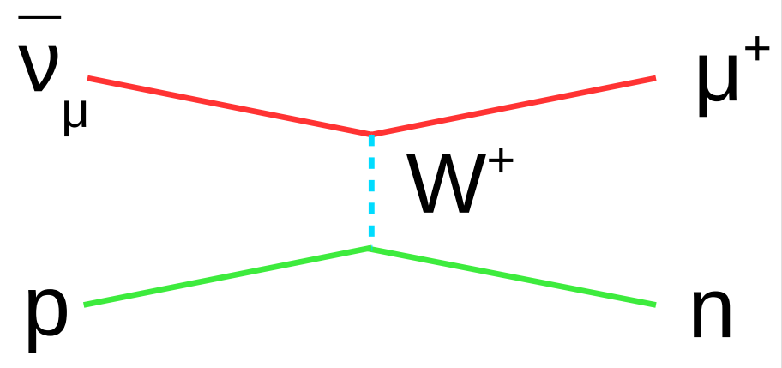
Charged-Current Quasi-Elastic Scattering at MINERνA

Kevin McFarland, University of Rochester and
Fermi National Accelerator Laboratory

on behalf of the MINERνA
Collaboration

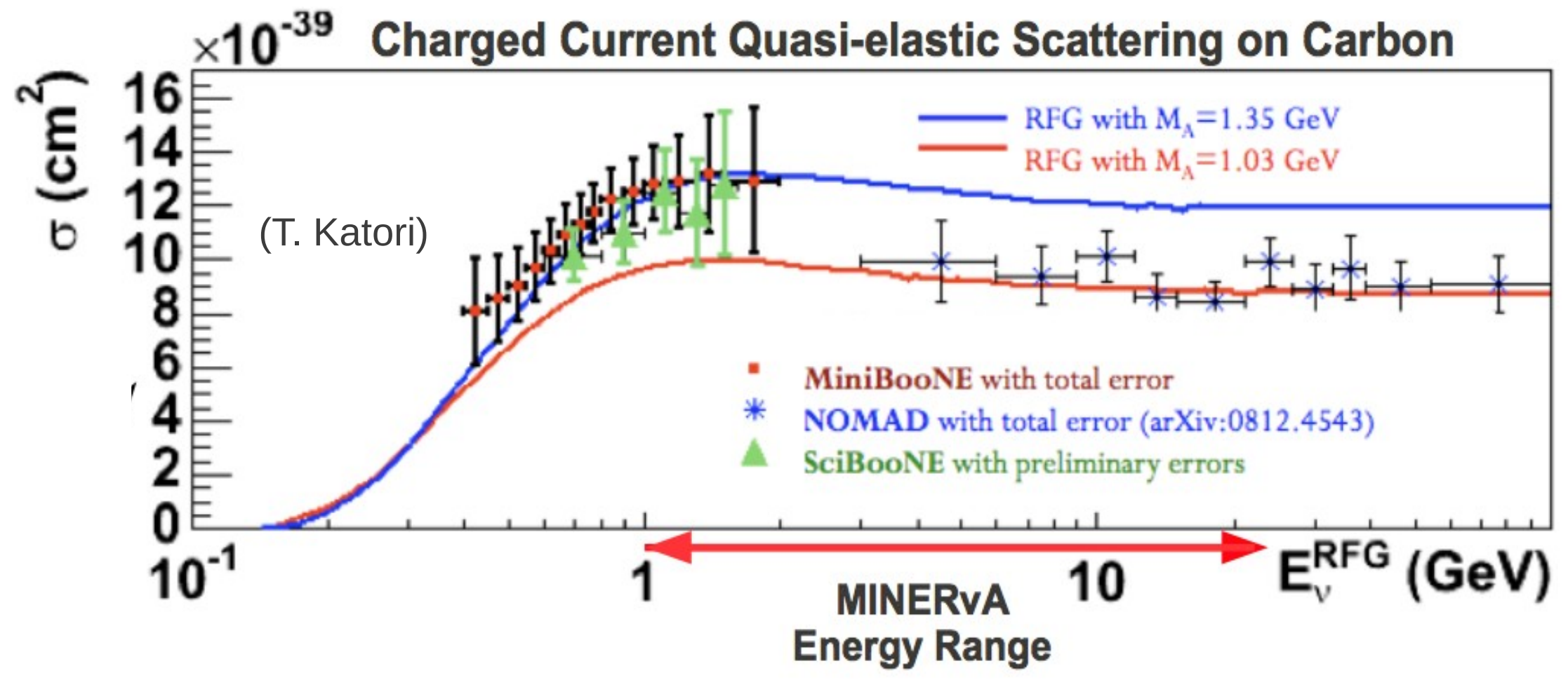
Quasi-Elastic Scattering



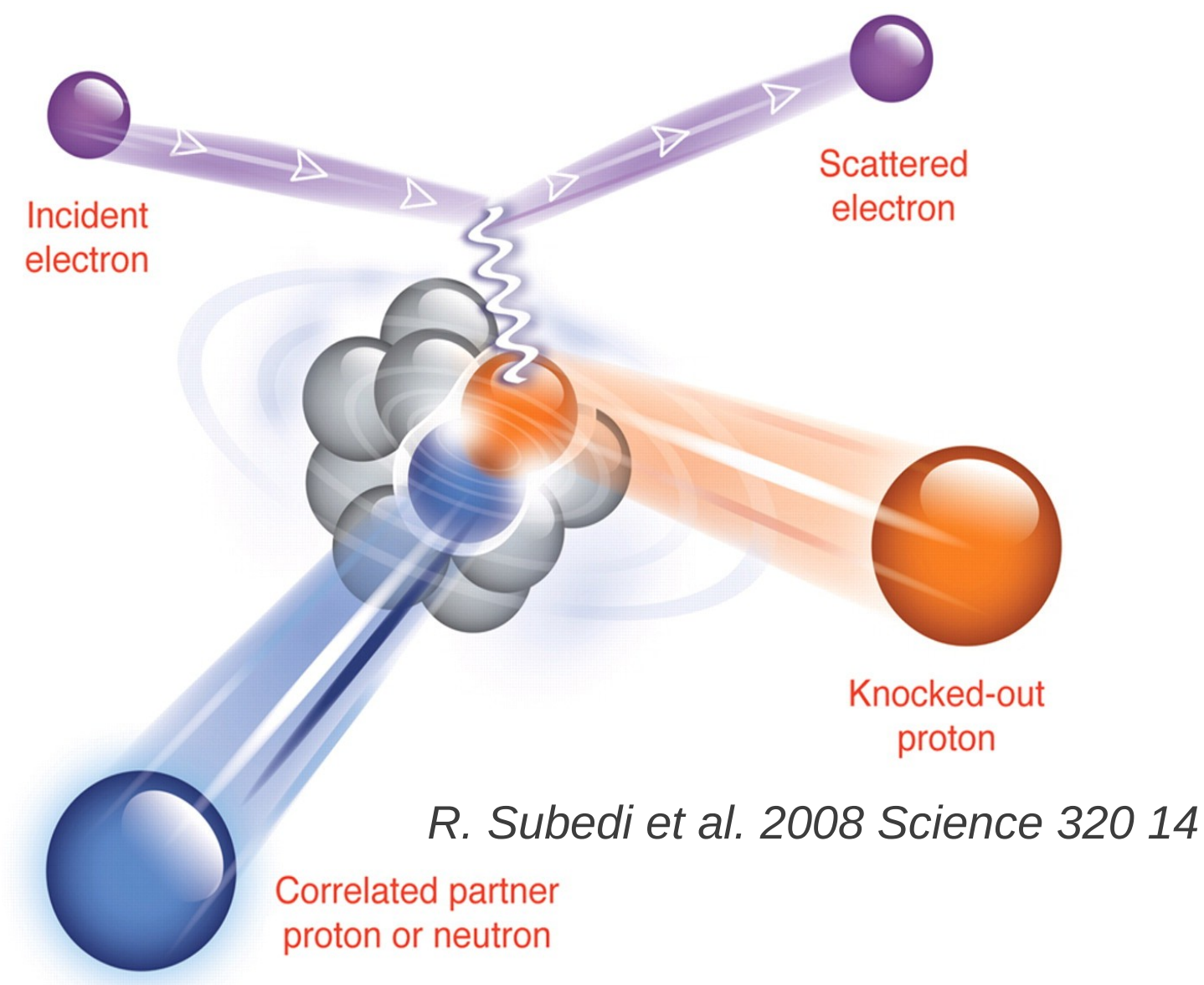
Charged current quasi-elastic scattering (CCQE) is a simple and well-understood reaction on free nucleons.

