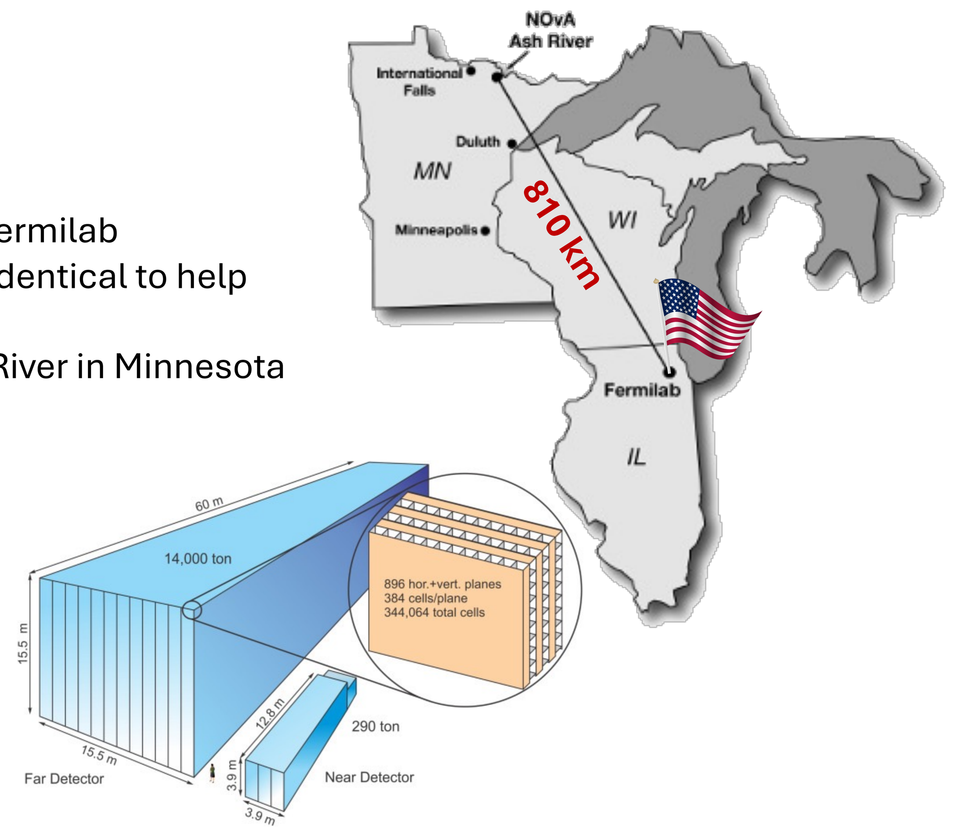
FERMILAB-POSTER-24-0016-PPD

Measuring muon antineutrino charged-current interactions without mesons in the final state, in the NOvA Near Detector

Queen Mary University of London
School of Physical and Chemical Sciences

Kevin Vockerodt, on behalf of the NOvA Collaboration
k.j.vockerodt@qmul.ac.uk
Supervisor: Dr Linda Cremonesi

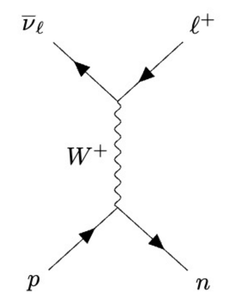
The NOvA Experiment



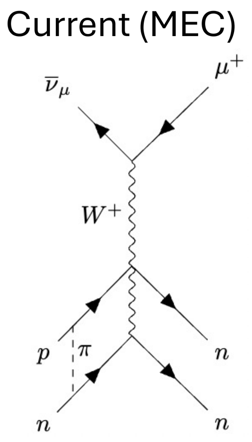
- Long baseline neutrino experiment:
  - High purity (anti)neutrino beam produced at Fermilab
  - Two off-axis detectors which are functionally identical to help reduce systematic uncertainties
  - Far Detector: 810km from the source, at Ash River in Minnesota
- Primary goals:
  - Observe and measure neutrino oscillations
  - Determine the neutrino mass ordering
  - Investigate the matter / antimatter asymmetry

Antineutrino Interactions

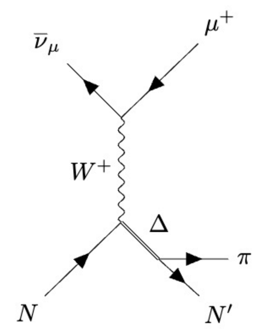
Quasi-elastic Scattering (QE)



