Status of MINERνA

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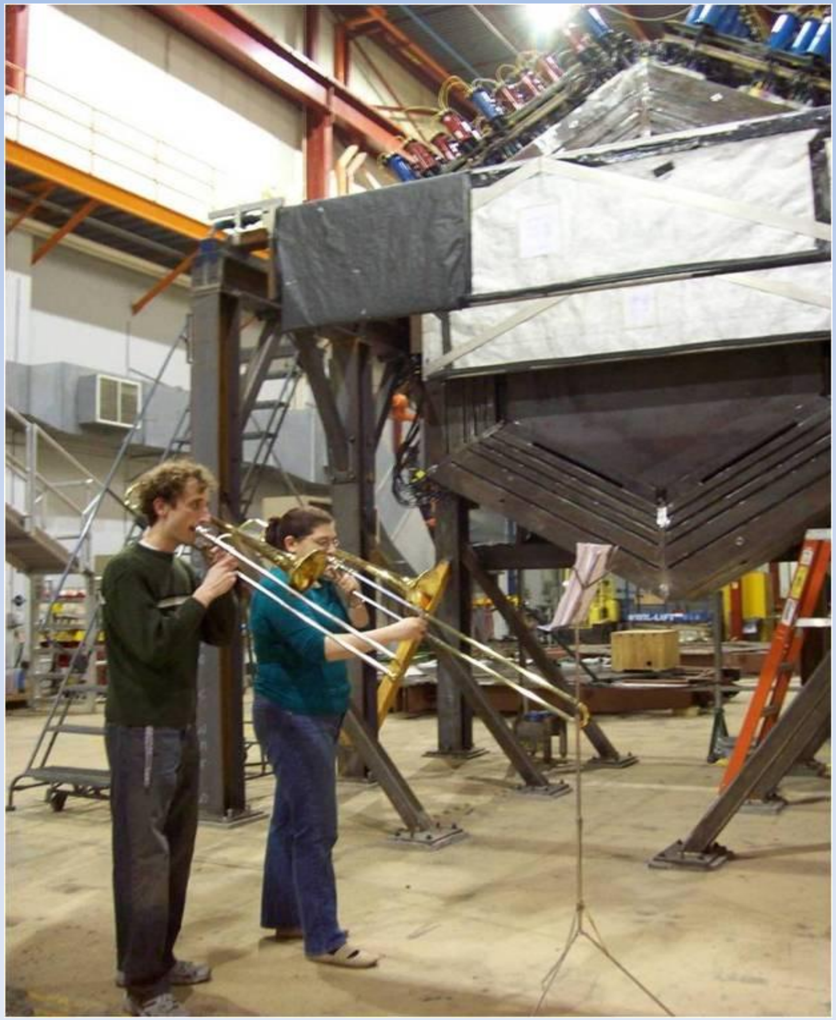
University of Pittsburgh
July 24, 2009

On behalf of the MINERνA collaboration

Introduction to MINERνA

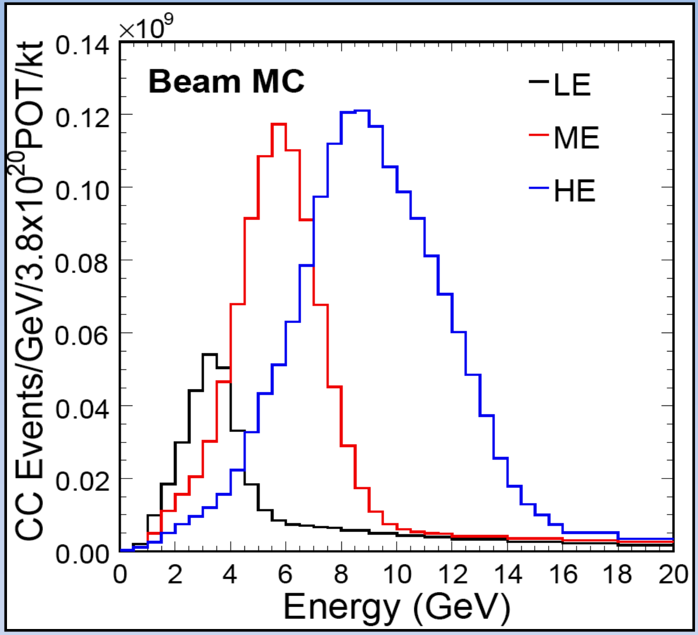
MINERνA: Main INjector ExpeRiment for ν-A

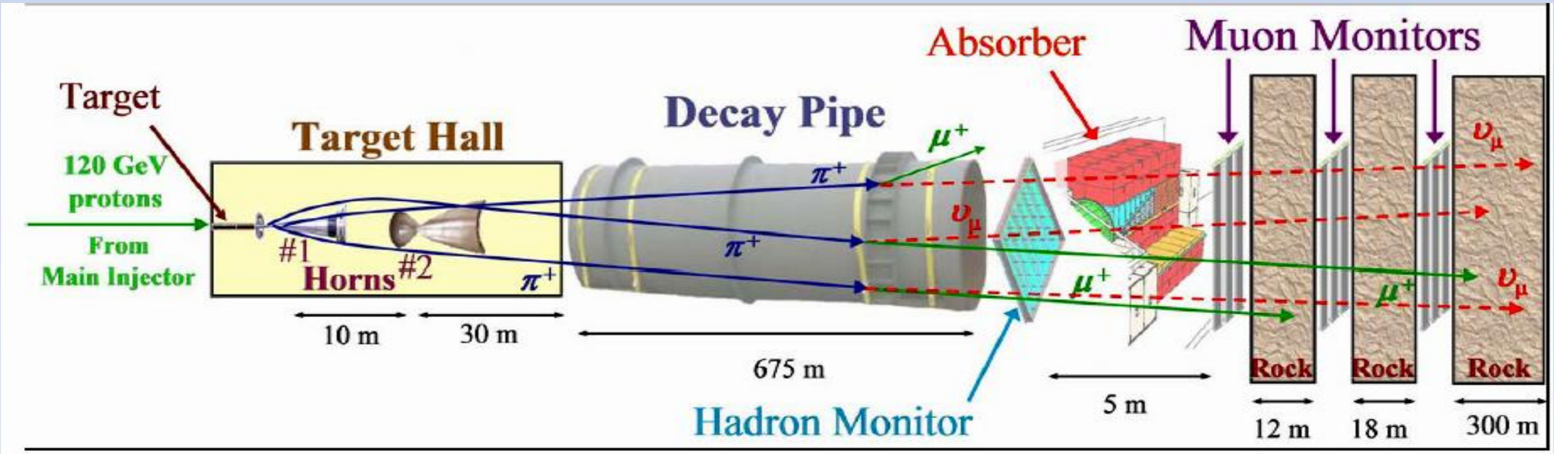
- Precision neutrino nucleon cross section measurements in the few GeV region
  - -study the physics of νA interactions
  - -supports oscillation experiments
- Finely segmented and fully active scintillator tracking volume enclosed by ECAL and HCAL
- Variety of nuclear targets (He, C, Fe, Pb) allow study of A dependence
- MINOS is our downstream muon spectrometer
- High intensity neutrino beam (NuMI)
- Tracking prototype finished its data taking run in June
- Installation of the full detector commences in August; current plan is to finish by February 2010



NuMI Beam

- Movable graphite target for flux studies
- Reversible horn current allows for ν_μ or ν_μ-bar beams
- Variable beam energy
- 92.9% ν_μ, 5.8% ν_μ-bar, and 1.3% ν_e in low energy (LE) configuration





Pictures/plots retrieved from http://www-numi.fnal.gov/talks/postedtalks.html

Beam Knowledge and Flux

•Absolute flux is a hard measurement!

•We think we can reach ~5% absolute flux uncertainty through a combination of methods:

1)In situ measurement using the muon monitors

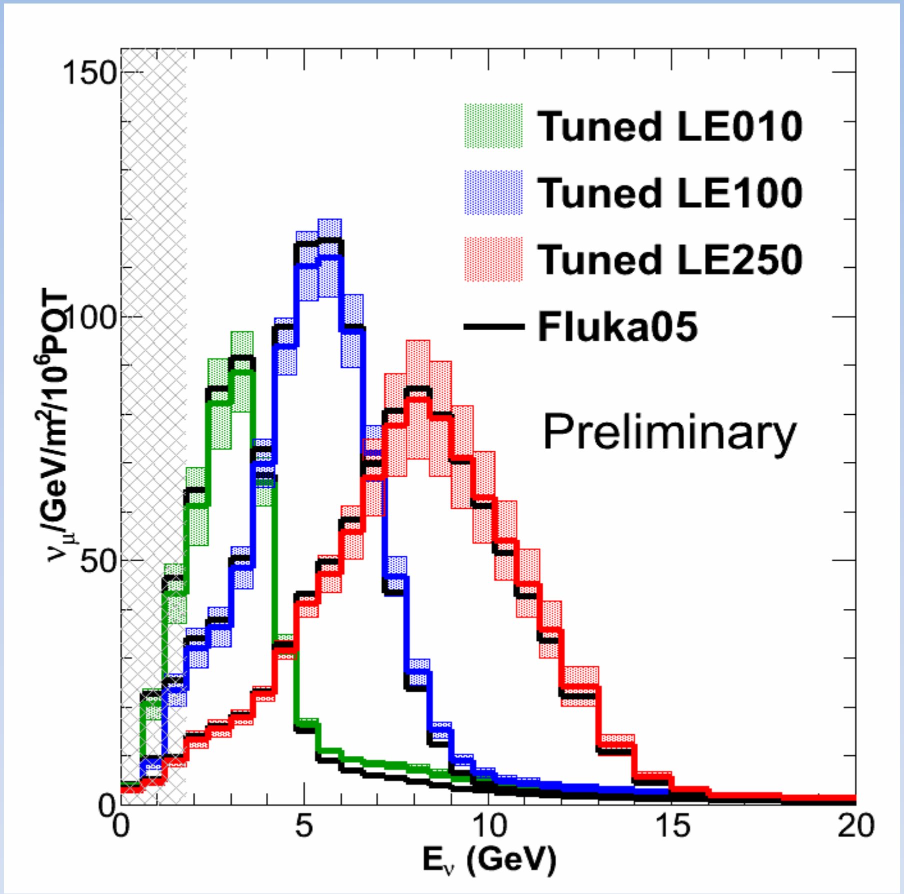
-See Laura Loiacono's NuFact presentation for details!

2)Beam simulation

-New g4numi simulation software

3)Particle production experiment

-MIPP underway

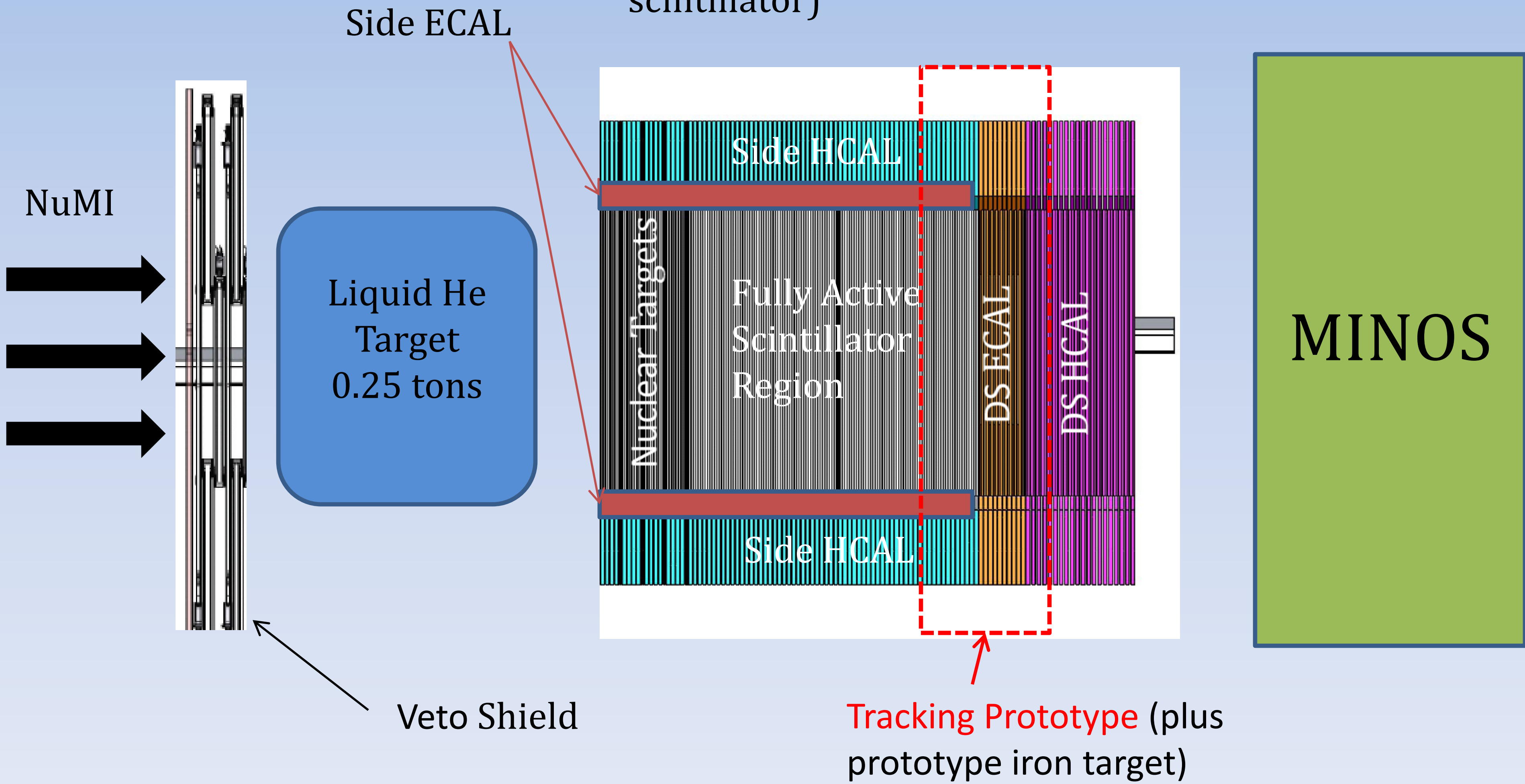


From NuFact 2009
Neutrino Beam Systematics
Laura Loiacono

MINERνA Diagram

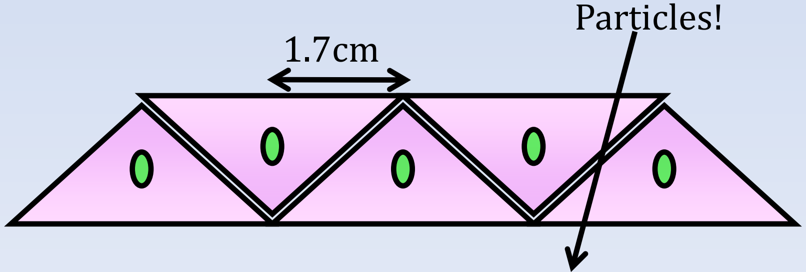
Current Plan:

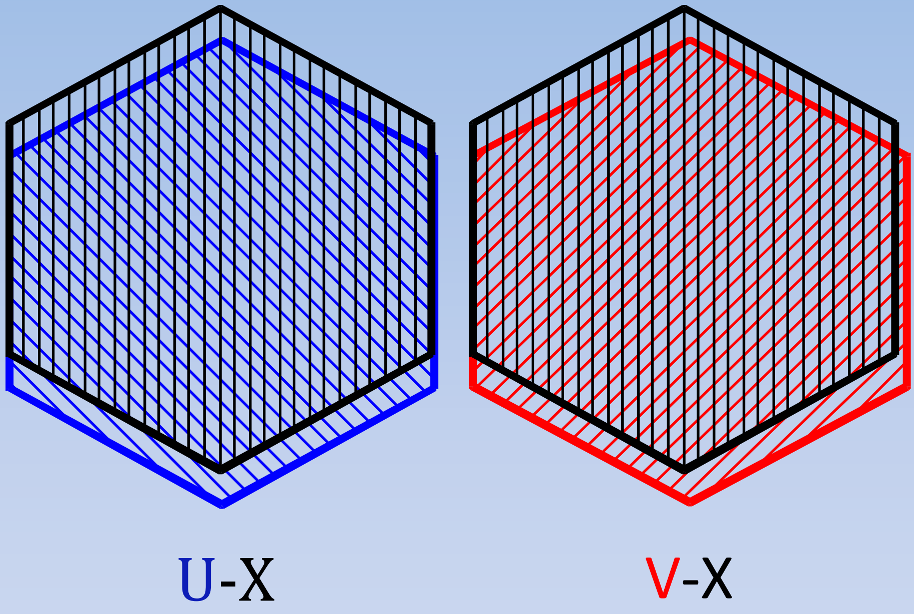
- Scintillator Region: 8.3 tons (~3 tons fiducial)
- Solid Nuclear Target Region: 6.2 tons (40% scintillator)

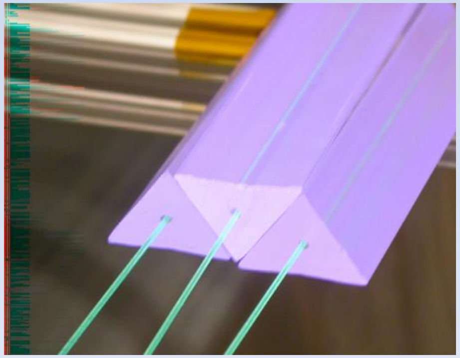


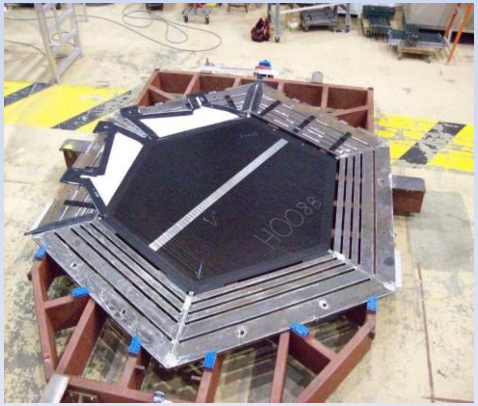
Planes and Optics

- 127 scintillator strips (channels) per plane, wavelength-shifting (WLS) fibers
- Triangular shape allows for greater position resolution (2.5mm) via light sharing
- Three different plane orientations
- Two planes plus outer calorimeter (outer detector, "OD") make a module (302 channels)
- Full detector has 108 modules, 6 nuclear target modules, and ~30k channels



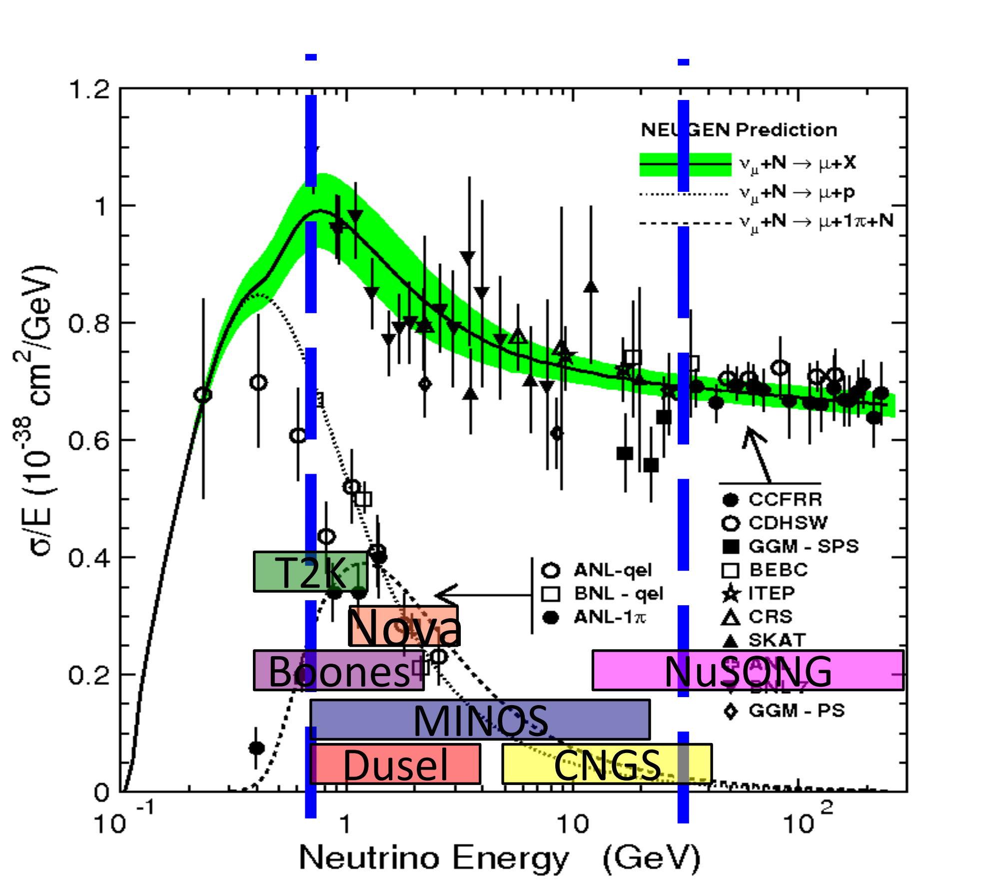






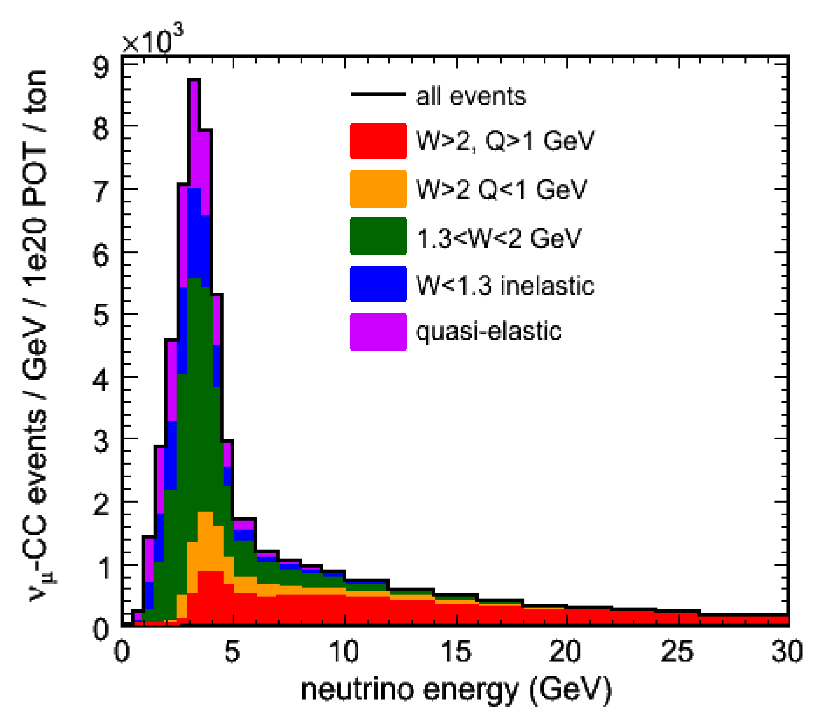
Energy Range

- Energy range fills in the gap between cross section measurements done in low and high energy regions
- Overlap with (and hence beneficial for) many oscillation experiments, including MINOS, T2K, Nova, and Dusel
- Note that the latest MiniBooNE and SciBooNE results are not on this plot; you'll see them on slide 9



Event Yields

- If assume a standard run:
  - $4x10^{20}$ POT LE
  - $12x10^{20}$ POT ME
- Results in ~14 million CC events
  - ~9 million on scintillator
  - ~5 million on nuclear targets

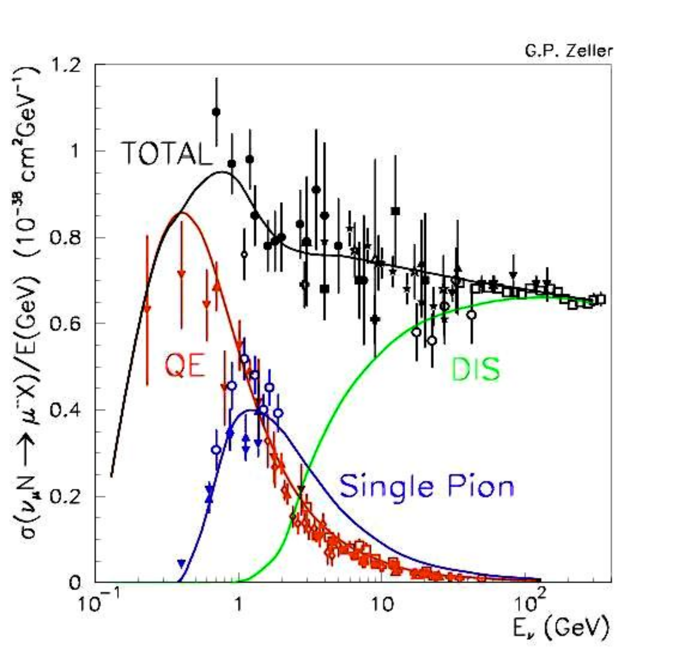


CC Process Type (on scint.)	Number of Events
Quasi-elastic	0.8M
Resonance Production	1.7M
Res-DIS Transition Region	2.1M
DIS Low Q2 & Structure Functions	4.3M
Coherent Pion	89k CC, 44k NC
Charm/Strange	230k

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

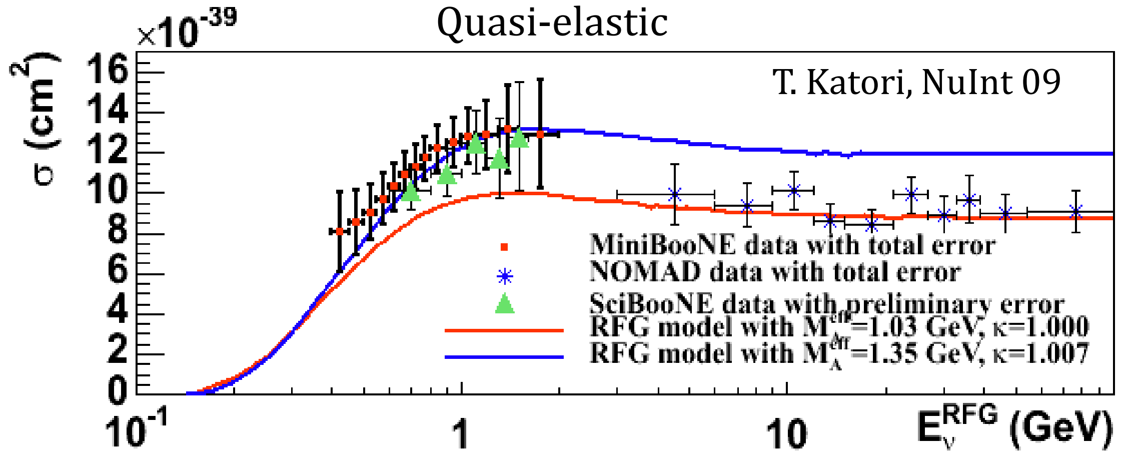
Physics: Cross Sections

- Finely segmented tracking volume allows reconstruction of exclusive final states
- In its energy region, MINERνA will reduce many current cross section uncertainties by a factor of five
- Suited to resolve 30% discrepancy between 1 GeV and 5 GeV quasi-elastic cross section measurements
- Resonance measurements will help us to understand this dominant background to neutrino oscillation experiments



