Thursday, May 1, 2014 6:30PM - 8:00PM –
Session A1 Public Lecture  Physics and Astronomy Building 102 - Oscar Vilches, University of Washington

6:30PM A1.00001 Pre-Talk Snacks —

7:00PM A1.00002 Lise Meitner, Her Escape from Germany and the Discovery of Fission  ANTHEA COSTER, MIT Haystack Observatory — Lise Meitner was one of the pioneers of nuclear physics and co-discoverer, with Otto Hahn and Fritz Strassmann, of nuclear fission. Albert Einstein once called her "the most significant woman scientist of the 20th century." Yet by the time her name was nearly forgotten. With the publication of the book by Ruth Lewin Sime, "Lise Meitner, A life in physics," to some extent her name has resurfaced. The chronology of the discovery of fission is considerably more complex than the facts, and clouded by events beyond the world of science. The facts are that on January 6, 1939, Hahn and Strassmann reported in Naturwissenschaften their chemical findings for fission. On February 11, 1939, Meitner and Frisch published in Nature the physical interpretation of the process they named fission. In 1944, Otto Hahn alone received the Nobel Prize in Chemistry "for his discovery of the fission of heavy nuclei." I became familiar with Lise Meitner and her story when, in 1972, Dr. Sime started writing my father for details about Lise Meitner’s escape from Germany. This is because in July 1938, my grandfather, Dirk Coster, was the person who escorted her out of Germany. In Sime’s book, Meitner’s escape from Germany reads like a spy novel, except that it is completely based in fact. At age 59, Meitner left Germany forever with 10 marks in her purse, one small suitcase, and a diamond ring given to her by Otto Hahn that he had inherited from his mother. This talk will be a combination of facts, excerpts from the film, “Path to Nuclear Fission: The Story of Lise Meitner and Otto Hahn” (a film by Rosemarie Reed), and personal stories heard from my father, aunts, and uncles. Lise Meitner’s early years, her role in the discovery of nuclear fission, her escape from Germany, and the consequences that followed will be covered.

Friday, May 2, 2014 8:20AM - 11:55AM –
Session B1 Plenary Session I  Alder Commons 104 (Auditorium) - Brian Milbrath, Pacific Northwest Laboratory

8:20AM B1.00001 Welcome —

8:30AM B1.00002 BICEP2 and the hunt for the axion  DAVID KAPLAN, Univ of Washington — The BICEP2 experiment has recently reported observation of primordial tensor perturbations which are consistent with predictions from inflation models with a high inflation scale. If true, this rules out many proposed particle physics models with scalar fields whose values in the early universe affect physics today, as induced fluctuations in such a field would lead to unacceptably high isocurvature fluctuations today, conflicting with observations of the Cosmic Microwave Background (CMB). In particular, axions produced above the inflation scale are ruled out, which closes a loophole by which these conjectured particles could escape detection. I give a survey of what we learn about axions, a fascinating story that brings together hadronic physics, inflationary cosmology, the hunt for dark matter, and the anthropic principle.

9:05AM B1.00003 Casting Light on Antimatter: Fundamental Physics with the ALPHA Antihydrogen Project at CERN1. MAKOTO FUJIWARA, TRIUMF/University of Calgary — ALPHA is an international project at CERN, whose ultimate goal is to test symmetry between matter and antimatter at highest possible precision via comparisons of the properties of atomic hydrogen with its antimatter counterpart, antihydrogen. After several years of development, we recently achieved significant milestones, including the first stable confinement of antihydrogen [1] for as long as 1000 seconds [2]. ALPHA has also succeeded in performing a spectroscopic measurement on antihydrogen atoms by driving its hyperfine transitions with microwaves [3]. Moreover, we have recently constructed an entirely new apparatus, ALPHA-2, which will allow laser access to the trapped anti-atoms, and provide improved magnetic field configurations for microwave spectroscopy. For the longer-term, possibilities for a measurement of antimatter-gravity interactions are being explored [4]. This talk will discuss the recent achievements and the future prospects of fundamental physics studies with ALPHA.


1Supported in part by NSERC, NRC/TRIUMF.

9:40AM B1.00004 The Many Paths Possible with a Physics Degree  LAURA PETICOLAS, Multiverse, Space Sciences Laboratory, UC Berkeley — Obtaining a degree in physics appears to be an excellent step in the path to finding a fulfilling career in a variety of professional endeavors. As someone with a Ph.D. in physics, I will present on my own path that has led me to directing a 12-person team in science education with partners around the country. My own career path can be understood as a case study for one possible path towards science education starting with a physics degree. I will share how physics has helped me make connections in unusual places. I will also share lessons I have learned about becoming a science educator, manager, and director. I will share a few stories of finding many fellow physics majors in many different careers: a CEO of an electric company in Michigan, the CEO of the Pixar Animation studios, a Wall Street stock market analyst, an economist, and several educators at science museums. In addition to this personal story, I will include references to results of excellent studies from the American Institute of Physics (AIP) Statistical Research Center, which publishes and analyzes data on education and employment in physics. And finally, I will also share how to find free and peer reviewed NASA education resources coming from the NASA physics education community.

10:15AM B1.00005 Break —
A model to predict the transition temperature for the unitary Bose gas with large number of particles. The system evolves from the liquid to the gas state. The connection of the phase-transition-like feature with Efimov physics will be discussed. At high temperature, the system is in the gas state in the intermediate temperature region. The energy, specific heat, and hyperradial distribution function are monitored as the system evolves from the liquid to the gas state.

The recent progress towards the creation of ultracold molecules of lithium and ytterbium, including the successful realization of a novel, long-lived Efimov “droplet” to normal gas system at unitarity. At low temperature, the system behaves like a \( N \)-body liquid droplet whose properties are tied to Efimov trimers. At high temperature, the system behaves like a gas consisting of Boltzmann particles. We observe a sharp phase-transition-like change from the droplet to the gas state in the intermediate temperature region. The energy, specific heat, and hyperradial distribution function are monitored as the system evolves from the liquid to the gas state. The connection of the phase-transition-like feature with Efimov physics will be discussed.

We acknowledge support by the NSF, AFOSR, and ARO-MURI.

We acknowledge funding from the NSF, AFOSR, and ARO-MURI.
Effective and intrinsic three-body interactions in ultracold harmonically-trapped few-atom systems

X.Y. YIN, Y. TIESINGA, D. BLUME, Washington State University

We derive the ground state energy for a small number of ultracold atoms in an isotropic harmonic trap using quantum field theory. Atoms are assumed to interact through pairwise energy-independent and energy-dependent delta-function potentials with strengths proportional to the scattering length and effective-range volume, respectively. Additionally, an intrinsic three-body potential with strength proportional to $g_3^{(0)}$ is accounted for. The calculations are performed systematically up to order $(a_{ho})^{-4}$, where $a_{ho}$ denotes the harmonic oscillator length. Effective-range volume dependent energy contributions are calculated up to order $(a_{ho})^{-5}$. We explain how our effective field theoretical results can be, if combined with independent energy calculations or measurements, used to obtain the renormalization scheme independent three-body contribution. The need for three-body counter-term interactions is discussed in the context of the effective-range volume dependent effective interactions.

Tunneling dynamics of two interacting one-dimensional particles

Seyed Ebrahim Gharashi, D. Blume, Washington State University

Motivated by recent cold atom experiments, the time evolution of two one-dimensional particles with attractive or repulsive short-range interaction is considered. We treat a realistic trapping potential that consists of an approximately harmonic optical trap plus a linear magnetic field gradient. This provides an "inside region," where the particles are trapped, and an "outside region," where the particles are free. When the barrier, which separates the two regions, is high enough, tunneling is suppressed. When the barrier is lowered, the time evolution of the system results in the loss of atoms from the trap. We find that pair tunneling dominates for strongly attractive interactions, while single-particle tunneling dominates for weak interactions.

Energy spectrum of harmonically trapped two-atom system with spin-orbit and Raman coupling

Q. Guan, X.Y. YIN, Seyed Ebrahim Gharashi, D. Blume, Washington State University

Ultracold atomic gases provide a novel platform with which to study spin-orbit coupling, a mechanism that plays a central role in the nucleus. Efficient coupling between ions and resonant photons is crucial for ion-photon and remote-ion entanglement protocols. We describe the operation of an RF ion trap in which a reflective parabolic surface serves as the trap's electrodes. This parabolic mirror covers a solid angle of approximately 2 Pi around the trapped ion, while a movable needle electrode allows precise ion placement at the focal point of the parabola. Operation of an RF ion trap in which a reflective parabolic surface serves as the trap's electrodes. This parabolic mirror covers a solid angle of approximately 2 Pi around the trapped ion, while a movable needle electrode allows precise ion placement at the focal point of the parabola. We measured approximately 40% solid angle fluorescence collection from a single Ba+ ion with this setup, with an image spot size of about twice the diffraction limit. Progress on image correction and fiber coupling will be reported.

Trapping ions in a 2-pi Parabolic Mirror

Chen-Kuan Chou, U of Washington

Gang Shu, Georgia Institute of Technology, Boris Blinov, U of Washington

Using multiple ion species allows ion-based quantum computing projects to overcome limitations of addressability and cooling in long ion chains. Namely, a single ion species would be used for quantum operations, while the other would be devoted to cooling of the entire chain. The cooling species are interspersed among the qubit ions to enable more efficient cooling while making individual addressing of the qubit ions easier. We attempt to measure and explore the effect of ion species ordering on the efficiency of the resultant cooling. Initially, the energy of spontaneous ion reordering is approximated via classical simulations. Then, the axial temperature and heating rate can be determined by measuring the time required for different length chains to reorder. Initial, approximate heating rates and work towards measuring ion species reordering effects are presented.

High sensitivity magnetometry with Cs vapor

Ruijie Li, Jiancheng Fang, Wei Quan, Beihang University

Spin-exchange relaxation free (SERF) magnetometry based on potassium has breakdown the magnetic field sensitivity record previously kept by the superconducting quantum interference devices (SQUIDs). We describe a Cs atomic magnetometer also operating in SERF regime. Utilizing a 20×20×20 mm vapor cell with a relative low temperature of 106 °C, we achieve the resonance linewidths 2.703Hz corresponding to an electron spin-exchange rate of 357 s$^{-1}$, and demonstrate magnetic field sensitivity of 8 fT/Hz1/2 in a single channel, as shown in fig. 1. Theoretical analysis shows that fundamental sensitivity limits of this device with a 1 cm$^3$ volume could approach 0.2 fT/Hz1/2. Taking advantage of the higher saturated vapor pressure, Cs magnetometry is particularly appropriate for lower temperatures applications.

Species Chains

John Wright, Tomasz Sakrejda, Richard Graham, Zhengzhou Zhou, Boris Blinov, University of Washington

Using multiple ion species allows ion-based quantum computing projects to overcome limitations of addressability and cooling in long ion chains. Namely, a single ion species would be used for quantum operations, while the other would be devoted to cooling of the entire chain. The cooling species are interspersed among the qubit ions to enable more efficient cooling while making individual addressing of the qubit ions easier. We attempt to measure and explore the effect of ion species ordering on the efficiency of the resultant cooling. Initially, the energy of spontaneous ion reordering is approximated via classical simulations. Then, the axial temperature and heating rate can be determined by measuring the time required for different length chains to reorder. Initial, approximate heating rates and work towards measuring ion species reordering effects are presented.

This work was supported by Key Programs of National Science Foundation of China under Grant No. 61227902 and 61374210.
4:21PM C1.00012 Empirical Method for Measuring the Photon Scattering Rate in a Magneto-Optical Trap*, JAMES BOOTH, British Columbia Institute of Technology, KAIS JOOYA, FUMIEI KOBAYASHI, NAM MUSTERER, KIRK MADISON, University of British Columbia—We have recently demonstrated an empirical technique for determining the photon scattering rate of atoms in a magneto-optical trap (MOT) [1]. This method provides a way to measure the in-situ saturation parameter experienced by the atoms in the trap, and, as a result, more accurately determine the atom number and the excited state fraction in the MOT. To validate the technique, we compared the atom number extracted from fluorescence measurements (which rely on the scattering rate) to an independent atom number measurement based on the absorption of an optical pumping beam. Minor deviations observed from the predictions of the generally accepted two-level atom model of light scattering led us to extend the standard analysis by describing the atoms as four-level systems. This approach incorporates the effects of the repump laser on the scattering rate and provides a better description of the observed fluorescence. The main advantage of the new technique is that it provides a straightforward, empirical method for determining the photon scattering rate of atoms in a MOT, therefore improving the atom number measurement accuracy from the fluorescence readings.


*This work was supported by NSERC, CFI, and BCIT SCAS.

4:33PM C1.00013 Charge Transfer Processes between H/D and Small Molecular Ions, K.G. BACANI, S.L. HEczKO, R.A. STROM, V.M. ANDRIANARIAJONa, Department of Physics, Pacific Union College, Angwin, CA 94508, USA, D.G. Seely, Physics Department, Albion College, Albion, MI 49224, USA, C.C. Havener, Physics Division, Oak Ridge National Laboratory, Oak Ridge, TN 37830, USA—Charge transfer on molecule proceeds through dynamically coupled electronic, vibrational, and rotational degrees of freedom. The inelastic vibrational processes, which go along with the reaction, can be experimentally investigated by using H/D systems, which do not allow multi-electron capture. Using the upgraded ion-atom merged-beams apparatus at Oak Ridge National Laboratory, absolute direct charge transfer cross sections for H+D, D+O2, CO+O2, O2+D, and H+D+ are measured from keV/u collision energies where the collision is considered “ro-vibrationally frozen” to few eV/u energies where collision times are long enough to sample vibrational modes. The measurements presented here benchmark high energy theory and vibrationally specific adiabatic theory (Phys. Rev. A 84, 062716, 2011).

Research supported by the NASA Solar & Heliospheric Physics Program NNH07ZDA001N, the Office of Fusion Energy Sciences and Division of Chemical Sciences, Geosciences, and Biosciences, the Office of Basic Energy Sciences of the US Department of Energy, VA et al. is supported by the National Science Foundation through Grant No. PHY-1068878.

Friday, May 2, 2014 1:30PM - 4:33PM

Session C2 Condensed Matter 1

1:30PM C2.00001 The Dynamic Hubbard Model: what might be missing in current descriptions of strongly correlated electrons in solids, FRANK MARsiglio, University of Alberta—Electrons move around and they interact with one another via the Coulomb interaction. When electrons form extended (i.e. Bloch) states in metals they do the same thing. Yet very often they form a collective exotic state like superconductivity. Is this the consequence of pairing via an attractive interaction, or is something more subtle at work? This talk will attempt to do several things: (i) present a “state of the union” summary of our understanding of superconductivity, (ii) explain the physics of the Dynamic Hubbard model (DHM) in terms that undergraduates can understand, and (iii) present some results achieved for the DHM.

1Support from NSERC and AITF gratefully acknowledged.

2:00PM C2.00002 d-Wave Superconductivity and Quasiparticle Dynamics in KFe2As2, MEgAN A. BOOThBY, A.J. KOENIG, WENDELL A. HUTTEMA, COLIN J.S. TRUNCH, NATALIE C. MURPHY, DAVID DEEPWELL, Simon Fraser University, XIANHUI CHEN, University of Physics and Technology of China, Heifei, DAVID M. BROUN, Simon Fraser University—Recent work in superconductivity focuses largely on unconventional superconductors that have a layered structure, such as the pnictide, KFe2As2. Amongst other potential benefits, these tend to display a much higher critical temperature than conventional superconductors. It is always interesting to investigate the mechanism for forming Cooper pairs. In our experiment, we probe the nodal structure of the superconducting energy gap in KFe2As2 to determine pairing symmetry by using milliKelvin microwave spectroscopy. We find that the superfluid density has a linear temperature dependence, which provides compelling evidence for line nodes and d-wave pairing. We also investigate the relaxation dynamics of thermally excited quasiparticles, wherein we discover a rapid collapse in scattering below Tc, much like the high-Tc cuprate superconductors. I will present surface impedance data taken at temperatures down to 0.1K, from which we obtain complex microwave conductivity and superfluid density.

1Financial support from the Natural Sciences and Engineering Research Council of Canada (NSERC) is gratefully acknowledged.

2:12PM C2.00003 Vibrating vortices as a probe of superconductivity, NATALIE MURPHY, XIAOQING ZHOU, ERIC THEWALT, WENDELL HUTTEMA, COLIN TRUNCH, KEVIN MORSE, Simon Fraser University, JOHN SARRAO, Los Alamos Natl. Lab., DAVID BROUN, Simon Fraser University—A characteristic property of ordered phases of matter is the spectrum of quasiparticle excitations they support at low energies. Examples include phonons in crystals, rotons in superfluid 4He, and Bogoliubov quasiparticles in BCS-type superfluids such as 3He and metallic superconductors. In the case of superfluid 3He, a set of particularly beautiful experiments by the Lancaster group used vibrating wire resonators to probe the quasiparticle spectrum. In short, the dynamics of the vibrating wire are modified by their interaction with the surrounding quasiparticle gas, and are detected electrically. We have developed an analogous technique for studying quasiparticles in superconductors, with the vibrating wire replaced by superconducting vortices oscillating at microwave frequencies. The key discovery that allows the technique to work is that, in certain unconventional superconductors, the vortex core contains very few states—the dynamics of the moving vortex instead are dominated by its interactions with the gas of extended quasiparticle states in which it is embedded. I will establish the validity of technique using data on high temperature superconductors, and then show how it can be used to obtain new physics in the heavy fermion superconductor CeCoIn5.

1Financial support from the Natural Sciences and Engineering Research Council of Canada (NSERC) is gratefully acknowledged.
2:24PM C2.00004 Optics with microwaves in heavy fermions. DAVID BROUN, Simon Fraser Univ. — In so-called “heavy-fermion” metals, the hybridization of the conduction band with electrons localized in partially filled f orbitals leads to the formation of heavy quasiparticles, for which the effective mass can be renormalized by a factor of 100 or more. However, the itinerant nature of these quasiparticles competes with a tendency to form more conventional, magnetically ordered states. These materials are therefore situated near a quantum critical point — a zero-temperature phase transition driven by the competition between kinetic energy and potential energy — in a conflict between itinerancy and localization that lies at the heart of all correlated electron materials. Along with mass enhancement, the scattering dynamics in heavy fermion compounds also undergo a strong renormalization. This critical slowing-down brings important electronic timescales, such as electronic scattering rates, down into the GHz range, where optical-type measurements and analyses can be carried out with microwaves. We have developed a dilution-refrigerator-based system for carrying out these measurements, and have used it to study a range of heavy fermion materials such as CeCoIn$_5$, UBe$_{13}$ and URu$_2$Si$_2$. An overview of our most striking results will be presented.

2:36PM C2.00005 Quantum well state induced oscillation of pure spin currents in Fe/Au/Pd(001) systems. ERIC MONTOYA, BRENT HEINRICH, EROL GIRT, Simon Fraser University — In normal metals, such as Au, Cu, and Ag, the transport of pure spin current is well described by spin diffusion theory. In nonmagnetic materials having a large Stoner enhancement, such as Pd and Pt, strong spin-spin correlation effects lead to local fluctuating magnetic moments known as paramagnons. Interaction with these paramagnons leads to decoherence of spin currents on much shorter length scales than in normal metals. Since spin transport through Au and Pd is governed by different mechanisms, it is interesting to investigate spin transport in Au/Pd heterostructures. GaAs/2.3 nm Fe/0.4 nm Au/9.7 nm Pd/4.1 nm Au samples were studied, where d, the Au spacer thickness, has been varied. The ferromagnetic resonance spin pumping mechanism was used to generate spin current at the Fe/Au interface. The net spin pumping rapidly decreased with increase in d. The rate was too great to be caused by spin diffusion in Au, indicating reflection of the spin current at the Au/Pd interface.

Furthermore, the spin pumping exhibited an oscillatory dependence on d. This represents, for the first time, the formation of quantum well states that affect the transport of spin currents involving contributions of electrons across the whole Fermi surface.

1Financial support from the Natural Sciences and Engineering Research Council of Canada (NSERC) is gratefully acknowledged.

2:48PM C2.00006 Break —

3:15PM C2.00007 Chalcogenide semiconductors for energy applications. JANET TATE, Department of Physics, Oregon State University — Materials discovery and research into the fundamental mechanisms at work in new materials development drives new technology, and vice versa. Chalcogenide semiconductors could be important components of several next-generation energy-related devices: as transparent conductors or channel layer in thin-film transistors or transparent transistors, as p-type membranes and absorbers in solar cells, and as light emitters in LEDs. I will discuss the wider challenges in some of these applications, why this particular materials set is relevant, the broad skills and collaborative effort necessary for success in this type of research, and some new results from the OSU collaboration. This work is partially supported by the National Science Foundation under DMR1035513.

