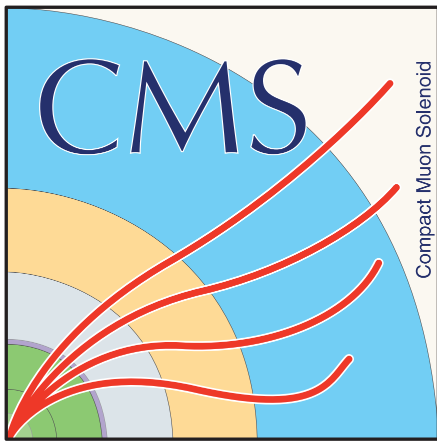
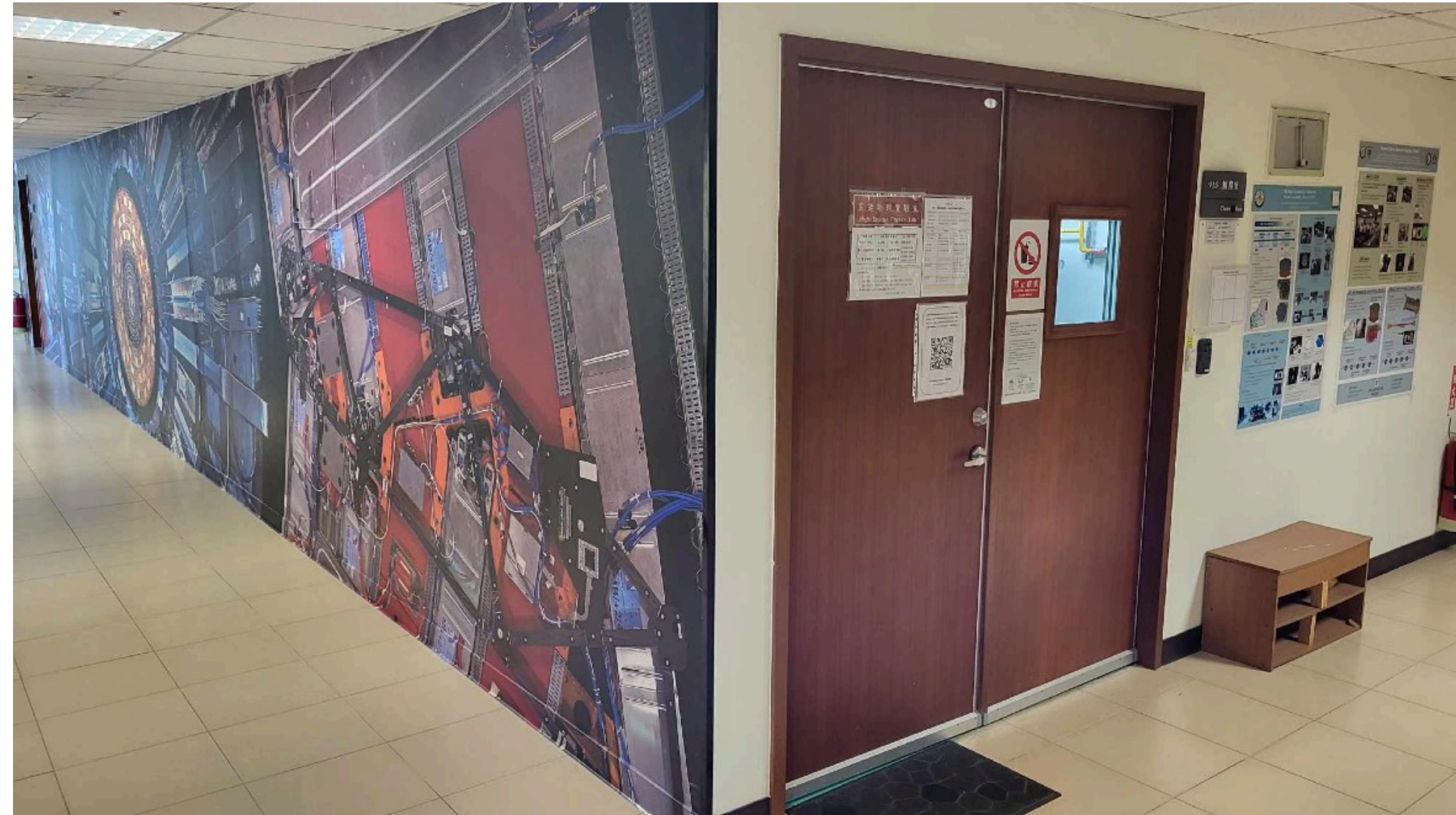




