The Design and Performance of the MINERνA Detector

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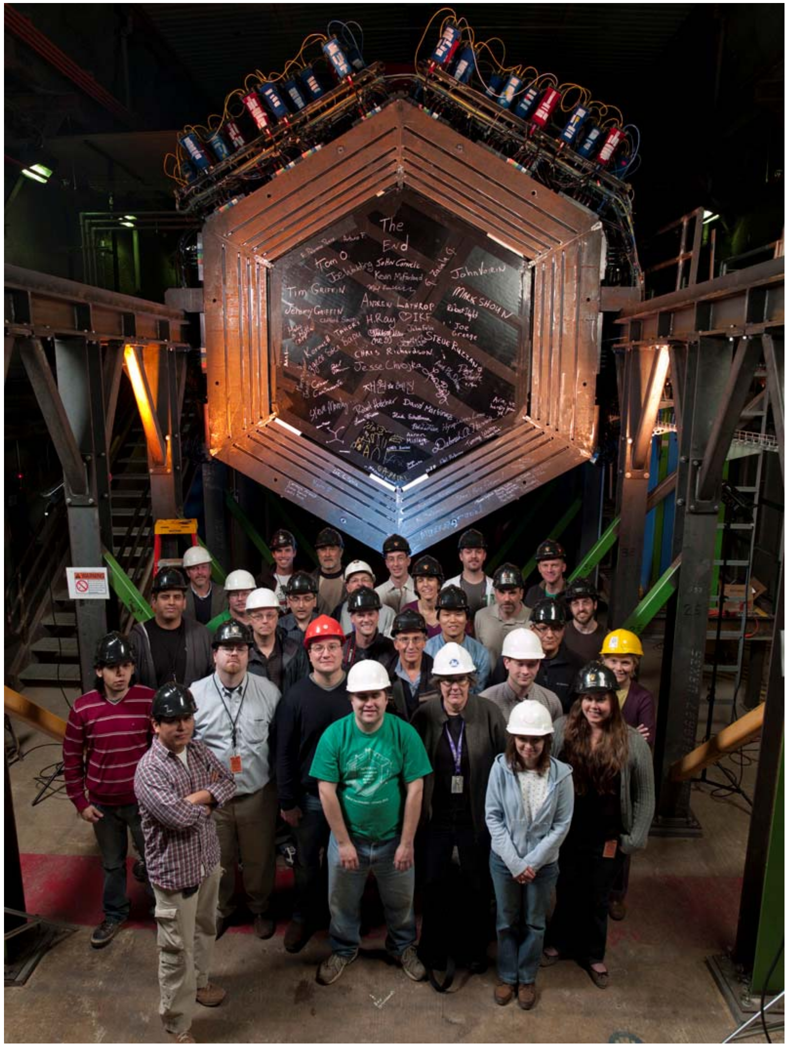
Technology and Instrumentation in Particle Physics 2011

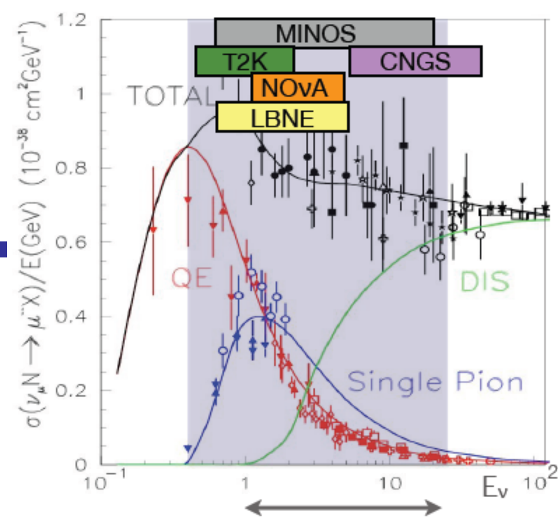
Outline

- MINERνA Goals
- MINERνA Detector
- MINERνA Event Displays
- Performance
- Test beam
- Summary

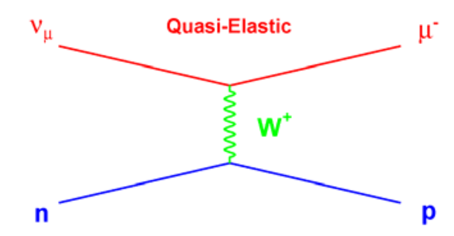


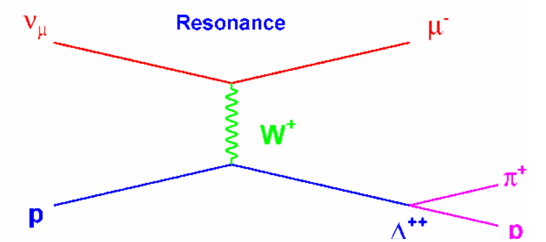
MINERνA

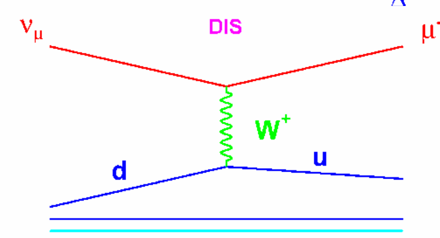
- Precision measurement, 1-10 GeV region
  - Understand the components of charged current and neutral current cross sections
    - From quasi-elastic -> deep inelastic scattering
- Study A dependence of ν interactions in a wide range of nuclei
- High intensity, well understood ν beam with fine grain, well understood detector.
- Design
  - Use existing technologies to speed the assembly as the beam is already running.
  - Make cost effective & repairable



