Spring 2017 Scholar Abstracts

Masters Students:

Miriama Rajaoalisoa

The current conceptual design beam flux of the Deep Underground Neutrino Experiment is not suitable for the study of ν_τ appearance. Indeed, using the LBNF/DUNE Conceptual Design Report optimized beam flux which uses a 80 GeV proton beam, in 1 year for 40 kTons,the number of ν_τ CC events with those beams is only 80 per year. This demonstrates that the current optimized beam design of 80 GeV is inadequate for ν_τ appearance searches. Whereas if we use a neutrino flux using a 120 GeV proton beam and 2 NuMI-style horn system optimized for ν_τ appearance, the number of ν_τ CC events, in a year for 40 kTons, will be 772 events, which represents almost a ten time increase in the number of events. Further improvements can be reached and the objective of this work is to optimize the DUNE experiment for the ν_τ appearance by optimizing the neutrino beam. This is achieved by using a Fast Monte Carlo (MC) simulation of the ν_τ signal and background interactions in the detector. After developing a ν_τ selection algorithm, the results from the Fast MC simulation will be used to optimize the beam for ν_τ appearance.

Herilala Soamasina Razafinime

For the Deep Underground Neutrino Experiment, current studies of neutrino oscillations are based on the use of the Fast Monte Carlo (Fast MC) simulation, which relies on the parametrization of the detector response. However, the assumptions on detector response used in the Fast MC are preliminary, and are expected to improve as the full detector simulation advances and more information on the performance of the actual detectors, used on the experiment, becomes available. The goal of this work is to do a detailed simulation and reconstruction of ν_τ appearances in the DUNE far detector using the full Geant4 Monte Carlo simulation. In the full simulation, no parametrizations are made, the actual energy deposited by the particle in the detector are considered. The first step of the study is to model the τ decays, in the detector and to develop a simulation algorithm to identify possible τ candidates. Then we will try to identify if we can find a signature of τ above the background which comes from other neutrino interactions. The neutrino fluxes from the ν_τ optimized beam will be used to model signals and backgrounds. Concerning the reconstruction process, initially, the selection criteria for ν_e appearance will be reversed to highlight the ν_τ appearance. Further improvements in selection algorithms will be exploited to enhance the ν_τ selection efficiency. Finally, using the improved algorithms, the sensitivity of DUNE to ν_τ appearance will be assessed.

Rowan Zaki

I will be supporting the DUNE/LBNF project in their search to find the level of charge-parity violation in the neutrino sector. As the sensitivity to this violation is highly related to the neutrino flux in the 2.0 – 3.0 GeV energy range, the beamline is being optimized to produce a higher flux in that region. With the use of magnetic horns the secondary particles, resulting from the proton on target collisions, will be focused in such a way to increase the desired flux.

By simulating the effect that parameters like target position and proton momentum have on the resulting flux at the far detector, we can choose the ones that fit our goals accordingly. In addition to this single parameter optimization, a genetic multidimensional algorithm has been constructed to tell us more about the coherence of these changes to single parameters.

I will also be assisting the design of a hadron and muon spectrometer, which is capable of measuring their flux right before the particles enter the decay pipe. If this spectrometer should be a small aperture single-arm or a fixed large aperture detector is what will be decided upon first. This decision requires understanding the amount of beamtime required to measure the hadron flux. The spectrometer requires a low intensity beam with no more than one proton per RF bucket. The fraction of RF buckets in the Fermilab test beam that contain one and only one proton is unknown. Using an array of scintillator counters, this duty factor will be quantified.

PhD Students:

Dominic James Barker

The research that is in accordance with the scholarship programme has two main goals. The first is the development of shower reconstruction software for the Short-Baseline Near Detector (SBND), with the help of Fermilab expertise. The algorithm will be created within the LArsoft framework. This software is required for a sterile neutrino analysis, a key scientific goal of the Short-Baseline Neutrino programme. The algorithm will provide a basis of which to work off after the end of the scholarship programme and will provide a strong foundation for a sophisticated shower reconstruction algorithm. The sophisticated algorithm will then be used to distinguished between background photons and electrons produced from low energy neutral current interactions. Such an analysis is required to obtain the neutrino oscillation flux. The second goal is to aid in the construction of the SBND Time Projection Chamber by testing prototype electronics and designing a quality control procedure. This will ensure SBND reaches its specified design goals and hence provide accurate physics data. The electronics testing and quality control procedure will be focused specifically on the Anode Plane Assembly which is key to the UK's involvement in SBND.

