Measurement of Neutrino-Electron Elastic Scattering at NOvA Near Detector

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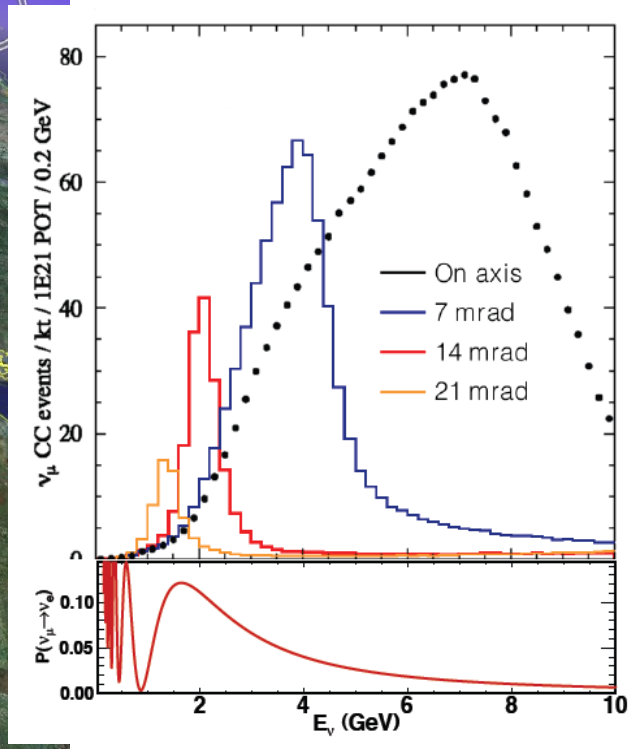
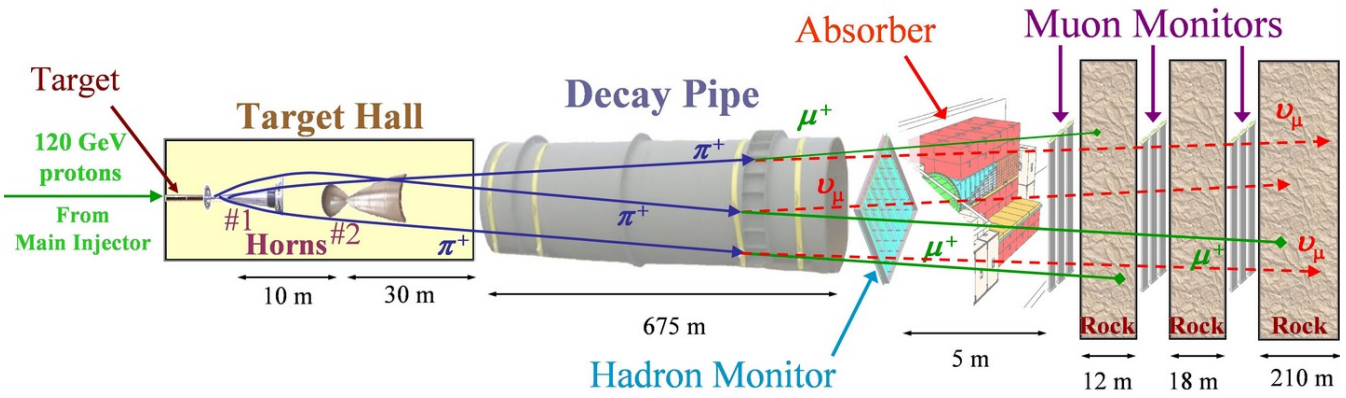
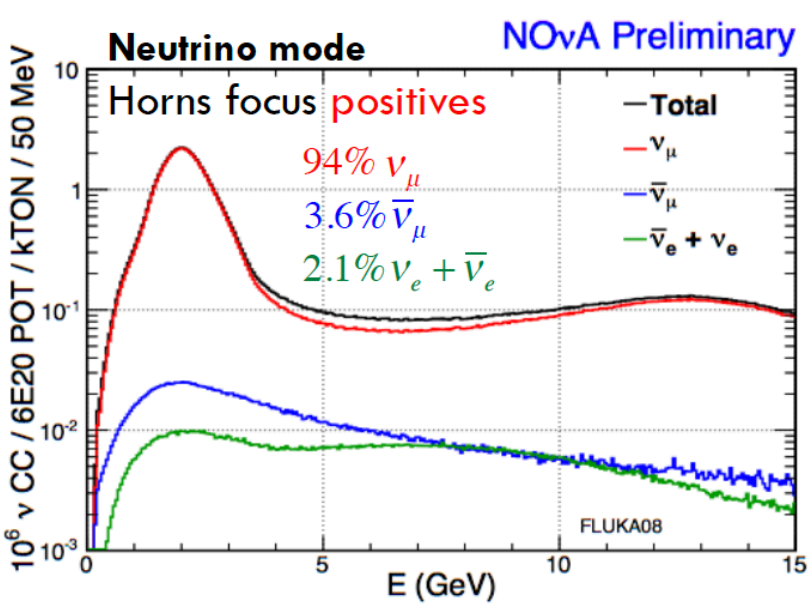
NuMI Off-Axis ν_e Appearance Experiment

