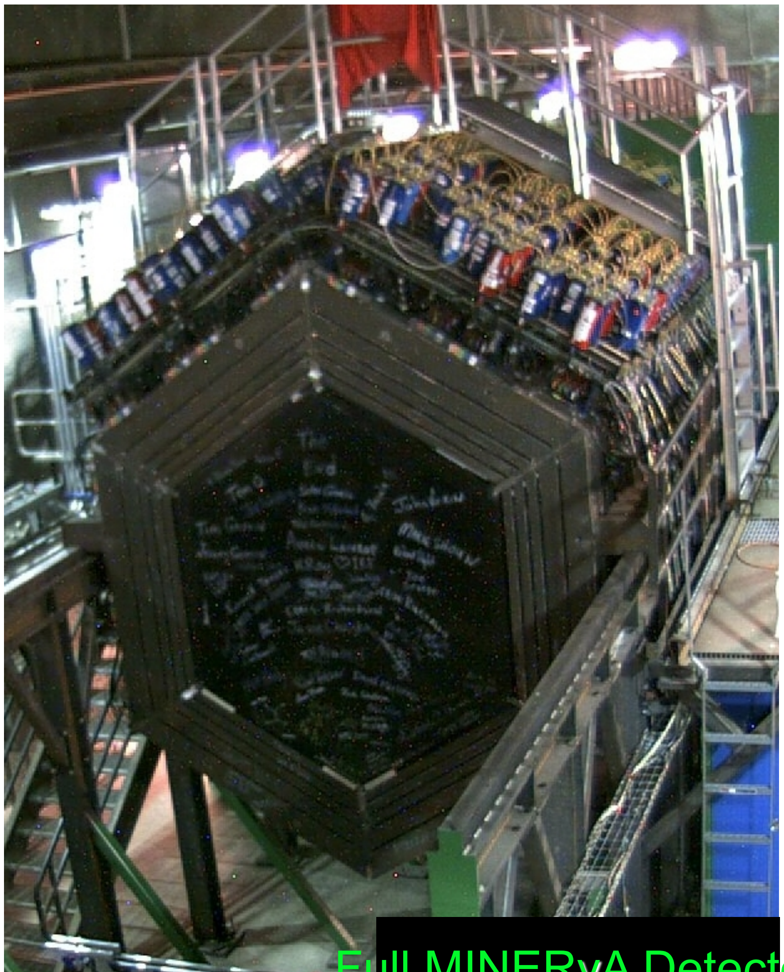
The MINERνA Experiment



Full MINERνA Detector

R. Ransome

Rutgers, The State University of New Jersey

for the MINERνA collaboration

The MINERνA Collaboration
Main Injector ExpeRiment ν-A

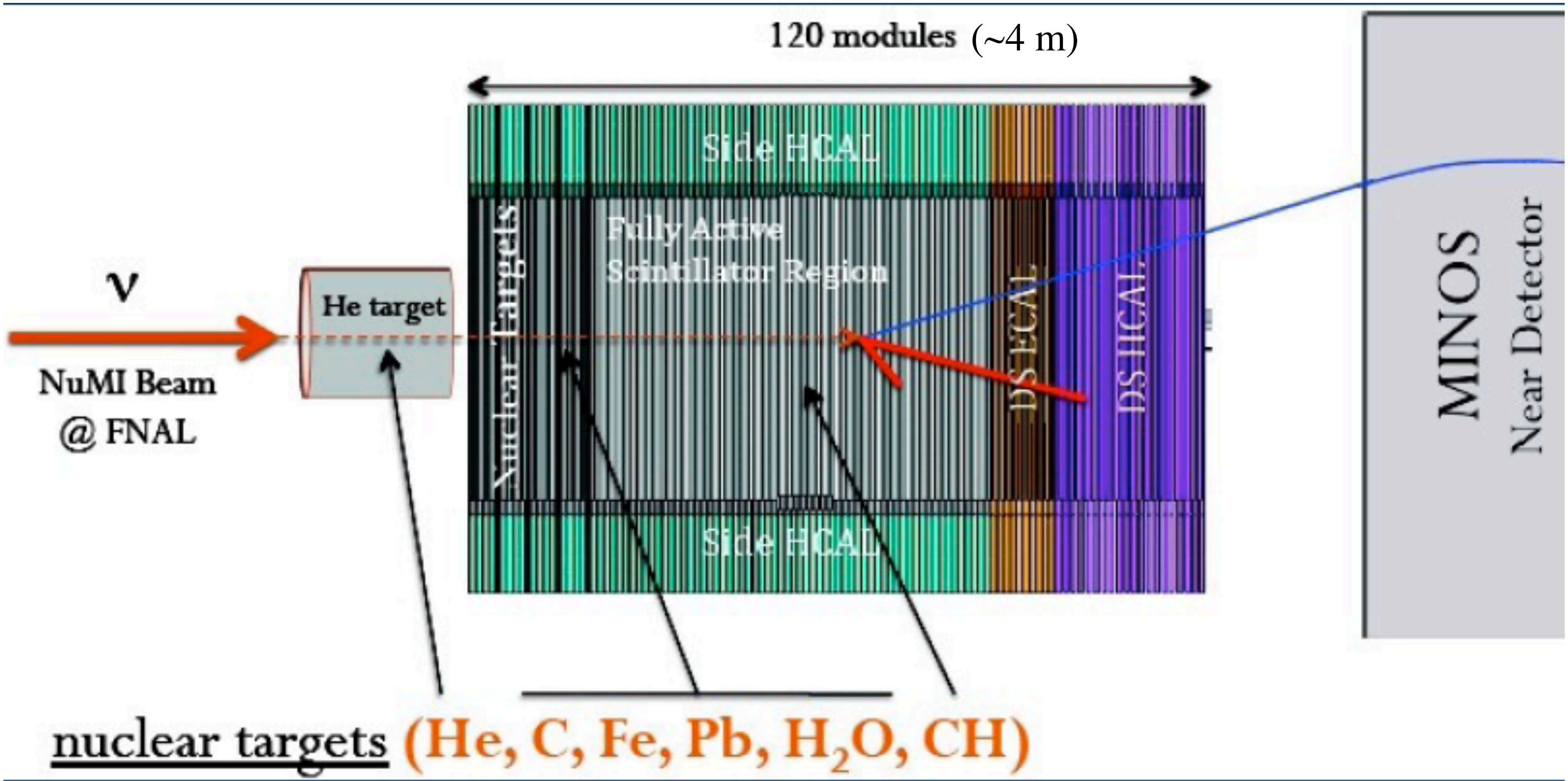
- University of Athens, Athens, Greece
- Centro Brasileiro de Pesquisas Fisicas, Rio de Janeiro, Brazil
- UC Irvine, Irvine, CA
- Fermi National Accelerator Lab, Batavia, IL
- University of Florida, Gainsville, FL
- Universidad de Guanajuato, Guanajuato, Mexico
- Hampton University, Hampton, VA
