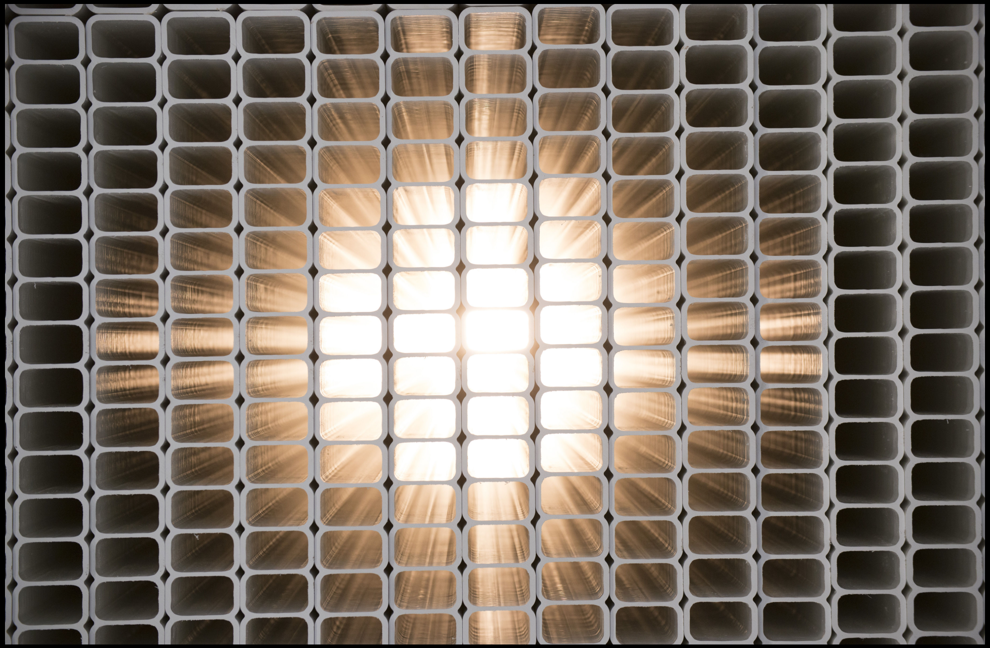
The NOνA Experiment



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NNN2014
November 5, 2014
APC Laboratory, Paris, France

NuMI Off-Axis ν_e Appearance Experiment

NOνA is a long-baseline neutrino oscillation experiment located 14 mrad off-axis from the NuMI beam designed to measure:

$P(\nu_\mu \to \nu_e)$ and $P(\bar{\nu}_\mu \to \bar{\nu}_e)$

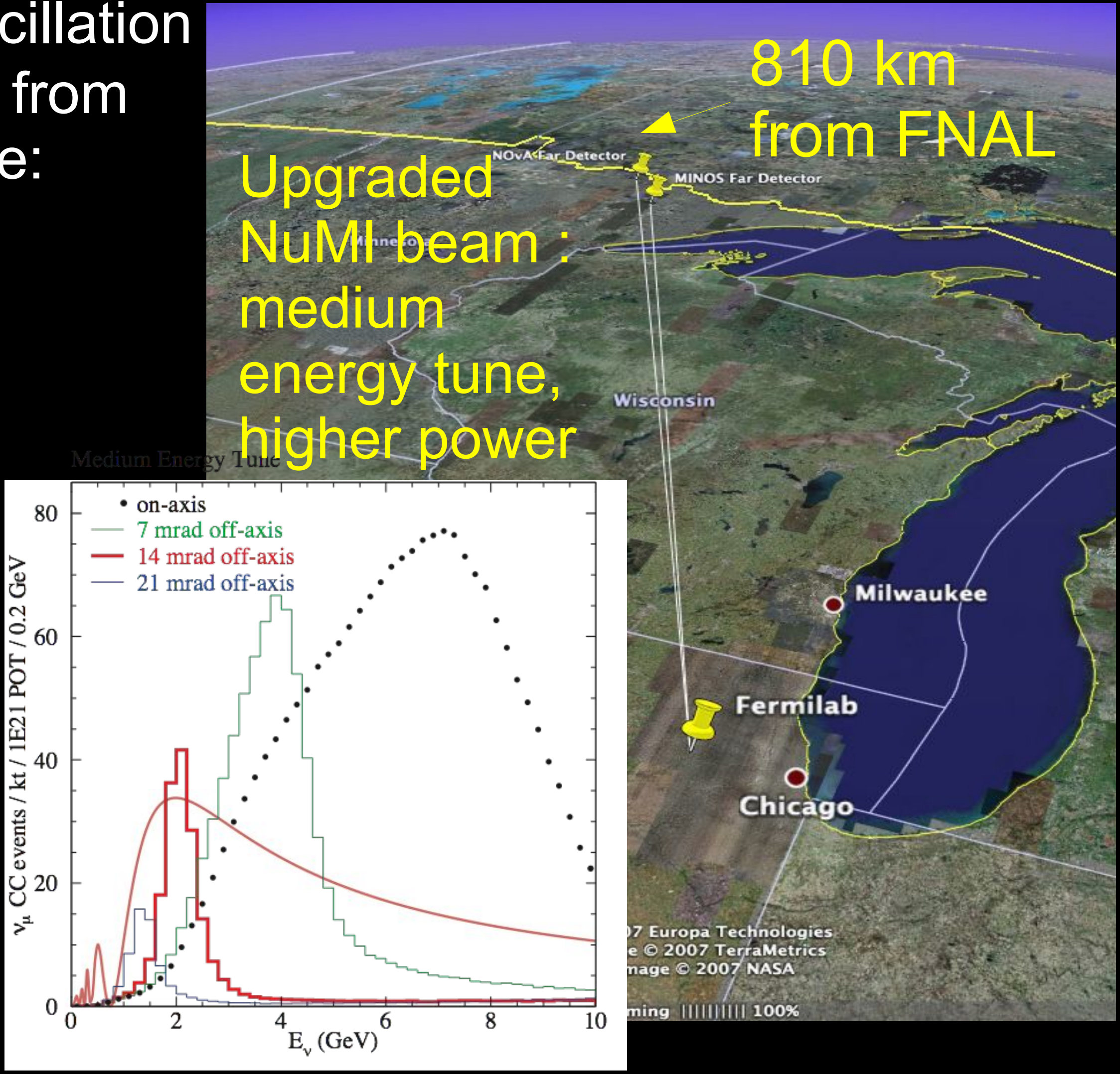
- θ_{13}
- Mass hierarchy
- θ_{23} octant
- CP violation