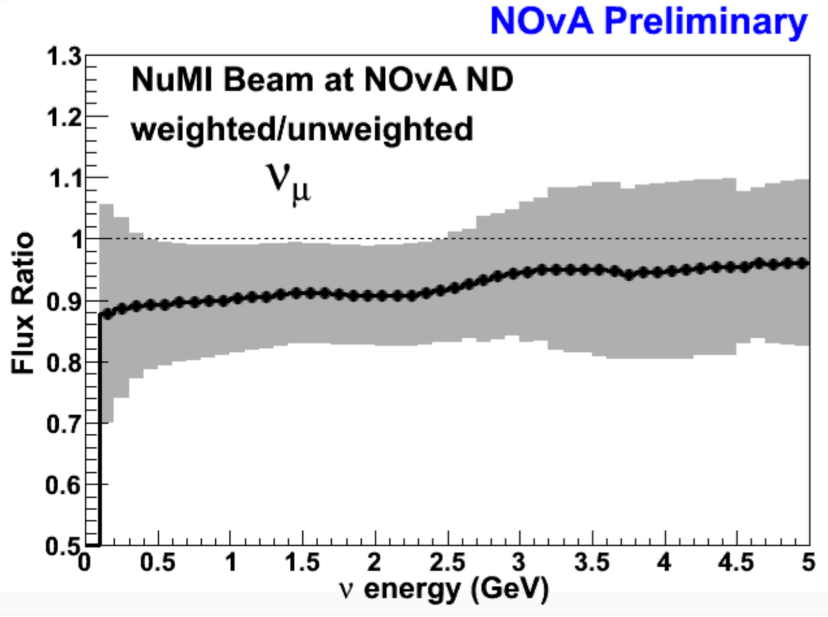


- Upgraded NuMI muon neutrino beam (2.3% ν_e in ν_μ beam) at Fermilab (700 kW design)
- Longest baseline in operation (810 km), large matter effect (±30%), sensitive to mass hierarchy
- **Far/Near detector is sited 14 mrad off-axis to produce a narrow-band beam around the oscillation maximum region**

NuMI Off-Axis ν_e Appearance Experiment



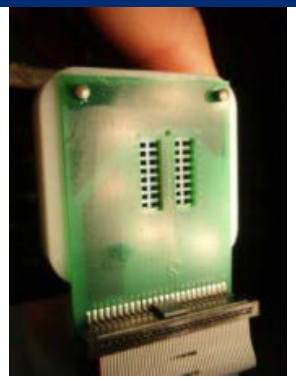


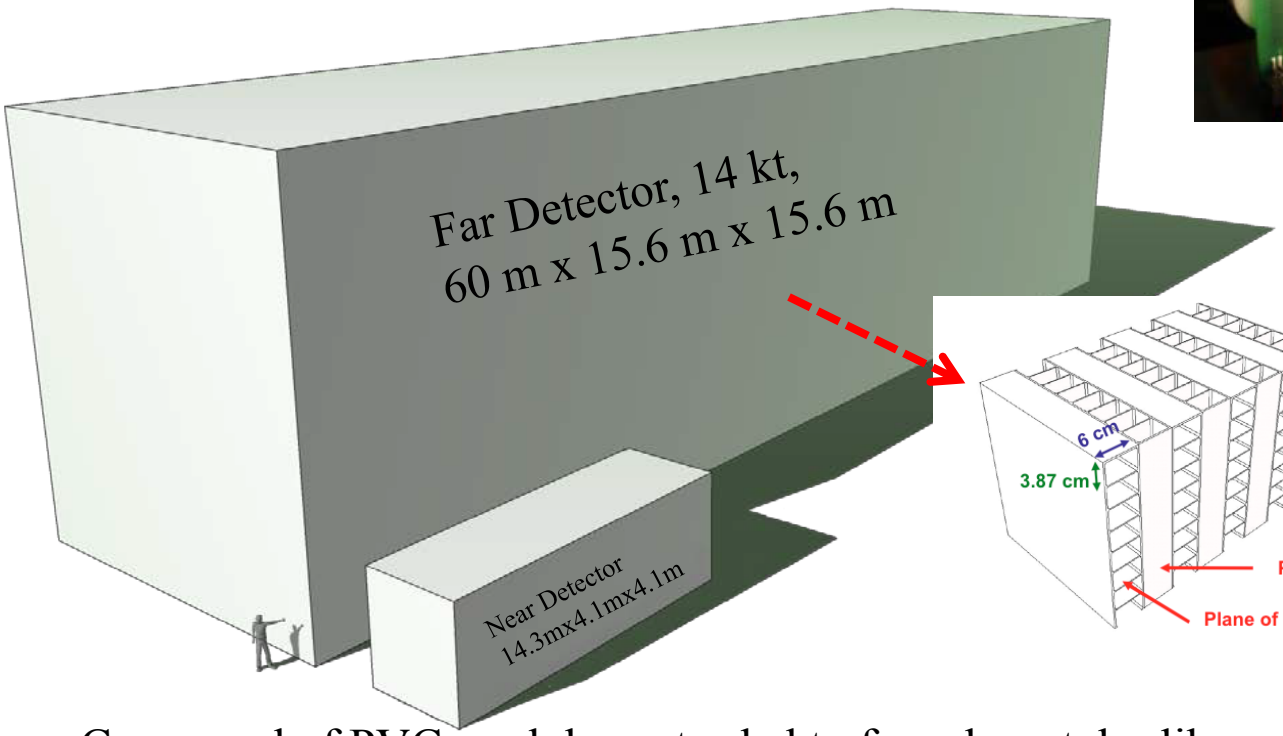


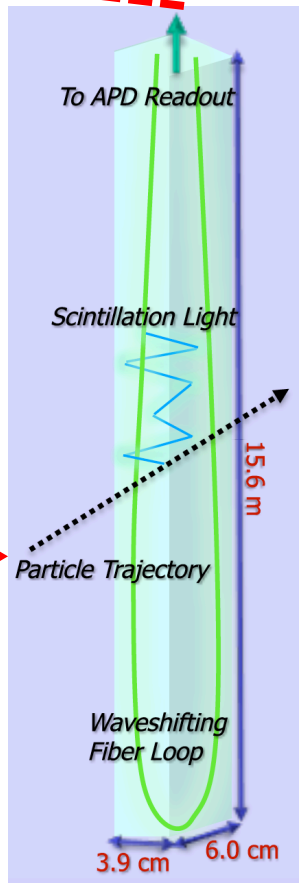
Flux uncertainty ~ 10%

The NOvA Detectors

- 14-kton Far Detector
- 344,064 detector cells
- 0.3-kton functionally identical Near Detector
- 18,432 cells

