

Electronics, DAQ & Monitoring

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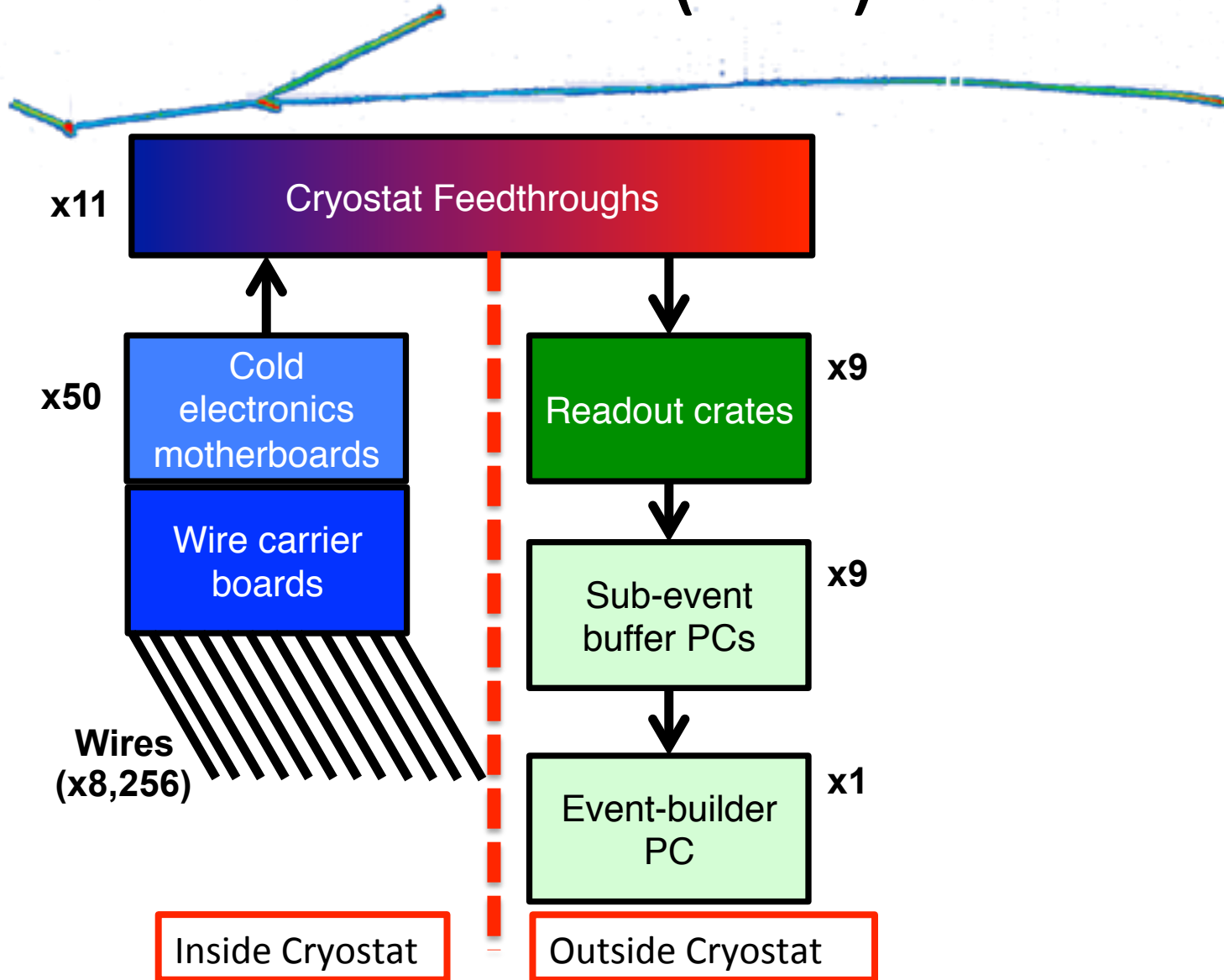
FNAL

