Electronics, DAQ & Monitoring

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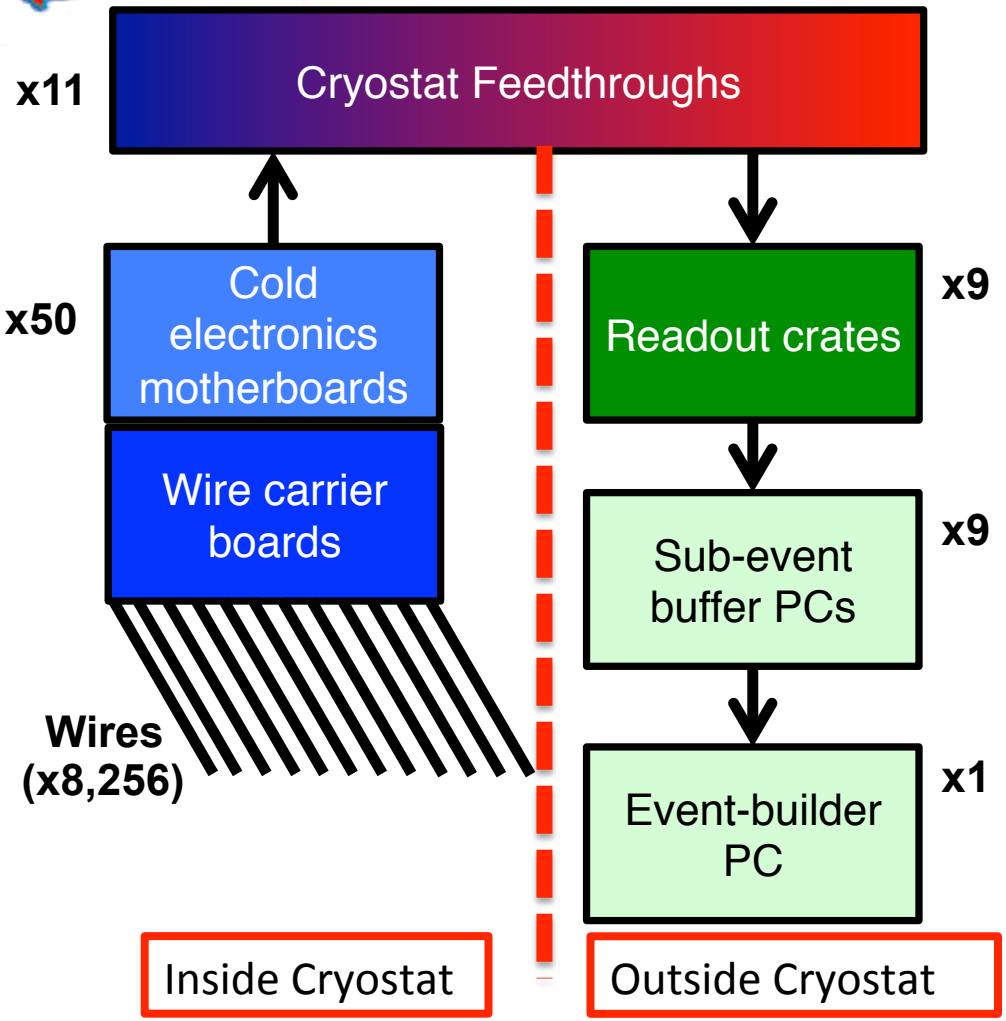
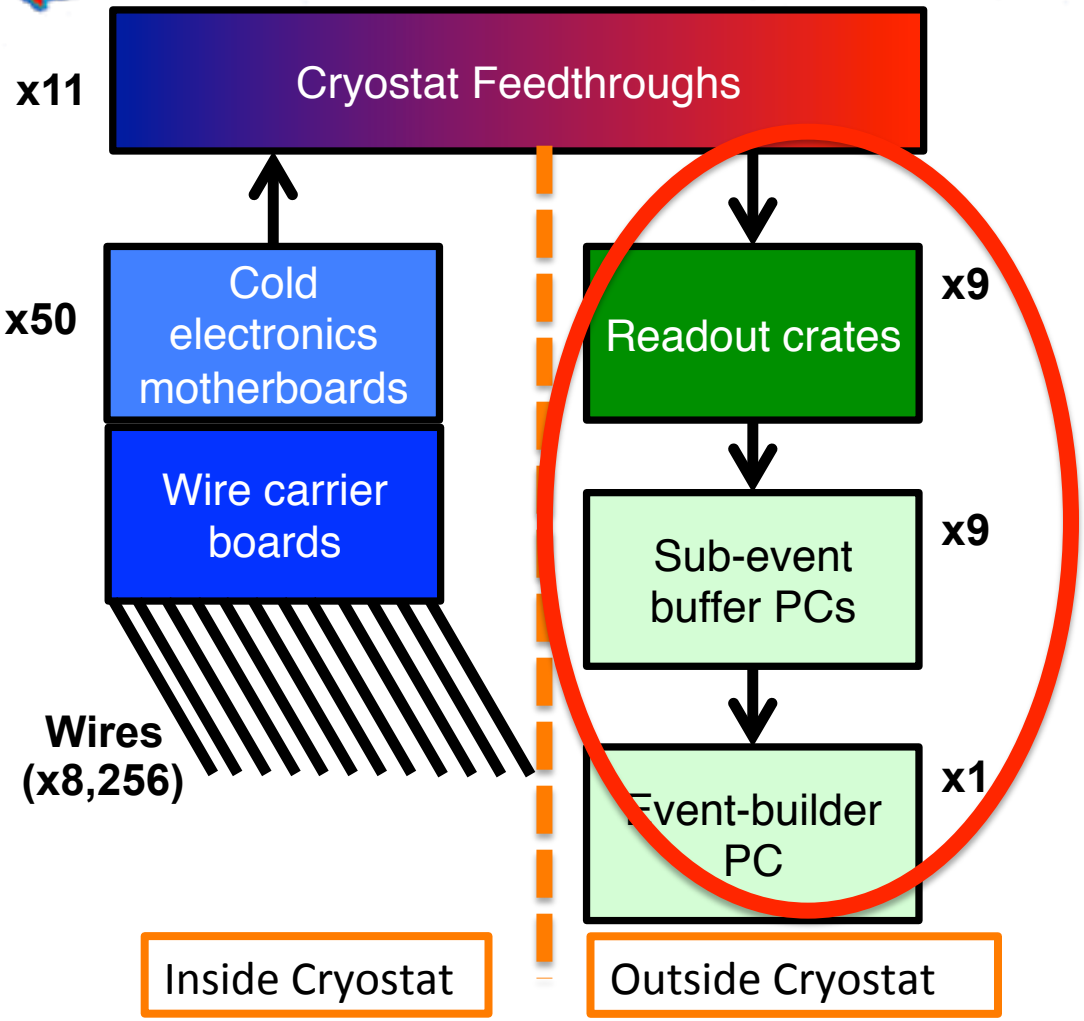
Outline

