STATUS OF MINERvA

Heidi Schellman DPF 2009

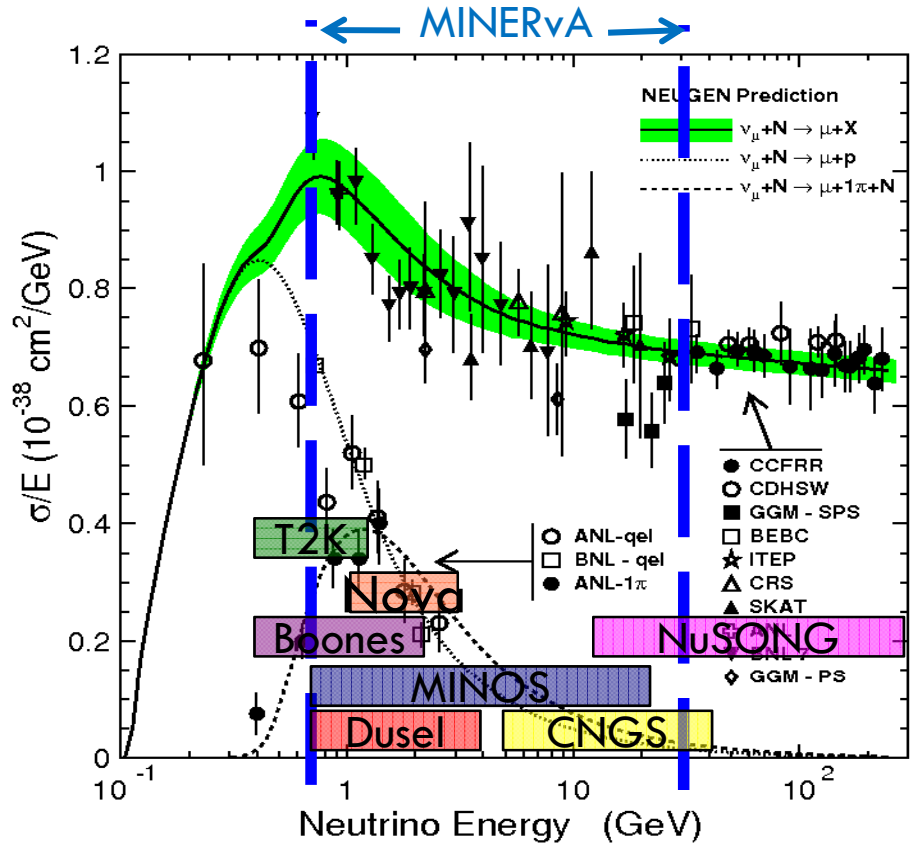
MINERvA GOALS

- 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

MINERvA

- Overlap with many oscillation experiments, including MINOS, T2K, Nova, and Dusel

- Note that the latest MiniBooNE and SciBooNE results are not on this plot.



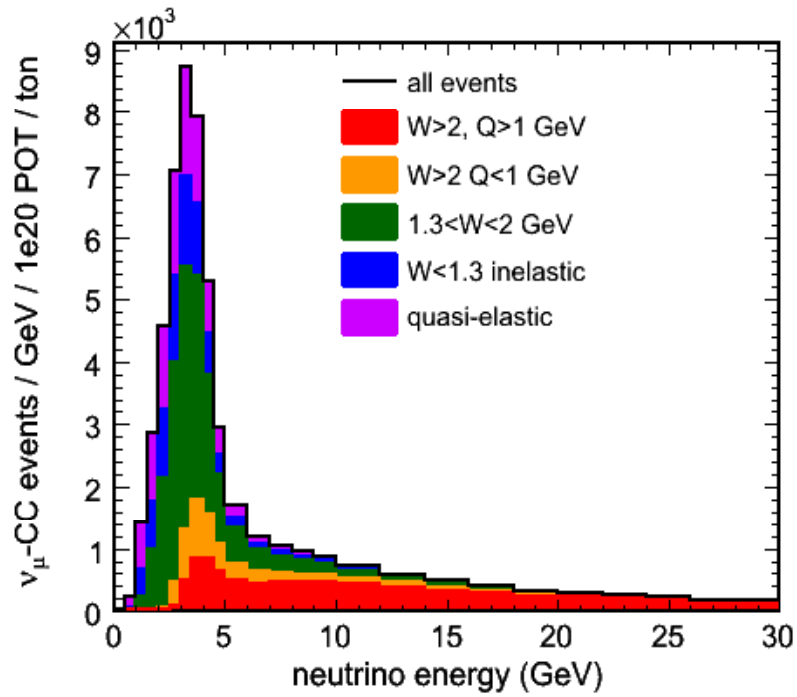
Note, doesn't include recent SciBoone, NOMAD and MiniBoone data

Estimated Event Yields

- If assume a standard run 2010-2014
  - 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	Number of Events
He	0.6M
C	0.4M
Fe	2.0M
Pb	2.5M

DPF09

MINERvA Institutions

MINOS

Tufts
William & Mary
FNAL
Duluth
Texas
Athens

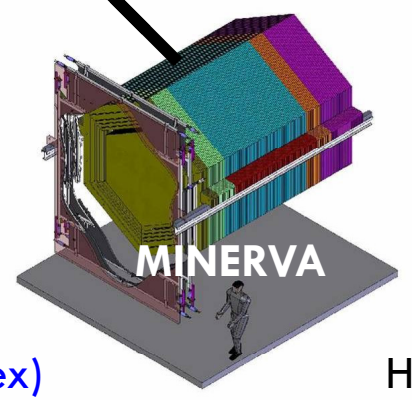
NOVA

MiniBooNE

Northwestern

Florida

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



Dortmund
INR, Moscow

Theory

Pitt

Jefferson Lab

Hampton
James Madison
Rutgers

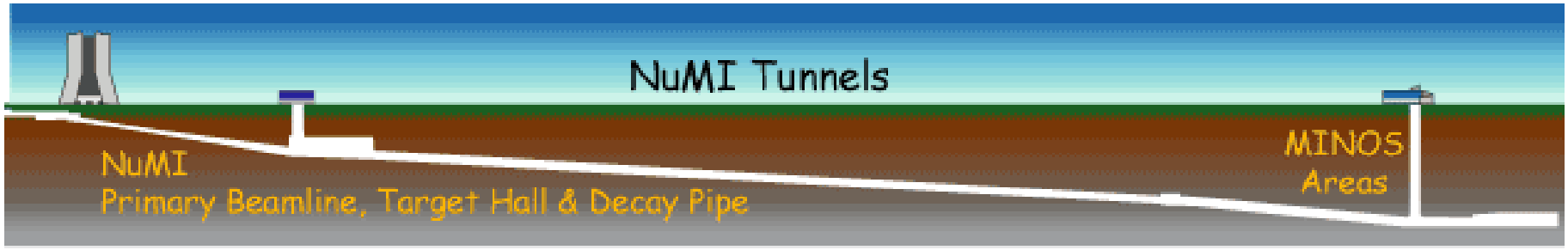
Irvine

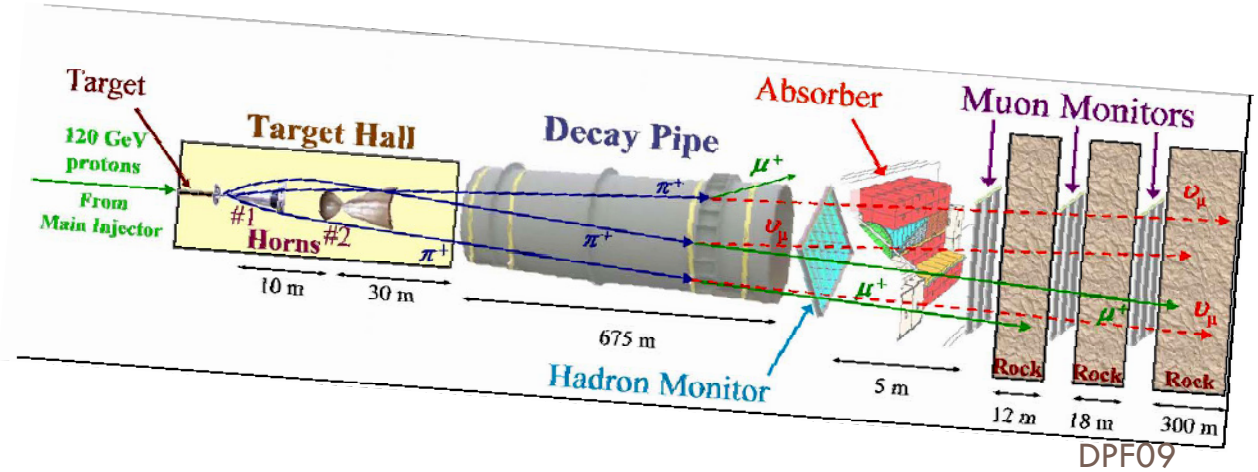
T2K

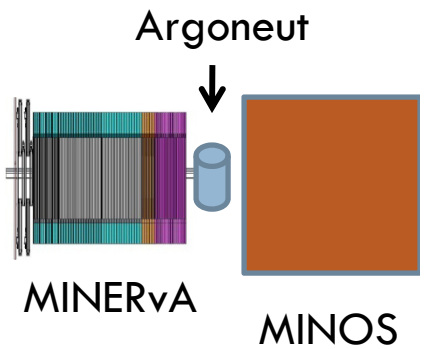
Rochester

Nuclear

NuMI Beam

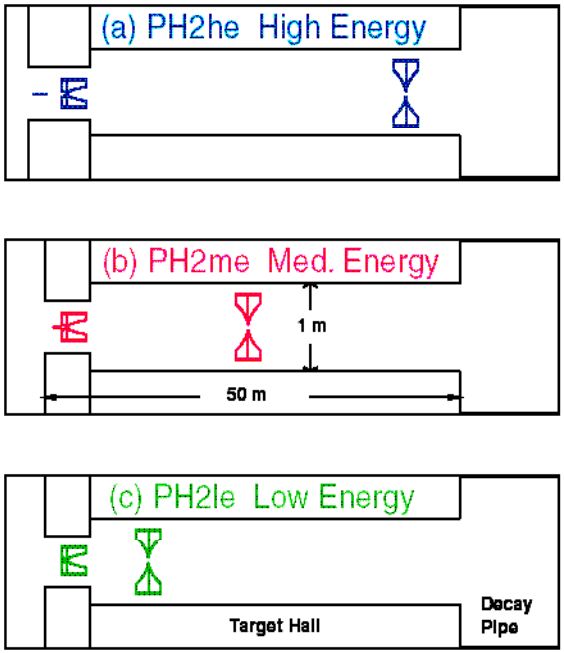

NuMI Tunnels
NuMI
Primary Beamline, Target Hall & Decay Pipe
MINOS
Areas

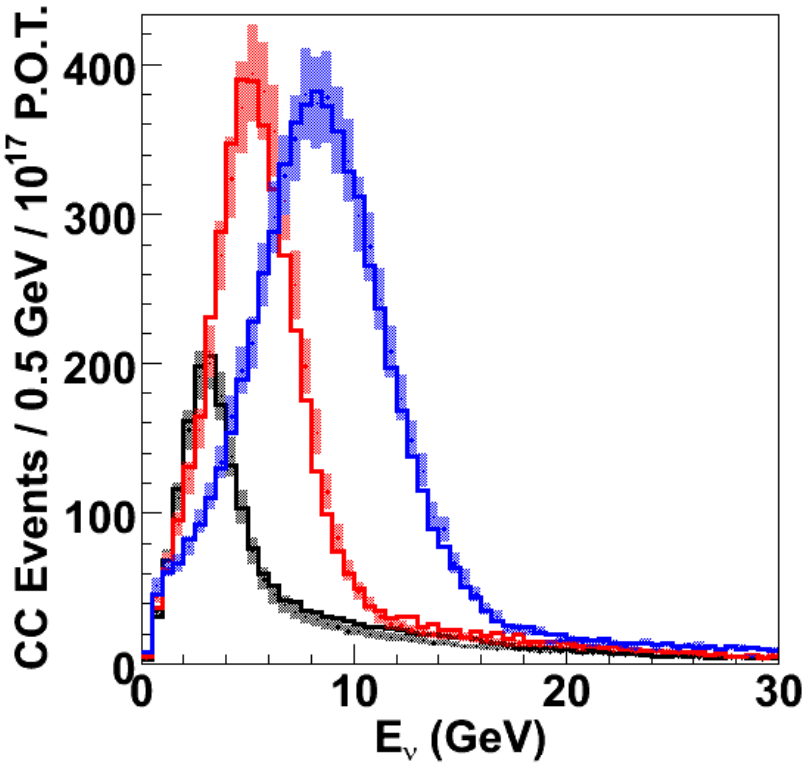

Target
120 GeV
protons
From
Main Injector
Target Hall
#1
Horns
#2
10 m
30 m
Decay Pipe
675 m
Absorber
Hadron Monitor
5 m
Muon Monitors
Rock
Rock
Rock
12 m
18 m
300 m
DPF09


