Status Report on the Calorimeter System

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on behalf of the Mu2e calorimeter group

Plenary session of the Mu2e Collaboration Meeting
LNF, 13 June 2025

Outline

- Commissioning at SiDet: Calo Run
- Online DB
- Calo DQM
- Data processing
- Transportation plans
- Integration, services and interlocks
- Cooling plant
- Source calibration system
- Laser calibration system

Commissioning @ SiDet: Calo Run

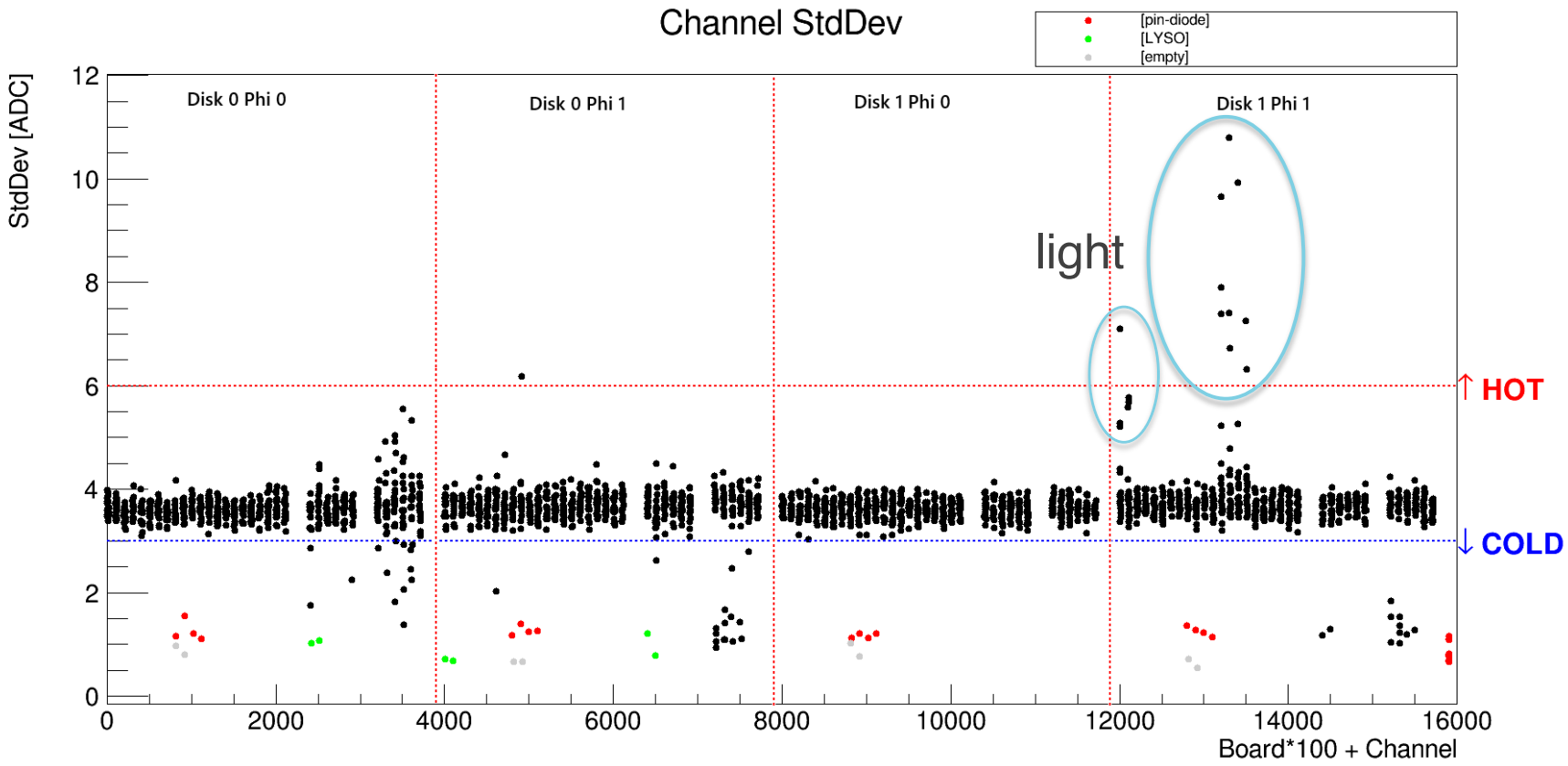
- 26-31 May 2025 – Continuous data taking for the entire calorimeter, half-disk at a time: 400-500 kevts for each half disk
- noise, laser and cosmic ray (CR) runs
- Different HV setting (Vop and equalized mip response)
- Smooth running and high quality data, allowing calo testing and calibration

Many thanks to the DAQ team for their support, which helped ensure a smooth test from the DAQ point of view

Goals:

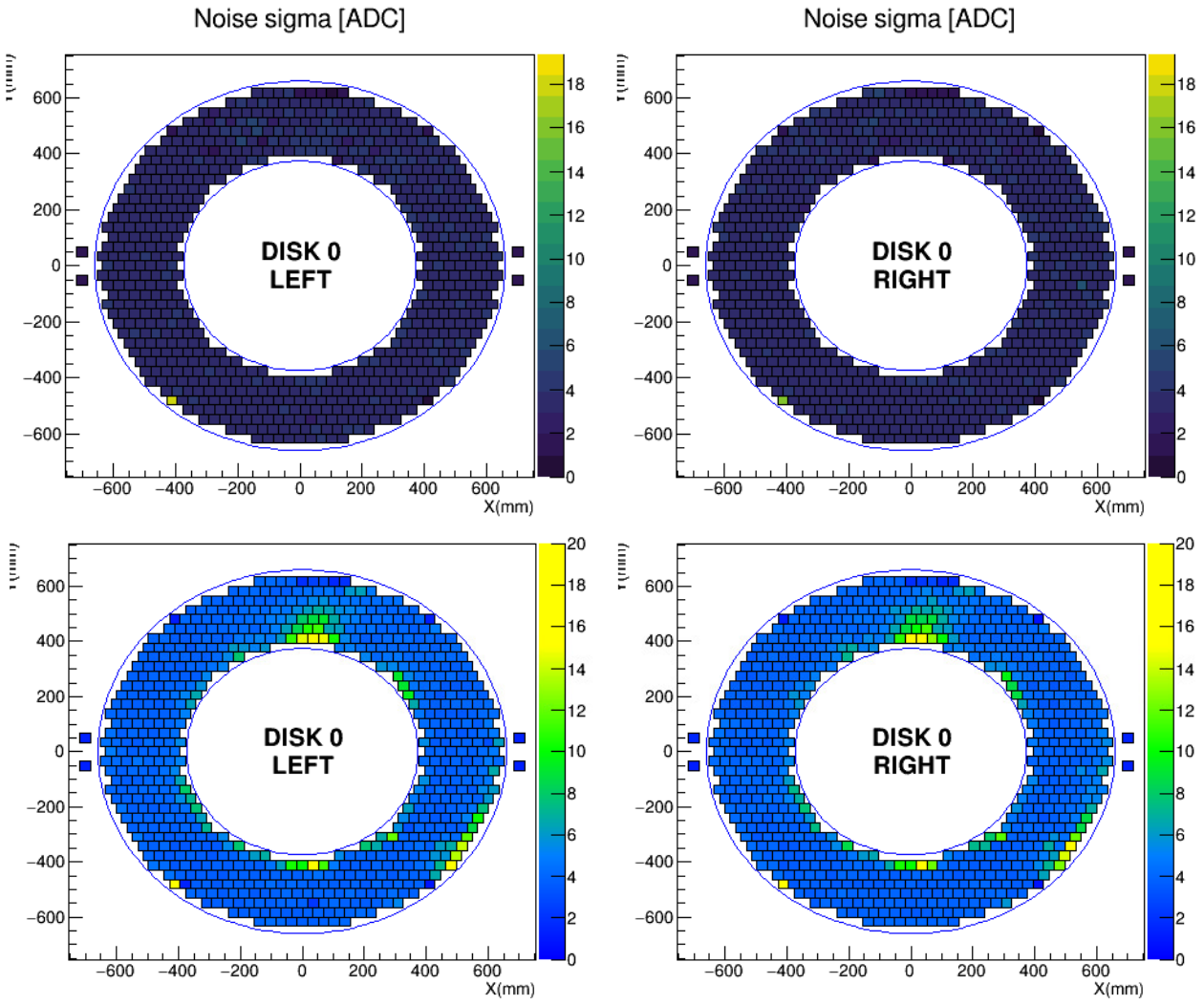
- Verify calo behaviour and sign it off for transportation to the Mu2e Hall
- Test DAQ system as in operations
- Test artdaq acquisition
- Test DQM

Commissioning @ SiDet: Noise Runs



- All channels alive, no major noise issues. Still some light infiltrations
- The few FEE units with the corrected SiPM voltage regulator shows a much lower standard deviation, as expected

Commissioning @ SiDet: Noise Runs



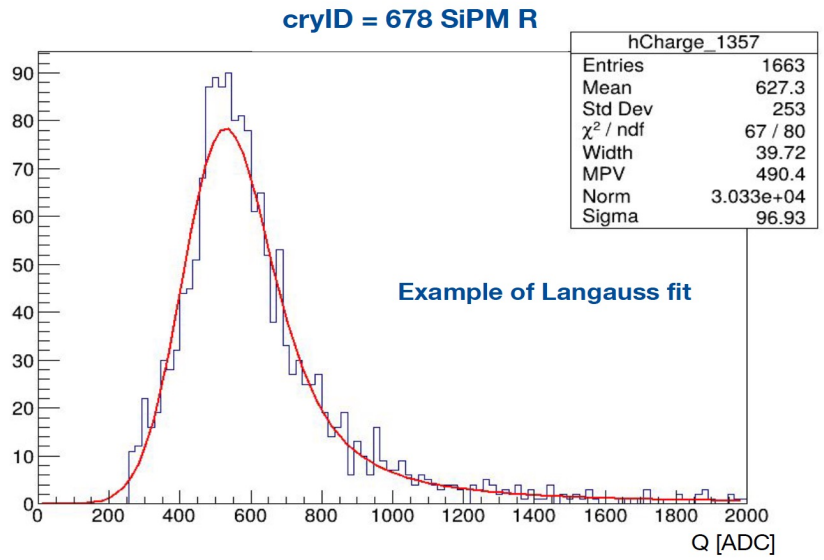
Light OFF

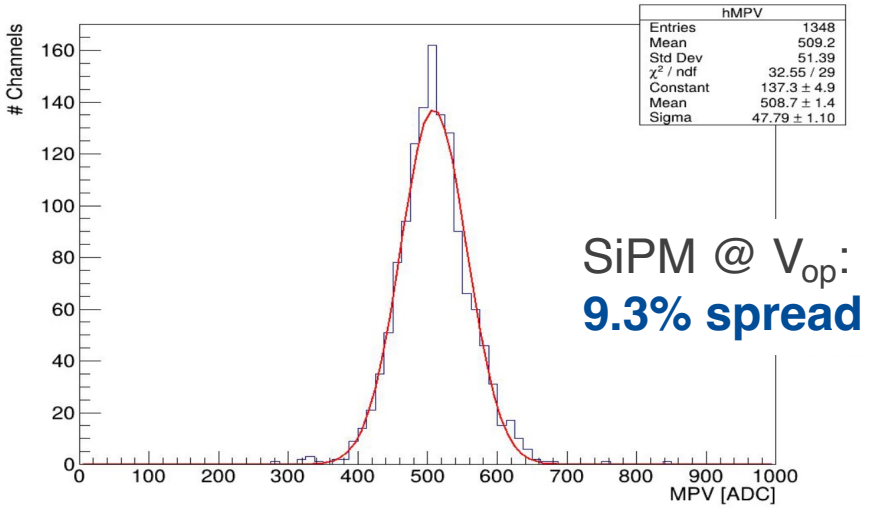
Light ON

Residual gaps between the calo structure and back/front planes, still causing light infiltration

