Introduction to MINERvA Experiment

David Martinez Caicedo Ph.D.

Illinois Institute of Technology

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Who Am I?

- I am a postdoctoral research associate at IIT :)
- Expend 5 years doing research (M.Sc. and Ph.D) at Fermilab on MINERvA neutrino scattering experiment.
- Currently I work on Daya Bay reactor neutrino experiment, and recently join to MicroBooNE and DUNE experiment in Fermilab!
- Spare time (Even if there is not to much): Leading muon tomography simulations to understand the Galeras volcano composition (project carried on with 2 undergrad students and 1 professor in Colombia!).
- Leading translation to Spanish of neutrinos in the classroom webpage! (+1 postdoc, 3 undergrads)

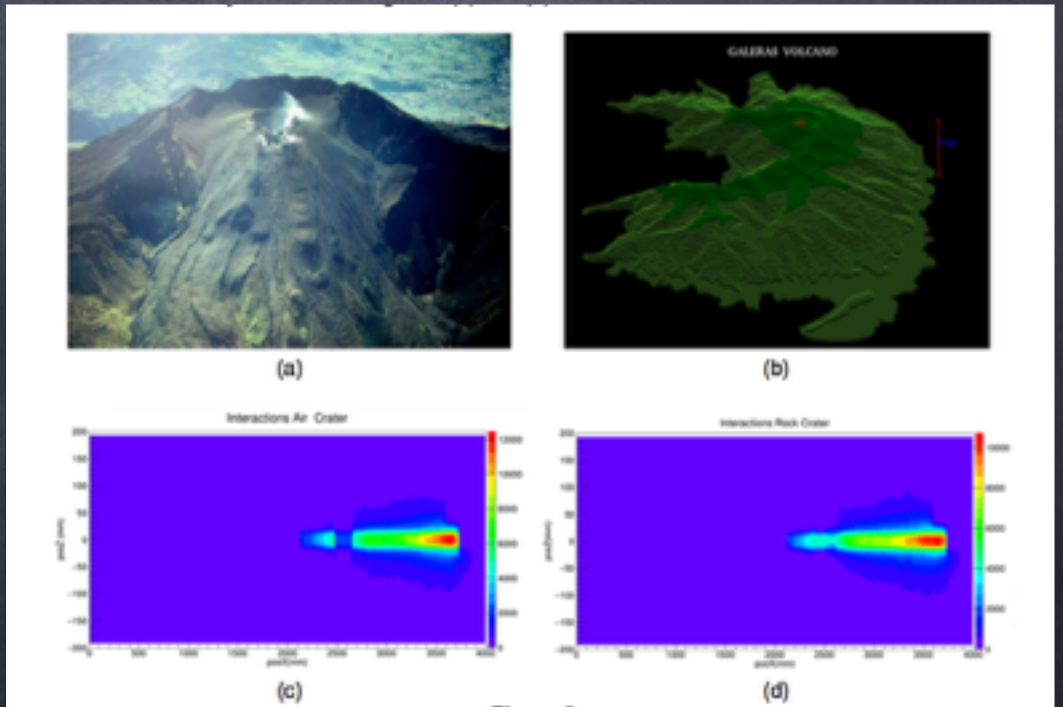
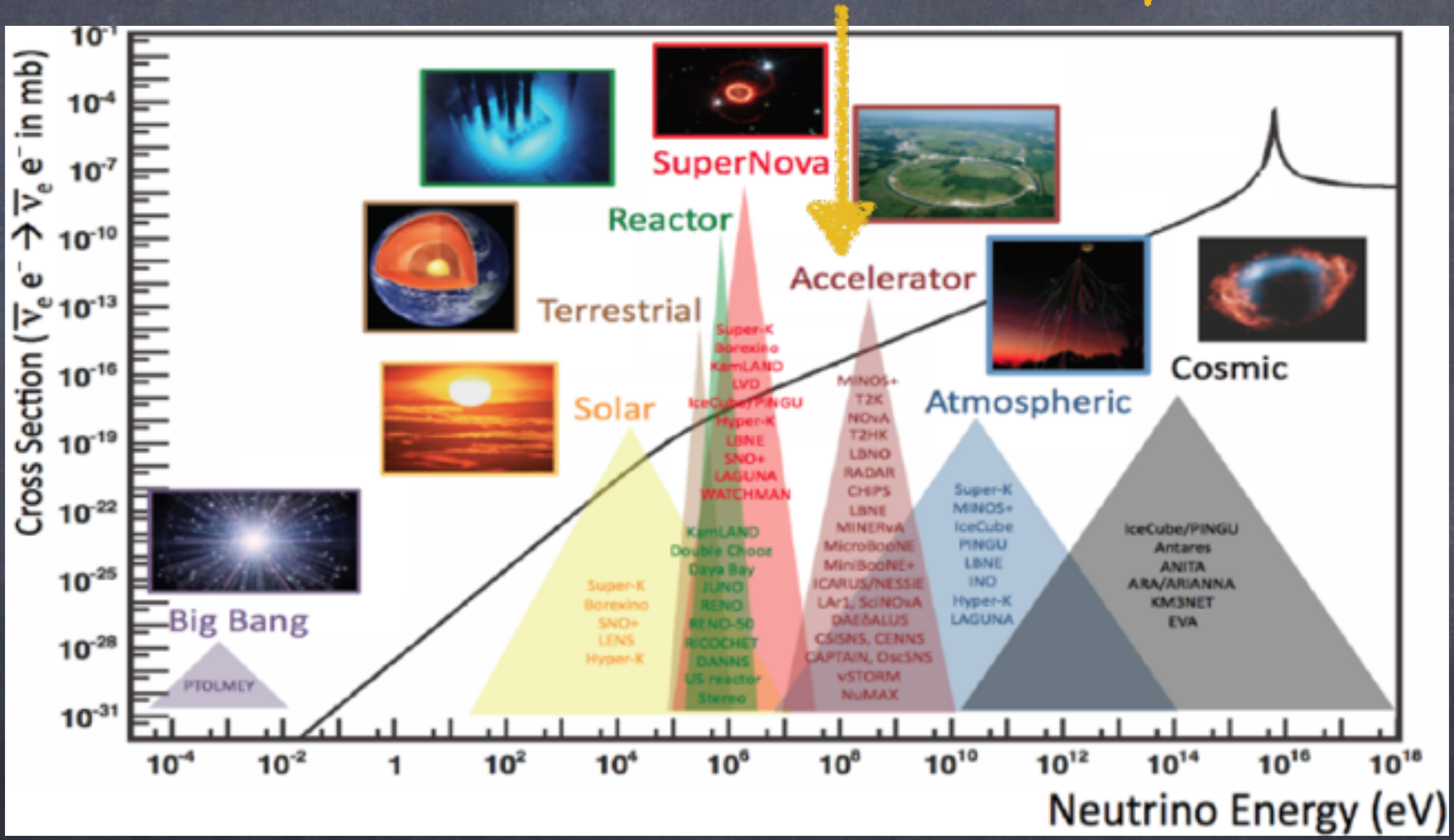


Figure 3

Motivation: Why study neutrinos is important?

- Measurements of neutrino-nucleus scattering cross sections is crucial to the global neutrino physics program to reveal the nature of neutrinos!!!.

- Part of the program that needs interaction cross sections are the accelerator based experiments