MINERvA Coverage

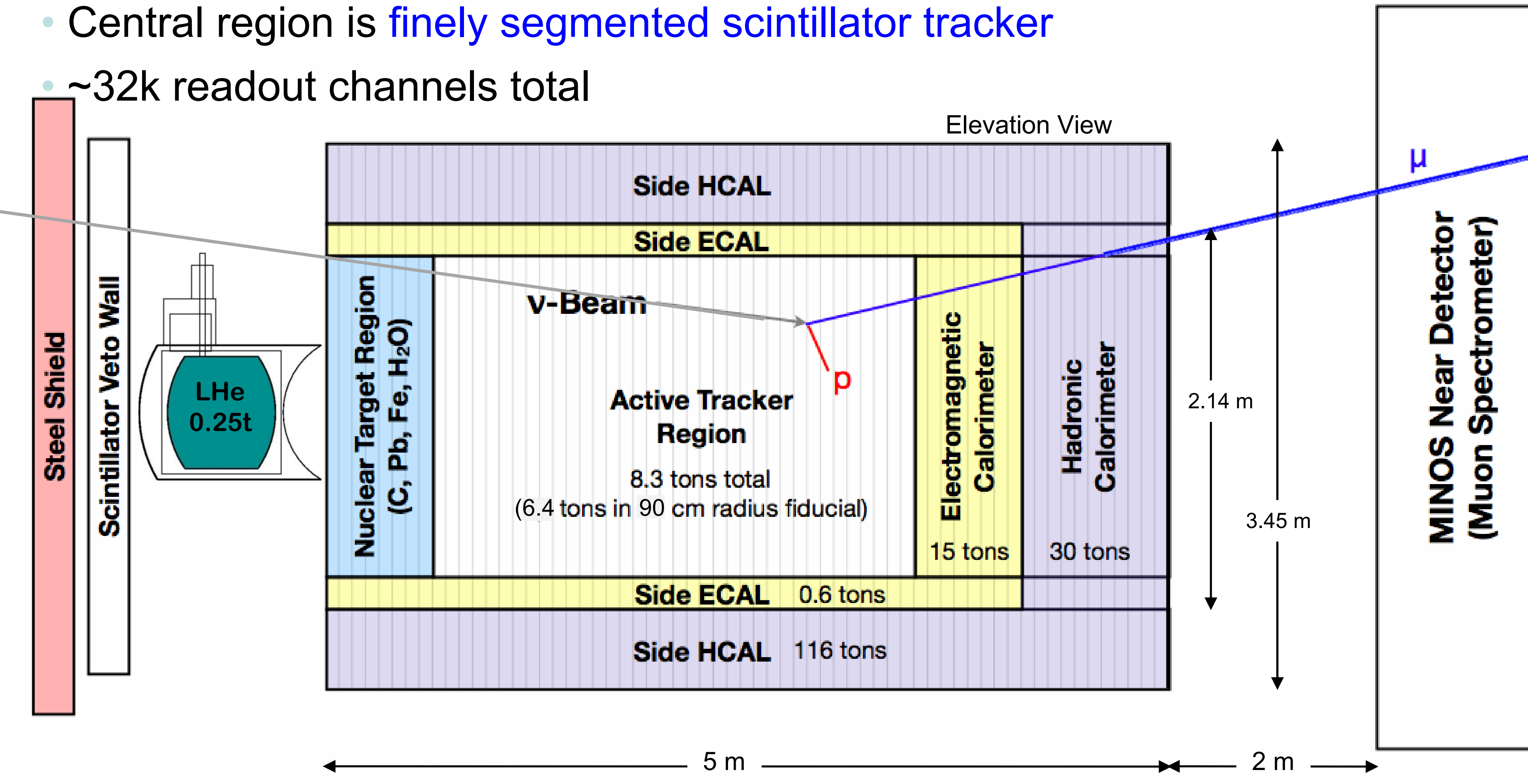






Detector Layout

- Detector comprised of 120 "modules" stacked along the beam direction
- Central region is finely segmented scintillator tracker
- ~32k readout channels total

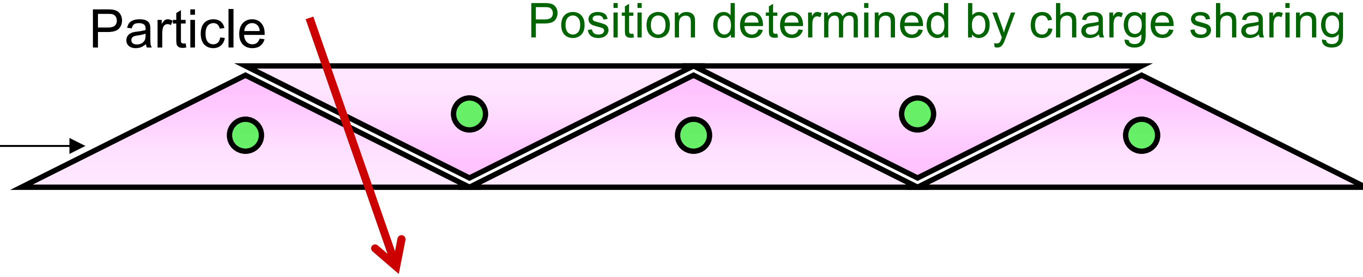


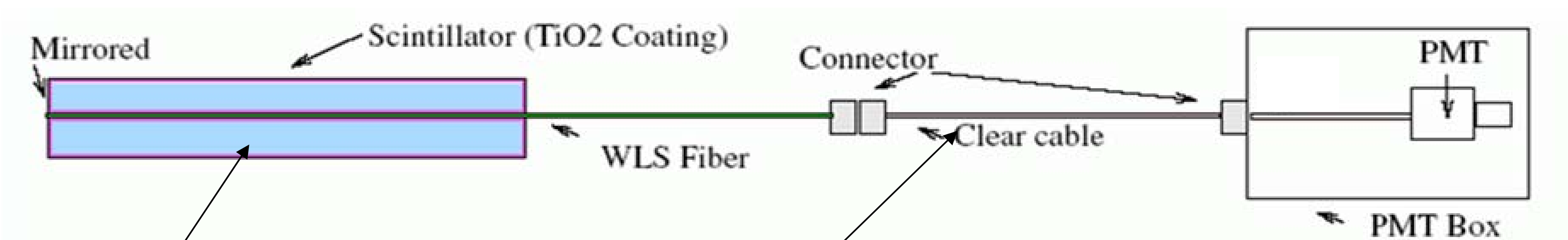
MINERνA Optics

Particle

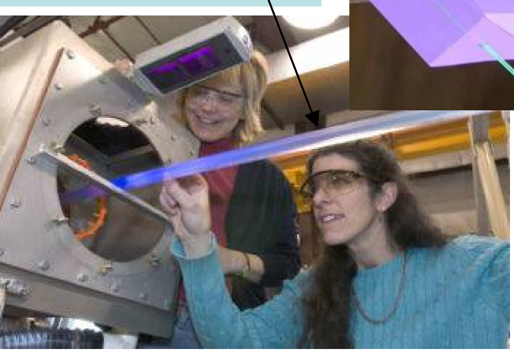
Position determined by charge sharing

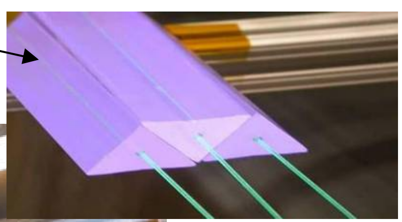
Extrusions built into planar structures.