When the initial state nucleon is inside a nucleus, as in future neutrino oscillation experiments,the situation is more complicated. The initial state nucleon may be modified in the medium, and multi-body scattering effects may contribute to what is apparently quasi-elastic scattering.

The MiniBooNE measurement of CCQE on a carbon target provides circumstantial evidence that these multi-nucleon effects may be large.

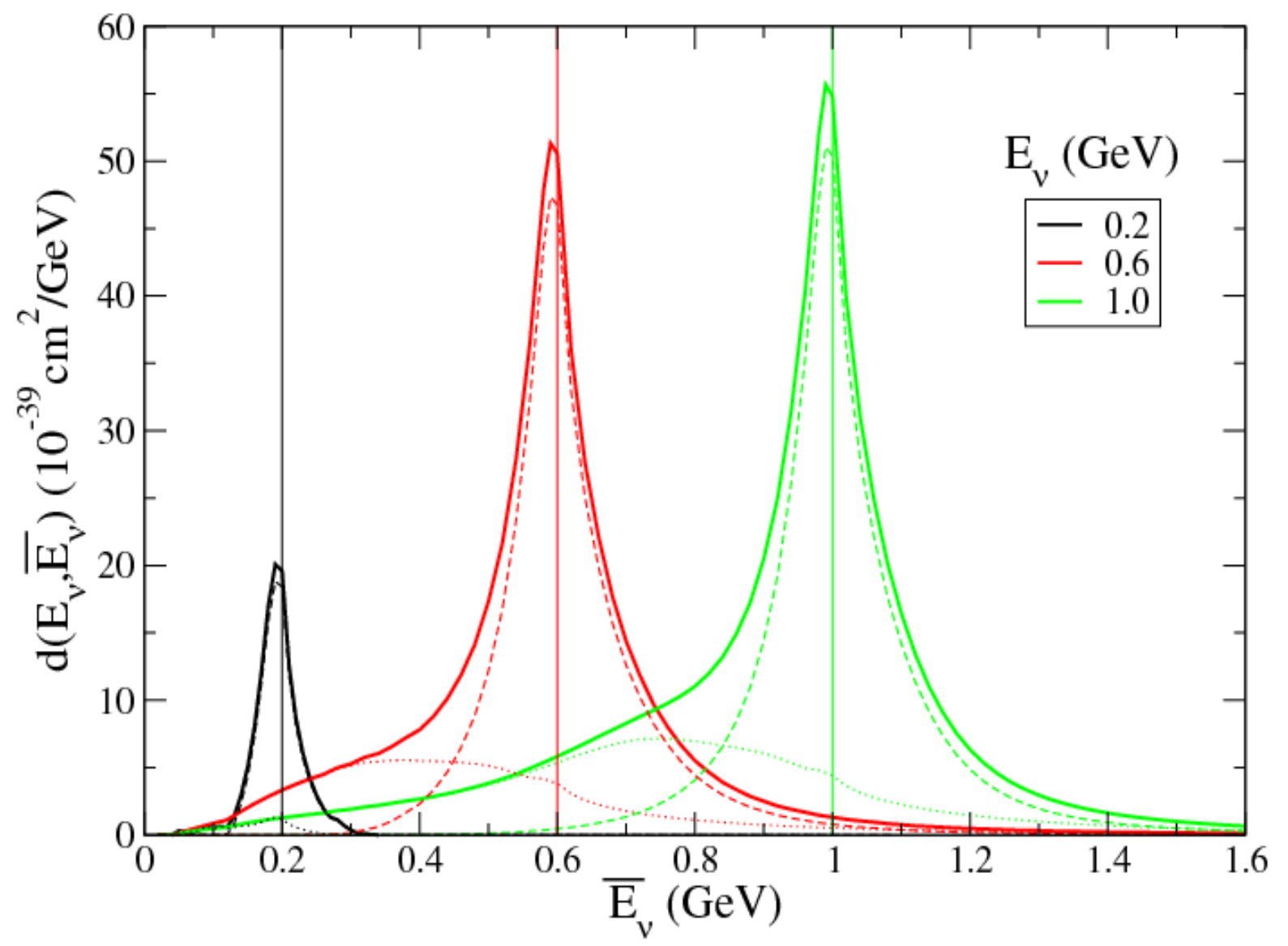


Electron scattering measurements which can directly probe the final state show a large fraction of quasi-elastic scattering events in carbon, ~20%, actually have pairs of correlated nucleons in the final state and that these are dominantly *pn* pairs. This is strong evidence for a large multi-nucleon component.



