Data-Driven constraint on the total neutrino flux using ν-e Elastic Scattering in the NOvA Near Detector

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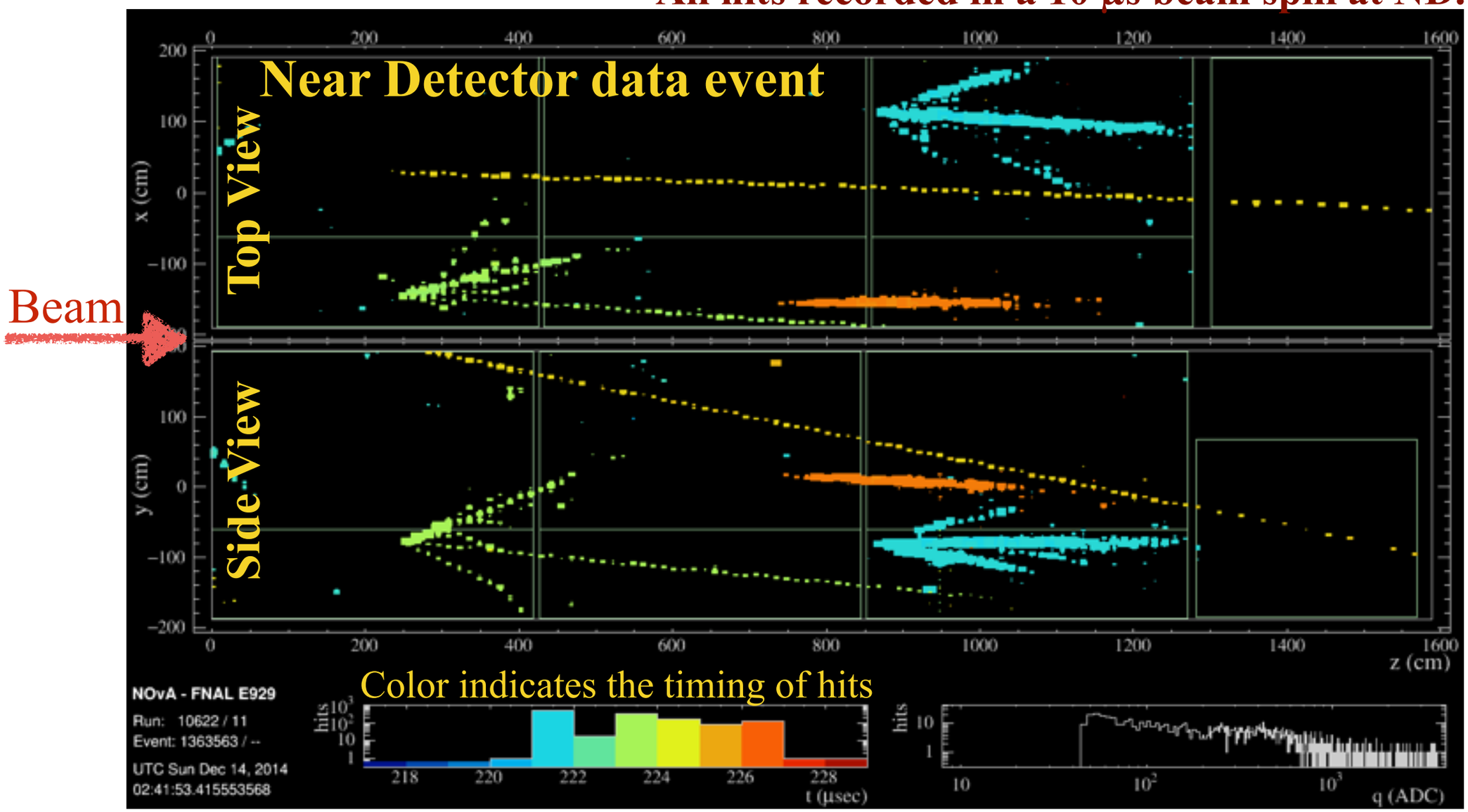
NOvA Near Detector

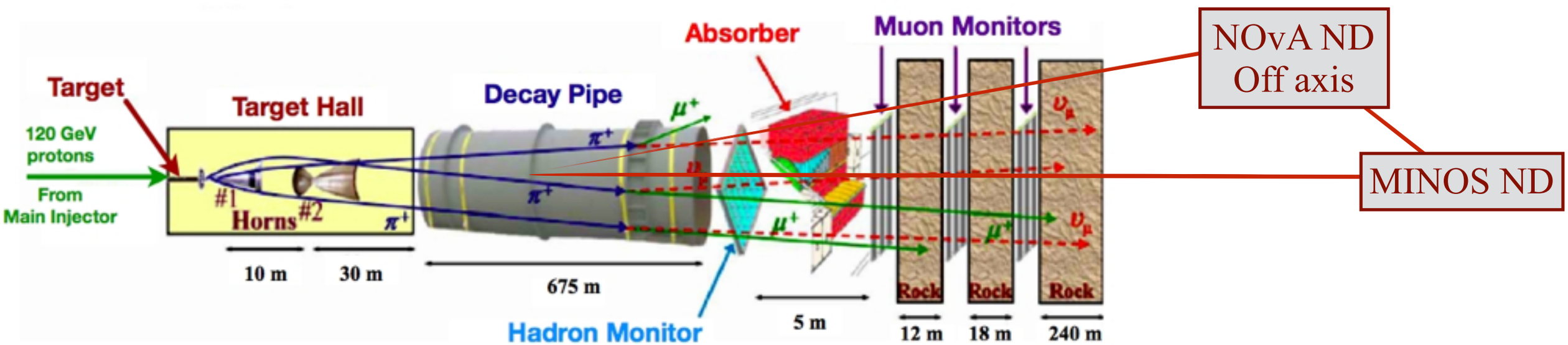
- NOvA can observe oscillations in two channels using a predominantly ν_μ beam (ν_e appearance & ν_μ disappearance).
- The Near Detector (ND), 1km from the source, used to measure composition of the un-oscillated beam.
- In addition to oscillation study, the NOvA near detector also provides an excellent opportunity for the measurement of various neutrino interactions.

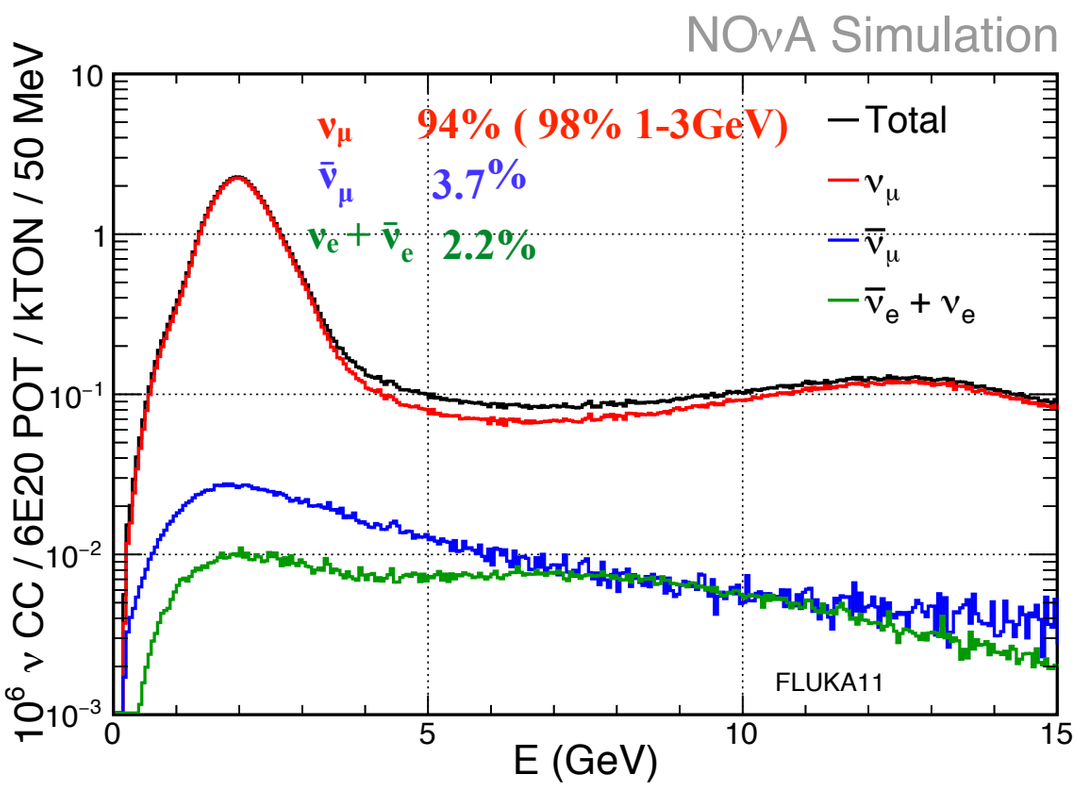
All hits recorded in a 10 μs beam spill at ND.



