HGCal Module Assembly and QA/ QC

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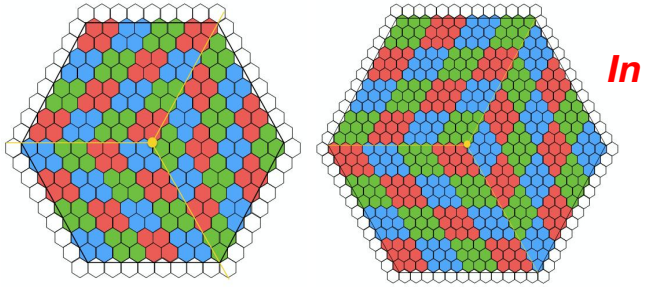
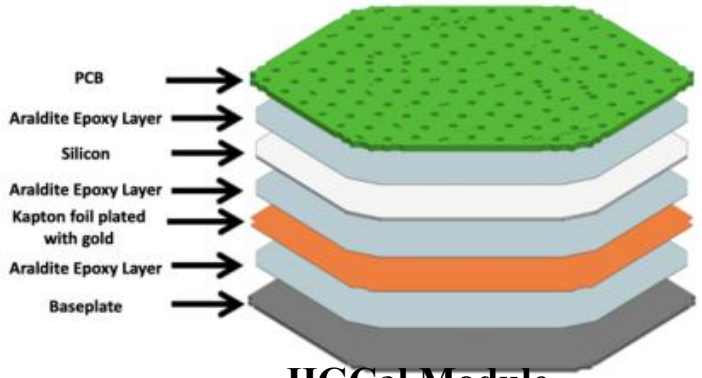
Introduction

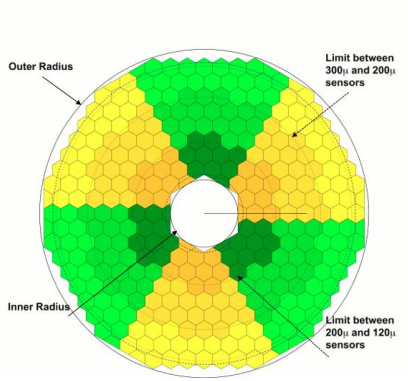
- HGCal (High Granularity Calorimeter) is a major upgrade for HL-LHC
- 1st silicon calorimeter
  - Higher radiation region: 620m² of silicon sensors (31000 Si modules)
  - Lesser radiation region: 370m² of scintillators
  - 6M Si channels, 0.5 or 1.1 cm² cell size



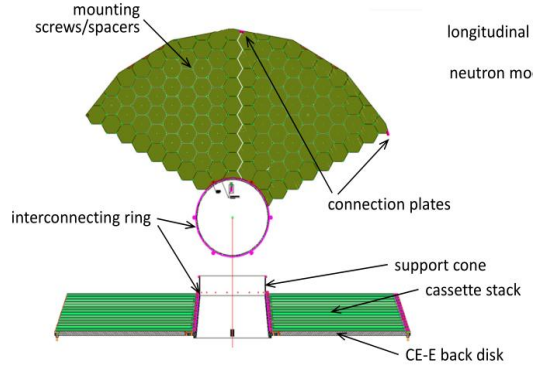
In IHEP lab



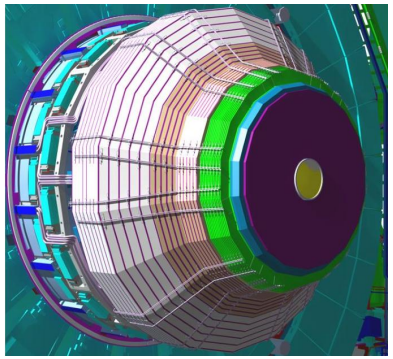
HGCal Module



Tiling



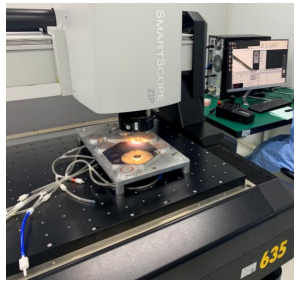
Stacking



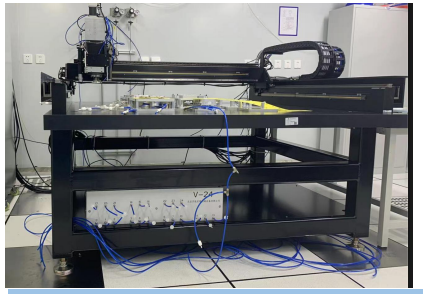
Endcap calorimeter

Introduction

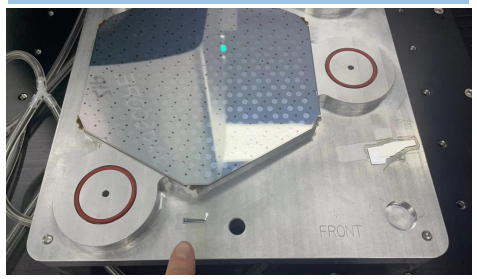
- IHEP lab perform assembly to HGCal modules
  - Module assembly processes on gantry
  - Wire bonding & encapsulation
- QA& QC tests
  - Module assembly quality control, photo taking
  - Noise test
  - QA/ QC test results will be uploaded to data base

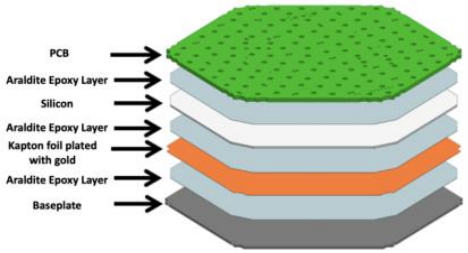


QA/ QC test for Hexa-board, Sensor &Base plate



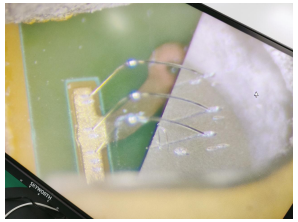
Module assembly on gantry



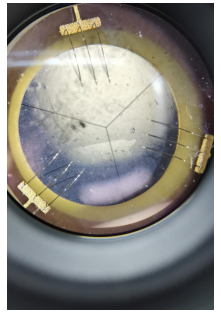


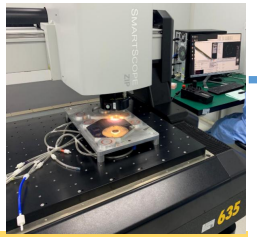
QA/ QC test for Module assembly accuracy, bonding and Encapsulation

Wire bonding



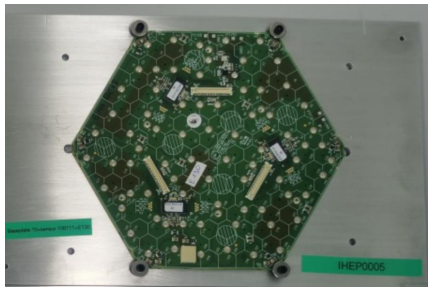
Encapsulation





Data Base

HGCal module



WorkFlow of QA/ QC

QA before Assembly

Baseplate:
OGP measurements& comparison to nominal

Sensor:
Visual inspection (OGP) for damage

Hexaboard:
OGP measurements& comparison to nominal
Electronics Test

Assembly on Gantry

QC after Gluing Sensor on Baseplate

Baseplate+ Sensor(Protomodule):
OGP measurements& comparison to nominal
(X, Y placement offset; rotation offset; average thickness...)
Visual inspection(OGP) for glue spillage

Assembly on Gantry

QC after Gluing Hexaborad on Protomodule

Hexaboard+ Protomodule:
OGP measurements
(X, Y placement offset; rotation offset; average thickness...)
Visual inspection(OGP) for glue spillage

Wire Bonding

QC after Wire bonding

HGCal module + both sides bonding wire:
Visual Inspection(OGP) of wirebonds
Pull Tests for frontside bonding