- Institute 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 80 nuclear and particle physicists from 21 institutions

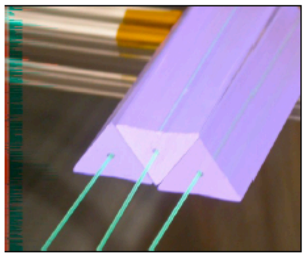
What is MINERνA

- A good resolution fully active detector designed to study neutrino reactions with unprecedented detail
- The detector sits upstream of the MINOS near detector in the FNAL NuMI hall
- Will study neutrino reactions on a variety of nuclei

The Detector

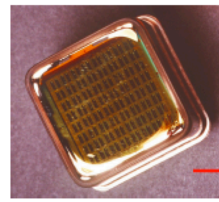


Tracking detectors

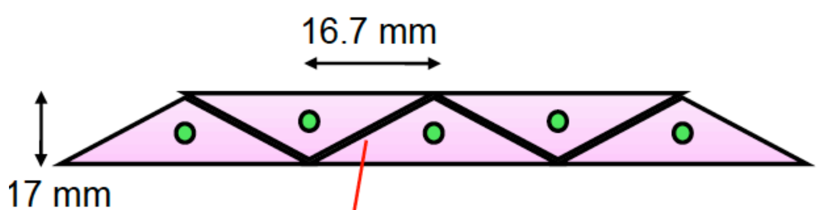


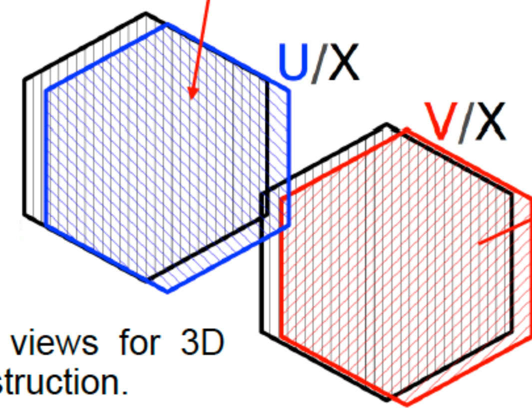
Extruded plastic scintillator + wavelength shifters.

