Report from the DAQ team

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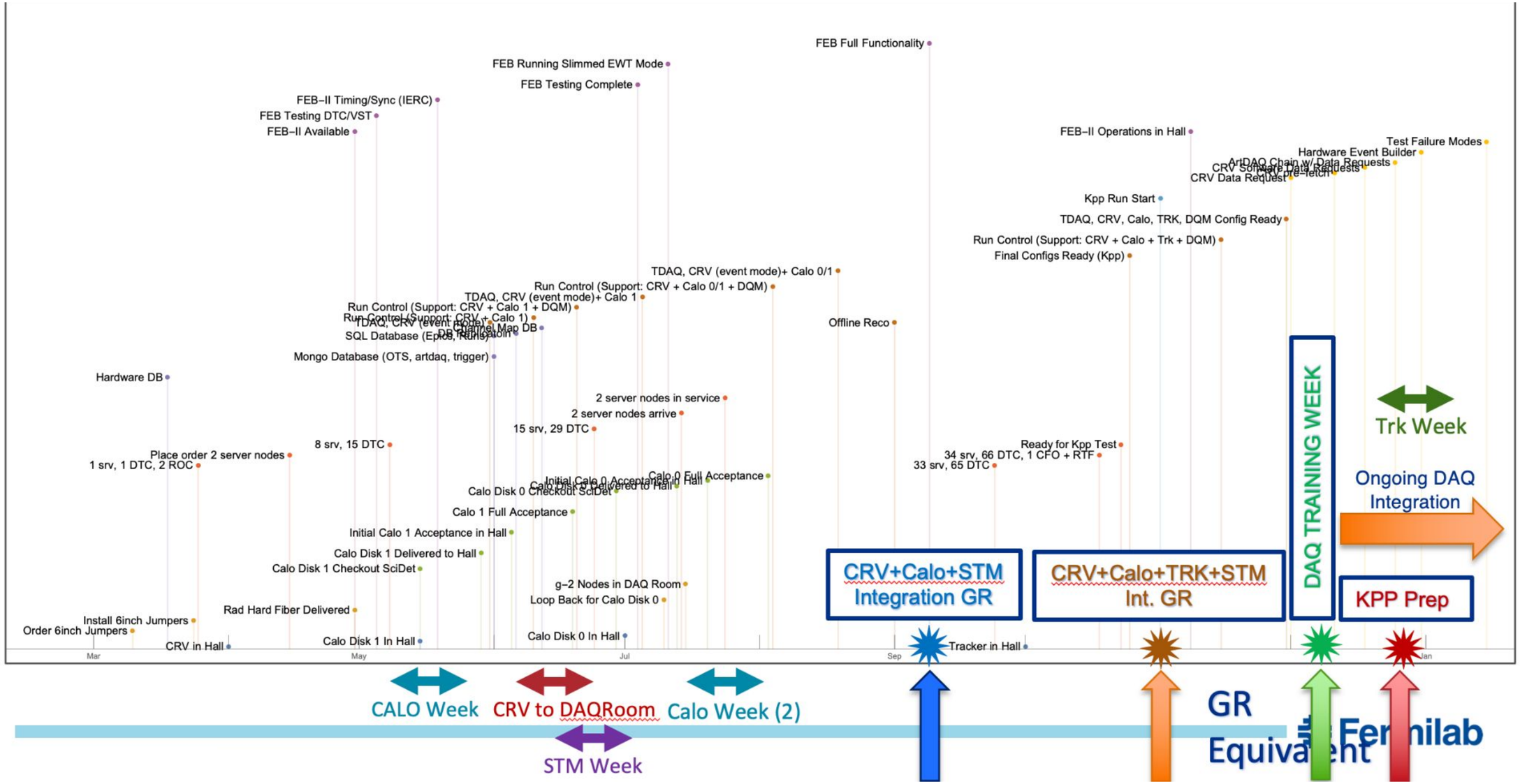
Outline

- Milestones achieved
- Calorimeter DAQ status
- Tracker DAQ status
- CRV DAQ status
- STM DAQ status
- DQM
- DCS
- Run conditions Db
- Trigger
- Sync tests
- DAQ room hardware installation
- Hardware event building

Milestones achieved

- Run individual board/chain tests of Calo, CRV, Tracker, STM via artdaq/ots
- Calo, CRV and Tracker have also done larger scale readout tests (i.e. multi-chain)
- Demonstrate common clock operation via CFO/RTF
  - Verify w/ pulse injection
- Run [limited] multi-subsystem configurations w/ test stand DTCs
- Configure DAQ software components via OTS interfaces
- Run simple software event building
- Run simple triggering (i.e. passthrough/zero bias)
- Record & visualize metrics via OTS and Grafana
- Write data to disk

DAQ roadmap


FEB Full Functionality
FEB Running Slimmed EWT Mode
FEB Testing Complete
FEB–II Timing/Sync (IERC)
FEB Testing DTC/VST
FEB–II Available
FEB–II Operations in Hall
Test Failure Modes
Hardware Event Builder
ArtDAQ Chain w/ Data Requests
CRV Data Request
Kpp Run Start
TDAQ, CRV, Calo, TRK, DQM Config Ready
Run Control (Support: CRV + Calo + Trk + DQM)
Final Configs Ready (Kpp)
TDAQ, CRV (event mode)+ Calo 0/1
Run Control (Support: CRV + Calo 0/1 + DQM)
TDAQ, CRV (event mode)+ Calo 1
Run Control (Support: CRV + Calo 1 + DQM)
Run Control (Support: CRV + Calo 1)
Offline Reco
SQL Database (Epics, Runs)
Mongo Database (OTS, artdaq, trigger)
Hardware DB
2 server nodes in service
2 server nodes arrive
15 srv, 29 DTC
8 srv, 15 DTC
Ready for Kpp Test
34 srv, 66 DTC, 1 CFO + RTF
33 srv, 65 DTC
Place order 2 server nodes
1 srv, 1 DTC, 2 ROC
Calo 0 Full Acceptance
Calo Disk 0 Checkout SciDet
Calo 1 Full Acceptance
Initial Calo 1 Acceptance in Hall
Calo Disk 1 Delivered to Hall
Calo Disk 1 Checkout SciDet
g–2 Nodes in DAQ Room
Loop Back for Calo Disk 0
Rad Hard Fiber Delivered
Install 6inch Jumpers
Order 6inch Jumpers
CRV in Hall
Calo Disk 1 In Hall
Calo Disk 0 In Hall
Tracker in Hall
Mar
May
Jul
Sep
Jan
DAQ TRAINING WEEK
Trk Week
Ongoing DAQ Integration
KPP Prep
CRV+Calo+STM Integration GR
CRV+Calo+TRK+STM Int. GR
CALO Week
CRV to DAQRoom
Calo Week (2)
STM Week
GR Equivalent

June: control room/daqroom software

- Need to rationalize our DAQ cluster setup
  - *Centralize and consolidate setup scripts*
  - Automate multi-system setup
    - i.e. spin up the required OTS state machines in the correct order on the correct machines, ports etc...
    - Reproducible startup and tear down of system
  - Clean up the accumulated working areas
  - Fix the access channels (i.e. move to VNC based instances under AL9)
  - Layout the correct data areas, mounts etc...
- Deploy db instances w/ updated schema to DAQ env.
  - Test db config unpacking & offline integration
- There are inconsistencies between machines in the cluster
  - Need to reconcile and “fix” everything to be the same (workstation group will help)

Summer 2025

June-July

- Develop and deploy dashboards and "views" of subsystems
  - Need new OTS pages for these, expect to be iterative process
- Deploy and test full data transfer paths and file registrations (in progress)
  - Needs coordination with offline
- VST week for STM
- CRV in DAQRoom config/run/monitor

