PROCEEDINGS OF SCIENCE

Recent MicroBooNE cross-section results: neutrino-induced baryon production

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The MicroBooNE detector is a liquid argon time projection chamber based at Fermilab that sits on-axis of the Fermilab's Booster Neutrino Beam and off-axis of Fermilab's NuMI beam. MicroBooNE has investigated the MiniBooNE anomaly and published a wide array of inclusive and exclusive neutrino-argon cross section results using both neutrino beams. These proceedings highlight recent public results from MicroBooNE on cross sections involving charged baryons in the final state without mesons. These results have been compared to various event generator simulations with agreement observed between the data and predictions.

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1. Introduction

MicroBooNE took data from 2015 until 2021. As a liquid argon time projection chamber, MicroBooNE can simultaneously detect trajectories and energies of charged particles through their ionization of the argon during their travels in the detector. It is exposed to neutrinos from the Booster Neutrino Beam (BNB) and the Neutrinos at the Main Injector (NuMI) beam [1].

MicroBooNE uses the GENIE event generator for its neutrino interaction simulation and an external tune to T2K muon neutrino CC0π ND280 data [2–7]. The external tune has four free parameters fitted to the data. Both GENIE and the external tune provide uncertainties on reweightable parameters; these uncertainties are used to generate toy experiments, which allow us to assess the impact of neutrino interaction modeling uncertainties on our results [3, 6].

2. Updates on Muon Neutrino Cross Sections without Pions

The BNB is a neutrino beam with a peak at around 1 GeV [8]. Neutrinos that interact typically lead to CCQE-like and CC2p2h events without mesons in the final state. Because of their high rate, samples of neutrino interaction data have led to muon neutrino studies on CC1μ1p (CCQE-like), CC1μ2p, and CC1μNp exclusive cross sections.

A CCQE-like cross section at MicroBooNE has been published previously [9]. The new analysis upgrades the simulation of the event generator to GENIE v3.0.6 using the MicroBooNE Tune and a retooled detector response simulation [6, 10]. The event selection identifies the muon and proton using a log-likelihood ratio that compares stopping muons to stopping protons [12]. It additionally analyzes the transverse kinematic imbalance (TKI) between the final state muon and proton relative to the presumed incoming muon neutrino direction, with an example shown in Figure 1 [11]. The MicroBooNE TKI measurements extracted are the first double-differential TKI measurements in any neutrino experiment.

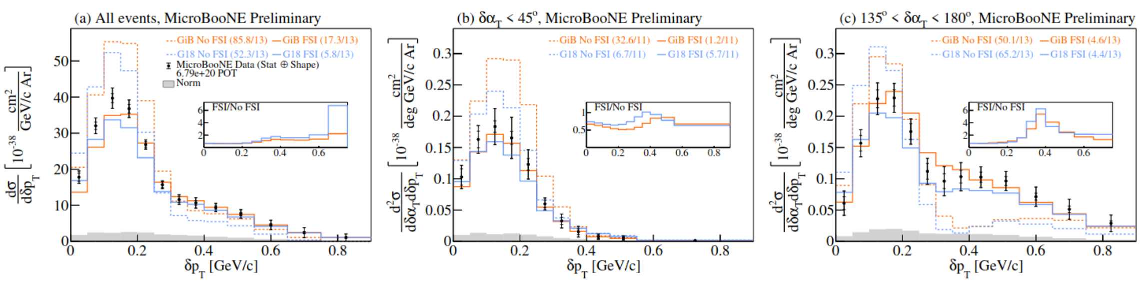

Figure 1: Three CCQE-like cross section distributions binned in missing transverse momentum (δp_{T}) for slices of the transverse angle of the missing momentum ($\delta\alpha_T$). Comparisons are made to predictions from GENIE (G18) and GiBUU (GiB) with and without final state interaction modeling used [4, 5, 11, 13]. The event generator predictions have good agreement with the data when including final state interactions.

Another new cross section analysis on argon from MicroBooNE is the CC1μ2p cross section with a formal publication in progress [14]. The result uses the same log-likelihood ratio used for the CCQE-like analysis to identify events with three particles in the final state, specifically two outgoing protons and one outgoing muon [12]. The analysis measures single-differential cross sections in two ways. First, it measures the angle of separation between the trajectories of the two protons. The second measurement is of the angle between the muon's trajectory and the two protons' total combined trajectory.

MicroBooNE has an in-progress double-differential cross section measurement for muon neutrinos with any number of protons and no mesons in the final state (CC1μNp) [15]. The study also uses the log-likelihood selection of muons and protons in the final state [12]. It is the first double-differential cross section on argon and improves on MicroBooNE's previous publication [16], which used an older detector simulation and the GENIE v2.12.2 event generator [6, 10].

3. Recent Progress on Electron Neutrino Exclusive Mesonless Cross Sections

MicroBooNE has released a public note on an exclusive cross section without mesons in the final state for electron neutrinos using the BNB. The analysis will be published as four single-differential results in terms of the leading proton kinetic energy, electron energy, cosine of the angle of the outgoing proton relative to the BNB, and the cosine of the angle of the electron relative to the BNB [17]. Figure 2 displays the results in terms of the outgoing electron energy [17]. The analysis is the first of its kind and will benefit future argon experiments when assessing model uncertainties for electron neutrino appearance measurements.

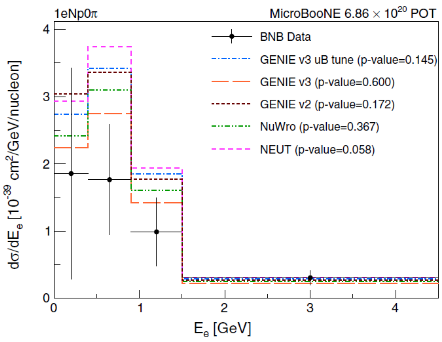

Figure 2: Cross section of CC1eNp0π BNB events binned in terms of outgoing electron energy with comparisons to GENIE, NuWro, and NEUT event generator predictions [4, 17–20].

4. Conclusion

The future of neutrino experiments on argon detectors requires precision measurements of neutrino-argon cross sections to reduce modeling uncertainties and improve the performance of neutrino interaction event generators. This contribution summarized the recent progress in the past year from 2021 to 2022 in exclusive cross section measurements without pions in the final state. MicroBooNE plans to publish each result discussed throughout 2022 and 2023.

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