Outline

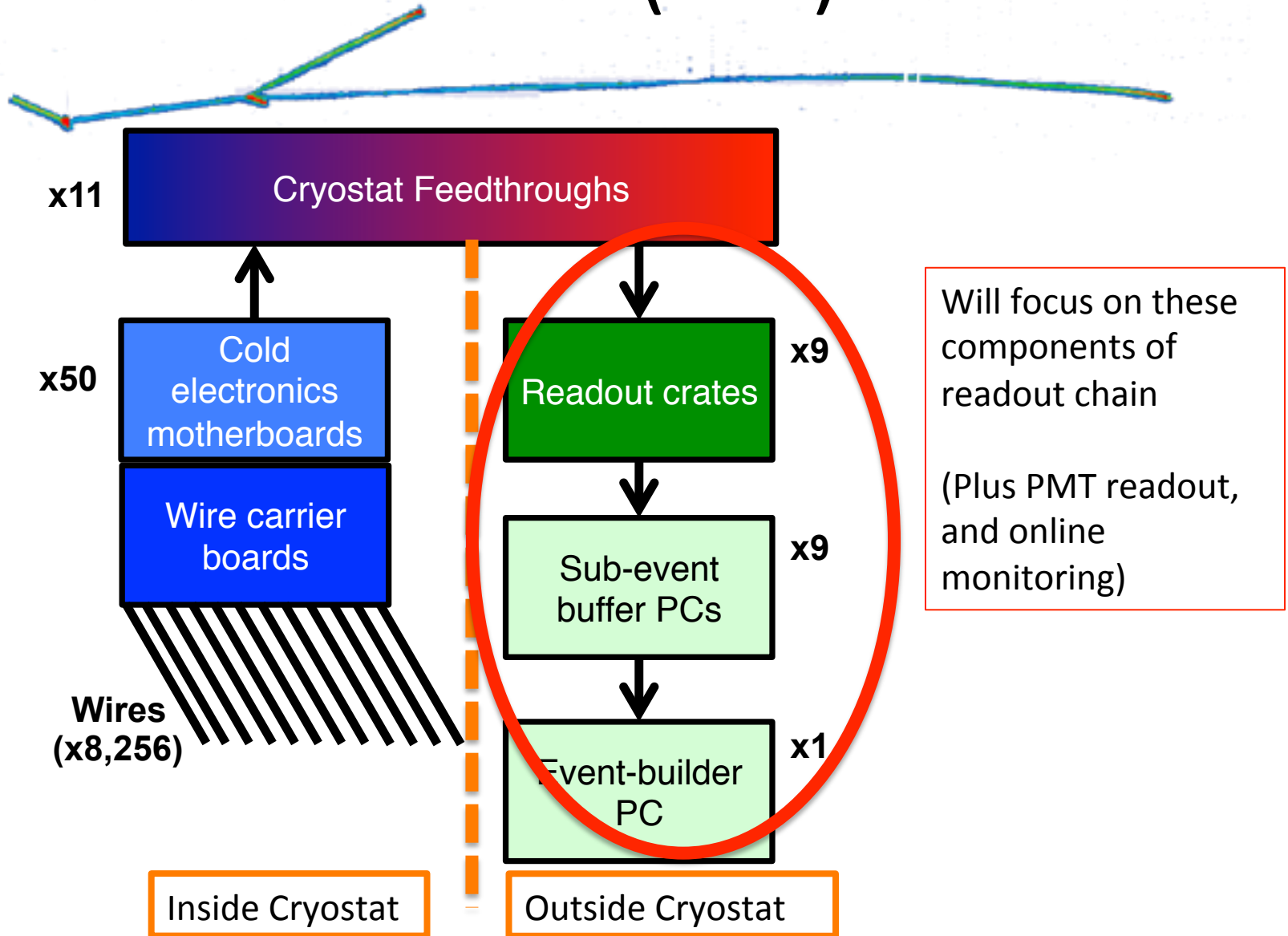


- Readout electronics
 - TPC, PMT, and trigger
- DAQ software
 - Data flow, configuration, and control
- Online monitoring
- Documentation
- Safety and support
- Throughout, addressing charge Q2:
 - *Has it been demonstrated that the detector is ready for physics-quality data taking? ... Is there a clear plan for monitoring the data quality and has the associated infrastructure been tested?*

