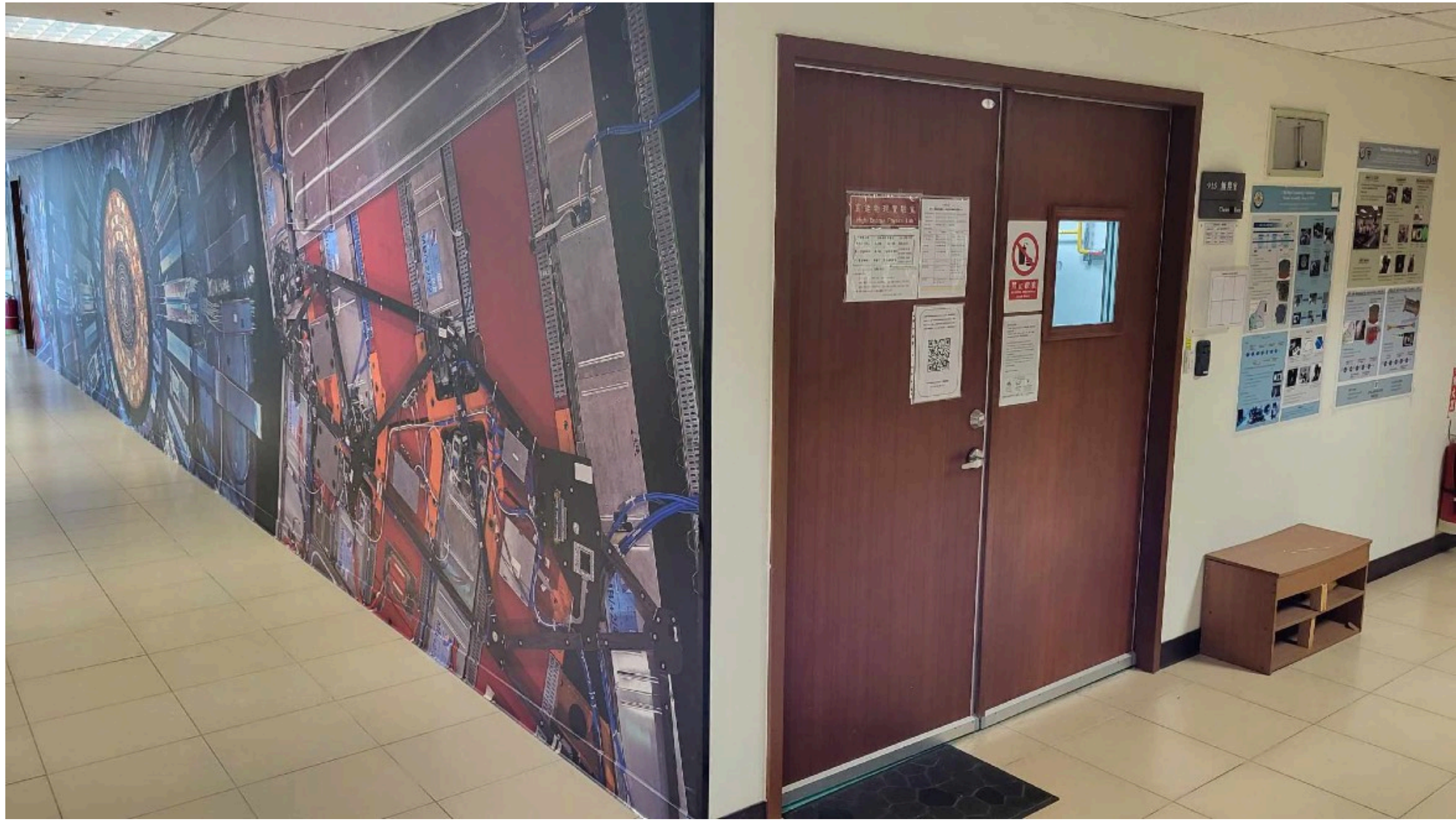
Taiwan Instrumentation and Detector Consortium
台灣偵測器聯合實驗室



# HGCAL Module Assembly Center in Taiwan

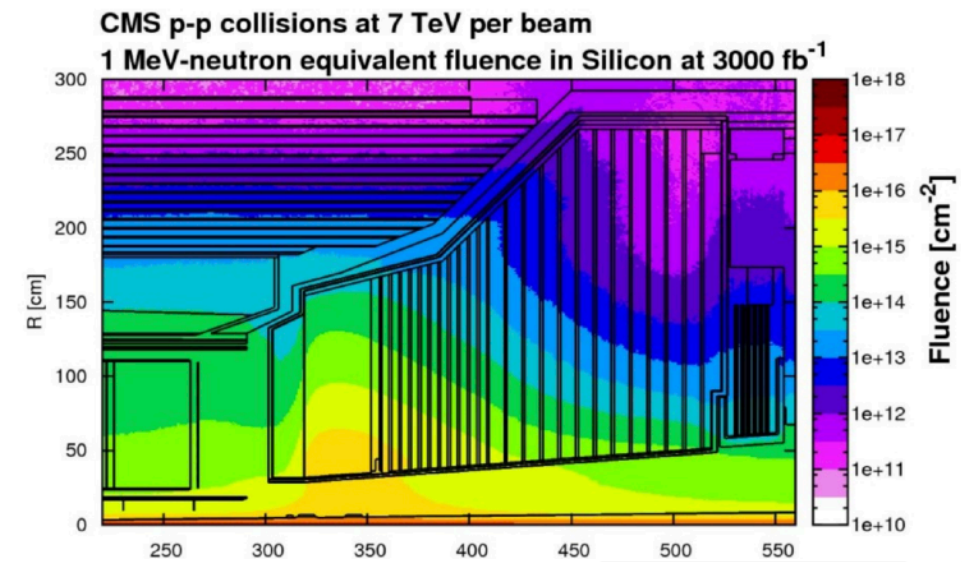
TIDC annual Meeting — November 25, 2023

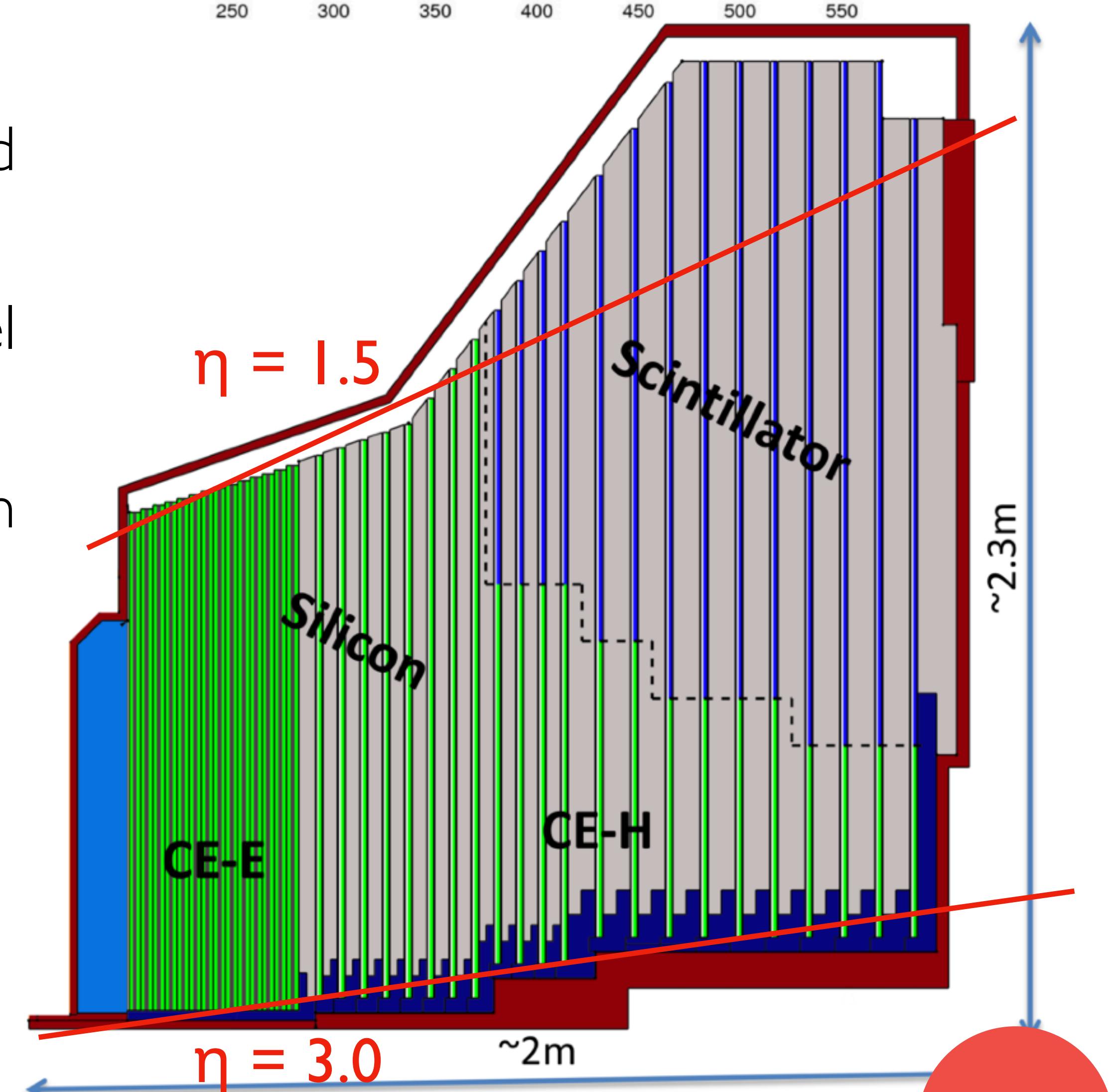
**<u>You-Ying Li</u> on behalf of Taiwan MAC**

National Taiwan University

# HCGAL overview

- The HGCAL detector, which is CMS Phase II upgrade, replaces the ECAL and HCAL endcap region to be against the high pileup environment of up to 200 interaction points.
- A sampling detector with three parts:
  - CE-E : 26 layers of silicon modules with Cu/Pb absorbers.
  - CE-H : 21 layers of silicon modules with Cu and thick steel absorbers.
  - Scintillator : SiPM to tiles with Cu and thick steel absorbers.
- The detector provides precise 5D information (position, time and energy) for particle showers.

