

Charged Current Neutrino Scattering in MINERvA



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On behalf of the MINERvA collaboration

<http://minerva.fnal.gov>



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Outline

What is MINERvA?

Detector Description

Inclusive Scattering

Quasi-elastic scattering

Future



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What is MINER ν A?

Main INjector ExpeRiment ν -A

MINER ν A is a high resolution neutrino cross section experiment in the NuMI beamline upstream of the MINOS near detector

Goal is to measure exclusive and inclusive neutrino cross sections in the energy range of 1-20 GeV with greatly improved precision, and on several nuclei

Has a fully active core of scintillator used as both a target and for tracking

Targets of scintillator (C-H), He, C, water, Fe, and Pb



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The MINERvA Collaboration



- ◆ University of Athens, Athens, Greece
- ◆ Centro Brasileiro de Pesquisas Fisicas, Rio de Janeiro, Brazil
- ◆ UC Irvine, Irvine, CA
- ◆ Fermi National Accelerator Lab, Batavia, IL
- ◆ University of Florida, Gainesville, FL
- ◆ Universidad de Guanajuato, Guanajuato, Mexico
- ◆ Hampton University, Hampton, VA
- ◆ Institute for Nuclear Research, Moscow, Russia
- ◆ James Madison University, Harrisonburg, VA
- ◆ Mass. Coll. of Liberal Arts, North Adams, MA
- ◆ University of Minnesota-Duluth, Duluth, MN
- ◆ Northwestern University, Evanston, IL
- ◆ Otterbein College, Westerville, OH
- ◆ University of Pittsburgh, Pittsburgh, PA
- ◆ Pontificia Universidad Catolica del Peru, Lima, Peru
- ◆ University of Rochester, Rochester, NY
- ◆ Rutgers University, Piscataway, NJ
- ◆ Universidad Tecnica Federico Santa Maria, Valparaiso, Chile
- ◆ University of Texas, Austin, TX
- ◆ Tufts University, Medford, MA
- ◆ Universidad Nacional de Ingenieria, Lima, Peru
- ◆ College of William & Mary, Williamsburg, VA



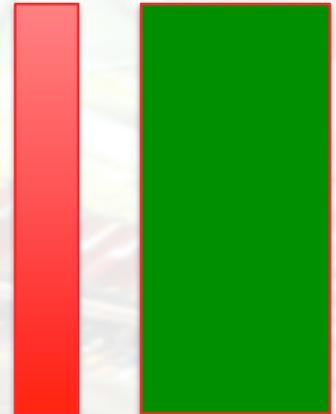
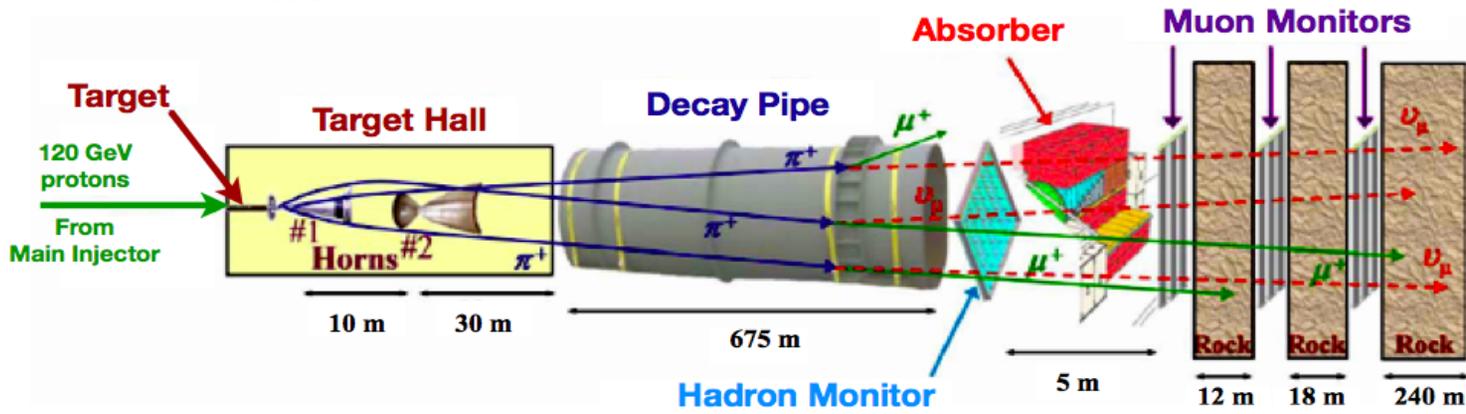
A collaboration of about 100 nuclear and particle physicists from 22 institutions



