Status of the Inclusive ν_e Charged Current Cross-Section Measurement in the NOvA Near Detector

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New Perspectives
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Motivation

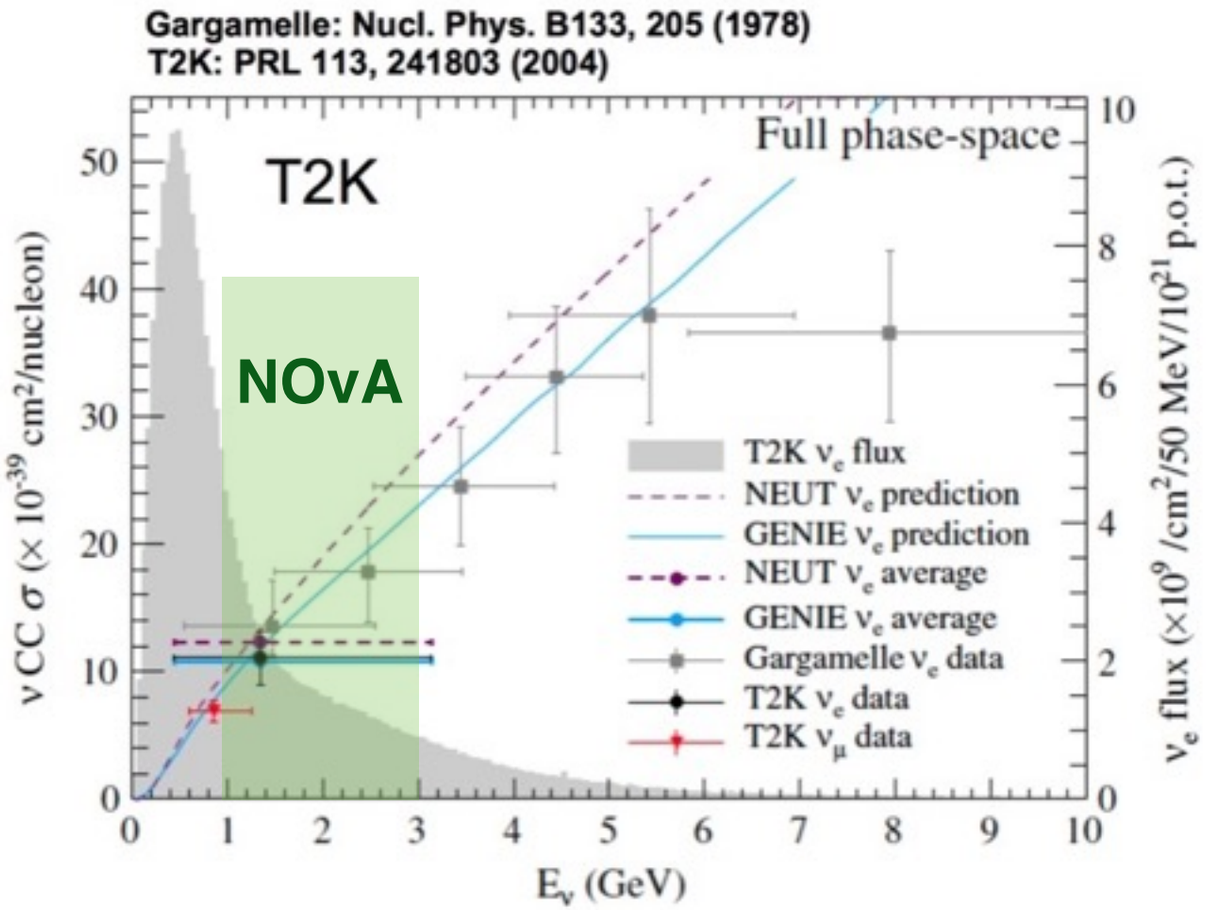
- Precision is becoming more important to the results of long baseline neutrino programs, with experiments looking to reduce uncertainties to the percent level.

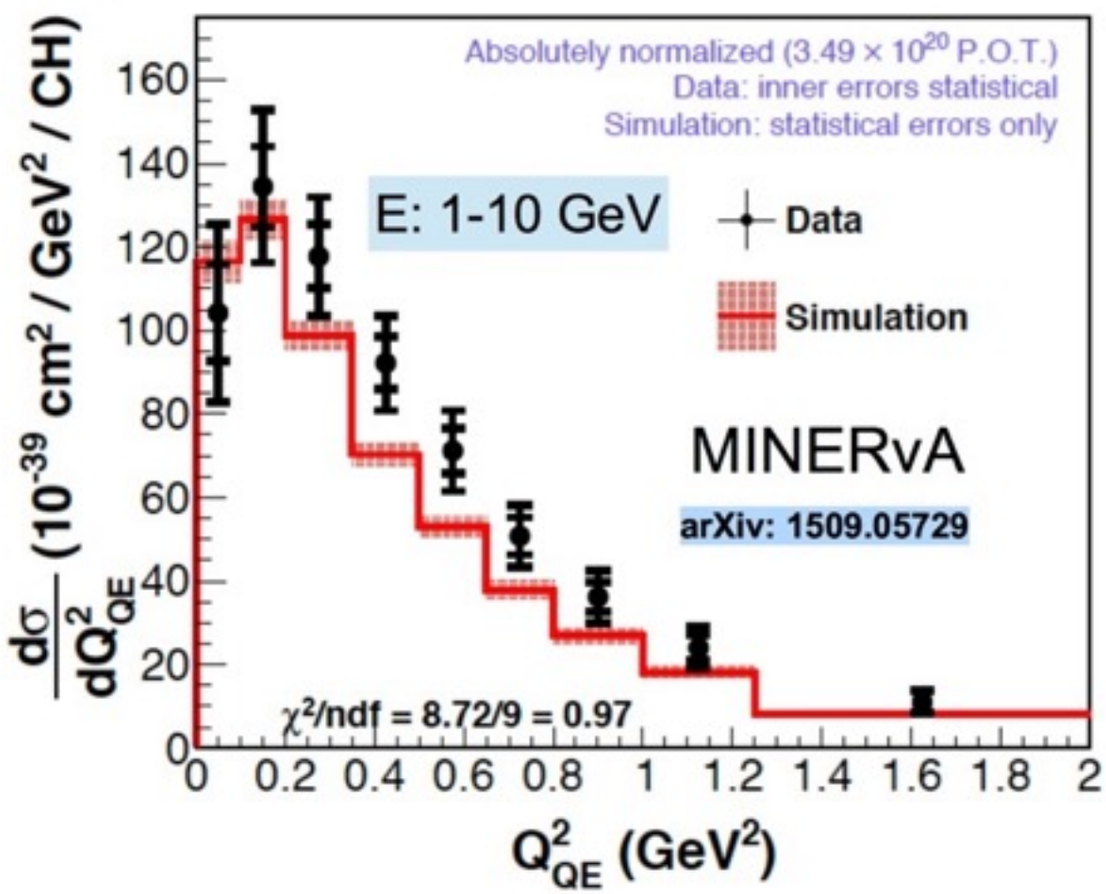
- Improving on the existing measurements of neutrino cross sections will play an important role in improving the precision of oscillation analyses and will influence future experiments.

