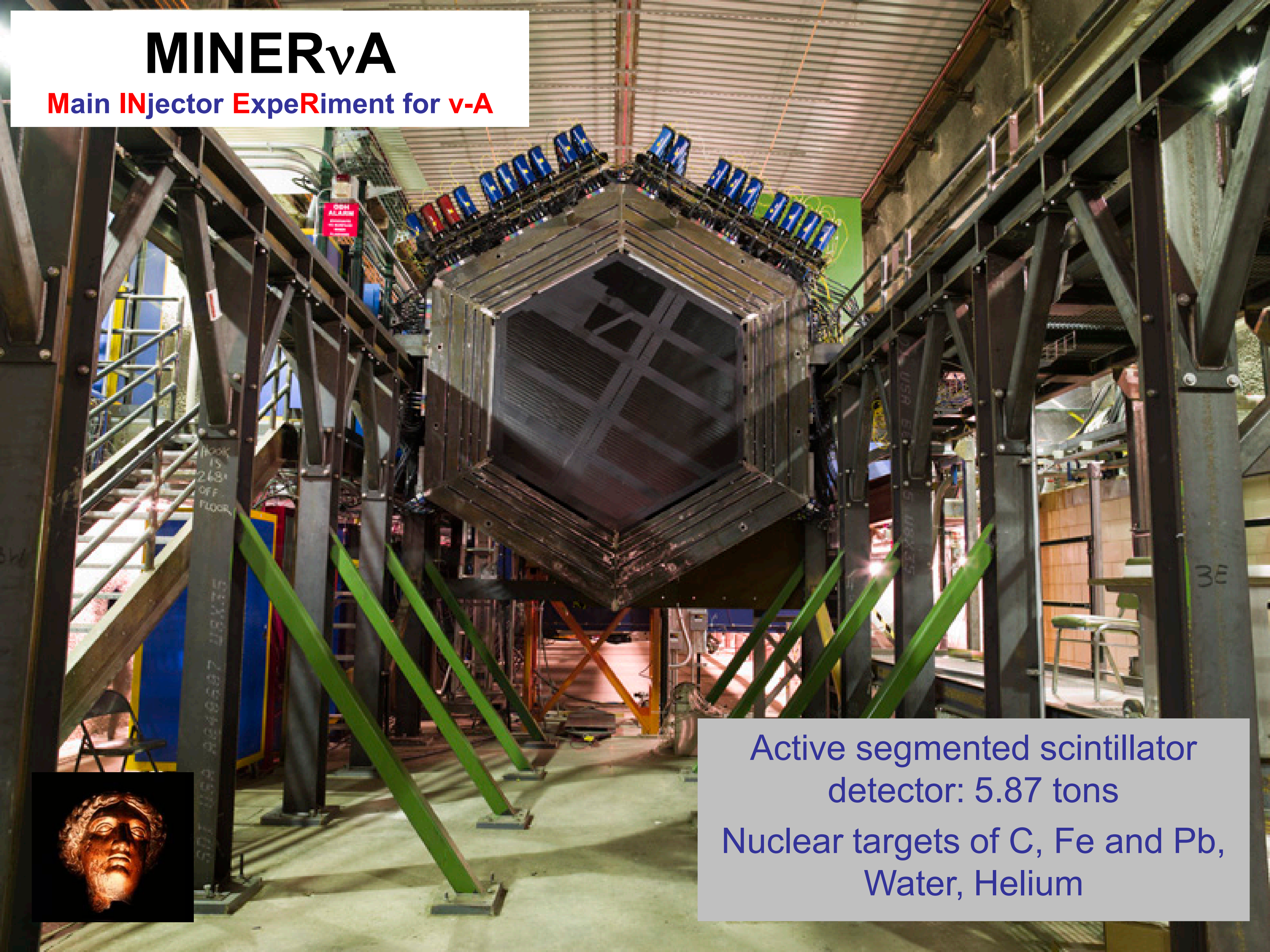
MINERνA

Main INjector ExpeRiment for ν-A



Active segmented scintillator detector: 5.87 tons

Nuclear targets of C, Fe and Pb, Water, Helium

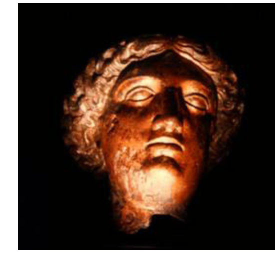
MINERvA in Brief

- MINER*v*A is a compact, fully active neutrino detector designed to study neutrino-nucleus interactions with unprecedented detail

- The detector is located in the NuMI beam line directly upstream of the MINOS Near Detector

