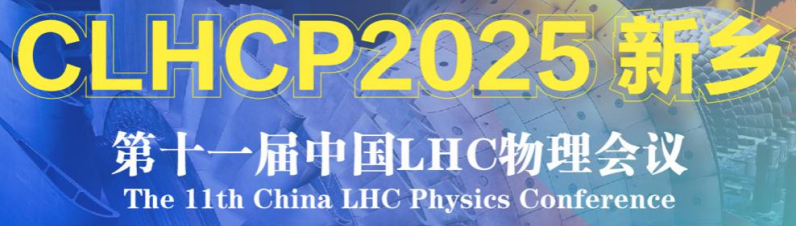
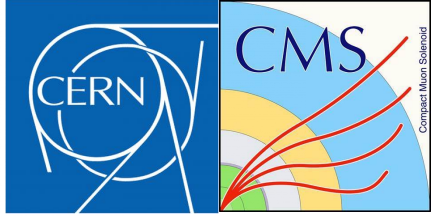
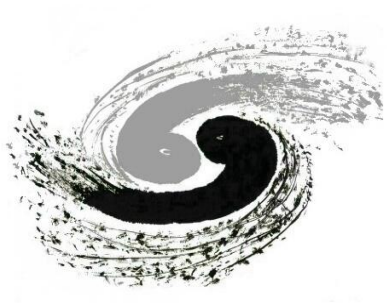




Status of HGCal Module Production at IHEP

Baorui Hou (IHEP)
On behalf of the Chinese HGCal group

Oct.31, 2025



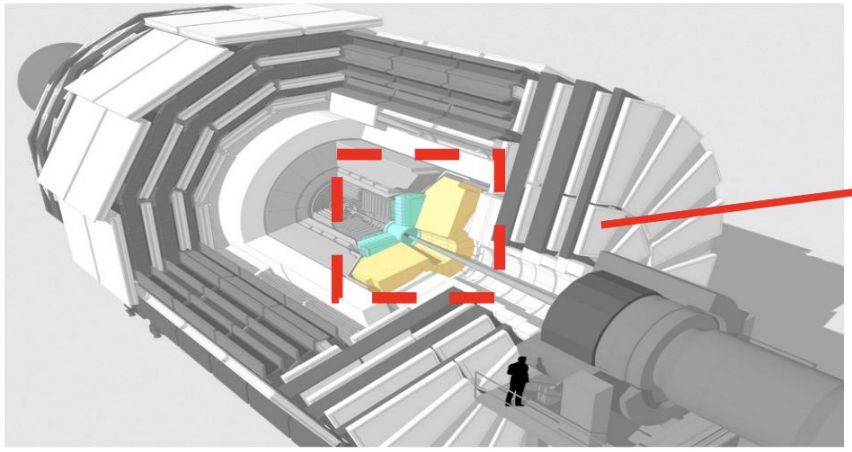
Outline

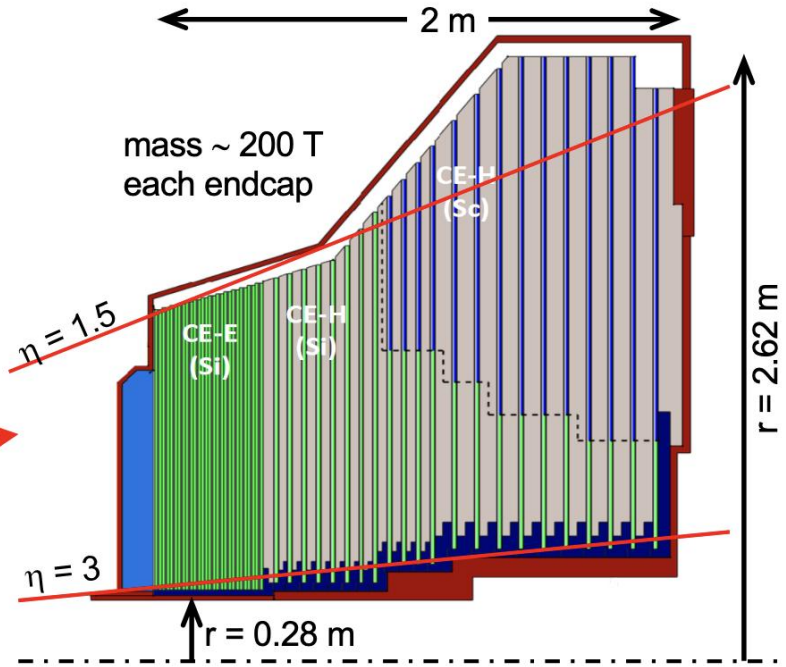
- Introduction
- Module Production Ramping-up Stage:
  - Module Assembly
  - Bonding & Encapsulation
  - Electronics Test
- Quality Control
- Database/GUI & Production Web UI
- Future Plan
- Summary

Introduction

❖CMS-HGCal upgrade

- Key Parameters:
  - HGCAL covers 1.5 < |η| < 3.0
  - Full system maintained at -30 °C
  - ~620 m² of silicon sensors
  - ~370 m² of scintillators
  - 6M Si channels, 0.5 or 1.1 cm² cell size
  - ~26000 Si modules
  - Power at end of HL-LHC: ~110 kW per endcap





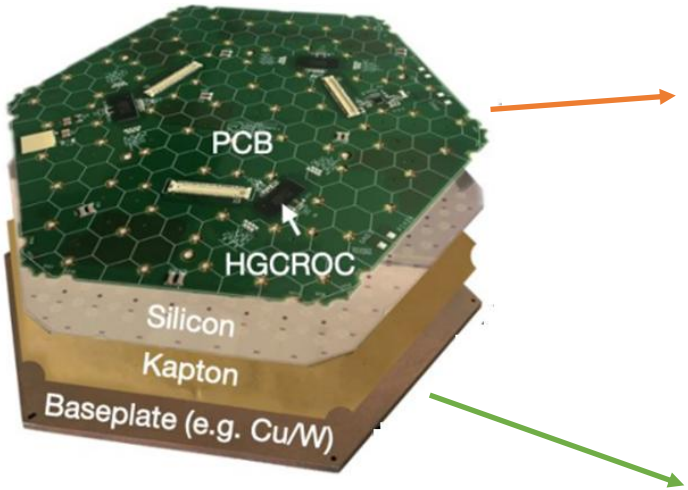
•Endcap Electromagnetic calorimeter (CE-E): Si, Cu & CuW & Pb absorbers, 26 layers, 25.5 X_0 & ~1.3 λ
•Hadronic calorimeter (CE-H): Si & scintillator, steel absorbers, 21 layers, ~8.5 λ