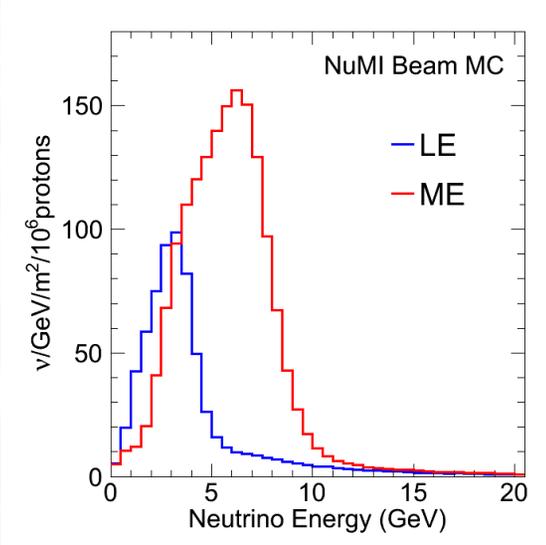
The NuMI Beamline



MINOS



MINERvA

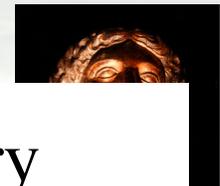


$$pC \rightarrow \pi^{+/-} \rightarrow \mu^{+/-} (\nu/\bar{\nu})$$

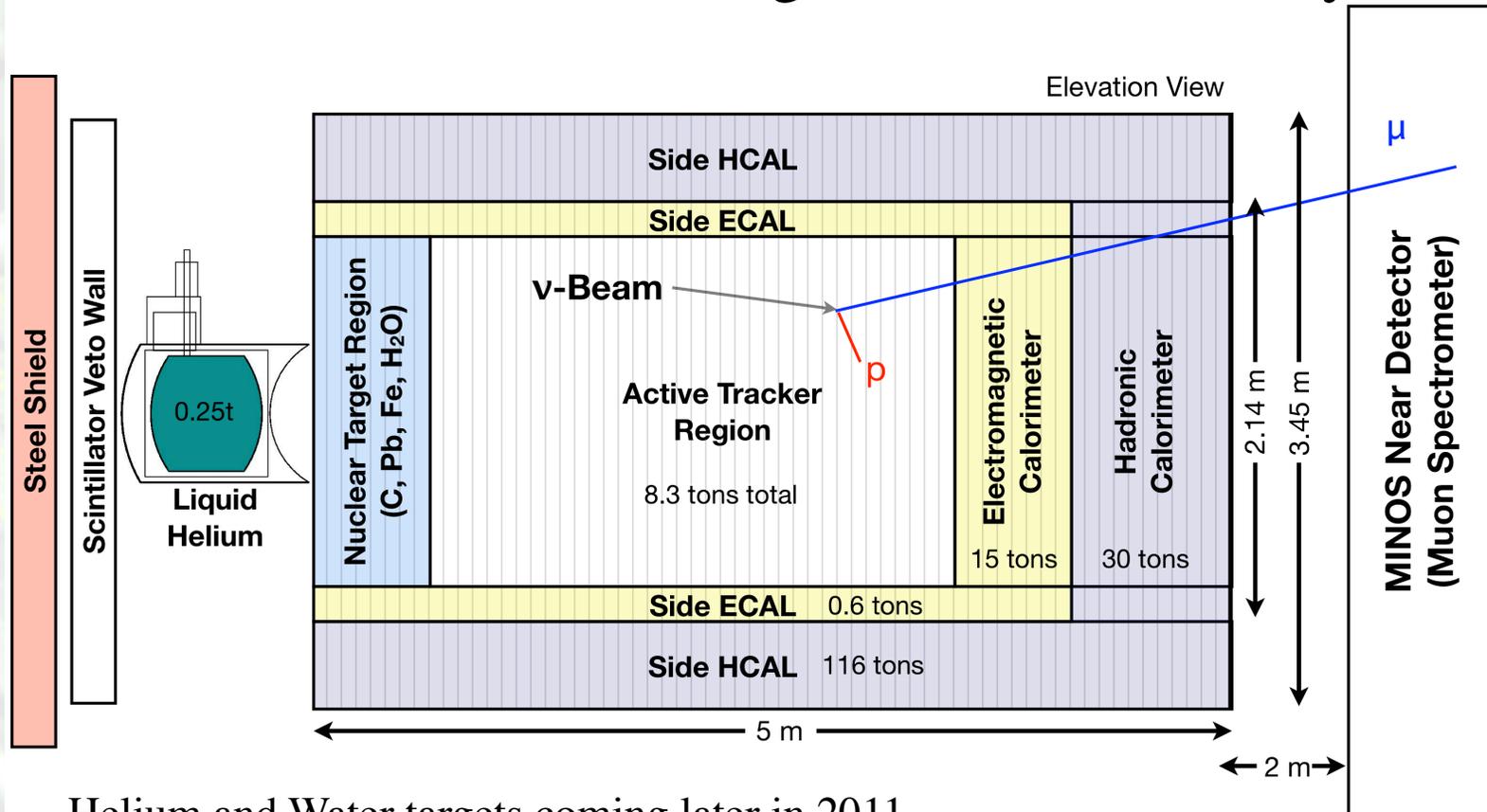


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The Detector



120 modules of tracker, targets, and calorimetry



Helium and Water targets coming later in 2011



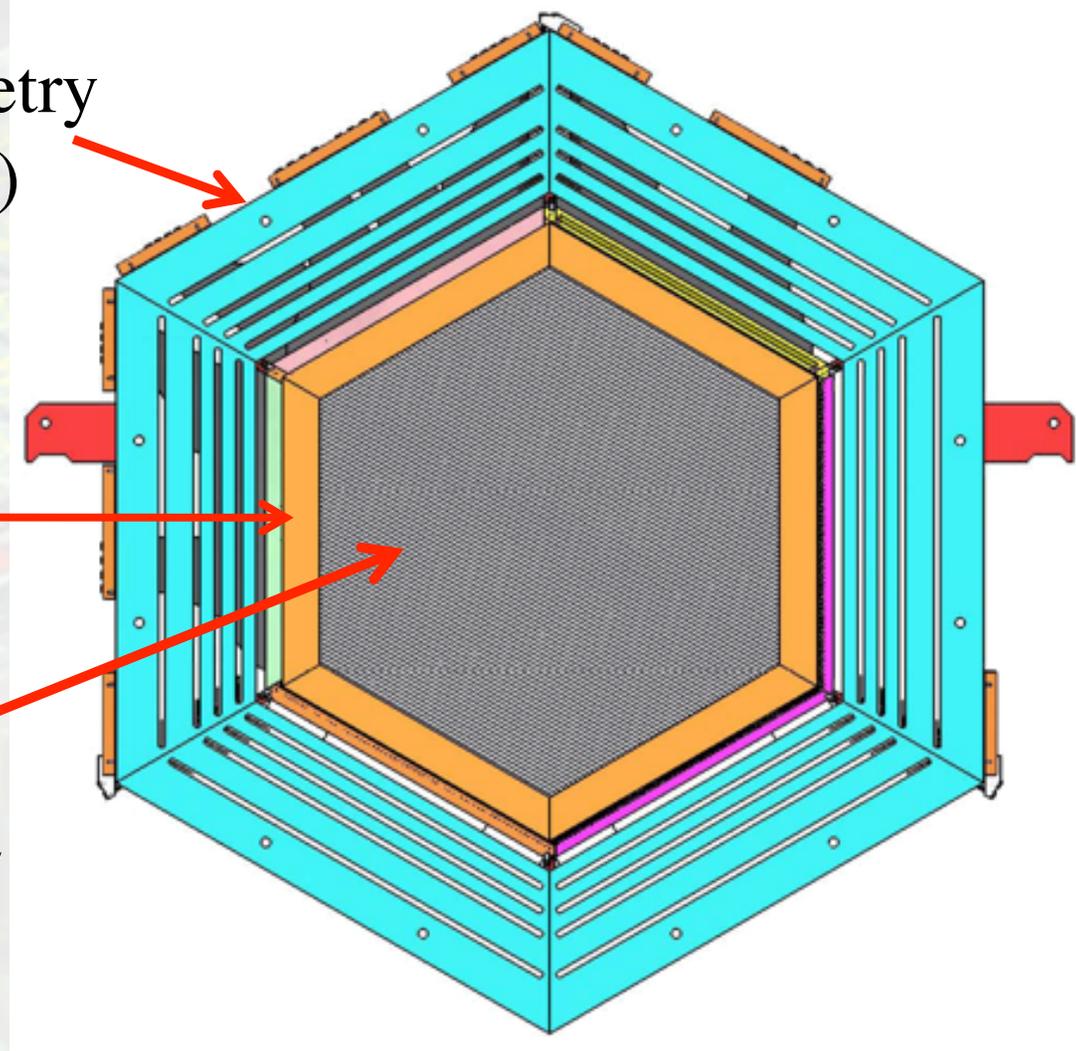
Tracking Module



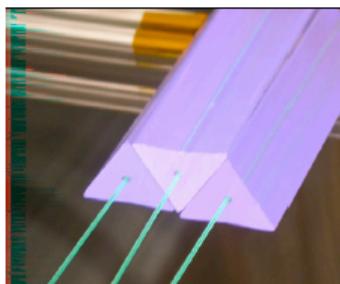
Outer hadron calorimetry
(steel + 4 layers scint.)

Inner EM calorimetry
(2mm Pb between
modules)

Tracking detectors
127 strips per plane, 2
planes per module

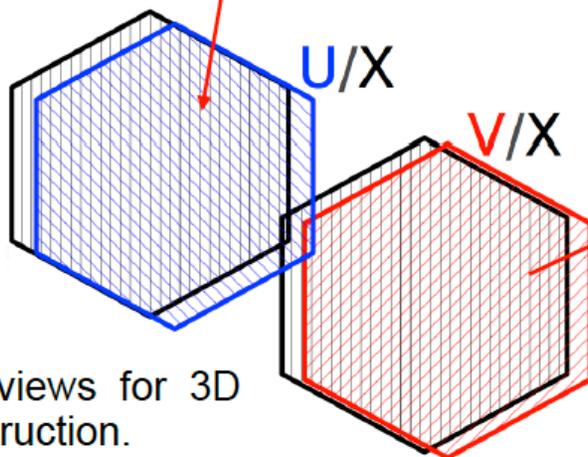
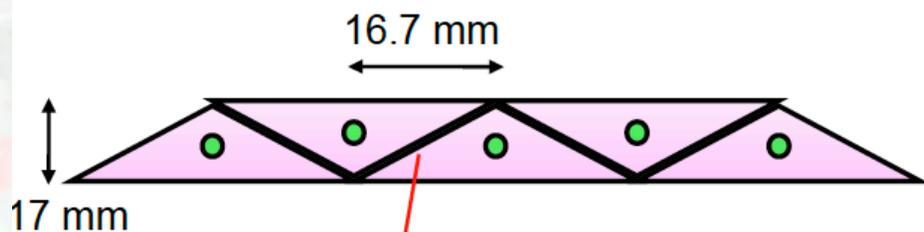


Tracking Detectors

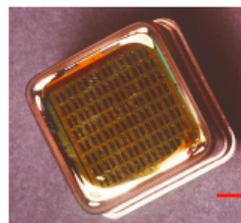


Extruded plastic scintillator + wavelength shifters.

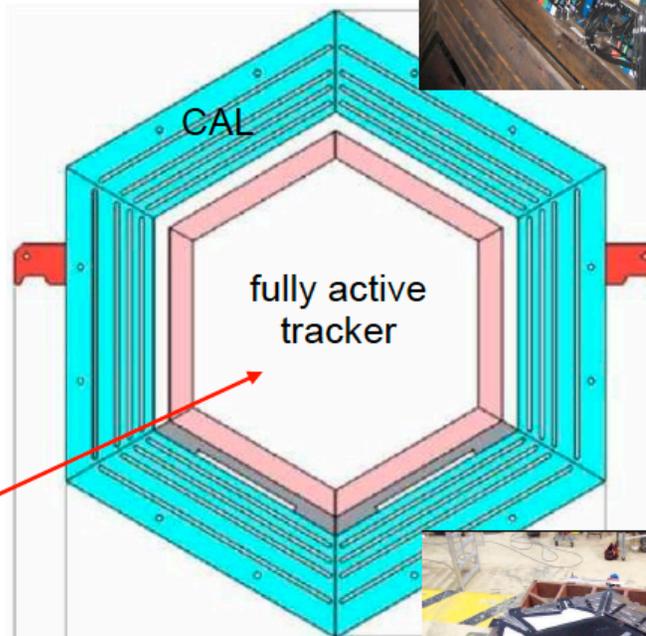
Triangular geometry allows charge sharing for better position resolution.



