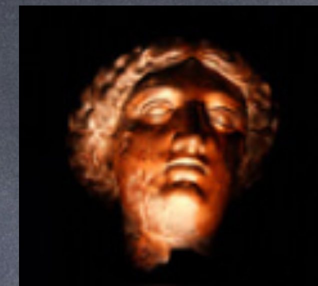


THE MINERvA Experiment

David Martinez
CBPF - Fermilab

June 9th 2014

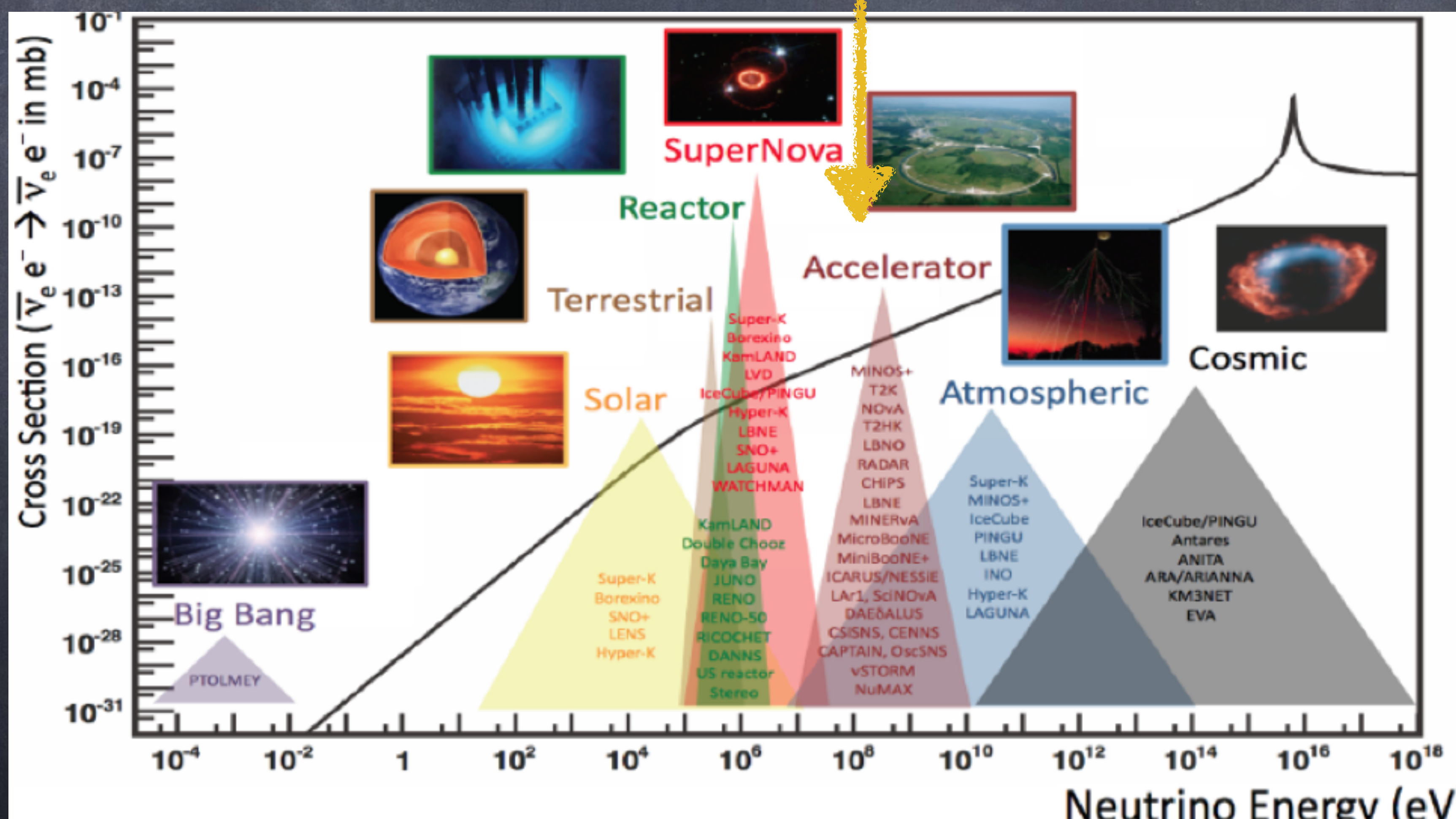
New Perspectives Conference

Outline

- Motivation: Why the neutrino scattering measurements are important?
- The NuMI beam and MINERvA Detector
- Conclusions & Future perspectives

Motivation: Why the neutrino scattering measurements are important?

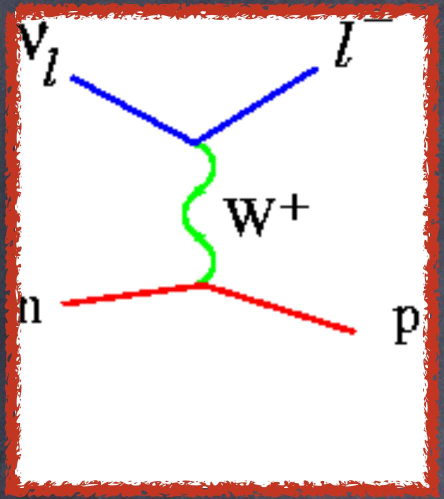
- Measurements of neutrino-nucleus scattering cross sections is crucial to the global neutrino physics program to reveal the nature of neutrinos!!!.
- Part of the program that needs interaction cross sections are the accelerator based experiments

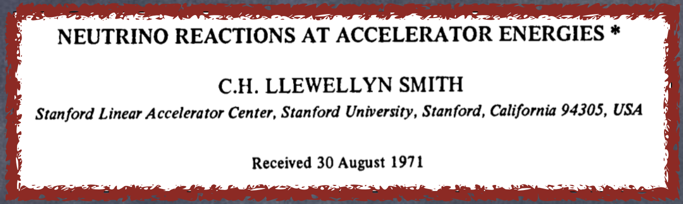


J.A. Formaggio and G.P. Zeller
Rev. Mod. Physics 84,1307-1341 2012

Motivation: Why the neutrino scattering measurements are important?

Quasi-Elastic (CCQE)
knockout nucleon
Formalism used in
all neutrino generators



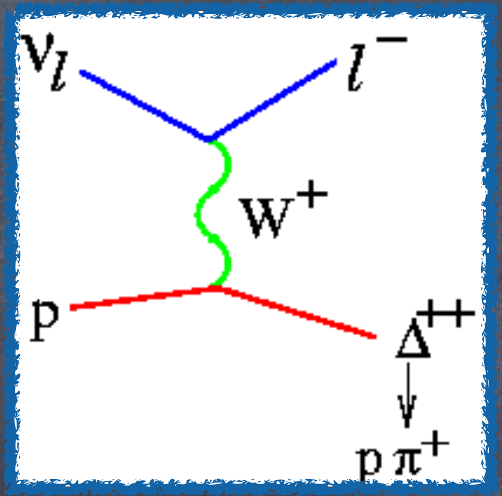

NEUTRINO REACTIONS AT ACCELERATOR ENERGIES *

C.H. LLEWELLYN SMITH

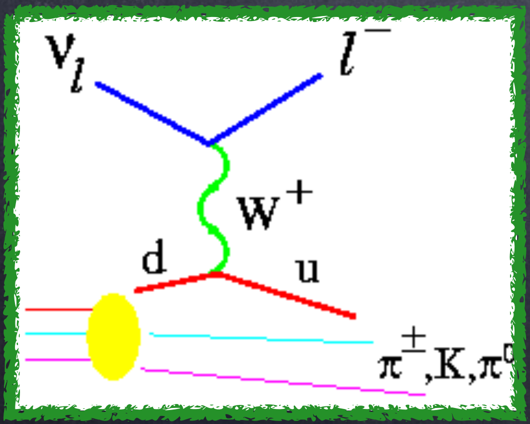
Stanford Linear Accelerator Center, Stanford University, Stanford, California 94305, USA

Received 30 August 1971

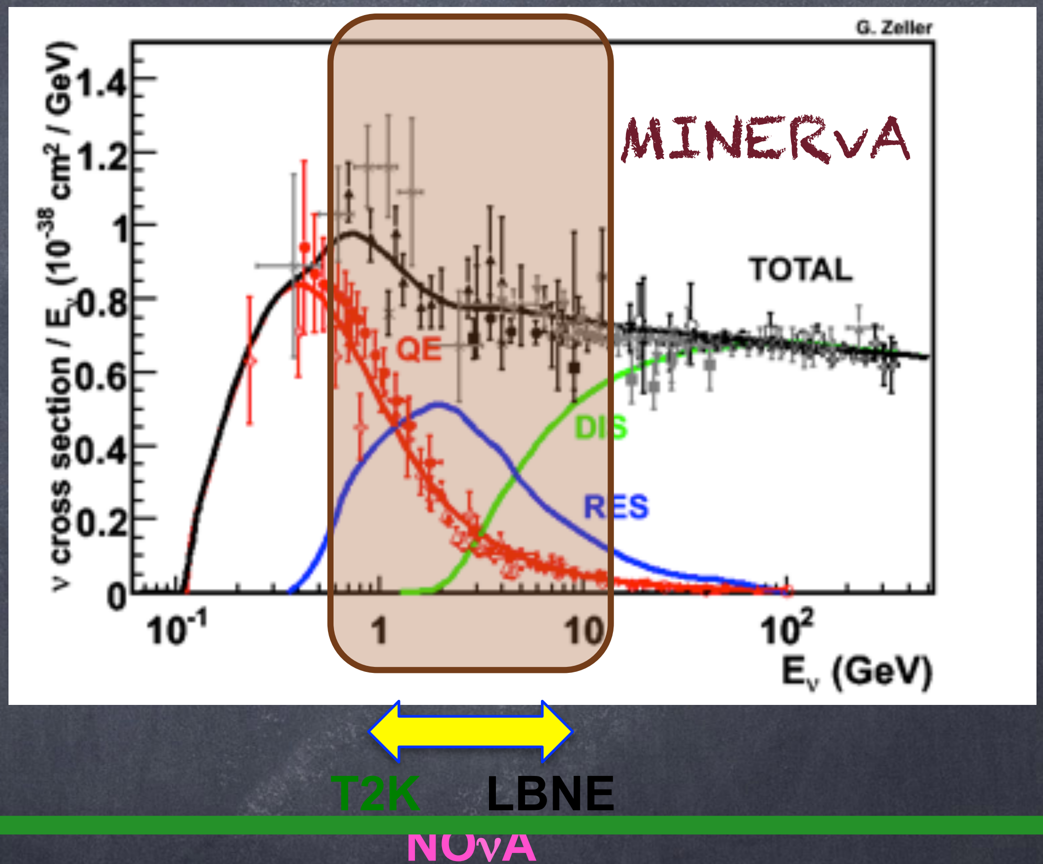
Resonance Production
(RES)
excite nucleon



Deep Inelastic Scattering
(DIS)
destroy nucleon



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



Accelerator neutrino experiments
in the energy region most complicated
by nuclear environment

Motivation: Why the neutrino scattering measurements are important?

Influence of Nuclear Physics

- Nuclear processes affect the final state content, and this need to be modeled correctly to reconstruct the neutrino energy.

- Need to understand nuclear physics to do neutrino physics

- If the current knowledge of neutrino-nucleus interactions does not improve, future experiments like LBNE will have a difficult time meeting their physics goals.

Motivation: Why are important the neutrino scattering measurements?

Oscillation Experiments

- T2K is a currently running oscillation experiment in Japan. Its latest results show the latest "state of the art" in predicting electron neutrino energy spectra

T2K uncertainty on the predicted number of electron neutrino events is ~9%
Uncertainty is dominated by uncertainties associated with understanding neutrino interactions in nuclei!

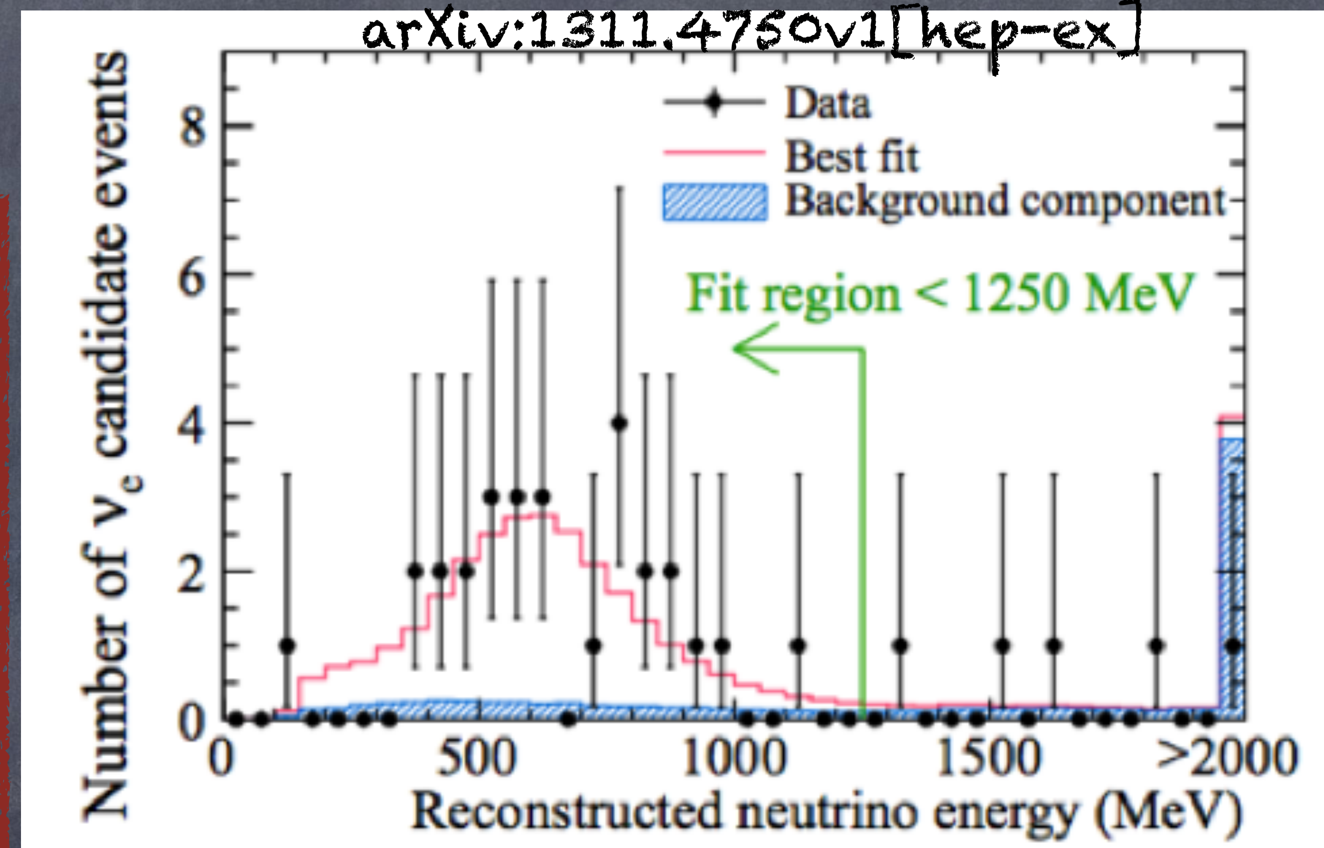
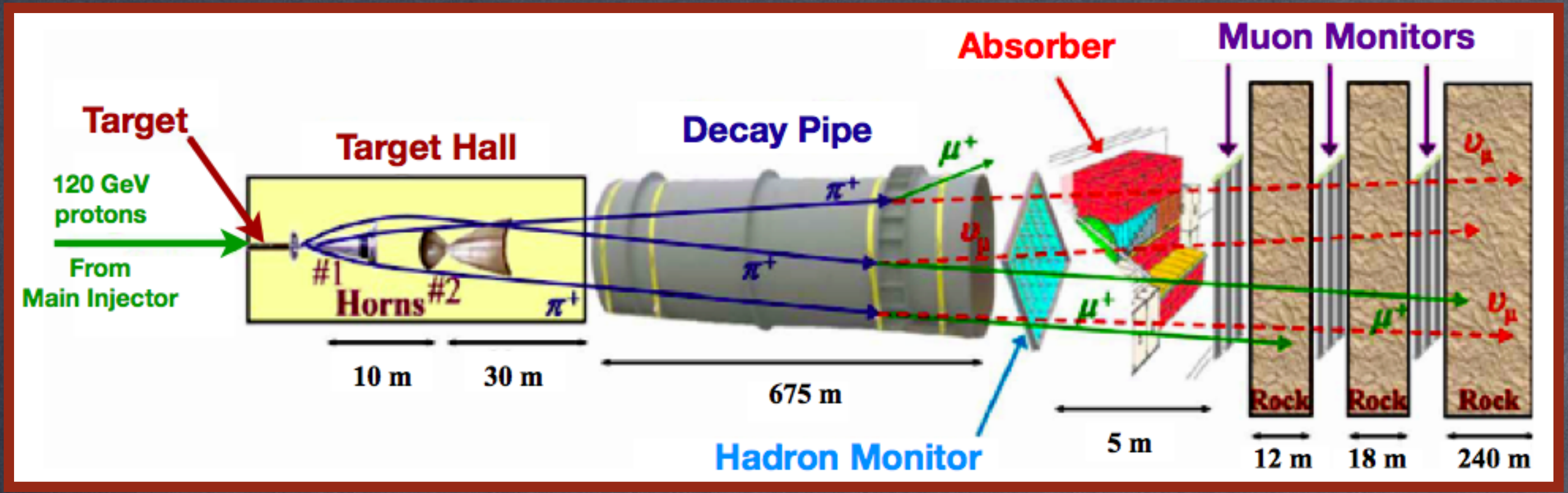