*First time apply HGCal to experiment

Introduction

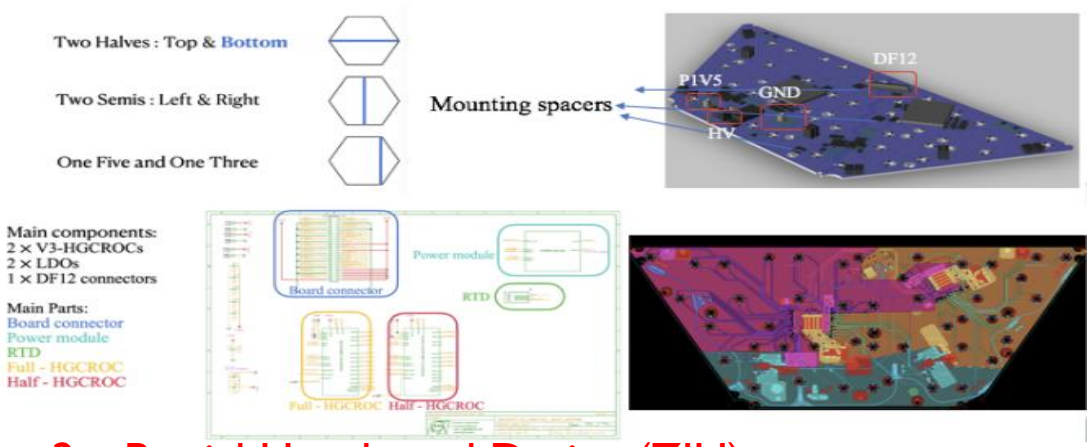
❖ Role of China in the HGCal module production

❑ The tasks mainly consist of three parts:

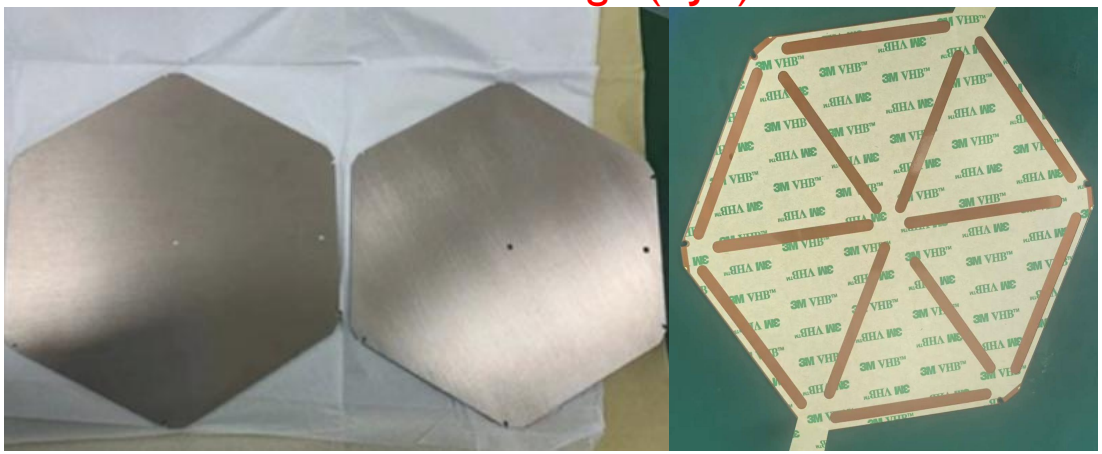


1、Module Assembly

- Basically like making a "sandwich"
- 1/5 (~5000) Low density (LD) full Si-modules production @IHEP MAC
- The total area is ~100 m^2



2、Partial Hexaboard Design (ZJU)



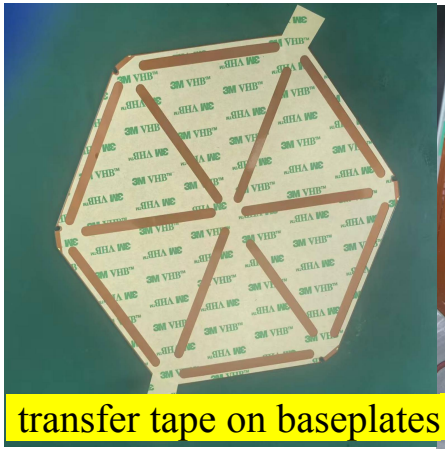
3、CuW Baseplates Production(Kapton, 3M tape)

- ~90% of the area CuW baseplates will be produced in China.
- 10k bps' K-Contract asigned, First 1200BPs delivered.

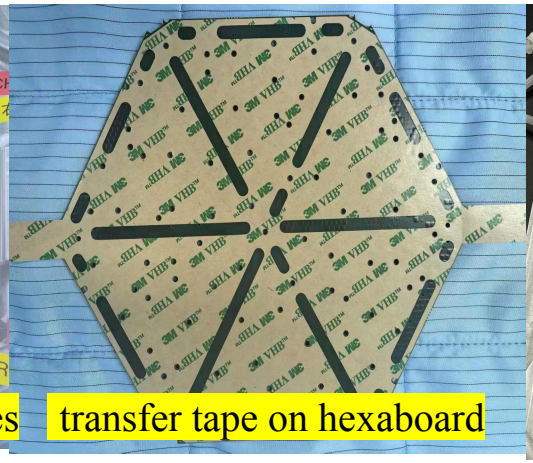
*For details, please refer to the talk from Hao Zhu.

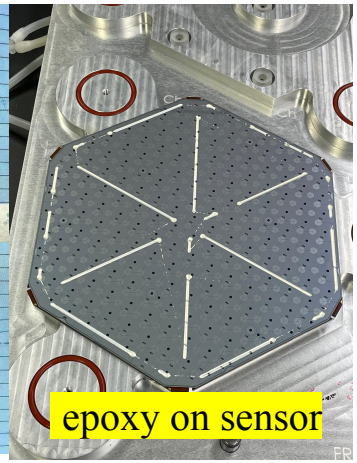
Ramping-up: Module Assembly

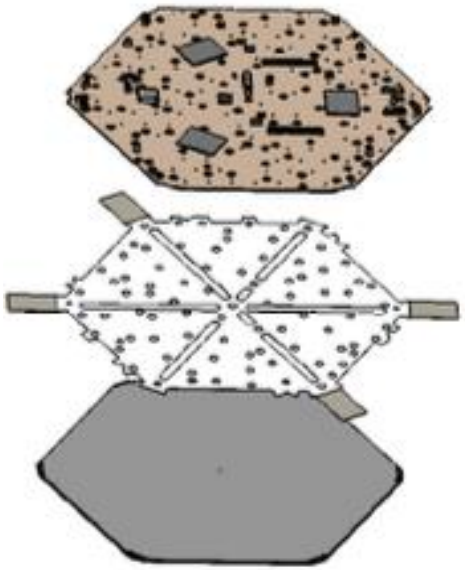
❖ Module Assembly: Module Production Process


