UW Physics REU 2013 Project List

Projects are offered from the following physics subfields:

- Cosmology and astrophysics
- Elementary particle physics
- Nuclear physics and astrophysics
- Atomic physics
- Physics education
- Condensed matter and nanostructure physics
- Numerical modeling and simulations

If you have a special interest not represented in the list below, feel free to contact either Subhadeep Gupta or Alejandro Garcia for help. They may be able to design new projects that align with your interests.

Experimental Projects

Fundamental Physics Measurements with Germanium Detector Arrays
Jason Detwiler

Our group is involved in the construction of the MAJORANA DEMONSTRATOR, an ultra-low background array of enriched germanium detectors that will perform a sensitive search for neutrinoless double-beta decay. The observation of this process would demonstrate that neutrinos are Majorana particles and that lepton number is not a conserved quantity, with implications for Grand Unification and the predominance of matter over antimatter in the universe. The same detector will also be sensitive to WIMP dark matter, solar axions, and other rare processes. We welcome students with computing or hardware skills to assist in construction activities, make auxiliary measurements in local detector test stands, perform detector simulations, and analyze detector data.

Ultracold Atoms and Molecules
Subhadeep Gupta

Through the orchestrated use of lasers and electronics, neutral atomic gases can be cooled and trapped at nano-Kelvin temperatures in a high-vacuum environment, where their properties are completely dominated by quantum mechanics. Here atoms interfere like laser beams and flow without friction. In our laboratory, we prepare and study such ultracold gases with a focus on understanding their behavior, testing fundamental quantum theories, and for future applications in quantum information science. In one project we work on resonantly interacting ultracold atoms to prepare and study ultracold molecules. in another, we are engaged in matter-wave interferometry with the major goal of precisely testing the theory of quantum electrodynamics (QED). Researchers in our group acquire a broad range of experimental skills while exploring frontier topics in low-temperature quantum physics. REU students can engage in multiple aspects of the experiments - past REU students have made significant contributions by (for instance) designing and building electromagnetic atom trapping coils and building diode laser assemblies. Please see our website http://www.phys.washington.edu/users/deepg/ for further details.

Optical Generation and Electrical Control of Valley Excitons and Pseudospins in monolayer Semiconductors
Xiaodong Xu

Electronic valleys are energy extrema of Bloch bands in momentum space. In analogy to electrons with spin degrees of freedom, valley indexes can be considered as pseudospins for new modes of electronic and photonic device operation. In this project, REU student will be involved in the investigation of these pseudospins using atomically-thin semiconductors, which are either single or bilayer group VI transition metal dichalcogenides. The students will learn material synthesis and device fabrication, and be involved in optical measurements of spin and valley physics through neutral and charged valley excitons with an electrical control.

Laser trapping of 6He
Alejandro Garcia

This project aims at determining the angular correlation between the electron and the neutrino in the decay of 6He in search for new forms of physics that would show as "tensor currents" contributions to radioactive decays. We plan to use a Magneto-Optical laser trap to hold the 6He atoms so that the decay particles can be observed with minimal interference. The student will participate in optimizing the production of 6He, in several ongoing improvements of the 6He trapping system, and on detection of the beta-decay particles.

Search for Dark Matter
Leslie Rosenberg

Our group is operating the Axion Dark Matter eXperiment (ADMX), a detector to search for the axion, a hypothetical particle that may form the dark matter in our galaxy. We recently commissioned a new data channel that looks for axions that have recently fallen into our galactic dark-matter halo. Also, we're in the process of rebuilding the detector for its next and more sensitive phase. We welcome someone with computing and mechanical skills who can join our group and who has an interest in experimental cosmology.

Quantum Computing with Trapped Ions
Boris Blinov

In the trapped ion quantum computing lab at the University of Washington we experimentally investigate the techniques for building a conceptually new type of computational device. A quantum computer will be extremely fast at solving some important computational problems, such as the factoring and the database search. While days of practical quantum computing may be quite far in the future, we are developing the main building blocks of such a device – the quantum bits ("qubits"), the basic logic operations, the qubit readout... The physical implementation of the qubit in our lab is the hyperfine spin of a single, trapped barium ion. Students in this REU project will participate in experiments with laser-cooled, RF-trapped single ions, will help develop techniques for single- and multi-qubit manipulation via microwaveinduced hyperfine transitions and ultrafast laser-driven excitations. They will gain valuable hands-on experience with lasers and optics, RF and digital electronics, and ultrahigh vacuum technology.