J.A. Formaggio and G.P. Zeller
Rev. Mod. Physics 84,1307-1341 2012

The NuMI Beam and MINERvA Detector

MINERvA

Main INjector ExpeRiment for ν-A

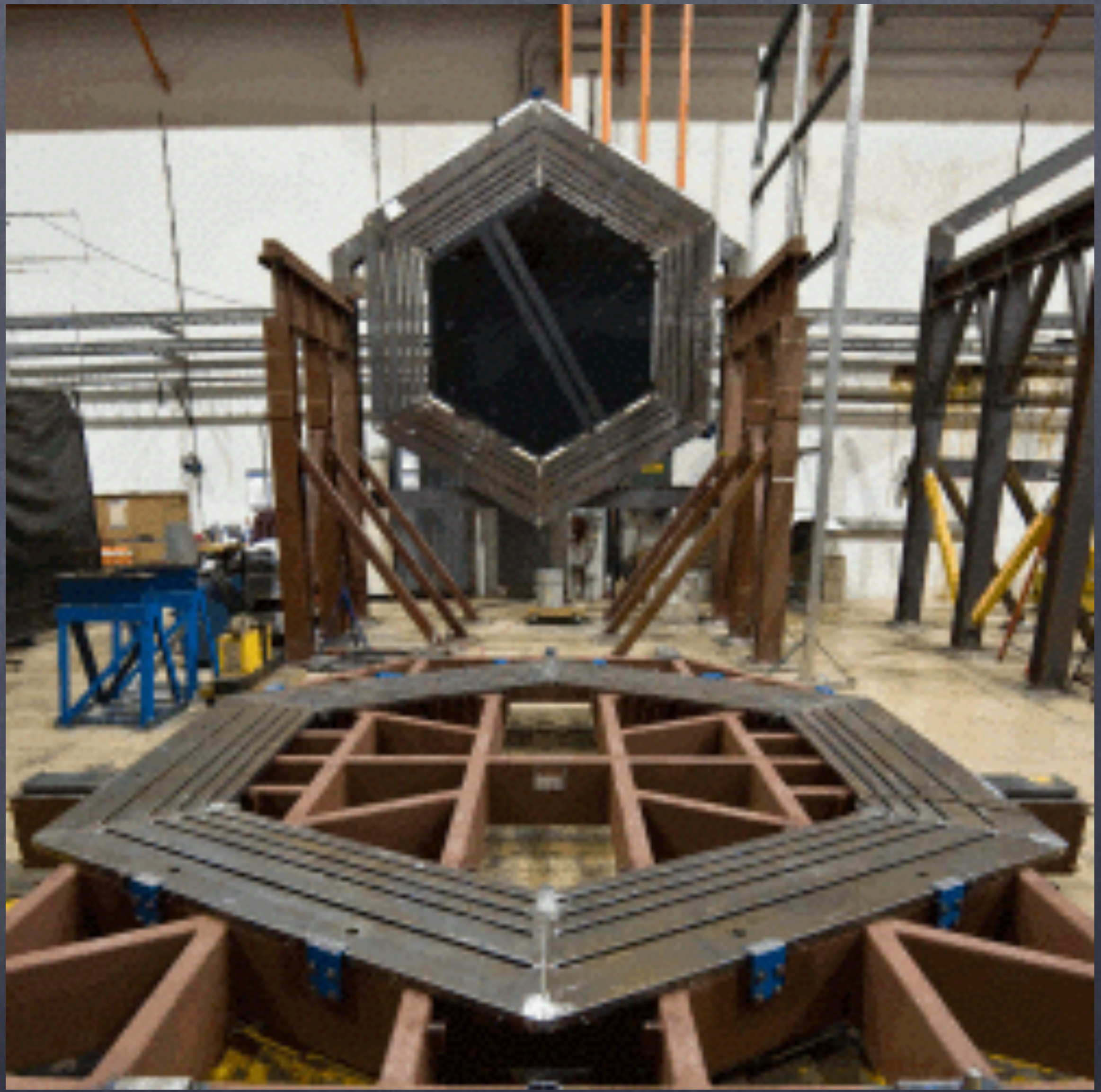
ν is the symbol for the neutrino. The beam that is sent to MINERvA is made out of neutrinos. In chemistry, an A stands for the symbol representing the mass number of the atom (the number of protons and neutrons). This symbolizes the different types of atoms found in MINERvA.

What is MINERvA?

- A neutrino scattering experiment
- Uses the NuMI beam at Fermi National Accelerator Laboratory (Fermilab).
- Seeks to measure low energy neutrino interactions (interactions of protons, muons and pions in particular)
- MINERvA sits directly in front of the MINOS Near detector which studies high energy particles

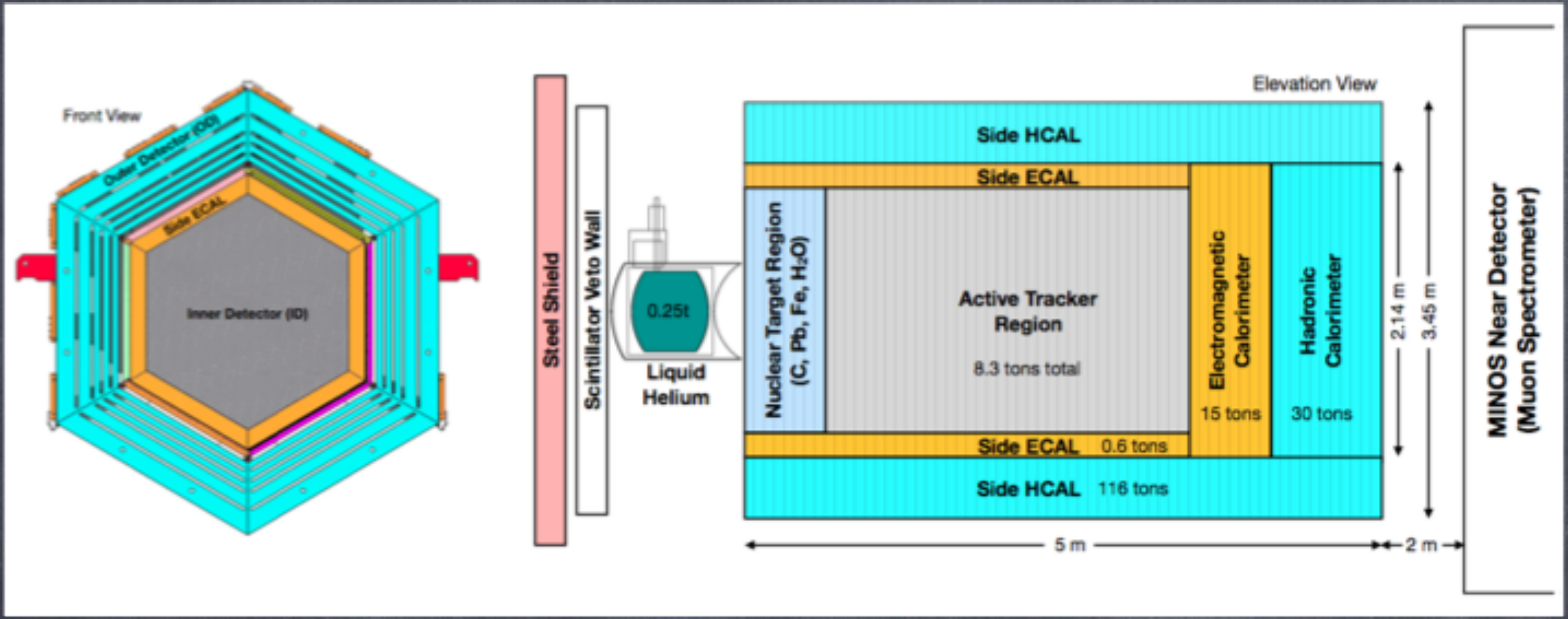
How was MINERvA constructed?

MINERvA is made of many planes of nuclear targets and scintillator material. The nuclear targets are dense materials which offer the particles a large nucleus to interact with. The scintillator material detects particles as they travel through the plane