TABLE II. The uncertainty (RMS/mean in %) on the predicted number of signal ν_e events for each group of systematic uncertainties for $\sin^2 2\theta_{13} = 0.1$ and 0.

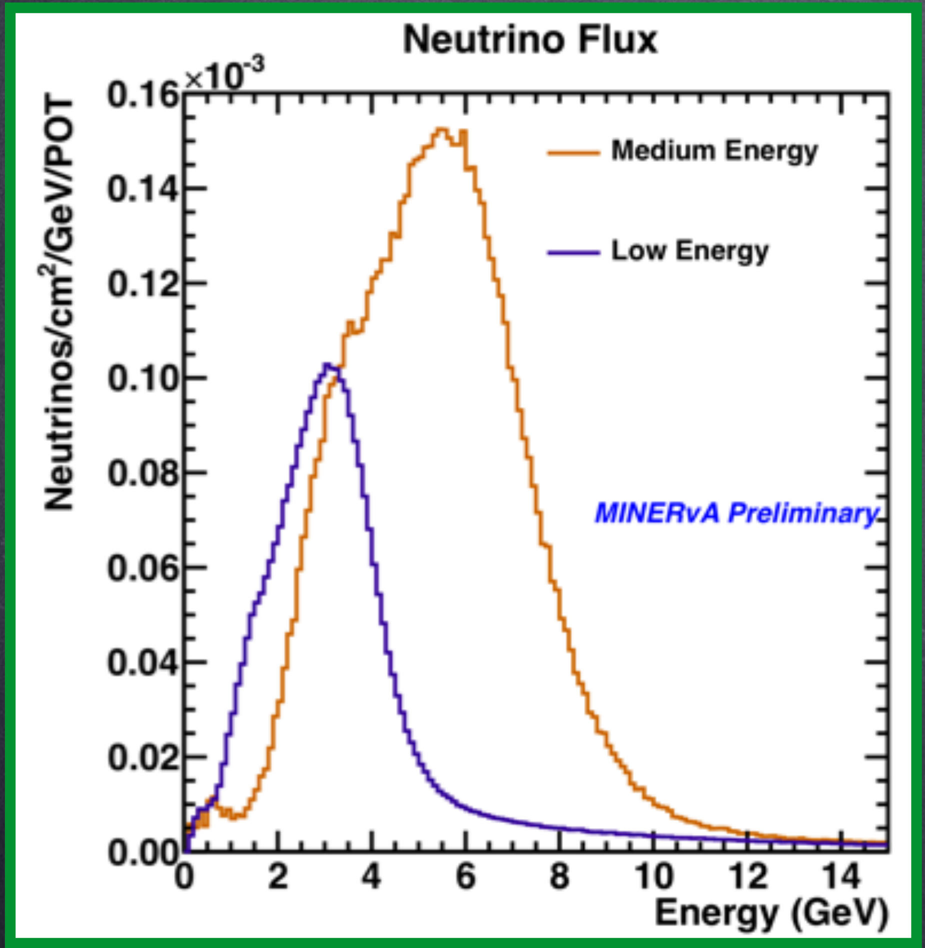
Error source [%]	$\sin^2 2\theta_{13} = 0.1$	$\sin^2 2\theta_{13} = 0$
Beam flux and near detector	2.9	4.8
(w/o ND280 constraint)	(25.9)	(21.7)
ν interaction (external data)	7.5	6.8
Far detector and FSI+SI+PN	3.5	7.3
Total	8.8	11.1

The NuMI Beam and MINERvA Detector

NuMI Beam (Neutrinos at Main Injector)



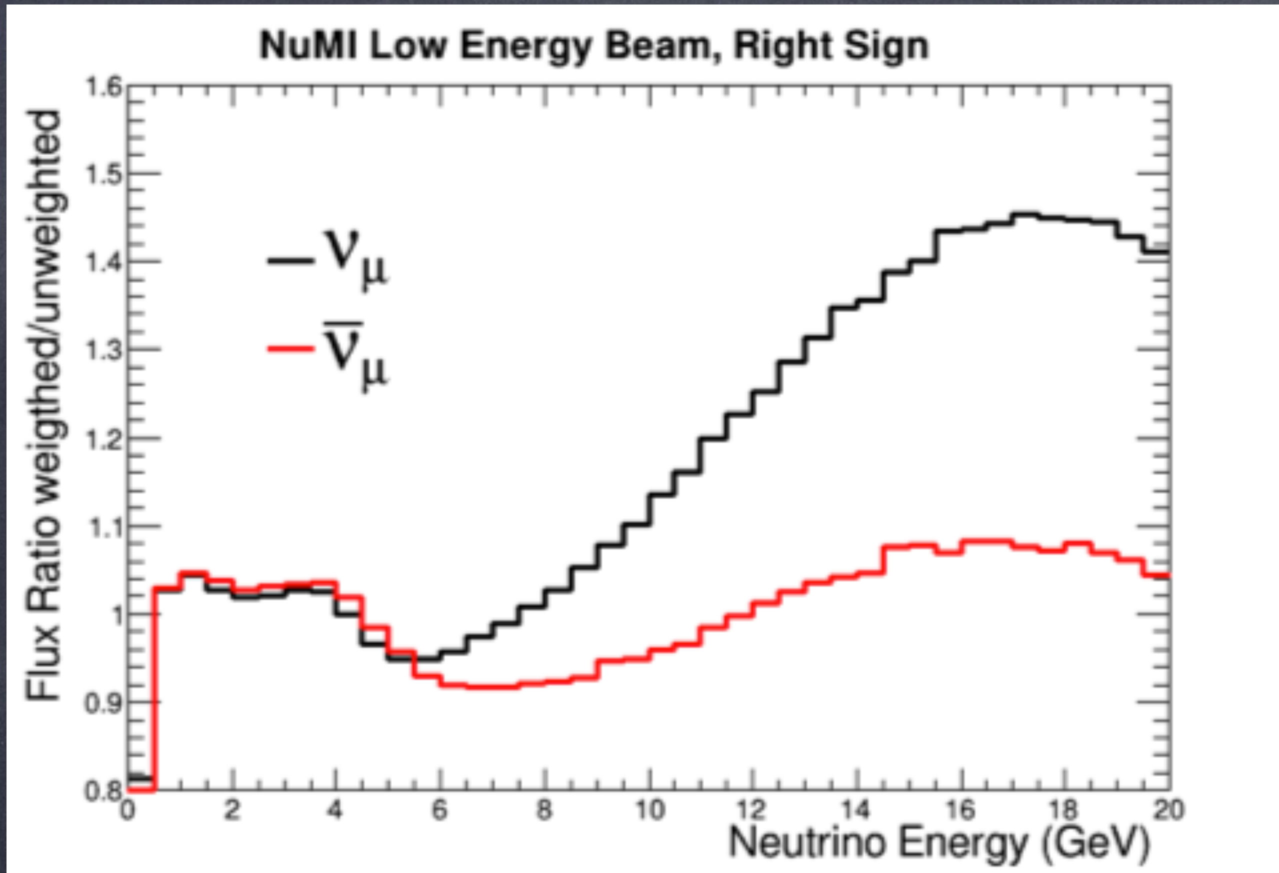
to MINERvA and MINOS

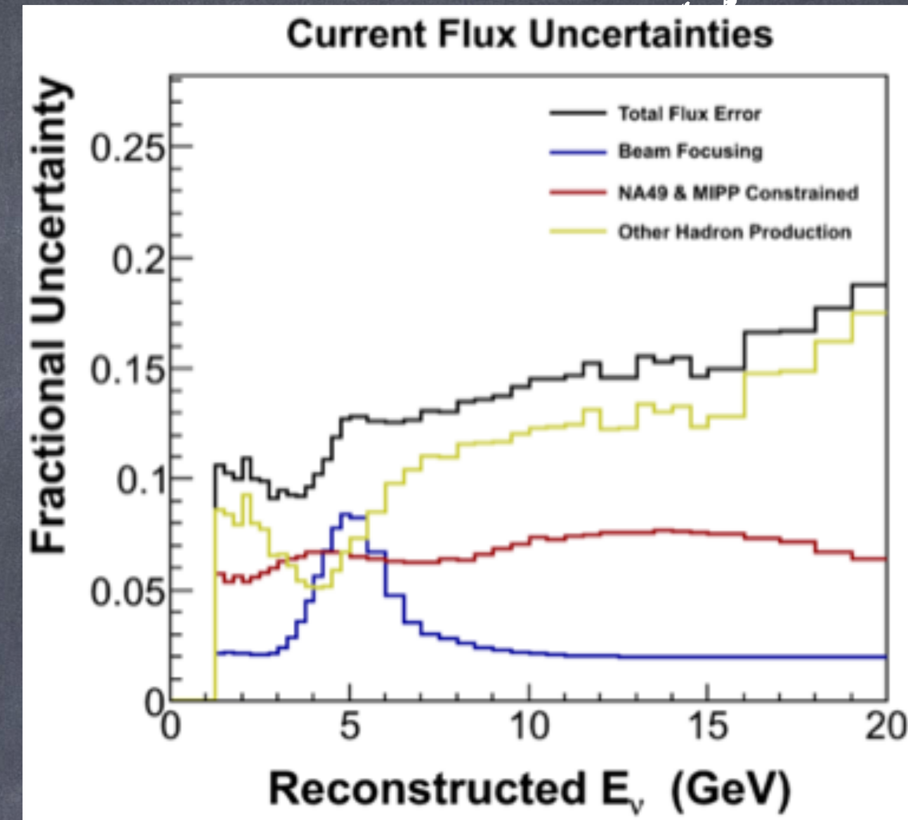


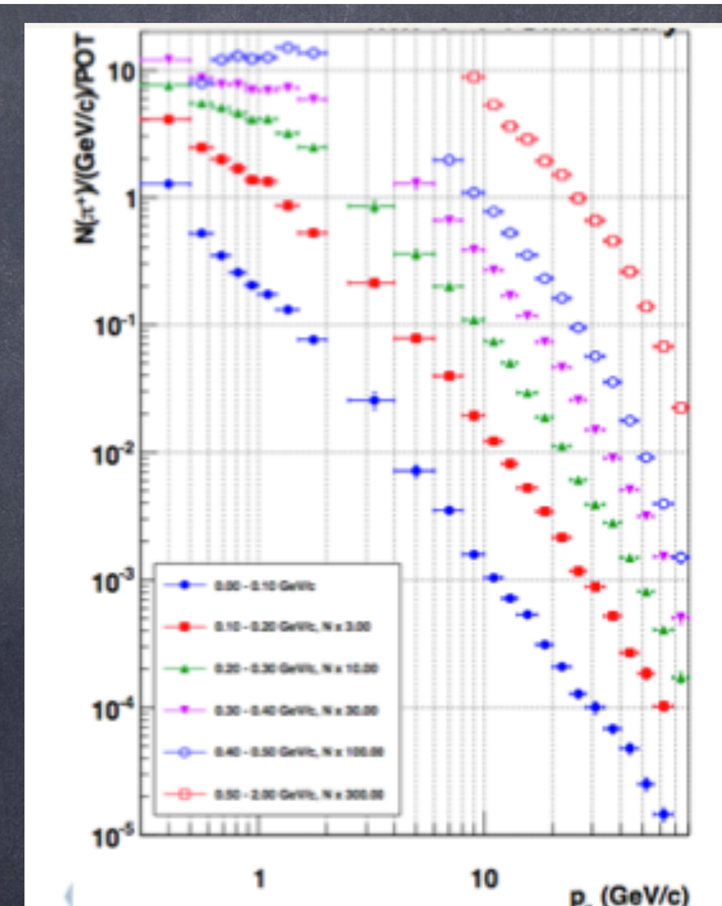
Flux estimate starts with a GEANT4 based simulation of the NuMI beam line