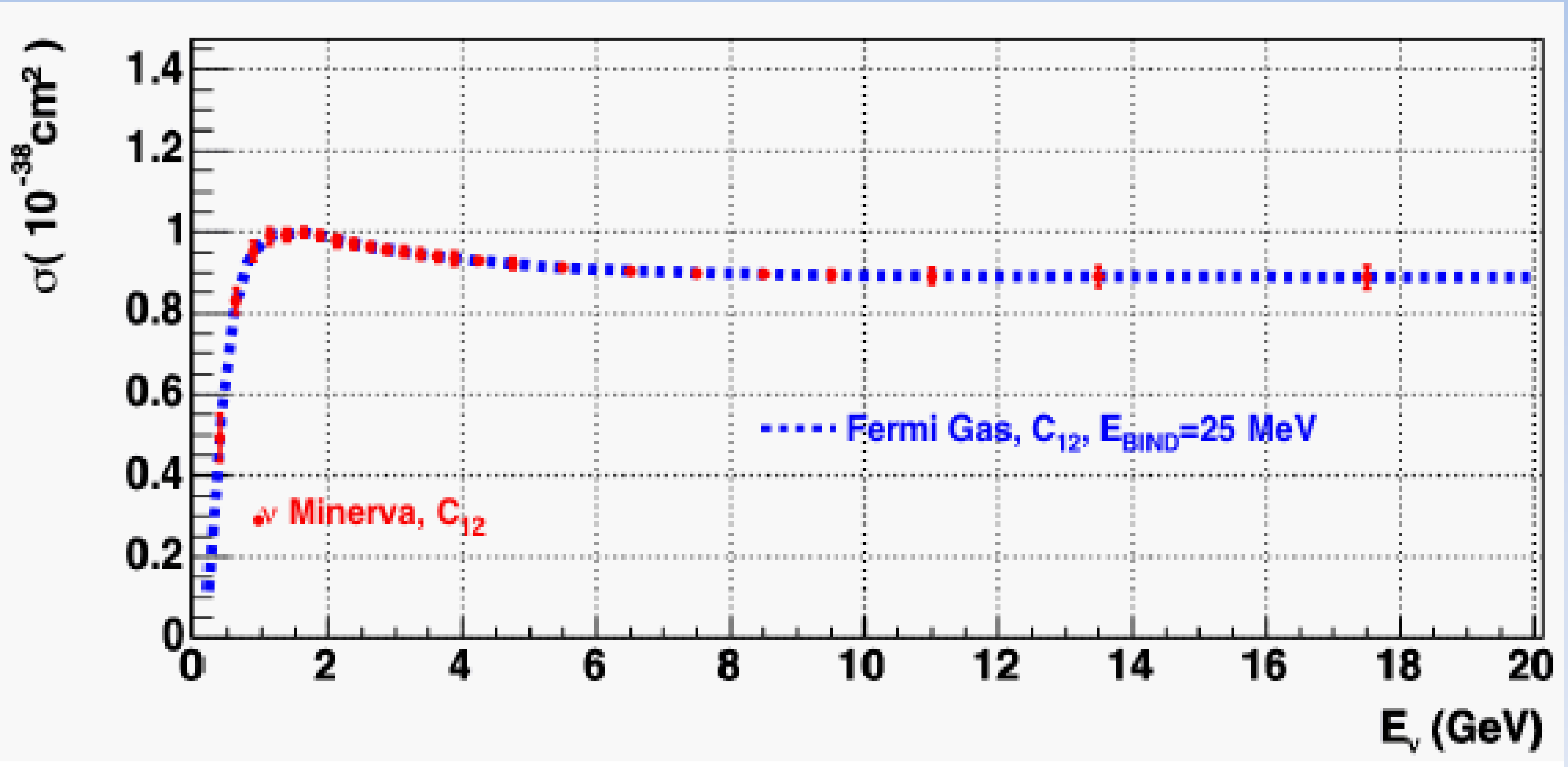
Estimated Cross section uncertainties

Process	Current	After MINERνA
QE	20%	5%
Res	40%	5/10%(CC/NC)
DIS	20%	5%
Coh	100%	20%

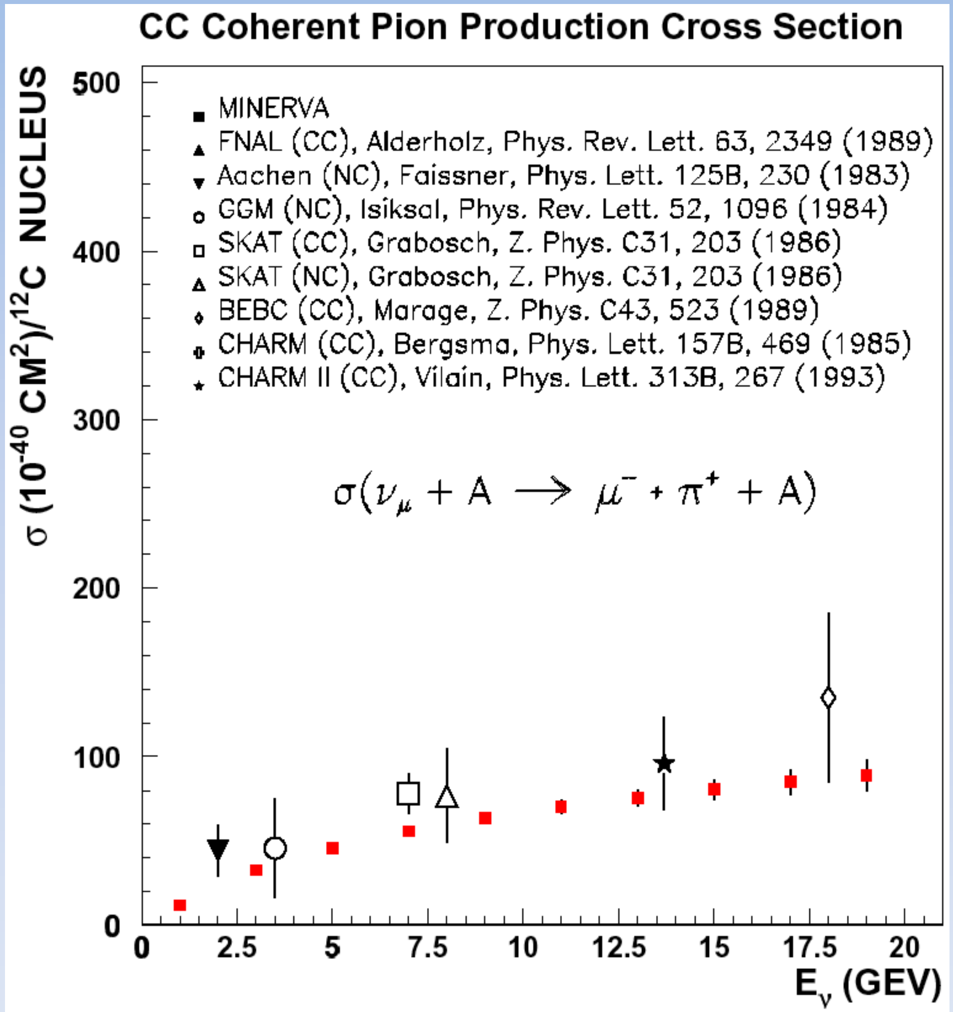


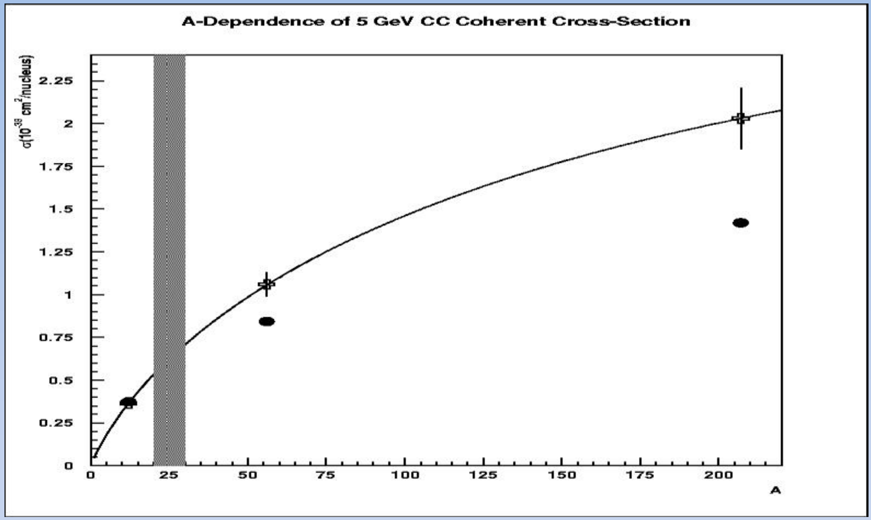
Physics: More Quasi-elastics

Plot of expected MINERνA quasi-elastic cross section result, with statistical errors including purity and efficiency



Physics: Coherent Pion σ





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

Physics: Form Factors

•There is a discrepancy in the measured value for the axial mass from older experiments (mostly on D_2) and more recent experiments (on heavier nuclei)

- •MINERνA, with its range of nuclear targets, will provide much more data that can help to resolve this question

•With high Q^2 range from NuMI, MINERνA will also test the assumed dipole form of F_A

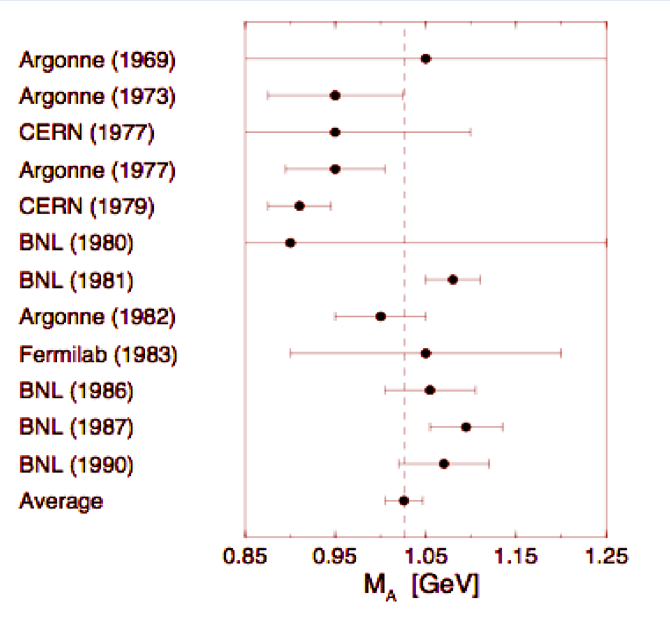
$$F_A = \frac{1.267}{\left(1 + \frac{Q^2}{M_A^2}\right)^2}$$

K2K SciFi (16O, Q^2>0.2)
Phys. Rev. **D74, 052002 (2006)**
M_A=1.20 ± 0.12 GeV

• **K2K SciBar (12C, Q^2>0.2)**
AIP Conf. Proc. **967, 117 (2007)**
M_A=1.14 ± 0.11 GeV

• **MiniBooNE (12C, Q^2>0)**
paper in preparation
M_A=1.35 ± 0.17 GeV

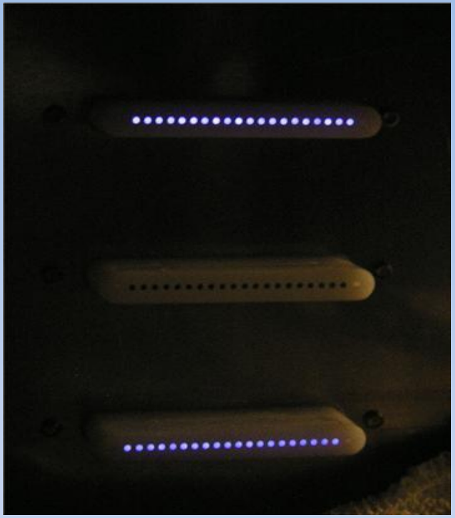
• **MINOS (Fe, Q^2>0.3)**
NuInt09, preliminary
M_A=1.26 ± 0.17 GeV

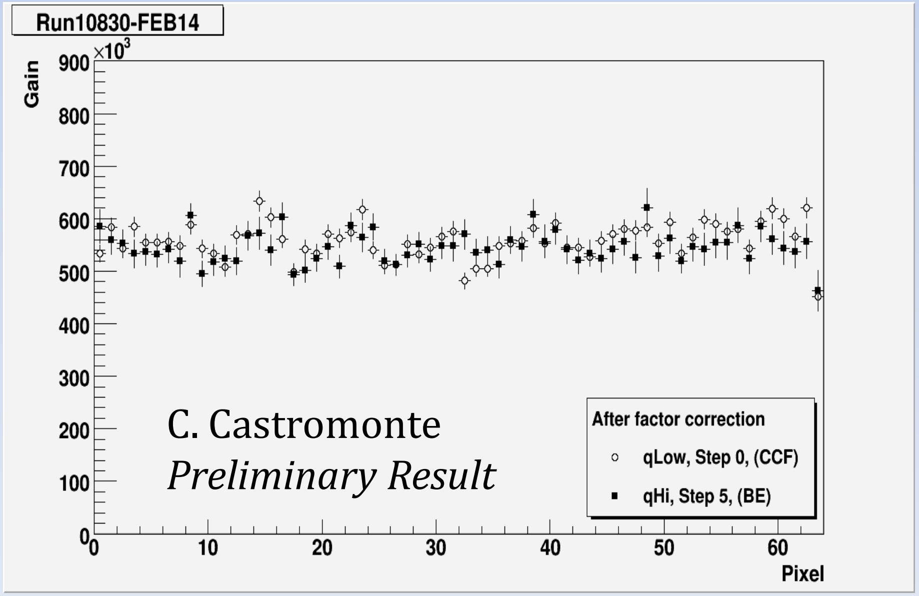


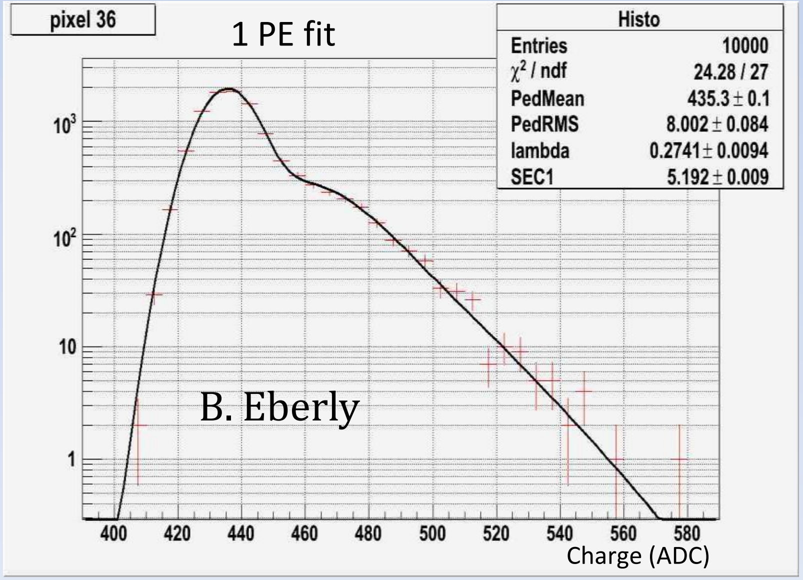
M_A (before 1990):
1.03 +/- 0.02 GeV
M_A (after 2000):
~1.2 GeV
What's going on?

