My REU Experience

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1 Introduction to MiniBooNE

MiniBooNE is a neutrino experiment designed to conclusively confirm or refute the results of the LSND (Liquid Scintillator Neutrino Detector) experiment, which saw a controversial oscillation signal five years ago. The Standard Model as it currently stands has neutrinos as massless particles which only interact weakly. Nonetheless, the fact that they are massless has not been conclusively shown experimentally, and a number of experiments have in fact suggested that neutrinos may have small but nonzero mass. Neutrino oscillations, if they in fact occur, would be evidence that neutrinos have some mass. If neutrinos are massive, their mass and weak eigenstates may be different, in which case as they propagate through space they may change from one flavor to another. Many experimental results from solar and atmospheric neutrinos suggest that this may indeed be the case, but LSND's particular result is so far uncorroborated.

MiniBooNE first takes protons of energy 8 GeV from the Booster accelerator at Fermilab. These protons are collided with a beryllium target to produce mostly pions and kaons. These pass through a magnetic focusing horn, which points them at the detector, and they then enter a 50 meter decay region, where they decay to muons and muon neutrinos. After that the neutrinos pass through 450 meters of dirt, which blocks all other particles and results in a neutrino beam at the detector. The detector is a sphere of radius 6 meters filled with mineral oil. The neutrinos interact in the mineral oil to produce charged leptons, and by detecting the charged leptons one can deduce the flavor of neutrino that interacted. The goal is to look for a significant number of electron neutrinos above background in what is predominantly a muon neutrino beam originally.

The detector sees charged particles as a result of their Cherenkov radiation. If a particle travels through the mineral oil at a velocity faster than that of light in the oil, it produces a shock wave of photons similar to a sonic boom. These photons hit the edge of the detector in a ring pattern, which is detected by photomultiplier tubes. The particle's type and momentum can be determined to some accuracy by the properties of the ring.

MiniBooNE plans to start running later this year and to provide a conclusive confirmation or rejection of the LSND signal within one or two years.

Apart from looking for neutrino oscillations, MiniBooNE can also investigate other interesting branches of neutrino physics. For example massive neutrinos may also have a non-vanishing magnetic moment, and MiniBooNE should be able to measure this moment more precisely than previous experiments. Also, an exploding supernova emits a stream of neutrinos at a certain energy before it emits light, so MiniBooNE could serve as a supernova early warning signal for astronomers. In addition, MiniBooNE will investigate cross-sections of neutrino interactions at low energies ($\sim$1 GeV), first because some of these are a source of background to our signal and also because interactions in this energy range have not been measured very precisely in the past.

2 Kaon production cross-sections at MiniBooNE

My work at MiniBooNE has focused specifically on rates for production of kaons in the detector as a result of neutrino-nucleon interactions. A description of my work so far can be found in my memo on "Kaon Production in the MiniBooNE Detector." First I researched the accuracy with which these measurements had been made in the past in order to determine whether or not MiniBooNE could improve on previous results. I researched past experimental work using SLAC's search database SPIRES and received a lot of help from physicists at Fermilab, both from MiniBooNE and others they introduced me to. As it turned out this particular type of process had not been investigated in much detail in the past and as a result it looks like MiniBooNE will indeed be able to make a contribution.

In order to make a preliminary estimate of event rates at MiniBooNE I had to first estimate the cross-sections for the various kaon production channels. I first looked for theoretical calculations of the event rates but found that there has in fact not been much theory work in this area. So I fitted a curve to data points from previous experiments to estimate the cross-section for the dominant channel and then used estimates about relative rates for the cross-sections of the other channels. I learned how to use PAW (Physics Analysis Workstation) and LaTeX to prepare and present my work. In the end I found that MiniBooNE can expect a raw event rate in the thousands after a year or two of running, compared to only dozens of events in previous experiments.

I gave a brief talk on my results towards the end of the summer, which I used LaTeX to prepare. Now I'm working on running kaon events through the MiniBooNE Detector Monte Carlo to understand the detection process and figure out efficiency. I've been learning a lot about how programming on a larger scale works, and how to successfully modify an existing complex program to run in a new way according to my needs. A lot of my work so far has been facilitated because of the analogs between pion production and kaon production, but differences, such as the fact that pion production is predominantly resonant and kaon production is predominantly nonresonant, will be more difficult to account for.

3 Other Opportunities

Apart from my work on kaon production, I have had a number of interesting other opportunities to learn more about high-energy physics at Fermilab. I worked with a graduate student to prepare a poster about MiniBooNE for the User's Meeting Poster Session. I also took a three week accelerated introductory C++ course offered on site. I attended a number of fascinating talks both within our experiment and outside it on various topics in contemporary particle physics. I met many interesting people working in both experimental and theoretical physics at various stages in their careers ranging from undergraduate student to established professor and I developed a feel for what the field is like, and I've gone a long way toward deciding that a career in physics is a good choice for me. In September I'll be going to the 2002 International Workshop on Neutrinos and Subterranean Science, and then in October to a conference for undergraduates organized by the Division of Nuclear Physics. All this would not have been possible without the generosity of the REU program.