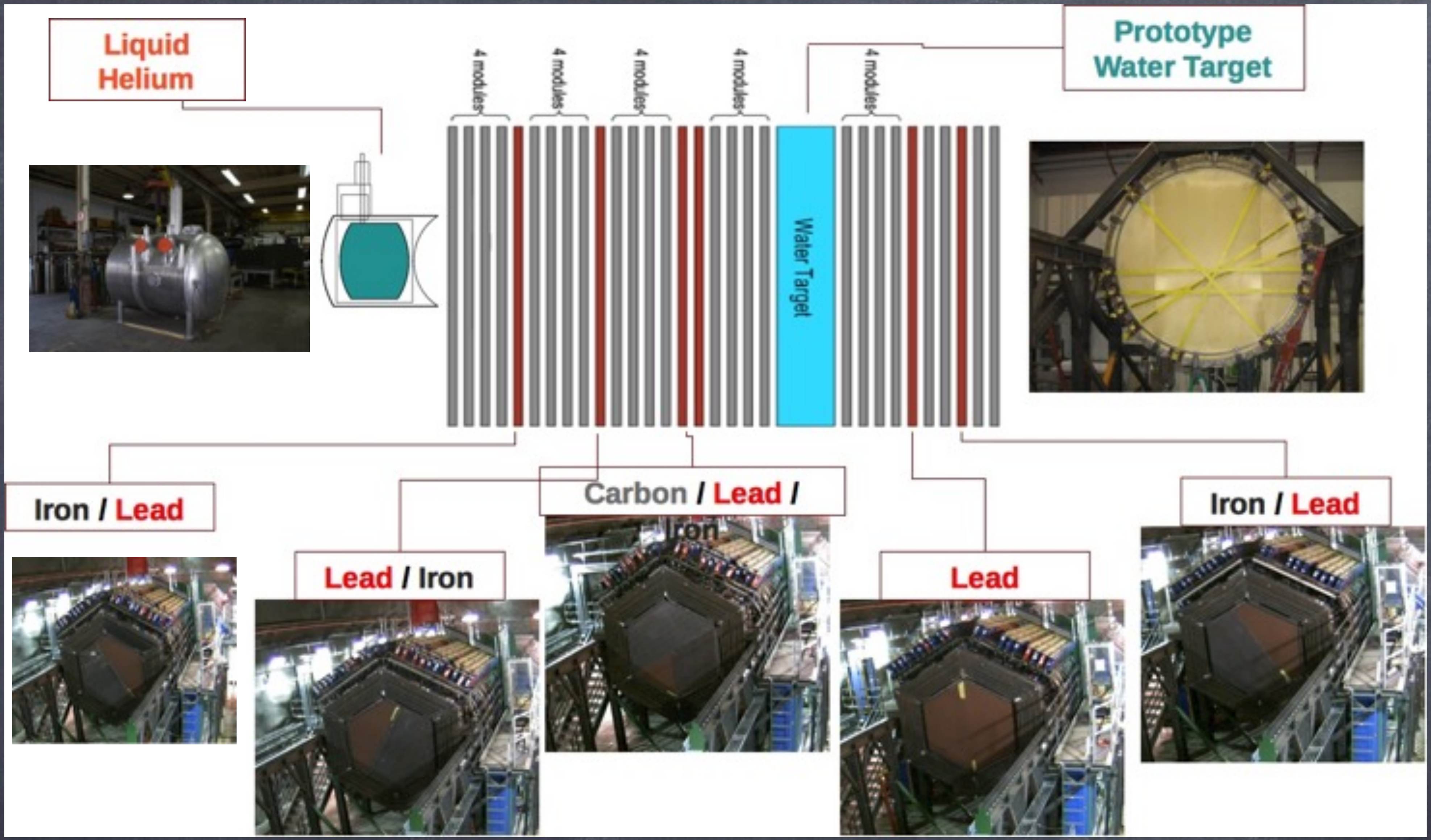
Here is one plane of MINERvA being prepared for installation. There are around 200 planes in MINERvA (it changes with every modification). The detector is in the shape of a hexagon. The center of the plane is filled with detection material.

Research in MINERvA



There are three general areas to the MINERvA detector. The fully active target contains lots of scintillator material necessary to detect specific particles. The ECAL contains material for detecting particles such as electrons and photons. The HCAL is specialized to detect particles such as pions and protons. You can see that there are both ECAL and HCAL areas in both the sides and back of MINERvA.

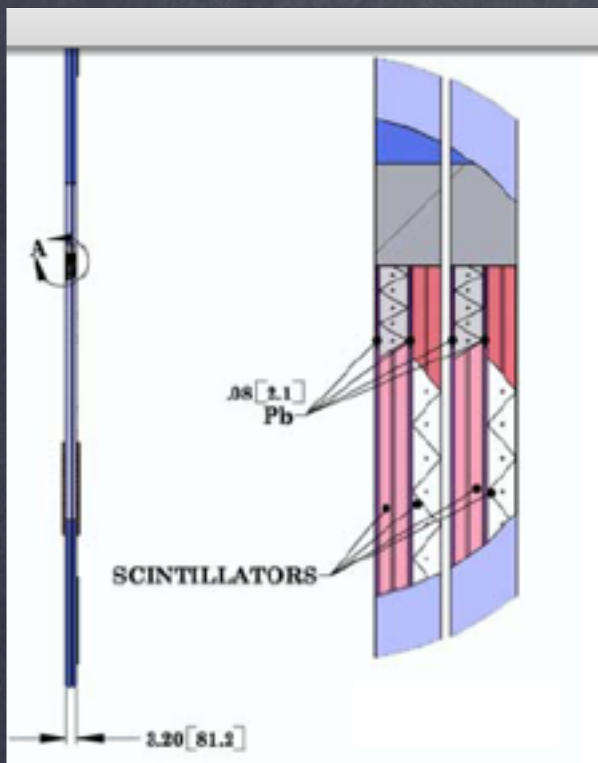
MINERvA Detector: Nuclear Targets



Event Rate Estimatives

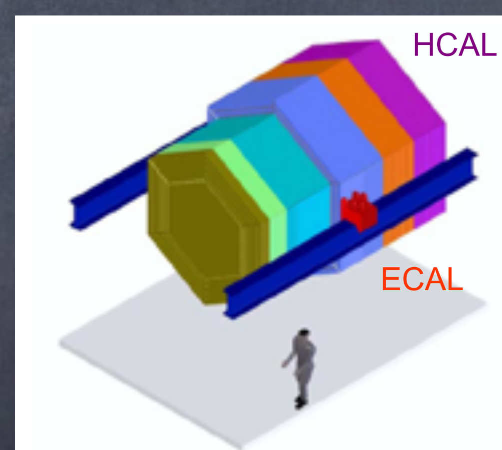
Target	Fiducial Mass (tons)	ν_μ CC Events in 1.0e20 POT
Plastic	6.43	313k
Helium	0.25	14k
Carbon	0.17	9.0k
Water	0.39	20k
Iron	0.97	54k
Lead	0.98	57k

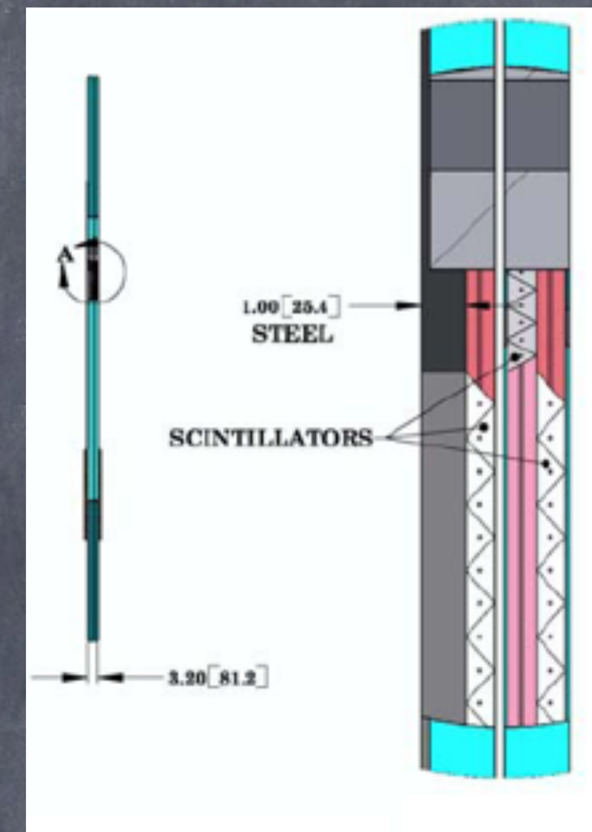
The ECAL and HCAL Modules



A typical ECAL Module

- Calorimeter modules are built by adding absorbers
  - one 1" steel absorber and one scintillator plane in HCAL
  - two 5/64" Pb absorbers and two scintillators in ECAL



