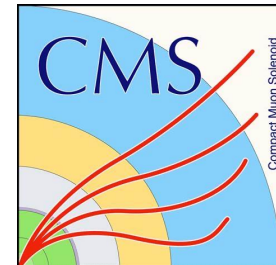
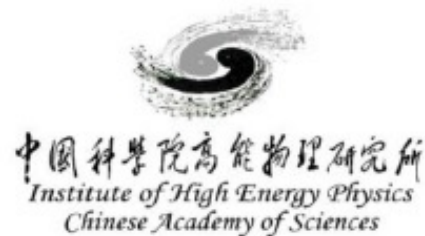


HGCal module test at IHEP

Zhipeng Cui, Pei-Zhu Lai
On behalf of the Chinese HGCal group

CLHCP 2024
November 15, 2024



Outline

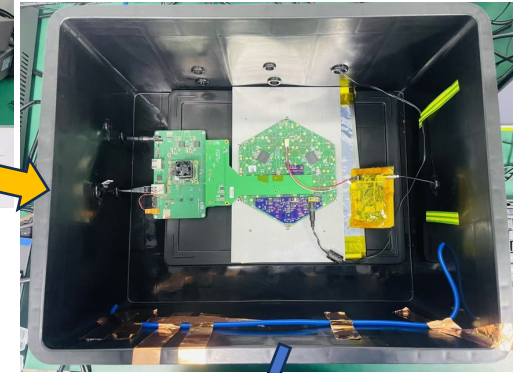
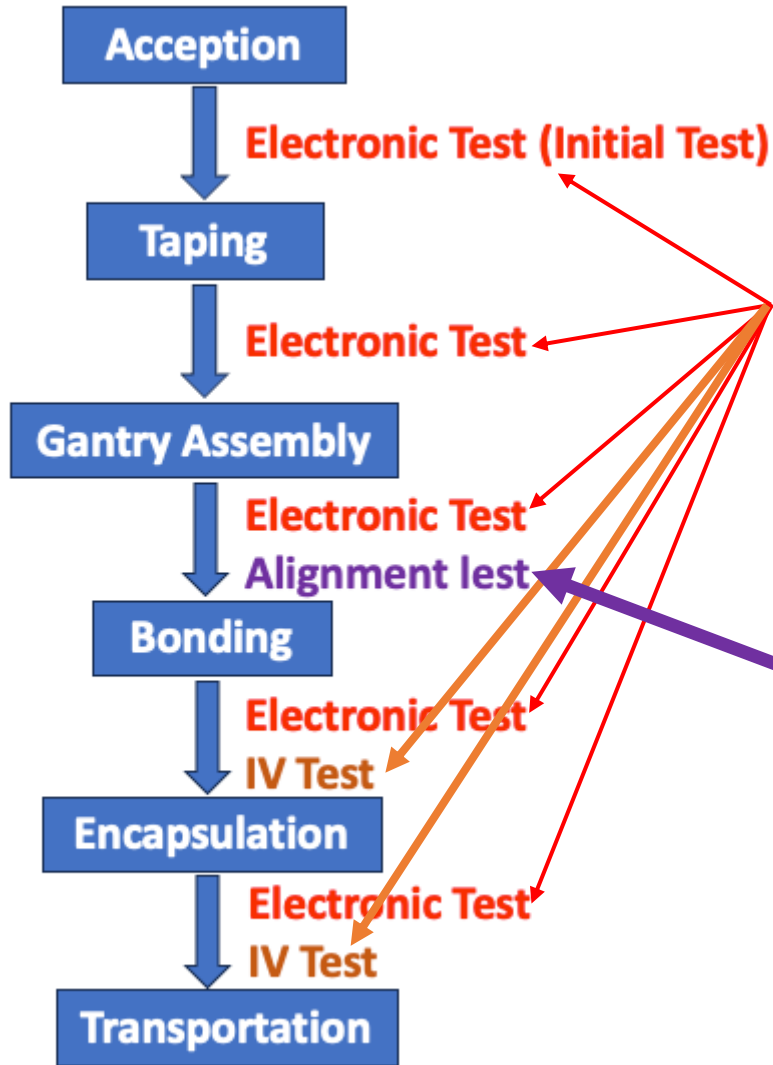
- Introduction
- Testing Procedure
- Quality Assurance & Control
 - Alignment
 - Electronic
 - IV Responce
- Database
- Summary and Outlook

Introduction

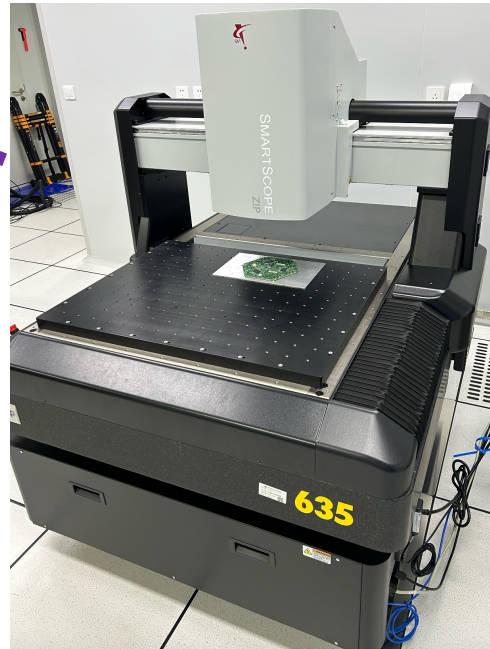
❖ Significance of Testing

- One of crucial procedures in HGICAL assembly.
 1. Identified the final quality of HGICAL 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



The blue tube is used to introduce dry gas to reduce humidity.



