2016 TUNL REU Nuclear Physics Projects

1. Physics Studies for a Large Liquid Argon Detector
Advisor: Kate Scholberg
Student: Alison Roeth

A 34 kton underground liquid argon detector is being designed for the proposed Long-Baseline Neutrino Experiment. Physics capabilities include neutrino oscillations with a long baseline beam, solar and atmospheric neutrinos, and supernova neutrinos. This project will involve participation in simulation and physics sensitivity studies for this detector. The student will gain experience with a variety of simulation and data analysis software tools. Programming experience will be useful but is not required.

2. Developing a Software-Controlled Beam Stabilizing System for TUNL
Advisor: Richard Longland
Student: Caitlin Seed

The Enge Split-Pole spectrometer at TUNL requires a precisely determined particle beam energy to ensure accurate nuclear cross section measurements. High energy protons, deuterons, and helium ions are focused though a set of 90-degree magnets to achieve this precision. However, this isn't the whole story. Those ions must also strike the target within a millimeter-diameter region to reduce any aberration effects in the spectrometer. It's critical that the ion beam does not stray from that position over week-long periods.

As part of the Enge upgrade project at TUNL, out group is implementing an advanced control system that's frequently used in high-energy beam facilities (the Advanced Photon Source at Argonne National Laboratory and TRIUMF in Vancouver, Canada are two examples). The REU student involved in this upgrade project will be tasked with implementing and characterizing a feedback beam stabilization system using this control system and a Rasberry Pi/Arduino microcontroller package. This will involve a combination of software and hardware development. The student will also have the opportunity to operate the accelerator and be involved in our existing experimental efforts. By the end of the summer, their feedback control package will be deployed and characterized under experimental conditions.

3. Nuclear Data Evaluation
Advisor: John Kelley
Student: Thinh Truong

The nuclear data group at TUNL compiles, evaluates and disseminates nuclear structure data relevant to A=2-20 nuclides. Our activities primarily involve surveying literature articles and producing recommended values for inclusion into various US Nuclear Data Program databases. We have projects related to analyzing beta-decay lifetimes, compiling structure data from recently published articles, and producing full nuclear structure data evaluations of nuclides based on all existing literature. An involved student could select activities based on their interests.

4. Measurement of ^{169}Tm(n,2n)^{168}Tm reaction cross section between 10 and 17 MeV
Advisors: Megha Bhike and Krishichayan
Student: Jennifer Soter

Recently ^{169}Tm(n,2n)^{168}Tm and ^{169}Tm(n,3n)^{167}Tm cross-section measurements have been carried out to obtain information on the density of the plasma created in inertial confinement fusion at the National Ignition Facility. We plan to extend these measurements to lower energy with special emphasis on the 10-14 MeV energy region to resolve discrepancies between different evaluations.

The REU student will measure the ^{169}Tm(n,2n)^{168}Tm cross section in the neutron energy range from threshold to 17 MeV using the neutron activation technique. After neutron irradiation of thulium foils, the de-excitation gamma rays from the first excited state of ^{168}Tm will be recorded off-line with a High-Purity Germanium (HPGe) detector in TUNL's Low-Background Counting Facility. Gold monitor foils will be irradiated simultaneously with the thulium sample for neutron fluence determination.

5. 3D Printing of Radiation Detectors
Advisor: Phil Barbeau
Student: Adele Zawada

Can modern, low-cost 3D printers be used to build detectors systems in the field of particle physics? There is a wide range of plastic scintillator, and plastic wavelength shifting material available to particle physics these days, but forming them into specific shapes can oftentimes be cost-prohibitive. 3D printing a plastic scintillator, or a wavelength shifter into a given shape may change this paradigm. This project will study the capability of modern 3D printers to produce custom shape scintillating detectors. In particular, the feed-stock material will need to be created using a plastic extruder; and the capabilities of the 3D printers to operate at higher working temperatures needs to be tested. A number of capabilities and detector configurations will be tested by the end of this summer project.

6. Characterization of the Upgraded Shielded Neutron Source at TUNL
Advisors: Werner Tornow and Calvin Howell
Student: Chad Hobson

The"Shielded Neutron Source (SNS)" at TUNL was rebuilt in 2015 with the goal of improving the effectiveness of the shield and adding features that allow for more convenient access to the neutron production target for maintenance. In addition, the new source features a rail system that enables convenient swapping of collimators with higher alignment precision than the original shielding wall. The SNS utilizes the $^{2}H(d,n)^{3}He$ neutron source reaction, but could also be used for the $^{7}Li(p,n)^{7}Be$ reaction.

The REU student will participate in the evaluation of the new SNS. This project includes performing measurements and data analysis for experiments in which neutrons and gamma rays are detected. The measurements include:(1) neutron beam profiles at two distances for the neutron production target; and (2) neutron and γ-ray background intensities at various locations in the SNS area. Plastic, liquid, and gaseous detectors will be used for neutron detection. High-Purity Germanium (HPGe), LaBr, and organic liquid scintillation detectors will be employed for γ-ray detection. Various shielding scenarios for these detectors will be investigated.