Brief overview of (TPC) data flow



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TPC Readout Electronics



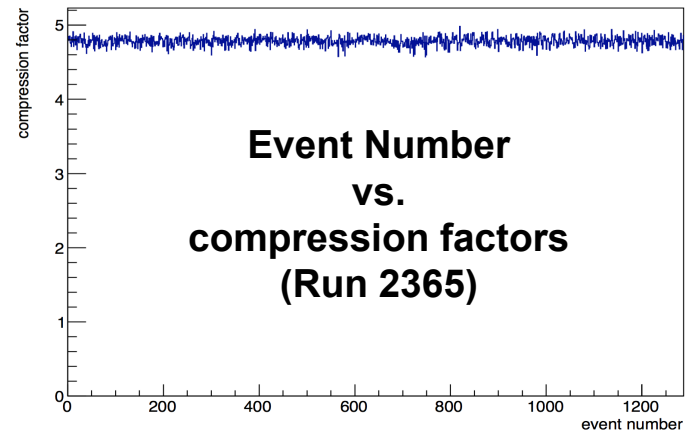
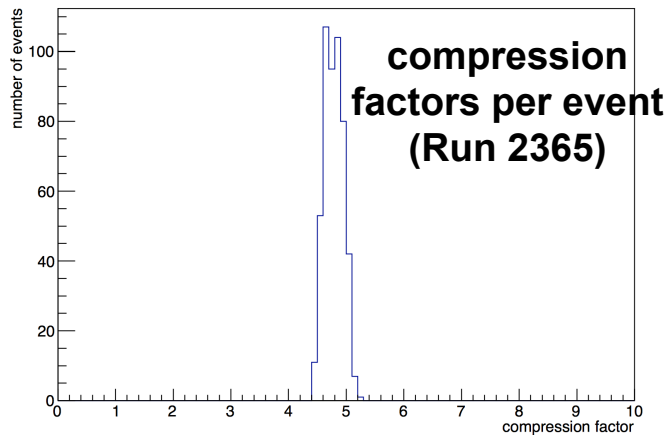
- Digitization + Front-end modules (FEM) + Transmission modules (XMIT)
 - 2 MHz digitization, 4.8 ms readout per event
 - 15 FEM cards, 1 XMIT per readout crate, and crate controller per crate (9 total)
 - Each FEM stamped with event number and “frame number” (1.6 ms interval counter from start of run)
 - Huffman compression in FPGA algorithm on FEMs

TPC Readout Electronics Operation



Charge Q2

- Operating TPC electronics throughout commissioning
- Uncompressed data rate: ~ 150 MB/event
- Huffman compression $\rightarrow \sim 33$ MB/event
 - Compression rate stable throughout run, and run-to-run



PMT Readout Electronics

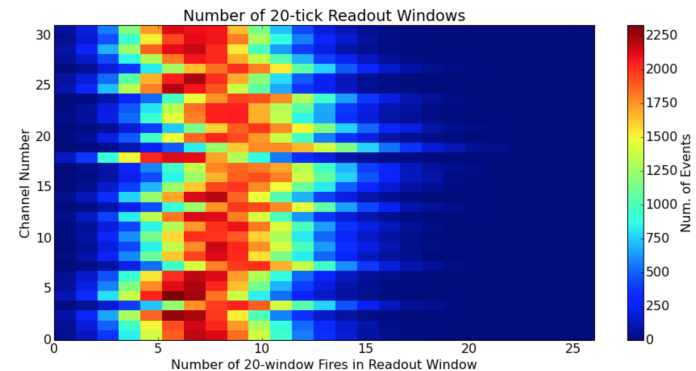
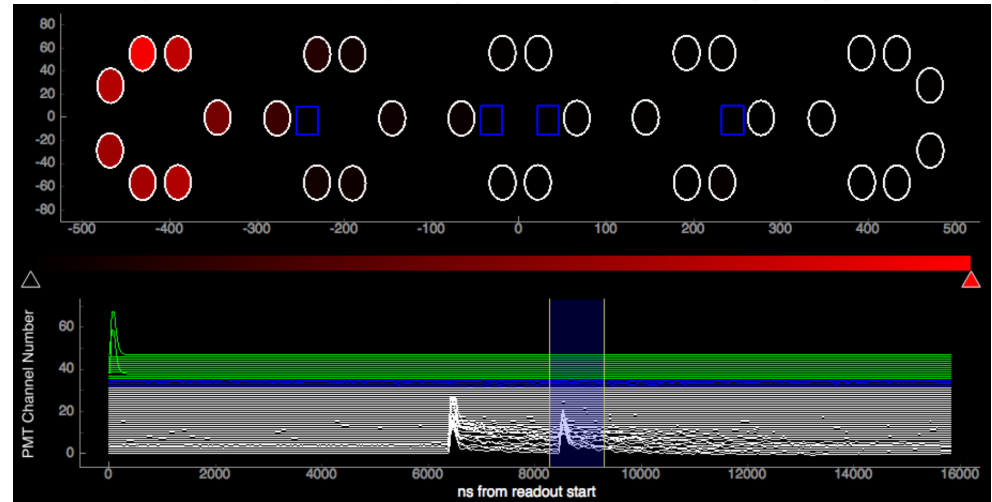