- 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+

NuMI : Neutrino Flux Tunning



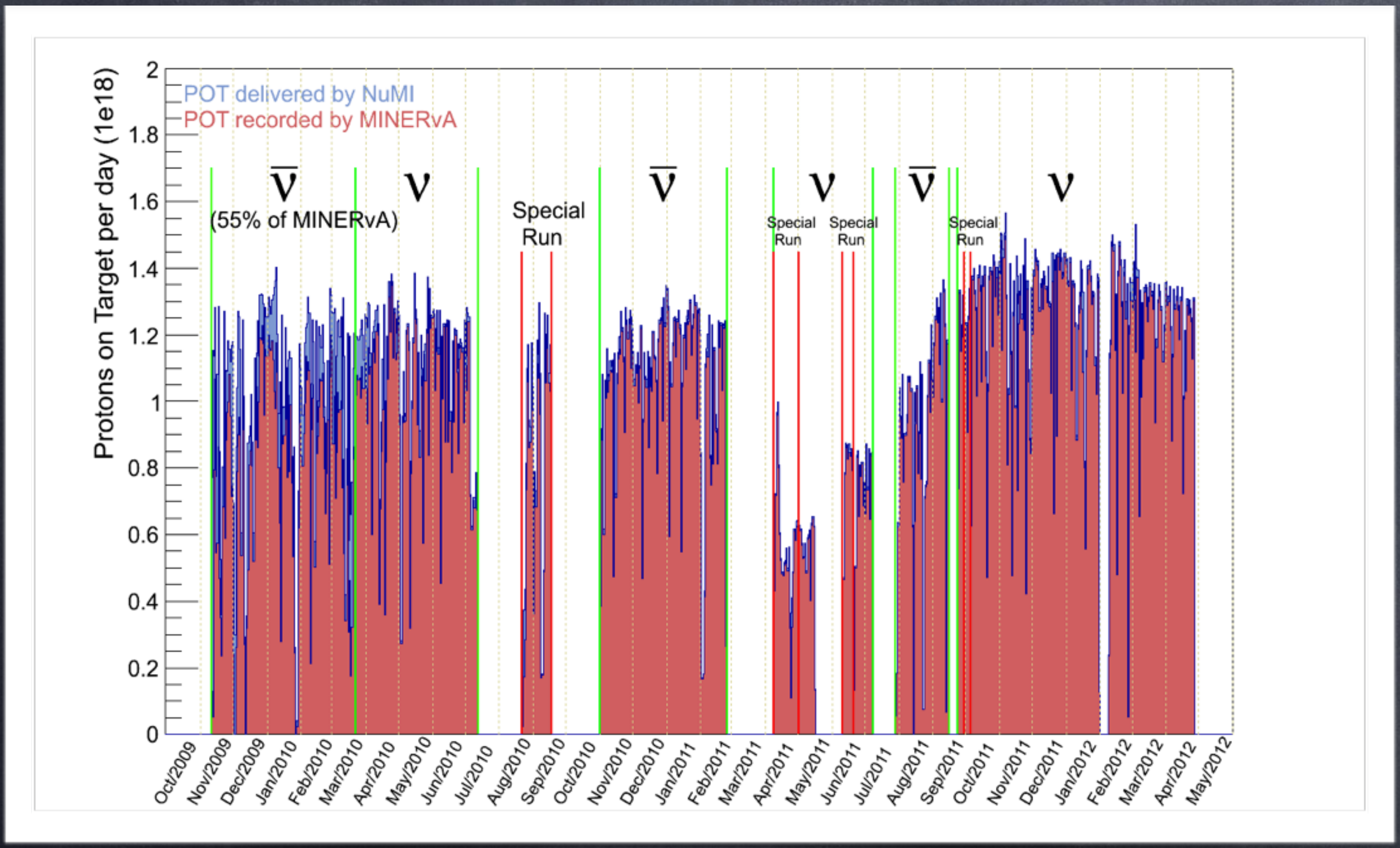




- GEANT4 model constrained by NA49 and MIPP (pi/k ratio only); current flux has ~10% uncertainties in focusing peak
- Currently working to incorporate MIPP's latest cross section results

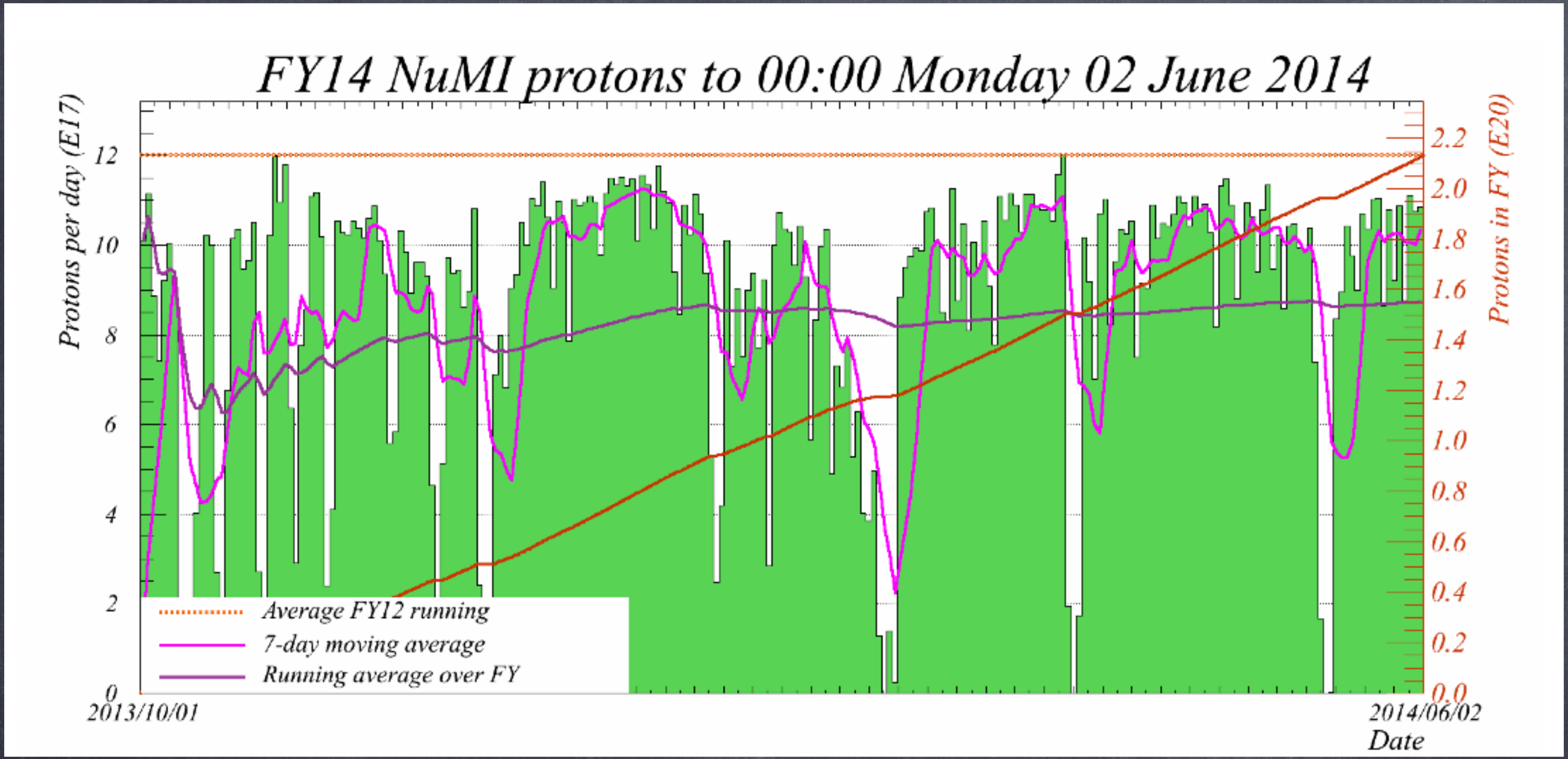
J.M.Paley,M.D.Messier
arXiv:1404.5882

NuMI: Total data collected (Low Energy Run)



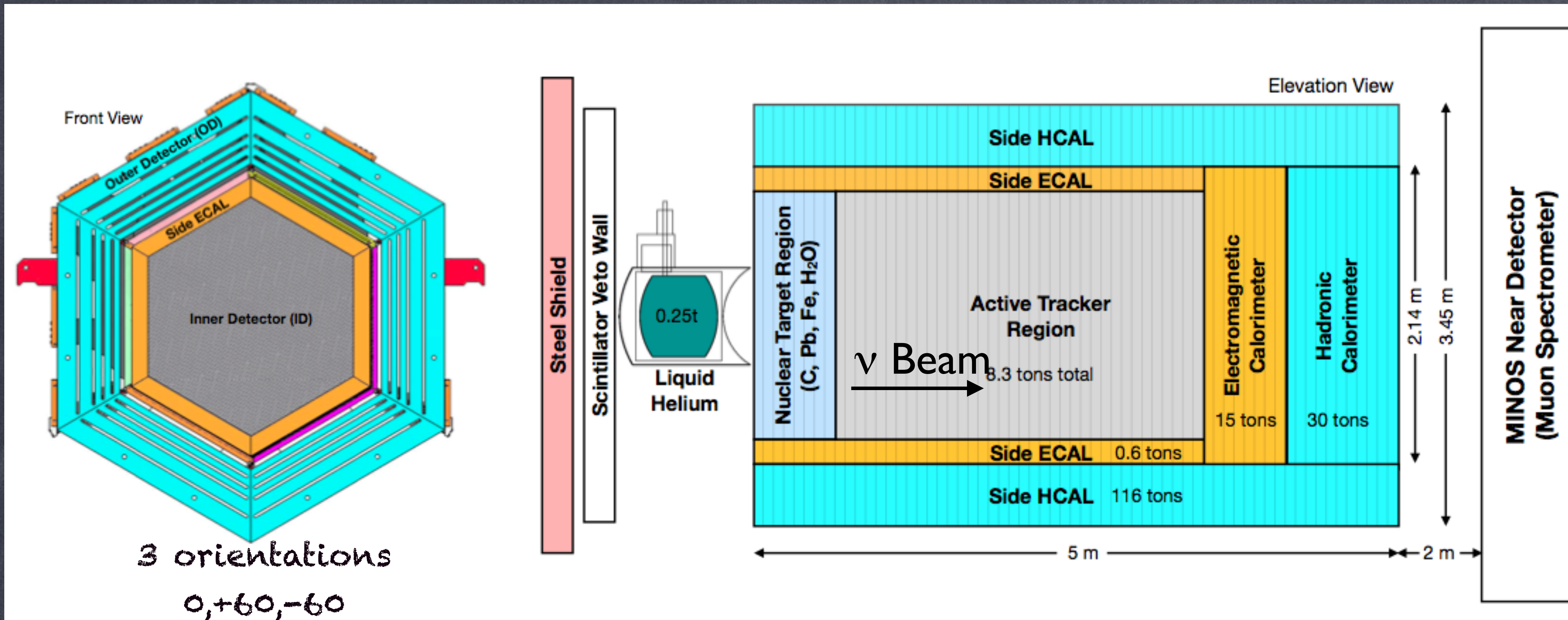
- Muon nu LE: 3.98e20 POT
- Muon antinu LE: 1.70e20 POT
- special runs: 4.94e19 POT
- Livetime: 97.2% MINERvA.
- 93.3% MINOS Near Detector

NuMI: Total data collected (Medium Energy Run)



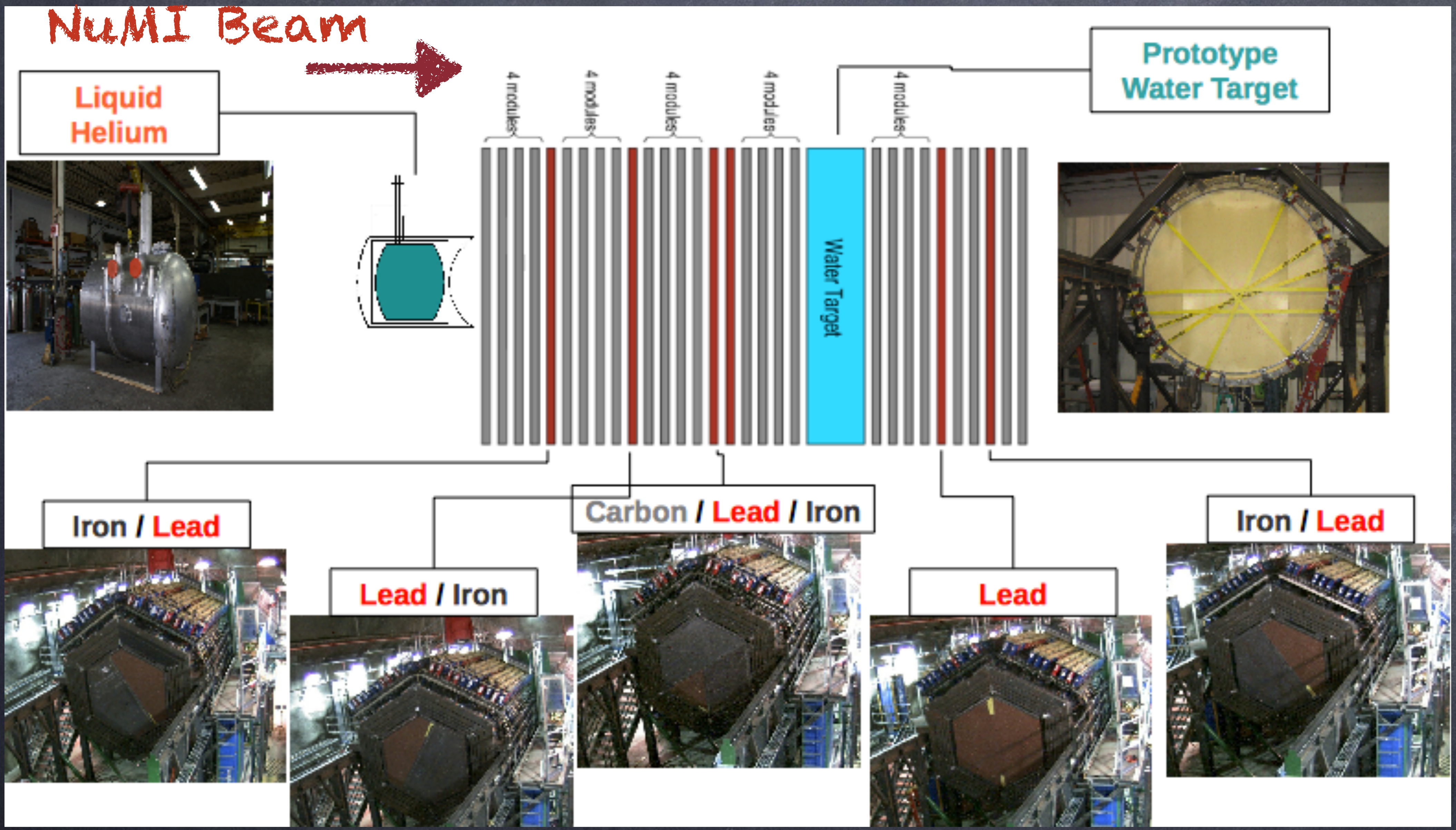
- Accumulated 2.2e20 POT -> Sept 2013 - May 2014
- More than half of LE POT already

MINERvA Detector



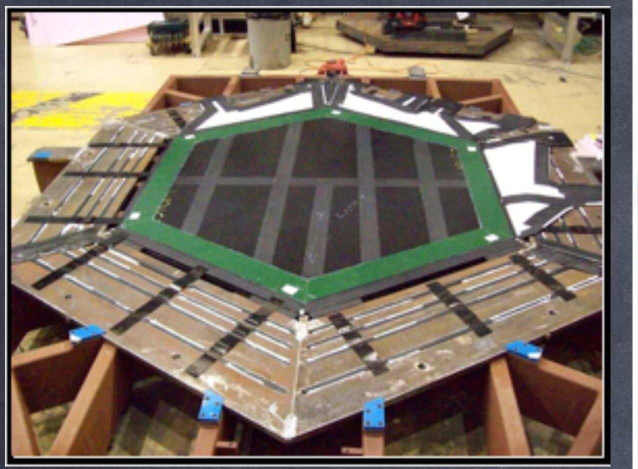
- Detector comprised of "120 modules" stacked along the beam direction
- Central region is finely segmented scintillator tracker
- Calorimeters are scintillator + Iron or Lead
- Upstream targets composed of Iron, Lead, Carbon, Water and Helium
- ~ 32k plastic scintillator strip channels total

