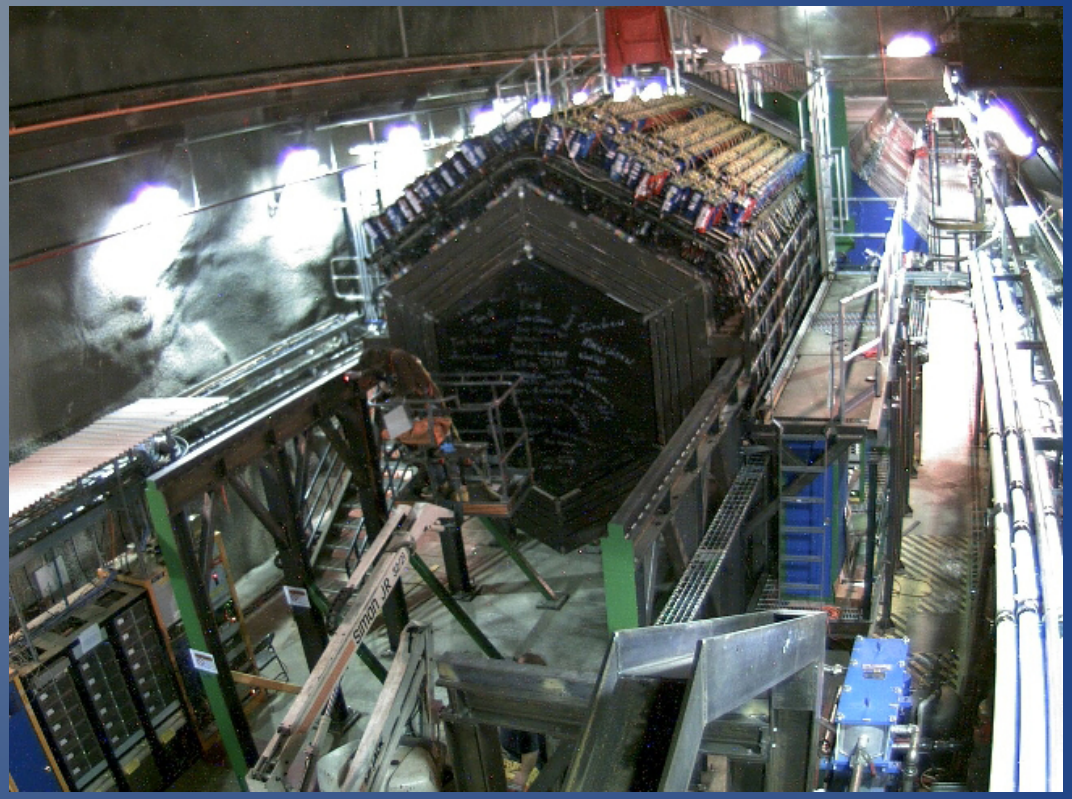
Highlights from MINERνA's First Year



Aaron McGowan
University of Rochester
on behalf of the MINERνA Collaboration
2011 APS Meeting of the DPF
Providence, Rhode Island

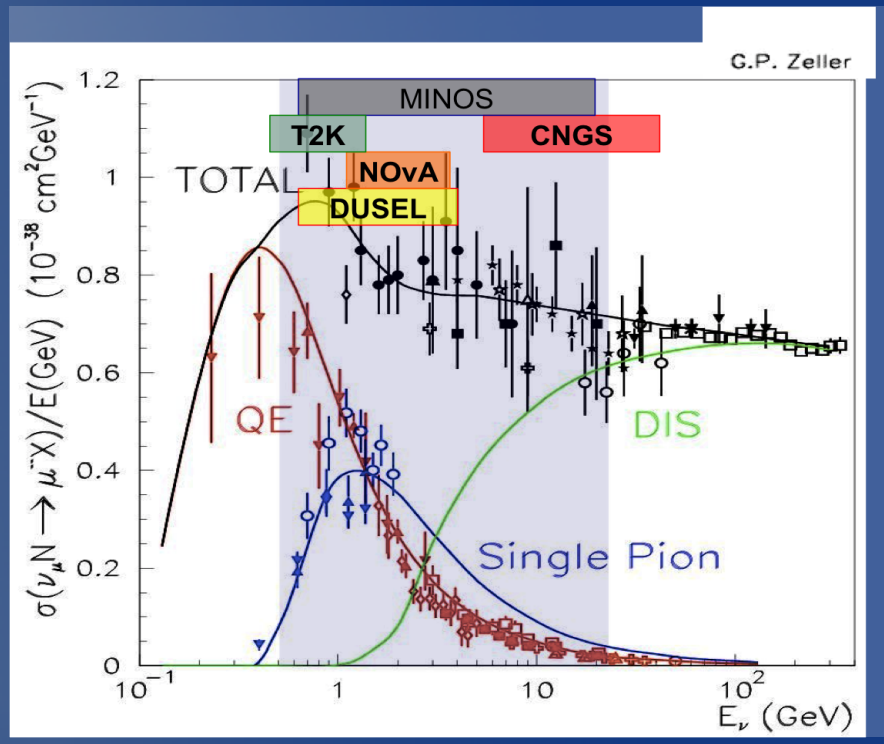
UNIVERSITY of ROCHESTER

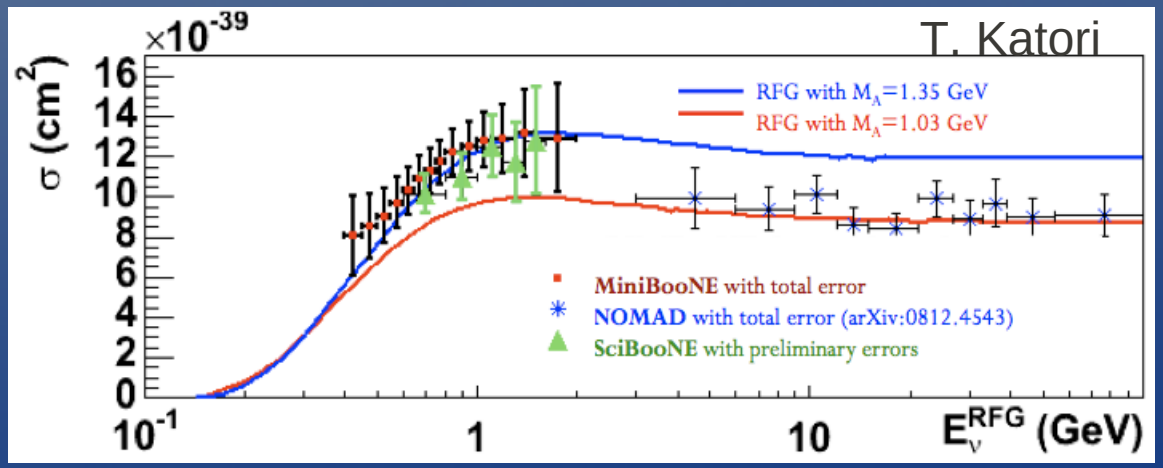
Outline

- MINERνA motivation and introduction
- Detector livetime and beam performance
- Tracking overview
- Charged current kinematic distributions
- Future plans

MINERνA: motivation

- Existing neutrino cross section data comes mainly from low-statistics results
- Conflict exists between recent high-statistics measurements
- MINERνA will address the 1-20 GeV region of E_ν





MINERνA: goals and capabilities

- We seek to measure inclusive and exclusive cross sections for both incoming neutrino and antineutrino beams

MINERνA: goals and capabilities

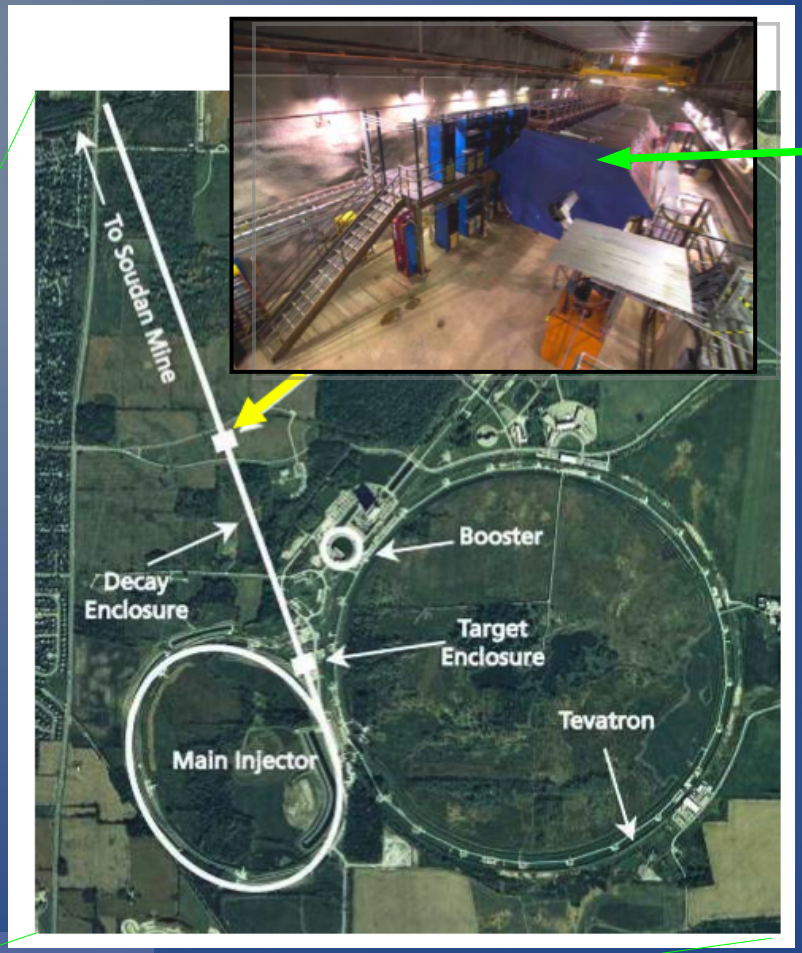
- We seek to measure inclusive and exclusive cross sections for both incoming neutrino and antineutrino beams
- High resolution tracking and vertexing allows identification of the struck target material, probing A-dependence
- Targets: plastic scintillator (CH), C, Fe, Pb, H_2O, LHe (see talk by B. Osmanov for initial results comparing rates)

MINERνA: goals and capabilities

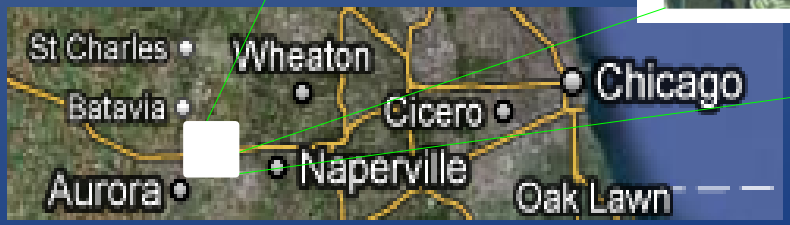
- We seek to measure inclusive and exclusive cross sections for both incoming neutrino and antineutrino beams
- High resolution tracking and vertexing allows identification of the struck target material, probing A-dependence
- Targets: plastic scintillator (CH), C, Fe, Pb, H_2O, LHe (see talk by B. Osmanov for initial results comparing rates)
- High-intensity NuMI beam provides high statistics and peaks in the few-GeV region
- MINERνA will reduce systematic uncertainties for long- and short-baseline neutrino oscillation experiments