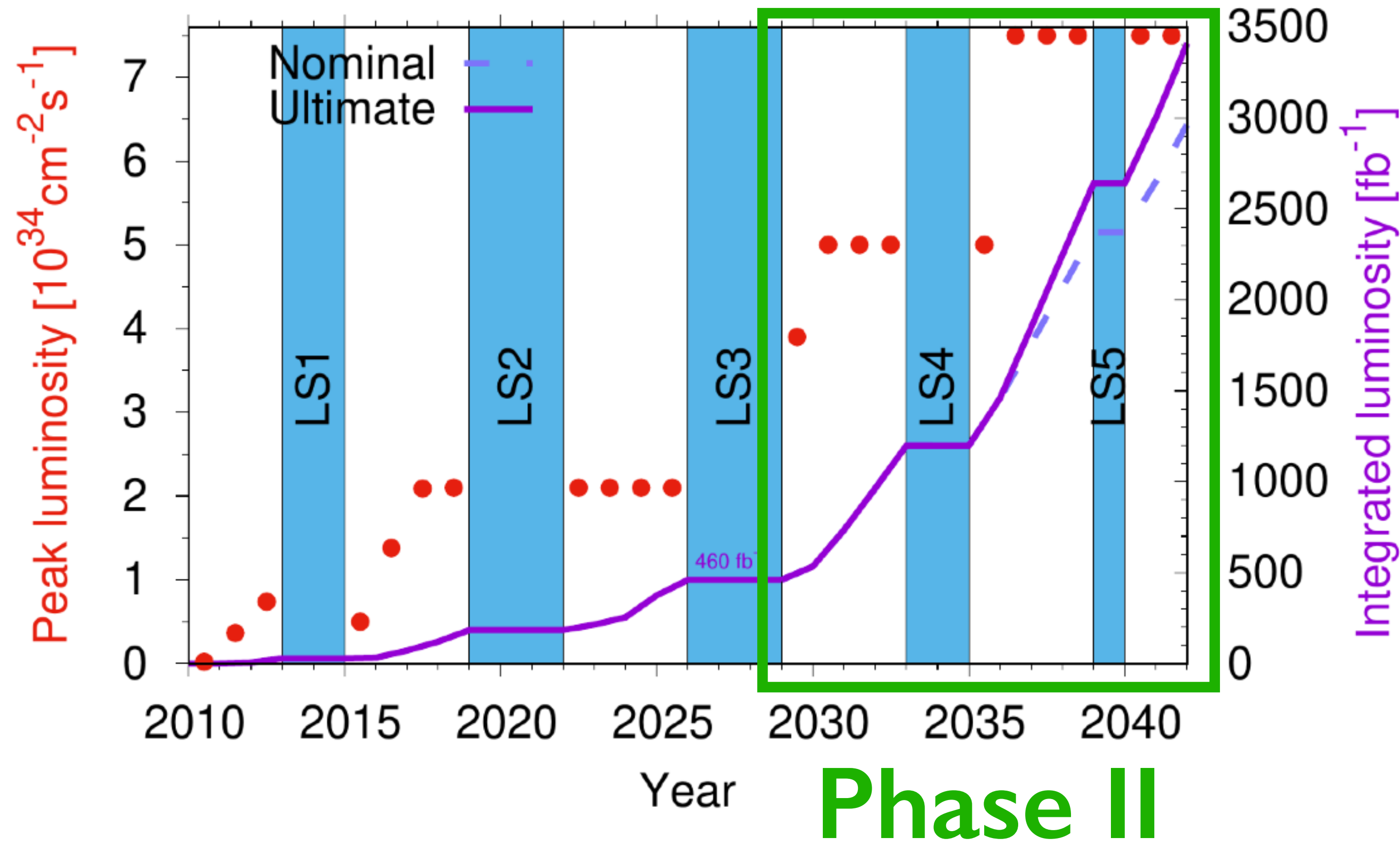
HGCAL Module Assembly Center in Taiwan

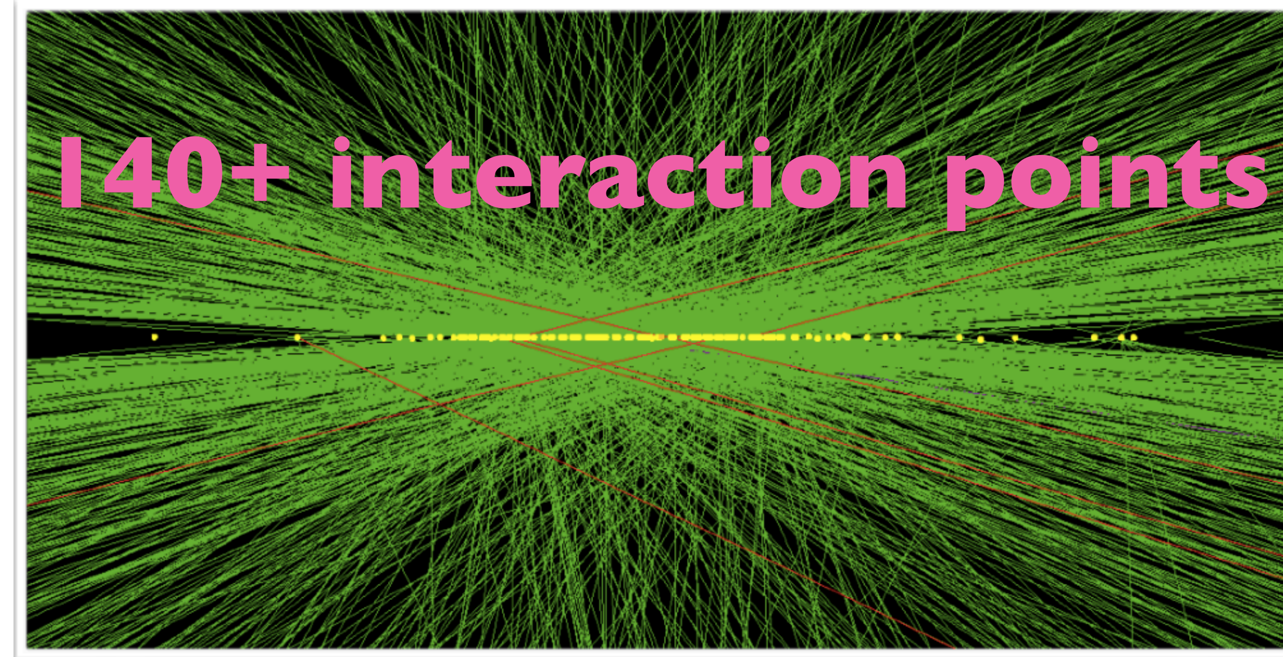
TIDC annual Meeting — November 22, 2024

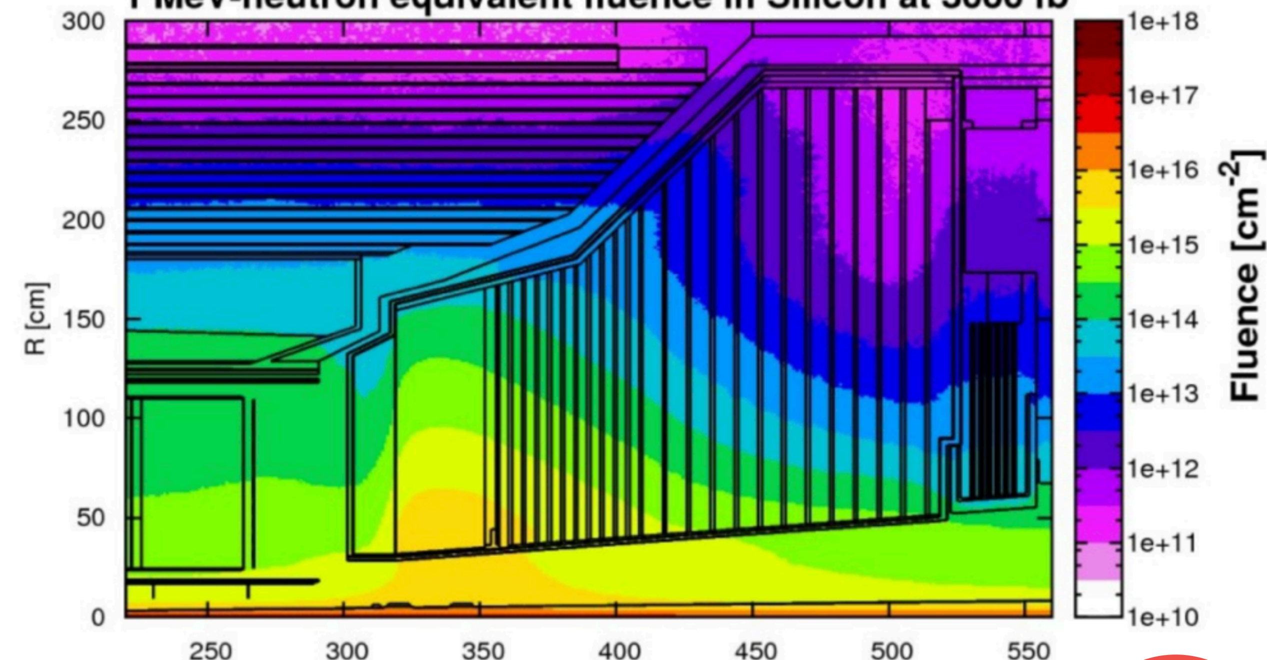
You-Ying Li on behalf of Taiwan MAC

National Taiwan University

HL-LHC project



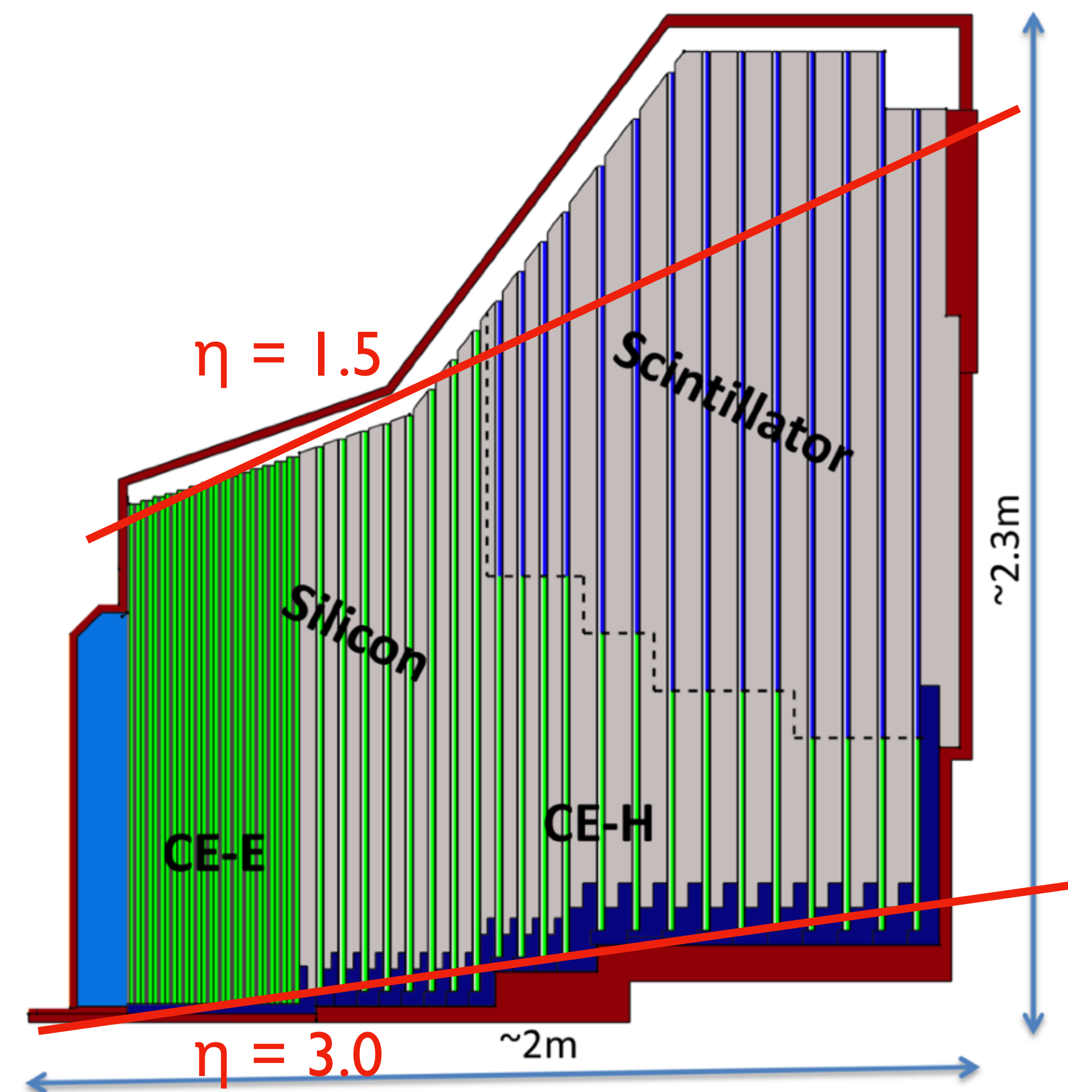




- Integrated luminosity will be increased over 3000 fb^{-1} to get more data statistics for new physics search.
  → More radiation, more pile-up, higher density of tracks …
- Calorimeter endcaps with high radiation background is especially challenge (10^{14} current → 10^{16} n_{eq} /cm^{-2} Phase II).
  → High radiation tolerance of sensors and electronics
  → Precise timing measurements and high granularity

HCGAL overview

- The HGCAL detector is CMS Phase II upgrade in the endcap calorimeter, replacing the ECAL and HCAL in endcap regions.
- 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.

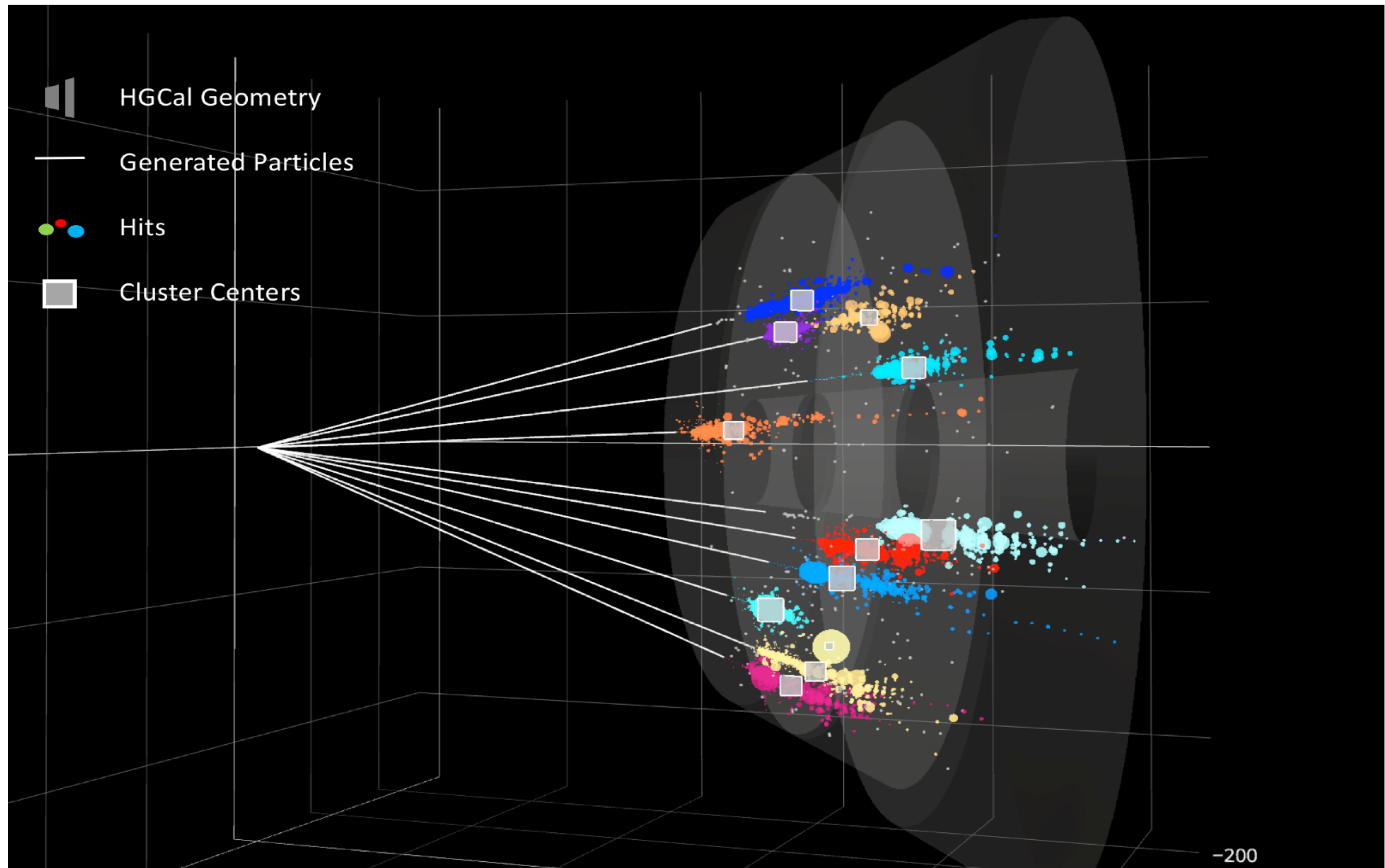


Key parameter:

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

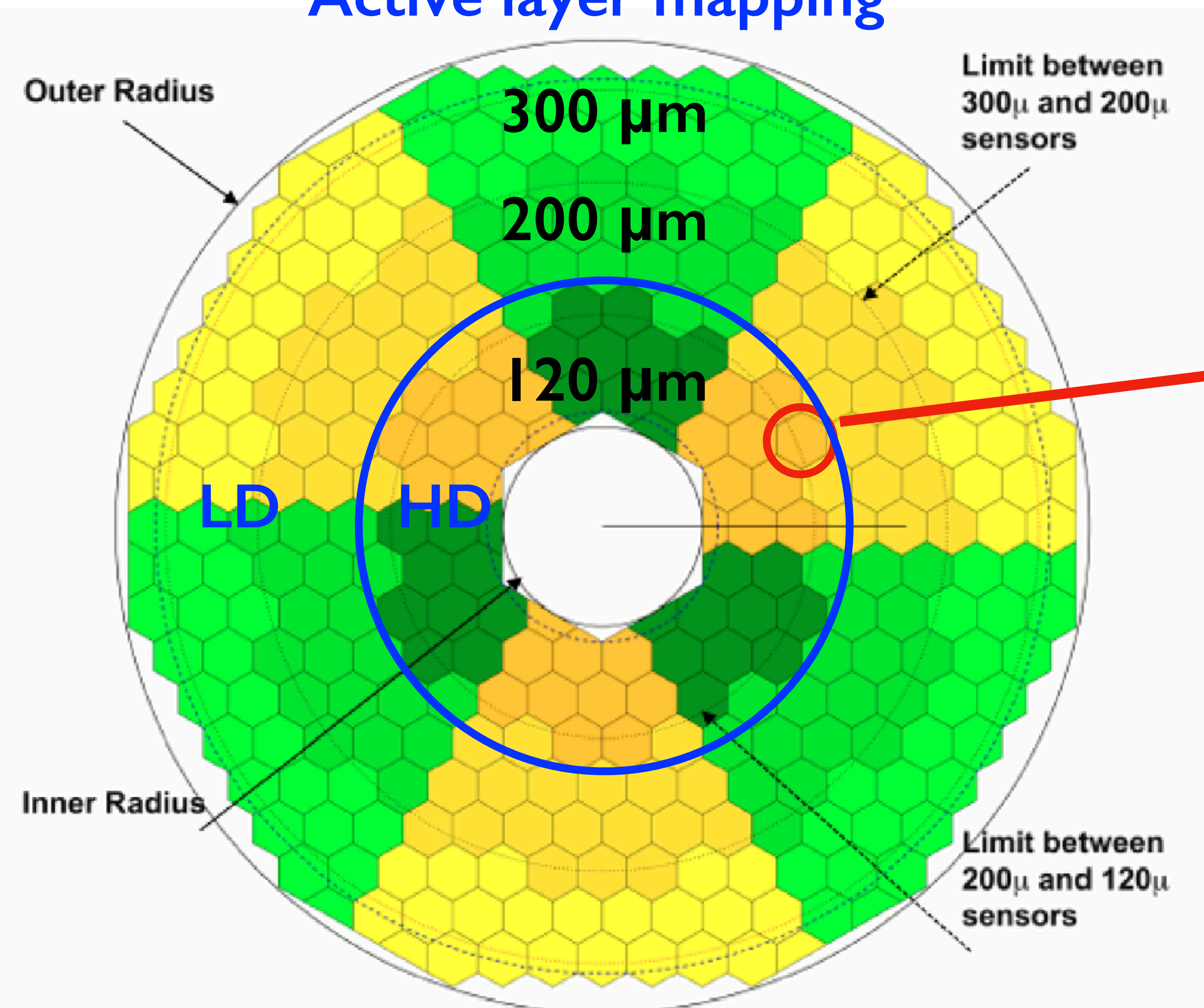
ECAL endcap is a size of **8.2** cm^2 front-face

