FERMILAB-POSTER-26-0062-PPD

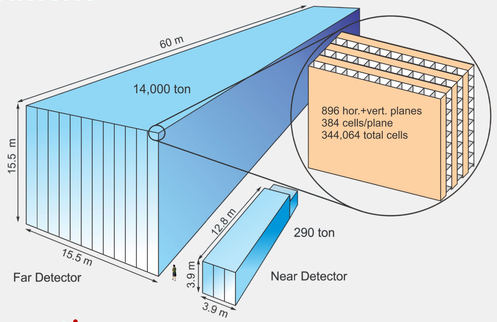
Measurement of $\bar{\nu}_\mu$ CC - 0 meson scattering, using the NOvA Near Detector

Kevin Vockerodt, Taylor Contreras, on behalf of the NOvA Collaboration

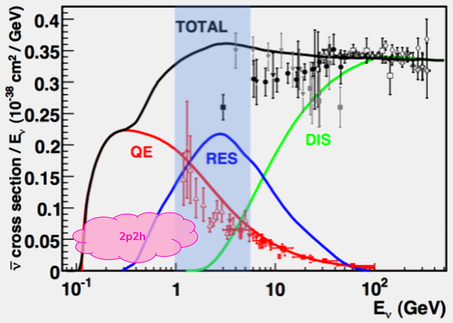
Queen Mary University of London · Fermilab · The Ohio State University

The NOvA Experiment

- Off-axis long-baseline neutrino experiment
- High-purity (anti)neutrino beam
- Near Detector: at Fermilab, IL
- Far Detector: 810 km from the source, at Ash River, MN

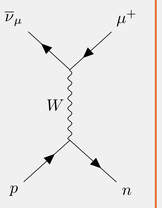


Antineutrino Interactions

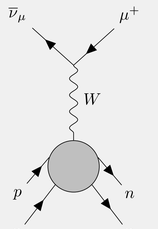


NOvA's neutrino flux (blue) lies in the transition region between the main interaction processes. (Image adapted from J. Formaggio and G. Zeller)

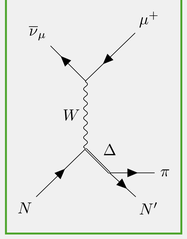
Quasi-elastic Scattering (QE)



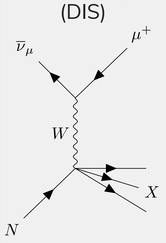
2p2h, e.g. Meson Exchange Current (MEC)



Resonant Production (RES)

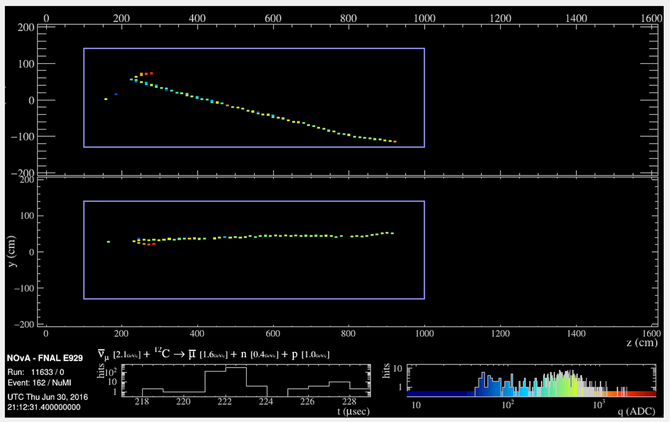


Deep Inelastic Scattering (DIS)



Physics Motivation

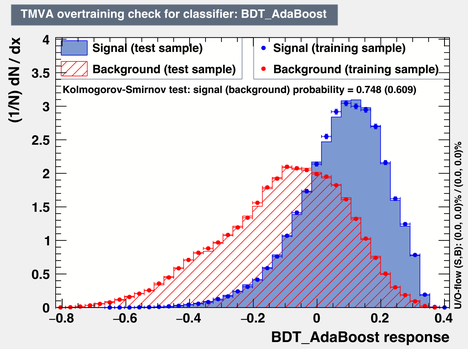
- NOvA has a high-statistics Near Detector dataset
- Selection strategy can yield a high purity 0-meson sample
- Precision measurements of antineutrino scattering with highly enriched QE and 2p2h rates enable detailed comparisons to models

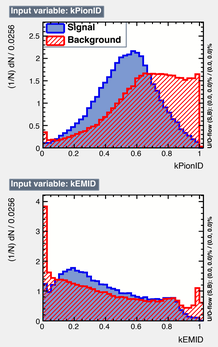


NOvA Near Detector zero-meson event display

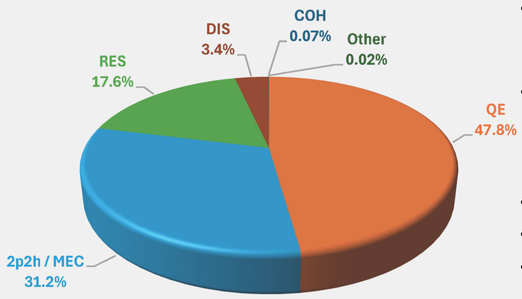
MERMAID: Zero-Meson BDT

- **Machine-Enhanced RHC Meson Abolition ID** – BDT trained to identify events without mesons
- Trained on multi-track events (e.g. one muon + *N* hadrons or mesons)
- Inputs:
  - convolutional neural network likelihood scores for pions, protons and electromagnetic particles
  - width of any shower
  - gap between the interaction vertex and shower
  - likelihood of the event containing a Michel electron





