Multi-differential ν_μ - ^{40}Ar charged current interactions with no pions in the final state with the MicroBooNE detector

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μBooNE

Introduction

In neutrino interactions with heavy elements, the nuclear modeling is not well understood.

→ As a consequence, not directly observed variables (for instance, E_ν) are not accurately estimated.

Main contributions are:
- final-state interactions (FSI)
- Fermi motion
- multinucleon correlation effects

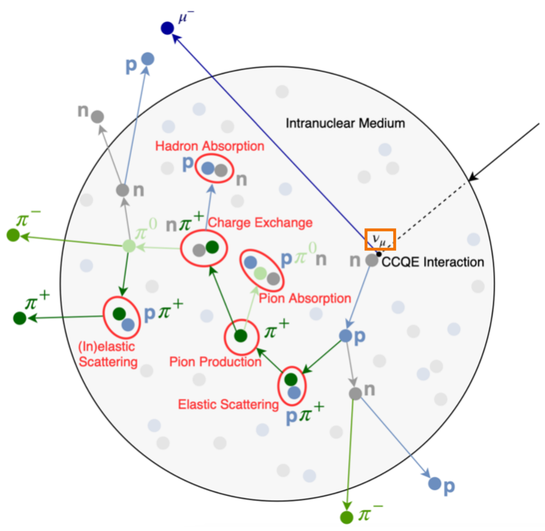

Figure 1: Illustration of FSI in a charged current (CC) quasi-elastic scattering of ν_μ with ^{40}Ar. Figure adapted from [1].

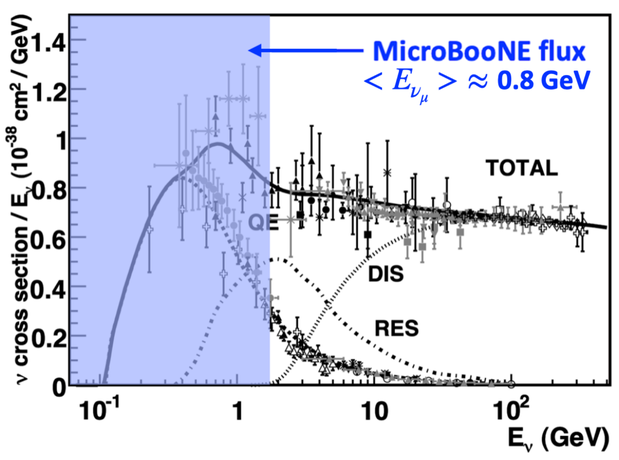

Figure 2: Total ν per nucleon CC cross sections per E_ν. In MicroBooNE, the quasi-elastic process is the most dominant interaction. Figure adapted from [2].

$CC0\pi$ is an exciting channel because:

❖ transverse kinematic imbalance variables, which are sensitive to nuclear effects, can be studied

❖ it can help to connect cross section models between oscillation experiments with different nuclear targets

The MicroBooNE detector operated from 2015 to 2021, accumulating the largest dataset of $\nu_\mu -$ ^{40}Ar CC interactions.

Signal Definition

- 0.1 GeV/c $\leq p_\mu \leq$ 1.2 GeV/c
- the final state contains:
  - at least one proton
  - no mesons and antimesons
- 0.25 GeV/c $\leq p_{p^{leading}} \leq$ 1. GeV/c

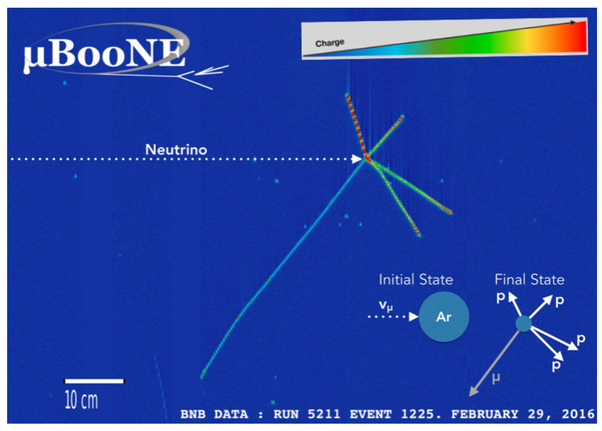

Figure 3: A MicroBooNE event display which includes reconstructed μ and p candidates.