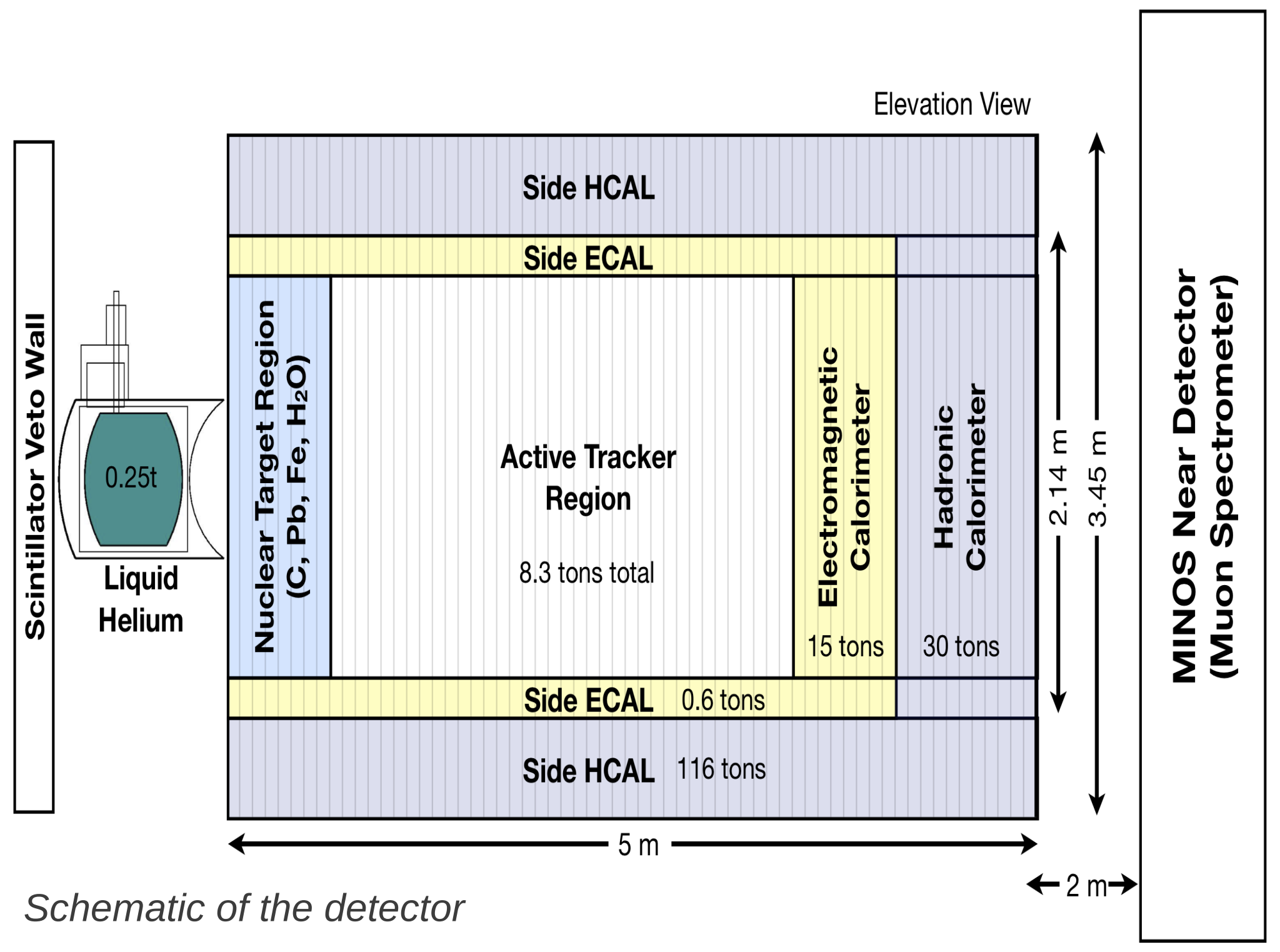
R. Subedi et al. 2008 Science 320 1476

Microphysical models for such processes, such as meson exchange current models, predict that they distort the energy reconstruction of neutrino interactions in oscillation experiments.



Martini et al, Phys. Rev. D87 013009 (2012)

