



中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences



Procedure of HGCal Si module assembly and electronics testing result in IHEP MAC

Taozhe Yu(IHEP) On behalf of the HGCal IHEP group

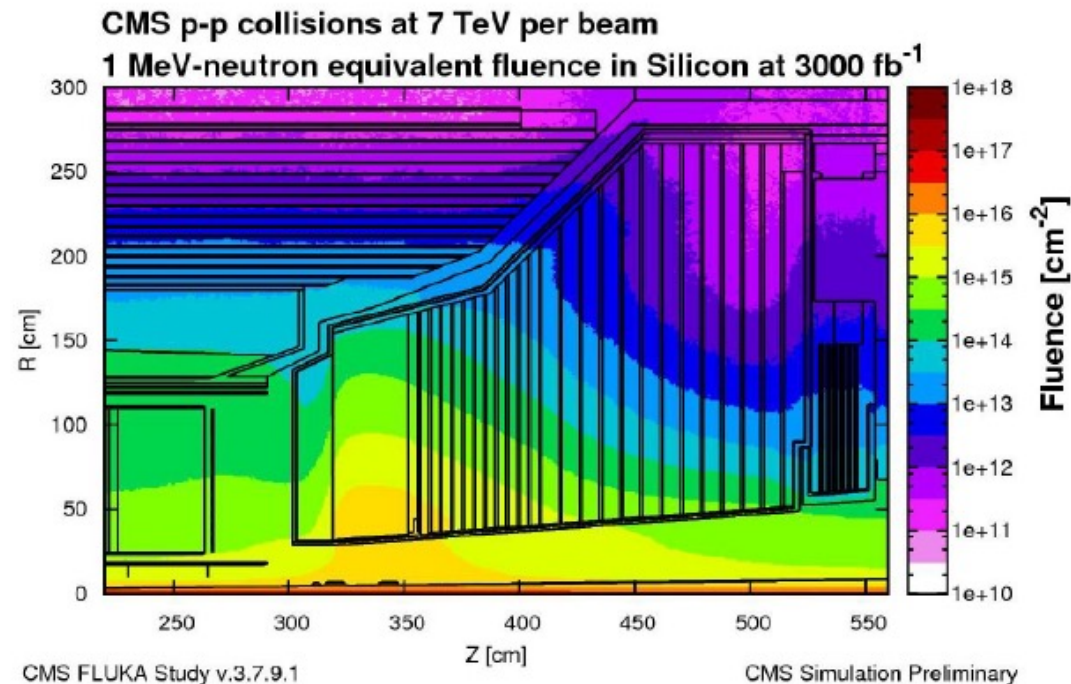
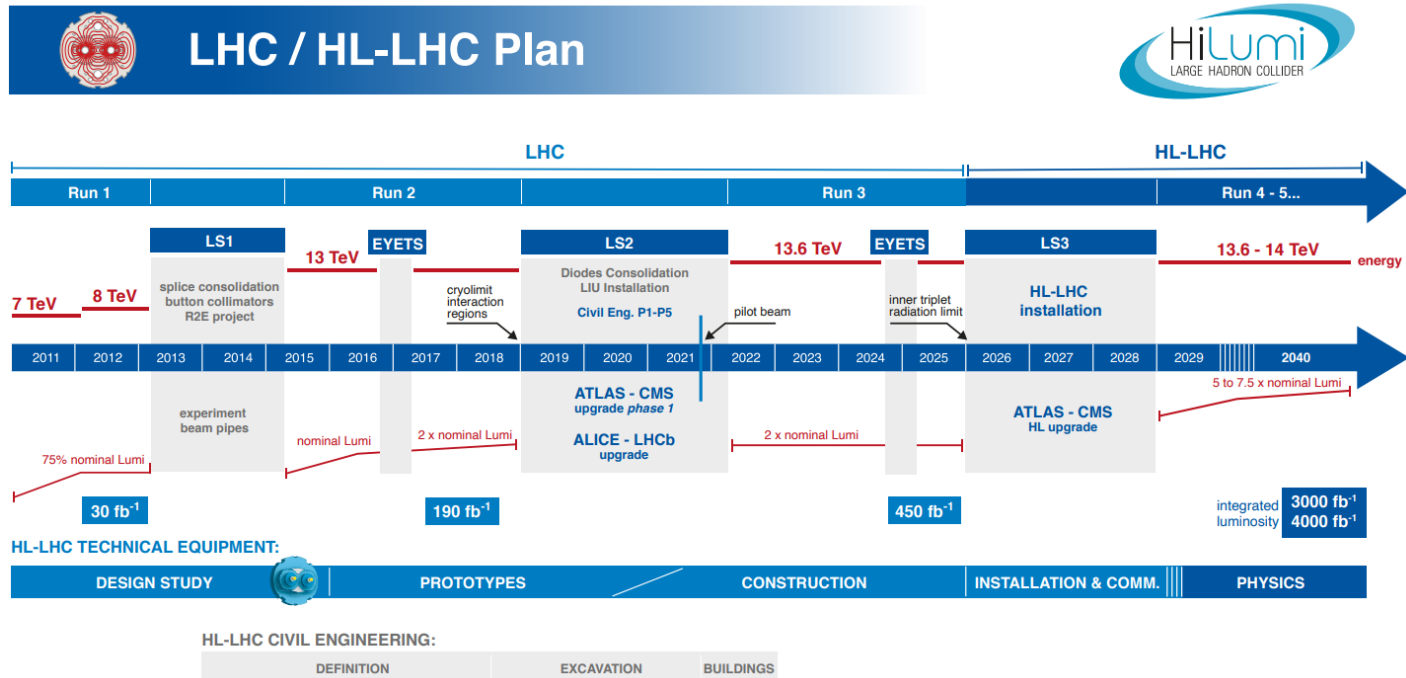
23-27 November 2022, Nanjing(China)