3:45PM C2.00008 Spin flip times of donor bound electrons in GaAs and InP as a function of magnetic field. TODD KARIN, RUSSELL BARBOUR, PATRICK WIEHL, KAI-MEI FU, Department of Physics, University of Washington — Donor bound electrons in III-V semiconductors may provide a qubit with high optical homogeneity and strong optical transitions. The fundamental limit to their performance in quantum information devices is the electron spin flip time $T_1$. However, the specific mechanisms responsible for spin flips of donor bound electrons are not well understood. We have measured the spin flip time $T_1$ for electron spins bound to donors in GaAs and InP as a function of magnetic field and donor density in order to help elucidate the mechanisms responsible for spin flips. Measuring $T_1$ in this way probes the fundamental limits for using bound electrons in semiconductors for quantum information applications.

3:57PM C2.00009 Room-temperature persistent photoconductivity in strontium titanate. MARIANNE TARUN, FARIDA SELIM, MATTHEW MCCLUSKEY, Washington State University, Pullman, WA — Strontium titanate (SrTiO$_3$) is an oxide material with unique properties and is often used as a substrate for oxide thin films such as high-temperature superconductors. Persistent photoconductivity (PPC) is investigated in SrTiO$_3$ single crystals at room temperature. Defects and impurities can have a strong effect on the electrical properties of SrTiO$_3$. Our prior work showed that hydrogen impurities form a defect complex in SrTiO$_3$ which we tentatively ascribed to a strontium vacancy passivated by two hydrogen atoms. The defect, alternatively, could be a partially passivated titanium vacancy. When a thermally treated sample is exposed to sub-bandgap light at room temperature, the free-electron concentration increases by over two orders of magnitude. After the light is terminated, the enhanced conductivity persists for several days, with negligible decay. We tentatively attribute the PPC to the excitation of an electron from a titanium vacancy defect into the conduction band, with a high barrier for recombination. The presence of titanium vacancies was investigated through positron lifetime measurements. Wavelength-dependence measurements showed an optical excitation threshold for photoconductivity of 2.9 eV.

1This work was supported by DOE and NSF.

4:09PM C2.00010 Strain-dependence of the structure and ferroic properties of epitaxial NiTiO$_3$ thin films grown on different substrates. T. VARGA, T.C. DROUBY, M.E. BOWDEN, S.A. STEPHENS, Pacific Northwest National Laboratory, S. MANANDHAR, EMSL, Pacific Northwest National Laboratory, V. SHUTTHANANDAN, R.J. COLBY, B.C. KABIUS, E. APRA, S.A. CHAMBERS, Pacific Northwest National Laboratory — Polarization-induced weak ferromagnetism has been predicted a few years back in perovskite TiO$_2$ (M=Fe,Mn,Ni). We set out to stabilize this metastable perovskite structure by growing NiTiO$_3$ epitaxially on different substrates, and to control the polar and magnetic properties via strain. Epitaxial Ni$_{1-y}$Ti$_y$O$_3$ films of different Ni/Ti ratios and thicknesses were deposited on Al$_2$O$_3$, Fe$_2$O$_3$/Al$_2$O$_3$, and LiNbO$_3$ substrates by pulsed laser deposition at different temperatures, and characterized using several techniques. The effect of substrate choice, film thickness, deposition temperature, and film stoichiometry on lattice strain, film structure, and physical properties was investigated. Our structural data from x-ray diffraction, electron microscopy, and x-ray absorption spectroscopy shows that substrate-evoked strain has a marked effect on the structure and crystalline quality of the films. Physical property measurements reveal a dependence of the Néel transition, the weak ferromagnetism, and lattice polarization on strain, and suggest that the choice of substrate and film stoichiometry can be used to control the ferroic properties in NiTiO$_3$ thin films. Our results are also consistent with the theory prediction that the ferromagnetism in acinet NiTiO$_3$ is polarization-induced.
We will present results from these tests and outline how they show that this novel detector will meet or exceed our design specifications. The work presented here represents contributions from the full collaboration. There is not sufficient space to provide all member names. Only name of the presenter is provided.

Development of this detector is ongoing and recent work includes cosmic ray tests to evaluate the effects of different crystal wrappings, operation of the calorimeter with SiPM readout, and displays, laser materials, dyes for biomedical assays, and wavelength-converting coatings for solar cells. Most of these applications make use of parity-forbidden transitions with the partially filled 4f shells of the trivalent lanthanide ions, which lead to emission lines at wavelengths spanning the visible spectrum. The desired excited state of the lanthanide ion is typically populated by energy transfer (ET) from a strongly absorbing “sensitizer,” rather than by direct excitation. We have observed a transient X-ray absorption spectroscopy signal associated with the ET in several luminescent dyes and a suspension of an inorganic Eu phosphor. This opens up a novel approach to studies of internal ET in luminescent materials, complementary to previous measurements at optical wavelengths. In addition, the transient signal shows an unexpected change in 5d electronic structure accompanying the 4f-4f transition, which suggests that the intrashell excitation is associated with a change in the degree of mixing of 4f-5d states.

1Research supported by the US DOE, Basic Energy Sciences, by Grant No. DE-FG02-09ER16106 and Contract Nos. DE-AC02-05CH11231 and DE-AC02-06CH11357

Friday, May 2, 2014 1:30PM - 4:45PM –
Session C3 Particle Physics  Alder Commons 105 - Justin Albert, University of Victoria

1:30PM C3.00001 The Higgs Boson: Discovery and Properties, MICHEL VETTERLI, Simon Fraser University / TRIUMF — The discovery of the Higgs boson by the ATLAS and CMS collaborations, announced in July 2012, is the culmination of a very long search for this elusive “cornerstone of electroweak symmetry breaking,” or in simpler terms “what gives subatomic particles mass?”. The effort since then has been to characterize the new particle (mass, spin, couplings) and determine whether it is the only such boson. This talk will describe the updated experimental evidence for the Higgs boson, built up from several production mechanisms and decay channels. Recent results have shown that the new particle is indeed consistent with the Standard Model Higgs boson. The presentation will focus on data from the ATLAS experiment.

2:00PM C3.00002 Two Higgs Doublets and CP Violation1, SEYDA IPEK, University of Washington — Electroweak Baryogenesis, a way to explain matter/anti-matter asymmetry, needs a first order electroweak phase transition as well as CP violation. The Standard Model can not accommodate these two properties. Adding a second Higgs field to the Standard Model is shown to give a first order phase transition. I consider CP violation in this extended Higgs sector. The amount of CP violation one can get from new physics is constrained by the electron electric dipole moment. Taking the electric dipole moments into account, CP violation of O(0.01) is allowed in the two Higgs doublet model. This CP violation could explain the matter/anti-matter asymmetry in the Universe.

1This work was supported in part by the U.S. Department of Energy under Grant No. DE-FG02-96ER40956.

2:12PM C3.00003 The New Muon g-2 Experiment: E989 Status and Progress Update, LORETO ALONZI, The University of Washington: Center for Experimental Nuclear Physics and Astrophysics (CENPA), THE NEW G-2 EXPERIMENT COLLABORATION1 — The Higgs Boson has been discovered at the LHC, locking in the final piece of the Standard Model. Now it is time to focus on the tensions around the edges of the model. Work in the neutrino and cosmic sectors indicate a need for new physics at higher energy scales. A key tool in that search is the precision measurement of Standard Model predictions. Measurement of the muon anomalous magnetic moment (\(a_\mu\)) has long proved to be a useful guide, due in part to the exceptional sensitivity of the measurement technique first developed at CERN and most recently implemented at BNL where the E821 experiment measured it to 540 ppb. This measurement resulted in a discrepancy from the Standard Model at a level greater than 3\(\sigma\). The New Muon g-2 experiment at Fermilab (E989) aims to improve this precision by a factor of 4, down to 140 ppb. Coupled with ongoing improvements in the theoretical calculation the new result will yield vital clues. The collaboration is making great progress and we will discuss: the completion of moving the superconducting electromagnet from Brookhaven National Lab to Fermilab, on site construction at Fermilab, detector development focusing on PbF\(_2\) calorimetry with SiPM readout, and precision magnetic field monitors based on NMR technology.

1The work presented here represents contributions from the full collaboration. There is not sufficient space to provide all member names. Only name of the presenter is provided.

2:24PM C3.00004 Calorimeter Development for the New Muon g-2 Experiment, AARON FIENBERG, University of Washington, MUON G-2 COLLABORATION — In the new muon g-2 experiment, determination of the anomalous magnetic moment requires energy and timing measurements of decay electrons. The calorimeter being designed to make these measurements is an array of lead fluoride (PbF\(_2\)) crystals coupled to silicon photomultipliers (SiPMs). Cherenkov light produced in the crystals allows for excellent timing and energy resolutions while the SiPMs’ insensitivity to magnetic fields makes them a great choice for the experiment. Development of this detector is ongoing and recent work includes cosmic ray tests to evaluate the effects of different crystal wrappings, operation of SiPMs in a 1.5 T magnetic field, and evaluation of a prototype crystal array with an electron beam provided by the Stanford Linear Accelerator. We will present results from these tests and outline how they show that this novel detector will meet or exceed our design specifications.
2:36PM C3.00005 Progress on the stationary pNMR array of the new muon (g-2) experiment at FNAL1, MARTIN FERTL, ALEJANDRO GARCIA, RACHAEL MORRIS, COLE HELLING, RONALDO ORTEZ, RACHEL OSOFSKY, ERIK SHAW, MATTHIAS SMITH, ERIK SWANSON, Department of Physics, University of Washington, NEW MUON G-2 COLLABORATION — One of the most stringent low-energy tests of the Standard Model (SM) of Particle Physics is the measurement of the muon’s anomalous magnetic moment, called \((g - 2)/2\). The BNL E821 collaboration has measured \((g - 2)/2\) to a precision of 0.54 ppm. This result deviates by more than three standard deviations from the SM prediction. Thus the FNAL E969 collaboration has set out to measure \((g - 2)/2\) to a precision of 0.14 ppm. The applied measurement technique relies on the accurate determination of the muon’s Larmor frequency in a highly homogeneous magnetic field (0.17 ppm in BNL E821, 0.07 ppm in FNAL E969) of an electric and magnetic storage ring. The spatial magnetic field distribution along the storage ring is determined by pulling a trolley with pulsed proton nuclear magnetic resonance (pNMR) probes through its vacuum chamber. Since this cannot be performed during the muon measurements the magnetic field is interpolated in time between the trolley measurements using a fixed array of about 400 pulsed pNMR probes distributed around the storage ring. We will present the efforts made at the Center for Nuclear Physics and Astrophysics at the University of Washington to prepare and test the stationary pNMR probes array. Here we will present the status of the system.

2:48PM C3.00006 Temperature dependence of the signal of the NMR probes for the muon (g-2) experiment, RACHAEL MORRIS, MARTIN FERTL, ALEJANDRO GARCIA, COLE HELLING, RONALDO ORTEZ, RACHEL OSOFSKY, ERIK SHAW, MATTHIAS SMITH, ERIK SWANSON, University of Washington — The latest investigation of the anomalous magnetic moment of the muon requires accurate and precise measurement of the magnetic field in the storage ring. The field is mapped using a series of pulsed proton NMR probes and knowing the response of the probes under different conditions is key to attaining the precision necessary for the experiment to take into account all possible systematic effects. While the temperature correction for the diamagnetic shielding of water in proton NMR is known experimentally and taken into account in previous incarnations of this experiment, the future probes will use petroleum jelly and the temperature dependence of the response of these probes is not well documented. We have been using a repurposed analyzing magnet used by the (g-2) group at the University of Washington for this investigation. Here I will discuss the methods, challenges and results we have obtained.

3:00PM C3.00007 Break —

3:15PM C3.00008 Messages for High Energy Physics from Astrophysics and Cosmology, ANN NELSON, University of Washington — I review some recently popular models of dark matter and baryogenesis and how the recent BICEP2 results, if confirmed, constrain the possibilities.

3:45PM C3.00009 The MAJORANA Demonstrator status and prospects, CLARA CUESTA, University of Washington, MAJORANA COLLABORATION — The MAJORANA Collaboration is constructing the MAJORANA Demonstrator, an ultra-low background, 40-kg modular high purity Ge detector array to search for neutrinoless double beta decay in Ge-76. In view of the next generation of tonne-scale Ge-based neutrinoless double-beta decay searches that will probe the neutrino mass scale in the inverted-hierarchy region, a major goal of the Demonstrator is to demonstrate a path forward to achieving a background rate at or below 1 count/tonne/year in the 4 keV region of interest around the Q-value at 2039 keV. The P-Type Point Contact design of the Demonstrator’s germanium detectors allow for significant reduction of background through pulse shape analysis. An introduction to the MAJORANA Demonstrator technical design will be given, progress of the detector’s construction at the Sanford Underground Research Facility at Homestake will be highlighted, and the sensitivity of the neutrinoless double beta decay search will be discussed.

3:57PM C3.00010 Axion and Dark Matter Searches with the MAJORANA Demonstrator, JULIETA GRUSZKO, Univ of Washington, MAJORANA COLLABORATION — The MAJORANA Demonstrator is an array of natural and enriched high purity germanium detectors that will search for the neutrinoless double-beta decay of germanium-76. The Demonstrator’s projected low background, low threshold, and multi-site rejection capabilities will enable searches for other Beyond-the-Standard Model physics, including solar axions and light WIMP dark matter. The mechanisms for detection of these particles will be discussed. Simulations and data from research and development efforts will be used to predict the Demonstrator’s performance in both axion and WIMP detection.

4:09PM C3.00011 Holographic entanglement entropy vs backreaction, CHRISTOPH Uhlemann, HAN-CHIH CHANG, ANDREAS KARCH, University of Washington — The degree of entanglement among two systems can be quantified by the entanglement entropy, which plays a role in many areas of physics. Its calculation in QFT, however, is challenging. If available, a holographic description in terms of AdS/CFT simplifies this considerably, and thus provides the tool of choice. Many interesting AdS/CFT dualities are realized as small deformations of simpler cases, with the addition of probe branes to describe CFTs with flavor as a prominent example. We discuss new tools to efficiently compute the entanglement entropy in that setting and apply them to the D3/D7 system.

4:21PM C3.00012 False Vacuum Decay in Deformed Gauge Theory, EVAN THOMAS, University of British Columbia — I present a calculation of the decay from a metastable vacuum state to the true ground state in a “deformed” QCD model. The deformed model coincides with undeformed Yang-Mills at strong coupling, but can be brought to weak coupling smoothly while preserving linear confinement, nontrivial vacuum structure, the proper \(\theta\)-dependence, and many other important aspects of true QCD. I show the presence of higher energy metastable vacuum states in this model, and discuss a euclidean bounce solution which gives a tunneling rate from one of these false vacua to the true vacuum state. The calculation has been carried out in the semiclassical approximation and I present the numerical results, making comparisons with some old predictions for SU(N) gauge theories.
4:33PM C3.00013 Ground State Masses of Charmonium Hybrids from QCD Sum-Rules1, DEREK HARNETT, University of the Fraser Valley, TOM STEELE, University of Saskatchewan, JASON HO, BRENDAN BULTHUIS, TIMOTHY RICHARDS, RYAN BERG, University of the Fraser Valley, ROBIN KLEIV, WEI CHEN, University of Saskatchewan, SHI-LIN ZHU, State Key Laboratory of Nuclear Physics and Technology, Peking University — Over the past decade or so, a number of new, charmonium-like resonances have been observed. However, few of these particles, collectively dubbed the XYZ resonances, can be neatly accommodated by a conventional charmonium meson interpretation as there are major discrepancies between theory and experiment with regards to masses, resonant widths, decay rates and branching fractions. The XYZ resonances are the hallmark of mass-dependent processes responsible for the cycling of sulfur. In this study, a high mass resolution MC-ICP-MS was used to measure the three most abundant stable isotopes of sulfur, free from oxygen interferences. The reliability of the analytical method was verified using international reference materials from IAEA. In addition, hair samples collected from wild animals were measured for their sulfur isotopic ratios. The present findings and comment on the phenomenonological implications.

1This work was funded through a pair of NSERC Discovery Grants.

Friday, May 2, 2014 1:30PM - 4:33PM

Session C4 Applied and Multidisciplinary Physics

1:30PM C4.00001 Measuring and Mitigating Ionospheric Effects on Global Navigation Satellite Systems, SUSAN SKONE, University of Calgary — Global Navigation Satellite Systems (GNSS) such as GPS are employed by many users worldwide for purposes of recreation, vehicle navigation, and safety-critical aviation marine and applications (to name a few). The GNSS signals experience propagation delays and attenuation in the Earth’s ionosphere - resulting in degradation of signal quality and positioning accuracy. Such effects must be mitigated, particularly for safety-critical systems, to ensure continuous service and integrity to meet system specifications. This presentation describes some of the major limitations and solutions for mitigating challenging ionospheric effects on GNSS. Ground-based and space-borne GNSS receivers may allow direct calibration of ionospheric parameters and therefore exploitation of GNSS as an ionospheric remote sensing tool. Applications include space weather, ionospheric profiling using radio occultation measurements and monitoring of natural hazards such as tsunamis using GNSS. This has fuelled a great deal of speculation that at least some of the newly discovered particles lie outside of the constituent quark model. Hybrids, hadrons with explicit quark and gluon degrees of freedom, represent one such possibility. In an effort to identify hybrid content within the XYZ resonances, we have performed a comprehensive QCD sum-rules analysis of ground state charmonium hybrid masses for a wide variety of quantum numbers. We present our findings and comment on the phenomenological implications.

2:00PM C4.00002 Toward a Rebirth of Laboratory-Based XANES1,2, Gopal SEIDLER, NEIL BALL, DEVON MORTENSEN, JOSEPH PACOLD, University of Washington — As a consequence of the necessary scarcity of synchrotron beamtime, advanced x-ray spectroscopies are nearly unique in having both high scientific and technical importance but also extremely low user access. This dilemma excludes the use of such methods in a wide variety of industrial applications and also negatively impacts education and applied research in energy sciences. Building upon recent results with an inexpensive, prototype system [G.T. Seidler, et al., submitted Rev. Sci. Instrum. 2014] we are designing and constructing a laboratory-based user facility for the measurement of x-ray absorption near edge structure (XANES) for the K-edges of the 3d transition metals. This system will maintain 1-eV energy resolution from 5 keV to 10 keV with flux as high as 10M/sec. As such, it will be substantially comparable to the performance at synchrotron x-ray beamlines for transmission-mode XANES studies in electrical energy storage and catalysis. We will discuss the technical details behind this instrument and the plans for its operation under the auspices of the new shared user facility being developed by the UW Clean Energy Institute (CEI). First light for the CEI-XANES facility is scheduled to occur late in the summer of 2014.

1This effort was supported by the UW Clean Energy Institute and by the US Department of Energy, Basic Energy Sciences under Grant No. DE-FG02-09ER16106.

2:12PM C4.00003 Design and Fabrication of Compact, Portable X-Pinch Driver Based on 2 LTD Bricks at the Idaho Accelerator Center1, ROMAN SHAPOVALOV, RICK SPIELMAN, WENDLAND BEEZHOLD, Idaho Accelerator Center — The compact and portable x-pincher driver able to supply of about 200-kA peak current with about 150-nsec rise time was proposed recently and currently under fabrication at the Idaho Accelerator Center. This driver will be able to produce a very unique x-ray radiation source, which could be used in many applications in physics, biology, and radiography. In this work we present the short-circuit test results of our compact and portable x-pincher driver.

1This work was partially supported by DTRA grant HDTRA1-11-1-0036.


2:24PM C4.00004 Evidence for mass dependent sulfur iso-mutation revealed by Multiple Collector Inductively Coupled Mass Spectrometry, YAHYA ALFAYFI, MICHAEL WIESER, M. MUSIANI, C. DUBESKY, None — The determination of the isotopic abundance of sulfur isotopes, in particular of S-33, using gas source mass spectrometry is complicated by the presence of oxygen isotopes and isotopeologues of sulfur dioxide and the majority of the published studies report only S-33 isotope amount ratios. However, it is desirable to obtain S-33 data, which can provide important information on the nature of mass-dependent processes responsible for the cycling of sulfur. In this study, a high mass resolution MC-ICP-MS was used to measure the three most abundant stable isotopes of sulfur, free from oxygen interferences. The reliability of the analytical method was verified using the international reference materials from IAEA. In addition, hair samples collected from wild animals were measured for their sulfur isotopic composition as part of a large study to explore the diet of wolves in west central Alberta. The accuracy of the S-33 and S-34 isotope amount ratios should enable the elucidation of food sources in the region affected by industrial activities.
The partitioning of copper isotopes reveals changes in metabolism due to prion protein expression in transgenic mice. KERRI MILLER, Dept. of Physics and Astronomy, Univ. Calgary, Canada, CATHARINE M. KEEFLN, Hotchkiss Brain Inst., Univ. Calgary, Canada, GARY R. MARTIN, The McCaig Inst. for Bone & Joint Health, Univ. Calgary, Canada, KEITH A. SHARKEY, Hotchkiss Brain Inst., Univ. Calgary, Canada, FRANK R. JIRIK, The McCaig Inst. for Bone & Joint Health, Univ. Calgary, Canada, MICHAEL WIESER, Dept. of Physics and Astronomy, Univ. Calgary, Canada — The partitioning of copper isotopes has provided a wealth of information regarding metal interactions in physical systems. Metabolic activities in animals can partition copper isotopes as the metabolic abundances of isotopes in living tissues may act as a biomarker for changes in metabolism and may vary in disease. Prion protein is a naturally occurring copper binding protein of importance in neurodegenerative conditions. Mice that lack prion, over express this protein and lack the copper binding motif are available and we used these animals to investigate whether changes in copper isotopic composition were present in the organs and tissues of these mice. The copper isotopic amount ratios were measured using an MC-ICP-MS. Changes in the copper isotope amount ratios due to the presence of this protein or its ability to bind copper were observed, most notably in the kidneys and the colon. These results suggest that isotope abundance data may be an innovative tool for identifying alterations in biological homeostasis and may provide novel diagnostic approaches in disease.

