NOvA Near Detector Status and Maintenance Plan

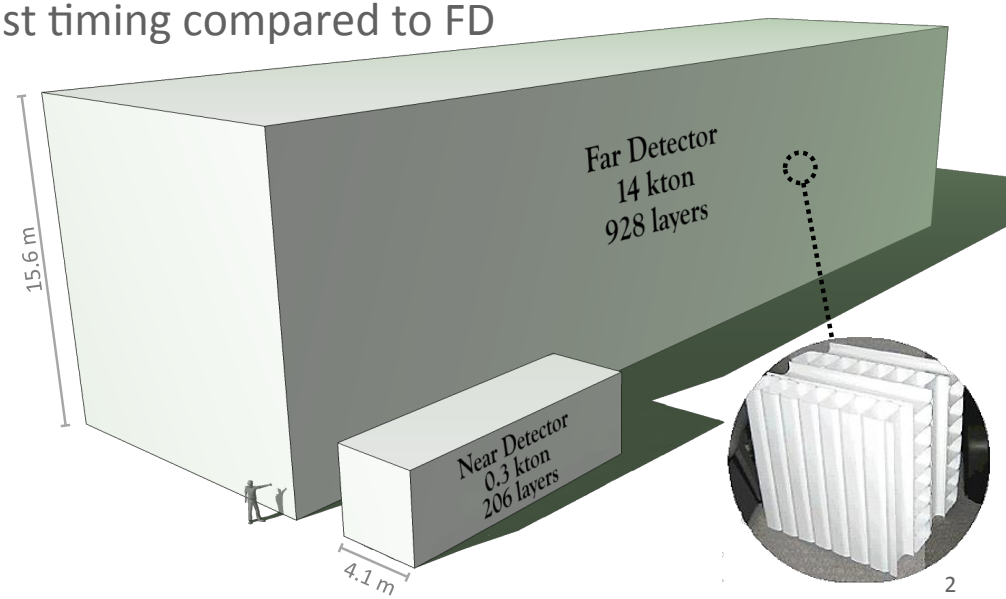
Louise Suter
Argonne National Laboratory

NOvA Operational Readiness Review
Tuesday 28th October

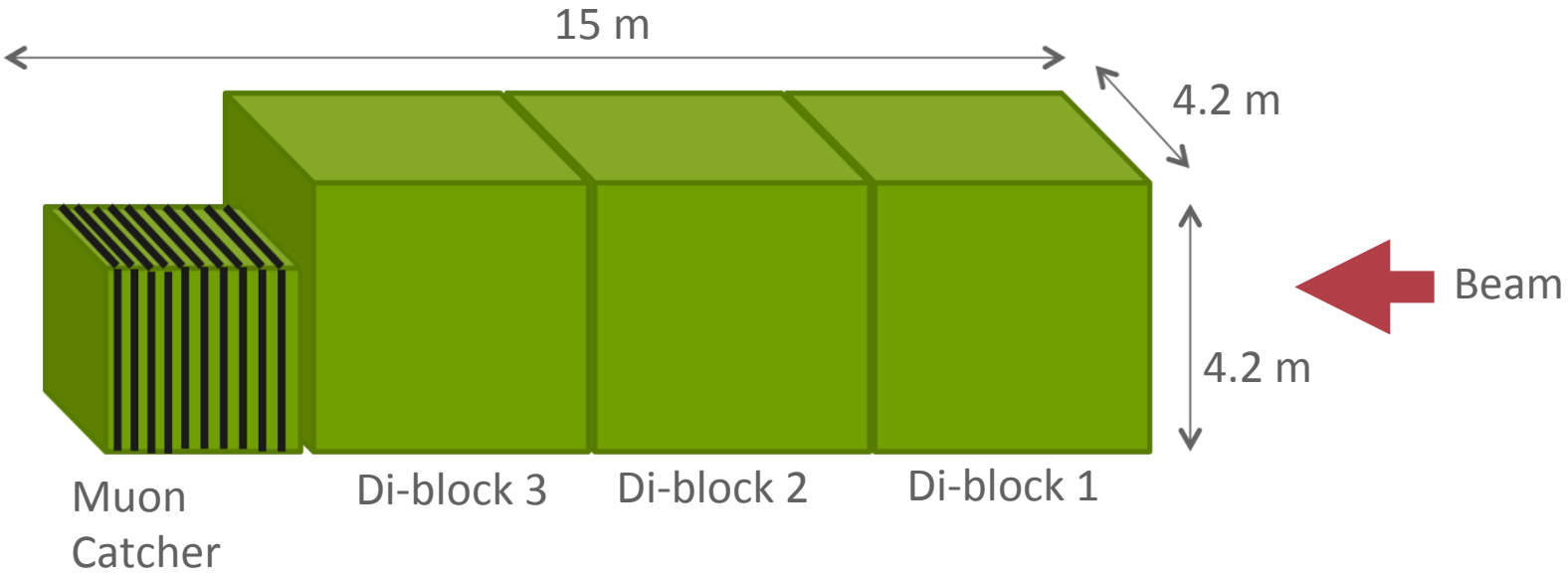
The NOvA Near Detector

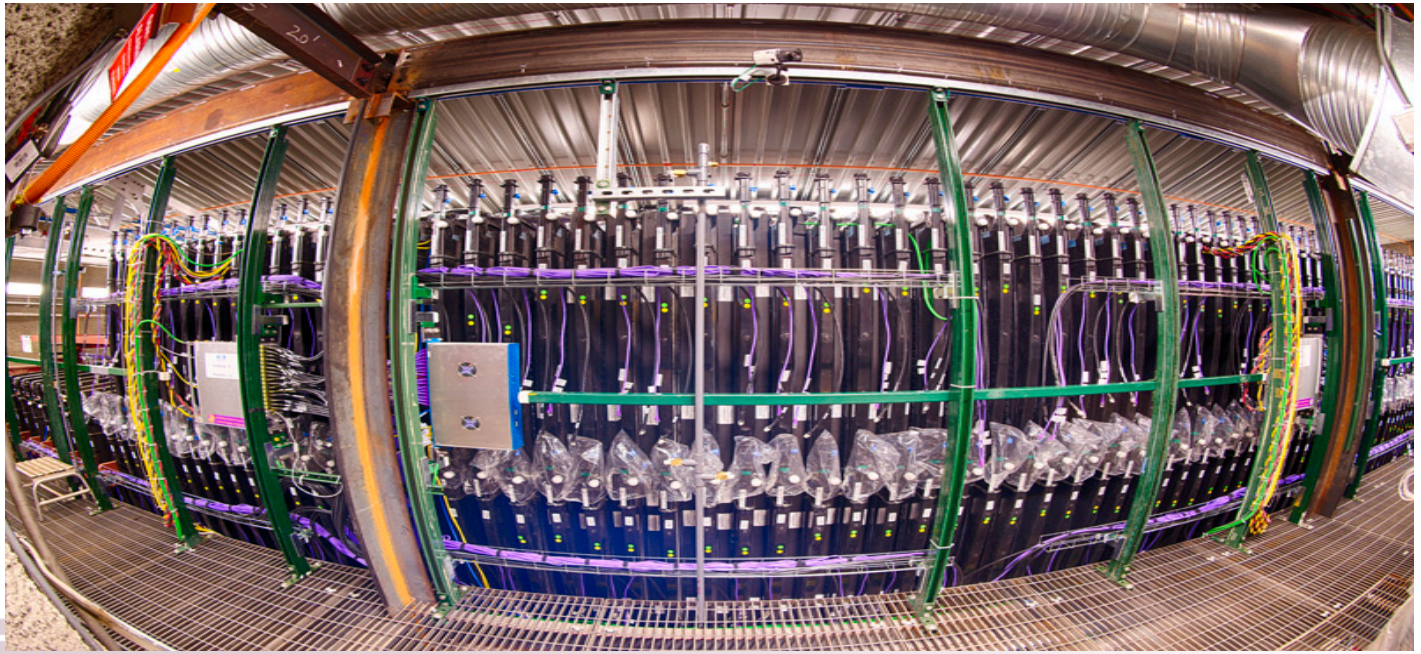
Functionally identical to the Far Detector except

- Located 100 m underground in the NuMI MINOS cavern
- 2% of the mass of the FD, M_{ND} = 294 tons, M_{FD} = 14.3 ktons
- 5% of the active channels: ND # 20,192 channels; FD # 344,064 channels
- Has additional semi-active region, the Muon Catcher, where the modules are alternated with 3” steel plates
- Steel hoses on all APDs (no water leaks, no need to retrofit)
- Installed with 631 baked APDs
- Front End Boards have four times as fast timing compared to FD