Low-Z, fine-grained (1 plane ~ 0.15X0), highly active tracking calorimeter, optimized for EM shower reconstruction

NuMI Beam

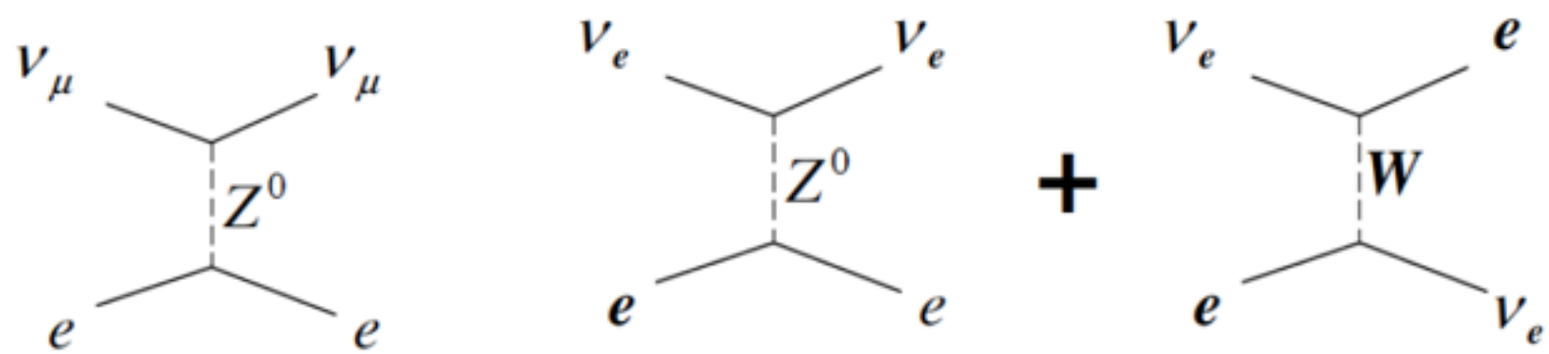




Neutrino mode: horns focus positives

- The sensitivity of the oscillation studies critically depends upon precise prediction of un-oscillated ν_μ, $\bar{\nu}_\mu$, $\nu_e+\bar{\nu}_e$ flux-ratio: FD/ND (E_ν).
- Dominant uncertainties in the neutrino flux come from poor knowledge of hadron production modeling.
- We need to constrain the flux using external hadron production data (MIPP, NA49…). Due to lack of data from the hadron production experiment.
- Flux constraint using Near Detector Data.

ν-e elastic scattering



$$\nu_\mu + e^- \rightarrow \nu_\mu + e^-$$
$$\bar{\nu}_\mu + e^- \rightarrow \bar{\nu}_\mu + e^-$$

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

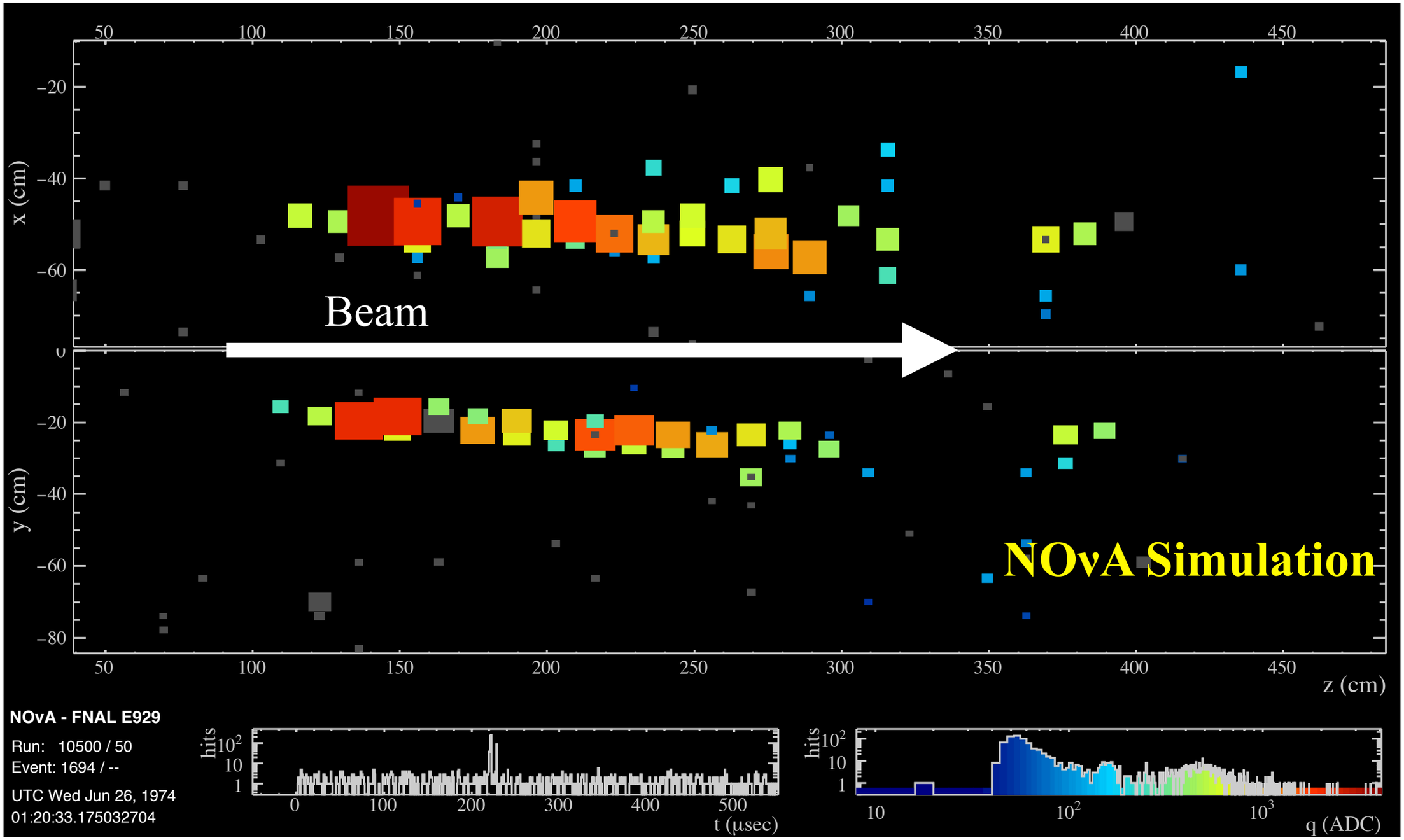
ν-e elastic scattering is pure leptonic process which can be calculated accurately (~1%), ν-e scattering measurement can be used to improve the flux in NOvA ND.

Very forward single electron final state

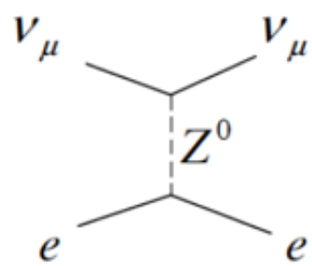
$$E_e\theta^2 < 2m_e$$

Because of the very small momentum transferred to the electron, the signal is a very forward single electron.