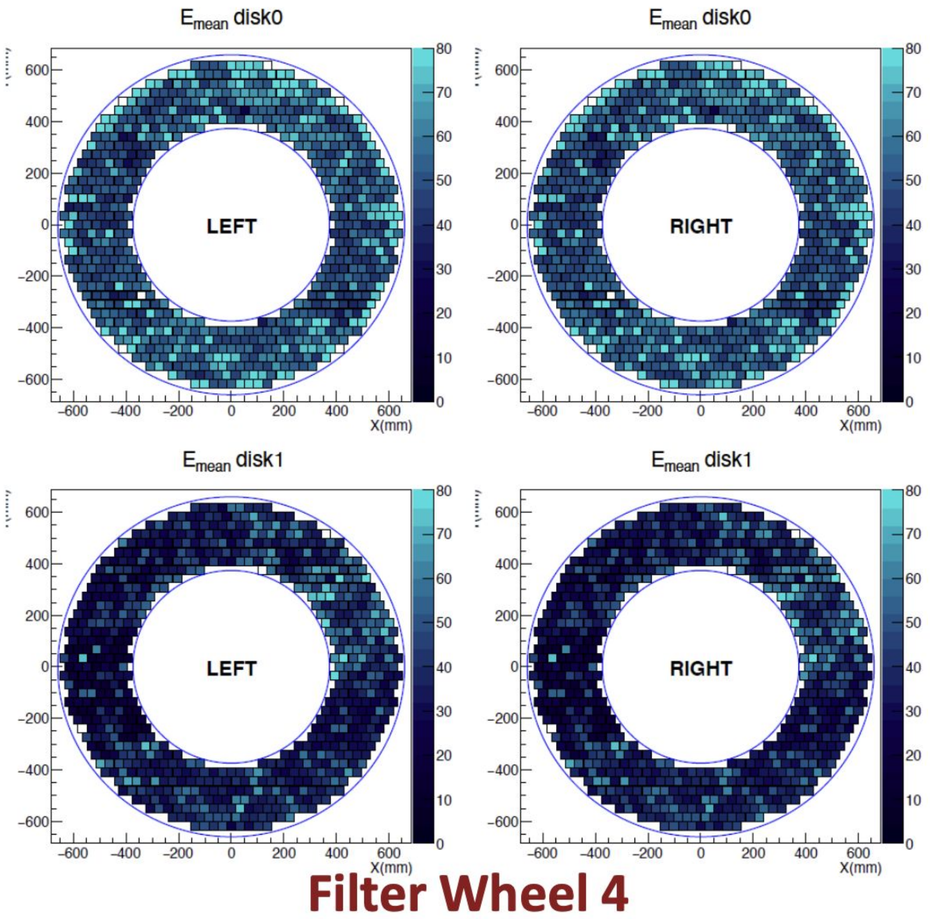
July-August

- Deploy and test calo disc configurations
  - Put configurations for ½ disc etc... into config DBs w/ DAQRoom specific parameters
  - Same for CRV module and STM
- Configure DAQRoom to match desired configs for Calo, CRV, STM commisioning
  - Requires DTC assignments and fibering to match physical positioning of detector elements (i.e. actual CRV install, STM location etc...)
  - Configure CFO and DTC chains to match longer term test configurations
  - Scale is O(30) DTCs
- Expect some reduced work scope in Aug.
  - Need configs in place to run system (w/ & w/o hardware)
  - Use this as "stability" testing time
  - Need DCS integration work to have alarms, monitoring, hw programming in place

Calorimeter commissioning

docdb-5008

- Full **commissioning of the 2 assembled disks completed** during last week of May (DAQ sprint) in SiDet!
  - A lot of thanks to Ryan, Eric, Giani, Paolo + calorimeter and DAQ experts that helped and made the test quite smooth from the DAQ point of view
- For each half-disk we set **the temperature of the chiller at 18C degrees** with **MBZ busy on** and proceeded in the following way:
  1. **Noise** run w/o light in the room, to compute the baseline and spot dead/hot channels
  2. Standard **laser runs** with filter wheel scan at 5kHz, about 10 kevents/run
  3. **Cosmic rays** runs with last version of the standard artdaq chain, about 2-3 hours
- **In summary**: we have taken a lot of good, **achieving the collection of about half million of good cosmic rays tracks** in few hours/disk -> **Good for calibration. Good for testing Offline reconstruction.**
- During last day of run the **mini-chiller** we used for the cooling **stopped to work**
  - Thanks to the help of Daniele we found out that the filter got dirty. In principle should be no corrosion and analysis for organic contamination are ongoing



Filter Wheel 4

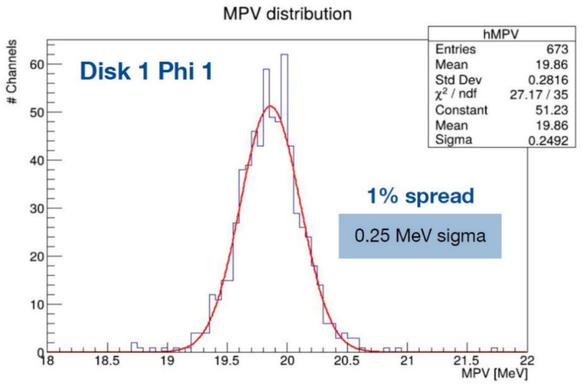
Calorimeter calibrations

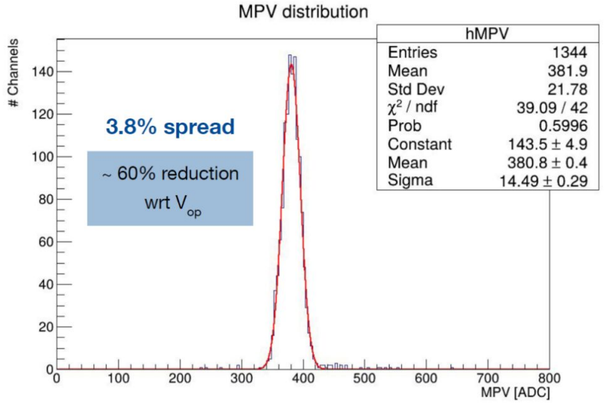
- Energy and time calibration procedures tested with real data
  - 1% spread in the MIP energy peak, dt<60 ps in the t0 offsets

➔ In order to be able to match the 6MIP dynamic range, data with rescaled HV were acquired

➔ The HV were rescaled using the MPV values extracted with Langauss fits from March 2025 data at Vop

➔ Data for half of each disk (Phi = 1)



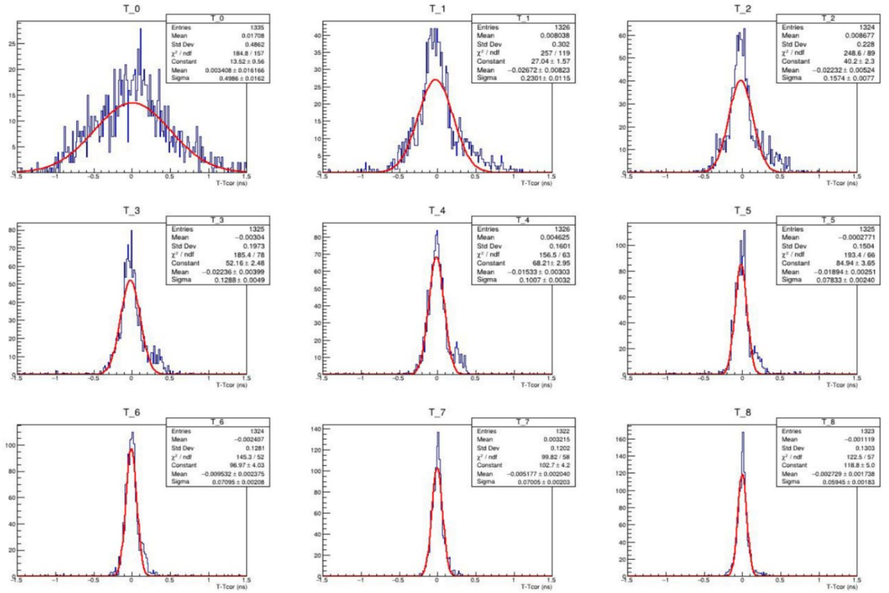


➔ To test the energy calibration procedure, the data sample for Disk 1 Phi 1 at Vop was split in half

➔ One half used to extract the MPV for each channel

➔ The other half was rescaled in MeV using the extracted MPVs

- The time offset calibration procedure has been tested over these new data and demonstrated to converge in a quite good way



Disk 0

The T0-alignment procedure is finally converging. The spread of the T0s improves from a starting 500 ps to around 60 ps after 9 iterations.

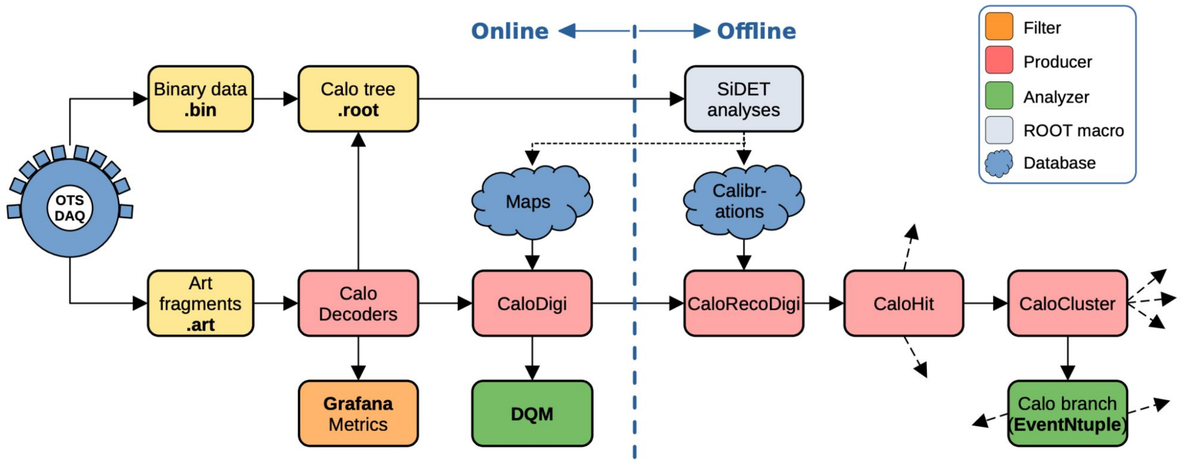
- Same procedure for disk-1 leads to worst results due to different fw version

[docdb-5008]

