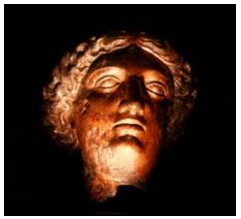
Preliminary Results from the MINERνA Experiment

Deborah Harris
Fermilab

on behalf of the MINERvA Collaboration

MINERvA Collaboration



MINERvA is a collaboration of ~100 members, 7 countries, 22 institutions,
With participation from both particle and nuclear physicists

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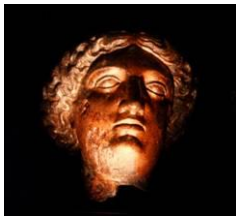
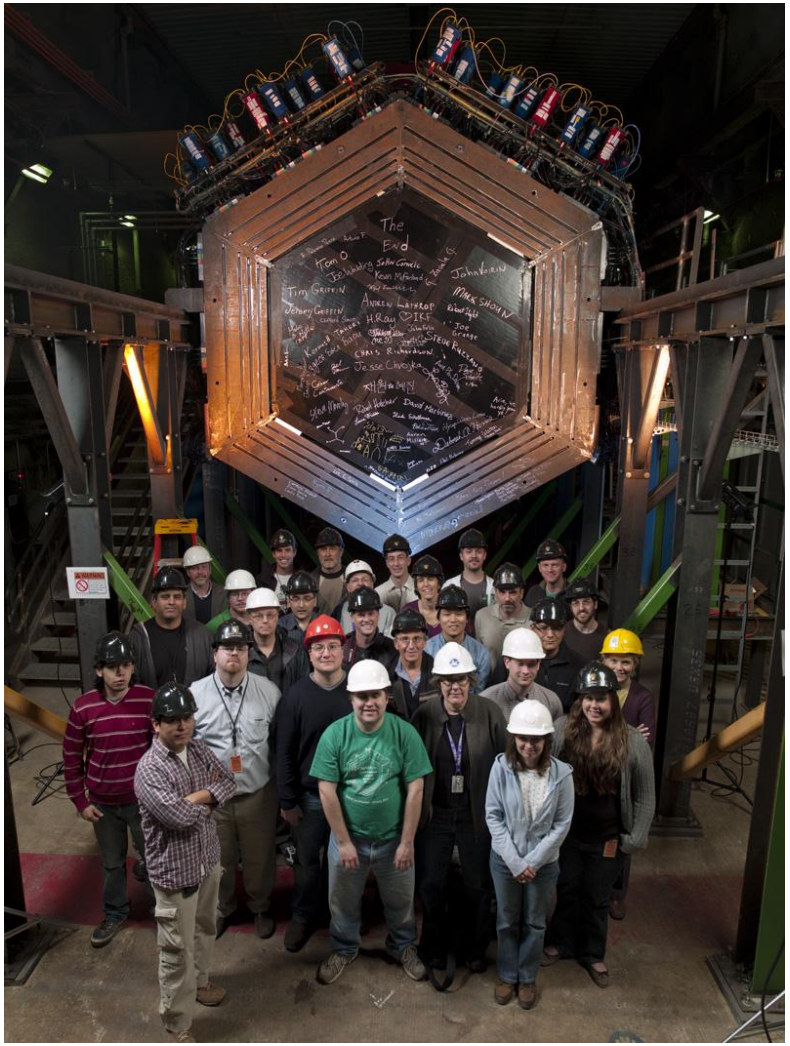
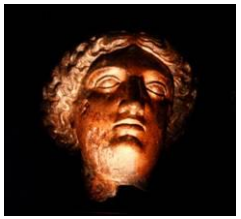
Outline

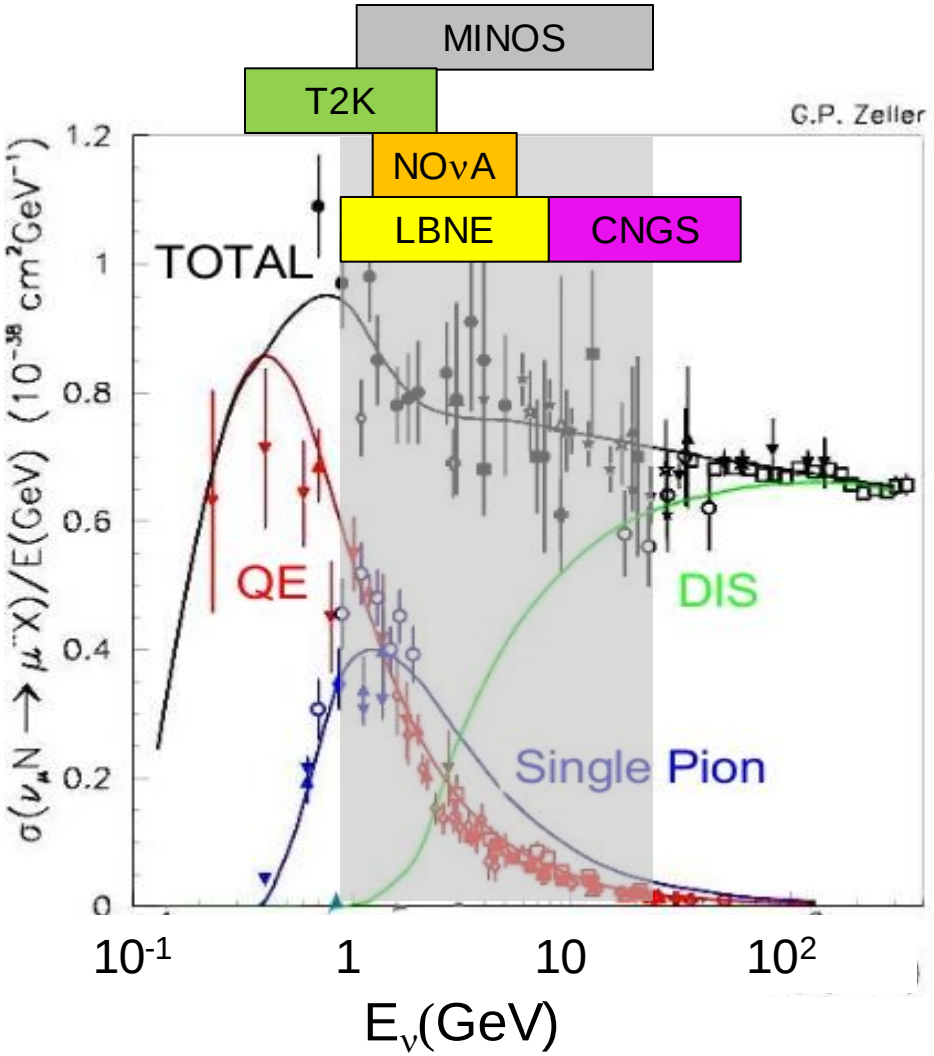


- On the Importance of Neutrino Cross Sections
- MINERνA Detector
- Quasi-elastic (anti-)Neutrino Scattering
- How will MINERvA understand its flux
- Studies of Nuclear Effects
- Summary