Triangular geometry allows charge sharing for better position resolution.

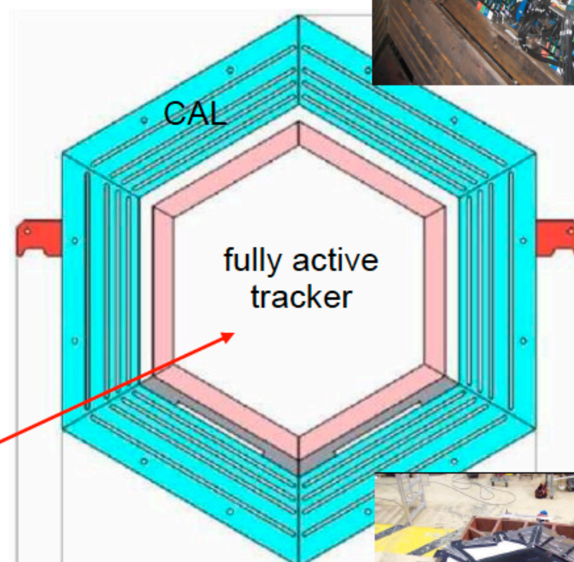


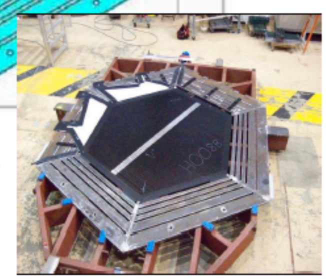
64 anode PMT's





Three views for 3D reconstruction.

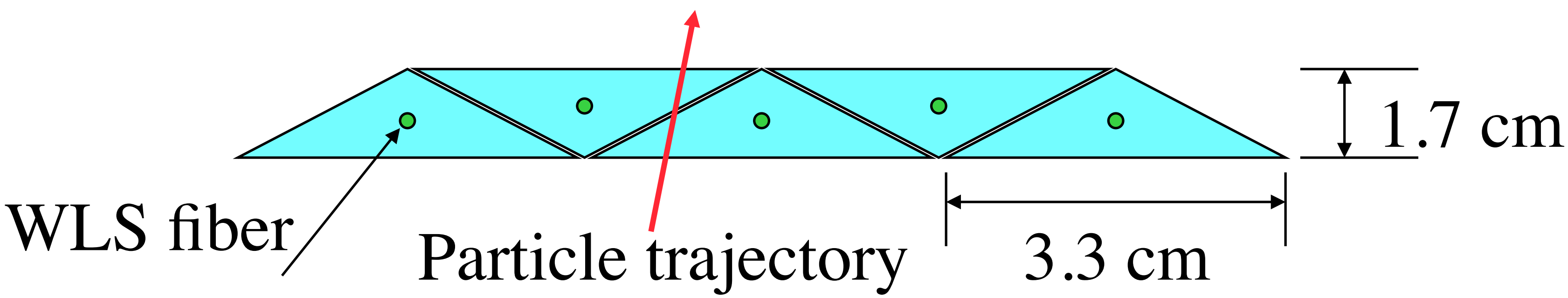




Iron outer detector instrumented for EM calorimetry.