2022 CLHCP

H. Cheng¹, H. Hua¹, J. Guo¹, X. Hou¹, Z. Liang¹, L. Sun¹, J. Tao¹, C. Wang¹, Co. Wang¹, D. Wang², F. Wang¹, C. Yuan¹, T. Yu¹, H. Zhang¹, X. Zhao¹, Z. Zhang¹, Z. Wang¹

Institute of High Energy Physics¹

Tsinghua University²



➤ CMS endcap calorimeters: Phase-2 upgrade

- Harsh environment at HL-LHC: high pile-up, high radiation level
- Required to replace the existing endcap calorimeters
- Construct a High Granularity Calorimeter: HGCAL project

➤ Key Parameter(update from the TDR):

- HGCAL covers $1.5 < |\eta| < 3.0$
- Full system maintained at -30°C
- $\sim 620 \text{ m}^2$ of silicon sensors in ~ 26000 modules
- $\sim 370 \text{ m}^2$ of scintillators in ~ 3700 boards
- 6M silicon channels: 0.6 or 1.2 cm^2 cell size
- 240k scintillator-tile-SiPM channels
- Power at end of HL-LHC: $\sim 125 \text{ kW}$ per endcap

➤ Active layers and elements

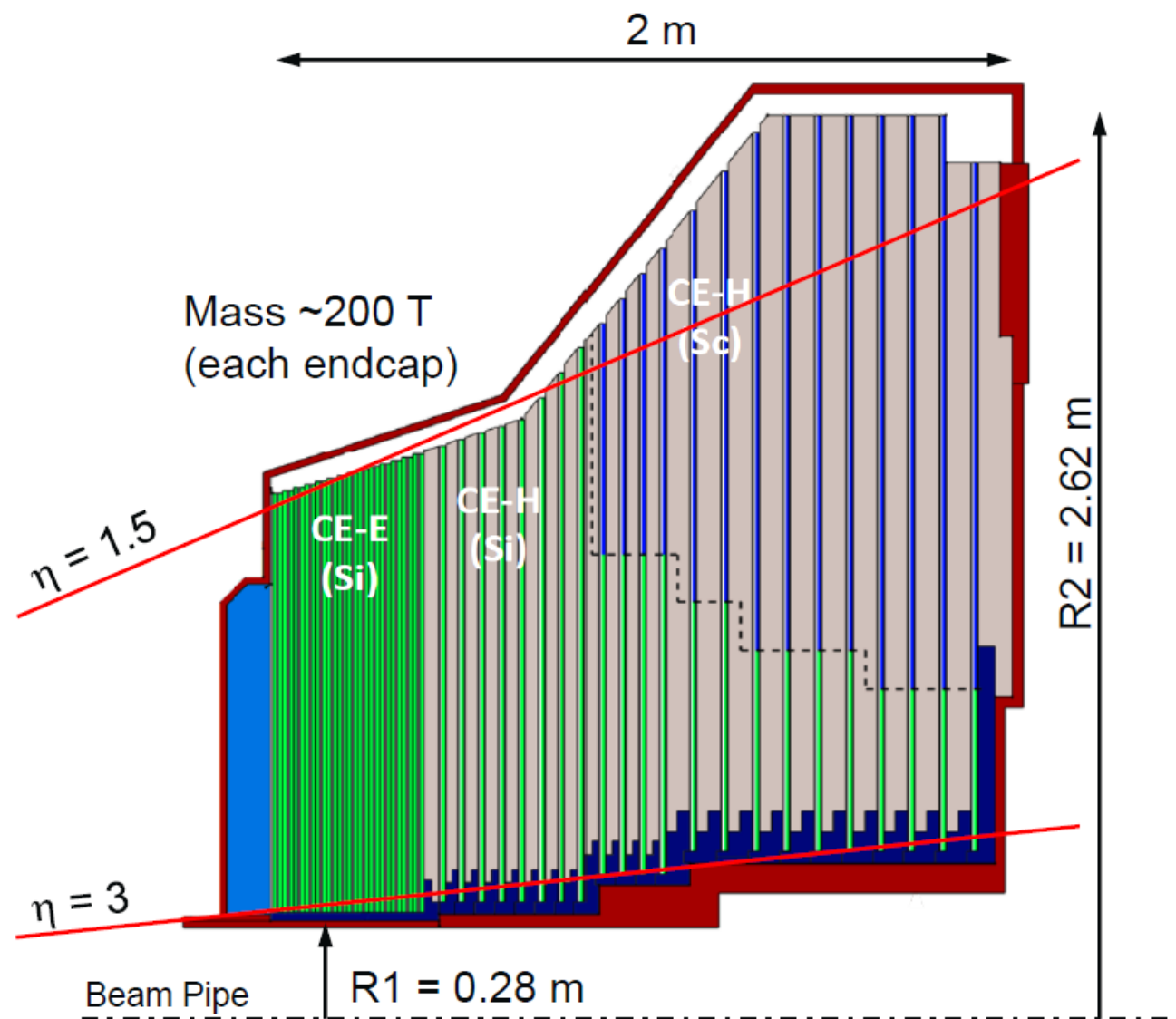
- Si-sensors (full and partial hexagons) in CE-E and high-radiation region of CE-H
- SiPM-on-Tile in low-radiation region of CE-H

➤ Electromagnetic calorimeter(CE-E):

- 26 layers, $27.7 X_0 (1.5 \lambda)$
- Si, Cu/CuW/Pb absorbers

➤ Hadronic calorimeter(CE-H):