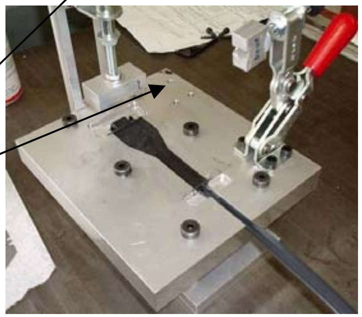




Extruded Scintillator

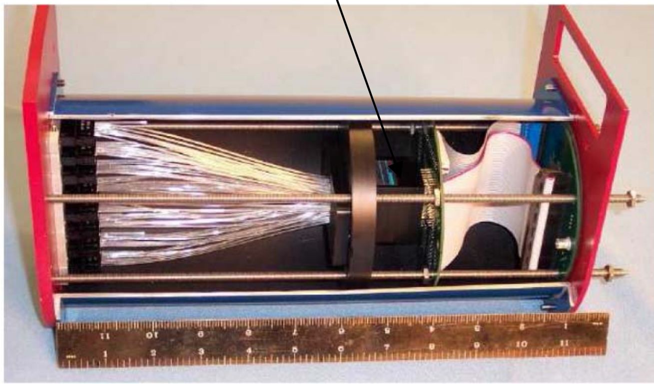




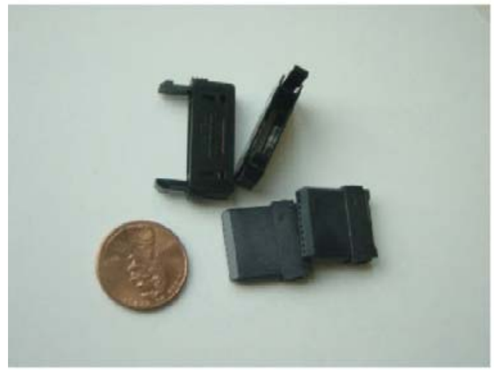


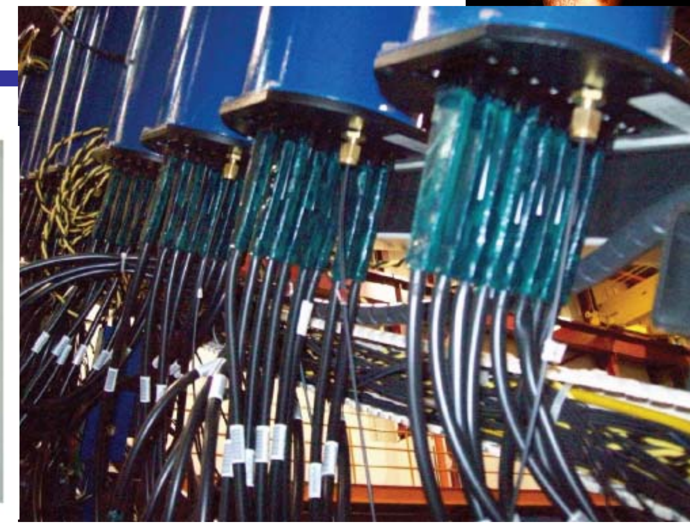
Clear Fiber Cable

64-Anode PMT



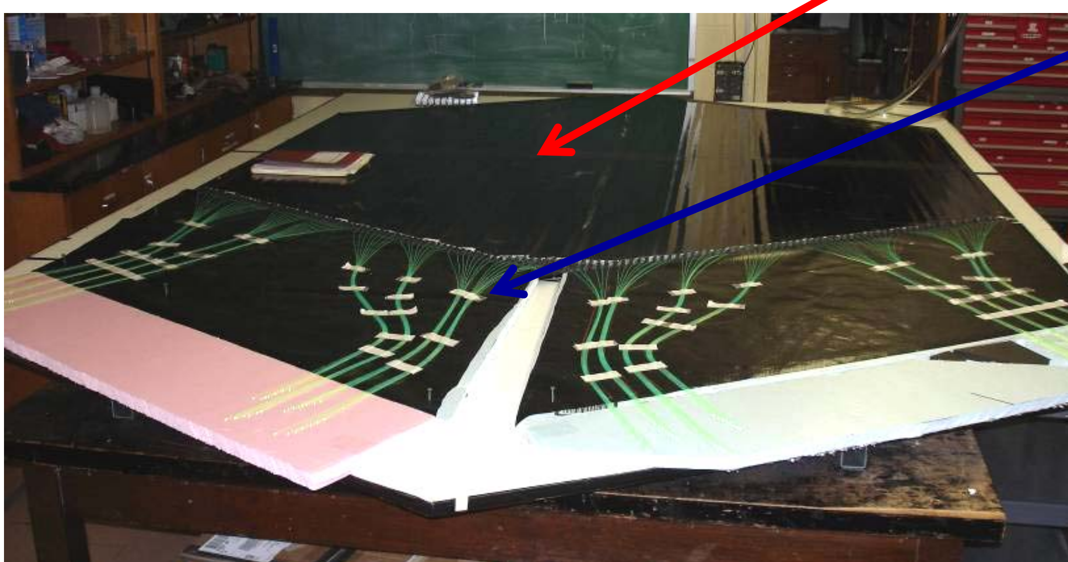
Scintillator and Fibers



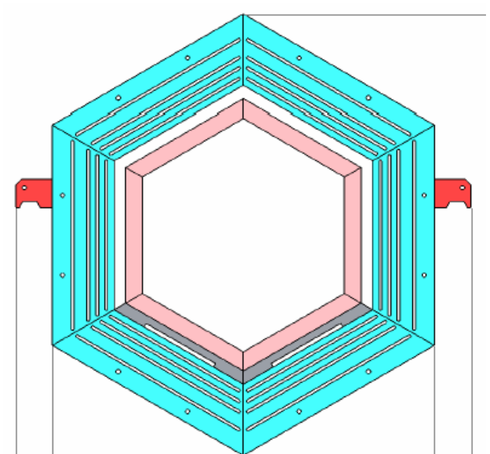


- Blue-emitting extruded plastic scintillator with a hole for a WLS fiber:
  - Scintillator produced at FNAL/NICADD Extrusion Line Facility at FNAL
- Wavelength Shifting (WLS) fiber glued into scintillator
  - 1.2 mm, 175 ppm (Y-11), S-35, multi-clad Kuraray fiber
    - Readout one end; mirror the other end (avg. WLS fiber length 2.7 m)
    - The S-35 is a more flexible fiber
- Clear fiber in light-tight optical cables takes light to PMT box & take light from optical cable to PMT
  - same fiber as WLS fiber, without dopant (“clear”):
  - Connectors design & made by DDK/Fujikura with the CDF Plug Upgrade

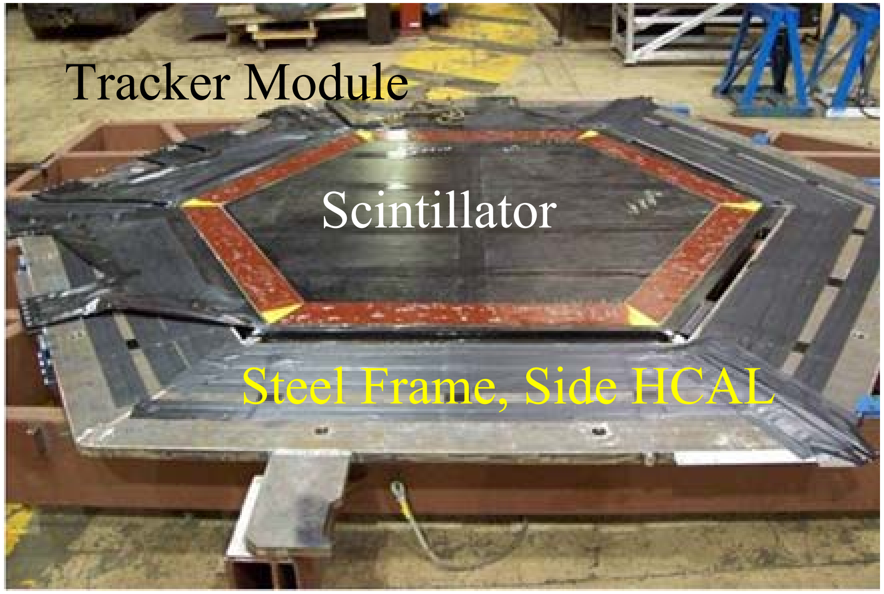
Scintillator Planes



- 1^{st} a set of scintillator pieces are glued in to "planks"
- Then these planks are glued together to form a plane
- The WLS fibers are inserted, routed to connector position and glued



Module Construction



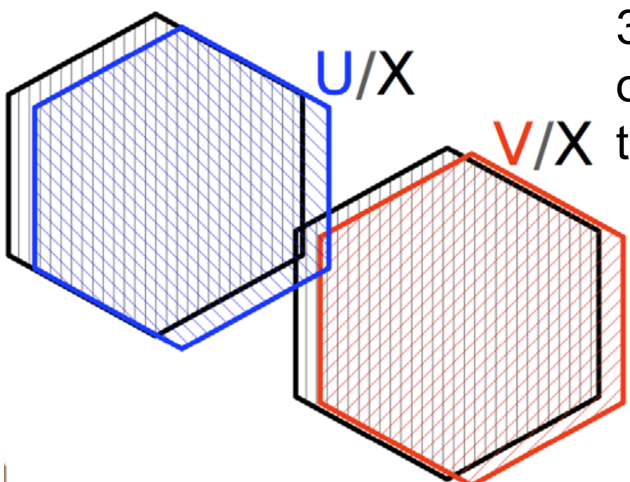
Steel + scintillator = module

Typical module:

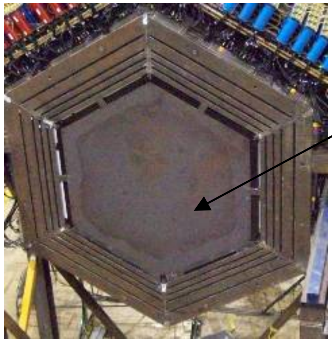
- has 302 scintillator channels
- weighs 3,000 lbs
- 3 types of modules

Full detector:

- 120 modules; ~32K channels.



