Neutrino-Electron Scattering at MINERνA

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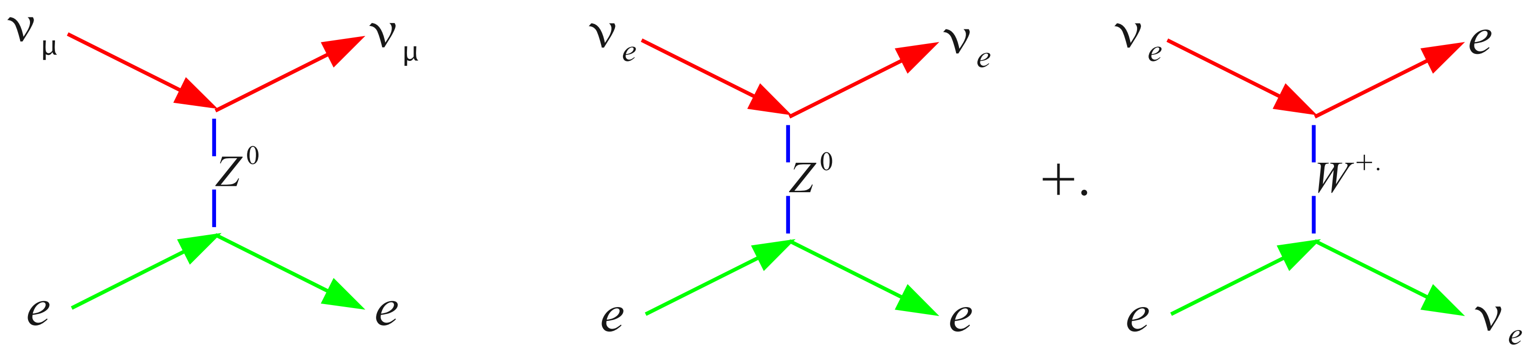
On behalf of MINERνA Collaboration

The neutrino-electron scattering can be divided into three categories, represented by the Feynman Diagrams.



$\nu_\mu + e \rightarrow \nu_\mu + e$

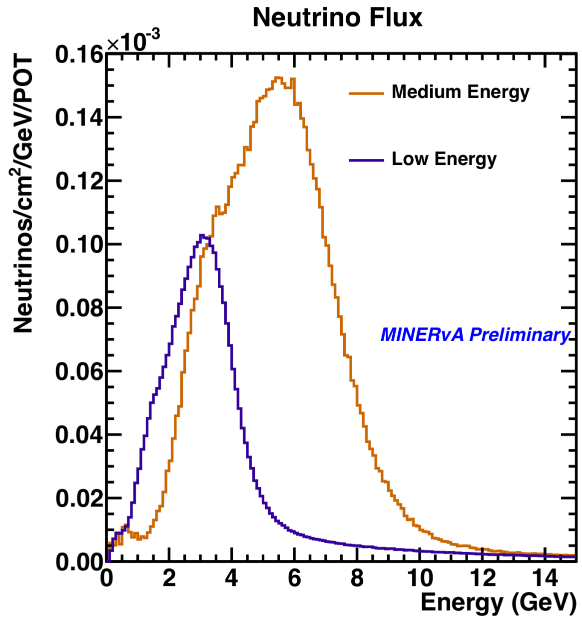
$\nu_e + e \rightarrow \nu_e + e$

The differential cross-section;

$$\frac{d\sigma}{dy}^{\nu_\mu e \rightarrow \nu_\mu e} = \frac{G^2{}_F m_e E_\nu}{2\pi} \left[\left(\frac{1}{2} - \sin^2\theta_W \right)^2 + \sin^4\theta_W (1-y)^2 \right]$$

where G_F, θ_W and y are the Fermi Constant, Weak Mixing Angle and Electron Kinetic Energy divided by Neutrino Energy, respectively.

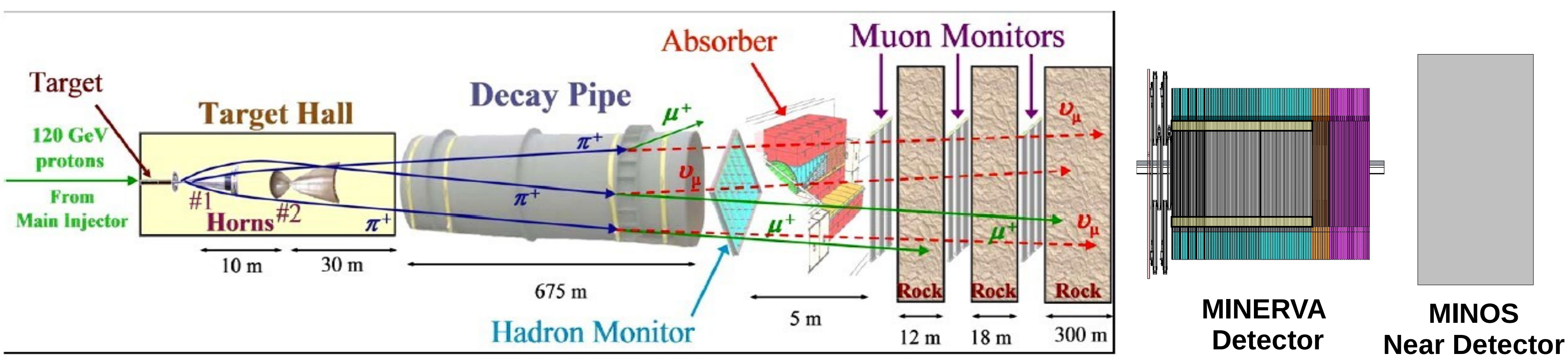
NuMI Beamline



The NuMI beamline provides the most intense neutrino flux in the world, produced by colliding 120 GeV protons with a graphite target and focusing the resulting pions and kaons before they decay to produce neutrinos.

Setting the Horn 2 position is possible to get a different energy range neutrino beam.

The MINERvA Detector is located in the MINOS Hall, at ~100m underground.

