Research Experience for Undergraduates (REU) @ TUNL Projects for 2012

Silicon-Based Tracking Detector Development
Advisors: Mark Kruse and Ayana Arce

Hardware-based project with the silicon stave test-stand setups at Duke and at CERN.

Using Color Flow Observables to Constrain Multiple-Parton Interaction Uncertainties
Advisor: Ayana Arce

Analysis project with ATLAS data (ttbar candidate events) and various simulated data samples.

Measurement of D meson Production in Central Pb-Pb Collisions
Advisors: Steffen Bass and Berndt Mueller

Heavy-flavor hadrons, containing charm and beauty, are effective probes of the conditions of the high-density color-deconfined medium (Quark Gluon Plasma) formed in nucleus–nucleus collisions at high energy. The ALICE experiment has studied charm production in proton-proton and Pb-Pb collisions via the exclusive reconstruction of D meson hadronic decay channels. During the stage experience, the student is expected to understand the details of the analysis, to get familiar with the ALICE computing environment, ROOT and AliRoot, and to practice in analyzing data on the GRID. Working in close contact with the experts, she/he will try to extend the transverse momentum (pt) range of the current measurements in central Pb-Pb collisions by exploiting the ALICE particle identification capability at low pt.

Jets in Proton-Proton and Heavy-Ion Collisions at the LHC
Advisors: Steffen Bass and Berndt Mueller

High energy partons serve as a probe of the hot, dense, strongly interacting plasma of quarks and gluons created in high energy heavy-ion collisions. The extent to which jets of particles associated with the parton shower are modified in the plasma as compared to the vacuum (p-p) case is expected to be the main tool to study the parton-medium interactions, but also, to be sensitive to dynamical properties of the quark-gluon plasma (QGP) itself.

The project aims at establishing the measurements of the jet structure in proton-proton and heavy-ion collisions within ALICE experiment. The measurements of jet shapes may provide necessary details on the parton energy loss in the QGP. Moreover, the sub-jet observables are a promising tool to discriminate against the underlying event backgrounds in high-flux environment of heavy-ion collisions. The student will get familiar with experimental analysis techniques and algorithmic approaches for complete jet reconstruction and study the observables mapping the jet structure in proton-proton and heavy-ion collisions within ALICE.

Calculation of Nuclear Matrix Elements for Double-Beta Decay
Advisor: Jon Engel

Calculating the nuclear matrix elements that govern double-beta decay is necessary for extracting information about neutrino masses from double-beta-decay experiments. This project will involve the application of of a group-theory based model of nuclear structure to double-beta decay. The model, though not completely realistic, includes enough of the physics that is important for double-beta decay to allow the testing of sophisticated many-body approximation schemes. The student will gain a knowledge of nuclear-structure physics, second quantization and quantum many-body theory, and the use of Lie algebras.

Development of K-43 Radioisotope Production for Plant Research
Advisors: Calvin Howell and Alex Crowell

The student assigned to this project will work with an experimental nuclear physics group in the Department of Physics at Duke University and the Triangle Universities Nuclear Laboratory (TUNL) to develop a technique for producing a radiosisotope of potassium (K-43) in an aqueous solution for plant research studies. The student will also be involved in demonstrating the use of K-43 in radiotracing in plants using single-photon emission computed tomography (SPECT). The development and testing of the K-43 production technique will be done in the tandem accelerator laboratory at TUNL.

Measurements of the K-43 radiotracer in plants using SPECT will be performed at the Duke University Phytotron, which is directly adjacent to TUNL. The topics covered in the project include: (1) radioactivity, (2) production of radioisotopes using charged-particle beams, (3) fluid dynamics, (4) general plant physiology, (5) substance transport in plants,(6) gamma-ray detection with inorganic scintillators, and (7) data analysis techniques.

Simulation Studies of the HALO Detector
Advisor: Kate Scholberg

The HALO (Helium and Lead Observatory) detector is under construction at SNOlab in Sudbury, Canada. This detector, composed of lead and He-3 neutron detectors, will have a unique sensitivity to the burst of neutrinos from a nearby supernova. This project will involve participation in simulation and physics sensitivity studies for HALO. The student will gain experience with a variety of simulation and data analysis software tools. Programming experience will be useful but is not required.

Physics Studies for a Large Liquid Argon Detector
Advisor: Kate Scholberg

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.