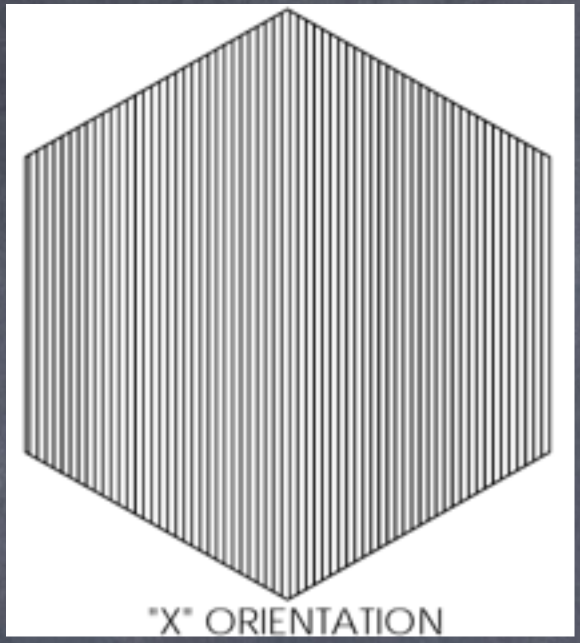


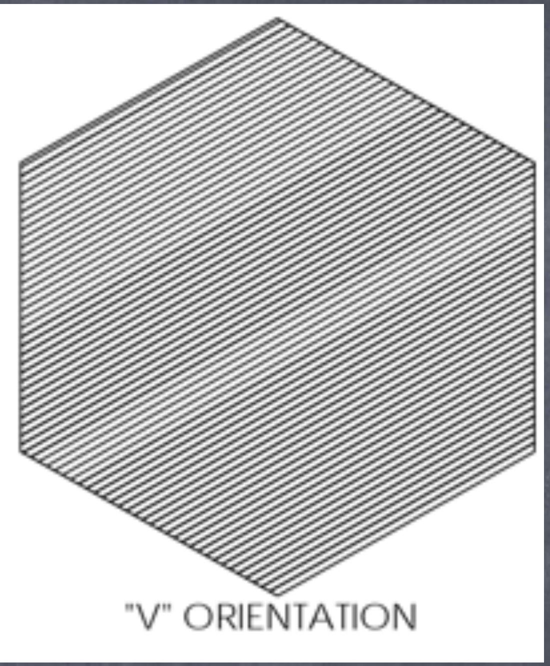
A typical HCAL Module

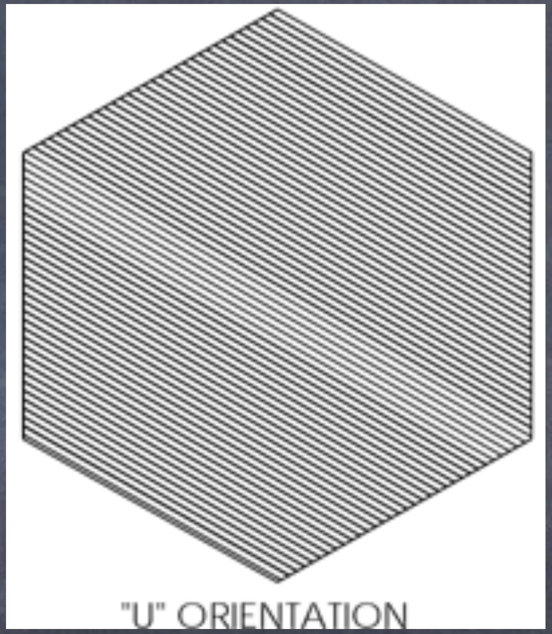
The ECAL is located in the outside border of each plane and also in the orange colored portion in the diagram. The HCAL modules are also located in the outer border of the plane and in the purple portion of the diagram.

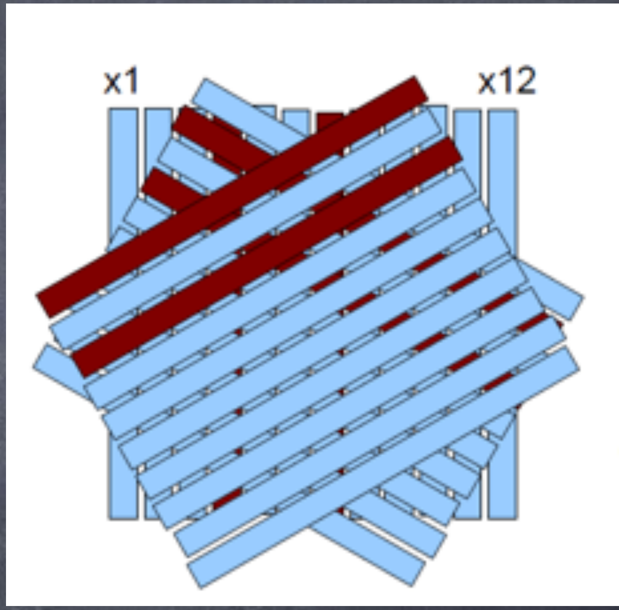
The Fully Active Target - The Fiducial Zone

This area is the "sweet spot" of the detector. It contains three different directional layers of triangular graphite material. This material is the scintillating material. It carries the energy released by the particles into the detector to tiny fibers inside the graphite which connect to photomultipliers which send the data to the computers. The computers can tell us even more about the particles.





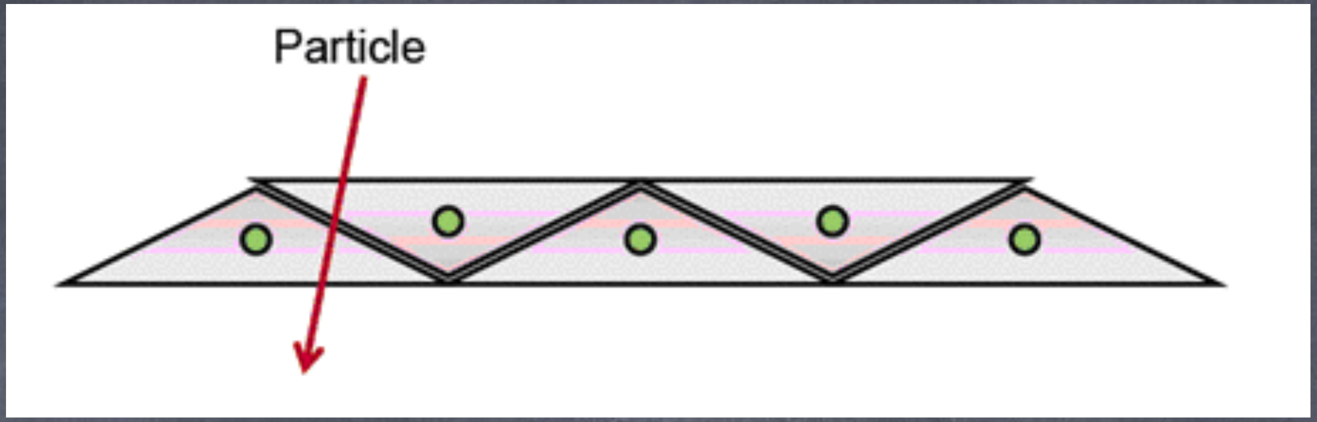




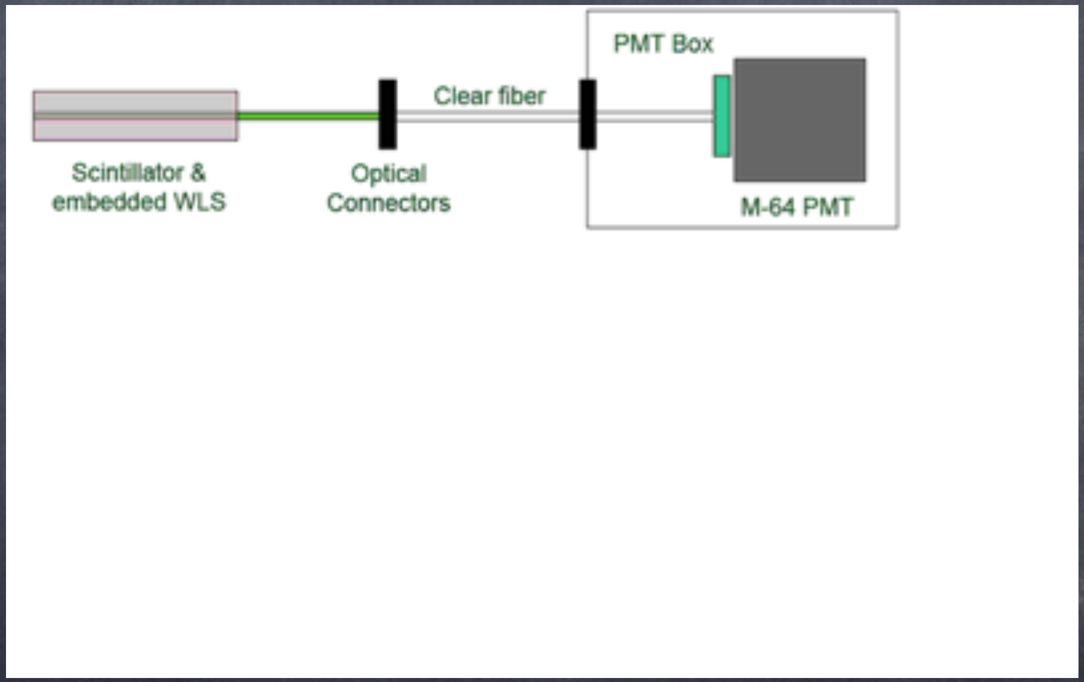
We label these layers the X, U and V views. Due to the three layers, we can "see" where the events happened in the detector.

The scintillator bars

These are small strips which are triangular shaped and are formed in long pieces. These strips take the energy from a particle interacting with the material in the detector and transform it into light. The wavelength shifting fiber runs through the length of the scintillator and collects the light. The light is then sent to the PMTs.