transfer tape on baseplates


epoxy on baseplates


transfer tape on hexaboard

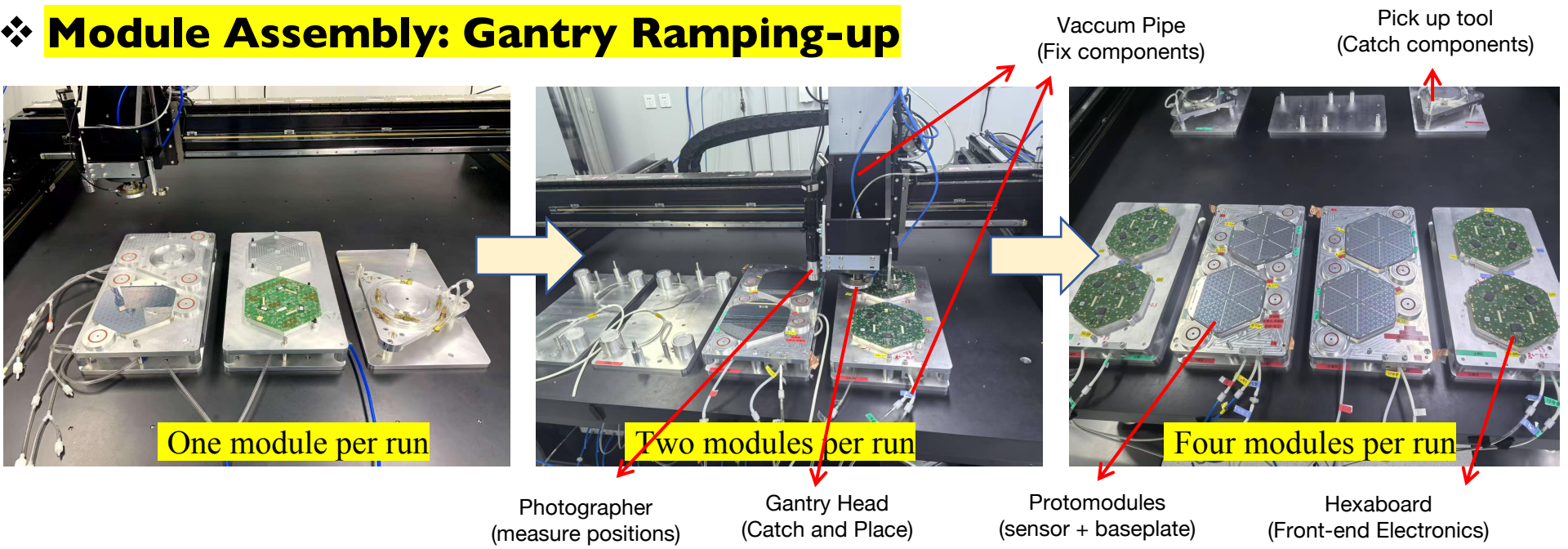

epoxy on sensor



- ❑ Hybrid assembly
  - Traditional expoxy only method needs much time for expoxy curing
  - Transfer tape and epoxy are using in sensor and hexaboard assembly
  - Tape is use for thickness control and epoxy for irradiation
  - Improve the production speed
    Waiting time before next step: ~3 hours to 20 minutes
- ❑ Optimize the automated dispensing program based on the updated dispensing patten.
  - The dispensing path is designed to prevent glue leakage into the bonding holes caused by glue stringing.
- ❑ A custom fixture is used to ensure the precise alignment of the transfer tape and prevent the bonding holes covered with tape.

