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To cite this article: R Castillo Fernández *et al* 2017 *J. Phys.: Conf. Ser.* **888** 012140

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Model uncertainties at MicroBooNE

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Abstract. The MicroBooNE experiment is a 170 ton Liquid Argon Time Projection Chamber (LArTPC) experiment designed for short-baseline neutrino physics, located at surface level in the Booster Neutrino Beam (BNB) at Fermilab. A muon neutrino-argon charged current (CC) cross section measurement in the energy range of ~ 200 MeV - 2 GeV has recently been started. These proceedings describe our first steps to understand the potential of MicroBooNE to distinguish between different theories for modeling nuclear effects in neutrino scattering and the interaction model systematics that apply to MicroBooNE measurements (in particular to the muon neutrino CC event selection), before the first neutrino-argon cross sections can be derived.

1. Introduction

The Micro Booster Neutrino Experiment (MicroBooNE), is the first large (89 tons of active mass) LArTPC to operate in the United States. The MicroBooNE experiment combines physics goals of short-baseline oscillations and neutrino cross section measurements with development goals to inform larger scale construction of LArTPCs for the long-baseline neutrino program. MicroBooNE is located on the axis of the BNB at Fermilab, as was its predecessor MiniBooNE. MicroBooNE finished commissioning in summer 2015 and has been collecting neutrino data since October 2015.

2. Selection of a ν_μ charged-current sample

Here we briefly describe the first strategies developed for the selection of a sample of ν_μ CC events in MicroBooNE, using an automated 3D event reconstruction.

The selection requires full containment of the interaction to remove cosmic muon tracks from this early analysis. A complete description of the selection can be found in [1] and [2]. The future goal of this study is a measurement of ν_μ CC inclusive cross section on argon.

In the following, we only show Monte Carlo (MC) simulated distributions after the event selection. These distributions include beam related backgrounds (neutral current events, $\bar{\nu}_\mu$ or $\nu_e/\bar{\nu}_e$ interactions) as well as mis-identified events where a cosmic is mistaken for a neutrino interaction. We will show, for a range of models, distributions of reconstructed kinematics of the muon candidate track. The two quantities we will show are the track range, i.e. the three-dimensional distance between the track end points, as this is related to the muon momentum, and



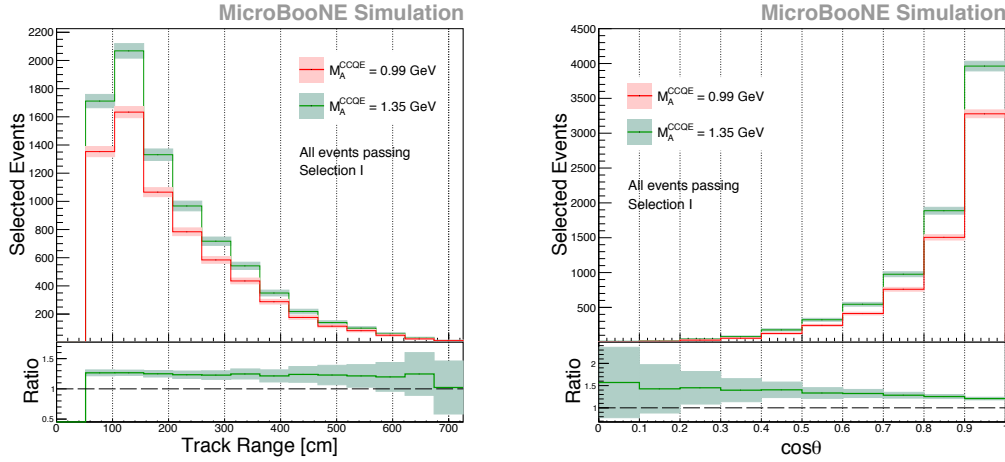


Figure 1. The effect of re-weighting the axial vector mass for quasi-elastic processes on the expected muon reconstructed kinematic distributions of the muon candidate track. The red distribution shows the baseline simulation using $M_A = 0.99$ GeV. The green curve shows the expected distribution using $M_A = 1.35$ GeV. Uncertainties shown are statistical only.

$\cos(\theta)$, where θ is the angle the track makes with the neutrino beam direction. The distributions of $\cos(\theta)$ are shown only for the range between 0 and 1 for better visibility. The simulation is normalized to expected event numbers during a run period of roughly one year. The uncertainties presented are statistical only.

