Data Quality and Performance of the $NO\nu A$ Prototype Detector

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Division of Particles and Fields of the American Physical Society 2011





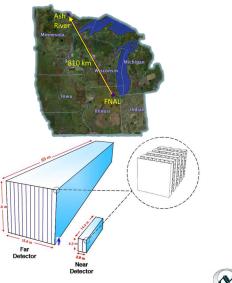
OVERVIEW

- NOvA Basics
- Monitoring Systems
- Prototype Performance



NUMI OFF-AXIS ν_e Appearance (NO ν A)

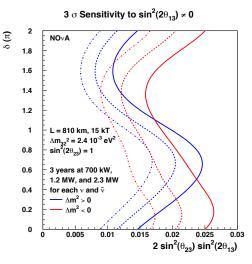
- NuMI Off-Axis ν_e Appearance (NOνA)
- Long-baseline neutrino experiment using NuMI (Neutrinos at the Main Injector) beam from Fermilab
- Two functionally-identical detectors, 810 km apart
- 14 milliradians off-axis from beam
- Currently running prototype; begin construction of far/near detectors soon





PHYSICS GOALS

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

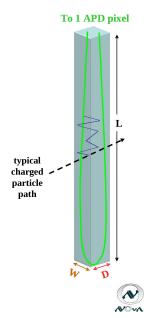


Dotted lines represent higher beam intensities



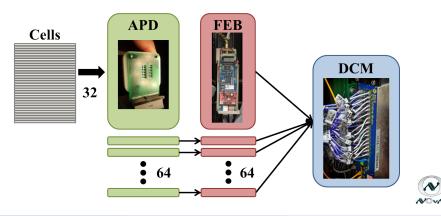
CELLULAR STRUCTURE

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

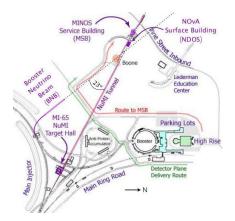






NEAR DETECTOR ON THE SURFACE (NDOS)

- 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

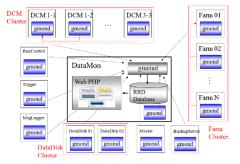
• Five levels of data monitoring:

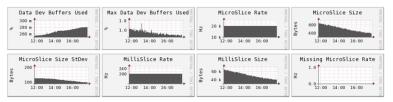
- DAQ Monitor (real time)
- Memory Viewer (real time)
- Event Display (real time)
- Online Monitor (real time)
- DataCheck (delay of \sim hour)
- Crucial to commissioning of detector



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







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MEMORY VIEWER

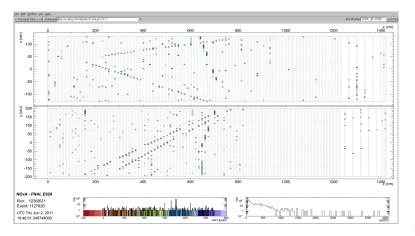
- Memory Viewer gives intuitive sense of data
- Visual, colored display of bytes in raw data
- Use pattern matching to tell if run is good, time windows are empty, etc.
- Event Dispatcher runs continuously on DAQ side and sends out a stream of events
- Note: "event" is "time window" (500 μsec)

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0x00000020	0x00000000	0x0000000c	0xaaaa00001	0x20ff012f	0x00002c82	0x00000000	0x00000000	0x0000000
0x00000040	0x6f4b1400	0x000b5f2a	0x4e386006	0x000e5ed0	0x00000004	0x6é4b1400	0x000b5f2a	0x0000000
0x00000060	0x00000000	0x000003e8	0x00000004	0x00000000	0x00000000	0x00000001	0xdabc0000	0x0000000
0x00000080	0x0000000a	0x00002c82	0x20000000	0x0ec35b27	0xdabc0000	0x000004ec	0x00630009	0x00002c1
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0x000000e0	0x002fcafe	0x3c1461b3	0x6f4b1468	0x002acafe	0x00006101	0x8c000044	0x6f4b19fc	0x000b5f
0x00000100	0x241e6013	0x6f4b1d0c	0x003dcafe	0x28166013	0x6f4b2070	0x002fcafe	0x2c006013	0x6f4b23c
0x00000120	0x0033cafe	0x241f60db	0x6f4b2210	0x0048cafe	0x381f6133	0x6f4b1e8c	0x003dcafe	0x000061
0x00000140	0x90000044	0x6f4b267c	0x000b5f2a	0x280760c3	0x6f4b2fcc	0x002bcafe	0x2c1860db	0x6f4b28
0x00000160	0x0060cafe	0x3801613b	0x6f4b2cb8	0x0092cafe	0x2c1a616b	0x6f4b2b98	0x0030cafe	0x201561
0x00000180	0x6f4b264c	0x002bcafe	0x00006101	0x94000028	0x6f4b32fc	0x000b5f2a	0x24036133	0x6f4b37
0x000001a0	0x004fcafe	0x2001613b	0x6f4b3a58	0x008dcafe	0x00005101	0×98000020	0x664b3f7c	0x000b5f
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0x00000200	0x240460ab	0x614b5420	0x01c9cafe	0x240560e3	0x6f4b5168	0x021bcafe	0x200360f3	0x6f4b51i
0x00000220	0x0050cafe	0x240060f3	0x6f4b5174	0x01d1cafe	0x340e60fb	0x6f4b516c	0x0182cafe	0x3016610
0x00000240	0x6f4b554c	0x003bcafe	0x2c04613b	0x6f4b5164	0x0099cafe	0x281c615b	0x5f4b5744	0x0032ca
0x00000260	0x300a6183	0x6f4b5178	0x0232cafe	0x340d6183	0x6f4b5164	0x0079cafe	0x3809618b	0x6f4b51
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EVENT DISPLAY