Encapsulation

QC after Encapsulation

HGCal module + both sides bonding wire:
Visual Inspection(OGP) of encapsulation

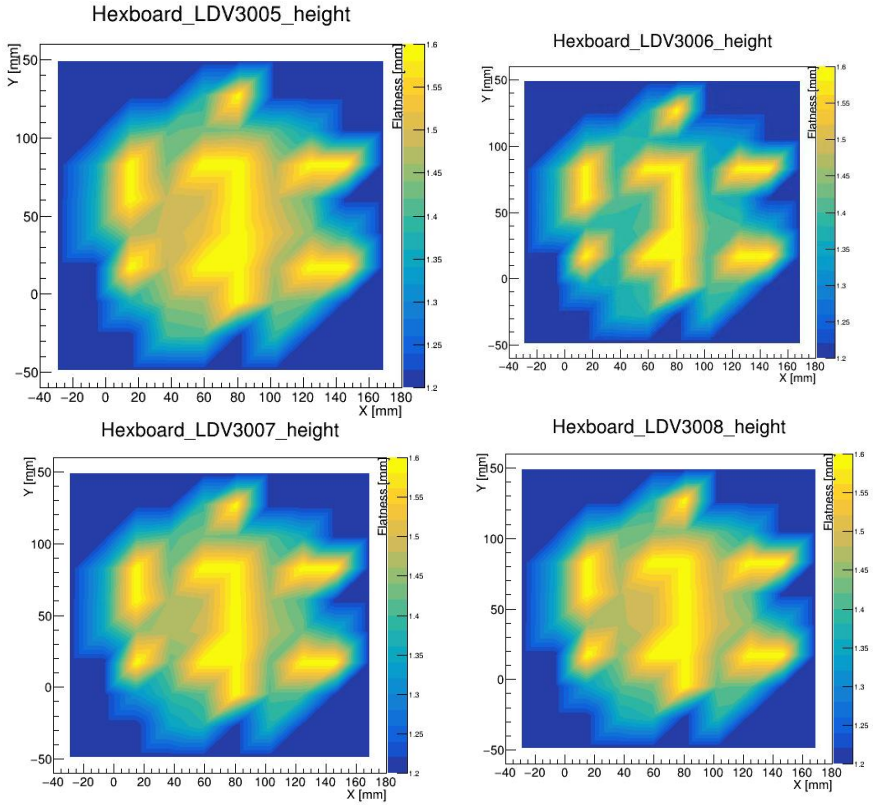
Encapsulation & curing

QC after Module Encapsulation& Curing

HGCal module:
Visual Inspection(OGP) of encapsulated module
Electrical Test of the final module
IV Curves
Single Module Test Stand

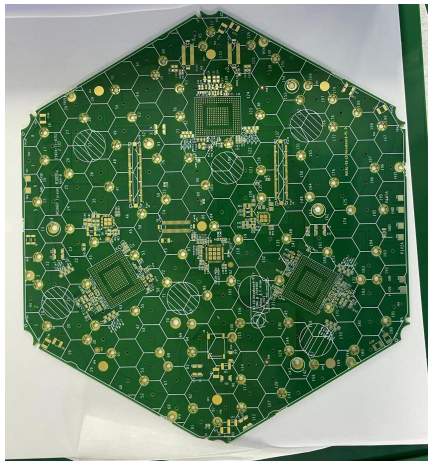
QA Test before Assembly

- **Perform QA/ QC test to Hexa-board, Sensor and base plate on OGP**
  - **Measure flatness, thickness and width of hexa-borads, baseplates and sensors**
  - **Sort sensors by quality**
- **All component passed the test**
  - **Thickness tolerance meets the requirement**
  - **Ready to be assembled**

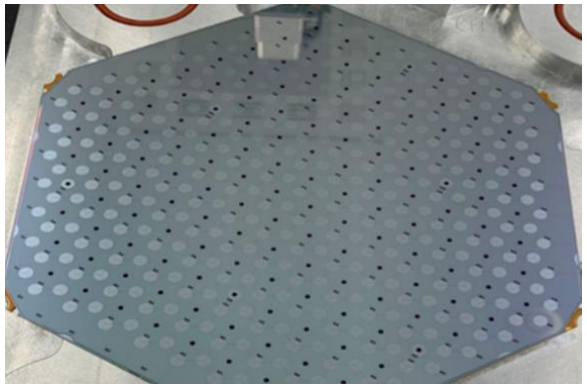


Flatness measurement of 4 hexaboards on 12 Oct 22

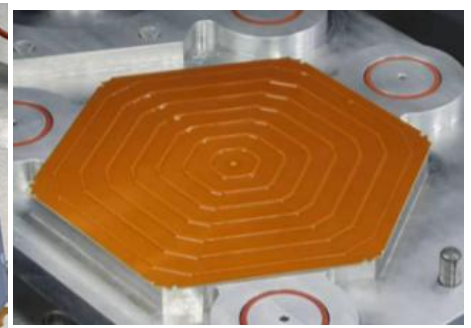
Hexaboard v3



silicon sensor



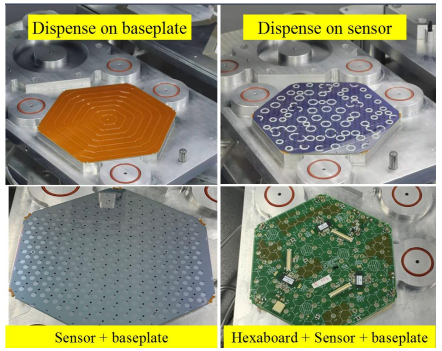
PCB base plate

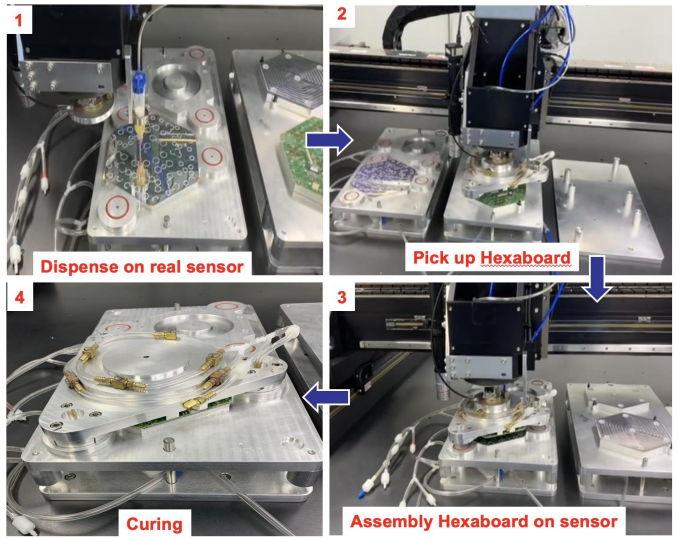


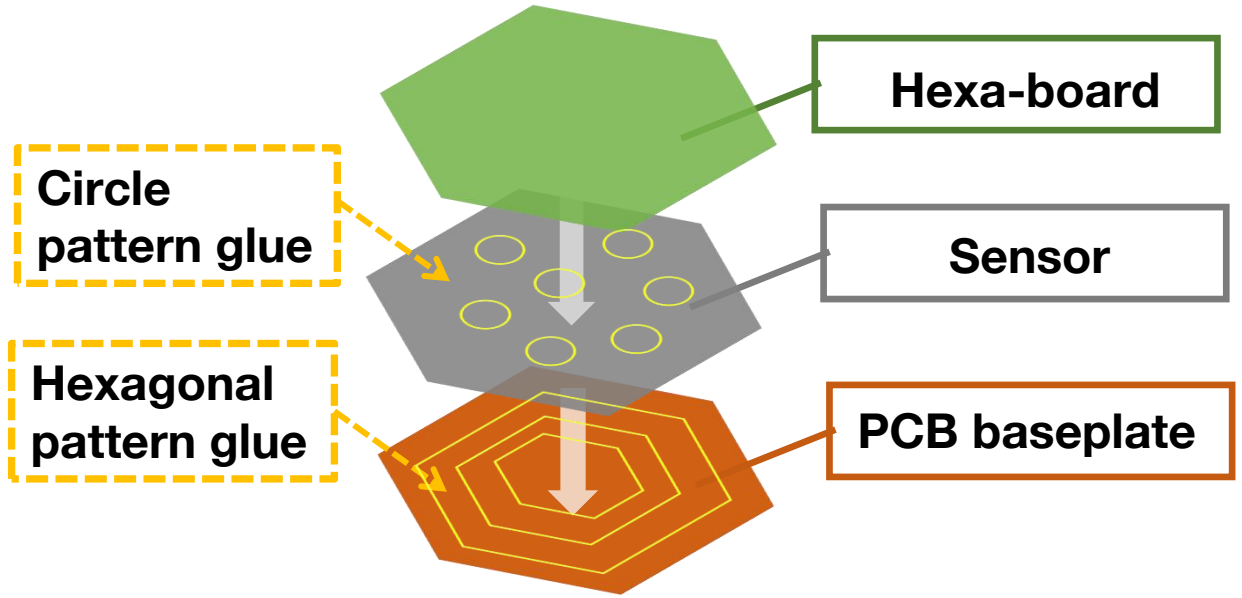
Shaowei Song, Xiao Zhao & Di Wang

Module Assembly on Gantry

- **HGCal low density module has 3 layers: baseplate, sensor and hexa-board**
  - **Mount sensor on PCB baseplate first, then mount hexa-board**
  - **3 layers are glued together**
    - **glue patterns are designed based on geometry**



