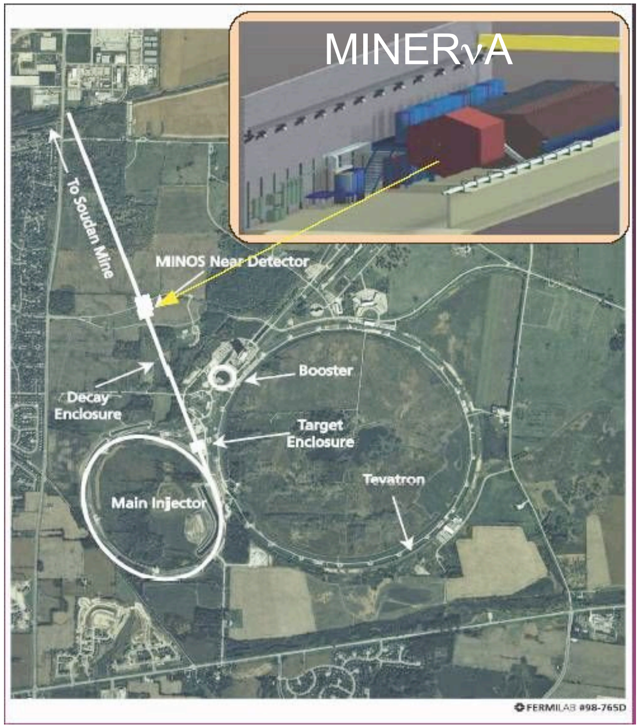
Prospects and Status of the MINERνA Experiment at FNAL

Tom Kafka for V. Paolone



- MINERνA physics
- Detector design
- Detector construction
- Tracking Prototype (TP)
- TP performance
- Conclusions

MINERνA Collaboration

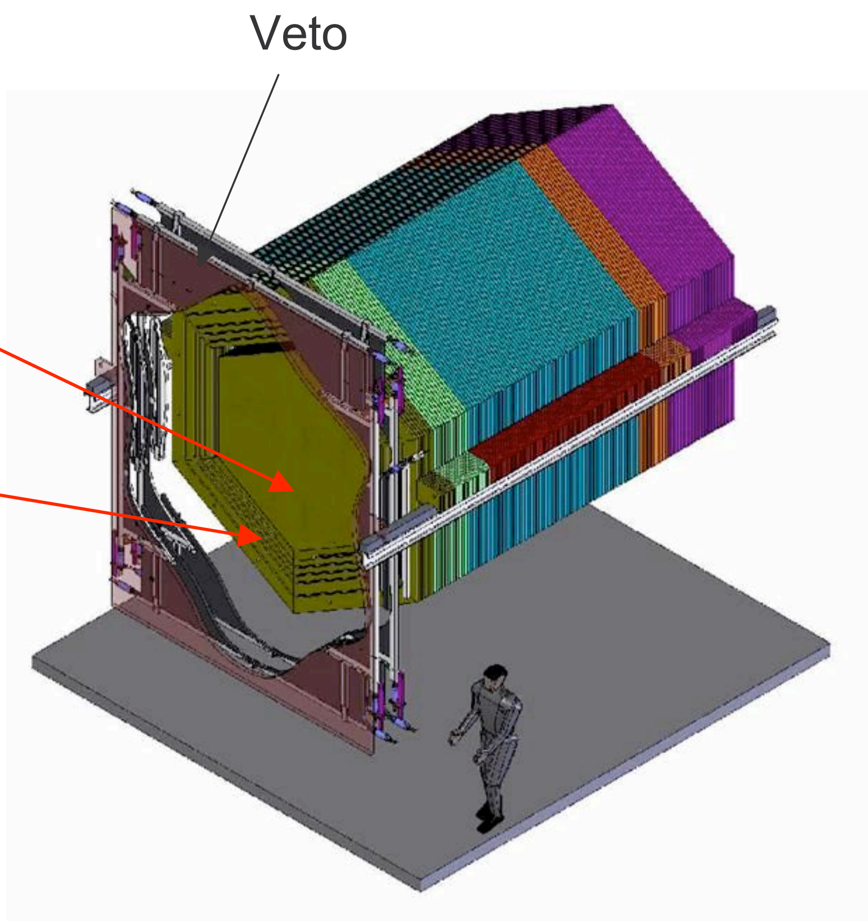
- University of Athens, Athens, Greece
- Centro Brasileiro de Pesquisas Físicas, Rio de Janeiro, Brazil
- University of California, Irvine, California
- University of Dortmund, Dortmund, Germany
- Fermi National Accelerator Laboratory, Batavia, Illinois
- University of Florida, Gainesville, Florida
- Universidad de Guanajuato, Mexico
- Hampton University, Hampton, Virginia
- Institute for Nuclear Research, Moscow, Russia
- James Madison University, Harrisonburg, Virginia
- Jefferson Lab, Newport News, Virginia
- Massachusetts College of Liberal Arts, North Adams, Massach
- University of Minnesota-Duluth, Duluth, Minnesota
- Northwestern University, Evanston, Illinois
- Otterbein College, Westerville, Ohio
- Pontificia Universidad Catolica del Peru, Lima, Peru
- University of Pittsburgh, Pittsburgh, Pennsylvania
- Purdue University-Calumet, Hammond, Indiana
- University of Rochester, Rochester, New York
- Rutgers University, New Brunswick, New Jersey
- University of Texas, Austin, Texas
- Tufts University, Medford, Massachusetts
- Universidad Nacional de Ingenieria, Lima, Peru
- The College of William and Mary, Williamsburg, Virginia

-> 24 institutions from 7 countries

What is MINERνA?

Main INjector ExpeRiment for ν-A

- New few-GeV ν scattering experiment under construction at Fermilab.
  - Active scintillator inner tracking volume
  - Outer calorimeter
  - Variety of nuclear targets (He, C, Fe, Pb)
- Optimized to study interaction physics across variety of scattering regimes.



What is it good for:

Single detector experiment -> Non-oscillation ν physics:

- Axial form factor of the nucleon
  - Accurately measured over a wide Q^2 range.
- Resonance production in both NC & CC neutrino interactions
  - Statistically significant measurements with 1-5 GeV neutrinos
  - Study of “duality” with neutrinos
- Coherent pion production
  - Statistically significant measurements of A-dependence
- Strange particle production
  - Important backgrounds for proton decay
- Parton distribution functions
  - Measurement of high-x behavior of quarks
- Generalized parton distributions
- Nuclear effects
  - Expect significant differences for ν-A vs e/μ-A nuclear effects

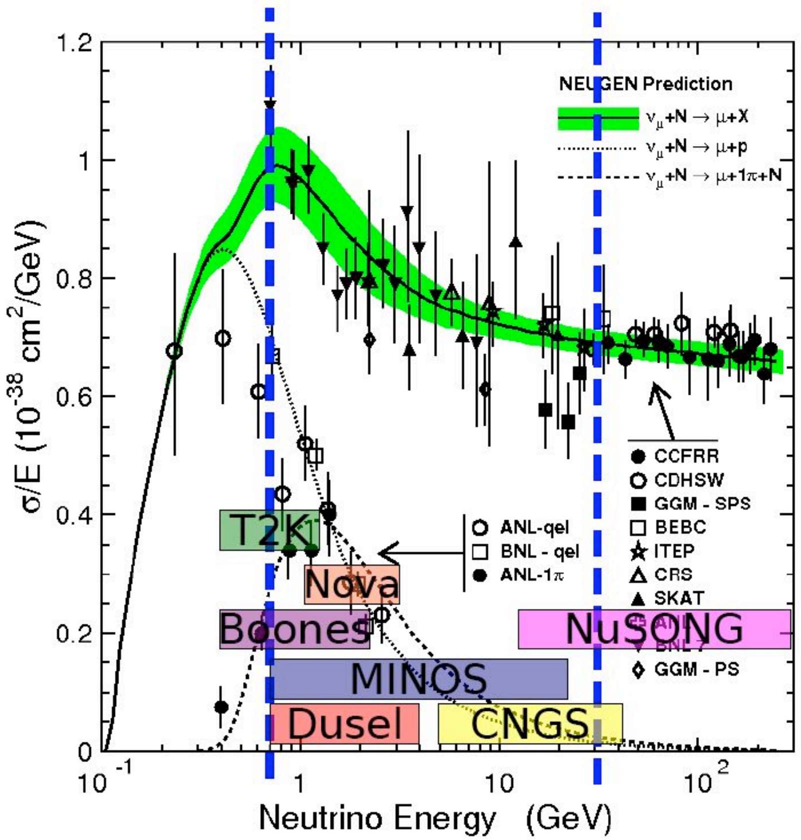
What is it good for: Help others

ν oscillation measurements in long-baseline experiments:

- Need precise understanding of low-energy (few GeV) neutrino cross sections.
- Need better understanding of final-state hadronic system.

Complications:

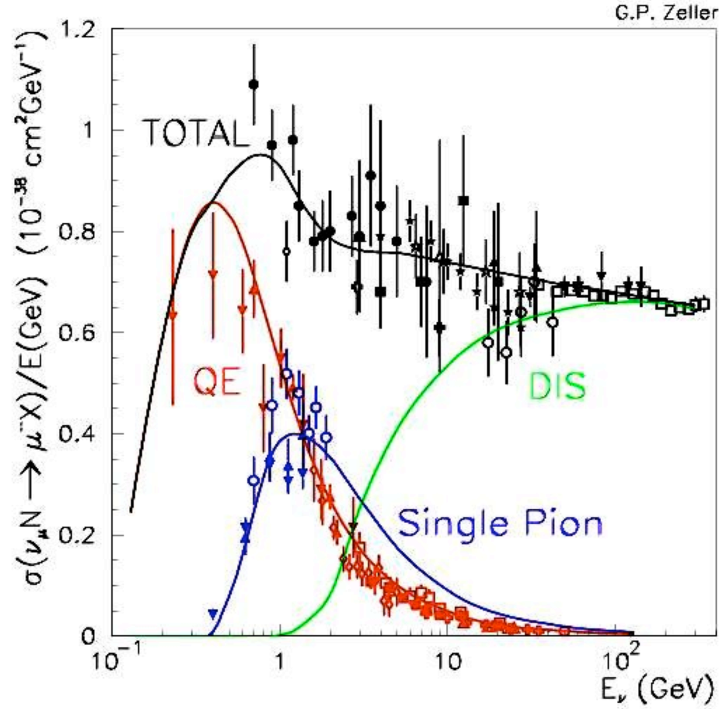
- Existing data:
  - Bubble chamber data (low statistics and large systematics)
  - K2K, Miniboone (lower energies)
- Presently must use models with many ad hoc features to simulate hadron production, nuclear effects.



