear structure, properties of nuclear reactor decay heat, and the underlying physics of the functional. Thus, this is how many independent parameters could be defined in the CDFT using fitting functionals. For example, linear parametric correlations exist between the $\rho_2$ and $g_3$ parameters in all of those functionals. In this talk, the author will present recent results from decays of neutron rich Rb isotopes in the transitional region near N=60 studied at the ORNL Tandem. In preparation for implementation of MTAS at CARIBU at Argonne National Laboratory, new auxiliary beam diagnostic detectors have been added to MTAS and preliminary results will be shown during the presentation.

1This research was supported in part by the Office of Nuclear Physics, U.S. Department of Energy under Award No. DE-FG02-96ER40983 (UTK).

10:18AM KN.00010 Parametric correlations in energy density functionals 1, A. TANINAH, S. E. AGBEMAVA, A. V. AFANASJEV, Mississippi State University, USA, P. RING, Technical University of Munich, Germany — Density functional theories (DFT) are defined by underlying functionals. Some of those functionals depend on substantial number of parameters. However, the parametric correlations between them have not been studied before. Using covariant DFT as an example and statistical tools, we study such correlations for major classes of covariant energy density functionals. These include the non-linear meson-nucleon coupling (NL) model, the density dependent meson-exchange (DD-ME) model and point coupling (PC) model. Their functionals are defined by properties of spherical nuclei and nuclear matter properties. It turn out that parametric correlations exist between a number of parameters in all of those functionals. For example, linear parametric correlations exist between the $\rho_2$ and $g_3$ parameters which are responsible for the density dependence in the NL model [1]. Observed correlations effectively reduce the number of independent parameters to five or six dependent on the structure and the underlying physics of the functional. Thus, this is how many independent parameters could be defined in the CDFT using fitting protocols based on ground state and nuclear matter properties.


1This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics under Award No. DE-SC0013037.

Wednesday, October 16, 2019 10:30AM - 12:54PM — Session LA Spin, Size and Structure of the Nucleon

10:30AM LA.00001 Precision studies of the DVCS process at JLab 1, JULIE ROCHE, Ohio University — Generalized Parton Distribution (GPDs) describe the correlation between the spatial distribution of the quarks and its longitudinal momentum fraction. Their definition in the mid 1990s has revolutionized our approach to the description of the internal structure of the nucleon. The study of the GPDs together with the study of similar quantities are at the forefront of today hadronics physics enterprise. Deeply Virtual Compton Scattering (DVCS) off the nucleon ($\gamma^{*}N \rightarrow \gamma N$) is the simplest process which is sensitive to the GPDs. It has been measured at Hera, COMPASS and JLab. In this talk, I will review the recent results of the Hall A @ JLab scheme, including results of the experiment performed with the upgraded JLab 12 GeV beam.

1The author’s work is supported by the National Science Foundation under Grant Award 1913170.

11:06AM LA.00002 Sea quark polarization results from STAR, JINLONG ZHANG, Stony Brook University — Polarized proton-proton collision experiments at RHIC provide unique opportunities to study the spin structure of nucleon. One of the primary motivations of RHIC spin program is to probe sea quark spin-flavor structure via the W boson production at $\sqrt{s}=500$ GeV proton-proton collisions. The W longitudinal single-spin asymmetry, $A_L$, measurements with STAR have provided significant constraints on the polarized Parton Distribution Functions and especially the first experimental indication of a flavor asymmetry of polarized sea. In this talk, the final $W^-$ $A_L$ results from STAR and their impacts on the sea quark polarization will be presented.
Contrary to naive assumptions, a remarkable asymmetry between the anti-down ($\bar{d}$) and anti-up ($\bar{u}$) quarks has been observed. This large of an asymmetry cannot be generated through perturbative QCD and demonstrates that at any energy scale, there is a fundamental anti-quark component in the proton. The Drell-Yan reaction is uniquely sensitive to antiquark distributions of the interacting hadrons because the reaction requires an anti-quark in one of the initial state hadrons. With the kinematics of the SeaQuest spectrometer, this reaction is particularly sensitive to the anti-quarks distributions in the target nuclei. The E906/SeaQuest collaboration has measured the ratio of deuterium to hydrogen Drell-Yan cross sections. From these data, we have extracted the ratio of $d/\bar{u}$. These data extend the range of previous measurements to larger $x_{Bj}$ and improve the statistical significance for a range of lower $x_{Bj}$. This talk will present these measurements and the extracted ratio. It will also highlight other continuing analyses and future Drell-Yan measurements at Fermilab.

1. This work is supported in part by the NSF MRI award PHY-1229153, the U.S. Department of Energy under Contract No. DE-FG02-03ER41231, Thomas Jefferson National Accelerator Facility and Duke University.

Wednesday, October 16, 2019 10:30AM - 12:30PM –
Session LB Neutrino Properties
Salon 2 - Nathaniel Bowden, Lawrence Livermore National Laboratory

10:30AM LB.00001 Could deficient knowledge in the $^{235,238}$U and $^{239,241}$Pu antineutrino spectra explain the reactor neutrino anomaly?1, ALEJANDRO SONZOGNI, Brookhaven National Laboratory, ROSS MACFADYEN, Department of Physics, Bard College at Simon’s Rock, ELIZABETH MCCUTCHAN, Brookhaven National Laboratory — The Daya Bay, Double Chooz and RENO collaborations have reported measurements of Inverse Beta Decay antineutrino spectra generated by nuclear reactors. Their results have not only confirmed an electron antineutrinos deficit of about 5% at short distances with respect to our current best models, but also revealed a spectrum distortion characterized by an overprediction at the top of the spectrum and an underprediction at around 5 MeV. Our numerical accounting of the antineutrino spectrum generated by a nuclear reactor is based on the electron spectra measured by ILL for $^{235}$U and $^{239,241}$Pu, the conversion of these electron spectra into the corresponding antineutrino spectra and the calculation of the $^{238}$U antineutrino spectrum using nuclear databases. Here we explore if uncorrelated or correlated adjustments to the spectra of these four fission isotopes are consistent with the data available, by describing the evolution of the adjusted models as a function of fuel burnup and comparing the adjusted antineutrino spectra to their corresponding electron ones via a novel reverse conversion process.

1. Work at BNL was sponsored by the Office of Nuclear Physics, Office of Science of the U.S. Department of Energy under Contract No. DE-AC02-98CH10886, and by the DOE Office of Science, WDTS Office, SULI Program.

10:42AM LB.00002 Antineutrino Spectra and Decay Heat Measurements with the Modular Total Absorption Spectrometer, BERTIS RASCO, Oak Ridge National Laboratory, MTAS COLLABORATION — Nuclear reactors are the largest man-made source of $\nu$S and as such they are excellent sources to directly measure $\bar{\nu}$S. The predicted $\bar{\nu}$ flux from nuclear reactors is not precisely known. One way to predict the $\nu$ flux, the summation method, requires precise knowledge of the $\beta$ decays of the many fission products. Because all reactor antineutrinos are created from $\beta$-decaying fission products it is imperative to experimentally measure these $\beta$ decays. In addition to producing a precise prediction of the $\nu$ flux, a proper understanding of the $\beta$ decay of fission products produced in nuclear reactors is important in order to understand how the decay heat energy is shared between $\gamma$ rays, $\beta$ rays, neutrons, and $\bar{\nu}$S. The improved $\beta$ decay information influences reactor safety, and the decay back to stability of the r process. In this talk we present an overview of the latest results from the Modular Total Absorption Spectrometer Collaboration and its impact on the predicted $\nu$ flux from nuclear reactors.
10:54AM LB.00003 Nuclear Structure Decay Studies for Reactor Antineutrino Physics¹, E.A. MCCUTCCHAN, S. ZHU, K. AURANEN, A.A. SONZOGNI, Brookhaven National Laboratory, K. KOLOS, N.D. SCI-ELZO, Lawrence Livermore National Laboratory, M.P. CARPENTER, G. SAVARD, J. CLARK, Argonne National Laboratory, A. GULA, Notre Dame University — There are several intriguing features involving recent measurements and calculations of reactor antineutrino spectra including a deficit in the total number of measured antineutrinos, a spectra distortion in the region of 5-7 MeV antineutrino energy, and a fine structure which can be attributed to the decay of just a few out of the total 800 fission fragments making up the spectra. A full understanding of these aspects requires a solid basis of the underlying nuclear physics, namely the beta-decay properties of fission fragments used as inputs to calculate the spectra. Using the CARIBU facility at Argonne National Laboratory, we have performed new measurements on several key isotopes including ¹²⁹⁰Rb, ¹⁴²⁰La, and ¹⁴¹⁰Cs. The decay of ¹²⁹⁰Rb was studied with the SATURN array, while the decays of ¹⁴²⁰La and ¹⁴¹⁰Cs were observed with the Gammasphere array. The results of these analyses will be presented and their impact on reactor antineutrino calculations will be discussed.

¹Work supported by DOE NP under Co. DE-AC02-06CH11357, DE-AC02-98CH10886, and DOE NNSA under Award DE-AC52-07NA27344

11:06AM LB.00004 Addressing Nuclear Data Needs with the PROSPECT Antineutrino Measurements , THOMAS LANGFORD, Yale University, PROSPECT COLLABORATION — The PROSPECT experiment at the High Flux Isotope Reactor (HFIR) at Oak Ridge National Lab has recently published the first modern measurement of the energy spectrum from ²³⁵U antineutrinos from a highly-enriched uranium reactor. With more than 30,000 detected antineutrino interactions, the PROSPECT spectrum uses six times higher statistics than the only previous measurement at the ILL reactor in 1981. Combined with the high-precision studies of Daya Bay and other medium baseline experiments at LEU reactors, the measurements of PROSPECT have stimulated the use of reactor antineutrinos to address nuclear data needs. We will discuss the recent antineutrino measurements with PROSPECT and their relevance for the evaluation of nuclear data.

11:18AM LB.00005 TRISTAN project - To search for keV-scale sterile neutrino with KATRIN¹, YUNG-RUEY YEN, Carnegie Mellon University, TRISTAN COLLABORATION — A viable candidate for dark matter, keV-scale sterile neutrinos would be detectable from their distinct distortion of the beta-decay spectrum. The KArSuRhe TRitiuM Neutrino (KATRIN) experiment has recently started its precision measurement of the endpoint spectral shape of the tritium beta-decay to directly probe the neutrino mass. To eventually take advantage of the KATRIN beamline, particularly the high luminosity tritium source, the TRISTAN project is currently an R&D effort to develop a new detector system optimized for the keV-scale sterile neutrino search where the measurement has to cover the entire tritium beta-decay spectrum energy range. This talk will discuss the design requirements for the TRISTAN detector as well as the latest results from the prototypes.

¹This work is supported by the DOE Office of Science under Award Number #DE-SC0019304.

11:30AM LB.00006 Phase II of the Project 8 neutrino mass experiment using Cyclotron Radiation Emission Spectroscopy¹, ELISE NOVITSKI, University of Washington, PROJECT 8 COLLABORATION — Project 8 is a neutrino mass experiment that uses a new technique, Cyclotron Radiation Emission Spectroscopy (CRES), to make a differential measurement of the tritium β⁻ spectrum. Project 8 aims to use the advantages of CRES to overcome the systematic and statistical limitations of current-generation direct measurement methods. It will proceed in a phased approach toward a goal of effective electron antineutrino mass sensitivity of ~40 meV/c². This talk will introduce CRES and Project 8, and will report on recent Phase II results. These include systematic studies using monoenergetic conversion electrons from ⁸³mKr, as well as analysis progress and preliminary data from the ongoing final Phase II molecular tritium spectrum measurement, which is the first continuous spectrum measured using CRES.

¹This work is supported by the US DOE Office of Nuclear Physics, the US NSF, the PRISMA+ Cluster of Excellence at the University of Mainz, and internal investments at all institutions.

11:42AM LB.00007 Modeling Transmitting Antennas to Simulate Phase-III of the Project 8 Experiment , PRANAVA TEJA SURUKUCHI, Yale University, PROJECT 8 COLLABORATION — Project 8 is an experiment designed to measure the mass of the electron neutrino using cyclotron radiation emission spectroscopy (CRES). Using the cyclotron frequency as a proxy for kinetic energy, the experiment aims to observe the end point of the electron spectrum of tritium beta-decay in an effort to reach neutrino mass sensitivity of 40 meV/c². Following the successful demonstration of CRES with a waveguide in Phase I and II, the Phase III of Project 8 will utilize a larger experimental volume instrumented with a phased array of antennas. Room temperature lab measurements using antennas for both transmission and reception will be used to test the Phase III design and make a comparison with numerical predictions using the Locust simulation software. We discuss the simulation work on modeling the transmission and detection using antenna of radiation near 26 GHz for the successful reconstruction of the beta decay electron kinematics in Phase III.

¹This work is supported by the US DOE Office of Nuclear Physics, the US NSF, the PRISMA+ Cluster of Excellence at the University of Mainz, and internal investments at all institutions.

11:54AM LB.00008 Time-domain Simulation of RF Antenna Response in the Project 8 Experiment , ARINA TELLES, Yale University, PROJECT 8 COLLABORATION — The Project 8 experiment aims to directly measure the neutrino mass down to ~40 meV/c² by reconstructing the kinematics of tritium beta decay, using a novel technique called cyclotron radiation emission spectroscopy (CRES). In this method, the electron source is placed in a uniform 1 T magnetic field and its cyclotron frequency is used to infer its kinetic energy. The distortion at the endpoint of its energy spectrum then constrains the effective neutrino mass. This technique has been demonstrated on a small scale in waveguides to detect radiation from single electrons. The next phase of the experiment (Phase III) will move to larger volume to increase sensitivity, requiring implementation of CRES in a free-space radiation environment. Feasibility will require detection of a 1 fW signal near 26 GHz. Accurate simulations are necessary to model the reception and transmission of this faint signal and to test electron energy reconstruction. In this talk we will describe time-domain modeling of microstrip antennas for the Phase III detector. A selection of antenna responses from the Locust simulation software are compared with results from commercial high-frequency simulations (ANSYS HFSS), and are applied toward CRES electron simulations.
Overview of atomic tritium efforts within Project 8

LUCIE TVRZNIKOVA, Lawrence Livermore National Laboratory, PROJECT 8 COLLABORATION — Neutrino flavor oscillation experiments prove that neutrinos have nonzero masses, but cannot determine the absolute mass scale. To address this question, the effective mass of the electron antineutrino $m_{\nu_e}$ can be determined from a sufficiently high-precision measurement of the tritium beta-decay spectrum around its endpoint ($Q = 18.6$ keV). Project 8 is a next-generation experiment using the novel Cyclotron Radiation Emission Spectroscopy (CRES) technique to perform a radio-frequency-based measurement of the decay electron energy. To achieve its design sensitivity of $m_{\nu_e} \sim 40$ meV, Project 8 will use an atomic tritium source to eliminate rotational and vibrational excitations of molecular tritium that perturb the tritium spectrum endpoint. The collaboration is developing techniques needed to produce, cool, and trap atomic tritium compatible with CRES. These efforts include tests to characterize the efficiency of production, formation, magnetic focusing, and cooling of a hydrogen, deuterium, and later tritium beam for injection into an atomic trap. I will present the latest progress toward atomic tritium within the collaboration.

This work is supported by the US DOE Office of Nuclear Physics, the US NSF, the PRISMA+ Cluster of Excellence at the University of Mainz, and internal investments at all institutions.

Hardware Design for Atomic Tritium in Project 8

ALEC LINDMAN, Johannes Gutenberg-Universität Mainz, PROJECT 8 COLLABORATION — Project 8 is a phased experiment using tritium beta decay to investigate the absolute neutrino mass. Good energy precision, high statistics, and well-controlled systematics are required to reach $m_{\nu_e} \lesssim$ 40 meV. Our technique, Cyclotron Radiation Emission Spectroscopy, has already achieved eV-scale resolution at 17.8 keV, near the tritium endpoint. Project 8 was the first to observe the $\beta^+$-scale cyclotron radiation from individual electrons. The event rate in a CRES experiment scales with volume; we will instrument our fiducial volume with a spatially-resolving antenna array, eliminating pileup even at high activity. Project 8 will be the first laboratory neutrino mass experiment to use atomic tritium. A decay in a tritium molecule excites rovibrational states that smear the observed energy by 1 eV. The decay of atomic tritium, however, has an energy smearing of just 0.1 eV. Our baseline design calls for trapping the 30 mK atomic tritium in a 2 T-deep, 10+ m$^3$ superconducting magnetic bottle. I will discuss our phased approach to building this large-volume atomic tritium CRES experiment, with emphasis on demonstration of production and handling techniques for the recombination-prone tritium atoms.

This work is supported by the US DOE Office of Nuclear Physics, the US NSF, the PRISMA+ Cluster of Excellence at the University of Mainz, and internal investments at all institutions.

Exploring short-range correlation effects with quantum Monte Carlo

DIEGO LONARDONI, FRIB-MSU and LANL — Quantum Monte Carlo (QMC) techniques provide a versatile and systematic approach to nuclear systems. Recent advances allow to perform calculations from light to medium mass nuclei for a variety of nuclear Hamiltonians, including those constructed using phenomenological potentials and local interactions derived from chiral effective field theory. The fully correlated nature of the many-body wave functions employed in QMC methods allows us to properly assess the short-distance and high-momentum behavior of calculated nuclear properties. In this talk, I will present QMC results for nuclei from $^3$H to $^{40}$Ca, enabling us to explore short-range correlation effects and connect to the experimental information extracted from electron scattering.

This work is supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under the FRIB Theory Alliance Grant Contract No. DE-SC0013617, and under the NUCLEI SciDAC grant. Computational resources have been provided by Los Alamos Open Supercomputing via the Institutional Computing (IC) program, and by the National Energy Research Scientific Computing Center (NERSC), which is supported by the U.S. Department of Energy, Office of Science, under Contract No. DE-AC02-05CH11231.

Bound and Free Nucleon Structure

ERFRAIN SEGARRA, A. SCHMIDT, Massachusetts Institute of Technology, D.W. HIGGINBOTHAM, Thomas Jefferson National Accelerator Facility, T. KUTZ, Stony Brook University, E. PIASETZKY, Tel Aviv University, M. STRIKMAN, Pennsylvania State University, L.B. WEINSTEIN, Old Dominion University, OR HEN, Massachusetts Institute of Technology — Understanding the partonic structure of the nucleus in the valence region (high $x_B$) is a long standing question. Constraining the neutron-to-proton structure function ratio ($F_2n/F_2p$) at high $x_B$ has been a goal of many experiments. Many approaches have been made since the 90’s towards this, such as neutron structure extractions from proton and deuterium deep inelastic scattering (DIS) measurements. However, how one treats nucleon smearing, off-shell effects, and more, lead to different extractions in the valence region. We present a new model approach to treat the proton structure at high $x_B$ using all world DIS data on the proton and on nuclei from deuterium to lead. By consistently accounting for nuclear modification effects, we obtain reduced uncertainty and find a $F_2n/F_2p$ consistent with predictions such as those of perturbative QCD, but in disagreement with predictions such as the scalar di-quark dominance model. Predictions are also made for $F_3H/F_3H$, recently measured by the MARATHON collaboration, the nuclear correction function needed to extract $F_2n/F_2p$ from $F_3He/F_3He$, and the systematic uncertainty associated with this extraction.

Investigating the EMC effect in highly-virtual nucleons at Jefferson Lab’s Hall B

CALEB FOGLER, Old Dominion University, CLAS COLLABORATION COLLABORATION — We are measuring how the quark-structure of the bound proton varies with its initial momentum to directly determine how and why the structure of bound protons differs from free ones. We will do this using Deep Inelastic Electron Scattering (DIS) from a bound proton in deuterium, detecting the backward spectator neutron to "tag" the initial momentum of the struck proton. This will help resolve the 35-year-old enigma of the EMC effect. We constructed and installed a Backward Angle Neutron Detector (BAND) just upstream of the existing CLAS12 spectrometer at Jefferson Lab to detect the backward spectator neutrons at scattering angles between 160 and 170 degrees. We detect the scattered electron with CLAS12 and the recoiling neutron with CLAS12 at intermediate angles or by BAND at backward angles, thereby "tagging" the DIS scattering off the proton in the deuterium. I will present the BAND detector and preliminary results from the Spring 2019 experimental runs.
11:06AM LE.00004 EMC Effect in Lighter Nuclei1. ABISHEK KARKI, Mississippi State University — As part of the 12 gev commissioning experiments in hall c at Jefferson Lab, e12-10-008 made measurements of the emc effect in selected light nuclei. This experiment is a measurement of inclusive electron scattering which aims to extract the ratio of nuclear structure function of several nuclei to those of deuterium. This is the first measurement of the Emc ratio for targets 10b and 11b, which was included to expand the set of lighter nuclei to test the idea that the local nuclear density plays an important role in quark modification. In this talk, I will be showing some preliminary results and our current analysis status.

1This research is supported by U.S. DOE Grant Number: DE-FG02-07ER41528

11:18AM LE.00005 Searching for the Onset of Color Transparency in Quasielastic 12C(e,e’p). JOHN MATTER, University of Virginia — Color Transparency (CT) is a prediction of QCD that at high momentum transfer Q2, a system of quarks which would normally interact strongly with nuclear matter could form a small color-neutral object whose compact transverse size would be maintained for some distance, passing through the nucleus undisturbed. A clear signature of CT would be a dramatic rise in nuclear transparency T with increasing Q2. The existence of CT would contradict traditional Glauber multiple scattering theory, which predicts constant T. CT is a prerequisite to the validity of QCD factorization theorems, which provide access to the generalized parton distributions that contain information about the transverse and angular momenta carried by quarks in nucleons. The E12-06-107 experiment at JLab measured T in quasielastic electron-proton scattering with carbon-12 and liquid hydrogen targets, for Q2 between 8 and 14.3 GeV2, a range over which T should differ appreciably from Glauber calculations. Supported in part by US DOE grant DE-FG02-03ER41240.

11:30AM LE.00006 A new comparison of the $F_2^A/F_2^p$ and $F_2^A/F_2^p$ structure function ratios \textit{fl}. NARBE KALANTARIANS, Virginia Union University, CYNTHIA KEPPLE, HOLLY SZUMILA-VANCE, Jefferson Lab — h — abstract — \textit{fl} Using electron scattering data from SLAC E139 and muon scattering data from NMC in the DIS region, we determine the $F_2^A/F_2^p$ and $F_2^A/F_2^p$ structure function ratios, spanning 0.07 le $x_B$ le 0.7 and 1 le $Q^2$ le 200 GeV2 and 0.006 le $x_B$ le 0.6 and 1 le $Q^2$ le 55 GeV2/c2, respectively. This region is of particular relevance to studies of EMC Effect. Assuming no Q2 dependence, we compare the structure function ratios for isoscalar nuclei and study non-isoscalar nuclei with the possibility to look for flavor dependence. This talk will present the results of the mentioned ratios for isoscalar nuclei using the new $F_2^p$ global data from the CTEQ-JLab Collaboration.\textit{fl} — abstract — \textit{fl}

11:42AM LE.00007 First Cross Section Results of D(e,e’p)n at Very High Recoil Momenta1. CARLOS YERO, Florida International University, HALL C COLLABORATION — Preliminary D(e,e’p)n electro-disintegration cross sections at $Q^2 = 4.25$ GeV2 with recoil momenta up to 900 MeV/c will be presented. The experiment ran for a total of 6 days of beam time in April 2018 at Jefferson Lab in Hall C and it seeks to study the short range structure of the deuteron by probing its high momentum components beyond 500 MeV/c, where currently no data exists. The experiment was part of a group of Hall C experiments that commissioned the new Hall C Super High Momentum Spectrometer (SHMS). At the selected kinematics, Meson Exchange Currents (MEC) and Isobar Configurations (IC) are suppressed. Final State Interactions (FSI) have also been suppressed by choosing a kinematic region where the neutron recoil angle is between 35 and 45 degrees with respect to the momentum transfer. This suppression was seen in a previous D(e,e’p)n experiment (Boeglin et al. Phys Rev Lett. 2011) and is also predicted in modern theoretical calculations (W. Boeglin & M. Sargsian Int.J.Mod.Phys. 2015). In this region, the Plane Wave Impulse Approximation (PWIA) dominates and comparisons between measured and predicted cross sections are sensitive to the deuteron momentum distributions. Comparisons between data and calculations with different NN potentials will be shown.

1Nuclear Regulatory Commission (NRC) graduate fellowship recipient Carlos Yero was supported by the NRC fellowships grant No: NRC-HQ-84-14-G-0040 to FIU. This work was also supported by the Department of Energy (DOE) grant DE-SC0013620 to FIU.

11:54AM LE.00008 Probe nucleon mass inside nuclei. TAOFENG WANG, Beihang University, CLAS COLLABORATION — Nucleon masses in the nucleus are believed less than those in free space due to the binding in nuclear medium, particularly in the Short-Range Correlation (SRC). Extraction of nucleon mass inside nucleus, especially depending on its initial momentum, is a long-standing problem for both nuclear experimental and theoretical fundamental studies. High-energy electron quasi-elastic scattering associated with a knock-out proton by the virtual photon in (e,e’p) reaction is an appropriate way to probe the mass of the partner neutron in a SRC pair from missing mass spectra. The results of mass decrease with momentum will be shown not only in mean-field but also in SRC region, which are analyzed from light nucleus and heavier ones. The intrinsic features reflected are the modifications of quark dynamical characteristics when the confinement space of nucleon located inside nucleus, especially in high local density environment of SRC.

Wednesday, October 16, 2019 10:30AM - 12:30PM – Session LG Mini-Symposium: Nuclear Physics and the r-Process in the Multimessenger Era I Salone A - Catherine Deibel, Louisiana State University

10:30AM LE.00001 Nuclear Astrophysics in the New Era of Multimessenger Astronomy1. JORGE PIEKARENICZ, Florida State University — One of the overarching questions animating nuclear physics today is “How does subatomic matter organize itself”. Neutron stars are cosmic laboratories uniquely poised to answer this fundamental question. The historical first detection of a binary neutron star merger by the LIGO-Virgo collaboration is providing fundamental new insights into the astrophysical site for the r-process and on the nature of neutron-rich matter. In turn, the study of nuclei at new exotic-beam facilities throughout the world will help elucidate the underlying dynamics of the r-process and the structure, dynamics, and composition of neutron stars. In this presentation I will discuss how this synergy – in combination with nuclear physics insights, modern theoretical approaches, and powerful statistical ideas – can pave the way to understanding these fascinating objects.

1Work supported by the U.S. Department of Energy under Award Number DE-FG02-92ER40750.
11:06AM LG.00002 Macroscopic-microscopic fission yields for nucleosynthesis¹, NICOLE VASSH, University of Notre Dame — The rapid neutron capture process (r-process) is believed to synthesize the heaviest elements found on the periodic table. This remarkable process is believed to occur in exotic environments such as compact object mergers and possibly supernovae. In the most neutron-rich components of explosive outflows, nuclear fission, or the splitting of heavy nucleus into smaller lighter fragments, may play a crucial role in directing the nuclear flow far from stability. Where exactly the fission fragments are distributed across the chart of nuclides is an open theoretical question. I will address these issues using recent state-of-the-art fission yield calculations that employ the theoretical macroscopic-microscopic framework. I will present the impact of these calculations in simulations of the r-process.

¹This work was supported by the US Department of Energy through the Los Alamos National Laboratory. Los Alamos National Laboratory is operated by Triad National Security, LLC, for the National Nuclear Security Administration of U.S. Department of Energy (Contract No. 89233218CNA000001).

11:18AM LG.00003 Sandblasting The R-process: Spallation Of R-process Nuclei Ejected From A NSNS Event¹, XILU WANG, University of Notre Dame, BRIAN FIELDS, University of Illinois at Urbana-Champaign, MATTHEW MUMPOWER, Los Alamos National Lab, TREVOR SPROUSE, REBECCA SURMAN, NICOLE VASSH, University of Notre Dame — Neutron star mergers are r-process nucleosynthesis sites, which eject materials at high velocity ranging from 0.1c to 0.3c for different regions. Thus the r-process nuclei ejected from a neutron star merger event are sufficiently energetic to have spallation nuclear reactions with the interstellar medium particles. The spallation reactions tend to shift the r-process abundance patterns towards the solar data, and smooth the abundance shapes. The spallation effects depend on both the initial r-process nuclei conditions, which is determined by the astrophysical trajectories and nuclear data adopted for the r-process nucleosynthesis, and the propagation with various ejecta velocities and spallation cross-sections.

¹This work is supported by U.S. National Science Foundation under grant number PHY-1630782 Focused Research Hub in Theoretical Physics: Network for Neutrinos, Nuclear Astrophysics, and Symmetries (N3AS) (X.W.), and is also supported by the U.S. Department of Energy under Nuclear Theory Contract No. DE-FG02-95-ER40934 (R.S.)

11:30AM LG.00004 ABSTRACT WITHDRAWN —

11:42AM LG.00005 Nuclear Masses, Neutron Capture, and the r-process¹, A. COUTURE, Los Alamos National Laboratory, R. F. CASTEN, Yale Univ. and Michigan State Univ/FRB, R. B. CAKIRLI, Istanbul University — Individual neutron capture cross sections play an important role in the final isotopic abundances from a wide range of r-process scenarios. Unfortunately, the isotopes which show the greatest impact are far from stability and not within experimental reach for direct measurements in the coming years. We have discovered a previously unrecognized correlation between the neutron capture cross-section and the two-neutron separation energy. While initial studies required independent correlations for regions of different nuclear structure, recent work has shown a simple way to treat multiple regions in a consistent way, drastically improving its predictive reach. Because two-neutron separation energies can be measured with achievable rare beam intensities, the quality and quantity of S2n data is far more extensive than what is available for neutron capture, allowing experimentally based extrapolations. In addition to providing extended predictions, this may offer hints into where traditional reaction theories have missed underlying physics that is needed to more accurately model the capture reaction process.

¹A.C. was supported by the US Department of Energy through the Los Alamos National Laboratory, operated by Triad National Security, LLC, for the National Nuclear Security Administration (Contract No. 89233218CNA000001). R.B.C. acknowledges support from the Max-Planck Partner group.

11:54AM LG.00006 Statistical uncertainties of Skyrme-type nuclear energy density functionals and r-process nucleosynthesis¹, TREVOR SPROUSE, University of Notre Dame, R. NAVARRO PEREZ, San Diego State University, R. SURMAN, University of Notre Dame, M.R. MUMPOWER, Los Alamos National Laboratory, G.C. MCLAUGHLIN, North Carolina State University, N. SCHUNK, Lawrence Livermore National Laboratory — Fully understanding the impact of uncertainties in models of neutron-rich nuclei represents one of several critical steps towards understanding the formation of the heaviest elements via the rapid neutron capture (r)-process of nucleosynthesis. In this work, we consider the statistical uncertainty in the UNEDF1 nuclear energy density functional. We begin by sampling 50 points within the posterior distribution of the UNEDF1 parameter space. For each sample, we calculate nuclear binding energies, along with the nuclear capture, decay, and fission properties necessary for r-process nucleosynthesis calculations. We perform nucleosynthesis calculations for all of these conditions using different types of astrophysical conditions in which the r-process is thought to occur each of these 50 datasets, and we report the resulting range in abundance patterns. Finally, we estimate the ability of future measurements at the Facility for Rare Isotope Beams to reduce statistical uncertainty in the UNEDF1 parameters. We repeat our analysis in order to quantify the resulting improvements to r-process nucleosynthesis simulations.

¹Supported in part by DOE DE-SC000309, DE-FG02-95-ER40934, DE-FG02-93ER-40756, DE-SC0018232, DE-SC0018223, DE-AC52-06NA25396, DE-AC52-07NA27344, and DE-AC52-07NA27344

12:06PM LG.00007 Examining lanthanide production in merger accretion disk winds: nuclear masses and the rare-earth peak, NICOLE VASSH, REBECCA SURMAN, University of Notre Dame, MATTHEW MUMPPOWER, Los Alamos National Laboratory, GAIL MCLAUGHLIN, North Carolina State University, FIRE COLLABORATION — The observations of the GW170817 electromagnetic counterpart suggested lanthanides were produced in this neutron star merger event. Lanthanide production in heavy element nucleosynthesis is subject to large uncertainties from nuclear physics and astrophysics unknowns. Specifically, the rare-earth abundance peak, a feature of enhanced lanthanide production at A~164 seen in the solar r-process residuals, is not robustly produced in r-process calculations. The proposed dynamic mechanism of peak formation requires the presence of a nuclear physics feature in the rare-earth region which may be within reach of experiments performed at, for example, the CPT at CARIBU and the upcoming FRIB. To take full advantage of such measurements, we employ Markov Chain Monte Carlo to “reverse engineer” the nuclear masses capable of producing a peak compatible with the observed solar r-process abundances and compare directly with experimental mass data. Here I will present our latest results and demonstrate how the method may be used to learn which astrophysical conditions are consistent with both observational and experimental data. The question of where nature primarily produces the heavy elements can only be answered through such collaborative efforts between experiment, theory, and observation.
12:18PM LG.00008 Actinide-Rich or Actinide-Poor, Same r-Process Progenitor .
ERIKA HOLMBECK, University of Notre Dame, ANNA FREBEL, Massachusetts Institute of Technology, G. C. MCLAUGHLIN, North Carolina State University, MATTHEW R. MUMPPOWER, Los Alamos National Laboratory, TREVOR M. SPOROUSE, REBECCA SURMAN, University of Notre Dame — The astrophysical production site of the heaviest elements in the universe remains a mystery. Incorporating heavy element signatures of metal-poor, r-process enhanced stars into theoretical studies of r-process production can offer crucial constraints on the origin of heavy elements. In this study, we introduce and apply the “Actinide-Dilution with Matching” model to a variety of stellar groups ranging from actinide-deficient to actinide-enhanced to empirically characterize r-process ejecta mass as a function of electron fraction. We find that actinide-boost stars do not indicate the need for a unique and separate r-process progenitor. Rather, small variations of neutron richness within the same type of r-process event can account for all observed levels of actinide enhancements. The very low-Yn, fission-cycling ejecta of an r-process event need only constitute 10–30% of the total ejecta mass to accommodate most actinide abundances of metal-poor stars. We find that our empirical Yn distributions of ejecta are similar to those inferred from studies of GW170817 mass ejecta ratios, which is consistent with neutron-star mergers being a source of the heavy elements in metal-poor, r-process enhanced stars.

Wednesday, October 16, 2019 10:30AM - 11:54AM –
Session LH Nucleon Structure II  Salon B - William Brooks

10:30AM LH.00001 The mechanical size of the proton ., VOLKER BURKERT, LATIFA ELOUADRHIRI, Jefferson Lab, FRANCOIS-XAVIER GIROD, University of Connecticut — Protons are fundamental building blocks of our universe. They are composed of elementary objects, quarks and gluons. It is well established that quarks do not exist in isolation but only in the confines of protons and other hadrons. The mechanical properties of the proton including the size of the confinement volume can in principle be probed in interactions that couple directly to the quark masses through gravitation. These properties are encoded in the proton’s matrix element of the energy-momentum tensor and are expressed in the gravitational form factors (GFF). Use of direct gravitational interaction in such measurements is impractical. However, recent theoretical developments have shown that the GFF may also be probed indirectly in deeply virtual Compton scattering (DCVS). This new direction of nucleon structure research has already resulted in the first determination of the pressure distribution inside the proton. Here we present the first results on the mechanical size of the proton employing the DCVS process in extracting the form factor D(t). We will compare our results to the frequently discussed charge radius of the proton and to the sizes of other hadrons.

10:42AM LH.00002 Partonic orbital angular momentum and contributions to the trace anomaly , ABHA RAJAN, Brookhaven National Laboratory — Quark gluon interactions are crucial to our understanding of partonic orbital angular momentum. Despite describing a quark quark correlation function, twist three Generalized Parton Distributions (GPDs) implicitly involve quark gluon contributions. They get contributions from leading twist GPDs, the quark mass in the axial vector case and a term involving the quark gluon quark correlation function also known as the genuine twist three term. We show how each of these contributions are derived by looking at the underlying kT structure. We also highlight the role of the gauge link both in the collinear limit and the generalized transverse momentum limit. Several open questions remain about the mass decomposition of the proton. As the constituent quarks are very light, the quantum effects that make the theory non conformal and hence give the proton most of its mass are encompassed in the trace anomaly. The quark and gluon contributions to the total energy momentum tensor are parameterized using the gravitational form factor. We show how to precisely write the trace anomaly in terms of these quantities.

10:54AM LH.00003 Charge Symmetry Violation in Quark Distributions using Semi-Inclusive Deep Inelastic Scattering1, HEM BHATT, Mississippi State University — Charge symmetry is the invariance of the strong interactions during specific isospin rotation of 180 degrees which results to the exchange of up and down quarks, while simultaneously interchanging protons and neutrons. It has generally been assumed to be valid in most parton distribution fits. The violation of this symmetry arises due to the small mass difference between up and down quarks and the electromagnetic interactions. Although charge symmetry violation (CSV) is expected to be very small, the precision of the existing data can only constrain it to be <10%. Jefferson Lab Hall-C experiment E12-09-002 aims to place constraints on the degree of CSV in the valence quark distributions in the nucleon via semi-inclusive deep inelastic scattering. In this experiment, a 10.6 GeV electron beam was incident on a liquid deuterium target with the scattered electrons and charged pions detected in coincidence in the HMS and SHMS spectrometers respectively. This experiment will measure the ratios of charged pion cross-sections with high precision to extract and place limits on the charge symmetry violating parton distribution. The current status of the data analysis will be discussed in this talk.

