Current Status of the MiniBooNE Experiment

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This paper reviews the current status of the Fermilab mini-Booster neutrino experiment (MiniBooNE). The experiment began taking beam data in late August 2002. We describe the experiment, status of the beamline and detector, and show the first neutrino candidate events.

1. Introduction

MiniBooNE[2] will make a definitive test of the LSND results[3]. The LSND experiment at Los Alamos ran from 1993-1998 and searched for $\overline{\nu}_\mu \rightarrow \overline{\nu}_e$ oscillations using $\overline{\nu}_\mu$ beam from μ^+ decays at rest. The LSND final result, combining all the data, yielded an excess of 87.9±22.4±6.0 events after background subtraction (Figure 1). This corresponds to an oscillation probability of (0.264 ±0.067 ±0.045)%. The allowed values of Δm^2 and $sin^2 2\theta$ corresponding to this result is shown in Figure 2. Also shown are the 90% confidence level excluded region for Bugey[4] and KARMEN[5] experiments. None of these experiments was able to confirm or rule out the LSND results.

MiniBooNE is in a unique position to help address this region because MiniBooNE has full coverage of the LSND allowed region. MiniBooNE will be capable of observing both $\nu_\mu \rightarrow \nu_e$ appearance and ν_μ disappearance. If the LSND signal is due to neutrino oscillations, MiniBooNE expects approximately 1000 ν_e events due to $\nu_\mu \rightarrow \nu_e$ oscillations in 2 calendar years (10^{21} protons on target).

2. The MiniBooNE Experiment

The MiniBooNE neutrino beam is initiated by a primary beam of 8 GeV protons from the Fermilab Booster accelerator. The Booster is a high intensity machine, expected to run at least 2×10^7 s per year, delivering $\sim 5 \times 10^{12}$ protons per 1.6 μs pulse at a rate of 5 Hz to MiniBooNE.

A secondary beam is produced when the 8 GeV protons strike a beryllium target located inside a magnetic focusing device called a "horn". Positive charged particles (essentially pions) are focused forward by the single horn into a 50 m decay region where they decay ($\pi^- \rightarrow \mu\nu$) producing a beam of neutrinos. The horn current can be of either sign in order to focus π^+ and defocus π^- or vice-versa. So, by choosing the sign of the current, MiniBooNE will be able to run with ν_μ or $\overline{\nu}_\mu$ beam. In either configuration, the intrinsic

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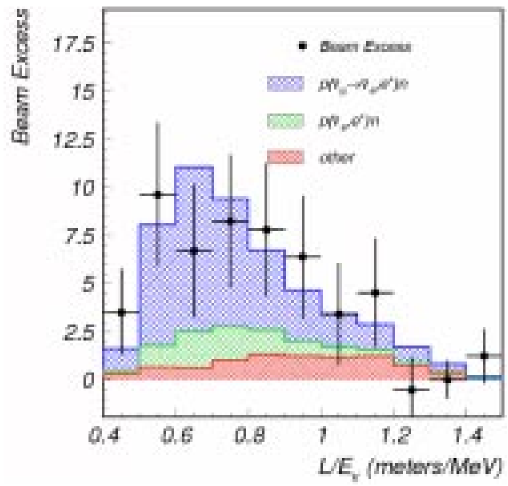

Figure 1. The LSND excess events shown as a function of L/E. Data points are after background subtraction, the blue distribution is expectation for oscillations and the red/green distributions are beam related backgrounds.

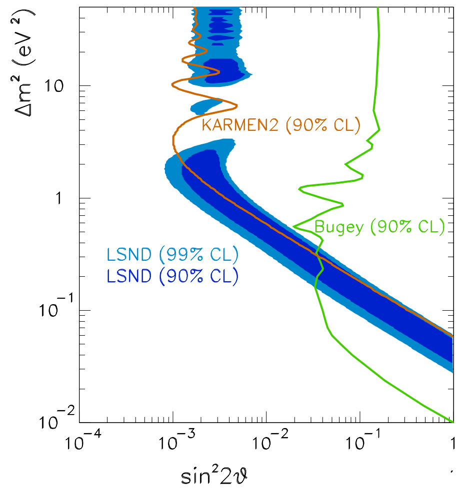

Figure 2. LSND allowed region. The light (dark) shaded regions correspond to 99%(90%) confidence levels. Also shown are the 90% confidence level limits from Bugey and KARMEN experiments.

ν_e or $\overline{\nu}_e$ contamination is low. The energy distribution of the neutrino flux for ν_μ and ν_e is shown in Figure 3.

The neutrino flux at the detector will be determined using different methods. MiniBooNE is collaborating with the HARP[6] experiment at CERN which, during the last summer, ran with the MiniBooNE Be target and collected 20 million triggers. Analyses of these data are ongoing. A measurement of the ν_μ charged-current rate in the detector will check the ν_μ flux as well as determine the energy distribution of the muons in the decay region. This will help us to understand the intrinsic ν_e background component in the beam coming from muon decay. The ν_e background coming from kaon decays will be determined by measuring the high-transverse momentum muons from $K^+ \to \mu^+\nu_\mu$. For the oscillation search, a systematic check of the signal can be done by lowering an intermediate absorber, which has been installed at the 25 meter position, into the decay region. Because the pions and muons have different decay lenghts, changing the length of the decay region will vary the signal to background ratio in a known way.