- The inclusive ν_e charged current (CC) cross-section is a basic measurement that can be used to directly tune simulations for the oscillation analysis.

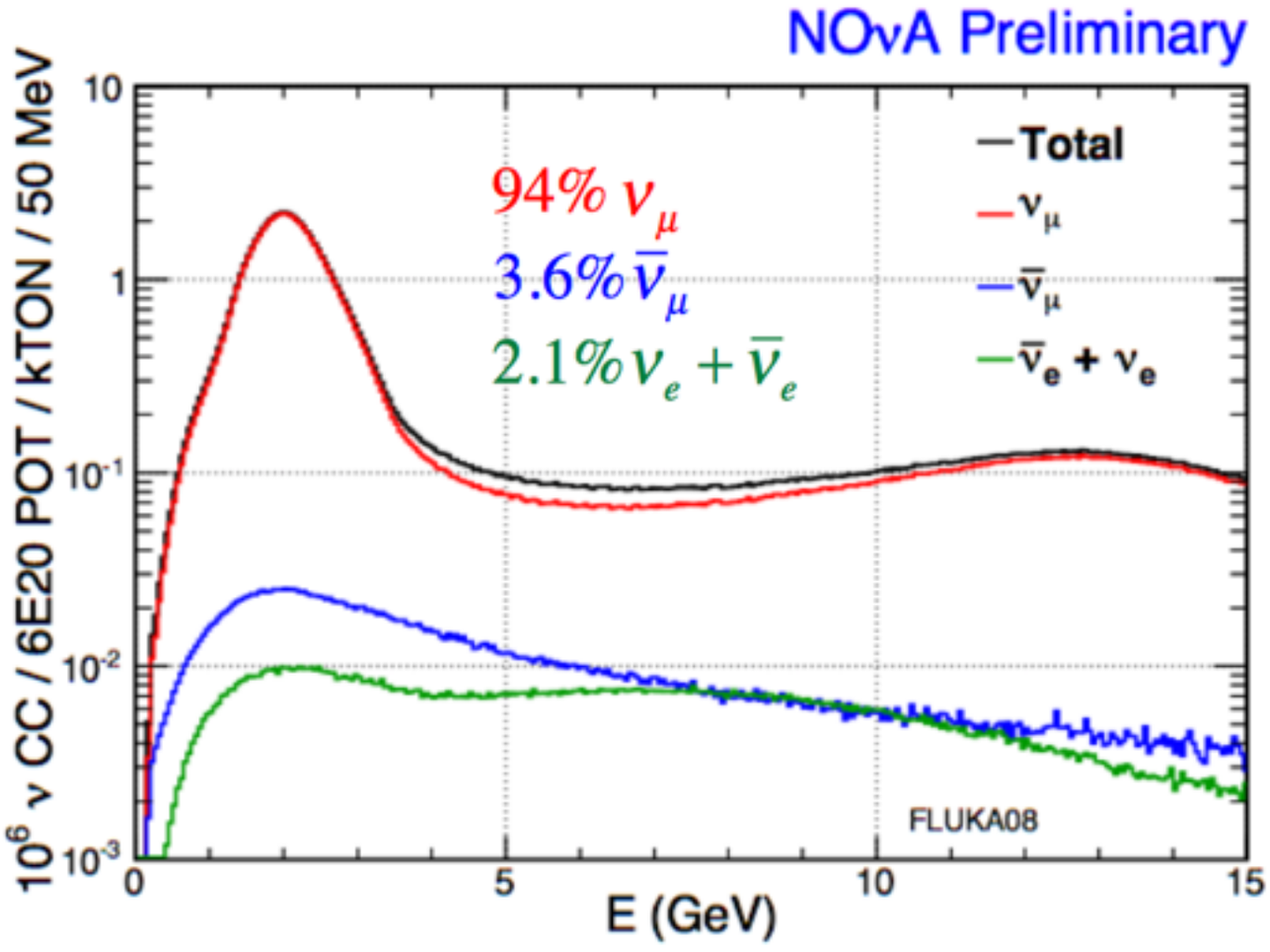
Electron Neutrino Cross-Section

There are few electron neutrino cross-section measurements at the GeV scale





Neutrino Flux at NOvA ND



Electron Neutrino flux is a small percent of the total flux, with a broad energy spectrum

Cross-Section Measurement

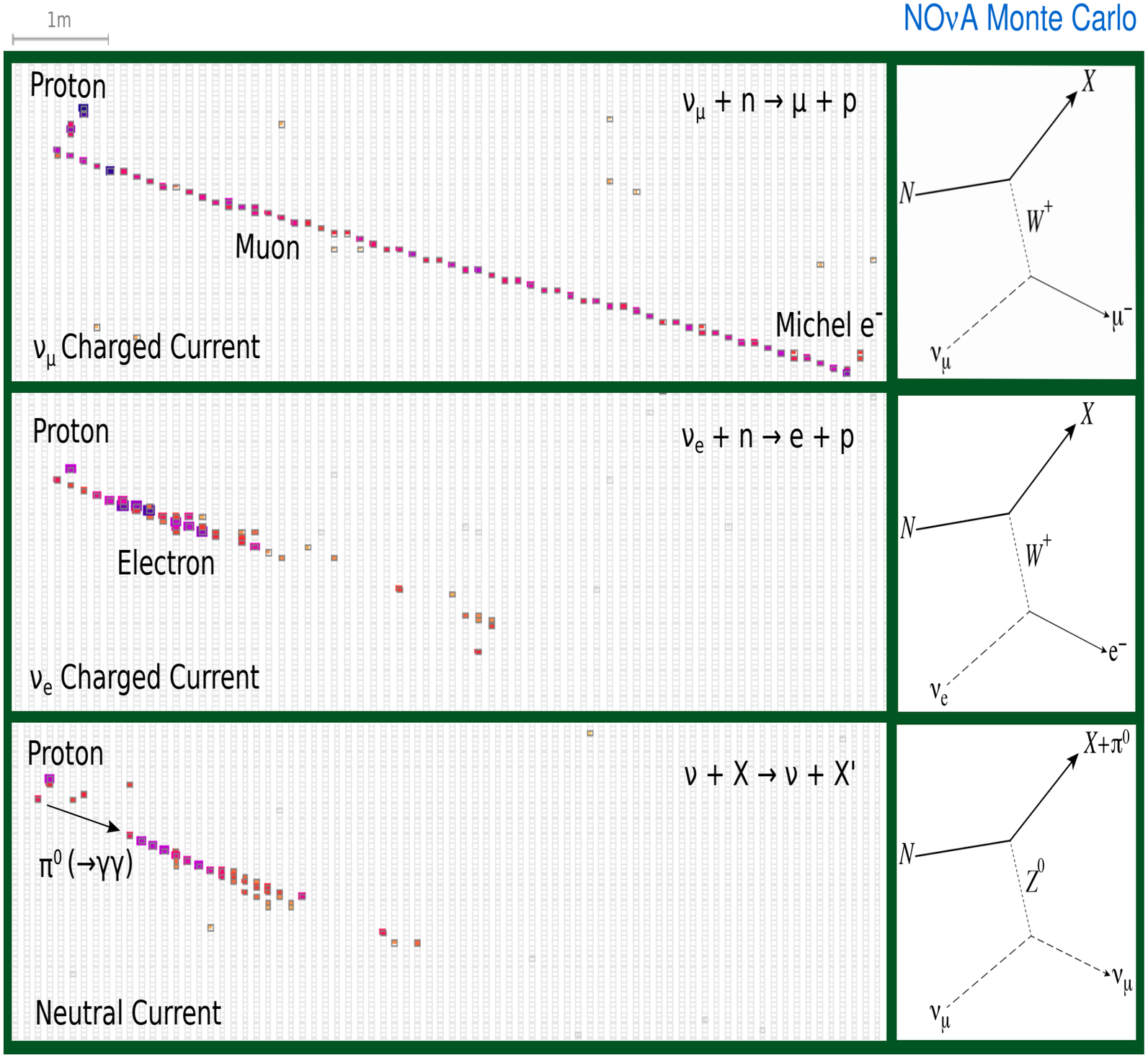
The NOvA Near Detector (ND) provides an excellent opportunity for the measurement of various neutrino interactions