- Shaping + Digitization + Front-end modules (FEM) + Transmission modules (XMIT)
 - Charge-integrating circuit shaper with 60 ns time constant
 - 64 MHz digitization
 - Discriminated readout (6.4 ms total per event)
 - 60 samples for “cosmic” discriminator
 - 1500 samples for “beam” (unbiased) discriminator
 - 2 FEMs, 1 XMIT in crate
 - Each FEM stamped with event number and frame number
 - FEMs also implement PMT trigger logic, send to trigger module (in same crate)

PMT Readout Electronics Operation

Charge Q2

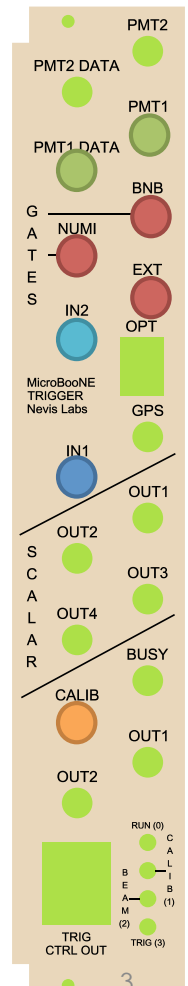
- Unbiased readout during period around beam gate from all channels
 - Used for identifying flashes from neutrino interactions
- Cosmic discriminator threshold tuned to give sustainable readout rate \rightarrow 5 PEs



Cosmic discriminator firing rate per event
(with suggested discriminator condition)

Trigger Module

- Module located in PMT crate
 - Accepts input from front-panel output on PMT board
- Three groupings of triggers
 - “Gate”: BNB, NuMI, Fake/EXT
 - Latter vetoed by first two
 - PMT: Neutrino or Cosmic
 - Calibration/Auxillary: Internal, Laser, Muon paddles
- Trigger signal sent to control module on each crate
 - Including PMT
- Data output
 - Data stream via optical fiber/PCIe receiver
 - Input counters at end of run