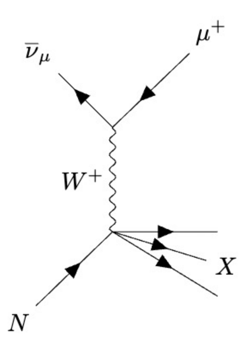
2p2h, e.g. Meson Exchange Current (MEC)



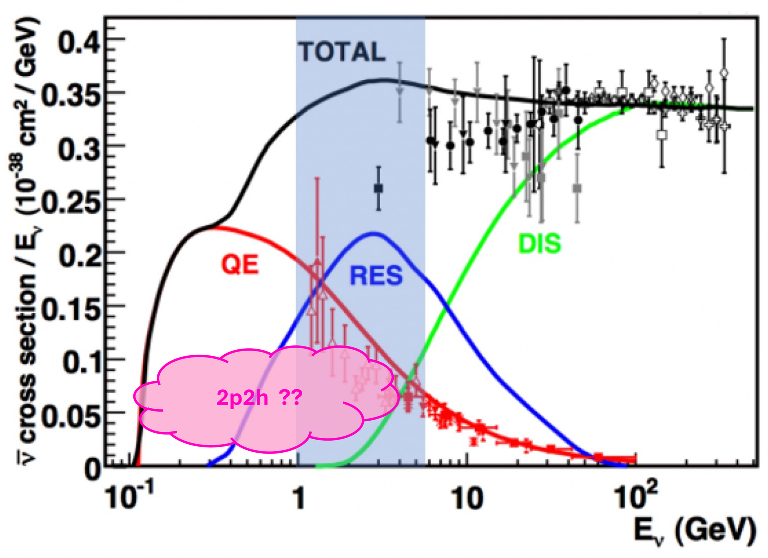
Resonant Pion Production (RES)



Deep Inelastic Scattering (DIS)

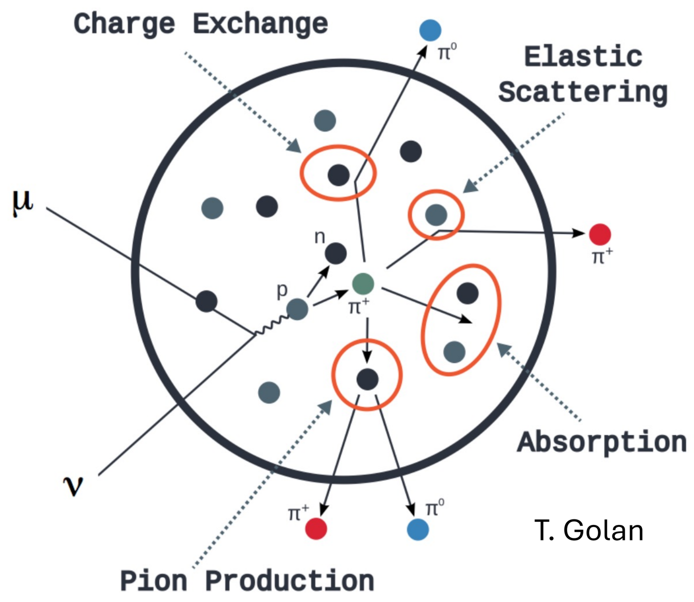


J. Formaggio and G. Zeller (arxiv:1305.7513) *(adapted)*



NOvA's neutrino flux (shaded blue) lies in the transition region between the main interaction processes.

Why is a NOvA Zero-Meson Antineutrino Analysis Interesting?