Kinematic Imbalance Variables

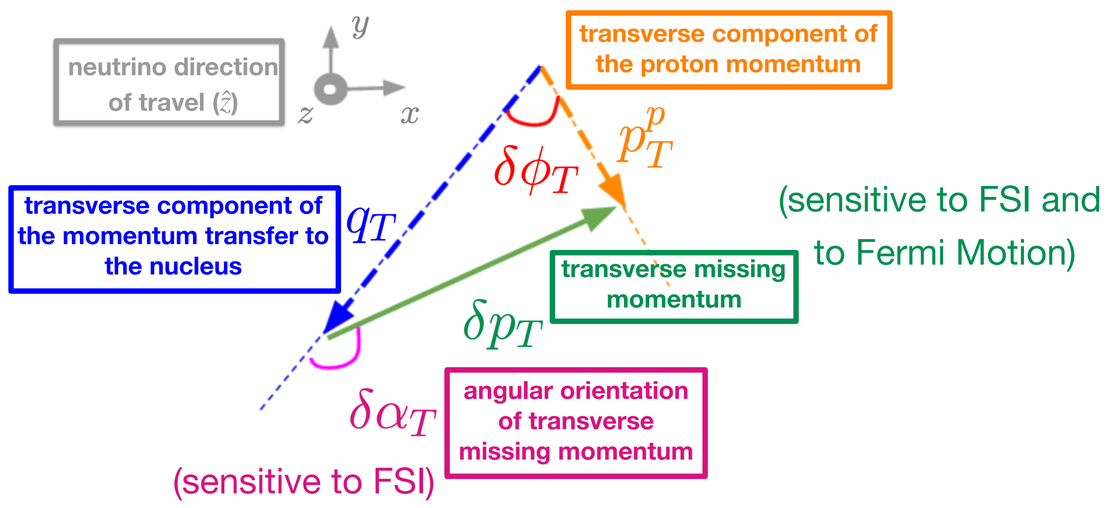

Figure 4: Representation of the kinematic imbalance variables on the transverse plane. Figure adapted from [3].

Results

We present flux-integrated multi-differential cross sections [4]. Statistical (shape-only systematic) uncertainties are included in the inner (outer) error bars. The remainder of the total uncertainty is shown by the gray band along the x-axis.

