Data Quality and Performance of the NOνA Prototype Detector

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Overview

- NOνA Basics
- Monitoring Systems
- Prototype Performance

NuMI Off-Axis ν_e Appearance (NOνA)

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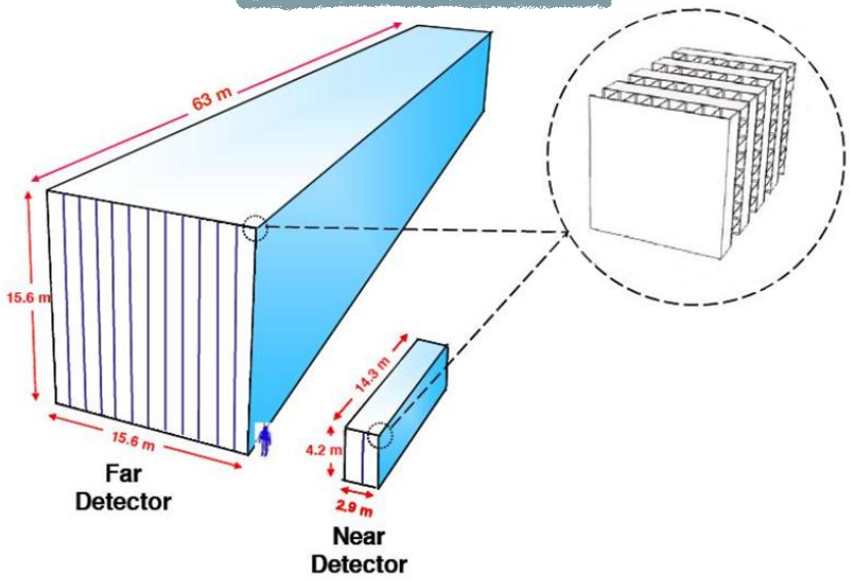
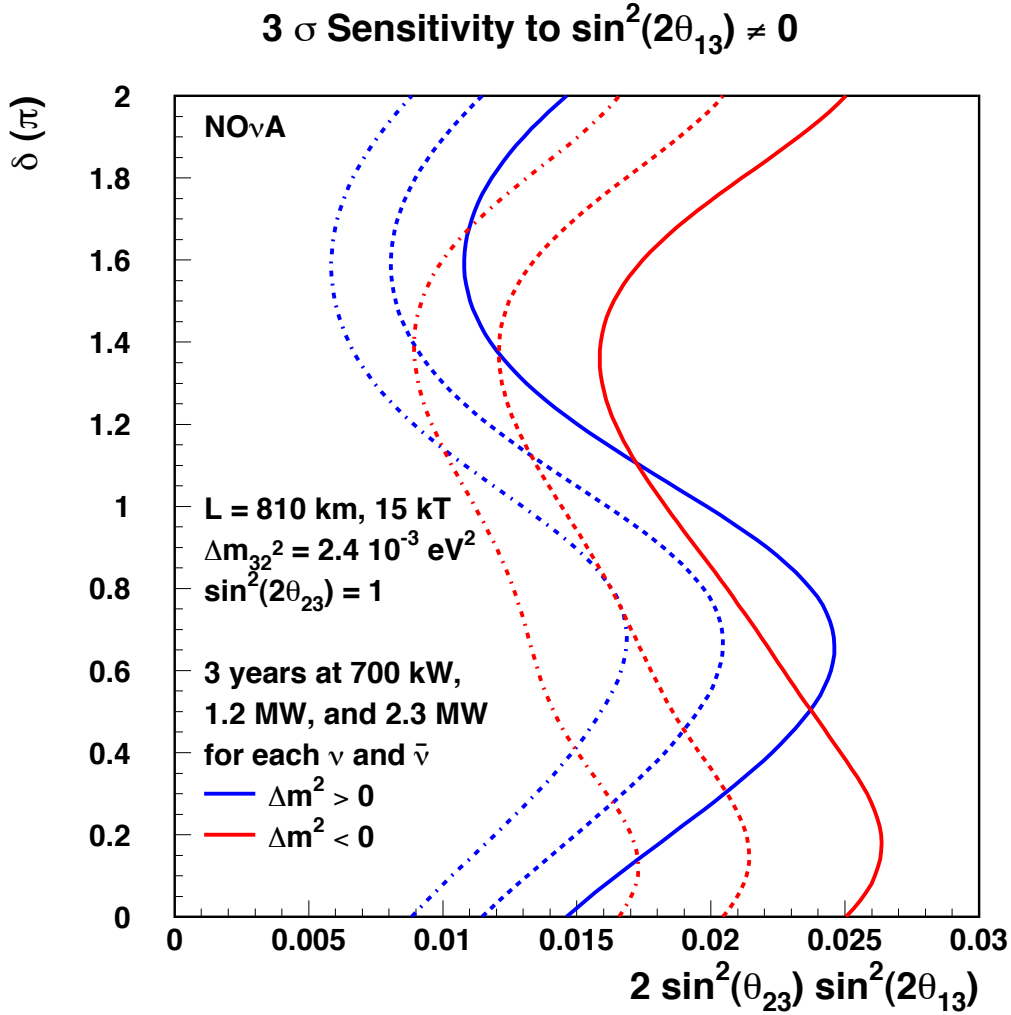
- Long-baseline neutrino experiment using NuMI (Neutrinos at the Main Injector) beam from Fermilab
- Two functionally-identical detectors, 810 km apart
- 14 milliradians off-axis from beam
- Currently running prototype; begin construction of far/near detectors soon



PHYSICS GOALS

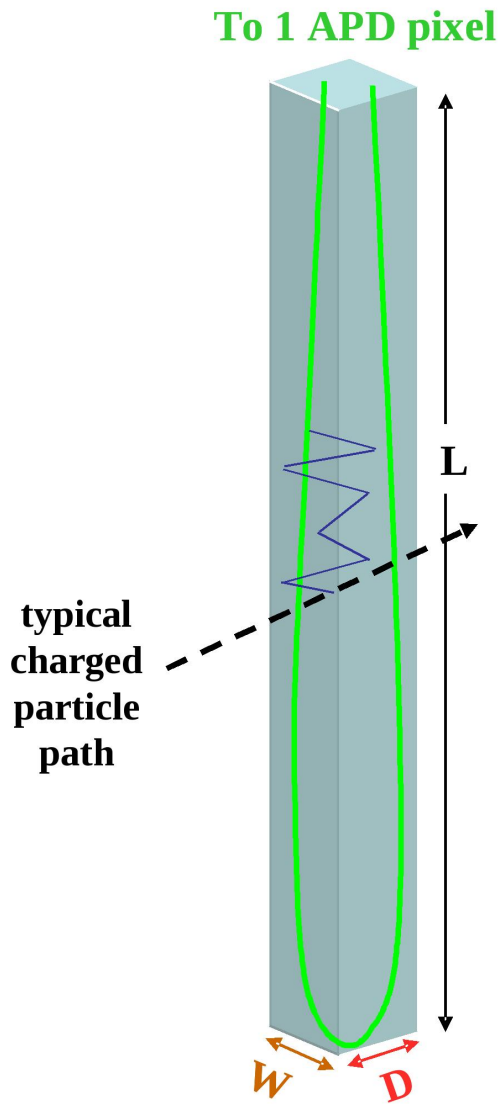
- Sensitive to θ_{13} and mass hierarchy
- Do oscillations violate CP?
- Precision measurements of θ_{23}, $|\Delta m^2_{32}|$