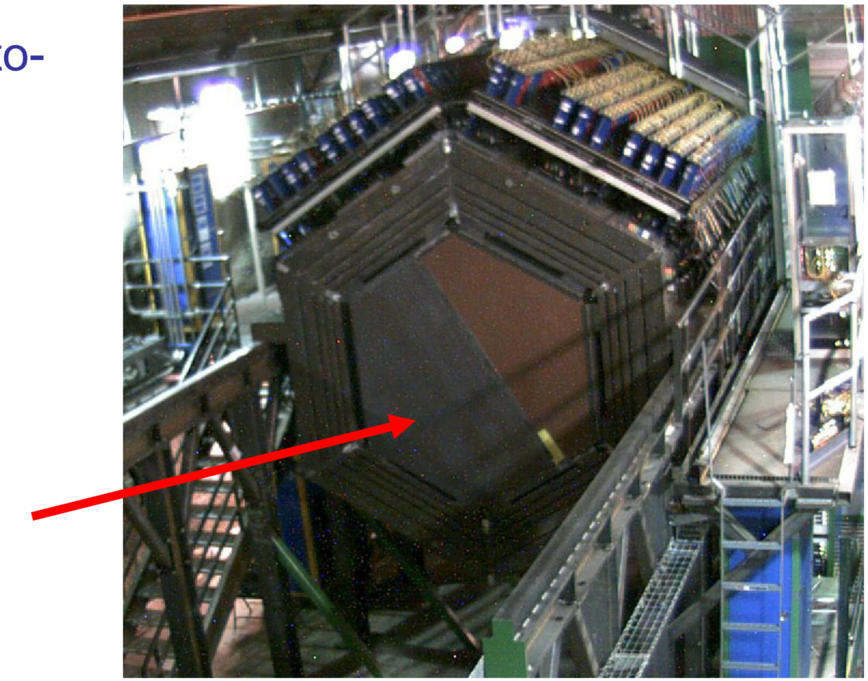
- MINERvA is unique in the worldwide program
  - The NuMI beam intensity provides
    - An opportunity for precision neutrino interaction measurements
    - A wide range of neutrino energies
  - The detector, with several nuclear targets, allows a first study of nuclear effects in neutrino interactions
  - MINERvA provides crucial input to current & future oscillation measurements

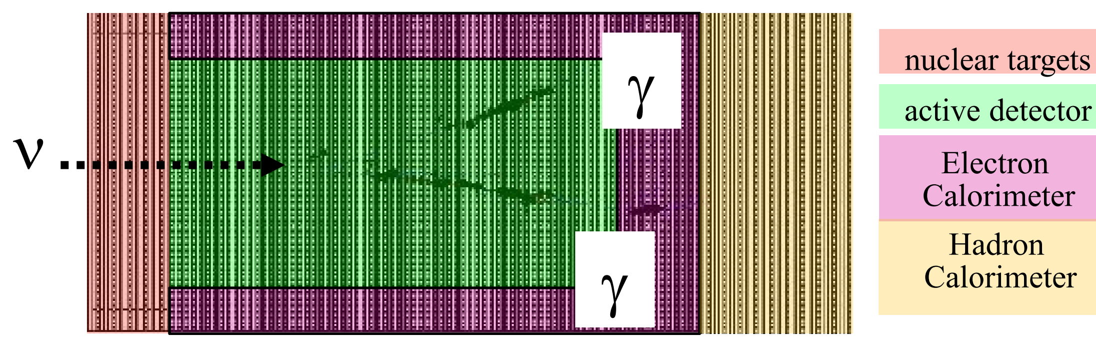
- The MINERvA Review Timeline
  - FNAL PAC Stage 1 Approval April 2004
  - CD-0 granted June 2006
  - DOE Combined CD-1/2/3a Review December 2006
  - CD-1/2/3a granted March 2007
  - DOE CD-3b Review August 2007
  - CD-3b granted November 2007
  - CD-4 projected: Spring/Summer 2010



MINERvA's Detector

- MINER*v*A's active detector is scintillator read out by fibers into a multi-anode photo-multiplier tube
- Fine segmentation of scintillator allows:
  - Tracking (including low momentum recoil protons)
  - Particle identification
  - 3 ns (RMS) per hit timing (track direction, identify stopped *K*)
  - Passive nuclear targets interspersed
- Core surrounded by electromagnetic and hadronic calorimeters
  - Photon (π^0) & hadron energy measurement
- MINOS Near Detector as muon catcher





MINERvA and Oscillations

The 2004 ***APS Multidivisional Neutrino Study Report*** which set a roadmap for neutrino physics predicated its recommendations on a set of assumptions about current and future programs including:

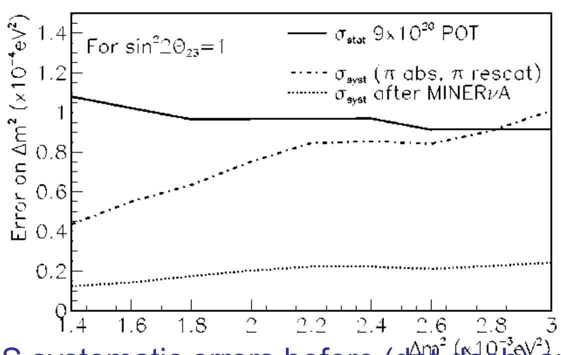
support for current experiments, international cooperation, underground facilities, R&D on detectors and accelerators, and

"determination of the neutrino reaction and production cross sections required for a precise understanding of neutrino-oscillation physics and the neutrino astronomy of astrophysical and cosmological sources. Our broad and exacting program of neutrino physics is built upon precise knowledge of how neutrinos interact with matter."

