Status Update for MINERνA

July 24, 2010

Gabriel N. Perdue
The University of Rochester

ICHEP Paris 2010 - Neutrino Parallel Session

35th International Conference on High Energy Physics

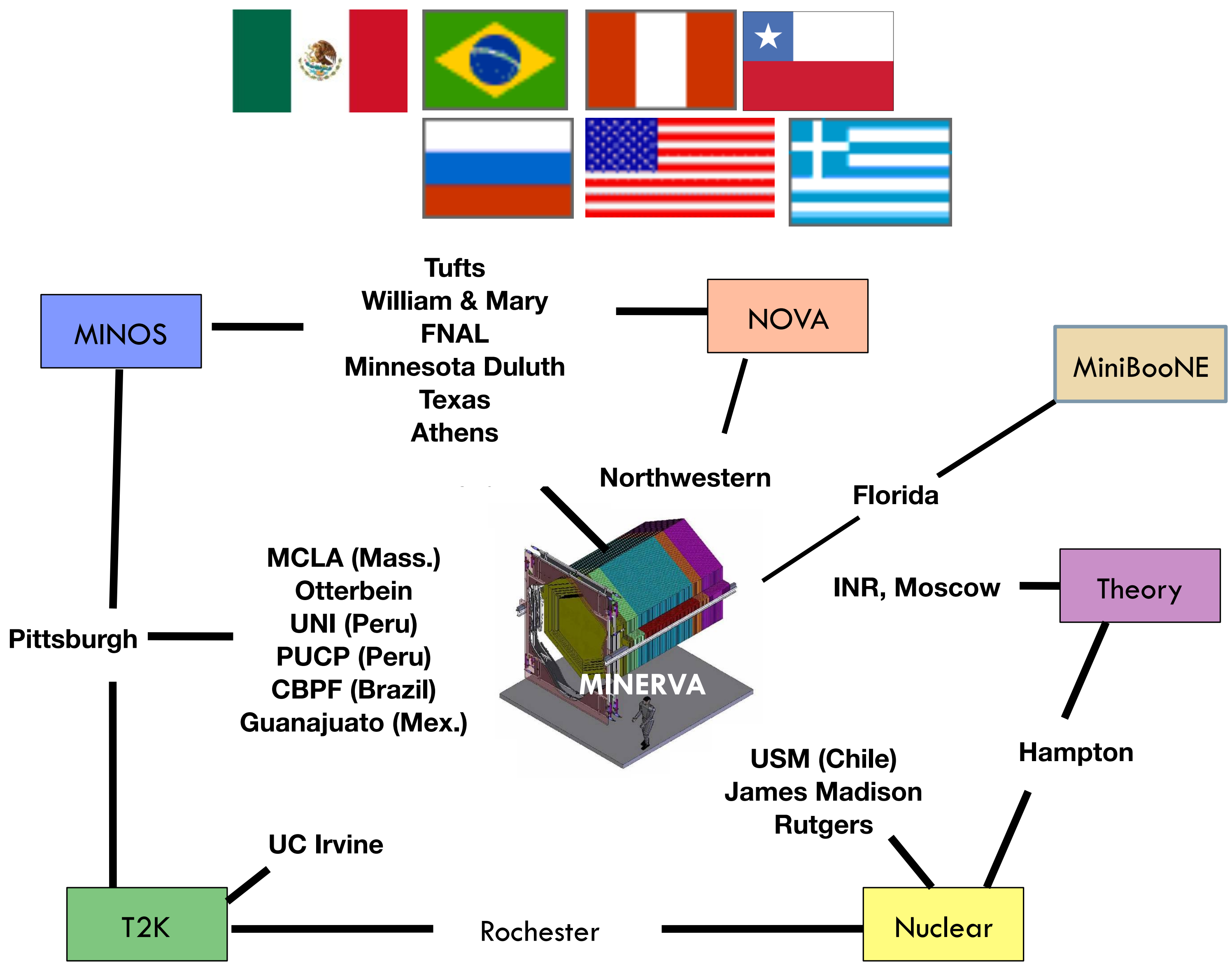
Overview

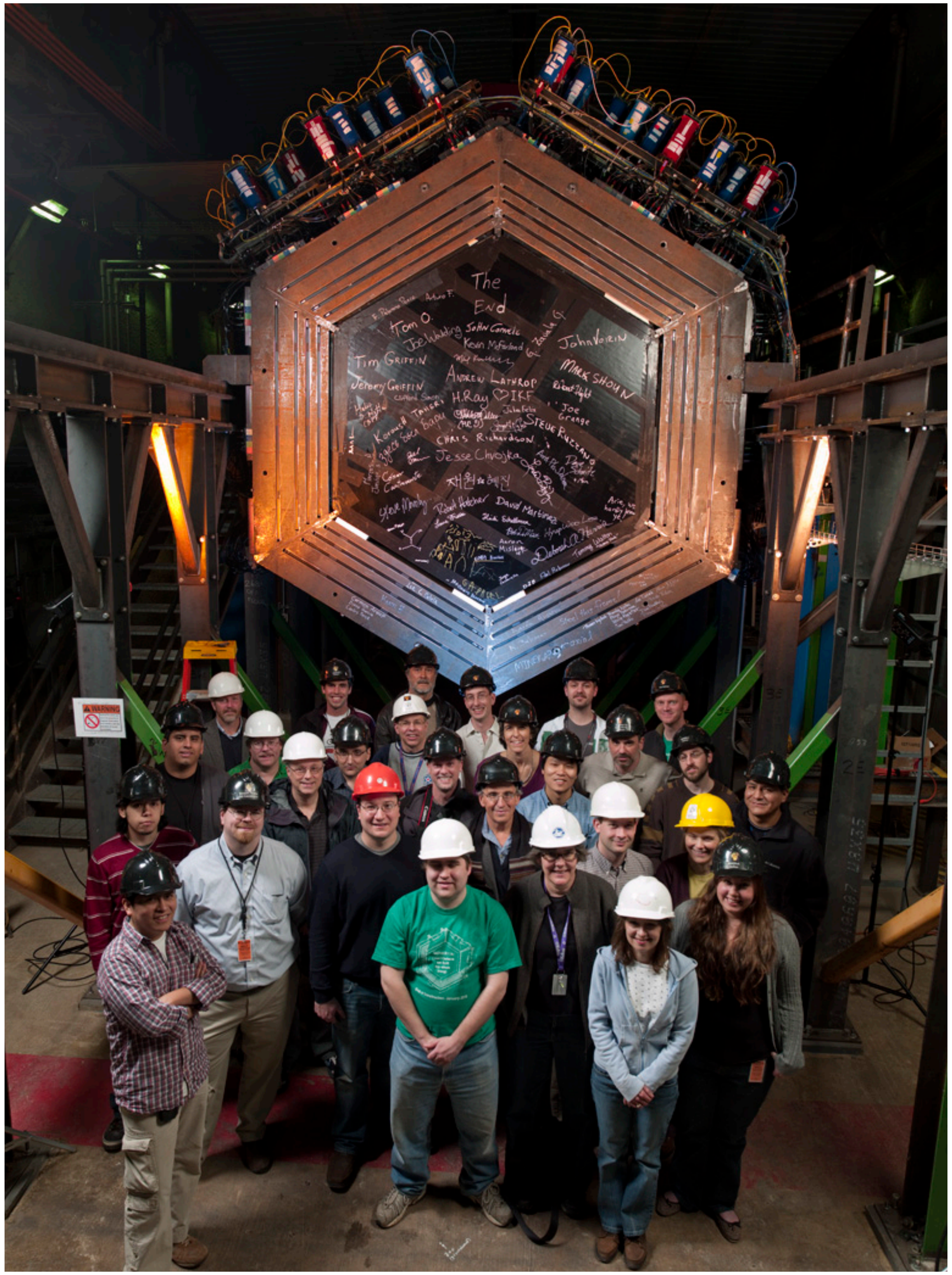
- Why MINERνA?
- Beam and Detector.
- Current Analysis Efforts.
- The MINERνA Test Beam.
- Conclusions and Future Outlook.

MINERνA

The MINERvA Collaboration

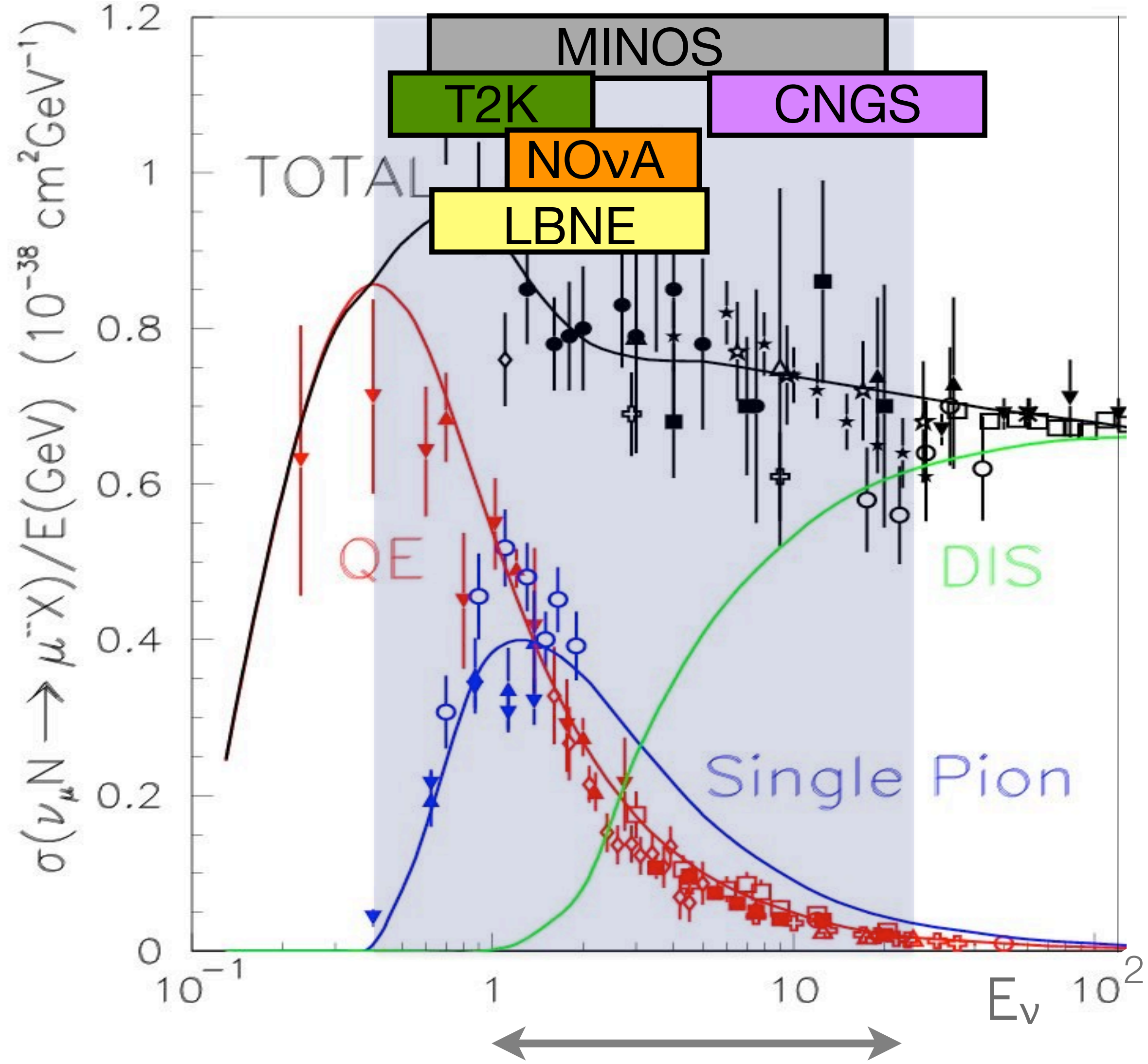
- **About 80 nuclear and particle physicists from 21 institutions.**





Why MINERνA?

- ***What***: Dedicated neutrino-nucleus cross-section experiment running at Fermilab in the NuMI beamline.
- ***Why***: Provides critical input to future neutrino oscillation experiments.
- ***Why***: Low energy (less than 10 GeV) cross-sections are poorly measured.
- ***Why***: Unique (weak-only) probe of the nucleus. Many poorly measured quantities of interest (axial form factors as a function of A and Q^2, quark-hadron duality, x-dependent nuclear effects, etc.).

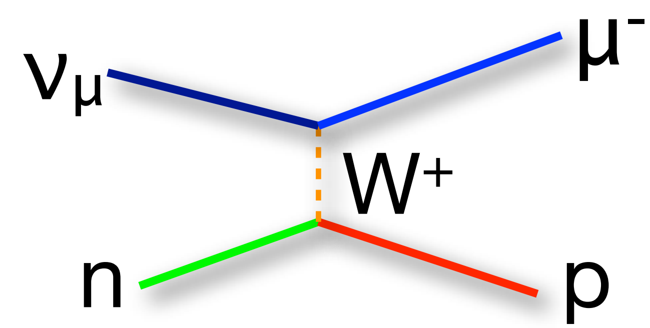


MINERνA Coverage

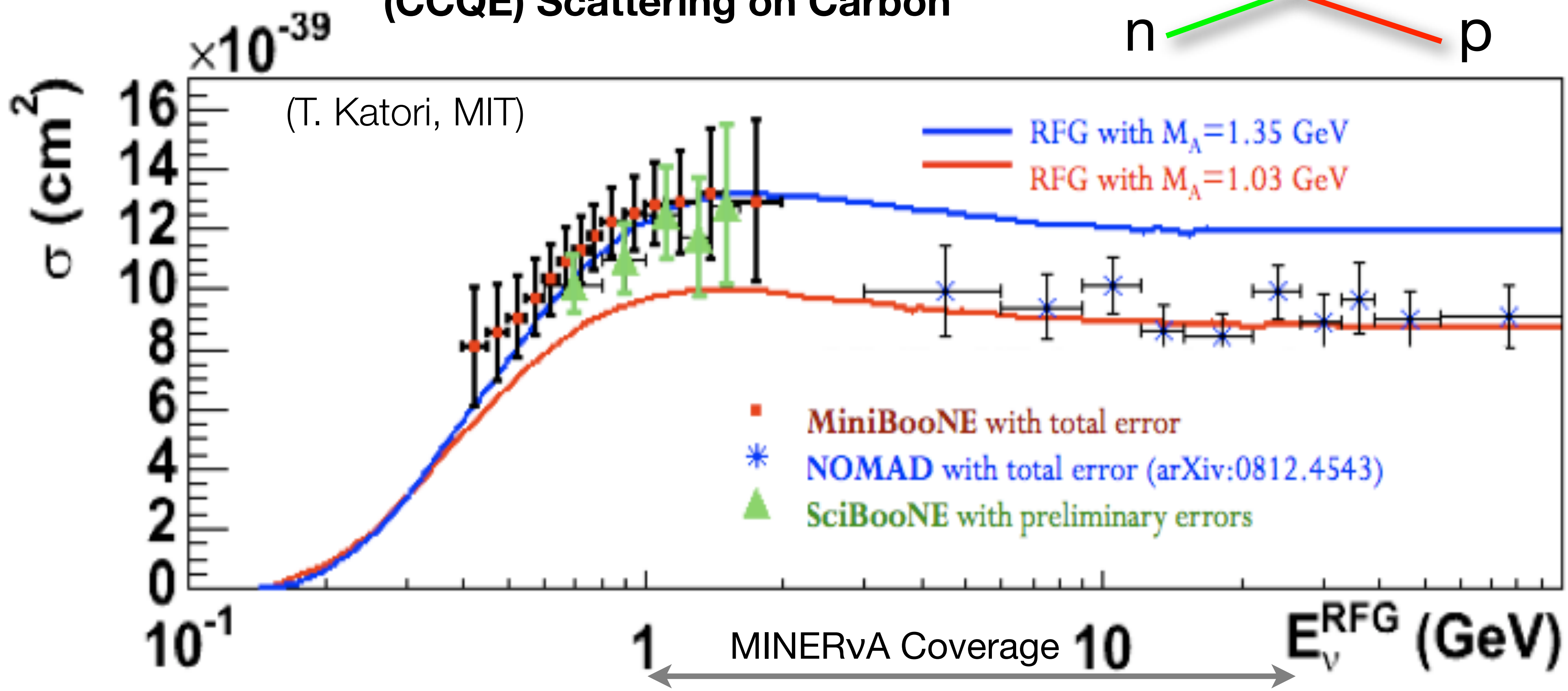
No MiniBooNE results on this plot, but hold that thought...