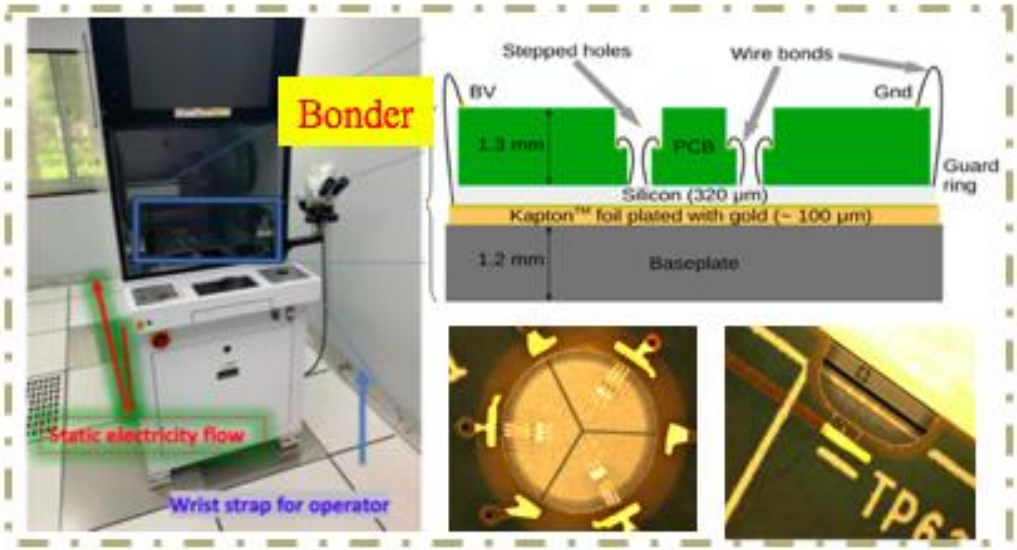
Ramping-up: Module Assembly

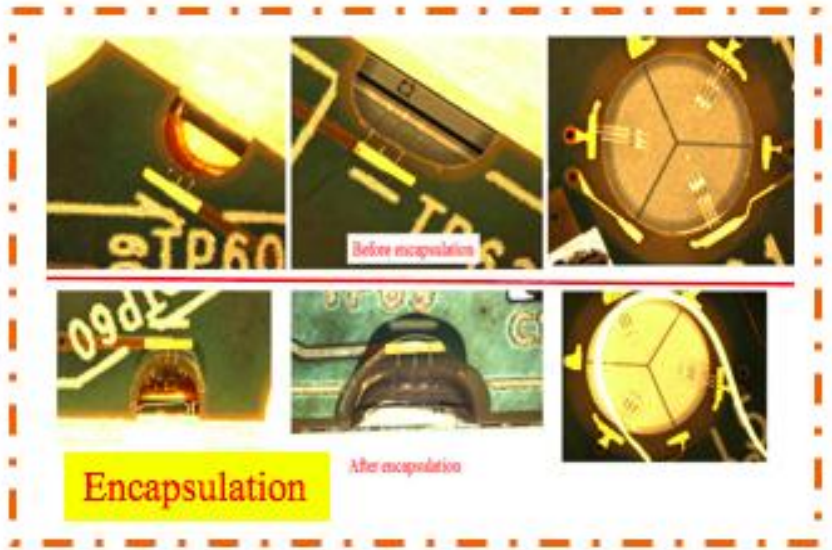
❖ Module Assembly: Gantry Ramping-up

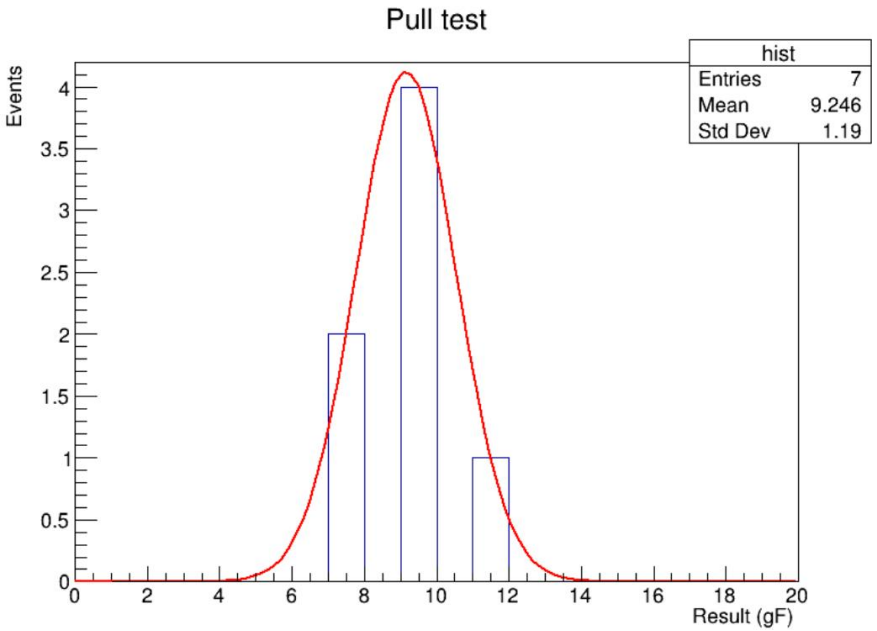


- Ramp up of module assembly on the gantry
  - Using vacumm absorbtion to fix every components.
  - Automatic assembly with gantry control system and assemble program.
  - Before 2025, the gantry system was capable of assembling a single module per run.
  - The capability for two module assembly per run on the gantry was implemented in March 2025.
  - Currently, the gantry can assemble four modules at once. This enhanced capability enabled the successful production of 28 V3C modules in September 2025.
  - In November, IHEP MAC will continue ramping-up from 8 modules per day to reaching the final production rate of 16 modules per day.

Ramping-up: Bonding & Encapsulation



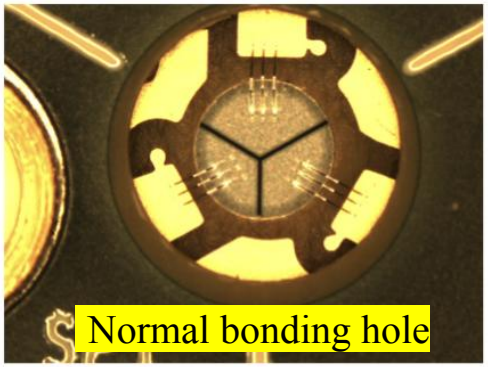




- Programmatic bonding
  - 30 mins per module
  - 5 modules bonded at most per day so far
  - Pull test of bonding wire meet the requirements (9g)
- Programmatic encapsulation
  - 15 mins per module once setup

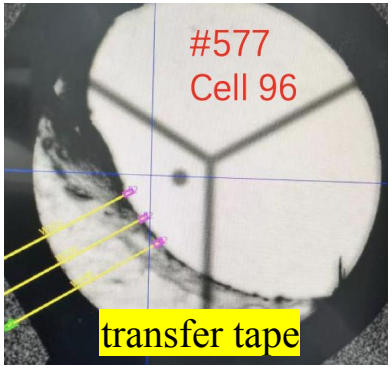
Ramping-up: Bonding & Encapsulation

❖ Bonding ramping-up

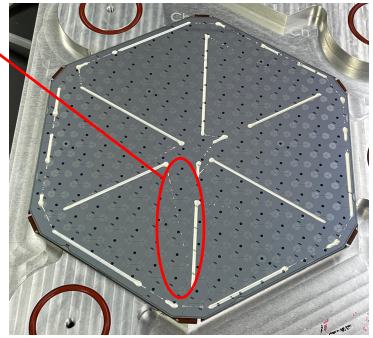

Normal bonding hole

Bad allignment

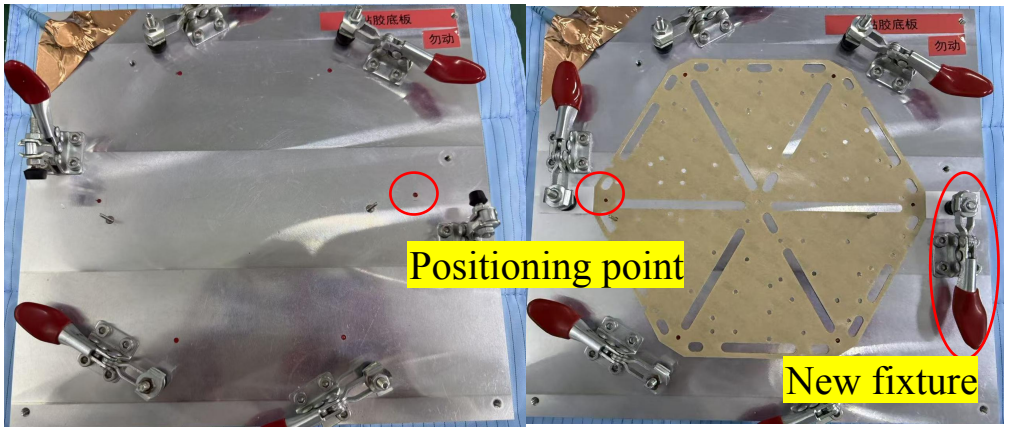

glue “tail” leakage



transfer tape



- The main reasons affecting bonding speed:
  - Allignment accuracy too bad (Solved by gantry caliberation)
  - Bonding hole is covered with expoxy or transfer tape
- Adjust the gantry dispense routine to solve the expoxy issue
- Improve the hexaboard adhesive tool to solve the coverage problem
  - Improve the tape fixture to avoid tape movement
  - Add red positioning point to double-check the tape allignment

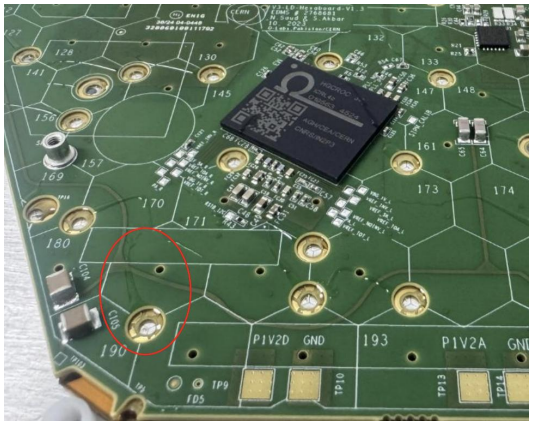

Positioning point

New fixture

In the recent production of 28 modules (4 modules/day), all module bonding went quite smoothly !

