HGCal module test at IHEP
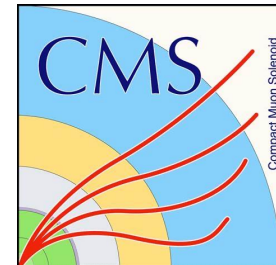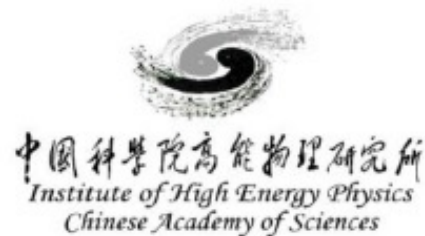
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On behalf of the Chinese HGCal group

CLHCP 2024
November 15, 2024

# Outline

☐ Introduction

☐ Testing Procedure

☐ Quality Assurance & Control

   ☐ Alignment

   ☐ Electronic

   ☐ IV Responce

☐ Database

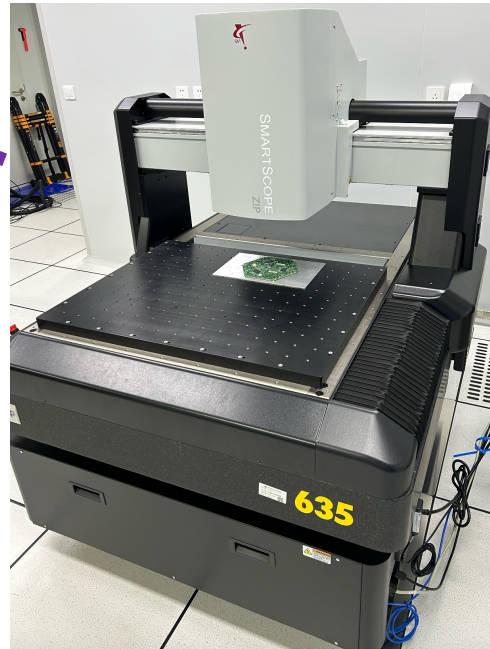☐ Summary and Outlook

Introduction

❖ <mark>**Significance of Testing**</mark>

- One of crucial procedures in HGCAL assembly.
    1. Identified the final quality of HGCAL modules.
    2. Make sure no damage caused after each assembly process.
- Quality assurance and control criteria
    1. Alignment
    2. Number of electronic readout and noise level
    3. IV response (Current v.s. Voltage)
- Also important features but not in the final grading
    1. Flatness of baseplate
    2. Bonding wire tightness
    …

Testing Procedure

Module production procedure

Optical Gaging Product (OGP)
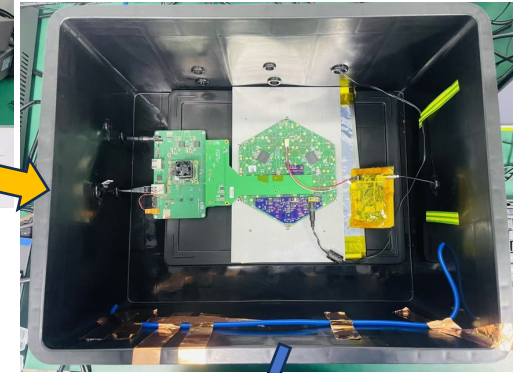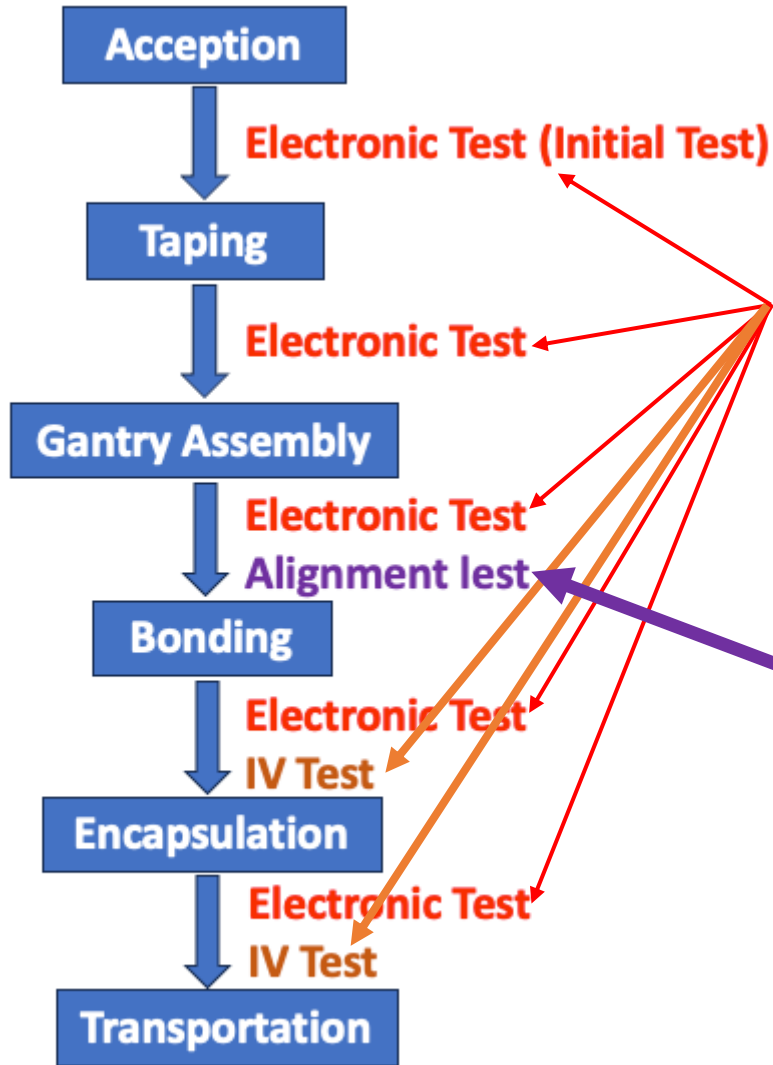
The blue tube is used to introduce dry gas to reduce humidity.