$P(\nu_\mu \to \nu_\mu)$ and $P(\bar{\nu}_\mu \to \bar{\nu}_\mu)$

- Improved precision on $|\Delta m^2_{32}|$ and θ_{23}

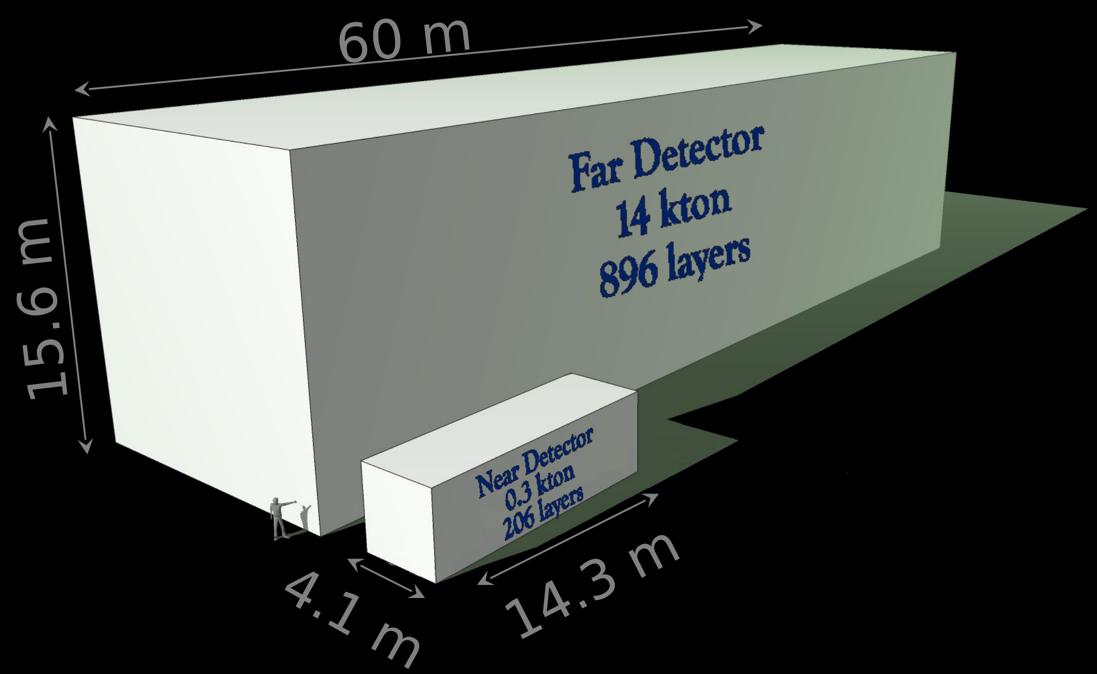
Others

- Cross-sections
- Steriles
- Supernovae
- Exotics



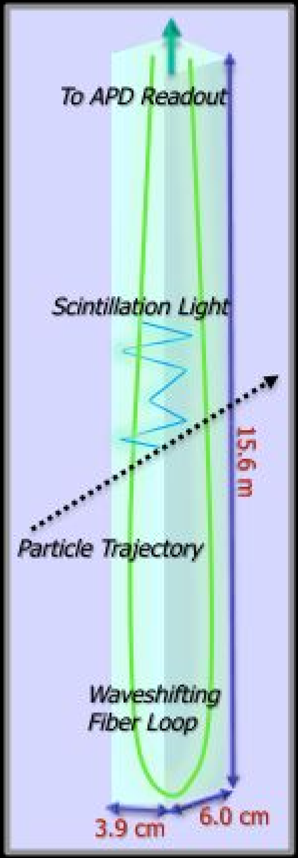
NOνA Design

Far detector:
- 14 kton, low Z tracking calorimeter
- Liquid scintillator filled PVC cells
- ~344,000 channels

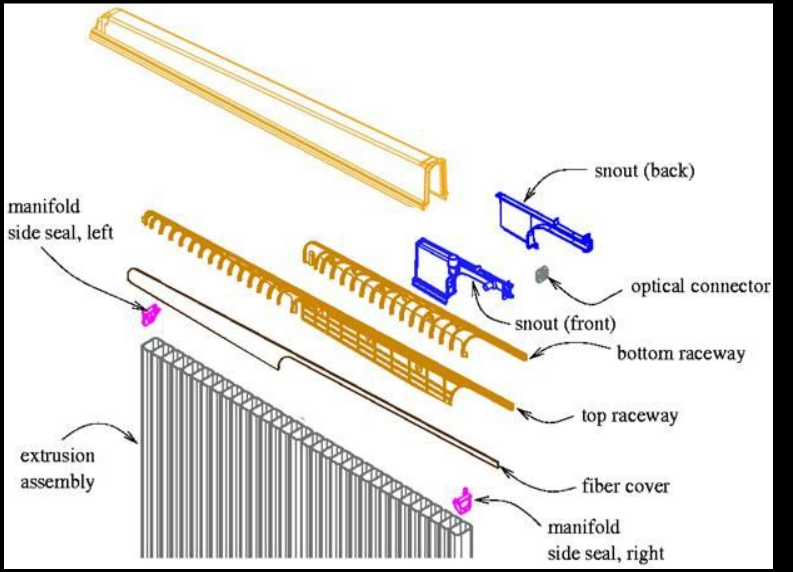


Near detector:
- 0.3 kton
- Functionally equivalent to FD
- 4x faster electronics to handle high rate environment
- ~20,000 channels

Readout Cell

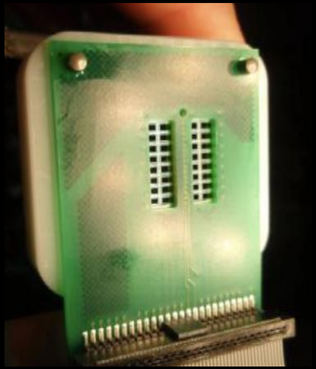


- 16 m x 4 cm x 6 cm PVC cells with 15% TiO_2 for high reflectivity
- Filled with liquid scintillator
- Light transported out by a wavelength shifting fiber loop
- 32 cells in a module read out by a single avalanche photodiode (APD)
  - APD's have high quantum efficiency (~85%) with good uniformity over the WLS fiber spectrum
  - Cooled to -15 °C to reduce dark current to ~2 pe equivalents
  - MIPs produce >30 pe at far end giving better than 10:1 signal to noise ratio



32 fiber pairs

32 pixel APD



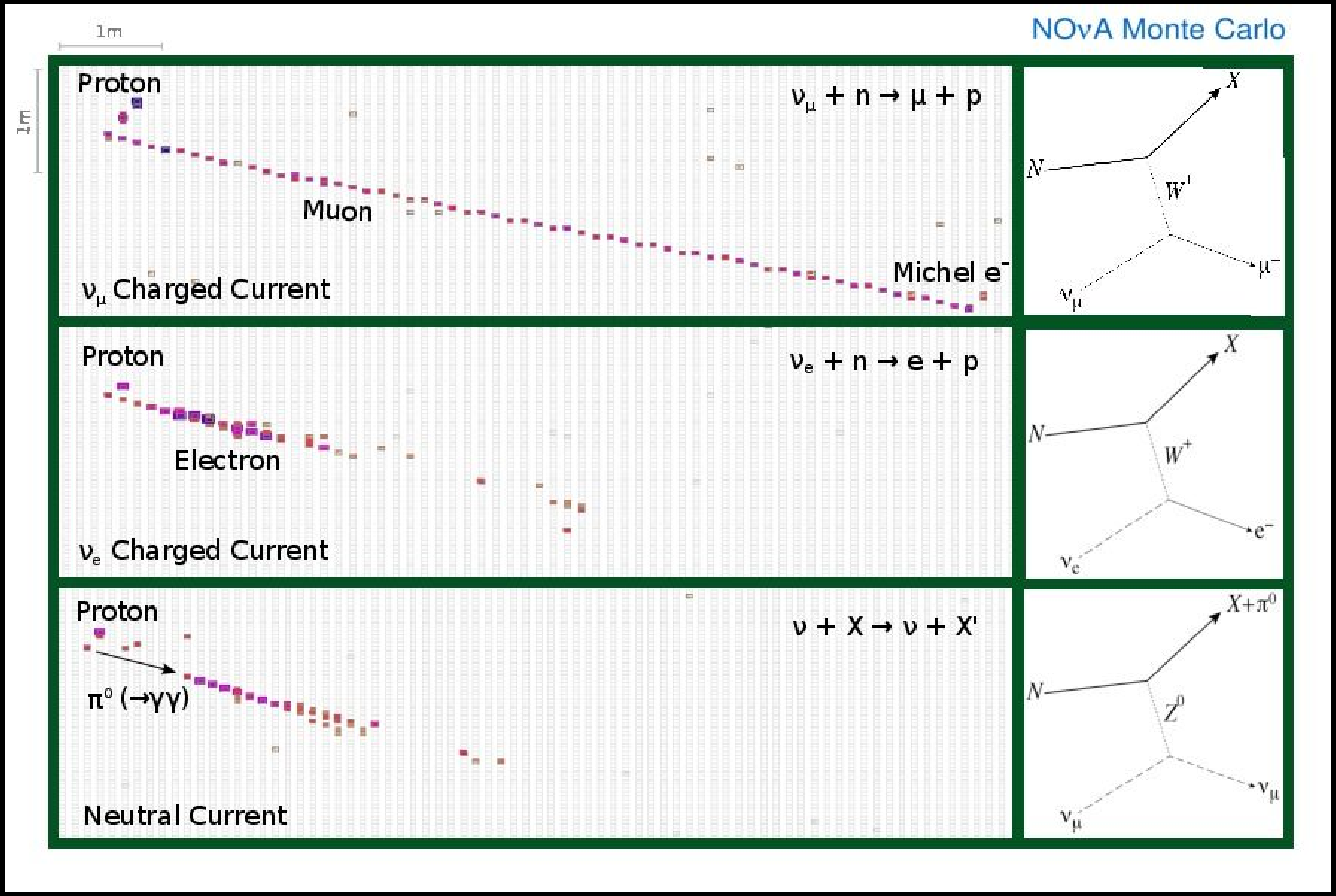
NOνA Event Topologies

Excellent spatial granularity

~0.15 X_0 per plane

Electron showers are ~8 cells wide and ~30 cells long

NC can look very similar to electron showers, but energy is lower → narrow band beam helps