3. Systematics and model variations

Model assumptions can impact a cross section measurement in two ways: the estimation of background contamination and the estimation of the efficiency for signal interactions. The impact of these uncertainties on future measurements at MicroBooNE needs to be understood. As well as this, we would like to be able to compare our data to different models and probe different theories modeling nuclear effects. MicroBooNE uses GENIE [3] to simulate neutrino interactions. The default version shown here is v2.8.6, however GENIE v2.10.6 was used to run simulations with new models which were not available previously. For simple parameter changes, we utilised the GENIE event re-weighting tool [4].

Here we use the above described selections for the ν_μ CC channel. This channel is not the channel most sensitive to many of the nuclear effects and model differences, but it is expected to be the first cross section measurement to come out of MicroBooNE and has therefore been chosen for a first study. The following sections describe the three models we have chosen to test.

3.1. Axial vector mass for quasi-elastic interactions

At high neutrino energies a Relativistic Fermi Gas (RFG) model of the nucleus, and a dipole axial form factor with axial mass of approximately 1 GeV, was found to agree well with data. In observations of CCQE events at MiniBooNE [8], this model was found to not agree well with the data, and fits resulted in an *effective* axial mass value of 1.35 GeV. Here we modify the axial vector mass, M_A , from the GENIE baseline value of 0.99 GeV to 1.35 GeV by re-weighting the GENIE baseline simulation. The primary effect of the axial mass increase is an increase in normalisation. Figure 1 shows the simulation with $M_A = 0.99$ GeV in red and with $M_A = 1.35$ GeV in green. The effect on the total number of expected selected events is of the order of 24%.

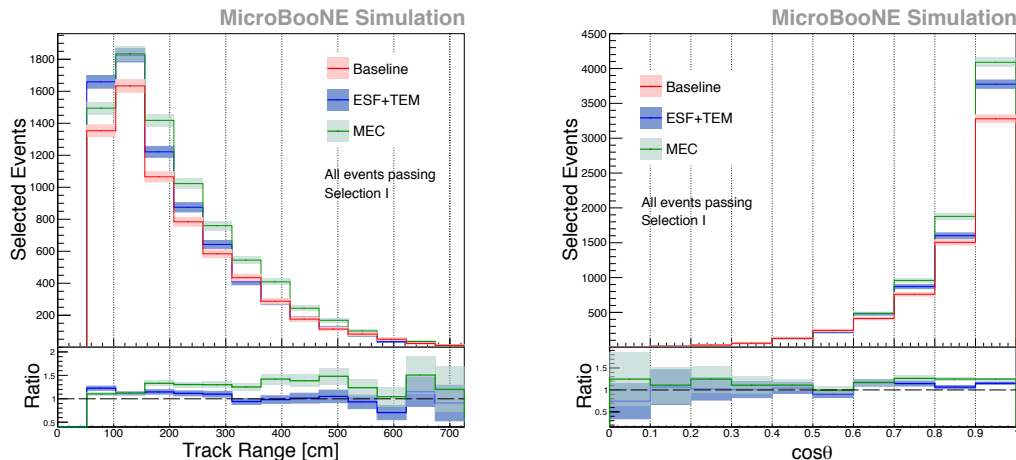


Figure 2. The effect of using different nuclear models in the neutrino simulation on the expected muon reconstructed kinematic distributions of the muon candidate track. The green distribution shows the effect of simulating MEC interactions in addition to the GENIE nominal ones. The blue one shows the effect of using the ESF+TEM model. Uncertainties are statistical only.

3.2. Meson exchange currents (MEC)

Rather than introducing an effective parameter, additional processes are proposed which would address the discrepancies seen in the MiniBooNE data. MEC are one way to model an additional process, where a neutrino interacts with a correlated pair of nucleons (which may be in a quasi-deuteron state). They are also often referred to as $2p2h$, or *multinucleon* interactions. As the correlation between nucleons is mediated by the exchange of a meson, this process is known as MEC. The model referred to as MEC in the following plots is a microscopic model for MEC by Nieves *et al.* [5]. Figure 2 shows the baseline simulation in red and with MEC interactions in green. The effect on the total number of expected selected events is of the order of 24%.

3.3. Effective spectral functions with transverse enhancement

The Transverse Enhancement Model (TEM) [7] is another way to model the nuclear effects. In this model, the transverse cross section is enhanced based on observations in electron scattering data. The empirical superscaling function is modeled with the effective spectral function (ESF) [6]. The ESF replaces the RFG model which is used in all other samples as the GENIE default. Only the lepton is affected by this - there is no impact on the hadronic side of the interaction. Figure 2 shows the baseline simulation in red and with ESF and TEM in blue. The effect on the total number of expected selected events is of the order of 13%.

The studies presented here indicate that the differences between some nuclear models propagated to measurable kinematic distributions will be larger than expected statistical and beam uncertainties. This will allow MicroBooNE to probe different theories of nuclear effects in neutrino-argon scattering.

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