

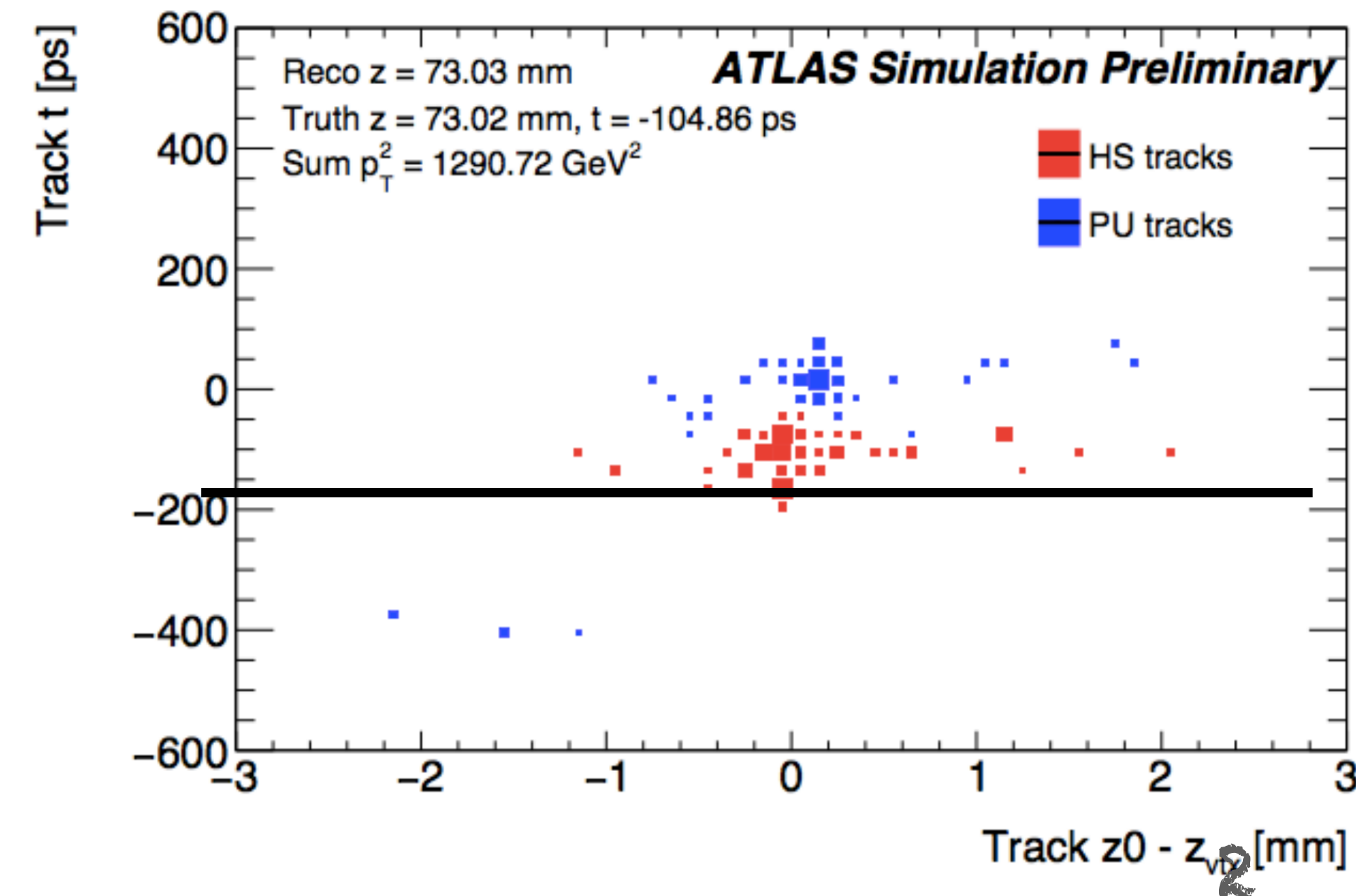
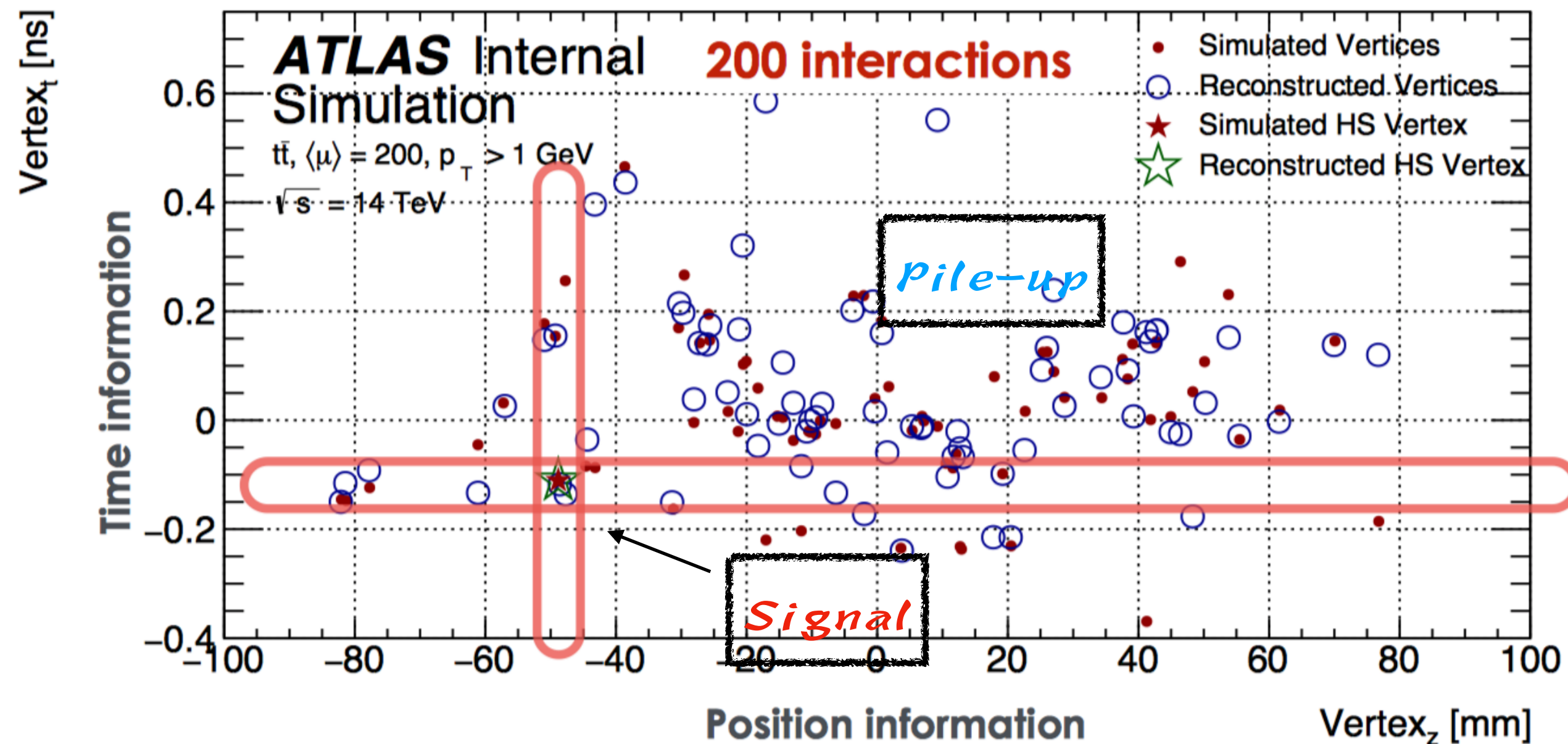
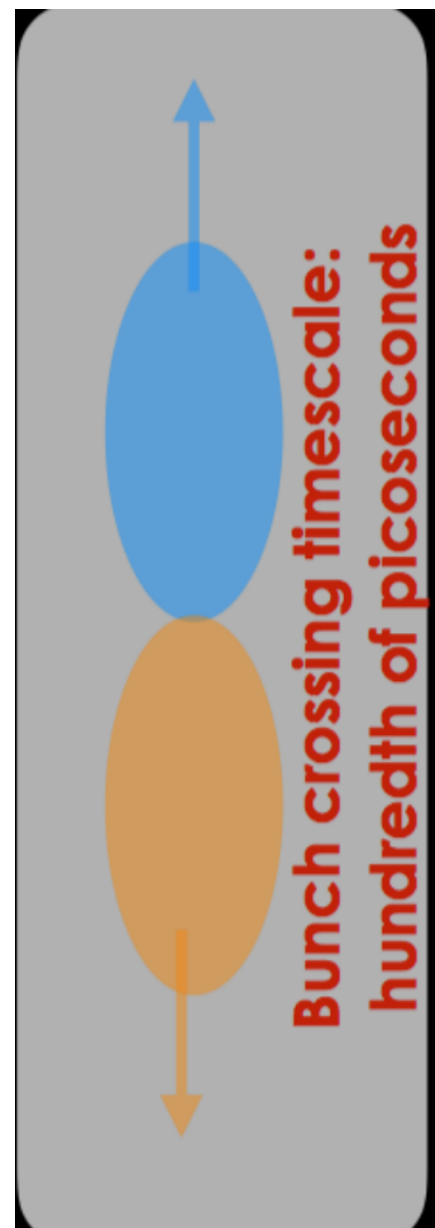
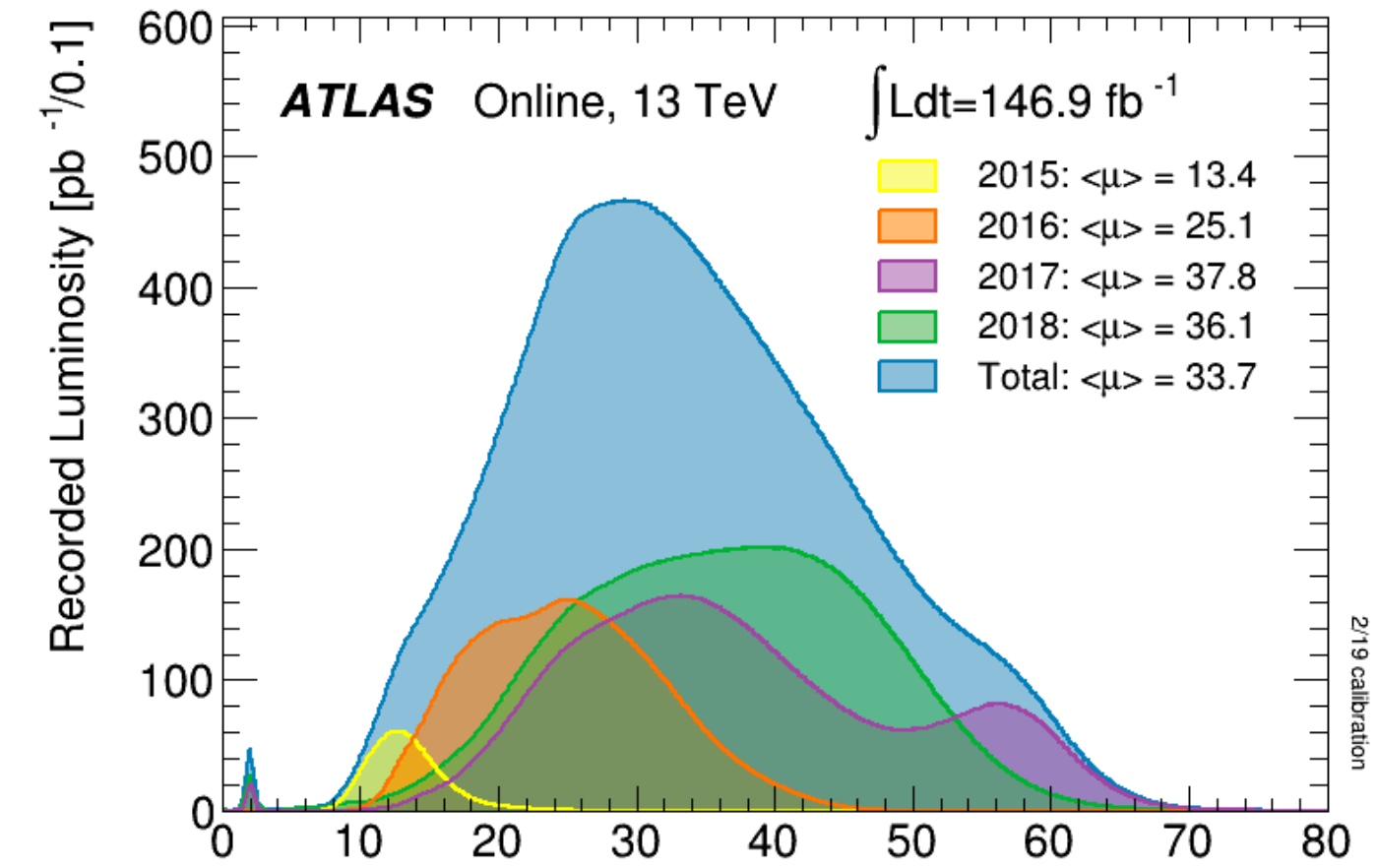