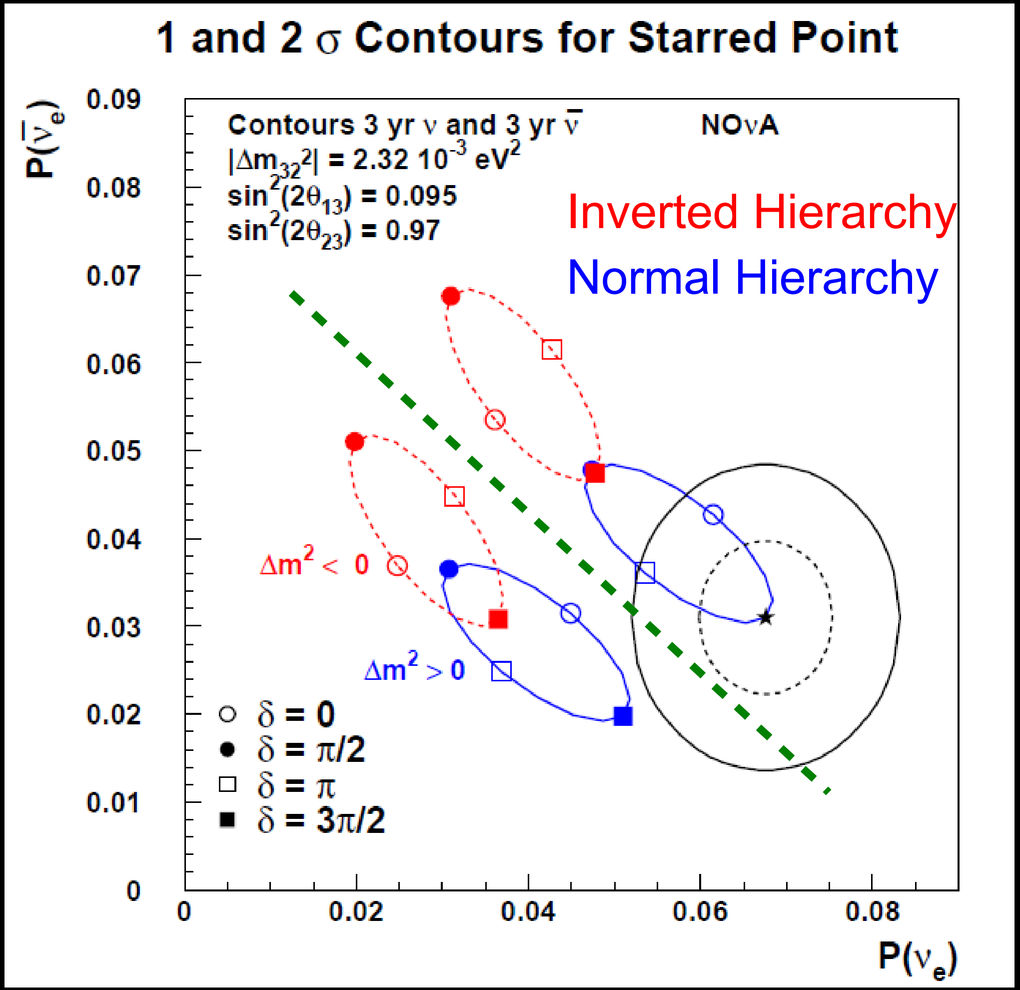
NC with π^0 production was irreducible in MINOS. In NOνA, gap and two showers can help with discrimination.

ν_e Appearance

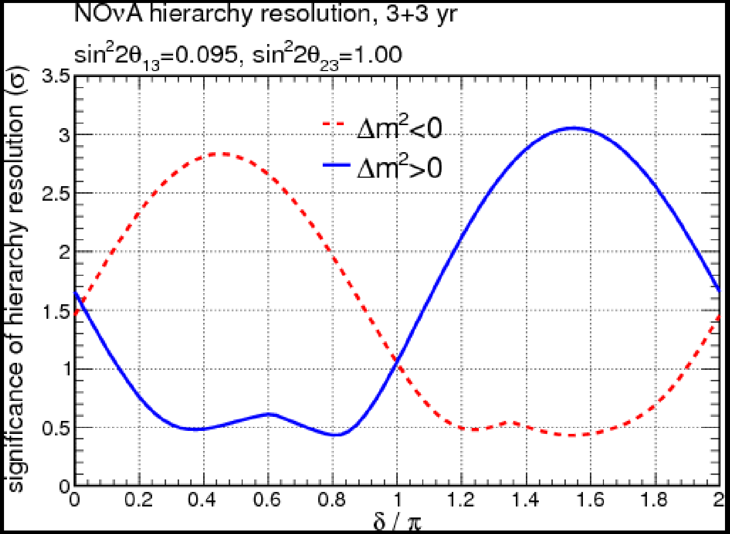
Measure $P(\nu_\mu \to \nu_e)$ and $P(\bar{\nu}_\mu \to \bar{\nu}_e)$ to give a ellipse in this plane

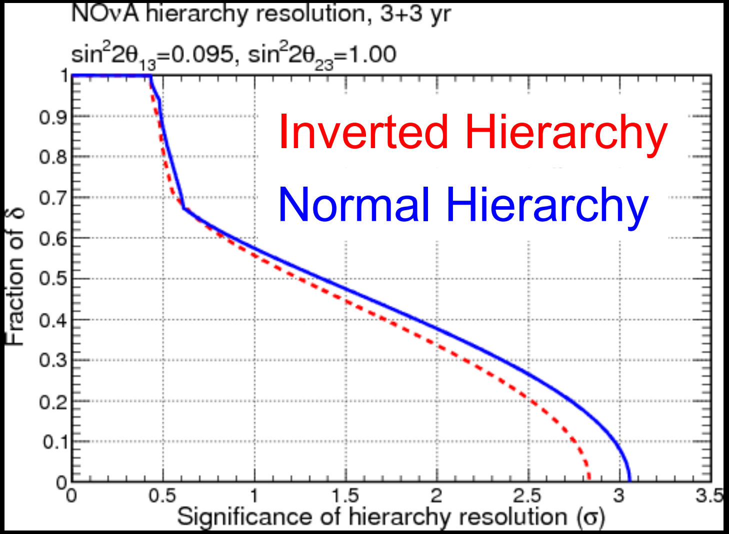
Placement in the plane gives information about θ_{23}, mass hierarchy, and δ_{CP}.

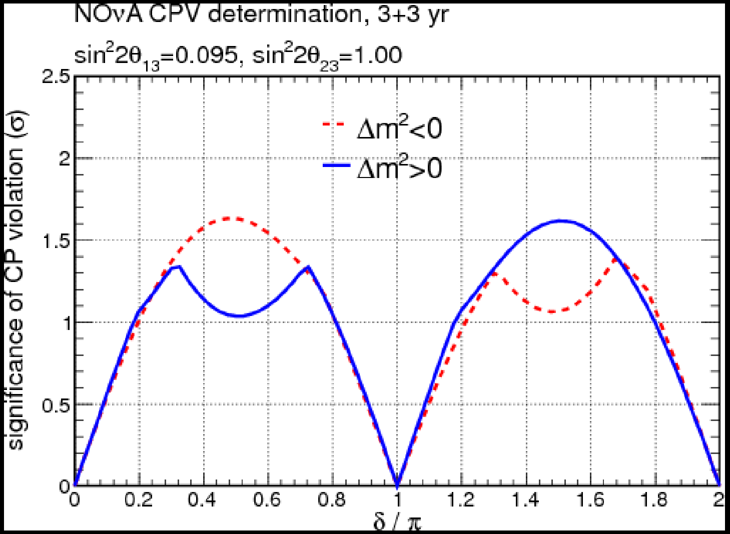
At the shown example point, we could measure the hierarchy at the 95% CL