Location

- MINERνA is installed on-axis in the NuMI beam line at Fermi National Accelerator Lab

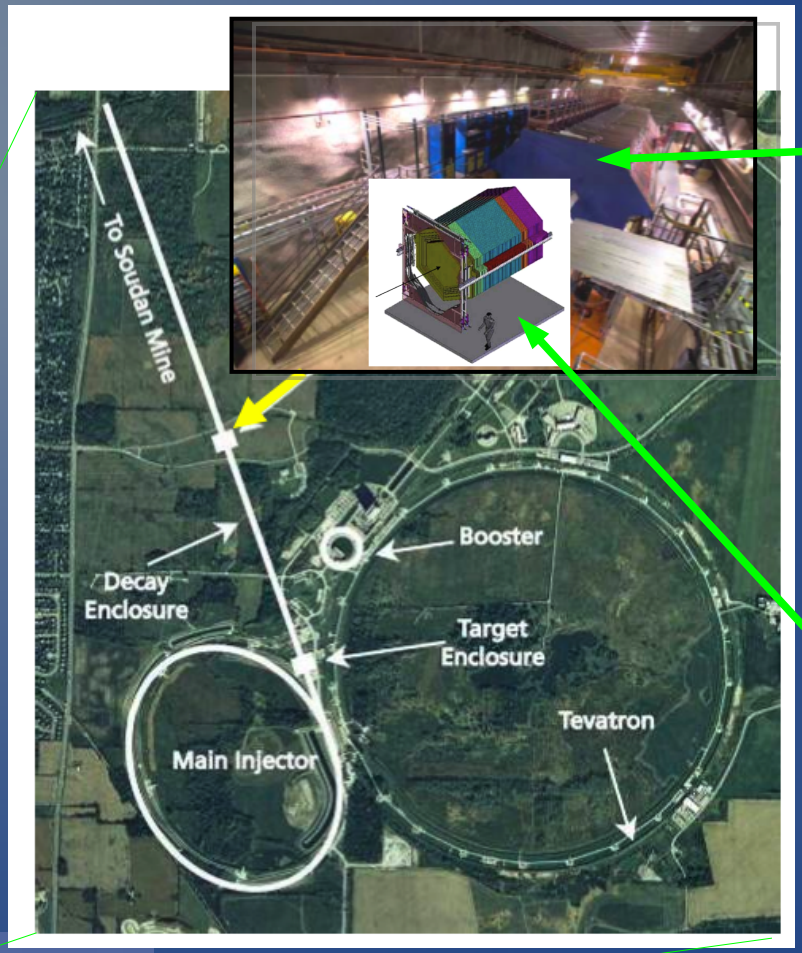


MINOS Near Detector
Steel + scintillator
muon spectrometer



Location

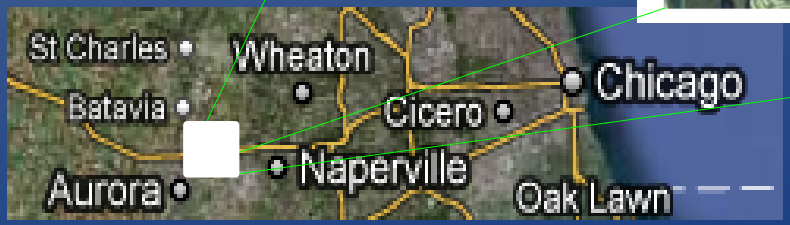
- MINERνA is installed on-axis in the NuMI beam line at Fermi National Accelerator Lab
- Detector sits in front of MINOS Near Detector, which serves as our muon spectrometer



MINOS Near Detector
Steel + scintillator
muon spectrometer

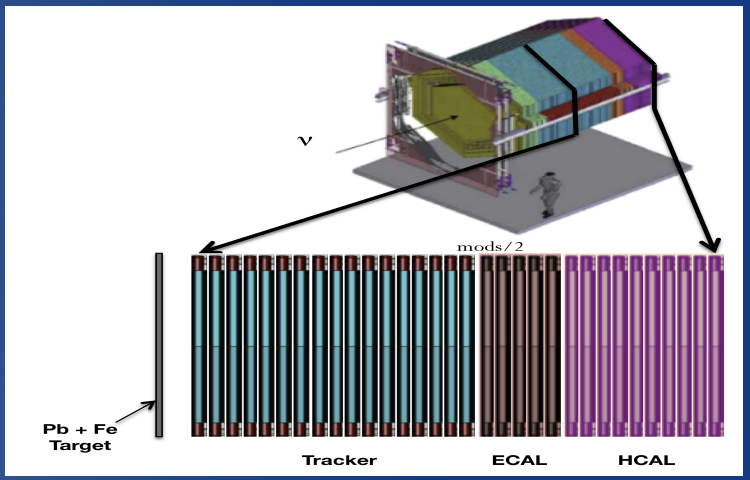
MINOS utilizes a toroidal magnetic field to identify muon charge and momentum by curvature (if exiting) or by range (if contained)

MINERνA gains charge ID for muons accepted into MINOS

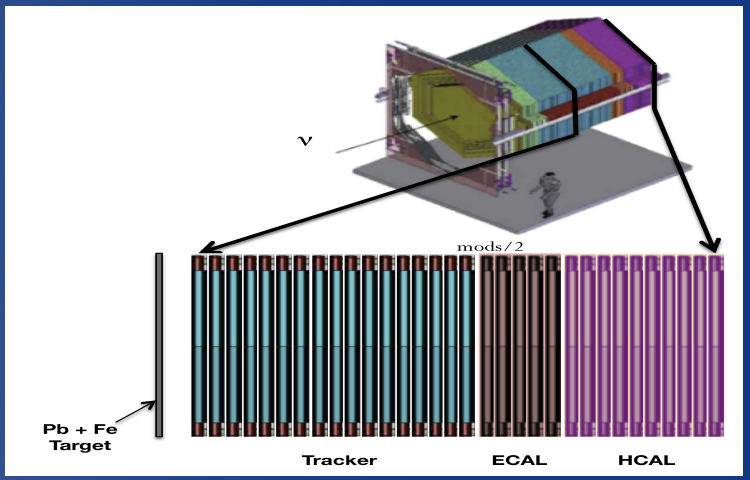


MINERνA detector

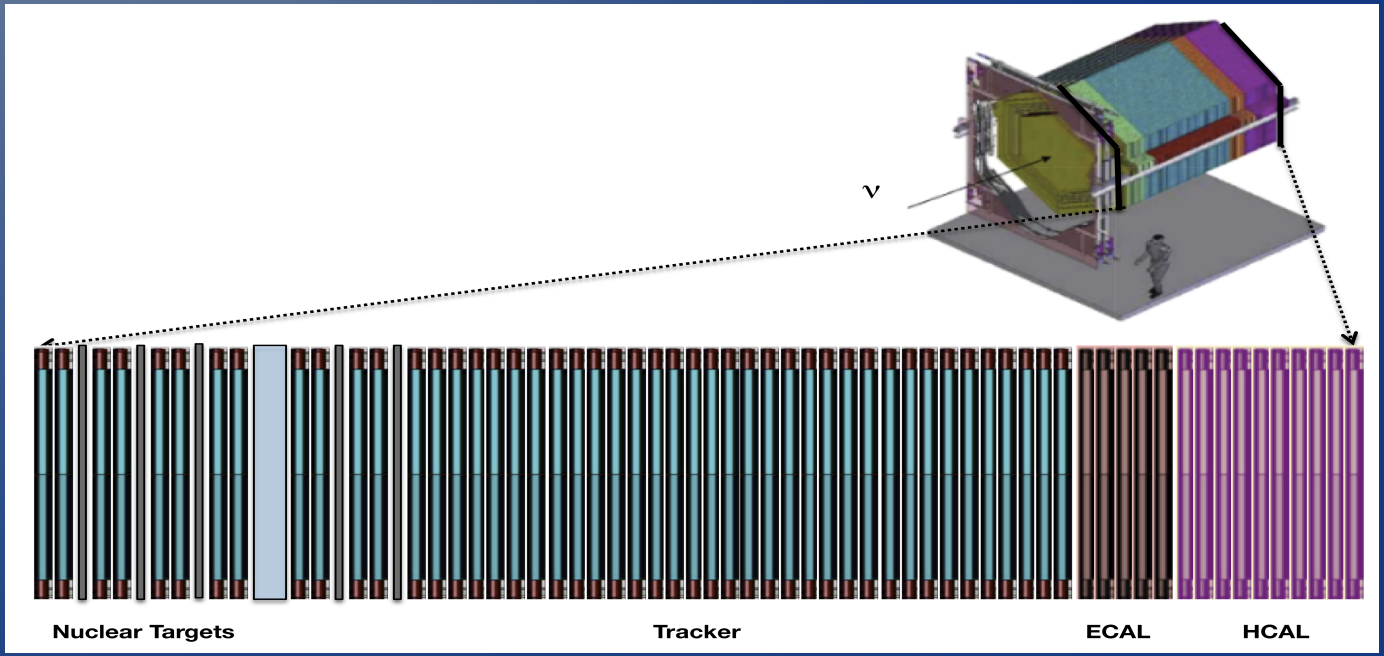
- **Partial (55%): Nov 2009 – Mar 2010**
  34 Tracking, 10 ECAL, 20 HCAL modules