Three views for 3D reconstruction.



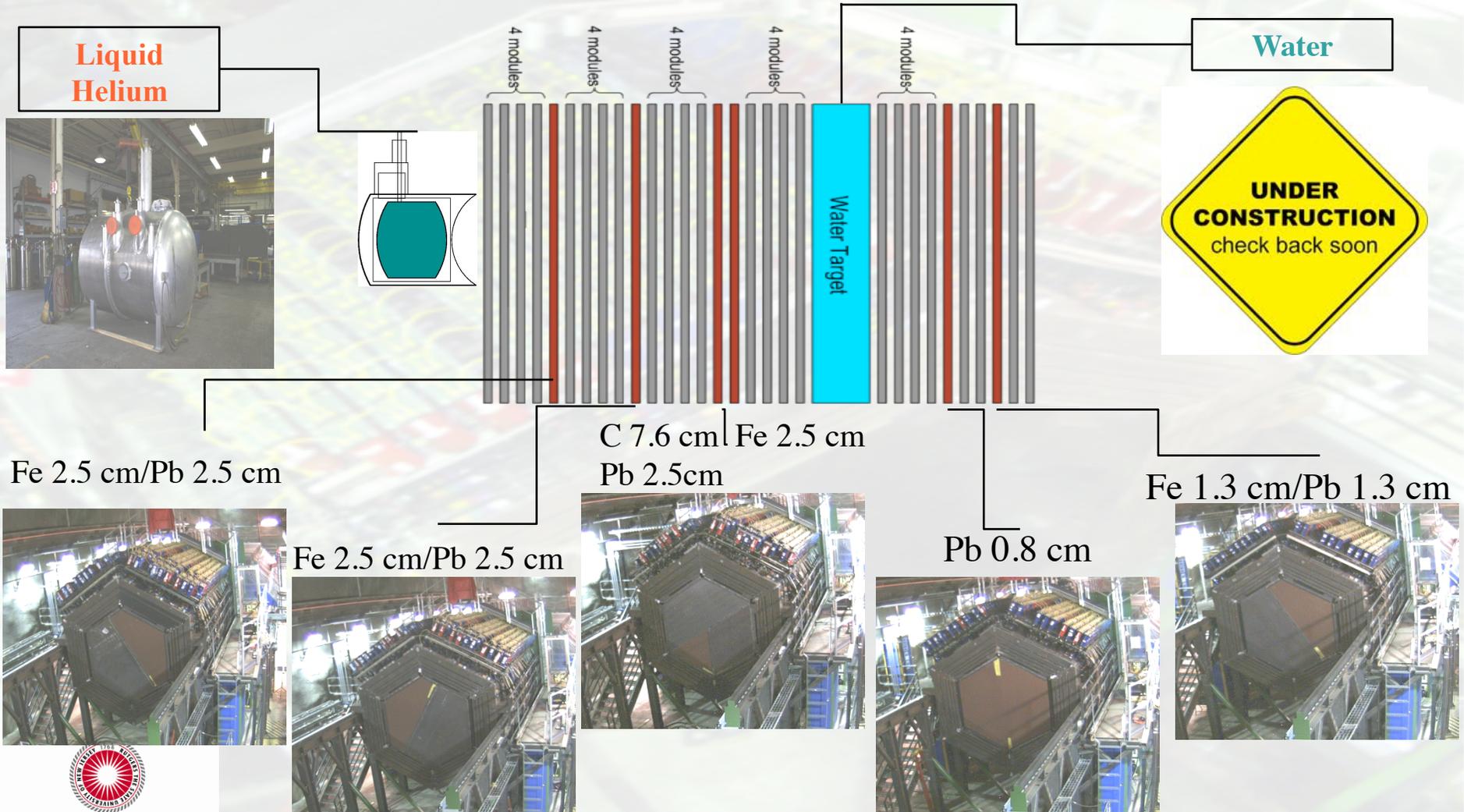
64 anode PMT's



Iron outer detector instrumented for EM calorimetry.



MINERvA Detector Passive Targets

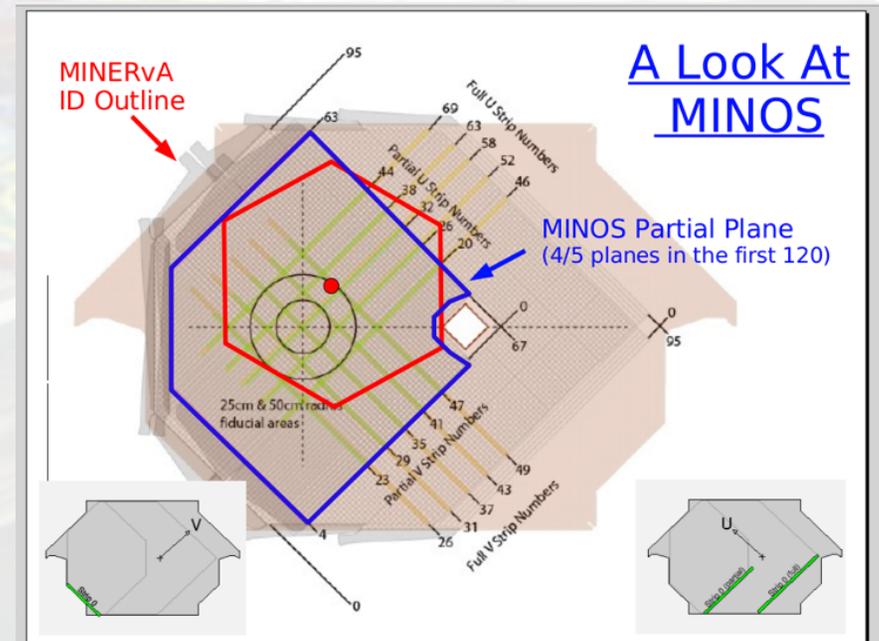


Muon Detection



The MINOS near detector serves as a forward muon spectrometer.

Energy threshold ~ 2 GeV
Good angular acceptance
up to scattering angles of
about 10 degrees, with
limit of about 20 degrees



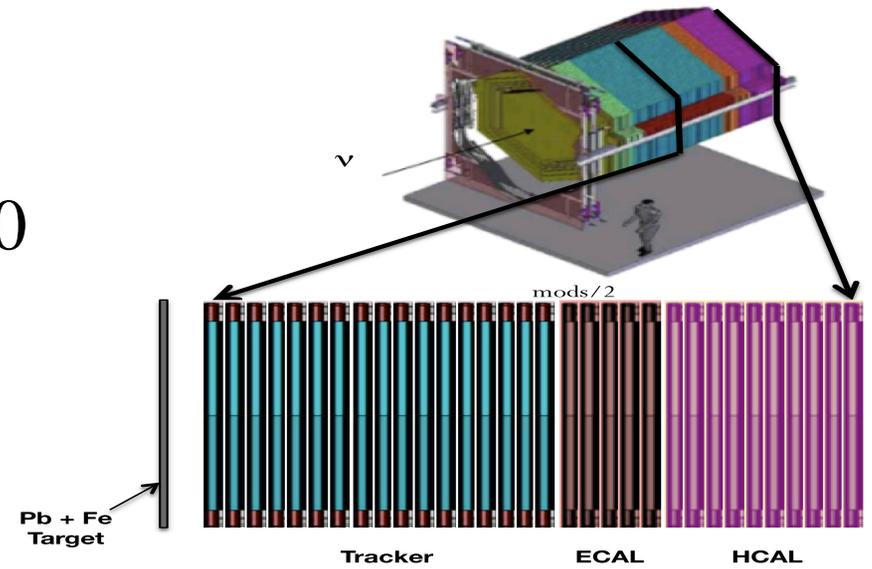
Muons stopped in MINERvA can also be used, but no charge determination. Studies presented today use only events with muon in MINOS matched to muon in MINERvA