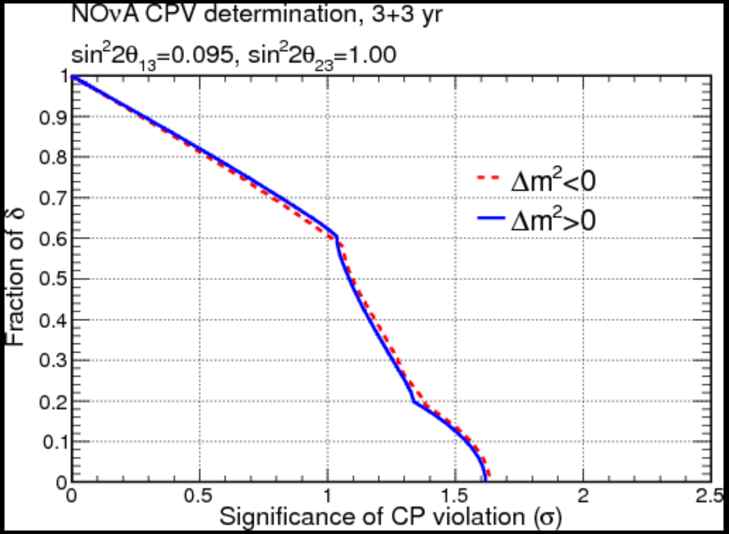


Mass Hierarchy/CP Violation Sensitivities



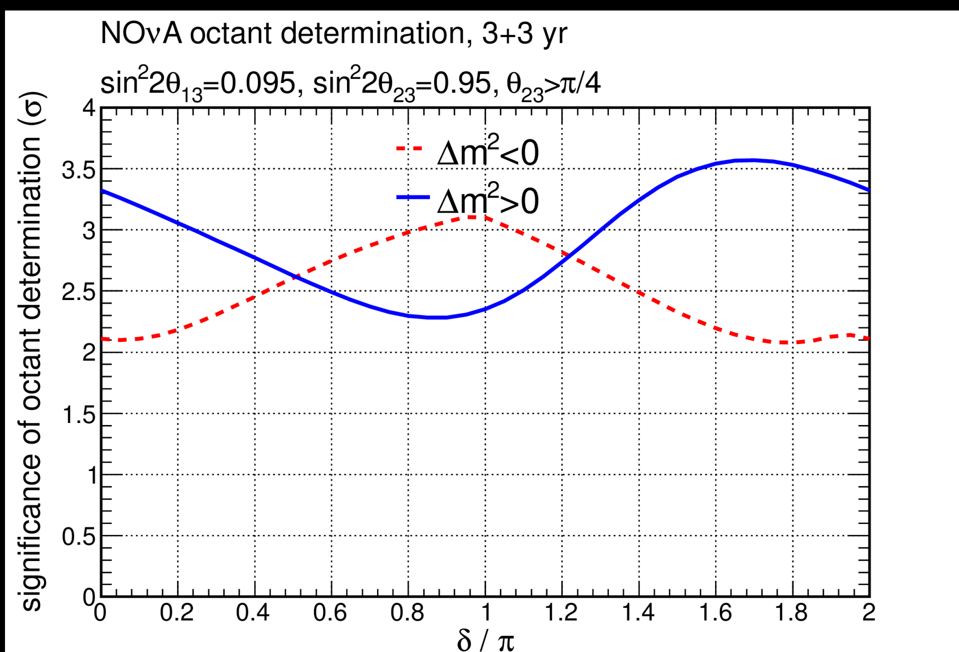




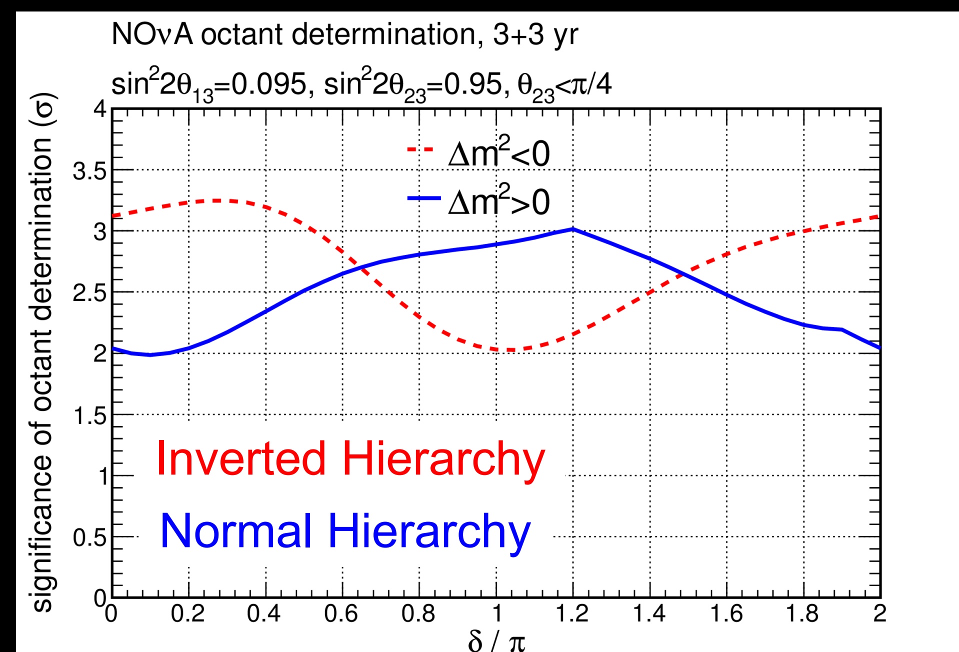


Octant Sensitivity

For $\sin^2 2\theta_{23} = 0.95$, we can measure the octant to 95% CL or better for all values of $\delta_{CP.}$