$$\sigma_k = \frac{\Sigma_j \, U_{kj} \left(N_j^{sel} - N_j^{bkg} \right)}{T \, \phi \, \varepsilon_k}$$

- N^{sel} is the number of selected data events
- N^{bkg} is the number of background events
- U is an unfolding matrix to unfolded to true space from reconstructed space
- Φ is the integrated neutrino flux
- T is the total number of nucleons in the target
- ε is the total event selection efficiency

Neutrino Interactions in the NOvA Detector

NOvA Monte Carlo

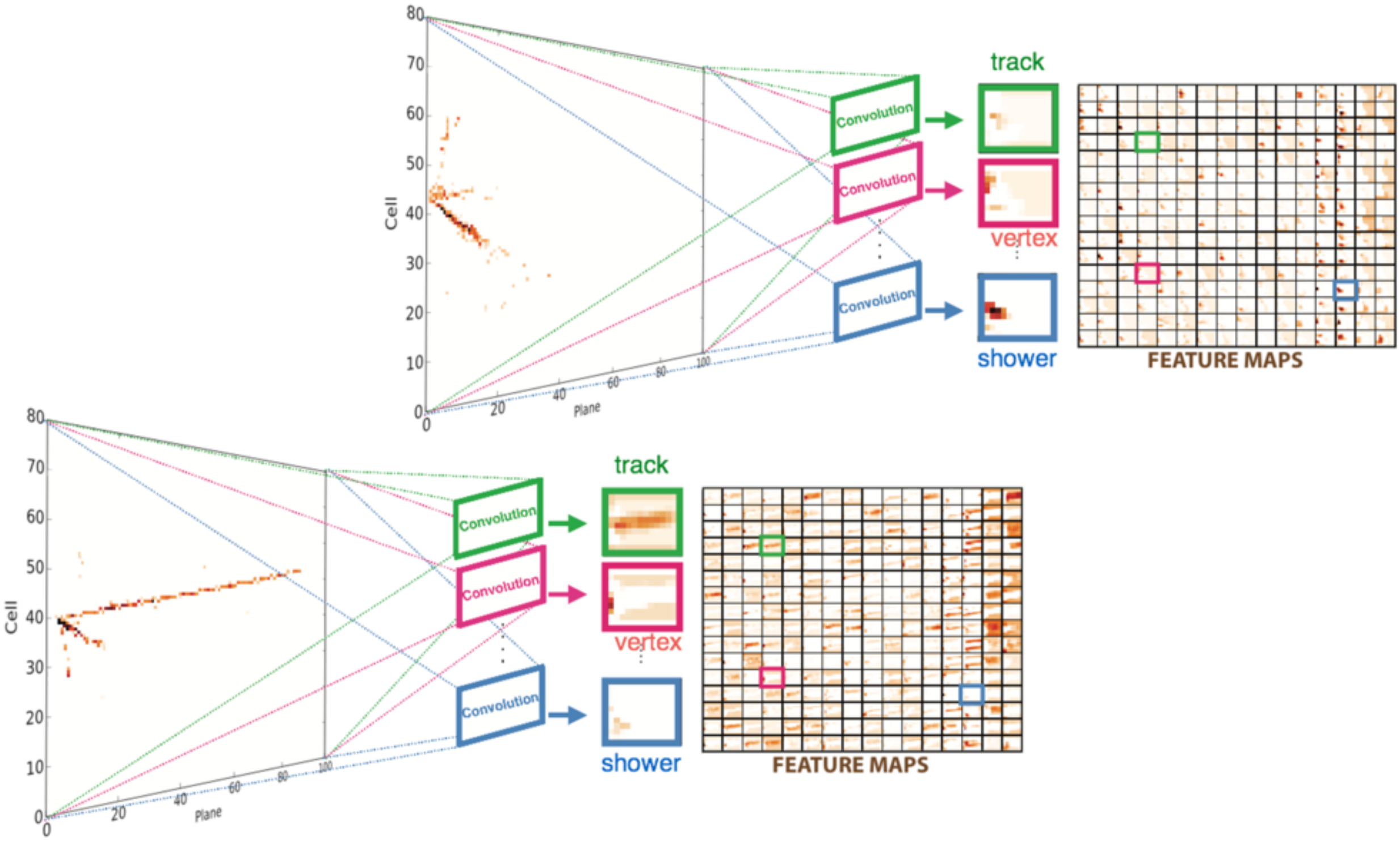


Simulated Events With 2 GeV Neutrino Energy

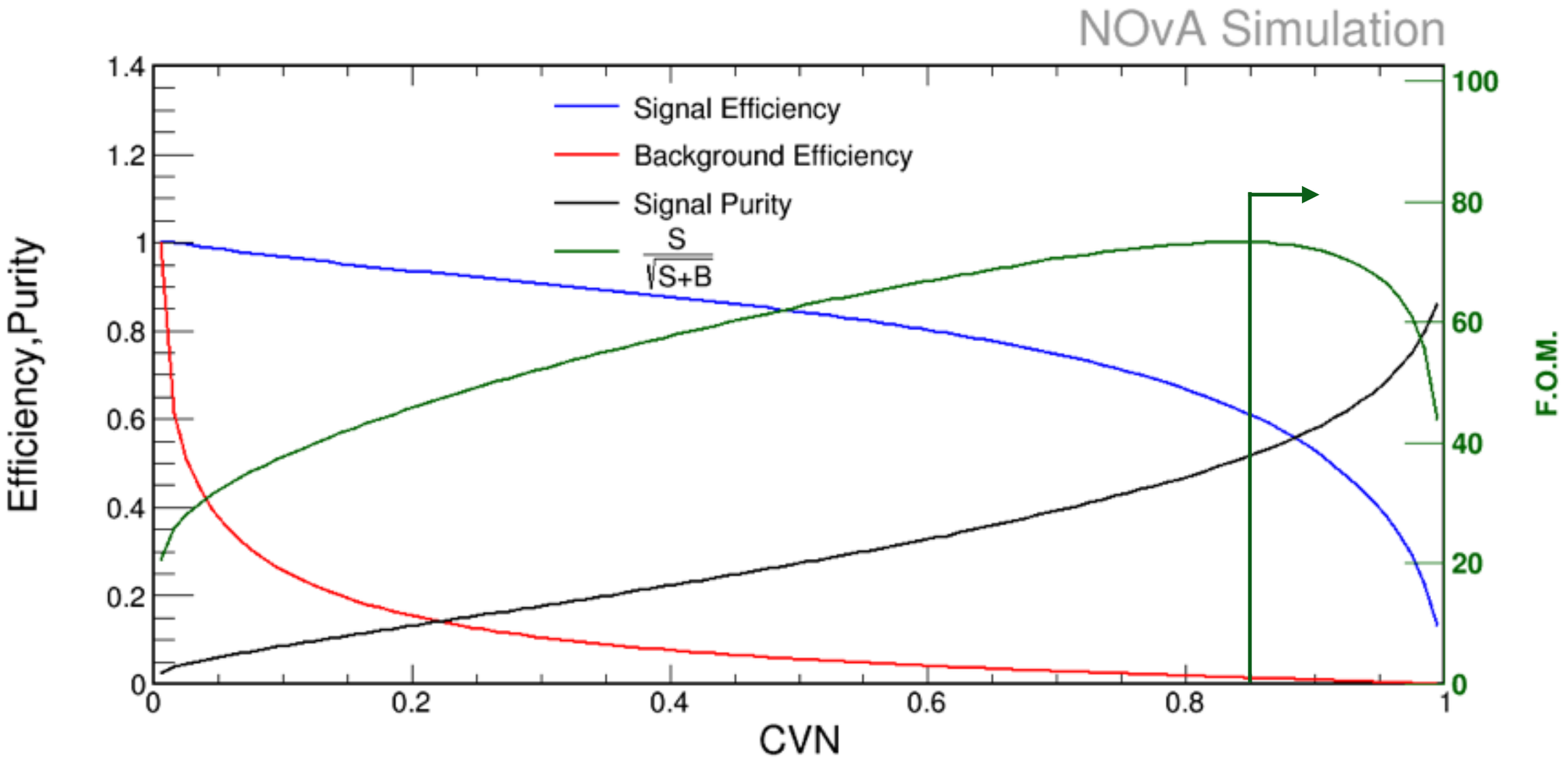
Event Selection

- A number of cuts are used to select a sample of electron neutrino events
- The final selection is made using a technique based on deep learning to select ν_e CC events
  - Events are classified based on topology:
    - ν_μ CC events can identified by the presence of long straight tracks
    - ν_e CC events can be identified through the presence of a shorter, wider shower
    - NC events lack a charged lepton in the final state and tend to only have activity from the nuclear recoil system
- A series of image processing transformations are used to extract features that can be used to distinguish these different types of events
- Convolutional Visual Network (CVN)