3 different strip orientations for 3D tracking



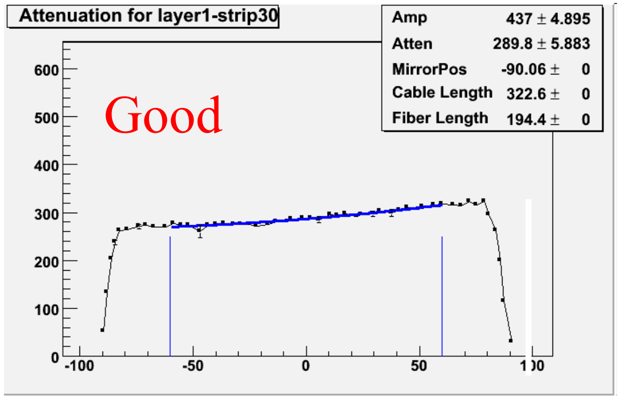
HCAL modules include 1” steel absorber

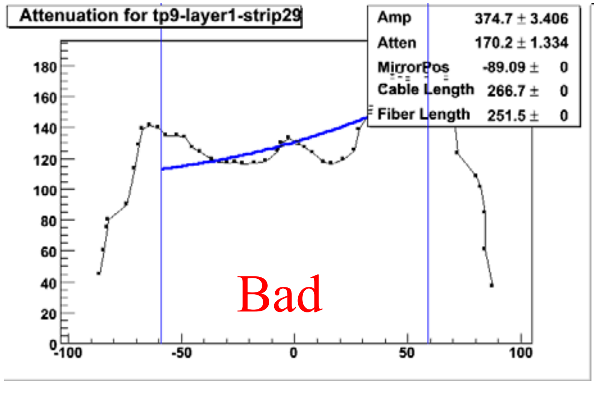
ECAL modules incorporate 2mm-thick Pb absorber

Mapping

- Source test of all modules after assembly.
- Scintillator scanned with Cs-137 source; read out scintillator response.
- Test:
  - Maps attenuation curve of each channel
  - Location of each strip
  - Localizes anomalies in scintillator or optics

Response





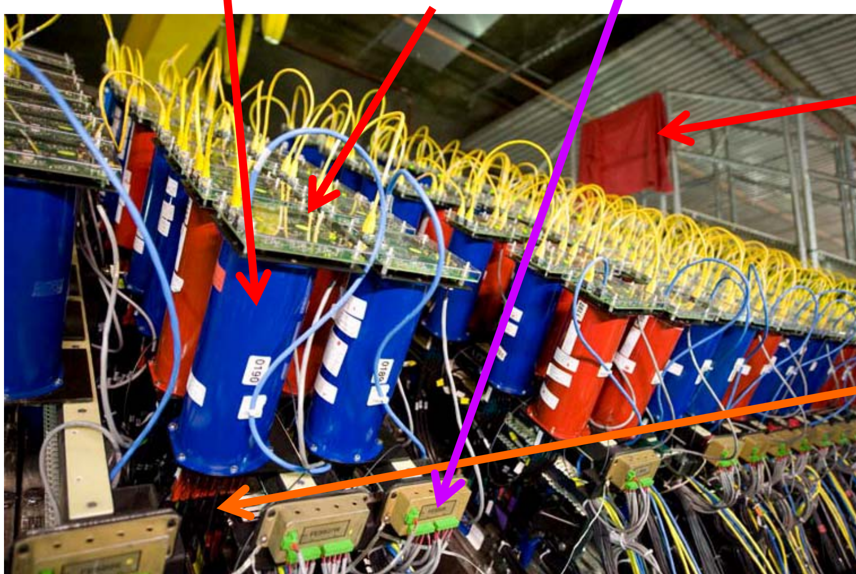
Longitudinal position

Electronics

- Front End Board (FEB)
- Designed around D0 TriP-t Chip
  - Designed at FNAL for D0 Central Fiber Tracker
  - Analogue pipeline
  - Allows storing charge for multiple events in a neutrino spill
  - Discriminator which acts a trigger for charged on channel to be stored
  - 2.5 ns timing bin resolution
- The HV to the PMT is supplied by a Cockcroft-Walton inside PMT Box
  - designed by the FNAL EE department
  - Reduces number of cables which go to PMTs
  - Reduces cost, complexity and makes detector more easily repairable

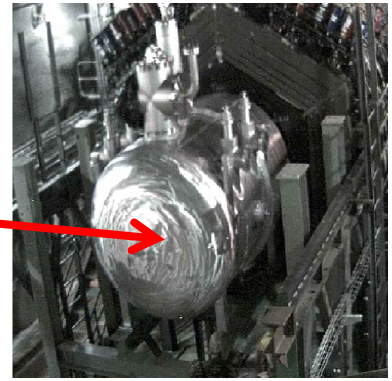
Electronics

- Daisy chain LDVS clock and data link
  - As many as 10 FEBs can be readout in one daisy chain
- 1 VME readout board can readout 4 daisy chains
- Readout all ~32000 channels with 2 VME crates, only need one rack
- Movable platform can be moved over any PMT or FEB
  - enabling the detector to be repairable
- Optical cables without screws enables the PMTs to easily replaced.
  - Replaced 14 PMTs

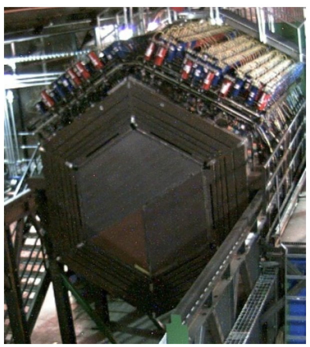


Broad Range of Nuclear Targets

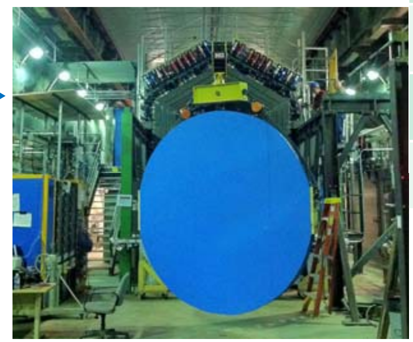
- 5 nuclear targets + water target
- Helium target upstream of detector



Target	Mass in tons	CC Events In 4E20POT
Scintillator	6/43	1360K
He	0.25	56K
C (graphite)	0.17	36K
Fe	0.97	215K
Pb	0.98	228K
Water	0.39	81K