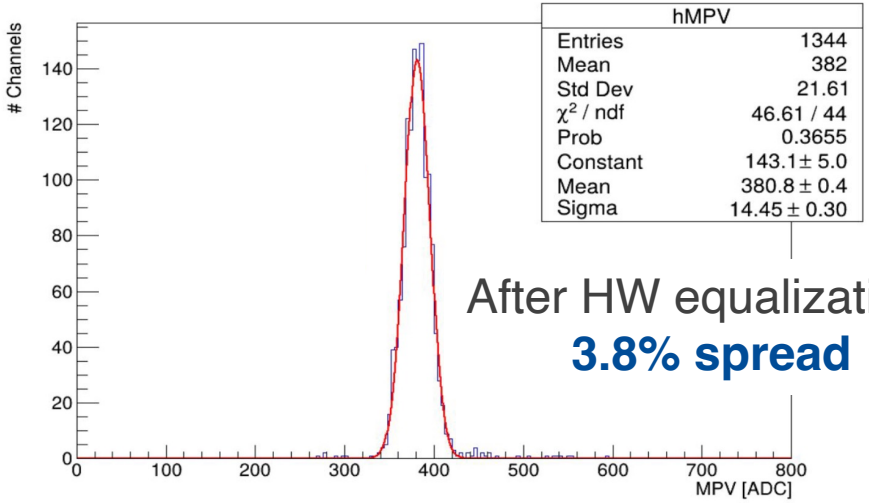
Commissioning @ SiDet: Energy Calibration

Selection of clean, straight CR tracks, more than 500 events /chan

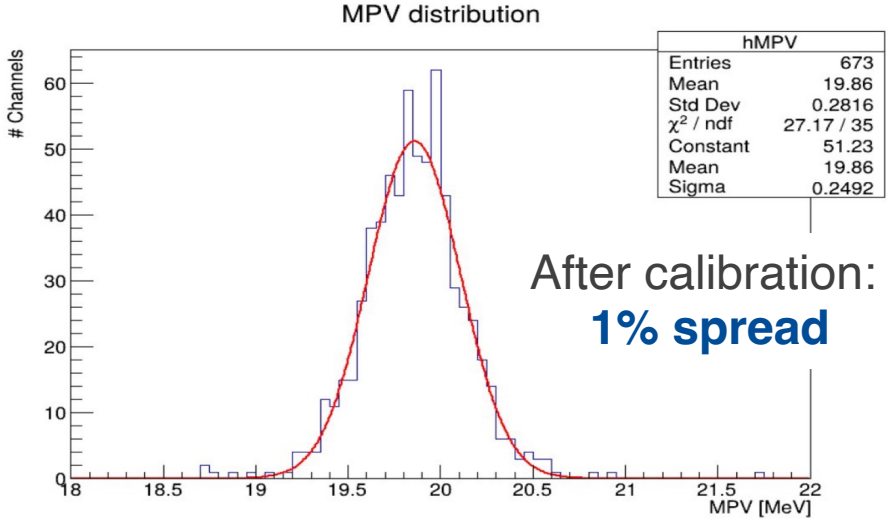




SiPM @ V_{op}:
9.3% spread



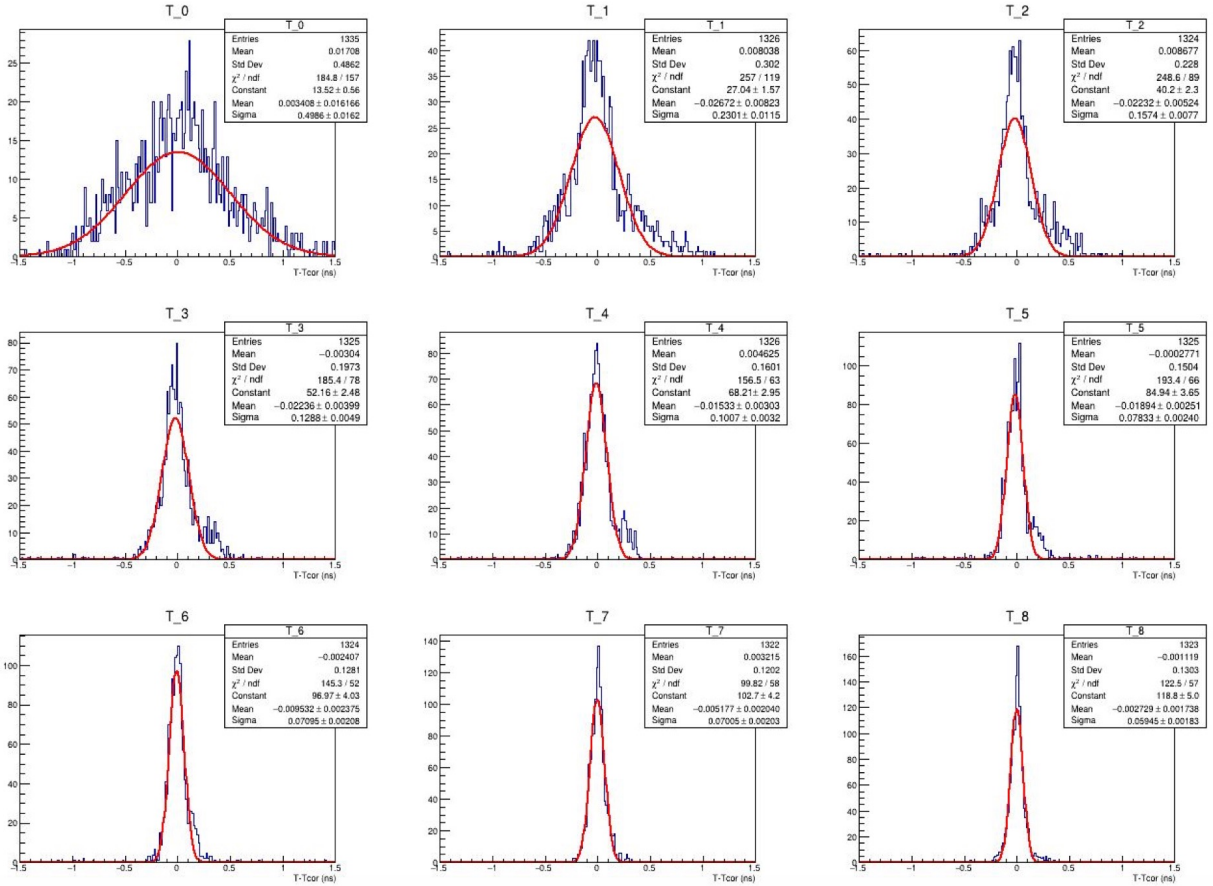
After HW equalization:
3.8% spread



After calibration:
1% spread

Commissioning @ SiDet: Time Calibration

- First step of Tcalib cannot be performed because of unexpected time offsets, not stable w.r.t. power cycles
- We are using a modified algo to temporary overcome this, using a single CR run



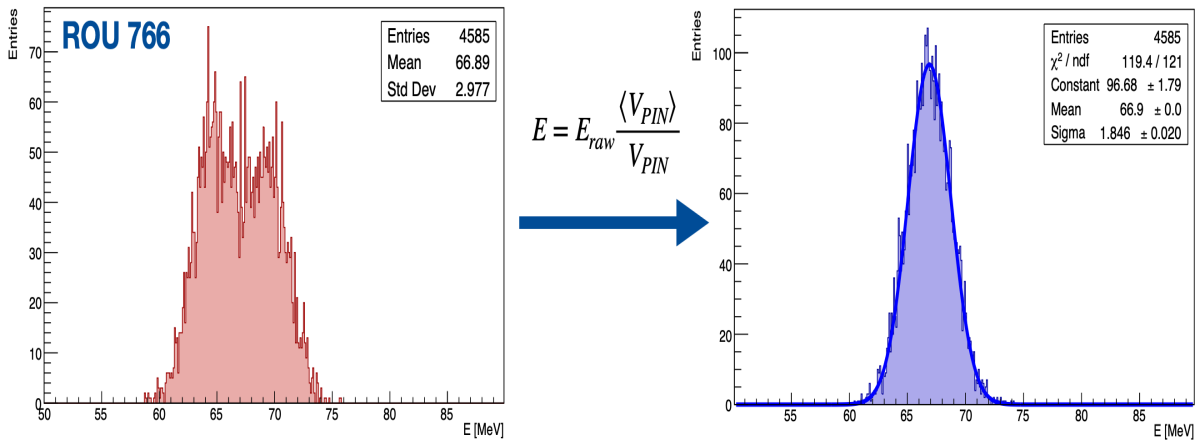
The time alignment is finally converging:

- For Disk 0, the spread of the T0s improves from a starting point of 500 ps to **60 ps** after 9 iterations
- Same procedure for Disk 1 leads to a larger spread (98 ps) due to a previous FW version

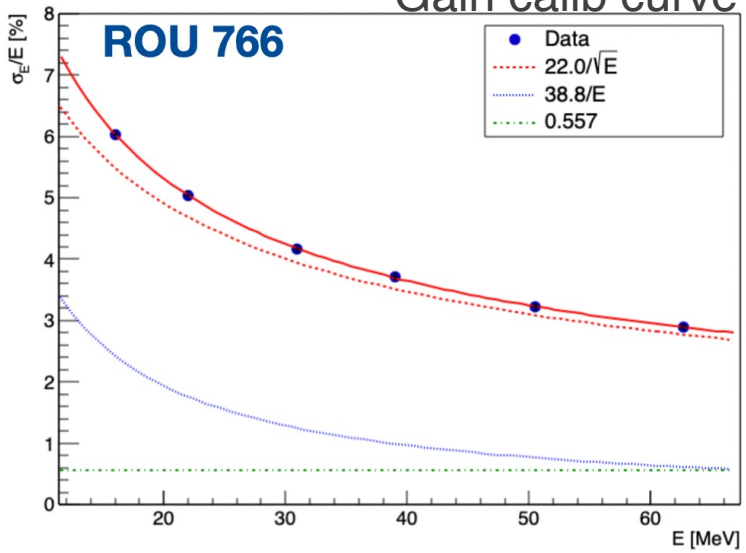
Commissioning @ SiDet: Laser Runs

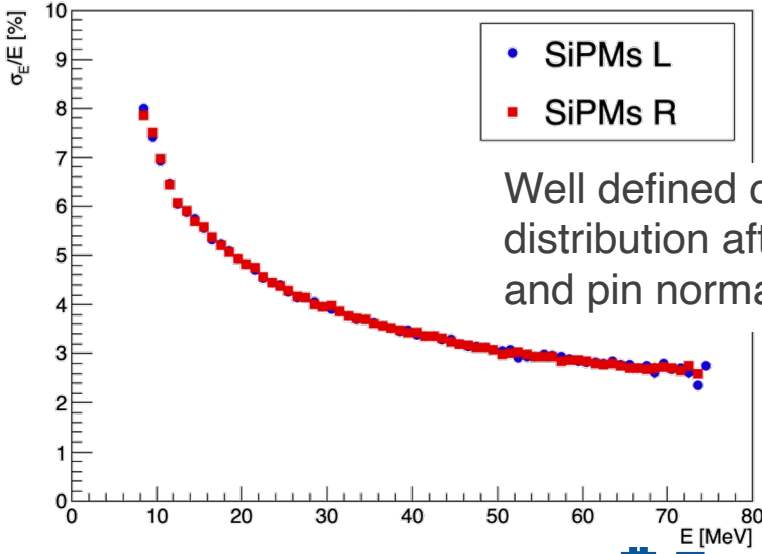
Analysis improvements:

- Channel-by-channel ADC/MeV conversion from CR events
- pin-diode normalization: laser fluctuations O(5%)



Gain calib curve

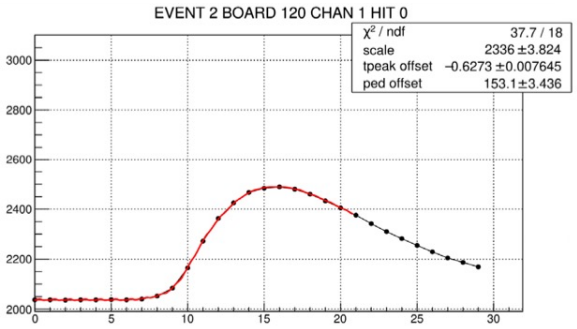


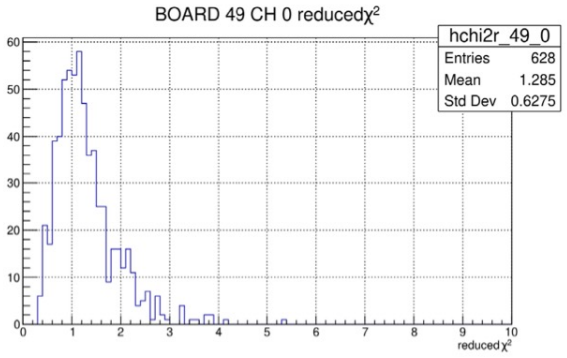


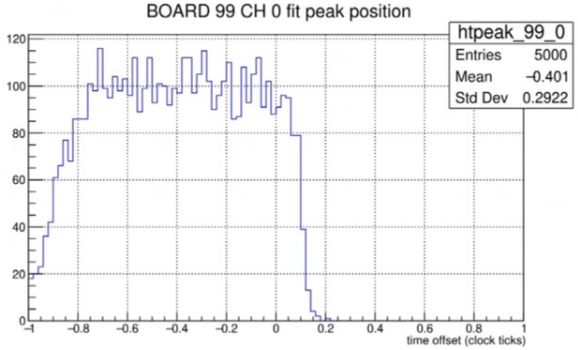
Well defined overall distribution after E_{calib} and pin normalization

Commissioning @ SiDet: template fit

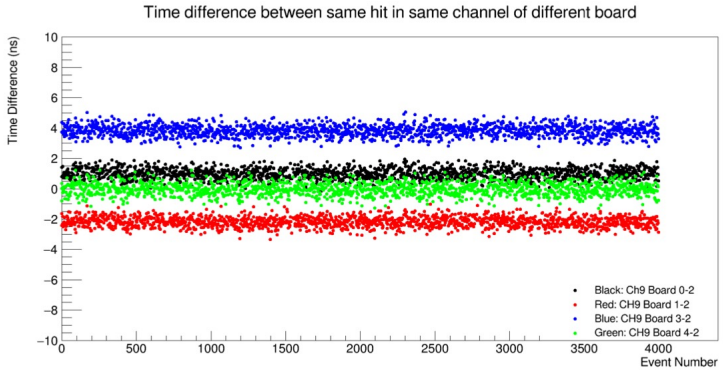
Templates for WF fit are built using a laser reference run for each half disk

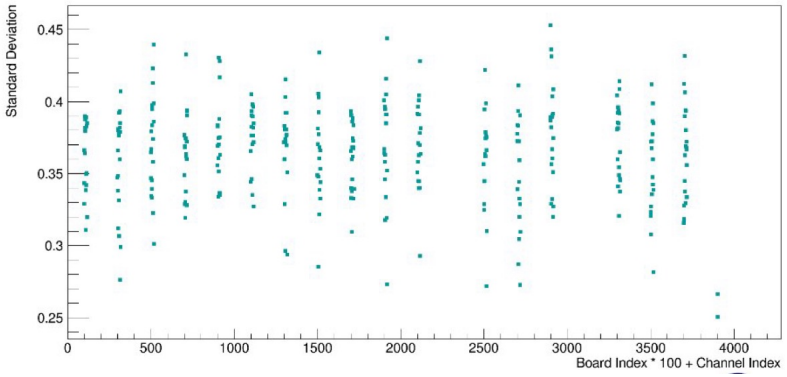




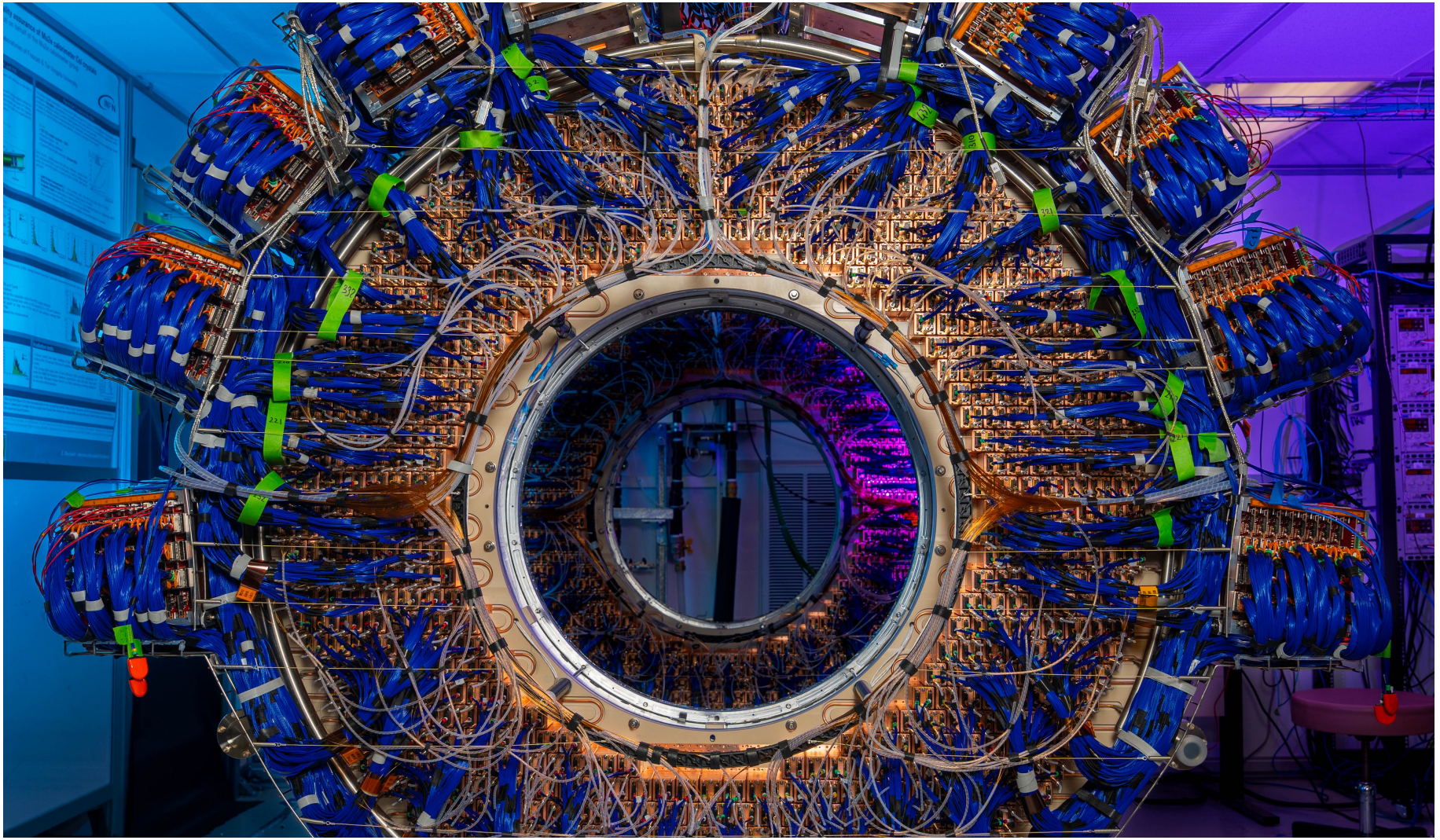


Within a single run, time differences remain stable, with a **DT_{LR} resolution** of **~ 300 ps** all across the entire calorimeter





Green light for calo transportation to MC-2!



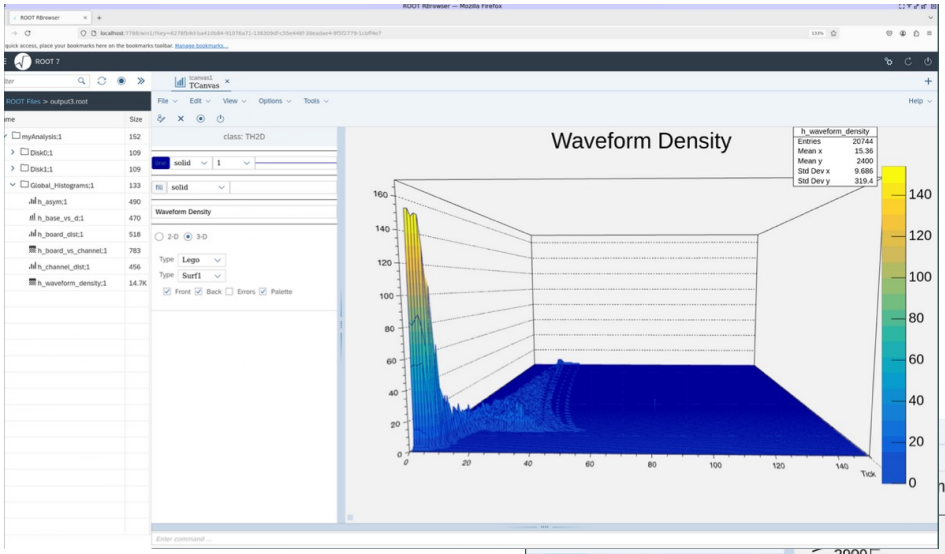
Online DB

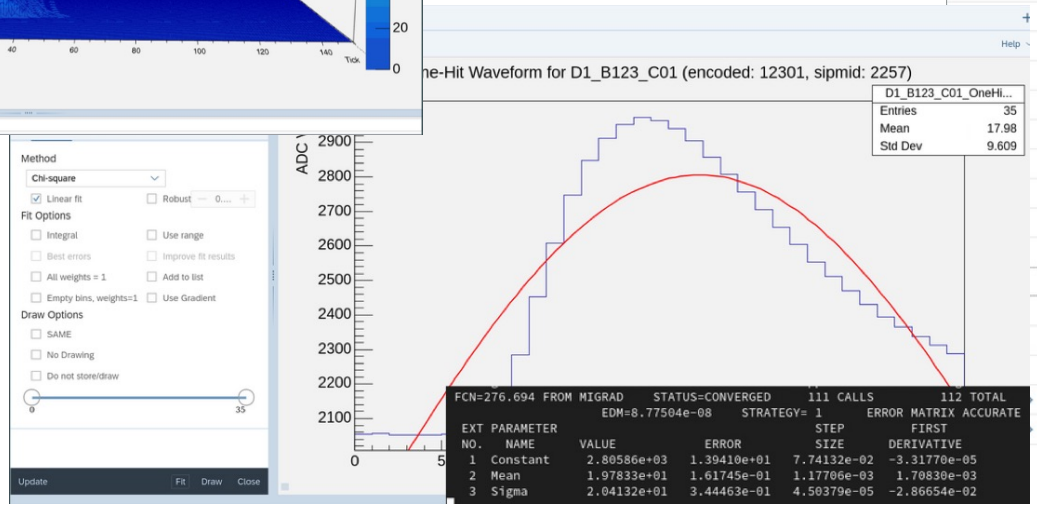
- Currently, the information needed for DAQ running is loaded from text files
- Work is in progress to create online DB tables through the otsdaq interface