1This work is supported by US DOE Grant Number: DE-FG02-07ER41528

11:06AM LH.00004 3D Partonic Structure of Nucleons and Light Nuclei , MOHAMMAD HATTAWY, Old Dominion University, CLAS COLLABORATION — The generalized parton distributions (GPDs) framework opens a new avenue to explore the nature of the medium modifications at the partonic level, i.e., quarks and gluons. The first step in this direction has been performed by the CLAS collaboration during the 6 GeV era, where the bound proton deeply-virtual Compton scattering (DVCS) off 4He is compared to the free proton. The results have indeed shown significant modification of the proton beam-spin asymmetry in 4He. A new groundbreaking measurement of coherent DVCS of the 20Ne nucleus is a critical step towards providing similar 3D pictures of the partonic structure of nuclei, and provides a new approach to understanding the modifications of protons and neutrons within the dense environment of a nucleus. The 4He nucleus is particularly important, as its partonic structure is encoded within a single chirally-even GPD. These results have proven the experimental feasibility of measuring such nuclear exclusive reactions and led the way to the approval of a next generation nuclear physics program to be carried out using the upgraded CEBAF electron beam. In my talk I will be presenting the recent results and the future planned measurements using the upgraded setup of the CLAS12 spectrometer at Jefferson Lab.

11:18AM LH.00005 Results on light quark fragmentation from Belle1, ANSELM VOSSEN, Duke University, BELLE COLLABORATION — Results on light quark fragmentation from Belle The knowledge of parton fragmentation functions are important for our understanding of semi-inclusive hard scattering processes. Fragmentation functions can be extracted from e+e- annihilation cross-section measurements independently of the knowledge of parton distribution functions. Using record breaking luminosities delivered by KEKB, the Belle experiment at KEK in Japan recorded about 1 ab−1 between 1999 and 2010, mostly at the Y(4S) resonance. This contribution will show recent results on measurements related to light quark fragmentation using Belle data and discuss prospects at Belle II.

1DOE Office of Science
within the framework of the Beam Energy Scan Theory (BEST) Topical Collaboration and grant No.
universal
SUSHAMA PRADEEP, MIKHAIL STEPHANOV, University of Illinois at Chicago — The universality of the QCD equation of state near the
critical point is expressed by mapping QCD pressure onto the Gibbs free energy in the Ising model. The mapping parameters are, in general, not
SUSHAMA PRADEEP, MIKHAIL STEPHANOV, University of Illinois at Chicago — The universality of the QCD equation of state near the

determination, which is the degree of overlap for the colliding particles. The STAR experiment currently uses the Time Projection Chamber
phase diagram for Quantum Chromodynamics (QCD). Most observables aimed at the determination of these phase properties rely on centrality
and kaon form factors and generalized form factors using numerical simulations within Lattice QCD. We employ the twisted mass fermion
action for an Nf=2+1+1 ensemble with pion mass of 260 MeV. Main focus is given to the electromagnetic form factors, the quark momentum
fraction, and the generalized form factors of the one-derivative unpolarized operator. Systematic errors due to excited states contamination are
investigated and controlled using various analysis methods.

Wednesday, October 16, 2019 10:30AM - 12:18PM –
Session LJ Mini-Symposium: Search for the Critical Point II
Salon C - Roy Lacey, Stony Brook University

10:30AM LJ.00001 Longitudinal De-correlation of Anisotropic Flow in Au+Au Collisions at 27 GeV from STAR, XIAOYU LIU, the Ohio State University, STAR COLLABORATION — Studies of longitudinal de-correlation of anisotropic flow provide unique constraints on the initial conditions and dynamical evolution of the quark gluon-plasma in heavy-ion collisions. The newly installed Event Plane Detector (EPD) in both forward and backward directions provides a unique opportunity to measure the flow de-correlation at STAR/RHIC. In this study, the factorization ratio for flow harmonics, \( r_n(\eta, \varphi)(\eta = 2.3) \), is obtained over a wide \( \eta \) range for 27 GeV Au+Au collisions as functions of centrality and transverse momentum. Comparing to results from LHC and 200 GeV Au+Au collision, a clear energy dependence is observed indicating a stronger longitudinal de-correlation at lower collision energies. The results may provide new insights into the three-dimensional modeling of the evolution of relativistic heavy-ion collisions and the shear viscosity of the QGP, especially their collision energy dependence.

10:42AM LJ.00002 Determining Collision Event Centrality Using the Event Plane Detector at the STAR Experiment, SKIPPER KAGAMASTER, Lehigh University, STAR COLLABORATION — Heavy ion physicists have been lately concerned with investigating the possibility of a critical point and a first order phase transition in the phase diagram for Quantum Chromodynamics (QCD). Most observables aimed at the determination of these phase properties rely on centrality determination, which is the degree of overlap for the colliding particles. The STAR experiment currently uses the Time Projection Chamber (TPC) to determine centrality; however, the TPC spans the same rapidity acceptance as many of the observables. This talk will focus on the potential to use the STAR Event Plane Detector (EPD), which is located at forward rapidity of \( 2.1 < |\eta| < 5.1 \), for this purpose in order to prevent autocorrelations in analysis. We will show how well centrality determinations from these two detectors agree for Au+Au collisions at \( \sqrt{S_{NN}} = 27 \) GeV.

1NSF grant numbers 1614474 and 1913696.
2STAR Collaboration at RHIC (BNL)

10:54AM LJ.00003 QCD critical point, universality, and small quark mass, MANEESHA SUSHAMA PRADEEP, MIKHAIL STEPHANOV, University of Illinois at Chicago — The universality of the QCD equation of state near the critical point is expressed by mapping QCD pressure onto the Gibbs free energy in the Ising model. The mapping parameters are, in general, not universal, i.e., determined by the unknown details of the microscopic physics, rather than by symmetries and universal long-distance dynamics. We point out that in the limit of small quark masses, when the critical point is close to the tricritical point, the mapping parameters show certain universal dependence on the quark mass and discuss possible phenomenological consequences of these findings.

1This work is supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, within the framework of the Beam Energy Scan Theory (BEST) Topical Collaboration and grant No. DE-FG0201ER41195

11:06AM LJ.00004 ABSTRACT WITHDRAWN –

1U.S. Department of Energy, Office of Science, Office of Nuclear Physics, contract no. DE-AC02-06CH11357
momentum (R) for and R_Q are taken into consideration. This allows access to the spatial and temporal characteristics of the systems produced in relativistic heavy-ion collisions. This presentation contains new measurements of the two-pion HBT radii, R_{long} and R_{side} which have been made for shape-engineered events by the STAR experiment. Shape selection was accomplished via cuts on the distributions of the second-order flow vector Q_2. Selected events, characterized with larger magnitudes of Q_2, indicate a systematic decrease for R_{long} and R_{side} with little, if any, change for R_{side}. Results obtained as a function of collision centrality and average pair transverse momentum (k_T) will be presented for the full range of the Au+Au beam energy scan (\sqrt{s_{NN}} = 7.7 - 200 GeV). The implications of these results for expansion dynamics of the collision systems will be discussed.

1STAR Collaboration

11:30AM LJ.00006 Magnetic field in expanding quark-gluon plasma

KIRILL TUCHIN, Iowa State University — Intense electromagnetic fields are created in the quark-gluon plasma by the external ultra-relativistic sources and, on the other hand, to investigate the dynamics of magnetic field in the background plasma. We also argue that the wake induced by the magnetic field in plasma is negligible.

1US Department of Energy Grant No. DE-FG02-87ER40371

11:42AM LJ.00007 A search for the magnetic field in the QGP by STAR

JOSEPH ADAMS, Ohio State University, STAR COLLABORATION — Lambda polarization \( P_{\Lambda/A} \) was measured by the STAR collaboration, confirming the existence of extremely large vorticities within the Quark Gluon Plasma (QGP). Additionally suggested is an enhanced \( P_\Lambda \) relative to \( P_\Lambda \) across all beam energies; however, the statistics are too limited to make a significant measurement. No such splitting is observed in the high-statistics \( \sqrt{s_{NN}} = 200 \) GeV data set, but this splitting is expected increase at lower beam energies. Such a splitting in polarization would be consistent with the effects of hyperon-magnetic-moment coupling with the magnetic field sustained in the QGP; it would have far-reaching consequences important to magnetic-field-dependent observables such as the chiral magnetic effect and would set the scale on the conductivity of the QGP. Recently, STAR has taken a high-statistics data set at \( \sqrt{s_{NN}} = 27 \) GeV which considered suitable to study the splitting between \( P_\Lambda \) and \( P_\Lambda \) now includes the recently installed Event-Plane Detector (EPD), leading to a significantly increased event-plane resolution. We will present the measurement of this splitting and discuss its implications.

11:54AM LJ.00008 System Size, Energy, and Centrality Dependence of the \( \eta \) to \( \pi^0 \) Ratio

YUANJIE REN, AXEL DREES, Stony Brook University — Data on the ratio of \( \eta \) to \( \pi^0 \) with respect to transverse momentum \( p_T \) from different experiments, different collisions systems (p+p, p+p+A, as well as A+A), and different center of mass energies \( \sqrt{s_{NN}} \) are collected and compared to each other. We find that the ratio is surprisingly similar in all systems. We characterize and quantify the universality of the ratio and determine an empirical function for \( \frac{\eta}{\pi^0} \) including its systematic uncertainties. With this function we can derive the invariant yield for the \( \eta \) meson based on \( \pi^0 \) measurements. Our procedure holds the promise to be more precise than the method of scaling with transverse mass (m_T), which is currently used in the PHENIX experiment. The new approach may reduce the systematic uncertainty on ongoing low \( p_T \) direct photon measurements by PHENIX. In this talk we will present our method and the results.

12:06PM LJ.00009 Effect of the GUP on the Entropy Density, Speed of Sound, and Bulk to Shear Viscosity Ratio of an Ideal QGP

NASSER DEMIR, Kuwait University — One of the candidates to reconcile quantum mechanics with general relativity is the generalization of the Heisenberg Uncertainty Principle to incorporate gravitational effects. As a result, the Generalized Uncertainty Principle (GUP) “deforms” the commutation relation given by the Heisenberg Uncertainty Principle via a GUP parameter \( \alpha \). We present a calculation of the entropy density, speed of sound, and the resulting impact on the bulk viscosity to shear viscosity ratio of an ideal quark gluon plasma when the effects of the GUP are taken into consideration. When the GUP parameter tends to zero, we obtain the value of the speed of sound for an ideal gas of massless particles i.e. \( c_s^2 = 1/3 \) and the expected result that the bulk viscosity vanishes. In addition, in the high temperature limit, the speed of sound tends to \( c_s^2 = 1/4 \). The consequence this has on the bulk viscosity is that in the high temperature limit, the ratio of the bulk to shear viscosity tends to \( \zeta/\eta = 5/48 \). Our results suggest that the GUP introduces a scale into the system breaking the a priori conformal invariance of a system of massless noninteracting particles. We sketch an attempt to find GUP modifications to the KSS bound.

Wednesday, October 16, 2019 10:30AM - 12:18PM – Session LL Mini-Symposium on Fundamental Symmetries: Theory and Experiment

10:30AM LL.00001 Status and Prospects in Neutron Beta Decay

LEAH BROUSSARD, ORNL — Neutron beta decay is an exceptional laboratory for sensitive experimental tests which can reveal new particles and interactions beyond our Standard Model of Particle Physics. Recent advances in both theory and experiment have opened the door for the neutron to play an increasingly important role as a reference system for unitarity tests of the Cabibbo-Kobayashi-Maskawa quark-mixing matrix and constrain extensions to the Standard Model which predict non-V-A currents. These low energy precision measurements have sensitivity to new physics at energy scales comparable to or above the reach of the Large Hadron Collider. This presentation will review the state of the art in experimental determinations of neutron beta decay observables and outlook for precision tests and probes for new physics in the next generation.
11:06AM LL.00002 The BL2 Experiment: An In-Beam Measurement of the Neutron Lifetime with planet-to-spacecraft distance yields a measure of \( \tau \) uncertainties in the analysis of the blinded data from the 2018 data cycle will be presented. Improved neutron and a monitor expressly for setting empirical limits on depolarization. These enhancements will be described and an update is now collecting data to achieve a total uncertainty around 0.25 seconds. Improvements for this cycle include a non-magnetic buffer volume containing polarized ultracold neutrons (UCN's) produced at Los Alamos National Lab for measuring the free neutron lifetime. This value is a major input parameter for Big Bang nucleosynthesis predictions and, with neutron decay correlation coefficients, can be used to probe beyond Standard Model physics. Additionally, over the past two years a significant discrepancy between lifetime measurements that count surviving neutrons, like UCNt, and those that detect decay products has prompted the creation of many exotic and exciting explanations. UCN\( \tau \) has dominated those in predicted primordial \(^4\)He abundance from Big Bang nucleosynthesis. Presently, there exist two classes of experiments that have successfully made measurements of \( \tau \). The 'Beam' class involves measuring the activation of cold neutron beams and the 'Bottle' class uses storage (material, magnetic and/or gravitational) to trap neutrons and measure the rate of decay during storage. However, there currently exists a 4 \sigma disagreement between the 'beam' and 'bottle' measurements. We have developed a new technique for using space-based neutron spectroscopy measurements to determine \( \tau \). Under this technique the change in planet-originating neutron flux with planet-to-spacecraft distance yields a measure of \( \tau \). Here, we will present an analysis of data from the neutron spectrometer on NASA's MESSENGER mission as a proof-of-principle demonstration of a space-based \( \tau \) measurement. In this talk, we will discuss the basis of the technique, statistical and systematic errors of the measurement, and preliminary results will be presented.

11:18AM LL.00003 Current Status of the UCN\( \tau \) Experiment with planet-to-spacecraft distance yields a measure of \( \tau \) uncertainties in the analysis of the blinded data from the 2018 data cycle will be presented. Improved neutron and a monitor expressly for setting empirical limits on depolarization. These enhancements will be described and an update is now collecting data to achieve a total uncertainty around 0.25 seconds. Improvements for this cycle include a non-magnetic buffer volume containing polarized ultracold neutrons (UCN's) produced at Los Alamos National Lab for measuring the free neutron lifetime. This value is a major input parameter for Big Bang nucleosynthesis predictions and, with neutron decay correlation coefficients, can be used to probe beyond Standard Model physics. Additionally, over the past two years a significant discrepancy between lifetime measurements that count surviving neutrons, like UCNt, and those that detect decay products has prompted the creation of many exotic and exciting explanations. UCN\( \tau \) has dominated those in predicted primordial \(^4\)He abundance from Big Bang nucleosynthesis. Presently, there exist two classes of experiments that have successfully made measurements of \( \tau \). The 'Beam' class involves measuring the activation of cold neutron beams and the 'Bottle' class uses storage (material, magnetic and/or gravitational) to trap neutrons and measure the rate of decay during storage. However, there currently exists a 4 \sigma disagreement between the 'beam' and 'bottle' measurements. We have developed a new technique for using space-based neutron spectroscopy measurements to determine \( \tau \). Under this technique the change in planet-originating neutron flux with planet-to-spacecraft distance yields a measure of \( \tau \). Here, we will present an analysis of data from the neutron spectrometer on NASA's MESSENGER mission as a proof-of-principle demonstration of a space-based \( \tau \) measurement. In this talk, we will discuss the basis of the technique, statistical and systematic errors of the measurement, and preliminary results will be presented.

11:30AM LL.00004 Measurement of the Free-Neutron Lifetime Using Space-based Neutron Data from NASA's MESSENGER Mission with planet-to-spacecraft distance yields a measure of \( \tau \) uncertainties in the analysis of the blinded data from the 2018 data cycle will be presented. Improved neutron and a monitor expressly for setting empirical limits on depolarization. These enhancements will be described and an update is now collecting data to achieve a total uncertainty around 0.25 seconds. Improvements for this cycle include a non-magnetic buffer volume containing polarized ultracold neutrons (UCN's) produced at Los Alamos National Lab for measuring the free neutron lifetime. This value is a major input parameter for Big Bang nucleosynthesis predictions and, with neutron decay correlation coefficients, can be used to probe beyond Standard Model physics. Additionally, over the past two years a significant discrepancy between lifetime measurements that count surviving neutrons, like UCNt, and those that detect decay products has prompted the creation of many exotic and exciting explanations. UCN\( \tau \) has dominated those in predicted primordial \(^4\)He abundance from Big Bang nucleosynthesis. Presently, there exist two classes of experiments that have successfully made measurements of \( \tau \). The 'Beam' class involves measuring the activation of cold neutron beams and the 'Bottle' class uses storage (material, magnetic and/or gravitational) to trap neutrons and measure the rate of decay during storage. However, there currently exists a 4 \sigma disagreement between the 'beam' and 'bottle' measurements. We have developed a new technique for using space-based neutron spectroscopy measurements to determine \( \tau \). Under this technique the change in planet-originating neutron flux with planet-to-spacecraft distance yields a measure of \( \tau \). Here, we will present an analysis of data from the neutron spectrometer on NASA's MESSENGER mission as a proof-of-principle demonstration of a space-based \( \tau \) measurement. In this talk, we will discuss the basis of the technique, statistical and systematic errors of the measurement, and preliminary results will be presented.

11:42AM LL.00005 Tau2: A next generation neutron lifetime experiment based on UCN\( \tau \) with planet-to-spacecraft distance yields a measure of \( \tau \). Here, we will present an analysis of data from the neutron spectrometer on NASA's MESSENGER mission as a proof-of-principle demonstration of a space-based \( \tau \) measurement. In this talk, we will discuss the basis of the technique, statistical and systematic errors of the measurement, and preliminary results will be presented.

11:54AM LL.00006 Simulations of the UCN velocity distribution at Los Alamos National Lab with planet-to-spacecraft distance yields a measure of \( \tau \). Here, we will present an analysis of data from the neutron spectrometer on NASA's MESSENGER mission as a proof-of-principle demonstration of a space-based \( \tau \) measurement. In this talk, we will discuss the basis of the technique, statistical and systematic errors of the measurement, and preliminary results will be presented.

12:06PM LL.00007 BL3: A next generation "beam" experiment to measure the neutron lifetime with planet-to-spacecraft distance yields a measure of \( \tau \). Here, we will present an analysis of data from the neutron spectrometer on NASA's MESSENGER mission as a proof-of-principle demonstration of a space-based \( \tau \) measurement. In this talk, we will discuss the basis of the technique, statistical and systematic errors of the measurement, and preliminary results will be presented.
10:30AM LM.00001 ABSTRACT WITHDRAWN

10:42AM LM.00002 Parity-violating electron-nucleus scattering at Mainz1, OLEKSANDR KOSCHCHII, Johannes Gutenberg University Mainz — Parity-violating (PV) elastic scattering of longitudinally polarized electrons by an unpolarized nucleus is a powerful tool for precision tests of the Standard Model (SM) and for studies of the nuclear structure. The respective left-right asymmetry (\(A_{PV}\)) probes one of the fundamental parameters of the SM - the weak mixing angle. Besides precision tests of the SM, parity-violating electron-nucleus scattering can be employed for a determination of the spatial distribution of neutrons within the nucleus and thus enables one to deduce the thickness of the neutron skin. Knowledge of the neutron skin can have a strong impact in many areas of physics. In my talk I will review the parity violating program at the MESA facility in Mainz and discuss our recent study of theoretical uncertainties for a measurement of \(A_{PV}\) on a \(^{12}C\) target. Our calculation is performed in a connection with the prospective measurement at MESA.  

1This work is supported by the Deutsche Forschungsgemeinschaft (DFG) through the German-Mexican research collaboration, grant SP 778/4-1.

10:54AM LM.00003 Uncertainty estimates for muon capture on the deuteron1, JOSE BONILLA, University of Tennessee, BIJAYA ACHARYA, Johannes Gutenberg University of Mainz, LUCAS PLATTER, University of Tennessee — Muon capture on the deuteron is a two-body electroweak process that can provide information on the properties of the electroweak current in nuclear effective field theory but also the three-body force in the nuclear Hamiltonian. I will discuss recent progress on the calculation of the rate for this process and corresponding uncertainty estimates.  

1National Science Foundation

11:06AM LM.00004 Spin Tracking for the Fermilab E989 Muon \(g - 2\) Experiment1, ABEL LOREnte CAMPOS, University of Kentucky, FERMIlAB E989 COLLABORATION — The E989 Muon \(g - 2\) Experiment at Fermilab studies the anomalous magnetic moment \(\mu\) of the muon with a precision goal of 140 ppb. Previous measurements at Brookhaven National Laboratory estimated a discrepancy greater than 3 sigma with respect to the Standard Model prediction. With 20 times more statistics, the E989 experiment aims to evaluate this discrepancy. The measurement of \(\mu\) depends on highly precise measurements of the magnetic field and the difference between spin precession and cyclotron frequencies, \(\omega_\mu\). By design, muons of "magic momentum" (3.094 GeV/c) are stored in the 1.45 T magnetic storage ring. This momentum is chosen to minimize distortions of \(\omega_\mu\) caused by the electrostatic quadrupoles used to vertically focus the beam. Deviations from the magic momentum and vertical oscillations induced by the quadrupoles result in sub-ppm corrections that must be calculated by precise reconstruction of the beam's motion, both in data and simulation. This talk will present an approach to evaluate these corrections via development of a spin tracking simulation. This simulation will be used to study the beam-related systematic errors to \(\omega_\mu\) and other studies such as beam tracking or convolution of the beam with the magnetic field.  

1We acknowledge support from the Fermi Research Alliance, LLC under Contract No. DE-AC02-07CH11359 with the U.S. DOE-OHEP. The author is supported by the National Science Foundation, under Award Number PHY-1714014.

11:18AM LM.00005 The Stopped-Kaon Decay Experiment TREK/E36 at J-PARC1, DONGWI DONGWI, Hampton University, TREK/E36 COLLABORATION — The TREK/E36 experiment conducted at J-PARC in Japan aims to test lepton universality in the ratio of decay widths, \(R_K = \Gamma(K_{\mu2})/\Gamma(K_{\mu2})\), by utilizing a superconducting toroidal spectrometer, a scintillating fiber target, particle identification systems in combination with a highly segmented CsI(Tl) photon calorimeter covering 75% of 4\(\pi\) and charged-particle tracking detectors. Additionally the set-up of the E36 detector system facilitates searches for light \(\nu(1)\) gauge bosons below 300 MeV/c\(^2\). These bosons could be associated with dark matter or explain the established muon-related anomalies such as the muon \(g - 2\) value, and the proton radius puzzle. The status and approach of the analysis will be presented.  

1This work has been supported by DOE awards DE-SC0003884 and DE-SC0013941 in the US, NSERC in Canada, and Kaken-hi in Japan

11:30AM LM.00006 Study of radiative pion and muon decays in the PEN experiment1, DINKO POCANIC, University of Virginia, PEN COLLABORATION — Radiative decays of the muon: \(\mu^+ \rightarrow e^+ + \nu_e + \nu_\mu + \gamma\), and pion: \(\pi^+ \rightarrow e^+ + \nu_e + \gamma\), or \(\pi^{+\mp}\), where the photon carries away an appreciable portion of the available energy, are sensitive in different ways to departures from the basic \(V - A\) dynamics of the weak interaction. Like other pion and muon decay channels, they are described with extreme precision in the standard model (SM) of elementary particles and fields. Hence, both processes are effective in studies of the limits on certain non-SM interactions. Additionally, the radiative pion electronic decay offers direct information on the weak form factors of the pion. The ratio of the axial-vector and vector pion form factors, \(F_A/F_V\) provides critical basic input for low energy chiral lagrangians, such as chiral perturbation theory. We discuss the physics reach, and present an analysis update, of the pion and muon radiative decay measurements in the PEN experiment.  

1Work supported by grants from the US National Science Foundation, most recently PHY-1614839.
11:42AM LM.00007 The Systematics of PEN: A Precision Measurement of the Pion Electronic Decay Branching Ratio1. CHARLES GLASER, University of Virginia, PEN COLLABORATION — The goal of the PEN collaboration, an international collaboration led by the University of Virginia, is to obtain the pion electronic decay branching ratio \( \Gamma(e \rightarrow \nu \gamma) / \Gamma(e \rightarrow \mu \gamma) \) with a relative uncertainty of 5 × 10^{-4} or better. This measurement provides the best test for electron muon universality. The PEN experiment was performed using stopped pions at the Paul Scherrer Institute in Zurich. The detector was comprised of active plastic beam counters and stopping target, a mini-time projection chamber, two cylindrical multi-wire proportional chambers, twenty plastic scintillator hodoscopes, and a 240 module pure CsI calorimeter with a solid angle coverage of 3π steradians. An ultra realistic Monte Carlo simulation was constructed by the PEN collaboration to obtain the acceptances and study the low energy tail in the CsI calorimeter. Branching ratio extraction requires precise descriptions of hard radiative decays, decays in flight, and corrections from the chamber efficiencies, timings, and the CsI low energy tail, the most difficult systematics in the analysis due to muon decay background, energy leakage and photonuclear effects. A detailed analysis of the uncertainty budget will be presented.

1Work supported by grants from the US National Science Foundation, most recently PHY-1614839

Wednesday, October 16, 2019 10:30AM - 12:30PM – Session LN Nuclear Structure IV  Salon K - Sam Tabor, Florida State University


10:42AM LN.00002 Beta-decay study on the neutron-unbound states in \( ^{133}\text{Sn} \) at ISOLDE Decay Station . ZHENGYU XU, MIGUEL MADURGA, ROBERT GRZYWACZ, University of Tennessee, THE IS632 COLLABORATION — In this contribution, we will present a recent experimental work studying the neutron-unbound states in \( ^{133}\text{Sn} \) from the beta decay of \( ^{133}\text{In} \) at ISOLDE Decay Station. The beta decay in this region (\( Z < 50 \) and \( N > 82 \)) is characterized by a large beta-decay energy window \( Q_{\beta} \) and low neutron separation energy \( S_{n} \). Due to the valence proton and neutron orbitals having opposite parities, Gamow-Teller transitions create deep-neutron holes in the \( ^{132}\text{Sn} \) core. The large \( N=82 \) shell gap makes these neutron-hole states in \( ^{133}\text{Sn} \) neutron unbound. The neutron time-of-flight detector VANDLE was used to identify these states for the first time. Neutron resonances were observed at energies between 1.5 and 3.7 MeV corresponding to candidate \( 11/2^- (h_{11/2}), 3/2^+ (d_{3/2}), 1/2^+ (s_{1/2}), \) and \( 7/2^+ (g_{7/2}) \). The neutron \( h_{11/2} \) state \( [2] \) was identified in the neutron time-of-flight spectra. Analysis of the data indicates several individual \( 1^+ \) states are fed in \( ^{132}\text{In} \). Strength fragmentation offers a compelling explanation for the experimental half-life of \( ^{132}\text{Cd} \) being longer than state-of-the-art calculations [2]. [1] K.L. Jones et al., Nature 465, 454 (2010). [2] P. Miller, B. Pfeiffer, and K.-L. Kratz, Phys. Rev. C67, 055802 (2003). [3] G. Lorusso et al., Phys. Rev. Lett. 114, 192501 (2015). [4] W. A. Peters et al., Nucl. Inst. Meth. A836, 122 (2016). [5] S.V. Paulauskas et al., Nucl. Instrum Meth. A737, 22 (2014).

10:54AM LN.00003 Chiral Wobbling in \( ^{135}\text{Pr} \). NIRUPAMA SENSCHARMA, UMESH GARG, STEFAN FRAUENDORF, JOSEPH L COZZI, KEVIN B HOWARD, Unif of Notre Dame, SHAOFEI ZHU, MICHAEL P CARPENTER, FILIP G KONDEV, DARIUSZ SEWERYNIAK, Annette Natl Lab, ROBERT V F JANSENS, Univ of NC - Chapel Hill, AKAA D AYANGAEKAA, DARYL HARTLEY, US Naval Academy, SANDEEP S GHUGE, UGC-DAE Consortium for Scientific Research, India, RUDRAJYOTI PALIT, Tata Institute of Fundamental Research, India — Chirality and wobbling are the two unique signatures that help in the identification of the rare triaxial shape in nuclei. While both these modes have been separately established in a few limited regions of the nuclear chart, the coexistence of chirality and wobbling in a nucleus, a Chiral Wobbler, has never been observed so far. Using a high statistics Gammasphere experiment with the \( ^{124}\text{Sn} + ^{16}\text{O} \) and \( ^{135}\text{Pr} \) reaction, the very first observation of a Chiral Wobbler in \( ^{135}\text{Pr} \) has been made. In addition to the previously established \( n_{\omega} = 1 \) and \( n_{\omega} = 2 \) wobbling bands, two chiral-partner bands with the configuration \( \nu h_{11/2} \times \nu h_{11/2} \) have been observed in this nucleus. Angular distribution analyses of the \( \Delta I = 1 \) connecting transitions between the two chiral partners have revealed their characteristic M1/E2 nature. Tilted axis cranking (TAC) calculations are found to be in good agreement with the experiment.

1This work has been supported by the U.S. NSF Grant No. PHY-1713857.

11:06AM LN.00004 Spectra of Heavy Nuclei in the Shell Model Monte Carlo Method1. SOHAN VARTAK, YORAM ALHASID, Yale University, MARCO BONNETT-MATIZ, University of Bridgeport — The shell model Monte Carlo (SMMC) method is calculating the thermal and ground-state properties of nuclei in model spaces that are many orders of magnitude larger than those that can be treated in conventional diagonalization methods. However, extracting information about individual excited states poses a challenge in SMMC. Recently, a method was developed to extract the energies of several excited states for given values of the spin and parity [1]. The method is based on solving a generalized eigenvalue problem that is satisfied by the imaginary-time response matrices of one-body densities. We are applying this method to calculate the energies of low-lying collective states in chains of rare-earth isotopes that describe a crossover from vibrational to rotational collective. [1] Y. Alhasid, M. Bonnett-Matiz and C.N. Gilbreth, to be published (2019).

1This work was supported in part by the U.S. DOE grants Nos. DE-FG02-91ER40608 and DE-SC0019521.
11:18AM LN.00005 Hexadecapole Vibration in $^{160}$Gd? , D.J. HARTLEY, A.D. AYANGEAKAA, United States Naval Academy, F.G. KONDEV, K. AURANEN, M.P. CARPENTER, J.A. CLARK, J.P. GREENE, C.R. HOFFMAN, T. LAURITSEN, J. LI, G. SAVARD, D. SEVERNYIKA, S. STOLZE, J. WU, S. ZHU, Argonne National Laboratory, K. VILLAFANA, M.A. RILEY, J. BARRON, Florida State University, R.V.F. JANSENS, D. LITTLE, University of North Carolina/TUNL, A.J. BOSTON, J. HEERY, E.S. PAUL, University of Liverpool, J. SIMPSON, Daresbury Laboratory, G.L. WILSON, Louisiana State University — Excited states in $^{160}$Gd were populated via Coulomb excitation of a $^{160}$Gd beam (at 1000 MeV) bombarding thick targets of $^{154}$Sm and $^{164}$Dy. The Gammasphere spectrometer, located at Argonne National Laboratory, was used to detect the emitted $\gamma$ rays. A rotational band based on the $K^\pi = 4^+$ state at 1071 keV was extended to higher spin. This state has been associated with a hexadecapole vibration, and the band is found to gain alignment at an unusually constant rate, which is different from that observed for the sequences based on the ground state and on the $\gamma$ vibration. A discussion based on the proximity of this nucleus to the $\mathrm{Ne}^\mathrm{n}=98$ shell gap will address this constant rate of alignment.

1Support from the NSF under grant numbers PHY-1520902 (USNA), PHY-1712953 (FSU) and the US DOE under grant numbers DE-AC02-06CH11357 (ANL), DE-FG02-97ER14014 (UNC), FG-02-97ER14033 is gratefully acknowledged.

11:30AM LN.00006 Spectroscopy above the 6-qp K-isomer in $^{176}$Hf, , P. CHOWDHURY, E. DOUCET, A.Y. DEO, S.S. HOTA, UMass Lowell, D.M. CULLEN, U. Manchester, G. MUKHERJEE, VECC-Kolkata, F.G. KONDEV, ANL, P.T. GREENLEES, P. JONES, S. KETELHUT, S. RINTA-ANTILA, P. RIOTSALAIEN, J. SAREN, J. SORRI, S. STOLZE, JYFL-Jyvaskyla, K. HAUSCHILD, A. LOPEZ-MARTENS, CNSTM-Osray, P.M. WALKER, U. Surrey — High-K yrst isomers are classic representations of the competition between independent particle and collective degrees of freedom in generating high angular momentum in a well-deformed nucleus. In $^{176}$Hf, 2-, 4- and 6-quasiparticle (qp) isomers were reported in early studies of high-K isomerism. The 6-qp $K^\pi = 22^-$ yrst isomer ($I_{yrs} = 43\mu$s, $E_x = 4864$ keV), in addition to its primary decay, exhibits a small and anomalously fast decay branch [1]. A predicted 8-qp yrst trap at $K=28$ has remained elusive, primarily due to the lack of suitable beam-target combinations to bring in high angular momentum. A recoil-decay-tagging experiment using the $^{48}$Ca($^{44}$Ca,2$n$) reaction was performed at JYFL to search for transitions feeding the 6-qp isomer, using the large angular acceptance of the JYFL Gammasphere gamma-ray detector. The most likely 176Hf implants and isomer decay is documented by the Gammasphere, with decay transitions detected in the focal plane. Results from the analysis will be presented and discussed. *Supported in part by the U.S.D.O. Grants DE-FG02-94ER40848 (UML) and DE-AC02-06CH11357 (ANL). 1. G. Mukherjee et al., Phys. Rev. C. 82, 054316 (2010).

11:42AM LN.00007 Coexistence in Neutron Deficient Mercury Isotopes , ANDREW MACLEAN, University of Guelph, GRIFFIN COLLABORATION — Neutron deficient nuclei near $Z=82$ exhibit one of the most extensive manifestations of shape coexistence across the nuclear chart. In the even-even mercury isotopes, $^{182-198}$Hg, Coulomb excitation experiments have provided a sensitive probe to determine the E2 matrix elements, giving information on the nature of the deformation. For transitions of $J^P \rightarrow J^P$ with $J \neq 0$, the determination of B(E2) values also depend on the E0 matrix element. One of the best methods to extract the mixing ratios is through $\gamma - \gamma$ angular correlation measurements following E/C$^4$/3 decay where a very high sensitivity can be achieved. The GRIFFIN spectrometer, located at TRIUMF-ISAC is ideal for such measurements and has been used with the decay of $^{188-200}$TI. Also included was measurement was the PACES array, used for the detection of conversion electrons to determine E0 transition strengths. The extraction of E0 components of mixed transitions are of utmost importance as they may be enhanced if there are significant mixings between the coexisting configurations. By combining measurements of mixing ratios, conversion electron intensities and lifetimes a direct measurement of the mixing by the shape coexisting structures will be presented.

1Work supported by the Canada Foundation for Innovation, the Natural Sciences and Engineering Research Council of Canada and the National Research Council of Canada.

11:54AM LN.00008 Insight into $\alpha$ clustering of proton-rich nuclei via their $\alpha$ decay , YIBIN QIAN, Nanjing University of Science and Technology — We focus on the $\alpha$ clustering phenomenon of proton-rich nuclei in terms of the preformation probability of $\alpha$ cluster before its penetration. Through the experimental $\alpha$ decay data, the $\alpha$ preformation factor $P_\alpha$ is extracted for a large range of nuclei in the neutron-deficient region. It is found that the present $\alpha$ preformation factor varies more smoothly towards the large neutron-proton ratio, as compared to those from the previous evaluations. This may come from the separate consideration of proton and neutron density distributions of related nuclei, while they are treated as the same form before. The similarity between the $P_\alpha$ value and the pairing gap is clearly demonstrated, indicating the crucial role of pairing correlation involved in the $\alpha$ decay process. As a further step, the correlation between the $\alpha$ preformation factor and the microscopic correction of nuclear mass, corresponding to the effect of shell and pairing plus deformation, is in particular investigated to pursue the valuable knowledge of $P_\alpha$ pattern over the nuclide chart. Owing to this, the systematical results on lifetimes of $\alpha$ emitters are obviously improved within the transfer matrix method.

1National Natural Science Foundation of China grant 11605089 and Natural Science Foundation of Jiangsu Province grant BK20150762

12:06PM LN.00009 Nuclear Excitation via Electron Capture with TITAN , JON RINGUETTE, KYLE LEACH, Colorado School of Mines, IRIS DILLMANN, ANIA KWIATKOWSKI, Triumf, ZACHARY HOCKENBERY, THOMAS BRUNNER, McGill University, CORINA ANDREOIU, Simon Fraser University, TITAN COLLABORATION — Nuclear Excitation via Electron Capture (NEEC) is the inverse process of internal electron conversion, where a free electron is captured into an atomic vacancy simultaneously exciting the nucleus to a higher-energy state. This process occurs naturally in hot astrophysical environments, and can excite nuclei in these isomeric states to shorter-lived states that would decay at a much faster rate than under terrestrial conditions, thus affecting reaction flows or survival rate of nuclei. Since NEEC is a resonant process, experimental access in the lab to study these cases requires strong atomic charge state control over the sample, as well as nuclear state selection and preparation of the nuclear states that may be compatible with efficient electron recombination. Using an open-aperture electron beam ion trap (EBIT) in the TITAN experiment at the TRIUMF facility we are able to perform these studies with a high level of control and sensitivity. In this talk I will discuss the experimental concept, cases that we plan on studying in the near future, as well as current and ongoing upgrades being made to the TITAN system.

1This work is supported by the US Department of Energy, Office of Science under grant DE-SC0017649.
12:18PM LN.000010 Overlaps of Deformed and Non-Deformed Basis States for Large-scale Shell-model Calculations, DAVID KEKEJIAN, JERRY DRAAYER, THOMAS DYTRYCH, KRISTINA LAUNEY, Louisiana State University — We provide a systematic approach for expanding non-deformed harmonic oscillator basis states in terms of deformed ones, namely we present analytical results for calculating these overlaps, transformation brackets between deformed and non-deformed basis states in cylindrical, spherical and Cartesian coordinates. The overarching objective is to integrate these results into shell-model codes to reduce the dimensionality of model spaces. This, in turn, will allow one to probe more deeply into the structure of nuclei and to provide ab initio or microscopic descriptions of medium-mass and heavy nuclei, short cutting a need to await the development of evermore robust computational resources for carrying out advanced microscopic nuclear structure calculations.

This work is supported by the NSF (OIA-1738287, ACI-1713690) and SURA, the Czech Science Foundation(16-16772S) and benefitted by access to computing resources provided by LSU.

