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An Expression of Interest to Build a MiniBooNE Near Detector:BooNE

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1. Executive Summary

The MiniBooNE experiment observes an unexplained excess of electron-like events at low energies in neutrino mode 1), which may be due, for example, to either a neutral current radiative interaction 2) or to neutrino oscillations involving sterile neutrinos 3,4,5,6,7,8) and which may be related to the LSND signal 9). No excess of electron-like events, however, is observed so far at low energies in antineutrino mode 10). In order to test whether the low-energy excess is due to neutrino oscillations, we propose building a second MiniBooNE detector at (or moving the existing MiniBooNE detector to) a distance of $\sim$ 200 m from the Booster Neutrino Beam (BNB) production target. With identical detectors at different distances, most of the systematic errors will cancel when taking a ratio of events in the two detectors, as the neutrino flux varies as $1/r^2$ to good approximation. This will allow a precision test for both ν_e and $\bar{\nu}_e$ appearance oscillations and ν_μ and $\bar{\nu}_\mu$ disappearance oscillations. Furthermore, a comparison between oscillations in neutrino mode and antineutrino mode will allow a sensitive search for CP and CPT violation in the lepton sector at short baseline ($\Delta m^2 > 0.1$ eV^2). Finally, by comparing the rates for a NC reaction, such as NC π^0 scattering or NC elastic scattering, a direct search for sterile neutrinos will be made.

2. The MiniBooNE Experiment at Fermilab

A schematic drawing of the MiniBooNE experiment is shown in Fig. 1. The MiniBooNE detector consists of a 12.2 m diameter sphere filled with $\sim$ 800 tons of mineral oil and covered on the inside by 1520 phototubes (PMTs), 1280 of which are detector PMTs and 240 are veto PMTs. The detector is located approximately 541 m downstream from the 71-cm Be target, which is fed by the 8 GeV protons from the Booster operating at a current of up to 4 μA and with a duty factor of $\sim 10^{-6}$. Protons interacting in the target produce pions and kaons, which are focussed by the magnetic horn and decay in a 50-m long decay pipe. Due to the relatively short decay pipe, the neutrino flux at 0° is approximately constant in shape for distances > 100 m 11) and decreases in magnitude as $1/r^2$.

2.1. MiniBooNE Neutrino Oscillation Results

Fig. 2 shows the reconstructed neutrino energy distribution for candidate ν_e data events (points with error bars) compared to the MC simulation (histogram) 1), while

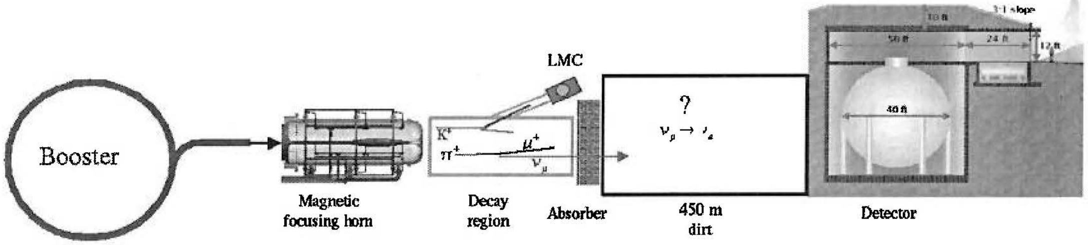

Figure 1: *A schematic drawing of the MiniBooNE experiment.*

Fig. 3 shows the event excess as a function of reconstructed neutrino energy. Good agreement between the data and the MC simulation is obtained for $E_\nu^{QE} > 475$ MeV; however, an unexplained excess of electron-like events, $128.8 \pm 20.4 \pm 38.3$ events, is observed for $E_\nu^{QE} < 475$ MeV. As shown in Fig. 3, the magnitude of the excess is very similar to what is expected from neutrino oscillations based on the LSND signal. Although the shape of the excess is not consistent with simple two-neutrino oscillations, more complicated oscillation models [3,4,5,6,7,8] have shapes that may be consistent with both the LSND and MiniBooNE signals.

2.2. Initial Antineutrino Oscillation Results

The same analysis that was used for the neutrino oscillation results is employed for the initial antineutrino oscillation results [10], which are shown in Figs. 4 and 5. It is quite surprising that no excess ($-0.5 \pm 7.8 \pm 8.7$ events) is observed so far in the low-energy range $200 < E_\nu^{QE} < 475$ MeV. No significant excess of events is observed at higher energies, $E_\nu^{QE} > 475$ MeV, although at present the data are inconclusive with respect to antineutrino oscillations at the LSND level. More antineutrino data should help resolve the question of LSND neutrino oscillations.