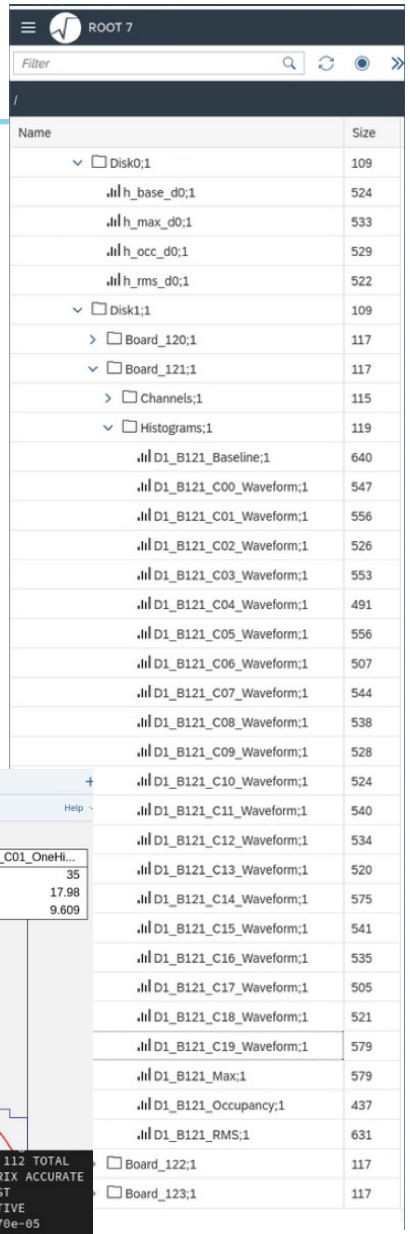
	Content	Number of entries	Expected update frequency	Needed by offline
BoardMap	DIRAC/MZB Serial #, DTC # / link	Fixed	Not frequent	No
Vbias config	Vbias, channel type	Fixed	Depends on the beam intensity	No
MZB Config	Calib params	Fixed	yearly	No
Channel mask	RO id, flag (dead/noisy/hot)	Variable	To be seen	Yes
Baselines	Baseline & threshold	Fixed	few hours	Yes

Offline Calo DQM

- art module producing histograms stored in a ROOT file
- Rbrowser (graphic FTP-SFTP client)







Online Calo DQM

- A dedicated **otsdaq** environment was configured with isolated DQM, Trigger, and Calorimeter subsystems to safely develop and test the new DQM module.
- Created contexts and configs for dqm, calo, trigger, and shift subsystems, allowing independent module execution without disrupting other users.
- To simulate data input, the CFO Emulator was successfully launched with a fixed-width event window setup (200 µs, 1001 markers). This allows testing of DQM histogram streaming functionality even without a live detector.

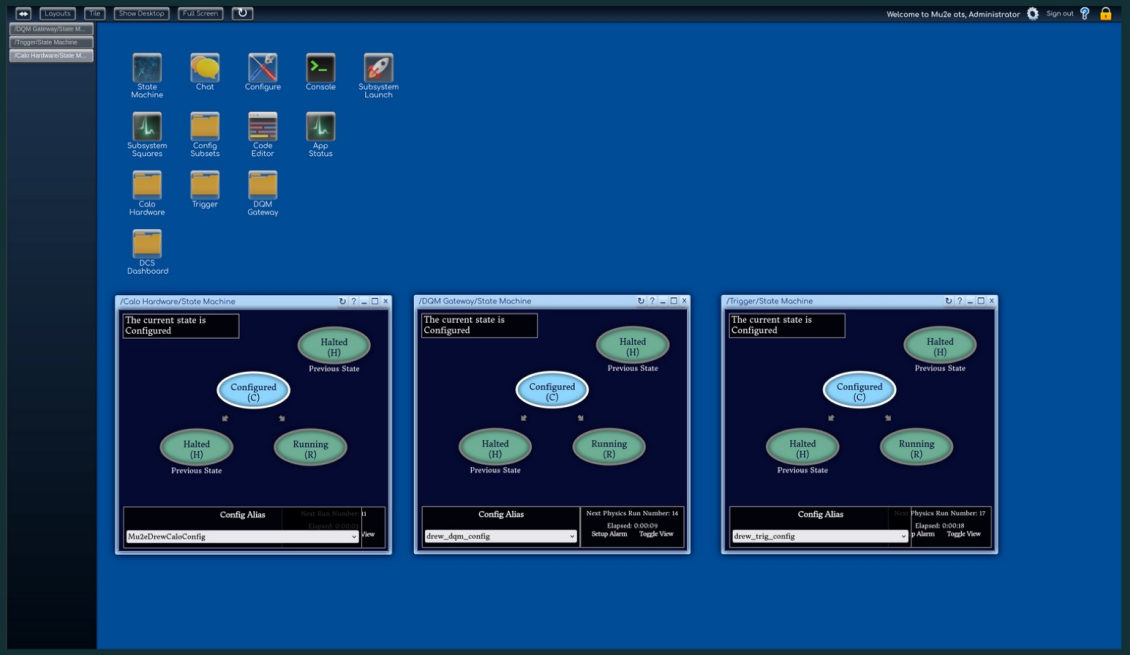


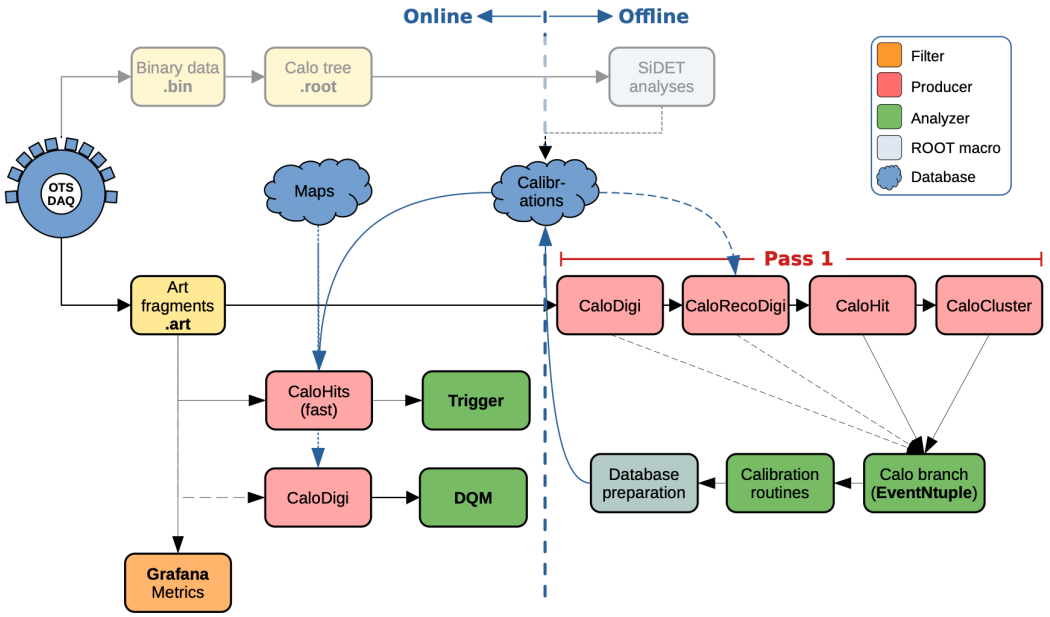
Figure 4: otsdaq with configured DQM, Trigger, and Calo subsystems

Next steps:

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

Data processing: transition to KPP

- Evolving rapidly to address calo and TDAQ needs
- Focus is shifting to a stable online & offline processing for commissioning in the hall



Online:

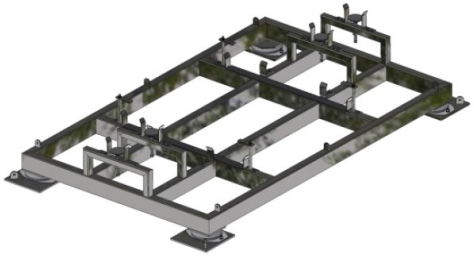
- Expand Grafana metrix for shifters and test DQM functionality
- Trigger: raw-to-hit fast module tested offline → online rate capability

Offline:

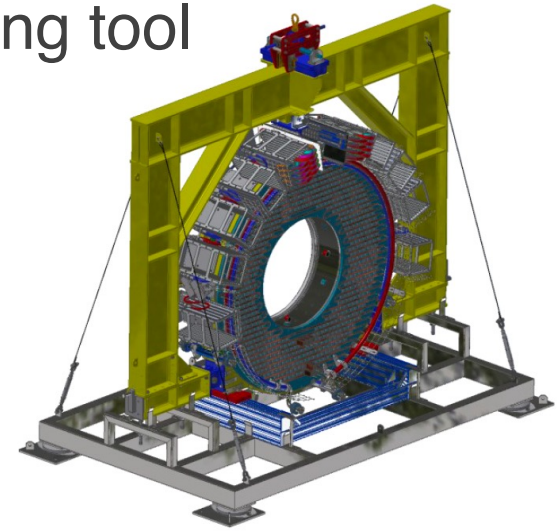
- DB: first calo experts' calibration table is on DB → production tables
- EventNtuple calo branch being developed and tested