Alignment

Summarized Accuracy Plot

- **Sensor wrt Baseplate** ● **Baseplate**
- **PCB wrt Baseplate**

Grade A: misplacement of X and Y < 150 μm & < 0.1 degree
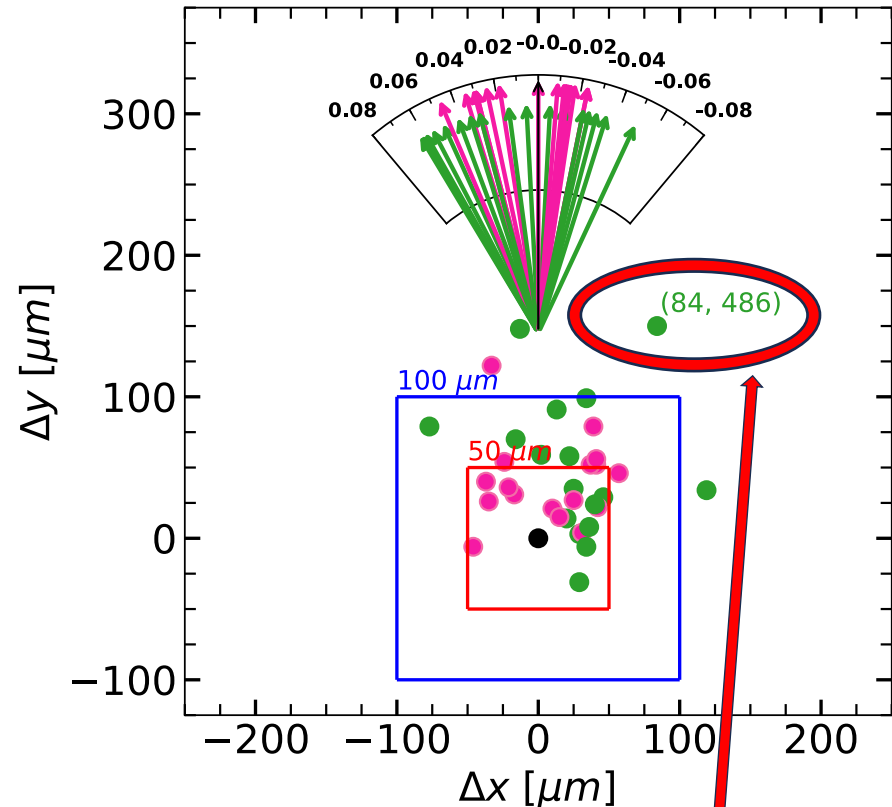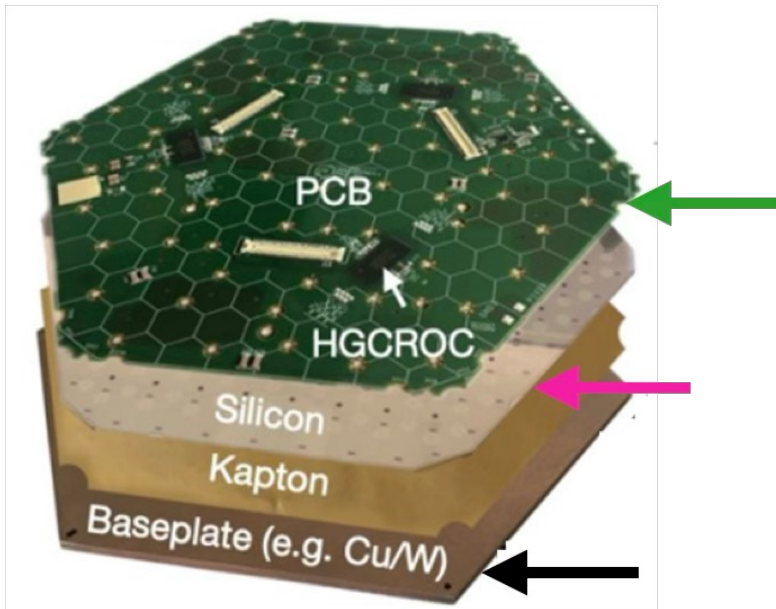
- ❑ **Basically like making a "sandwich".**
- ❑ **All alignments met the grade A criteria except one manual accident.**
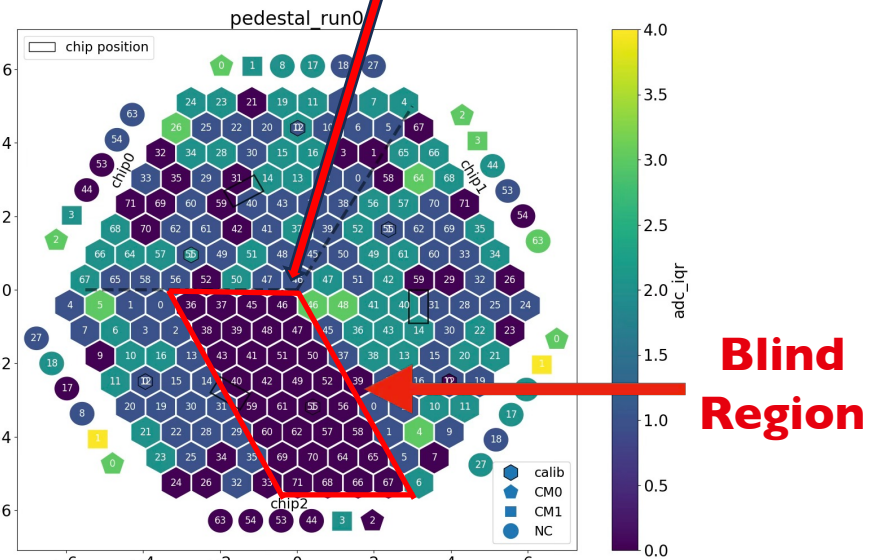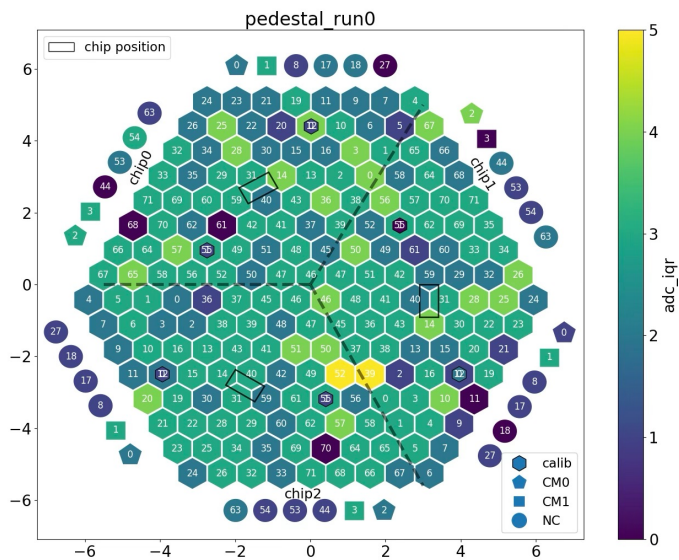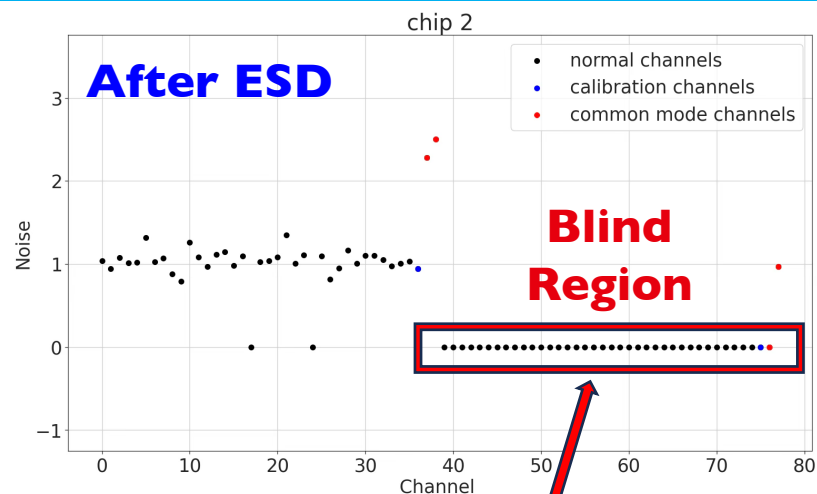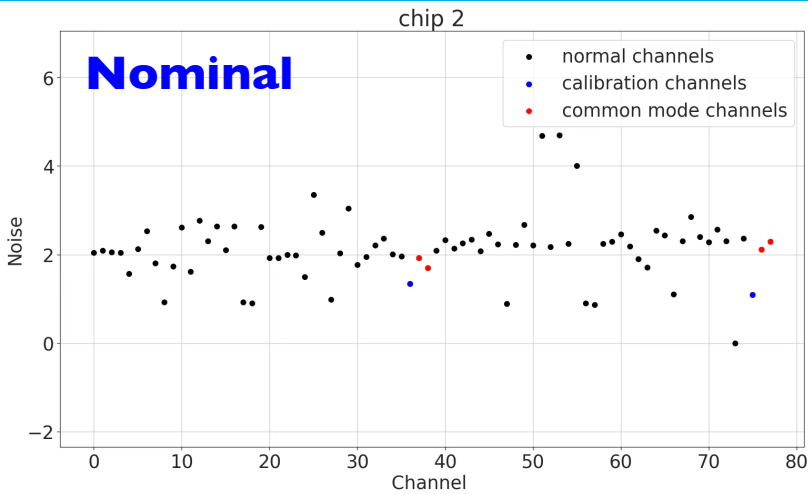- ❑ **Gantry guys did a good job!**

