Automatic High-Granularity Timing Detector Module Assembly with Gantry System

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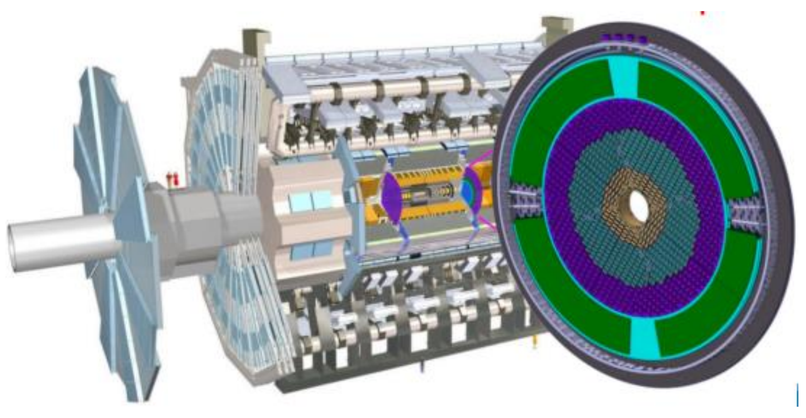
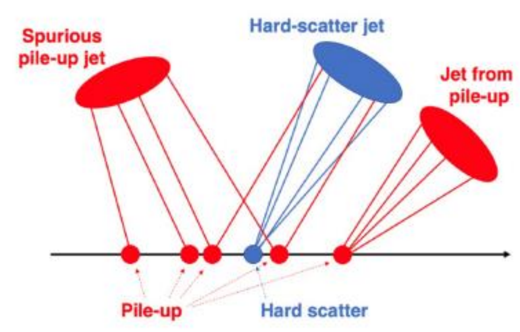
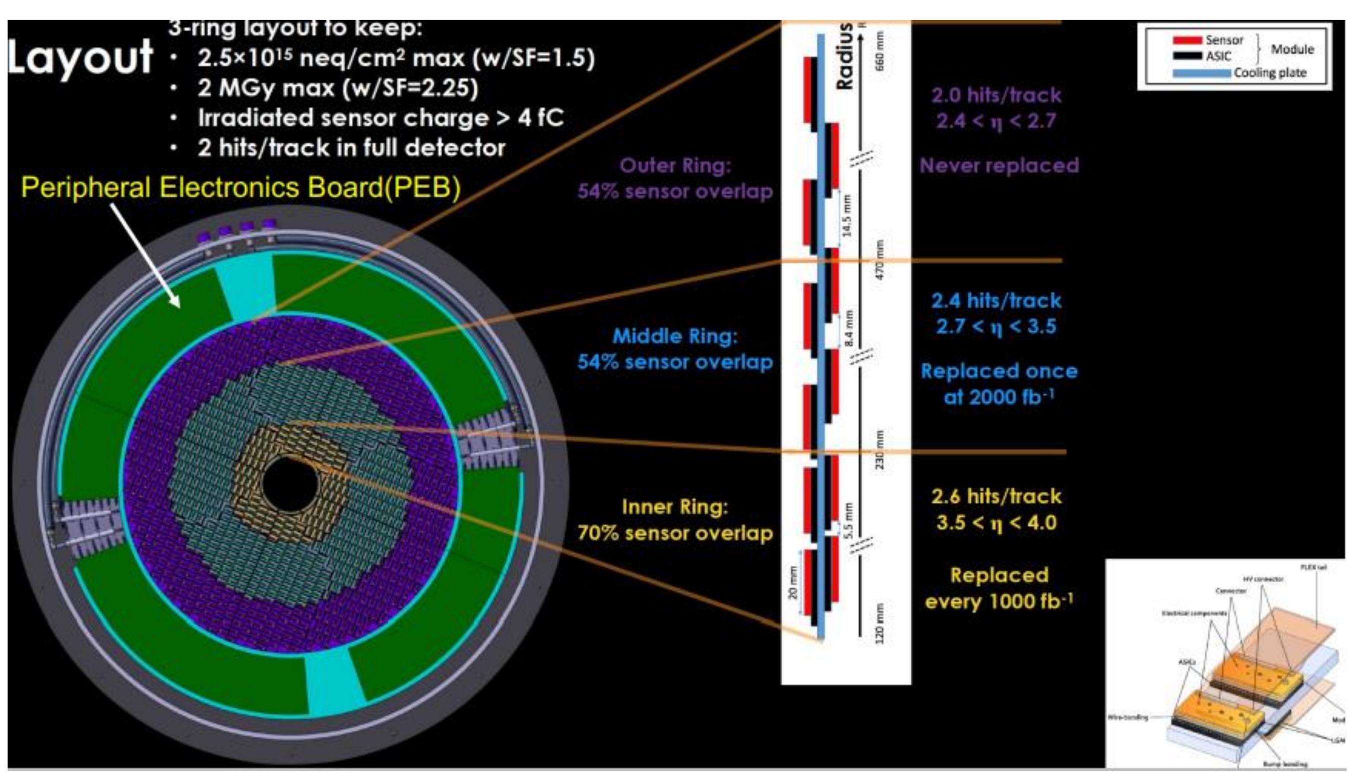
Introduction

