MTD BTL **Thermal** Test Setup

2024 CLHCP QingDao

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on behalf of

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Outline

- General Introduction
- SM QA/QC Thermal Test
- DM QA/QC Thermal Test
- BTL Tray QA/QC setup
- Summary

General Introduction

Assembly of MTD BTL

- Sensor Module Assembly
  - 1 Lyso + 2 Sipm
  - SM QA/QC

↓

- Detector Module Assembly
  - 1 Cupper Housing
  - 2 SM 1 FE board
  - DM QA/QC

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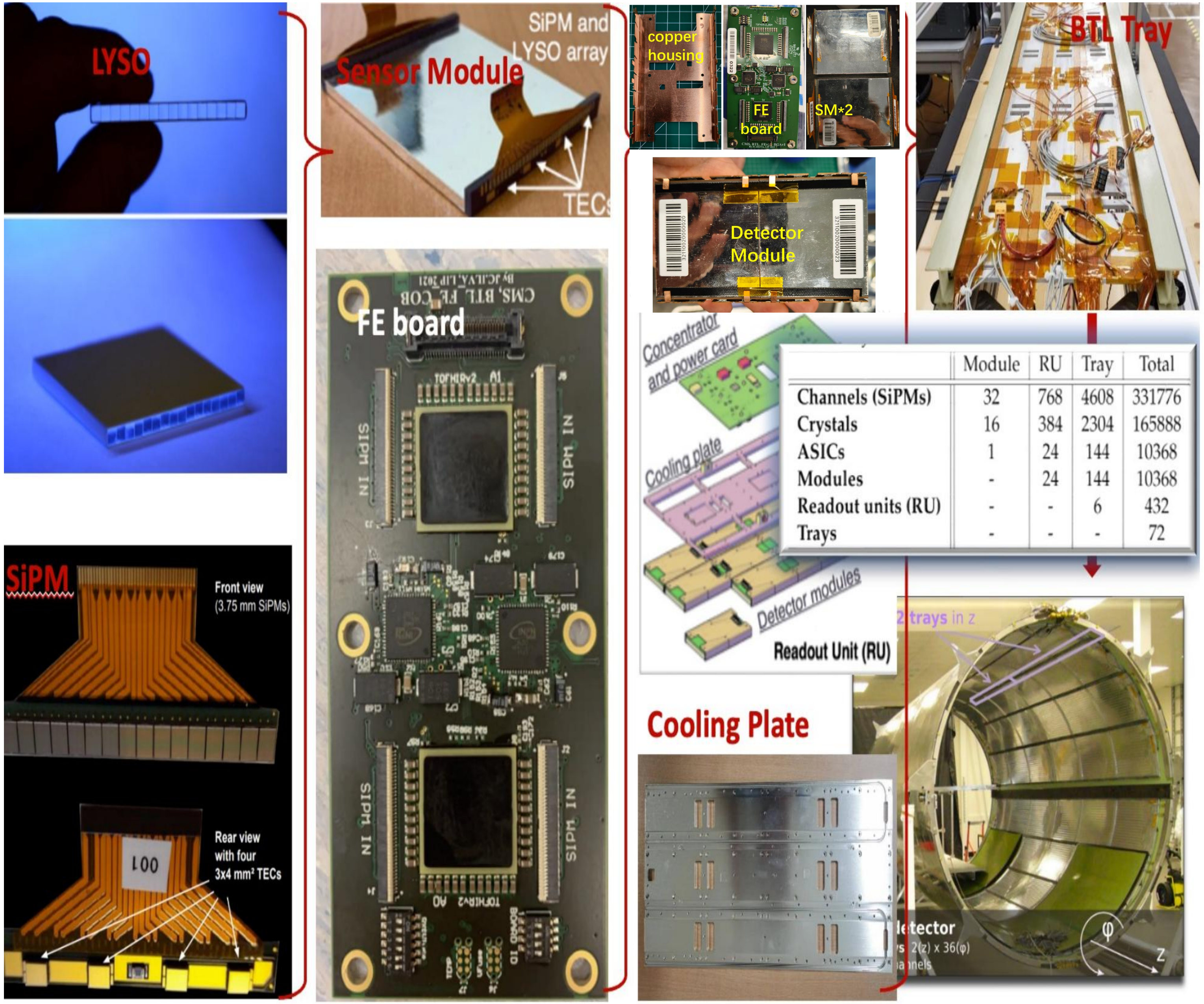
- BTL Tray Assembly
  - ~72 DM 6 Readout Units 12DMs/RU
  - BTL Tray QA/QC



	Module	RU	Tray	Total
Channels (SiPMs)	32	768	4608	331776
Crystals	16	384	2304	165888
ASICs	1	24	144	10368
Modules	-	24	144	10368
Readout units (RU)	-	-	6	432
Trays	-	-	-	72

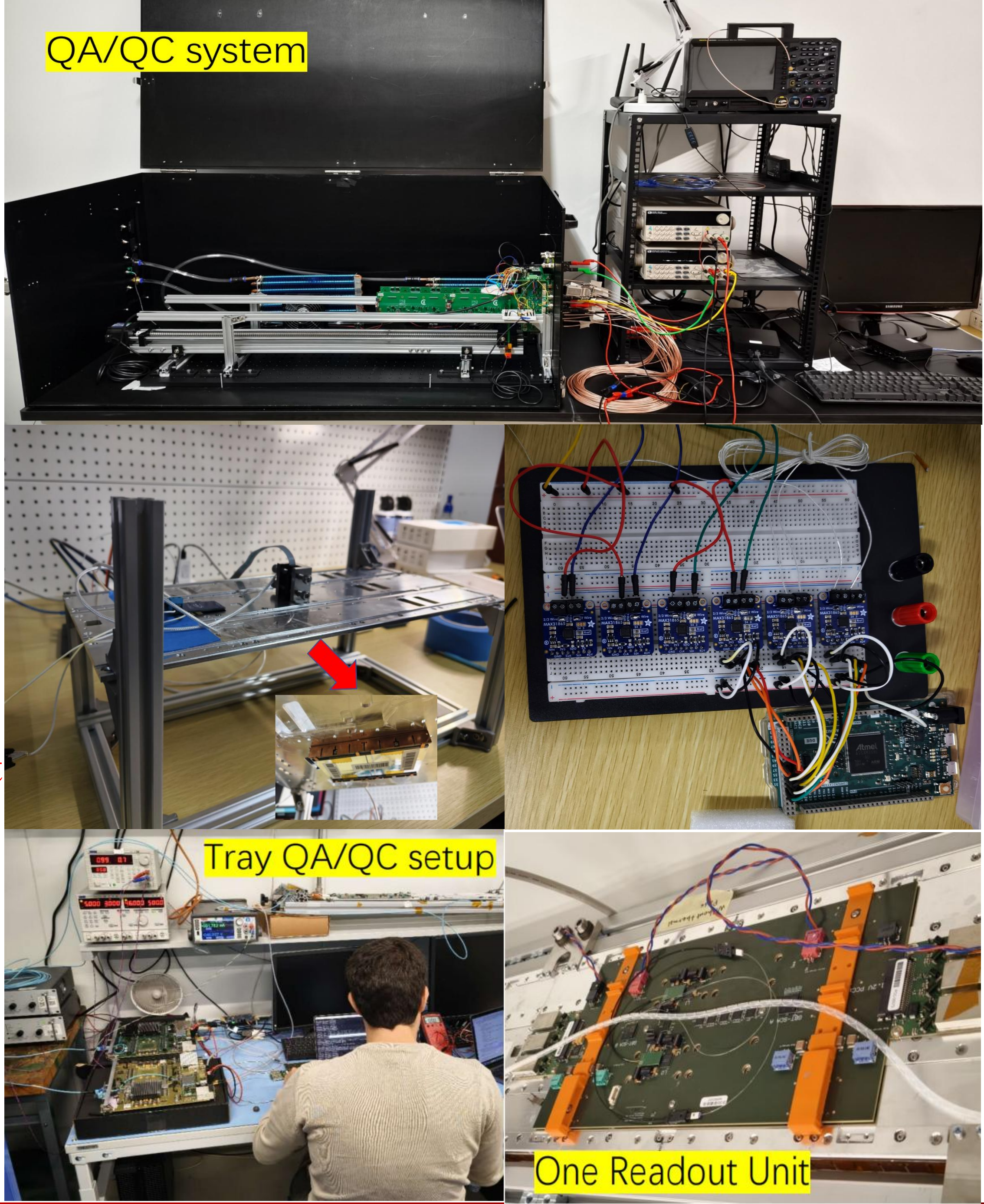
QA/QC & Thermal Test

➢ QA/QC

- **SM QA/QC**: measure the light yield of each channel of sensor moudle to show the assembly quality
- **DM QA/QC:** mainly involves thermal coupling testing
- **BTL Tray QA/QC:** including bias power supply, temperature testing and DAQ, etc., while optimizing QA/QC

➢ Why Thermal Test

- SM QA/QC Thermal test covers temperature control and measurement in QA/QC experiment condition, standardizing SM QA/QC conditions across four BACs for consistency
- Ensures good contact between the TECs on the SiPM and copper
- SiPM and DAQ system have strict temperature requirements, making temperature control and real-time monitoring essential in QA/QC

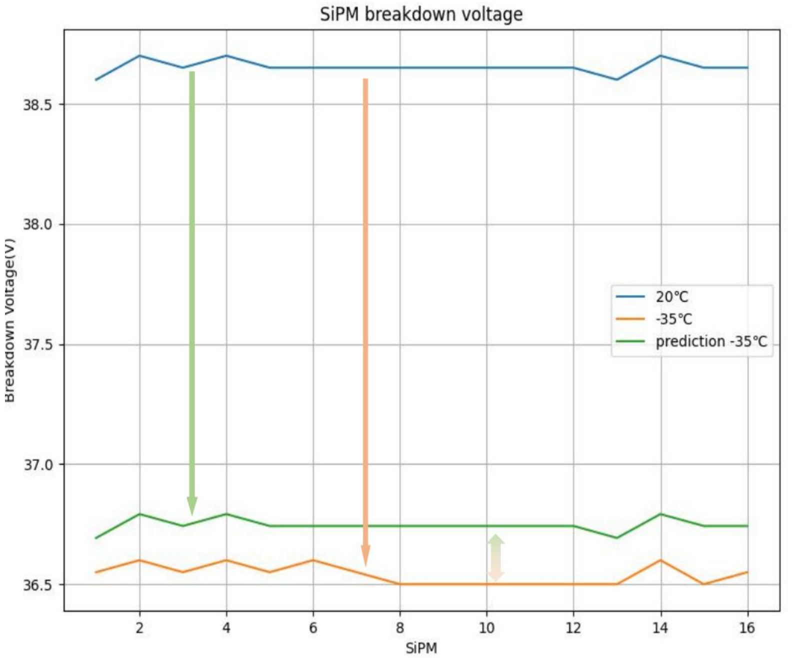


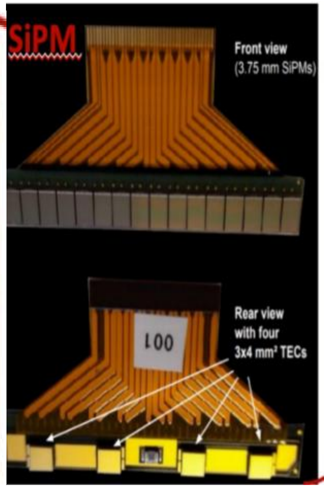
SM QA/QC Thermal Test

Why SM QA/QC Thermal Test

- Different SiPMs has different breakdown voltage, V_{br} , The temperature has large impact on the V_{br}
- Compared to the actual temperature of CMS (~ -35℃), the lab temperature (~20℃) causes a significant difference in the V_{br} of the same SiPM
- Since the SM QA/QC voltage is proportional to V_br, during batch testing temperature inconsistencies in SiPMs will cause significant deviations in the final light yield.
- Therefore, all BACs standardize the SM QA/QC temperature to 23℃ for consistent metrics