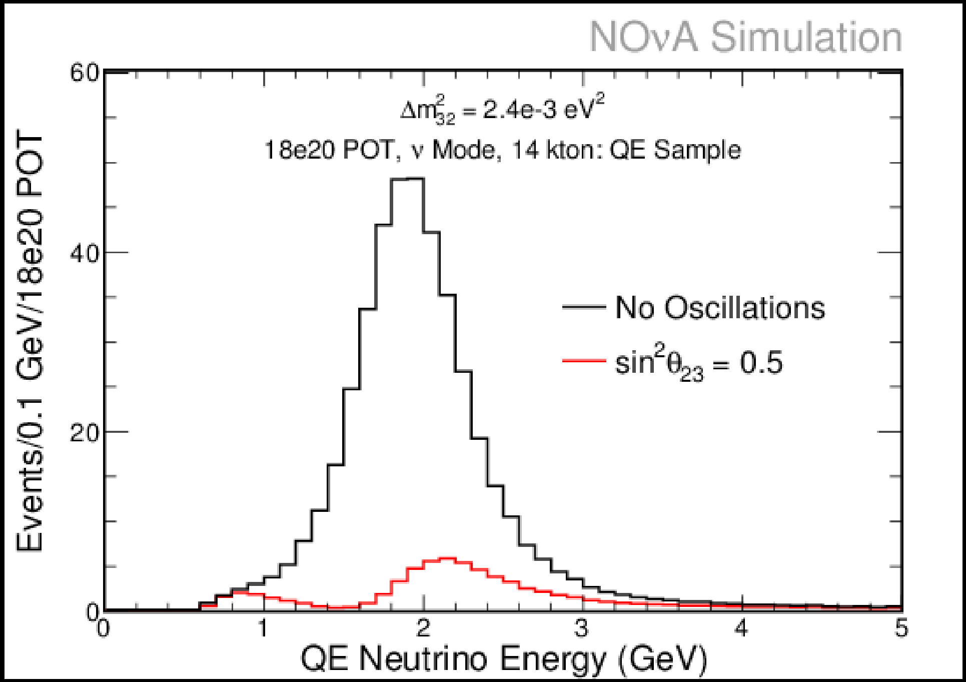


Upper Octant



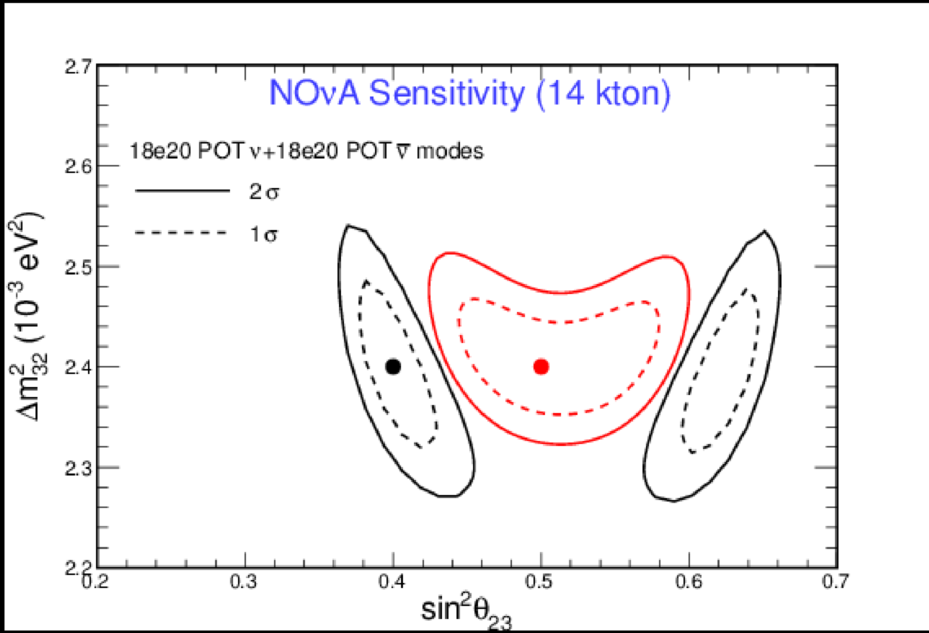
Lower Octant

ν_μ Disappearance



Excellent resolution of the first oscillation minimum

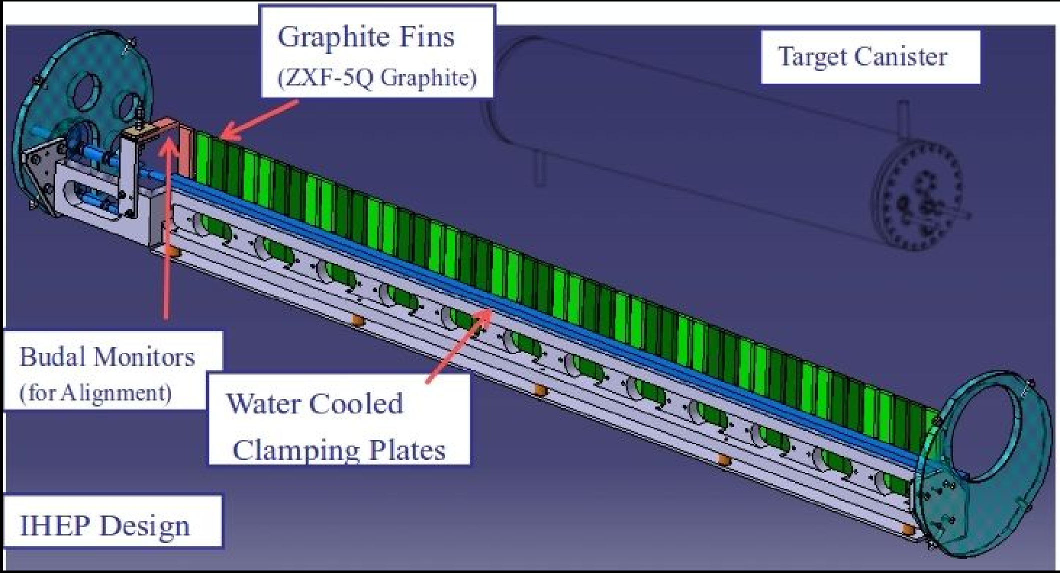
- 4.5% resolution for QE events
- 6% for non-QE events

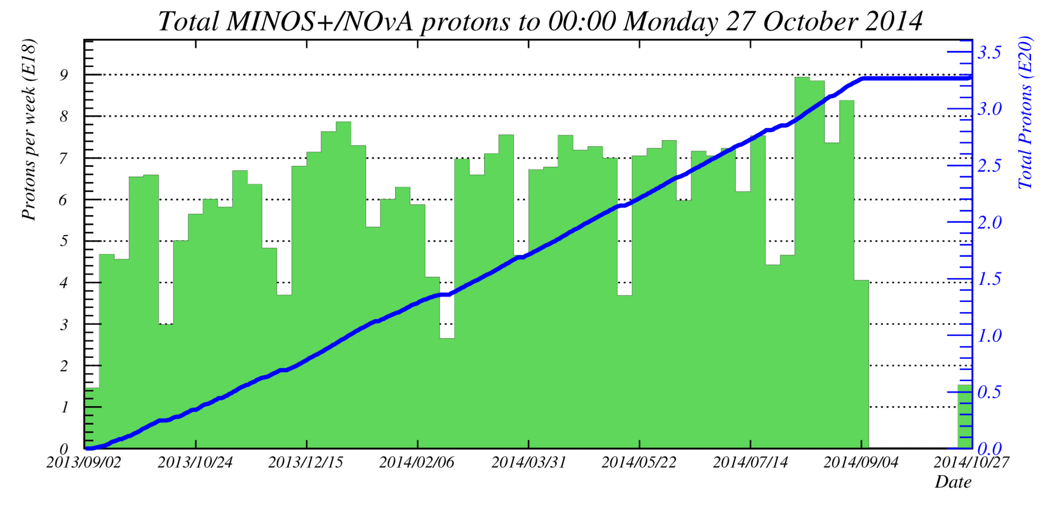


For baseline exposure, NOνA will improve on the current best value of θ_{23} and possibly exclude maximal mixing

NuMI Beam

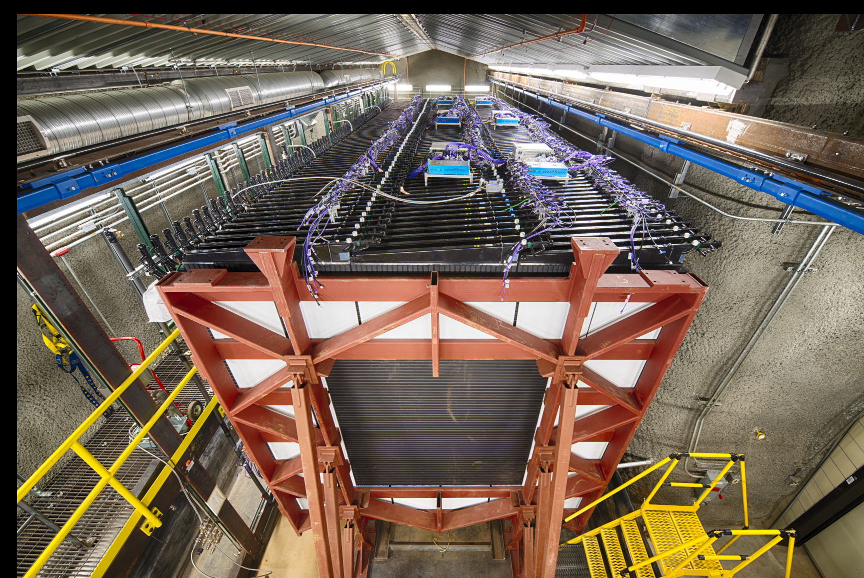
- Using new NOνA target and medium energy tune
- Throughout 2014, the NuMI beam has operated at ~280 kW
- Proton Improvement Plan is ongoing
  - 2015 → 410 kW
  - 2016 → 700 kW (design power)
- Data already collected:
  - FD (14 kton equiv): 0.7×10^{20} POT
  - ND: 0.2×10^{20} POT
- By the 2015 shutdown:
  - FD: ~3.0×10^{20} POT
  - ND: ~2.5×10^{20} POT





Detectors Complete!

As of September 4, 2014, both detectors are fully commissioned.



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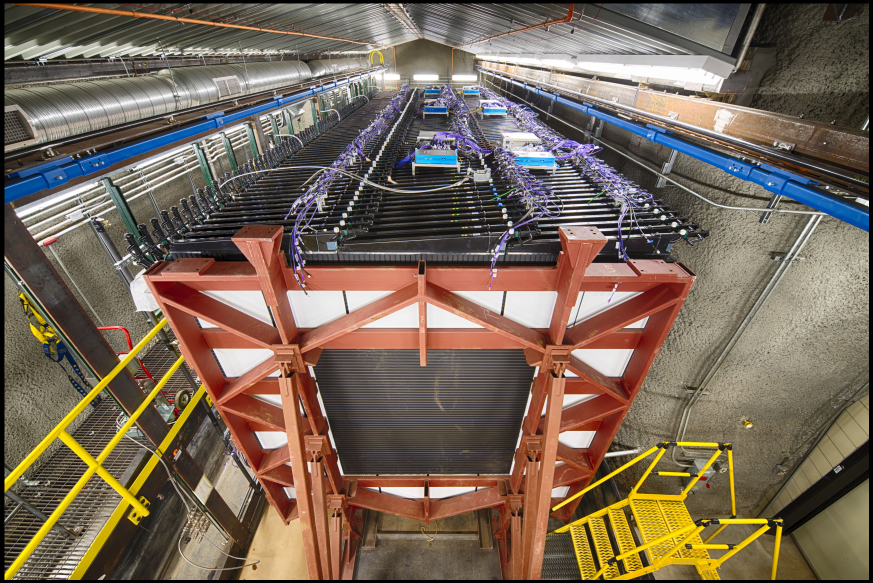
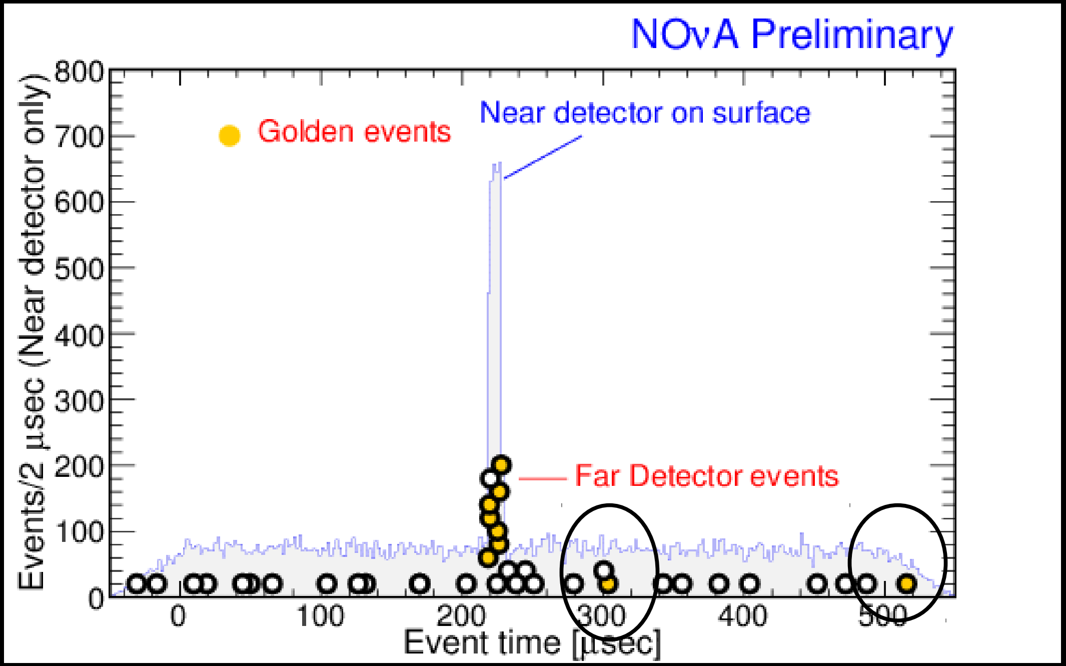