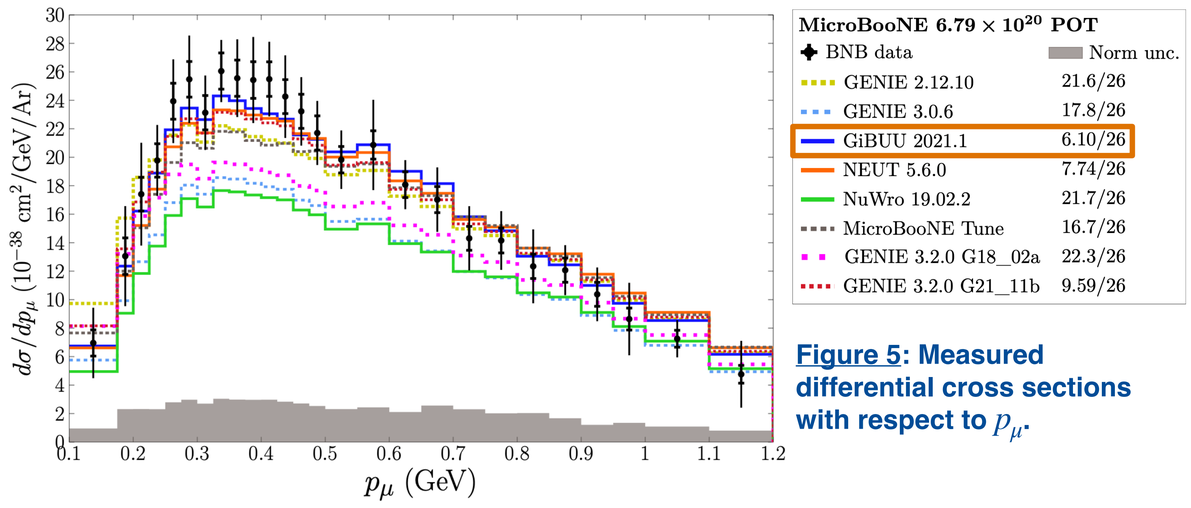

Figure 5: Measured differential cross sections with respect to p_μ.

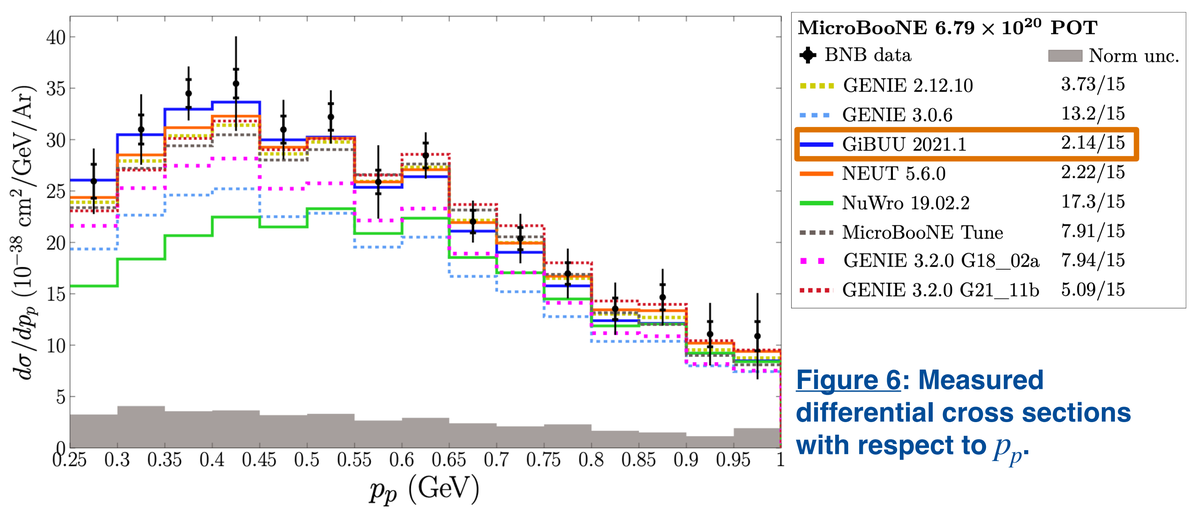

Figure 6: Measured differential cross sections with respect to p_p.

➡The GiBUU 2021.1 model achieves the best level of agreement with data.

➡At moderate p_μ and at low p_p, the measured cross-sections are noticeably larger than the predicted ones. In these regions, the NuWro 19.02.2 model significantly underpredicts.