Modern challenges and progress in the measurement of the atomic weights of the elements. ADAM MAYER, MICHAEL WIESER, University of Calgary — Throughout history, the atomic weights of the elements had been regarded as constants of nature. However, in the late 1930s it was discovered that the atomic weights of some elements could vary naturally, either by radioactivity or by physical and chemical processes. This can lead to challenges in determining, and even defining, the atomic weight to an element. How do you define the weight of an element, when different samples have different weights? In this talk, I will discuss these challenges and how they are addressed by the International Union of Pure and Applied Chemistry when they publish the table of Atomic Weights. I will discuss the natural variability among some elements and how this variability changes how the atomic weight can be defined. I will also discuss how measurement bias can affect results, and how modern measurement techniques are used to correct the measurement biases based on reference materials traceable to organizations such as the National Institute of Standards and Technology. I will center this discussion around my own recently accepted atomic weight measurement for Molybdenum, which was referenced in the September 2013 issue of Popular Science.

The quantification of auroral patches: Musings of a neuroscientist. SIMON SPANSWICK, Hotchkiss Brain Institute, University of Calgary — The aurora is a consequence of processes occurring in the near-Earth space environment. Details about auroral structure and behavior can provide clues about plasma processes occurring in regions of space that are rarely sampled by spacecraft. By using the aurora to indirectly measure aspects of plasma dynamics we can gain a system-level snapshot that would not otherwise be observable. One common type of aurora is patchy aurora, which refers to irregularly shaped "blobs" that form a characteristic pattern in auroral image data. Patches are most often observed at mid- to low-auroral latitudes, equatorward of the peak in the proton aurora. One of the remarkable features of patchy aurora is the apparent coherent and relatively consistent shape of the patches, which can be present for minutes at a time in the field of view of a single all-sky camera. The structure of an individual patch is often maintained as it drifts in longitude through a camera field of view. This behavior is thought to be a consequence of both plasma dynamics and structure in the region Earthward of the central plasma sheet. Here we describe a cross-disciplinary approach to quantifying auroral patches. Statistics are derived from a collaboration between the fields of neuroscience and space physics. Specifically, we employ a modified stereological approach to quantify length and orientation of patchy aurora. Stereological quantification has been successfully employed within the neurosciences to estimate the length, volume, or number of objects within a specific region of interest. One of the central tenets of stereology is the random, systematic sampling method, which has been demonstrated as both highly accurate and efficient. We adopt a modified stereological procedure, using random, systematic sampling to produce an unbiased estimate of patch length and orientation within the aurora. The output of this procedure can also be adapted to follow individual patches and produce velocity fields in a given image. These techniques allow us to quantify the evolution of both individual patches, and the patchy aurora region as a whole. We also discuss the future possibility of using this technique to produce a semi-automated convection map for specific events. We assert that these maps will provide a time-evolving picture of the 2D convection velocity in the ionosphere with excellent spatial and temporal resolution.

Molybdenum as a tracer to anthropogenic activity. ALEXANDER TENNANT, STEPHEN LANE, University of Calgary Department of Physics and Astronomy, BERNADETTE PROEMSE, University of Calgary Department of Geoscience, MICHAEL WIESER, University of Calgary Department of Physics and Astronomy — The trace metal molybdenum (Mo) is not very abundant in the environment, but has numerous applications in anthropogenic activities. For instance, Mo sulphide (MoS2) is a component of diesel fuel. Mo is used as a catalyst in many engines and is believed to be the most efficient catalyst for the hydro-cracking of bitumen, and has even been found in the emissions of coal-fired power plants. Hence, anthropogenic activities may release Mo in larger amounts to the environment that may affect terrestrial and aquatic ecosystems (e.g. via its coupling with the N cycle). We have therefore investigated the potential of Mo concentration and isotopic abundances as a tracer of anthropogenic emissions. Using a method of elemental double spiking, we measured Mo concentrations and isotopic composition of aerosols throughout the city of Calgary, Alberta, Canada. Airborne Mo was collected at several locations, ranging from an isolated weather station to a busy bus garage where buses were left to idle for extended periods of time. Mo concentrations ranged from 0.07 ng/m3 in the laboratory 19.0 ng/m3 in the bus garage. The isotopic compositions were variable throughout the sampling sites. These results suggest that Mo has the potential to be used as a tracer of anthropogenic activity.
4:21PM C4.00011 Identification of geographical origins of exotic wood using $^{87}$Sr/$^{86}$Sr isotope ratios as a forensic tool., AMANDA KILLERICH, KERRI MILLER, Department of Physics and Astronomy, University of Calgary, 2500 University Drive NW, Calgary, AB, T2N 1N4, Canada, HAIPING QI, TYLER COPLEN, US Geological Survey, 12201 Sunrise Valley Drive, Reston, VA, 20192, USA, MICHAEL WIESER, Department of Physics and Astronomy, University of Calgary, 2500 University Drive NW, Calgary, AB, T2N 1N4, Canada — Exotic rosewood species of the Amazon rainforest have desirable properties that have made them valuable for commercial use. Unsustainable logging has resulted in overexploitation. In an effort to protect the endangered species they are illegal to trade and controlled by the Washington Convention (CITES). Despite united efforts of international trade officials to prevent trade and export of the species it is still an ongoing business. The goal of this study is to use variations in isotopic composition of strontium to assist in the identification of the geographical origin of wood samples. This can be used to target illegally logged wood and aid the effort to prevent the trade. The $^{87}$Sr/$^{86}$Sr isotope amount ratios in 25 samples have been analyzed using thermal ionization mass spectrometry. The samples were identified by their species and country of origin. The result of this study is the most recent expansion of a database consisting of more than 250 samples with ratios between 0.704174(4) and 0.790396(3) with typical external reproducibilities of the order 10 ppm. Of the different geographic locations represented by the set of samples many exhibit distinct isotopic fingerprints that facilitate the strontium isotopic abundances as a forensic tool.

4:30PM - 4:30PM — Session D1 Poster Session (16:30 - 18:00) — Alder Commons 102/103 (Common Area) - Gina Passante, University of Washington

D1.00001 Search for hep neutrinos at the Sudbury Neutrino Observatory, TIMOTHY MAJOR, NIKOLAI TOLICH, Uni of Washington — The sun fuses hydrogen into helium though a variety of pathways. All pathways produce the “hep” reaction, $^3\text{He} + p \rightarrow ^4\text{He} + e^+ + \nu_e$. Despite their high energy, hep neutrinos remain undetected because of their small flux relative to other solar neutrinos. Previous analyses hint at the possibility of the flux of hep neutrinos being much higher than theory predicts. A new analysis of data from the Sudbury Neutrino Observatory is being conducted to measure or set the best possible limit on the flux of hep neutrinos by including data that was previously unused and applying a new fitter to distinguish signal events from backgrounds.

D1.00002 Muon Capture on the Deuteron: The MuSun Experiment, MICHAEL MURRAY, University of Washington, MUSUN COLLABORATION — Basic few-body nuclear systems are increasingly understood in terms of QCD-based effective field theories (EFT). These calculations precisely predict electro-weak observables and establish rigorous relations between muon capture and fundamental astrophysical processes like p-p fusion and neutrino break-up of the deuteron. Experimentally, the muon capture rate on the deuteron tests this modern EFT description and determines the single, poorly known low-energy constant appearing in the two-nucleon sector. The MuSun experiment will achieve an order of magnitude improvement over previous measurements of this rate using a cryogenic deuterium TPC target designed to be insensitive to muon atomic kinetics. The capture rate is measured via the lifetime of negative muons in deuteron, so it is critical to avoid decay-time-dependent event selection cuts. Data collected at the Paul Scherrer Institute in 2011 and 2013 is being analyzed and the MuSun collaboration is implementing detector upgrades for a beam period in 2014.

D1.00003 Comparing Different Treatments Are Used for Mesothelioma Cancer, SAMIRA REZAEI, None — The goal of this research was to survey the literature of studies on mesothelioma treatments and comparing their rates of success. The focus was on the radiation therapy which used with the chemotherapy or surgery treatment of this specific type of cancer. The research is based on the chosen treatment of the 13 patients shared in different websites to compare the number of survived years. The result shows that the average of survived years in patient who sued mind-body therapy is more than other patients who use radiation therapy with chemotherapy or surgery treatment and immune therapy as treatment for mesothelioma. The significant of this research was to find the best treatment for mesothelioma cancer and figure out the advantage of using radiation therapy in this specific type of cancer treatment.

D1.00004 Searching for Tensor Current in $^3\text{He} \beta$-Decay, RAN HONG, YELENA BAGDASAROVA, CENPA, University of Washington, KEVIN BAILEY, Physics Division, ANL, XAVIER FLECHARD, LPC, CAEN, France, ALEJANDRO GARCIA, CENPA, University of Washington, ANDREAS KNECHT, Paul Scherrer Institute, ARNAUD LEREDDE, Physics Division, ANL, ETIENNE JENARD, LPC, CAEN, France, PETER MUELLER, Division, ANL, OSCAR NAVILAT-CUNIFIC, NSCL, Michigan State University, THOMAS O’CONNOR, Physics Division, ANL, MATTHEW STERNBERG, DEREK STORM, ERIK SWANSON, FREDERIK WAUTERS, DAVID ZUMWALT, CENPA, University of Washington — Precision measurement of the $\beta-\bar{\nu}_e$ angular correlation coefficient $\alpha$ can be used for searching for the Beyond-Standard-Model-tensor-type weak currents. We produce $10^{10}$ $^6\text{He}$ atoms per second using the Van de Graaff accelerator at CENPA, and deliver them to a magneto-optical trap (MOT) in a low background experiment hall. We measure the time-of-flight spectrum of the recoiling $^6\text{Li}$ ions from $^3\text{He} \beta$-decay and then extract the $\beta-\bar{\nu}_e$ angular correlation coefficient $\alpha$. The $\beta$-particles are detected by a multi-wire proportional chamber and a plastic scintillator, while the recoil ions are guided by an electric field and detected by a micro-channel plate. We developed a Monte Carlo simulation program to construct the fitting templates of the time-of-flight spectrum and study the systematic effects. We currently acquire coincidence data with the short term goal of reaching a 1% uncertainty for $\alpha$.

1This work is supported by DOE, Office of Nuclear Physics, under contract nos. DE-AC02-06CH11357 and DE-FG02-97ER41020.

D1.00005 Converter and Target Optimization for the Photonuclear Production of Radioisotopes Using Electron Linac, BINDU KC, V. STAROVOITOVA, Idaho Accelerator Center, Idaho State University, 1500 Alvin Ricken drive, Pocatello, ID 83201, USA, D.P. WELLS, Idaho Accelerator Center — Photonuclear production of radioisotopes using an electron accelerator can be an excellent alternative method of radioisotope production to conventional methods that use nuclear reactors and cyclotrons. With the right choice of electron beam parameters, irradiation time, bremsstrahlung converter and target design, the specific activity of photo-produced radioisotopes may be increased significantly. An optimum converter thickness and target geometry was found for the photon-proton production of Cu-67 through $^{64}\text{Zn}(\gamma,p)^{67}\text{Cu}$ reaction was found.

This work is supported by DOE, Office of Nuclear Physics, under contract nos. DE-AC02-06CH11357 and DE-FG02-97ER41020.
D1.00006 Violating the Heisenberg Uncertainty Relation: An Entangled Approach
JACOB COLLINS, JEAN-FRANÇOIS VAN HUELE, Brigham Young University — Since Heisenberg introduced the relation \(\Delta q_1 \sim \hbar\) in 1927, great effort has been made to refine this expression and better understand its meaning. Recent work has shown that the term “uncertainty” applies to two different quantum properties. The first pertains to preparation uncertainty, the principle that one cannot prepare a quantum system such that two incompatible observables are arbitrarily well-defined. The second pertains to measurement uncertainty, the principle that the measurement with a certain degree of accuracy of one observable disturbs the subsequent measurement of a second incompatible observable. We review recent experiments showing evidence for a violation of the measurement uncertainty. We illustrate the different relations with examples using spin measurements. We explore how entanglement affects the difference components of the proposed relations.

D1.00007 Toward Remote Entanglement with \(^{138}\text{Ba}\)\(^{+1}\)
CAROLYN AUCHTER, THOMAS W. NOEL, CHEN KUAN CHOU, BORIS B. BLINOV, University of Washington — We present work toward remote ion entanglement using systems of singly trapped \(^{138}\text{Ba}\)\(^{+}\) ions. Remote ion entanglement will be achieved through photon mediated entanglement swapping using spontaneously emitted 493 nm photons. This scheme is an excellent candidate for a “loophole-free” Bell Inequality test due to the low decoherence and capability for fast control and detection of the \(^{138}\text{Ba}\)\(^{+}\) qubit and the suitability of the relatively long wavelength of the emitted photons for fiber optic transmission. In order to improve the future rate of remote ion entanglement generation, we present work on employing ultrafast pulses from a mode-locked Ti:Sapphire laser to increase the rate of ion-photon entanglement and improve fidelity. Progress toward ion-ion entanglement of ions in adjacent traps will be reported.

1This work is supported by NSF.

D1.00008 Ultracold Heteronuclear Mixture of Ground and Excited State Atoms
WILLIAM DOWD, RICHARD ROY, RAJENDRA SHRESTHA, ALAINA GREEN, SUBHADEEP GUPTA, University of Washington — Ultracold atomic gases are fruitful systems in which to study exotic quantum phenomena such as Bose-Einstein condensation, superfluidity, and BCS pairing of fermions like that in superconductors. In this regard, single atomic species experiments have covered significant ground in studies of few and many-body physics. However, the addition of a second species opens up a large variety of new physics to be explored. Recent advances in the field of ultracold mixtures include the coherent production of heteronuclear diatomic molecules, from which point one can coherently control the many degrees of freedom of the molecule (e.g. rotational, vibrational, and electronic) with the use of external fields. This forms the starting point for realizing a number of quantum information and computation applications and studies of controlled chemical reactions. Here we report recent progress towards the creation of ultracold molecules of lithium and ytterbium, including the successful realization of a novel, long-lived mixture of ground state lithium and metastable excited state ytterbium atoms.

D1.00009 Harmonically trapped two-atom systems: Interplay of short-range s-wave interaction and spin-orbit coupling
X.Y. YIN, Washington State University, S. GOPALAKRISHNAN, Harvard University, D. BLUME, Washington State University — We investigate the interplay between the single-particle spin-orbit coupling term of Rashba type and the short-range two-body s-wave interaction for cold atoms under external confinement. Treating the spin-orbit term with strength \(k_{so}\) perturbatively, we determine the correction to the ground state energy for various parameter combinations. We find that the interplay between the spin-orbit coupling term and the s-wave interaction enters, depending on the exact parameter combinations of the s-wave scattering lengths, at order \(k_{so}^2\) or \(k_{so}^4\) for the ground state and leads to a shift of the energy of either sign. Additionally, we find that, for certain parameter combinations, the spin-orbit coupling term turns sharp crossings into avoided crossings with an energy splitting proportional to \(k_{so}\). Our perturbative results are confirmed by numerical calculations that expand the eigenfunctions of the two-particle Hamiltonian in terms of basis functions that contain explicitly correlated Gaussians.

1XYY and DB acknowledge support by the NSF and SG by the Harvard Quantum Optics Center

D1.00010 Multiplexed Fluorescence Spectroscopy with Holographic Optical Tweezers
MATTHEW CIBULA, DAVID MCINTYRE, Oregon State University — We are developing a multiplexed spectroscopy system which employs holographic optical tweezers to manipulate trapped sensor particles and an imaging spectrometer to simultaneously detect their fluorescence of spatially separated sensors is detected on the spectrometer. The spectrometer aperture must remain open to view multiple positions of infrared optical traps to manipulate sensors into regions of interest. The sensors are excited with a 532-nm laser source and the fluorescence spectra. This system has potential applications to studying the internal or external environment of cells undergoing chemical reactions.

D1.00011 Progress toward a polarization rotation measurement of the \(6S_{1/2} \leftrightarrow 5D_{3/2}\) magnetic dipole transition amplitude in \(^{138}\text{Ba}\)
ANUPRIYA JAYAKUMAR, SPENCER R. WILLAMS, MATTHEW R. HÖFFMAN, BORIS B. BLINOV, NORVAL FORTSON, University of Washington — We report our progress on the measurement of the magnetic dipole transition moment \((M1)\) in \(^{138}\text{Ba}\)\(^{+}\) for the \(6S_{1/2}(m) \leftrightarrow 5D_{3/2}(m')\) transition with a linearly polarized 2051 nm laser. The motivation behind this study is to make a precise measurement of \(M1\), which is the leading source of systematic error in our planned parity nonconservation measurement. To date there are only two theory calculations that have been reported for \(M1\) in \(^{138}\text{Ba}\)\(^{+}\) which are \(8 \times 10^{-9}\mu_B\) \([1]\) and \(20 \times 10^{-9}\mu_B\) \([2]\). In our technique, the Rabi frequency was measured for the \(6S_{1/2} \leftrightarrow 5D_{3/2}\) transition with \(\Delta m = 0\) and \(\Delta m = 2\) as a function of the linear polarization angle of the 2051 nm beam. We used the \(\Delta m = 2\) transition (that has no \(M1\) contribution) as a check for systematics in the polarization of the beam. By measuring the polarization dependence of the \(\Delta m = 0\) transition Rabi frequency we can extract the ratio of the \(M1\) to the much larger and well known electric quadrupole amplitude, from which we can extract \(M1\).

1PRA 74, 062504
2PRA 88, 034501
D1.00012 High Efficiency Collection and Fiber Coupling of Ion Fluorescence1. RICHARD GRAHAM, JOHN WRIGHT, ZICHAO ZHOU, TOMASZ SAKREJDA, BORIS BLINOV, University of Washington — Efficient collection of fluorescence light from trapped ions is important for robust qubit state detection and for generating remote entanglement of states. Implementing a modular and scalable ion-trap quantum computer will require a low cost solution for fiber coupling a large fraction of the fluorescence light. We are developing a solution using custom aspheric lenses with a design collection efficiency of 38%.

1This work is funded by IARPA under the MUSIQC project.

D1.00013 Precision Measurements of Ba+ Properties1, MATTHEW HOFFMAN, SPENCER WILLIAMS, ANUPRIYA JAYAKUMAR, E.N. FORTSON, BORIS B. BLINOV, University of Washington — Single trapped barium ions continue to offer a wealth of information about atomic and nuclear structure, oscillator strengths, and polarizabilities. We report progress towards a series of precision measurements that will provide stringent tests of theorists’ predictions of these various properties. The first of these is a measurement of the 6S_{1/2} ↔ 5D_{3/2} magnetic dipole transition moment (M1), using a frequency stabilized laser operating at 2051 nm.1 This measurement is of interest, as knowledge of M1 is necessary in a proposed measurement of atomic parity nonconservation (PNC). The second is a radio-frequency (rf) spectroscopic measurement of the hyperfine structure of the 5D_{3/2}, resulting in a measurement of the nuclear magnetic octupole moment of ^{137}Ba+. Finally, we have begun work on measuring the branching ratio of spontaneous decay from 5D_{5/2} to 6S_{1/2} and 5D_{3/2}. The underlying theory and motivation behind these measurements will be presented, as well as experimental upgrades and recent results.

1This research is supported by the National Science Foundation, Grant No. PHY-09-06494.

D1.00014 Abnormal Superfluid Fraction of Harmonically Trapped Few-Fermion Systems1, YANQIANG YAN, D. BLUME, Washington State University — Superfluidity is a fascinating phenomenon that, at the macroscopic scale, leads to dissipationless flow and the emergence of vortices. While these macroscopic manifestations of superfluidity are well described by theories that have their origin in Landau’s two-fluid model, our microscopic understanding of superfluidity is far from complete. Using analytical and numerical ab initio approaches, this work determines the superfluid fraction and local superfluid density of small harmonically trapped two-component Fermi gases as a function of the interaction strength and temperature. At low temperature, we find that the superfluid fraction is, in certain regions of the parameter space, negative. This counterintuitive finding is traced back to the symmetry of the system’s ground state wave function, which gives rise to a diverging quantum moment of inertia I_q. Analogous abnormal behavior of I_q has been observed in even-odd nuclei at low temperature. Our predictions can be tested in modern cold atom experiments.