MINERvA and Oscillations

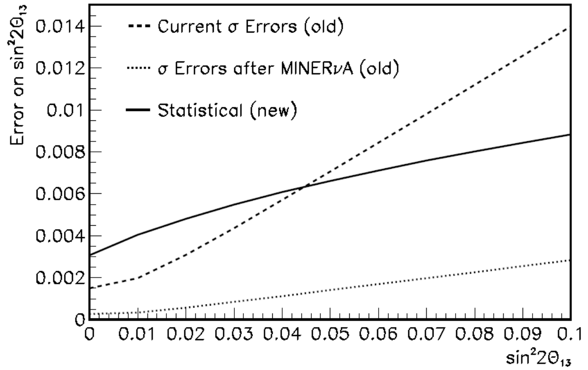
- MINERvA helps oscillation physics
  - by studying effect of nuclear medium on signal and background processes
  - by studying backgrounds over a wide neutrino energy range
- NuMI beam and nuclear targets are unique, enabling technologies

- MINOS: MINERvA can help with better Intranuclear Rescattering Measurements

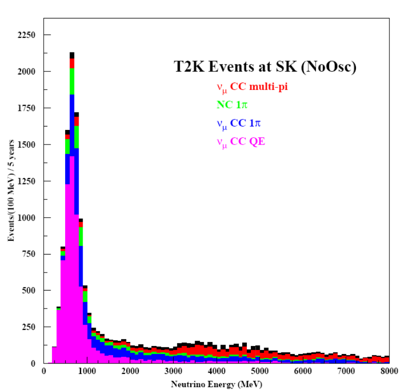


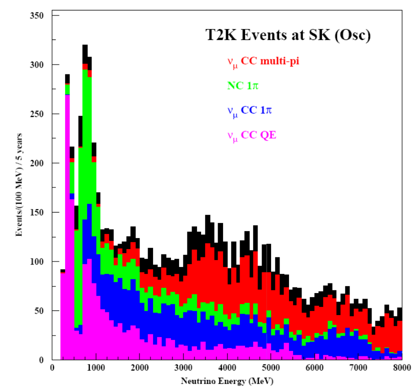
MINOS systematic errors before (dot-dash) and after (dot-dot) input from MINERvA

- NOvA: MINERvA distinguishes both background and SIGNAL cross sections in way that NOvA near detector cannot

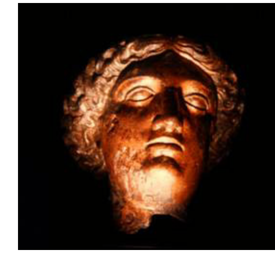


- T2K: MINERvA helps by measuring backgrounds from high energy neutrinos that the T2K near detectors cannot access



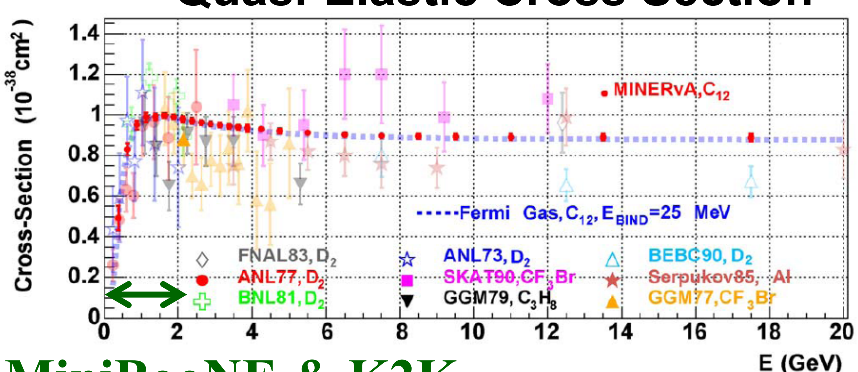


MINERvA and Cross Section Measurements (examples)



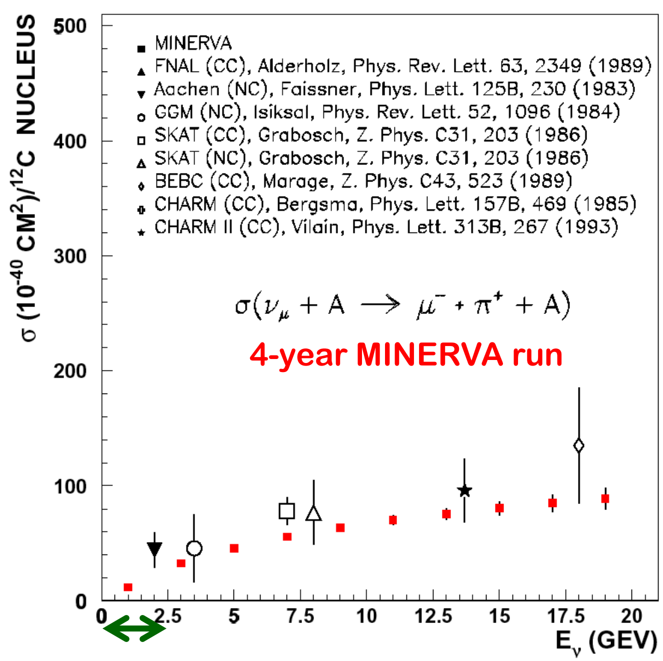
- Quasi-elastic Cross Section
  - First precise measurements at high Q^2 of proton axial form factor
  - First study in nuclear modification of form factors conjectured at low Q^2
- Coherent π production Cross Section
  - Overwhelming statistics (> 100 increase)
  - Wide energy range
  - Range of nuclear targets (C, Fe, Pb, H_2O, He)
  - MINERvA is in a position to measure this important background for ν_e appearance and to check recent surprising K2K null result