Ramping-up: Bonding & Encapsulation

❖ Encapsulation ramping-up



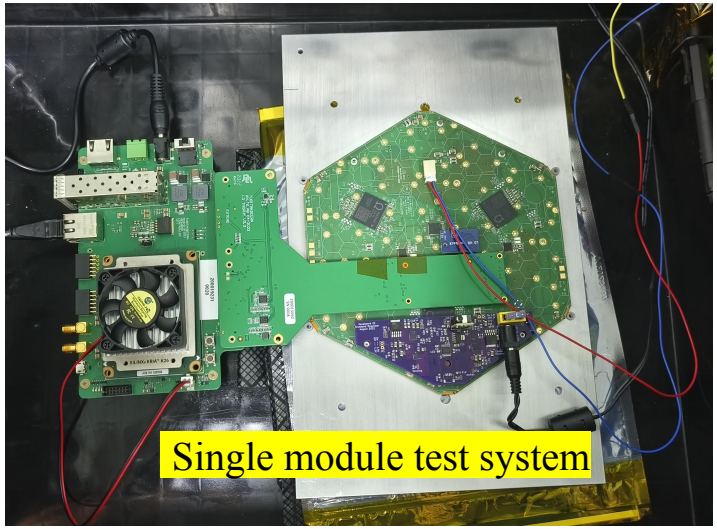
- We had solved the encapsulation expoxy "tail" problem
  - Viscosity of the encapsulated epoxy resin causes "tail"
  - Solved by adjust the dispense time and the waiting time (the time before stopping dispensing and moving to the next hole)
- Using a constant temperature chamber to reduce curing time (48h to 4h)
  - Change to bigger chanmber to meet the requirement of 16 modules/day

For verification
Contain 4 modules

For production
Contain 16 modules

Ramping-up: Electronics Test

❖ Electronics Test ramping-up


Single module test system

Thermal chamber of MMTS

Chiller

Shelters

- IHEP MAC is changing the test system from single test system to MMTS (Multi Module Test System)
  - 30 mins per module using single test system.
  - Most of the components of MMTS received
  - Relevant personnel have completed the power supply technology training
- MMTS
  - Electronics test: 3 modules per run
  - Temperature cycling test: 24 modules per run
- MMTS setup is about to begin in November


HV power supply

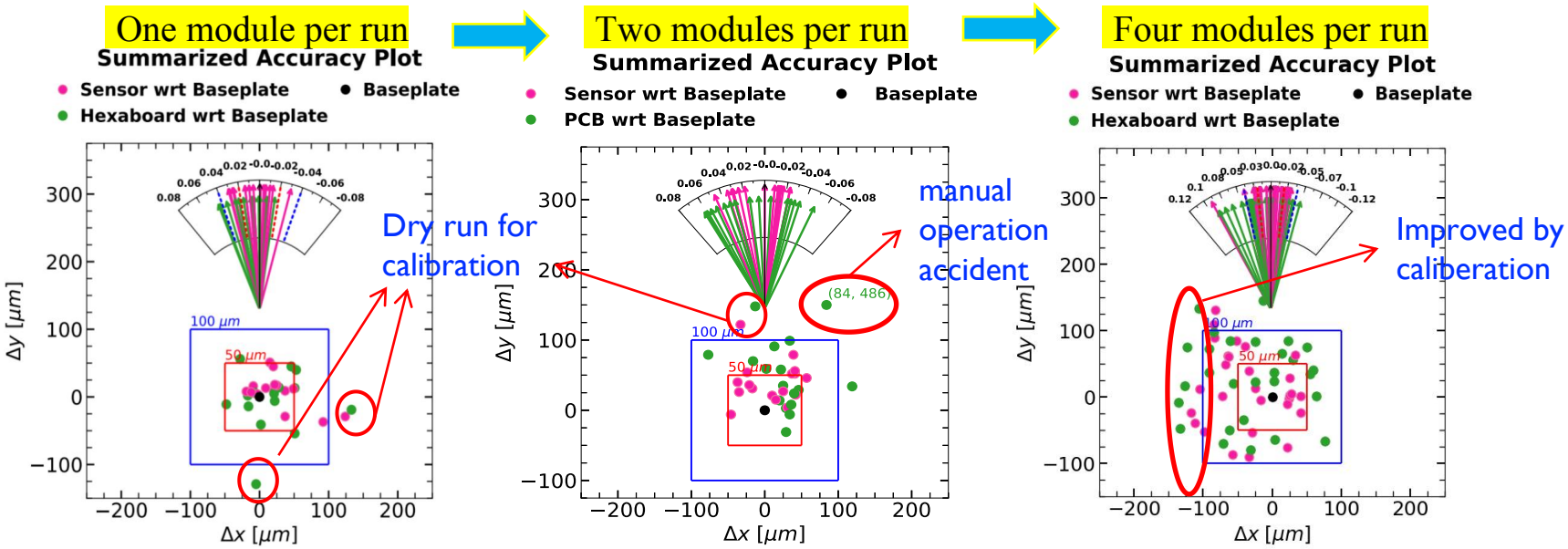

LV power supply


HV switch

Quality Control

❖ Alignment Accuracy

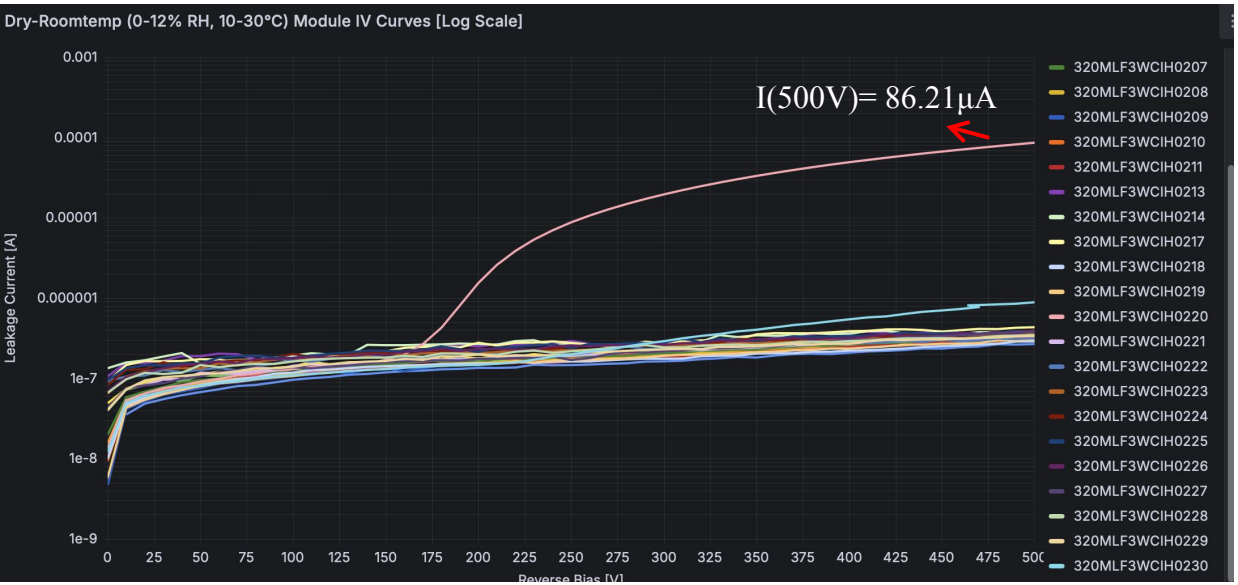
One module per run → Two modules per run → Four modules per run