Calibrations: PMT Gains

- Gain measured by two methods: low photoelectron (PE) spectra fits and high PE Poisson statistics
  - Agreement to within 10%
- Low PE fit method has a combined statistical and systematic error of ~3-5%
- Light injection (LI) box is calibration light source
  - Coming soon: Pin diode monitor

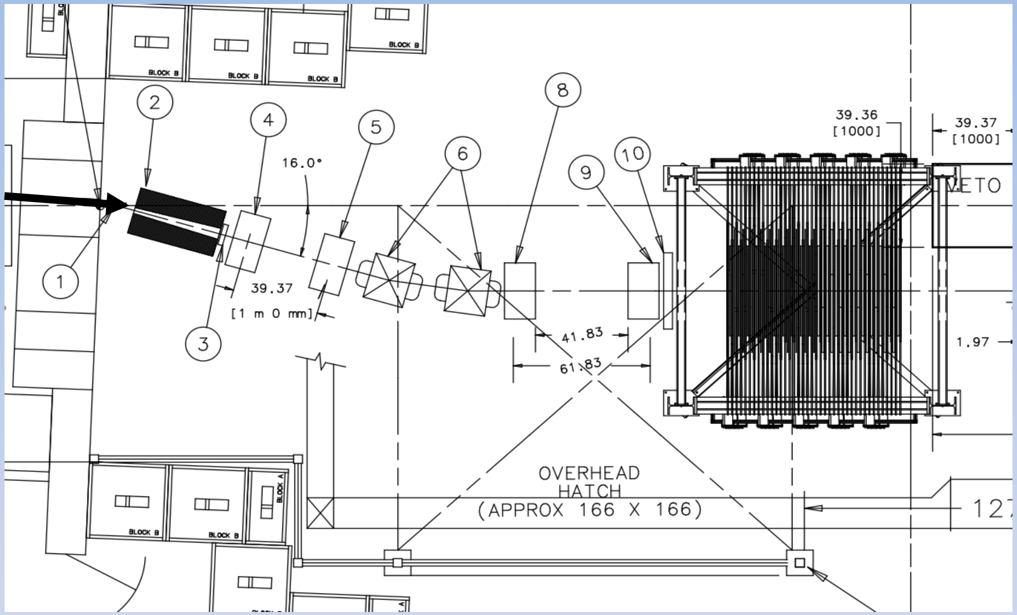


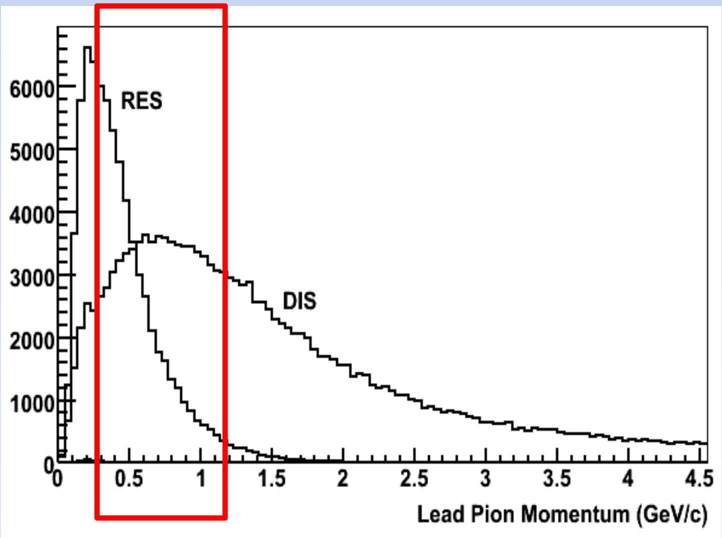


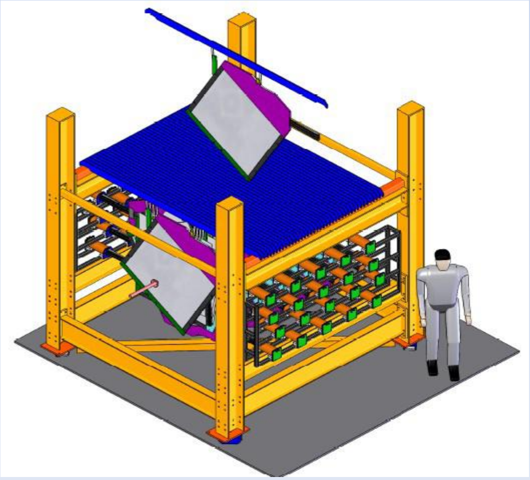


Calibrations: Test Beam

- Reconfigurable Pb, Fe, and Scintillator modules to emulate different detector regions
- 16 GeV pion beam creates tertiary beam of 300 MeV – 1.2 GeV
- Will provide the hadronic response calibration







Legend:
1: Pion Beam
3,10: Time of Flight Triggers
4,5,8,9: Wire Chambers
6: Magnets

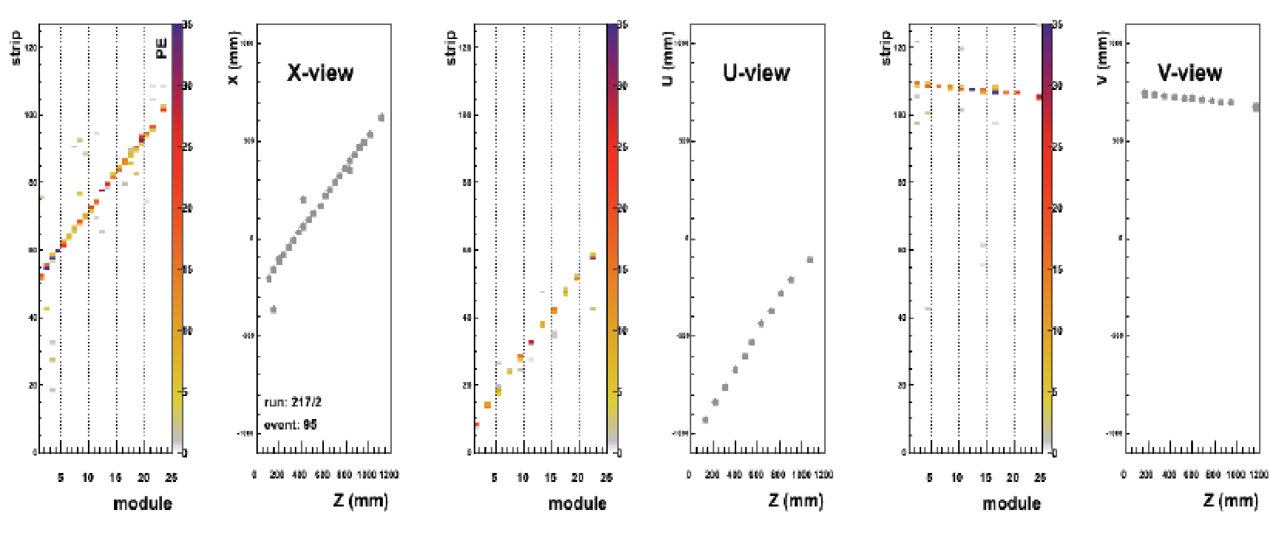
Tracking Prototype

- 24 full-sized MINERνA modules assembled into a detector (~20% of full detector)
  - 10 tracking modules
  - 10 ECAL modules
  - 4 HCAL modules
  - 1 prototype iron target

- Test stacking tolerances and interplay of many basic detector and readout components

- Built and Commissioned above ground June 2008 – March 2009

- Took cosmic ray run using veto wall as trigger (32.6k single track events)

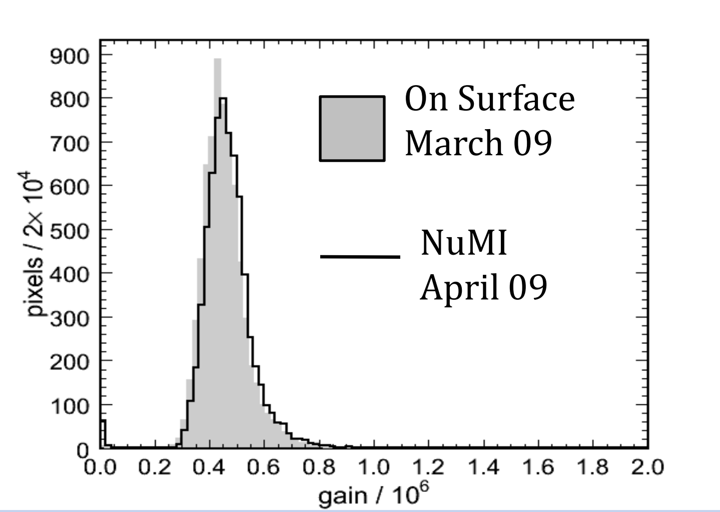


Tracking Prototype in NuMI

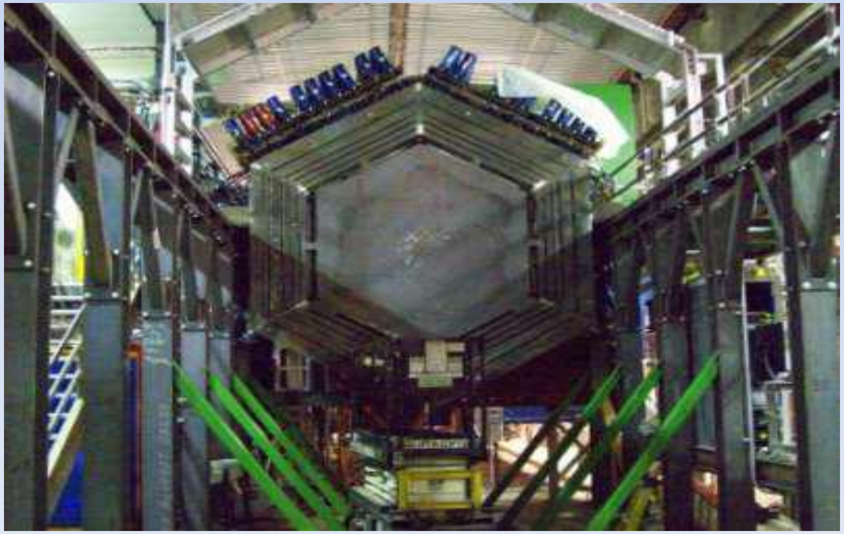
•Moved the tracking prototype into the NuMI Beam March 16 – April 17

•Estimated that we have collected 16k-19k CC ν_μ events in a 0.9 ton fiducial volume during 2 month run

•We are gearing up for analysis of these events!