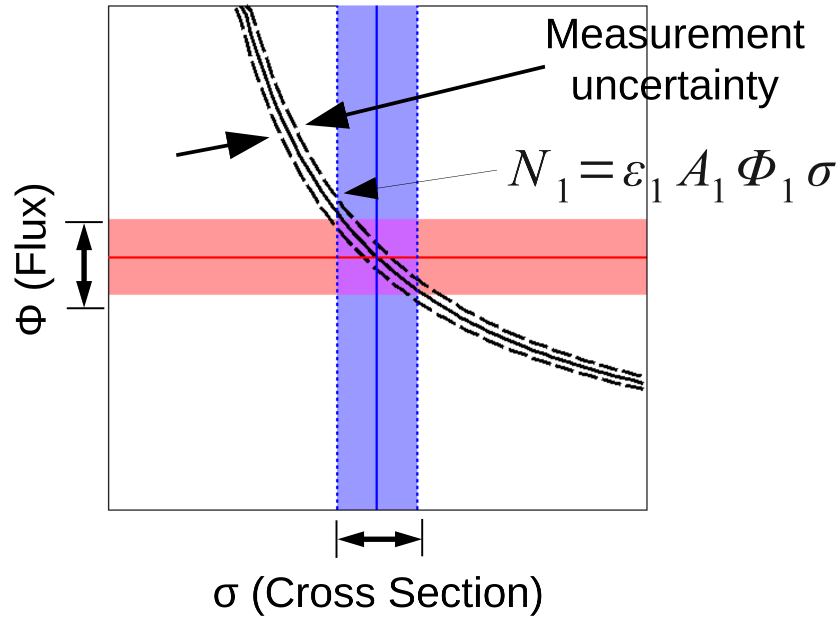


Constraining the Flux with Neutrino-Electron Scattering

MINERνA

$$\sigma = \frac{N}{\varepsilon A \Phi}$$

Flux uncertainty goes into cross-section uncertainty



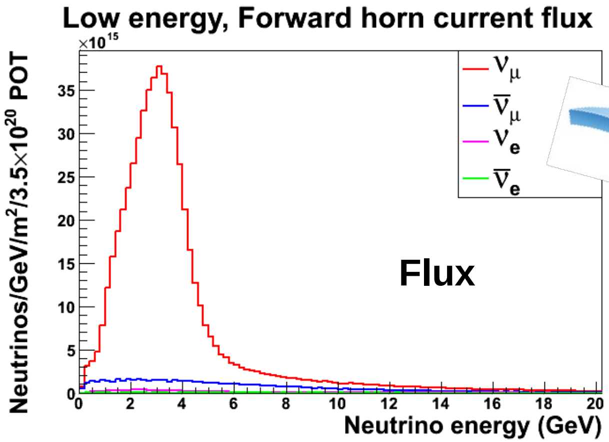
Flux constraint using Near Detector

$$\Phi = \frac{N}{\varepsilon A \sigma}$$

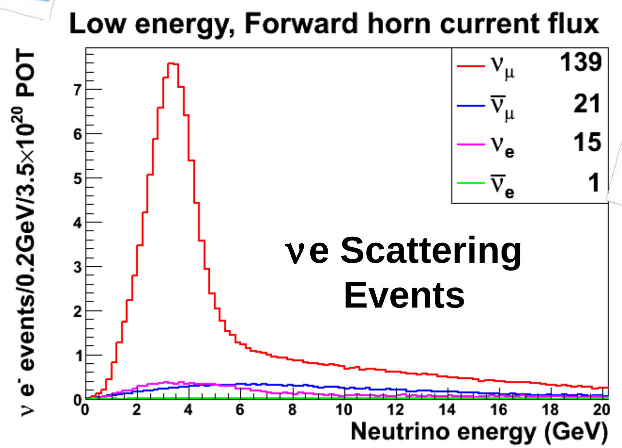
Cross-section uncertainty goes into flux uncertainty

- **Flux prediction is important for MINERνA's absolute cross-section measurement.**
- **Future precision neutrino oscillation experiment requires low uncertainty on flux prediction.**
- **Flux has large uncertainty due to poor knowledge of hadron production.**
- **Use of external data is useful but it can't handle all the uncertainties ν-e scattering provides a direct measurement of flux.**

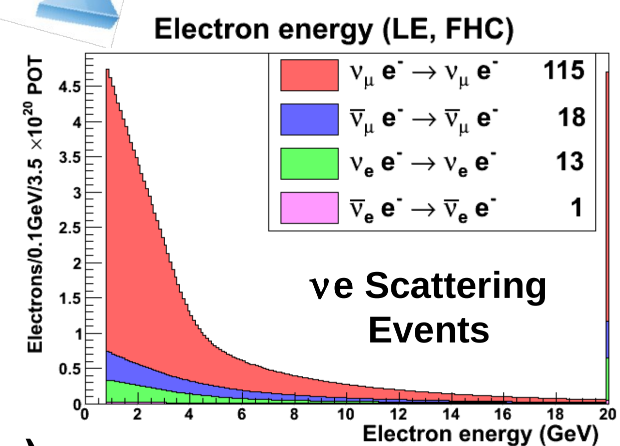
Flux → Event Rate → Electron Spectrum
Low Energy Era