Why MINERνA?, Cont.

- Open questions in interaction physics abound. For example:
  - MiniBooNE & SciBooNE are in agreement, but conflict with NOMAD data at higher energy. MINERνA is well suited to address this discrepancy.

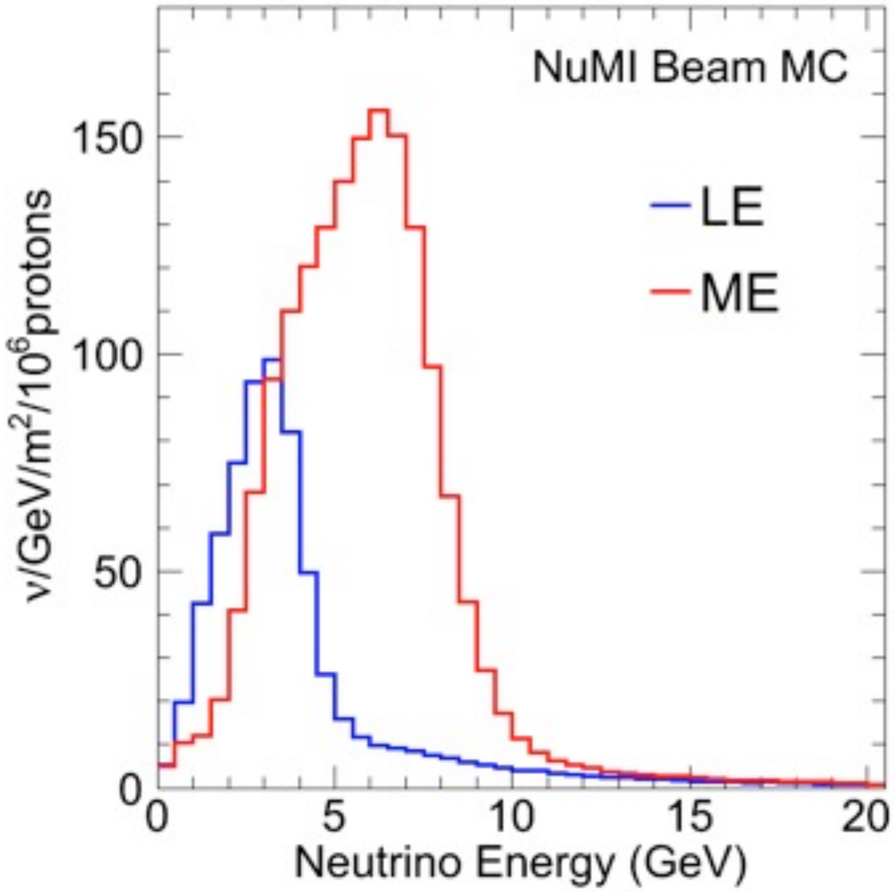


Charged Current Quasi-elastic (CCQE) Scattering on Carbon

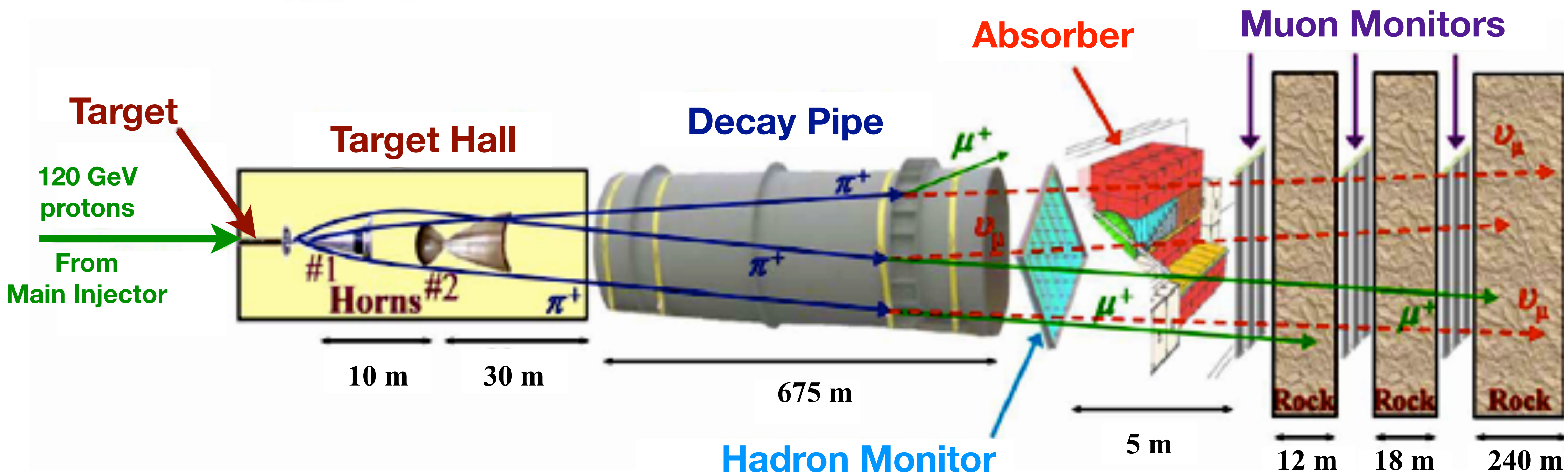


We will fill this gap!

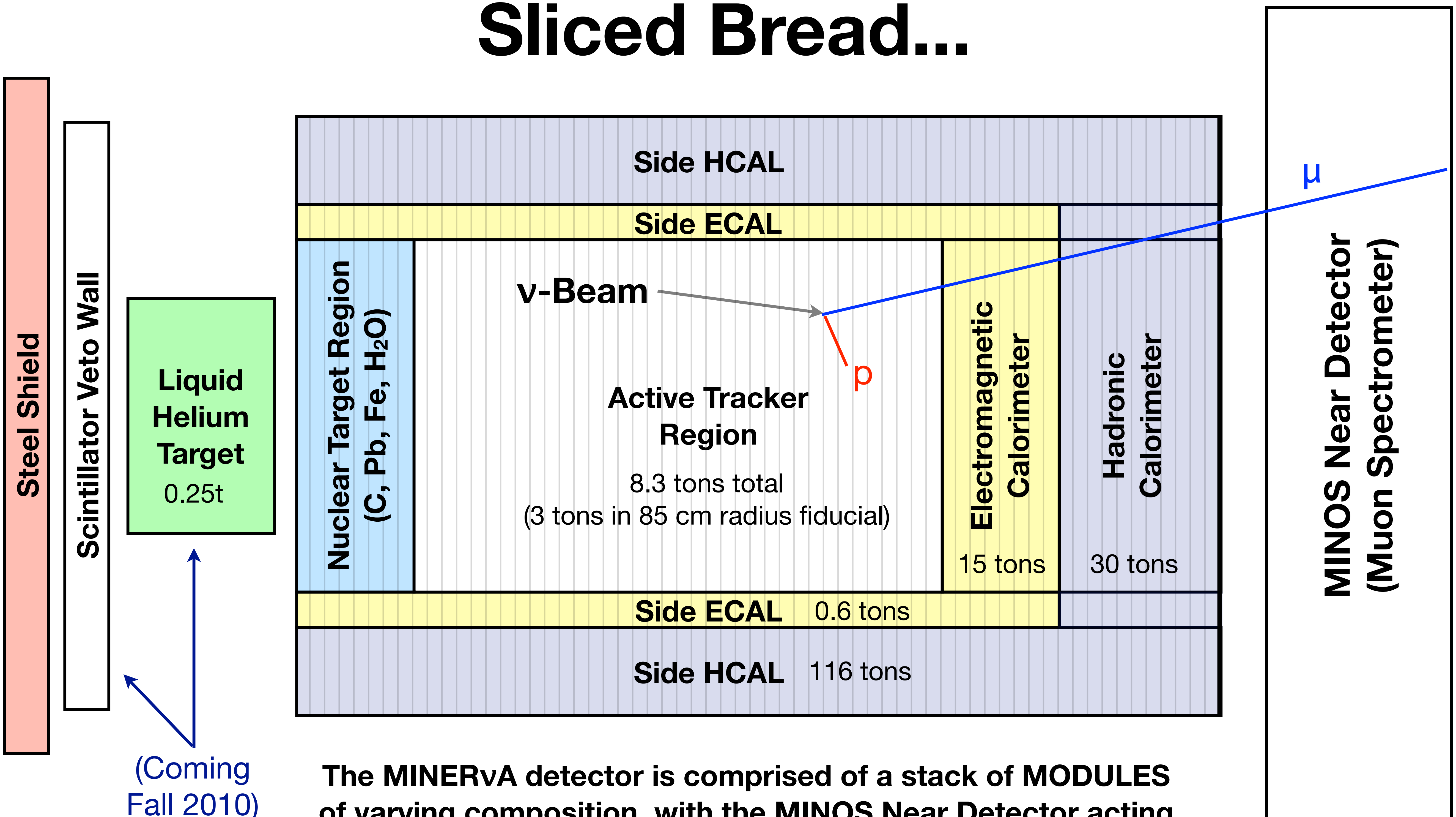
The NuMI Beam



- The mean energy of the NuMI ν beam is tuned by changing the position of the target relative to the focusing horns (move the target in or out of the first horn).
- Extremely intense - <35e12> P.O.T. per spill at 120 GeV with a beam power of 300-350 kW at ~0.5 Hz.
- Current run plan is 4e20 P.O.T. in the “low-energy” (LE) configuration and 12e20 P.O.T. in the “medium-energy” (ME) configuration.
- Targeting ~10% for the absolute flux uncertainty.

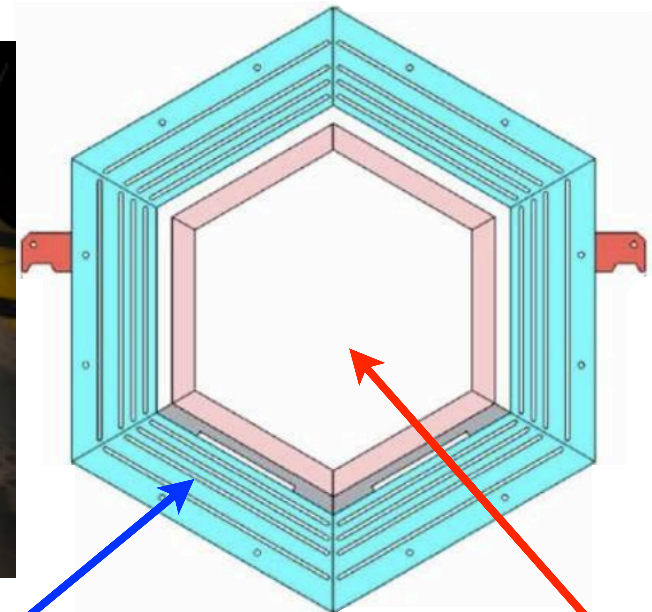


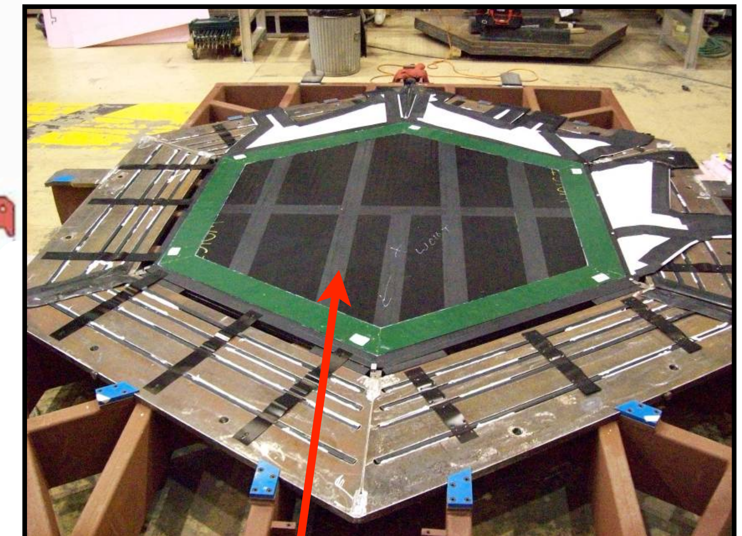
The Best Thing Since Sliced Bread...



The MINERνA detector is comprised of a stack of MODULES of varying composition, with the MINOS Near Detector acting as a muon spectrometer. Finely segmented (~32 k channels) with multiple nuclear targets (C, CH, Fe, Pb, He, H_2O).

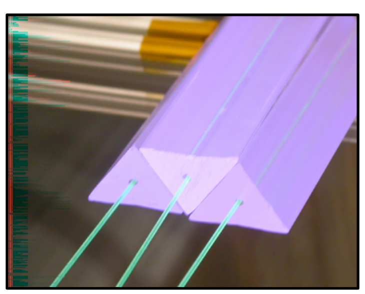
MINERνA Modules



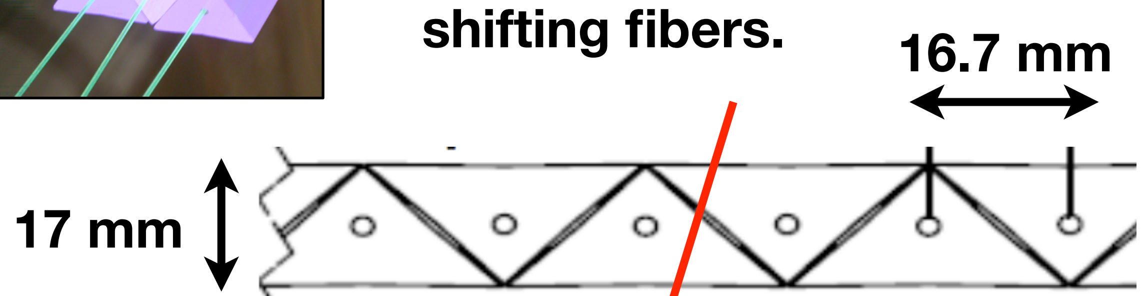


Modules have an outer detector frame of steel and scintillator...

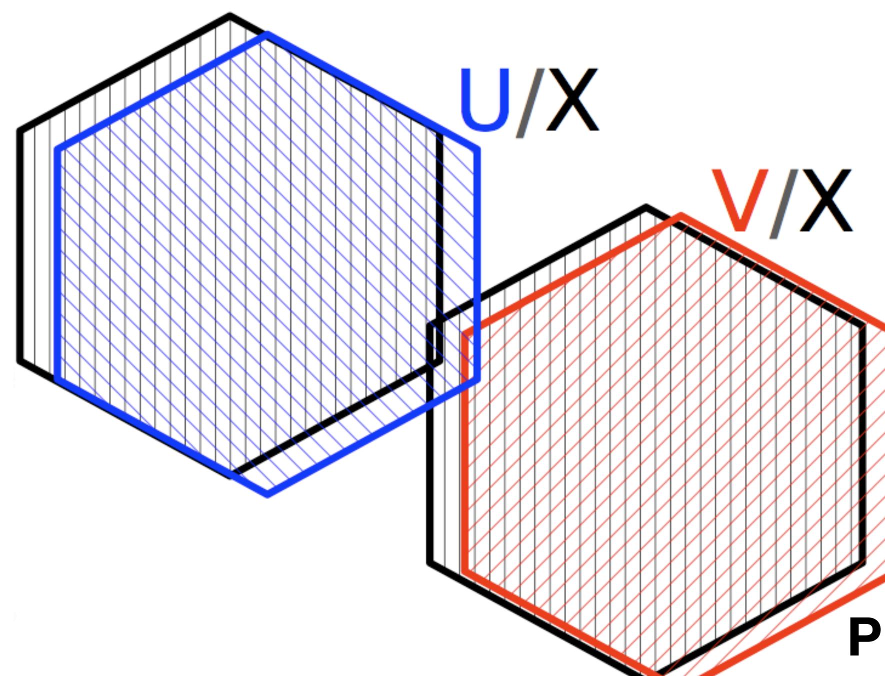
...and an inner detector element of scintillator strips and absorbers/targets.