Far Detector

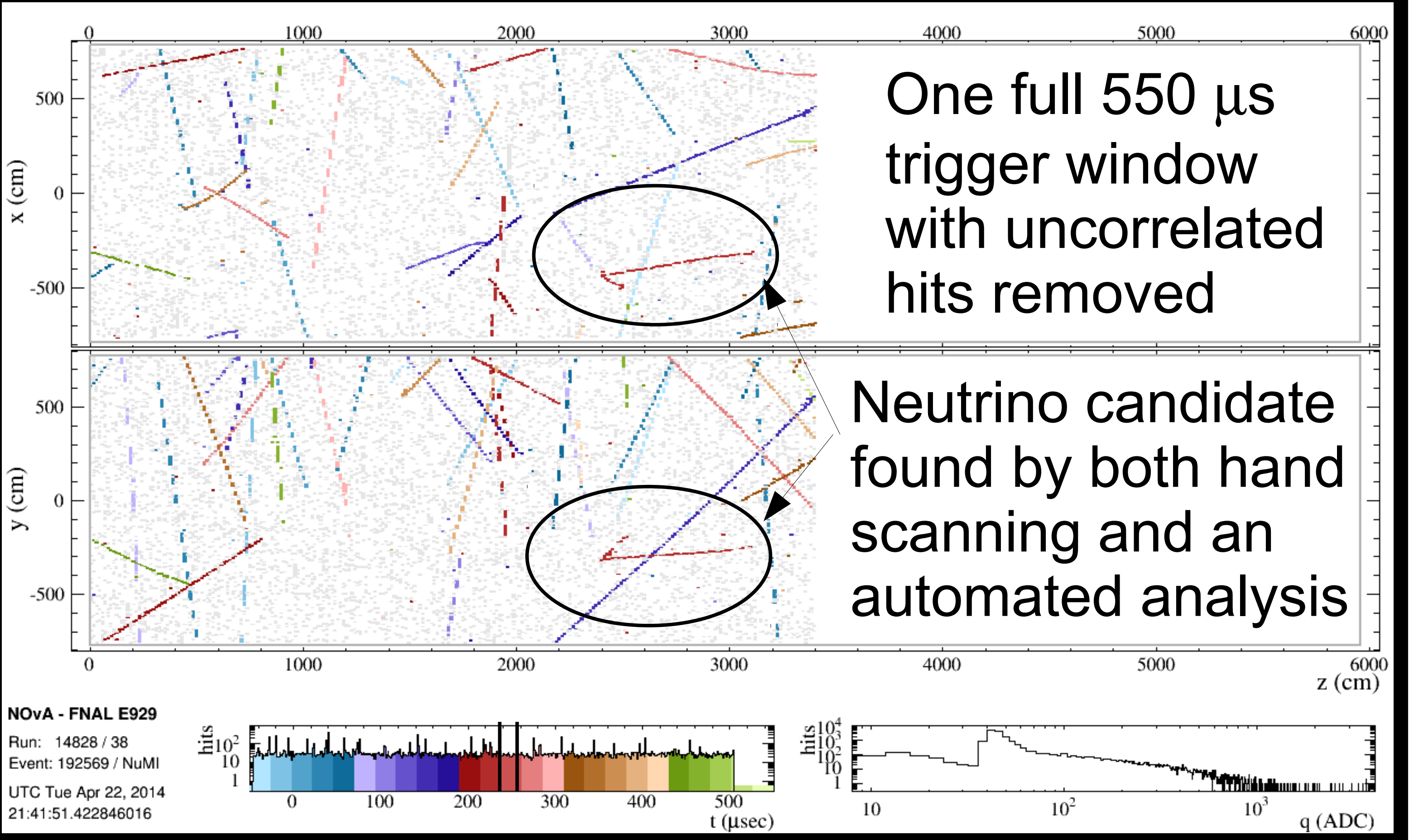
- During commissioning, we assessed if the far detector was seeing neutrinos using two techniques
  - Hand-scanning
  - Automated analysis with similar cuts to final analysis
- Both performed blind to the event time
- Golden events are ones deemed highly likely to be neutrinos
- Clearly found the timing peak



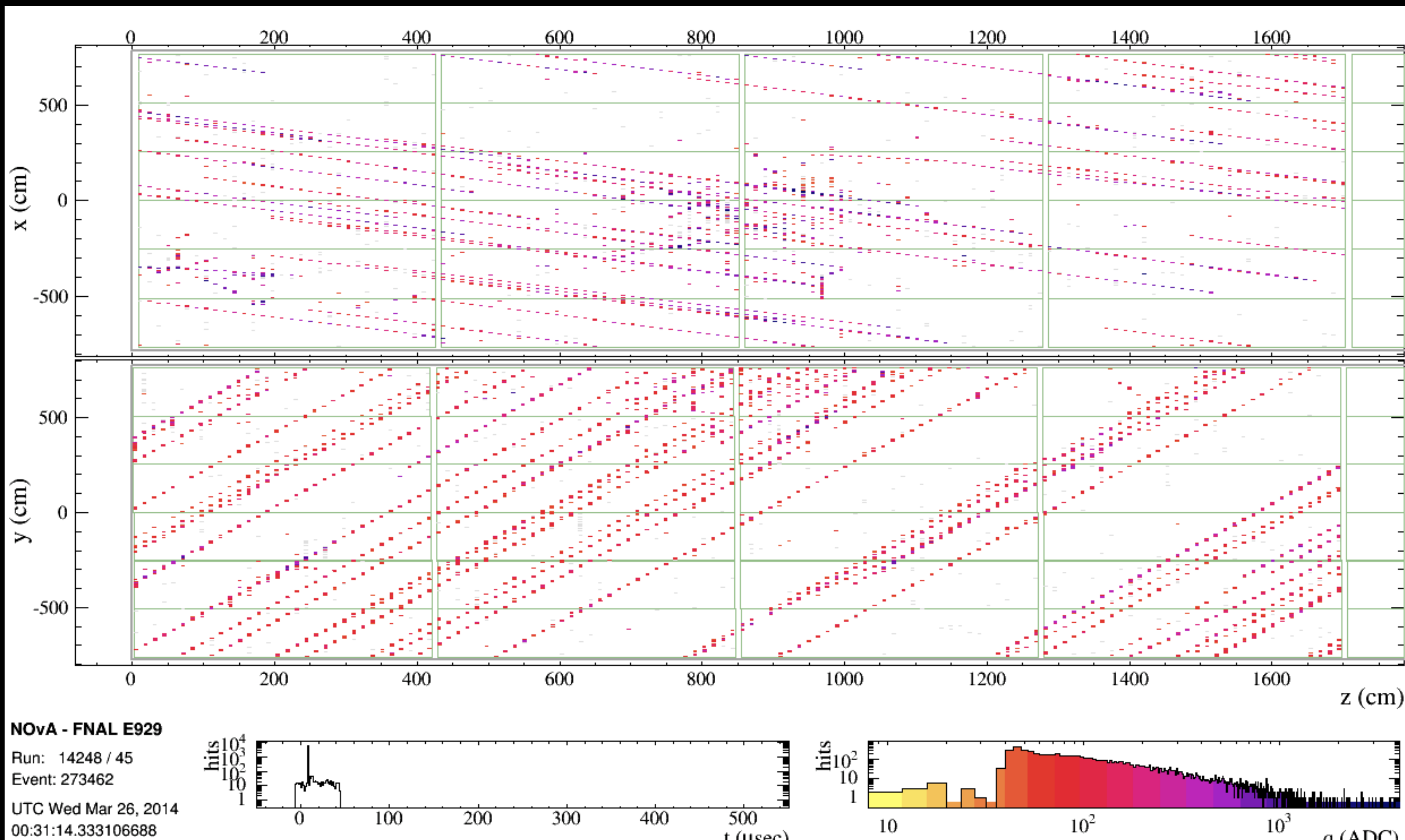
These golden events look like neutrinos in all ways except their event time – probably cosmic ray induced neutrons