MINERνA - fine grained detector in high intensity neutrino beam – Fermilab NuMI beamline (**Ne**u**t**rinos at the **M**ain **I**njector)

Low energy neutrino scattering

Precision measurements of low energy neutrino cross sections in an energy region where reaction channels overlap.



Contributions to total cross section:

$\sigma_{TOT} = \sigma_{QE} + \sigma_{RES} + \sigma_{DIS}$

σ_{QE} - Quasi-elastic: $\nu(\overline{\nu})\, n(p) \to \mu^-(\mu^+)\, p(n)$

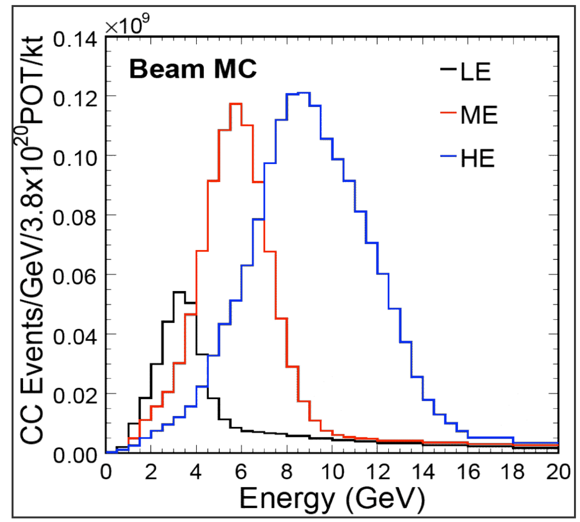
σ_{RES} - Resonance: $\nu N \to \mu N^*$ Inelastic, Low-multiplicity final states

σ_{DIS} - Deep Inelastic Scattering: $\nu N \to \mu X$ Inelastic, High-multiplicity final states

What we expect: Event yields

- Assume the following exposures:
  - $4x10^{20}$ POT LE
  - $12x10^{20}$ POT ME (NOvA)
- Result in ~14 million CC events
  - ~9 million on scintillator
  - ~5 million on nuclear targets

NUMI Beam Spectra



CC Process Type (on scint.)	Number of Events
Quasi-elastic	0.8M
Resonance Production	1.7M
Res-DIS Transition Region	2.1M
DIS Low Q2 & Structure Functions	4.3M
Coherent Pion	89k CC, 44k NC
Charm/Strange	230k

Nuclear Target	Number of Events
He	0.6M
C	0.4M
Fe	2.0M
Pb	2.5M

MINERνA's cross section measurements:

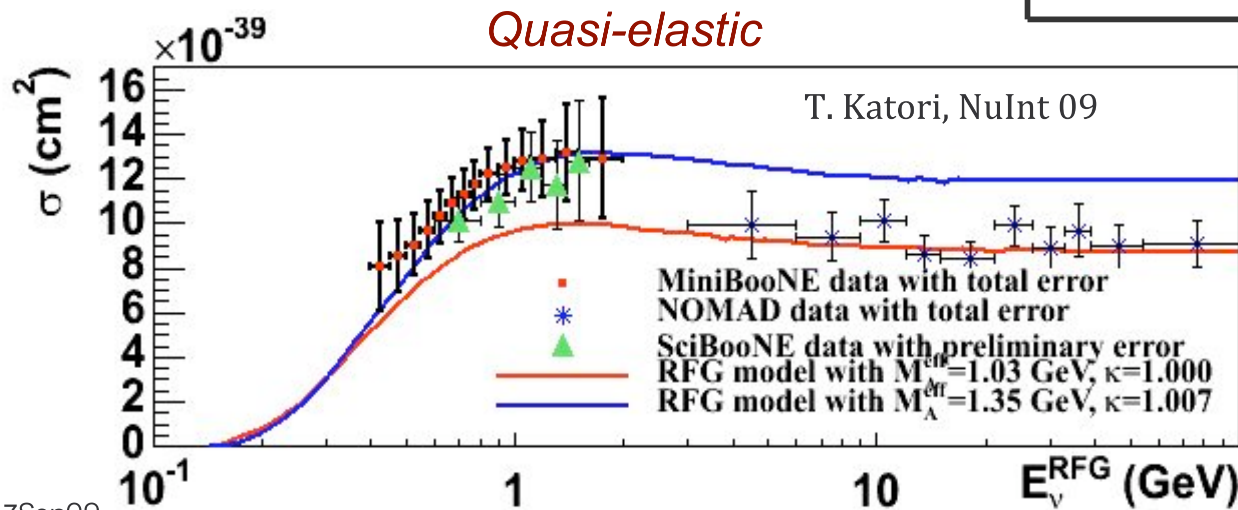
- Finely segmented tracking volume allows reconstruction of exclusive final states.
- Study properties of final-state hadrons – important as input for simulations of long-baseline experiments (presently using ad-hoc modeling).
- MINERνA will reduce many current cross section uncertainties by a factor of 4 – 5.
- Suited to resolve 30% discrepancy between 1 GeV and 5 GeV quasi-elastic cross section measurements.

Estimated cross section uncertainties:

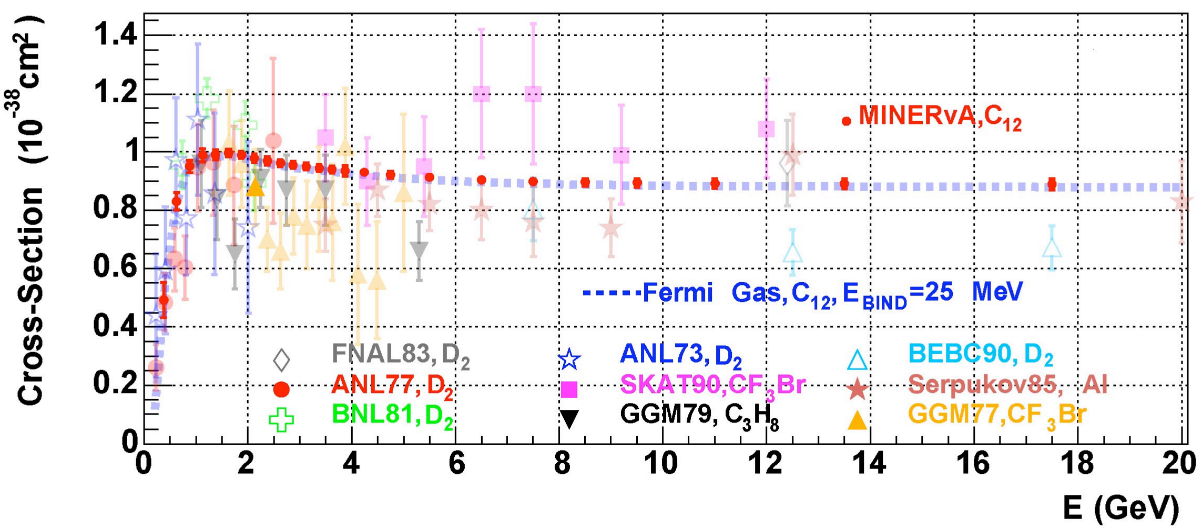
	A.M.	*P.M.*
QE	20 %	5 %
Res	20% CC / 40% NC	5% CC / 10% NC
DIS	20 %	5 %
Coherent	100 %	20 %

