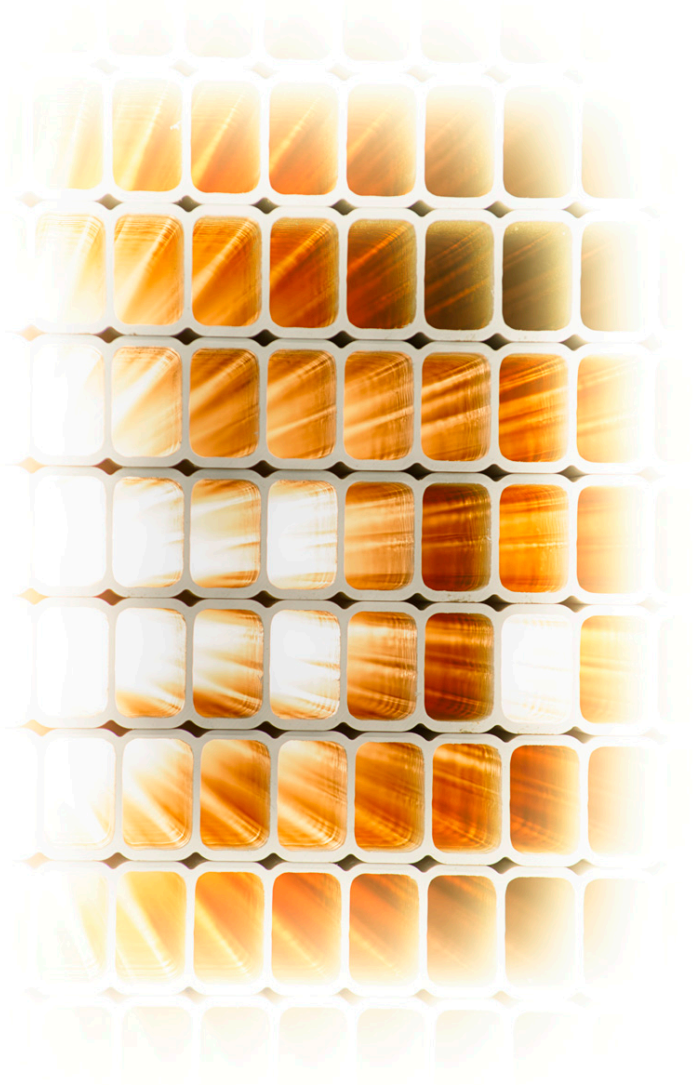
Muon Neutrino Disappearance at NOvA

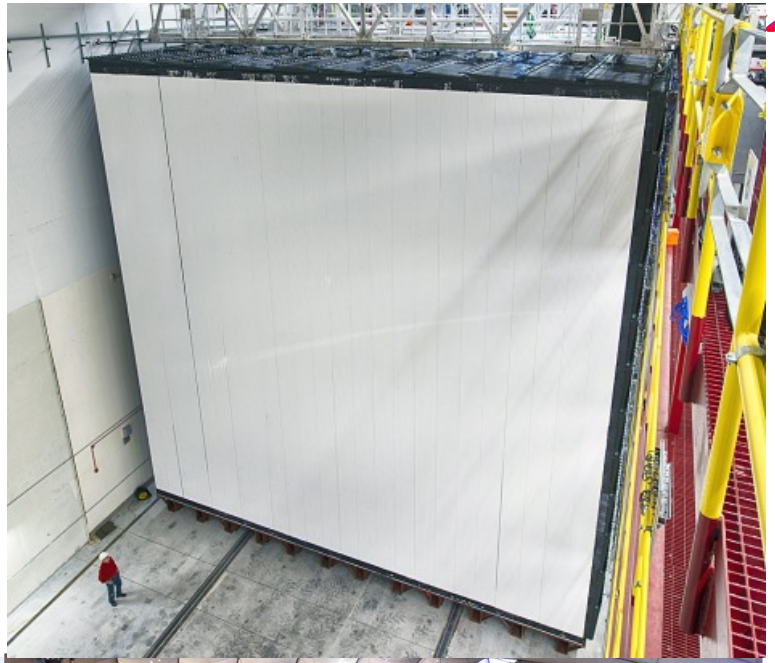
New Perspectives, Fermilab June 2014

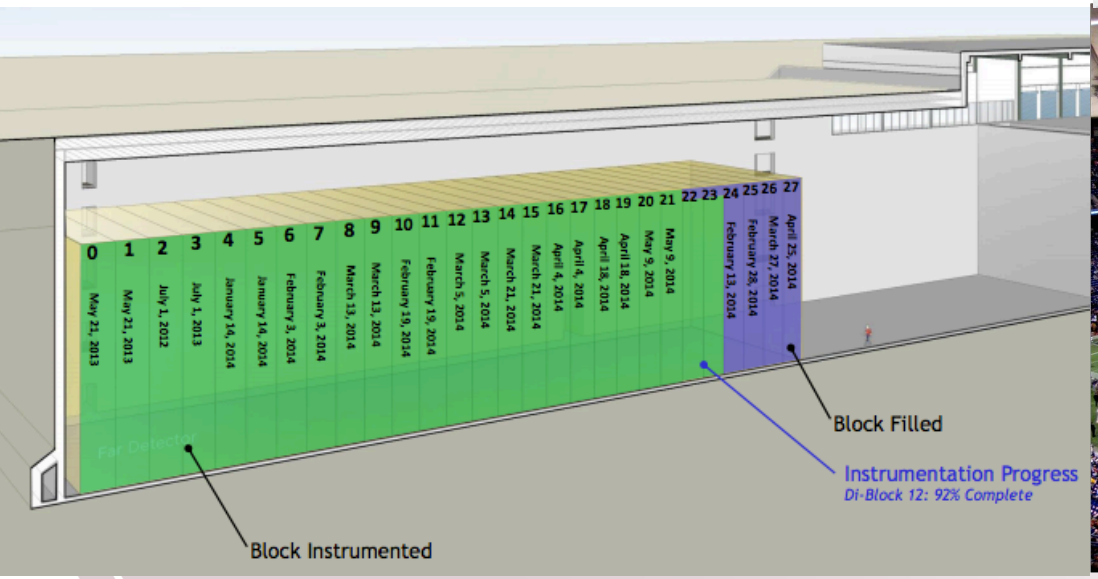
Louise Suter, Argonne National Lab



Far detector construction status

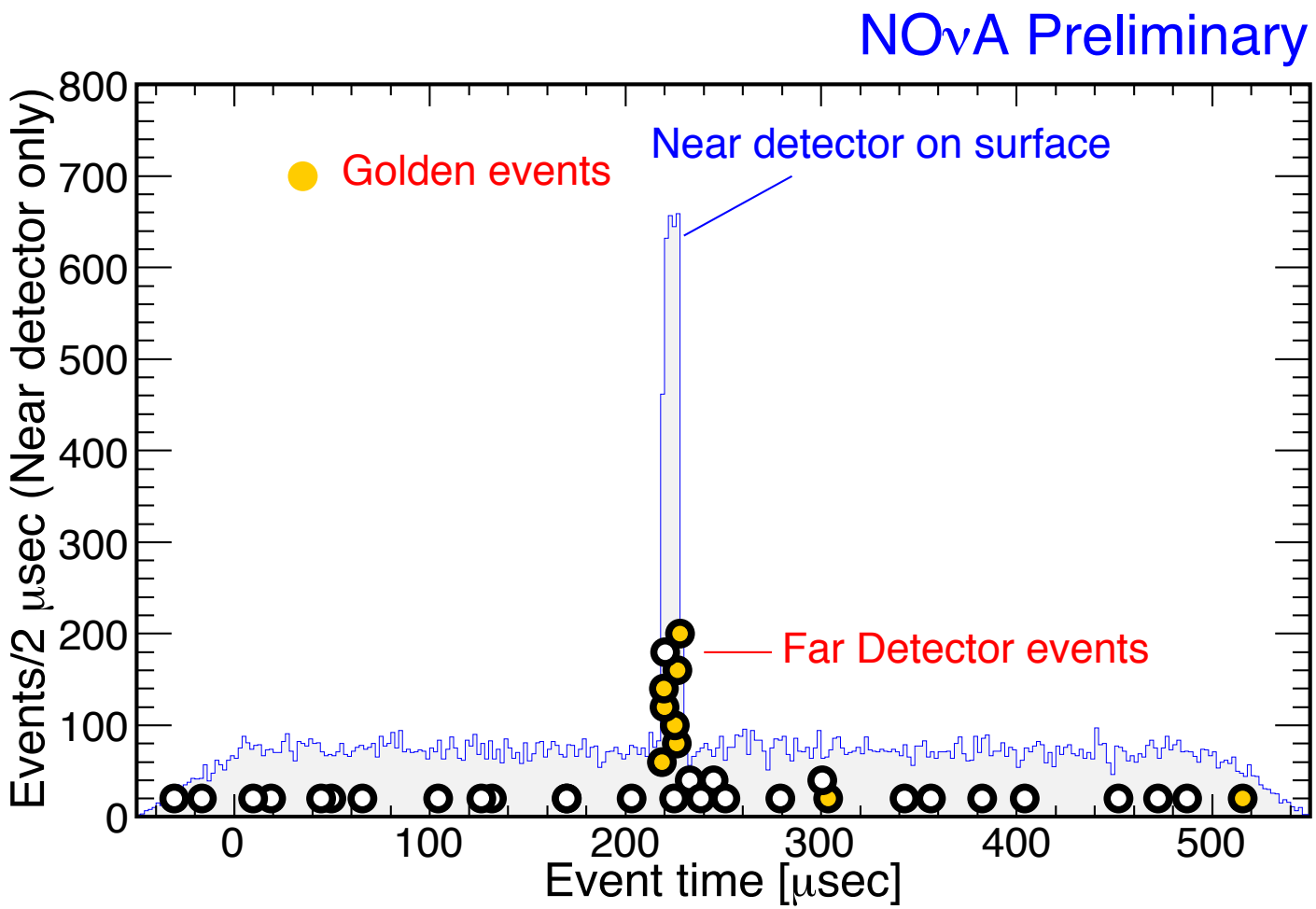
- NOvA far detector is big …. really big
  - 15.6 meters wide, 15.6 meters tall, and 67 meters long
- Detector built modularly so can take data with segments of the detector while others are under construction
- Detector nearly finished with expected finish date summer 2014





First neutrinos at the Far Detector

First neutrinos seen in Far Detector in December last year, using only 1/7 of the complete FD.