Event Selection

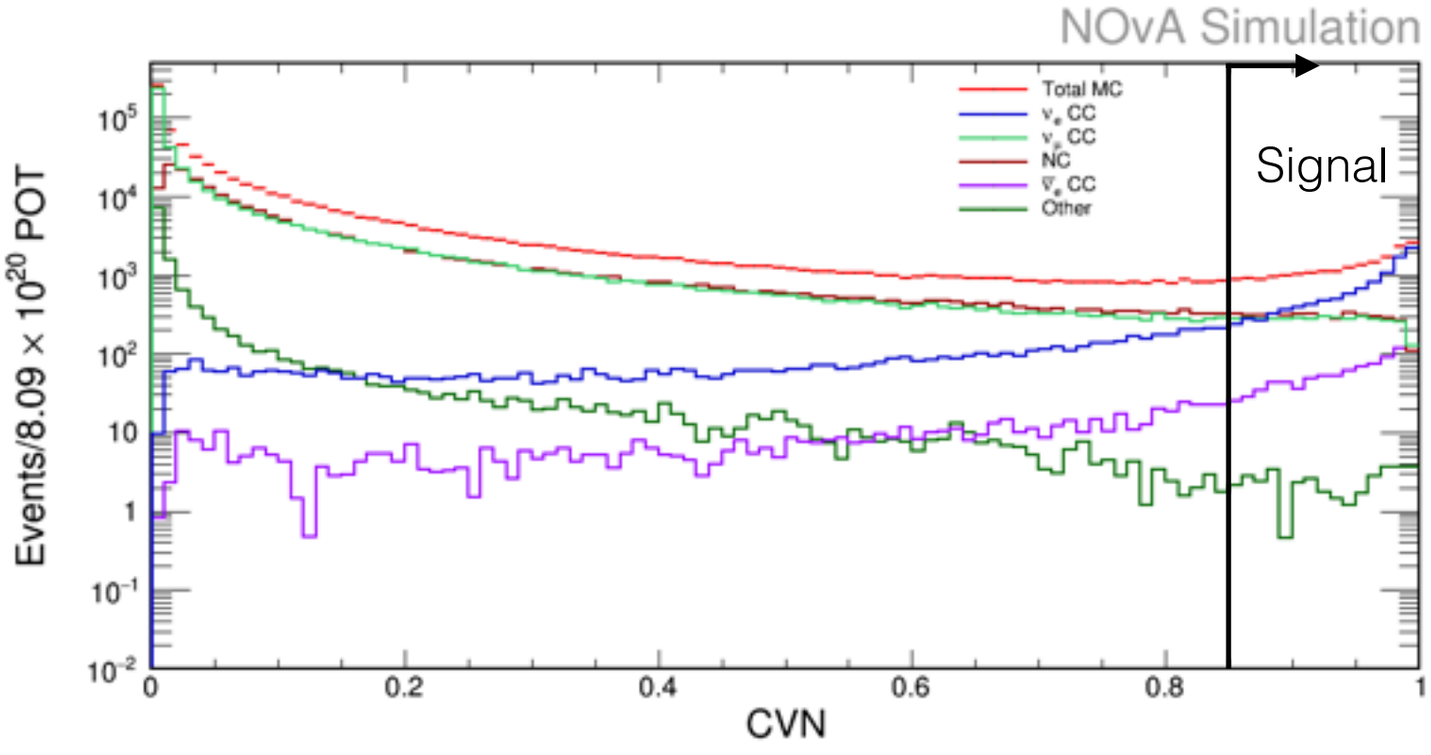


Efficiency and Purity



- Signal = ν_e CC, Background = All other interactions
- Defining figure of merit (F.O.M.) as Signal/sqrt(Signal + Background)
- Maximum value of the F.O.M. is found at requiring CVN > 0.85

Event Selection

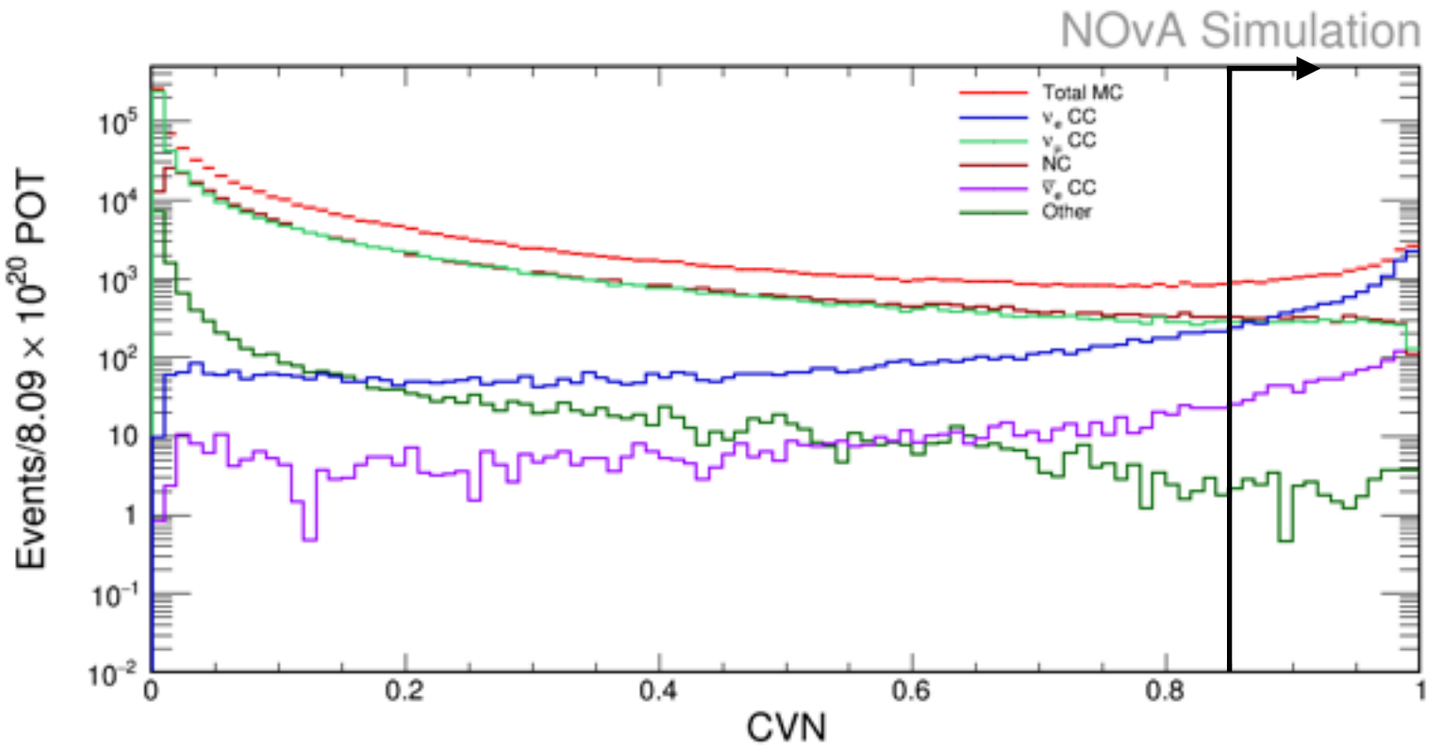


