UW Physics REU 2014 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

On-Chip Entanglement of Solid-State Emitters
Kai-Mei Fu

We are developing a platform to realize scalable quantum information processing with the NV center in diamond. An undergraduate researcher will build an external-cavity diode laser needed to characterize the optical properties of NV centers. This is part of a larger effort to engineer these properties in integrated devices. If time permits, the student will use the laser to characterize device-integrated NVs and evaluate their suitability for information processing.

Searching for New Physics Using the ATLAS Detector at the LHC
Shih-Chieh Hsu

The UW Elementary Particle Experiment group is working on new physics search in proton-proton collisions at the LHC using the ATLAS detector. We are also working on the upgrade of the new pixel detector to account for high radiation environment in the future LHC run. All projects require moderate knowledge of Linux and C++. The REU student could work on one of the projects listed below:
1) Searching for extra dimension Graviton or heavy Higgs using innovative jet substructure techniques. This project will use Monte Carlo simulations and innovative jet substructure techniques to optimize the best discovery strategy of exotic particle. Recommended knowledge: David Griffith's Introduction to Particle Physics (up to Ch6).
2) Development of new DAQ system for the T3MAPS CMOS sensor. This project provides hands-on tasks in the system design and software implementations to build a new DAQ system for characterization of new pixel sensor. Recommended Skill: Verilog/HDL (not required).
3) Performance study of the future Tracker Upgrade. This project uses GEANT4 to simulate the new layout of the future tracking system for the ATLAS. The student will learn working principles of charged particle detection and analysis skills for performance studies.

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.

Searching for new physics in the muon's magnetism and NMR
Alejandro Garcia and Eric Swanson

The magnetic moment of the muon is a fundamental quantity that is calculable with high precision. However, recent measurements show disagreement with expectations that may be hints of new physics. In order to determine the muon magnetic moment, reliable determination of magnetic fields are needed and will be done via nuclear magnetic resonance (NMR). The project will consist of building NMR probes and doing calculations to understand limitations. The student will get hands-on experience building equipment, working with NMR probes signals, developing electronics and data acquisition systems, and doing associated calculations.

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 microwave-induced 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 the SNO+ experiment 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. SNO+ uses liquid scintillator as the neutrino detection medium. An REU student could help us simulate new detector designs, or could help us make measurements of the optical properties of the liquid scintillator. Such measurements are necessary for us to understand the data that we will soon be obtaining from our detector. 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.

A Beamline in Box
Jerry Seidler

Advanced x-ray methods at synchrotron light sources are the basis for numerous advances in condensed matter and atomic physics, biology, physical and organic chemistry, and materials sciences, to name a few examples. However, at the same time, the scarcity of access to such facilities has become a limiting factor in several fields. This is perhaps noticeable in clean energy research where progress in developing improved battery chemistry and performance is often greatly aided by x-ray spectroscopies that have only been available at the large synchrotron facilities. Recently, however, the Seidler group at UW has developed a table-top x-ray spectroscopy system capable of performing many of the necessary studies on batteries. In the summer of 2014, we will finish construction and begin commissioning of a user facility for UW clean energy researchers that is based on our 'beamline in a box' strategy. The involved REU student will be given responsibility for part of this process and will actively participate in x-ray spectroscopic studies of the electronic structure of model batteries and other systems important for sustainable energy.

Theory/Numerical Modeling Projects

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

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.

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 for Complex Systems

John J. Rehr

This project deals with high performance computer calculations of electronic response functions, such as the absorption and emission of x-rays using modern real-space and real-time computational algorithms. Our real-space codes are based on real-space Green's function (RSGF) and time-dependent density functional theory (TDDFT) as implemented in the FEFF and RTXS codes. These codes are applicable to complex and nano-scale systems ranging from supported catalysts to water and ice. This project is appropriate for students with an interest in theoretical condensed matter physics and computational physics.