Role of Cross Sections in Oscillation Experiments

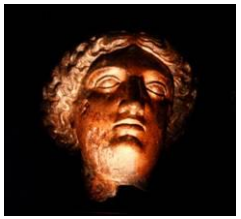




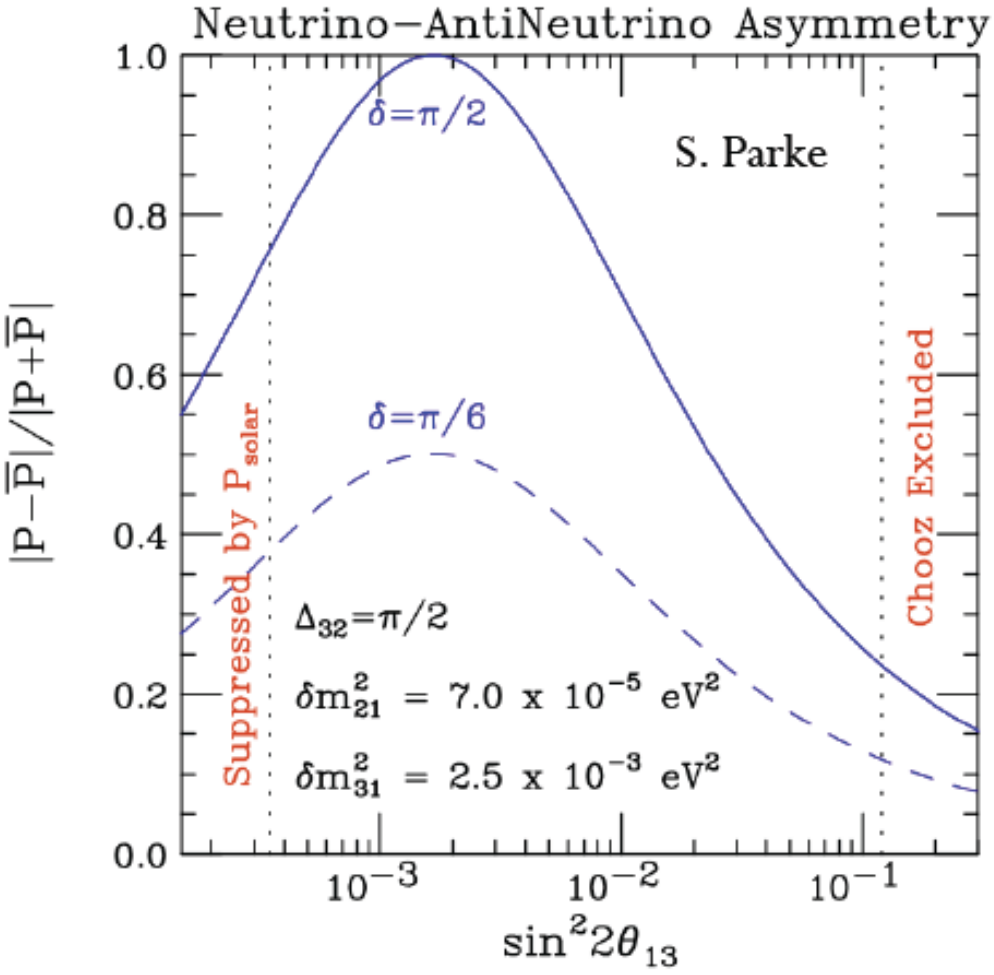
note: plot does not include MiniBooNE or SciBooNE data

- Given the beam energies we have, have to understand cross sections where many competing processes occur
  - Quasi-elasic
  - Single-Pion (Resonance production)
  - DIS
- Given the detectors we have, need to understand interactions on heavy targets
  - Carbon, Fe, H_2O, Ar

Do cross sections still matter if θ_{13} is large?

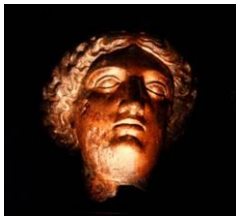


- In fact cross sections will matter even more in a universe where θ_{13} is large
  - Higher statistics in far detector means better statistical precision, need systematics low to keep up with statistics
  - CP-violating differences are smaller, will need to make comparisons of neutrino anti-neutrino differences at the per cent level (Parke)