$\sigma(\nu e) \propto E_\nu$



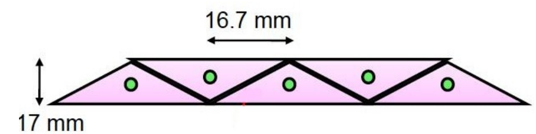
$\frac{d\sigma}{dy}$

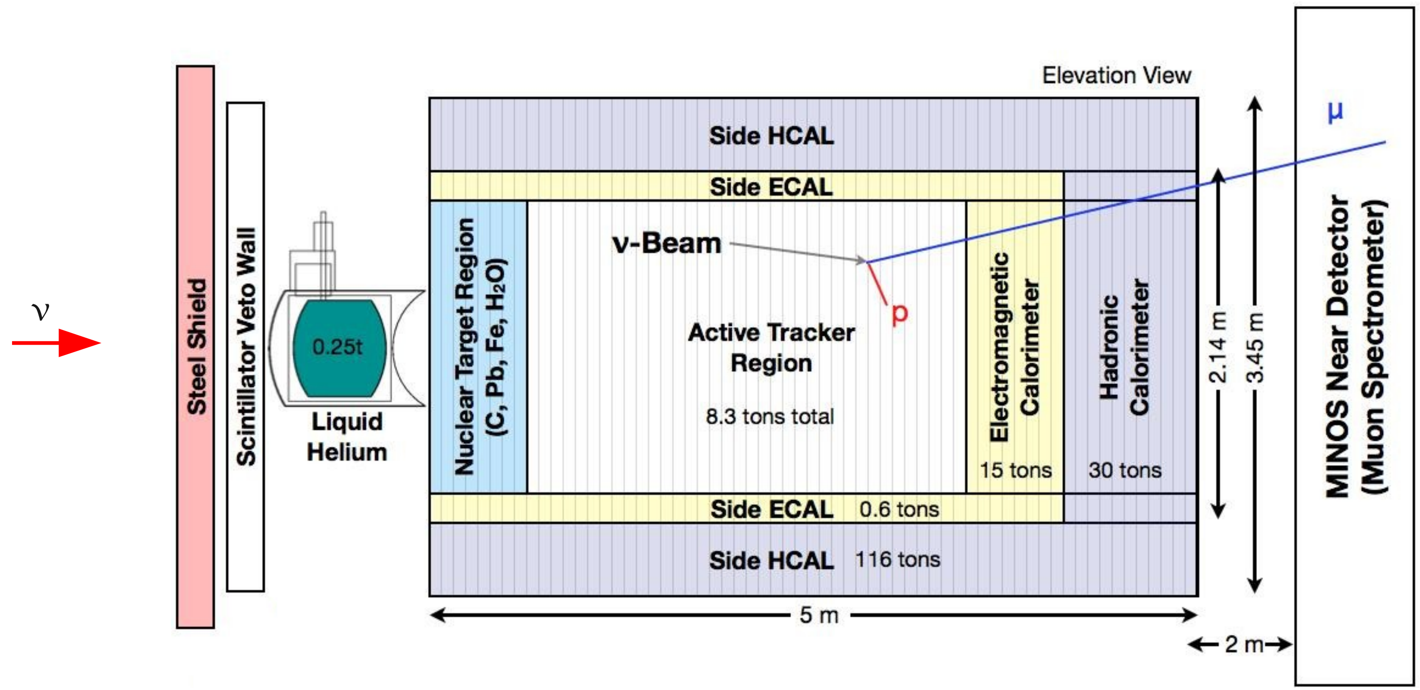


- **Low center of mass energy due to light electron.**
- **Very small cross section (~1/2000 of ν-nucleon scattering).**
- **Very forward electron final state (Experimental signature).**
- **E > 0.8 GeV (High background rate and tough reconstruction at low energy).**
- **Neutrino-electron scattering offers a flux measurement since its theory is well predicted by the standard model of particle physics.**

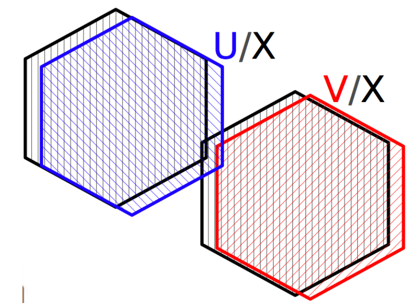
The MINERνA Detector

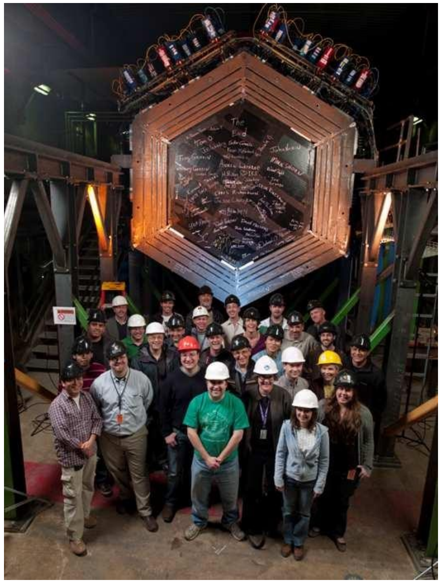
Active segmented polystyrene scintillator strips.
Passive nuclear targets of He, C, Water, Fe and Pb.



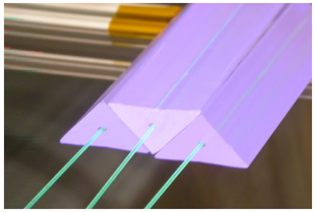


3 strip orientations
-60°, 0°, +60°



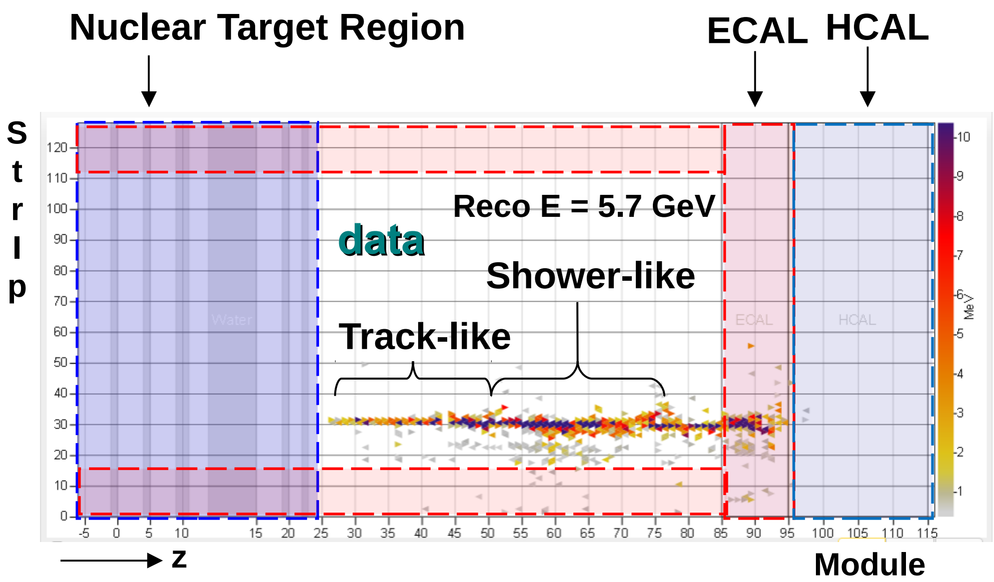


- **Total 120 modules:**
  - **84 Tracker**
  - **10 ECAL**
  - **20 HCAL**
  - **6 Nuclear Targets**



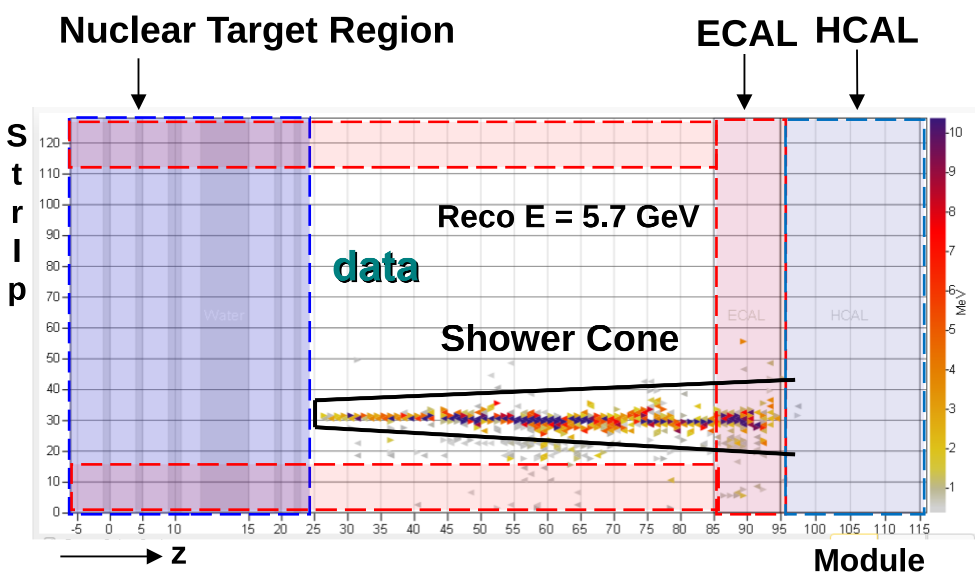
Single Plane Resolution: 2.65 mm.
Single Hit Timing resolution 4.20 ns.