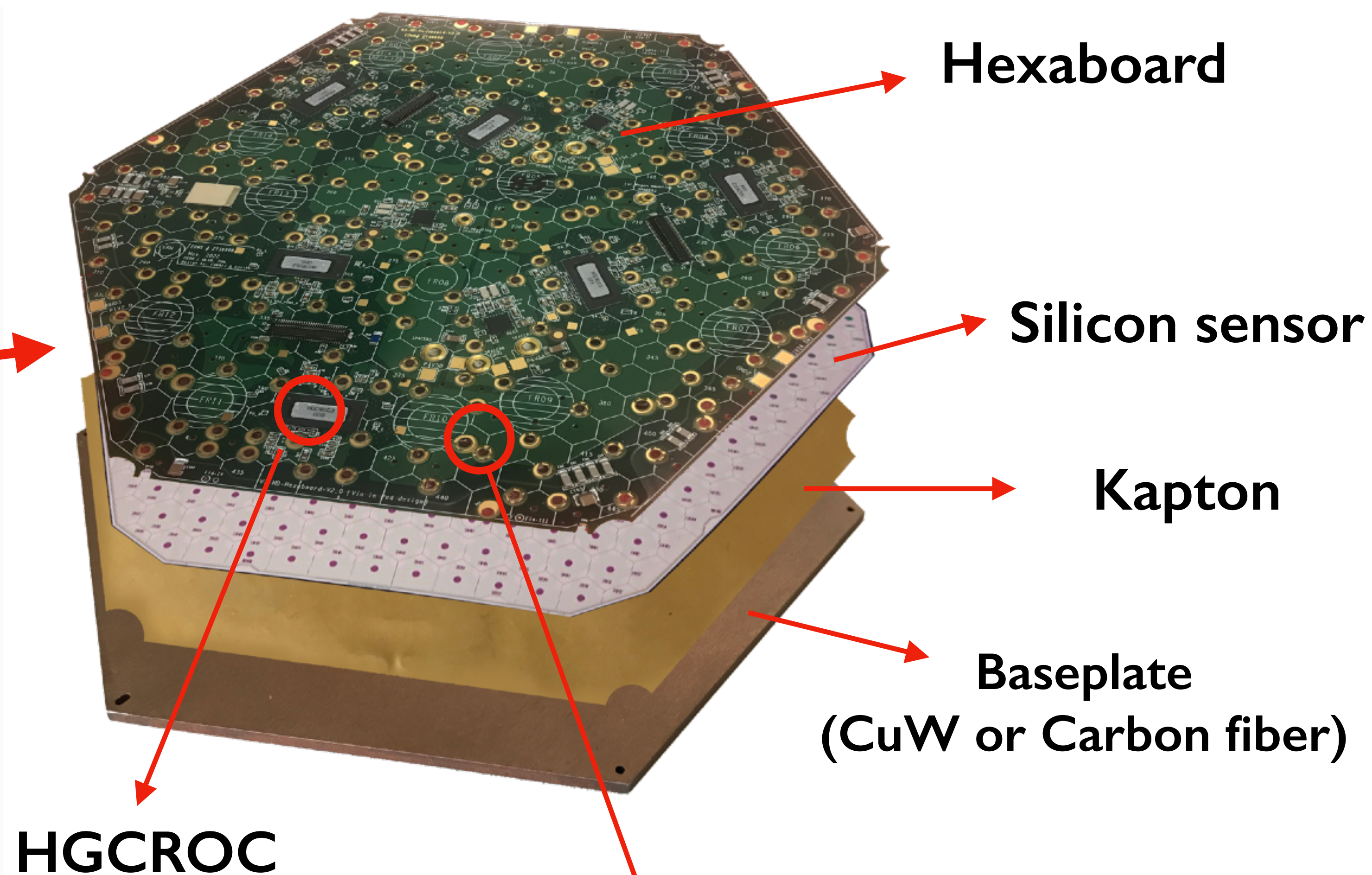
HCGAL shower

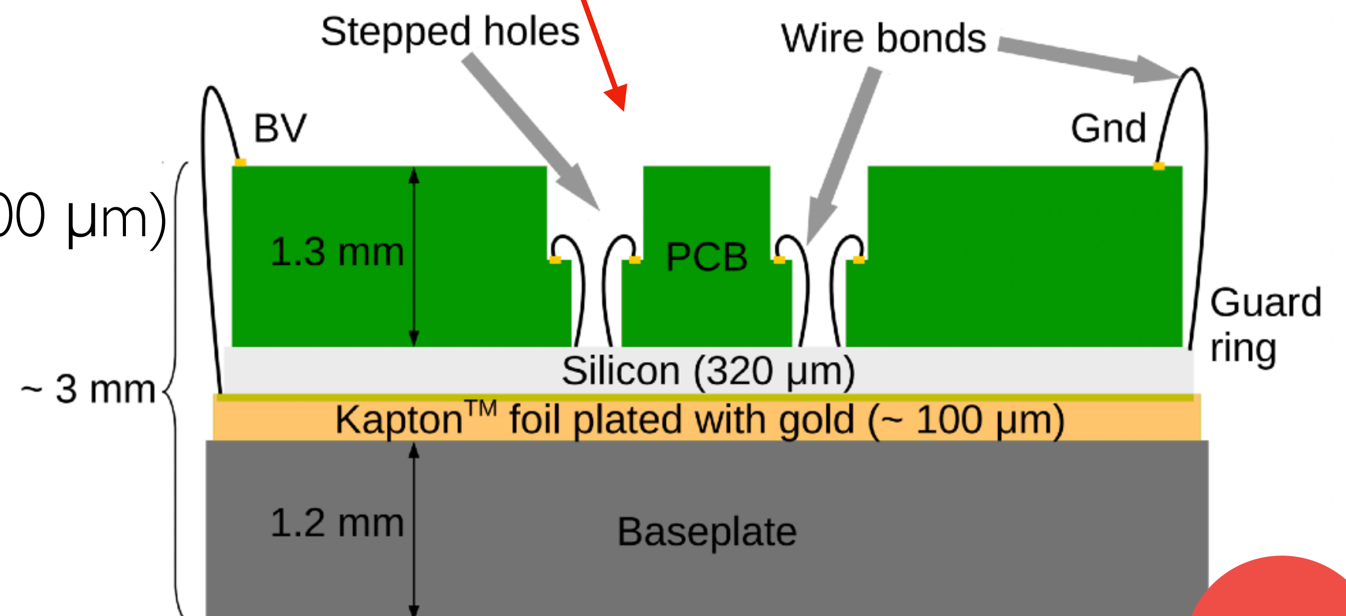


Precise 5D information (position, time and energy) for particle showers

8 inch Silicon Module





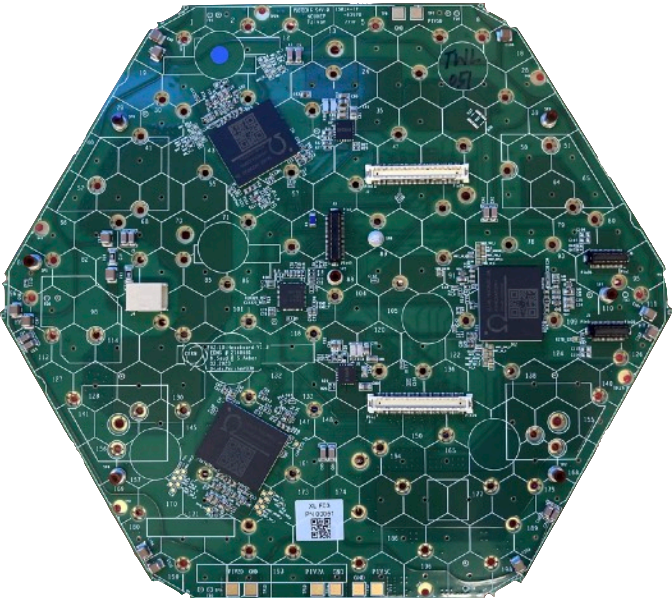


Requirement

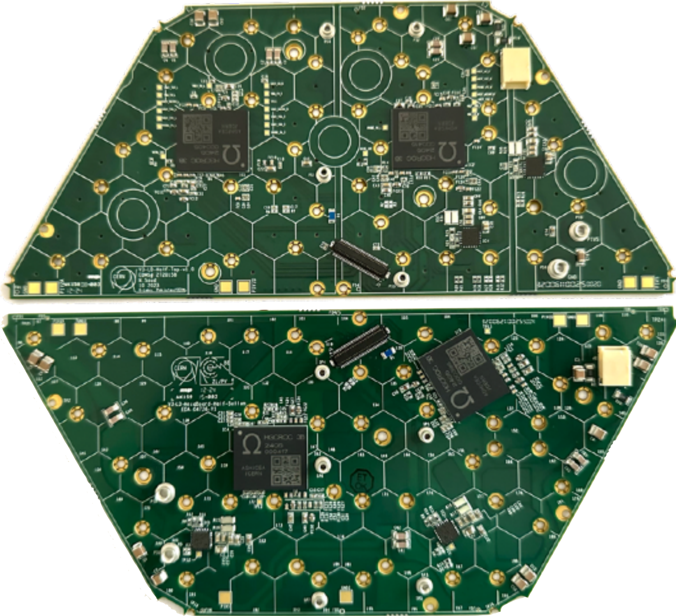
- ☑ Small offset between HB/Sensor/Baseplate (< 100 µm)
- ☑ High radiation tolerance (> 1.5 MGy)
- ☑ 850 HV available for bias
- ☑ Low noise for each readout channel
- ☑ Temperature change tolerance (-40~20°C)

More shapes

LD FULL

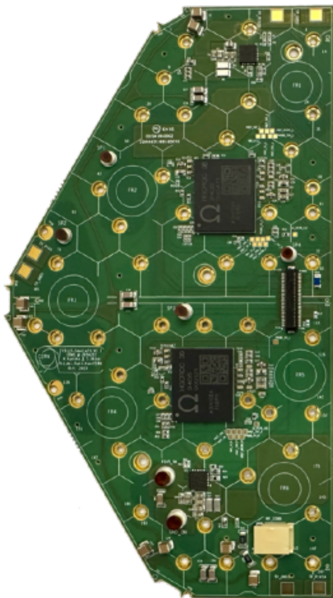


LD TOP



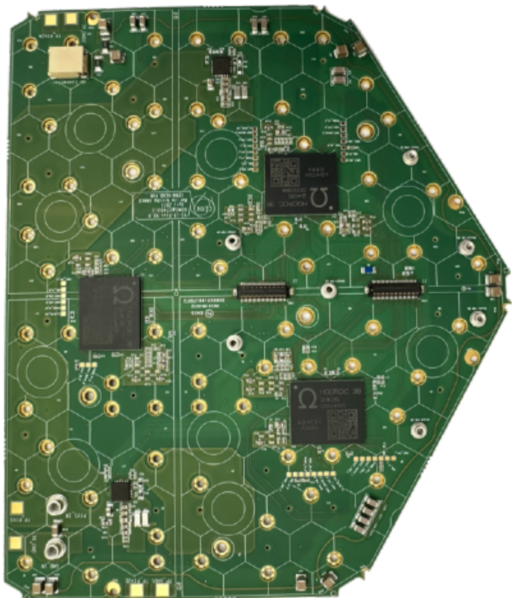
LD BOTTOM

LD LEFT

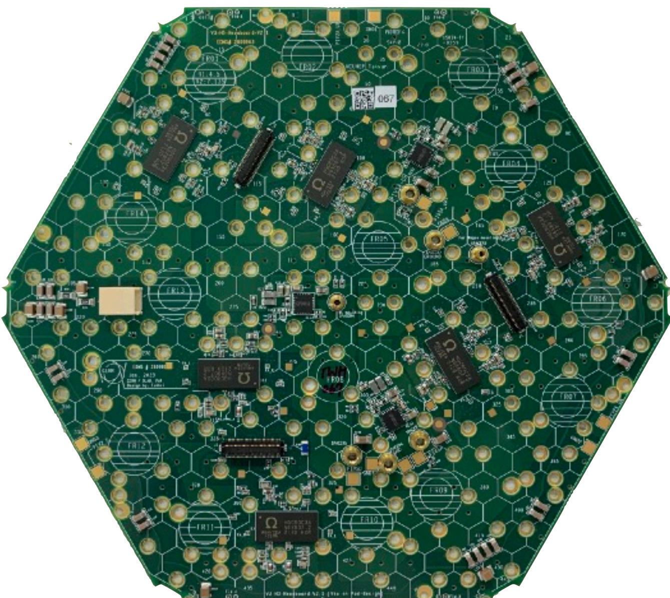


LD RIGHT

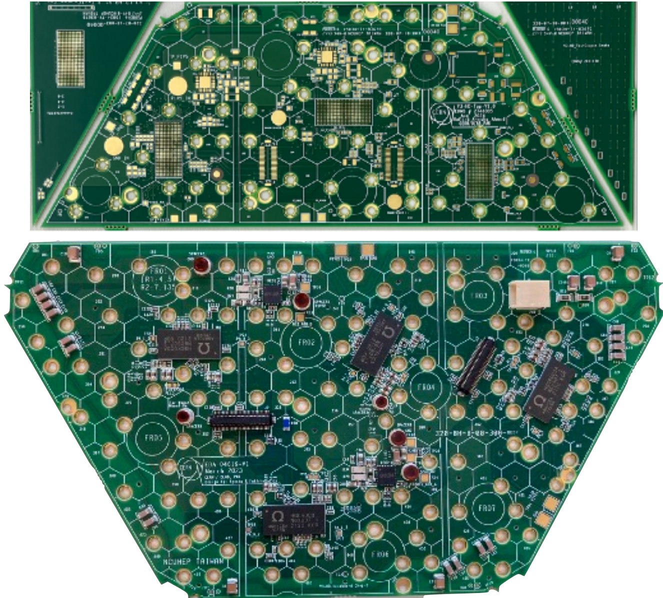
LD FIVE



HD FULL

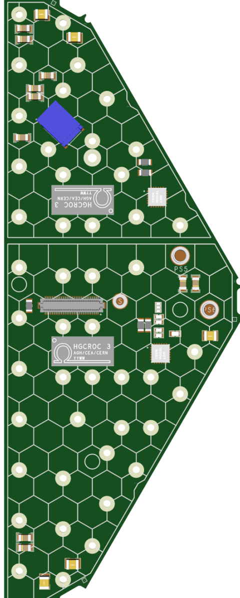


HD TOP



HD BOTTOM

HD LEFT

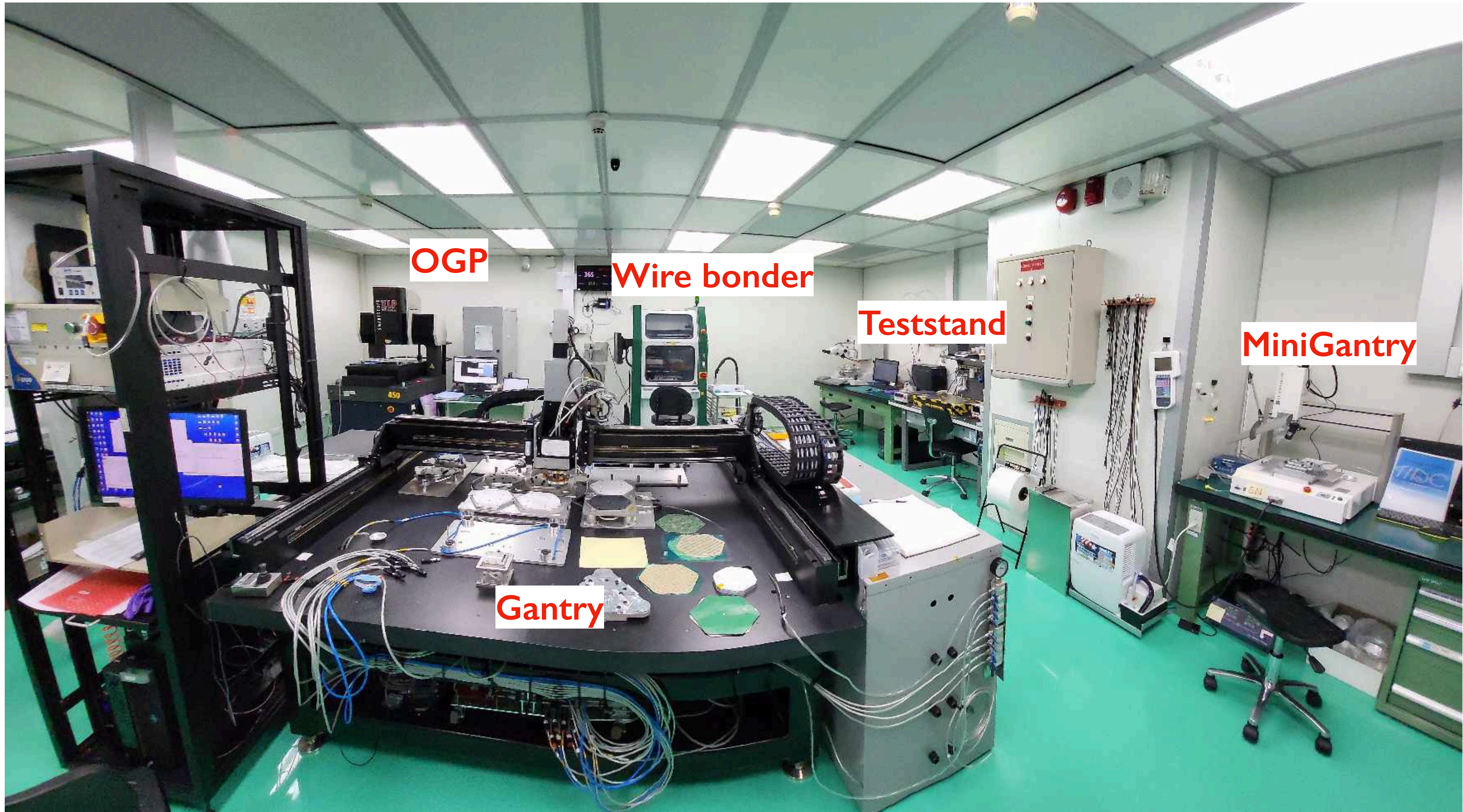


HD RIGHT

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)
- 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.