HGTD Module Assembly and Loading Development at IHEP

Xuan YANG on behalf of the team
Institute of High Energy Physics

Introduction to HGTD



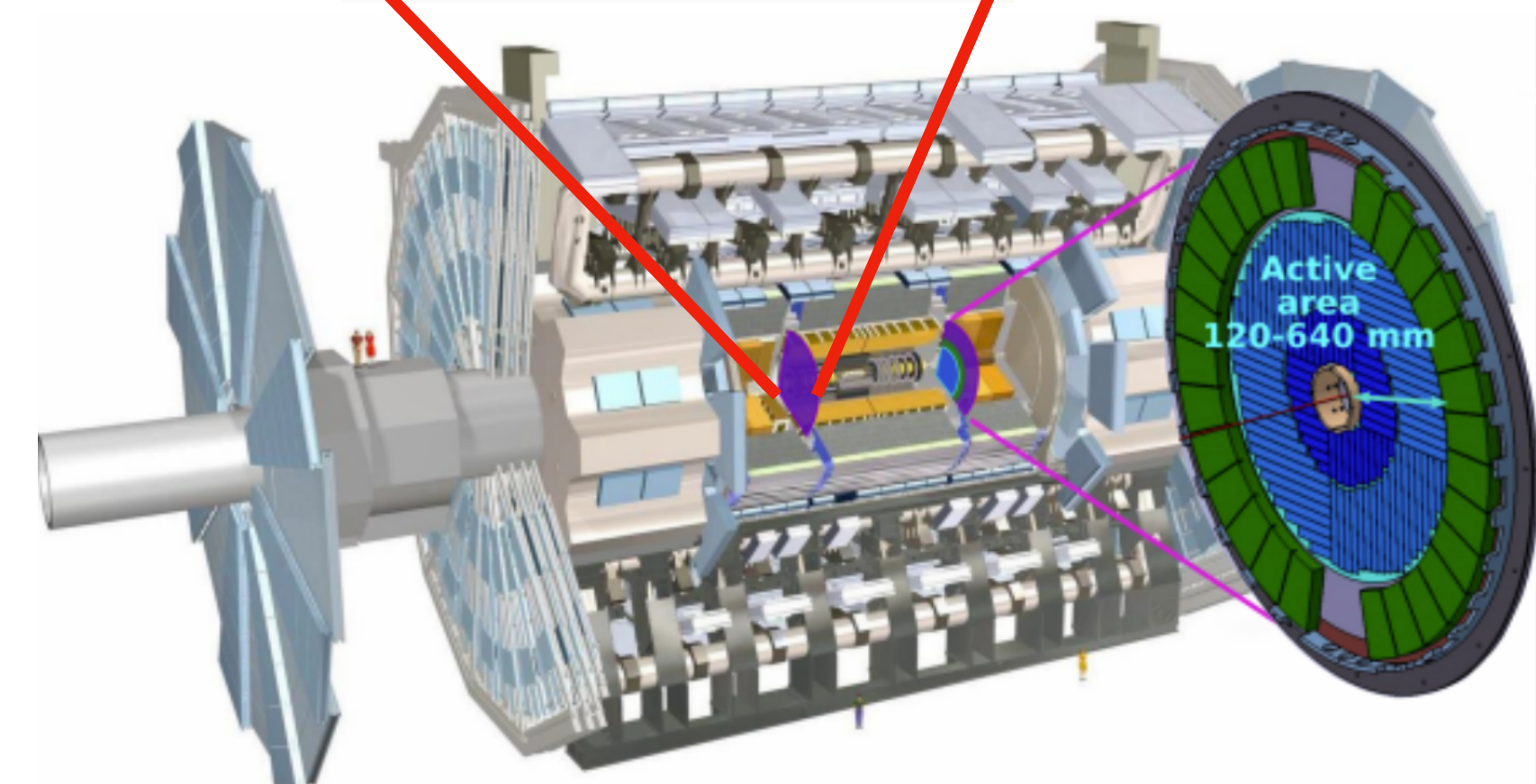