Wednesday, October 16, 2019 2:00PM - 4:00PM –
Session MB Mini-Symposium: Particle Emission and Exotic Nuclei
Salon 2 - Andrew Rogers, University of Massachusetts, Lowell

2:00PM MA.00001 DNP Mentoring Award Talk: A Collective Solution to an Individual Particle Problem, SAMUEL TABOR, FSU — As the exciting opportunities FRIB offers to better understand nuclear structure further from stability approach, it becomes more important to strengthen the foundations of our current understanding at higher spin and neutron excess. One of these foundations has been the configuration-interaction models of sd-shell nuclei based on effective interactions (USD, USDA, USDB) fitted to a wide range of nuclear states. Perhaps one of its greatest successes has been the failure to describe the binding energies of low Z - high N nuclei like 31Na. This island of inversion has been investigated with precursors to FRIB and is generally understood as involving excitations into the fp-shell which are not included in the USD family of interactions. The higher spins accessible with heavy-ion reactions and the large high-resolution gamma detector arrays both call for a more comprehensive theoretical treatment of cross-shell excitations and provide the data to tackle it. An experimental-theoretical collaboration of FSU researchers from graduate students to professors has determined such a more comprehensive cross-shell effective interaction based on nuclei from 13C to 51Ti. Examples of comparisons with experimental energy levels, spectroscopic factors, lifetimes, shell migration, isobaric analog states, and island of inversion effects will be presented.

2:36PM MA.00002 Stuart Jay Freedman Award Talk: From Electrons to Neutrinos: Nuclear Effects in Oscillation Measurements, OR HEN, MIT — Precision accelerator-based neutrino oscillation measurements relay on precise and accurate modeling of the interaction of neutrinos with atomic nuclei. At the moment, our insufficient understanding of such interactions is a dominant systematic in extraction of neutrino oscillation parameters and can stand as a significant challenge for achieving the goals of next-generation neutrino oscillation experiments such as DUNE and T2-HyperK. Following the spirit of Stuart Freedman's own research, this talk will focus on the synergy between nuclear and particle physics in searching for a deeper understanding of our universe. Specifically, I will present new results from novel experimental constraints on neutrino-nucleus interactions, from synergic measurements of wide phase-space neutrino and electron exclusive scattering reactions using the MicroBooNe (Fermilab) and CLAS (JLab) detectors. I will also show how such data allow addressing outstanding issues in neutrino physics such as the accuracy of incident neutrino energy reconstruction for oscillation analyses, and constraints on searches for physics beyond the standard model.

3:12PM MA.00003 Dissertation Award in Nuclear Physics Talk: The Hunt for Astrophysical Neutrinos, SHIRLEY LI, SLAC — Astrophysical neutrinos are excellent probes of neutrino properties, the solar core, and high-energy cosmic accelerators. But their detection suffers from high backgrounds and from uncertainties in how we reconstruct and interpret events. For example, solar neutrino signals in Super-Kamiokande are overwhelmed by beta-decay backgrounds initiated by cosmic-ray muons. Meanwhile, the detection of high-energy astrophysical neutrinos in IceCube opened new ground for studying cosmic accelerators, but IceCube cannot effectively distinguish ντ from νe, as both generate similar-looking events. Using understanding of the common shower physics underlying both problems, I will show new methods to reject spallation backgrounds in Super-Kamiokande, applicable to their solar neutrino analysis, and to improve the measurement of flavors of astrophysical neutrinos in IceCube.

3:36PM MA.00004 Dissertation Award in Nuclear Physics Talk: Global polarization of Lambda hyperons in Au+Au Collisions at RHIC, ISAAC UPSAL, Brookhaven National Lab and Shandong University — Non-central heavy-ion collisions have large (~ 10^7 h) angular momentum which may be transferred, in part, to the quark-gluon plasma (QGP) through shear forces that generate a vortical substructure in the hydrodynamic flow field. The vortical nature of the system can polarize emitted hadrons along the direction of system angular momentum. Λ and Λ̅ hyperons, which reveal their polarization through decay topology, should be polarized similarly. These same collisions are also characterized by dynamic magnetic fields with magnitude as large as 10^14 Tesla. A splitting between Λ and Λ̅ polarization may signal a magnetic coupling and provide a quantitative estimate of the field strength at freeze out. Details of the magnetic field and its evolution are of particular interest to other novel phenomena in heavy-ion collision physics. The STAR Collaboration made the first non-trivial observation of global hyperon polarization in non-central Au+Au collisions in the RHIC Beam Energy Scan. A magnetic splitting is hinted at, but the improved statistics and resolution achievable with future runs are required to make a definitive measurement of the magnetic field. Using a simple magneto-hydro equilibrium framework for interpreting the data allows for the direct extraction of the physical parameters relevant to this measurement, the vorticity and magnetic field. The extracted vorticity in this system is found to be considerably larger than any previously measured value, lending a new superlative to the QGP: “the most vortical fluid.”
Recent discoveries on particle emitting nuclei\(^1\) , KALLE AURANEN, Brookhaven National Laboratory — In this presentation I will provide a brief introduction to the concepts of particle emission from exotic nuclei. Measuring the energies of the emitted particles, ideally correlated to residue implantation event or subsequent decay events, provides a clean and precise probe to study the underlying nuclear structure and masses of the initial and final nuclei. Such correlations can also be used in experiments with very limited statistics, making it suitable for the identification of new elements and new isotopes. Particle emission studies are important in understanding of the structure of atomic nuclei, but they also serve an experimental probe to study the astrophysical processes, such as the r- and rp processes, occurring far away from the valley of β-stability. I will introduce these topics by summarizing a few of the recent highlights on particle emitting nuclei including, but not limited to, the discovery of “superallowed” α-decay chain \(^{108}\text{Xe}\rightarrow^{104}\text{Te}\rightarrow^{100}\text{Sn}\) [1], and a very weak proton emission branch in \(^{108}\text{I}\) [2]. The former is an important benchmark for the models of α decay, whereas the latter observation allowed us to study the termination of the astrophysical rp process.

1 We acknowledge support from the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under Contract No. DE-AC02-06CH11357 (ANL). This research used resources of ANL’s ATLAS facility, which is a DOE Office of Science User Facility.

Particle Decay of the 6.15 MeV Level in \(^{18}\text{Ne}\)\(^1\), K.A. CHIPPS, S.D. PAIN, Oak Ridge National Laboratory, P. THOMPSON, University of Tennessee Knoxville/Oak Ridge National Laboratory, R.L. KOZUB, Tennessee Technological University, JENSA COLLABORATION — The \(^{15}\text{O}(p,\alpha)^{14}\text{F}\) reaction rate is important as a trigger reaction in x-ray bursts and has significant impact on the burst light curve and final abundances. In addition, the reaction provides a pathway to alter the ratio of \(^{14}\text{O}\) to \(^{15}\text{O}\) in the accreted material over time. A \(7\)^\(r\) resonance in \(^{18}\text{Ne}\) above the \(^{14}\text{O}+\alpha\) threshold is expected to dominate the reaction rate at temperatures relevant to Type I x-ray bursts, but the particle decay widths for this level are not well known. The relative strengths of the proton decay branches to the ground and first excited state of \(^{17}\text{F}\), which are critical to calculation of the reaction rate from the time-inverse reaction \(^{17}\text{F}(p,\alpha)^{14}\text{O}\), are not fully constrained. Potentially competing alpha and even 2p decays may also be important. To address these discrepancies, \(^{20}\text{Ne}(p,\alpha)^{18}\text{Ne}\) data from the JENSA gas jet target system were examined, utilizing a new technique to observe particle decays of the excited levels in \(^{18}\text{Ne}\). The technique and preliminary results will be presented, along with plans for a future jet target system for reaccelerated beams from FRIB.

1 This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics under contract number DE-AC05-00OR22725 (ORNL) and DE-FG02-96ER40955 (TTU). Research sponsored by the Laboratory Directed Research and Development Program of Oak Ridge National Laboratory, managed by UT-Battelle, LLC, for the U.S. Department of Energy.

Proton Emission from \(^{31}\text{S}\) and the Astrophysical \(^{30}\text{P}(p,\gamma)^{31}\text{S}\) Reaction\(^1\), SEAN BURCHER, K.L. JONES, J. HOOKER, University of Tennessee, J.M. ALLMOND, K.A. CHIPPS, S.D. PAIN, Oak Ridge National Laboratory, J. BURKE, R.O. HUGHES, Lawerence Livermore National Laboratory, S. AHN, H. CLARK, H. JAYATISSA, S. OTA, A. SAASTAMOINEN, S. UPADHYAYULA, Texas A&M University, N. COOPER, C. REINGOLD, A. SIMON, Notre Dame University, J.A. CIZEWSKI, Rutgers University, K. SCHMIDT, National Superconducting Cyclotron Laboratory — The \(^{30}\text{P}(p,\gamma)^{31}\text{S}\) reaction rate has been identified as the largest remaining source of uncertainty in the abundances of intermediate-mass nuclei produced in classical nova explosions involving oxygen-neon white dwarfs, and is critical to interpreting the origin of certain meteoritic presolar grains. To inform the astrophysical proton capture rate, the \(^{32}\text{S}(p,d)^{31}\text{S}\) reaction has been used to populate proton unbound states in \(^{31}\text{S}\). The Hyperion array was used to measure the reaction deuterons in coincidence with decay protons and rays. Angular correlations between the reaction products and decay protons have been measured and used to constrain the angular momentum of states in \(^{31}\text{S}\) above the proton threshold. In addition, proton-decay branching ratios have been measured for these states and used to inform resonance strengths.

1 U.S. DOE under DE-FG02-96ER40983 (UTK), DEAC05-00OR22725 (ORNL), DE-NA-0003780 (Notre Dame), DE-AC52-07NA27344 (LLNL), and DE-FG03-93ER40773 (TAMU), The Welch Foundation, The NSF under PHY-1430152 (JINA-CEE). Laboratory Directed Research and Development Program of ORNL
3:12PM MB.00005 Measurement of near-threshold states in 12C using beta-delayed charged particle decay, JACK BISHOP, School of Physics & Astronomy, Texas AM University, TX, 77840, GRIGORY ROGACHEV, SUNGHOUN AHN, EVGENY KOCHISCHY, ERIC ABOUD, MARINA BARBUI, ALEXANDRA BOSH, CURTIS HUNT, JOSHUA HOOKER, HESHANI JAYATISSA, RORY O'DWYER, Cyclotron Institute, Texas AM University, TX, 77840, EMMANUELLE POLLACO, IRFU, CEA, Saclay, Gif-Sur-Ivette, France, COLE PRUITT, Department of Chemistry, Washington University, St. Louis, Missouri, BRIAN ROEDER, ANOTTI SAASTAMOINEN, Cyclotron Institute, Texas AM University, TX, 77840, LEE SOBOTKA, Department of Chemistry, Washington University, St. Louis, Missouri, SRITEJA UPADHYAYULA, Cyclotron Institute, Texas AM University, TX, 77840 — The TexAT detector, an active target Time Projection Chamber (TPC), has recently been upgraded at the Cyclotron Institute at Texas AM University. By utilizing the advantage of a TPC (4π geometrical coverage), radioactive ion beams implanted into the chamber can be readily studied for rare processes. Of particular interest, to demonstrate the sensitivity of such a technique to probing 3-body correlations, is the decay mechanism of the $^{12}$F state in $^{12}$C, known as the Hoyle state. Using TexAT, this state is populated using $\beta^+$-decay of $^{12}$N and the $\beta$-delayed charged particles are measured and stopped inside the TPC. This talk will detail the latest results of this experiment and demonstrate the versatility of this technique.

3:24PM MB.00006 Properties of Proton-Emitting $^{72,73}$Rb Isotopes, D.E.M. HOFF, UMass Lowell (UML), A.M. ROGERS, UML, S.M. WANG, National Superconducting Cyclotron Laboratory (NSCL), P.C. BENDER, UML, K. BRANDBENBURG, Ohio University (OU), K. CHILDERS, NSCL, J. CLARK, Argonne National Laboratory, A.C. DOMBOS, NSCL, E.R. DOUCET, UML, S. JIN, R. LEWIS, S.N. LIDDICK, NSCL, C.J. LISTER, UML, Z. MEISEL, OU, C.M. MORSE, UML, W. NAZAREWICZ, H. SCHATZ, K. SCHMIDT, NSCL, D. SOLTESZ, S.K. SUBEDI, OU, S. WANIGANETHTHI, UML — Properties of proton-emitting nuclei at the limits of nuclear binding, along the proton drip line, impact the rapid proton-capture ($\gamma p$) process and can reveal interesting nuclear structure. $\beta$-delayed protons emitted from $^{73}$Sr, produced by the fragmentation of $^{92}$Mo primary beam on a Be target, were measured via ion implantation-decay correlations at the NSCL using the Beta-Counting Station (BCS), providing a direct measurement of the $^{73}$Sr lifetime. Low-energy protons were observed that are consistent with transitions from $^{72}$Rb(g.s.) to $^{72}$Kr(g.s.), and the resulting proton separation energy of $^{72}$Rb was determined by a Bayesian analysis of the data. A substantial amount of $^{72}$Rb was also observed allowing for a limit to be placed on the fragmentation cross section.

1 We acknowledge support from the U.S. DOE, Office of Science, Office of Nuclear Physics under Award No. DE-FG02-94ER40848 (UML) and DE-AC02-06CH11357 (ANL); the NNSA through the Nuclear Science and Security Consortium under Award Number(s) DE-NA0003180, DE-NA0003221, and/or DE-NA0000979; and the NSF under Contract No. PHY-1102511.

3:36PM MB.00007 $\beta$-Delayed Proton Emission of $^{71}$Kr, S. WANIGANETHTHI, UMass Lowell (UML), D.E.M. HOFF, A.M. ROGERS, P.C. BENDER, UML, K. BRANDBENBURG, Ohio University (OU), K. CHILDERS, National Superconducting Cyclotron Laboratory (NSCL), J.A. CLARK, Argonne National Laboratory, A.C. DOMBOS, NSCL, E.R. DOUCET, UML, S. JIN, R. LEWIS, S.N. LIDDICK, NSCL, C.J. LISTER, UML, Z. MEISEL, OU, C.M. MORSE, UML, H. SCHATZ, K. SCHMIDT, NSCL, D. SOLTESZ, S.K. SUBEDI, OU — Mirror nuclei above $Z=31$ states of this mirror system were investigated in an implant-decay experiment conducted at the NSCL using a beam containing $^{71}$Kr, produced by fragmentation of a $^{92}$Mo primary beam on a Be target, and purified with the RF Fragment Separator, that was implanted into the Beta Counting Station surrounded by SeGa. $\beta$-decay branching to the lowest states of $^{71}$Kr was observed as well as delayed-proton emission feeding the lowest states of $^{70}$Se. The results obtained from charged particle and $\gamma$-ray spectroscopy as well as implications for the structure of nuclei with $N\sim Z$ will be presented.

1 This material is based upon work supported by the U.S. DOE, Office of Science, Office of Nuclear Physics under Award No. DE-FG02-94ER40848, DE-FG02-88ER40387 and DE-AC02-06CH11357; the NNSA through the Nuclear Science and Security Consortium under Award No. DE-NA0003180, DE-NA0003221, and/or DE-NA0000979; and the NSF under Contract No. PHY-1102511.

3:48PM MB.00008 Beta-Delayed Neutron Spectroscopy of Deformed Rubidium Isotopes with VANDLE, THOMAS KING, University of Tennessee, ROBERT GRZYWACZ, KRZYSZTOF RYKACZEWSKI, DAN STRACENER, ORNL, ALEXANDRA FIJAKOWSKA, Rutgers University, VANDLE COLLABORATION — Beta-delayed neutron emission becomes an important or even the dominant decay mode for many neutron-rich isotopes. The neutron emission after beta decay is often followed by, or competes with, the gamma-ray transformation. Therefore, the detection system needs to be optimized for simultaneous measurements of neutrons and gammas. A measurement of the complete decay pattern provides information necessary to extract the beta-strength distribution, which is sensitive to the nuclear structure of the involved nuclei. A series of measurements was performed at the On-Line Test Facility at Oak Ridge National Laboratory with the Versatile Array of Neutron Detectors at Low Energy (VANDLE). These experiments revisited decays of nuclei produced in proton induced fission of 238U. Unique data sets with neutron and gamma ray coincidences were collected. Achieving high coincidence efficiency required the addition of high-efficiency gamma-ray detectors consisting of LaBr3 (HARGiD) and NaI to VANDLE. Preliminary results on the decay of $^{97}$Rb will be presented.

1 This research was sponsored in part by the National Nuclear Security Administration under the Stewardship Science Academic Alliances program through DOE Cooperative Agreement No. DE-FG52-08NA28552, and the Office of Nuclear Physics, U. S. Department of Energy under contracts DE-AC05-00OR22725 and DE-FG02-96ER40983.
2:00PM ME.00001 Gluon Field Digitization for Quantum Computers. HENRY LAMM IV, University of Maryland, NUQS COLLABORATION — Simulations of QCD on quantum computers in the NISQ-era require the digitization of gluon field variables that uses the minimum amount of qubits. We present a scheme for digitizing $SU(3)$ gauge theories via its discrete subgroup $S(1080)$ with a modified action that allows simulations in the scaling regime down to lattice spacings of order $a \approx 0.08$ fm. With a classical Monte Carlo, we compute a set of observables with sub-percent precision at multiple lattice spacings and show that the continuum extrapolated value agrees with the full $SU(3)$ results.

1This work was supported in by National Science Foundation CAREER grant PHY-1151648, and by U.S. Department of Energy under Contract No. DE-FG02-95ER-40097 and No. DE-FG02-93ER-40762.

2:12PM ME.00002 Towards analog quantum simulations of lattice gauge theories with trapped ions, ZOHREH DAVOUDI, MOHAMMAD HAFEZI, CHRISTOPHER MONROE, GUIDO PAGANO, ALIREZA SEIF, ANDREW SHAW, University of Maryland, College Park — Gauge field theories play a central role in nuclear physics and are at the heart of the Standard Model of elementary particles and interactions. Despite significant progress in applying classical computational techniques to simulate gauge theories, it has remained a challenging task to compute the real-time dynamic of systems described by these theories, such as the evolution of matter under extreme conditions after heavy ion collisions. An exciting possibility that has been explored in recent years is the use of highly-controlled quantum systems to simulate, in an analog fashion, properties of a target system whose dynamics is difficult to compute. Engineered atom-laser interactions in a linear crystal of trapped ions offer a wide range of possibilities for quantum simulations of complex physical systems. Here, we present practical proposals for analog simulation of lattice gauge theories whose dynamics can be mapped into spin-spin interactions in any dimension. Future possibilities to extend such a mapping to a larger class of gauge field theories include devising higher-order spin interactions and taking advantage of the control over phononic excitations.

2:24PM ME.00003 Extending the Reach of Real-Time Lattice Gauge Theory Evolution on Near-Term Quantum Devices1, ANDREW SHAW, ZOHREH DAVOUDI, University of Maryland, College Park — Certain computational problems in physics are estimated to require more classical computing resources than next-generation Exascale hardware will provide. A notable example is the calculation of real-time dynamics, as the time-complexity of classical evolution algorithms scales super-polynomially with the system size. Quantum computing algorithms may offer a relative speedup, and present an exciting alternative to study the evolution of lattice gauge theories. However, calculations on near-term quantum devices are limited by noise accumulation, setting a limit on the range of real-time dynamics that can be accessed. We present a new hybrid algorithm called segmented trotterization that extends the range of evolution through the use of quantum tomography (QT), which enables one to determine an unknown quantum state. In this algorithm, a quantum state is extracted with QT before the characteristic time-scale of the noise, so the state can be determined with only perturbative corruption due to decoherence. Subsequently reinitializing the state on fresh qubits allows one to continue the evolution. We demonstrate on the publicly available IBMQ-14 device that the evolution of the two-site Schwinger model can be extended by a factor of $\sim O(10)$.

1U.S. Department of Energy Office of Advanced Scientific Computing Research (ZD, AS); NSF Bridge to the Doctorate Fellowship (AS)

2:36PM ME.00004 Towards Quantum Simulating Non-Abelian Lattice Gauge Theory, INDRAKSHI RAYCHOWDHURY, University of Maryland, College Park — In this talk, we discuss a complete and efficient formulation for SU(2) lattice gauge theory with fundamental matter and establish this to be a practical framework for digital as well as analog quantum simulation. Key features of this framework include a gauge-invariant and readily-digitized basis, together with a representation of the Hamiltonian in terms of simple ladder operators. We show that within this formulation, the physical sector of the non-Abelian lattice gauge theories are made equivalent to Abelian theories. Utilizing this feature, we can directly generalize the simulation techniques, already present for Schwinger model towards constructing proposals for simulating non-Abelian lattice gauge theories.

2:48PM ME.00005 Matrix elements of bound states in a finite volume, ANDREW JACKURA, Old Dominion University, RAL BRICEO, Old Dominion University & Jefferson Lab, MAXWELL HANSEN, CERN — Recently, a framework was developed for studying form factors of two-body states probed with an external current. Finite volume matrix elements that may be computed via lattice QCD are converted to infinite volume generalized form factors. These generalized form factors allow us to study the structure of composite states. In this talk, we consider the application of this formalism to bound states, and compare the leading finite volume effects to the general results of the framework. Specifically, we pay close attention to the implication of this formalism for the extraction of the form factors of the deuteron.

3:00PM ME.00006 Taming Excited-state Contributions to Matrix Elements of Boosted Hadrons, COLIN EGERER, JOE KARPIE, William and Mary, RAZA SUFIAN, DAVID RICHARDS, KOSTAS ORGINOS, JIANWEI QIU, ROBERT EDWARDS, BALINT JOO, FRANK WINTER, Thomas Jefferson National Accelerator Facility, TANJIB KHAN, William and Mary — Lattice field calculations provide an ab initio method to non-perturbatively study strongly-coupled theories, such as Quantum Chromodynamics (QCD), with controllable systematic errors. However due to the strong coupling characteristic of low-energy QCD, any operator used to interpolate a hadronic state from the vacuum is a best-guess and necessarily couples to all single and multi-particle states in the same symmetry channel. Spatial smearing and variational methods to improve operator-state overlaps are two well-established methods that facilitate the study of ground-state hadronic properties in lattice QCD. Overcoming excited-state contamination and a degrading signal-to-noise ratio becomes a formidable task as a hadron’s momentum is increased. In this presentation we discuss a modification of distillation, an efficient type of smearing, which when combined with the variational method leads to a particularly powerful prescription that not only separates ground- and excited-states to high precision, but continues to do so for large lattice momenta. This development is of particular importance to the many lattice efforts seeking to determine parton distributions, form factors (FFs) and transition FFs, for which high momenta is an essential ingredient.

3:12PM ME.00007 Pion-pion Scattering with Elongated Boxes, CHRISTOPHER CULVER JR, ANDREI ALEXANDRUD, MAXIM MAI, FRANK LEE, MICHAEL DORING, George Washington University — Pion-pion scattering offers an important benchmark for a lattice QCD study of hadron-hadron interactions. Scattering can happen in one of three isospin channels, each having distinct properties. The attractive $I = 0$ and $I = 1$ channels are dominated by the broad $\sigma$ and narrow $\rho$ resonances, respectively, while the $I = 2$ channel has no low energy resonance. Our group has calculated the $\sigma$ and $\rho$ resonance properties using elongated boxes to scan the relevant kinematic region at two pion masses. Here we present new results for the isospin-2 channel, thus completing the full study of $\pi \pi$ scattering. In addition, we establish a link to the physical point of all three channels simultaneously using the Inverse Amplitude Method.
**Wednesday, October 16, 2019 2:00PM - 4:00PM — Session MG Mini-Symposium: Nuclear Physics and the r-Process in the Multi-messenger Era II**  
Salon A - Artemis Spyrou, MSU

**2:00PM MG.00001 Measuring $^{84}$Se(d,p) at 45 MeV/A to reduce uncertainties in spectroscopic factors of states in $^{85}$Se**  
HARRISON SIMS, JOLIE CIZEWSKI, ALEXANDRE LEPAILLEUR, DAVID WALTER, Rutgers University, SUNGHOON AHN, TAMU, STEVEN PAIN, ORNL, ANDREW RATKIEWICZ, LLNL, ORRUBA - S800 COLLABORATION — Neutron-transfer reactions with radioactive ion beams (RIBs) probe the single-neutron components of the wave function of nuclei. This is crucial to our understanding of the direct component of neutron capture. With (d,p) reactions, spectroscopic factors can be extracted through a normalization of the differential cross section calculated using ADWA theory to that observed through experiment. They are, therefore, heavily dependent on the parameters chosen to model the final bound state nucleus. A combined method using high and low energy RIBs allows for both a peripheral and more central probe of the nucleus, thereby constraining the bound state parameters and reducing the uncertainties on the extracted spectroscopic factors. Using this method for the first time with heavy, neutron rich RIBs, the spectroscopic factors of low lying states in $^{85}$Se are being studied through $^{84}$Se(d,p). With the low-energy measurement at 4.5 MeV/A already completed [1], the high-energy measurement at 45 MeV/A was performed at the NSCL. ORRUBA and SIDAR were used to detect reaction protons in coincidence with heavy ion recoils using the S800 spectrograph. Preliminary results, including spectroscopic factors will be presented. [1] J.S. Thomas et al., Phys. Rev. C 76, 044302 (2007)

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**2:12PM MG.00002 ABSTRACT WITHDRAWN —**

**2:24PM MG.00003 Developments and prospects for GODDESS at FRIB**  
STEVEN PAIN, KELLY CHIPPS, MICHAEL FEBBRARO, ROBERT VARNER, Oak Ridge National Laboratory, ANDREW RATKIEWICZ, Lawrence Livermore National Laboratory, JOLIE CIZEWSKI, GWENAILLE SEYMOUR, HARRISON SIMS, CHAD UMMEL, Rutgers University, RAJESH GHIMIRE, KATE JONES, University of Tennessee, GODDESS COLLABORATION, ORRUBA COLLABORATION — GODDESS is a coupling of an upgraded version of the highly-segmented silicon detector array ORRUBA (Oak Ridge Rutgers University Barrel Array) to the large HPGe detector arrays currently in operation the US. The commissioning campaign in 2015 employed Gammasphere for a series of stable-beam experiments; in early 2019, the system has been deployed with GRETINA for a campaign of measurements using stable, re-accelerated and in-flight radioactive beams at ATLAS at ANL for understanding nova and r-process nucleosynthesis. For this campaign, the instrumentation for GODDESS has been upgraded, along with a set of new beam detectors. These provide event-by-event particle identification and tracking of beam-like particles, critical for both the analysis of the experiments as well as real-time diagnostics for tuning radioactive beams. In parallel to these developments, ORRUBA has recently been coupled to the S800 at the NSCL for fast beam experiments with r-process nuclei. A brief summary of the upgrades, and prospects for deployment with Greta for experiments at FRIB will be presented.

This work is supported by the U.S. Dept. of Energy, Office of Science, Office of Nuclear Physics, the NNSA SSAA Program, and the National Science Foundation.

**2:36PM MG.00004 Level structure of $^{96}$Mo from the $(d,p\gamma)$ measurement with $^{95}$Mo beams and GODDESS**  
H. GARLAND, A. LEPAILLEUR, J.A. CIZEWSKI, H. SIMS, G. SEYMOUR, C.C. UMMEL, Rutgers, S.D. PAIN, ORNL, A. RATKIEWICZ, LLNL, GODDESS COLLABORATION — When used in conjunction with radioactive ion beams in inverse kinematics, the surrogate reactions method (SRM) can inform neutron capture cross sections on isotopes of interest to the r process. The use of SRM requires a modern nuclear reaction model of the (d,p) reaction that includes deuteron break-up and a level scheme that is as detailed as possible. Recently, the (d,p) reaction was confirmed as a surrogate for (n,\gamma) reactions in normal kinematics using a $^{96}$Mo target. To extend the benchmarking of the surrogate reactions method to inverse kinematics, a (d, p\gamma) measurement with $^{95}$Mo beams was performed using GODDESS (Gammasphere ORRUBA: Dual Detectors for Experimental Structure Studies) at ATLAS. This GODDESS experiment is the first (d, p\gamma) measurement on $^{95}$Mo to populate two-neutron configurations of states below 4 MeV. This (d, p\gamma) study is an important step in refining the reaction theory and current level analysis. Preliminary results detailing the differential cross sections of low-lying states in $^{96}$Mo and extension of the $^{96}$Mo level scheme will be presented. [1] A. Ratkiewicz et al, Phys. Rev. Let., 122 052502 (2019)

This work is supported in part by the U.S. Department of Energy and the National Science Foundation.

**2:48PM MG.00005 Measuring the $^{134}$Te(d,p\gamma)$^{135}$Te Reaction with GODDESS to Deduce the Single-Particle Structure of $^{135}$Te and Inform Neutron Capture**  
C.C. UMMEL, J.A. CIZEWSKI, Rutgers University, S.D. PAIN, Oak Ridge National Laboratory, A. RATKIEWICZ, Lawrence Livermore National Laboratory, GODDESS COLLABORATION, ORRUBA COLLABORATION, GRE Tina COLLABORATION — $^{134}$Te (t_{1/2} = 42 minutes), a beta-decay precursor to stable $^{134}$Xe, can be destroyed in an r-process environment by neutron capture. Constraint of the $^{134}$Te(n,\gamma)$^{135}$Te cross section is key to explaining an overabundance of $^{134}$Xe observed in pre-solar grain[4]. Due to its proximity to the Z = 50 and N = 82 closed shells, neutron capture on $^{134}$Te is expected to largely occur via direct capture into low-lying states in $^{135}$Te (Z = 52, N = 83), which can be constrained via the measurement of level energies, spin-parities, and spectroscopic factors using neutron transfer reactions such as (d,p). Previous studies of $^{135}$Te revealed a fragmented level structure that cannot be resolved by charged particles alone[5]. However, level energies can be constrained via the detection of gamma rays emitted by $^{135}$Te in coincidence with charged ejectiles. The $^{134}$Te(d,p)$^{135}$Te reaction was thus measured with the coupled GODDESS (GRETINA-ORRUBA: Dual Detectors for Experimental Structure Studies) detectors at the ATLAS facility at Argonne National Laboratory. Preliminary results will be presented.

This work was supported by the U.S. Department of Energy and the National Science Foundation.

3:00PM MG.00006 Cross-section measurement of the $^{85}\text{Br}(\alpha,xn)$ and its implication in the weak r-process.\textsuperscript{1} NABIN RIJAL, Michigan State Univ, HABANERO COLLABORATION — The fast-expanding neutron rich neutrino-driven winds in the core-collapse supernovae is one of the most favorable scenario for the nucleosynthesis of the Z = 38-47 elements. Charge particle reactions, especially ($\alpha,xn$) on heavy nuclei of the range $40 < A < 90$) create seeds for the weak r-process populating abundances of near stable isotopes for the Sr-Cd range. These abundances are significantly sensitive to the ($\alpha,n$) and ($\alpha,2n$)reaction rates. Only very few of these ($\alpha,xn$) reactions had been measured in the energy range relevant for weak r-process astrophysical conditions. Sensitivity studies of such scenario show that $^{85}\text{Br}(\alpha,xn)$ is one of the most significant reaction to impact the abundances of the seeds to the weak r-process. To measure the cross-section of $^{85}\text{Br}(\alpha,n)$ and ($\alpha,2n$), the HABANERO detector is used, which is a neutron counter system that includes either BF$_3$ or He gas-filled proportional counter tubes embedded in the matrix of polyethylene, designed to achieve somewhat constant and energy independent efficiency for neutrons up to 20 MeV. Preliminary results from the RIB experiment $^{85}\text{Br}(\alpha,xn)$ along with brief details of the experimental setup will be presented.

\textsuperscript{1}This material is based upon work supported by the National Science Foundation under Grant No. PHY-1430152 (JINA-CEE)

3:12PM MG.00007 Properties of neutron-rich $^{71,72,73}\text{Ni}$ , S.N. LIDDICK, R. LEWIS, A. SPYROU, S. LYONS, K.L. CHILDERS, A.C. DOMBOS, C. HARRIS, A. PALMISANO, D. RICHMAN, M SMITH, NSCL / MSU, D.L. BLEUEL, N.D. SCIELZO, LLNL, B.P. CRIDER, M. LARSEN, S. GEORGE, MPIK, Z. MEISEL, OU — The r-process plays a significant role in nucleosynthesis of elements. The recent LIGO and Virgo gravitational-wave detection from two colliding neutron stars combined with the wealth of electromagnetic follow-ups of these events created a unique situation to understand the r-process event. To constrain the scenario, the production of heavy nuclei in a r-process. Despite knowing at least one location for the r-process, many open questions remain. The uncertainties in the nuclear physics inputs present a large barrier to accurately model the abundance distributions in large-scale nucleosynthesis calculations. In particular, neutron-capture rates are the most uncertain theoretical input and the most difficult to constrain directly. The $\beta$-Oslo method is one indirect approach for constraining the neutron-capture cross section. The $\beta$-delayed neutron emission is used to populate the high-energy states in a daughter nucleus and the subsequent photon decay is used to determine the nuclear level density (NLD) and $\gamma$-ray strength function ($\gamma$SF). NLD and $\gamma$SF are then input into a Hauser-Feshbach model to constrain the neutron capture cross section. A series of experiments have been performed at the National Superconducting Cyclotron Laboratory along the Ni elemental chain. The preliminary results obtained for $^{71,72,73}\text{Ni}$ will be presented.

3:24PM MG.00008 $\beta$-decay studies of Co isotopes using total absorption spectroscopy S. LYONS, National Superconducting Cyclotron Laboratory, A. SPYROU, R. LEWIS, S. LIDDICK, Michigan State Univ, D. BLEUEL, Lawrence Livermore National Laboratory, K. CHILDERS, Michigan State Univ, B.P. CRIDER, Mississippi State Univ, A.C. DOMBOS, C. HARRIS, Michigan State Univ, M. LUTTORMSEN, A.C. LARSEN, University of Oslo, A. PALMISANO, D. RICHMAN, Michigan State Univ, N. SCIELZO, Lawrence Livermore National Laboratory, A. SIMON, University of Notre Dame, M.K. SMITH, National Superconducting Cyclotron Laboratory, A. TORODE, Michigan State Univ, A. URECHE, UC Berkeley, R. ZEGERS, Michigan State Univ — The rapid neutron capture process (r-process) is responsible for the synthesis of approximately half of the abundance of the heavy elements. This material is based upon work supported by the National Science Foundation under Grant No. PHY-1430152 (JINA-CEE).

3:36PM MG.00009 Constraining the cross section of $^{82}\text{Se}(n,g)\text{Se}$ to validate the beta-Oslo method KATHERINE CHILDERS, SEAN LIDDICK, ARTEMIS SPYROU, ALEX DOMBOS, FARRAH NAQVI, CHRISTOPHER PROKOP, ANDREAS RICHARD, STEVEN QUINN, Michigan State University, ANN-CECILIE LARSEN, MAGNE GUTTORMSEN, LUCIA CAMPO, SUNNIVA SIEM, THERESE RENSTROM, University of Oslo, DARRÈN BLEUEL, Lawrence Livermore National Laboratory, JEREMY CRIDER, Mississippi State University, AARON COUTURE, SHEA MOSBY, Los Alamos National Laboratory, GEORGE PERDIKAKIS, Central Michigan University — The r-process is believed to be one of the most important processes in the formation of heavy elements. In order to better understand the r-process, neutron-capture cross sections are needed. Neutron-capture cross sections of many r-process nuclei are poorly known due to short half-lives. This has led to the development of techniques such as the beta-Oslo method, which uses beta decay of a short-lived nucleus to populate the high-energy states in a daughter nucleus and the subsequent $\gamma$-ray decay is used to determine the nuclear level density and $\gamma$-ray strength function. The NLD and $\gamma$SF are then input into a Hauser-Feshbach model to constrain the neutron capture cross section. A validation will be performed with the $^{82}\text{Se}(n,g)\text{Se}$ reaction. The beta decay of $^{83}\text{As}$ to $^{83}\text{Se}$ has been studied at the NSCL. The NLD and $\gamma$SF of $^{83}\text{Se}$ have been extracted using the beta-Oslo method and fed into TALYS to constrain a neutron-capture cross section. The constrained cross section will be compared to a direct measurement.

3:48PM MG.00010 Mass Measurements of r-process Nuclei Using the TOF-B$\beta$ Technique at the NSCL\textsuperscript{1} K. WANG, CMU, M. FAMIANO, WMU, A. ESTRADE, T. CHAPMAN, N. NEPAL, G. ZIMBA, CMU, K. BHATT, B. FAMIANO, J. JENKINS, L. KLAN, WMU, H. SCHATZ, T. BAUMANN, D. BAZIN, T. GINTER, S. JIN, S. LIDDICK, J. PEREIRA, N. RIJAL, O. TARASOV, NSCL, J. DOPPER, M. GILES, A. ROGERS, UML, S. GEORGE, MPIK, Z. MEISEL, OU — The r-process plays a key role in the nucleosynthesis of more than half of the nuclei heavier than iron. Mass is one of the most fundamental nuclear data for r-process models because it is essential to calculate other nuclear properties such as Q-values for $\beta$-decays, neutron capture rates and equilibrium abundance distributions. The trends of masses along the isotopic chains towards N=82 can help us to test the models calculating the masses in the r-process path which is out of reach for current facilities. At the NSCL, we have conducted a mass-measurement experiment using time-of-flight–magnetic-rigidity (TOF-B$\beta$) technique for neutron-rich isotopes from Zr to Ru around N=70 produced by the projectile fragmentation of $^{124}\text{Sn}$. We present the preliminary results of this experiment.