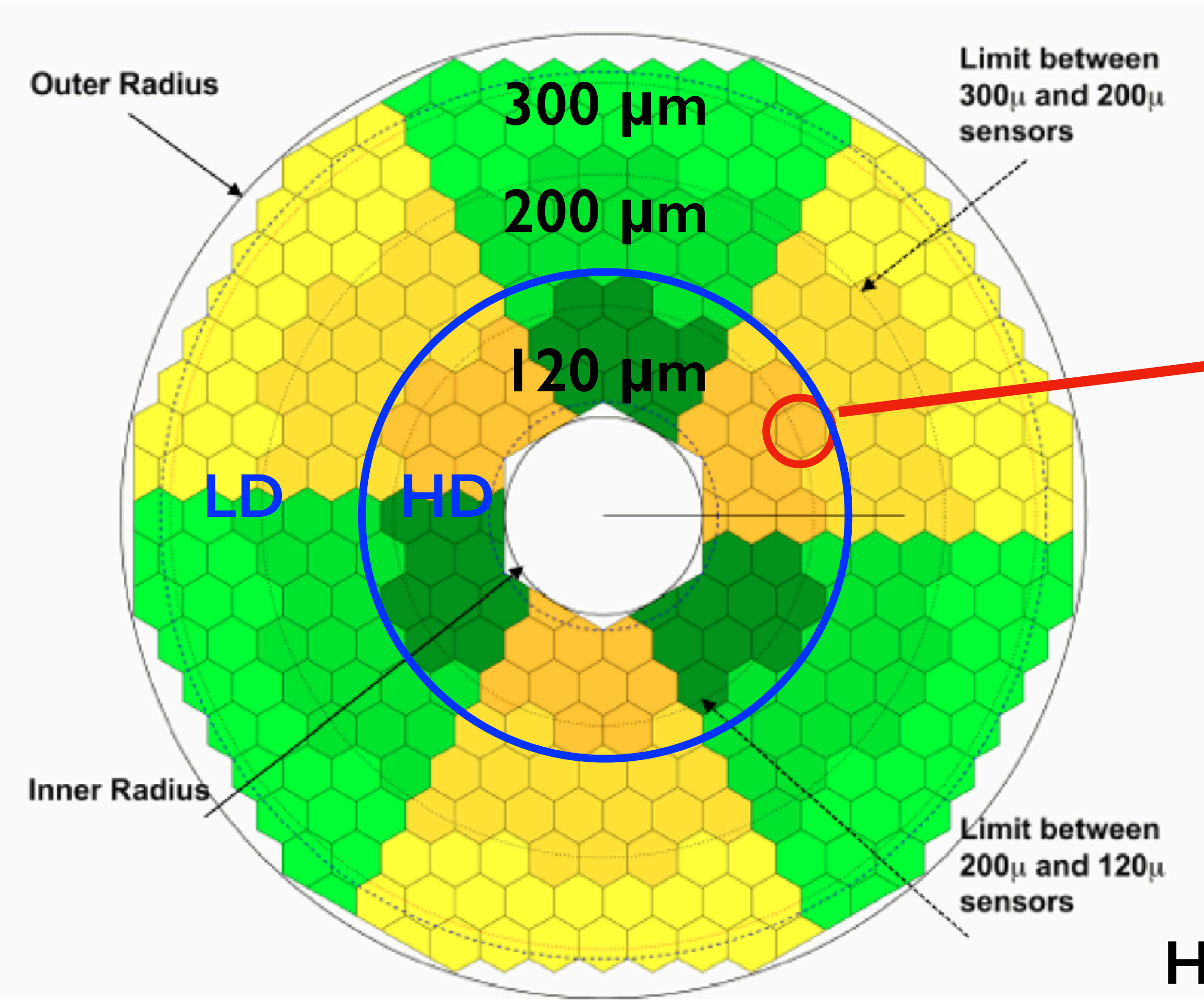


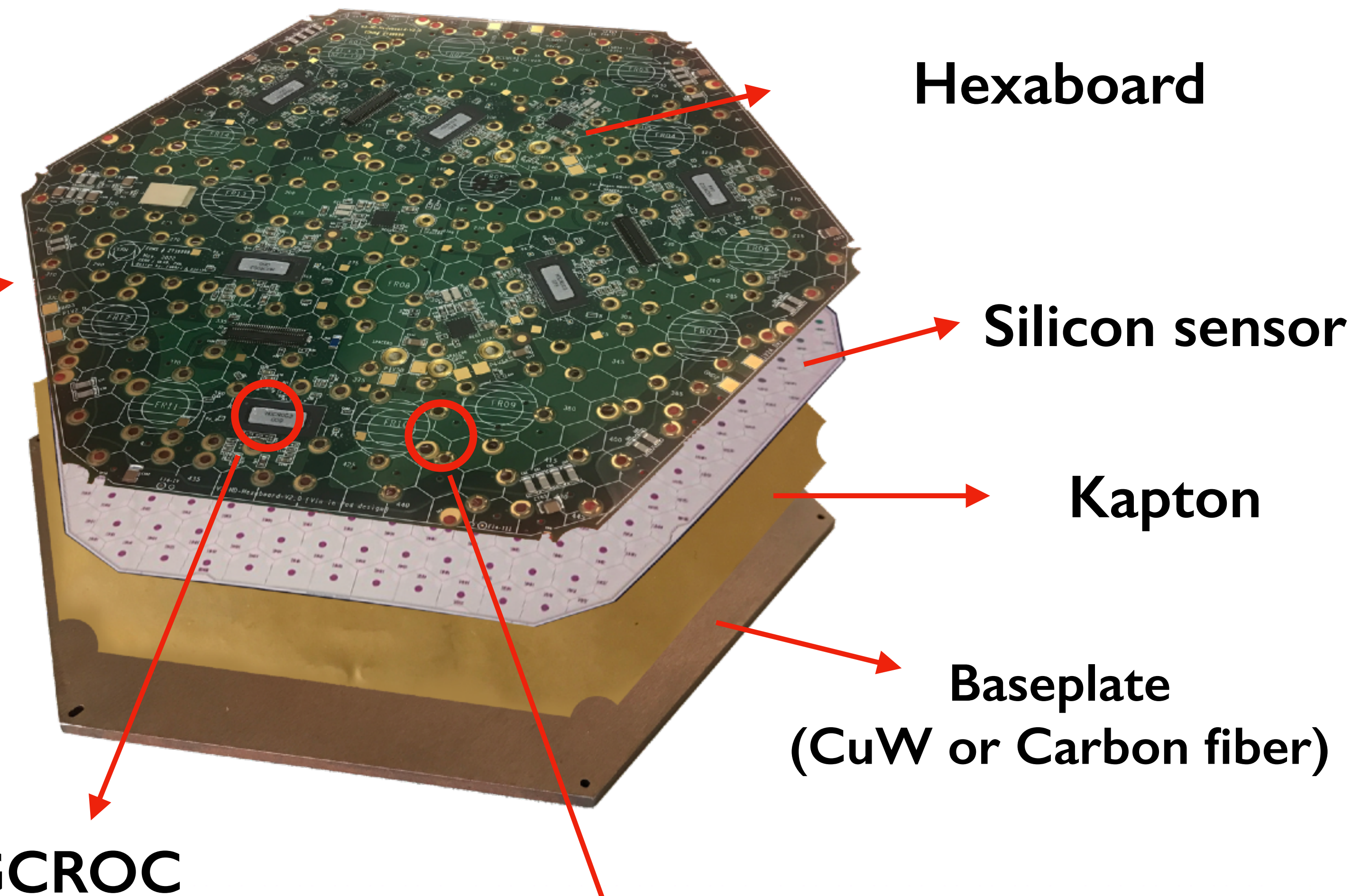




**Key parameter:**

- Cover $1.5 < |\eta| < 3.0$
- Full system maintained at -30°C
- 6 M channels with 27 K silicon modules
- Silicon cells of size (≈0.5/1.1 cm$^2$)

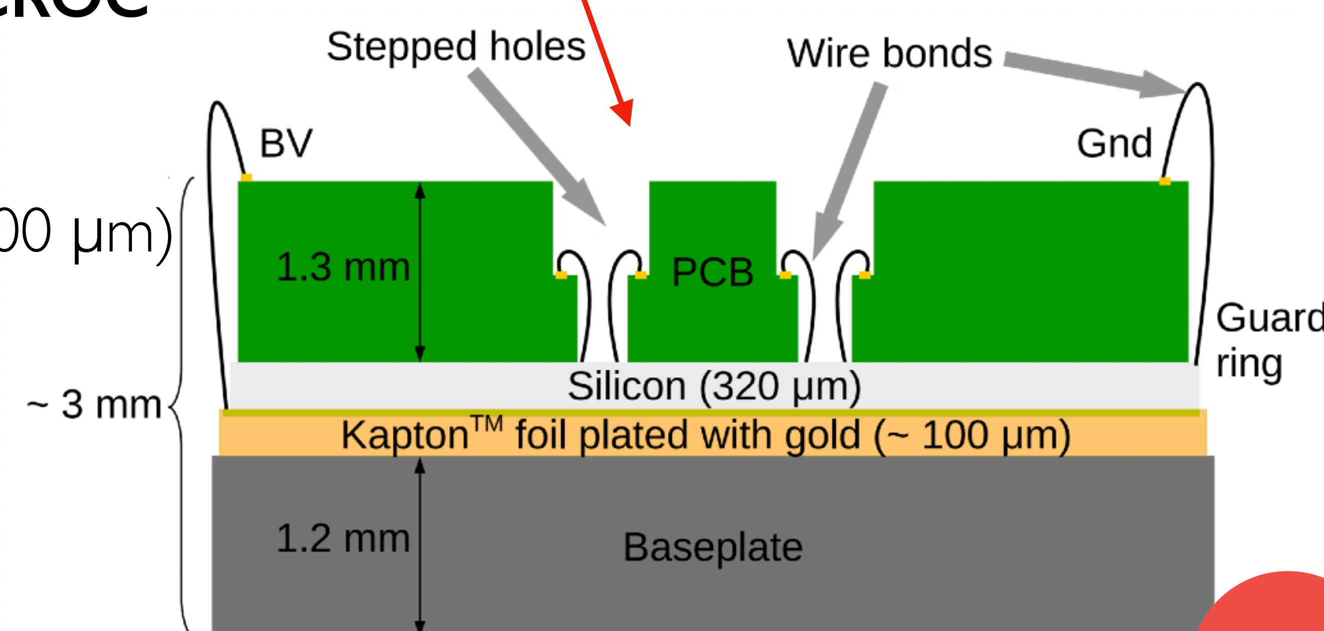
# 8 inch Silicon Module




**Requirement**

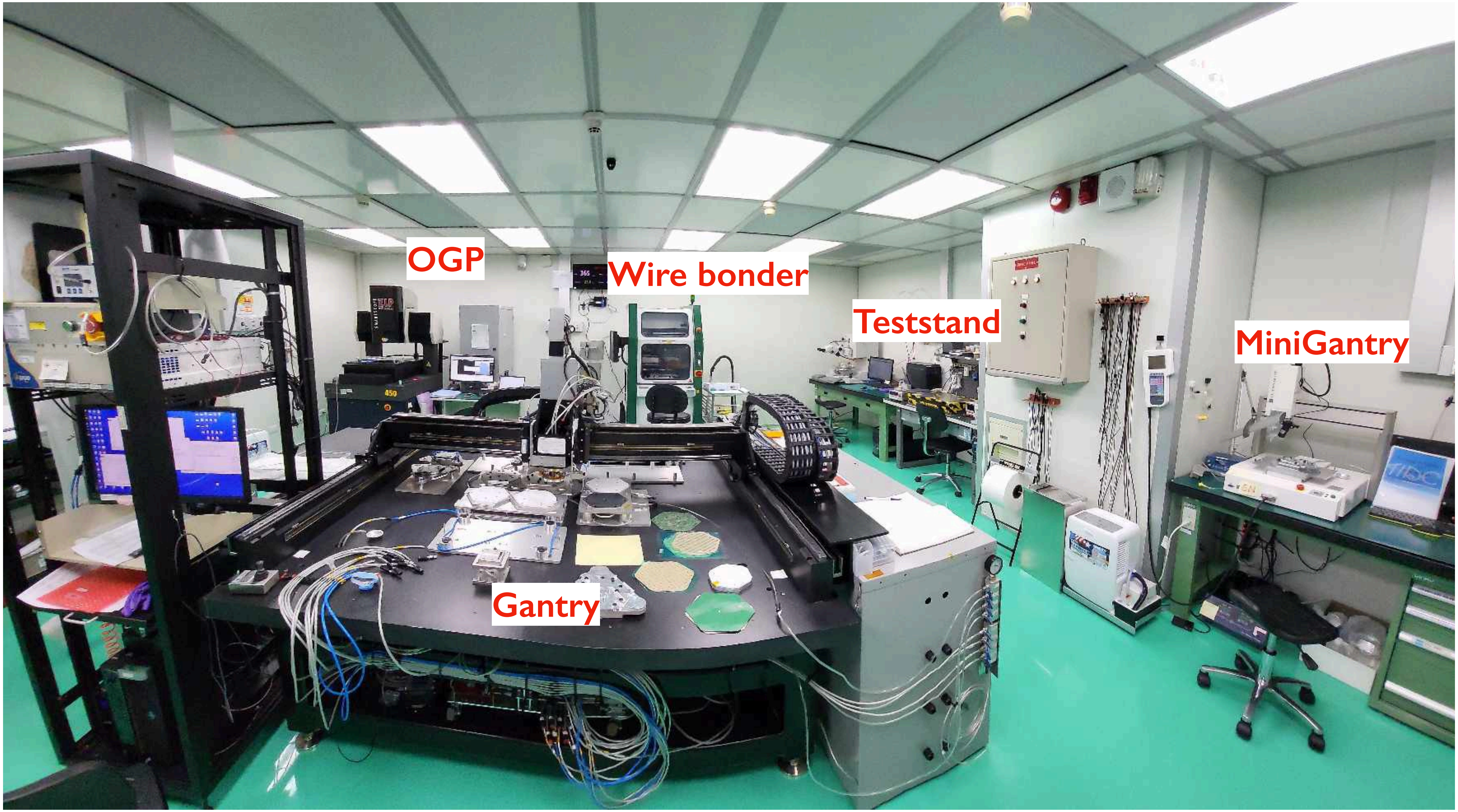
- ☑ Small offset between HB/Sensor/Baseplate (< 100 μm)
- ☑ High radiation tolerance (> 1.5 MGy)
- ☑ 850 HV available for bias
- ☑ Low noise for each readout channel
- ☑ Temperature change tolerance (-40~20°C)



# Taiwan HGCAL MAC overview

- The HGCAL MAC in Taiwan are established in 2018.
- Taiwan MAC (NTU+NCU) is one of 6 HGCAL MACs (NTU+NCU Taiwan, IHEP China, TIFR India, UCSB US, TTU US, CMU US)
- Three PIs (Stathes Paganis, Rong-Shyang Liu, Chia-Ming Kuo) and more than seven postdoc and assistants
- Hosts main module assembly and shipping and contact Ploteck for hexaboard fabrication.
- Around 5000 pieces of silicon modules need to be made in two years.