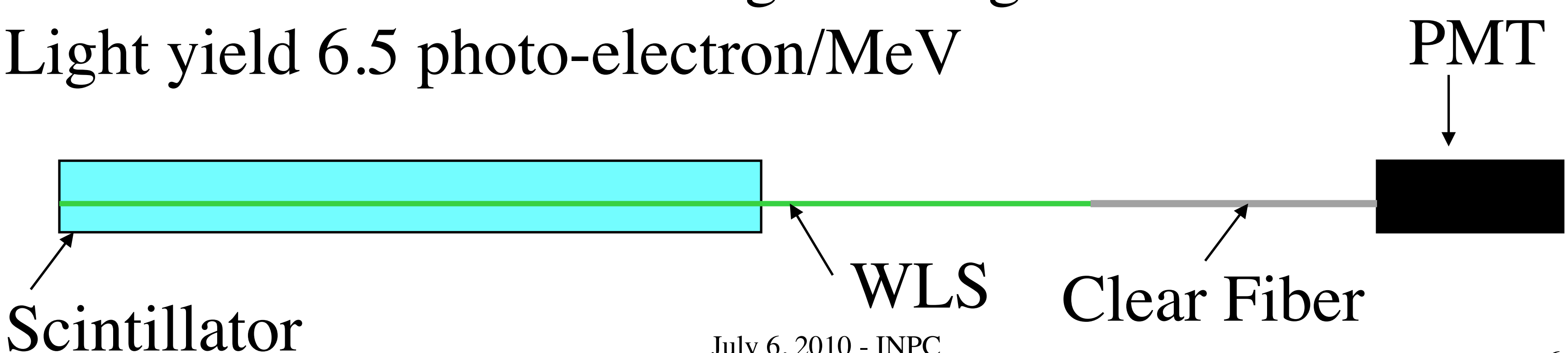
Active Scintillator Target

Triangular scintillators are arranged into planes – Wave length shifting fiber is read out by Multi-Anode PMT



~3 mm resolution with charge sharing

Light yield 6.5 photo-electron/MeV



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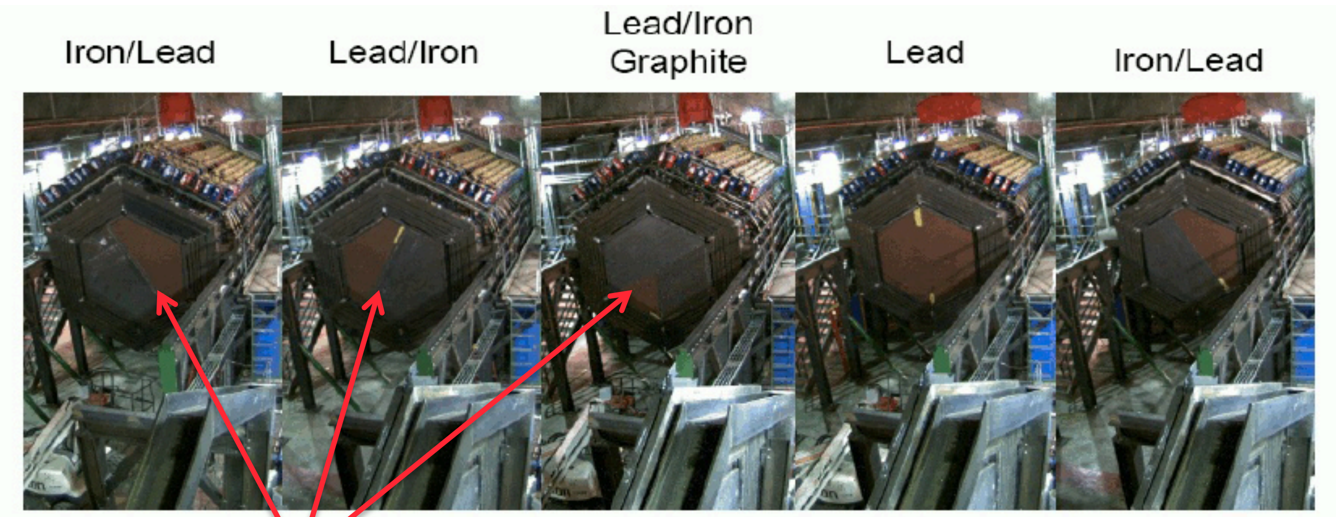
Summary of detector capability

- Good tracking resolution (~3 mm)
- Calorimetry for both charged particles and EM showers
- Containment of events from neutrinos < 10 GeV (except muon)
- Muon energy and charge measurement from MINOS
- Particle ID from dE/dx curve, and energy+range
  - But no charge identification ☹ except muons into MINOS

Nuclear targets



2.5 cm thick Pb/Fe

7.6 cm C

.75 cm Pb

1.25 cm Pb/Fe

15 cm H_2O

Approximate total CC interactions – 4 year run

No efficiency correction included

Tgt	4He	Scint.	H20	C	Fe	Pb
CC Events	0.6 M	9 M	0.7 M	0.4 M	2.9 M	2.9 M
Mass	.25 t	3 tons	.3 t	0.15 t	0.9 t	0.9t