Two-Body Photodisintegration of 3He with Double Polarizations
Advisors: Pinghan Chu, Haiyan Gao, Georgio Laskaris and others

The experiment on two-body photo-disintegration of 3He with double polarizations was proposed to HIGS PAC 2011 and it was approved for 60 hrs of beam time for the optimization of the experimental setup and beam test. One of the important goals of this experiment is to test the state-of the-art three body calculations on 3He. This project will involve participation in all stages of the preparation of a flagship nuclear physics experiment: construction of a new apparatus for the positioning of the 3He target and the detectors, measurements of the 3He polarization using NMR and EPR techniques, testing of Silicon Surface Barrier detectors, simulation of the experiment using GEANT4. This project is ideal for a self-motivated student with a deep interest in many aspects of modern physics.

Neutron-Induced Reactions on 136Xe and natXe below 20 MeV
Advisor: Werner Tornow

The noble gas 136Xe is used in searches for the neutrino-less double-beta decay in the EXO and KamLAND-Zen experiments. Natural xenon is used in a number of experiments aimed at the detection of “dark matter” (WIMP particles). In both types of experiments neutron-induced reactions on xenon and the surrounding detector components can be the main source of background. Although these experiments are located underground in mines, neutrons produced either by muon induced reactions or alpha-particle induced reactions in the rock or detector hardware are always present. The REU student will 1) analyze data recently taken at TUNL for the reactions 136Xe(n,xg) and natXe(n,xg) at an incident neutron energy of 11 MeV and 2) will participate in a measurement at 8 MeV and 3) will analyze the 8 MeV data.

Measurements Using the New TUNL Detector Setup at KURF
Advisor: Werner Tornow

Presently a detector system to study two-neutrino double-beta decay to excited states in the daughter nucleus and zero-neutrino double-electron capture is being installed at the Kimballton Underground Research Facility (KURF) in Virginia. The REU student will participate in the completion and commissioning of this new apparatus and afterwards will have his own physics project to work on. Frequent travel between Duke and KURF is required.

Measurement of a Reaction Cross Section Relevant to Fusion Energy Production
Advisor: Mohammad Ahmed

An effort is underway to produce energy using the aneutronic reaction 11B(p,alpha)alpha alpha. The developers of this fusion reactor have requested TUNL researchers to provide detailed accurate cross sections for this reaction at energies between 0.15 and 6.0 MeV. These measurements have been performed and the results are now being used in simulations of the reactor.

One of the concerns of the developers of the reactor is the production of radioactive 7Be via the 10B(p,alpha)7Be reaction. 7Be has a 53.3 day half life and the resulting daughter nucleus decays by emitting 477 keV gamma rays.

The student involved in this project will help set up the scattering chamber,which will contain an array of eight silicon surface-barrier detectors, and the associated electronics. A one week run using the TUNL FN tandem accelerator will then take data on the 10B(p,alpha)7Be reaction in 100 keV steps from 0.2 up to 6.0 MeV. The lower energy beams will be produced using degrader foils, since the tandem cannot produce these beams directly. The student will also work on extracting alpha particle yields as a function of beam energy and scattering angle. The resulting cross section data as a function of angle will be fitted to an expansion in terms of LeGendre Polynomials in order to extract the angle integrated cross sections. These results will be used in reactor simulations to predict the amount of 7Be which can be expected.

Digitizing the APEX Detector
Advisor: Art Champagne

In the old days people used analog electronics to process signals from detectors - a voltage or current pulse was fed into an amplifier and maybe some other modules before going to an analog-to-digital converter. The only problem with this approach is that sometimes the shape of the voltage or current pulse can carry information about what sort of interaction occurred in the detector, for example, was it a gamma ray or a neutron? Once the signal is filtered and amplified, all of that information is lost. A more modern way to do pulse processing is to store a digital copy of the actual pulse, which can then be analyzed offline. We're slowly trying to move in this direction, but first we have to demonstrate that the technique works for our particular application - that's where you come in.

We have a 24-element gamma-ray detector that measures both the energy of the gamma as well as where the gamma hit. We do this right now with analog electronics, but there are 48 signals to process (each detector is read out from 2 ends) and it's very slow. Also, the way the detector is read out now, 2 gamma rays hitting any one of the elements simultaneously can't be distinguished from a single hit and we're doing a thesis project right now where what we're trying to measure are only single-gamma events. We have a desktop digitizer that we can use to see if storing pulses will help (my guess is that a multi-gamma hit produces a different current curve than a single hit). Here are the steps:
1) figure out how it works (we have some experience with it already)
2) set it up for this kind of detector (different detectors behave differently, this one is a sodium-iodide scintillator and we haven't worked out the settings yet)
3) collect some pulses and see what's there