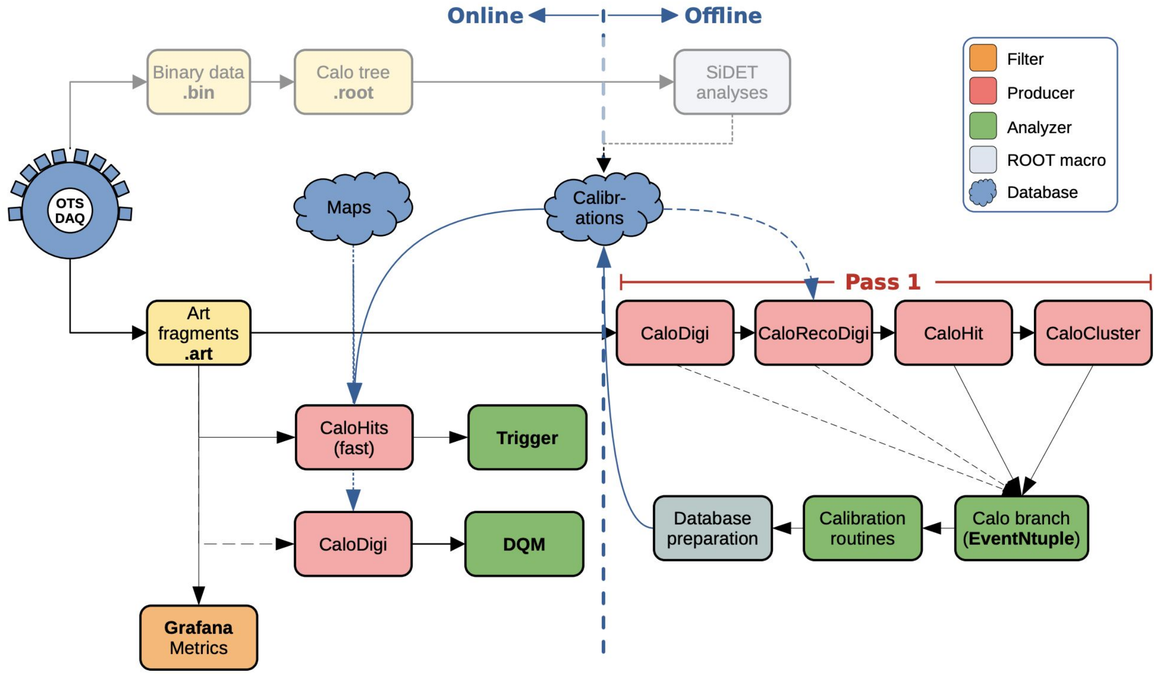
Calorimeter data processing

Commissioning @SiDet

(From March CM)



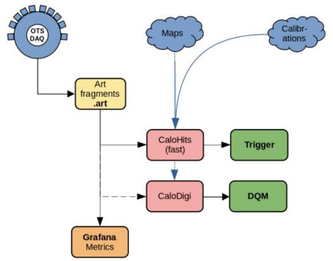
Transition to KPP



[docdb-53053]

Calorimeter data processing

Online processing



- Online data taking of art files is stable
- **Grafana** monitoring
  - Tested at SiDet with basic
  - Next: expand with metrics useful for shifters
- **DQM**
  - Started testing online DQM modules at SiDet
  - Mark's complete module installed, pending extensive testing
  - Next: test data rate capability with full disks – current dispatcher prescale 1/100
- **Trigger**
  - Raw-to-hit fast module prepared and tested offline
  - Next: test online rate capability for trigger purposes

New hit structure

```
struct Hit_Header_t {
  uint32_t hit_RESERVED_1    : 12; // Bit 84-95
  uint32_t hit_BOARD_ID      : 8;  // Bit 76-83
  uint32_t hit_DET_ID        : 3;  // Bit 73-75
  uint32_t hit_CH_NUMBER     : 5;  // Bit 68-72
  uint32_t hit_HITTIME       : 16; // Bit 52-67
  uint32_t hit_EWTAG         : 16; // Bit 36-51
  uint32_t hit_BASELINE      : 12; // Bit 24-35
  uint32_t hit_INDEX_OF_MAX  : 10; // Bit 14-23
  uint32_t hit_ERRORS        : 4;  // Bit 10-13
  uint32_t hit_NSAMPLES      : 10; // Bit 0-9
};
```

+

```
vector<uint32_t> hit_SAMPLES; //12-bit words
```

- New hit structure collects header info at the beginning and the waveform at the end
- Knowing NSAMPLES before the waveform will greatly improve fast decoders for trigger purposes
- 4-bit error flag to link underflow/overflow of each channel's FIFO
- Baseline and max_index words for fast reconstruction
- Reserved words for sanity checks
- To be deployed and fully tested

[docdb-53053]

Tracker status

Tracker data-taking categories

For foreseeable future, will have three categories of data-taking

- Stable cosmic rays (precise calibration, alignment, "physics")
- Charge injection (loose calibration)
- Unstable cosmic rays (HV trip isolation)

Setups: station $\rightarrow$ full tracker $\rightarrow$ tracker + station

Tracker DAQ — our working setup

Frontend

- Firmware is a large project, always evolving
- Each "digi" has a finite per-event buffer, which matters

1 $\times$ DAQ computer

- 2 $\times$ DTCs (exactly 12 links, for 12 panels)
- 1 of which emulates a CFO

Data is processed by `artdaq`*

- Instrumented with additional dispatching of e.g. data rates

`MIDAS` is the puppet master

- Run start/stop; both manual and logically-sequenced
- Configuration store for both hardware and software

docdb-53032

Tracker developments

Tracker DAQ — what we can do ii

Taken together: cannot run with 100% livetime

- One solution is sparse EW trains: N events followed by deadtime
- Another solution is online filtering, e.g. discard noise-only events

But: filtering itself saturates at ~ 3 kHz

- So to process high rates, need multiple parallel filter processes
- Last file of run is not closed, and we lose associated data

- A single Datalogger instance saturates at ~3 kHz of event-rate and it creates back-pressure above it
- **Need to improve communication with the core DAQ group**

Tracker DAQ — future

Looking toward the KPP, need software convergence for integrated running

That aside, there will be pain points in scaling

- Single-ROC timeouts should not induce latency in rest of system
- Already see changes in time sync. b/t 2 DTCs — so imagine with 36
- Configuration: cannot just "loop over" 20k channels

Functional considerations:

- Can run $\sim 100\%$ livetime using single panel
- May be good enough, or we may want data from rest of detector
- This would require higher data logger throughput

Additionally:

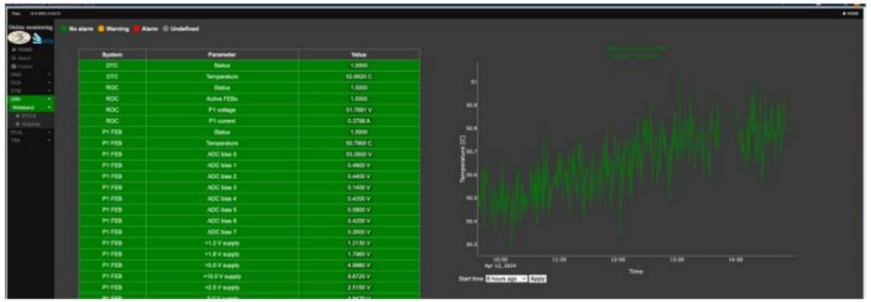
- Need reliable last-file-of-run, even with multiple EBs

docdb-53032

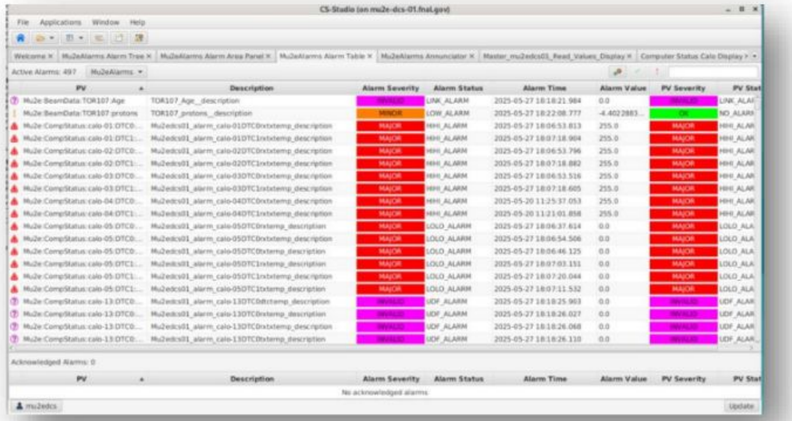
CRV status

docdb-53002

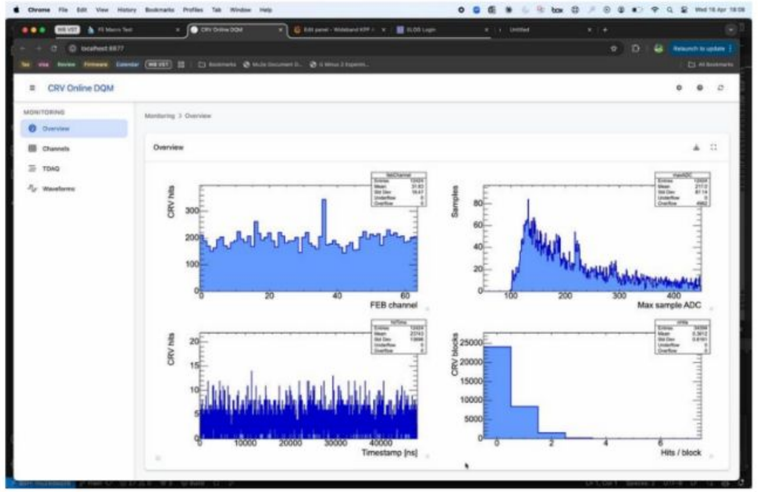
Calibration GUI DocDB-51868
(Ralf Ehrlich)



EPICS monitoring DocDB-48597
(Sam Grant, Simon Corrodi)



Alarms DocDB-52858 (Merrill Jenkins)