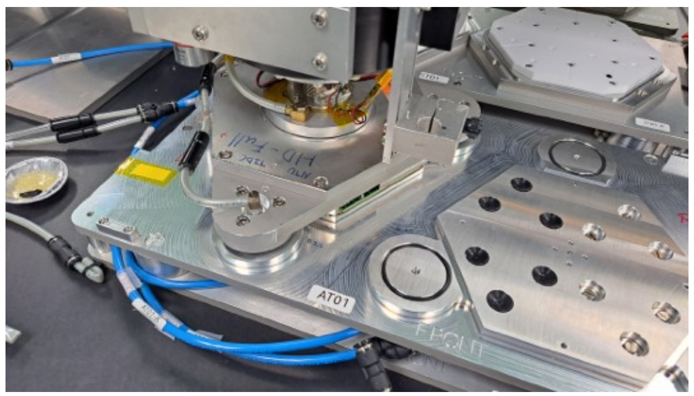
# Clean room for Taiwan MAC



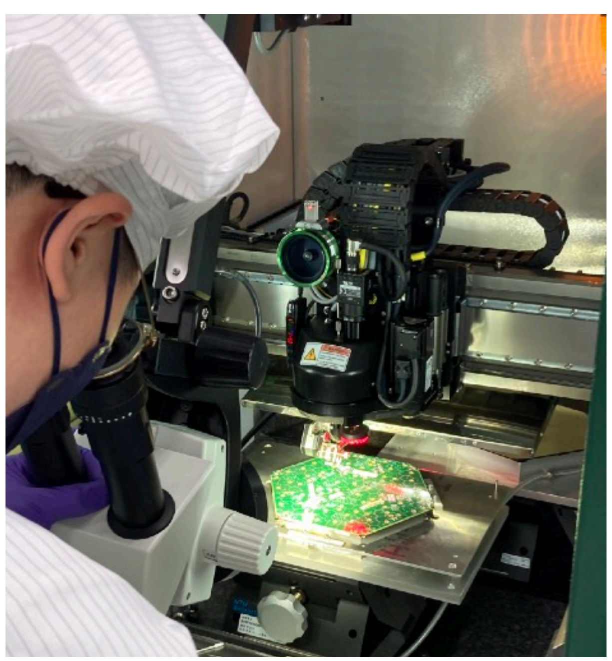
# MAC : From material to module

**Material (HB/sensor/PCB)**

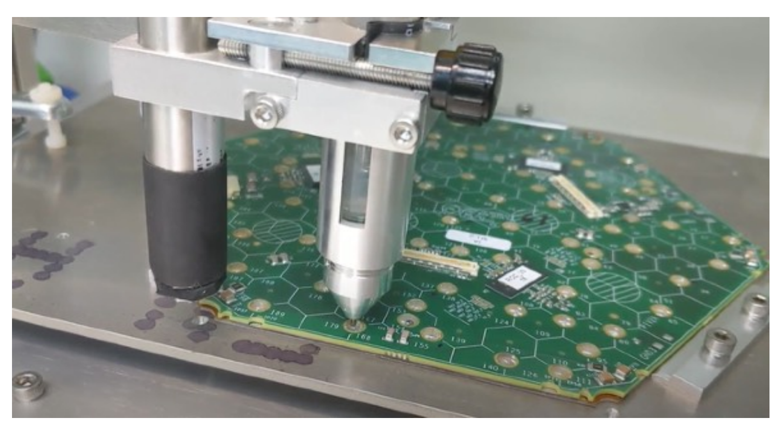
**Assembly**



**Wire bonding**



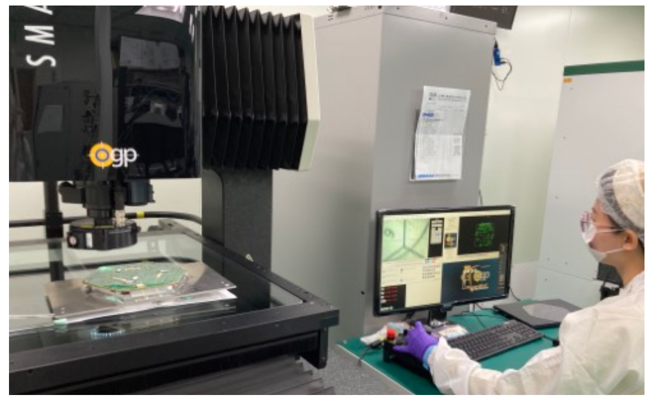
**Encapsulation**



**Module**

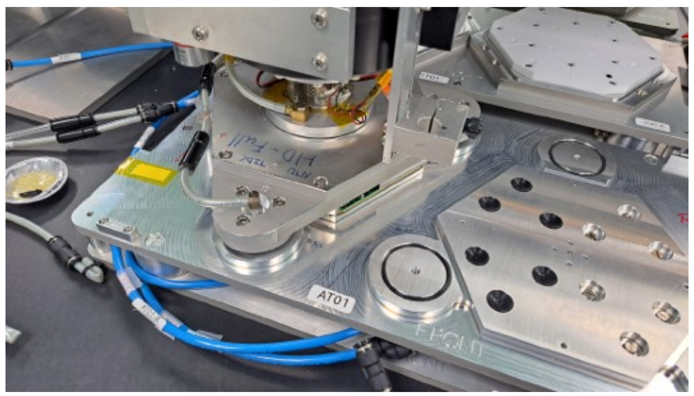
# MAC : From material to module

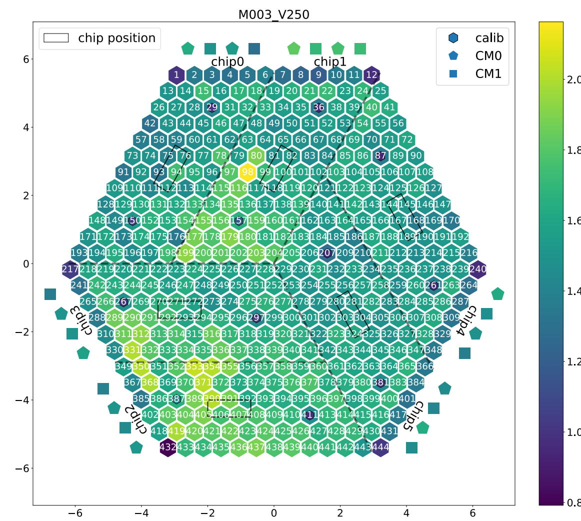
**Material**



OGP QC

**Assembly**

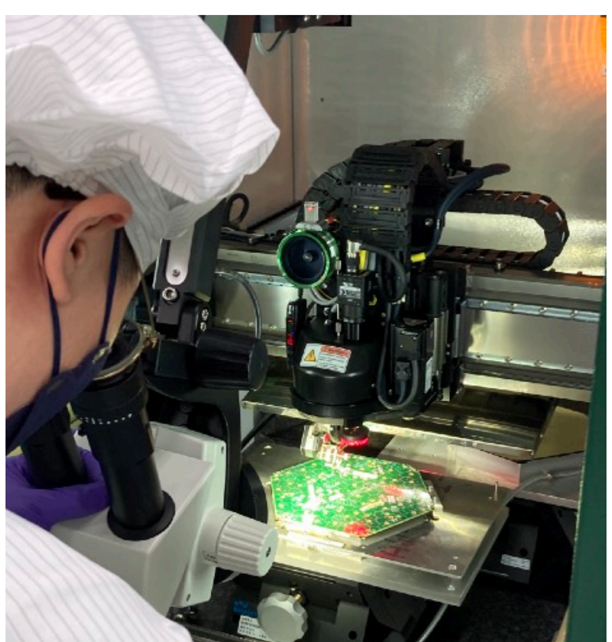




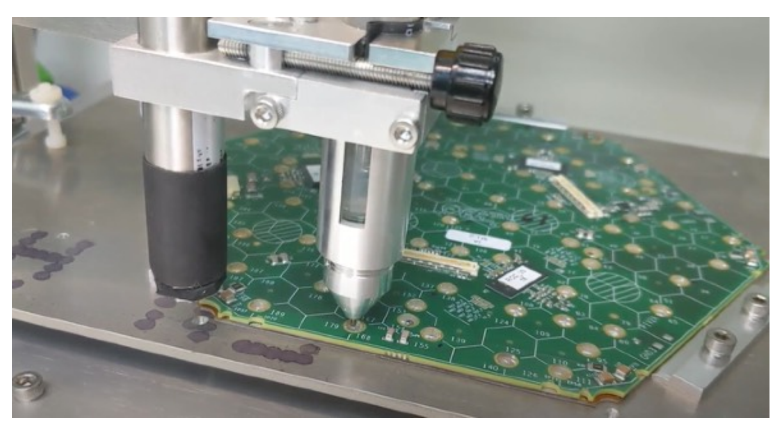

**Electronic test**

**Thermal cycle**

**Wire bonding**

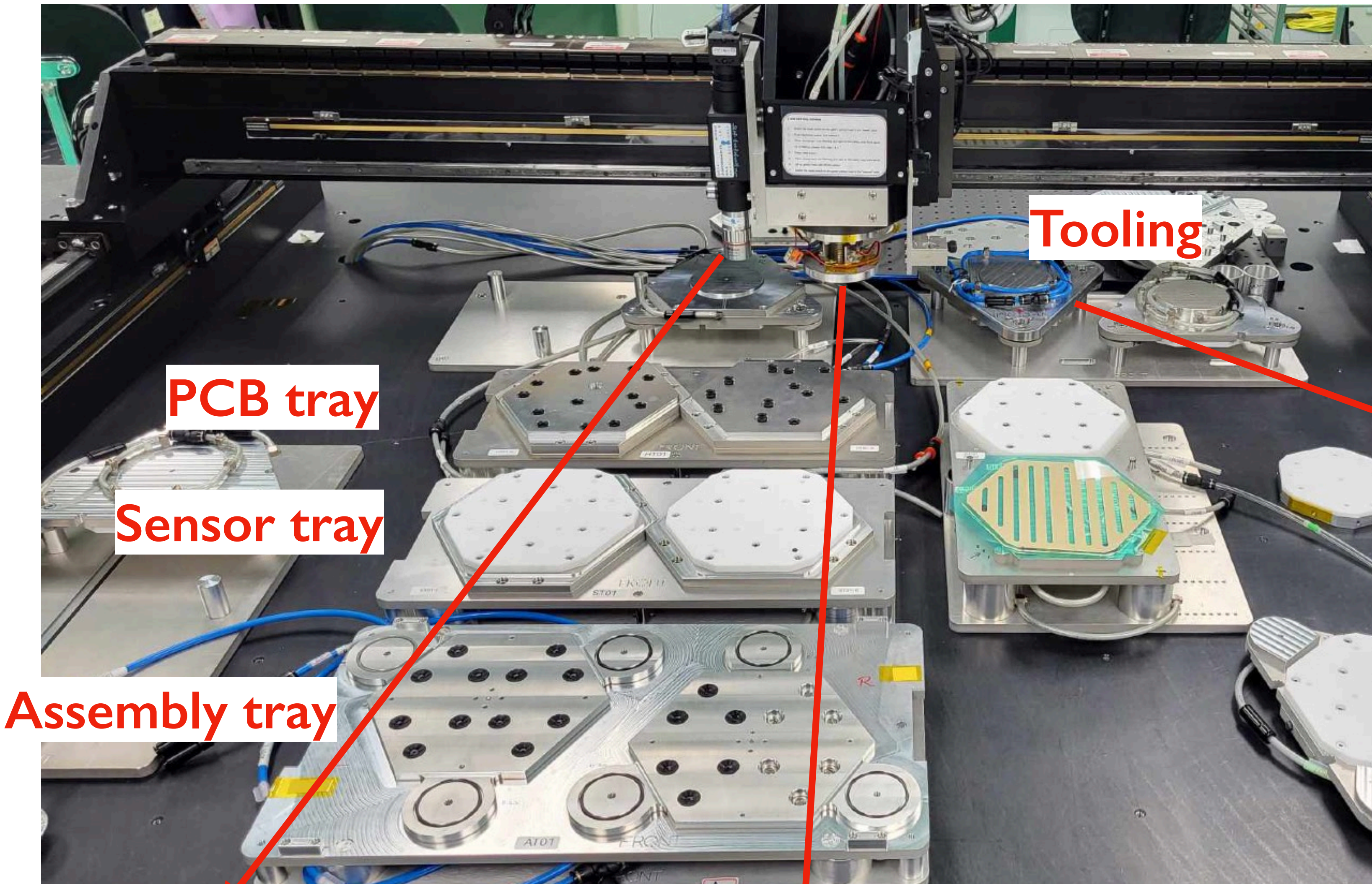


**Encapsulation**

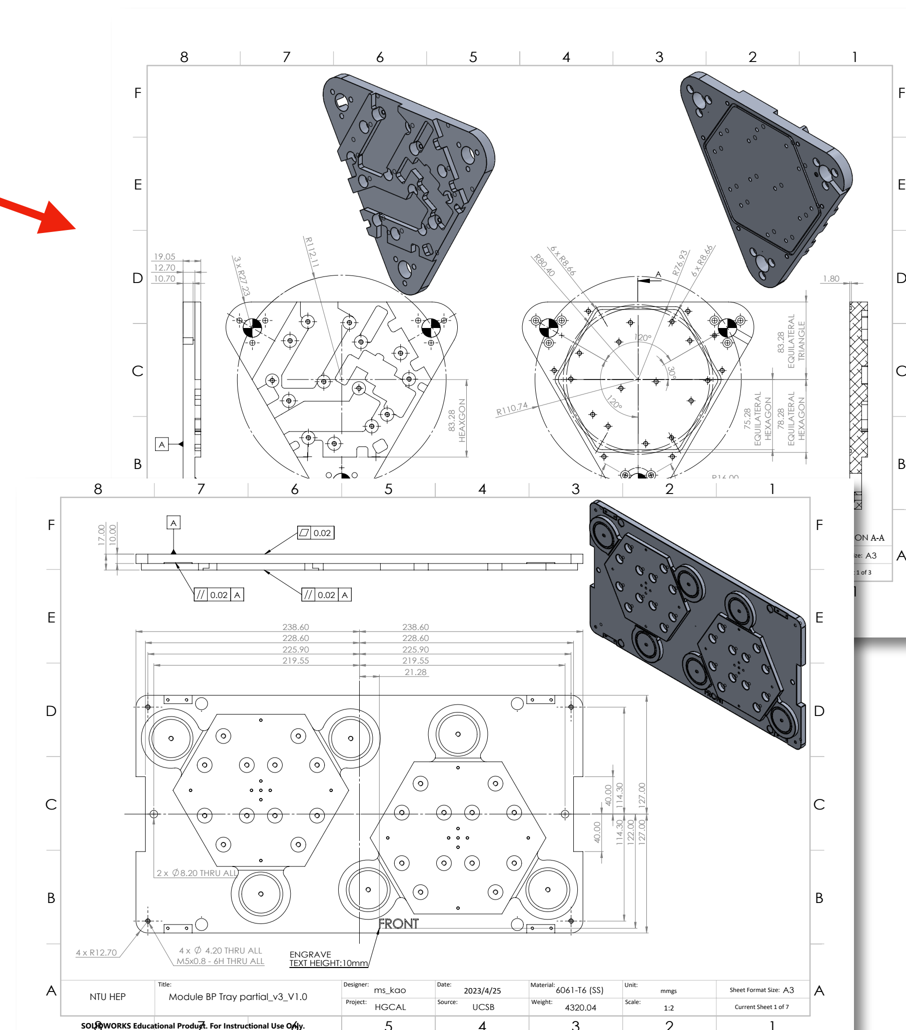


**Module**

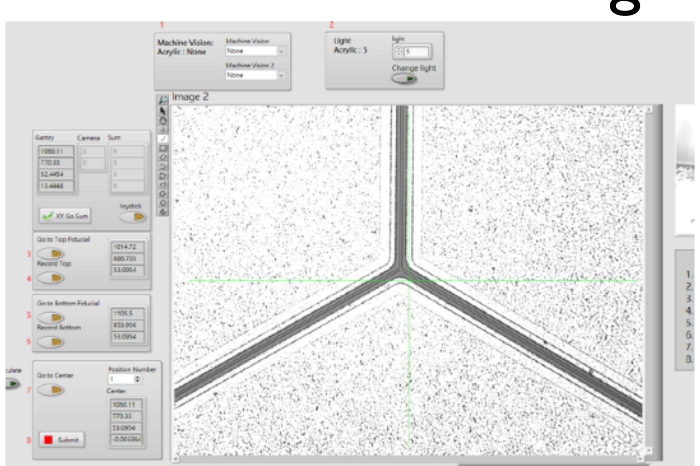
# Gantry overview



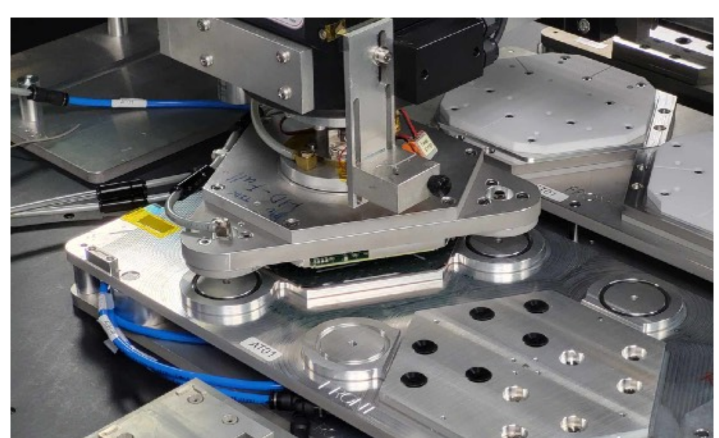

Assembly jigs designed at NTU and fabricated at AS




Camera for locating

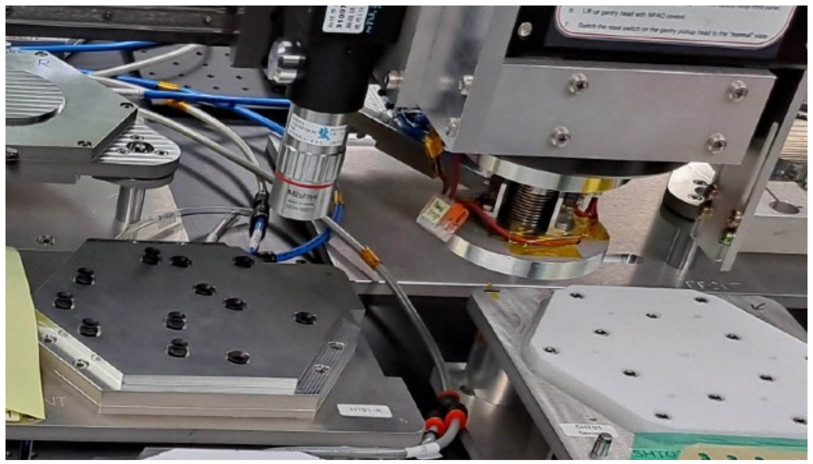