Extruded scintillator & wavelength shifting fibers.

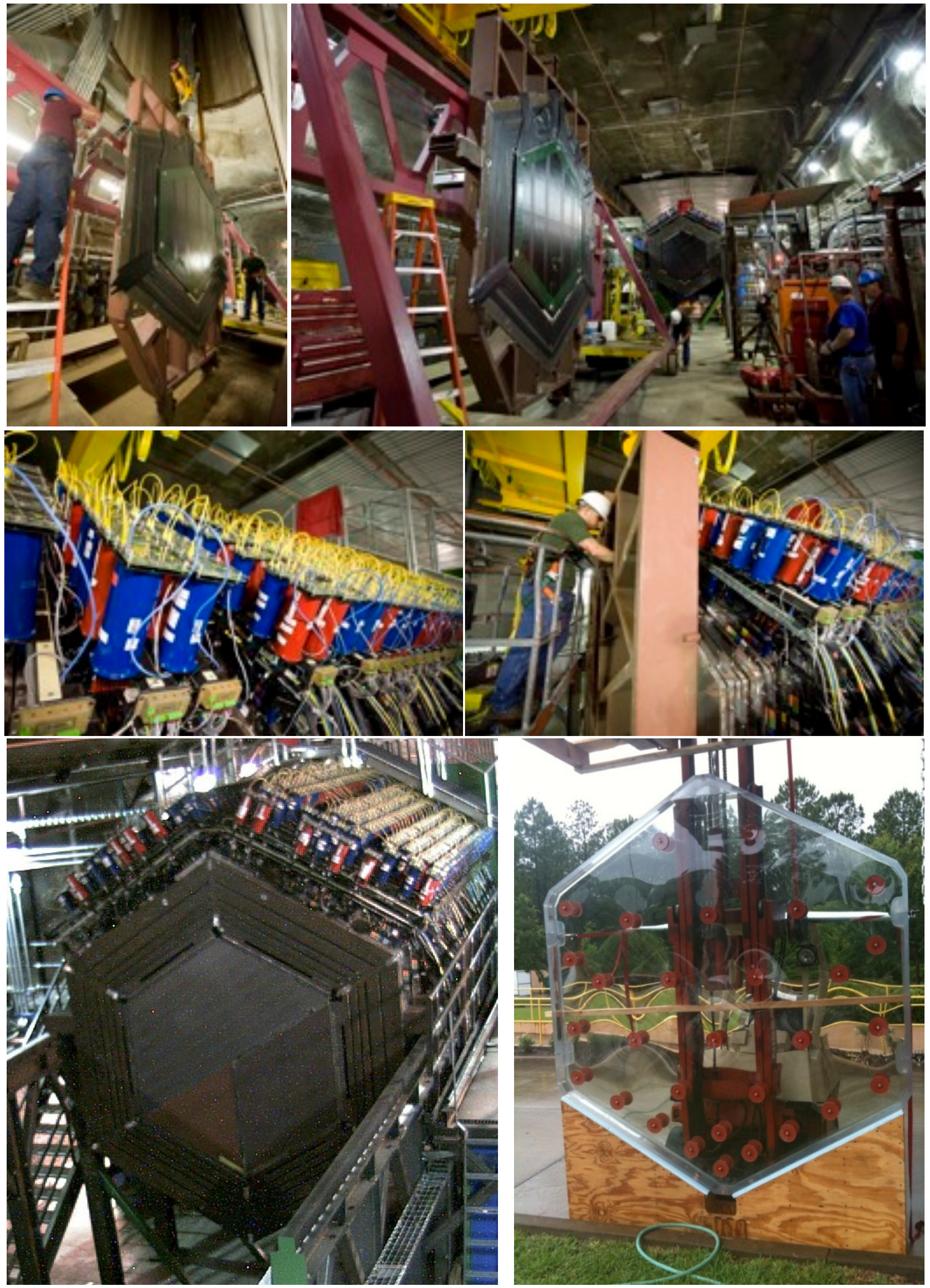


Charge-sharing for improved position resolution (~3.5 mm).



Planes are mounted stereoscopically in XU or XV orientations for 3D tracking.

Installation Highlights



- **Modules constructed above ground and lowered ~100 meters by crane into the NuMI Near Detector Hall.**
- **~3/5 installed November 12, 2009. Our “Frozen Detector.” Ran in anti-ν mode through Spring 2010.**
- **Began installation of final ~2/5 in early January, 2010. Continued anti-ν run during construction.**
- **Installation completed (including all nuclear targets except He and H_2O) on March 18, 2010 & began ν data run on March 22, 2010.**

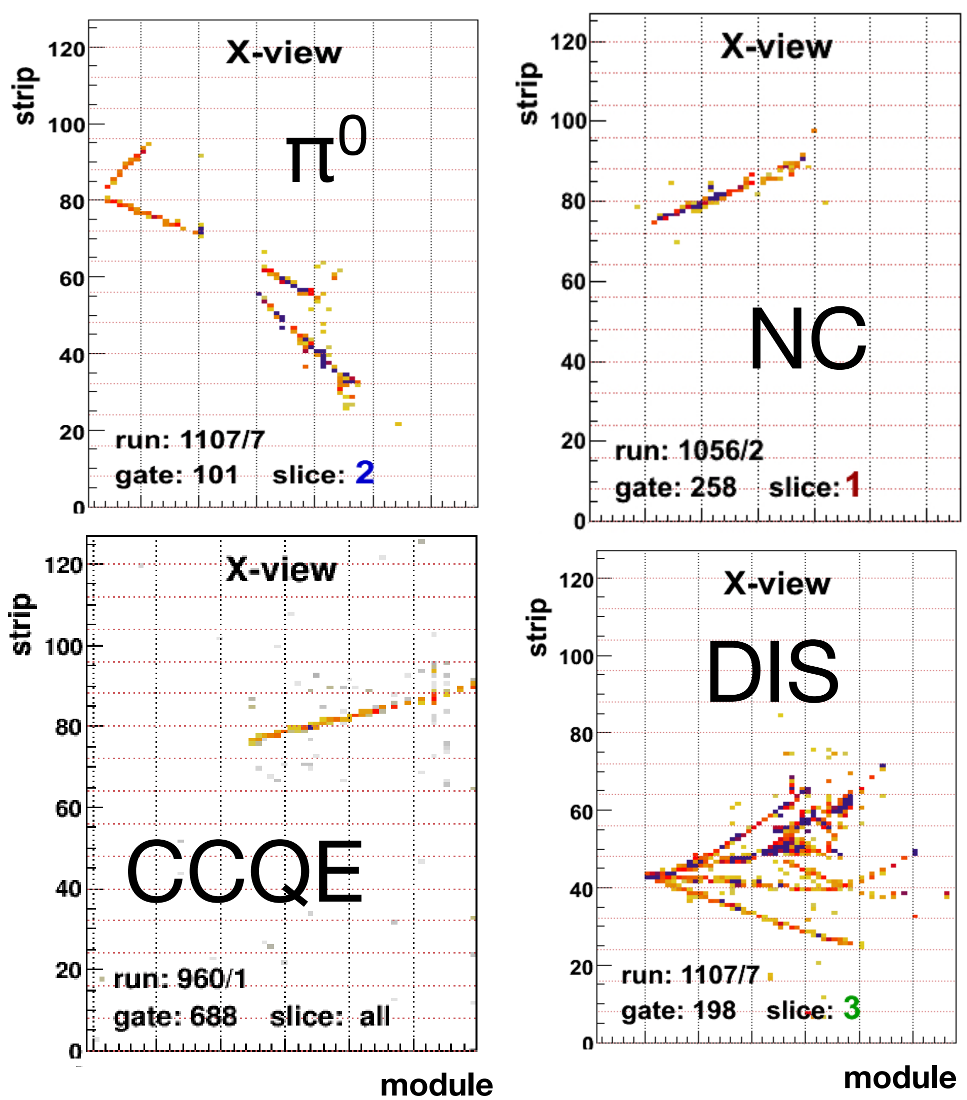
Analysis Efforts

- GAUDI based software framework (ATLAS, LHCb).
- Grid-based production (300 slots).
  - Can re-process our current anti-ν data set in ~couple of days of real time.
- Primary focus is calibration, validation, and automation for our anti-ν and growing ν data sets.
  - Also producing preliminary kinematic distributions for our anti-ν data set.
- Validation of the full detector ongoing - not ready for the public yet.
  - Expect ~9 million CC events in the active scintillator over the course of our full Run Plan (LE+ME, NEUGEN prediction).

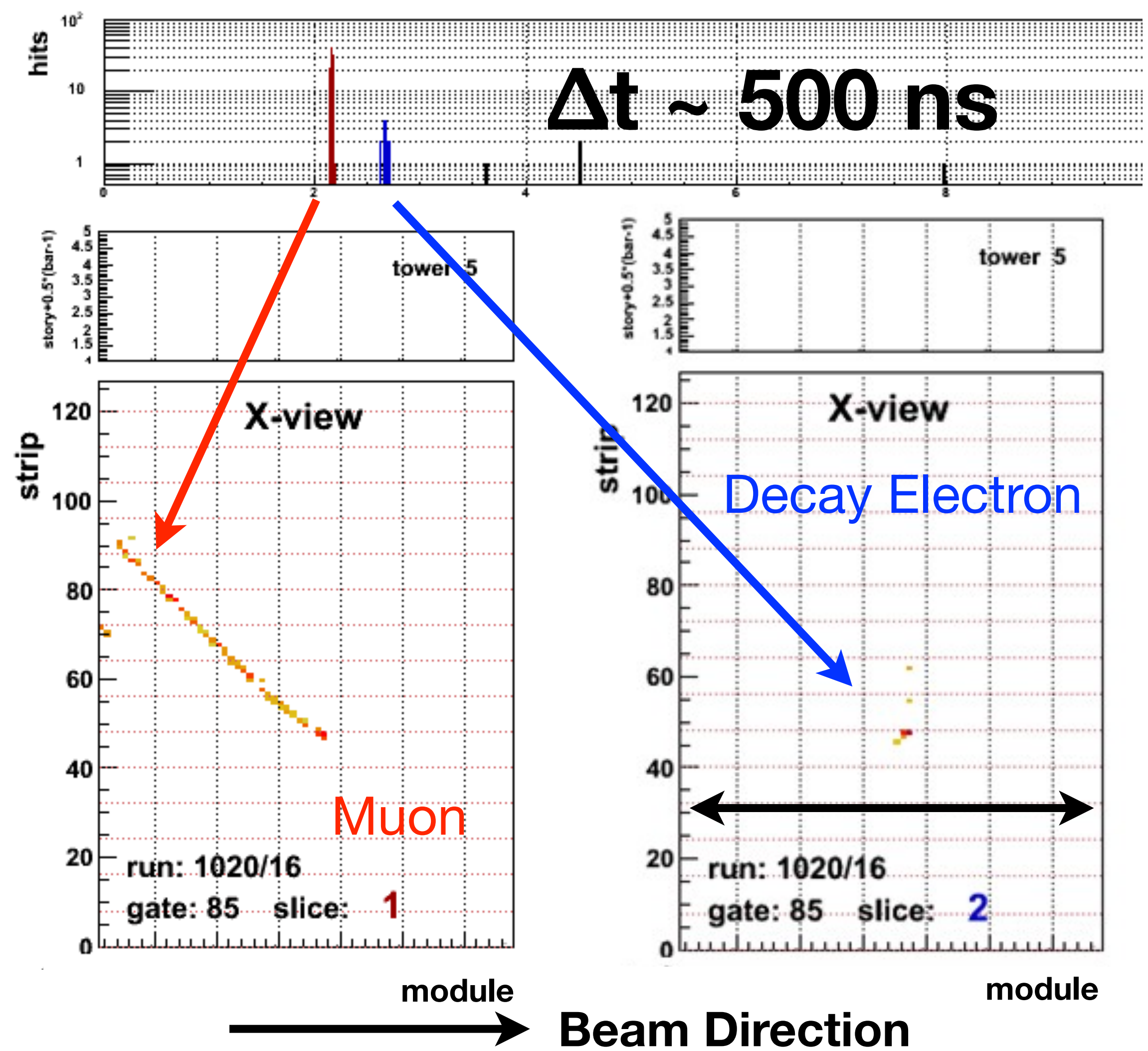
Anti-ν Data Set Analysis

- **Understanding MINERνA Event Displays:**
  - **Typically show only one view, scintillator strip vs. module (Z) position.**
  - **X view is essentially looking at the detector from above.**
  - **Tracking resolution is ~3.3 mm; Timing resolution is ~4.5 ns.**