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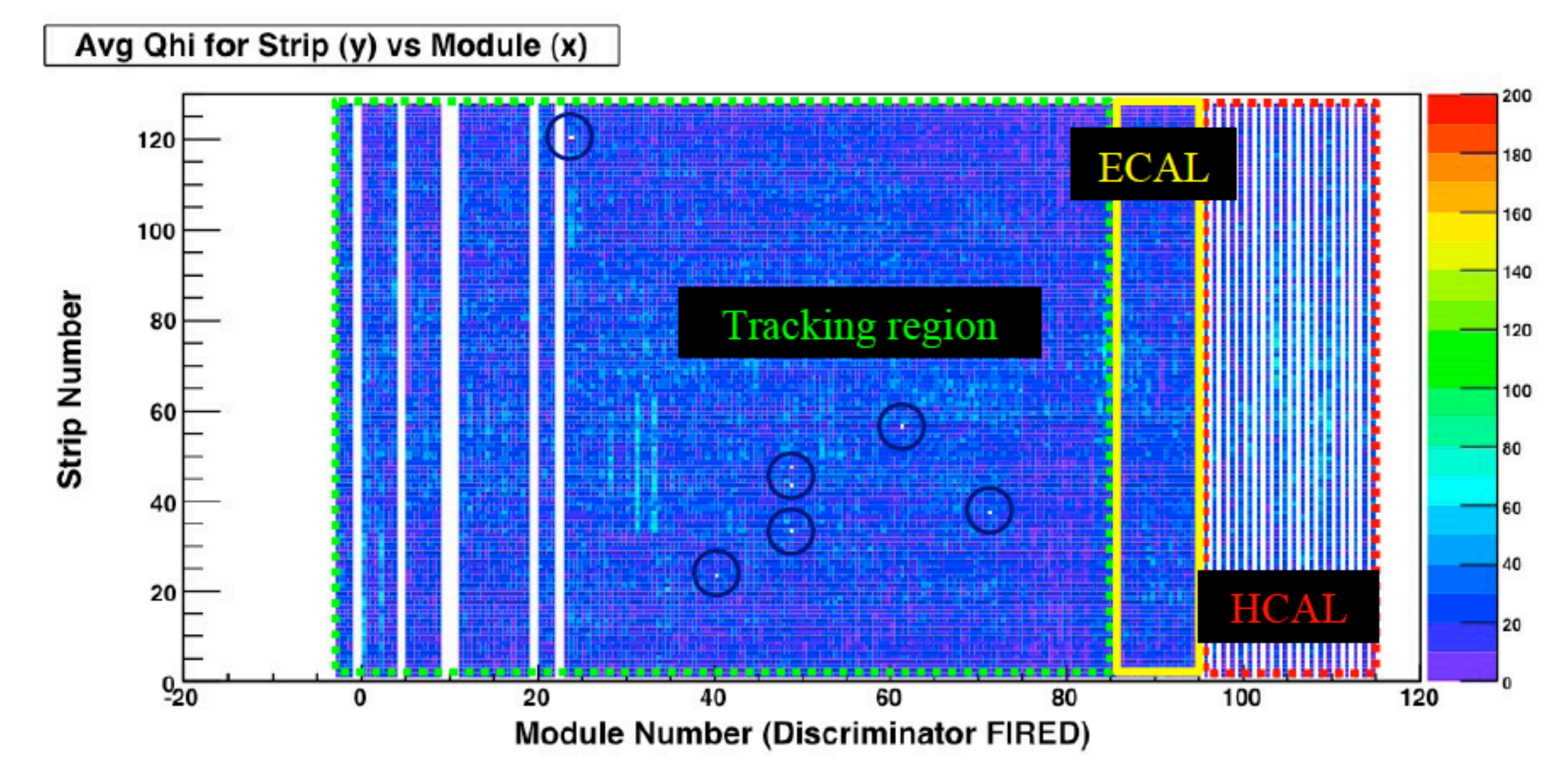
Schedule