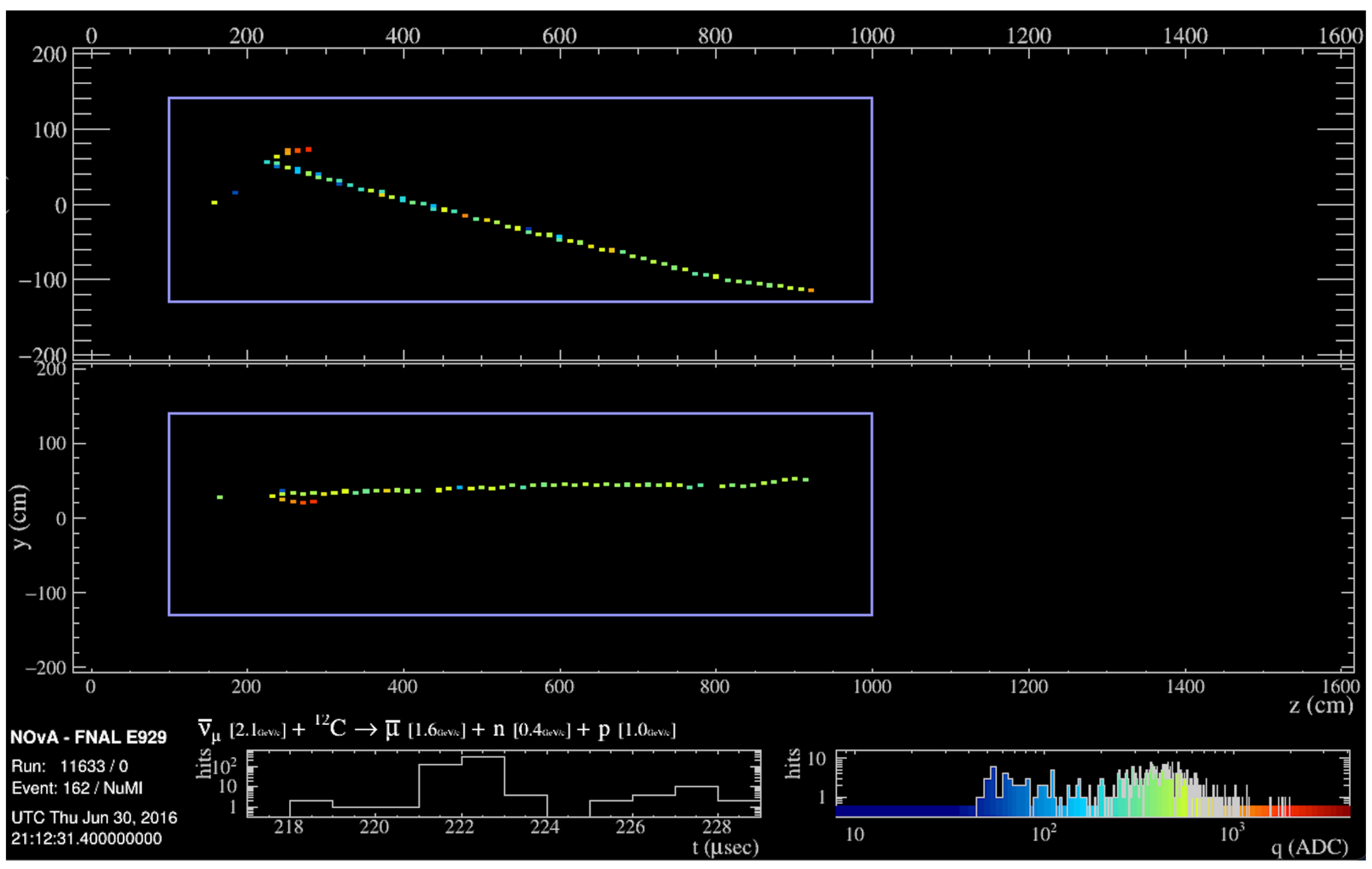


- High purity sample with low statistical uncertainties
- Study 2p2h processes in the antineutrino sector, and compare data with current QE and MEC models
- Investigate final-state interactions (FSI) by probing the low energy region close to the nucleus