Pick and place by vacuum

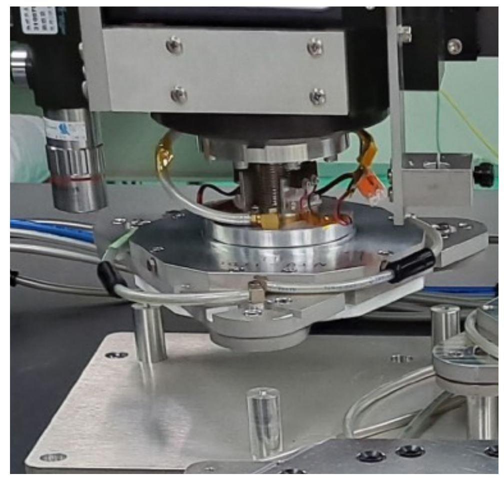


# Module assembly step

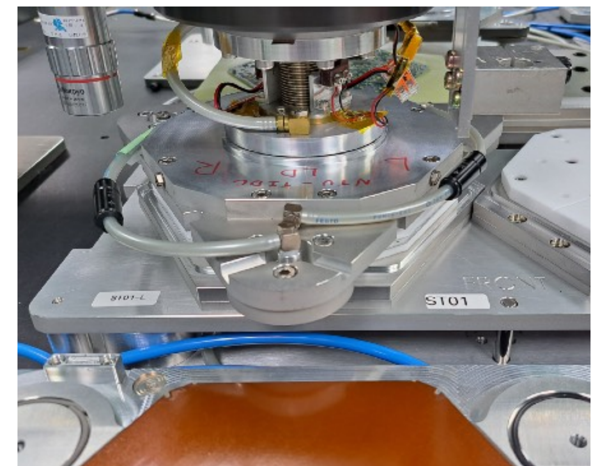
Locating



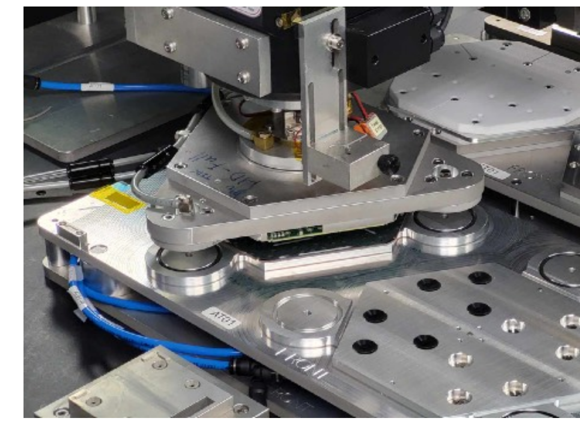
Pick up the sensor tool



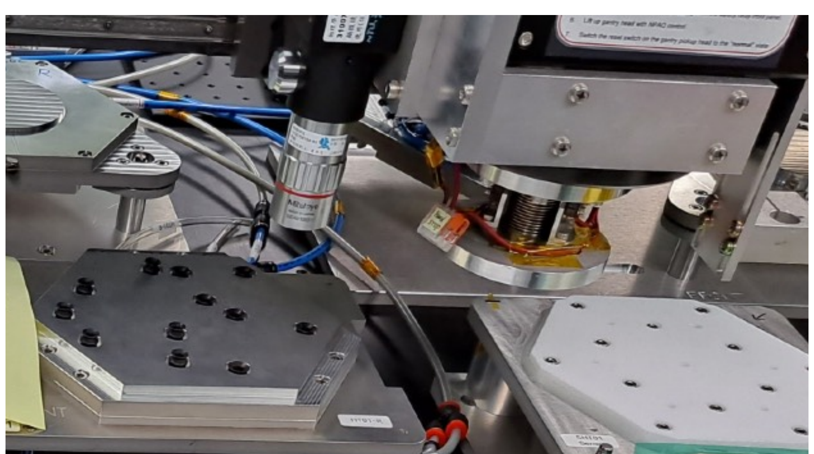
Pick up the sensor



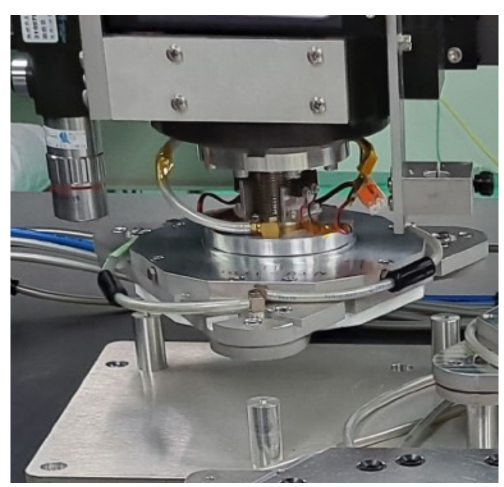
Place the sensor on the baseplate



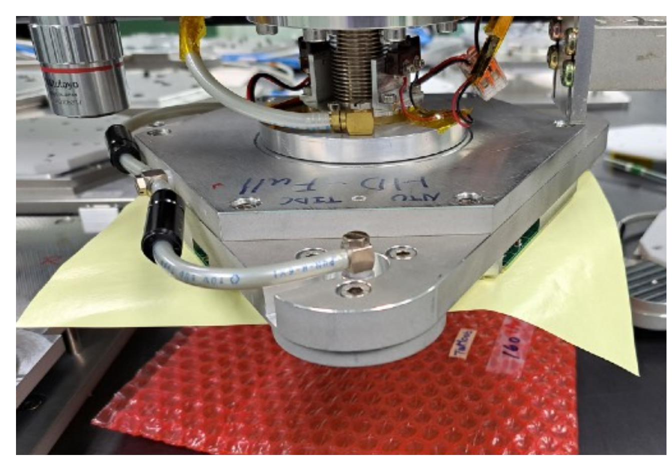
Locating



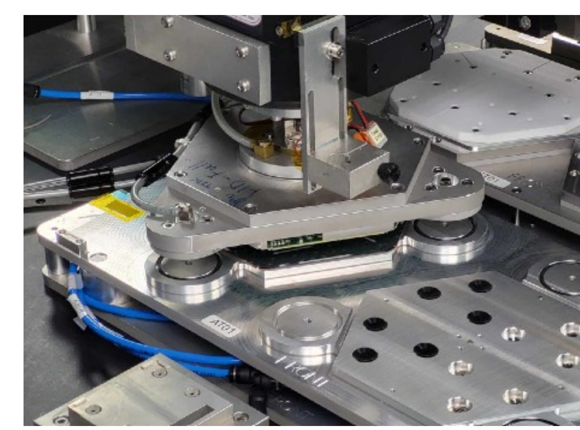
Pick up the PCB tool



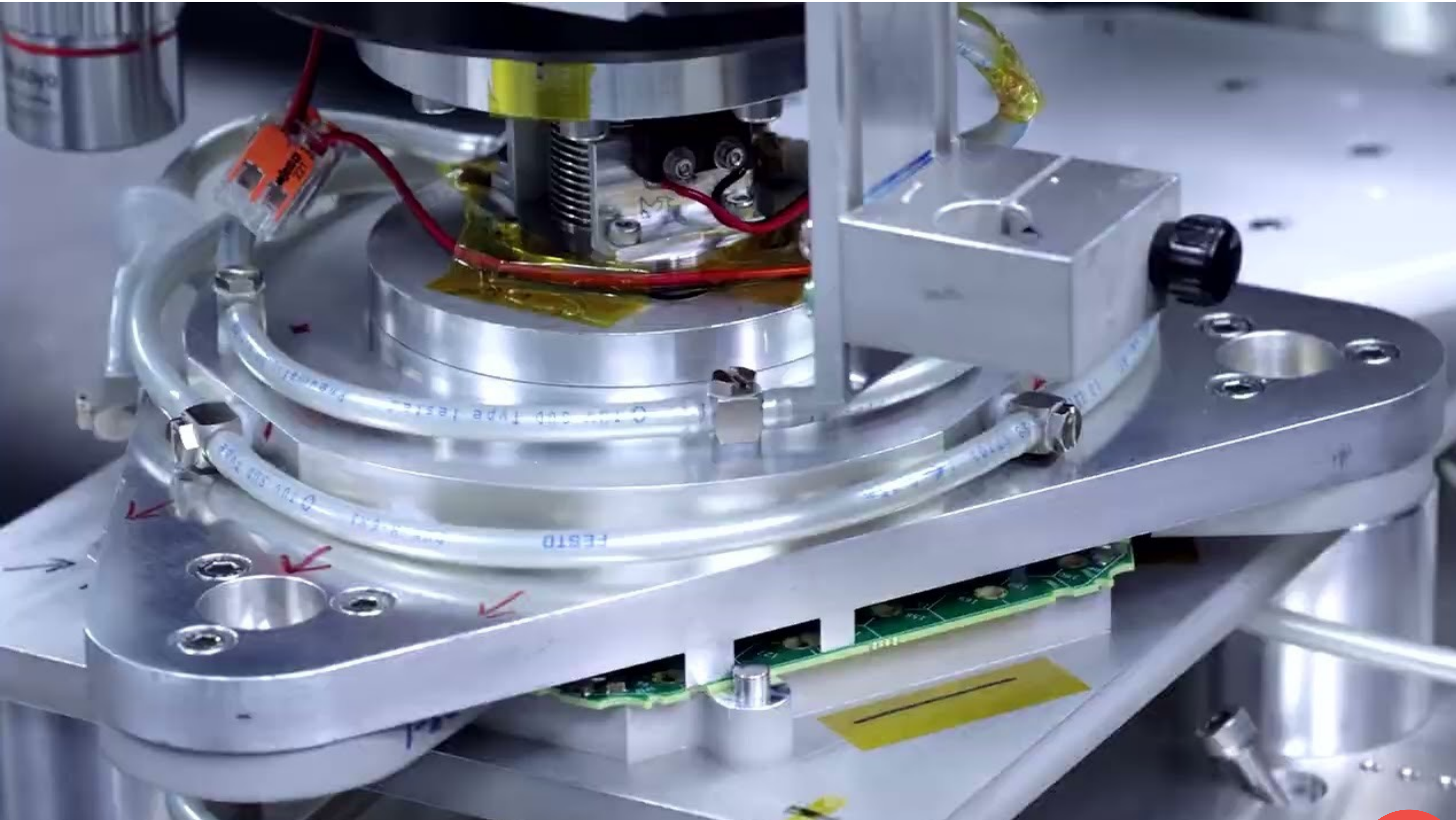
Pick up the PCB



Place the PCB on the silicon module

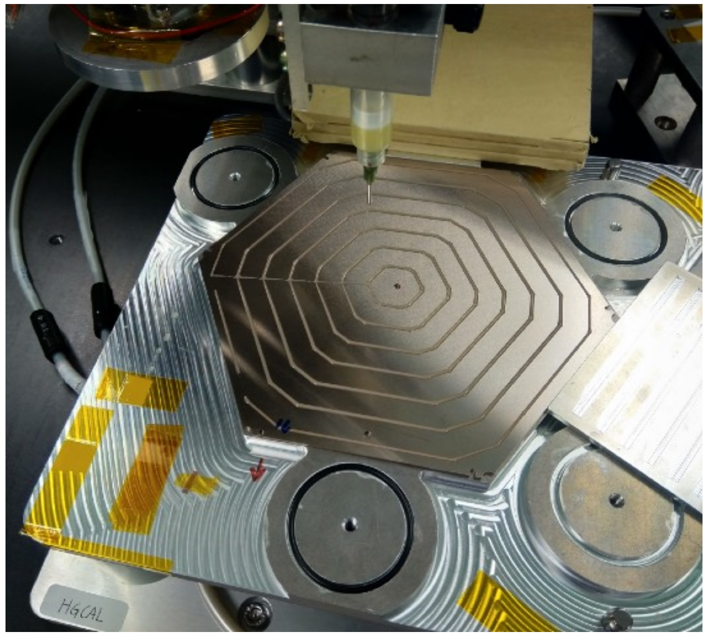


# Module assembly step



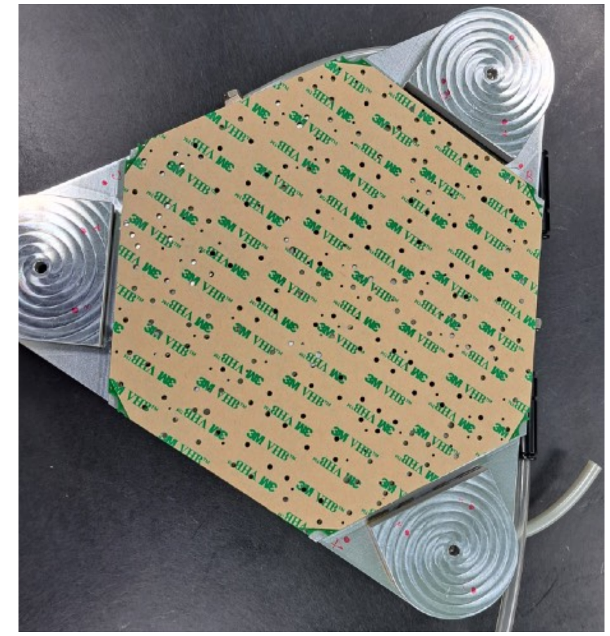
# Module assembly method

## Araldite



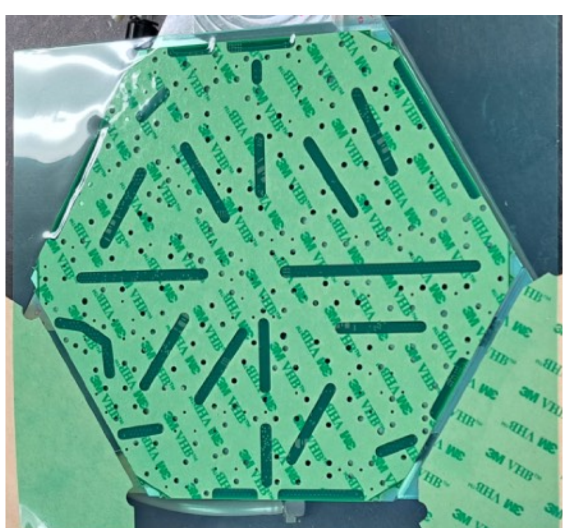
- High radiation tolerance
- Inefficiency (1 day for glue and dry)

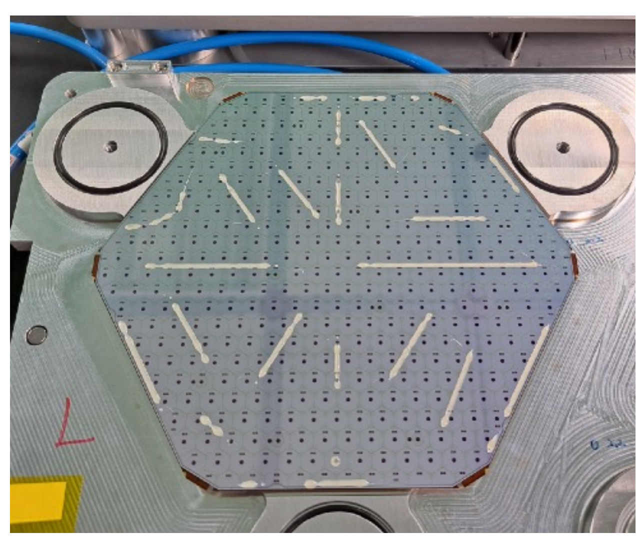
## Transfer tape



- Transfer tape with laser cutting by company
- Efficiency (20 mins)
- Low radiation tolerance