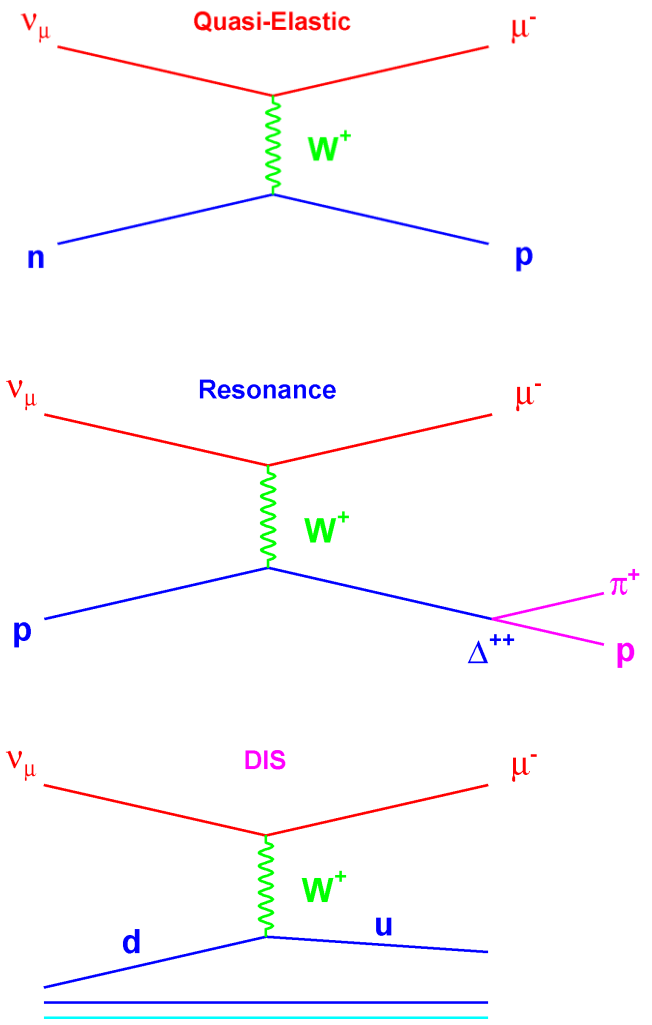


Parke, FNAL ν Summer School 2009

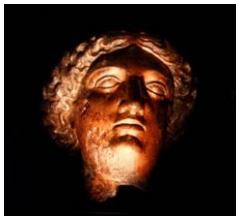
MINERνA

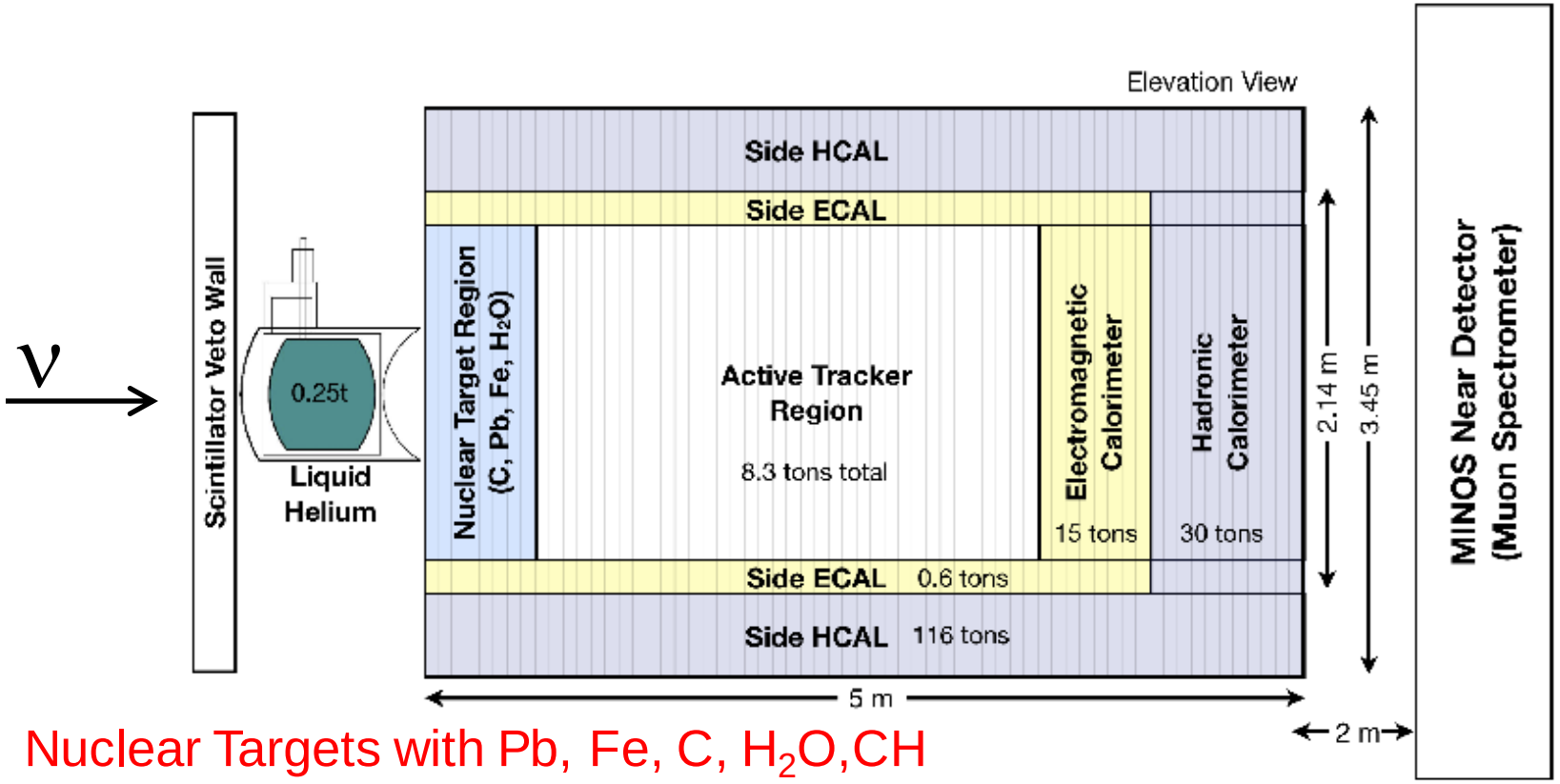


- Precision measurement of cross sections in the 1-20 GeV region
  - Understand the various components of cross section both CC and NC
    - CC & NC quasi-elastic
    - Resonance production, $\Delta(1232)$
    - Resonance↔deep inelastic scattering, (quark-hadron duality)
    - Deep Inelastic Scattering
- Study A dependence of ν interactions in a wide range of nuclei



MINERνA Detector

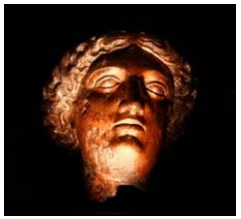




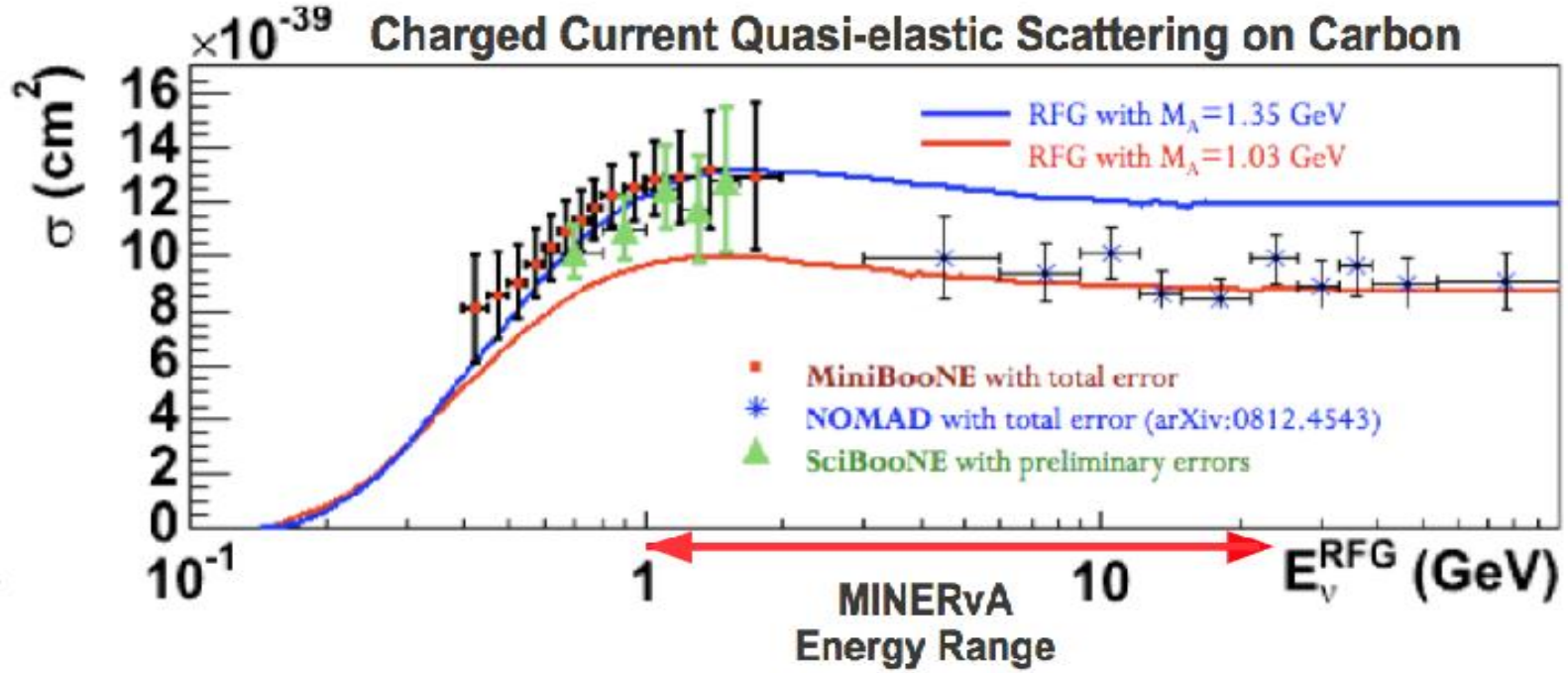
Nuclear Targets with Pb, Fe, C, H_2O,CH
In same experiment reduces systematic errors between nuclei
Side and downstream Calorimetry: Both Electomagnetic and Hadronic

