Physics Topics in MINERνA

David Boehnlein - Fermilab
for the MINERνA Collaboration

The owl is the symbol of Minerva, goddess of crafts, poetry and wisdom. It is often used as the unofficial symbol of the MINERνA experiment.

Overview of MINERνA

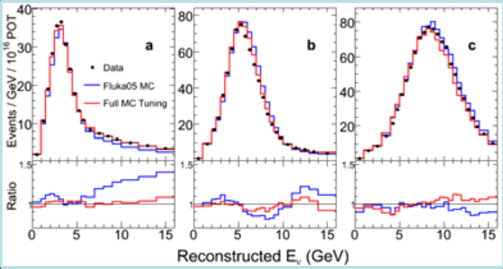
The high intensity of the NuMI beamline at Fermilab provides an unprecedented opportunity to study many aspects of neutrino physics. The Main INjector ExpeRiment: ν-A (MINERνA) Project will conduct high-rate studies of neutrino-nucleus (ν-A) interactions. A variety of nuclear targets provides the opportunity to study A-dependence of neutrino-nucleus interactions, as well as reducing systematic errors for long-baseline oscillation experiments.

The NuMI Beam

NuMI produces a beam of ν_μ by focusing pions into a 675-m decay tunnel. The pion energy spectrum is controlled with a set of focusing horns and a movable target, offering a wide range of configurations to vary the neutrino energy spectrum. An array of muon monitors allows for precise characterization of the beam. A good understanding of the neutrino flux will allow precise cross-section measurements.

NuMI Beam Spectra

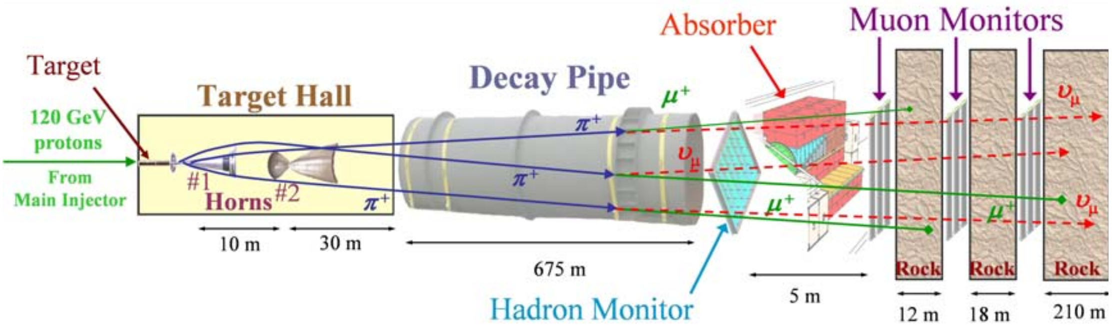
Neutrino energies as reconstructed in the MINOS Near Detector

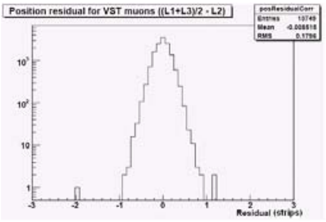


a,b & c represent 3 NuMI target configurations without horn movement

D. Michael *et al.* **PRL 97,** 191801 (2006)

Schematic Diagram of the NuMI Beamline



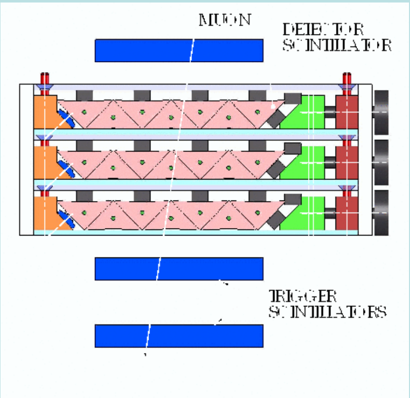


J. Chvojka – MINERvA
Vertical Slice Test Report

Detector Construction

The detector comprises a fine-grained scintillator core, with electromagnetic and hadronic calorimetry on the outer edges. Wavelength-shifting optical fibers conduct scintillation light out of the scintillator bars, to clear fibers and then to a multi-anode photomultiplier tube. The front-end electronics are daisy-chained to a VME-based DAQ system. The detector will be installed upstream of the MINOS Near Detector, which will serve as a muon spectrometer.