Electronic Test

For example:
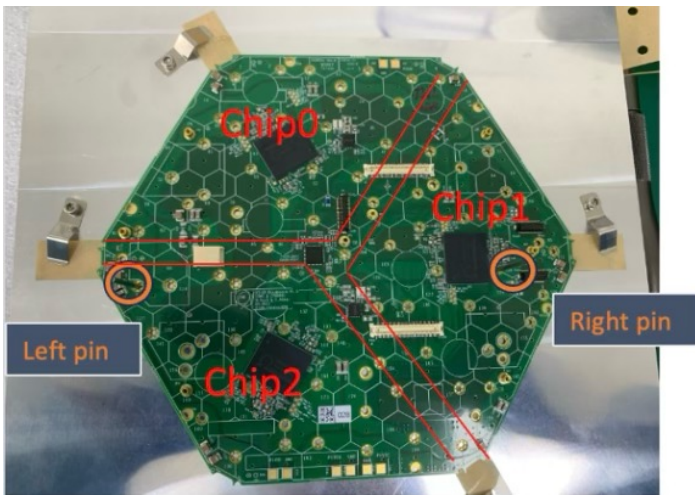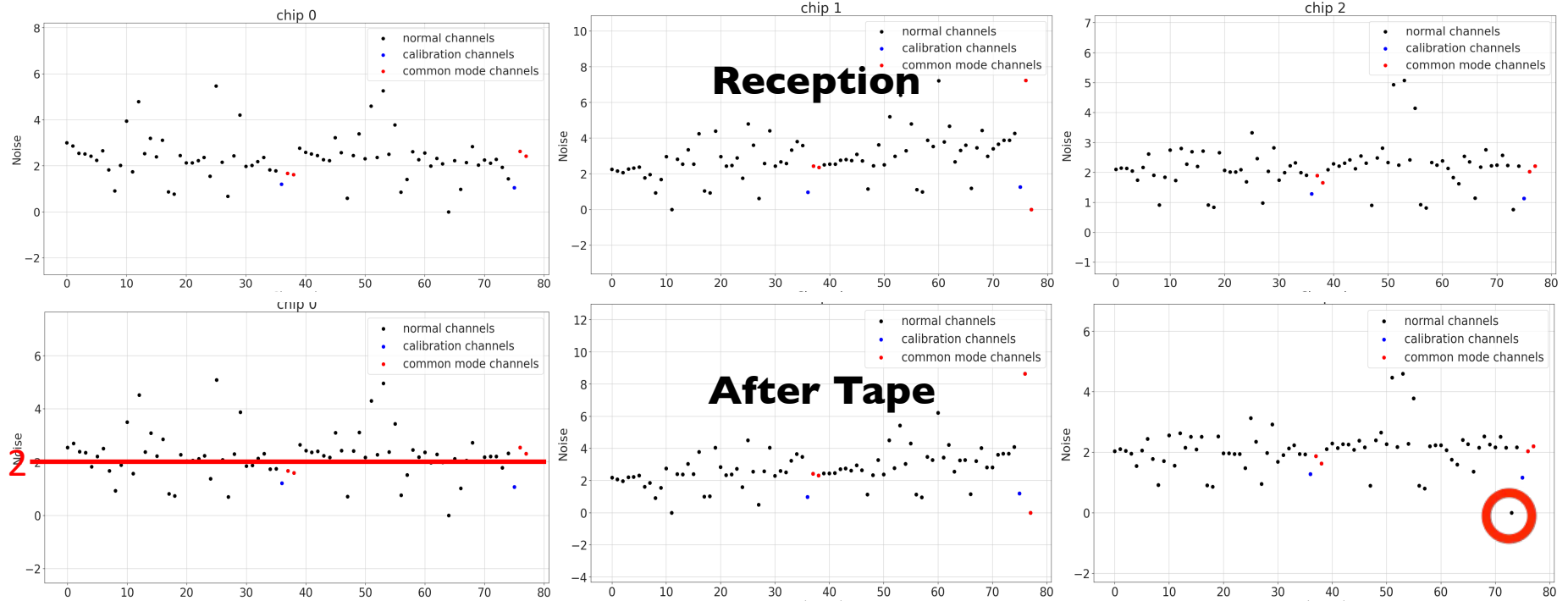
1. Check whether introduce additional dead channels after each process.
2. Exam whether the noise level is reasonable, (2 ADCs).