MINERνA detector

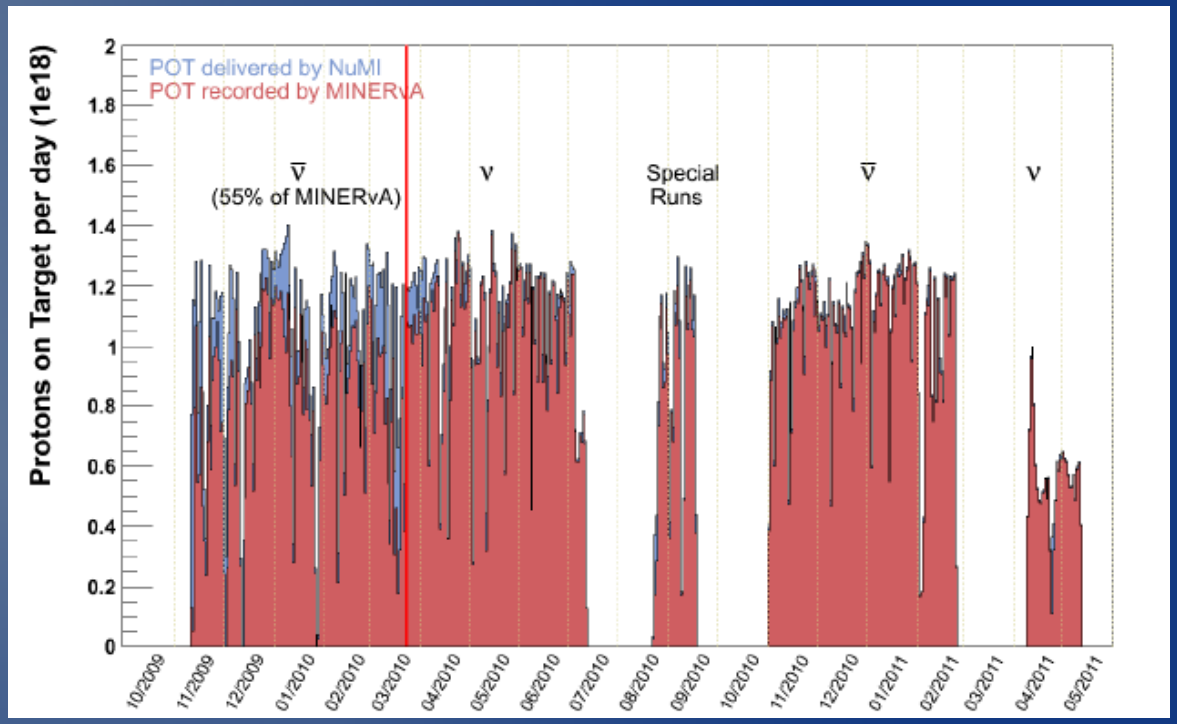


- **Partial (55%): Nov 2009 – Mar 2010**
  34 Tracking, 10 ECAL, 20 HCAL modules
- **Full: March 2010 – present**
  30 Nuclear Target, 60 Tracking, 10 ECAL, 20 HCAL modules
- Nuclear target region contains various target modules interspersed with fully-active tracking modules



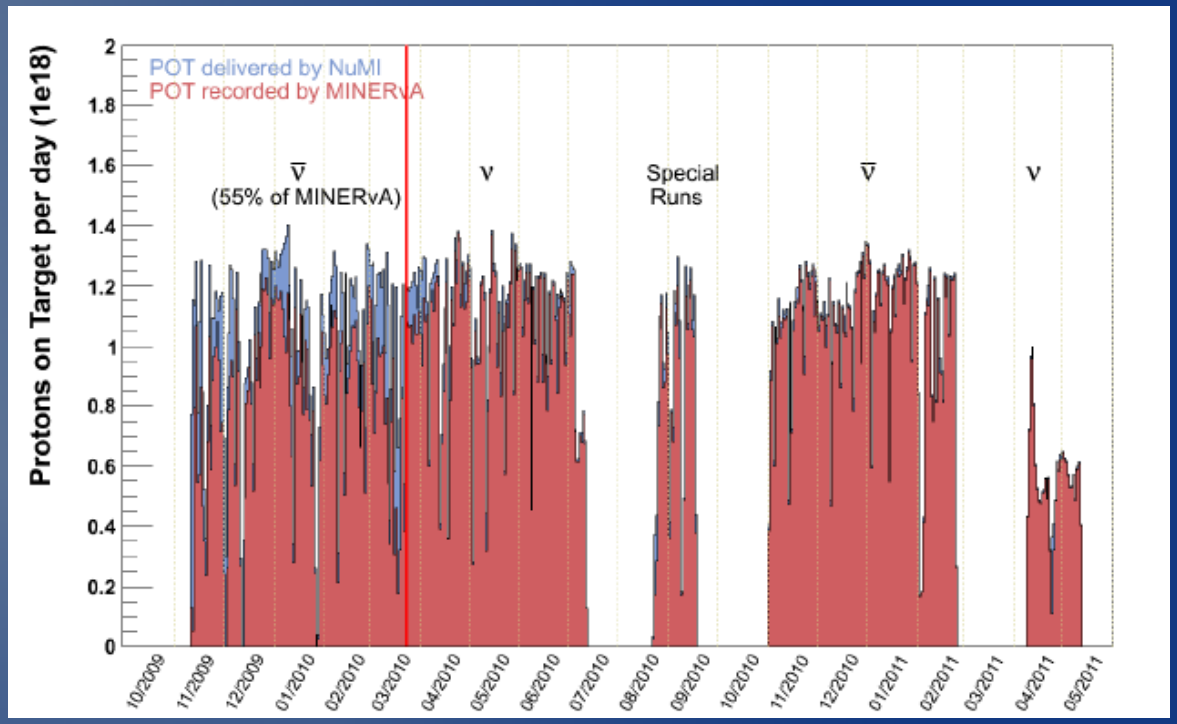
Data collected to date

- Collected 0.8×10^{20} protons on target (POT) of LE antineutrino data with Partial detector
- Collected 1.5×10^{20} POT of LE neutrino data with Full detector
- Collected 1.3×10^{20} POT of LE antineutrino data with Full detector



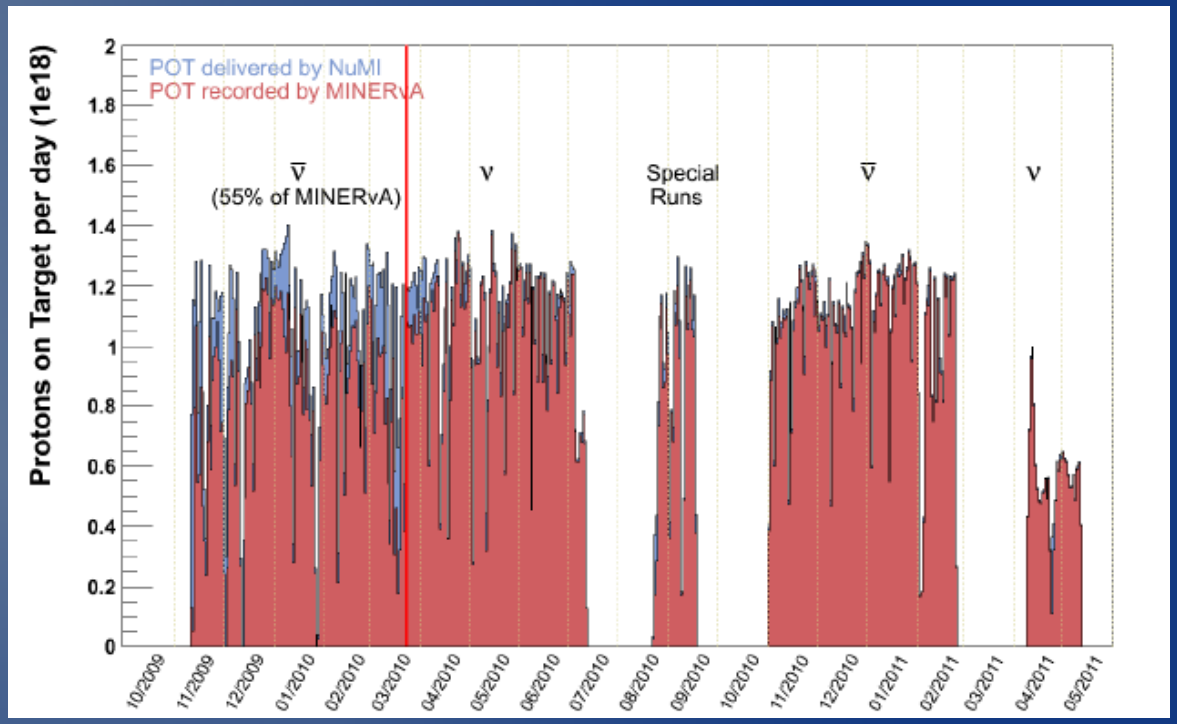
Data collected to date

- Collected 0.8×10^{20} protons on target (POT) of LE antineutrino data with Partial detector
- Collected 1.5×10^{20} POT of LE neutrino data with Full detector
- Collected 1.3×10^{20} POT of LE antineutrino data with Full detector
- Detector livetime > 98% and live channels ~99.9%



Data collected to date

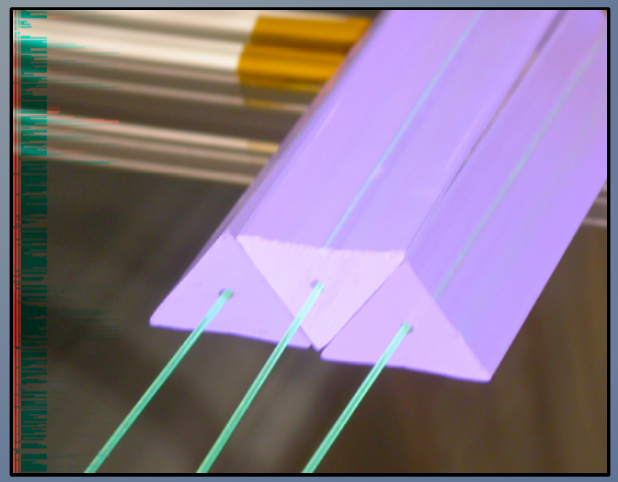
- Collected 0.8×10^{20} protons on target (POT) of LE antineutrino data with Partial detector
- Collected 1.5×10^{20} POT of LE neutrino data with Full detector
- Collected 1.3×10^{20} POT of LE antineutrino data with Full detector
- Detector livetime > 98% and live channels ~99.9%



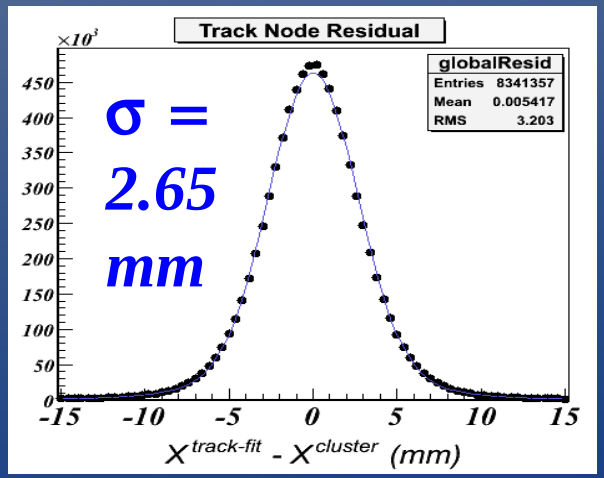
→ Expect $>4\times10^{20}$ POT in the LE neutrino beam

→ Expect $\sim12\times10^{20}$ POT in the ME neutrino beam (NOvA era)