1We acknowledge support by the NSF.

D1.00015 Ion-photon entanglement with trapped Ba-138 ions1, THOMAS W. NOEL, CAROLYN AUCHTER, CHEN-KUAN CHOU, BORIS B. BLINOV, University of Washington — We demonstrate entanglement between the polarization state of spontaneously emitted photons and the Zeeman state of a single trapped Barium ion. The Barium ion is weakly excited with a short (~20 ns) pulse of CW laser light. The ion subsequently decays emitting a single photon at 493 nm. Entanglement is verified by measuring the states of the ion and photon in multiple bases, yielding an overlap of 0.84 with the appropriate maximally entangled Bell state. Furthermore, the CHSH form of the Bell inequality is shown to be violated by over eight standard deviations. This work demonstrates elements of an apparatus states of the ion and photon in multiple bases, yielding an overlap of 0.84 with the appropriate maximally entangled Bell state. Furthermore, the

1Work supported by the NSF.

D1.00016 Design and Construction of a Super-Resolution Ground State Depletion Microscope to Optically Isolate GaAs Donors, SARAH HARVEY, KAI-MEI FU1, TODD KARIN, Univ of Washington — The ability to optically isolate single gallium arsenide electron donors has many implications both in quantum information science as well as semiconductor physics. However, conventional methods of fluorescence microscopy are fundamentally limited by diffraction, which sets a minimum resolvable feature size preventing the direct optical imaging of nanoscale structures. At the University of Washington Optical Spintronics and Sensing laboratory we are building a super-resolution optical microscope, based on ground state depletion, to isolate single GaAs donors. A critical component of the microscope is the raster scanning of laser beams over the sample, for which we have elected to use a piezoelectric fast-steering mirror. I have designed a scanning system capable of under 1 nm mechanical resolution, which will be sufficient for our target optical resolution of about 100 nm to isolate single donors. I will present preliminary results on the performance of the test system using a transmission electron microscope (TEM) grid as a test sample, which will allow us to evaluate the achieved accuracy and resolution of the imaging due to its regular features. Isolating single donors in GaAs using this super-resolution microscopy technique may lead to new insights in how to localize and evaluate impurities such as donors and acceptors for quantum information as well as classical applications.

1Principle Investigator

D1.00017 Thermal conductivity measurements of amorphous metal thin films via the 3\omega method1, KAI ZHAN, JANET TATE, Department of Physics, Oregon State University, JOHN MCGLONE, JOHN WAGER, School of Electrical Engineering and Computer Science, Oregon State University, KRIS OLSEN, DOUGLAS KESZLER, Department of Chemistry, Oregon State University. Amorphous multicomponent metals have promising applications in novel electronic devices because of their atomically smooth surface morphology and lack of grain boundaries. It is important to understand the thermal transport properties of amorphous metals and an accurate measurement of their thermal conductivity will be essential for further improvement of device performance and reliability. Here, the 3\omega method has been improved and extended to investigate the room temperature thermal conductivity of amorphous metals. Iterative, amorphous multicomponent metallic films are deposited on silicon substrate by magnetron sputter deposition. A thin layer of hafnium oxide film is deposited on top of amorphous metals by atomic layer deposition, providing a reliable insulation between an aluminum heater and the amorphous metal film. The room temperature thermal conductivities of thin-film hafnium oxide and silicon nitride are also measured to demonstrate the capability and reliability of the 3\omega technique.

1This work was funded by Hewlett-Packard Company.
D1.00018 Photometric study of single-shot energy-dispersive X-ray diffraction at a laser plasma facility, OLIVER HOIDN, GERALD SEIDLNER, University of Washington — The low repetition rates and possible shot-to-shot variations in laser-plasma studies place a high value on single-shot diagnostics. For example, white-beam scattering methods based on broadband backlighter x-ray sources are used to determine changes in the structure of laser-shocked crystalline materials by the evolution of coincidences of reciprocal lattice vectors and kinematically-allowed momentum transfers. We demonstrate that white-beam techniques can be extended to strongly-disordered dense plasma and warm dense matter (WDM) systems where reciprocal space is only weakly structured and spectroscopic detection is consequently needed to determine the static structure factor and thus the ion-ion radial distribution function.

D1.00019 Volumetric adsorption isotherms of hydrogen on exfoliated graphite, OSCAR VILCHES, HAN YE, ALEX PODSCHWIDT, University of Washington — We report volumetric adsorption isotherm measurements of molecular hydrogen on a good quality exfoliated graphite foam substrate (H2/gr) at temperatures above 20K performed with the goal of understanding the initial stages of adsorption on this two-dimensional (2d) system at temperatures well above the known phase transitions of the monolayer H2(gr).

We obtain the isosteric heat of adsorption of H2/gr as a function of coverage. On the very low coverage region below 10% of a monolayer we are currently working towards obtaining (1) a measurement of the binding energy of non-interacting H2 on graphite, (2) the highest coverage at which heterogeneities in the substrate produce deviations from a linear dependence of the equilibrium 3d pressure vs. coverage (Henry’s law), and (3) the 2d van der Waals coefficients of the weakly interacting 2d gas of H2 molecules. We compare our results to the ones obtained with similar measurements using carbon nanotube bundles as the substrate.

1Work supported by the NSF DMR 120208

D1.00020 The Pressure Dependence of the Unscreened 4f Magnetic Moments of the Early Lanthanides, DEVON MORTENSEN, University of Washington, MAGNUS LIPP, JOSEPH BRADLEY, Lawrence Livermore National Laboratory, PAUL CHOW, YUMING XIAO, Carnegie Institution of Washington, GERALD SEIDLNER, University of Washington, WILLIAM EVANS, Lawrence Livermore National Laboratory — Using the satellite structure of the L1-1 line in non-resonant x-ray emission spectra, we probe the high-pressure evolution of the bare 4f moments of the early light lanthanides at ambient temperature. For Ce and Pr, we report a peak experimental value at 5 GPa with a subsequent pressure-induced decrease at pressures above 10 GPa. Conversely, we find that Nd exhibits an unexpected increase in bare 4f moment that is independent of any reported structural or delocalization transition. All of these results differ sharply from prior state-of-the-art dynamical mean field theory calculations. These measurements emphasize the importance of studying microscopic observables, rather than macroscopic thermodynamic susceptibilities (e.g., the equation of state), to obtain the most discerning test of the underlying, fundamental 4f-electron phenomenon at high pressures.

D1.00021 Evaluation of Electric Propulsion Systems for Asteroid Sample-Return Missions, ANDREW FRENCH, SARAH GADY, ANSH SEHGAL, Whitworth University — This study evaluated the suitability of eight existing ion and Hall thrusters to meet one of the key requirements of sample-return missions to near-Earth asteroids. The OSIRIS-REx mission was used as a baseline for evaluation, and all thrusters were expected to transport a dry mass of at least 750 kg to the asteroid 1999RQ36, land on it in 2019 and stay for an extended period, and return with a sample of the asteroid to Earth. Then, the values of the dry mass to be transported, required stay time on the target, and the mass of the sample to be returned were considered as parameters to be varied. The thrusters were evaluated for this mission at their measured performance levels, and their suitability was evaluated for various values of the specific mass of the power plant. The spacecraft was allowed to coast without thrust at appropriate places in its trajectory to reduce fuel consumption. The resulting values of total trip time and wet mass at LEO for the various cases are presented and compared with the baseline case of the OSIRIS-REx mission.

1Supported by NASA Washington Space Grant Consortium

D1.00022 Searching for Evidence of White Dwarf Core Crystallization in 47 Tucanae, ALYSA C. OBERTAS, HARVEY RICHER, JEREMY HEYL, University of British Columbia — White dwarfs (WDs) are remnants of stars like our Sun. About 98% of all stars in the Galaxy will end their lives as white dwarfs. Young WDs are very hot, but lose energy initially by neutrinos and then by the emission of photons from the surface. Eventually, enough energy is lost that the core of the WD begins to crystallize. WD cooling is crucial for understanding a variety of issues from the formation of the Galaxy to the age of the Universe. Current cooling models incorporate crystallization of WDs and the release of latent heat that slows the cooling temporarily. In this poster, the cumulative luminosity function of white dwarfs in 47 Tuc is compared to modelled luminosity functions. The results suggest that crystallization is occurring at the expected age, verifying this component of current models used to age ancient star clusters.

1Supported by NSERC & CFI

D1.00023 Dynamics of Laboratory Astrophysical Jets with Magnetized Helical Flows, ERIC LAVINE, JENS VON DER LINDEN, KEON VEREEN, EVAN CARROLL, MANUEL AZUARA ROSALES, ALEX CARD, MORGAN QUINLEY, IMAN DATTA, SETTHIVOINE YOU, University of Washington — A novel planar plasma gun experiment is under construction to investigate the dynamics of plasma jets with magnetized helical flows. The goal is to observe the effects of current profiles, flow profiles, and launch boundary conditions on the length, collimation, and stability of jets. The apparatus is carefully designed to provide boundary conditions relevant to astrophysical jets. The gun has three, planar, concentric electrodes that can be biased at different potentials to mimic an acceleration disk rotation profile when coupled to the vacuum magnetic field. The dimensionless parameters are appropriate for protostellar jets and numerical simulations of astrophysical jets. Diagnostics include internal B-dot probes, and vector tomographic reconstruction of ion Doppler spectroscopic measurements capable of reconstructing 3D flow fields. Measurements will be interpreted with a two fluid model of canonical flux tube evolution that describes how magnetic helicity is converted to stabilizing shear helical flows while a system’s total canonical helicity (sum of magnetic field and momentum helicity) is conserved. The study aims to address the question: 1) Why are jets highly collimated, straight, and very long? 2) How are jet irregularities related to plasma instabilities and boundary conditions?

1Supported by US DoE Early Career Grant DE-SC0010340.
D1.00024 Content knowledge for teaching energy: An example from middle-school physical science, AMY ROBERTSON, RACHEL SCHERR, LANE SEELEY, STAMATIS VOKOS, Seattle Pacific University — “Content knowledge for teaching” is the specialized content knowledge that teachers use in practice – the content knowledge that serves them for tasks of teaching such as making sense of students’ ideas, anticipating conceptual challenges students will face, selecting instructional tasks, and assessing student work. We examine a middle-school physical science teacher’s interactions with a group of students for evidence of content knowledge for teaching energy (CKT-E). Our aims are to develop our theory of CKT-E as well as criteria for its observational assessment. We identify CKT-E as potentially including elements of consensus energy models, elements of alternative energy models, elements of a sophisticated understanding of the nature of science, and a repertoire of instructional tasks or activities that exemplify or support instructional goals.

D1.00025 Periscope: Looking into learning in best-practices physics classrooms, RACHEL SCHERR, Seattle Pacific University, RENEE MICHELLE GOERTZEN, American Physical Society — Periscope is a set of materials to support university instructors in observing, discussing, and reflecting on best practices in university instruction. Periscope is organized into short “video workshops,” each introducing a significant topic in the teaching and learning of physics, such as formative assessment or cooperative learning. The workshops are appropriate for university professors, two-year college faculty, graduate student teaching assistants, and undergraduate learning assistants. Key topics in teaching and learning are introduced through captioned video episodes of introductory physics students in the classroom, chosen to prompt collaborative discussion. Video episodes from exemplary sites (including the University of Maryland, University of Colorado – Boulder, Harvard University, and Florida International University) showcase a variety of research-tested instructional formats such as Peer Instruction and Tutorials in Introductory Physics. Discussion questions prompt participants who view the episode to reflect on their pedagogical beliefs, on their own practice, and on the results of physics education research. Periscope materials may be flexibly adapted for settings ranging from brief introductory sessions to all-day workshops or weekly meetings.

D1.00026 Learner understanding of energy degradation, ABIGAIL DAANE, STAMATIS VOKOS, RACHEL SCHERR, Seattle Pacific University — Learners’ everyday ideas about energy often involve energy being “used up” or “wasted.” In physics, the concept of energy degradation can connect these ideas to the principle of energy conservation. Learners’ spontaneous discussions about aspects of energy degradation have motivated us to introduce new learning goals into our K-12 teacher professional development courses. One of our goals is for teachers to recognize that since energy degradation is associated with the movement of some quantity towards equilibrium, the identification of energy as degraded or free depends on the choice of the objects involved. Teacher discussions of a particular energy scenario (about a wind-powered heating system) led to productive conversations about the nature of energy degradation and its possible dependence on the choice of what to include in the scenario.

D1.00027 Models for Teaching Modern Physics, ROBERT CLOSE, Clark College — The great nineteenth century physicist William Thomson (Lord Kelvin) judged his understanding of physical phenomena by whether or not he could construct a mechanical model. Although this attitude is no longer in vogue, mechanistic models can still be useful in teaching modern physics to students. We present mechanistic models or analogues of special relativity, atomic spectra, Dirac wave functions, quantum operators, electromagnetic potentials, antimatter, and gravity. Mechanistic models may help to build intuition for all students of physics, and may also serve as an introduction to the mathematics of modern physics.

D1.00028 Improving student reasoning about advanced electrostatics concepts, RYAN HAZELTON, PAULA HERON, Univ of Washington — This poster describes student difficulties with advanced electrostatic concepts related to electric potential and describes the results of tutorials developed for Tutorials in Introductory Physics. After lecture instruction, the majority of students cannot correctly reason about advanced electrostatic concepts. Common incorrect reasoning patterns emerge in student responses about electric potential energy and electric potential difference, and about electric potential in conductors. We have developed tutorial worksheets that seek to address these incorrect reasoning patterns. Results from questions posed after the tutorials indicate that the tutorials are successful at improving student learning about these difficult and abstract ideas.

D1.00029 Research as a guide for adapting curriculum on special relativity to a new population, ALEXIS OLSHO, PETER SHAFFER, University of Washington — Student understanding of special relativity has been examined by the Physics Education Group at the University of Washington over a period of many years. A Tutorial sequence on this topic had been developed for use in courses for advanced physics undergraduates. Special relativity, however, is being taught increasingly often in introductory physics courses. Preliminary research indicates that for many students, the current Tutorial curriculum is not sufficient for addressing common difficulties with the concepts of reference frames, observers, and causality. Post-tests on the relativity of simultaneity show only modest gains in student ability to determine the time order of events in different reference frames, and reveal significant gaps in student understanding of these fundamental concepts. The results are informing modifications to the tutorials in order to adapt them to this new population.

D1.00030 Assessing effectiveness of lab curriculum in promoting student understanding of kinematics, CHANDLER DENNISON, EMILY GRANSTON, ANDREW BOUDREAX, Western Washington Univ — Prior research in physics education has identified specific aspects of the concepts of velocity and acceleration that introductory calculus-based physics (ICBP) students tend to struggle with (Trowbridge and McDermott, 1980, 1981; Shaffer and McDermott, 2005). At Western Washington University, ICBP students complete guided inquiry labs that target these difficulties explicitly. The labs draw on and adapt existing research based curricula such as Tutorials in Introductory Physics (McDermott and Shaffer, 2001), use MBL sensors for real time data collection, include targeted use of PHET simulators, and ask students to reflect on changes in their understanding. Student learning has been assessed by administering free-response pre- and post-test questions similar to those used in prior studies. Three researchers collaboratively constructed rubrics to categorize student responses. Interrater reliability was found to be greater than 85%. Results of the data will be presented as evidence for the effectiveness of the kinematics lab activities.

1This material is based upon work supported by the National Science Foundation under Grants No. 0822342 and 122732.
transition by varying gelation temperatures from 23 °C to 37 °C at room temperature are inhomogeneous and show many fiber bundles, while gels formed at 37 °C and the collagen matrix is characterized by analyzing variations in fiber density and orientation. Gel homogeneity is quantified by calculating the distribution of these bundles depending on the conditions during gelation. We study how the collagen concentration and temperature during gelation influence the network becomes very apparent. During gelation, collagen fibers can group together to form larger fiber bundles, with the size, shape, and functionality of these bundles depending on the conditions during gelation. We analyze the trajectories of these molecules, we find that they exhibit a behavior that is characteristic of the physical properties of the collagen matrix. By analyzing these trajectories, we can infer the physical properties of the collagen matrix and understand how these properties influence the gelation process.

We study how the collagen concentration and temperature during gelation influence the network becomes very apparent. During gelation, collagen fibers can group together to form larger fiber bundles, with the size, shape, and functionality of these bundles depending on the conditions during gelation. We find that the dynamics of small non-functional molecules in the cell depend on spatial position along the long-axis of the cell as well as temporal segregation mechanism, we need to define totally passive motion. Using time-lapse wide-field fluorescence microscopy, we imaged small, non-functional fluorescent MS2-mRNA molecules throughout the entire cell cycle. By analyzing the trajectories of these molecules, we find that they exhibit a behavior that is characteristic of the physical properties of the collagen matrix. By analyzing these trajectories, we can infer the physical properties of the collagen matrix and understand how these properties influence the gelation process.

This work is supported by NSF DUE 1347728, 1256352, and 1245490.

Research-based assessment resources to improve teaching in your classroom and department1, SARAH MCKAGAN, ADRIAN MADSEN, American Association of Physics Teachers, ELEANOR SAYRE, Kansas State University — Often physics faculty want to know how their students are doing compared to other “students like mine.” As part of the PER User’s Guide (http://perusersguide.org), we are developing a national database of research validated assessment results and an accompanying data explorer. Here faculty can securely upload their students’ anonymized assessment results and compare them to students from peer institutions and the national data set, view a question-by-question breakdown and compare results over time. “One-click analysis” allows faculty members to visualize their data, view statistics and download a report of the results. Results can be used to improve teaching, to make hiring decisions, for tenure decisions, for improvement of education programs, for investigation of research validated assessments and access to the tests themselves. We will showcase our new online system and provide information about how you can use it.

1This work is supported by NSF DUE 1347728, 1256352, and 1245490.

Physicist Make Better Athletes: If You Understand Physics You Can Be Better At Sports, MIN HYUNG KIM, YEON JAE LEE, SUN MEE LEE, Choice Research — Physics plays a dominant role in the way athletes perform and the way the sport is played. In high school, many students would complain because they do not know why they have to learn all about physics. Some will say that they would not need it in the future for they do not dream to be a physicist someday or they just cannot see the reason why. They say this because they do not know that physics can be applied to sporting situations, they would be able to improve their performances and their teams' records - not just through repetitious conditioning on the field, but through conditioning of their minds to understand the basic laws and terms of physics. By illustrating how is physics related to sports, athletes can be taught to use their brain muscles to improve their athletic ability and control and improve their physical performances. This paper help the people who do not know that physics can really help in understanding sports. It will define how fundamentals of various athletic performances can be significantly improved when the athlete understands the physics involved in his particular sports. This paper presents simple explanations of physics, defines relevant terms, and demonstrates the application of physics in various sports, and illustrate how to garner better results and records in sports.

Internet Promotes and Facilitates Learning Physics, YEON JAE LEE, MIN HYUNG KIM, SUN MEE LEE, Choice Research — An ever-increasing amount of information in myriad of subjects is readily available on the Internet; and students and teacher alike can access this vast array of information as learning aids. The idea presented in this article is to help both teachers and students realize how technology can be used to incorporate into currently popular youth-oriented websites and applications and procure the interest of young future physicists. The instructional resources and materials used nowadays in the teaching of physics in middle and secondary schools are still largely the same as those used in past years, books and charts. However, the way many young people obtain and retain information has been experiencing a dramatic change in light of the computer applications and materials that the young people use outside of schools in their personal lives; many receive majority of their information via internet, audio and video peripherals, World-Wide Web, etc. In contrast, the methodology many teachers of physics use in their teaching has not changed with the times. This paper presents how the internet and, in particular, computer-based resources and software programs, will be of great assistance to teachers in regard to their pedagogical activities. Also this paper shows instructors and students can engage in more dynamic and interactive learning methods by using those utilities and devices.

Theoretical studies of asymmetric, multicomponent, lipid bilayers, HA GIANG, MICHAEL SCHICK, Univ of Washington — We consider an asymmetric bilayer in which the two leaves are coupled solely by the fact that cholesterol can be distributed between the two leaves. The coupling is the same as the one used in past years, books and charts. However, the way many young people obtain and retain information has been experiencing a dramatic change in light of the computer applications and materials that the young people use outside of schools in their personal lives; many receive majority of their information via internet, audio and video peripherals, World-Wide Web, etc. In contrast, the methodology many teachers of physics use in their teaching has not changed with the times.

Internet allows faculty members to visualize their data, view statistics and download a report of the results. Results can be used to improve teaching, to make hiring decisions, for tenure decisions, for investigation of research validated assessments and access to the tests themselves. We will showcase our new online system and provide information about how you can use it.