Expected Event Fraction From Simulation		
Interaction	**Fraction(%)**	**Number**
ν_e CC	51.2	10,446.70
Anti - ν_e CC	4.4	904.66
ν_μ CC	21.1	4,316.67
NC	23.0	4,691.16
Other	0.18	37.67

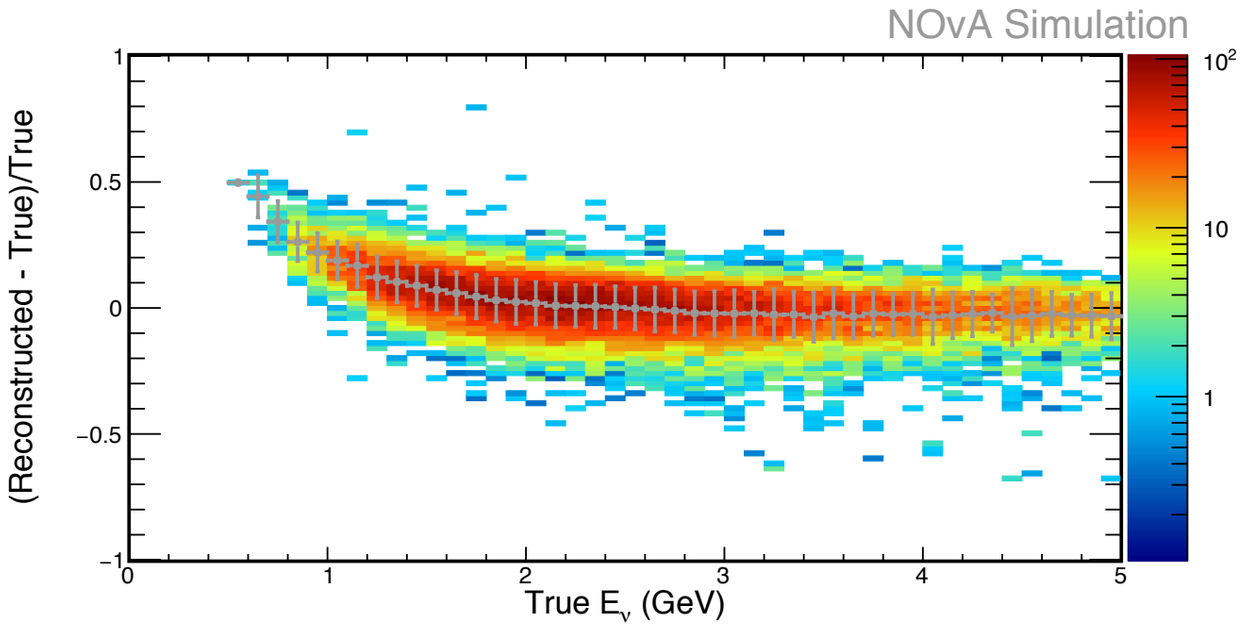
- Events with CVN > 0.85 are selected as candidate ν_e CC events
- All other interaction types are defined as backgrounds