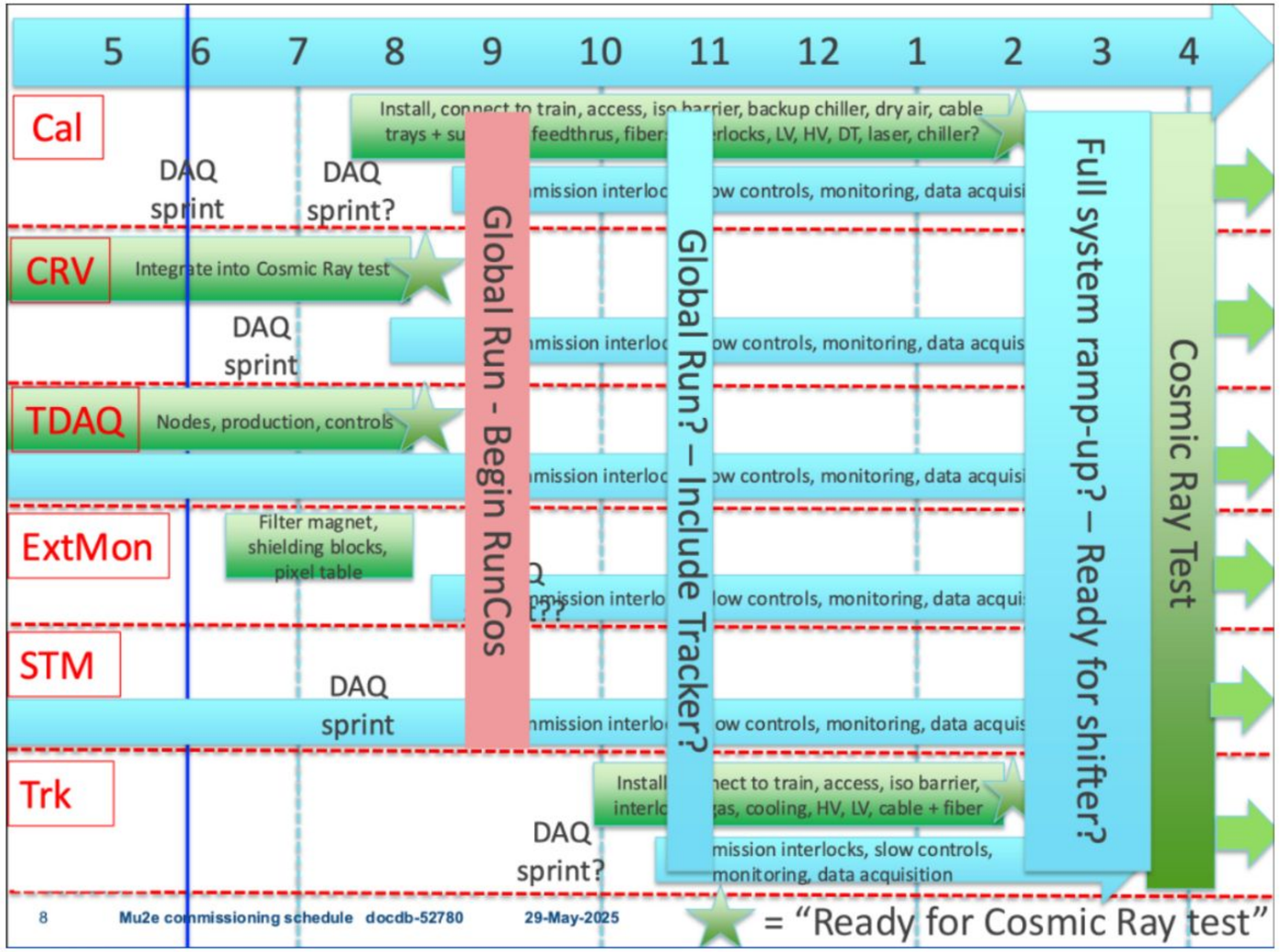
Online DQM DocDB-52465
(Sam Grant, Simon Corrodi)

CRV plans

docdb-53002

Phases

1. **Transport and install CRV modules** at Mu2e in mid-July 25
2. **Commission CRV for integration tests** ready for global runs and KPP by end of Aug 25
3. **Commission CRV for 24/7 operations** ready for Cosmic Ray Run by Apr 26



Schedule DocDB-52780 (Greg Rakness)

STM status

Firmware

STM firmware is in a very advanced state:

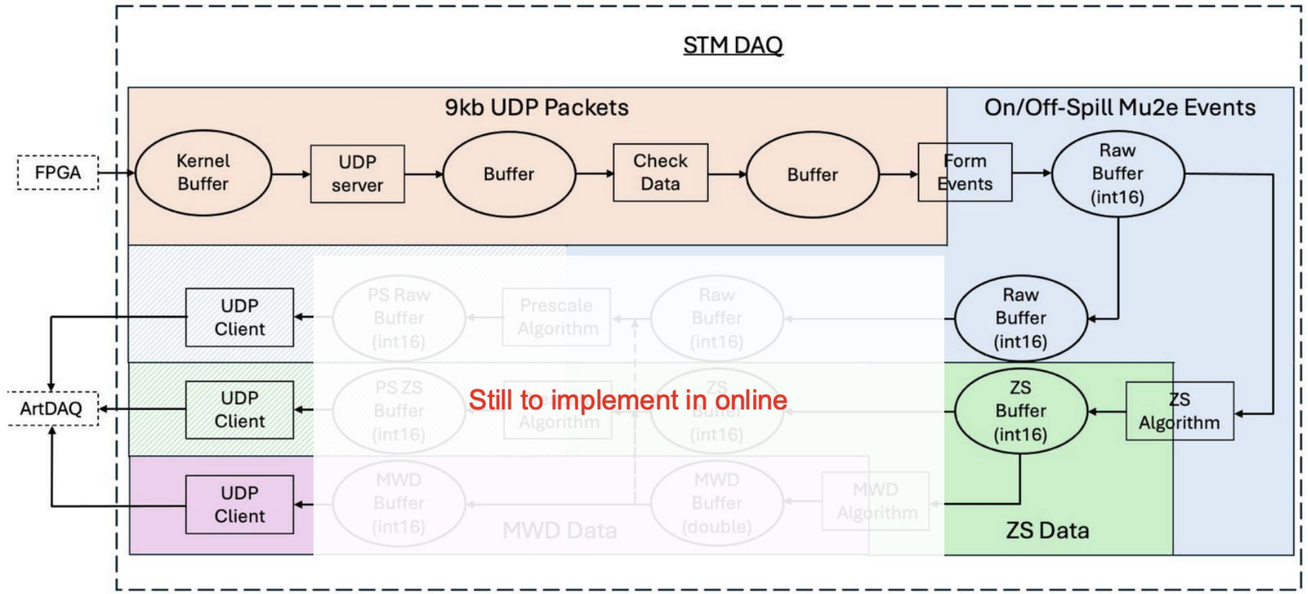
- DTC interface stable.
  - Implemented STM ROC checks for heartbeat/event marker errors.
- ADC records data continuously at ~ 300 Msamples/s.
  - For both channels.
  - Records everything: on-spill/off-spill and long spill gap.
  - Results in ~2 GB of data per MI cycle.
- FPGA logic → ADC data + CFO/DTC timing information = Mu2e events.
  - Each event comes with header data from:
    - Heartbeat + event marker info.
    - STM info (clocks, counters).
- Data sent from FGPA to servers over fiber via UDP.

Currently working on firmware updates to:

- Load firmware (bitfile) onto FPGA via fiber.
- Control/configure firmware via fiber.
- Requires implementation of linux based OS on FPGA.
- Almost complete!

→ Crucial to move the STM server(s) up into the server room.