Signal Reconstruction



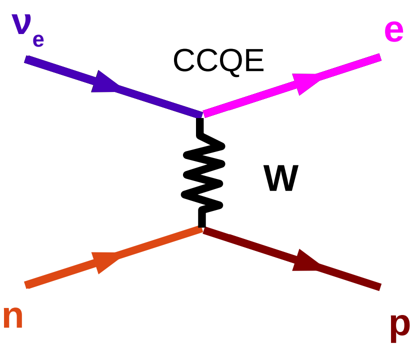
- Mixture of $\nu_{\mu}e^{-}, \overline{\nu}_{\mu}e^{-}, \nu_{e}e^{-}$, and $\overline{\nu}_{e}e^{-}$ in Medium Energy Forward Current.
- Can not distinguish neutrino flavor
- To reconstruct the Electromagnetic Shower only is used the information from Tracker Region and ECal Region.

- When (thin) track finder fails on fuzzy shower, isolated blob finder is used and then track fitter can handle fuzzy shower.
- Once vertex and direction is known, shower cone can be applied.

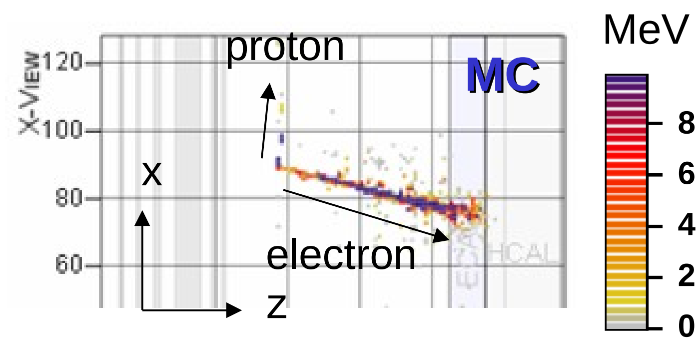


Background Events

$$\nu_e + n \rightarrow e^- + p$$
$$\bar{\nu}_e + p \rightarrow e^+ + n$$



Electron neutrino fraction in flux is small ~ 1%.



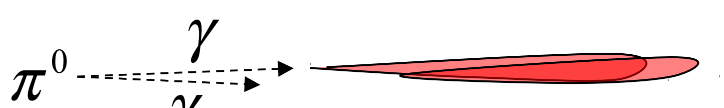
If recoil nucleon is not observed, it looks similar to signal
Angles of electron have wide spread while signal is very forward

Neutral current single π^0

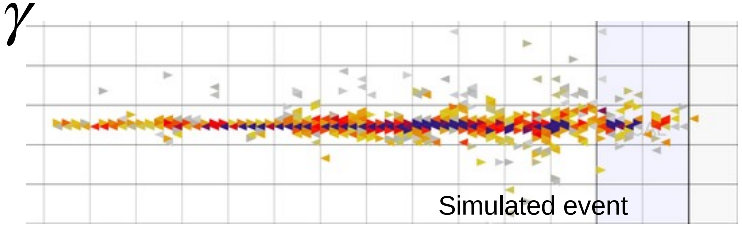
$$\nu_\mu A \rightarrow \nu_\mu A \pi^0$$ **NC-coherent π^0**

$$\nu_\mu N \rightarrow \nu_\mu N \pi^0$$ **NC-resonant π^0**

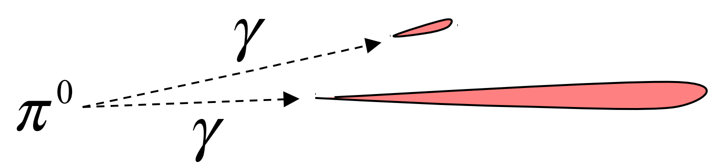
1. Small opening angle between two gammas



π^0 (7.5 GeV)

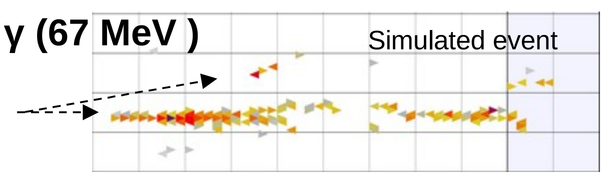


2. One of gammas is not observed in the detector



γ (67 MeV)

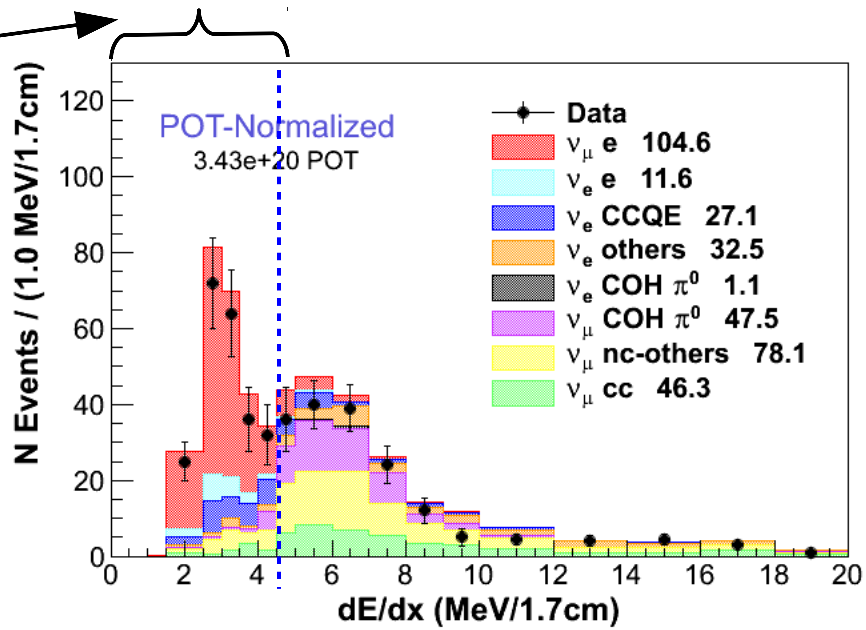
π^0 (1.1 GeV)