Electrostatic Discharge (ESD)

- IHEP was the first lab aware of ESD, which was later confirmed by CERN.
- The corresponding ESD protection measures have been applied.

ESD Protection Measures
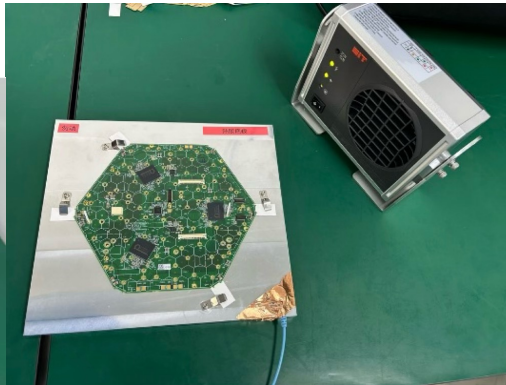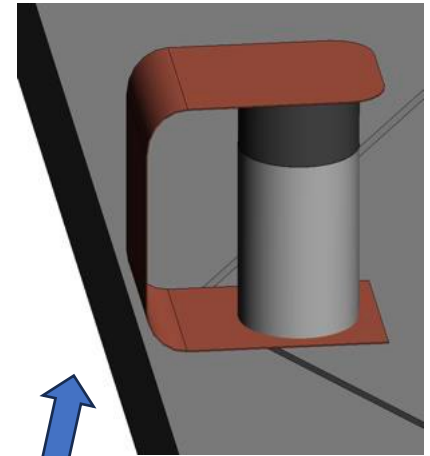

Grounding

Anti-static Gloves & Wrist Strap

Ionizing Fan

Anti-static box

Additional protection applied:
- Ground HV capacitor using a conductor connected to fixture used for transfer tape tasks

Initial ESD protections measures:
- Both People and equipment are grounded
- Anti-electrostatic gloves for operation
- Ionizing Fan
- Anti-electrostatic box for transportation

Electronic Test Summary

❖ <mark>**7 Pre-Production**</mark>

Module IDs	PCB ID	# of Dead Channels	Grade A (# < 10)
ML_F3WX_IH_00014	02	0	A
ML_F3WX_IH_00015	09	0	A
ML_F3WX_IH_00016	10	0	A
ML_F3WX_IH_00017	03	0	A
ML_F3WX_IH_00018	01	0	A
ML_F3WX_IH_00019	04	0	A
ML_F3WX_IH_00020	101	0	A
# of A			7

- The quality of this batch of PCB boards is exceptionally high.

Electronic Test Summary

❖ <mark>10 Pre-Series</mark>

| Module IDs	PCB ID	# of Dead Channels	Grade A (# < 10)
ML_F3WX_IH_00021	84	6	A
ML_F3WX_IH_00022	60	3	A
ML_F3WX_IH_00023	53	14	A*
ML_F3WX_IH_00024	45	4	A
ML_F3WX_IH_00025	54	8	A
ML_F3WX_IH_00026	55	3	A
ML_F3WX_IH_00027	56	2	A
ML_F3WX_IH_00028	57	8	A
ML_F3WX_IH_00029	58	13	A*
ML_F3WX_IH_00030	59	8	A
# of A			8

• Did not introduce any additional dead channel from our assembly.
(All dead channels are from initial PCB itself.)
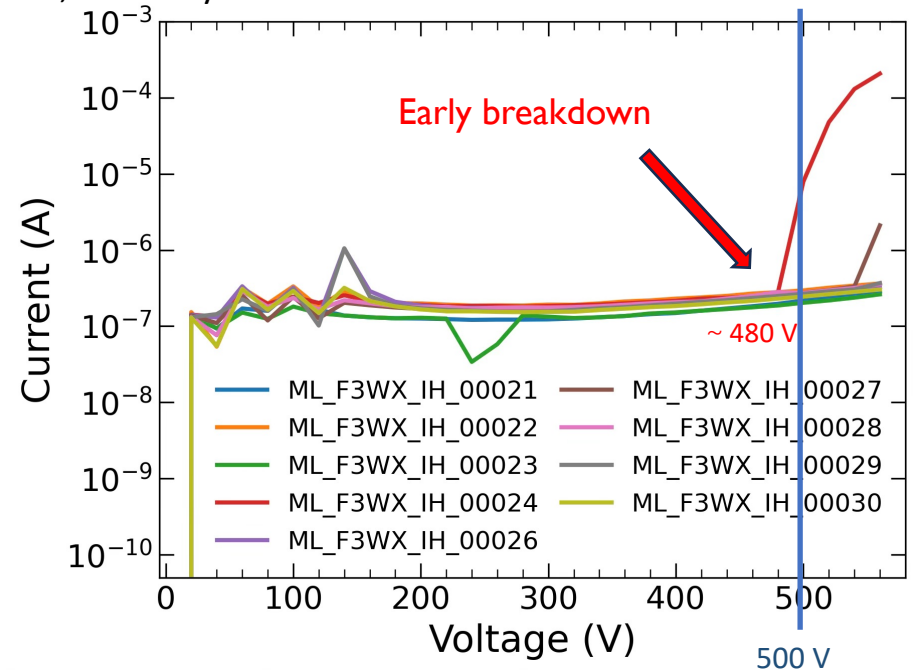• 8 PCBs were "A" when we received them; the other 2 were A*.