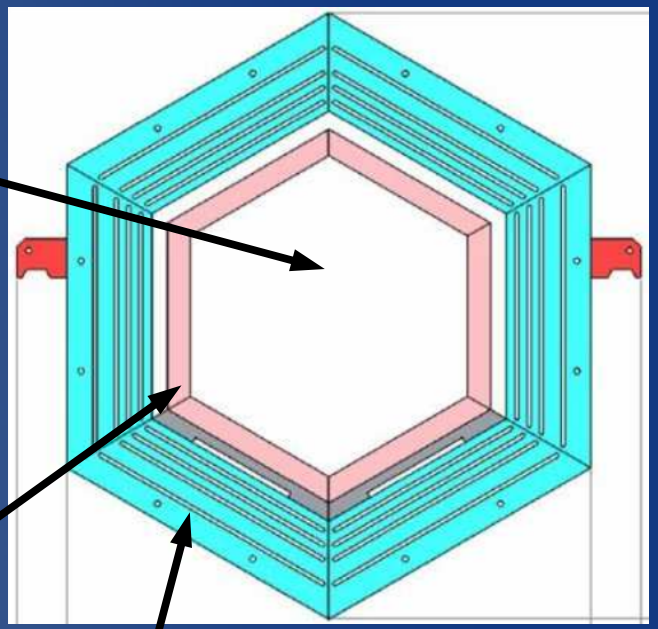
Tracking with MINERνA



Alternating triangular strips take advantage of charge sharing, permit ~3mm track node resolution



Each plane contains 127 strips in the Inner Detector (ID) region

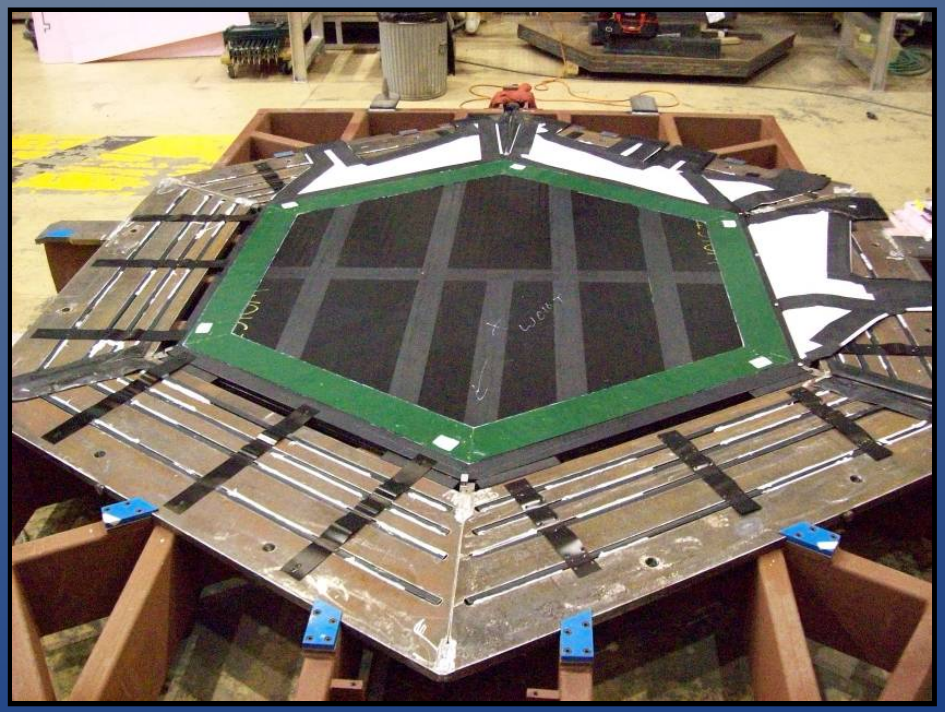


Each ID plane is laminated at the periphery by Side ECAL lead strips

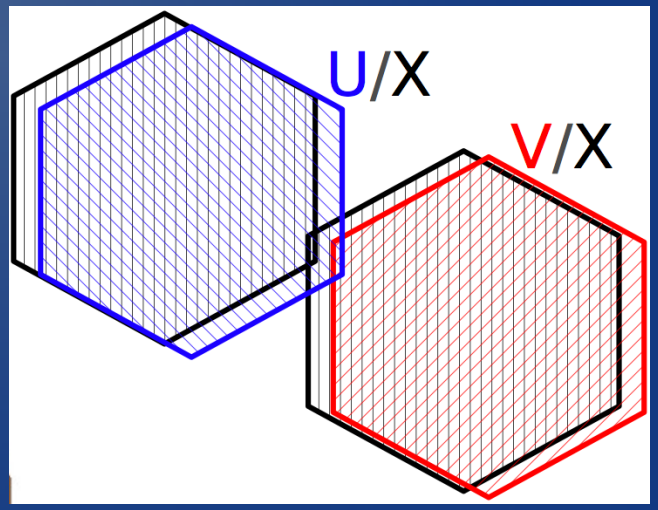
Each ID plane is surrounded radially by six Outer Detector HCAL sectors (steel + scint)

Inner Detector: Tracking modules

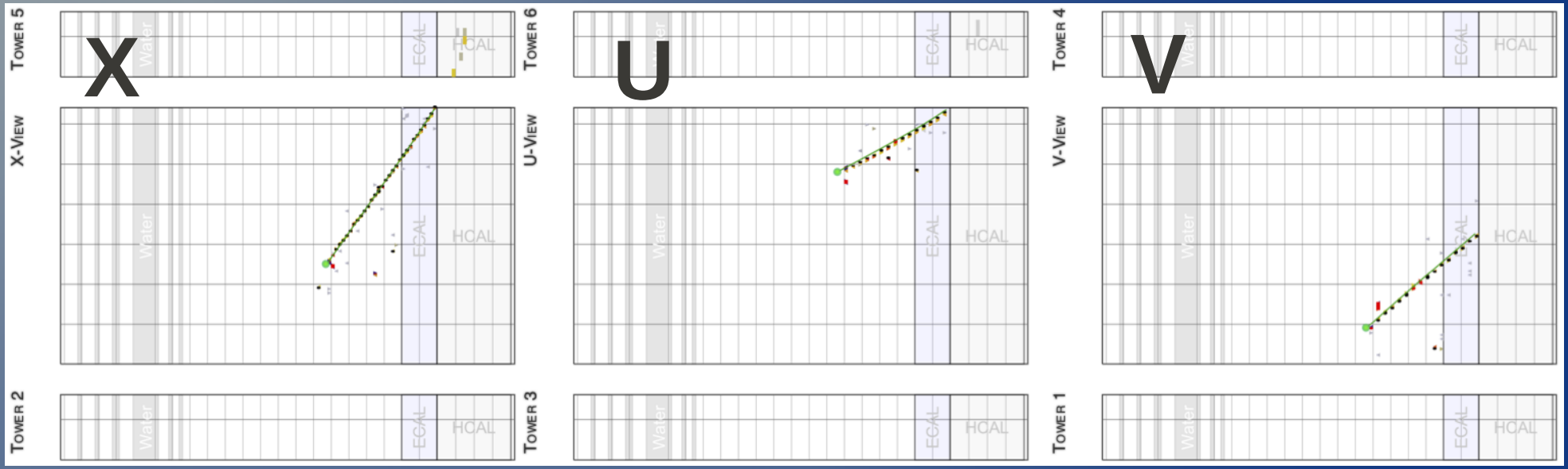
- Tracking modules each contain two ID planes
- One X view (vertical strips) and one of either U (+60° from vertical) or V views (-60°)



Alternating UX, VX, UX, VX module structure provides stereoscopic 2D hit views

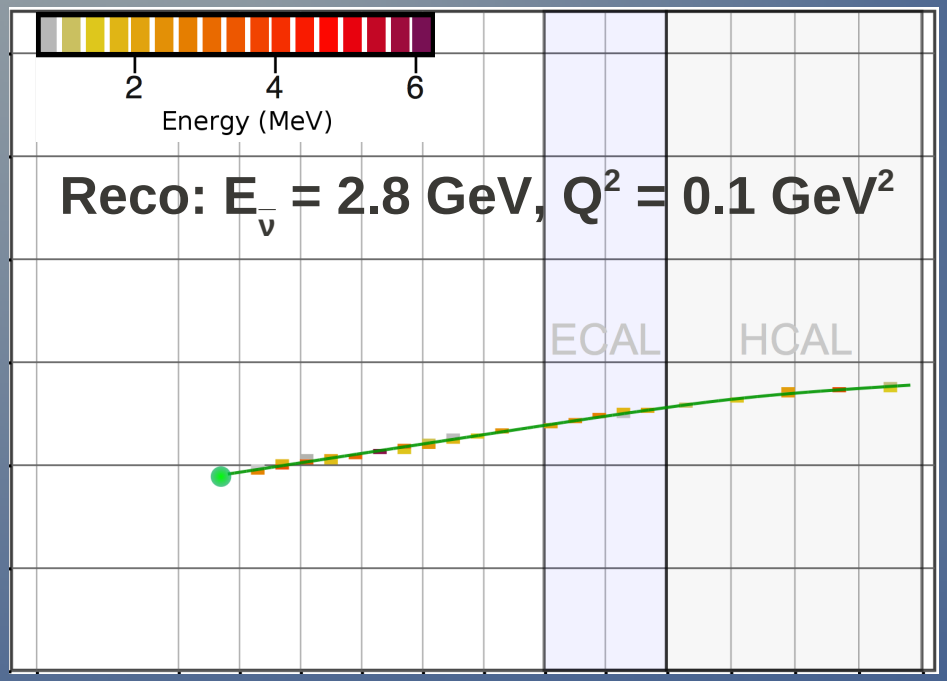


Particle tracking



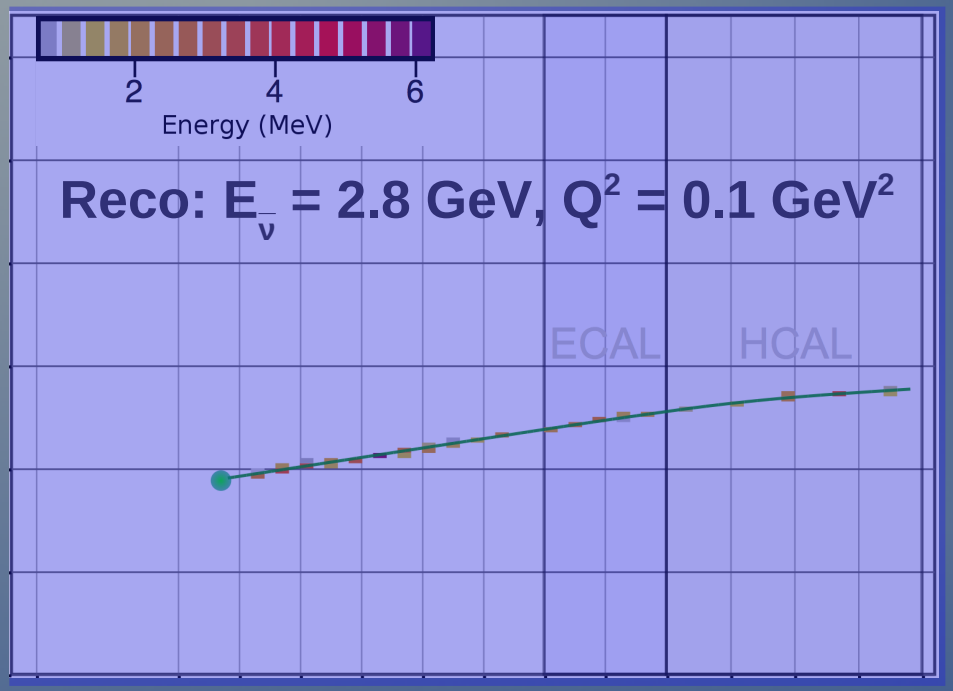
- Hits in each view are joined into 2D track seeds
- Three 2D views provide means to associate these track seeds into 3D tracks

