THE MINERVA EXPERIMENT

Heidi Schellman DIS 2010

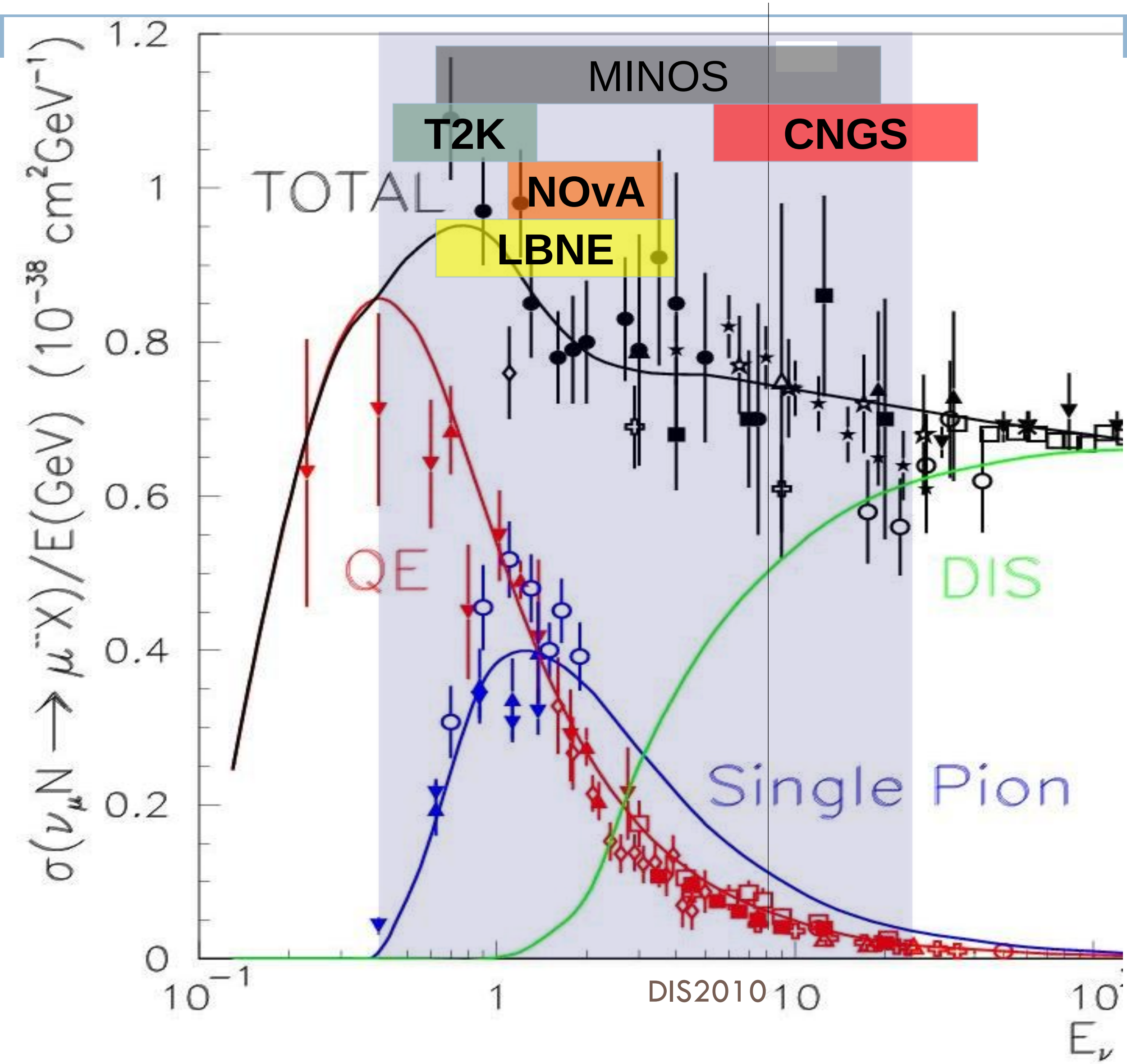
Outline

- MINERvA Goals
- MINERvA detector
- MINERvA data
- MINERvA future

MINERvA GOALS

- High precision measurements of neutrino scattering cross sections.
  - Fine granularity
  - High statistics in the NuMI beam
  - Mainly C (scintillator) but also nuclear targets
- Goals
  - Basic understanding of neutrino interactions in the 1-10 GeV range.
  - Important inputs for neutrino oscillation experiments

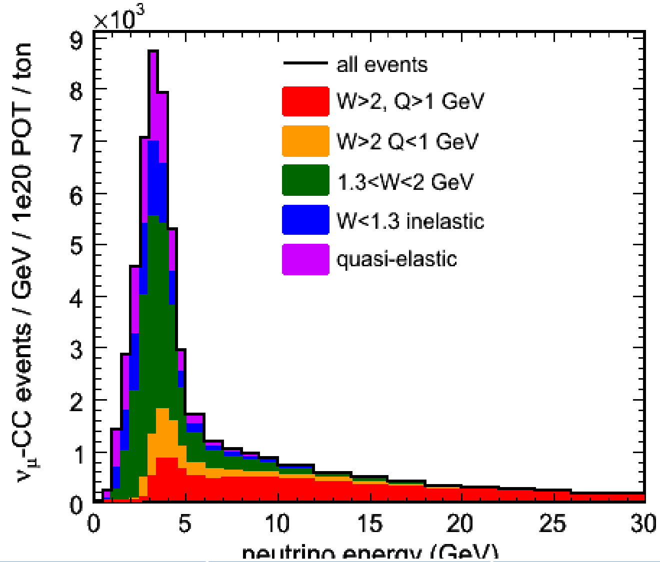
Neutrino Charged Current Cross Sections



Monte Carlo Estimated Event Yields

- If assume
  - 4×10^{20} POT LE
  - 12×10^{20} POT ME

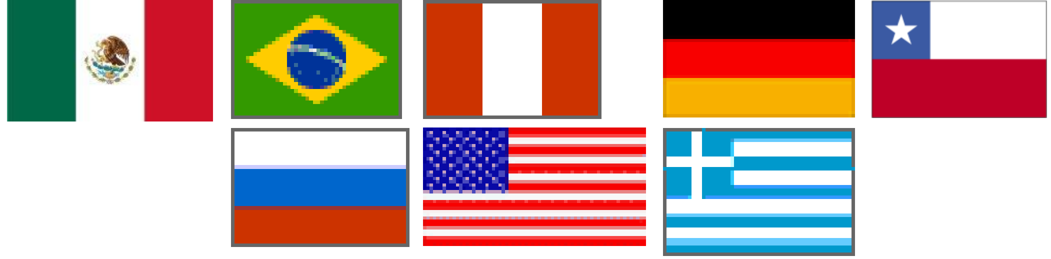
- Results in ~14 million CC events
  - ~9 million on scintillator
  - ~5 million on nuclear targets



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	Fiducial mass, tons	Number of Events
Helium	0.25	0.6M
Scint.	3	8.6M
Carbon	0.6	1.4M
Iron	1	2.9M
Lead	1	2.9M
Water	0.3	0.7M

MINERvA Institutions



MINOS

Tufts
William & Mary
FNAL
Duluth
Texas
Athens

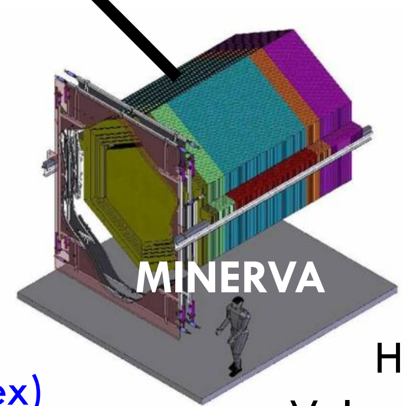
NOVA

Northwestern

MiniBooNE

Florida

MCLA (Mass.)
Otterbein
UNI (Peru)
PUCP (Peru)
CBPF (Brazil)
Guanajuato (Mex)



Dortmund
INR, Moscow

Theory

Pitt

Hampton
Valparaiso (Chile)
James Madison
Rutgers

Jefferson Lab

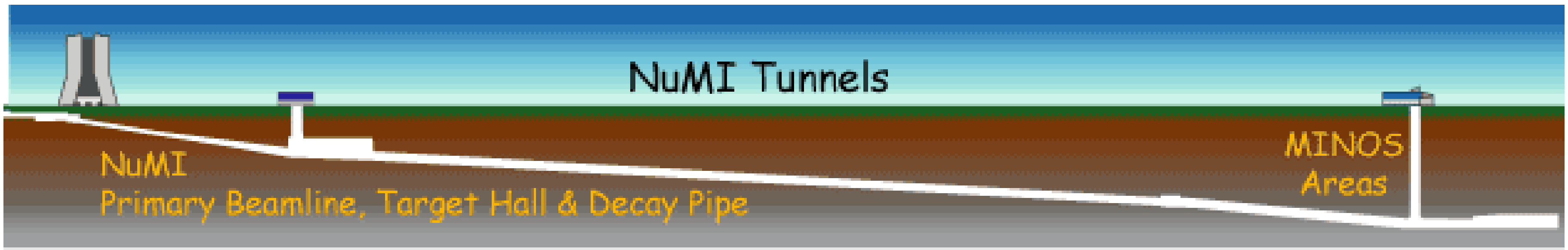
Irvine

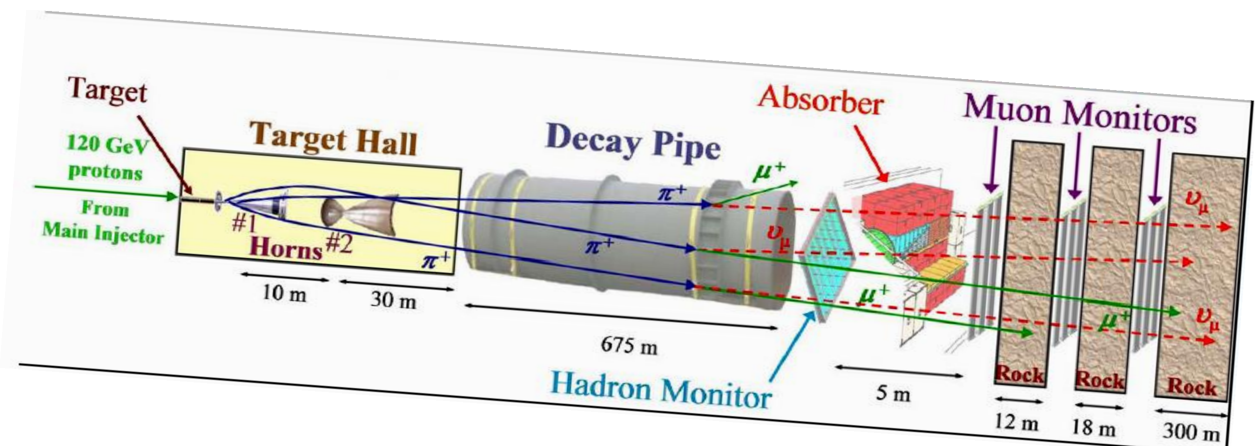
T2K

Rochester

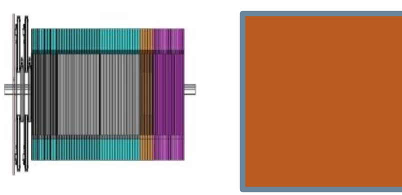
Nuclear

NuMI Beam



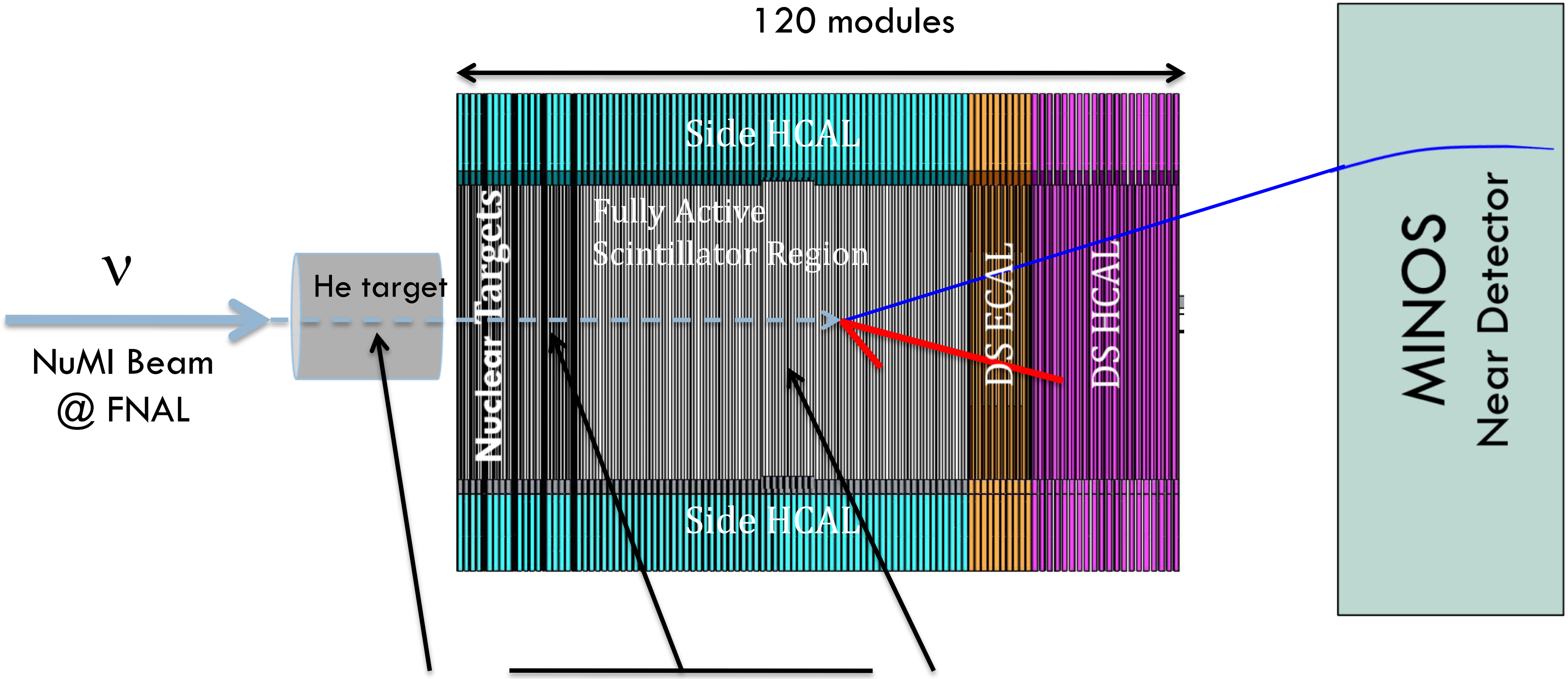


DIS2010



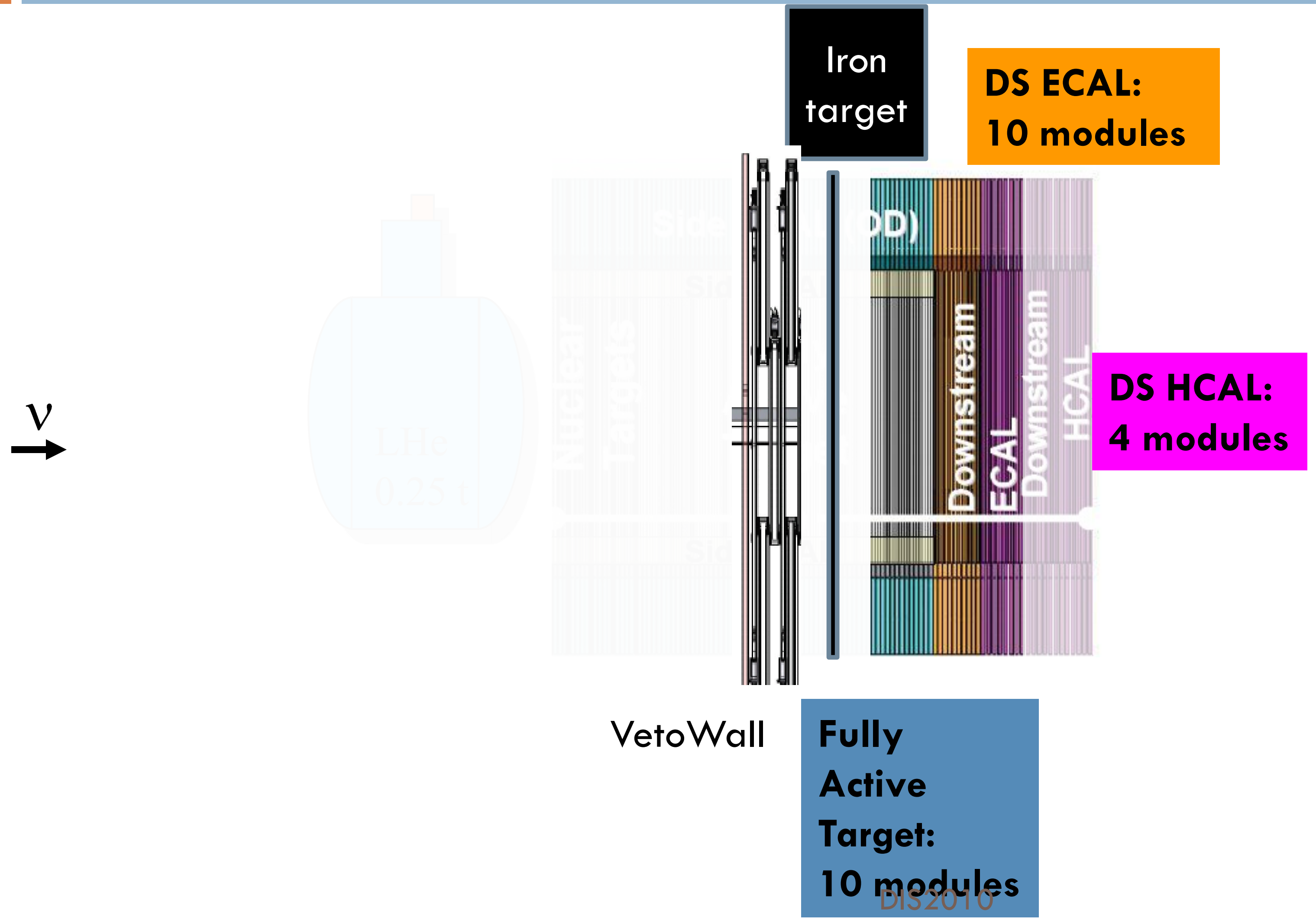
MINERνA

Finely segmented, fully active scintillator tracking region surrounded by ECAL and HCAL, ~32,000 channels



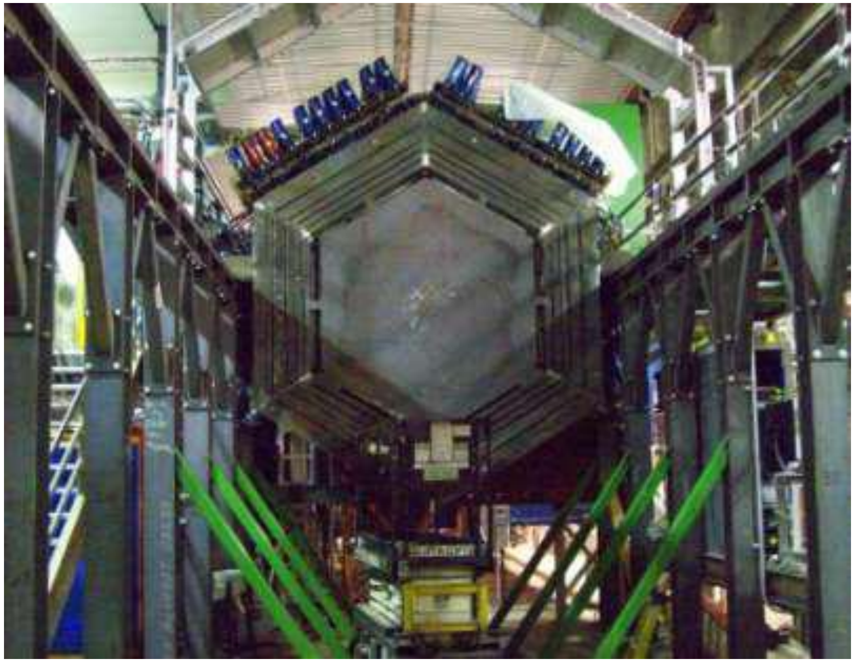
<u>nuclear targets</u> **(He, C, Fe, Pb, H_2O(late spring), CH)**