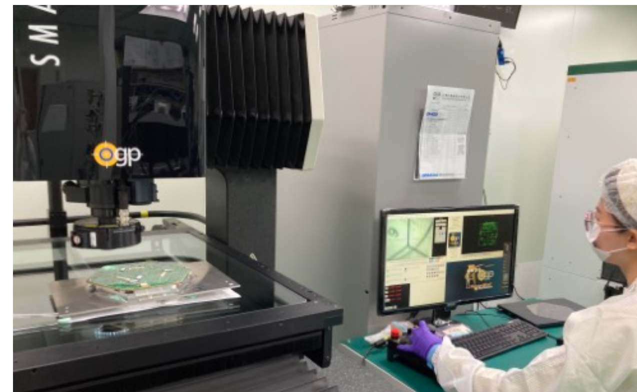
Clean room for Taiwan MAC



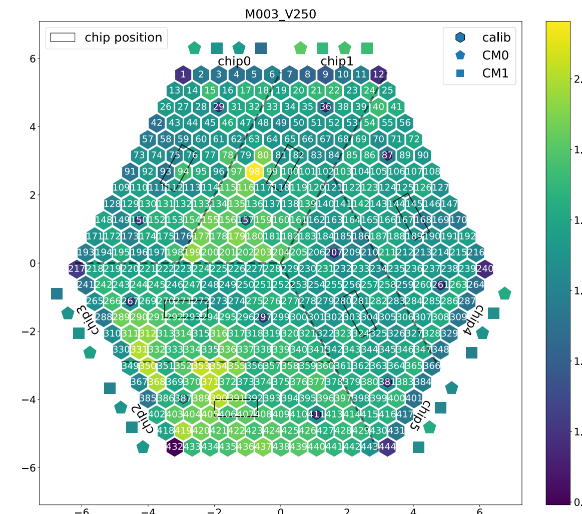
MAC : From material to module

Material

Assembly



OGP QC



Electronic test

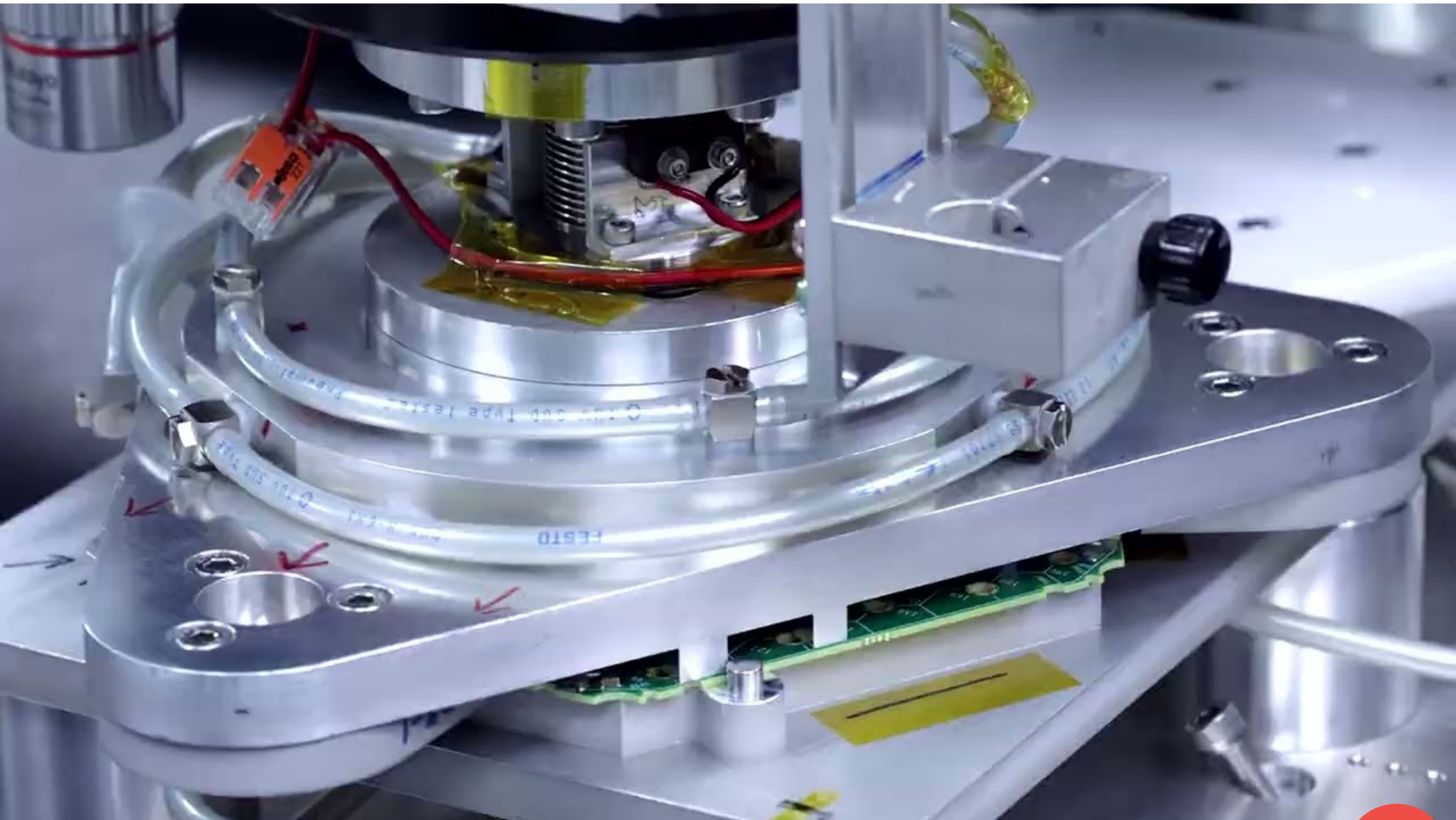
Thermal cycle

Wire bonding

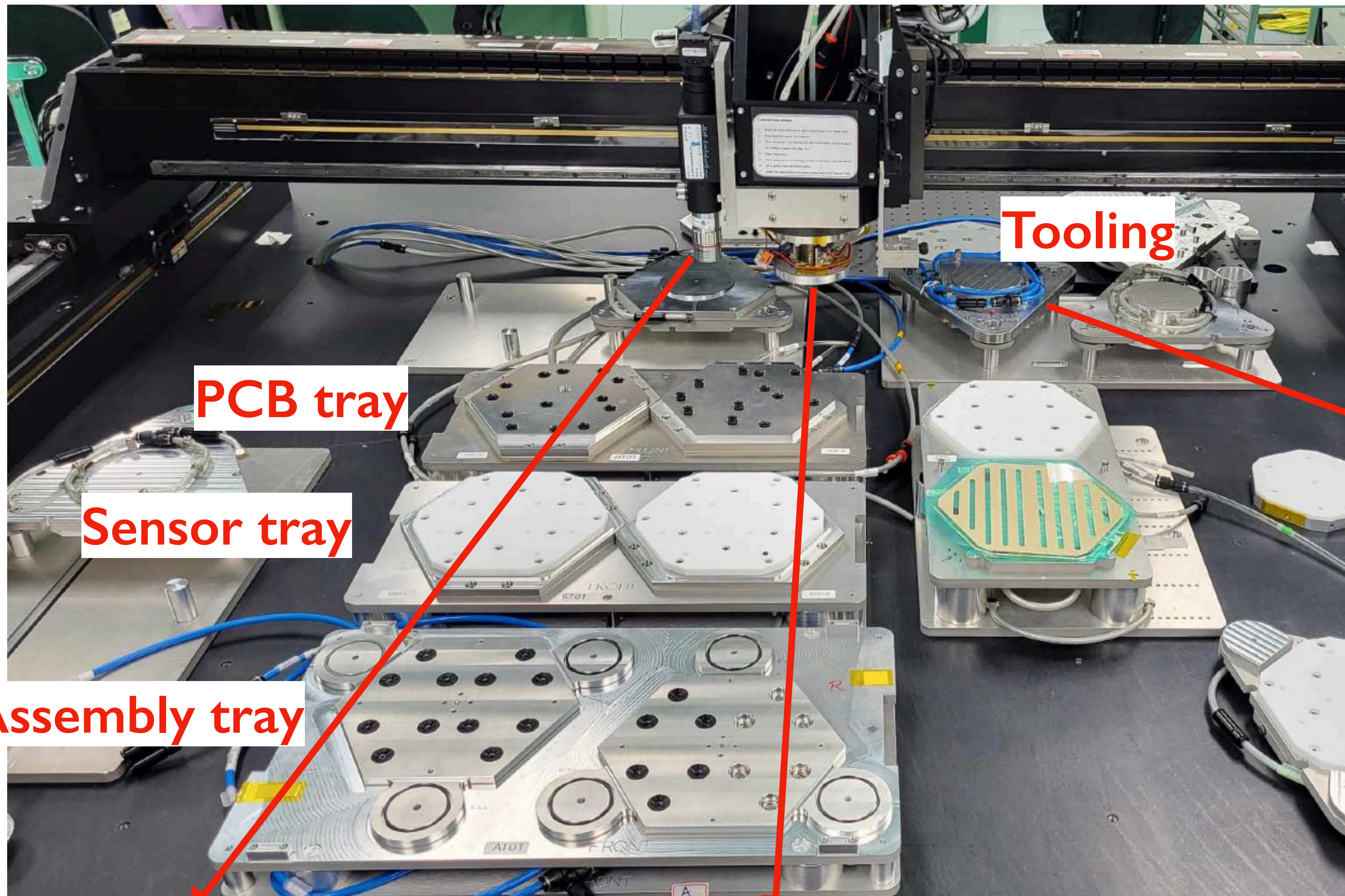
Encapsulation

Module

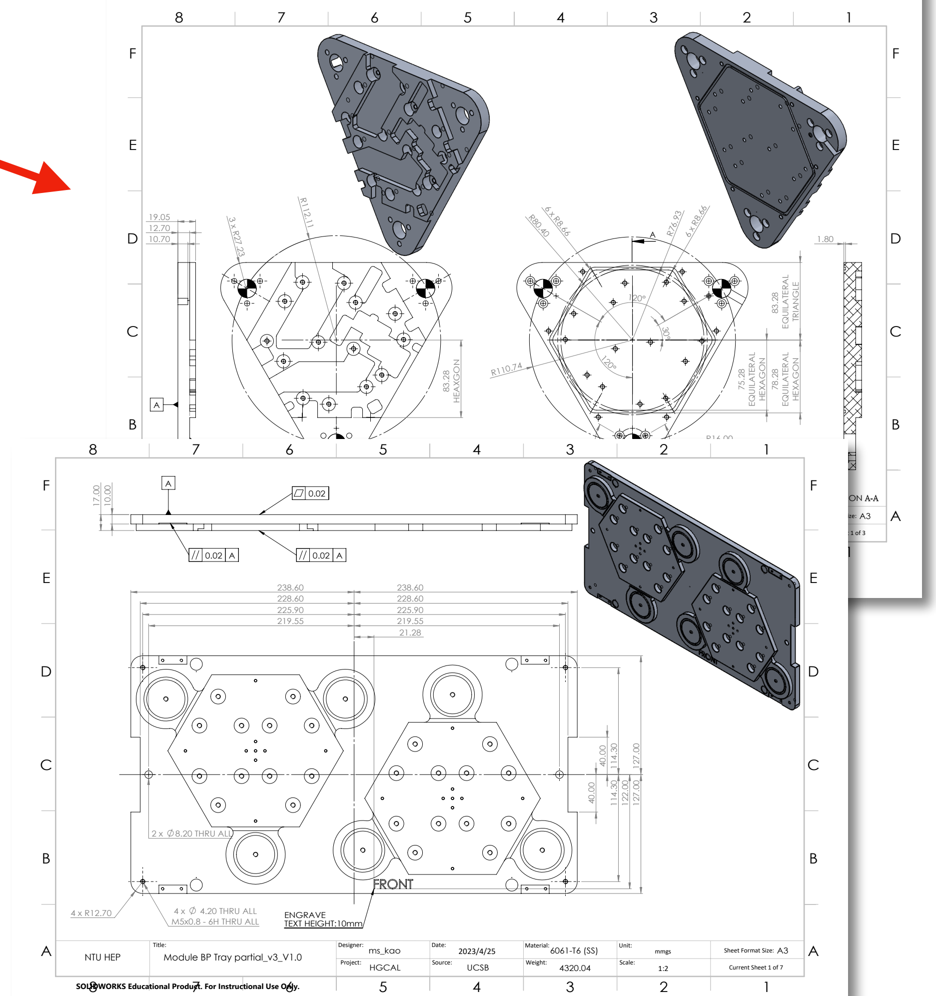
Module assembly step



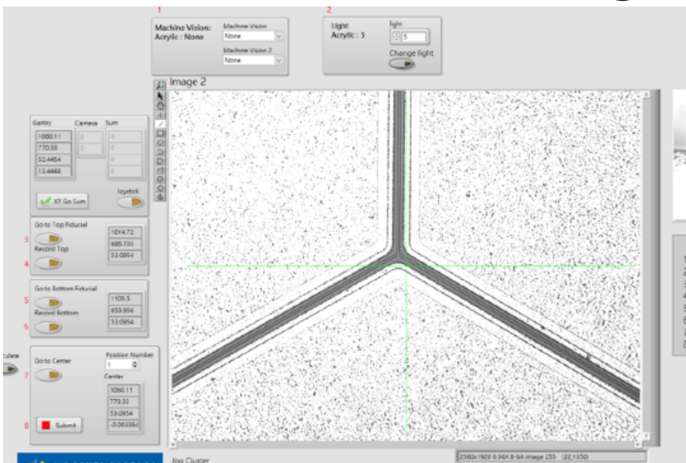
Gantry overview



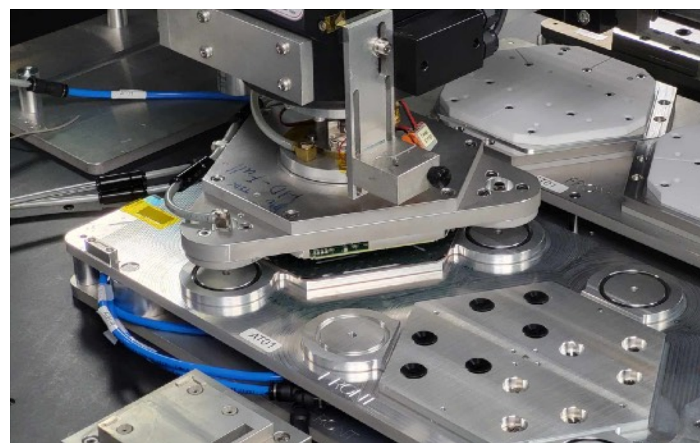
Assembly jigs designed at NTU and fabricated at AS



Camera for locating



Pick and place by vacuum

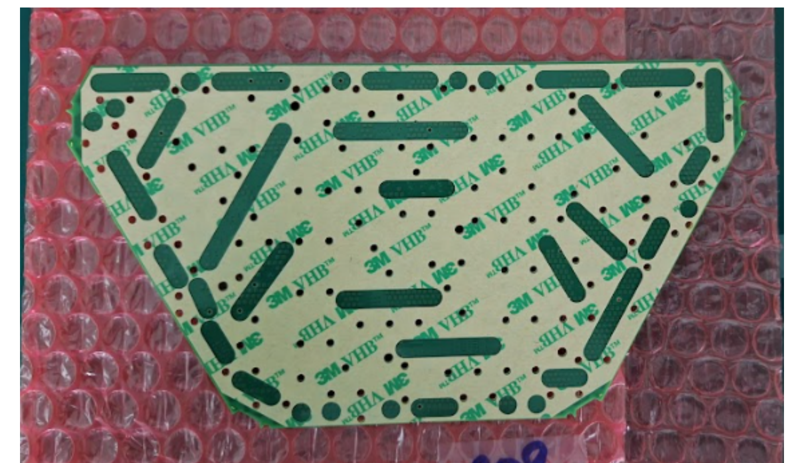


Module assembly method

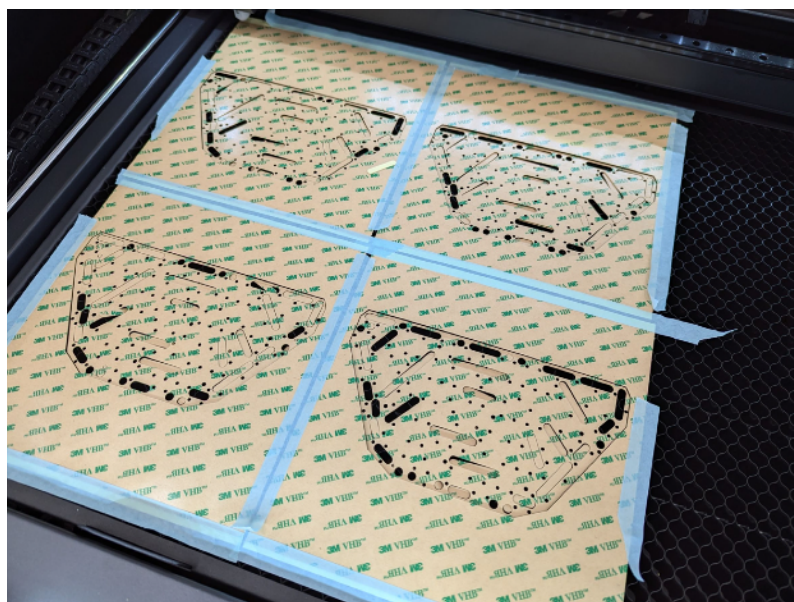
- Module assembly method combines Araldite and double sided tapes methods to be the hybrid one with the glue patten matching to the tape' hollow.
  - Araldite : High radiation tolerance but inefficiency (1 day).
  - Double sided tapes : High efficiency (20 mins) but low radiation tolerance.
- The dedicated transfer tapes are made by our laser cutting machine with an efficiency of 3 min/per piece