- 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



Brief overview of (TPC) data flow



Will focus on these components of readout chain

(Plus PMT readout, and online monitoring)

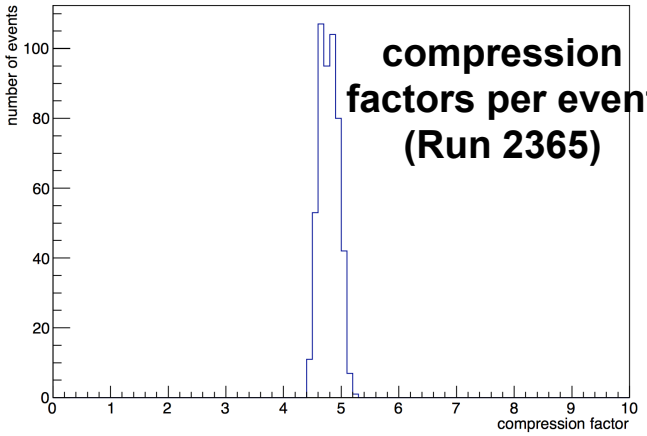
TPC Readout Electronics

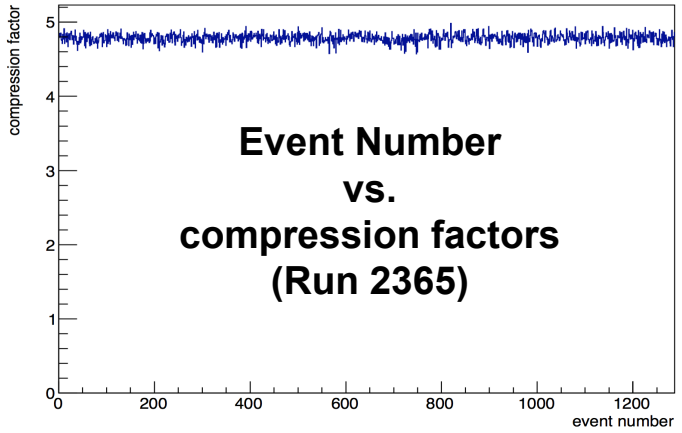
- Digitization + Front-end modules (FEM) + Transmission modules (XMIT)
  - 2 MHz digitization, 4.8 ms readout per event
  - 15 FEM cards, 1 XMIT per readout crate, and crate controller per crate (9 total)
    - Each FEM stamped with event number and "frame number" (1.6 ms interval counter from start 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 → ~33 MB/event
  - Compression rate stable throughout run, and run-to-run





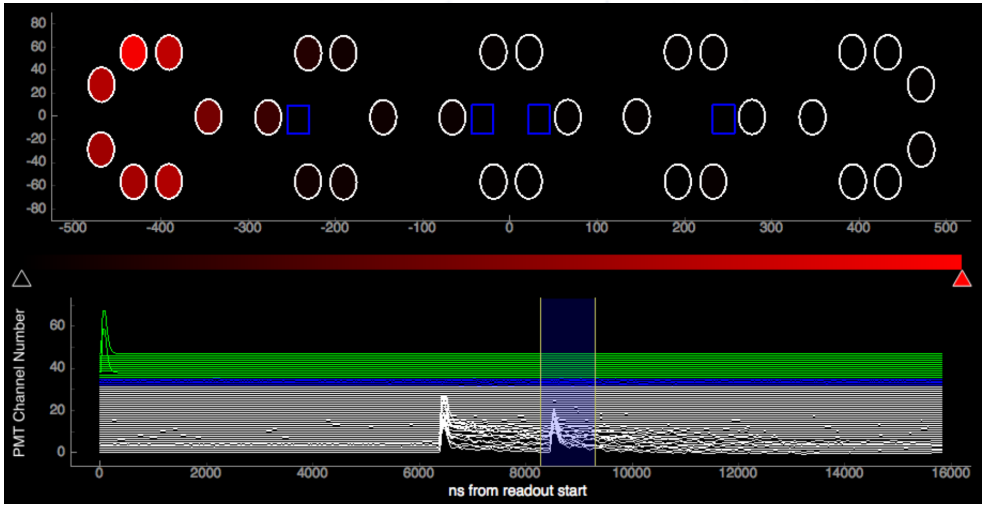
PMT Readout Electronics

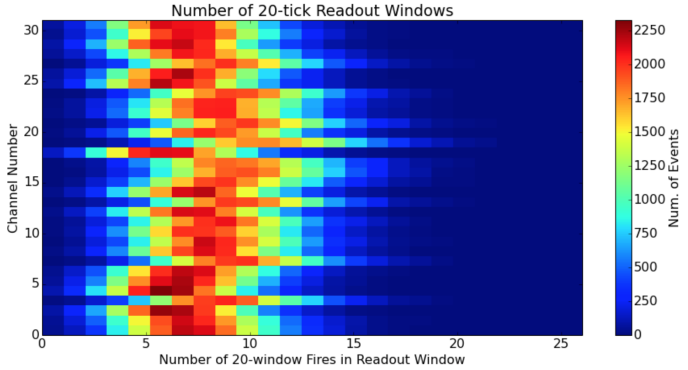
- Shaping + Digitization + Front-end modules (FEM) + Transmission modules (XMIT)
  - Charge-integrating circuit shaper with 60 ns time constant
  - 64 MHz digitization
  - Discriminated readout (6.4 ms total per event)
    - 60 samples for “cosmic” discriminator
    - 1500 samples for “beam” (unbiased) 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 → 5 PEs

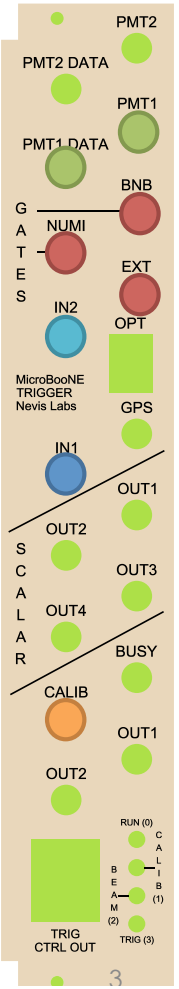




Cosmic discriminator firing rate per event
(with suggested discriminator condition)