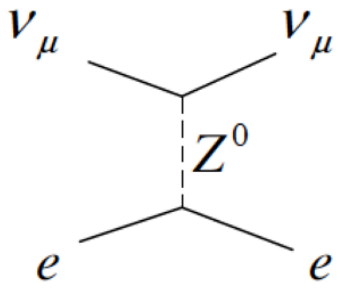


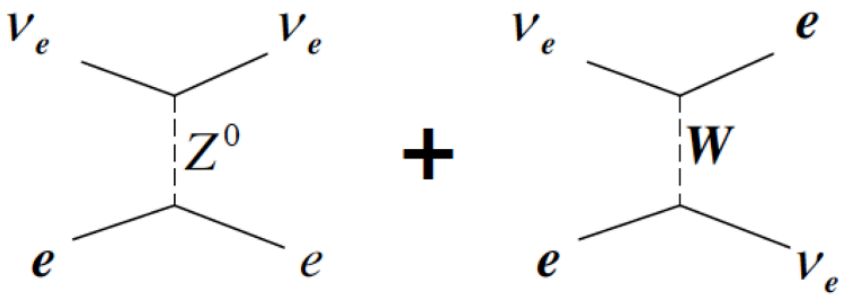




- Composed of PVC modules extruded to form long tube-like cells : 16m long in FD, 4m ND
- Each cell is filled with liquid scintillator and has a loop of wavelength-shifting fiber (WLS) routed to an Avalanche Photodiode (APD)
- Cells arranged in planes, assembled in alternating vertical and horizontal directions
- **Low-Z and low-density, each plane just 0.15 X_0. Great for e^- vs π^0**

Neutrino-Electron Elastic Scattering





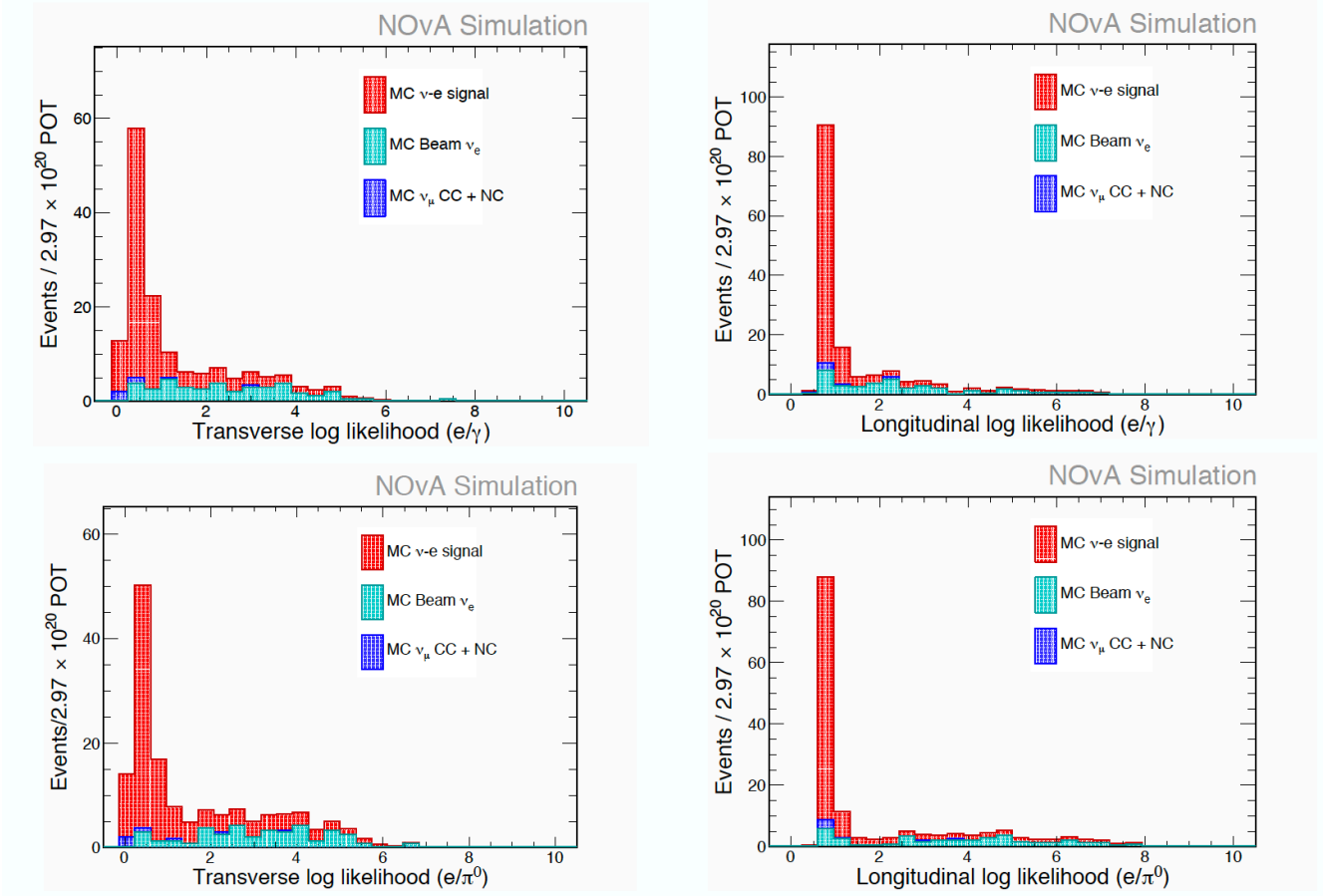
$$\nu_\mu + e^- \rightarrow \nu_\mu + e^-$$
$$\bar{\nu}_\mu + e^- \rightarrow \bar{\nu}_\mu + e^-$$