Argoneut
MINERvA
MINOS

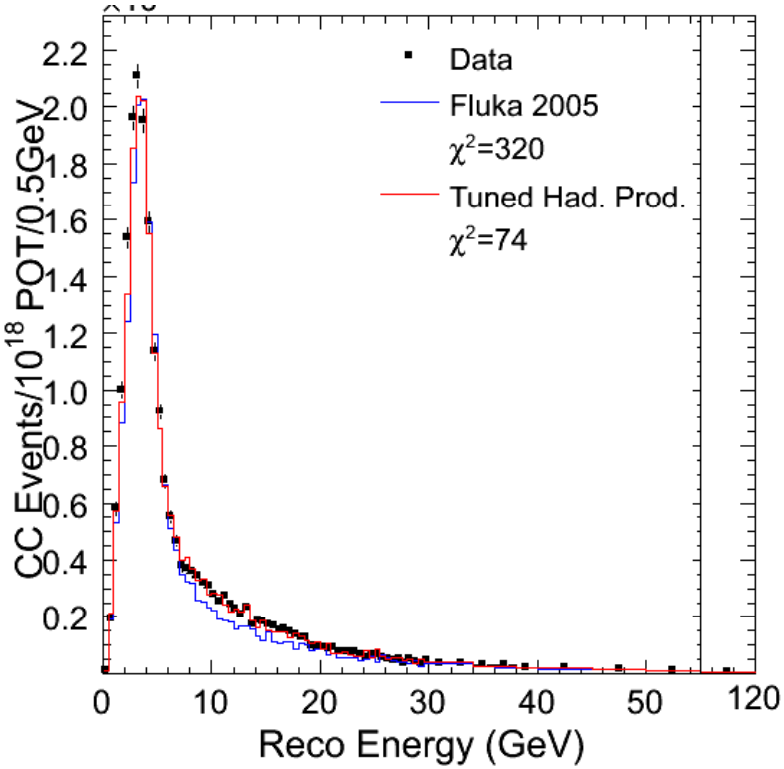
Neutrino Flux Estimates from MINOS

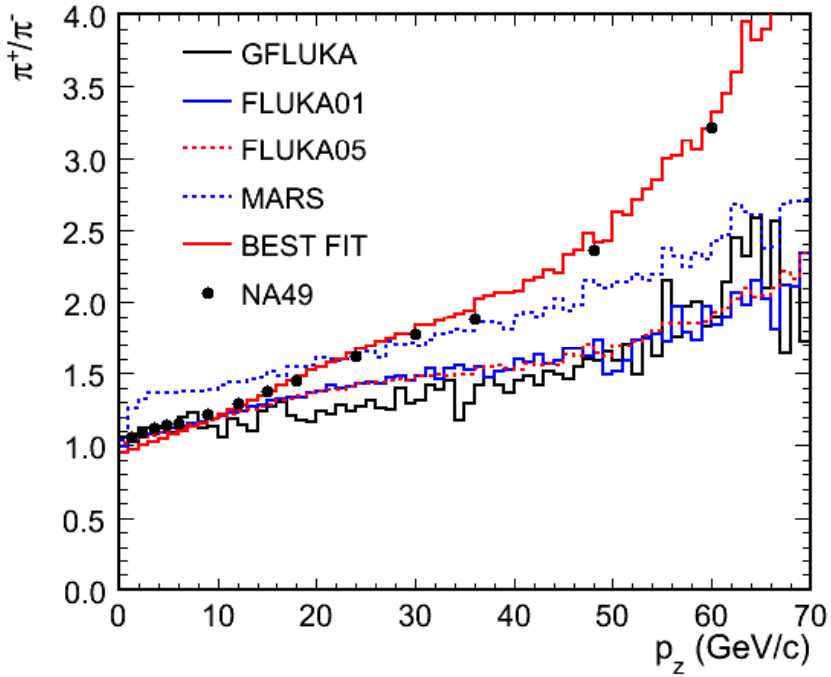
Sacha Kopp – report 9/19/2008



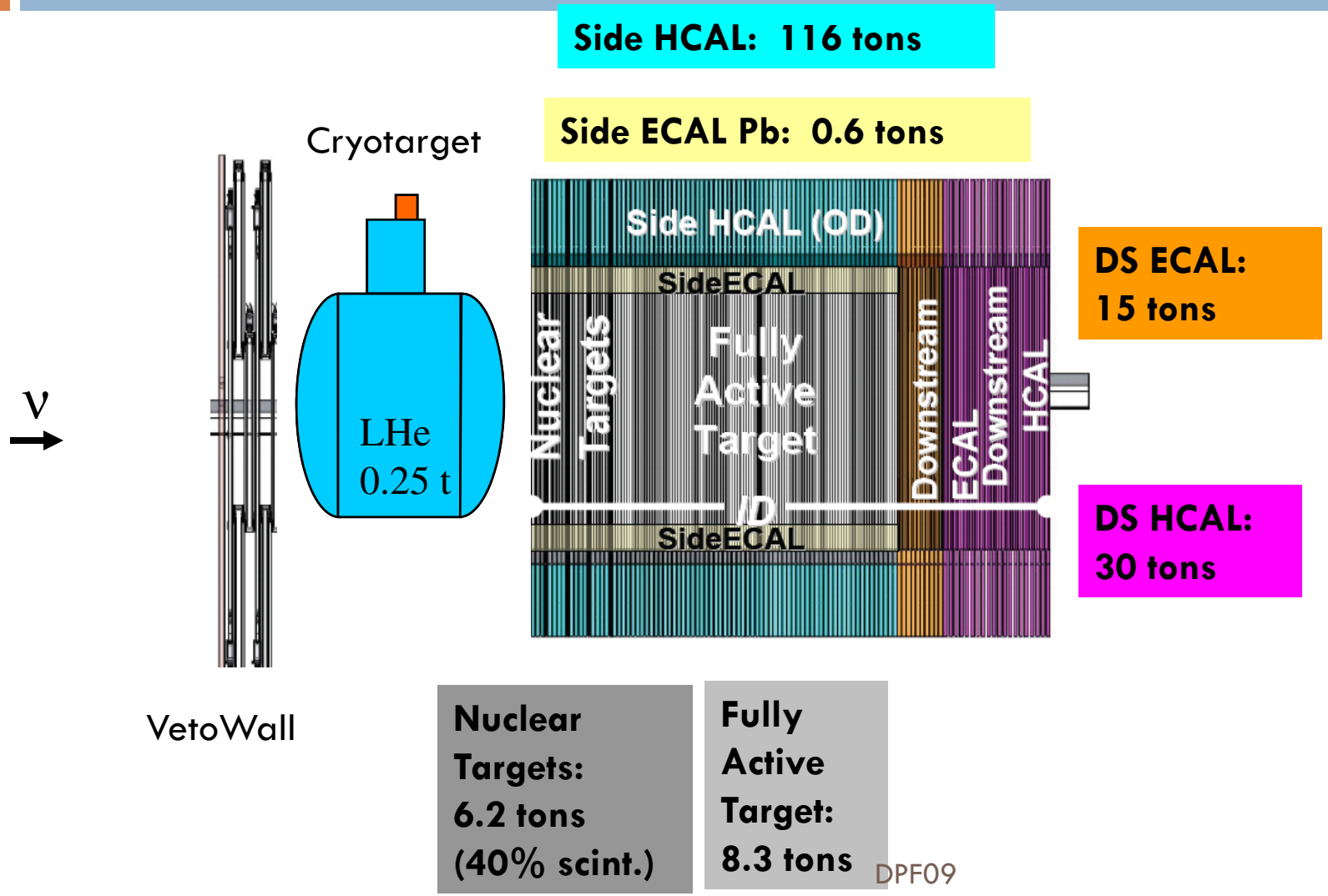


Comparisons with MINOS/NA49 data

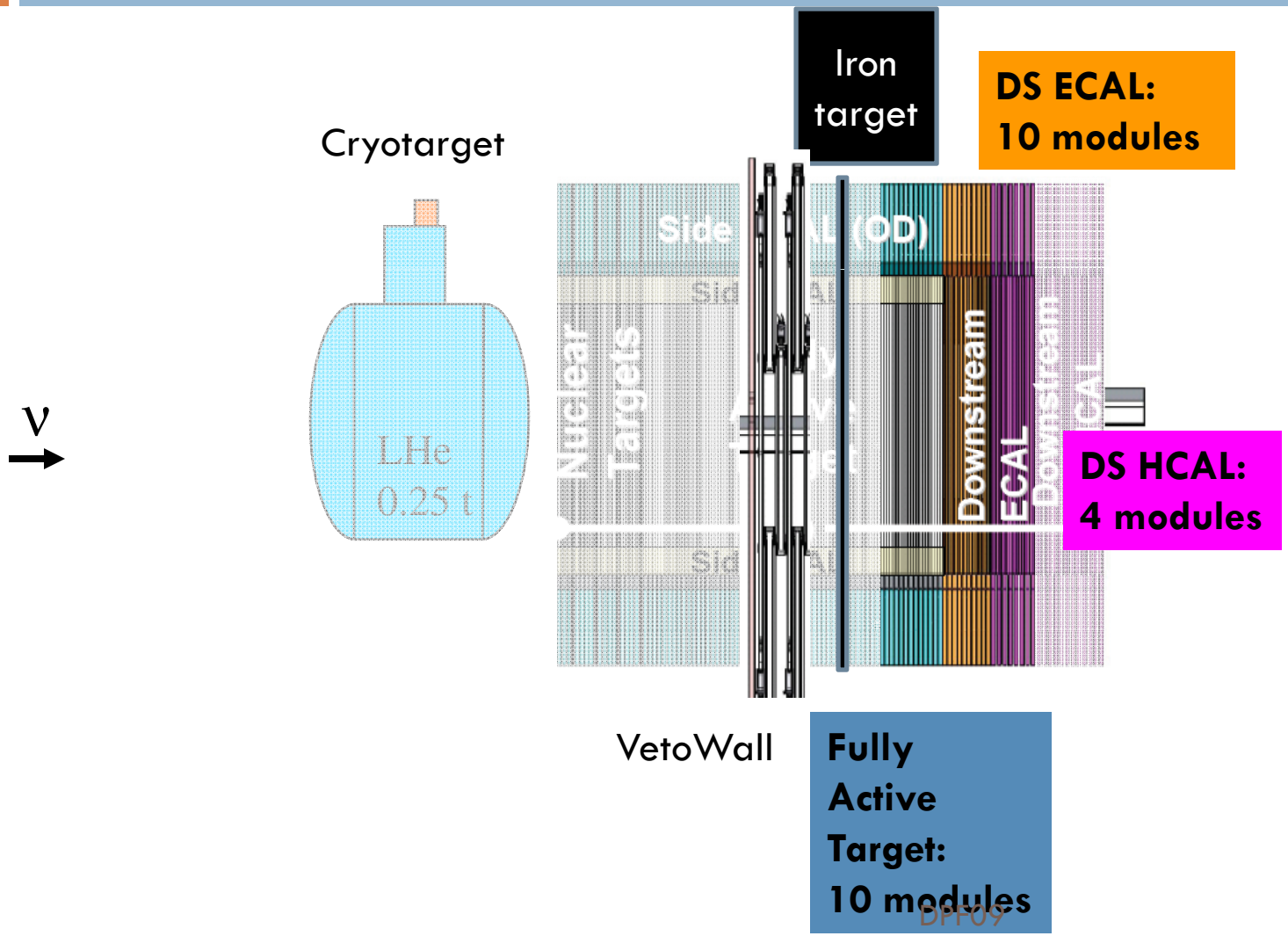




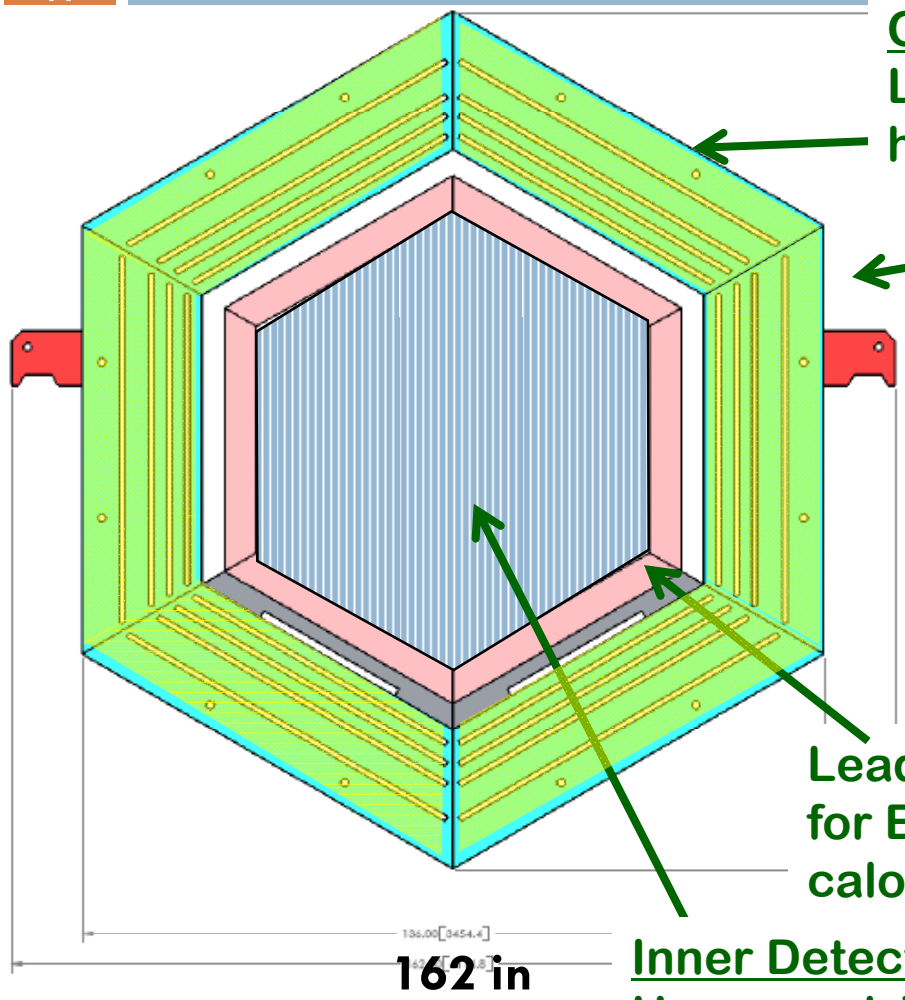
Future MINERνA Experimental Set-up



Tracking prototype Spring 2009



MINERνA Detector Module



Outer Detector (OD)
Layers of iron/scintillator for hadron calorimetry. 6 "Towers"

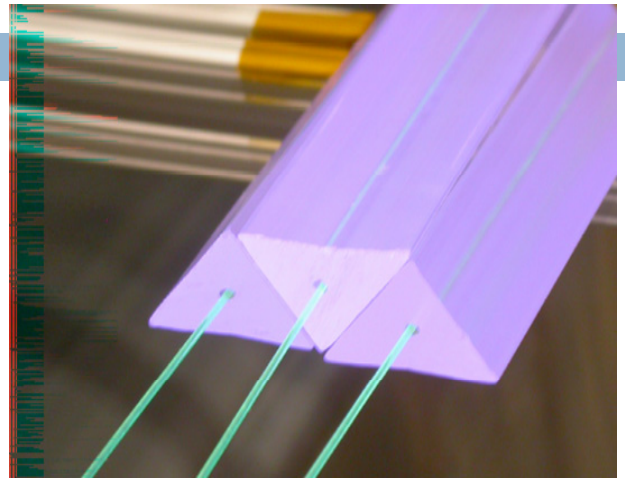
Lead Sheets for EM calorimetry

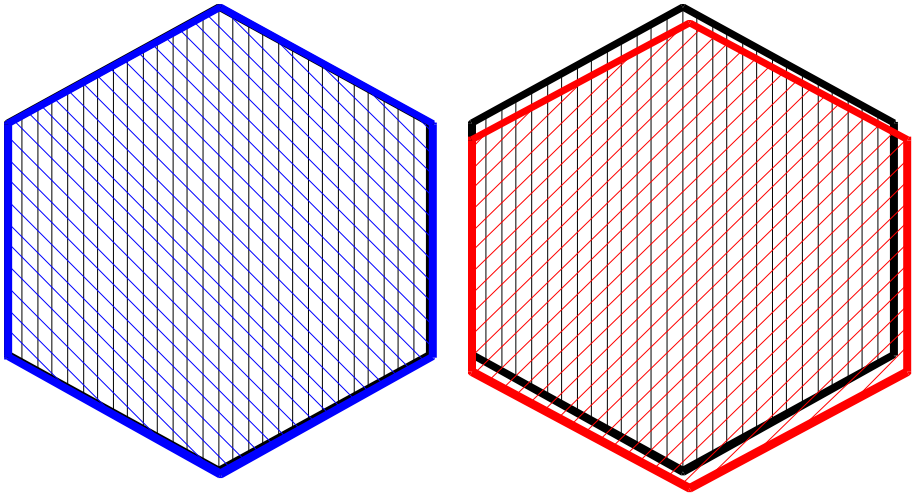
Inner Detector (ID)
Hexagonal X, U, V planes for 3D tracking

- 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.