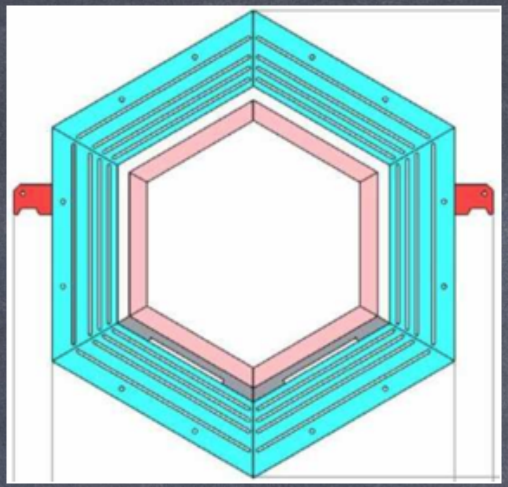
MINERvA Nuclear Passive Targets



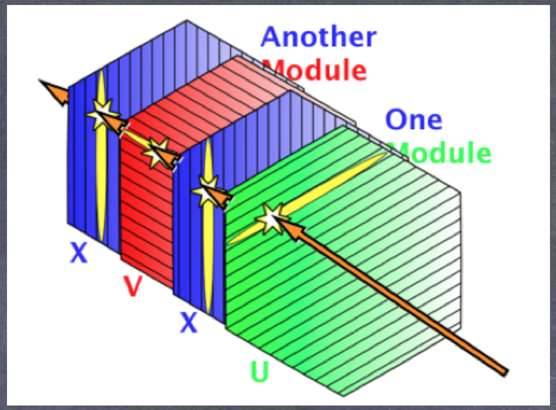
Target	Fiducial Mass (tons)
Plastic	6.43
Helium	0.25
Carbon	0.17
Water	0.39
Iron	0.97
Lead	0.98

MINERvA Detector

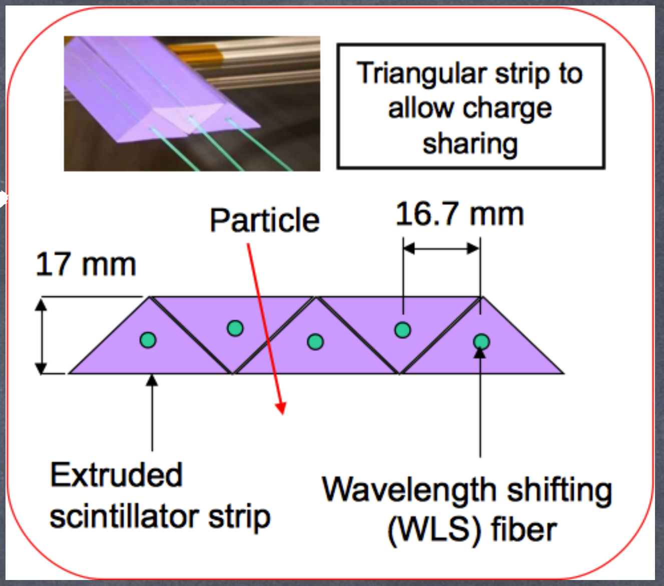


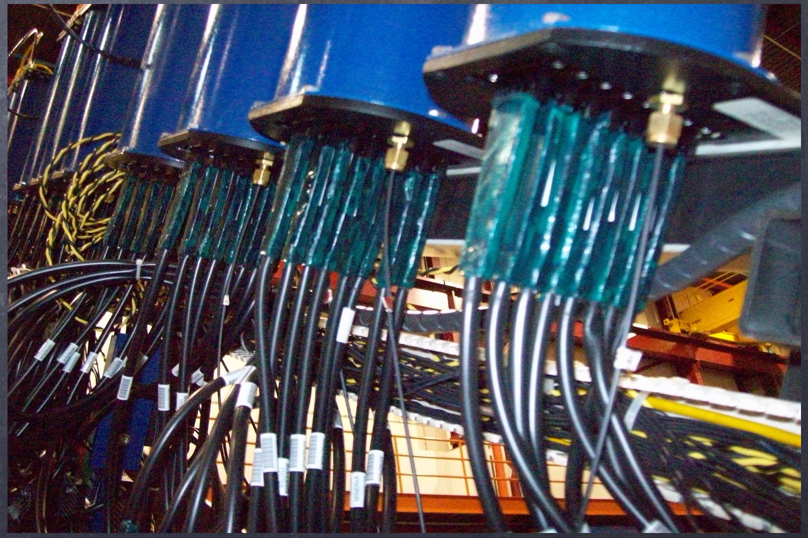


Tracker module = 2 planes
ECAL module = 2 planes + 2 (2 mm thick) sheet of lead
HCAL module = 1 plane + 1 (1 inch thick) sheet of steel

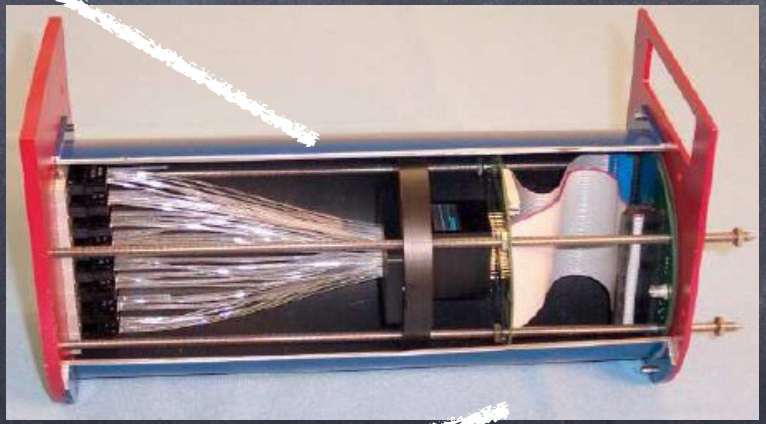


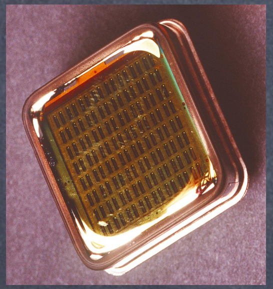
127 scintillator strips per plane.





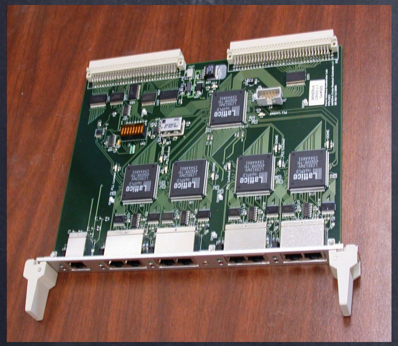
PMT Box

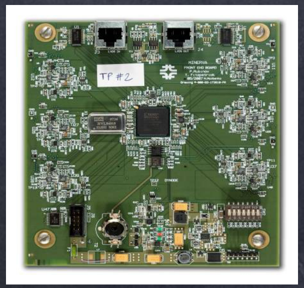




Hamamatsu
MA 64 PMTS

CROC
VME Readout



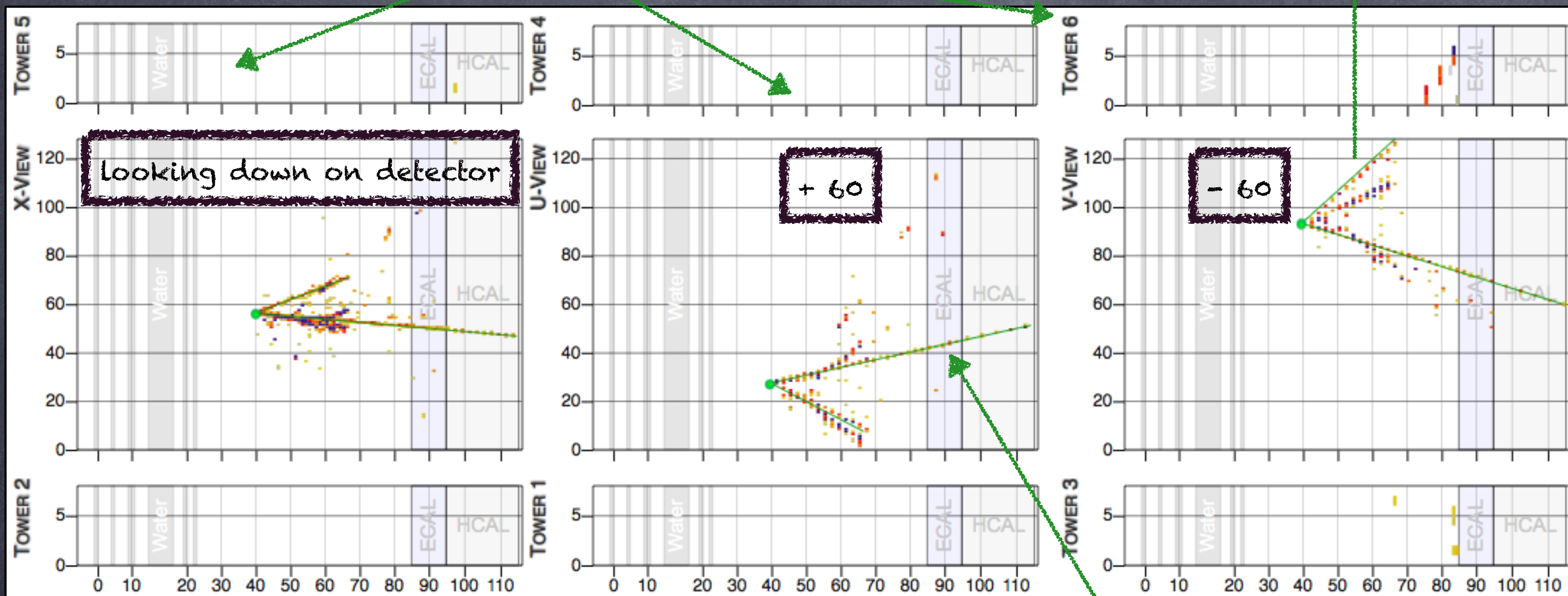


Front End Board FEB
Trip-T chip interface the PMTs

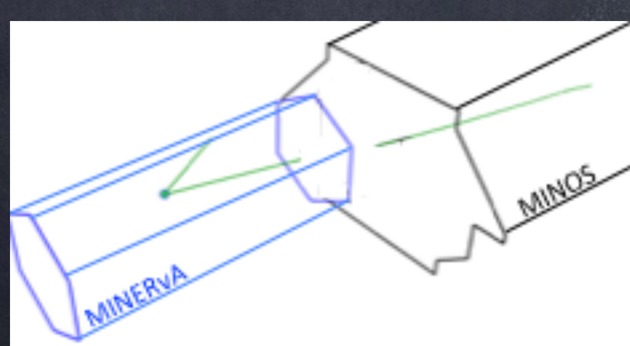
MINERvA Detector

Particle leaves inner detector stops in outer iron calorimeter

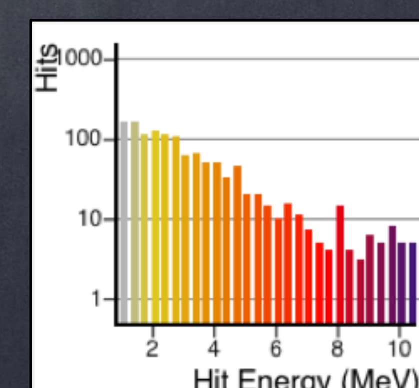
3 stereo views X-U-V show separately



Modules



Muon leaves the back of the detector headed toward MINOS



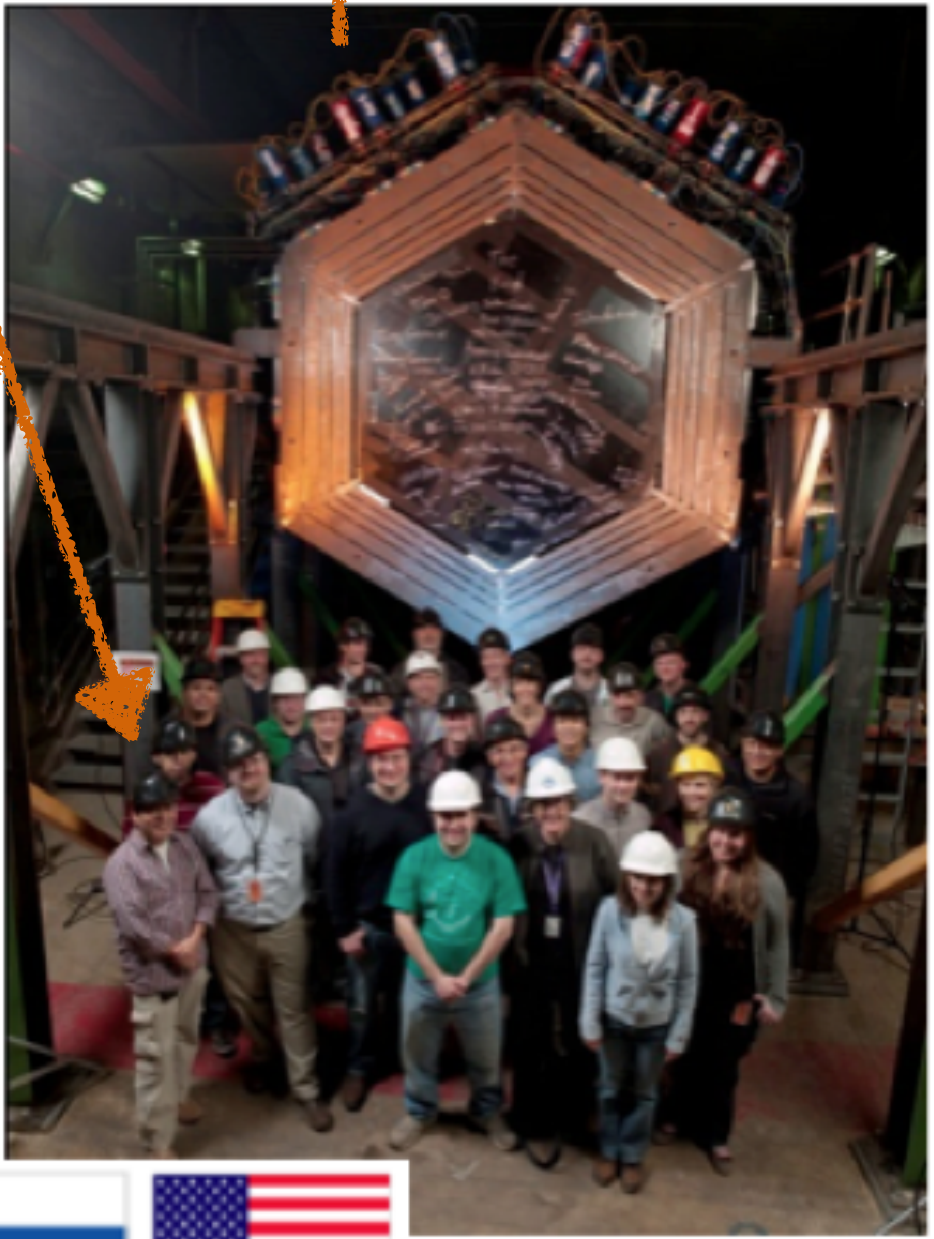
MINERvA Detector: More than just a detector!