ν-e elastic scattering



Known interaction (standard candle)



$$\nu_\mu + e^- \rightarrow \nu_\mu + e^-$$
$$\bar{\nu}_\mu + e^- \rightarrow \bar{\nu}_\mu + e^-$$

Flux constraint using Near Detector

$$\sigma = \frac{N}{\phi \cdot A \cdot \epsilon}$$

$$\phi = \frac{N}{\sigma \cdot A \cdot \epsilon}$$

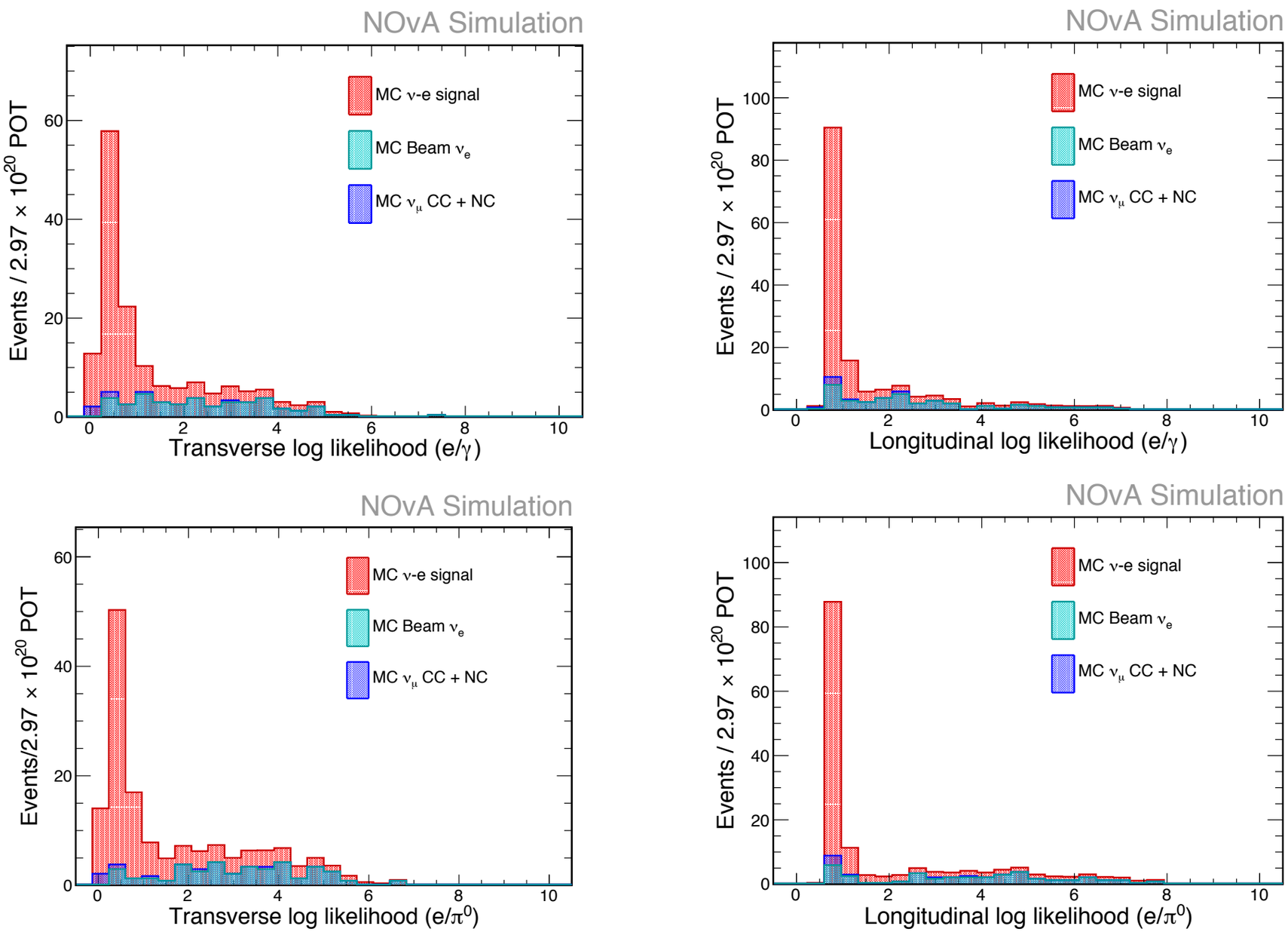
Flux uncertainty goes into cross section uncertainty

Cross-section uncertainty goes into flux uncertainty

ν-e scattering is well known interaction we can use to constrain the neutrino flux

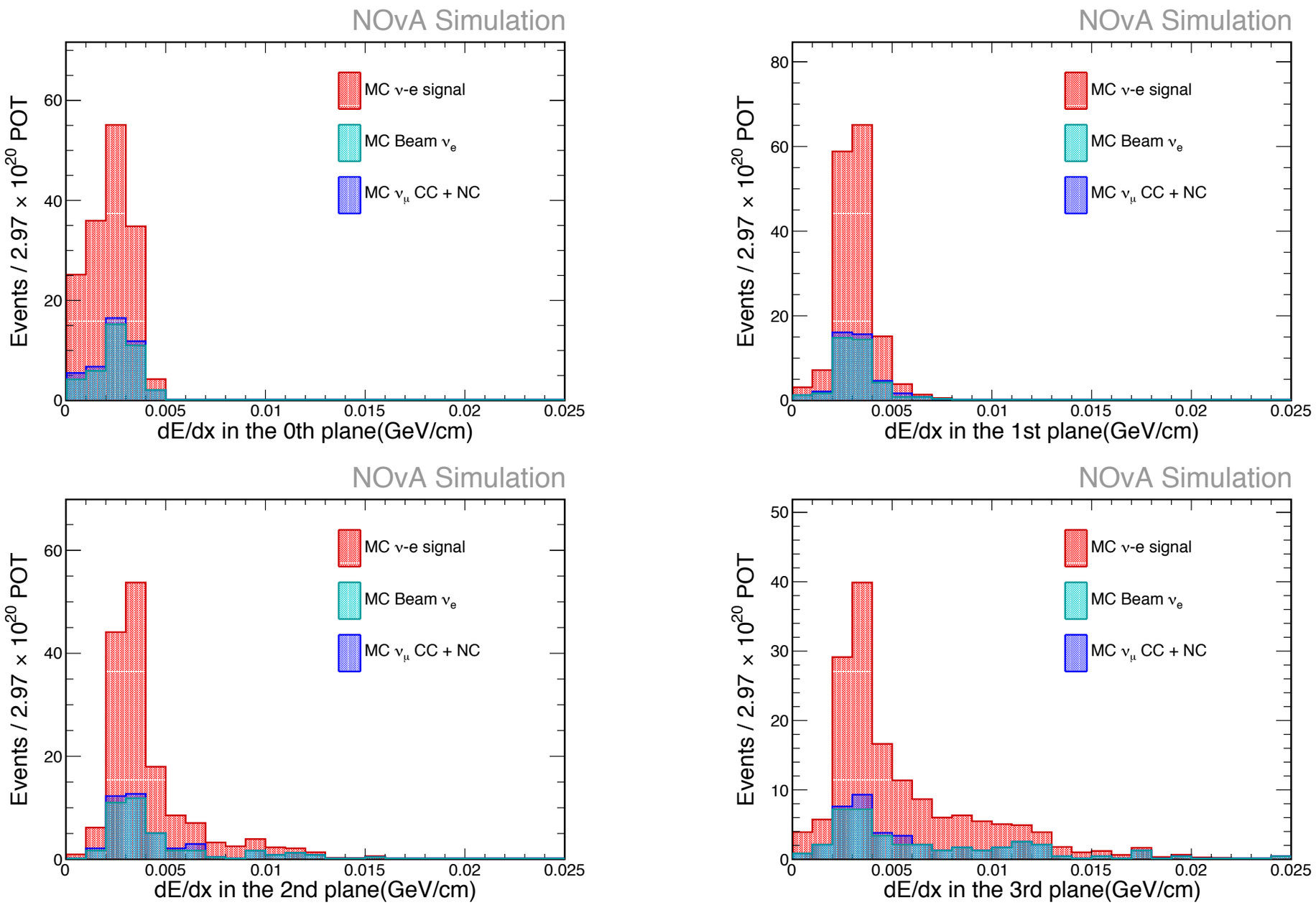
ν-e elastic scattering

- After pre-selection cuts, fiducial, single shower cut and E > 0.5GeV.
- Background (ν_e-CC, ν_μ-NC, coh-π^0) rejection is very important to identify the signal as the cross section is very low (~10^{-4} of total).
- ν-e event identification is implemented into PID based on ANN.