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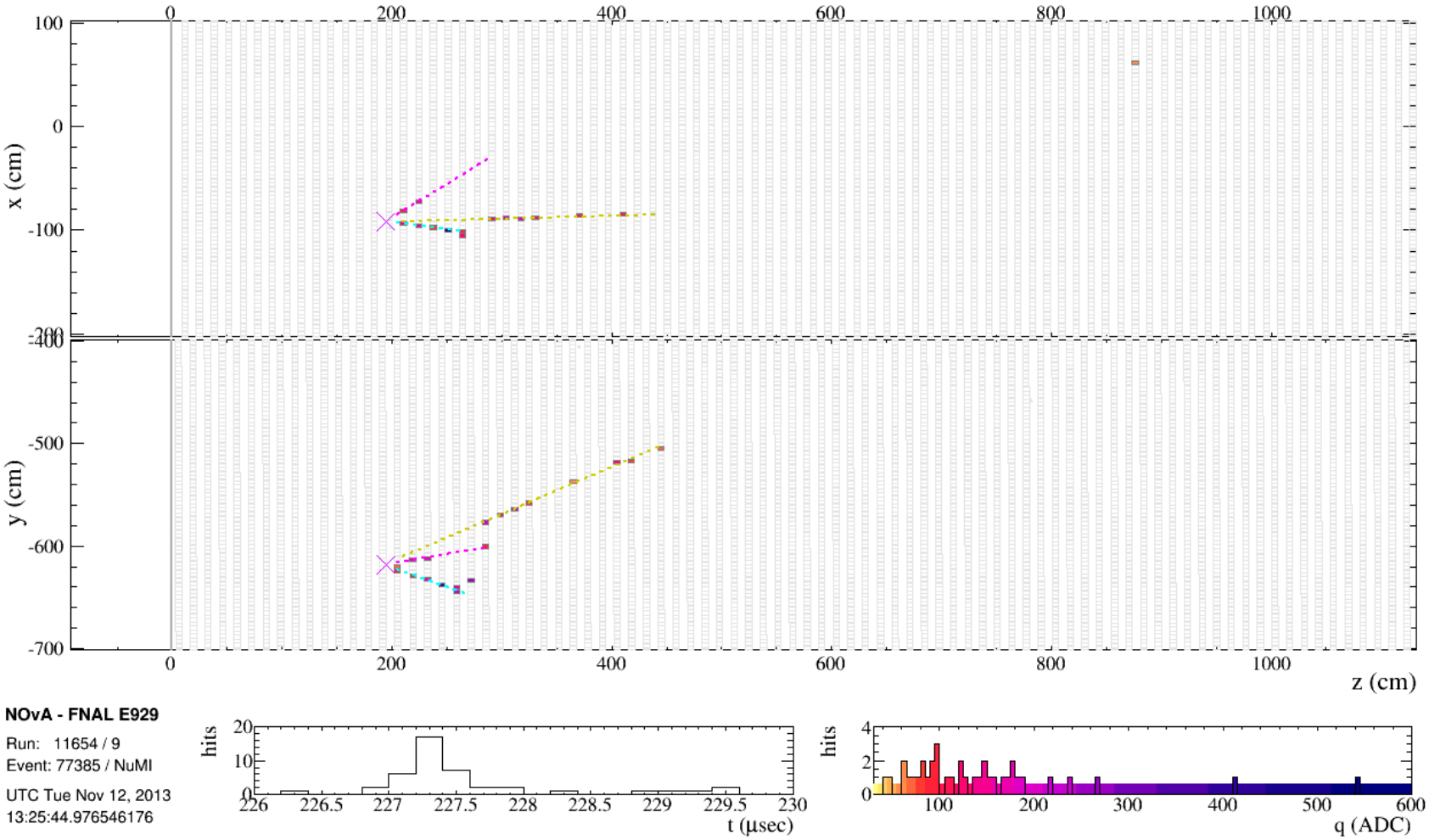

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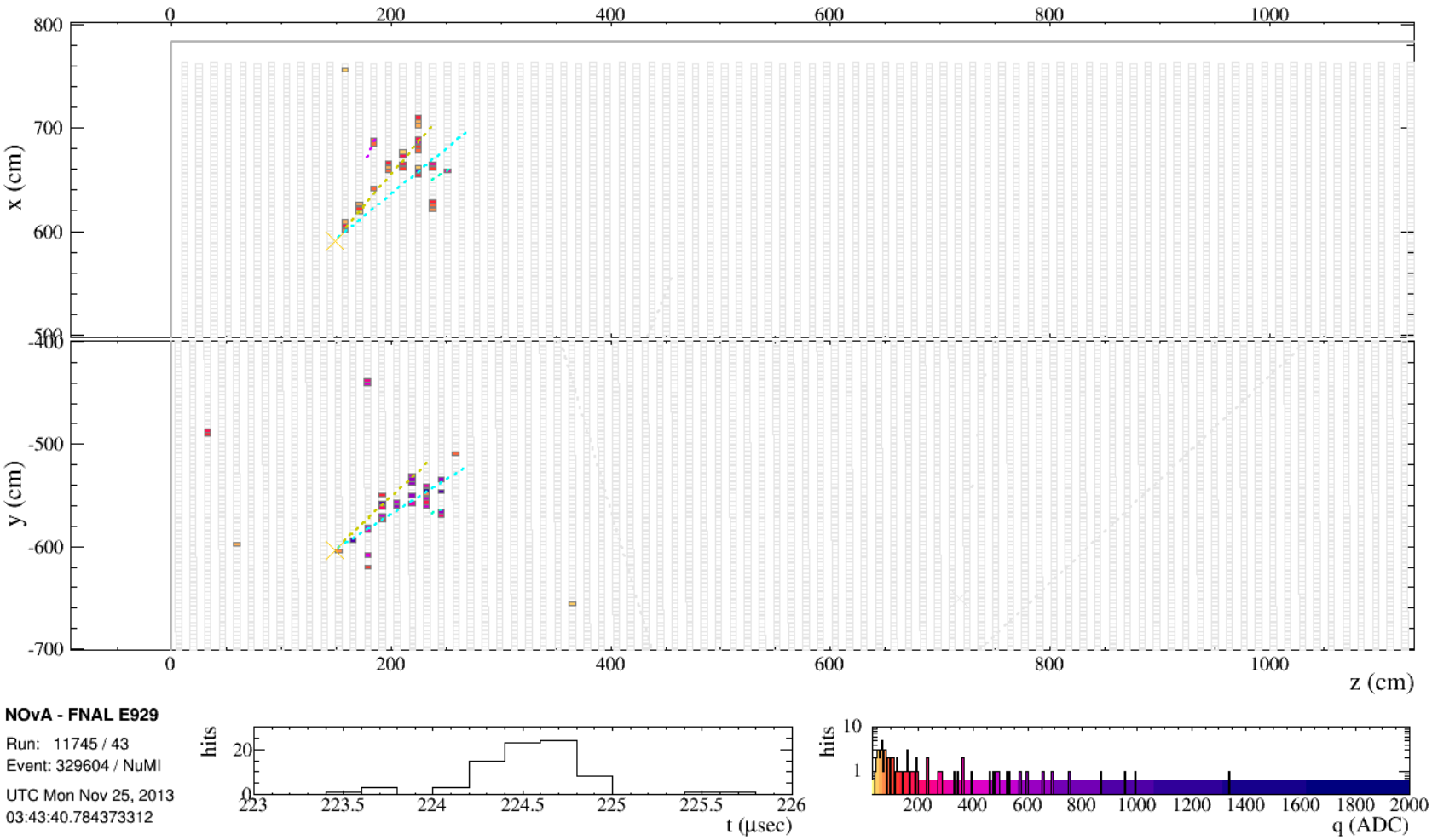

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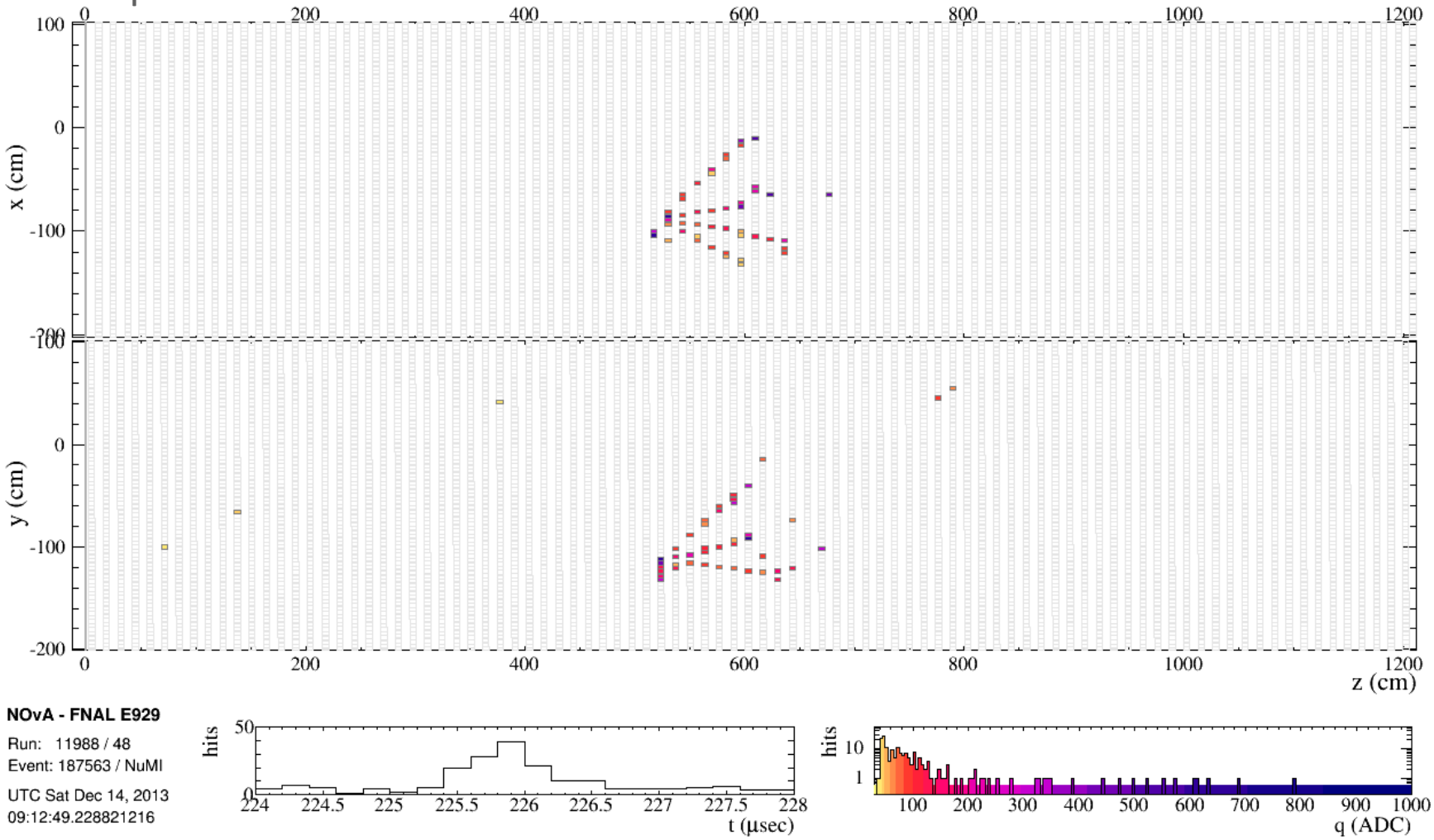