The Near Detector

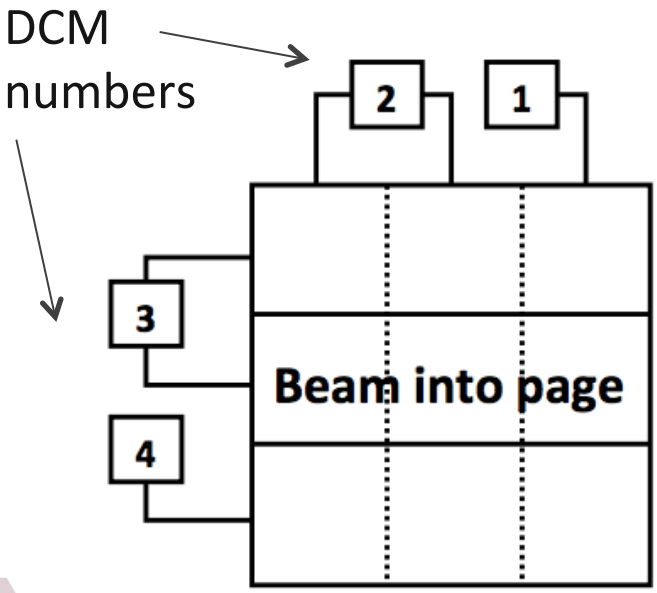


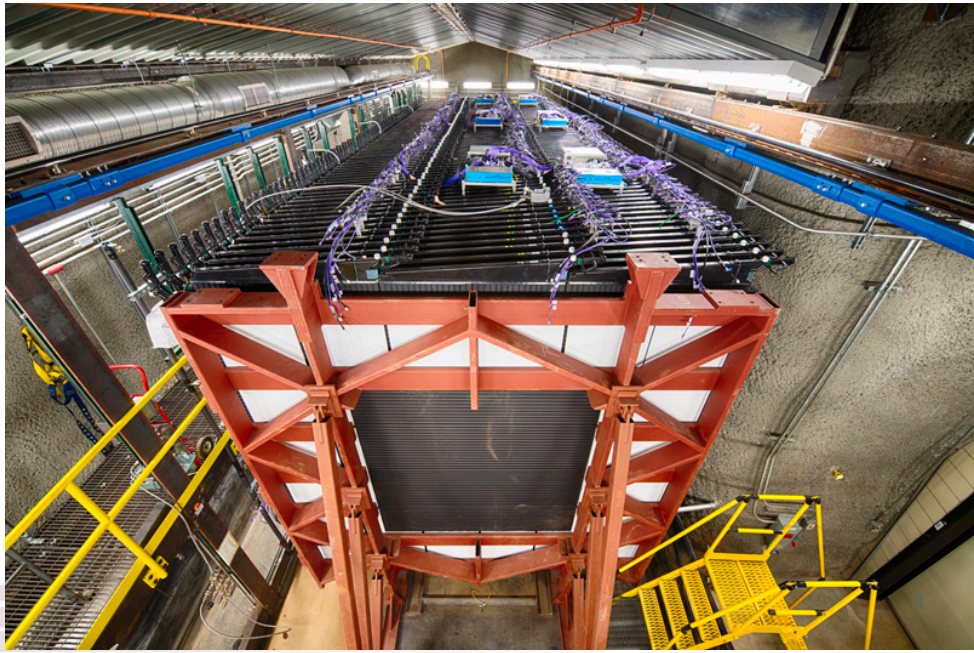


The Near Detector
Electronics Map

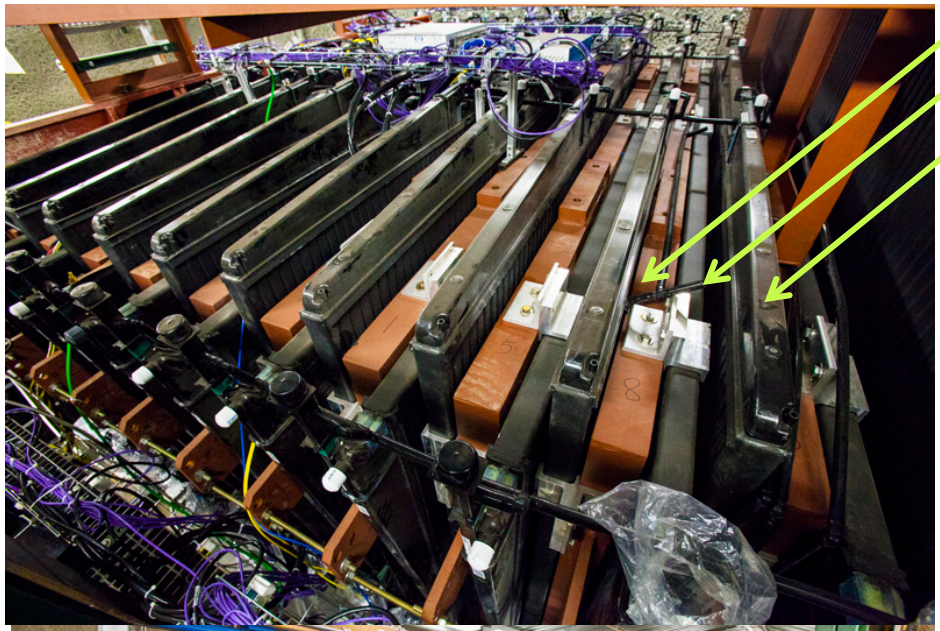
Many of the monitoring tools used at ND are displayed in electronics space. For the ND this can be unintuitive

- Displayed as Data Concentrator Module (DCM) as function of di-block
- 1 APD per plane each with 32 pixels
- 96 APDs per view per di-block in ND. DCM have occupancy for 64 APDs
- Results in 2 DCMs per side of a ND di-block, but one only half occupied

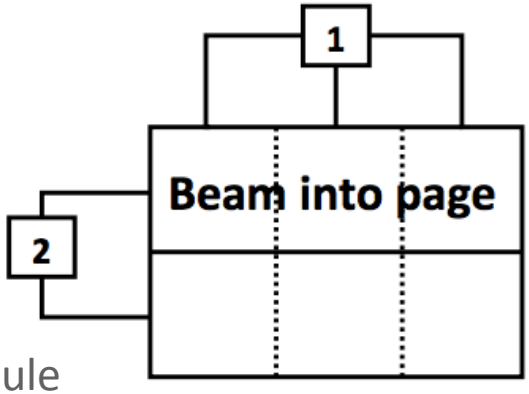




The Muon Catcher

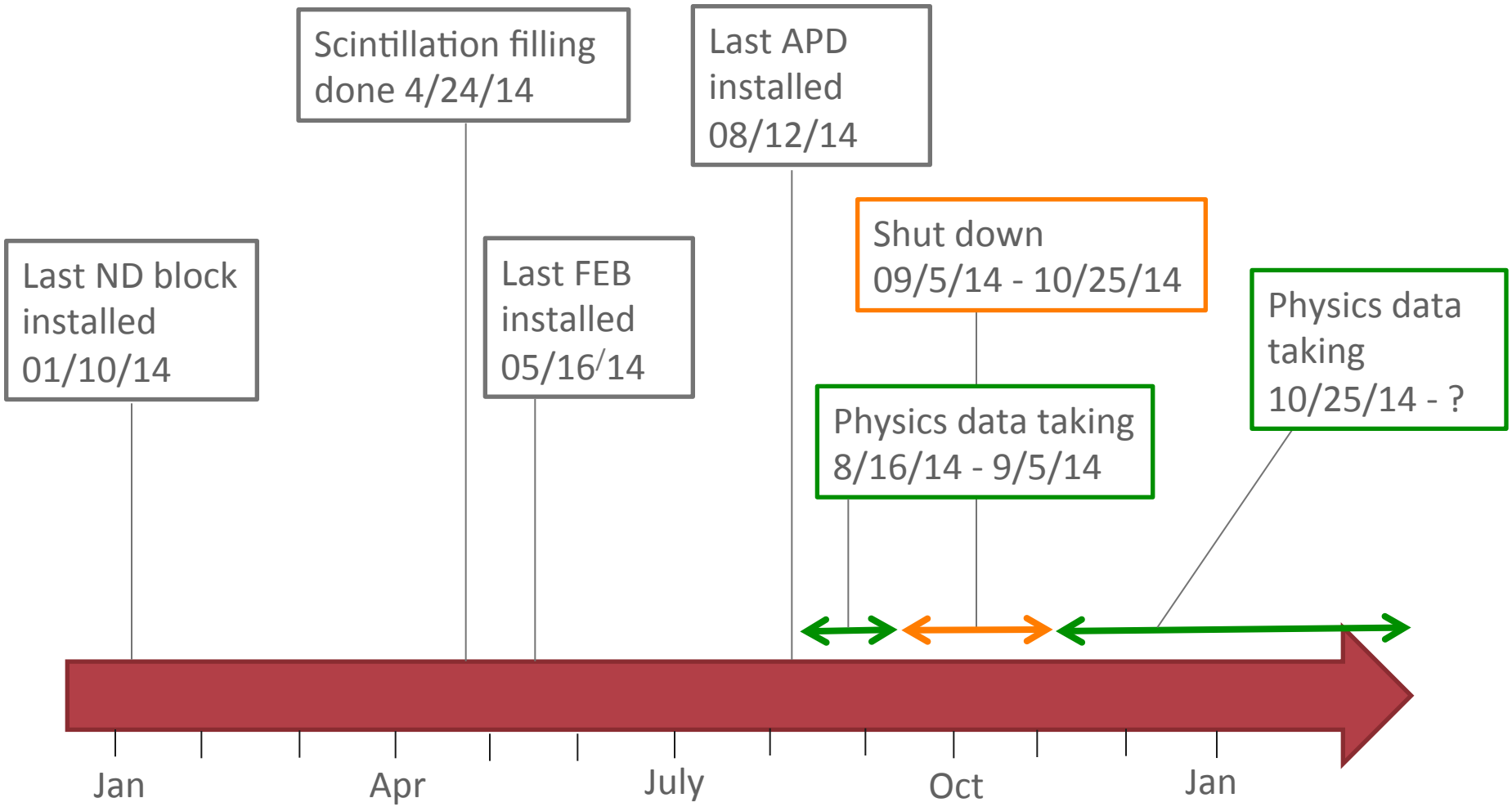


- Muon Catcher has 3” steel plates alternated between the horizontal and vertical planes
- Increases the efficiency to contain muons
- Steel plates were recycled from the NOvA ND prototype
- Muon Catcher 2/3 height of the rest of the ND