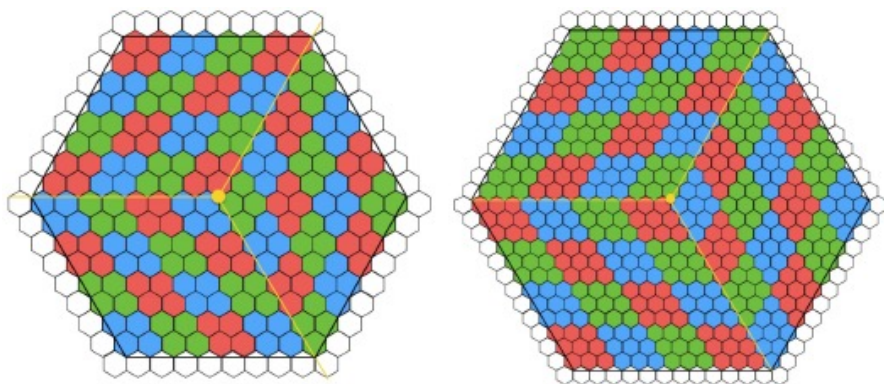
- 21 layers, $\sim 8.5 \lambda$ (including CE-E)
- Si & scintillator, steel absorbers



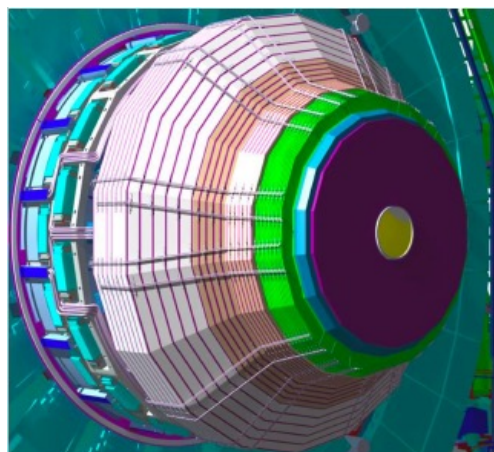
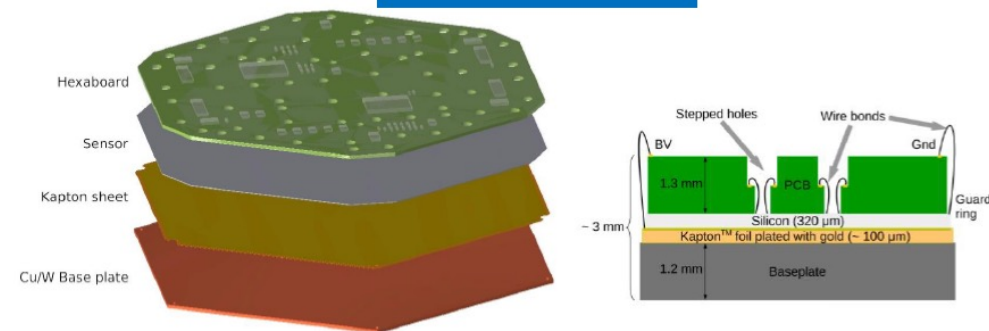
Structure of CMS endcap calorimeter