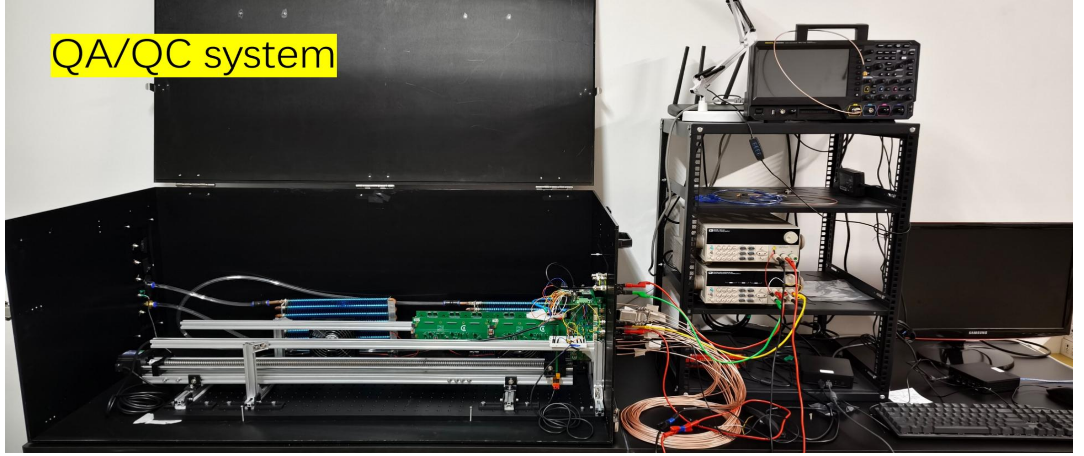
$$V_{T_A} = V_{T_B} - 34mV/°C \cdot (T_B - T_A)$$



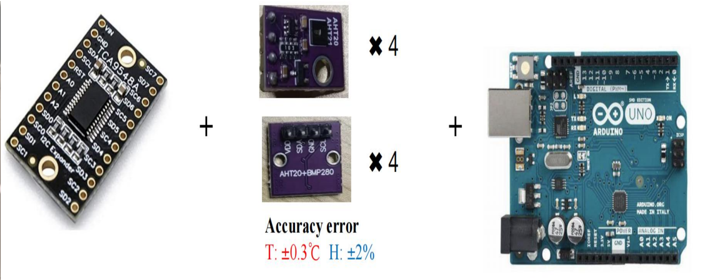


Introduction of SM QA/QC Thermal Test

- To maintain the temperature of 23℃ for SM QA/QC we use a water cooling system , fans and air conditioner to control the temperature in the dark box



- Use 8 AHT20 sensors connected to a TCA9548A, which are mounted on an Arduino Uno, for real-time temperature monitoring in 8 module board positions within the dark box

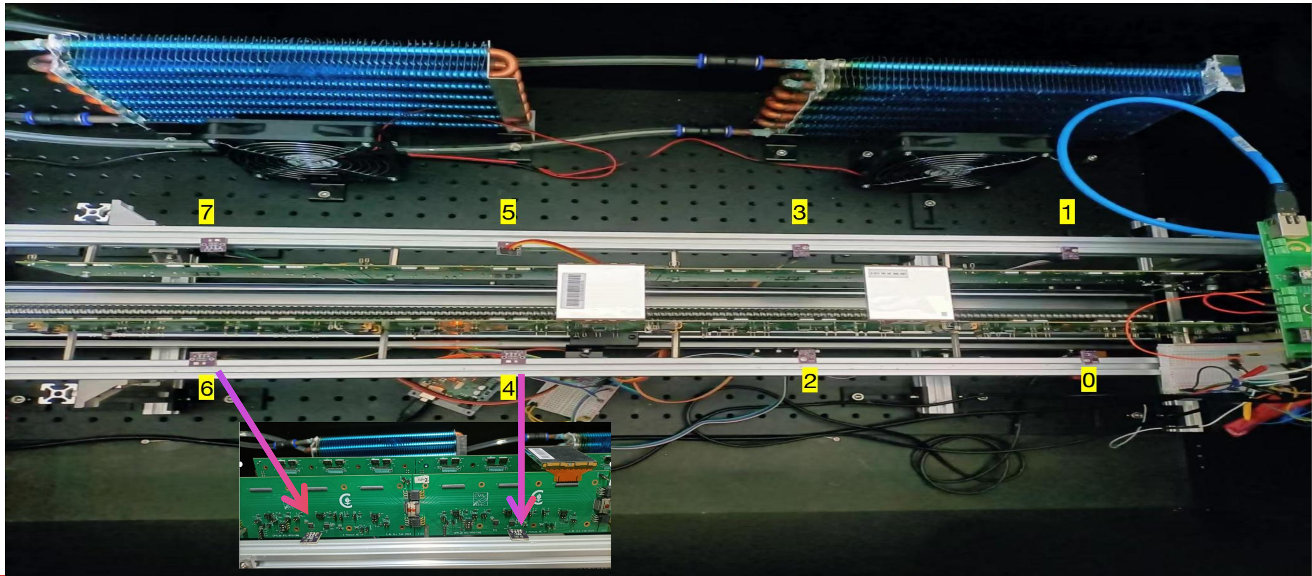


Mutiple AHT20s Tem&Hum system (MODboard_0 ~ MODboard_7)

- This system provides temperature and humidity data for 8 positions and calculates the average temperature for the whole dark box.

- Monitoring temperature and humidity at 8 locations reflects the uniformity of conditions across the dark box.

- The stable average temperature(~23 ℃) in the dark box can ensure the smooth progress of SM QA/QC testing



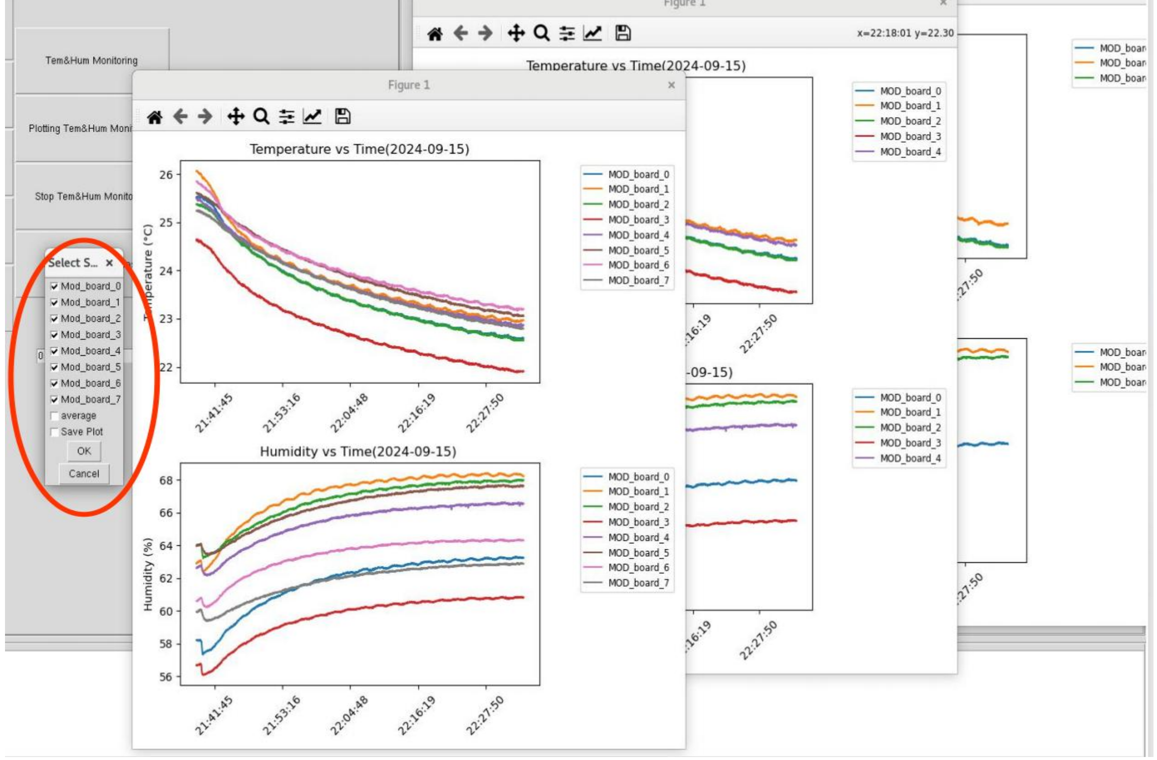
Temperature monitoring GUI panel

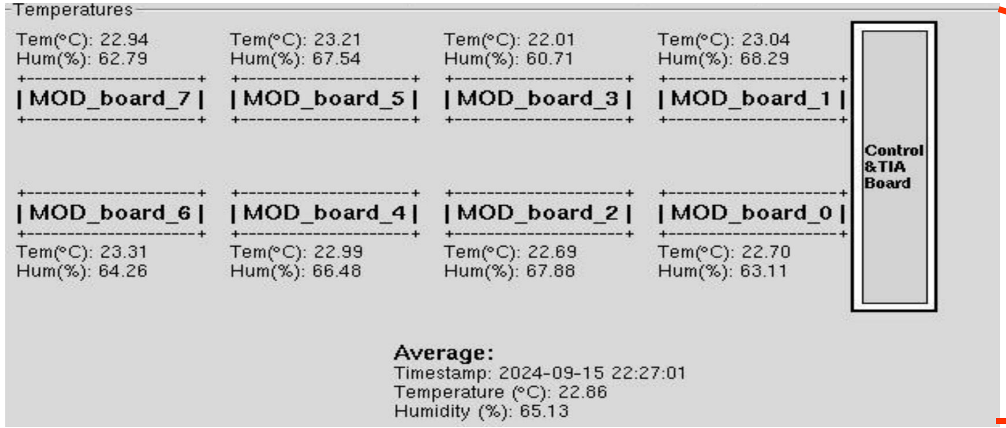
- Use the "Tem&Hum monitoring" button to perform temperature monitoring and save the data at regular intervals

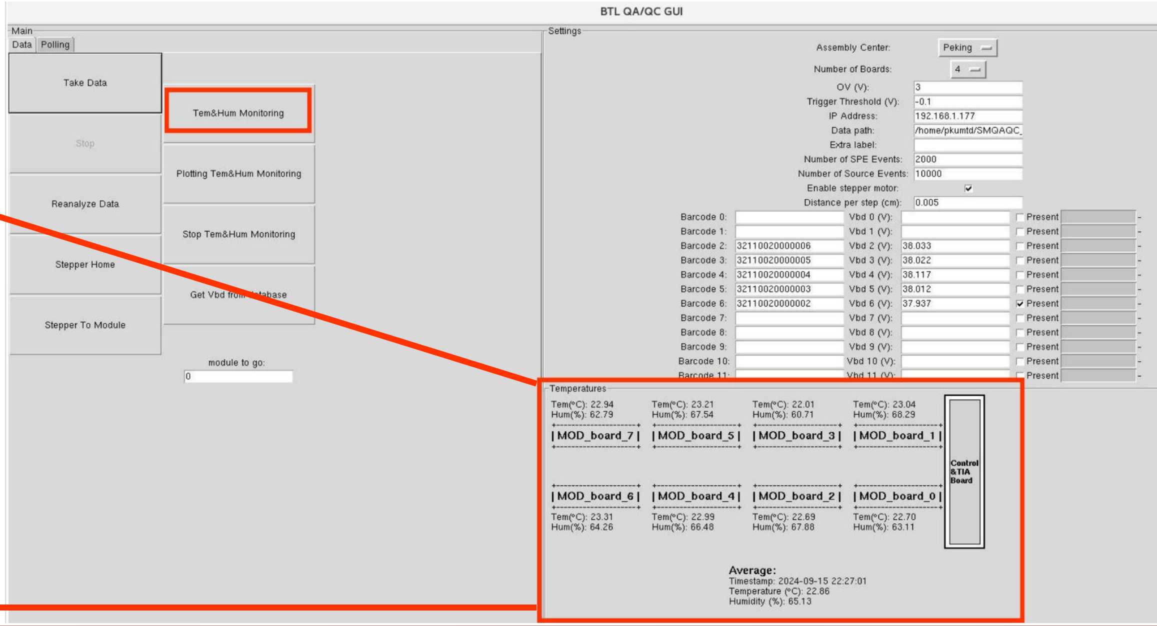
- During the testing process, the temperature and humidity data of each module position will be displayed in real-time on the GUI panel.

