NOvA Near Detector

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For the NOvA collaboration

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NOνA: NuMI Off-axis ν_e Appearance

- **Study of $\nu_\mu \rightarrow \nu_e$ oscillation**
  - Sensitivity is an order of magnitude beyond current limit to θ_{13}
  - Potential to determine mass hierarchy and CP-violating phase δ depending on parameters.

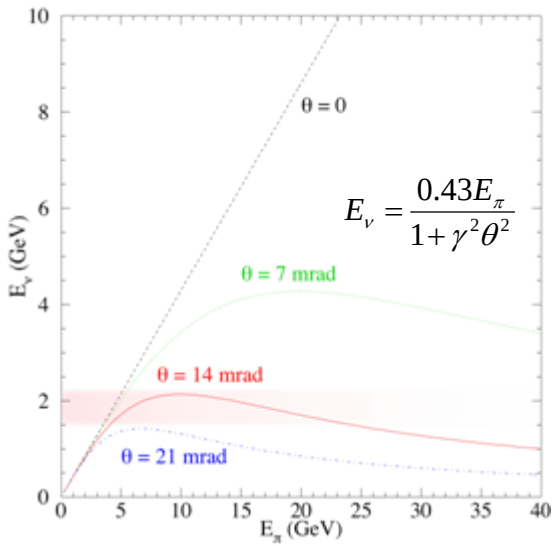
- **Further improvement of $\nu_\mu \rightarrow \nu_\tau$ oscillation measurement**

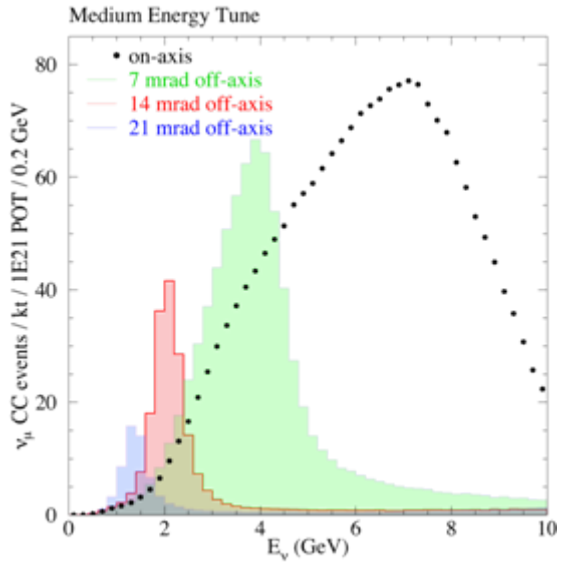
NOvA aims physics targets with:

- ✓ **Intense neutrino and anti-neutrino beams by NuMI.**
- ✓ **Two identical detectors with 810km baseline.**
- ✓ **Narrow-band beam at off-axis detectors sites.**
- ✓ **Optimized detector technology for electron signals.**

NuMI Off-axis beam

14.6mrad off-axis narrow-band beam on oscillation maximum.

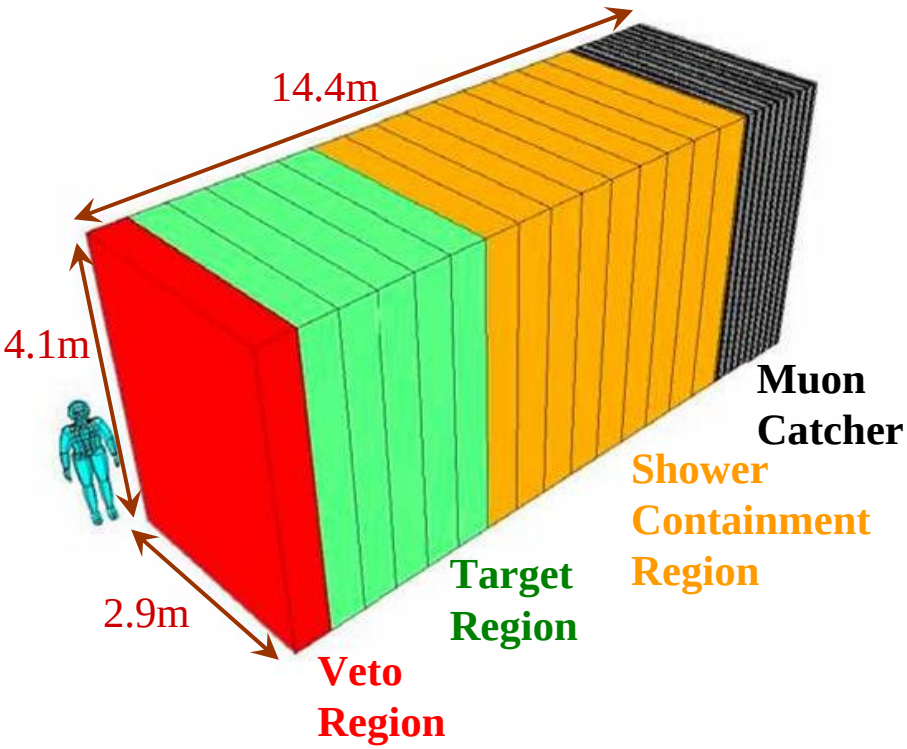




Accelerator and NuMI upgrade prior to NOvA:

- 120GeV protons from Main Injector
- 700kW → 1.2MW
- 4.9E13ppp (6E20POT/yr) → 8.3E13ppp (10E20POT/yr)
- 1.3 second cycle time
- 12 Booster batches/cycle