Next generation neutrino detectors
Nikolai Tolich

Our group is involved in a number of experiments to detect neutrinos. Neutrinos are elusive particles that pass through matter almost completely unhindered, which makes them excellent probes of the physics occurring deep inside objects such as the earth and the sun, but also makes them extremely difficult to detect. We are currently working on ides for two different neutrino detectors, which both use liquid scintillator as the detection medium. One detector, around 1 kton in mass, could be used to measure neutrinos coming from the earth. This would allow us to measure the main source of heat within the Earth, which is thought to power mantle convection, earthquakes, and plate tectonics. The other detector, around 50 to 100 kton in mass, could measure neutrino oscillations from a man-made neutrino source. This would allow us to understand the nature of neutrinos. An REU student could help us simulate new detector designs, or could help us make measurements of the optical properties of the liquid scintillator to see if such detectors would be possible. For more information on our research group, see: http://www.phys.washington.edu/users/ntolich/

Research-based Instructional Strategies for Teaching Physics
Lillian C. McDermott, Paula Heron, Peter Shaffer

The Physics Education Group conducts research on student understanding of physics and uses the results to guide the design of instructional materials, which are intended for national distribution. The effectiveness of these curricula is assessed at the University of Washington and at many other institutions. REU students will have the opportunity to participate in programs shaped by the group's research, such as the summer program for K-12 teachers and the tutorials for the introductory physics course. In addition to taking part in classroom activities, previous REU participants assisted in investigations of the effect of different instructional strategies on student understanding of important fundamental concepts.

Chiral photocurrent in carbon nanotubes and graphene
David Cobden

In our group we look for new physics in devices made from single nanotubes, nanowires and nanosheets (such as graphene). For example, one can see low-dimensional phenomena, unusual collective excitations, topological quantum effects and phase transitions in them. The combined techniques of laser optics and electrical transport can be brought to bear simultaneously on one of these devices. As an example, which is the suggested topic of this project, we will set out to measure the circular photocurrent effect in chiral carbon nanotubes and bilayer graphene. This light-generated current, which changes direction with the handedness of the light, has been recently predicted to offer a new means to probe interaction effects such as Luttinger-liquid and Wigner-crystal behavior in low dimensional electronic systems.

Transparent Conductive Oxides
Marjorie Olmstead

Gallium oxide is transparent into the near ultraviolet, and yet can be made to conduct electricity. This REU project would focus on understanding the growth of gallium oxide nanoscale films with pulsed laser deposition, including alloying with other materials (e.g. Aluminum or chromium oxide) and the nanoscale mechanical and electronic structure of electrical contacts. Depending on student interest, experiments may include photoemission spectroscopy, optical spectroscopy, scanning probe microscopy or electrical transport measurements.

X-ray Optics, Nonlinear Spectral Signatures, and Economics
Jerry Seidler

The Linac Coherent Light Source (LCLS), recently completed and commissioned at SLAC, is the world's first hard x-ray laser. It will allow measurements with unprecedented spatial and time resolution across multiple disciplines of science. Specific endstations are under construction to focus on: nonlinear x-ray optics in atomic physics, correlated electron physics in solid state and nanophase materials, pump-probe studies of biological and synthetic photochemistry, and plasma physics relevant for astrophysical nebula and planetary and stellar interiors. Science at the LCLS will, however, be constrained by a fundamental limit: it costs approximately $100,000 per hour to operate the light source, and therefore beam time is a scarce resource and high-efficiency experimental methods become precious. Our group has recently developed two new types of x-ray emission spectrometers that can greatly decrease the measurement time for x-ray emission spectroscopy at the LCLS, and similarly increase experimental throughput at other time-resolved x-ray facilities. Interested students will get an in-depth experience in experimental instrument design, including both a broad introduction to modern x-ray techniques and also complete training in CAD software. Scheduling permitting, students will also participate in one of my group’s trips to a synchrotron x-ray light source.