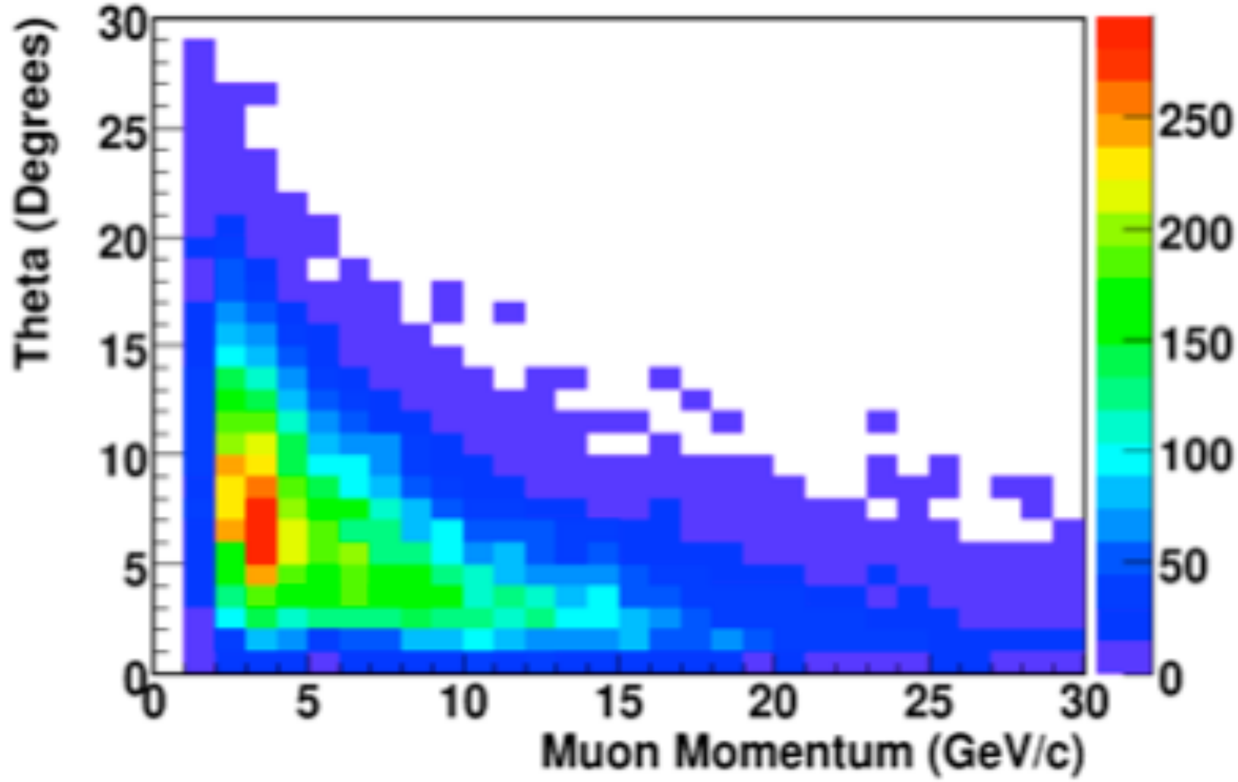
- Downstream half of detector installed Nov 2009 – began running with anti-neutrinos
  - Low energy beam – average energy ~4 GeV
- Detector completed March 2010, began running with neutrinos
  - Low energy beam – will run until spring 2012
  - 4e20 POT
- Spring 2012- spring 2013 – shutdown for NuMI upgrade for NOvA
- 2013-2016 continued neutrino running
  - Medium energy beam – average energy ~8 GeV
  - 12e20 POT