High Granularity Timing Detector (HGTD)

- HGTD aim to reduce pileup contribution at HL-LHC
  - Timing resolution is required to be better than 50ps
  - $6.4m^2$ area silicon detector and ~ 3.6×10^6 channels
  - High Granularity: Pixel pad size: $1.3mm \times 1.3mm$
  - Radiation hardness: $2.5 \times 10^{15}\ N_{eq}\ /cm^2$ and 2MGy
- About 3000 modules are planned to be assembled at IHEP
- Automation assembly with robotic gantry system is the best choice due to its high positioning precision and assembly rate.

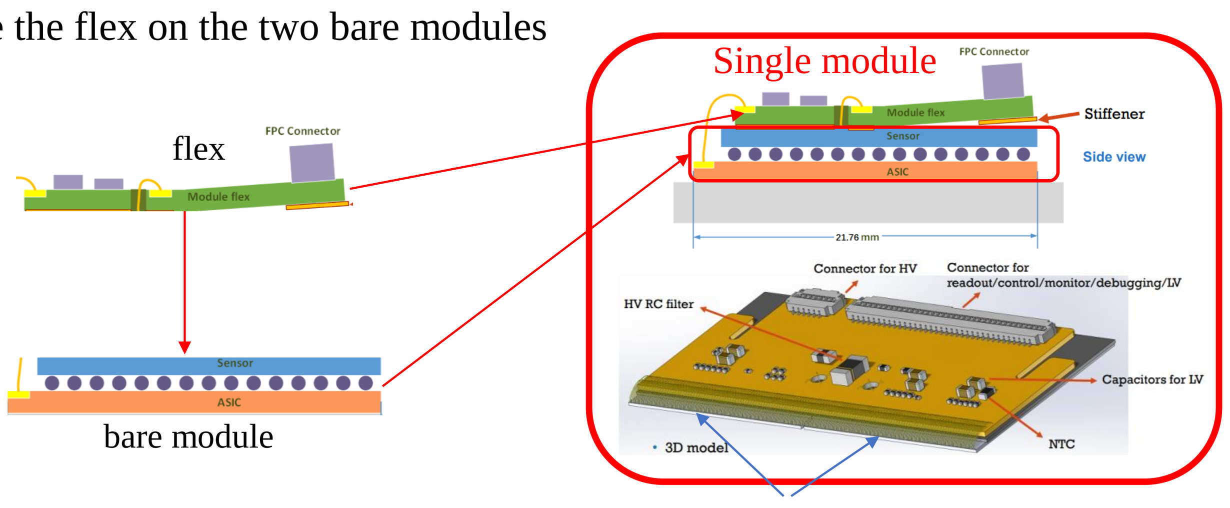




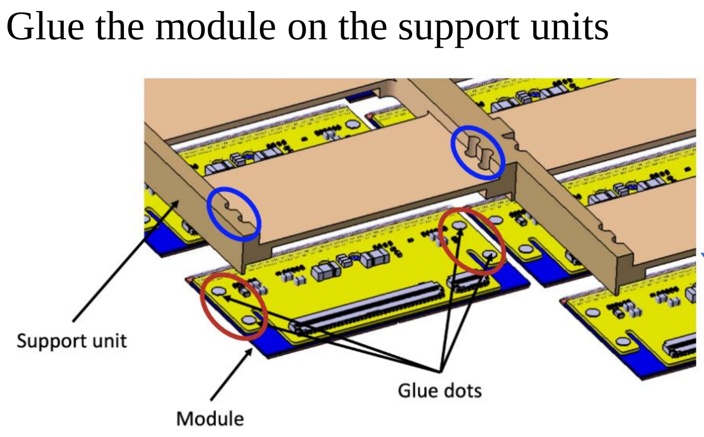


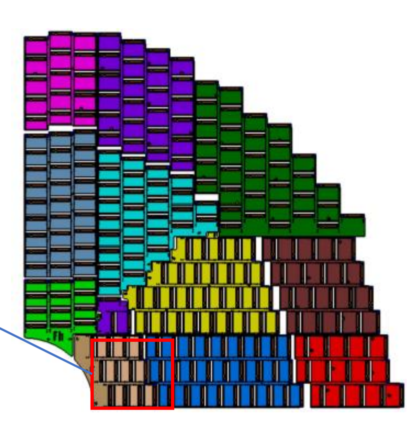
Task of the HGTD module assembly with gantry system