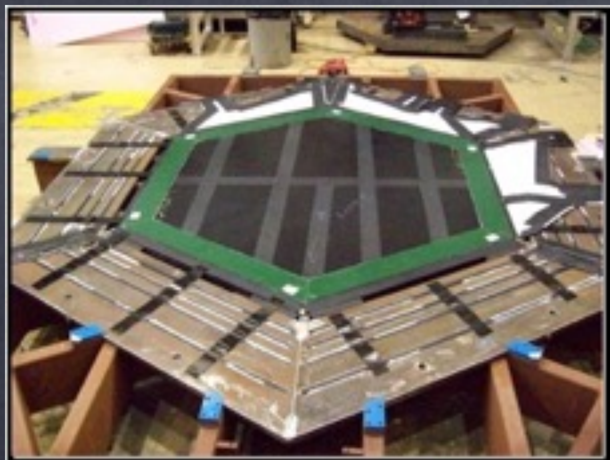


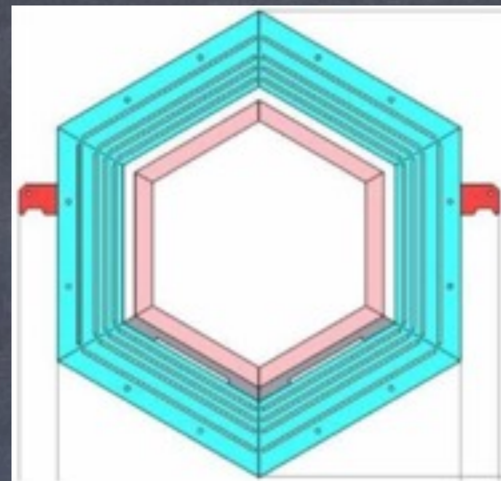
This shows how the scintillator strips fit together in a panel. Because of their shape, each particle will leave energy in at least two strips. This helps the computers to identify more accurately where the event happened in the detector.



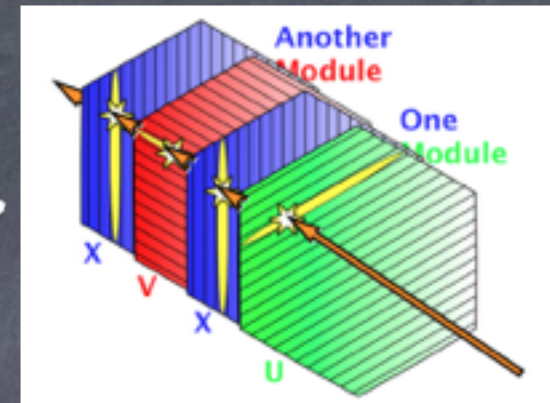
Here is the "big picture". You can see the scintillator and wavelength shifting fiber on left connected to the PMT box. The PMTs are photomultipliers which transform the light energy into electricity and strengthen the signal. This needs to take place since the amount of light emitted per event is very small.

MINERvA Detector: Summary :)

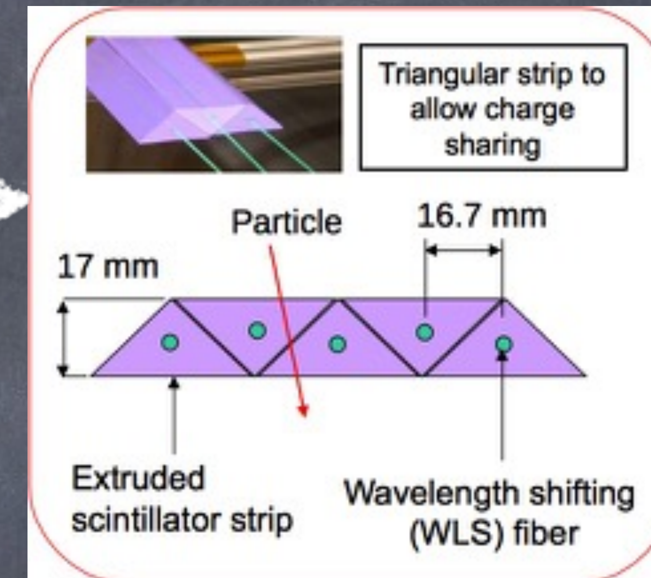




Tracker module = 2 planes
ECAL module = 2 planes + 2 (2 mm thick) sheet of lead
HCAL module = 1 plane + 1 (1 inch thick) sheet of steel



127 scintillator strips per plane.



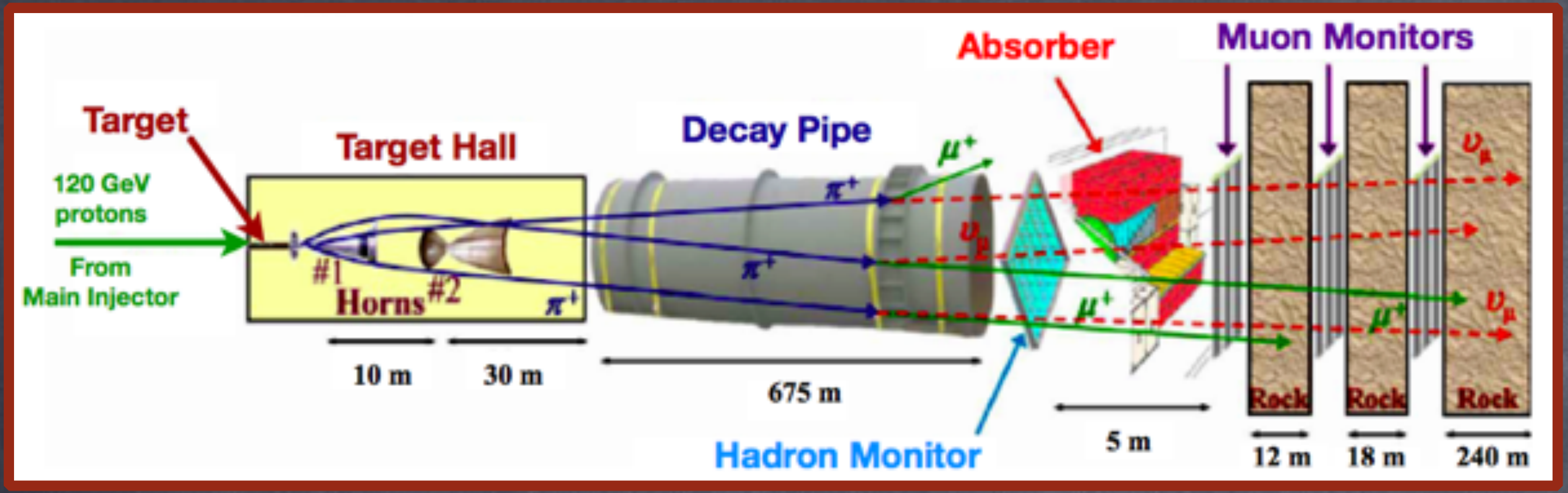
CROC
VME Readout

Hamamatsu
MA 64 PMTS

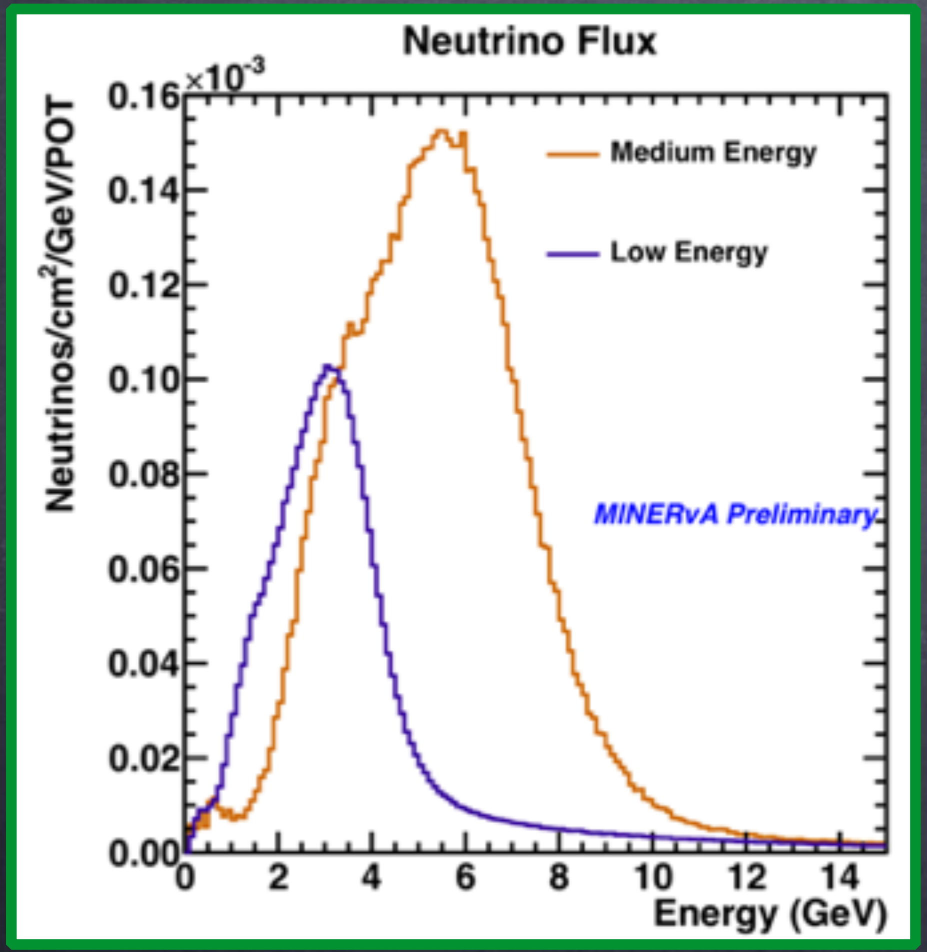
PMT Box

Front End Board FEB
Trip-T chip interface the PMTs

NuMI Beam (Neutrinos at Main Injector)