Dotted lines represent higher beam intensities

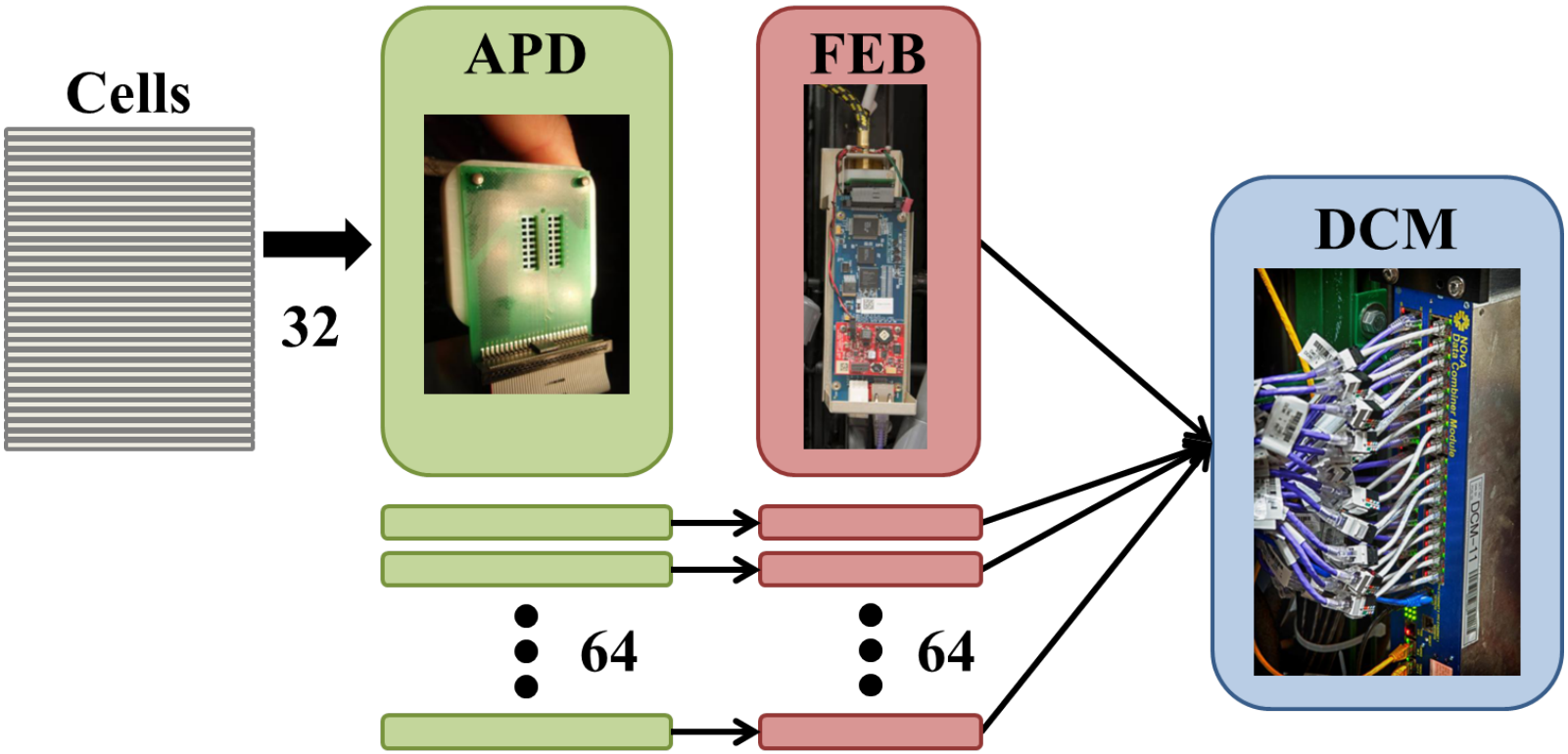
CELLULAR STRUCTURE

- NOνA detectors are cellular
- Each cell is a tube of reflective PVC
- 4 cm x 6 cm x 15 m (far detector) or 4 m (near detector)
- 0.15 radiation length per layer
- Inside is a loop of wave-length shifting fiber
- This is immersed in scintillator
- Charged particle travels through scintillator; makes photons
- Photons bounce around and are absorbed by fiber
- Light transported to ends and read out by an Avalanche Photodiode (APD)



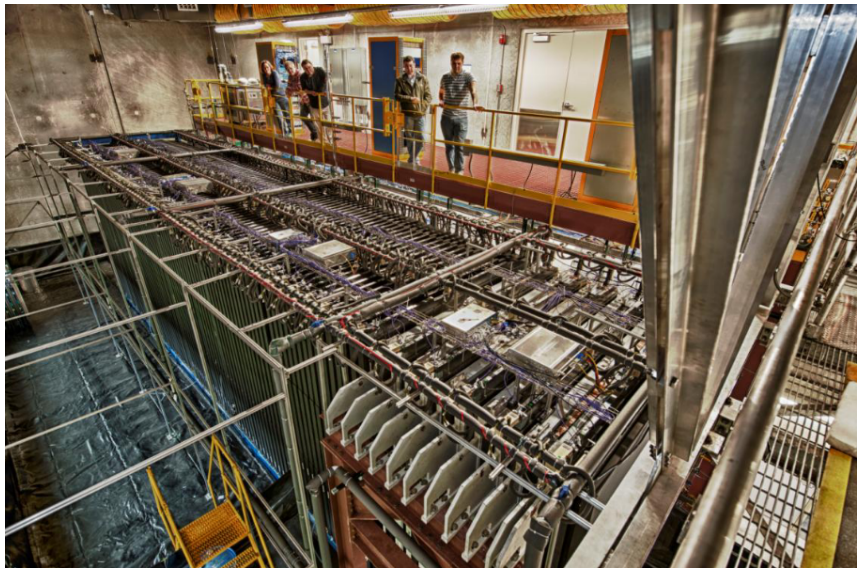
Electronics Readout

- Each APD reads out 32 cells
- Each APD is connected to a Front End Board (FEB)
- The FEB digitizes signal, sends it to a Data Concentrator Module (DCM)
- Each DCM can read 64 FEBs
- See Xinchun Tian's talk (next) for more info