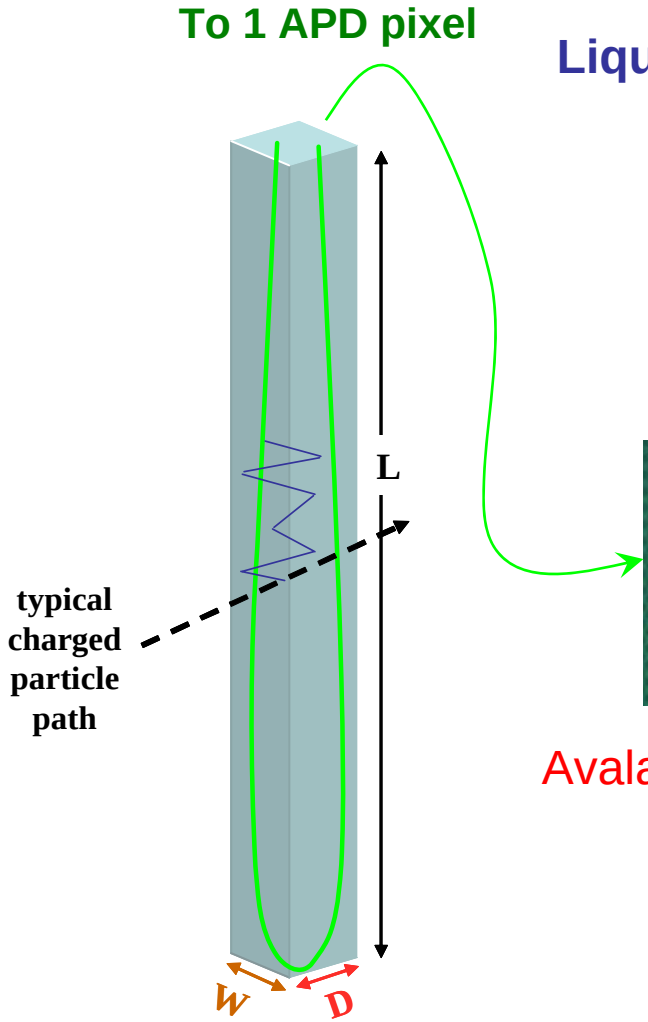
NOvA Near Detector



Totally Active Scintillator Detector

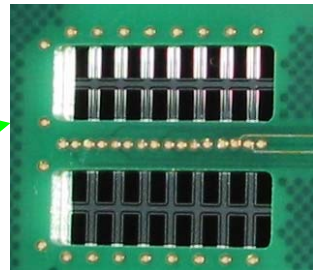
- Same technology as NOvA Far Detector
- 209T total mass
- 126T active detector mass
- Segmented by 6x3.9(5.7x3.8) cm^2 cell
- 64(H)x96(V) Scintillator Cells
- 196 active planes
- 10 steel planes in Muon Catcher

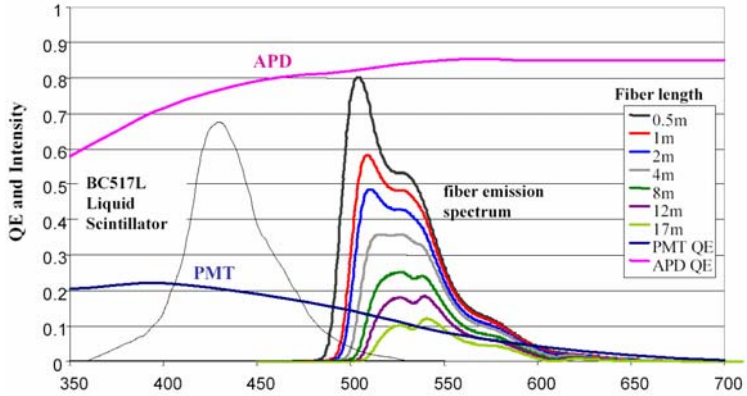
NOvA Detector Technology



Liquid scintillator:

- Mineral oil with 5% Pseud-cumene
- Contained in PVC structure cell
- Read out by a wavelength-shifting fiber

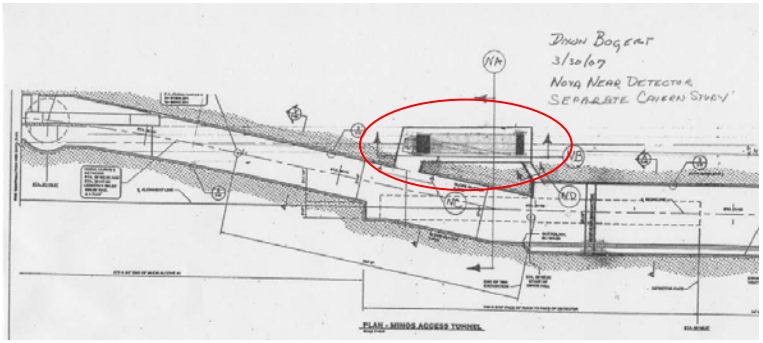




Avalanche Photodiode (APD):

- Quantum Efficiency (>525nm) ~85%
- Gain ~100
- Operating temperature -15C (~2PE noise)
- 20PE from Muon at far end in the NOvA FD (15.7m)

