PROCEEDINGS OF SCIENCE

The NOνA Test Beam Program

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NOνA is a long-baseline off-axis beam neutrino experiment. By measuring ν_μ disappearance and ν_e appearance at the 14 kiloton NOνA Far Detector, the experiment is addressing outstanding questions in neutrino physics, including the neutrino mass hierarchy and existence of leptonic CP violation. The NOνA Test Beam program, under deployment at the Fermilab Test Beam Facility, will use a scaled-down NOνA detector to sample beams of tagged electrons, muons, pions, and protons in the momentum range of 0.3 to 2 GeV/c. It will further the NOνA physics reach by precisely measuring the detector's muon energy scale and electromagnetic and hadronic response, and provide real data for detailed studies of particle identification techniques. Ongoing efforts on beam-line instrumentation, data acquisition, simulation, momentum reconstruction and particle identification are presented. Implications for the neutrino oscillation measurements are discussed.

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1. Introduction

The success of the NOνA experiment depends, in part, on the ability to understand the limits of the collected data. As the experiment continues to take data the statistical uncertainties will naturally decrease making it more important to understand and possibly address the causes of systematic errors. Among the leading systematics on the latest measurement of the neutrino oscillation parameters by NOνA [1] are calibration, detector response, and the muon energy scale. A visual representation of the impact of these systematics can be seen in Figure 1. These all impact NOνA's ability to accurately measure the energy deposited by neutrinos and understand the activity of final state particles emerging from those neutrinos. To address these issues, NOνA is deploying a scaled down version of its detectors at the Fermilab Test Beam Factility (FTBF) that will be exposed to a beam of primarily pions, protons, muons, and electrons. Along with a closer characterization of the detector response and validation of the calibration procedure, the test beam effort will result in a library of particles at known energies that can be used in the development and training of new simulation and particle identification techniques.

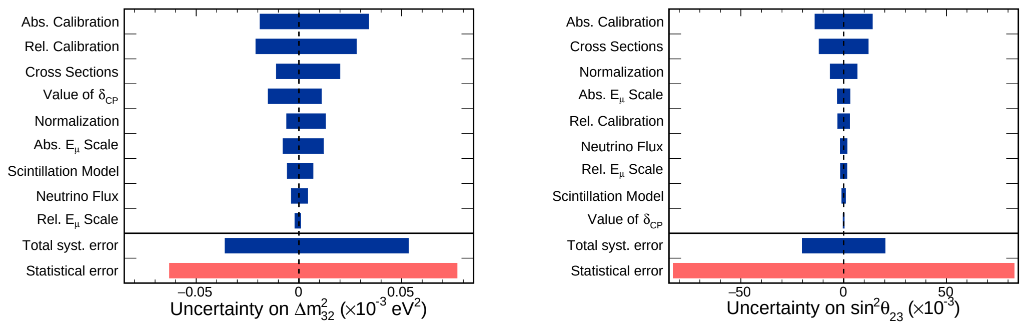

Figure 1: Leading uncertainties on the measurement of Δm^2_{32} (left) and $sin^2(\theta_{23})$ (right).

2. Secondary and Tertiary Particle Beams

FTBF will provide a beam consisting of primarily pions with a tunable energy from 8 to 80 GeV [2]. This secondary beam will collide with a copper target and pass through a collimator to produce a tertiary beam that will then be momentum selected by a magnet which can be tuned to deliver particles with momenta from 0.3 to 2 GeV/c. Each spill will last 4.2 seconds and produce on the order of tens of particles that will trigger the beam-line data collection and detector readout. These particles will be primarily protons and pions allowing for detailed investigation of the hadronic response of the NOνA detector. The tertiary beam will also contain muons and electrons providing the ability to characterize the muonic and electromagnetic response as well.

3. The NOνA Detector

The test beam effort will use the same detector technology currently in use by the NOνA near and far detectors [3]. This consists of planes of PVC cells filled with liquid scintillator and arranged in alternating vertical and horizontal layers to provide 3D particle tracking. Each PVC cell contains a loop of wavelength shifting fiber that is viewed by two pixels of an avalanche photodiode. The test beam detector is $2.6 \times 2.6 \times 4.1$ m^3 (compared to about $16 \times 16 \times 60$ m^3 for the far detector and $4 \times 4 \times 16$ m^3 for the near detector) allowing for full containment of muons up to 0.9 GeV while containment for 2 GeV pions is greater than 95% longitudinally and greater than 98% transversely.

4. Beam-line technology

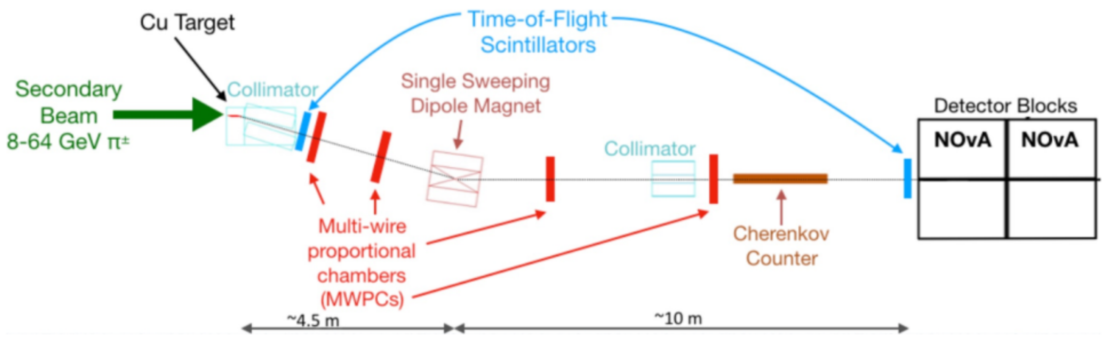

Figure 2: Layout of the tertiary beam-line components

The tertiary beam-line will consist of a combination of detectors for momentum measurement and particle identification along with a single sweeping dipole magnet with a maximum field of 1.8 T for momentum selection. Two time of flight (TOF) scintillators will be placed on either end of the tertiary beam-line. With a resolution less than 200 ps the TOF system will provide particle identification with good separation between protons and pions. A Cherenkov counter filled with CO_2 at 1 atm will enable further separation of electrons with a threshold energy of 20 MeV. The multi-wire proportional chambers (MWPCs) in conjunction with the sweeping magnet will provide the ability for momentum tagging of tertiary beam particles.

5. Summary

The NOνA test beam program will start data taking at the beginning of 2019 and run until the summer of 2019. The results obtained will be used not only to further constrain leading systematics related to detector calibration and response it will also allow the calibration procedure to be tested in more detail thus giving more confidence in the methods used. The detailed information gathered on particle and event topologies can be used to refine current particle identification methods and further to develop and train new techniques for simulation, identification, and reconstruction.

References

[1] M. A. Acero et al. (NOvA Collaboration), Phys. Rev. D 98, 032012 (2018)

[2] FTBF (Fermilab Test Beam Facility), http://ftbf.fnal.gov/beam-delivery-path/

[3] NOvA Technical Design Report, FERMILAB-DESIGN-2007-01

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