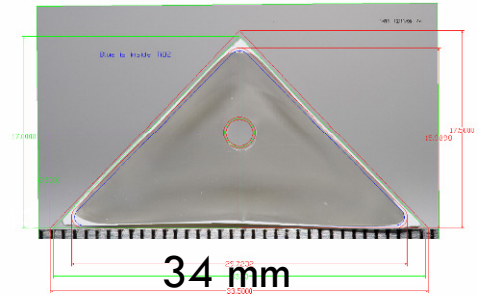


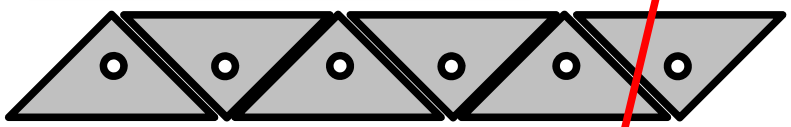


U X VX

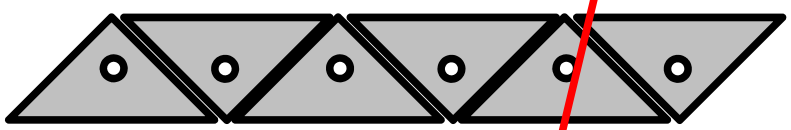
- Three different plane orientations +- 60 degrees
- Two planes (UX or VX) make a module
- Full detector has 108 modules, 6 nuclear target modules, and ~30k channels

Scintillating strips in ID

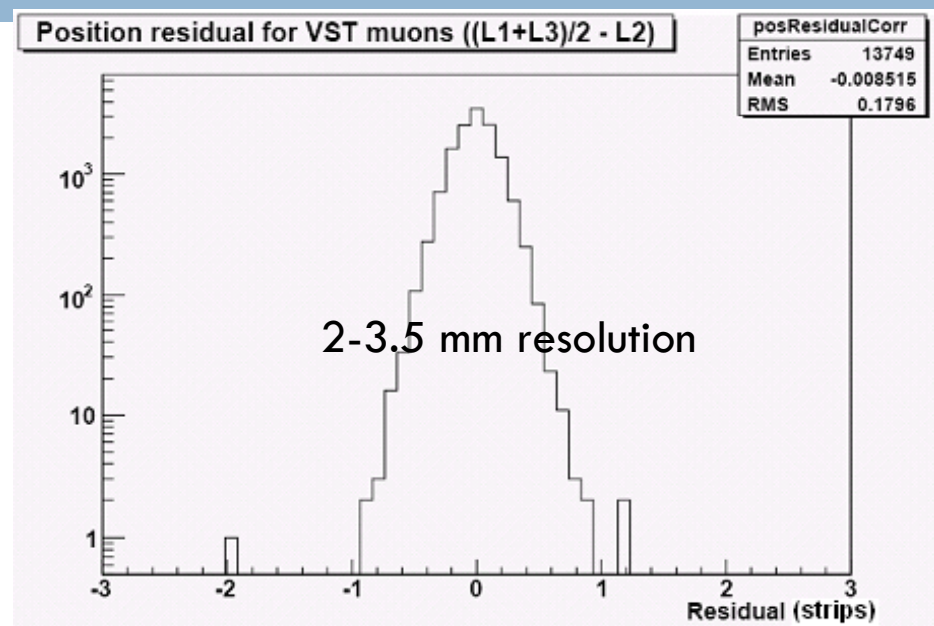




17 mm fiber to fiber



127 strips/plane

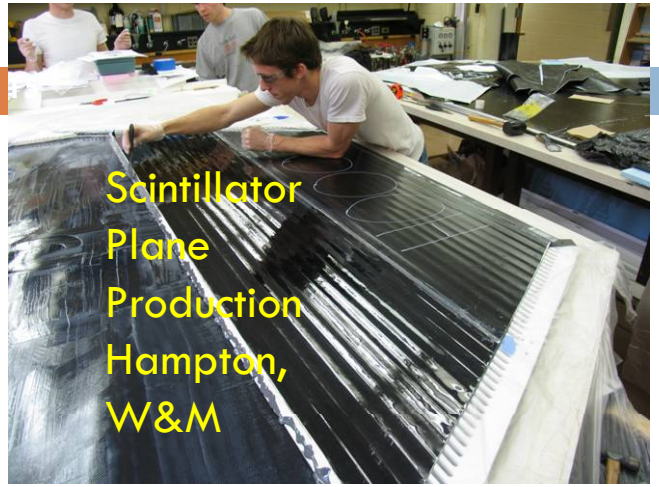


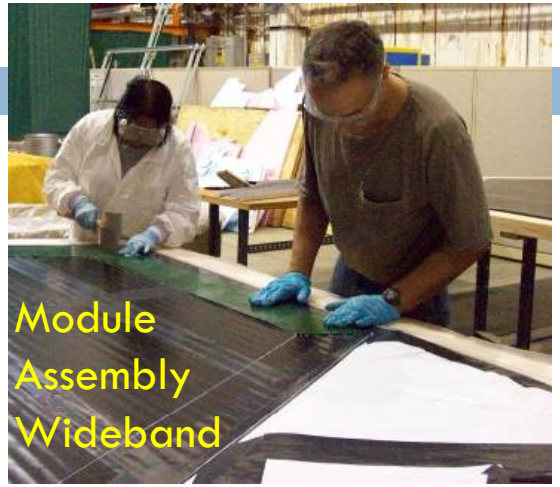
- Response is measured with a dedicated mapper before installation underground.

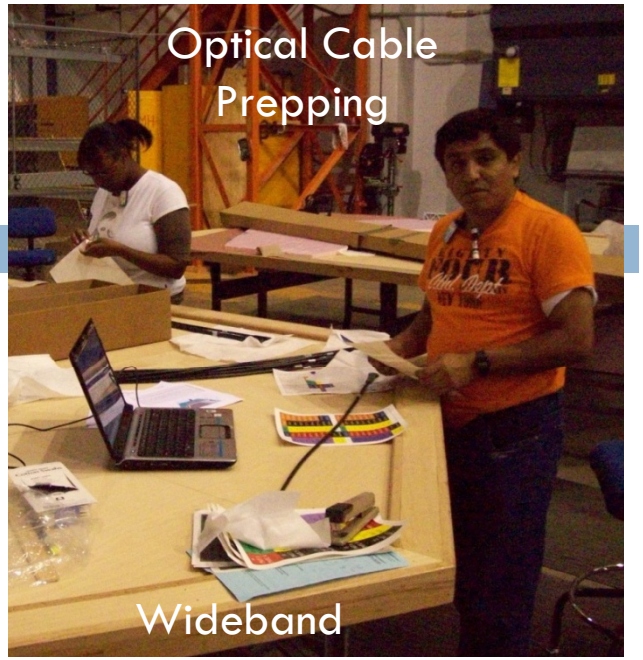
Inner Detector Plane Fabrication at Hampton, William + Mary and Fermilab

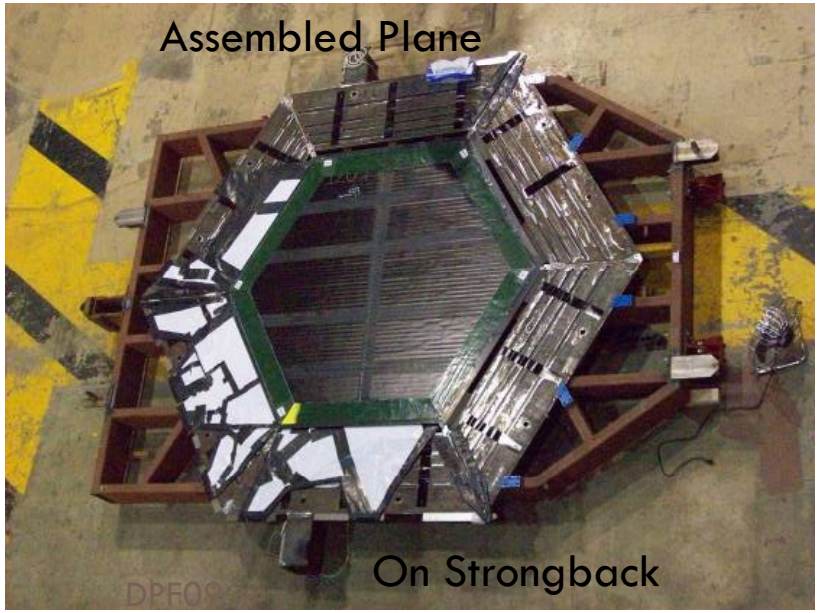
1) Scintillator Bars are cut and formed into planks
2) Planks are joined together to make hexagonal plane
3) Planes are instrumented with fibers and connector
4) Plane is made light tight

