Mariani has been responsible for the muon detection system in Double Chooz. Muon detector development and characterization is a good platform to introduce students to particle physics. Muons are of primary importance for various neutrino experiments from reactors to accelerators. They are a source of background and they are used for calibration and to measure detector performance. A project for an REU student would be to build and characterize a small portable muon detector. The detector can then be used to characterize the CHANDLER/SoLid detectors and equalize the gain of the various photomultiplier tubes. The student will learn how to work with analog and digital electronics, will work on data analysis with both real data and Monte Carlo simulation and it will produce a framework that will allow the photomultiplier tubes equalization. The student will be guided during the first weeks in the assembly of the muon detector and learning the DAQ and analysis software. Then one of the CNP post doctoral associates will introduce the REU to the Monte Carlo simulation and analysis software package guiding him through the software framework. A second project would be to involve the student in several aspects of the data analysis and simualtion of the argon electron scattering experiment at Virginia Tech [**?**]. The experiment (guided by Mariani as proponent, spokesperson and contact person) took data in 2017. Prof. Pitt and post doctoral associate V. Pandey will involve the REU students in the simulation of the electron scattering experiment, for example on the optics and Hall A magnets acceptance. The goal for the work of the REU will be to understand the experiment and help with calibration of the cerenkov and calorimeter of Hall A. We will select a student with previous experience in programming for this project during the recruitment and Pandey will closely follow the student during the first few weeks of this project.

Vogelaar's expertise in solar neutrino experiments is unique in the U.S. Some solar-neutrino detectors can reveal signs of the neutrino direction. At lower energies, where scintillators are required, the light emitted is isotropic. A summer undergraduate research project would examine whether the direction of even low-energy electrons traveling through a scintillator could be determined by adding an electric field to the region (50 kV/cm). Electrons traveling against the field should gain energy and emit more light than electrons traveling with the field. The first two weeks would have two components: 1) a background study about scintillators, radioactive sources, the interaction of gammas with material (especially Compton scattering), the range of betas, PMTs, DAQ systems, and high-voltages; and 2) the design of small scintillator chamber between two planer electrodes, along with a gamma source, detector mounting, and reversible HV connections. The third and fourth week would be construction of the device. The fifth and sixth week would involve taking data to determine whether a shift in the Compton edge of a gamma source could reveal the direction of the electric field. The seventh and eighth week would involve data analysis, quantifying any shift observed, and drafting a short paper to explore the potential applicability to highly segmented detectors.

Several new neutrino detector designs involve the transport of photons down channels via total internal reflection. The specularity of the channel surfaces is thus an important consideration, and techniques to rapidly quantify optical quality during construction need to be developed. The first two weeks of the summer would involve conceiving and designing techniques to quantify surface quality, under the guidance of the faculty mentor. There are actually many potential avenues, and the student would be encouraged to develop criteria to select one or two approaches. For example, one method would be to image (using a digital camera) a specialized target (either in transmission or reflection) and examine its Fourier spectrum. Another method would be to image a fixed printed text, and look at the error rate of OCR software. The third and fourth week would be to set up the experimental procedure and collect results. The fifth and sixth week would be quantify/correlate the results with actual (but tedious and slow) direct measurement of surface features. The seventh and eighth weeks would be to propose and then build a Quality Assurance station capable of rapidly examining surfaces as either passing or failing. It would also involve writing up the procedures and perhaps a brief paper describing the process and its application. Calibration of the Borexino solar neutrino detector requires the insertion of radioactive sources within the detector. For betas, these have always been sealed sources where the scintillator liquid around the source was not physically the same scintillator within the detector. The possibility to use thin-walled micro-pipettes where the betas can easily range through the glass and into the detector scintillator itself has been proposed, but never implemented. The project would begin in weeks one and two with an overview of how the Borexino detector works, and the types of calibration required, and undertaking the training and procedure development to obtain a P-32 source (a good candidate source). During this time, techniques for constructing thin-walled (or even open) sources would be developed and evaluated. Weeks three and four would be constructing the hardware to test the most promising design. Weeks five and six would use standard detectors and monitoring equipment to test properties of the source, and search for any possible external contamination. While the actual deployment of such sources within Borexino would be beyond the scope of a summer project, the development and testing of such a source is an essential element toward future calibration efforts.

Persistent, unproven hints of an eV-scale sterile neutrino have been around since the late 1990's, when the LSND $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ signal [**?**] was shown to be incompatible with the emerging 3-neutrino oscillation framework. Recent results [**?**, **?**] and reanalyses of older data [**?**, **?**] continue to suggest the possibility of this new physics, but no experiment has been able to definitively demonstrate or rule out their existence. Prof. **Link** in collaboration with Profs. Huber and Mariani is pursuing a new short-baseline reactor experiment as a definitive test of reactor antineutrino anomaly. In preparation for this project we are building an 80 channel prototype to be deployed at a commercial nuclear power plant. Many studies with the prototype hardware and data would be well suited for an REU student.