Tracking prototype Spring 2009



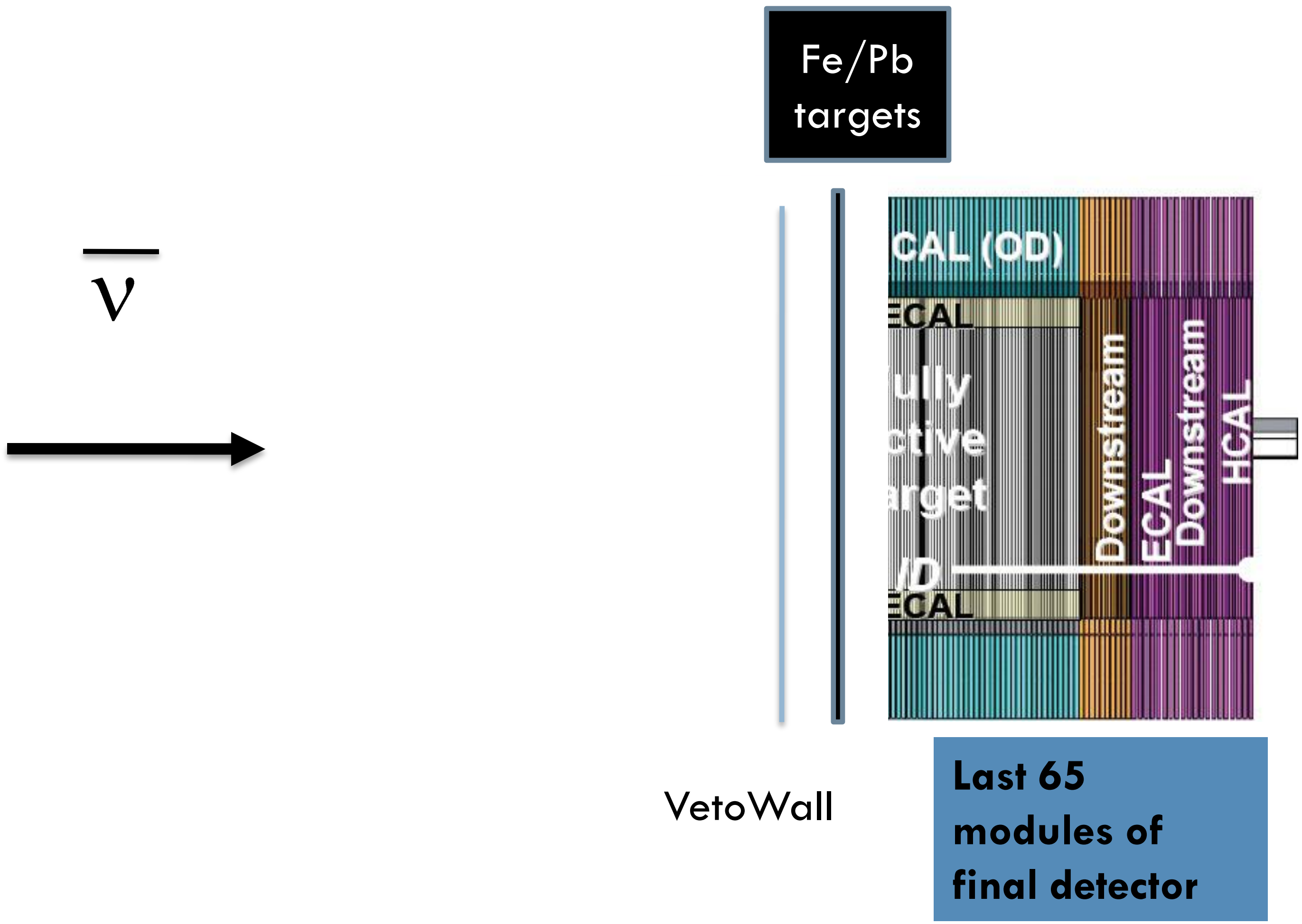
Tracking Prototype in NuMI

•24 module tracking prototype ran in the NuMI Beam March 16 – June 12



Process Type	% of Total (MC)
Safe DIS	32
Low Q DIS	9.5
Transition	31
Delta	12
Quasi-Elastic	15
Coh. Pi Prod.	0.5

Partial Detector Winter 2009-10

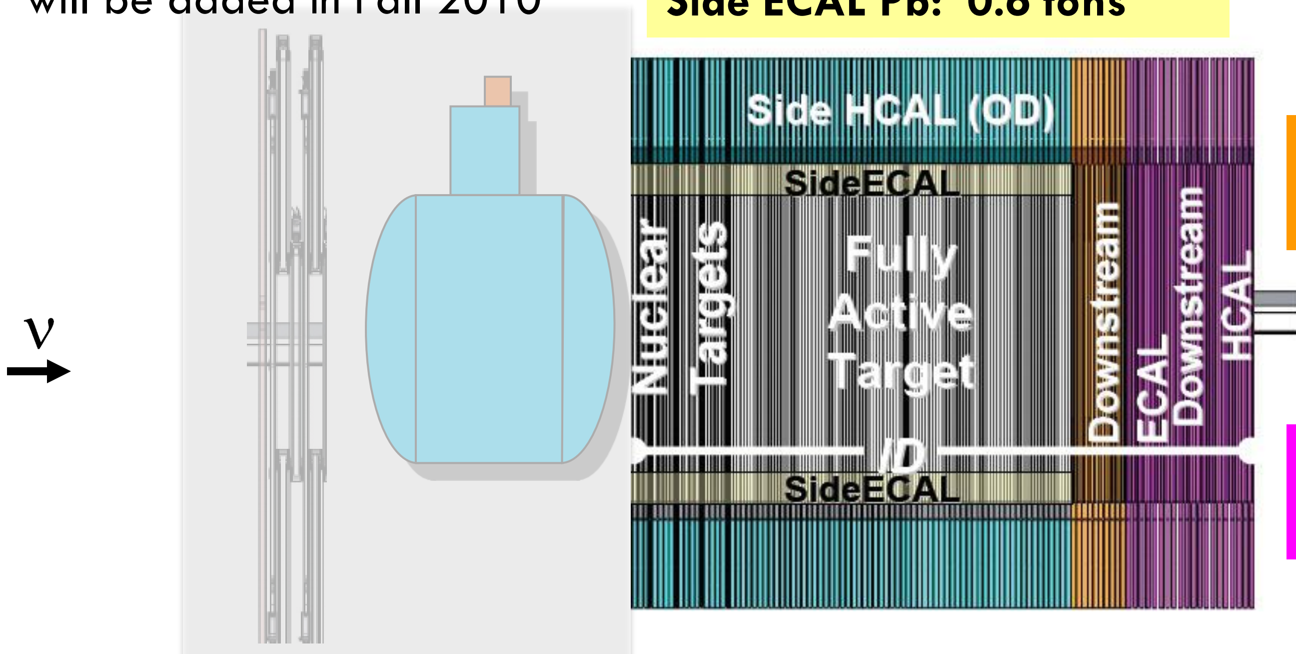


Present MINERνA Experimental Set-up

All Modules installed
Veto wall and liquid target will be added in Fall 2010

Side HCAL: 116 tons

Side ECAL Pb: 0.6 tons



DS ECAL: 15 tons

DS HCAL: 30 tons

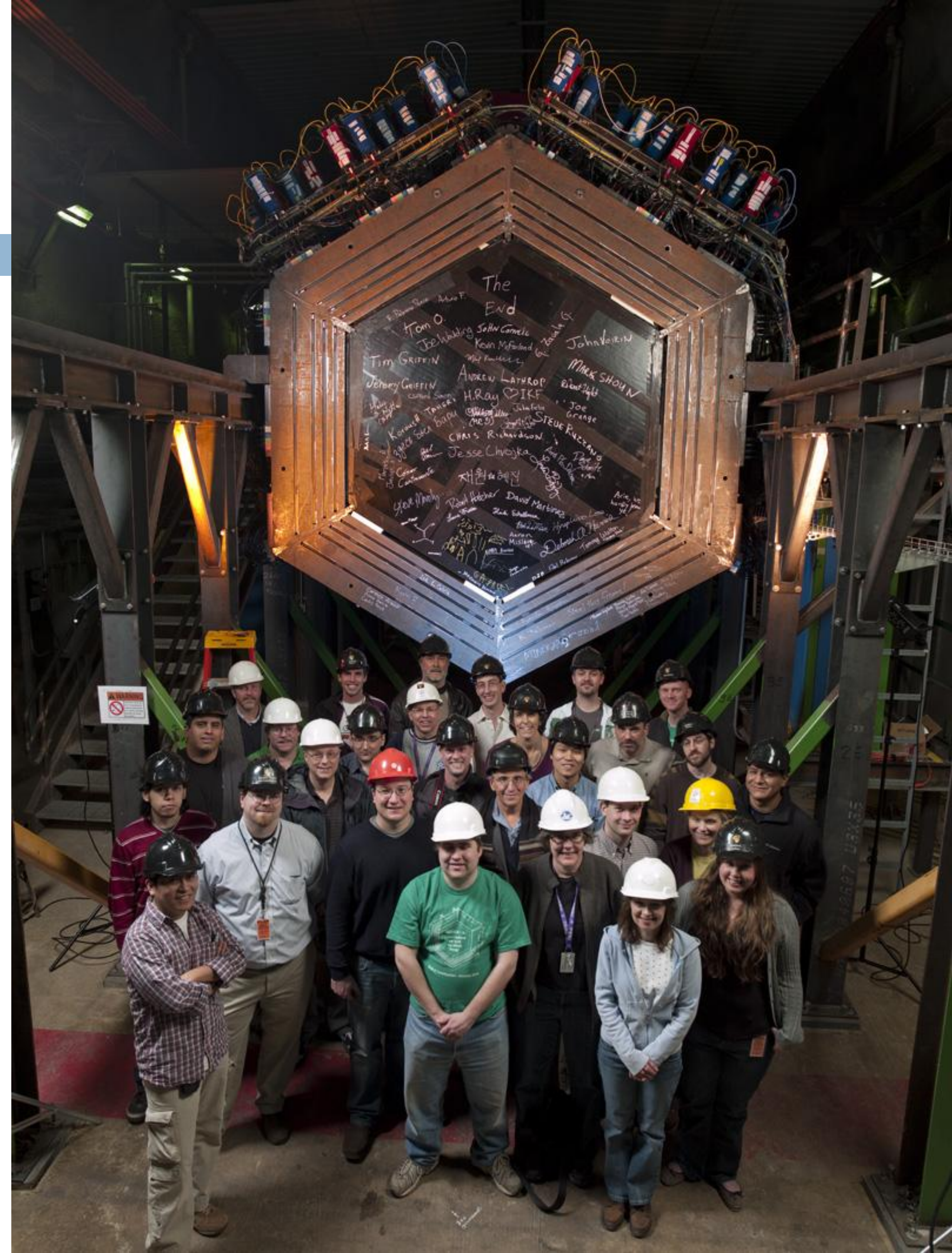
VetoWall

Nuclear Targets: 6.2 tons (40% scint.)

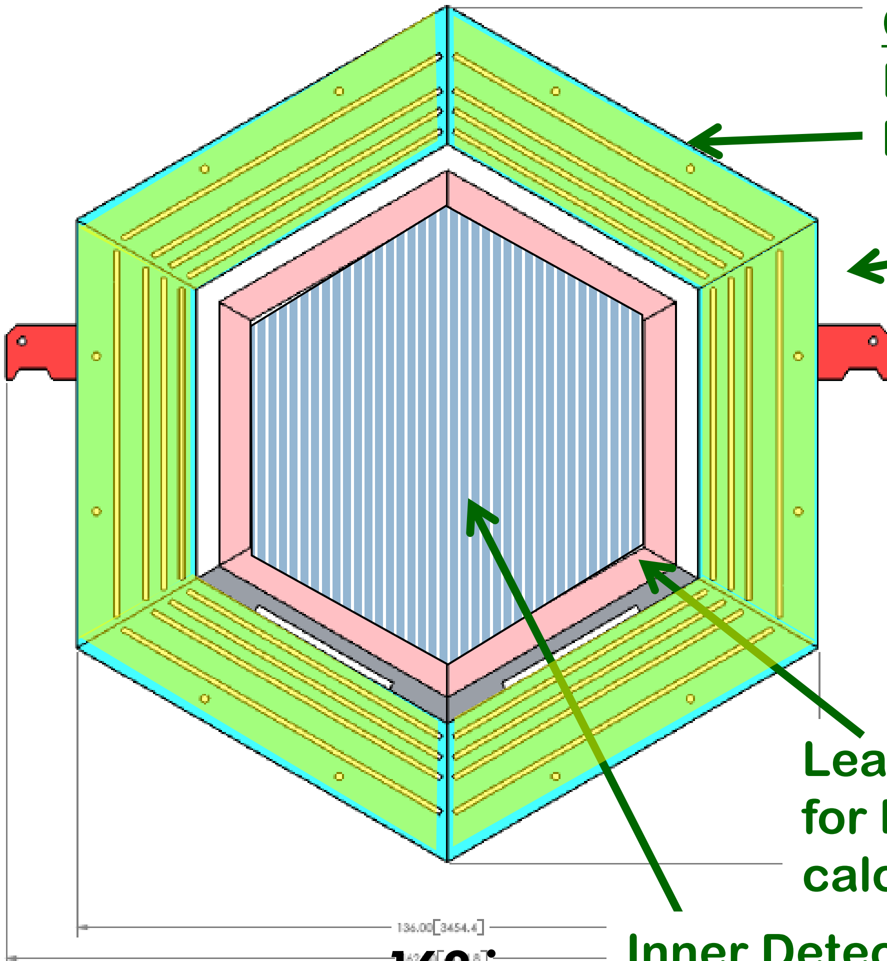
Fully Active Target: 8.3 tons

Added a water target!!

Done!



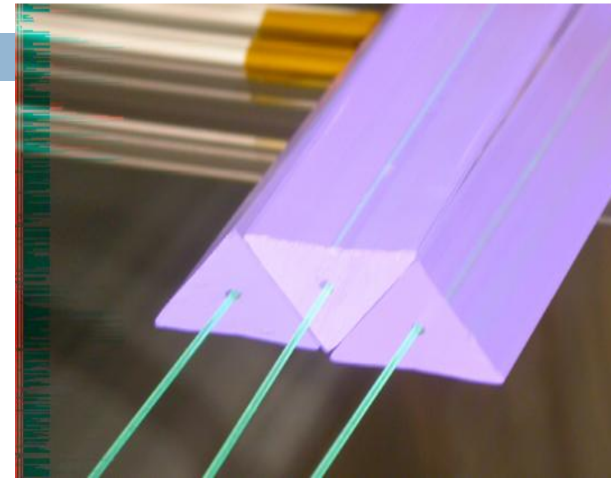
MINERνA Detector Module

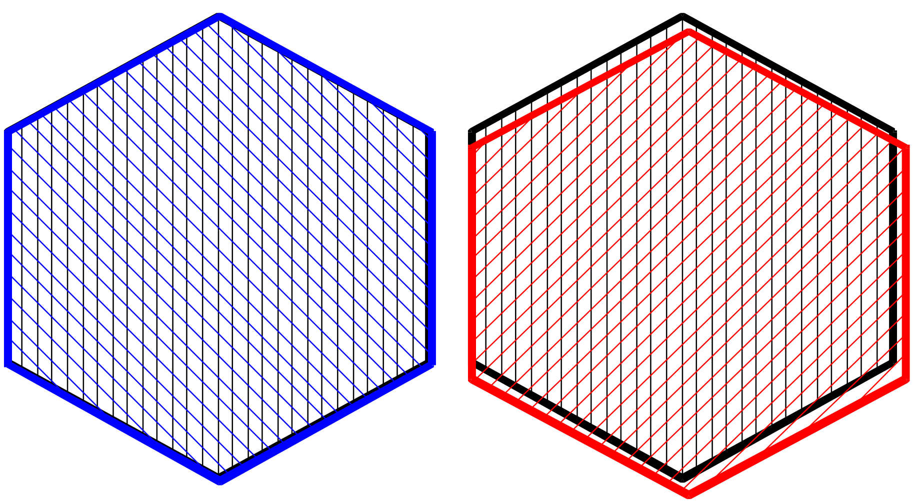


- A frame with two planes has 302 channels
  - 254 in inner detector
  - 48 in outer detector (two per slot)
- 4-5 M-64 PMTs per module
  - OD readout ganged in groups of four planes

Inner detector

•127 scintillating strips per plane, read out by wavelength-shifting (WLS) fibers.
•Alternating triangle design improves position resolution.



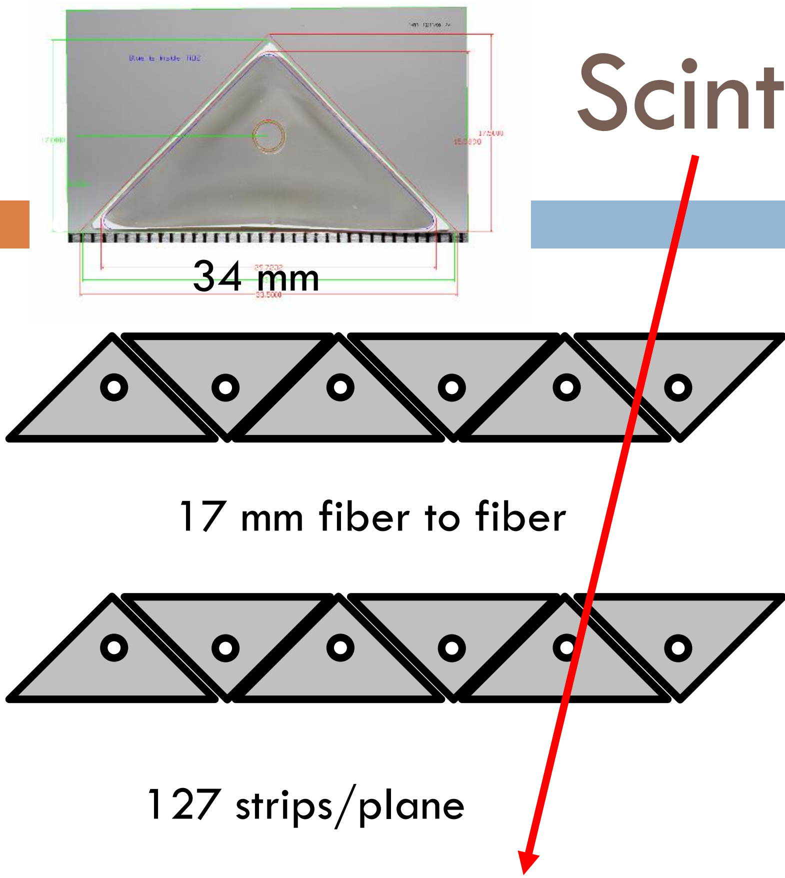


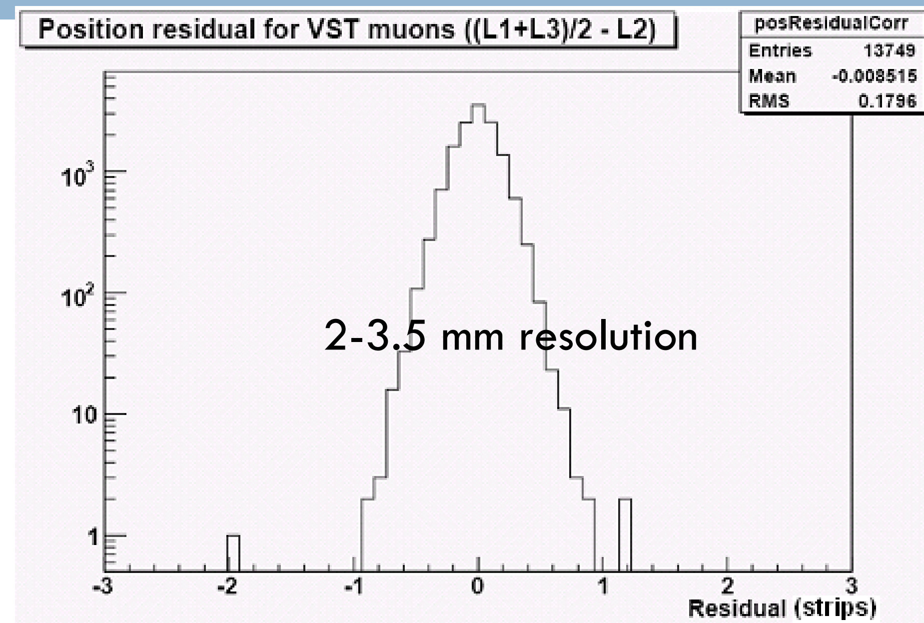
U X

VX

- Three different plane orientations +- 60 degrees
- Two planes (UX or VX) make a module
- Full detector has 114 modules, 6 nuclear target modules, and ~31k channels

Scintillating strips in ID



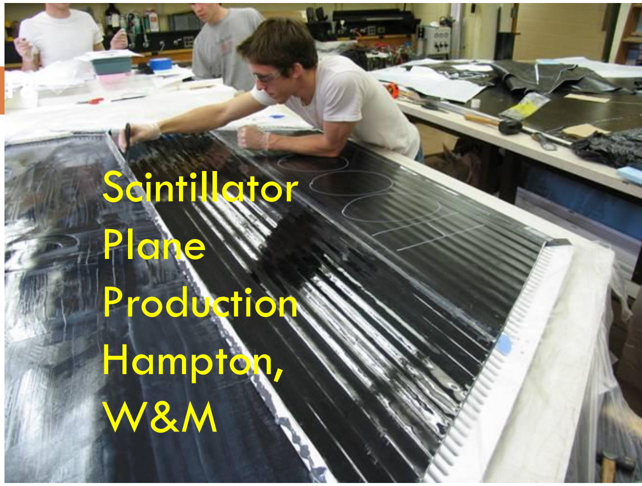


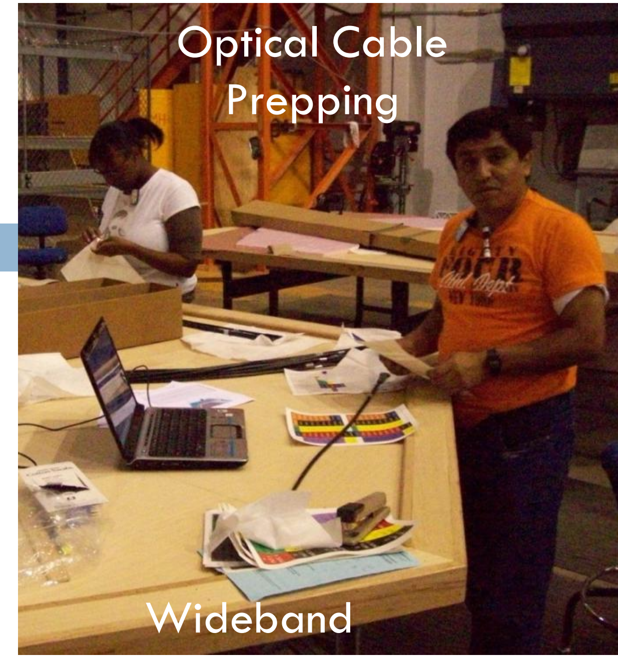
- Response is measured with a dedicated mapper before installation underground.