\textsuperscript{1}We acknowledge support from NSF grants (PHY-1712832, PHY-1430152) and FRIB-CSC program.
2:00PM MH.00001 Results of the Proton Charge Radius Experiment (PRad) at JLab1, WEIZHI XIONG, Duke University, PRAD COLLABORATION — In order to investigate the proton charge radius puzzle, the PRad experiment (E12-11-106) was performed in 2016 in Hall B at Jefferson Lab, with both 1.1 and 2.2 GeV unpolarized electron beams. The experiment aims to measure the $e^- p$ elastic scattering cross section in an unprecedented low values of momentum transfer squared region ($Q^2 = 2 \times 10^{-4} - 0.06 \text{ (GeV/c)}^2$), with a sub-percent precision. The PRad experiment utilizes a calorimetric method that is magnetic spectrometer free. Its detector setup includes a large acceptance and high resolution calorimeter (HyCal), and two large area, high spatial resolution Gas Electron Multiplier (GEM) detectors. To have a better control over the systematic uncertainties, the absolute $e^- p$ elastic scattering cross section is normalized to that of the well-known Möller scattering process, which was measured simultaneously within similar kinematics and detector acceptances. The windowless $H_2$-gas-flow target utilized in the experiment largely removes a typical background source, the target cell windows. In this talk, we will present results of the experiment.

1This work is supported in part by the NSF MRI award PHY-1229153, the U.S. Department of Energy under Contract No. DE-FG02-03ER41231, Thomas Jefferson National Accelerator Facility and Duke University

2:12PM MH.00002 Unravelling the $^3\text{He}$ Electromagnetic Form Factors1, SCOTT BARCUS, The Thomas Jefferson National Accelerator Facility — New global fits of the $^3\text{He}$ elastic cross section world data will be presented along with extractions of both electric and magnetic form factors and charge densities. The updated $^3\text{He}$ fits were motivated by new high $Q^2$ data. The resultant $^3\text{He}$ first magnetic form factor minimum is found to have shifted up in $Q^2$ by several fm$^{-2}$. Further, large discrepancies exist between theory predictions of the magnetic form factor and those determined by elastic electron scattering. To address this discrepancy a new experiment has been proposed for Jefferson Lab’s Hall C to measure the double-polarization asymmetry of $^3\text{He}$. This would be the first extraction of $^3\text{He}$ form factors using polarization observables. The advantage of this double-polarization measurement is that, unlike traditional Rosenbluth methods, the extraction is sensitive to the signs of the form factors. As a result, the sign of the asymmetry flips at each form factor minima. Double-polarization experiments have found large disagreement, particularly at high $Q^2$, between proton form factors extracted via polarization observables and unpolarized Rosenbluth separations. This experiment will determine if such a disagreement exists for $^3\text{He}$, while also allowing for hypothesis testing of theoretical models.

1DOE, JSA Fellowship

2:24PM MH.00003 Measuring the electric form factor of the proton at high momentum transfer in Hall A at Jefferson Lab2, GABRIEL NICULESCU, James Madison University, SBS COLLABORATION, HALA A COLLABORATION — For more than 50 years, proton scattering has provided a wealth of information about the structure of protons and neutrons through the extraction of nucleon form factors. These, in turn, have been the subject of intense theoretical scrutiny using various techniques ranging from first principles QCD calculations to several phenomenological models. Moreover, as the first moments of the generalized parton distributions are related to the elastic Dirac form factors of the nucleon through model independent sum rules, elastic electron scattering studies help sharpen our 3D picture of a nucleon. Here we will give an update/status report on a Jefferson Lab experiment aiming to extend, with good statistical and systematic precision, the measurements of the electric form form factor of the proton to four momentum transfers up to 12 GeV$^2$ using the JLab 11 GeV electron beam and a super big bite spectrometer in Hall A in conjunction with a highly segmented electromagnetic calorimeter. The experimental technique as well as the potential impact of such measurement on the field will be discussed.

2:36PM MH.00004 Neutral Pion Electroproduction in the Deeply Virtual Regime at 12 GeV Jefferson Lab3, SALINA ALI, TANJA HORN, The Catholic University of America, CARLOS MUNOZ-CAMACHO, IPN-Orsay, JULIE ROCHE, Ohio University, CHARLES HYDE, Old Dominion University, JLAB HALL A DVCS-3 COLLABORATION COLLABORATION — Deep exclusive processes can allow access to Generalized Parton Distributions (GPDs), a concept that lies at the root of 3D imaging of the proton's quark-gluon substructure, as GPDs contain information about the transverse spatial distribution of quarks and their longitudinal momentum inside hadrons. The key to extracting GPDs from experiments are the Quantum Chromodynamics (QCD) factorization theorems. Deeply Virtual Compton Scattering (DVCS) is the cleanest way to study GPDs. While DVCS data have given hints of the factorization regime being attained, such hints have not been observed for Deeply Virtual Meson Production (DVMP) data. Exclusive $\pi^0$ electroproduction has been measured by experiment E12-06-114 in Hall A of JLab in order to test factorization in DVMP processes. Cross sections have been measured at three fixed Bjorken-x ($x_F$): 0.36, 0.48 and 0.6 in the $Q^2$ range 3 to 9 GeV$^2$. High statistical measurements of polarized and unpolarized cross sections of $f(e, e'\pi^0)p$ could allow mapping and extraction of GPD information from the nucleon. In this talk, I will show the experimental setup, calibration and preliminary results of the neutral pion electroproduction cross sections for $x_F > 0.3$ from this experiment.

3Supported in part by NSF award PHY1714133

2:48PM MH.00005 Extraction of Twist-3 Observables from Deeply Virtual Compton Scattering, BRANDON KRIESTEN, University of Virginia — Imaging the 3D partonic structure of the nucleon is a fundamental goal of every major nuclear experimental program, including the EIC. Ji first proposed Deeply Virtual Compton Scattering (DVCS) as a probe for understanding the spatial distribution of the partons by fourier transform of the exchanged momentum transfer between the initial and final proton. The extraction of observables from Deeply Virtual Exclusive Reactions in a clear and concise formalism, such that the various twist components and angular dependencies can be untangled, is key. We present a completely covariant description of the DVCS process that can be extended to any kinematics, either fixed target or collider. In our helicity formalism, we extract observables such that the dependence on $Q^2$ is clear and kinematic supressions are not confused with higher twist observables. We have extended our formalism to other Exclusive Reactions, such as Timelike Compton Scattering (TCS), which we demonstrate is key in the extraction of Twist-3 observables used to study the orbital angular momentum of the proton.
3:00PM MH.00006 Science opportunities with a Neutral Particle Spectrometer in Hall C at Jefferson Lab.1, VLADIMIR BERDNIKOV, The Catholic University of America, NPS COLLABORATION COLLABORATION — The two-arm combination of a high-resolution neutral-particle spectrometer (NPS) and a magnetic spectrometer offers unique scientific capabilities for studies of the transverse spatial and momentum structure of the nucleon in Hall C. It makes possible measurements of the basic semi-inclusive neutral-pion cross section to validate QCD factorization, a cornerstone of 3D transverse momentum imaging. It enables precision measurements of the deeply-virtual Compton scattering cross section at different beam energies to extract the real part of the Compton form factor without any assumptions. The combination of high precision calorimetry with NPS allows measurements to push the energy scale of real Compton scattering, the process of choice to explore factorization in a whole class of wide-angle processes, and its extension to neutral pion photo-production. The combination of high precision calorimetry with NPS and a novel compact high intensity photon sources greatly enhances scientific benefit to exclusive processes like wide-angle and time-like Compton scattering with transverse polarized targets. In this talk I will give an overview of the science program and discuss the status of the NPS construction including data from recent prototype tests.

1Supported in part by NSF award PHY1714133

3:12PM MH.00007 Source for Compton Scattering from Solid Polarized Targets1, TANJA HORN, The Catholic University of America, DONAL DAY, University of Virginia, ROLF ENT, Jefferson Lab, DAVID HAMILTON, University of Glasgow, DUSTIN KELLER, University of Virginia, GABRIEL NICULESCU, James Madison University, BOGDAN WOJTSEKOWSKI, Jefferson Lab, JIXIE ZHANG, University of Virginia, NEUTRAL PARTICLE SPECTROMETER COLLABORATION COLLABORATION — Wide angle Compton scattering (WACS) from polarized protons holds great promise: access to the generalized parton distribution functions $\tilde{H}$ and $\tilde{E}$ with different weighting and moments than in other hard exclusive processes, emphasizing the $\bar{u}$-quarks and the valence region. Previously, experiments were proposed using bremsstrahlung from polarized electrons striking a radiator. Unfortunately, the mixed electron-γ beam limits the polarized target performance due to radiation damage and restricted luminosity owing to the heat load. We will present the technical design concept of a compact, high intensity photon source (CPS) to be used with dynamically nuclear polarized targets. The novel CPS technique opens access to physics processes with very small scattering probabilities, not possible with currently existing facilities. Capable of producing $10^{12}$ equivalent γ/sec, the CPS will result in a large gain in polarized experiment figure-of-merit (by a factor of ~ 30). Compared to a traditional bremsstrahlung photon source the CPS will present several advantages, including much lower radiation levels, both prompt and post-operational due to the beam line elements radio-activation.

1Supported in part by NSF PHY-1714133

Wednesday, October 16, 2019 2:00PM - 4:00PM –
Session MJ Mini-Symposium: Search for the Critical Point III Salon C - Derek Teaney, Stony Brook University

2:00PM MJ.00001 Search for the QCD Critical Point at RHIC, ROLI ESHA, Stony Brook University — At large baryon chemical potentials, QCD-based models predict the phase transition from the Quark Gluon Plasma phase to the Hadron Gas phase to be a first-order phase transition that ends in a second-order critical point. The Beam Energy Scan (BES) program at the Relativistic Heavy Ion Collider (RHIC) focuses on the searches for a possible critical point in the quark-hadron phase diagram. The experimental searches rely on studies of fluctuations of conserved quantum numbers, namely the baryon, strangeness or charge fluctuations. In this talk, the results and implications from such experimental measurements at RHIC will be reviewed. Future plans for the BES-II program will also be discussed.

2:36PM MJ.00002 Search for the QCD critical end point with finite-size susceptibility scaling functions1, ROY LACEY, Stony Brook University — Finite-size and Finite-time effects complicate the search for the critical endpoint (CEP) as well as its characterization because they impose non-trivial constraints on the growth of the correlation length. Thus, the observation of non-monotonic experimental signatures for the CEP is not sufficient to identify its location and assign its universality class. In this talk, I will discuss how susceptibility scaling functions can be leveraged to locate and characterize the CEP. To date, this constitutes the only credible experimental approach to discovering and characterizing the CEP.

1This research is supported by the US Department of Energy, Office of Science, Office of Nuclear Physics, under contract DE-FG02-87ER40331.A008

2:48PM MJ.00003 Fluctuation dynamics near the QCD critical point1, LIPEI DU, ULRICH HEINZ, Ohio State University, KRISHNA RAJAGOPAL, YI YIN, Massachusetts Institute of Technology — Near the QCD critical point (CP), critically slow processes can invalidate the conventional (dissipative) hydrodynamic description, which simply integrates out all non-hydrodynamic modes. We explore the critical dynamics near the QCD CP with the novel Hydro+ framework which extends the conventional hydrodynamic description by coupling it to additional explicitly evolving slow modes. Their slow relaxation is controlled by the correlation length in the critical region, which is independent from the density inhomogeneities of the QCD matter that control the evolution of the hydrodynamic quantities. In this presentation we study the evolution of a single critical slow mode on top of a simplified matter background with non-zero net baryon density undergoing Gubser flow, as a function of its wave number and the correlation length. We also discuss how the non-equilibrium slow mode affects the bulk properties of the matter, such as the pressure and entropy density. We find that over a wide range of wave numbers the non-equilibrium effects are dominated by the fluid expansion rather than by critical slowing-down. Last but not least we explore the critical fluctuation dynamics in systems of various sizes and at different collision energies.

1Supported by DOE Award No. DE-SC0004286 and Award No. DE-SC0011090
for Au + Au at $\sqrt{s_{NN}} = 1$ results for two-particle correlations stemming from fluctuations away from the critical point are presented to distinguish the effects of criticality and correlation length, and of the medium expansion are systematically investigated. Differences of our findings from those obtained using deterministic hydro-kinetic equations for out-of-equilibrium two-point functions, and the effects of critical behaviour of transport coefficients in a system undergoing Bjorken expansion which passes close to the QCD critical point. The dynamics of fluctuations are described systems as they transit the critical domain. In this work, we study two-particle rapidity correlations induced from fluctuations of hydrodynamic heavy ion collisions which may be potential signatures of long-range correlations and large fluctuations taking place in the hot and dense the Ohio State University — A novel way of locating the QCD critical point is to look for correlations in certain final state observables of heavy ion collisions which may be potential signatures of long-range correlations and large fluctuations taking place in the hot and dense systems as they transit the critical domain. In this work, we study two-particle rapidity correlations induced from fluctuations of hydrodynamic variables in a system undergoing Bjorken expansion which passes close to the QCD critical point. The dynamics of fluctuations are described by deterministic hydro-kinetic equations for out-of-equilibrium two-point functions, and the effects of critical behaviour of transport coefficients and correlation length, and of the medium expansion are systematically investigated. Differences of our findings from those obtained using a straightforward extrapolation of the traditional theory of hydrodynamic fluctuations to the critical regime are discussed. Comparisons with results for two-particle correlations stemming from fluctuations away from the critical point are presented to distinguish the effects of criticality.

Supported by DOE, Award No. DE-SC0004286

3:36PM MJ.00007 Proton Yields, Multiplicities, and Event-by-event Fluctuations for Au + Au at $\sqrt{s_{NN}}$ from 3 GeV

SAMUEL HEPPELMANN, University of California, Davis, STAR COLLABORATION — The first RHIC Beam Energy Scan (BES-I) was run from 2010-2014 to search for the turn-off of signatures of the quark-gluon plasma (QGP), evidence for the first-order phase transition, and the possible QCD critical point. Motivated by the findings of BES-I, STAR has initiated a phase II of the BES program (BES-II). The BES-II program improves upon the earlier BES-I program with detector upgrades to extend the acceptance, higher luminosity to probe 10-20 times better statistics at each energy, and a Fixed-Target program to extend the range of BES-II below the expected critical point. In this talk, results from the first dedicated fixed-target physics run at $\sqrt{s_{NN}} = 3$ GeV will be presented. We present proton (and antiproton) yields and multiplicities. These measurements will be compared with results from AGS experiments E866 and E895. We will discuss the implications of the observed multiplicities and efficiency corrections to the study of cumulants of event-by-event net-proton multiplicities up to the fourth order as a function of rapidity. Results at this energy will help to understand the trends observed in the previous results from the BES program and preliminary results from HADES. We will discuss the future of BES-II fixed-target measurements at RHIC.

National Science Foundation Grant No. 1812398

3:48PM MJ.00008 Initial Conditions from Gluon Multiplicity in Heavy Ion Collisions

PATRICK CARZON, JACQUELYN NORONHA-HOSTLER, MATTHEW SIEVERT, Rutgers University — A great uncertainty in heavy-ion collisions is the initial state immediately after the collision. A question remains regarding the optimal method of determining the energy density deposited at mid-rapidity by a collision. This is important because the viscosity of the quark-gluon plasma is very small, and the final-state flow will be sensitive to this choice in the initial state. TRENTO accomplishes this in a phenomenological way by taking $\sqrt{T_A T_B}$ to provide a reduced thickness function, that when scaled by a data-determined factor provides an entropy density. Another way of calculating the initial energy density is using a proportionality to $T_A T_B$, which comes from Color-Glass Condensate calculations at $\tau = 0$. I will present a new method of calculating the reduced thickness using the single-inclusive gluon cross section in the dilute-dense limit of the CGC framework. There is a noticeable difference, across system size, between observables in the standard setting of TRENTO and this new method. We also study quantitatively various approximations which are commonly made in such calculations. The gluon distribution employed here provides a platform on which to later introduce new conserved charges into hydrodynamics when supplemented by quark splitting functions.

Wednesday, October 16, 2019 4:30PM - 6:00PM – Session NC Business Meeting (4:30pm-6:00pm) Salon 3 -

4:30PM NC.00001 Business Meeting (4:30pm-6:00pm) –

Wednesday, October 16, 2019 6:30PM - 7:00PM – Session PA Cash Bar Reception (6:30pm-7:00pm) Grand Foyer/Sky View -
Wednesday, October 16, 2019 7:00PM - 9:30PM –
Session PB Banquet (7:00pm-9:30pm) Grand Ballroom -

7:00PM PB.00001 Dinner (7:00pm-8:30pm) — Dinner (7:00pm-8:30pm)

8:30PM PB.00002 A Theoretical Physicists Impressions From The Front Lines of Policy Advising , SYLVESTER JAMES GATES, University of Maryland, College Park — Though the speaker is a theoretical physicist researching mathematical foundations of "supersymmetry" in particle, field, and string theory, by quirks of fate his second life has seen advising stints with the NSF, DoE, DoD, the State of Maryland Board of Education, and the Executive Office of the President of the United States. The "laws of nature in this second life" are very different from those in his first. Reflections on these differences are the subject of this talk.

Thursday, October 17, 2019 8:30AM - 10:18AM –
Session RA Hydrodynamic Simulations of the QGP: Successes and Challenges Salon 1 - Michael Strickland, Kent State University

8:30AM RA.00001 Hydrodynamic flow in large and small QCD systems formed in relativistic collisions1. JULIA VELKOVSKA, Vanderbilt University — The quark-gluon plasma (QGP) produced in ultra-relativistic collisions between large nuclei, such as gold or lead, is a state of QCD matter with extremely high temperature and energy density. The particles produced in these collisions exhibit collective behavior, which is well described by viscous hydrodynamics with very low specific viscosity. The success of hydrodynamics in describing simultaneously a large number of observables led to the notion that QGP is perhaps the most perfect liquid in nature. In the quest for understanding how the perfect fluid emerges, experiments at the Large Hadron Collider (CERN, Switzerland) and the Relativistic Heavy Ion Collider (BNL) studied collisions between protons or other small nuclei with large nuclei, which were not expected to produce QGP but only cold QCD matter. Surprisingly, collective behavior was also found in these small-system collisions. Hydrodynamical models again provide an excellent simultaneous description of a large body of data. How small can a system be and still behave as a liquid, and what are the limits of applicability of hydrodynamics? This talk will focus on the successes and challenges of hydrodynamics applied to large and small QCD systems formed in relativistic collisions.

1This work was supported in part by DOE grant DE-FG02-92ER40712.

9:06AM RA.00002 Hydrodynamic simulations in challenging environments1. CHUN SHEN, Wayne State University — Relativistic viscous hydrodynamics is an effective description of the bulk dynamics of high energy relativistic heavy-ion collisions. Understanding the collective origin in the high multiplicity pp and pA collisions experiments at Relativistic Heavy-Ion Collider (RHIC) and the Large Hadron Collider (LHC) has been pushing the successful fluid paradigm to its limits. In this talk, I will discuss the current theoretical uncertainties in the hydrodynamic modeling of these small collision systems and highlight recent developments to go beyond hydrodynamics. Furthermore, I will also present the theoretical challenge of describing the bulk dynamics of relativistic heavy-ion collisions at lower RHIC Beam Energy Scan (BES). At those collision energies, the overlapping time for the two nuclei to pass each other becomes comparable to the system lifetime.

1This work is supported by the DOE Contract No. DE-SC0013460.

9:42AM RA.00003 Recent theoretical developments in hydrodynamics1. GOKCE BASAR, University of North Carolina, Chapel Hill — In this talk we focus on two recent developments in relativistic hydrodynamics which is an important tool in understanding the physics of heavy ion collisions. i) We review the theory of fluctuations in relativistic hydrodynamics and its implementation in numerical simulations. In particular we present a general systematic formalism describing dynamics of fluctuations in an arbitrary relativistic hydrodynamic flow. We derive a deterministic evolution equation for the fluctuation modes which nontrivially matches the kinetic equation for phonons propagating on an arbitrary background, including relativistic inertial and Coriolis forces due to acceleration and vorticity of the flow. We also describe the procedure of renormalization of short-distance singularities which eliminates cutoff dependence, allowing efficient numerical implementation of these equations. ii) We briefly discuss the asymptotic nature of the derivative expansion and show that the way the expansion diverges is related to the existence of certain non-hydrodynamic modes and show how quantitative information about these modes can be extracted from the late terms in the derivative expansion.

1We acknowledge the support of The US Department of Energy grant DE-FG0201ER41195

Thursday, October 17, 2019 8:30AM - 10:18AM –
Session RB Neutrinoless Double Beta Decay Salon 2 - David Radford, Oak Ridge National Laboratory

8:30AM RB.00001 EXO-200 Result with Full Dataset , ZEPENG LI, Yale University, CAIO LICCIARDI, Laurentian University, EXO-200 COLLABORATION — The EXO-200 Collaboration has been searching for neutrinoless double beta decay ($0\nu\beta\beta$) using a liquid xenon time projection chamber filled with $\sim 150$ kg of enriched $^{136}$Xe. EXO-200 began data taking in September 2011 and has now completed operations as of December 2018. This talk will present the most recent result from the collaboration accounting for the full dataset. The new analysis introduces the use of a convolutional neural network to maximize the topological discrimination between $0\nu\beta\beta$ signal and background, while the signal detection efficiency is near maximal and the energy resolution is 1.15%. No statistically significant evidence for $0\nu\beta\beta$ was observed, leading to a lower limit on the half-life of $3.5 \times 10^{25}$ yr at the 90% confidence level and corresponding search sensitivity of $5.0 \times 10^{25}$ yr, placed among the world’s best in the field.
8:42AM RB.00002 First Results from KamLAND-Zen 800. CHRISTOPHER GRANT, Boston University. KAMLAND-ZEN COLLABORATION — KamLAND-Zen is searching for the neutrinoless double beta decay of $^{136}$Xe with a 1-kiloton liquid scintillator detector. The experiment was one of the first to reach a half-life sensitivity of $10^{26}$ years, which was obtained by instrumenting roughly 380 kg of enriched Xe in a small balloon. Since then, a new balloon was constructed in order to increase the amount of enriched Xe and further improve the half-life sensitivity. This major detector upgrade finished just last year, and in January of 2019, KamLAND-Zen began taking data with nearly a ton (~750 kg) of enriched $^{136}$Xe. New results from the 750 kg data will be presented, along with an outline of future upgrades leading to KamLAND-Zen.

8:54AM RB.00003 Status and Results from the NEXT Experiment. KATHERINE WOODRUFF, University of Texas at Arlington — The search for neutrinoless double beta decay requires detection techniques with unprecedented low background contamination in the signal ROI. The NEXT program aims to meet these requirements using high-pressure xenon gas electroluminescent time projection chambers. This talk will present results from the NEXT-White detector, the presently running phase of the NEXT detector program, demonstrating radio-purity energy resolution and topological discrimination. Additionally, techniques to eliminate remaining backgrounds by identifying the barium daughter ion are being developed to be implemented in later stages of the NEXT program. The latest results and progress on the barium tagging program will be presented.

9:06AM RB.00004 Update on the Status of the CUPID-Mo Demonstrator. JONATHAN OUELLET, Massachusetts Institute of Technology. CUPID-MO COLLABORATION — CUPID is the first ton-scale cryogenic bolometer experiment searching for neutrinoless double-beta decay. The successor to CUORE, called CUPID, is designed to improve the half-life sensitivity of CUORE by almost two orders of magnitude and fully probe the so-called inverted hierarchy region of the effective majorana neutrino mass. The technology for CUPID is currently being employed in the CUPID-Mo demonstrator, which is searching for the $0\nu\beta\beta$ decay of $^{100}$Mo. CUPID-Mo consists of 20 enriched $\sim 0.2$ kg $^{121}$I$^{150}$MoO$_4$ scintillating crystals complemented by 20 light-detecting Ge bolometers. By comparing the heat vs light signals, CUPID-Mo is able to distinguish $\alpha$ events from $\beta/\gamma$ events for a powerful background discriminant. CUPID-Mo began data taking in Spring 2019. In this talk, we will present early results from the first data collected with CUPID-Mo, an updated prediction for its expected sensitivity, and an outlook on the prospects of CUPID.

9:18AM RB.00005 The nEXO Neutrinoless Double Beta Decay Experiment. BRIAN LENARDO, Stanford University. NEXO COLLABORATION — The nEXO experiment is a proposed next-generation search for the neutrinoless double beta decay of $^{136}$Xe. The discovery of this process would simultaneously demonstrate lepton number violation and the existence of fundamental Majorana fermions, establishing new physics beyond the Standard Model. The primary detector will be a 5-ton, monolithic liquid xenon TPC with a target enriched to 90% in the isotope of interest. In this talk, we will introduce the science goals of nEXO and discuss how the detector has been designed to meet them. The experiment is projected to reach an exclusion sensitivity of approximately 10$^{28}$yrs, superseding existing limits by two orders of magnitude and entirely covering the inverted hierarchy region.

9:30AM RB.00006 Calibration of nEXO light response. PRAKASH GAUTAM, Drexel University. NEXO COLLABORATION — nEXO is a proposed 5 tonne liquid xenon experiment which seeks to detect neutrinoless double beta decay($0\nu\beta\beta$) in Xe-136 using Time Projection Chamber(TPC) technology. The experiment will use the combination of scintillation and ionization signals to reconstruct events with an energy resolution of 1% $\sigma/E$ at the $0\nu\beta\beta$ Q-value. The scintillation light will be collected by silicon photomultipliers (SiPMs) around the sides of the detector, and their collection efficiency will vary as a function of event position. In this talk, we present the strategy for calibrating light response in the nEXO detector. We will deploy a suite of calibration sources, including external $\gamma$-ray sources and internal sources dissolved in the liquid xenon. Using nEXO Monte Carlo data, we have demonstrated the use of machine learning techniques to effectively map the light response of the detector while minimizing calibration time.

9:42AM RB.00007 Searching for the neutrinoless double-beta decay of $^{76}$Ge with the LEGEND experiment. ALEXEY DROBIZHEV, Lawrence Berkeley National Laboratory. LEGEND COLLABORATION — LEGEND—the Large Enriched Germanium Experiment for Neutrinoless Double-Beta Decay—is an experiment that will search for the neutrinoless double-beta ($0\nu\beta\beta$) decay of $^{76}$Ge. The observation of this lepton number violating process would establish the Majorana nature of the neutrino, with implications for physics beyond the standard model. The MAJORANA DEMONSTRATOR and GERDA, two $^{76}$Ge experiments currently operating, lead the field in the key design parameters of energy resolution and background reduction. Building on their success, the LEGEND collaboration is developing a phased next-generation ($0\nu\beta\beta$) decay search. LEGEND-200, currently ramping up, will host ~200 kg of enriched HPGe detectors in the existing GERDA infrastructure at the Laboratori Nazionali del Gran Sasso in Italy. The subsequent LEGEND-1000 detector will be a tonne-scale HPGe array with a $^{76}$Ge ($0\nu\beta\beta$) half-life sensitivity greater than $10^{28}$ years. In this talk, we present the plans and physics reach of LEGEND.

This material is based upon work supported by the U.S. NSF, DOE-NP, NERSC and through the LANL LDRD program, and the Oak Ridge Leadership Computing Facility; the Russian RFBR, the Canadian NSERC and CFI; the German BMBF, DFG and MPG; the Italian INFN; the Polish NCN and Foundation for Polish Science; and the Swiss SNF; the Sanford Underground Research Facility, and the Laboratori Nazionali del Gran Sasso.
9:54AM RB.00008 Detector Acceptance Characterization for the LEGEND-200 Experiment\textsuperscript{1}, MORGAN CLARK, University of North Carolina at Chapel Hill, LEGEND COLLABORATION — The LEGEND-200 experiment will search for neutrinoless double beta decay in 76Ge using approximately 200 kg of high purity germanium (HPGe) detectors enriched to >86\% in 76Ge. To reach the total mass, we will reuse 60 kg of p-type point contact (PPC) detectors from the GERDA and MAJORANA DEMONSTRATOR experiments and are working with several vendors to fabricate 140 kg of a new type of HPGe detectors known as inverted coaxial point contact detectors (ICPC). The ICPC detectors have the advantage of being larger than the PPC detectors. The collaboration needs to fully characterize these detectors post production before they are deployed in the experiment’s liquid Ar cryostat. The standard acceptance tests include measurements of each detector’s efficiency and energy resolution, timing response, and dead layer. We also plan additional specialized measurements including radial and longitudinal scans of the detectors with selected sources, measurements in a liquid argon (LAr) immersion test apparatus, and alpha- and beta-source scans across the detectors’ passivated surfaces. A description of the overall LEGEND-200 characterization program including some initial measurement results will be presented.

\textsuperscript{1}This work is supported by U.S. NSF, DOE-NP, NERSCC and the LANL LDRD program, Oak Ridge Leadership Computing Facility; the Russian RFBR, the Canadian NSERC and CFI; the German BMBF, DFG and MPG; the Italian INFN; the Polish NCN and Foundation for Polish Science; and the Swiss SNF; SURF, and LNGS.

10:06AM RB.00009 Signal Readout Electronics for the LEGEND-200 Experiment\textsuperscript{1}, MICHAEL WILLERS, Lawrence Berkeley National Laboratory, LEGEND COLLABORATION — LEGEND (Large Enriched Germanium Experiment for Neutrinoless Double-Beta Decay) is a ton-scale experimental program searching for neutrinoless double beta decay (0vbb) using high-purity germanium detectors enriched in the isotope 76Ge. On-site construction of its first 200-kg stage (LEGEND-200) will start at the Gran Sasso underground laboratory (Laboratori Nazionale del Gran Sasso, LNGS) in early 2020. To achieve the projected half-life sensitivity of >10^{27} years, ultra-clean low-noise signal readout electronics are essential. In this presentation, the current status of the signal readout electronics for LEGEND-200 as well as the characterization of prototype devices will be presented.

\textsuperscript{1}This material is based upon work supported by the U.S. NSF, DOE-NP, NERSCC and through the LANL LDRD program, and the Oak Ridge Leadership Computing Facility; the Russian RFBR, the Canadian NSERC and CFI; the German BMBF, DFG and MPG; the Italian INFN; the Polish NCN and Foundation for Polish Science; and the Swiss SNF; SURF, and LNGS.

Thursday, October 17, 2019 8:30AM - 10:30AM – Session RC Mini-Symposium: Excited State Lifetime Measurements for Nuclear Structure and Astrophysics  Salon 3 - Peter Bender, University of Massachusetts, Lowell

8:30AM RC.00001 Recent highlights from lifetime measurements with rare isotope beams: techniques and results , HIRONORI IWASAKI, National Superconducting Cyclotron Laboratory, Michigan State University — Two of the compelling questions identified for nuclear science today are “How does subatomic matter organize itself and what phenomena emerge?” and “How did visible matter come into being and how does it evolve?”. Excited-state lifetime measurements provide precise and model-independent nuclear structure data of key atomic nuclei to validate nuclear models and pin down scenarios of astrophysical processes. With the advent of advanced gamma-ray arrays such as GRETINA, new experimental techniques have been developed extending the reach of lifetime programs far from the valley of stability. This talk will provide a brief overview of new implementation of Doppler-shift attenuation techniques with rare isotope beams and present recent science highlights including findings on shape coexistence phenomena in neutron-rich nuclei, shape evolution along N=Z, and properties of drip-line nuclei. Then discussion will focus on electromagnetic responses of weakly-bound neutron-rich nuclei and a possible interplay between a nuclear halo and deformation.

9:06AM RC.00002 Influence of the neutron pf shell on the structure of 28\textsuperscript{Mg}, JONATHAN WILLIAMS, Simon Fraser University — Excited states in \textsuperscript{28}Mg were studied in an experiment at the ISAC-II facility at TRIUMF to investigate the lowering in energy of pf intruder orbitals predicted near the N = 20 'island of inversion'. A \textsuperscript{12}C(\textsuperscript{18}O,2p)\textsuperscript{28}Mg fusion-evaporation reaction was used to populate states at high excitation energy where the influence of intruder orbitals is expected. Data corresponding to \textsuperscript{28}Mg was extracted via time coincident identification of gamma rays using the TIGRESS array at ISAC-II and protons using a new CsI(Tl) scintillator array, part of the TIGRESS Integrated Plunger (TIP) infrastructure. Lifetime measurements of excited states were performed using the Doppler shift attenuation method (DSAM). Three new excited states of \textsuperscript{28}Mg were identified near its neutron separation energy. Multiple intruder state candidates were also observed, including an unusually long-lived state thought to decay by an M2 transition (I\textsuperscript{T} = (0, 4)\textsuperscript{−}). The observed level energies are consistent with shell model calculations in the sdpf shell, where negative parity levels arise from single neutron excitation to the pf shell. Experimental results and their interpretation with respect to the lowering of intruder orbitals near the 'island of inversion' will be discussed.
9:18AM RC.00003 Recoil distance method lifetime measurement of the $2^+_1$ state in $^{94}$Sr and implications for the structure of neutron-rich Sr isotopes, AARON CHESTER, Michigan State University, GREG HACKMAN, TRIUMF, JACK HENDERSON, Lawrence Livermore National Laboratory, KRYSZTOF STAROSTA, Simon Fraser University, PHILIP VOSS, Albion College, JONATHAN WILLIAMS, Simon Fraser University, GAMMA-RAY SPECTROSCOPY AT ISAC COLLABORATION — The TIGRESS Integrated Plunger (TIP) device [1] has been constructed to enable Doppler-shift lifetime measurements at TRIUMF’s ISAC-II facility. TIP was commissioned using a stable $^{14}$Kr beam by coupling the recoil distance method with unsafeguard Coulomb excitation in inverse kinematics [2]. A high-precision lifetime measurement of the $2^+_1$ state in $^{94}$Sr was performed using the same Coulomb-RDM technique. The data set had low statistics due to the luminosity of the radioactive $^{94}$Sr beam. A lifetime of $\tau = 7.80^{+0.50}_{-0.40}$ (stat.) $\pm 0.04$ (sys.) ps was determined by comparing experimental data to Geant4 simulations using a likelihood ratio $\chi^2$ method. The corresponding $B(E2; 2^+_1 \rightarrow 0^+)$ value is approximately 25% larger than previously reported while the relative error has been reduced by a factor of approximately 8. A baseline deformation has been established for Sr isotopes with $N \leq 58$ [3]. The experimental results, data analysis methods, and a comparison to existing theoretical models are presented. [1] Voss et al., NIM A 746 87–97 (2014). [2] Chester et al., NIM A 882 69–83 (2018). [3] Chester et al., PRC 96 011302(R) (2017).

9:30AM RC.00004 Probing large collectivity $^{32}$Mg with a recoil-distance lifetime measurement, ROBERT ELDER, H. IWASAKI, J. ASH, National Superconducting Cyclotron Laboratory, MSU, D. BAZIN, National Superconducting Cyclotron Laboratory, P. C. BENDER, University of Massachusetts, Lowell, T. BRAUNROTH, Universiti zu Kln, B. A. BROWN, National Superconducting Cyclotron Laboratory, MSU, C. CAMPBELL, H. CRAWFORD, Lawrence Berkeley National Laboratory, B. ELMAN, A. GADE, M. GRINDER, National Superconducting Cyclotron Laboratory, MSU, N. KOBAYASHI, Research Center for Nuclear Astrophysics, B. LONGFELLOW, National Superconducting Cyclotron Laboratory, MSU, A. O. MACCHIANELLI, Lawrence Berkeley National Laboratory, T. MJATOVIC, Ruder Boskovic Institute, J. PEREIRA, A. REVEL, National Superconducting Cyclotron Laboratory, D. ROHDES, National Superconducting Cyclotron Laboratory, MSU, J. TOSTEVIN, University of Surrey, D. WEISSHAAR, National Superconducting Cyclotron Laboratory, T. HAYLETT, University of York, T. MIJATOVIC, Ruder Boskovic Institute, A. DEWALD, S. HEIL, M. MATHY, Institut fur Kernphysik der Universitat zu Kln — The nuclear shell structure significantly evolves in the neutron-rich region at the traditional magic numbers $N=20$ and 28, resulting in rapid shape transitions as predicted by shell model calculations. The energy ratios between the first 2$^+$ and 4$^+_1$ states in $^{32}$Si as the turning point in this transition. The lifetime measurement of $^{38}$Si was performed at the National Superconducting Cyclotron Laboratory based on the Recoil-Distance Method using the Gamma-Ray Energy Tracking In-beam Nuclear Array (GRETINA). The data are used to extract the $B(E2)$ ratio which provides a useful measurement to assess the nature of collective modes.

9:42AM RC.00005 Precision Lifetime Measurements of Excited States in $^{38}$Si$^{1}$, M. GRINDER, H. IWASAKI, R. ELDER, J. ASH, A. REVEL, N. KOBAYASHI, D. BAZIN, J. BELARGE, P. BENDER, B. ELMAN, A. GADE, C. LOELIUS, B. LONGFELLOW, E. LUNDERBERG, D. WEISSHAAR, K. WHITMORE, Michigan State University/NSCL, T. HAYLETT, University of York, T. MIJATOVIC, Ruder Boskovic Institute, A. DEWALD, S. HEIL, M. MATHY, Institut fur Kernphysik der Universitat zu Kln — The nuclear shell structure significantly evolves in the neutron-rich region at the traditional magic numbers $N=20$ and 28, resulting in rapid shape transitions as predicted by shell model calculations. The energy ratios between the first 2$^+$ and 4$^+_1$ states in $^{32}$Si as the turning point in this transition. The lifetime measurement of $^{38}$Si was performed at the National Superconducting Cyclotron Laboratory based on the Recoil-Distance Method using the Gamma-Ray Energy Tracking In-beam Nuclear Array (GRETINA). The data are used to extract the $B(E2)$ ratio which provides a useful measurement to assess the nature of collective modes.

1This material is based upon work supported by the Department of Energy National Nuclear Security Administration through the Nuclear Science and Security Consortium under Award Number DE-NA0003180

9:54AM RC.00006 Fast-timing capabilities of GRIFFIN$^1$, BRUNO OLAIZOLA, TRIUMF — GRIFFIN is the decay spectroscopy facility at TRIUMF-ISAC in Canada. The core of GRIFFIN is an array of 16 large-volume HPGe clover detectors. One of its main features is the variety of ancillary detectors that can be coupled to the main array. SCEPTAR for $\beta$-particle tagging, the 70 liquid scintillators of DESCANT for neutrons or PACES (5 Si(Li) detectors) with high-energy resolution for conversion electrons. A new ancillary array of 8 LaBr$_3$(Ce) detectors for $\gamma$-rays and a fast plastic-scintillator called Zero Degree for $\beta$-particles is optimized for fast-timing experiments with GRIFFIN. The 51 mm x 51 mm cylindrical LaBr$_3$(Ce) crystals are coupled to Hamamatsu R2083 PMT with an integrated pre-amplifier in the PMT base. Timing resolutions as good as FWHM~ 300 ps and time-walks $\pm 50$ ps have been obtained using a hybrid analogue and digital DAQ system. A set of BGO shields minimize the Compton background, one of the main limiting factors in lifetime measurement. The LaBr$_3$(Ce) array has been used in a number of experiments to date, measuring lifetimes down to $\tau \sim 20$ ps. The general fast timing capabilities of GRIFFIN will be presented and some of the measured lifetimes in $^{198-200}$Hg and $^A144-146$Ba, La and Ce discussed.