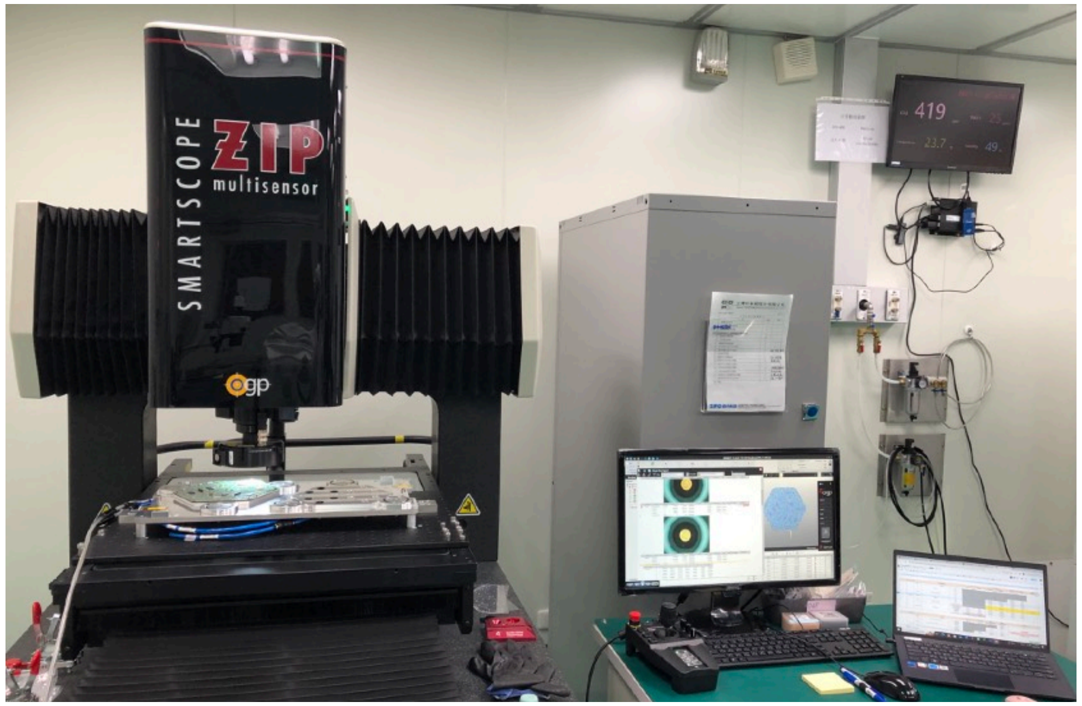
## Hybrid

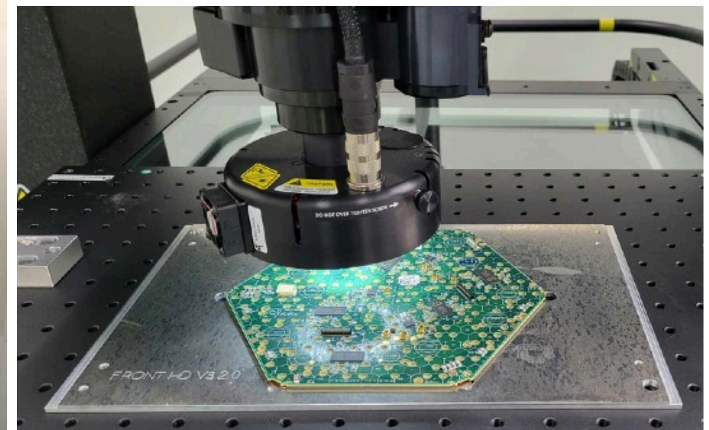




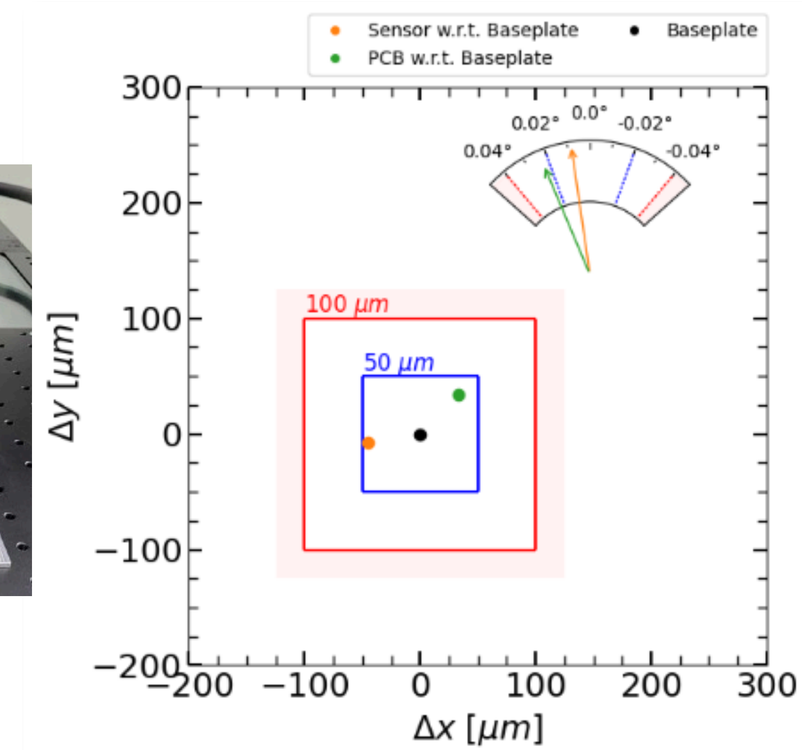
- Compromising method to combine araldite and transfer tape
- Medium radiation tolerance
- Efficiency (20 mins)
- **Under development**

# QGP QC



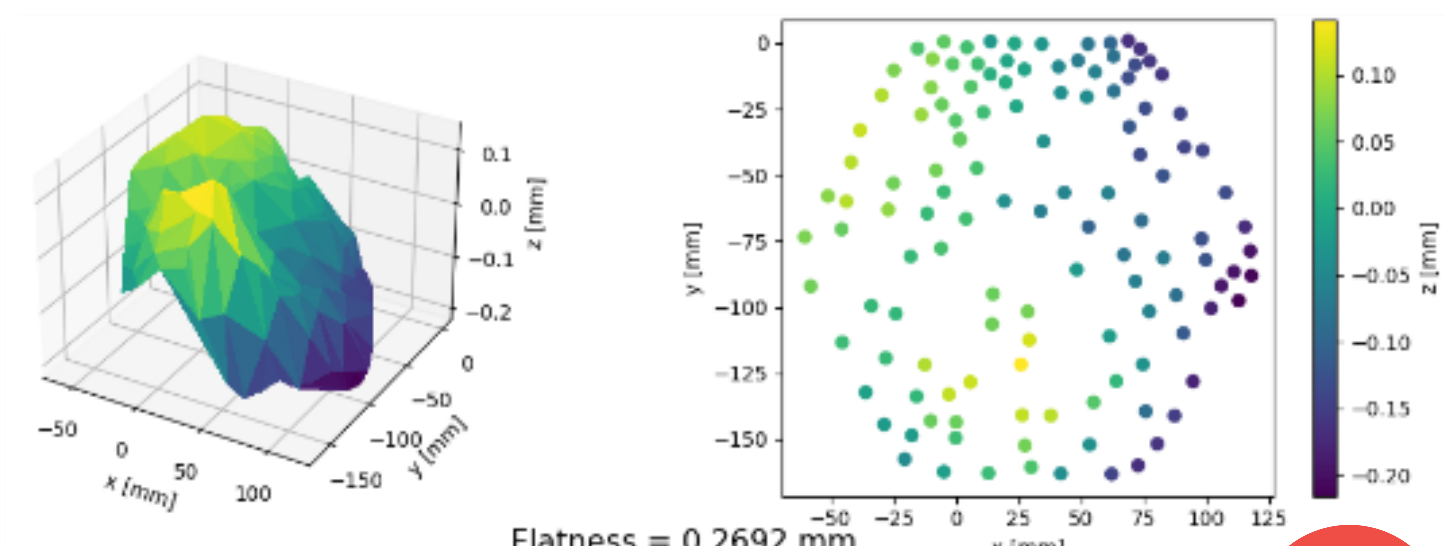



Alignment

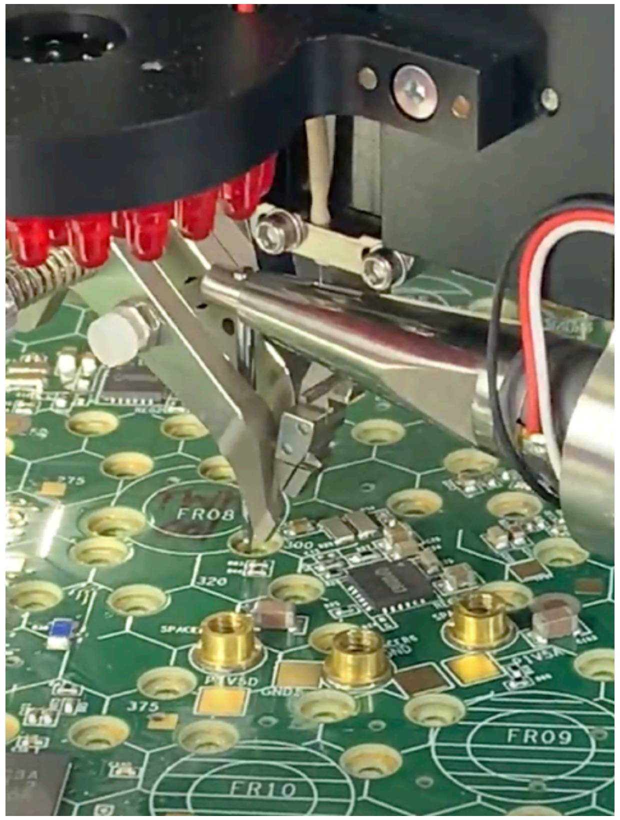


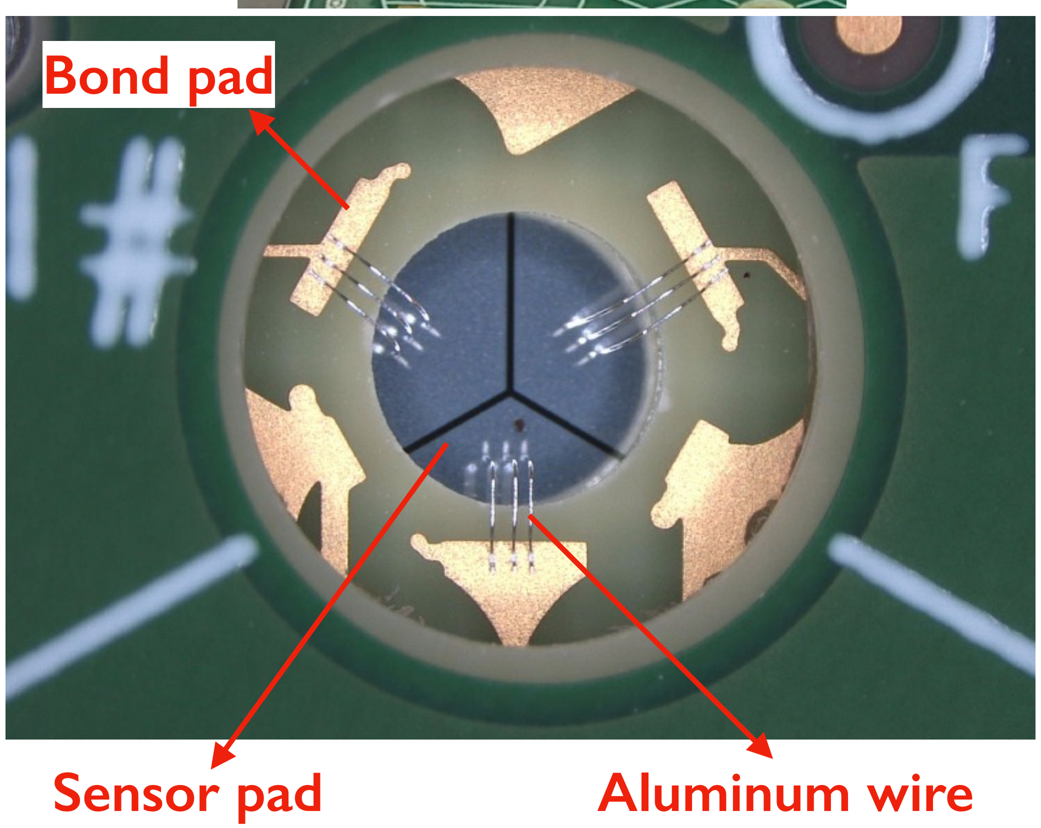

- OGP provides optical high-precision (~μm) locating and image processing for modules to measure modules' quality indicators.
- Alignment information such as offset between baseplate/sensor/HB and flatness.
- Measurement result visualization by python.

