Neutrinos from the NuMI beamline in the MiniBooNE detector

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Abstract. With the startup of the NuMI beamline early in 2005, the MiniBooNE detector has the unique opportunity to be the first user of an off-axis neutrino beam (110 mrad off-axis). MiniBooNE is assembling a rich sample of neutrino interactions from this source.

Keywords: Neutrino, Oscillations, MiniBooNE, NuMI, off-axis
PACS: 14.60.Pq,14.60.Lm,13.15.+g

INTRODUCTION

The NuMI beamline [1] produces neutrinos for the MINOS experiment [2] and serves as a secondary neutrino source for MiniBooNE [1] [3]. MiniBooNE is located 82.5 m away from the NuMI beam axis and at a longitudinal distance of 745.25 m from the NuMI target (110 mrad off axis). The neutrino flux is determined by this geometry. NuMI has run in three different beam configurations: low energy (LE10), pseudo medium energy (PME) and pseudo high energy (PHE), owing their names to the characteristics of the neutrino energy spectrum at the MINOS far detector [4].

GEOMETRY, EVENTS, AND MONTE CARLO PREDICTIONS

Seen from above, the NuMI and the MiniBooNE beam lines (Figure 1) intersect each other approximately at the location of the MiniBooNE detector at an angle of $\sim 23^\circ$. In an elevation view, the beam lines do not intersect but diverge at an angle of $\sim 3^\circ$. Neutrinos reaching the MiniBooNE detector are produced by the decay of mesons created in the NuMI target and beam dump. Mesons from the target moving along the decay pipe decay into neutrinos with an energy spectrum determined by the off-axis angle of the detector (110 mrad). The rate of neutrino candidates per proton delivered to the NuMI target (p.o.t.) as a function of time (0.51×10^{-15} ν/p.o.t.) is constant as seen in Figure 2, and is roughly half of that from the on-axis Booster neutrino beam. We use the `gnumi` Monte Carlo to simulate the NuMI beamline and calculate ν_μ, $\bar{\nu}_\mu$, ν_e, and $\bar{\nu}_e$ fluxes at the location of MiniBooNE in the three beam configurations. The NUANCE [5] event generator produces interactions in the detector ($\sim 96\%$ ν_μ, $\bar{\nu}_\mu$),

[1] For a detailed description of MiniBooNE see the talks by J.M. Conrad, M.O. Wascko, R.H. Nelson., and Z. Djurcic in these proceedings

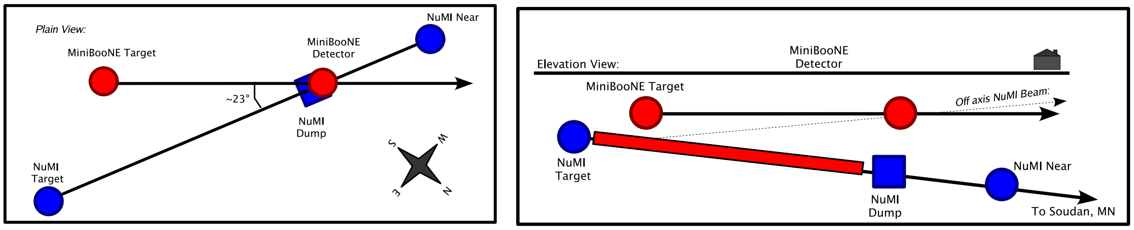

FIGURE 1. Schematics showing the geometry between the NuMI and MiniBooNE beamlines. Left: plain view. Right: elevation view

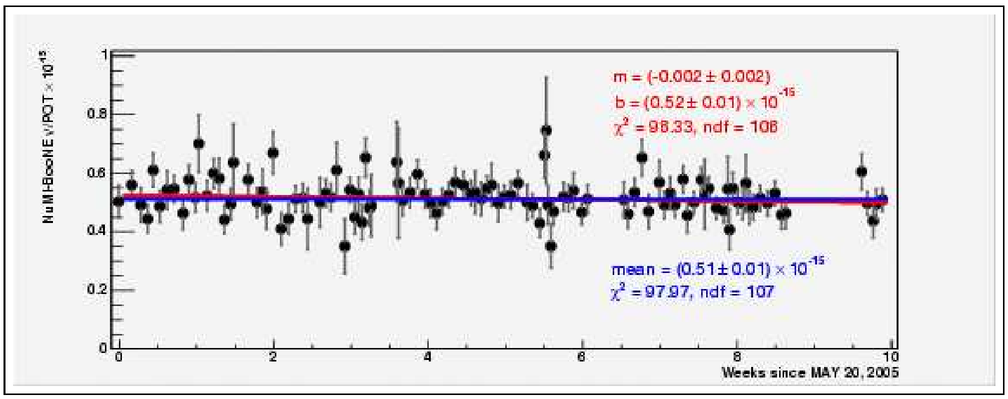

FIGURE 2. Rate of neutrino candidates per NuMI p.o.t. as a function of time. The fits to a constant and a line with a slope are consistent with a constant rate.

which are simulated with the MiniBooNE detector Monte Carlo. Figure 3 (left) shows the comparison of the rate of neutrino candidates as a function of true neutrino energy. In Figure 3 (right) the composition of the interactions of all neutrino types in the LE10 configuration is shown. The composition in the PME and PHE configurations is similar.