Theory/Numerical Modeling Projects

Nuclear Dynamics and Cold Atoms: Computational Many-Body Physics
Michael Forbes and Aurel Bulgac

Many aspects of nuclear physics, astrophysics (neutron stars), and cold atomic superfluids can be described with the similar (universal) many-body dynamics. This allows one to study many different systems with similar techniques, and to apply results from one field to problems in another. The current challenge is to solve the many-body problem: to calculate macroscopic properties -- e.g. vortex dynamics in neutron stars and in cold atoms, shock-waves in colliding atomic clouds, cold-atoms in optical traps and lattices, and quantum turbulence -- from a microscopic description of the system (force between particles). An REU student could contribute in several areas developing tools for applying density functional theory (DFT) to systems of cold atoms, and neutron matter. Projects could include: developing large-scale optimization techniques for finding stationary and ground state properties, developing parallel and GPU based simulations for studying real-time dynamics of superfluids, designing and analyzing simulations of cold atom experiments and neutron star crusts, comparing results with experiments and Monte Carlo simulations to validate and improve the density functional techniques. Students will gain experience developing and working with numerical simulations using various high-performance computing platforms -- skills that can be leveraged to solve realistic problems in many different fields. Based on interest, students will also gain experience with different aspects of many-body physics, providing good preparation for further studies in nuclear physics, condensed matter physics, particle physics, and fluid dynamics. Students should have a strong background in mathematics, and some experience with quantum mechanics and programming (python, Matlab, and C/C++ will be used, but prior experience with these languages is not required). Actual projects will be tailored to the student's experience and interests.

Calculating Hadronic Couplings for Dark Matter Searches
Huey-Wen Lin

Astrophysical evidence suggests that the dark matter making up the bulk of the mass in the universe must consist of cold nonbaryonic particles. Such cold particles will have non-relativistic velocities, giving them a Compton wavelengths above the width of a proton. This means they will interact with nuclei (such as those making up a detector) at low energy, and the hadronic couplings calculated in the nonperturbative regime of quantum chromodynamics (QCD) will be important to constrain theoretical uncertainties. Once calculated, these couplings can be combined with high-energy models of new physics (such as supersymmetry) to make predictions about cross-sections that can be compared with dark-matter experiments (such as XENON100). In this REU project, the student will analyze data from lattice gauge theory simulations of QCD to determine the couplings for spin-independent dark-matter scattering. Students will have a chance to learn statistical analysis, lattice gauge theory, phenomenology of hadronic physics and some dark-matter physics. Students with experience programming in Mathematica are preferred, but not required.

Light Front Quantum Mechanics
Jerry Miller

In 1947 Dirac introduced a new form of relativistic quantum mechanics in which the variable ct +z acts as a “time” coordinate and ct-z acts as a “space” coordinate. This so-called light front formalism was largely forgotten until the 1970's, when it turned out to be useful in analyzing a variety of high energy experiments. Despite the phenomenological success of this formalism, it has enjoyed only limited use in computing wave functions of particles and atomic nuclei. The present project is devoted to using the light front formalism to solve quantum mechanics problems involving bound and scattering states. A mathematically strong REU student would learn about relativistic quantum mechanics through the process of solving the relevant relativistic equations. This project would involve working on interesting and timely topics and could provide great preparation for graduate school quantum mechanics, field theory or even string theory. A full year of quantum mechanics is a necessary prerequisite.

Computational Condensed Matter Theory and Response Functions: Real-time and Real-space Methods and Cloud Computing Platforms
John J. Rehr

This project deals with high performance computer calculations of electronic response functions, such as the absorption and emission of x-rays, modern real-space and real-time computational algorithms. Our real-space codes are based on a Green's function (RSGF) formalism as implemented in the FEFF codes. Our real-time codes are based on time-dependent density functional theory using an extension of SIESTA. These codes are applicable to complex, nano-scale systems. Recently we have extended the code for execution on the Amazon EC2 Cloud Computer using our new Scientific Cloud Computing tools. This project is appropriate for students with an interest in theoretical condensed matter physics and computational physics.