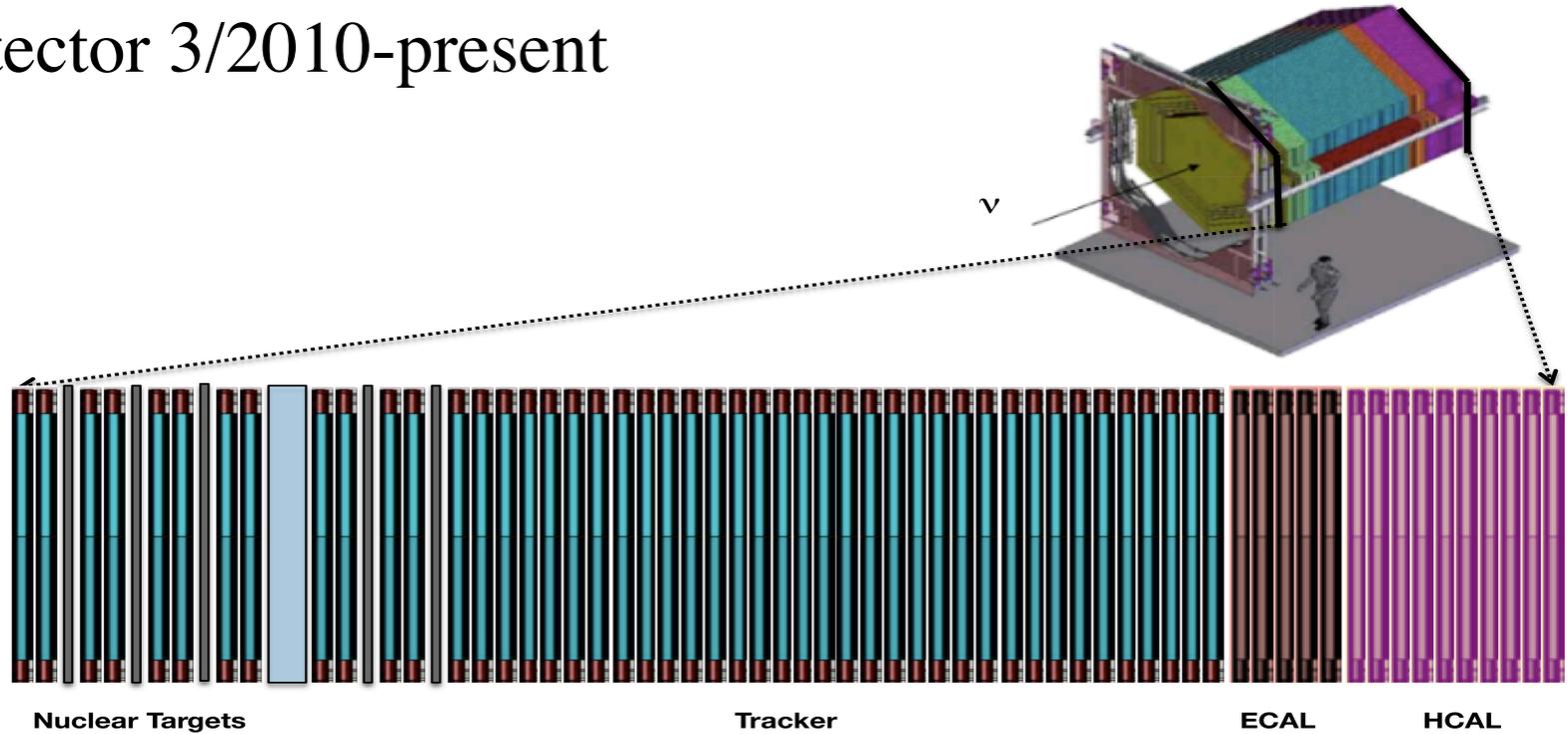
Data Taking since 10/2009

“Frozen” detector 10/2009-3/2010

55% of full detector

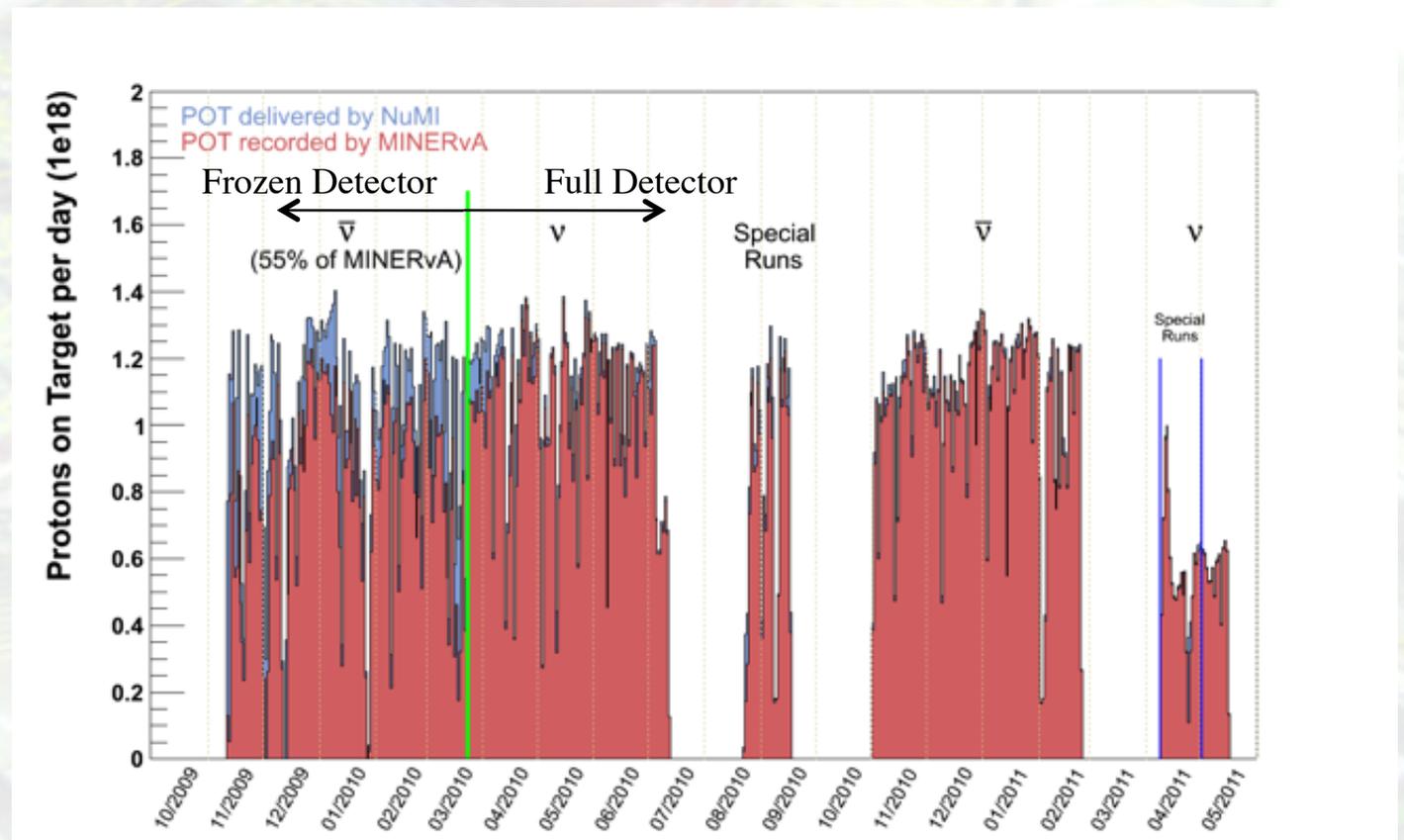


Full detector 3/2010-present



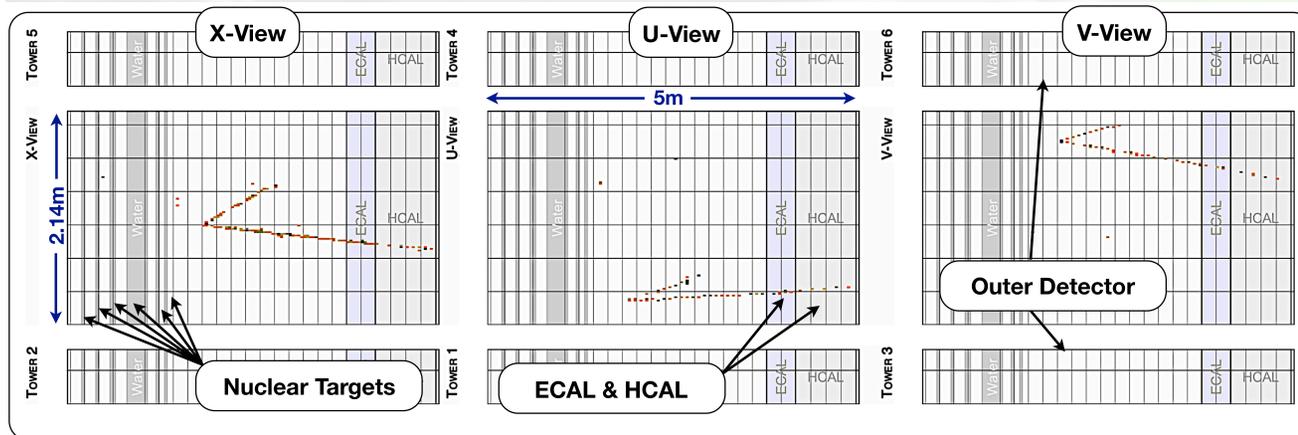
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MINERvA has been running with high efficiency and collected data in both the neutrino and antineutrino mode