Electronics map
1 DCM per side
11 APDs per module

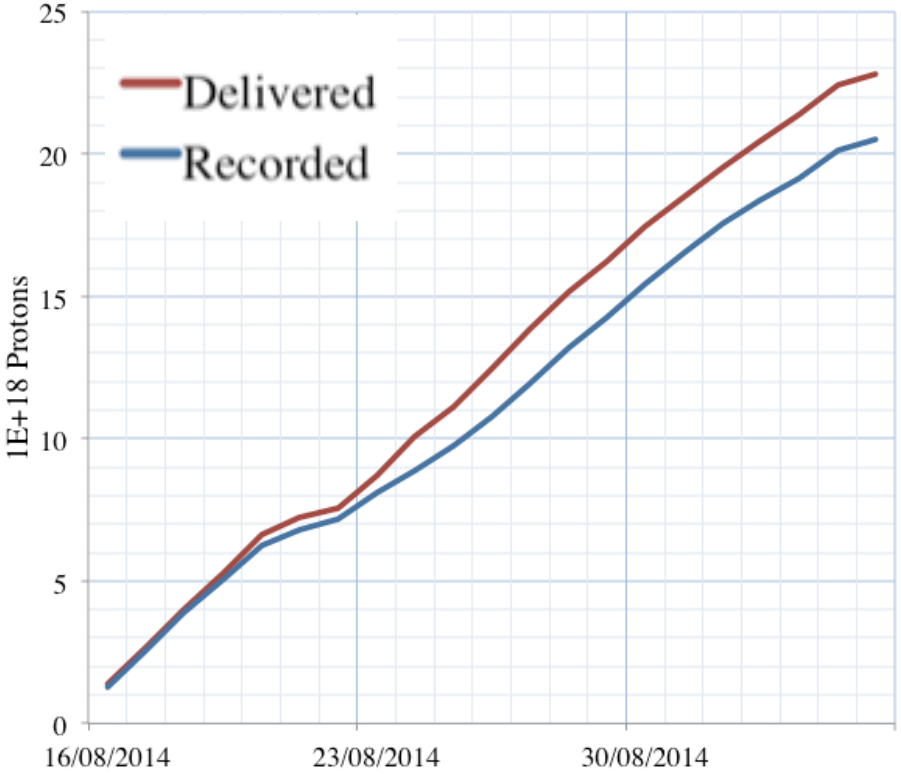
Construction Timeline



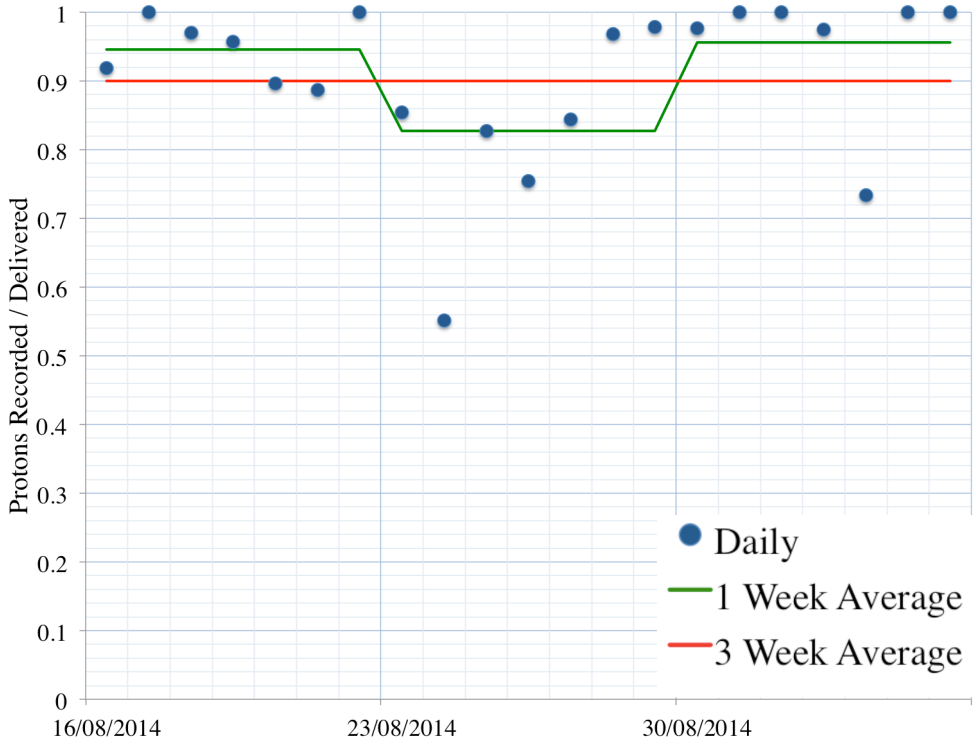
Physics Data Recorded

The ND recorded 3 weeks of physics data before the shutdown

POT Recorded



Data Taking Efficiency



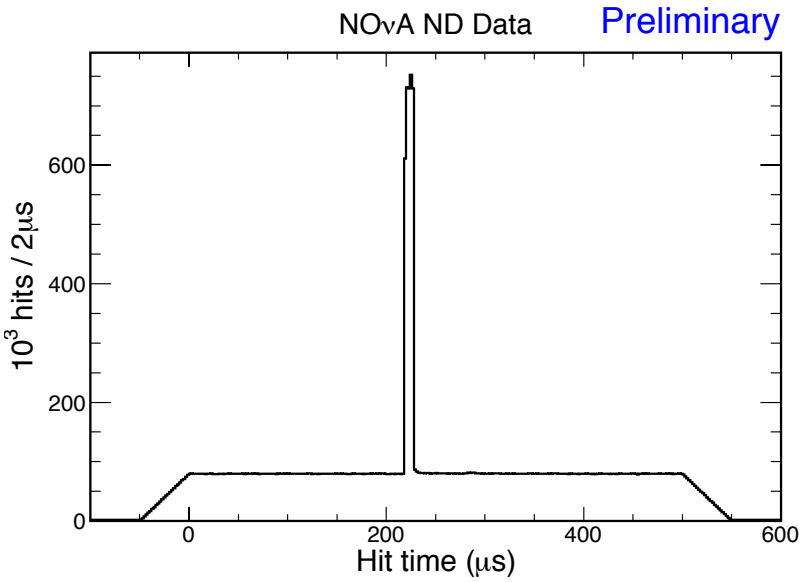
Delivered 23×10^{18} POT
Recorded 20.5×10^{18} POT

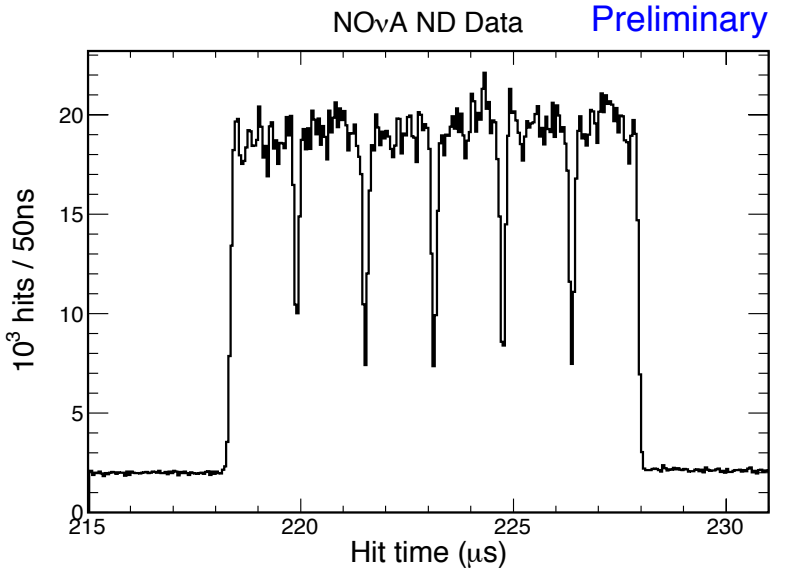
90% data taking efficiency

ND Physics Data

- High quality data recorded
- From first spills recorded in ND timing peak was immediately apparent
- Data recorded with detector running as designed
  - At full gain
  - Cooled to -15C
  - Using multipoint readout
- Currently being used to validate our ND MC in preparation for the first physics results