Occupancy plot



>99.9% of 31K channels working

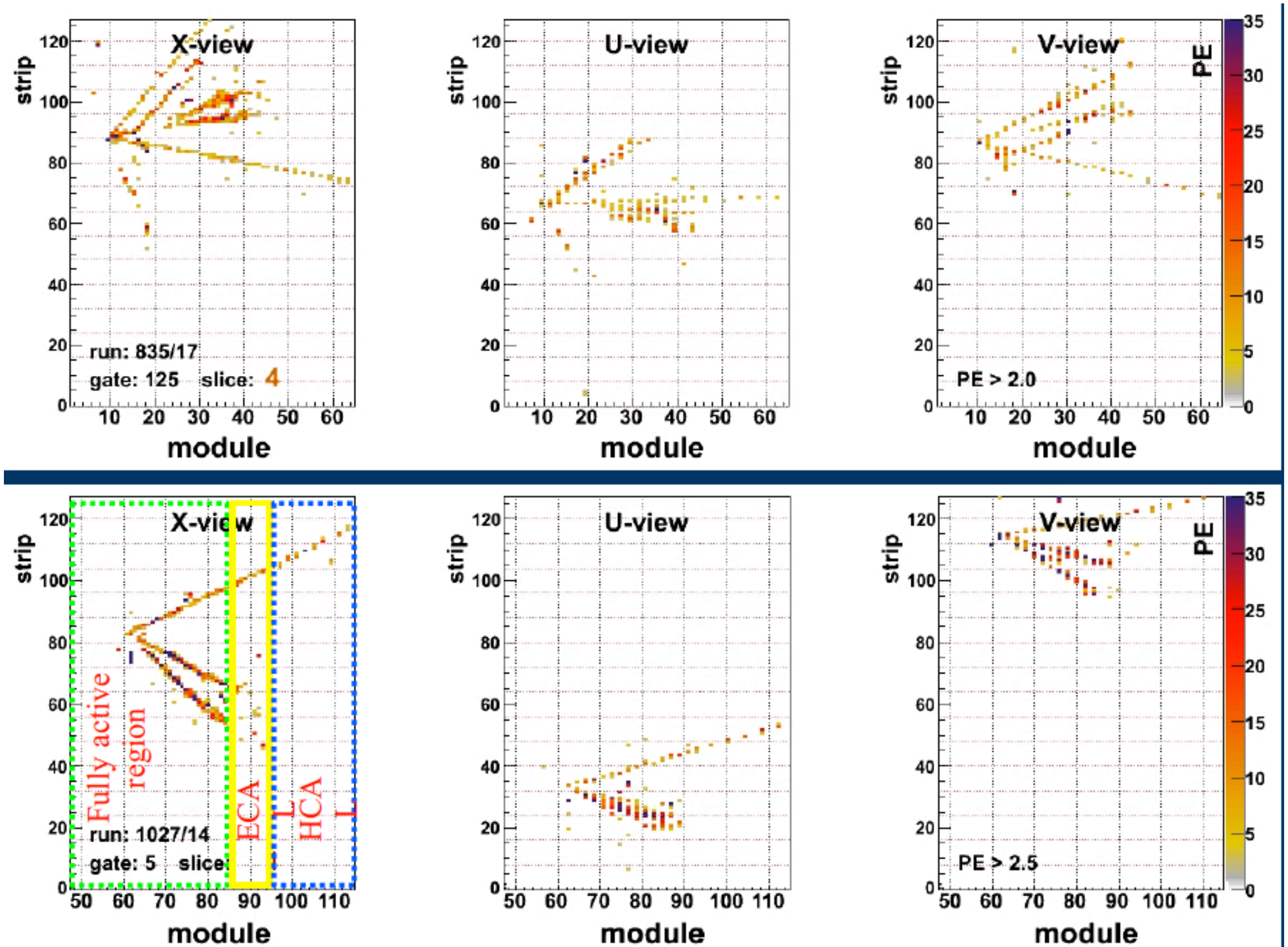
Muon Angle vs momentum



Muons tracked from MINERvA into MINOS show reasonable spectrum and angular dependence

Event display

Events from antineutrino running period



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Neutrinos – Advantages

- Neutrinos are unique among scattering probes in their flavor sensitivity for charged current scattering
  - For example, νn -> μp is sensitive to d, $\bar{u}$, s distributions
- Combining neutrino and antineutrino scattering allows determination of parton structure functions
- Neutrinos interact weakly giving easy access to the weak charge structure of nucleons (in contrast to electron scattering, which requires very precise parity violation experiments)

Neutrinos – Experimental difficulties

- Beam has broad energy range (the LE beam energy 1-10 GeV, plus low intensity up to nearly 100 GeV)
- Don't know directly the actual energy for any particular reaction
  - Need to use summed energy of final state particles. The fully active central region will allow a much better determination of neutrino energy than experiments with large fractions of passive material
- Even with high intensity of NuMI, need massive detectors
- Can't even measure the scattering neutrino for neutral current scattering

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Physics Goals of MINERνA

- Study the A-dependence of neutrino interactions with unprecedented detail – Scintillator (C-H), ^4He, C, H_2O, Fe, Pb targets
- High precision measurement of the axial form factor to high Q^2, and study the A dependence
- Study quark-hadron duality in neutrino interactions, complementary to Jlab work
- Search for x-dependent nuclear effects in neutrino scattering
- Precision cross section measurement and studies of final states
    - Important for understanding systematics of oscillation experiments