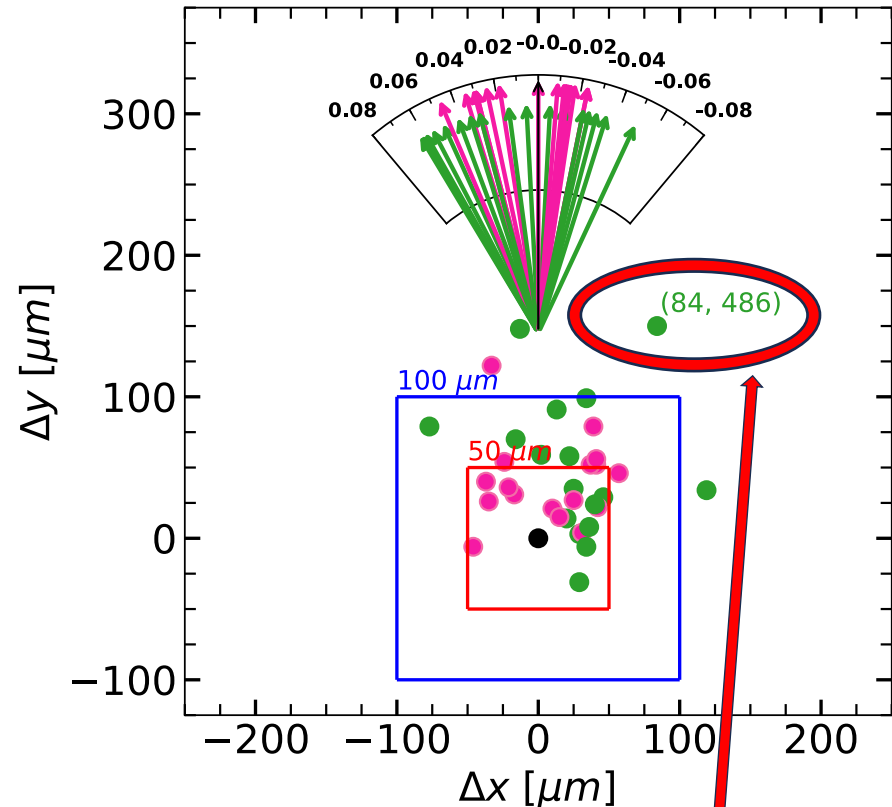
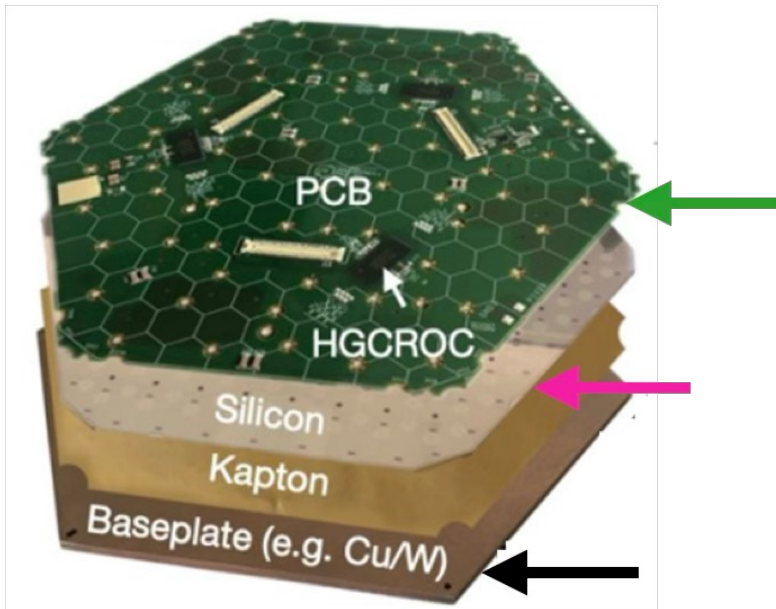
Optical Gaging Product (OGP)

Alignment

Summarized Accuracy Plot

Grade A: misplacement of X and Y
< 150 μm & < 0.1 degree

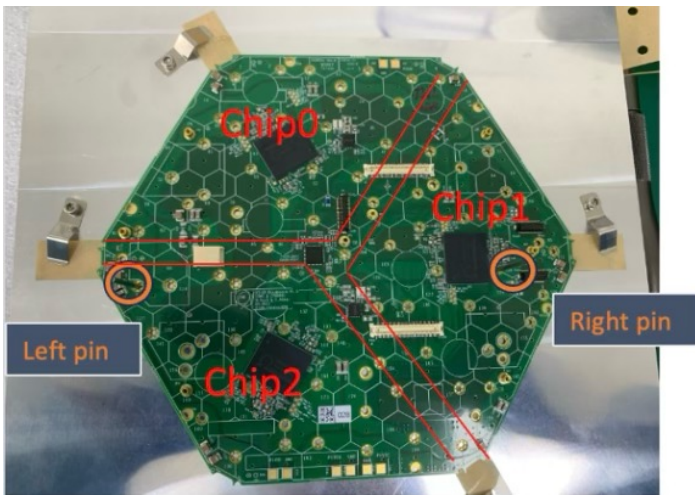
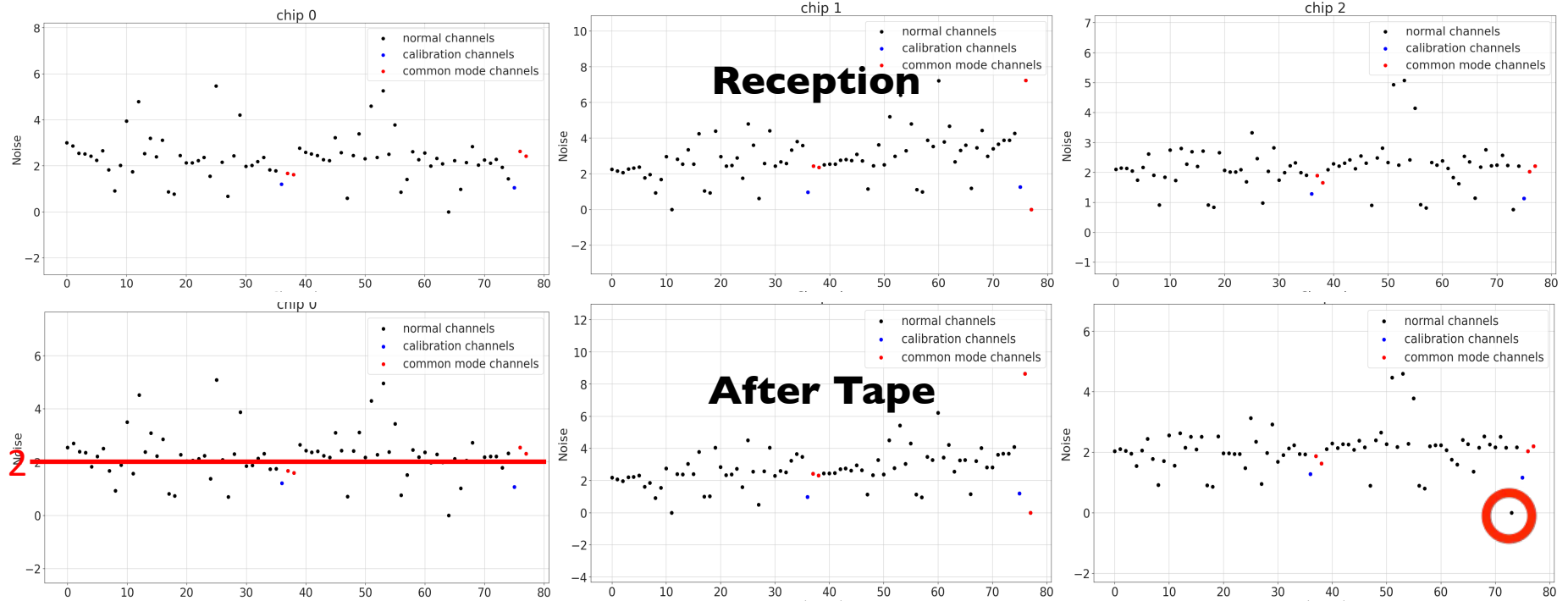
- Sensor wrt Baseplate
- Baseplate
- PCB wrt Baseplate



