KAON MONITORING USING THE MINIBOONE LITTLE MUON COUNTER

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Abstract

The Little Muon Counter (LMC) is a permanent magnet spectrometer designed to constrain ν_e backgrounds to the MiniBooNE experiment's neutrino oscillation signal, $\nu_\mu \rightarrow \nu_e$. A description of the LMC components; analysis milestones including track momenta, muon identification penetration depth, and event displays; and the status of the LMC are presented.

MINIBOONE INTRODUCTION

MiniBooNE, at Fermi National Accelerator Laboratory, is a neutrino detecting experiment searching for the oscillation of muon neutrinos to electron neutrinos. BooNE is designed to conclusively confirm or refute LSND's (Liquid Scintillating Neutrino Detector at Los Alamos National Laboratory) positive $\nu_\mu \rightarrow \nu_e$ oscillation result.

MiniBooNE uses 8 GeV protons from Fermilab's Booster accelerator as the primary beam. The protons strike a beryllium target embedded in a magnetic focusing horn which produces a secondary beam of pions, kaons, and muons. These secondary beam particles decay into neutrinos; an absorbing wall of steel and concrete ensures that neutrinos are the only particles which reach the MiniBooNE detector. Figure 1 shows the main components of the MiniBooNE beamline.

BACKGROUNDS TO THE OSCILLATION SIGNAL

The MiniBooNE neutrino flux is almost entirely muon neutrinos with an approximately 0.3% electron neutrino component (from muon and kaon decays). However, the expected number of electron neutrinos from oscillations is comparable to the number of electron neutrinos expected from kaon and muon decays. Accounting for these background electron neutrinos to the oscillation signal is of vital importance in obtaining a reliable oscillation measurement.

The measurement of the intrinsic electron neutrino content will be approached in several ways. Measurement of the muon neutrino rate at the detector will provide kinematic constraints on the intrinsic electron neutrino rate. MiniBooNE has the option of stopping the secondary beam with a 25 m (instead of the nominal 50 m) absorber which should alter the relative rates of ν_μ and ν_e at the detector in a predictable way. We will also take advantage of improved particle production modeling using GEANT4 [1] and cross section measurements from HARP [2] and BNL910 (latest publication is [3]).

MiniBooNE is also commissioning a permanent magnet fiber spectrometer located 7° off-axis from the secondary beam line to constrain the kaon content of the secondary beam which will, in turn, provide valuable information about the number of electron neutrinos from kaons. The spectrometer, the LMC, will measure the momenta of muons decaying from pions and kaons. As kaons have a much higher mass than pions, muons from kaons have a much higher maximum transverse momentum than pionic muons. Therefore, the parentage of muons which reach the LMC after traveling at a large angle off the beam axis will be ascertained by their momentum; muons from kaons have a momentum of about 2 GeV, and muons from pions have a momentum of about 0.2 GeV.

LITTLE MUON COUNTER COMPONENTS

The LMC is designed to measure the momenta of muons between 0.2 and 3.0 GeV/c with about 10% resolution. Figure 2 shows a schematic drawing of the LMC. The primary component of the LMC is a permanent magnet fiber spectrometer. The permanent magnet provides an upward-pointing magnetic field of 2.27 kgauss over 23 cm. The LMC spectrometer has six planes of scintillating fibers. The LMC coordinate system is defined as z along the collimator axis, y pointed upward and x horizontal so that x is the bend coordinate for charged particles traveling through the magnetic field. Four of the planes are upstream of the magnet, and two are downstream of the magnet. Two of the upstream planes are segmented along x and the other two are segmented along y. Both the downstream planes are segmented along x and are wider than the upstream planes as low momentum tracks will have a large bend. Each fiber plane consists of two parallel rows of 1 mm diameter scintillating fibers, staggered by 1/2 fiber diameter in order to remove inefficiency from gaps between fibers. The upstream planes each have a total of 29 fibers; the first plane downstream of the magnet and the final plane have 99 and 177 instrumented fibers respectively. Each fiber is routed to a 3/4 inch Hamamatsu R1666 photomultiplier tube mounted below the tracker. The PMT bases are built on custom circuit cards with four PMT sockets and a single high voltage input per card. A two-stage solid state amplifier circuit enhances the signal from each PMT. In the outer regions of the downstream planes, bundles of several fibers are combined to a single PMT to reduce the number of readout channels.