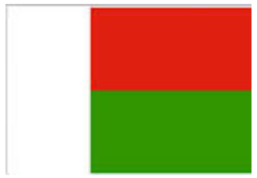
~ 60 collaborators from nuclear and particle physics

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
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

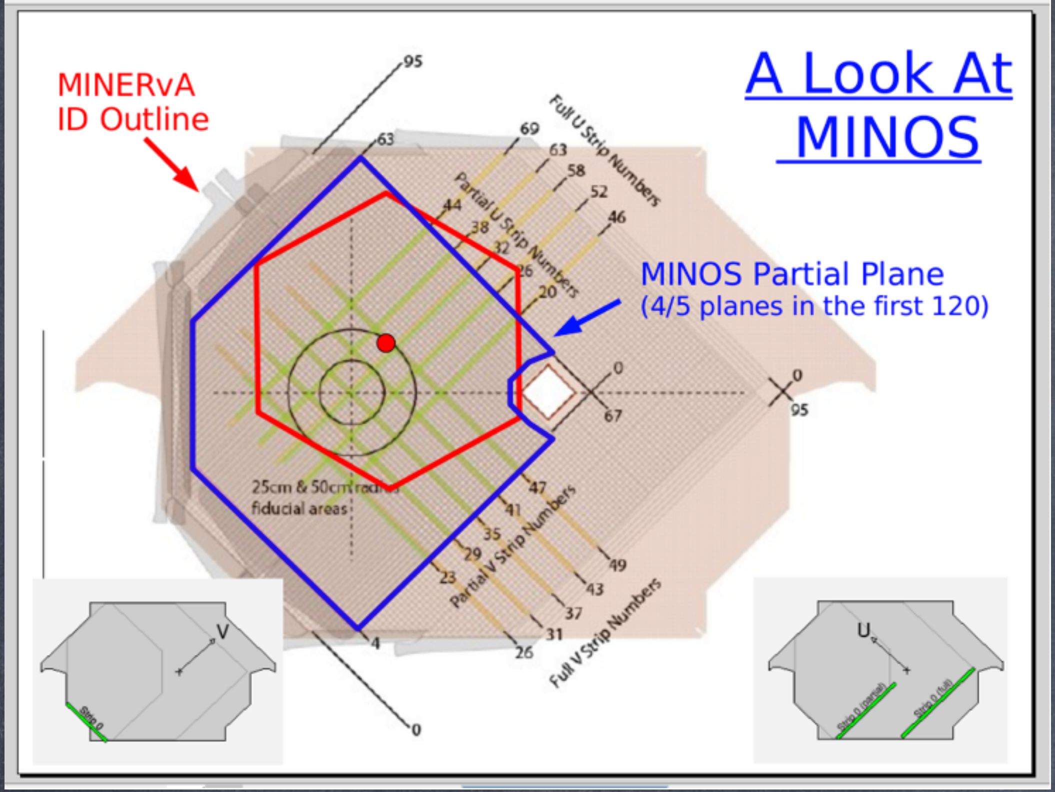
I am here!! :)

The awesome PMTs !!!



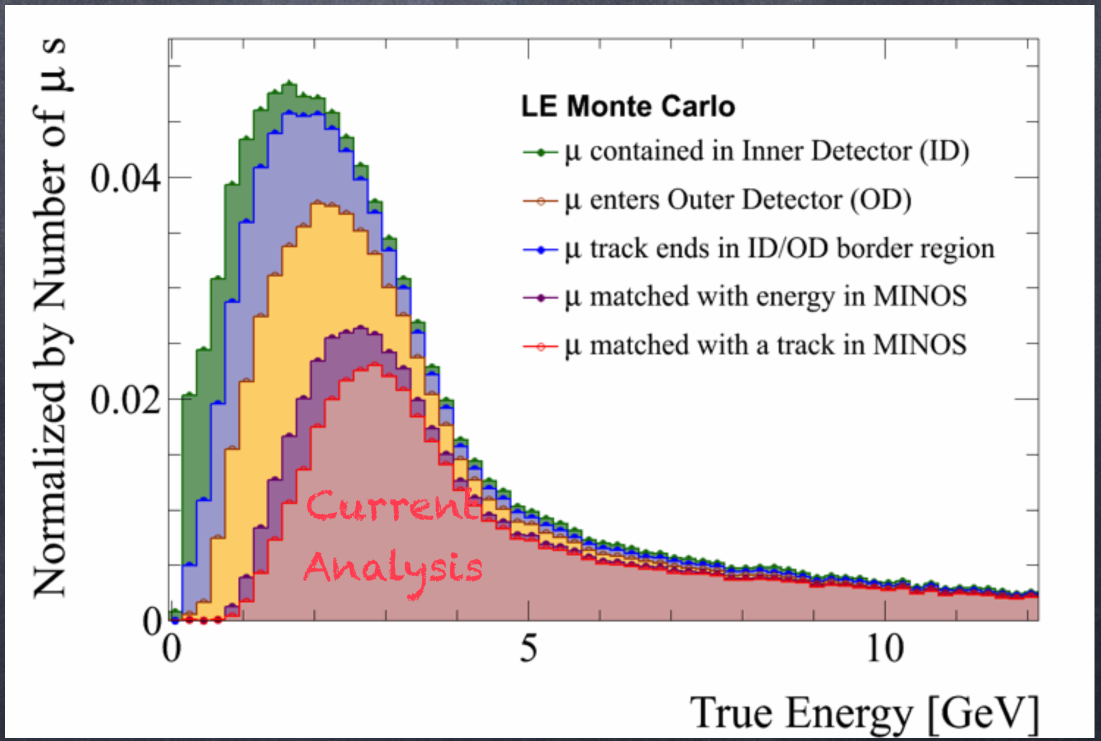


MINERvA Detector : Where do the muons go?



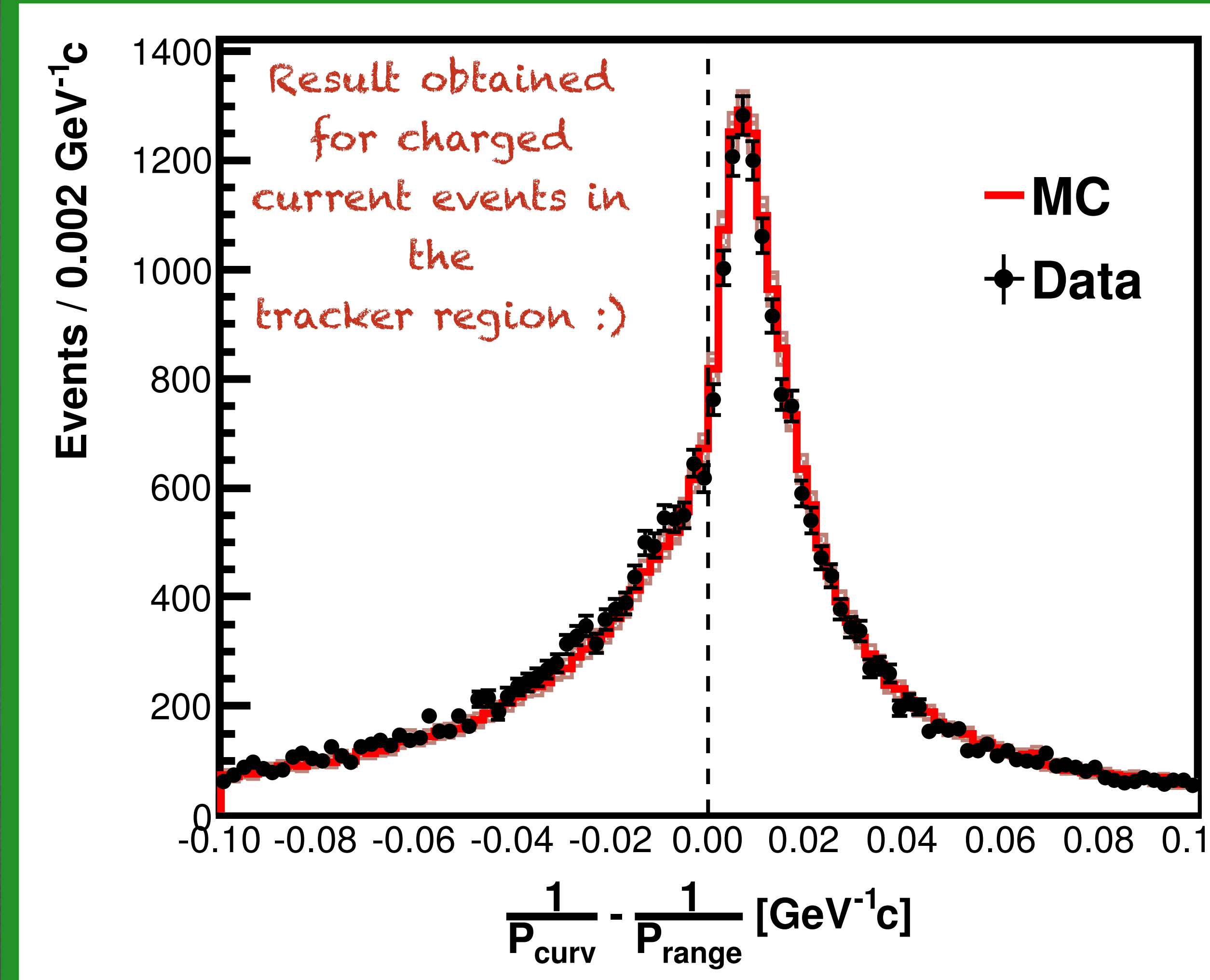
- MINOS near detector is used as a forward muon spectrometer. MINOS magnet allows the reconstruction of the charge and the momentum of the muon generated in the MINERvA detector.

- Energy threshold for a muon to exit MINERvA and be tracked into MINOS is around 2 GeV
- Good angular acceptance up to scattering angles of about 10 degrees with limit about 20 degrees.
- Muons that does not reach MINOS can also be analyzed but no charge measurement is possible. We are currently developing algorithms in reconstruction for muons contained in the detector



MINERvA Detector: Muon Energy Scale

- All muons used in the MINERvA analyses are momentum analyzed in MINOS near detector - By range in the steel or by curvature in the magnetic field!

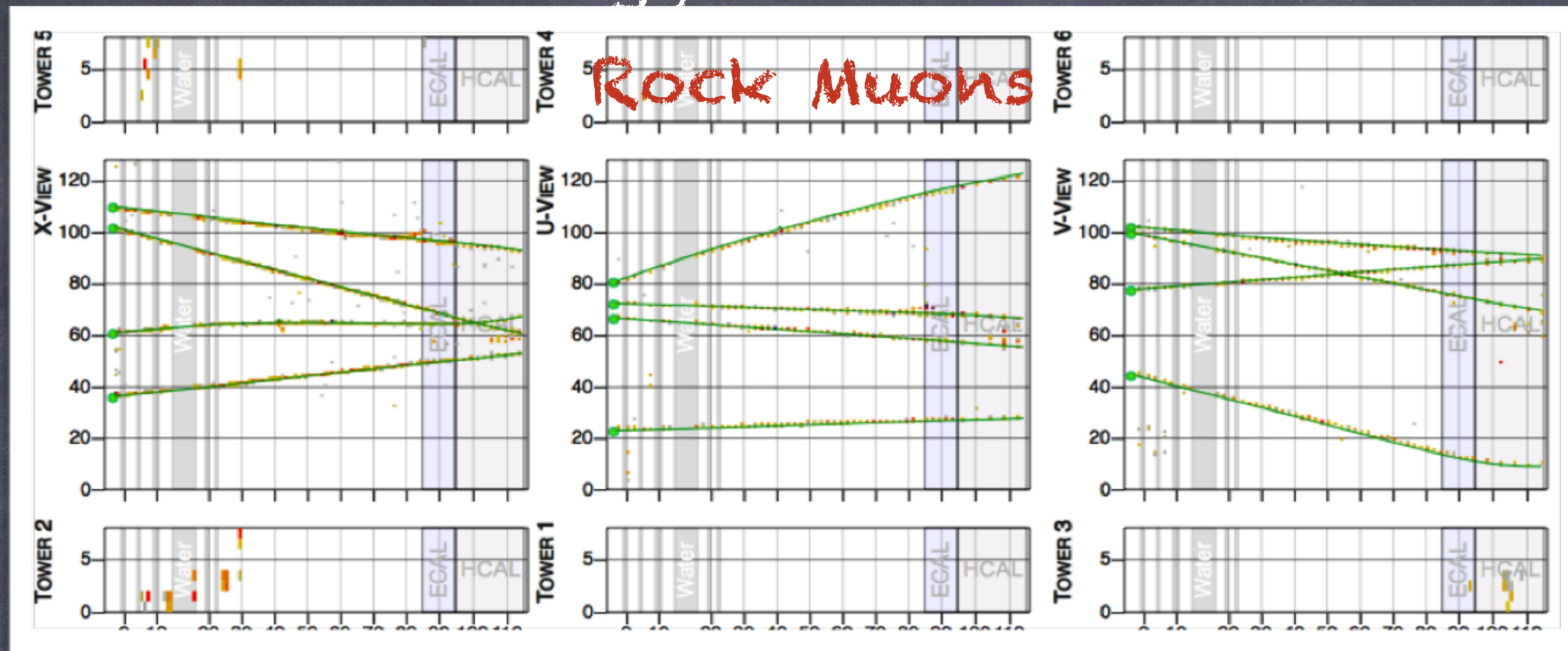


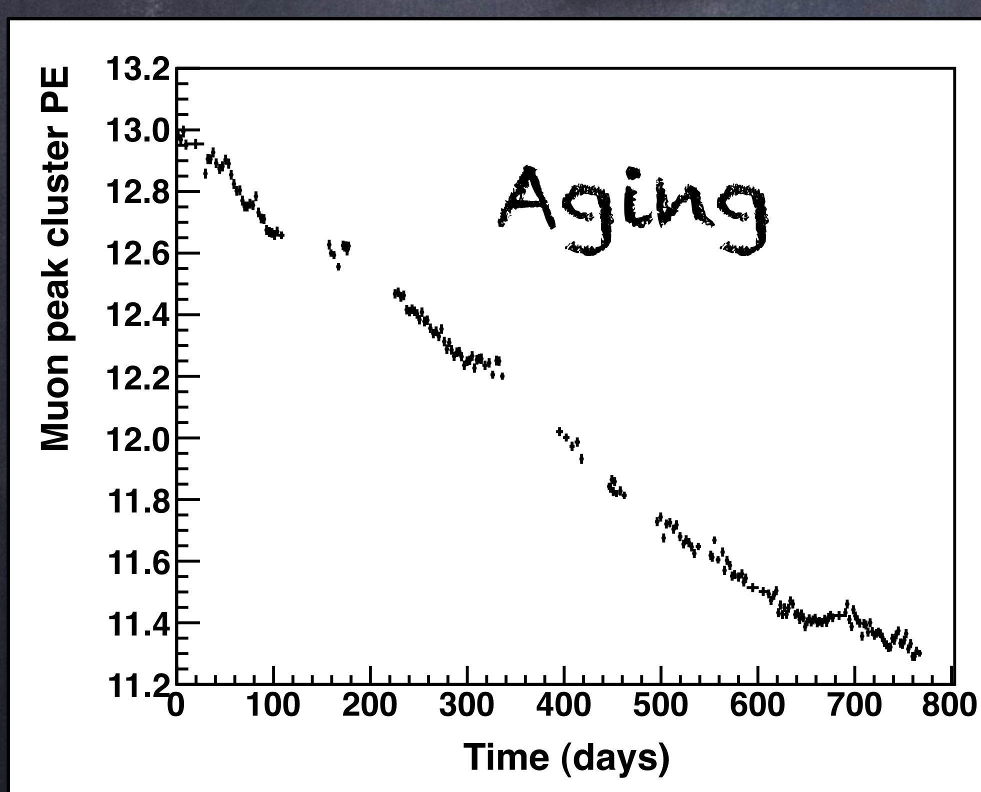
Error Source	Error
MINOS Range	2.0%
MINOS Curvature ($p_\mu < 1\text{GeV}/c$)	2.5%
MINOS Curvature ($p_\mu > 1\text{GeV}/c$)	0.6%
MINERvA dE/dx (scintillator events)	30 MeV
MINERvA dE/dx (C, Fe, Pb events)	40 MeV
MINERvA mass (scintillator events)	11 MeV
MINERvA mass (C, Fe, Pb events)	17 MeV