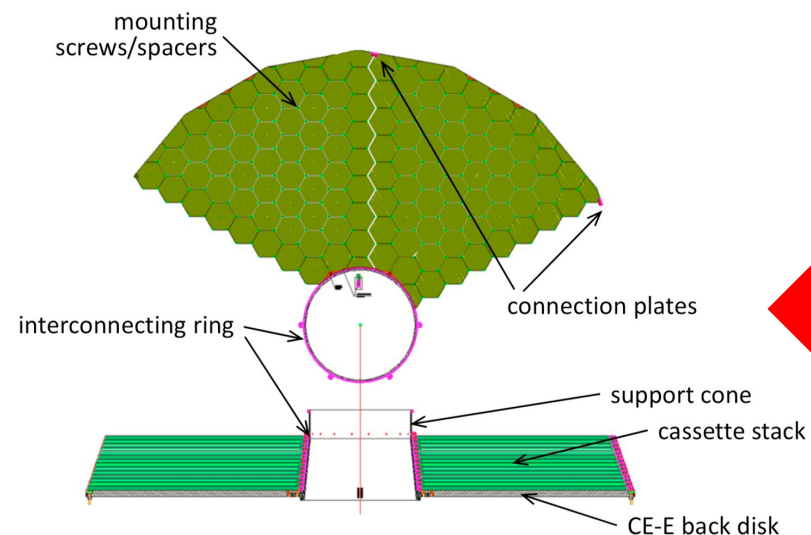
8 inch sensor



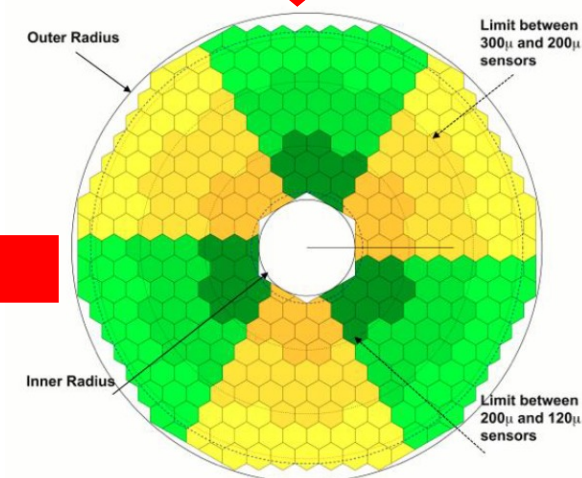
Silicon modules



Endcap calorimeter

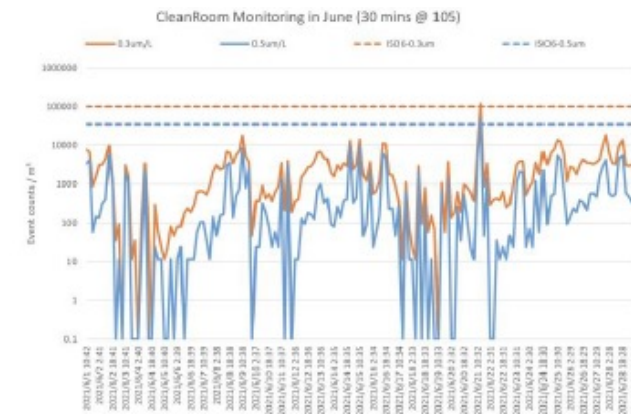
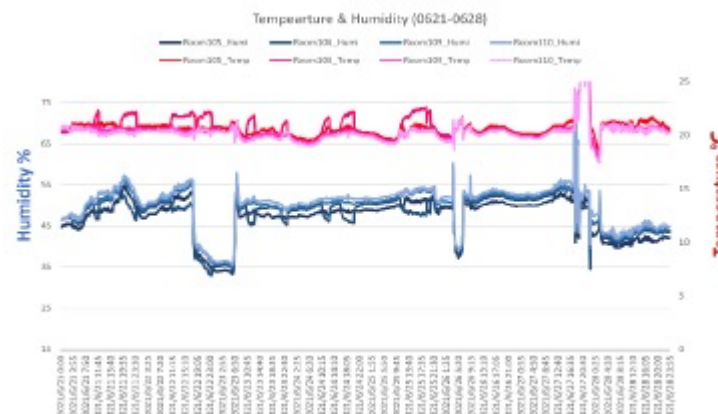
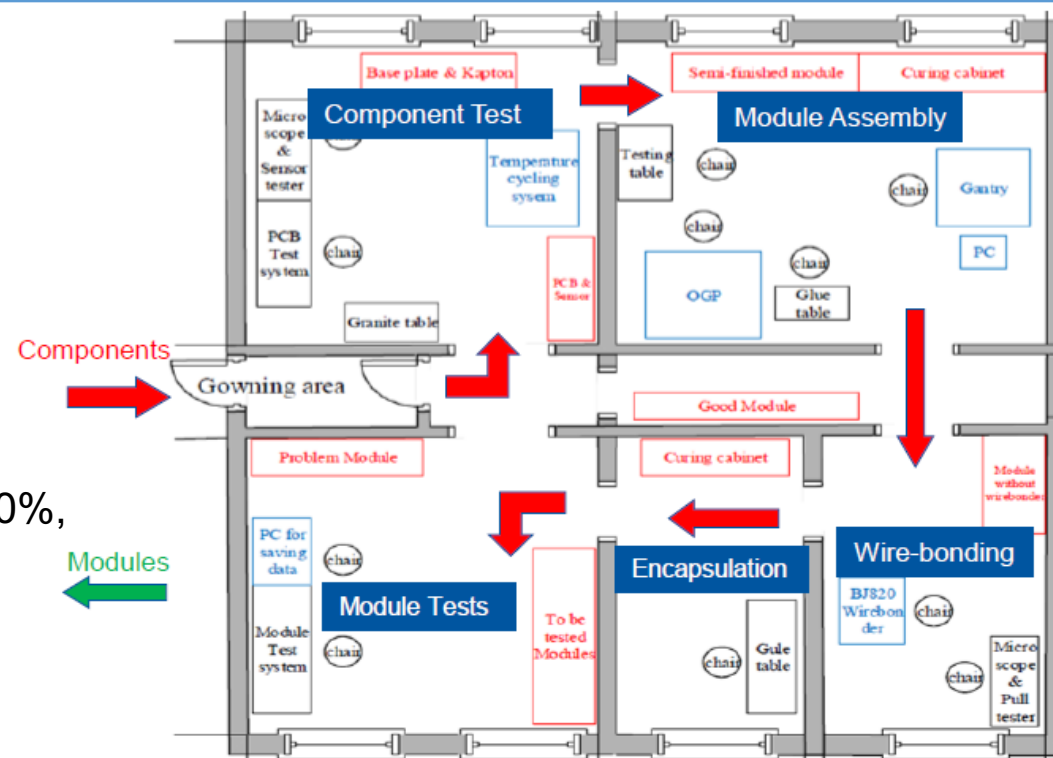


Stacking



Tiling

- HGCAL: ~26000 silicon modules
 - Module assembly chain established
- Module Assembly Center(MAC)
 - 6 MACs world wide: 3 in Asia, 3 in US
 - Each MAC expected to assembly ~5000 silicon module
 - MAC-Beijing: a dedicated silicon lab on IHEP campus
- MAC at IHEP
 - 140m² Clean room: temperature $21 \pm 1^\circ\text{C}$, humidity: $45 \pm 10\%$, Monitoring of particle level: better than Class 1000