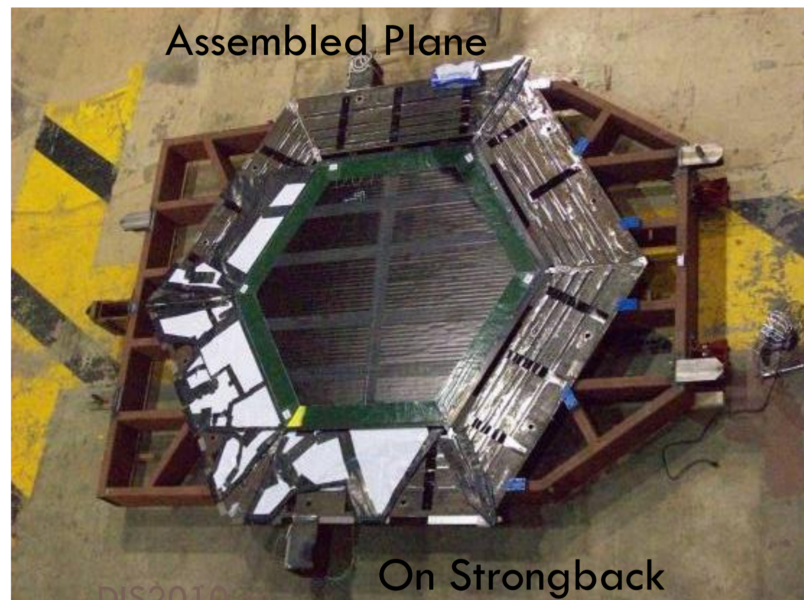
Inner Detector Plane Fabrication at Hampton, William + Mary and Fermilab

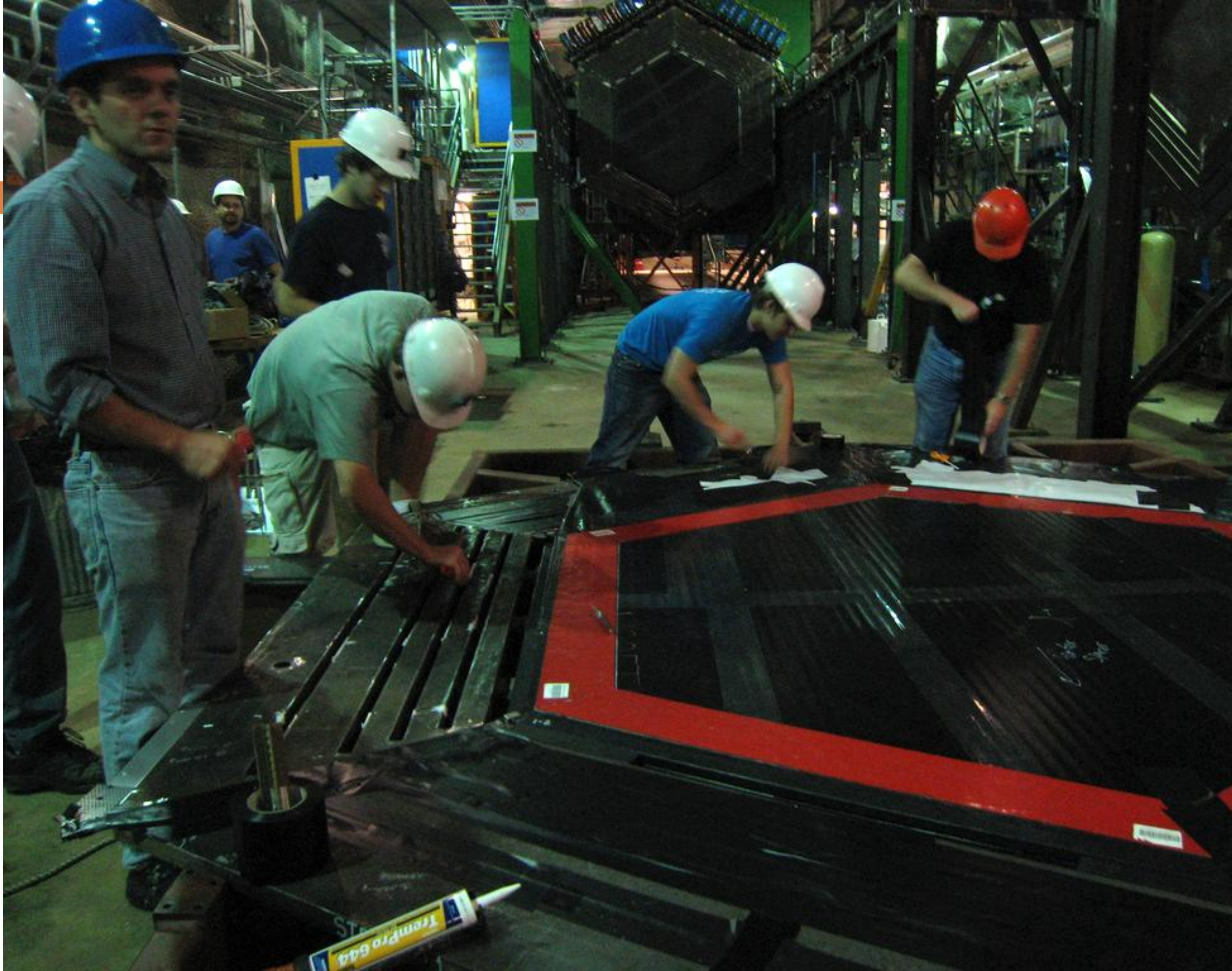
1) Scintillator Bars are cut and formed into planks
2) Planks are joined together to make hexagonal plane
3) Planes are instrumented with fibers and connector
4) Plane is made light tight

Module Construction

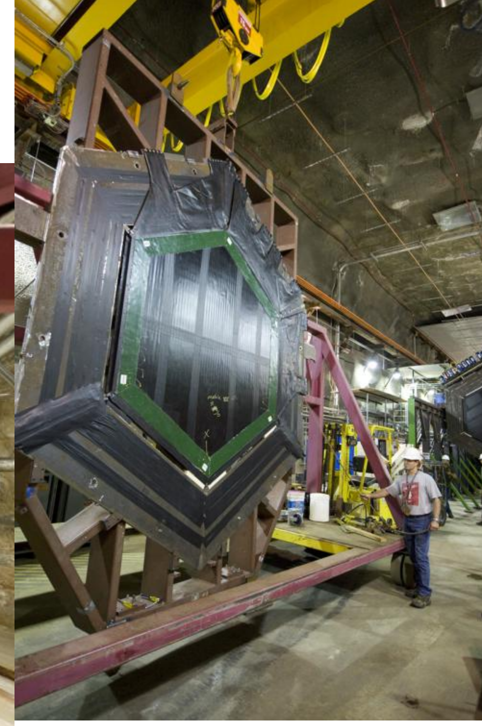


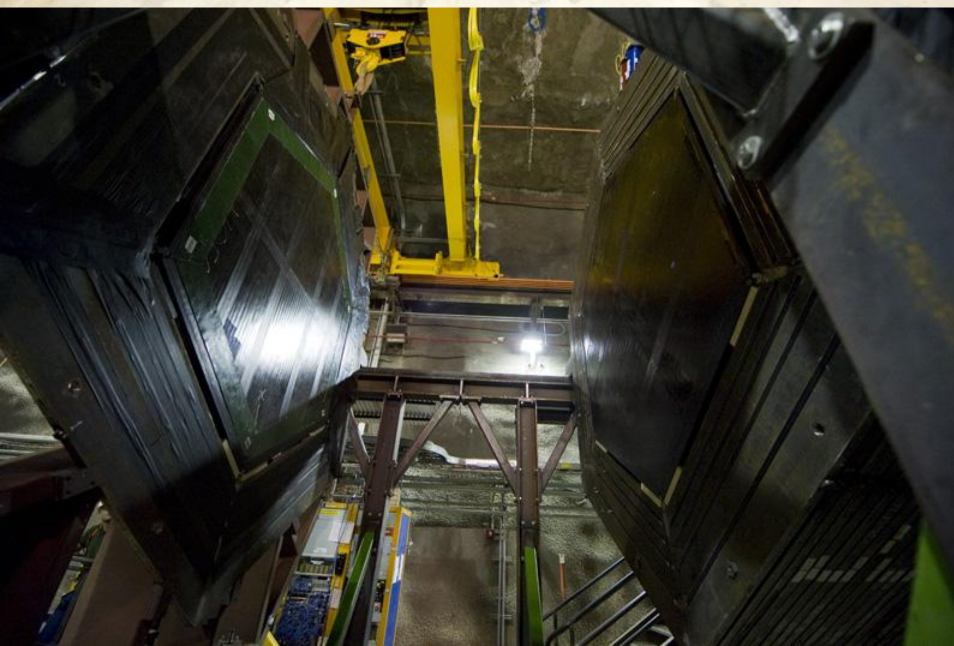


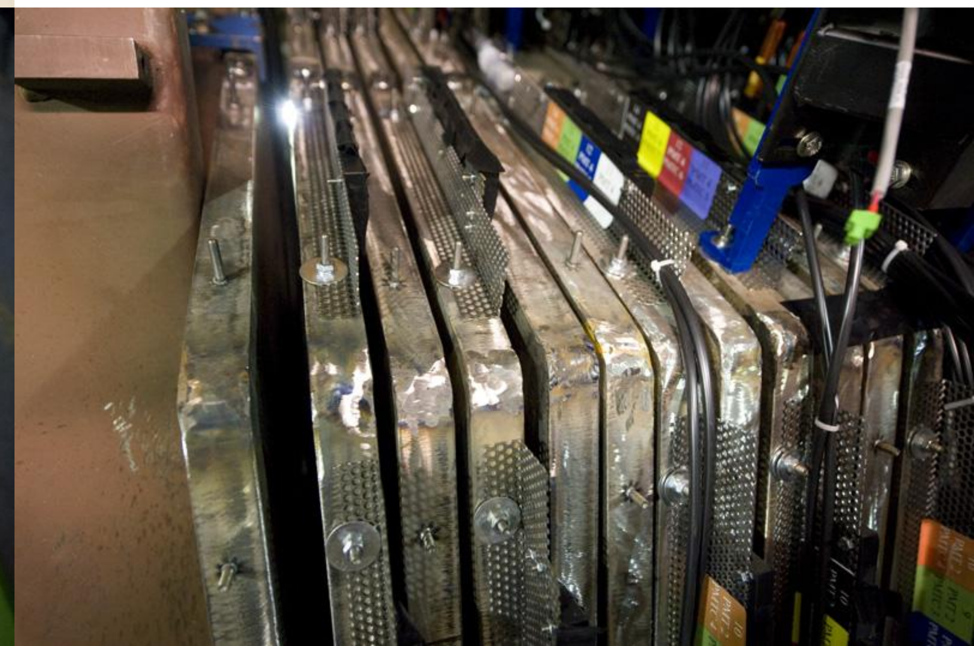



TremPro 644

LAST PLANE 3/15/10







Data taking

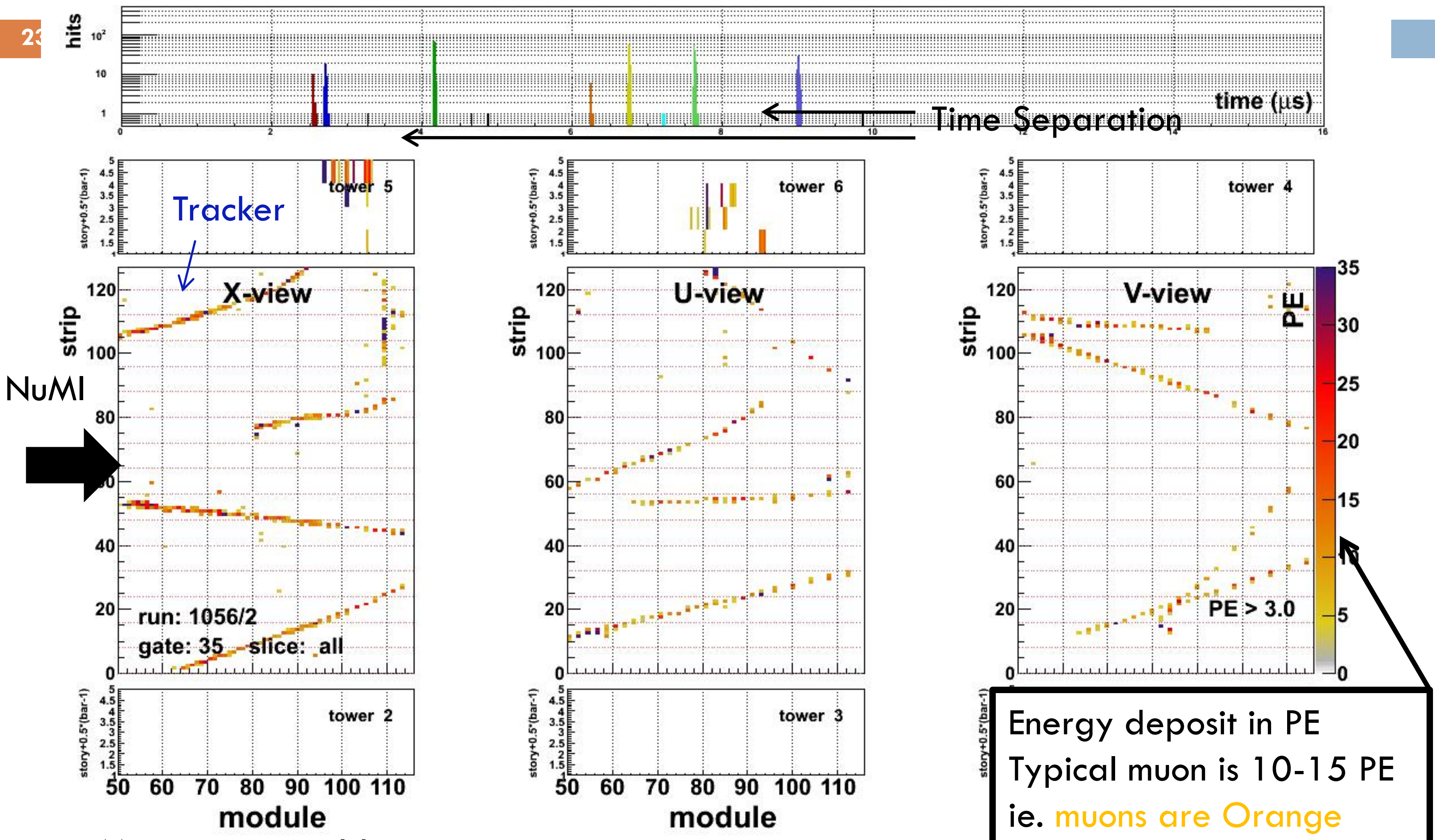
- Prototype run with 24 modules
  - April-June 2009
  - 1.2 M beam gates (1 gate every ~2 seconds)
- Anti-neutrino run with 65 modules
  - November 2009 – March 2010
  - 3.3M beam gates
- Neutrino run with 120 modules
  - March 2010 ….
  - 0.7M beam gates so far…

Neutrino scattering rate in the full fiducial volume is expected to be around 0.07 events/beam gate.