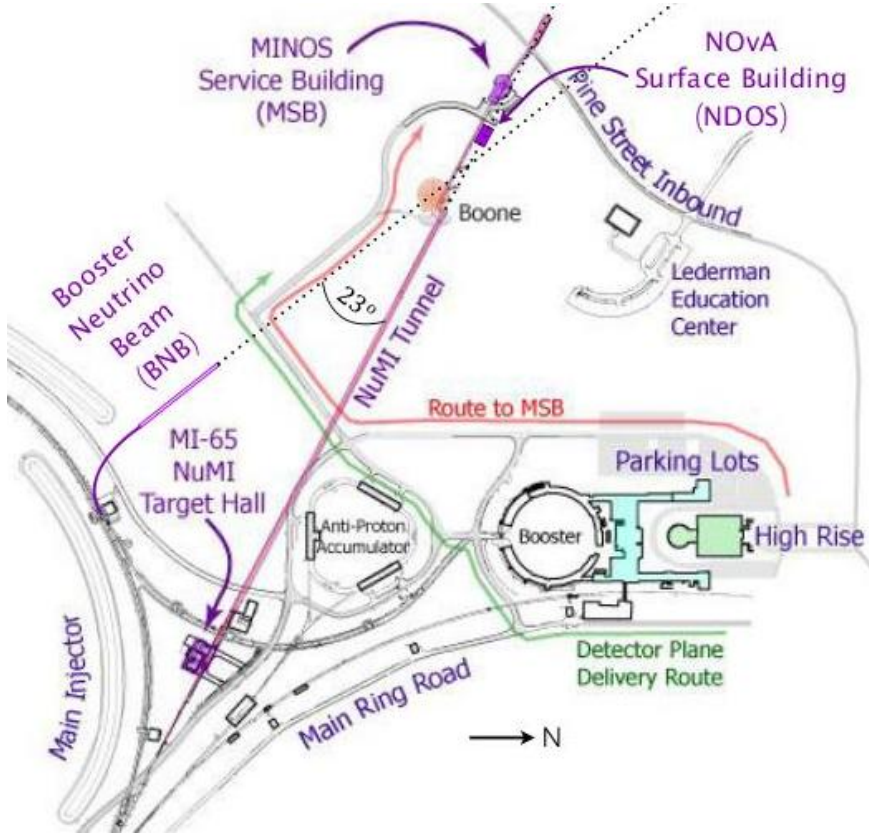
Near Detector On the Surface (NDOS)

- Prototype detector
- $\sim$ 200 ton
- Size / functionality of future near detector
- Located on the surface
- Prototype of this scale has proved invaluable



NEAR DETECTOR ON THE SURFACE (NDOS)

- NDOS sees neutrinos from the Booster beam as well as NuMI
- 110 mrad off-axis of NuMI beam; detector axis in same plane as beam axis
- Nearly on-axis of Booster beam; detector axis is 23° rotated to Booster beam

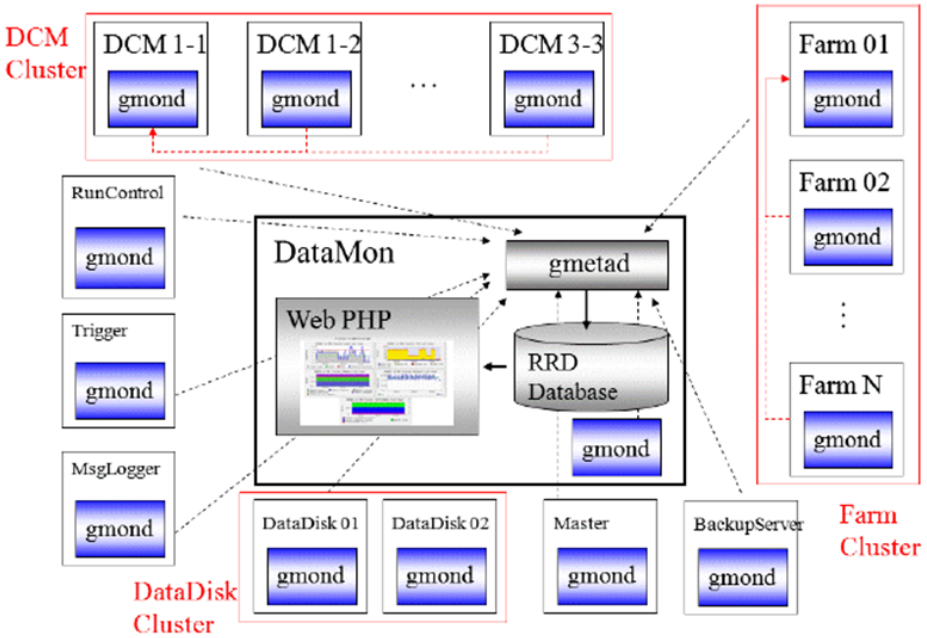


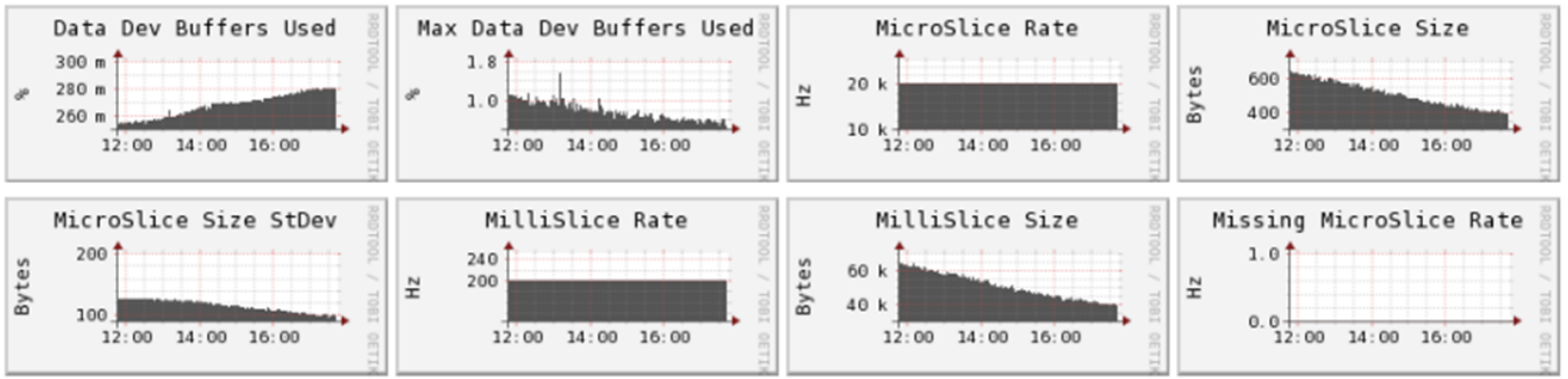
Monitoring Systems

- Five levels of data monitoring:
  - DAQ Monitor (real time)
  - Memory Viewer (real time)
  - Event Display (real time)
  - Online Monitor (real time)
  - DataCheck (delay of $\sim$ hour)
- Crucial to commissioning of detector

Data Acquisition (DAQ) Monitor

- Monitors health / performance of Data Acquisition System
- Uses Ganglia as base - third-party, open-source software
- Tracks stats for computer systems like memory and network usage
- Customized for NOνA specific needs like monitoring data and trigger rates, data sizes, errors, data corruptions ...
- Web interface that reads from database, allows for user plotting



