# 2014 TUNL REU PROJECTS

## 1. Commissioning the Enge Spectrometer's Focal Plane Detector
**Advisor: Richard Longland**
**REU Student: Robert Leonard (Georgia Tech)**

The Enge Split-Pole spectrometer makes use of the Lorentz force to focus high-energy charged particles onto a focal plane. By measuring the energy, position, and rate of energy loss of these particles, they can be identified and used to measure nuclear reaction cross-sections. This measurement is done using a complex detector package located at the focal plane in the spectrometer. While the detector is built, it has not been fully tested and integrated with a data acquisition system.

The student involved in this project will help commission this detector. They will take charge of detector operation and signal-path routing through electronics hardware in order to analyze events. This project will involve construction of a test stand for characterizing the detector components with radioactive sources. The student will also work closely with other researchers to integrate detector signals with a data acquisition system ready for experiments, and will have the opportunity to work with the spectrometer and vacuum system.

## 2. Simulation and data analysis for coherent elastic neutrino scattering
**Advisor: Kate Scholberg**
**REU Student: Jaclyn Schmitt (Clemson University)**

Coherent neutral current neutrino-nucleus elastic scattering is a process in which a neutrino interacts with a nucleus, giving it a recoil kick. Although the probability for such a process to occur is relatively high, the process has never before been detected because typical nuclear recoil energies are very small. However, detection of the process may be within the reach of the new generation of low-threshold detectors. Because the rate of the process can be quite precisely predicted, a deviation of measurement from prediction could indicate new physics beyond the Standard Model. There are promising prospects for performing this experiment at the Spallation Neutron Source at Oak Ridge National Laboratory in Tennessee.  This project will involve participation in design, simulation and background evaluation work for a neutrino scattering experiment at the SNS.  The student will gain experience with a variety of simulation and data analysis software tools.  Programming experience will be useful but is not required.

## 3. Measurement of the $^{86}$Kr(n,$\gamma$)$^{87}$Kr reaction cross section between 0.5 and 15 MeV
**Advisors: Megha Bhike and Werner Tornow**
**REU Student: Elizabeth Rubino (Florida Atlantic University)**

In low neutron density stellar environments the slow neutron capture (s-process) reaction on $^{86}$Kr (magic neutron number N=50) synthesizes the stable nucleus $^{87}$Rb (also N=50) after β-decay of $^{87}$Kr with half-life time $T_{1/2}$=76.3 min. Experimental data for the neutron capture cross section on $^{86}$Kr do not exist in the neutron energy regime of interest for nuclear astrophysics. This cross section is also of interest to the National Ignition Facility (NIF) at Lawrence Livermore National Laboratory for measuring important parameters of the Deuterium-Tritium (DT) Inertial Confinement Fusion (ICF) plasma.

The REU student will measure the $^{86}$Kr(n,γ)$^{87}$Kr cross section in the neutron energy range from 0.5 to 15 MeV using the neutron activation technique. After neutron irradiation of $^{86}$Kr, the de-excitation γ-rays from the first excited state of $^{87}$Rb will be recorded with a High-Purity Germanium (HPGe) detector. Indium and gold monitor foils will be irradiated simultaneously with the $^{86}$Kr sample for neutron fluence determination.

**4. Improving the LENA ECR Beam-line with Solenoidal Lenses and a High-Power Beam-Stop**
**Advisors: Christian Iliadis and Tom Clegg**
**REU Student: Eric Machado (University of North Carolina)**

Construction is nearly complete on an improved acceleration system for proton beams from the high-voltage platform for the electron-cyclotron-resonance ion source. To transport its expected full 30 mA beam to target without loss over the desired energy range between 100 and 240 keV, two new magnetic solenoid lenses need to be designed and fabricated to replace the magnetic quadrupole lenses used now. These solenoids were shown by calculations to accommodate, far better than the quadrupole lenses, the requirement for a tight 1” beam waist at the analyzing magnet which directs the beam to target. In addition to the solenoids, two new chilled-water-cooled beam stops are needed to accommodate the increased beam power. Design and fabrication of these beamstops will be completed during the summer REU program. It is expected that all these new beam acceleration and transport components will be installed for testing and use by early 2015.

**5. Neutron Scatter Camera & Backgrounds at TUNL**
**Advisor: Phil Barbeau**
**REU Student: Shaquann Seadrow (Hampton-Sydney U.)**

Neutrons can can be a major background problem for several of the rare event search experiments that the Barbeau group participates in. Such projects include searches for neutrinoless double beta decay, coherent neutrino-nucleus scattering and searches for Light WIMP dark matter.

The goal of this project is to build a neutron scatter camera that will be used to characterize neutron fluxes and create images of the neutron sources, in support of these experiments. The camera will be built using detectors and electronics on hand at TUNL. The successful detector will find uses on site in the neutron Time-of-Flight room, in the Barbeau laboratory, as well as likely in potential experimental sites at Oak Ridge National Laboratory and the Kimbalton Underground Research Facility.

**6. A Proton Back-Scattering Beam Monitor for Quenching Factor Studies**
**Advisor: Phil Barbeau**
**REU Student: Aaron Magner (IPFW)**

The Barbeau group uses the Tandem Van de Graaff accelerator at TUNL as part of a state-of-the-art facility that produces a monochromatic, tunable, pulsed and collimated neutron beam. The neutron beam (generated using the $^{7}$Li(p, n)$^{7}$Be process) is used to calibrate the detector responses to low energy nuclear recoils (quenching factor) for a range of ultra-low threshold, low background detectors that are used in searches for coherent neutrino-nucleus scattering and Light WIMP dark matter.