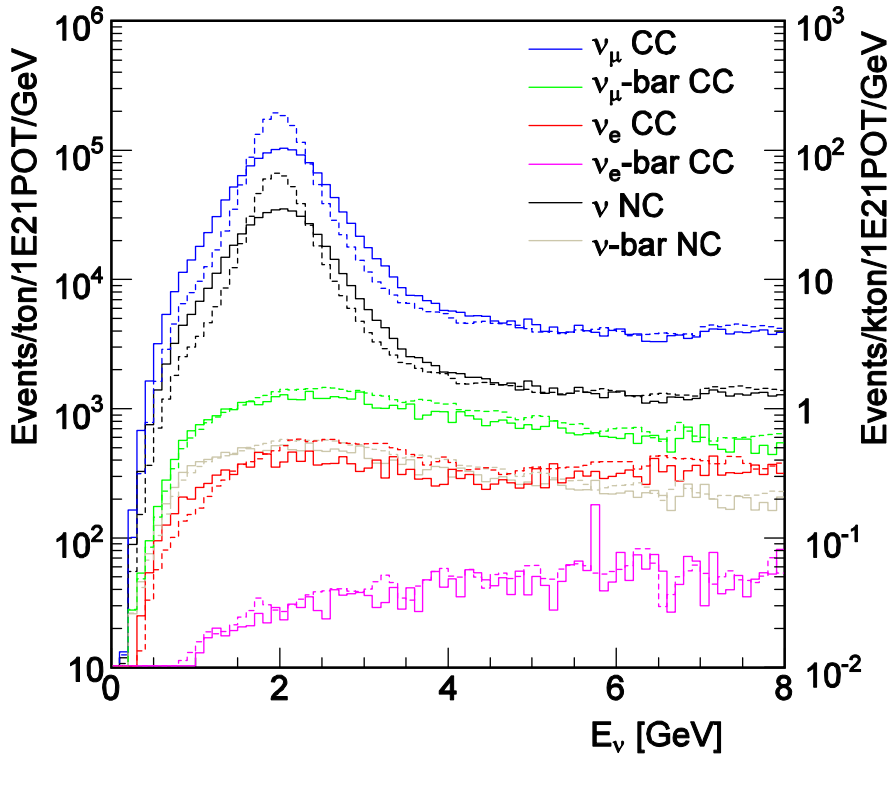
Near Detector Location



Plan is alcove in MINOS tunnel:

- ~1km downstream from target.
- Same 14.6mrad off-axis provides very similar flux as NOvA Far Detector.

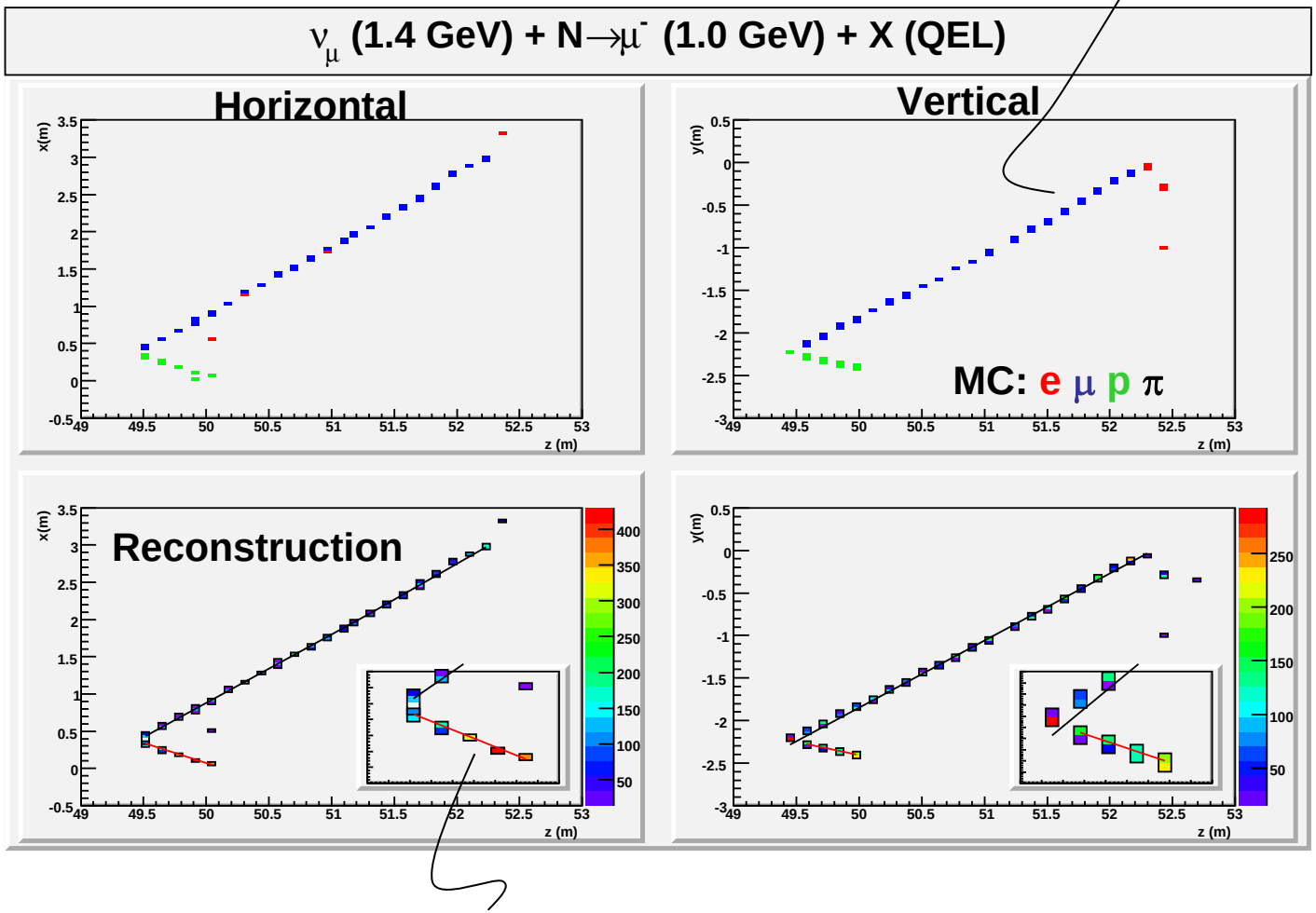
Expected Spectrum in NOvA Far and Near Detectors (no oscillation is included).