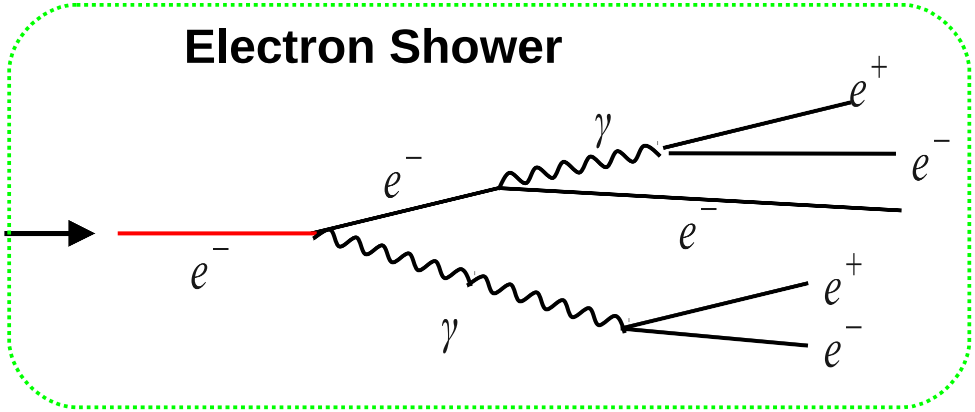


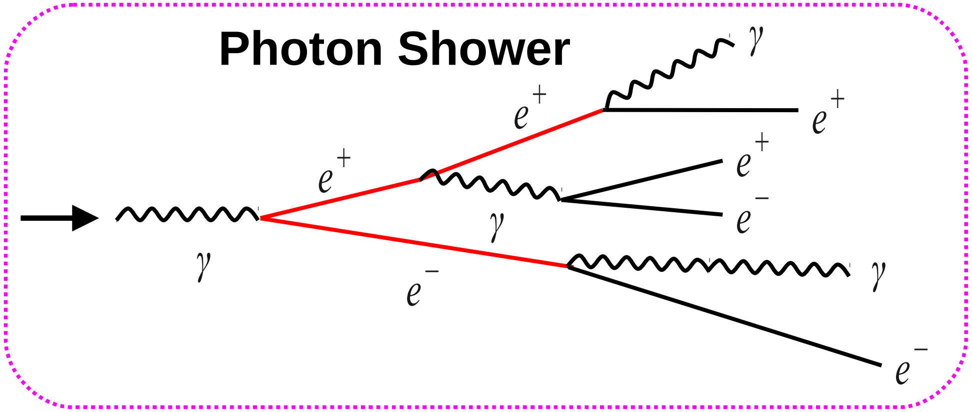
Photon Rejector
dEdx on the first 4 planes

Signal Region

$dEdx < 4.5\ MeV / 1.7\text{cm}$

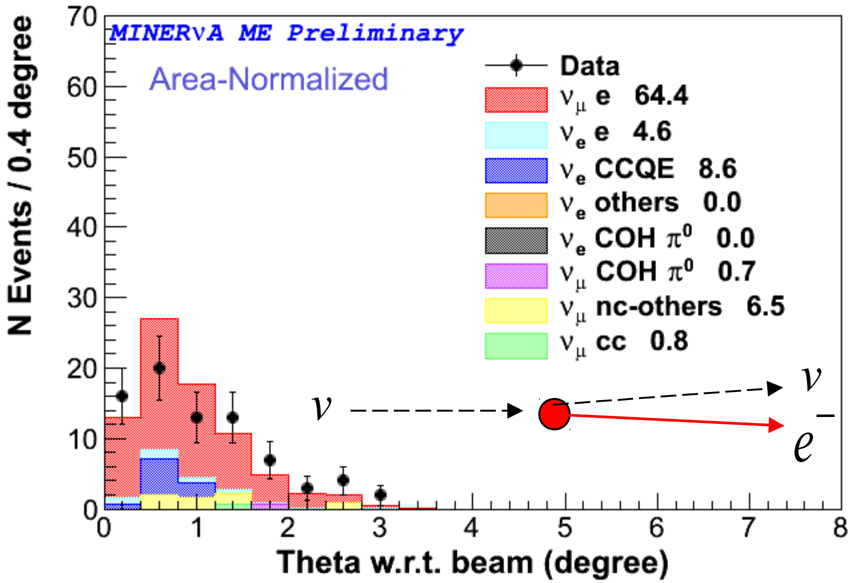


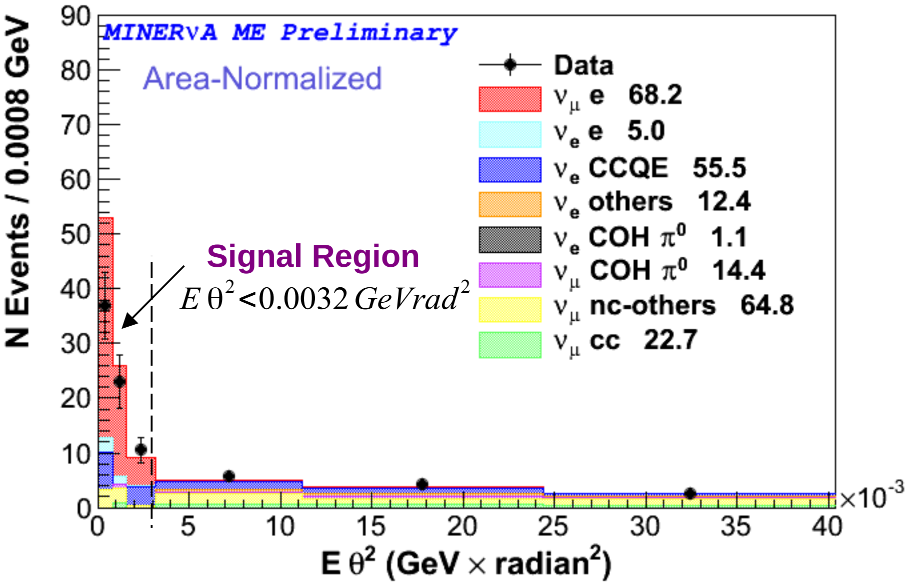




Photon shower has twice energy loss per length (dE/dx) at the beginning of shower than electron shower.