→ to MINERvA and MINOS

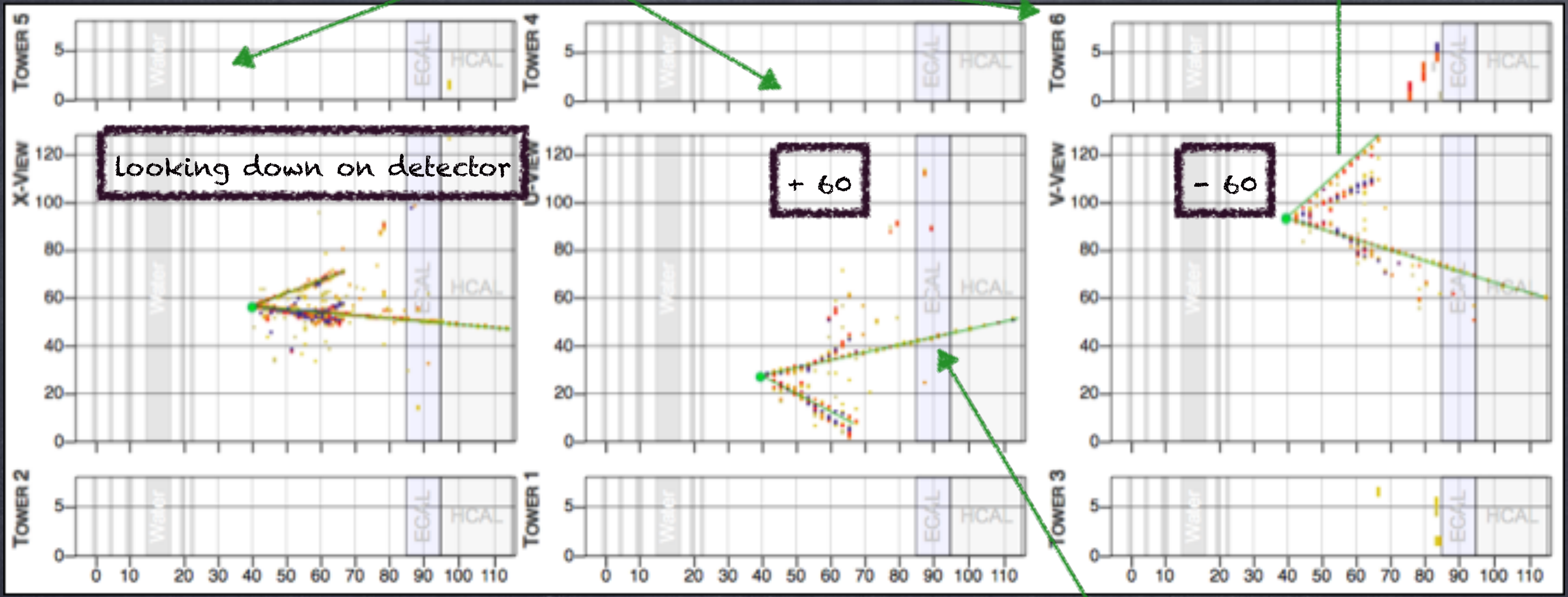


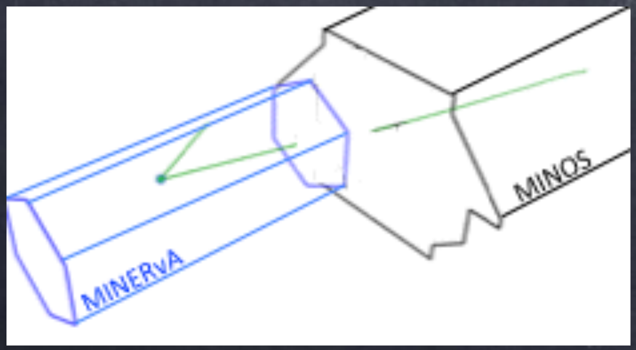
- Very intense neutrino beam with a power of 300 -350 kW and ~ 35e12 POT (Protons on Target) per spill.
- Spill : 10 microseconds durations at ~0.5 Hz frequency.
- Energy distribution can be tuned by changing position of the target with respect to the horns.
- Antineutrino beam is obtained by reversing the current in the magnetic horns to focus Pi- instead of Pi+