The Sample

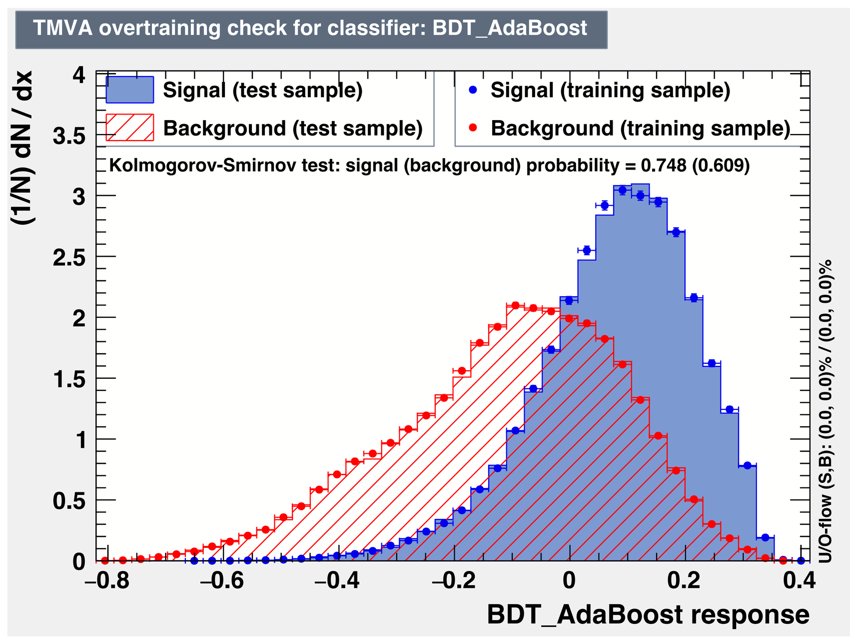
- Signal: Charged-current muon antineutrino event with no true mesons above a threshold energy of 100 MeV (542,576 events)
- Main backgrounds: Neutral-current events, wrong sign (muon neutrino) beam contamination, and all events with meson energy > 100 MeV (165,217 events)
- Sample Purity: 76.7%
- Efficiency: 27.6%