Online software

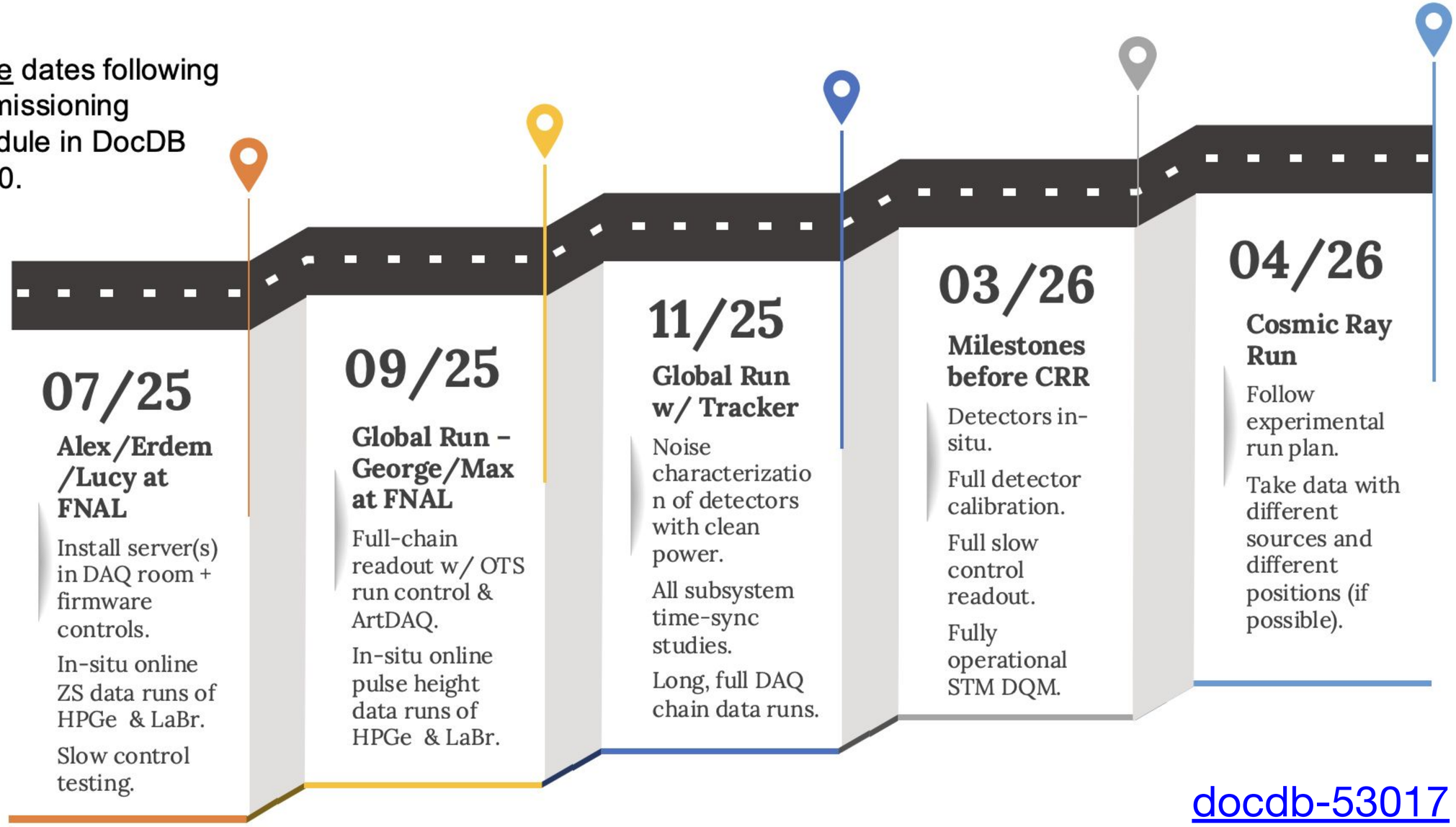


Data-handling, algorithms and their implementations are different for each detector:
HPGe pulse ~ 200 μs, LaBr pulse ~ 30 ns.

docdb-53017

STM plans

Loose dates following commissioning schedule in DocDB 52780.



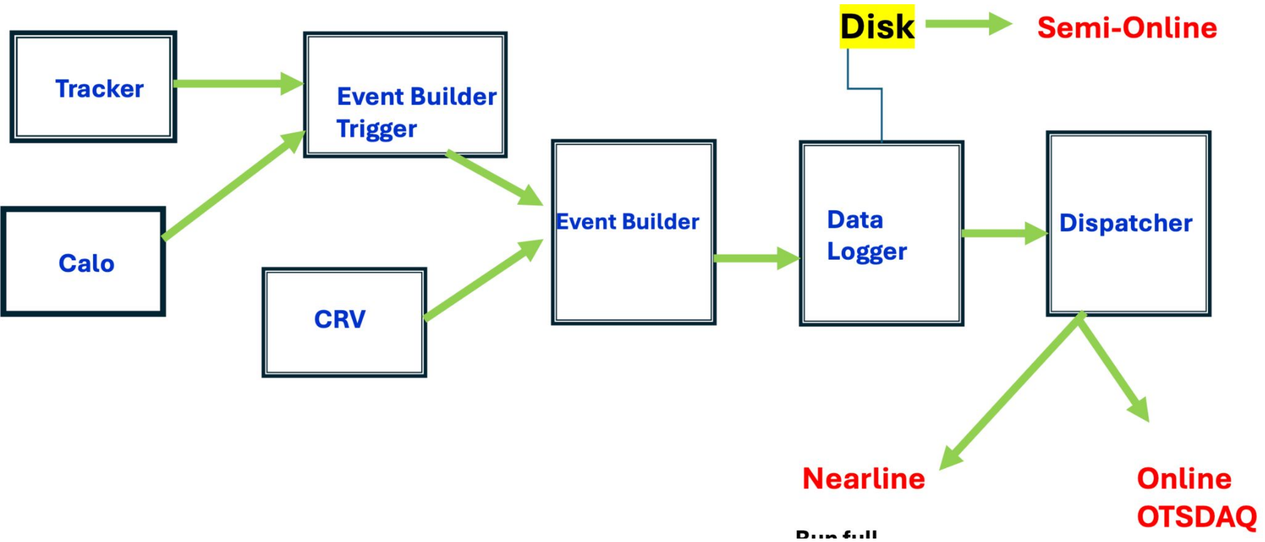
docdb-53017

DQM status

docdb-52999

Components of DQM in Mu2e

- **Metrics DQM**: it collects the various metrics we want to monitor as a time series related to the DAQ processing and trigger rates
- **Online DQM:** it refers to real time assessment of the performance of the different subsystems including the trigger
- **Nearline DQM:** it refers to running the full reconstruction (or a simplified version) on a fraction of data (5-10%) to further assess the performance of the detector at the hit, track and cluster levels, and get physics related plots
- **Offline DQM:** it refers to running the full reconstruction on the full data set to further assess the quality of the full dataset



Status of Online DQM (2)

Work Completed

- DQM module implemented in otsdaq-mu2e-dqm (personal branch)
- Created complete configuration and isolated contexts for DQM, Trigger, Calo, and Shift subsystems.
- Launched CFO Emulator with a fixed 200 µs event window (1001 markers) to simulate event flow.

Work in Progress

- Configure otsdaq FSM
- Test histogram streaming and real-time GUI display
- Validate performance with live or emulated data

Slow controls

- Mu2e DAQ reads data from experimental electronics and stores this information
  - Online/Offline monitoring.
  - Offline Analysis
- Slow controls uses **EPICS** to communicate to the detector electronics
  - Reads out information
  - Sends commands
  - **Phoebus** – Graphical User Interface to EPICS
  - **OTS DAQ** – Web-based GUI to display detector information and DAQ orchestration

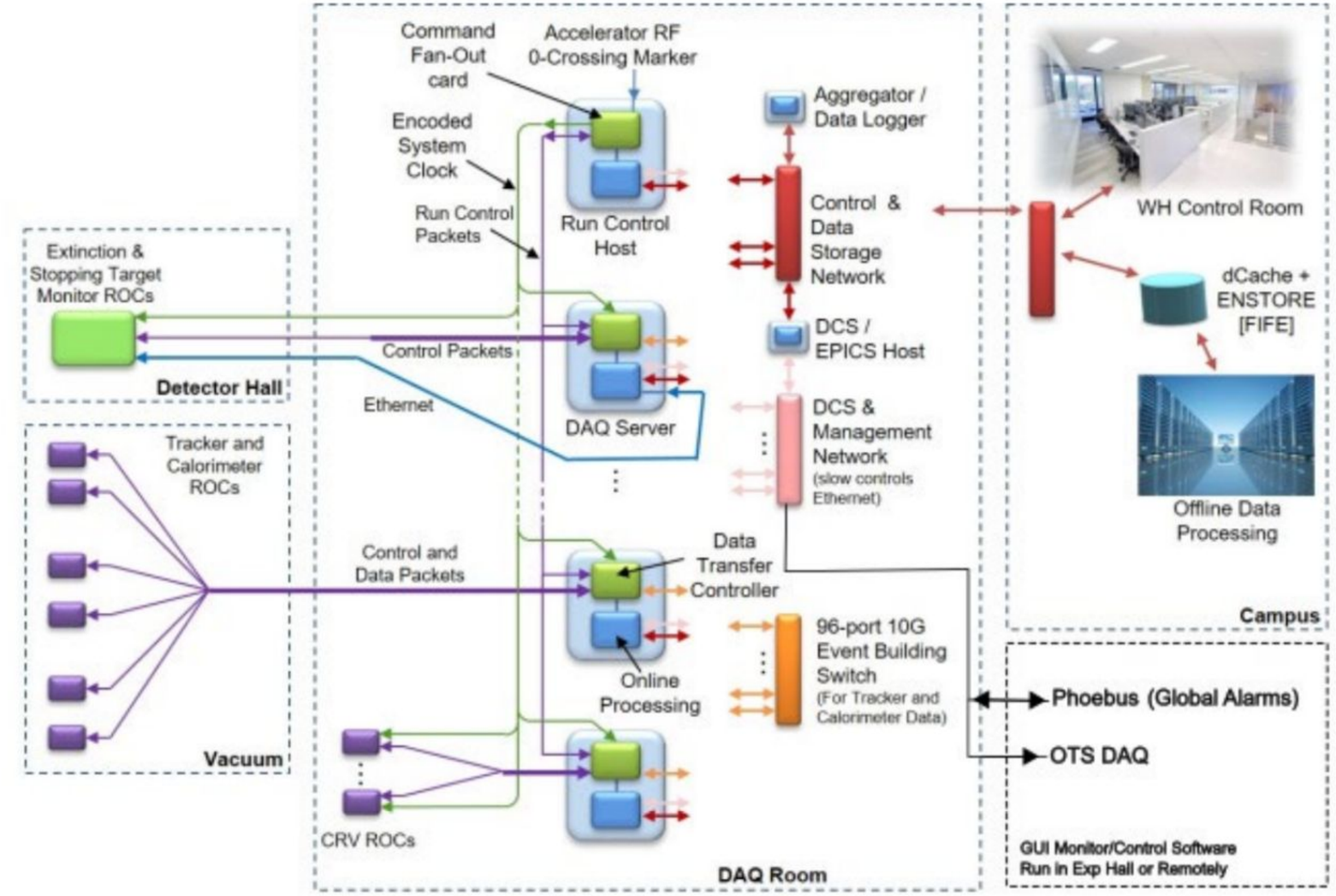
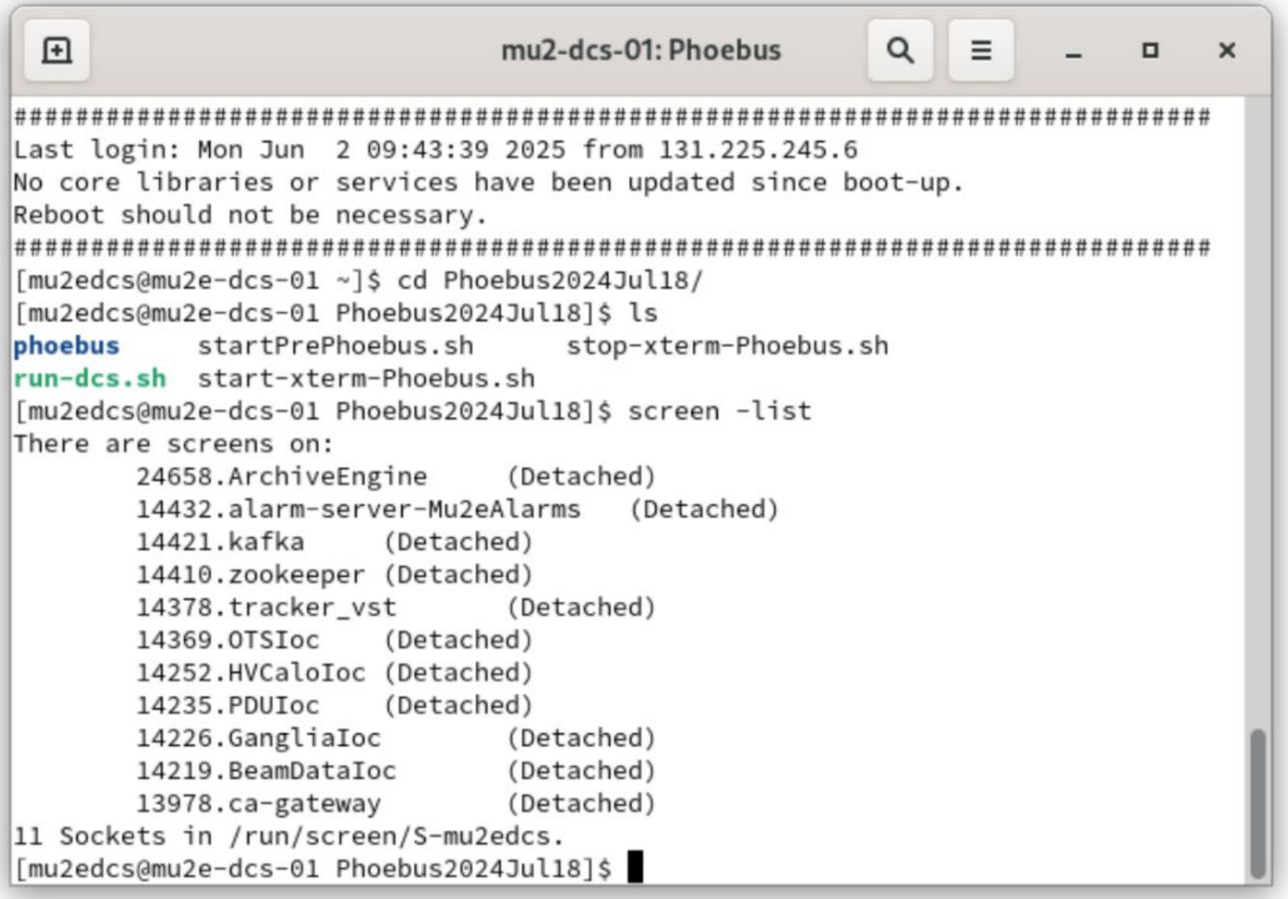