Quasi-Elastic Cross Section

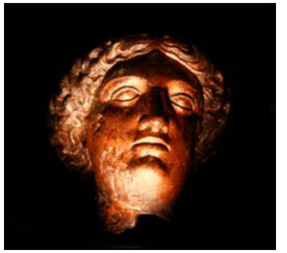


MiniBooNE & K2K measurements

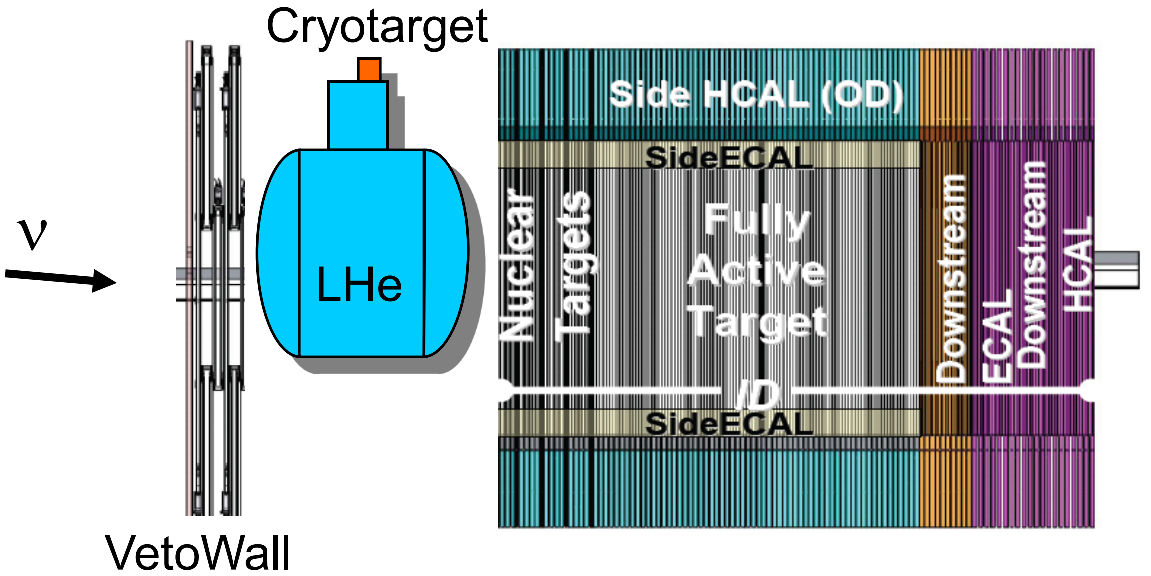
CC Coherent Pion Production Cross Section



MiniBooNe & K2K

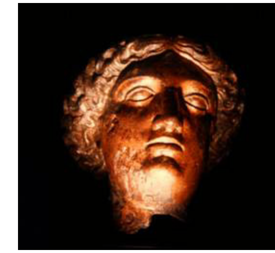


Basic Detector Geometry

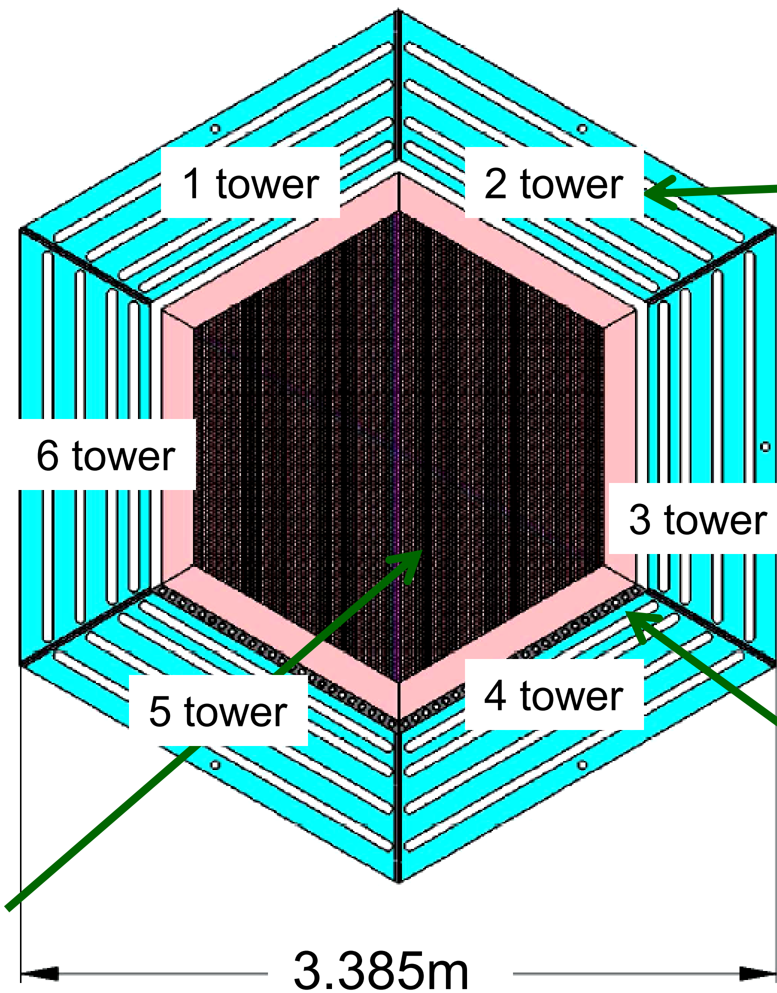


Target Material	Fiducial Mass (ton)	Charged Current Sample
Helium	0.25	0.6M
Hydrocarbon	3	8.6M
Carbon	0.6	1.4M
Iron	1	2.9M
Lead	1	2.9M
Water	0.3	0.7M