As an REU project, the student would use data from the 80-channel prototype to search for and study stopped muon decays in the detector. Electrons from stopped muons, known as Michel electrons, have a well measured energy spectrum and can be used as a standard candle to help calibrate the detector. Additionally the delayed coincidence between the parent muon and Michel electron is a good proxy for the delayed coincidence in a reactor antineutrino interaction between a positron and a delayed neutron capture. To complete such a project the student would first have to learn the ROOT data analysis package, which will be included in the first week training of the REU program. The student will work closely with their faculty mentor and other members of the group to learn the data structure. As a starting point the student will be given a working ROOT macro that produces a variety of standard plots such as the primary (muon track) and secondary (Michel electron) energy spectra, and the coincident time and spatial distributions. A detailed project description will guide the student though producing these plots with various data selections and challenge them to produce specific new distributions. The student will have frequent interactions with their mentor to ensure that they understand the significance of what they are doing, the broader physics context, and how their studies are leading them closer to the goals of the study. Eventually, the student will be challenged to figure out appropriate next steps in the study. In consultation with the mentor, the results of earlier studies will guide future work. The student may find that detailed simulations or new types of data runs are needed. The student would be given the necessary resources and help in setting up and running these studies within the 10 week program.

Recently, **Huber** and his group demonstrated the applicability of reactor antineutrino monitoring towards non-proliferation safeguards [**?**]. This topic is interdisciplinary and at the intersection of basic science, nuclear engineering and international policy and thus exemplifies the broader impact basic science can have. The key advance achieved by Huber's group was to include the information of the energy spectrum of antineutrinos based on the unique expertise available in his group [?]. In the original study backgrounds were largely neglected, and thus a natural extension is to derive a scalable background model from the literature and to determine the impact of backgrounds on the quantitative results presented in Ref. [?]. In the first week, this will require a review of the existing experimental results on backgrounds in reactor antineutrino detectors (also drawing on the expertise of Link in Daya Bay and Mariani in Double Chooz). In the second and third week the student will learn the basics of a simple χ^2-analysis in Mathematica. The actual calculation will allow the student to apply a χ^2-analysis to a complex scenario, a skill, once mastered, which will be most useful during her/his career. The software framework used is Mathematica, because thus the intricacies of memory allocation and other low level programming details can be avoided. Thus we expect to have a first result after about 5–6 weeks and then can explore what the natural next step would be.

One of the major hot topics in neutrino physics has been the reactor antineutrino anomaly (RAA) [?] and a subsequent revival of interest in eV-scale sterile neutrino searches using non-accelerator methods like radioactive sources and new reactor experiments. Huber independently confirmed [?] the initial reactor flux calculation [?] which gave rise to the RAA. So a natural project for a student is the phenomenology of eV-scale sterile neutrinos, specifically evaluating the sensitivities of the proposed short-baseline reactor experiment within a common framework like GLoBES [?]. This project would require a student with reasonably good programming skills.

GLoBES [?] naturally also can fit actual data, and this functionality has been tested extensively in the current development version available at Virginia Tech. Given that NOvA and T2K are expected to have comparable event statistics by the summer of 2017 an interesting exercise would be a joint fit with a focus on testing the mutual compatibility of the two data sets with each other and the Daya Bay result on θ_{13}. In combination these three data sets should have good sensitivity towards new physics in the form of non-standard interactions. For this project the initial emphasis would neutrino oscillation phenomenology and to use simple toy versions of the experiments existing within the GLoBES framework to explore potential sensitives. Fitting real data would then be the final step of this project.

The REU project proposed by **Horiuchi** will involve constructing the latest catalog of nearby supernova discoveries and interpreting the results. In the past few years, the *completeness* of nearby supernova discoveries has rapidly matured, thanks to surveys such as ASAS-SN which monitors a large portion of the sky for transients to a limiting magnitude of $m_{V,lim} \sim 16$ [?, ?]. This contrasts with earlier surveys that targeted a list of known galaxies, which invariably has led to supernova samples that are biased by the galaxy list(s) used, e.g., [?]. Already, initial results from ASAS-SN (May 2014 onwards) show that the survey has discovered more nearby supernovae than all other surveys combined. The REU student's task will be to construct the latest sample of nearby supernovae (using publicly available data) and validate the degree of completeness. Several strategies will be used, including calculating volumetric rates [?], comparison with cosmic measurements [?], and making comparisons to their host galaxy star-formation rates [?].

The project will initially be primarily data analysis, but interpretation will require the student to have a firm grasp of the relevant physics. Therefore, after the orientation week, the REU student will be mentored through two-weeks of hands-on training, where the relevant literature, techniques, and analysis codes will be introduced. The subsequent weeks will involve more independent work, applying the techniques and codes to new data. By the final weeks of the REU, it is expected that the REU student will have generated plots which can be used in a publication in a refereed journal, and generate power-point presentation slides which include the motivations of the study and implication of the results. Depending on the progress of the student, manuscript preparation will also be attempted.

The REU student in **O'Donnell**'s group would work on data analysis for CUORE. Each of the 988 detectors in the array essentially operates as an independent detector, with its own energy resolution, energy scale, background level and time stability of operation. The student will study uniformity of the detector response and experiment with thermal models to help improve this uniformity. Carrying out this project the student will be engaged in diverse concepts including neutrino physics, operation of cryogenic bolometers, radioactivity and radiation detection, low-background experimental techniques, signal processing, scientific computing, and data analysis. The student will also receive mentorship on writing technical documentation and presenting results. Although this project will be in the context of neutrino physics and specifically $0\nu\beta\beta$ decay, many of skills attained will be sufficiently general that he/she should be able to apply them to future research efforts in other areas of experimental physics. Although not working directly on KamLAND-Zen the student will be exposed to concepts relevant to liquid scintillator detectors during the weekly group-wide meetings.