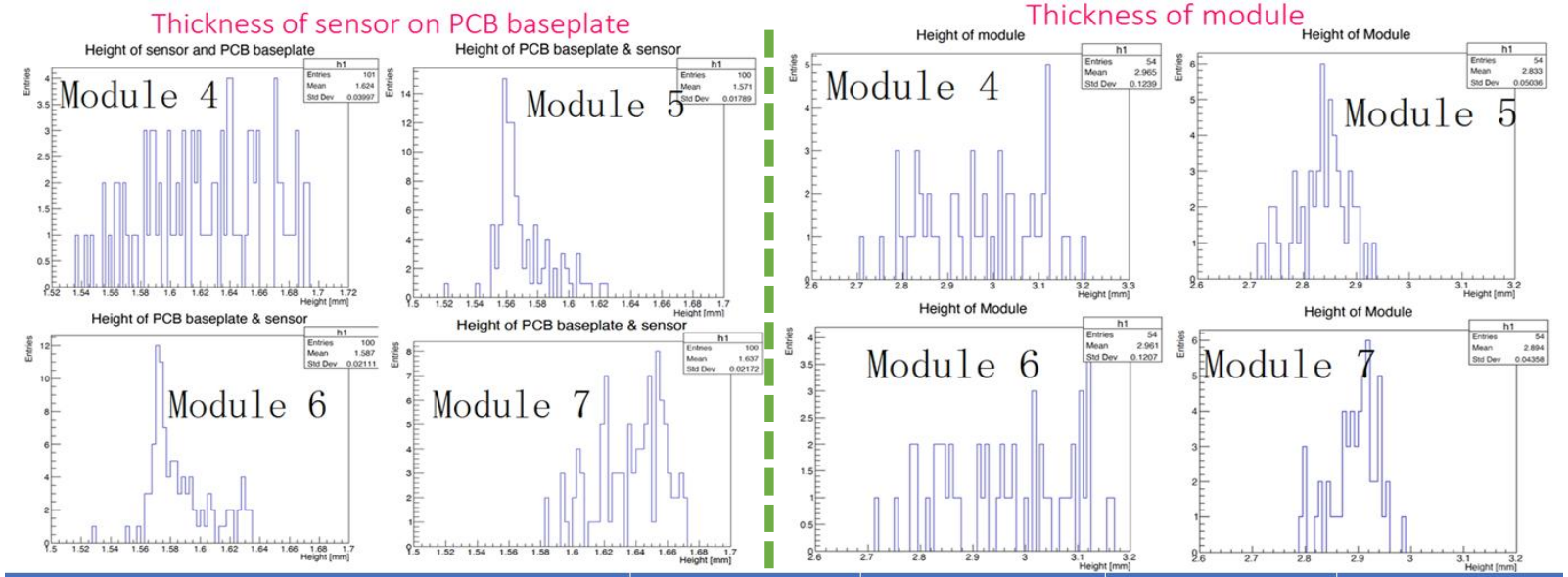




Feng Wang, Shaowei Song, Zhenxuan Zhang & Di Wang

Module Assembly Accuracy

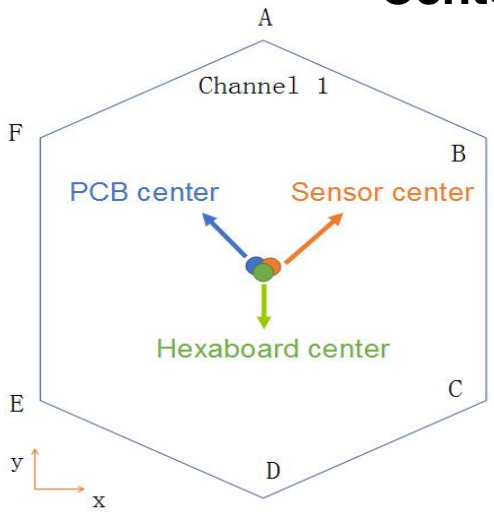
- **Thickness tolerance meets requirements for all modules**
  - **QC procedures are followed in whole module assembly process**
  - **Standard tolerance: 250μm**
  - **Thickness tolerance of sensor on PCB < 40 μm**
  - **Thickness tolerance of module (hexa-board+sensor+PCB) < 125 μm**

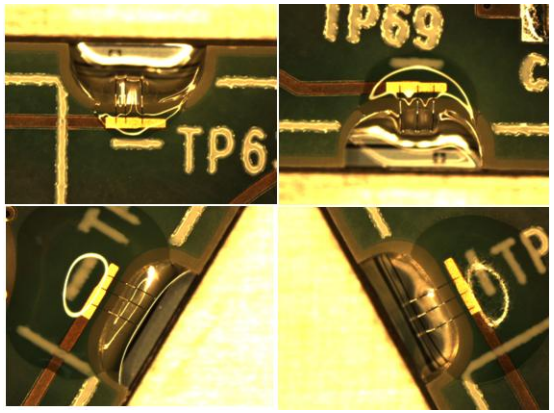


mm	Module 004	Module 005	Module 006	Module 007
Glue thickness (pcb baseplate-sensor)	0.051	0.029	0.032	0.075
Glue thickness (sensor-hexaboard)	0.141	0.77	0.161	0.164
Thickness (pcb baseplate+sensor)	1.624	1.571	1.587	1.637
Module thickness (pcb baseplate+sensor+hexaboard)	2.965	2.833	2.961	2.894

Module Assembly Accuracy

- **Assembly accuracy meet requirement for all modules**
  - **Center-to-center & edge-to-edge accuracy are measured**
  - **Each edge of sensor is inside PCB baseplate**
  - **Standard tolerance: No bigger than 100 μm**
  - **Center-to-center tolerance around 50μm**

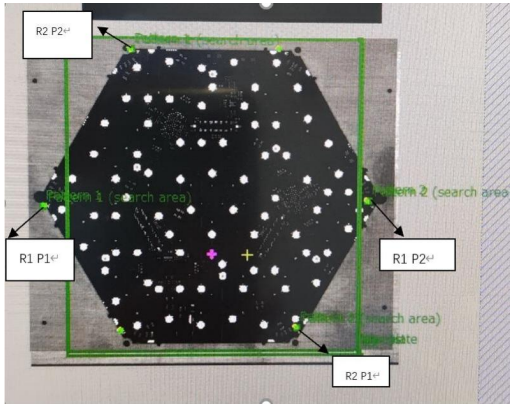


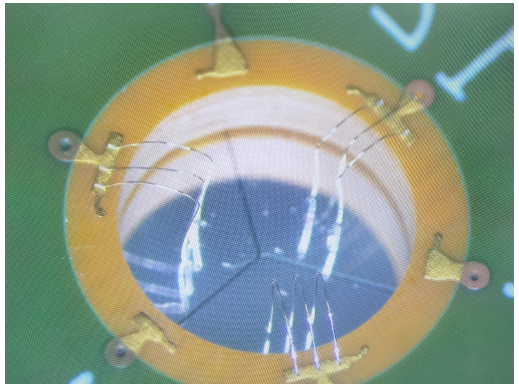


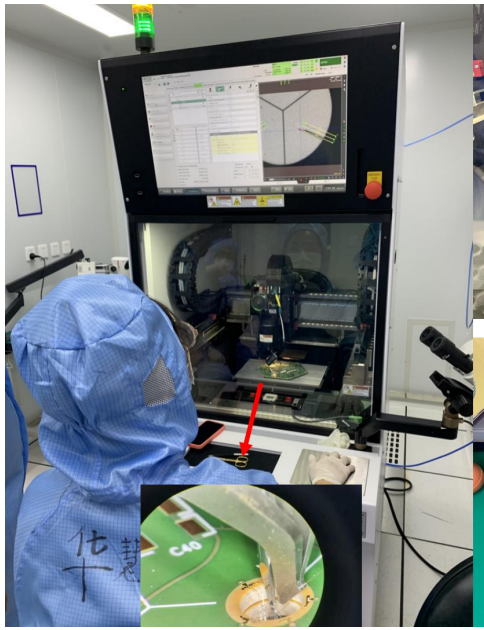
μm	Module 004	Module 005	Module 006	Module 007
Assembly accuracy of center-to-center				
Δx (pcb baseplate-sensor)	16	53	48	31
Δy (pcb baseplate-sensor)	25	14	19	9
Δx (hexaboard-sensor)	24	44	66	52
Δy (hexaboard-sensor)	45	12	17	12
Δx (hexaboard-pcb baseplate)	8	12	25	21
Δy (hexaboard-pcb baseplate)	19	42	16	20
Assembly accuracy of edge-to-edge (pcb baseplate - sensor)				
ΔAB	187	162	160	364
ΔBC	162	137	139	367
ΔCD	135	158	167	394
ΔDE	151	202	202	417
ΔEF	197	240	229	417
ΔFA	213	215	212	413