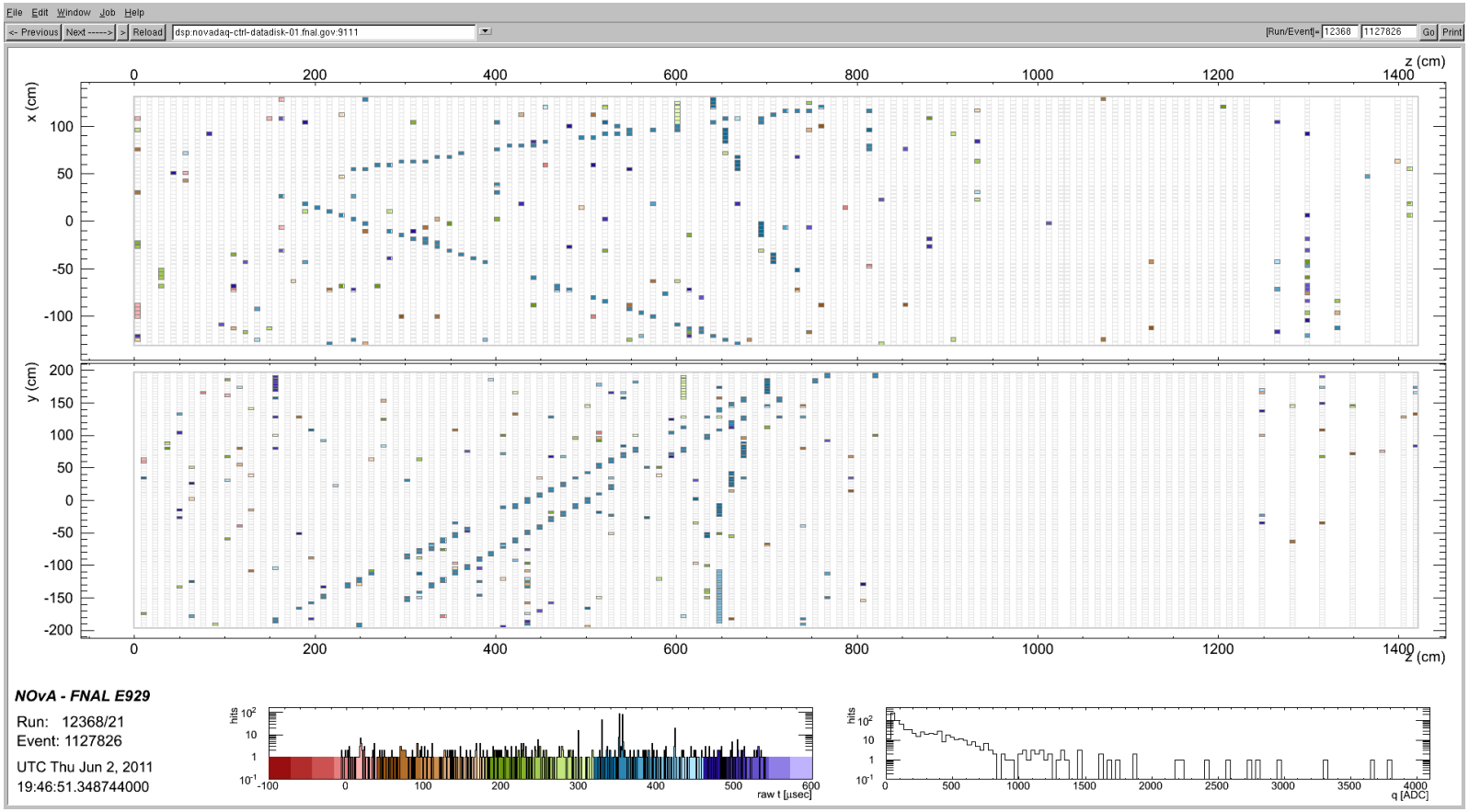


Memory Viewer

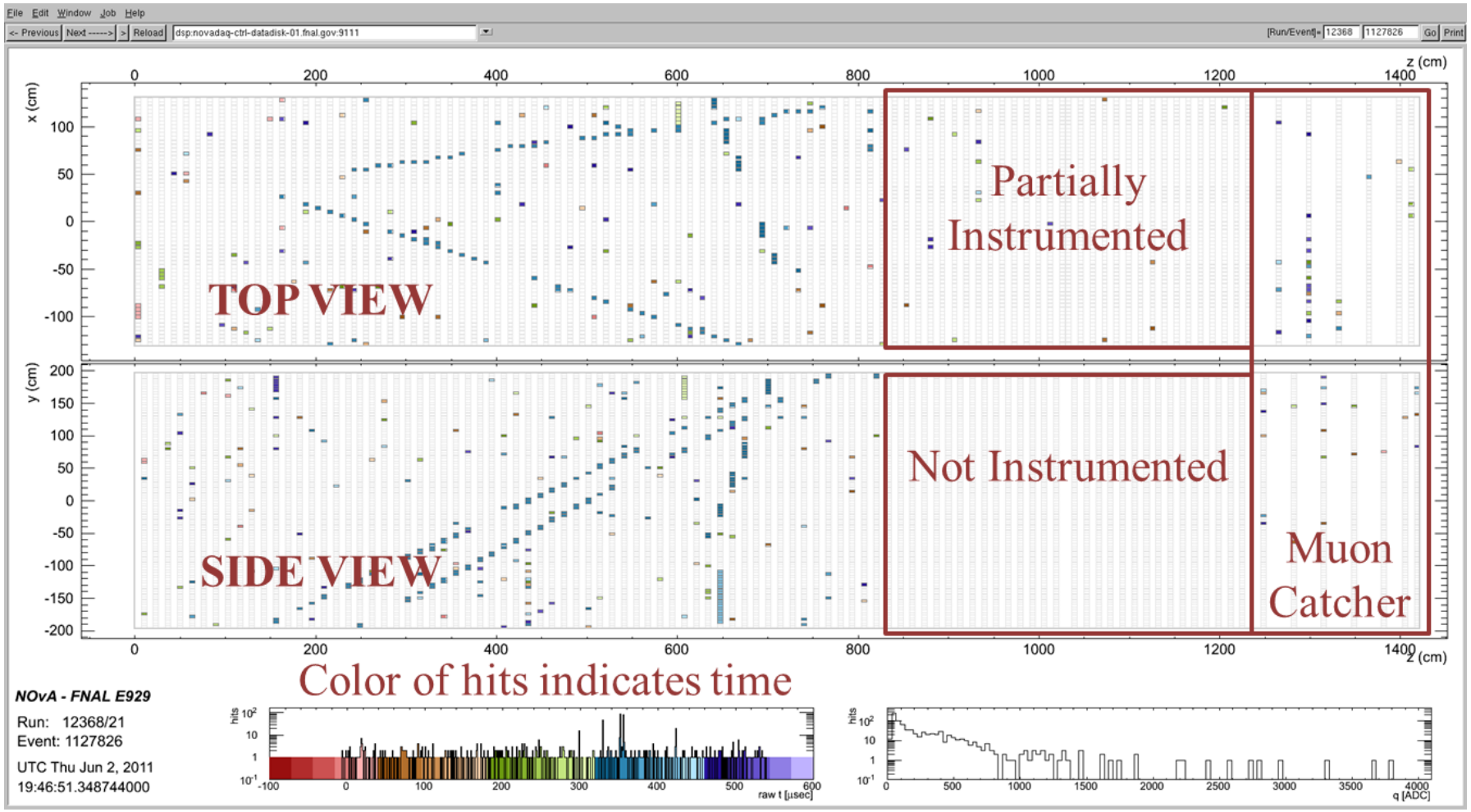
- Memory Viewer gives intuitive sense of data
- Visual, colored display of bytes in raw data
- Use pattern matching to tell if run is good, time windows are empty, etc.
- Event Dispatcher runs continuously on DAQ side and sends out a stream of events
- Note: “event” is “time window” (500 μsec)