3. BooNE

The BooNE experiment involves building a second detector at a cost of ~ \$8M along the BNB at FNAL at a closer distance of ~ 200 m. With two detectors, many of the systematic errors will cancel, as the neutrino flux varies as $1/r^2$ to good approximation, so that a simple ratio of events in the two detectors will provide a sensitive search for ν_e appearance and ν_μ disappearance. Furthermore, by comparing the rates for a NC reaction, such as NC π^0 scattering or NC elastic scattering, a direct search for sterile neutrinos can be made. An even cheaper option would be to move the MiniBooNE detector to a different location at a cost of only ~ \$4M. For example, if the MiniBooNE detector were moved to a distance of 200 m from the neutrino source, then the event rate would increase by a factor of ~ 6 due to the $1/r^2$ dependence of the neutrino flux. In either case, after less than a year of running, the comparison of the event rates at the two locations will determine whether the low-

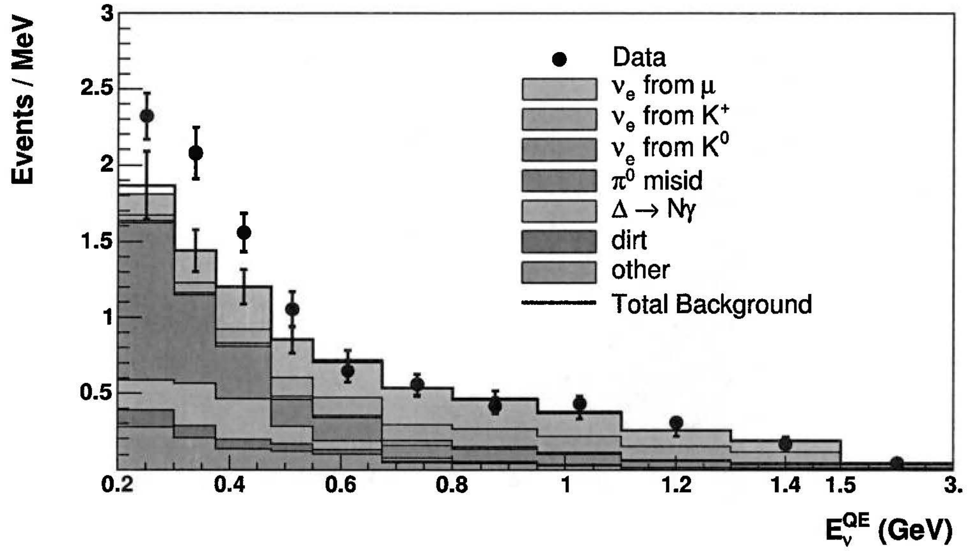

Figure 2: *The MiniBooNE reconstructed neutrino energy distribution for candidate* ν_e *data events (points with error bars) compared to the Monte Carlo simulation (histogram).*

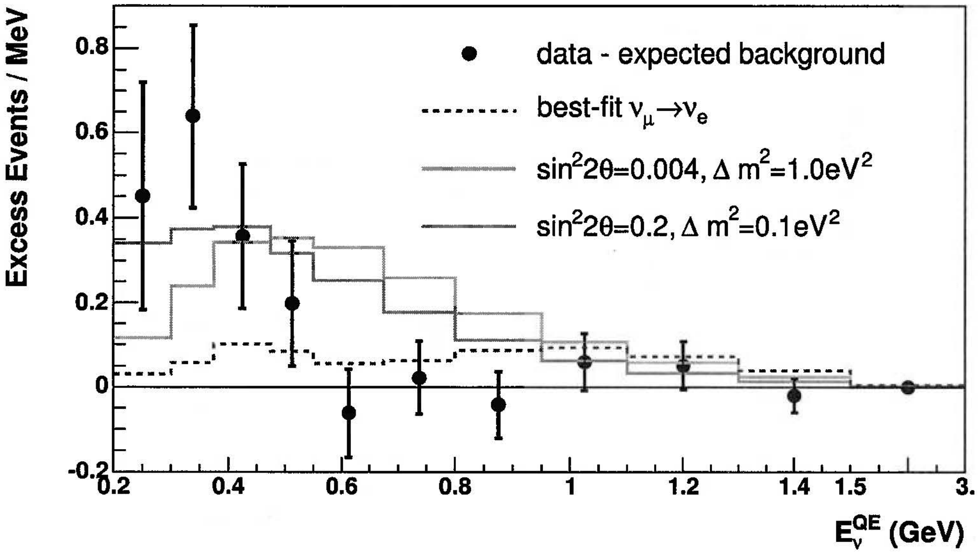

Figure 3: *The MiniBooNE event excess as a function of* E_ν^{QE}. *Also shown are the expectations from the best oscillation fit (*$\sin^2 2\theta = 0.0017$, $\Delta m^2 = 3.14\ eV^2$*) and from neutrino oscillation parameters in the LSND allowed region. The error bars include both statistical and systematic errors.*