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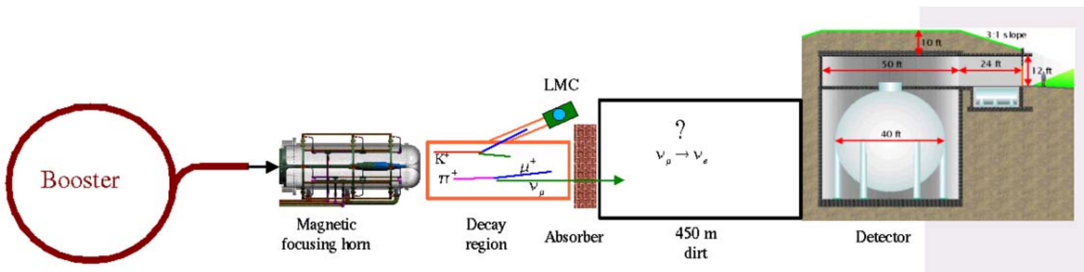

Figure 1: The MiniBooNE beamline.

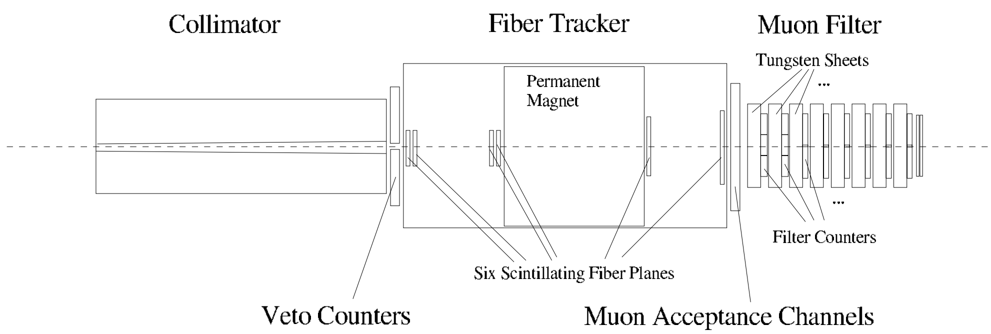

Figure 2: Schematic Drawing (top view) of the LMC.

Upstream of the fiber tracker is an 81 inch long steel collimator with a tungsten core. The tungsten core includes a tapered hole so that tracks traveling down the hole without any collisions must have originated from the MiniBooNE secondary beamline. After the collimator and before the tracker are four veto counters which surround the downstream end of the collimator hole.

After the tracker are four counters designed to serve as muon acceptance channels. Two of the counters are in the beam line and the other two are above and below the beamline.

The final component of the LMC is the muon filter, a range stack designed to identify high energy muons. The filter consists of eight layers of alternating tungsten sheets and scintillating counters. A muon with momentum larger than 1.3 GeV/c will penetrate all eight layers.

LMC ANALYSIS

Our track reconstruction algorithm requires a sixfold coincidence of fiber tracker hits, at least one hit from each of the tracker planes, each within 5 ns of the mean times of the hits. Hits within 5 ns of the mean time from the veto counters, muon acceptance counters, and muon filter are also included in the events.

As the bend angles for charged tracks are small, small angle approximations can be used for track reconstruction and momentum determinations. For each of the six planes, track positions and track position uncertainties are determined from the locations and widths of the fiber bundles from each hit. In the x direction (the bend direction), the upstream and downstream track segments comprised of four hits are constrained to meet at the center of the magnet. From this constraint, a bend angle (and consequently a momentum) and a χ^2 are determined. Since we have y location information in the upstream planes (two hits), track candidates are required to have their y position projected back to the downstream planes to go through the active areas of the downstream planes. For 6-fold coincidences with more than one hit on a plane, the hit that produces the smallest track χ^2 is selected.

Figure 3 shows an event display of a data muon candidate. The event display demonstrates that the fiber tracker and its track reconstruction, the muon acceptance (MACC) counters, and the muon filter counters are working.

The muon filter data, together with the tracker data which provides the track momenta measurements, has been shown to identify muon candidates. Figure 4 shows a plot of the track momentum versus the muon filter penetration depth for positively charged tracks. The two-dimensional plot shows an approximate linear correlation from muons, and a population with shorter penetration depth from hadrons.