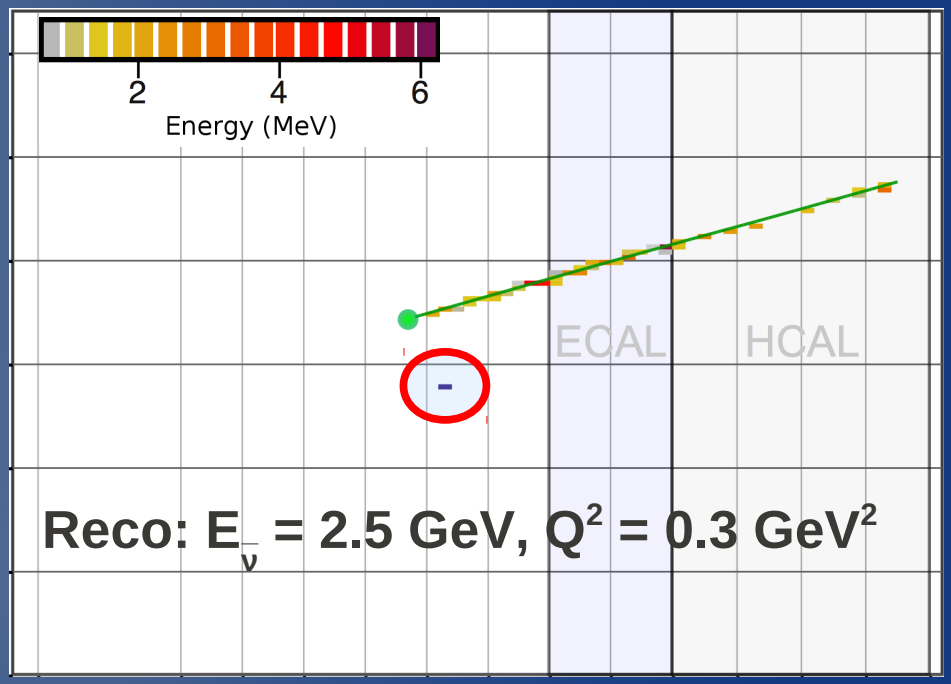
Recoil energy: $\bar{\nu}$ candidates



- After tracking, we form a calorimetric sum of the recoil energy away from the muon track

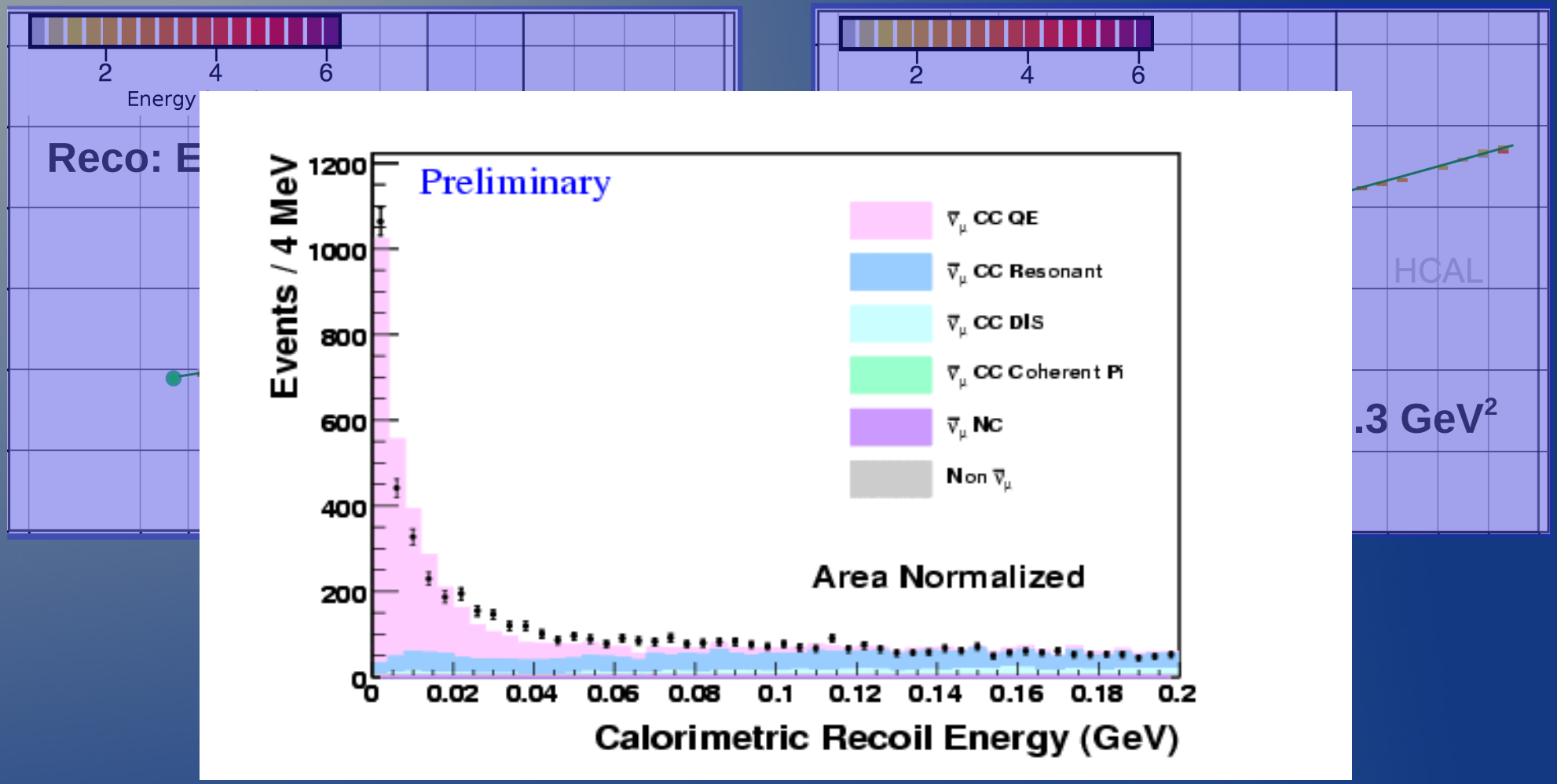
Recoil energy: $\bar{\nu}$ candidates





- After tracking, we form a calorimetric sum of the recoil energy away from the muon track
- Event on the right exhibits probable neutron interaction with a 30 MeV energy deposition

Recoil energy: $\bar{\nu}$ candidates



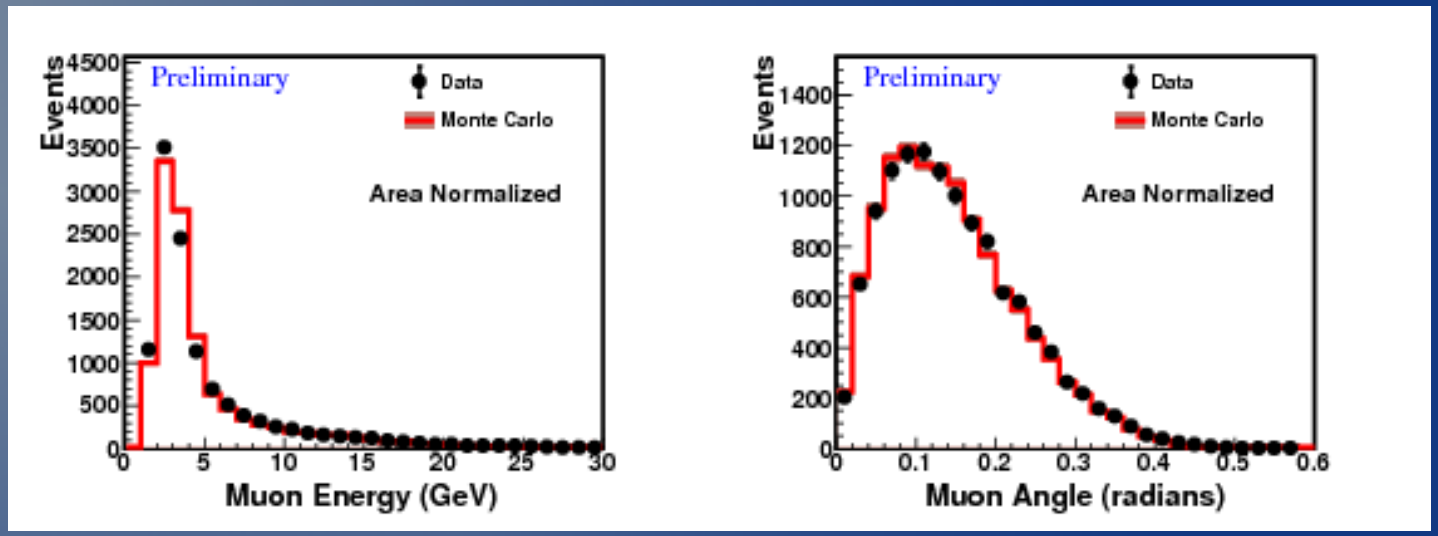
- Data shows good agreement with MC, with some shape discrepancy at low recoil energy

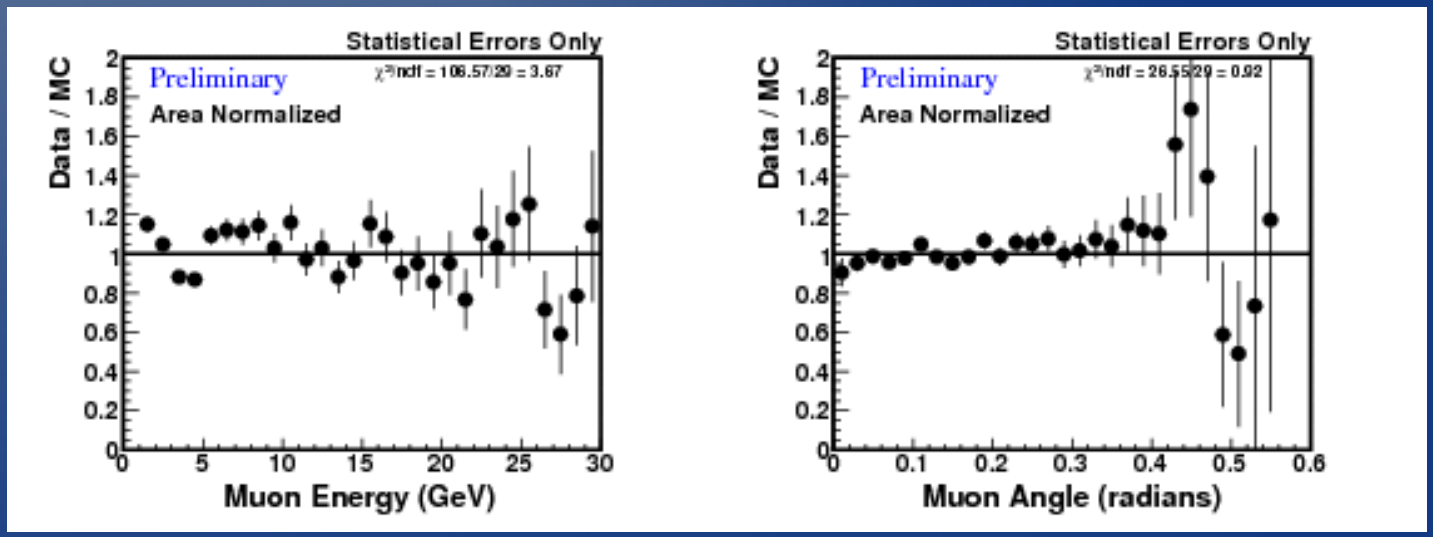
Antineutrino results

- Partial detector configuration
- Simulation uses GENIE 2.6.2, $M_A = 0.99$
- Data: 0.4×10^{20} POT, MC: 1.0×10^{20} POT
- Selection requires positive muon charge ID for inclusive sample
- Additional cut on recoil energy for exclusive CCQE candidates (dynamic in Q^2)