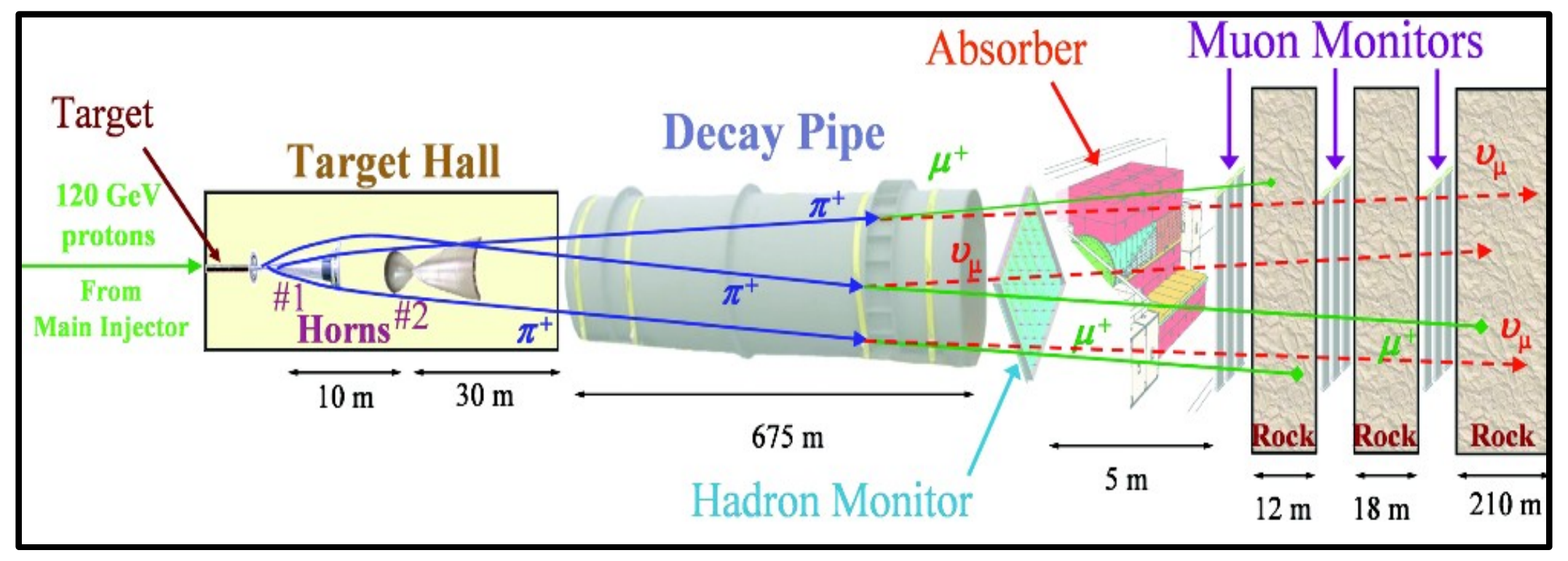
The MINERνA Detector



Schematic of the detector

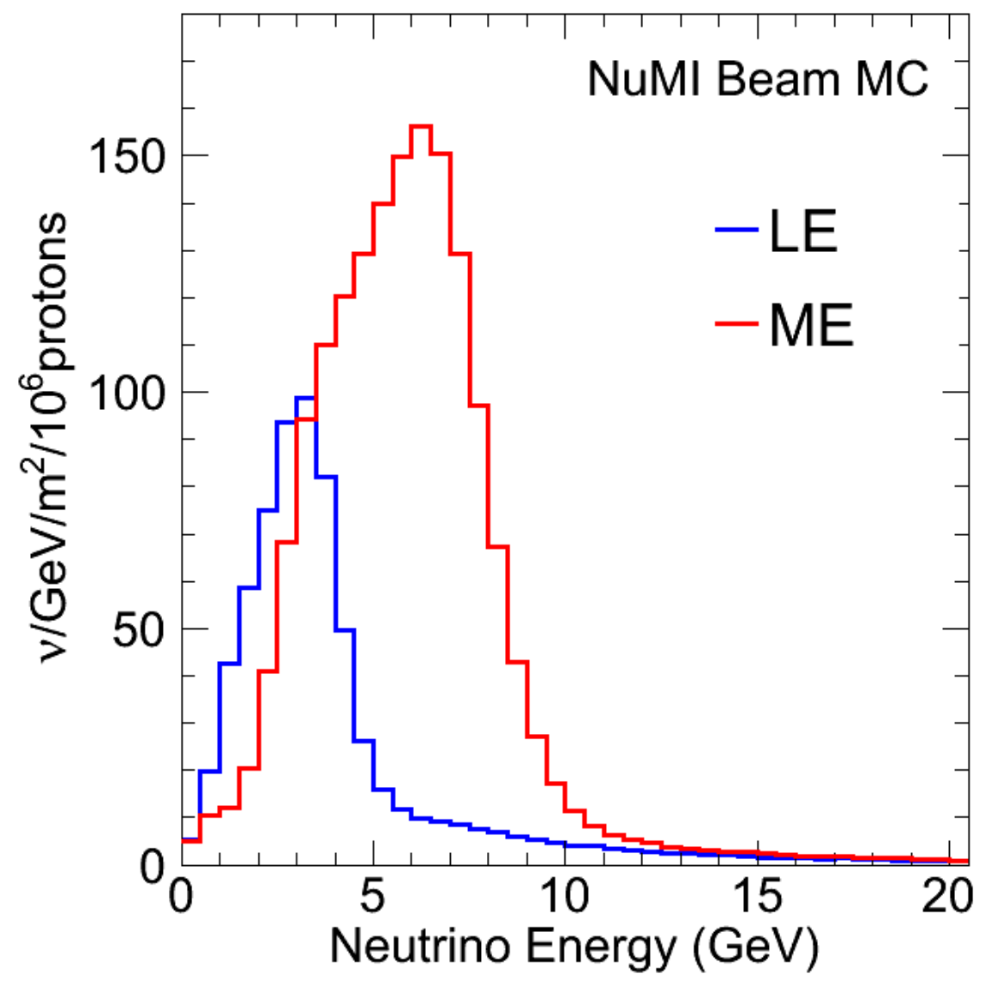
The MINERνA detector contains both active segmented polystyrene scintillator strips and passive nuclear targets of He, C, Water, Fe and Pb. The segmentation of the detector allows localization of energy to a few cm, with much better resolution on long tracks. Events in the thin passive targets are observed by reconstructing outgoing particles in adjacent scintillator strips. The active center is surrounded by sampling electromagnetic and hadronic calorimetry. The MINOS near detector serves as a downstream muon spectrometer.

The NuMI Beamline



Beamline upstream of MINERvA

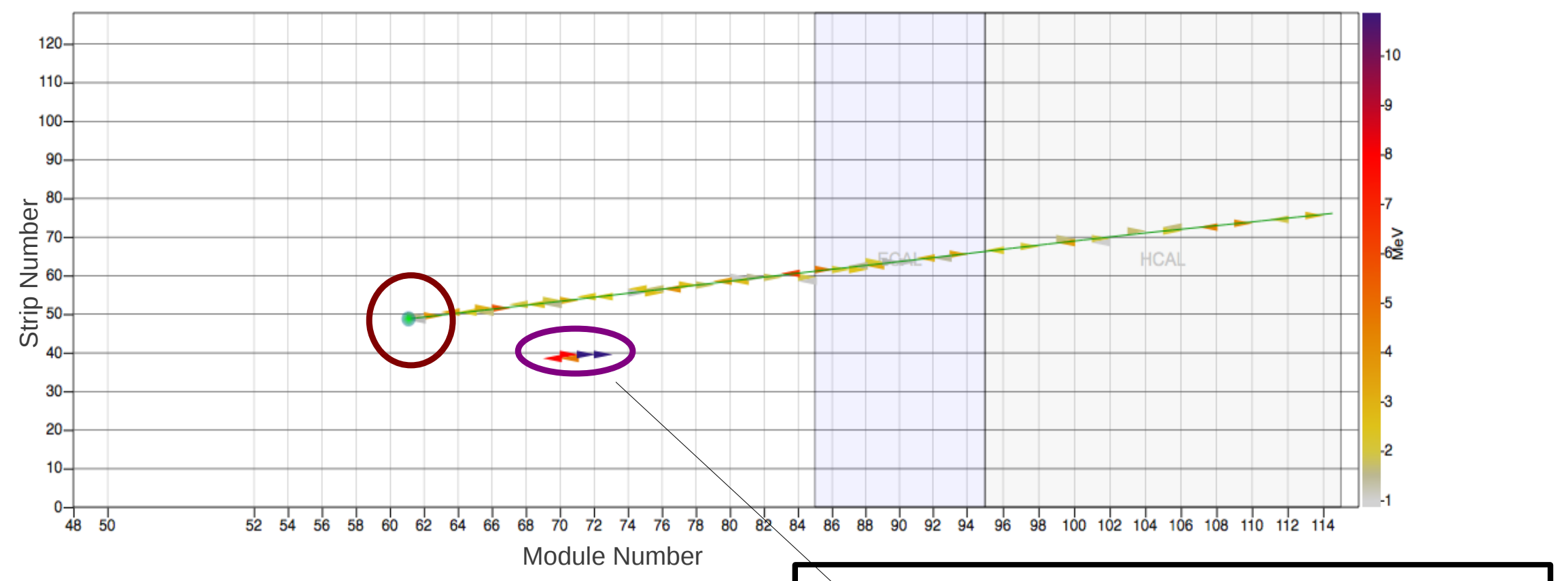
The NuMI near-detector hall provides the most intense neutrino flux in the world, produced by colliding protons with a graphite target and focusing the resulting pions and kaons before they decay to produce neutrinos. The focusing horn polarity is used to select either a neutrino or anti-neutrino rich beam.