Other data analysis in progress is correlating projected track positions determined from the tracker with veto and muon acceptance counters hits. Tracks that emerge from the collimator hole and go through the upstream layers of the tracker before encountering the magnet will travel in a straight line. The two upstream layers of the tracker are instrumented in the x and y directions providing two points of the each track's trajectory. The trajectory from these two points are projected back to the location of the veto coun-

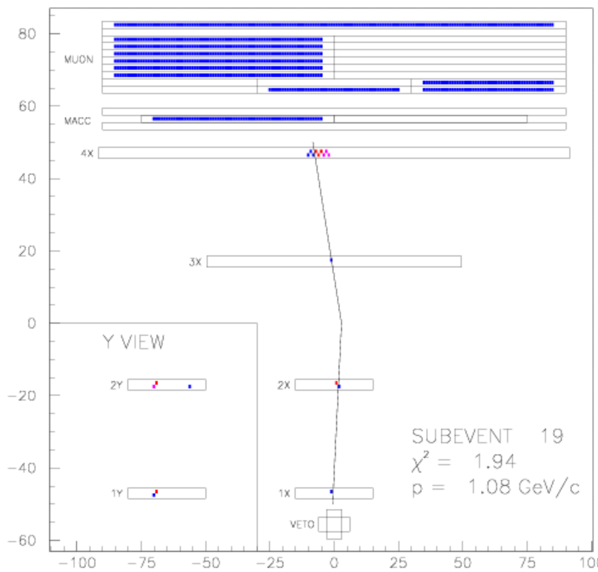

Figure 3: Muon candidate event display from LMC data.

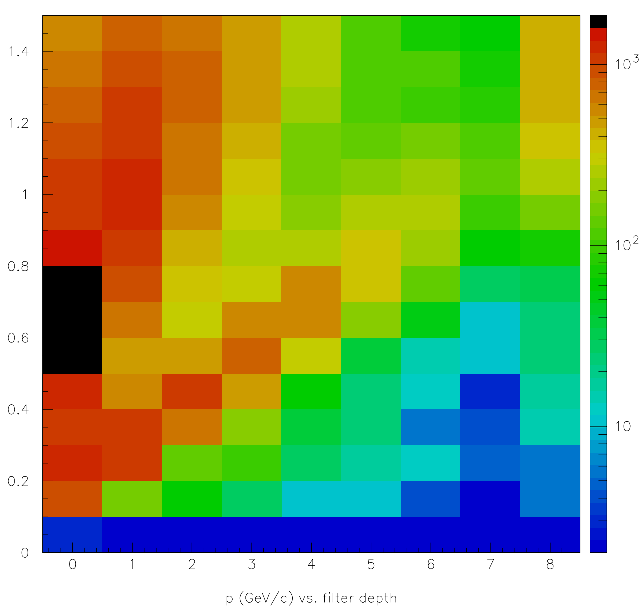

Figure 4: Track momentum versus muon filter penetration depth. An approximate linear correlation from muons is evident from the yellow-orange band from the lower left to upper right of the plot.

ters. If a track segment originated from just outside the collimator hole or if a veto counter blocks part of the collimator hole, then tracks would hit the veto counters, and this would be seen with tracker-veto counter correlations. Similar checks of the muon acceptance counters (between the tracker and the muon filter) can also be made by projecting the upstream y positions and downstream x positions to the location of the muon counters. Preliminary analysis shows that track candidates are coming from the collimator hole and after deflection by the magnetic field, are going through the muon acceptance counters located in the LMC beam line.

STATUS OF THE LMC

The LMC currently has its tracker and muon filter operational providing momentum measurements and muon identification. The veto counters and muon acceptance counters are also working. The main task for data analysis is to determine the number of background muons. Background muons are those that reach the LMC after collisions in the collimator hole or at the edges of the entrance into the drift pipe to the collimator. Muons that undergo such collisions will have low momentum (less than 0.5 GeV/c), and can not be used in the sample which kinematically separates pionic muons from kaonic muons. Veto counter and upstream tracking projections should help determine this background.

Turning a background corrected muon momentum distribution into a constraint on the kaon content of the secondary beam requires extra knowledge about secondary beam cross sections and kinematics. The LMC Monte Carlo simulations allow for various cross section models as inputs. Different models are being included in the LMC simulations. In addition, experimental data from HARP and BNL 910 will help with our secondary beam and LMC modeling.

Once the analysis procedure and Monte Carlo parameterizations are finished, our goal is to determine the rate of ν_e's from kaons, one of the backgrounds to the $\nu_\mu \rightarrow \nu_e$ oscillation signal, to about 10%.

REFERENCES

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