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



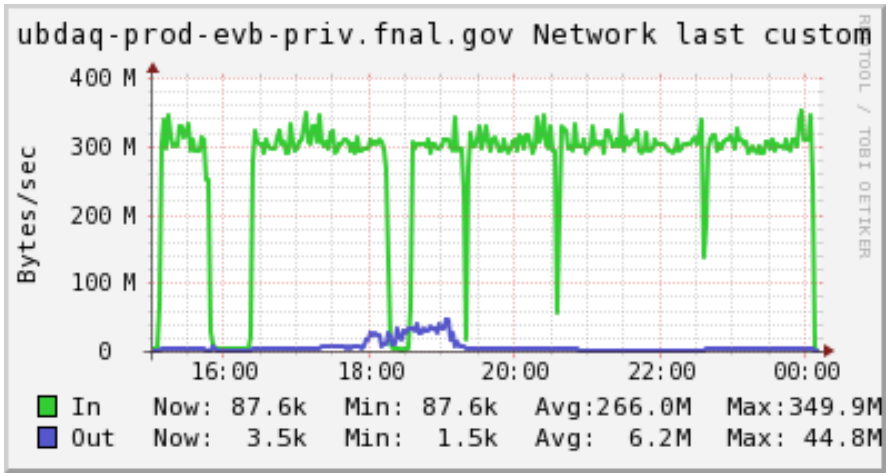
Data Acquisition Software

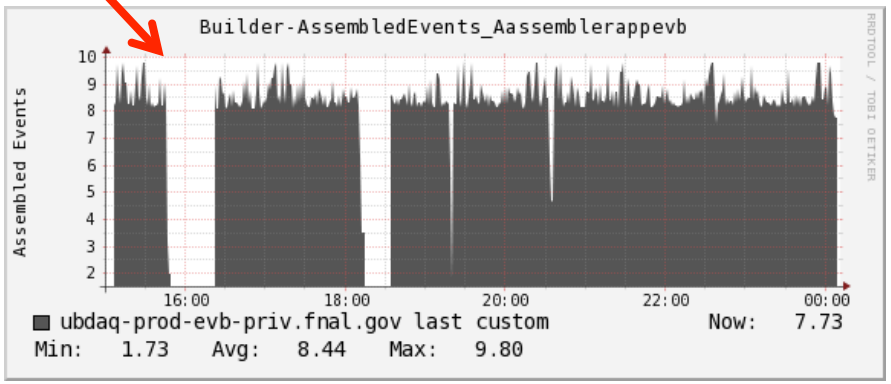
- One commodity server per readout crate
  - 9 for TPCs, and one for PMT+trigger crate
- Data from each server sent to event-builder server which writes fully-built events
  - Events matched based on frame number
- Ganglia cluster monitoring
  - Monitors cluster status, and allow for custom metrics showing 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

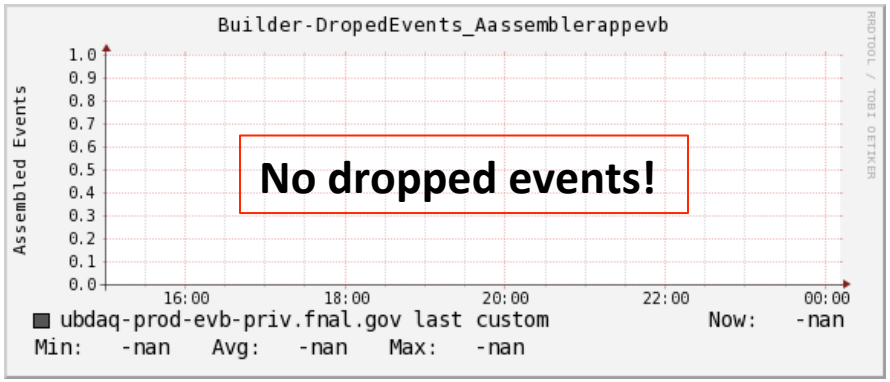
– Reading/writing data at ~8 Hz (300 MB/s)