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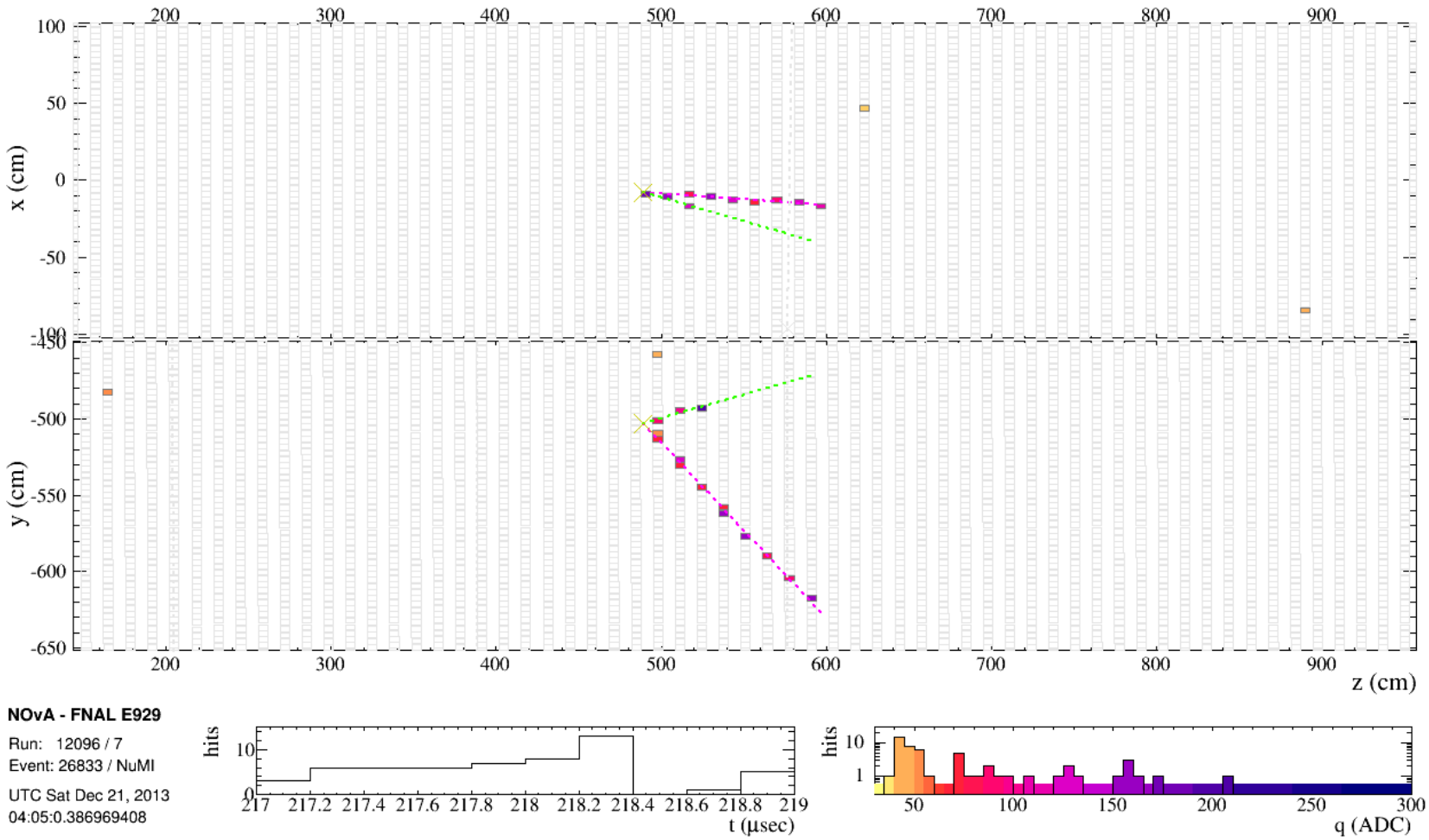
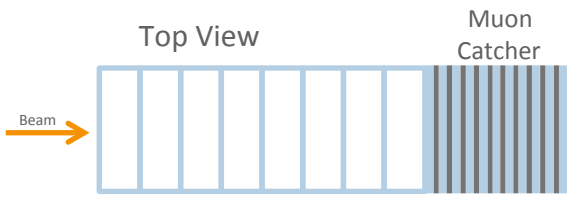
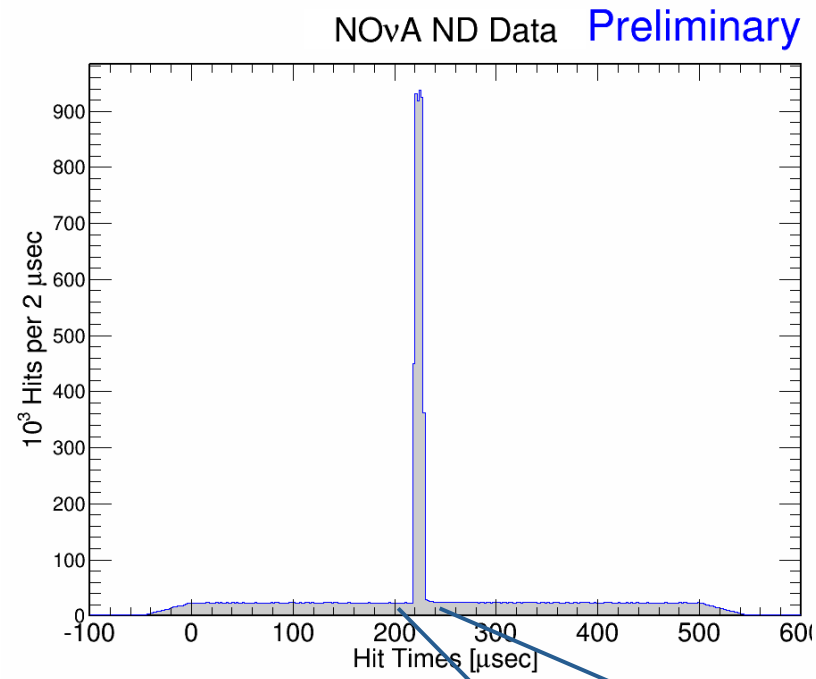


Near detector construction

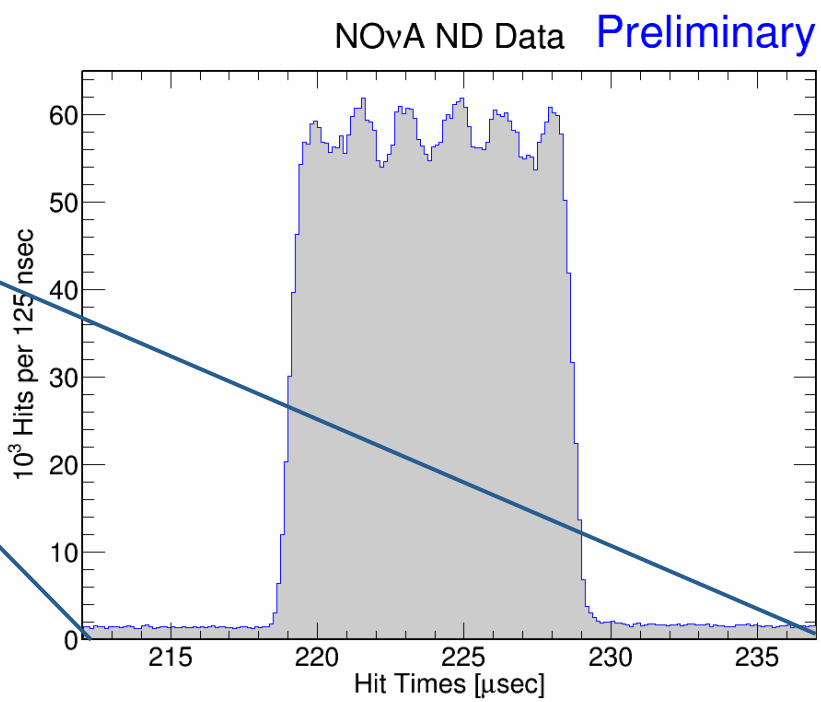
- Constructed in purpose-built hall in the MINOS underground cavern
- Using the same design and technology as FD
- One exception is 'Muon Catcher' with layers of steel are inserted in the back ¼
- Due to be finished summer 2014
- ~1/3 of ND is fully instrumented and first events were recorded May 2014



First ND data

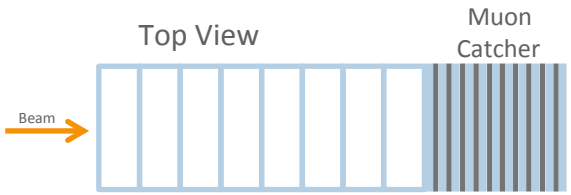


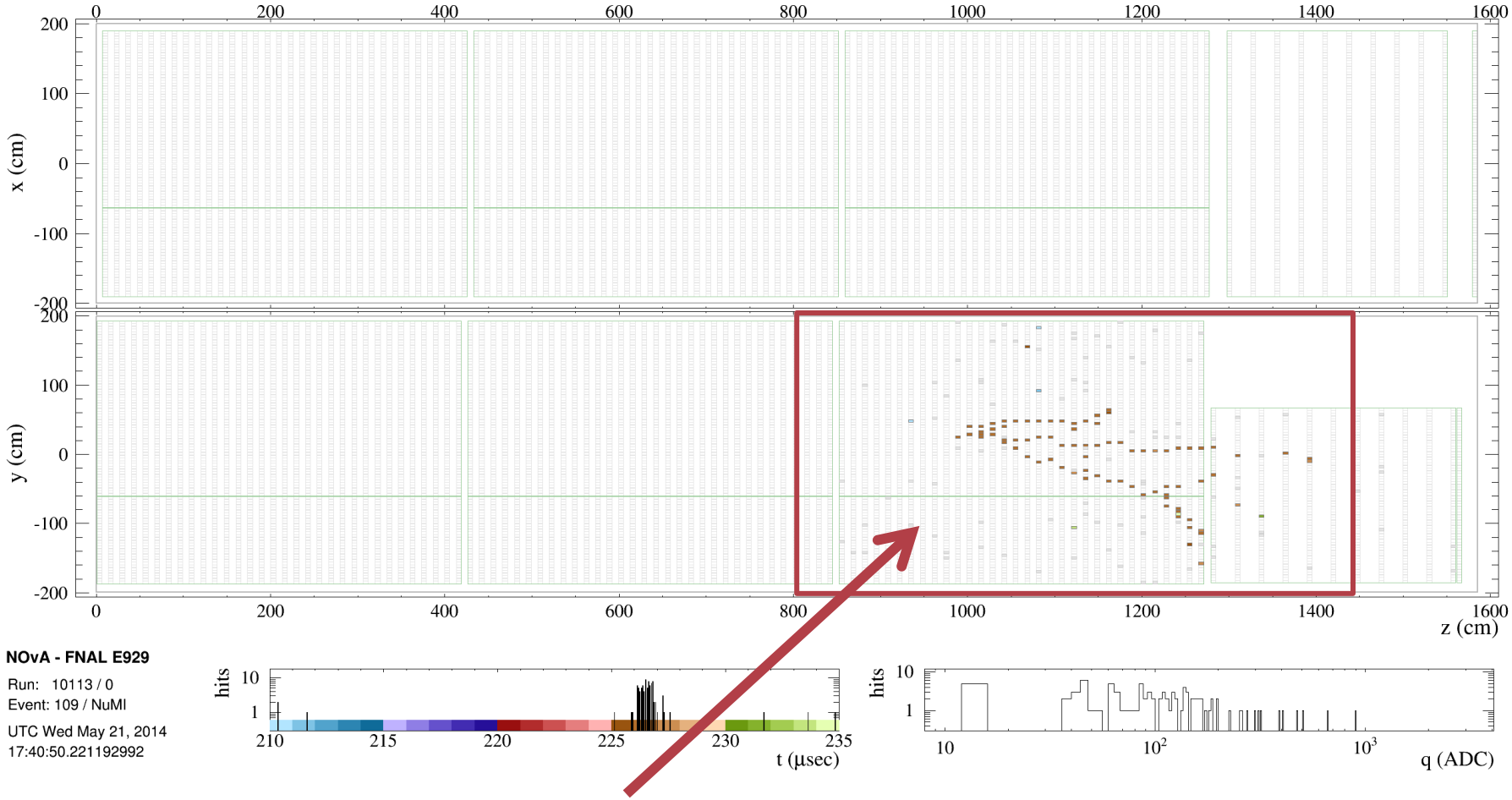
Can clearly see booster batch structure



- ~1/6 of ND detector instrumented
- Only showing 12 hours of data
- Showing all recorded hits against time