Antineutrino: muon energy, angle (CC inclusive)

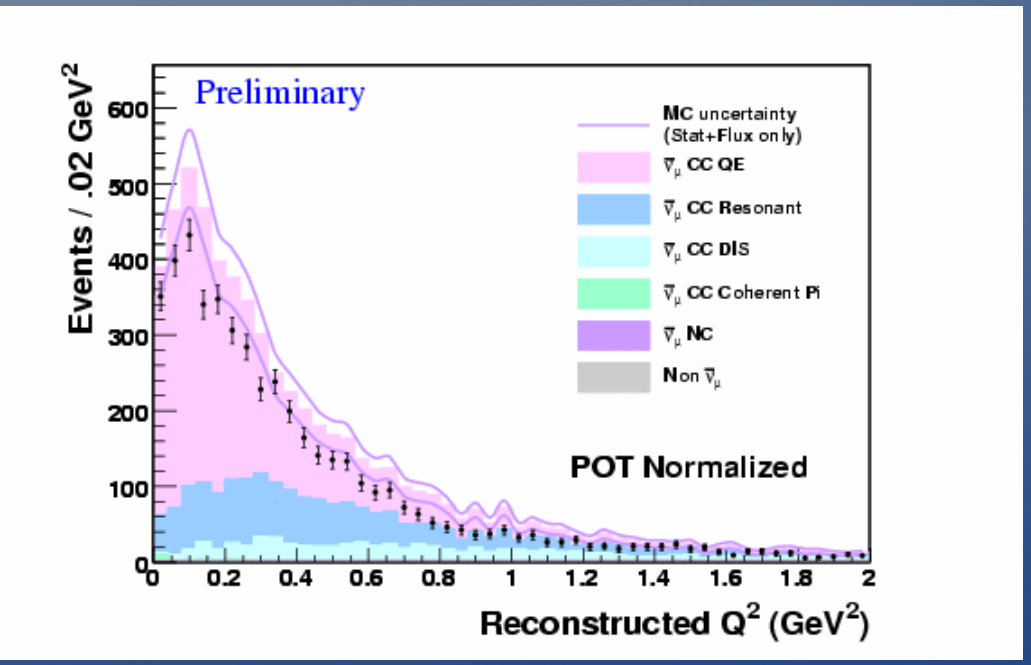
- Sample is ~1/8 of collected antineutrino data
- Data/MC shape in agreement

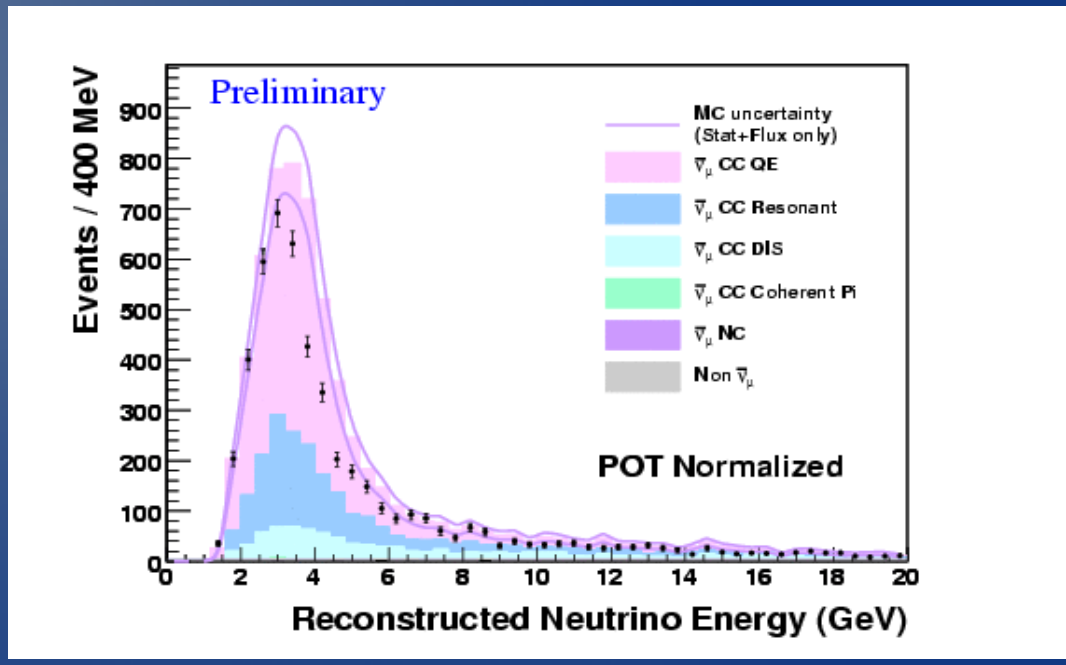




Antineutrino: CCQE rates by Q^2 and E_ν

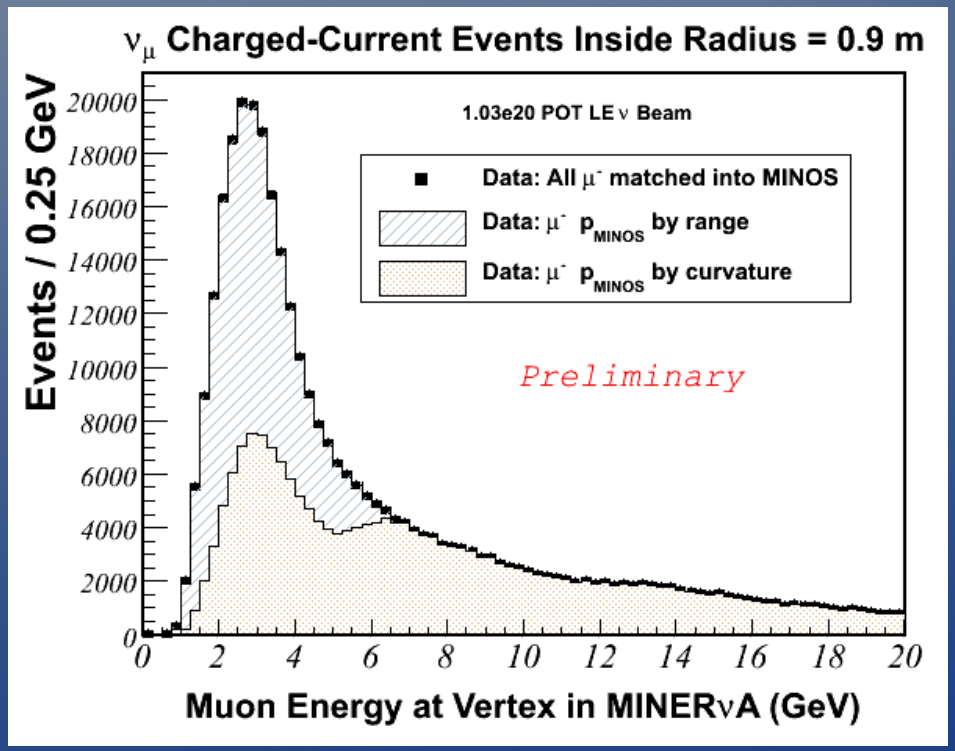
- Exclusive $\bar{\nu}p \rightarrow \mu^+ n$ candidates
- Observed deficit is flat in Q^2, but confined mainly to the falling edge of the focusing peak in E_ν

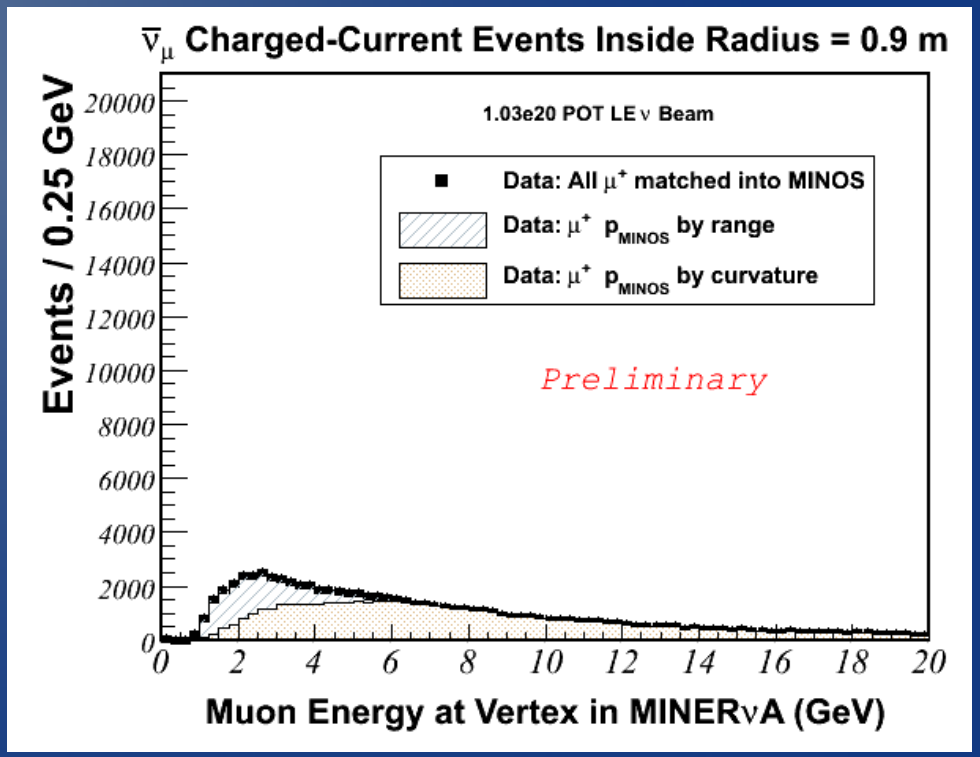




Neutrino run: muon energy (CC inclusive)

- Data taken with Full detector, 1.03×10^{20} POT
- Require fiducial vertex in MINERνA and muon charge ID from MINOS





Future plans

- Apart from CCQE and CC inclusive cross sections analyses, several other final states are being actively studied:
  - CC inclusive pion
  - CC exclusive single-pion production
  - CC DIS
  - CC Coherent
  - NC elastic scattering
- Stay tuned!