- Made of 120 planar "modules".
  - Total Mass: 200 tons
  - Total channels: ~32K

Quasi-elastic Analysis

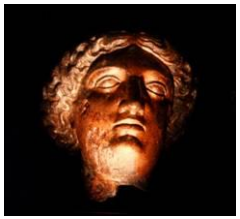


- Currently there is an outstanding mystery about low and high energy quasi-elastic measurements
- Different beams, energies, detectors, analyses
- Many theories around for what is causing this
- MINERvA is optimally placed to solve this mystery



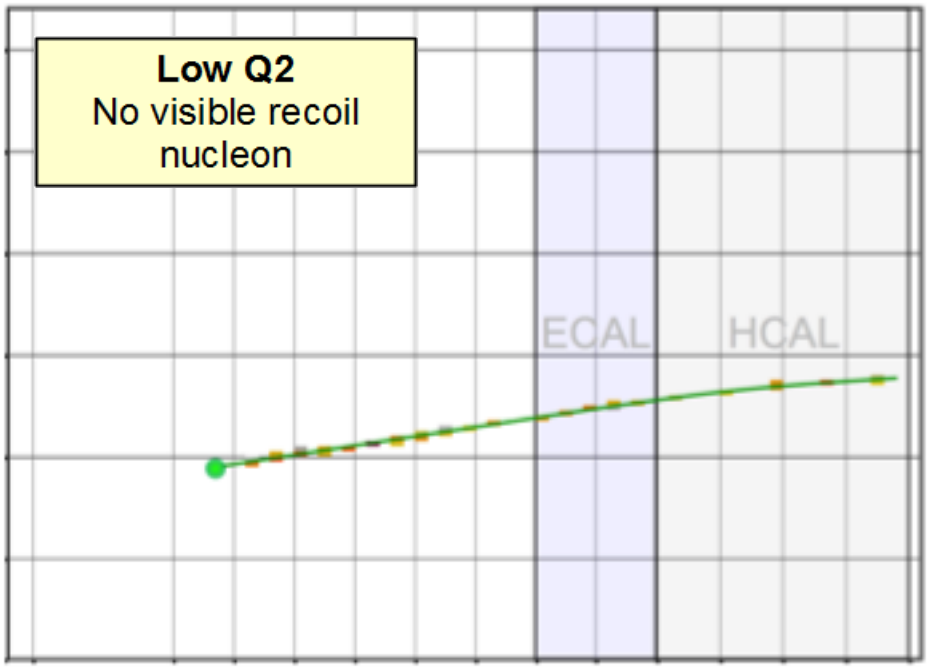
T. Katori, NuInt09

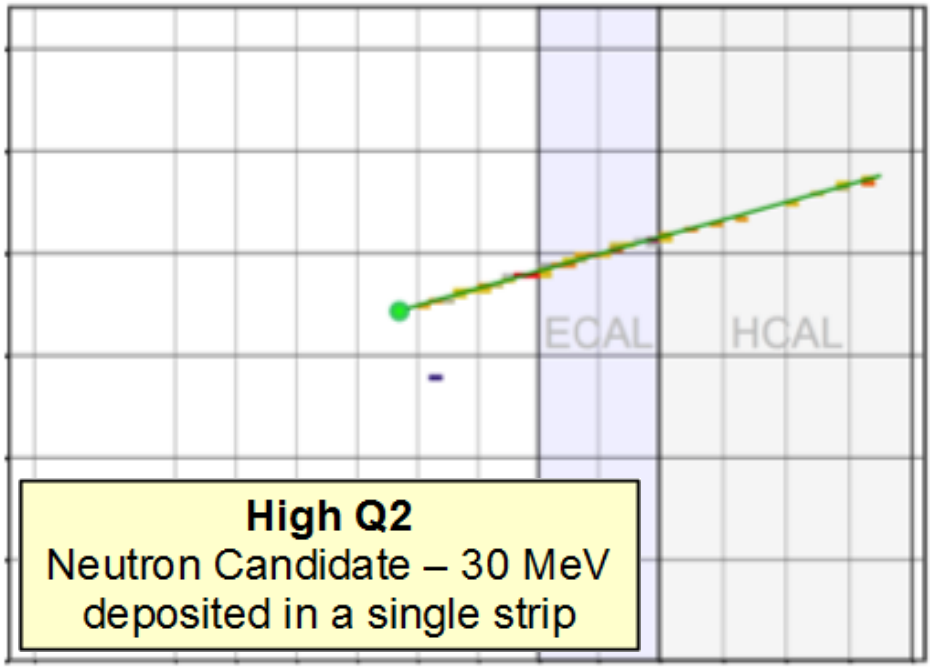
Anti-Neutrino Signature



- In anti-neutrinos, signature is particularly simple:

$$\bar{\nu}_\mu p \rightarrow \mu^+ n$$

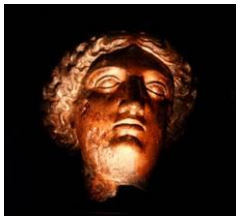




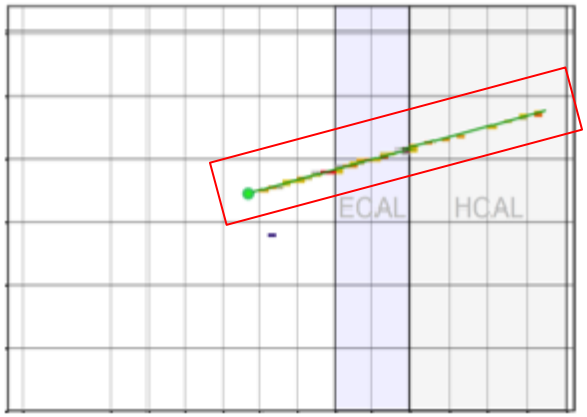
If elastic kinematics,
$E_\nu = 2.8\text{GeV}$, $Q^2 = 0.1\text{GeV}^2$

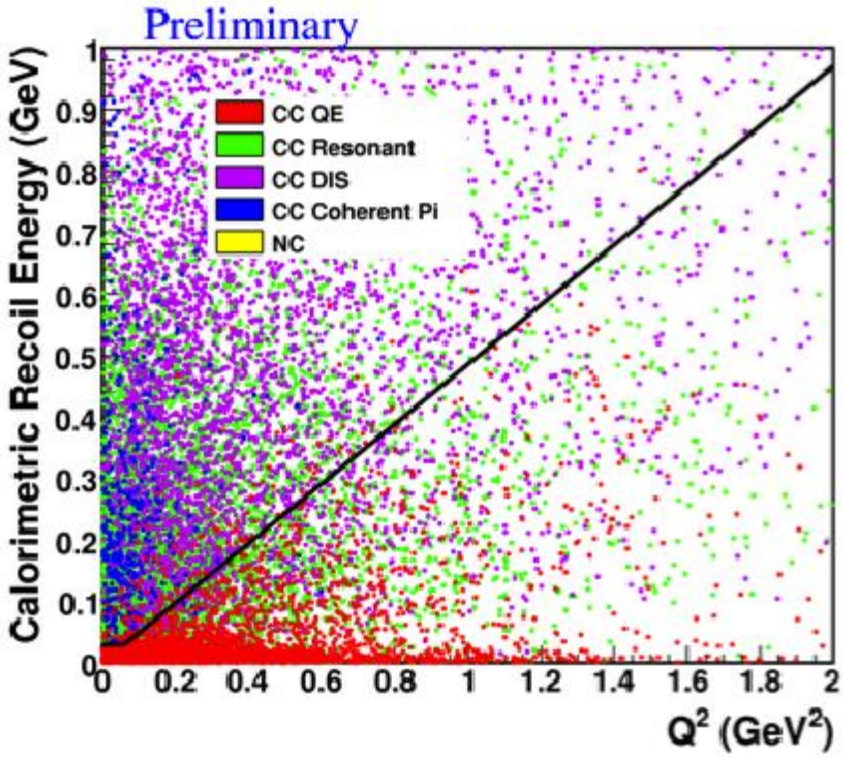
If elastic kinematics,
$E_\nu = 2.5\text{GeV}$, $Q^2 = 0.3\text{GeV}^2$

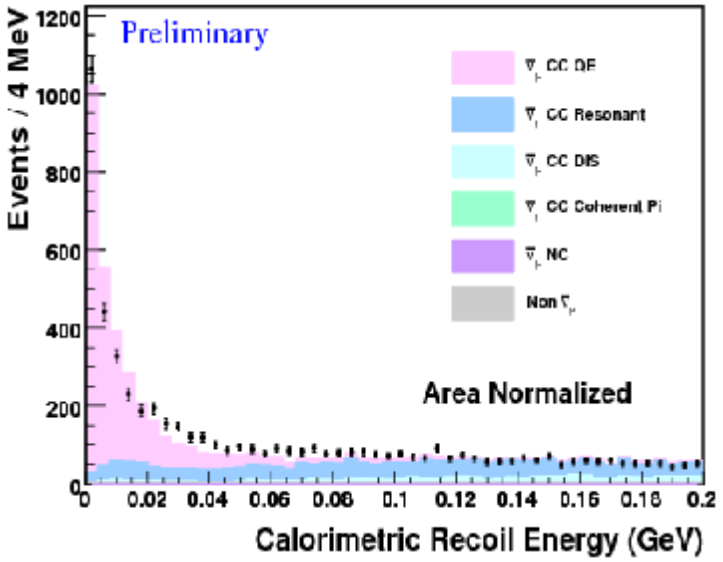
Quasi-Elastic Event Selection



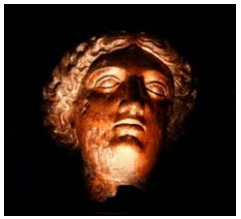
- Require muon in MINOS Near Detector
- Require event to start in fiducial region
- Cut to remove non-quasi-elastic events: look at recoil energy