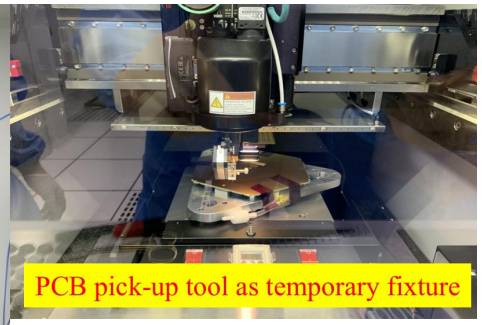
Wire Bonding

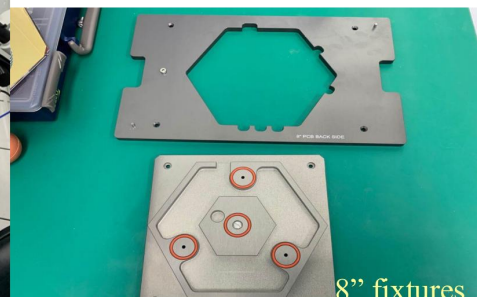
- **Wire bonding is automatically done for back side and front side at each bonding point**
  - **Uninterrupted wire bonding for 200- 400 points**
  - **Pull test for the bonding wires**
    - $\mu > 8g$, $\sigma < 1g$
  - **QA/ QC test by OGP after bonding**
    - **All modules passed the performance test**

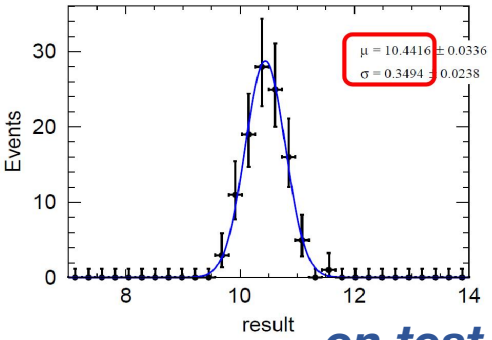


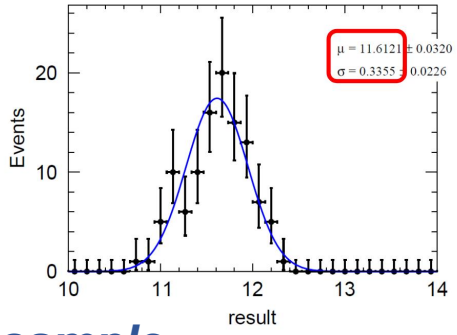




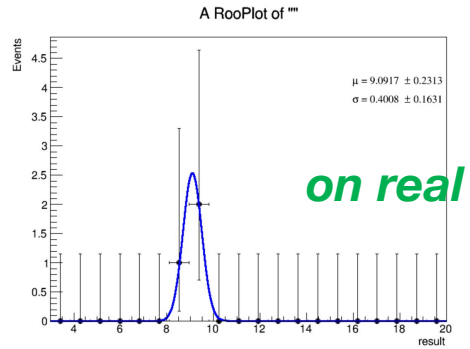








PCB, 114 wires ***on test sample*** Sensor, 110 wires

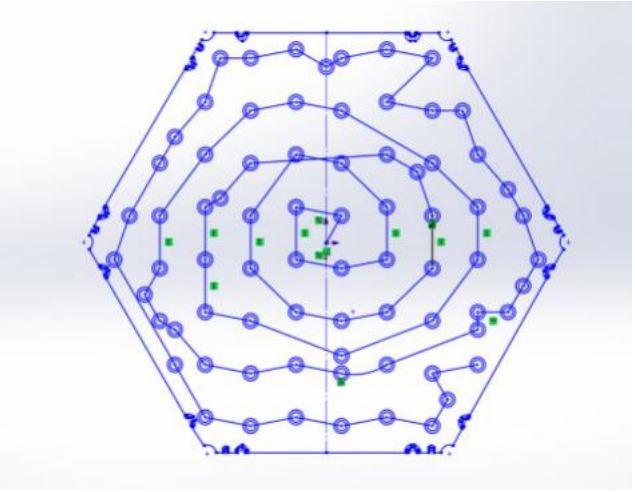


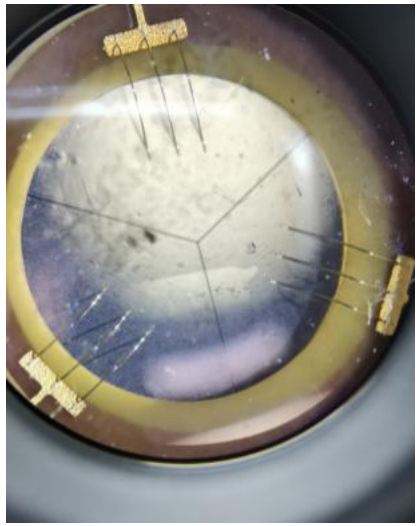
on real module

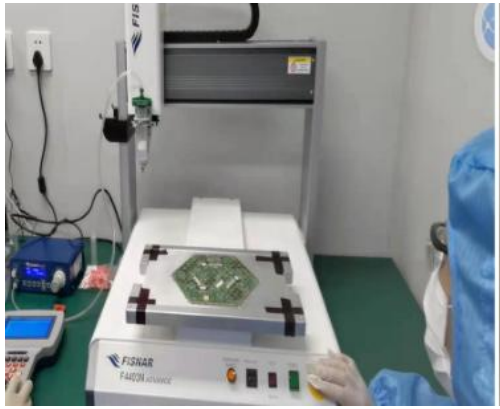
Y.Gu, X.Hou, H.Hua, J.Tao, C.Wang, Ch.Wang

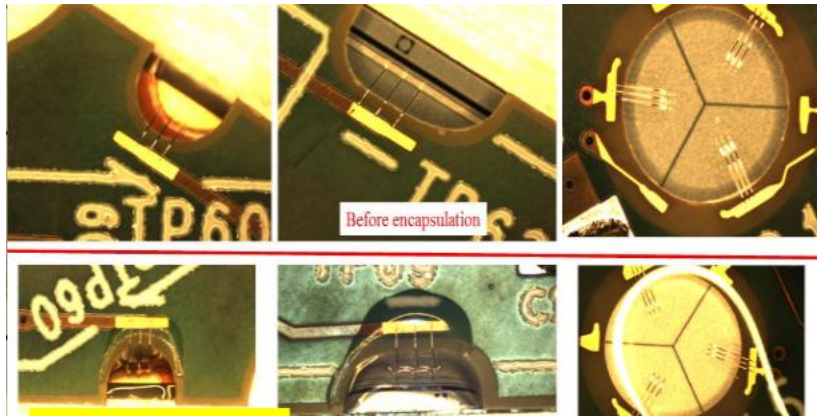
Encapsulation

- **Each bonding point is encapsulated automatically with mini-gantry**
  - **Mostly no bubbles found in bonding points**
  - **All bonding wires are covered by glue**
  - **QA/ QC test by OGP after Encapsulation**





