NuFact 2022
The 23rd International Workshop on Neutrinos from Accelerators

μBooNE

MicroBooNE cross sections with protons in the final state

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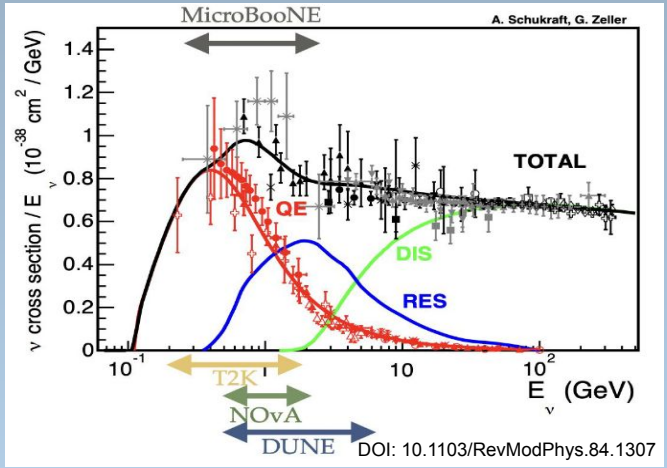
NuFact 2022, Salt Lake City, UT

HARVARD UNIVERSITY Fermilab

Signal Definition

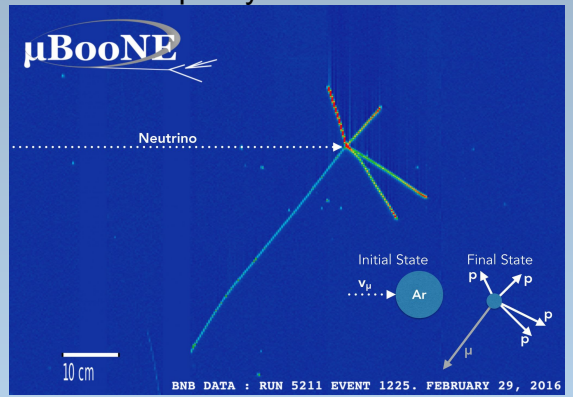
Motivation

- Charged-current quasi-elastic scattering events are the most common event topology in MicroBooNE
- CCQE events also contribute significantly in longer-baseline experiments



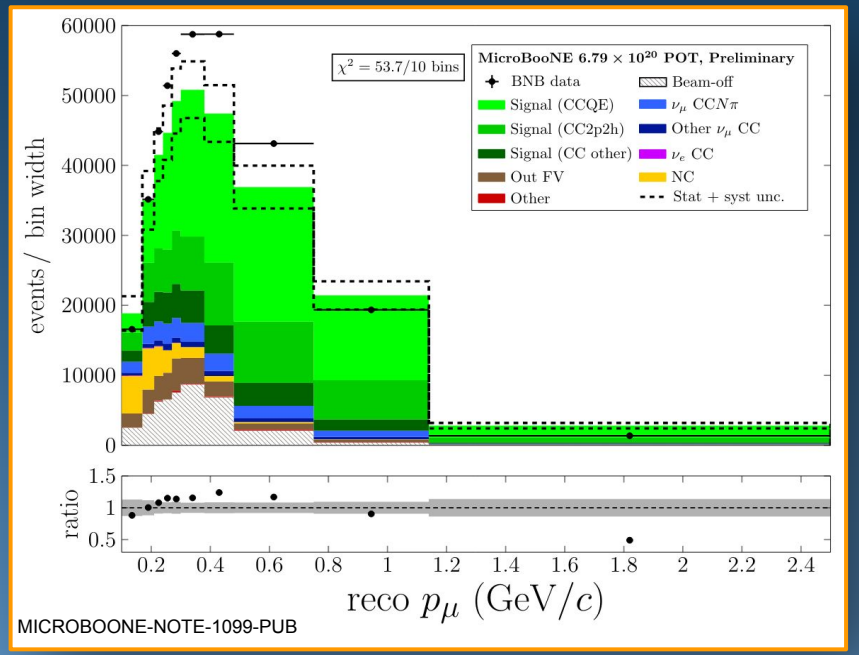
The Signal

- Muon-neutrino events with no mesons and
  - at least one proton in the final state: CC0πNp, single-differential measurement
  - exactly one proton above 0.3 GeV in the final state: CC0π1p, transverse variable measurement
- Events must be fully contained within the fiducial volume and pass a series of quality cuts to be included in each analysis