7 Pre-Production Modules

10 Pre-Series Modules

Temperature ~ 20℃, Humidity ~ 1%
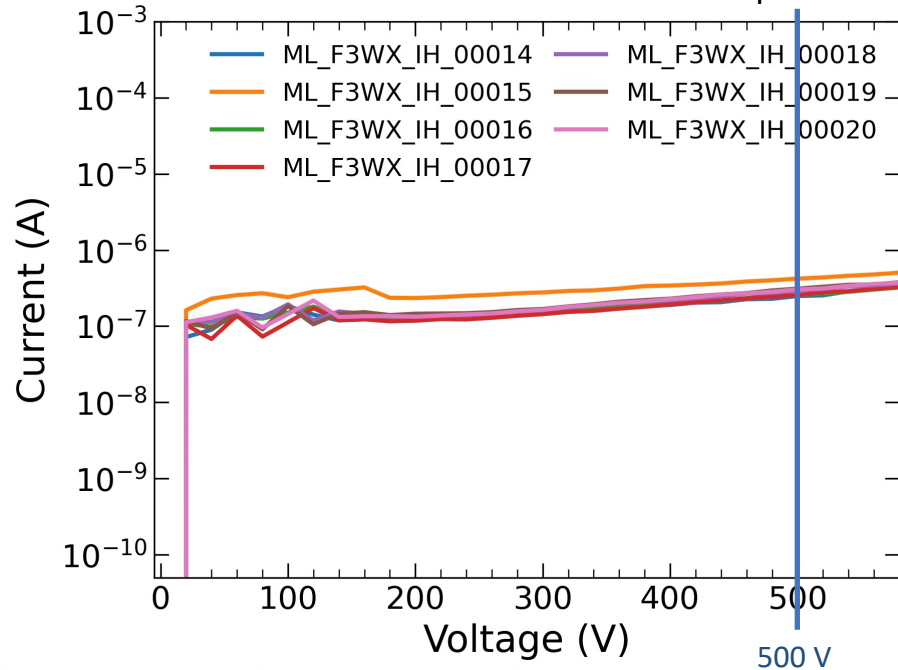
- Grade A: Breakdown voltage > 500 V for now and I(850 V) / I(600 V) < 2.5 will be added in future.
- 16 modules are graded as A.
- Potential reasons for early breakdown:
  - Humidity between the layers need to be dissipated.
    - …
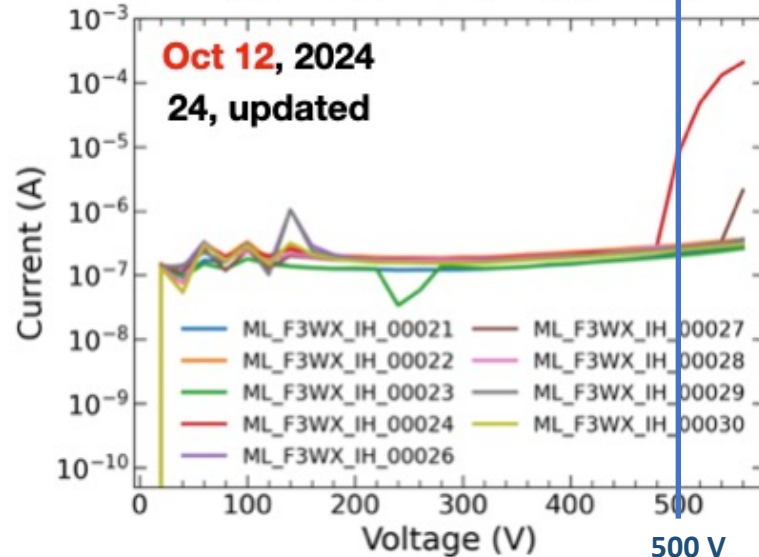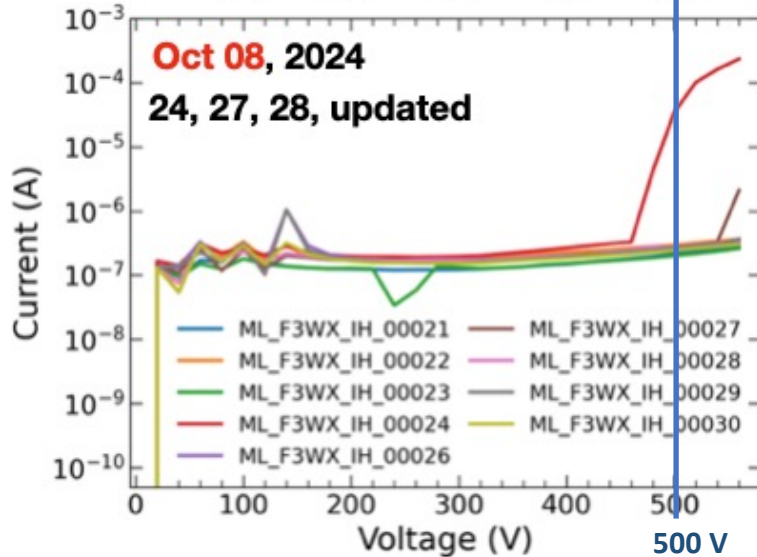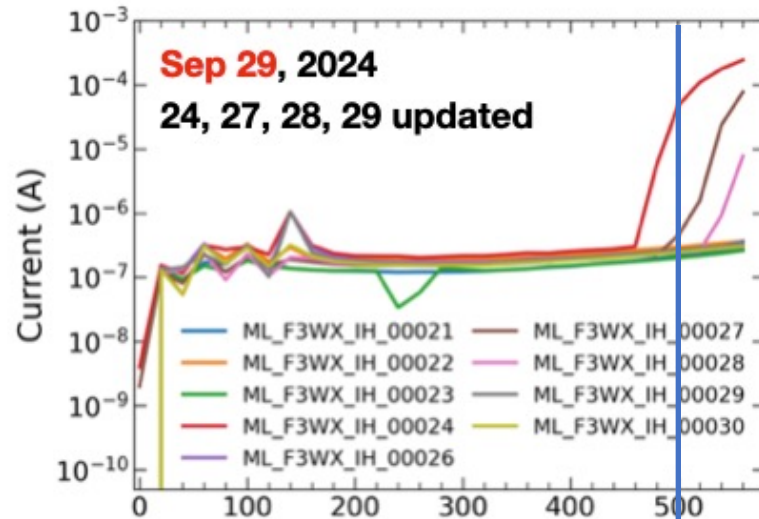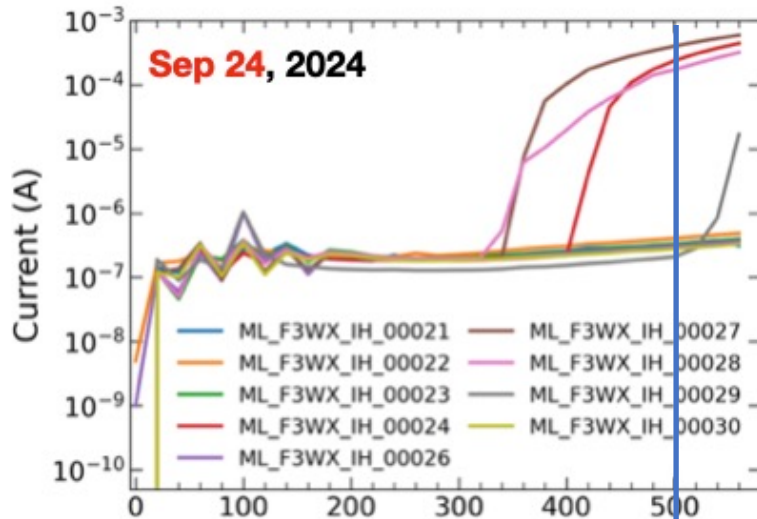
- Break down voltages of module number 24, 27, 28, 29 are getting greater as time pass by.
- Humidity, glue spreading across the guard ring, and insufficient drying may be the causes.