- ❑ Basically like making a “sandwich”.
- ❑ All alignments met the grade A criteria except **one manual accident**.
- ❑ Gantry guys did a good job!

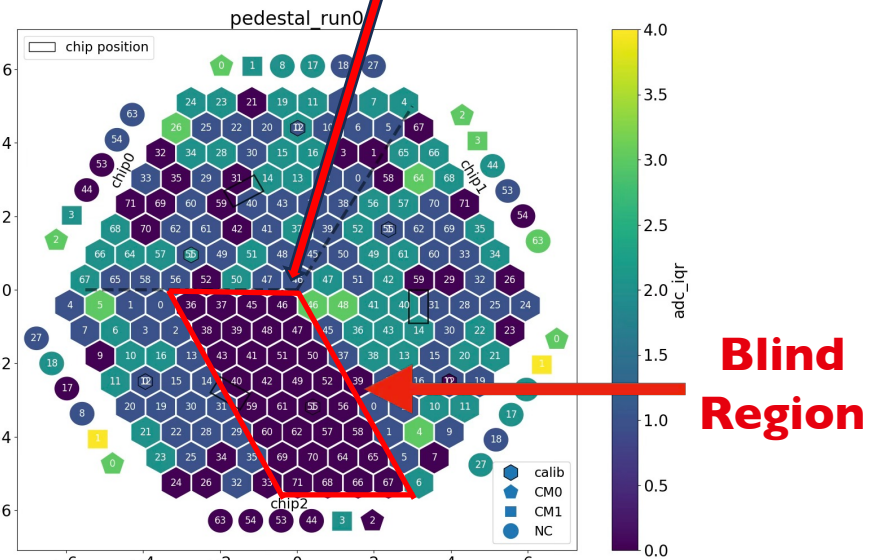
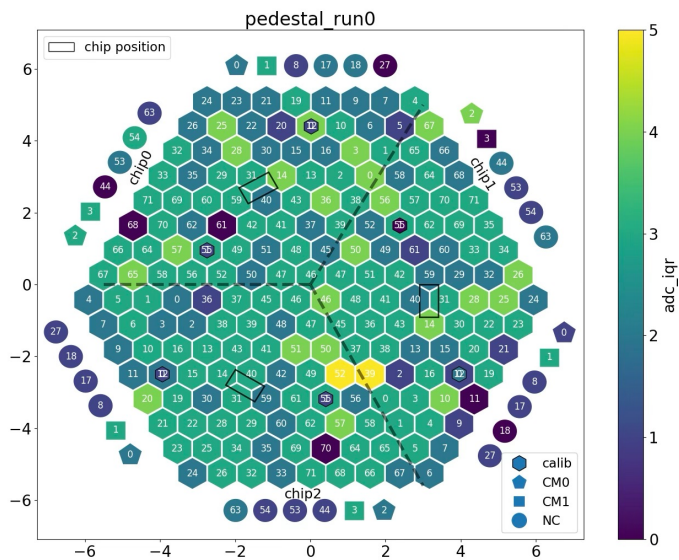
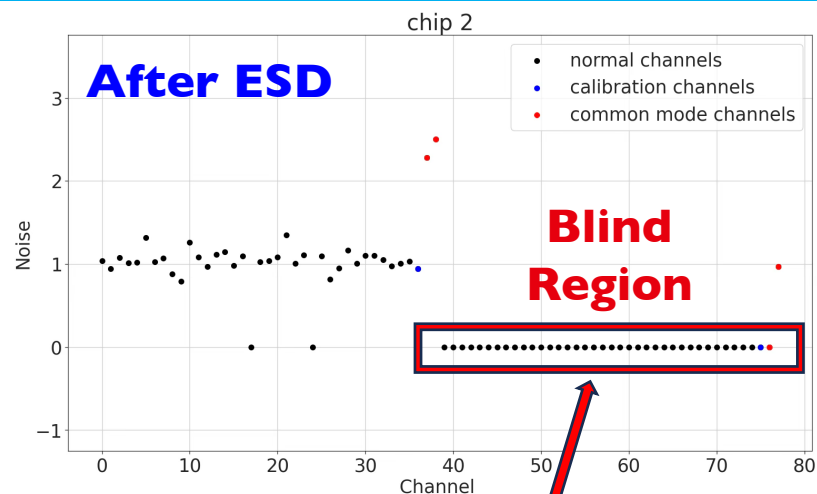
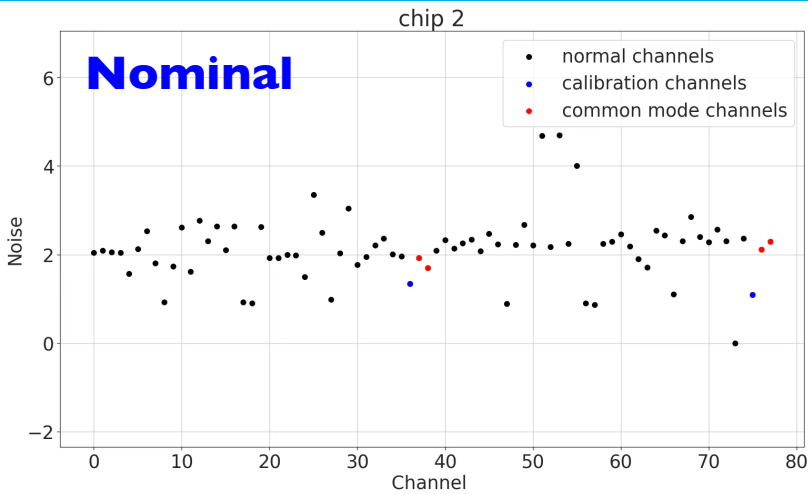
Electronic Test