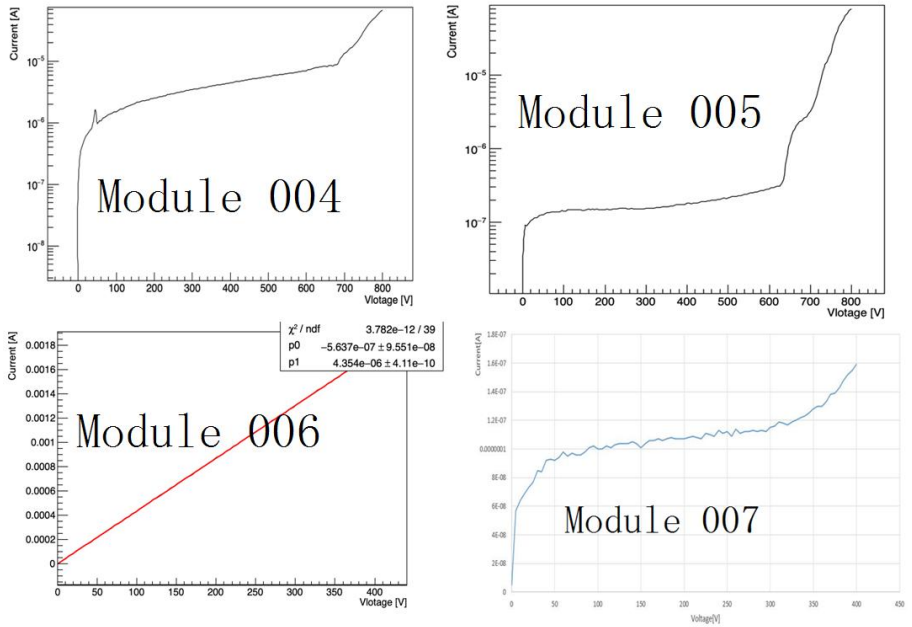


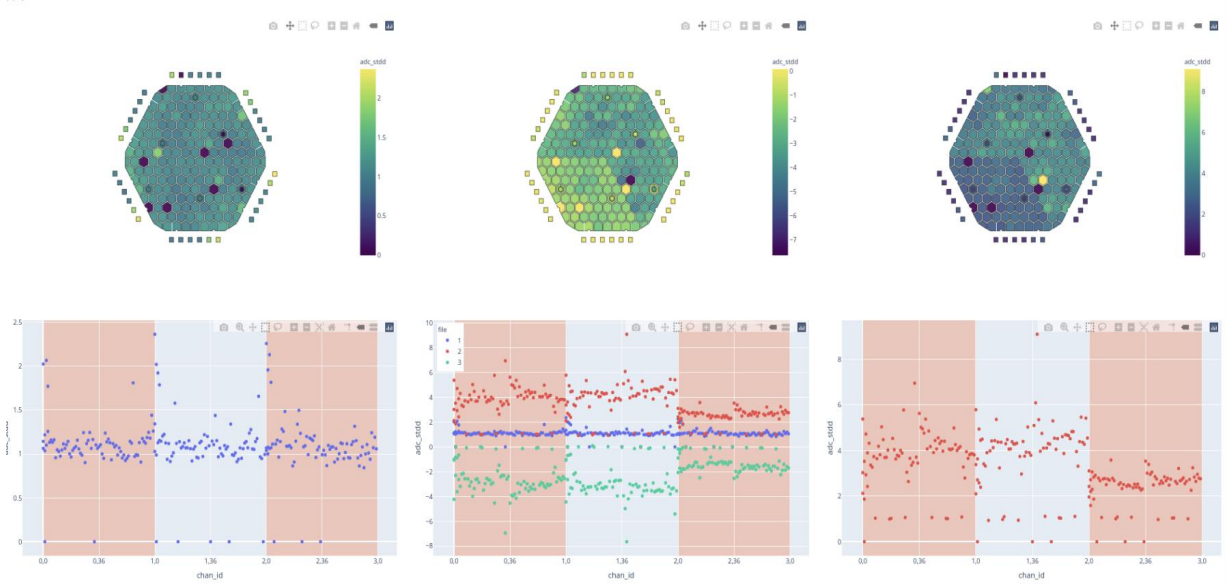


Jialin Guo, Zhengchen Liang

Module Test

- **4 Modules I-V tests have done in 2022**
- **Noise after assembly is about 3-6 ADC for each module**
  - **All channels work well**
  - **Different behaviour of module 006: Discharge at around 600V, then become ohmic**
    - **Due to old guard ring design**
- **Assembly process is sucessful!**
- ***For more details please see Taozhe Yu's talk!***

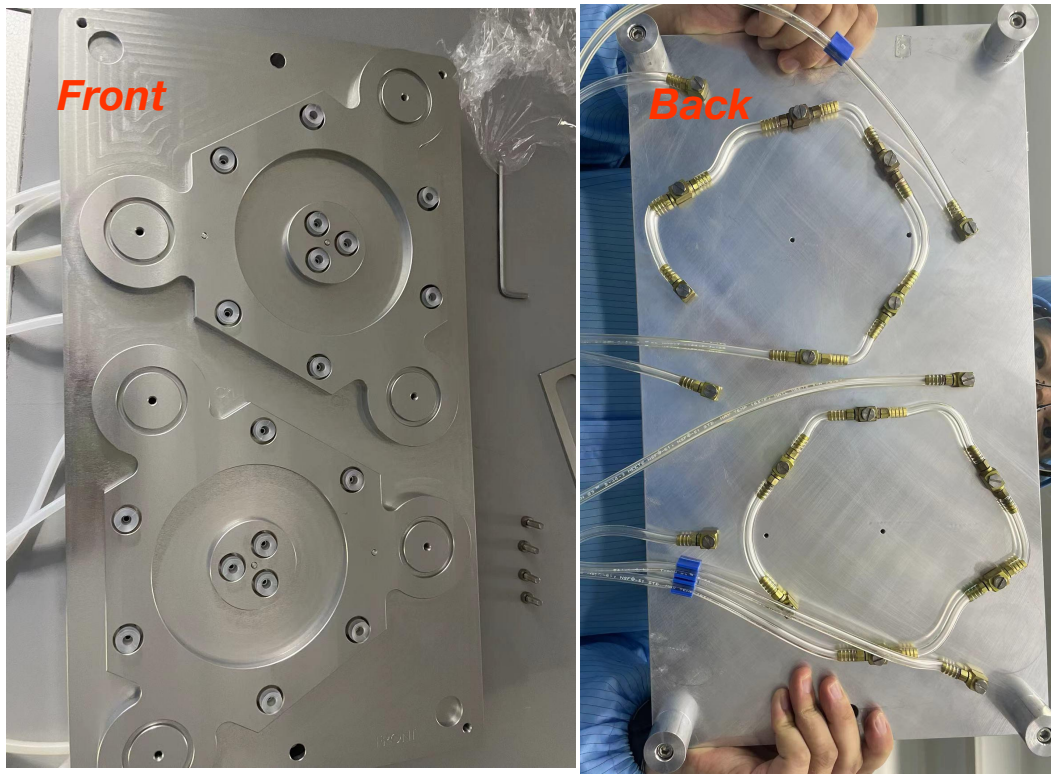




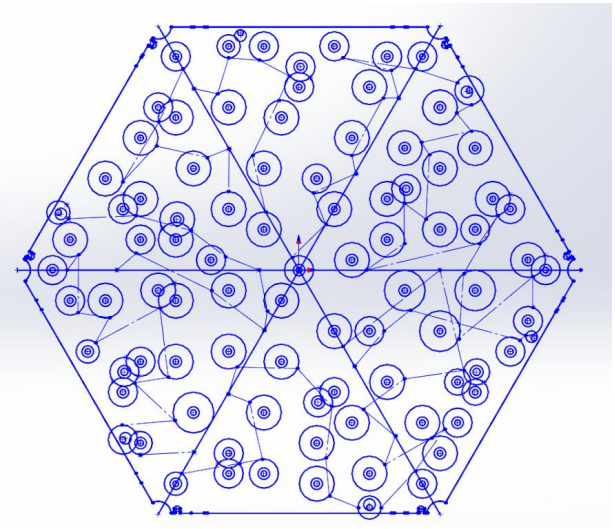
Taozhe Yu

Ready for the Coming Production

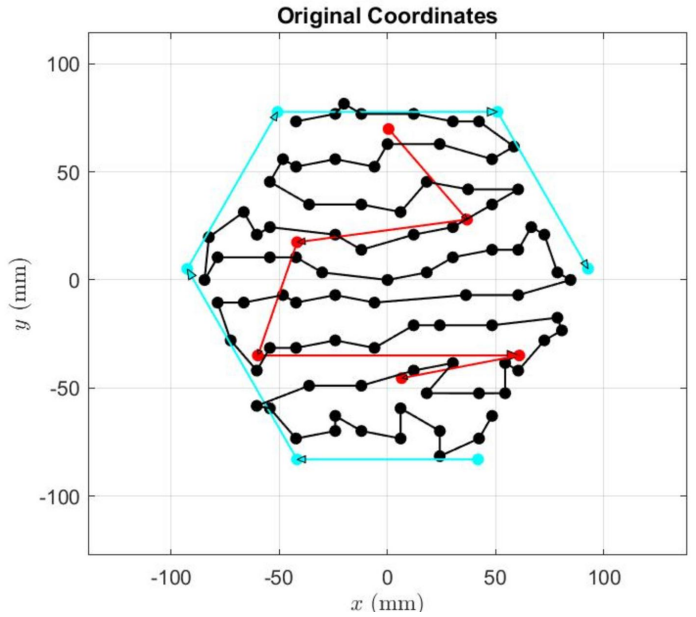
- **Update assembly tools to adopt new modules**
  - **Performed QA test on them with OGP**
- **Designed new glue patterns based on new bonding points**
  - **Impact into assembly code and tested on gantry**