Anti-ν Event Candidates



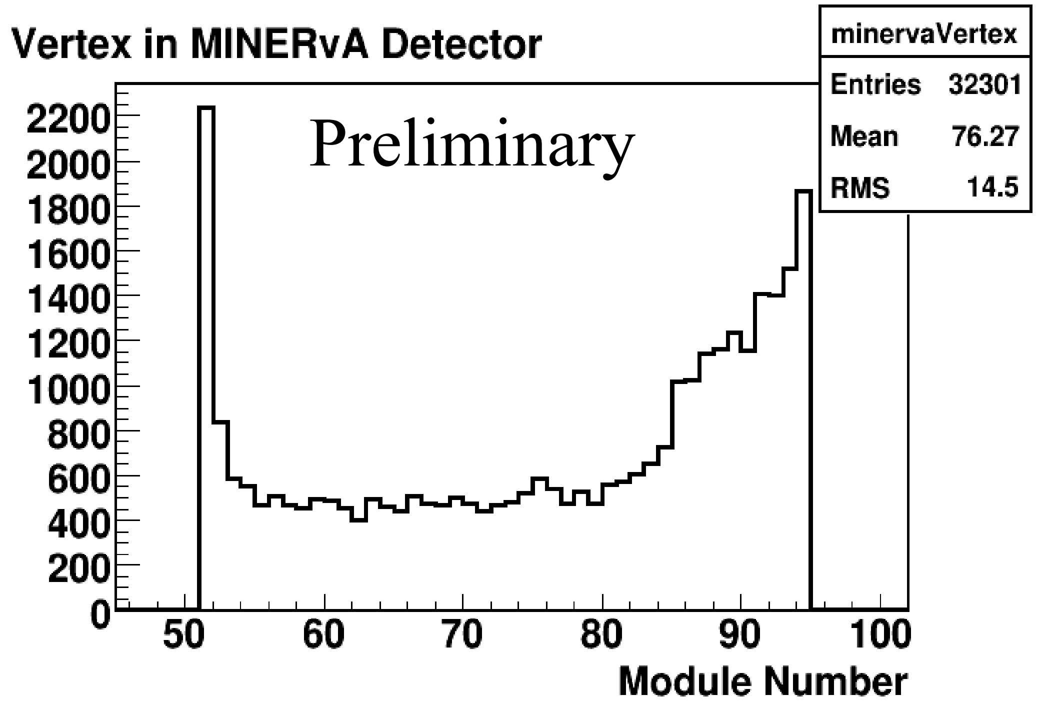
Michel Electron Candidate

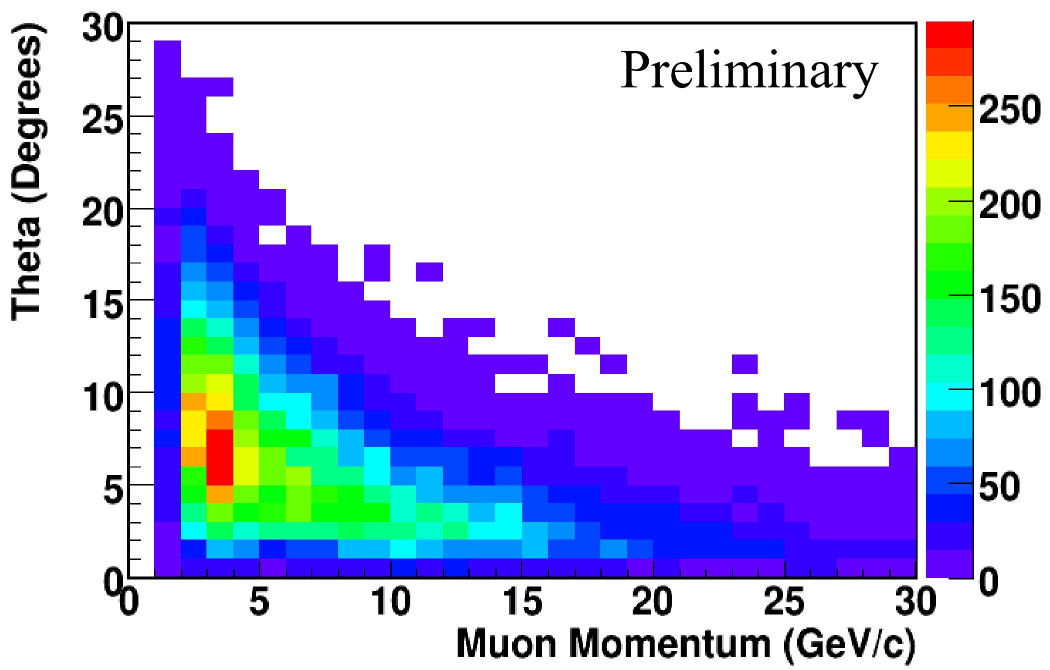


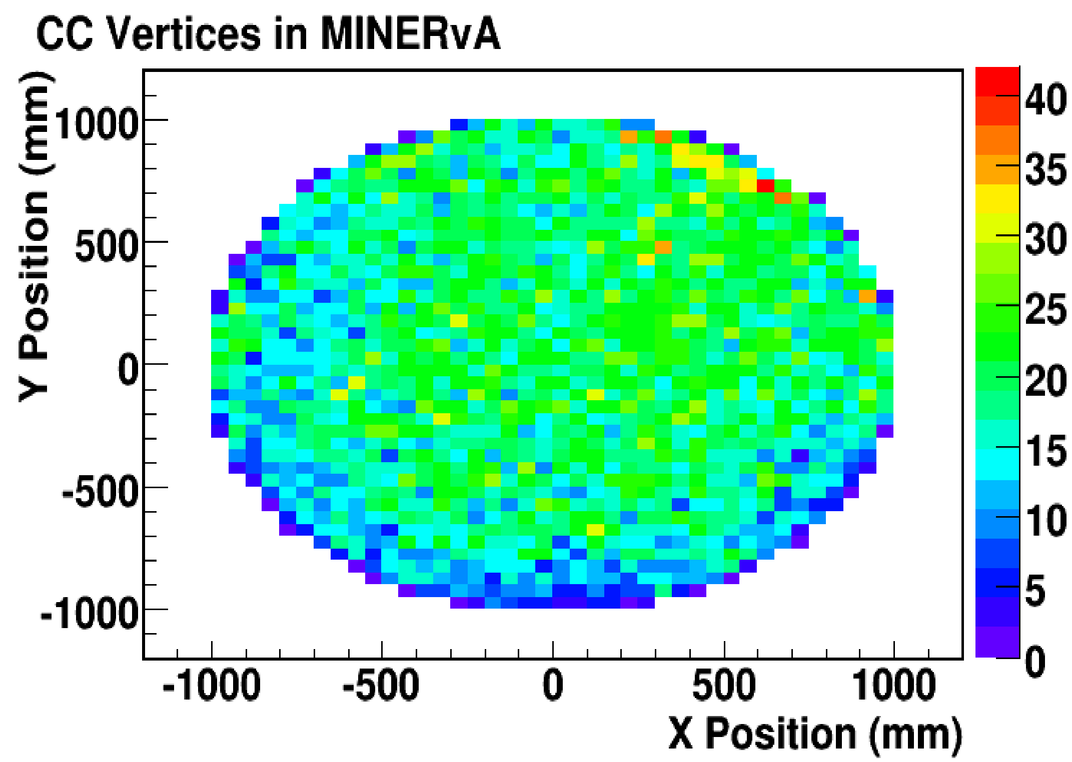
64 Modules ~ 3.5 m

Kinematic Distributions
Anti-ν Data

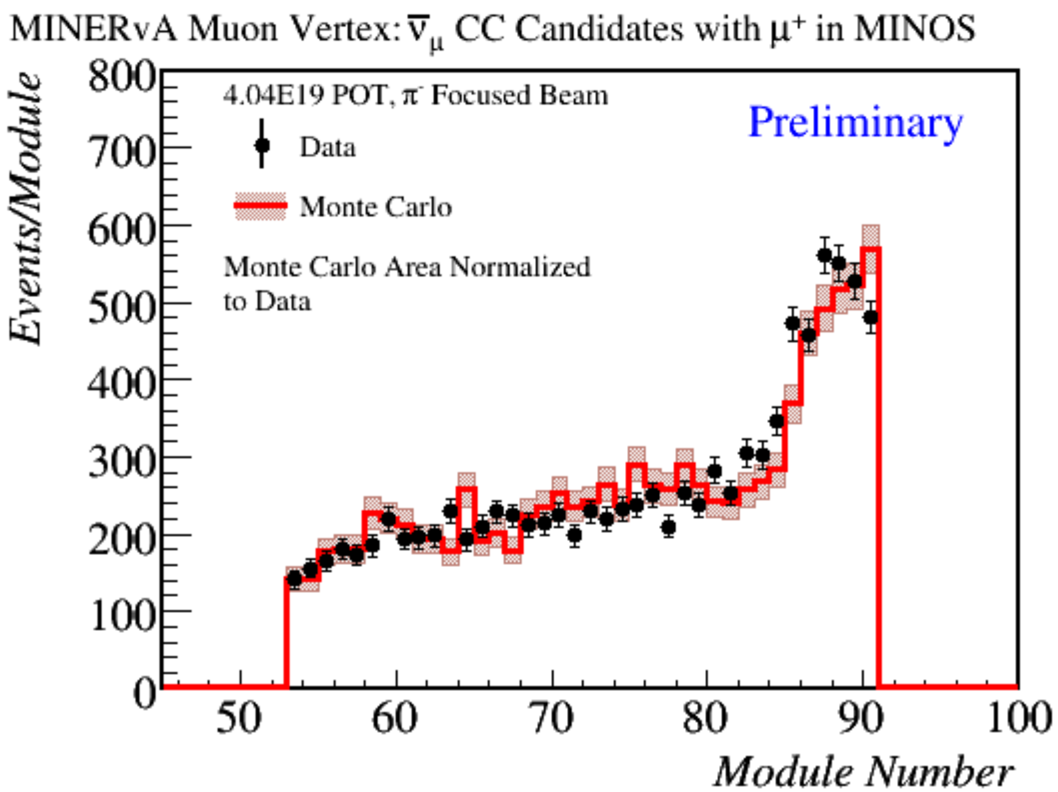
- **Anti-ν Data: Inclusive CC analysis.**
  - **Momentum analyze muons in MINOS using curvature - implies a few GeV cutoff. Momentum is at the vertex.**
  - **Cut on high quality tracks in both detectors and clean vertices - characterization still a work in progress.**

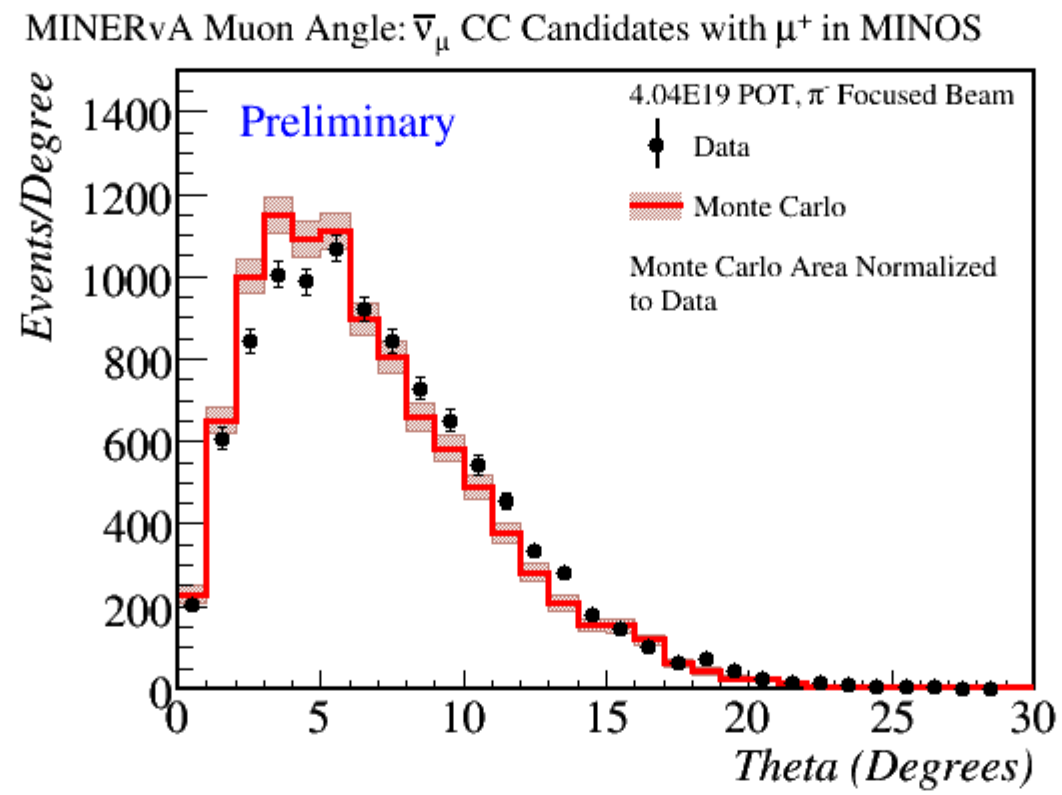




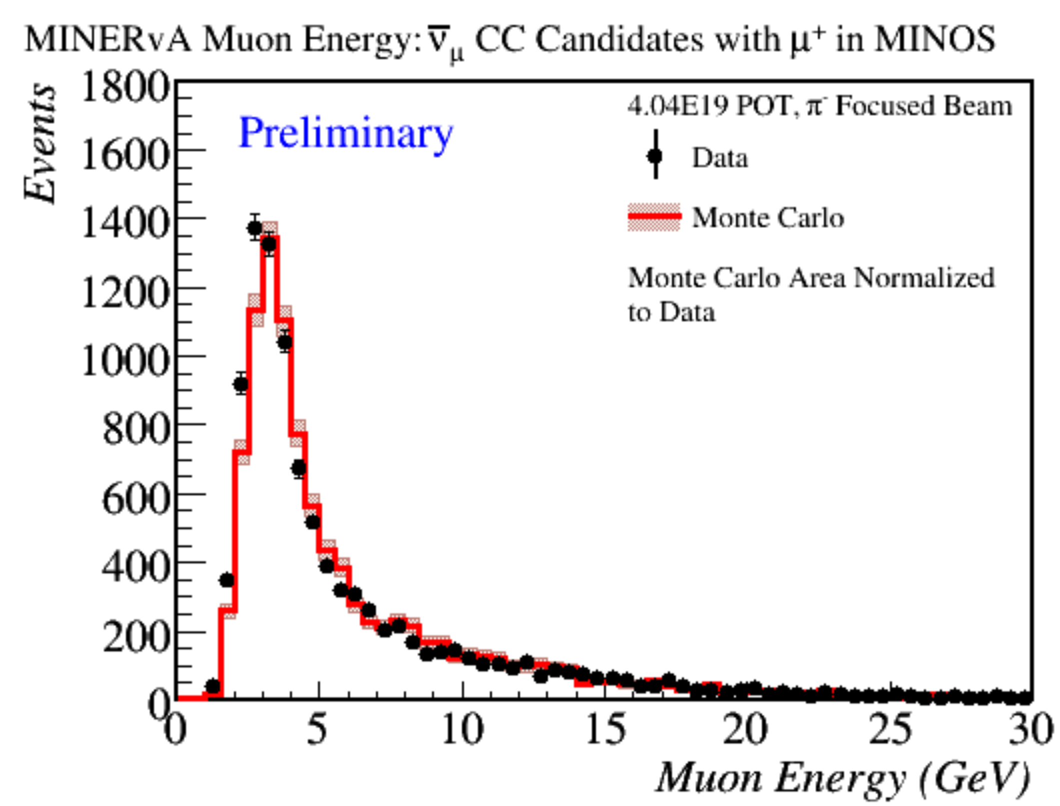


Kinematic Distributions
Anti-ν MC



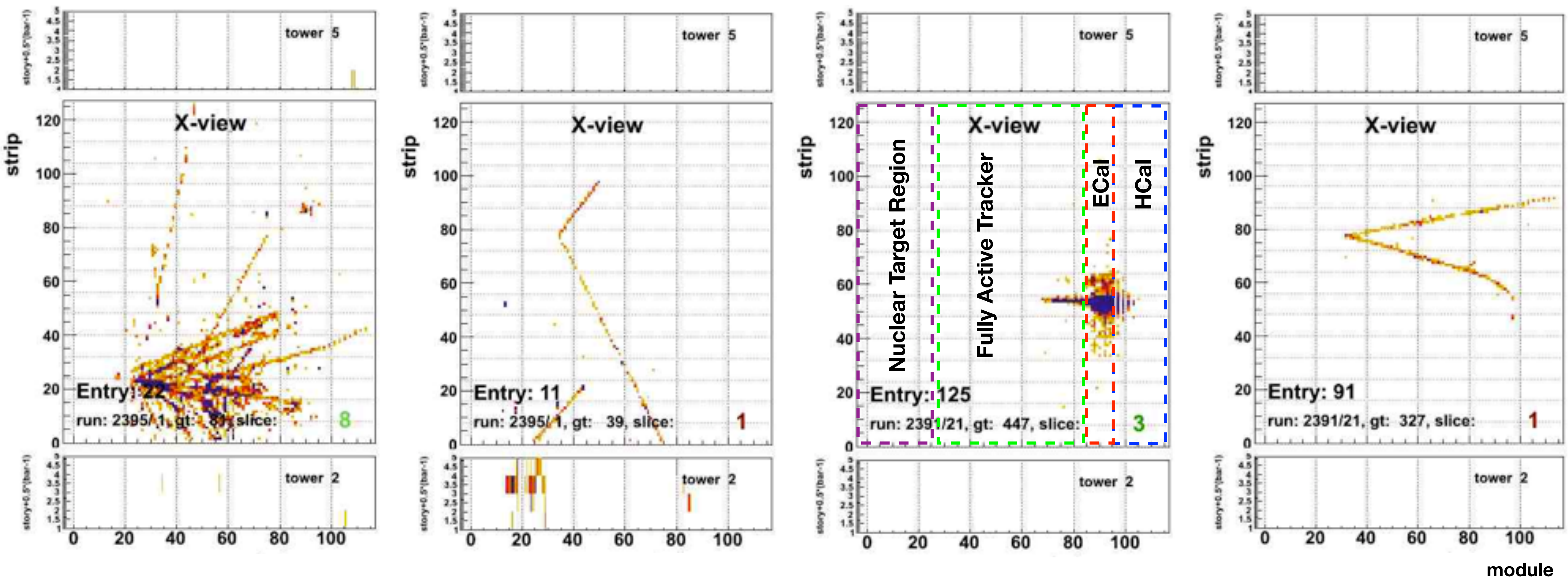


- **MC generator is GENIE v2.6.0 with a full GEANT4 detector simulation.**
- **4.04e19 P.O.T. in anti-ν mode (RHC).**
- **Studying inclusive anti-ν QE events - signature is a single muon (reconstruct sign in MINOS). Note the cut-off in momentum - this is not our full kinematic range!**
- **Current absolute flux uncertainty on the (untuned anti-nu) MC is ~30-40%. (This error is not shown.)**