Database

- A one-stop user interface.
- With one click, it can run all tests and upload the test results to the database.

7 Pre-Production Summary

Time:
Apr 2024 -> Aug 2024

			AAA	AA	A	—
	# of Modules		7	0	0	0

Module IDs	PCB ID	< 150 μm Placement	# of dead < 10 Electronic	500 V < Break IV	Summary
ML_F3WX_IH_00014	02	A	A	A	AAA
ML_F3WX_IH_00015	09	A	A	A	AAA
ML_F3WX_IH_00016	10	A	A	A	AAA
ML_F3WX_IH_00017	03	A	A	A	AAA
ML_F3WX_IH_00018	01	A	A	A	AAA
ML_F3WX_IH_00019	04	A	A	A	AAA
ML_F3WX_IH_00020	101	A	A	A	AAA
# of A		7	7	7	

- The quality of this batch of PCB boards and sensors is very high.
- This is a unique batch of modules that CERN specifically requested IHEP to assemble, intended exclusively for preliminary beam testing.

10 Pre-Series Summary

Time:

Aug 2024 -> Nov 2024

			AAA	AA	A	—
# of Modules			6	3	0	1

Module IDs	PCB ID	< 150 μm Placement	# of dead < 10 Electronic	500 V < Break IV	Summary
ML_F3WX_IH_00021	84	A	A	A	AAA
ML_F3WX_IH_00022	60	A	A	A	AAA
ML_F3WX_IH_00023	53	A	—	A	AA
ML_F3WX_IH_00024	45	A	A	—	AA
ML_F3WX_IH_00025	54	(Misaligned)	A	—	—
ML_F3WX_IH_00026	55	A	A	A	AAA
ML_F3WX_IH_00027	56	A	A	A	AAA
ML_F3WX_IH_00028	57	A	A	A	AAA
ML_F3WX_IH_00029	58	A	—	A	AA
ML_F3WX_IH_00030	59	A	A	A	AAA
# of A		9	8	8	

- This unique batch of pre-series modules was assembled as a practice run for the upcoming official production. Due to its purpose, the quality of these modules is expectedly lower, allowing us to refine our processes.
- We've already upgraded our system to handle two modules at once, and we've further enhanced our software to prevent human error during assembly.

Summary and Outlook

- As of now, IHEP has assembled 40 modules, of which 31 (or 77%) are graded A. The best from the same level of MACs.
- The quality assurance and control (QA/QC) standards are followed.
- QA/QC Standards
  - Alignment
  - Number of Electronic Readout and Noise Level
  - IV Response (Current v.s. Voltage)
- One of crucial procedures in HGCAL assembly.
  - Identified the final quality of HGCAL modules.
  - Make sure no damage caused after each assembly process, including initial quality, taping, gantry assembly, bonding, and encapsulation (Final).
- IHEP was the first institute that identified electrostatic discharge when apply double sides tape onto hexaboard. The corresponding protections were applied.
- GUI, one-stop, multiple test user interface is ongoing.

Thanks!

Backup

- Name and Function inside Box
- Placement Accuracy Plots for 7 Pre-Production Modules
- Placement Accuracy Plots for 10 Pre-Series Modules
- ESD Verification by CERN
- IV curve as Humidity