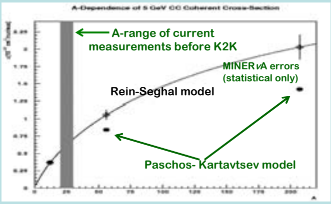
Vertical Slice Test



- Hit residual < 3 mm
- Timing resolution < 3 ns

Nuclear Targets

Coherent cross-section dependence on atomic number is not well-known. MINERvA will measure neutrino interactions on a variety of targets with a wide range of atomic number. These include lead, iron, carbon and helium.



Hexagonal Configuration

The hexagonal configuration of MINIERvA allows for three stereo views. The scintillator bars are arrayed in the x, u, and v. directions. The core is pure scintillator, surrounded by electromagnetic and hadronic calorimetry. There are additional EM and hadron calorimeters downstream. The MINOS Near Detector is immediately downstream and can observe muons produced in MINERvA.

Detector Capabilities

Simulations using GEANT3 and results of a Vertical Slice Test:

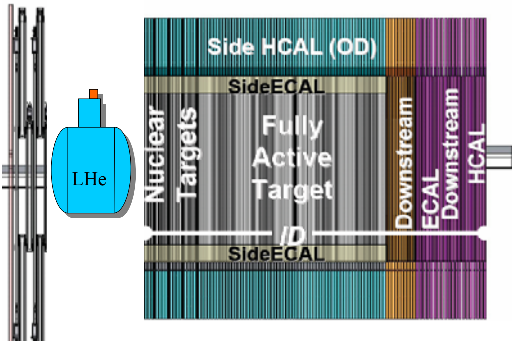
- muon angular resolution < 1º
- em energy resolution:

$$\frac{\sigma}{E} = \frac{6\%}{\sqrt{E}}$$

- hadronic energy resolution:

$$\frac{\Delta E_h}{E_h} = 4\% + \frac{18\%}{\sqrt{E_h(\mathrm{GeV})}}$$

The MINERvA Detector



Resonance production

$$\nu_\mu + N \rightarrow \Delta + \mu / \nu$$

and

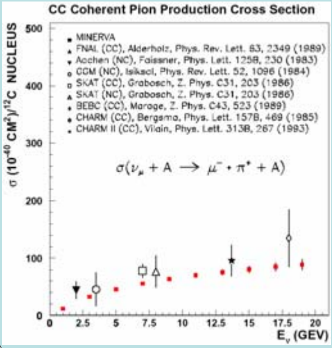
$$\Delta \rightarrow p + \pi$$

MINERvA will recognize final-state topologies, with the muon, recoil proton from resonance decay and either charged pion or two-gamma decay from neutral pion.

MINERvA expects about 1600 resonance events.

Coherent Pion Production

A comparison of anticipated MINERvA measurements and existing results. MINERvA errors are statistical only.



Deep-Inelastic Scattering

$$\nu_\mu + q \rightarrow \mu^- + q'$$

$$F_1^{\nu N}(x,Q^2) \qquad F_2^{\bar{\nu} N}(x,Q^2)$$

$$F_1^{\bar{\nu} N}(x,Q^2) \qquad xF_3^{\nu N}(x,Q^2)$$

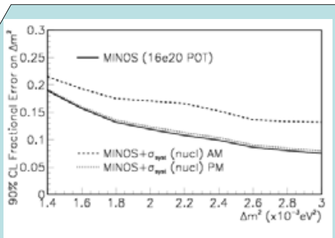
$$F_2^{\nu N}(x,Q^2) \qquad F_3^{\bar{\nu} N}(x,Q^2)$$