1The GRIFFIN infrastructure has been funded jointly by the Canada Foundation for Innovation, the British Columbia Knowledge Development Fund (BCKDF), the Ontario Ministry of Research and Innovation (ON-MRI), TRIUMF and the University of Guelph. This work was supported by the Natural Sciences and Engineering Research Council of Canada.
tracking planes for Q² tube with a quartz window for UV light transmission. The focal plane detector packages also each include three 10x20 cm² fused-silica tiles as an active Cerenkov medium for counting electrons. Each tile is optically polished and coupled to a photo-multiplier. Details on flux rates scattered on the main integrating detectors. As a result, the PREX-II main detectors employ radiation-hard, high-purity SpectroSil statistics limited measurement of a sub-ppm parity violating asymmetry. To achieve this goal in a relatively short time requires high (GHz-level) hardware which helped achieve parity quality beam for PREX-II and CREX.

This work has been supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, and China Scholarship Council.

10:18AM RC.00008 DSAM lifetime measurements in 7,8Li. C. MORSE, LBNL, E.A. MCCUTCCHAN, BNL, C.J. LISTER, G.L. WILSON, UML, G. HACKMAN, M. BOWRY, R. CABALLERO-FOCH, L.J. EVITTS, A.B. GARNSWORTHY, I. HENDERSON, A. KURKJIAN, J.P. MEASURES, M. MOUKADDAM, P. RUOTSALAINEN, J. SMALLCOMBE, J.K. SMITH, D. SOUTHALL, M. WILLIAMS, TRIUMF, A.J. MITCHELL, ANU, C.Y. WU, LLNL — The lithium isotopic chain is an ideal laboratory for studying magnetic properties of nuclei. Recently, ab initio theoretical calculations have investigated charge current distributions in light nuclei, which give rise to M1 transition rates and magnetic moments, and have achieved precision comparable to available experimental data. Therefore, new experimental efforts are necessary to fill in the gaps for the further development of nuclear models. We have performed new lifetime measurements of the bound excited states of 7,8Li in order to precisely determine the M1 transition strengths in these nuclei. The experiment was performed at TRIUMF using the TIGRESS array, populating excited states through (d,p) reactions in inverse kinematics. The lifetimes were determined using the Doppler Shift Attenuation Method, and the results of these measurements will be discussed.

Thursday, October 17, 2019 8:30AM - 9:54AM — Session RD Instrumentation for Electron Scattering Experiments Salon 4 - Paul Reimer

8:30AM RD.00001 Performance of the PREX-II Apparatus¹, CIPRIAN GAL, Stony Brook University, PREX-II AND CREX COLLABORATION — The PREX-II and CREX experiments at the Thomas Jefferson National Accelerator Facility will measure the neutral weak form factors for 208Pb and 48Ca respectively at one judiciously chosen Q² value each that enhance the sensitivities to their respective neutron RMS radii. The results of these experiments will constrain the density dependence of the symmetry energy of neutron-rich matter, with implications for three-neutron forces and the properties of neutron stars. The experimental designs require dense isotopically pure targets capable of withstanding high luminosity, radiation hard detectors, precision electronics and diagnostic tracking detectors to calibrate the acceptance and absolute momentum scale and precision polarimetry. We will report on the performance of various subsystems and the projected sensitivity of the data collected to date.

¹Work supported by DOE, NSF and NSERC

8:42AM RD.00002 Polarized Electron Beam for the PREX-II Experiment. CARYN PALATCHI, University of Virginia, PREX COLLABORATION — PREX and CREX are parity violating electron scattering experiments currently running at Jefferson Lab. These experiments aim to map the weak charge distribution in nuclei and thus constrain nuclear structure models with implications for the equation of state of highly dense matter, neutron stars, and gravitational waves produced in neutron star collisions. One common crucial component of these experiments is control of helicity correlated false asymmetries in the polarized electron beam. To achieve the parity quality beam necessary for the small systematic uncertainties required in PREX-II, innovative techniques in the electron source were required. A key technology is the newly installed RTP Pockels cell system in the laser optics of the polarized electron source. This talk will describe the development of the this new RTP Pockels cell system in the injector source with precision nano-meter level control capabilities which helped achieve parity quality beam for PREX-II and CREX.

8:54AM RD.00003 Focal Plane Detector Package for PREX-II¹, DUSTIN MCNULTY, Idaho State University, PREX/CREX AND JLAB HALL A COLLABORATION — The Pb Radius Experiment, PREX, aims to make a high precision, statistics limited measurement of a sub-ppm parity violating asymmetry. To achieve this goal in relatively short time requires high (GHz-level) scattered flux rates on the main integrating detectors. As a result, the PREX-II main detectors employ radiation-hard, high-purity Spectrosil 2000 fused-silica tiles as an active Cerenkov medium for counting electrons. Each tile is optically polished and coupled to a photo-multiplier tube with a quartz window for UV light transmission. The focal plane detector packages also each include three 10x20 cm² active area GEM tracking planes for Q² normalization, and two auxiliary quartz detectors for monitoring parity non-violating asymmetry backgrounds from any residual transverse polarization of the electron beam. Detailed studies of expected flux rates, detector photo-electron yields, and pmt gains have been made in order to optimize the detector design as well as test and minimize the systematic uncertainty associated with pmt non-linearity. In this talk, we will present the design of the PREX-II focal plane detector package and report on the key performance parameters achieved during the experiment.

¹NSF Award No.’s 1307340 and 1615146
9:06AM RD.00004 Use of gemdetectors for the proton polarimeter trackers of the super bigbite spectrometer in JLAB.1, ANURUDDHA RATHNAYAKE, University of Virginia, SBS COLLABORATION COLLABORATION — The Jefferson lab’s 12 GeV beam upgrade and the newly designed super bigbite spectrometer make possible a new generation of experiments to measure nucleon form factors, which is essential for our understanding of the structure of the nucleon, with high precision at high q^2 values over 10 GeV. The concept of the super bigbite spectrometer, which provides large solid angle and the capability to operate at high luminosity, is based on new gas electron multiplier (gem) based particle trackers. The Jlab gem chambers are expected to provide a good position resolution of 70 μm, while operating in high rate conditions up to 0.5 Mrz/s. A set of 44 gem detector modules, each with an active area of 60x30 cm, has been built in the gem detector lab at UVA for the proton polarimeter trackers of SBS. This talk will report on the assembly and commissioning of the 60x200 cm2 gem tracker layers for the SBS polarimeter using the gem modules.

1Department of Energy

9:18AM RD.00005 Commissioning of the Gas Electron Multiplier System for the E12-17-004 Neutron Polarimeter1, MALINGA RATHNAYAKE, Hampton University, E12-17-004 (GEN-RECOIL) COLLABORATION — A large set of Gas Electron Multiplier (GEM) detectors is being commissioned for a novel neutron polarimeter based on elastic and charge-exchange recoil proton detection in experiment E12-17-004 under preparation for the Super-Bigbite Spectrometer (SBS) program at Jefferson Lab. The status of the commissioning activity and performance of the GEM detectors will be presented.

1This work is supported by DOE award DE-SC0013941.

9:30AM RD.00006 A Novel Neutron Polarimeter for the E12-17-004 Experiment1, THIR GAUTAM, Hampton University, E12-17-004 (GEN-RECOIL) COLLABORATION — A novel neutron polarimeter design has been conceived for the E12-17-004 experiment prepared for the Super-Bigbite program at JLab to measure the neutron electric-to-magnetic form factor ratio via neutron recoil polarization in quasielastic electron-deuteron scattering. Three analyzing processes are pursued: np elastic scattering with detection of small-angle neutrons and tracking of large-angle protons, as well as charge-exchange np scattering with tracking of forward-angle protons. The concept and layout of the experiment and expected performance of the polarimeter is presented.

1This work is supported by DOE award DE-SC0013941.

9:42AM RD.00007 Software and simulation framework for the Super Bigbite Spectrometer, ERIC FUCHHEY, University of Connecticut, SUPER BIGBITE SPECTROMETER COLLABORATION COLLABORATION — Super Bigbite Spectrometer is a new instrument in preparation to take data in Hall A at Jefferson Laboratory starting in 2021. It will consist of large aperture magnet with a modular detector package, and will be combined together with another arm (that will vary depending on the measurement). Its core physics program consists in the measurement of the nucleon form factors at large values of Q^2, but is versatile enough to perform other measurements such as semi-inclusive DIS or even tagged DIS. Those measurements have in common to require high luminosity, which, combined with the large solid angle and open geometry, induces large trigger and background rates, which makes those measurements particularly challenging. Overcoming those challenges will require a lot of preparation including simulations to both evaluate actual experimental conditions and prepare pseudodata samples to develop the analysis chain. In this talk I will review the simulation and software framework, their capabilities and potential further developments. I will also illustrate the experimental challenge we have to face and overcome with the example of the tracking for the measurement of the proton electric form factor G_E.

Thursday, October 17, 2019 8:30AM - 10:30AM — Session RE Mini-Symposium: Lattice QCD for PDFs — Salon 5 — David Richards, Thomas Jefferson National Accelerator Facility

8:30AM RE.00001 Light-cone PDFs using Lattice QCD: an overview of results, successes and challenges1, MARTHA CONSTANTINOU, Temple University — Lattice QCD is a theoretical non-perturbative approach for the study of QCD dynamics numerically from first principles. The lattice formulation is widely used for hadron structure calculations and is becoming a reliable tool, striving for control of various sources of systematic uncertainties. Parton distribution functions (PDFs) have a central role in understanding hadron structure, and have been calculated in lattice QCD mainly via their Mellin moments. In this talk we will present results for alternative new methods to access PDFs, that is, quasi-PDFs, pseudo-PDFs and good lattice cross sections. The main focus of the talk is to demonstrate the successes and challenges in these approaches and the need of a careful investigation of systematic uncertainties. Lattice data will be compared against results from global fits of PDFs. Of particular importance are the lattice results on the transversity PDFs, which are not well-constrained experimentally. This presents a major success for the emerging field of direct calculations of distribution functions using lattice QCD.

1Supported by NSF (Grant No. PHY-1714407) and DOE (within the TMD Topical Collaboration)

9:06AM RE.00002 Gluon PDF Calculation from Lattice QCD Using Pseudo-PDF Technique, TANJIB KHAN, CONSTANTINOS ORGINOS, College of William & Mary, DAVID RICHARDS, Thomas Jefferson National Accelerator Facility — In this talk, I report on our calculation of the unpolarized gluon parton distribution function (PDF) in the nucleon using Pseudo-PDF technique. The computation is done on a 32^3 × 64 isotropic lattice with a pion mass of 380 MeV and lattice spacing, a = 0.098 fm using 2+1 flavor of Clover-Wilson fermion. This is the first application of the distillation method for constructing the nucleon interpolating fields for gluonic matrix elements. The bare matrix elements are calculated using the summation method. In order to reduce the statistical fluctuations, the gluonic operators are smeared using gradient flow. The systematic effects introduced by this smearing are studied as a function of the flow-time and the renormalized matrix elements are extracted by taking the small flow-time limit. Finally the lattice matrix elements are factorized to the MTS scheme PDF, at the small z-separation limit, using NLO matching formula.
9:18AM RE.00003 Valence PDF of pion from fine lattices using quasi- and pseudo-PDF frameworks¹, NIKHIL KARTHIK, TAKU IZUBUCHI, Brookhaven National Laboratory, LUCHANG JIN, University of Connecticut, CHRISTOS KALLIDONIS, Stonybrook University, SWAGATO MUKHERJEE, PETER PETRECKZY, CHARLES SHUGERT, Brookhaven National Laboratory, SERGEY SYRITSYN, Stonybrook University, XIANG GAO, Brookhaven National Laboratory, BNL-SBU-UCONN TEAM — We present numerical results on valence PDF of pion from our lattice computations at two fine lattice spacings of 0.04 and 0.06 fm. We employ both quasi- as well as pseudo-PDF methods to place a tighter constraint on the PDF as determined through corresponding perturbative matching. We will also present some preliminary analysis of pion GPD on the same lattice ensembles.

¹The U.S. Department of Energy, Office of Science, Office of Nuclear Physics and High Energy Physics through the Contract No. de-sc0012704

9:30AM RE.00004 Pion Valence Quark Distribution from Hadronic Lattice Cross Sections¹, RAZA SUFIAN, Jefferson Lab, COLIN EGERER TEAM, JOSEPH KARPIE TEAM, KOSTAS ORGINOS TEAM, JIAN-WEI QIU TEAM, DAVID G. RICHARDS TEAM — It has been shown that a class of matrix elements of two spatially-separated currents, which are computable directly in Lattice QCD, can be factorized into parton distribution functions with calculable hard coefficients [Phys. Rev. Lett. 120 (2018) no. 2, 022003]; in the same manner as the parton distribution functions are extracted from the hadronic cross sections measured computable directly in Lattice QCD, can be factorized into parton distribution functions with calculable hard coefficients. In this presentation, we present the progress towards solving the large-x behavior of pion valence quark distribution using Lattice QCD calculation from spatially separated current-current correlations in the coordinate space. Results are presented on several lattice ensembles, thereby addressing finite-volume, discretization and quark mass effects in the extracted distributions.

¹This work is supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics under Contract No. DE-AC05-06OR23177, within the framework of the TMD Collaboration.

9:42AM RE.00005 On the inverse problem of obtaining parton distribution functions from lattice QCD¹, KOSTAS ORGINOS, College of William & Mary — Computations of parton distribution functions (PDFs) of hadrons form first principles represent an important challenge for lattice QCD. Recent theoretical developments, have identified a class of hadronic matrix elements that in principle provide access to the desired PDFs. However, accessing the PDFs requires solving an ill-defined inverse problem. In this talk I will discuss methods that allow us to address that problem and compare several of the available options.

¹This work has been supported by the U.S. Department of Energy through Grant Number DE-FG02-04ER41302, and through contract Number DE-AC05-06OR23177, under which JSA operates the Thomas Jefferson National Accelerator Facility. Computations were performed at ORNL, NERSC, JLab and the WM SciClone cluster.

9:54AM RE.00006 Machine Learning for Quasi-PDF Matrix Elements¹, HUEY-WEN LIN, Michigan State Univ — The largemomentum effective theory (LaMET) framework has been widely used to calculate the Bjorken-x dependence of PDFs in latticeQCD hadron-structure calculations. However, achieving sufficient precision for large-momentum hadrons can be computationally expensive on super-fine lattice ensembles and their lattice artifacts are seldom addressed. In this talk, we will report on-going progress on the study of systematics in quasi-PDFs using multiple lattice spacings and volumes. Then, we apply machine learning algorithms to a few selected quasi-PDF matrix elements and determine how much it can help the PDF determination.

¹This work is supported by the US National Science Foundation under grant PHY 1653405 CAREER: Constraining Parton Distribution Functions for New-Physics Searches.

10:06AM RE.00007 Confronting lattice parton densities within global QCD analysis, JACOB BRINGEWATT, University of Maryland, College Park, M. CONSTANTINOU, Temple University, W. MELNITCHOUK, J. QIU, N. SATO, Jefferson Lab, F. STEFFENS, Bonn University, JEFFERSON LAB ANGULAR MOMENTUM (JAM) COLLABORATION — Recent progress in lattice QCD simulations of parton quasi-distributions is paving the way towards the study of the momentum dependence of PDFs from first principles. We present the first combined global QCD analysis of inclusive deep-inelastic scattering, Drell-Yan and other high-energy scattering data with recent results from lattice calculation of the u − d PDF in the proton. We examine how the lattice results match with phenomenological determinations of PDF parameters, and determine which regions of parton fraction in the lattice data induce constraints on the d − u PDF asymmetry in the proton.

10:18AM RE.00008 From Qubits to Quarks: Parton Physics on a Quantum Computer, SCOTT LAWRENCE, University of Maryland, College Park, NUQS COLLABORATION — Quantum computers provide a unique way of computing real-time correlators from first principles, a task not yet achievable on classical computers due to the sign problem. The determination of parton distribution functions on the euclidean lattice is obstructed by an inability to properly calculate real-time correlators. This is a match made in heaven: a lattice field theory simulation on a quantum computer may provide access to PDFs. In this talk we outline recent progress on simulating field theories on a quantum computer, and show how this progress may be leveraged to obtain PDFs.

Thursday, October 17, 2019 8:30AM - 10:06AM –
Session RF Muon-Proton Scattering  Salon 6 - Evie Downie, George Washington University
8:30 AM RF.00001 The Role of Lepton Mass in QED Corrections for Muon Scattering on a Nucleon.\(^1\), ANDREI AFANASEV, George Washington University — In order to address the proton radius puzzle through measuring the muon-proton and electron-proton elastic cross sections in the same experiment (MUSE), QED corrections have to be taken into account. In this talk, we will report both kinematic and dynamical sources of the differences between muon-nucleon and electron-nucleon elastic scattering. In addition, single-spin asymmetries caused by muon beam polarization will be shown to affect the scattering cross section at 0.1 per cent level. Novel effects due to the lepton mass are incorporated into a Monte-Carlo code ELRADGEN.

\(^1\)The author acknowledges collaboration with Oleksandr Koshchii and Alex Ilyichev. This work is supported in part by NSF PHY-1812343.

8:42 AM RF.00002 Hyperfine splitting in muonic hydrogen and two-photon exchange on nucleons, OLEKSANDR TOMALAK, University of Kentucky — Future precise measurements of the ground state hyperfine splitting (HFS) in muonic hydrogen by CREMA and FAMU collaborations as well as at J-PARC will provide strict constraints on the low-energy proton structure. Two-photon exchange (TPE) enters as a leading proton structure correction to HFS. Exploiting the precise HFS measurements in electronic hydrogen, I will extract the TPE correction and make an accurate prediction for the HFS in muonic hydrogen. Moreover, I will present TPE correction to the Lamb shift and HFS on the neutron inside a nucleus and contrast it with the correction on the proton.

8:54 AM RF.00003 The Muon Proton Scattering Experiment (MUSE), EVANGELINE DOWNIE\(^2\), George Washington University, MUSE COLLABORATION — The proton radius puzzle began in 2010 when the CREMA Collaboration released their measurement of the proton radius (Pohl et al. (2010)) from muonic hydrogen spectroscopy: \(r_p=0.84184(67)\) fm, This was five standard deviations smaller than the accepted CODATA value at that time \(0.8768(69)\) fm, and sparked an enduring and intriguing puzzle MUSE, the MUon proton Scattering Experiment, was first proposed in 2012 to be the first muon proton elastic scattering experiment with sufficient precision to address the proton radius puzzle. MUSE has the capacity to simultaneously measure elastic muon-proton, and electron-proton scattering, and switch polarities to measure with opposite charge states. As such, MUSE can directly measure the two-photon effect by comparing charge-states, and compare muon and electron scattering with minimal systematic error. We will review the motivation for and status of MUSE, which is due to begin running in 2019.

\(^2\)This material is based upon work supported by the National Science Foundation under Grant Numbers PHY-1614850 and PHY-1714833.

9:06 AM RF.00004 MUSE experiment status - Recent test program, SHRADDHA DOGRA, Rutgers University, New Brunswick, MUSE COLLABORATION — The Muon proton Scattering Experiment (MUSE) uses the PiM1 beam line of the Paul Scherrer Institute to simultaneously measure elastic scattering of electrons and muons from a liquid hydrogen target to extract the charge radius of the proton. By comparing the two measured scattering cross sections, the experiment will provide more data for the proton radius puzzle and determine if the radius is the same when using different particle types in obtaining the proton radius. This presentation will show test run results from the summer 2019 beam time, which is measuring detector performance and beam properties, and performing initial cross section tests.

9:18 AM RF.00005 Recent Test Results and Experiment Status at MUSE, WAN LIN, Rutgers University, New Brunswick, MUON PROTON SCATTERING EXPERIMENT (MUSE) COLLABORATION — The Muon proton Scattering Experiment (MUSE) at the PiM1 beam line of the Paul Scherrer Institute is aiming to simultaneously measure elastic scattering of electrons and muons from a liquid hydrogen target to extract the charge radius of the proton. By comparing the two scattering cross sections, the experiment will provide more data for the proton radius puzzle and determine if the radius is the same when using different particle types in obtaining the proton radius. This presentation will show test run results from the summer 2019 beam time, which is measuring detector performance and beam properties, and performing initial cross section tests.

9:30 AM RF.00006 The Liquid Hydrogen Target for MUSE, HALEY REID, University of Michigan — The MUon Scattering Experiment (MUSE) at the Paul Scherrer Institute (PSI) in Switzerland aims to resolve the proton radius puzzle by simultaneously measuring elastic scattering of electrons and muons from a liquid hydrogen target. MUSE requires a target system with a vertically movable assembly that can accommodate five target positions. The main target is a cylindrical Kapton-wall cell with copper end caps containing 280 mL of LH2. Other target positions are for a dummy cell, two solid targets for vertex reconstruction and detector alignment, and an empty position. In this presentation we report on the technical design and implementation of the target system and present data demonstrating the successful operation of the LH2 target.

\(^1\)This work has been supported in part by US National Science Foundation grants PHY-1614938, PHY-1614456 and PHY-1614773.

9:42 AM RF.00007 Understanding the Paul Scherrer Institute's PiM1 Beamline for MUSE, ETHAN CLINE, Rutgers University, New Brunswick, MUSE COLLABORATION — The MUon proton Scattering Experiment (MUSE) at the PiM1 beam line of the Paul Scherrer Institute will simultaneously measure elastic scattering of electrons and muons from a liquid hydrogen target to extract the charge radius of the proton. By comparing the two scattering cross sections, the experiment will shed light on the proton radius puzzle and test lepton universality and the two-photon exchange. This talk will present results from the summer 2019 beam studies. It will be shown how the beam line can be used as a relative momentum spectrometer to extract the momentum of each particle species in the beam. The understanding of the production source distributions will also be presented.

\(^1\)This work has been supported in part by US National Science Foundation grants PHY-1614938, PHY-1614456 and PHY-1614773.
Thursday, October 17, 2019 8:30AM - 9:42AM —
Session RK Nuclear Reactions: Hadrons / Light Ions  Salon F/G -  Heather Crawford, Lawrence Berkeley National Laboratory

8:30AM RK.00001 Spin responses to pion quasi-free scattering. , R. J. PETERSON, University of Colorado, Boulder — Parity conservation for the scattering of spin zero beams implies only transverse (S x q) spin transfer. This allows a decomposition of spin transfer S=0 and S=1 in terms of elementary spin amplitudes, similar to use of the Rosenbluth decomposition as used for relativistic electron scattering. For pion beams these amplitudes are known for scattering and charge exchange on nucleons, so a separation of spin and nonspin single nucleon responses is possible for quasi-free pion scattering from nucleons within complex nuclei. A large body of pion quasi-free data, with and without charge exchange, allows single-nucleon responses of complex nuclei to be determined across a wide range of nuclei for several pion beam energies. Nonspin intercepts and transverse spin slopes will be presented to test this concept for consistency and a summary will be provided.

8:42AM RK.00002 Inelastic reaction of 14 MeV neutrons from 7Li . CHAD FORREST, Laboratory for Laser Energetics — Results of measurements are reported for the double-differential cross section (d²σ/dEₙdΩₙ) for the inelastic scattering and reaction of 14-MeV neutrons with ⁷Li. In the experiment, the bright neutron source (L = 10²⁴ s⁻¹) created by the OMEGA pulsed Laser System was used. For scattering and reaction we detected with a high-yield neutron time-of-flight spectrometer. In a forward-angle geometry (θ = 0° to 7.5°), the differential neutron cross section, measured for the neutron energy range 0.5 MeV ≤ En ≤ 6 MeV, shows significant deviations from evaluated data in the nuclear database. This material is based upon work supported by the Department of Energy Nuclear Security Administration under Award Number DE-NA0003856.


8:54AM RK.00003 Effect of nuclear transparency from the (p,2p) measurements on 6Li and 12C at 1 GeV. , VITALY BATURIN, Old Dominion University, EUGENY KOMAROV, VLADIMIR NELYUBIN, VALENTINE SULIMOV, VLADIMIR VIKHROV, Petersburg Nuclear Physics Institute, Russia — We studied the production of protons to the backward direction in (p,2p) reactions on 6Li and 12C, accompanied by a proton emitted into the forward hemisphere. The momenta of the final two protons were measured in a wide range with the two-arm time-of-flight spectrometer. For each event we reconstructed the mass of the intermediate off-shell particles. We have discovered a strong narrow dip in the mass spectra of intermediate mesons at the mass of the real pion. We explain this effect as an abrupt decrease of the absorption probability for on-shell mesons (the pion–nuclear transparency).

9:06AM RK.00004 L/T separated cross sections and beam asymmetries in kaon electroproduction above the resonance region¹, MIREILLE MUHOZA, RICHARD TROTTA, The Catholic University of America — The 12 GeV JLab beam energy and the new Super-High Momentum Spectrometer (SHMS) in Hall C have enabled measurements of precision longitudinal-transverse separated cross sections in exclusive K⁺ production from the proton above the resonance region. The data acquired by experiment E12-09-011, and the anticipated L/T separated cross sections will be an important step forward in understanding the nonperturbative structure of hadrons including strangeness and the transition from hadronic to partonic degrees of freedom in exclusive processes. Kaons were detected in the SHMS in coincidence with scattered electrons in the H1S. Kaon-proton separation was provided by a threshold aerogel detector and kaon-pion separation by a gas Cherenkov detector. Data were taken in near-parallel kinematics to two electron beam energies. Fitting the azimuthal angle dependence of the measured unpolarized cross section allows for a full separation of the structure functions σ₅, σ₇, σ₉ and σ₁₀. The beam single spin asymmetry from a longitudinally polarized beam leads to a fifth structure function σ₇,₂₉. Kaon and pion asymmetries were acquired at Q² = 3.0, W = 2.32, x = 0.40. I will give an overview of the experiment and show initial results.

¹Supported in part by NSF award PHY1714133

9:18AM RK.00005 Deuteron-alpha scattering: separable vs nonseparable Faddeev approach. , LINDA HLOPHE, Michigan State University, LEI JIN, CHARLOTTE ELSTER, Ohio University, ANDREAS NOGGA, Forschungszentrum Jülich, FILOMENA NUNES, ARNAS DELTUVA, Institute of Theoretical Physics and Astronomy, Vilnius University — Deuteron-induced nuclear reactions are an essential tool for probing nuclear structure as well as extracting properties of astrophysical interest. Those (d,p) reactions may be viewed as three-body reactions and described with Faddeev techniques. Specifically, the Alt-Grassberger-Sandhas (AGS) formulation of the Faddeev equations is adopted in this work. A great simplification of the Faddeev-AGS equations occurs if the subsystem interactions are of separable form. However, it needs to be demonstrated that observables calculated based on separable interactions agree exactly with those based on nonseparable forces. We thus use the example of deuteron-alpha scattering to benchmark the separable expansion approach to solving the Faddeev equations without the Coulomb potential. To do so, elastic as well as breakup observables are calculated and compared to results in which the interactions in the two-body sub-systems are represented by separable interactions derived in the Ernst-Shakin-Thaler (EST) framework. We find that the calculations based on the original interactions and their separable presentations give results that are in excellent agreement.
Experiments

16 Gamma efficiency is not currently known for existing experiments and could be a source of a hidden systematic error. This proposed calibration technique for in one or both types of experiments. Absolute proton counting is an essential to the "beam" experimental approach. The absolute detector "storage" methods of measuring the lifetime of the neutron. A possible reason for this is a systematic uncertainty that is not properly accounted efficiency for use in "beam" determinations of the free neutron lifetime. There is currently a 4-sigma disagreement between the "beam" and "bottle" measurements. Here, we discuss new techniques to measure the neutron lifetime using space-based neutron spectroscopy. We will present several possible designs for space-based experiments suitable for use at the Moon or terrestrial planets. These instruments are based on detectors previously flown on NASA planetary science missions including Lunar Prospector and MESSENGER. We will discuss the scale of expected systematics and place constraints on the mass, power and orbital characteristics required to make a measurement of neutron lifetime with sufficiently small uncertainty to help resolve the current discrepancy.

8:30AM RL.00001 Space-based Approaches to Resolving the Neutron Lifetime Anomaly1, DAVID LAWRENCE, JACK WILSON, Johns Hopkins University Applied Physics Laboratory, VINCENT EKE, JACOB KEGGERREIS, Durham University, PATRICK PEPLOWSKI, Johns Hopkins University Applied Physics Laboratory — Free neutrons decay via the weak interaction with a mean lifetime of around 882 s. Knowledge of this lifetime is important as it provides constraints on the unitarity of the CKM matrix and is a key parameter for studies of Big Bang nucleosynthesis. Two classes of experiments have successfully made measurements of neutron lifetime: the ‘Beam’ class involve measuring the activation of cold neutron beams and the ‘Bottle’ class uses storage (material, magnetic and/or gravitational) to trap neutrons and measure the rate of decay during storage. However, there currently exists a 4-sigma disagreement between the ‘beam’ and ‘bottle’ measurements. Here, we discuss new techniques to measure the neutron lifetime using space-based neutron spectroscopy. We will present several possible designs for space-based experiments suitable for use at the Moon or terrestrial planets. These instruments are based on detectors previously flown on NASA planetary science missions including Lunar Prospector and MESSENGER. We will discuss the scale of expected systematics and place constraints on the mass, power and orbital characteristics required to make a measurement of neutron lifetime with sufficiently small uncertainty to help resolve the current discrepancy.

1This work is supported by the JHU/APL Independent Research and Development Program

8:42AM RL.00002 An experiment to measure the Proton Branching Ratio in Neutron Beta Decay (UCNProBe)1, MD HASSAN, ZHAOWEN TANG, CHRIS CUDE-WOODS, STEVEN CLYTON, TAKEYASU ITO, Los Alamos National Laboratory, BO JHONSON, Utah State University, MARK MAKELA, CHRIS MORIS, CHRIS O’SHAUGHNESSY, ANDY SAUNDERS, Los Alamos National Laboratory, UCNPROBE COLLABORATION — The free neutron decays into an electron, proton, and antineutrino with a characteristic lifetime with a 100% branching ratio according to the Standard Model. The neutron lifetime has been measured primarily in two methods: the beam method and the ultracold neutron (UCN) bottle method. The lifetime measured in these two methods differs by about five standard deviations. One potential explanation for this discrepancy is that some fraction of neutron decays produce undiscovered decay particles instead of protons. The UCNProBe experiment aims to resolve this inconsistency by implying a novel technique to determine the neutron decay branching ratio using a deuterated scintillator box as a UCN storage volume to detect electrons from the beta decay. An overview and update of the UCNProBe experiment will be presented.

1Department of Energy, Los Alamos National Laboratory LDRD

5:44AM RL.00003 Precision Measurement of Cold Neutron Flux using Alpha-Gamma1, EVAN ADAMEK, University of Tennessee — The Alpha-Gamma device at NIST utilizes the interaction of neutrons with a totally absorbing 10B target to precisely measure the flux of a monochromatic neutron beam. This measurement provides a calibration of the 6Li(n,α)3H based flux monitor used in the NIST neutron lifetime experiment to better than 0.1

1Funding is provided by DOE DE-FG02-03ER41258

9:06AM RL.00004 Absolute Proton Detection Efficiency Determination in “Beam” Experiments1, GRANT RILEY, University of Tennessee — This talk introduces a new proposed method to measure proton detector efficiency for use in “beam” determinations of the free neutron lifetime. There is currently a 4-sigma disagreement between the “beam” and “storage” methods of measuring the lifetime of the neutron. A possible reason for this is a systematic uncertainty that is not properly accounted for in one or both types of experiments. Absolute proton counting is an essential to the “beam” experimental approach. The absolute detector efficiency is not currently known for existing experiments and could be a source of a hidden systematic error. This proposed calibration technique can also be extended to new, large area particle detectors designed for future experiments.

1DOE DE-FG02-03ER414258

9:18AM RL.00005 Magnetic Field Characterization of the UCNτ Magneto-gravitational Ultracold Neutron Trap1, ADAM HOLLEY, Tennessee Technological University, UCNTAU COLLABORATION — The UCNτ experiment employs a large-volume magneto-gravitational trap to measure the free neutron lifetime by counting surviving ultracold neutrons (UCN) following storage in a combined magnetic and gravitational potential. In this "bottle" approach, loss of UCN from any non-UCN-type neutrons produces a systematic error. Magnetic field gradients generated by, for example, an array of permanent magnets can be used to confine polarized UCN, eliminating wall interactions that lead to such losses, the dominant systematic effect in non-magnetic (material) bottles. What remains is a small residual systematic effect associated with the dynamics of UCN spin in the trap. Assessing both the effectiveness of the trapping potential at preventing wall collisions, as well as spin dynamics, requires measuring the magnetic field with ~mm spatial precision near the surface of the trap. We have constructed an automated magnetic mapper capable of performing in situ magnetic field maps of the UCNτ Halbach array with high spatial precision, and are engaged in an ongoing mapping campaign to characterize the UCNτ trap. We will describe this instrument, present a first set of detailed scans, and discuss implications for magnetic field related systematic effects.

1This work was supported by the National Science Foundation, no. PHY-1553861
9:30AM RL.00006 Measuring Systematic Effects in the UCN$^+$ Experiment\textsuperscript{1}. FRANCISCO GONZALEZ, Indiana University Bloomington, UCN$^+$ COLLABORATION — The UCN$^+$ experiment at Los Alamos National Laboratory measures the neutron lifetime by storing ultracold neutrons (UCN) in a magnetogravitational trap for variable holding times. Loss mechanisms besides $\beta$-decay add systematic uncertainties by potentially removing UCN before detection. Magnetic field anomalies can enhance UCN depolarization rates. Field mapping and in-situ detection help place limits on this effect. Before storage, UCN with energies above the trapping potential are removed, but over-threshold UCN could escape due to heating or insufficient cleaning. In-situ detection at various heights and an improved cleaner detector monitor high-energy UCN, constraining these losses. Detection and spectral cleaning efficiency couple to UCN phase-space distribution. Comparing UCN arrival times quantifies phase-space evolution. A buffer volume installed between the UCN source and trap has improved characterization of the UCN spectrum and reduced the effect of the beam structure on normalization. Alongside these improvements, Monte Carlo simulations of UCN trajectories give insight needed to understand and minimize loss mechanisms. We will present work done to constrain these systematic effects as part of an effort to reduce UCN$^+$'s total uncertainty to about 0.25s.

\textsuperscript{1}DOE, LANL LDRD, NSF

9:42AM RL.00007 ABSTRACT WITHDRAWN –

9:54AM RL.00008 Preliminary Design of the Magnet System for the LANL nEDM Experiment. JARED BREWINGTON, University of Kentucky, LANL-NEDM COLLABORATION — Permanent electric dipole moments represent a prospective avenue for the discovery of beyond standard model physics. The advent of experimental techniques using stored ultracold neutrons (UCNs) has placed the neutron electric dipole moment (nEDM) at the forefront of EDM searches. The current experimental upper limit for the nEDM is \( d_n < 3 \times 10^{-26} \text{ e-cm} \) (90\% CL). The neutron EDM search to be conducted at Los Alamos National Laboratory (LANL) aims to advance the experimental measurement of the nEDM by an order of magnitude. Achieving the goal sensitivity of \( 3 \times 10^{-27} \text{ e-cm} \) requires a highly uniform \( B_0 \) holding field as well as efficient transport of UCN polarization from the neutron source into the storage volume. This talk will discuss the design techniques and preliminary design of the \( B_0 \) coil and the spin transport coil system for the LANL-nEDM experiment. This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under Award Number DE-SC0014422, the NSF under Award Number PHY-1828568, and by the LANL LDRD program.

Thursday, October 17, 2019 8:30AM - 10:30AM –
Session RM Nuclear Astrophysics: Supernovae Salad J - Alfredo Estrade, Central Michigan University

8:30AM RM.00001 Nucleosynthesis of $^{60}$Fe and constraints on the nuclear level density and photon strength function. DEBRA RICHMAN, ARTEMES SPYROU, MALLORY SMITH, KATIE CHILDERS, REBECCA LEWIS, SEAN LIDICK; STEPHANIE LYONS, ALICIA PALIMISANO, CHANDANA SUMITHRARACHCHI, Michigan State University, ALEX DOMBOS, FARHEEN NAQVI, University of Notre Dame, ANN-CECILIE LARSEN, MAGNE GUTTMORSEN, JOERGEN MIDD-BOE, University of Oslo, PANOS GASTIS, GEORGIOS PERDIKAKIS, Central Michigan University, AARON COUTURE, CHRIS PROKOP, Los Alamos National Laboratory, ADRIANNA URECHE, University of California Berkeley, BEN CRIDER, Mississippi State University — $^{60}$Fe is created in massive stars prior to core collapse supernova. The signature $\gamma$-rays from $\beta$-decay of this isotope indicate ongoing nucleosynthesis in the Galaxy among other interesting astrophysical processes. In order to understand these observations a complete understanding of the creation, destruction and nuclear properties of $^{60}$Fe in the astrophysical environment are required. Due to the short half-life of $^{59}$Fe a direct capture reaction experiment to determine the cross section of $^{59}$Fe($n,\gamma$)\textsuperscript{60}Fe has been a challenge and remains the most uncertain link in the reaction chain to date. Using the $\beta$-decay of a $^{60}$Mn radioactive beam to populate high energy states in the $^{60}$Fe nucleus, an indirect constraint for this reaction was made using the $\beta$-Oscalo Method. Results from this analysis were used as input in TALYS and the new constraint on $^{59}$Fe($n,\gamma$)\textsuperscript{60}Fe will be presented.