New Assembly Tools



New glue pattern for assembly



New glue pattern for Encapsulation

HGCal Database

- **All QA/QC results will be uploaded to database**
  - **HGCal database has been installed to IHEP MAC**

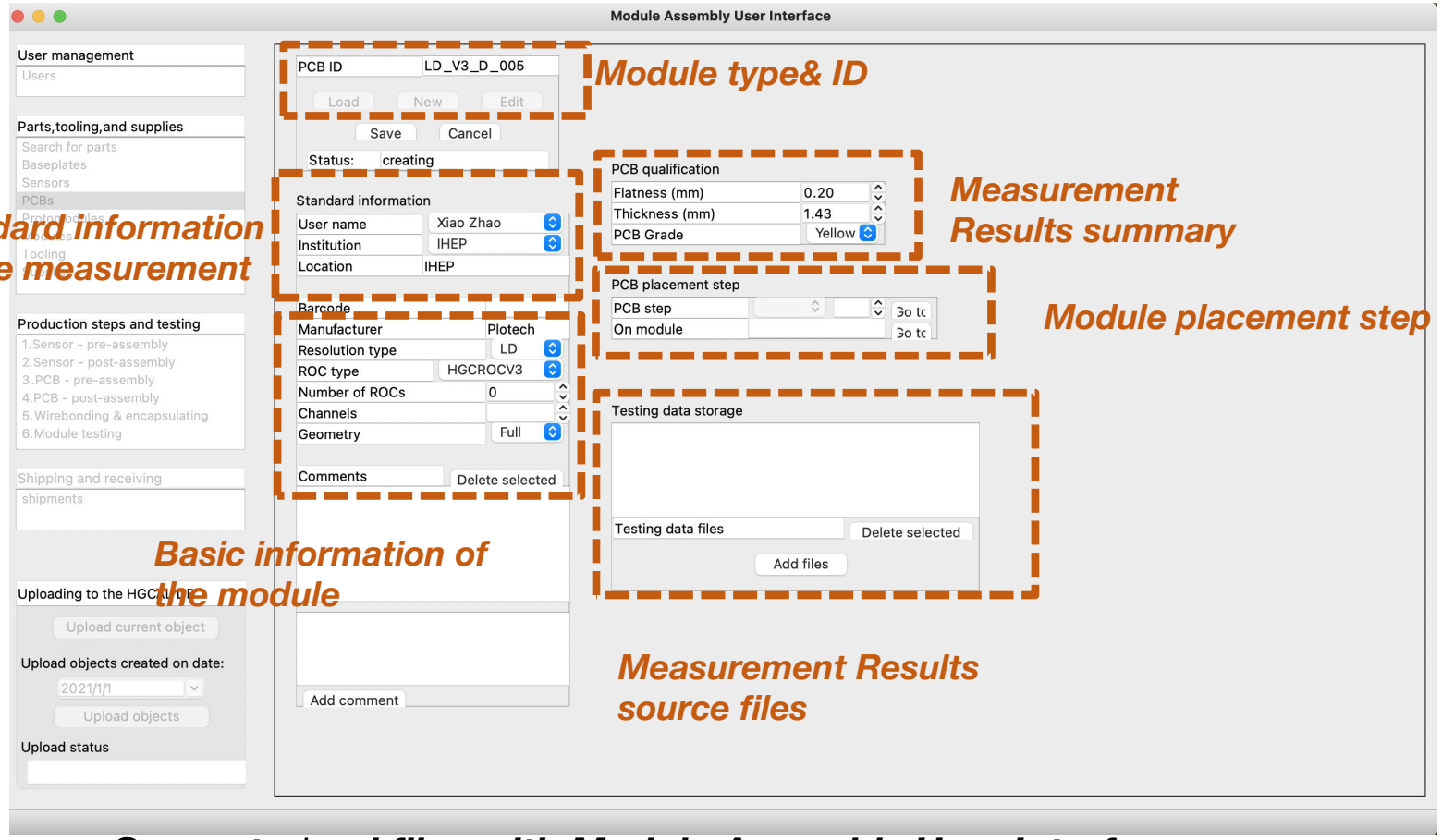
Measurement Results from OGP

↓

Upload to Module Assembly User Interface

↓ ****xml files***

Upload to INT2R Database Server

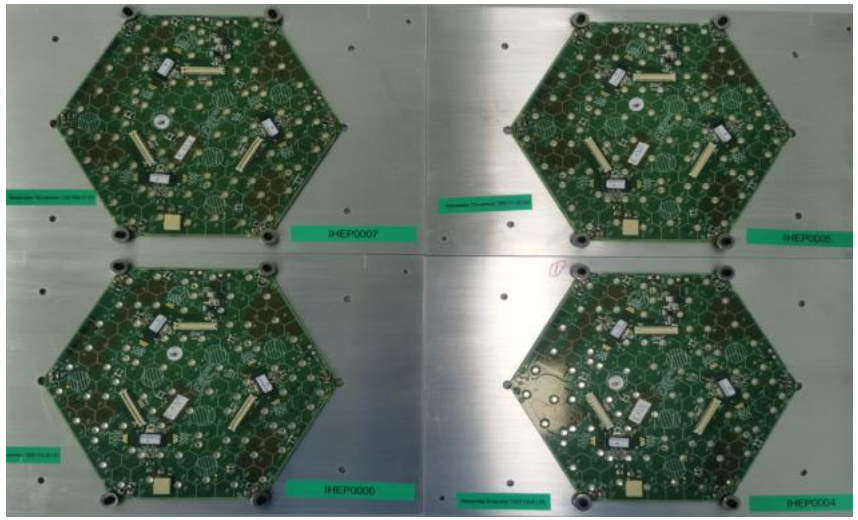


*Generate *xml files with Module Assembly User Interface*

Xiao Zhao

Summary & To-do List

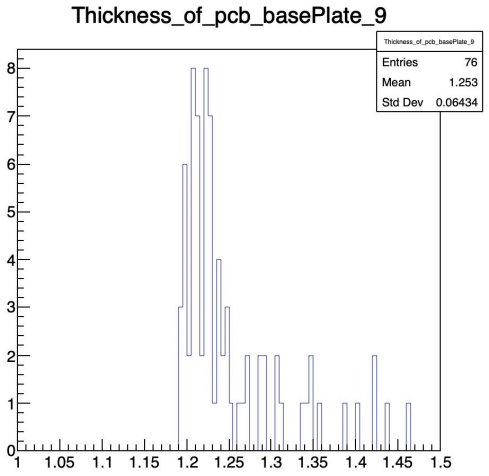
- **Summary**
  - **7 modules are successfully produced**
    - **4 modules produced in 2022 (delivered to Fermilab)**
    - **3 modules produced in 2021 (2 of them are sent to CERN for beam test, 1 is in IHEP)**
    - **QA/ QC test data are took for the modules**
  - **HGCal module assembly and QA/ QC processes are settled**
  - **Installed HGCal database**
  - **Upgrade assembly tools& glue pattern design for mass production**
- **To-do list**
  - **Upgrade Labview software for gantry**
  - **Optimize production & QA/QC process**
  - **Productivity goal: 24 modules per day**

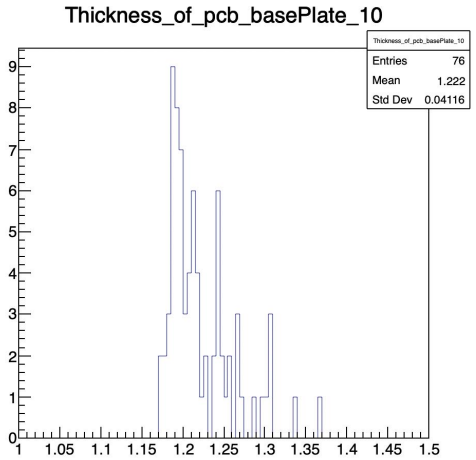


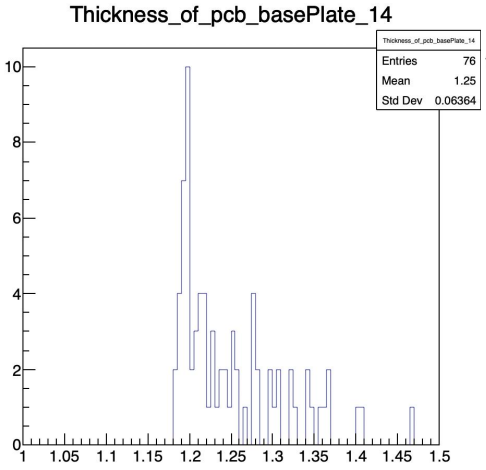
Thanks!