ν_μ charged-current interaction in NOvA

Clear muon track in NOvA detector

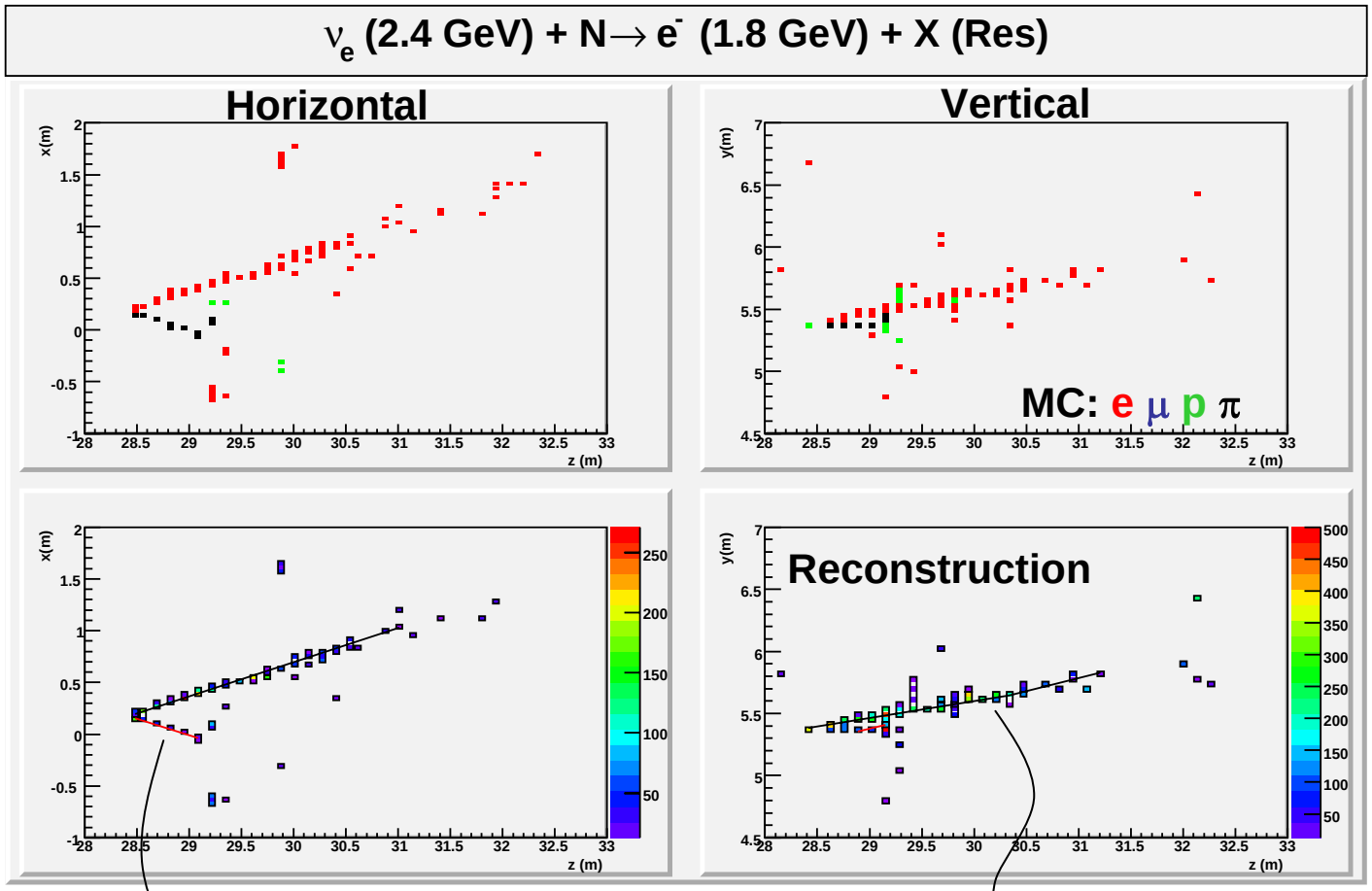
NOvA MC simulation



Larger energy deposit at the end track is available to identify recoil protons.