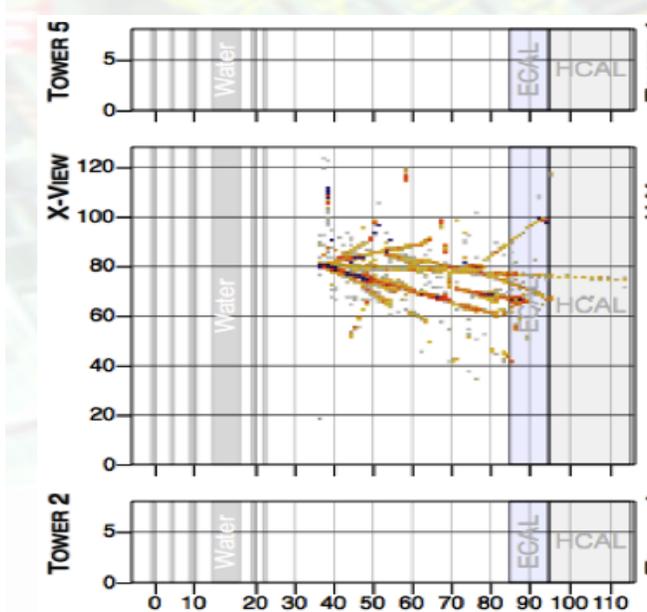


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Sample events

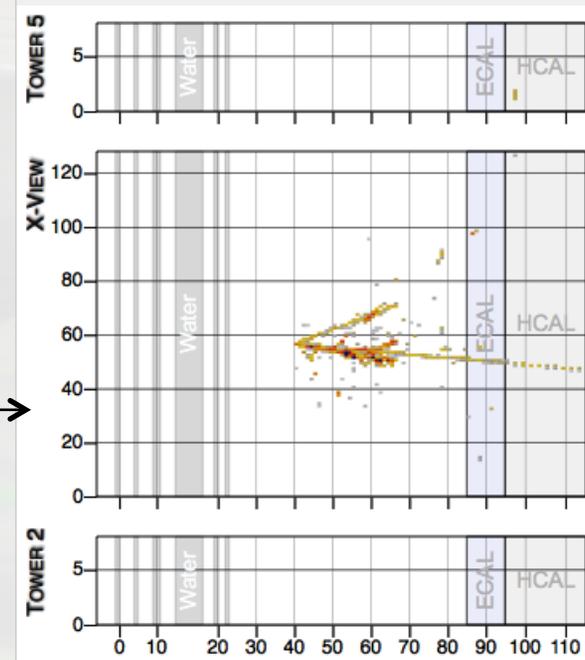


QE candidate



DIS candidate

Resonance candidate





Inclusive ratio

One of our first goals is to measure the inclusive cross section ratios of various nuclei.

Ratio depends both on the relative neutron to proton cross section, and possible nuclear modifications to the total cross section.

Expected ratios per kg for $E_\nu > 2 \text{ GeV}$

$\text{Pb/Fe} = 1.04$, $\text{Pb/CH} = 1.10$, $\text{Fe/CH} = 1.05$

Analysis done with neutrino data, on most downstream
Pb/Fe target



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Event Selection

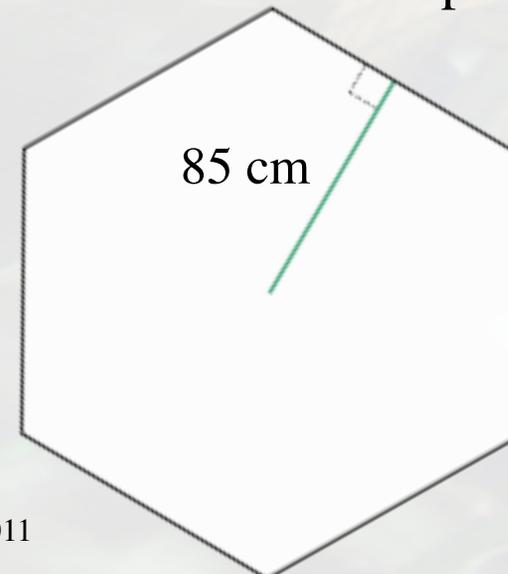


- (1) Require that there is one muon reconstructed in MINOS and matched in MINERvA
- (2) Require that the event vertex is in the target or in the first module downstream of the target

US Cut: vertex must be DS of center of 1st plane US of target

DS Cut: vertex must be US of center of 3rd plane DS of target

- (3) Require that the event vertex is inside the 85 cm fiducial apothem



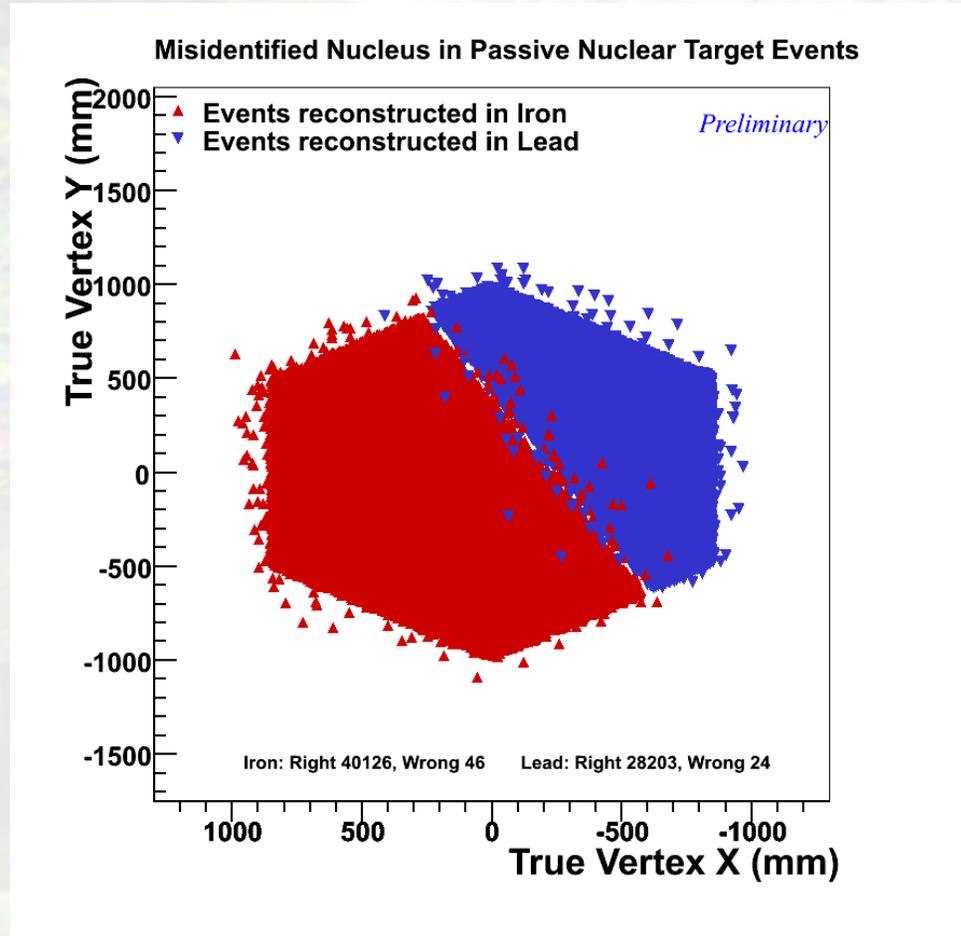
x-y tracking to plane is good, MC indicates that misidentification of target is a very small effect.