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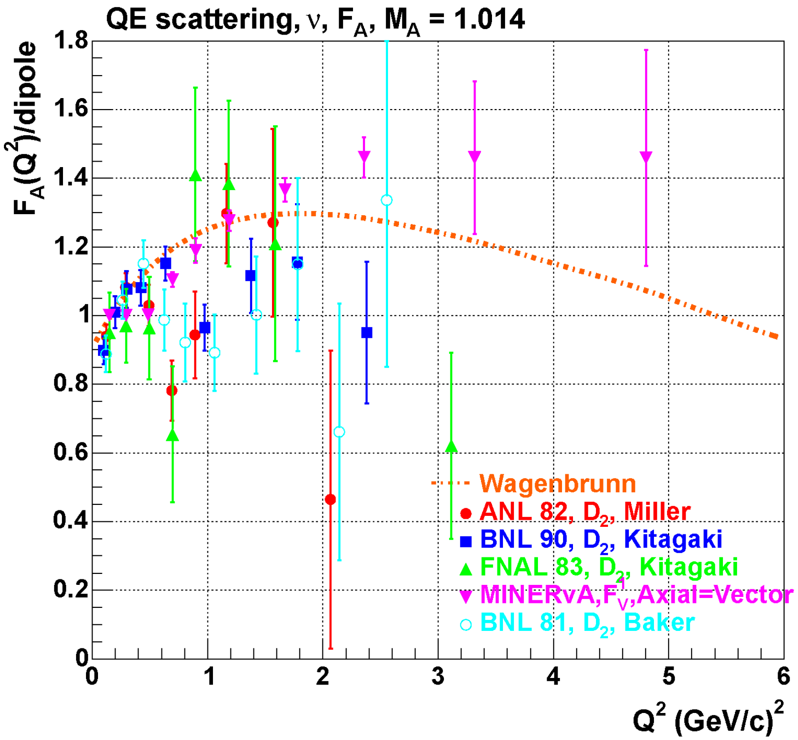
Axial form factor



Estimated statistics including estimated acceptance and efficiency

Axial form factor can be extracted with much higher precision at low Q^2, and Q^2 range is greatly increased over previous measurements.

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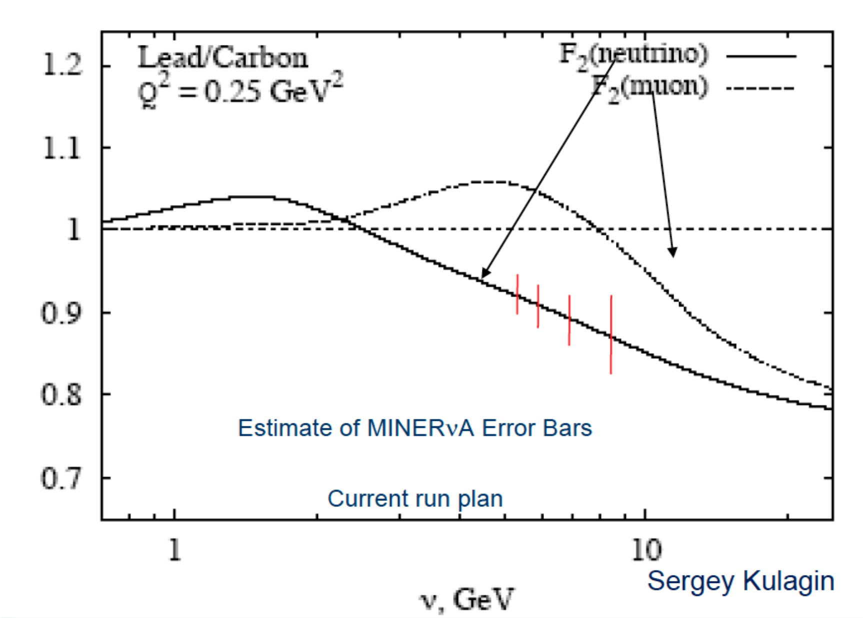
A dependence of form factor

- The form factor may be modified in the nuclear medium
  - Model predictions that form factor will be modified by a few percent, (Saito, Tsushima, Thomas, Progress in Particle and Nuclear Physics **58,** 1 (2007)
  - Extraction of form factor may be influenced by conventional effects – final state interactions, for example, which effect identification of QE
- We anticipate sufficient statistics to study final states and potential changes in the form factor at low Q^2 at the percent level
  - Estimated total interactions, no efficiency or solid angle correction ~800 K in CH, ~300 K in Pb/Fe, ~100 K in H_2O in 4 year run

Nuclear Shadowing



S. Kulagin PRD 76, 094023, 2007
and private communication

Shadowing in F_2 measurement for muons and neutrinos predicted to be substantially different. MINERνA will be able to determine this for C/Fe/Pb

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Other reactions

- Coherent pion production (single pion production off nucleus)
  - Important background for oscillation experiments
  - First measurement of A dependence
  - Estimated 89 K CC, 44 K NC in scintillator
  - Forward peaked, in some ways easier to measure than with electrons
- Resonant pion production
  - ~1.7 M interactions – first detailed study of A dependence
- DIS structure functions
  - ~ 4 M interactions in scintillator
- Strange and Charm particle production
  - ~240 K interactions in scintillator

Summary

- MINERvA is a high statistics neutrino experiment
- Greatly improved statistics on all neutrino-nucleus cross sections
- Precision measurements of A dependence of axial form factor
- Data coming in now! Results soon!