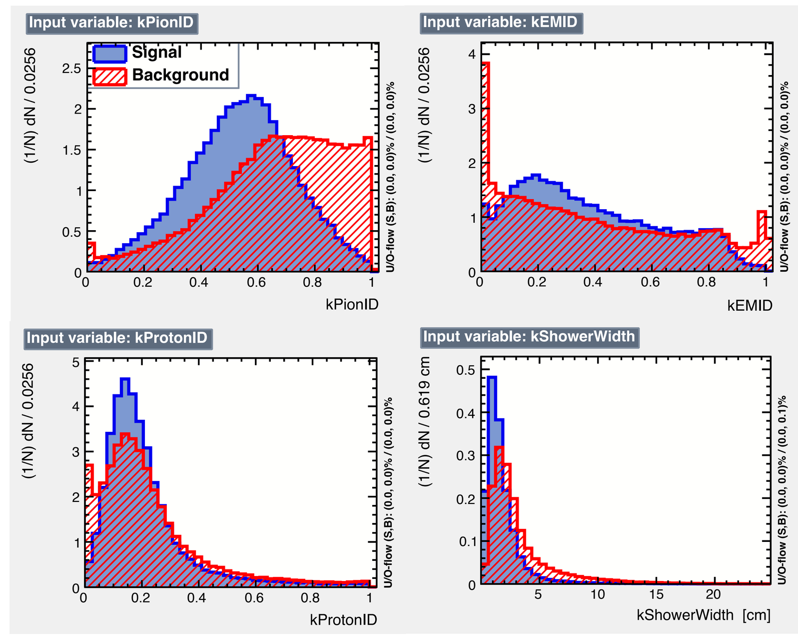
Zero-Meson Event Display



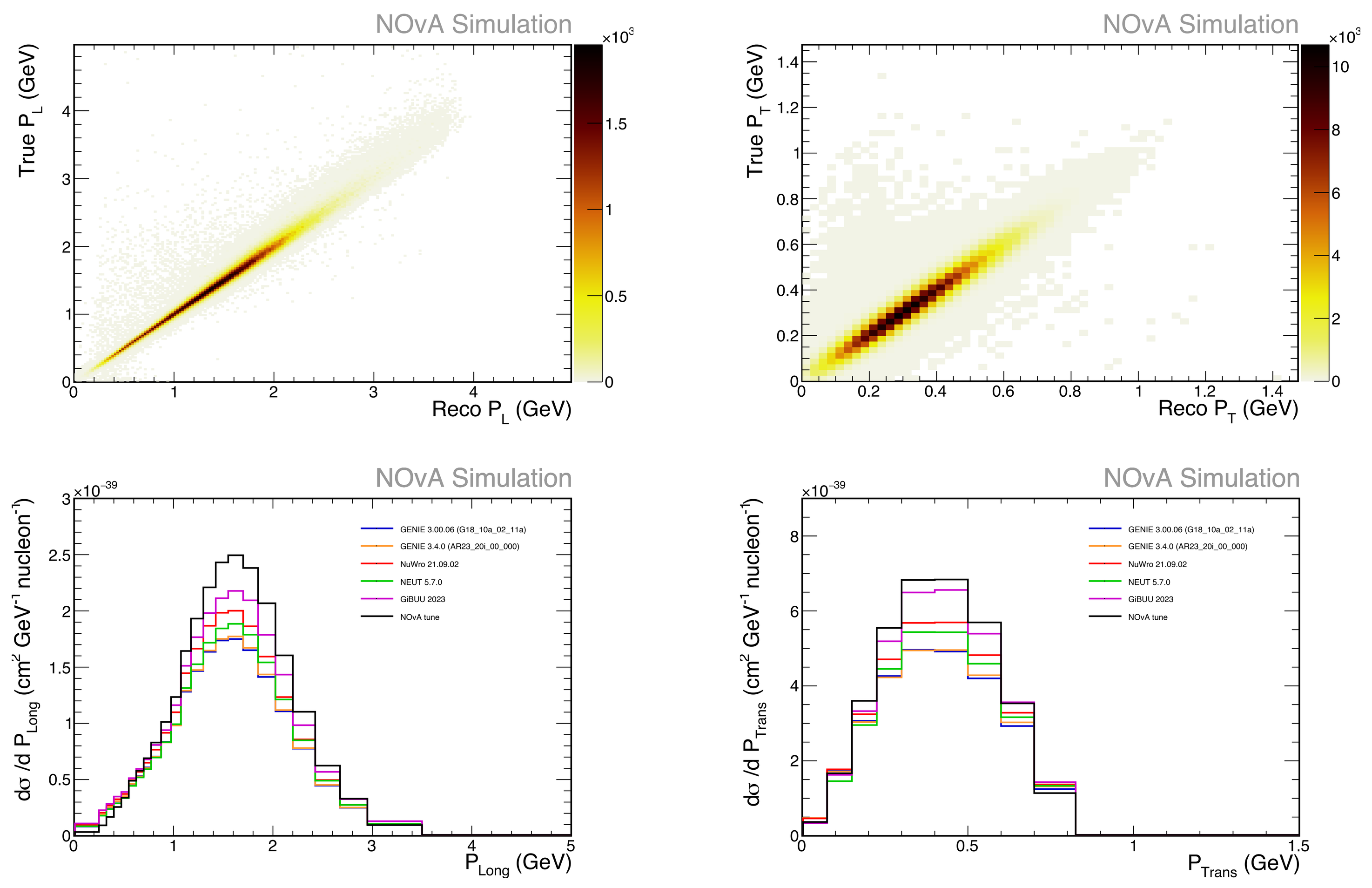
MERMAID: Zero-Meson BDT

- **Machine-Enhanced RHC Meson Abolition ID** – a novel BDT trained to identify events without mesons.
- Trained on multitrack events (e.g. one muon + *N* hadrons)
- Inputs include: convolutional neural network likelihood scores for particle identification, the width of any identified shower and the gap between the interaction vertex and the shower