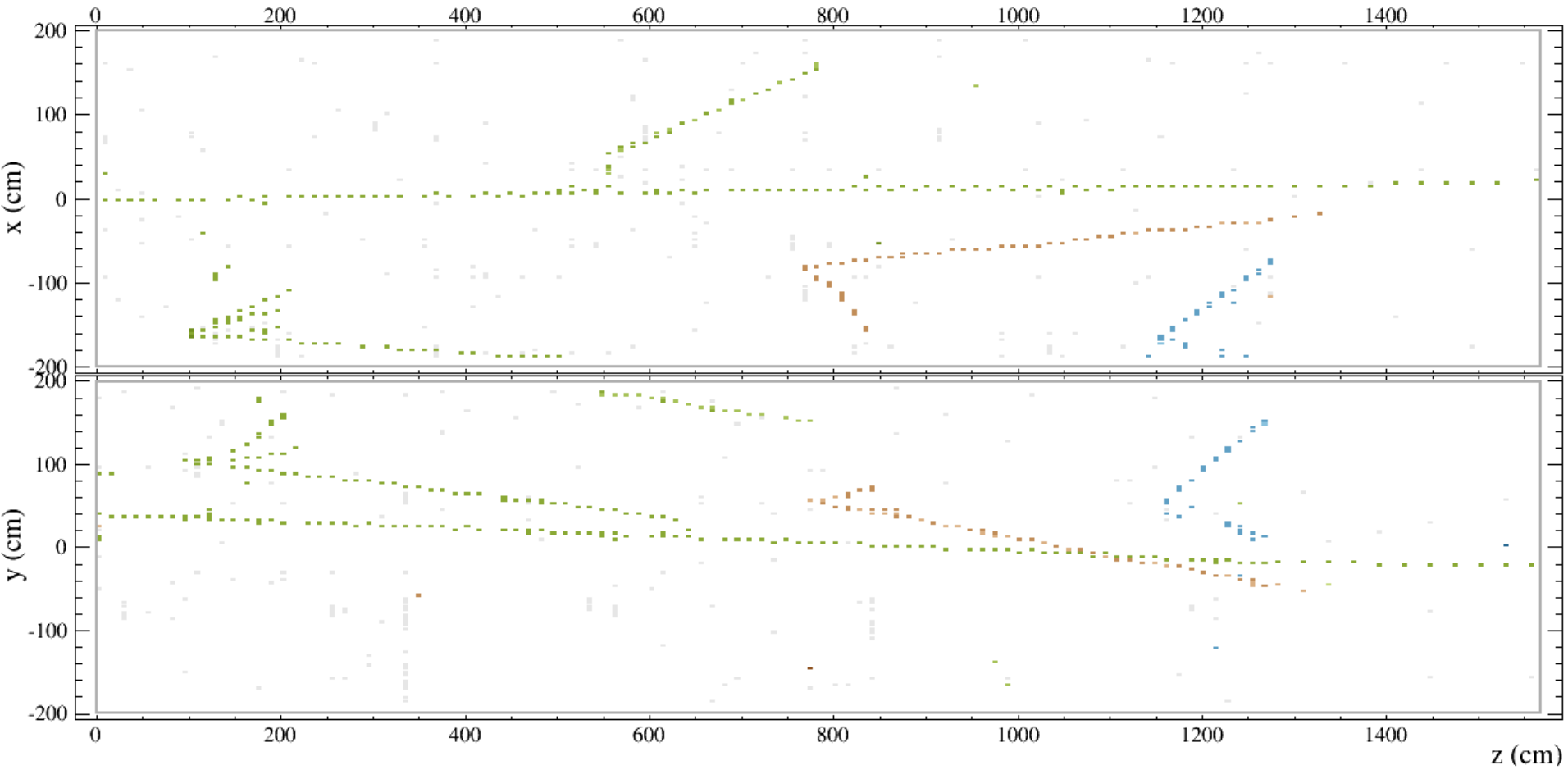
All Hits recorded

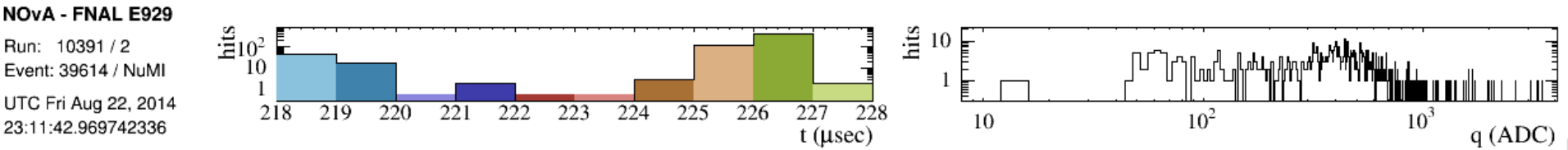




ND Event Display

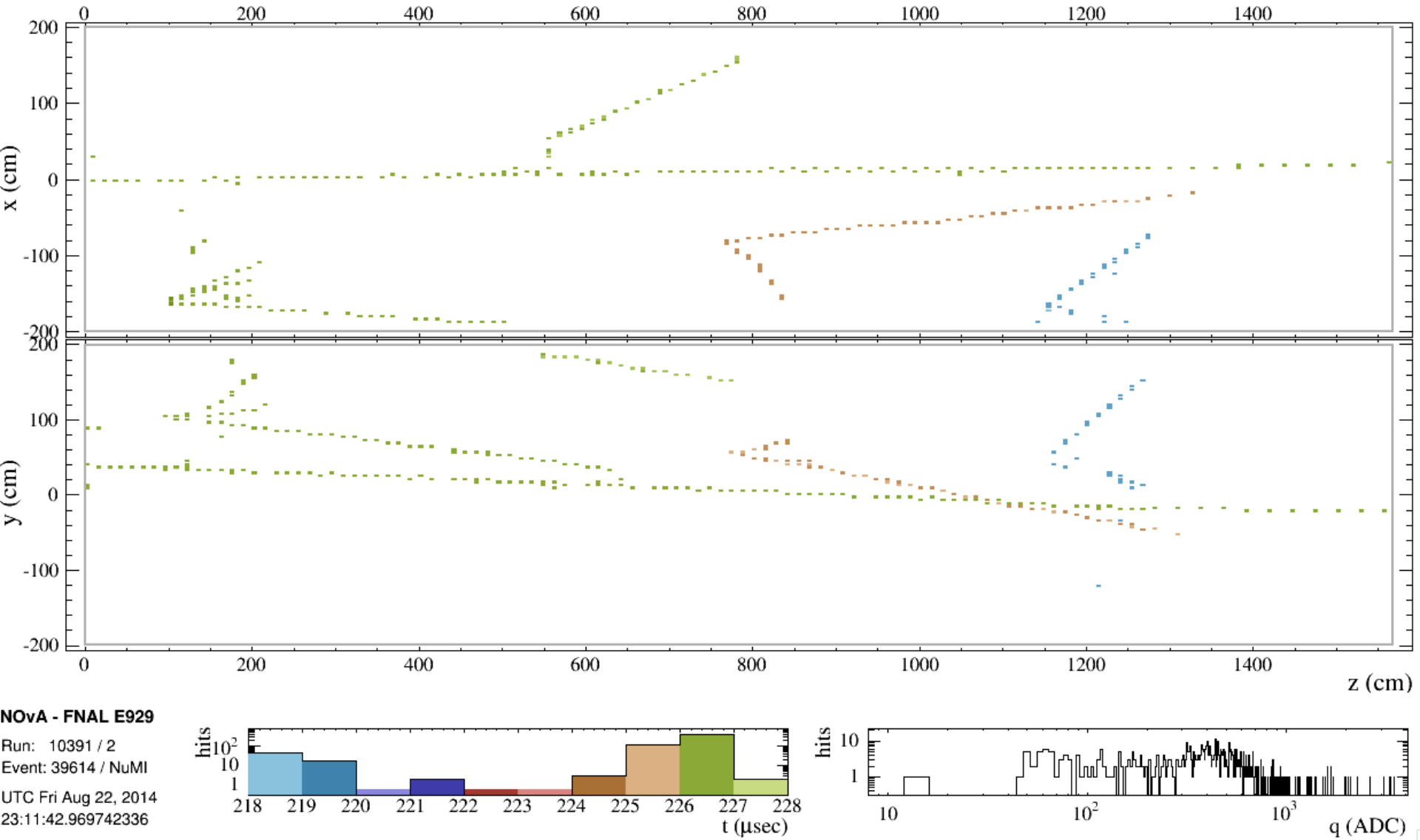
- Multiple events in the ND per beam spill
- Showing 550us of data, zoomed in on beam spill time window





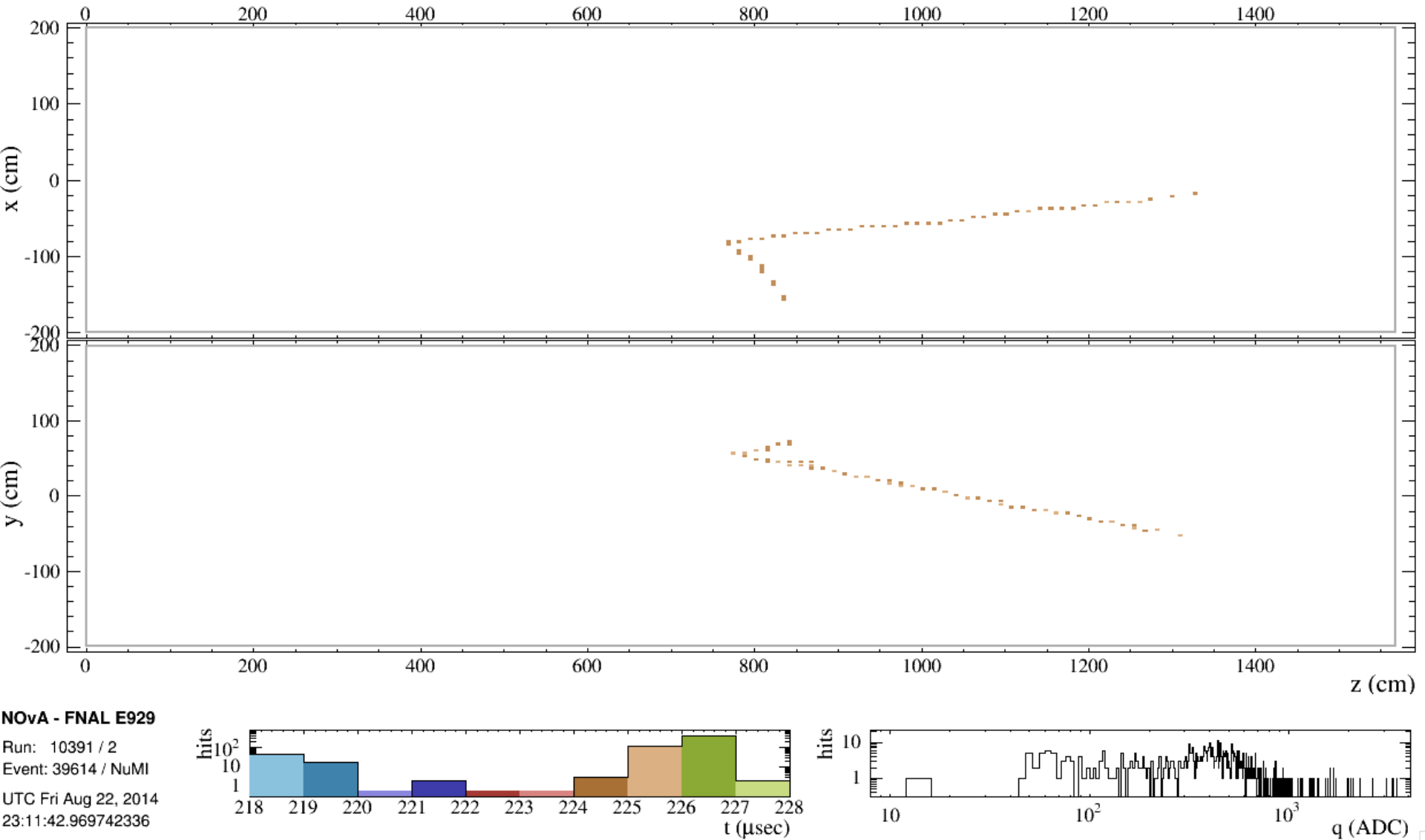
ND Event Display

- Noise hits easily removed by our clustering algorithms



ND Event Display

- Clustering algorithms easily separates individual neutrino events



Hardware Monitoring Tools

NOvA employs continuous hardware monitoring

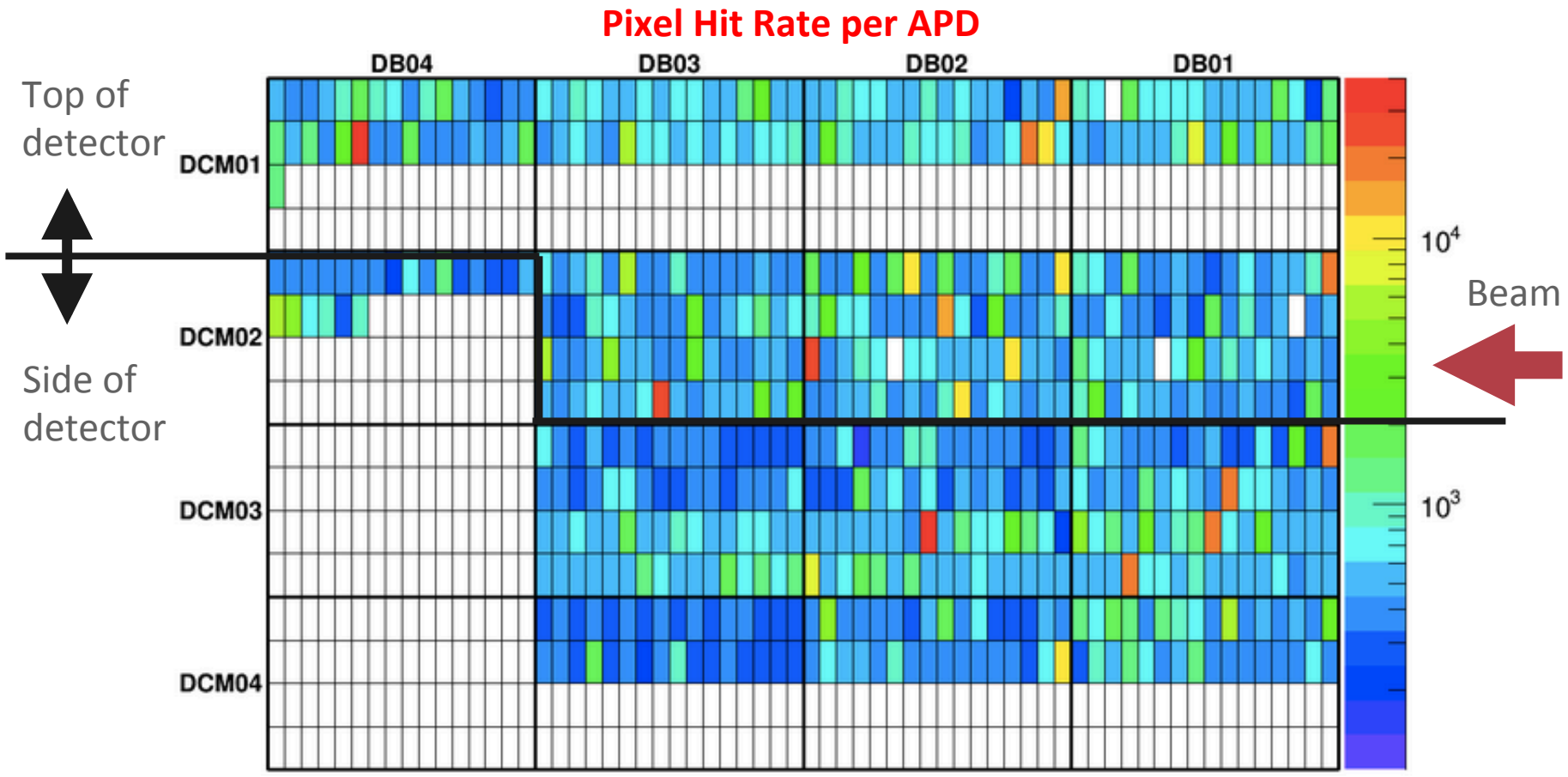
Real time

- Online monitoring of electronics and detector systems in the control room 24 hours a day, 365 days a year
- Used to determine immediate issues
- On call experts available to diagnose and fix issues