CC0πNp Event Rate

- Clear excess of interactions in the lower reconstructed muon-momentum range
- The Data/MC ratio shows a difference in shape between data and our Monte Carlo prediction
- This disagreement emphasizes the need for better understanding on neutrino-nucleon interactions, especially in liquid argon
- Final cross-section extraction ongoing
- A fruitful area for that better understanding is the study of Transverse Kinematic Imbalance (TKI)



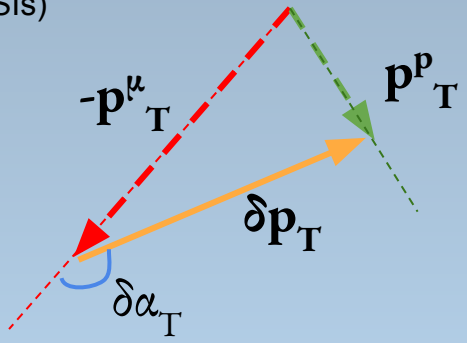
MICROBOONE-NOTE-1099-PUB

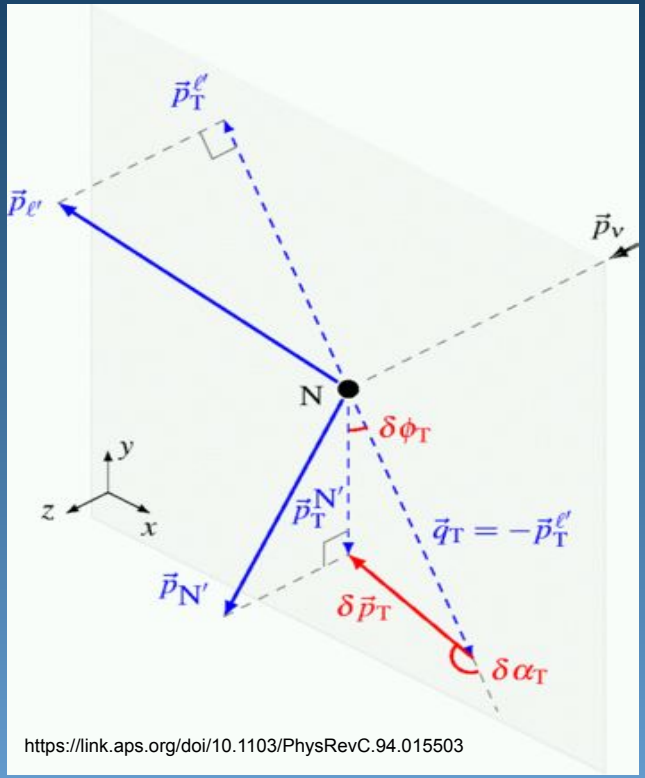
For further information, see the public note or contact lead analyser Steven Gardiner, gardiner@fnal.gov