Image courtesy of Michael Ma

docdb-52858

DCS: phoebus global alarms

- Phoebus software stack installed, built and running
- Pre-Phoebus programs running in detached screens
- Phoebus may be started in an x-term that is called by a script
- Script could be in cron job upon system startup
- Phoebus monitoring know live channels mu2edcs01
  - (Crate voltages, temperatures, weather)
- **Will add live channels as they become available**
  - **(please let me know)**
- **There may be a character size limit for PV names in both EPICS and Phoebus**
- Archiver (running on a second legacy version of Phoebus) is running



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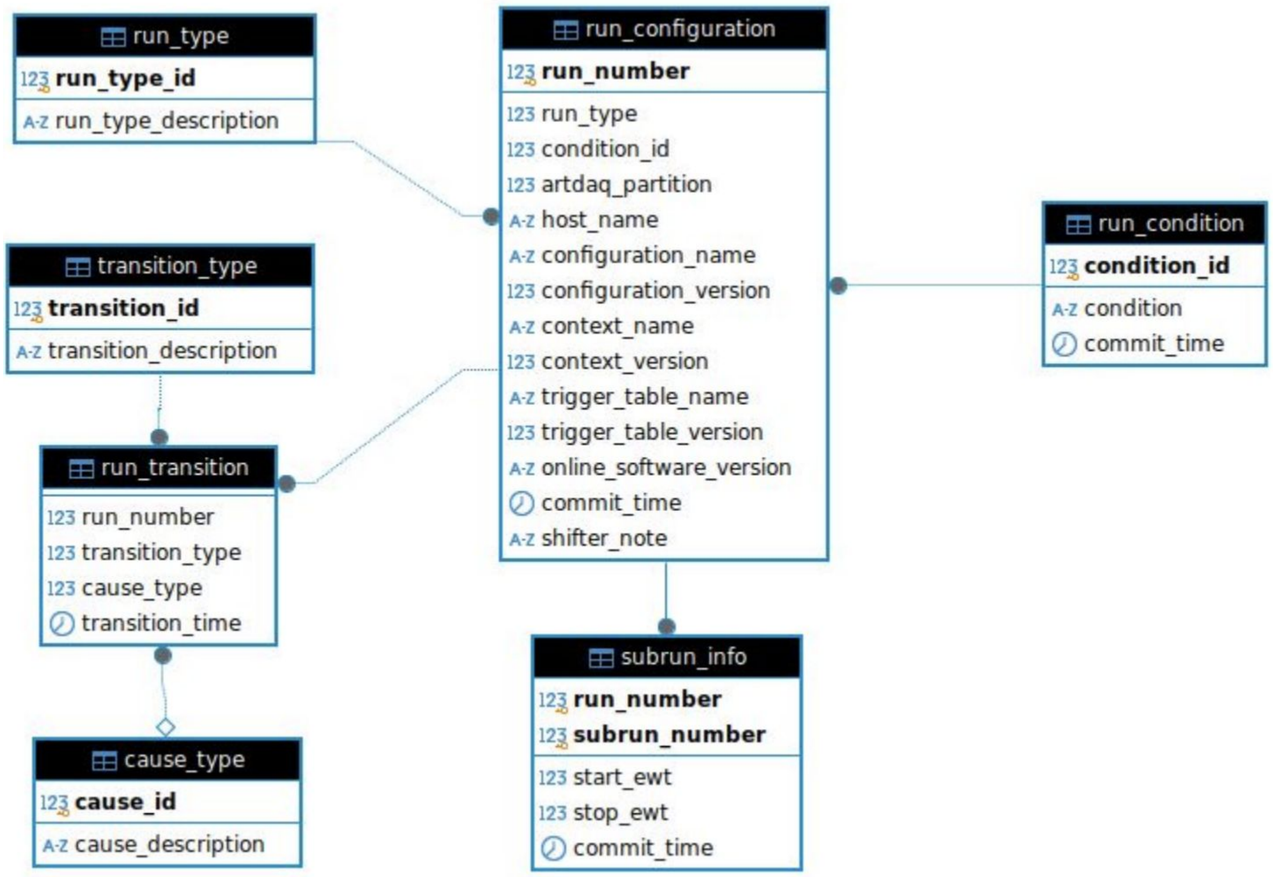
Run Db development

Db tables



Plans

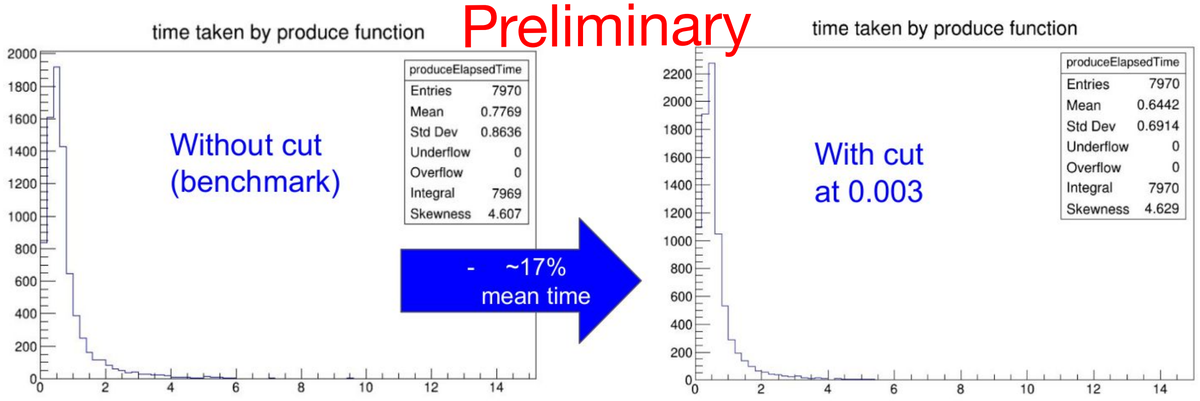
- Thinking more on the blob content of the otsdaq configuration now stored in a text blob:
  - We will use a format like JSON or fcl
    (MongoDB tables present a format closed between {})
- Using more definitions into cause_type table
- Thinking on more fields to use into subrun_info table
- Start to use the Daq Room database server