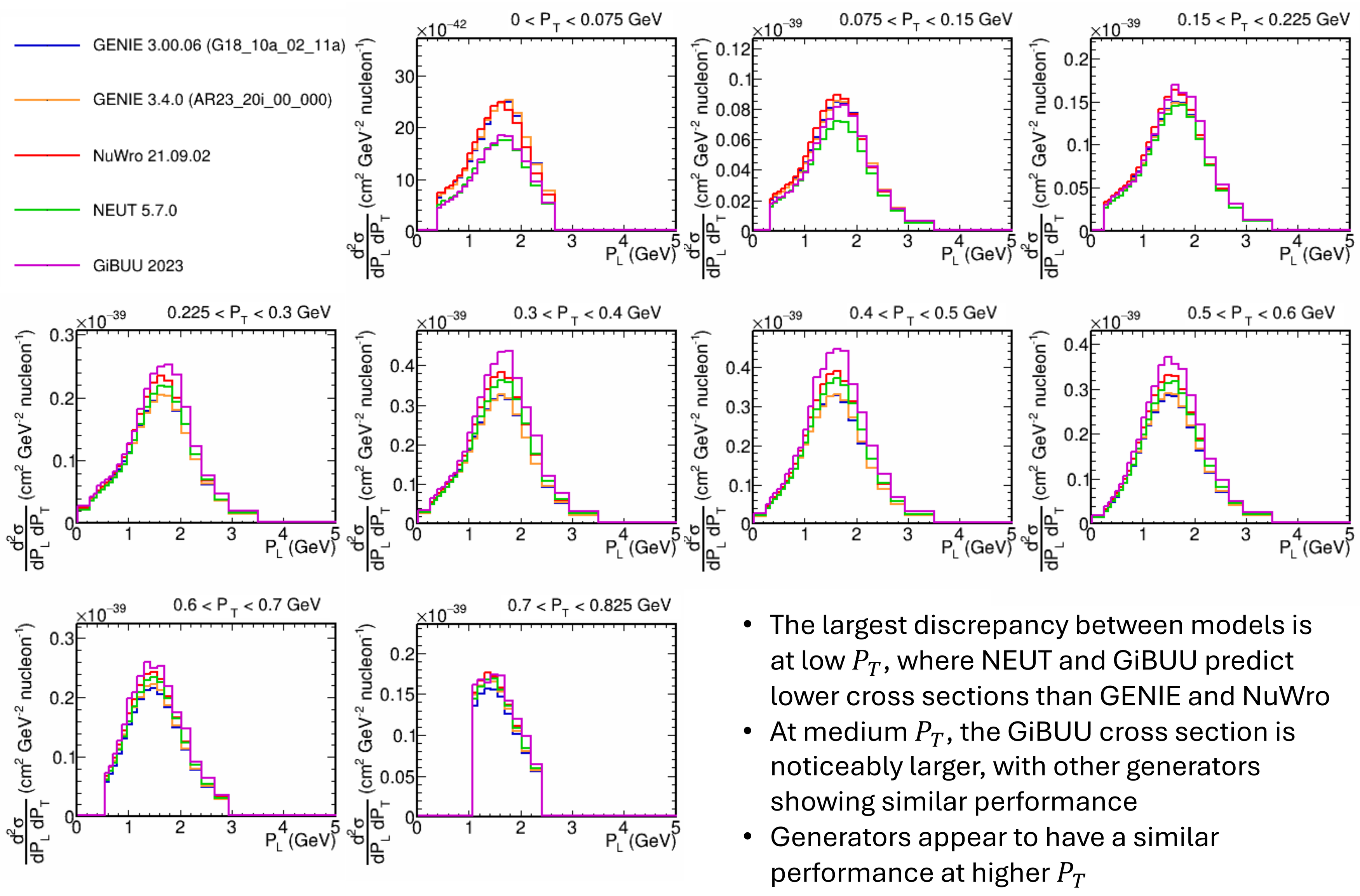


Longitudinal and Transverse Muon Momentum



Double-Differential Cross Section Measurement

$$\left(\frac{d^2\sigma}{dP_L\, dP_T}\right)_i = \frac{\sum_j U_{ij}\left[N^{sel}(P_L,P_T)_j\, \mathrm{Pur}(P_L,P_T)_j\right]}{\mathrm{Eff}(P_L,P_T)_i\,(\Delta P_L)_i\,(\Delta P_T)_i\, N_{\mathrm{targets}}\,\Phi}$$



- The largest discrepancy between models is at low P_T, where NEUT and GiBUU predict lower cross sections than GENIE and NuWro
- At medium P_T, the GiBUU cross section is noticeably larger, with other generators showing similar performance
- Generators appear to have a similar performance at higher P_T

Outlook

- New measurement of zero-meson antineutrino charged-current interactions in the NOvA near detector, reporting a double-differential cross section in muon kinematics (longitudinal and transverse momentum) and single-differential cross sections in the derived variables Q^2 and E_ν
- A range of FSI, QE and MEC models used by different generators can be tested and evaluated with this measurement
- Next Steps:
  - Unfolding and Fake Data studies
  - Systematic Uncertainty study
  - Unblinding – finally look at real data!
  - Further model comparisons

Fermilab
NOvA
UKRI Science and Technology Facilities Council

This document was prepared by NOvA Collaboration using the resources of the Fermi National Accelerator Laboratory (Fermilab), a U.S. Department of Energy, Office of Science, Office of High Energy Physics HEP User Facility. Fermilab is managed by Fermi Research Alliance, LLC (FRA), acting under Contract No. DE-AC02-07CH11359