Module Construction

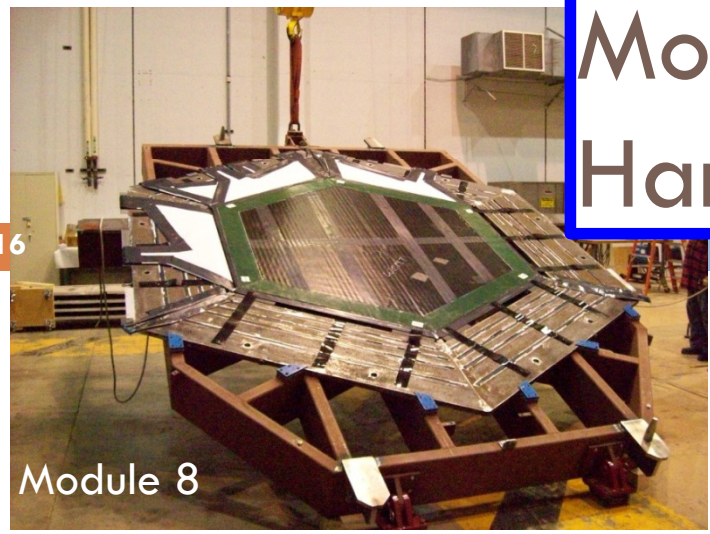


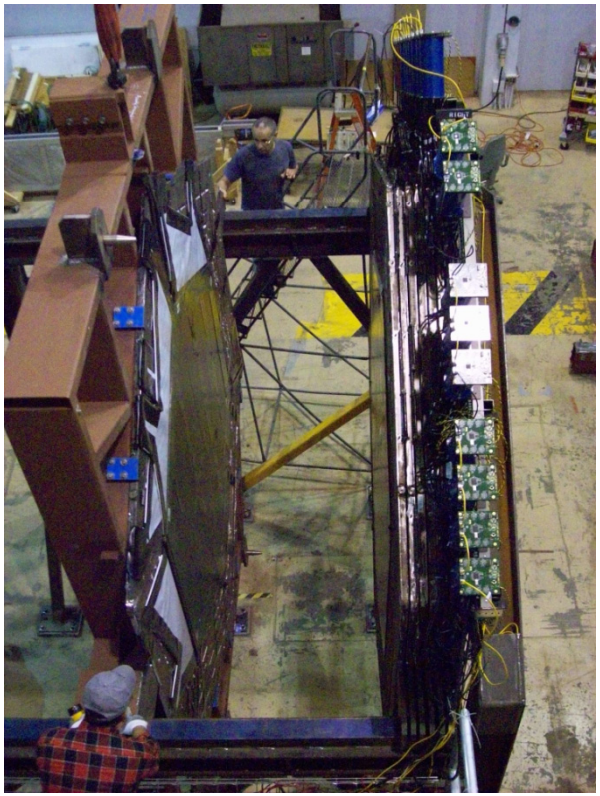


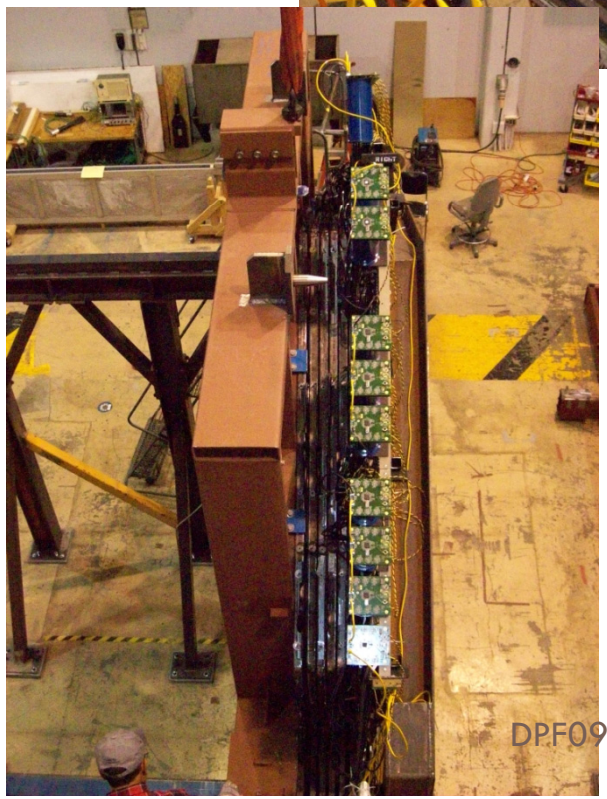




Module Hanging



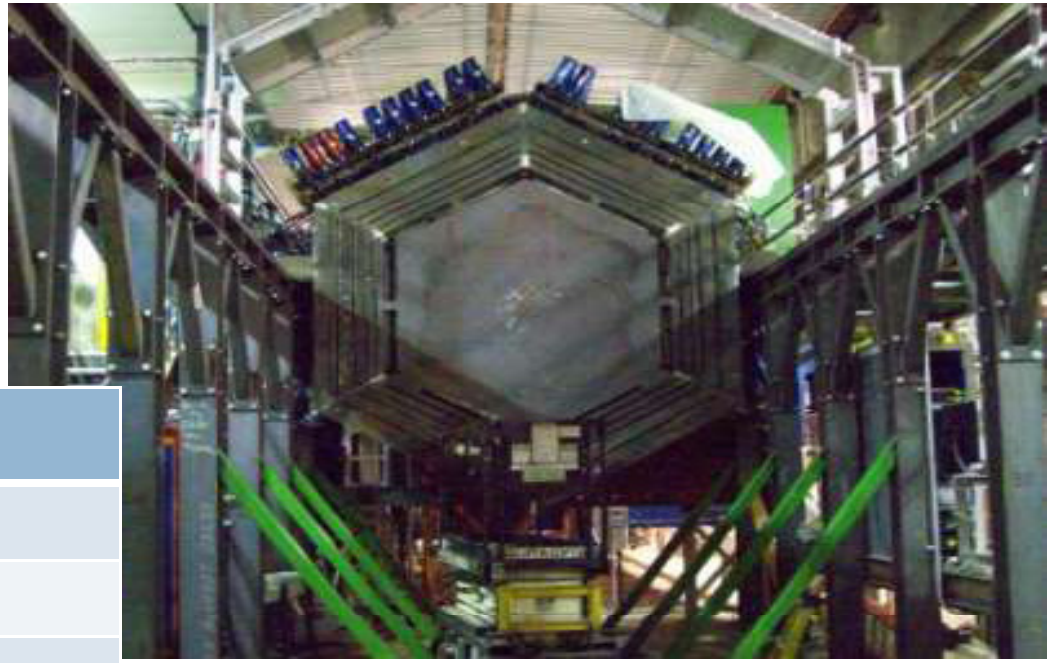




Tracking Prototype in NuMI

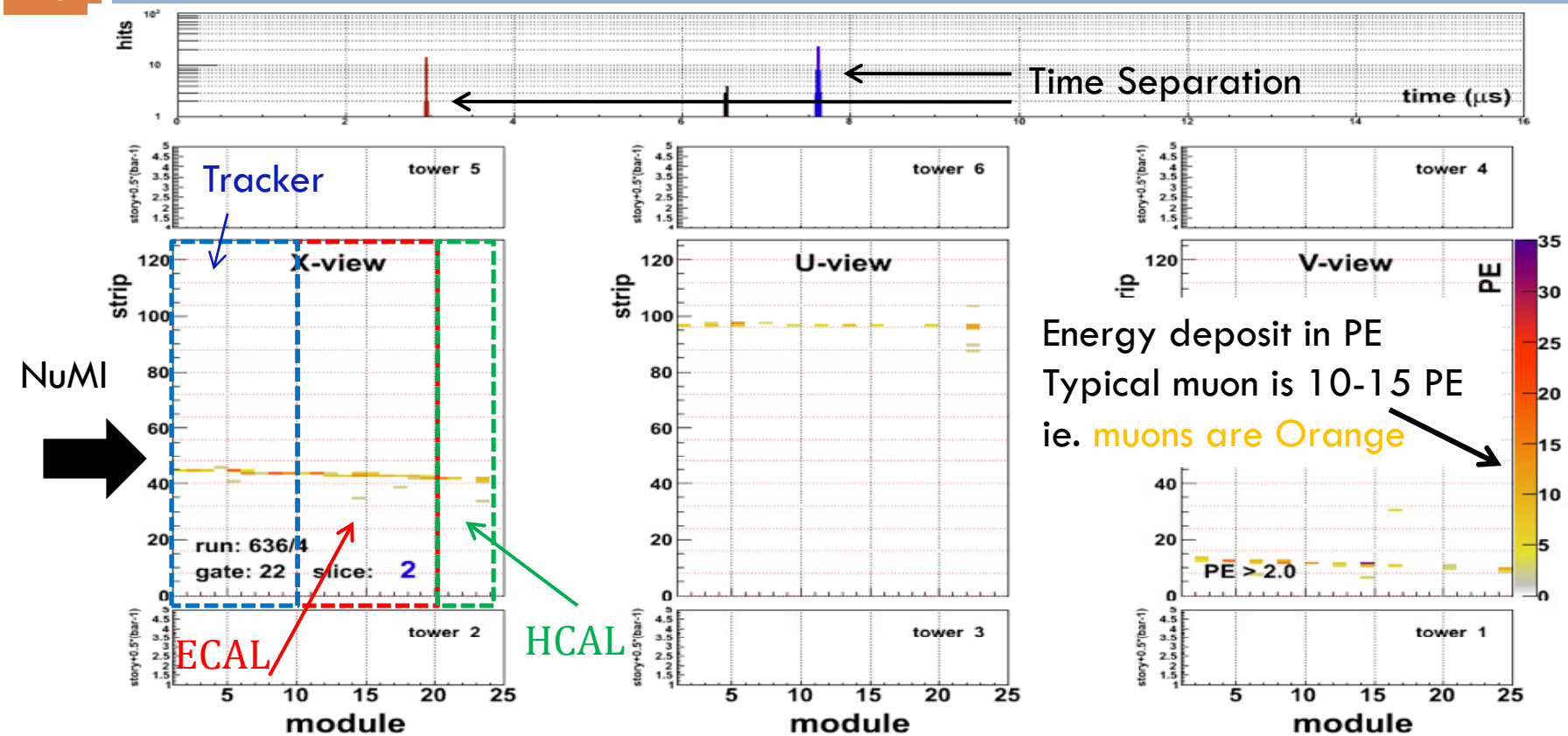
- 24 module tracking prototype ran in the NuMI Beam March 16 – June 12

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



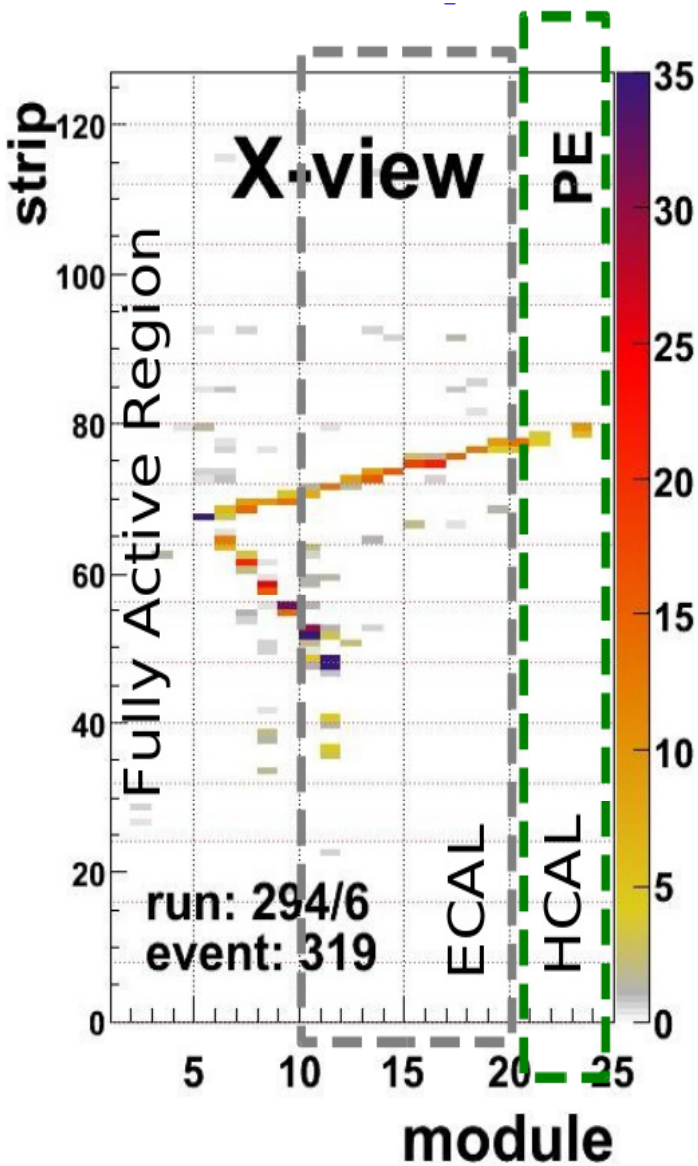
Process Type	Events	% of Total
Safe DIS	6.1k	32
Low Q DIS	1.8k	9.5
Transition	5.9k	31
Delta	2.3k	12
Quasi-Elastic	2.8k	15
Coh. Pi Prod.	~80	0.5

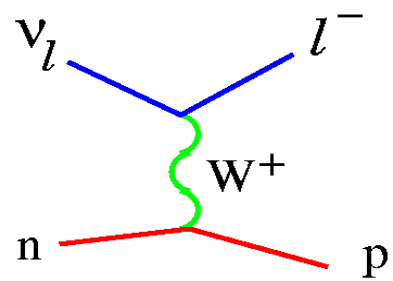
Rock Muons – most common



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

Events: Quasi-elastic Candidates





Muon kinematics from angle, range and momentum in MINOS.

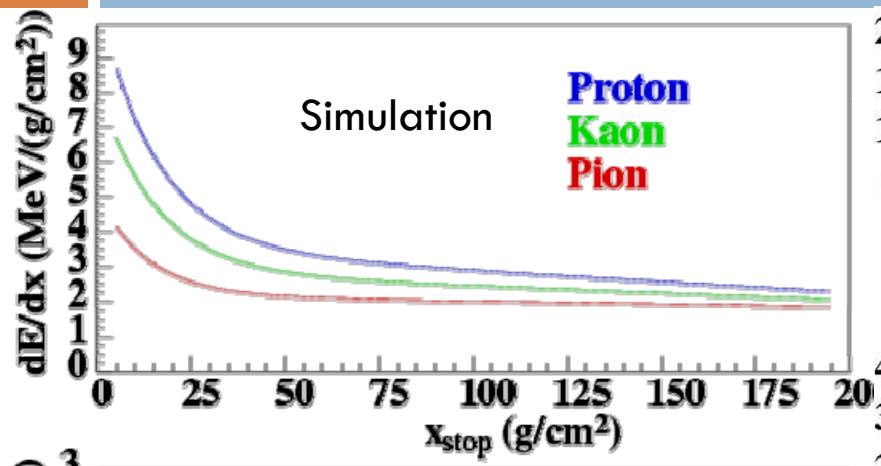
Proton kinematics from angle, range.

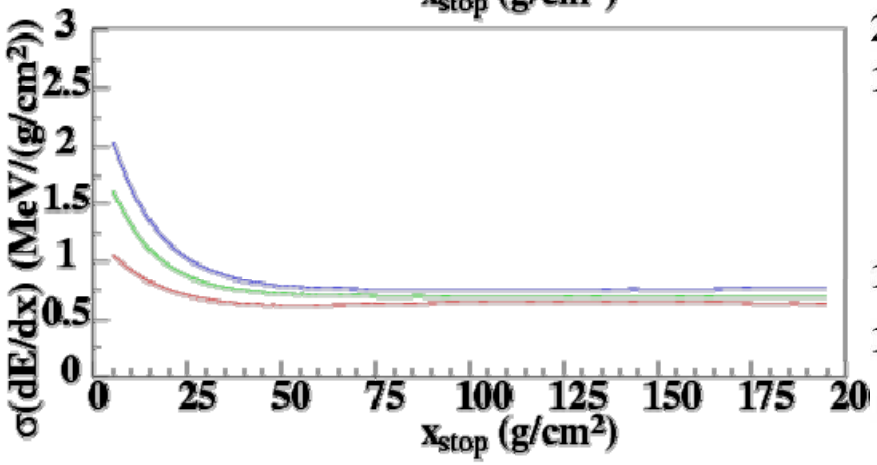
Pattern recognition not fully automatic yet. (muons easy, short active volume makes interacting particles harder to track.)

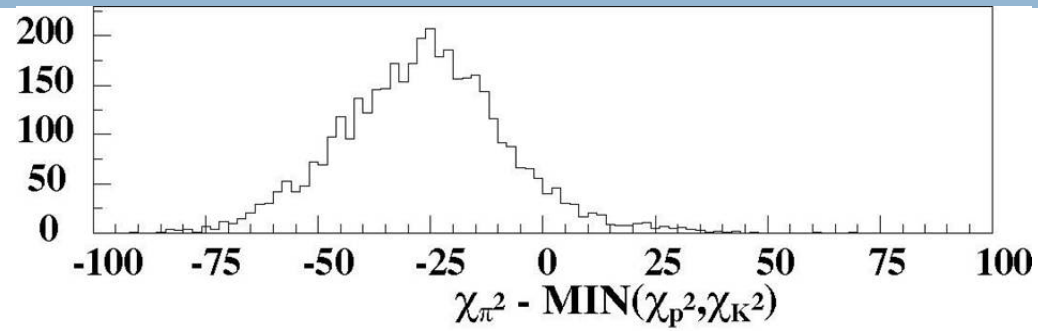
Particle Identification

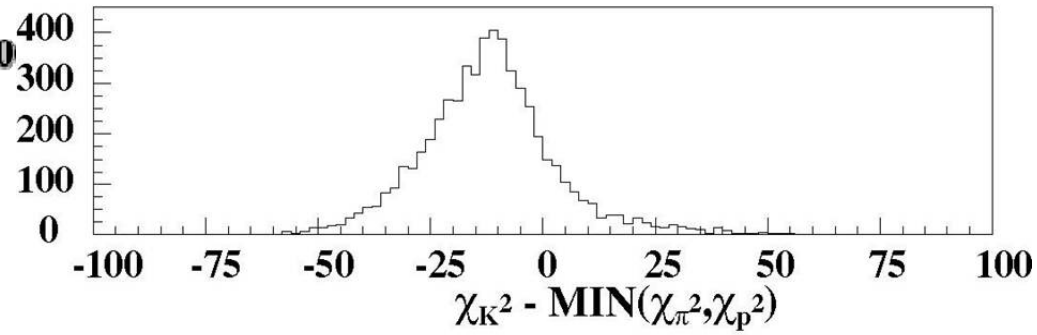
- Particle ID by dE/dx in strips and endpoint activity

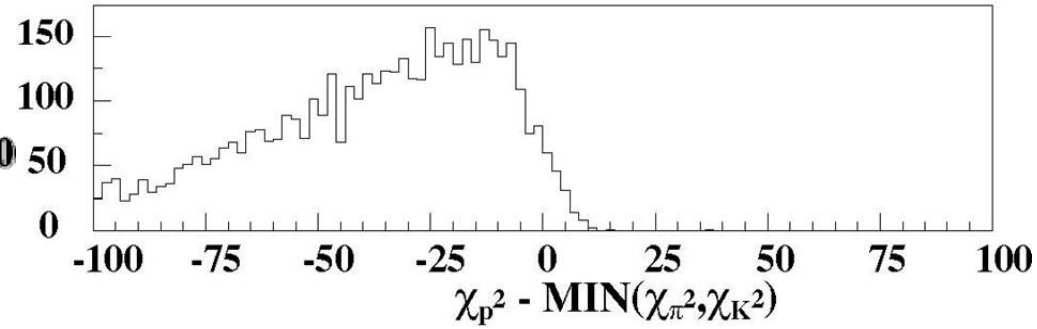
X^2 differences between right and best wrong hypothesis