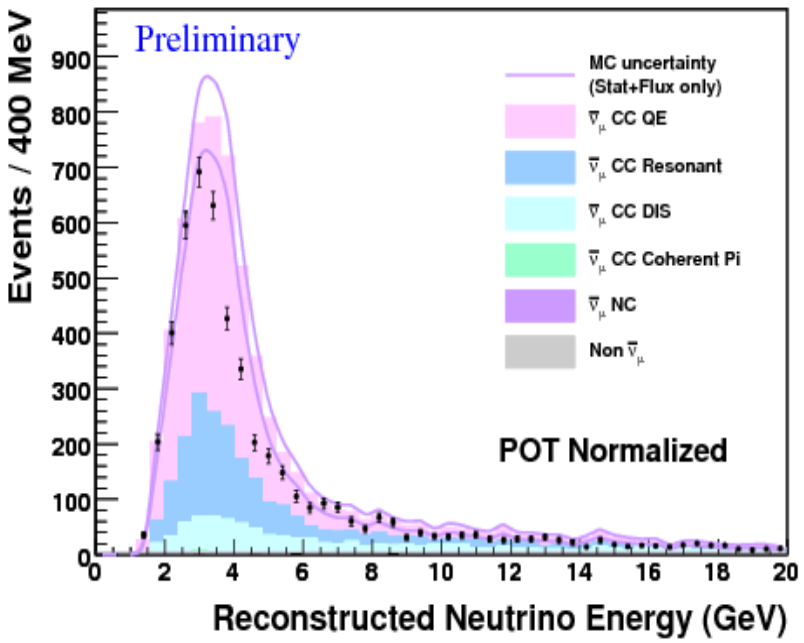


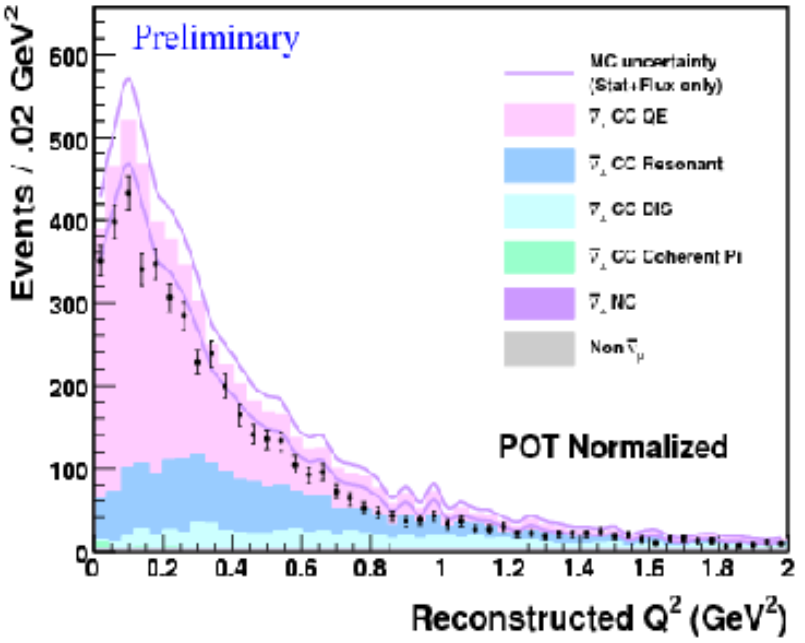


Neutrino Energy and Momentum Transfer



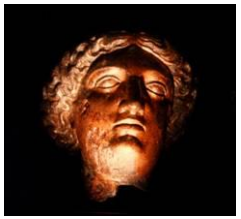
- Energy spectrum shows discrepancy in falling edge of the neutrino spectrum, this is the hardest part to model
- Momentum transfer distribution looks consistent with simulation (axial mass at 0.99 GeV^2), but overall normalization off



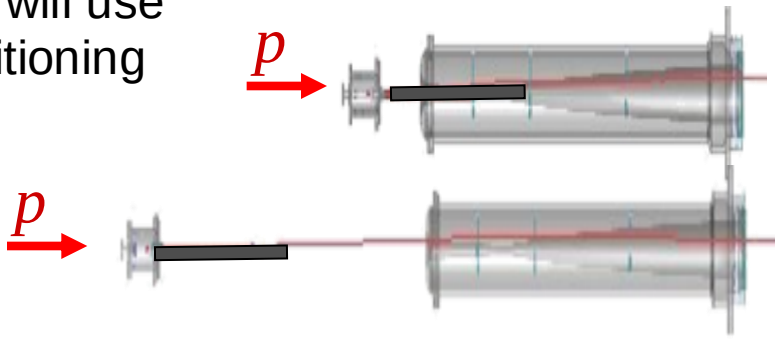


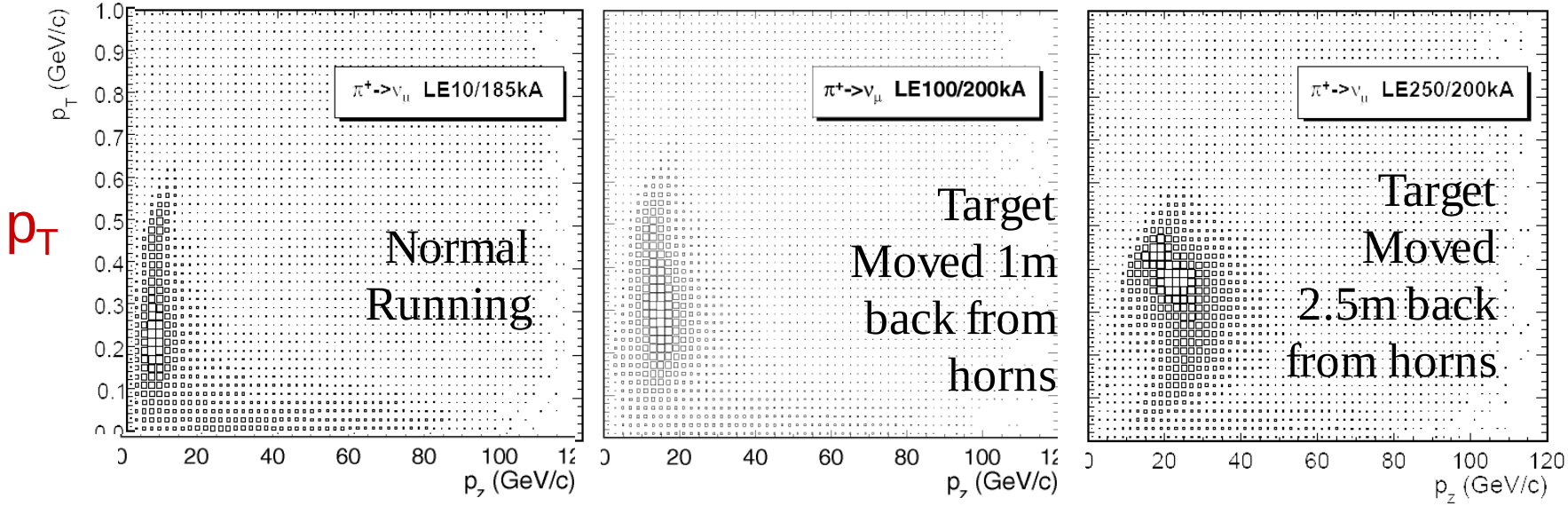
- QE Hypothesis Assumed in energy and Q^2 reconstruction

Getting to Absolute Cross Sections: understanding the neutrino flux

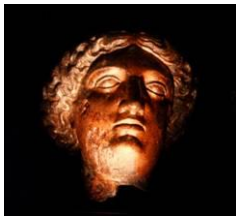


- MINERvA located in NuMI Beamline at Fermilab: same beamline that MINOS has used, and that NOvA will use
- Target is mounted on a rail drive for remote positioning
- Provides *in situ* method to measure flux
- Vary (p_Z ,p_T) of π^+ contributing to n flux.
  - Horn current (p_T kick supplied to π's)
  - Target Position (p_Z of focused particles)