Event Display

- Displays events from Event Dispatcher
- Serves as quick check data is useable, noise levels decent, which DCMs in readout ....
- Used to find swapped channels

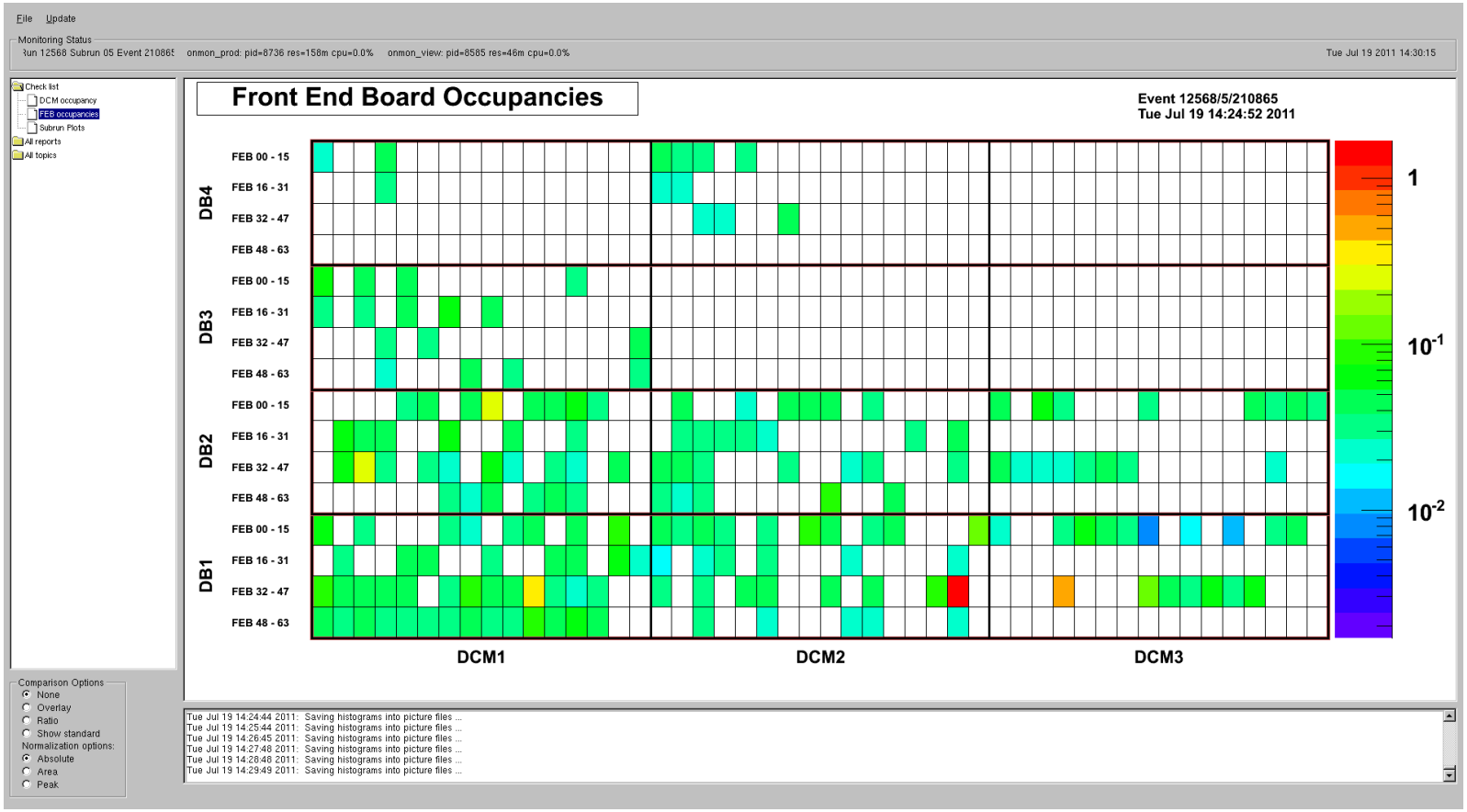


EVENT DISPLAY



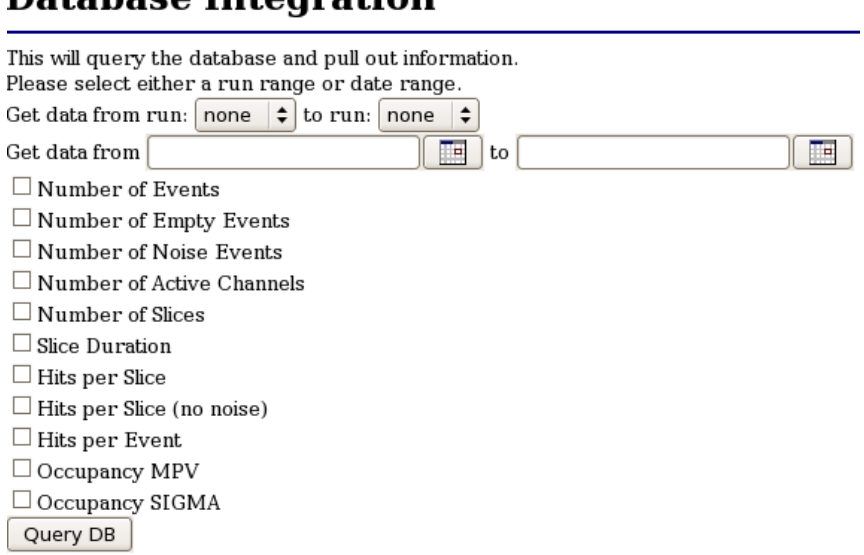
Online Monitor (OnMon)

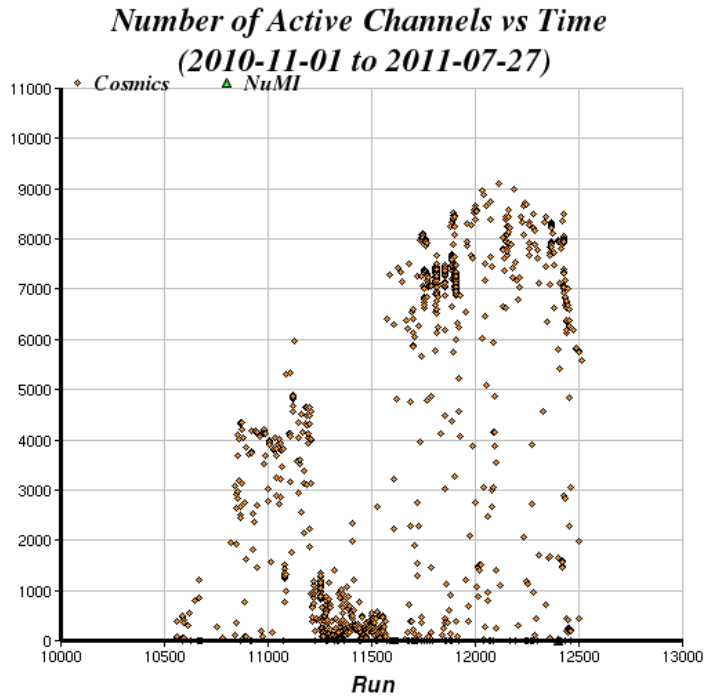
- OnMon allows us to look at run metrics in real time
- OnMon Producer reads in from Event Dispatcher and processes events
- OnMon Viewer is a GUI that communicates with Producer through a ROOT TMapFile
- For example: FEB occupancy plots to track noise levels in detector