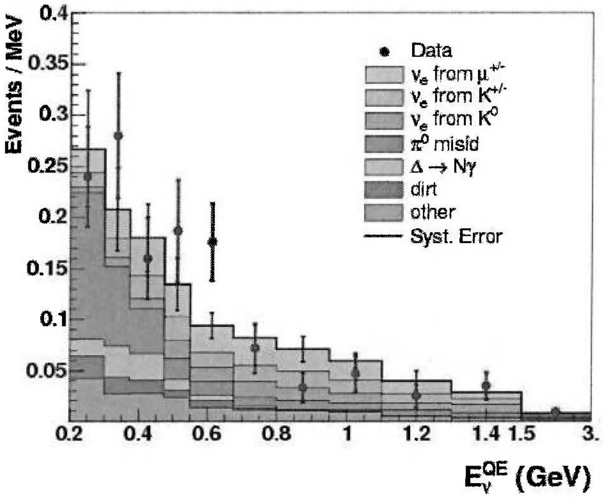

Figure 4: *The comparison between data and Monte Carlo expectation as a function of reconstructed neutrino energy for the present MiniBooNE antineutrino data sample corresponding to 3.4E20 POT.*

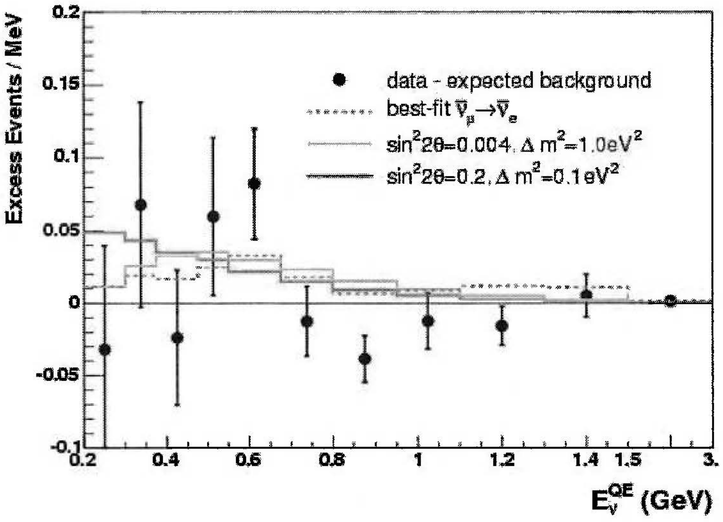

Figure 5: *The excess number of events as a function of reconstructed neutrino energy for the present MiniBooNE antineutrino data sample corresponding to 3.4E20 POT. Also shown are the expectations from the best oscillation fit and from oscillation parameters in the LSND allowed region.*

energy excess observed by MiniBooNE was due to neutrino oscillations. In addition, ν_μ and $\bar{\nu}_\mu$ disappearance will be searched for with high precision in the $\Delta m^2 > 0.1$ eV^2 mass region. By comparing neutrino oscillations to antineutrino oscillations, BooNE will be able to search for CP and CPT violation in the lepton sector at short baseline ($\Delta m^2 > 0.1$ eV^2).

4. Cost Estimate

Table 1 shows a breakdown of the cost estimate for constructing a second BooNE detector in a near location. The estimate is based on the MiniBooNE construction costs. The total estimated cost is \$7.3M, including contingency ($\sim 30\%$) and escalation (3% per year). The BooNE construction is assumed to start in 2010 and last for 3 years. The estimated cost for moving MiniBooNE to a near location is $\sim$ \$4M.

Item	Cost (\$K)
Tank and support structure	1065
PMT's	1759
Electronics/DAQ	512
Oil	1429
Calibrations	412
Miscellaneous	198
Engineering & Construction	1894
Total	7269

Table 1: A breakdown of the BooNE cost estimate, including contingency and escalation.

5. References

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