ν Data Set Analysis (Full Detector)

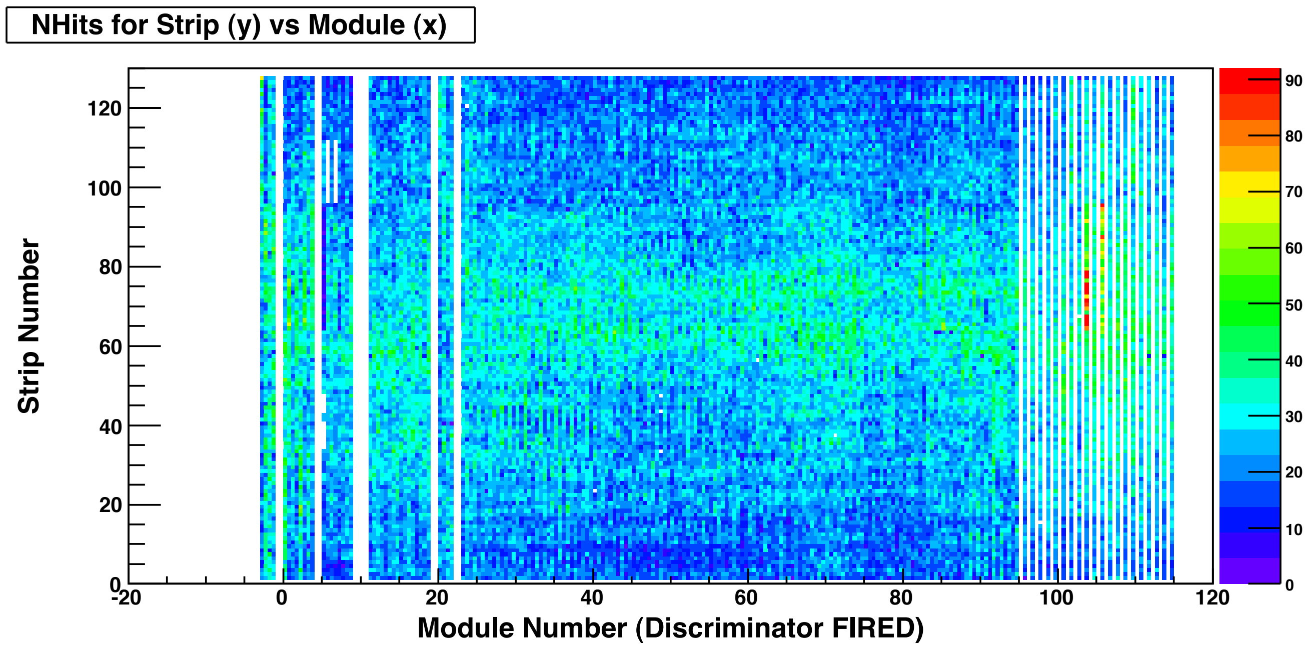
Began taking data on March 22.
Kinematic distributions and early analyses coming soon!



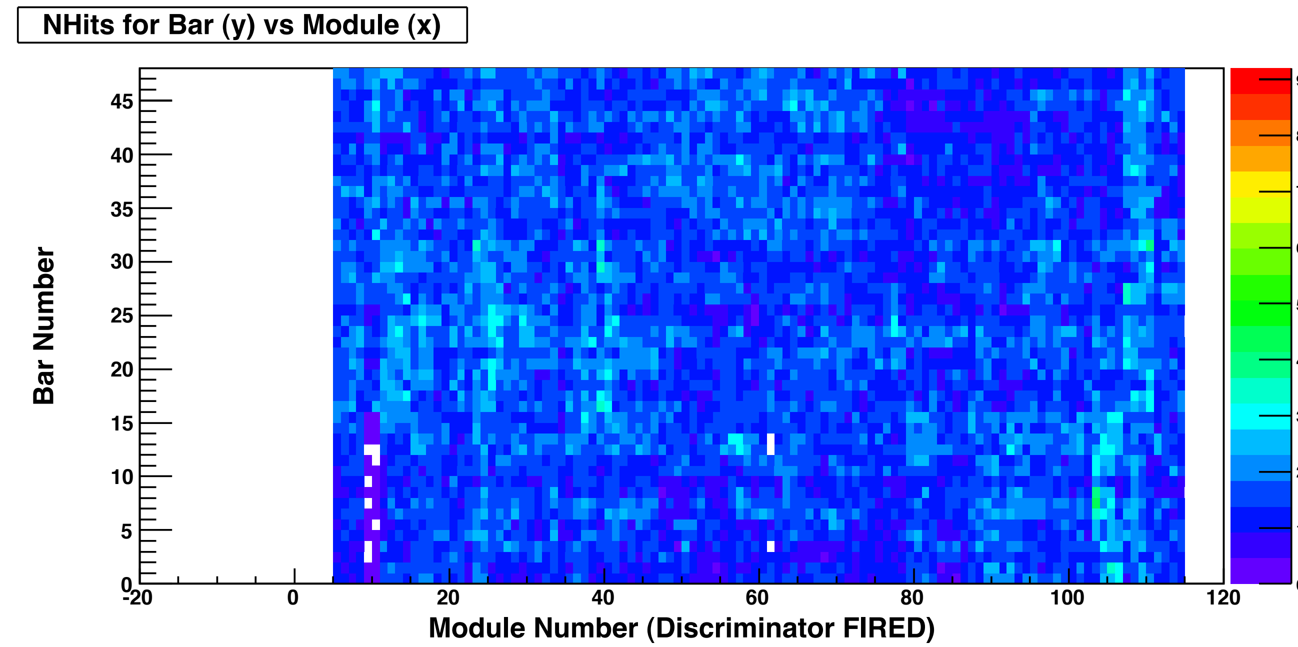
Beam Direction

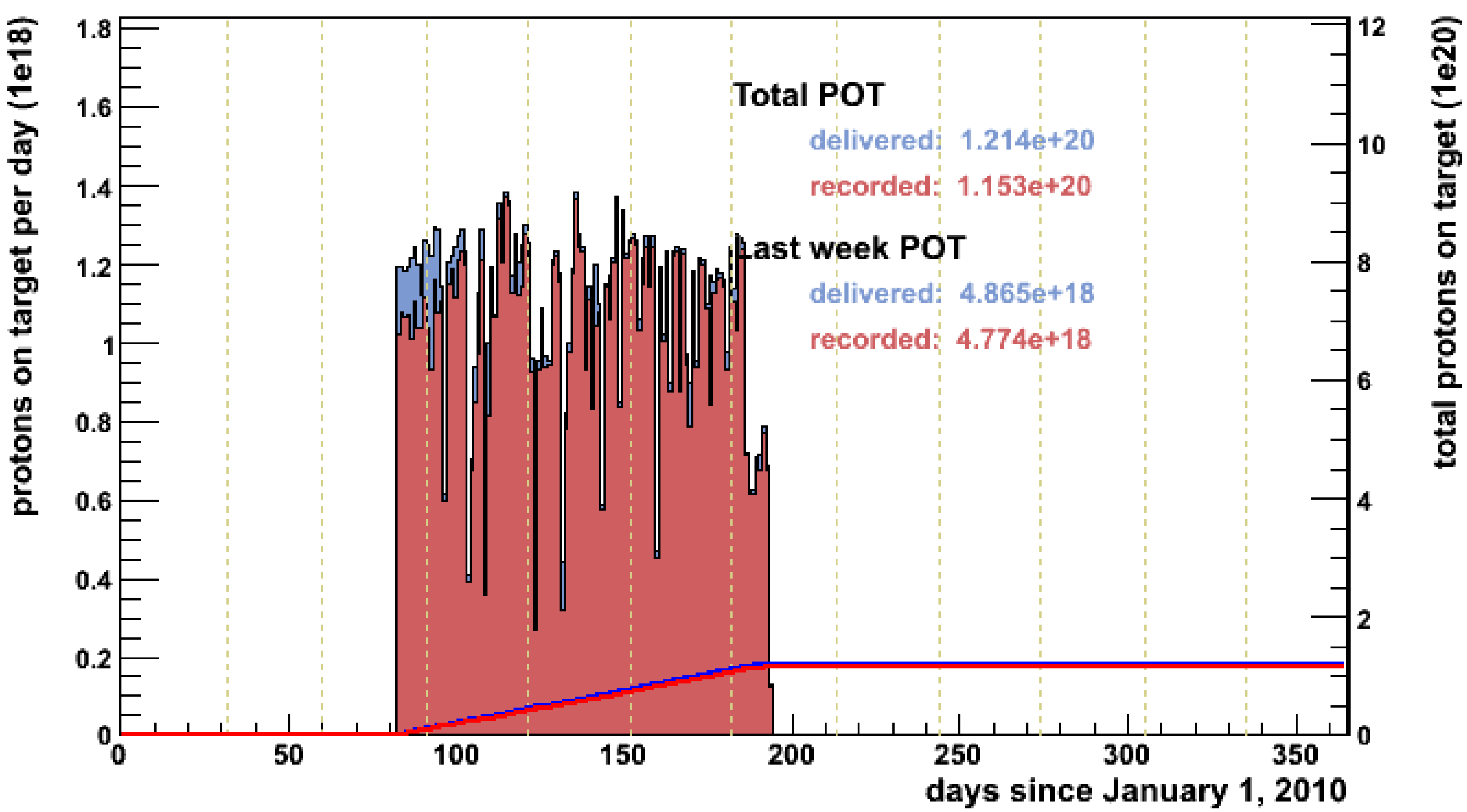
Data Quality Checks - Live-time, Live Channels, Occupancy

Inner Detector - Hit Occupancy



Outer Detector - Hit Occupancy





→ **Beam Direction**

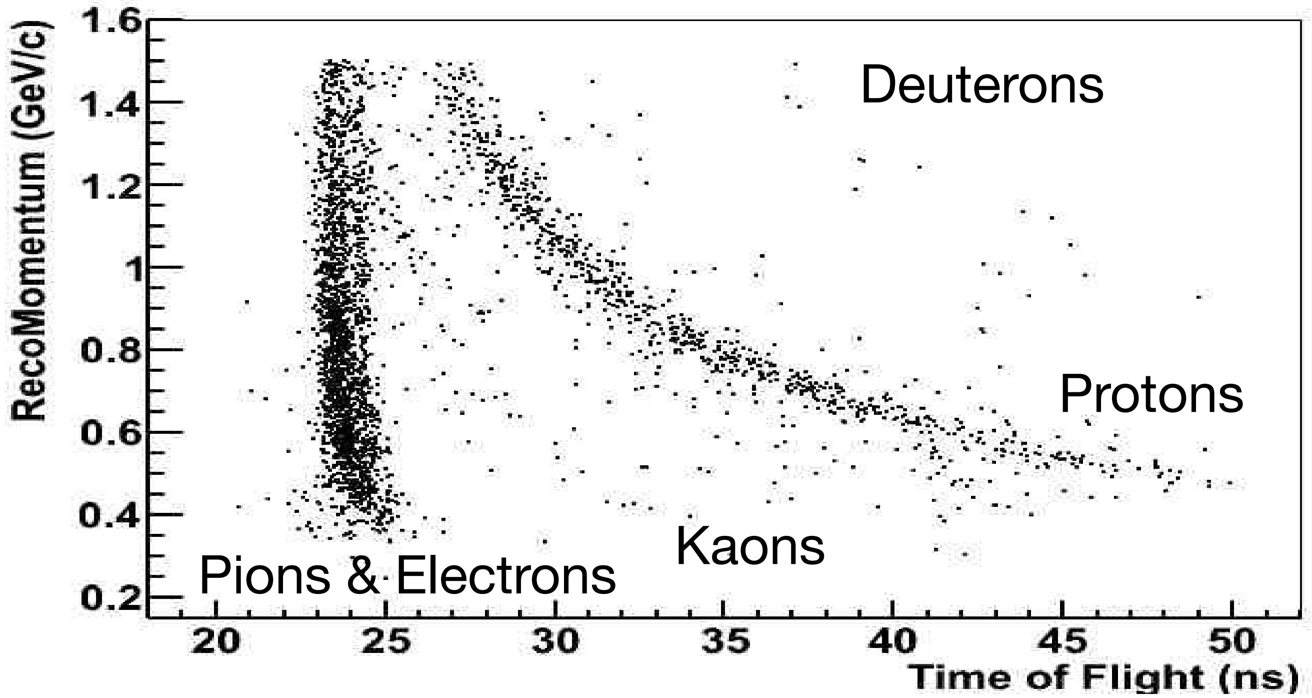
Detector Health:

- >95% livetime
- ~20 (inner detector) + ~10 (outer detector) dead channels out of ~32,000!

MINERνA Test Beam

- Running at the FNAL Meson Test Beam Facility (MTBF).
- Provide hadronic response calibration (ratio of π/μ).
- 40 planes in XUXV stereoscopic orientation using the same scintillator and absorber geometry.
- Reconfigurable - can shuffle absorber configuration to mimic any part of the detector.
- Just finished first physics run June 10 - July 17, 2010.

Test Beam - New Tertiary Beamline



- **16 GeV pion beam on a Cu target produces tertiary pion beam from 400 MeV to 1.2 GeV.**
- **Four wire chambers, two dipole magnets, and time-of-flight system for triggering.**
- **Now part of the facility!**

Conclusions

- MINERνA is in the early stages of analysis of our anti-ν data set, and just beginning the analysis of the first leg of our “low-energy” ν data set.
- Everything is on track for a useful and interesting set of measurements!
- Look for some exciting distributions and preliminary results in the near future!

Thanks for Listening!