- Glue the flex on the two bare modules



- Glue the module on the support units





- Specification of the module mass and dimension

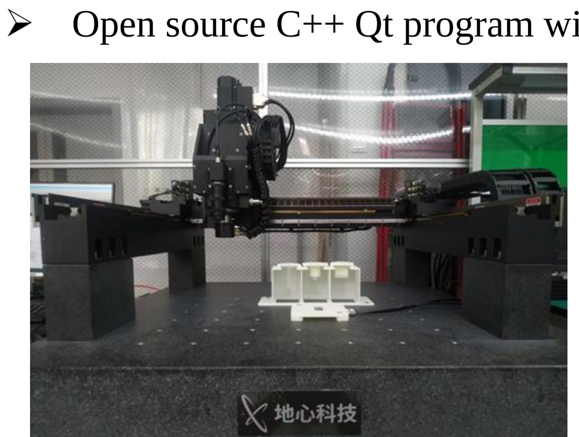
Module weight: 3.0 g	Nominal thickness of the module: 2.52 mm
Maximum thickness of the module: 3.32 mm	Maximum width of the module: 40.6 mm
Nominal gap between two bare modules: 200 μm	Minimum gap between two bare modules: 50 μm

- Specifications on the module flex to bare module attachment

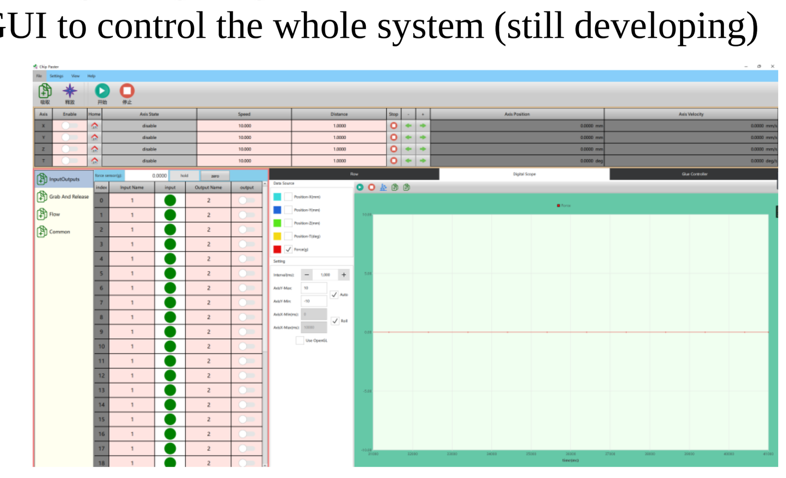
Glue thickness	50±30μm
Single lap shear force	>2N
Total coverage of glue area	80%, no spillage
Alignment between module flex and bare modules	< 100μm displacement, < 0.1° rotation

