1 Introduction:

- NOvA is a two detector long baseline neutrino oscillation experiment.
- The two detectors, one located 1 km from the beam target at Fermilab and the other located 810 km away in Minnesota, are functionally equivalent.
- The main analyses are the disappearance of muon neutrinos and the appearance of electron neutrinos in Fermilab’s NuMI beam.
- These are used to make measurements of the neutrino mass hierarchy, the exponent of the large mixing angle, and CP-violation.
- Assessment of systematic uncertainties and cross-check studies are crucial steps in making precise measurements.

2 Evaluating Systematics

- The ND selected νμ are oscillated to the far detector in decomposed components to make a prediction of the background components. The νμ signal prediction is made by oscillating ND selected νμ to the FD.
- Sources of systematic uncertainties are measured by producing shifted ND and FD simulation samples by either event reweighting or producing specially shifted files.
- The extrapolation process is carried out using these modified simulation samples and the effect of the systematic can be evaluated by comparing the predicted number of events.
- Extrapolated FD prediction in 3 PID bins for the dominant absolute calibration systematic is shown here as an example with the systematic error band.
- In the neutrino mode the systematic shift is -2.81% / +1.37%, whereas in antineutrino mode, it is +0.58% / -0.59%.

3 Systematics

- The ND is functionally equivalent to the FD. Using this, extrapolating ND spectra to FD spectra greatly reduces systematic uncertainties.
- The overall uncertainty in the νμ signal is reduced from 15% to 8.5% for neutrinos and from 12.5% to 5.5% for antineutrinos.

4 MRE Cross-Check:

- The ND data allows a close look at backgrounds to the νμ appearance signal, but offers little information about what may be expected of the signal events.
- Muon removed electron (MRE) events are constructed from νμ CC interactions by removing the primary muon track and simulating an electron in its place. Performed on both data and simulation.
- This combines electron showers that are simulate well, with hadronic shower data, which aren’t well simulated, and helps understand how the mismodeling of hadronic showers impacts νμ selection.

5 MRBrem Cross-Check:

- A key cross-check for the νμ signal induced electromagnetic (EM) shower PID selection efficiency in FD, is to compare with that of Muon-Removed Bremsstrahlung Showers (MRBrem) PID selection efficiency.
- In 2018 neutrino analysis, the data/MC difference is of the order of 6% in core and 7% in peripheral samples respectively.
- Good data and MC agreement is found in EM shower selection from cosmic samples.

6 Summary and Conclusions:

- Systematics are integral to NOvA oscillation results. We fit the antineutrino and neutrino joint νμ + νe predictions to extract the oscillation parameters.
- The measurement of the oscillation parameters is primarily limited by statistics.
- MRE and MRBrem cross-check studies show a good agreement between data and MC.

For more NOvA posters:
- L. Kukupolana, A. Back NOvA joint νμ,νe oscillation results in neutrino and antineutrino modes
- T. Alon Systematic Uncertainties in the NOvA νμ Disappearance Analysis
- M. Baird Reconstructing Neutrino Energies with the NOvA Detectors
- G. Davies Short-Baseline Sterile Neutrino Searches with the NOvA Near Detector
- D. Hwang Measurement of Neutrino-Electron Elastic Scattering at NOvA Near Detector
- P. Pshas, M. Groh Neutrino physics with deep learning. Techniques and applications on NOvA.
- J. Hewes Search for sterile neutrinos in neutrino data in the NOvA near and far detectors
- D. Monzor First νμe, νeνμ Disappearance Results from the NOvA experiment
- A. Mavicevic, J. Wolcott Neutrino Interaction Model Tuning at NOvA
- M. Muether Status of the Neutrino-Induced Neutral Current Neutral Pion Production Cross Section Measurement from NOvA

S. Yu, T. Nosek. Data-driven Techniques for νe Signal and Background Predictions in NOvA
A. Shekhovtsov, A. Halik. J. Vaseil Detection of Galactic Supernova Neutrinos at the NOvA Experiment
E. Smith. M. Baird Reconstructing Neutrino Energies with the NOvA Detectors
M. Strait Astrophysics with NOvA