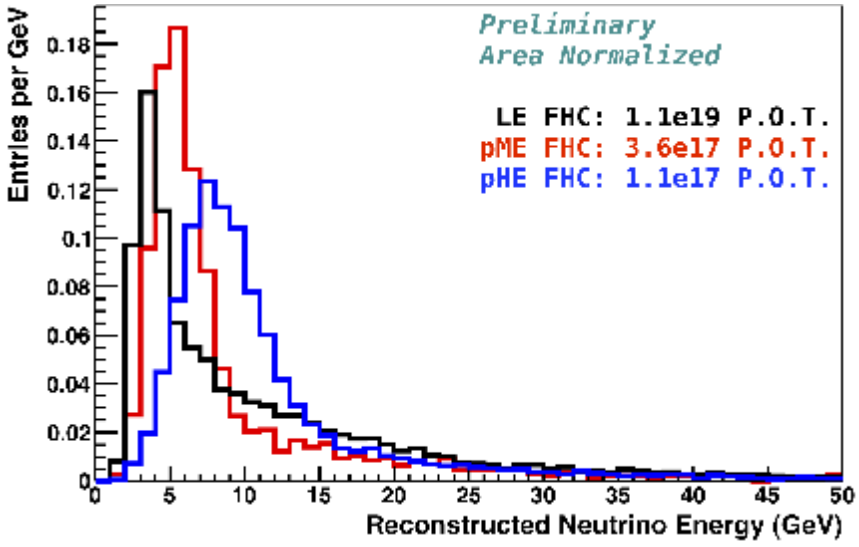


Status of data analysis during special flux-tuning runs

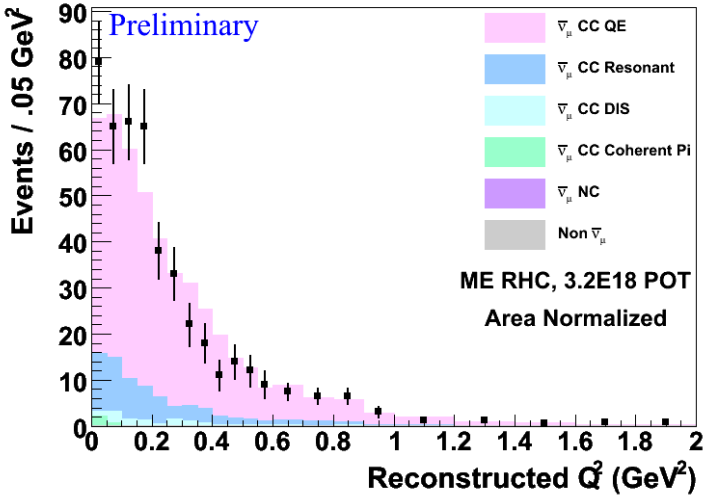


- MINERvA will run in several different target positions and horn currents to check that cross sections don't depend on initial flux
- Two "standard candles": total charged current (CC) event samples, and Quasi-elastic event energy distribution for a given axial mass
- partial data sets shown below, analysis in progress

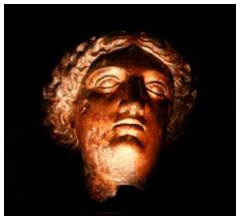
3 ν special runs, 3 energy distributions
Inclusive CC candidates

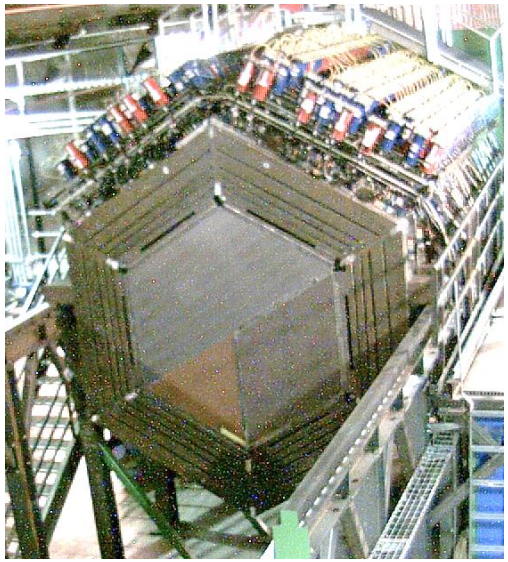


Special "Medium Energy"
Anti-neutrino run, QE candidates



MINERvA's Nuclear Targets

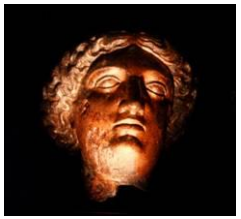




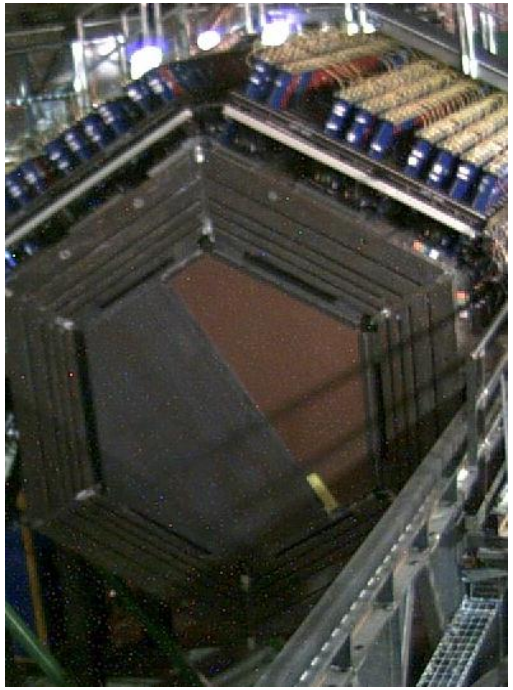
- MINERvA will be able to study interactions in both plastic and other materials,
  - C, Fe, Pb installed now in 5 upstream slices,
  - Cryostat installed, He coming soon
  - Water target scheduled to arrive in the fall