- **Downstream Calorimeters: 20 modules, 2% active, sheets of lead (Electromagnetic Calorimetry) or steel (Hadronic calorimetry) between scintillator planes**
- **Side Calorimeters: 2 thin lead "rings" for side Electromagnetic Calorimetry, 4 layers of instrumented steel**



MINERvA Detector Plane



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

Lead Sheets for EM calorimetry

Inner Detector Hexagon – X, U, V planes for stereo view

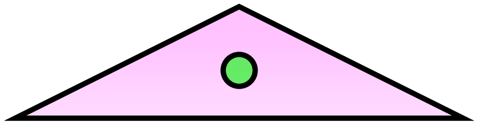
- **32,448 channels**
  - 80% in inner hexagon
  - 20% in Outer detector
- **507 M-64 PMTs** (64 channels)

- **1 wave length shifting fiber per scintillator**, which transitions to a clear fiber and then to the PMT
- **127 pieces of scintillator per Inner Detector plane**
- **8 pieces of scintillator per Outer Detector tower, 6 OD detector towers per plane**

MINERvA Optics

(Inner detector scintillator and optics shown, Outer Detector has similar optics but rectangular scintillator)

Scintillator

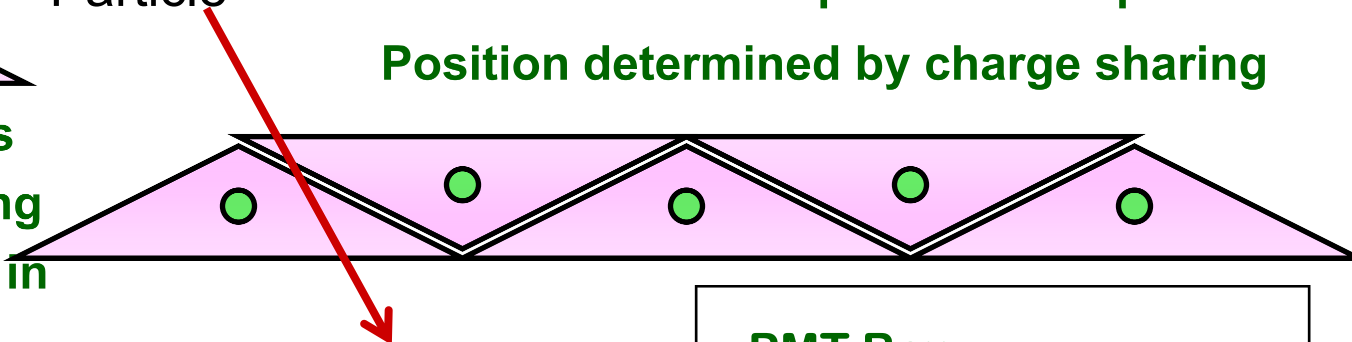


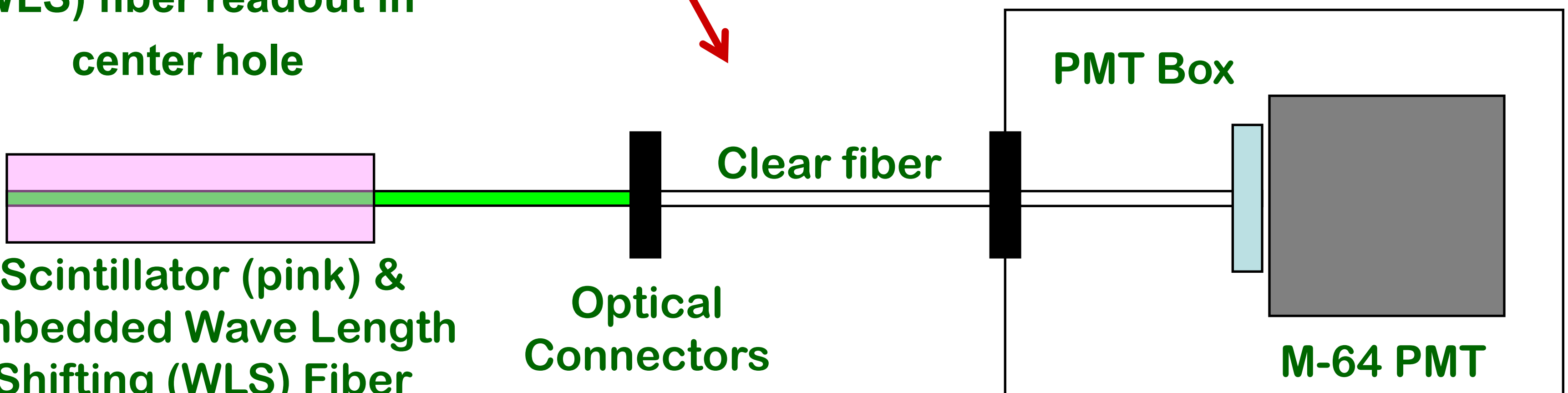
1.7 3.3 cm^2 strips

Wave Length Shifting (WLS) fiber readout in center hole

For the Inner Detector, scintillator is assembled into 128 strip scintillator planes