FD Neutrino Candidate

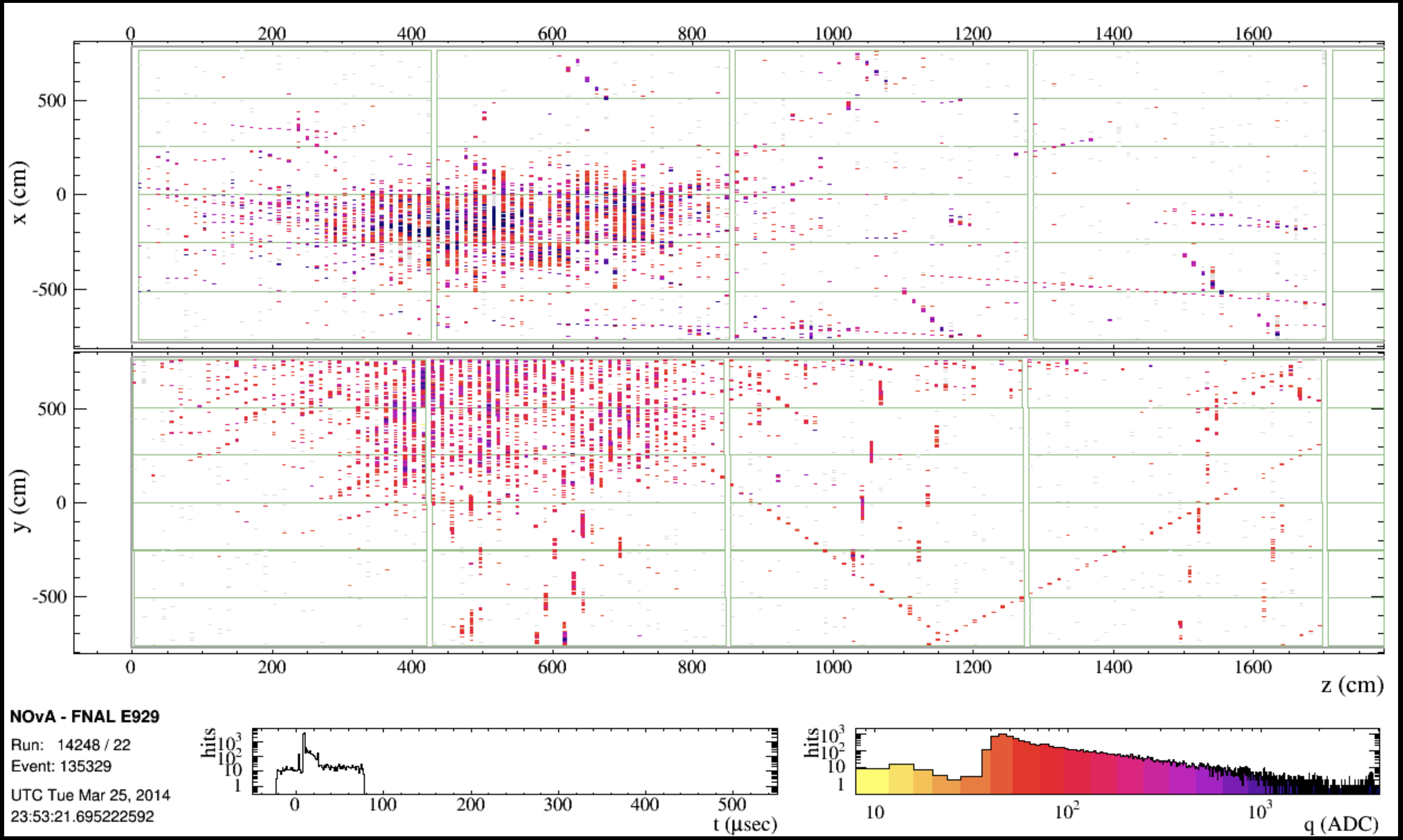
- Pulsed beam: spill window is 10 µs
- Every beam trigger carries 245 µs of minimum bias data on either side of spill
- Clustering in space and time + pulsed beam helps remove most cosmic rays



Cosmic Air Shower

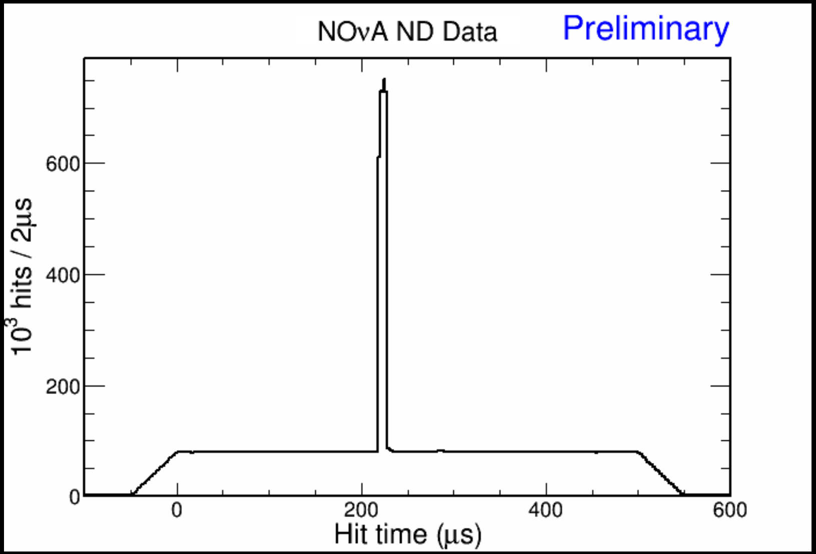


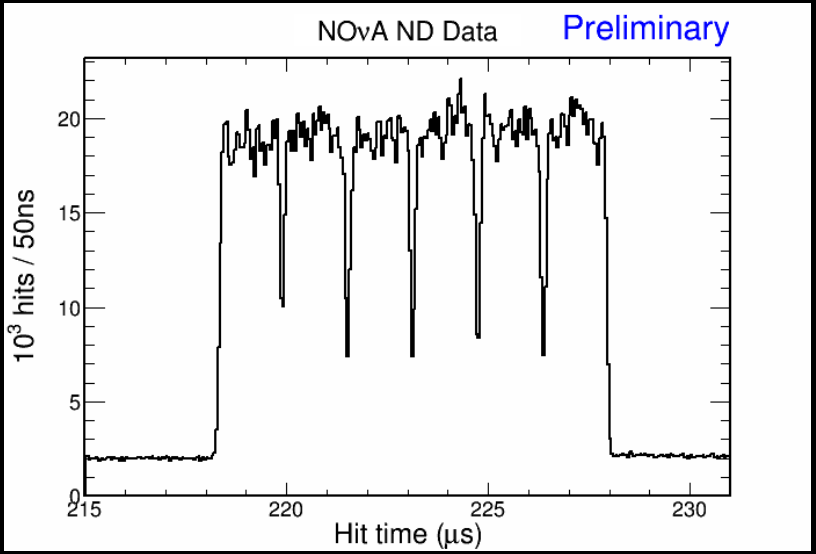
High Energy Trigger



Near Detector

- Timing 24,333 NuMI spills collected (~13.38 s of live time)
- No reconstruction/cuts → raw hit times
- Fast timing gives good enough timing resolution to see the structure of the beam