Charge Q2

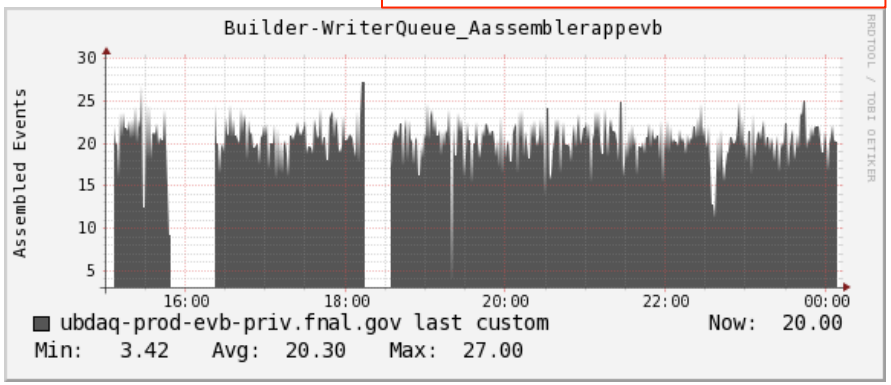




Writing Queue Steady



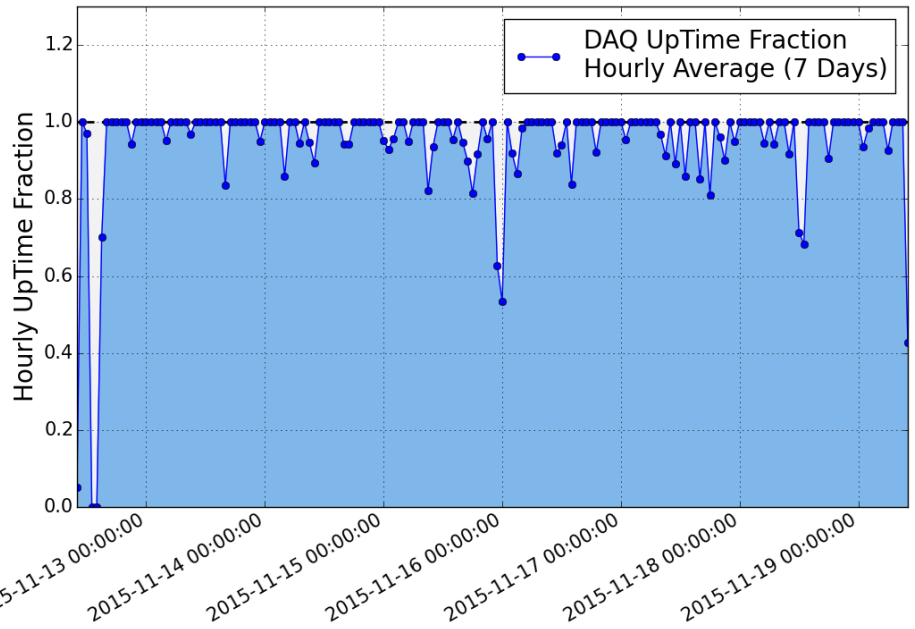
No dropped events!



Performance checks

Charge Q2

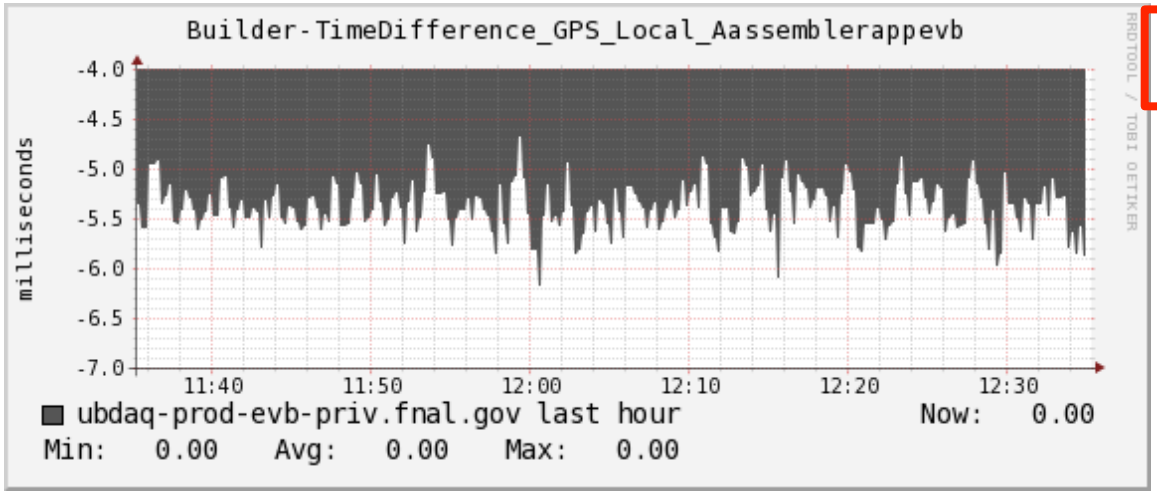
- Collect and write data on disk up to 10 Hz average rate
- Can handle 15 Hz instantaneous rates for tens of minutes
- Can handle random trigger rate (~3 Hz cosmic muon trigger)
- Good uptime
  - >97% average