Araldite

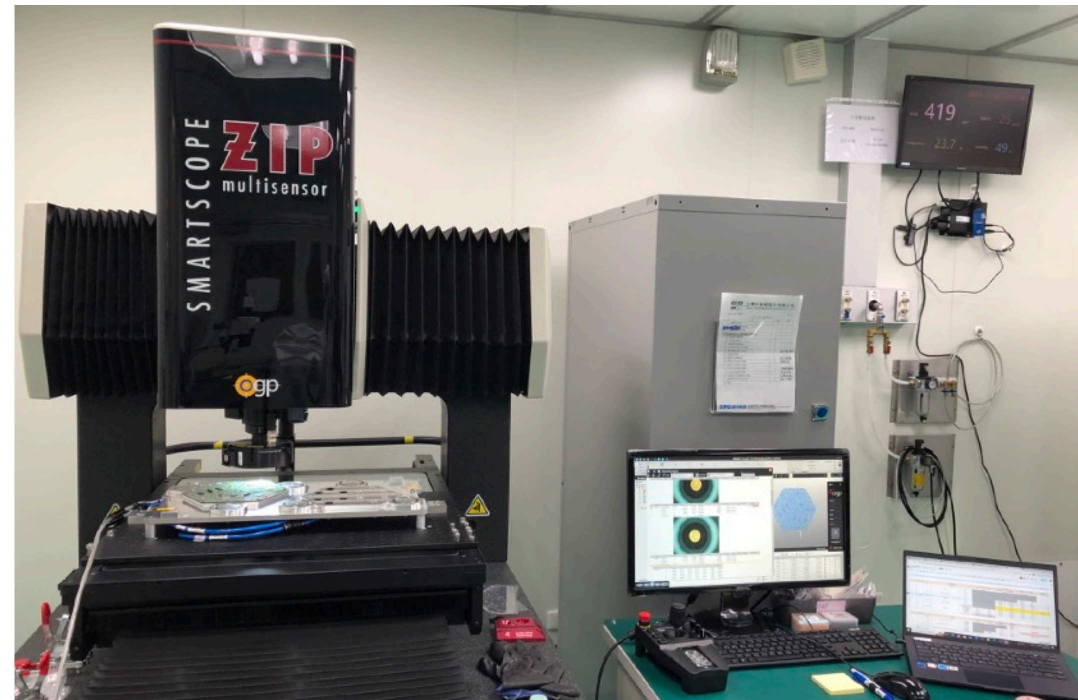
Double sided tape

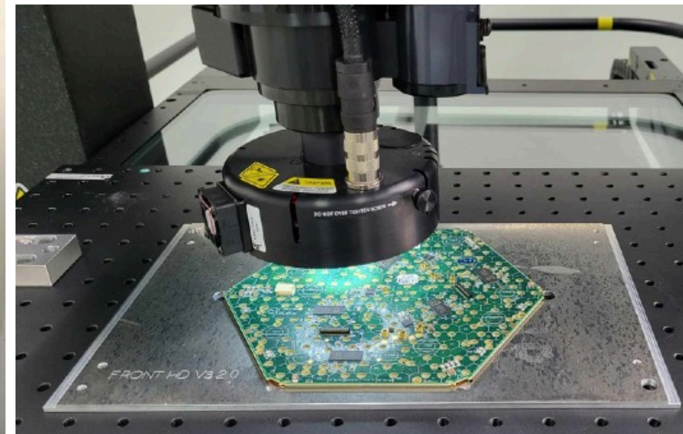


Laser cutting

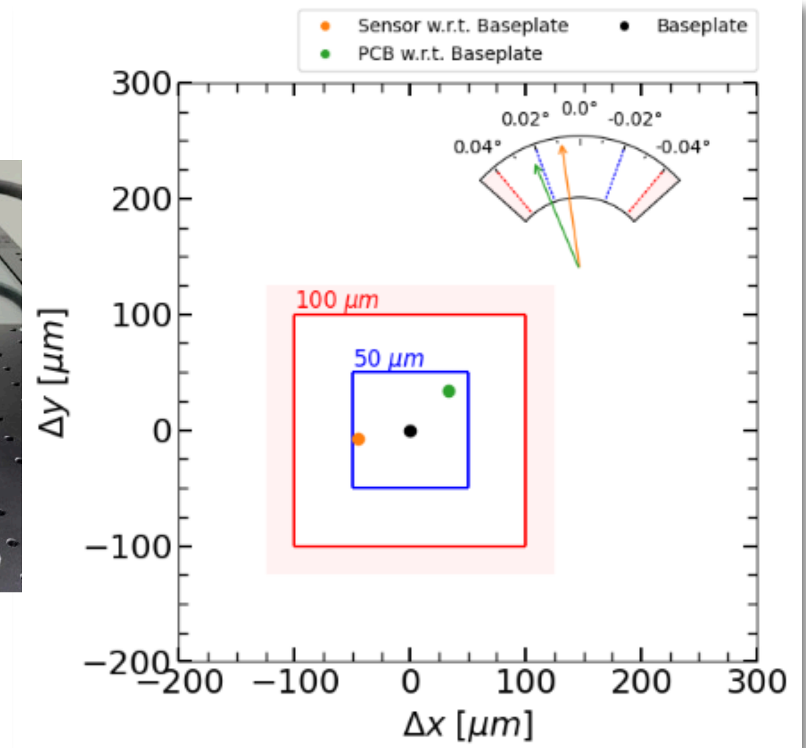


QGP QC

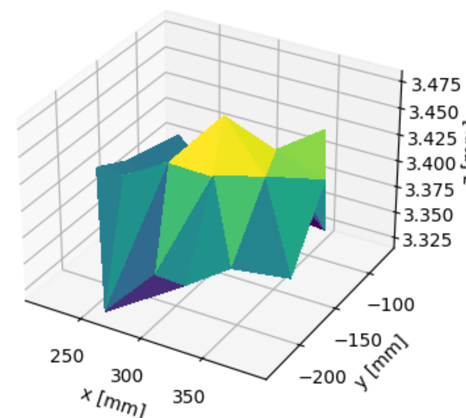


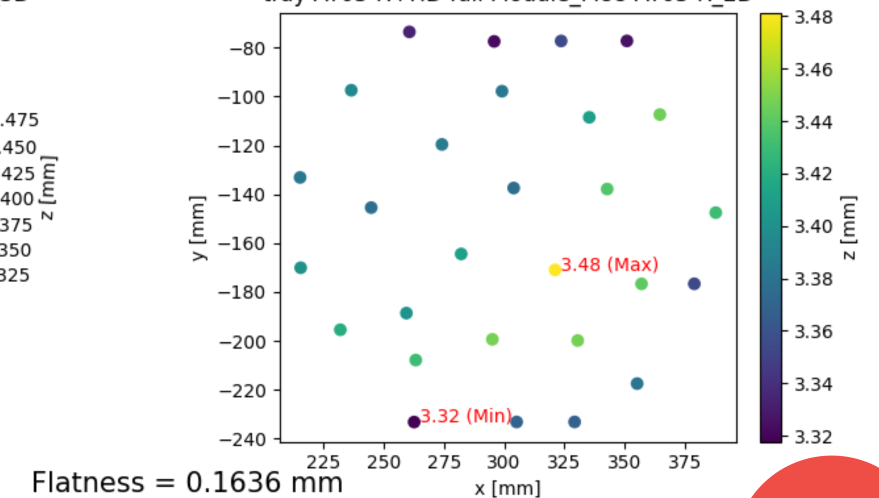


Alignment



Flatness

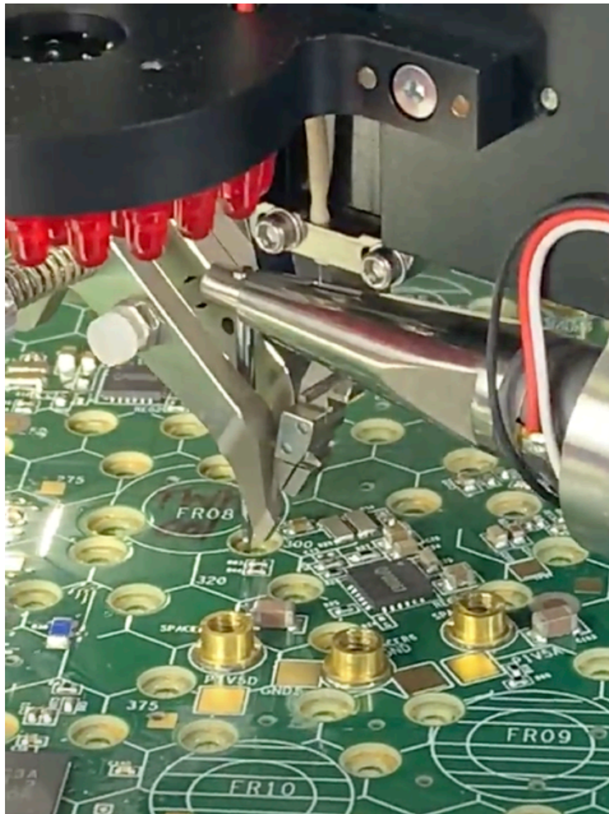


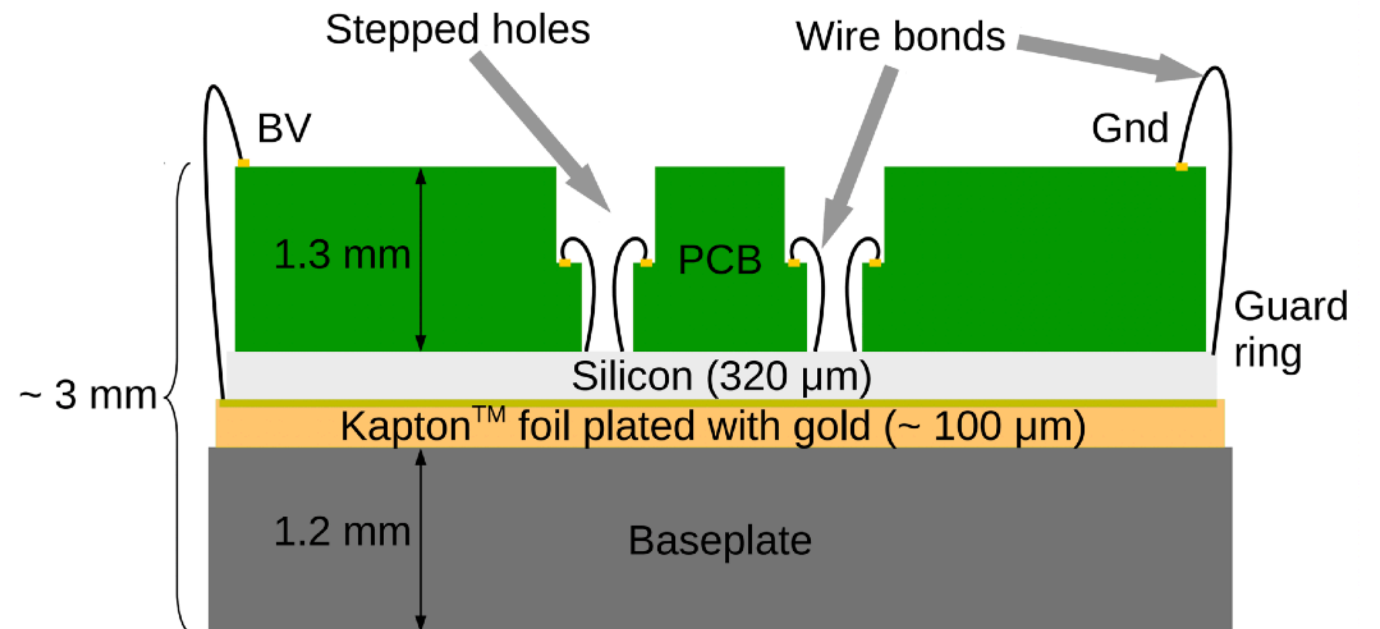


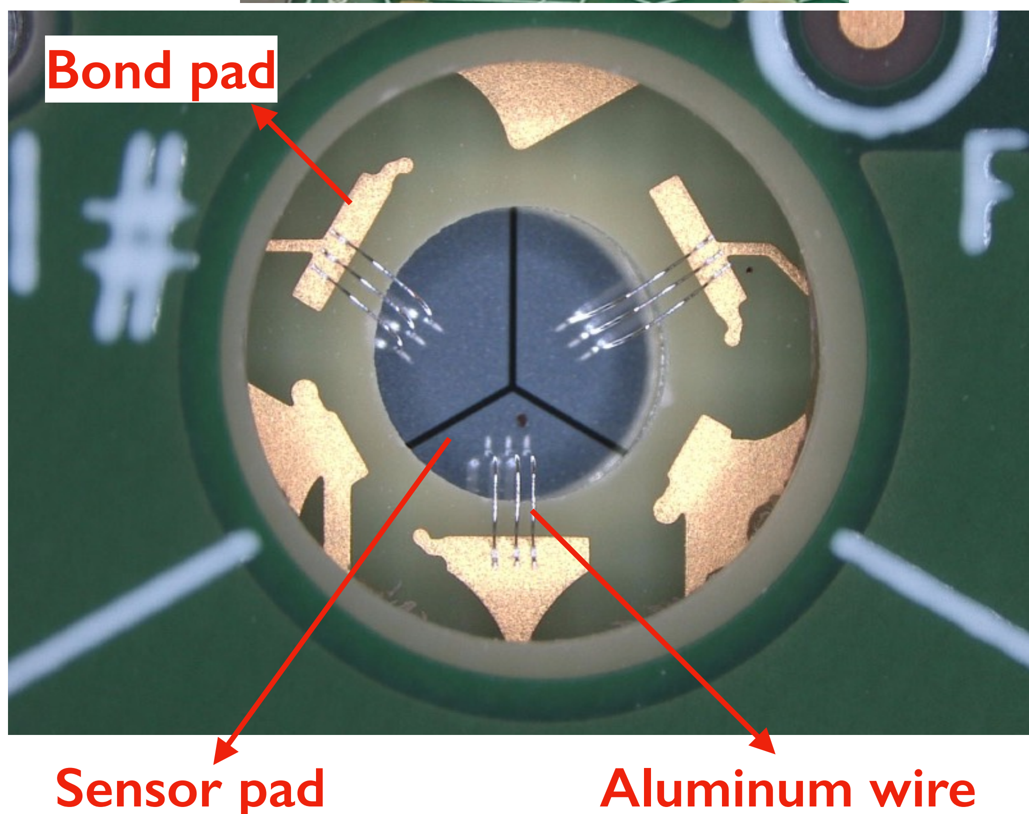
Flatness = 0.1636 mm

- 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.