Physicist Make Better Athletes: If You Understand Physics You Can Be Better At Sports, MIN HYUNG KIM, YEON JAE LEE, SUN MEE LEE, Choice Research — Physics plays a dominant role in the way athletes perform and the way the sport is played. In high school, many students would complain because they do not know why they have to learn all about physics. Some will say that they would not need it in the future for they do not dream to be a physicist someday or they just cannot see the reason why. They say this because they do not know that physics can be applied to sporting situations, they would be able to improve their performances and their teams' records - not just through repetitious conditioning on the field, but through conditioning of their minds to understand the basic laws and terms of physics. By illustrating how is physics related to sports, athletes can be taught to use their brain muscles to improve their athletic ability and control and improve their physical performances. This paper help the people who do not know that physics can really help in understanding sports. It will define how fundamentals of various athletic performances can be significantly improved when the athlete understands the physics involved in his particular sports. This paper presents simple explanations of physics, defines relevant terms, and demonstrates the application of physics in various sports, and illustrate how to garner better results and records in sports.

Promoting quantitative reasoning in the PET curriculum with supplemental invention tasks, KELSEY MORK, ANDREW BOUDEAUX, Western Washington University — At Western Washington University, preservice elementary teachers take a required content course taught with the Physics and Everyday Thinking (PET) curriculum (Goldberg, Robinson, and Otero, 2008). While PET has led to consistent, strong gains in conceptual understanding and qualitative reasoning, informal observations of students have suggested that basic quantitative reasoning is not as well supported. Invention tasks, based on the approach of Dan Schwartz and colleagues, have been used to supplement the PET activities. In these tasks, students construct quantitative measures to make meaningful comparisons between contrasting cases. This poster describes the invention tasks and presents preliminary assessment data to both identify specific difficulties with quantitative reasoning and evaluate the effectiveness of the supplemental tasks.

Characterizing the effect of temperature on gelation and inhomogeneity of type I collagen gels, CHRISTOPHER JONES, BO SUN, Oregon State Univ — Type I collagen gels are commonly used as the substrate for experiments on cell mechanotransduction because collagen is the most abundant protein in the ECM of most animals. The gels are commonly approximated as homogeneous elastic materials; however, on smaller length scales, the inhomogeneity of the collagen fiber network becomes very apparent. During gelation, collagen fibers can group together to form larger fiber bundles, with the size, shape, and distribution of these bundles depending on the conditions during gelation. We study how the collagen concentration and temperature during gelation affect the inhomogeneity of collagen fiber networks. Confocal reflection microscopy is used to image the collagen as it polymerizes, and the collagen matrix is characterized by analyzing variations in fiber density and orientation. Gel homogeneity is quantified by calculating the spatial correlation of fiber orientation and density for various temperatures and collagen concentrations. We find that collagen gels formed at room temperature are inhomogeneous and show many fiber bundles, while gels formed at 37 °C are very homogeneous. We explore this transition by varying gelation temperatures from 23 °C to 37 °C for several different collagen concentrations.
D1.00038 Macroscopic Phase Separation, Modulated Phases, and Microemulsions: A Unified Picture of Rafts

1. ROY SHLOMOVITZ, LUTZ MAIBAUM, MICHAEL SCHICK, University of Washington — We simulate a simple phenomenological model describing phase behavior in a multi-component membrane, a model capable of producing macroscopic phase separation, modulated phases, and microemulsions, all of which have been discussed in terms of raft phenomena. We show that one effect of thermal fluctuations on the mean-field phase diagram is that it permits a direct transition between either one of the coexisting liquid phases to a microemulsion. This implies that one system which exhibits phase separation can be related to a similar system which exhibits the heterogeneities characteristic of a microemulsion. The two systems could differ in their average membrane composition or in the relative compositions of their exoplasmic and cytoplasmic leaves. The model provides a unified description of these raft-associated phenomena.

1The work of MS is supported in part by the National Science Foundation under grant No. DMR-1203282. RS acknowledges support from the Raymond and Beverly Sackler Foundation.

D1.00039 Analysis of the Aortic Pressure Waveforms Using Numerical Method

DOO HYUN NAM, SOO YEON KIM, RICHARD KYUNG, Choice Research — Aortic valve disease is the most common valvular disease in our cardiovascular system. It causes the calcification of the aortic valve leaflets, leading to obstruction to blood flow from the left ventricle to the aorta. During the past couple of decades, the numerical analysis of blood flow and its relationship with disease has become appreciated by medical and biological researchers. Also numerical analysis of blood flow in the cardiovascular system has been considered as a key factor in both the cause of cardiovascular disease and the regulation of cellular biology in normal and diseased arteries. Modeling the biofluid systems experimentally and numerically is an important component to fundamental research of cardiovascular disease. However, numerical methods offer the advantage of changing flow variables that affect the outcome quickly for the entire biofluid system.

D1.00040 Study on the Knee Pressure Causing Fatigue in the Tibial Bone

DOO HYUN NAM, SOO YEON KIM, RICHARD KYUNG, Choice Research — Computational stress analysis is widely used in cases where figuring out the clinical conditions of patients is difficult. The purpose of the present research is to evaluate stresses and fracture conditions in the tibial bone caused by various sports activities or accidents, using biomechanical and numerical analysis. The research procedures will include three steps: Examination of biomechanical properties of bones, development of biomechanical and mathematical modeling of the bone, and finding the solutions -stress and fracture conditions in the tibia. By using the above procedure together with the bone remodeling technique, the physiological solutions (maximum stress) of the bones and impact conditions causing the fracture in the bone can be found. The result can be compared to the empirical results found by other scientists and the data could help improve knee arthroplasty, which is a surgical treatment. For the computational and numerical analysis, the bone model can be meshed using a two dimensional element and the nodes on the bottom of the proximal tibial model will be constrained in all directions. To obtain stress distribution in the bone, pressure force will be applied on the top of the bone: For example, total load of 500 N; 150 N on lateral and 350 N on medial compartment. In this paper, different loads on the lateral and medial compartment are applied to observe the variations in the stress distribution of the tibial component.

D1.00041 A Novel Method of Line Detection without Noise Interferences using Pixel Voting

DANIEL LIN, BO SUN, Oregon State Univ — Images generated by machines are often plagued with noises, or unwanted signals generated by machines, that might degrade the visibility of the images and thus make objects on them such as lines hard to be detected by computers and the naked eyes. Existing line detection algorithms, such as Canny Edge Detection, pre-processes the image using filtering algorithms such as Gaussian Smoothing to perform noise removal. However, most filters require the user to adjust their input parameters, which can add computational complexities to the algorithm depending on the parameter size. We designed a versatile line detection algorithm that can detect lines on images without the need of filters. The algorithm accepts a raw, unprocessed image, generates a noise-free reference image of the same size, and overlaps the reference image to the raw image. Our algorithm successfully detected fiber structures in the real confocal reflection images of collagen gel that was filled with various image noises.

D1.00042 Evaluation of Gamma-Ray Spectroscopy Software for On-Site Inspection under the Comprehensive Nuclear-Test-Ban Treaty

BRIAN MILBRATH, DAVID JORDAN, Pacific Northwest National Laboratory, AUGUSTINE CAFFREY, Idaho National Laboratory, NATHAN WIMER, Lawrence Livermore National Laboratory — The Comprehensive Nuclear-Test-Ban Treaty (CTBT) would ban all nuclear explosions worldwide. As part of the verification regime of the Treaty an On-Site Inspection (OSI) may be called to investigate a location to determine if a nuclear explosion has occurred. Per the Treaty, in order to protect sensitivities of the inspected country, the measurement of radioisotopes may be limited to those relevant to the inspection. This means, for example, that gamma spectroscopy detectors would be limited in their function so as to only detect certain gamma-rays (and their corresponding radioisotopes). How to impose this limitation in a robust and reliable manner is not currently agreed upon. In order to investigate this issue technically we have developed a gamma spectroscopy software that includes an information barrier called OSIRIS (OSI Radiosotopic Spectroscopy). We have also developed a set of fission-product spectra, both Treaty compliant and non-compliant, for testing the software to compare its performance relative to expert analysis. An ORTEC Trans-SPEC-DX-100T HPGE spectrometer serves as the OSIRIS prototype instrument.

D1.00043 Design Considerations for Implementing Halbach Arrays and High Temperature Superconductors for Contact-Free Flywheel Energy Storage Systems

CHRISTOPHER MIRABZADEH, CHRIS BIRKINBINE, DANIEL SCHNEIDER, JOE LAW, CHRISTINE BERVEN, University of Idaho — We have investigated the use of Halbach magnet arrays in combination with Type II High-Temperature Superconductors for use as a levitating thrust bearing for a fly-wheel energy storage system. Halbach arrays were selected because they have effectively one-sided flux and a greater flux gradient which would be expected to result in a greater levitation force and effective restoring force stiffness; each being beneficial in the design of such a system. To find the optimum orientation of the magnets for the arrays, we used Infolytica Magnet, a finite-element computation software package. To iterate over all permutations of magnet arrays costing of 3 and 5 magnets of single and double layers. The fields and levitation forces as well as the width of the magnet arrays relative to the width of the superconductor were analyzed. Within our given design constraints, we found that, compared to a single magnet, a single-pole Halbach array was predicted to increase levitation force and stability, reduce stray fields, focus the flux, and increase the bearing stiffness. We present our findings and suggest guidelines to increase levitation force of a superconducting magnetic bearing with qualifiers and rationale for optimizing such a system.
D1.00044 Analysis of the Light Response of Lead Fluoride Crystals for the New \( g-2 \) Experiment, KAZIMIR WALL, Univ of Washington — The new \( g-2 \) experiment hopes to test the difference between the experimental and theoretical values of the anomalous magnetic moment of the muon out to a greater statistical precision than has been previously accomplished. Such a discovery would provide strong evidence of new physics such as dark photons, supersymmetry, or possibly something not yet considered. During the experiment, muons are injected into a large superconducting ring. A muon decays to an electron and the electron curls to the inside of the storage ring and strikes an array of lead fluoride crystals. When an electron hits a crystal, it produces light that is proportional in intensity to the energy of the electron. The energy and the time of its arrival help to indicate the direction of the spin which is used in the calculation of \( g-2 \). My research investigates how light is propagated and distributed in these crystals and how different reflective or absorptive wrappings affect this distribution. I measure light yield and pulse width, which correspond to two different extremes of wrapping material. For maximum light yield, I use white Milliopore paper, while shorter pulse widths are achieved using black Tedlar. I have developed a \( 2 \times 2 \) array of crystals coupled to light sensitive photomultiplier tubes. This setup captures cosmic ray muons that hit the surface of the earth. Capturing these muons simulates the conditions of the experiment. I analyze the resulting data by fitting the pulses and extracting the functional form of the light distribution. The results of this research will ultimately contribute to the development of more complete theories of the fundamental building blocks of the universe.

D1.00045 Liquid Helium Level Sensor, KEVIN JAMISON, University of Washington — The spins of electrons bound to donors are promising candidates as qubits for quantum information processing. The quantum properties of these donor-bound electrons are studied in high magnetic fields while immersed in liquid helium at 4K. For stability reasons, the level of liquid helium in the experiment must be monitored with a sensor. An effective way of implementing a sensor is with a superconducting wire. Super conductors have the property of having zero electrical resistance when they are cooled below a critical temperature. Above this critical temperature, the superconductor has significant electrical resistance. Using these characteristics, a superconducting wire can be used to construct a liquid helium level sensor. When current is run through a thin wire submerged in liquid helium, a relationship can be established between the voltage drop across the sensor and the amount of wire submerged in the liquid helium, allowing the liquid helium level to be measured. Results will be presented on the sensor design and performance.

1Supported by Oxford Superconducting Technology.

D1.00046 Heteroepitaxial ZnS Films on Si for Photovoltaic Applications, CHRISTOPHER REIDY, PETER ESCHEBACH, JANET TATE, Oregon State Univ — Many novel photovoltaic devices have been designed recently that rely on heterojunctions to induce carrier multiplication. To that end, high-quality ZnS thin films were grown on (111) and (100) oriented Si wafers via pulsed laser deposition. ZnS is a good candidate for such a device, since its band gap is wider than that of silicon, and the lattice constants of these materials differ by only 0.3% at 25°C. The ZnS growth was found to depend strongly on orientation and surface reconstruction of the silicon substrates. Epitaxial ZnS formed on (111) silicon at a substrate temperature between 300°C and 350°C. With optimized growth conditions, the film stoichiometry was 1:1 Zn:S as measured by energy dispersive x-ray spectroscopy and electron probe microanalysis. The structure of the films was investigated by convergent beam electron diffraction, and high-resolution transmission electron microscopy shows that the films formed with abrupt junctions and limited diffusion across the interface.

1This research was supported by the National Science Foundation under DMR 1035513.

D1.00047 Thermoelectric Properties of \( \text{Cu}_{12}\text{Sb}_{4}\text{S}_{13} \) and Derivatives, RODNEY SNYDER, JOSH MUTCHE, DANIEL SPEER, CHRIS REIDY, JANET TATE, Oregon State Department of Physics, JOHN WAGER, GREG ANGELOS, Oregon State School of Electrical Engineering and Computer Science, JAESEOK HEO, Oregon State Department of Chemistry — The room-temperature Seebeck coefficient and resistivity of thin film variants of the mineral tetrahedrite \( \text{Cu}_{12}\text{Sb}_{4}\text{S}_{13} \) and its derivatives were measured. In bulk form, tetrahedrite has shown promise as a good thermoelectric material. Thin films of \( \text{Cu}_{12-x}\text{M}_{x}\text{Sb}_{4}\text{S}_{13} \) (\( M = \text{Cu}, \text{Zn} \)) were produced by e-beam deposition, and we also produced films with a second metal on the Cu site. The Seebeck coefficients ranged from 10 to 113 \( \mu \text{V/K} \) and the resistivity from 8 to 50 m\( \Omega \text{cm} \). Together, these values yield power factors \( S^2/\rho \) ranging from \( 10^{-7} \) to \( 10^{-4} \) W/mK\(^2\), approaching the range of their bulk counterparts at the upper end. As a comparison, the power factors for \( n- \) and \( p- \) doped silicon were measured and compared to published values. For both \( p-\text{Si} \) and \( n-\text{Si} \), the power factor was \( 3.0 \times 10^{-3} \) W/mK\(^2\).

1This project was supported by NSF under DMR 1031153.

D1.00048 Electrically tunable light-emitting diodes based on monolayer WSe\(_2\) p–n junctions, MARIE SCOTT, JASON ROSS, XIAODONG XU, University of Washington, XU LAB TEAM — Following the discovery of graphene, other two-dimensional (2D) materials have been identified including a variety of truly 2D semiconductors. These new semiconductors are exciting candidates for next-generation optoelectronic devices because of their unique optical properties. Further, despite being atomically thin, techniques have recently been developed to transfer and stack these monolayer materials and produce arbitrarily complex heterostructures. Here, we present our adaptation of these transfer techniques in conjunction with electron beam lithography to produce the first monolayer LED using 2D crystals of tungsten diselendide(WSe\(_2\)). We stack monolayer WSe\(_2\) along with boron nitride onto metal gates to form a lateral p–n junction. This structure allows effective injection of electrons and holes, and, combined with the high optical quality of WSe\(_2\), yields bright electroluminescence with 1,000 times smaller injection current and 10 times smaller linewidth than seen in MoS\(_2\) schottky junction electroluminescence. By increasing the injection bias we can tune the electroluminescence between regimes of impurity-bound, charged and neutral excitons.

D1.00049 Low-Density Measurements of Gas Adsorption on Carbon Nanotubes, BORIS DZYUBENKO, DENISE SCHMITZ, HAO-CHUN LEE, OSCAR E. VILCHES, DAVID H. COBDEN, Department of Physics, University of Washington — We have studied the adsorption of noble gases on suspended individual single-walled carbon nanotubes in the limit of low density (coverage). The coverage, determined from the shift of the mechanical resonance frequency of the nanotube due to mass loading is seen to scale with about 30 atoms adsorbed on the entire nanotube. Due to the high homogeneity of the nanotube substrate and the sensitivity of the technique we are able to observe Henry’s law, in which the coverage is proportional to the gas pressure. In this limit the adsorption isotherm is determined by single-atom effects, allowing unprecedentedly accurate \( \pm 2\% \) determination of the single-particle binding energies of Ar and Kr to a nanotube.

1Supported by NSF DMR 1206208.
D1.00050 Electrical transport measurements on few-layer MX2. ZAIYAO FEI, JOE FINNEY, PAUL NGUYEN, BOSONG SUN, XIAODONG XU, DAVID COBDEN, Department of Physics, University of Washington — Transition metal dichalcogenides (MX2) have recently been shown to have excellent optical properties, but their intrinsic electrical properties remain undetermined mainly due to a lack of good electrical contacts to these materials, especially at lower temperatures. We investigated a range of device geometries and contact techniques to improve the situation. So far we have achieved ambipolar gate tuning of the linear-response conductance persisting at temperatures down to 4 K with contact resistance for both carrier of around 50 kiloohm at room temperature. Four terminal Hall-bar measurements is also been made to separate the contact resistance, sheet resistivity, carrier density and mobility.

D1.00051 Observation of time-dependent PL intensity of excitonic transitions in III-V semiconductors. TODD KARIN, RUSSELL BARBOUR, PATRICK WILHELM, KAI-MEI FU, Department of Physics, Univ of Washington — We study the time dependence of the excitonic photoluminescence (PL) intensity under resonant and above-band excitation using pump-probe techniques in InP and GaAs. We find that the PL intensity of both free and bound excitons increases to a steady-state value on a microsecond time-scale upon optical excitation. The system recovers to its initial state on the time-scale of tens of microseconds in the absence of excitation. Understanding the mechanism of this time-dependent intensity is important for the interpretation of pump-probe measurements designed to measure the spin-relaxation time of bound carriers in III-V semiconductors.

D1.00052 Second Harmonic Generation and Two-Photon Absorption in Few-Layer Transition Metal Dichalcogenides. KYLE SEYLER, JOHN SCHAIBLEY, SANFENG WU, JASON ROSS, XIAODONG XU, University of Washington — Atomically thin crystals of transition metal dichalcogenides (TMDs) have recently stimulated great interest due to their 2D optoelectronic properties, including strongly bound and tunable excitons and trions, and valley polarization and coherence. To date, most research efforts have been focused on the linear optical properties of TMDs. However, the recent observation of strong second harmonic generation and two-photon absorption in TMD monolayers suggests that the nonlinear optical properties may provide important insights into the excitonic physics of TMDs and lead to the observation of new phenomena. Here we present results of two-photon absorption and second harmonic generation experiments on monolayer and bilayer WS2e, under varied incident photon energy, photon polarization, and external electric field. We discuss the implications of these results on our understanding of the 2D excitonic physics in few-layer TMDs.

D1.00053 Band Gap and Phase Stability in (AlxGa1−x)2O3 Alloy Films. BENJAMIN KRUEGER, Univ of Washington, JOHN WALSETH, Roosevelt High School, FUMIO OHUCHI, MÁRJORIE OLMSTEAD, University of Washington — Gallium oxide is a transparent semiconductor (Eg = 4.8 eV) that exhibits n-type conductivity; it has been proposed for a variety of uses ranging from “solar-blind” conductive coatings to chemical sensing. An intriguing possibility is development of transparent, high power transistors based on carrier accumulation at an epitaxial Ga2O3-Al(Ga1−x)2O3 alloy interface. Using pulsed laser deposition, composition-spread (AlxGa1−x)x2O3 thin films were fabricated on sapphire and silicon substrates, with x varying smoothly across the surface. Position-dependent X-ray diffraction revealed [201]-oriented Ga2O3 on c-plane sapphire, and unoriented Ga2O3 on silicon with native oxide. Alloy (AlxGa1−x)x2O3 films on sapphire remain in the β-Ga2O3 phase for x < 0.30 then relax to the α-Al2O3 phase, whereas films on silicon remain in the β-Ga2O3 phase for x < 0.35 and then relax into the cubic γ-Al2O3 phase. Photoemission spectroscopy shows core and valence levels shifting to higher binding energy and decreasing work function, while spectroscopic ellipsometry reveals the absorption edge moving to higher photon energy, consistent with a widening band gap.

D1.00054 Dynein Motility Modeling. DAVID ROUNDY, WEIHONG QIU, KARL HELDT, ELLIOTT CAPEK, Oregon State University — Dynein is a motor protein which travels along microtubules. It is responsible for transporting organelles and other molecules around the cell. Dynein’s stepping pattern is very irregular when compared to other motor proteins, which makes it particularly interesting. I will present a computational model of Dynein’s motion, which takes into account the Brownian dynamics which are important for molecules of Dynein’s size. I will discuss what is currently known about Dynein motion and the methods we use in modeling the protein’s behavior.

D1.00055 Quark Nugget Dark Matter. KYLE LAWSON, University of British Columbia — While it is frequently assumed that the Dark Matter consists of a new fundamental particle an alternative possibility is that it represents a new phase of well known standard model particles. In this context I will discuss a model in which the dark matter consists of heavy “nuggets” of standard model quarks and antiquarks bound in a colour superconducting phase. After a brief review of the properties of these objects I will highlight a range of possible observational consequences and establish the current limits, and future detection prospects, for dark matter of this type.