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

- ν-e scattering is pure leptonic process which can be calculated accurately (~1%). **So it can be used to absolutely constrain flux**
- Because of the small Q^2, the scattered electron is very forward, $E_e\theta^2<2m_e$
- The cross-section is very low (~10^{-4} of total), so PID and background rejection is very important to identify the signal
- $2.97*10^{20}$ POT used

Neutrino-Electron Elastic Scattering identification

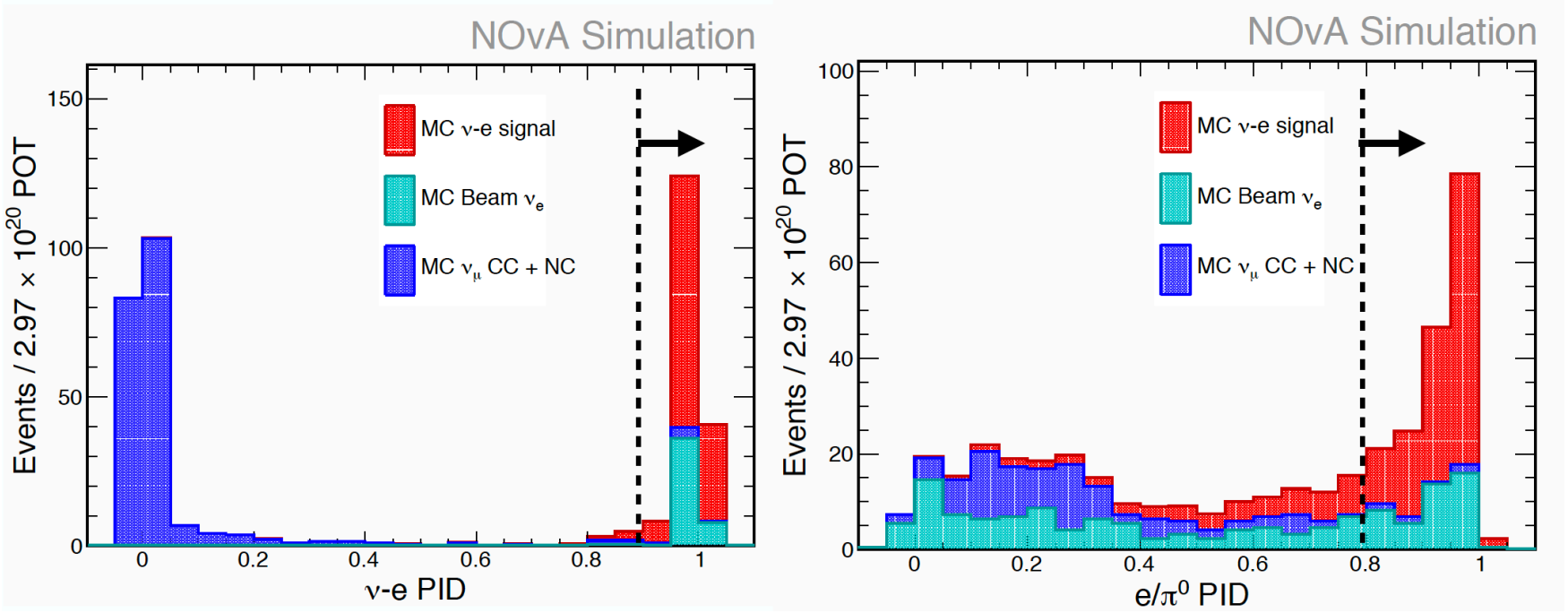
- ν-e scattering identification: dE/dx based shower likelihoods in longitudinal and transverse directions



Neutrino-Electron Elastic Scattering identification

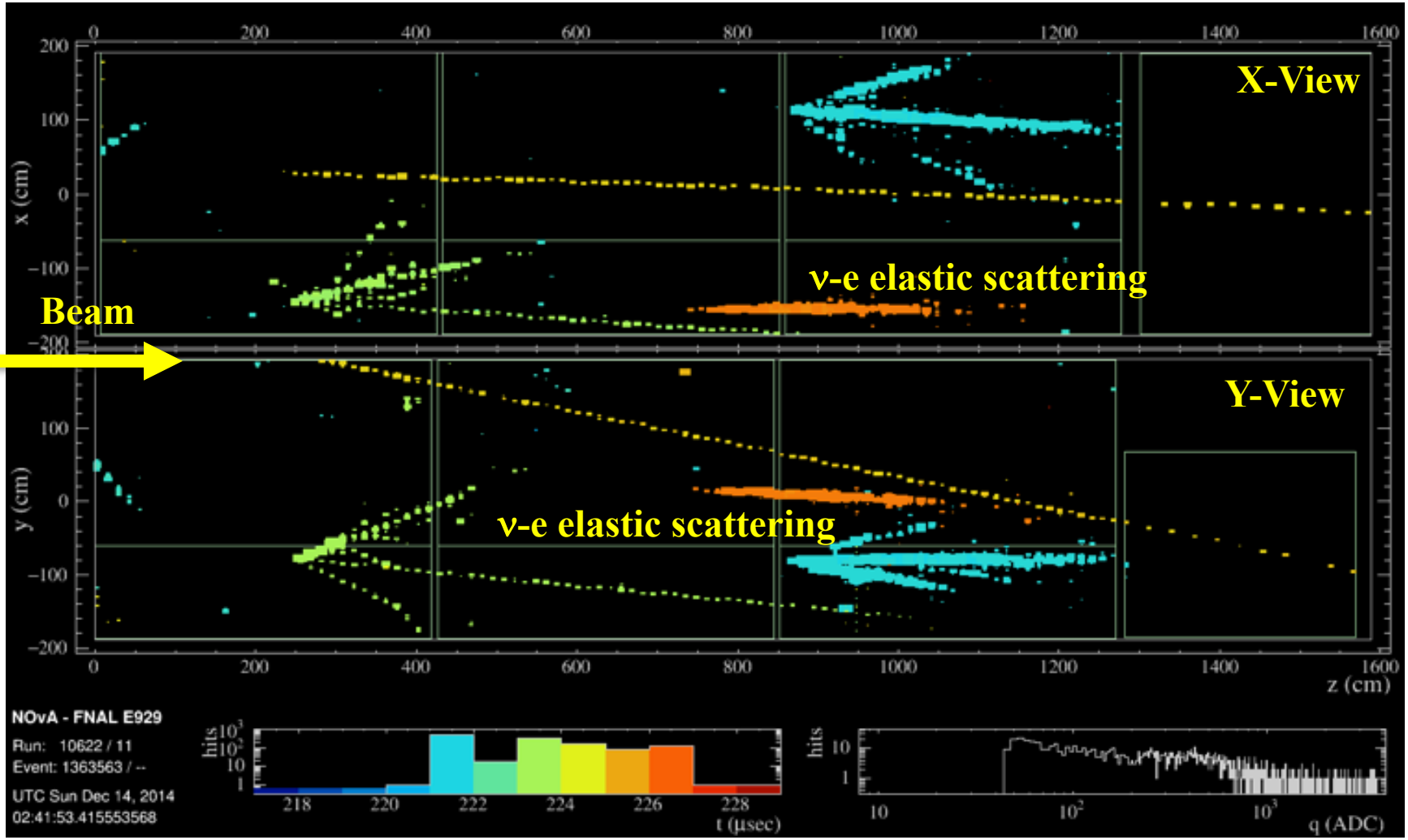
- ν-e scattering identification: plane dE/dx and shower likelihoods
  - 1) beam background rejection
  - 2) π^0 rejection
- Other requirements: Containment, single shower, 0.5<energy<5GeV (oscillation region)