Event gallery

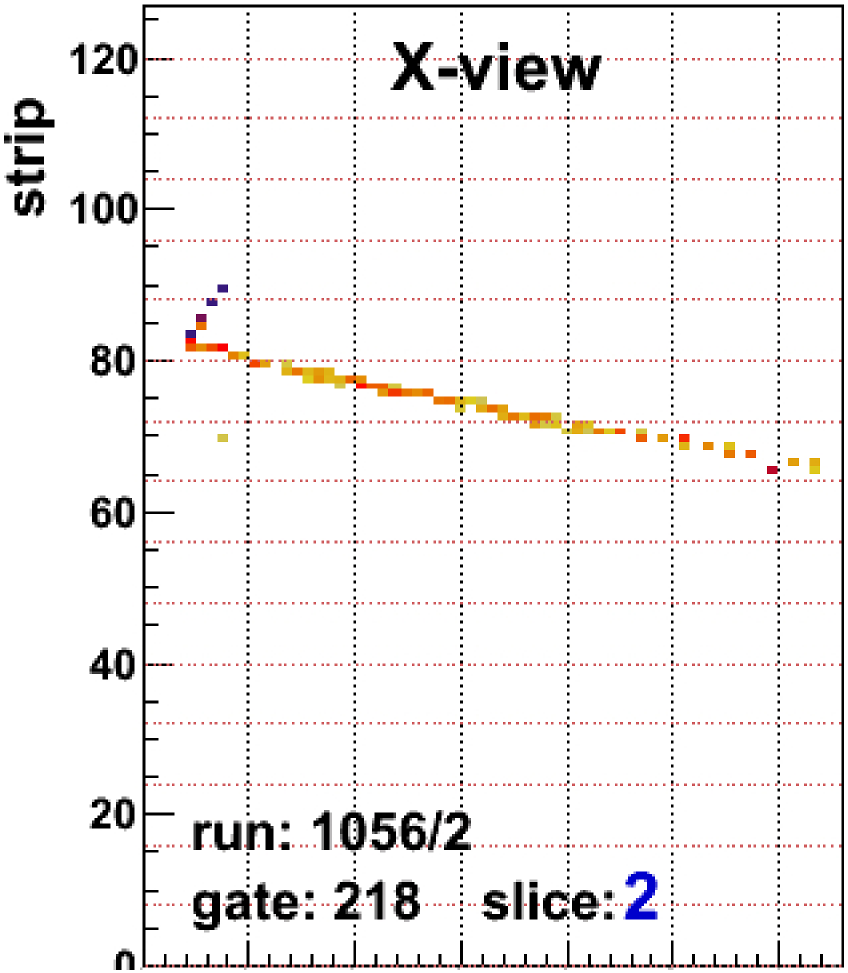
- Rock muons for calibration
- Quasi-elastic $\nu n \rightarrow \mu p$?
- Elastic $\nu p \rightarrow \nu p$
- Pions and electrons
- DIS nightmares

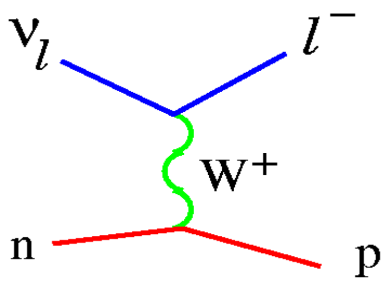
Rock Muons – most common



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

Events: Quasi-elastic Candidates



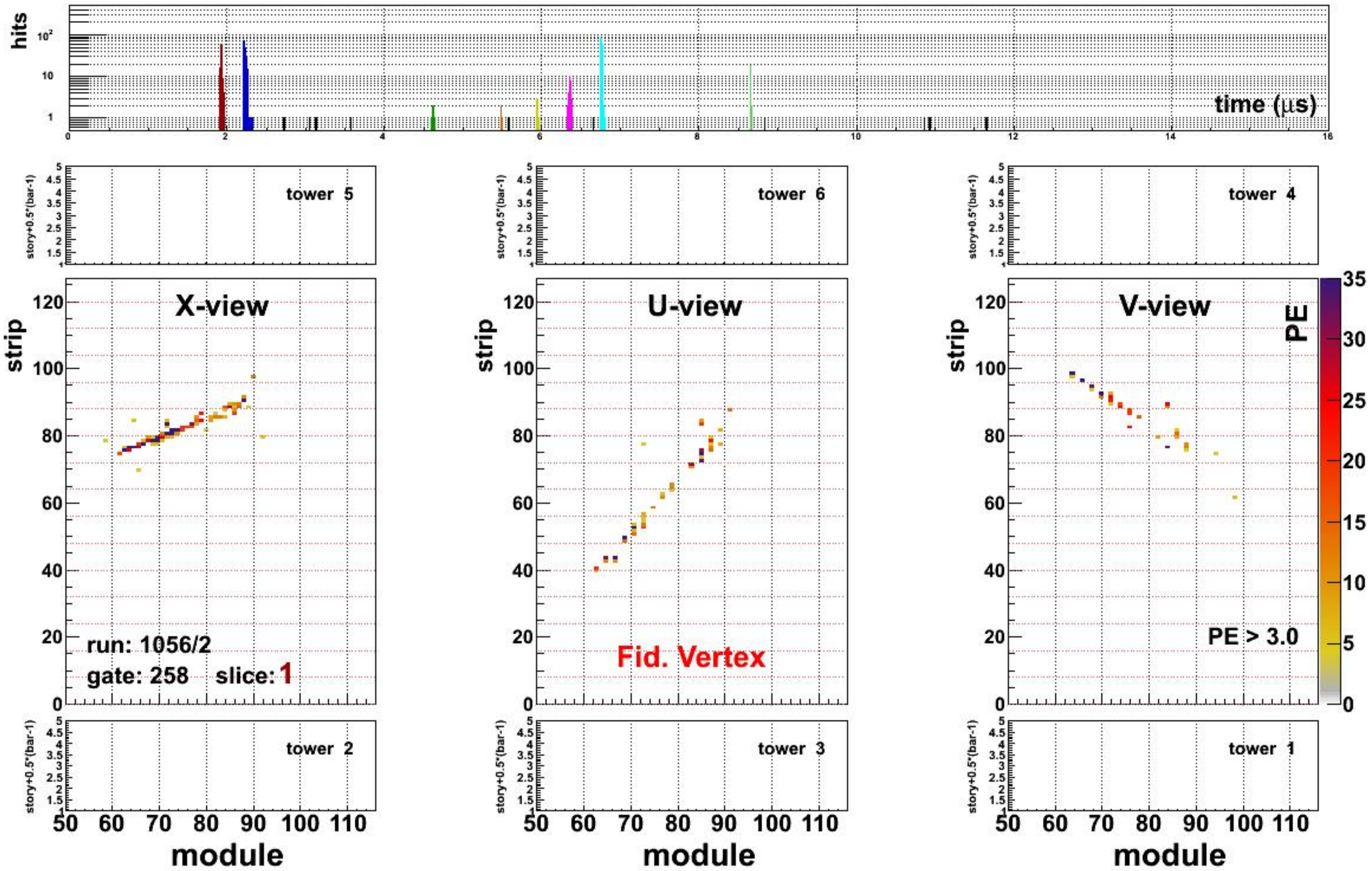


Muon kinematics from angle, range and momentum in MINOS.

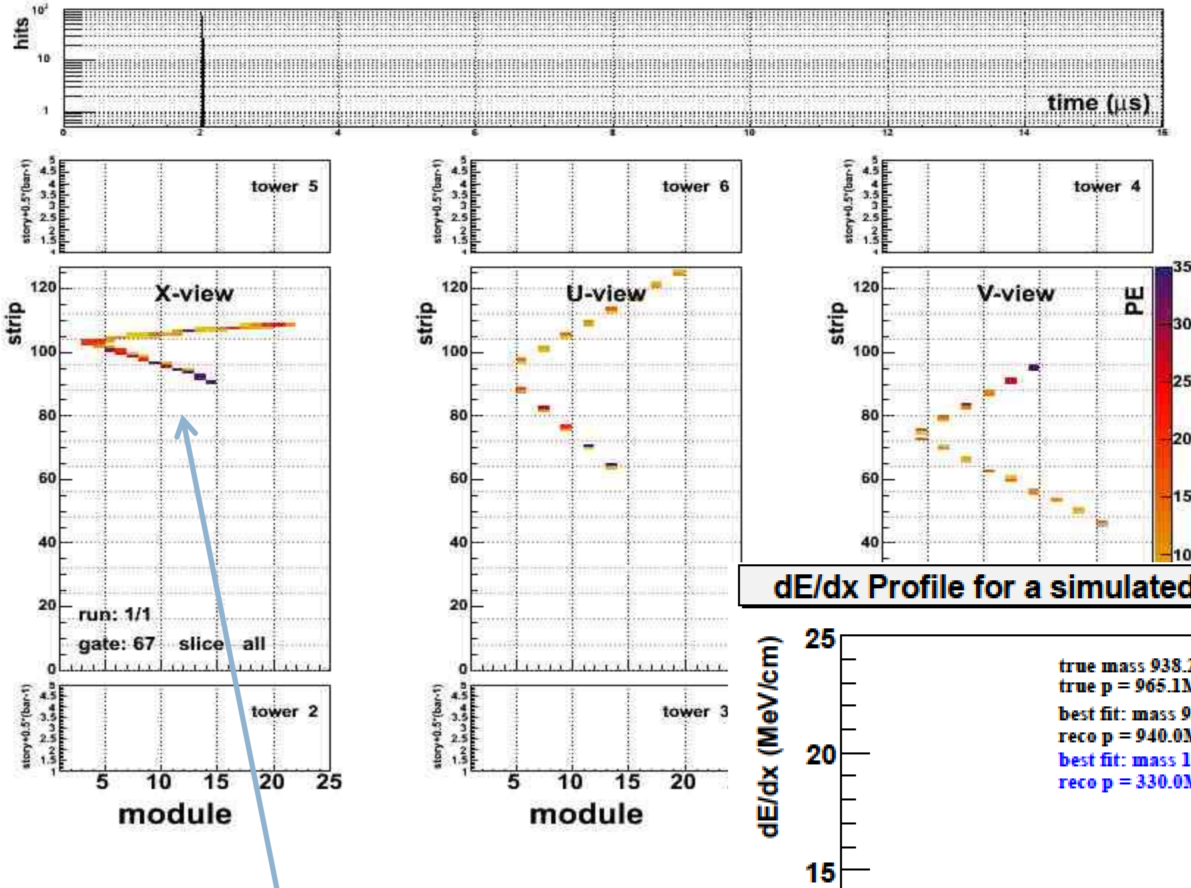
Proton kinematics from angle, range.

Pattern recognition not fully automatic yet. (muons easy, short active volume makes interacting particles harder to track.)

Elastic NC proton candidate?