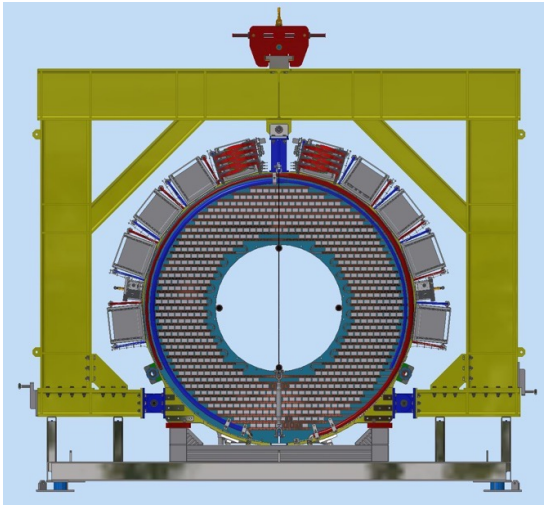
Transportation tools and procedure

Transport stand

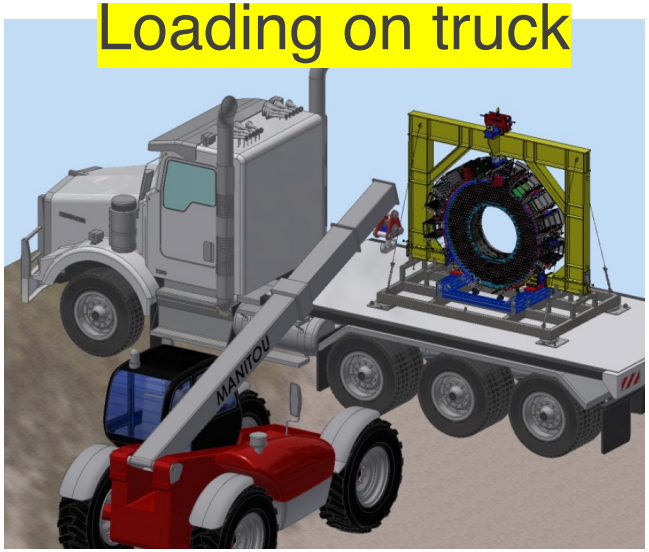


Lifting tool

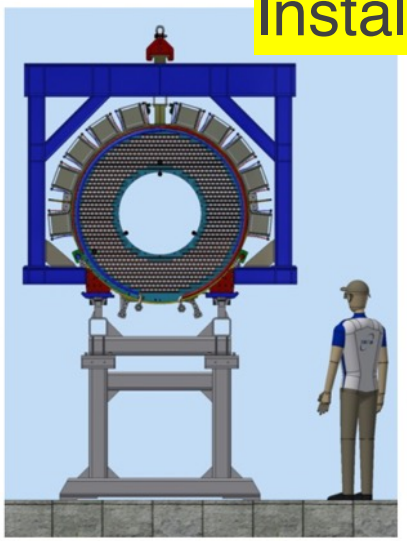


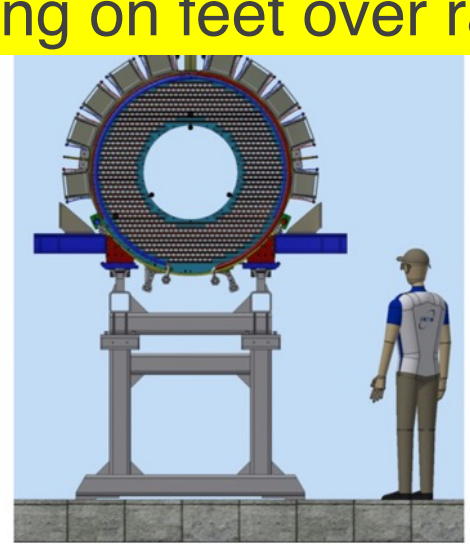


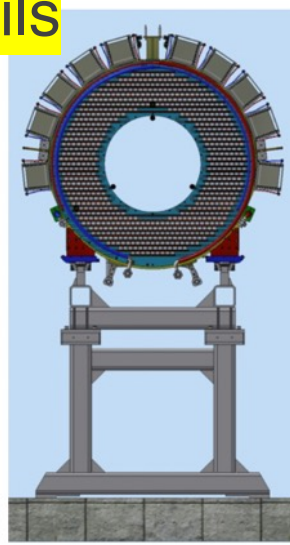
Loading on truck



Installing on feet over rails



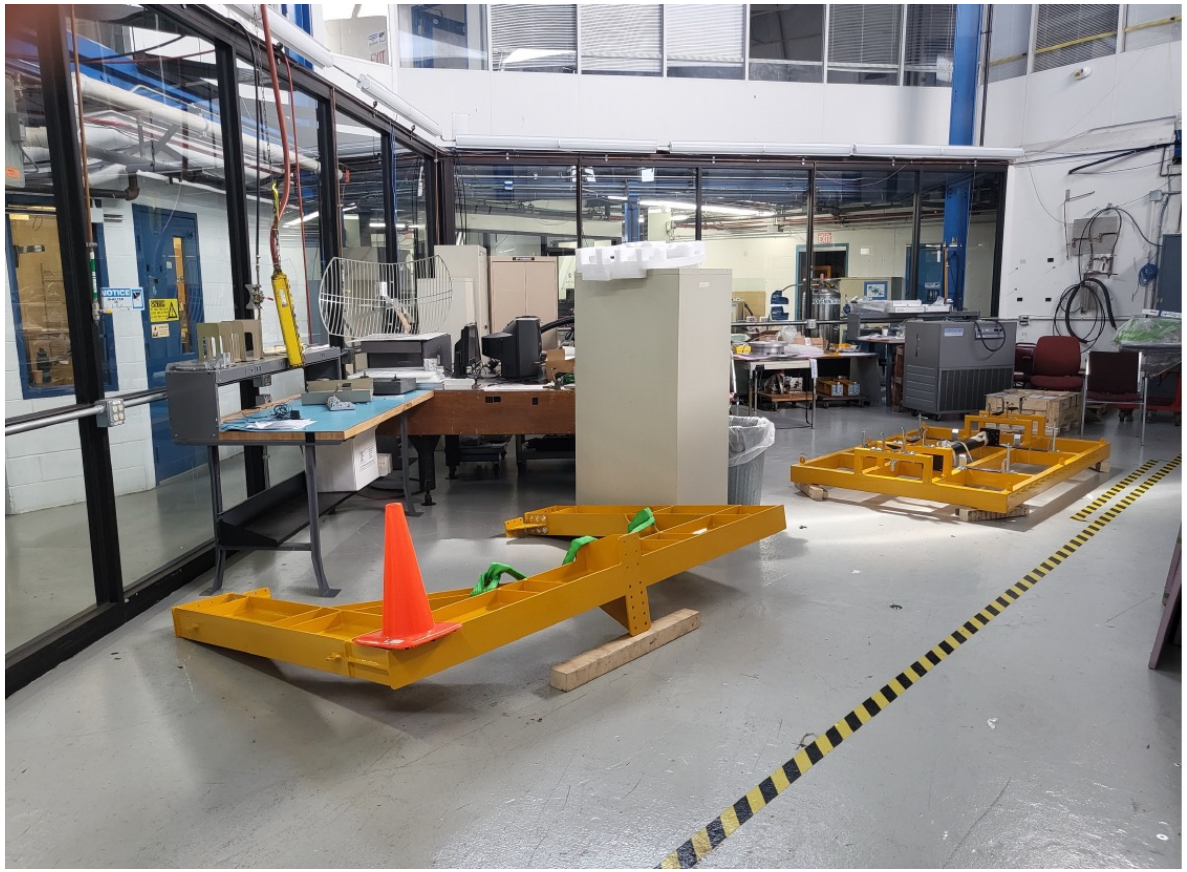




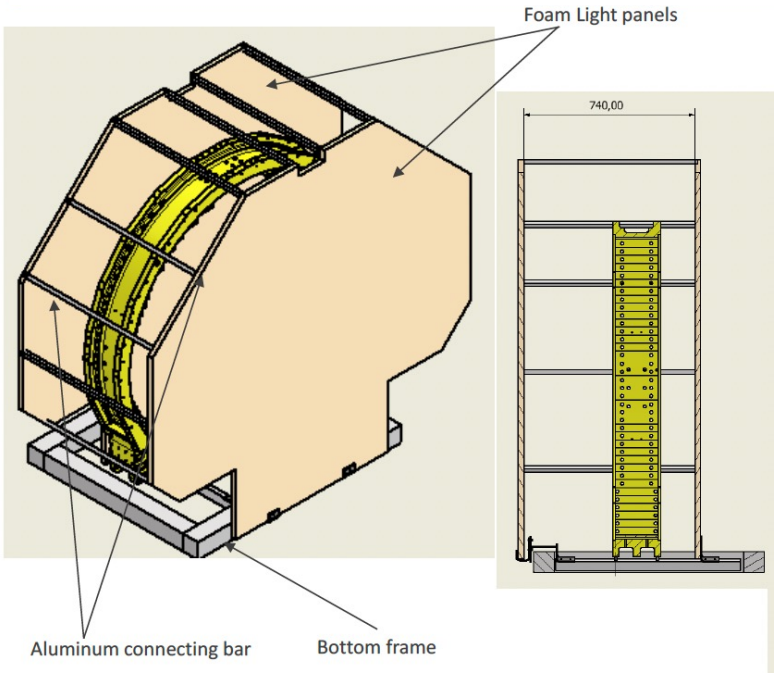
Status of transportation tooling

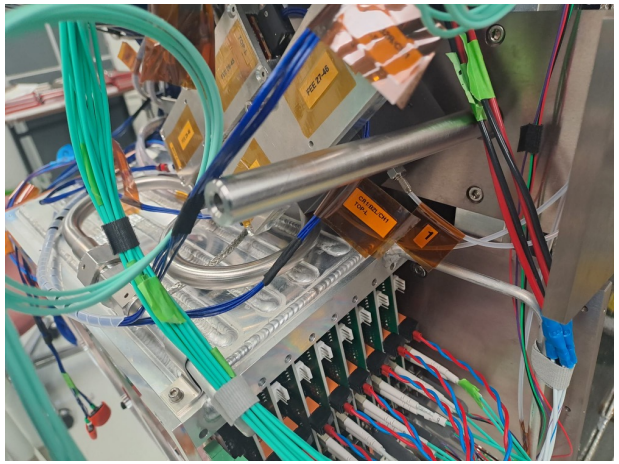
Loading test in Italy
@Cerasa Mechanics

Material for lifting tools and transport stand unpacked and being checked and prepared at SiDet, Lab-A



Transport coverage and final survey



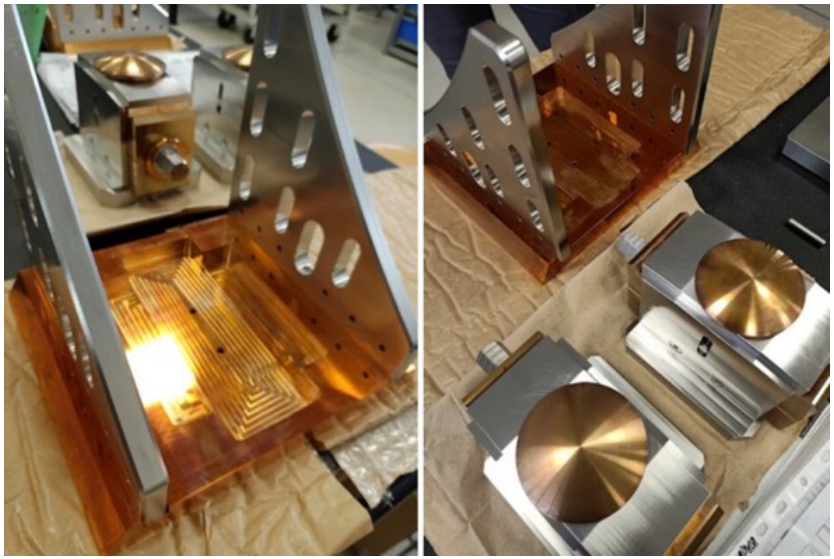


Wrapping ready for 1 disk

- it will be installed at the last moment around the disk + apply an anti-static
- trim it to shape to avoid interferences
- survey of Disk 1, Disk 0 done at SiDet

Preparation for installation in MC-2

Feet already at SIDET,
unpacked and pre-assembled



Fabio and George checked
the sequence of feet
mounting on the detector train

Expected sequence (calo perspectives)

- Fabio and tech will be there from **15 June to June 29**
- Stefano, Luca and another tech from **22 June to 1-4 July**

16-18 → mounting Calorimeter feet on rails

17-19 → test of road + Lifting tool assembly

→ test of stand + aob

22-24 → dismount Disk-1 connection

→ dry again the disk cooling lines

→ **mount protection panels**

24-26 → Transport to the Mu2e Hall

27-28 → Test Disk1 and repeat with Disk0?