Wire bonding

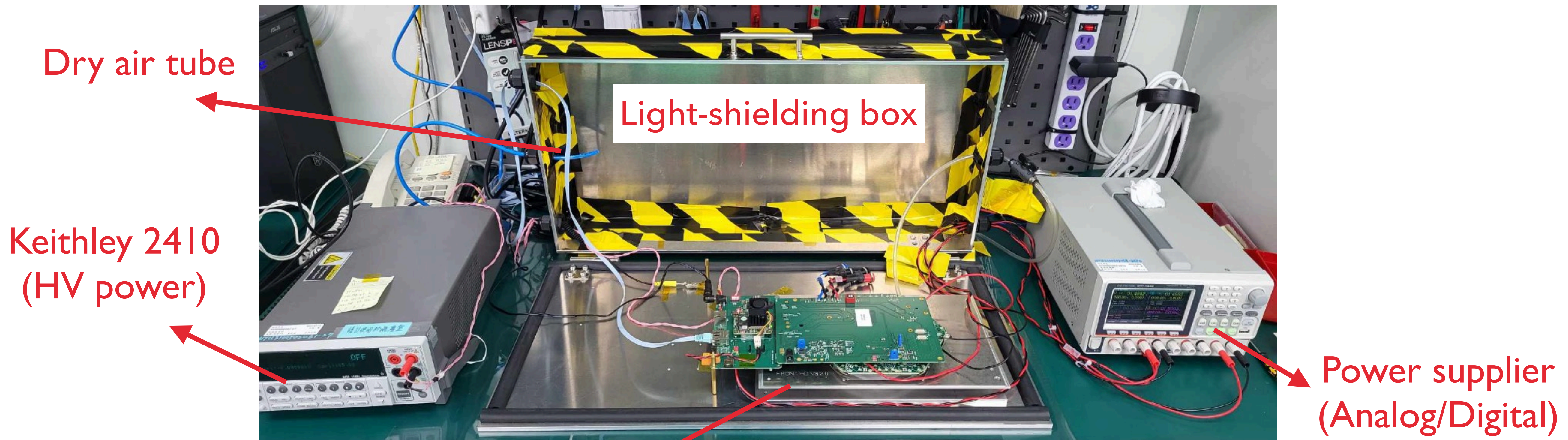




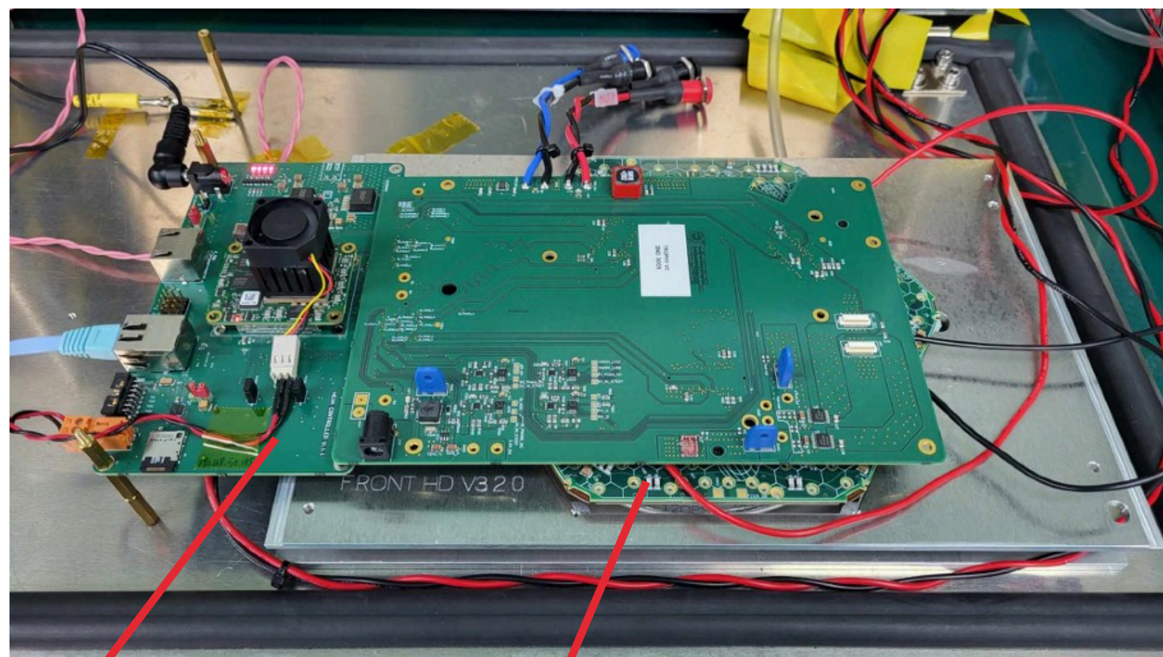


- Connect the silicon sensor to pads on the hexaboard through aluminum wire for signal readout and HV/GND.
- 15 mins can finish a module with 432 bond pads.
- Use OGP to snapshot bond pads and sensor to check the failure of wire bonding.
- Consider vision recognition (machine learning by ourselves) to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

Electronic test setup



Teststand



HexaController
(with FPGA)

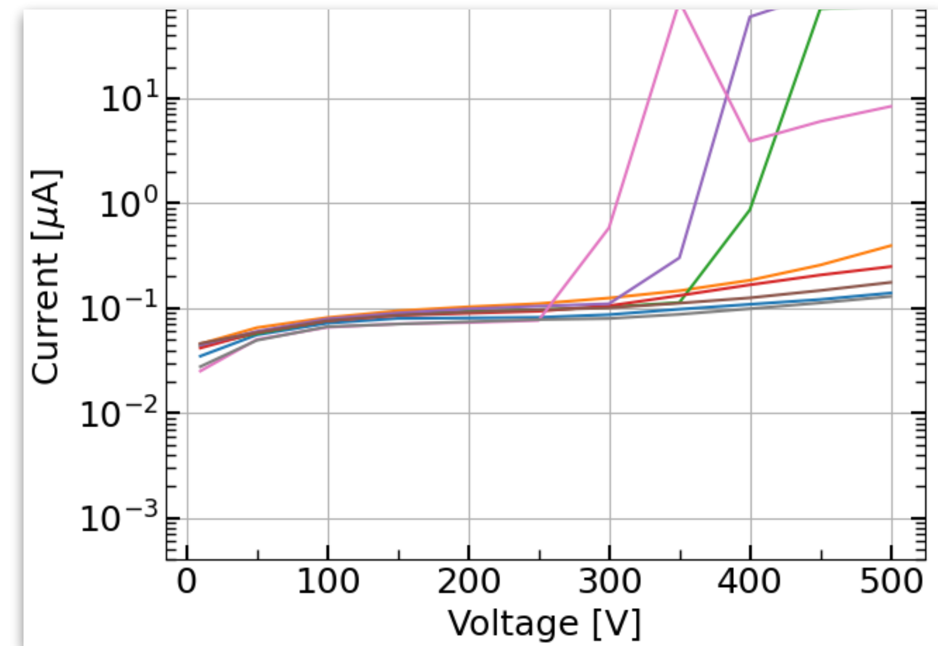
Module

- 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.

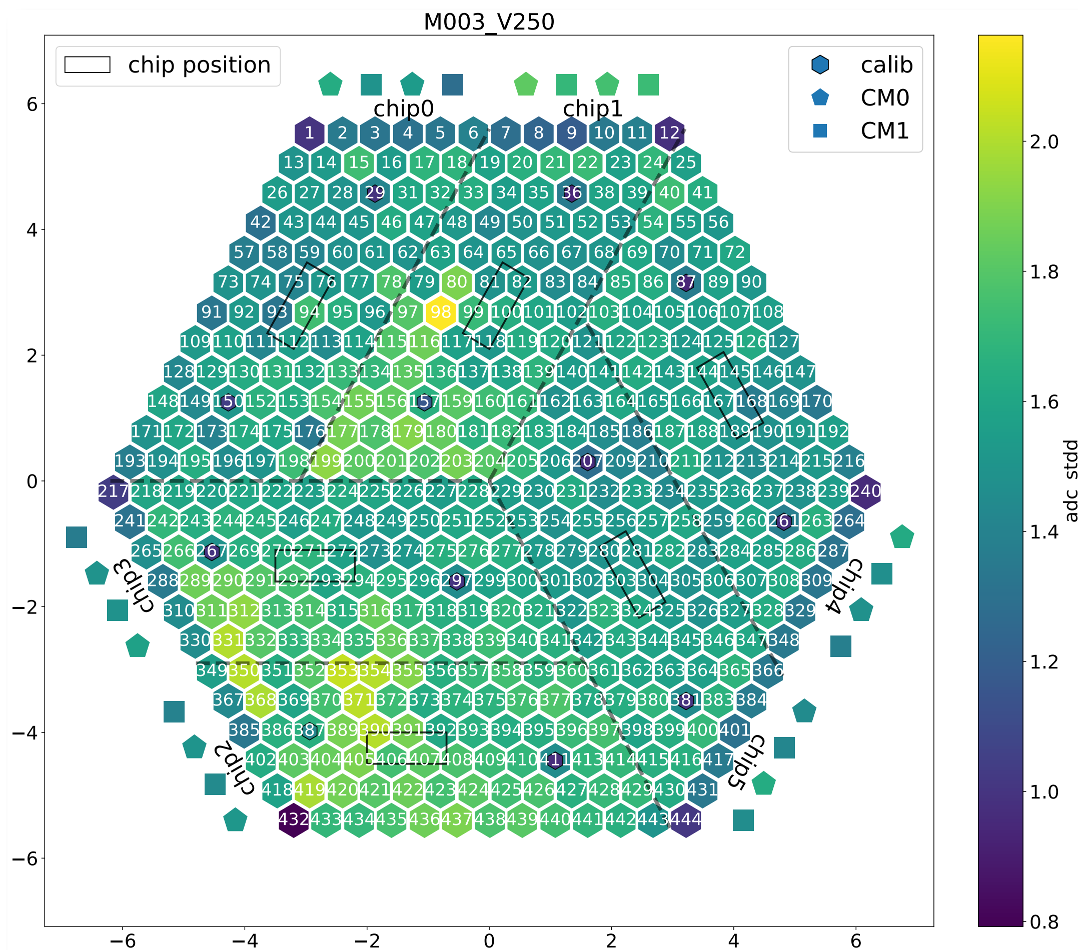
Electronic functionality

- 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)