Low energy part can be used to measure neutrino magnetic moment, see Poster 268, B. Wang

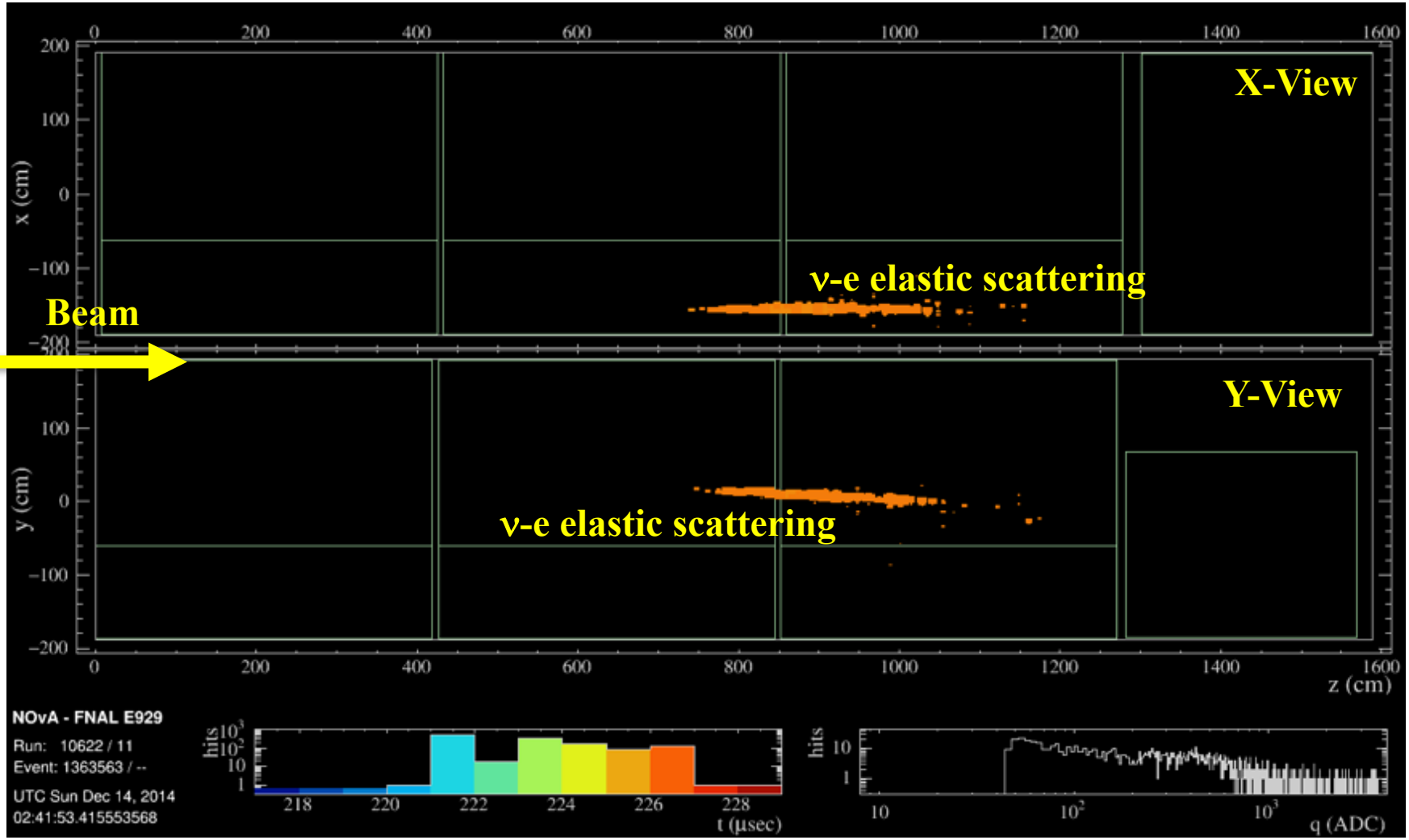


Neutrino-Electron Elastic Scattering in a Trigger Window (ND)