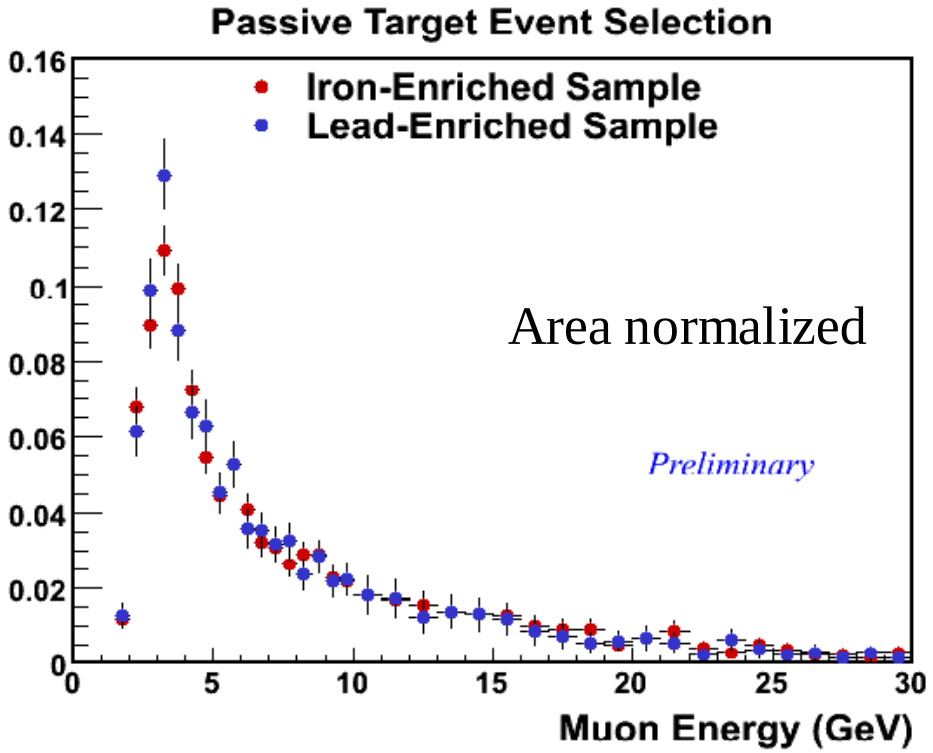
Target	Fiducial Mass	ν_μ CC Events in 4e20 P.O.T.
Plastic	6.43 tons	1363k
Helium	0.25 tons	56k
Carbon	0.17 tons	36k
Water	0.39 tons	81k
Iron	0.97 tons	215k
Lead	0.98 tons	228k

First nuclear target analysis

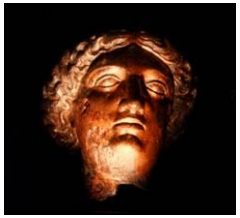


- Look at events originating in most downstream nuclear target
- Two materials in that target, reconstruction most straightforward
- Require muon to be momentum analyzed in MINOS, vertex position gives target material



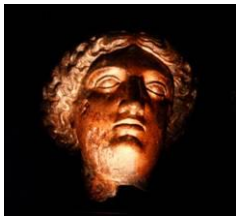


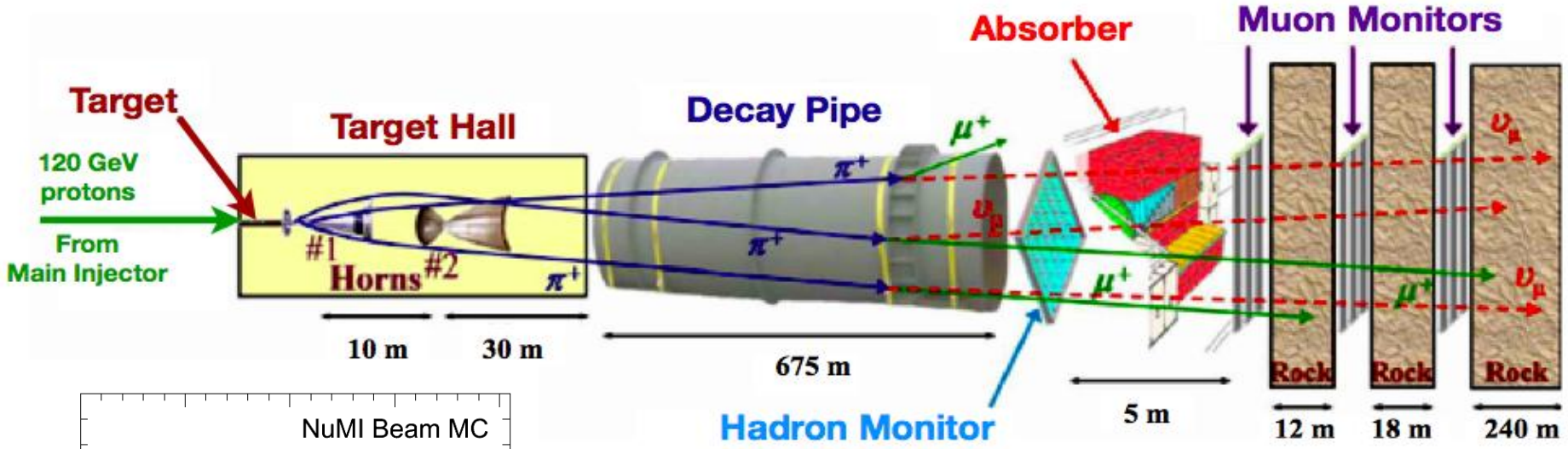
Conclusions

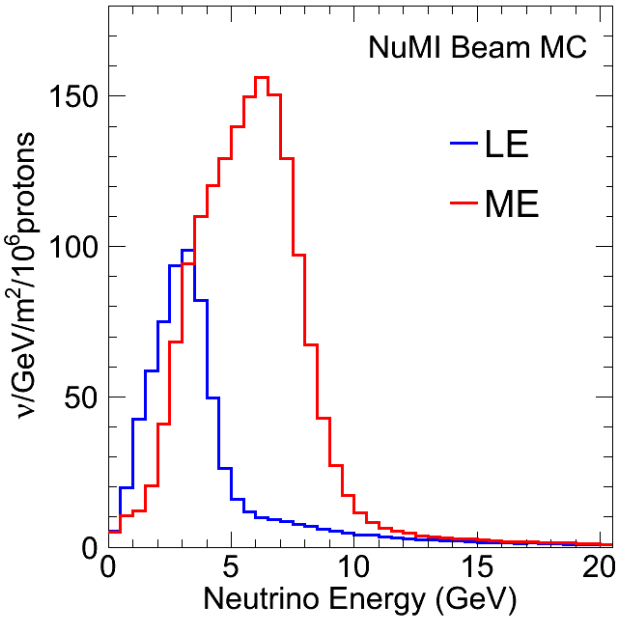


- MINERvA is up and running: official run started in March 2010
- Have collected about a third of the low energy neutrino beam we are planning to get (1.7E20 out of 4.9E20)
- Many different data analyses underway
- Helium and Water targets coming soon
- Quasi-elastic antineutrinos providing new look at NuMI beam, and new look at axial mass
- Flux tuning apparatus will provide new precision on flux prediction
- Solid Nuclear Target analysis underway
- Medium Energy running in NOvA Era will give new program:
  - structure functions on nuclear targets
- Stay tuned for more results!

NuMI Beamline







- Intensity: ~35e12 P.O.T per spill, 300 – 350 kW
- Mean energy of beam can be tuned by changing positions of the target and horns
- Primary focus:
  - Low Energy: exclusive final states
  - Medium Energy (with NOvA): structure functions

MINERvA Data