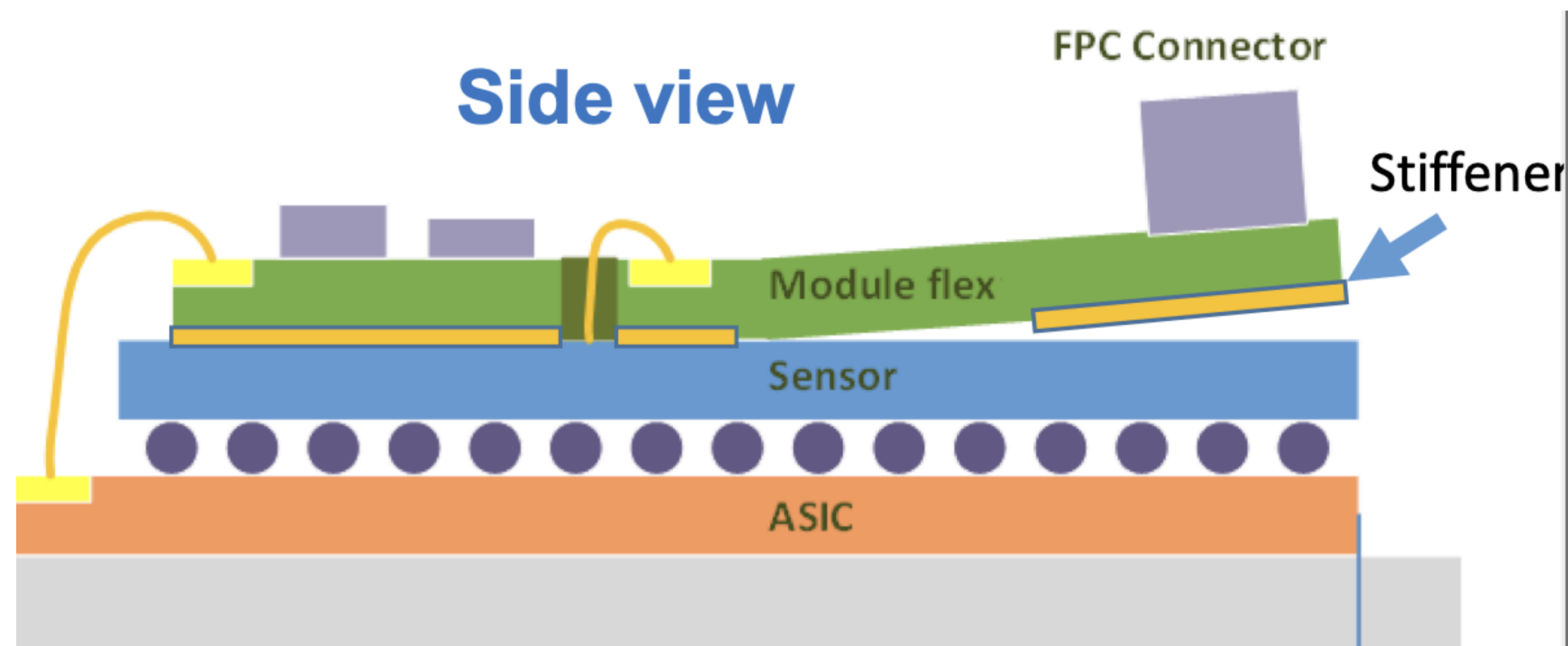
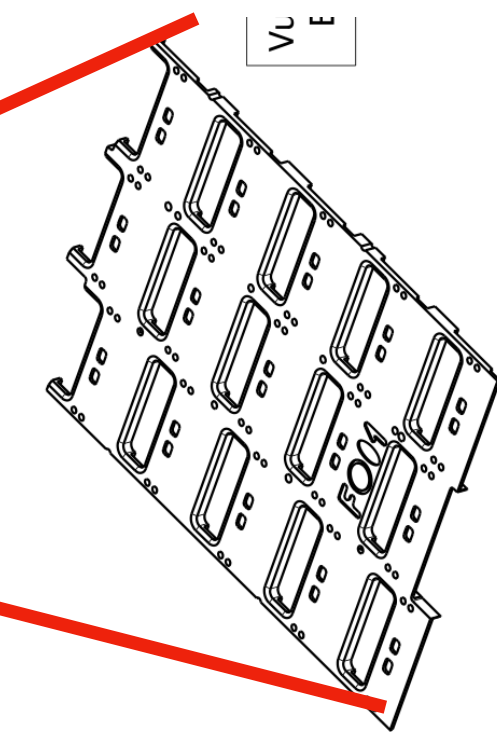
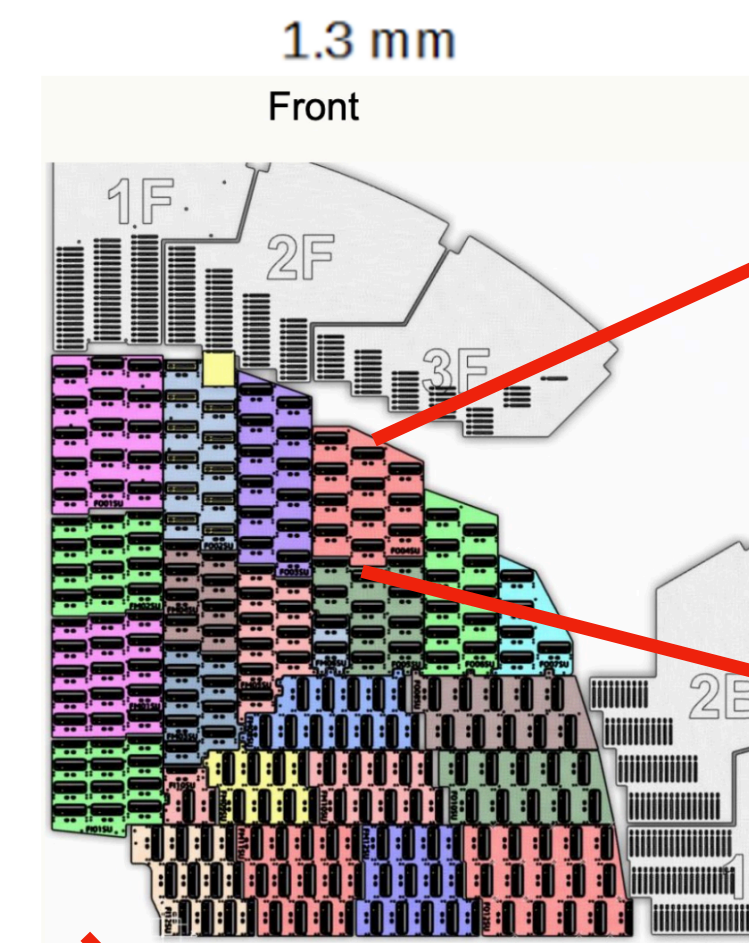
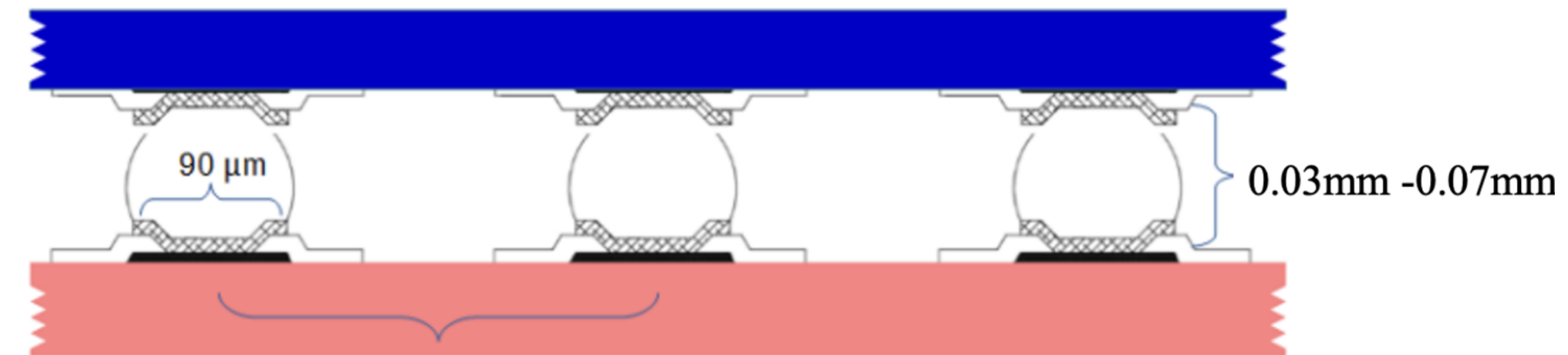