Thank you, from the MINERνA Collaboration

G. Tzanakos
University of Athens

J. Cravens, M. Jerkins, S. Kopp, L. Loiacono, J. Ratchford, R. Stevens IV
University of Texas at Austin

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

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

D. Boehnlein, R. DeMaat, N. Grossman, D. A. Harris, J. G. Morfn, J. Osta, R. B. Pahlka, P. Rubinov, D. W. Schmitz, F.D. Snider, R. Stefanski
Fermilab

J. Felix, A. Higuera, Z. Urrutia, G. Zavala
Universidad de Guanajuato

M.E. Christy, C. Keppel, P. Monagham, T. Walton, L. Y. Zhu
Hampton University

A. Butkevich, S.A. Kulagin
Inst. Nucl. Reas. Moscow

G. Niculescu, I. Niculescu
James Madison University

E. Maher
Mass. Col. Lib. Arts

L. Fields, B. Gobbi, L. Patrick, H. Schellman
Northwestern University

N. Tagg
Otterbein College

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

A. M. Gago, N. Ochoa, J.P. Velasquez
Pontificia Universidad Catolica del Peru

S. Avvakumov, A. Bodek, R. Bradford, H. Budd, J. Chvojka, M. Day, H. Lee, S. Manly, C. Marshall, K.S. McFarland, A. M. McGowan, A. Mislivec, J. Park, G. Perdue, J. Wolcott
University of Rochester

G. J. Kumbartzki, T. Le, R. D. Ransome, E. C. Schulte, B. G. Tice
Rutgers University

H. Gallagher, T. Kafka, W.A. Mann, W. P. Oliver
Tufts University

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

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

M. Alania, A. Chamorro, K. Hurtado, C. J. Solano Salinas
Universidad Nacional de Ingeniera

W. K. Brooks, E. Carquin, G. Maggi, C. Pea, I.K. Potashnikova, F. Prokoshin
Universidad Tcnica Federico Santa Mara

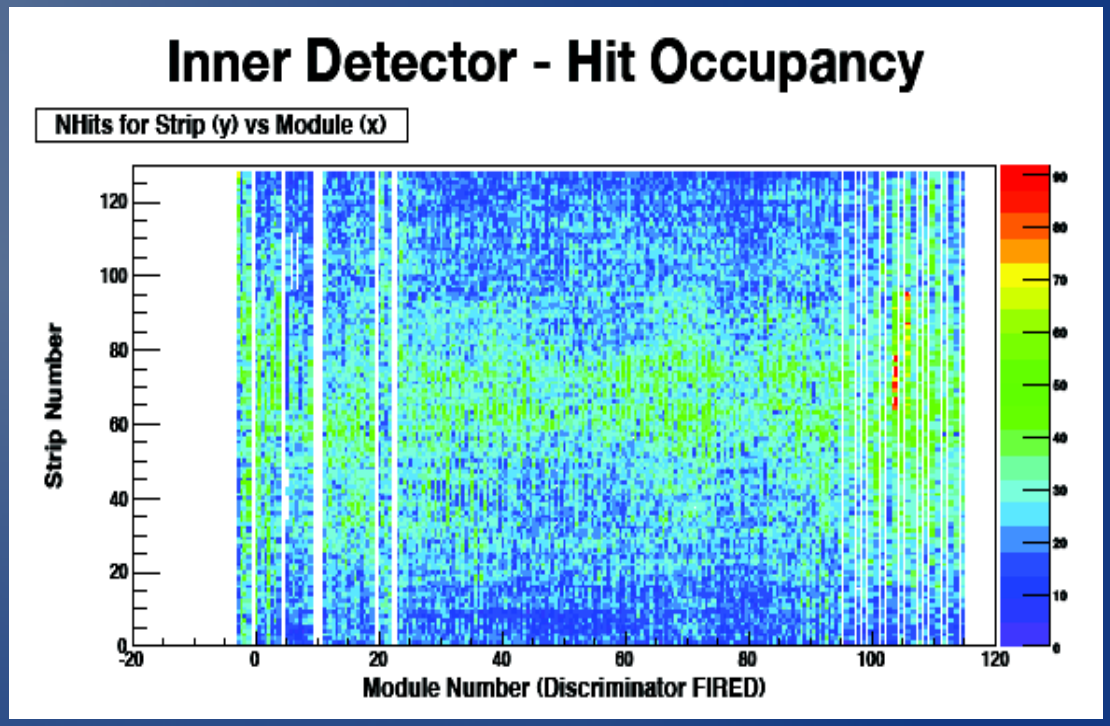
L. Aliaga, J. Devan, M. Kordosky, J.K. Nelson, J. Walding, D. Zhang
College of William and Mary

Overflow

Jesse Chvojka
David Martinez
Heidi Schellman
Aaron Mislivec
Steel this frame!
MINERvA
axial

Detector performance

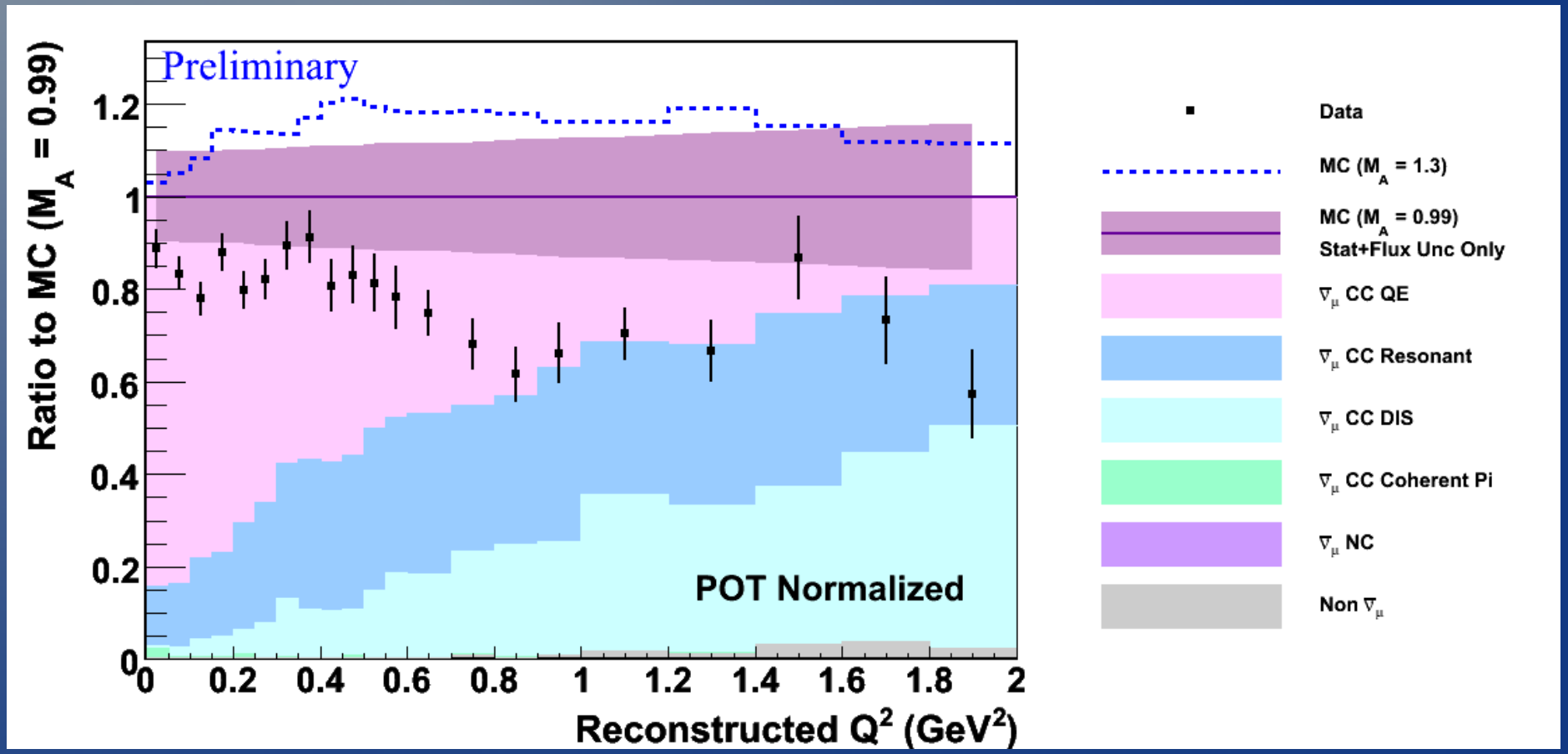
- Live time > 98% since completion of commissioning runs
- Dead channels:
  O(20) inner detector
  O(10) outer detector
  < 0.1% of ~32k active channels



Passive target and absorber regions appear as white stripes

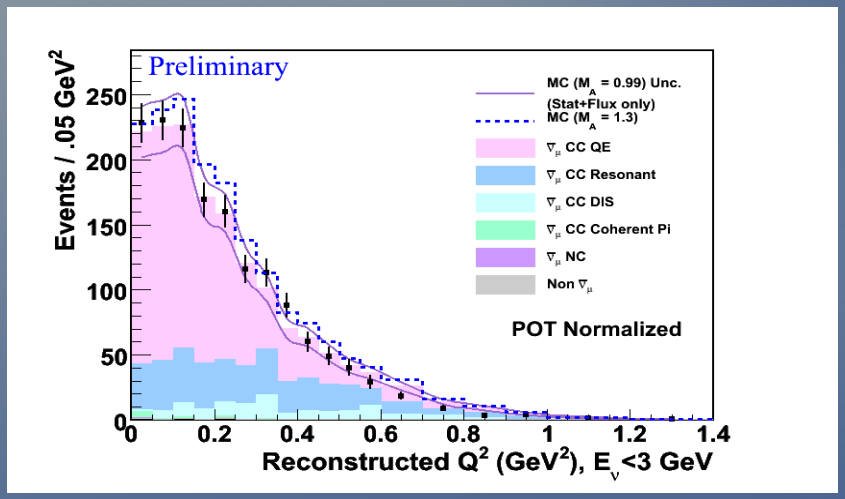
M_A reweighting

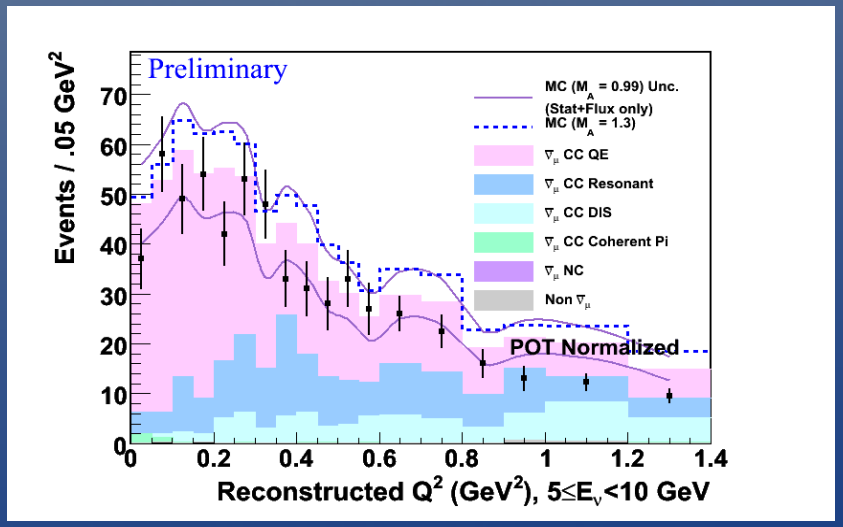
- Set M_A = 1.3, plot ratio to M_A = 0.99, integrated over all neutrino energies