Back-Up Slides

The MINERvA Collaboration

D.A.M. Caicedo, C. Castromonte, G.A. Fiorentini, H. da Motta, J.L. Palomino
Centro Brasileiro de Pesquisas Físicas, Rio de Janeiro, Brazil

C. Simon, B. Ziemer
University of California, Irvine, California

L. Bagby, D. Boehnlein, R. DeMaat, D.A. Harris*, J. Kilmer, J.G. Morfin, J. Osta, A. Pla-Dalmau, P. Rubinov, D. Schmitz, R. Stefanski
Fermi National Accelerator Laboratory, Batavia, Illinois

J. Grange, J. Mousseau, R. Napora, B. Osmanov, H. Ray
University of Florida, Gainesville, Florida

J. Felix, A. Higuera, Z. Urrutia, G. Zavala
Universidad de Guanajuato, Division de Ciencias e Ingenierias, Leon Guanajuato, Mexico

M.E. Christy#, R. Ent, C.E. Keppel, P. Monaghan, T. Walton, L. Zhu
Hampton University, Hampton, Virginia

A. Butkevich, S. Kulagin
Institute for Nuclear Research, Moscow, Russia

I. Niculescu, G. Niculescu
James Madison University, Harrisonburg, Virginia

E. Maher
Massachusetts College of Liberal Arts, North Adams, Massachusetts

R. Gran, M. Lanari
University of Minnesota-Duluth, Duluth, Minnesota

L. Fields, H. Schellman
Northwestern University, Evanston, Illinois

N. Tagg
Otterbein College, Westerville, Ohio

A. M. Gago, N. Ochoa, C. E. Perez, J. P. Velasquez
Pontificia Universidad Catolica del Peru, Lima, Peru

S. Boyd, S. Dytman, I. Danko, B. Eberly, Z. Isvan, D. Naples, V. Paolone
University of Pittsburgh, Pittsburgh, Pennsylvania

A. Bodek, R. Bradford, H. Budd, J. Chvojka, M. Day, R. Flight, H. Lee, S. Manly, K.S. McFarland*, A. McGowan, A. Mislivec, J. Park, G. Perdue, J. Wolcott
University of Rochester, Rochester, New York

G. Kumbartzki, T. Le, R. Ransome#, B. Tice
Rutgers University, New Brunswick, New Jersey

M. Jerkins, S. Kopp, L. Loiacono
University of Texas, Austin, Texas

H. Gallagher, T. Kafka, W.A. Mann#, W. Oliver
Tufts University, Medford, Massachusetts

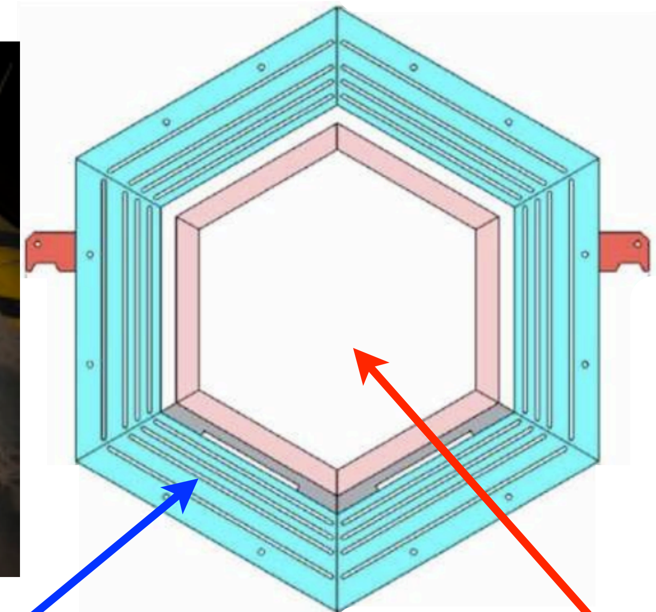
M. Aliana, C.J. Solano Salinas
Universidad Nacional de Ingenieria, Lima, Peru

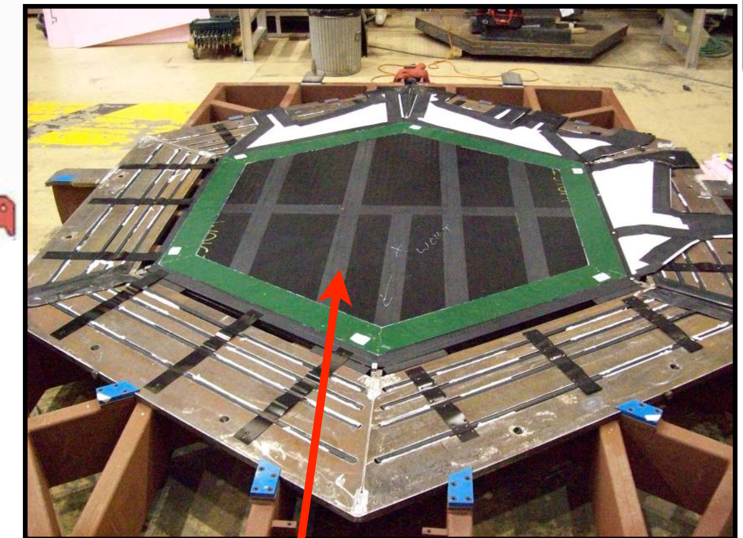
W. Brooks, E. Carquina, G. Maggi, C. Peña, I. Potashnikova, F. Prokoshin
Universidad Técnica Federico Santa María, Valparaíso, Chile

L. Aliaga, J. Devan, M. Kordosky, J.K. Nelson, J. Walding, D. Zhang
The College of William and Mary, Williamsburg, Virginia

* Co-Spokespersons
# Members of the MINERvA Executive Committee
@ Currently at Universidad Técnica Federico Santa María, Valparaíso, Chile

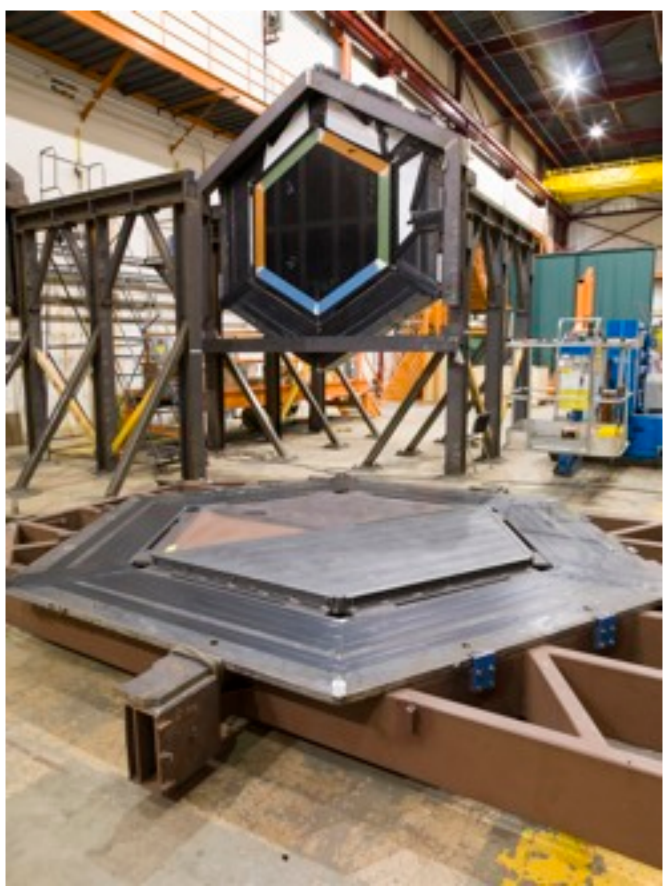
MINERνA Modules





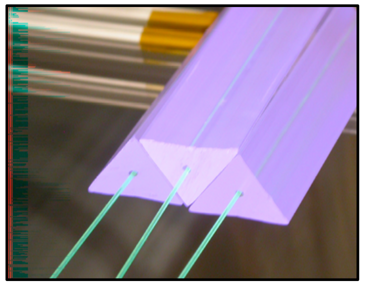
Modules have an outer detector frame of steel and scintillator...

...and an inner detector element of scintillator strips and absorbers/targets.

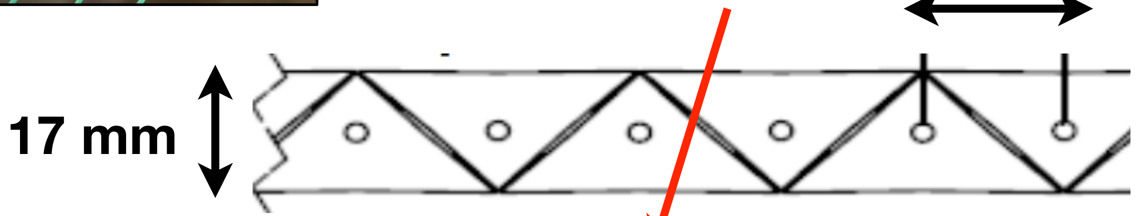


- **Four basic module types:**
  - **Tracker: two scintillator planes in stereoscopic orientation.**
  - **Hadronic Calorimeter: one scintillator plane and one 2.54-cm steel absorber.**
  - **Electromagnetic Calorimeter: two scintillator planes and two 2-mm lead absorbers.**
  - **Nuclear Targets: absorber materials (some with scintillator planes).**
- **Instrumented outer-detector steel frames.**
- **120 Total Modules: 84 Tracker, 10 ECAL, 20 HCAL, 6 Nuclear Targets.**

Plastic scintillator strips form the active detector elements.



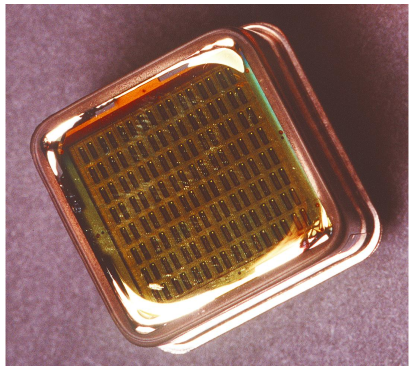
Extruded scintillator & wavelength shifting fibers.

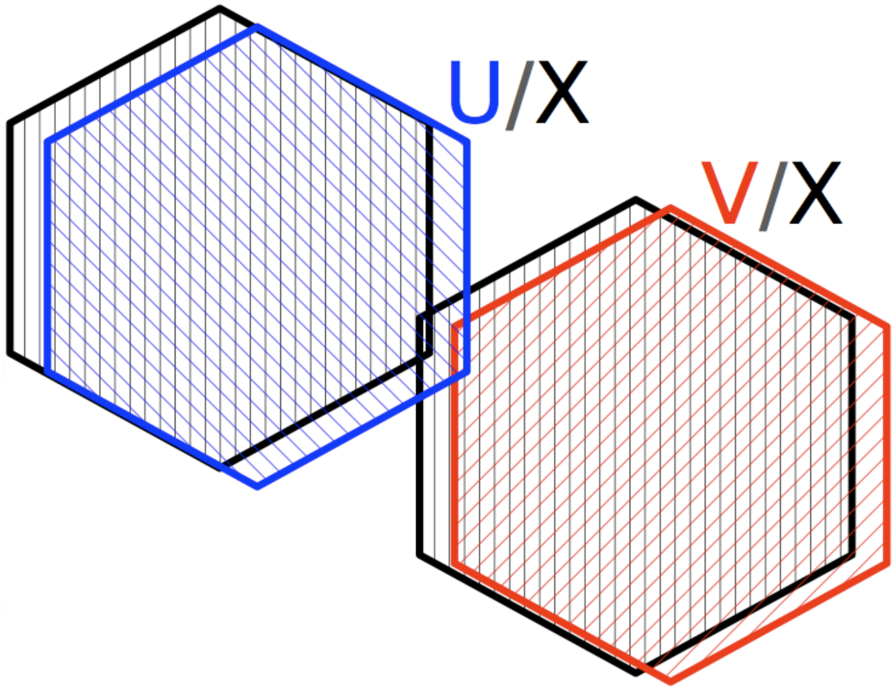


Charge-sharing for improved position resolution (~3.5 mm).

Strips are bundled into PLANES to provide transverse position location across a module.

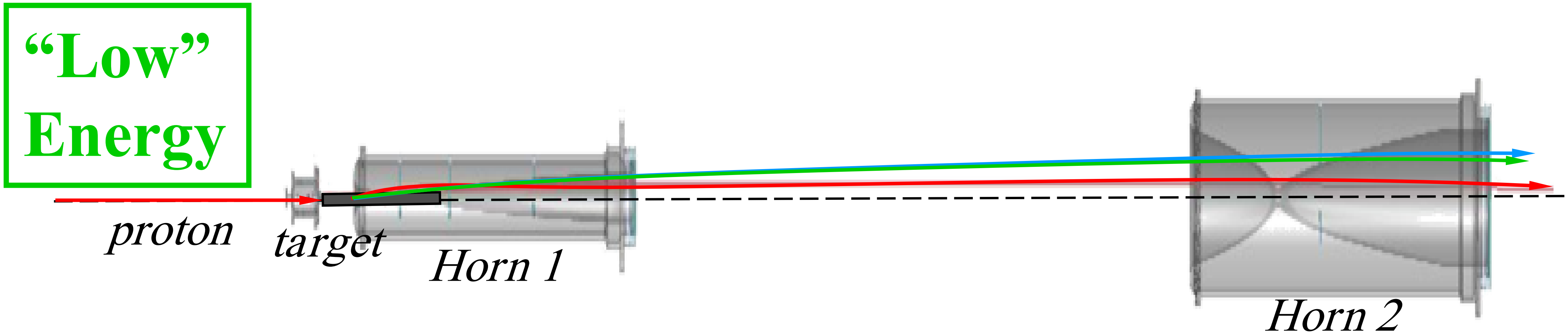
Fibers bundled into cables to interface with 64 channel multi-anode PMT's.





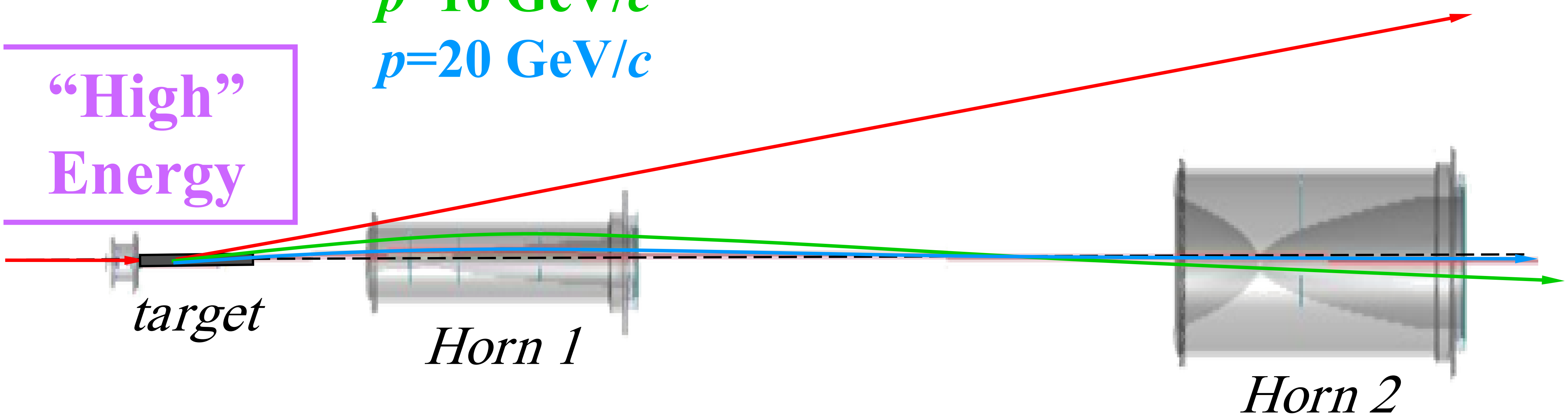
Planes are mounted stereoscopically in XU or XV orientations for 3D tracking.