Longer term

- Hardware watch: List of noisy, quiet, and non-reporting channels based on at least one week of data
  - Used to produce the list of electronics that need maintenance
- Watchdog group: Dedicated group of experts that meet once a week to discuss the ongoing state of the detector and identify issues
- Data Quality group: A dedicated group of people meet once a week to develop tools needed for meeting long term monitoring needs

Real Time: Online Monitoring



The hit rate for each APD (summed for all 32 pixels)

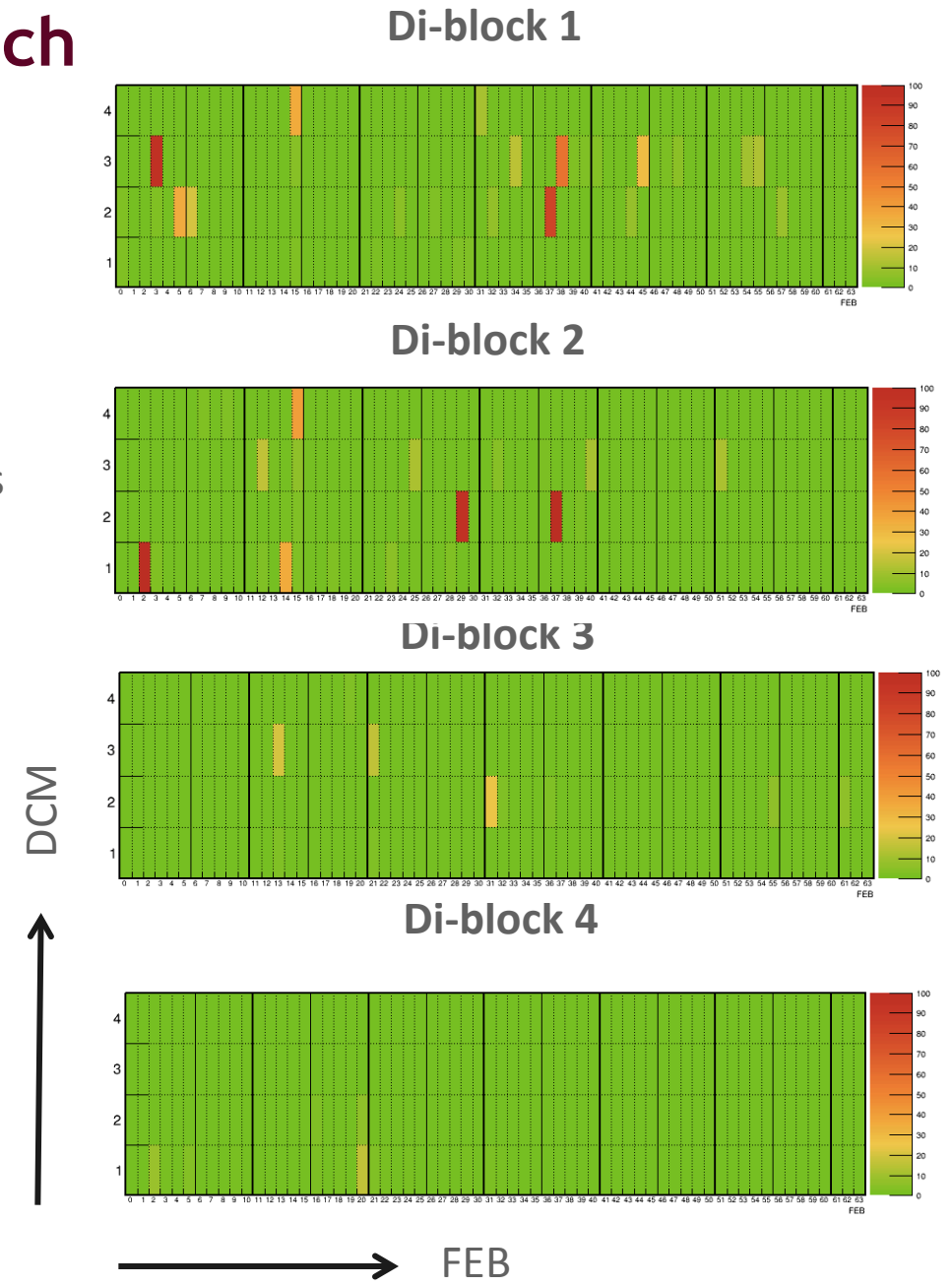
- 4 noisy channels = 0.6%
- 5 unresponsive channels = 0.6%
- 7 un-cooled channels = 1.1%

Total: 2.3%

Shown in electronics space. Due to ND small size not all channels in DCM occupied

Long term: Hardware Watch List

- Maintenance for ND is planned based on number of issues and known beam down time
- A Hardware Watch list is produced from information on the state of the electronics over time
- Tracks noisy, quiet and non-reporting pixels
- Reports when issues arise, along with a rating on how severe
- Ratings of issues based on frequency and number of APD pixels affected
- Web based system with information available to download in several easy to use formats



Shut Down Maintenance Work

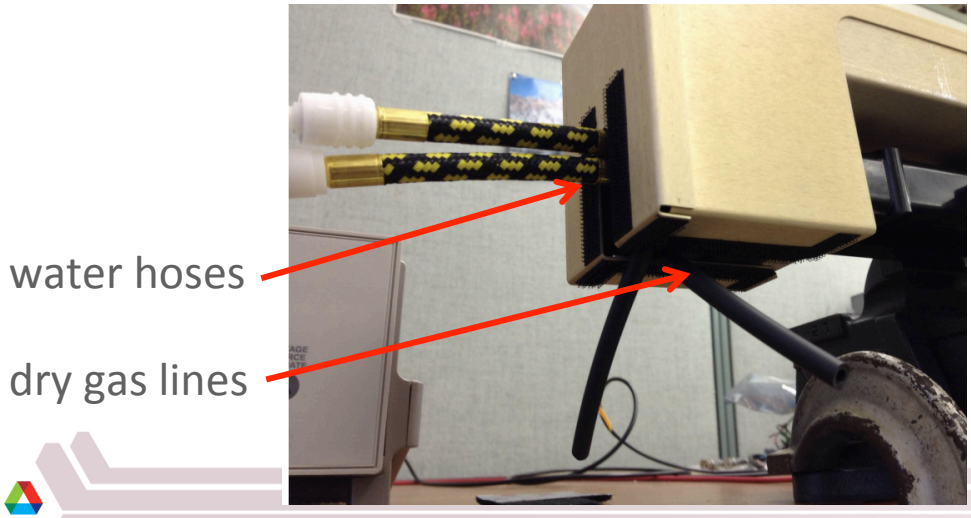
Getting ready for long term data taking

- After ND was fully instrumented it ran continuously until the shut down
- No maintenance work was done on the detector during that time
- Resulted in running with the detector more noisy than is optimal, especially on the last regions to be installed with APDs
- During shut down replaced all APDs which were operating outside of the nominal
- 29 APDs replaced, as determined by the Hardware Watch List
- First time this procedure was used on the ND. Enabled testing and validation of the system that will be used going forward
- Additional maintenance work is still needed to replace 2% of channels with issues
- Swapped channels are monitored by Hardware Watch to determine if issues are resolved

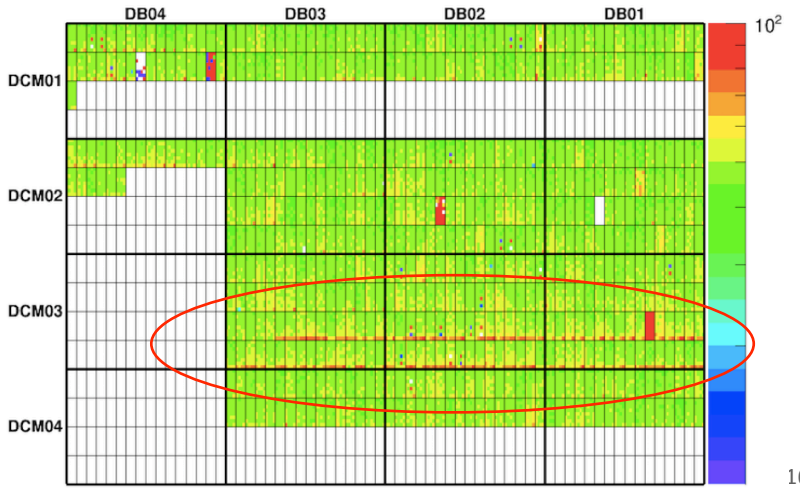
Shut Down Maintenance Work

Getting ready for long term data taking

- Accelerator shutdown gave us time to make improvements to ND systems
- The box containing the APD has a slit for the water and dry gas cables making APDs susceptible to light pollution
- For the FD the APDs close to overhead lights had been guarded against ambient light using black Velcro covering the slit
- Due to small size and the proximity of the lights to electronics in the ND all APDs were protected in this way
- During normal running only emergency lights on in hall



