FERMILAB-CONF-10-675-E

Prospects and Status of the MINERνA Experiment at FNAL

T. Kafka,[1] V. Paolone,[2]
for the MINERνA Collaboration

[1]Tufts University, Medford, MA, USA
[2]University of Pittsburgh, Pittsburgh, PA, USA

November 20, 2009

Abstract

MINERνA is a detector designed to precisely study ν-nucleus interactions in the 1-10 GeV energy range in the NuMI high-intensity neutrino beam at the Fermi National Accelerator Laboratory. MINERνA will improve our knowledge of neutrino cross sections at low energy and low Q^2, and of the A-dependence in ν interactions. These data will be interesting in their own right, and will be important to reduce systematic errors in ν oscillation experiments.

1 Introduction

MINERνA (**M**ain **IN**jector **E**xperiment for $\boldsymbol{\nu}$-**A**) is a new few-GeV ν scattering experiment under construction at Fermilab, optimized to study neutrino interactions across a variety of scattering regimes in the intense NuMI (**Neu**trinos at the **M**ain **I**njector) beam. Large statistics data samples with high resolution tracking combined with calorimetry will allow cross-section measurements with improved precision to advance low-energy neutrino physics in general, and provide input to modeling neutrino interactions for long baseline ν oscillation experiments in particular.

NuMI beam. Reversing the horn current provides beams with either a majority of muon neutrinos or antineutrinos. Movable graphite target allows variable beam energy - Low-Energy (peak at 3 GeV), Medium-Energy (6 GeV) and High-Energy (9 GeV) configurations. To improve the knowledge of the ν beam flux, MINERνA Collaboration will, together with MINOS Collaboration, use *in situ* measurement using muon monitors, use improved beam simulation based on GEANT4 and FLUGG, and utilize new data on particle production from the NuMI target provided by the MIPP particle production experiment. As of Sept. 2009, the NuMI beamline has a new target installed, as well as new Hadron Monitor downstream of the decay pipe.

2 MINERνA Detector

The MINERνA detector (Fig. 1) is a fine-grained tracking calorimeter with a fully active solid-scintillator Tracker forming the bulk of the **I**nner **D**etector (ID). Upstream of the Tracker is an area of nuclear targets - He (not shown), carbon, iron, and lead, interleaved with tracking planes. The downstream part of the ID contains **E**lectromagnetic **CAL**orimeter (ECAL) and **H**adronic **CAL**orimeter (HCAL).

Operated by Fermi Research Alliance, LLC under Contract No. De-AC02-07CH11359 with the United States Department of Energy.

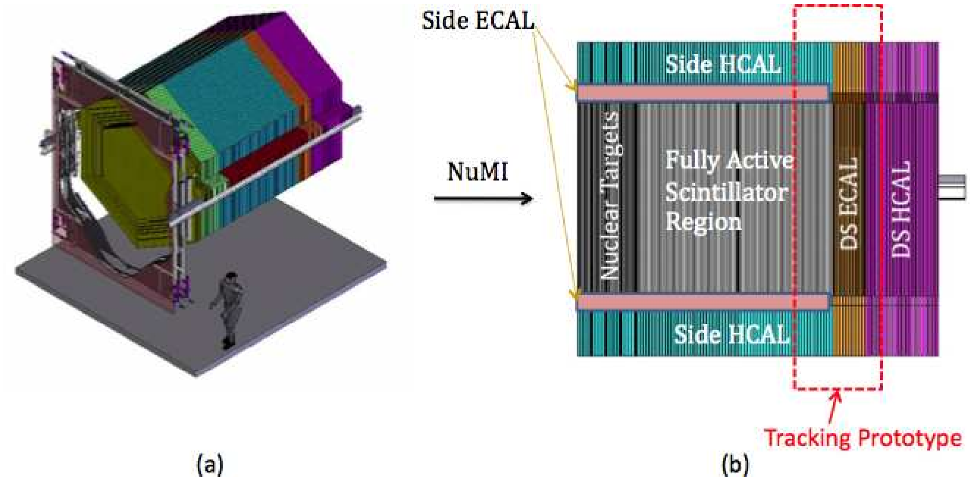

Figure 1: The MINERνA detector: (a) 3D rendition, (b) 2D slice. The extent of the Tracking Prototype is indicated by the dashed lines.

The ID is surrounded by side ECAL and side HCAL. The upstream Veto Wall is shown with a cutout in Fig. 1a. The downstream MINOS Near Detector (not shown) will serve as a muon spectrometer for MINERνA.

The active detector elements are solid-scintillator strips of triangular cross-section (3.3 cm base, 1.7 cm high), arranged in planes in such a way that neighboring strips alternate in their orientation with respect to the beam, base-top-base-top etc. Charge sharing between neighboring strips allows to achieve a spatial resolution of 2.5 mm. The scintillation light due to a charged particle is collected by a wavelength shifting optical fiber located at the center of each strip, and routed through clear optical fibers to M64 Hamamatsu photomultiplier tubes (PMT). The electricala signals from Front End Boards mounted atop each PMT enclosure are then brought to the data acquisition computer.