Probing Nuclear Effects

Transverse Kinematic Variables

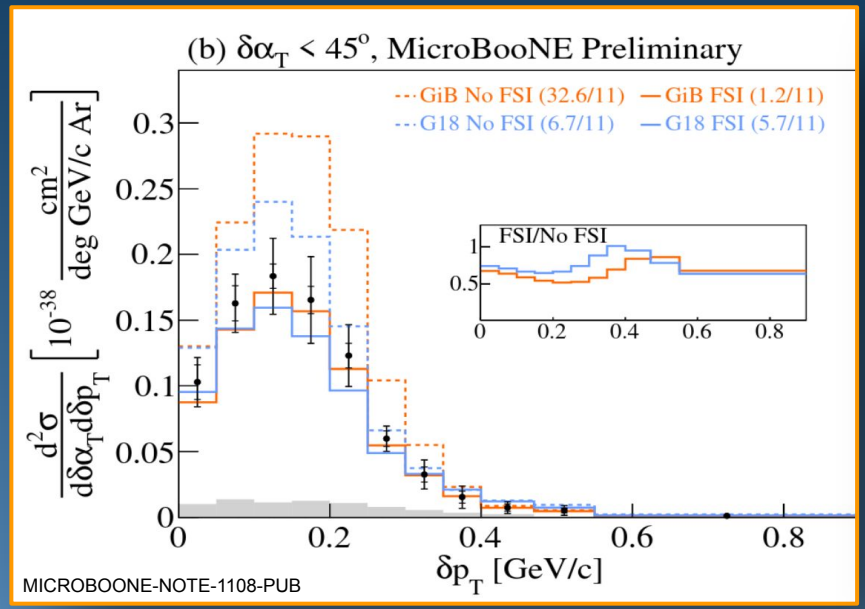
- Neutrino energy is calculated from measured kinetic energies of particles emitted by the neutrino interaction
- The kinematic properties of these final state particles are influenced by nuclear effects, leading to imbalances in the transverse plane
- Transverse variables are built to characterize these nuclear effects e.g. Fermi motion and final-state interactions (FSIs)

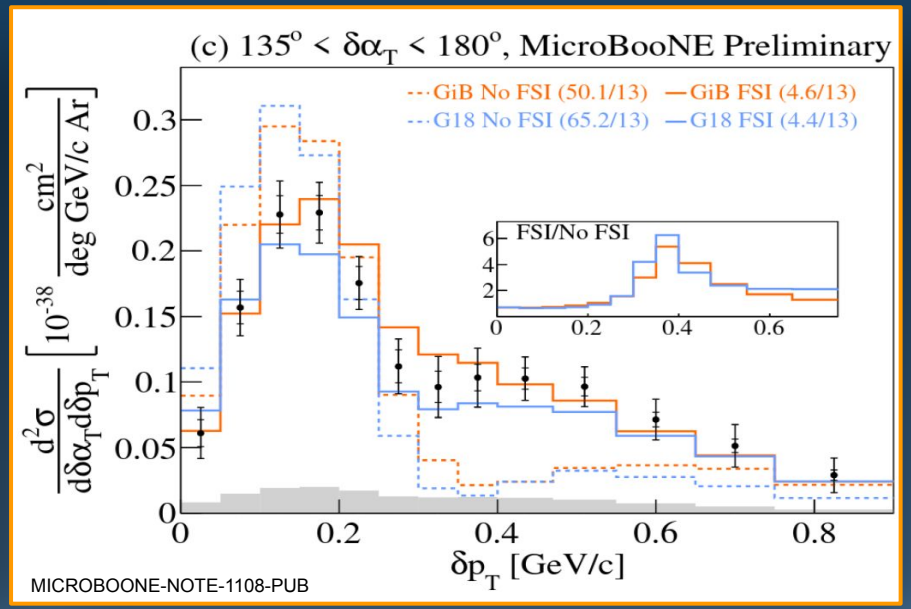




https://link.aps.org/doi/10.1103/PhysRevC.94.015503

CC0π1p TKI Cross Sections





The CC0π1p double-differential cross section in terms of the transverse variables $\delta\alpha_T$ and δp_T. Predictions from GENIE (G18) and GiBUU (GiB) with and without final state interactions (FSIs) are shown, with χ^2/dof for each. The transverse variable cross-sections begin the work of model discrimination, strongly disfavoring the no-final state interaction hypothesis.