[docdb-53068]

Trigger status

Timing studies

- **Using a strict hit energy deposition cut on triplet seed hits improves the APR timing by ~15% with negligible loss in the signal efficiency**
- This is due to many potential signal triplets passing this strict threshold, while significantly reducing proton hits in this stage



Documentation

- **We have added note that summarizes the trigger estimates for the primary physics trigger paths: docdb 52246**
  - We will update this note version as the trigger progresses, adding triggers for alternate physics topologies and improving the trigger reconstruction
  - This fixed docdb number allows people to quickly check the expected trigger performance

docdb-53086

Trigger plans

- **We have a group of undergraduate students from Yale working with us this summer on Mu2e**
  - Hope A., Andrea B., Benny G., Powell H., Nikita M., and Iffat Z.
- They are working on several projects related to the trigger:
  - Improving the APR helix reconstruction timing tails
  - Improve two track reconstruction (photon conversions, antiproton annihilations)
  - Improve APR IPA reconstruction
  - Make CPR more agnostic to particle trajectory and mass
  - Online luminosity reconstruction, output stream characterization, and DQM
  - Add flattened PBI trigger
  - Add Online-Offline reco object matching from trigger matching

docdb-53086

Sync tests

- To study this loopback timing we need a system with at least two ROCs and a coincident signal to identify in each ROC
- The Tracker team set up two pulse injection stands for us to use in this study
  - **Thank you Pasha and Vadim for setting this up**
- This test stand injects the RTF pulse at 10 kHz into two separate ROCs
- **This allows us to reconstruct the hit time in each ROC and measure the timing difference between the two ROCs**
- With **Monica's** help we've added new OTS FE macro tests to set up the ROCs for this test
- We've updated our OTS setup for this configuration using the V5 TDAQ release
- We've managed to acquire some data in art format, where **Ed** has helped us produce initial ntuples of the data
- **Pasha** has also helped us understand the Offline digi decoding

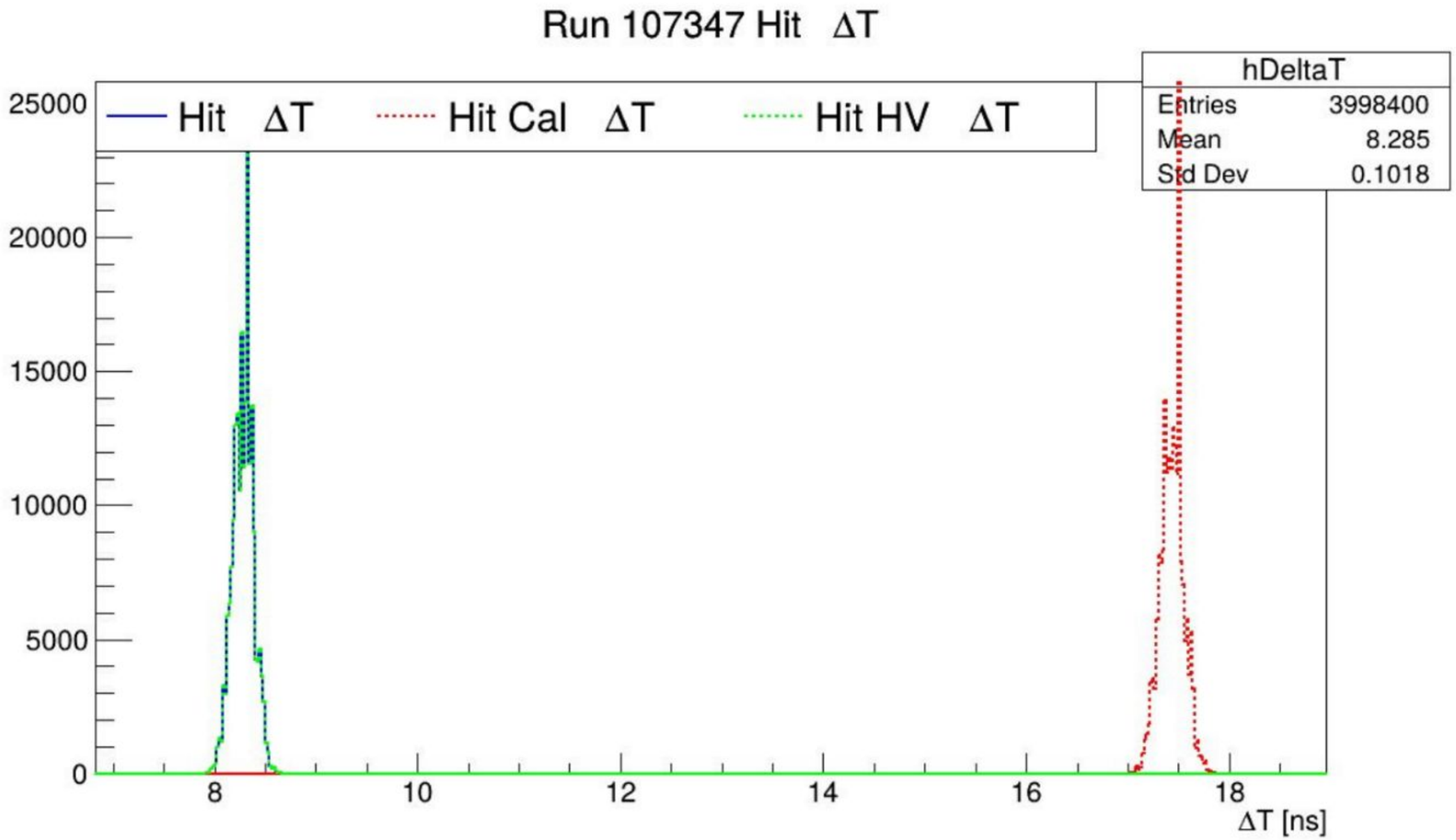
docdb-53089

Sync tests

docdb-53089

- The timing difference after many resets/reprograms/etc.
- **Unclear why the loopback (2.5 ns) and the Cal delta T (0.5 ns) shifted but HV delta T didn't**

ROC	Loopback (ns)
1	1253.30
2	1253.28

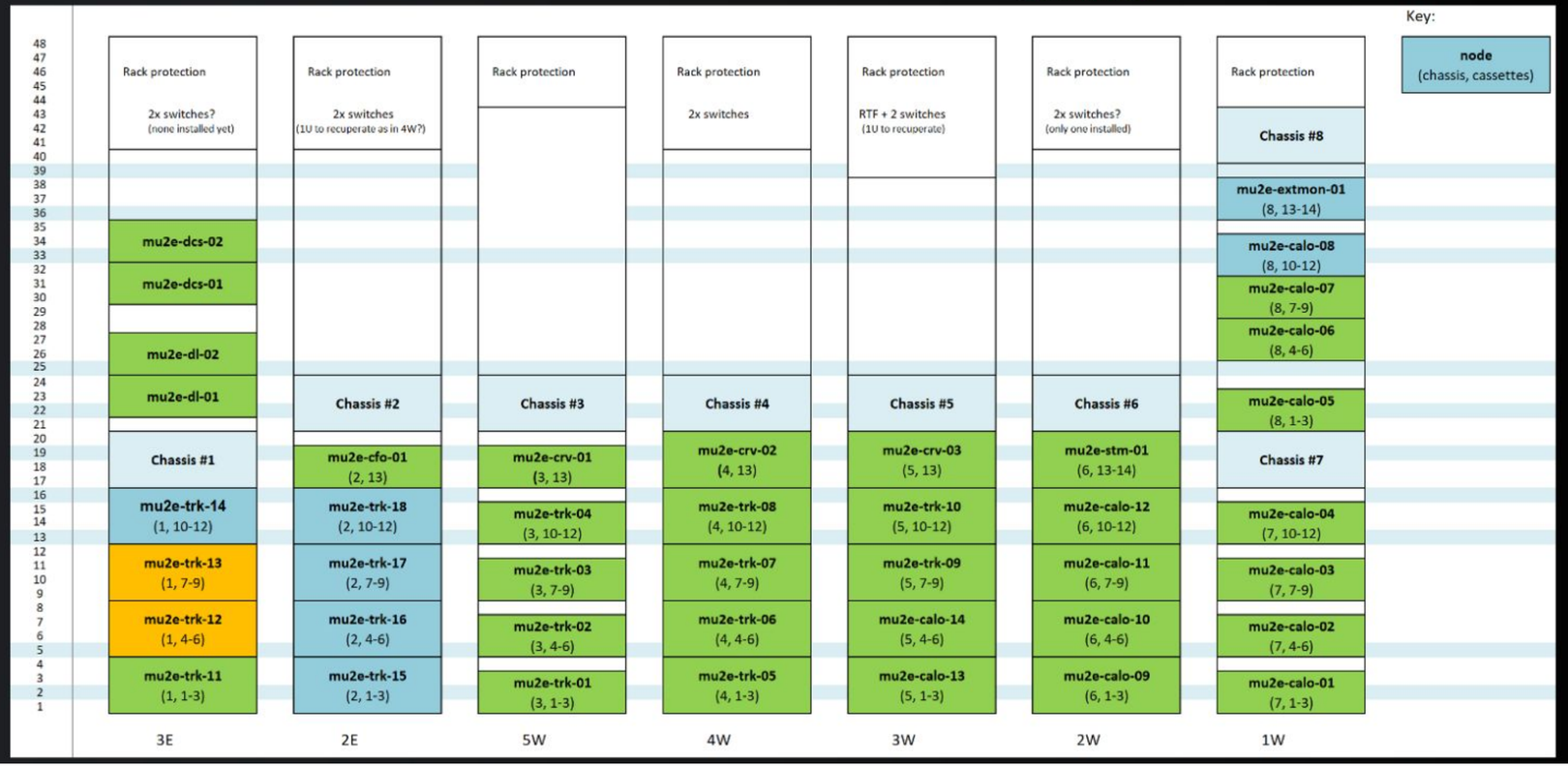


DAQ room hardware installation

- mu2e-trk-12 and mu2e-trk-13 were removed from rack 3E and transported to Lab 3 for Tracker testing.
- mu2e-calo-06 and mu2e-calo-07 were installed in rack 1W.
  - Missing hardware.
- mu2e-dl-02 and mu2e-dcs-02 were installed in rack 3E.
- Additional datalogger (dl) server to be delivered to mc-1.
- Awaiting approval by g-2 to move remaining 4u servers from mc-1 to mc-2.
  - Exact readiness date unknown.

docdb-53014

FIG. 1: DAQ room server racks. Graphic by Greg Rakness, found in mu2e-doc-37376.