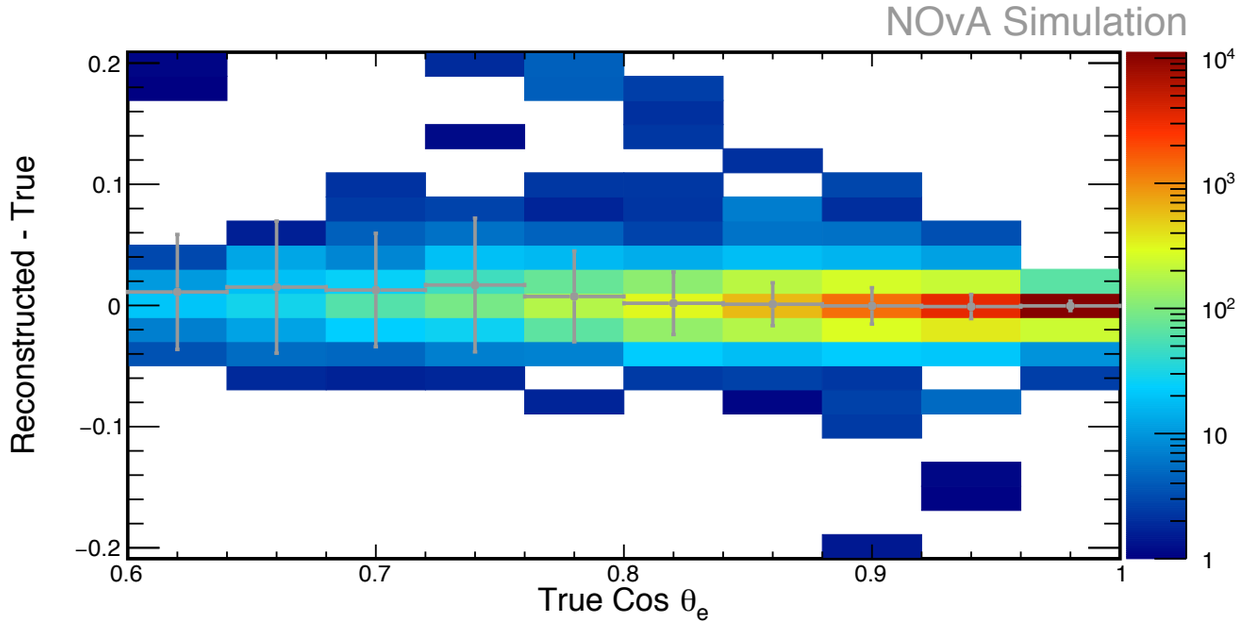
Background Estimation

- There are two major contributions to the background in the signal region, ν_μ CC and NC.
- We are going to constrain the background components using a sideband to our signal region.
- The sideband will have high statistics and should be background dominated
- This will use a data-driven technique of fitting the background components to the data in the region to get an estimate of the amount of background in the signal region
- The determination of the background component will be done in Leading Prong E - Remaining Slice Energy space to give more information on the measurable components