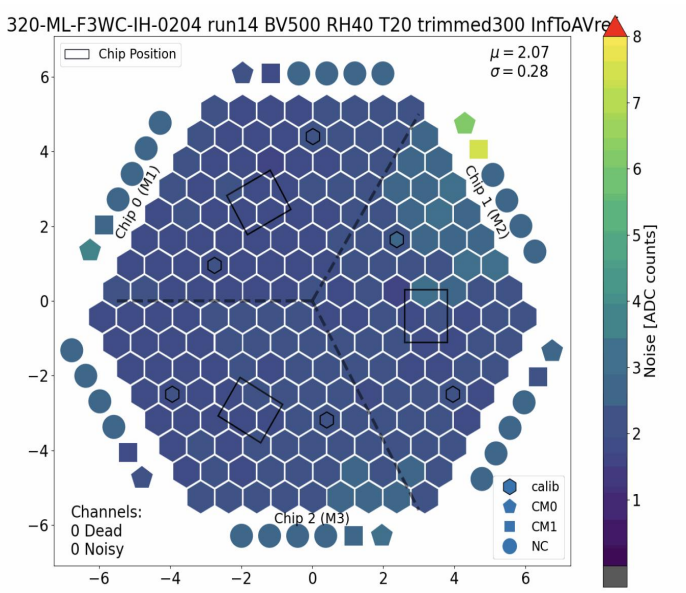


- Using OGP (Optical Gaging Product) to measure the alignment accuracy of XY
  - No-touch measurement with resolution of ~1μm.
- Most modules have an XY alignment accuracy within 150 μm (Grade B), with many even within 100 μm (Grade A).
- The allignment accuracy will be relaxed in future.
- All the modules (Grade A & Grade B) can be used normally on detector.
- Subsequent efforts will focus on refinements to the automated process and hardware setup, aimed at improving the consistency of assembly precision.

Quality Control

❖ **Electronics Test** Temperature ~ 20°C, Humidity ~ 1%

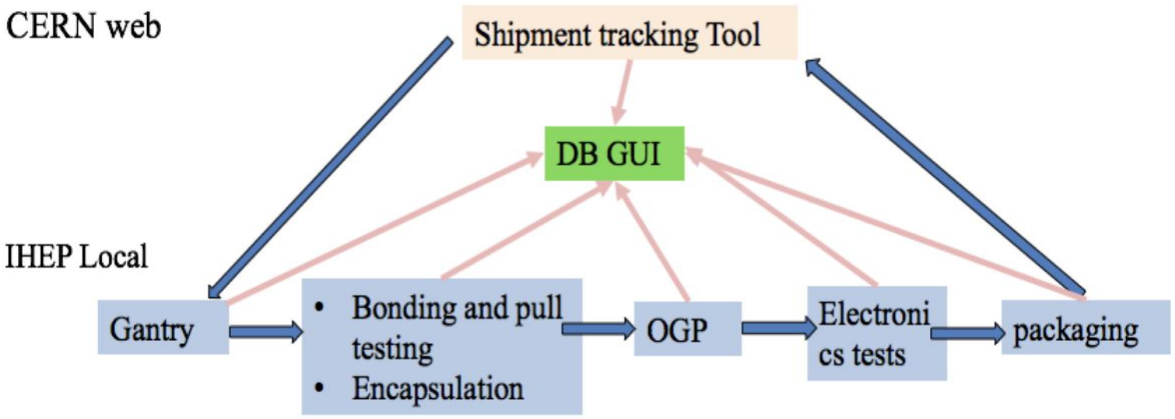


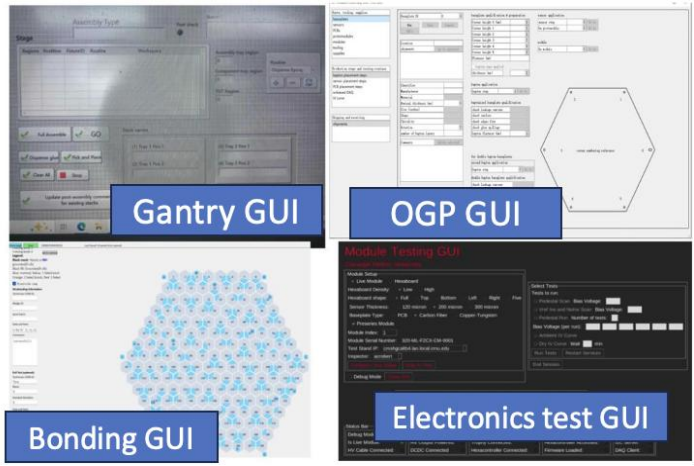


- Electronics test contains two parts: IV test and pedestal test.
  - Grade A requirements for IV: I(500 V) < 100 μA
  - Grade A requirements for pedestal: channel(dead + noisy + unbonded) ≦ 4
- All noise test results are consistent with the example illustrated in the plots on the right.
- All of the 28 modules produced in September perfromed good (Grade A) in electronics test.

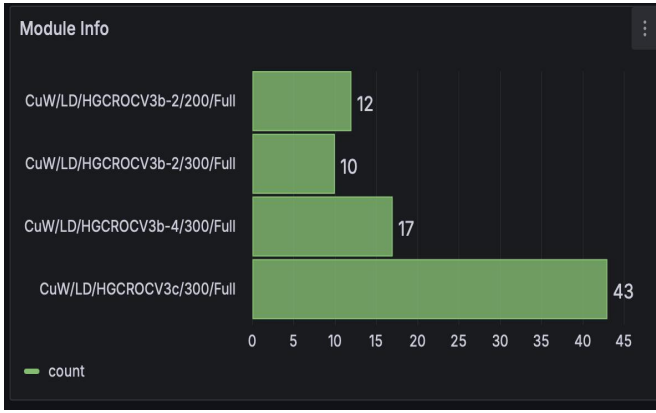
Database/GUI & Garafana Web

❖ Database&Grafana Web





- DataBase(DB) is to record informations and classifications of every components and modules.
  - Graphical User Interface (GUI) set up for every production steps
  - GUIs can automatically upload production information to the database during the production process
  - Can track key parameters, components, modules, operators, and other related information
  - IHEP MAC had completed coordinating the DB and various GUIs
  - We have used and helped improve the DB system
  - DB information can be visualized through the Grafana website
- All of the modules produced by IHEP are in DB.