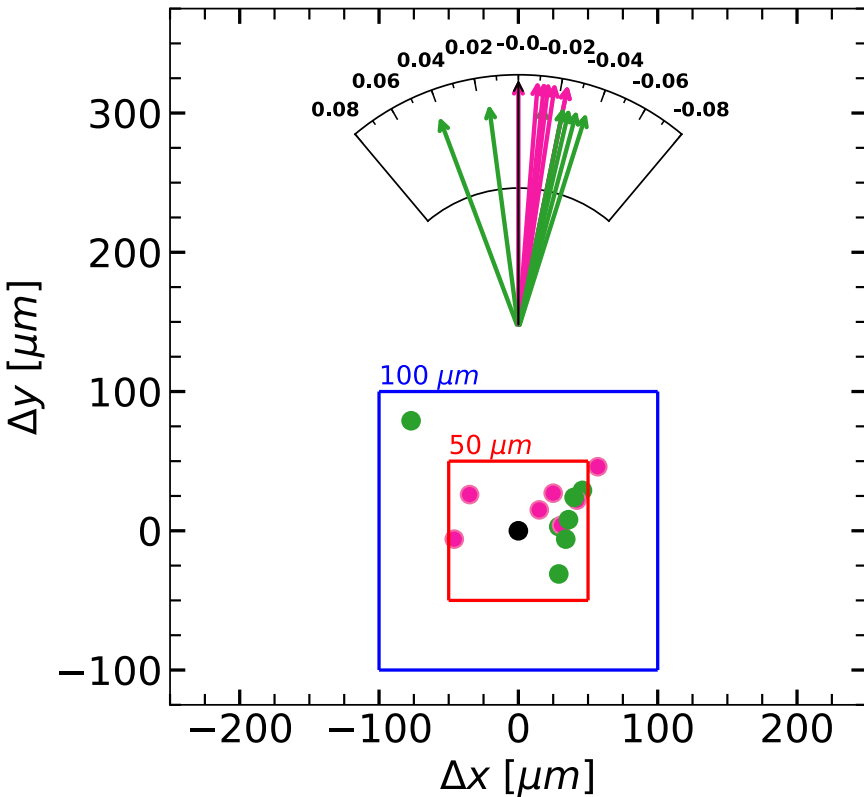# Name and Function inside Box
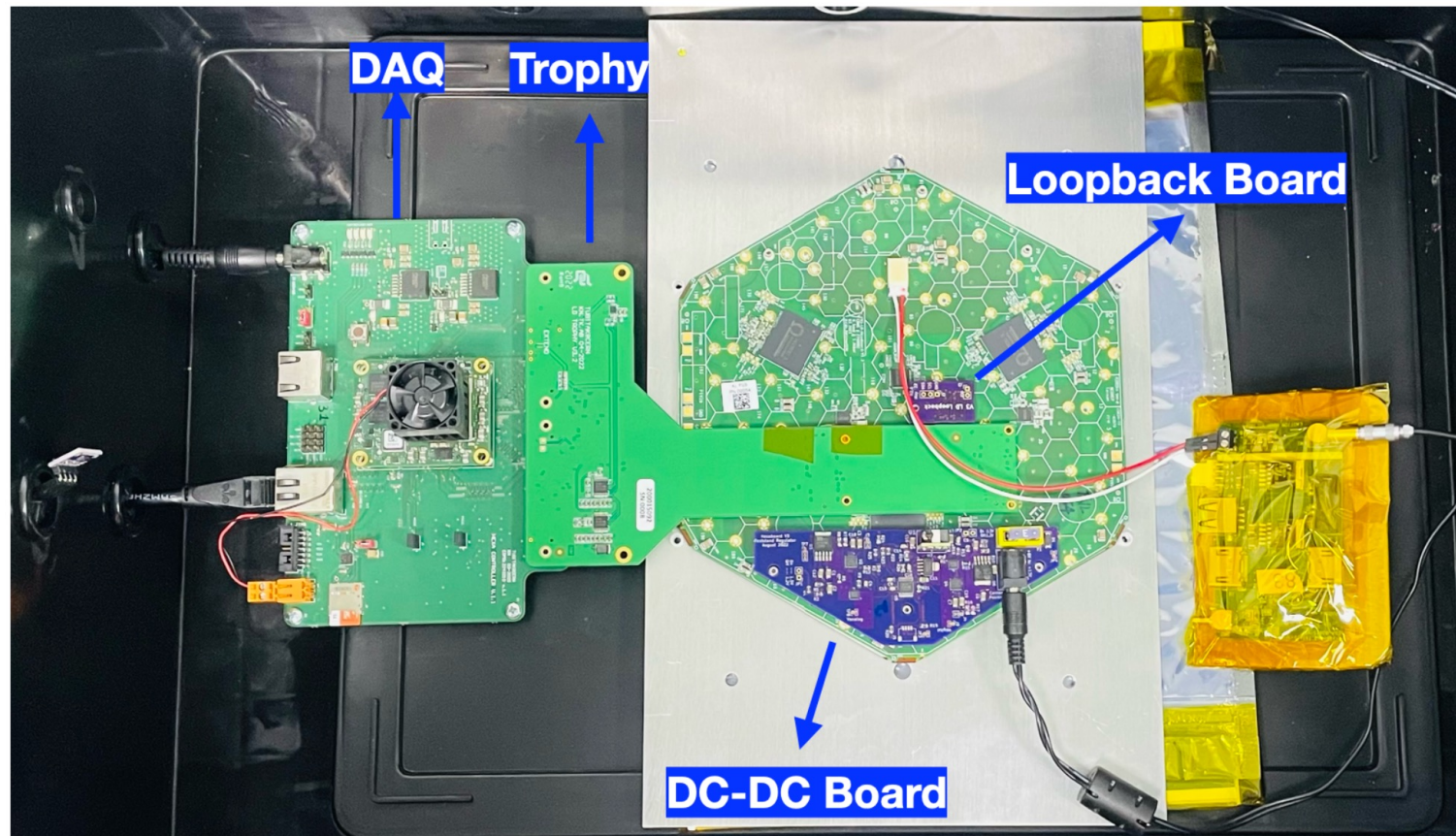
- DAQ: where the microcomputer is and it convert analog to digital
- Trophy: a connector
- DC-DC board: supply low voltage
- Loopback board: distributed the low voltage to other part of module.
- Red-white wire: for measuring IV respond.
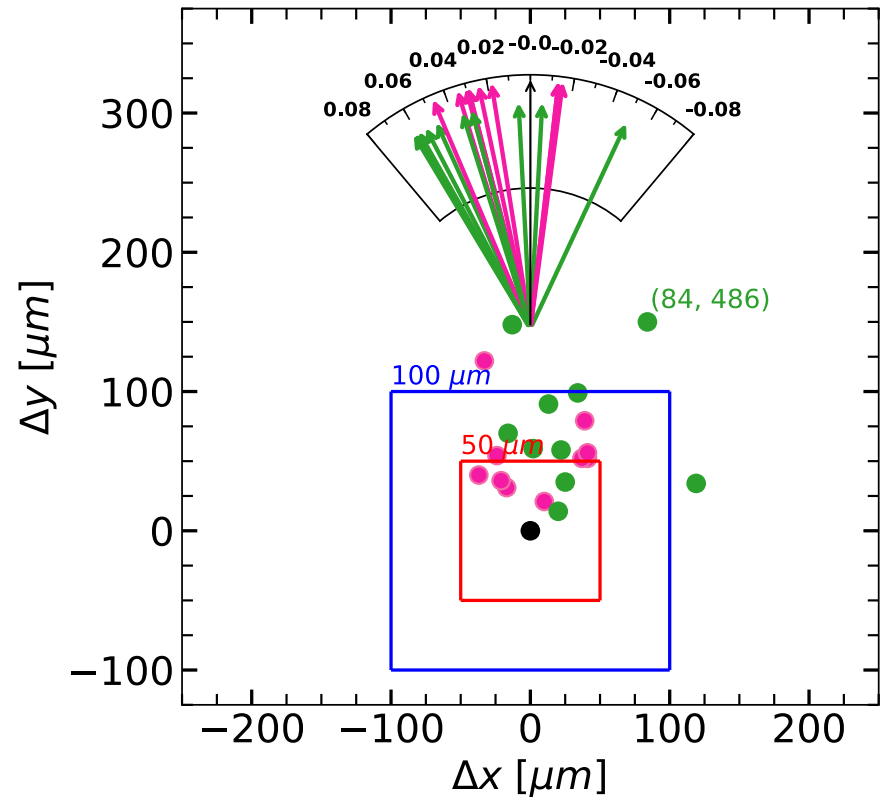
Summarized Accuracy Plot