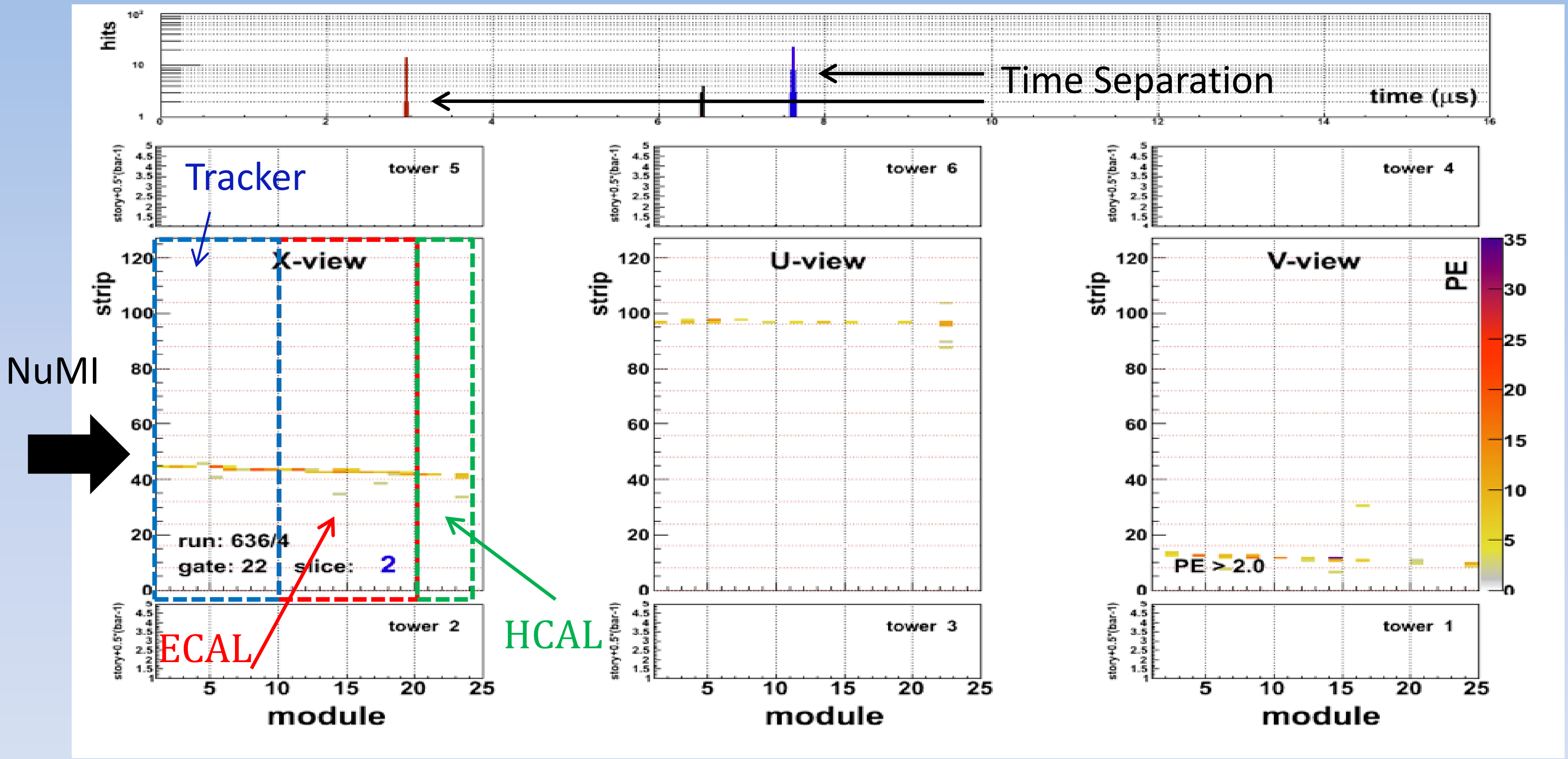


Plot: M. Kordosky



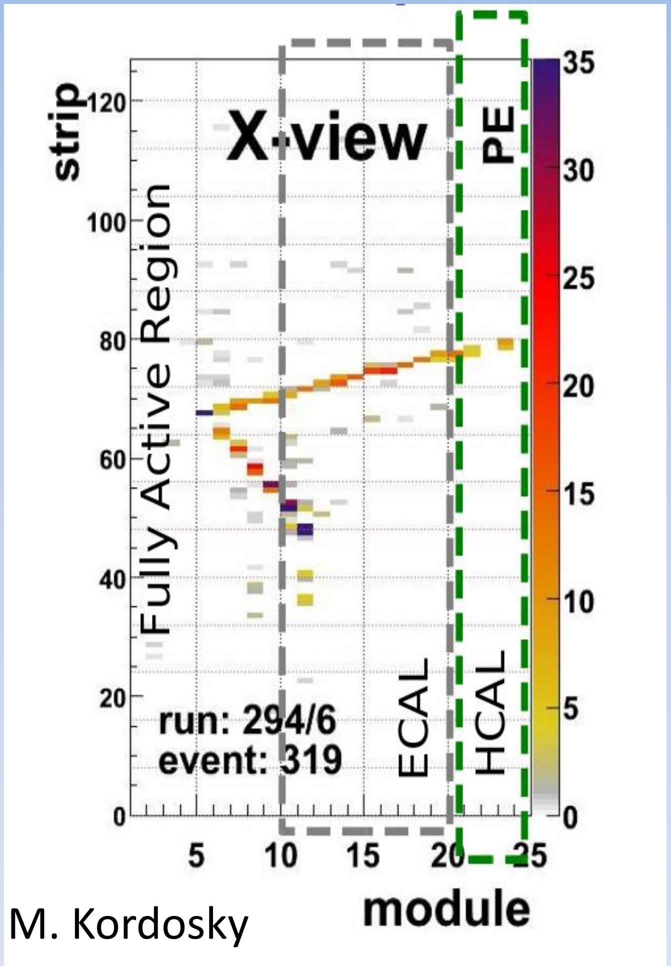
Process Type	Events	% of Total
Safe DIS	6.1k	32
Low Q DIS	1.8k	9.5
Transition	5.9k	31
Delta	2.3k	12
Quasi-Elastic	2.8k	15
Coh. Pi Prod.	~80	0.5

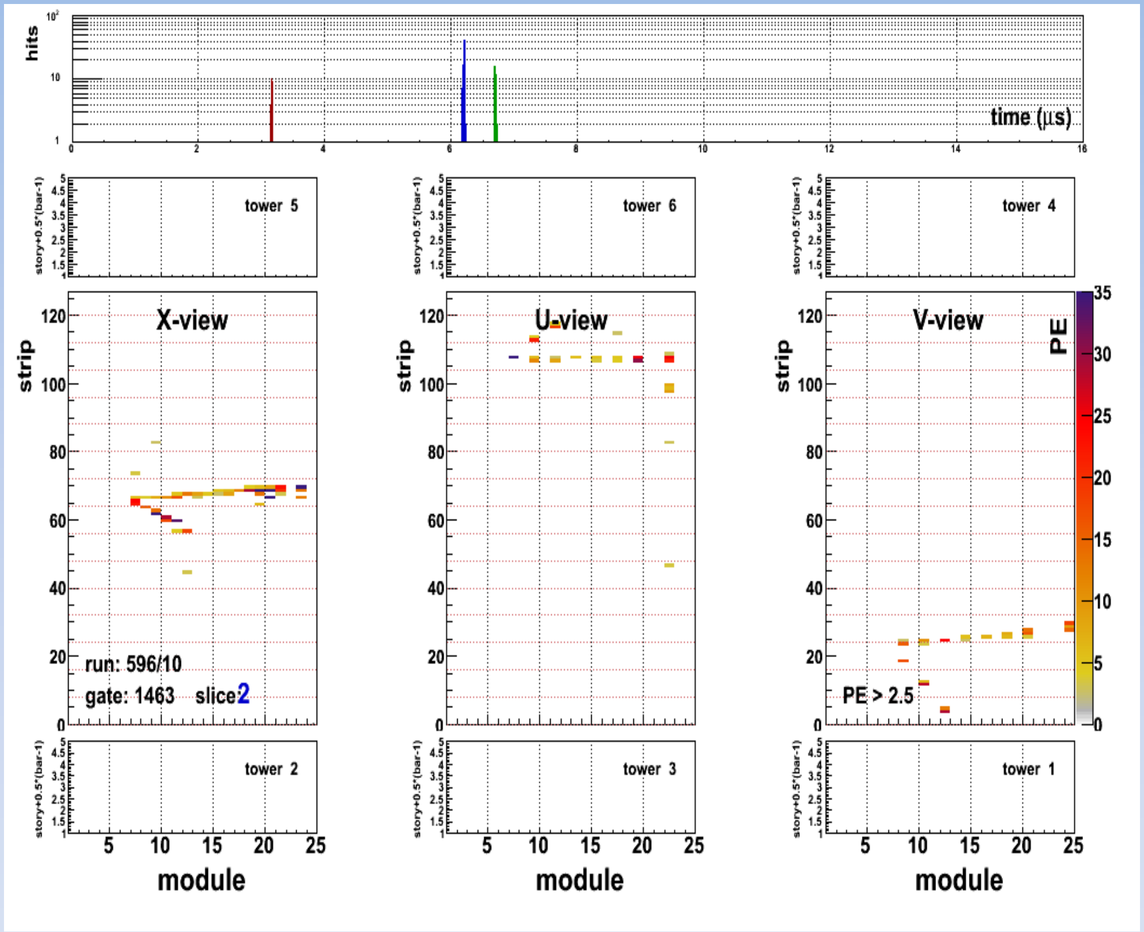
Rock Muons



- Tower = OD
- Muons created by upstream neutrino interactions
- Valuable absolute energy calibration tool

Events: Quasi-elastic Candidates

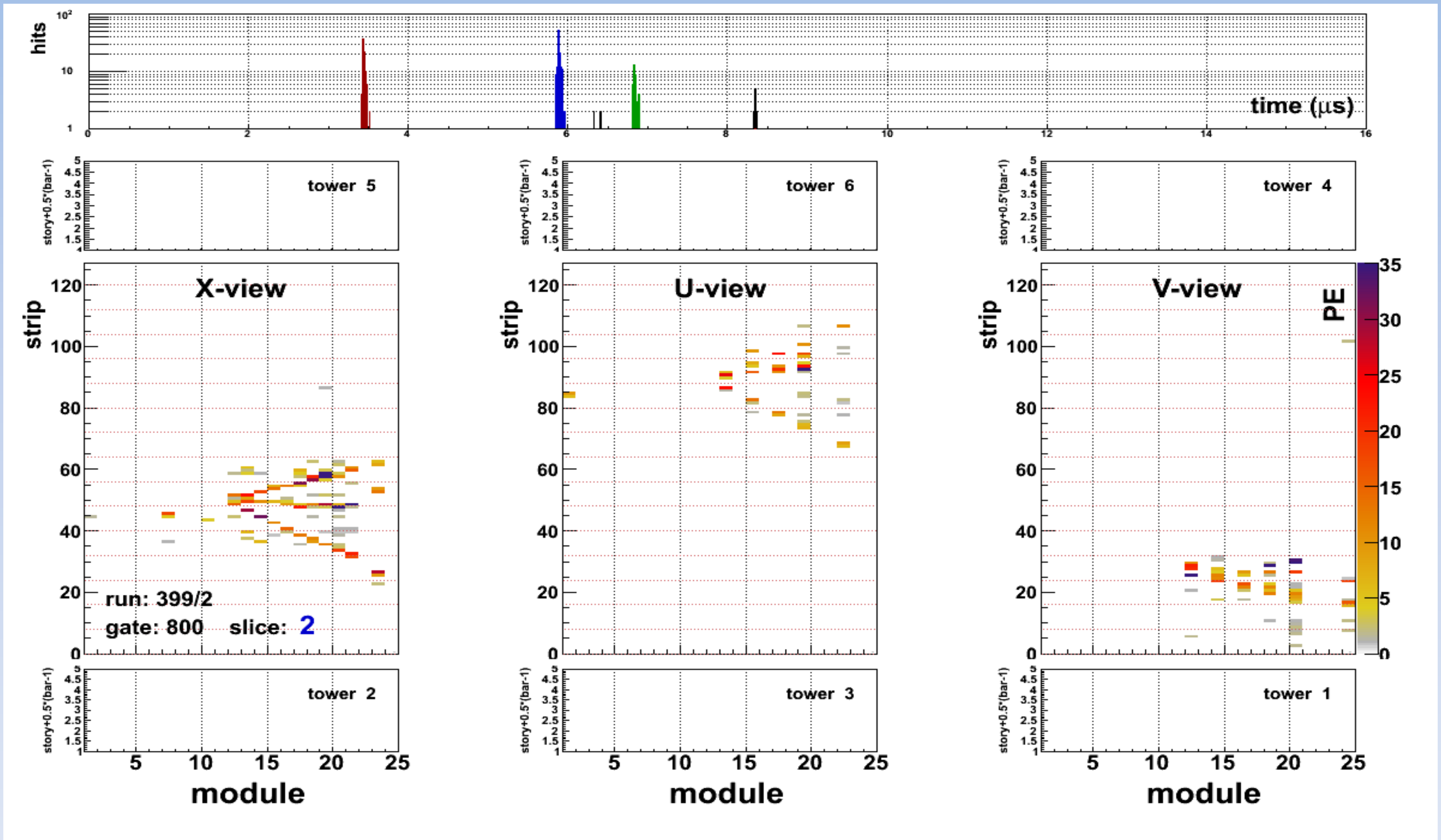




$\nu_\mu + n \rightarrow \mu^- + p$

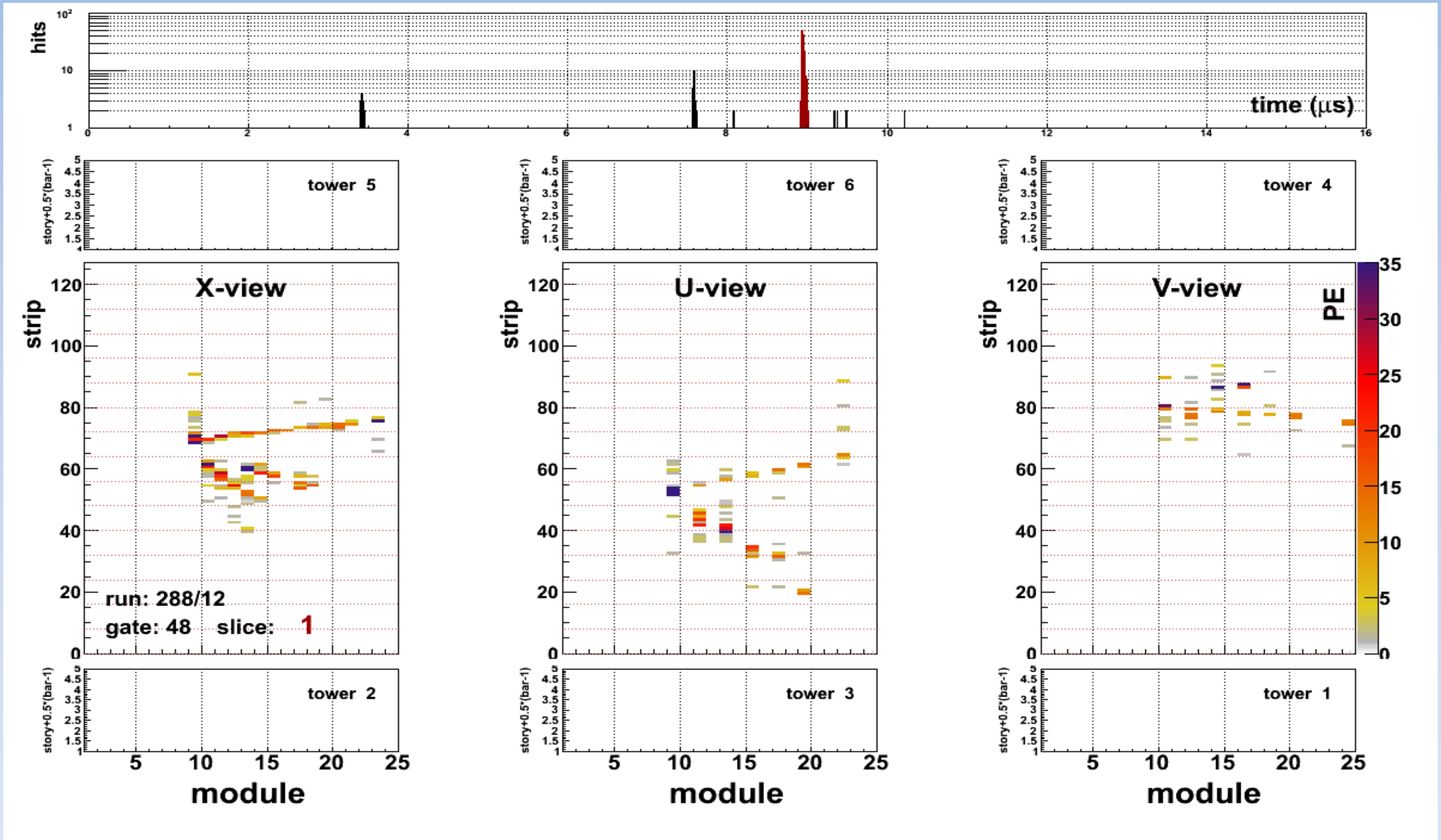
Two different events: Both have long track exiting detector (muon) and short contained track with increased dE/dx at endpoint (proton)