Components
testing

Module Assembly
by Gentry

Wire-bonding

Module
Encapsulation

Module testing

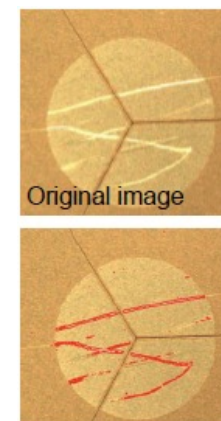
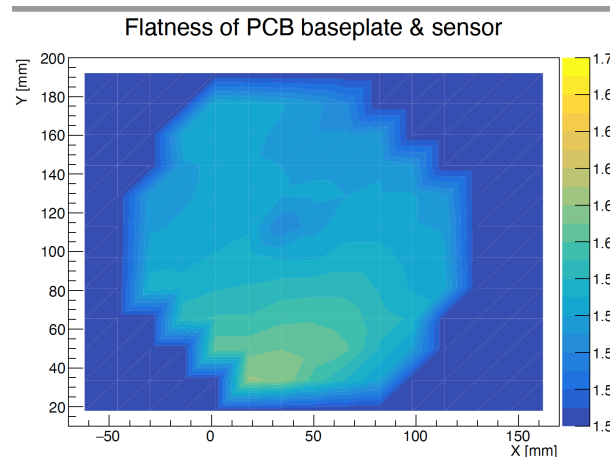
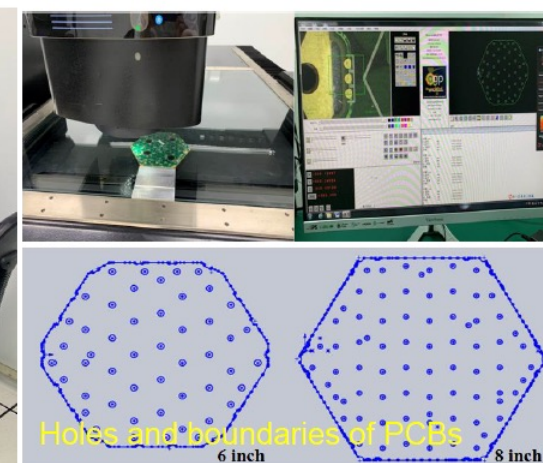
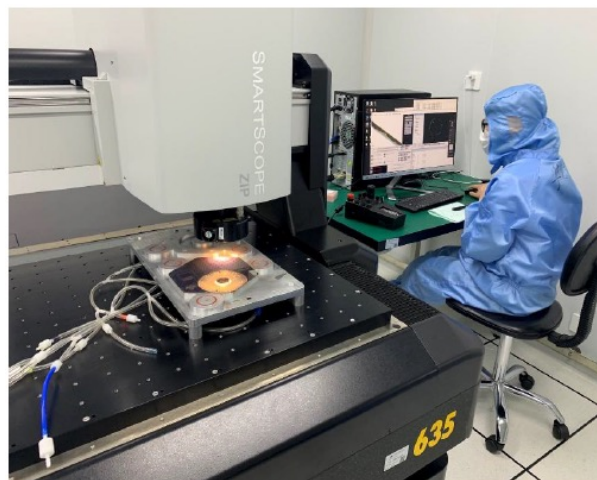
➤ PCB testing: Optical gauging product(OGP)

- Extensive measurements performed for baseplates, PCBs: size, boundaries, thickness, flatness
- Visual inspection boosted by machine learning: identify and categorize scratches on silicon sensors

- Thickness tolerance of sensor on PCB < 40 μ m
- Thickness tolerance of module < 125 μ m
- Standard tolerance: 250 μ m
- **Flatness meeting the requirement**

Hex-sensor

- Delta_x ~ 24 μ m
- Delta_y ~ 45 μ m
- **Center-to-center tolerance: 50 μ m**



	X(mm)	Y(mm)
Baseplate	40.34447	104.39552
	40.35422	104.41038
Sensor	40.35995	104.36856
	40.36047	104.37022
Hexaboard	40.33810	104.41023
	40.33637	104.41361

Component
testing



Module Assembly
by Gentry



Wire-bonding



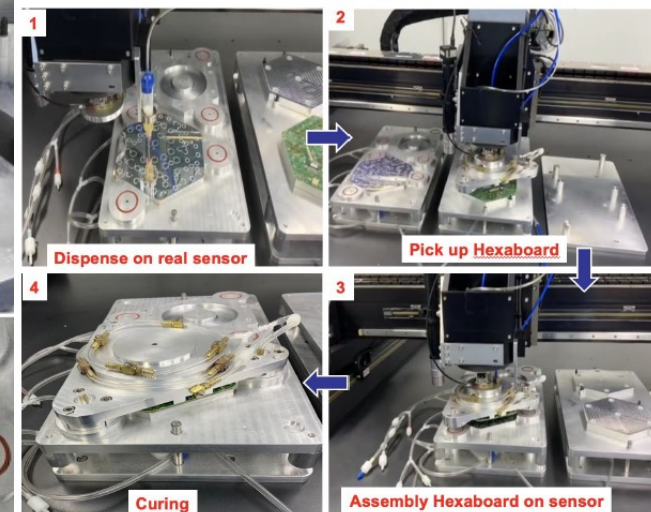
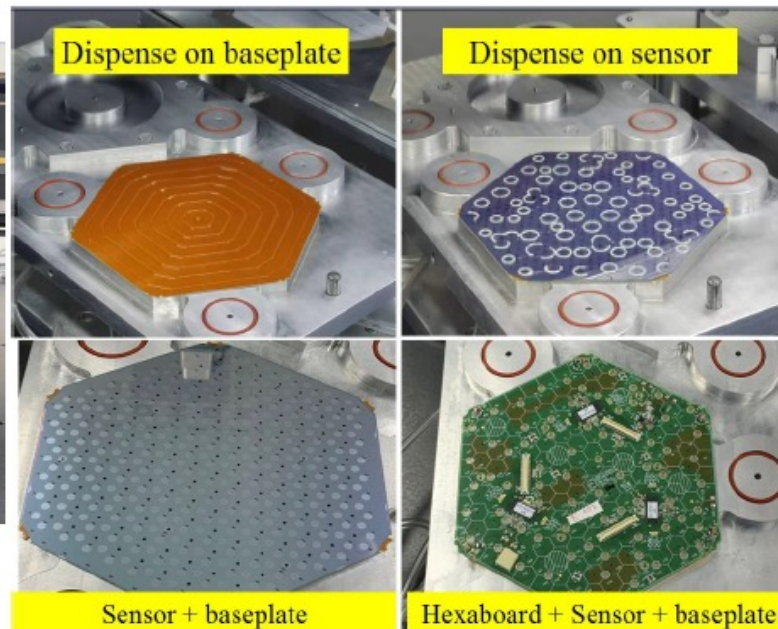
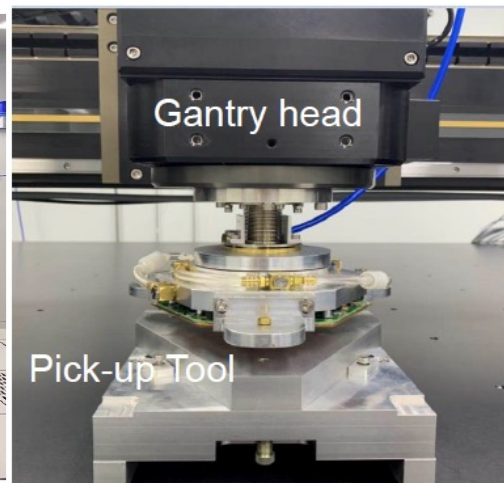
Module
Encapsulation