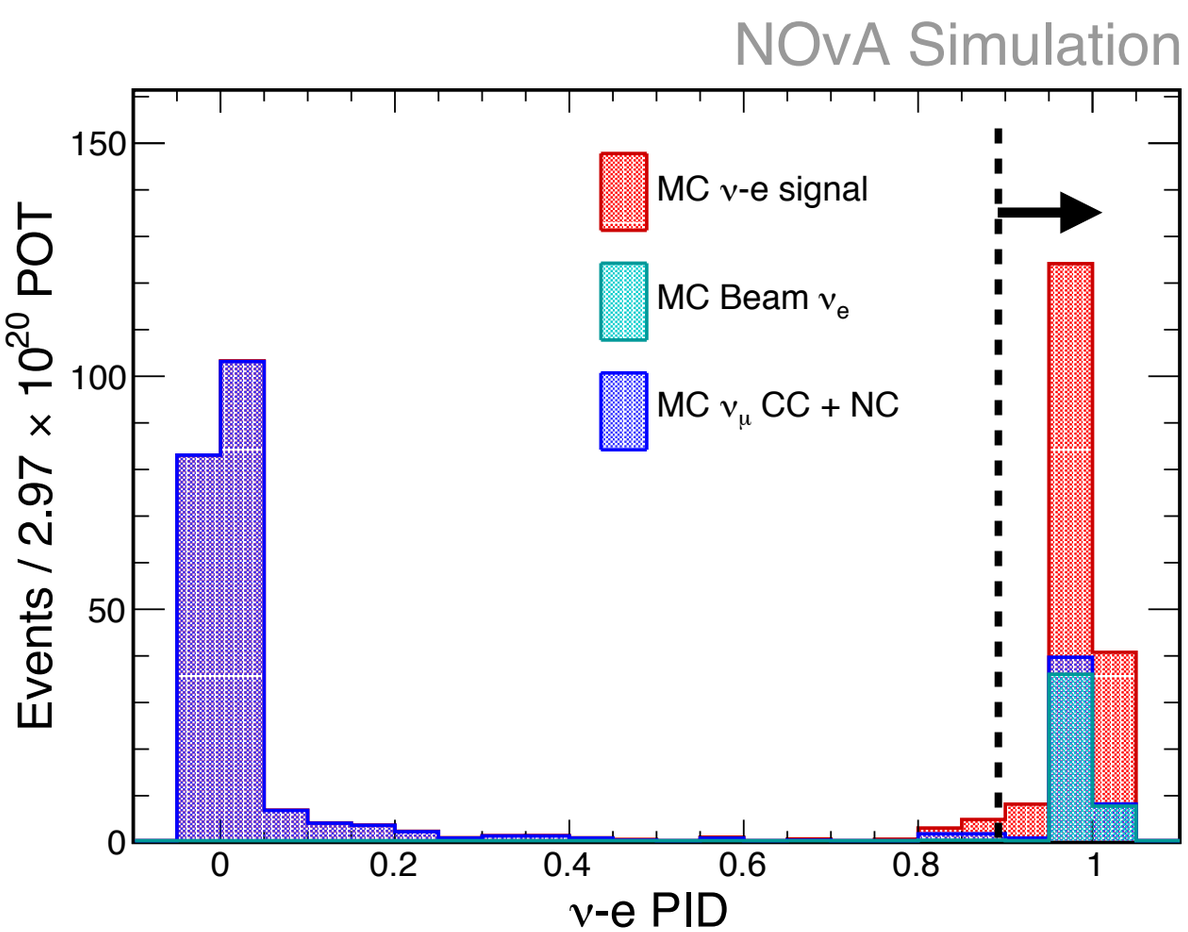
ν-e elastic scattering

- Coherent π^0 production process is also with small momentum transfer almost collinear with the incident neutrino and manifest itself an electromagnetic shower.
- Needed another PID for the rejection of coherent π^0 background.
- dE/dx inputs in first four plane

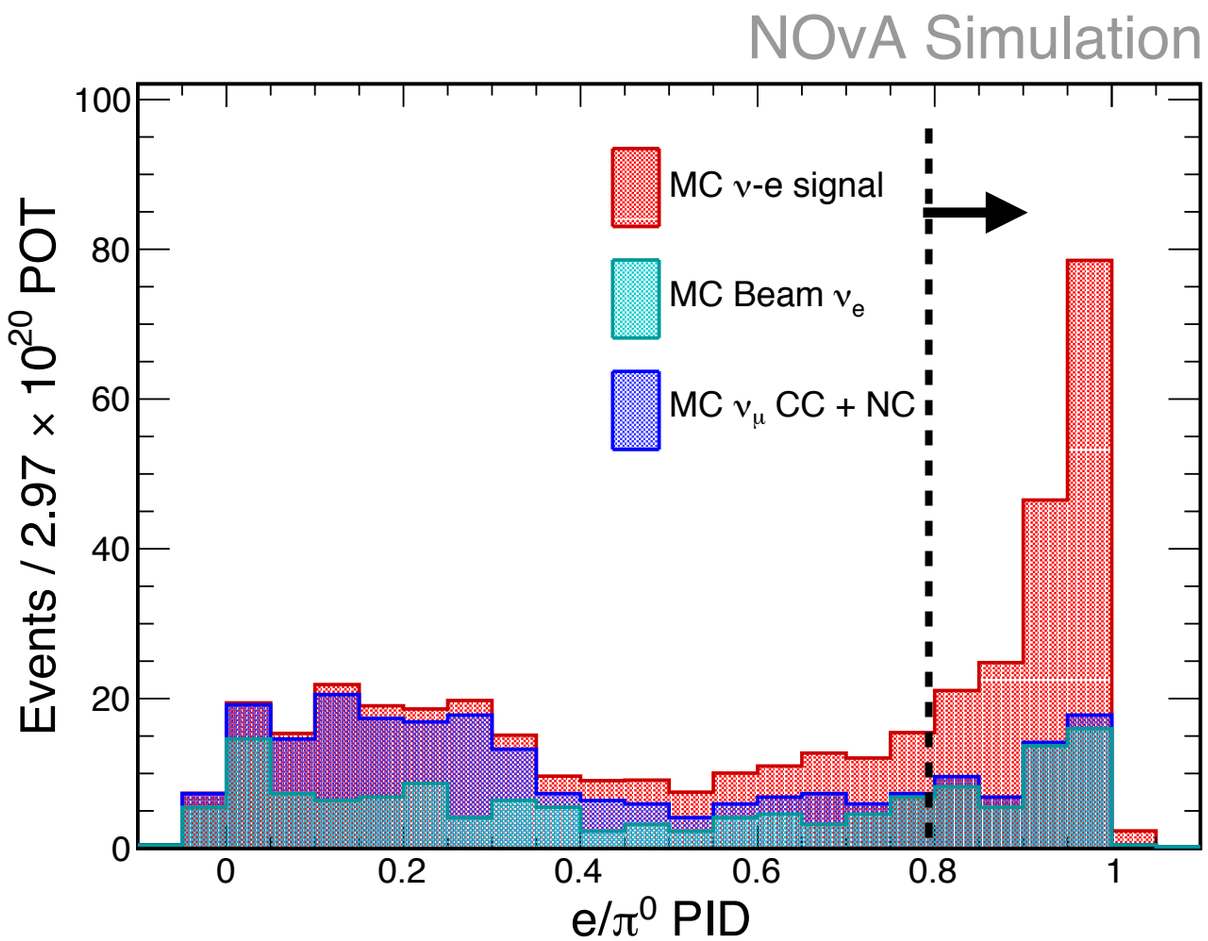


ν-e elastic scattering

PID distributions to reduce the background (ν_e-CC, ν_μ-NC, coh-π^0).