Production Web UI

❖ Production Web UI

	Step	Status
0	OGP Before Assembly	✅
1	Hexaboard Electronic Test - Untaped	✅
2	Apply Double-sided Tap Beneath Hexaboard	✅
3	Hexaboard Electronic Test - Taped	✅
4	Assemble Sensor	✅
5	OGP After Assemble Sensor	✅
6	Assemble Hexaboard	✅
7	OGP After Assemble Hexaboard	✅
8	Live Module Electronic Test: Assembled	✅
9	Bonding	✅
10	OGP After Bonding	❌
11	Live Module Electronic Test - Fully Bonded	❌
12	Encapsolation	❌
13	OGP After Encapsolation	❌
14	Live Module Electronic Test - Fully Encapsulated	❌

Select a step

OGP After Assemble Sensor

Previous Step | Next Step

Inspection of glued base plate + sensor Flag:

- ✅ Green
- ⚠️ Yellow
- ❌ Red

OGP After Assemble Sensor Steps Overview

	Step	Status	Status Changed by
0	Inspection of glued base plate + sensor	✅	houbr@ihep.ac.cn

OGP After Assemble Sensor Check List: ✅

Save Flags to File

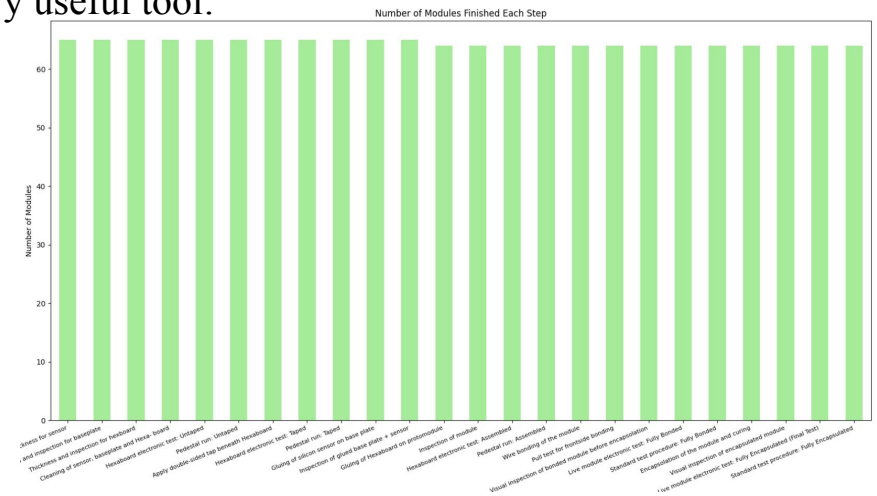
- Production Web UI is developed by IHEP MAC, a very useful tool:
  - Standardizing our production steps
  - Visualizing current production status
  - Can auto-email next-step operators
- Double-check with DB of all the key parameters

```
Dear Bonding and OGP Teams,

        Please be informed that the status of the step: Bonding has changed.

        Status: ✅
        Changed by: tycao@ihep.ac.cn
        Module Number: MLF2W2IH0061
        Sensor ID: 200132
        Hexboard Number: 320XLF42MH00216
        Baseplate Number: 320BAFLWKA00150
        Remeasurement Number: 0
        Comment:

        Best regards,
        IHEP MAC Checklist Website
```



X-axis represents production steps,
Y-axis represents the number of modules in this step

Future Plan

❖ Production plan

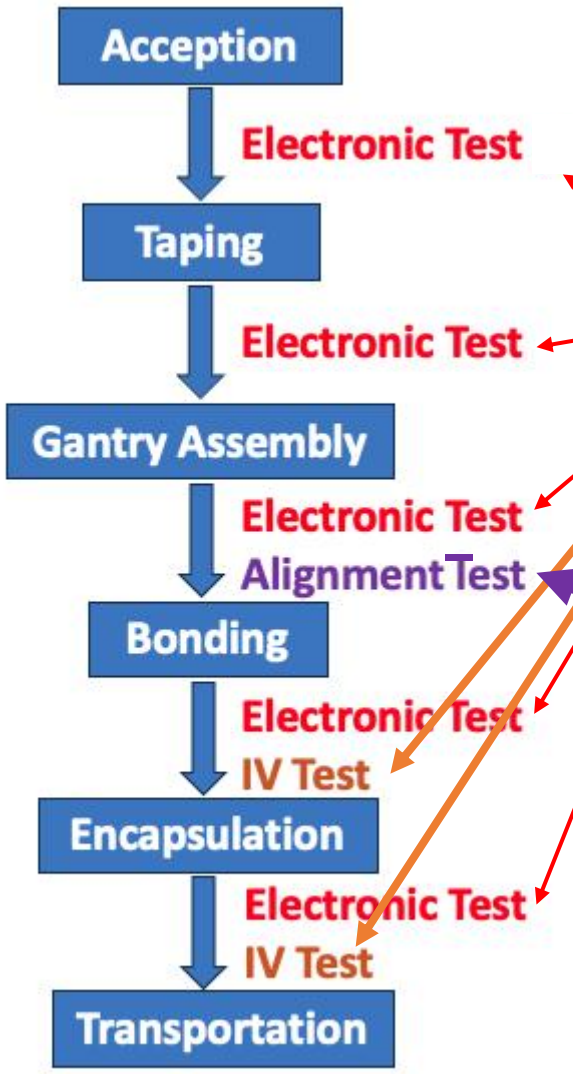
- We have increased the production rate from 1 module per day to the current 4 modules per day for the last year.
- The main limitation is the shortage of components (Hexaboards).
- Next step is producing 8 modules per day, then 12 modules per day, 16 modules per day finally.
- The target for this year is ~200 modules (82 modules finished).

Summary

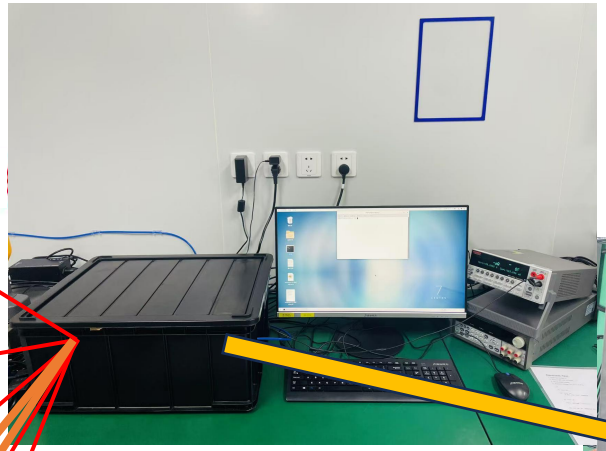
- HGCal modules assembly @IHEP
  - IHEP MAC have produced ~80 HGCal modules from last November.
  - The newest 28 pre-production V3C modules perform good in electronics test.
  - All the modules were sent to CERN, some used in beam test, 28 pre-production modules are used on Cassettes (real detector).
  - Continue ramping-up module production rate to 16 modules per day .
  - The shortage of components is solved temporarily.
  - IHEP MAC had made great efforts optimizing production workflow.
- DB & Web UI
  - Had implemented DB,GUI and production Web UI in production successfully
  - All these useful tools can help standardizing production.