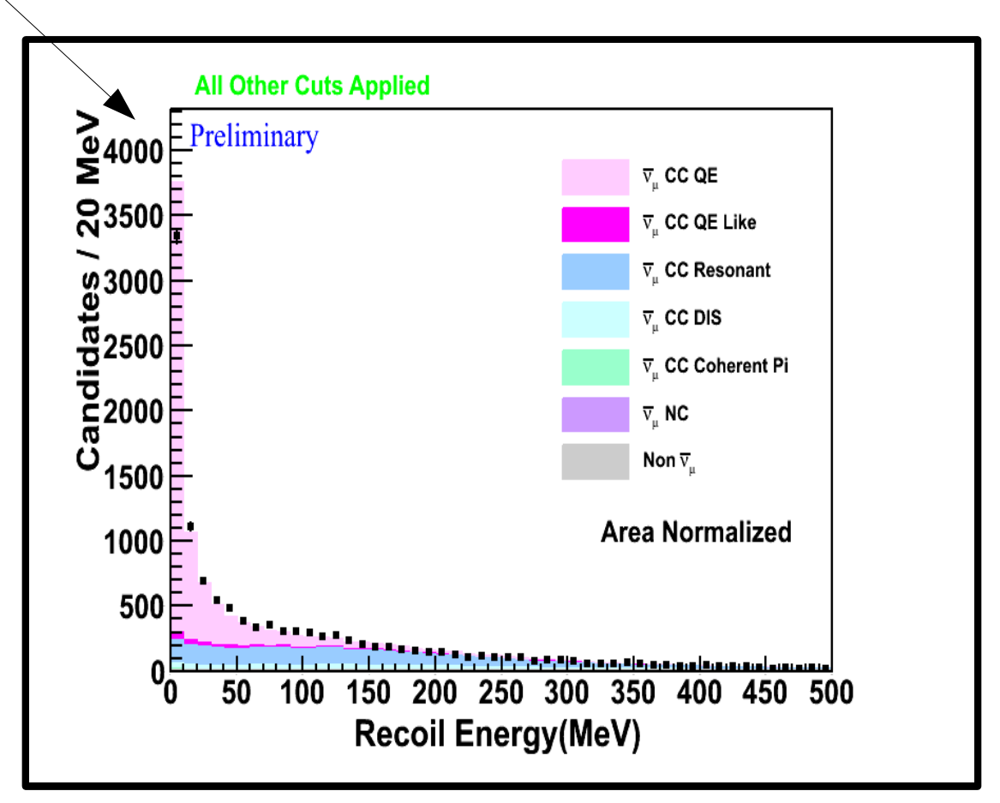


The target and horn geometry can be altered to vary the neutrino energy spectrum. MINERvA's current data uses a low-energy beam (LE) configuration. Future runs will use a higher energy beam (ME) starting in 2013.

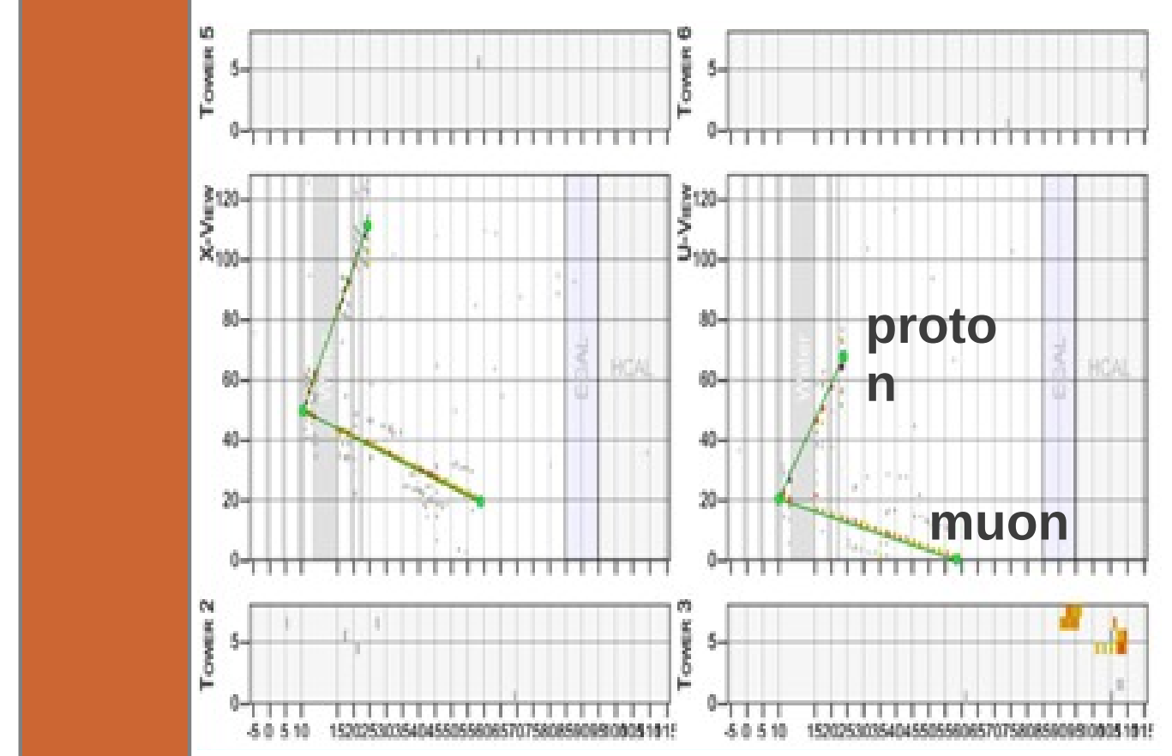
Event Selection

Event selection requires a muon with minimal calorimetric recoil, consistent with recoiling nucleons from the energy transferred to the nucleus.