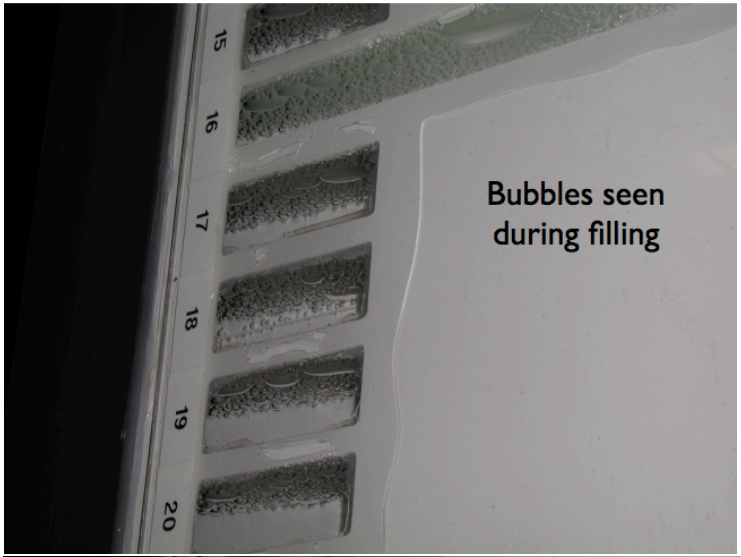
Pixel thresholds with lights on

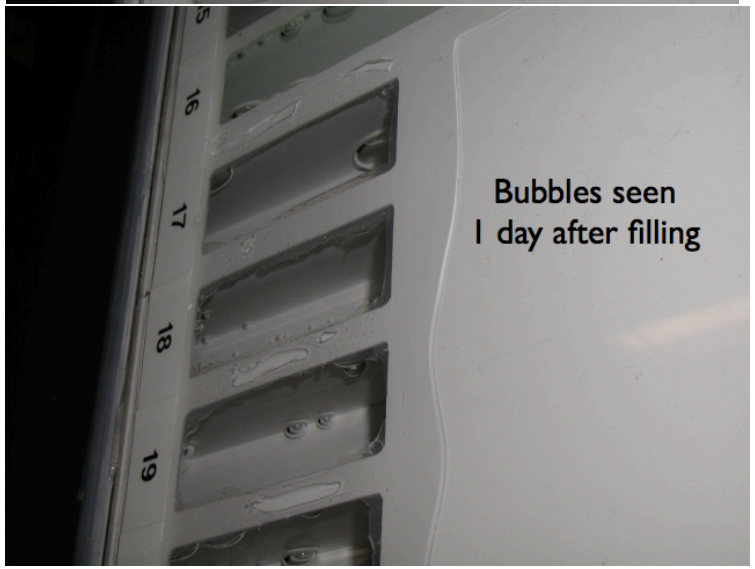


Shut Down Maintenance Work

Getting ready for long term data taking

- The oil levels in the modules will settle over time as air bubbles work their way out of the system
- The oil filling was completed on 4/24 giving bubbles 6 months to move to the surface
- Oil levels across the detector were measured and only two modules were found to be low
- There is 700 gallons of the blended oil pseudocumene mixture on site which can be used for top ups





Going Forward
Spare Electronics and Components

70 FEBs v5:

- This is all the spare FEB v5s. Caltech has ability to produce more if needed
- Without any water leaks, expect slow rate of failure

7 APDs:

- These are for immediate work. We do not store APDs at lab at the moment as we do not have a temperature and humidity controlled environment
- Spares for replacements are overnighted from Caltech

Power supplies:

- 1 spare LV power supply (more will be ordered), 1 spare HV main frame, and 2 spare HV modules
- Failure rate expected less than 0.5 per year

DCMs:

- DCMs were made by Fermilab, all spares are onsite
- 11 spares for both ND and FD. With an additional 20 that could be used if needed

PDB:

- 1 spare PDB on site. These were specifically build for NOvA by Uni. of Virginia

Going Forward
Dry Gas and Water System Support

- All parts of the system are continuously monitored and can be controlled by IFIX
- System is designed with redundancy and automatic protection systems

Most major parts have spares on site at Fermilab

- Compressors, dryer, water pump, pressure transmitters and dew point transmitters
- Rebuild kits for the desiccant are on hand, which will be replaced annually.
- Many spare water filters, water and dry air hoses, and fittings for ongoing maintenance

What we do not have on hand:

- Control Valve – commercially available in a few weeks
- Heat Exchanger – commercially available in a 1-2 days

Everything else is commercially available and can be sourced quickly

Maintenance Manpower

Electronics maintenance work

APDs:

- 3 Fermilab technicians and 2 collaborators trained to swap APDs on detector
- 6 collaborators trained to test ADPs before installation

FEB and TECCs:

- 3 collaborators based at Fermilab trained to do maintenance work

DCMs:

- 3 collaborators trained to do maintenance work

Power supplies:

- 2 collaborators trained to do maintenance work

Dry Gas and Water systems

- Long term support and maintenance provided by Fermilab
- 4 collaborators trained as experts in these systems
- 5 collaborators trained to fix immediate issues (i.e. dry gas leaks)

On call 24/7

NuMI Cavern area

- Weekly checks of the underground area and 24 hour monitoring by shifters via webcams
- Controlled by restricted key access to underground elevator
- Shifters responsive for checking that trainings and work permissions for people seeking access underground
  - All people working on the ND must take NuMI underground specific training
  - All work in ND cavern must be approved by ND Operations Manager
- Web passed system that checks database for trainings and web page listing work permissions
- Run Coordinators inform shifters if work will be preformed on the ND

- For work on ND need specific trainings, oil handling, fail protection. Operation manager is responsible to make sure all people have relevant trainings

Conclusions

- The ND is finished and ready to take data
- Three weeks of physics quality data was taken using the whole detector
- The accelerator shutdown was used to our advantage to perform maintenance and improve on the detector
- The maintenance work during the shutdown tested all aspects of the our new long term maintenance strategy and proved it ready to go for long term data taking
- The ND and the collaboration is ready for long term physics quality data taking

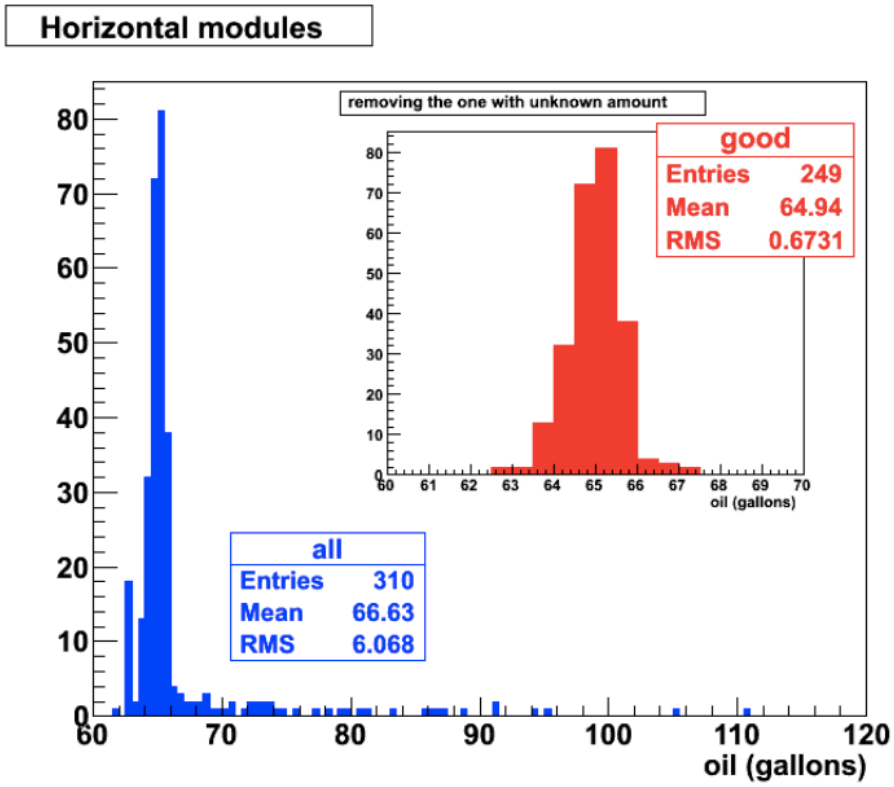
Backup

Differences FEB v4 and FEB v5

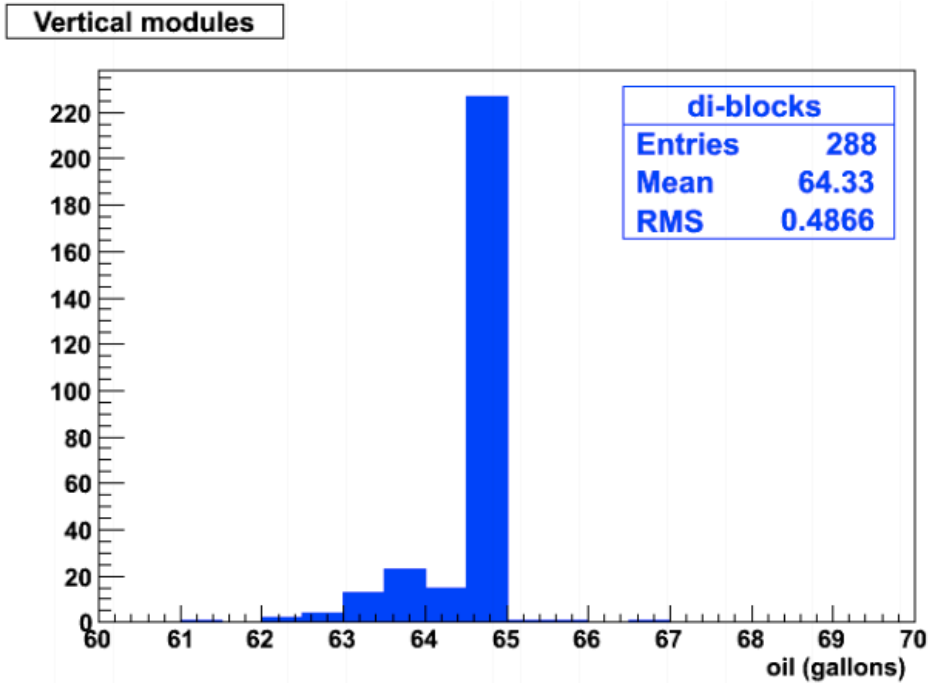
- The only functional change between FEB4.1 and FEB5.21 is sampling rate. The 4-channel semi-custom ADC (Chip Ideas – AD41240) is replaced by two commercial octal ADCs (Analog Devices AD9222) for 16 channels total.
- A second difference is the choice of FPGA. The FEB4.1 uses a Xilinx 6SLX16-FG324 while the FEB5.21 uses a Xilinx 6SLX45-FG484. The lager is a larger device needed to handle the increased number of ADC channels and 4x higher data throughput.
- The increase in ADC channel count and FPGA resources result in approximately 35% increase in power dissipation and increase in power supply current from 0.75 Amp to 1.1 Amp
- All interfaces to the outside world are identical in the FEB4.1 and the FEB5.21. Specifically, the APD interface, the DCM interface, TECC connector, and the power cable connectors are identical, as is the physical size of the board and the mounting-hole locations.