Module testing

➤ Module assembly: with the main gantry and tooling (camera, gantry head, fixtures, etc.)

- Precision pick-and-place movements with components, fine glue dispensing
- Automated operations with dedicated software



Component
testing



Module Assembly
by Gentry



Wire-bonding



Module
Encapsulation



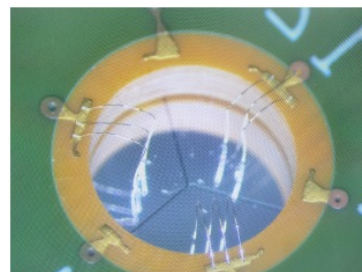
Module testing

➤ Wire-bonding: to build electrical connections between silicon sensors and PCB

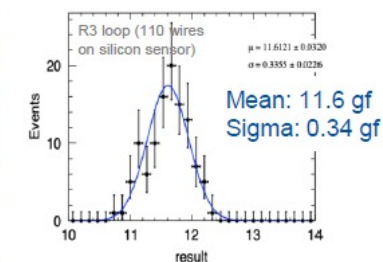
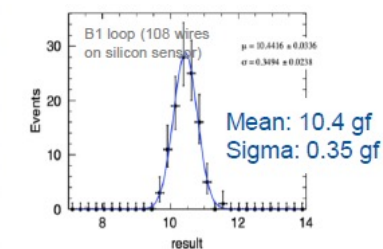
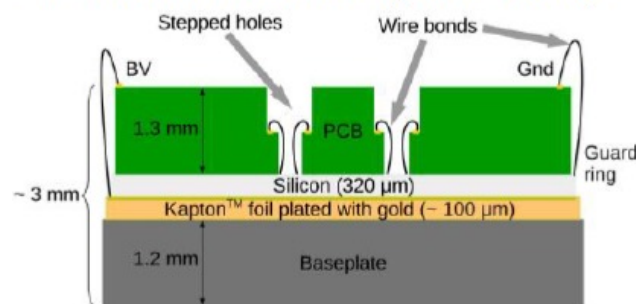
- Exercises with dummy sensors and PCBs and optimize bonding parameters
- Applied optimized parameters for the assembly 8-inch real modules

➤ Wire-bonding quality (by pull tester): wire-bonds can fulfill the strength requirement

- Destructive pull test: measure the strength of bonding wires and feet
- Non-destructive test: to extract the correction factor to be applied for destructive pull tests
- Wire-bond in a triangle form (max. 5gf strength set)



Schematics of wire-bondings
of silicon modules (side view)



Key procedure in module assembly: Encapsulation



Component
testing



Module Assembly
by Gentry



Wire-bonding



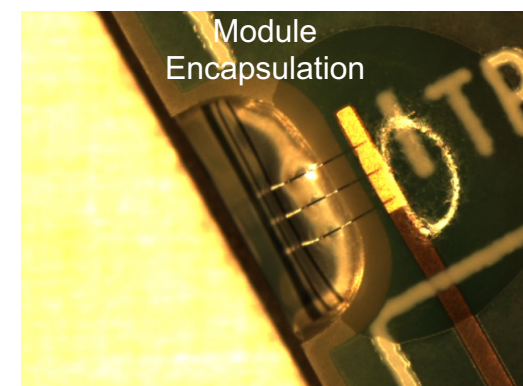
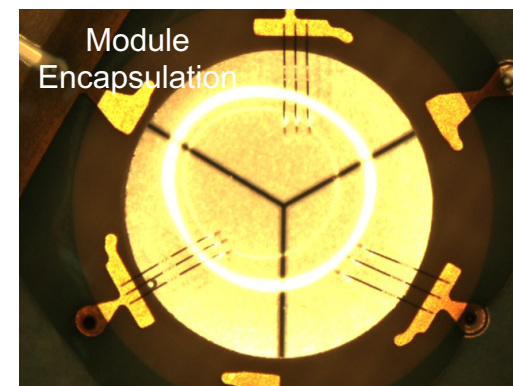
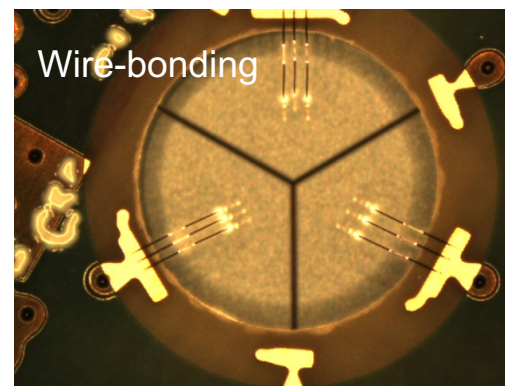
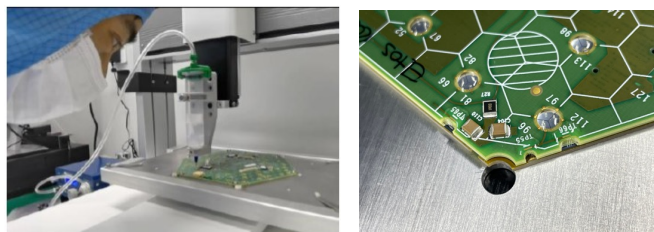
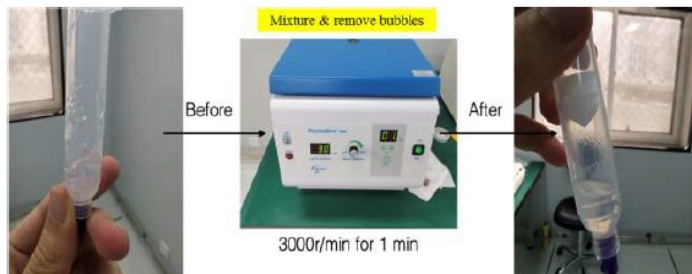
Module
Encapsulation