Main Signal Isolator
$E\theta^2$



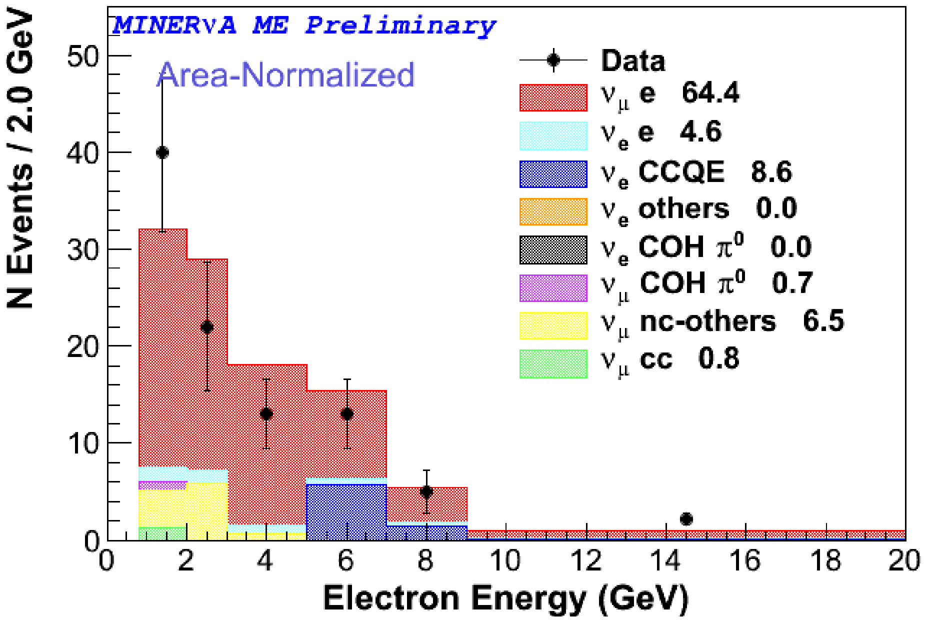


- **Kinematic limit $E\,\theta^2 < 2m_e$; where E: Electron energy and θ: Electron angle with respect to the neutrino.**

Clean separation of signal using cut.
Good angular resolution (0.4°) is critical to use $E\,\theta^2$ cut.

Preliminary Results

Using the first Medium Energy run sample with ~1e20 pot, we have a prediction of 69.1 signal and 16.6 background events.

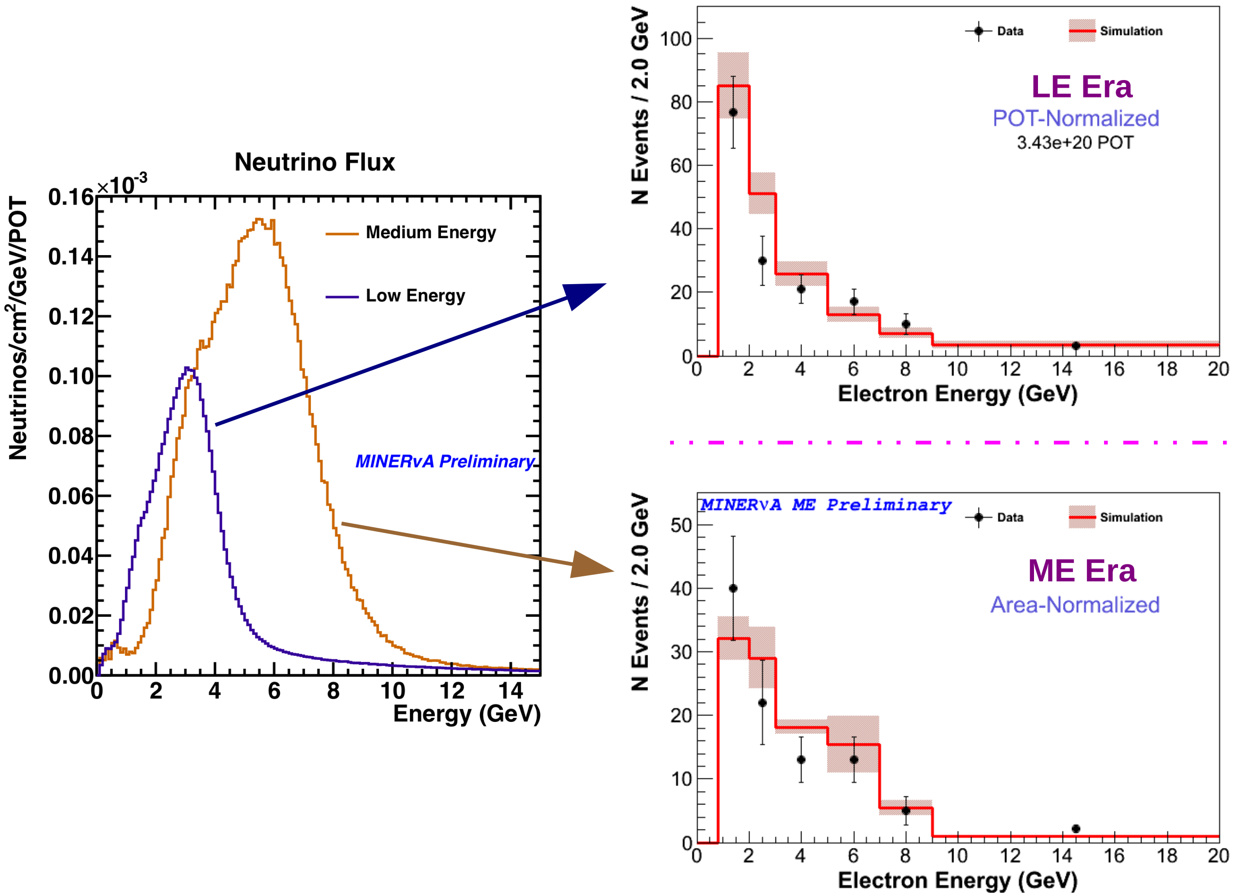


Making a comparison between Low Energy (LE) results and Medium Energy (ME) ν-e at 1e20pot:

	LE	ME
Signal	30.5	84.9 ± 4.0
Background	8.8	20.4 ± 7.8
Sig_Bkg ratio	3.5	4.2 ± 1.6
Purity	0.8	0.8 ± 0.1

In ME, for the same pot quantity, we expect to have almost the same purity and background ratio, but with ~3 times more signal events.

Conclusions
From LE to ME



- Measured ν-e scattering events
  123.8 ± 11 (stat)
- Prediction from Simulation
  104.7 ± 7.4 (flux)

MC bkg
37.2 ± 2.2(stat) ± 3.3 (sys)

- Measured ν-e scattering events
  78 ± 8.6 (stat)
- Prediction from Simulation
  69.1 ± 3.2 (flux)

MC bkg
16.6 ± 5.6 (stat) ± 2.8 (sys)

- **Minerva is expecting to have ~10e20 pot exposure, so more statistics, then low flux uncertainty.**
- **Using neutrino electron scattering, in addition to other studies in MINERvA, we will improve our knowledge of the flux normalization.**