ν_e charged-current interaction

NOvA MC simulation

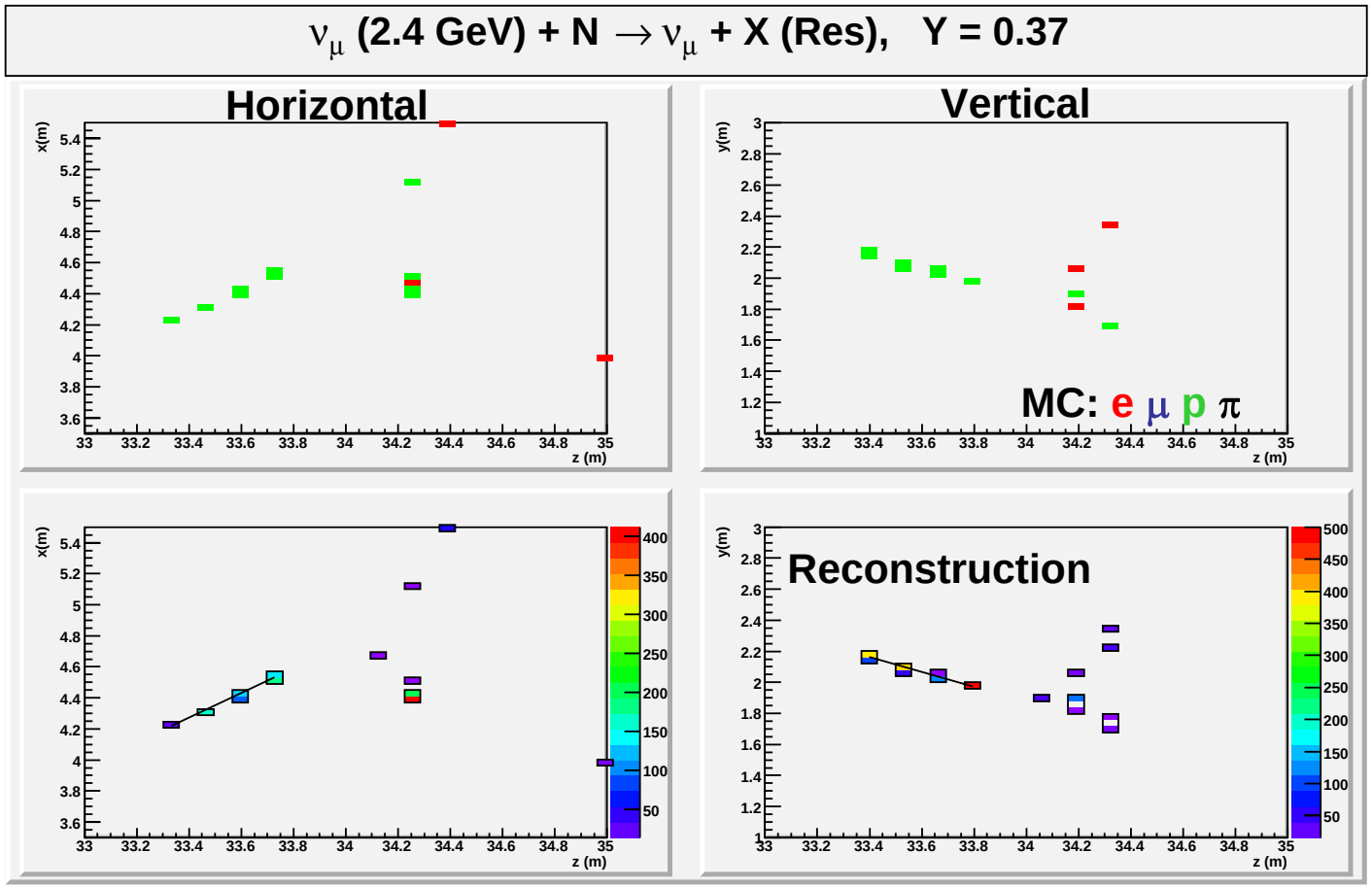


Electrons are reconstructed as clear tracks in NOvA detector.

Pion is identified as second track.

Low energy neutral-current interaction

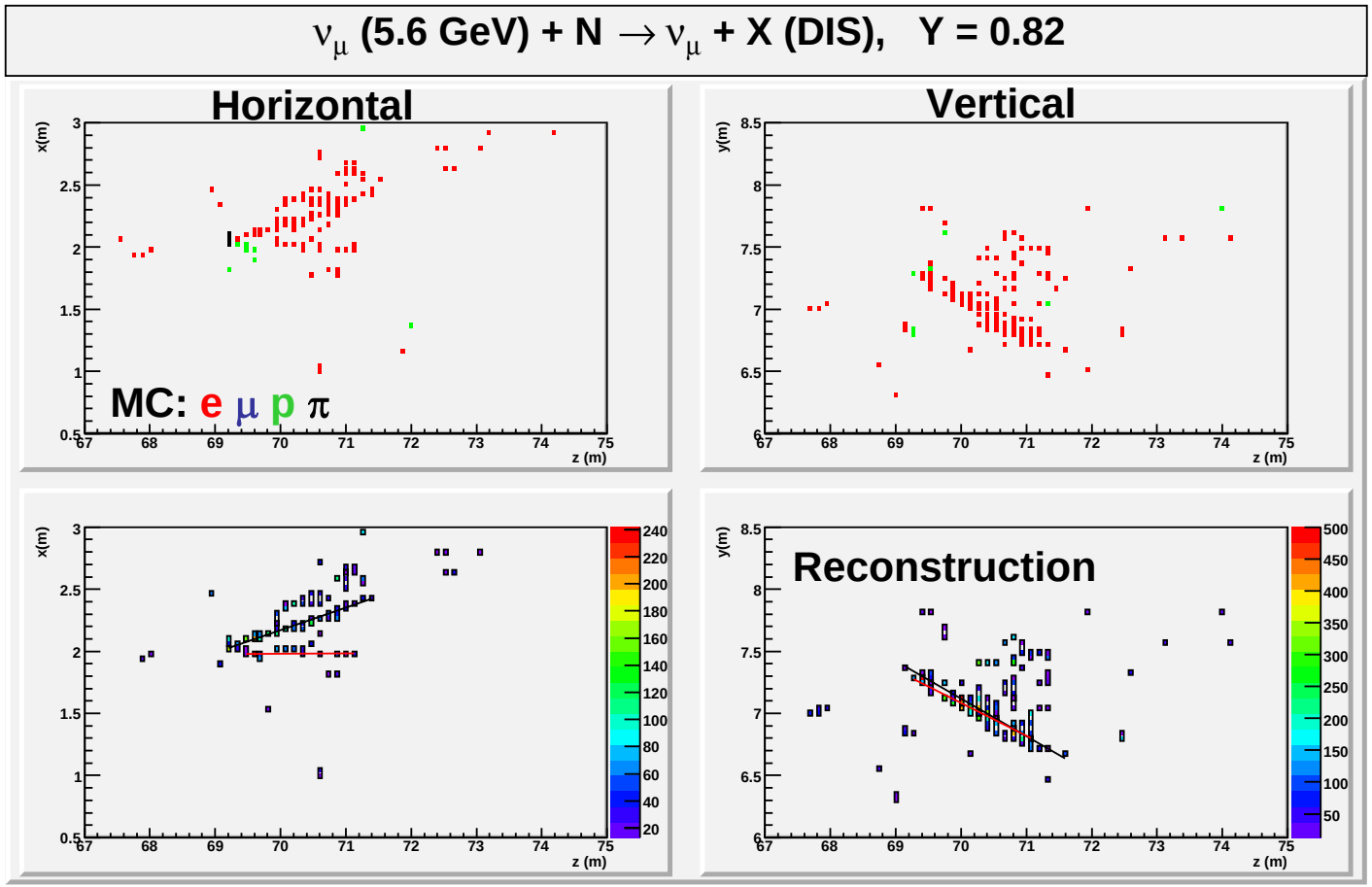
NOvA MC simulation



Low energy neutral-current interactions are easily distinguished from charged-current interactions.