Color indicates actual target

Position of triangle indicates MC location of vertex

Only about 0.1% identified in wrong target



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Background Subtraction



z location of vertex is more difficult to determine

With one track not possible to distinguish from downstream scintillator and target

Multiple track vertex location uncertainty can be comparable to target thickness

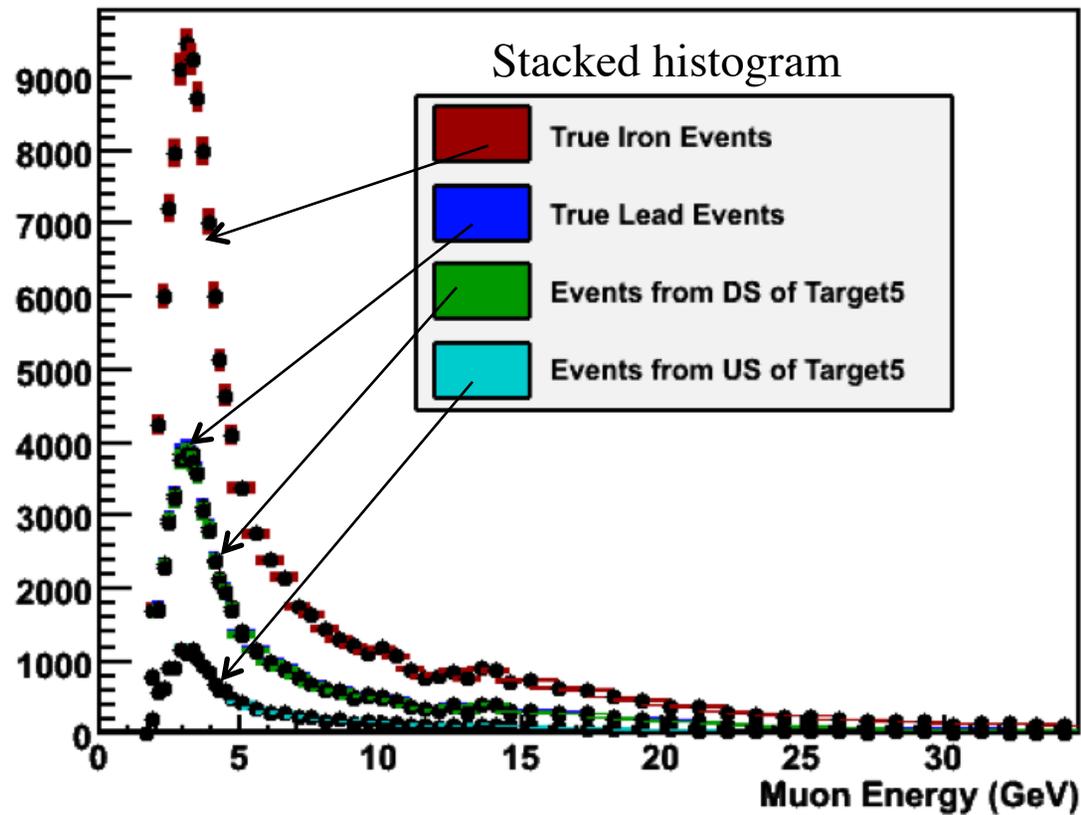
Background subtracting by finding events/plane downstream and extrapolating to nuclear target.