Predicted Resolution

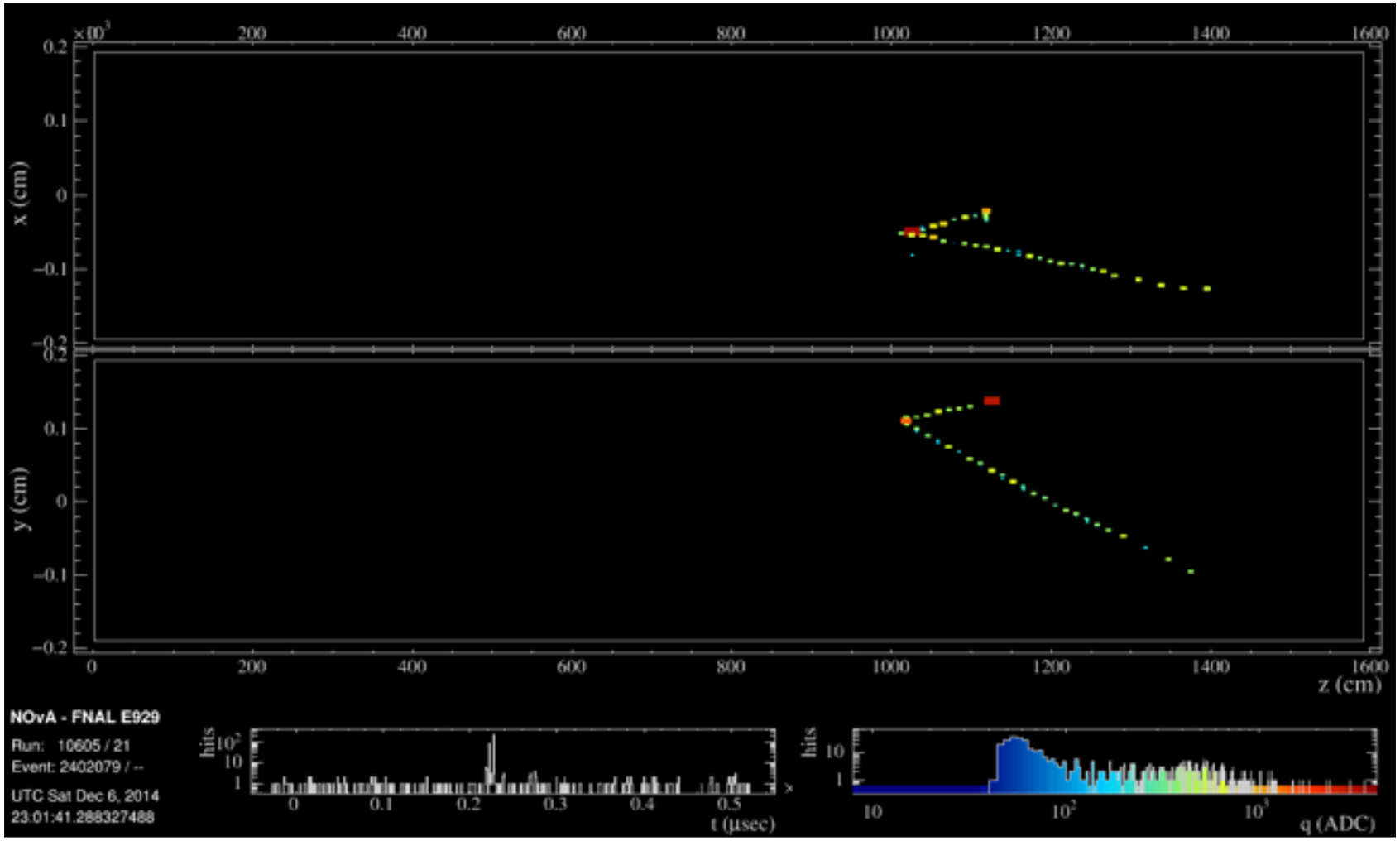




- Markers show the mean and error bands show RMS of each slice of Reconstructed - True neutrino energy(electron angle) with respect to true neutrino energy (electron angle)
- The predicted energy resolution is ~400 MeV averaged over the entire sample from 1 to 3 GeV in true Neutrino Energy
- The predicted angular resolution is ~4° averaged over the region shown in true electron angle

Muon Removed Sample

- ν_e CC measurement has a unique data-driven technique to determine a correction to the efficiency of selecting electron neutrino signal events
- This is done through a technique called Muon Removed Electron Added



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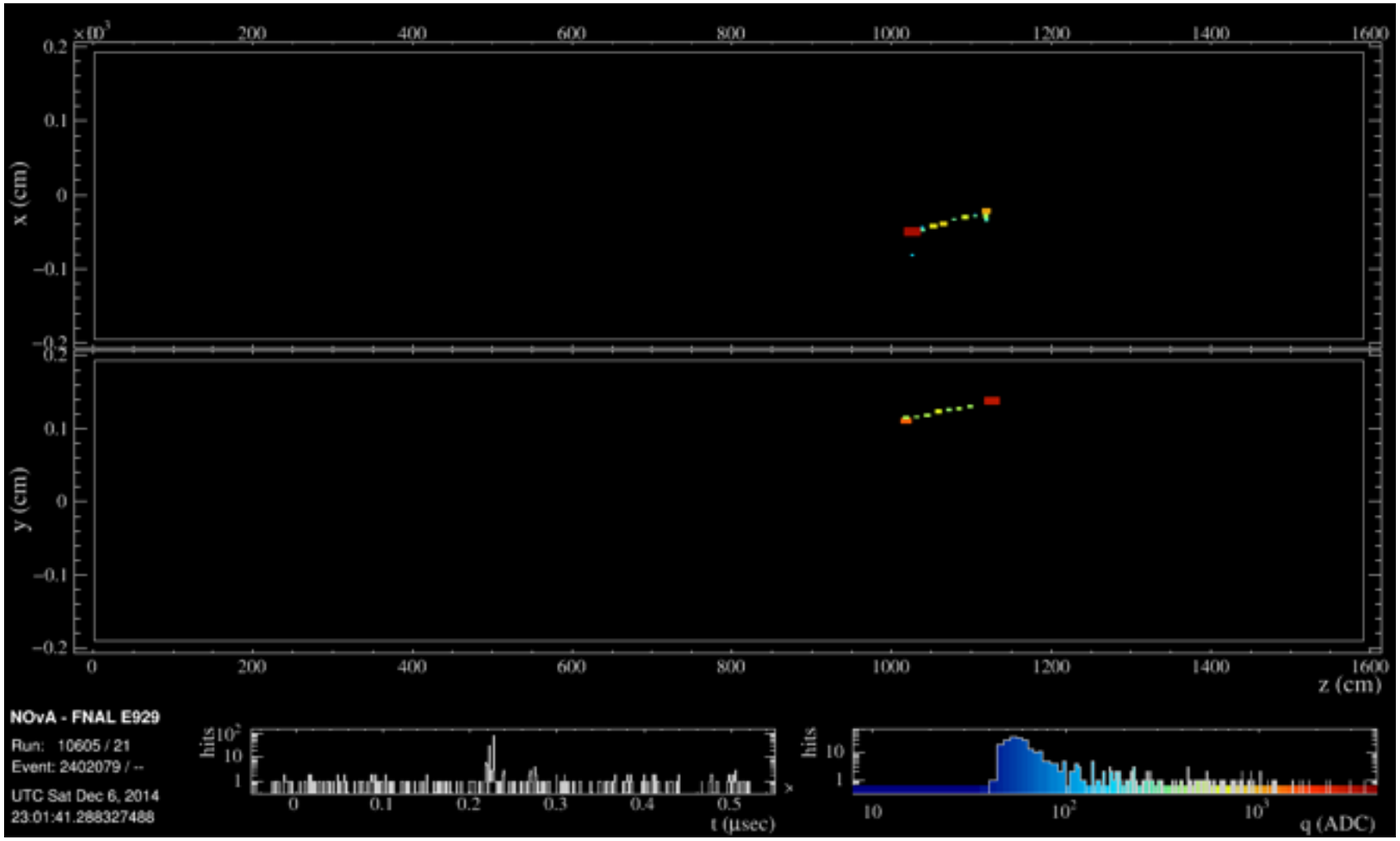