Timing slicer separates different interactions in a spill

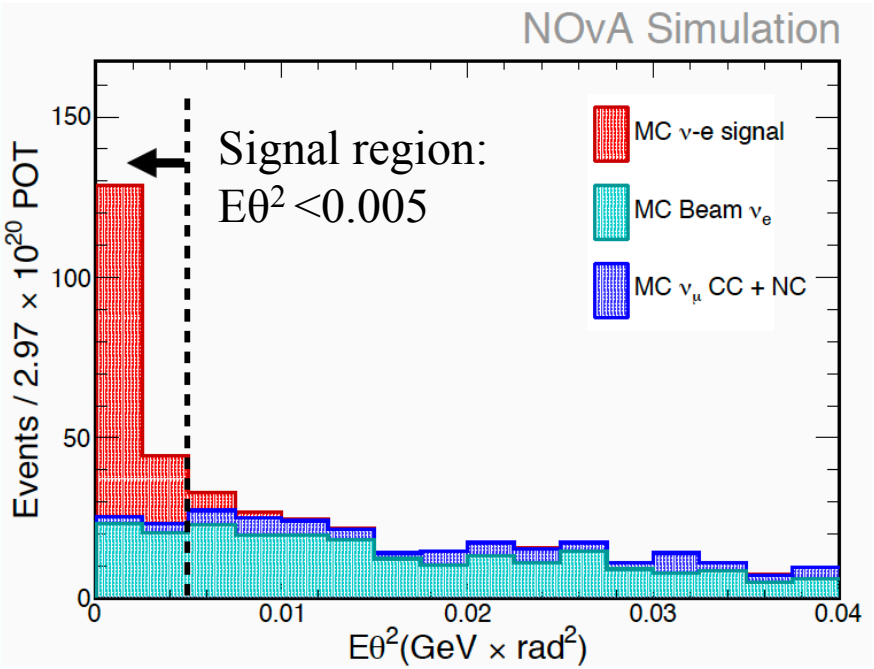


Neutrino-Electron Elastic Scattering after event selection (ND)