Flexible Energy of the NuMI Beam



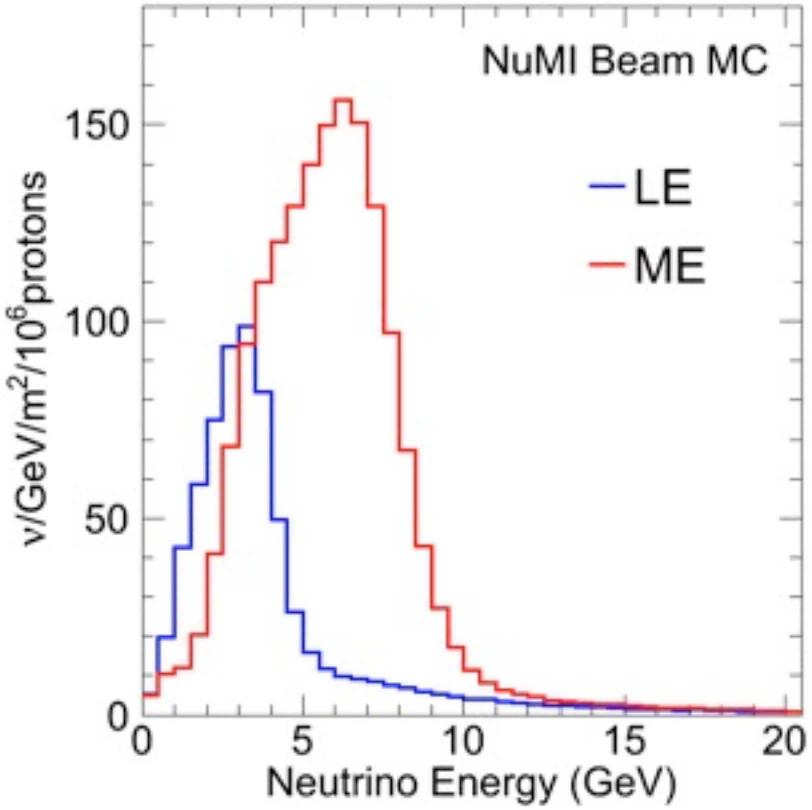
Pions with
p_T=300 MeV/c and
p=5 GeV/c
p=10 GeV/c
p=20 GeV/c

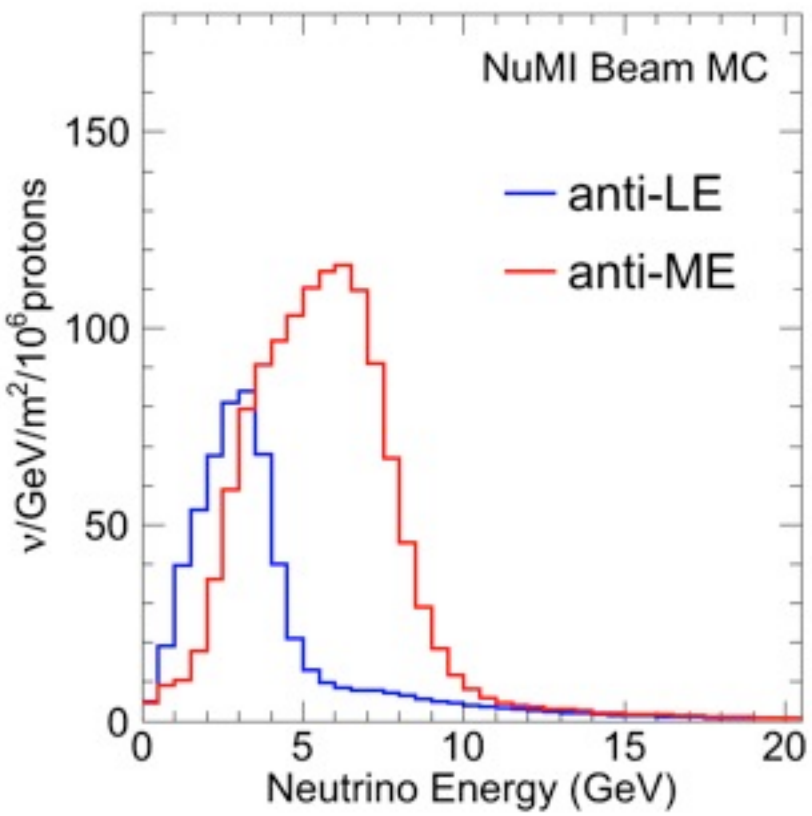
Vary ν beam energy by sliding the target in/out of the 1st horn



(Slide courtesy of S. Kopp.)

The NuMI Beam - Flux





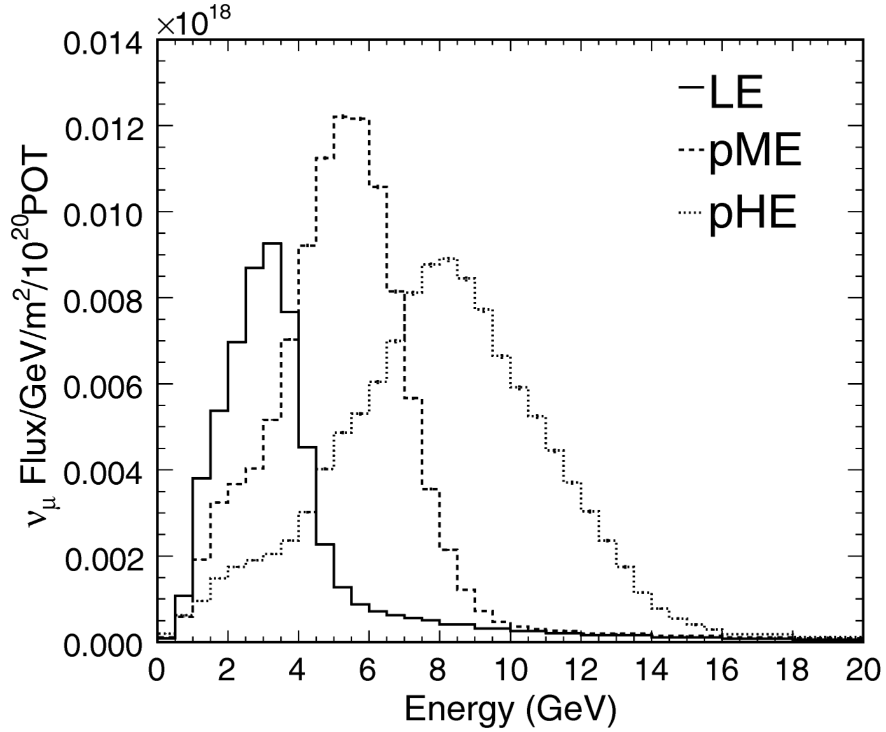
- **GEANT3−based Monte Carlo using FLUKA to calculate the flux of particles off the target.**
- **Evacuated decay pipe (now filled with He gas).**
- **Fluxes calculated at the center of the detector (1030.99m from the upstream end of horn 1).**
- **All fluxes (for display purposes) are plotted at a single point, whereas the MINERνA detector is large in transverse size. This is properly taken into account when calculating Monte Carlo data sets for MINERνA.**
- **Goal for the flux uncertainty is ~10%.**

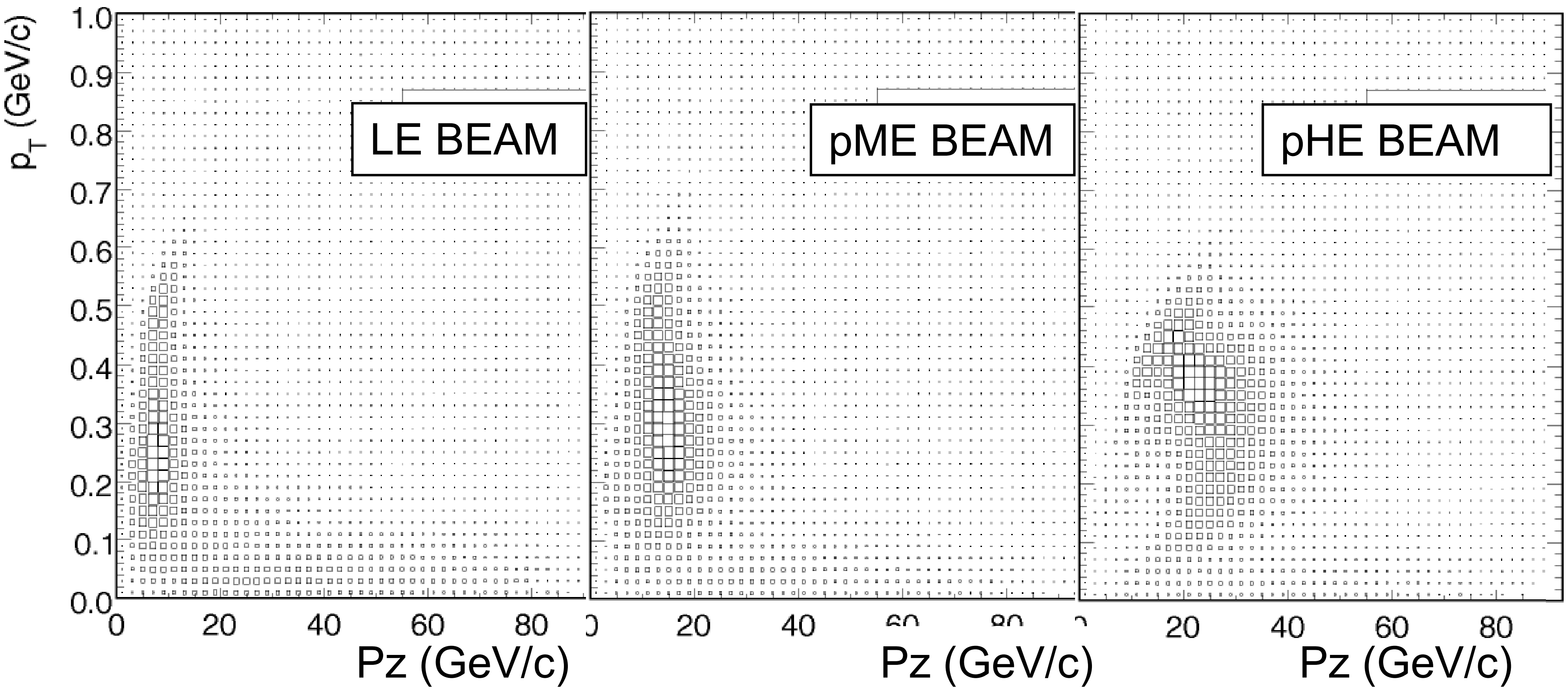
LE = low energy target, horns separated by 10m, target at z= −10cm; LE010/185kA.
ME = low energy target, horns separated by 23m, target at z= −100cm; ME100/200kA

We can plot the neutrino flux in terms of $\phi_\nu(E_\nu)$

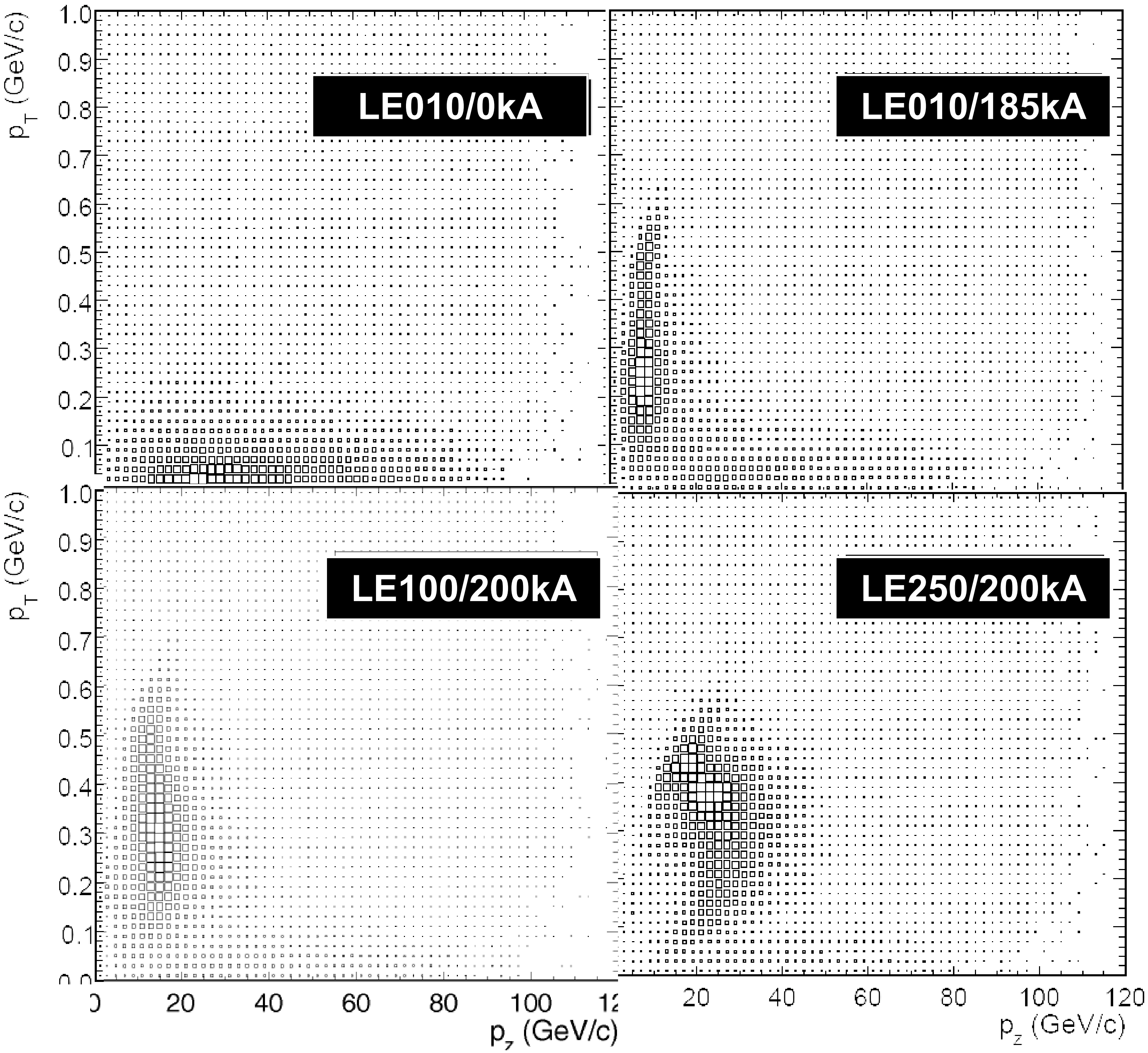
OR

in terms of variables related to hadron yields off the target $\phi_\nu(x_F,p_T)$





NuMI Beam Configurations



- Can vary
  - Horn current (p_T kick supplied to π's)
  - Target Position (x_F of focused particles)
- Plots show (x_F ,p_T) of π^+ contributing to neutrino flux.
- Similar plots exist for kaons
- Minerva will acquire data from total of 8 beam configurations

Explanatory Notes for Previous Page

- Graphs are made with older Geant3-based Monte Carlo in which fluka was used to calculate flux of particles off the target, these were fed into Geant3 for tracking through the resto fo the beam line.
- Fluxes are calculated at 1040m from the target (front face of MINOS), so off by ~0.2% for Minerva and not worth addressing in a talk.
- Keep in mind that all fluxes (for display purposes) are plotted at a single point, whereas the Minerva detector is large in transverse size. The transverse location of the neutrino interaction in the detector will affect the flux and the energy spectrum of the beam by a small amount, which is properly taken into account when calculating Monte Carlo data sets for Minerva, but is left out of these display plots.
- In the box plots, the z axis of the plot is proportional to the vertical axis of the 1D histograms – flux at the detector location. Thus, the box plots are telling us which particles off the target largely contribute to the neutrino flux at the detector.

