Work at Fermilab

Melanie Novak
Bucknell University, Lewisburg, PA 17837

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Fermi National Accelerator Laboratory

I have just finished a summer of working with Professor Janet Conrad of Columbia University at Fermi National Accelerator Laboratory (Fermilab). During my time at the lab, I was able to further my experience and knowledge in the field of high energy physics research, develop new skills, and contribute to a very interesting neutrino experiment, MiniBooNE.

Neutrino physics is an important topic in high energy physics. Neutrinos are the only particles that interact primarily through the weak force, and so neutrino interactions provide a clean method with which to experimentally investigate the weak force. Neutrinos are included in the Standard Model as massless, chargeless particles with three flavors. There are many questions about their exact nature and whether the Standard Model describes them correctly. The most current and important issue in neutrino physics is whether neutrinos have mass and therefore, able to oscillate between flavors. The MiniBooNE experiment, which I worked on this summer will help to answer these questions.

The MiniBooNE Experiment

MiniBooNE is a neutrino oscillation experiment that will begin taking data in 2002. MiniBooNE will search for neutrino oscillations of ν_μ to ν_e, and will confirm or refute the results of the Liquid Scintillator Neutrino Detector (LSND) experiment at Los Alamos National Laboratory. LSND was the first experiment to report an appearance of electron neutrinos from a muon neutrino source, suggesting neutrino oscillations.

MiniBooNE will receive 8 GeV protons from the Fermilab Booster ring. These protons will strike a beryllium target, producing primarily pions, which will decay in flight producing muons and muon neutrinos. The muons will be stopped in a steel beam dump and about 500 m of earth before reaching the MiniBooNE detector, leaving a high energy muon neutrino beam. The MiniBooNE detector is a 12 m diameter, oil filled, spherical tank made of carbon steel. The detector will contain 1,280 signal photomultiplier tubes facing into the tank and 330 veto photomultiplier tubes facing outwards. Approximately

5×10^{20} protons will strike the MiniBooNE target each year. MiniBooNE expects to make a definitive statement about neutrino oscillations after one year of running. I worked on two projects related to the MiniBooNE experiment.

Eliminating Backgrounds to an Oscillation Signal

The primary background to an oscillation signal of ν_μ to ν_e is the intrinsic ν_e content of the beam. The ν_e contamination in the beam is due to kaon and muon decays. I performed a study on reducing the background due to kaon decays using a timing cut. I developed Fortran code to make a computer generated simulation more realistic. I used the Physics Analysis Workstation (PAW) to analyze the effectiveness of a timing cut in separating the ν_e from Kaon decay from the possible ν_e from neutrino oscillations. I also got some first-hand knowledge of the Fermilab Booster. I studied the structure of the proton beam as it will be for the MiniBooNE experiment, and learned about the available tools for looking at and altering the beam. I included what I learned about the beam structure in my study. My analysis is presented in a memo attached to this report (Time of Arrival Distribution Differences in Neutrinos from Kaon vs. Pion Decay and Timing Cut Development: Draft 1). Due to time constraints, I submitted the memo to the collaboration as a draft. I have also presented the analysis at two collaboration meetings.

Sensitivities to the KARMEN Timing Anomaly

The KARMEN collaboration at the ISIS spallation neutron facility at the Rutherford Appleton Laboratory uses a pulsed neutrino beam from stopped pion and muon decays to study neutrino-nucleon interactions. They have reported an anomaly in the timing distribution of neutrino interactions from stopped muon decays. One possible explanation for the anomaly is an exotic pion decay where a neutral and weakly interacting or sterile particle (Q^0) with a velocity of 4.9 $m/\mu s$ is produced. This particle, with a mass of 33.9 MeV/c^2 measured from the time of flight, then decays in the KARMEN detector to $e^+e^-\nu$. Should this be the explanation to the KARMEN timing anomaly, MiniBooNE could detect the Q^0 particle.

This summer I finished and submitted to the *Physical Review* D for publishing, a paper on MiniBooNE's sensitivities begun by Sarah Case, a previous student. The paper (Sensitivity to the KARMEN Timing Anomaly at MiniBoNE), is attached at the end of this report, and is also available in preprint format in the Los Alamos Archives (http://arXiv.org/abs/hep-ph/0108023). For this paper, I also used Fortran code and PAW. I worked in the LaTeXtypesetting program, a technical document typesetting program. I learned about what it takes to get a paper ready for submission, and about the process of submitting a paper for publishing.

Special Opportunities

In addition to these projects, I also had special opportunities to learn about high energy physics. I attended a course held for the graduate and summer students working on MiniBooNE. This course taught about high energy physics in general, and also about neutrino physics and the details of the MiniBooNE experiment. I also attended many of the talks open to the entire laboratory. Weekly collaboration meetings were an excellent place to learn about the process of getting an experiment up and running. I would like to thank the REU program for giving me the opportunity to work at Fermilab this summer, and to learn and experience so much.