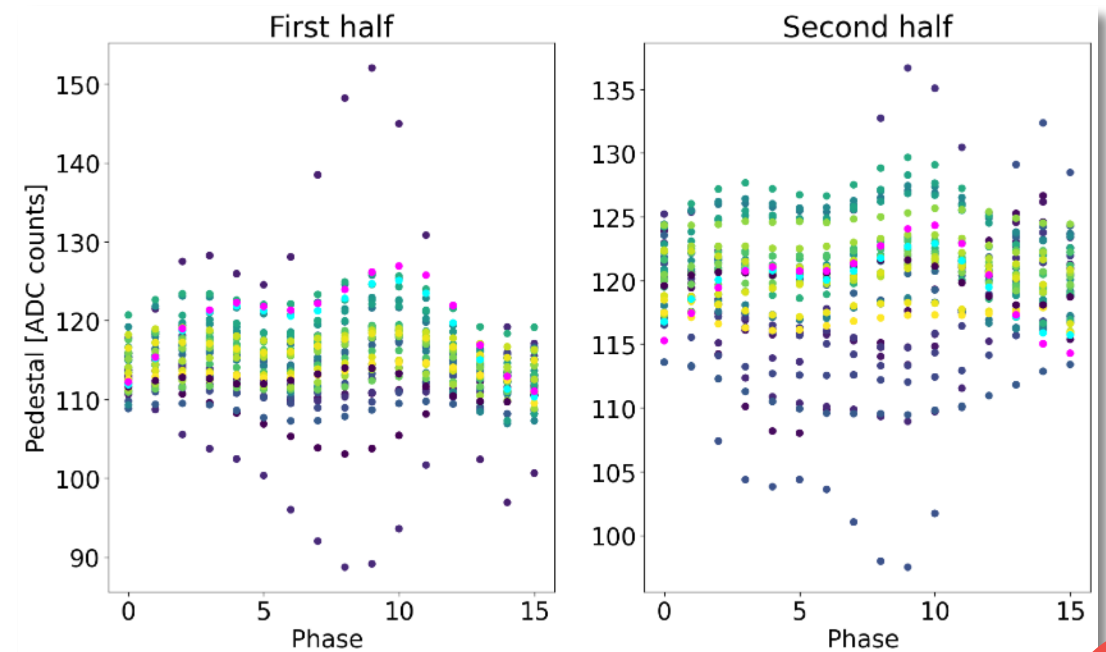
IV curve



Noise mapping

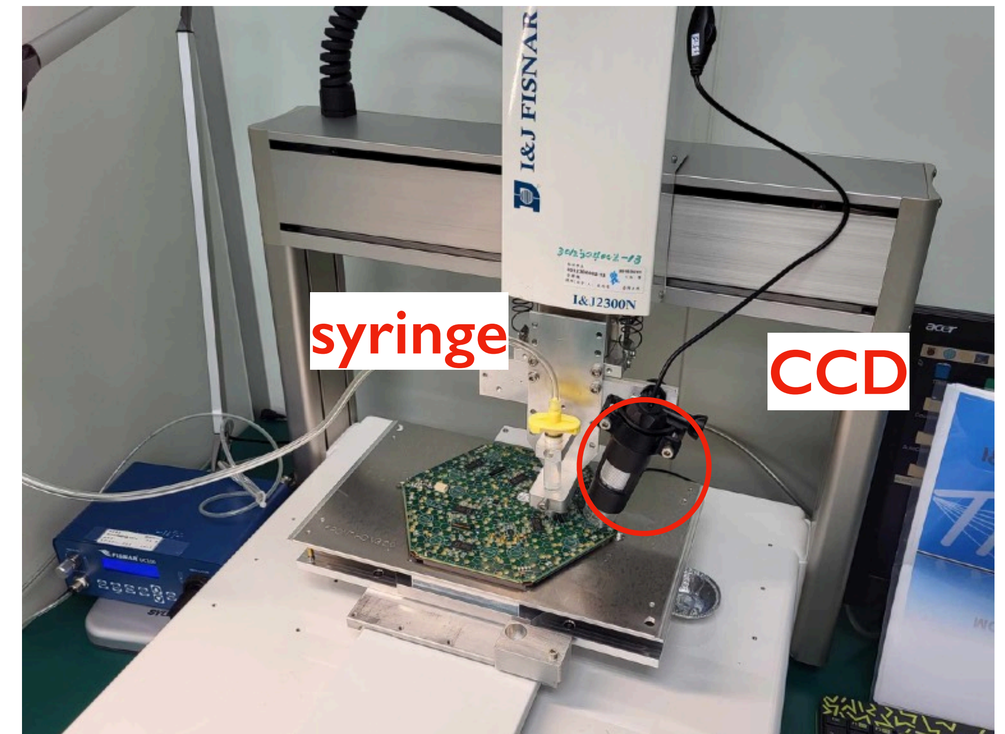


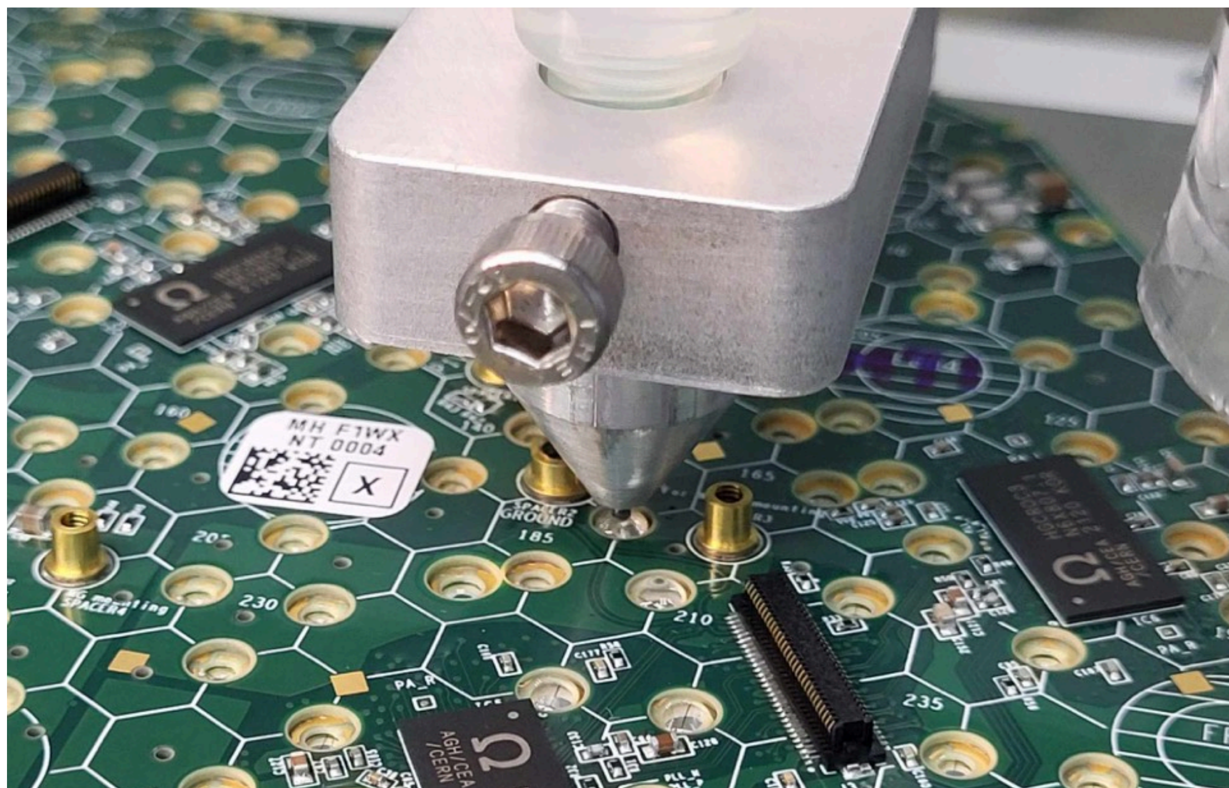
Phase scan

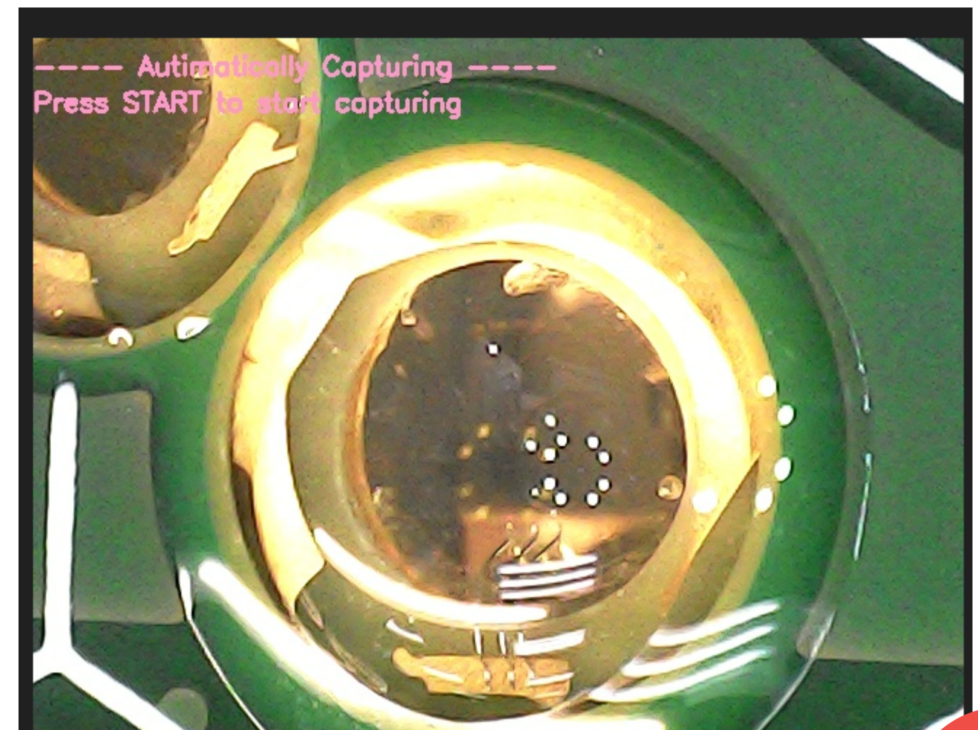


Encapsulation

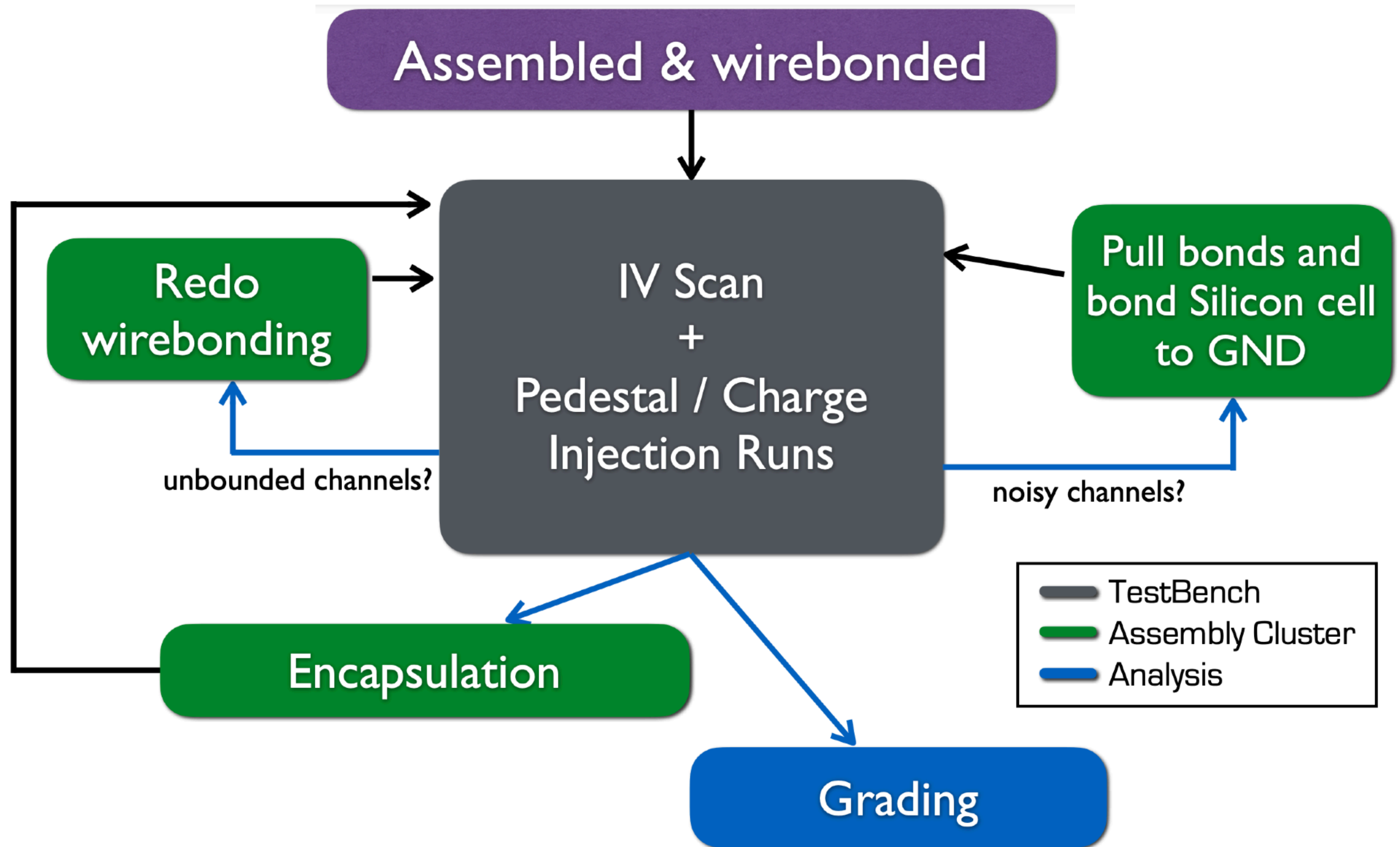
- Wire encapsulation is performed using glue coverage to avoid dust to touch wires and cause short.
- Programmable miniGantry and air jets are automatically controlled for syringe position and the timing of glue squeezing.
- CCD camera scans all step holes to check the status of like bubble or glue overflow.







Electronic functionality

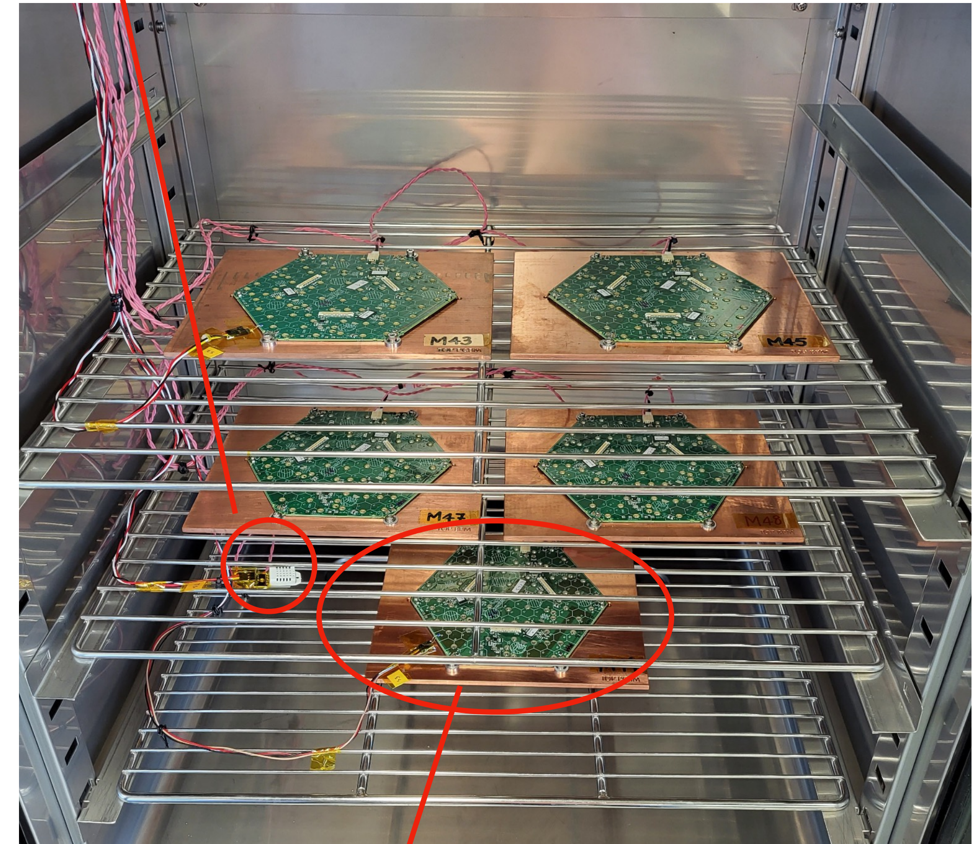


Thermal cycle test setup

- 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.

Temperature/Humidity sensor

Inside the chamber



Keithley 2410

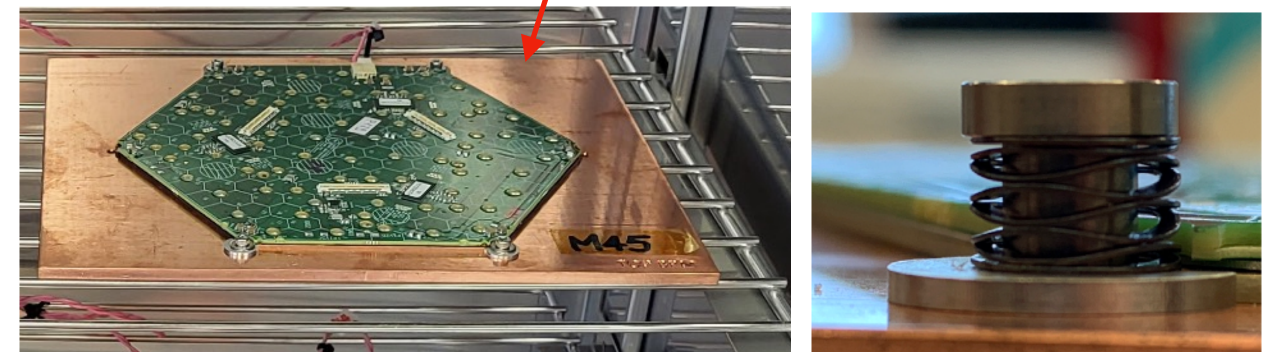
HV wires

Overview

Raspberry Pi

Macbook

HITACHI chamber



Mmodule mounted on copper plate

Thermal cycle test

20 °C period

One cycle period

IV

IV

IV

IV

Temperature (°C)

Humidity (%)

Time (HH:MM)