MINERvA Detector

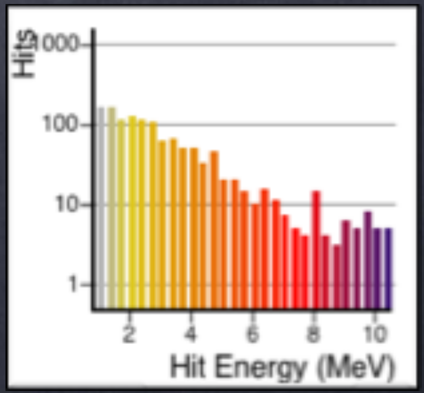
3 stereo views X-U-V show separately

Particle leaves inner detector stops in outer iron calorimeter

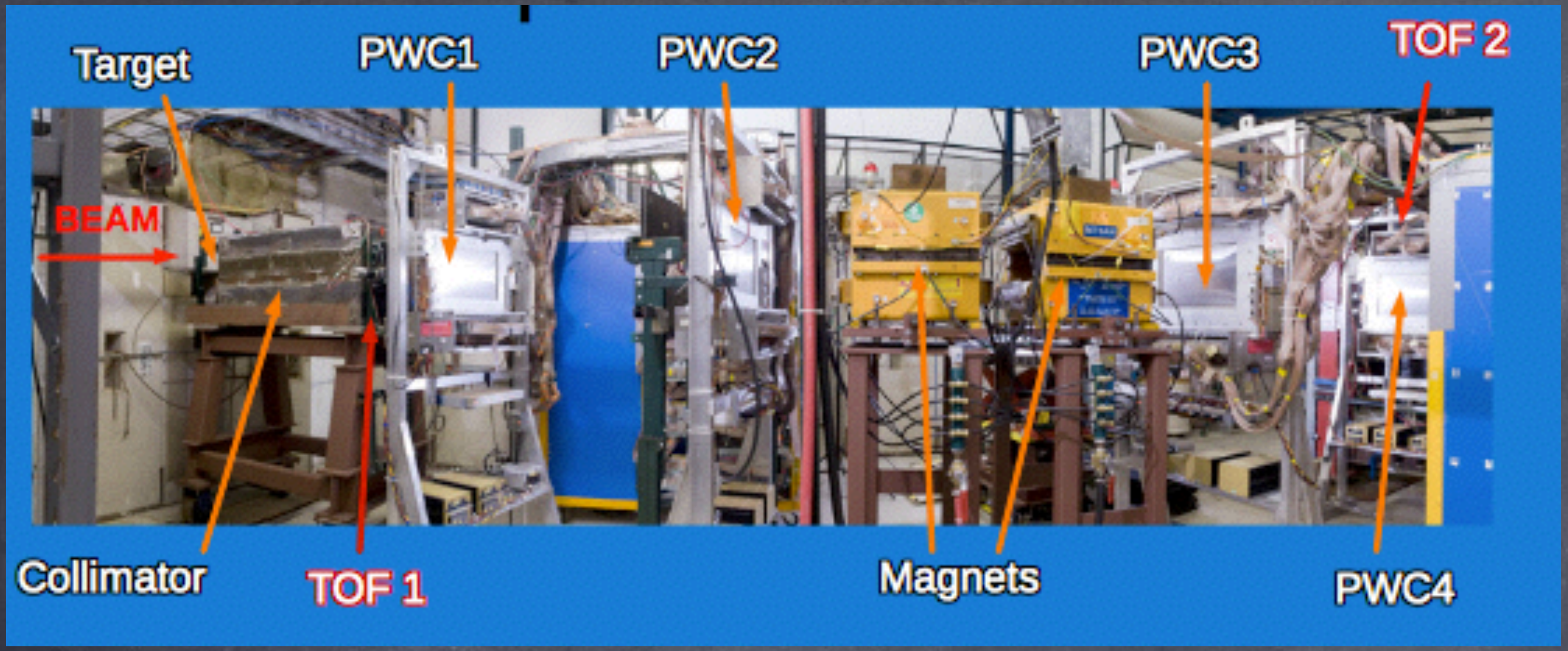




Muon leaves the back of the detector headed toward MINOS



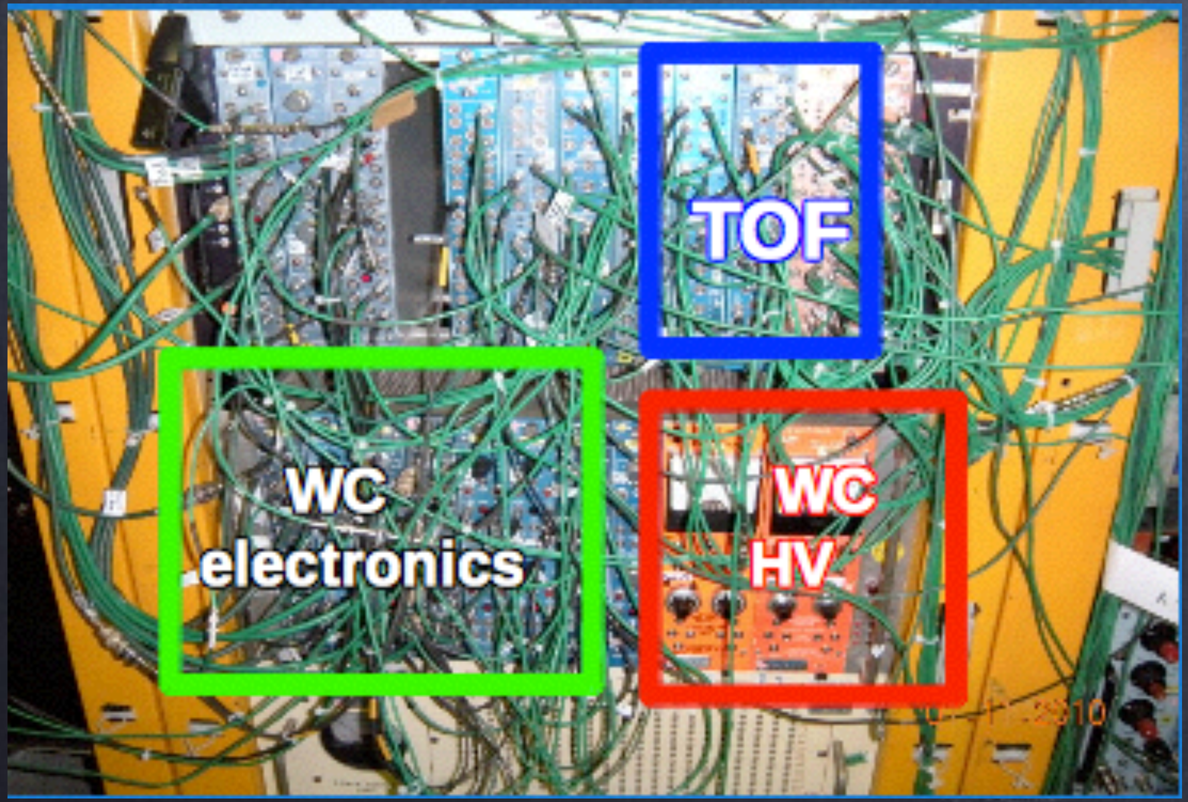
MINERvA Detector : Recoil energy scale

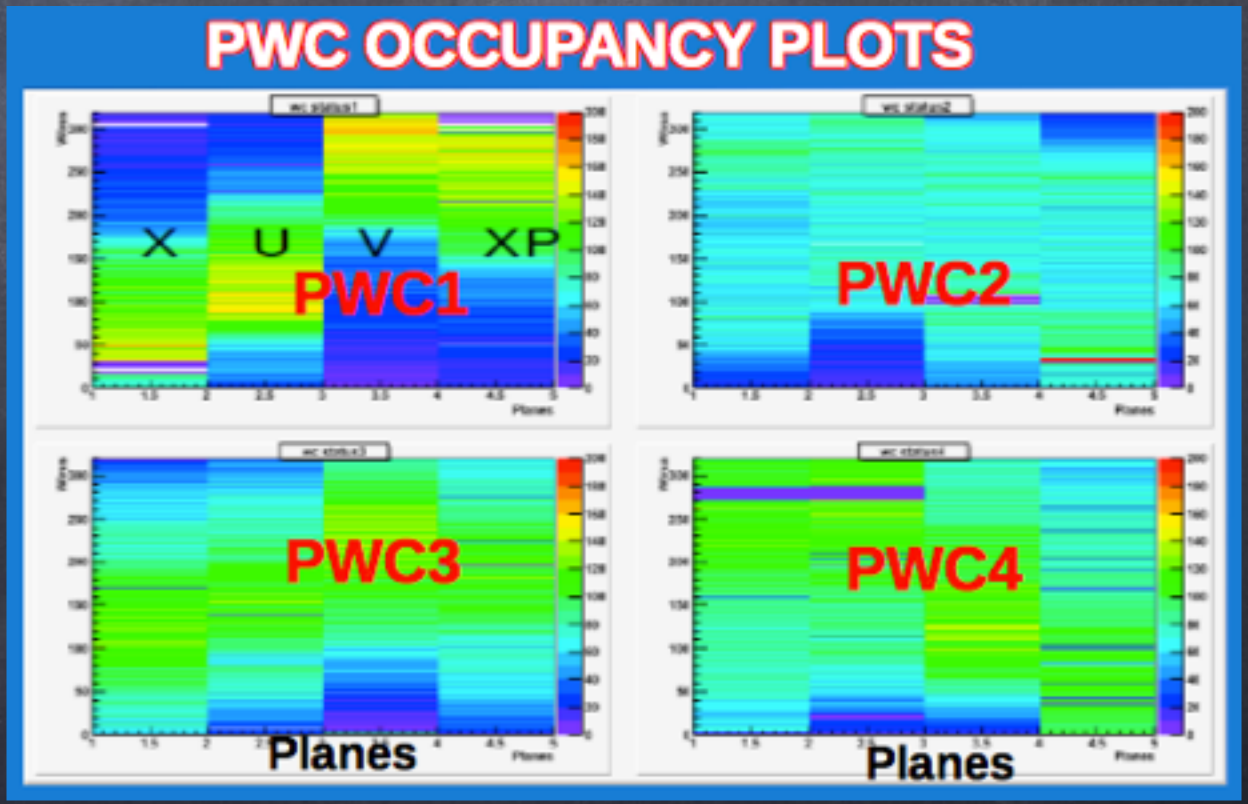


Beamline overview

- Incoming 16 Gev pions -> 0.4 - 2 GeV
- Time of flight TOF scintillator counters, measure transit time of particles
- Hits on WC1 through WC4 help reconstruct the trajectory of the charged particle.

Beamline electronics





MINERvA Detector: More than just a detector!

The awesome PMTs !!!

~ 60 collaborators from nuclear and particle physics

University of California at Irvine
Centro Brasileiro de Pesquisas Físicas
University of Chicago
Fermilab
University of Florida
Université de Genève
Universidad de Guanajuato
Hampton University
Inst. Nucl. Reas. Moscow
Mass. College Liberal Arts
University of Minnesota at Duluth

I am here!! :)

Universidad Nacional de Ingeniería
Northwestern University
Otterbein University
Pontificia Universidad Catolica del Peru
University of Pittsburgh
University of Rochester
Rutgers, State University of New Jersey
Universidad Técnica Federico Santa María
Tufts University
William and Mary

THANK YOU!
GRACIAS!
OBRIGADO!