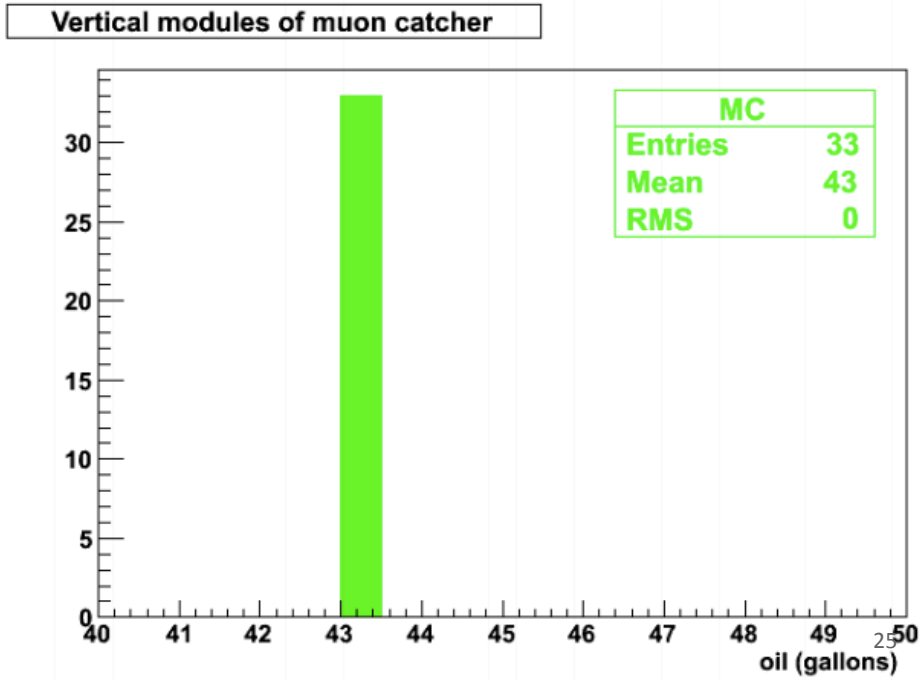
Oil Filling

- Finished oil filling 4/24/2014
- These measurements taken as filling
- Expect bubbles to come out over time
- More information doc-db 11193, 11110



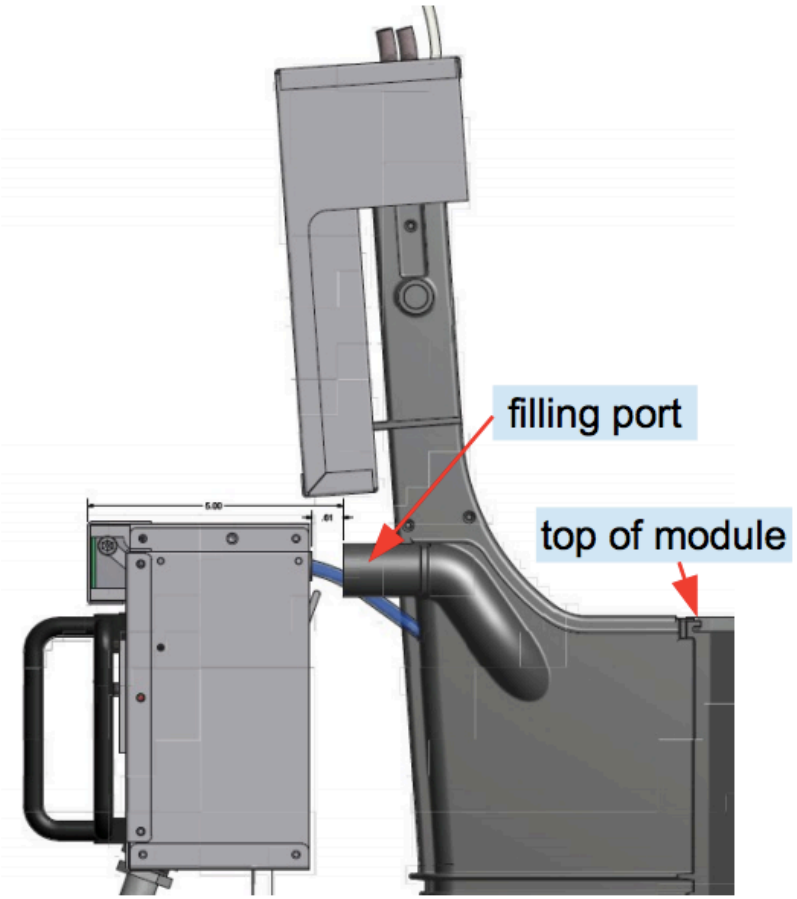
High outliers due to issues with filling machine calibration





Oil Filling

- Filled up detector as much as could on first pass
- The top-off is quite challenging as the filling port is too close to the top edge of the horizontal module
- We used filling machine with highest sensor to top up as much as was possible
- Can determine levels using data, but due to low rates in ND need to run for a while for good measurement
- Have ~700 gallons oil left
- Verticals have more flexibility as the vertical modules stick up ~10cm above the horizontals

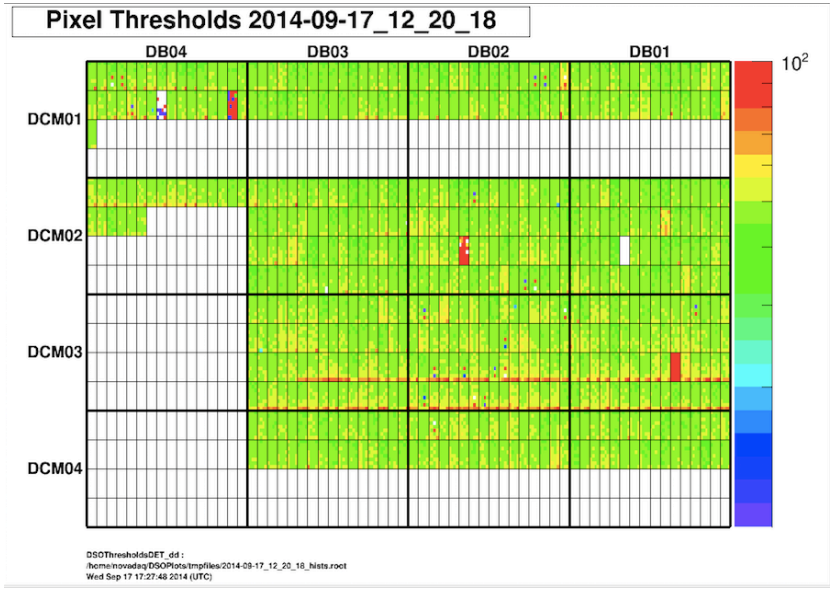


from docDB 9735

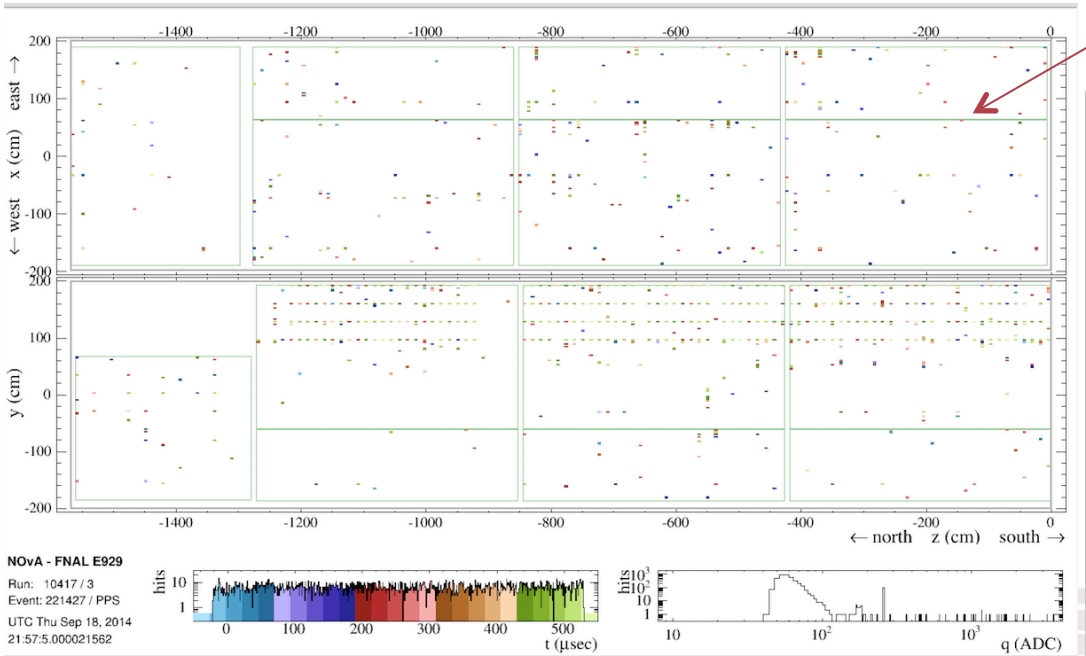
Near Detector light protection

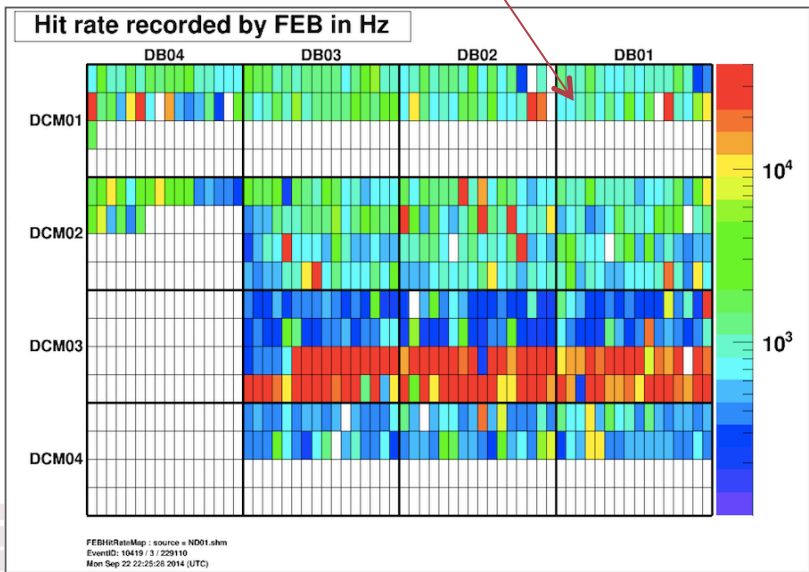
Motivation

- The ND never never had any Velcro light protection
- The FD has Velcro light protection in the regions where light is expected to be the most issue
- The ND is small enough that the light protection was placed everywhere.