DataCheck

- DataCheck is an offline software tool that looks at detector performance
- DataCheck lets us look at metrics over multi-run periods
- About hour delay from data-taking
- Has a web interface; uses PHP to make plots from database



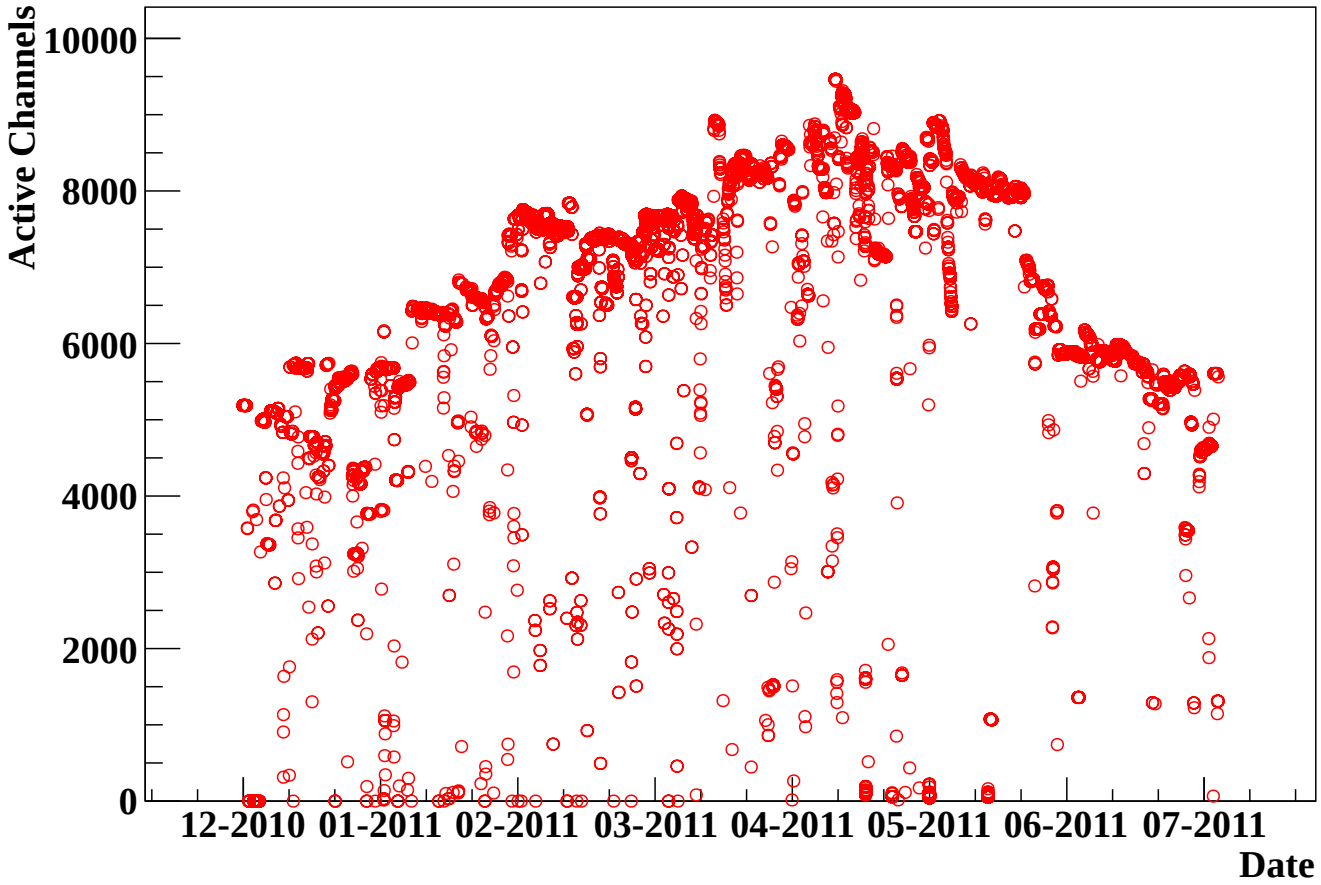


DataCheck Metrics

- DataCheck monitors:
  - Number of active channels
  - Average number of hits per channel
  - Number of active Front End Boards (FEBs)
  - Time of neutrino candidates
- and many other metrics like:
  - Number of empty time windows
  - Cosmic ray rate ($\sim$2.5 kHz)
  - .....