The detector consists of hexagonal modules containing one or two active planes mounted on a steel frame. The orientation of strips in the planes can be vertical (X), +60° (U), or -60° (V). Three types of modules were built: *(i)* tracker modules, strip orientations X+U, X+V etc; *(ii)* ECAL with Pb+X+U, Pb+X+V etc (0.2 cm thick Pb sheets); and *(iii)* HCAL with Fe+X, Fe+U, Fe+V etc (2.54 cm thick steel plates). All modules were scanned with Cs-137 source in order to measure position of all strips, to obtain the attenuation curve for each strip, and to localize anomalies in the scintillator/fiber system.

The detector includes a Light Injection system that brings a measured amount of light to each PMT enclosure via two clear optical fibers for calibration of the PMT response.

The MINERνA Collaboration is building a reduced-size *Test Beam Detector* to be exposed to a beam of charged particles (e, μ, π, p) in 2010. As the available test beam in Fermilab's Meson Laboratory did not have suitable momentum range, the Collaboration designed and built a terciary beam to extend this range to lower momenta, $250 < p < 1500$ MeV/c, to be fully commissioned by Nov. 2009.

3 MINERνA Tracking Prototype

The full MINERνA detector will have 108 modules with over 30,000 channels. A **T**racking **P**rototype (TP, see Fig. 2a) of 24 full-size modules was built and commissioned with cosmic rays between June 2008 and March 2009. As indicated by dashed lines in Fig. 1b, the TP consisted of 10 tracker modules, 10 ECAL modules, and 4 HCAL modules. In March/April 2009, the TP was moved underground into the NuMI beam to a position upstream of the MINOS Near Detector. A Veto Wall and an iron target

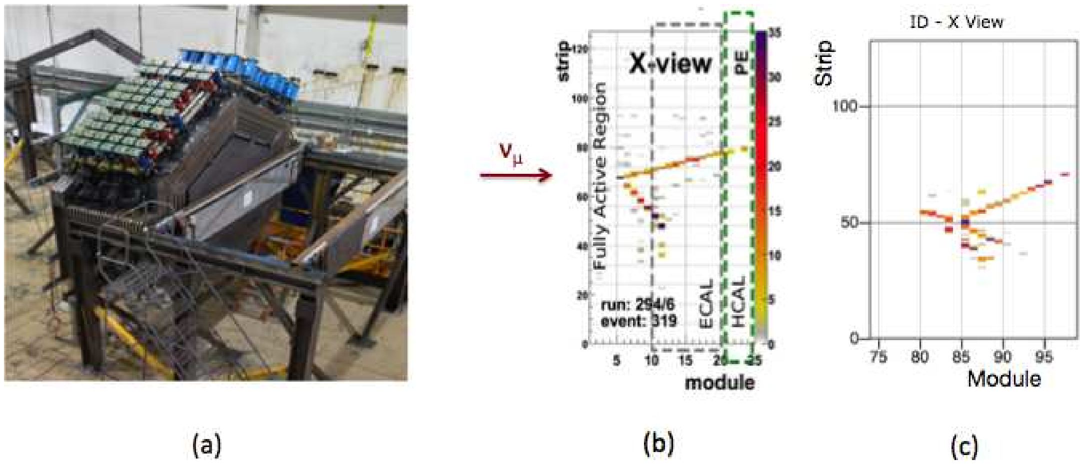

Figure 2: (a) MINERνA Tracking Prototype before moving into the NuMI beam. (b) NuMI neutrino quasielastic interaction candidate with a vertex in the fully active Tracker region. (c) A neutrino interaction in a TP lead plate in ECAL producing an exiting track (μ), a forward stopping track, and a backward stopping track.

prototype were installed upstream of the TP. The TP was then operating until the end of the FNAL run period in mid-June 2009, accumulating a neutrino interaction sample that contains an estimated 15000 CC events in a 0.9 ton fiducial volume. Two examples of TP neutrino events are also displayed in Fig. 2. Fig. 2b shows an event with an exiting track and a stopping track, a candidate for a quasi-elastic reaction $\nu_\mu + n \to \mu^- + p$. Fig. 2c depicts a ν interaction with a Pb nucleus producing a leaving (μ) track, and, in addition to forward hadrons, a stopping track directed backward (spectator proton).

4 MINERνA Status and Prospects

In summer 2009, the TP was dismounted, and installation of the full detector has commenced, starting with HCAL modules. The NuMI beam returned in mid-September in ν_μ mode, to switch into a Reverse-Horn-Current $\bar{\nu}_\mu$ mode in October 2009. MINERνA detector installation is to be frozen in November 2009 for $\bar{\nu}_\mu$ data taking until the end of the year. The installation will then resume in January 2010 for a timely completion to allow full-detector data taking when NuMI will return to ν_μ running in March 2010.

MINERνA Collaboration requested a physics exposure of 4×10^{20} Protons On Target (POT) to the NuMI neutrino beam in the Low-Energy configuration. In addition, the Collaboration requested an exposure of 1.2×10^{20} POT for study of the Low-Energy beam flux using variable target positions and target currents. The Collaboration requests to continue running in the Medium-Energy neutrino beam once set up for NOνA. The requested exposure is estimated to result in a sample of ν interactions containing 14 millions charged-current interactions, of which 9M will have a vertex in the scintillator, and 5M in the nuclear target plates or in the liquid He target. Such large statistics, along with improved knowledge of the ν flux, should enable MINERνA to reduce cross-section measurement uncertainties by a factor of four for all reaction channels of interest, including quasielastic reaction, resonance production, deep inelastic scattering, and coherent neutrino-nucleus reactions.