Comparing Generator Predictions of Single Transverse Variables in Neutrino-Argon Scattering

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Modeling needs for DUNE & SBN
- Liquid argon time projection chambers (LArTPCs) are a powerful technology for neutrino detection
- In the coming years, high-precision measurements of neutrino oscillations will be pursued by two major LArTPC-based neutrino experiments:
  1. The Deep Underground Neutrino Experiment (DUNE)
  2. The Short-Baseline Neutrino Program (SBN)

- The success of these efforts will require substantial improvements in our understanding of neutrino-argon interactions
- Limited data available for argon, extrapolation from better-studied targets (e.g., carbon) not necessarily straightforward
- The theory is complicated: multiple reaction modes over a wide energy range
- Nuclear effects pose a particularly difficult challenge

Generator predictions for MicroBooNE
- MicroBooNE is a 170-ton LArTPC currently operating in the Fermilab Booster Neutrino Beam
- Several years of data collected so far → potential to provide the first measurement of STVs in neutrino-argon interactions
- To examine what might be learned from such a measurement, we compared predictions for MicroBooNE from four widely-used neutrino event generators
  - Event topology of interest is CC1p0n0p: one muon, zero pions, and at least one proton in the final state (N ≥ 1)
  - Models used are shown underlined in green

Single Transverse Variables (STVs)
- Observables that quantify the momentum imbalance between the final-state muon and leading proton in the transverse plane
  - ∆pT: Magnitude of the momentum imbalance
  - ∆pT, ∆θT: Angles specifying its direction
- Provide enhanced sensitivity to nuclear effects → data can help us to improve interaction models
- Not yet measured for argon

Selected Results
What is the main driver of the ∆θT asymmetry?
All 4 generators predict an enhanced cross section at high ∆θT

A double-differential measurement of STVs could help to discriminate between these possibilities

Measuring ∆pT in the high-∆θT region highlights the difference between GiBUU and the other generators

Conclusion
- Precise modeling of neutrino-argon scattering is a crucial requirement for the DUNE and SBN neutrino oscillation programs
- Single transverse variables provide a powerful handle on theoretically-challenging nuclear effects in neutrino-carbon scattering, but they remain unmeasured for argon
- The MicroBooNE experiment has the opportunity to achieve the first measurement of STVs in a LArTPC
- The first detailed study of generator predictions for STVs in νµ-Ar scattering, reported in this poster, reveals substantial opportunities for model discrimination
  - Relative contributions of CCQE vs. 2p-2h interactions
  - Treatment of nucleon pair initial state
- We encourage MicroBooNE to pursue a measurement of this kind. Many more generator comparisons from our study are available in [5]