Events: Resonance Candidate



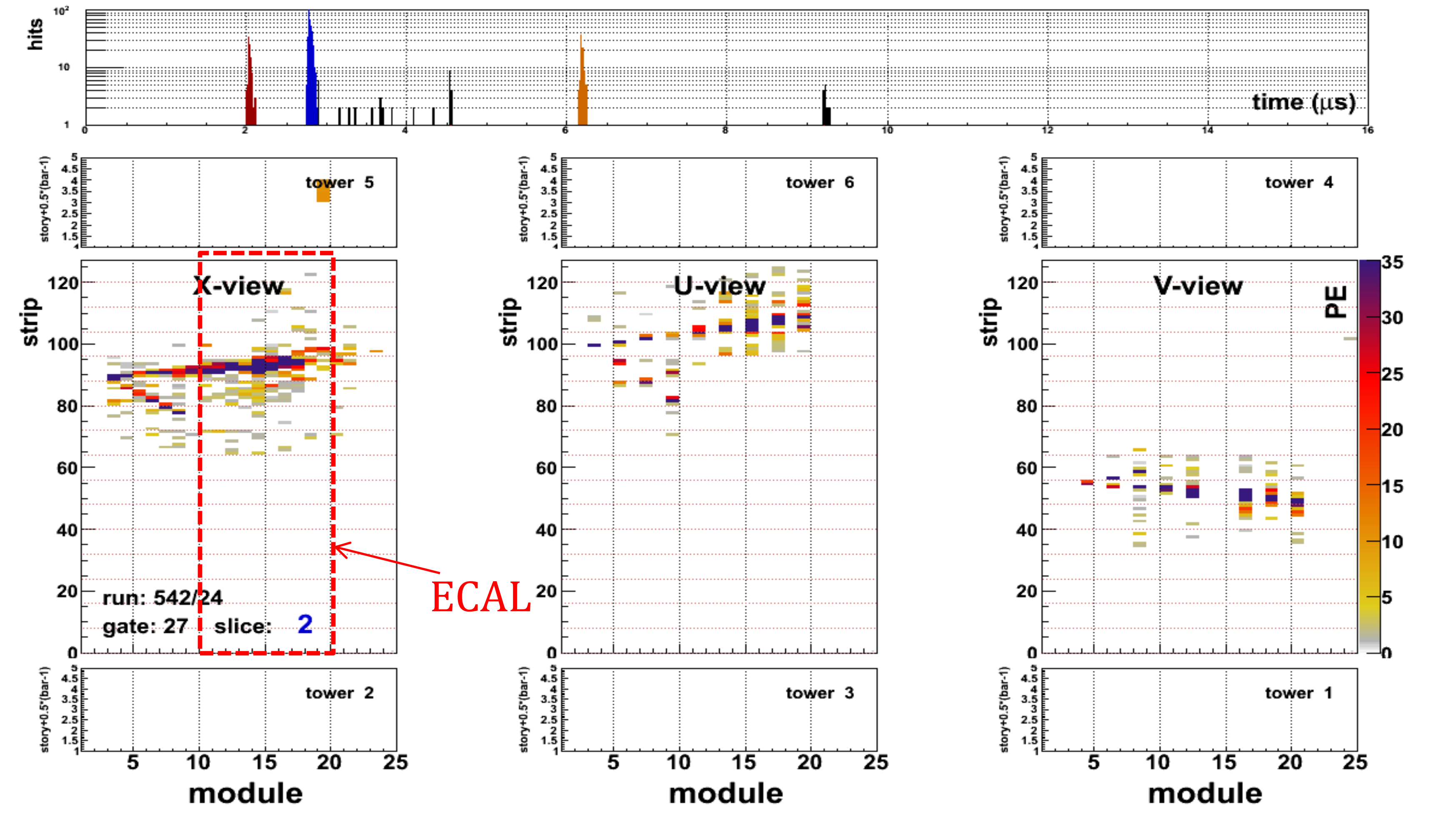
$\nu_\mu + N \rightarrow \mu^- + p + \pi$

Events: π^0 Candidate



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

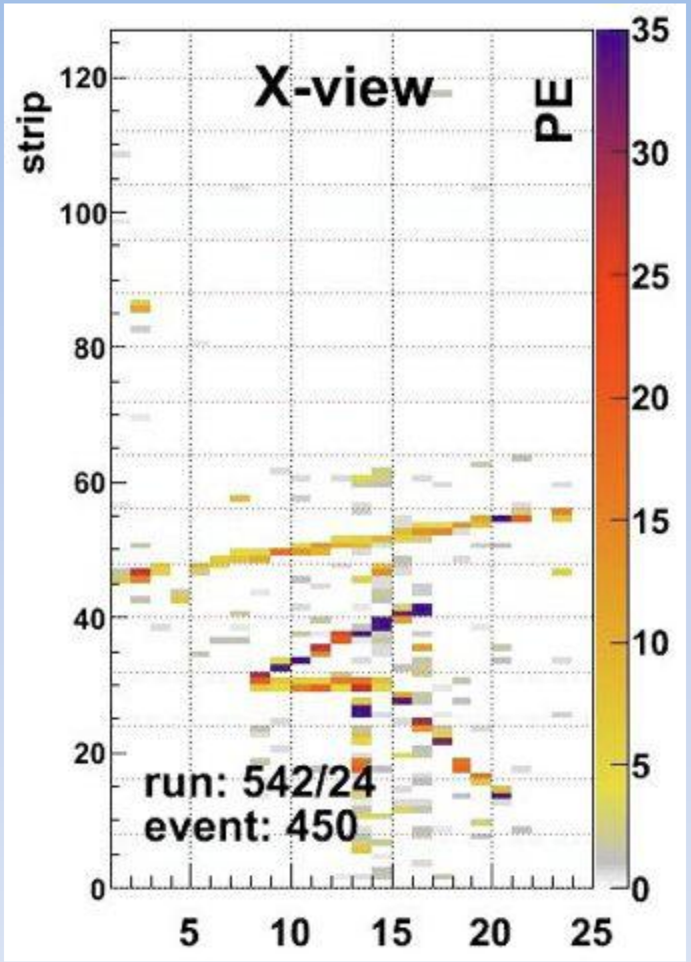
Events: ν_e Candidate



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

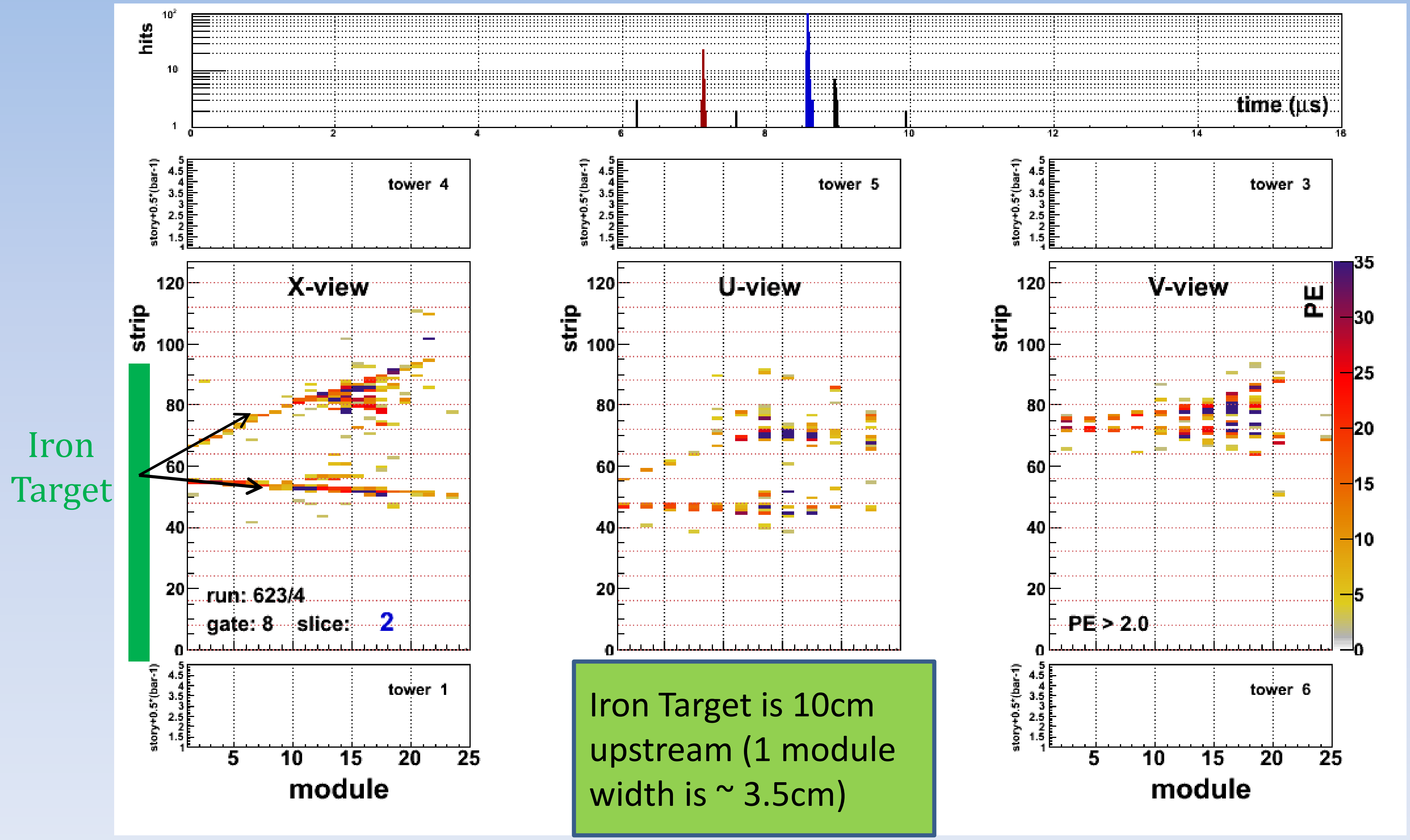
Events: Neutral Current Candidate

- Looks like a NC pion production event
- Upper track is short and highly ionizing – looks like a proton
- Lower track scatters then stops in the HCAL – ionization more consistent with pion
- Apparent transverse momentum does not balance



$\nu + N \to \nu + p + \pi$

Events: Iron Target Interaction



Iron Target is 10cm upstream (1 module width is ~ 3.5cm)

Current and Future Plans

- Beginning this week, the tracking prototype will be de-instrumented and disassembled

- In early August, installation of the full MINERνA detector will commence, starting with the HCAL modules

- NuMI beam returns in September, running in ν_μ-bar mode

- Current plan is to install ~60% of the detector modules by mid October

- Module installation will finish in February 2010 under current plan

- If the above holds true, then the full detector will be ready to take data by March 2010!!!

Conclusions

- MINERνA is a neutrino cross section experiment in the few GeV region, designed to support current and future neutrino oscillation experiments and address current nuclear physics questions

- An early look at the data after a two month tracking prototype run shows that the detector works; we see neutrino events!