8:42AM RM.00002 Constraining electron capture rates in core-collapse supernovae for nuclei near $N\approx550$. REMCO ZEGERS, Michigan State Univ, NSCL E15112 COLLABORATION, NSCL E16006 COLLABORATION — Electron captures on medium-heavy nuclei play an important role in the late stages of the evolution of core-collapse supernovae, just prior to the explosion. In particular, nuclei around $N=550$, just above $^{78}$Ni, have been identified as especially important for the deleptonization of the core. The astrophysical simulations require accurate electron-capture rates. One has to largely rely on theoretical models, which must be benchmarked and guided by experimental data. This work describes a broad effort to improve the electron capture-rates for nuclear astrophysical simulations, focusing on nuclei near $N=550$. This includes ($^3$He) charge-exchange experiments for extracting Gamow-Teller strengths, the comparison with theoretical models used for calculating electron-capture rates for the astrophysical simulations, and results from sensitivity studies by using 1D core-collapse simulations.

This work is supported by the US National Science Foundation PHY-1430152 (Joint Institute for Nuclear Astrophysics Center for Evolution of the Elements) and PHY-1565546

8:54AM RM.00003 The Effects of Neutrino Oscillations on Core-Collapse Supernova Explosions\textsuperscript{1}. CHARLES STAPLEFORD, CARLA FRHLICH, JAMES KNELLER, North Carolina State University — At the present time even the most sophisticated, multi-dimensional simulations of core-collapse supernovae do not (self-consistently) include neutrino flavor transformation. This physics is missing despite the importance of neutrinos in the core-collapse explosion paradigm. Because of this dependence, any flavor transformation that occurs in the region between the proto-neutron star and the shock could result in major effects upon the dynamics of the explosion. We present the first hydrodynamic core-collapse supernova simulation which simultaneously includes flavor transformation of the free-streaming neutrinos in the neutrino transport. These oscillation calculations are dynamically updated and evolve self-consistently alongside the hydrodynamics. Using a $M = 20 \, M_\odot$ progenitor, we find that while the oscillations can have an effect on the hydrodynamics, flavor transformation alone does not lead to a successful explosion of this progenitor.

\textsuperscript{1}Funded by GAANN Grant P200A150035 and DOE Office of Science, Office of Nuclear Physics Award No. DE-FG02-02ER41216
9:06 AM RM.00004 Effects of the nuclear equation of state on the outcome of core-collapse supernovae. SOMDUTTA GHOSH, SANJANA CURTIS, CARLA FROHLICH, Department of Physics, North Carolina State University, Raleigh, NC 27695, USA — Massive stars end their lives when their core collapses under gravity, resulting in either a core-collapse supernova (successful explosion) or a black hole (failed explosion). Despite many efforts, it is not yet fully understood which massive stars will successfully explode in a core-collapse supernova and which ones will collapse to a black hole. Here, we investigate the impact of the nuclear equation of state (eos) on the outcome of core collapse (successful or failed explosion) and the subsequent nucleosynthesis. We model the explosion in spherical symmetry using the effective push method together with general-relativistic hydrodynamics and neutrino transport. We use several supernova eos(s) and study the variation in explosion properties and nucleosynthesis yields for stars with different masses. We find that the eos significantly impacts the outcome of our simulations.

9:18 AM RM.00005 The Design, Validation, and Future Plans for a New Neutron Detector at Ohio University1. KRISTYN BRANDENBURG, Ohio University — Though (α,n) reaction cross sections play a key role in nuclear astrophysics and applications, many are poorly constrained by nuclear experiments and have significant uncertainties in theoretical predictions. Improving this situation will be done in part using a newly developed neutron long counter, HeBGB, at the Ohio University Edwards Accelerator Lab. The detector was designed using MCNP6 to have near constant efficiency in the neutron energy range relevant for core-collapse supernovae and special nuclear materials. Efficiency validation measurements have been performed with HeBGB, which utilize well-characterized reactions with constrained cross sections and known neutron energies. The first measurement planned for HeBGB is $^{27}$Al(α,n) near threshold, which dominates the astrophysical rate and has disagreement between theoretical predictions and the only prior measurement in this energy regime. In preparation, various aluminum targets have been tested for purity using RBS, PIXE, and PIGE nuclear reaction analysis techniques. We find that store bought aluminum foils offer higher purity than traditional foil suppliers. In addition to these results, an update will be provided on the validation measurements of the HeBGB long counter.

1This work was supported in part by the U.S. DOE through Grant No. DE-FG02-88ER40387 and DE-NA0003883.

9:30 AM RM.00006 Reaction rates that limit $^{44}$Ti from core-collapse supernova as dense matter constraint: Shocking results1. SHIV SUBEDI, ZACH MEISEL, GRANT MERZ. Ohio University — Recent observational advances have enabled high resolution mapping of $^{44}$Ti in core-collapse supernova (CCSN) remnants. Comparisons between observations and 3D models provide stringent constraints on the CCSN mechanism. However, recent work has identified several uncertain nuclear reaction rates that influence $^{44}$Ti and $^{56}$Ni production in model calculations of shock-driven nucleosynthesis. We evolved $15M_{⊙}$, $18M_{⊙}$, $22M_{⊙}$ and $25M_{⊙}$ stars from ZAMS to CCSN in MESA (Modules for Experiments in Stellar Astrophysics) and investigated previously identified sensitivities of $^{44}$Ti and $^{56}$Ni production in CCSN to varied reaction rates. I will present our final results of this sensitivity study. I will also briefly discuss ongoing experimental work motivated by this study namely a direct cross section measurement of $^{19}$K(α,γ)$^{23}$Ca.

1This work was supported in part by the DOE Office of Science under grants DE-FG02-88ER40387 and DE-SC0019042.

9:42 AM RM.00007 Crustal Heating During the Epoch of Crust Replacement , MATTHEW CAPLAN, Illinois State University, ANDREW CUMMING, McGill University — Neutron stars in X-ray binaries may completely freeze the material in their crust, which dominates their cooling rate. Recent work has calculated the composition and heat sources in steady state neutron star crusts and uses them to study the evolution of the heating in partially replaced ‘hybrid’ crusts. In addition, we report calculations of the heating in crusts formed during the replacement of cold catalyzed crusts by accreted matter and make suggestions for resolving crust replacement observationally.

9:54 AM RM.00008 Cross Section Measurements of $(p,γ)$ Reactions in A=100-110 region relevant to the p-process , ORLANDO OLIVAS-GOMEZ, ANNA SIMON, University of Notre Dame, PATRICK MILICAN, Ohio State University, REBEKA KELMAR, University of Notre Dame, EMILY CHUCHMAN, NC State University, ADAM CLARK, SAMUEL HENDERSON, SEAN KELLY, DANIEL ROBERSTON, EDWARD STECH, WANPENG TAN, University of Notre Dame — How to accurately model and predict the observed abundances of the 35 stable p-nuclei remains an open question in the field of nuclear astrophysics. Recent sensitivity studies with regard to reaction network models predicting p-nuclei abundances have identified several radiative capture reactions whose uncertainties have the largest impact on the network model. In order to constrain those uncertainties, the $^{102}$pd(p,γ)$^{103}$Ag, $^{108}$Cd(p,γ)$^{109}$In, and $^{110}$Cd(p,γ)$^{111}$In cross section measurements were measured at the University of Notre Dame Nuclear Science Laboratory. The measurements were performed at lab energies $E_{p} = 3 - 8$ MeV using the HECTOR detector and γ-summing technique. Our results are compared to various theoretical models from the Talys 1.9 and NON-SMOKER reaction codes as well with previous measurements. The theoretical model that best fits the experimental data is used to calculate the inverse $(γ,p)$, $(γ,n)$ reaction rates. Discrepancies with the new reaction rates compared to older theoretical calculations which may have an impact on the reaction network are discussed. This work is supported by the NSF under grants: PHY-1614442, PHY-1713857 (NSL) and PHY-1430152 (JINA-CEE).

10:06 AM RM.00009 Searching for $(γ,α)/(γ,n)$ branching points in the γ-process path around A=1001. REBEKA KELMAR, ANNA SIMON, ORLANDO OLIVAS-GOMEZ, PATRICK MILICAN, CRAIG REINGOLD, EMILY CHUCHMAN, ADAM CLARK, SAMUEL HENDERSON, SEAN KELLY, DANIEL ROBERSTON, EDWARD STECH, WANPENG TAN, University of Notre Dame — In order to model the γ-process it is important to determine the branching points along isotopic chains. The $^{90}$Zr(α,γ)$^{94}$Mo, $^{102}$Pd(α,γ)$^{106}$Cd, and $^{108}$Cd(α,γ)$^{112,114}$Sn cross sections were measured to determine the γ-process path around A=100. Measurements of $^{102}$Pd(α,γ)$^{106}$Cd and $^{110}$Cd(α,γ)$^{112,114}$Sn were branching points in the γ-process reaction flow. The reactions were measured at the University of Notre Dame using the High Efficiency Cy TOTal absorption spectrometer (HECTOR). The $^{90}$Zr(α,γ)$^{94}$Mo and $^{108}$Cd(α,γ)$^{112,114}$Sn measurements extended the range of previously measured cross sections down to lower energies and the $^{102}$Pd(α,γ)$^{106}$Cd and $^{110}$Cd(α,γ)$^{112,114}$Sn reactions were measured for the first time. The measurements were compared to theoretical models from Talys 1.9. The $(γ,α)$ and $(γ,n)$ rates were then calculated using the best fit model and compared in order to investigate the relative intensity between the reaction pathways. It was found that in all cases the $(γ,α)$ reaction pathway begins to dominate within the temperature range of 1.5-3.5 GK.

1This work is supported by the NSF under grants: PHY-1614442, PHY-1713857 (NSL) and PHY-1430152 (JINA-CEE).
10:18AM RM.00001 Photoneutron reaction cross section measurements on \( ^{94}\text{Mo} \) and \( ^{90}\text{Zr} \) relevant to the \( p\)-process nucleosynthesis, A. BANU, E. G. MEEKINS\(^1\), Department of Physics and Astronomy, James Madison University, Harrisonburg, VA 22807, USA, J. A. SILANO\(^2\), H. J. KARIWÓWSKI, TUNL, Durham, NC 27708, USA & University of North Carolina at Chapel Hill, Chapel Hill, NC 27516, USA, S. GORELEY, Institut d’Astronomie et d’Astrophysique, ULB, 1050 Brussels, Belgium — The photodisintegration cross sections for the \( ^{94}\text{Mo}(\gamma,n) \) and \( ^{90}\text{Zr}(\gamma,n) \) reactions have been experimentally investigated with quasi-monochromatic photon beams at the High Intensity \( \gamma\)-ray Source (HI\(S\)) facility of the Triangle Universities Nuclear Laboratory (TUNL). The energy dependence of the photoneutron reaction cross sections was measured with high precision from the respective neutron emission thresholds up to 13.5 MeV. These measurements contribute to a broader investigation of nuclear reactions relevant to the understanding of the \( p\)-process nucleosynthesis. The results are compared with the predictions of Hauser-Feshbach statistical model calculations using two different models for the dipole \( \gamma\)-ray strength function. The resulting \( ^{94}\text{Mo}(\gamma,n) \) and \( ^{90}\text{Zr}(\gamma,n) \) photoneutron stellar reaction rates as a function of temperature in the typical range of interest for the \( p\)-process nucleosynthesis show how sensitive the photoneutron stellar reaction rate can be to the experimental data in the vicinity of the neutron threshold.

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Thursday, October 17, 2019 8:30AM - 10:30AM — Session RN Nuclear Reactions: Heavy-Ions / Rare Isotope Beams Salon K - Dariusz Seweryniak, Argonne National Laboratory

8:30AM RN.00001 Fission Product Chain Yield Measurements at NCERC, T.A. BREDEWEG, E.M. BOND, D.E. DRY, M.E.GOODEN BOND, S.K. HANSON, L.A. HUDSTON, M.R. JAMES, I. MAY, W.J. OLDHAM, R.S. RUNDBERG, Los Alamos National Laboratory — Fission product chain yields were historically determined by chemical separation and beta counting of fissile samples irradiated in carefully controlled fission chamber experiments.\(^1\)\(^2\)\(^3\) These measurements provided the means to extract absolute fission product yields (yield per fission, or \( Y_i/f \) for the \( i\)\(^{th}\) fission product) that are included in the international nuclear data libraries, and ultimately used to model and characterize multiplying systems. However, re-evaluations conducted at Los Alamos National Lab and Lawrence Livermore National Lab in 2005-2009 for neutron-induced fission of \( ^{235}\text{U} \) and \( ^{239}\text{Pu} \) highlighted disagreement among many of the measurements.\(^1\)\(^2\)\(^3\) This led to several new, targeted experimental programs to resolve these disagreements. In this presentation we will highlight recent efforts to address these discrepancies using energy-integral measurements at the National Criticality Experiments Research Center (NCERC), and outline our plans to complete the work over the next several years.

\(^1\)H.D. Selby, et al., Nucl. Data Sheets 111, 2891 (2010)
\(^3\)J. Laurec, et al., Nucl. Data Sheets 111, 2965 (2010)

8:42AM RN.00002 Investigating Nuclear Statistical Properties for Indirect Radiative Capture Cross Section Measurements, C.S. REINGOLD, A. SIMON, University of Notre Dame, N. COOPER, Univ. of Notre Dame, R.O. HUGHES, J.T. BURKE, LLNL, S.P. BURCHER, Univ. of Tennessee Knoxville, K.A. CHIPPS, ORNL, S. AHN, TAMU, D.T. BLANKSTEIN, Univ. of Notre Dame, J.A. CIZEWSKI, Rutgers Univ., M. HALL, Univ. of Notre Dame, S. OTA, A. SAASTAMOINEN, TAMU, K. SCHMIDT, MSU, NSCL, B. SCHROEDER, S. UPADHYAYULA, TAMU — Radiative capture reactions between neutrons and lanthanides are of particular importance to nuclear applications, stellar nucleosynthesis, and stockpile stewardship. Experimental constraints, however, can make direct measurements of these cross sections nontrivial. Therefore, it is essential to have a reliable method for predicting \( (n,\gamma) \) cross sections. One alternative to direct measurement over the relevant mass and energy regions is to calculate the relevant cross section in Hauser-Feshbach formalism, using experimentally constrained nuclear statistical properties. These statistical properties can be extracted from particle-\( \gamma\)-coincidence data via the Oslo method. Indirect measurements for \( ^{145,146}\text{Sm}(n,\gamma) \) and \( ^{159,160}\text{Dy}(n,\gamma) \) have been conducted using the Hyperion detector array at Texas A&M University. Particle-\( \gamma\)-coincidence data for \((p,d)\) and \((p,t)\) reactions on self-supporting \( ^{148}\text{Sm} \) and \( ^{162}\text{Dy} \) targets have been analyzed. Preliminary results will be presented.

\(^1\)This work was supported by the NNSA under grant no. DE-NA0003780 and DE-NA0002132, LLNL contract no. DE-AC5207NA27344, and Texas A&M Nuclear Physics grant no. DE-FG02-93-ER40773

8:54AM RN.00003 Studies of the angular correlations between complementary fragments in multinucleon transfer reactions Xe-136 + Pt-198, S. ZHU, Brookhaven National Laboratory, ATLAS 1713 COLLABORATION — A deep understanding of multi-nucleon transfer reactions is important for the future development in producing the neutron-rich nuclei of interests. The angular correlations of the complementary fragments produced in the reaction of a \( ^{136}\text{Xe} \) beam (8MeV/A) on a \( ^{198}\text{Pt} \) target (1mg/cm\(^2\)) were measured using the CHICOII detector at ATLAS. The results were simulated by using the quantum molecular dynamics (QMD) model. Different Skyrme interaction parameters were applied. It is found that the effect of reaction \( Q\) values almost governs the production of primary fragments with about six or less nucleons being transferred. With the increase of the number of transferred nucleons, the dynamical processes, such as the dissipation of collective motion and the statistical fluctuation of multinucleon transfer, play more important role in the mass distributions. Further detailed study will focus on the mass and isotopic yields with respect to different angles between the target-like and projectile-like fragments. It will provide another direction to improve the model and explore the mechanisms of this type of reactions.

\(^1\)For ATLAS 1713 collaboration: BNL, ANL, LLNL, LBNL, NSCL, Uni. of Rochester, Oregon State Uni., and CIAE. This work was supported in part by the U.S Department of Energy, Office of Science, Office of Nuclear Physics, the National Science Foundation and China Scholar Council.
9:06AM RN.00004 Energy Dependence of Fission Product Yields from $^{235}U$, $^{238}U$ and $^{239}Pu$ for Incident Neutron Energies Between 0.5 and 14.8 MeV, MATTHEW GOODEN, TODD BREDEWEG, DAVID VIEIRA, JERRY WILHELMY, Los Alamos National Laboratory, WERNER TORNOW, Duke University/Triangle Universities Nuclear Laboratory, JACK SILANO, MARK STOYER, ANTON TONCHEV, Lawrence Livermore National Laboratory, SEAN FINCH, FNU KRISHICHAYAN, Duke University/Triangle Universities Nuclear Laboratory — Under a joint collaboration between TUNL-LANL-LLNL, a set of absolute fission product yield measurements has been performed. The energy dependence of a number of cumulative fission product yields (FPY) have been measured using quasi-monoenergetic neutron beams for three actinide targets, $^{235}U$, $^{238}U$ and $^{239}Pu$, between 0.5 and 14.8 MeV. The FPYs were measured by a combination of fission counting using specially designed dual-fission chambers and $\gamma$-ray counting. Each dual-fission chamber is a back-to-back ionization chamber encasing an activation target in the center with thin deposits of the same target isotope in each chamber. This method allows for the direct measurement of the total number of fissions in the activation target with no reference to the fission cross-section, thus reducing uncertainties. Reported are absolute cumulative fission product yields for incident neutron energies of 0.5, 1.37, 2.4, 3.6, 4.6 and 14.8 MeV. New data in the second chance fission region of 5.5 – 11 MeV are included to complete the measurements in the energy range of interest. These results are compared to previous measurements and theoretical estimates.

9:18AM RN.00005 Observation of dynamics in fusion of neutron-rich oxygen nuclei at above-barrier energies, SYLVIE HUDAN, ROMUALDO DE SOUZA, Indiana University Bloomington — The recent observation of heavy element nucleosynthesis in the merging of two neutron stars, underscores the importance of better understanding the fusion of neutron-rich nuclei. While the fusion of stable nuclei has been well studied for several decades, only recently have radioactive beam facilities made it possible to systematically investigate fusion for an isotopic chain of nuclei. Investigating the fusion of neutron-rich nuclei with an extended neutron density distribution can reveal whether fusion dynamics for neutron-rich nuclei differs significantly from that of beta stable nuclei. It also allows one to explore the influence of pairing at low density. To address this question the fusion excitation functions for $^{16,17,18}O + ^{12}C$ will be compared to that of $^{16}O + ^{12}C$. The experimental results will be compared to both simple barrier penetration models as well as the predictions of a density constrained time-dependent Hartree-Fock model (DC-TDHF).

This work was supported by the US Department of Energy under Grant No. DE-FG02-88ER-40404

9:30AM RN.00006 Measurement of the fusion excitation functions for $^{41,45}K + ^{28}Si$ and $^{36,44}Ar + ^{28}Si$ at near-barrier energies, JAMES JOHNSTONE, REKAM GIRI, SYLVIE HUDAN, ROMUALDO DE SOUZA, Indiana University Bloomington, DIETER ACKERMANN, ABOOU CHBIHI, QUENTIN HOURDILLE, GANIL, AUSTIN ABBOTT, CATHERINE BALHOFF, ANDY HANANAN, ALAN MCINTOSH, MAXWELL SORENSEN, ZACHARY TOBIN, ADITYA WAKHLE, SHERRY YENNELLO, Texas AM University — Fusion in neutron-rich environments is presently a topic of considerable interest. Experiments for an isotopic chain allow systematic exploration of the dependence of fusion on neutron number. Recent measurement of the near-barrier fusion excitation functions for $^{40,41,42}K + ^{28}Si$ revealed a 7-fold enhancement in the cross-section for the radioactive isotope relative to the stable isotope. To expand the study of this system away from the closed N=20 and N=28 shells and to explore the role of proton pairing, Experiment 17002 was conducted at NSCL’s ReA3 facility with low-intensity (approximately $10^4$ ions/s) beams. The experiment measured the fusion cross section for $^{41,45}K + ^{28}Si$ and $^{36,44}Ar + ^{28}Si$ for E/A = 2-3 MeV by detecting and identifying fusion products using E-TOF with high efficiency. Details of the experimental setup as well as the measured experimental fusion excitation functions will be presented. Cross-sections will be compared to the previous $^{39,41,43}K + ^{28}Si$ measurements as well as to coupled channels calculations.

This work was supported by the US Department of Energy under Grant Nos. DE-FG02-88ER-40404

9:42AM RN.00007 Experimental Constraints from Heavy-ion Collisions on the Momentum dependence of the Symmetry Potential, KYLE BROWN, Michigan State Univ — Nucleons in dense nuclear matter appear to have reduced inertial masses due to momentum-dependent interactions they experience with other nucleons. This reduction of their masses is often referred to as their effective mass, and at saturation density the masses are reduced to about 70% of their vacuum mass. In asymmetric matter the effective masses of neutrons and protons can be different, leading to an effective mass splitting. The sign and magnitude of this splitting is poorly constrained at densities away from saturation density. Recent experiments at the National Superconducting Cyclotron were performed to help constrain these momentum dependent interactions. By measuring the kinetic energy spectra of neutrons and protons, or analogously using “pseudo neutrons” from measured tritons and helium-3, the sign and magnitude of this effective-mass splitting can be extracted, with the help of transport models. Collisions of beams of $^{40,44}Ca$ at 50 and 140 MeV/A impinged on targets of $^{58,60}Ni$ and $^{112,116}Sn$. Light charged particles up to boron were detected in the upgraded High-Resolution Array and neutrons were detected in the Large-Area Neutron Array. I will present details about the experiment setup and then discuss some first results on the spectral ratios with comparisons to transport model calculations. This research is supported by the National Science Foundation under Grant No. PHY-1565546 and the Department of Energy under Grant No. DE-NA0002923.

9:54AM RN.00008 Stability of spectrum unfolding in extraction of neutron spectra for rare isotope beam physics, MICHAEL FEBBRARO, STEVEN PAIN, Oak Ridge National Laboratory, REBECCA TOOHEY, Rutgers University, FREDERICK BECCHETTI, University of Michigan, THOMAS MASSEY, ZACH MEISEL, Ohio University, RICHARD DEBOER, University of Notre Dame, CARL BRUNE, Ohio University — As the FRIB era approaches, it is important that the tools and techniques are in place to scientifically maximize the capabilities of such facilities. Neutron spectroscopy for transfer reaction physics is one important area which tools and techniques are needed. Traditionally, neutron time-of-flight (ToF) detectors have been used for extraction of neutron energy spectra. While this is a proven technique, the method often suffers from poor energy resolution for short flight paths. This can be improved by increasing the flight path, but at a cost to detection efficiency. An alternative method - based on a combination of short-path ToF and spectrum unfolding - maximizes detection efficiency without sacrificing energy resolution. The stability of the approach for low-statistics data has been investigated using neutron beams from the Edwards Accelerator Laboratory at Ohio University. Application of the technique for the measurement of single nucleon transfer reactions important for nuclear astrophysics will be discussed.

Work supported by the U.S. DOE, Office of Science, Office of Nuclear Physics DE-AC05-00OR22725 and DG-FG02-88ER40387. Also supported in part by U.S. DOE, NNSA Grant DE-NA0003883 and NSF Phys-0758100.
1:00AM RN.00006 Calculation of Quantum Processes Induced by Pion Nucleon Collisions

1:06AM RN.00007 Confirmation of High Neutron Yields for Ba-Mo from SF of 252Cf


— A careful analysis of the yield matrix of coincident pairs of barium (Z = 56) and molybdenum (Z = 42) fission fragments has been made in the present study. The neutron multiplicity yields of Ba-Mo, Ce-Zr, Te-Pd and Nd-Sr have been studied with improved precision by using γ-γ coincidence data and the latest level scheme structures of these nuclei. The results clearly confirm that the Ba-Mo yield data have a second hot fission mode where 8, 9, and 10 neutron evaporation channels are observed. These higher neutron evaporation channels are not observed in other fission pairs. The second mode has an intensity of ~1.3%. This mode can indicate that 144Ba is likely hyperdeformed at scission to give rise to such high neutron multiplicities. A new experiment is being planned to do fission fragment-γ coincidence studies to investigate details of the fission process and to study new more neutron-rich nuclei.

1:01AM RN.00009 Confirmation of Short-lived Fission Product Yields Using a Rapid Transit System

— SEAN FINCH, CALVIN HOWELL, WERNER TORNOW, Duke University, JACK SILANO, MARK STOYER, ANTON TONCHEV, Lawrence Livermore National Laboratory, MATTHEW GOODEN, JERRY WILHELMY, Los Alamos National Laboratory

— A joint TUNL-LLNL-LANL collaboration was formed to measure the absolute fission product yields from 235U, 238U, and 239Pu. Our goal is to study the energy evolution of fission products by using mono-energetic neutrons from 0.5 to 14.8 MeV. In order to extend our successful fission product yield measurements to include products with shorter half-lives, a RApid Belt-driven Irradiated Target Transfer System, named RABITTS, was constructed. This system allows us to perform cyclic activation and quantify fission products with γ-ray spectroscopy using HPGe detectors. Both a 1 meter and 10 meter transfer system have been developed, with transit times of 0.4 and 1.0 seconds, respectively. Using these systems, we have measured sub-second half-lives. In addition to neutron-induced fission, we have used the 1 meter RABITTS to measure fission product yields from photofission. A detailed characterization of the system’s performance will be shown, including preliminary fission product measurements, and the expected sensitivity.

Thursday, October 17, 2019 10:30 AM - 12:18 PM
Session SA Particles, Nuclei and Stars via Beta Decay
Salon 1 - Kelly Chipps, Oak Ridge National Laboratory

10:30 AM SA.00001 Polarized angular correlations in 37K: Recent results from TRINAT

— DAN MELCONIAN, Texas AM University — Nuclear β decay has a long-standing history of shaping and testing the standard model of particle physics, and it continues to this day with elegant, ultra-precise low-energy nuclear experiments. Measurements of the (un)polarized angular correlations between the electron, neutrino and recoil momenta following nuclear β decay can be used to search for exotic currents contributing to the dominant (V − A) structure of the weak interaction. Precision measurements of the correlation parameters to < 0.1% would be sensitive to (or meaningfully constrain) new physics, complementing other searches at large-scale facilities such as the LHC. This talk will discuss recent work from the TRIUMF Neutral Atom Trap (TRINAT) collaboration. We utilize neutral atom trapping techniques with optical pumping methods to highly-polarize (> 99%) a very cold and localized (< 1 nK and < 1 IIII111 source of short-lived (~ 1 s) 37K atoms. Recently, we measured the β asymmetry parameter, Aβ, of this decay to 0.3%, the best relative accuracy of any β-asymmetry measurement in a nucleus or the neutron. These methods and recent results will be presented along with future prospects for improving the precision to < 0.1%.

1Work supported by the US DOE Award No DE-FG02-93ER40773

11:00 AM SA.00002 Beta-Delayed Neutron Measurements for R-Process Isotopes with BRIKEN

— ALFREDO ESTRADE, Central Michigan University — Most of the unstable isotopes produced during the rapid neutron capture process (r-process) are expected to be β-delayed neutron emitters; a decay mode that populates neutron-unbound states in the daughter nuclei. The probability for β-delayed neutron emission is a key input for models of r-process nucleosynthesis in neutron star mergers and other astrophysical sites. β-delayed neutrons contribute to the density of free neutrons in the astrophysical environment, in particular during the late stages of the neutron capture phase of the r-process, and this decay mode also affects the final abundance of the elements produced once unstable isotopes have decayed to β-stability. A significant number of nuclei along the path of the r-process are finally within reach of decay experiments, thanks to a new generation of laboratories designed to produce intense beam of neutron-rich isotopes coupled with sensitive experimental setups. Beta-delayed neutrons at RIKEN (BRIKEN) is a setup for β-decay measurements at the Radioactive Isotope Beam Factory (RIBF) in RIKEN, Japan, which achieves a high detection efficiency with a state-of-the-art neutron detector based on 3He proportional counters. Since the first BRIKEN experiment, in 2017, our collaboration has studied β-delayed neutron emission in regions of the nuclear chart extending from cobalt (Z=27) to gadolinium (Z=64). The experiments covered regions that affect salient features of the r-process: the A=130 and the rare-earth elements abundance peaks. I will present the program of experiments of the BRIKEN collaboration, and discuss some of the first results and their impact in r-process models.

1This work was supported in part by the National Science Foundation grant PHY-1714153 and PHY-1430152, and by the Office of Nuclear Physics, U. S. Department of Energy under contract DE-AC05-00OR22725

2For the BRIKEN collaboration
11:42AM SA.00003 Gamma-ray Spectroscopy Experiments with Rare-Isotope Beams and Highly-Efficient Arrays at TRIUMF-ISAC. CORINA ANDREIOIU, Simon Fraser University — Located at the TRIUMF laboratory in Vancouver, Canada, the Isotope Separator and Accelerator – ISAC – facility is one of the world’s most advanced isotope separator on-line facilities providing high-intensity and high-purity radioactive ion beams for a wide variety of science programmes. ISAC’s γ-ray spectroscopy programme for studying nuclear structure, nuclear astrophysics and tests of fundamental symmetries is centred around two major research instruments: (i) the GRIFFIN γ-ray spectrometer for β- and β-delayed γ-ray spectroscopy experiments with the low-energy beams provided by ISAC-I, and (ii) the TIGRESS γ-ray spectrometer for in-beam experiments with the accelerated radioactive-ion beams provided by ISAC-II. Both GRIFFIN and GRIFFIN consist of 16 Compton-suppressed HPGe clovers and are augmented with powerful suites of ancillary detectors for coincidence measurements and channel selection leading to comprehensive spectroscopy studies of exotic nuclei. An overview of these facilities and recent results from the nuclear structure studies they enable are presented. The infrastructures of TIGRESS and GRIFFIN have been funded through contributions from the Natural Sciences and Engineering Research Council of Canada, the Canada Foundation for Innovation, TRIUMF, University of Guelph, British Columbia Knowledge Development Fund and the Ontario Ministry of Research and Innovation. TRIUMF receives funding through a contribution agreement through the National Research Council Canada. This work is supported by the Natural Sciences and Engineering Research Council of Canada. Replace this text with your abstract.

Thursday, October 17, 2019 10:30AM - 12:30PM – Session SB Instrumentation I  Salon 2 - Maxim Mai, GWU

10:30AM SB.00001 High Luminosity Spin-Polarized Target for the SpinQuest Experiment. JOSHUA HOSKINS, University of Virginia — The SpinQuest collaboration will measure the sea quark Sivers asymmetry using Drell-Yan production from the 120 GeV proton beam of the Fermilab Main Injector incident on transversely polarized proton and deuteron targets. Measuring a nonzero Sivers asymmetry would provide strong evidence for nonzero orbital angular momentum of sea quarks. The use of both polarized hydrogen and deuterium targets will provide an independent extraction of the u̅ and d̅ contributions in the range of 0.1 < x < 0.5. In order to provide high figure-of-merit measurements of the sea quark Sivers functions, high luminosity, transversely polarized targets are required. The polarized target system constructed by UVA-LANL consists of a 5T, split-coil, superconducting magnet and uses a 140 GHz microwave source to provide highly polarized protons and deuterons via dynamic nuclear polarization (DNP). The expected average target polarization for SpinQuest is 80% and 32% for the hydrogen and deuterium targets, respectively. A brief overview of the SpinQuest experiment and a survey of the high luminosity polarized target will be presented.

10:42AM SB.00002 Thermal Analysis and Simulation of the Superconducting Magnet in the SpinQuest Experiment at Fermilab. ZULKaida AKBAR, University of Virginia, SPINQUEST COLLABORATION — The SpinQuest experiment at Fermilab aims to measure the Sivers asymmetry for the u and d sea quarks in the nucleon using the Drell-Yan process. The experiment will utilize a target system consisting of a 5T superconducting magnet, transversely polarized NH₃ and ND₃ targets, a ¹⁴N evaporation refrigerator, a 140 GHz microwave source and a large pumping system. The proposed beam intensity is 1.5 x 10¹² of 120 GeV proton/sec. A quench simulation in the superconducting magnet is performed to determine the maximum intensity of the proton beam before the magnet transition to the resistive state. A GEANT based simulation is used to calculate the heat deposited in the magnet and the subsequent cooling processes are modeled using the COMSOL Multiphysics.

10:54AM SB.00003 E-1039 FPGA Trigger¹, NOAH WUERFEL, University of Michigan, SPINQUEST COLLABORATION — The SpinQuest (Fermilab E-1039) experiment will measure an azimuthal asymmetry in the Drell-Yan production of μ⁺μ⁻ pairs from 120 GeV/c proton interactions with polarized nucleons to extract the Sivers function for u and d. A large combinatorial background from muons produced in the beam dump requires a trigger which is capable of identifying dimuon pairs originating from the target in a high rate environment. The trigger system consists of four stations of scintillator hodoscopes whose 96 channels are digitized and processed by field-programmable gate array (FPGA) based VMEbus modules. TDC outputs can be adjusted channel-by-channel in 1-ns steps for realignment with the beam RF clock. Hodoscope hit patterns are compared to predetermined sets, chosen from Monte Carlo simulations, in a tiered lookup table to generate trigger decisions. The design and current status of the FPGA trigger are presented and planned upgrades to the trigger logic discussed.

¹This research was supported in part by NSF grant 1807338 and funds from the University of Michigan

11:06AM SB.00004 Tracking Low-Momentum Protons in a Radial Time Projection Chamber. DAVID PAYETTE, Old Dominion University, BONUS12 COLLABORATION — A Radial Time Projection Chamber (RTPC) has been designed and built for installation in Jefferson Labs Hall B as part of the BONuS12 (Barely Off-shell Nucleon Structure) experiment. The goal of BONuS12 is to accurately measure the structure function of the neutron by scattering the 11 GeV electrons from the upgraded CEBAF and detecting them with the CLAS12 spectrometer. Deuterium gas is used as an effective neutron target, and the new RTPC is used to detect low-momentum spectator protons. Protons follow a curved path in the 5 Tesla solenoid that is part of CLAS12, ionizing the He-CO₂ gas in an annular drift region surrounding the target. These ionization electrons are radially drifted outwards, amplified using cylindrical GEM (Gaseous Electron Multiplication) foils and recorded using readout pads located along the entire outer face of the cylindrical detector. Tracking software uses the signals from the pads to build tracks, which are reconstructed into the drift region using the arrival times of the signals and the positions of the pads. The proton momentum is measured from the tracks curvature and thus used to extract information about the struck neutron. We will present the status and performance of the tracking hardware and software.

11:18AM SB.00005 ABSTRACT WITHDRAWN
**11:30AM SB.00006 Status of the JLab Eta Factory (JEF) experiment**¹, **SIMON TAYLOR**, Jefferson Lab. **GLUEX COLLABORATION** — The JLab Eta Factory (JEF) experiment is designed to study various decays of the \( \eta \) meson using the GlueX detector in Hall D at Jefferson Lab. The experimental program includes measuring the Dalitz distribution from \( \eta \to \pi^+\pi^-\pi^0 \) to determine the up/down quark mass difference, looking for evidence for new C-violating/P-conserving physics, providing input to higher-order chiral perturbation theory calculations, and searching for evidence of dark matter. The latter two items rely on measuring the rare \( \eta \to \pi^0\gamma\gamma \) decay mode that will require an upgrade to the existing GlueX equipment, which is a fixed target apparatus based on a 2-Tesla solenoid magnet. Charged tracks are reconstructed using drift chambers within the magnet and neutral particles are detected in the forward direction in the Forward Calorimeter (FCAL), an array of lead glass blocks. The JEF program calls for replacing the \( \sim80 \times 80 \, \text{cm}^2 \) region of the FCAL around the beam line with an array of \( 2 \times 2 \times 20 \, \text{cm}^3 \) lead tungstate crystals. The status of this upgrade will be presented.

¹This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics under contract DE-AC05-06OR23177.

**11:42AM SB.00007 Gamma-Calibration of the Scattered-Particle Scintillators for MUSE**¹, **ANNIE FLANNERY**, University of South Carolina, MUSE COLLABORATION — The MUon Proton Scattering Experiment (MUSE) at the Paul Scherrer Institute seeks to address the proton radius puzzle through measuring the muon-proton and electron-proton elastic cross sections in the same experiment. The MUSE setup includes scattered-particle scintillators (SPS) which are part of the event trigger and help with particle separation and reaction identification via time-of-flight measurements. The SPS system consists of two front walls with eighteen 120-cm long EJ-204 scintillation bars and two rear walls with twenty-eight 220-cm long bars. The wall pairs are placed symmetrically about the beam line. The vertical scintillators are read out at their long ends with Hamamatsu R13435 photomultiplier tubes. The precise knowledge of the detection threshold and efficiencies, as well as quantitative comparisons with Monte Carlo simulations, require an absolute energy calibration of the scintillators. In this presentation, we will discuss the gamma-calibration methods for the SPS detectors.

¹This work is supported in parts NSF PHY-1614773.

**11:54AM SB.00008 Construction of a Set of Gas Electron Multiplier Detectors with Novel Design**¹, **JESMIN NAZEER**, **ISHARA FERNANDO**, **TANVI PATEL**, **MICHAEL KOHL**, Hampton University — A set of Gas Electron Multiplier (GEM) detectors optimized for low material budget has been constructed for use in low-energy tracking applications. A novel GEM construction technique is used where all layers are stretched and assembled mechanically within a double frame. The readout is based on Analog Pipeline Voltage (APV) frontend cards and Multi-Purpose Digitizers (MPD). The key features of these detectors allow them to be used very flexibly in high-rate environments for high-resolution charged particle tracking. The present status of the construction and performance of the GEM detectors will be discussed.