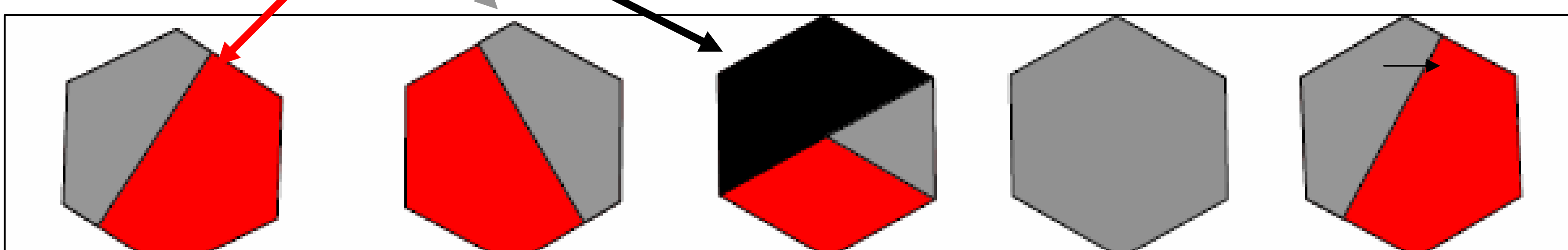


Water target →



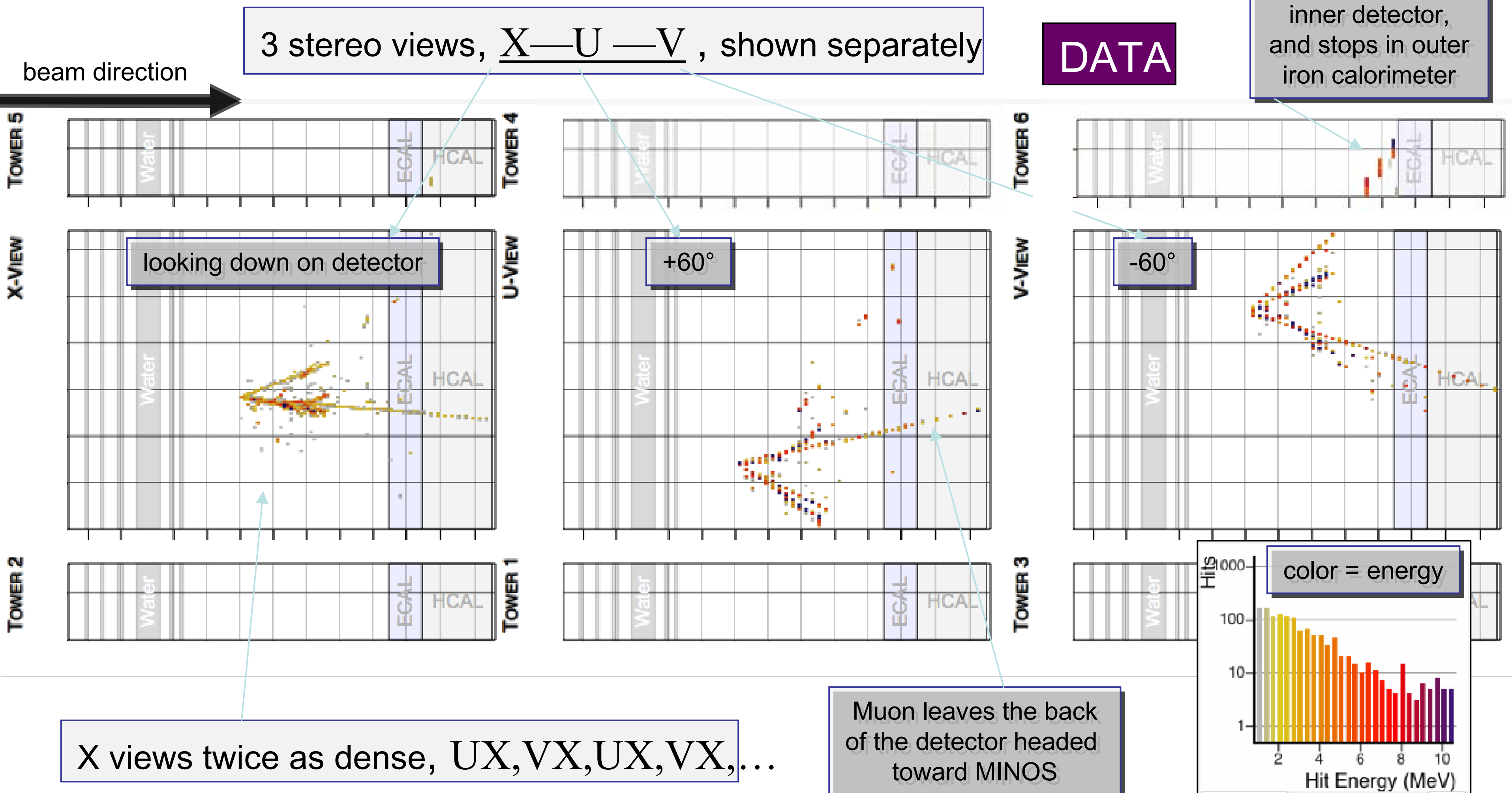
5 Nuclear Targets

Fe Pb C



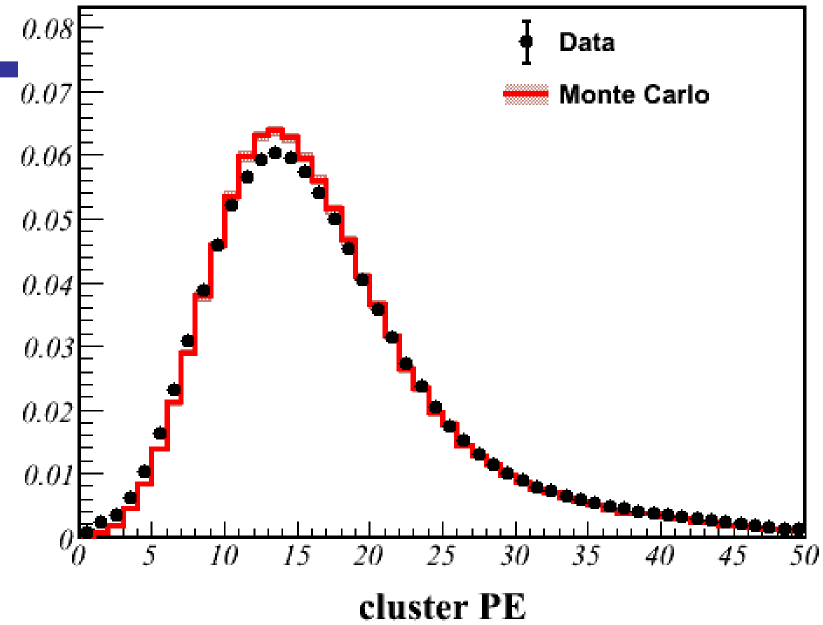
Event Display

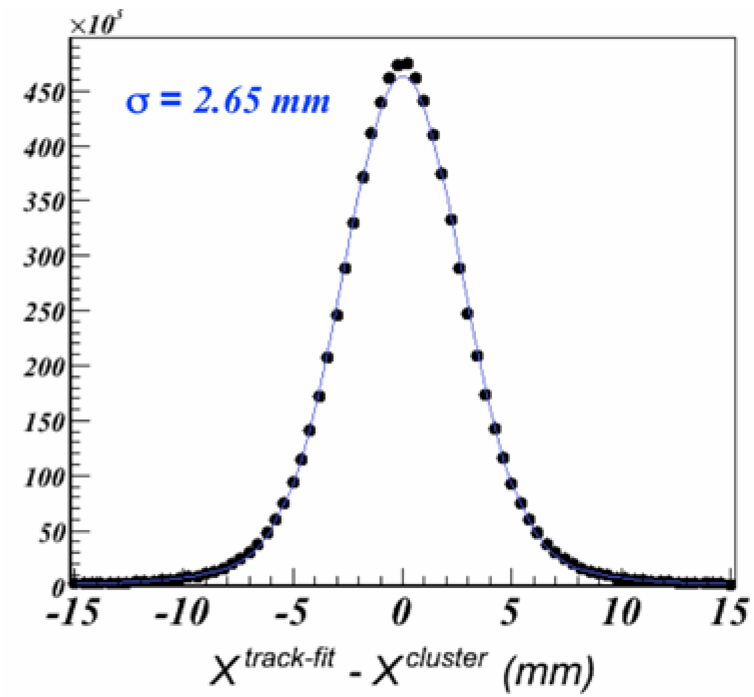
- **MINERνA shows fine details of the event**