ESD Verification by CERN
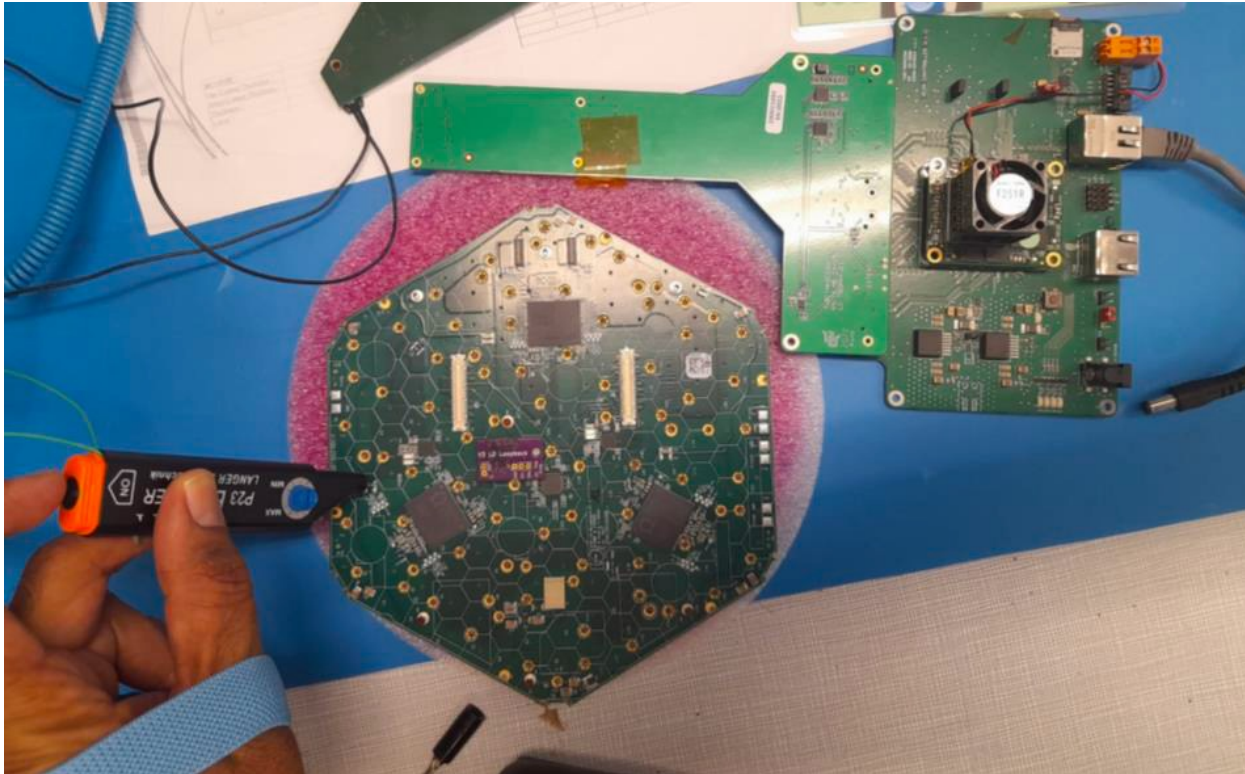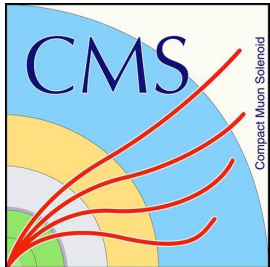
Injected ESD pulses across the CM capacitor on pad towards chips.

Key conclusions:

❖ Any analog pin, normal or CM, can be destroyed by an ESD pulse above 600 V if injected at the pins.
❖ Not only the CM pins but also HV Decoupling Cap can be damaged by ESD.

Advice:

Basic ESD handling precautions must always be followed at every stage, from chip testing to module assembly and beyond.

IV Test as Humidity

320-ML-F3CX-CM-0009 module IV Curve Set 2024-10-22
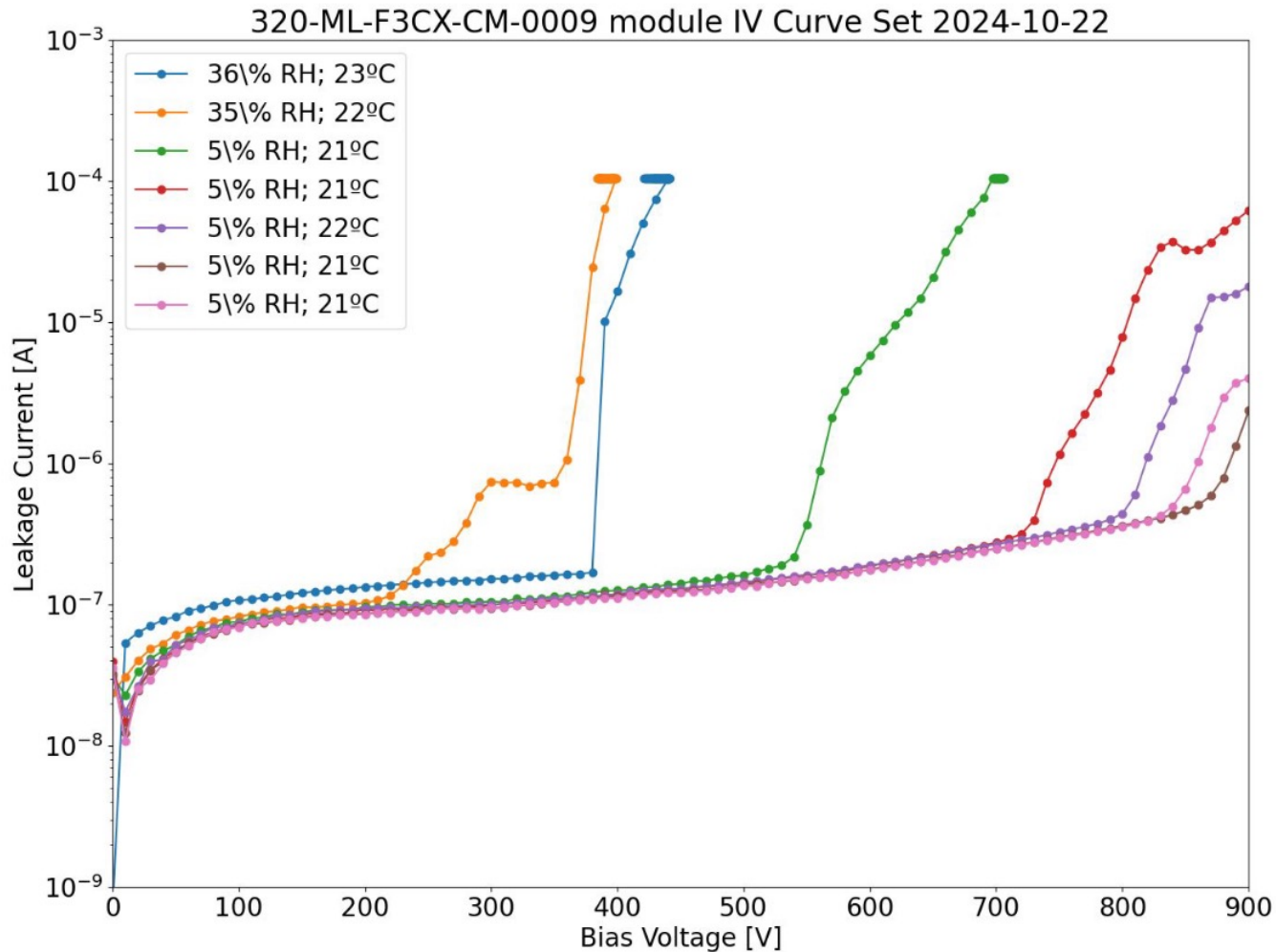
- Humidity can have a noticeable impact on IV curve