(Ante-Minerva) *(Post-Minerva)*

Quasi-elastic



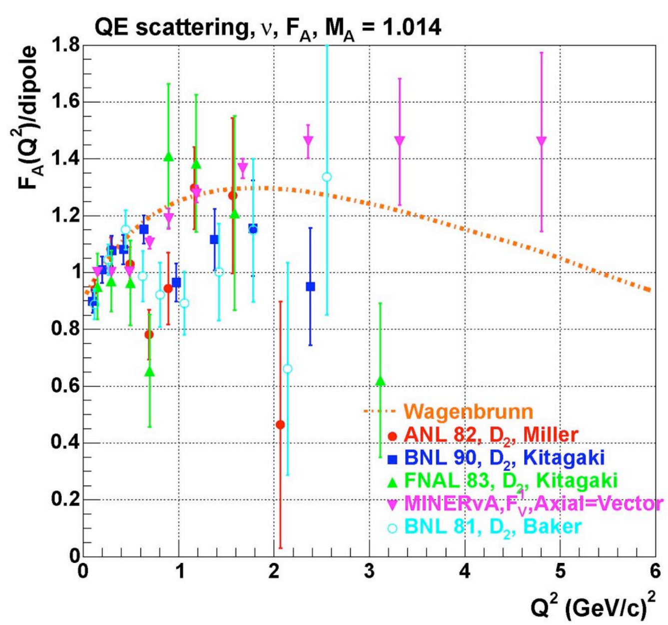
σ_{QE}



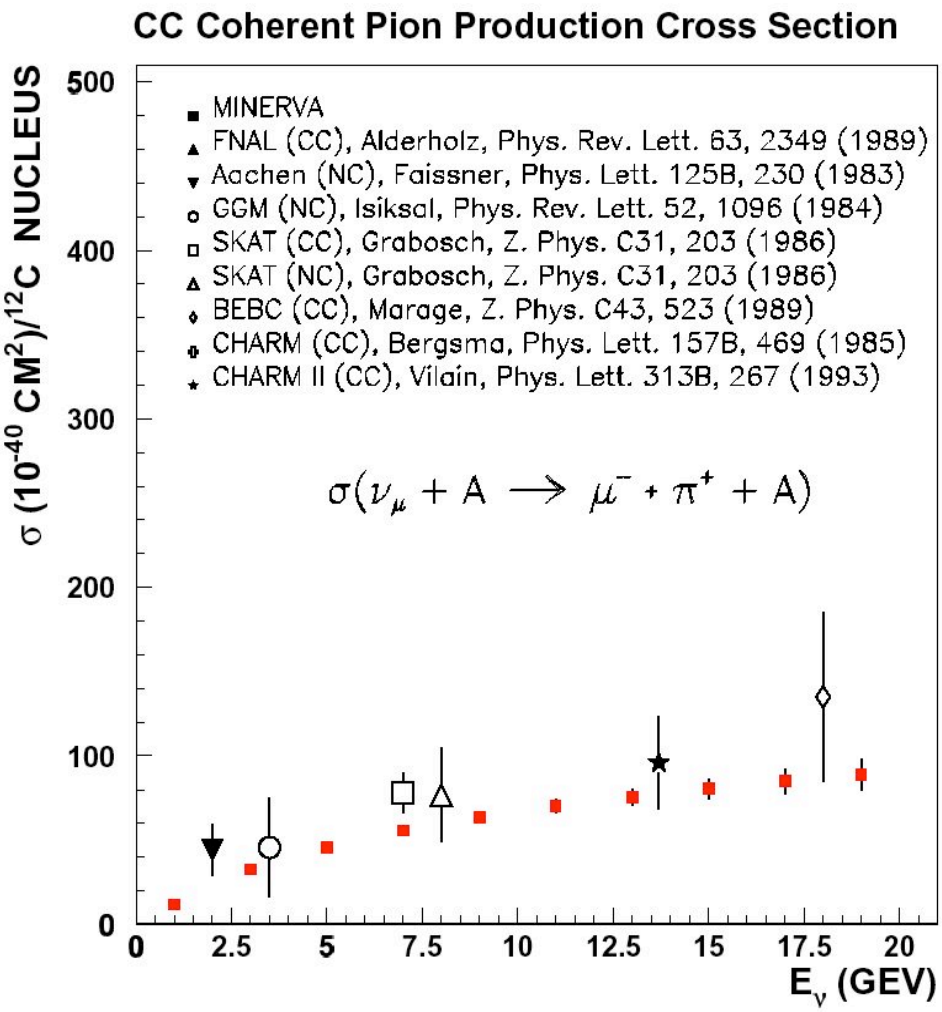
QE cross-section

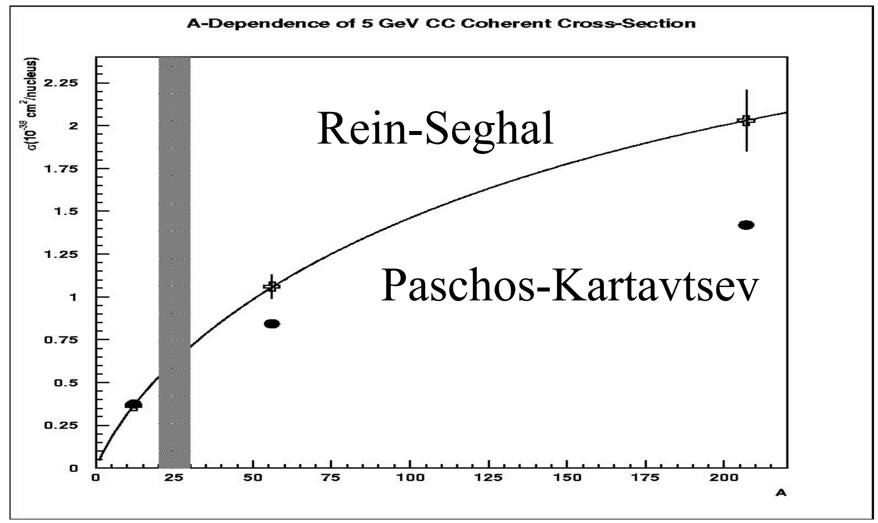
F_A form factor:

- M_A = 1.0? GeV (all old expts, NOMAD)
  1.2? GeV (K2K, MiniBoone)
- non-dipole?



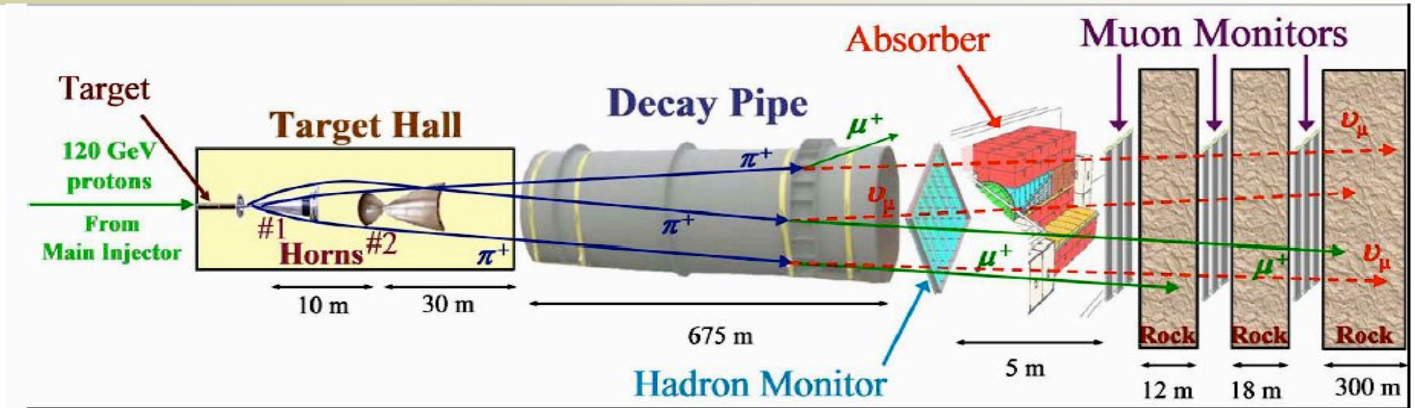
Coherent ν-nucleus reactions



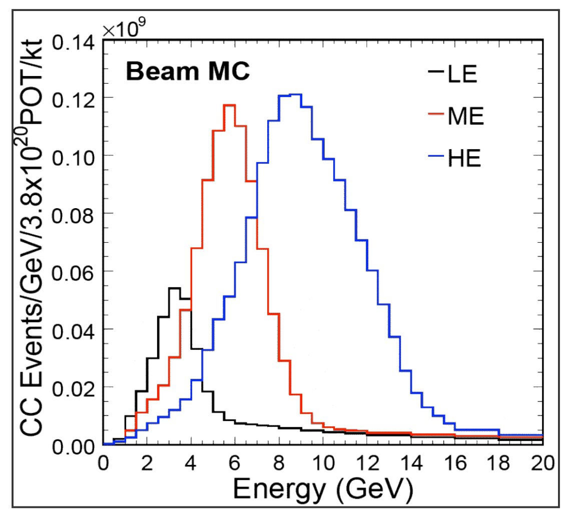


MINERvA's nuclear targets allow the first measurement of the *A*-dependence of σ_{coh} across a wide *A* range

Fermilab NuMI beam

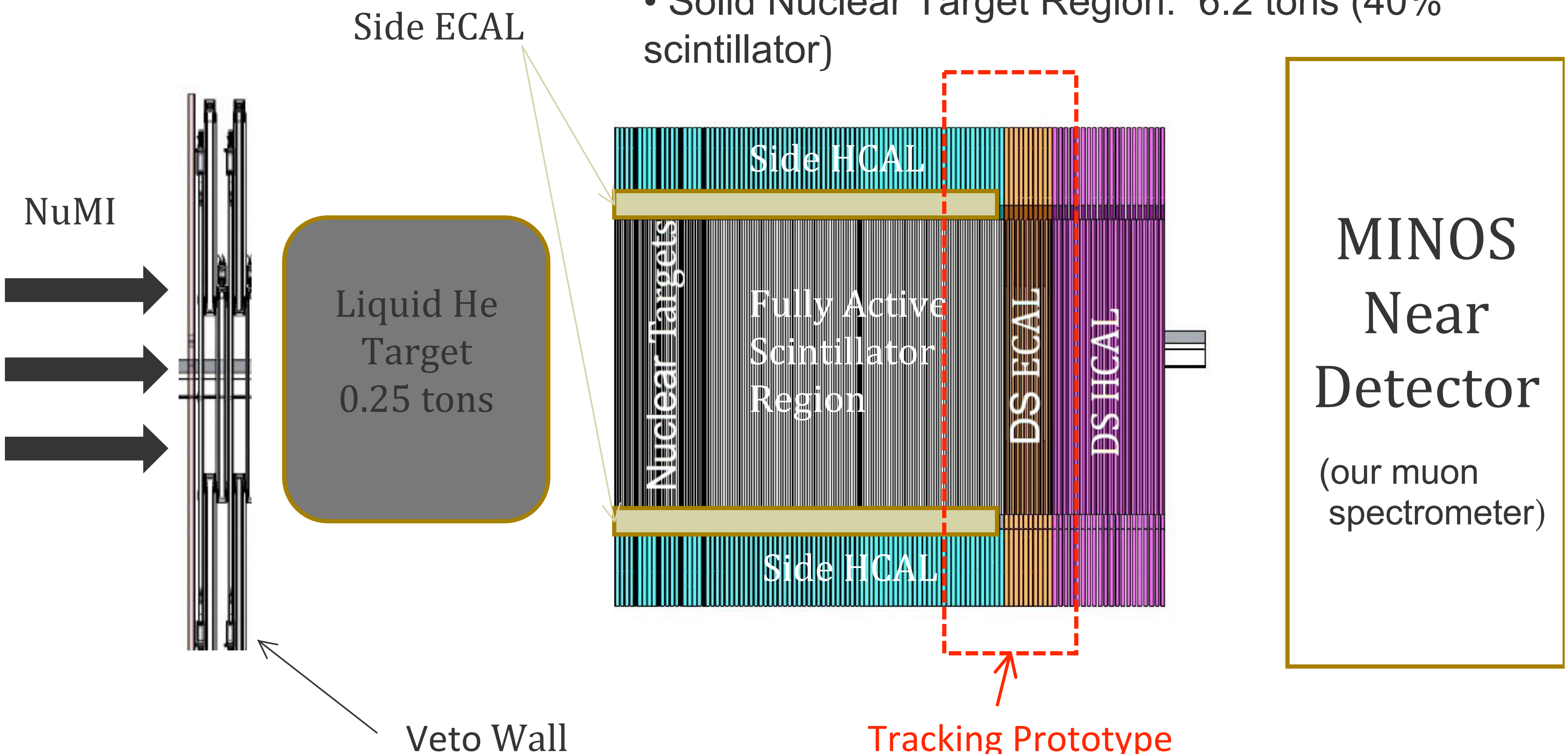


- Reversible horn current allows for ν_μ or $\bar{\nu}_\mu$ beams.
- Movable graphite target allows variable beam energy.
- 91.7% ν_μ , 7 % $\bar{\nu}_\mu$, and 1.3% ν_e in LE configuration.
- *To improve our knowledge of the ν flux:*
  - In situ measurement using the muon monitors;
  - Beam simulation improved: GEANT4 based software, FLUGG;
  - MIPP particle production experiment using NuMI target: data on hand, analysis underway.
- Sept'09: new target, new Hadron Monitor.