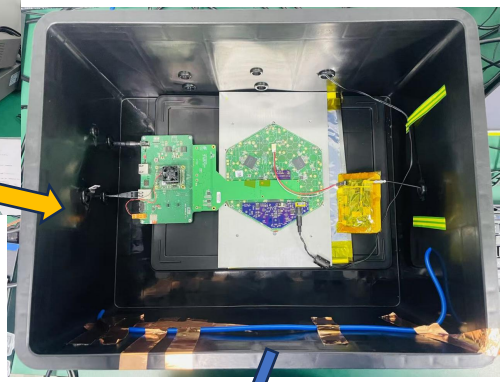
Thanks!

Module Production Workflow

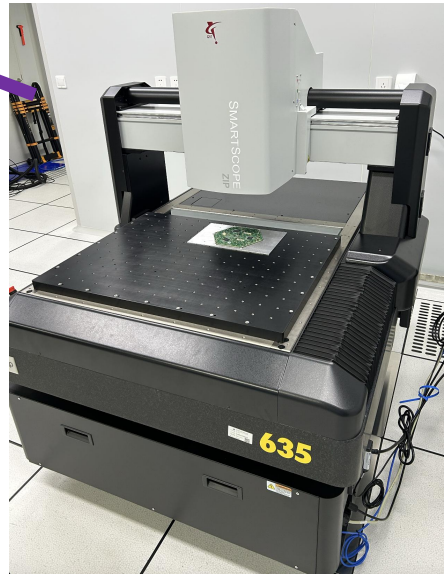


Module production procedure





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



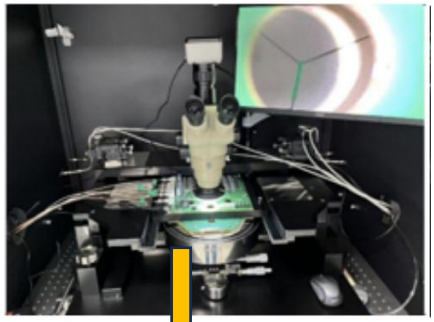
Optical Gaging Product (OGP)

Production Facilities at IHEP

Electronics Testing System:
Electronic/IV test

Bonder:

Bonding



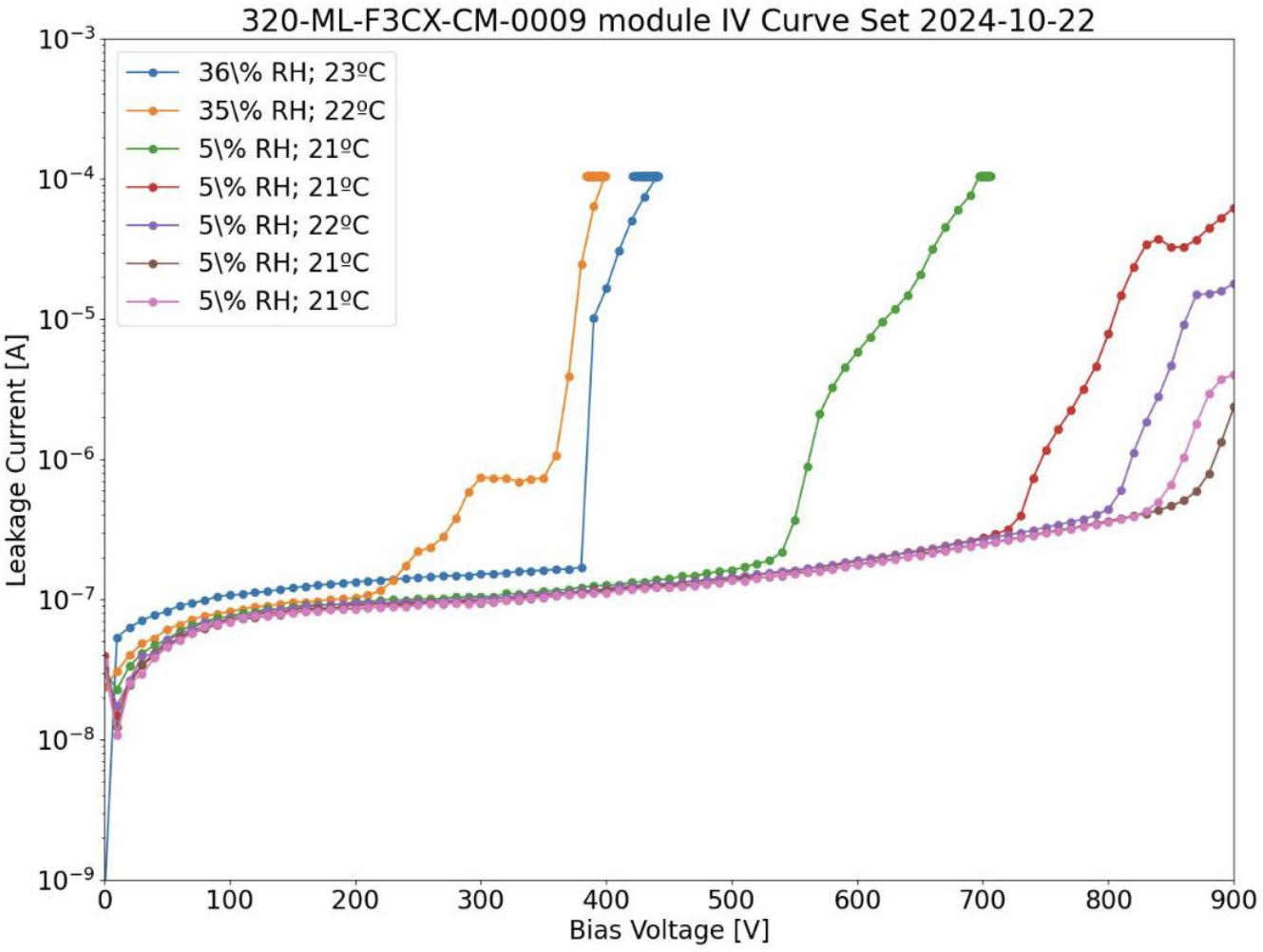
Sensor Testing System:
Sensor quality control

Gantry:
Module assembly

Dispensing Machine:
Encapsulation

Optical Gaging Product (OGP):
Alignment test

IV Test as Humidity



- Humidity can have a noticeable impact on IV curve