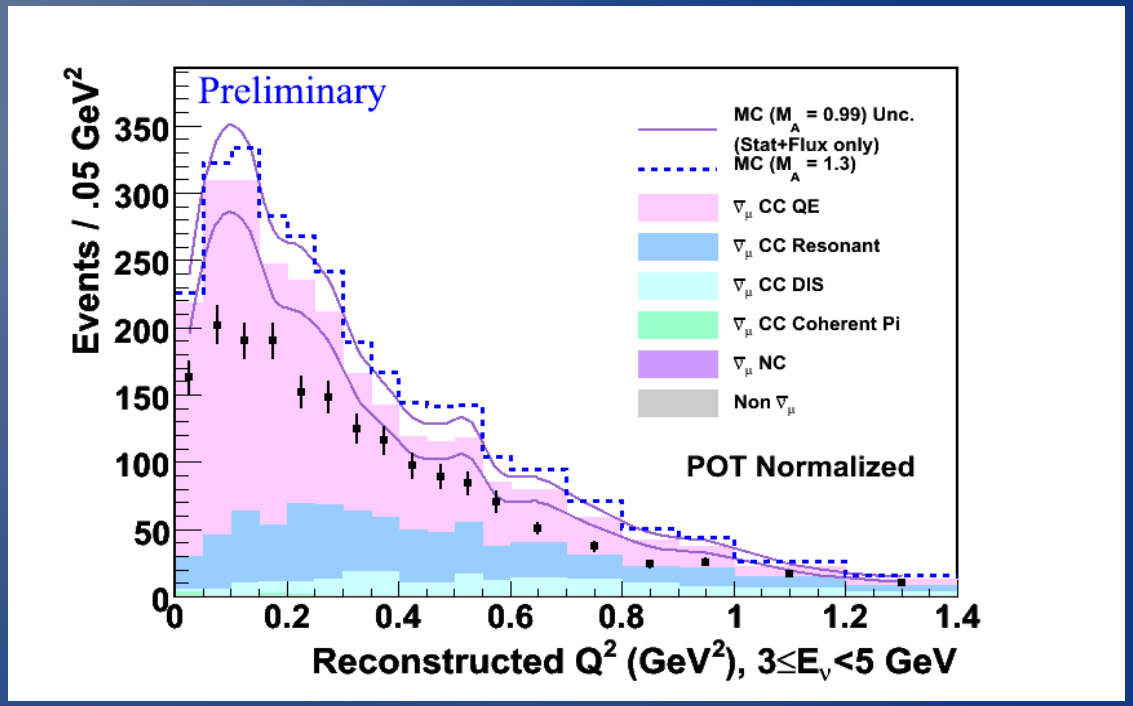


Binned by neutrino energy

- Most of the discrepancy lies between 3-5 GeV (focusing peak falling edge)





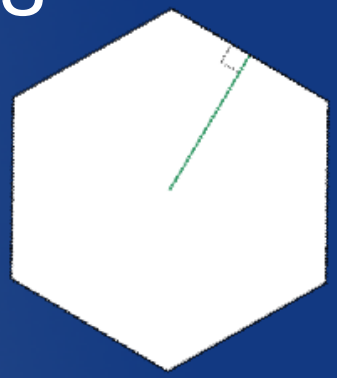


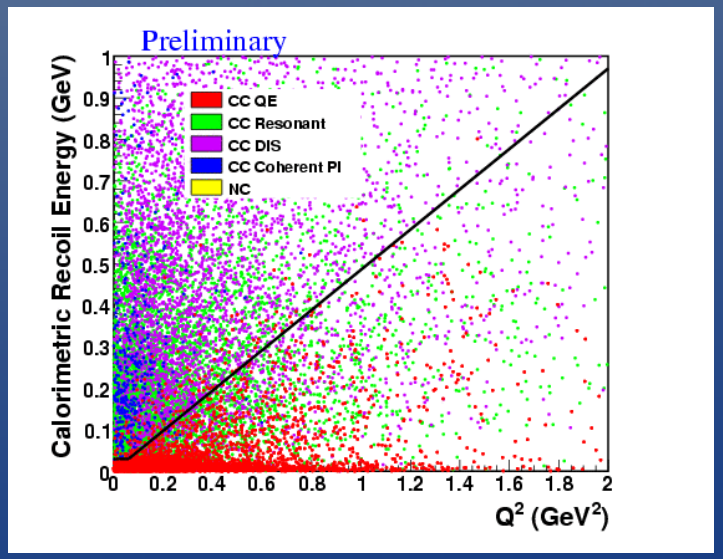
GENIE 2.6.2 details

- For QE Generation, specific details of model are:
  - General equation is Llewellwyn-Smith (with lepton mass terms).
  - The pseudo-scalar form factor is taken from PCAC.
  - Electromagnetic form factors are BBBA2005 (hep-ex/0602017).
  - The axial form factor is assumed to have a dipole form, and M_A=0.99 GeV/c2.
  - The nuclear model is a Fermi gas, with a high momentum component included (taken from Bodek and Ritchie - Phys.Rev. D23 (1981) 1070).
  - Pauli blocking is applied by requiring that the outgoing nucleon have momentum above the Fermi momentum for the nucleus in question, 221 MeV/c for carbon.

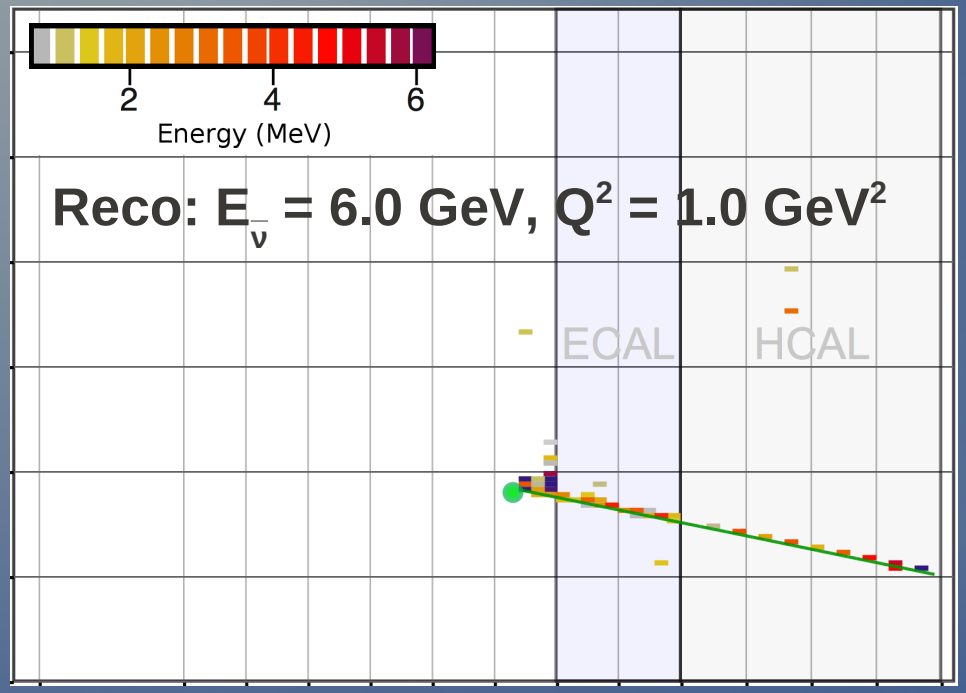
Event selection

- Hexagonal fiducial region is defined by 87cm apothem
- Muon vertex between module 54 and 83 inclusive
- Recoil energy has dynamic cut

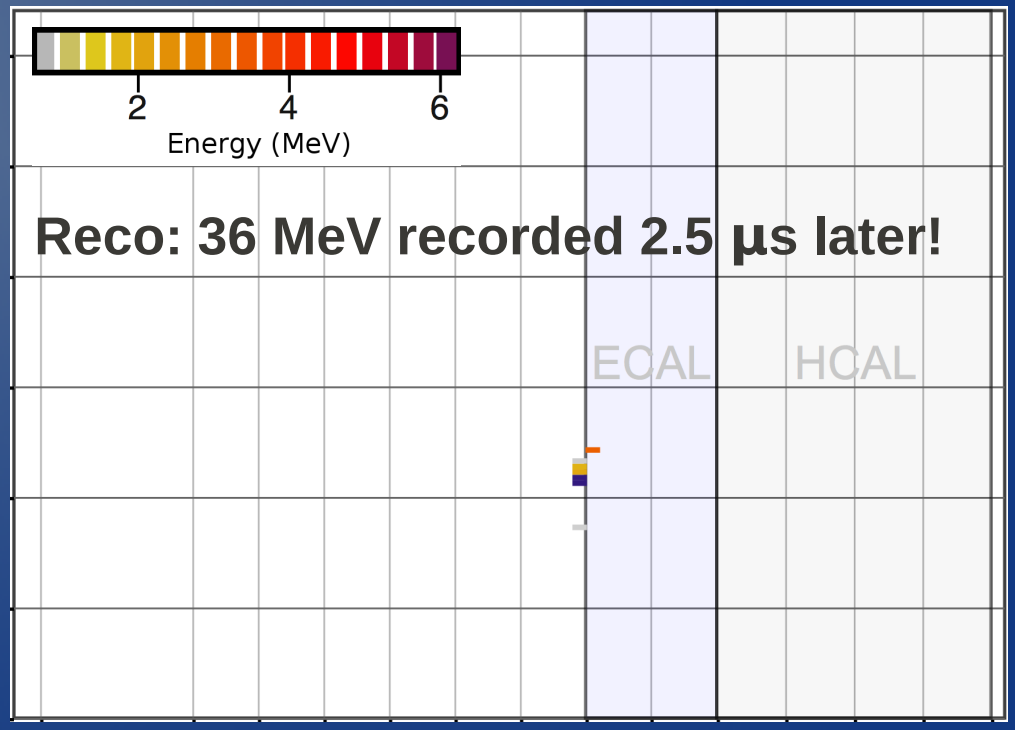




Likely background: $\bar{\nu}$ candidate



This data event passed the recoil energy cut, which permits larger recoil at higher Q^2.



We are working on Michel electron tags to eliminate background events with a final state pion.