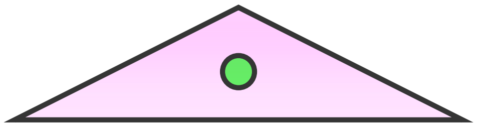


MINERνA detector layout

- Scintillator Region: 8.3 tons (~3 tons fiducial)
- Solid Nuclear Target Region: 6.2 tons (40% scintillator)



Details of MINERνA optics



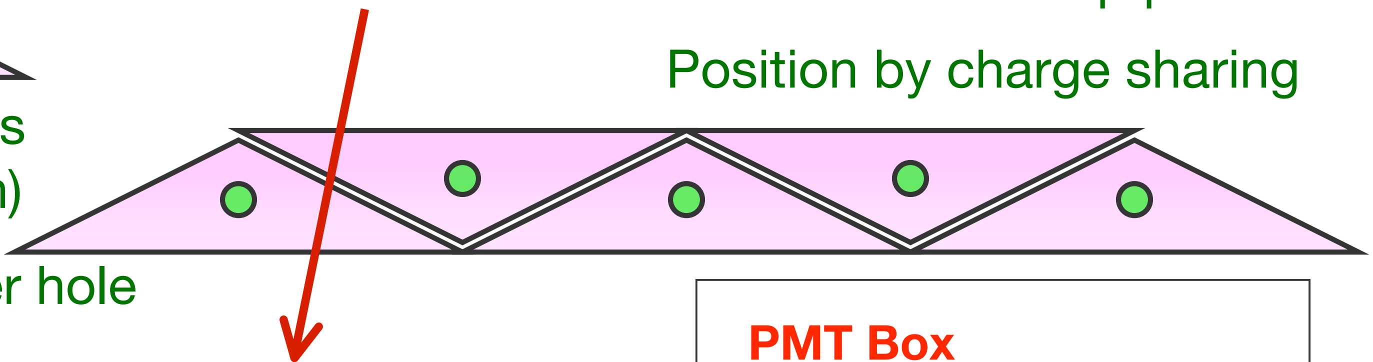
1.7 x 3.3 cm^2 strips
(2.5 mm resolution)