Test of Disk 1 (once on the rail)

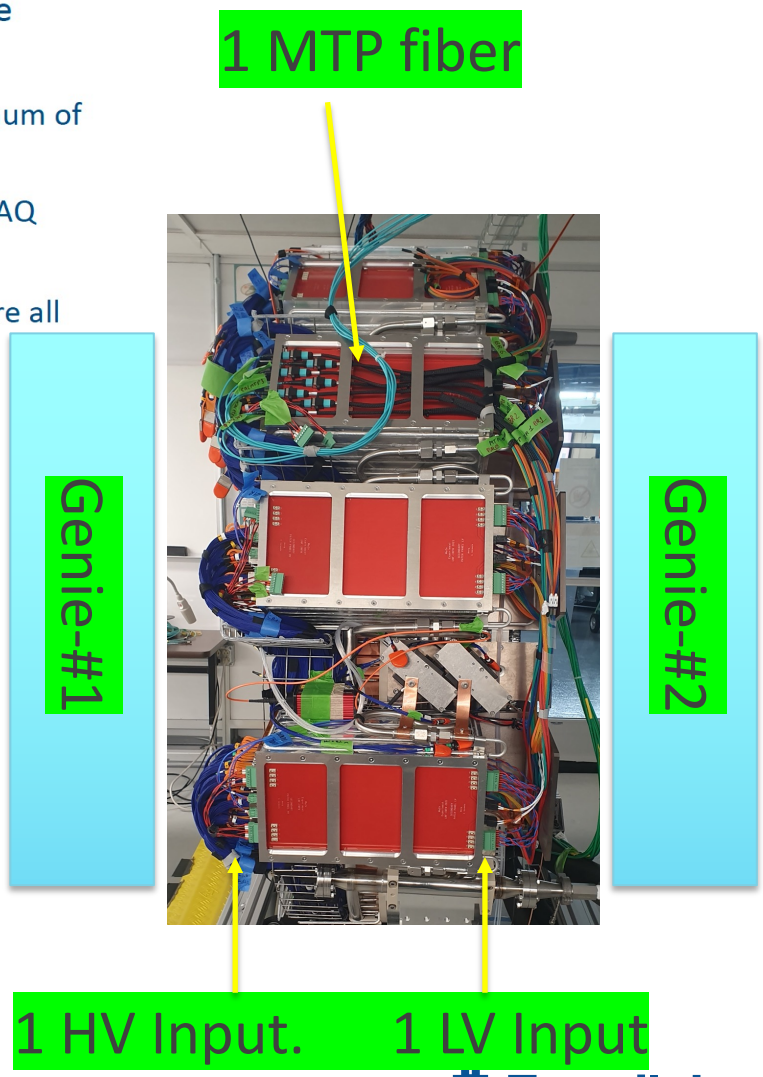
Once in the hall **services and cooling won't be ready**, so we planned a fast-testing procedure that will allow to **evaluate eventual damages** due to the transportation **while avoiding the overheating**

- **One LV + one HV power supplies** to poweron one crate at a time for a maximum of 2 minutes
- **One MTP cable** (n. 22, tested in March) + one cassette + **one DTC** from the DAQ side (tested)
- We'll read the **slow control** from each DiRAC and Mezzanine boards to be sure all the channels still connected, collect a **noise run** and a **very short cosmic run**
- ORC is being written in these days
  - Keep moving on different crates
  - Full Survey in 1-2 days
  - If OK, move Disk 0 and repeat

Needs: Two genies

If getting too late, Disk-0 will be brought middle of July

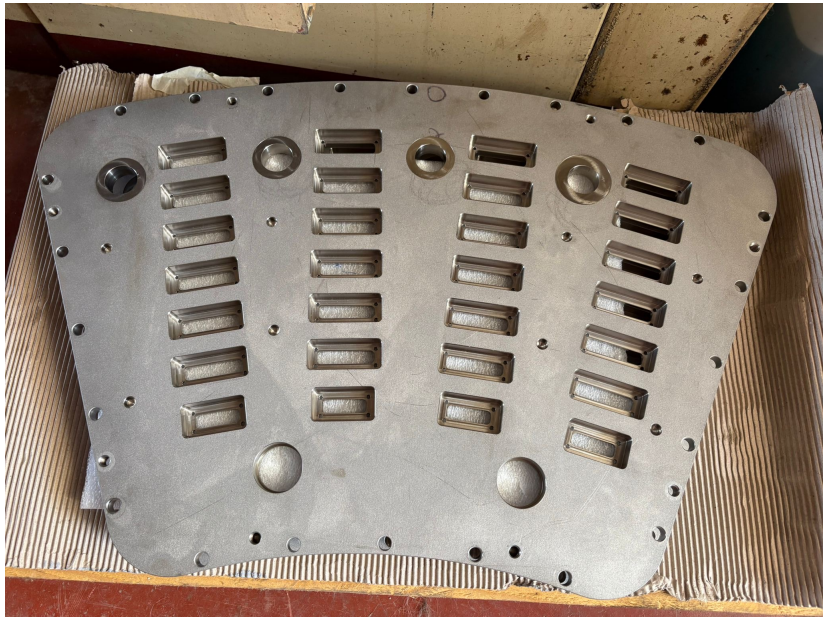
Relevant to have isolation barrier + dry air soon after or we should keep it dressed



Important steps for integration: flanges

Preparation of Rear Flanges:

- Received full flanges from FNAL in April
- Machining completed this week, ship to LNF next week
- Installation of feedthroughs + test in vacuum
- Ship to FNAL in July

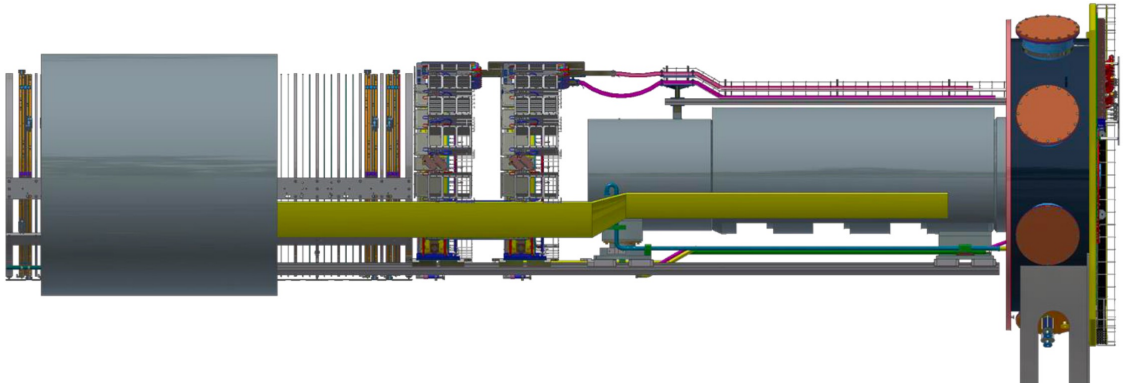


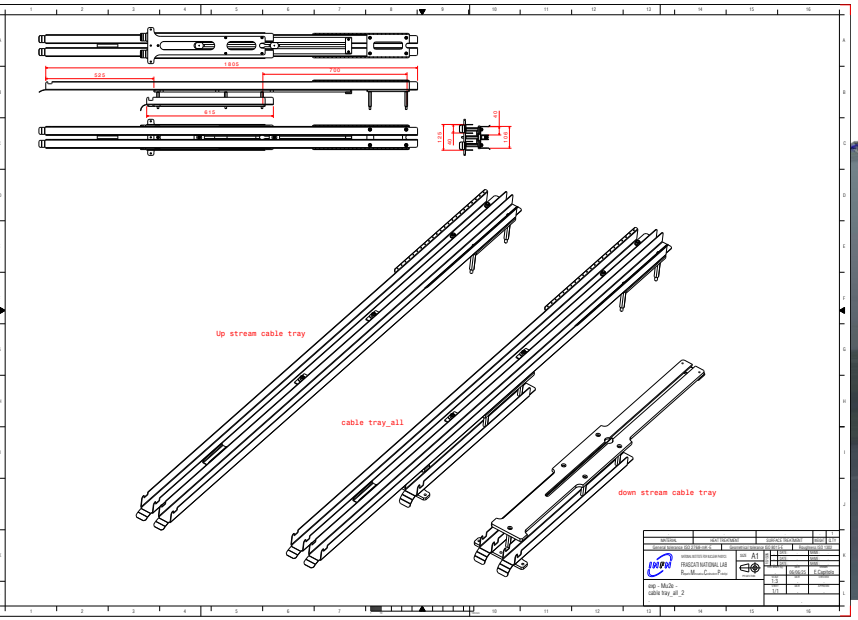
Organizing a similar effort for Radial Flange for pipes

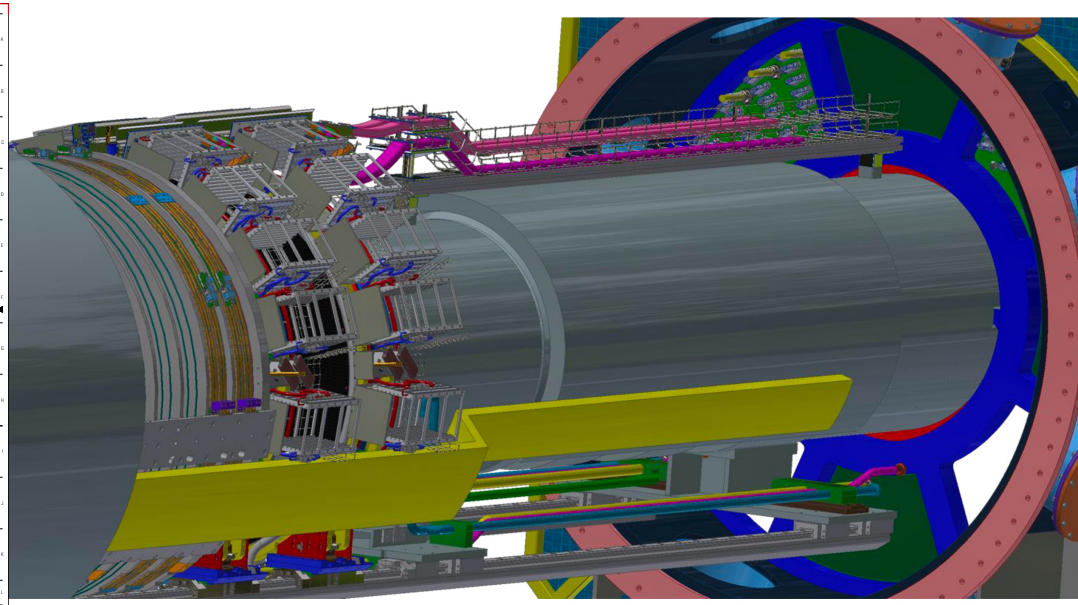
Service cables: preparation of support on DS

Procurement + LNF machine-shop work on going for making:

- Cable trays on calo
- Supports of cable trays on muon beam stop
- Procure CabloFil structures







Expected sequence: next steps

- Bring Disk 0 in July (if not done in first round)
- Prepare Cable supports on Muon beam Stop
- Receive IFB rear flanges
- Test IFB rear flanges at SiDet
- Test Disk-0