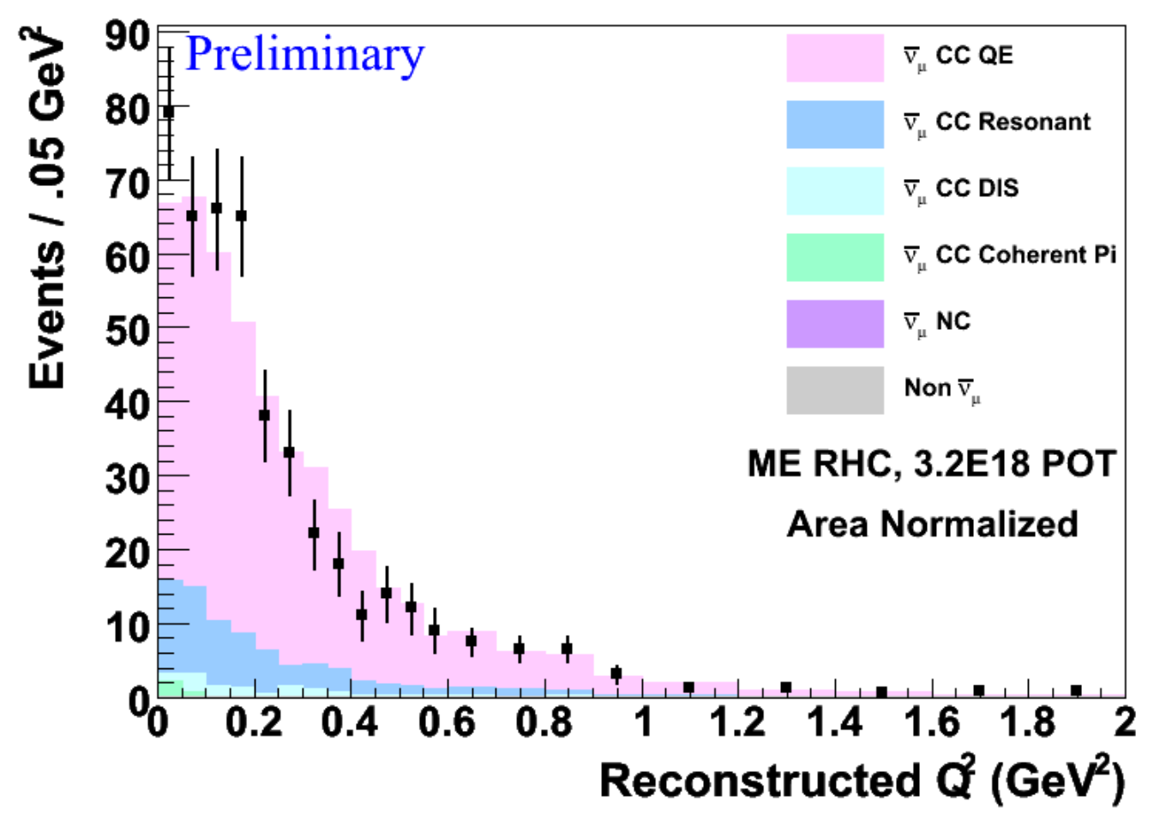
Events with large recoil energy provide a constraint of background reactions with low visible recoil.



In the passive nuclear targets, we identify both the muon and the final state proton, and require the event vertex to be inside the target material.

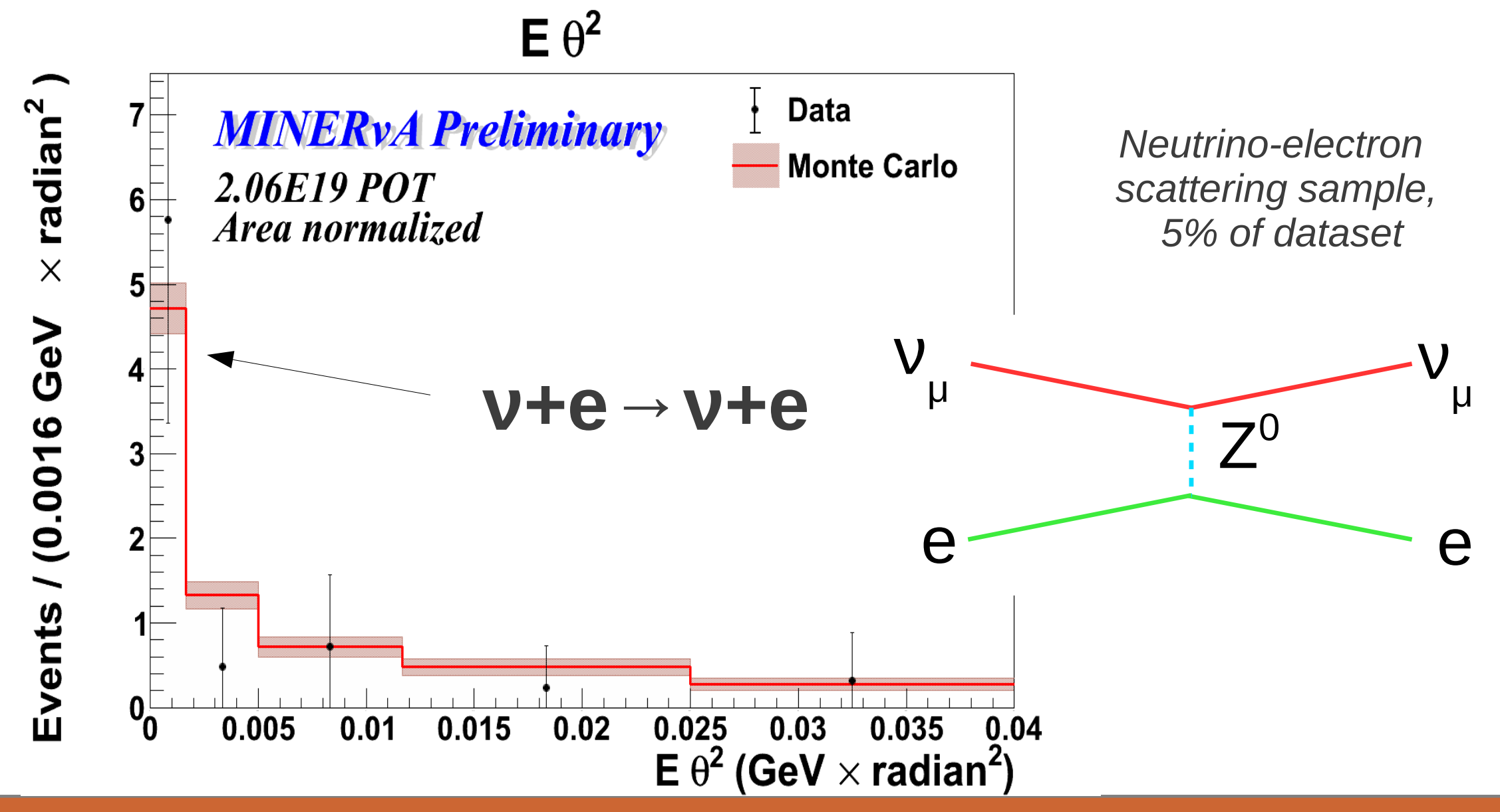
Flux Determination

The MINERvA flux is determined using hadron production data from the NA49 experiment and a detailed model of the target and focusing. This simulation will be tuned with various data, including special runs" with alternate NuMI configurations."