Data Acquisition Software

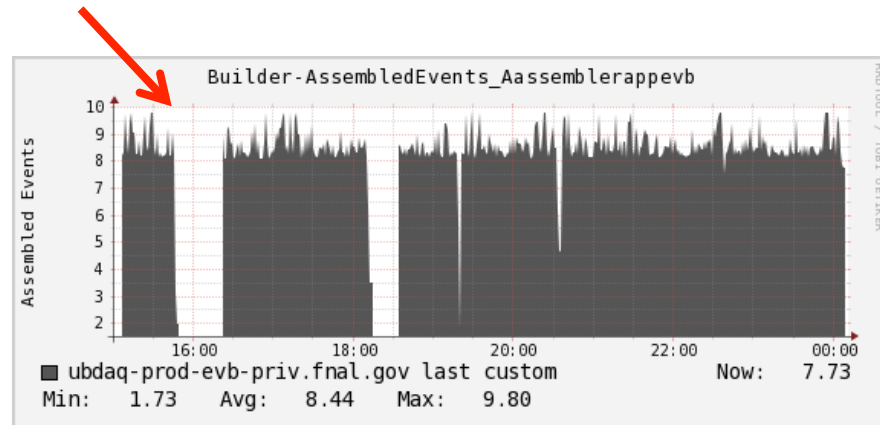
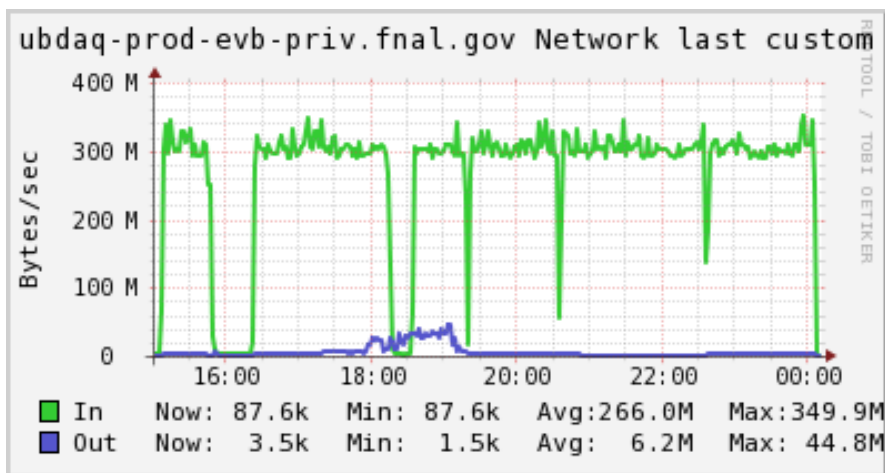


- One commodity server per readout crate
 - 9 for TPCs, and one for PMT+trigger crate
- Data from each server sent to event-builder server which writes fully-built events
 - Events matched based on frame number
- Ganglia cluster monitoring
 - Monitors cluster status, and allow for custom metrics showing data flow/rates
 - Webpage available remotely for shifters/experts to view
 - Metrics to slow-monitoring for shifter alarms and long-term history

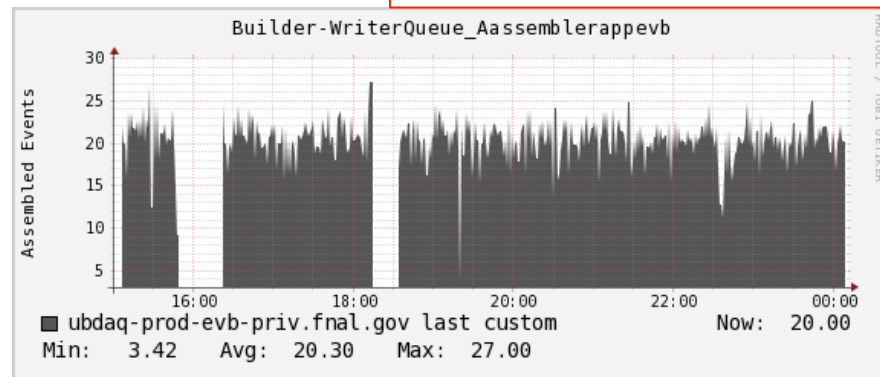
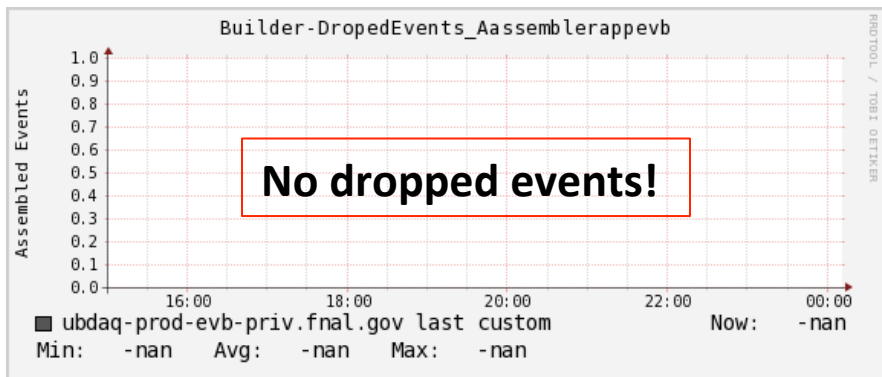
DAQ Performance Example