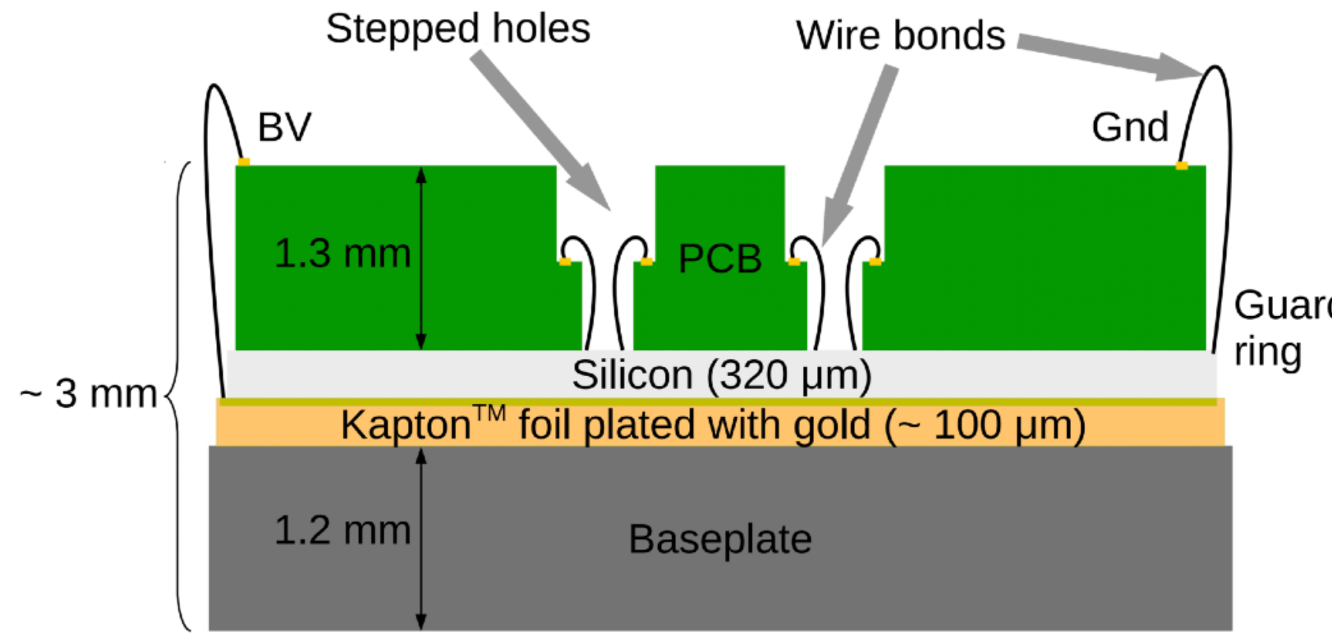
Flatness



# Wire bonding





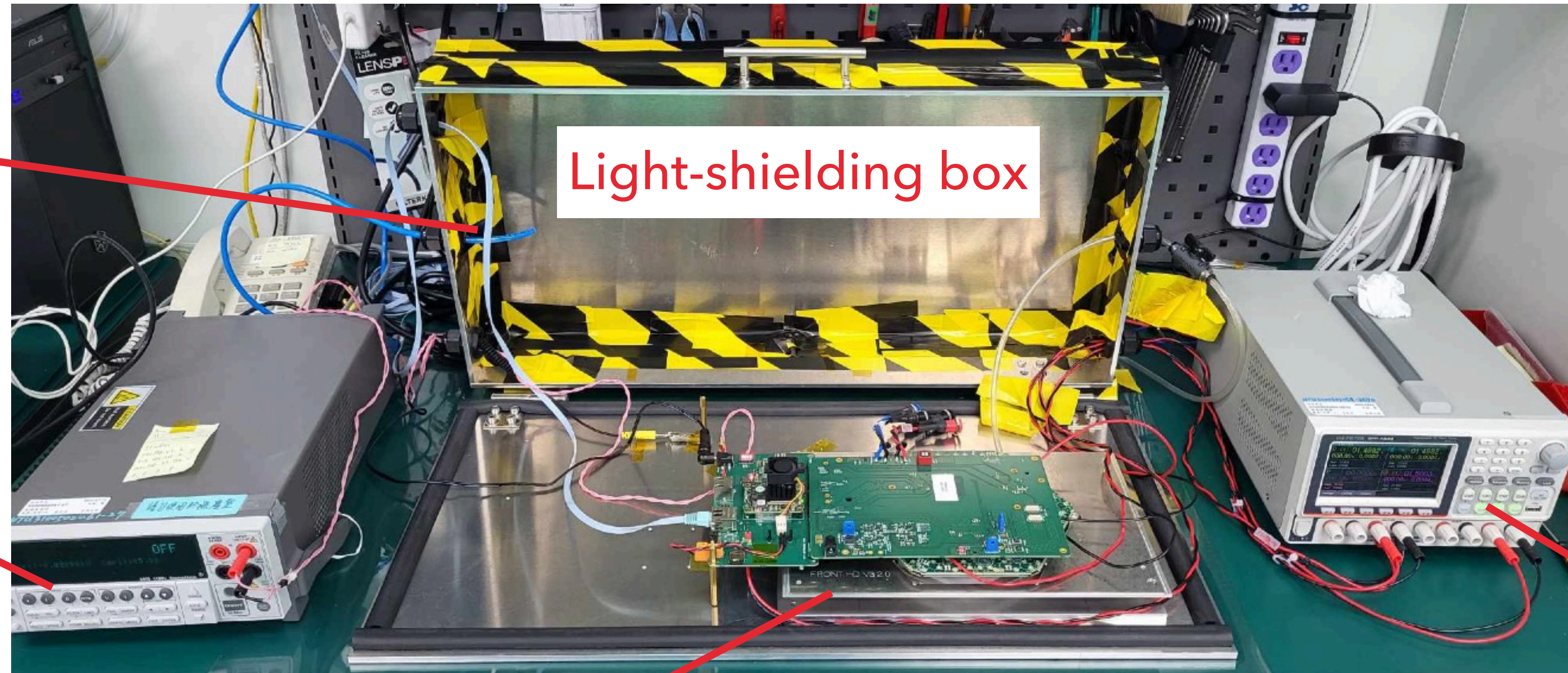




- Connect the silicon sensor to pads on the hexaboard through aluminum wire for signal readout and HV/GND.
- 15 mins can finish a module with 432 bond pads.
- Use OGP to snapshot bond pads and sensor to check the failure of wire bonding.
- Consider vision recognition (machine learning by ourselves) to identify the failure of wire bonding in future.

# Electronic test setup

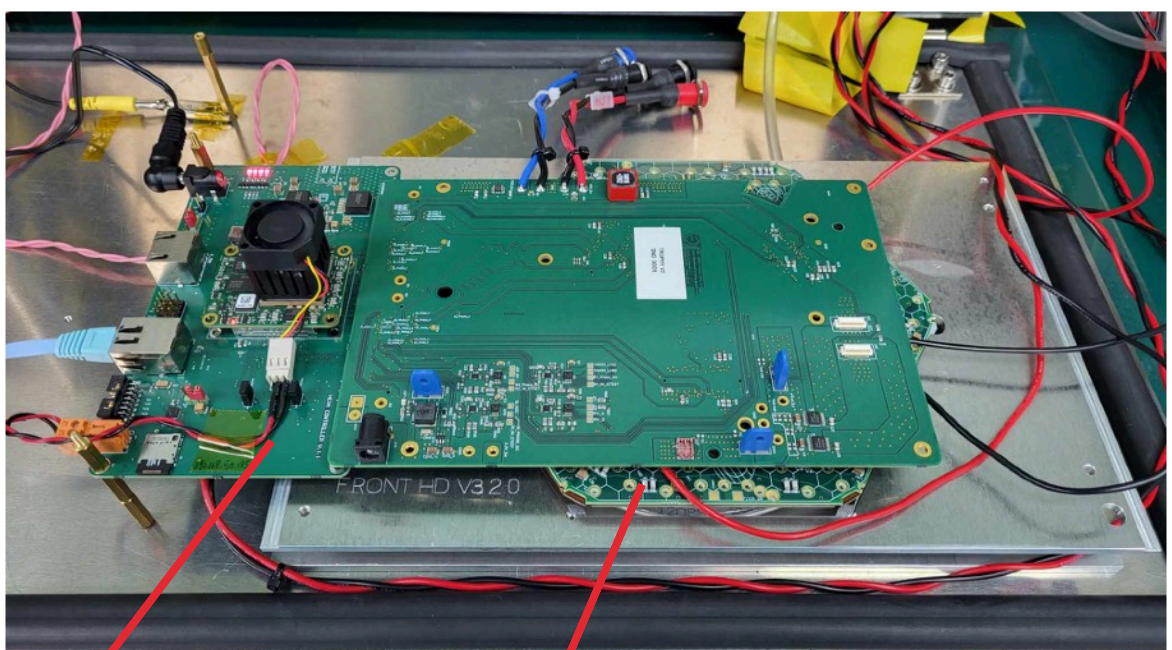
Dry air tube

Keithley 2410
(HV power)




Power supplier
(Analog/Digital)

**Teststand**




HexaController
(with FPGA)

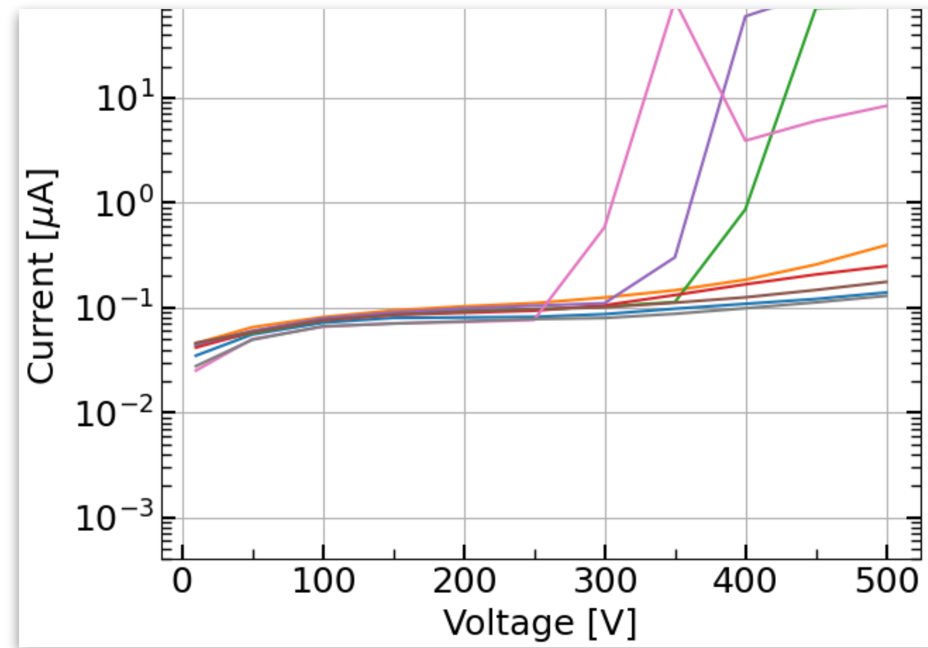
Module

- HV (up to 300 V) as bias voltage is applied to tested module to achieve full depletion.
- The test stand is placed in the light-shielding box with injected dry air to avoid high leakage current; vacuum system is applied to hold the module position for stability.
- Hexacontroller controls DAQ and HGCROC through i2c.
- Python module controls HV power supplier.

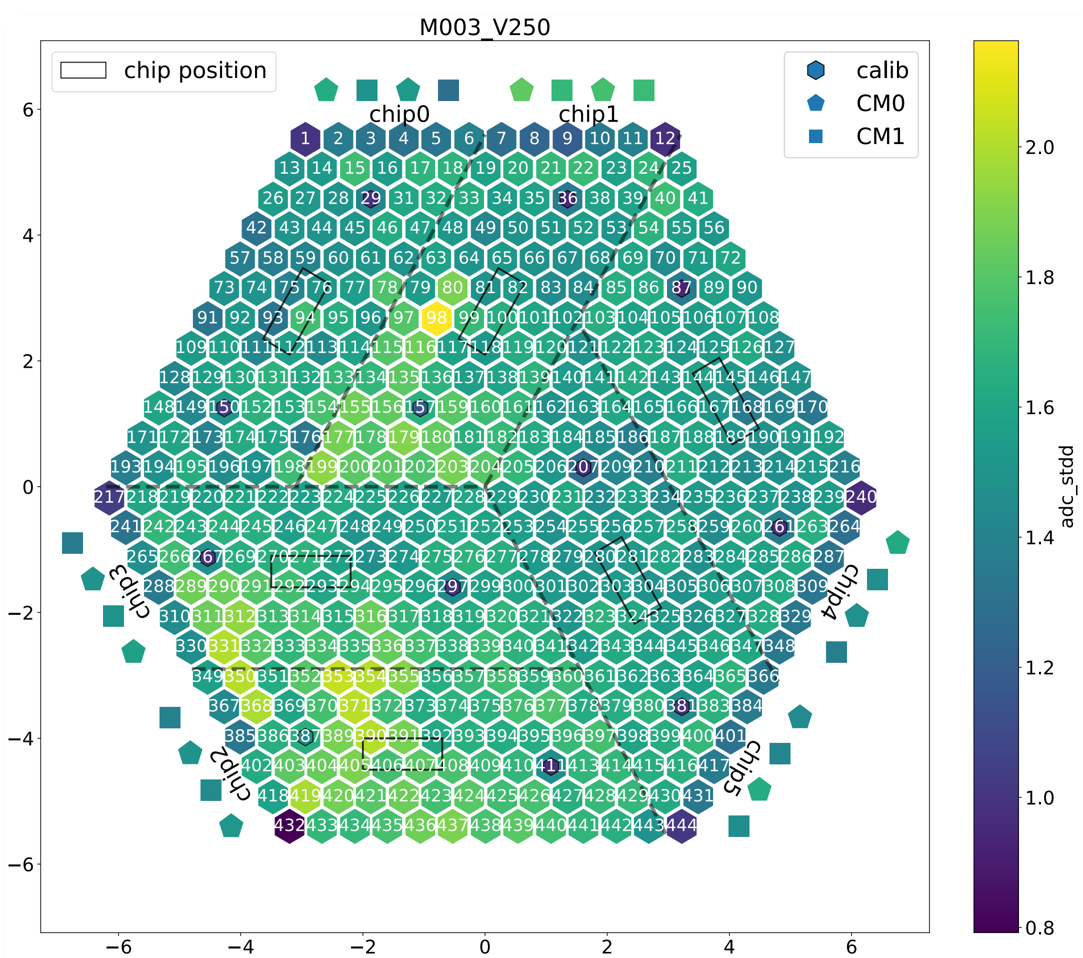
# Electronic functionality

- IV curve checks damage of sensor after assembly.
- Noise mapping provides quality of HGCROC, PCB design and wire bonding.
- Phase scan test gives pedestal stability (16 phase = 25 ns)