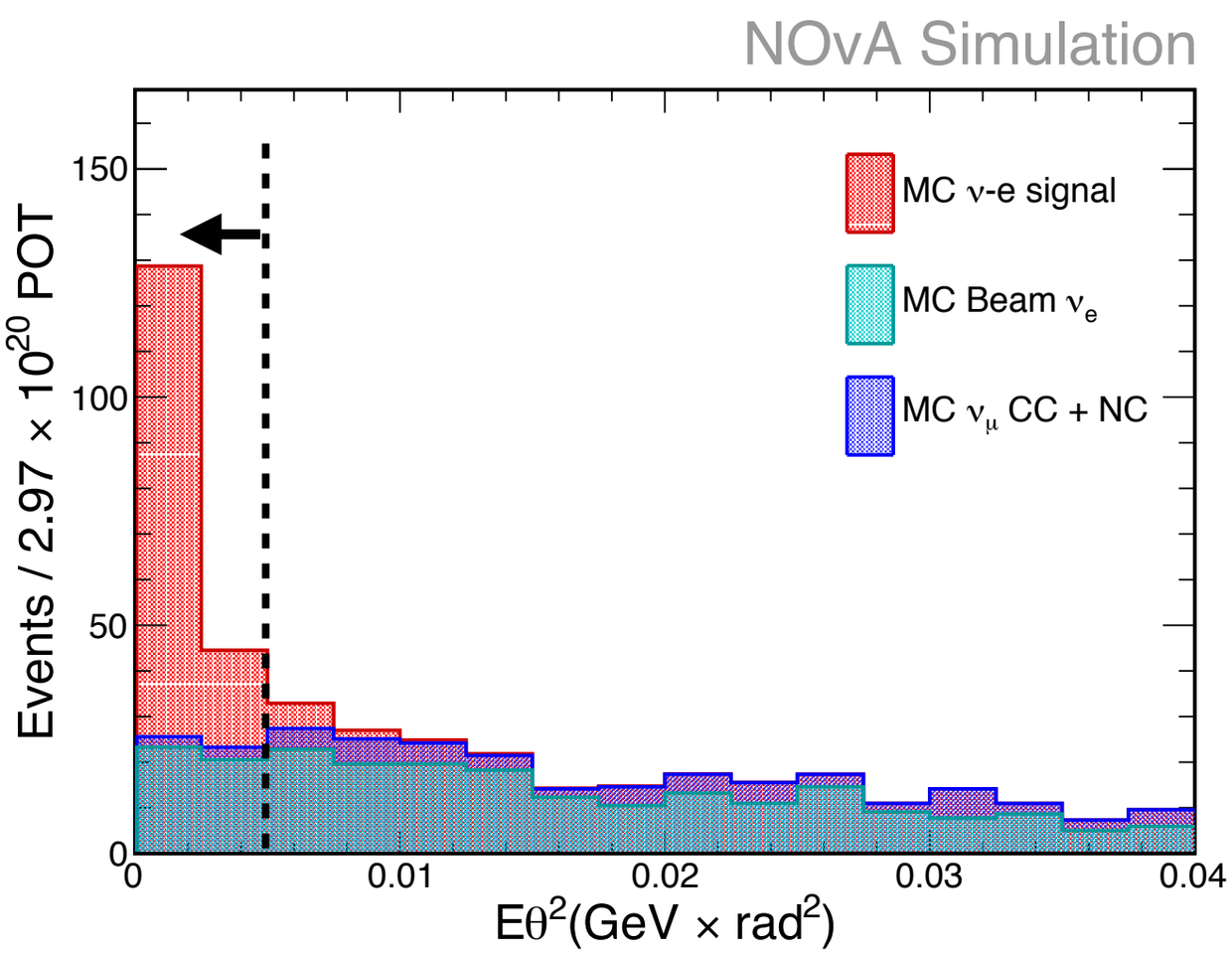
Preselection cuts+π^0PID+ $E\theta^2$<0.005+E>0.5



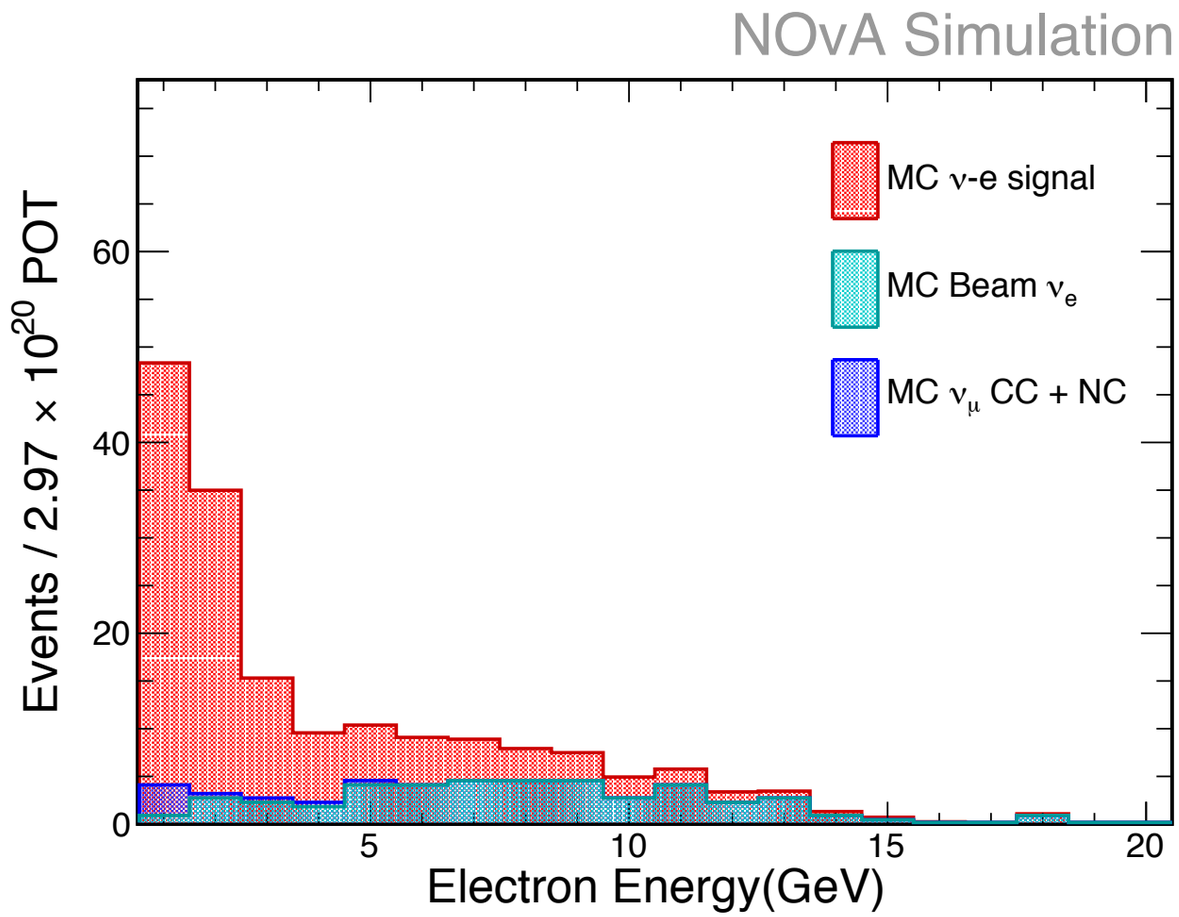
Preselection cuts+ν-e PID+ $E\theta^2$<0.005+E>0.5