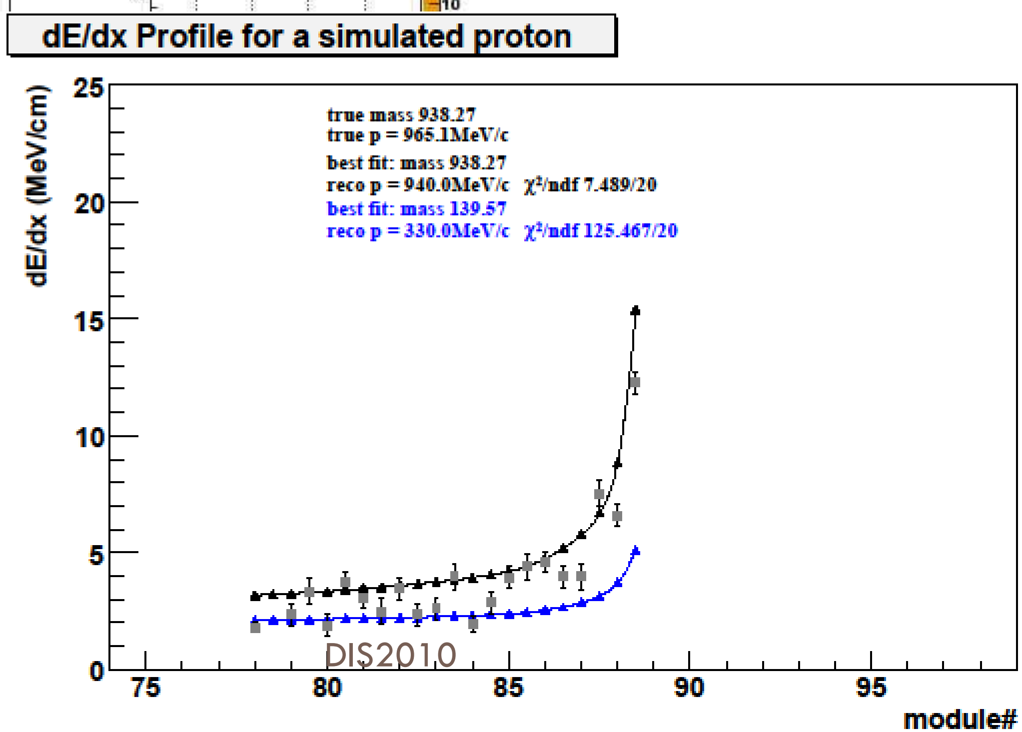


Particle ID by dE/dx : GENIE Simulation



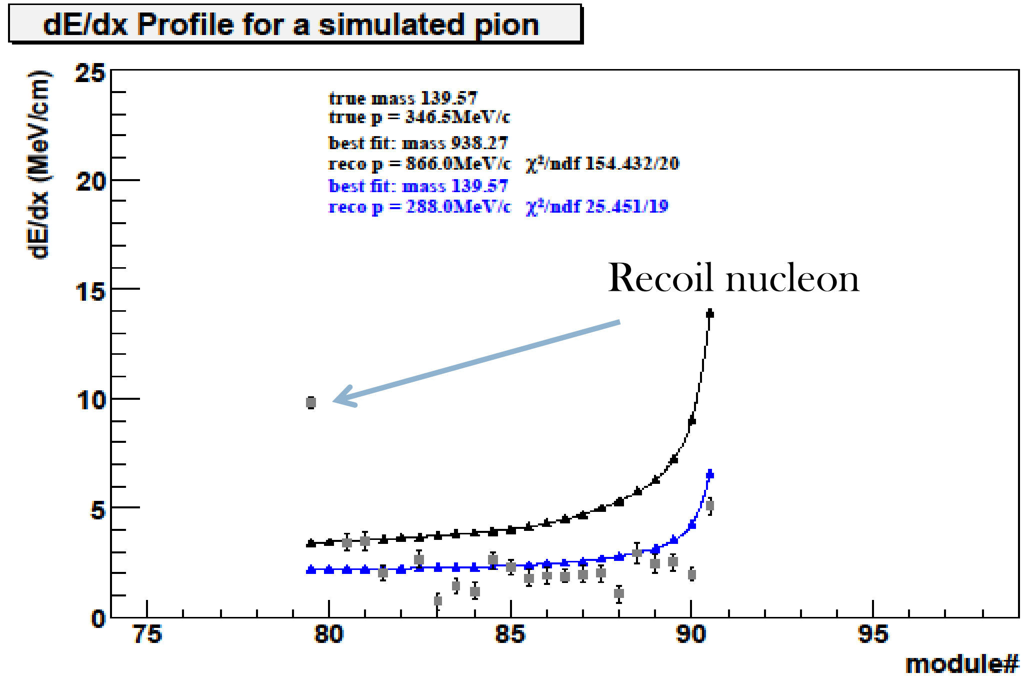
Contained proton prong

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

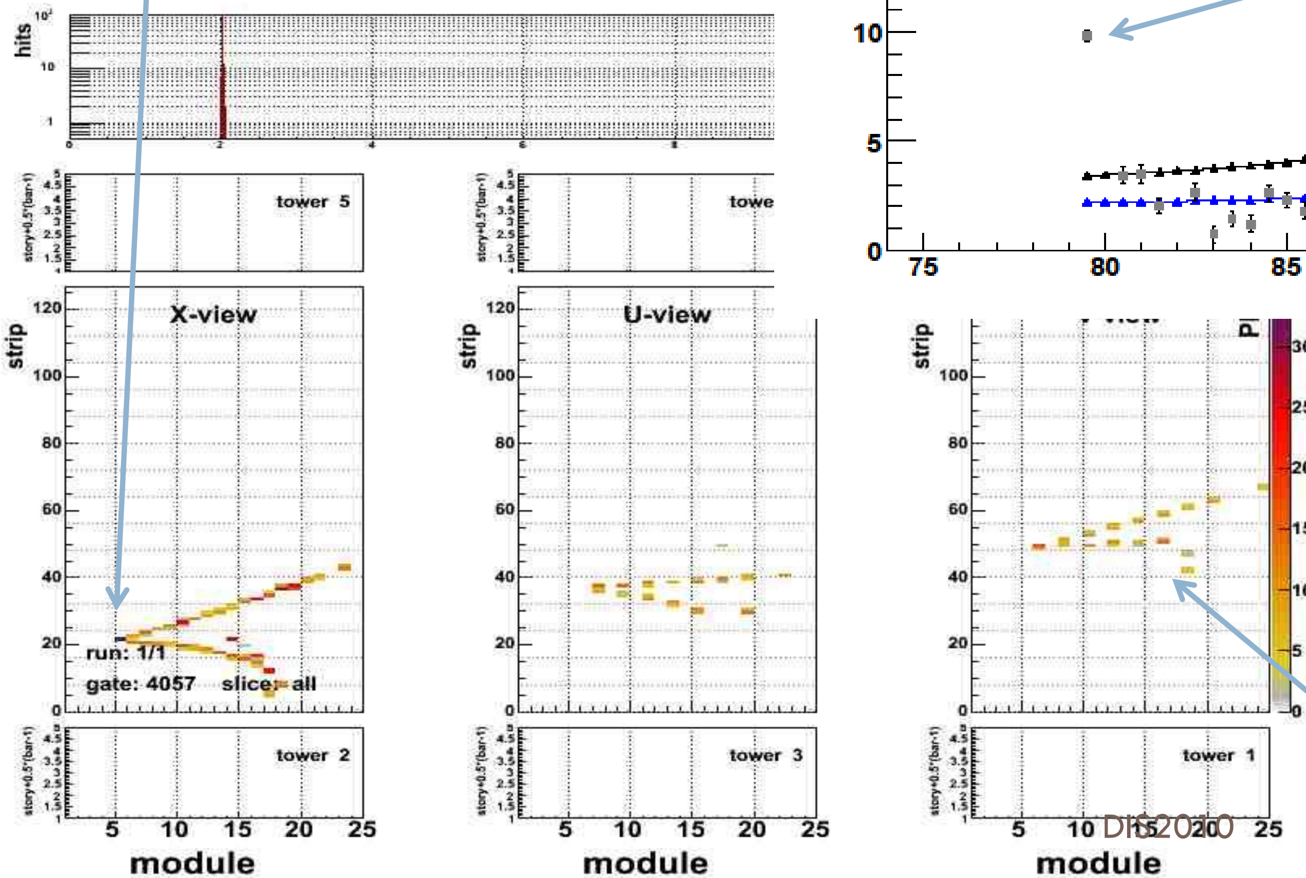


Particle ID by dE/dx : GENIE Simulation

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

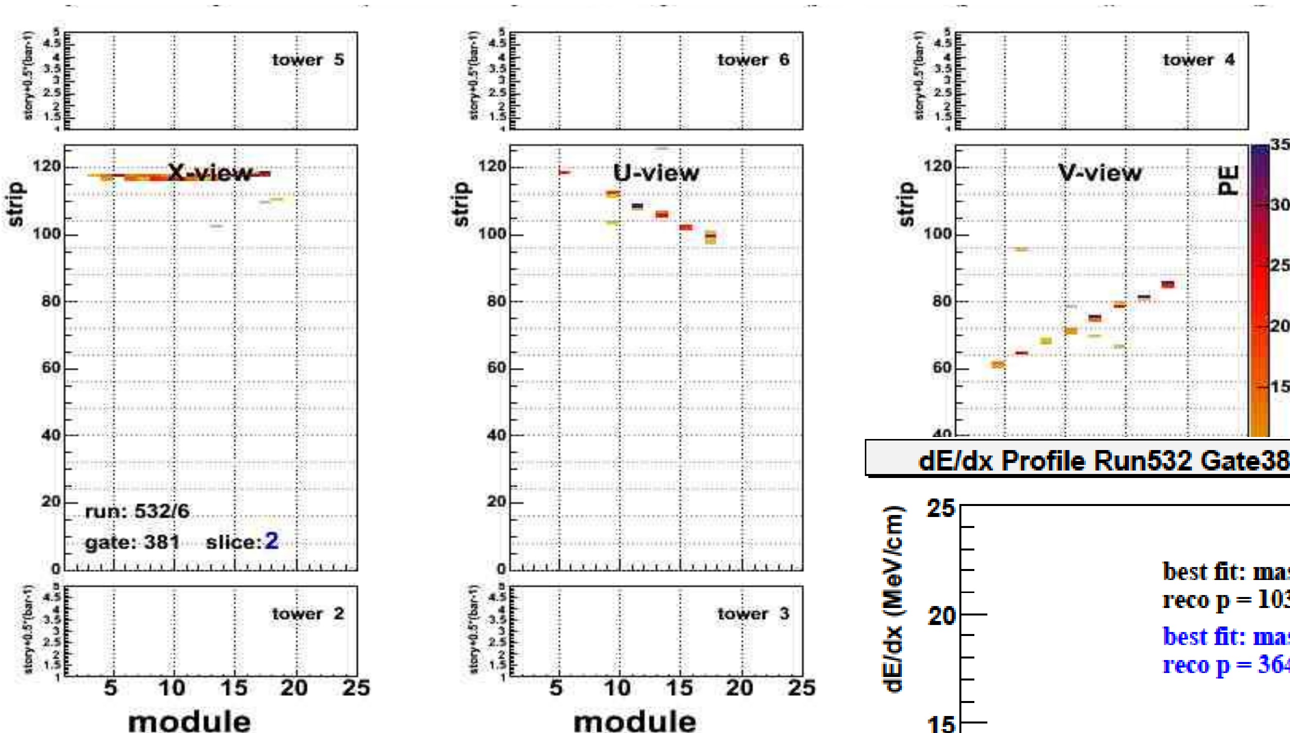


Heavy ionizing vertex

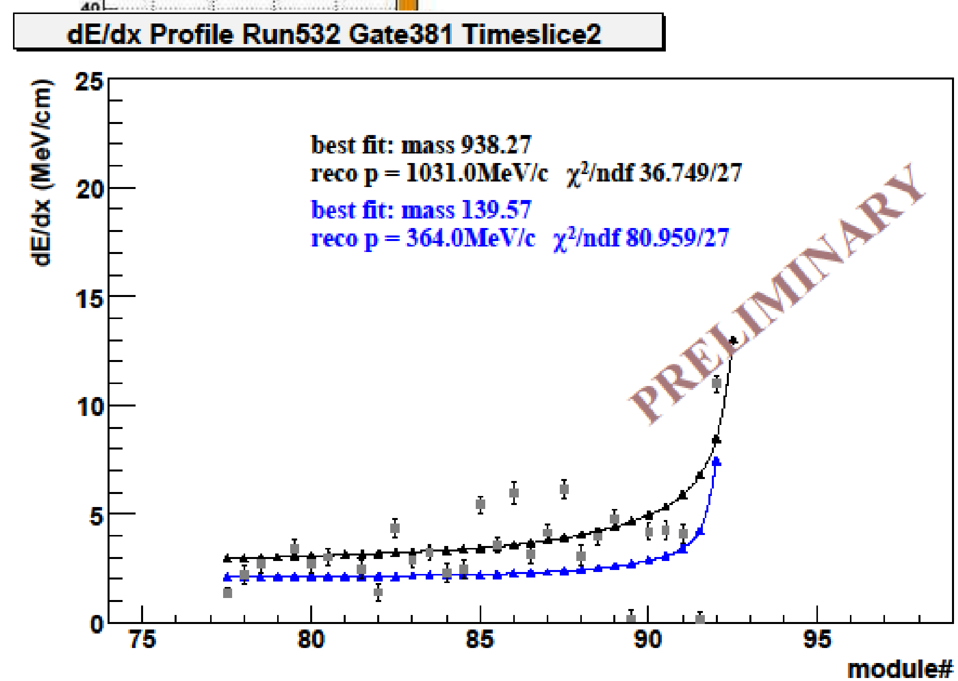


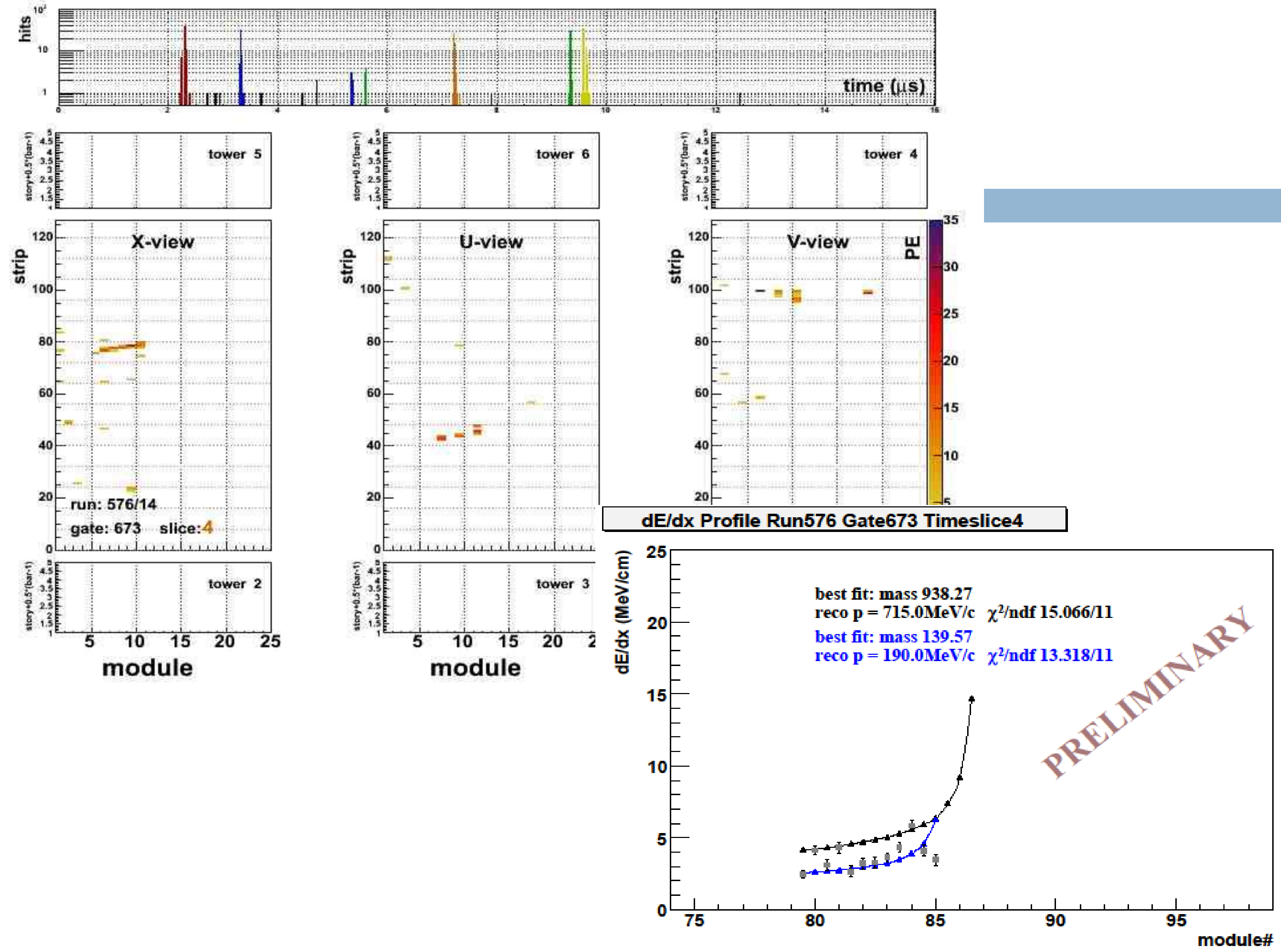
Contained pion prong

Particle ID: TP data



Neutral Current Quasi-Elastic Candidate

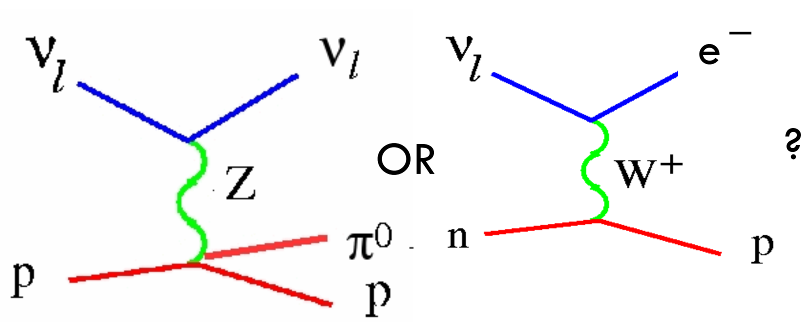




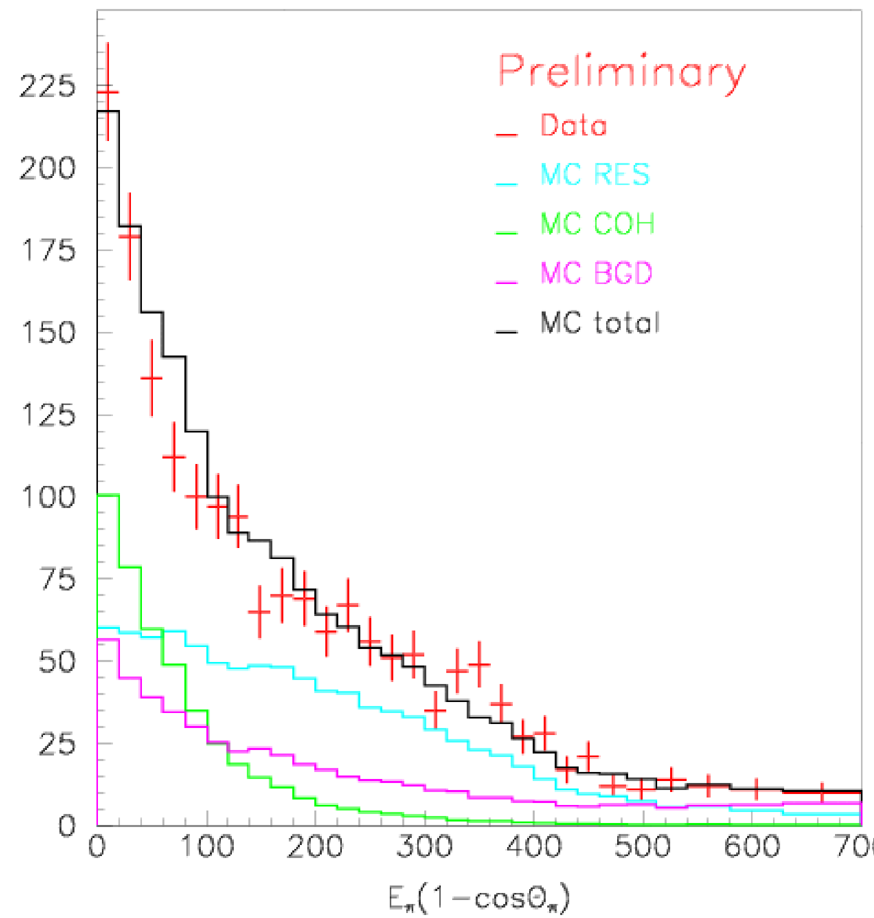
hits
time (μs)
tower 5
tower 6
tower 4
X-view
U-view
V-view
strip
PE
run: 576/14
gate: 673 slice: 4
tower 2
tower 3
module
dE/dx Profile Run576 Gate673 Timeslice4
best fit: mass 938.27
reco p = 715.0MeV/c χ²/ndf 15.066/11
best fit: mass 139.57
reco p = 190.0MeV/c χ²/ndf 13.318/11
dE/dx (MeV/cm)
module#
PRELIMINARY

Low energy inclusive and exclusive cross sections

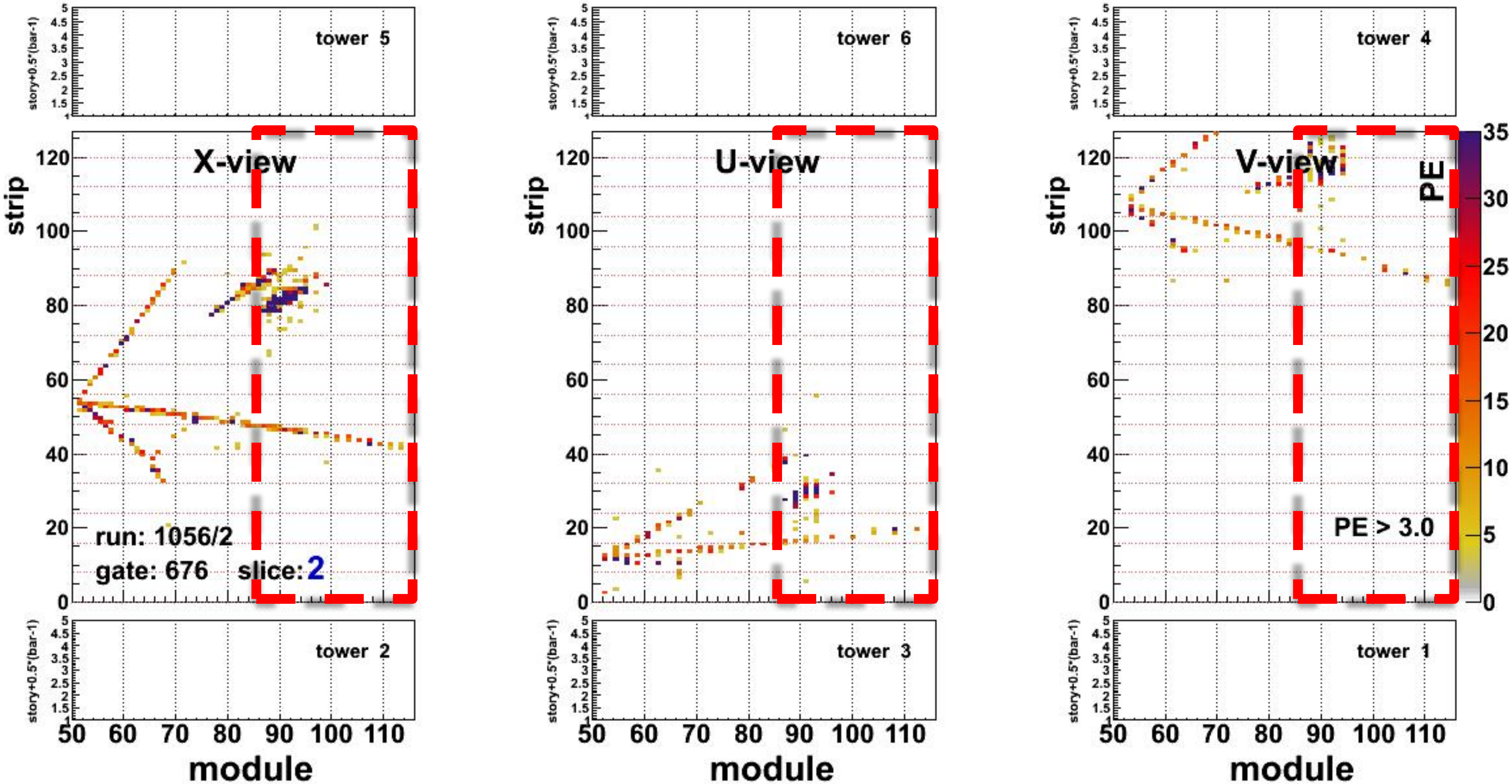
- π^0 NC important for oscillation experiments



MiniBoone Coherent π^0 measurement

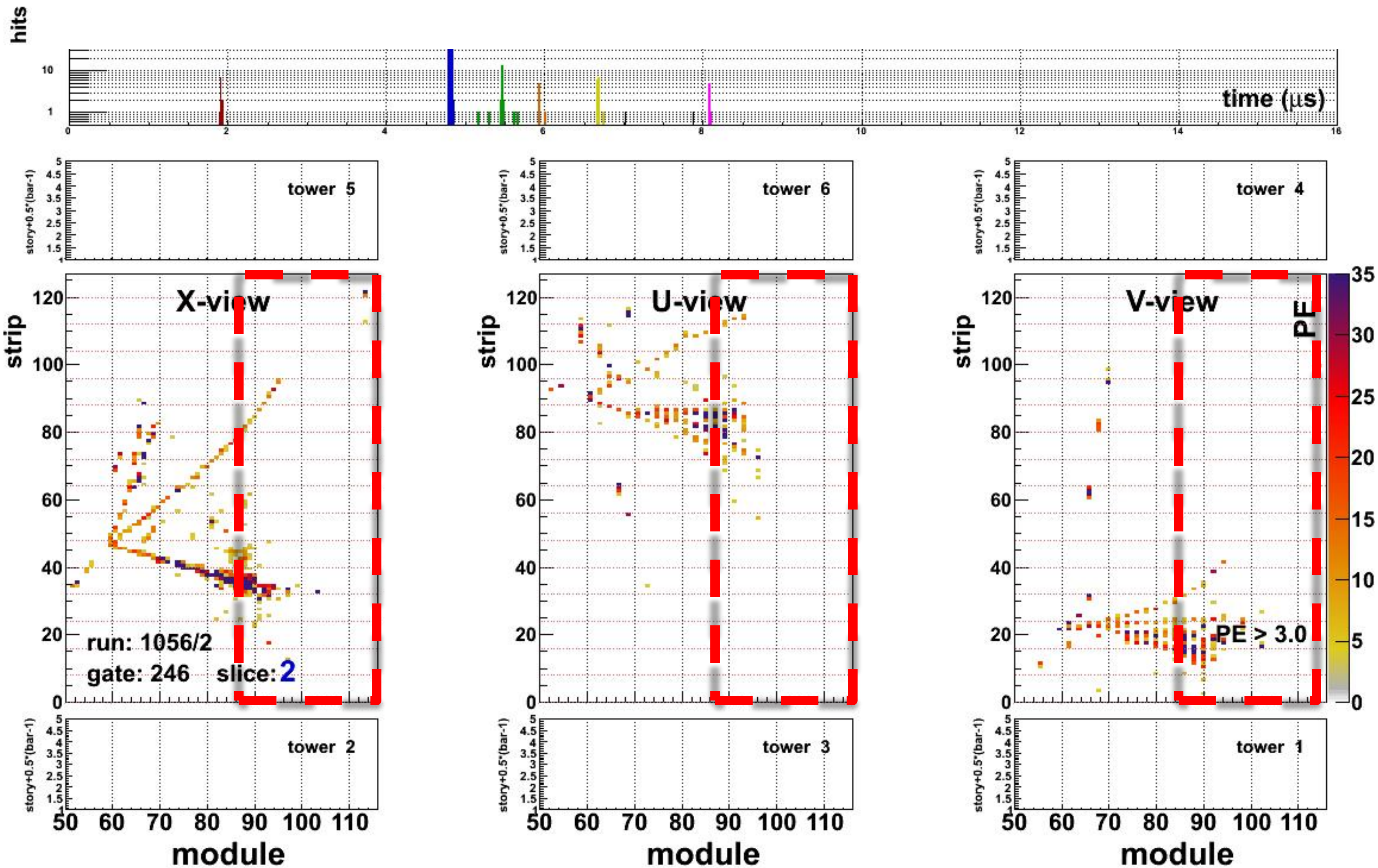


Events: π^0 Candidate

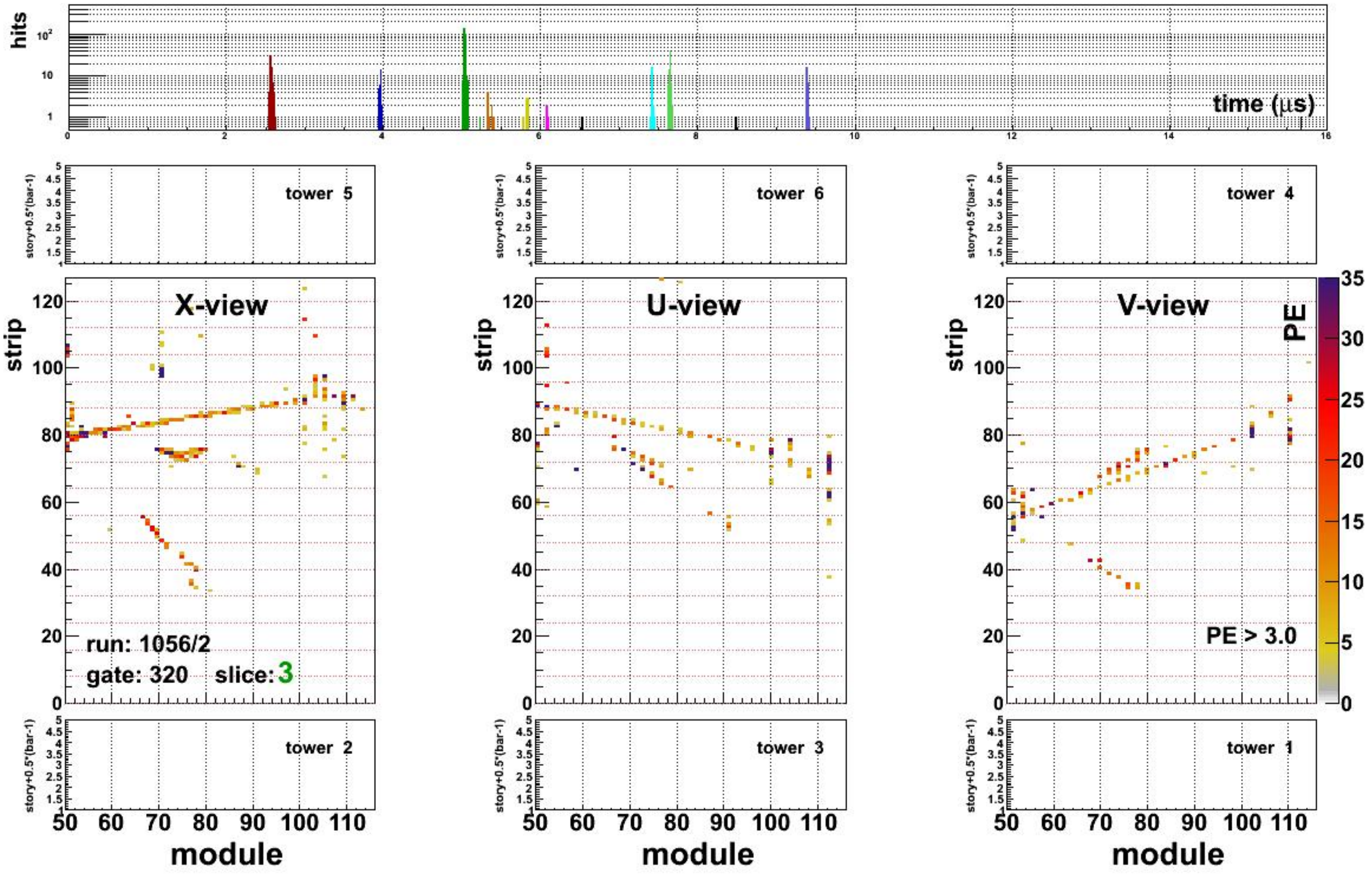


$\pi^0 \rightarrow \gamma\gamma$ $\gamma \rightarrow e^+ e^-$

Event with EM shower π^0 or electron?