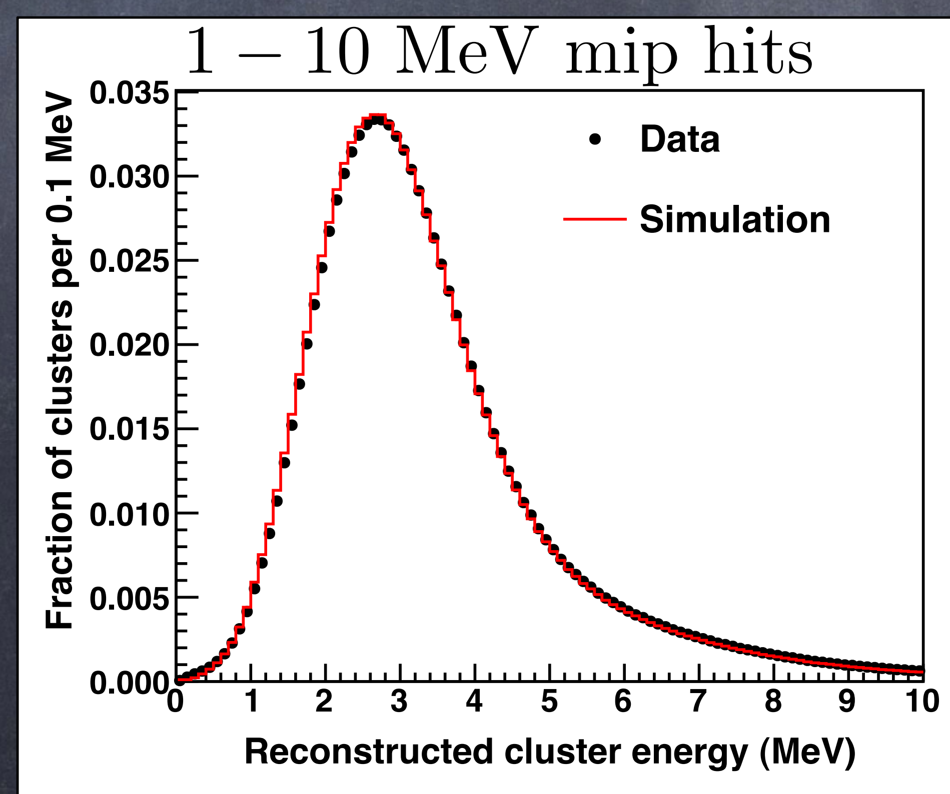
- Error on reconstruction by curvature relative to range is taken to be the difference between the mean of the Gaussian fits in Data and MC

MINERvA Detector: and what about the Recoil Energy Scale?

High Statistics monitoring of the detector energy response with rock muons



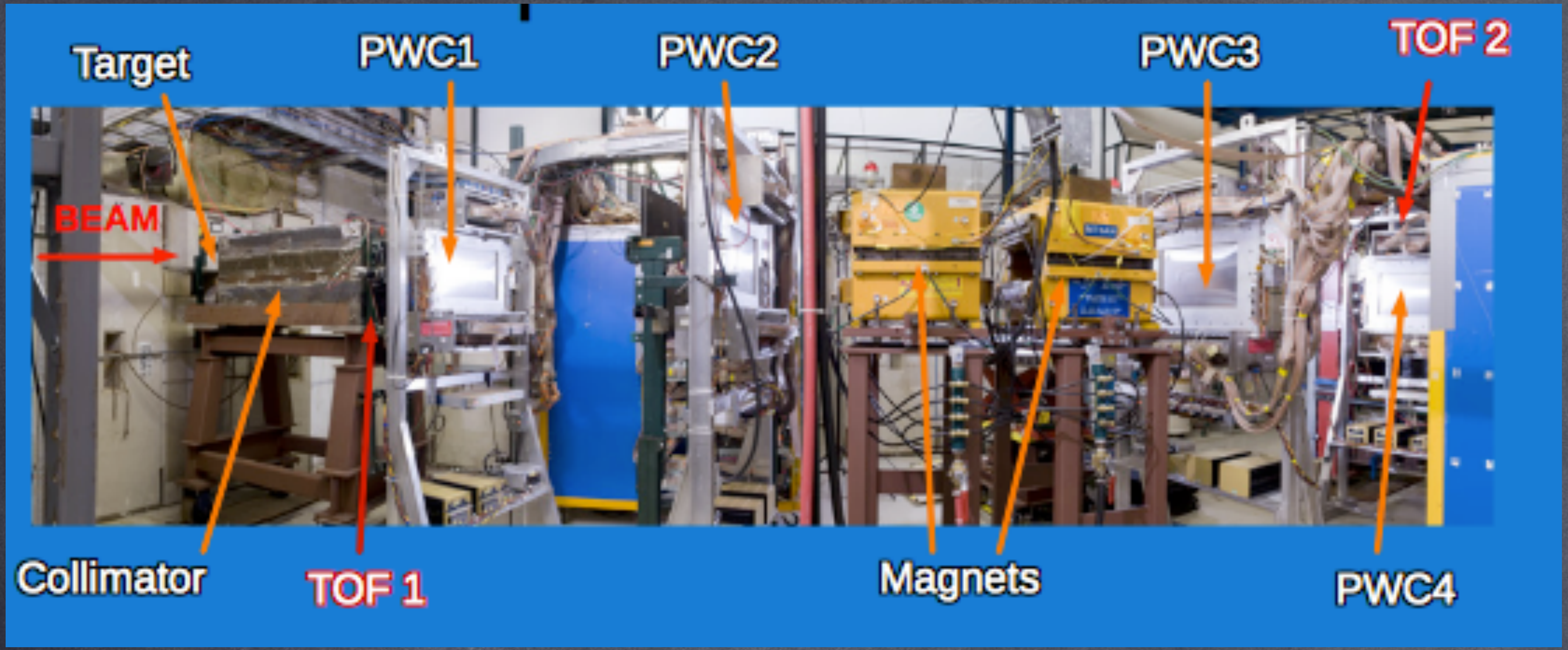




MIP: Minimum Ionizing Particle

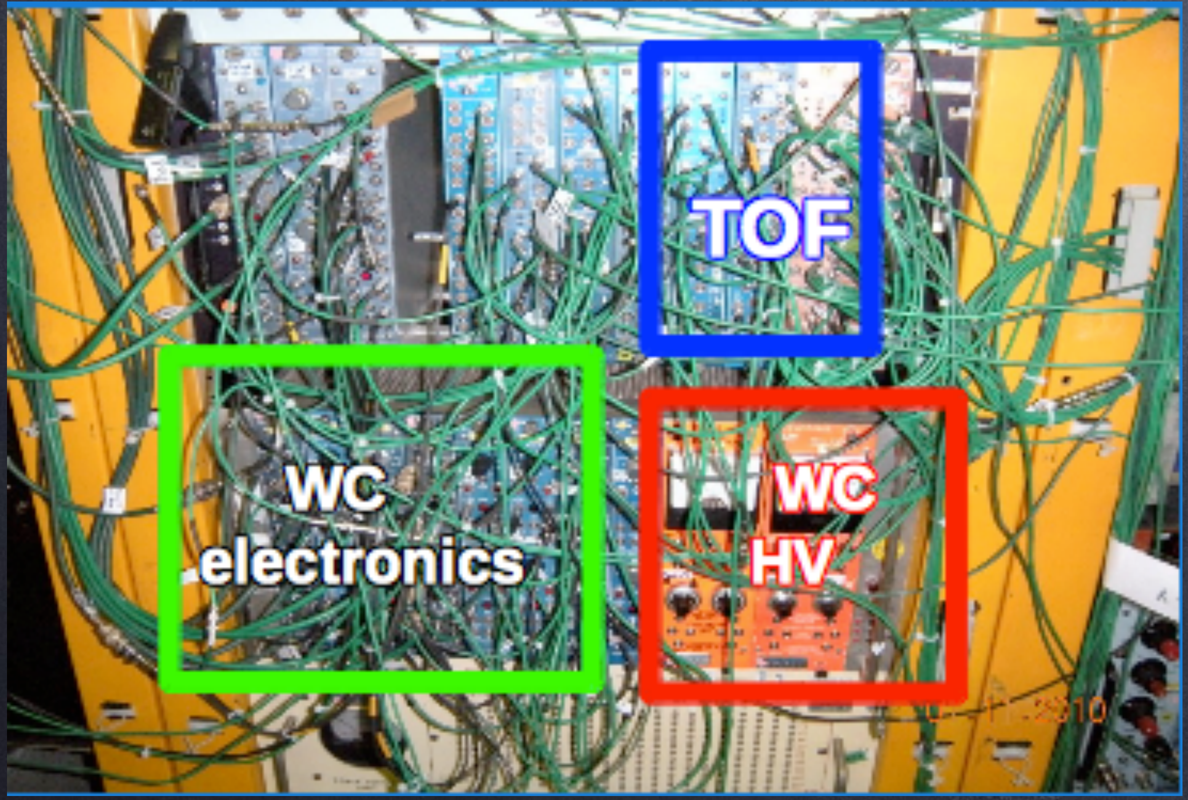
MINERvA Detector : Recoil Energy Scale

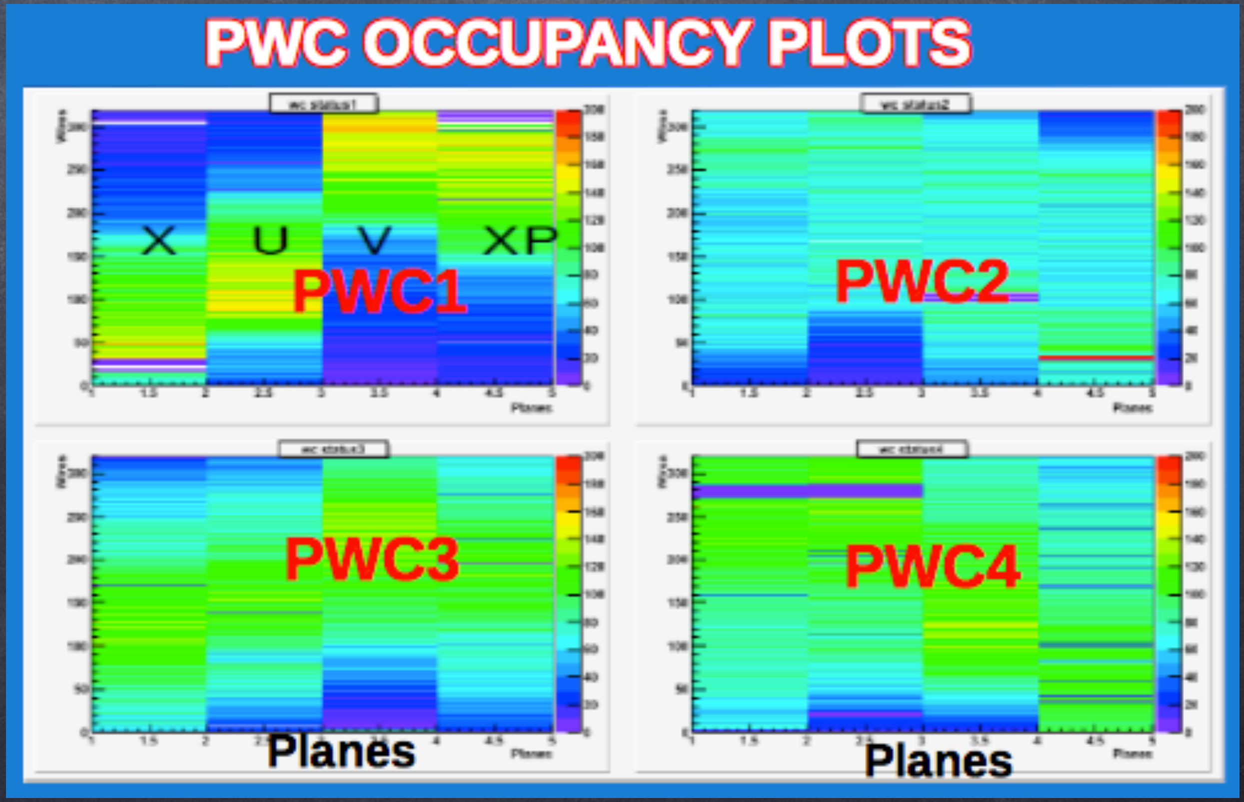
Beamline overview



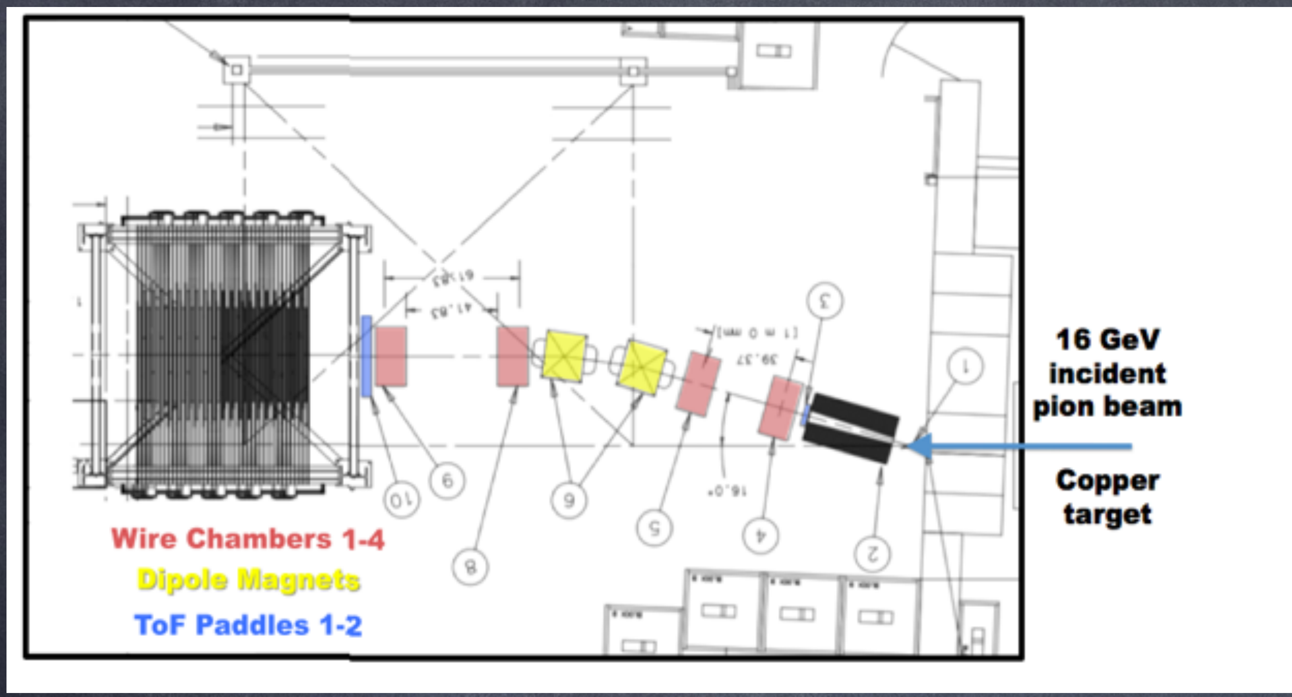
- Incoming 16 Gev pions -> 0.4 - 2 GeV
- Time of flight TOF scintillator counters, measure transit time of particles
- Hits on Proportional Wire Chambers(PWC) PWC1 through PWC4 help reconstruct the trajectory of the charged particle.

