Constraining the Kaon Content in the MiniBooNE Secondary Beam With the Little Muon Counter

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Abstract. K^+ and K^0_L decays are sources of intrinsic ν_e background to the MiniBooNE (Mini-Booster Neutrino Experiment) neutrino oscillation experiment. In order to constrain this background, MiniBooNE uses a novel technique of measuring the momentum spectrum of off-axis muons from the secondary beam. Muons from kaon decays are kinematically distinguishable from those from pion decays at large angles because of the K/π mass difference. A momentum spectrometer, the Little Muon Counter (LMC), is set at 7° off-axis from the MiniBooNE beamline to perform this measurement. The concept, experimental setup, and physics reach will be presented.

Keywords: Neutrino Oscillations, Backgrounds, MiniBooNE
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INTRODUCTION: THE ν_e BACKGROUND

Assuming oscillation parameters within the allowed region of the LSND experiment [1] ($\Delta m^2 \simeq 0.7$ eV^2) MiniBooNE expects roughly equal ν_e contributions from $\nu_\mu \rightarrow \nu_e$ oscillations, misidentified pions and muons, and intrinsic backgrounds [2, 3]. The intrinsic ν_e backgrounds come from the decays μ^+, K^+, and K^0_L, as shown Figure 1. Kaon production at the MiniBooNE primary beam energy of 8.9 GeV is poorly understood, as external measurements do not cover the full range of momentum and angle. MiniBooNE would like to understand these uncertainties at the 10% level.

MiniBooNE approaches this problem by performing a combined Sanford-Wang [4] fit to both *ex* and *in-situ* measurements. The internal measurements come from two complementary sources: the high-energy neutrino sample(E_ν>1.7 GeV) and the LMC. As shown in Figure 1, the dominant portion of the high-energy neutrino flux comes from kaons. These neutrinos are outside of the expected oscillation signal [2], which is below 1 GeV. A measurement of the flux of these neutrinos constrains the amount of kaon production.

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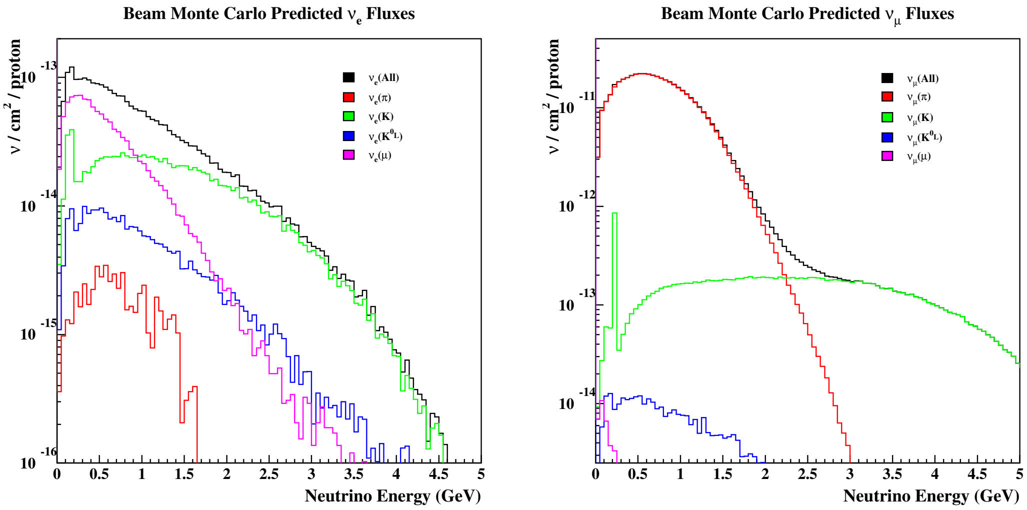

FIGURE 1. Intrinsic ν_e (left) and ν_μ (right) fluxes vs. E$_\nu$ by parent at the MiniBooNE detector. Low energy ν are dominated completely from π decay, while the high energy ν come solely from K decays.

THE LITTLE MUON COUNTER

A beam of 8 GeV protons is extracted from Fermilab's Booster accelerator and is incident upon a 70 cm (1.7 interaction length) beryllium target. The proton beam comes in $\sim$80 2 ns bunches over a 1.6 μs beam spill. Each spill contains about 5×10^{12} protons. The resulting beam debris (pions and kaons) are focused by a magnetic horn. The horn pulses between 2-5 Hz at 174 kA, focusing by a factor of six the produced positively(negatively) charged mesons to study $\nu(\bar{\nu})$ [5] at the MiniBooNE tank. The pion and kaon secondary beam then decays in flight along a 50 m decay pipe[2] full of air. The daughter neutrinos then propagate through 450 m of dirt before they reach the MiniBooNE detector.

An evacuated 60' drift pipe branches off the decay pipe at a 7° angle. The LMC is located at the end of the drift pipe and consists of a steel/tungsten collimator, a scintillating veto, a fiber spectrometer, and an alternating tungsten/scintillator range stack. The collimator is 81" long, composed of steel with a tungsten core. The core has a tapered $\sim$ 1 cm hole through the center. Attached to the downstream face of the collimator is an active veto of four scintillator paddles which detect particles that scatter through the tungsten and steel.

The fiber spectrometer measures the momentum of charged particles that pass through a 2.27 kGauss dipole field (p_T^{kick} =16.4 MeV/c). There are a total of 4 fiber planes; the upstream planes measure x and y positions, while the downstream planes only measure the x positions. A one degree-of-freedom χ^2 minimization is performed to measure the bend angle and momentum. The spectrometer is designed to be sensitive to a momentum range of 0.2-3.0 GeV/c with charged sign selection up to 4 GeV.

[2] the decay region can be shortened to 25 m to study μ decay.

TABLE 1. The maximum p_T given to the μ by particles in the secondary beam.

Decay	Max p_T (MeV/c)
$\pi^+ \rightarrow \mu^+ \nu_\mu$	29.8
$K^+ \rightarrow \mu^+ \nu_\mu$	235.5
$K^+ \rightarrow \pi^0 \mu^+ \nu_\mu$	213.7

EXPECTED SIGNAL

The LMC exploits kinematics in order to differentiate between muons from pion and kaon decays. Kaons, being more massive, can impart a higher transverse momentum to its daughter muons as shown in Table 1. Therefore, high angle decays lead to a separation in energy between muons from pions and kaons. The off-axis angle of 7° is selected to optimize this separation. The momentum spectrum of daughter muons from pions rapidly decreases around 1.0 GeV/c, while the daughter muons from kaons continue out to 2.0 GeV/c.

CONCLUSION

The LMC complements the high-energy box as an *in-situ* measurement without the added complication of neutrino interaction cross-section uncertainties or detector systematics. Special low-intensity booster runs must be used for this measurement to reduce the amount of channel saturation. These, and other systematic runs are currently being taken[3]. Progress is being made in understanding LMC backgrounds through Monte Carlo studies. Once these studies are completed a background subtracted fit will be performed to the measured muon momentum spectrum. This will be used to help constrain the kaon content of the secondary beam.

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[3] finished by the time of this publication.