– Reading/writing data at ~ 8 Hz (300 MB/s)

Charge Q2



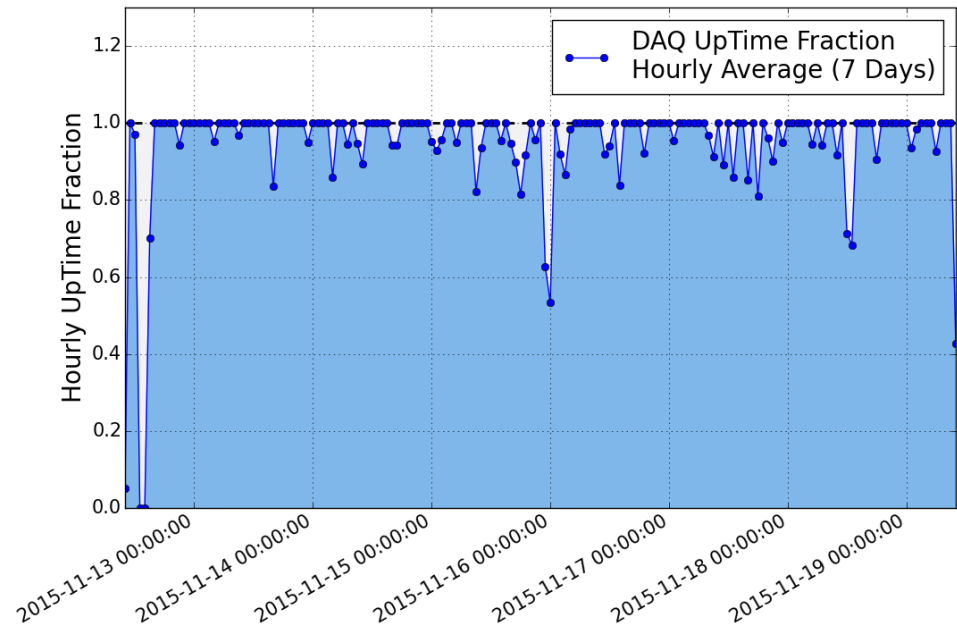
Writing Queue Steady



Performance checks

- Collect and write data on disk up to 10 Hz average rate
- Can handle 15 Hz instantaneous rates for tens of minutes
- Can handle random trigger rate (~ 3 Hz cosmic muon trigger)
- Good uptime
 - $>97\%$ average

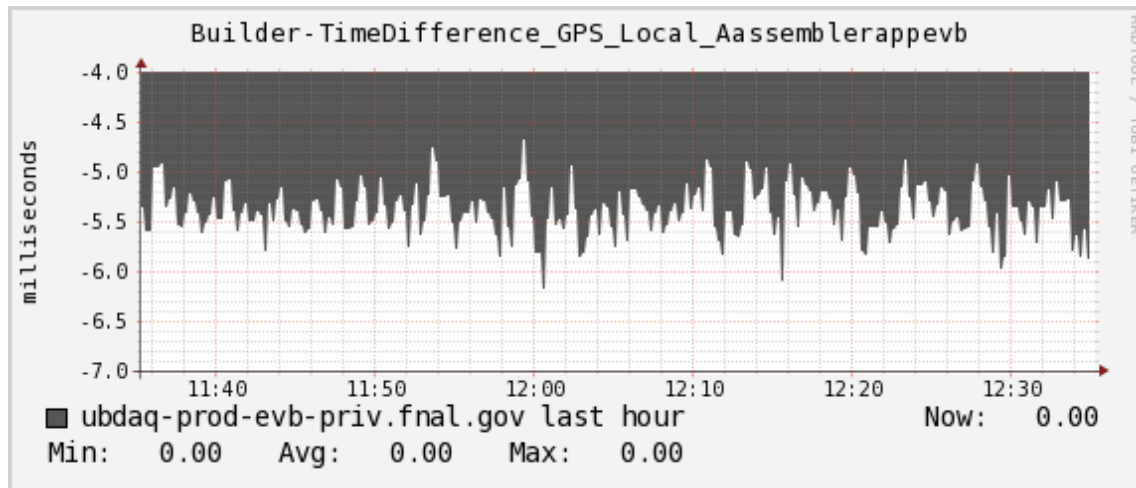
Charge Q2



DAQ Timing



- Electronics clock (event frame and sample numbers) stamped into FEM headers
- System (NTP) time stamped for each event at detection of trigger fragment
- GPS time stored in each event
 - GPS PPS signal sent to trigger board, generates GPS time \leftrightarrow electronics clock time translation
- Monitor (ganglia) local and GPS time differences
 - Monitored in Slowmon