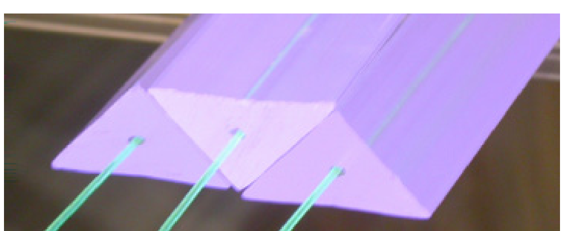
Position determined by charge sharing

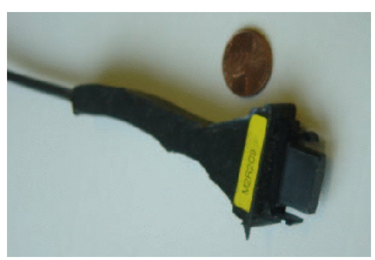


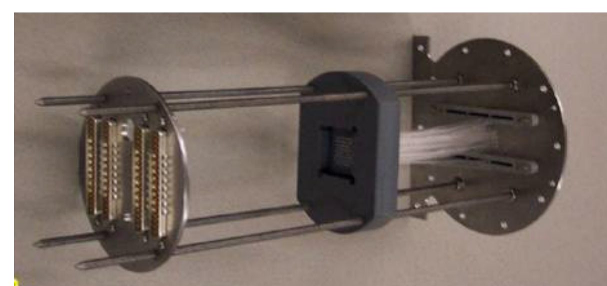


Scintillator (pink) & embedded Wave Length Shifting (WLS) Fiber

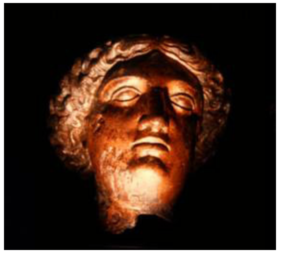
Optical Connectors



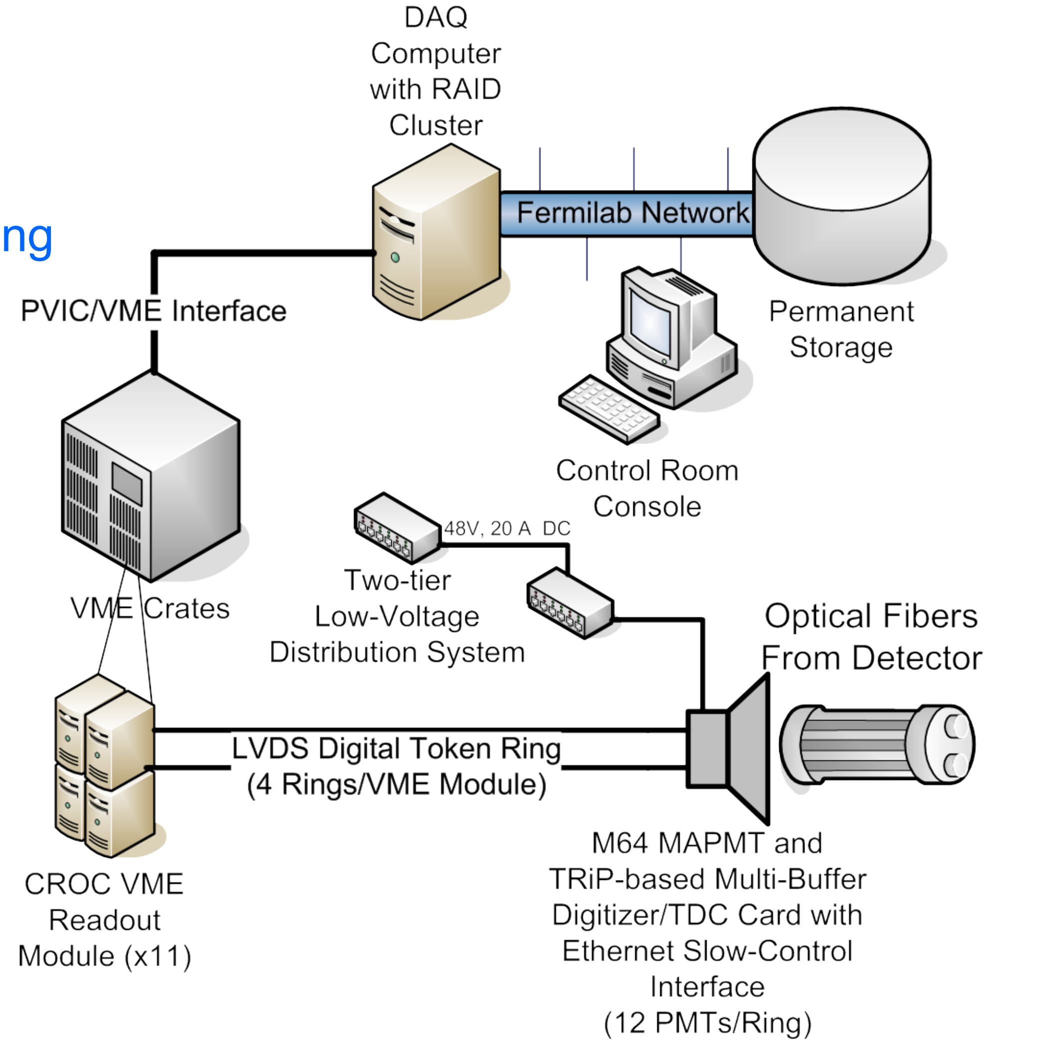




MINERvA Electronics



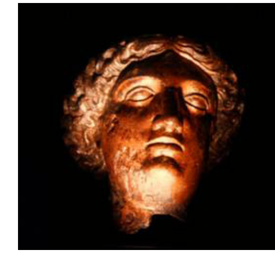
- **Front End Boards**
  - One board per PMT
  - High Voltage (700-800V)
  - Digitization via Trip Chips, taking advantage of D0 design work
  - Timing
- **CROC Boards and DAQ**
  - One board per 48 PMT's
  - Front-end/computer interface
  - Distribute trigger and synchronization
  - 3 VME crates & one DAQ computer
- **Power and rack protection**
  - Uses 48V power
  - 7kW needed



MINERvA’s Timeline

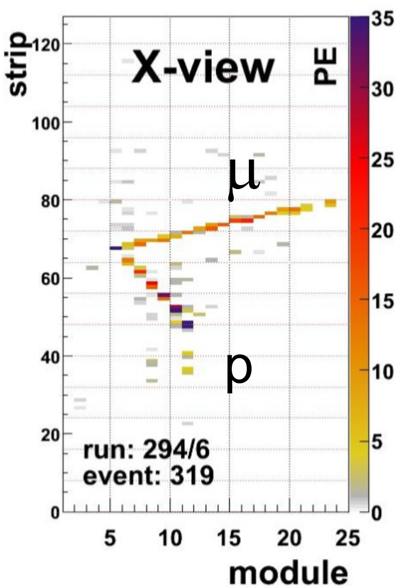
- **FY06-FY07: R&D and Assembly and Testing Process Prototyping**
  - Make co-extruded scintillator and test
  - R&D on making bulk clear fiber cables
  - WLS fiber qualification and prototypes