First ND events



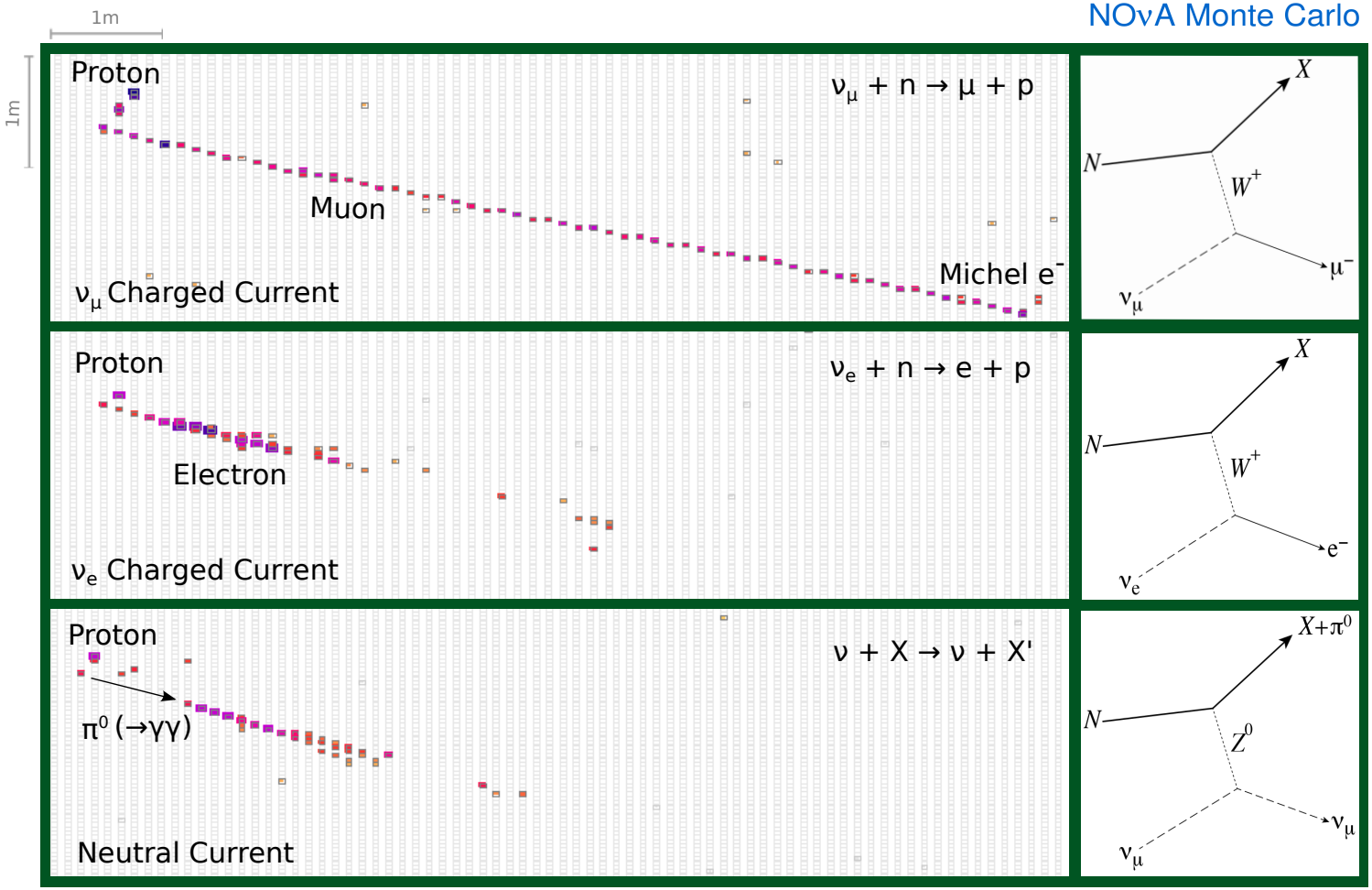


Red box outlines instrumented region

What do ν_μ CC events look like in NOvA?

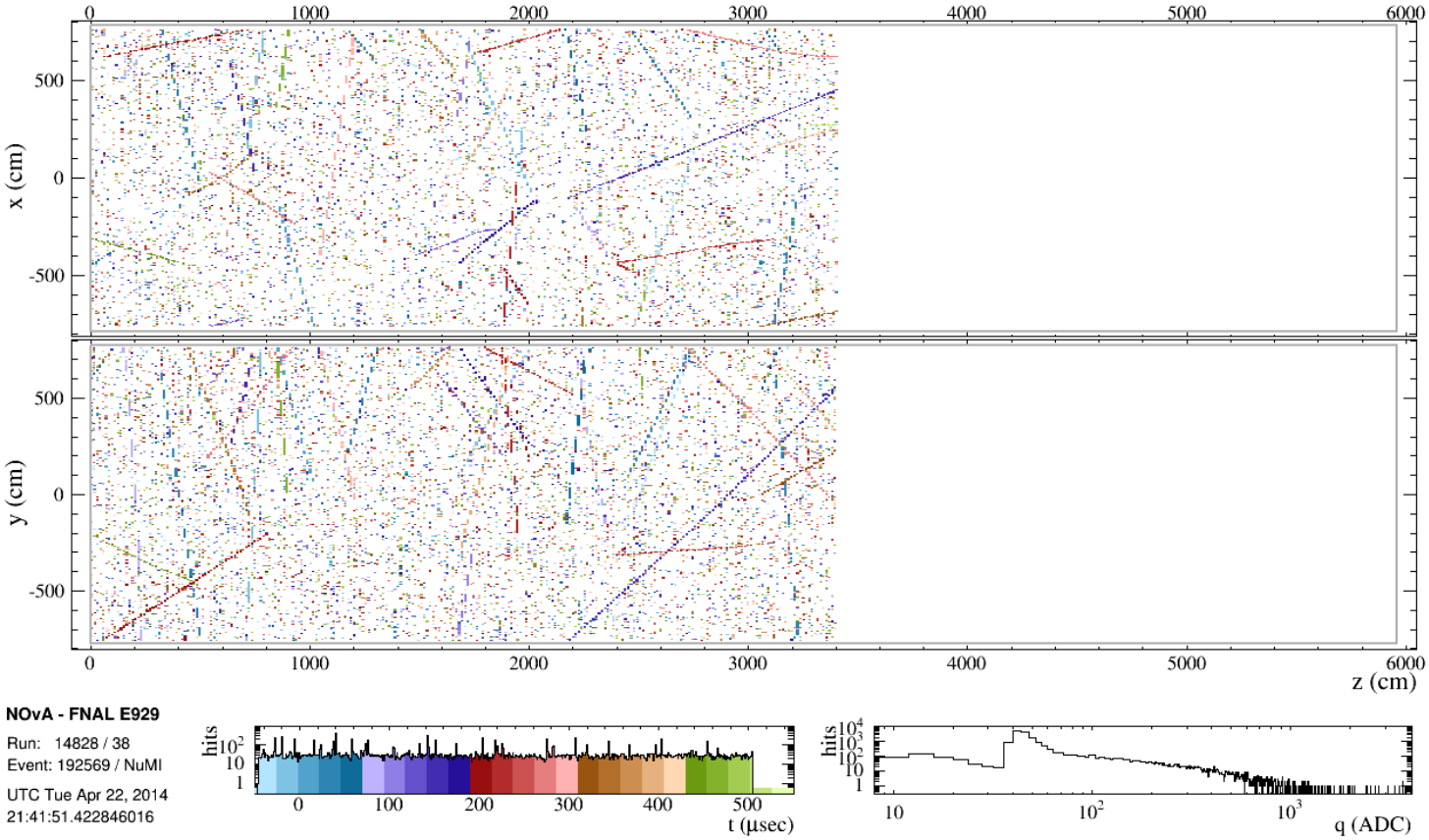
i.e. what are we looking for?

NOvA Monte Carlo



Event reconstruction with NOvA

- FD is on the surface, large cosmic ray background
- Events recorded using both topological trigger and using spill triggers
- Record 500 µs window around spill, allows us to collect large cosmic sample



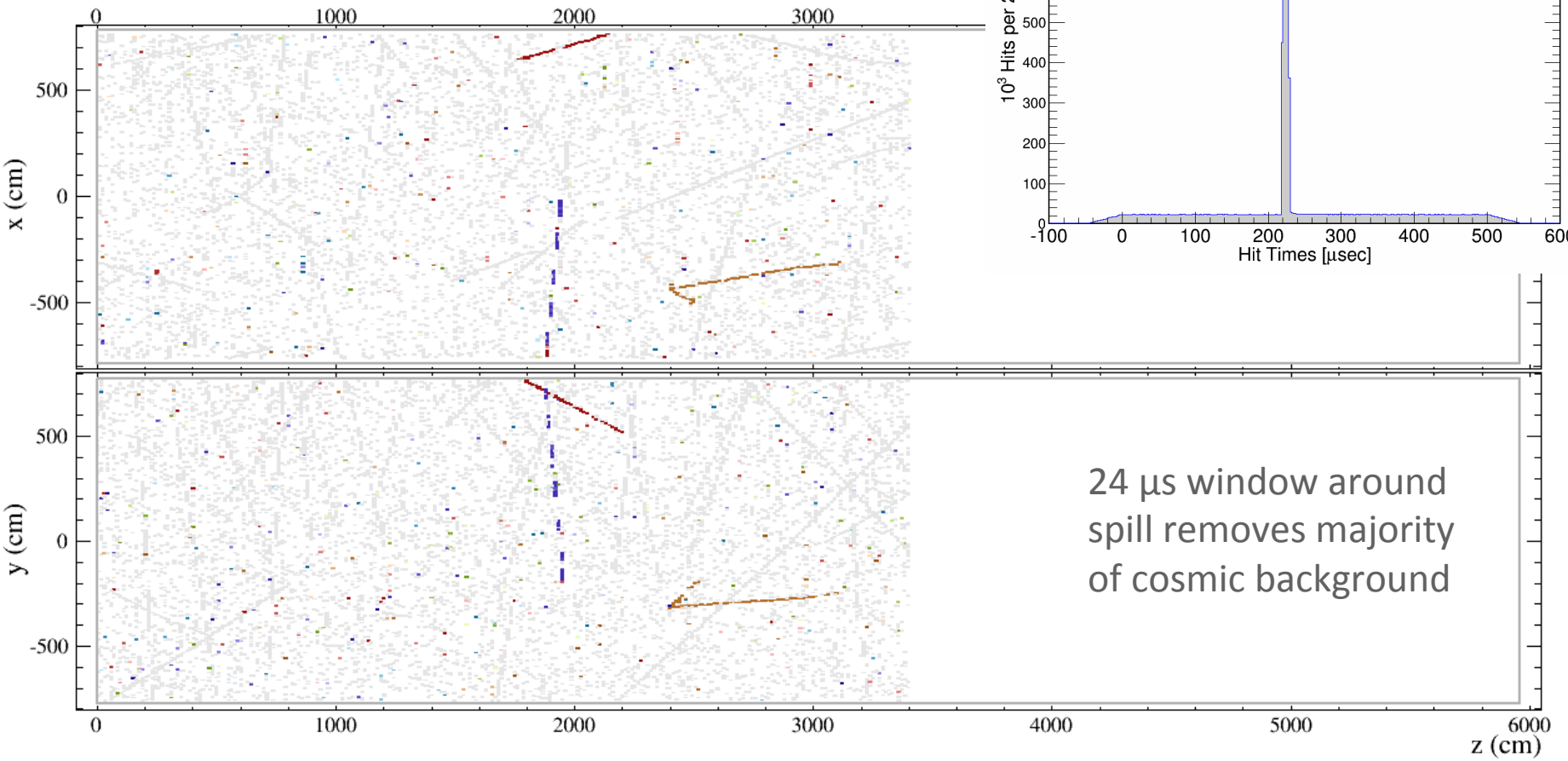
A lot happens in 500 µs

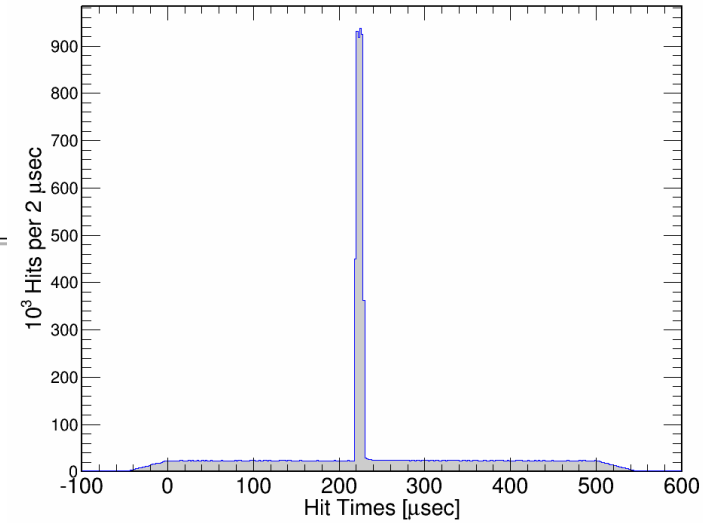
So how do we find the neutrino?