High energy neutral-current interaction

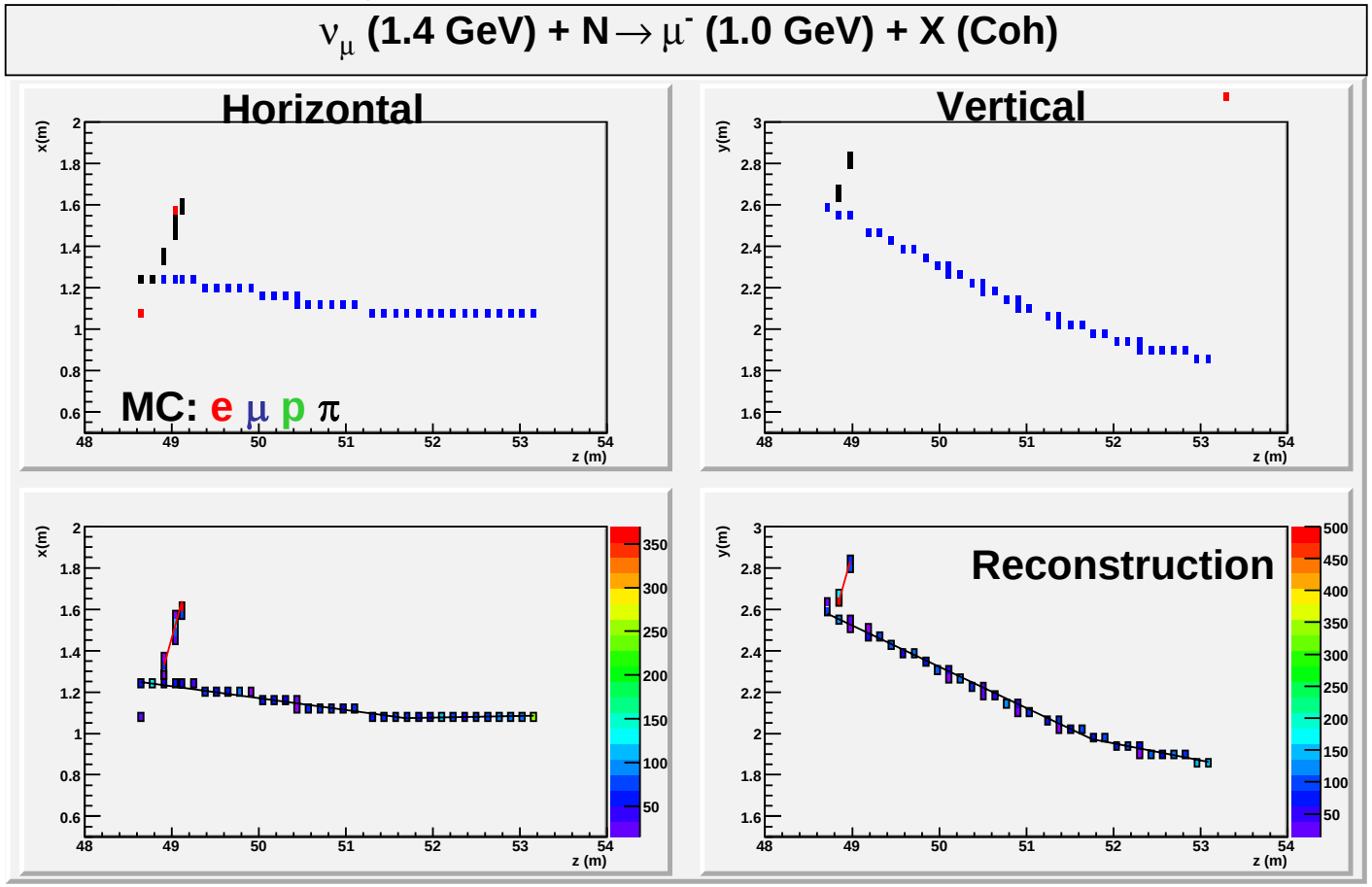
NOvA MC simulation



- Two tracks from π^0 decay are reconstructed.
- High energy NC interactions are distinguished from CC by the event topologies.