7. Monte-Carlo Simulation of Experiment to Measure Parity Violation in Photodisintegration of Deuterium
Advisor: Calvin Howell
Student: Michael Wolff

The elementary weak interactions between quarks and leptons are well established in the Standard Model. However, the weak interaction between composite hadrons remains only partly understood. The main challenges of developing a theory of the hadronic weak interaction (HWI) include: (1) the weak interaction takes place in an environment of strong color interactions between quarks, thereby making the hadronic weak interaction different from the weak interaction between the pointlike constituents; (2) the interaction between hadrons most important for nuclei occur at low momentum transfer where the theory of quantum chromodynamics is nonperturbative; and (3) measurements of weak-interaction effects, e.g., parity violation, are very difficult when entangled with the dominant strong nuclear force. Investigations of strangeness-changing HWI, e.g., decays of neutral kaons, have resulted in a number of puzzles that are not explained in the Standard Model. A central question is whether the features of kaon decay are due to properties of strangeness or a consequence of the dynamical interplay between the strong and weak interactions. Studying strangeness-conserving HWIs might provide some insight into this question. Parity violation in low-energy nuclear systems is the primary mechanism for probing non-leptonic flavor and strangeness-conserving weak interactions, of which the nucleon-nucleon interaction is the source of the observed effects.

This project is part of an effort to design an experiment to measure with high precision the parity non-conserving (PNC) asymmetry in photodisintegration of deuterium. The experiment is to be carried out using a high intensity monoenergetic and circularly polarized gamma-ray beam at a "next generation" gamma-ray beam source. The student working on this project will develop a Monte-Carlo simulation of the experiment using GEANT4. The main goal of the simulation is to study sources of instrumental asymmetries, e.g., helicity dependent changes in the gamma-ray beam properties.

8. Compton Scattering Experiments at the High Intensity Gamma Ray Source (HIGS)
Advisor: Mohammad Ahmed
Student: Adam Anthony

The electromagnetic (EM) polarizabilities (alpha and beta) describe the stiffness of an object to applied electric and magnetic fields. Thus by measuring the polarizabilities, we learn about the EM structure of the object. This concept can be used to study the EM structure of the nucleons, such as protons and neutrons. However, in this case, large-magnitude fields are required since the charge and current distributions are very localized and a relatively large force is needed to displace them. Such fields can be generated by short-wavelength or high-frequency photons, or gamma-rays. One such process of probing nucleons with gamma rays is called Compton scattering. In nucleon Compton scattering, gamma-rays of high energy (>60 MeV) are scattered off a target and their angular distribution measured. This angular distribution is dependent on the strength of the polarizabilities. The gamma rays are produced at the High Intensity Gamma Ray Source (HIGS) at TUNL. The target is a liquid deuterium or hydrogen cell surrounded by a set of scintillation detectors to measure the angular distribution of the scattered gamma rays. This project will involve learning the fundamentals of the Compton scattering process, studying and comparing methods of analyzing data from the scintillation detectors, and participating in executing a Compton scattering experiment at HIGS.

High Energy Physics / CERN Projects

1. Evalution of Alternative Electron Cuts in Diphoton Resonance Searches
Advisors: Ashutosh Kotwal
Student: Spencer Griswold

Because of hints of a diphoton resonance in LHC data collected in 2015, there is now considerable interest in high purity searches for new heavy resonances decaying to a W or Z boson and a photon. This project will involve evaluating alternative electron selection methods for reconstructing Z bosons in such events.

2. Background Rejection Tests in Diphoton Resonance Searches
Advisor: Al Goshaw
Student: Emily Stump

Because of hints of a diphoton resonance in LHC data collected in 2015, there is now considerable interest in high-efficiency searches for new heavy resonances decaying to a W or Z boson and a photon. This project will investigate cuts to reject the gamma+jet background to the hadronic W/Z decay channel for the resonance search.

3. Hadronic Reconstruction Tests in Diphoton Resonance Searches
Advisors: Ayana Arce
Student: Hannah Glaser

Because of hints of a diphoton resonance in LHC data collected in 2015, there is now considerable interest in high-efficiency searches for new heavy resonances decaying to a W or Z boson and a photon. This project will investigate alternative hadronic boson reconstruction tools including jet recluse ring for intermediate resonance masses.

4. R&D for the ATLAS Silicon Strip Tracker Upgrade
Advisors: Mark Kruse
Student: Ifeanyi Achu

This project has two parts: The first is hardware based, to be carried out at Duke, and involves developing test infrastructure and procedures for the new cooling system for the ATLAS inner tracker upgrade strip tracker R&D platform. The second is programming based, and involves to develop visualization tools for boosted jets and other important event topologies, to improve analysis and dissemination of events selected in high profile analyses for 2016 LHC data.