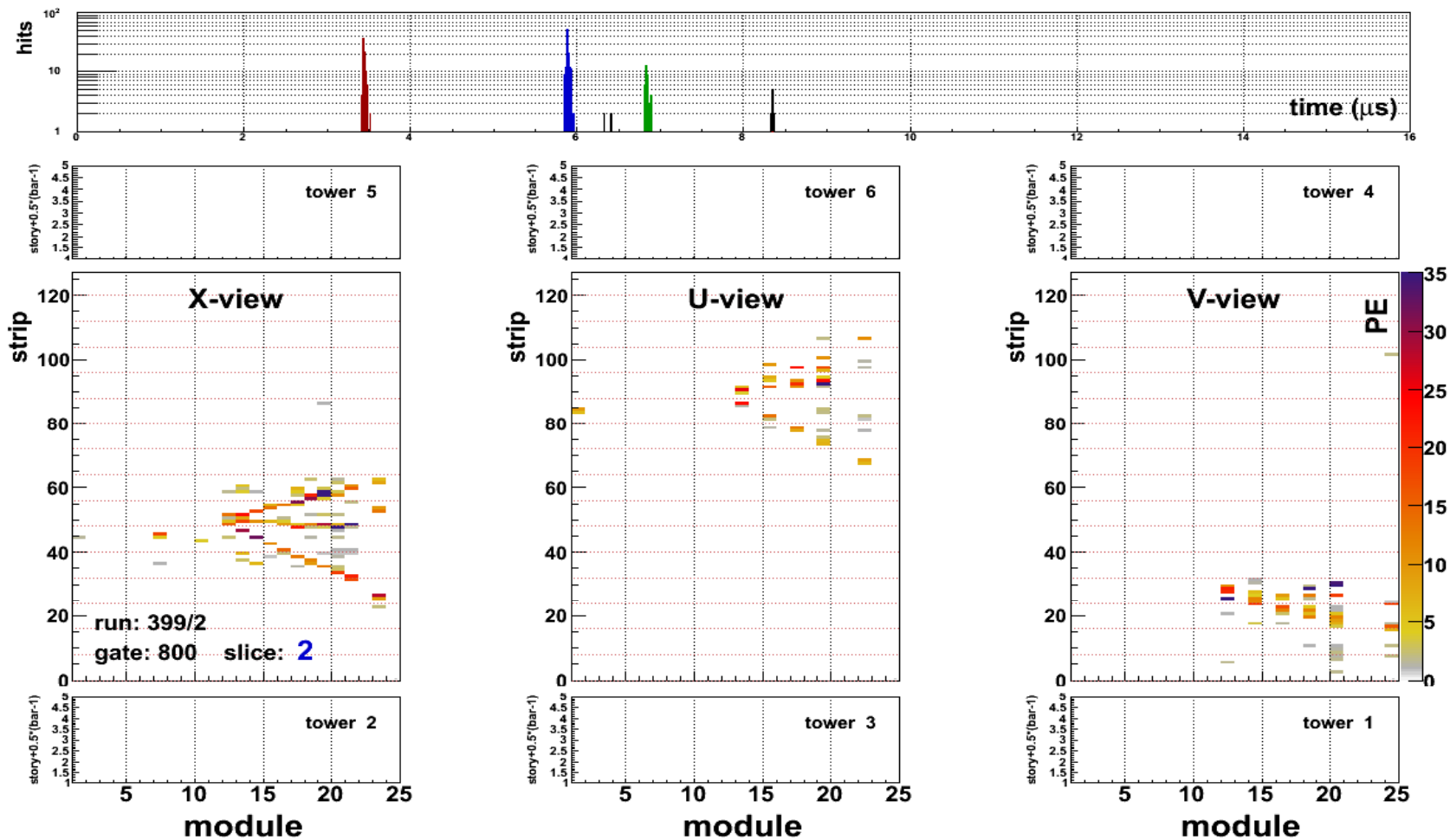








Events: Resonance Candidate



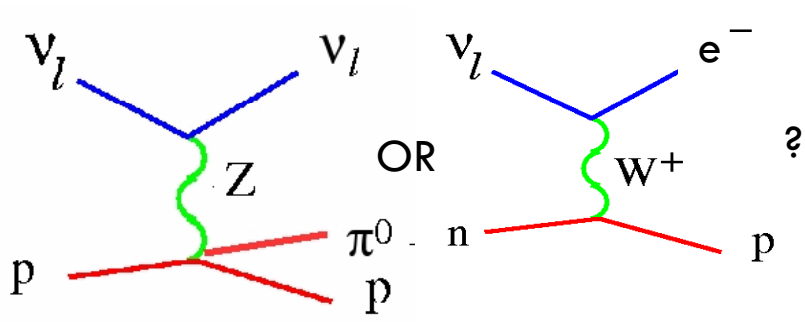
$\nu_\mu + N \rightarrow \mu^- + p + \pi$