The gantry system at IHEP

- Robotic pick-and-place for systematic module assembly (gantry), consists of:
  - Coretech gantry positioning system with ACS motion controller (500 mm * 500 mm * 150 mm * 340° travel, repositioning resolution ~ $1\mu m$)
  - Integrated with Keyence vision system, pressure sensor, multi-channel electro-valves (maximum 32), Nordson EFD Glue Dispensing controller, flexible vacuum and air pressure piping system, and custom picking and gluing tools
  - Open source C++ Qt program with GUI to control the whole system (still developing)



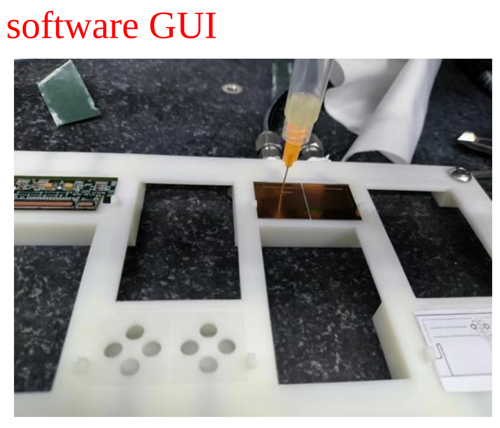
gantry table



software GUI

Dispensing controller