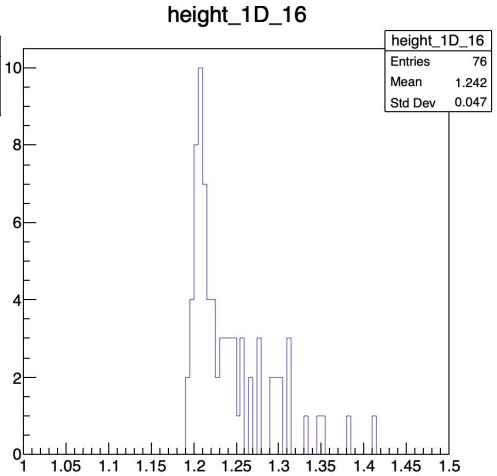
Backup

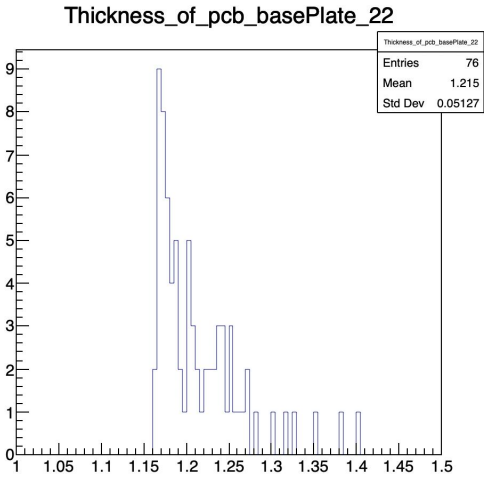
Thickness and Flatness of PCB Baseplate

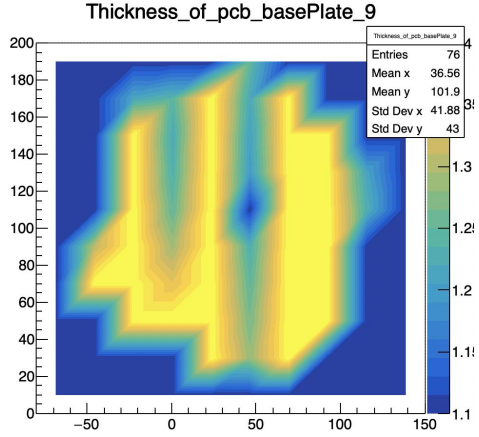


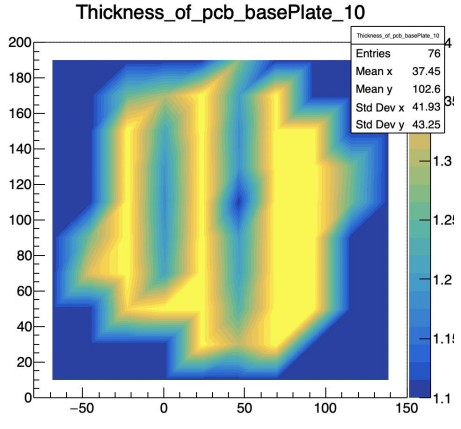


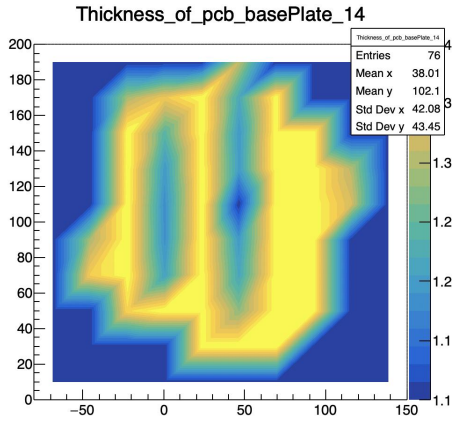


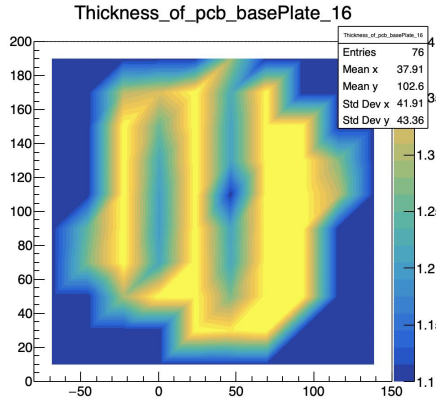


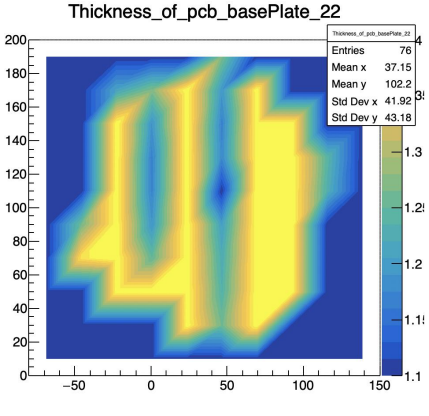




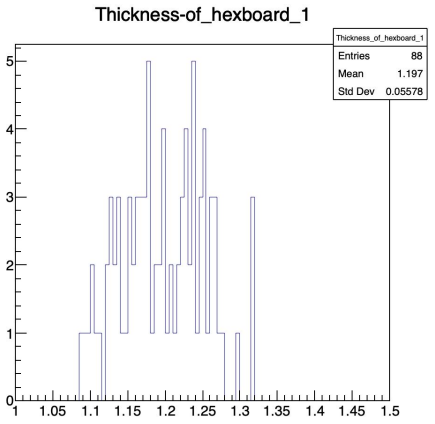


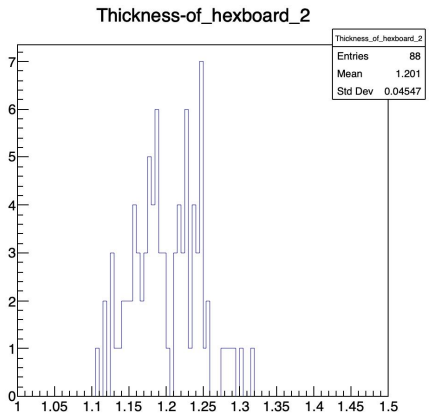


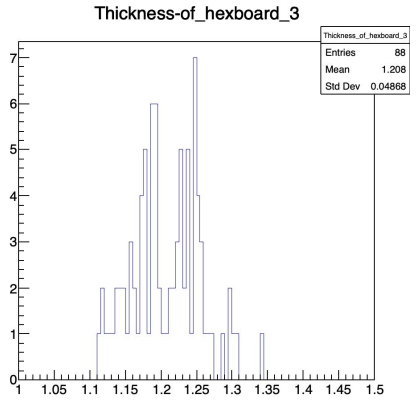


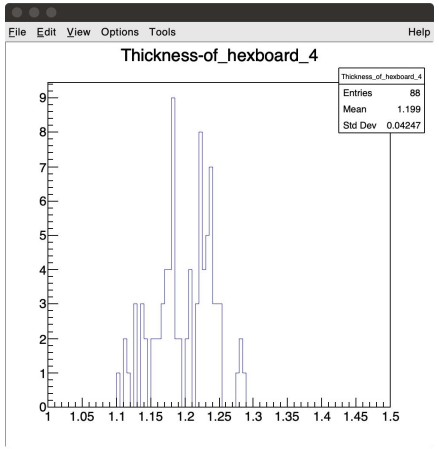


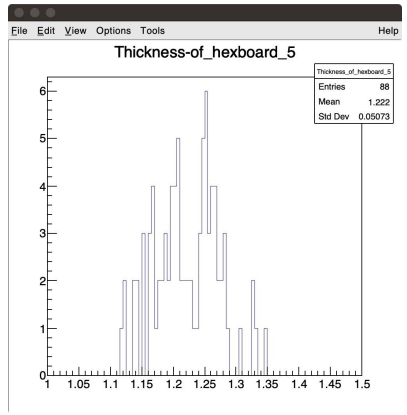
Thickness and Flatness of Hexa-board

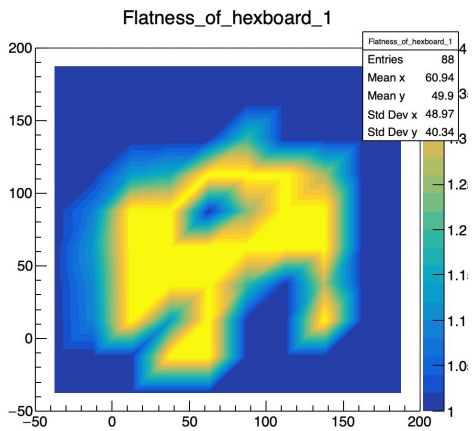


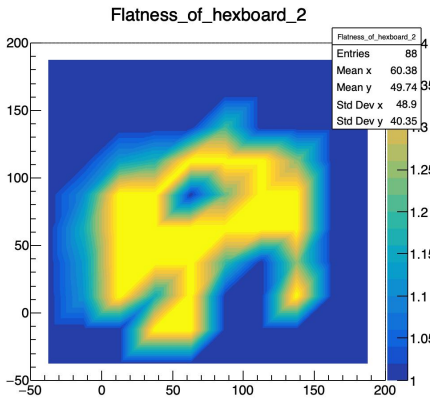


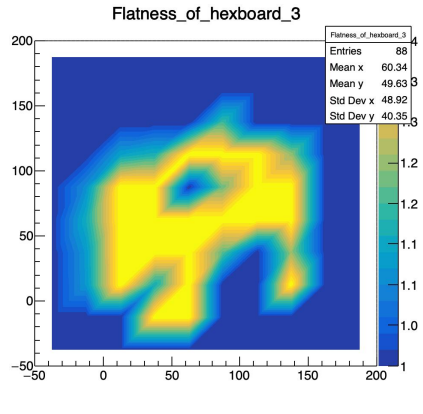


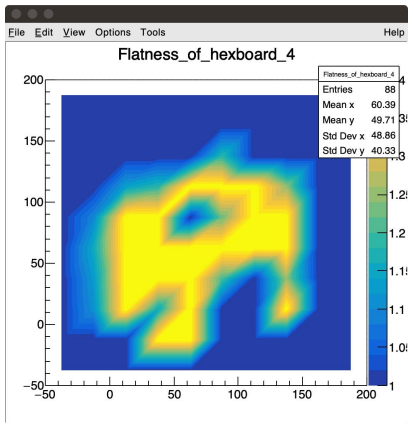


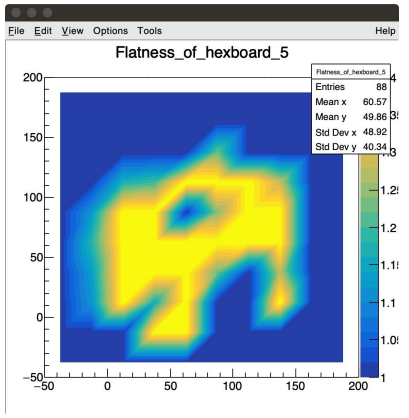








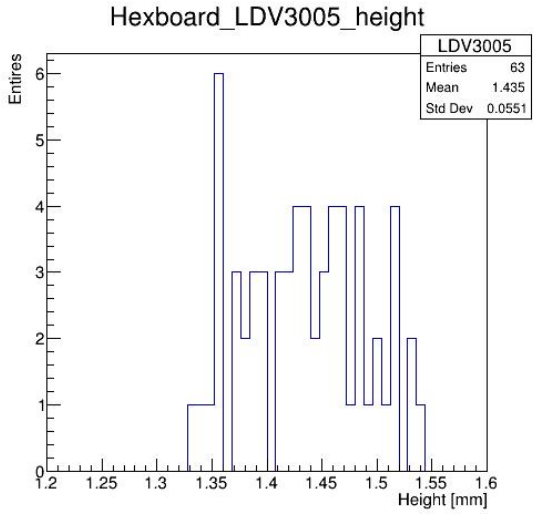




Thickness and Flatness of PCB Baseplate

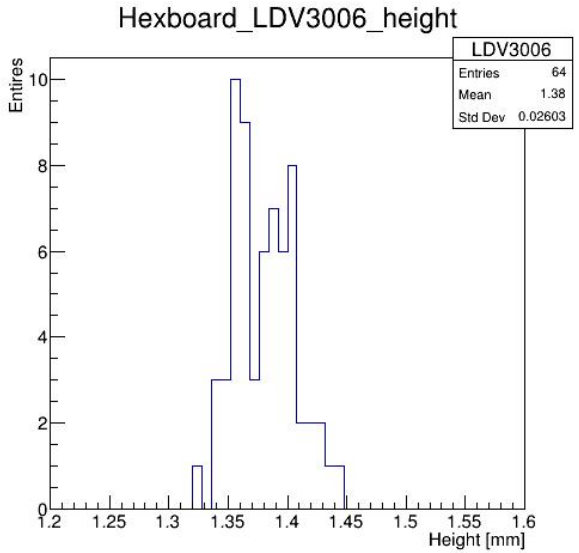
Flatness: 201um

名称	单位	公称值	实测值	公差
宽度	mm	+166.79370	+166.83060	+000.03690