Charged-current coherent π

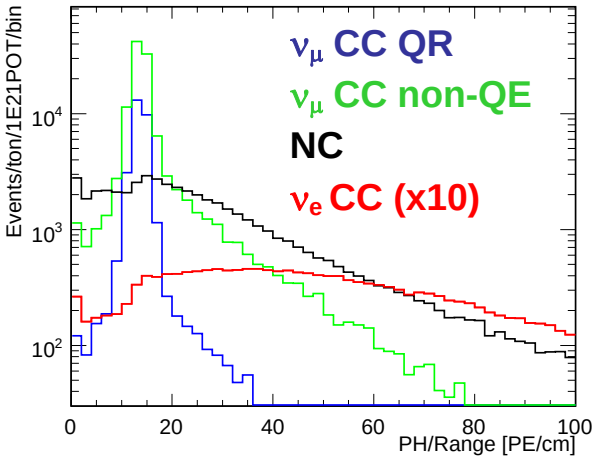
NOvA MC simulation



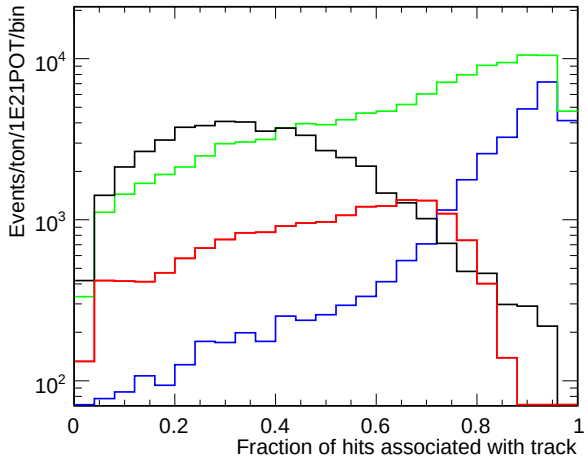
- No evidence of coherent pion production was observed in the K2K experiment ($\sigma_{coh}/\sigma_{CC} < 0.6 \times 10^{-2}$ at 90%CL, M. Hasegawa et al., Phys.Rev.Lett. 95 (2005) 252301)
- NOvA aims to confirm the result by the Near Detector.

Performance of event classification

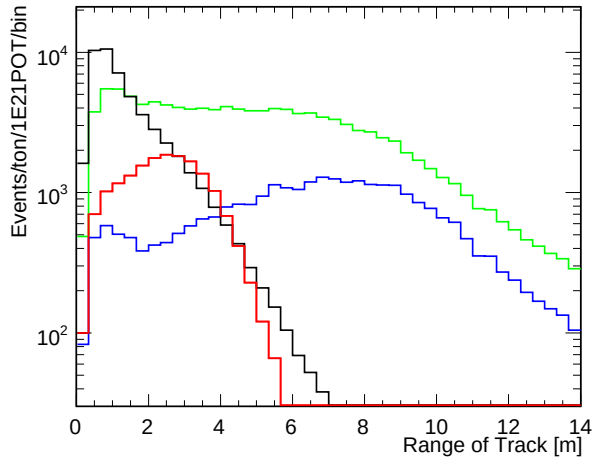
PH/range of track (=dE/dx)



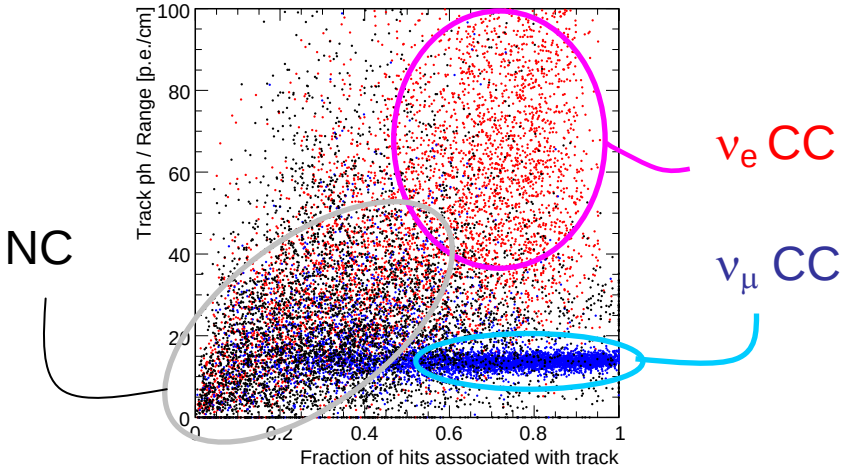
Fraction of hits in track



Track range



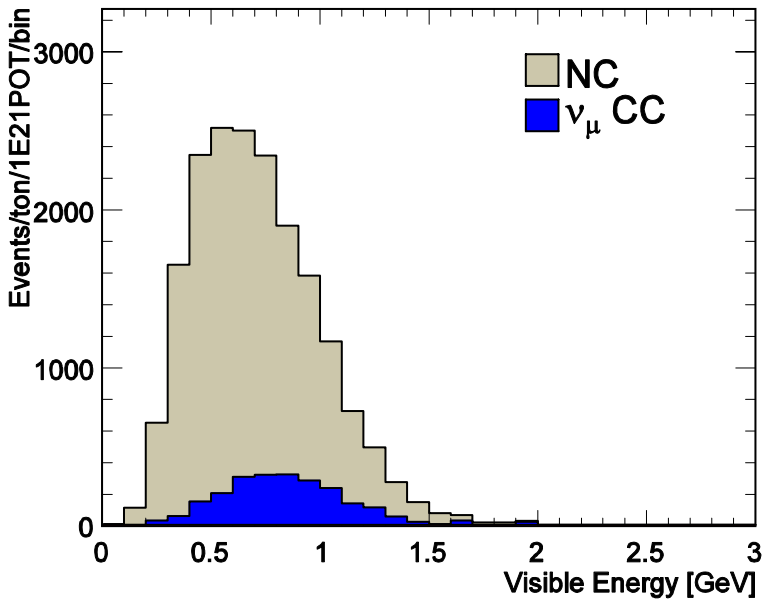
Correlation of 2 variable



- **ν_μ charged-current:**
  Long range track with constant dE/dx
- **ν_e charged-current:**
  Medium range track with large dE/dx
- **Neutral-current:**
  Diffused hits with short range tracks