Gluing tool

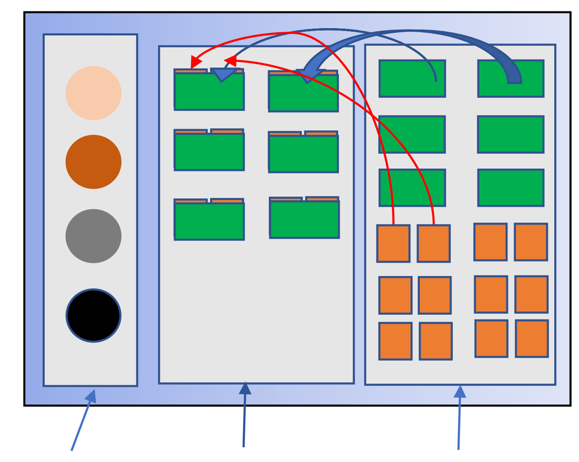


Glue dispensing

Automation Assembly Procedures

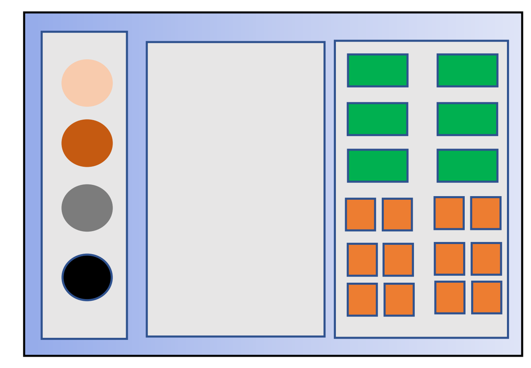
Gluing of the flex on the bare module

Gantry table

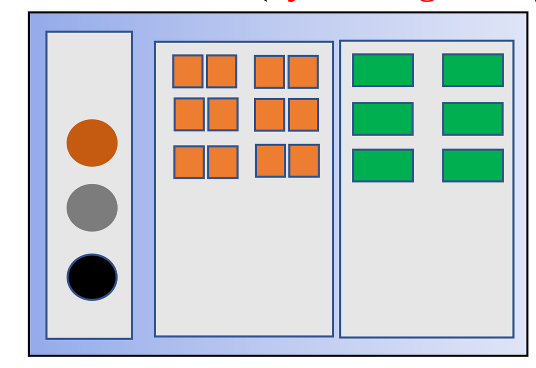


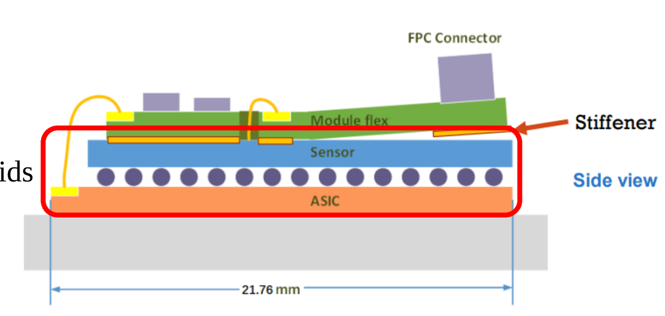
Tool rack vacuum chuck Flex cable chuck

Prepare the tools, flex and hybrids

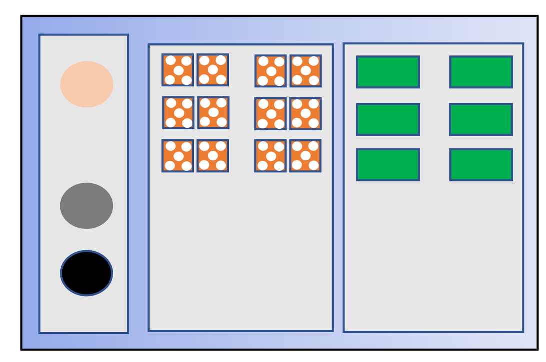


Pick-and-place the hybrids to the vacuum chuck (hybrid alignment)

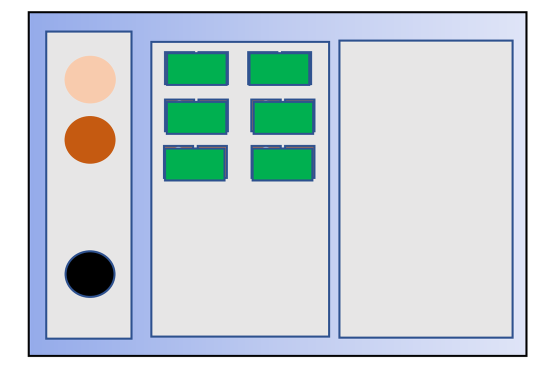




Dispense glue on the hybrids (glue weight, glue pattern)



Pick the flex and place it on the hybrids (flex alignment, glue thickness)