For a complete explanation of these results, see talk by Afroditi Papadopoulou at 11:15am today, and consult the corresponding public note

Take Home Message

These results point to data-MC disagreement and indicate that FSIs are present, paving the way for nuclear interaction model discrimination for use in future measurements.

A complete double-differential cross section in terms of transverse variables is a significant piece of this ongoing work.

The full double-differential CC0πNp TKI study is already underway and we're hoping to publish it soon.

Learn More

Cross section measurements presented here are described in MICROBOONE-NOTE-1108-PUB and MICROBOONE-NOTE-1099-PUB.

For further cross section results from MicroBooNE, see August 5th talks by Afroditi Papadopoulou and Elena Gramellini.

These results are one piece of MicroBooNE's comprehensive neutrino-LAr cross-section measurement program, covering muon- and electron- neutrino cross sections in a wide variety of interaction types.

Thanks to Mark Ross-Lonergan for summarizing elegantly in his talk on Thursday AM, and h/t to Steven Gardiner for maintaining this list (right).

For applications of these and other cross-section results, refer to Steven's Thursday talk on developments in the GENIE neutrino event generator

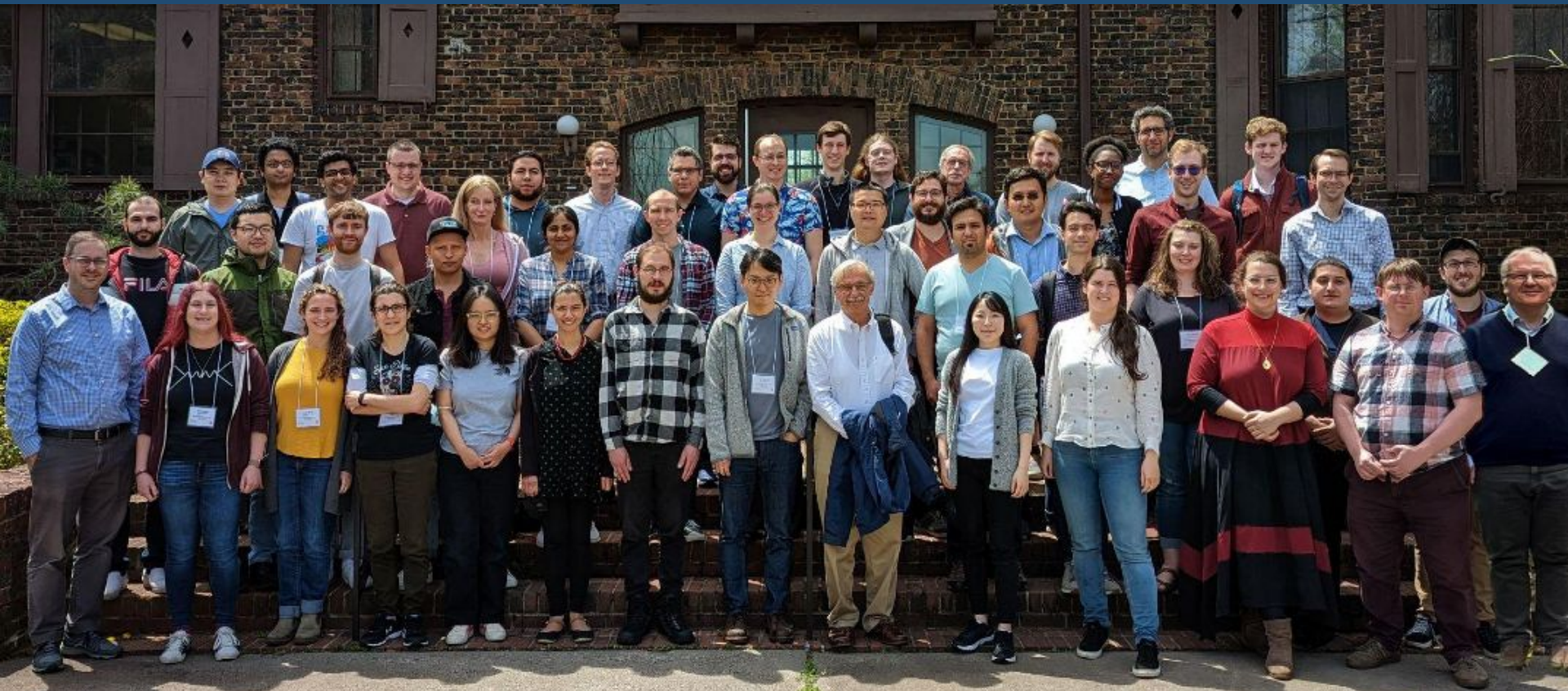