Module testing

➤ Mini-gantry system: dispense glue to encapsulate the wire-bonds for better mechanical stability

- Mini-gantry: to dispense glue points into the stepped holes of PCBs, exercises with mock-ups
- Centrifuge: to remove bubbles in 2-component glue mixture



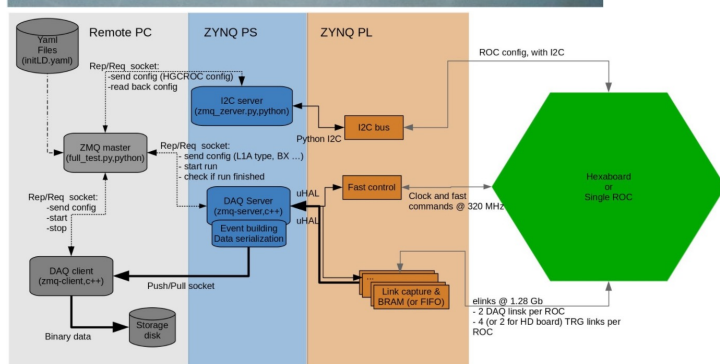
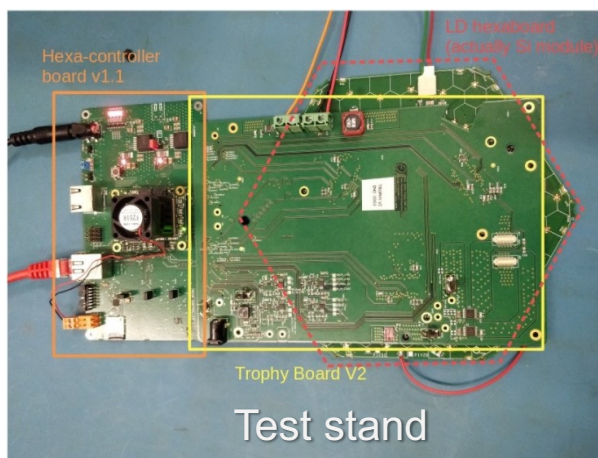
Component
testing

Module Assembly
by Gentry

Wire-bonding

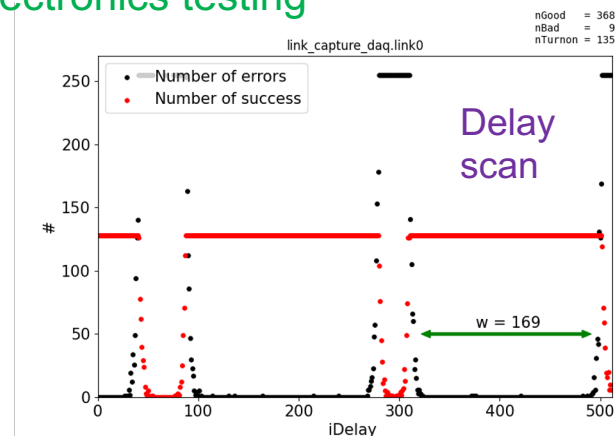
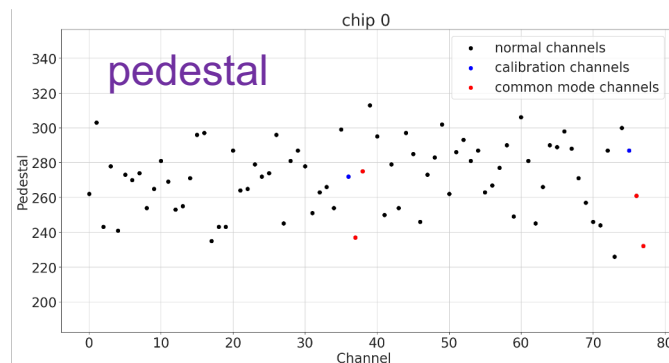
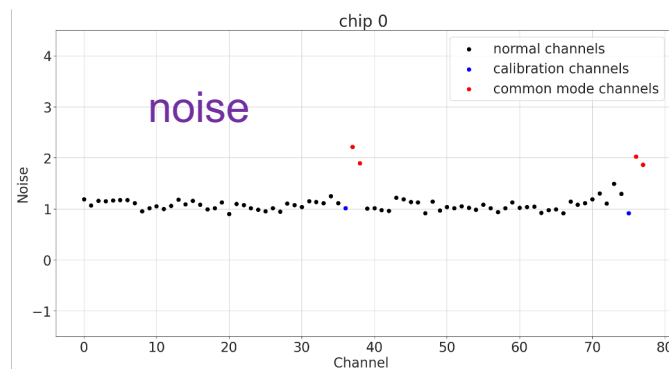
Module
Encapsulation