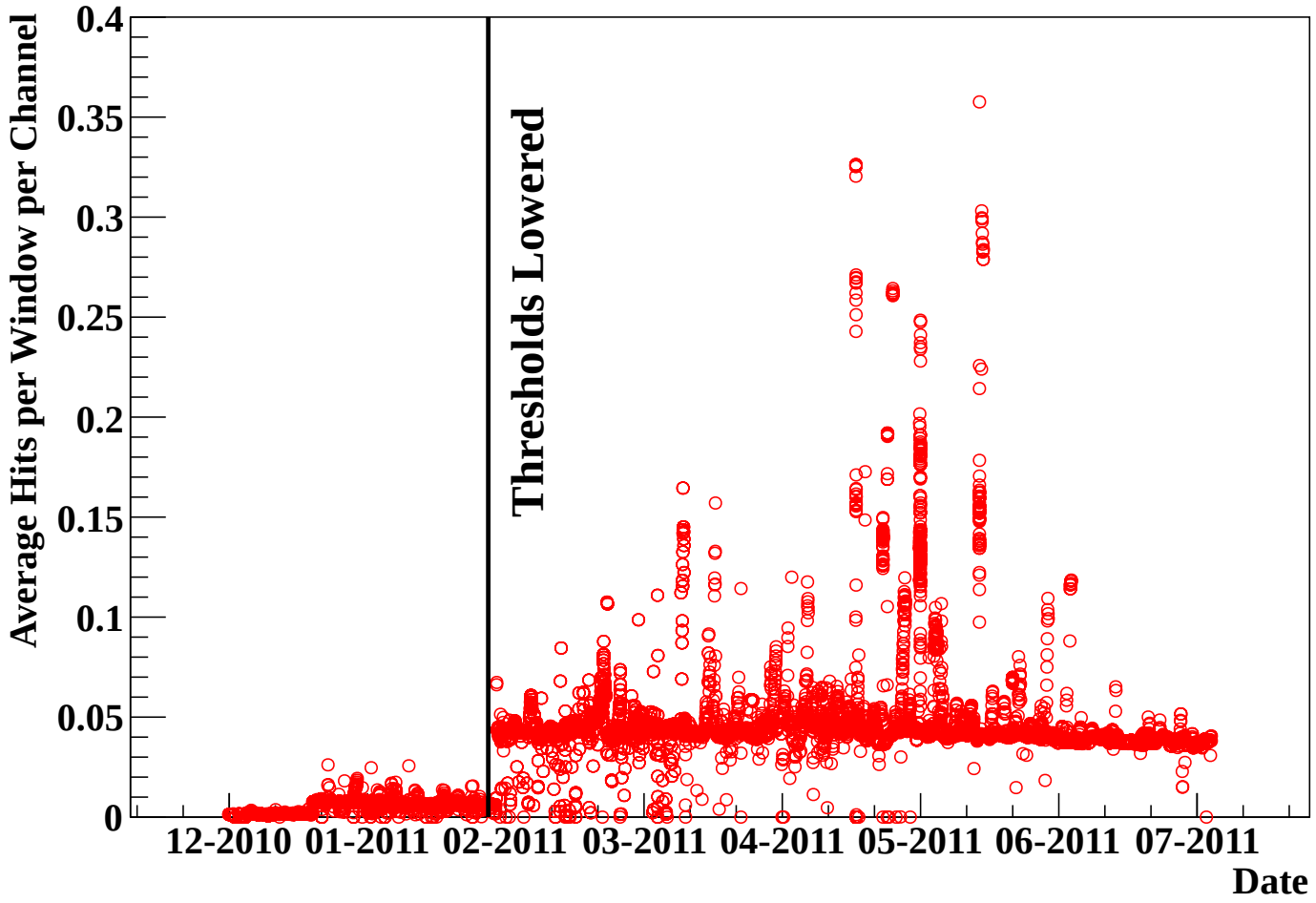
DataCheck: Active Channels

- Steadily installed channels through spring
- In May began actively removing questionable channels for study
- Drops due to running with only partial detector, etc.
- Fully-instrumented NDOS would have 15,900 channels



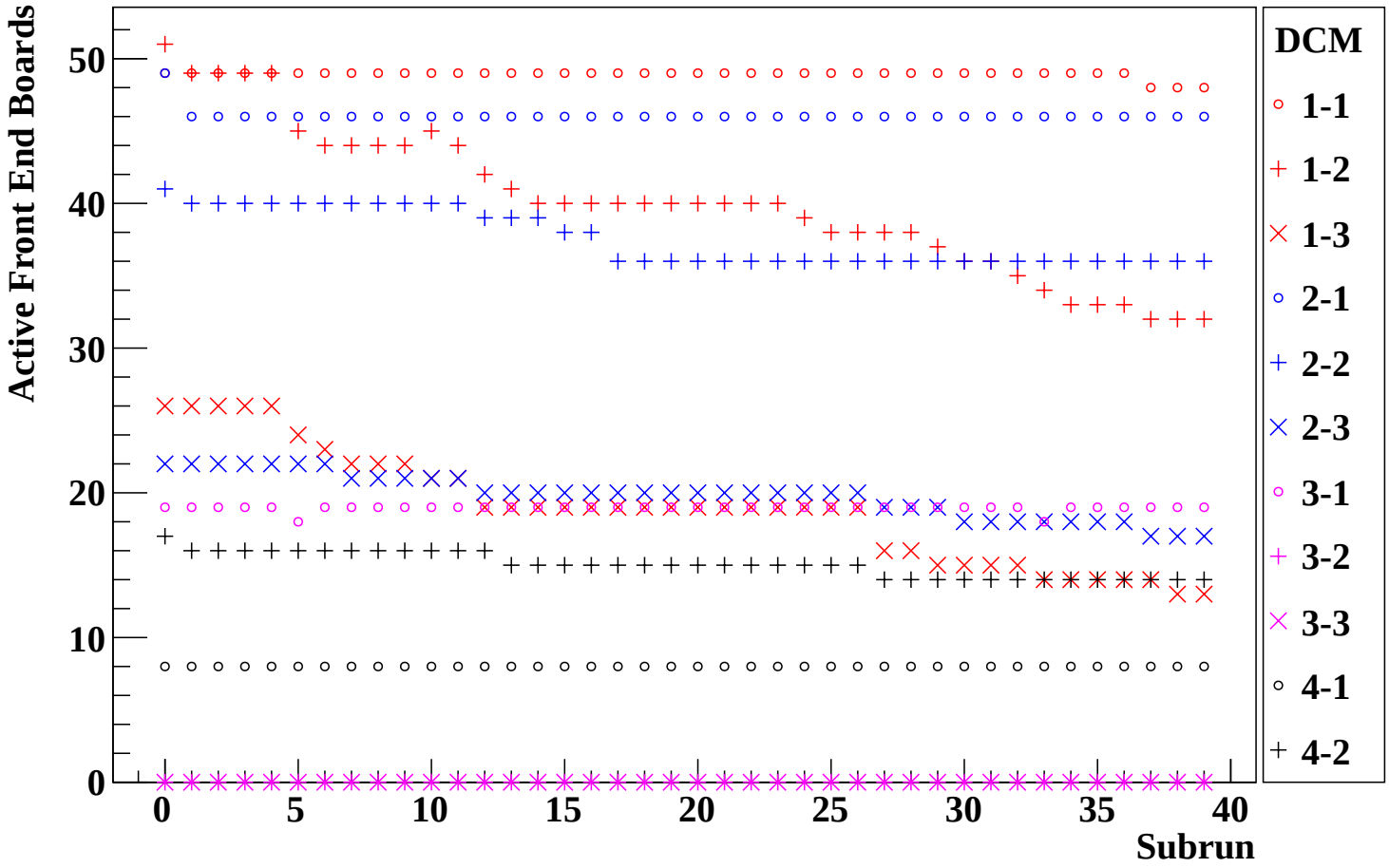
DataCheck: Hits Per Channel

- One metric is hits per trigger window (500 μsec) per good channel
- Generally is 0.05 (used to be lower with high thresholds)
- Sometimes prototype gets noisy (humidity effects, electronic noise, etc.)