Recent Publications and Preprints

PRD 102, 112013 (2020)	ν_μ CC 0π (≥1)p
PRD 102, 052002 (2021)	Total $\nu_e + \bar{\nu}_e$ CC inclusive
PRD 105, L051102 (2022)	Differential $\nu_e + \bar{\nu}_e$ CC inclusive
PRL 128, 151801 (2022)	Energy-dependent ν_μ CC inclusive
PRD 105, 072002 (2022)	MicroBooNE GENIE Tune
arXiv:2205.07943, submitted to PRD	Total NC $1\pi^0$

Recent Public Notes

MICROBOONE-NOTE-1107-PUB	ν_μ CC $1\pi^0$
MICROBOONE-NOTE-1108-PUB	ν_μ CC 0π 1p TKI
MICROBOONE-NOTE-1109-PUB	ν_e CC 0π
MICROBOONE-NOTE-1110-PUB	Methods for 3D ν_μ CC
MICROBOONE-NOTE-1111-PUB	NC (≥1)π^0
MICROBOONE-NOTE-1112-PUB	$\bar{\nu}_\mu$ CC Λ
MICROBOONE-NOTE-1117-PUB	ν_μ CC 0π 2p

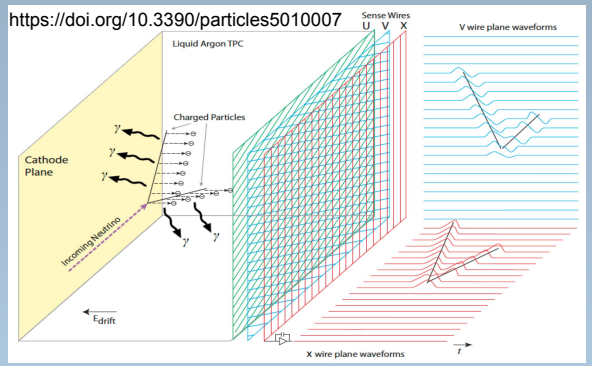
Thank you!



MicroBooNE and LAr-TPCs

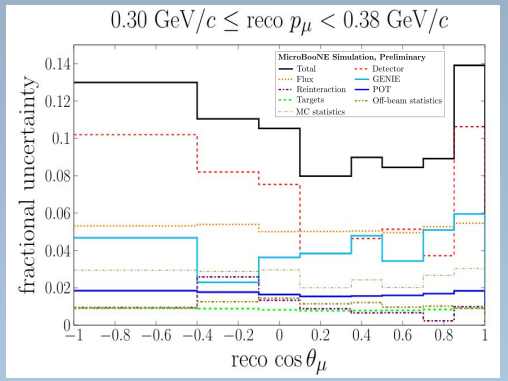
The Detector

- The MicroBooNE detector is an 85 tonne LAr-TPC in the BNB at Fermilab, 470 m from the target
- Results in the poster summarized here use data from Runs 1-3, with a total exposure of 6.79×10^{20} POT



Uncertainties in LAr-TPCs

- The leading source of uncertainties Liquid Argon Time Projection Chambers (LAr-TPC) experiments is the neutrino-argon cross section
- Advanced cross-section measurements from MicroBooNE can reduce these uncertainties by more than a factor of five



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