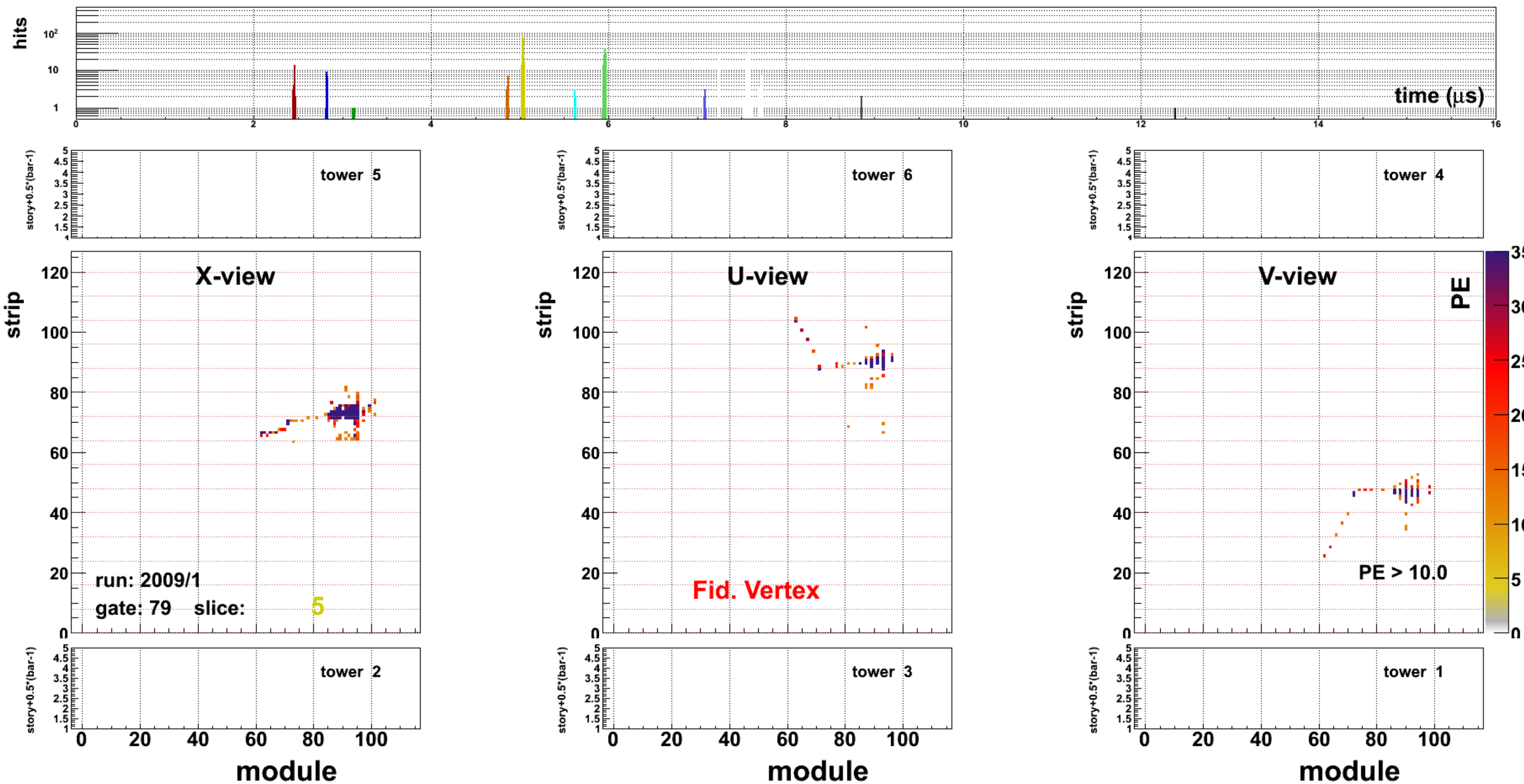


π^0 conversion candidate in the tracker

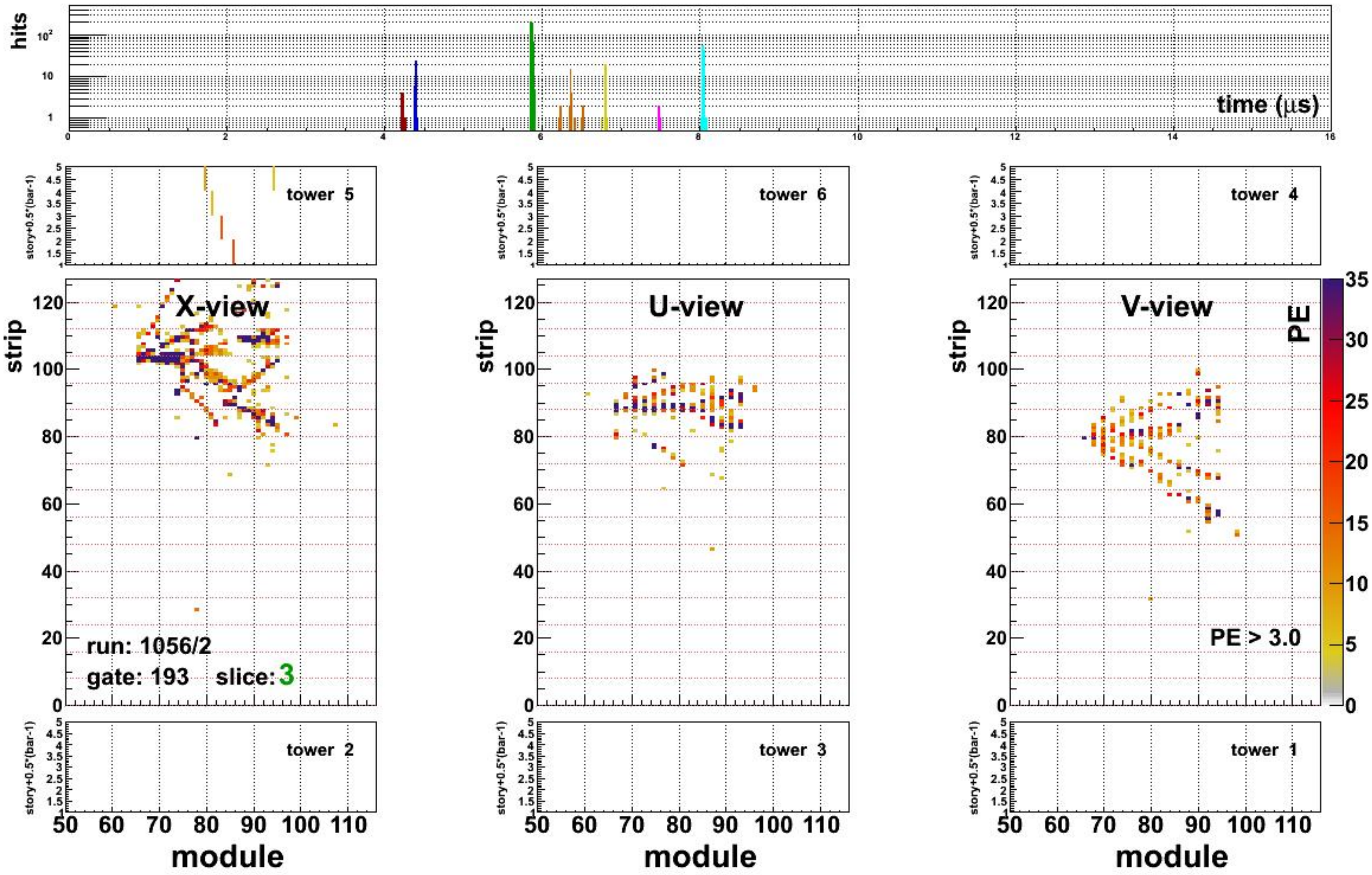


Event with EM shower in ECAL (candidate νe?)

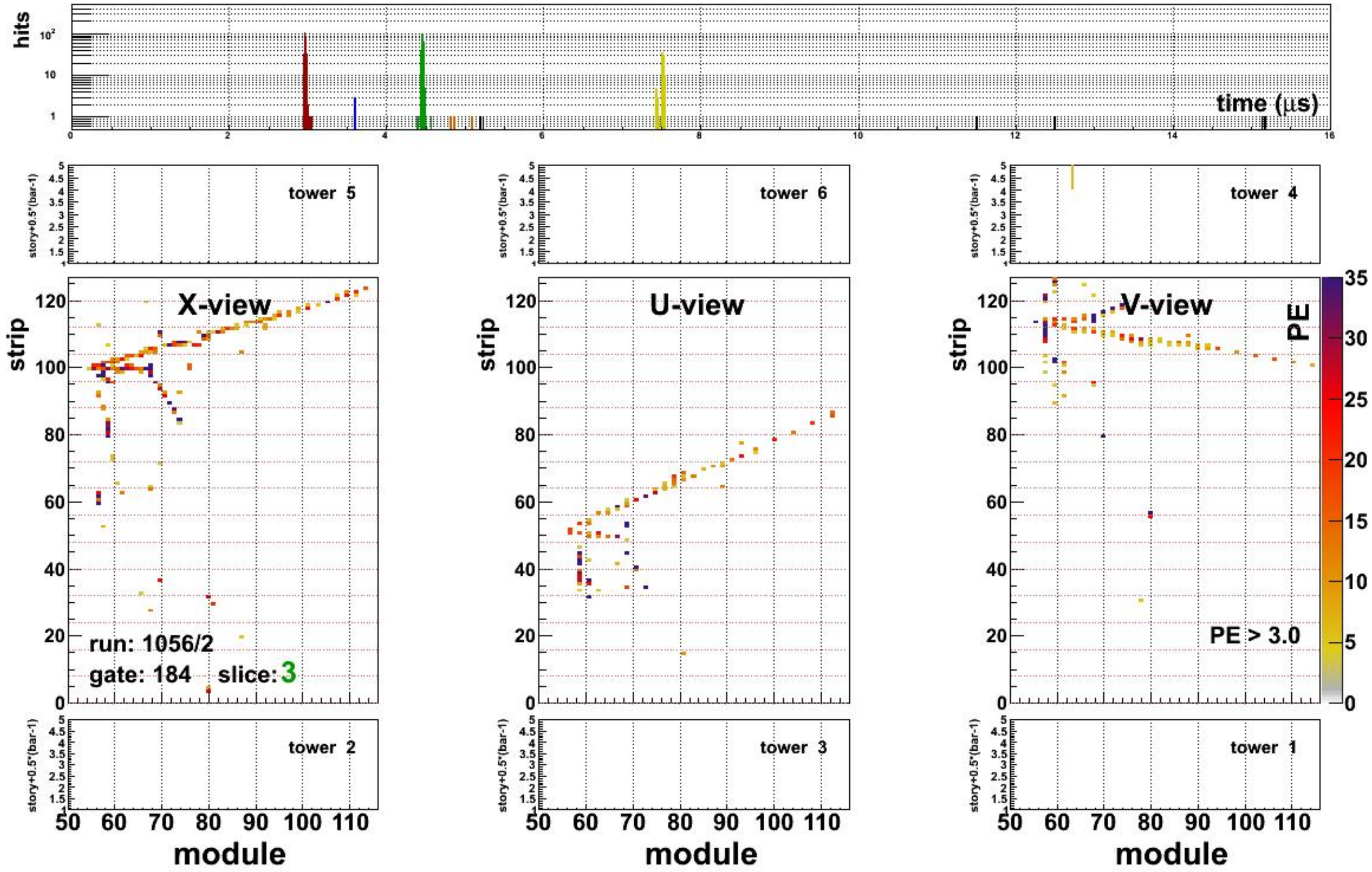
- And a backwards going track



Complex interaction

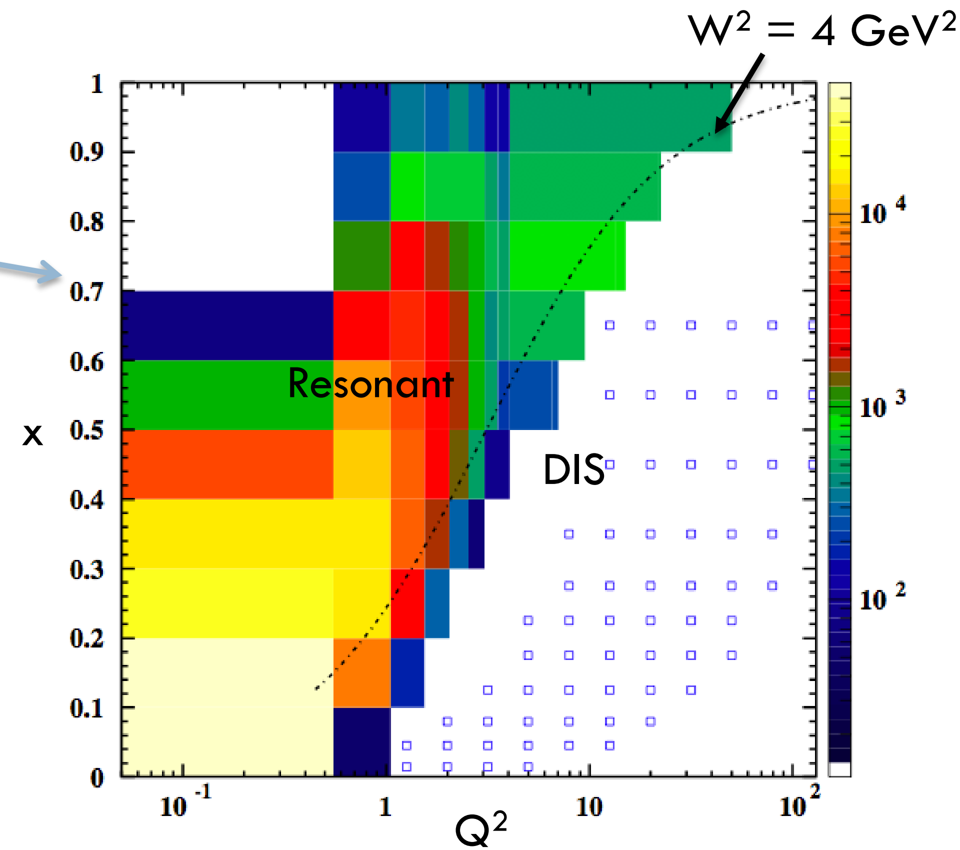


Secondary interaction in tracker



What can you expect for DIS2016?

- Take data with Low Energy beam 2010-2012 4E20 Pot
- Take data with Medium Energy beam 2013-… 12E20 Pot
- Expected numbers of events in (x,Q^2) for 4-6 years of running in the Resonant → DIS transition region
- Study transition between perturbative and nonperturbative QCD regimes
- High statistics at high x



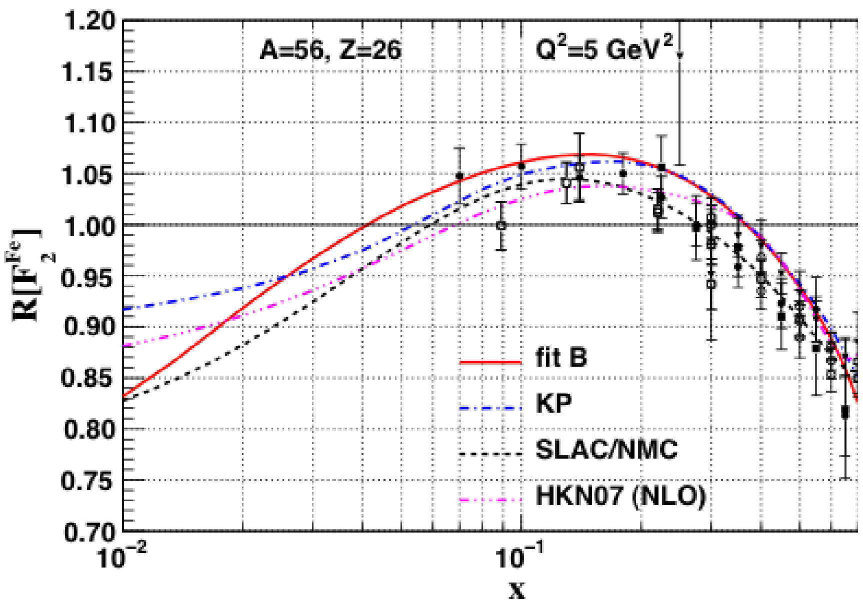
DIS2010

Deep Inelastic Scattering Physics: PDFs and Nuclear Effects

arXiv:0907.2357v2 [hep-ph]

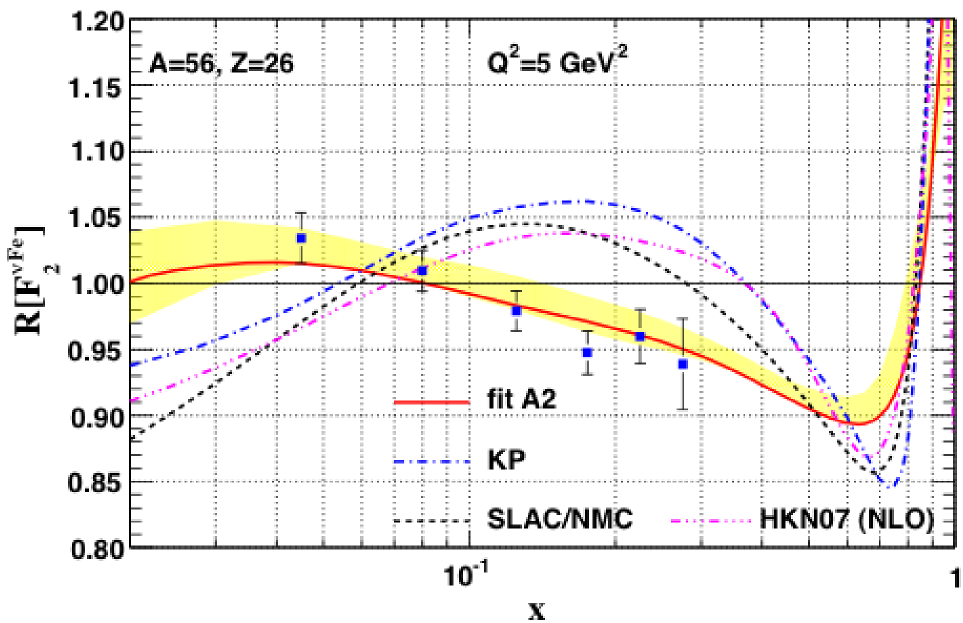
Electron and muon scattering

- Red curve is a pdf fit with A dependent coeff.



Neutrino scattering (NuTeV Fe)

- Red curve uses same method but gets different coeff.



So what?

- Much of our information on the anti-quark content of the proton comes from neutrino experiments on Iron.
- We don't know much because we don't understand how to correct Fe→ p
- Precision of LHC measurements (Tevatron less affected) depends on doing this right.
- Minerva can measure the A dependence of the inclusive structure functions and, possibly, test mechanisms by looking at final state differences.

Current and Future Plans

- We have completed a 4 month run in ν_μ-bar mode with 60% of the detector.
- We have started reconstruction of those data.

- Installation of the full detector was completed in March 2010.
- We are now taking data with ν_μ beam with the full detector.

Conclusions

•MINERvA is designed to study neutrino interactions in great detail and to support current and future neutrino oscillation experiments.

•An early look at the data after a run with 60% of the detector shows that the detector works very well. We can distinguish different particle species! We are using these events to tune our calibration and reconstruction algorithms.