ν-e elastic scattering

Kinematic ($E\theta^2$) Selection and Electron Spectrum



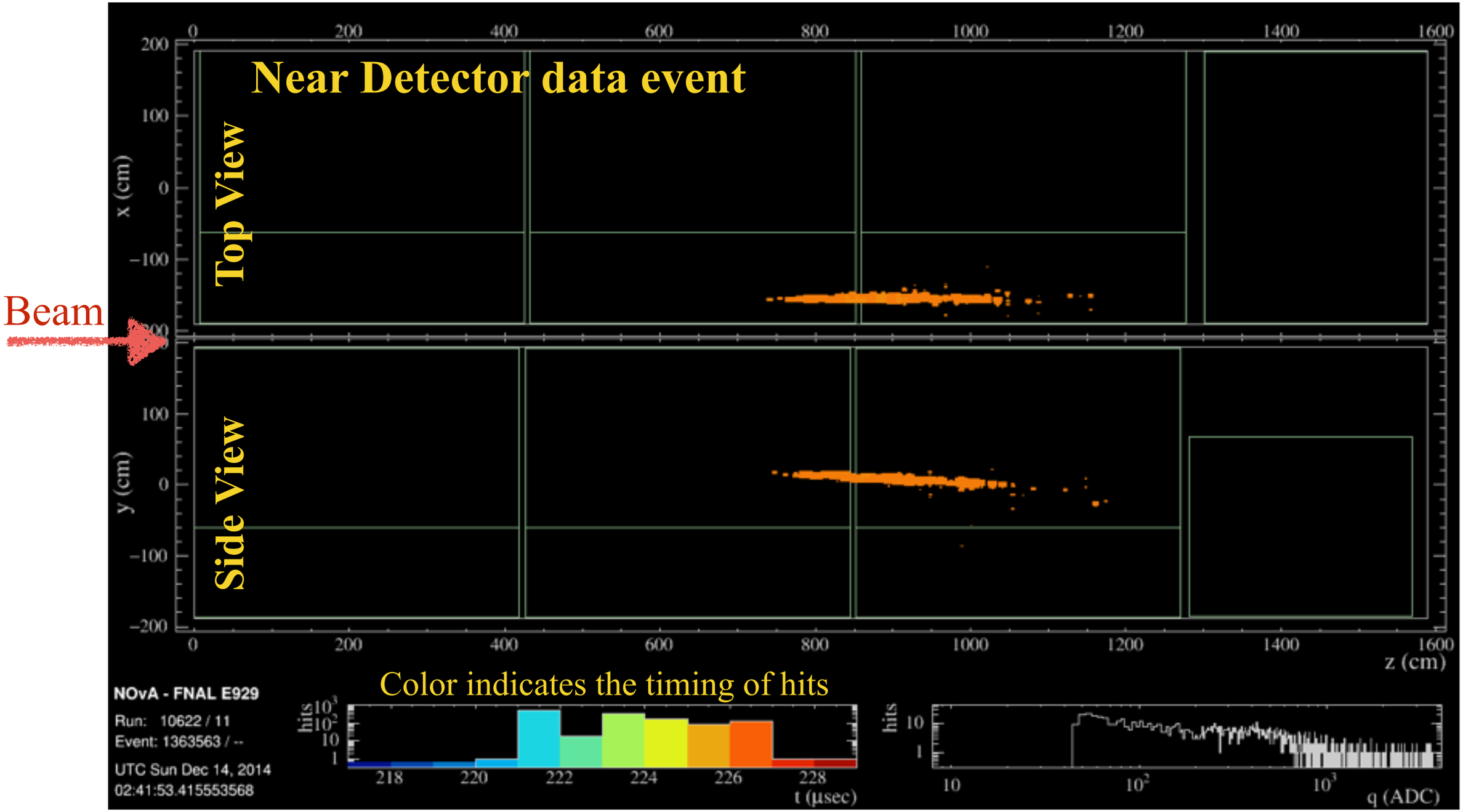
Preselection cuts+PIDs+E>0.5



Preselection cuts+PIDs+ $E\theta^2$<0.005+E>0.5

ν-e elastic scattering event candidate

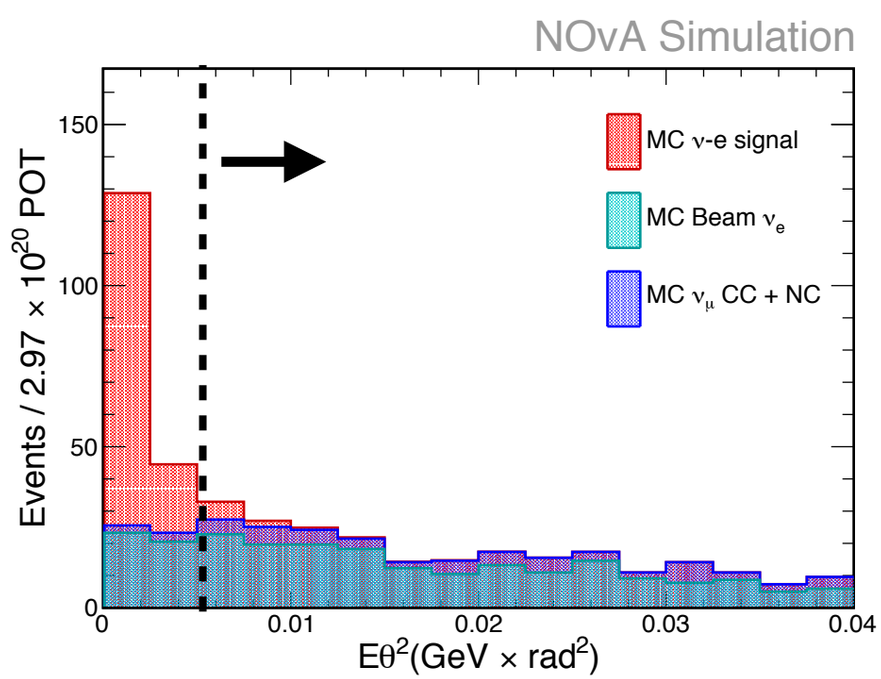
All hits recorded in a 10 μs beam spill at ND.



ν-e Elastic Scattering

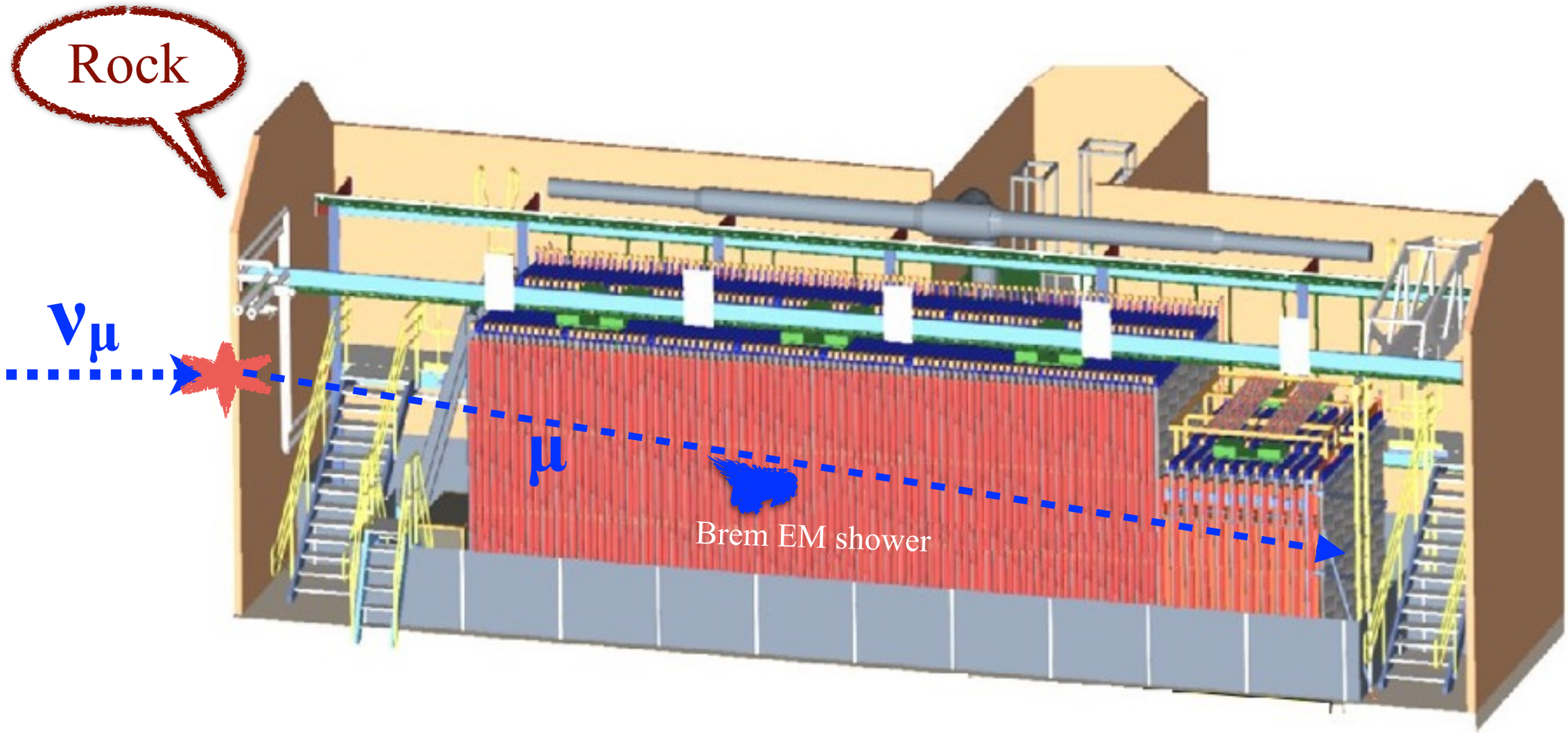
Important Systematics Studies for ν-e Elastic Scattering Measurement