Q^2 distribution of quasi-elastic candidates from the medium energy beam configuration

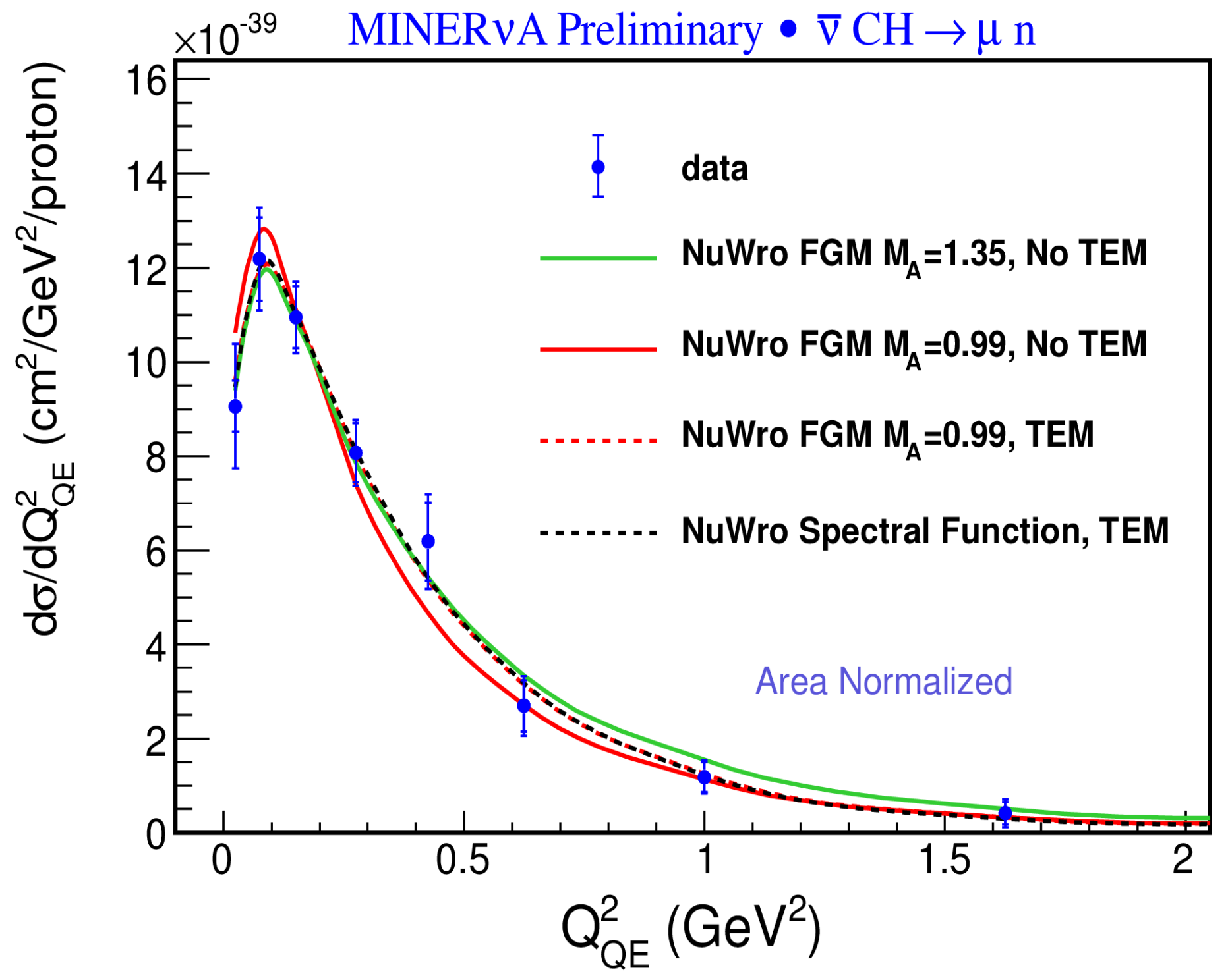
MINERvA can also use its sample of neutrino-electron scattering events to constrain the flux.



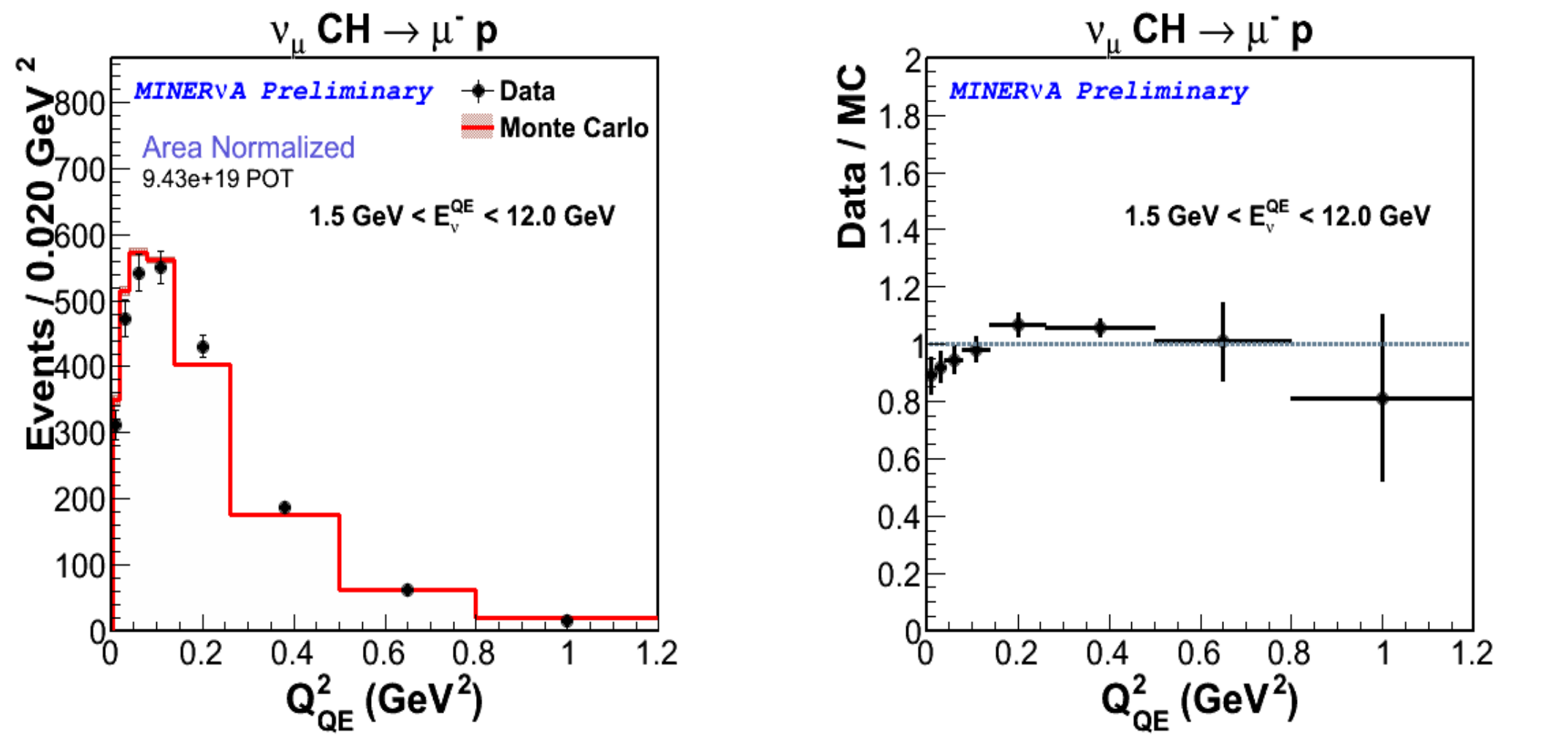
Neutrino-electron scattering sample, 5% of dataset