Color represents when in the 500 µs window the hit occurred

NOvA ND Data Preliminary

Select based on known time of neutrino spill



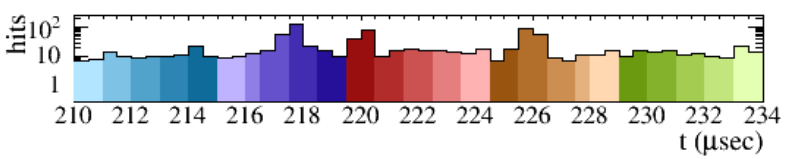


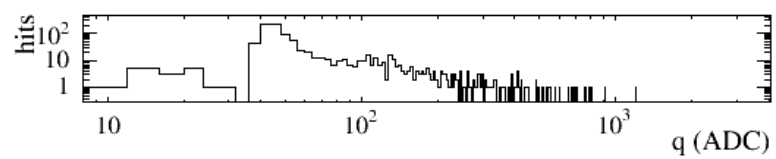
24 µs window around spill removes majority of cosmic background

NOvA - FNAL E929

Run: 14828 / 38
Event: 192569 / NuMI

UTC Tue Apr 22, 2014
21:41:51.422846016





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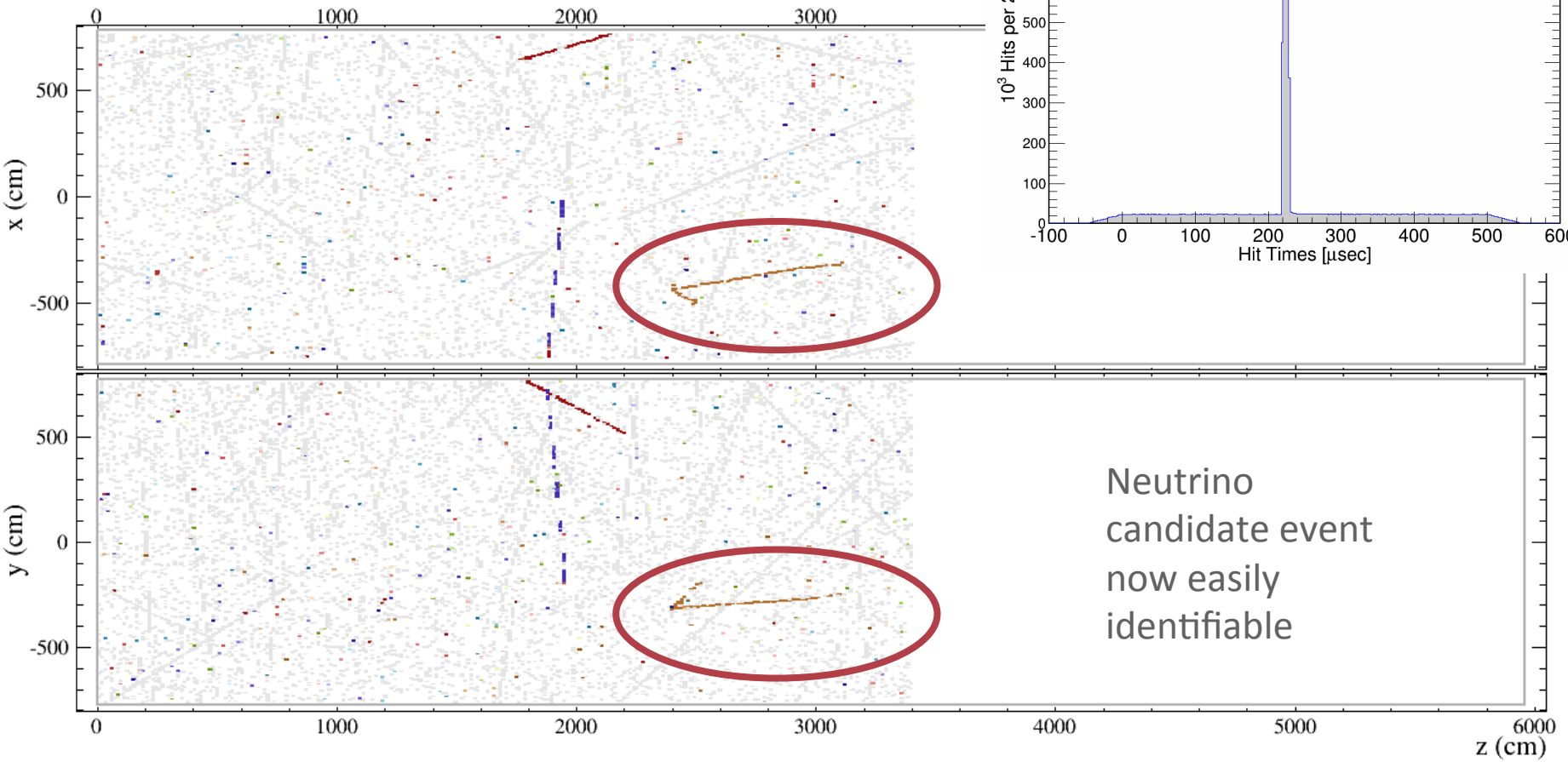

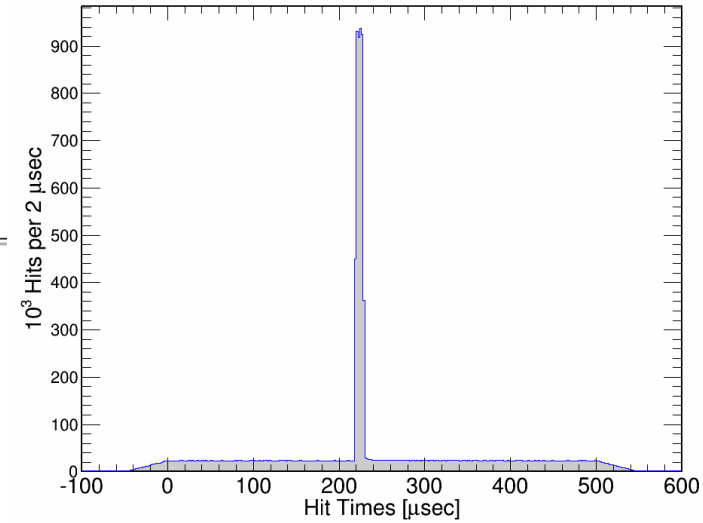

Neutrino candidate event now easily identifiable

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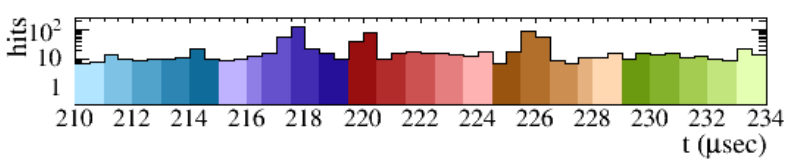
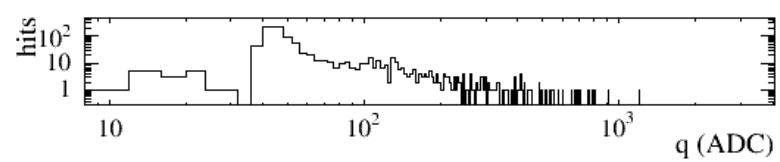
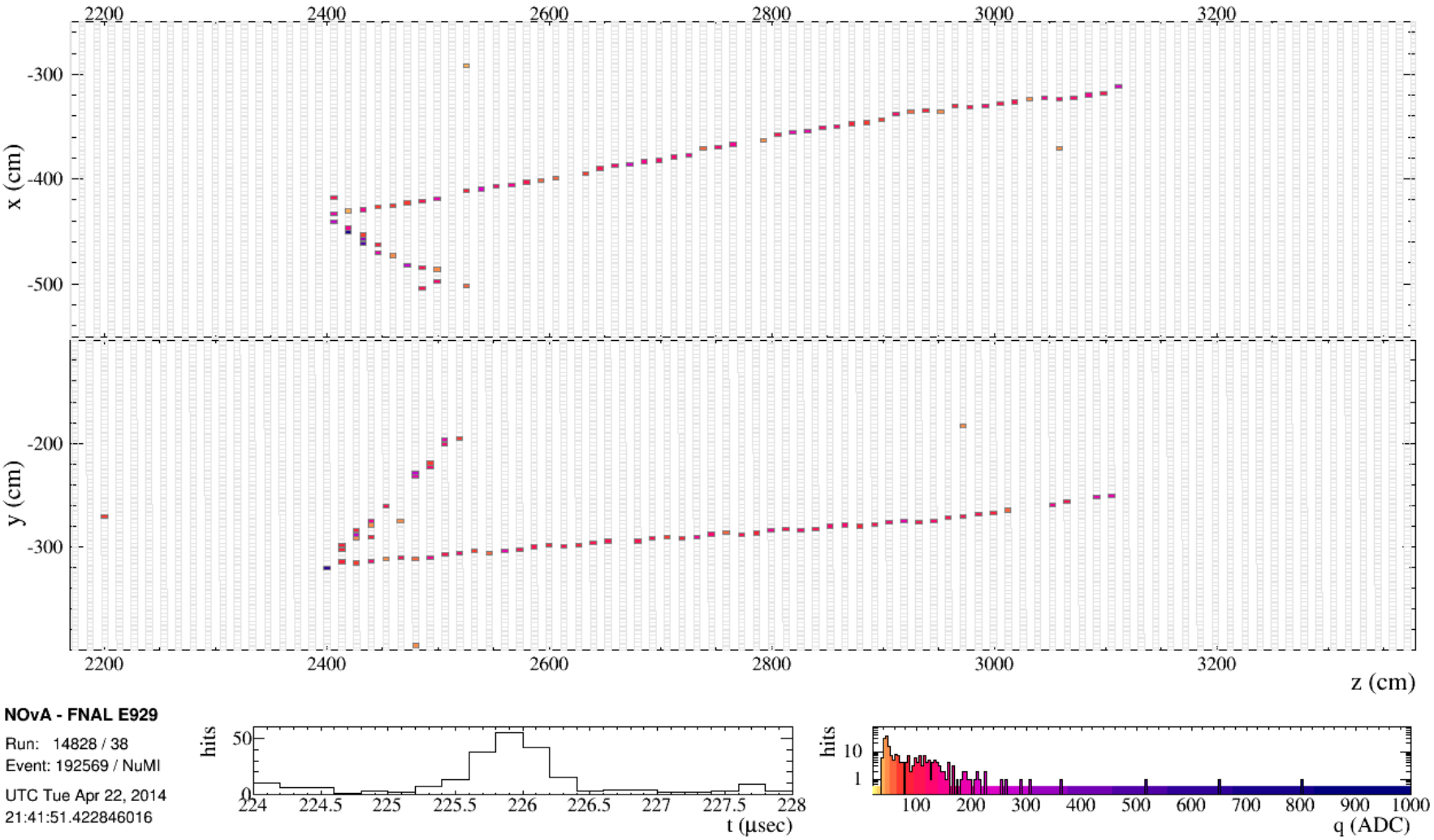




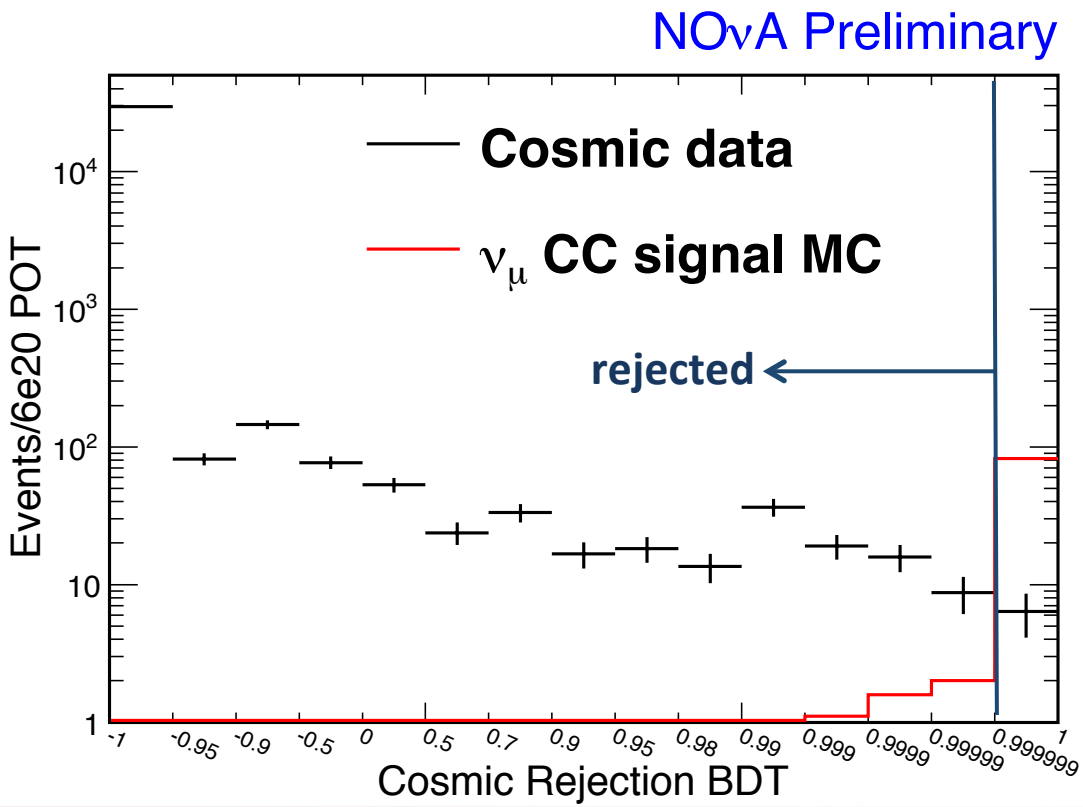
Select tracks originating from vertex consistent with ν_μ CC event