10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00

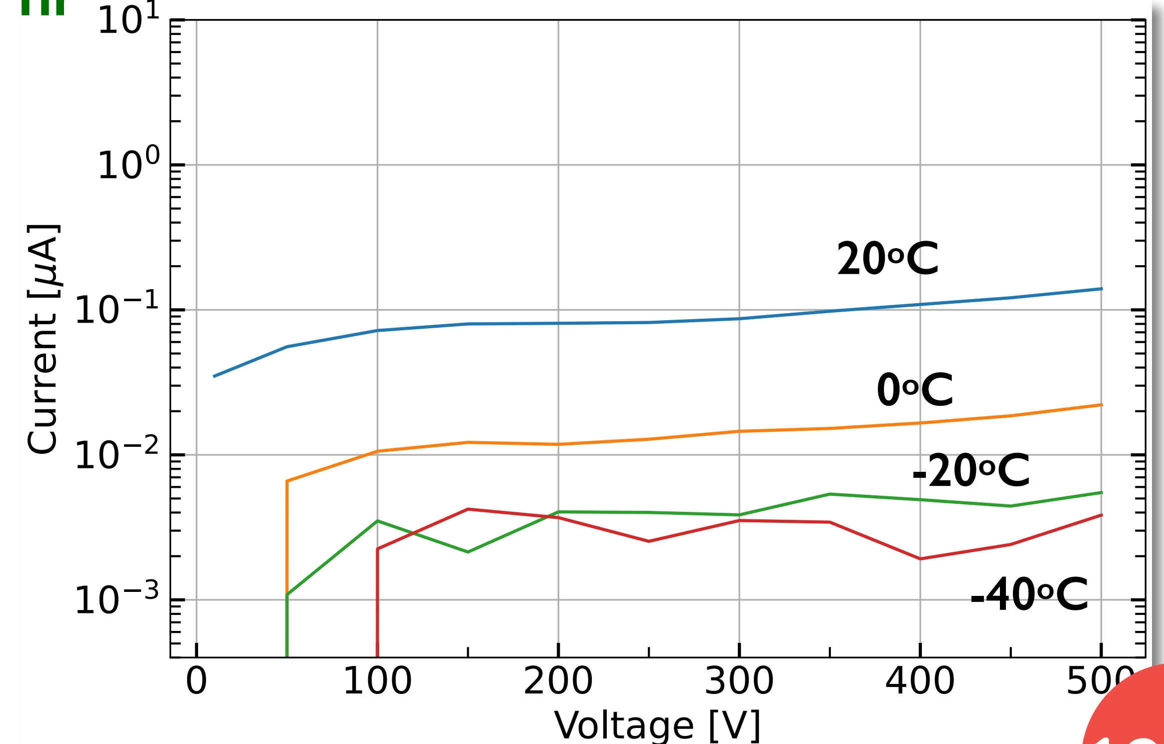
Pedestal/noise

Thickness/Flatness

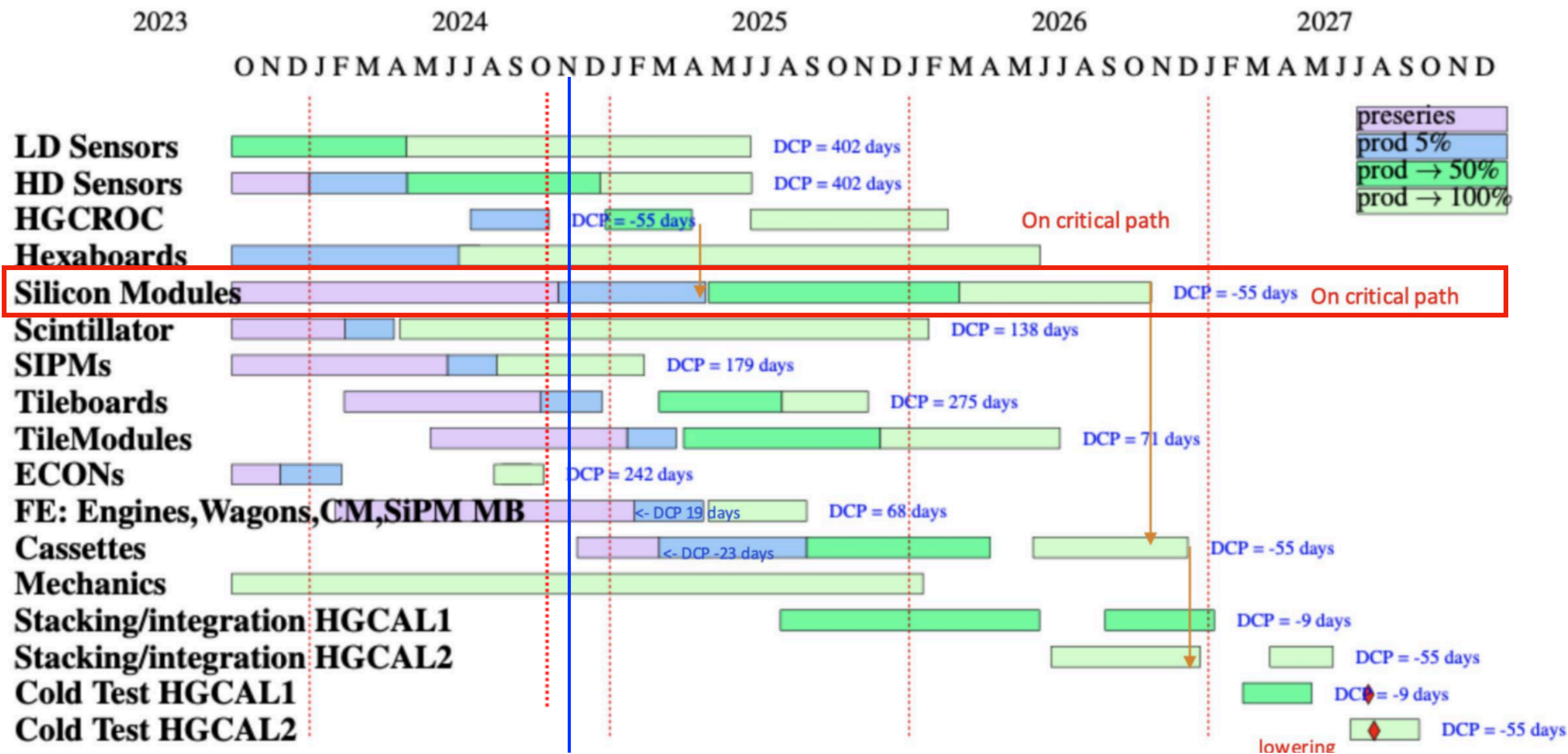
~ 30 min

7 hr

- 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



We are here

Production Ramp-up

October 2024

Expect to receive 45 to 50 hexaboards early November (CMU, IHEP, TTU) ...UCSB, NTU HD/partials not shown

November

Build 16 modules November

Practice "mini ramp up" with one tray

December / January 2025

Build 32 modules December/January

Practice with 1 tray in 2nd region on gantry, 2 trays if possible

Ideal: "mini ramp up" with two trays

February 2025

Cycles of 2 weeks on within a month
Build 4 per day x 2 weeks

March

Build 8 per day x 2 weeks

April

Build 12 per day x 2 weeks

May

Build 16/day x 2 weeks

Reaching 16/MAC-day Spring 2025

Multi-Module test system

@CERN

Control PC

PLC Control System

Dry air valve

Thermal box

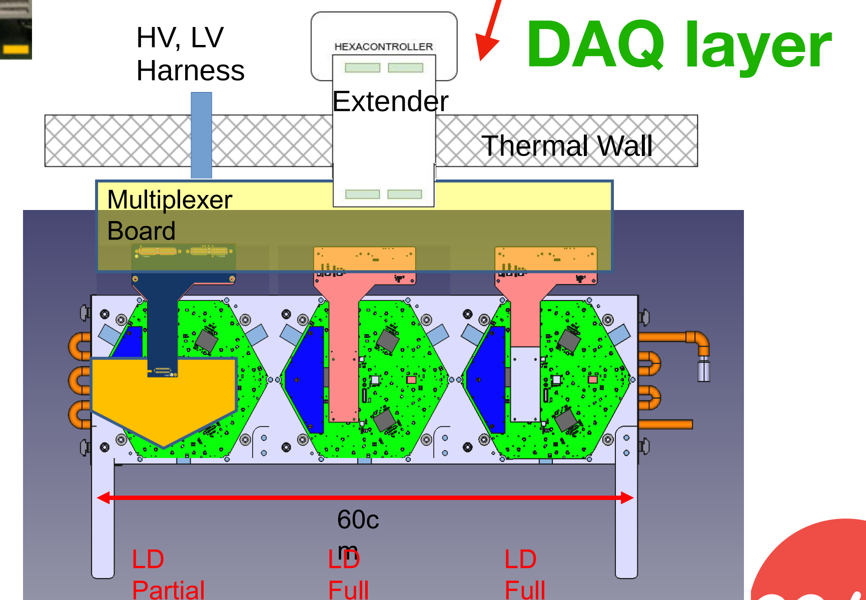
Chiller

Multi Module Test System for Silicon Modules

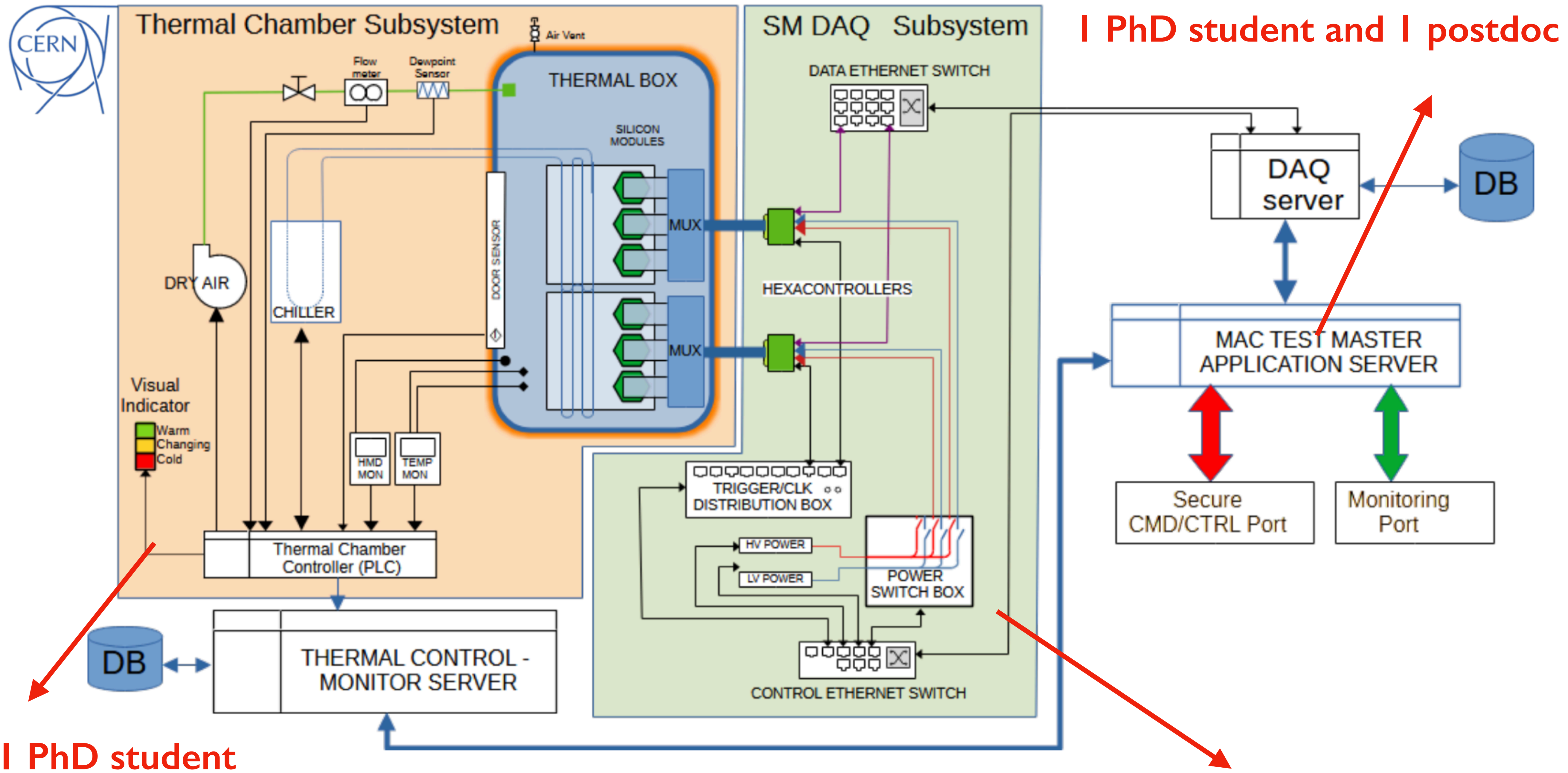
Build a multi-mode test system that synchronizes electronic test, IV measurement and thermal cycle together.

- 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

DAQ layer



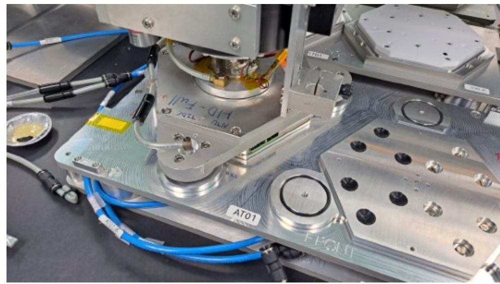
Multi-Module test system



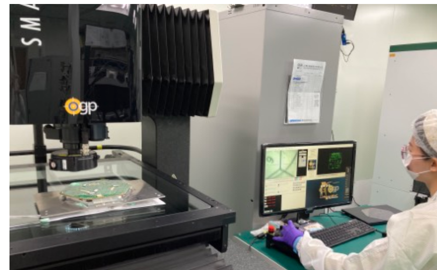
Multi Module Test System for Silicon Modules

GUI and Database

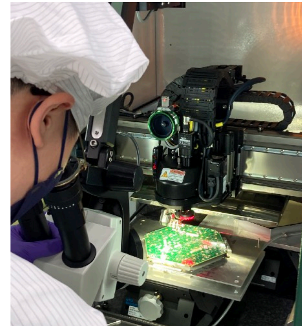
Assembly



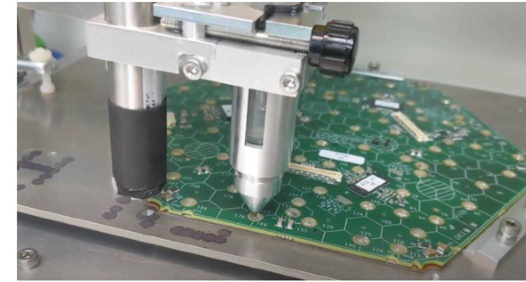
OGP QC



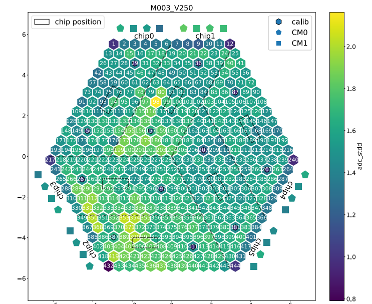
Wire bonding



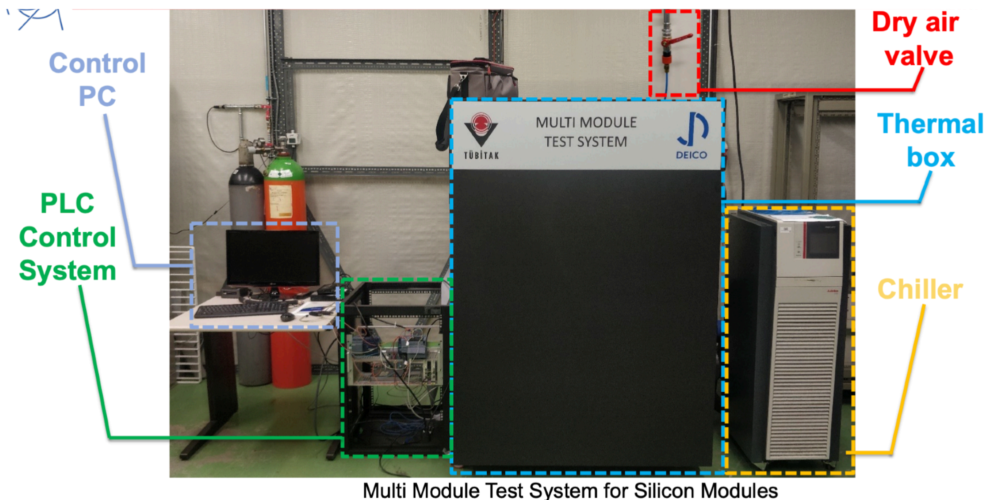
Encapsulation



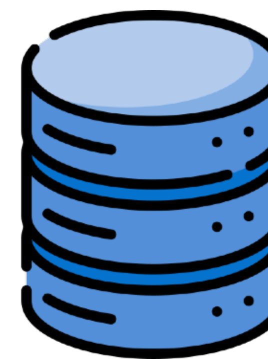
Electronic test



MMTS



Multi Module Test System for Silicon Modules



Local DB

CERN DB

Summary

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