- ▶ Pile-up events will be one of the most important backgrounds at HL-LHC
 - ▶ Expected $\langle \mu \rangle$ at HL-LHC ~ 200
 - ▶ Will be very challenging for physics analysis at HL-LHC
- ▶ **Timing detector can provide more information to enhance the separation power**
 - ▶ Timing resolution ~ 30 ps
- ▶ Quite large collaboration including IFAE, IJCLab...
 - ▶ **IHEP is the largest group involved in many important tasks**



HGTD Module



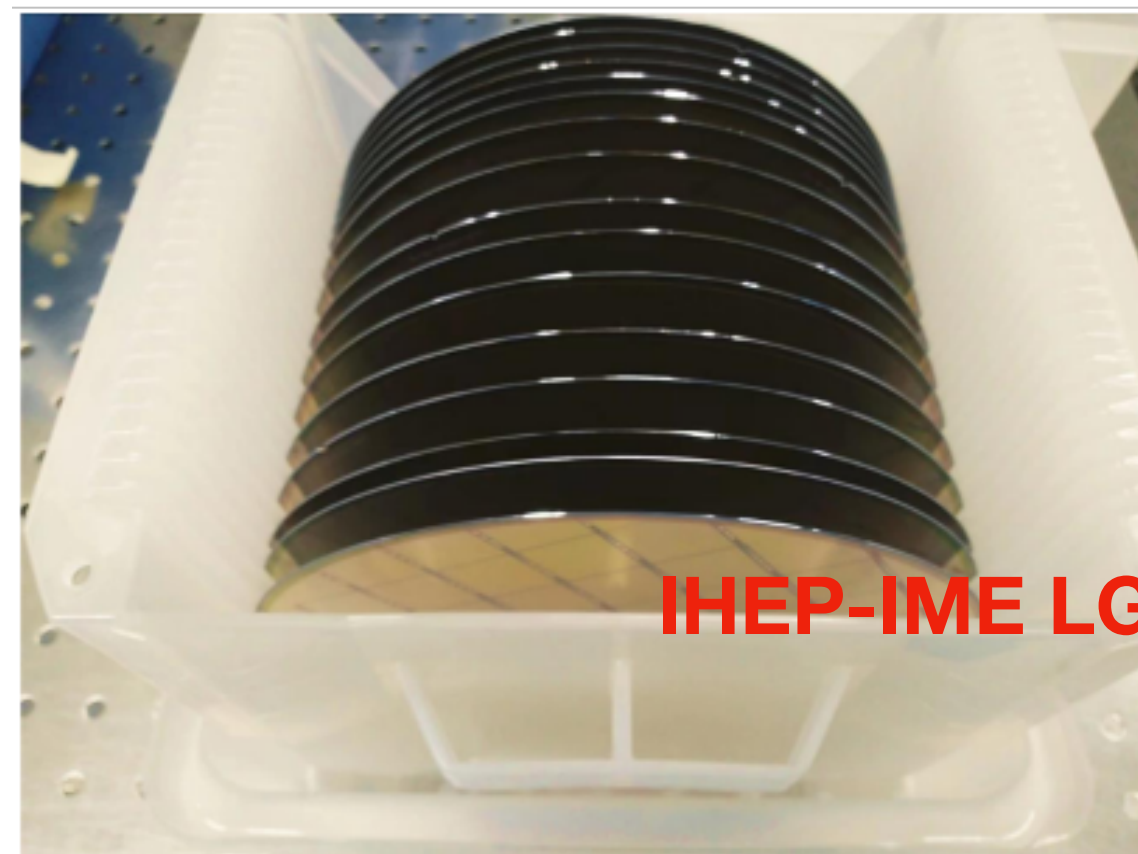
- ▶ Basic element to detect and provide timing information