Full MINERνA Event Rates

Assume 4e20 POT in LE and 12e20 PT in ME Configurations

Fiducial Mass: CH = 3 tons, He = 0.2 tons, C = 0.15 tons, Fe = 0.7 tons, Pb = 0.85 tons, H_2O = 0.3 tons

NEUGEN Predictions

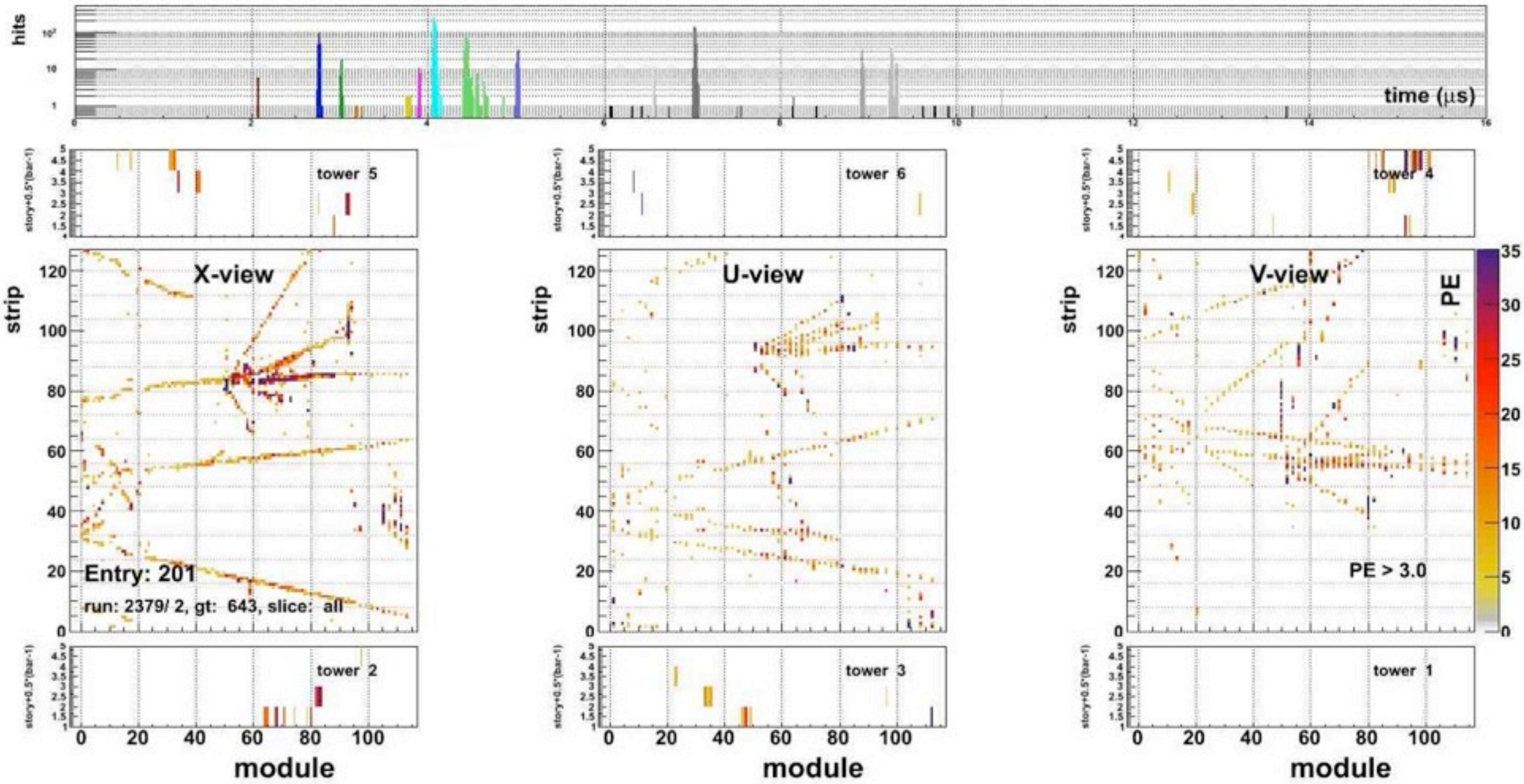
Target	Expected CC Event Sample (millions)
CH	9
He	0.6
C	0.4
Fe	2.7
Pb	2.7
H_2O	1

Main CC Physics Topic	Statistics in CH Scintillator
Quasi-Elastic	0.8 M
Resonance Production	1.7 M
Transition: Resonance to DIS	2.1 M
DIS, Structure Functions, High-x PDF’s	4.3 M DIS
Coherent Pion Production	89 K CC, 44 K NC
Strange & Charm Production	>240 K
Generalize Parton Distributions	~10 K

Performance

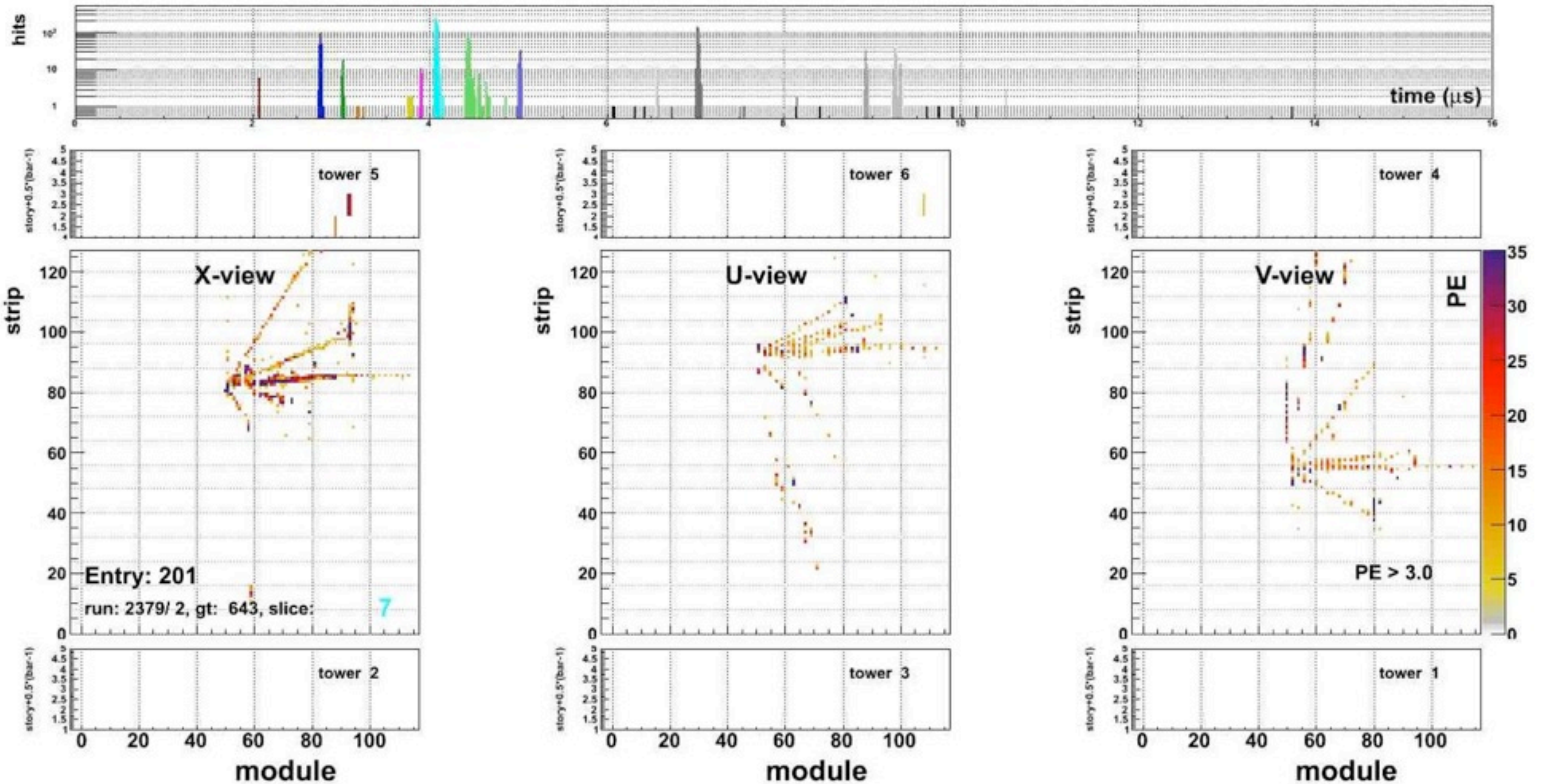
- **Kinetic energy needed to cross 10 planes:**
  - **p > 175 MeV, $\pi^{\pm}$ > 85 MeV, μ > 70 MeV.**
  - **EM shower e,γ > 50-60 MeV.**
- **μ Reconstruction:**
  - **85-90% stop in MINERνA or MINOS.**
  - **δp/p ~5% for stoppers, 10-15% via curvature.**

Full Detector Analysis



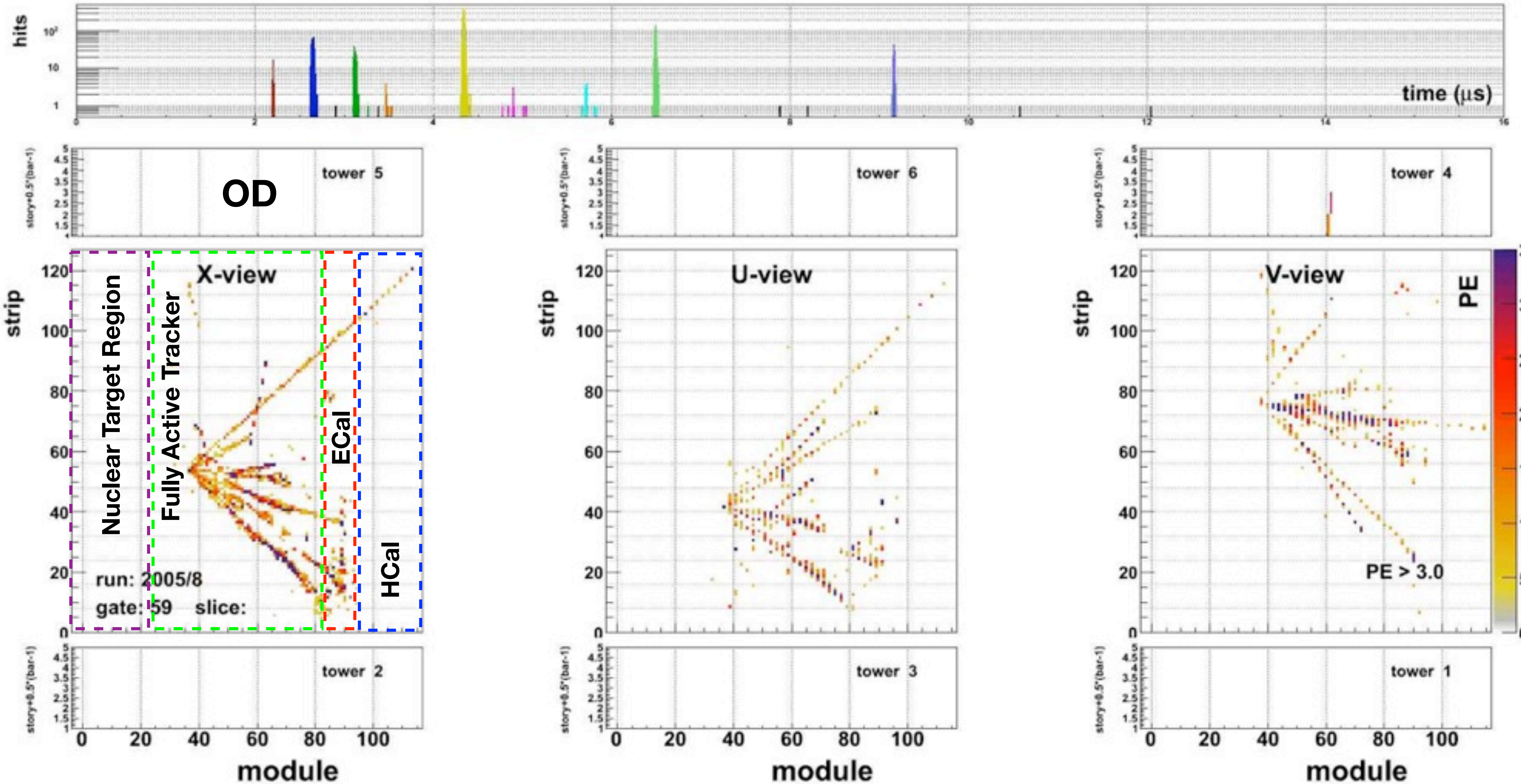
Events in the full detector are very busy...

Full Detector Analysis

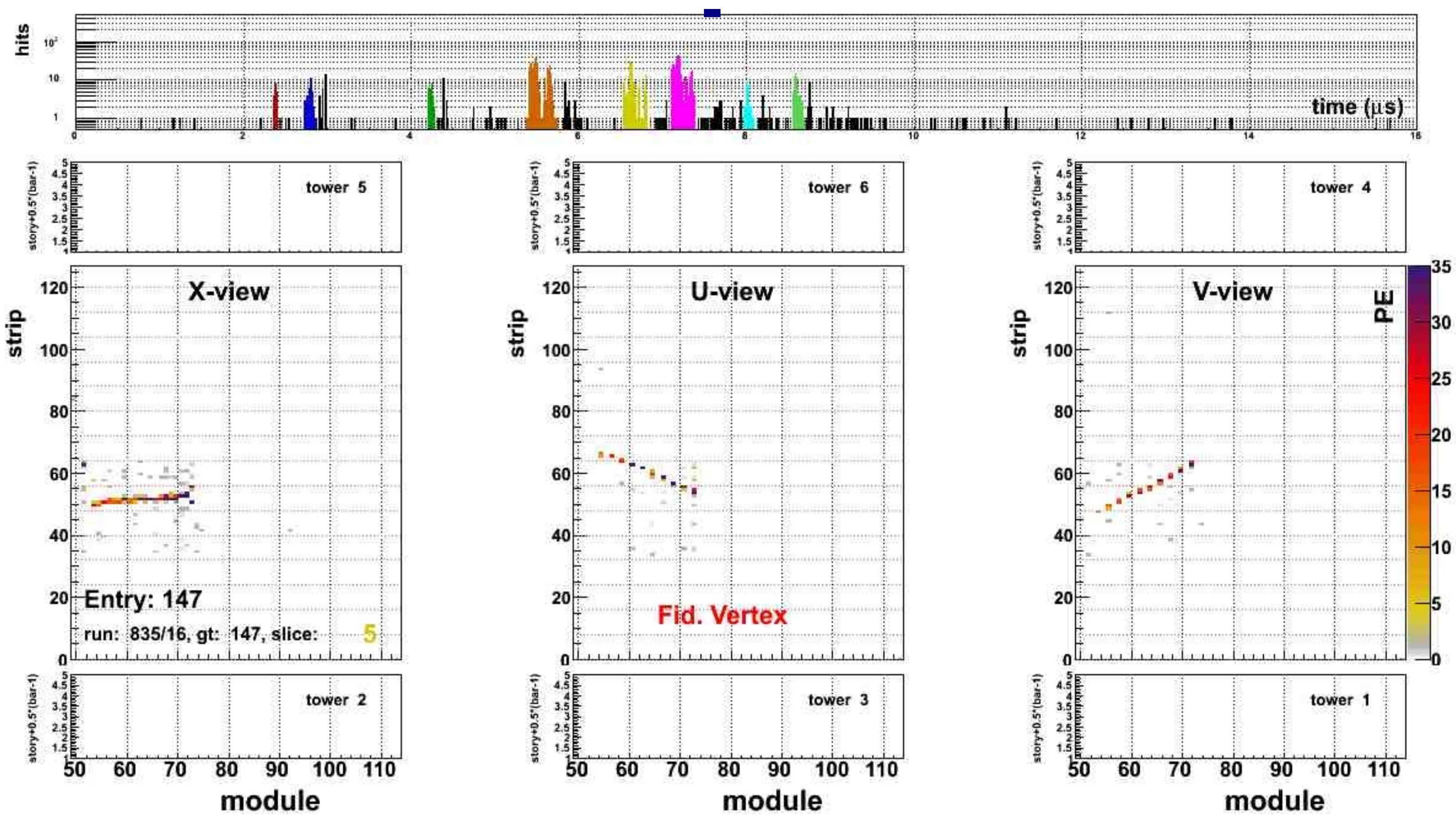


...time separation is critical!

Full Detector Analysis



PID with dE/dX



Candidate proton track from the anti-ν data set.

MC indicates this will be a successful method.