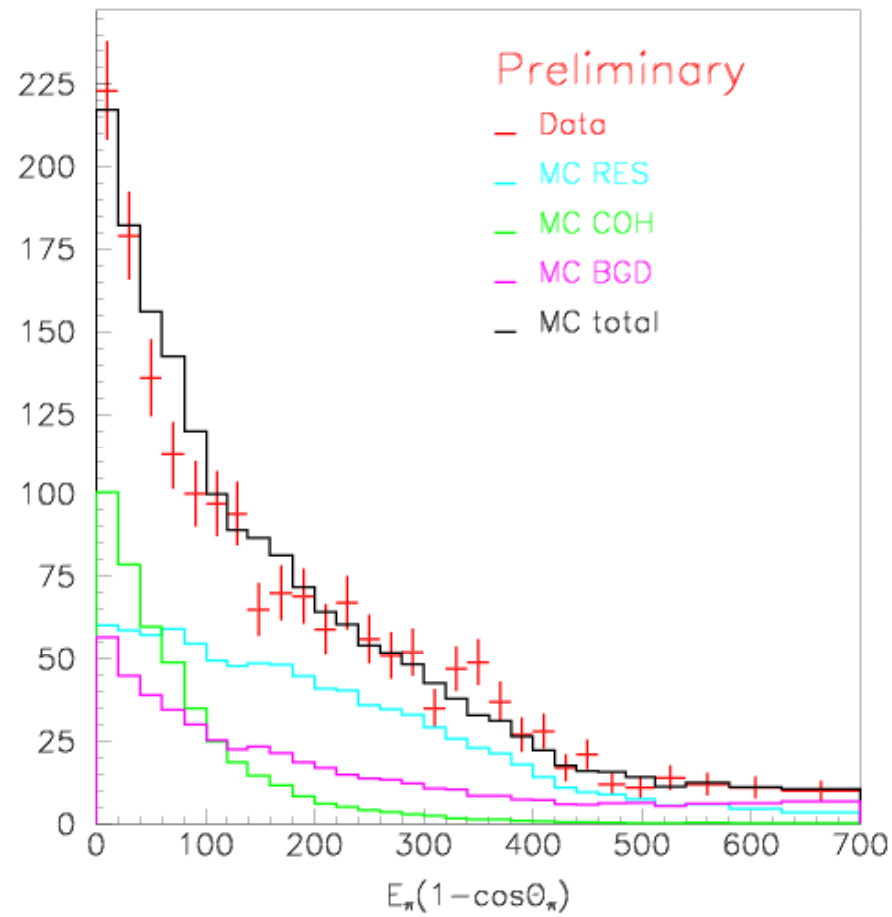
DPF09

Low energy inclusive and exclusive cross sections

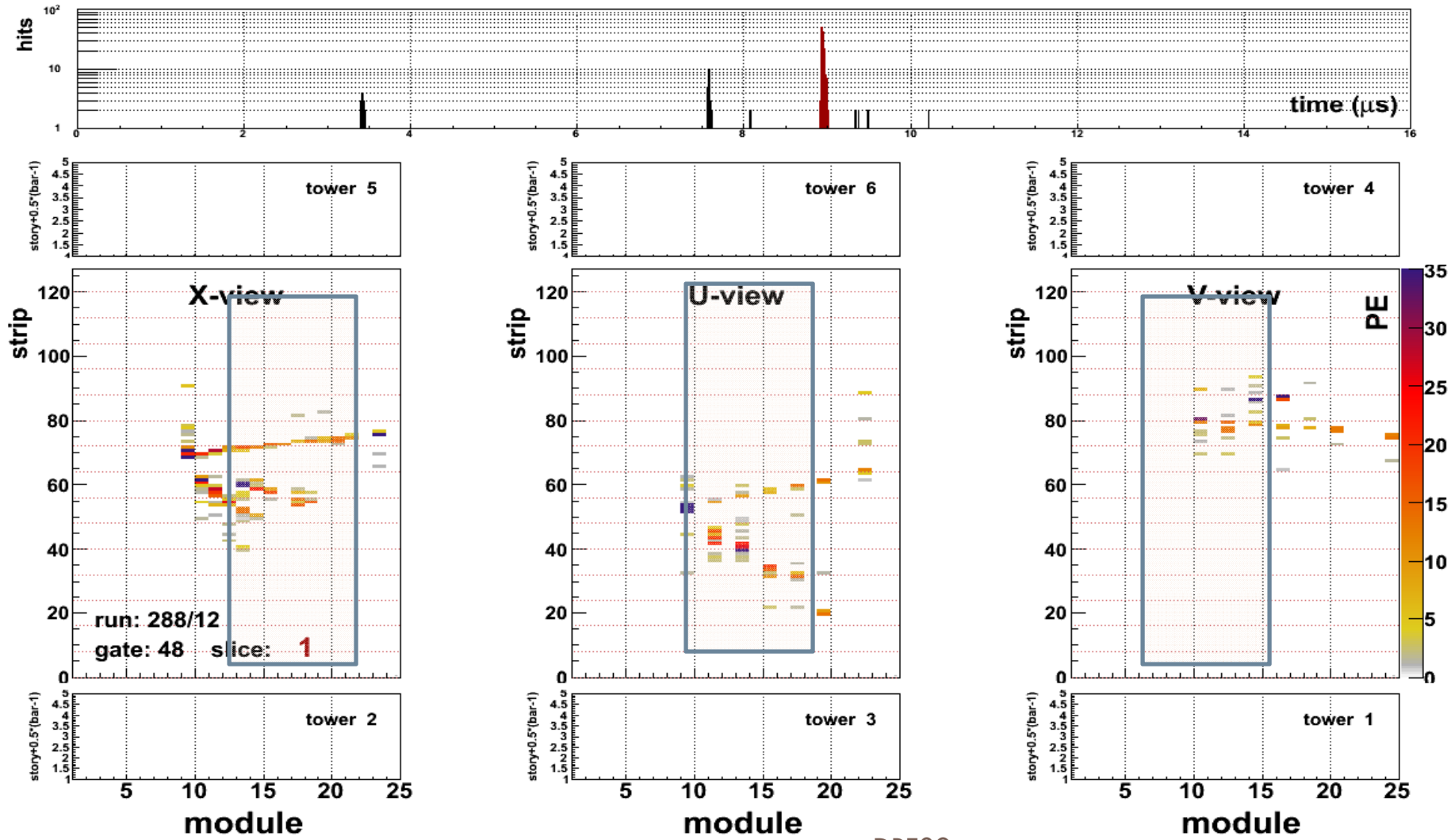
MiniBoone Coherent π^0 measurement

- π^0 NC important for oscillation experiments





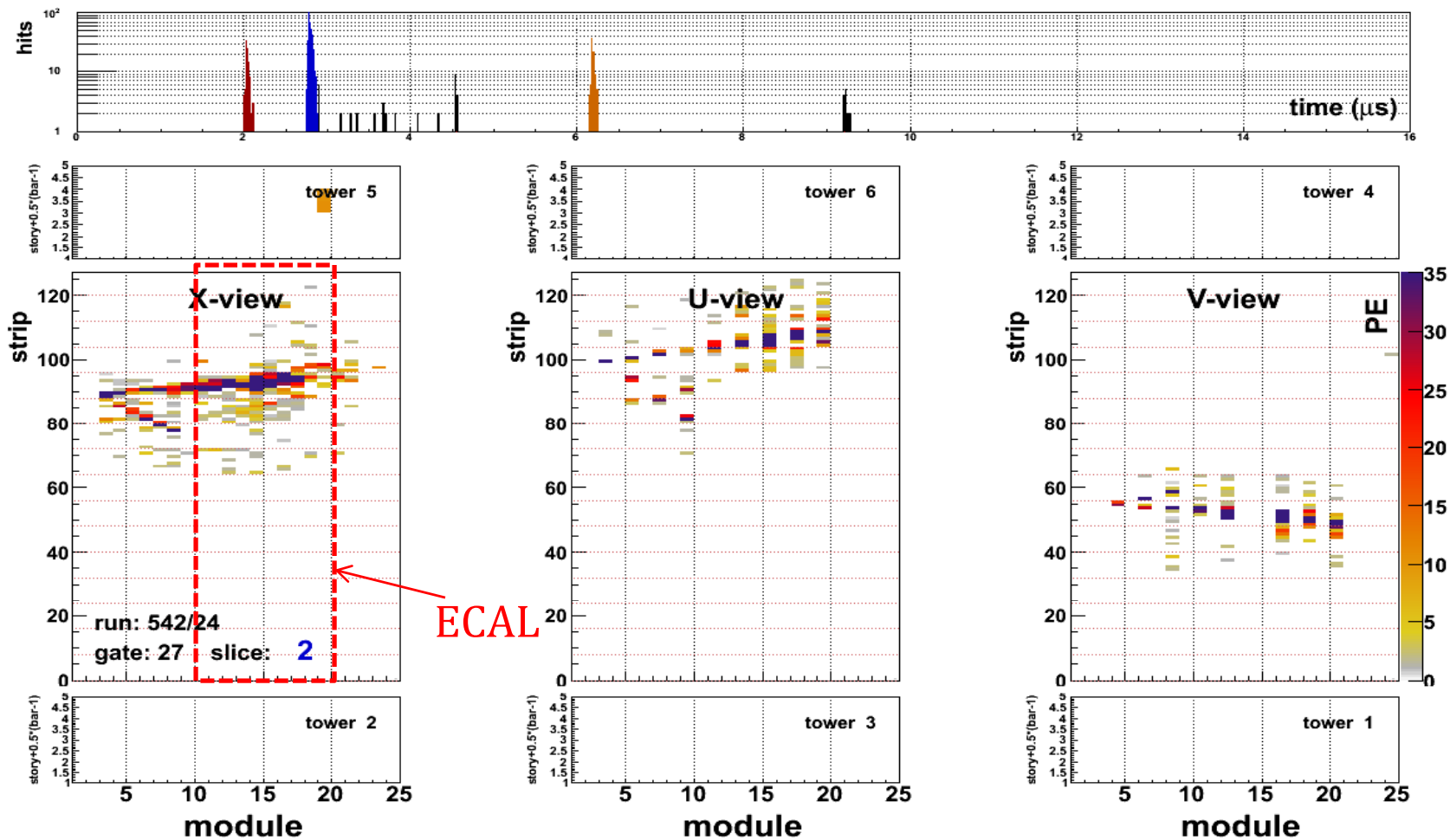
Events: π^0 Candidate



DPF09

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

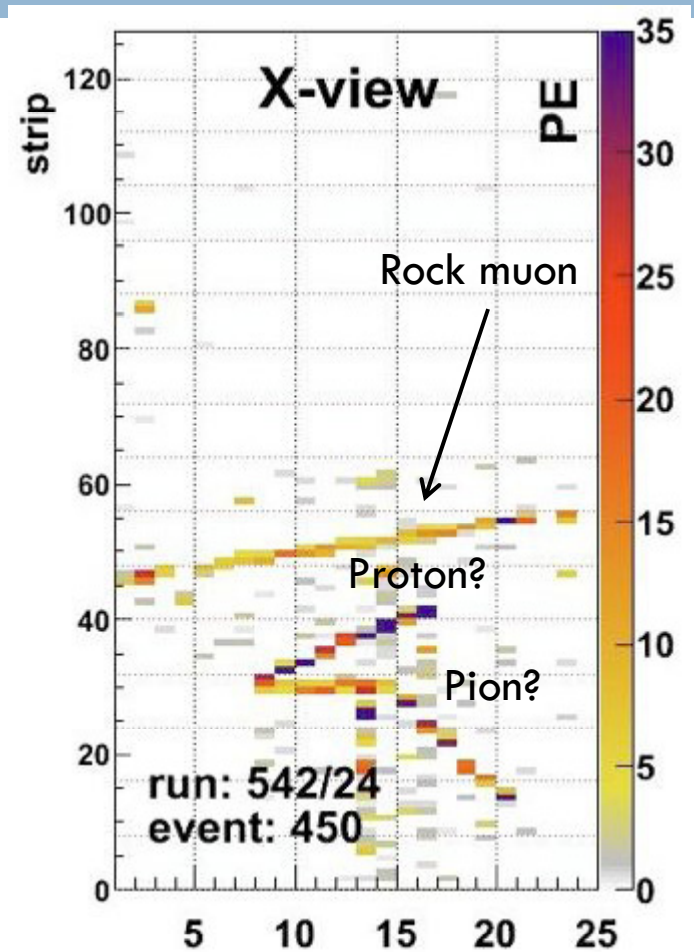
Events: ν_e Candidate



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

DPF09

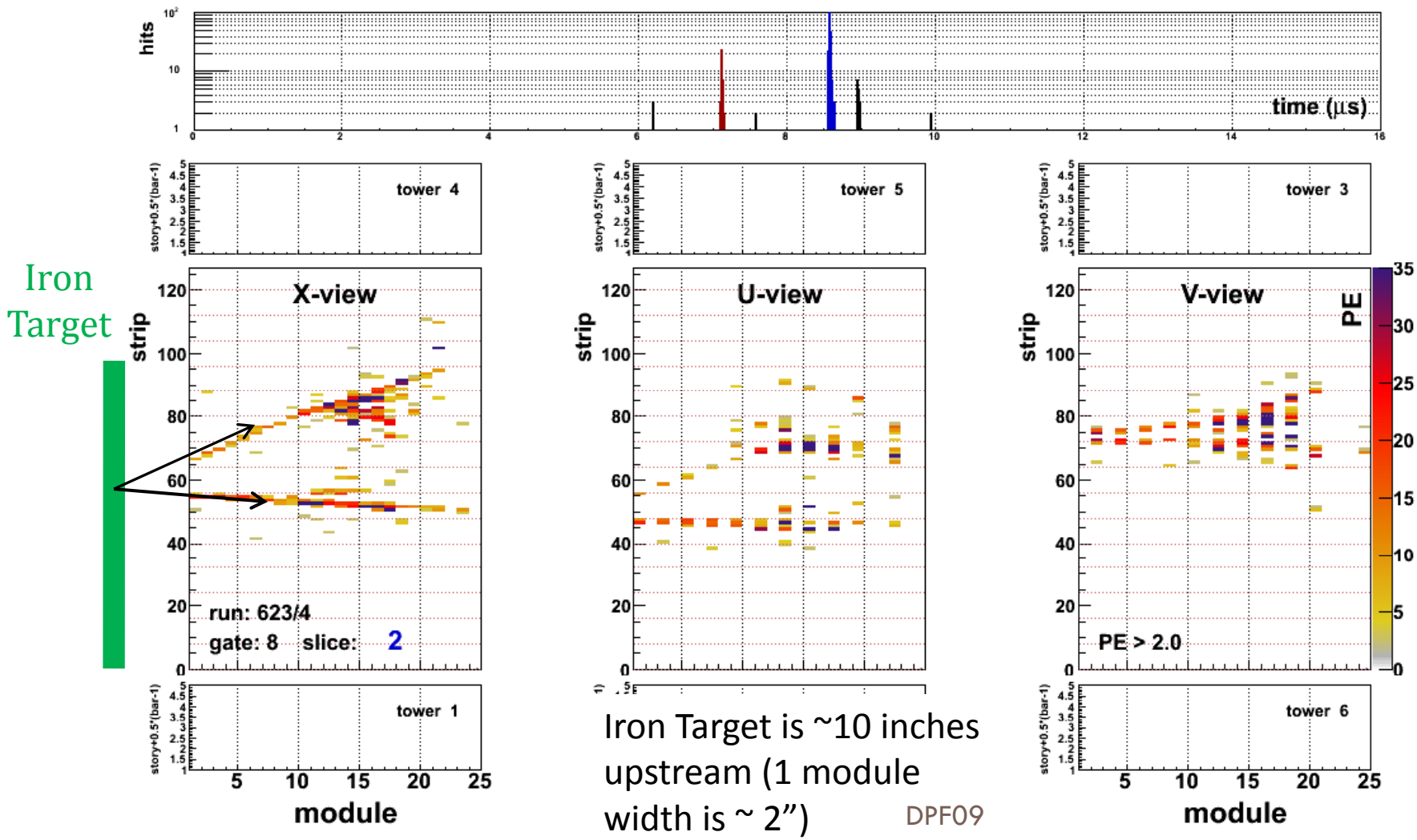
Events: Neutral Current Candidate



- 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

$\nu + N \rightarrow \nu + p + \pi$ DPF09

Events: Iron Target Interaction



Iron Target is ~10 inches upstream (1 module width is ~ 2”)

Current and Future Plans

- The tracking prototype is being taken apart and repaired
- In early August, installation of the full MINERvA detector will commence, starting with the HCAL modules
- NuMI beam returns in September, running in ν_μ-bar mode
- 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

•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 two month tracking prototype run shows that the detector works very well. We can distinguish different particle species! We will use these events to tune our reconstruction so that we are ready for data with the full detector.

•There is still a lot to do: We have a detector to assemble and ~16-19k tracking prototype neutrino events to analyze The full detector should be taking data by March 2010

BACKUP SLIDES

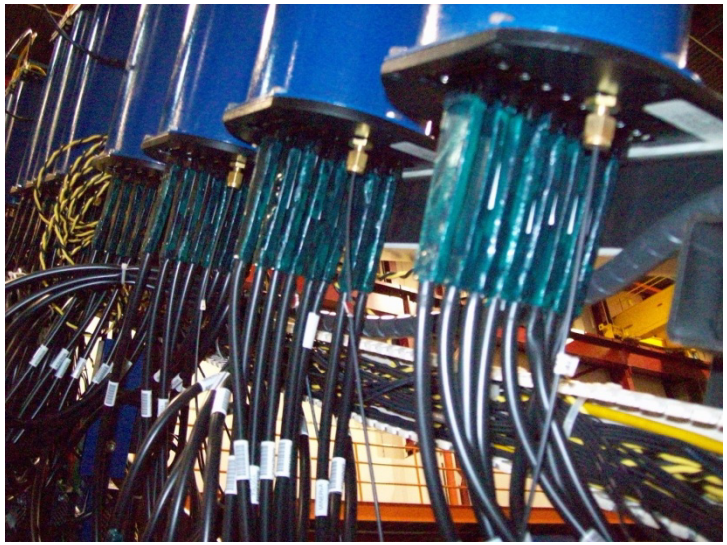
MINERνA Collaboration

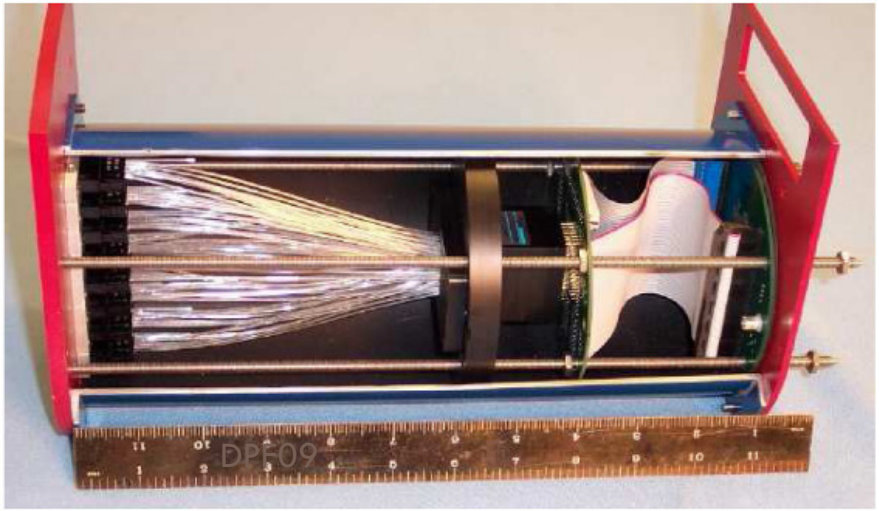
30

- 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

Electronics

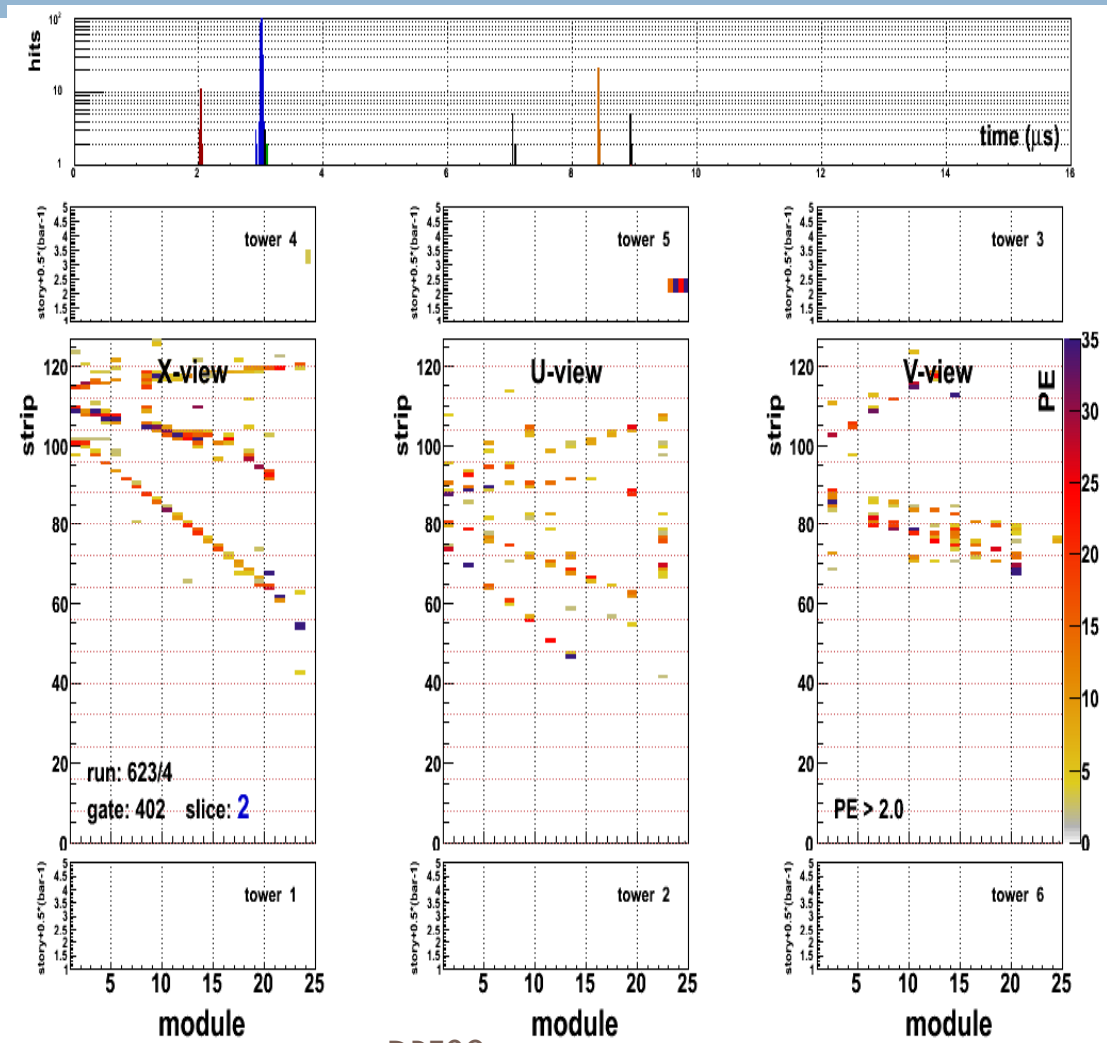
- Light measured by Hamamatsu 64 anode PMTs (newer version of MINOS model)
- Front end board (FEB) with Trip-t chips interface the PMTs
- Discriminators allow us to trigger at 1PE and resolve overlapping events during a spill