Tejin Cai

Neutrons are common hadronic final states in neutrino experiments, but they are not well reconstructed and measured because neutrons only interact via the nucleon mean field. I have developed a crude infrastructure to reconstruct neutron signatures in the MINERvA detector in order to measure their directions of flight which could lead to interesting physics measurements. The algorithm looks for collection of clusters isolated inside the detector and mark them as neutron candidates. The procedure works for low activity and multiplicity events where neutrons are expected, and events where the neutron did not undergo signficant rescattering. I plan to characterize the neutron signatures to look for selection variables that can distinguish between neutron and non-neutrons. Since a neutron could rescatter multiple times in the detector, a single neutron could leave behind multiple neutron signatures. I will also work on an algorithm that analyze all neutron signatures and determine if they belong to the same neutron or to different neutrons.

Daniel Scott Devitt

MicroBooNE is a 170 ton liquid argon time projection chamber (LArTPC) and the first of three detectors built for the short-baseline programme at Fermilab. MicroBooNE's flagship analysis will be the investigation of the low energy excess observed by the MiniBooNE experiment. Additionally, it will make new measurements of neutrino interactions on argon, important for both the short-baseline and long-baseline LArTPC neutrino programmes at Fermilab.

The MicroBooNE experiment began operating in August 2015, and the collaboration's first results were presented at the Neutrino 2016 conference. These results included the first ν_μ charged-current (CC) inclusive event selection. Since then, much work has been done to better understand and simulate the detector, improve reconstruction, increase the selection efficiency, assess systematic uncertainties, and ultimately derive a ν_μ CC inclusive cross section.

With the ν_μ CC inclusive analysis on track, MicroBooNE is now turning its attention to exclusive cross section measurements. As an NPC fellow, I will develop a new cross section analysis focusing on the charged-current, single charged pion ($CC\pi+$) channel. MicroBooNE will make the first high-statistics measurement of the $CC\pi+$ cross section on argon in the ~1 GeV energy range. Previous measurements of this channel by MiniBooNE and MINERvA using lighter nuclei are currently in tension, making a MicroBooNE measurement particularly relevant. Moreover, measurements of $CC\pi+$ cross sections on argon are important for both short-baseline and long-baseline neutrino oscillation physics.

Jessica N Esquivel

MicroBooNE, being a Liquid Argon Time Projection Chamber(LArTPC) allows for very detailed images from an event due to the fine granularity and pitch in the detector. A standard candle measurement MicroBooNE will do is a Charged Current (CC) Inclusive Cross-Section measurement. A CC-inclusive cross-section measurement is the energy dependent probability of an event that consists of a neutrino charge exchanging a W with an argon atom producing a charged lepton and any number of final state particles. A prominent background to this measurement are Neutral Current (NC) events that contain a pion. It is possible to have a neutral current interaction with a $\pi + p$ event signature that looks like a charged current $\mu + p$ event. The purpose of this Neutrino Physics Center (NPC) Scholar Program proposal is to continue the work being done using Convolutional Neural Networks (CNN) to separate μ's and π's for use in increasing the acceptance rate of μ's below the implemented 75cm track length cut in the Charged Current Inclusive (CC-Inclusive) event selection for the CC-Inclusive Cross-Section Measurement.

Lucas Mendes Santos

The Photon Detection System (PDS) for DUNE is responsible for providing a precise triggering timestamp (T0), when no other timestamp is provided, like in proton decay, atmospheric and supernova neutrino induced events which depend strongly on the trigger time provided, thus requiring a high detection efficiency.

On the other hand, the scintillation light produced in the interactions of the charged particle with the liquid argon carries with it ~ 60% of the energy deposited at the nominal drift field, with the rest going into the electrons which drift to the TPC. So, the use of the PDS beyond the trigger timestamp purpose is very appealing.

It can be used as a complementary calorimetric measurement, potentially improving the energy resolution, improving our sensitivity to neutrino oscillations and for nucleon decay. Right now, there is no reconstruction algorithm for photon calorimetry in DUNE. The idea of this project is to develop it. First comes a use case study: study of methods in the field for calorimetry using the scintillation light and evaluation of feasibility for DUNE's different channels of detection.

The next step will be writing reconstruction code, based on the studies and testing with the use of simulation.