- The average data will also be displayed on the GUI panel in real-time

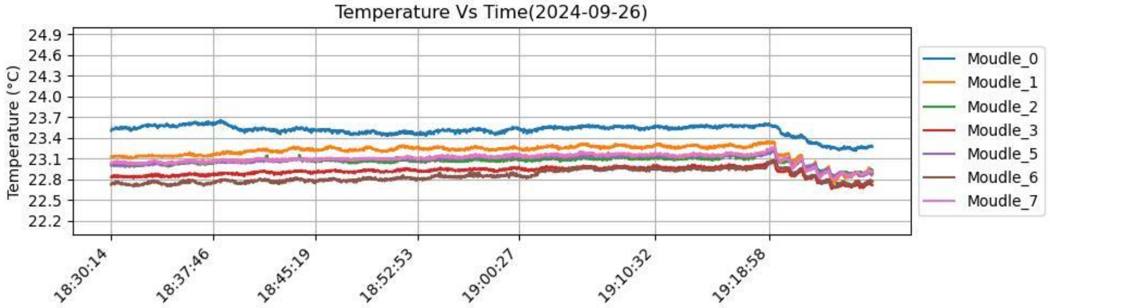
- You can choose any Moudle’s data (including average) drawn on a canvas at any time

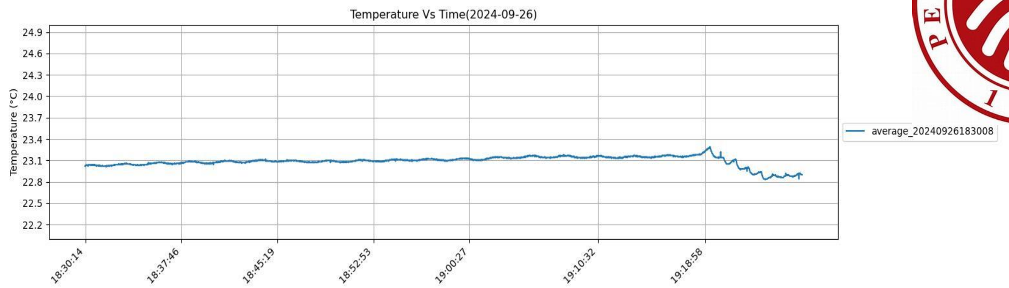


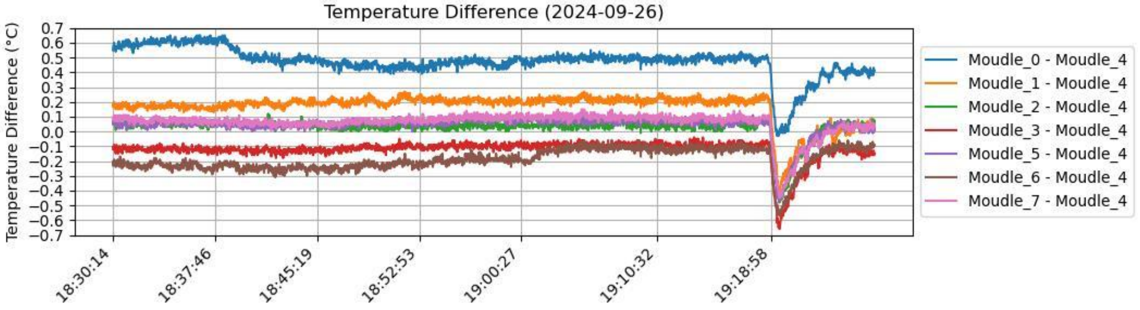


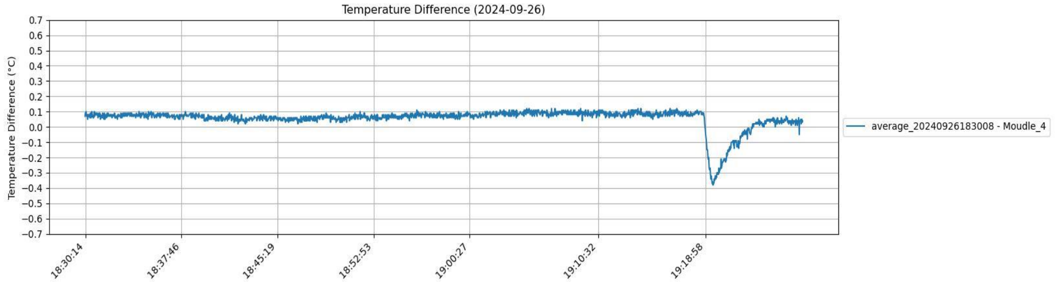


Temperature detection in formal QA/QC testing









- Before SM QA/QC, the temperature data of Moudle_4 sensor will calibrate the others, as it has been calibrated with a higher precision thermometer
- After correction, the temperature differences across 8 positions are minimal (± 0.1℃ ~ ± 0.2℃), indicating temperature uniformity in the entire dark box
- Only the temperature near Moudle_0 is relatively high (because it is close to control board, is affected by heat from it)
- The average temperature inside the box remained stable at ~23℃ during the QA/QC process, and the QA/QC test went smoothly

DM Thermal Test

Introduction of DM QAQC Thermal Test

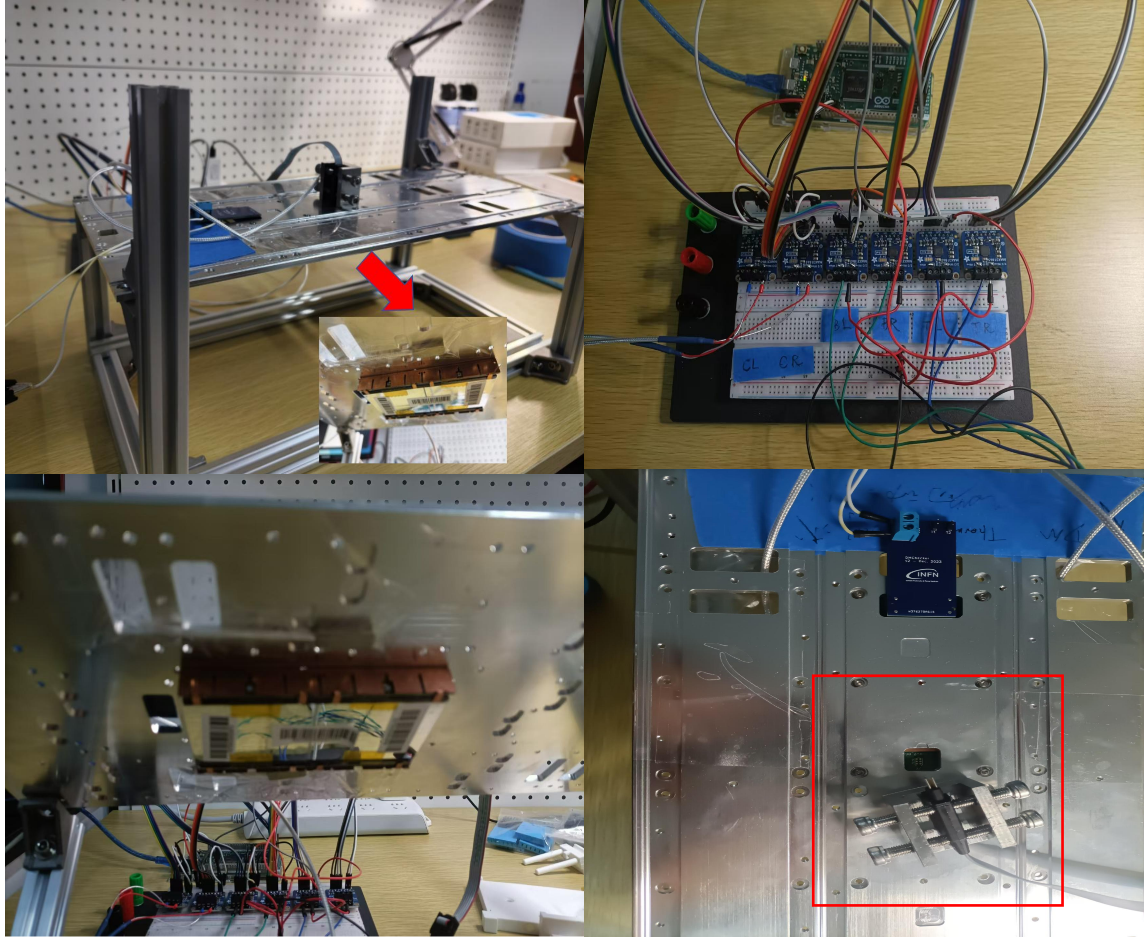
- Detector Module : Sensor module, FE front-end electronic board, and copper housing shell for heat exchange

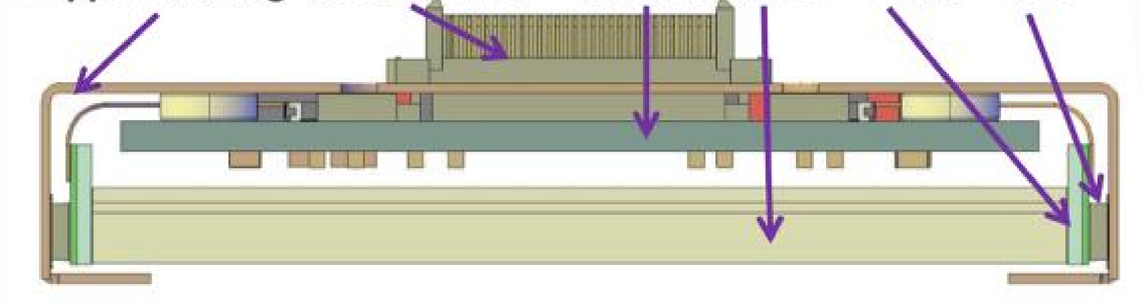
- The temperature of the DM QA/QC system is measured using 6 MAX31865 modules and 2 Pt1000 sensors