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

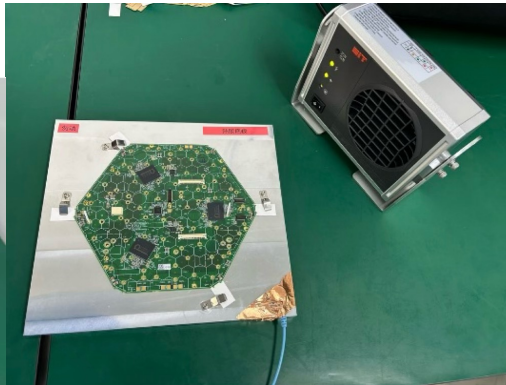


Grounding

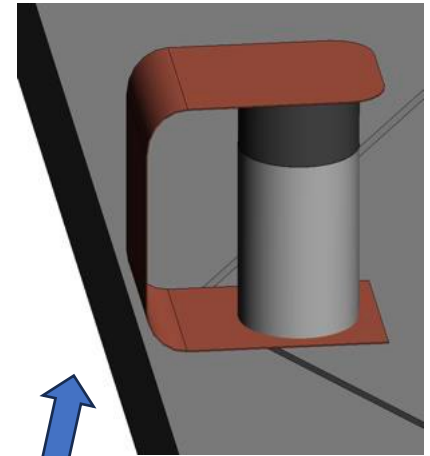
**Anti-static
Gloves & Wrist Strap**



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

❖ 7 Pre-Production

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

❖ I0 Pre-Series

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.

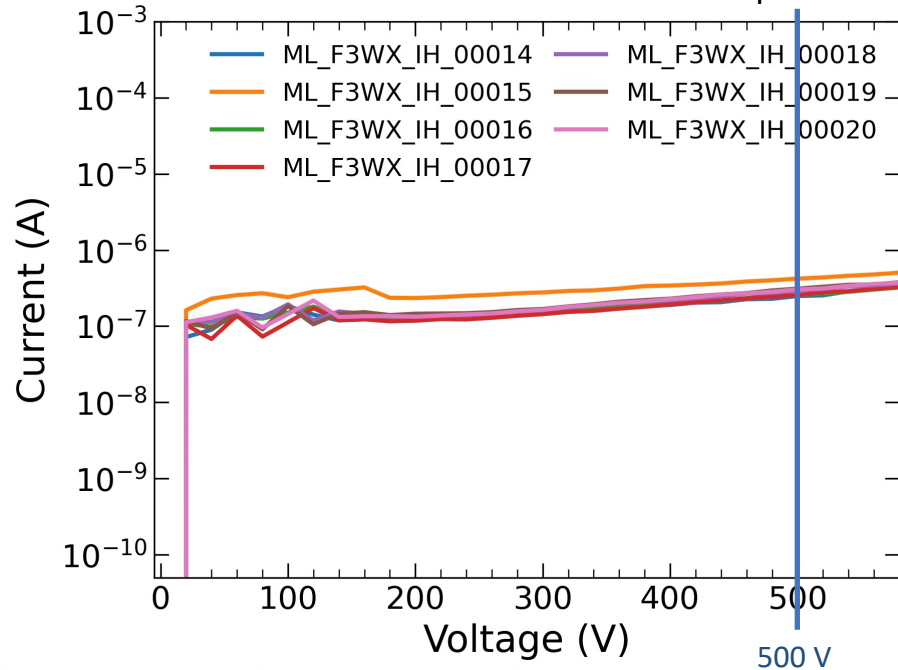
(All dead channels are from initial PCB itself.)

•8 PCBs were “A” when we received them; the other 2 were A*.