D1.00056 In Research of electromagnetic wave mass, YONGQUAN HAN, 15472518079 — 1, Einstein is pointed out that E = mc2. Assuming that the mass of an electromagnetic wave particle is m, according to Einstein’s mass energy equation, an electromagnetic wave particle energy is: E = mc2. 2, Quantum mechanics, electromagnetic wave particle energy is the product of the Planck constant and the frequency of electromagnetic radiation, E=hν. 3, For an electromagnetic wave particle, hν = mc2, m = h γ/c2. Because h is Planck’s constant, c2 is the speed of the light is a constant, so the electromagnetic wave particle mass is related to the electromagnetic wave particle frequency, the greater frequency is, the greater the mass of the electromagnetic wave particle is 4, analysis of Einstein’s theory of relativity mass and velocity relationship can not be the photon mass confusion: electromagnetic wave particle mass is only related with the frequency of electromagnetic wave particle, it doesn’t related to the electromagnetic wave particle velocity, although the propagation of electromagnetic wave particle velocity is as fast as the speed of light, the mass will not tend to infinity.
9:00AM F1.00003 Sculptures Inspired by Physics, Proteins, and People. JULIAN VOSS-ANDREAE. Sculptor — Julian Voss-Andreae is a German sculptor based in Portland, Oregon. Starting out as a painter he later changed course and studied physics, mathematics, and philosophy at the Universities of Berlin, Edinburgh and Vienna. Voss-Andreae pursued his graduate research in experimental physics, participating in a 1999 experiment at Anton Zeilinger’s lab in Vienna that demonstrated quantum behavior for buckyballs. He moved to the United States to study Sculpture at the Pacific Northwest College of Art from where he graduated in 2004. Julian Voss-Andreae will talk about his sculpture, often inspired by his background in physics. Recent institutional commissions include large-scale outdoor sculptures for the new Physics and Nanotech Building of the University of Minnesota and Rutgers University, New Jersey.

9:30PM F1.00004 Banquet Wrap Up —

Saturday, May 3, 2014 8:20AM - 11:55AM —
Session F1 Plenary Session II Alder Commons 104 (Auditorium) - Jo-Anne Brown, University of Calgary

8:20AM F1.00001 Announcements —

8:30AM F1.00002 Single molecule nanopore sequencing of DNA. JENS GUNDLACH, Department of Physics, University of Washington — Nanopores are a new tool to study single bio molecules. We have developed the biologic pore Mycobacterium smegmatis porin A (MspA) for nanopore sequencing of DNA. A single molecule of DNA is drawn into the pore by a voltage applied across the pore, while an ionic current passing through the pore reveals the DNA’s composition, its interactions with the pore and its dynamics. A polymerase is used to control the translocation velocity through the pore. We will demonstrate how this technique leads to a simple and fast electronic DNA reader.

9:05AM F1.00003 Physics of Earthquakes and Tsunamis: Implications for the Pacific Northwest1. ANNE TREHU, Oregon State University — We are all familiar with the iconic volcanoes of the Pacific Northwest, which are a product of the Cascadia subduction zone, where the Juan de Fuca plate descends into the mantle beneath the North American plate. Earthquakes and tsunamis are another product of this subduction zone, and other subduction zones around the world, although no very large subduction zone earthquakes have occurred in Cascadia since the advent of seismic recording networks. The longer geologic record, however, indicates that large earthquake have occurred in the past, most recently on January 26, 1700. Several very large subduction earthquakes, however, have occurred elsewhere during the past decade, including the 2004 and 2005 Sumatra earthquakes, the 2010 Chile earthquake and the 2011 Tohoku earthquake in Japan. Modern networks of seismometers and GPS stations provide detailed information on the strain accumulation prior to and the rupture history during these events, and on the impact of the rupture history on the characteristics of the resulting tsunami. These three events were quite different in terms of the area of rupture, distribution and amount of slip on the rupture plane, and relationship between rupture in the earthquake and existing geologic structure. Studies of these earthquakes, coupled with studies of crustal structure and deformation in Cascadia, may provide some further clues about what we should expect in a future Cascadia subduction earthquake.

1An overview based on the work of many colleagues, generally supported by the National Science Foundation and US Geological Survey.

9:40AM F1.00004 Electron-Proton Parity Violation & the Qweak Experiment . LARRY LEE, University of Manitoba/TRIUMF — The “weak charge” of the proton (Qweak P) is the neutral current (weak interaction) analog of the proton’s electric charge. It is both precisely predicted and suppressed in the Standard Model, making this an ideal observable to use in searches for “new physics,” beyond the Standard Model. By measuring parity violation in the scattering of longitudinally polarized electrons from liquid hydrogen, the Qweak experiment can measure the weak charge of the proton, as “seen” by the Z-boson. This measured weak charge is “screened” by clouds of virtual particles in the vacuum, so by taking into account all “known” particles, Standard Model calculations attempt to make firm predictions for what our result should be. Nature, on the other hand, will use all particles, including ones not yet discovered, so a discrepancy between our measurement and the Standard Model prediction would be a sign of new physics. At our predicted accuracy, a ±4% measurement of Qweak P could see the effects of new physics at the TeV scale. The Qweak experiment, which was carried out in Hall C at the Thomas Jefferson National Accelerator Facility, has completed data-taking and is currently in the analysis phase.

10:15AM F1.00005 Break —

10:45AM F1.00006 Antimicrobial Photodynamic Therapy - a Decade of Development . NICOLAS LOEBEL, Ondine Biomedical — For every human cell in our bodies, approximately 9 microbes live within us, colonizing our digestive tracts, our eyes, teeth, skin and hair. We co-evolved with specific microbes—on the order of 1,000 different species—in order to provide us with a host of symbiotic advantages. However, the delicate balance between human and microbe can be upset by injury, stress, disease or even normal aging. When that happens, commensal microbes can turn into killers. As we learn more about normal and dysbiotic microorganisms, our ability to wipe out marauding microbes is paradoxically waning fast, as antibiotic resistance rises from rampant overuse. At Ondine, we’ve been developing a novel approach to infection control, by capitalizing on the ability of certain dyes to selectively stain microbes over human cells, and produce a potent killing flux of oxygen-derived free radicals (OFDR) when illuminated by light. Efficient OFDR generation from this approach to human and animal infection control.

11:20AM F1.00007 Physics and Sustainable Buildings. ROBERT KNAPP, Evergreen State Coll — Buildings account for roughly 40% of energy use and large fractions of water, materials and other dimensions of the national and global sustainability challenge. Physics imposes limits and creates opportunities for reducing resource demands and impacts while maintaining high performance. Using measured energy flows in instrumented buildings as a guide, this talk will highlight key physics aspects of the critical thermal, optical, fluid and electrical processes used in the current generation of high-performing buildings such as the Packard Foundation’s and Bullitt Foundation’s new “net zero” office buildings. Topics will include heat engines and heat exchangers, infra-red radiation, reflection and absorption spectra, and solar geometry.
How a noisy signal can be a useful spectroscopic tool: understanding noise from quantum interference, SHANNON O’LEARY, Lewis & Clark College — Naively one might assume that unavoidable fluctuations in laser frequency, intensity, and phase always diminish the precision of spectroscopic applications. But light-matter interactions sensitive to laser fluctuations encode useful information about the medium in the transmitted light’s fluctuations, and analysis of these fluctuations can enhance measurement precision. Diode lasers in particular have significant phase noise and a resonant atomic vapor converts this phase noise into transmitted intensity noise. Further, intensity noise from two orthogonally polarized fields originating from the same laser can be either correlated or anti-correlated, depending very sensitively on detuning from a resonance. In this talk I will present a noise correlation technique using a single “noisy” diode laser interacting with rubidium vapor on a sharp resonance feature from quantum interference, Electromagnetically Induced Transparency (EIT). Of particular interest is a narrow band of correlation that coincides with the quantum interference. The linewidth of this noise correlation peak has been shown in earlier work to be power-broadening resistant at low laser powers. I will present recent experimental noise correlation studies, including power broadening of this correlation peak at higher powers. This noise correlation technique holds promise in high-resolution applications such as atomic EIT-noise magnetometry.

This work is supported by NSF and NIST.

Stress Induced Birefringence in Atom Trap Viewports, CLAIRE WARNER, University of Waterloo, ALEXANDRE GORELOV, JOHN BEHR, TRIUMF — At TRIUMF Neutral Atom Trap (TRINAT), the current goal is a measurement of the angular asymmetry of beta particles with respect to the nuclear spin, \( \Delta \alpha \), from the beta decay of \(^{13}\)K nuclei. Trapped atoms are spin-polarized by optically pumping with circularly polarized light. We characterize the degree of circular polarization of the light with the Stokes parameter \( S_3 \); with an \( S_3 \) value of 0.999 required to spin polarize the atoms to a proportional degree of accuracy of 10\(^{-3}\). One major difficulty we have encountered is stress induced birefringence on the viewports of the atom trap, which alters the \( S_3 \) value. Fully anodized copper gaskets consistently achieved \( S_3 \) values of over 0.999 with reproducibility down to 0.999 and a strong dependence on the torque applied to the bolts sealing the CF flange. Using elastomer o-rings to seal the viewports, we achieved \( S_3 \) values of over 0.999, corresponding to a birefringence of \( \Delta n = 3 \times 10^{-6} \) [see Solmeyer, Rev. Sci. Instrum. 82 (2011) 066105]. The drawbacks of this method are outgassing and permeation. We achieved \( 3 \times 10^{10} \) Torr with Viton and Kalrez o-rings, and we are testing Neoflon. In this talk methods of producing and quantifying circularly polarized light will be discussed, as well as techniques for reducing stress-induced birefringence.

Characterization of Electron Orbital Angular Momentum Transfer to Nanoparticle Plasmon Modes, TYLER HARVEY, JORDAN CHESS, JORDAN PIERCE, Univ of Oregon, PETER ERCIUS, National Center for Electron Microscopy, Lawrence Berkeley National Laboratory, BENJAMIN MCMORRAN, Univ of Oregon — We observed the decay of an electron vortex beam from a state with orbital angular momentum \( m = 1 \hbar \) to \( m = 0 \hbar \) by interaction with gold nanoparticle surface plasmon modes. We produced electron vortex beams with \( m = 1 \hbar \) orbital angular momentum in a transmission electron microscope at 300 kV. We observed an increase in the intensity of the zero orbital angular momentum component of the beam upon interaction with a gold nanoparticle. By conservation of orbital angular momentum, we see that we transferred orbital angular momentum to the nanoparticle. Because this scattered intensity peaked when the radius of the beam matched the radius of the nanoparticle, and because preliminary electron energy loss spectra show a peak at 2 eV, we speculate that orbital angular momentum was transferred to plasmon modes in the nanoparticle. Several optical studies have induced plasmon vortices using optical vortices and circularly polarized light and suggested their use in nanophotonic and plasmonic devices. Direct observation of angular momentum transfer from electron vortices allows for unique identification of the orbital angular momentum associated with localized plasmon excitations down to the nanometer scale.

Nonlinear Terahertz Spectroscopy of Single-Layer Graphene, ZACHARY THOMPSON, MICHAEL PAUL, ANDREW STICKEL, JENNA WARDINI, ETHAN MINOT, YUN-SHIK LEE, Department of Physics, Oregon State University — Graphene has unique electronic properties which lead to remarkably strong optical nonlinearities in the terahertz (THz) regime, thus making it an attractive material for active photonic devices. Using THz free-space transmission spectroscopy, we demonstrate large THz transmission enhancement (>15%) in single-layer CVD graphene at high THz intensities. The nonlinear effects, caused by charge acceleration and carrier-carrier scattering, exhibit non-Drude behavior in the THz conductivity, where THz fields induce extreme non-equilibrium electron distributions.

Large Enhancement of Nonlinear Terahertz Absorption in Intrinsic GaAs by Plasmonic Nano Antennas, MICHAEL PAUL, Oregon State University, YOUNG-GYUN JEONG, Seoul National University, SEUNG-HYUN KIM, KI-JU YEE, Chungnam National University, DAI-SIK KIM, Seoul National University, YUN-SHIK LEE, Oregon State University — We present our preliminary properties on nonlinear THz effects in GaAs and their huge enhancement by plasmonic nano-antennas. We fabricated nano-antenna arrays on a 500-µ m-thick, intrinsic (100) GaAs wafer, using an electron beam lithography technique. THz pulses were generated by tilted-pulse-front optical rectification in LNO\(_3\). The THz field amplitude (central frequency, 1 THz; bandwidth, 1 THz) varies from 20 to 120 kV/cm. We measured the transmitted THz pulses using a L-He cooled Si:Bolometer to obtain either spectrally-integrated total THz transmitted power or transmission spectra via Michelson interferometry. We observe (1) a transmission decrease (\( \Delta T/T \)) of about 5% at around 100 kV/cm incident field strength in bare GaAs wafers and (2) a transmission decrease of more than 30% over the incident field amplitude range from 40 to 120 kV/cm in nano-antenna-on-GaAs samples. Our experimental study demonstrates that strong THz pulses induce nonlinear THz absorption in intrinsic GaAs. The nonlinear THz effects are intensified by the field enhancement in a nano-antenna array.
3:00PM G1.00007 Terahertz Spectroscopy of Metal-Insulator Transition in Vanadium Dioxide. ANDREW STICKEL, ZACK THOMPSON, Oregon State University, YOUNGGYUN JEONG, Seoul National University, MICHAEL PAUL, ALI MOUSAVIAN, GOMI University, DAISHIK KUM, GOMI University, YUN-SHIK LEE, Oregon State University, OREGON STATE UNIVERSITY TEAM, SEOU NATIONAL UNIVERSITY COLLABORATION — Vanadium Dioxide is an attractive material for high-speed optical and electrical switching as it undergoes a metal-insulator transition near room temperature (340 K). We examine the phase transition using free-space THz transmission spectroscopy. THz probe is sensitive to the metal-to-insulator transition, because the insulating phase is transparent at THz frequencies while the metallic phase is highly reflective. We demonstrate that THz transmission exhibits hysteresis of the metal-insulator transition during a temperature cycle. The phase transition gives rise to not only a reduction in transmission but also a spectral broadening as temperature increases.

2:12PM G2.00003 Finding the coldest star-forming regions in our Galaxy. WILL NETTKE, University of British Columbia Dept. of Physics and Astronomy — Surveys of the sky at different wavelengths are the pathfinders for driving astronomical research. In particular, catalogues of sources found in new surveys give us objects that can be followed up with other observations to probe the physical conditions in the distant Universe. The sub-millimetre part of the electromagnetic spectrum is ideal for studying the coldest and dustiest regions, and in particular to trace star-formation. However, the use of these wavelengths requires high-and-dry sites and state-of-the-art instruments. Such data come from the Sub-millimetre Common User Bolometer Array 2 (SCUBA-2) on the James Clerk Maxwell Telescope, located at an altitude of 4000m on the summit of Mauna Kea, Hawaii. Using data obtained from the SCUBA-2 'All-Sky' Survey (SASSy), which covers a large part of the Milky Way, I have been extracting and cataloguing compact sources of interstellar dust and gas. Efficient source extraction methods have been developed by utilizing a matched-filtering approach to increase the signal-to-noise ratio in large mosaicked maps of the sub-millimetre sky. I have created a catalogue of sources, testing the efficiency of the extraction procedure through the use of artificial stars inserted into the real images. Some of these objects are previously unknown, and have properties characteristic of the earliest stages of star formation. Further study of these objects may tell us more about the birth of stars from clouds of gas and dust.

2:24PM G2.00004 Characterizing thermal sweeping: a rapid disc dispersal mechanism. MATHIAS HUDOBA DE BADYN, University of British Columbia, JAMES E. OWEN, Canadian Institute for Theoretical Astrophysics, University of Toronto, CATHIE J. CLARKE, Institute of Astronomy, University of Cambridge, LUKE ROBBINS, University of Cambridge — Protoplanetary discs form from the remnants of the accretion discs left over after star formation. Inside these discs, planets and other planetary objects are formed. To constrain timescales of planet formation, an important area of research is in protoplanetary disc dissipation. We study the photoevaporation of discs in their late lifetimes, in particular a dynamically short period of intense dissipation called thermal sweeping, ending in the destruction of the disc. This mechanism is proposed to occur when the inner edge of the disc reaches a sufficiently low surface density, and the disc is dynamically unstable to runaway x-ray penetration. We present numerical simulations that show thermal sweeping has a linear x-ray luminosity dependence, and we discuss the critical surface density for the process to occur.

3:36PM G2.00005 Quantum Raychaudhuri equation. SAURYA DAS, University of Lethbridge — We compute quantum corrections to the Raychaudhuri equation, by replacing classical geodesics with quantal (Bohmian) trajectories, and show that they prevent focusing of geodesics, and the formation of conjugate points. We discuss implications for the Hawking-Penrose singularity theorems, for curvature singularities, for the Einstein equation of state and for Cosmology.

2:48PM G2.00006 Parallel-Plate Test of Gravity At Sub-Millimeter Distances. CHARLES HAGEDORN, MATTHEW TURNER, KRISHNA VENKATESWARA, JENS GUNDLACH, University of Washington/CENPA — Gravity has not been experimentally observed at scales smaller than the diameter of human hair, barely smaller than the dark energy length-scale of 85 microns. Our sensitive $(10^{-14} \text{ N} \cdot \text{m} / \sqrt{\text{Hz}})$ torsion balance uses a parallel-plate mass configuration to maximize signal and to create a Gauss’s Law null-test of short range gravity. The measurement’s sensitivity is comparable to the existing best limits at $\sim 56$ microns, but with complimentary sources of systematic uncertainty. The talk will highlight our approach to systematic uncertainty and data analysis.
3:00PM G2.00007 Dark Matter Halo Models and ADMX

The Axion Dark Matter eXperiment (ADMX) searches for dark matter axions by stimulating the decay of axions to photons using a magnetic field and a tunable resonant cavity. In this talk, I will discuss what could be learned about the velocity distribution and density of dark matter in our galaxy if ADMX successfully detects axion dark matter.

3:12PM G2.00008 Resonant modes of a high Q microwave cavity in the detection of Axions

The Axion Dark Matter eXperiment (ADMX) searches for axions by placing a high Q microwave cavity in a strong magnetic field. The magnet stimulates the conversion of axions into photons with a frequency that corresponds to the axion mass. Although the mass of the axion is unknown, the range in which axions contribute significantly to dark matter is well constrained and the resonant frequency of the cavity can be tuned to cover a range of masses. The resonant frequency is dependent on the size of the cavity as well as the position of tuning rods placed inside. By adjusting the position of these rods the detector can search over a range of frequencies corresponding to mass of the axion. Here I will give an overview of the application of resonant modes of the microwave cavity in the context of ADMX.

3:24PM G2.00009 Break —

4:00PM G2.00010 Overview of the Canadian Hydrogen Intensity-Mapping Experiment, CHIME

CHIME is a radio interferometer in the interior of British Columbia specifically designed to map cosmic structure over a redshift range of 0.8 < z < 2.5. An initial 40 x 37 m² instrument with 128 dual-polarization feeds has seen first light, and construction of the full-sized, 100 x 100 m² instrument is funded. CHIME is projected to provide a measurement of the dark energy equation of state that will be competitive with Stage IV Dark Energy Task Force experiments but at a tiny fraction of the cost and starting now. I will give an overview of CHIME, its science goals as well as the challenges, key among which is the task of separating the galactic foregrounds from the cosmic 21 cm signal.

4:30PM G2.00011 Discovering the Epoch of Reionization

The Murchison Widefield Array seeks to directly detect the Epoch of Reionization, the era of early structure formation, via the 21 cm hyperfine transition of hydrogen. With a possible detection of 14σ on the anisotropies of ionized hydrogen bubbles during the early universe, significant advancements in astrophysics will be made, including topics on the physics of galaxy formation, quasars, and mean free path of photons in the early universe. Recent breakthroughs in foreground subtraction of the hydrogen signal have prepared the state-of-the-art radio interferometry analysis for the incoming slew of over two petabytes of data in the coming months.

4:42PM G2.00012 The Axion Dark Matter Experiment Receiver Chain

The Axion Dark Matter Experiment (ADMX) is a search for axionic dark matter consisting primarily of a microwave cavity immersed in a strong magnetic field. Dark matter axions in the presence of the experiment’s magnetic field should resonantly convert into detectable photons in the cavity. The expected power due to the conversion of dark matter axions is very small; to detect the signals above the background thermal noise, ADMX requires a specialized receiver. I will describe the ADMX receiver, tracing the signal path from the microwave cavity to data analysis.

4:54PM G2.00013 In-Situ Noise Temperature Characterization of a SQUID MSA in Axion Dark Matter Experiment (ADMX)

Axions are hypothetical particles proposed to solve the strong CP problem and are also good candidates for cold dark matter. ADMX is an experiment directly searching for axion dark matter converting to photons in a microwave cavity. Superconducting Quantum Interference Device (SQUID) Micro-Strip Amplifiers (MSA) are a key component in the ADMX receiver chain because they introduce only quantum limited noise, maximizing sensitivity to axion signal. I will discuss how ADMX tunes a SQUID MSA to achieve optimum noise performance while in a high magnetic field.