  - Scintillator Plane assembly R&D, prototype plane and module assembly
  - PMT box assembly and Electronics R&D
  - PMT testing and alignment procedures defined and tested
  - Outer Detector frame prototypes and Module assembly R&D
- **FY08-09: construction begins**
  - Remaining R&D: mostly electronics design
  - Bulk purchases: PMT’s, WLS fiber, Clear fiber, PMT box components, steel and lead purchases
  - Plane Assembly, PMT Box Assembly and Testing, ½ of all modules assembled
  - Commission 24-module prototype with cosmic rays and neutrino beam
- **FY10: complete construction**
  - Install 55% of detector in early FY10
  - Run in antineutrino beam with 55% of detector and Fe/Pb nuclear target
  - Complete remaining 45% of module assembly, and nuclear targets

MINERνA Sees!

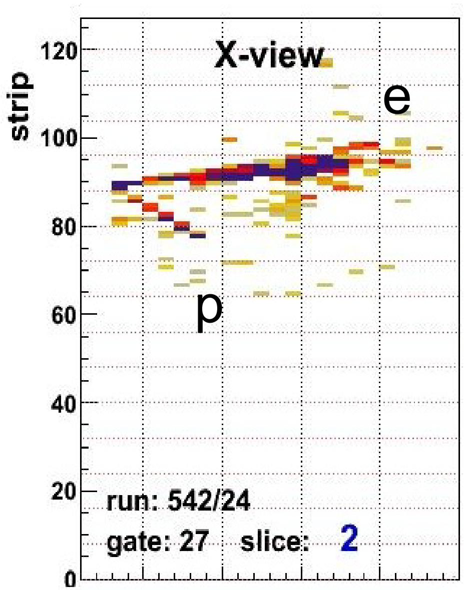


- Took ~4 x10^{19} Protons On Target April-June 2009, neutrino beam
- 15k event raw data sample

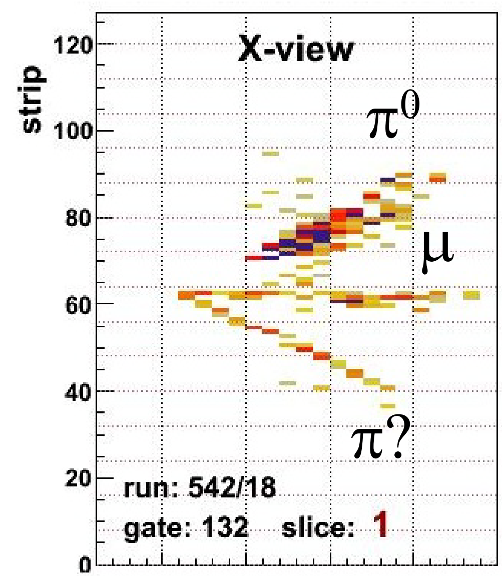
- Exclusive Channel Reconstruction
- Following are real data events…
- Candidate reaction given below