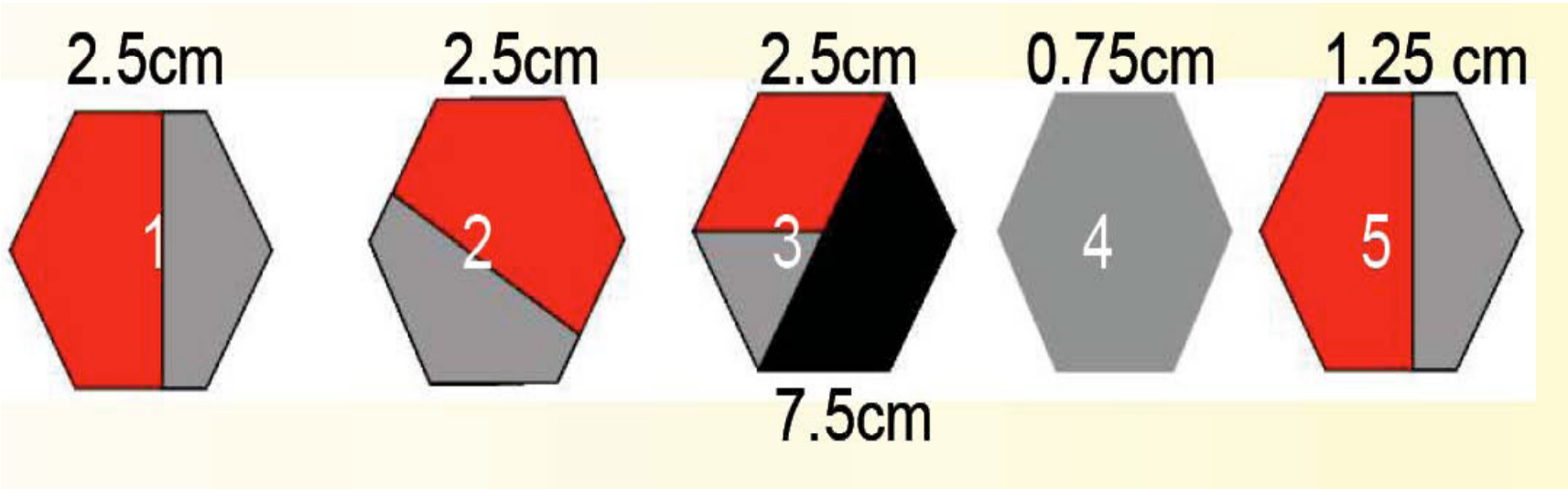


Physics: Nuclear Effects

- 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

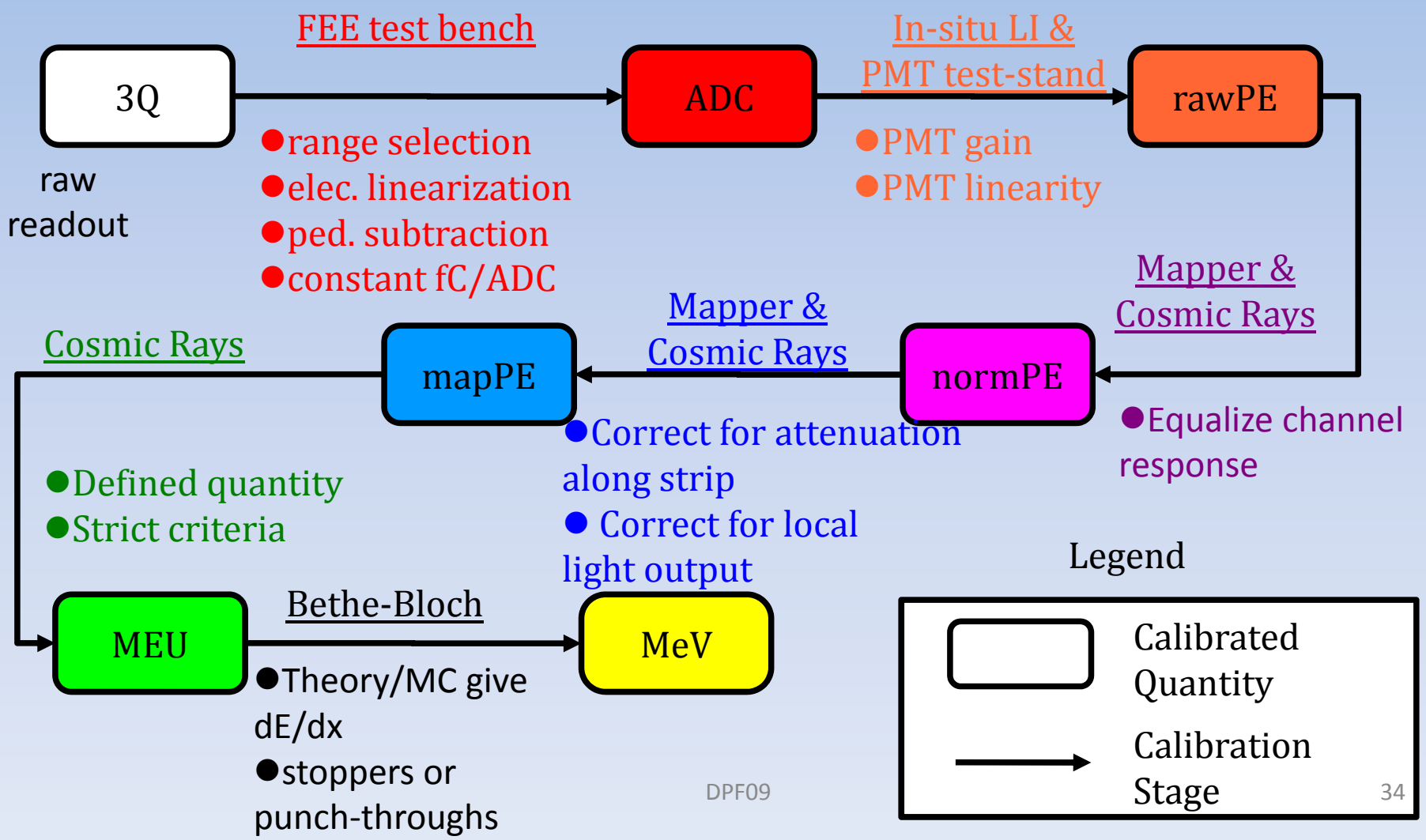


Red = Iron, Grey = Lead, Black = Carbon

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

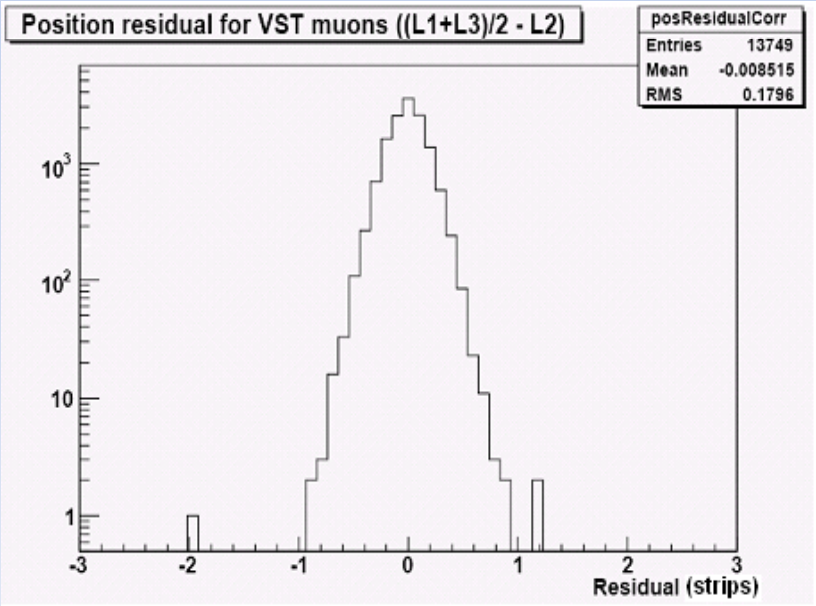


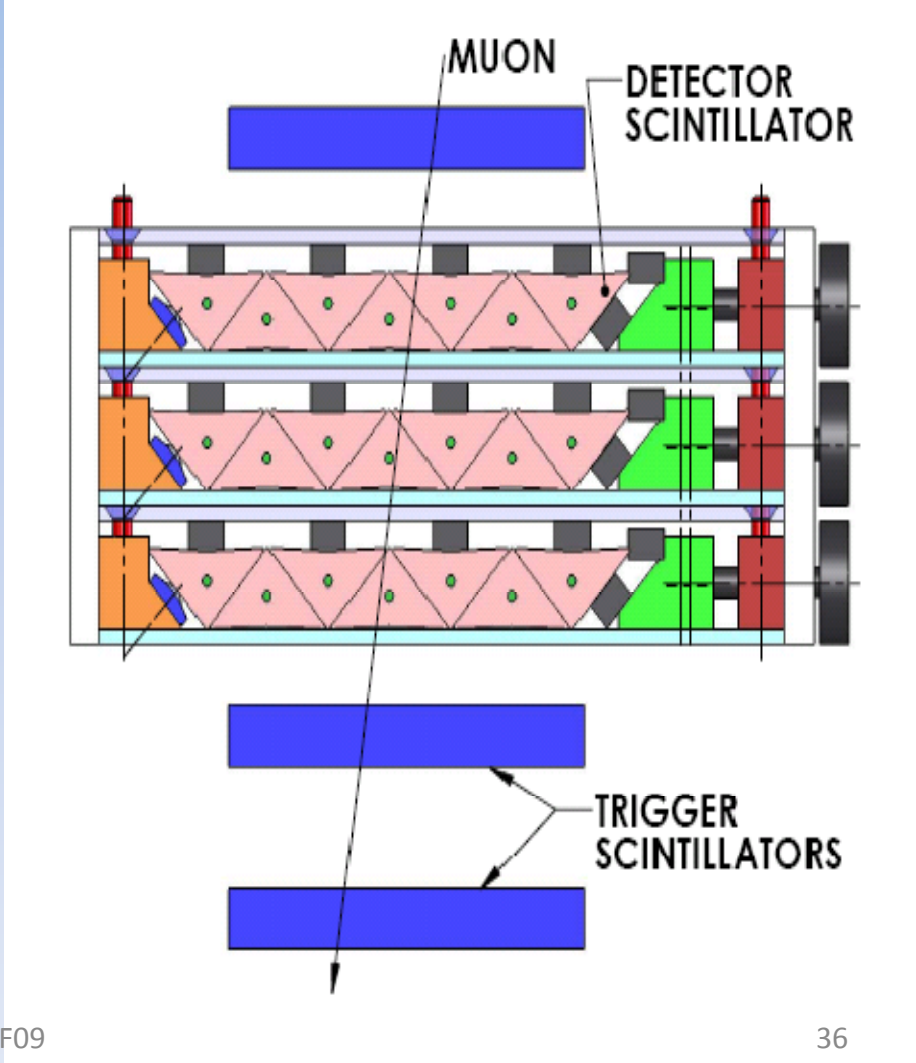
Detector Performance

- 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
  - $\delta p/p \sim 5\%$ stoppers, 10-15% via curvature

Vertical Slice Test

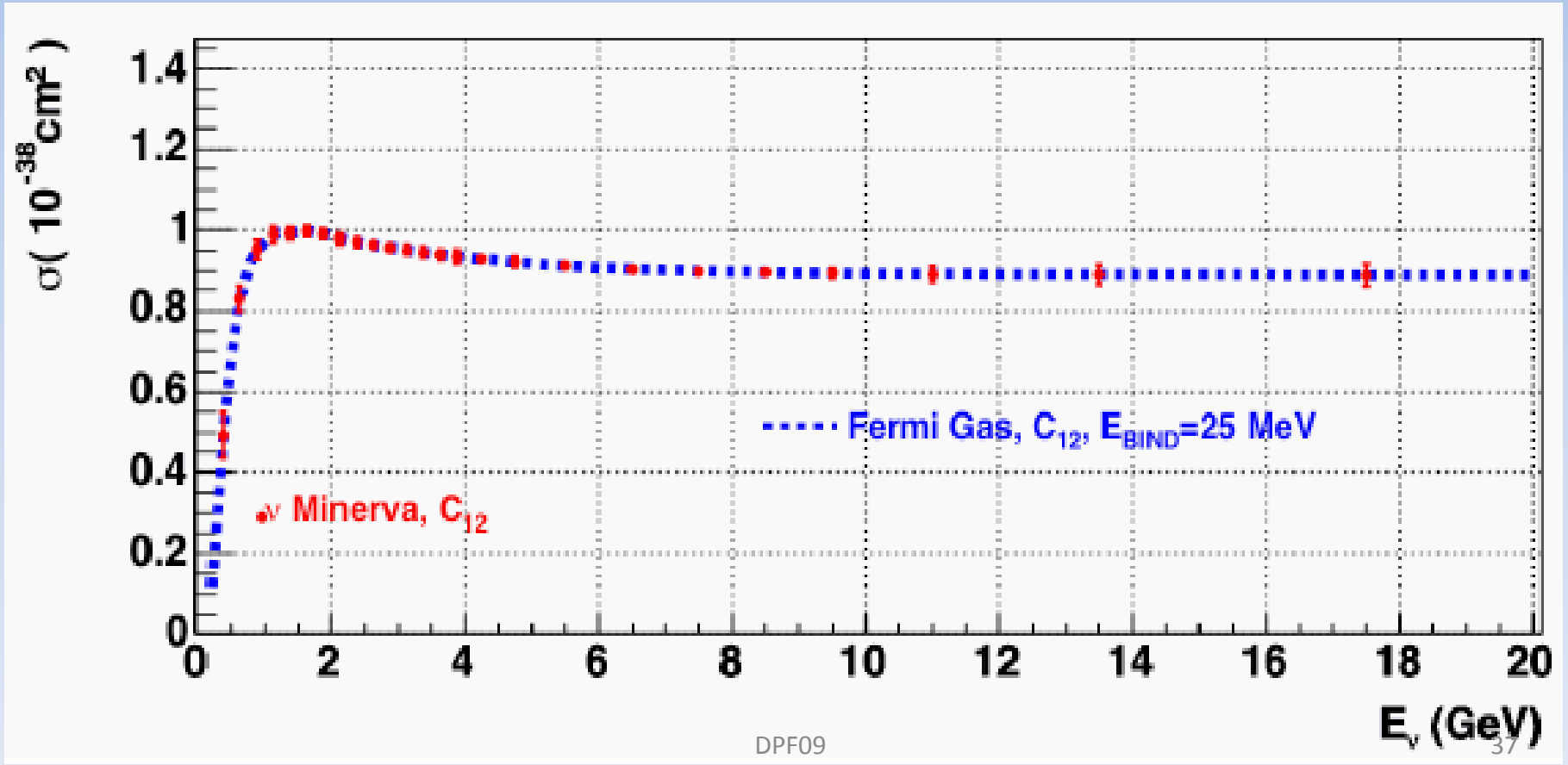
- Position resolution of 2.5mm
- Distance between center of strips is 1.7cm