- Two Pt1000s are connected to the bottom of the DM QA/QC cooling plate for measuring its temperature

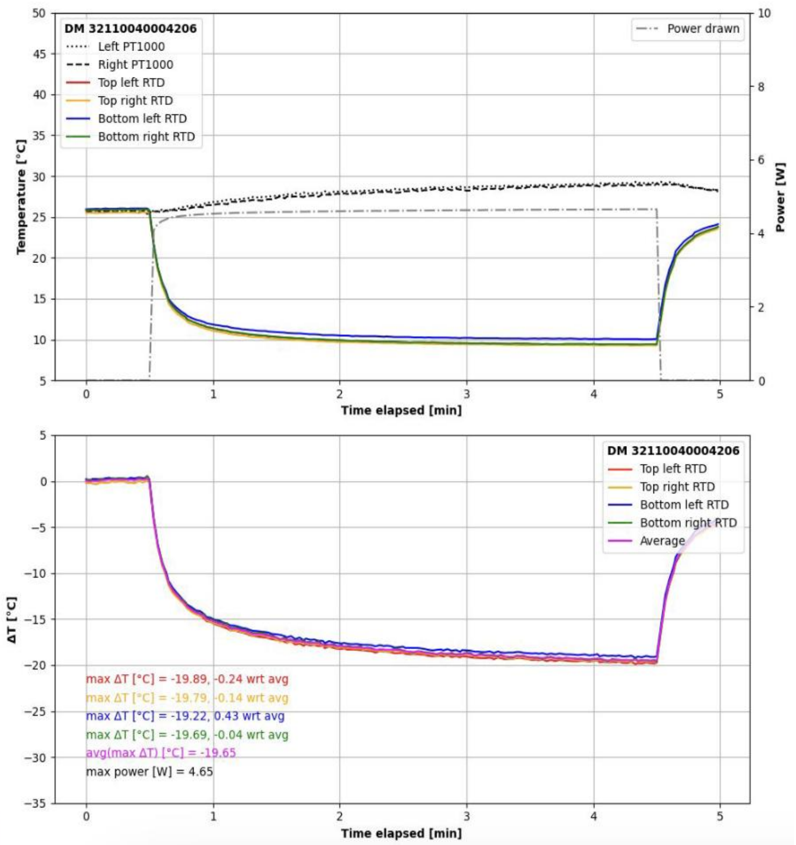
- The remaining four MAX31865 modules are pinned through the cooling plate's top opening to the DM slots, measuring temperature at four SiPMs(TL,TR,BL,BR).

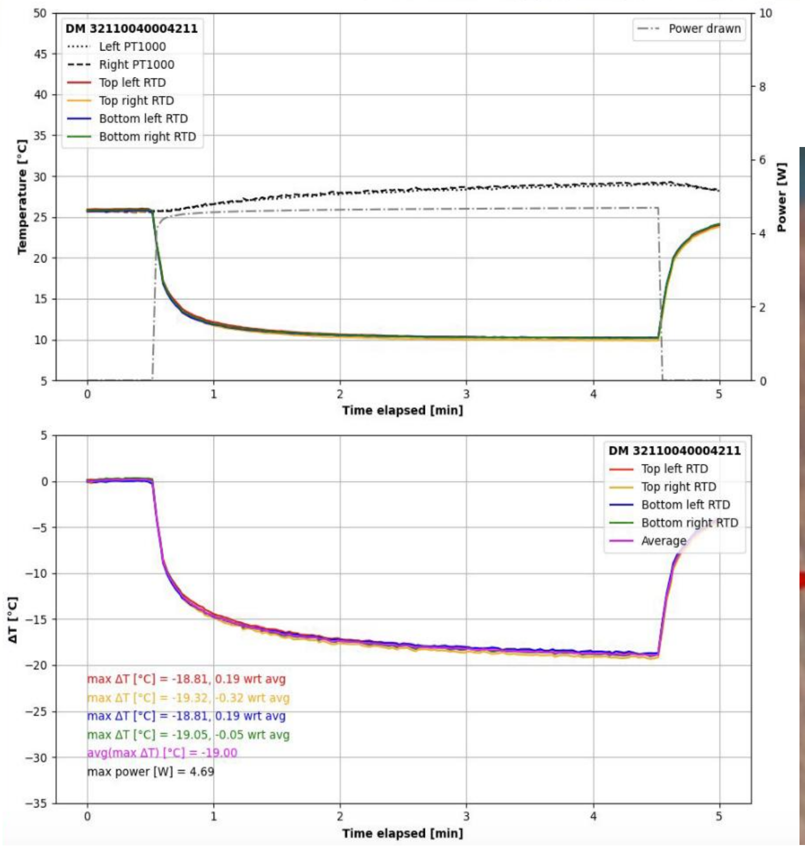
- Injecting currents to 16 TECs of SiPMs from the DM and measuring temperature differences at four locations, along with the cooling plate temperature, ensures good contact between the TECs on the SiPM and copper, evaluating the DM's assembly quality and thermal conductivity.

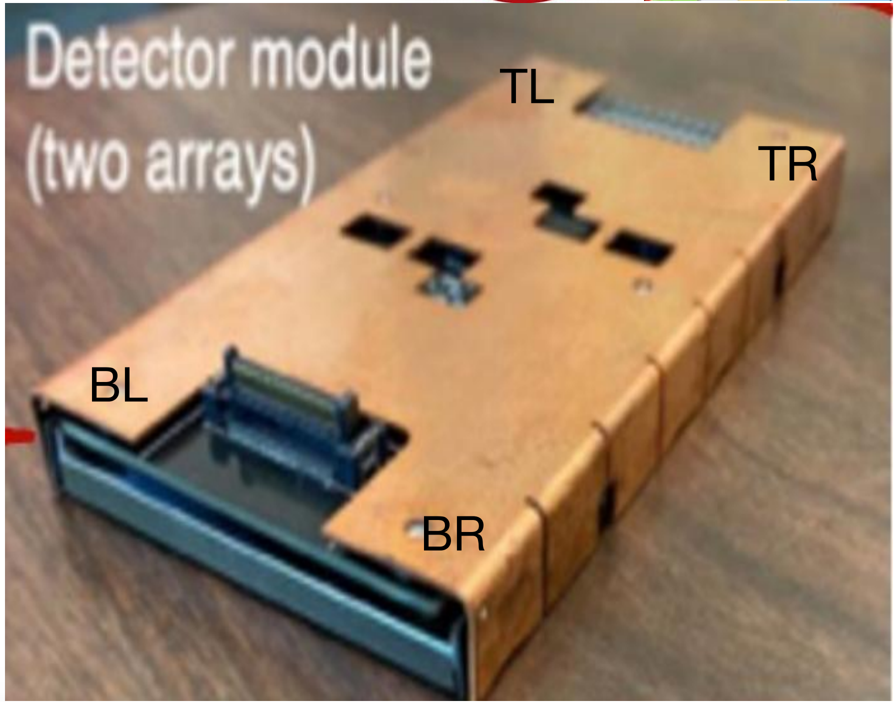




DM QAQC Thermal Test Status





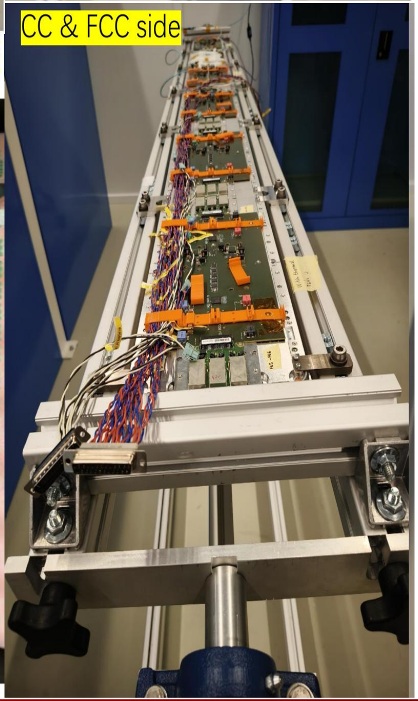


- Applying voltage to the TECs causes the SiPMs temperatures to decrease.
- As the temperature decreases, the small temperature differences (RMS(ΔT)~0.4℃) across the four positions indicate good temperature uniformity in the DM and a well-assembled structure
- The maximum temperature difference with the cooling plate, max ΔT (-19.65, -19.00), is within the DM QA/QC standard range, indicating that the assembly quality from SM to DM meets the standard.

Tray Thermal Test Setup

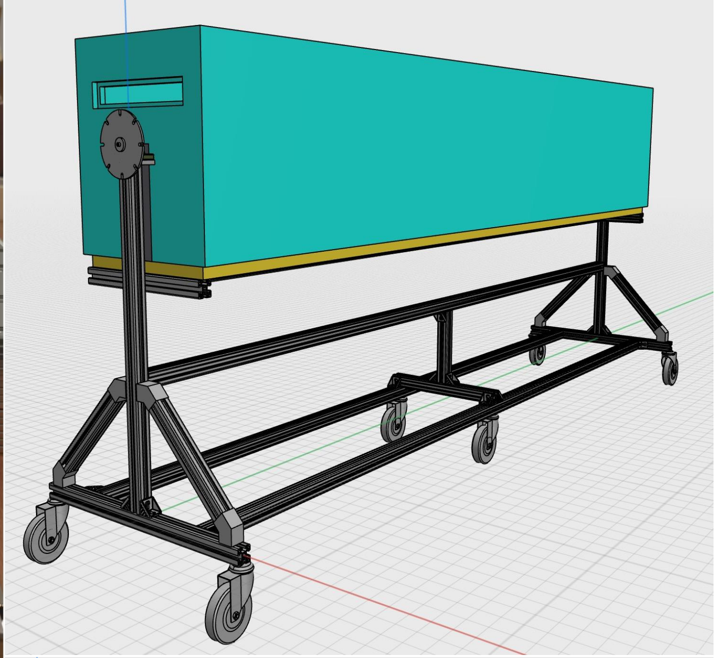
Introduction of Tray QAQC Thermal Test

- The tray QA/QC system based on Serenity board and custom tray powering board is currently being established
- In March 2024, the first RU was established during the pre-production phase at CERN
- The Tray Thermal test includes time and temperature acquisition, with a constant temperature environment needed for electronic input/output detection to ensure normal operation.
- The Tray consists of RU, DM, and SM, so Tray QA/QC requires constant temperature control and real-time temperature measurement.
- Cooling plate and CO_2 circulation installed on it ensure the normal operation of the modules and chips.