Selection

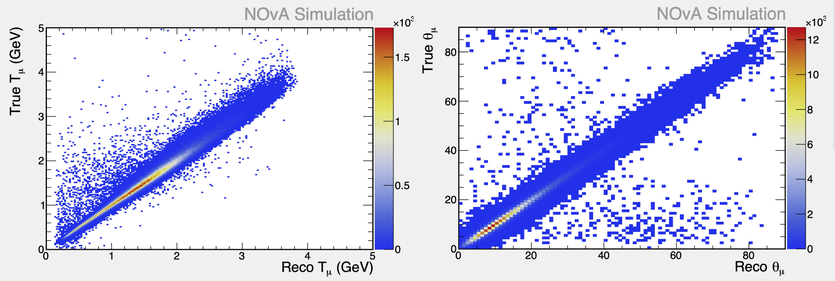


Breakdown of the final sample, in terms of the true interaction mode

- **Signal**: $\bar{\nu}_\mu$ events with no true mesons above a threshold energy of 100 MeV
- **Main backgrounds**: Neutral-current events; wrong sign (ν_μ) interactions; below-threshold mesons
- **Sample Size**: 453,122 events
- **Purity**: 80.3%
- **Efficiency**: 25.0%

Measurement Observables

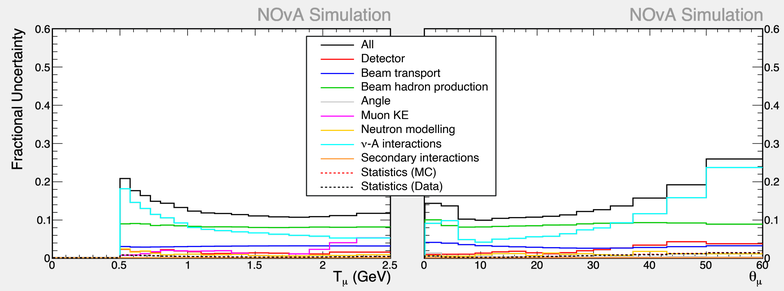
- Double-differential measurement in muon kinematics: kinetic energy (T_μ) and scattering angle (θ_μ)
- Measurements of neutrino energy and momentum transfer



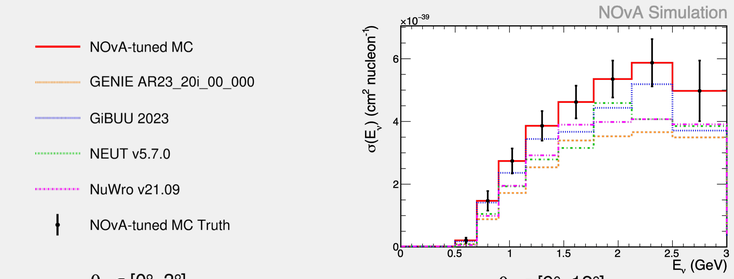
Migration matrices for the muon kinematic variables

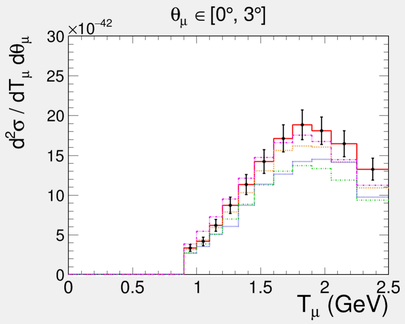
Uncertainties

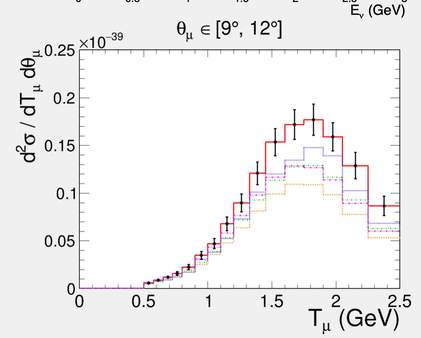
- Systematic uncertainties are dominated by cross-section modelling uncertainties, and a beam flux uncertainty of ~ 9%



Cross Section Generator Comparisons







- For all E_ν and for high T_μ, the GENIE AR23 tune (the default DUNE tune) shows the greatest discrepancy with the NOvA-tuned simulation, while GiBUU gives closer agreement in terms of the normalisation
- At low T_μ, GENIE AR23 and NuWro show the closest agreement with the NOvA tune, with GiBUU and NEUT performing less well
- Comparing unfolded MC with MC Truth demonstrates closure and partially validates the analysis framework

Next Steps

- Further 2p2h systematic studies
- Data-driven background constraint studies
- Box-opening to look at real NOvA data

Acknowledgements

This poster was prepared 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 Forward Discovery Group, LLC, acting under Contract No. 89243024CSC000002.