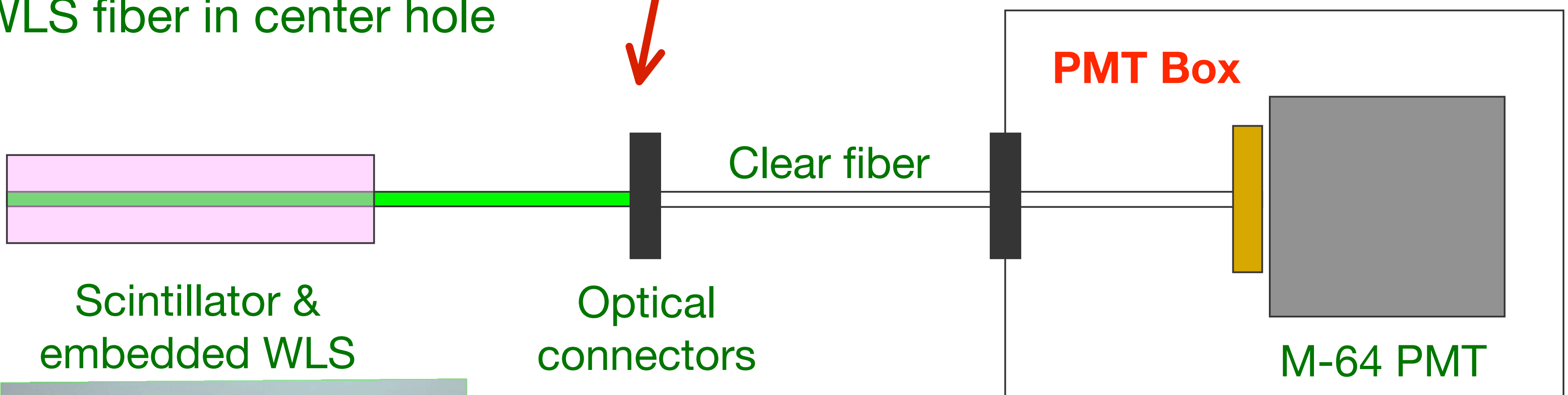
WLS fiber in center hole

Assembled into 127-strip planes

Position by charge sharing

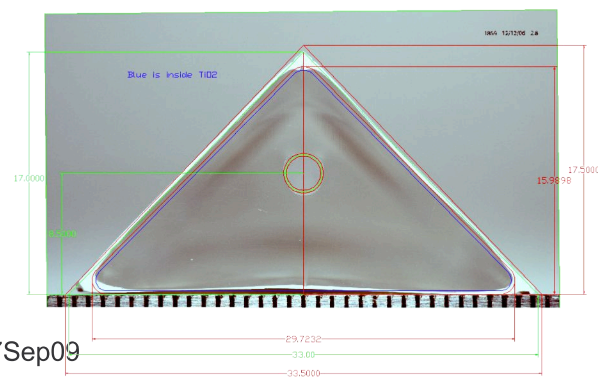
Particle

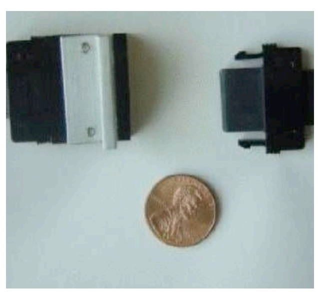


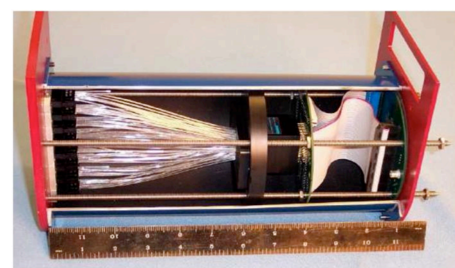


Scintillator & embedded WLS

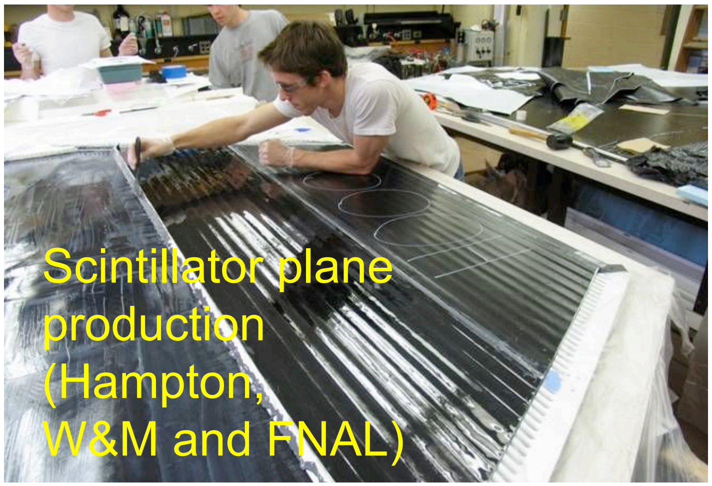
Optical connectors

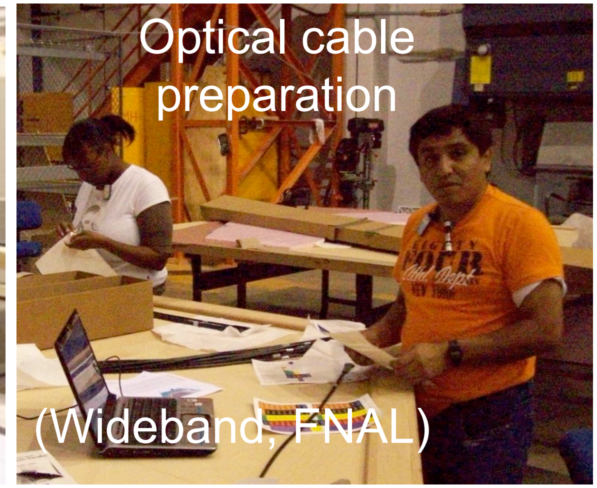


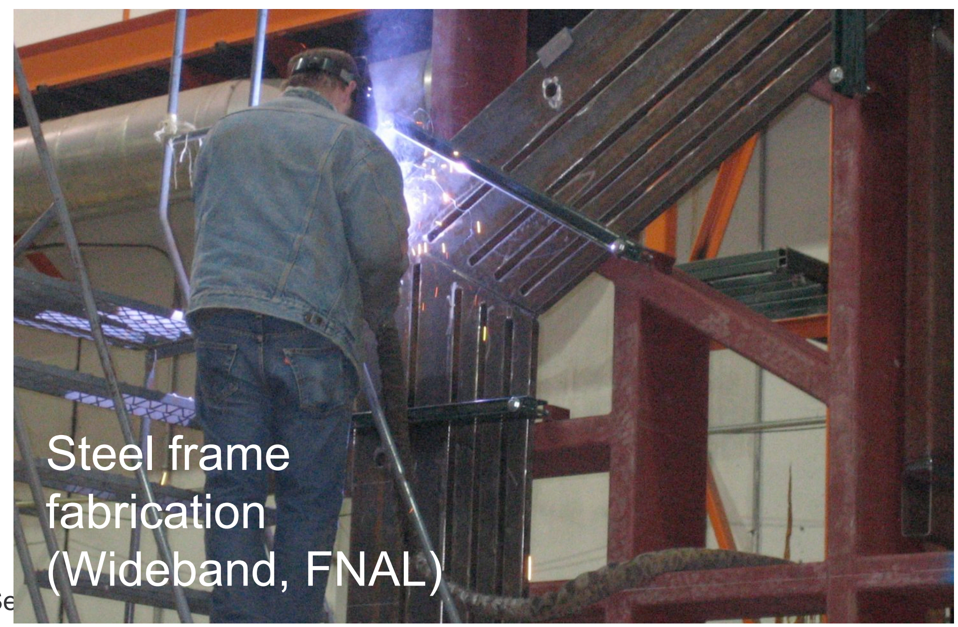


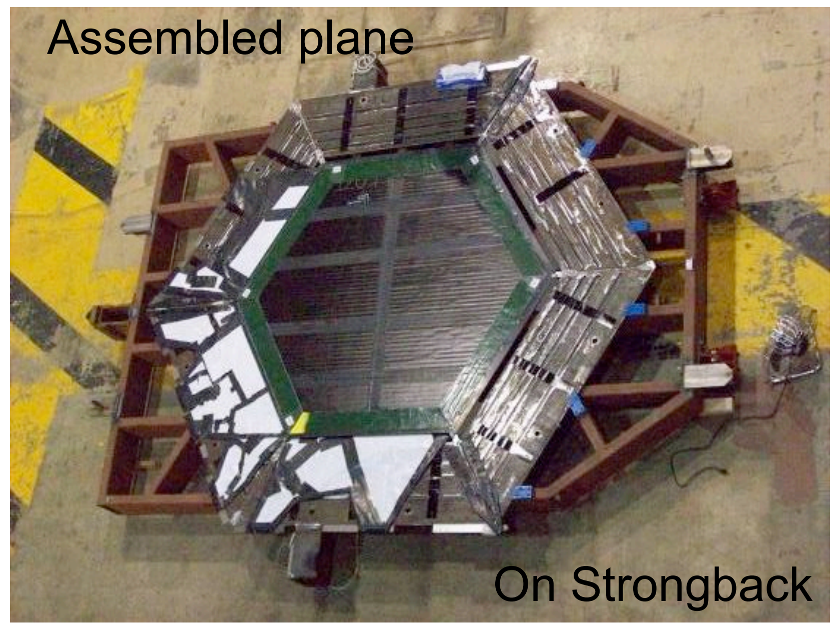


Detector module construction







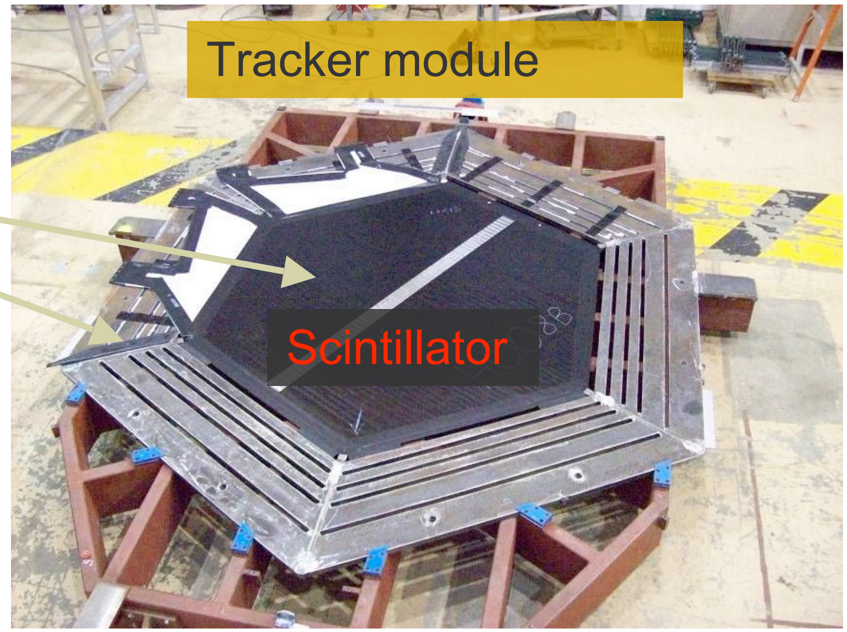


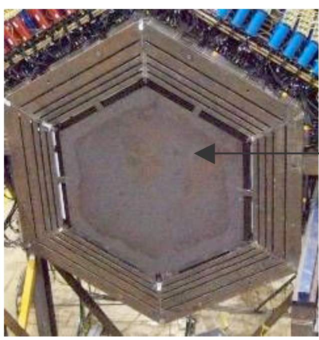
Detector module

Steel + scintillator = module

Typical module:
- has 302 scintillator channels
- weighs 3,000 lbs
- 3 types of modules

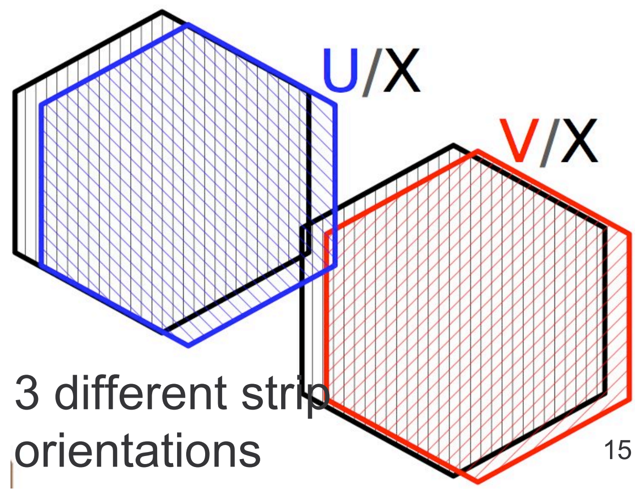
Full detector:
- 108 modules; ~30K channels.





HCAL modules include 1” steel absorber

ECAL modules incorporate Pb absorber



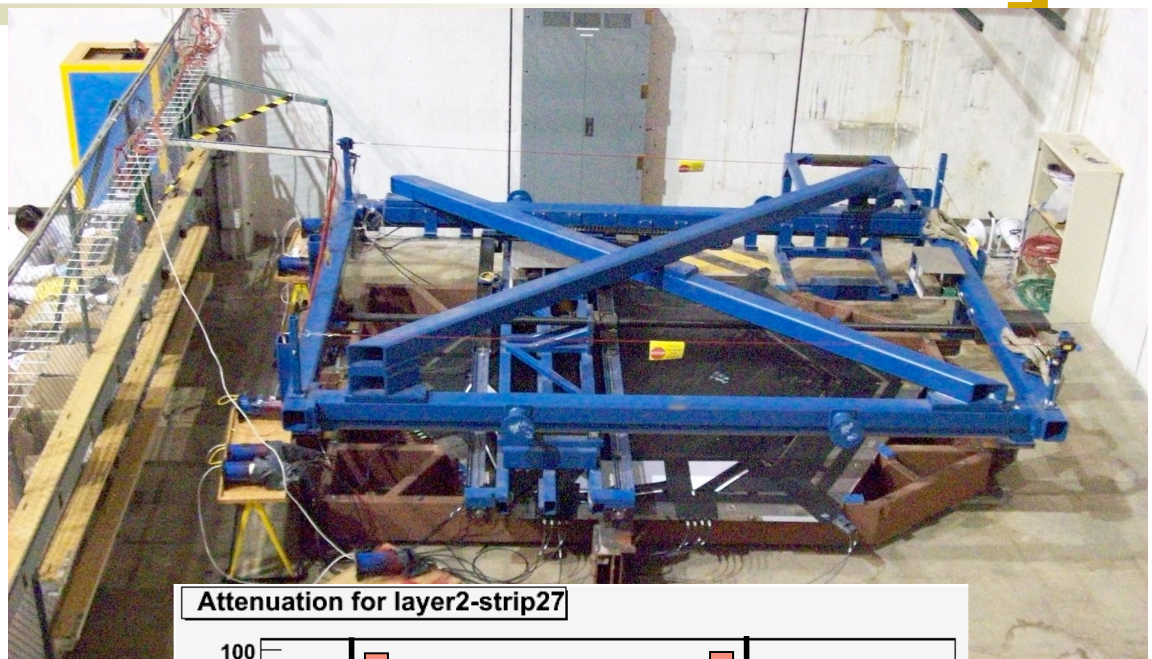
3 different strip orientations

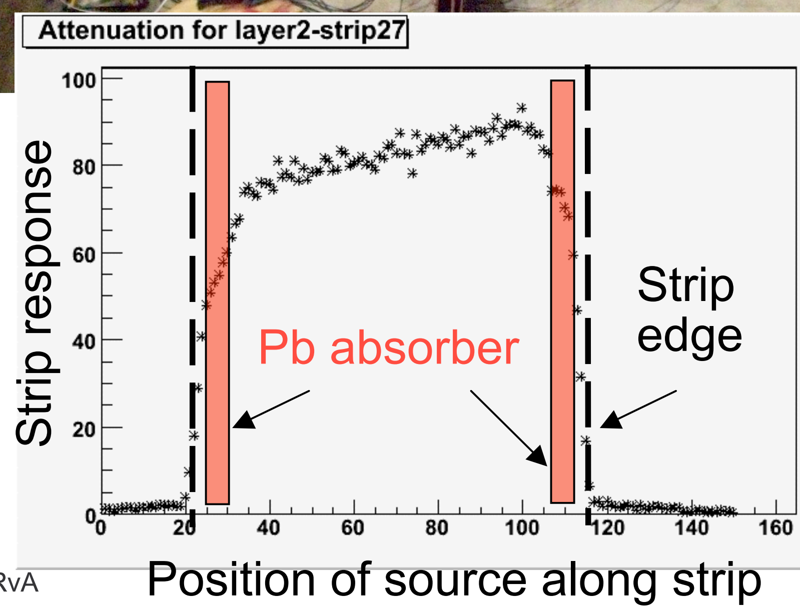
Module mapping

- Comprehensive test of all modules after assembly.
- Scintillator scanned with Cs-137 source; read out scintillator response.
- Mapper functions:

  - Maps attenuation curve and position of all strips.

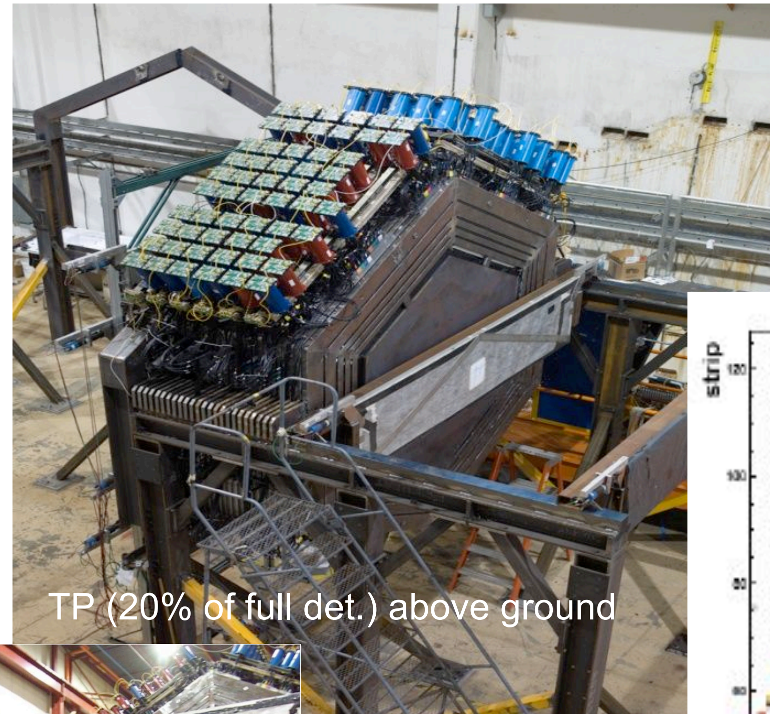
  - Localizes anomalies in scintillator.