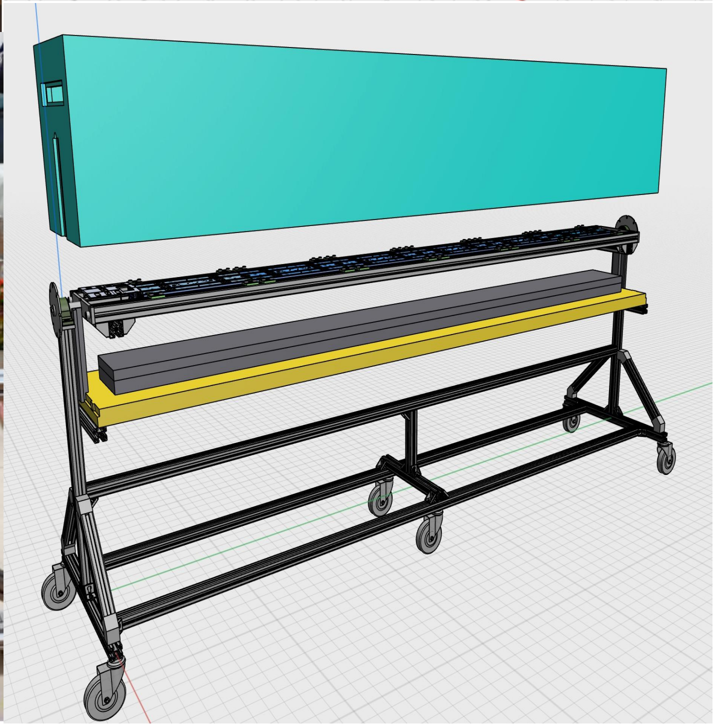


Tray QAQC Thermal Test Setup

- 2.5 × 0.2 × 0.03m Aluminum plate with 2 embedded cooling loops
- Plate segmented in 6 pieces (RUs)
- Cooling loops are held in place with laminas that are attached with screws to the cold plate.
- At PKU, we designed a tray shelf to carry the tray, and we also plan to mount a thermal dark box made of foam on the tray
- We plan to install a cooling system in the thermal dark box and use AHT20 sensors with TCA9548A for real-time temperature monitoring



Tray shelf for Tray assembly and QAQC



Summary

Summary

- SM QA/QC:
  - To ensure consistent QA/QC result(light yield), temperature is controlled and monitored by using AHT20 sensors and TCA9548A in the dark box system, stabilizing the temperature at 23℃

- DM QA/QC:
  - Temperature measurements with MAX31865 modules and Pt1000 sensors ensure good TEC-copper housing contact and uniform temperature across four DM areas, indicating quality assembly.

- Tray QA/QC:
  - PKU is planning a Tray QA/QC system with a design blueprint to meet the environmental and testing requirements for Tray thermal tests, including temperature control and real-time monitoring.

Back Up

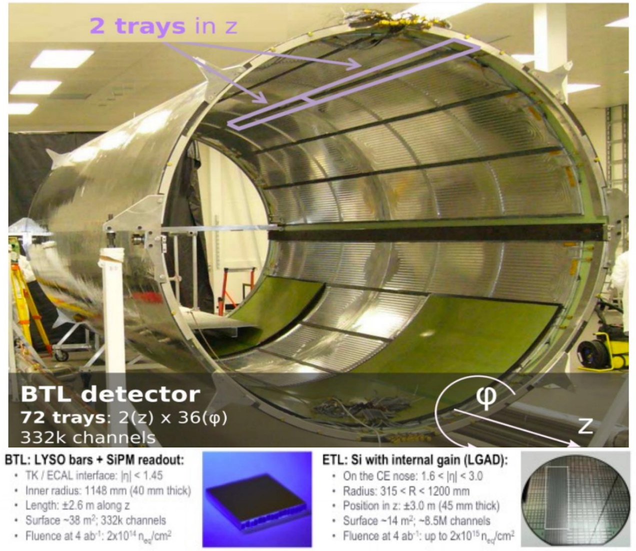
MTD BTL Overview

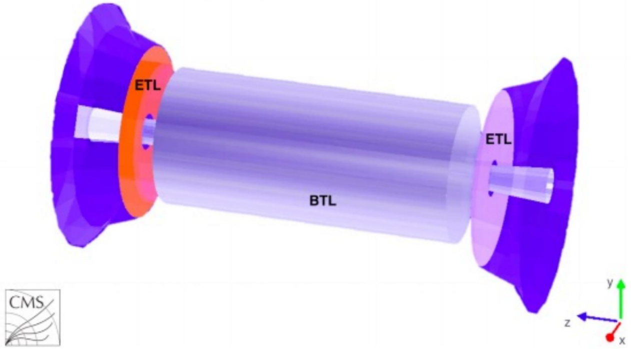
➢ Physics Motivation of MTD

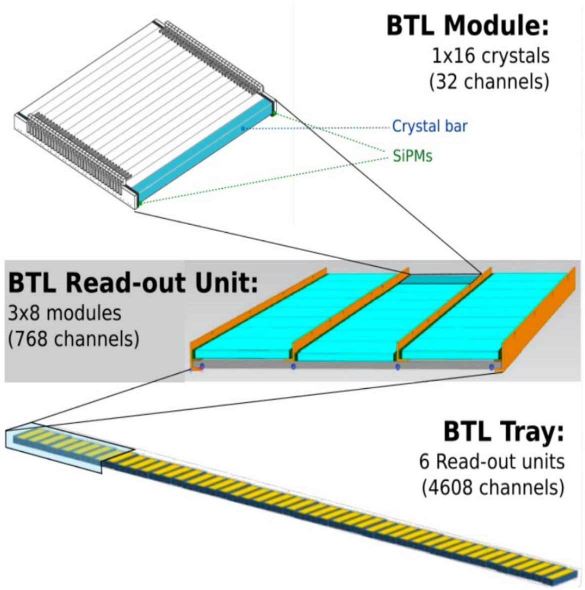
- MTD can effectively suppress pileup, improving the overall accuracy of physical measurements
- MTD provides TOF data, enhancing Higgs precision by 20-30%, increasing Di-Higgs acceptance by 20%, reducing SUSY background by 40%, and boosting sensitivity to long-lived particles

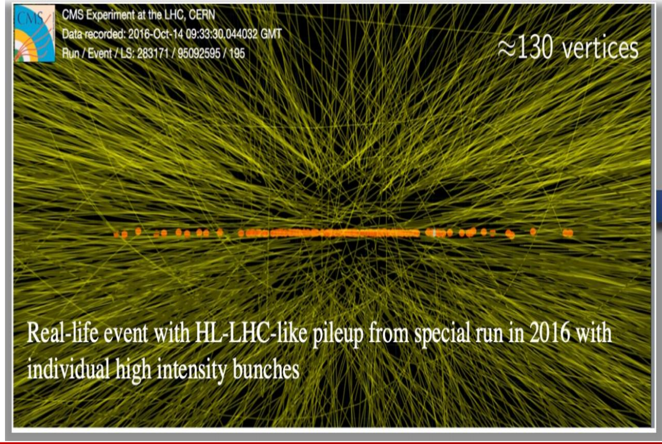
➢ What is MTD BTL ?

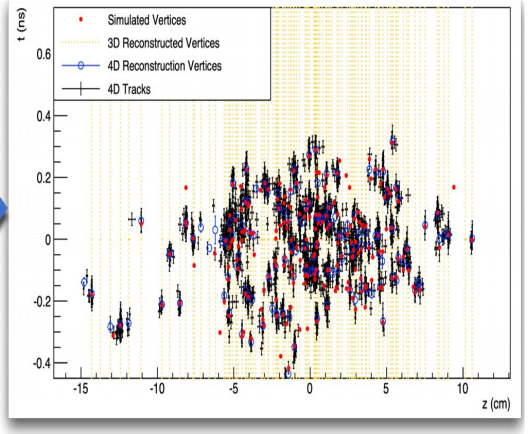
- BTL is a single-layer MIP detector located in-between the outer tracker (OT) and the inner wall of the BTL_x0002_Tracker Support Tube (BTST)
- It will measure time with ~30-60ps resolution.
- Thin (< 4cm), large area ($38m^2$) detector covering |η| < 1.5
- ~10k Sensor Modules, each containing 16 scintillating LYSO crystal bars and two 16-channel SiPM arrays







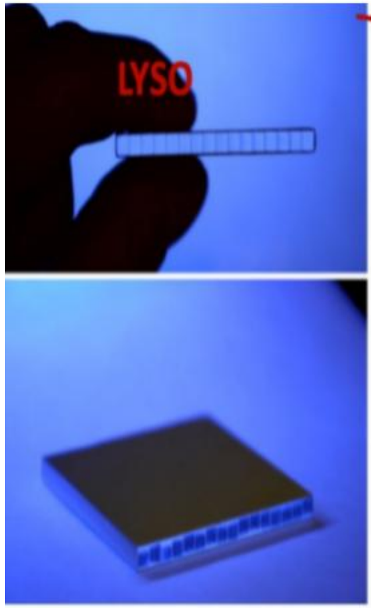




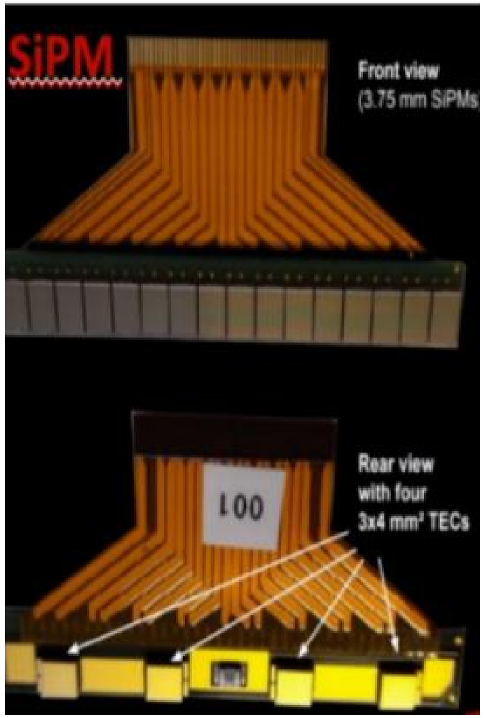
SiPM and Lyso

LYSO stands for **Lutetium-Yttrium Oxyorthosilicate**. This is an inorganic scintillator material, formally known as **Lutetium Yttrium Orthosilicate ($Lu_2(SiO_4)O$)**.