Neutral-current measurement

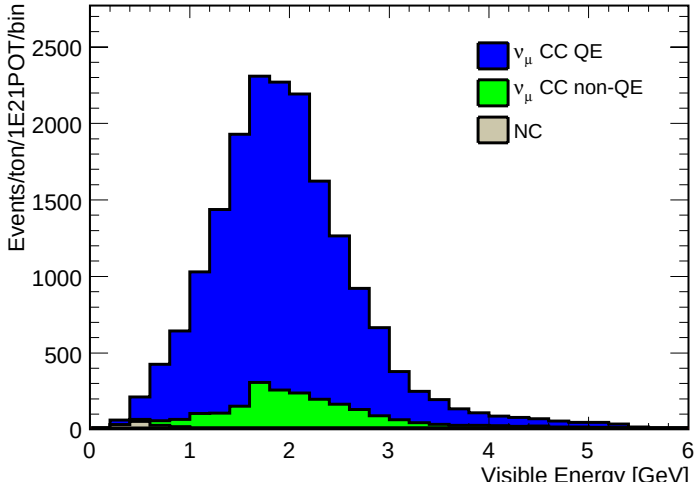
NOvA neutral-current sample selected by Artificial Neural Network.

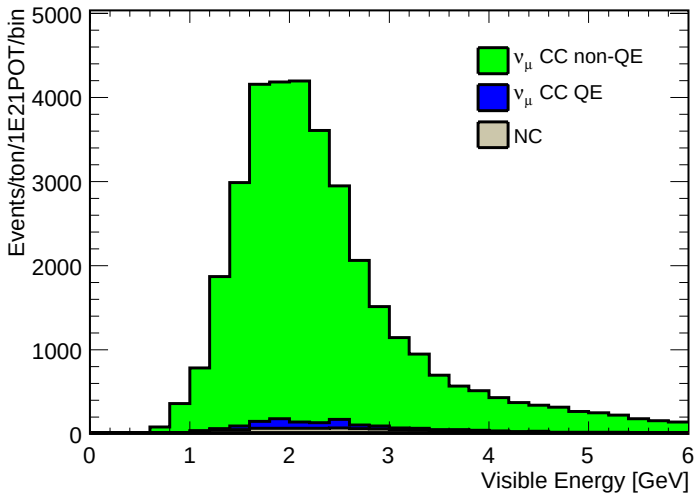


- Neutral current π^0 production is main background to ν_e appearance signal in the NOvA Far Detector.
  - Measurement of NC cross-section in the Near Detector reduces systematic errors of oscillation measurement.
  - Neutral-current interactions are selected by event topologies e.g. two γ tracks from π^0 decay
- Signal for tests to exotic models, which include neutrino decay, sterile neutrinos.

ν_μ charged-current QE/non-QE measurement

NOvA charged-current QE and non-QE samples each selected by ANN.





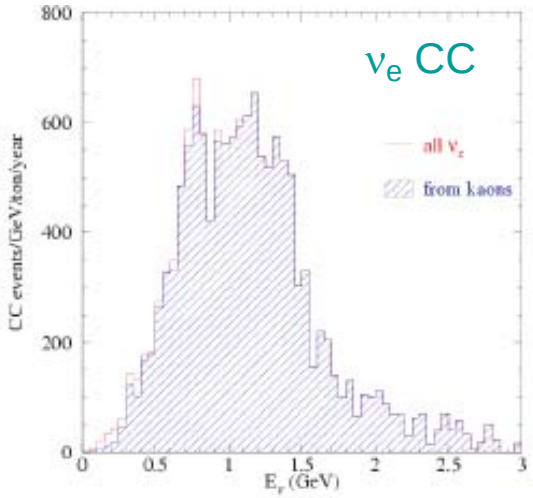
- ν_μ CC QE is signal of $\nu_\mu \rightarrow \nu_\tau$ oscillation.
- ν_μ CC non-QE could be background with relatively worse energy resolution than CC QE due to hadronic energies.

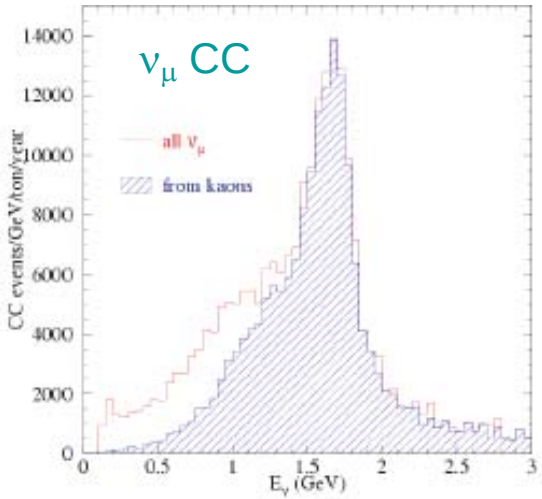
- Measurement of CC QE/non-QE cross section improve $\nu_\mu \rightarrow \nu_\tau$ oscillation parameter measurement in the NOvA Far Detector.
- ν_μ CC interactions are easily distinguished from NC or ν_e CC with clear muon track.

Prototype

IPND: **I**ntegration **P**rototype **N**ear **D**etector

- Test production of all detector elements.
- To be located at MINOS service building.
- **Taking data from late 2007/early 2008.**





Low energy beam configuration.

Flux is dominated by K decays at 107mrad off-axis.

Summary

NOvA will search for ν_e appearance an order of magnitude beyond the current limit to θ_{13}.

- Intense neutrino and anti-neutrino beam from upgraded NuMI.
- Narrow-band beam on oscillation maximum at off-axis detector site.
- Fine grained totally active large detector.

NOvA Near Detector will make precise measurements

- Same technology as NOvA Far Detector.
- Almost identical spectrum shape is expected with same off-axis beam.
- Large statistic events is available in the Near Detector.
- **Precise measurements of neutrino cross-sections will be achieved by NOvA Near Detector with high performance of particle identifications.**