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

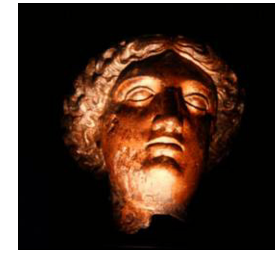


$\nu_e + n \rightarrow e^- + p$

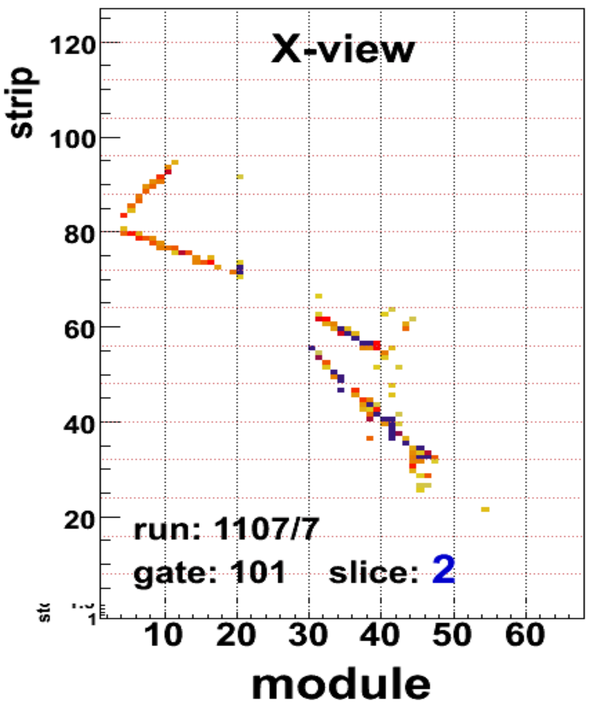


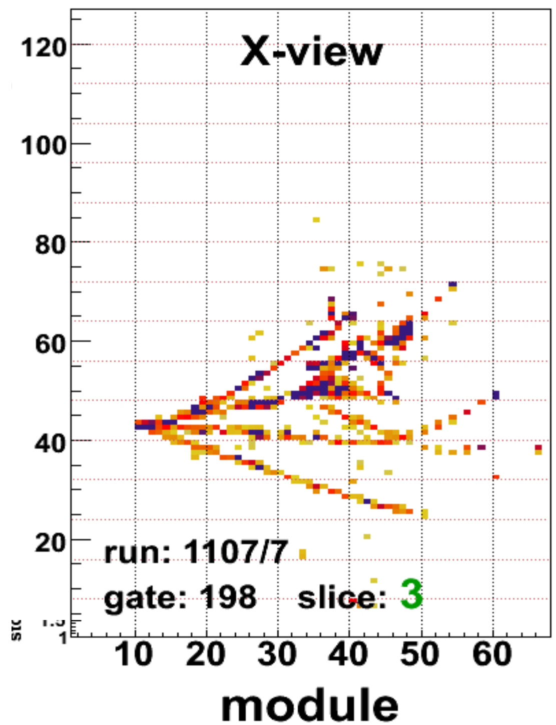
$\nu_\mu + n \rightarrow \mu^- + \pi^0 + X$

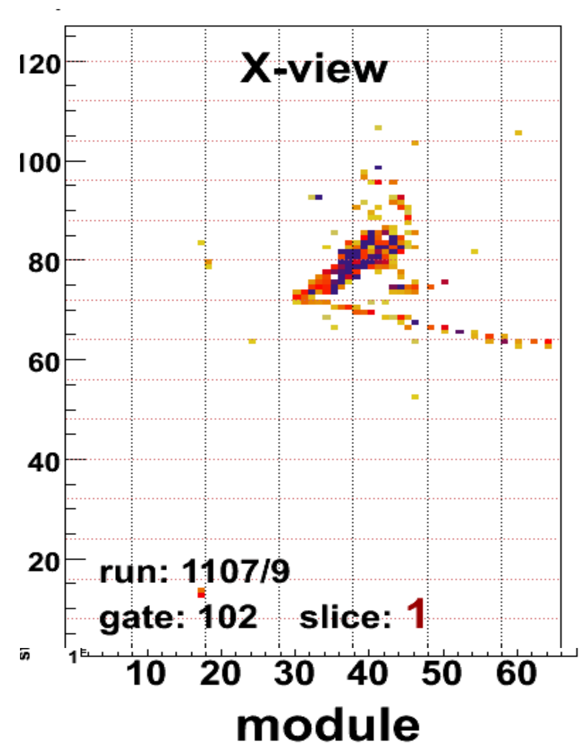
MINERvA Sees Antineutrinos



- Took ~1.3 x10^{20} Protons On Target November 2009 –March 2010
- 55% of detector installed
- Expect to have world's largest sample of several indentified exclusive anti-neutrino reactions







MINERvA Run Plan Summary

- Low Energy Anti-neutrino beam: November 2009– March 2010
- Low Energy Neutrino Beam: March 2010 – March 2012
- Analyze data during long Fermilab accelerator shutdown in 2012
- Medium Energy Neutrino beam with NOvA after 2012 shutdown
- Approved for $16x10^{20}$ Protons on Target