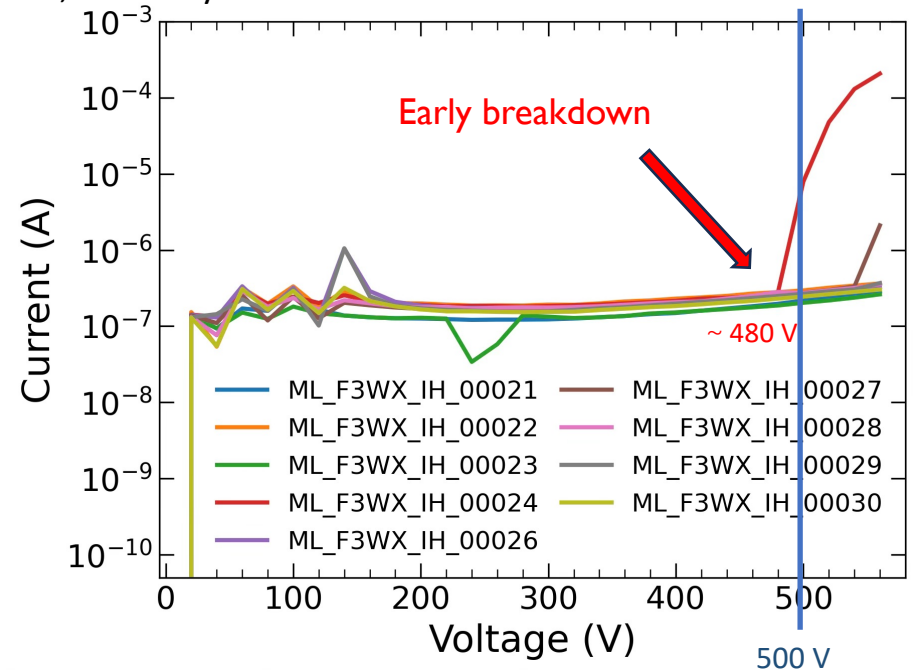
IV Test Summary

7 Pre-Production Modules

Temperature ~ 20°C, Humidity ~ 1%



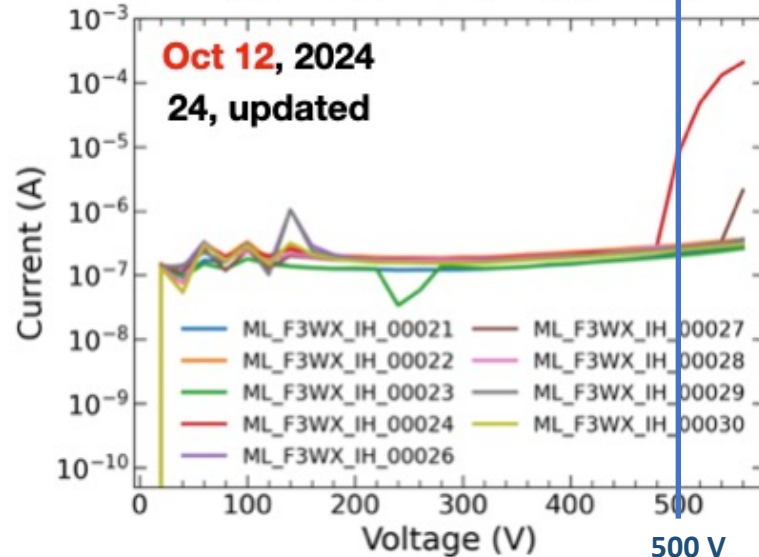
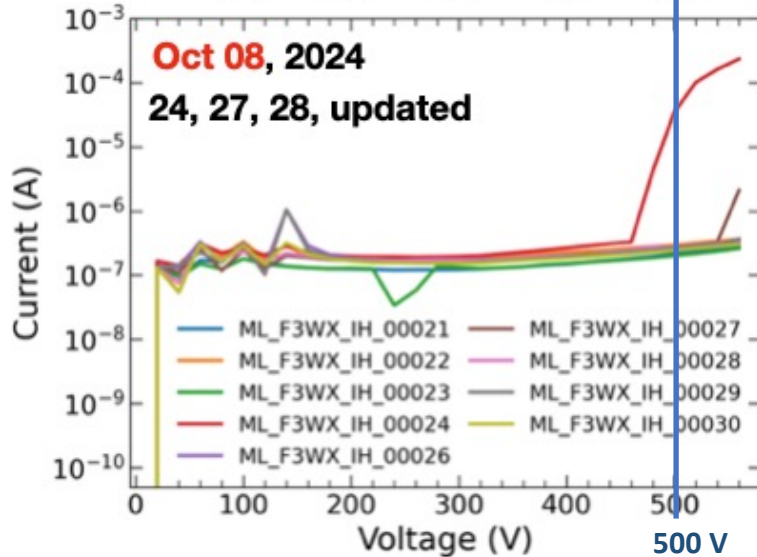
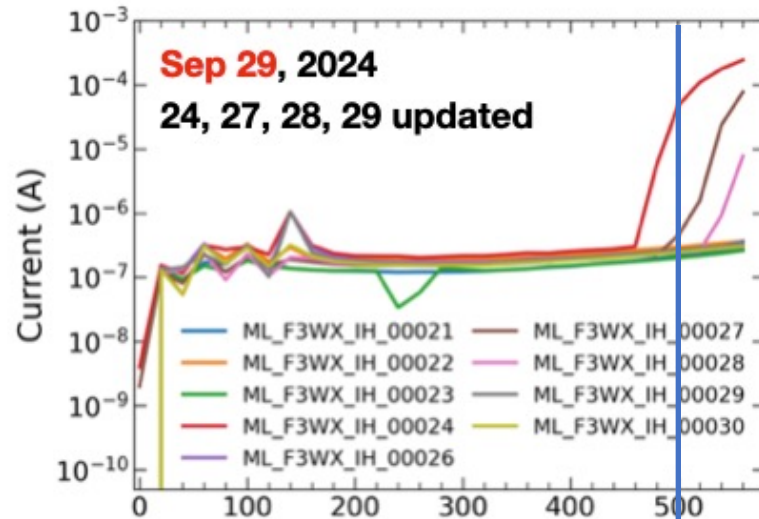
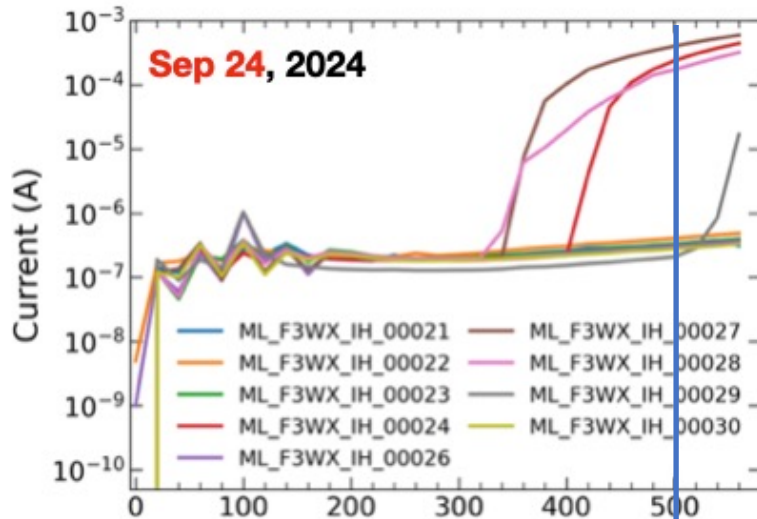
10 Pre-Series Modules



- Grade **A**: Breakdown voltage > 500 V for now and $I(850\text{ V}) / I(600\text{ V}) < 2.5$ will be added in future.
- **16** modules are graded as A.
- Potential reasons for early breakdown:
 - Humidity between the layers need to be dissipated.

...