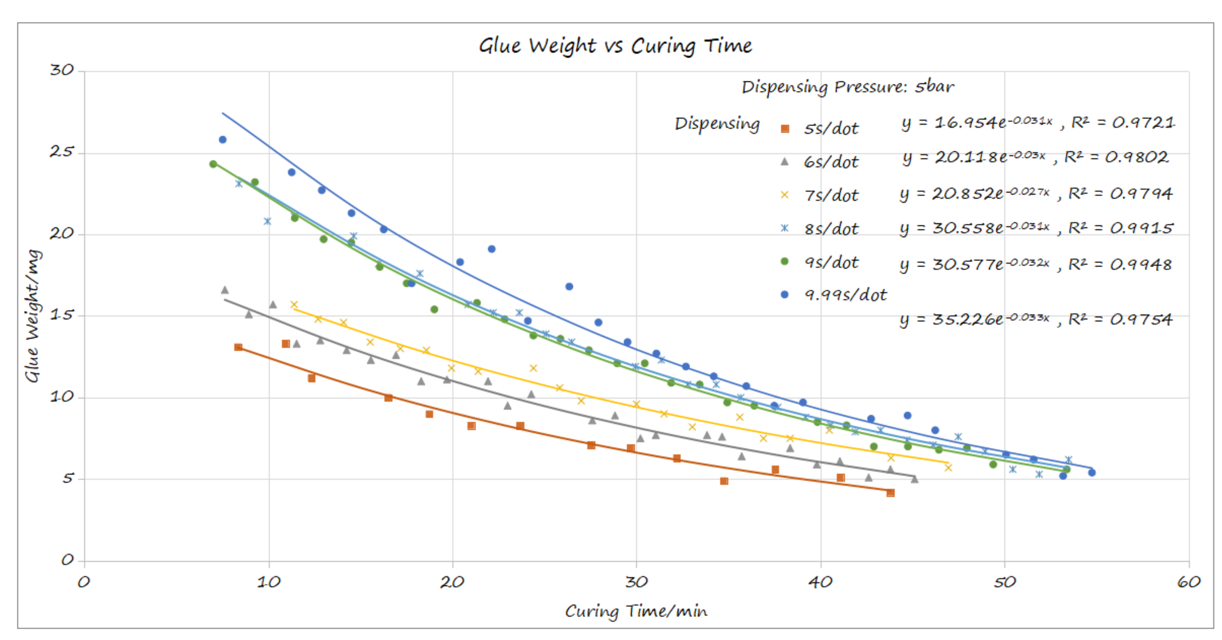


Current status at IHEP

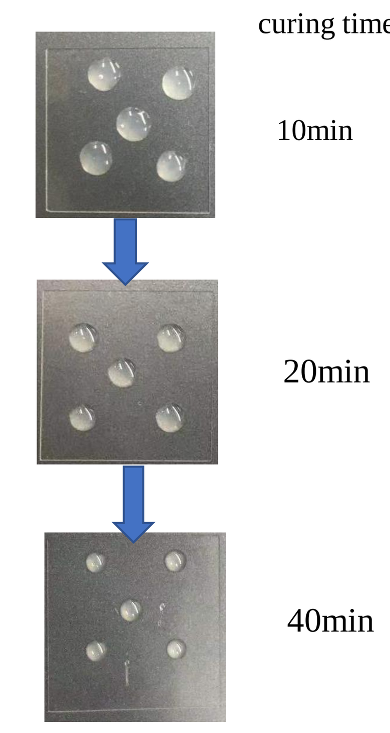
- Gantry system has already been installed with all hardware components in a clean room:
  - Vacuum system, air pressure system and vision system
- Positioning resolution validation was done with laser system (<$1\mu m$)

Axis	Calibration interval	Test interval	Specification	Result
X	50mm	500mm	$3\mu m$	$1\mu m$
Y	50mm	500mm	$3\mu m$	$0.4\mu m$
Z	15mm	150mm	$0.8\mu m$	$0.8\mu m$
Theta	15°	360°	5arc sec	2.074arc sec

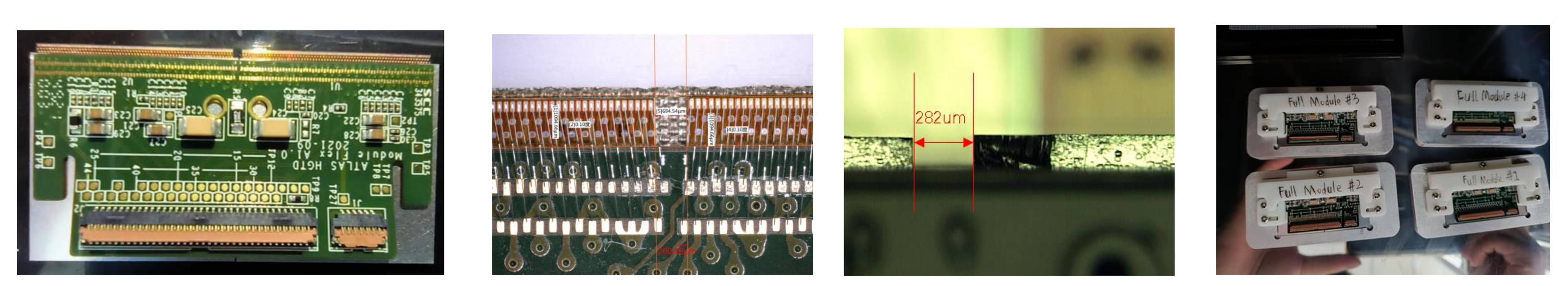
- Glue dispensing function is integrated
  - Glue weight measurement depending on the pressure and curing time has been done using the integration software