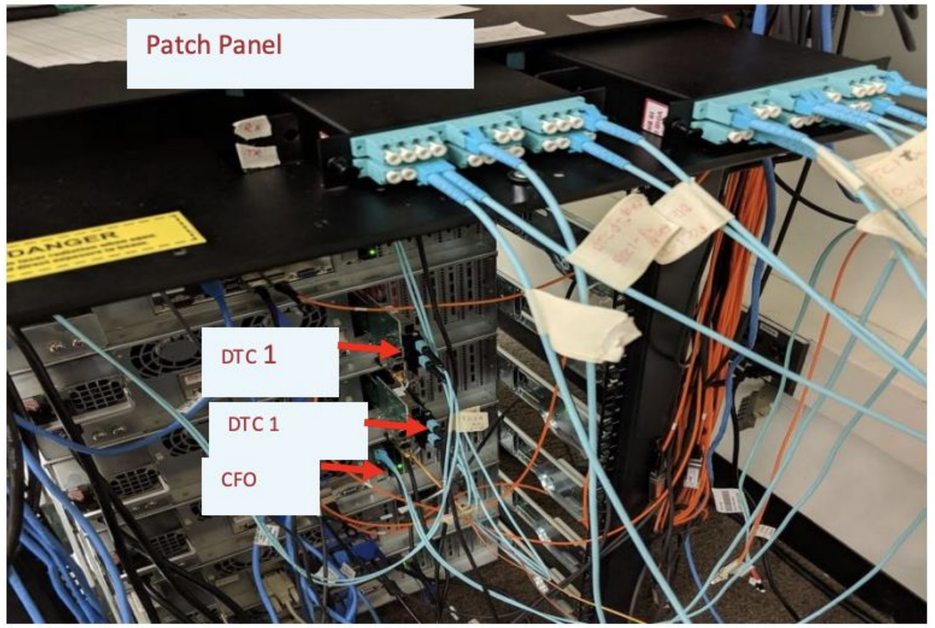
DAQ room hardware installation

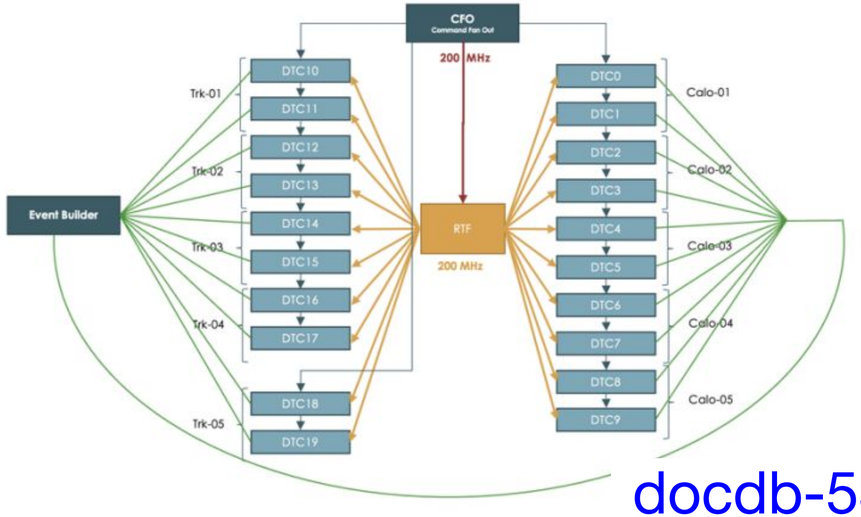
- 33/42 servers are installed in the DAQ room.
  - Waiting for approval from g-2 to move more servers from mc-1 to mc-2.
- 49/53 DTCs are installed in their servers.
- Final quantity is 70 DTCs.
  - 12 DTCs to be completely ready for calorimeter testing by late June.
- All DTCs to be completely ready by September.
  - Order more LC-LC fibers?
- Bit Error Rate testing of 66m MTP fibers.
- Resolve water leak issue in extinction monitor room.

docdb-53014

Hardware eventbuilder: platform

- In DAQ Room:
  - 10 DTC servers (calo-{01..05} and trk-{01..05}) for a total of 20 DTCs.
  - DTCs are arranged in 3 timing chains (10, 8, 2) from the CFO.
  - Each DTC is connected to the 10G 32-port FS Event Builder network switch.
  - An additional 16 g-2 nodes were installed, DTC install and cabling/fibering and Linux administration in progress.
  - Lost 2 nodes to Tracker, as of March-2025, were replaced with 2 new nodes in May-2025, and 6 nodes remaining at g-2 to be moved in Summer 2025.





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Hardware eventbuilder: progress

Tests operated in May

And stable all weekend!

```
                                                                0x9158 | 0x00000000 |
EVB Stats                                                              |
                                                                       | BRAM Stat - Received Packet Count:                DTC_mac #0   4 = 0x       0 0
                                                                       | BRAM Stat - Received Packet Count:                DTC_mac #0   5 = 0x 73df107 121499911
                                                                       | BRAM Stat - Last Received Sequence Tag:           DTC_mac #0   4 = 0x       0 0
                                                                       | BRAM Stat - Rx Missing Packet Count:              DTC_mac #0   4 = 0x       0 0
                                                                       | BRAM Stat - Rx Missing Packet Count:              DTC_mac #0   5 = 0x       0 0
                                                                       | BRAM Stat - Received Byte Count:                  DTC_mac #0   5 = 0x80000036 2147483702
                                                                       | BRAM Stat - Rx Last Packet Arrival [10gbe clocks]: DTC_mac #0   4 = 0x       0 0
                                                                       | BRAM Stat - Rx Last Packet Arrival [10gbe clocks]: DTC_mac #0   5 = 0xad 4f6f8 2908026616
                                                                       | BRAM Stat - Last Transmitted Sequence Tag:        DTC_mac #0   4 = 0x      2a 42
                                                                       | BRAM Stat - Last Transmitted Sequence Tag:        DTC_mac #0   5 = 0x       c 12
```

```
                                                                0x9158 | 0x00000000 |
EVB Stats                                                              |
                                                                       | BRAM Stat - Received Packet Count:                DTC_mac #0   4 = 0x 74bc52c 122406188
                                                                       | BRAM Stat - Received Packet Count:                DTC_mac #0   5 = 0x       0 0
                                                                       | BRAM Stat - Last Received Sequence Tag:           DTC_mac #0   4 = 0x      3c 60
                                                                       | BRAM Stat - Rx Missing Packet Count:              DTC_mac #0   4 = 0x       0 0
                                                                       | BRAM Stat - Rx Missing Packet Count:              DTC_mac #0   5 = 0x       0 0
                                                                       | BRAM Stat - Received Byte Count:                  DTC_mac #0   5 = 0x       0 0
                                                                       | BRAM Stat - Rx Last Packet Arrival [10gbe clocks]: DTC_mac #0   5 = 0xad59d928 2908346664
                                                                       | BRAM Stat - Rx Last Packet Arrival [10gbe clocks]: DTC_mac #0   5 = 0x       0 0
                                                                       | BRAM Stat - Last Transmitted Sequence Tag:        DTC_mac #0   4 = 0x      d3 211
                                                                       | BRAM Stat - Last Transmitted Sequence Tag:        DTC_mac #0   5 = 0x      ed 237
```

- No dropped packets identified after 3 days!
- Chipscope was back over the weekend and showed no errors but was down again on Monday.

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Hardware eventbuilder

- Conflicting priorities with TDAQ focus weeks and synchronization studies have slowed progress
- NEXT: Continue to increasing complexity of tests (so far at 2 DTCs) with actual switch and validate counting and throughput results based on packet size and rate
- Summer students to assist with testing and validating results
- Maintaining Estimated Deployment Date: November 2025

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Summary

- Solid development during the last month supported the commissioning of the calorimeter
- All the subsystems are using the artdaq suite to debug their firmwares and commissioning their detector
- The DQM group is focusing on consolidating the current tolls and deliver documentation
- We got to the point where we need to consolidate the structure of the DCS alamars and the Phoebus interface
  - Efforts ongoing to harmonize and coordinate the subsystems developments
- We are ready to consolidate also the content of the Run record and focus on its interface to the Offline
- The Trigger group keeps improving the timing performance of the online reconstruction and aims to consolidate the Lumi-stream structure with many students participating
- Synchronization tests using the Tracker ROCs + OTSDAQ + artdaq were valuable on **many** aspects - we hope to continue them in the future (maybe including the calo ROCs as well?)
- The DAQroom is getting more and more REAL, and we are gearing up to scale up our continuous data-rate/load tests
- The hardware EvB development continues and on track to match the delivery date of November ‘25