5:06PM G2.00014 Josephson Junction Quantum Electronics and ADMX

Josephson junctions have numerous applications in quantum electronic devices. One specific application of Josephson junctions is used in the Axion Dark Matter eXperiment in the form of a highly sensitive SQUID microwave amplifier. I will review the basic physics of Josephson junctions as well as their characterization at both cryogenic and room temperatures. Preliminary data from Josephson foundry process developed at the Washington Nano-fabrication facility will be presented.

Supported by DOE Grants DE-FG02-97ER41029, DE-FG02-96ER40956, DE- AC52-07NA27344, DE-AC03-76SF00098.
5:18PM G2.00015 Instrumentation and Thermal Design of the Axion Dark Matter Experiment (ADMX)¹, SCOTT MCCULLOCH, Univ of Washington, ADMX COLLABORATION — The axion, a hypothetical elementary particle, may prove to be a component of cold dark matter in the universe. ADMX has been searching for this elementary particle through the conversion of axions into microwave photons in a resonant cavity within a high magnetic field. To maximize sensitivity to the axion signal, the cavity and associated electronics must be cooled to millikelvin temperatures. This talk will discuss the design and performance of the cryogenic system that meets ADMX’s unique needs.

¹Supported by DOE Grants DE-FG02-97ER41029, DE-FG02-96ER40956, DE-AC52-07NA27344, DE-AC03-76SF00098

5:30PM G2.00016 Helium Recovery at the Axion Dark Matter Experiment, KELLY OLSEN, University of Washington, ADMX COLLABORATION — ADMX (Axion Dark Matter eXperiment) is a search for the axion, an elementary particle first postulated to solve the strong CP problem and later realized to be a promising dark matter candidate. ADMX stimulates the resonant conversion of axions into detectable photons. However, because the expected power resulting from the conversion is so weak, sophisticated cryogenic electronics are necessary to amplify the signal and minimize thermal noise. The low temperature refrigeration and superconducting magnets require prodigious amounts of liquid helium. I will discuss the closed loop recovery and reliquefaction system that allows ADMX to continue operating at low temperatures with minimal helium loss.

5:42PM G2.00017 Searching for Higher Mass Dark Matter Axions¹, ROBERT PERCIVAL, Univ of Washington, ADMX COLLABORATION — Axions are a promising dark matter candidate with masses constrained to be roughly between a \( \mu eV \) and a MeV. Experiments searching for axions with masses of 1-10 \( \mu eV \) using microwave cavities are already in operation. However, some models favor axions with 40 \( \mu eV \) and above. More sophisticated cavity experiments face significant challenges. This mass range may be accessible with a series of wire planes placed inside an open resonator or Fabry-Perot etalon. I will describe a prototype of this technique searching for axions of approximately 70 \( \mu eV \) corresponding to cavity and receiver operating in the 17GHz range.

¹Supported by DOE Grants DE-FG02-97ER41029, DE-FG02-96ER40956, DE-AC52-07NA27344, DE-AC03-76SF00098

Saturday, May 3, 2014 1:30PM - 5:54PM — Session G3 Nuclear Physics Alder Commons 105 - Sonia Bacca, TRIUMF

1:30PM G3.00001 Atomic weights are not constants of Nature! Reading the stories told by the isotopes, MICHAEL WIESER, University of Calgary — The observation of two stable isotopes of neon by J. J. Thompson in 1912 was the first chapter in what would become arguably one of the most significant breakthroughs in Science. Thompson’s ingenious yet simple device employed electric and magnetic fields to reveal the existence of isotopes and this original design is the basis for modern instrumentation used in the measurement of isotope abundances. The mass spectrometer quickly became an important tool in the determination of the atomic weights of the elements, quantities that were thought at the time to be Constants of Nature. However, with increasing instrumental precision came the remarkable discovery that not all occurrences of an element had the same atomic weight values because of differences in isotopic composition. Researchers saw this discovery as a remarkable opportunity to use variations in isotopic composition to learn intimate information about physical, nuclear, and biological processes that may affect a particular element. Over the past 100 years technical and instrumental advances have enabled investigations supported by isotope abundance data to have an impact on our scientific understanding of our world and our health and well being in this world. In this talk, I will review the major discoveries that led to the development of modern isotope amount ratio measurement techniques and illustrate the insights made possible by these methods. I will highlight the knowledge we have gained as a result of reading the stories told by the isotopes.

2:00PM G3.00002 Nonperturbative renormalization of the chiral nucleon-nucleon interaction up to next-to-next-to-leading order¹, EHAB MARJI, College of Western Idaho, Nampa, Idaho 83684, USA, AMRAH CANUL, QUINN MACPHERSON, REBECCA WINZER, Department of Physics, Florida State University, Tallahassee, Florida 32306, USA, DAVID ENTEM, Universidad de Salamanca, E-37008 Salamanca, Spain, RUPRECHT MACLEIDT, Department of Physics, University of Idaho, Moscow, Idaho 83844, USA — We study the nonperturbative renormalization of the nucleon-nucleon \( (NN) \) interaction at next-to-leading order (NLO) and next-to-next-to-leading order (NNLO) of chiral effective field theory. A systematic variation of the cutoff parameter is performed for values below the chiral symmetry breaking scale of about 1 GeV. The accuracy of the predictions is determined by calculating the \( \chi^2 \) for the reproduction of the \( NN \) data for energy intervals below pion-production threshold. At \( NLO, NN \) data are described well up to about 100 MeV laboratory energy and, at NNLO, up to about 200 MeV—with, essentially, cutoff independence for cutoffs between about 450 and 850 MeV.

¹This work was supported in part by the U.S. Department of Energy under Grant No. DE-FG02-03ER41270. The work of D. R. E. was funded by the Ministerio de Ciencia y Tecnolog under Contract No. FPA2010- 21750-C02-02 and the European Community-Research

2:12PM G3.00003 Understanding The Proton Radius Puzzle: “Nuclear Polarizability Corrections in Muonic Deuterium”, OSCAR HERNANDEZ, Univ of Manitoba, CHEN JI, TRIUMF, SONIA BACCA, TRIUMF, Univ of Manitoba, NIR NEVO DINUR, NIR BARNEA, Racah Institute of Physics, The Hebrew University — In 2010 the accuracy of the rms proton radius was improved ten-fold by new spectroscopic measurements of the Lamb shift in muonic hydrogen. However, this new value differed by \( \sigma \tau \) from what was previously determined in ordinary hydrogen. This large discrepancy was coined the “proton radius puzzle” and challenges our understanding of physics based on the standard model. New high-precision measurements on various muonic atoms are planned at PSI to study whether this discrepancy persists or varies with mass and charge numbers. The accuracy of the nuclear charge radii determination from their data is limited by the uncertainty in the nuclear polarizability corrections. For \( m_D \), these nuclear corrections have been most recently calculated by Pachucki with the AV18 nuclear potential. In this contribution I would like to show how we complement Pachucki’s pioneering work by performing ab-initio calculations in \( m_D \) with state-of-the-art nuclear potentials from chiral effective field theory. We take into account multipole corrections, Coulomb, relativistic and finite-nucleon-size corrections. Furthermore, performing a systematic study in chiral effective field theory will allow us to better assess the theoretical error associated to the polarizability.
2:24PM G3.00004 Alternative Similarity Renormalization Group Generators in Nuclear Structure Calculations

NUIOK DICAIRE, Univ of Ottawa, CONOR OMAND, University of British Columbia, PETR NAVRATIL, TRIUMF — The Similarity Renormalization Group (SRG) has been successfully applied to soften interactions for ab initio nuclear calculations. In almost all practical applications in nuclear physics, an SRG generator with the kinetic energy operator was used. With this choice, a fast convergence of many-body calculations can be achieved, but at the same time substantial three-body interactions are induced even if one starts from purely two-nucleon (NN) Hamiltonian. Three-nucleon (3N) interactions can be handled by modern many-body methods. However, it has been observed that when including initial chiral 3N forces in the Hamiltonian, the SRG transformations induce non-negligible four-nucleon interactions that cannot be currently included in calculations for technical reasons. Consequently, it is essential to investigate alternative SRG generators that might suppress the induction of many-body forces while at the same time might preserve the good convergence. We present different alternative generators with operators of block structure in the harmonic oscillator basis. In the no-core shell model calculations for \(^{3}\text{H},^{4}\text{He}\) and \(^{6}\text{Li}\) with chiral NN force, we demonstrate that they appear quite promising.

2:36PM G3.00005 Towards Ab-Initio Calculations of Electromagnetic Reactions in Medium-Mass Nuclei

MIRKO MORELLO, University of British Columbia, Vancouver, Canada / TRIUMF, Canada; SONIA BACCA, TRIUMF / University of Manitoba, Canada, NIR BARNEA, Racah Institute of Physics, The Hebrew University, Jerusalem, Israel, GAUTE HAGEN, Oak Ridge National Laboratory / University of Tennessee, Knoxville, GIUSEPPINA ORLANDINI, Dipartimento di Fisica, Università di Trento and Istituto Nazionale di Fisica Nucleare, Gruppo Collegato di Trento, Trento, Italy, THOMAS PAPENBROCK, Oak Ridge National Laboratory / University of Tennessee, Knoxville — Electromagnetic reactions with nuclei are important in many fields of physics ranging from nuclear physics to astrophysics. The response of a nucleus to the interaction of an external electromagnetic probe is a crucial observable to test our understanding of nuclear dynamics. Until very recently, most of the ab-initio calculations of such reactions where the nucleus is broken in several pieces, were restricted to very light nuclei \((A \leq 7)\). By merging coupled-cluster theory and the Lorentz integral transform method one can extend the ab-initio study of electromagnetic break-up reactions to the region of medium-mass nuclei. We first benchmark the new method in \(^{4}\text{He}\) and then address the photo-disintegration of \(^{16}\text{O}\). We then move to \(^{40}\text{Ca}\) and \(^{48}\text{Ca}\), and investigate the electric dipole polarizability. Preliminary results indicate a correlation between the polarizability and the neutron-skin radius of \(^{40}\text{Ca}\). This latter is attracting a lot of attention in nuclear physics and experiments to measure both the polarizability and the neutron-skin radius are planned/ongoing at RCNP and JLAB respectively.

2:48PM G3.00006 Nuclear thermodynamics from chiral low-momentum interactions

JEREMY HOLT, University of Washington, CORBINIAN WELLENHOFER, NORBERT KAISER, WOLFRAM WEISE, Technical University of Munich — The thermodynamical equation of state of asymmetric nuclear matter is an important input for simulations of core-collapse supernovae. In the present work we take advantage of recent improvements in nuclear force models based on chiral effective field theory to construct an equation of state of nuclear matter at finite temperature. Nuclear two-body forces fit to elastic nucleon-nucleon scattering phase shifts and three-body forces fit to the binding energy and lifetime of the triton form the microscopic basis for our perturbative calculations. Bulk properties of symmetric nuclear matter at zero temperature are used to benchmark our many-body methods and nuclear force models, and uncertainty estimates on the equation of state are obtained by varying the resolution scale at which nuclear dynamics are resolved.

3:00PM G3.00007 A Microscopic Approach to Neutron-Rich Matter

LARZ WHITE, FRANCESCA SAMMARRUCA, Univ of Idaho — Our group is concerned with the properties of the nuclear force in the medium, particularly in the presence of unequal densities of protons and neutrons. The approach we take is “ab initio,” in the sense that realistic nucleon-nucleon forces are used as the input of many-body calculations, without phenomenological contributions. Intense computation is an essential element in microscopic nuclear physics. Our most recent effort consists of the solution of a large number of coupled integral equations describing scattering of nucleons in nuclear matter. Our solution method does not rely on partial-wave decomposition of the scattering amplitude and removes the need for standard approximations typically applied when including the Pauli blocking mechanism.

3:12PM G3.00008 The Cooling of the Cassiopeia A Neutron Star as a Probe of the Nuclear Symmetry Energy and Nuclear Pasta

KYLEAH MURPHY, Univ of Oregon, WILLIAM NEWTON, Texas A&M University -Commerce, JOSH HOOKER, Texas A&M University, BAO-AN LI, Texas A&M University -Commerce — X-ray observations of the neutron star in the Cas A supernova remnant over the past decade suggest the star is undergoing a rapid drop in surface temperature of \(\approx 2-5.5\%\). One explanation suggests the rapid cooling is triggered by the onset of neutron superfluidity in the core of the star, causing enhanced neutrino emission from neutron Cooper pair breaking and formation (PBF). Using consistent neutron star crust and core equations of state (EOSs) and compositions, we explore the sensitivity of this interpretation to the density dependence of the symmetry energy \(L\) of the EOS used, and to the presence of enhanced neutrino cooling in the bubble phases of crustal “nuclear pasta.” Modeling cooling over a conservative range of neutron star masses and envelope compositions, we find \(L \geq 70\text{ MeV}\), competitive with terrestrial experimental constraints and other astrophysical observations. For masses close to the most likely mass of \(M \geq 1.65\text{M}_{\odot}\), the constraint becomes more restrictive \(35 \leq L \leq 55\text{ MeV}\). The inclusion of the bubble cooling processes decreases the cooling rate of the star during the PBF phase, matching the observed rate only when \(L \leq 45\text{ MeV}\).

3:24PM G3.00009 Break

4:00PM G3.00010 Testing the Majorana Nature of the Neutrino with Germanium Detectors

JASON DETWILER, University of Washington — Among the known fundamental particles, only the neutrino could be a Majorana particle, a fermion for which the particle and antiparticle states are identical. The discovery of neutrino mass and its tininess relative to the other leptons and quarks has greatly strengthened the theoretical motivation for Majorana neutrinos. Far from being just a matter of trivia, the nature of the neutrino has deep implications for issues as far reaching as Grand Unification, the symmetries of the Standard Model, and the prevalence of matter over antimatter in the universe. I will discuss the neutrino’s role in these important issues, and introduce the only known viable experimental probe of this physics: searches for neutrinoless double-beta decay. I will make the case for performing such searches using germanium semiconductor detectors, and I will discuss the status of current experiments as well as future capabilities of large-scale germanium detector arrays.
4:30PM G3.00011 Development of Low Background Components for the MAJORANA DEMONSTRATOR, IAN GUINN, University of Washington, MAJORANA COLLABORATION — The MAJORANA collaboration will search for neutrinoless double beta decay ($0\nu\beta\beta$) of $^{76}$Ge using high purity germanium detectors. In order to achieve a sensitivity of up to $10^{26}$ years in the $0\nu\beta\beta$ half-life, background contributions in the $4$ keV region of interest around the $2039$ keV Q-value of the decay will need to be below~$1$ count per tonne-year. Radio-purity constraints require novel designs for many components of the detector and the development of improved assay capabilities. I will present some of the design challenges and solutions of the MAJORANA experiment, with a focus on the signal cables developed at the University of Washington.

4:42PM G3.00012 Low-noise preamplifier with forward biased reset for CoGeNT and MAJORANA, JONATHAN LEON, JASON DETWILER, DAVID PETERSON, HAMISH ROBERTSON, TIM VAN WECHEL, University of Washington, COGENT COLLABORATION, MAJORANA COLLABORATION — The CoGeNT and MAJORANA projects both make use of hyperpure Ge detectors that are in principle sensitive to very low energy nuclear recoil signals, such as those produced by coherent scattering of dark matter particles or neutrinos from Ge nuclei. However, this sensitivity can only be realized if sub-keV thresholds can be achieved. We are developing a low-noise charge preamplifier which is continuously reset by the forward-biased gate-to-source junction of the input JFET. Similar to pulsed-reset preamplifiers, this design avoids the noise contributions of a feedback resistor, while providing the added benefit of continuous operation. To achieve the lowest possible threshold, it is imperative to reduce all extraneous sources of noise. We will discuss methods to measure and reduce noise contributions, focusing in particular on capacitor dissipation noise. We will also report on characterization and performance of our latest prototypes.

1This research is supported under NSF Subaward FP044186.

4:54PM G3.00013 KATRIN Progress Toward a Neutrino Mass Measurement, DIANA PARNO, University of Washington, KATRIN COLLABORATION — The Karlsruhe Tritium Neutrino experiment (KATRIN), now under construction in Germany, will use the kinematics of tritium beta decay to probe the neutrino mass with a designed sensitivity of 0.2 eV. The KATRIN collaboration recently completed a first commissioning phase of the main spectrometer, investigating electron transmission and background processes. We will show preliminary commissioning results and summarize the current status of the experiment.

1This research is partially supported by DOE Grant DE-FG02-97ER41020.

5:06PM G3.00014 The Tritium-Recoil Ion Mass Spectrometer: examining molecular effects in neutrino mass experiments, LAURA BODINE, DIANA PARNO, R.G. HAMISH ROBERTSON, University of Washington — Detailed molecular final state calculations are required for the next generation of tritium-based neutrino mass experiments. The calculations also predict the branching ratio to the bound molecular ion $^7\text{He}^+_\text{T}$, which is directly measurable. The Tritium Recoil-Ion Mass Spectrometer is a time-of-flight spectrometer designed to measure molecular dissociation in tritium beta decay as a test of the calculations used in neutrino-mass analyses. We report on the status and outlook of the experiment.

1This work is supported by DOE Grant DE-FG02-97ER41020.

5:18PM G3.00015 Weak interaction studies with laser-trapped $^6\text{He}$, DAVID ZUMWALT, Univ of Washington, YELENA BAGDASAROVA, ALEJANDRO GARCIA, RAN HONG, MATT STERNBERG, DEREK STORM, ERIK SWANSON, FREDERIK WAUTERS, University of Washington, KEVIN BAILEY, ARNAUD LEREDDE, PETER MUELLER, TOM O’CONNOR, Argonne National Laboratory, XAVIER FLECHARD, ETIENNE LIÉNARD, Université de Caen, OSCAR NAVILIAT-CUNCIC, Michigan State University — $^6\text{He}$ beta decay is an excellent case to test the nature of the weak interaction through a precise measurement of the $\beta-\gamma$ angular correlation parameter $a$. The pure Gamow-Teller decay of $^6\text{He}$ should be ruled by an axial-vector interaction only, which leads to $a = -1/3$. Any deviation due to tensor coupling contributions would indicate new physics beyond the Standard Model. The high precision goal of this experiment, $\Delta a/a = 0.1\%$, requires a large statistical sample along with small and well known systematic uncertainties. To satisfy these constraints, neutral $^6\text{He}$ atoms are captured with laser light in a magneto-optical trap (MOT). $^6\text{He}$ ($t_{1/2} = 807$ ms) is produced on-line through the $^7\text{Li}(d,^3\text{He})^6\text{He}$ nuclear reaction by impinging a molten lithium target with an intense 18 MeV deuteron beam. Up to $10^{10} 6\text{He}$ atoms per second are extracted from the target and trapped in a two stage MOT. The angular correlation parameter is obtained by detecting the $\beta^+$ recoil ions in coincidence with the beta particle. Details of the setup and first results will be presented.

1This work is supported by DOE, Office of Nuclear Physics, under contract nos. DE-AC02-06CH11357 and DE-FG02-97ER41020.

5:30PM G3.00016 Corrections to Eikonal Approximation for Nuclear Scattering at Medium Energies, MICAH BUUCK, GERALD A. MILLER, University of Washington — Interpretation of the results of future experiments at the upcoming Facility for Rare Isotope Beams (FRIB) will require accurate modeling of low energy nucleus-nucleus interactions. The Glauber theory is a very successful high-energy approach, but its accuracy suffers at some of the lower beam energies of experimental interest to FRIB. A prescription developed by Wallace that treats the Glauber approximation as the zeroth order term in an expansion around an eikonal propagator has the potential to extend the range of validity of the approximation to lower energies. Here we examine the properties of this expansion, and calculate the corrections for both simple potential scattering and for nuclear reactions involving halo nuclei. We find that the corrections improve the accuracy of Glauber theory, so that it can be used at energies as low as about 40 MeV per nucleon.

1Supported by US DoE Grant No. DE-FG02-97ER4104.
5:42PM G3.00017 Gluon Saturation Effects on Three-particle Angular Correlations in p-p and p-Pb collisions at LHC, SENER OZONDER, University of Washington — The di-hadron correlations from the CMS experiment for the high multiplicity p-p and p-Pb collisions at LHC revealed a ridge structure that looked like the ridge induced by collective flow in A-A collisions. This discovery attracted great interest since the formation of quark gluon plasma (QGP) and collective flow were not anticipated in p-p and p-Pb collisions. It has been recently shown that the p-p and p-Pb ridge can be explained by the multiladder QCD diagrams (“glasma diagrams”) that were enhanced at the saturation scale at small $x$. In this framework, the ridge is purely due to the interference of the wave functions of the colliding hadrons/nuclei and the saturation effects encoded in the wave functions. We calculate tri-hadron correlations from the glasma diagrams for p-p ($\sqrt{s} = 7$ TeV) and p-Pb ($\sqrt{s} = 5.02$ TeV) collisions at LHC. We make quantitative predictions on the associated hadron yield for the high multiplicity events, which have yet to be measured by the experimental collaborations. Our results show that the glasma diagrams give rise to the structures in the three-hadron correlation which are clearly distinguishable from the possible QGP medium effects such as collective flow, energy loss and deflection of hadrons.

