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NOνA: Current Status and Future Reach

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Abstract

NOνA, the NuMI Off-Axis ν_e Appearance experiment will study $\nu_\mu \to \nu_e$ oscillations, characterized by the mixing angle θ_{13}. A complementary pair of detectors will be constructed ∼14 mrad off beam axis to optimize the energy profile of the neutrinos. This system consists of a surface based 14 kTon liquid scintillatior tracking volume located 810 km from the main injector source (NuMI) in Ash River, Minnesota and a smaller underground 222 Ton near detector at the Fermi National Accelerator Laboratory (FNAL). The first neutrino signals at the Ash River site are expected soon after the completion of 2012 Fermilab accelerator upgrades. In the meantime, a near detector surface prototype has been completed and neutrinos from two sources at FNAL have been observed using the same highly segmented PVC and liquid scintillator detector system that will be deployed in the full scale experiment. With the recent measurements of θ_{13} as input, updated sensitivities of NOνA's capability to ultimately determine the ordering of the neutrino masses and measure CP violation in neutrino oscillations will be provided. Additionally, design and initial performance characteristics of the surface prototype system along with implications for the full NOνAprogram will be presented.

Keywords: neutrino oscillations, neutrino detector technology

1. Introduction

NOνA, the NuMI Off-Axis ν_e Appearance experiment will study $\nu_\mu \to \nu_e$ oscillations at a baseline of 810 km (L/E of 400 km/GeV) beginning in 2013, at which point it will become the flagship experiment for Fermilab. With the recently measured value of θ_{13} [1], NOνA will have the reach to determine the ordering of the neutrino masses and constrain the CP violating phase, δ [2]. Additionally, NOνA will study the differences in oscillations of neutrinos and antineutrinos, as well as make a precision measurement of θ_{23} by observing the muon neutrino disappearance.

Achieving these goals requires three main components: a far detector with 14 kTons of material capable of suppressing ν_μ charge current (CC) and neutral current (NC) backgrounds at the 99% level and providing good ν_e detector efficiencies [2], a functionally identical near detector to characterize the beam at the source (rate shown in Figure 1), and an upgrade 700 kW neutrino beam line. This paper will focus on the experimental design of NOνA, present preliminary data from a running prototype, update the project status, and provided current expected physics sensitivities.

2. Experimental design

Each component of the NOνA design is described.

2.1. Beam

To achieve the goal of the NOνA project, detectors will be placed 14 mrad off-axis to the primary direction of the NuMI (Neutrinos from the Main Injector) source (need reference). As shown in Figure 2, the ν_μ flux near the first $\nu_\mu \to \nu_e$ oscillation maximum at around 2 GeV

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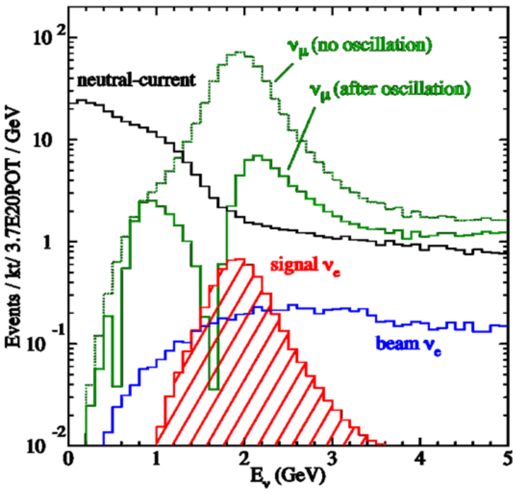

Figure 1: Expected raw signal and background rates for the NOνA far detector. Interaction spectra at 810km, 14 mrad off axis. Oscillations parameters: δm^2=2.5x10^{-3} eV^2, $sin^2(2\theta_{13})$=0.01 [2].

is optimized at this angle [2]. The off-axis beam also reduces high energy neutral current background events. To accommodate the needs of the experiment, the NuMI beam power is being doubled to 700 kW during the shutdown of the accelerator from March to May 2013.

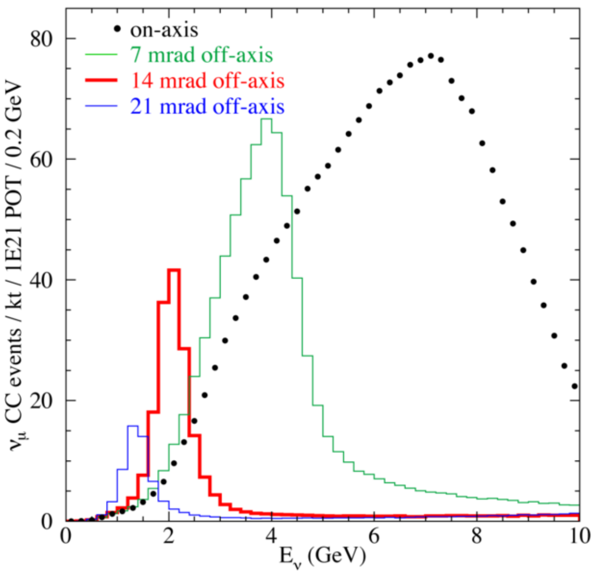

Figure 2: ν_μ CC energy distribution for off-axis angles with medium energy tune [2].

2.2. Detector Summary

The NOνA detector system consists of a complementary pair of detectors. Both detectors will be highly segmented tracking calorimeters built entirely from low Z (~0.15 radiation lengths per layer) PVC, glue, and mineral oil based liquid scintillator with a 65% active volume [2]. The far detector will be a surface based 14 kTon volume located 810 km from NuMI in Ash River, Minnesota with about 10 radiation lengths of barite overburden. A smaller 300 Ton unit will be built 1.1 km from the source at Fermilab in a 105 meters deep underground cavern. Additionally, a 222 ton prototype detector is already in operation on the surface at Fermilab. The full set of detectors is shown in Figure 3.

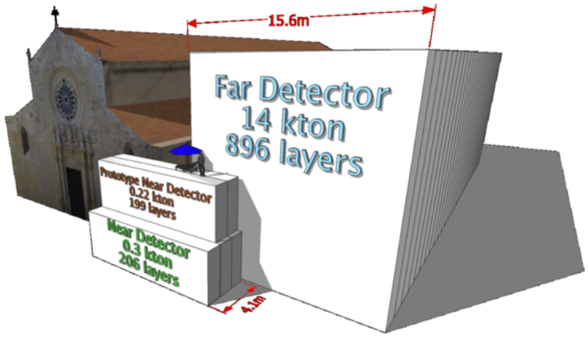

Figure 3: Image of the NOνAdetectors shown against the the Cathedral of Otranto.

2.3. Detector modules

The NOνA detector is built up from modules of extruded TiO_2 loaded PVC cells [2]. Each cell is 3.8 cm by 5.9 cm in cross section with 90% reflectivity for light at 430 nm. Extrusions are joined together to produce a sealed module of 32 cells. In the near detector, the modules will be 4.2 m long while far detector modules are 15.6 m long. These modules are glued together into alternating planes of horizontal or vertical orientation to create self-supporting 32 layer blocks. ~360,000 cells make up the 14 kTon far detector.

Internal to each cell is a 0.7 mm diameter looped fiber routed to an optical connector. The fiber shifts the light collected in the scintillator to 490-550 nm [2]. The fiber ends are routed through the manifold covered to an optical connector where they are available for single sided readout. ~11,500 km of fiber is needed for both the far and near detectors.

Once in blocks and positioned, modules are filled with a "home brew" of mineral oil containing 5% pseudocumene and wavelength shifters to produce 400-450