References

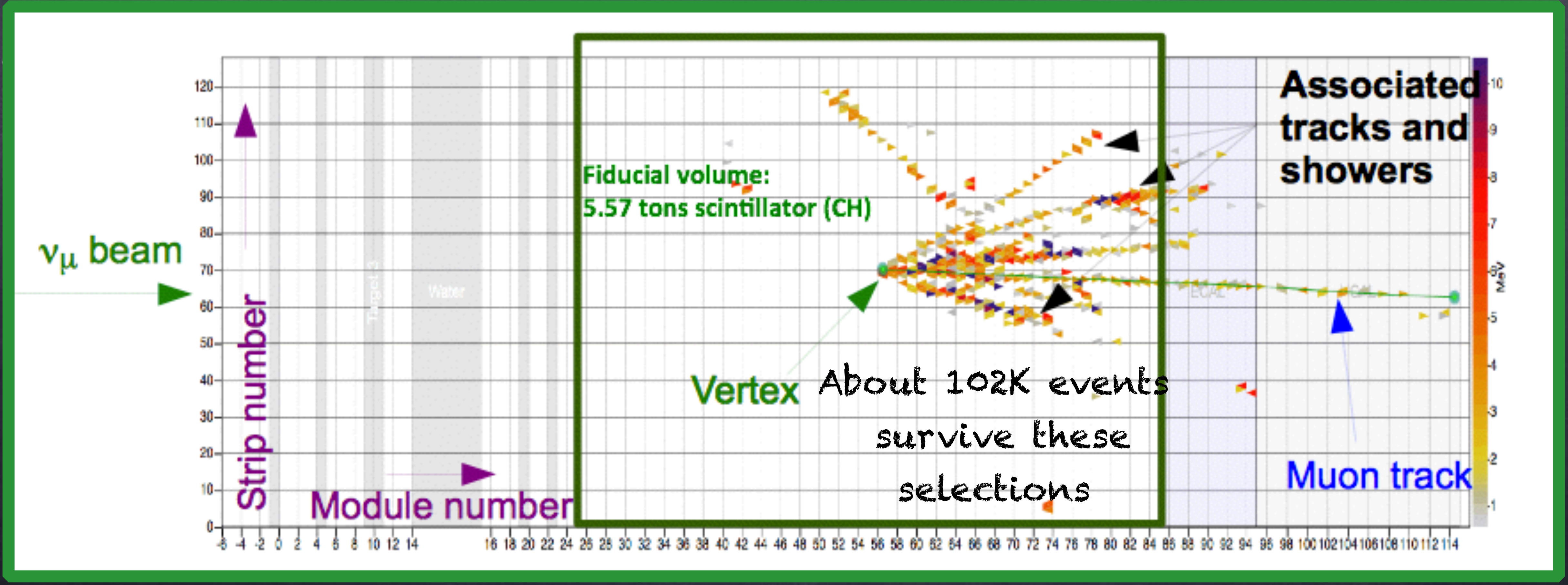
- Neutrinos in the classroom: MINERvA experiment supplemental material (http://neutrino-classroom.org/concepts.html)

$\nu_\mu + A \rightarrow \mu^- + X$

Event Selection

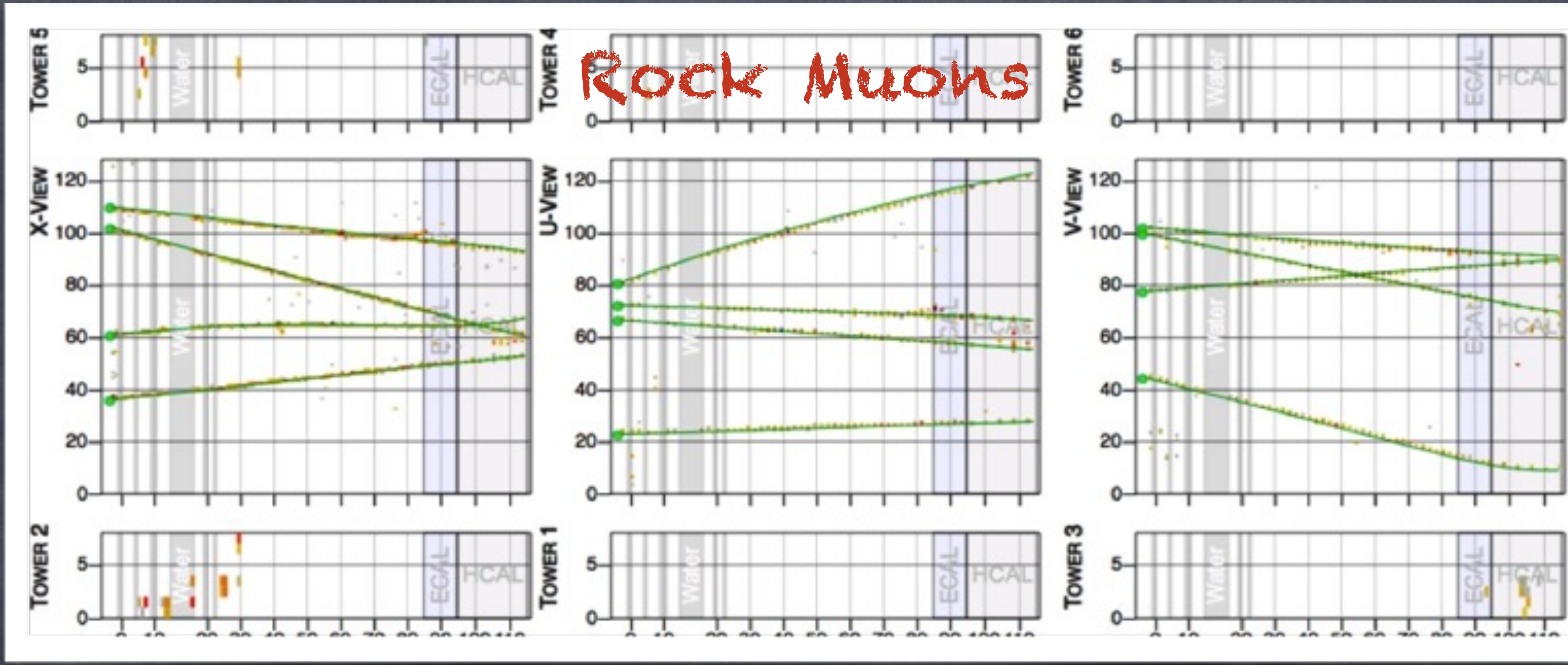
$E_\nu = E_\mu + recoil$

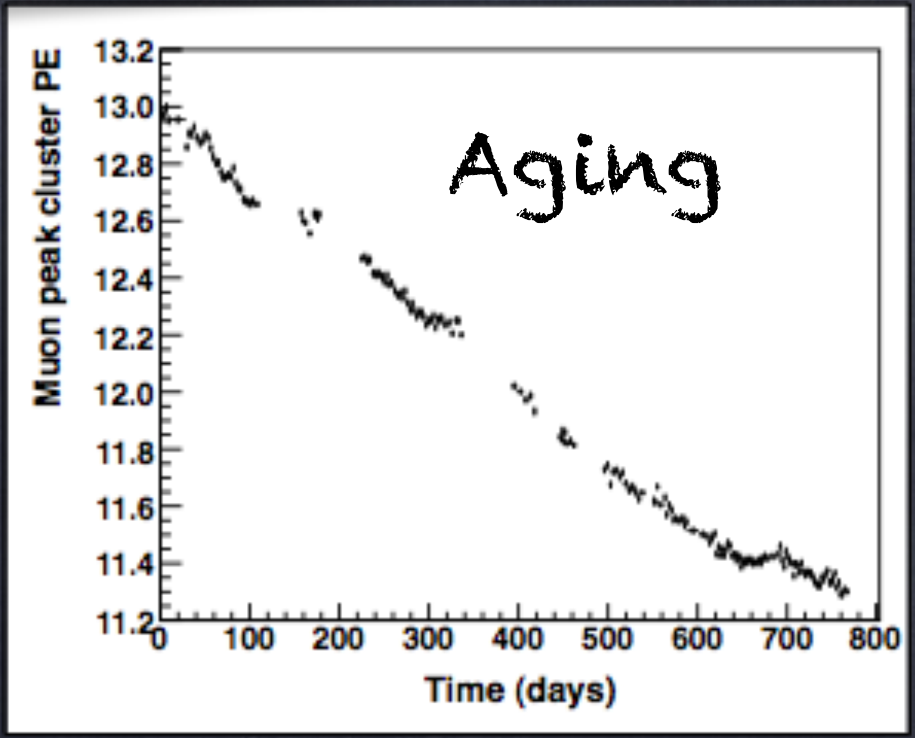
- Muon Track matched in the MINOS near detector : Restrict the explored kinematic space due to the geometrical relationship of MINERvA to MINOS and the tracking threshold in MINOS.
- Muon charge must be negative : Accomplished by selecting events in which the MINOS Track has a negative curvature (q/p <0)
- Reconstructed vertex inside the fiducial tracker region : 85 cm apothem hexagon and modules 27-80



MINERvA Detector: and what about the Recoil Energy Scale?

High Statistics monitoring of the detector energy response with rock muons





The standard model of particle physics

- Particles: 6 quarks and 6 leptons!
- 4 forces: Strong, electromagnetic, weak, gravity.