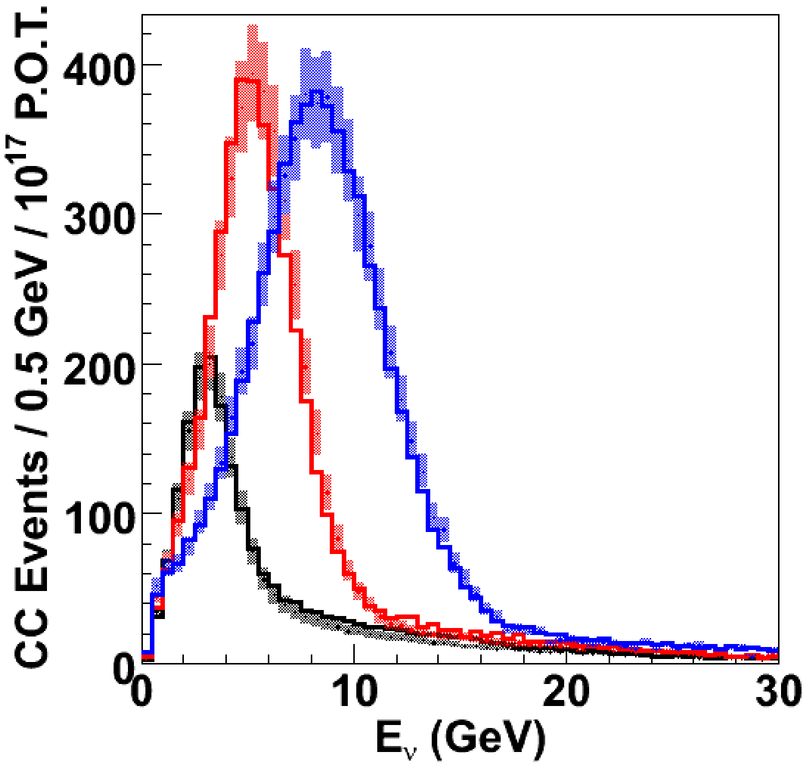
•MINERvA is on its way

•Stay tuned for cross section and exclusive measurements at the next DIS!

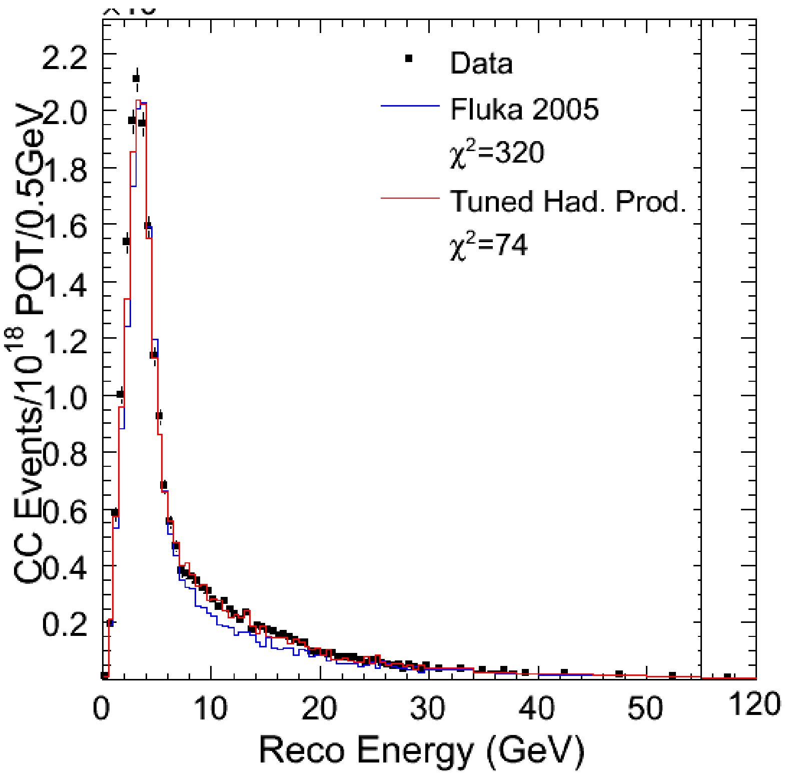
BACKUP SLIDES

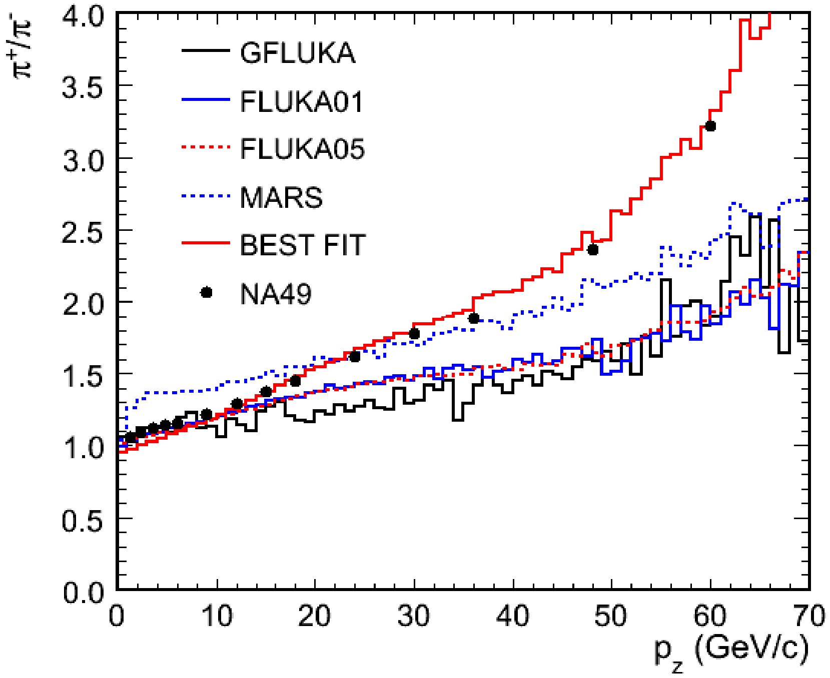
Neutrino Flux Estimates from MINOS

Sacha Kopp – report 9/19/2008



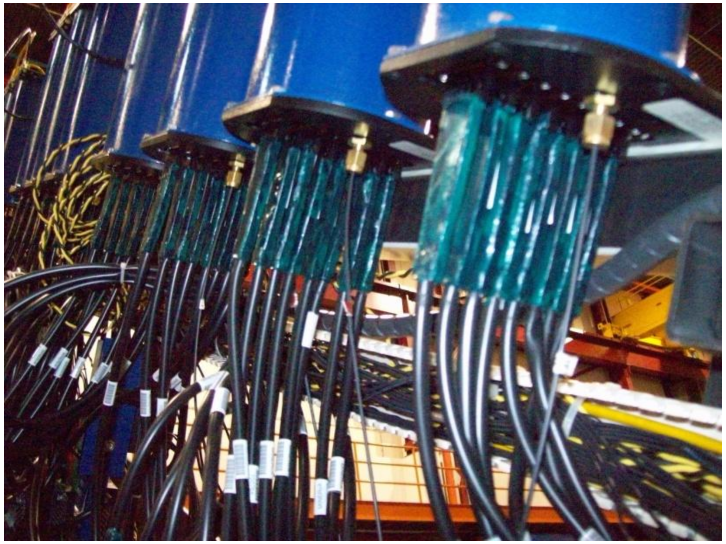
Comparisons with MINOS/NA49 data

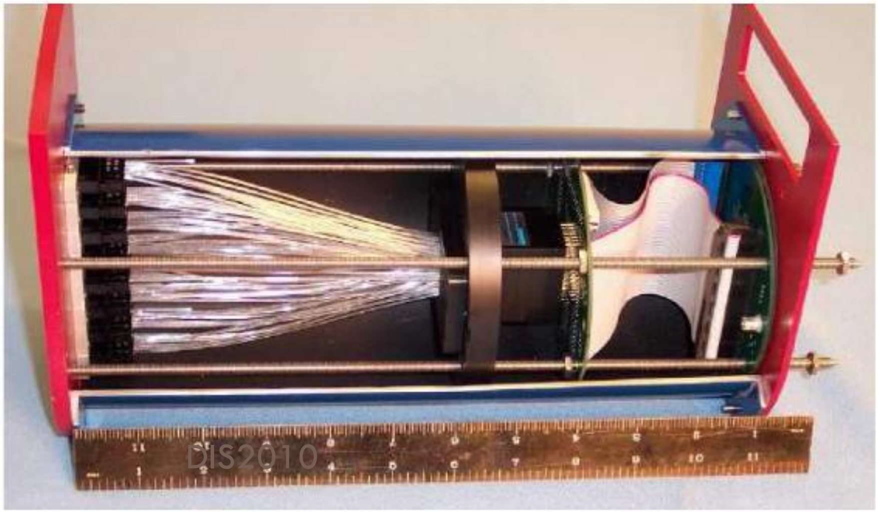




Electronics

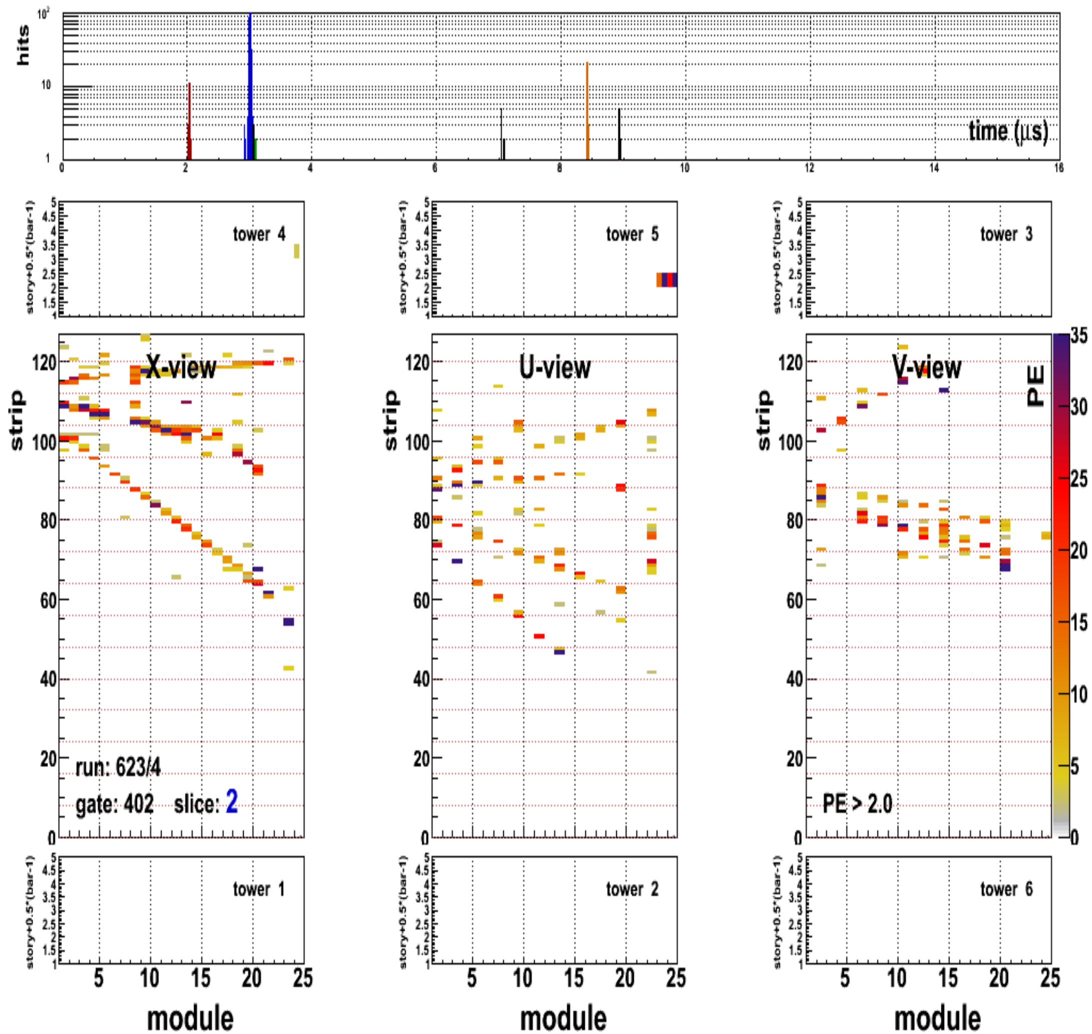
•Light measured by Hamamatsu 64 anode PMTs (newer version of MINOS model)
•Front end board (FEB) with Trip-t chips interface the PMTs
•Discriminators allow us to trigger at 1PE and resolve overlapping events during a spill