IV Test as Time



- 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

❖ Graphic User Interface (GUI) System --developed by CMU

Ongoing

The screenshot displays a GUI for a database system, divided into several sections:

- Module Setup:** Includes radio buttons for 'Live Module' and 'Hexaboard'. Under 'Hexaboard Density', 'Low' is selected. 'Hexaboard shape' has 'Full' selected. 'Sensor Thickness' has '200 micron' selected. 'Baseplate Type' has 'Carbon Fiber' selected. A 'Preseries Module' checkbox is checked. 'Module Index' is '9999'. 'Scan QR Code' has a 'Clear' button. 'Module Serial Number' is '320-ML-F2CX-CM-9999'. 'Test Stand IP' is 'cmshgcaltb4.lan.local.cmu.edu'. 'Inspector' is 'acrobert'. 'Module Status' is 'Frontside Encapsulated'. Buttons for 'Configure Test Stand' and 'Only IV Test' are present. At the bottom, 'Debug Mode' and 'Skip Electrical Checks' are checked, with a 'Close GUI' button.
- Select Tests:** A red arrow points to the 'Tests to run:' section. It includes checkboxes for 'Standard Test Procedure', 'Trim Pedestals' (with 'Bias Voltage: 300'), 'Pedestal Run' (with 'Number of tests:'), 'Other Test Script' (with 'Bias Voltage: 300'), 'Ambient IV Curve', and 'Dry IV Curve' (with 'Number of tests:' and '800V Bias in Wait Period'). 'Wait Periods (per run - minutes)' has three input fields. Buttons for 'Run Tests', 'Restart Services', and 'End Session' are at the bottom.
- Grade Module:** A red arrow points to a 'Grade Module' button.
- Status Bar:** A grid of status indicators with green or black dots: 'Debug Mode: ●', 'Is Live Module: ●', 'HV Cable Connected: ●', 'Dark Box Closed: ●', 'HV Output Powered: ●', 'DCDC Connected: ●', 'DCDC Powered: ●', 'Trophy Connected: ●', 'Hexacontroller Connected: ●', 'Hexacontroller Powered: ●', 'Hexacontroller Accessed: ●', 'Firmware Loaded: ●', 'DAQ Server: ●', 'I2C Server: ●', 'DAQ Client: ●'.

- 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 μ m 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
		< 150 μ m	# of dead < 10	500 V < Break		
Module IDs	PCB ID	Placement	Electronic	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

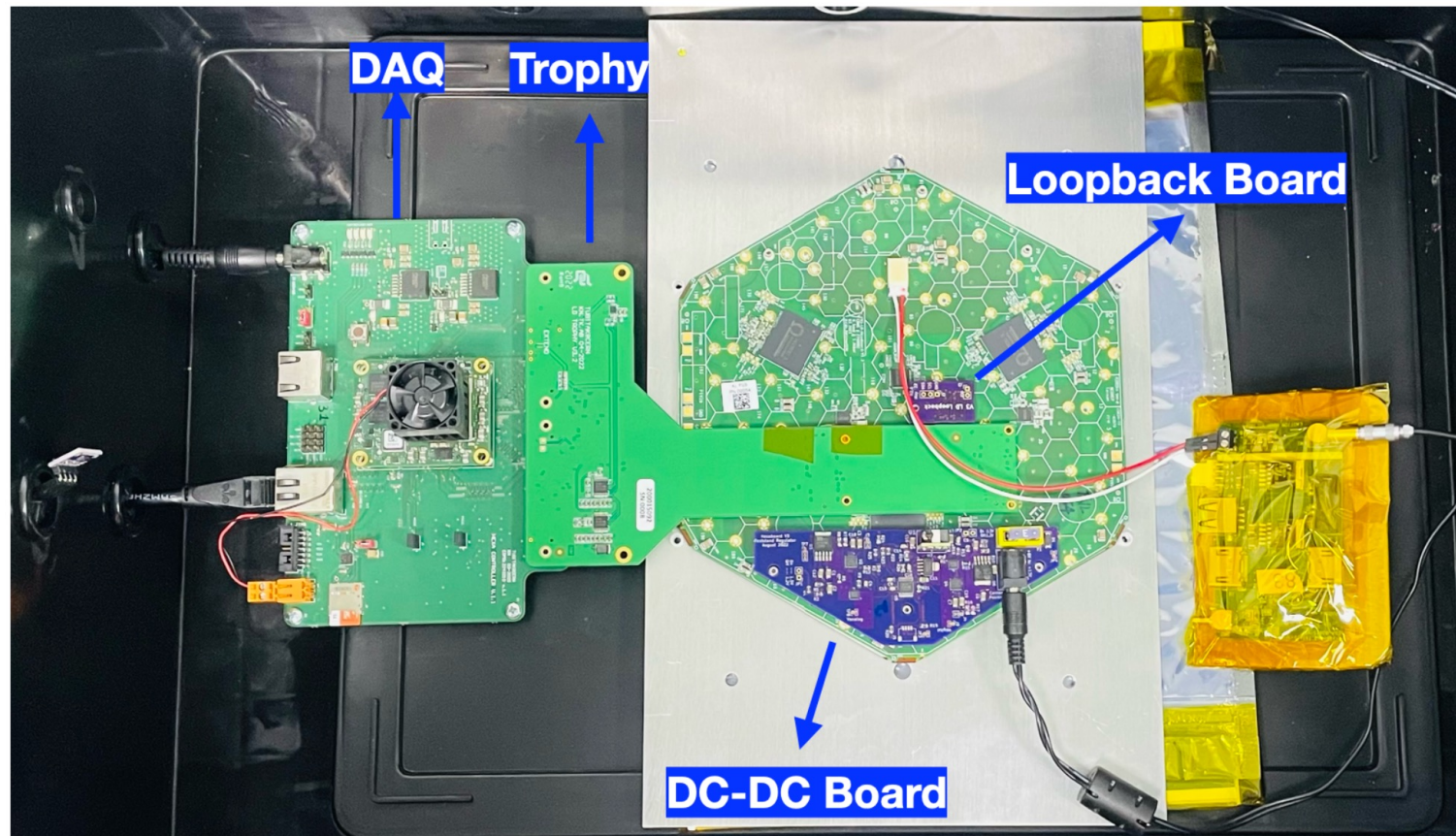
- As of now, IHEP has assembled 40 modules, of which 31 (or 77%) are graded A. The best from the same level of MACs.
- The quality assurance and control (QA/QC) standards are followed.
- QA/QC Standards
 - Alignment
 - Number of Electronic Readout and Noise Level
 - IV Response (Current v.s.Voltage)
- One of crucial procedures in HGICAL assembly.
 - Identified the final quality of HGICAL 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