¹This work has been supported by NSF grants PHY-1505934, 1436680, 1812402, and a DOE/SCSR Fellowship.

**12:06PM SB.00009 Progress toward a measurement of the shape of the \( ^{14}\text{C} \) \( \beta \) spectrum**¹, **ELIZABETH A. GEORGE**, **PAUL A. VOYTAS**, Wittenberg University, L.D. KNUTSON, University of Wisconsin-Madison — Precision beta-decay experiments can constrain possible extensions to the Standard Model of the weak interaction. We report on progress toward a new measurement of the \( ^{14}\text{C} \) \( \beta \) spectrum shape as a test of the strong form of the Conserved Vector Current hypothesis. This measurement will complement a previous measurement of the shape factor in the \( ^{14}\text{O} \) analog transition, which was carried out with a superconducting beta spectrometer and achieved a relative precision of 3% on the linear term of the shape factor. A comparable precision is the goal of the \( ^{14}\text{C} \) shape measurement. For this measurement we have constructed a new iron-free magnetic beta spectrometer with the same geometry as the \( ^{14}\text{O} \) spectrometer but with conventional field coils. Because of the low \( ^{14}\text{C} \) endpoint energy (156 keV), scattering within the spectrometer may cause energy-dependent distortions at the target precision. We report on the design of the spectrometer, Monte Carlo simulations aimed at addressing scattering issues, and results from initial test runs.

¹Supported in part by NSF grant PHY-1506084

**12:18PM SB.00010 Radioactive Source Insertion System for the Nab Experiment** , **CHRISTOPHER HAYES**, North Carolina State University — The Nab experiment at the Spallation Neutron Source is designed to provide high statistics measurements of the electron-neutrino correlation coefficient and the Fierz interference term in free neutron beta-decay. Of critical importance to the success of Nab is the use of a Radioactive Source Insertion System (RSIS) designed to insert weak conversion-electron sources of known energy into the 70K Ultra High Vacuum (UHV) bore of the Nab magnet–spectrometer. The RSIS incorporates precise positioning of the sources throughout the neutron decay volume to scan individual pixels of two segmented Silicon detectors placed at 5 m and 1.5 m from the source. Beta response functions from individual pixels can then be evaluated for energy loss and calibration of detectors. I will discuss detailed aspects of the RSIS design features including the UHV system outside the magnet, the electro-mechanical system, and requirements for precise motion of the sources.

Thursday, October 17, 2019 10:30AM - 12:30PM — Session SC Instrumentation II Salons 3 - Stuart Fegan, GWU
10:30AM SC.00001 ND-Cube: An active-target detector for radioactive beam experiments and detector development. This work has been supported by NSF Grant no. PHY 17-13857.

10:42AM SC.00002 Design, Simulation, and Construction of MuSiC@Indiana. This work was supported in part by the National Science Foundation, Grant No. PHY-15-65546.

10:54AM SC.00003 Characterization of a low background counting facility at the Kamiballton Underground Research Facility. This work is supported by MRI grant #1827840 and RUI grant #1713522.

11:06AM SC.00004 Charged Particle Detector Telescope for Studies of Neutron-rich Systems. This work has been supported by NSF Grant no. PHY 17-13857.

11:18AM SC.00005 Precise Calibration of Laser Frequency for determination Sc Charge Radii. This work was supported in part by the National Science Foundation, Grant No. PHY-15-65546.

11:30AM SC.00006 Application of experimental methods of nuclear physics for studies of fundamental quantum physics. VIP2 is partially supported by Austrian Science Fund, project P-30635.
11:42AM SC.00007 Electron Population Manipulation of Transition Metal Isotopes in an RFQ Ion Trap1. JEREMY LANTIS, KEI MINAMISONO, DAVID GARAND, COLTON KALMAN, NAMRATA KASARANENI, National Superconducting Cyclotron Laboratory, YUAN LIU, Oak Ridge National Laboratory, ANDREW MILLER, JOEL ZUZELSKI, National Superconducting Cyclotron Laboratory — Collinear laser spectroscopy (CLS) is a powerful tool for determining the differential mean-square charge radii and nuclear electromagnetic moments of rare isotopes. CLS measurements of the first and second-row transition metals are difficult due to low production rates and unfavorable electronic populations. An optical pumping technique has been developed at the BECEOLA facility at the NSCL/MSU to manipulate electronic populations and improve sensitivity in laser spectroscopy measurements. The technique was tested with stable Zr beams, whose neutron-deficient isotopes have important implications for stewardship science. A \(^{93}\text{Zr}\) ion beam was produced in a plasma discharge source and trapped in an RFQ ion trap. The electronic populations of the trapped ions were manipulated with pulsed laser light followed by laser-resonant fluorescence measurements. Details and results from commissioning tests will be discussed.

\(^{1}\)This work was supported by the U.S. Department of Energy under Award No DE-NA0002924, and is supported in part by the National Science Foundation, Grant No. PHY15-65546

11:54AM SC.00008 Neutron Spectroscopy Studies with the CATRiNA Detector System1. JESUS PERELLO, SERGIO ALMARAZ-CALDERON, BENJAMIN ASHER, LACY BABY, NATHAN GERKEN, Florida State University — Experimental studies of exotic neutron-rich and neutron-deficient nuclei are becoming available due to the emergence of advanced radioactive beam facilities. New neutron detection systems are in need to study nuclear reactions with these exotic nuclei which involve neutrons as reaction by-products. Neutron detector arrays should be capable of performing neutron spectroscopy studies and using neutrons to ‘tag’ other by-products (e.g., \(-\alpha\) – particle). The Compound Array for Transfer Reactions in Nuclear Astrophysics (CATRiNA), developed at Florida State University (FSU), is an array of 16 deuterated-benzene (C6D6) scintillators as neutron detectors with fast-response time, pulse-shape-discrimination capabilities and a structured pulse-height spectrum which combined with time-of-flight (ToF) information, allows for multiple correlations for neutron spectroscopy studies. CATRiNA was designed to perform spectroscopy studies of bound- and resonant-states and to be coupled with other detection systems to measure reactions relevant for nuclear structure and nuclear astrophysics. In this work, we will discuss preliminary results on experiments performed at FSU.

\(^{1}\)NNSA, NSF

12:06PM SC.00009 Fusion measurements of exotic beams with “Encore”, the new Active Target Detector at FSU. BENJAMIN ASHER, SERGIO ALMARAZ-CALDERON, JESUS PERELLO, LACY BABY, Florida State University — Exotic nuclei and beams are on the forefront of nuclear science and with them, new detector systems to exploit these beams to their greatest extent. These radioactive beams allow the measurement of new exotic fusion systems which will in turn help understand fusion processes near the coulomb barrier as well as energy production within stars. At Florida State University (FSU) we have developed ‘Encore’, a Multi Sampling Ionization Chamber which works as an active target detector consisting of a segmented anode to measure energy losses of the beams and the subsequent reactions as the beam passes through the detector. Preliminary Results on the characterization of the detector, future improvements and first measurements of the 17 \(^{1}\text{F} + 12 \:^{1}\text{C} \) system performed at FSU using a radioactive 17 \(^{1}\text{F} \) beam will be presented. This work was supported by the State of Florida and the NSF under grant PHY-1712953

12:18PM SC.00010 Gas-production reaction studies: 54Fe(N,Z) measurements with LENZ at LANSCE1. ANASTASIA GEORGIADOU, HYE YOUNG LEE, SEAN KUVIN, Physics Division, Los Alamos National Laboratory, Los Alamos, NM, 87545, USA, LUKAS ZAVORKA, Physics Division, Los Alamos National Laboratory, Los Alamos, NM, 87545, USA, HYE YOUNG LEE, Korea Atomic Energy Research Institute, Daepogen, South Korea — The development of the LENZ (Low Energy NZ-neutron induced charged particle detection) set-up at LANSCE gives the capability of studying neutron induced reactions in detail. The wide neutron spectrum of LENZ, in addition to the large solid angle coverage of LENZ, provides a unique tool for the disentanglement of the excited states. In addition, it improves the information we have up to now, giving the angular distribution of the different channels as well as information useful on statistical models such as Hauser-Feshbach used for many neutron induced reactions. Fe is one of the mostly used structural materials. Its importance lies not only in applications but also in nuclear astrophysics. The total and differential cross sections, as well as angular distributions

\(^{1}\)This work benefits from the LANSCE accelerator facility and is supported by the U.S. Department of Energy under contracts DE-AC52-06NA25396

Thursday, October 17, 2019 10:30AM - 12:30PM – Session SD Instrumentation III Salon 4 - Olga Cortes Becerra, GWU

10:30AM SD.00001 Recent progress in the development of the CHIPTRAP mass spectrometer1. NADEESA GAMAGE, RAMESH BHANDARI, MADHAWA HORANA GAMAGE, RACHEL SANDLER, PHILIP SNOAD, MATTHEW REDSHAW, Central Michigan University — At Central Michigan University we are developing a high-precision Penning trap (CHIP-TRAP) for precise mass measurements with stable and long-lived isotopes with application, for example, to neutrino mass determinations with 187\(^{1}\text{Re}\) and 195\(^{1}\text{Ho}\). CHIP-TRAP will consist of a pair of hyperbolic precision measurement traps and a cylindrical capture/fILTER trap in a 12 T magnetic field. Ions will be produced using a laser ablation ion source and a recently commissioned Penning ion trap source. Ions will be transported to the capture trap at low-energy using electrostatic ion optics and identified via FT-ICR techniques; enabling unwanted ion species to be removed. The ion of interest will then be moved to one of the precision measurement traps. The goal is to simultaneously measure the cyclotron frequency of single ions of two different species, each confined in one of the precision measurement traps, resulting in a cancellation of magnetic field fluctuations and a reduction in statistical uncertainty. In this presentation we will report on the design, construction and operation of the ion sources and will discuss the current status of the CHIP-TRAP project including the recent installation and commissioning of the capture trap.

\(^{1}\)This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics under Award Number DE-SC0015927, and the National Science Foundation under Grant No. 1307233 and 1607429.
10:42AM SD.00002 Deuterated Organic Scintillators for the Absolute Normalization of Gamma Beam Flux\textsuperscript{1}. AIDAN WALSH, Oak Ridge National Laboratory, University of Surrey, MICHAEL FEBBRARO, STEVEN PAIN, Oak Ridge National Laboratory — The measurement of the absolute photon flux is a challenging task and can contribute to large uncertainties in gamma-ray beam experiments. Currently, flux determination relies on either Compton scattering at low energies or the photodissociation of deuterium at higher energies. The latter method requires the detection of neutrons, which is tied to the uncertainties and inefficiencies of neutron detectors. To reduce these uncertainties it would be desirable to detect the recoil proton rather than the neutron. To accomplish this the source of deuterium must be active. To this extent we are developing deuterated scintillator tiles, for determination of absolute photon flux. Efforts are underway to produce thin tiles in a minimal loss procedure, due to the high cost of the deuterated monomer. Tiles have been successfully produced and their characterization with gamma-ray sources will be presented. Applications toward beam diagnostics for current and upcoming gamma-ray beam facilities will be discussed.

\textsuperscript{1}Work Supported By U.S. DOE, Office of Science, Office of Nuclear Physics DE-AC05-00OR22725

10:54AM SD.00003 Report on the performance of a dual-mode inorganic scintillator TLYC\textsuperscript{1}, CHING-YEN WU, JACK HENDERSON, Lawrence Livermore Natl Lab — TLYC (Tl\textsubscript{2}LiYCl\textsubscript{6}) is a dual-mode inorganic scintillator with the capability to detect both neutrons and gamma rays with good energy resolution. The gamma-ray energy resolution better than 4\% was reported for a crystal size of 1" x 1". Unlike most neutron detectors which depend on the time-of-flight technique to determine the energy, TLYC can be used to measure the neutron energy directly through charged-particle creating reactions on the constituent isotopes. A resolution better than 10\% for fast neutrons with energies up to 8 MeV was obtained for the same class of scintillator, CLYC (Cs\textsubscript{2}LiYCl\textsubscript{6}), where cesium is replaced by thallium for the molecular formula of TLYC. It opens the door for many applications. A crystal size of 1" x 1" is acquired recently and an extensive study is carried out using a \textsuperscript{237}Np PPAC to characterize the pulse-shape discrimination between neutrons and gamma rays as well as the energy and timing resolution. The prompt fusion neutron and gamma-ray spectra can be measured by TLYC in coincidence with the detection of fission fragments by PPAC. The detector response for both neutrons and gamma rays can be measured simultaneously using this coincident technique. The characterization of those performances will be presented.

\textsuperscript{1}Work at LLNL is supported by the U.S. DOE under Contracts No. DE-AC52-07NA27344.

11:06AM SD.00004 Neutron-induced fission measurements with the NIFFTE fissionTPC\textsuperscript{1}. MICHAEL MENDENHALL, Lawrence Livermore Natl Lab, NIFFTE COLLABORATION — The NIFFTE collaboration’s fission time projection chamber (fissionTPC) is a 2 x 2π charged particle tracker designed for measuring neutron-induced fission. Detailed 3D track reconstruction for fission products enables evaluation of systematic effects and corresponding uncertainties which are less directly accessible by other measurement techniques. This talk describes measurements of cross-section ratios between \textsuperscript{235}U(n,f), \textsuperscript{235}U(n,e), and \textsuperscript{239}Pu(n,f) reactions, for incident neutron energies from 0.2 to 20 MeV from a spallation source at the Los Alamos Neutron Science Center. We also discuss exploration of the \textsuperscript{6}Li(n,α)\textsuperscript{3}H reaction as a complementary reference in actinide cross-section ratio measurements.

\textsuperscript{1}LLNL-ABS-779767 . This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

11:18AM SD.00005 Using timing to improve low-momentum tracking in silicon trackers . SPENCER KLEIN, Lawrence Berkeley National Laboratory — Silicon detectors offer many advantages for tracking charged particles – they provide outstanding position resolution, so they provide unequalled resolution at for high momentum particles. However, the silicon detectors, being solid, induce more multiple scattering than gaseous trackers like TPCs. In this talk, I will explore the use of high-precision (~10 - 30 psec) timing to alleviate the effects of multiple scattering, by measuring directly the path-length that charged particles take between silicon detectors, and from that path length, the particle’s curvature. A timing resolution of 30 psec has been demonstrated in silicon detectors, while 10 psec seems achievable in future devices. I will show that the use of timing can significantly improve the momentum resolution for lower momentum particles. This technique may be useful for detectors at a future Electron-Ion Collider. Time permitting, I will also discuss using timing to help reduce track confusion in high-luminosity environments.

11:30AM SD.00006 Use of a CeBr\textsubscript{3} implantation scintillator in beta-decay studies of rare isotopes\textsuperscript{1}. B. P. CRIDER, Y. XIAO, T. H. OGUINEKU, U. SILWAL, D. P. SIWAKOTI, D. C. SMITH, Mississippi State University, S. N. LIDDICK, K. L. CHILDERS, R. LEWIS, B. LONGFELLOW, S. LYONS, A. L. RICHARD, M. K. SMITH, NSCL/MSU, P. CHOWDHURY, E. LAMERE, UMass Lowell, S. K. NEUPANE, D. PEREZ-LOUREIRO, UTK, C. J. PROKOP, LANL — Beta-decay experiments enable studies of many interesting nuclear phenomena, such as shape coexistence near closed-shell nuclei. Shape coexistence describes where states associated with deformed shapes appear at relatively low excitation energy alongside spherical ones and is indicative of the rapid change in structure that can occur with the addition or removal of a few protons or neutrons. The use of a Cerium Bromide (CeBr\textsubscript{3}) scintillator as an implantation detector for detecting accelerated rare isotopes and subsequent decays to study shape coexistence far from stability provides a number of desirable quantities, namely high light yield, a fast response, and a high density for the stopping of accelerated ions. A thin CeBr\textsubscript{3} implantation scintillator coupled to a position-sensitive photomultiplier tube has been utilized in a recent experiment at NSCL in combination with ancillary detection arrays. First results on the characterization and performance of the CeBr\textsubscript{3} scintillator will be presented.

\textsuperscript{1}This work was supported in part by the National Science Foundation (NSF) under Grant No. PHY-1848177 (CAREER), and DOE National Nuclear Security Administration through the Nuclear Science and Security Consortium, under Award No. DE-NA0003180.
11:42AM SD.00007 Highlights from the first year of operating the new ATLAS in-flight facility (RAISOR)\textsuperscript{1} — C. R. HOFFMAN, C. DICKERSON, Argonne National Laboratory, L. WILSON, Louisiana State University / Argonne National Laboratory, RAISOR TEAM — The ATLAS Accelerator facility at Argonne National Laboratory recently completed upgrades to its in-flight radioactive beam capabilities. The new in-flight facility, RAISOR, was designed specifically for the production of in-flight beams through transfer reactions at ideal energies for nuclear structure work, direct reaction studies, and nuclear astrophysics measurements ($\sim$5 - 15 MeV/u). RAISOR is comprised of an achromatic momentum chicane with bookend quadrupole doublets followed by rebunching and sweeper radio-frequency elements. In both ways, a momentum and velocity selection takes place in the identification of desired in-flight beams of interest. Since the RAISOR commissioning in the Fall of 2018, the facility has been used in six different experimental measurements delivering beams from Li up to P. Milestones include the first in-flight beams at new target stations, increases in the production yields and masses by factors of ten and two over the previous facility. Details on the characteristics of the in-flight beams produced and future facility directions will be presented in addition to the physics highlights.

\textsuperscript{1}This research used resources of Argonne National Laboratory’s ATLAS facility, which is a Department of Energy Office of Science User Facility. This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under Contract Nos. DE-AC02-06CH11357 (ANL) and DE-FG02-96ER40978 (LSU).

11:54AM SD.00008 Characterization of an Iridium Based TES Light Detector for Neutrinoless Double Beta Decay Search — JIANJIE ZHANG, Argonne National Laboratory, ANL-BERKELEY CUPID LIGHT DETECTOR R&D GROUP TEAM\textsuperscript{1} — Reading out both the heat and light signals from the cryogenic calorimeters used in neutrinoless double beta decay search and direct dark matter detection is a powerful way to reject the background events on an event-by-event basis. For this purpose, we are developing a superconducting transition edge sensor (TES) based light detector targeting O(10) eV energy threshold and O(100) $\mu$s response time, to measure the scintillation or Cherenkov light produced in the target material by particle interactions. The light detector is fabricated by patterning an iridium/platinum bilayer TES at room temperature at the center of a two-inch silicon wafer. The superconducting transition temperature of the TES is tuned to achieve the target energy resolution and response time using the proximity effect. We will present the design, fabrication, and static characterization of such detectors, including the measured dependence of the transition temperature on normal metal thickness, electrical and thermal parameters of the TES, and their calorimetric performance.

\textsuperscript{1}Group of 28 members to develop the low Tc TES light detector for the CUORE Upgrade with Particle ID (CUPID) project.

12:06PM SD.00009 Development of a Fast-Spectrum Self-Powered Neutron Detector for use in Sodium-Cooled Fast Reactors — KATHLEEN GOETZ, University of Tennessee, SACIT CETINER, Oak Ridge National Laboratory — Self-powered neutron detectors (SPND) have been an essential diagnostic tool for in-core neutron flux mapping in thermal nuclear reactors for more than 45 years [1]. As next-generation reactors are on the horizon, it is imperative to develop diagnostic tools tuned to their faster neutron spectra [2]. For example, the neutron spectrum in sodium-cooled fast reactors peaks around 0.5 MeV [2]. SPNDs are transistor-like detectors that produce an electrical current as a result of neutron-capture reactions within the neutron-sensitive portion of the detector [1]. The current state-of-the-art for SPNDs is optimized for thermal neutron interactions. We will therefore be discussing our efforts to develop fast-spectrum SPNDs sensitive to neutrons with energies approaching 1 MeV. We have performed an in-depth analysis of ENDF neutron-capture cross sections and have identified 5 novel materials that are suitable to make up the neutron-sensitive portion of our detector, all are stable mid-shell nuclei in the region between doubly-magic $^{122}$Sn and $^{208}$Pb. We will also be discussing the results of Geant4 simulations with the chosen materials as well as detector optimization and the exploration of complex detector geometries. [1] Todt, W. H. “Characteristics of self-powered neutron detectors used in power reactors.” Core Instrumentation and Core Assessment, Nuclear Energy Agency, Boulogne-Billancourt, France (1996). [2] Verma, Vasudha, et al. “Self powered neutron detectors as in-core detectors for Sodium-cooled Fast Reactors.” NIM A: 860 (2017): 6-12.

12:18PM SD.00010 Performance of the Neutron dEtector with Xn Tracking (NEXT) prototype — SHREE NEUPANE, JOSEPH HEIDEMAN, DAVID PEREZ-LOUREIRO, ROBERT GRZYWACZ, CORY THORNSBERRY, LAWRENCE HEILBRONN, KYLE SCHMITT, University of Tennessee, MUSTAFA RAJABALI, COLE HOWELL, LEONARD MOSTELLA, JOSEPH OWENS, Tennessee Technological University, ERIN PETERS, ANTHONY RAMIREZ, STEVEN YATES, University of Kentucky, KEITH VAIGNEUR, Agile Technologies, Inc. — The ATLAS Accelerator facility at Argonne National Laboratory is to analyze polarized proton-proton collisions in order to constrain the polarized gluon contribution and its contribution to the spin of the proton. This is one of the motivations for an upgrade to the STAR detector, consisting of a Forward Tracking System (FTS) and Forward Calorimeter System (FCS). These components will be located in the forward rapidities 2.8 $\leq$ y $\leq$ 4.2. This upgrade will provide more complete information than previously available at STAR in this region. The FCS will include not only an electromagnetic calorimeter (ECal), but also STARs’ first hadronic calorimeter (HCal). We will describe the design of these two calorimeters and the different steps in their assembly procedure, e.g., the installation of the light guides on the ECal and the construction of the scintillator plates for the HCal.

1This work is supported by US DOE-NNSA contract DE-NA0002934.

Thursday, October 17, 2019 10:30AM - 12:30PM Session SE Undergraduate Research II

10:30AM SE.00001 The STAR Forward Upgrade and Proton Spin — ANDREW EDWARDS, Valparaiso University, STAR COLLABORATION — One of the goals of the STAR (Solenoidal Tracker at RHIC) detector, located at Brookhaven National Laboratory, is to analyze polarized proton-proton collisions in order to constrain the polarized gluon contribution and its contribution to the spin of the proton. This is one of the motivations for an upgrade to the STAR detector, consisting of a Forward Tracking System (FTS) and Forward Calorimeter System (FCS). These components will be located in the forward rapidities 2.8 $\leq$ y $\leq$ 4.2. This upgrade will provide more complete information than previously available at STAR in this region. The FCS will include not only an electromagnetic calorimeter (ECal), but also STARs’ first hadronic calorimeter (HCal). We will describe the design of these two calorimeters and the different steps in their assembly procedure, e.g., the installation of the light guides on the ECal and the construction of the scintillator plates for the HCal.
The LANL neutron Electric Dipole Moment (nEDM) experiment is an effort to set a sensitivity limit of a few $10^{-27}$ e•cm on the electric dipole moment of the neutron, an order of magnitude smaller than the current limit. This measurement makes use of Ramsey's method of separated oscillatory magnetic fields. In a prototype test apparatus based on a small magnetically shielded room (MSR), ultra-cold neutrons precess in a magnetic field produced by solenoid. The magnetic field must be spatially uniform enough for a neutron dephasing time longer than the neutron storage time. The time projection chamber (TPC) uses liquid xenon, enriched in Xe, as a decay source and detection medium. Its architecture allows for the reconstruction of decay events based on their position and energy from light and charge depositions.

Decays throughout the medium. Its architecture allows for the reconstruction of decay events based on their position and energy from light and charge depositions. Neutrinos as Majorana particles. The time projection chamber (TPC) uses liquid xenon, enriched in Xe, as a decay source and detection medium. Its architecture allows for the reconstruction of decay events based on their position and energy from light and charge depositions. Neutrinos as Majorana particles. The time projection chamber (TPC) uses liquid xenon, enriched in Xe, as a decay source and detection medium. Its architecture allows for the reconstruction of decay events based on their position and energy from light and charge depositions. Neutrinos as Majorana particles. The time projection chamber (TPC) uses liquid xenon, enriched in Xe, as a decay source and detection medium. Its architecture allows for the reconstruction of decay events based on their position and energy from light and charge depositions. Neutrinos as Majorana particles. The time projection chamber (TPC) uses liquid xenon, enriched in Xe, as a decay source and detection medium. Its architecture allows for the reconstruction of decay events based on their position and energy from light and charge depositions. Neutrinos as Majorana particles.

Results of magnetic field measurements inside the apparatus, before and after degaussing the MSR and with and without the solenoid, as well as the design of the mapper will be presented.

Mentors: Dr. S Clayton (LANL), Prof. S Stanislaus (Valparaiso University)

Supported by NSF grants PHY-1659847 and PHY-1812431.

Bucknell University, National Science Foundation
11:42AM SE.00007 Urca Nuclide Production in Type-I X-ray Bursts and Implications for Nuclear Physics Studies1, GRANT MERZ, ZACH MEISEL, Ohio University — The thermal structure of accreting neutron stars is affected by the presence of urca nuclei in the neutron star crust. Nuclear isobars harboring urca nuclides can be produced in the ashes of Type I X-ray bursts, but the details of their production have not yet been explored. Using the code MESA, we investigate urca nuclide production in a one-dimensional model of Type I X-ray bursts using astrophysical conditions thought to resemble the source GS 1826-24. We find that urca nuclei are generally produced late in the X-ray burst, during hydrogen-burning freeze-out that corresponds to the tail of the burst light curve. The relevant temperature for urca nucleosynthesis is therefore somewhat lower than the canonical conditions often assumed for nuclear physics experiments, altering the excitation energy range of interest in compound nuclei.

1This work was supported by the U.S. Department of Energy under grants DEFG02- 88ER40387 and DE-SC0019042.

11:54AM SE.00008 Improving Measurements of Beam Dynamics for Fiber Harp System in Muon g-2 Experiment1, DAT TRAN, FREDERICK GRAY, Regis University, MUON G-2 COLLABORATION — The Muon g-2 experiment at Fermi National Accelerator Laboratory will improve the precision with which the muon’s anomalous magnetic moment is known from 540 ppb to 140 ppb. “Fiber harp” beam monitoring devices provide a measurement of the time dependence of the muon beam’s vertical and radial profiles by using scintillating fibers. The fiber harps measure the betatron tune (ratio of the betatron to cyclotron frequency) as a function of momentum. These measurements are crucial to understand the coherent betatron oscillation (CBO), which is a source of systematic error in the measurement of the muon spin precession. Furthermore, these measurements allow us to validate beam dynamics predictions from simulation models. Improvements in methods of extracting cyclotron and betatron frequencies as well as a better understanding of the uncertainties in extracting those frequencies will be presented.

1This material is based upon work supported by the National Science Foundation under Grant numbers PHY-1811832.

12:06PM SE.00009 Prototype Readout System Software for The STAR Interlock Safety System at BNL1, JOSEPH D’ALESIO, Creighton University — RHIC, located at BNL, collides nuclei at relativistic speeds to artificially recreate the initial conditions of the universe. The STAR Collaboration studies these collisions using a detector, the Solenoidal Tracker At RHIC. The Interlock Safety System is responsible for monitoring and displaying parameters in the STAR control room. These parameters include the temperature and pressure of the TPC gas mixture, the Oxygen Deficiency Hazard status, the Uninterruptable Power Supply status and the water cooling system status. If these parameters fall outside an accepted range, alarms will sound to notify the control room. The readout system and software allow for the shift operator to adjust detector variables while the experiment is running and thus prevent circumstances in which fires and explosions are likely. This project focuses on upgrades to the Interlock monitoring system. The current Interlock Readout monitor uses a VME to communicate with various STAR systems while the upgraded monitor uses a Programmable Logic Controller interfaced to a PC. Device support for the upgraded monitor has been written and compiled using a prototype input/output controller program to communicate to the new readout PLC. Functionally, the existing and upgraded system will have the same capabilities. However, the new readout system will be easier to maintain and more easily updated to include, for example, additional safety signal outputs. In turn, this will result in a critical readout system prepared for future operations.

1Fermilab Summer Undergraduate Research Fellowship

12:18PM SE.00010 E1039 Luminosity Monitor Testing and Installation1, EMILY BRANSON, Abilene Christian University, SPINQUEST COLLABORATION — E1039 will collide a 120 GeV unpolarized proton beam from Fermi National Accelerator Laboratory with hydrogen and deuterium targets polarized transversely to the beam. Then, asymmetries of dimuon pairs produced in the Drell-Yan process will be measured to find the Sivers Function, a transverse momentum dependent parton distribution function. A non-zero measurement of the Sivers Function implies orbital angular momentum of the quark sea. In measuring these asymmetries, variances in beam luminosity must be accounted for, as changes in the beam could skew our data. For this reason, E1039 is outfitted with a luminosity monitor for measuring beam intensity and accuracy. The monitor is composed of four hodoscopes on an aluminum rail and is installed in the target cave at 90 degrees relative to the beam line. The testing and installation of this beam will be presented.

1Fermi National Accelerator Laboratory

Thursday, October 17, 2019 10:30AM - 12:18PM – Session SF Current and Future Jet Measurements

10:30AM SF.00001 ABSTRACT WITHDRAWN –

10:42AM SF.00002 Testing and Characterization of the Scintillator Tiles for the sPHENIX Hadronic Calorimeter1, UTTAM ACHARYA, Georgia State University, SPHINX COLLABORATION — sPHENIX is a new experiment at RHIC that is designed to quantify the properties of quark-gluon plasma created in relativistic heavy ions collisions with measurements of jets and quarkonia. A crucial component of the sPHENIX detector design for jet measurements is the hadronic calorimeter (HCaI) which is located outside of the magnet and composed of plastic scintillating tiles sandwiched between tapered, steel plates, and read out with wavelength shifting fibers and Silicon Photomultipliers (SiPM). The HCaI includes 7,680 scintillating tiles that are currently being produced at Uniplast plant in Russia. A test station has been built at Georgia State University to test the quality and performance of each of these tiles with cosmic rays. The results of this test will also be used to optimize the performance of the device towers that will be constructed from these tiles by grouping the tiles with similar performance in each tower. This talk is focused on the design of the test station and the current result of the performance characterization studies of the sPHENIX HCaI tiles.
10:54AM SF.00003 Validation of Production SiPMs for the sPHENIX Experiment¹

, NATHAN GRAU, Augusta University, SPHENIX COLLABORATION — The sPHENIX detector is designed to measure calorimetric jets and heavy flavors to study the microscopic properties of the quark-gluon plasma produced in ultrarelativistic heavy ion collisions at RHIC. The electromagnetic and hadronic calorimeters will cover full azimuth and —→1. The calorimeters are readout through common electronics and use silicon photomultipliers (SiPMs) as the optical sensor. The total detector requires 106,000 SiPMs, with the Hamamatsu S12572-01SP having been chosen as the device to instrument the full detector. The production of this large order is ongoing and monthly shipments of 8,500 SiPMs began arriving at the University of Michigan in March of 2019. In this talk we outline the test stand developed at the University of Debrecen, the strategy to validate the SiPMs received, and the results of that evaluation.

¹National Science Foundation

11:06AM SF.00004 Measurement of D0 production in jets in heavy-ion collisions at the LHC with ALICE

, ANTONIO CARLOS OLIVEIRA DA SILVA, University of Tennessee - Knoxville, ALICE COLLABORATION — Charm quarks are considered ideal probes of the Quark-Gluon Plasma (QGP). Due to their large mass they are produced in the early stages of ultra-relativistic heavy-ion collisions in hard-scattering processes. D0-tagged jets are valuable tools to investigate the charm interaction with the QGP. Furthermore, charmed jets can provide information to study the mass-dependent energy loss by analysing the modification of their yield in Pb-Pb collisions with respect to pp collisions as a function of the jet transverse momentum. D0 mesons are reconstructed through their hadronic decay channels. The large combinatorial background is rejected by applying topological selections exploiting the relatively large lifetime of D0 mesons and the particle-identification capabilities of the detector. The signal is extracted using an invariant mass analysis. Charged-track jets are reconstructed with anti-k algorithm. The ALICE detectors allow us to measure D0-tagged jets down to low pT, where the probes are more sensitive to the effects of the hot medium. This contribution will present the current analysis status and results of the measurement of D0-tagged jets in Pb-Pb collisions at √sNN = 5.02 TeV.

11:18AM SF.00005 Recent Jet Results From ALICE

, PATRICK STEFFANIC, University of Tennessee — The ALICE experiment at the Large Hadron Collider at CERN is optimized to study the properties of the hot, dense matter created in high energy nuclear collisions in order to improve our understanding of the properties of nuclear matter under extreme conditions. Measurements from pp and p-Pb collisions provide a baseline for QCD. Measurements in heavy ion collisions indicate that the matter created in collisions at the LHC is hotter and larger than that at lower energies and behaves like a strongly interacting, nearly perfect liquid. Showers of particles-jets—resulting from hard interactions early on in the collision probe the full evolution of nuclear medium. Recent measurements of charged jet spectra, jet transverse momentum distributions and jet substructure measurements from ALICE will be presented.

11:30AM SF.00006 Jet vn in Heavy Ion Collisions at ALICE

, WILLIAM WITT, University of Tennessee, ALICE COLLABORATION — The extreme temperature and density produced in a heavy ion collision leads to the formation of a phase of matter called the quark gluon plasma (QGP). When a parton within one of the colliding nuclei scatters off a parton in the other nucleus, it results in collimated sprays of particles known as jets. These jets can be identified from clusters of final state particles observed by ALICE (A Large Ion Collider Experiment) at the LHC (Large Hadron Collider). Due to the non-uniformity of the initial QGP state, these jets exhibit angular asymmetry, quantified by jet vn. Measuring jet vn reveals information about the energy loss of partons traveling through the QGP. Results from Pb-Pb collisions at 2.76 TeV and the status of measurements in Pb-Pb collisions at 5.02 TeV will be presented.

11:42AM SF.00007 Two-particle correlation distributions on transverse momentum in relativistic heavy-ion collisions

, ROBERT RAY, University of Texas at Austin, STAR COLLABORATION — Two-particle correlation projections onto two-dimensional transverse momentum coordinates allow access to relativistic heavy-ion collision dynamics beyond that accessible in previous, complementary studies of two-particle angular correlations. We report charged-particle correlations from minimum-bias Au+Au collisions at √sNN=200 GeV taken by the STAR experiment at RHIC. These new correlations are constructed using all charged particles within the STAR acceptance. Correlations are presented for like-sign and unlike-sign charge-pair combinations and for specific azimuthal angle projections. The major correlation features include a saddle shape and a peak extending from pT = 0.5 to 4.0 GeV/c. The measurements are compared to HIJING and EPOS predictions. The features of the correlations are also described by a blast-wave model and a two-component fragmentation model, representing two distinct frameworks for understanding relativistic heavy-ion collisions [Ray and Jentsch, Phys. Rev. C 99, 024911 (2019)]. Implications of these new measurements and analysis with respect to equilibration, the origin of transverse-momentum fluctuations, longitudinal and transverse parton fragmentation, and interactions within the dense, partonic medium are discussed.

¹Research supported in part by the U.S. D.O.E. under grant no. DE-SC0013391.

11:54AM SF.00008 Quality Assurance of the 2012 Endcap 0 data at STAR and Analyzing 2013 Data

, JOSEPH SNAIDAUF, Valparaiso University, STAR COLLABORATION — The Solenoidal Tracker at RHIC (STAR) experiment based at Brookhaven National Laboratory uses collisions of polarized protons to study, among other things, the contributions of gluons to the spin of the proton. The STAR detector’s Endcap Electromagnetic Calorimeter (EEMC), located in the pseudorapidity range 1 ≤ η ≤ 2, provides sensitivity to gluons carrying a low fraction of the proton momentum (x ≲ 0.05), where the gluon spin contribution is still relatively poorly constrained. The gluon spin contribution can be determined by studying the 0 production from p+p collisions with different orientations of the spins of the colliding protons. 0 s are reconstructed using the energies deposited in the EEMC by the two decay photons and the opening angle between them. To ensure that the data from 2012 longitudinally polarized p+p collisions at s = 510 GeV under study are of useable quality, a C++ script was written to plot, as a function of run number, several key characteristics of the neutral pion reconstruction process obtained from ROOT trees. In addition, 0 s were reconstructed via ROOT from the 2013 longitudinally polarized p+p collisions at s = 510 GeV. The results of these studies will be presented.

12:06PM SF.00009 (CEU) Calculating Corrections to Transverse Energy in Relativistic Heavy Ion Collisions

, BENJAMIN SMITH, TANNER MENGEL, BISWAS SHARMA, NATHAN WEBB, SOREN SORENSSEN, CHRISTINE NATTRASS, University of Tennessee, Knoxville — By colliding heavy nuclei at relativistic velocities, the resulting increase in temperature and density of the collision volume can cause a phase transition of the nuclear matter to what is called a quark-gluon plasma. Several experiments to observe the behavior of this phase occur at the Relativistic Heavy Ion Collider (RHIC) in New York. As an effect of the collision, many particles are ejected transverse to the beam axis. Using published single particle spectra, the total transverse energy is calculated and can provide an independent cross check of transverse energy measurements. These calculations are used to estimate the effects of the electromagnetic and hadronic calorimeters, and the results are needed to test the performance of Monte Carlo models.
10:30AM SK.00001 Sensitivity of FREYA to model inputs in simulations of 252Cf(sf)$^1$. RAMONA VOGOT, Lawrence Livermore Natl Lab. JORGEN RANDRUP, Lawrence Berkeley National Lab. PATRICK TALOU, Los Alamos National Laboratory. — Employing the complete fission event generator FREYA, we study the sensitivity of neutron observables to the input yield function $Y(A,Z,TKE)$ [1]. We first perform a statistical analysis of the available fission data to determine the distribution of possible yield functions and construct an ensemble of 15,000 such yield functions. For each of these, FREYA is used to generate one million fission events, leading to a corresponding ensemble of fission observables, including the neutron multiplicity distribution and its factorial moments, the neutron energy spectrum, and the neutron-neutron angular correlation. Thus we can study the sensitivity of those neutron observables to the uncertainty in the input yields. Particular attention is given to the anti-correlation between the mean neutron multiplicity $\langle \ell \rangle$ and the mean total fragment kinetic energy $TKE$. Because $\langle \ell \rangle$ is very well determined, we employ this anti-correlation to derive a significantly stricter tolerance on $TKE$. We also study the sensitivity to the FREYA input parameters. 