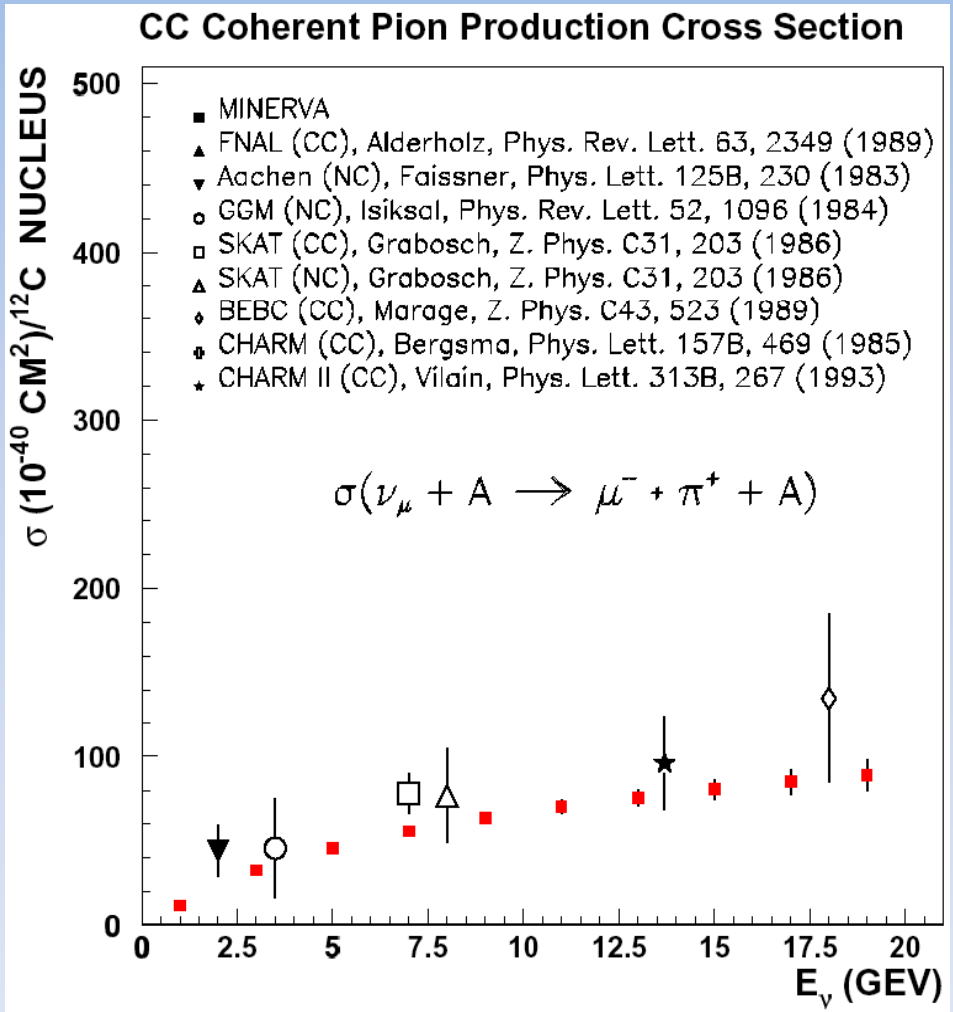


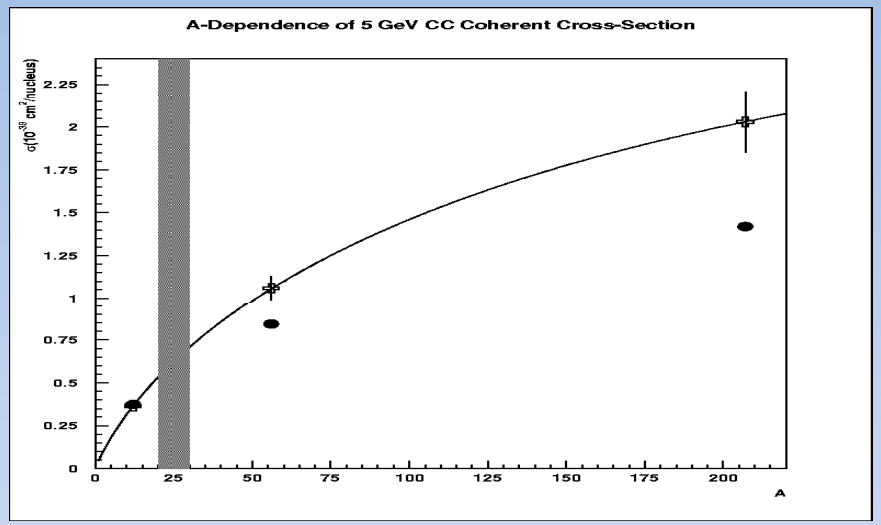
Physics: More Quasi-elastics

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

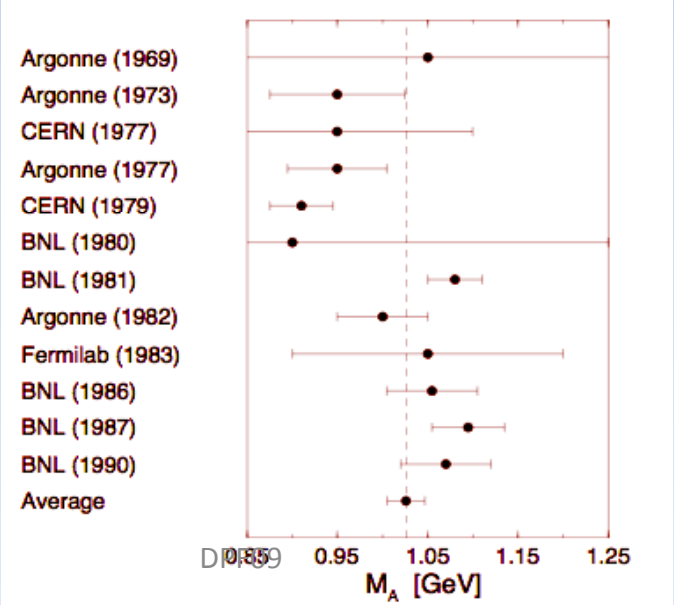
$$F_A = \frac{1.267}{\left(1 + \frac{Q^2}{M_A^2}\right)^2}$$

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

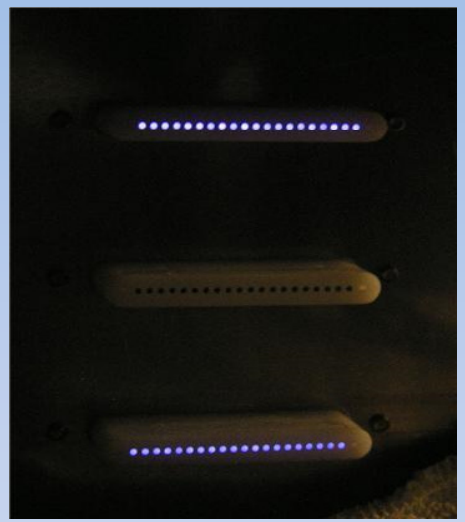
- **MINOS (Fe, Q^2>0.3)**
NuInt09, preliminary
M_A=1.26 ± 0.17 GeV

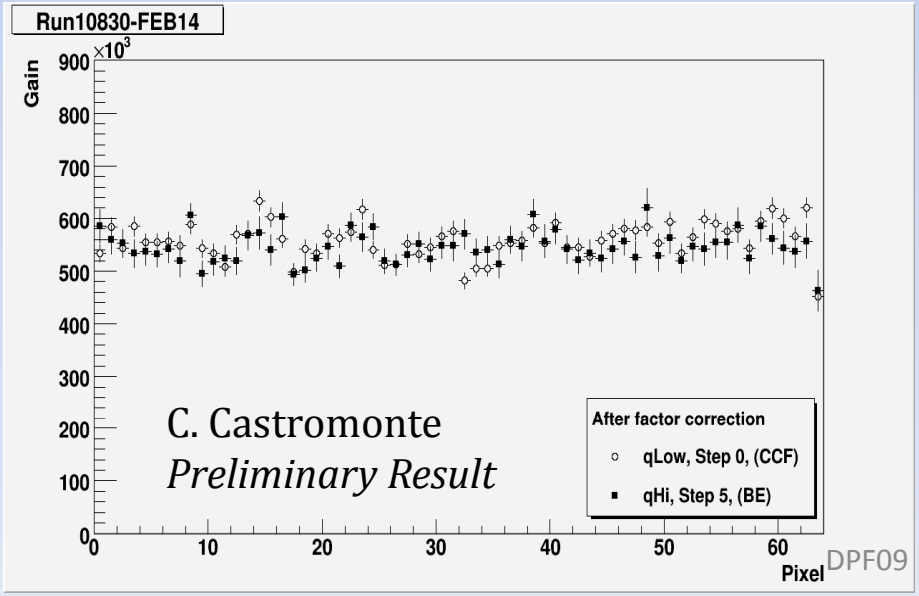


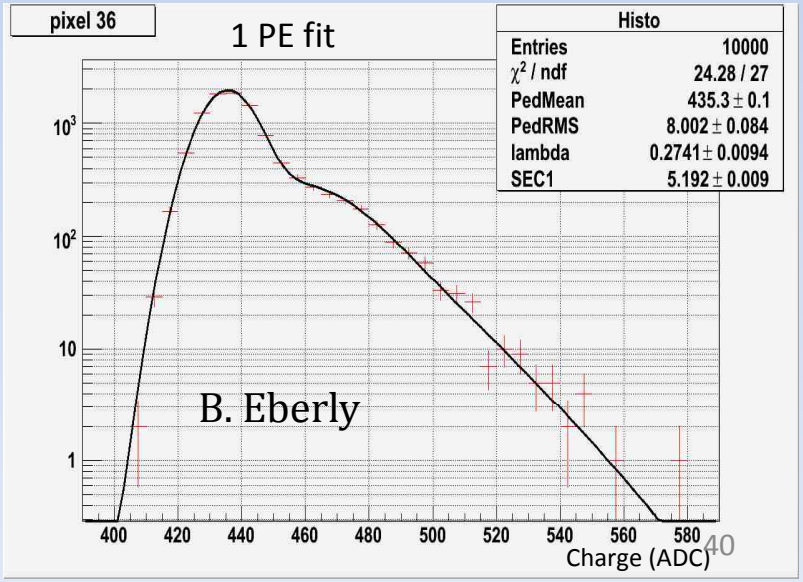
M_A (before 1990):
1.03 +/- 0.02 GeV
M_A (after 2000):
~1.2 GeV
What's going on?

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

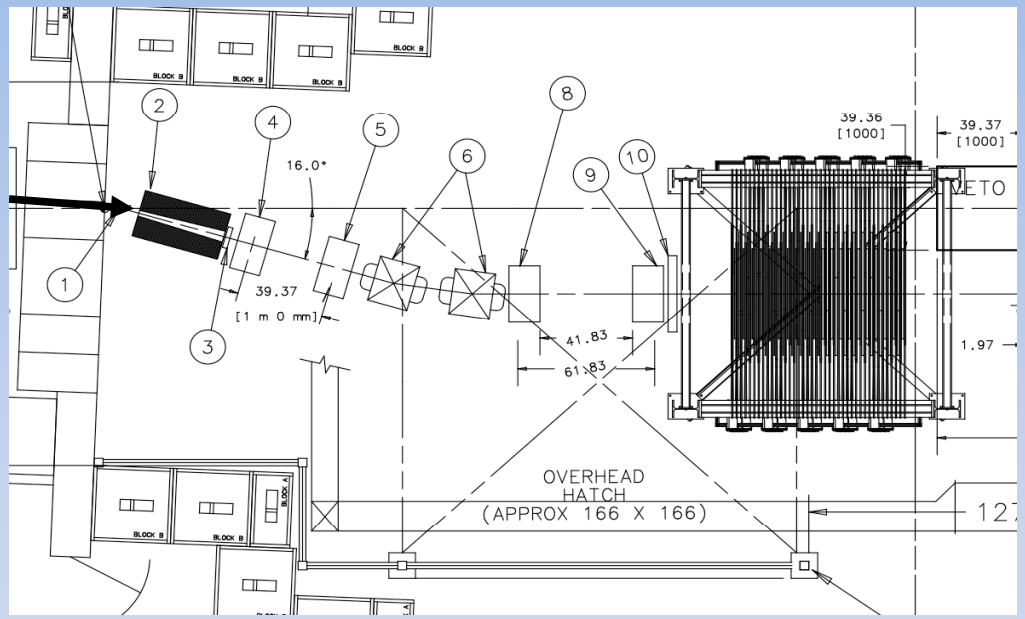


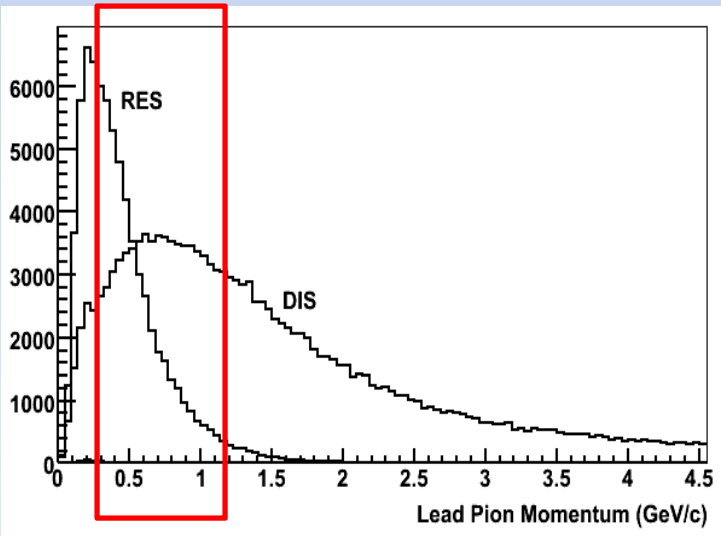


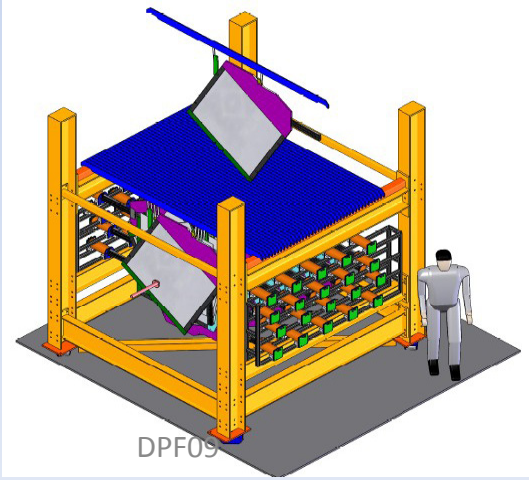


Calibrations: Test Beam

- 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



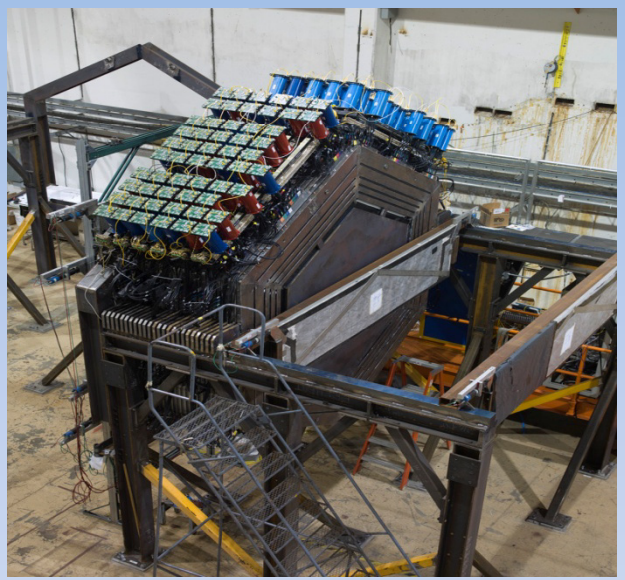




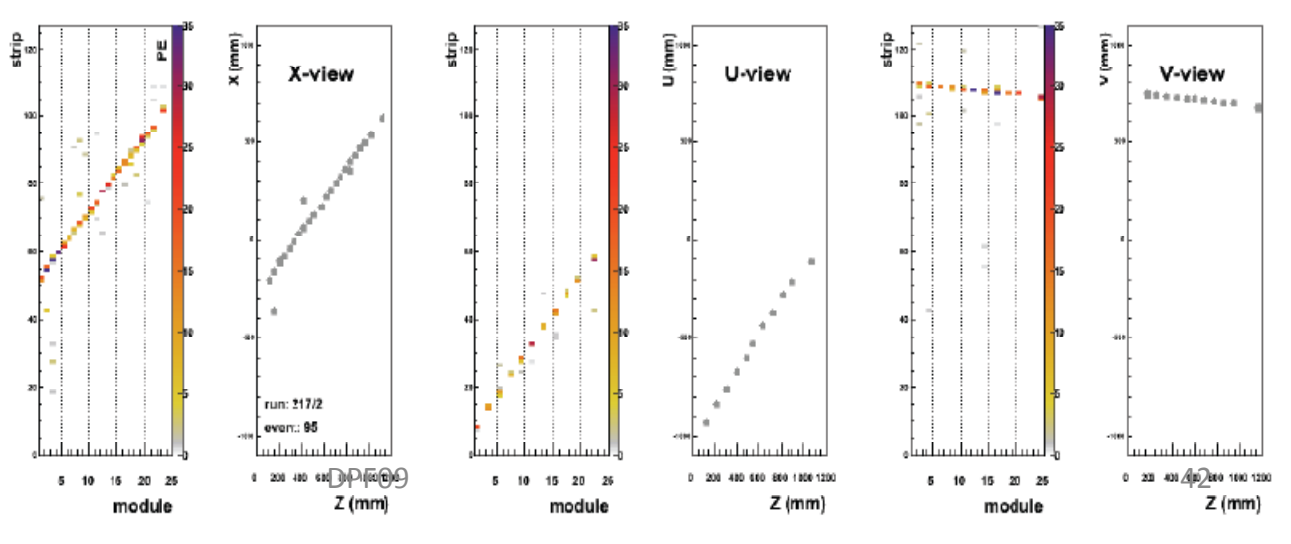
Legend:
1: Pion Beam
3,10: Time of Flight Triggers
4,5,8,9: Wire Chambers
6: Magnets

Tracking Prototype

- 24 full-sized 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)