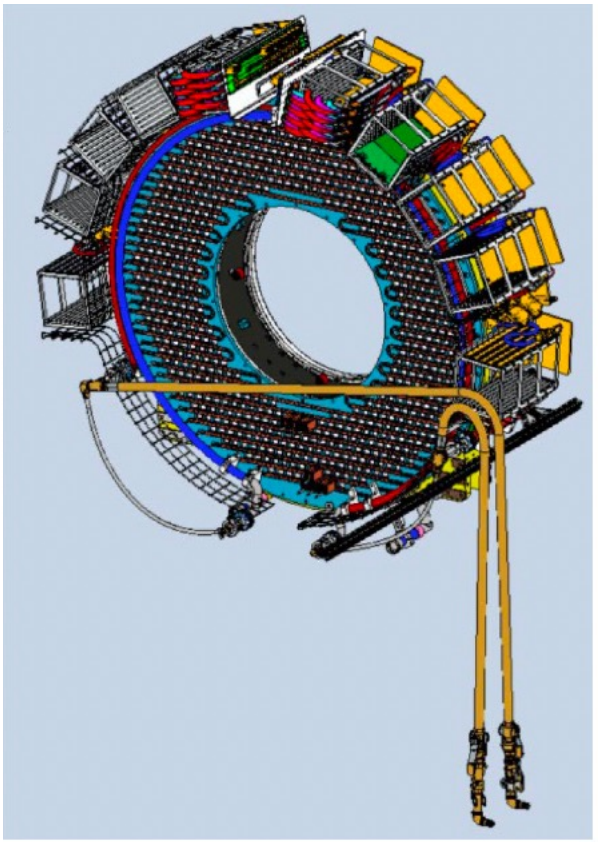
Other relevant priorities:

- Mini-chiller installation (see next slide)
- Interlocks/controls
- Laser at TDAQ room
- If we succeed to do this, in September will proceed with connection of services (LV, HV .. fibers)

Backup cooling plant: from here to KPP

The final cooling station won't be ready yet, so **we are going to install a temporary movable chiller**:

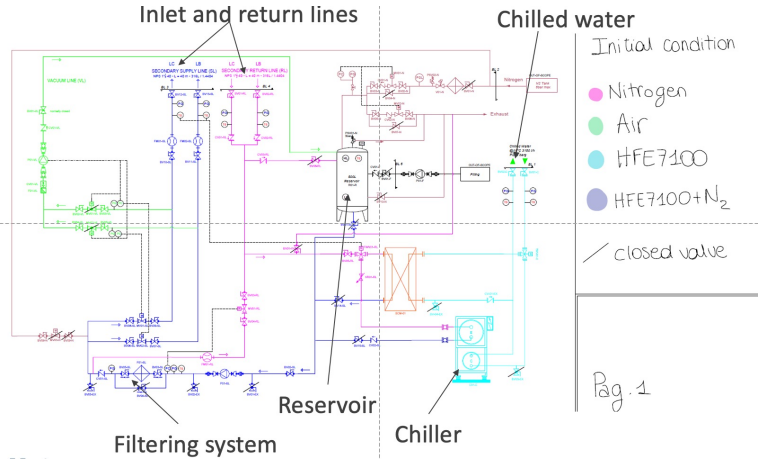
- 1 chiller per disk (1 new and one recicled from Sidet Lab) for both crates and FEEs cooling
- Using **demineralized water** (with anti fungi additives)
- Using **flexible lines** to accommodate chiller location adjustment
- Using **separation valves** and **quick connection** to disentangle the piping if necessary



To operate this, we need to complete the work on the interlocks. At the very least, the following is required:

- temperature sensors
- pressure and flow sensors
- same interlock shutdown of Power Supplies as for final system

Final cooling plant for operations and beam



CUSTOMER:

Fermilab

FILLING AND DRAINING PROCEDURES
RT3825002-00

Mu2e
CALORIMETER COOLING
PLANT

PLANT:

Fermi National Accelerator Laboratory
Kirk and Wilson Sts.
Batavia, IL 60510-0500 US

delta-ti		Job:	C3825
		N° Doc.	RT3825002-00
Cliente: Fermilab	Type of document : Technical report	Rev.:	00
		Data:	16/04/2025
Subject: Mu2e Calorimeter Cooling Plant	Description:	ANSWERS TO OBSERVATIONS	

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REV.	DATE	DESCRIPTION	WRITTEN BY:	CHECK:	APPROVED:
00	16/04/2025	Emissione	CPL/DLL/TMG	TMG	MRT

Cooling Plant Design steps:

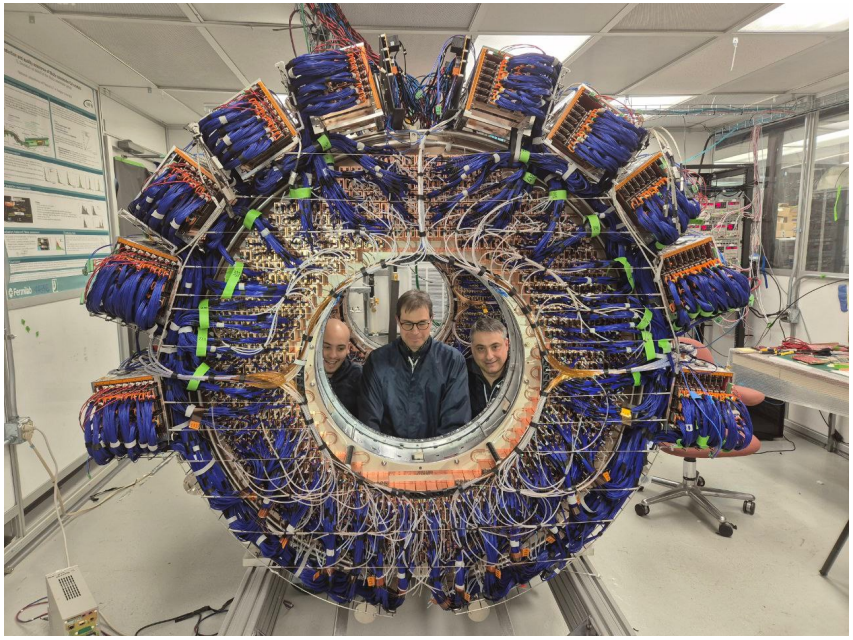
1. Finalize the PID diagram
2. Finalize the procedures
3. Preliminary design review
4. Waiting for final comment
5. Proceed to Final Design
6. Identify the commercial components
7. Review the proposed components
8. Final CAD Design of the cooling station
9. Review the cooling station design

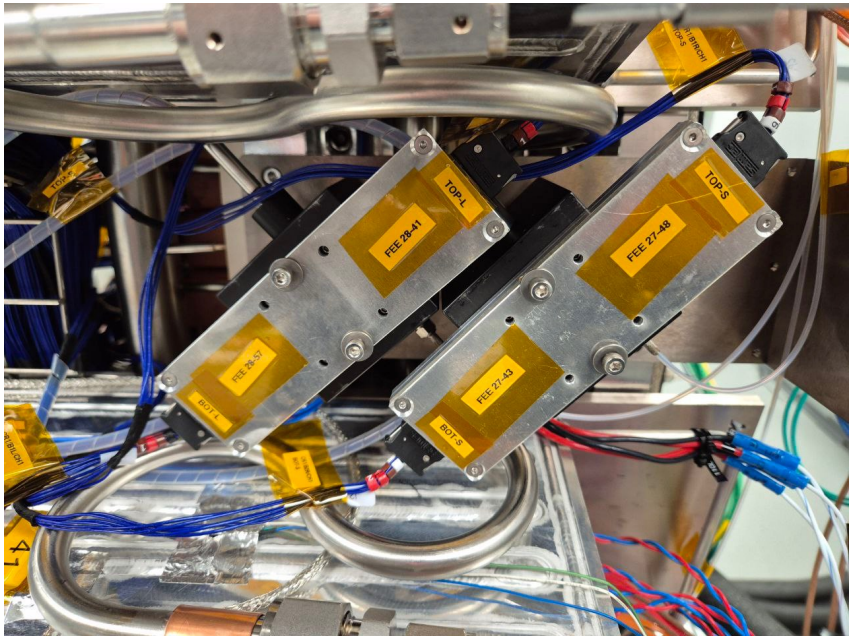
Done
In progress
Not yet started

Aiming to have a final design for Fall 2025

Laser system: status and plans

- Fiber bundles + integration spheres: both disks completed and tested

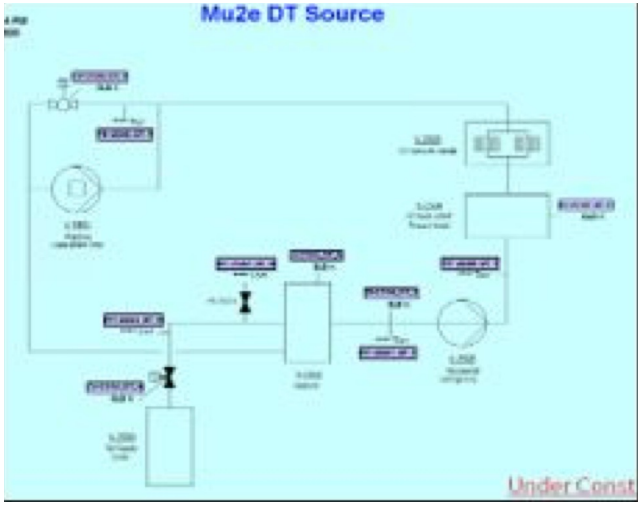




- Primary distribution used for calo commissioning is not the final one
- New laser (Innolas) procured, new optical components and table available
- Installation of the laser system in the Mu2e Hall foreseen this summer

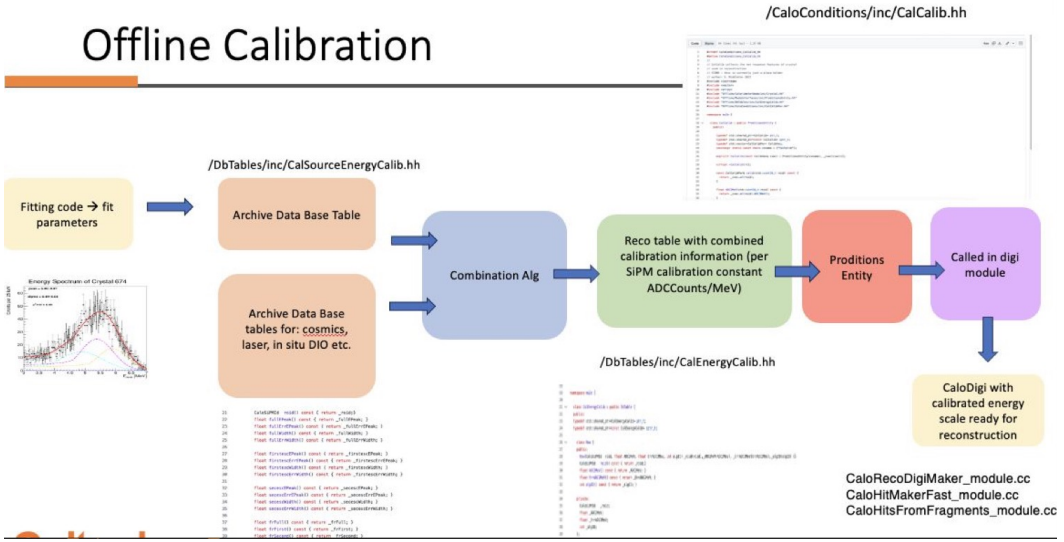
Source system: HW status

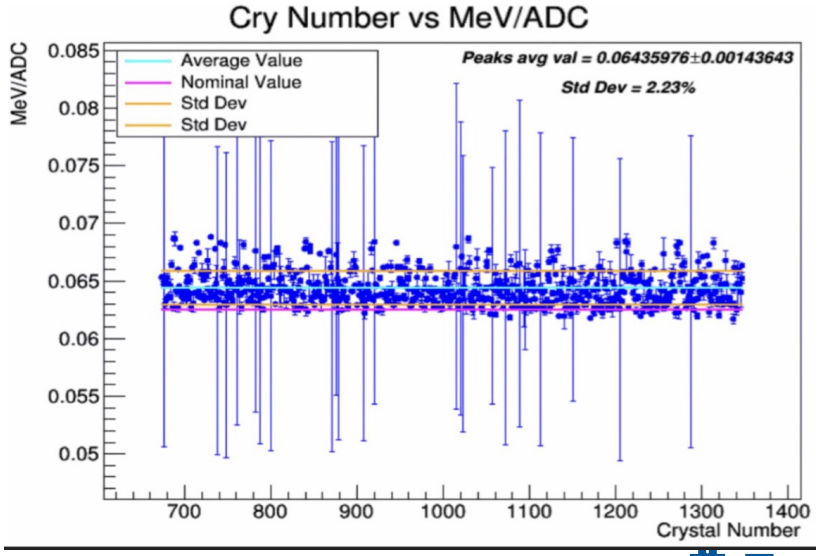
- Remote operations are being finalized
  - controls PC in the alcove above alcove-3, extending our USB cable straight up through the existing hole (20m limit on the ethernet so far)
  - Lots of progress on control system and iFix control diagram created
- Still, some work to be finalized both on design and installation
- Ongoing discussion on DT source manifold connection: conflat vs disk welding pipes