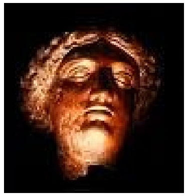
Backup

The MINERνA Collaboration
~65 Nuclear and Particle Physicist

- University of Athens, Athens, Greece
- Centro Brasileiro de Pesquisas Físicas, Rio de Janeiro, Brazil
- University of California, Irvine, California
- Fermi National Accelerator Laboratory, Batavia, Illinois
- University of Florida, Gainesville, Florida
- University of Geneva
- *Universidad de Guanajuato, Guanajuato, México*
- Hampton University, Hampton, Virginia
- Institute for Nuclear Research, Moscow, Russia
- James Madison University, Harrisonburg, Virginia
- University of Minnesota-Duluth, Duluth, Minessota
- Northwestern University, Evanston, Illinois
- University of Chicago, Chicago, Illinois
- Purdue University Calumet
- Otterbein College, Westerville, Ohio
- University of Pittsburgh, Pittsburgh, Pennsylvania
- Pontificia Universidad Católica del Perú, Lima, Perú
- Massachusettes. Colllege of Liberal Arts
- University of Rochester, Rochester, New York
- Rutgers University, New Brunswick, New Jesrsey
- Universidad Técnica Federico Santa Maria, Valparaíso, Chile
- University of Texas, Austin, Texas
- Oregon State University
- Tufts University, Medford, Massachusetts
- Universidad Nacional de Ingeniería, Lima, Perú
- The College of William and Mary, Williamsburg, Virginia

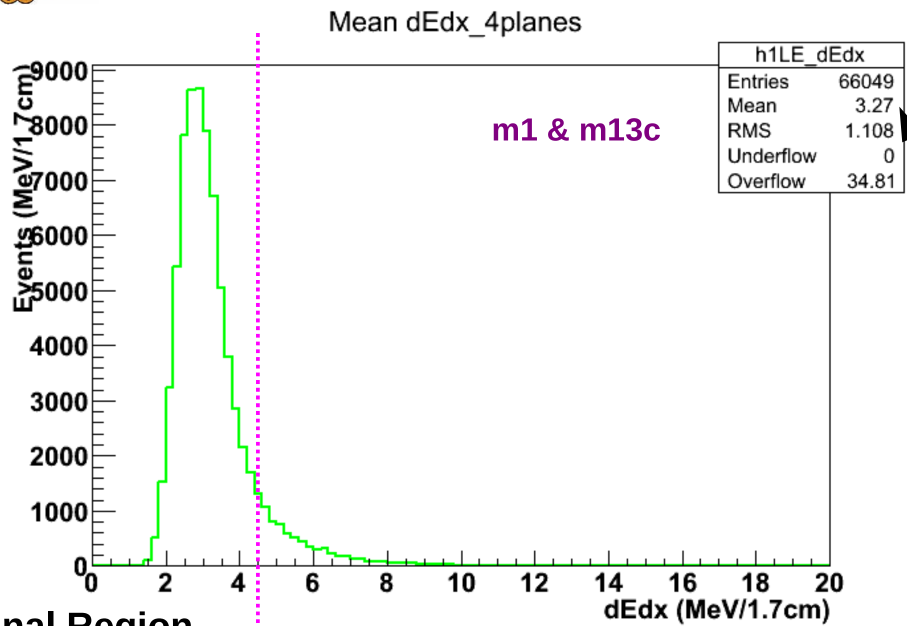
Goals

- Precision measurement of coherent single-pion production cross-sections, whit particular attention to target A-dependence.
- Study the A-dependence of neutrino interactions with unprecedented detail – Scintillator (C-H), ^{4}He, C, H_2O, Fe, Pb targets.
- Search for x-dependent nuclear effects in neutrino scattering.
- Precision cross section measurement and studies of final states (Important for understanding systematics of oscillation experiments).