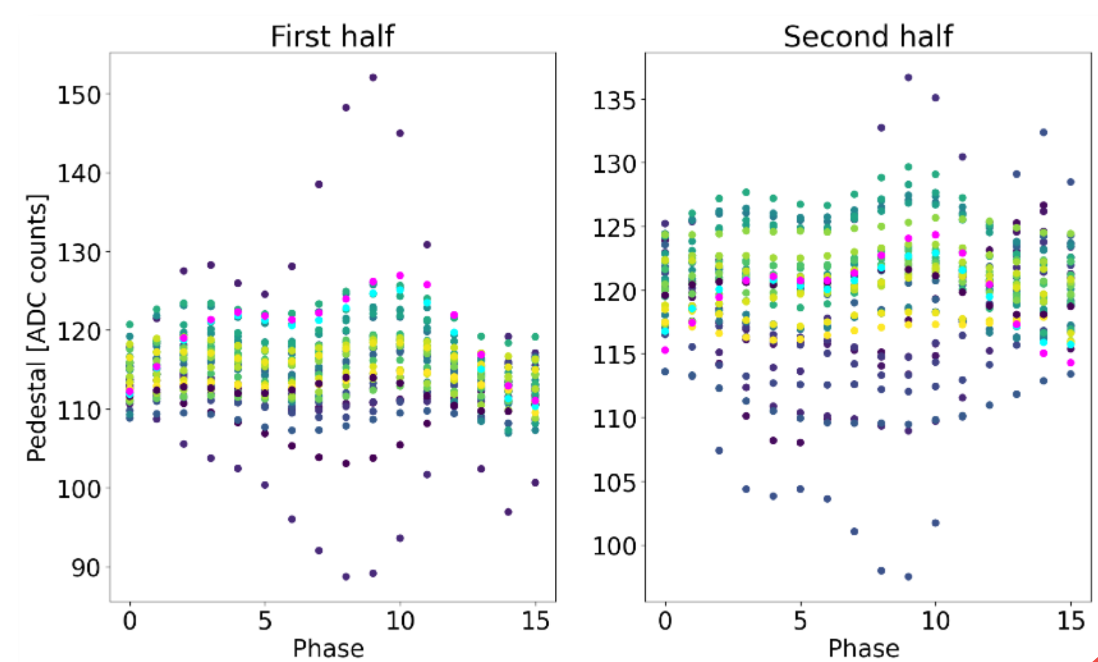
IV curve




Noise mapping

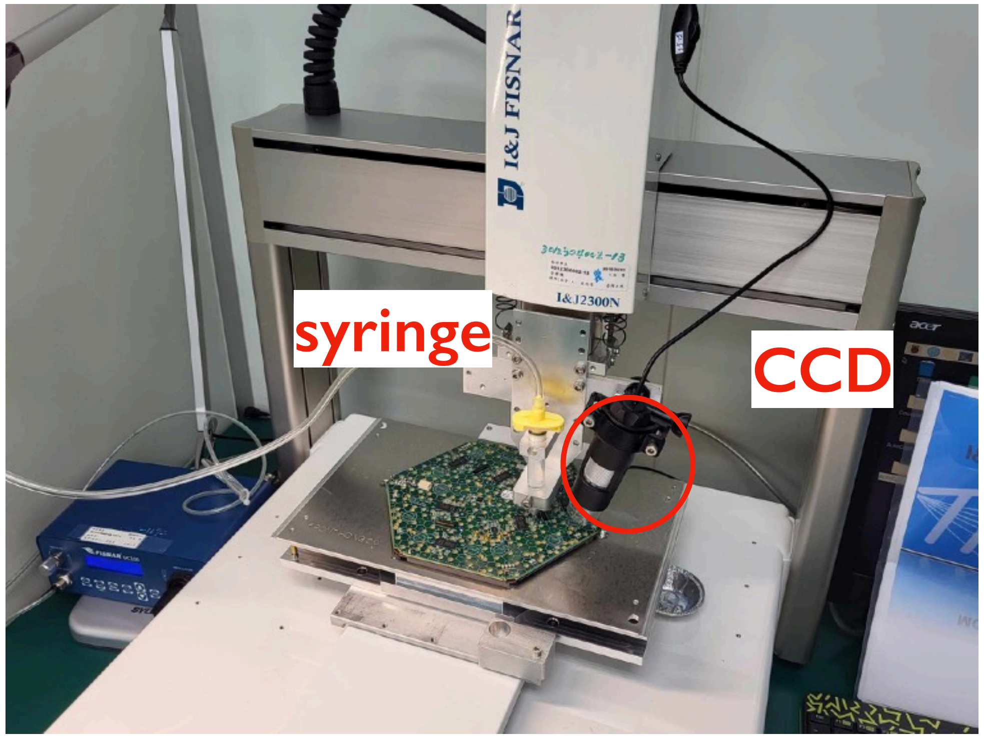


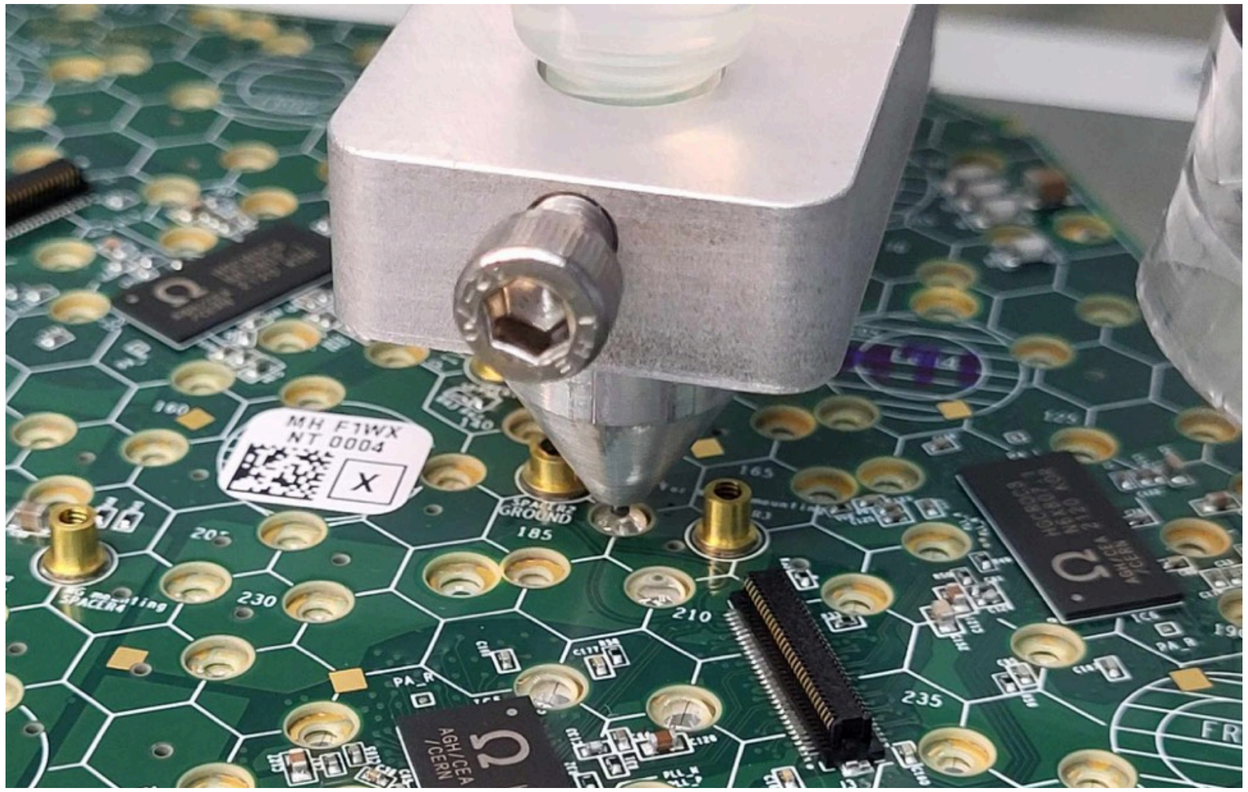

Phase scan

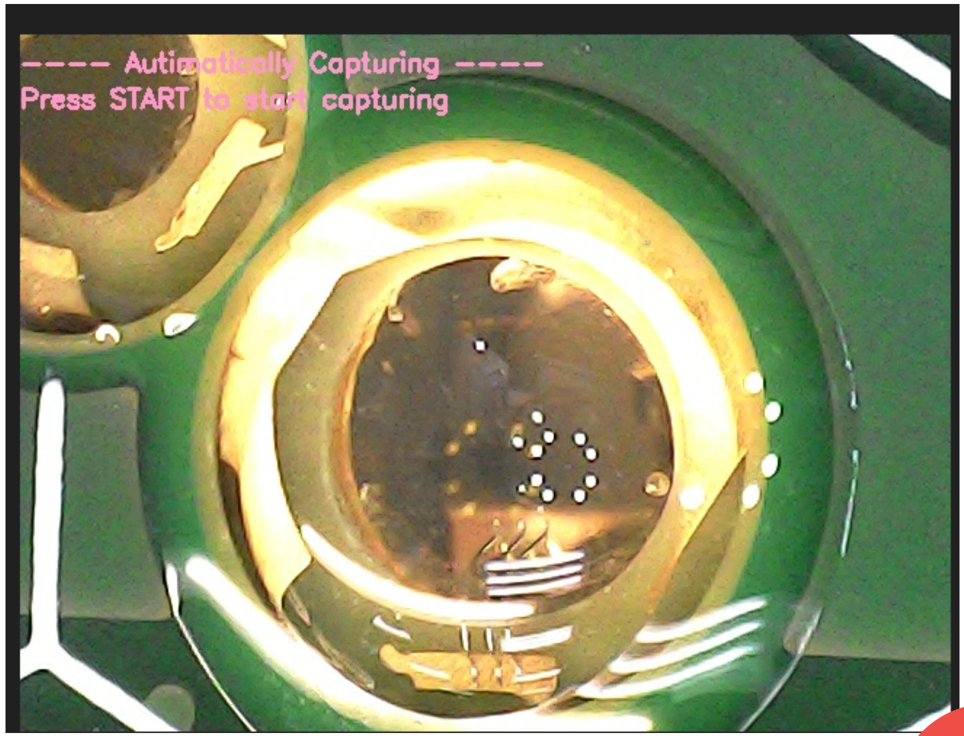


# Encapsulation

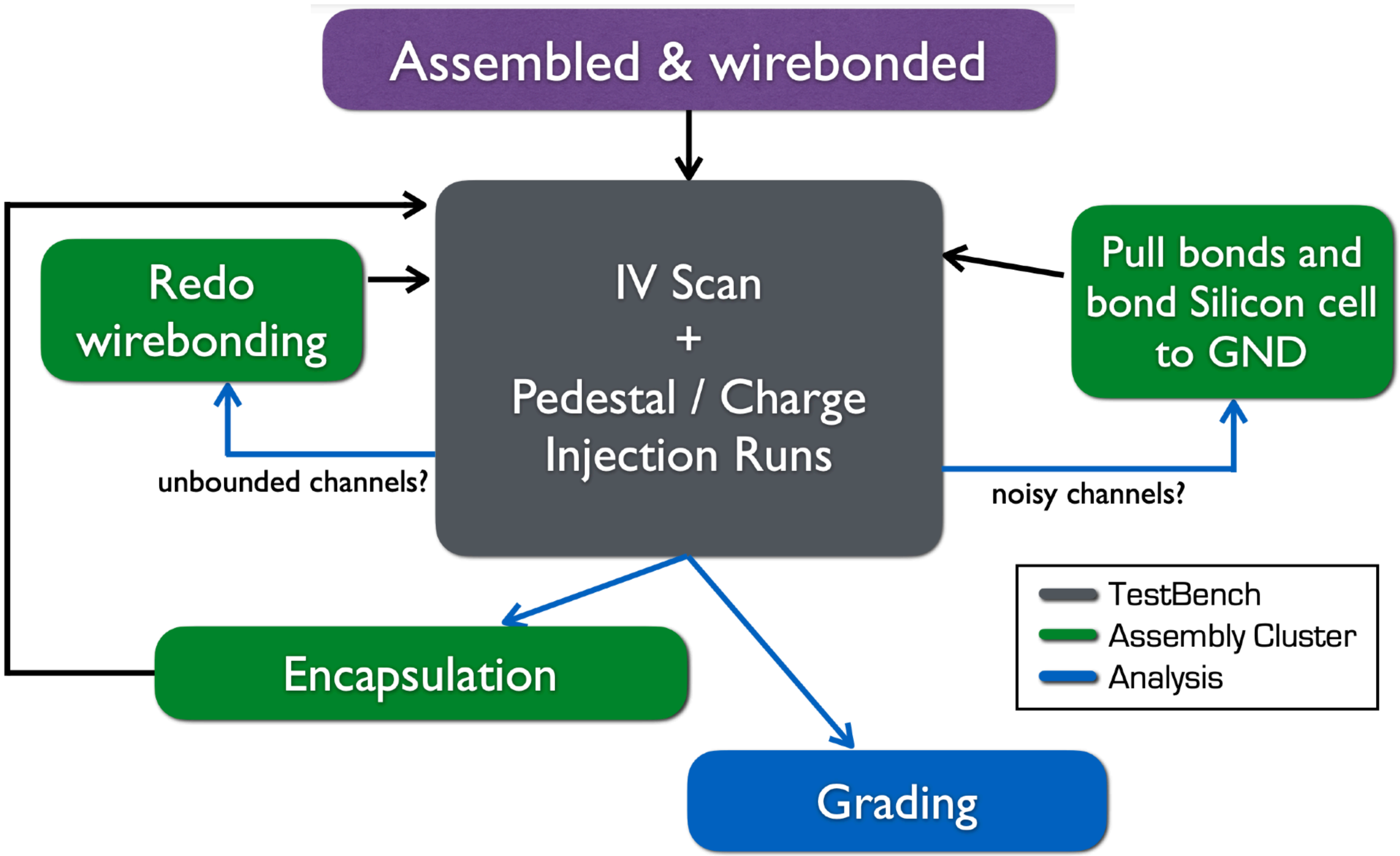
* Wire encapsulation is performed using glue coverage to avoid dust to touch wires and cause short.
* Programmable miniGantry and air jets are automatically controlled for syringe position and the timing of glue squeezing.
* CCD camera scans all step holes to check the status of like bubble or glue overflow.





# Electronic functionality



# Thermal cycle test setup

- Test of module structure damage or electronic functionality glitch during temperature raising/lowering.
- Tested modules mounted on copper plates to simulate modules on cooling plates through dedicated screws.
- HV cables are also extended into the chamber to test IV curve.