Radioactive Source



optical signal



electrical signal

The APD (avalanche photodiode)

The MPPC (multi-pixel photon counter)

Silicon PhotoMultipliers

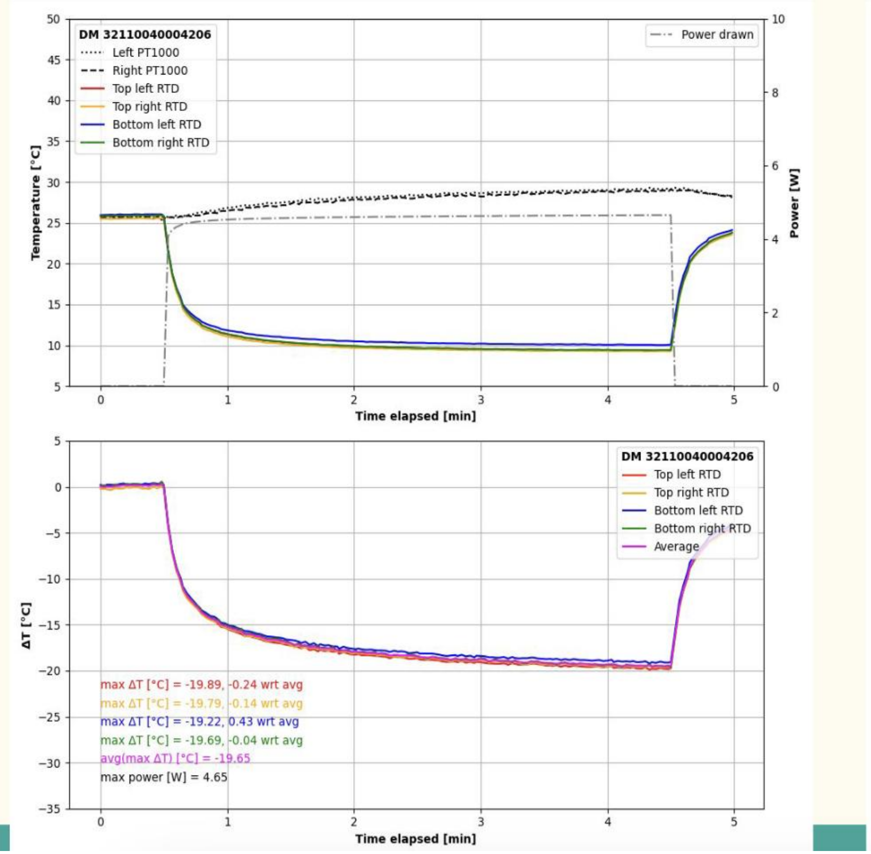
Defination of dark count rate

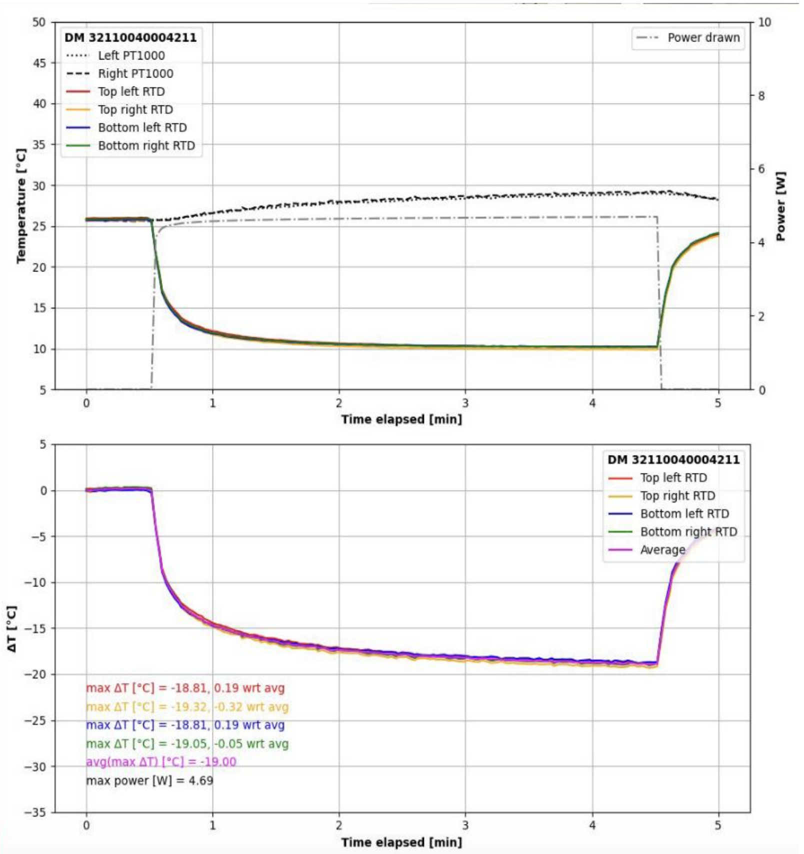
In the MPPC operation just the same as with APD, pulses are produced not only by photon-generated carriers but also by thermally-generated carriers. The pulses produced by the latter are called the dark pulses. The dark pulses are

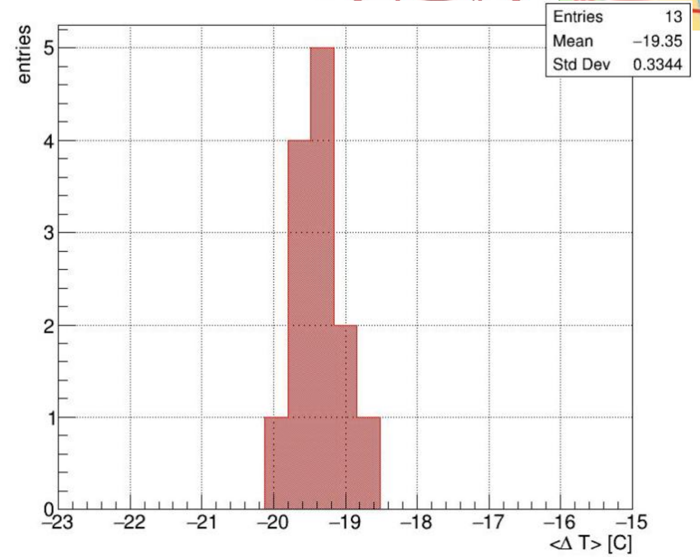
In a dark state, the number of pixels where avalanche multiplication occurred equals the dark count rate, so the dark current I_D can be approximated to equation (9) using $N_{0.5\,p.e.}$ and Pcrosstalk. If the gain and crosstalk probability at a particular reverse voltage are known, then the dark current can be roughly estimated from the dark count rate and vice versa.

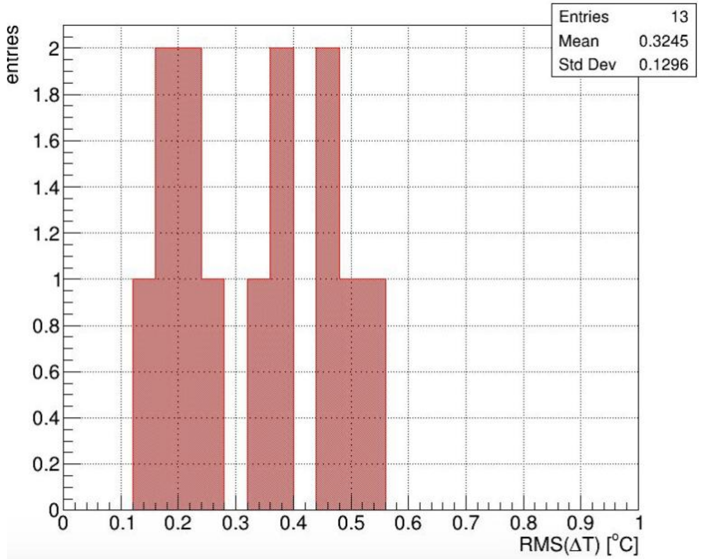
$$I_D \approx q\, M\, N_{0.5\,p.e.} \frac{1}{1 - P_{crosstalk}} \quad \cdots\cdots\cdots \quad (9)$$

DM QA/QC RMS


DM 32110040004206
Left PT1000
Right PT1000
Top left RTD
Top right RTD
Bottom left RTD
Bottom right RTD
Power drawn
Temperature [°C]
Power [W]
Time elapsed [min]
Average
ΔT [°C]
max ΔT [°C] = -19.89, -0.24 wrt avg
max ΔT [°C] = -19.79, -0.14 wrt avg
max ΔT [°C] = -19.22, 0.43 wrt avg
max ΔT [°C] = -19.69, -0.04 wrt avg
avg(max ΔT) [°C] = -19.65
max power [W] = 4.65

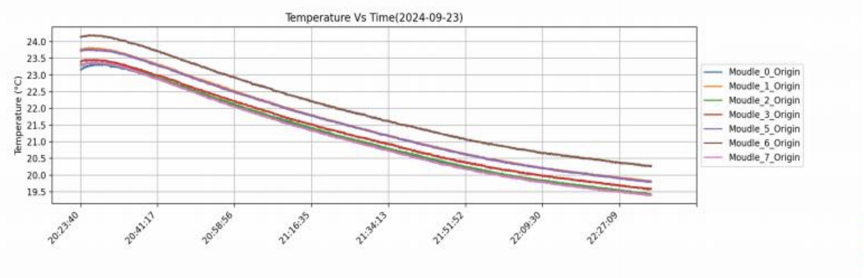

DM 32110040004211
Left PT1000
Right PT1000
Top left RTD
Top right RTD
Bottom left RTD
Bottom right RTD
Power drawn
Temperature [°C]
Power [W]
Time elapsed [min]
Average
ΔT [°C]
max ΔT [°C] = -18.81, 0.19 wrt avg
max ΔT [°C] = -19.32, -0.32 wrt avg
max ΔT [°C] = -18.81, 0.19 wrt avg
max ΔT [°C] = -19.05, -0.05 wrt avg
avg(max ΔT) [°C] = -19.00
max power [W] = 4.69

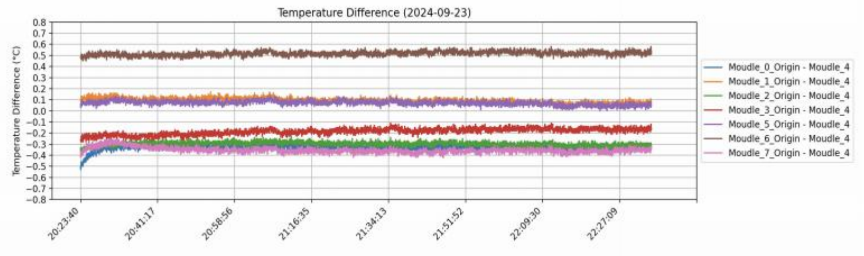

Entries 13
Mean −19.35
Std Dev 0.3344
entries
<Δ T> [C]

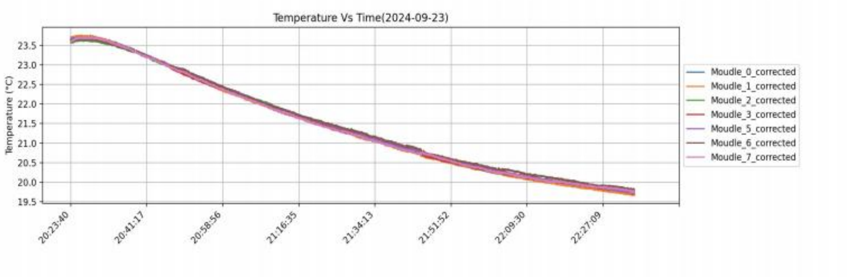

Entries 13
Mean 0.3245
Std Dev 0.1296
entries
RMS(ΔT) [°C]

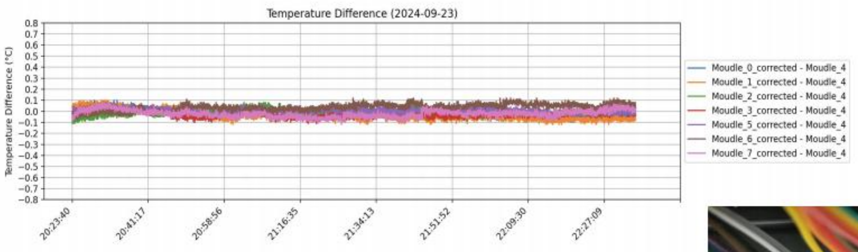
[QAQC_Tem%26Hum_PKU.pdf](#) [AHT20_system_code](#)