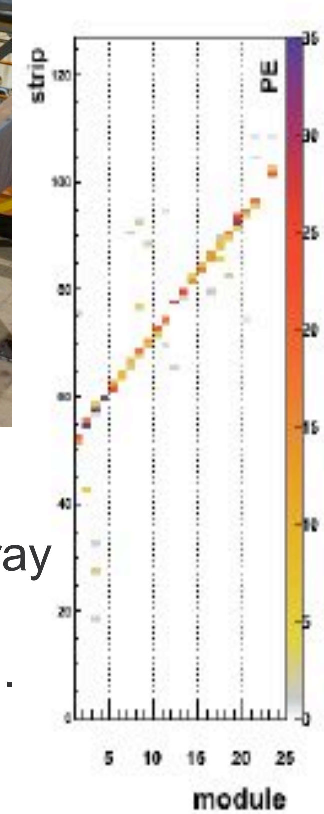
MINERνA Tracking Prototype

- 24 full-sized MINERνA modules (~20% of full detector)
  - 10 tracking modules
  - 10 ECAL modules
  - 4 HCAL modules
  - Veto Wall & trigger counters
  - Test stacking tolerances and interplay of detector and readout components.
  - Built and commissioned June 2008 – March 2009.


TP (20% of full det.) above ground

Reason to celebrate!

- Taking cosmic ray data throughout the construction.

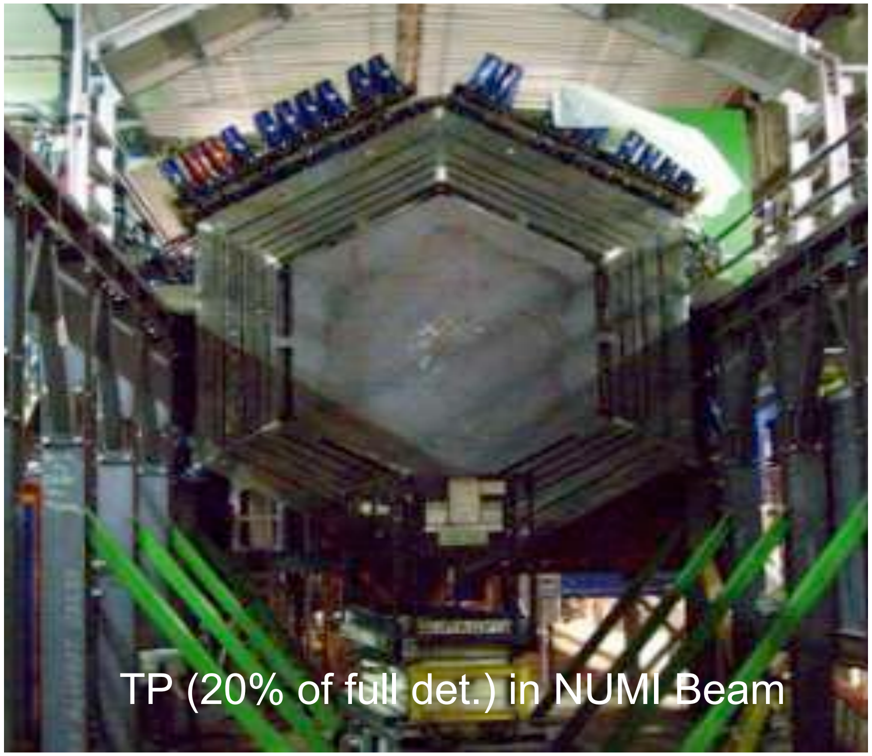


Tracking Prototype moved underground

- Moved the Tracking Prototype into the NuMI beam March 16 – April 17
- MINERvA was taking NuMI data mid-April to mid-June, 4×10^{19} POT.
- We estimate that we have collected 15k-20k CC ν_μ events in a 0.9 ton fiducial volume.
- We are now studying the events…

Expect

Process Type	Events	% of Total
Safe DIS	6.1k	32
Low Q DIS	1.8k	9.5
Transition	5.9k	31
Delta	2.3k	12
Quasi-Elastic	2.8k	15
Coh. Pi Prod.	~80	0.5



TP (20% of full det.) in NUMI Beam

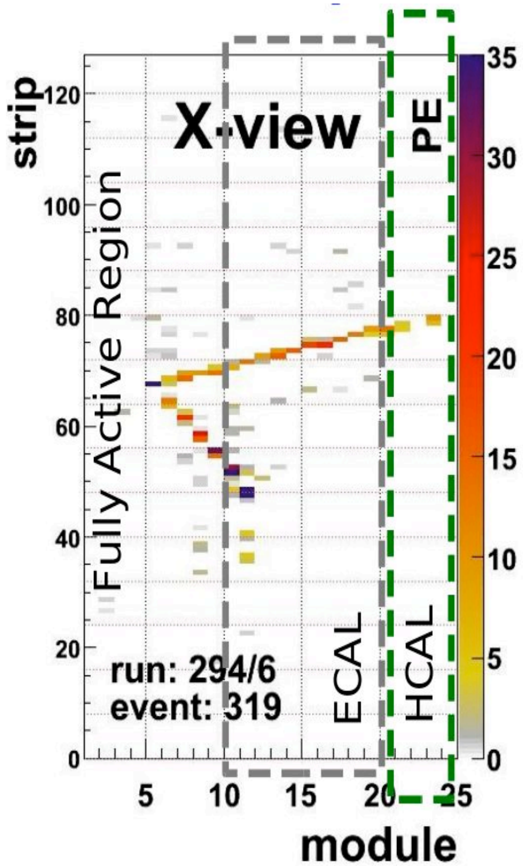
Added: Prototype Fe target plate

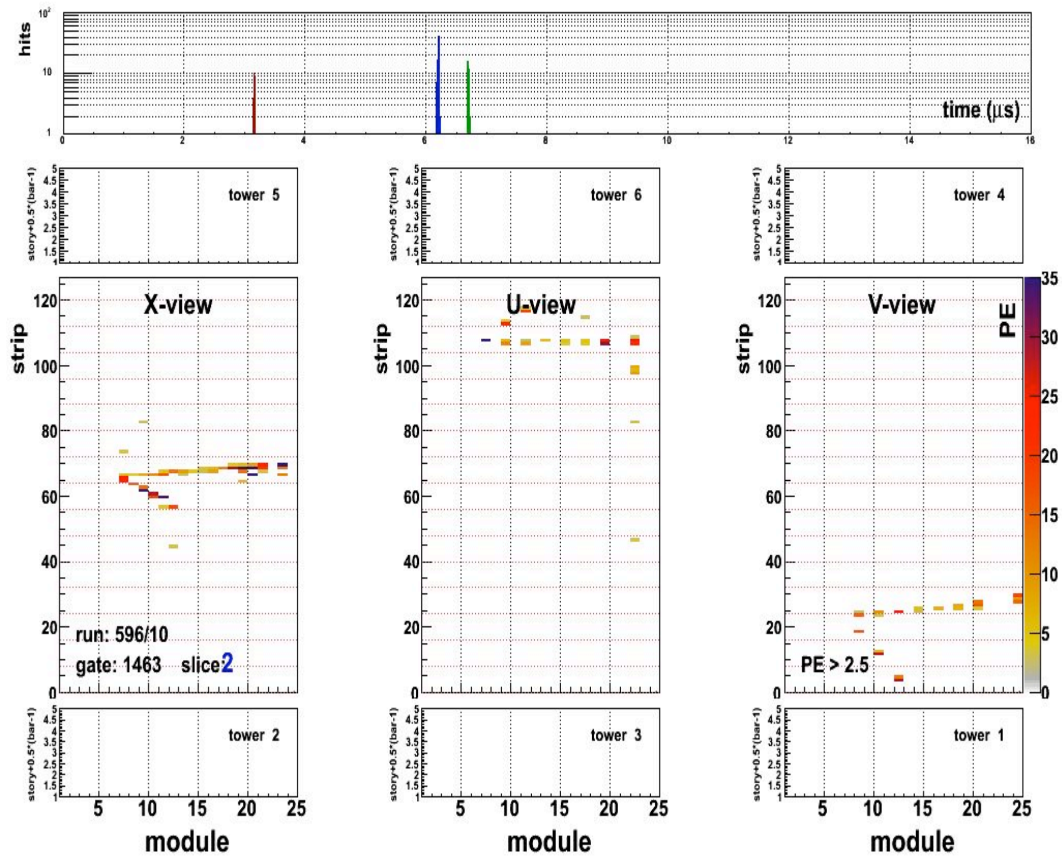
Detector performance

- Energy thresholds: what can we see?
  - Kinetic energy needed to cross 10 planes: $p > 175$ MeV, $\pi^{+/-} > 85$ MeV , $\mu > 70$ MeV
  - Resolving an electromagnetic shower: e, $\gamma > 50$-60 MeV
- Particle identification:
  - *dE/dx:* For tracks which stop in the plastic we expect to correctly ID 85% K, 90% π, > 95% p
  - Electrons vs. gammas: By separation from the vertex.
- Muon reconstruction:
  - 85-90% of μ stop in either MINERvA or are analyzed in MINOS. Above 2 GeV/*c* majority are in MINOS.
  - $\delta p/p \sim 5\%$ from range, 10-15% from curvature