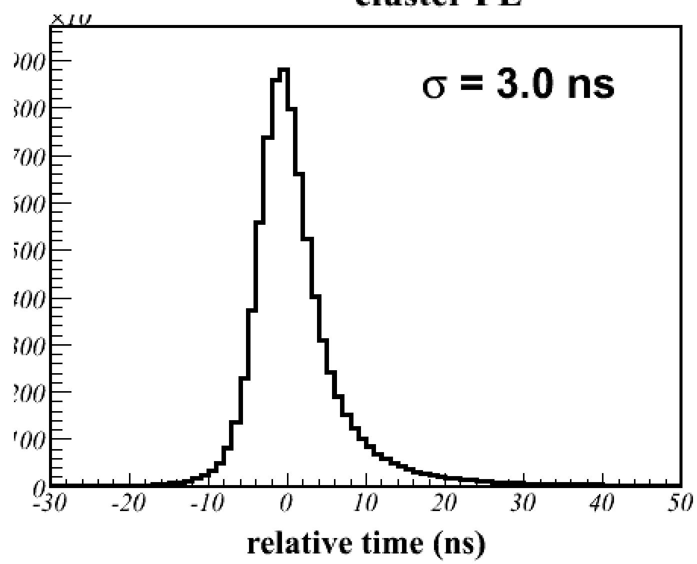


Detector Performance

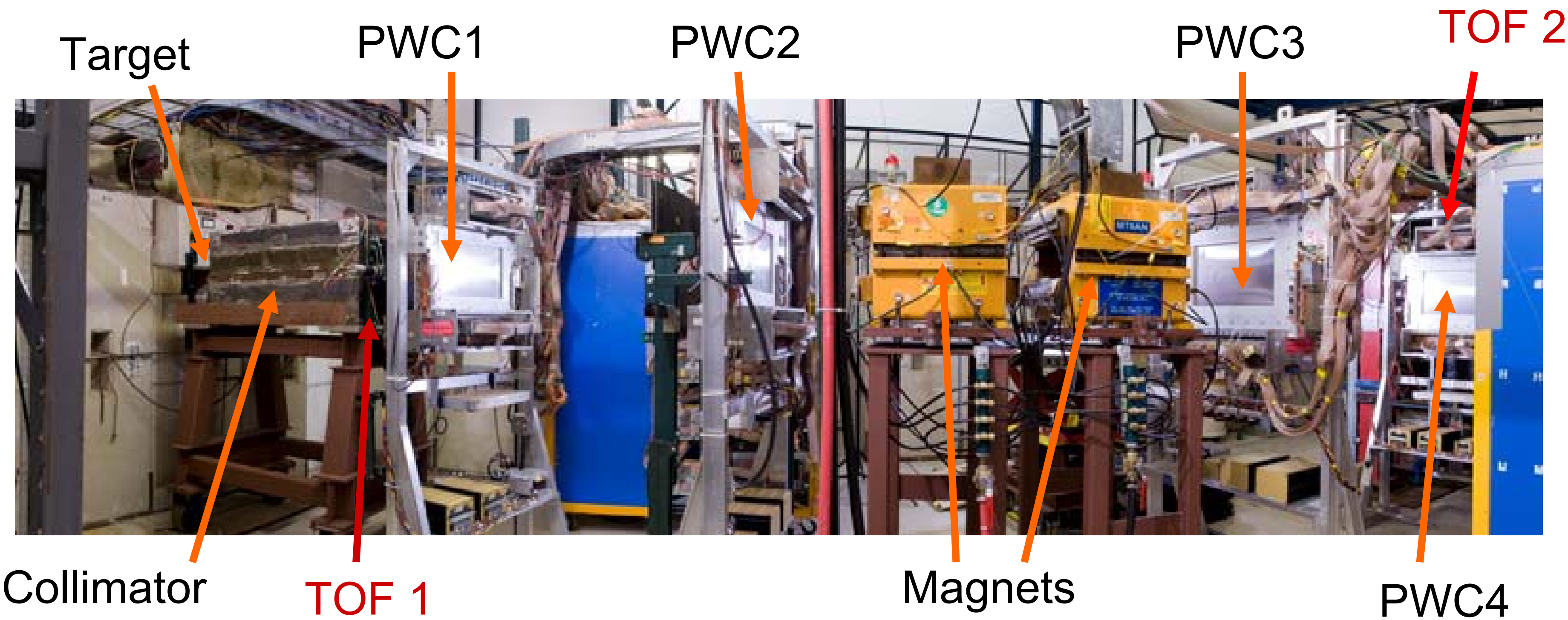
- PE/ layer for MIP, 1.7 cm scintillator
- Timing resolution – 3 ns σ
  - Track time – time in a layer
  - Resolution determined by light
- Track position – position in layer





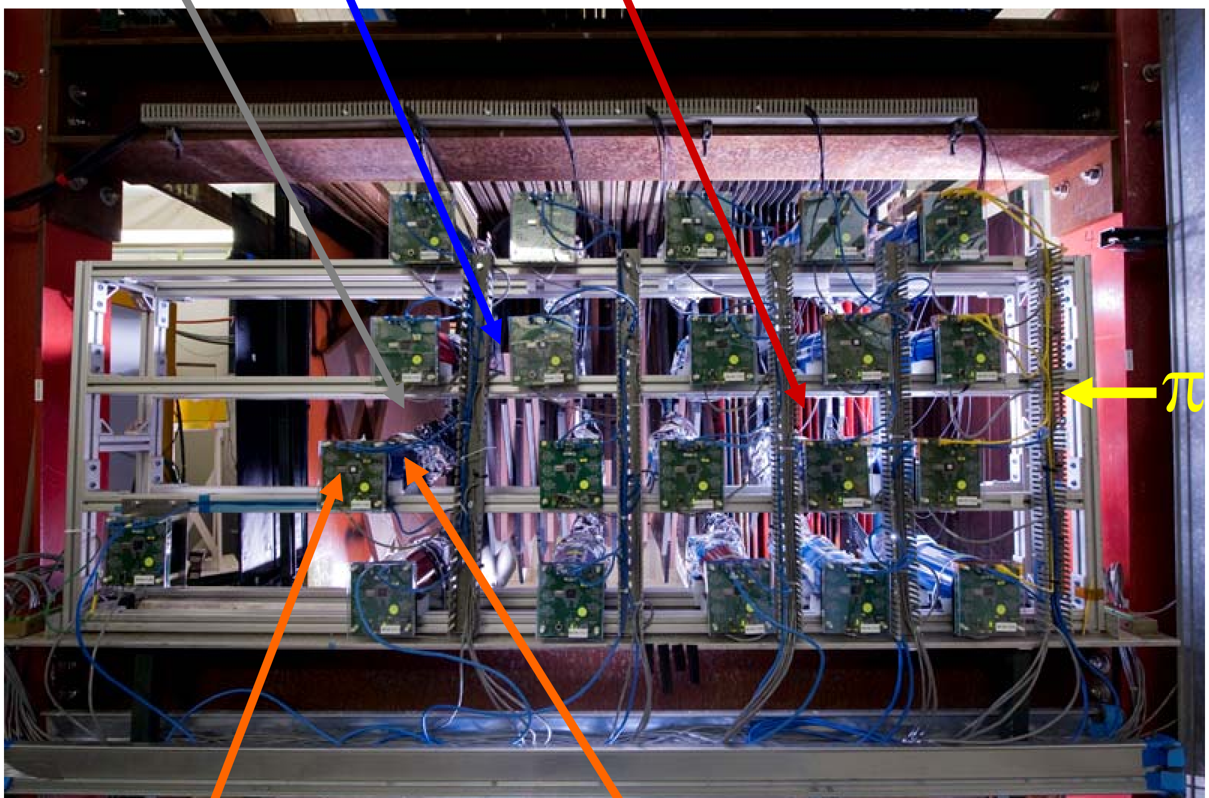


Low Energy Beam Facility



- Tertiary beam, built by the MINERνA collaboration in conjunction with Fermilab Test Beam Facility
- In coming 16 GeV $\pi \rightarrow \pi$, proton beam from 0.4-1.5 GeV
- Time of flight (TOF) scintillator counters, measures transit time of particles
  - TOF 1 upstream of PWC1, TOF 2 downstream of PWC4
- The beamline and MINERνA DAQ merged for full event reconstruction