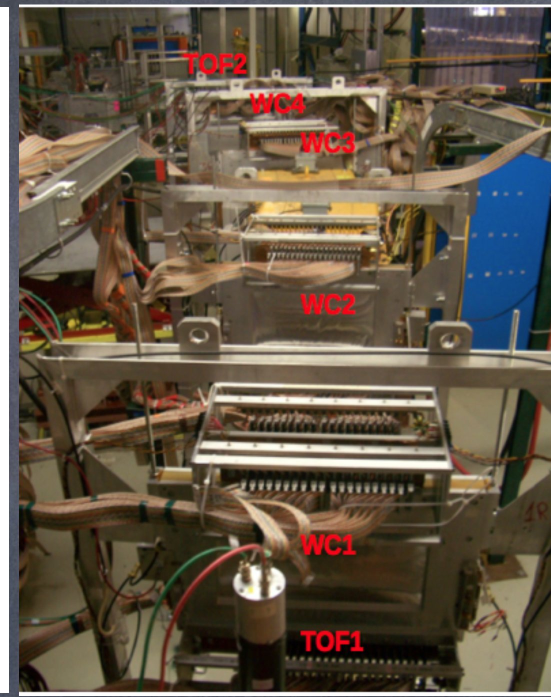
Beamline electronics

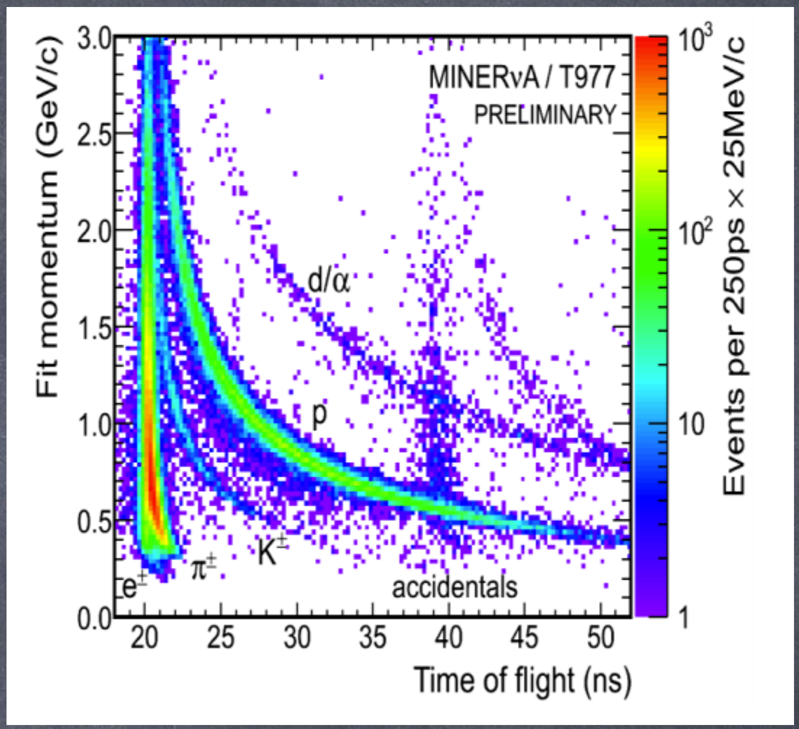


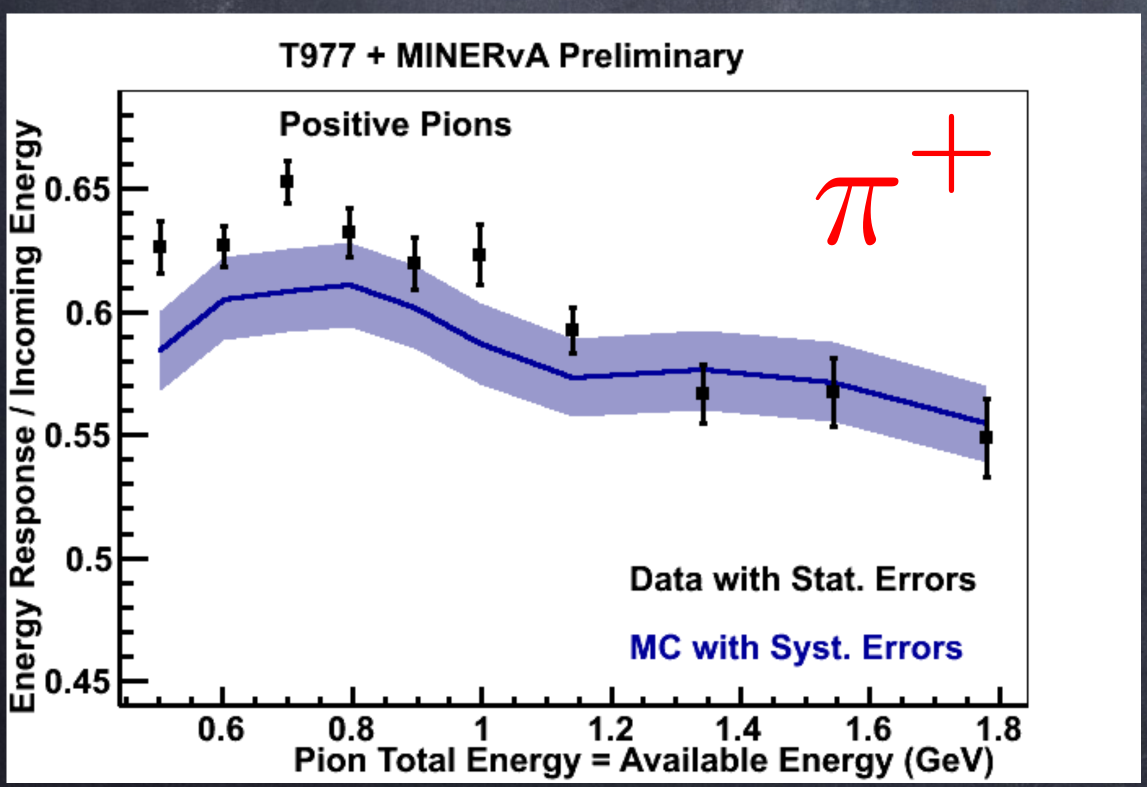


MINERvA Detector : Recoil Energy Scale









- Mini-MINERvA + MTest Tertiary Beam
- The test beam had a major importance project to calibrate absolute energy response (hadron calibration) of the MINERvA detector.
- high energy charged pion response uncertainty is ~ 5%

Conclusions & Future perspectives

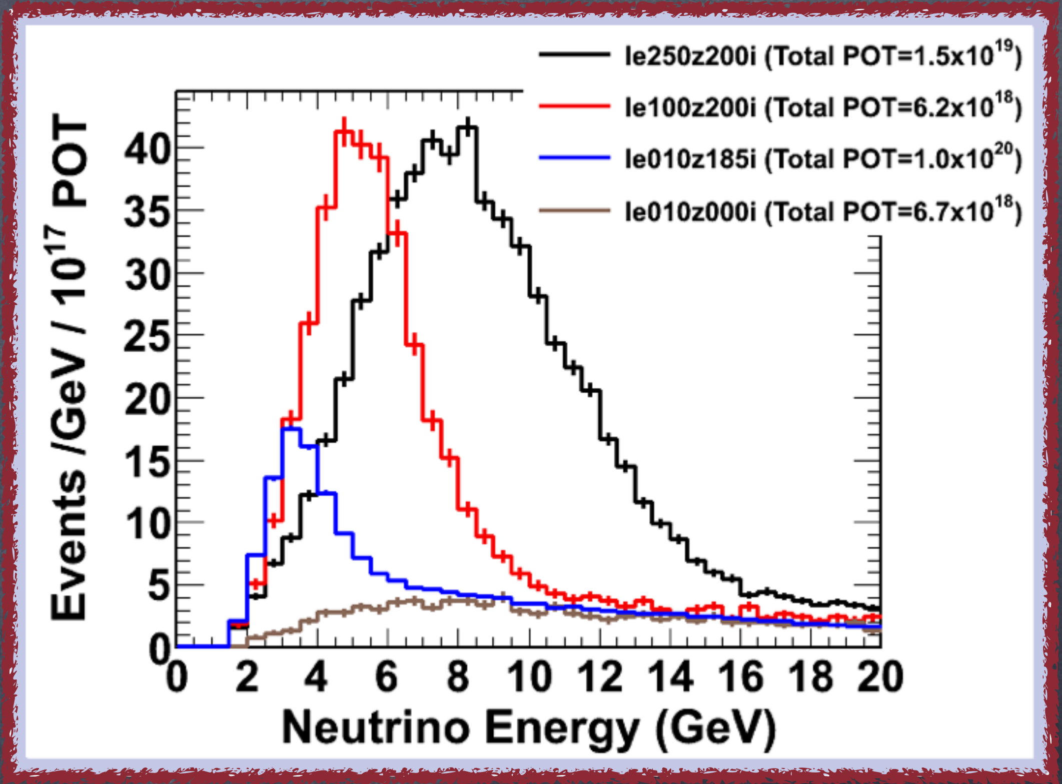
- MINERvA detector is working well and meeting its design specifications.
- MINERvA has all its Low Energy (LE) data and is very busy analyzing it (Also the ME data will be great for future analysis and new ideas!)
- Stay tuned for the exciting incoming talks about MINERvA in this conference
- Chris Marshall -> Charged kaon production at MINERvA
- Cheryl Patrick -> Quasi-elastic neutrino scattering at MINERvA

THANK YOU!
GRACIAS!
OBRIGADO!

backup

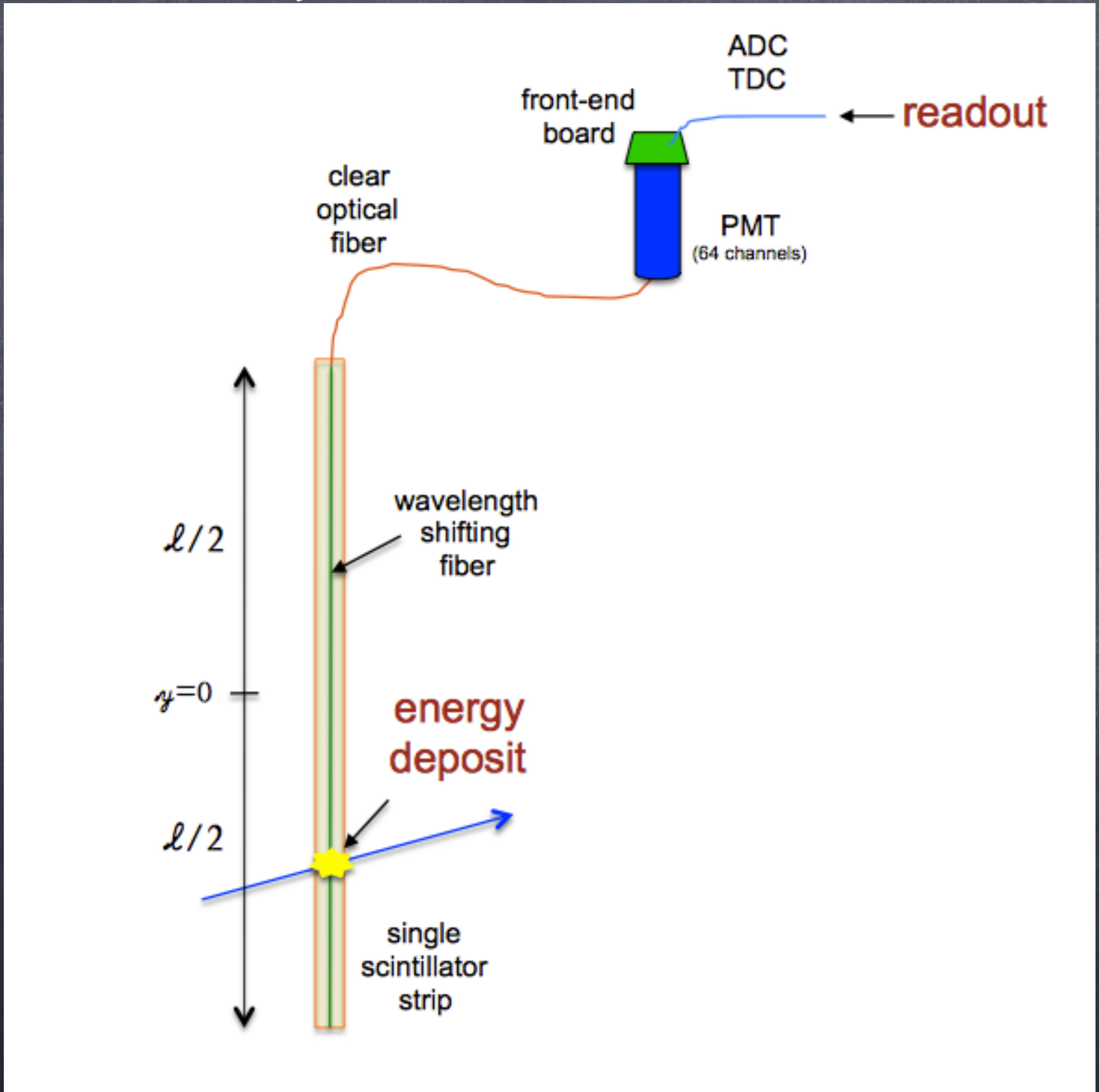
NuMI : Future of Neutrino Flux Tunning

- Future flux measurements will be improved by multi-pronged attack: Data with different horn current and target position configurations (special runs)



