MINERvA detector: description and performance

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*(on behalf of MINERvA collaboration)*
OUTLINE

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Experiment overview

Detector: finely-segmented scintillator with electromagnetic and hadron calorimetry regions as well as nuclear targets

Location: Fermilab, 330 ft underground

Goals: precise measurements of neutrino-interaction cross-sections for various channels; study of nuclear effects in neutrino interactions
Neutrino flux (I)

- variable beam mode (\(\nu_\mu\) or \(\bar{\nu}_\mu\)) through changing horn polarity

- variable energy beam through changing horn current and target position

- source-detector distance is \(\sim\) 1 km

- monitors for proton, hadron and muon beams
Neutrino flux (II)

“Low” Energy

π⁺ p = 300 MeV/c and:
- p = 5 GeV/c
- p = 10 GeV/c
- p = 20 GeV/c

“High” Energy

“Horn off”

DPF-2011, Brown University, RI, USA, August 9-13, 2011
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Neutrino flux (III)

Special runs

Aim: to reduce the flux uncertainties that come from hadron production at the target

Geant4 LE beam simulation with the same geometry but different hadron production models

Results in ~ 10% spread
Neutrino flux (IV)

Special runs

Approach: take a series of beam runs with varying target position and horn current and then tune hadron production in MC to match the observed spectra in data

LE, target at 10 cm, horn current 185 kA

LE, target at 100 cm, horn current 200 kA
Neutrino flux ($\nu$)

Resulting reduction of errors

![Graph showing neutrino flux and error reduction](image)

- Flux error band pre-fit
- Flux error band post-fit

Uncertainties due to kaon production and tertiary production are not included.
Neutrino flux (VI)

Preliminary results from special runs data (analysis in progress)

Reconstructed neutrino energy of CC inclusive candidates in standard running and special runs (data only)

Reconstructed $Q^2$ of CC quasi-elastic candidates in anti-neutrino special run (data and MC)
Detector description

- 30K scintillator channels grouped into inner and outer detectors
- Electromagnetic (lead) and hadronic (iron) calorimetry regions
- Nuclear targets ($^4$He, C, Fe, Pb, H$_2$O)
- Veto wall in front of the detector
- MINOS near detector as muon catcher

scintillator light
WLS fiber
clear fiber

→ PMT

→ front-end board

→ crate

→ storage
Nuclear targets (I)

- One of the physics goals of MINERvA experiment is to study nuclear effects in neutrino interactions

- Several nuclear targets inside and in front of detector

- Active scintillator (6.43 tons) as a plastic (CH) target

- $^4\text{He}$ (0.25 tons) in front of the detector

- C (0.17 tons), Fe (0.97 tons) and Pb (0.98 tons) inside the detector

- $\text{H}_2\text{O}$ (0.39 tons) target under construction
Nuclear targets (II)

Location of targets in the detector

$^4$He

Active Scintillator Modules

Tracking Region

<table>
<thead>
<tr>
<th>Carbon</th>
<th>Iron</th>
<th>Lead</th>
</tr>
</thead>
</table>
Event rates

• Approved for $4.9 \times 10^{20}$ POT in low-energy and $1.2 \times 10^{20}$ POT in medium-energy beam configuration

• So far: $1.5 \times 10^{20}$ POT for LE neutrino and $1.3 \times 10^{20}$ POT for LE antineutrino (full detector geometry)

<table>
<thead>
<tr>
<th>Target</th>
<th>Fiducial Mass</th>
<th>$\nu_\mu$ CC Events in $1.2 \times 10^{20}$ P.O.T.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic</td>
<td>6.43 tons</td>
<td>409k</td>
</tr>
<tr>
<td>Helium</td>
<td>0.25 tons</td>
<td>16.8k</td>
</tr>
<tr>
<td>Carbon</td>
<td>0.17 tons</td>
<td>10.8k</td>
</tr>
<tr>
<td>Water</td>
<td>0.39 tons</td>
<td>24.4k</td>
</tr>
<tr>
<td>Iron</td>
<td>0.97 tons</td>
<td>64.5k</td>
</tr>
<tr>
<td>Lead</td>
<td>0.98 tons</td>
<td>68.4k</td>
</tr>
</tbody>
</table>

(interaction rates from Genie 2.6.2. event generator)
Physics goals (I)

- Final state interactions (e.g. pion absorption in the nucleus)

Kinetic energy spectrum of final state and primary $\pi^+$ from $\nu + \text{Fe}^{56}$ interactions at 1 GeV (from GENIE manual at http://projects.hepforge.org/genie)
Physics goals (II)

- $x$-dependence of nuclear effects

Modification of $F_2$ in comparison with charged-lepton scattering and other analyses

A2 – CTEQ fit to NuTeV data on iron (blue points) with free nucleon PDFs for deuterium

KP – Kulagin-Petti nuclear model

SLAC/NMC – charged-lepton nucleus scattering

HKM07 – KEK theory center nuclear pdf analysis

HKM07: Modification of $F_2$ in comparison with charged-lepton scattering and other analyses.
Physics goals (III)

Proposal to fill the cryotarget with deuterium

High-precision nuclear-to-D (A/D) ratio measurements
Analysis chain

• studying the most downstream target (Fe/Pb)
• CC $\nu\mu$ events in lead, iron and plastic
• one muon track matched to MINOS with reconstructed energy and charge(-)
• fiducial volume – 85 cm hexagon
• z position of muon vertex in nuclear target or the first module downstream
• data sample: 0.9E20 POT LE neutrino mode
• MC sample: 11.2E20 POT LE neutrino mode
• statistical + flux errors
• Plastic reference target with the same divide as the real target (with the aim to compare CH to Fe and Pb)
Preliminary results (I)

Event misidentification (MC)
Preliminary results (II)

Reconstructed muon energy CC numu (data/MC)

Iron

Lead

Iron ref

Lead ref

POT-Normalized
Preliminary

N Events / GeV

Muon Energy (GeV)

Data

Monte Carlo

POT-Normalized
Preliminary

N Events / GeV

Muon Energy (GeV)

Data

Monte Carlo
Preliminary results (III)

Reconstructed muon energy CC numu (data/MC)

Iron

Lead

Preliminary results (III)

Reconstructed muon energy CC numu (data/MC)

Iron's Plastic Reference, Enriched Sample

Lead's Plastic Reference, Enriched Sample
Preliminary results (IV)

Plastic to plastic comparison (data/MC)

Data: 0.9E20 POT LE neutrino mode
MC: 11.2E20 POT LE neutrino mode

Lead's Plastic Reference / Iron's Plastic Reference (Signal)

Data Mean = 0.95 +/- 0.04
Monte Carlo Mean = 0.95 +/- 0.01

Muon Energy (GeV)
Future plans

- Detector is up and running and taking a data
- Work in progress on reconstruction and various analysis channels
- For nuclear targets we will have 4x more POT and 4x more mass for final analysis – very precise measurement
- Ratio plots among nuclear targets and CH are coming very soon
- Stay tuned
THANK YOU