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 ←→ electronics clock time translation
- Monitor (ganglia) local and GPS time differences
  - Monitored in Slowmon

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



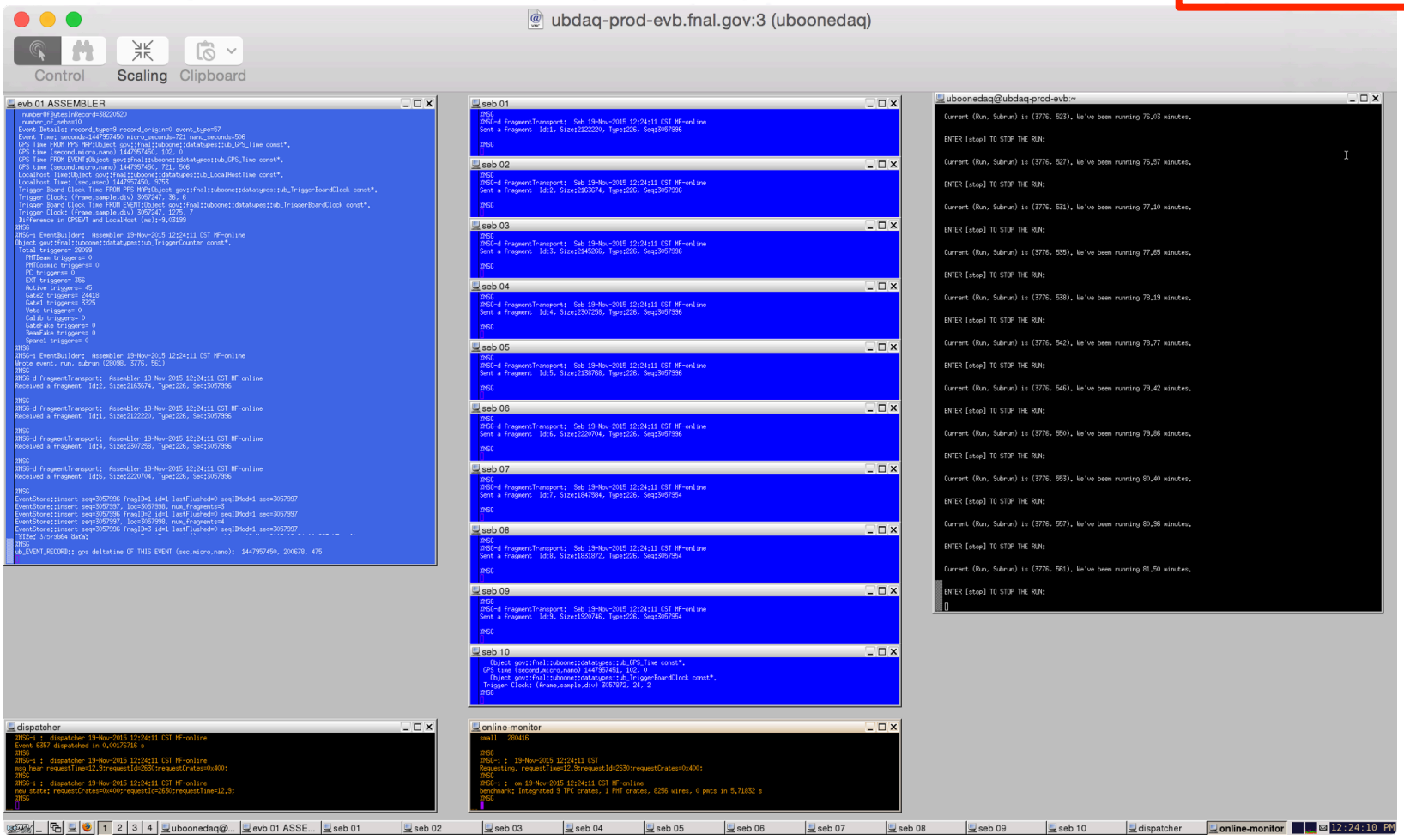
Charge Q2

DAQ Configuration and Control

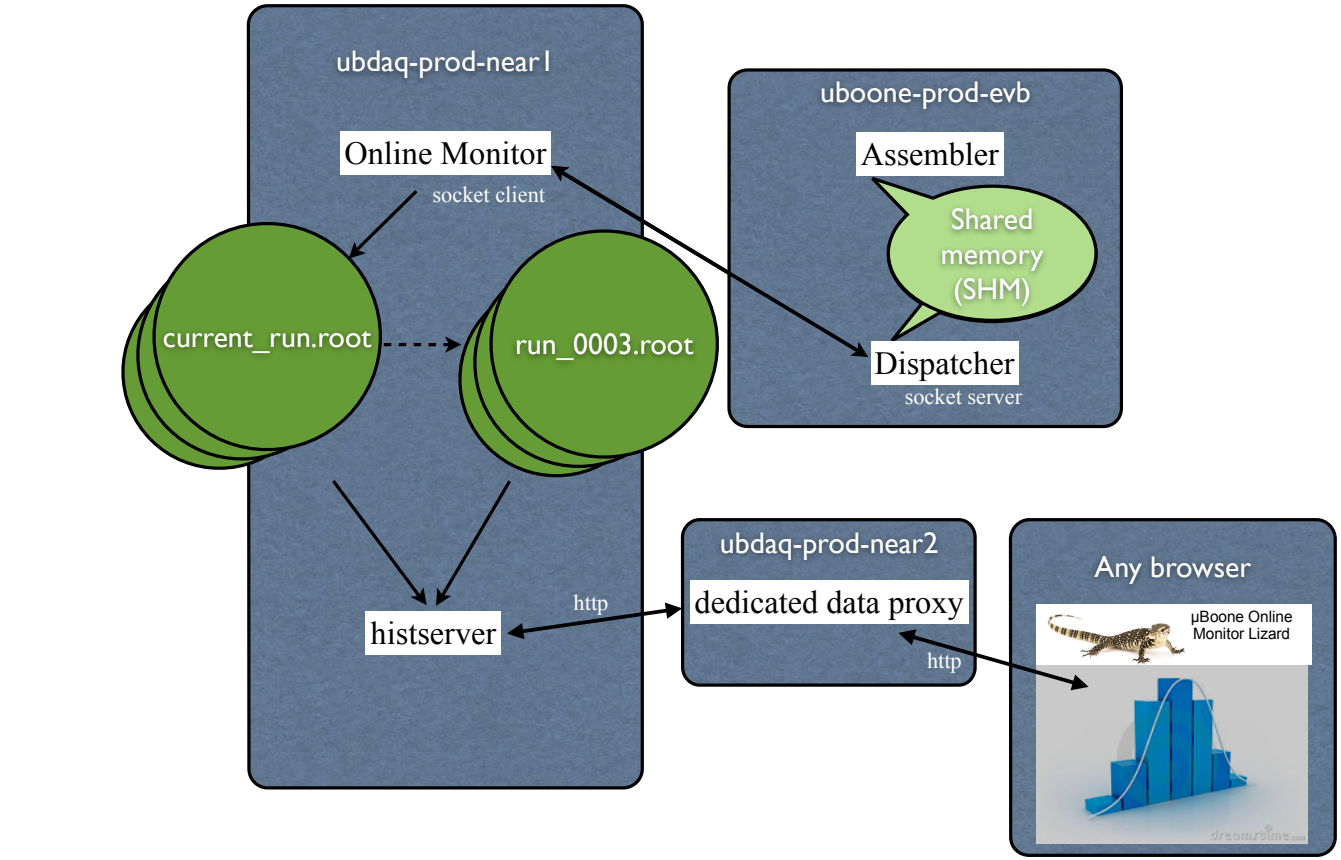
- Run configurations created by / stored in database
  - Tracks electronics hardware and software configurations
- DAQ control requests run config, duration, and goes
  - Automatically restarts runs
  - Automatic entries into Elog
  - Audible alarms if run restarts too frequently or abnormal error conditions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