Diana Patricia Mendez Mendez

NOvA has observed a similar beam intensity effect as MINOS+, where results have shown a decreased number of selected events in the Near Detector as a function of increased POT. A distorted energy spectrum can be a false indication of oscillation hence the monitoring and study of these effects is a priority for NOvA and specially relevant for our Muon Neutrino Disappearance Analysis: by the beginning of 2017, NOvA reached a exposure of 9e20 POT with a high intensity NuMI beam. With these increased data, we will better constrain the allowed regions for the oscillation parameters Δm^2_{32} and $\sin^2\theta_{23}$. Furthermore, the Dissapearance Analysis Group has been pushing to increase our sensitivity, using an optimized energy binning and hadronic energy fractions and is looking forward to testing the improvements with real data. Therefore, I will simultaneously work on two very correlated projects starting this Summer.

The first is to study the NuMI beam intensity effects on the NOvA Near and Far Detectors using data from November 2016 to before the 2017 summer shutdown. The second project is to provide the first preliminary results for the ν_μ disappearance third year analysis performed by NOvA with an exposure to 9e20 POT and to set the basis for our first analysis with antineutrinos.

Nitish Nayak

NOvA is a long-baseline neutrino experiment which aims to pin down the structure of the PMNS matrix and resolve the neutrino mass hierarchy. For this purpose, it uses an upgraded NuMI beam to measure electron-neutrino appearance and muon-neutrino disappearance at the 14-kT Far Detector which is located in Ash River, Minnesota. It also includes a 0.3-kT Near Detector near Fermilab which characterizes the unoscillated neutrino beam and predicts the signal at the Far

Detector. The data collected at the Near Detector will also be used to make precise measurements of various neutrino interaction cross-sections. My research will aim to contribute predominantly in the electron-neutrino appearance and electron-neutrino cross-section analyses, specifically in relation to flux and Near Detector physics. In particular, one of my goals is to study the systematic effects of the new flux model that has recently been incorporated into the analysis. In addition, I will continue to be involved with the electron-neutrino inclusive cross section analysis where I will look for ways to estimate the antineutrino contamination in the electron-neutrino spectrum with a view to incorporate the methodology developed here for future measurements.

Another aspect of my research at Fermilab will be to develop the DAQ and a relay-based slow control for the purity monitoring system that is designed to measure the electron drift times in a LAr detector. This would act as a safety check against any unnoticed contamination in the liquid Argon for ProtoDUNE where the purity monitors will be installed.

Irene Nutini

The Liquid Argon In A Testbeam (LArIAT) experiment aims to characterize LArTPC performance in the energy range relevant to the experiments which are part of the Fermilab Short-Baseline (MicroBooNE, SBND, ICARUS) and Long-Baseline (DUNE) neutrino program. The primary higher-level physics analyses on the collected data are the measurement of charged hadron-Ar interaction cross sections and the study of exclusive channels in the (0.2 - 2.0) GeV energy range in order to reduce the uncertainty on the hadron interaction models adopted in Geant4 MC simulations for Ar target when dealing with neutrino interaction products. One of the main goals of the LArIAT experiment is to develop pion identification algorithms based on their interaction modes in argon and to exploit direct and precise measurement of the pion-nucleus cross section. Refinements to the analysis are ongoing to improve the spatial and energy resolution of reconstructed tracks, to utilize tracks' calorimetry information to do particle identification, to completely identify the topologies of background events and to evaluate all the contributions to the systematic uncertainties on the measured cross-section.

Pedro Simoni Pasquini

Neutrino oscillations are a very important tool to analyze and probe SM physics and to search for physics beyond the standard model. In special, DUNE experiments provides a suitable environment to measure the important CP phase of the leptonic sector. Nevertheless, new physics may spoil this measurement and should be analyzed carefully. Thus, this project aims to a systematic study of new effects on neutrino oscillations, such as Non-standard Interactions, Neutrino mixing Matrix Non-unitarity and Sterile neutrinos, in order to contribute to the current scenario of neutrino physics.

Jason Stock

My research at the Neutrino Physics Center is performed in the framework of the Deep Underground Neutrino Experiment (DUNE): A future long-baseline neutrino experiment planning to shoot a neutrino beam from Fermilab to the Sanford Underground Research Facility (SURF) in South Dakota. I focus on LArSoft simulation development, primarily targeted at the needs of the radiological simulation for DUNE as well as purity modeling. In addition, I conduct data analysis of the 35 ton prototype, aiming at in situ low-energy calibration with Michel electrons, constituting an overlap with low-energy backgrounds from radiologicals and probing timing capabilities to discriminate tracks from low-energy backgrounds. These topics are also of great interest for supernova neutrino detection and other low-energy physics possible with DUNE.