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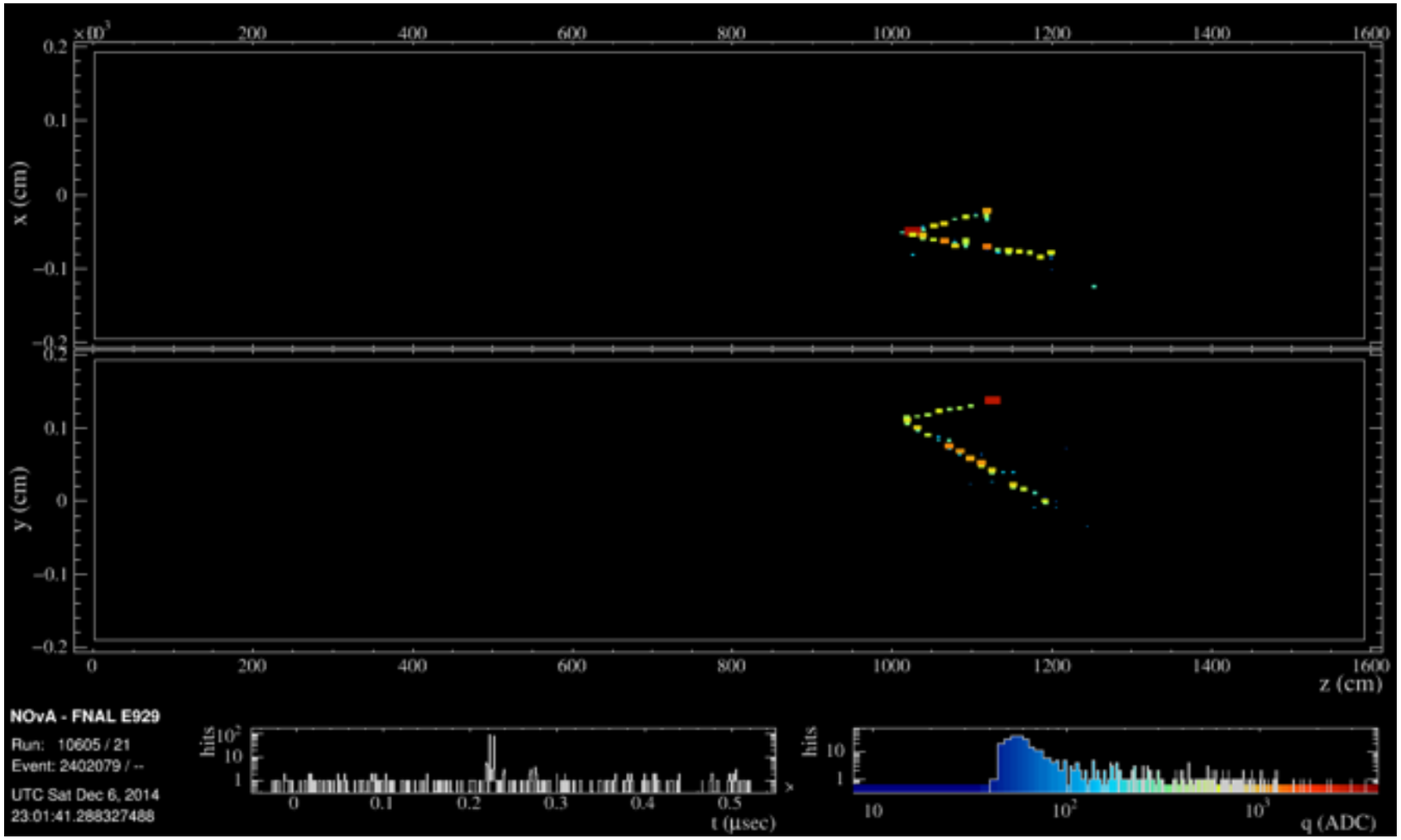

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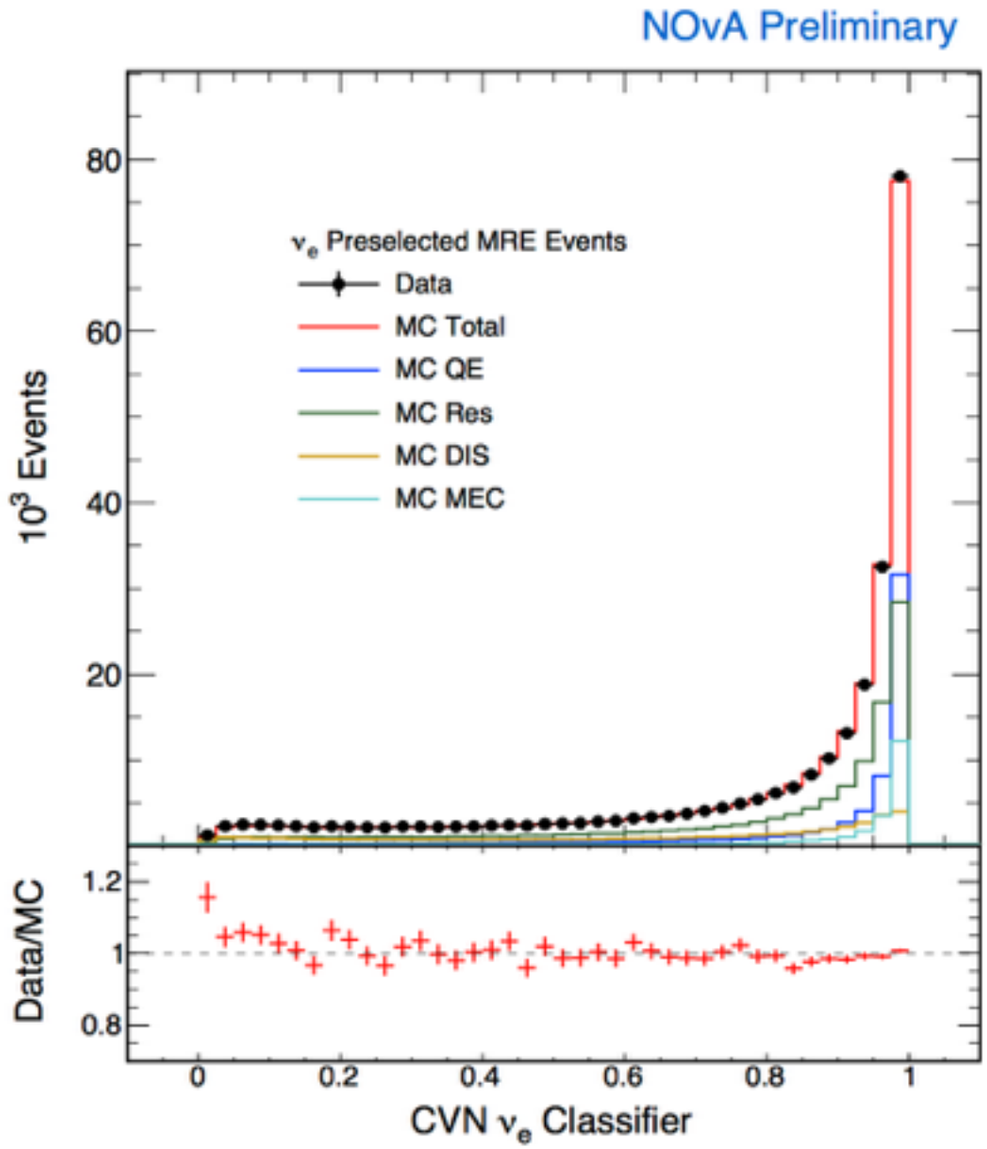

- Calculate the efficiency of PID selection from the MRE sample in Data and MC
- Calculate the correction of the efficiency of the electron neutrino signal by comparing the Data and MC efficiencies of the selection using leading prong kinematics

Summary

- The NOvA ND provides an excellent opportunity to measure the inclusive ν_e charged current (CC) cross-section

- We have done studies on resolution, background estimation, energy reconstruction, etc.

- The expected uncertainty on the measurement should be ~14%

- Aiming to have results later this year