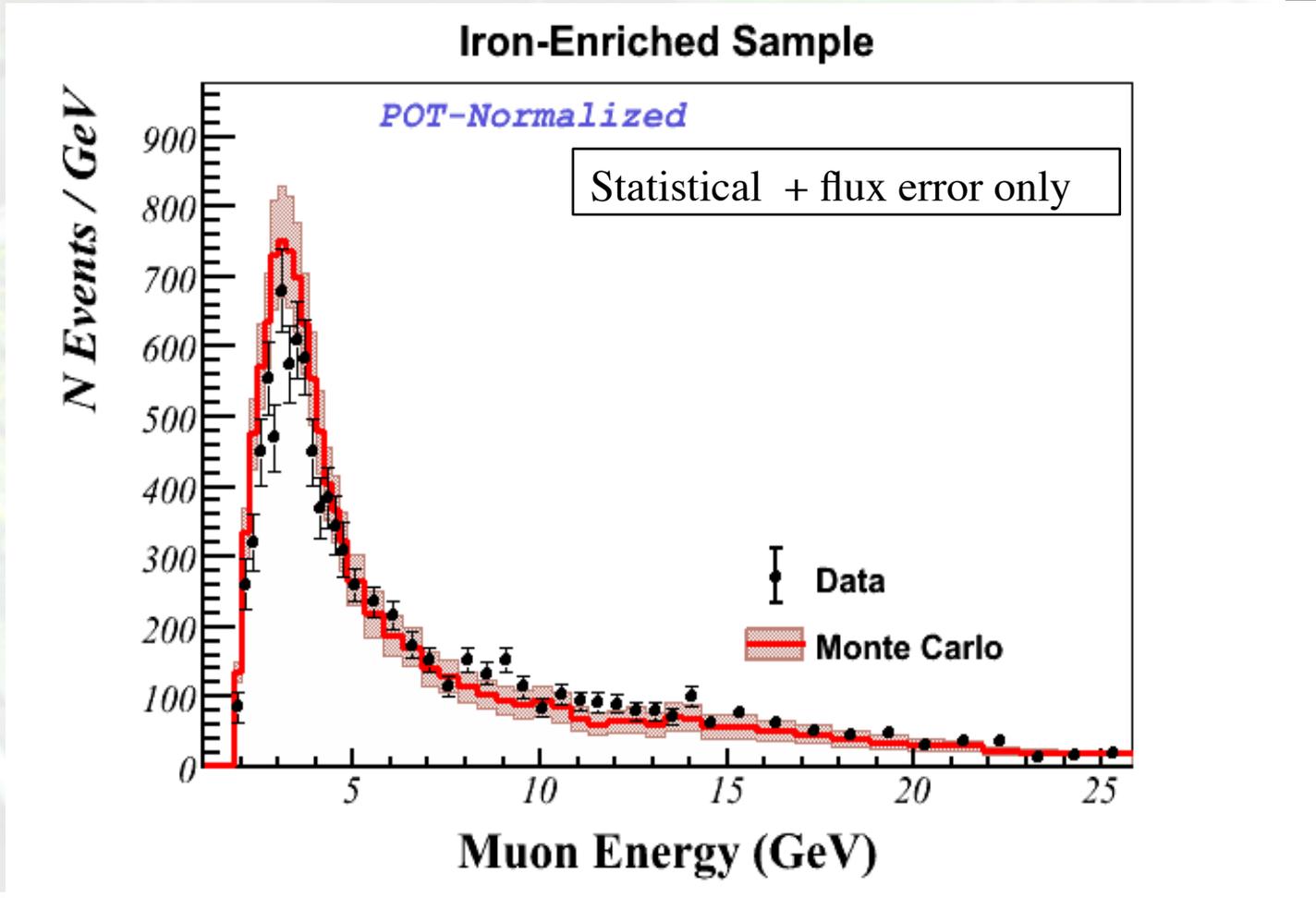
Breakdown of events from “Fe” from MC



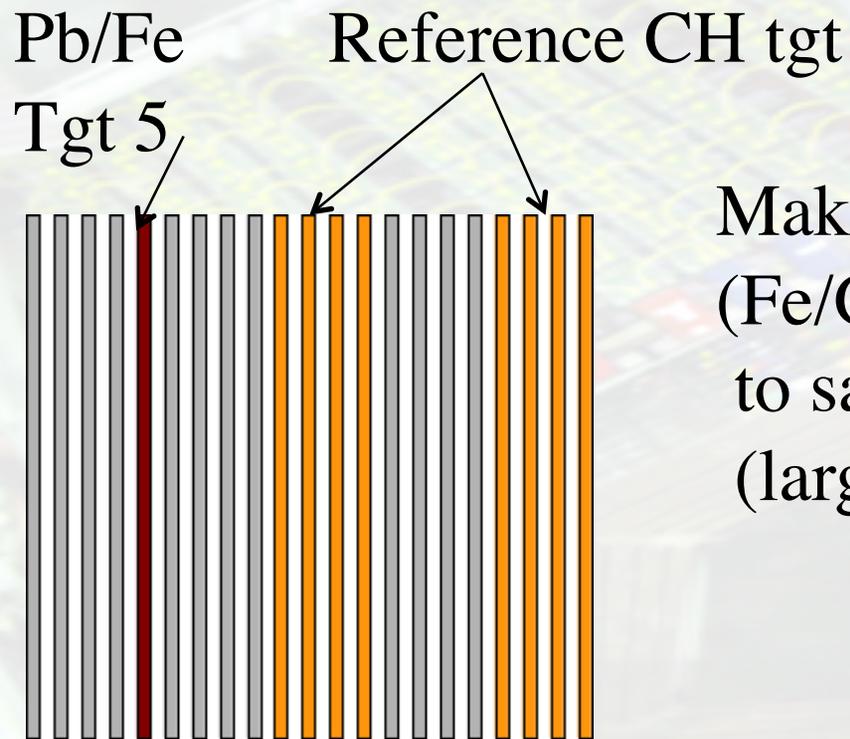
Breakdown of Iron-Enriched Sample



Data-MC comparison for most downstream iron target. No background subtraction



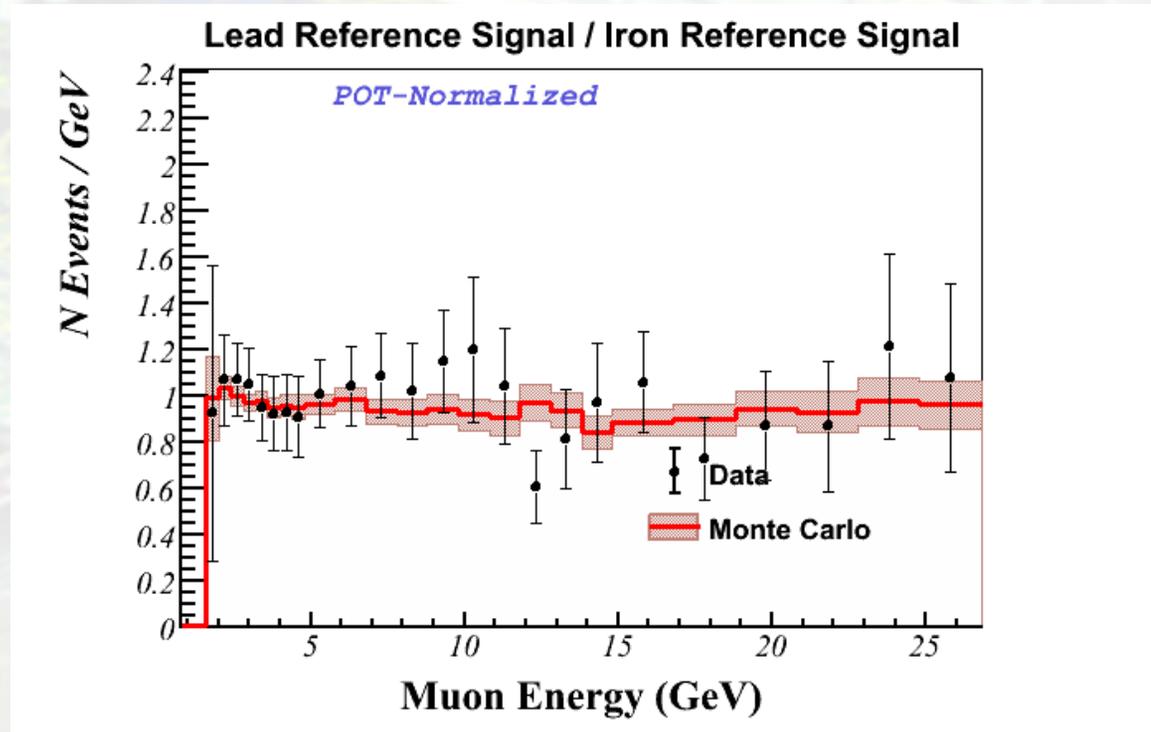
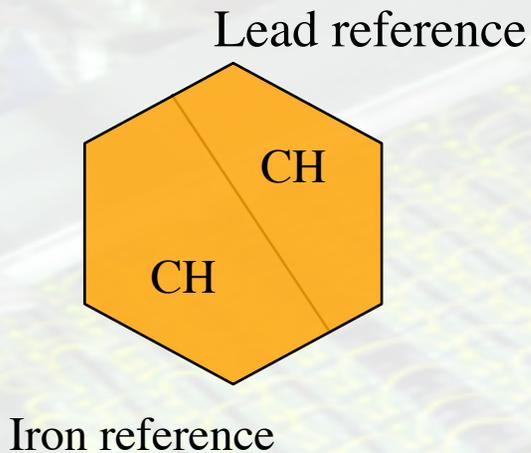
Making the Fe/Pb ratio also requires correcting for the acceptance difference for muons into MINOS, and subtracting the scintillator background



Making double ratio
 $(\text{Fe}/\text{CH})/(\text{Pb}/\text{CH})$ of each nucleus
to same area scintillator cancels
(largely) acceptance difference



Comparison of Reference Targets



Acceptance correction works well.
Analysis of Pb/Fe still underway.



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Quasi-elastic cross section



Quasi-elastic scattering is the two body neutrino-nucleon reaction with a muon in the final state.



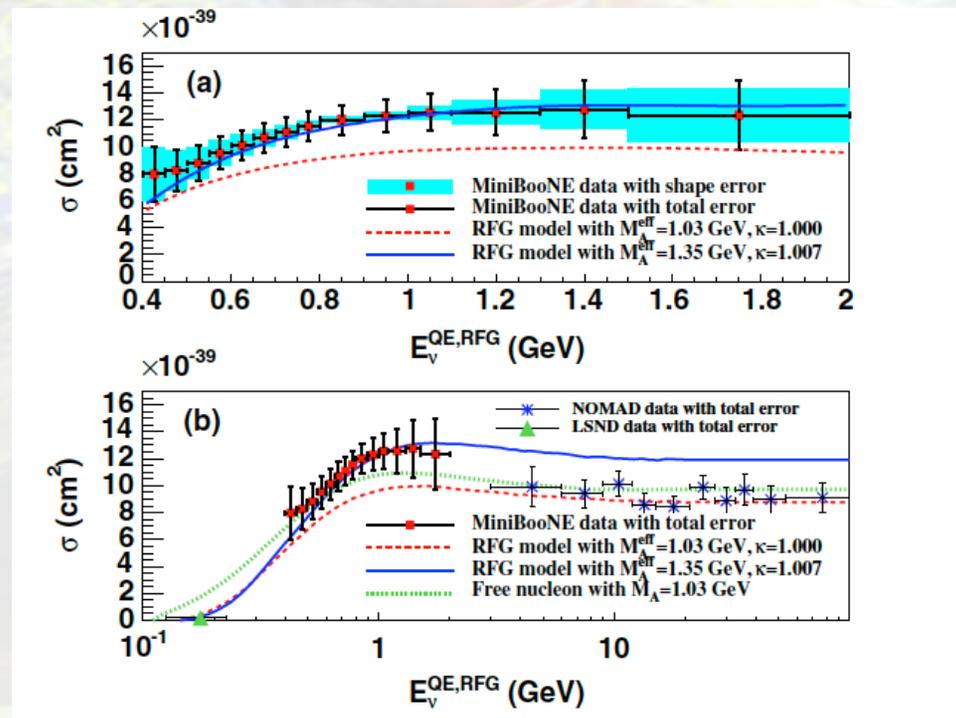
Cross section is a function of EM form factors (determined from electron scattering) and the axial form factor, generally parameterized as:

$$F_A = \frac{-g_A}{\left(1 + \frac{Q^2}{M_A^2}\right)^2} \quad \begin{array}{l} g_A \text{ determined from neutron beta decay} \\ M_A \text{ fit to scattering data} \end{array}$$





Recent MiniBooNE data for QE scattering on carbon appears inconsistent with NOMAD data. MiniBooNE is about 30% higher than expected, and is best fit with M_A of 1.35, vs 1.03 for NOMAD.



