Measurements of muon neutrino charged-current interactions by the MicroBooNE experiment

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Abstract. MicroBooNE is a 170 ton Liquid Argon Time Projection Chamber (LArTPC) experiment located at Fermi National Accelerator Laboratory. It has been operating in the Booster neutrino beam since October 2015 and is already demonstrating the superb imaging capabilities of LArTPC detectors. MicroBooNE is the first large LArTPC detector to be exposed to a high-intensity neutrino beam. Among its primary physics goals are precise measurements of muon neutrino charged-current (CC) interactions on argon. In order to analyse its high-statistics data, a suite of fully automated techniques have been developed that reconstruct the LArTPC images and separate muon neutrino CC interactions from their cosmic-ray and neutral current backgrounds. These proceedings will describe the reconstruction and selection of muon neutrino CC event candidates, and present measured distributions of the observed events based on 5e19 protons on target from the first MicroBooNE data-taking period.

1. Introduction

During its run time, MicroBooNE will produce some of the first measurements of neutrino-argon cross sections, which will be important for both the short baseline programme at Fermilab [1] and the upcoming DUNE experiment [2]. The first of these measurements will be the $\nu_\mu$ charged-current ($\nu_\mu$ CC) inclusive cross section outlined in references [3] and [4].

The MicroBooNE detector [5] makes use of the Liquid Argon Time Projection Chamber (LArTPC) technique, by which ionisation electrons produced by charged particles in the detector are drifted to a readout assembly using an applied electric field. Signals produced by the drift electrons, along with scintillation light collected by the optical system, are used for event reconstruction. MicroBooNE is located on the surface, which combined with the characteristic slow readout time of LArTPCs means that many cosmic induced tracks are expected in any given 2.3 ms readout window. Successful reconstruction and selection of neutrino interactions is therefore paramount to all analyses that will be performed at MicroBooNE.

2. Reconstruction and Selection of $\nu_\mu$ CC events

In order to separate neutrino events from events with only cosmic tracks, a software triggering condition is applied demanding that a certain amount of scintillation light is detected within the 1.6 $\mu$s beam window, which is assumed to originate from a neutrino interaction. This constitutes a significant part of the background rejection at MicroBooNE, increasing the signal to background ratio from approximately 1:600 to around 1:6.

During reconstruction, shown graphically in Figure 1, raw TPC waveforms undergo noise filtering as outlined in reference [6] and so-called hits are created. The second part of
reconstruction, known as the cosmic pass, acts to reconstruct and tag cosmogenic tracks by identifying those which are both entering and exiting the detector. Hits associated to cosmically-tagged tracks are identified and removed. During the subsequent neutrino pass, dedicated neutrino reconstruction algorithms are run on the remaining hit collection.

**Figure 1.** A graphical representation of the reconstruction chain.

Two selection schemes, developed in parallel, use different algorithms and techniques allowing for a comparison of features. The two selections are sensitive to different topologies, with only one third of passing events shared between the selections.

Post-reconstruction samples still contain a number of backgrounds, the largest of which are outlined in Figure 2. The first selection scheme treats all track multiplicities equally, where multiplicity is defined as the number of tracks associated to a vertex. Instead it demands full containment of the candidate CC interaction, and chooses the most forward going interaction using a faux-momentum variable constructed from the length and direction of each track in order to distinguish neutrino induced muons from cosmic muons. The purity for this selection is \( \sim 50\% \), with an efficiency \( \times \) acceptance of 12\%. Kinematic distributions for the candidate muon can be found in Figure 3.

**Figure 2.** The three largest backgrounds to the \( \nu_\mu \) CC inclusive analysis.

Selection II (Figure 4) has three separate treatments for interactions with multiplicity = 1, 2, and greater than 2. Candidate interactions with multiplicity = 1 are subject to the same constraint of containment as in selection I; however the direction is found by using calorimetric information. Multiplicity = 2 interactions undergo checks to remove broken tracks and cosmic muons that decay into electrons. Finally, those interactions with a multiplicity of greater than 2 are automatically accepted. The efficiency \( \times \) acceptance and purity are larger in this selection, being 30\% and 65\%, respectively.

Despite earlier cosmic rejection, a majority of backgrounds are still cosmogenic. The first of these corresponds to those events where a flash occurs in the beam window, but the flash is
Track range [cm]

No. of events

POT):

1910 × Data (4.95

On-beam minus off-beam

Monte Carlo Simulation:

CC signal & bgr

\( \mu \nu \)

Selected

Cosmic bgr events

NC bgr events

CC Out of FV bgr events

\( \mu \nu \) bgr events

\( e \nu \) & \( e \nu \) bgr events

\( \mu \nu \)

MicroBooNE Preliminary

Selection I

Figure 3. Kinematic distributions for the track range (left), and the track \( \cos(\theta) \) (right) for Selection I. Error bars for the kinematic distributions shown here are statistical only.

due to a cosmic track rather than a neutrino. These backgrounds are removed via a statistical subtraction of a beam-off sample, the details of which can be found in reference [3]. The second largest background is due to so-called “cosmic in BNB” events, where there is a flash caused by a neutrino interaction in the beam window, but the selected candidate muon is cosmogenic. The third largest background is due to neutral current events, where a pion is selected as the candidate muon. There are several smaller backgrounds from other neutrino species in the beam.

It is clear that MicroBooNE is able to select out neutrino events from large backgrounds. Improvements to the reconstruction and selections, and installation of physical cosmic-ray taggers, are expected to yield improvements in efficiency and purity for future analyses. Systematics (see reference [7]) must also be evaluated before a \( \nu_\mu \) CC inclusive cross-section measurement can be attained.

References

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