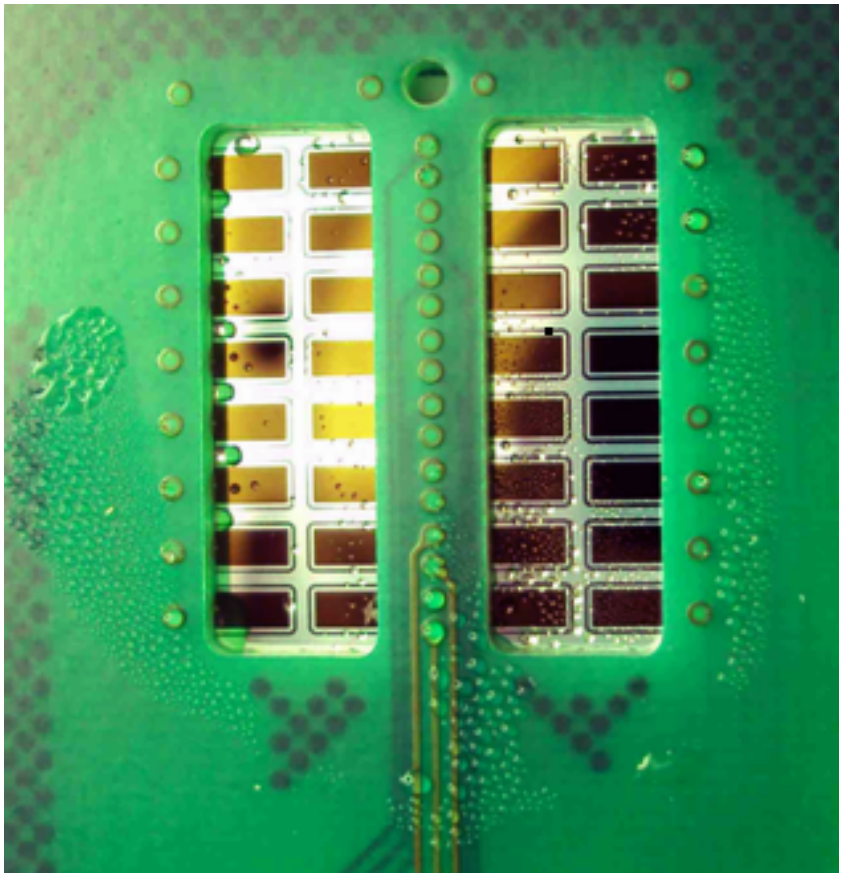
DataCheck: Front End Boards (FEBs)

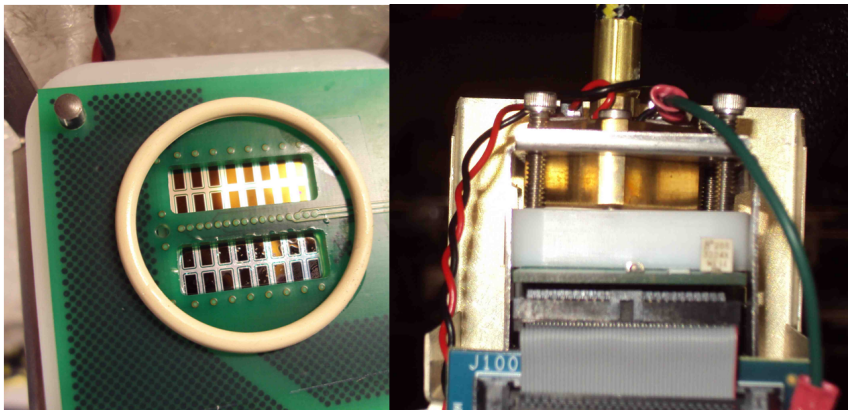
- Our FEBs shutoff during a run if data buffer overflows (usually noisy APD)
- Run $\sim$ 24 hours; subruns $\sim$ 1 hour
- We can track this behavior



Front End Board (FEB) Shutoffs

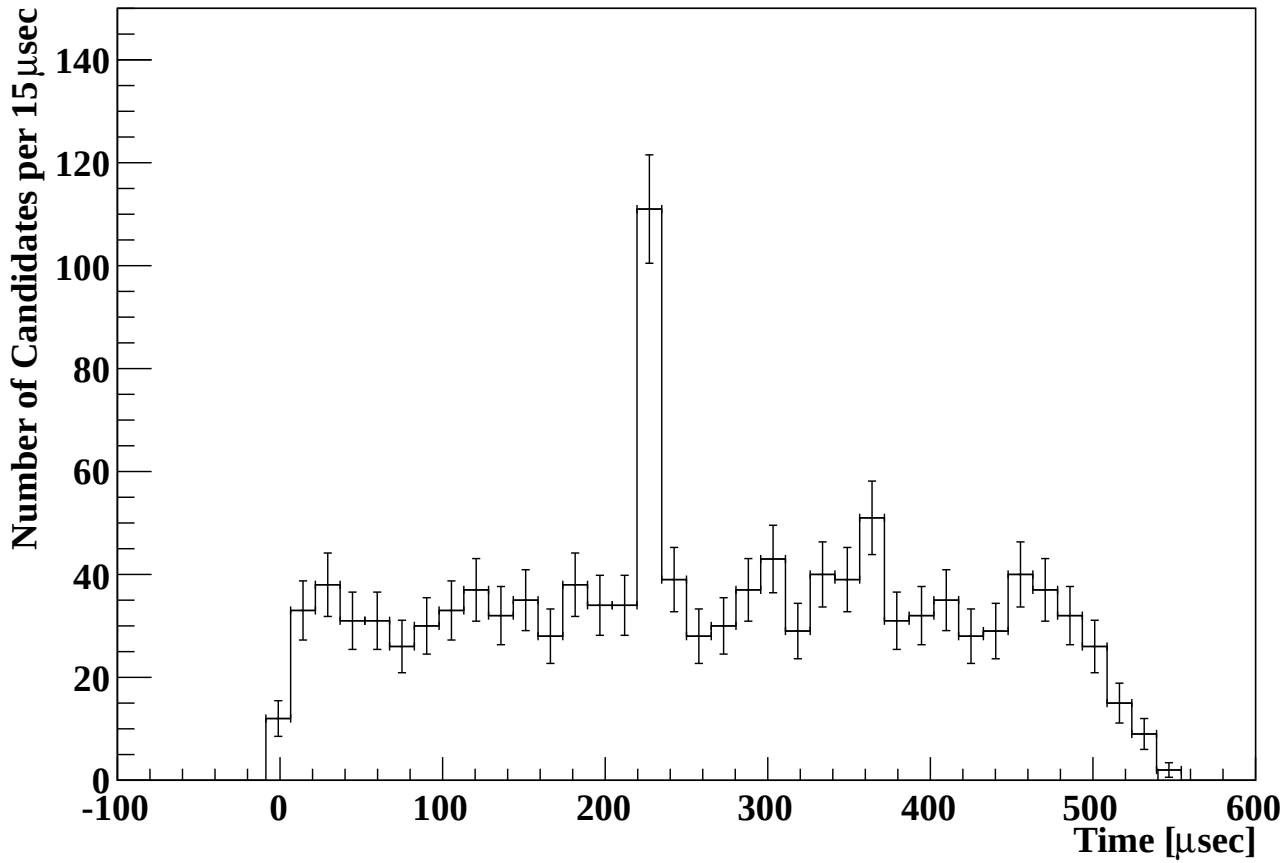
- One reason our FEBs shutoff: moisture on the APD
- Can see humidity effects
- Cool APDs to - 15°C (to reduce noise)
- Some become noisy; remove quickly, have water on surface
- Redesigning system to prevent for far detector





DataCheck: NuMI Timing Plots

- Enough statistics to see NuMI neutrino timing peak on weekly basis
- Also track Booster neutrino peak but on longer scale
- Use ROUGH activity, fiducial, and direction cuts to find candidates
- Tracking NuMI peak allows us to verify if timed in correctly



From 4/16 to 4/25; $2.7x10^{18}$ protons on target

Summary

- NDOS has been taking data for almost a year
- Systems in place to monitor detector and data quality
- This helps us commission our prototype and prepare for far detector construction

BACKUP

NuMI Candidate Cuts

- Number of hits in each view > 4
- Fiducial cuts of y$<$150 cm, abs(x)$<$110 cm, 25$<$z$<$770
- Cosine with respect to beamline $>$0.7