Module testing



DAQ system diagram

Hex-aboard Electronics testing



- Low noise for hex-aboard
- Good pedestal for hex-aboard

Component
testing



Module Assembly
by Gentry



Wire-bonding

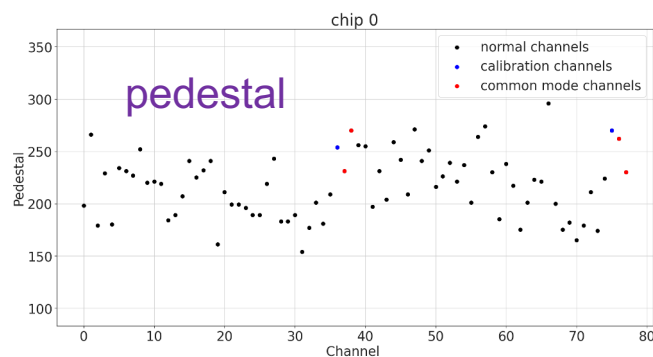
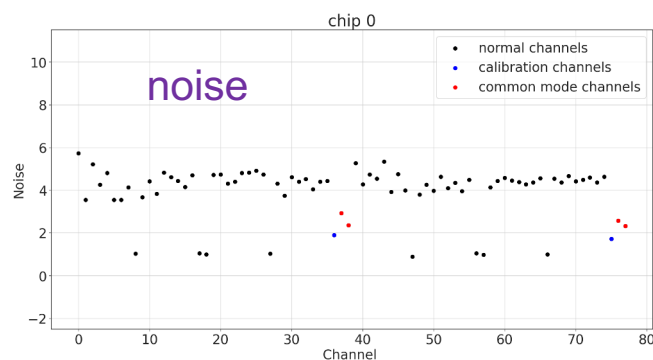


Module
Encapsulation

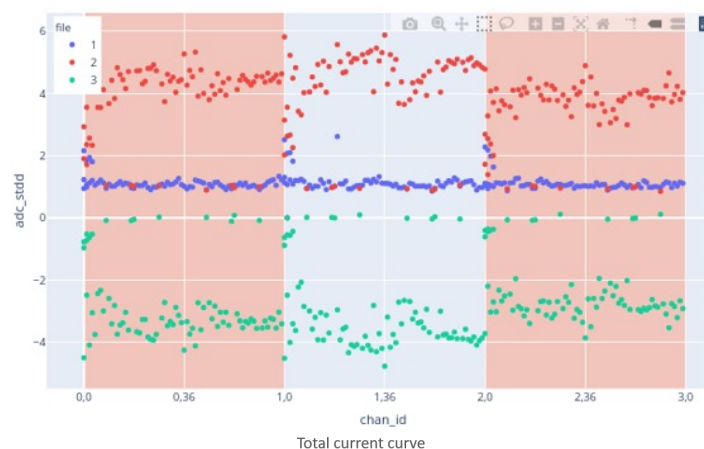


Module testing

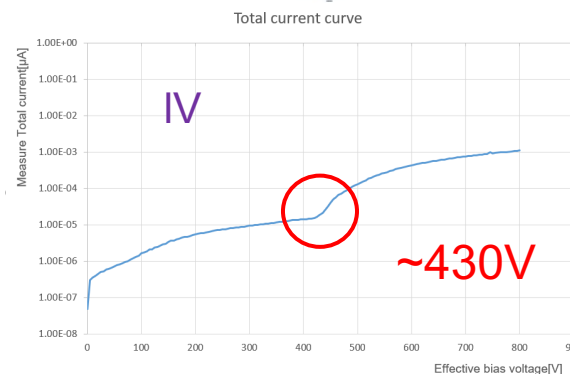
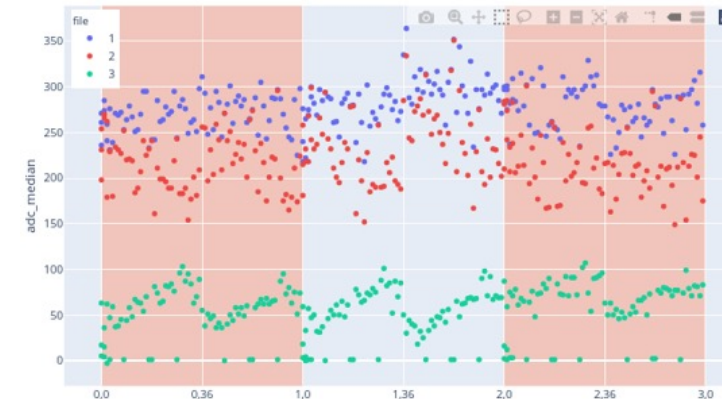
Module Electronics testing



Noise before/after assembly

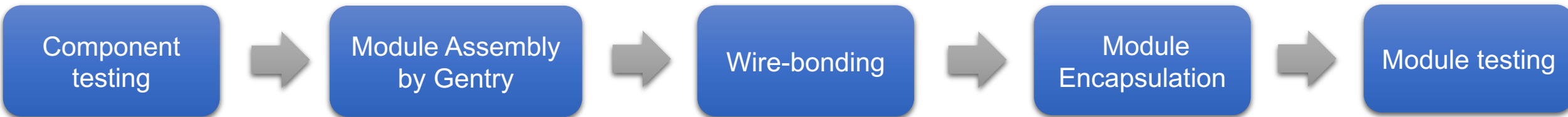


Pedestal before/after assembly



- Low noise before/after assembly
- Good pedestal before/after assembly
- Good IV for the Module

- Infrastructure established: 140m² clean room, key equipment, test stands, services
- Have the ability to do full chain module assembly and electronics testing in IHEP MAC



- Next step
 - Update our software for the new LD-V3 hexa-boards assembly
 - Update our device for the new LD-V3 hexa-boards testing

Thank you for your time !