- To recover the Data/MC difference for the background in the signal region $E\theta^2 < 0.005$, we will use sideband samples for $0.005 < E\theta^2 < 0.04$.



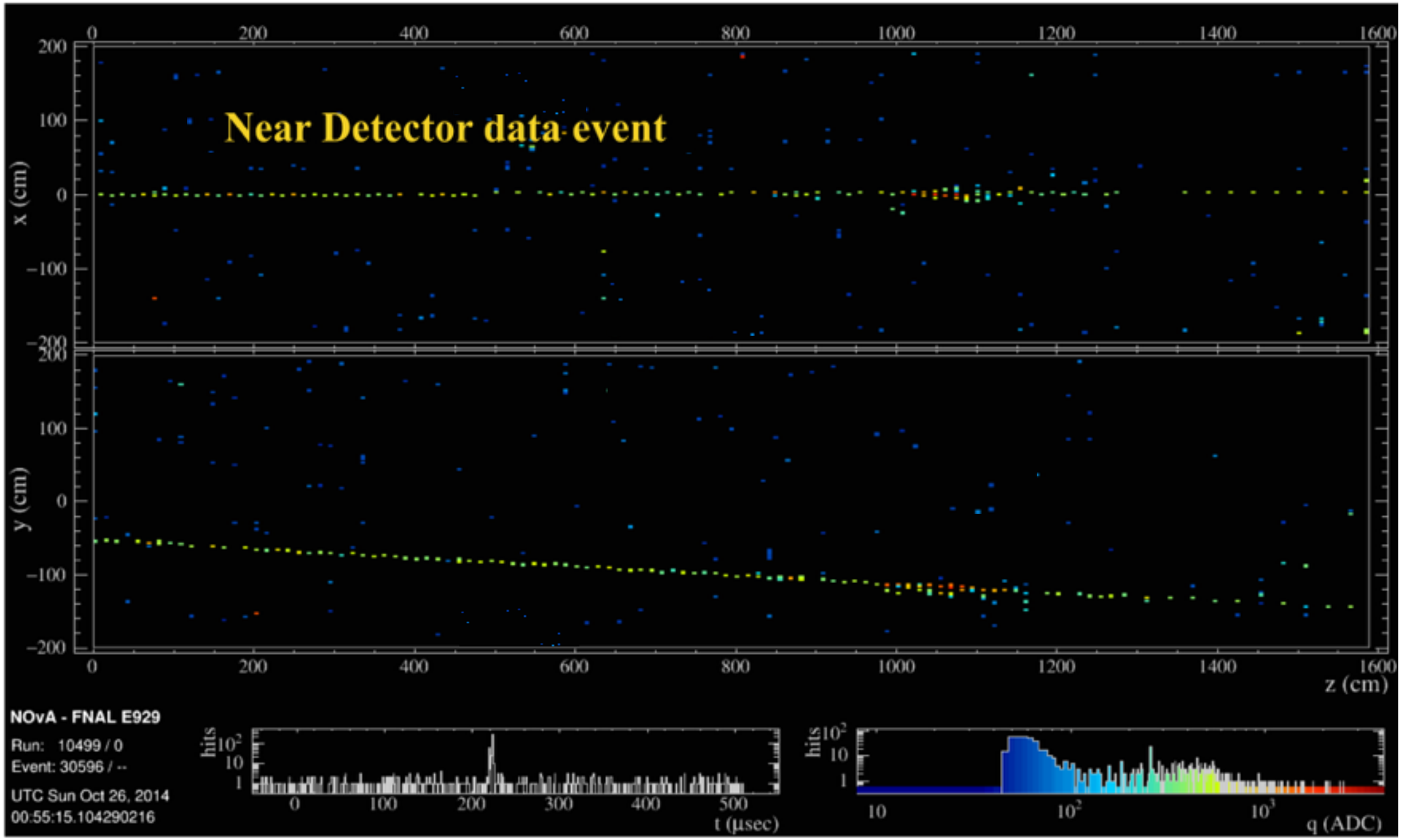
- Signal Efficiency Uncertainty, we are using muon induced EM showers to validate the shower selection efficiencies in both data and MC (will explain this in the following slides)