- There is still a lot to do: We have a detector to assemble and ~16-19k tracking prototype neutrino events to analyze

- Under current plan, the full detector will be ready to take data by March 2010

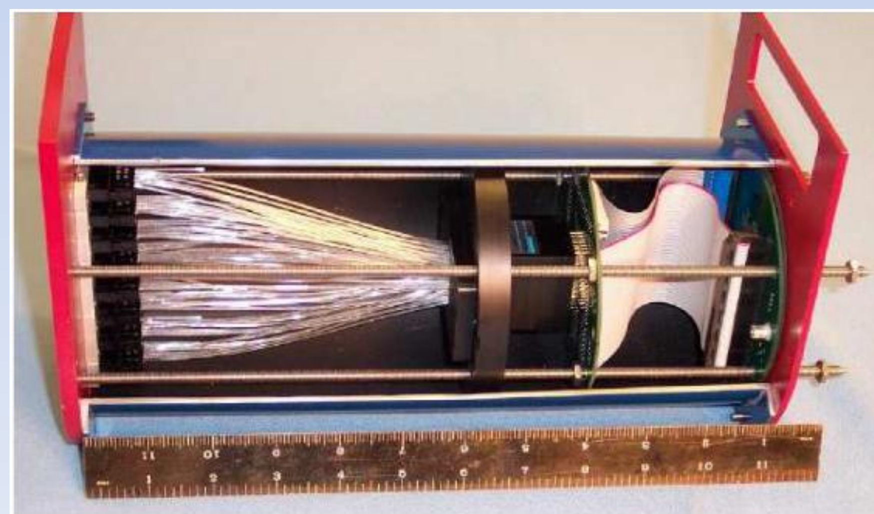
MINERνA Collaboration

- 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, Division de Ciencias e Ingenierias, Leon 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, Massachusetts
- 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

Backup Slides

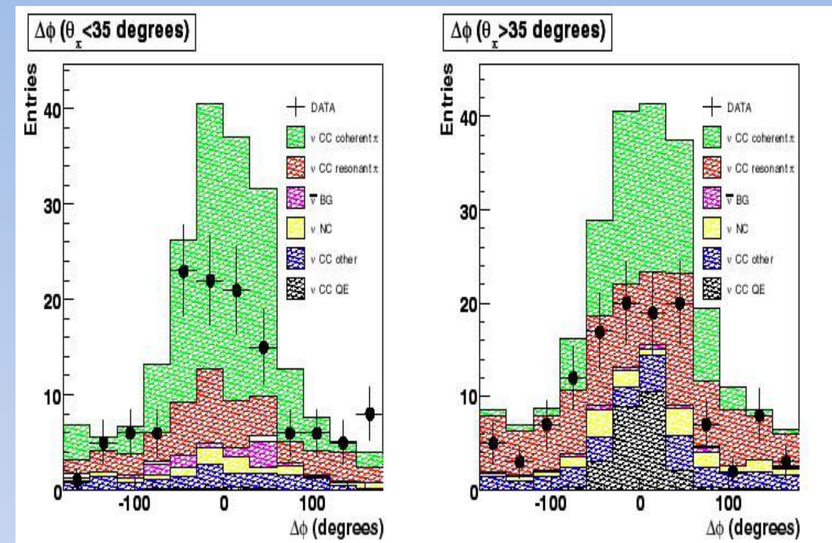
Electronics

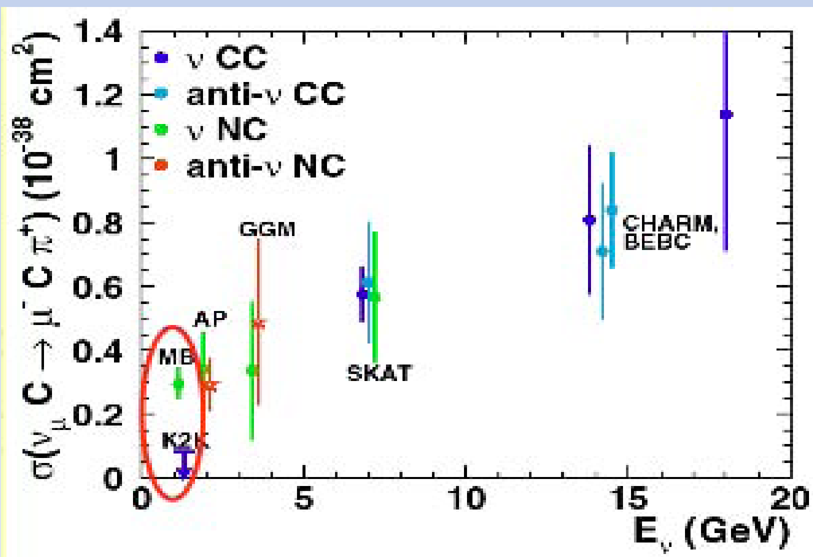
- Light measured by Hamamatsu 64 anode PMTs (newer version of MINOS model)
- Front end board (FEB) with Trip-t chips interface the PMTs
- Discriminators allow us to trigger at 1PE and resolve overlapping events during a spill

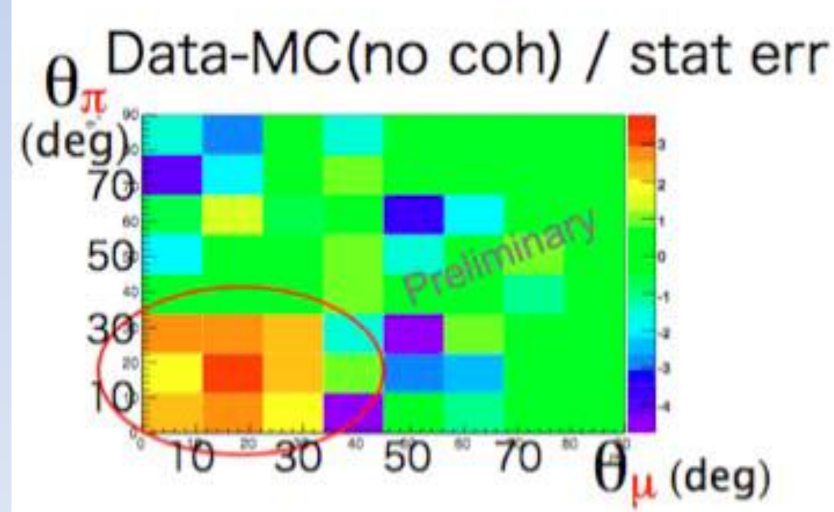


Physics: Coherent Pion

- MiniBooNE sees NC coherent pion production, but K2K has a null result for CC coherent pion
- SciBooNE has overall low E_ν null result but sees excess events at low pion angles
- MINERνA, with up to 90k CC events, has an excellent chance to detect CC coherent pions at low E_ν



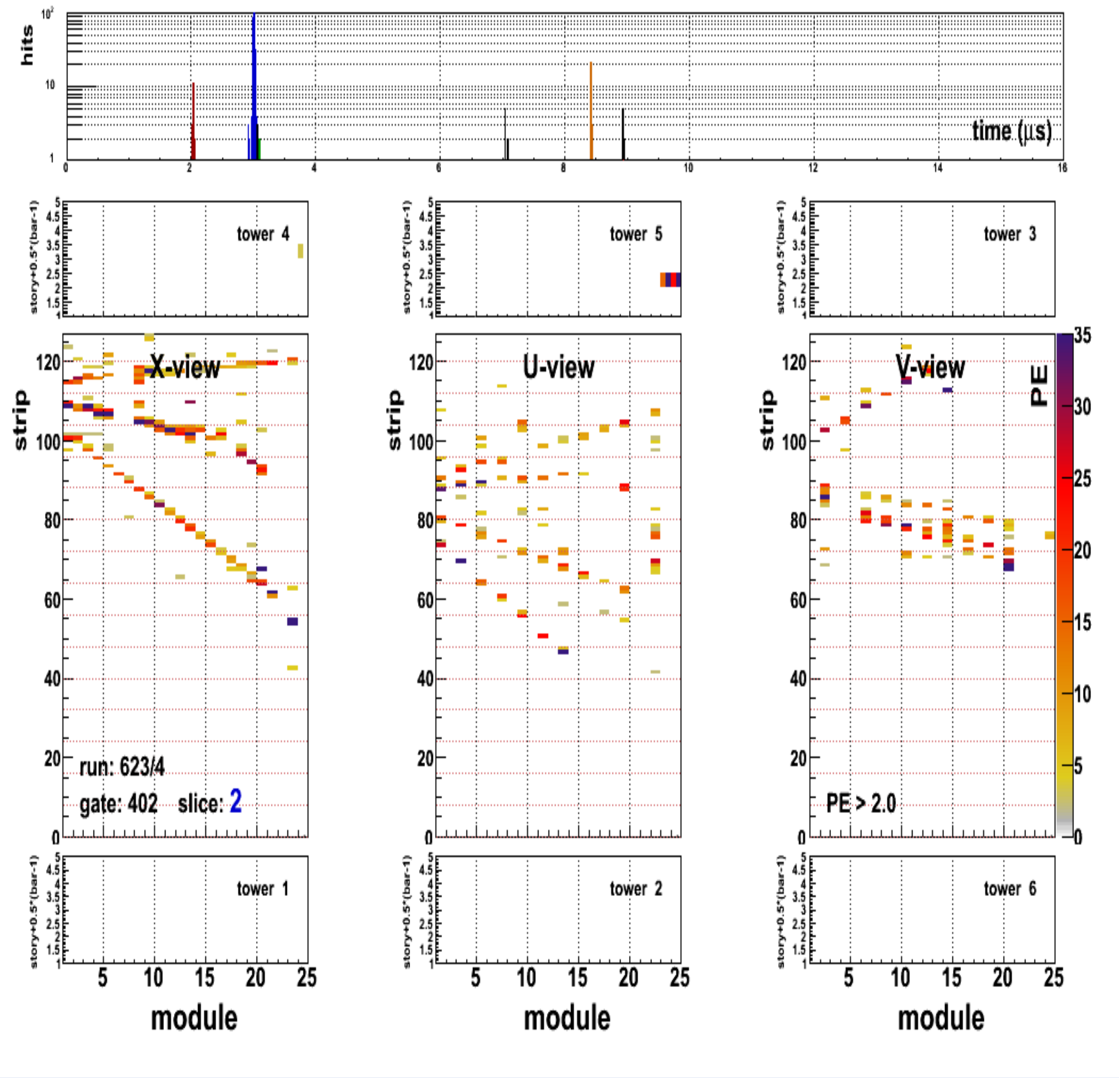




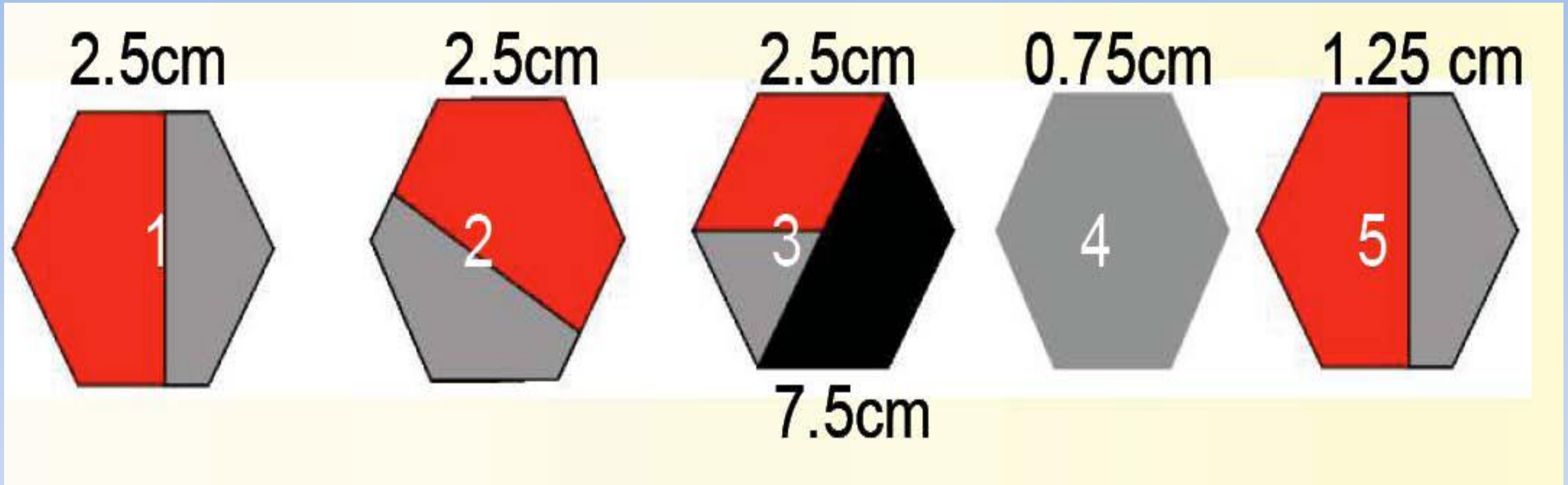
Plots: K. Hiraide, NuInt 2009
Search for neutrino charged current coherent pion production at SciBooNE

Physics: Nuclear Effects

- Study effects of Fermi motion
- Test the dipole form of the axial form factor and study structure functions and pdfs
- Study A dependence of various processes
- Measure hadron spectrum and multiplicity
- Examine final state interactions within the nucleus



Nuclear Targets



Red = Iron, Grey = Lead, Black = Carbon

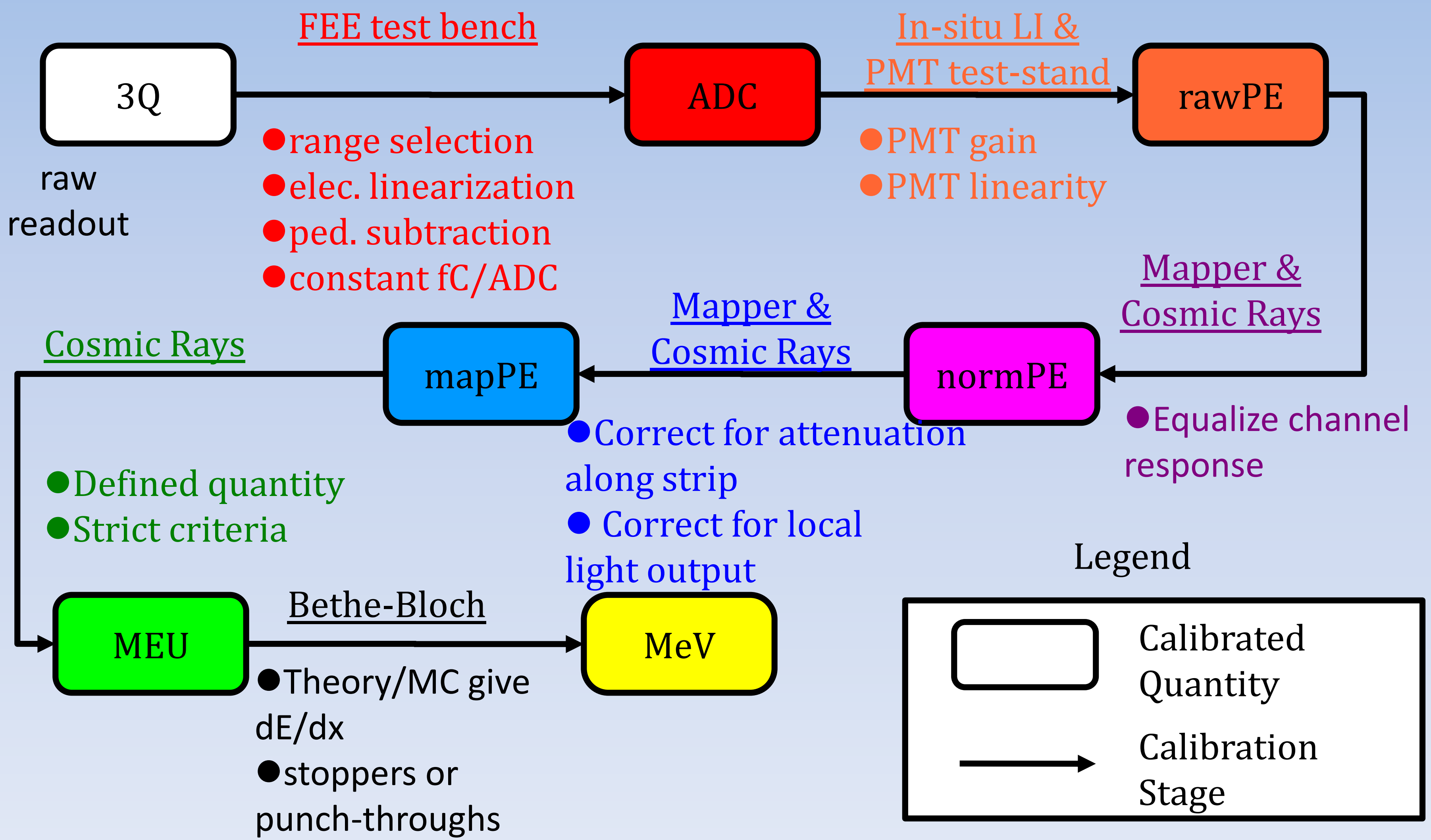
First two targets: High statistics, compare lead and iron
Third target: Compare lead, iron, and carbon with same detector geometry
Last targets: Thin for low energy particle emission studies, high photon detection