Preliminary Results

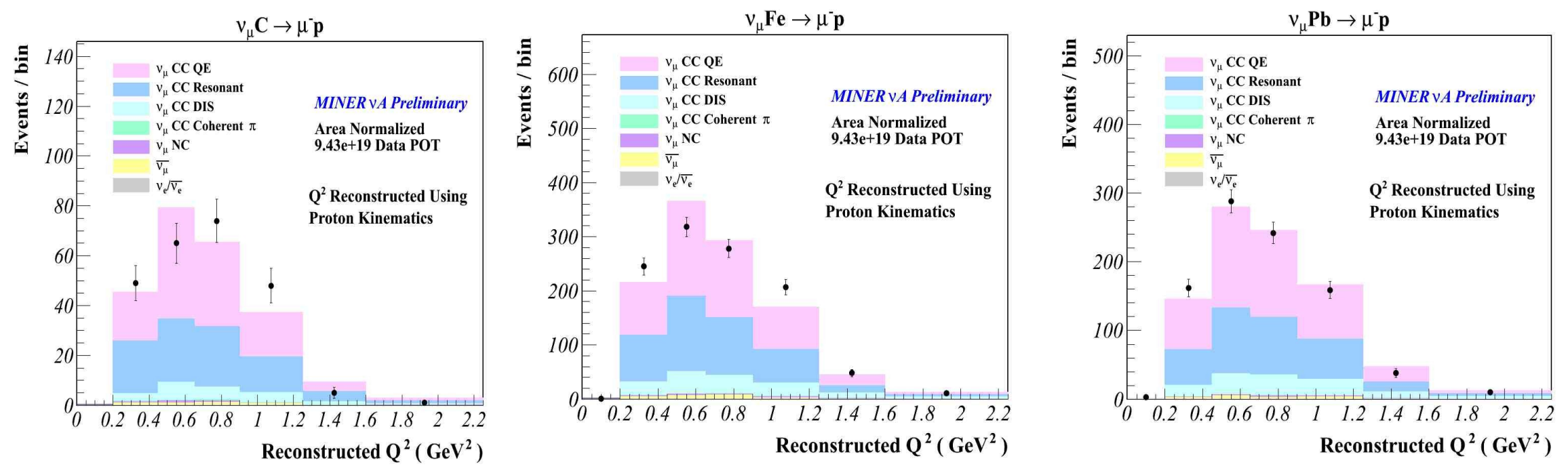
Anti-neutrino CCQE dσ/dQ^2 and Models



Neutrino CCQE and Free Nucleon Rates

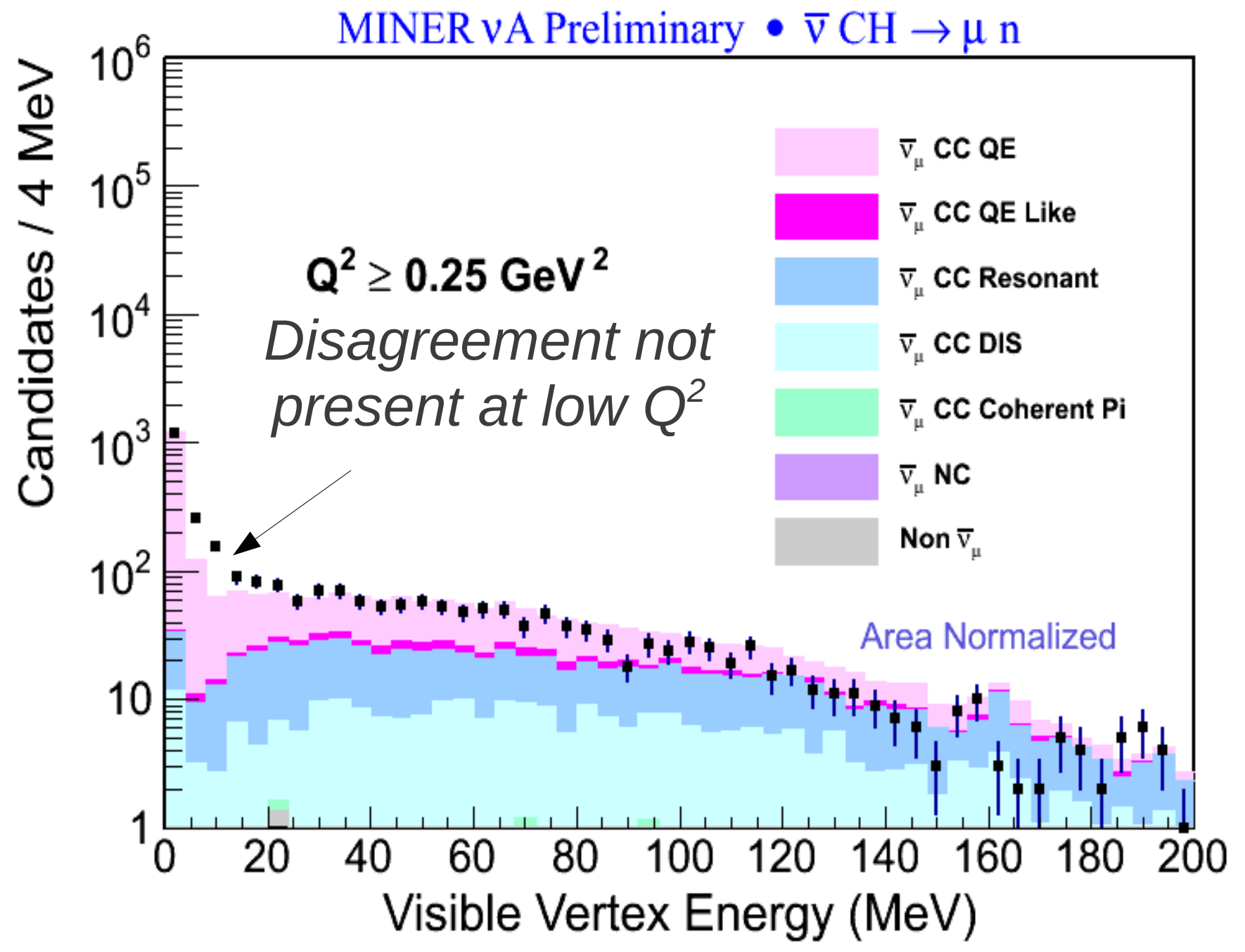


Neutrino CCQE in Passive Targets



Prospects for The Future

We plan an updated analysis and first publication in spring 2013. In addition to Q^2 distributions, we also plan to look for the presence of additional energy near the event vertex as a signature of multi-nucleon scattering.



Energy near the vertex in the anti-neutrino beam, moderate and high Q^2