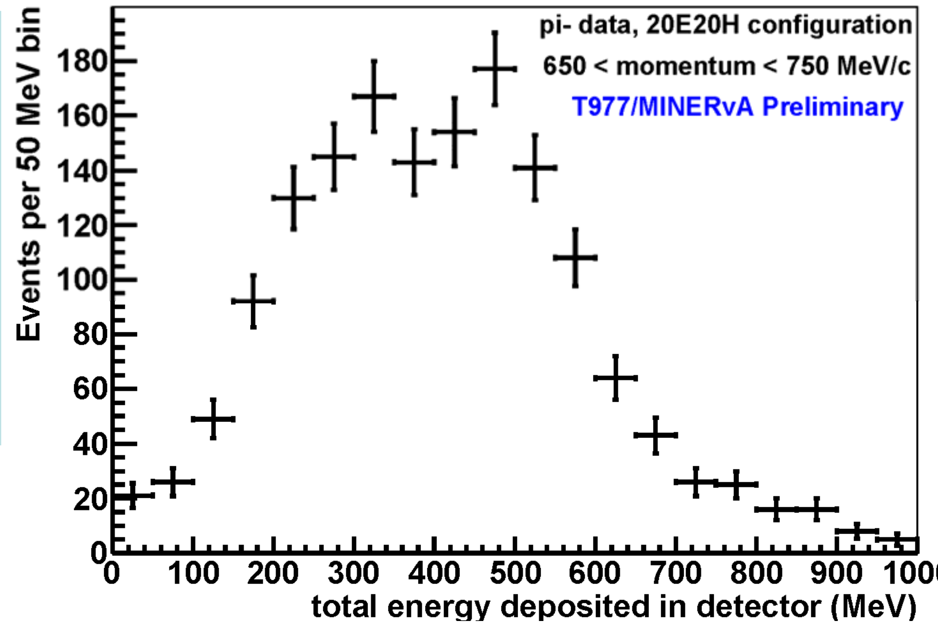
MINERνA Test Beam

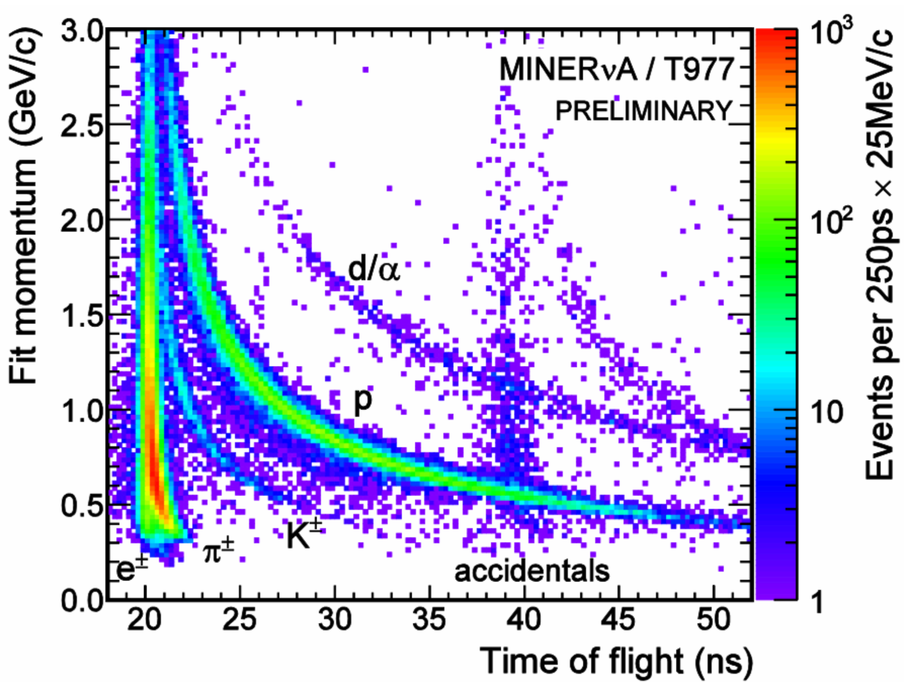


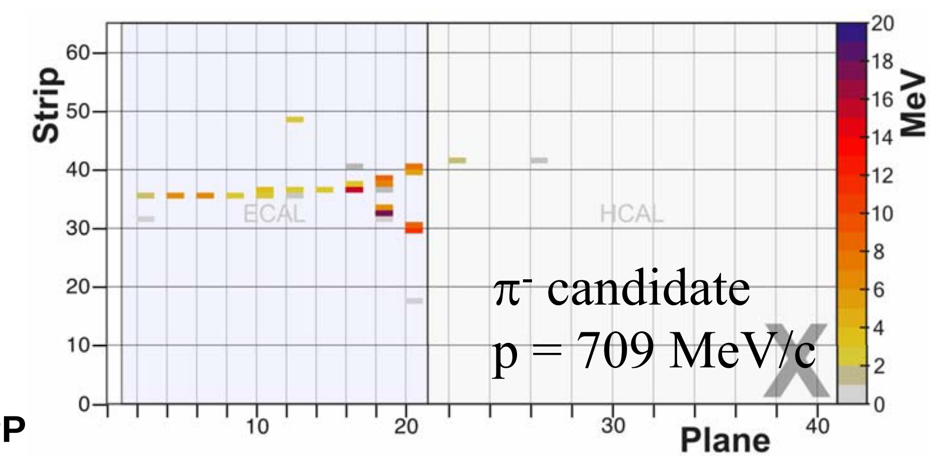
- In order to make precise measurements we need a precise a calibration
  - Low energy calibration
- 40 planes, XUXV,1.07 m square
- Reconfigurable can change the absorber configuration. Plane configurations:
  - 20ECAL-20HCAL
  - 20Tracker-20ECAL

Detector Calibration

- TOF to distinguish π & protons
- Plot show beam data
  - π^- in 20 ECAL 20 HCAL
  - $650 < p_\pi < 750$ MeV/c
  - 107k passing beam cuts, - & +