The MiniBooNE detector consists of a 12.2 m diameter spherical steel tank filled with 941,300 liters of mineral oil. Neutrino interactions in the oil produce Cherenkov and scintillation light which are detected by the 8-inch photomultiplier tubes (PMTs). The detector is divided into main and veto regions. The main region, painted black to minimize rescattering, is viewed by 1,280 PMTs, providing 10% photocathode coverage of the 445 ton fiducial volume. The veto region, whose surfaces are painted white to maximize light collection efficiency, contains 240 PMTs mounted in pairs on the tank wall.

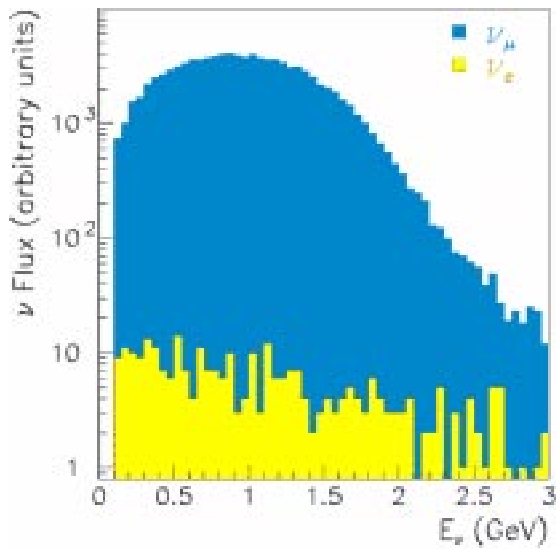

Figure 3. Neutrino flux energy distribution for ν_μ (dark shaded region) and ν_e (light shaded region).

The center of the detector is positioned about 500 m from the end of the decay region, and about 6 m below ground. The tank is housed in a cylindrical concrete vault. A room above the vault contains the experiment's electronics.

Calibration for the detector is obtained through three different systems. A pulsed laser is used to determine the time and gain of the PMTs. A muon tracker system located above the detector combined with scintillator cubes hanging inside the main region allows energy calibration. In addition, cosmic-ray muons provide a constant source of data for calibration.

3. First Glance at the Data, and Future Plans

The MiniBooNE detector and beamline are operational and data-taking has begun. The initial energy and timing calibrations have been performed during the two months of commissioning and the detector is operating well. Good progress on understanding the beamline has been made since MiniBooNE started taking data late August. However, the experiment is running with beam intensities that are a factor six lower than desired. Nevertheless, even with this low neutrino intensity, the first neutrino candidate events (ν_μC $\rightarrow \mu^-$ X) have been seen. In Figure 4 is shown a typical μ event candidate as viewed by the event display, and in Figure 5 is shown the reconstructed event times with respect to the beam trigger.

The current plan is to run ν_μ mode until MiniBooNE collects 5×10^{20} protons on target, with the possibility of changing to $\overline{\nu}_\mu$ mode afterwards. First results are expected by 2005 and if the LSND signal is confirmed, MiniBooNE will be upgraded to the BooNE experiment (two detectors).

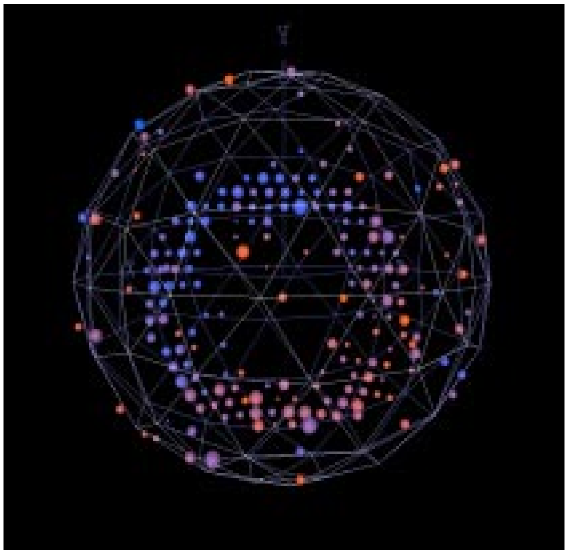

Figure 4. A display of a μ candidate.

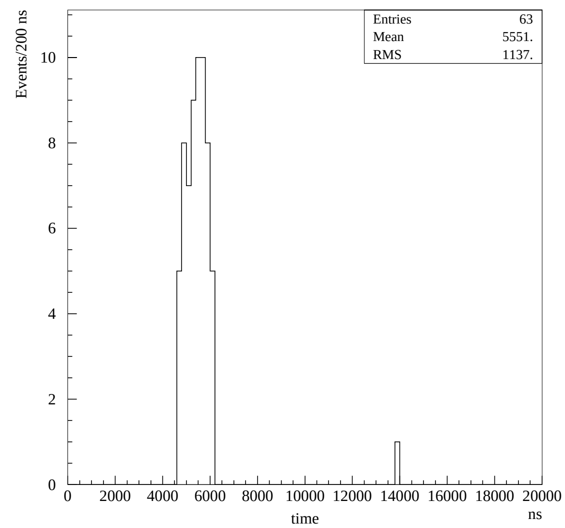

Figure 5. Reconstructed event times with respect to the beam trigger.

REFERENCES

1. The BooNE collaboration consists of the following institutions: University of Alabama; Bucknell University; University of California, Riverside; University of Cincinnati; University of Colorado; Columbia University; Embry Riddle Aeronautical University; Fermi National Accelerator Laboratory; Indiana University; Los Alamos National Laboratory; Louisiana State University; University of Michigan and Princeton University.
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