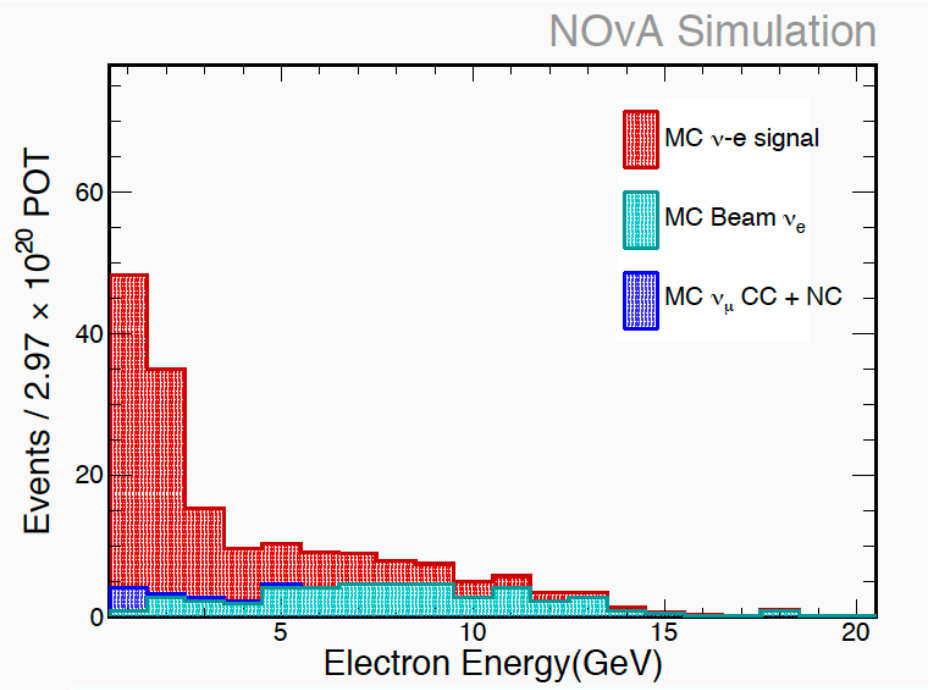


Neutrino-Electron Elastic Scattering after event selection

$E\theta^2$ distribution

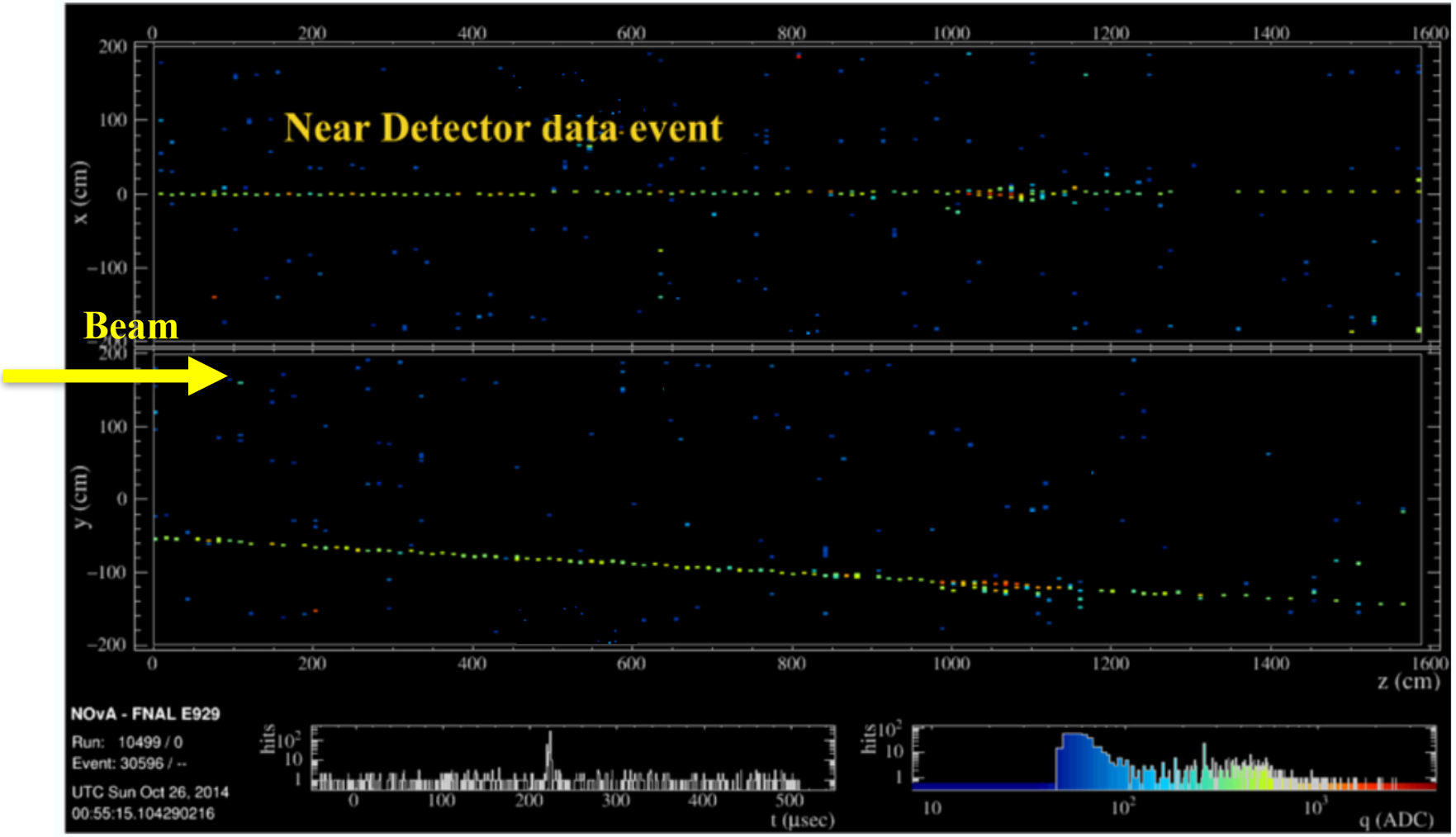


Electron energy spectrum in signal region



In signal region, expect to see ~140 signal events and ~20 background events
Background in signal region corrected by sideband Data/MC