TP events: ν_μ quasi-elastic candidates

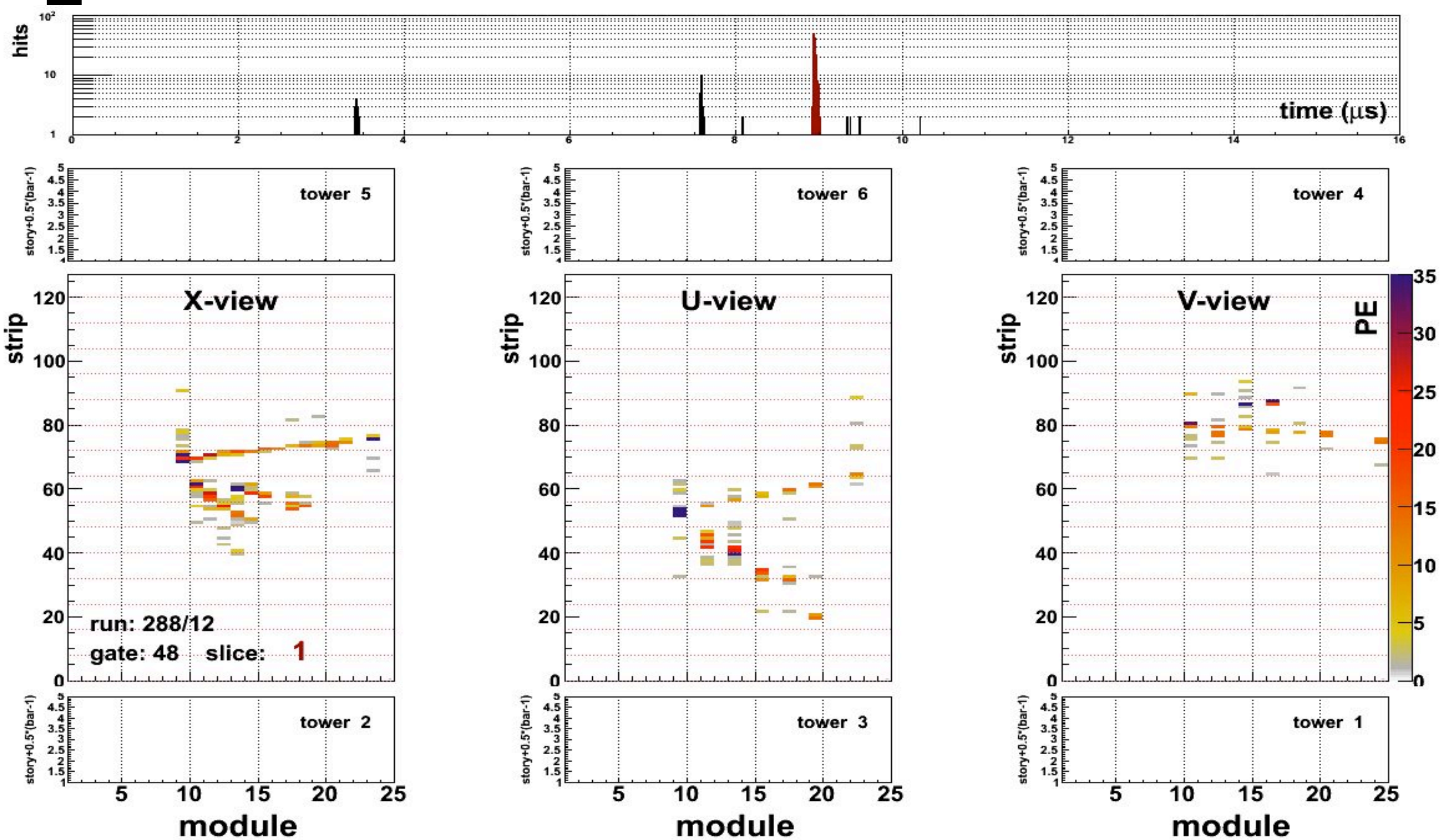
$\nu_\mu + n \rightarrow \mu^- + p$





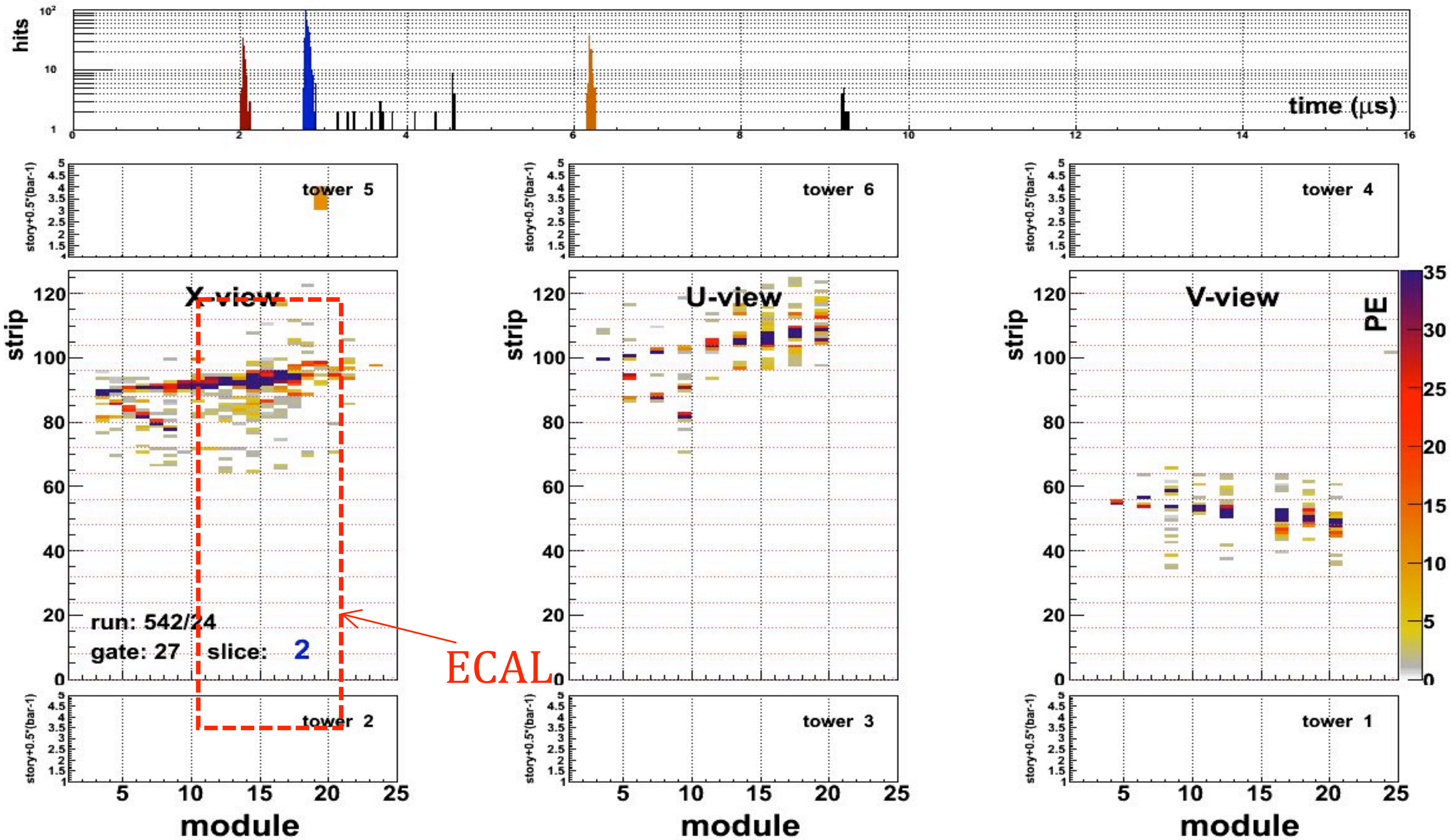
…Both have long track exiting detector (muon) and short contained track with increased *dE/dx* at endpoint (proton)

TP events: π^0 candidate



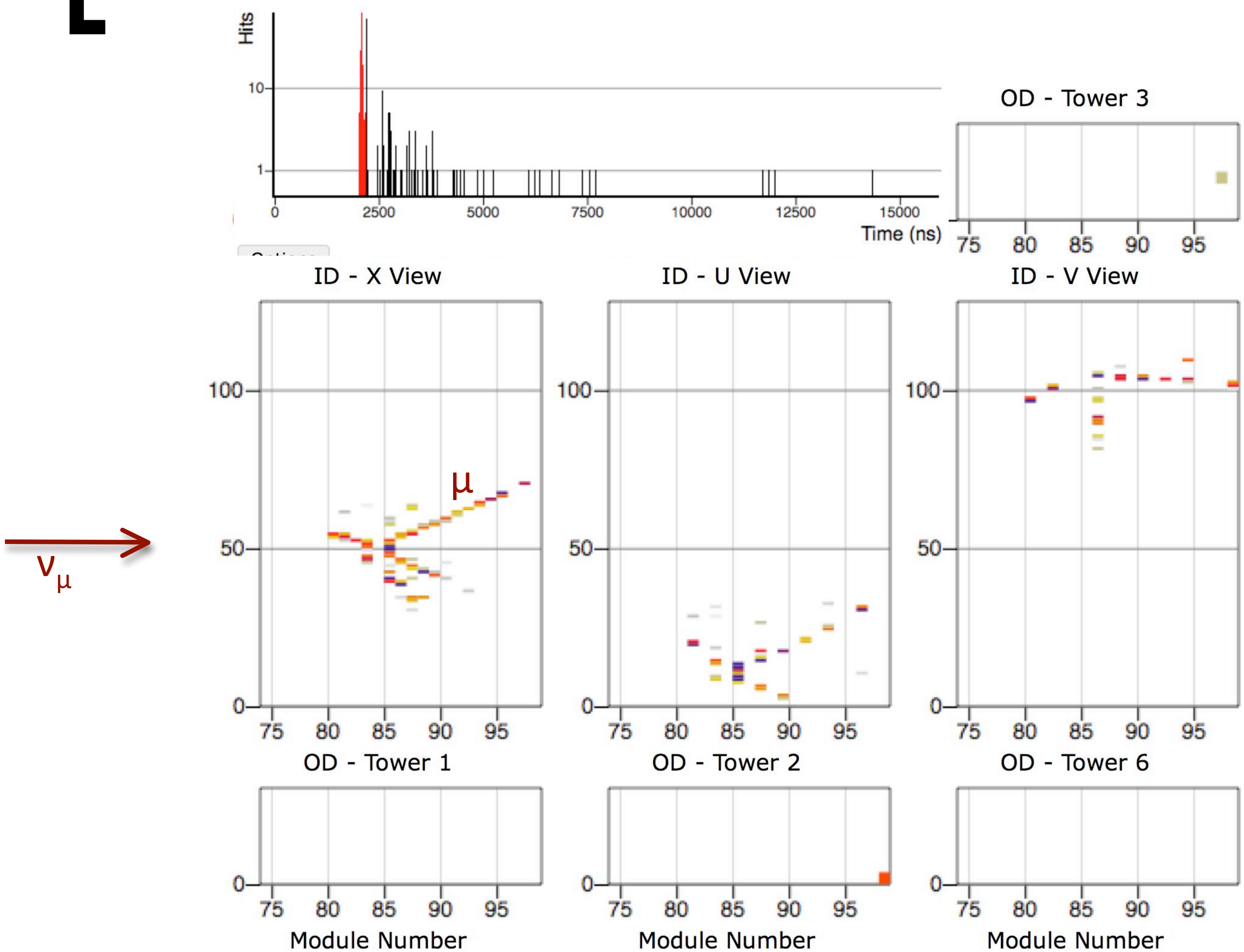
$\pi^0 \to \gamma\gamma \qquad \gamma \to e^+ e^-$