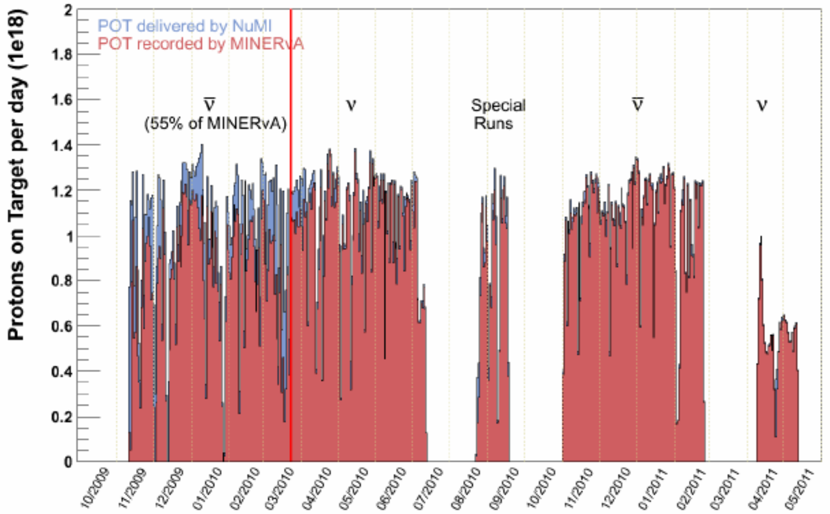
Summary

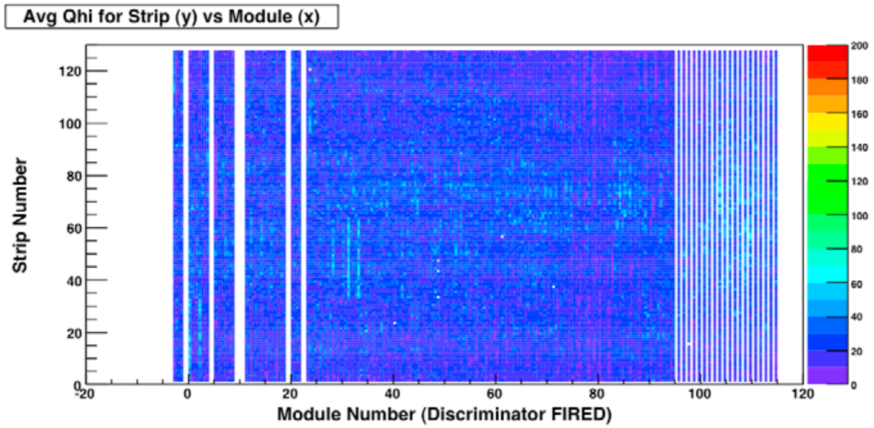
- MINERνA was constructed using existing technologies
  - Enabling detector to come on sooner with better understood costs and schedules.
  - The performance meets the design goals
  - The hardware is designed to be accessible to enable it to be repairable.
- We are on the air !
- Detector working very well
- Precision measurement of various cross section and support current and future ν experiments
  - QE, Resonance, DIS,
- Analysis is proceeding, Preliminary results are being present in conferences.

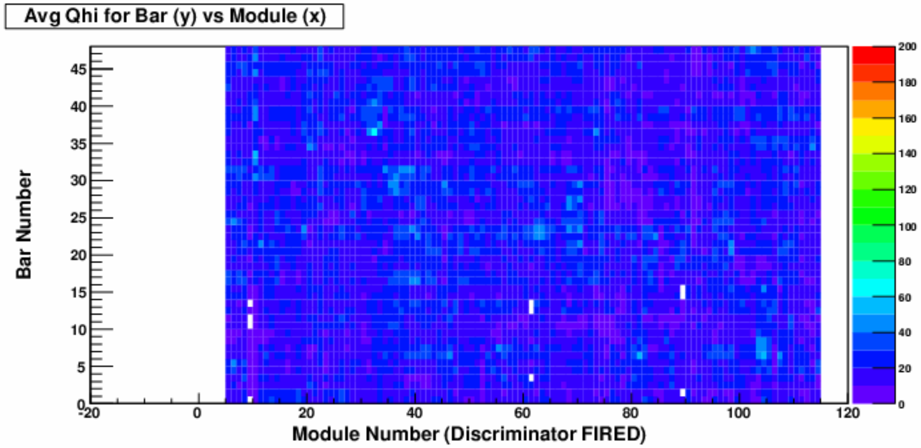
Back-up Slides

MINERνA Running Status

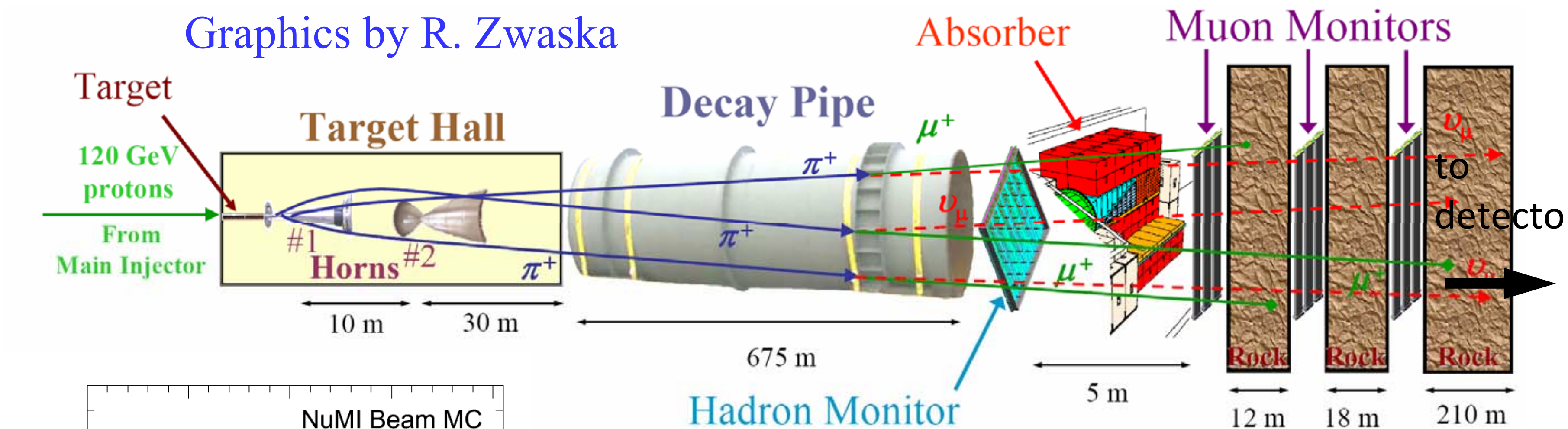
- Accumulated 1.3×10^{20} Protons on Target of anti-ν beam with full detector
- Accumulated 1.5×10^{20} POT in Low Energy neutrino Running with full detector
- Detector Live times typically above 98%
- Less than 20 dead channels out of 32k channels

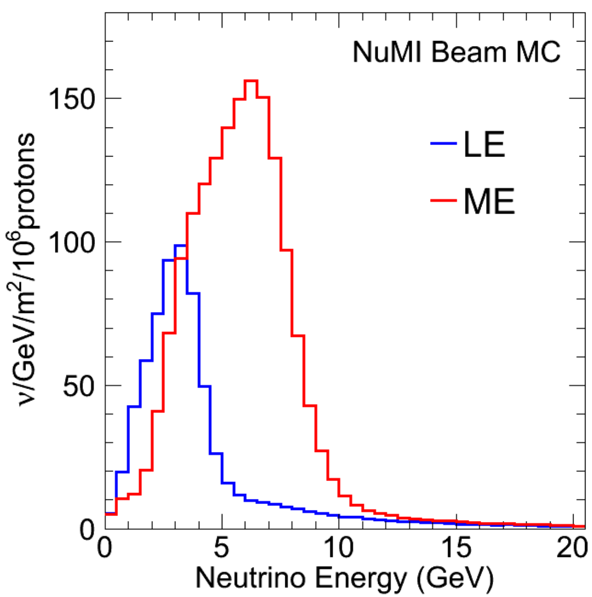






NuMI Beamline





- 120 GeV P Beam $\rightarrow$ C target $\rightarrow$ π^{+-} & K^{+-}
- 2 horns focus π^+ and K^+ only
- Mean E_ν increased by moving target upstream
- π^+ and $K^+ \rightarrow \mu^+\nu_\mu$
- Absorber stops hadrons not μ
- μ absorbed by rock, $\nu \rightarrow$ detector
- Before mid 2012 LE beam, After 2012 ME beam