John Patrick Stowell

In the energy ranges relevant to future long baseline oscillation analyses the neutrino cross-section still has a large systematic uncertainty, as no theoretical model has been found that can reliably fit all neutrino cross-section data in this regime. The MINERvA collaboration has made a large contribution to this global dataset covering several different possible interaction channels and targets. Performing a Charged-Current (CC) Inclusive fit to the MINERvA data will be the first step in using the NUISANCE framework to build a generator model that can predict the neutrino cross-section with a good precision in the 0.5-10 GeV range. We aim to produce a set of model tunings for the NEUT, and GENIE event generators, identifying where additional freedom may be needed in each generator to accurately describe the data. If successful, these tunings will provide a standard set of model parameters and uncertainties that can be used as cross-section inputs in future long baseline oscillation analyses. Performing this tuning within the NUISANCE framework will also allow the MINERvA collaboration to easily update approved tuning results as new data from their ongoing analyses becomes available.

Gray L Yarbrough

The neutrino beam flux uncertainties currently form the dominant systematics for both cross section and oscillation measurements. My project is a two-part approach to improving the Booster Neutrino Beam (BNB) flux prediction and related systematics for the MicroBooNE experiment: 1. Analyze BNB target scan data to accurately measure the delivery of protons on target (POT) along with optimizing the beam optics to minimize POT losses, and 2. Incorporate the long target and proton production data from the HARP experiment into the MicroBooNE BNB flux prediction and validate it. The first task will begin with analysis of current target scan data with a focus on examining observed asymmetry, potentially caused by the beam being at an angle and scraping part of the target or apparatus. While at Fermilab, I plan to take more BNB target scan runs with varying angles and position of the beam to observe such effects. The second task will incorporate thick (40 cm) Be target data and proton production data from HARP into the BNB simulation currently used in MicroBooNE and validate it. The plan is to then extrapolate this to the full 71cm target and study the implications for the neutrino flux prediction and systematics.

Postdoctoral Researchers:

Christian Farnese

I am a post-doc experimental physicist presently working at Padova University. I have been working within the ICARUS collaboration on the event selection, reconstruction and analysis, both for the CNGS beam and for the atmospheric neutrino interactions. In view of the SBN project I am deeply involved on the development of analysis tools and on the integration of the ICARUS reconstruction tools within the LArSoft framework. During this NPC fellow, my activity will be devoted to the preparation of a detailed simulation of the neutrino interactions expected in the ICARUS T600 detector during the data taking at the Booster Neutrino Beam, using a detailed simulated geometry of the detector and the expected neutrino flux for the T600 detector (located at 600 m from the neutrino source). I will also study and test on the simulated events the available tools for the identification and reconstruction of the neutrino events. I will also start to prepare a simulation of the neutrino interactions with the primary vertex in the materials surrounding the active liquid Argon volume, to study the possible contributions of these events to the electron neutrino analysis. I will finally contribute to the commissioning activities starting with the arrival of the T600 detector at FNAL.

Shao-Feng Ge

Shao-Feng is a postdoc at Max-Planck-Institut fuer Kernphysics (MPIK) at Heidelberg in Germany and has been working on model building and phenomenological studies of neutrino physics, especially the leptonic CP phase. He plans to come to Fermilab for exploring future experiment configuration and their phenomenological consequences. The leptonic CP phase has profound importance among the remaining unknown parameters of neutrino oscillation, especially the possibility of explaining the existence of matter and our whole world. Currently a maximal CP violation is preferred by global fits. It is highly promising for neutrino mixing to play an extremely important role in the evolution of the Universe and a huge treasure might lay in front of us. The proposed project would focus on precision CP measurement, its constraint on model building, and turning neutrino oscillation experiment to neutrino collider for direct probe of new physics. This would pave a future path to go beyond the DUNE experiment at Fermilab and push neutrino study into a precision era of neutrino study.

Philip A Hamilton

During my NPC scholarship, I will work on three experiments: SBND, LArIAT, and MicroBooNE. I will carry out the first full test wind of a prototype anode plane assembly for the SBND experiment, testing the ability of our wire-winding system to deliver precise wire placement, tension, and electrical performance, as well as performing the first cold tests of the completed assembly. These tests are essential to ensure the proper functioning of the SBND readout planes before the full-sized frames are immersed.

I will also assist in the production of the new LArIAT wire planes for LArIAT run 3. These new wire planes will give LArIAT data with 3 mm, 4 mm and 5 mm wire spacing, which will allow us to test the effects of differing wire spacing on real TPC data.