Source system: calibration procedure

- Calibration scheme defined
- Fitting algorithm refined
- Simulated workflow has evolved to match data
- Good understanding of rates and run plan
- Planning of analysis procedures in progress, including flagging issues
- In progress: algorithm to combine source and cosmic calibration to extract chan-by-chan ADC/MeV conversion





Conclusions

- The calorimeter Disk 0 and Disk 1 are completed
- Commissioning run at SiDet completed
- Channel survey: all acceptable, ready for transportation
- Calibration scheme with MIPs and laser successfully tested
- Calibration scheme with source planned
- Transportation tools at Fermilab and review almost completed
- Planning to move and test Disk 1 in two weeks
- Next steps: preparation of services
- In parallel: keep working on improving FW/DAQ/DQM/DCS and Offline reconstruction of collected data

Interlocks

Offline DQM: RBrowser

- ROOT-based
- Handles large datasets efficiently
- ROOT macro support
- Real-time data analysis
- Optimized memory management
- Advanced 3D visualization

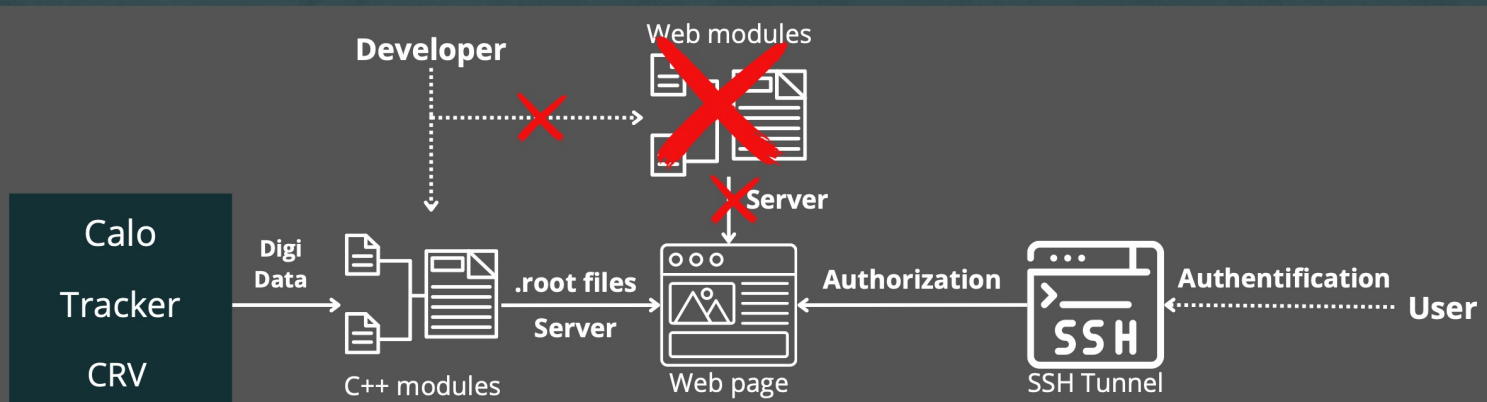
Updated Project Structure with RBrowser

Developer

1. Sets up environment using Spack-recipe
2. ROOT version v6.32.08
3. RBrowser initialized with developed C++ modules

User

1. Authenticate with Kerberos
2. Establish an SSH Tunnel:
   ssh -f -KXY -N -L 3127:mu2egpvm05:3127
   mvakulen@mu2egpvm05.gov.fnal
3. Access RBrowser in the Browser:
   http://localhost:PORT/



Fermilab

Source system: next steps

Remaining Work: Installation

47507.8.003040: source installation (Luke and others):

What are the associated activities?

- Install reservoir, Luke & techs, welder?
  - Install level gauge
- Install drain pump, Luke&techs
- Install flow meter, Luke&techs
- Install head gas system, Luke&techs
- Drain pump
  - Agree on or alter quote, Luke

47507.8.003100: electrical/controls (Tarunima and others)

What are the associated activities?

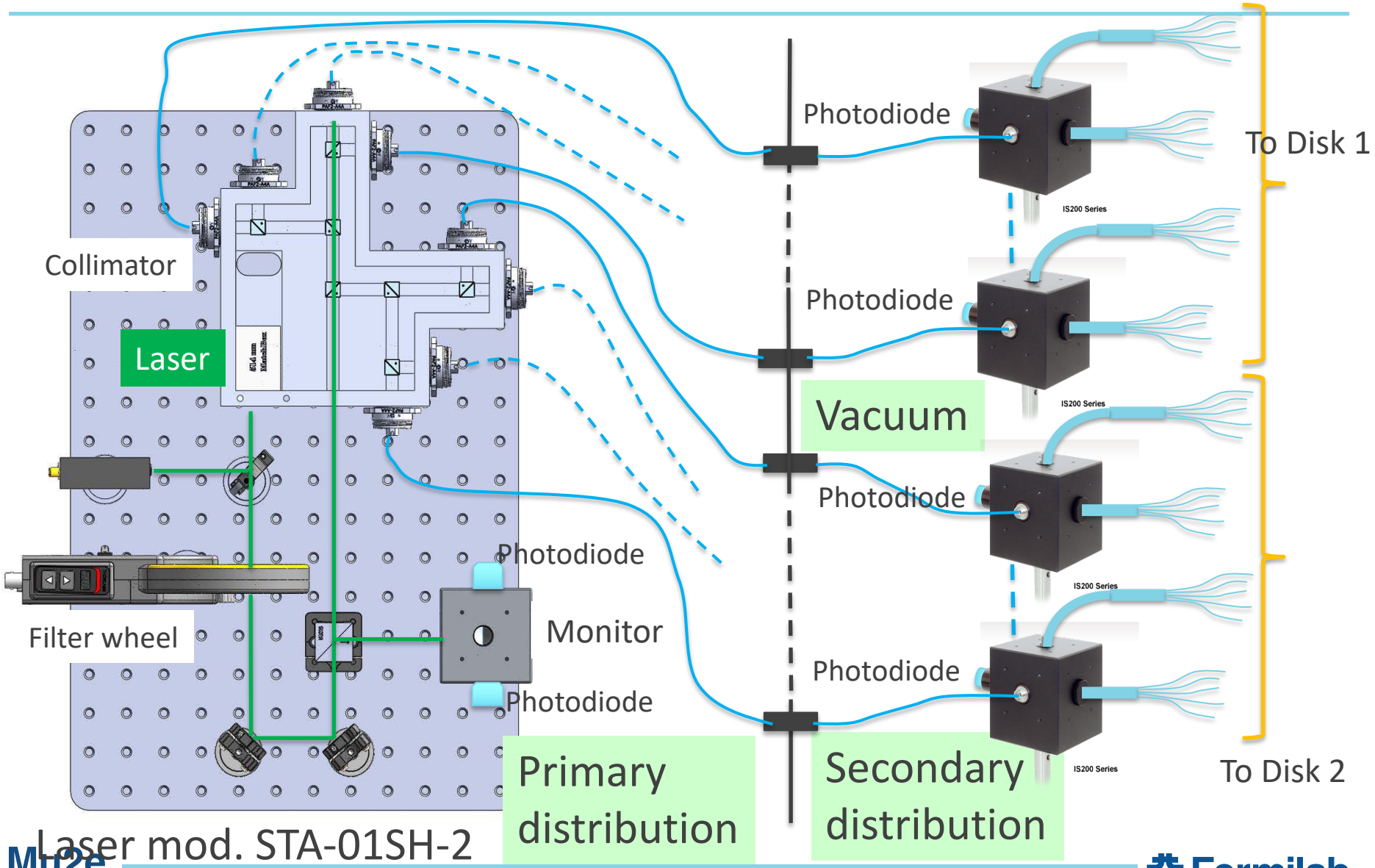
- Cable drain pump control, Tarunima&techs
- Cable level gauge, Tarunima&techs
- Cable flow meter, Tarunima&techs
- Cable head gas controls, Tarunima&techs
- Cable valve controls, Tarunima&techs
- Cable DT generator controls/interlocks, Tarunima&techs
- Cable sensors, Tarunima&techs
  - Pressure
  - temperature
- Program controls, Tarunima, controls sw engineer
  - GUI
  - Testing

Remaining Work: Design

Associated activities for tasks 47507.6.001040:

- Reservoir:
  - Complete reservoir design, Luke
  - Gain approval through review of the design
  - Order parts needed to complete design
  - Order reservoir, Caltech
  - SOW expires: March 31, 2026
- Flow meter
- Level gauge
  - Agree on or alter quote, Luke
  - Order, Caltech
- Control valves:
  - Order, Caltech
- Drain pump
  - Agree on or alter quote, Luke
  - Order, Caltech
- Head gas system
  - Complete specifications for orders, Luke
  - Order, Caltech
- Other:
  - Pipes:
    - Complete design of routing, Luke
  - Pressure gauges:
    - Finalize specification, Luke/Tarunima
    - Order, Caltech

Laser System Scheme



Laser mod. STA-01SH-2

New laser performance: data from INNOLAS

Laser Energy Performance 200 Hz - 5 kHz

	1064nm			532nm		
Diode Osc. [A]	200Hz (µJ)	1kHz (µJ)	5kHz (µJ)	200Hz (µJ)	1kHz (µJ)	5kHz (µJ)
3.0	38.0	30.3	27.9	22.0	8.3	4.7
3.4	51.0	44.5	41.2	27.0	15.2	11.3
3.8	61.0	53.6	51.1	32.0	20.9	17.7
4.2	71.5	61.6	60.9	37.0	26.2	21.6
4.6	80.5	72.0	70.5	43.0	30.1	27.1
4.8	88.0	77.4	76.8	44.5	32.7	29.1
5.0	93.0	86.8	82.7	44.5	35.5	30.7

Energy + Stability 532nm 200Hz (RMS +/-2.2%)