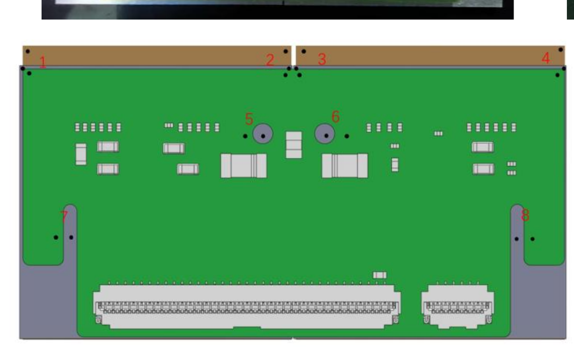


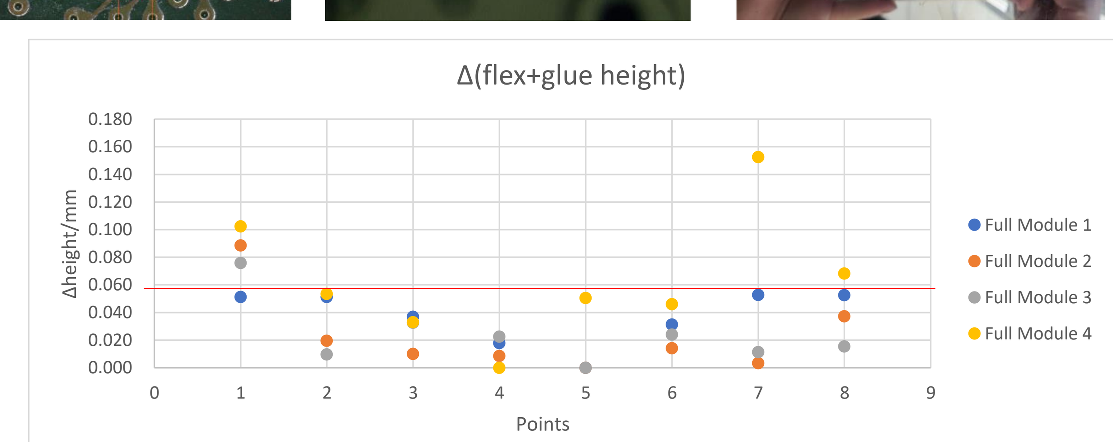
curing time

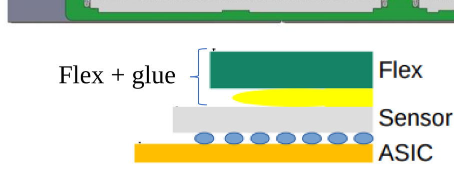


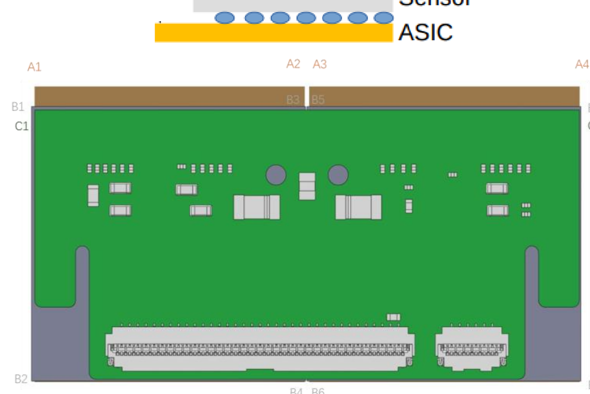
- Several digital module and full module has been assembled using the gantry and custom tooling
  - Wire-bonding was performed successful
  - The metrology results are very close the specifications











	B3B5(mm)	B4B6(mm)	Nominal gap(um)	Average Δ nominal(um)
Full Module 1	0.215	0.200	280	-72
Full Module 2	0.235	0.311	280	-7
Full Module 3	0.157	0.196	280	-104
Full Module 4	0.282	0.285	280	3

	Full Module 1	Full Module 2	Full Module 3	Full Module 4
Average rotation angle[°]	-0.067	0.128	0.070	-0.182

Summary and outlook

- A high precision positioning gantry system has been built in IHEP for automatic HGTD module assembly
- We performed basic testing for the gantry, it satisfied the module assembly requirements.
- Software development and custom tooling design have made huge progress.
  - Gluing dispensing integration
  - Fully 3D-printed tooling
- Several HGTD full modules has been assembled using the gantry system and the metrology results of these modules are very close to the HGTD module specification.
- Outlook:
  - Machining tooling design is on-going for better glue thickness flatness control
  - Software integration with pattern recognition using the CCD camera for better alignment
    - Alignment between two bare modules (hybrids)
    - Alignment between flex and bare module