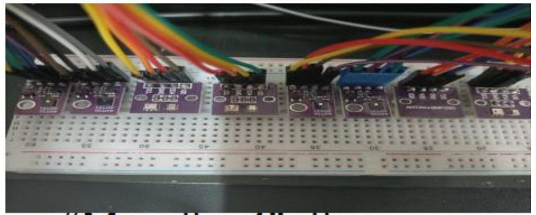
Temperature Correction





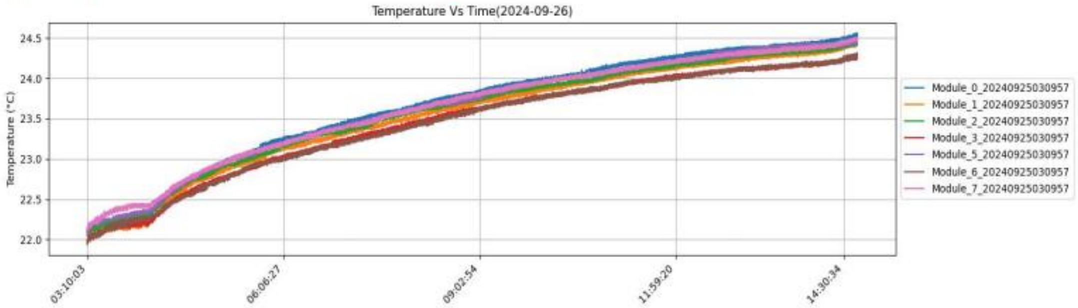


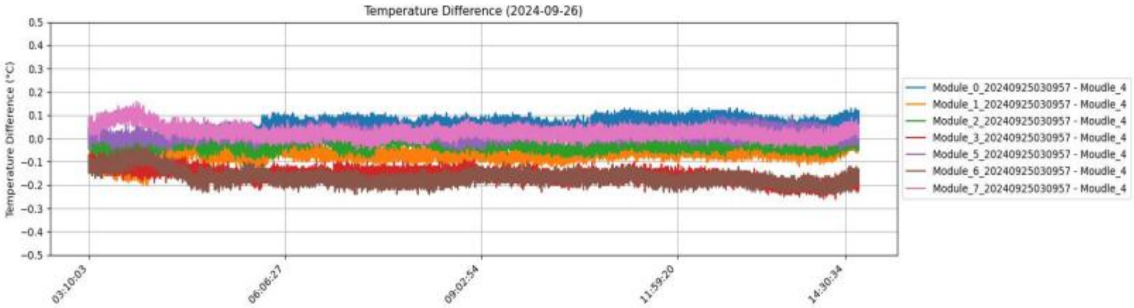


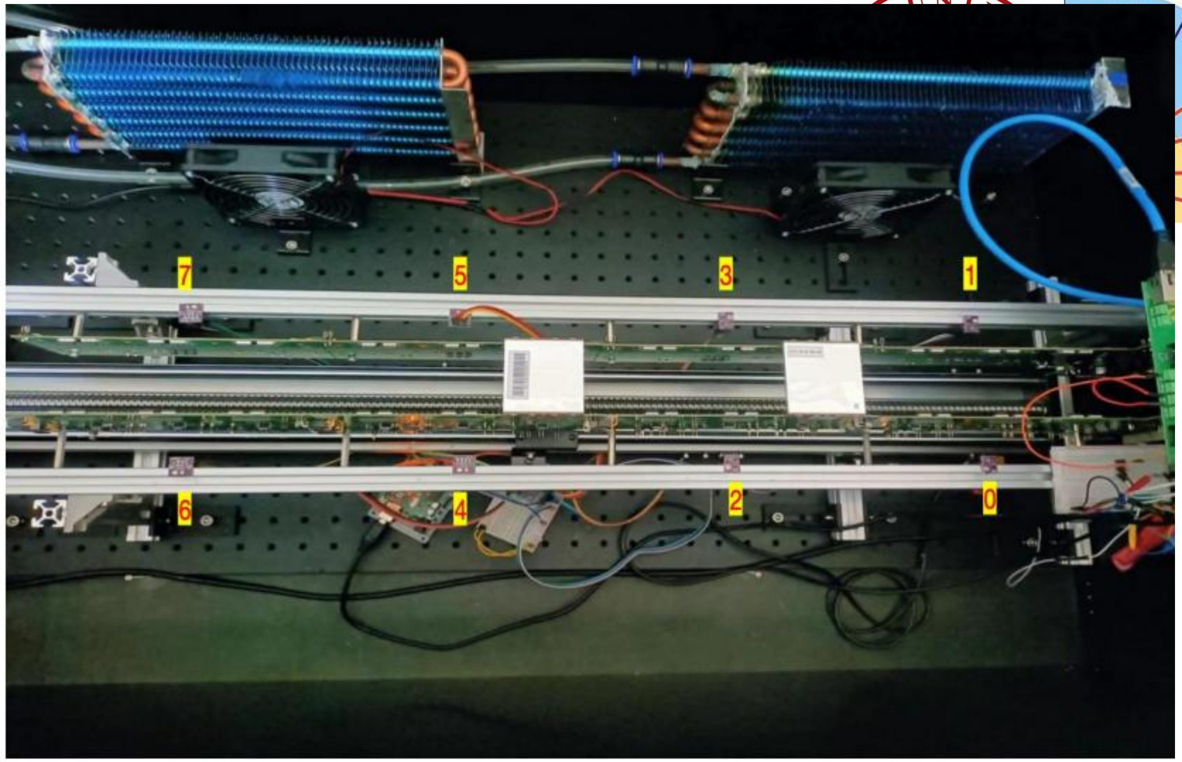


- Firstly, eliminate the temperature measurement differences between each sensor
- Place all 8 sensors together to measure temperature, then correct their readings based on “Moudle_4”, the most accurate sensor.
- Only the air conditioning is on, without turning on water cooling system and QAQC test system
- According to this cooling process (24℃ to 19.5℃) , we create correction [JSON files](#) with the temperature differences between "Moudle_4" and other sensors at each 0.1℃ step
- After correction by [JSON files](#), the temperature error is about ±0.1℃, which is within the acceptable range

T(℃) differences at 8 postions After correction







- We sealed the dark box and completed the simple test with only the air conditioning on, without turning on water cooling system and QAQC test system
- After correction, the temperature differences across 8 positions are minimal (±0.1℃~±0.2℃), indicating uniformity in the dark box.

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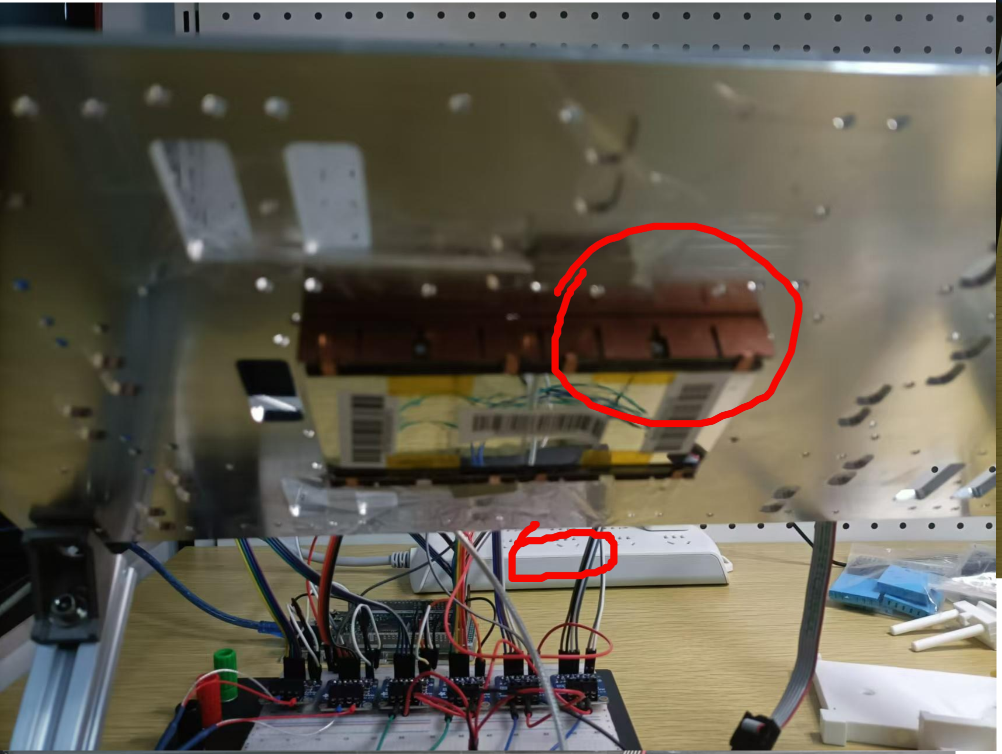
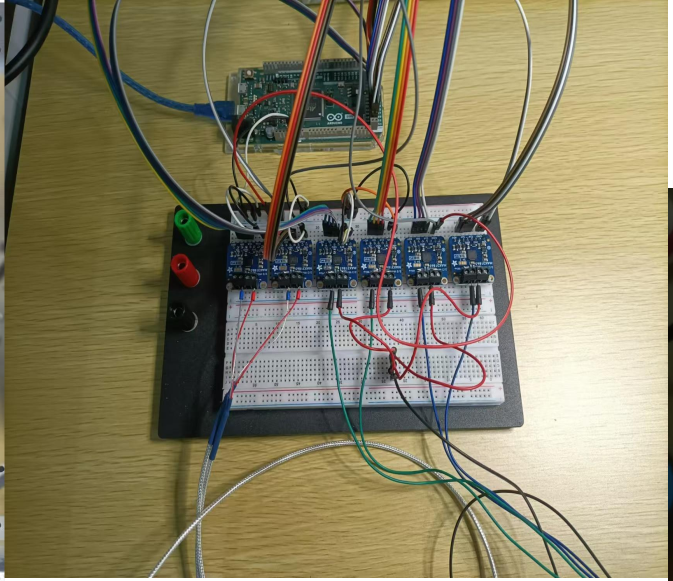
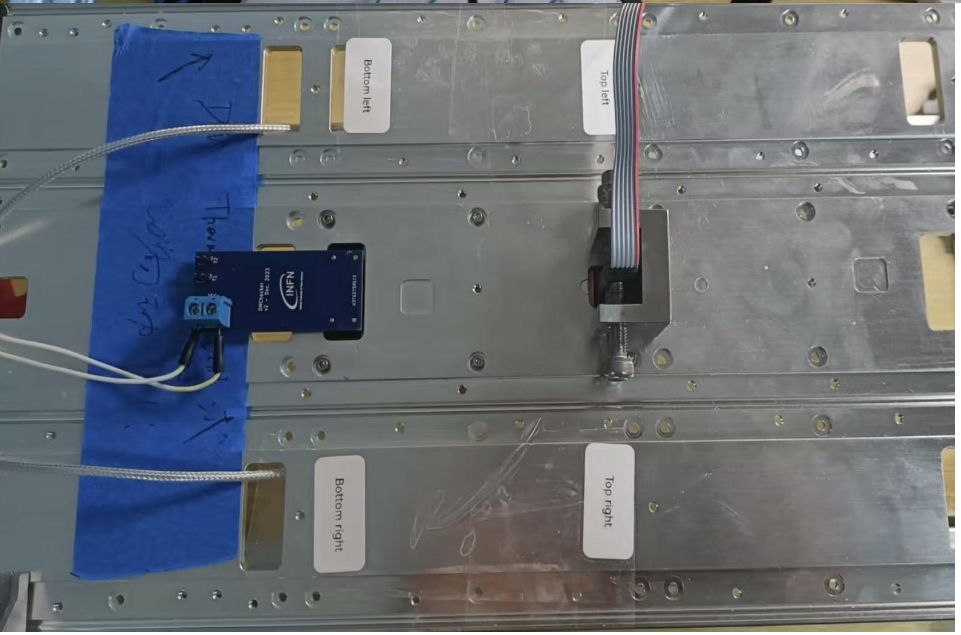
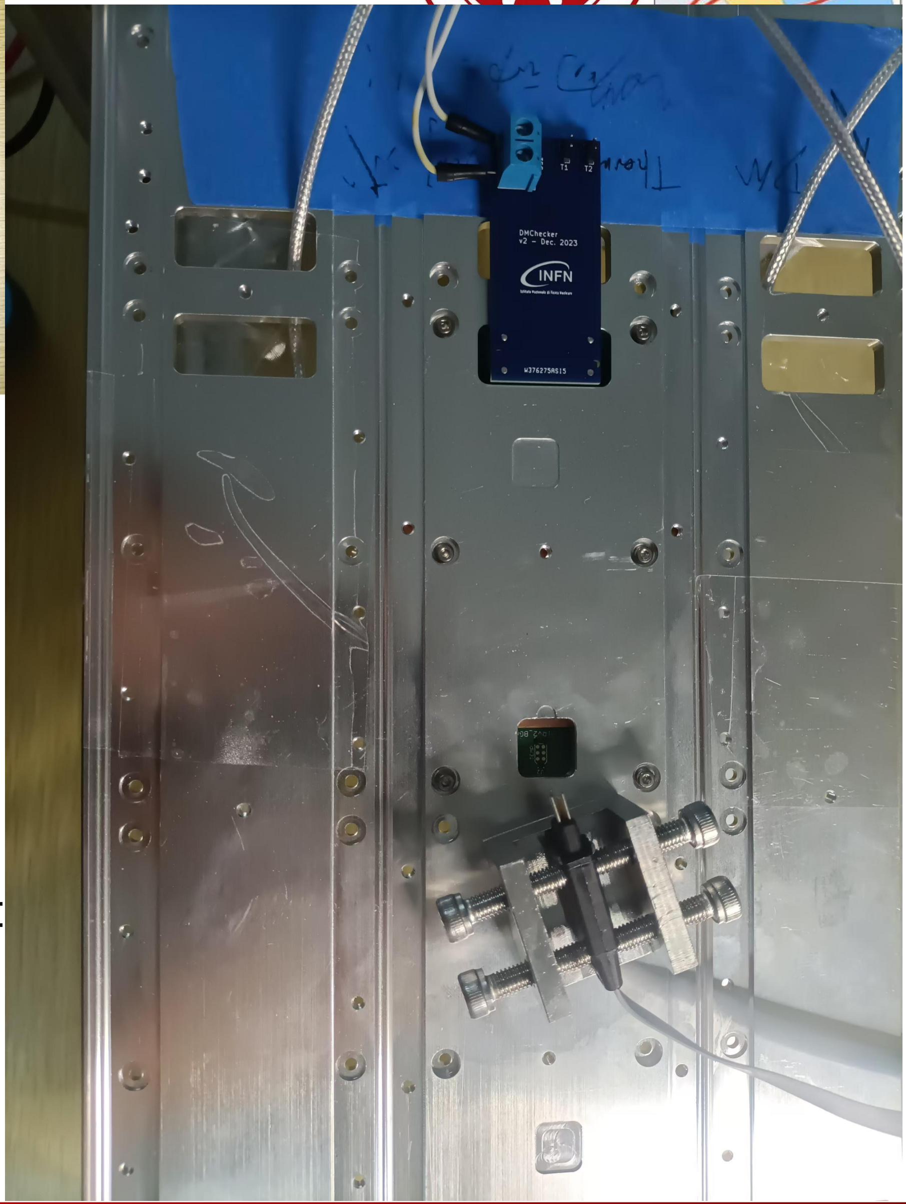