Charge Q2

Note: need ~20 ms resolution for matching to BNB spill

DAQ Configuration and Control



- Run configurations created by / stored in database
 - Tracks electronics hardware and software configurations
- DAQ control requests run config, duration, and goes
 - Automatically restarts runs
 - Automatic entries into Elog
 - Audible alarms if run restarts too frequently or abnormal error conditions occur
 - VNC for experts and remote control rooms

Console DAQ

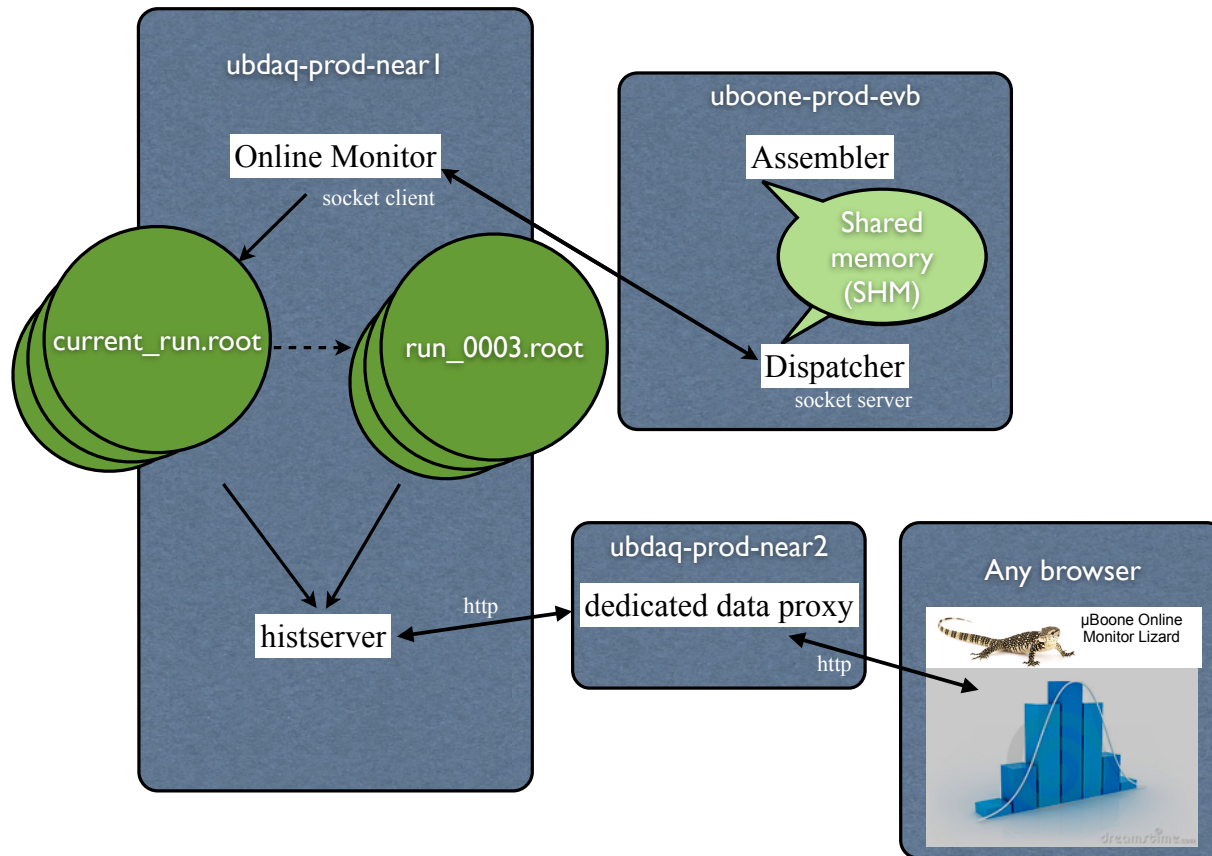
Charge Q2

The screenshot displays the 'ubdaq-prod-evb.fnl.gov:3 (uboonedaq)' console interface. At the top, there are control buttons for 'Control', 'Scaling', and 'Clipboard'. The main area is divided into several terminal windows:

- evb 01 ASSEMBLER**: Shows detailed event processing statistics, including event counts, trigger rates, and assembly status. It reports 'Total Triggers: 2008' and 'EventBuilder: Assembler 19-Nov-2015 12:24:11 CST HF-online'.
- evb 01 - evb 10**: A vertical stack of monitors for sub-detectors 'seb 01' through 'seb 10'. Each window shows 'PHS' status, fragment transport details (ID, Size, Type, Seq), and 'ENTER [stop] TO STOP THE RUN;' prompts.
- dispatcher**: Shows the central dispatcher's status, including 'Event SDD' and 'Requesting' information.
- online-monitor**: Displays overall system performance metrics, such as 'mail 200416', 'Requesting_rate=12.3', and 'RequestRate=0.400'.

The bottom status bar shows the system is running on 'uboonedaq@...' at '12:24:10 PM'.

Online Monitoring: System



Online Monitor: Appearance



Charge Q2

Navigation

Reload Index

- headers
- pmt
- stats
- tpc
 - crate1
 - crate2
 - crate3
 - crate4
 - crate5
 - crate6
 - crate7
 - crate8
 - crate9
 - mapccc
 - mapwire
 - DirectoryInfo
 - h_bad
 - h_chirpy
 - h_compression
 - h_hits_over_ped
 - h_hits_over_ped_frac
 - h_mean_pulse_height
 - h_occupancy
 - h_pedestal
 - h_pedestal_width
 - h_pulses_per_record
 - h_readouts
 - h_rms
 - h_wavy
 - h_zigzag
 - plane0
 - plane1
 - plane2
- h_01_raw
- h_02_pedcorr
- h_06_pulseheight
- h_07_pusetime
- h_51_q_vs_walltime
- h_52_samples_above_pedestal
- h_53_pulses_vs_walltime
- h_54_pulseheight_vs_walltime
- h_70_trigframe
- h_70_trigsample
- h_70_trigsample_vs

Pedestal Width

Value (b) Reference Diff Sigma Diff

log-scale Show Raw Histogram

Shown: 8256
Mean: 4.168 RMS: 2.210
Logical Wire Number: 5489
Crate: 7 Card: 7 Channel 49
Plane: 2 Wire in plane: 691
Value: 3.198±0.002284

Online Monitor Performance



- Automatically started with DAQ processes
- Does not affect data-taking
 - Parasitic, and if it crashes doesn't crash DAQ
- Updates promptly (within a few minutes)
- Sees roughly 1 in 100 TPC fragments
 - Much more for PMT/trigger fragments
- Detects data format problems, as well as basic checks of data quality
 - Noise, pedestals, time matching, etc.
- Integrated part of checklist
 - Includes reference histograms

Charge Q2

Documentation



Charge Q2

- Internal technical documents for readout, DAQ software, and online monitor
- Collection of descriptive talks on each system
- Shifter-friendly documentation on operations wiki
 - Includes guide on starting/stopping/monitoring runs
- Experts available for help
 - Chat window for quick communication → lowers the bar for asking about something

Safety and Support

Charge Q2

- ORCs on all readout/DAQ racks
 - Rack monitor units with temperature and smoke sensors
 - Monitoring via slow control
- DAQ servers managed/supported by SCD Scientific Linux Architecture & Management team
 - Configuration and backup of machines
 - Emergency and non-emergency support
 - Support and recommendations for network configuration and safety

Conclusions



Charge Q2

- Readout system running well
 - Proven capability to handle necessary rate
 - DAQ requires little shifter intervention
 - Efficient collection of data, with full-system uptime of >97% on average
- Monitoring ensures efficient collection of quality data
 - Integration of data rate/volume metrics in central alarming server
 - Online monitoring plots for higher-level checks
 - Tools available for shifters and experts



BACKUP SLIDES