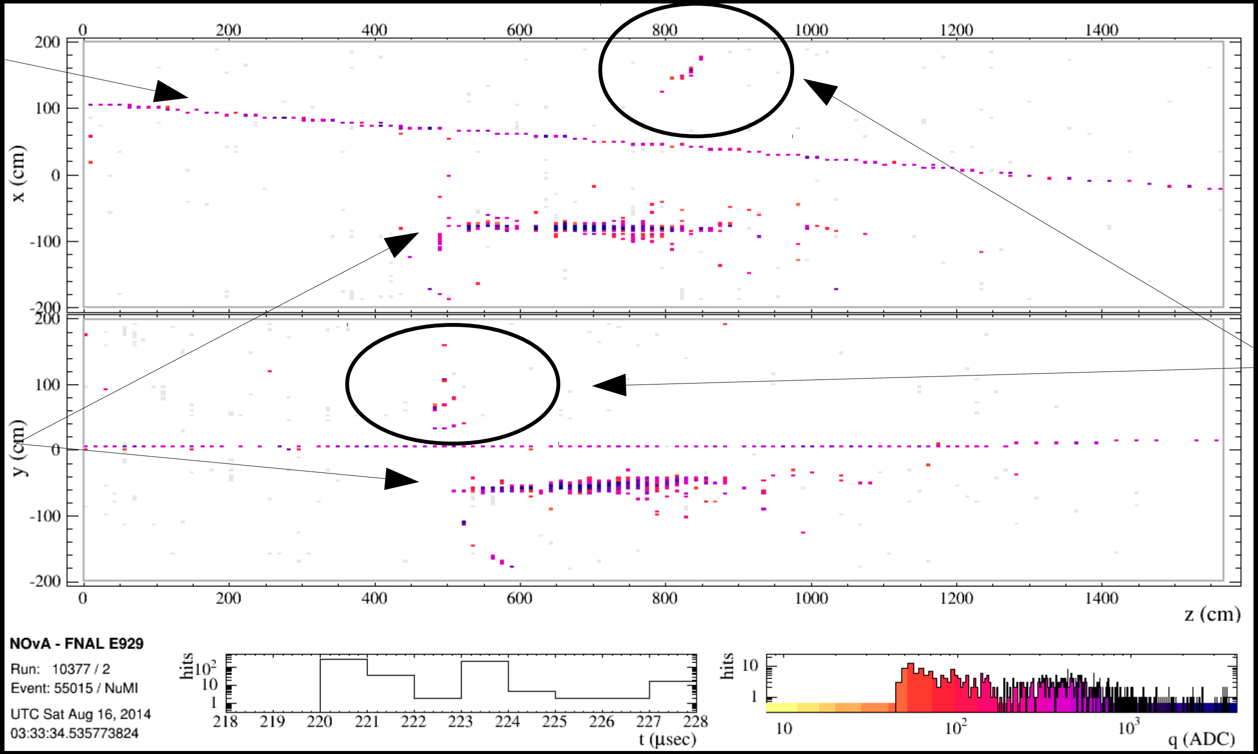




Near Detector: Neutrino Candidate

Rock μ

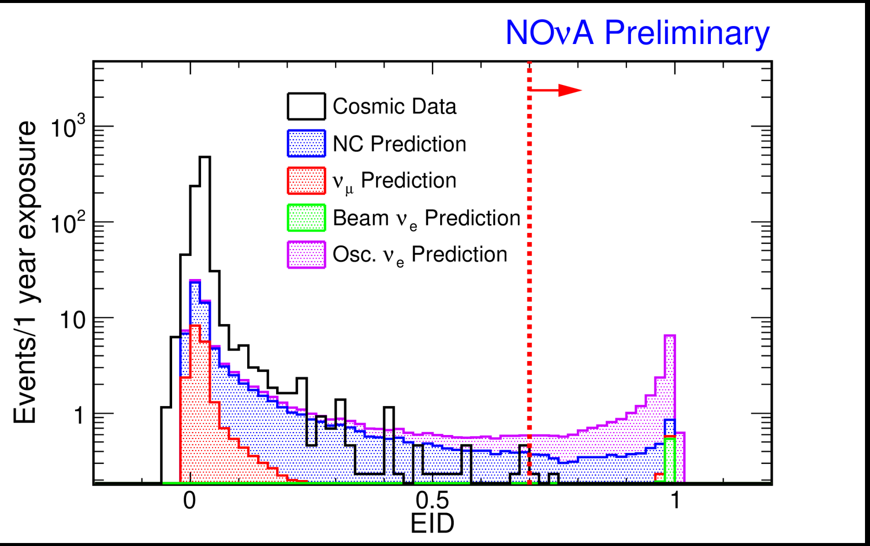
ν_e candidate: ~5 νs/spill at 700 kW

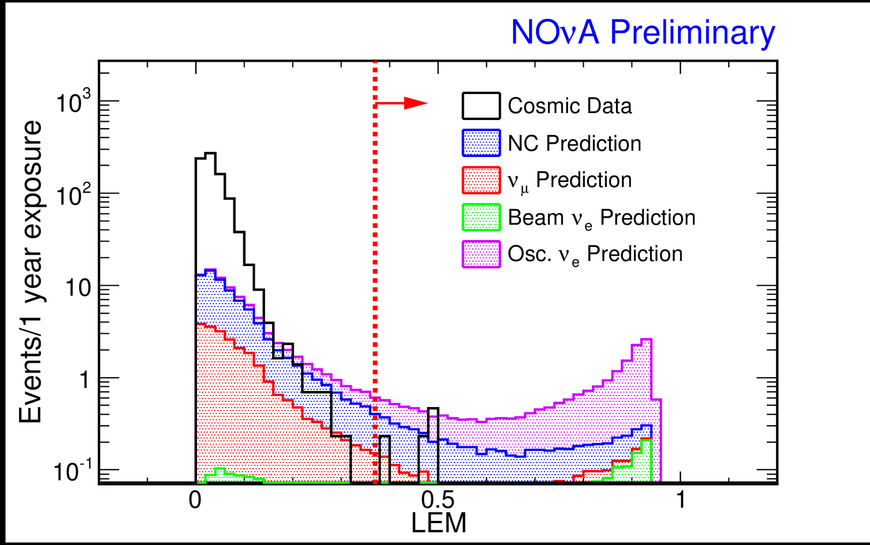


Noise easily removed using spatial and temporal clustering

ν_e Selection

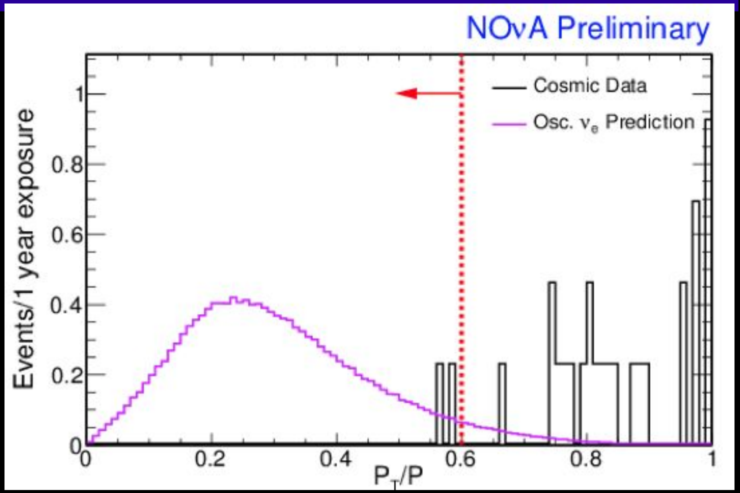
- Two complementary methods of identifying electron showers
  - EID → A neural net based on shower development
  - LEM → A matching approach based on comparing a library of simulated electron showers to reconstructed showers

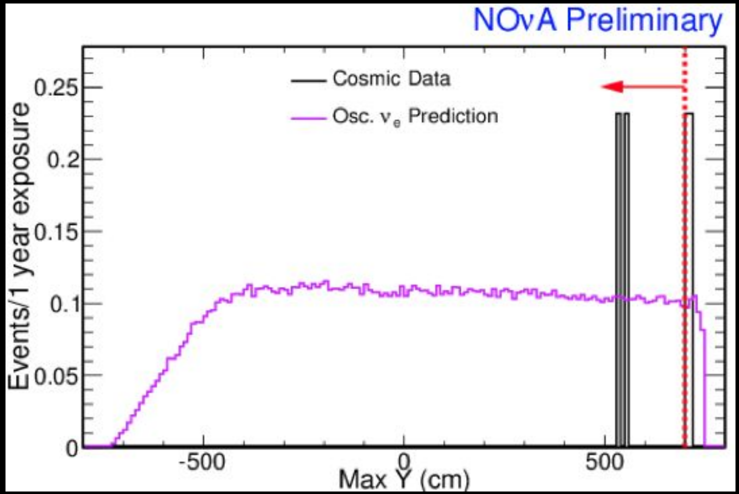




Cosmic Rejection

- FD is on the surface → ~20 million cosmic rays/year
- Electron particle ID already removes many cosmic rays
  - Cosmic rays usually do not look electron-like
- Use three extra cosmic rejection cuts based on simple idea that events of interest come from the beam while cosmic rays come from the sky
  - P_t/P → require shower to point in the direction of the beam
  - Max Y → remove showers with hits near the top of the detector
  - Vertex gap → remove showers with start points far from the reconstructed vertex
- Achieves 40 million to 1 rejection!





After all cuts (1 year):
14 ν_e, 6 beam bkg, 0.5 cosmic rays

Summary

- Both the near and far detectors are now operational
- Beam is operating at ~280 kW and 25×10^{12} POT/spill
- First analysis results expected in early 2015
- Stay tuned!

Thank you!

Mass Hierarchy/CP Violation Sensitivities + T2K