^{4}He cryogenic target in front of detector

Detector Performance

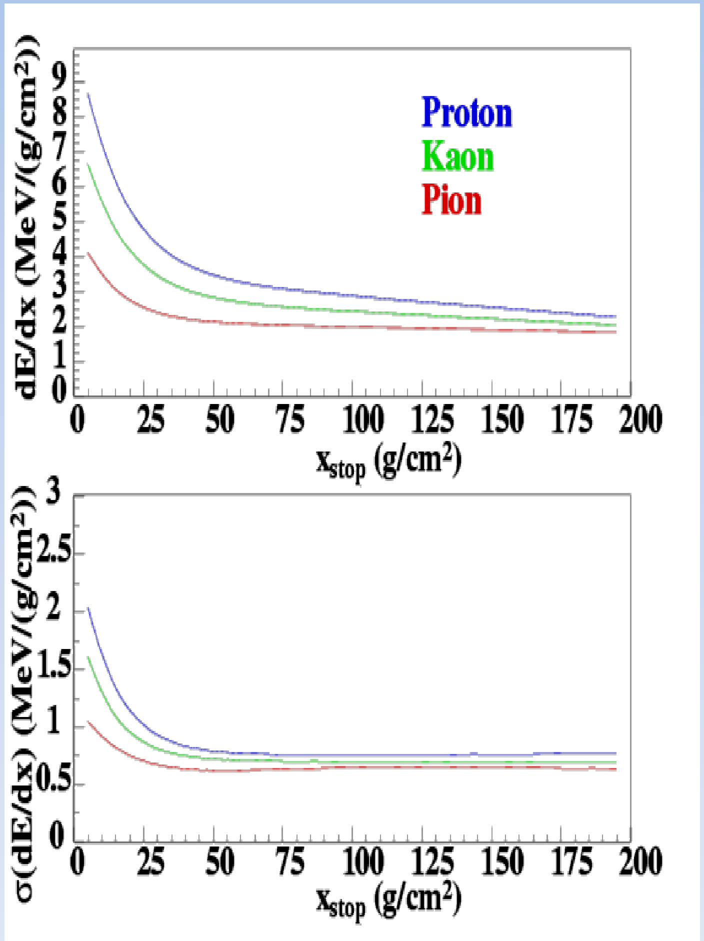
- Kinetic energy needed to cross 5 modules (10 planes)
  - p > 175 MeV, $\pi^{+/-}$ > 85 MeV, μ > 70 MeV
  - EM shower: e, γ > 50-60 MeV
- Particle ID
  - dE/dx – For tracks stopping in plastic,
    expect correct ID ~85% K, 90% $\pi^{+/-}$, > 95% p
- Muon Reconstruction
  - 85-90% of muons stop in MINERvA or MINOS
  - Above 2 GeV majority in MINOS
  - δp/p ~ 5% stoppers, 10-15% via curvature

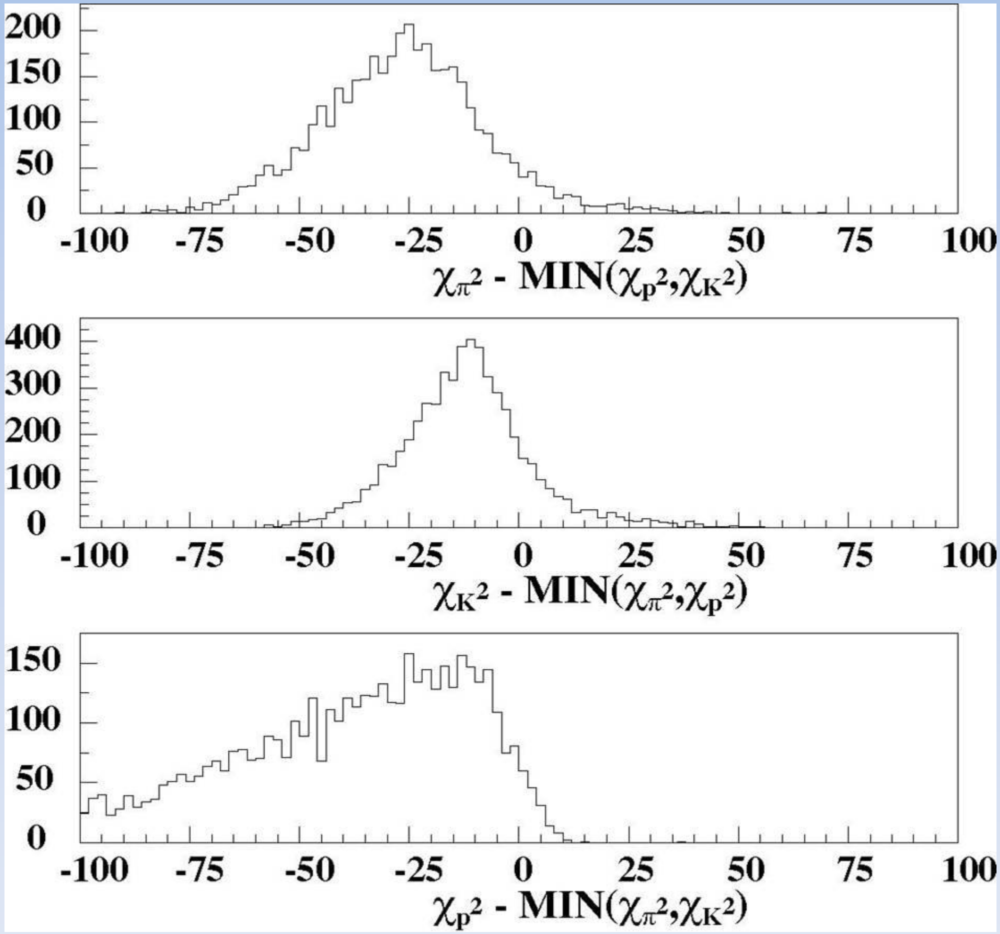
Calibration Chain



Particle ID

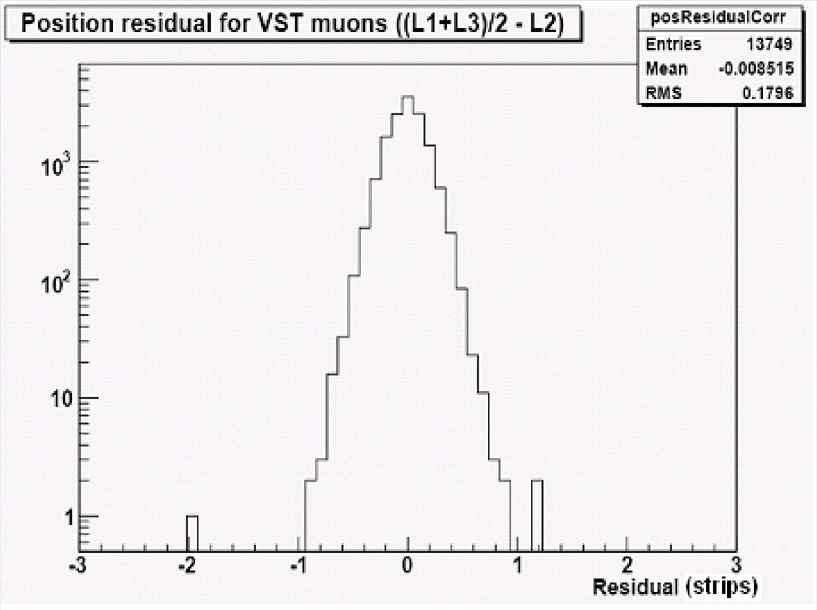
- Particle ID by dE/dx in strips and endpoint activity

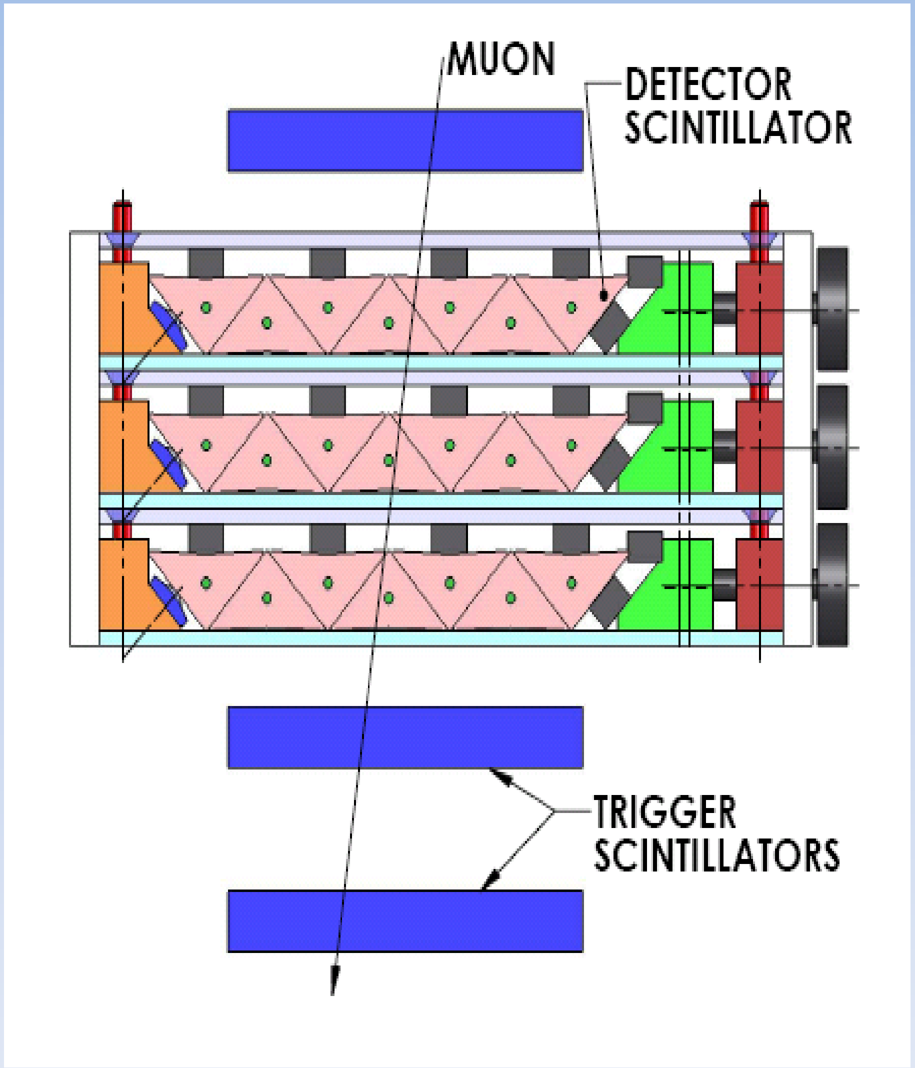




Vertical Slice Test

- Position resolution of 2.5mm
- Distance between center of strips is 1.7cm



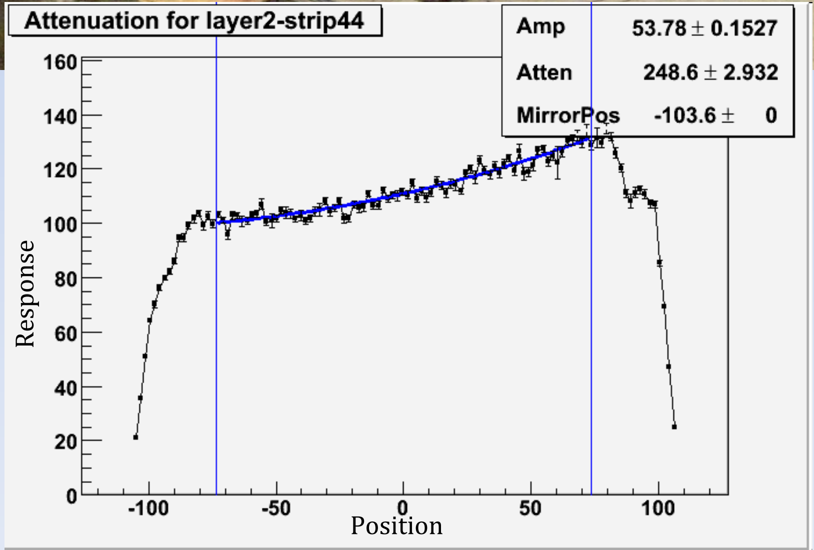


Calibrations: The Mapper

- •Upon completion of a module, each scintillator strip is scanned with a Cs-137 source and response is read out.

- •Data provides the attenuation curve along the strip length

- •Strip quality control



Plot from FNAL 2009 Users Meeting Talk
MINERvA – Bob Bradford