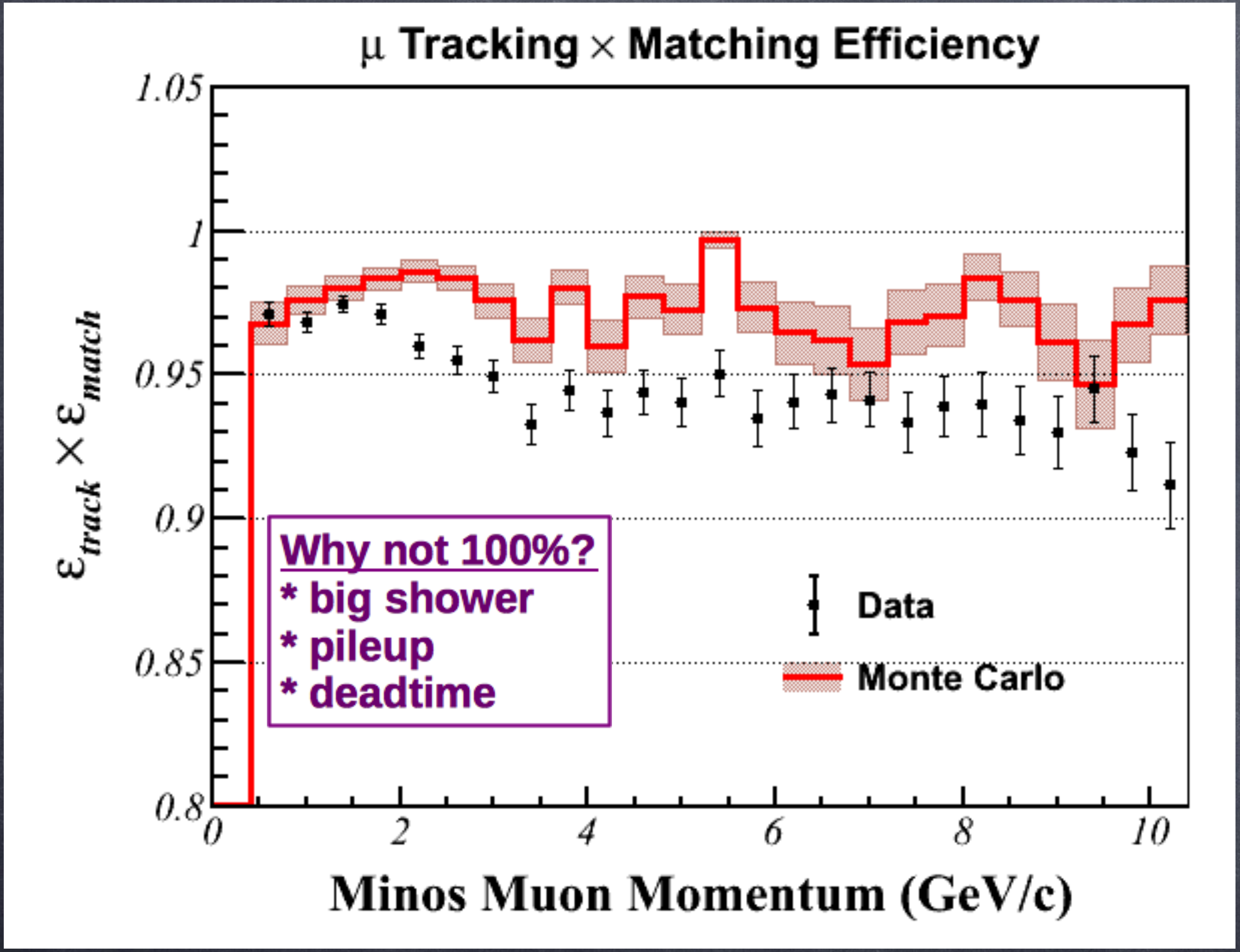
- New hadron production data (NA61 experiment at CERN)
- In situ measurement from muon flux via muon monitors

READOUT



ADC
TDC
front-end board
readout
clear optical fiber
PMT
(64 channels)
$\ell/2$
wavelength shifting fiber
y=0
energy deposit
$\ell/2$
single scintillator strip

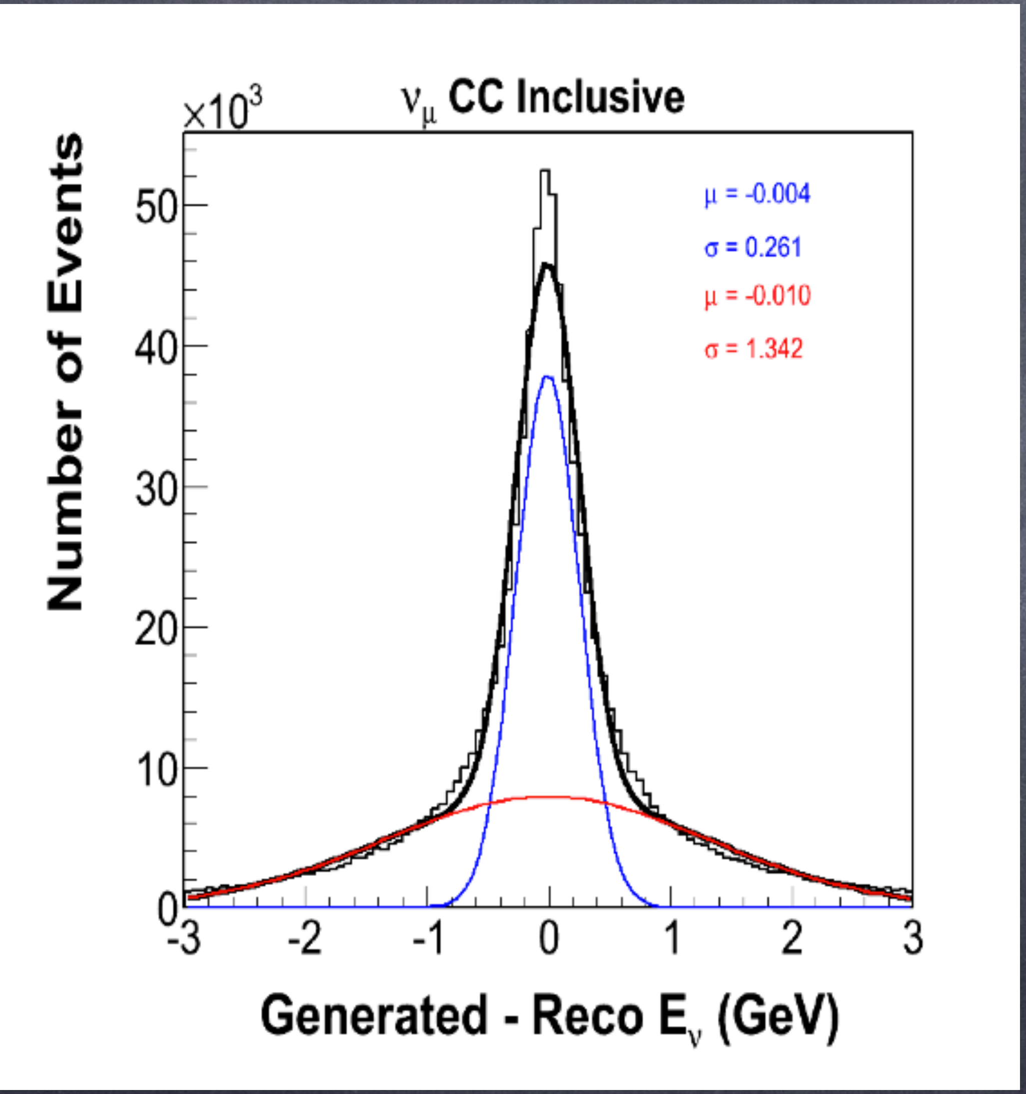
MINERvA Detector : Muons Tracking X Matching Efficiency



Method

Use muon in MINOS that point backs to MINERvA and try to find a match in MINERvA

Neutrino Energy resolution inclusive

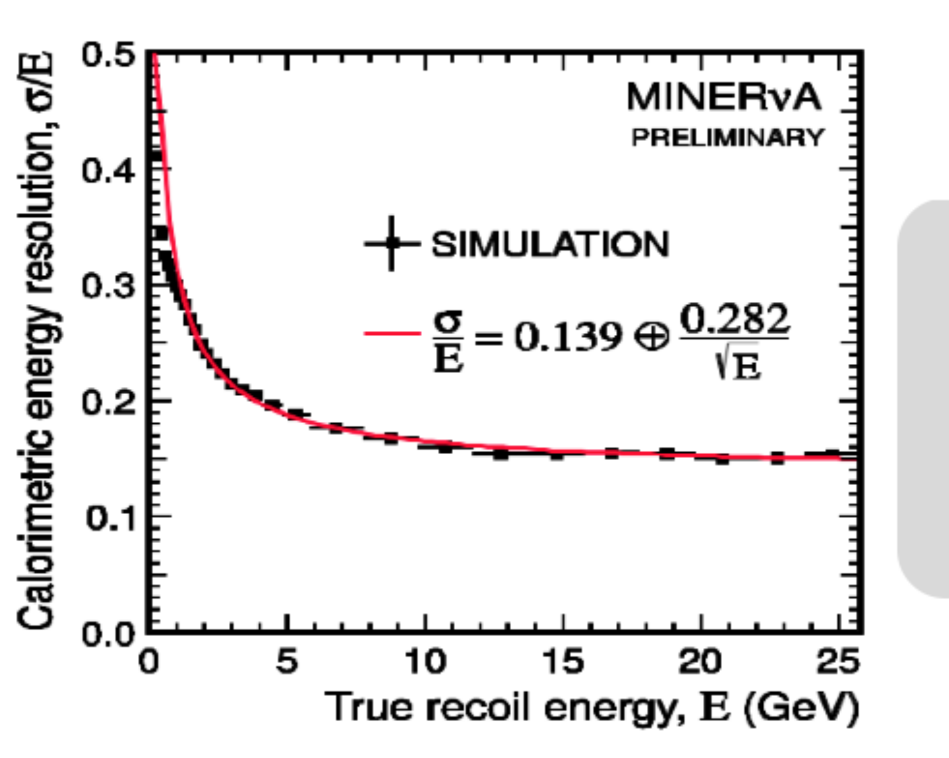


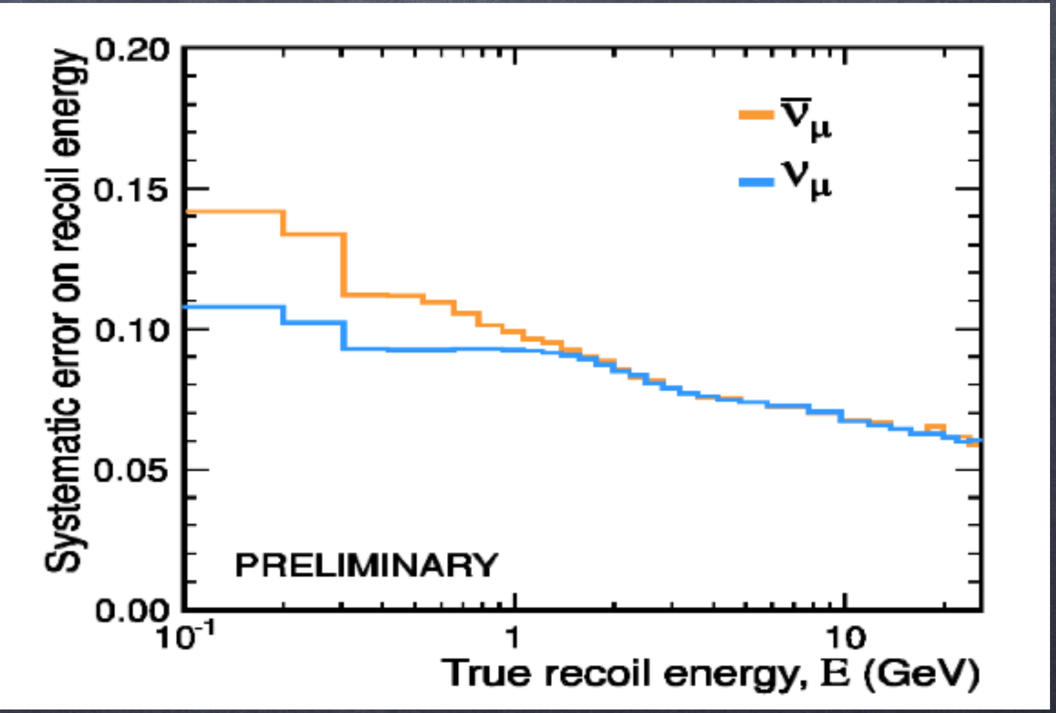
Recoil reconstruction

- Weighted sum of all visible energy except muon energy.

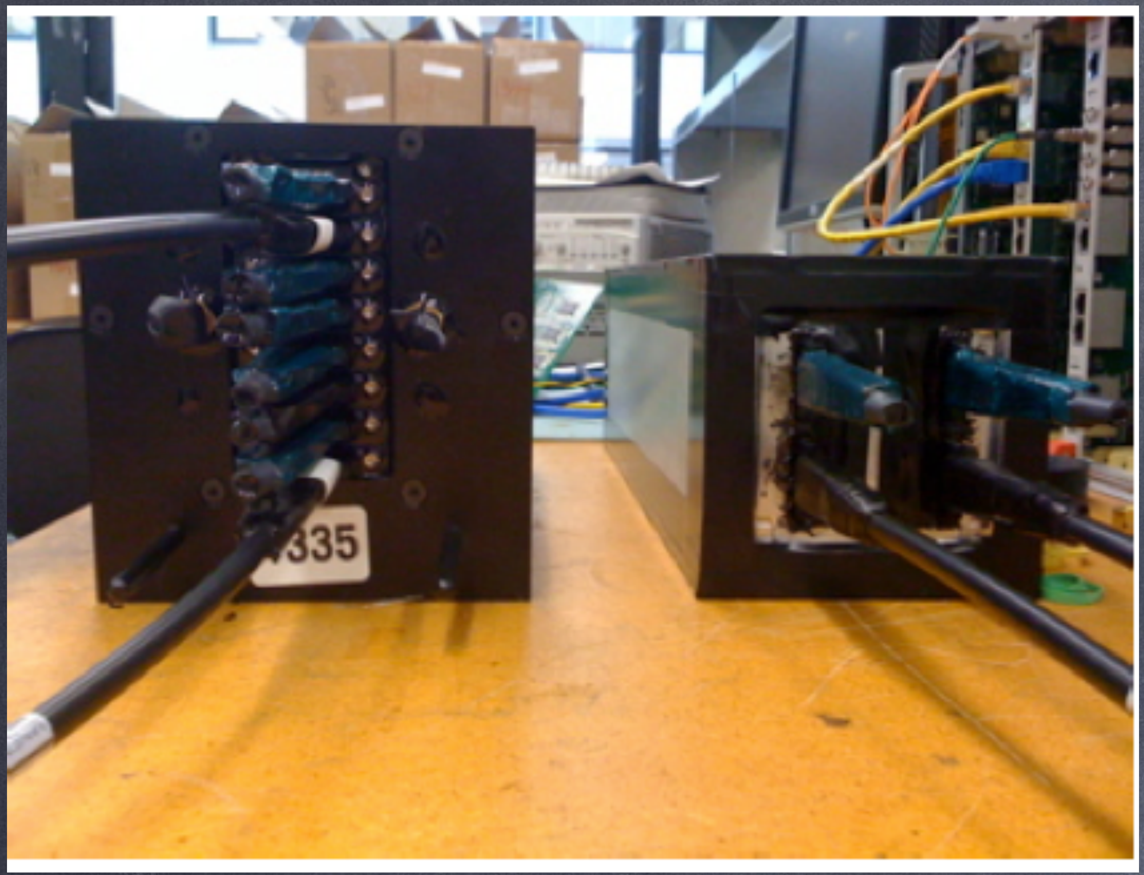
$$\text{calorimetric } E_{\text{recoil}} \equiv \alpha \times \sum_i c_i E_i$$

$$i = \{\text{tracker}, \text{ECAL}, \text{HCAL}, \text{OD}\}$$





PMT Testing



Example of aPMT Charge distribution in each pixel