MINERvA will use neutrino scattering to study structure functions

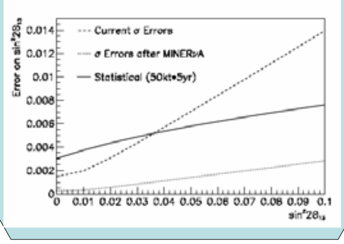
Strangeness Production

MINERvA Exclusive States
400 × earlier samples
3 tons and 4 years

$\Delta S = 0$	
$\mu^- K^+ \Lambda^0$	42 K
$\mu^- \pi^0 K^+ \Lambda^0$	38 K
$\mu^- \pi^+ K^0 \Lambda^0$	26 K
$\mu^- K^- K^+ p$	20 K
$\mu^- K^0 K^+ \pi^0 p$	6 K
$\Delta S = 1$	
$\mu^- K^+ p$	65 K
$\mu^- K^0 p$	10 K
$\mu^- \pi^+ K^{0n}$	8 K
$\Delta S = 0$ - Neutral Current	
$\nu K^+ \Lambda^0$	14 K
$\nu K^0 \Lambda^0$	4 K
$\nu K^0 \Lambda^0$	12 K



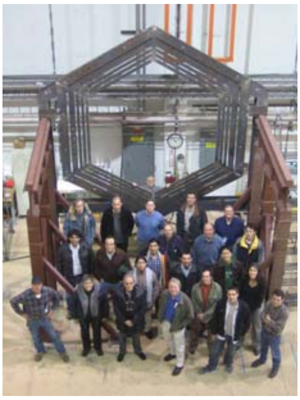
Estimated improvements to MINOS (top) and NOvA (bottom) measurements from MINERvA



A symbiotic relationship: The MINOS Near Detector will serve as a muon spectrometer for MINERvA.

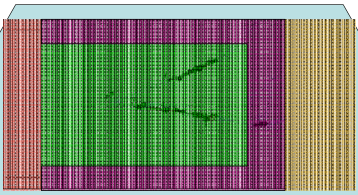
Collaboration

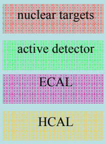
University of Athens; University of Dortmund; University of Minnesota – Duluth; Fermi National Accelerator Laboratory; Hampton University; Illinois Institute of Technology; Institute for Nuclear Research – Moscow; University of California – Irvine; Thomas Jefferson National Laboratory; James Madison University; Northwestern University; Pontificia Universidad Catolica del Peru; University of Pittsburgh; Rutgers, The State University of New Jersey; Tufts University; Universidad Nacional de Ingenieria – Peru; University of Rochester; College of William & Mary; St. Xavier University; Centro Brasileiro de Pesquisas Fisicas - Brazil



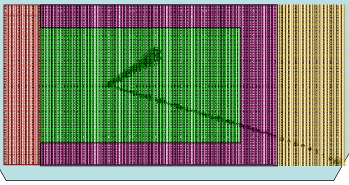
Precision Measurements

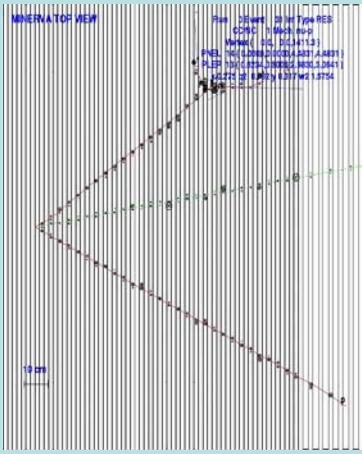
The fine granularity and timing resolution of the MINERvA detector allows the measurement of final state topologies. Simulations show good resolution of final states from resonance decay, π^0 decay from neutral-current interactions and proton recoil from quasi-elastic charged-current events.





Simulations show photon separation from a π^0 decay in MINERvA (above) and proton recoil + muon track for a CCQE event. (K. McFarland NuInt05)





J. Nelson NuInt07

MINERvA Schedule and Run Plan

Current plans call for MINERvA to complete installation and begin taking neutrino data in Fall 2009. For a 4-year run using both low-energy and medium-energy configurations of the NuMI beam. With 16.0 x 10^{20} protons on target, 4.0 x 10^{20} LE and 12.0 x 10^{20} ME, the anticipated data set will include 14.5 million charged-current events.