See talk by Arie Bodek on this topic later today



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From Aguilar-Arevalo et al PRD 81, 092005 (2010)

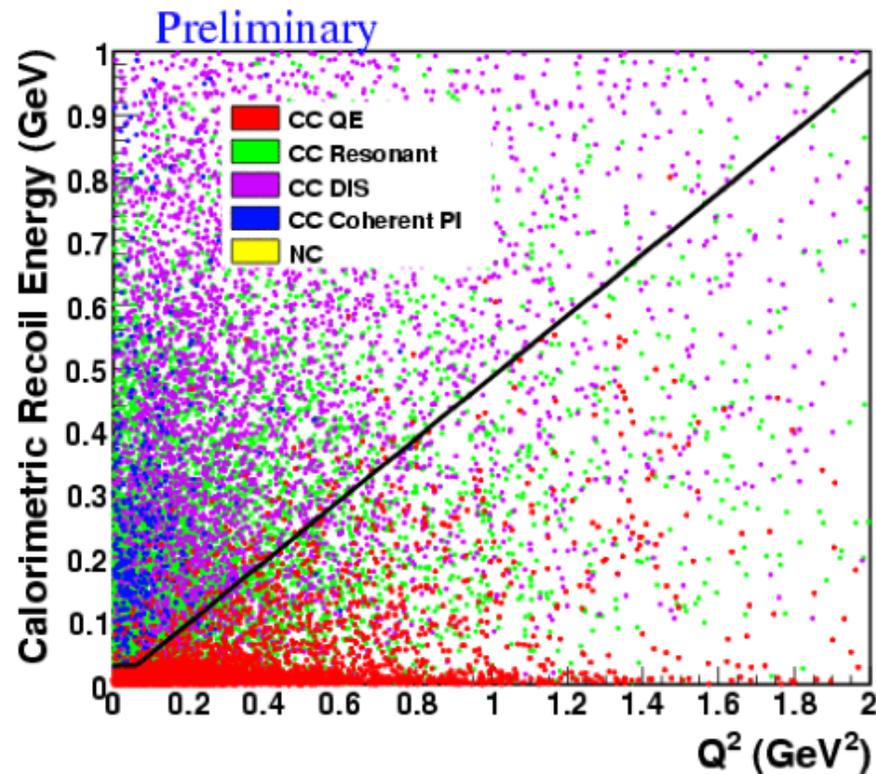
R. Ransome - PANIC July 26, 2011

Event Selection for $\bar{\nu}$ QE



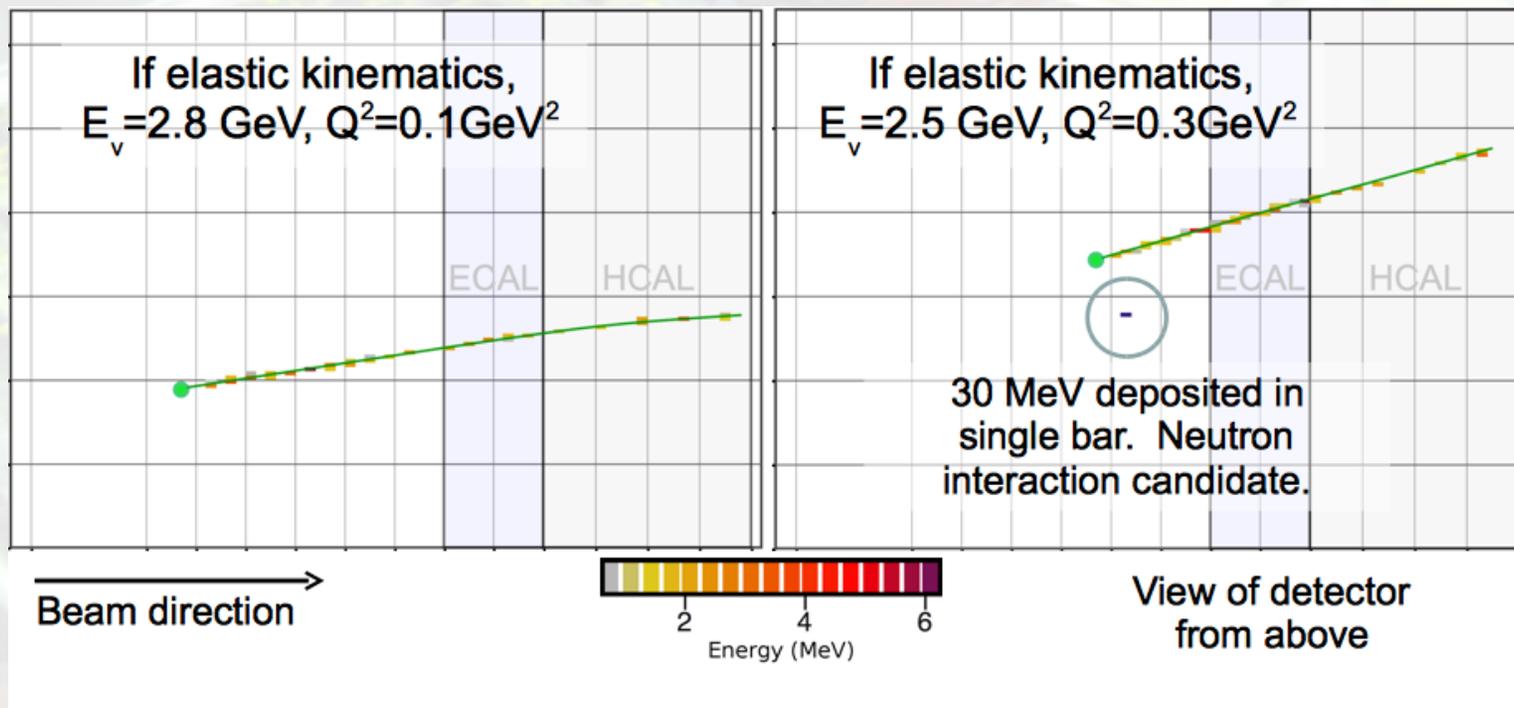
Require 1 positive muon in MINOS matched to MINERvA

Recoil energy is nominally $Q^2/2m_{\text{prot}}$ — require recoil energy to be consistent with this value.



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Anti-neutrino QE candidates

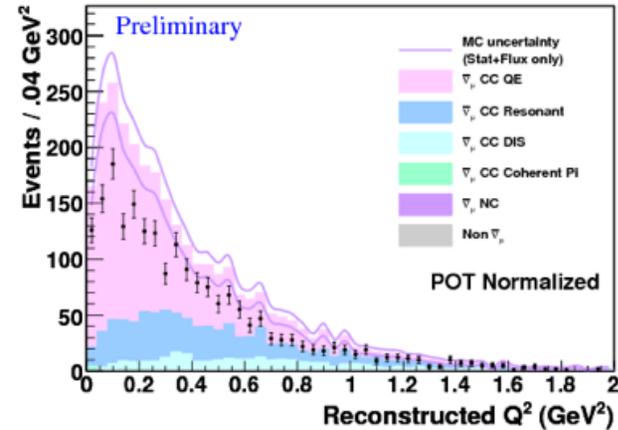
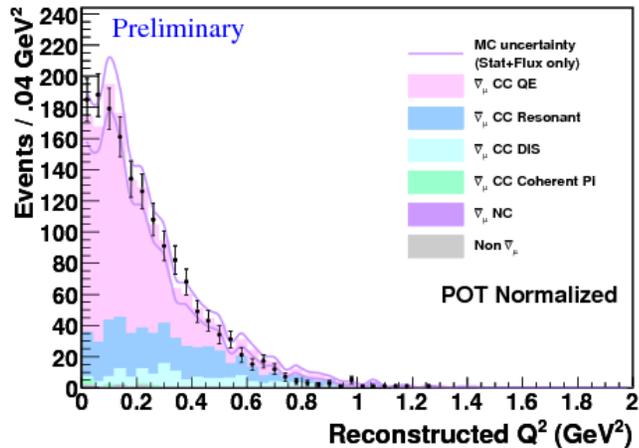


Absolute (POT) normalization

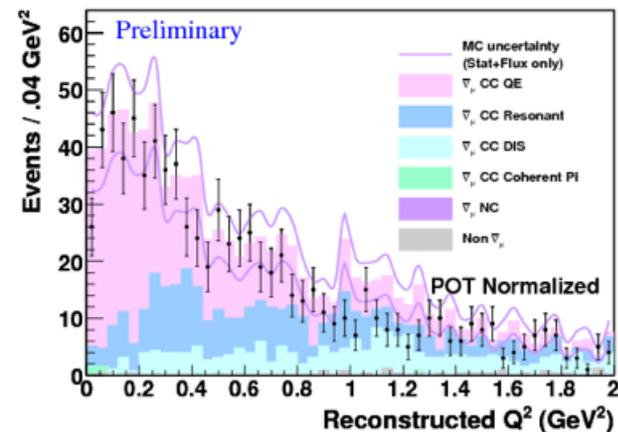


0-3 GeV

3-5 GeV



5-10 GeV



3-5 GeV somewhat lower than MC prediction. Cannot be explained by changing M_A



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The cause of the discrepancy between MC and data is still uncertain. Further refinement of event selection is underway.

We will continue the QE analysis with data from the full detector runs, and additionally for neutrino data.



The Future



Only a small fraction of data has been analyzed.

Studies QE scattering with neutrinos and on the various nuclear targets are well underway.

Other exclusive channels, including pion production, coherent pion production, and neutral current scattering are being studied.



Summary



MINERvA began data taking with a partially complete detector in October 2009, and with the full detector in March 2010

Detector is working well and as expected

Initial QE analysis for anti-neutrinos appears to show smaller cross sections than anticipated.

Using M_A extracted from MiniBooNE does not explain the discrepancy.

Many more results coming soon!