Muon Disappearance at NOvA

Stage 1: Cosmic removal

- At FD have ~100 kHZ of cosmic ray background
- Remove large portion of this background using kinematic selection
- Train Boosted Decision Tree (BDT) to remove remaining
- Achieve 7 orders of magnitude reduction with 10% loss of signal events

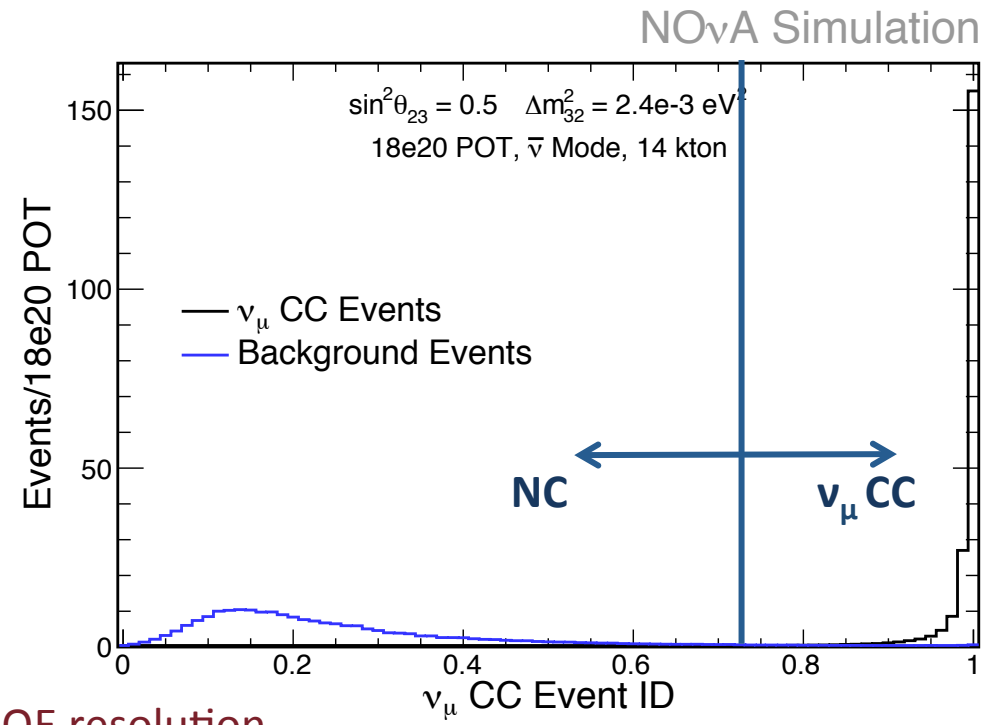


1 full run year = 6e20 POT

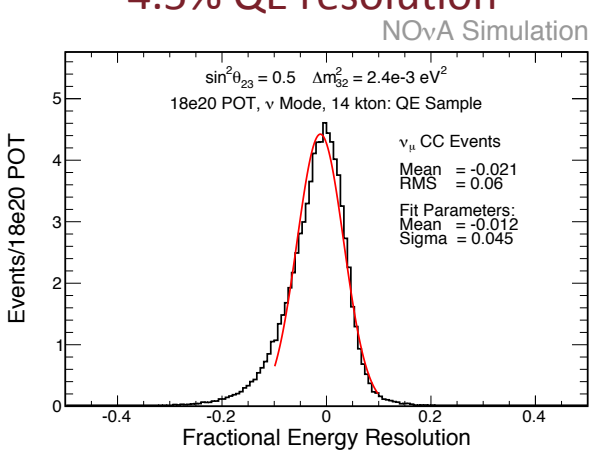
Muon Disappearance at NOvA

Stage 2: ν_μ CC selection

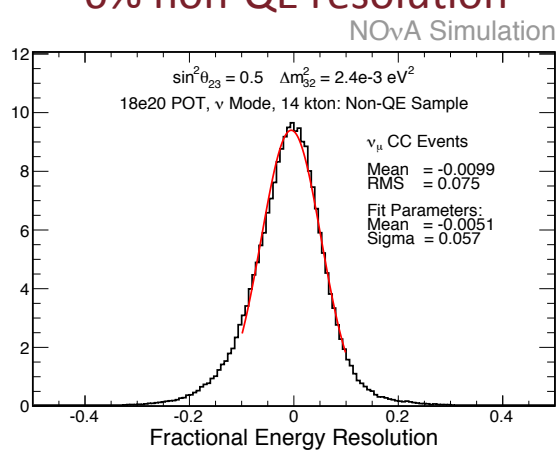
- A k-Nearest Neighbour (kNN) algorithm is used to select ν_μ CC signal from low energy NC background
- Select with 88% efficiency, 94% purity and 93% of NC events are rejected
- Separate ν_μ CC into different subsamples based on reconstructed energy resolution
- Increases sensitivity to oscillation parameters



4.5% QE resolution



6% non-QE resolution

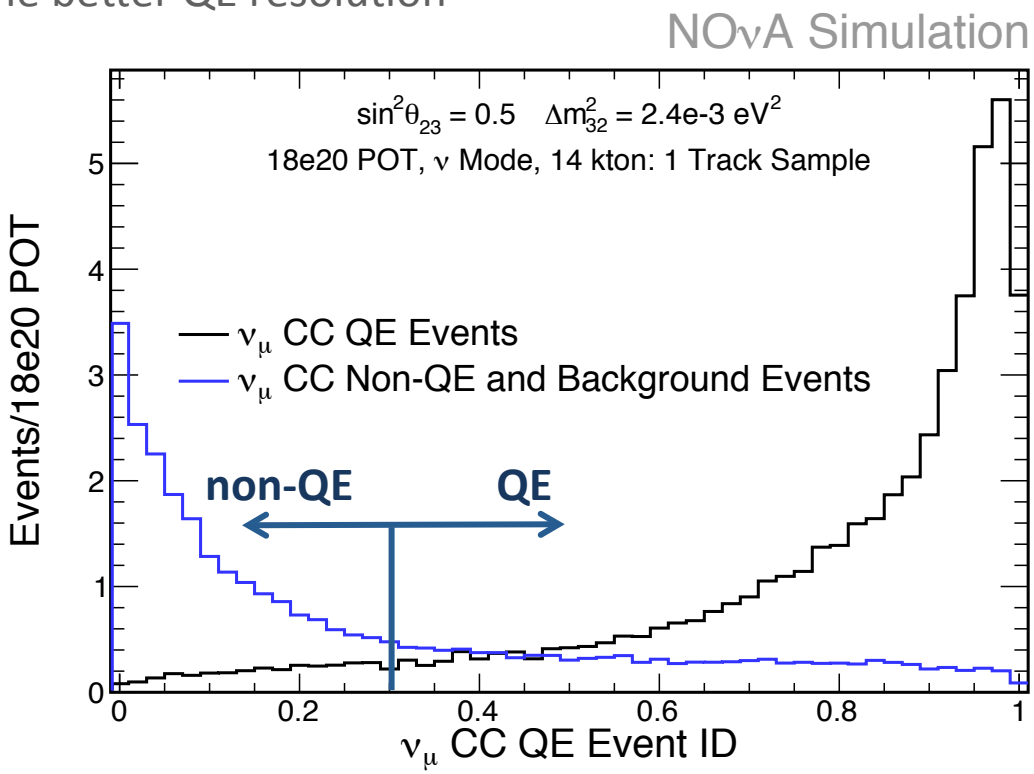


Muon Disappearance at NOvA

Stage 3: ν_μ CC subsamples

- First separated into contained and uncontained events
  - Uncontained events with identifiable muon retained
  - Energy exciting the detector results in lower energy resolution for uncontained events
- Contained events subdivided into QE and non-QE using a kNN
- Lets us take advantage of the better QE resolution

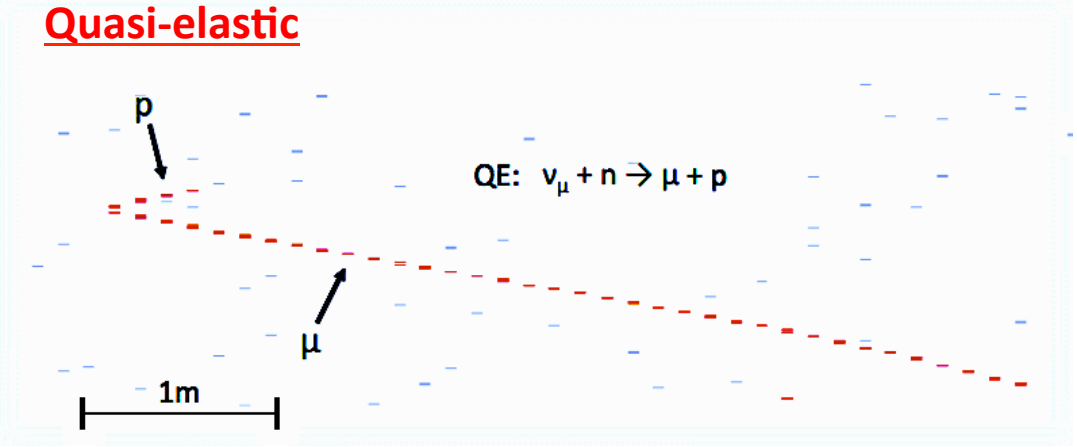
For 1 track events select QE events with an 90% efficiency and 82% purity