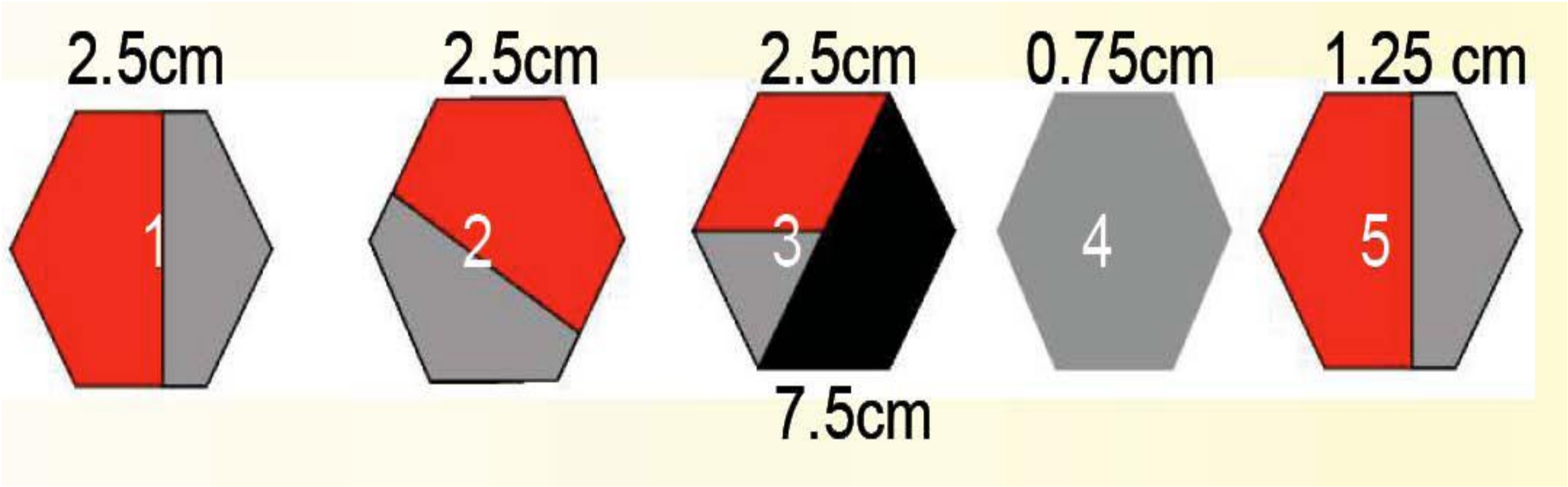


Physics: Nuclear Effects

- 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

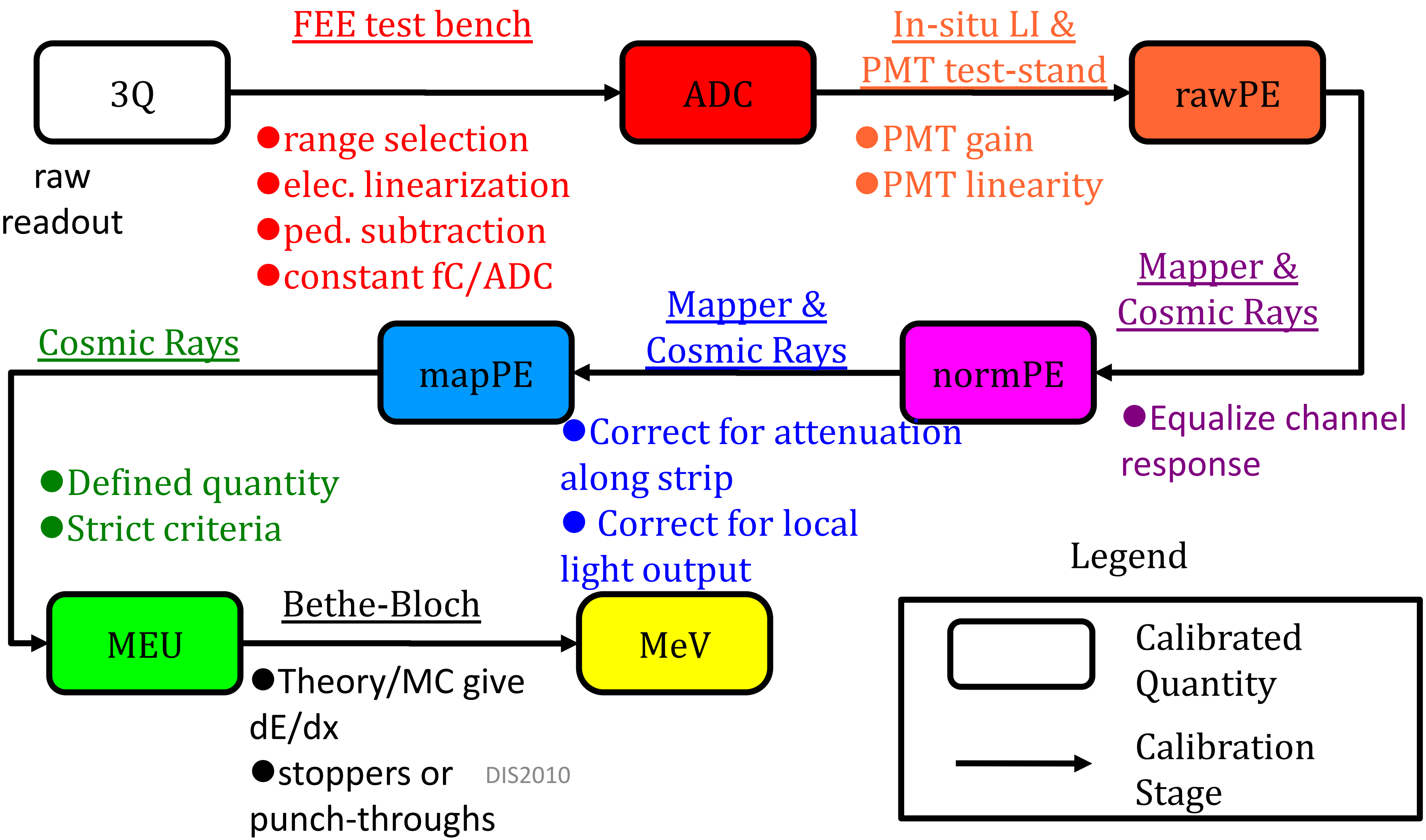


Red = Iron, Grey = Lead, Black = Carbon

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

Calibration Chain

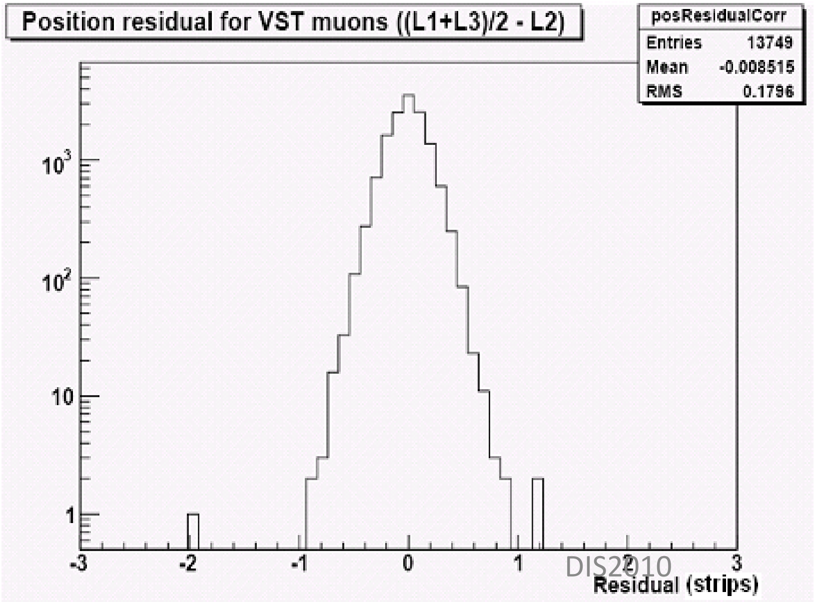


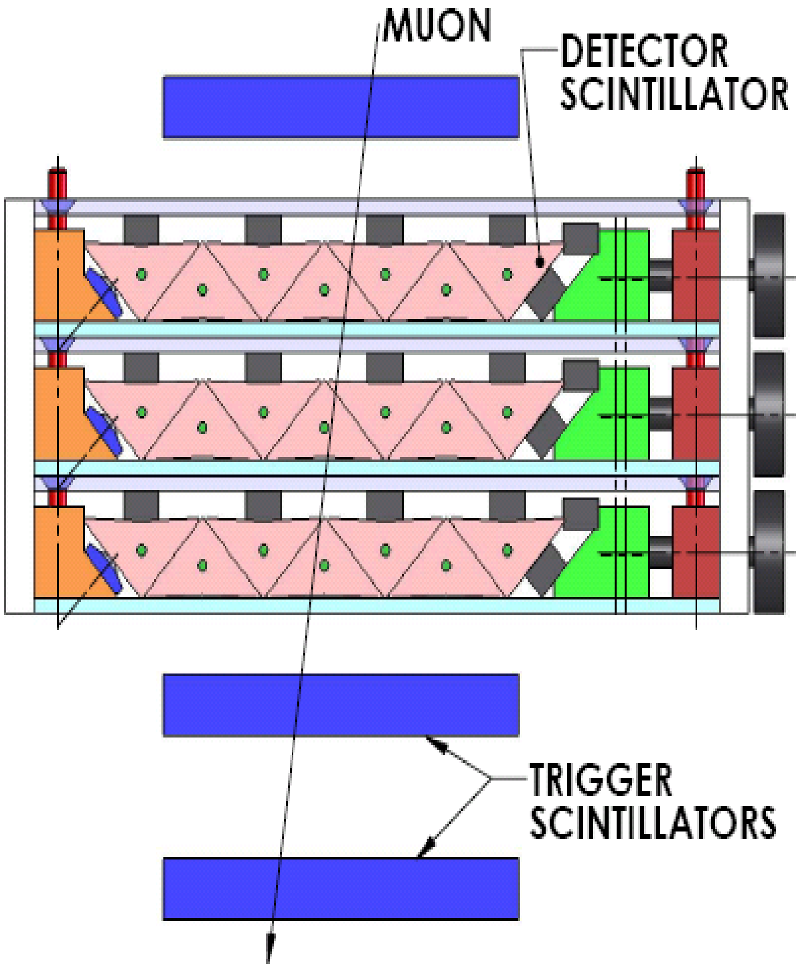
Detector Performance

- 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

Vertical Slice Test

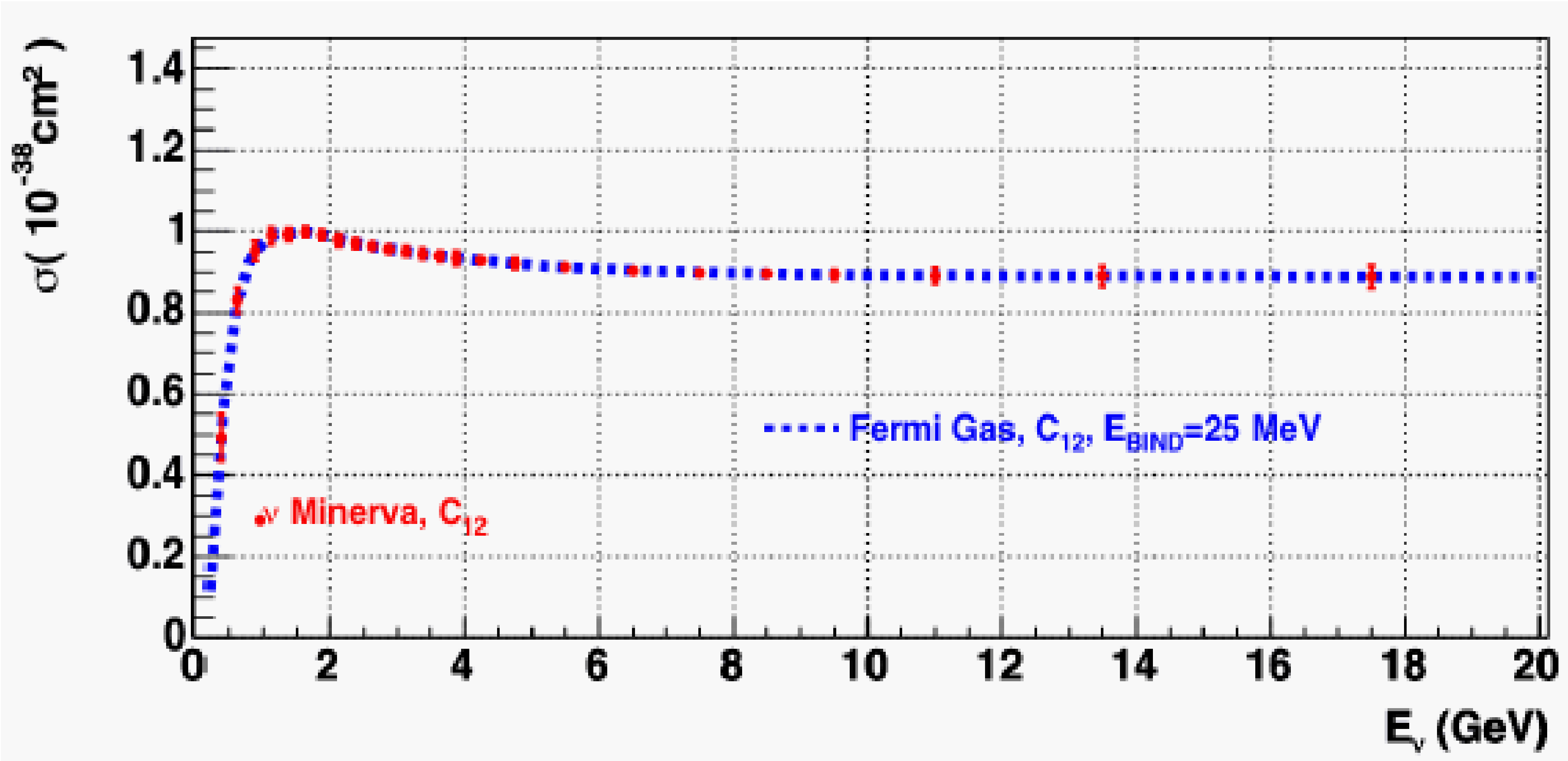
•Position resolution of 2.5mm
•Distance between center of strips is 1.7cm



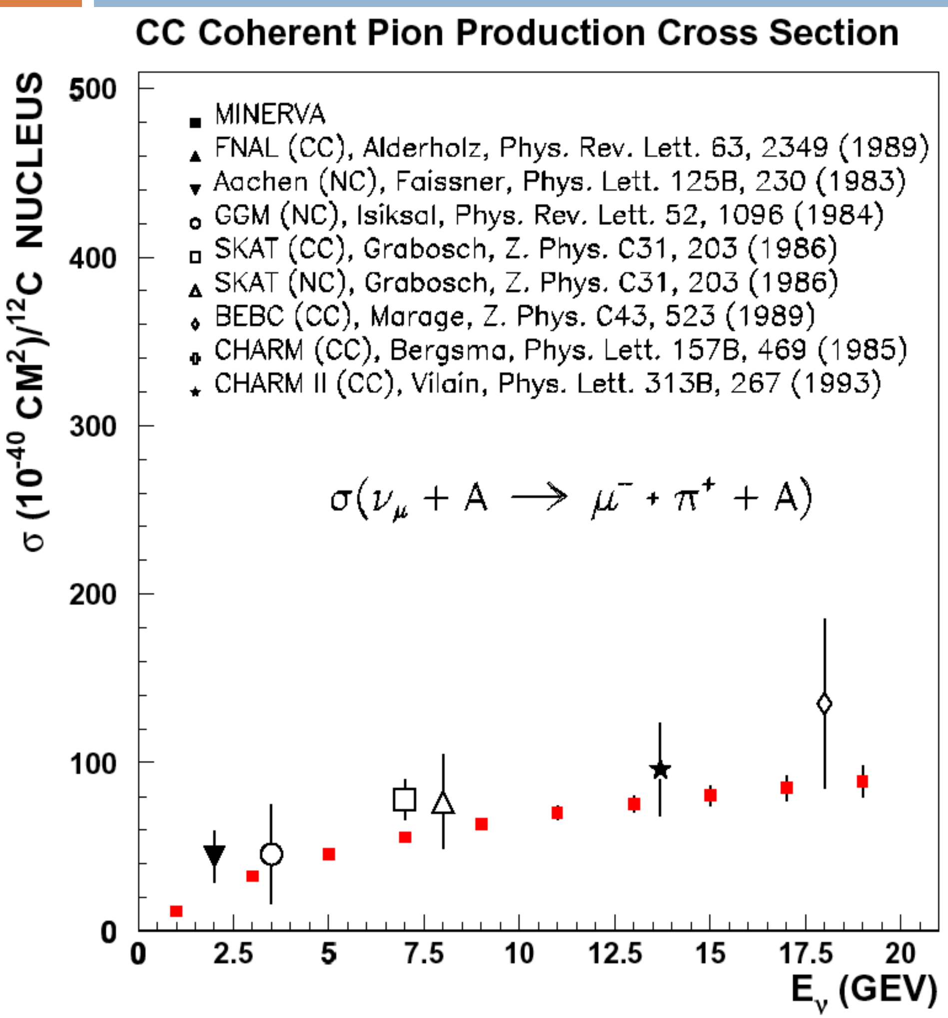


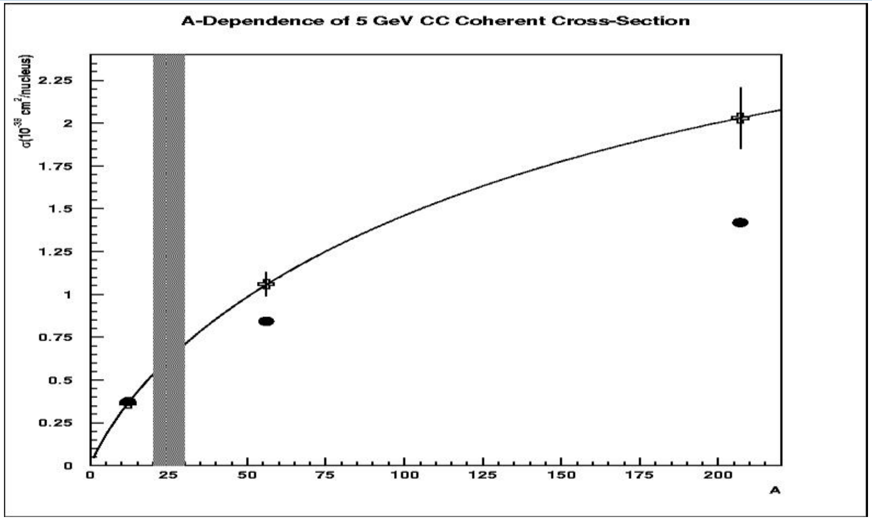
Physics: More Quasi-elastics

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

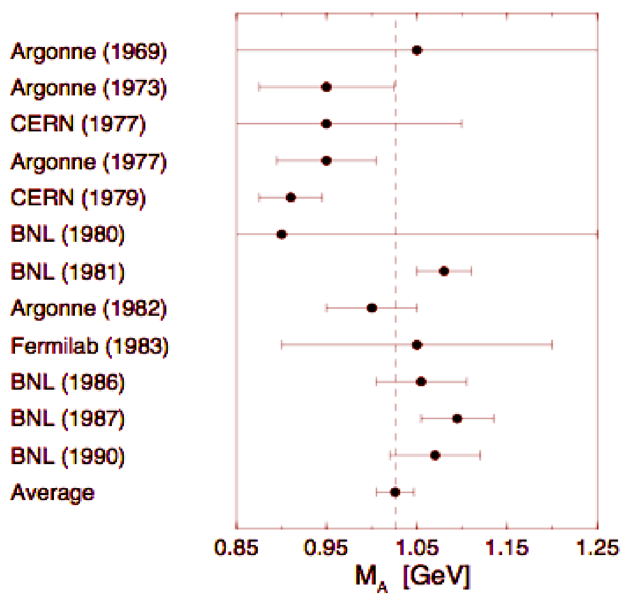
Physics: Form Factors

- 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

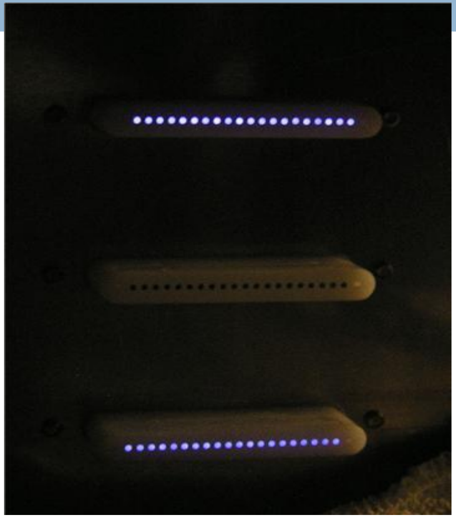
- **K2K SciBar (12C, Q^2>0.2)**
AIP Conf. Proc. **967, 117 (2007)**
M_A=1.14 ± 0.11 GeV
- **MiniBooNE (12C, Q^2>0)**
paper in preparation
M_A=1.35 ± 0.17 GeV
- **MINOS (Fe, Q^2>0.3)**
NuInt09, preliminary
M_A=1.26 ± 0.17 GeV

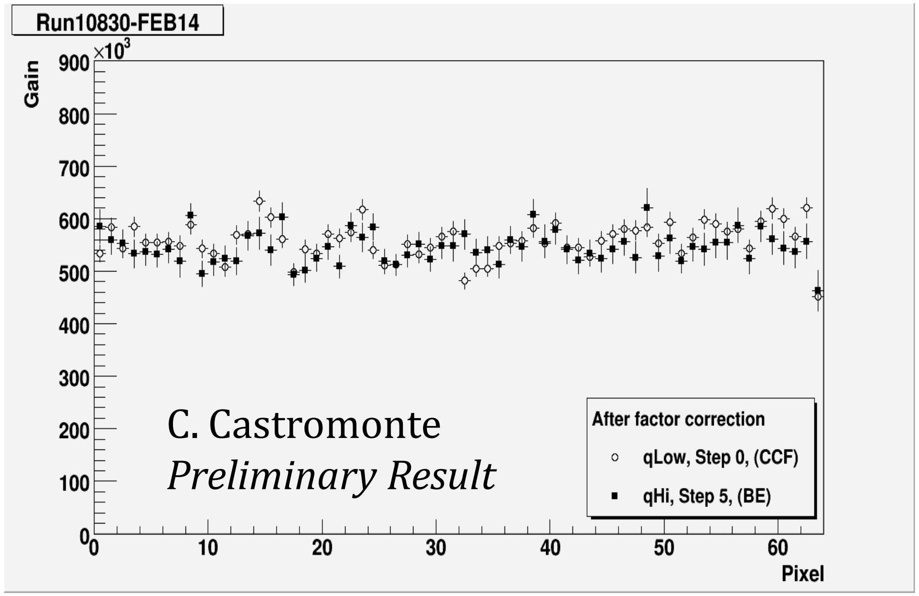


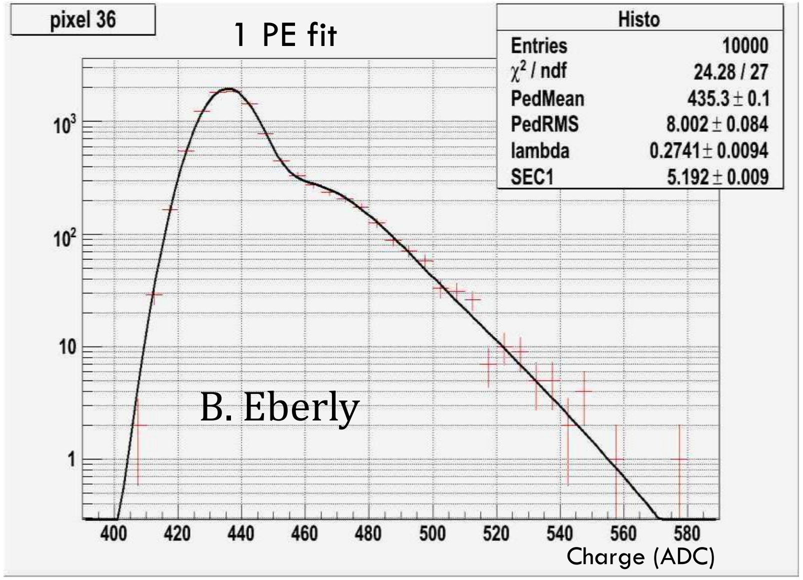
M_A (before 1990):
1.03 +/- 0.02 GeV
M_A (after 2000):
~1.2 GeV
What's going on?

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

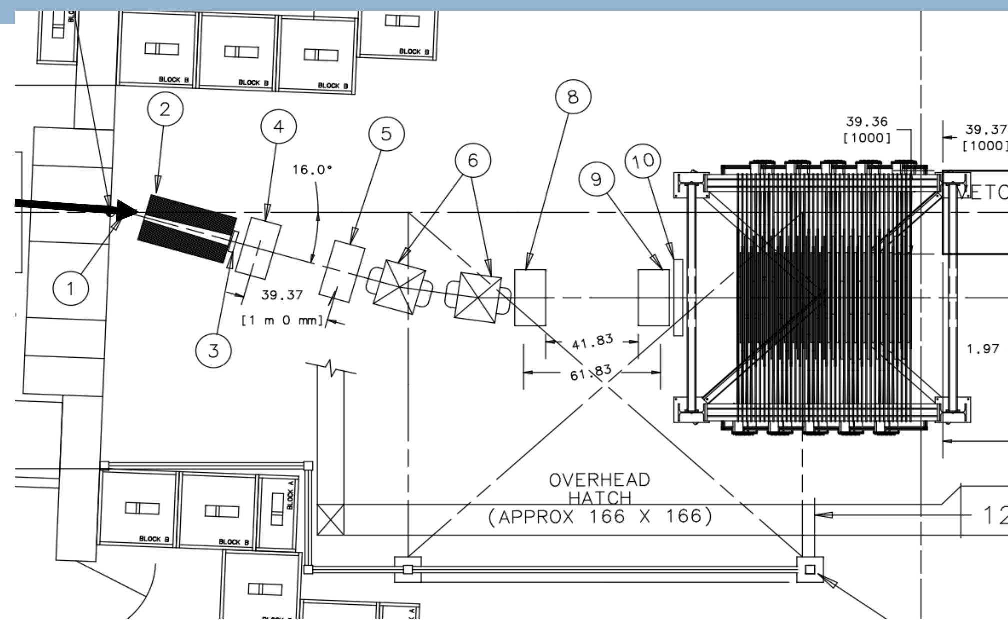


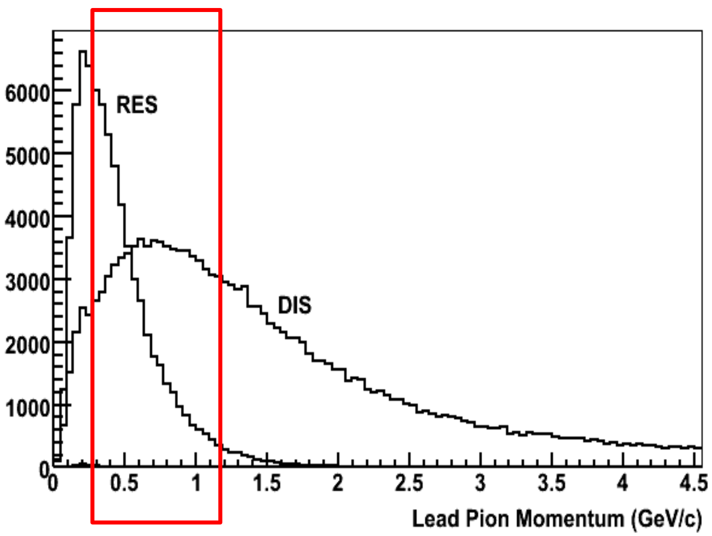


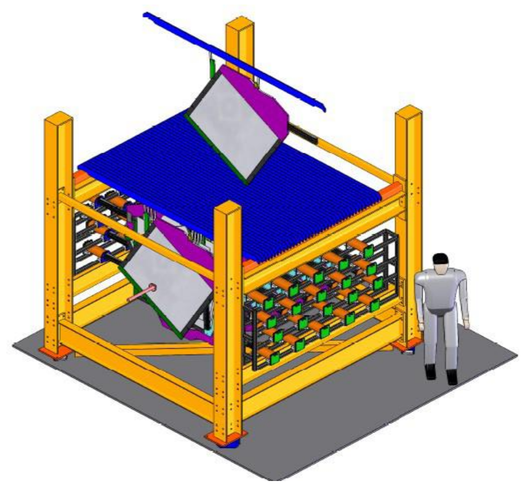


Calibrations: Test Beam

- 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 MINERvA 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)