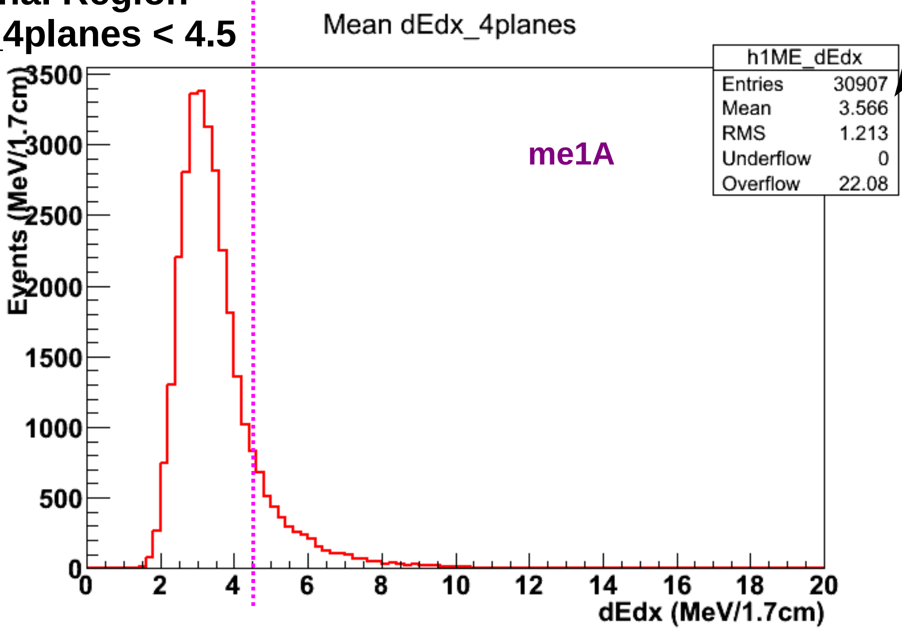


Mismatch Issues; LE vs ME

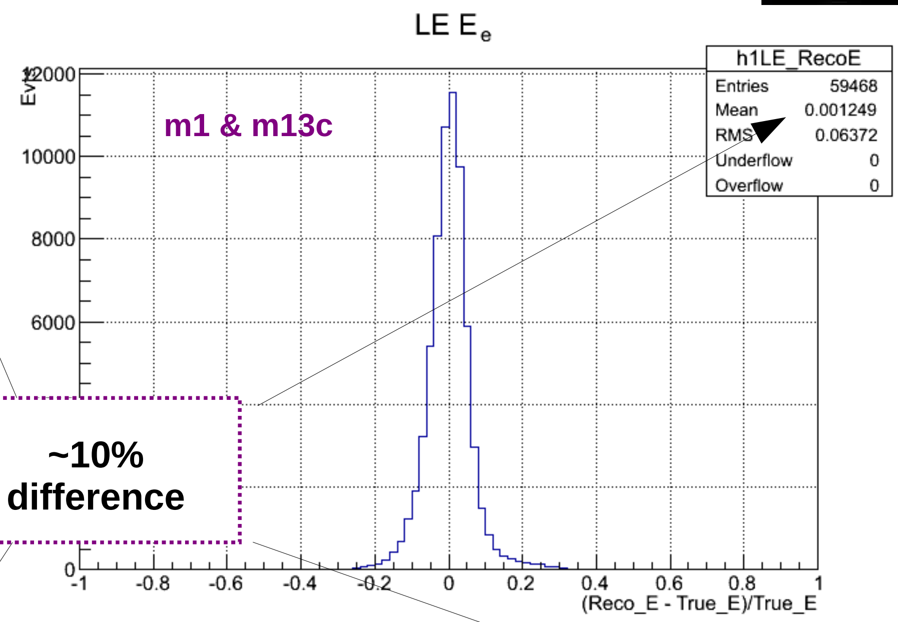
dEdx_4planes



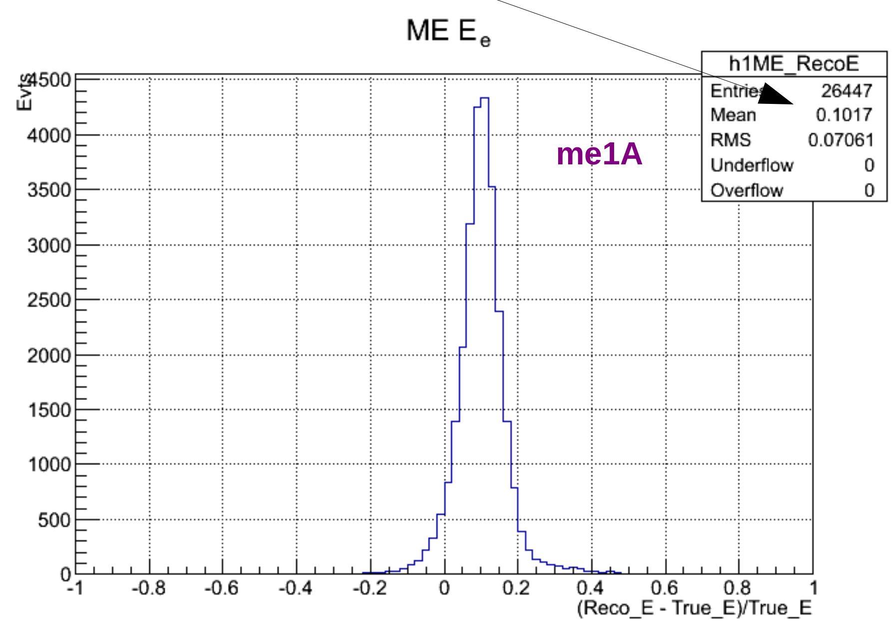
Signal Region
dEdx_4planes < 4.5



Electron Energy

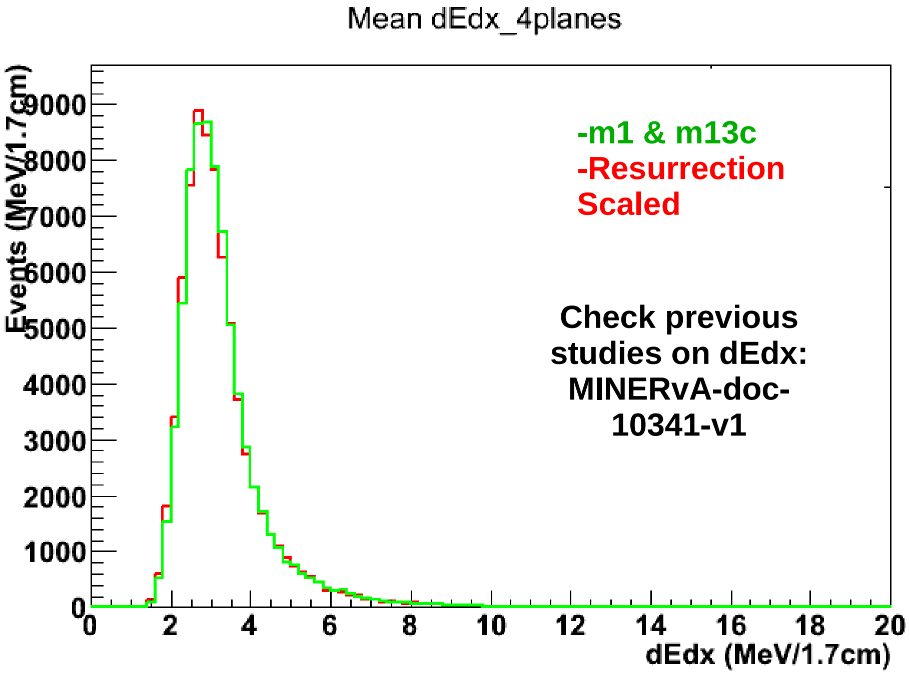


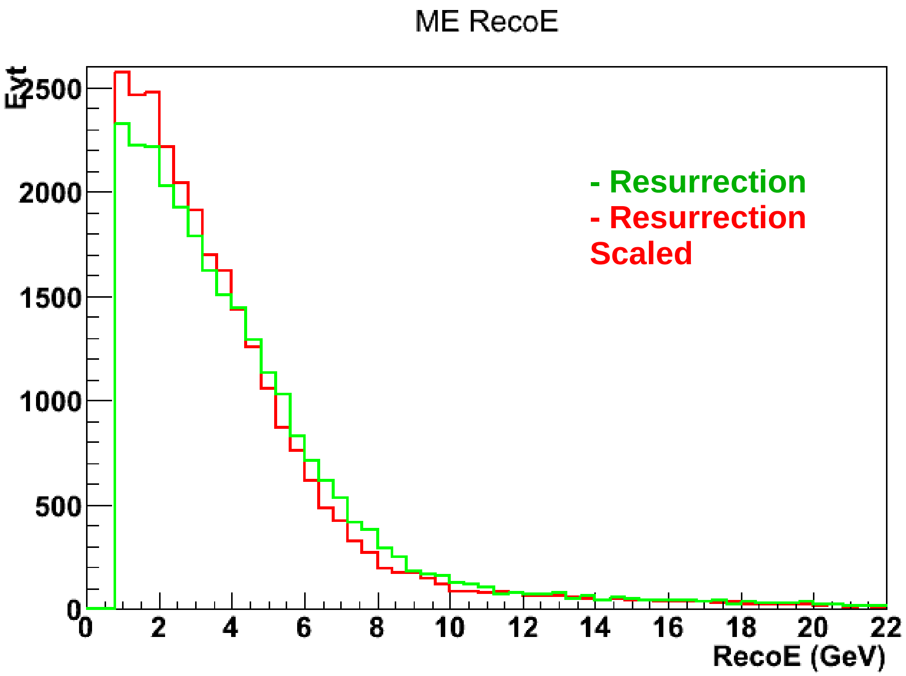
~10% difference



Applying ~10% Reduction Scale
dEdx_4planes and Electron Energy

- I'm using my previous studies on dEdx for different energy ranges.
- I'm taking the mean value of dEdx in LE and ME, this is 0.91, applied it on dEdx variable in Resurrection ME.
- Taking the resolution factor form TrueE and RecoE on Resurrection: 0.90.
- Applying this factor over Reconstructed energy in Resurrection ME.





Background Subtraction and Efficiency Correction