The goal of this project is to upgrade the target holder to incorporate monitoring detectors inside the vacuum so that the health and stability of the proton beam and Li target can be monitored during a run. To do this, the energy of backscattered protons will be measured with a Si PIN diode detector. The new target holder will result in a significant upgrade to the existing quenching factor facility, and will be incorporated into experimental runs that will occur later in the summer.

**7. Construction of a 1 MeV Electron Accelerator for High Precision Beta-Decay Studies**
**Advisors: Albert Young and Calvin Howell**
**REU Student: Brendan Longfellow (University of North Carolina)**

The Young research group at TUNL is heavily involved in measurements of the properties of neutrons, especially those that pertain to a fundamental understanding of the weak interactions between nucleons.  To facilitate the calibration and testing of equipment used in these searches, a small 1 MeV electron accelerator is being designed and constructed at TUNL.  The REU student on this project will be heavily involved in multiphysics simulations of the beam transport using the commercial software suite COMSOL as well as hands-on work in fabricating and assembling the parts for the accelerator.

**8. Modeling Sugar Allocations in Plants using Radioisotope Tracer Data**
**Advisor: Calvin Howell**
**REU Student: Cora Karamitsos (William & Mary)**

The allocations of carbon and nitrogen are major factors in determining growth priorities in plants. The relative distribution of these resources within a plant depends on many factors, including the plant's development stage, e.g., early vegetative, mature vegetative or reproductive (seeding or flowering) and on external conditions (e.g., availability of water, nutrients, light and $CO_2$). There is considerable evidence that a change in the exogenous resource conditions in one organ (e.g., leaf) elicits a whole-plant response in the relative allocation of resources. The mechanisms that regulate resource allocation in plants are poorly understood. In this project radiotracer techniques are used to identify and quantify dynamical feedback responses of plants to changes in environmental conditions. We are developing a software package to analyze the radiotracer data from our measurements. Sugar movement and allocation within the plant is modeled as a combination of pressure- and concentration-driven fluid flow and diffusion. The histogram analysis is performed using the CERN ROOT package. This summer the main goals are to develop a user interface that will facilitate general use of the analysis package and to use the package to analyze our data on barley plants. The student working on this project will gain experience with: (1) plant physiology, (2) nuclear imaging technologies and particle counting techniques, (3) building mathematical models of biological systems, (4) fluid dynamics, and (5) the CERN ROOT data analysis software package.

**9. Development of a Neutron Detector with Kinetic Energy Measurement Capability**
**Advisor: Calvin Howell**
**REU Student: Robert Johnson (Florida A&M University)**

A neutron detector capable of spectroscopy without using time-of-flight methods is being developed. Such a detector would be useful for measuring the energy spectrum of fast neutrons from γ-irradiated materials. Of special interest are neutrons emitted by γ-ray stimulated fission. An important requirement for this detector is that it has particle identification with the capability of better than 1000:1 γ-ray rejection. A prototype detector module filled with BC-523A liquid scintillator and loaded with 4.41% $^{10}B$ is being investigate as a candidate. This isotope of Boron has a high thermal neutron reaction cross section (3,800 b), and thereby enables tagging of events in which the full neutron energy is deposited in the scintillator. This summer the detector will be characterized using measurements of the energy and pulse-shape spectra and the detection efficiency. The student working on this project will gain experience with (1) assembly and testing liquid organic scintillation detectors, (2) detection of fast neutrons using an organic scintillator, (3) data acquisition with a waveform digitizer, (4) waveform analysis of digitized detector signals, and (5) the CERN ROOT data analysis software package.

**10. Jet substructure and charmonium production at the LHC**
**Advisors: Thomas Mehen and Ayana Arce**
**REU Student: Max Krackow (Swarthmore College)**

This project will use Monte Carlo simulation of LHC collisions that produce J/psi particles within jets to investigate which properties of these jets can distinguish between J/psi production mechanisms. The result of the study will be a classification of different jet properties and substructure observables, based on both their usefulness in differentiating different J/psi production mechanisms, and on the feasibility of measuring them in ATLAS 2012 data.

**11. Silicon strip detector R&D for the LHC luminosity upgrade**
**Advisors: Mark Kruse and Ayana Arce**
**REU Students: Ashlyn Burch (Georgia College and State U.) and Gina Mayonado (McDaniel College)**

This project explores hardware infrastructure for the silicon strip detector readout system being designed for the Large Hadron Collider high-luminosity upgrade. It involves small electronics and software interface work (C++) to understand and improve the tests that can be carried out on the silicon strip electronics test-stands at Duke and CERN, as well as tests of the silicon sensors themselves at CERN. Some software simulation work would also be possible. (The specific project activities can be divided between two participants depending on their preferences and expertise. )

**12. Use of W and Z boson polarization in searches for anomalous gauge couplings**
**Advisor: Al Goshaw**
**REU Students: Aaron Webb (Duke University)**

Many searches have been made for anomalous couplings of W and Z bosons. These use an excess production at high transverse energy of the bosons above Standard Model predictions. We plan to improve the sensitivity of these searches by measuring the polarization of the W/Z since many new physics models introduce helicity amplitudes with structure different from those in the SM. Our project is to develop tools for making W/Z polarization measurements, and evaluating their sensitivity in identifying anomalous gauge couplings.