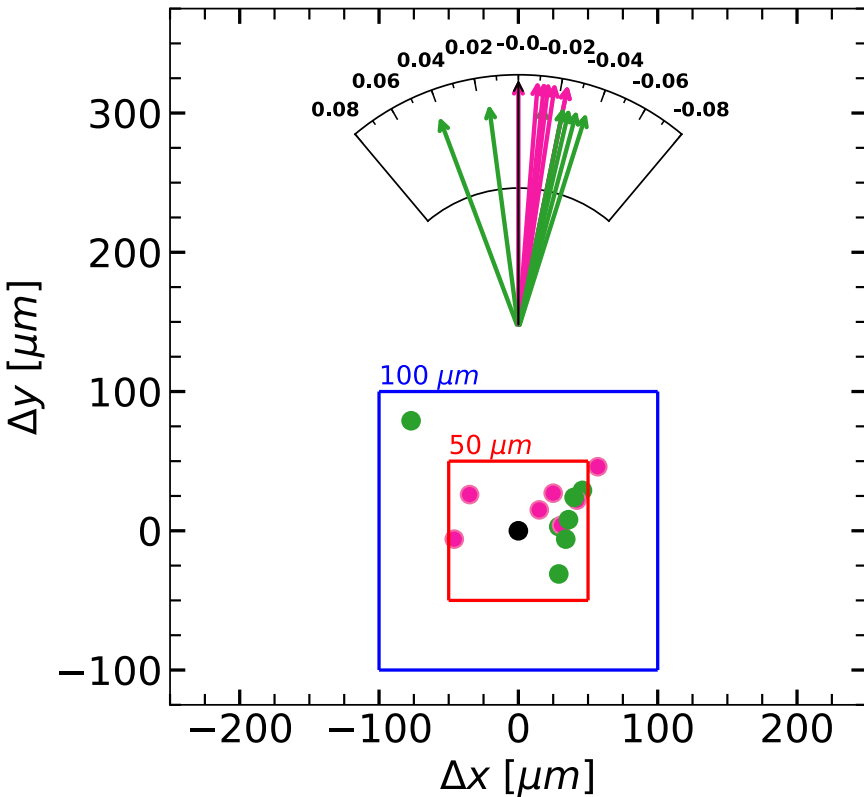


- DAQ: where the microcomputer is and it convert analog to digital
- Trophy: a connector
- DC-DC board: supply low voltage
- Loopback board: distributed the low voltage to other part of module.
- Red-white wire: for measuring IV respond.