宽度	mm	+166.79370	+166.81523	+000.02153
宽度	mm	+166.79370	+166.85016	+000.05646
宽度	mm	+192.59600	+192.66613	+000.07013
宽度	mm	+192.59600	+192.58167	-000.01433
宽度	mm	+192.59600	+192.67444	+000.07844



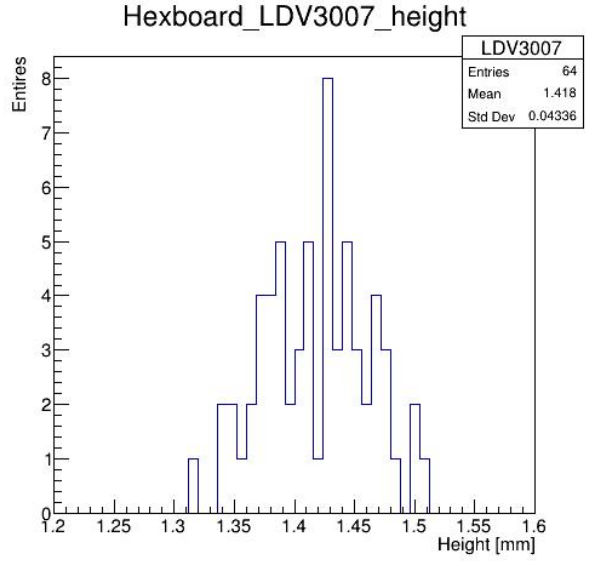
Flatness: 146um

名称	单位	公称值	实测值	公差
宽度	mm	+166.79370	+166.84358	+000.04988
宽度	mm	+166.79370	+166.81769	+000.02399
宽度	mm	+166.79370	+166.85760	+000.06390
宽度	mm	+192.59600	+192.67668	+000.08068
宽度	mm	+192.59600	+192.57648	-000.01952
宽度	mm	+192.59600	+192.69468	+000.09868



Flatness: 167um

名称	单位	公称值	实测值	公差
宽度	mm	+166.79370	+166.83025	+000.03655
宽度	mm	+166.79370	+166.80267	+000.00897
宽度	mm	+166.79370	+166.85843	+000.06473
宽度	mm	+192.59600	+192.64081	+000.04481
宽度	mm	+192.59600	+192.57653	-000.01947
宽度	mm	+192.59600	+192.69570	+000.09970



Flatness: 182um

名称	单位	公称值	实测值	公差
宽度	mm	+166.79370	+166.84309	+000.04939
宽度	mm	+166.79370	+166.81257	+000.01887
宽度	mm	+166.79370	+166.85522	+000.06152
宽度	mm	+192.59600	+192.65882	+000.06282
宽度	mm	+192.59600	+192.58058	-000.01542
宽度	mm	+192.59600	+192.69808	+000.10208