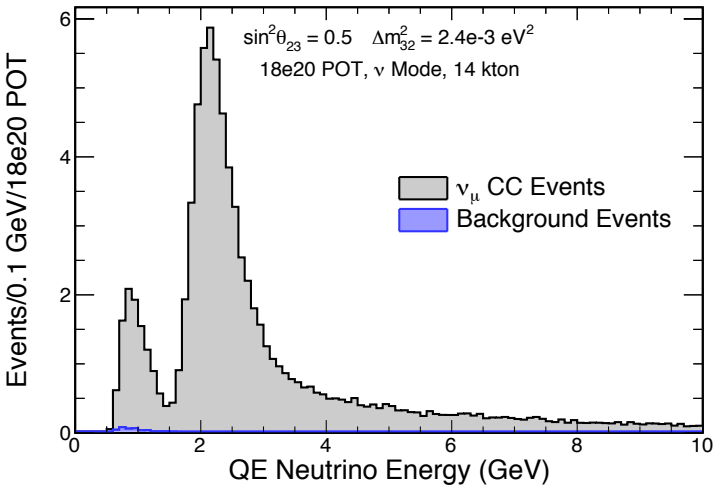
Muon Disappearance at NOvA

Stage 3: ν_μ CC subsamples

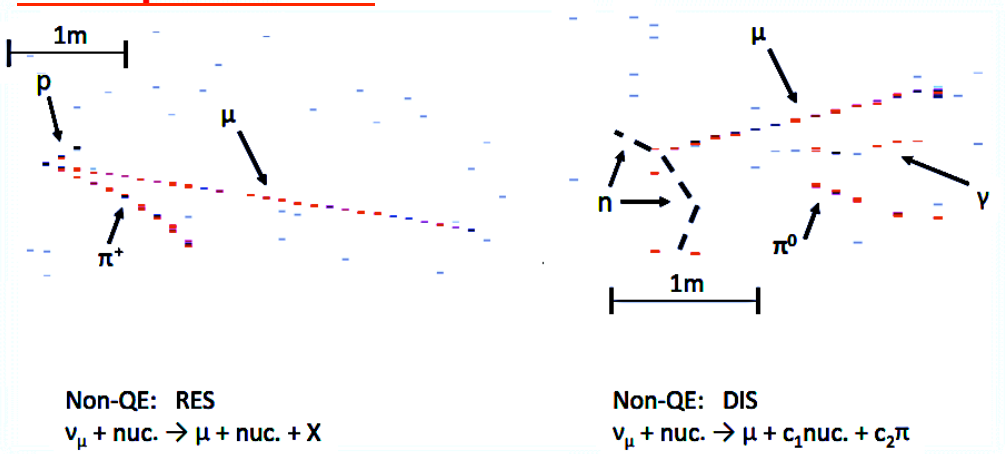
Quasi-elastic



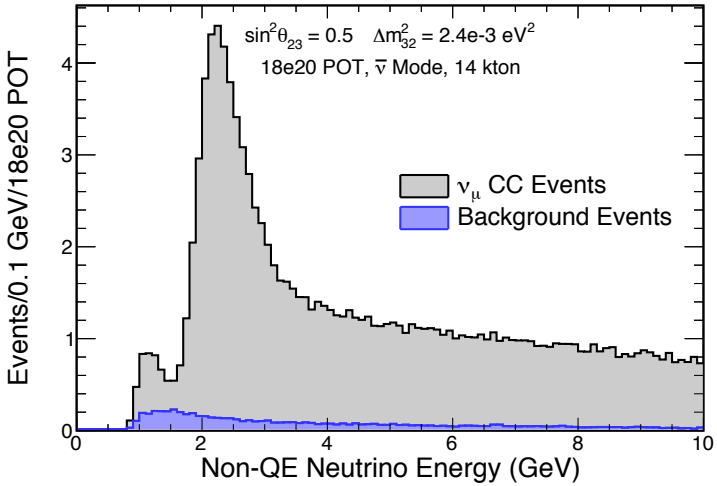
17% of ν_μ CC events NOνA Simulation



Non- quasi-elastic

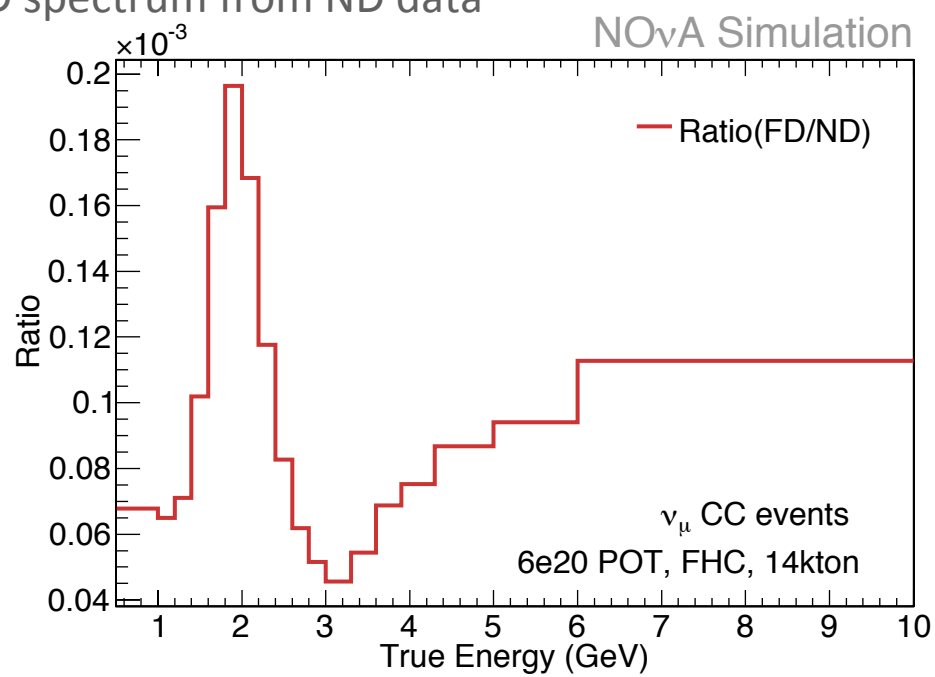


47% of ν_μ CC events NOνA Simulation



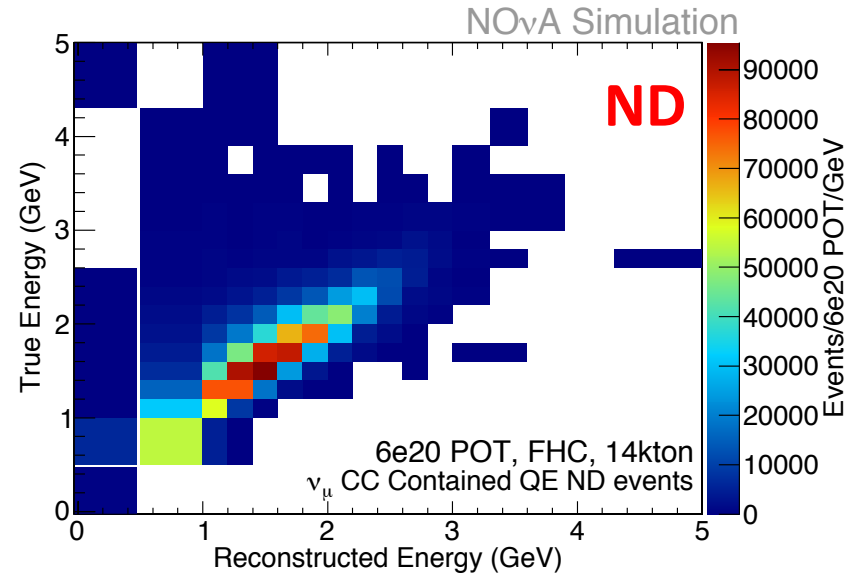
ND to FD extrapolation
The concept

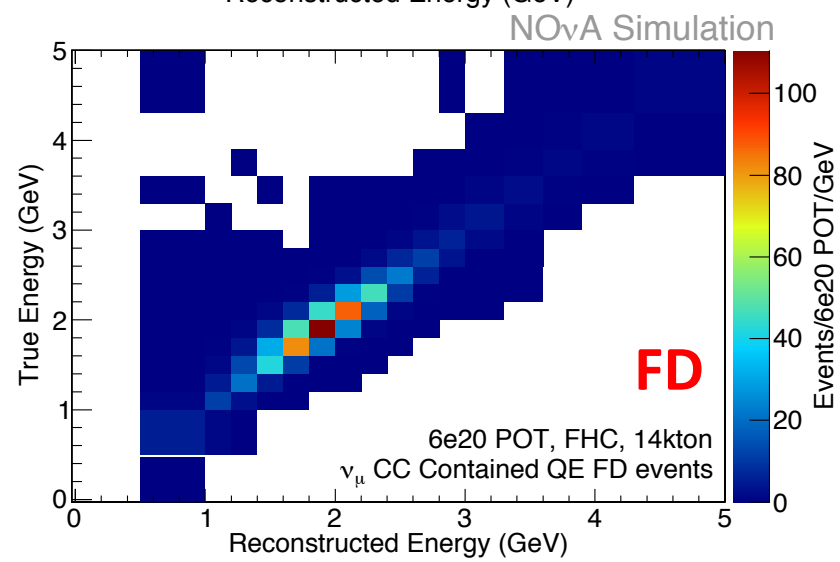
- Two detectors enable a data-driven method to predict energy spectrum at ν at FD
- Removes the dependence on MC predictions of flux which can suffer from large uncertainties
- The detectors have identical construction, cancelling of many of the remaining systematic uncertainties
- NOvA uses a direct extrapolation method where predicted FD/ND ratio is used to predict the FD spectrum from ND data



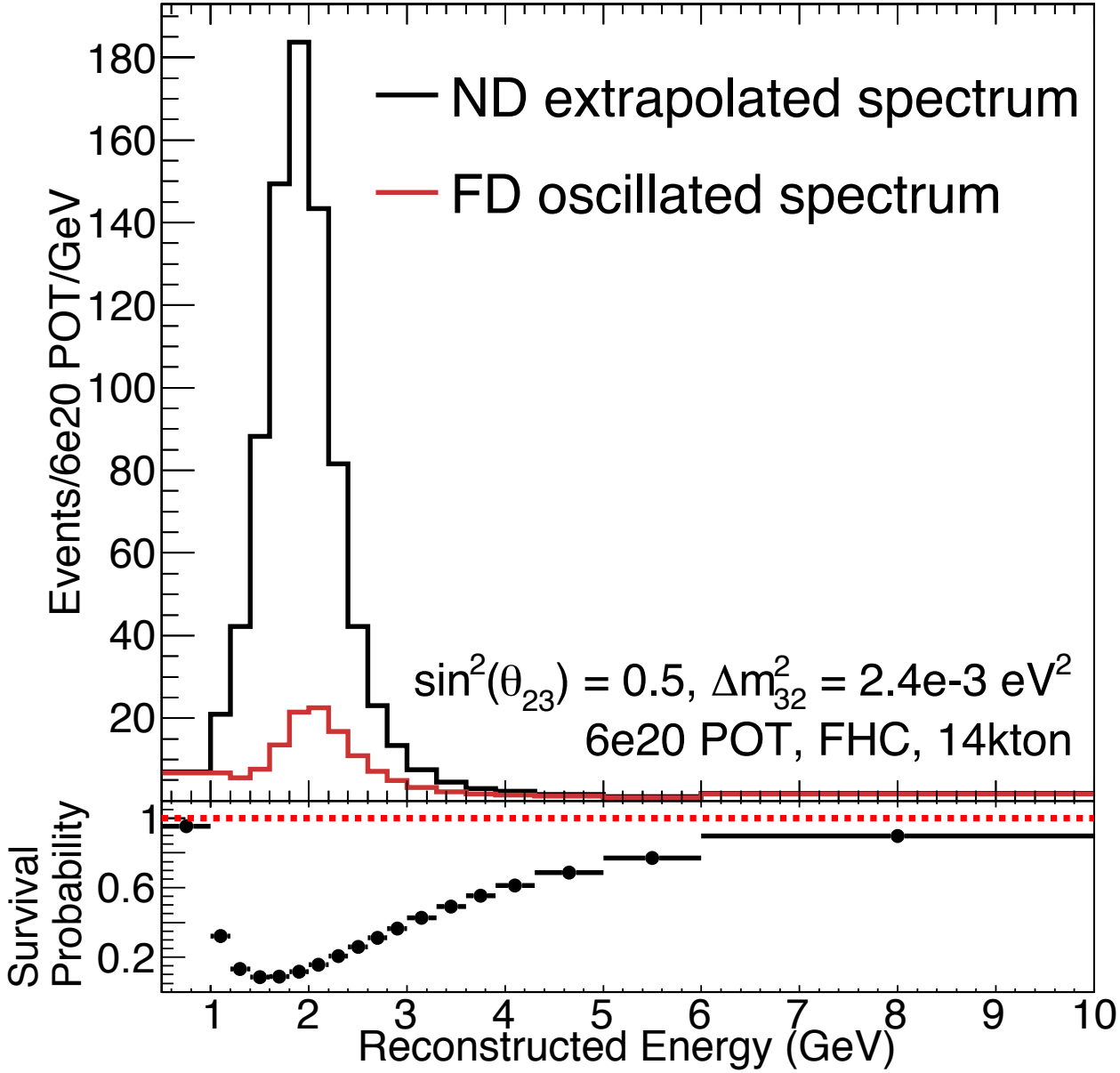
ND to FD extrapolation
The method

- Need to correct for acceptance, efficiency and purity effects between ND and FD
- To account for bin to bin migration and differences in ND and FD energy reconstruction must unfold data to the true energy distribution
- Use Singular value Decomposition based unfolding via ROOTs TSVDunfold package