$^1$This work was performed under the auspices of the U.S. Department of Energy under Contracts DE-AC52-07NA27344 (R.V.), DE-AC02-05CH11231 (J.R.) and DE-AC52-06NA25396 (P.T.)

10:42AM SK.00002 Development of $^{129}$I AMS at the Nuclear Science Laboratory for Sampling in the Great Lakes Region, MICHAEL SKULSKI, TYLER ANDERSON, LAUREN CALLAHAN, ADAM CLARK, AUSTIN NELSON, PHILIPPE COLLON, University of Notre Dame, MICHAEL PAUL, The Racah Institute of Physics, The Hebrew University of Jerusalem — $^{129}$I in the environment primarily comes from its release from nuclear fuel reprocessing centers in Europe. Iodine moves through the environment very easily because it is highly soluble and easily incorporated into biological organisms. This high mobility makes $^{129}$I an excellent environmental tracer in a variety of fields including geology, nuclear forensics, and nuclear safeguards. However, because of its long half-life of 15.7 Myr, detection of $^{129}$I through direct decay counting methods is often unachievable because of the sample size that would be required. Accelerator mass spectrometry (AMS), on the other hand, is well suited to the detection of $^{129}$I as it can identify individual ions through isotopic and isobaric discrimination. The environmental sampling throughout the United States has been primarily limited to the areas surrounding nuclear facilities, but there are few measurements of the concentrations of $^{129}$I throughout the rest of the country. This has inspired the AMS group of the Nuclear Science Laboratory at the University of Notre Dame to measure the concentrations in the Great Lakes region to establish a baseline for measuring the change of these concentrations in the future. Preliminary results of $^{129}$I measurements and future plans will be discussed.

$^1$This work is supported by the NSF through grant number PHY-1713857

10:54AM SK.00003 In-Situ Beam Current Monitoring Reaction for in-air Particle-Induced Gamma Emission Spectroscopy, JOHN WILKINSON, University of Notre Dame — Particle-induced gamma emission spectroscopy performed in-air takes advantage of the nuclear monitoring reaction of $^{40}$Ar(p,$\gamma$)$^{40}$K for beam current normalization. The second excited state of $^{40}$K deexcites with characteristic gamma line 770 keV and is easily observed using the same HPGe detector as for sample analysis. Experimentation has been conducted at the University of Notre Dame’s Nuclear Structure Laboratory using 4 MeV protons impinged on targets of interest using a modified Alphatross ion source with a 3 MV 9S tandem accelerator. Preliminary data shows this technique has reduced analysis uncertainty and simultaneously tracks both beam intensity and optics over several hours.

11:06AM SK.00004 Nuclear Physics and Planetary Exploration, KATHERINE MESICK, DANIEL COUPLAND, KURTIS BARTLETT, Los Alamos National Laboratory — Neutron and gamma-ray spectroscopy (NGRS) of planetary bodies has become a standard technique for measuring distinctive geochemical compositions and volatile abundance signatures for key elements relevant to planetary structure and evolution. These measurements also provide important information for in-situ resource utilization and human exploration. On airless or near-airless bodies, Galactic Cosmic Rays (GCRs) interact within the top meter of planetary surfaces, producing spallation neutrons. Moderation of GCR spallation neutrons by hydrogen provides a unique signature indicating the presence and abundance of near-surface water. These neutrons also undergo inelastic scattering or capture with the surrounding material, resulting in gamma-ray emission at distinct energies. Neutron and gamma-ray detectors onboard orbiting spacecraft or landed rovers detect the leakage neutron and gamma-ray signatures and require good gamma-ray energy resolution, neutron energy determination over twelve orders of magnitude, and operation in harsh environments under mission resource constraints. This talk will describe NGRS basics and the Elpasolite Planetary Ice and Composition Spectrometer under development at LANL for next-generation, low-resource planetary science missions.

$^1$This work was supported by LANL Laboratory Directed Research and Development and NASA

11:18AM SK.00005 Updated Sensitivities for Accelerator Mass Spectrometry at the Notre Dame Nuclear Science Laboratory, ADAM CLARK, TYLER ANDERSON, LAUREN CALLAHAN, AUSTIN NELSON, MICHAEL SKULSKI, PHILIPPE COLLON, University of Notre Dame — Accelerator Mass Spectrometry (AMS) is an ultra-sensitive measuring technique excelling for long-lived isotopes where direct decay counting becomes impractical. At the University of Notre Dame’s Nuclear Science Laboratory (NSL), AMS capabilities for a select few isotopes have been developed over the last decade for studies ranging from radiocarbon dating ($^{14}$C), to nuclear astrophysics ($^{46}$Ca, $^{44}$Ti, $^{60}$Fe, $^{93}$Zr), and nuclear forensics ($^{129}$I). However, limitations and shortcomings in the accelerator system were identified. This prompted upgrades and modifications to both the low energy injection to the accelerator system and to the AMS beamline. The current status of the accelerator system and its recent improvements will be presented along with updated measurement sensitivities and developments toward measuring new isotopes at the NSL. This work is supported by the NSF: PHY-1713857 (NSL) and PHY-1337608 (MRI)
VI

Salon H - Grant Riley, University of Tennessee
and our timeline for the construction of a research reactor. The current status of NEXT will be presented including the breath of research across many disciplines. Molten salt research and test reactor. The current status of NEXT will be presented including the breadth of research across many disciplines.

Lab mission is to provide global solutions to the world’s needs for energy that is less expensive and safer, water that is pure and abundant, and medical isotopes used to diagnose and treat cancer by advancing the technology of molten salt reactors while educating the next generation of leaders in nuclear science and engineering. The NEXT Collaboration is focusing on advancing the technical readiness level of molten salt as a reactor. molten salt research and test reactor. The current status of NEXT will be presented including the breadth of research across many disciplines and our timeline for the construction of a research reactor.

Thursday, October 17, 2019 10:30AM - 12:18PM – Session SL Mini-Symposium on Fundamental Symmetries: Theory and Experiment VI
Salon H - Grant Riley, University of Tennessee

10:30AM SL.00001 The Nab Neutron Decay Correlation Experiment1, Christopher Crawford, University of Kentucky, NAB COLLABORATION — Neutron decay correlations provide a clean probe of the CKM matrix element Vub, and provide limits on new tensor and scalar interactions. The Nab experiment is currently being commissioned at ORNL to measure the antineutrino-electron correlation a with a relative uncertainty of 10^3, and the Fierz interference term b with an overall uncertainty of 3 x 10^3. This experiment uses a new technique to determine the antineutrino-electron angle from the energy of the electron and proton, detected in coincidence. I will present the physical design, modes of running, and projected sensitivity of this experiment.

1This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under Award Number DE-SC0014622.

10:42AM SL.00002 Magnetometry of the Nab Spectrometer1, Elizabeth Scott, University of Tennessee, THE NAB COLLABORATION — The Nab experiment uses a novel asymmetric superconducting magnetic spectrometer and two large-area segmented Si detectors to extract the neutron beta decay electron-neutrino correlation coefficient a and the Fierz interference term b from the proton momentum and electron energy spectrum. Nab was designed to achieve a 10^{-3} relative uncertainty in a, and this requires a detailed characterization and analysis of the magnetic field in the spectrometer. Using a Hall probe calibrated to better than 10^{-3} relative precision and the laser trackers that can measure distances within tens of microns, we mapped a field that ranged from tens of gauss to 4.2 Tesla over 7 meters. This talk will cover the measurement technique, results of the field characterization scheme, and the field expansion methods used.

1The Nab experiment is supported by grants from the US NSF and DOE DE-FG02-03ER41258, as well as Canada’s NSERC.

10:54AM SL.00003 Towards Polarimetry for the Nab Experiment1, Chelsea Hendrus, University of Michigan, NAB COLLABORATION — The Nab experiment at the Fundamental Neutron Physics Beamline (FnPb) at the Spallation Neutron Source (SNS) aims to make precision measurements of the electron-neutrino correlation, a, and Fierz interference term, b, associated with the beta decay of free neutrons. Tiny residual polarization of the incident beam presents a potential source of systematic error in the measurement of a. In order to understand and mitigate these effects we must measure the beam polarization and the efficiency of our neutron spin flipper. If we use 3He polarizers to accomplish these measurements, it will require careful control of the magnetic environment along the beam, in order to both assure adiabatic spin transport of the neutrons, and prolong the polarization lifetime the 3He cells. However the space for incorporating the necessary components is limited, and requires the use of novel approaches to magnet construction to obtain the requisite fields. This talk will describe the polarimetry setup and simulated spin transport results.

1 The Nab experiment is supported by grants from the US NSF and DoE, as well as Canada’s NSERC(∗).
11:06AM SL.00004 Nab Detector Timing Studies. GLENN RANDALL, Arizona State University. NAB COLLABORATION — Precise measurements of neutron beta decay correlations provide a potential window to new physics related to the weak sector. The Nab experiment will measure the electron-neutrino correlation coefficient and Fierz interference term to as of yet unattained precision. Observables for Nab are electron energy and proton time of flight, which can be converted to proton momentum. Nabs’s error budget calls for proton time of flight uncertainty less than or equal to 0.3 ns. One major systematic in proton time of flight is detector charge collection time. To characterize this, Nab will have to do a high precision in situ measurement of the Nab Si detector charge collection time as a function of particle ID and energy. This talk will focus on our planned procedure as well as detector background and other measurements done in preparation.

This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Workforce Development for Teachers and Scientists, Office of Science Graduate Student Research (SCGSR) program. The SCGSR program is administered by the Oak Ridge Institute for Science and Education for the DOE under contract number DESC0014664. The Nab experiment is supported by grants from the US NSF and DoE, as well as Canada’s NSERC.

11:18AM SL.00005 (CEU) Simulating Inside Detector Physics for the Nab Experiment. TOM SHELTON, University of Kentucky, LEAH BROUSSARD, Oak Ridge National Lab, NAB COLLABORATION COLLABORATION — The Nab experiment will measure the electron-neutrino correlation coefficient and the Fierz interference term in unpolarized free neutron beta decay with high precision allowing the probing of the standard model and the weak interaction. To meet these precision goals, uncertainty in the average proton time-of-flight must be within 0.3 ns. To achieve this precision, we must account for the systematic bias created from deposition depth of the particles in the silicon detector due to drift times of quasi-particles resulting in differing charge collection timings. Simulation of the inner detector physics is critical in understanding the significance of this consequence. By characterizing data sets from CASINO and integrating these into custom charge propagation code, we were able to construct the resultant waveforms and determine the timing offset. We will present the process of said simulations along with analysis of this effect.

This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under Award Number DE-SC001462, and in part by the U.S. Department of Energy, Office of Science, Office Workforce Development for Teachers and Scientists (WDTs), under the Science Undergraduate Laboratory Internship program.

11:30AM SL.00006 (CEU) Pile-up Detection in Silicon Detector Signals via Machine Learning for the Nab Experiment. DAVID PERRYMAN, University of Tennessee, NAB EXPERIMENT COLLABORATION — Pixelated Silicon detectors and shaping electronics in the Nab Experiment will produce digitized waveforms from which energy and timing information can be extracted. Electrons that escape and return to the same pixel, or particles that accidentally arrive in the same waveform can distort results if not detected and accounted for. This talk will present a machine learning approach to detecting these events using feedforward dense, convolutional, recurrent, recurrent convolutional, and residual convolution networks. 1-dimensional variations of the popular ResNet50 and ResNet152 have been implemented. This talk will also discuss a Generative Adversarial Networks (GANs) and dimensionality reduction approach to investigating weaknesses in pile-up detection.

The NVIDIA Titan used for this research was donated by the NVIDIA Corporation.

11:42AM SL.00007 GPU Based Nearline Analysis for the Nab Experiment. DAVID MATHEWS, University of Kentucky. THE NAB COLLABORATION COLLABORATION — The Nab neutron decay correlation experiment will use two 127-pixel silicon detectors digitized at 250 MS/s to record the energy and time-of-flight of electron-proton coincidences for full kinematic reconstruction of $\theta_{\beta\nu}$. Raw waveform data will be collected from 30 pixels per event at an anticipated rate of 50 kHz for offline analysis. While first-order timing and energy are available from the data acquisition firmware, higher resolution is desired for immediate analysis. We developed a GPU-based least-squares fitter which decompresses the raw datastream and fits the amplitude of multiple template waveforms and background noise in real time as part of the data acquisition pipeline. These same algorithms will be used on GPU farms for offline processing of the final results.

This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under Award Number DE-SC001462.

11:54AM SL.00008 Characterizing a silicon detector alpha response for the Beta-decay Paul Trap. LOUIS VARRIANO, GUY SAVARD, Univ of Chicago. Argonne Natl Lab, JASON A CLARK, Argonne Natl Lab, NICHOLAS D SCELZ, Lawrence Livermore Natl Lab, DANIEL P BURDETTE, Univ of Notre Dame, Argonne Natl Lab, MARY BURKEY, AARON GALLANT, Lawrence Livermore Natl Lab, TSVIKI Y HRISH, Soreq NRC, RALPH SEGEL, Northwestern Univ — The Beta-decay Paul Trap (BPT) at Argonne National Lab studies the weak interaction with short-lived radioactive ions at low energies. The BPT measures the beta-neutrino angular correlation coefficient $a_{\beta\nu}$ in the pure Gamow-Teller decay of $^6$Li and $^8$B (decaying to $^7$Be) with immediate break up to 2 alpha particles) to search for a tensor component of the weak interaction. By using double-sided silicon strip detectors (DSSSDs) to detect the decay products, the BPT has improved the tensor current limit from the low energy side for the first time in over fifty years. To further improve this limit, with a measurement goal of 0.1% uncertainty in $a_{\beta\nu}$, it is necessary to fully understand the DSSSD response to alphas across a broad range of energies, including all undetected energy losses. In addition, it is necessary to understand the calibration source alpha distribution, as the sources used by the BPT are not lossless. This work characterizes the source alpha distribution and the DSSSD alpha response, which can be applied to other experiments that rely upon an accurate measurement of alpha energy.

The authors acknowledge the U.S. DOE under Contract No. DE-AC02-06CH11357 [ANL] and DE-AC52-07NA27344 [LLNL] and the NSF under Grant No. PHY-1713857 and DGE-1746045.
12:06PM SL.00009 Every Fundamental Particle, Nucleus, Atom, Molecule, Compound and/or Ion or Heavenly Bodies Exhibit No Motion, Linear, Rotational and/or Vibrational Motion, Singly or in Some Combination When Created Which May Be Modified By External Forces: A Natural Law. STEWART BREKKE, Northeastern Illinois University — All masses and mass groups, when created, will have due to excess energy when created, Linear, Rotational, and/or Vibrational motion, singly or in some combination, all, some or none, may be altered by external forces. The basic energy equation for any newly created mass is $E = m_0c^2 + 1/2m_0v^2 + 1/2I\omega^2 + 1/2kx^2$. $I\omega^2$ is the rotational kinetic energy and the factor $kx^2$ is the kinetic energy of a simple harmonic oscillator although any type of oscillator may result from excess energy of the mass’s creation. Since all masses and mass groups obey this behavior apparently everywhere in space. for example all galaxies, stars, planets and satellites have been found to be capable of moving linearly (orbital motion is linear motion under the influence of an external force field such as gravitational force), rotating and vibrating as are all nuclei, molecules, ions and compounds, are capable of moving linearly, rotating and/or vibrating singly or in some combination on earth, this behavior can be considered a natural law describing the type of motion possibilities.

Thursday, October 17, 2019 10:30AM - 12:30PM —
Session SM Nuclear Astrophysics: Neutron Star Mergers and CEMP Stars Salon J - Aaron Couture, Los Alamos National Laboratory

10:30AM SM.00001 Uncertainties in Kilonova Heating from Nuclear Physics Inputs, KELSEY LUND, YONGLIN ZHU, North Carolina State University, JENNIFER BARNES, Columbia University, GAIL MCLAUGHLIN, North Carolina State University, MATTHEW MUMPPOWER, Los Alamos National Laboratory, REBECCA SURMAN, University of Notre Dame — The rapid neutron capture process ($\nu$-process) is one of the main mechanisms whereby elements heavier than iron are synthesized, and is responsible for the creation of the heaviest stable isotopes of the actinides. Observations of the gravitational wave event GW170817, and its optical counterpart, AT2017gfo, support neutron star mergers as an $\nu$-process production site. Efforts to accurately and reliably model yields and observational signatures from these sites require inputs from nuclear physics, which introduce potentially large uncertainties. We use nucleosynthesis modeling to evaluate the role of these inputs, including different nuclear mass models, fission decay rates, and daughter product distributions in lanthanide and actinide production. I will show that applying different nuclear physics inputs generates discrepancies in abundances of key isotopes which contribute significantly to the overall nuclear energy generation in the merger event, which is a necessary component of kilonova lightcurve modelling.

10:42AM SM.00002 ABSTRACT WITHDRAWN —

10:54AM SM.00003 Modeling Kilonova Light Curves from Neutron Star Mergers: Dependence on Astrophysical Conditions and Nuclear Inputs, YONGLIN ZHU, Department of Physics, North Carolina State University, JENNIFER BARNES, Department of Physics and Columbia Astrophysics Laboratory, Columbia University, KELSEY LUND, Department of Physics, North Carolina State University, TREVOR SPROUSE, NICOLE VASSH, University of Notre Dame, MATTHEW MUMPPOWER, Center for Theoretical Astrophysics, Los Alamos National Laboratory, GAIL MCLAUGHLIN. Department of Physics, North Carolina State University, REBECCA SURMAN, University of Notre Dame — The unprecedented observations of the gravitational wave event GW170817, and its optical counterpart, AT2017gfo, suggest neutron star mergers as a production site of the heaviest elements. In order to create accurate estimates of these signals, we need nuclear models, astrophysical models of the site, as well as models of the radioactive transfer. We evaluate and provide a comprehensive estimate of the nuclear and astrophysical uncertainties with nucleosynthesis informed kilonova light curve modeling. We find that the combined nuclear and astrophysical uncertainties have a significant contribution to the uncertainty the light curves associated with neutron stars mergers (kilonova). We evaluate the role of fission decay rates and fission daughter product distributions in nuclear energy generation and the production of the lanthanides and actinides, both key quantities for setting the overall luminosity and the timescale for the decay of the optical counterpart.

11:06AM SM.00004 Deep neural networks for real-time detection and characterization of gravitational waves from compact binaries, PLAMEN KRASTEV, Harvard University — Deep neural networks are computational models with the ability to learn from observational data and have already had spectacular success in tasks such as computer vision and natural language processing. I present a deep learning framework for real-time detection, classification and parameter estimation of gravitational waves from compact binaries, with a particular attention to systems involving neutron stars. The implications for detection and interpretation of recent and future gravitational-wave signals from neutron-star binaries, and the equation of state (EOS) of dense matter will be discussed.

11:18AM SM.00005 Hyperon Bulk Viscosity in Neutron Star Mergers, ALEXANDER HABER, MARK ALFORD, Washington University, St. Louis — In hyperonic matter, a phase lag between an imposed density oscillation and the beta reequilibration of the particle content, gives rise to a hyperonic bulk viscosity. Hyperonic bulk viscosity has been computed in the past for low temperatures and mostly by using a contact interaction matrix element. In neutron star mergers, much higher temperatures and densities than in an isolated star are reached. Therefore, it is necessary to reevaluate this phenomenon in the physical environment of neutron star mergers by including all possible reactions and going beyond the simple Fermi surface approximation. If bulk viscosity is sufficiently strong, it can significantly dampen density oscillations and should be included in merger simulations.
11:30AM SM.00006 Connecting Nuclear Structure to Stellar Astrophysics: Neutron Skin in Tin Isotopes, J. Jack Silano, A. P. Tonchev, N. Schunck, Lawrence Livermore National Laboratory, W. Tornow, F. Krishichayan, S. Finch, Duke University, and TUNL, D. Little, M. Jones, R. Janssens, UNC - Chapel Hill and TUNL, C. Pruitt, L. Sobotka, Washington University, St. Louis, A. Banyo, James Madison University, J. Vavrek, MIT, N. Tsonveva, ELLI-NP — The first observation of a neutron star merger by the LIGO-Virgo collaboration in 2017 highlights the need to improve our fundamental understanding of the equation of state (EOS) of dense, neutron rich matter. The origin of heavy elements in the r-process and the structure of neutron stars are governed by the properties of neutron rich matter, for which experimental data is limited. Further analysis of this historic event and all future neutron star mergers rely on constraining the nuclear EOS with experimental observables. We propose a novel method for systematically studying the evolution of the neutron skin in stable tin isotopes, by measuring the low-energy nuclear dipole strength over the broadest possible range of neutron-to-proton ratios in a single element. Nuclear resonance fluorescence with 100% linearly polarized photons from the High Intensity γ-ray Source facility will be used to selectively measure the E1 photoabsorption strength of $^{121}$Sn and $^{123}$Sn at excitation energies from $\sim 3$ MeV up to neutron separation, where the Pygmy Dipole Resonance dominates. Progress on the measurement campaign will be presented.

1This work was performed under the auspices of US DOE by LLNL under contract DE-AC52-07NA27344.

11:42AM SM.00007 Constraining neutron-capture reactions for the astrophysical i-process, Artemis Spyrou, Caleb Harris, Mallory K Smith, Sean N Liddick, Katie Childers, Rebecca Lewis, Stephanie Lyons, Alcira Palmasano, Andrea L Richard, Debora Richman, Chandana Sumithrarachchi, Michigan State University, Magne Guttormsen, Vethle Ingeberg, Ann-Cecilie Larsen, University of Oslo, Alex Dombos, Rebecca Kelmar, Farheen Naqvi, University of Notre Dame, Paul DeYoung, Hope College, Panagiotis Gastiis, Central Michigan University, Christina Burbage, Ewa Kasanda, Dennis Muecher, University of Guelph, Darren Bleuel, Nicholas D Scielzo, Lawrence Livermore National Laboratory, Adrianet — The synthesis of heavy elements in the Universe has been one of the main open questions in Nuclear Astrophysics. Recent astronomical observations of carbon enhanced metal-poor stars (CEMP) showed a significant number of stars with abundance patterns that cannot be reproduced by the traditional neutron-capture processes (s and r).

An alternative process was introduced for this purpose with intermediate neutron densities, called the i-process. From the nuclear physics point of view, most nuclear properties are known experimentally, and the main uncertainty comes from neutron-capture reaction rates. This talk will focus on an experimental program taking place at the NSCL to provide indirect constraints for the ($\beta$,γ) reactions using the β-Oslo method.

11:54AM SM.00008 Constraining i-process Nucleosynthesis via the Neutron-Capture Cross sections of $^{102,103}$Mo, Andrea L Richard, S. N. Liddick, A. C. Dombos, A. Spyrou, T. Baumann, K. Childers, T. Ginter, E. Kwan, R. Lewis, S. Lyons, F. Naqvi, W.-J. Ong, A. Palmasano, J. Pereira, C. Prokop, S. J. Quinn, M. K. Smith, C. S. Sumithrarachchi, Michigan State University, A. Simon, University of Notre Dame, P. A. DeYoung, J. Gomas, Hope College, O. Clarkson, F. Herwig, University of Victoria, B. P. Crider, Mississippi State University, A. Algara, Instituto de Fisica Corpuscular — Recent observations and stellar evolution models suggest that an intermediate process, known as the i-process, exists between the s- and r-processes, and is necessary to explain observed abundances in the Ge-Te region. Uncertainties associated with nuclear physics inputs, especially neutron-capture cross sections, limit the predictive power of i-process simulations. In this work the β-Oslo method was used to study $^{103,104}$Mo at the NSCL via the β-decay of $^{103,104}$Nb which were detected using the Summing NaI(Tl) (SU) total absorption spectrometer. Results on the NLD, γSF, neutron-capture cross sections of $^{102}$Mo and $^{103}$Mo, and i-process calculations from the Nucleosynthesis Grid (NuGrid) Collaboration will be presented.

1This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0003180.

12:06PM SM.00009 Indirect Study of Neutron Capture for $^{63}$Fe(n,g) , Mallory Smith, Artemis Spyrou, NSCL, WEJ Jia Ong, LLNL, SungHoon Ahn, TAMU, Alex Dombos, Univ. of Notre Dame, Sean Liddick, Fernando Montes, NSCL, Farheen Naqvi, Univ. of Delhi, Debra Richman, Hendrick Schatz, Justin Browne, Katie Childers, NSCL, Ben Crider, Mississippi State Univ., Chris Prokop, LANL, Eric Deleew, NSCL, Paul De Young, Hope College, Christoph Langer, Univ. of Frankfurt, Becky Lewis, NSCL, Zach Meisel, Ohio University, Jorge Pereira, NSCL, Steve Quinn, J Hopkins Univ. Applied Physics Lab, Konrad Schmidt, TU Dresden, Ann Cecilie Larsen, Magne Guttormsen, Univ. of Oslo — Far from stability, little is known about neutron capture. This is an indirect method known as the βOslo method allows n-capture rates to be experimentally constrained for radioactive nuclei. The reaction product is populated in β-decay, and the γ strength functions (γSFs) and nuclear level densities (NLDs) are extracted simultaneously. These are used to constrain the n-capture rate. In the FeCd region, an unexpected low-energy enhancement (LEE) in the γ-decay probability has been observed. The presence of this can have a significant influence on neutron capture rates. The LEE is expected in the neutron-rich Fe isotopes. At the NSCL, 64Fe was measured with the Summing NaI detector. Recent results will be presented with a focus of the LEE.

12:18PM SM.00010 Analysis of Astrophysical Reaction Rates Using ENDF/B-VIII.0 and TENDL-2015 Libraries in 0.01-10 GK Range of Temperatures, Boris Pritychenko, Brookhaven National Laboratory — Recent observations of neutron stars merger (GW170817) renewed interest in stellar nucleosynthesis calculations. Stellar nucleosynthesis modeling requires fully traceable, unbiased, high fidelity nuclear data. The Evaluated Nuclear Data File (ENDF) libraries contain complete collections of reaction data sets over the nuclear industry standard 10⁻⁵ eV - 20 MeV energy span. For the first time ($\alpha$,γ), (n,fission), (n,p), and (n,α) astrophysical reaction rates were computed within 0.01-10 GK range of temperatures using ENDF/B-VIII.0 and TENDL-2015 libraries, and REACLIB fit parameters were deduced. The present results were used to estimate the slow neutron capture timescale for multiple libraries. These findings demonstrate the potential astrophysical applications of the ENDF libraries and the complementary relations between the nuclear industry and astrophysics data developments.

1Work at BNL was funded by the US DOE, Office of Nuclear Physics under Contract No. DE-AC02-98CH10886 with Brookhaven Science Associates, LLC.

Thursday, October 17, 2019 10:30AM - 12:30PM – Session SN Undergraduate Research I Salon K - Shelly Lesher, University of Wisconsin, La Crosse
10:30AM SN.00001 Advice for Running Successful Undergraduate Research Programs – Observations of 50 Years of Methodology at an Undergraduate Institution\textsuperscript{1}

LARRY DONALD ISEHOWER, Abilene Christian University — This year, 2019, marks 50 years of a successful undergraduate research program at Abilene Christian University. This talk is an update of the author’s invited talks for the 2015 APS Prize for Outstanding Research at an Undergraduate Institution given at the March and April 2015 APS Meetings. During the past 5 years ACU’s undergraduate research program has increased in size and breadth. Likewise, during the past 5-10 years there has been an increased emphasis on research experiences as part of undergraduate education at many schools. What are the most important aspects that maximize the benefits for both the student and the institution? There are some important distinctions observed that seem to predict success. Emphasis is given to what the faculty members must do and how to make the research experience much better for the student. There are pitfalls that must be avoided, which requires more work by faculty and staff members. The rewards are significant in the development of students, who by their third year are able to function almost independently and can be assigned critical path tasks, increasing the roles an undergraduate can take on, including critical work in large collaborations well beyond ordinary construction tasks.

\textsuperscript{1}Primary support from U.S. DOE Office of Science - Intermediate Energy, grant DE-FG02-03ER41424.

10:42AM SN.00002 Constructing a Low Cost, Portable Cosmic Ray Muon and Neutron Detector . JAMES SHIRK, XIAOCHUN HE, Georgia State University — A modular, portable, low-cost, and state-of-the-art cosmic ray muon and neutron detector called a ‘cosmic ray telescope’ has been developed at Georgia State University. It has been designed to measure surface level cosmic ray muon and neutron flux, and is portable to allow for worldwide deployment. The telescope consists of three layers of plastic scintillator tiles used to measure muons, and a ‘neutron-cell’, or tank, filled with liquid scintillator to measure both muons and neutrons. Cosmic ray particles cause the scintillators to emit light which is captured by an embedded wavelength shifting fiber routed to a silicon photo-multiplier (SiPM). The data acquisition (DAQ) is performed via custom built SiPM interface boards connected to a Raspberry Pi. This presentation will highlight the construction of thirty telescopes and their performance tests. A Geant4-based Monte Carlo simulation of the telescope performance will also be presented.

10:54AM SN.00003 Simulation and Random Coincidence Rejection of 2νββ Decay Background in the CUPID Experiment . RUOXI WANG, East China Normal University — The CUPID experiment (CUORE Upgrade with Particle ID) is a proposed experiment to search for neutrinoless double beta decay using both light and heat detectors. Due to the time resolution limits of those detectors, the random coincidence of two-neutrino double beta decay events (pile-up events) in the same crystal has become the main background that could limit the experimental sensitivity. Therefore, it is crucial to distinguish and reject pile-up events of two-neutrino double beta decay in CUPID. In this project, software simulations of two-neutrino double beta decay backgrounds have been built. Algorithms of pile-up rejection, such as the mean-time method and derivative mean-time method, are discussed. Background index of pile-up two-neutrino double beta decay events is also computed with rejection efficiencies of such algorithms, and requirements on the risetime and signal-to-noise ratio of the detector pulses are derived. These results can provide possible constraints on detector sampling rate, energy and time resolutions, which are essential for future development of CUPID and the next-generation bolometric experiments.

10:06AM SN.00004 ABSTRACT WITHDRAWN –

11:18AM SN.00005 A Ring Imaging Cherenkov Detector for CLAS12 at Jefferson Lab\textsuperscript{1} . CONNORPECAR, FATIHA BENCHMHTAR, Duquesne University, MARCO MIRAZITA, INFN Laboratori Nazionali di Frascati, CLAS12 RICH COLLABORATION — A hybrid proximity Ring Imaging Cherenkov (RICH) detector has been built and is functional in the CLAS12 spectrometer in Jefferson Lab’s Hall B. The RICH was constructed for separation of kaons from pions and protons in the 3-8 GeV/c momentum range. The RICH contains a wall of aerogel tiles (refractive index \( n = 1.05 \)) which cause the production of Cherenkov radiation as particles under investigation enter the detector. Depending on the incident angle of the particle, the radiation ring will either travel directly to the readout photosensors or be redirected via a system of spherical and planar mirrors towards the readout electronics panel. The radiation is detected by a panel of 391 Multi-Anode Photomultiplier Tubes (MAPMTs) with pixel size of 6 mm and recorded by the readout electronics with accurate time resolution below 1 ns. In the last year, data has been taken using one RICH module and a second module is currently under construction. The performance of the RICH during the CLAS12 data-taking will be presented.

\textsuperscript{1}NSF Grant F. Benchmhtar 1615067 and DOE/INFN

11:30AM SN.00006 Acceptance tests of Fast Interaction Trigger modules for the upgrade of the ALICE experiment . ISAIAH MORGAN, RYAN STEMPEK, AUSTIN HARTON, EDMUNDO GARCIA-SOLIS, Chicago State University, YURI MELIKYAN, Institute for Nuclear Research of the Russian Academy of Sciences, MACIEJ SKRZYPEK, Helsinki Institute of Physics, University of Jyvaskyla, FIT-ALICE COLLABORATION — CERN (European Center for Nuclear Research) is a global laboratory devoted to proton and heavy-ion collisions at the Large Hadron Collider (LHC). ALICE (A Large Ion Collider Experiment) is one of four major experiments at the LHC. ALICE is dedicated to the study of the transition of matter to Quark-Gluon Plasma in heavy ion collisions. In Run 1 and 2, ALICE used several sub-detectors to provide, for instance, minimum bias trigger, multiplicity trigger, beam-gas event rejection, precise collision time, online vertex, multiplicity, and event plane determination. For Run 3 and 4 the former Forward Detectors will be replaced by the Fast Interaction Trigger (FIT) system. In this talk, we describe the key components of FIT, show the characteristics of the FIT detector, present sample results of based photosensor modules designed for the FIT Cherenkov array of FIT. The MCP modules tests are taking place at CERN and involve six different characterization procedures to confirm the design parameters of the MCPs. This work is partially supported by the National Science Foundation under Grants No. NSF-PHY-1613118, NSF-PHY-1625081, and NSF-PHY-1719759.

11:42AM SN.00007 Analytical Studies of EIC Collider Kinematics . SEAMUS GALLAGHER, BERND SURROW, Temple University — A US-based collider facility capable of colliding high-energy polarized electron (e) and ion beams (Proton (p) / Nucleus (A)) at high luminosity will address some of the most profound questions concerning the emergence of nuclear properties. The precise reconstruction of relativistic-invariant variables such as the negative four-momentum transfer squared, \( Q^2 \), and the Bjorken-\( z \) scaling variable is a crucial aspect for any physics measurements in deep-inelastic ep/eA scattering (DIS). ep/eA scattering can be viewed as the scattering of a lepton (e) with a struck quark (\( q \)) resulting in a scattered lepton (e) (Energy \( E_e' \) and polar angle \( \theta_{e'} \)) and a struck quark (\( q \)) (Energy \( E_q' \) and polar angle \( \theta_q' \)) in the final state. Relativistic invariant variables can be reconstructed by any two of the four measured quantities, \( E_e' \), \( \theta_{e'} \), \( E_q' \) and \( \theta_q' \), resulting in six distinct reconstruction methods. The full determination of DIS relativistic-invariant quantities will be presented in terms of those measured quantities including a full analytical error analysis including a discussion of the properties of each of the six reconstructions methods and further plans such as the comparison to a MC simulation.
11:54AM SN.00008 Engineering the resistive bases of the electromagnetic calorimeter in hall a at Jefferson Lab. JORGE PENA, Student Researcher, GABRIEL NICULESCU, IOANA NICULESCU, Research Professor, JEFFERSON LAB SUPER BIGBITE SPECTROMETER COLLABORATION, JEFFERSON LAB HALL A COLLABORATION — The Super Bigbite Spectrometer (SBS) to be used in Hall A at Jefferson National Accelerator Lab to carry out a number of seminal experiments, such as the measurements of the electric and magnetic form factors of the proton and neutron. The JMU Particle and Nuclear Physics group is working on preparation of the 1700+ channel electromagnetic calorimeter, including construction of the new voltage dividers that will be used to power and extract the signal from the Photomultiplier Tubes (PMTs). In the talk the design of new resistive base and the layout of its electronic circuit will be presented. The challenges and solutions of the design work and electrical measurements of the existing resistive bases will be shown.

12:06PM SN.00009 Development and Testing of Thermal Conductivity Test Stand, DONOVAN DAVINO, University of Connecticut — This Research and Development program, conducted at L’Institut de Physique Nucléaire d’Orsay (France), is aimed at developing and mastering innovative Vacuum Heat Treatment (VHT) processes in order to produce high functional performance bulk niobium (Nb) superconducting radio frequency cavities for accelerators. VHT of Nb has a strong impact on thermal conductivity k(T) at cryogenic temperature and especially on the phonon peak at T=2 K. A new test-stand dedicated to the measurement of k(T) in the temperature range 1.6 K-30 K is developed. The test-cell allows the measurement of 4 samples simultaneously, drastically improving samples turn-over. The samples are tested as received and then tested once subjected to VHT (hydrogen outgassing, nitrogen infusion). My role was largely in the mechanical assembly of the test-cell and instrumentation, including preparation and preliminary tests: Currently, I have performed k(T) measurement at T=77K-85K, and similar measurement will be performed in liquid helium. The data is reported, discussed, and compared to literature.

1The work was supported by National Science Foundation IRES Award No. 1658713.

12:18PM SN.00010 Measuring the efficiency of counter-flow heat exchangers for the nEXO cryogenic system, SHOHAM WEISS, Undergraduate Researcher, LIANG YANG, Research Professor — Neutrino-less double beta decay is a still undetected phenomenon. Its detection could shift our understanding of particle physics. In double beta decay, two neutrons decay into two protons, two electrons and two neutrinos. Theoretically, the two neutrinos could annihilate, and the decay would be neutrino-less, thus confirming that neutrinos are “Majorana” particles. This decay is detected using enriched xenon, which decays into barium through double beta decay and possibly through the neutrino-less version. A 5-ton detector called the next Enriched Xenon Observatory (nEXO) is being planned, hoping to observe this phenomenon. The big chamber contains impurities that seep into the xenon, so we recirculate the xenon to purify it, then condense it to detect any decay. The current process of evaporating and then condensing is inefficient. Our research investigates using heat exchangers to save power in the recirculation process. The heat exchanger is used to transfer heat from the hot xenon entering the chamber into the cold xenon exiting the chamber. This would be instead of heating one and cooling the other separately and thus save power. Our setup recirculates xenon and compares the cooling power used with a heat exchanger versus without a heat exchanger. Our results show that using a heat exchanger is 90% efficient and would be a good addition to nEXO.

1Acknowledgments: This material is based upon work supported by the National Science Foundation under Grant No. 1654495, the United States Department of Energy under Grant No. DE-SC0014332, and the Department of Physics at the University of Illinois at Urbana-Champaign. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the funding agencies.