Keithley 2410

HV wires

Overview

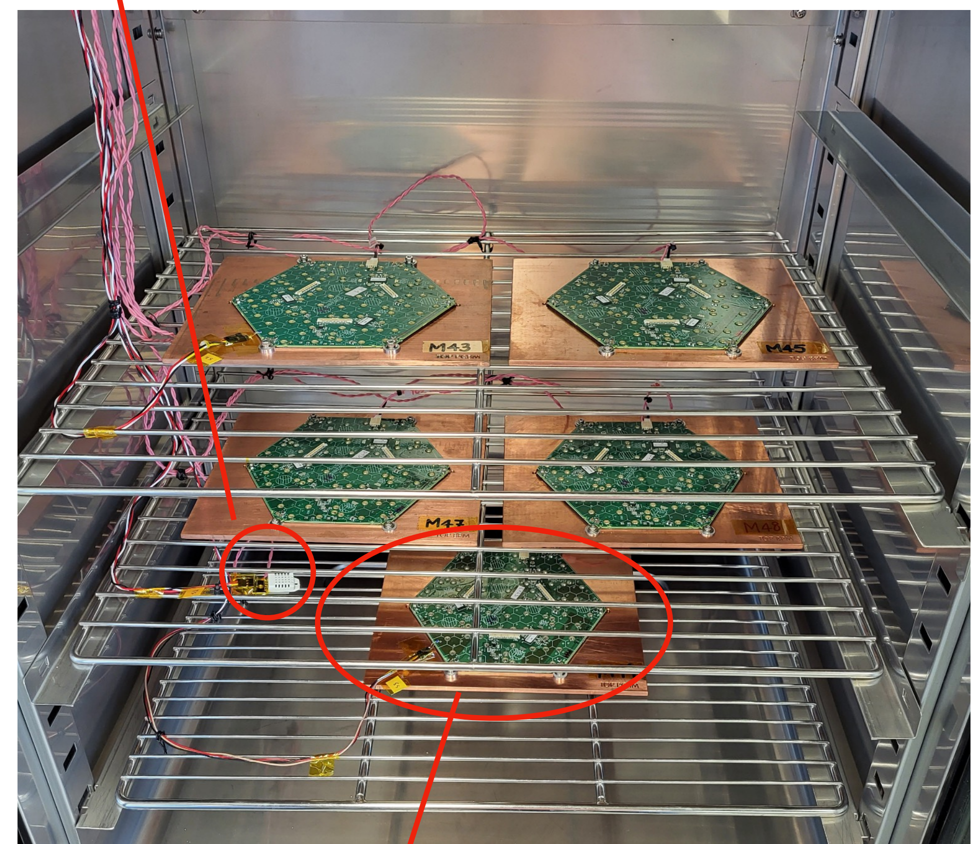
Raspberry Pi

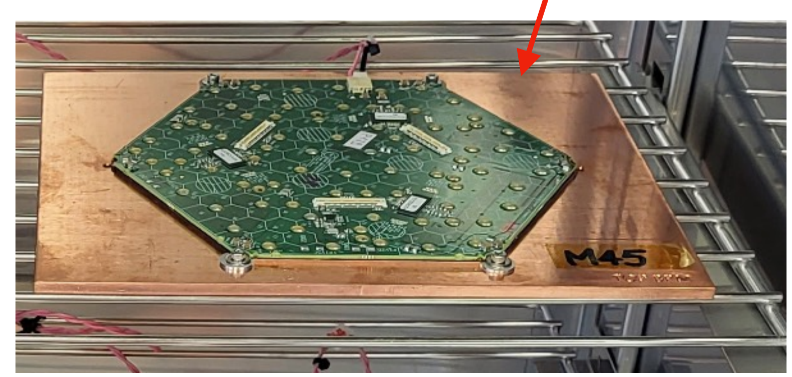
Macbook

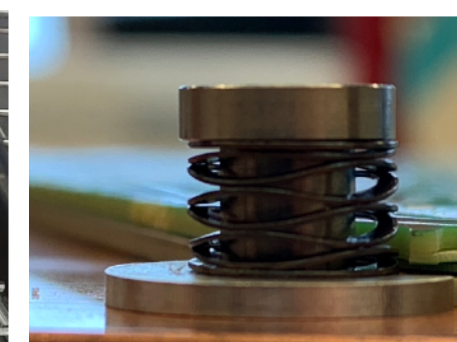
HITACHI chamber

Temperature/Humidity sensor

Inside the chamber

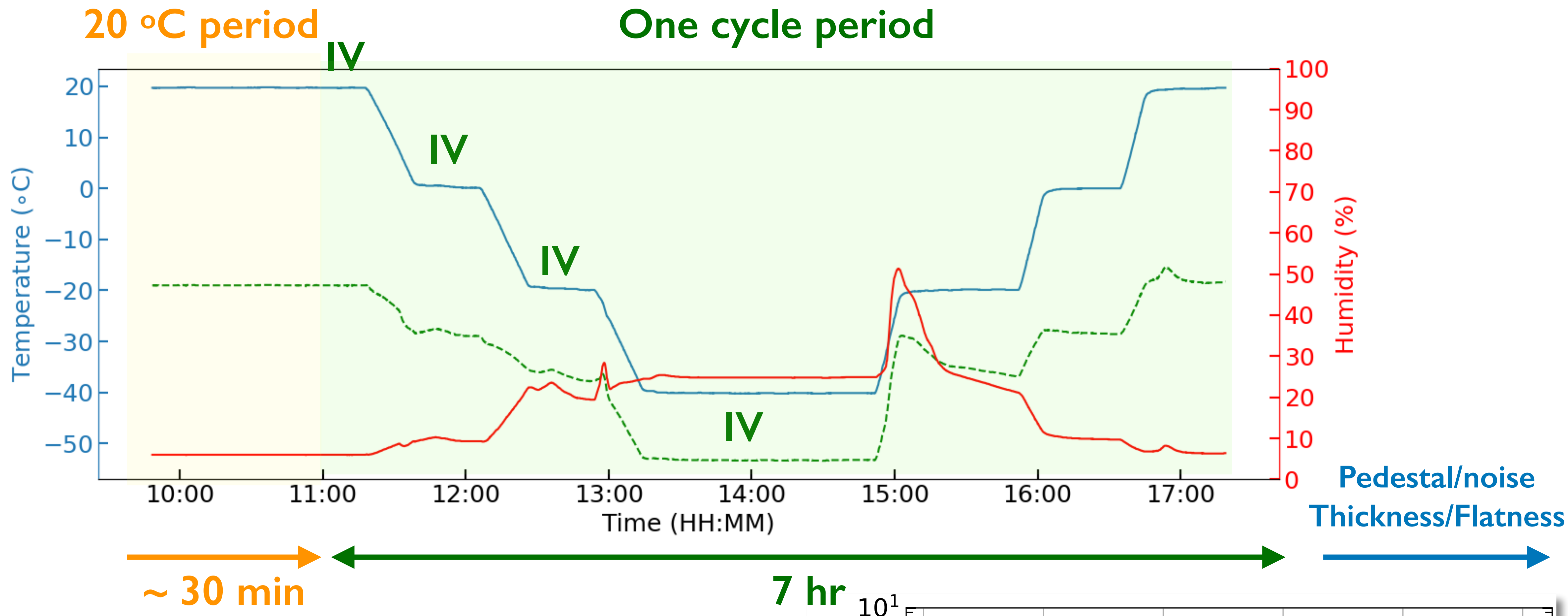


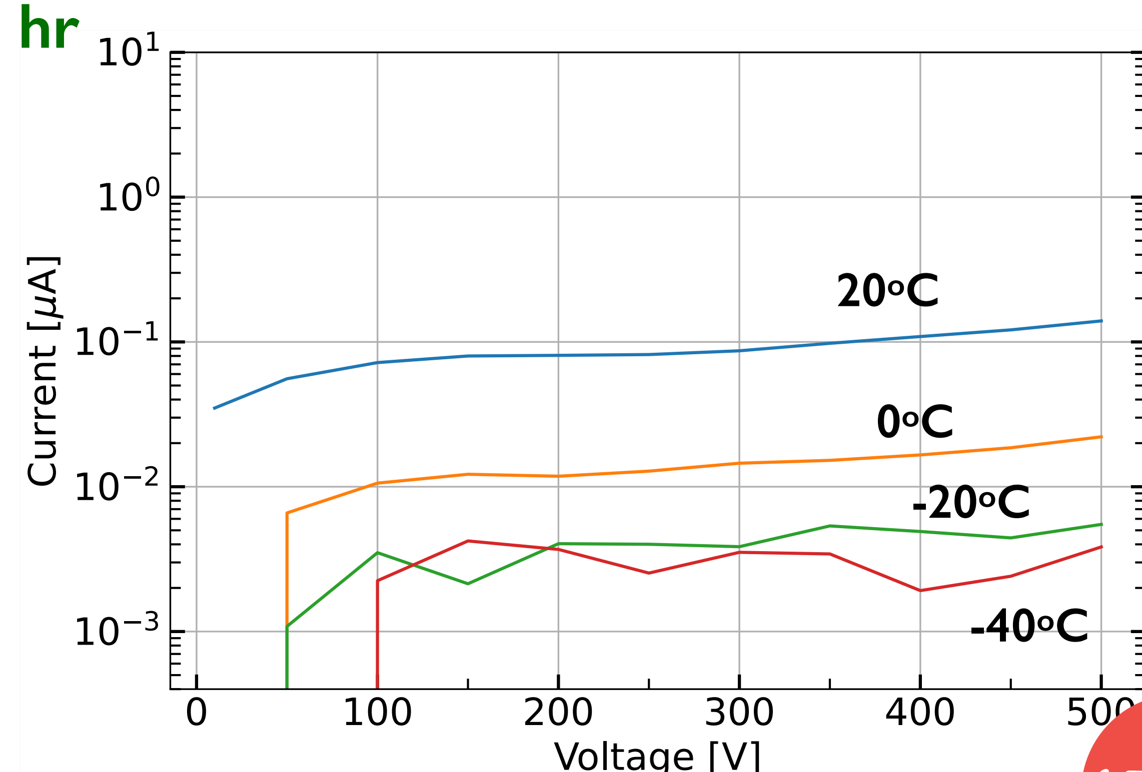


Mmodule mounted on copper plate

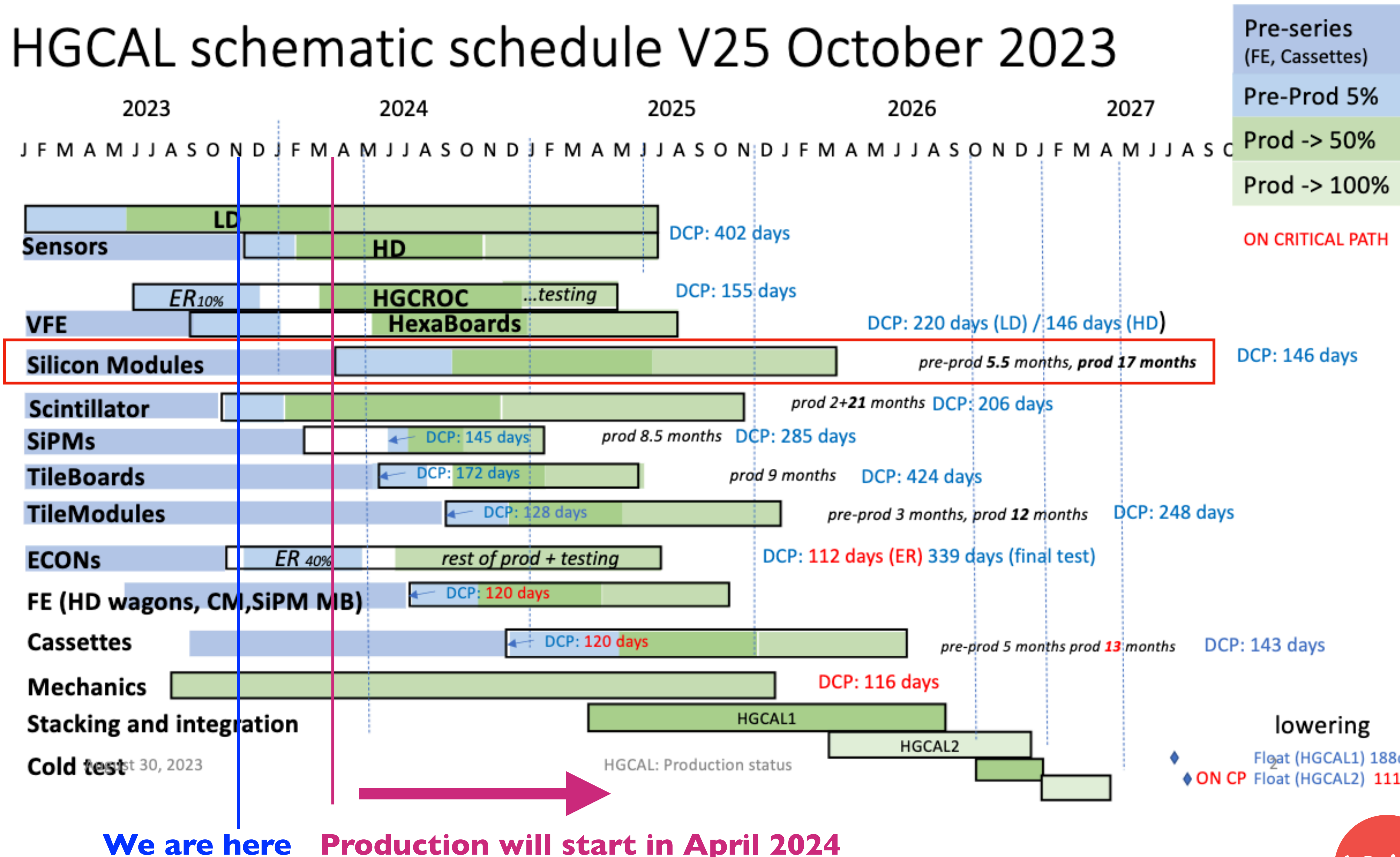
# Thermal cycle test



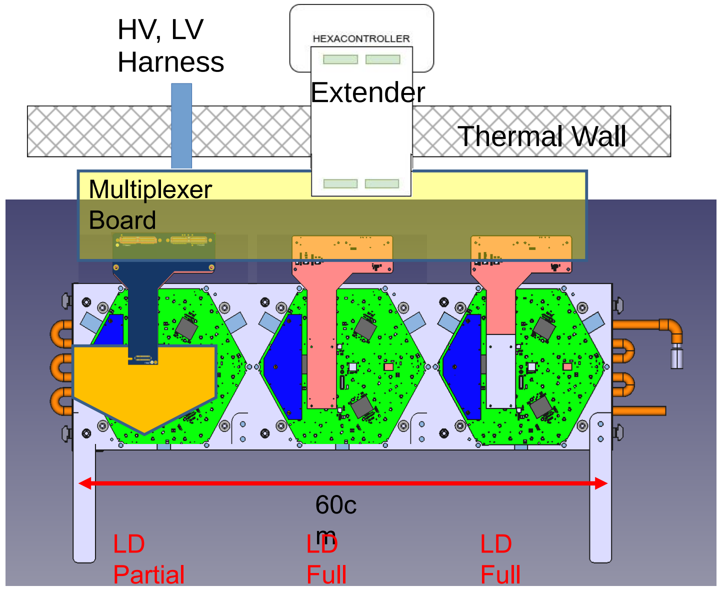

- Temperature range of -40 ~ 20°C at least 10 cycles.
- IV curve is measured during thermal cycle.
- OGP QC and electronic functionality test is redone after thermal cycle.
- Humidity inside the chamber needs to be taken care to avoid water droplets on modules.

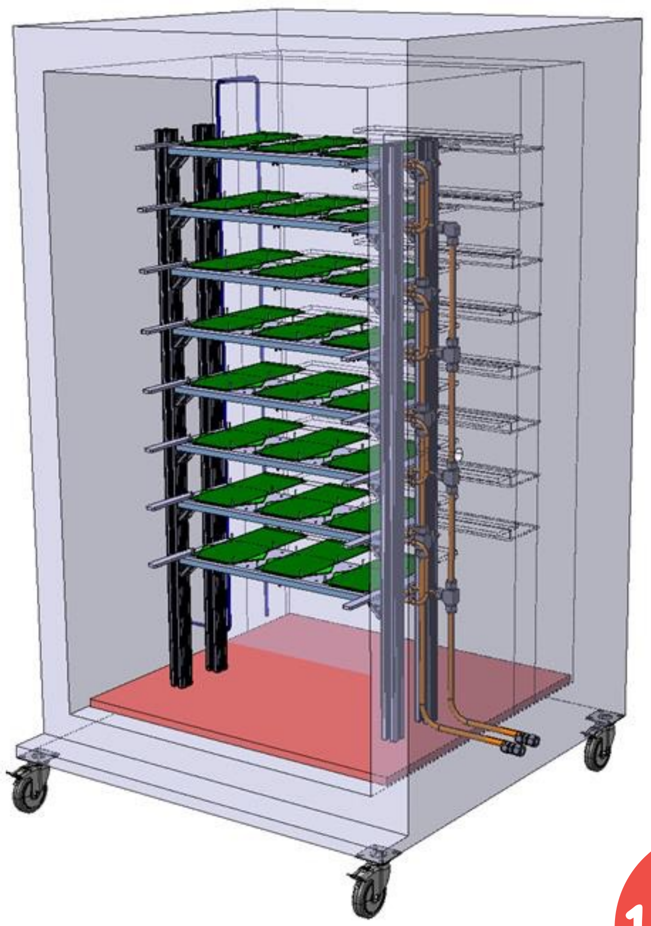
# Schedule


HGCAL schematic schedule V25 October 2023
Pre-series (FE, Cassettes)
Pre-Prod 5%
Prod -> 50%
Prod -> 100%
2023
2024
2025
2026
2027
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O
Sensors
LD
HD
DCP: 402 days
ON CRITICAL PATH
VFE
ER 10%
HGCROC
...testing
DCP: 155 days
HexaBoards
DCP: 220 days (LD) / 146 days (HD)
Silicon Modules
pre-prod 5.5 months, prod 17 months
DCP: 146 days
Scintillator
prod 2+21 months
DCP: 206 days
SiPMs
DCP: 145 days
prod 8.5 months
DCP: 285 days
TileBoards
DCP: 172 days
prod 9 months
DCP: 424 days
TileModules
DCP: 128 days
pre-prod 3 months, prod 12 months
DCP: 248 days
ECONs
ER 40%
rest of prod + testing
DCP: 112 days (ER) 339 days (final test)
FE (HD wagons, CM,SiPM MB)
DCP: 120 days
Cassettes
DCP: 120 days
pre-prod 5 months prod 13 months
DCP: 143 days
Mechanics
DCP: 116 days
Stacking and integration
HGCAL1
HGCAL2
Cold test
lowering
Float (HGCAL1) 188d
ON CP Float (HGCAL2) 111d
August 30, 2023
HGCAL: Production status
We are here
Production will start in April 2024

# Future plan

* Develop a user friendly GUI system for our electronic test through python instead of console mode.
* Build a multi-mode test stand that synchronizes electronic test, IV measurement and thermal cycle together
  → DAQ system, Power supplier (normal and HV), ColdBox, Chiller, Dryair system, PLC
  → There can be 24 hexaboards within the coldbox and 3 hexaboards for data taking at the same time
* Optimize the jigs' layout and assembly procedure to maximize our MAC production rate (~12 pieces per day).



# Summary

- Overall procedure from materials to modules in Taiwan MAC gradually becomes mature.
- Some important steps like multi-mode test stand or assembly by using hybrid method is still under development.
- It's expected that the Taiwan HGCAL MAC will transform into production stage.