Console DAQ

Charge Q2

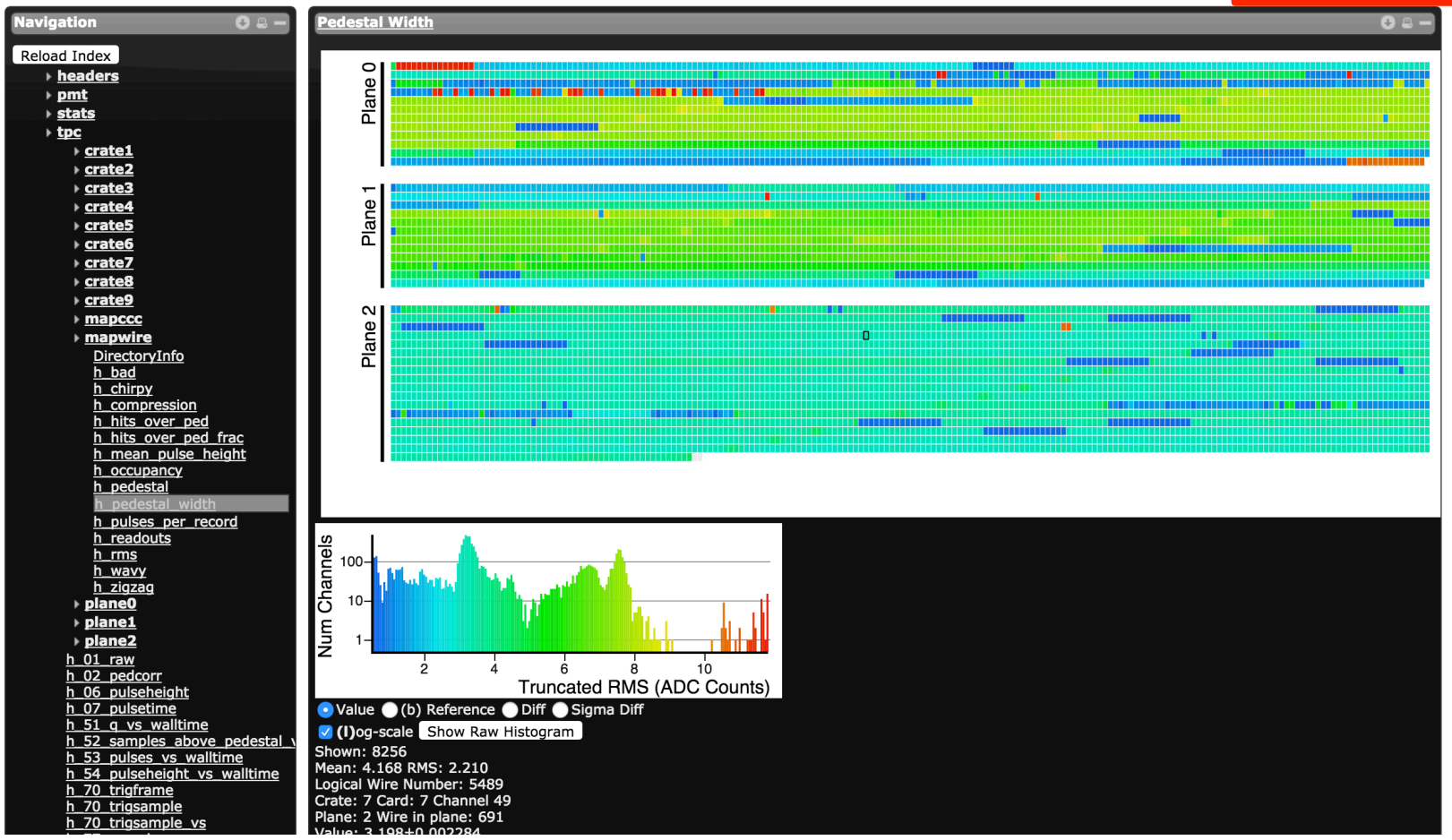


Online Monitoring: System



Online Monitor: Appearance

Charge Q2



Online Monitor Performance

Charge Q2

- Automatically stared 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

Documentation

- 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