Summarized Accuracy Plot

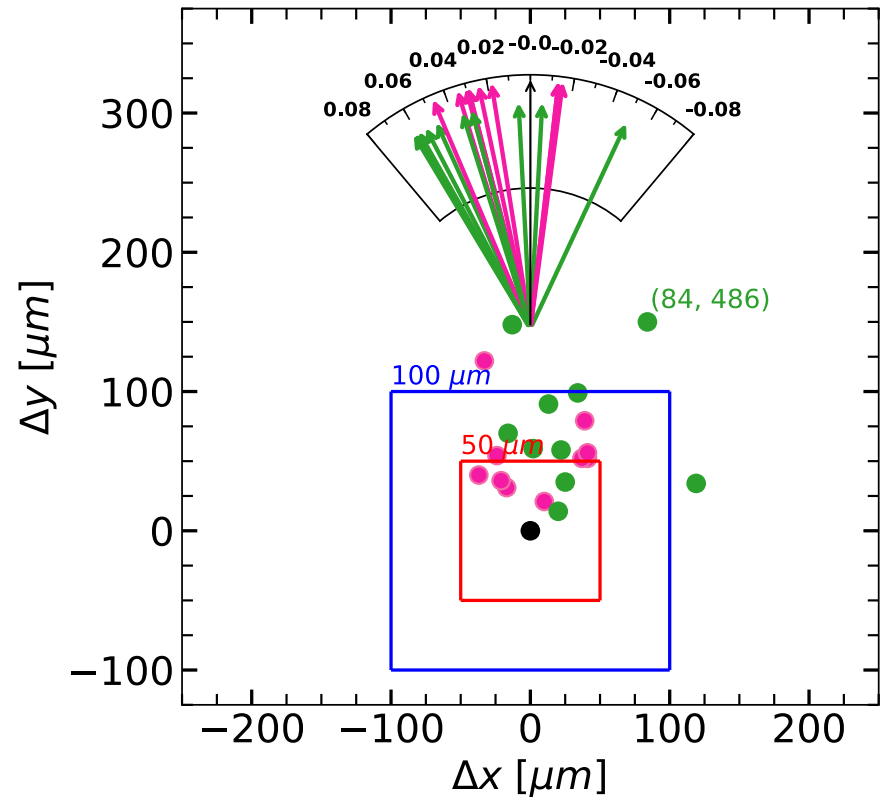
7 Pre-Production

- Sensor wrt Baseplate
- Baseplate
- PCB wrt Baseplate

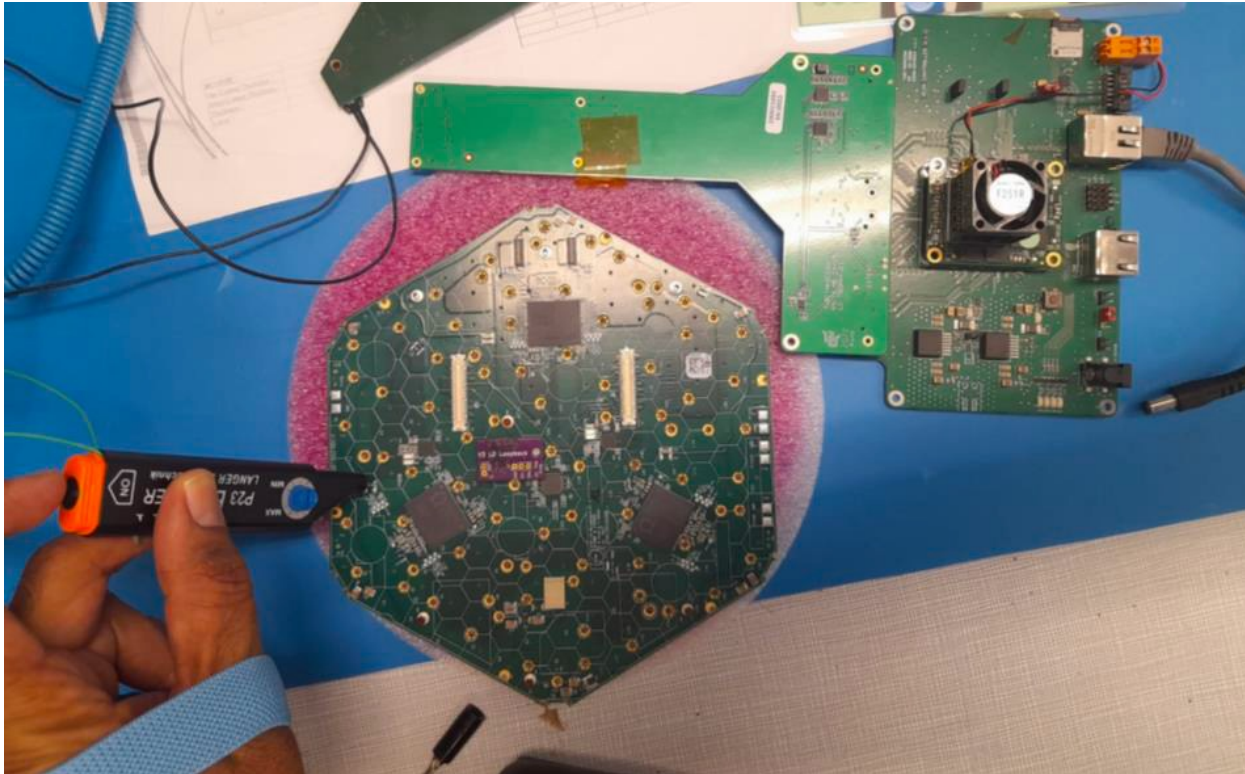
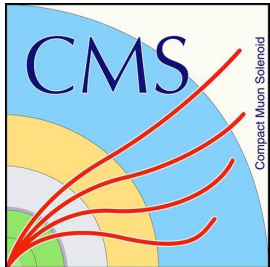


10 Pre-Series

- Sensor wrt Baseplate
- Baseplate
- PCB wrt Baseplate



ESD Verification by CERN



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

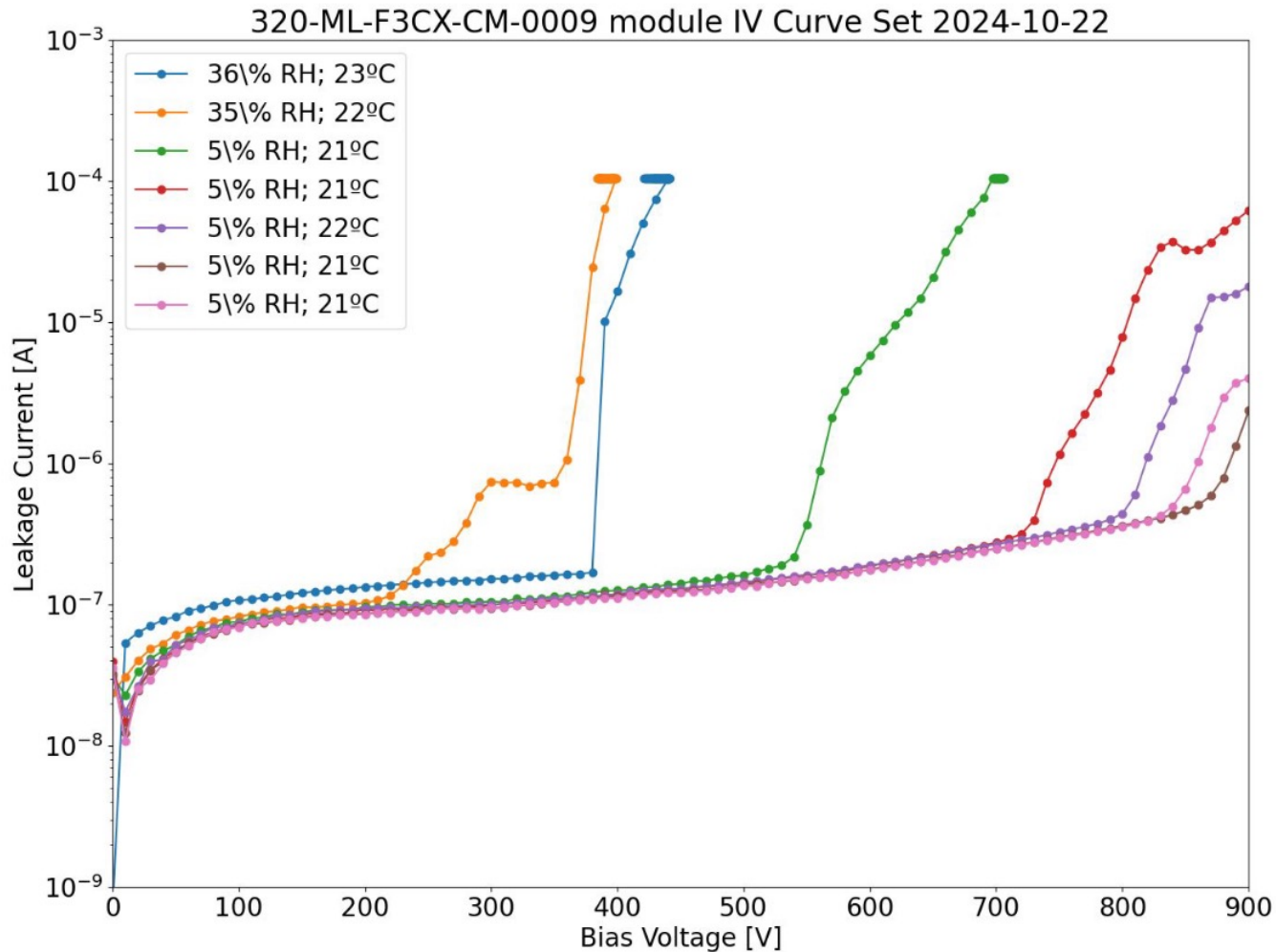
Key conclusions:

- ❖ 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



- Humidity can have a noticeable impact on IV curve