TP events: ν_e candidate



$\nu_e + n \rightarrow e^- + p$

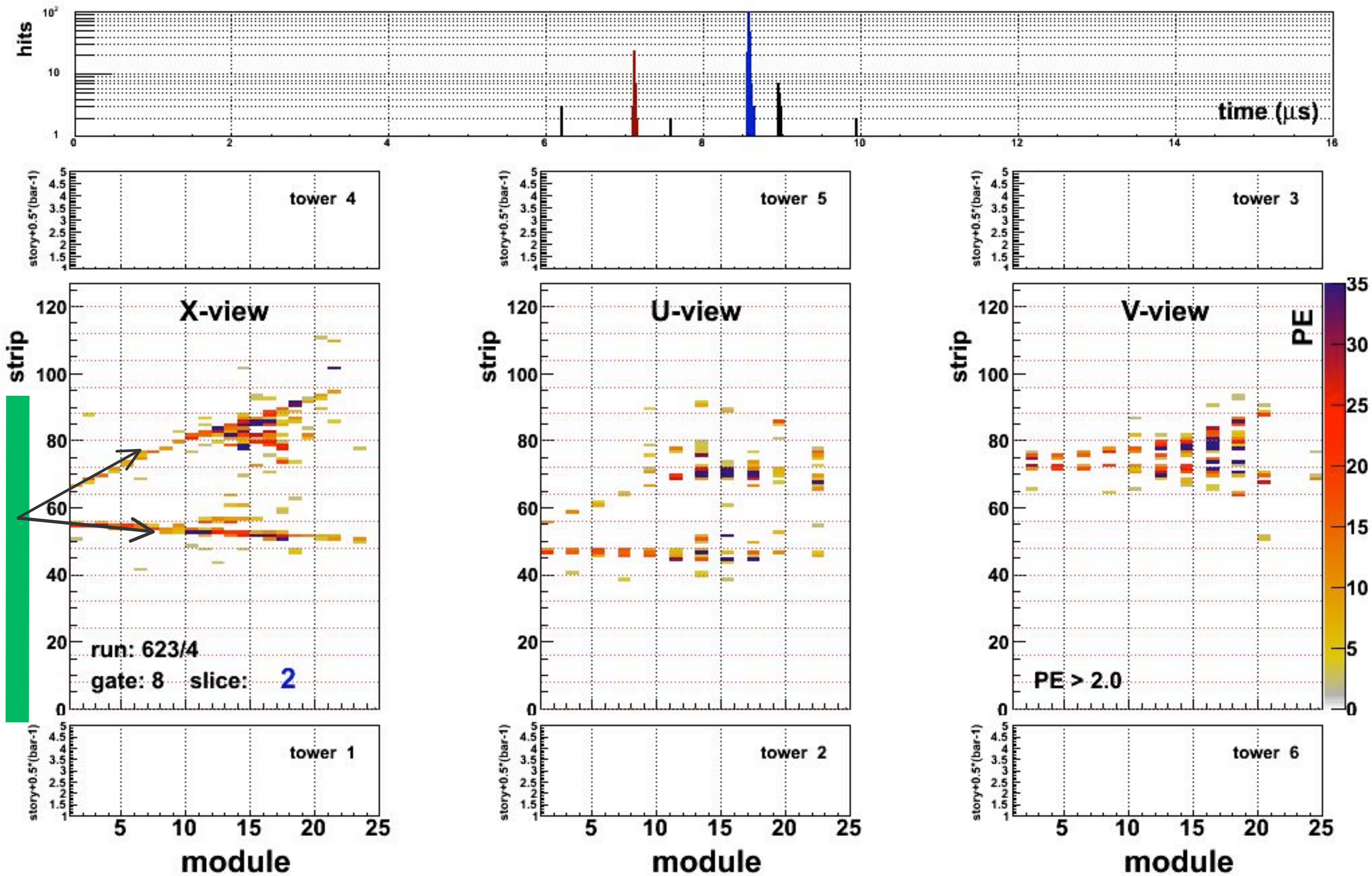
TP events: Pb in ECAL->Bwd tracks



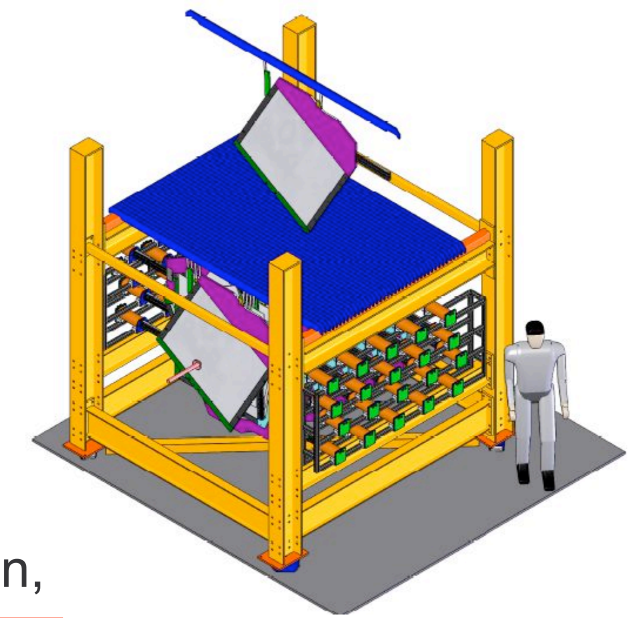
ν_μ + Pb -> μ^- + fwd_trk + bwd_trk

TP events: Iron target

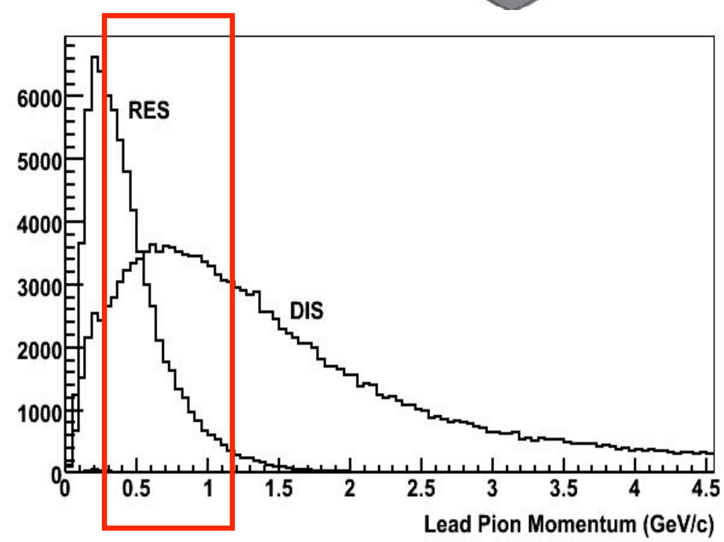
Iron Target (10 cm away)



Aside: Test Beam Detector



- (3 planes at JLAB)
- 40 planes, XUXV orientation as in full MINERvA
- Smaller than full detector: ~1.2 x 1.2 m^2
- Removable lead and iron absorbers
- *Fermilab Test Beam Facility upgrade:* Tertiary test beam designed to yield e, μ, π, p in range 250 < *p* < 1500 MeV/*c*, under construction, fully commissioned by November '09.
- Test Beam Detector to be finished, and MINERvA test beam operations to commence, in 2010.



MINERνA Status and Schedule

- The Tracking Prototype has been dismounted.

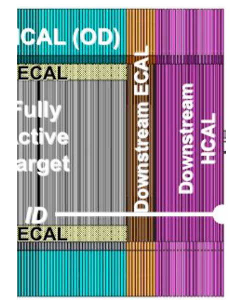
- Installation of the full MINERvA detector has commenced, starting with the HCAL modules.

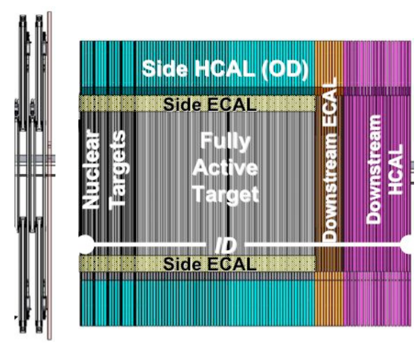
- NuMI beam is returning now, running in $\bar{\nu}_\mu$ mode.

- Plan to install ~60% of the detector modules by mid October.

- Module installation should finish in February 2010.

- Full detector should be ready to take ν_μ data by March 2010…





Conclusions

MINERνA will precisely study ν–nucleus interactions at 1-10 GeV:
- Fine-grained, high-resolution, detector
- High flux NuMI beam.

MINERνA will improve our knowledge of:
- Neutrino cross sections at low energy, low Q^2.
- *A*-dependence in neutrino interactions (He, C, Fe, Pb targets)

These data will be interesting in there own right, and will be important to minimize systematic errors in oscillation experiments.

Expect to turn on early in 2010 ...

Proposed FNAL NuMI run schedule

- Start Physics Run in March 2010.
- MINERνA requests to start with LE neutrino beam and accumulate 4 x 10^{20} POT.
- Before converting to the ME beam MINERνA requests

  1.2 x 10^{20} POT for study of LE beam flux using variable target position and horn currents.
- Continue with ME neutrino beam and accumulate 12 x 10^{20} POT.