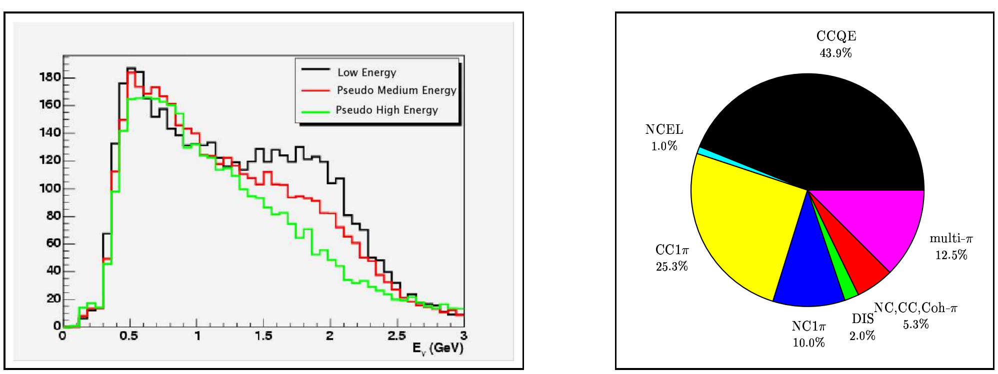

FIGURE 3. Left: Event rate *vs.* true neutrino energy in the three configurations. LE10 in black, PME in red, PHE in green. The peak at ~ 2 GeV corresponds to K^+ off-axis decays, and is the smallest in the PHE beam. Right: Breakdown of interactions in the LE10 configuration.

In Figure 4, we compare the shapes of the visible energy distribution of neutrino candidates. The red bands shown are estimates of optical model and cross section systematic uncertainties, assumed to be uncorrelated.

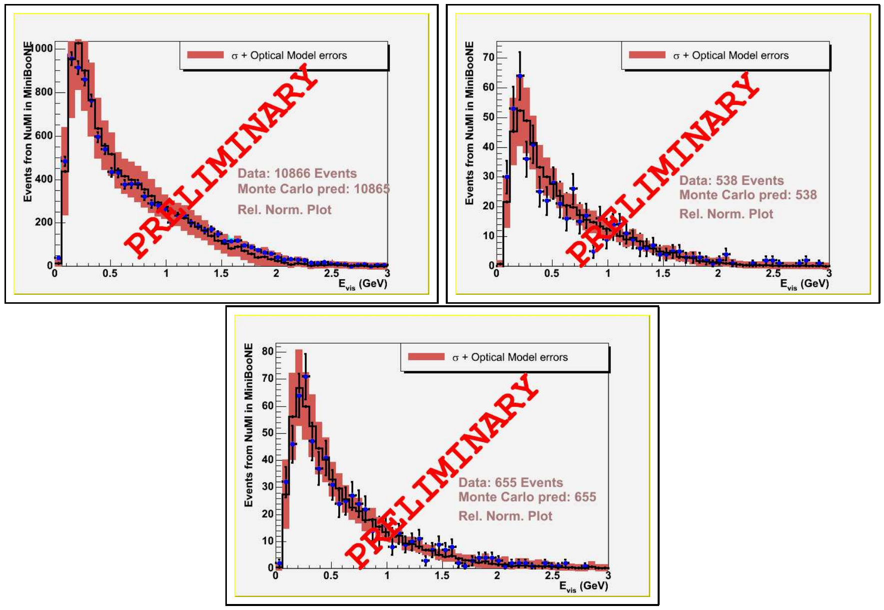

FIGURE 4. Shape comparisons of the visible energy distribution of neutrino candidates in data (blue points) and Monte Carlo (histogram with error bands) in the three beam configurations. Top Left: LE10, Top Right: PME; Bottom: PHE.

The Monte Carlo predicts that the fraction of neutrino candidates from the decay of a K^+ is around 62%. A simple shape fit to the data suggests a value of 66% (with no attempt to account for systematic errors). This kind of measurement can help to put constraints on the K^+ production models of NuMI and is of special interest to the MINOS collaboration. MiniBooNE, on the other hand, can benefit from making systematic checks of its various analyses using this new dataset. We expect to collect more than 40,000 neutrino candidates in the LE10 configuration by the next shutdown.

ACKNOWLEDGMENTS

This work is supported by the National Science Foundation and the Department of Energy. The author was funded by NSF grants PHY 00-98826 and PHY 05-00492.

REFERENCES

1. The Fermilab NuMI Group, “NuMI Facility Technical Design Report”, October 1998, Fermilab Report NuMI-346.
2. E. Abes *et al.* [MINOS collaboration], FERMILAB-PROPOSAL-0875
3. A. Aguilar-Arevalo *et al.* [MiniBooNE collaboration], “The MiniBooNE Run Plan”, `http://www-boone.fnal.gov/publicpages`, (2003)
4. M. Kostin *et al.* "Proposal for a continuously-variable beam energy", October 2001, Fermilab Report NuMI-783. The LE10 beam has 10 cm upstream target offset; PME has 100 cm, PHE beam has 250 cm. Pseudo beams were run with 200 kA horn current. LE10 beam ran with 185 kA.
5. D.Casper, Nucl. Phys. Proc. Suppl., 112,161 (2002)