NOνA Simulation

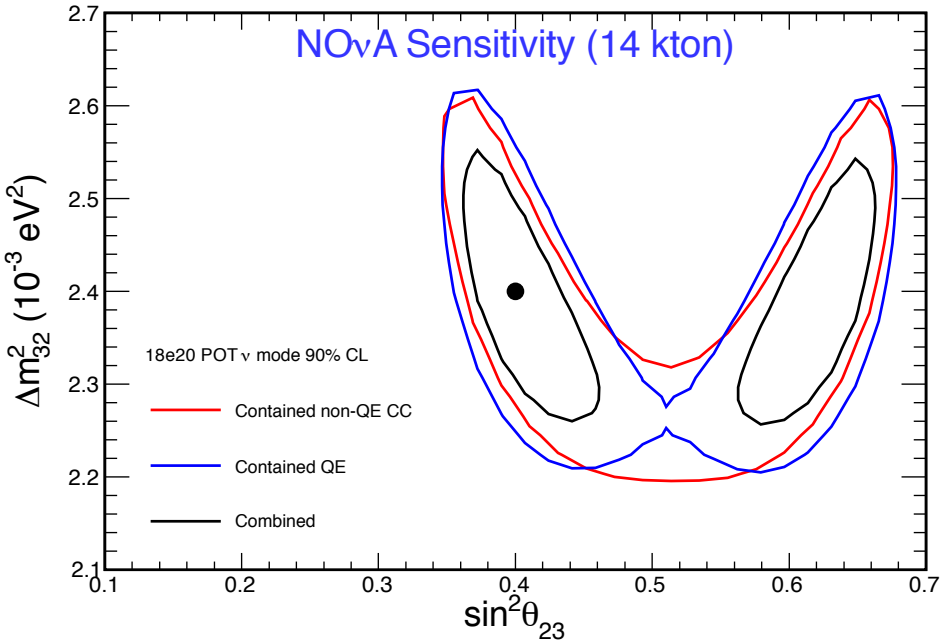


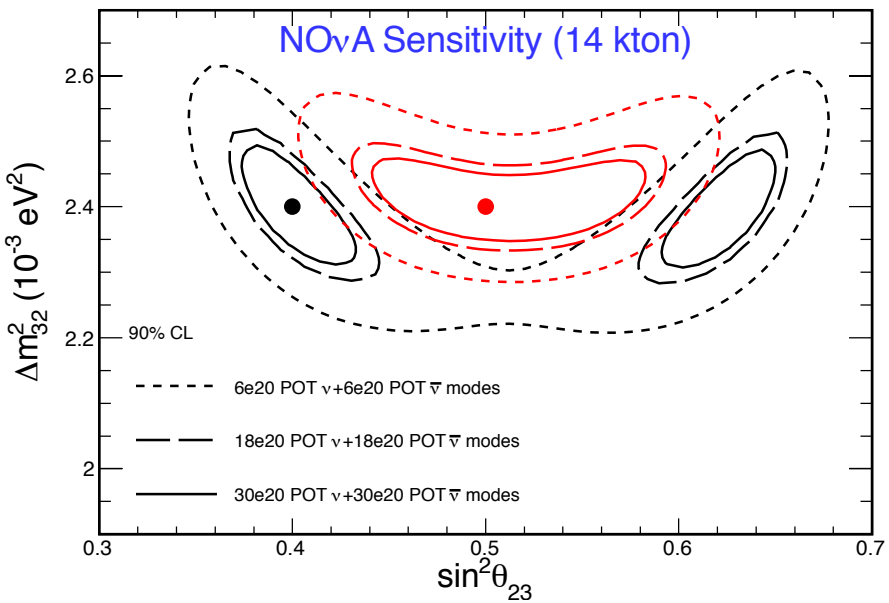
Extrapolated spectrum compared to the observed FD spectrum

The difference in shape gives us information on neutrino oscillation

Predicted sensitivities for ν_μ CC disappearance

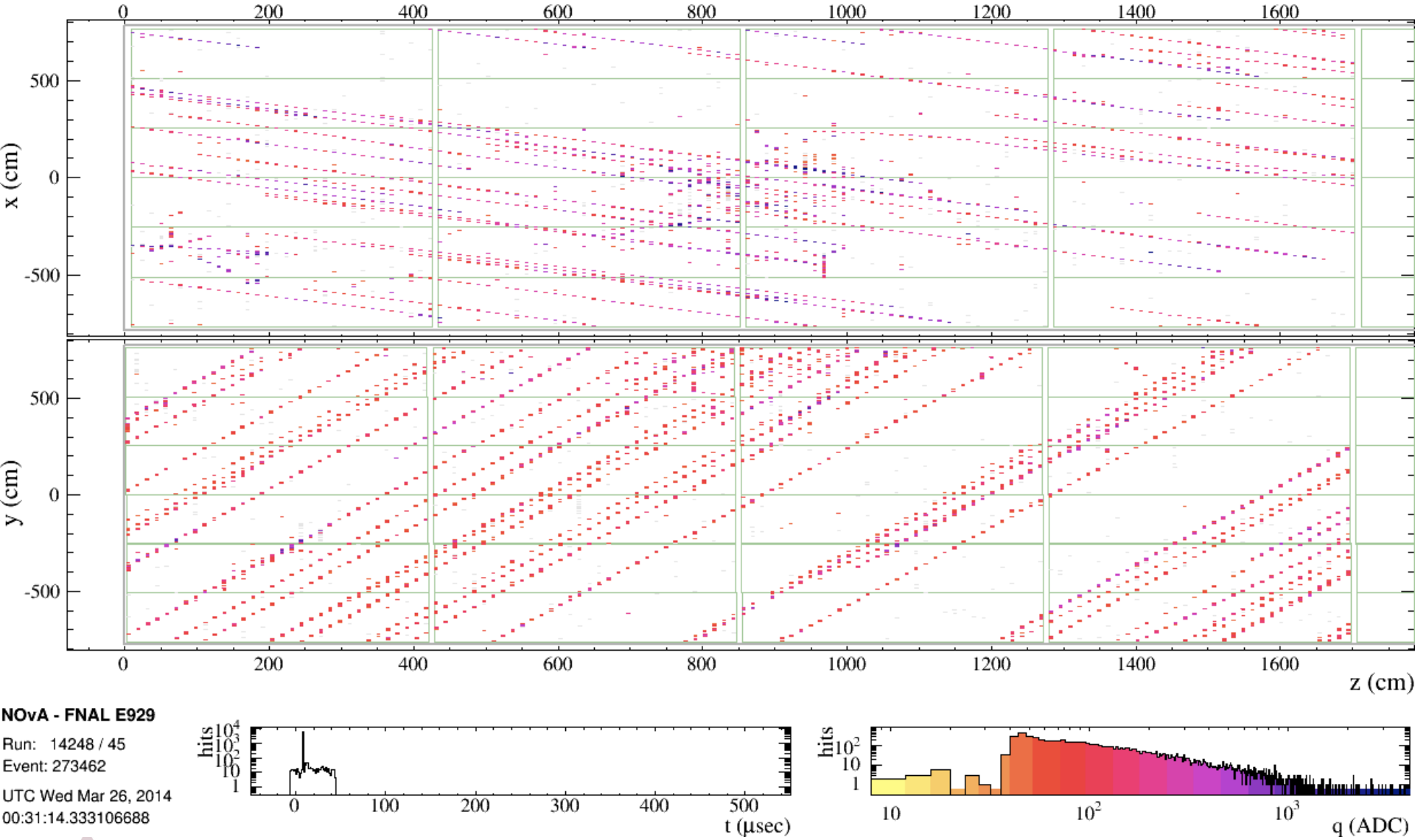
The sensitivity of the NOvA experiment is dependent on where in Δm^2_{32}-$\sin^2\theta_{23}$ parameter space we live



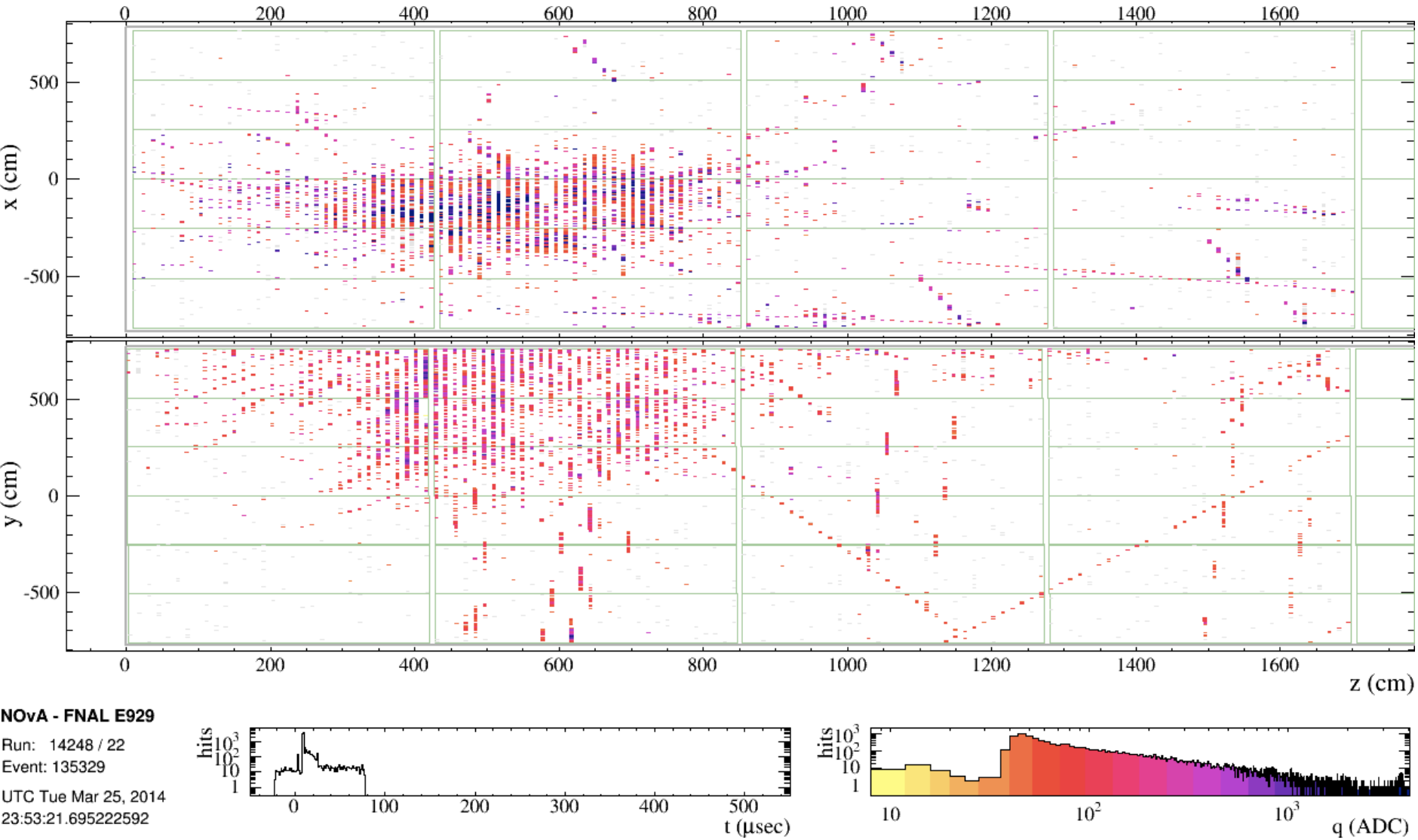


Red $\sin^2\theta_{23} = 0.4$
Black $\sin^2\theta_{23} = 0.5$

Thanks for listening



Questions?


x (cm)
y (cm)
z (cm)
NOvA - FNAL E929
Run: 14248 / 22
Event: 135329
UTC Tue Mar 25, 2014
23:53:21.695222592
hits
t (μsec)
q (ADC)