Select rock muon induced EM showers

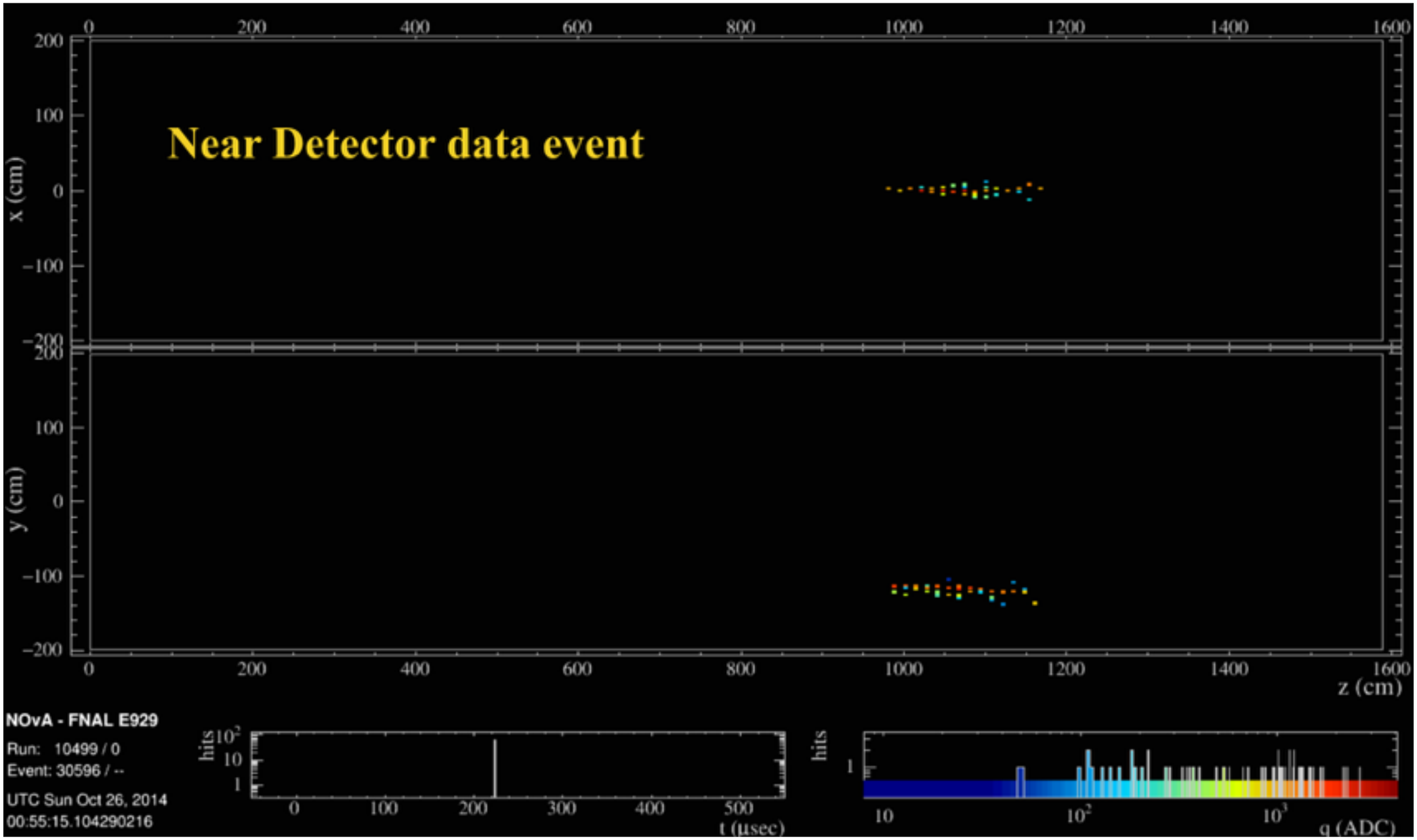


Data-driven method to select EM showers to confirm the shower reconstruction and PID. We select EM showers from bremsstrahlung muons, which are produced from muon neutrino interactions in the rock upstream of the detector.

Select rock muon induced EM showers



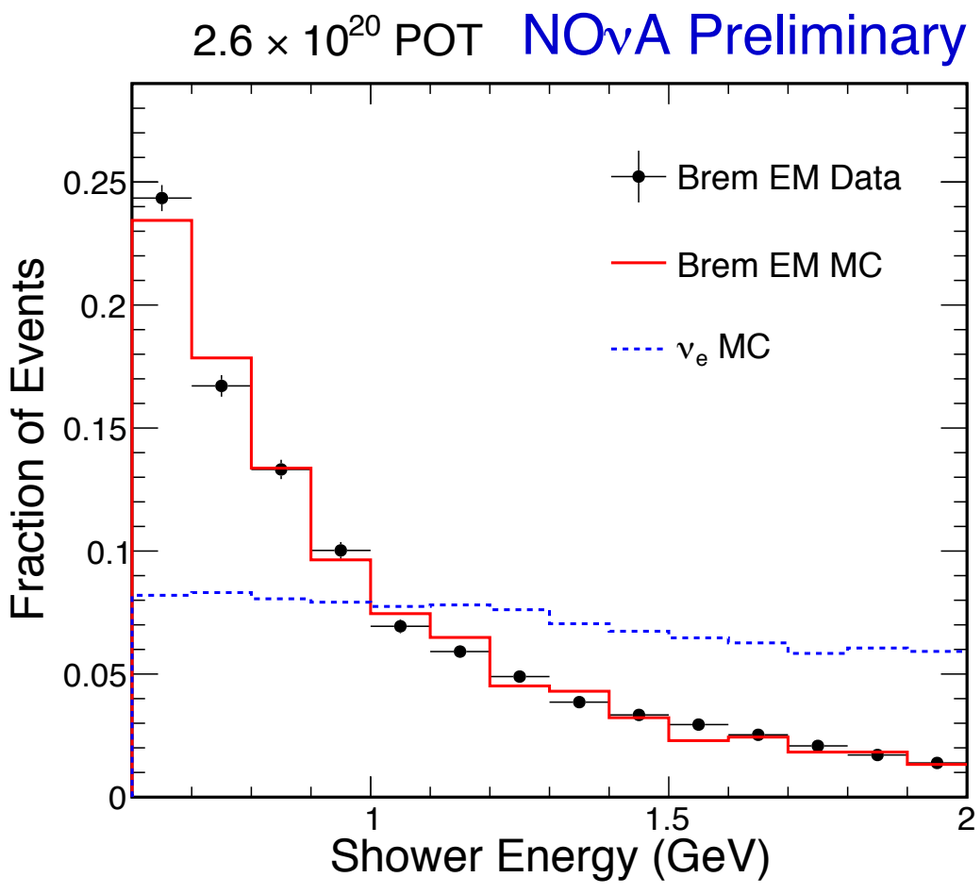
Select rock muon induced EM showers

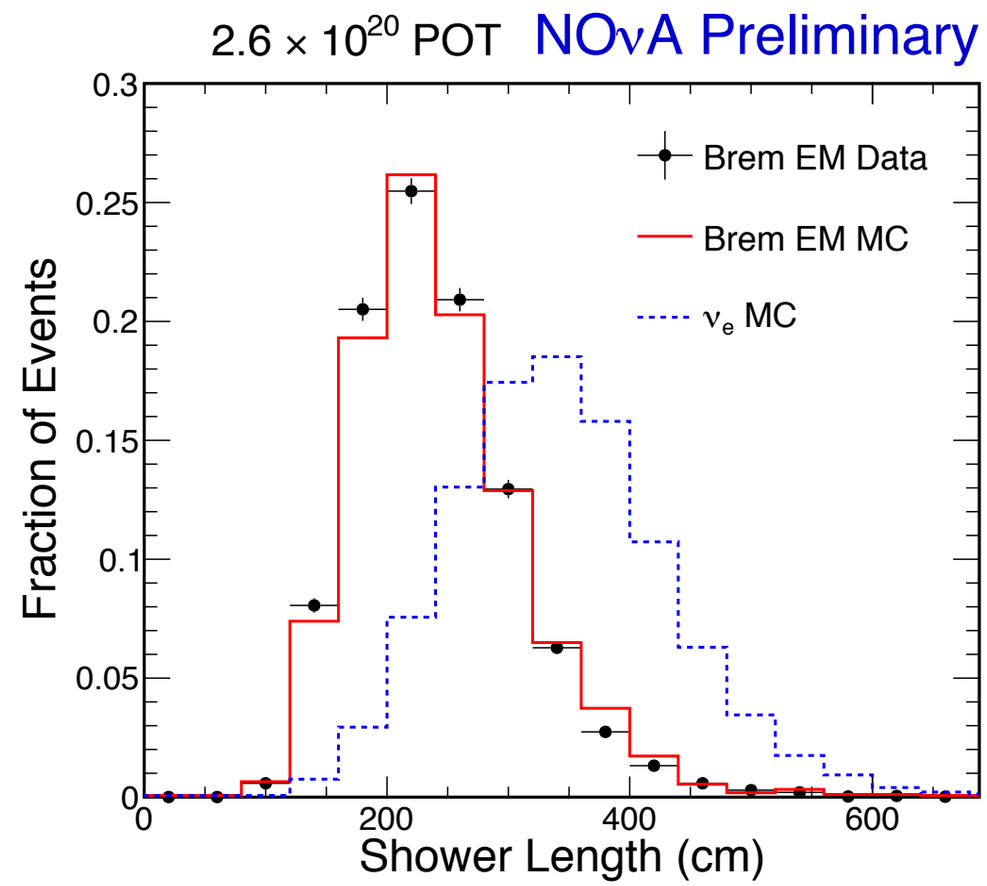


Select rock muon induced EM showers

- Use rock muon EM showers to check the signal uncertainty

- Rock Muon induced EM showers(Brem EM showers) have similar shower properties as the nu-on-e events.





Take the data/MC difference in selection efficiency as systematics.

Summary

- An accurate knowledge of neutrino flux will benefit current and future oscillation experiments.
- Data/MC from ν-e elastic scattering measurement will be used to constraint the neutrino flux.
- Current systematics error ~9% and statistical error ~10% for (0.5-20)GeV range.
- Work is in progress.