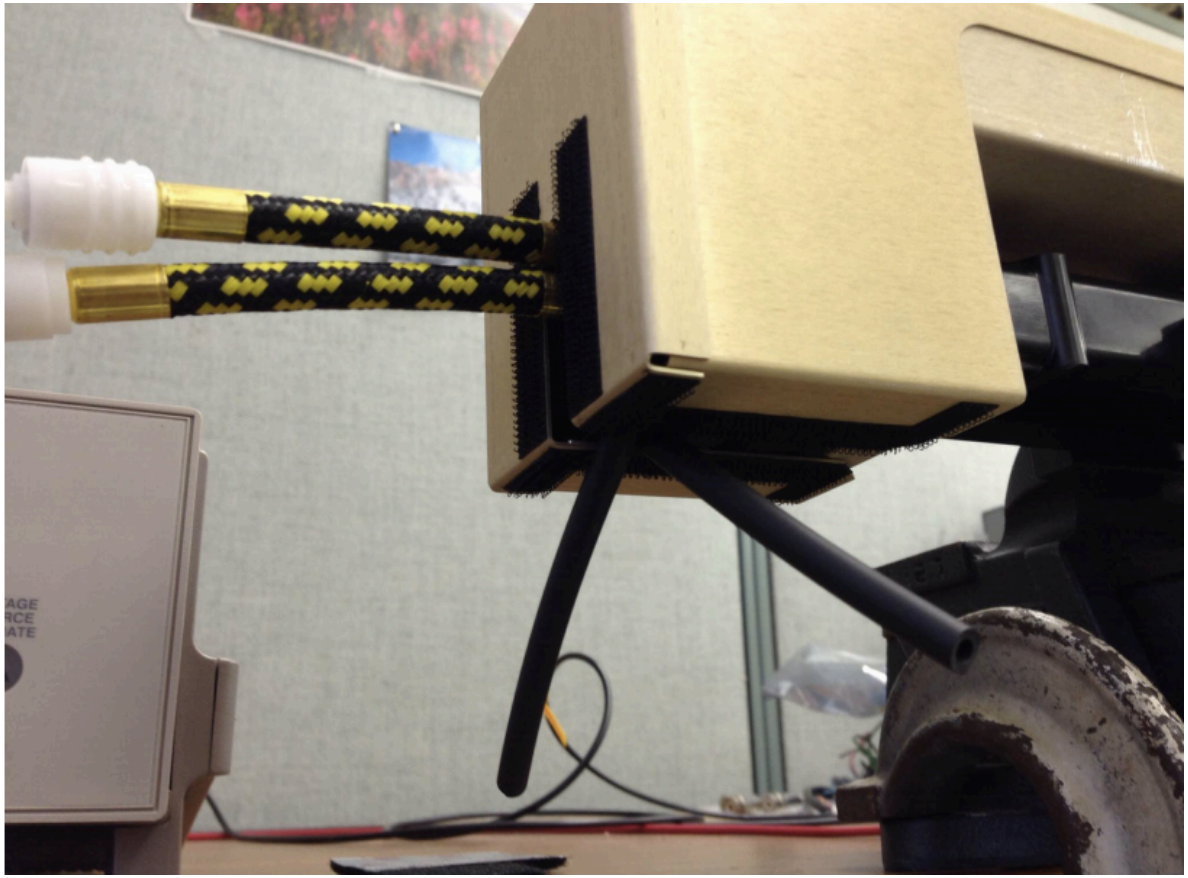


Run with thresholds taken with lights off



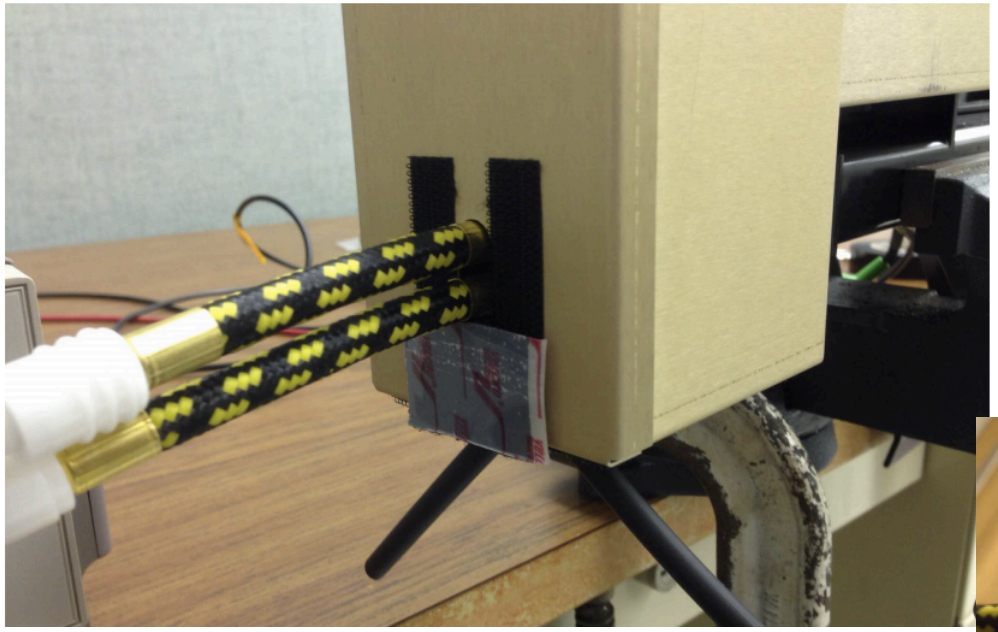


Light protection method



NOvA document database
10174 and 10023

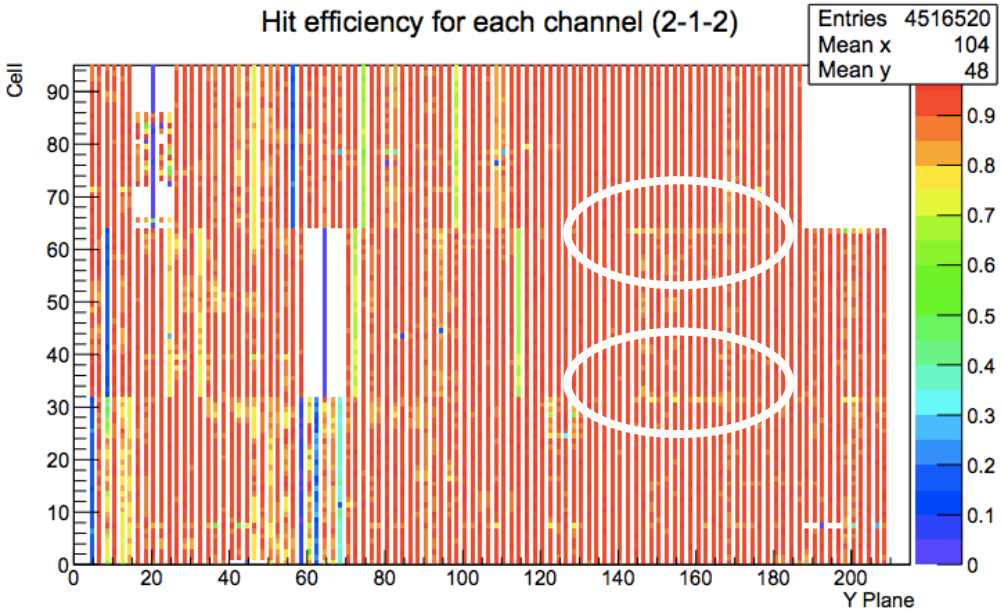
Light protection



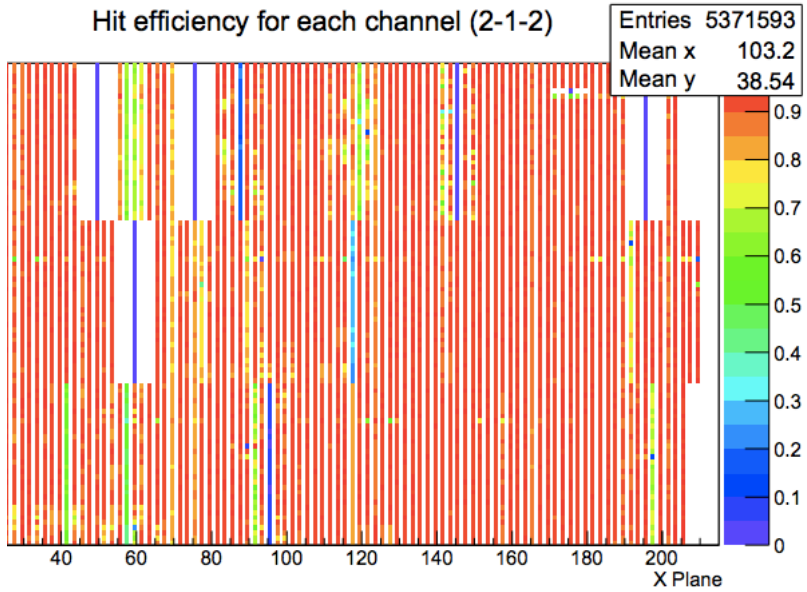
Oil filling
Data driven methods

- Very preliminary work done by Pengfei suggest that there could be regions in the modules lacking in oil
- Looked at hit efficiency in pre-shutdown ND data
  - For hit in cell i and plane j, require are hits in adjacent planes in same view (i.e. cell I or plane j± 2)
  - Studying now in more detail with more stats

Y view



X view



Hardware watch lists

Hardware Watch List: All Diblocks

Listing Hardware address sorted by number of issues per subrun

Download latest HWwatch .csv

Runs 10488 - 10495 **The 4 day period ending on October 21 2014 16:50:43.**

DB-DCM-FEB	BLK-PL-MOD-V	issue rate (score)	noisy rate	quiet rate	non-rep rate	issue pixels
1-1-2	0-5-0-1	100.	0.00	0.00	100.00	32
1-2-37	0-11-2-1	100.	0.00	0.00	100.00	32
1-2-29	2-11-1-1	97.28	0.00	4.38	92.90	32
2-3-3	2-22-1-2	97.14	0.00	9.11	88.03	32
2-2-37	3-3-2-1	81.22	0.00	0.05	81.17	32
2-3-38	3-4-2-2	58.44	0.00	7.64	50.80	32

APD Cooling Failures

- Low rate of APD cooling failures
- Rate increased by thermocycling detector
- APDs can run and take physics data warm
- APD that have failed cooling are swapped at same time as noisy unresponsive channels

- Ongoing discussion to automate this so list of warm channels is automatically generated