Saturday, May 3, 2014 1:30PM - 3:24PM — Session G4 Biophysics Alder Commons 106 - Douglas Juers, Whitman College

1:30PM G4.00001 Differential Diffusion as a Root Cause of Cracking of Protein Crystals, DOUGLAS JUERS, Whitman College — Protein crystals are nanoporous materials important for high resolution structure determination of proteins via X-ray diffraction. Additionally, their nanoporous character has made protein crystals useful for other applications including separations, catalysis and drug delivery. As materials, protein crystals contain both an ordered array of protein molecules and a disordered aqueous phase, which permeates the crystal inside the pores. The combination of order and disorder confers on the crystals interesting structural, thermal and transport properties. Here we focus on the transport of molecules through the pores and how such transport affects the structural integrity of the crystal. During their use, protein crystals are often subjected to solution changes that can cause damage, including cracking. When a crystal is transferred between two solutions of different composition, solutes and water molecules may enter and/or leave the crystal via its pores. The severity of cracking correlates with differences in both concentration and diffusibility of the entering and exiting molecules. The observed behavior motivates a model in which the key aspect of crystal cracking is differential diffusion of solutes, which causes an osmotic pressure induced stress on the crystal beyond its elastic limit. The result points to some simple guidelines for improved crystal handling.

In collaboration with Rose Cotter, Whitman College.

2:00PM G4.00002 Spatial organization of proteins due to membrane-induced interactions, KAYLA SAPP, LUTZ MAIBAUM, Univ of Washington — We investigate the interaction between lipid bilayers and other cellular components using mathematical modeling and numerical simulations. A biologically relevant example is a collection of actin filaments that suppress membrane shape fluctuations locally. We present a model that takes into account the membrane’s elastic behavior, a generic non-specific interaction between proteins, and the coupling between these two systems that we assume to be dominated by geometric effects. This model combines a continuum description of the lipid bilayer with a particle representation of membrane-bound proteins, and employs Brownian Dynamics to study both dynamical and fluctuation effects. We find that the presence of the proteins significantly changes the fluctuations of the membrane, while the bilayer induces an effective interaction between proteins that may lead to the formation of protein clusters even in the absence of protein-protein attractive forces.

2:12PM G4.00003 Probing interleaflet coupling in phase separated lipid bilayers under high shear, MATTHEW BLOSSER, Univ of Washington, AURELIA HONERKAMP-SMITH, Univ of Cambridge, SARAH KELLER, Univ of Washington — Lipid membranes composed of at least three lipid types can phase separate into micron-scale, coexisting liquid phases. Domains in each leaflet are never observed to move out of registration, which indicates a strong interleaflet coupling. Our group has found that this strong coupling persists in asymmetric membranes, where lipid ratios are different in each leaflet [1]. For membranes that lack transmembrane proteins or gel phases, the origin of this strong coupling is not intuitive [2]. Previously, we have found that domain registration persists in supported bilayers to shear rates of 6 seconds$^{-1}$. Here, we use microfluidic techniques to apply higher shear to supported bilayers with the goal of overcoming coupling by moving the membrane’s upper leaflet with respect to the lower leaflet. We use a flow cell design by Jönsson which was previously shown to move bilayers across a substrate [3]. In this system, the leaflet proximal to the substrate flows much slower than the leaflet proximal to the solution, leading to a macroscopic spatial shift between initially apposed regions. This technique of subjecting supported bilayers to high shear allows us to probe interactions between leaflets in the monolayer.


2:24PM G4.00004 Phase-locked spiking and stochastic resonance of hair cells, ROY SHLOMOVITZ, University of Washington, YUTTANA ROONGTHUMSKUL, SEUNG JI, DOLORES BOZOVIC, ROBIJN BRUINSMA, University of California, Los Angeles — The inner ear constitutes a remarkably sensitive mechanical detector. This detection occurs in a noisy and highly viscous environment, as the sensory cells - the hair cells - are immersed in a fluid-filled compartment and operate at room temperature or higher. We model the active motility of hair cell bundles of the vestibular system with the Adler equation, which describes the phase degree of freedom of bundle motion. We explore both analytically and numerically the response of the system to external signals, in the presence of white noise. The theoretical model predicts that hair bundles poised in the quiescent regime can exhibit sporadic spikes - sudden excursions in the position of the bundle. In this spiking regime, the system exhibits stochastic resonance, with the spiking rate peaking at an optimal level of noise. Upon the application of a very weak signal, the spikes occur at a preferential phase of the stimulus cycle. We compare the theoretical predictions of our model to experimental measurements obtained in vitro from individual hair cells. Finally, we show that an array of uncoupled hair cells could provide a sensitive detector that encodes the frequency of the applied signal.  

1 R.S. acknowledges financial support from the Raymond and Beverly Sackler Foundation. D.B. acknowledges NIH for support under grant 1R01DC011380. R. B. thanks the NSF for support under DMR Grant 1006128.
State University, DAVID KLUMPAR, Montana State University — At Montana State University – Bozeman undergraduate and graduate students take part in hands-on experiential involvement for undergraduate students at Montana State University. Fast-tracking our students for STEM careers in a technologically advanced society, we emphasize the importance of completely documenting their design and development process. The speaker will describe how professionally-mentored, yet collaborative work complements the core scientific and engineering knowledge they draw from their formal coursework. An equally high-priority goal is to conduct unbiased simulation. Significant differences were found between matched and mismatched pairs in structure, hydrogen bonding, and base flip. Mismatched pairs show greater movement in the x-y plane and a lower free energy barrier for base flip than do matched pairs. This supports experimental findings that the primary mechanism utilized by mismatch repair enzymes is to fully flip the base into the active site. Because the free energy of base flip is lower for mismatched systems, mismatch repair enzymes should show an enhanced preference for mismatched pairs.

A View to a Kill: T6SS-Mediated Cell Killing Visualized by Fluorescence Microscopy\(^1\), JACQUELINE CORBITT, MICHELE LEROUX, JOSEPH MOUGOUS, PAUL WIGGINS, University of Washington — The Type Six Secretion System (T6SS) is a bacterial toxin-delivery system targeting bacterial cells which neighbor the donor, promoting recipient cell death. The T6SS is widely conserved among Gram-negative bacteria and may be a central determinant in bacterial fitness in polymicrobial communities of particular relevance to chronic infection. Sequence homology of secretion system components to the T4 bacteriophage tail spike, cryoEM reconstructions of the secretion system and fluorescence imaging are all consistent with a dynamic mechanism of secretion. The complex system, which is composed of at least 15 proteins, forms a puncturing apparatus/delivery system which uses a donor protein filament to puncture the recipient cell wall to deliver protein toxins. Using quantitative imaging analysis of multiple fluorescent fusions, we present a detailed characterization of T6SS system dynamics visualized in single cells in multiple bacterial species, developing a model of T6SS function. We present quantitative measurements of the dynamics of the secretion system - from the assembly to disassembly - in conjunction with quantitative measures of system function, including recipient cell lysis.

Robustness of MinD oscillation in E. coli with diverse cell shapes, JEFF SCHULTE, RENE ZETO, DAVID ROUNDY, Oregon State University — The dynamics of the Min-protein system help Escherichia coli regulate the process of cell division by identifying the center of the cell. We model the Min-protein reaction cycle, using a set of reaction-diffusion differential equations, in bacteria that have been forced into unusual flattened shapes as have recently been experimentally observed. We find that a regular two pole oscillation pattern is robust and exhibited in a large variety of cell shapes and sizes. Stability analysis of an infinite slab that many physics students express essentially the same (incorrect) ideas both before and after instruction. It is frequently assumed that these ideas can be identified by research and then addressed through “interactive” teaching approaches such as hands-on activities and small-group collaborative work. In many classrooms, incorrect ideas are elicited, their inadequacy is exposed, and students are guided in reconciling their prior knowledge with the formal concepts of the discipline. Variations of this strategy have proven fruitful in science instruction at all levels from elementary through graduate school. However, this summary greatly over-simplifies the use of students’ ideas as the basis for effective instructional strategies. Examining what students have actually learned after using research-based curriculum is essential for improving the curriculum and validating its effectiveness. I will illustrate the process with examples from introductory physics.

Is “Interactive” Teaching Sufficient to Promote Conceptual Development in Physics?\(^1\), PAULA HERON, University of Washington — Over the past few decades, systematic research has shown that many physics students express essentially the same (incorrect) ideas both before and after instruction. It is frequently assumed that these ideas can be identified by research and then addressed through “interactive” teaching approaches such as hands-on activities and small-group collaborative work. In many classrooms, incorrect ideas are elicited, their inadequacy is exposed, and students are guided in reconciling their prior knowledge with the formal concepts of the discipline. Variations of this strategy have proven fruitful in science instruction at all levels from elementary through graduate school. However, this summary greatly over-simplifies the use of students’ ideas as the basis for effective instructional strategies. Examining what students have actually learned after using research-based curriculum is essential for improving the curriculum and validating its effectiveness. I will illustrate the process with examples from introductory physics.

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1Supported by NSF.

Today’s Students; Tomorrow’s Engineers and Scientists: A Program of Hands-on Experiential Involvement for Undergraduate Students at Montana State University, DAVID KLUMPAR, Montana State University — At Montana State University – Bozeman undergraduate and graduate students are fully engaging in the practice of their future careers as aerospace scientists and engineers through design, development and flight of small-cost spacecraft hardware, and its operation in space. Objectives of the student-focused program include hands-on experiential training that complements the core scientific and engineering knowledge they draw from their formal coursework. An equally high-priority goal is to conduct scientific investigations in space and to push the technological state-of-the-art in small low-cost spacecraft systems. A bonus of the program includes the opportunity for students to “test-drive” their potential careers before it becomes too late to make career path adjustments. These extracurricular involvements include developing systems engineering and project management skills; realizing the importance of working together as a highly interdisciplinary well-coordinated team; utilizing systematic and methodological processes and procedures; and understanding the importance of completely documenting their design and development process. The speaker will describe how professionally-mentored, yet completely extracurricular hands-on activities can work to complement the traditional formal educational activities of colleges and universities to fast-track our students for STEM careers in a technologically advanced society.

Supported in part by the NSF.
5:00PM G5.00003 Techniques for teaching critical thinking in a first year physics laboratory , N.G. HOLMES, D.A. BONN, University of British Columbia — One of the highest aims of education research is to explore how students can learn scientific reasoning and critical thinking skills. At UBC, we took on the ambitious goal of engaging students in meaningful reflection of the data they collect in an introductory physics lab. Our aim was to develop habits of mind that were essential to critical thinking. This included a procedural subgoal to teach students a set of data handling skills that spanned from histograms and standard deviation to weighted least-squares fitting. These analytic skills supported the development of advanced experimentation behaviours, including reflecting on data to identify systematic errors and adjusting models based on the quality of fit. This presentation will describe some of the new teaching techniques and course elements that went into achieving these goals and present the dramatic improvements in students’ unsupported experimentation behaviours over previous iterations of the course.

5:12PM G5.00004 The Use of Representations in Physics , XIMENA CID, ORLALA WEATNICK, University of Washington — Physics concepts are often presented with multiple representations (mathematical, diagrammatical etc.). The use of these representations can be extremely useful for students learning new physics concepts. In some cases, however, the representation can introduce difficulties unforeseen to the creator. This talk will discuss specific representations that are having difficulty with.

5:24PM G5.00005 Student reasoning about superposition in quantum mechanics , PAUL EMIGH, GINA PASSANTE, PETER SHAFFER, Univ of Washington — Superposition is at the heart of quantum mechanics, and yet we have found that many students struggle with this idea even at the end of instruction. Although most students can successfully use the idea of superposition to calculate probabilities of different measurement outcomes, we have found that they often fail to recognize how a superposition state differs from a mixture or from a system whose initial state is unknown. This distinction is one of fundamental importance in quantum mechanics and has implications for more complex topics such as entanglement. We present data from undergraduate and graduate-level quantum mechanics courses that illustrate some of the difficulties that students have with superposition. We also discuss how the results have guided the design of a lecture-tutorial that improves student understanding both immediately and months after instruction.

5:36PM G5.00006 Tutorials on Angular Momentum in Quantum Mechanics , PAUL EMIGH, GINA PASSANTE, PETER SHAFFER, University of Washington — As part of our examination of student understanding of quantum mechanics, the Physics Education Group at the University of Washington has probed student ideas related to angular momentum. Results from interviews and long-answer questions administered in a junior-level course for physics majors have revealed significant difficulties. For example, even after lecture instruction, many students use reasoning appropriate to classical mechanics rather than quantum mechanics. There is also substantial confusion between the different symbols, notations, and representations associated with angular momentum. We have developed a sequence of two tutorials to address these difficulties, modeled on Tutorials in Introductory Physics, the materials our group is developing for introductory physics courses. Results from pre- and post-tests suggest that this pair of tutorials can help improve student understanding of angular momentum, but there is still more that can be done.

Saturday, May 3, 2014 4:00PM - 5:42PM
Session G6 Condensed Matter II Alder Commons 104 - Kai-Mei Fu, University of Washington

4:00PM G6.00001 Optoelectronics of Two-Dimensional Transition Metal Dichalcogenides , XIAODONG XU, University of Washington — Monolayer transition metal dichalcogenides (TMDs) are a new class of 2D semiconductors with the band edge at the corners of the hexagonal Brillouin zone. There has been rapid progress in demonstrating the interesting 2D excitonic properties of TMDs, such as tunable exciton charging effects, large exciton and trion binding energies, and valley exciton polarization and coherence. In this talk, I will discuss the role of excitons in solid-state light emitting devices made from monolayer TMDs, as well as intralayer and interlayer excitonic properties in both TMD bilayers and heterostructure devices. The results are relevant for energy-efficient optoelectronics based on 2D layered materials.

4:30PM G6.00002 High Resolution Nonlinear Spectroscopy of 2D Excitons in Monolayer MoSe2 , JOHN SCHAIBLEY, TODD KARIN, University of Washington, HONGYI YU, University of Hong Kong, JASON ROSS, PASQUAL RIVERA, AARON JONES, MARIE SCOTT, University of Washington, JIAQIANG YAN, Oak Ridge National Laboratory, DAVID MANDRUS, University of Tennessee, WANG YAO, University of Hong Kong, KAI-MEI FU, XIAODONG XU, University of Washington — Monolayer transition metal dichalcogenides (mTMDs), such as MoSe2, have emerged as the first truly 2D semiconductors, exhibiting a wide range of novel electro-optical phenomena which arise from the material’s graphene-like honeycomb lattice. The optical response of mTMDs is dominated by strongly bound excitons which are localized in momentum space to two sets of inequivalent valleys (+K, -K) at the edge of the Brillouin zone. We report the first high resolution nonlinear spectroscopy measurements on monolayer MoSe2. Differential reflection measurements reveal that the degenerate nonlinear optical response agrees with the previously reported photoluminescence and reflectivity measurements, showing a broadened linewidth on order of 5 meV. Non-degenerate spectral holeburning measurements reveal narrow optical resonances approximately 1000 times narrower (order of 2 micro eV), indicating that excitons in mTMDs are dominantly inhomogenously broadened and exhibit an intrinsic lifetime on the order of 1 ns, over an order of magnitude longer than all previously reported lifetimes obtained through time domain techniques. Polarization dependent spectral holeburning measurements probe valley dependent processes such as the intervalley relaxation rates.

4:42PM G6.00003 Vapor-Solid Growth of WSe2 Monolayers and Lateral Heterostructures , GENEVIEVE CLARK, PASQUAL RIVERA, SANFENG WU, CHUNMING HWANG, GRANT AIVAZIAN, DAVID COBDEN, XIAODONG XU, University of Washington — Monolayer transition metal dichalcogenides (TMDCs) are atomically thin direct-gap semiconductors that show a variety of novel electronic and optical properties such as valley-polarization of Bloch electrons, due to their symmetry and two-dimensional nature. Heterostructures and devices combining various TMDCs via vertical or lateral stacking have shown further promise for applications in nanoelectronics and nano-optics, however the need for exfoliated samples limits the investigation of such materials and devices. Here, we present the synthesis of WSe2 monolayers and lateral WSe2-MoSe2 heterostructures on insulating substrates using a catalyst-free physical vapor deposition method. Monolayers and heterostructures up to 15 microns in size show high optical quality, demonstrated by a high degree of valley-polarization observed via low temperature polarization-resolved photoluminescence measurements.
4:54PM G6.00004 Exciton and charge carrier dynamics in high-performance small-molecule bulk heterojunctions, KESHAB PAUDEL, BRIAN JOHNSON, Oregon State University — We will present a study of the convergence properties of renormalization group theory when applied to the square well (SW) liquid. RGT is a recursive process that allows us to make accurate predictions of properties of a liquid near its critical point by accounting for the effects of fluctuations at multiple length scales. This can be computationally intensive, with the computing time scaling as an exponential of the longest length-scale fluctuations considered—that is, the recursion depth.

I will present an overview of this method, a discussion of the computational difficulties and limitations that I have encountered, and some preliminary results comparing SW and SW+RGT.

5:06PM G6.00005 Hybrid GaP/diamond waveguide-integrated resonators for quantum information processing applications1, NICOLE THOMAS, RUSSELL BARBOUR, University of Washington, YUNCHEONG SONG, MINJOO LARRY LEE, Yale University, KAI-MEI C. FU, University of Washington — Nitrogen-vacancy (NV) centers are considered a promising qubit system for on-chip entanglement generation in future quantum information processing (QIP) platforms. Optical networks for creating entanglement between NV centers require efficient collection and enhancement of the NV emission, photon routing along the diamond surface and entanglement generation via measurement-based schemes. As a first building block for such a network, we present gallium phosphide (GaP) waveguide-integrated disk resonators on a diamond substrate, and demonstrate coupling between 1 μm diameter resonators and waveguides with loaded quality factors of 3,800. The devices were fabricated from single-crystalline GaP transferred onto the diamond using an epitaxial lift-off process. A hybrid GaP/diamond system is ideal in that the GaP device layer provides both a high-index material for efficient waveguiding and the potential for the integration of active optical switches due to its linear electro-optic properties. Our devices show quality factors and coupling characteristics that are extremely promising for a future integration with near-surface NV centers in diamond, with the efficiency of on-chip photon collection in bus waveguides being several magnitudes higher than in comparable platforms utilizing free-space collection.

1This work was supported by the NSF under Grant No. 1343902. N. Thomas acknowledges financial support from Intel Corp.

5:18PM G6.00006 Applying Renormalization Group Theory to the Square Well Liquid, DAN ROTH, DAVID ROUNDY, Oregon State University — We will present a study of the convergence properties of renormalization group theory (RGT) when applied to the square well (SW) liquid. RGT is a recursive process that allows us to make accurate predictions of properties of a liquid near its critical point by accounting for the effects of fluctuations at multiple length scales. This can be computationally intensive, with the computing time scaling as an exponential of the longest length-scale fluctuations considered—that is, the recursion depth. I will present an overview of this method, a discussion of the computational difficulties and limitations that I have encountered, and some preliminary results comparing SW and SW+RGT.

5:30PM G6.00007 Softening the Hard-Sphere Fluid, ERIC KREBS, SAMUEL LOOMIS, PATRICK KREITZBERG, DAVID ROUNDY, Oregon State University — The hard-sphere fluid is a widely used reference fluid for theoretical frameworks for real fluids that, while well studied and understood, doesn’t match particularly well with real physical fluids. For inhomogeneous hard-sphere fluids, Fundamental Measure Theory (FMT) is a standard classical density functional theory that predicts the hard-sphere free energy. A “soft” FMT (SFMT) was introduced by Schmidt [1] which is based on FMT and allows for penetrable spheres determined by a pair potential. We study a soft fluid with a simple potential describing slightly penetrating spheres at moderate temperatures based on SFMT. We compare the predicted equation of state against Monte-Carlo simulation for a homogeneous soft fluid and for soft spheres near a hard wall.


Friday, May 2, 2014 12:15PM - 1:15PM –
Session H1 Northwest Section Executive Meeting TBD - Brian Milbrath, Pacific Northwest National Laboratory

12:15PM H1.00001 NWS Executive Meeting –

Friday, May 2, 2014 5:30PM - 6:30PM –
Session H2 Northwest Section Business Meeting Alder Commons 104 - Brian Milbrath, Pacific Northwest National Laboratory

5:30PM H2.00001 Business Meeting –

Saturday, May 3, 2014 6:00PM - 6:15PM –
Session H4 Closing Remarks Alder Commons 104 (Auditorium) - Jo-Anne Brown Oscar Vilches, University of Calgary, University of Washington

6:00PM H4.00001 Closing Remarks –