In addition to this wire plane work, I will serve as deputy run coordinator for MicroBooNE, carrying out several essential upgrades and investigations during the summer shutdown. These include the replacement of the PMT high voltage supply, a possible increase in the drift voltage, and investigations into the argon filter bypass, residual “zig-zag” noise, and the effect of workers on the platform on data-taking.

David Alejandro Martinez Caicedo

MicroBooNE is a short baseline 170 ton (89 ton active mass) Liquid Argon Time Projection Chamber (LArTPC) that has been taking data since late 2015 on Fermilab’s Booster Neutrino Beam-line (BNB). The major physics goals of the MicroBooNE experiment are to address the low energy excess measured by MiniBooNE experiment and make high statistics cross section measurements of neutrino interactions on liquid argon. As demonstrated throughout the course of MicroBooNE’s operation Run coordination is a key responsibility to the continued health, successful operation and data taking to be able to accomplish the main physics goals of the experiment. I have been the deputy Run coordinator for MicroBooNE in the period between

January to March of 2017 acquiring the experience necessary to led the operations team in the coming months. As a NPC fellow I will led the operations team of MicroBooNE detector acting as the Run Coordinator in the period of May and June of 2017, during July of 2017 I will work to oversee and guide the workload of the subsequent run coordinator. Furthermore I will participate actively into the cross section team group's goals and responsibilities in the period between June and July 2017.

Laura Paulucci Marinho

My fellowship at Fermilab will be devoted to implementing the ARAPUCA Light Trap detector into the LArSoft software framework based on the results already obtained with a standalone Geant4 simulation. This device is a box made of highly reflective internal surface material and with an acceptance window for photons composed of two shifters and a dichroic filter and is expected to achieve a photon detection efficiency larger than 1%. The project will also be devoted to the simulation of the electronic response of the SBND light detectors by emulating and implementing the noise response, the single photoelectron shape, and the non-linearity effects into a LArSoft module that will be used by the SBND simulation. This will be done for the SiPM-based ARAPUCA modules as well as for the primary PMT-based system. This will allow the evaluation and refinement of the prediction capabilities of the SBND light collection system in terms of parameters such as arrival time distribution, time resolution, calorimetric resolution, position resolution, and the effects of saturation.

Erica S Smith

NOvA is a neutrino oscillation experiment probing the most important physics in the Intensity Frontier. NOvA aims to determine the neutrino CP-violating phase and mass ordering, as well as improve limits on current neutrino oscillation parameters, by measuring oscillations of muon neutrinos and muon anti-neutrinos produced in the NuMI beam at Fermilab. Recent results from NOvA already show indications of interesting physics, including the first suggestion of non-maximal mixing for the $\theta 23$ mixing angle, as well as disfavoring certain values of CP-violation for the inverted mass ordering. The future of NOvA is promising especially due to the limiting uncertainty on these results being from low statistics. The most straightforward way to increase statistics is to maximize detector uptime while the NuMI beam is running; this is the primary responsibility of the NOvA run coordinator. This requires proper coordination and management of groups performing detector upgrades, as well as constant monitoring of the detector systems such that emergencies that cause interruptions in data-taking are handled quickly and efficiently. To perform these duties well, it is critical that the run coordinator is at Fermilab while they are on duty. I am honored to have been selected for an NPC Award to support my term as NOvA run coordinator.

Marta Torti

The project I proposed for the NPC Scholar Fellowship is focused on the integration of the ICARUS detector geometry within the LArSoft framework. In fact, the starting point for any analysis and simulation is the description of the detector geometry, which is still not fully developed for ICARUS T600 in this framework. Two identical T300 modules, contained into two separated cryostats, compose the T600. Each module is divided in two TPC chambers, which share a common cathode. Three wire planes collect the ionizing particle charge, while the scintillation light is detected by means of cryogenic Photo-Multiplier Tubes (PMTs). These are the main parts of the ICARUS detector and, in addition, it is mandatory to include in the description also the experimental hall and the Cosmic Ray Tagger system. During the period spent at Fermilab within the NPC Scholar Fellowship, I am planning to complete all the parts described above and to start testing the full ICARUS T600 geometry within the LArSoft simulation tools.

Professors:

Emmanuel Paschos

I will be studying neutrino and antineutrino reactions within the standard model and its extensions. The investigations will include several reactions: resonance production, coherent production of pions, neutrino-electron elastic scattering, etc. Special attention will be devoted to models with Left-Right Symmetry and the presence of a Majorana mass term which induces reactions with leptons of the opposite charge in the final states.