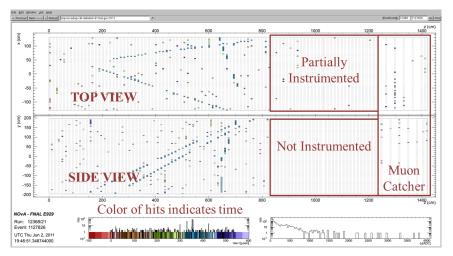
- Displays events from Event Dispatcher
- Serves as quick check data is useable, noise levels decent, which DCMs in readout
- Used to find swapped channels





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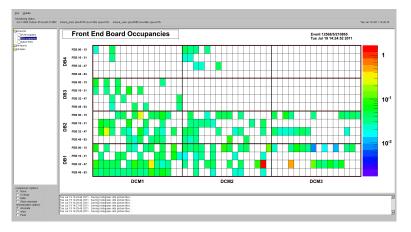
EVENT DISPLAY





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





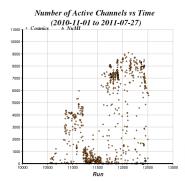
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DATACHECK

- 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

Database Integration

This will query the database and pull out information. Please select either a run range or date range. Get data from run: none 💠 to run: none 🗘 to to Get data from 0 □ Number of Events Number of Empty Events Number of Noise Events Number of Active Channels Number of Slices Slice Duration □ Hits per Slice Hits per Slice (no noise) Hits per Event Coccupancy MPV Occupancy SIGMA Ouery DB





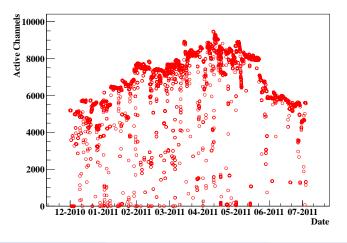
DATACHECK METRICS

- 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 (~2.5 kHz)
 -



DATACHECK: ACTIVE CHANNELS

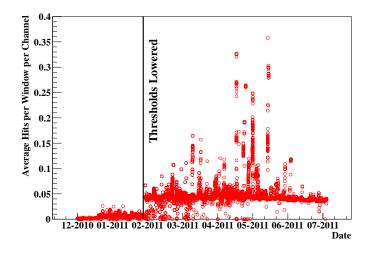
- Steadily installed channels through spring
- In May began actively removing questionable channels for study
- Drops due to running with only partial detector, etc.
- Fully-instrumented NDOS would have 15,900 channels





DATACHECK: HITS PER CHANNEL

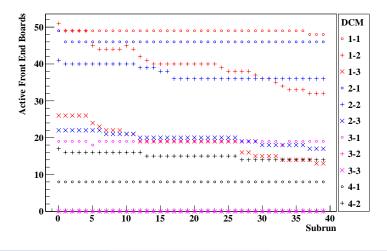
- One metric is hits per trigger window (500 μ sec) per good channel
- Generally is 0.05 (used to be lower with high thresholds)
- Sometimes prototype gets noisy (humidity effects, electronic noise, etc.)





DATACHECK: FRONT END BOARDS (FEBS)

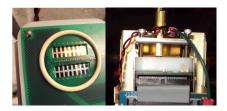
- Our FEBs shutoff during a run if data buffer overflows (usually noisy APD)
- Run \sim 24 hours; subruns \sim 1 hour
- We can track this behavior

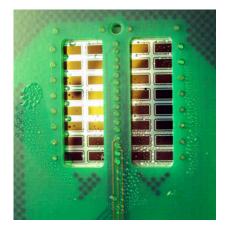




FRONT END BOARD (FEB) SHUTOFFS

- 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

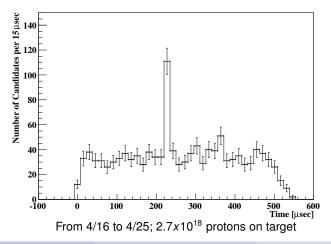






DATACHECK: NUMI TIMING PLOTS

- 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





- 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



23/22

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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