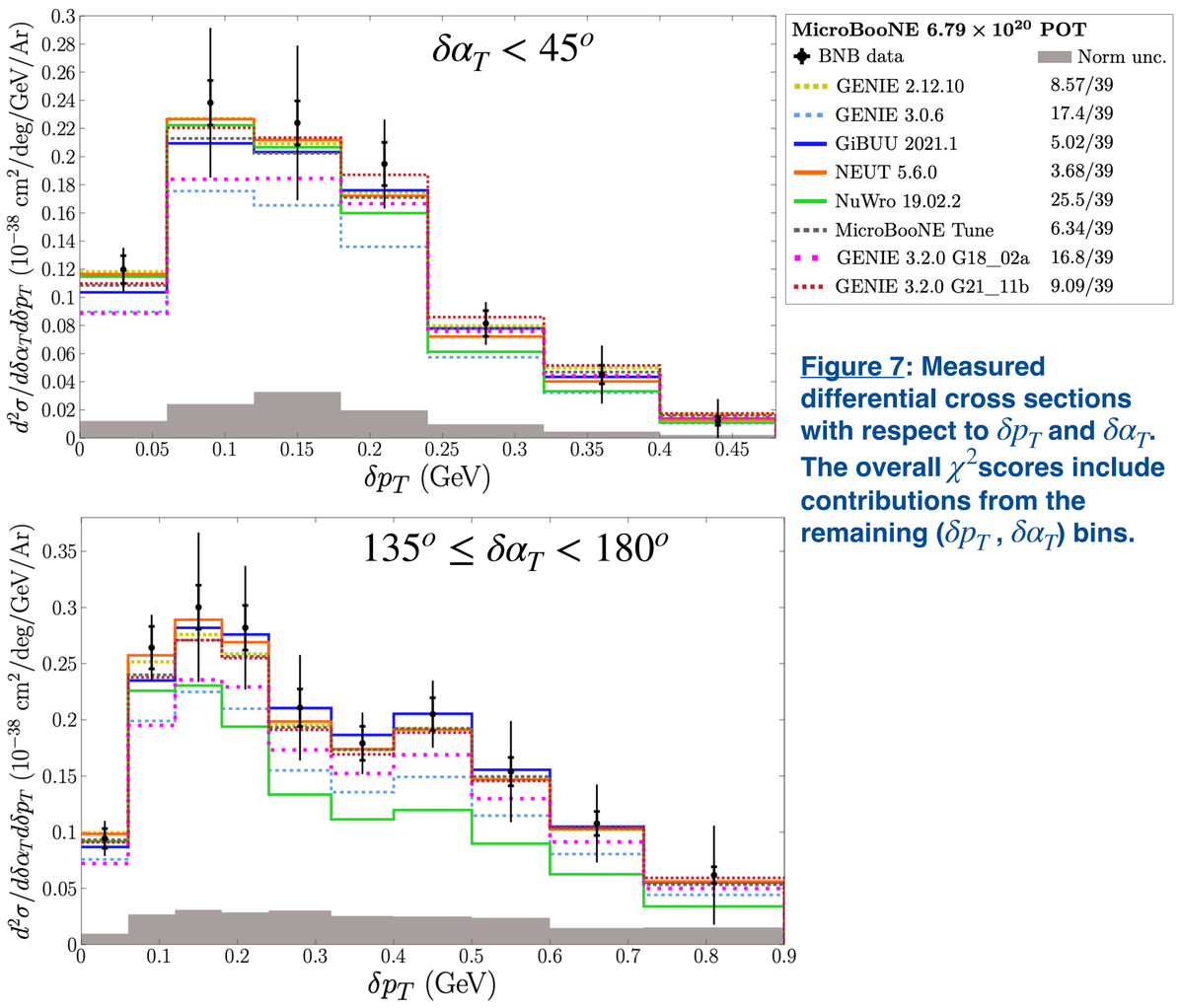

Figure 7: Measured differential cross sections with respect to δp_T and $\delta\alpha_T$. The overall χ^2scores include contributions from the remaining (δp_T , $\delta\alpha_T$) bins.

➡The NuWro 19.02.2 model agrees well with data at low $\delta\alpha_T$, but diverges at high $\delta\alpha_T$. This concludes that, in this generator, proton FSI are underestimated.

References

[1] L. Bathe-Peters et al., arXiv:2201.04664 (2022)

[2] J. A. Formaggio et al., Rev. Mod. Phys. 84, 1307 (2012)

[3] P. Abratenko et al. (The MicroBooNE Collaboration), Phys. Rev. D 109, 092007 (2024)

[4] P. Abratenko et al. (The MicroBooNE Collaboration), arXiv:2403.19574v2 (2024)

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