Rock muon induced EM showers for efficiency study



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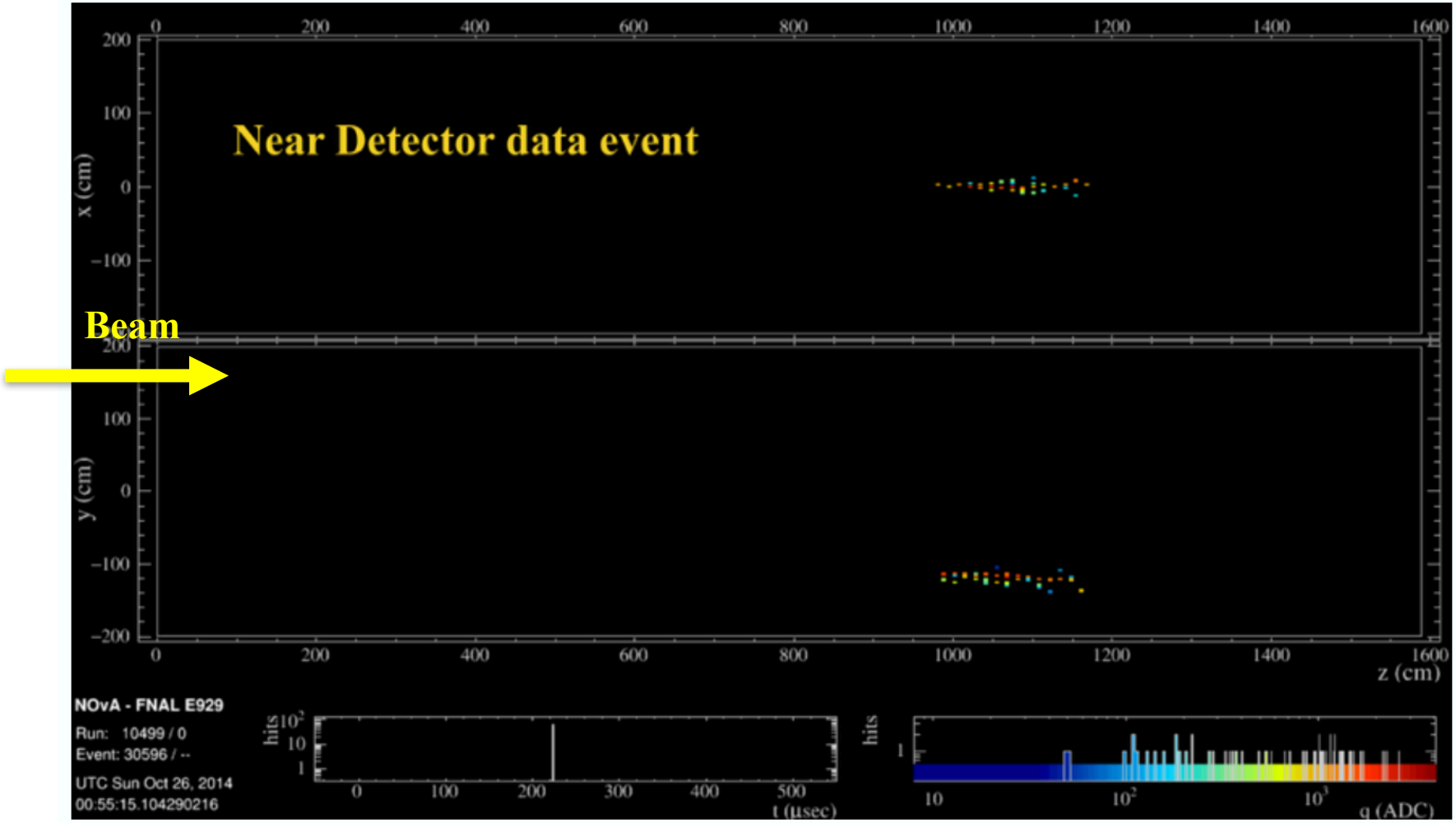
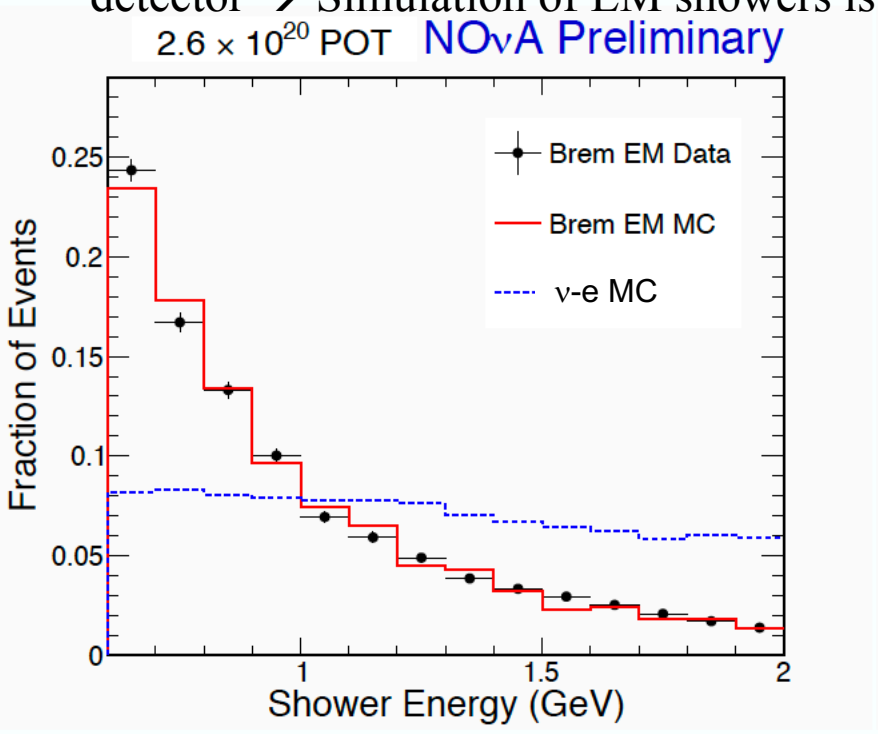
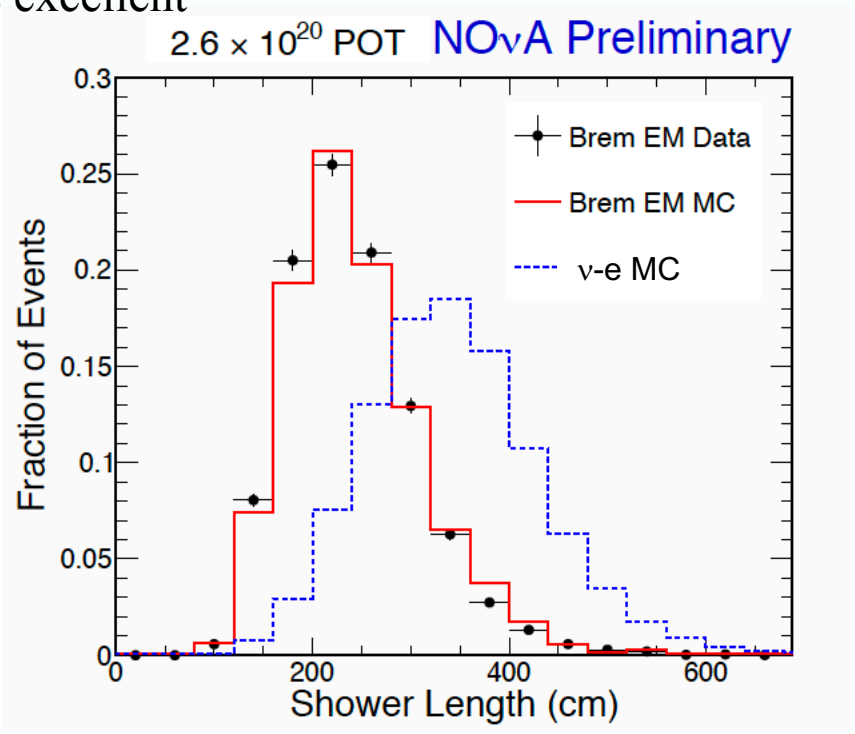


Rock muon induced EM showers for efficiency study

Remove muon tracks in rock events to select Brem showers in the near detector → Simulation of EM showers is excellent





Use rock muon induced showers to estimate uncertainty in ν-e scattering signal efficiency → ~5%

Systematic errors

Source	Relative syst.
Signal efficiency	5%
Single shower requirement	4%
Background correction	0.2%
Background difference between signal and background regions	0.7%
Background neutrino interactions (GENIE)	1%
Background energy scale	1%
Detector modeling	1%
Intensity effects	1%
Total Syst.	6%

Summary

- ν-e elastic scattering measurement at NOvA is under way
- Data/MC from ν-e elastic scattering measurement will be used to constrain the neutrino flux for ND analyses and FD oscillations
- With $3*10^{20}$ POT ND Data, systematics error ~6% and statistical error ~10% for (0.5-5) GeV
- Results coming out soon!