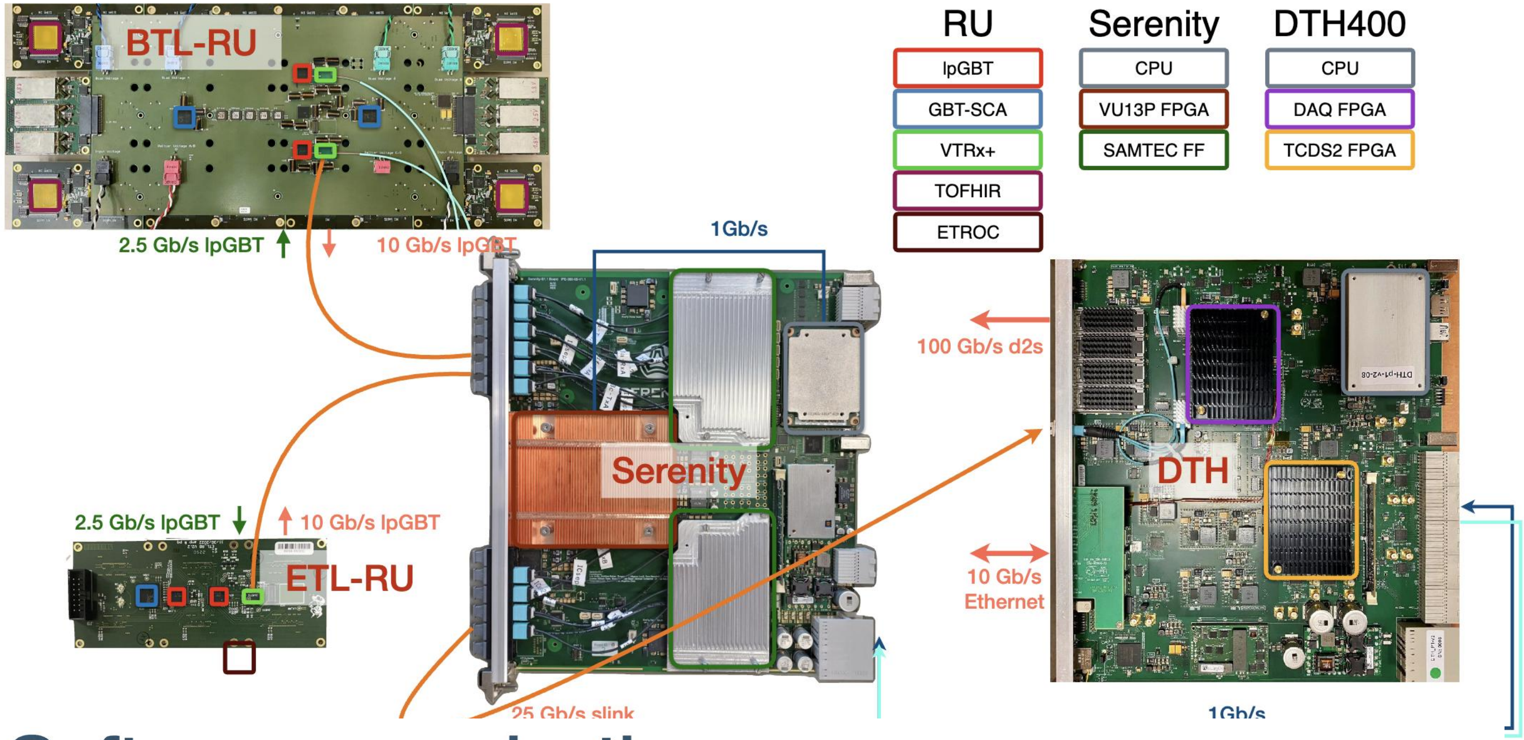




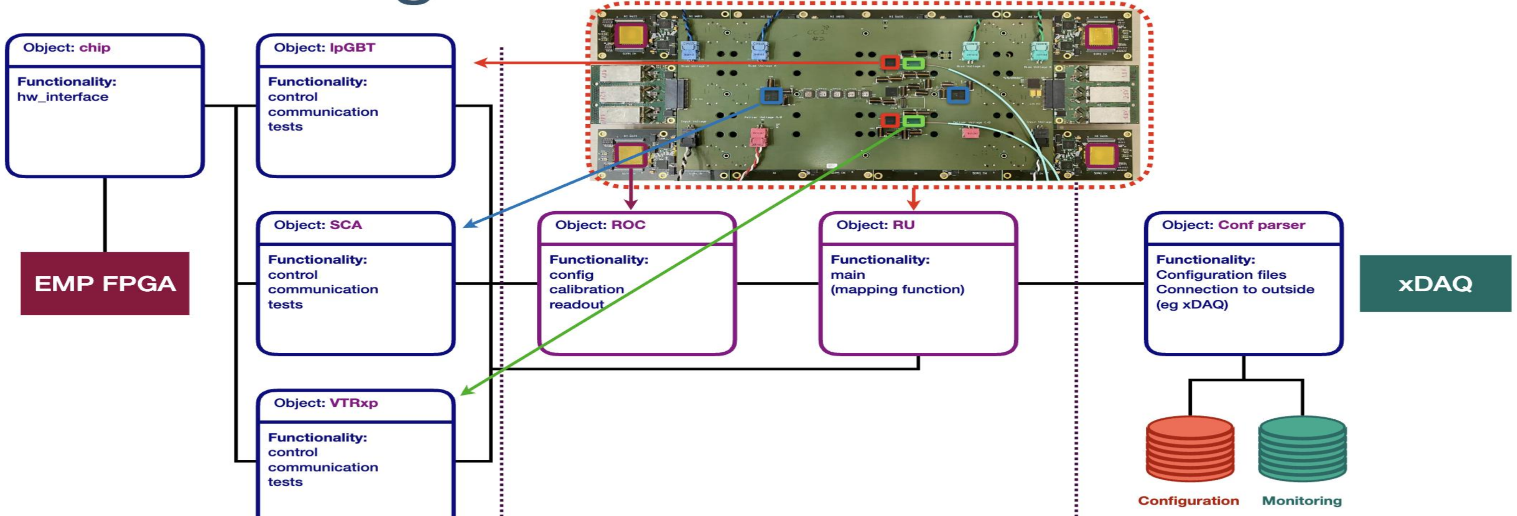
DMchecker:

The DM Checker operates by connecting the SiPMs to an external LCR meter, which enables precise measurement of the Detector module's resistance.





Software organization



FMTD_DAQ_Hackathon.pdf

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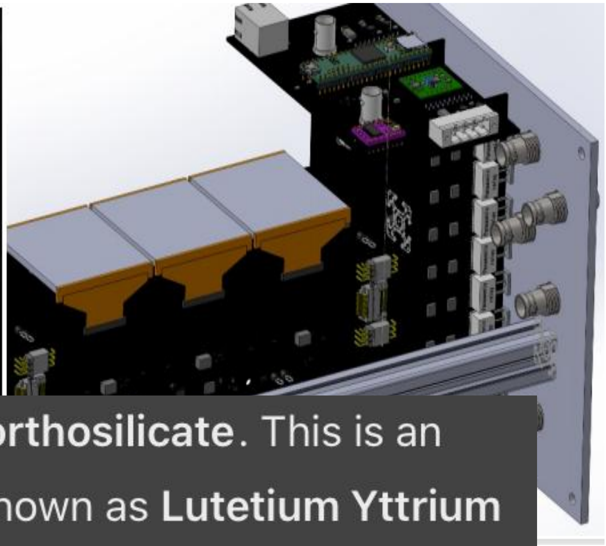
Reason for high temperature at Moudle-0

Heat



LYSO stands for **Lutetium-Yttrium Oxyorthosilicate**. This is an inorganic scintillator material, formally known as **Lutetium Yttrium Orthosilicate ($Lu_2(SiO_4)O$)**.