 - ▶ Plan to produce 8032 modules, total area ~ 6.4 m²
 - ▶ ~ 4000 modules will be assembled at IHEP
- ▶ Hybrid consists of a **LGAD sensor** and an **read-out asic (Altiroc)**
 - ▶ Connected by bump-bonding
 - ▶ Timing resolution determined by hybrid performance



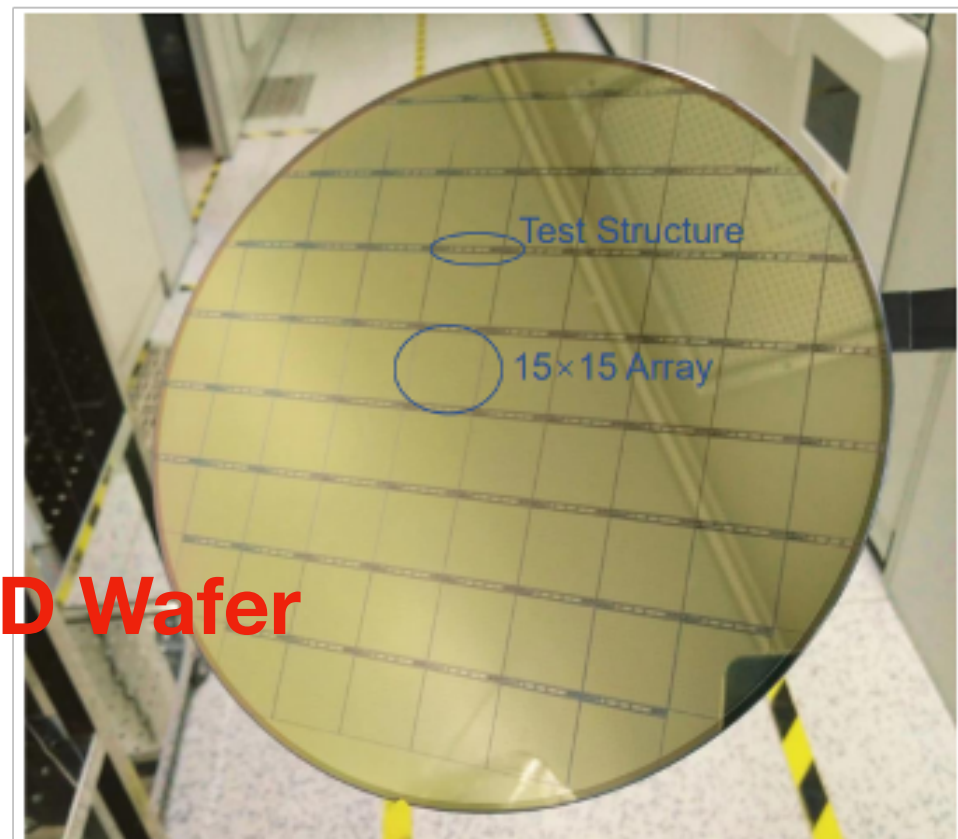
LGAD Sensor



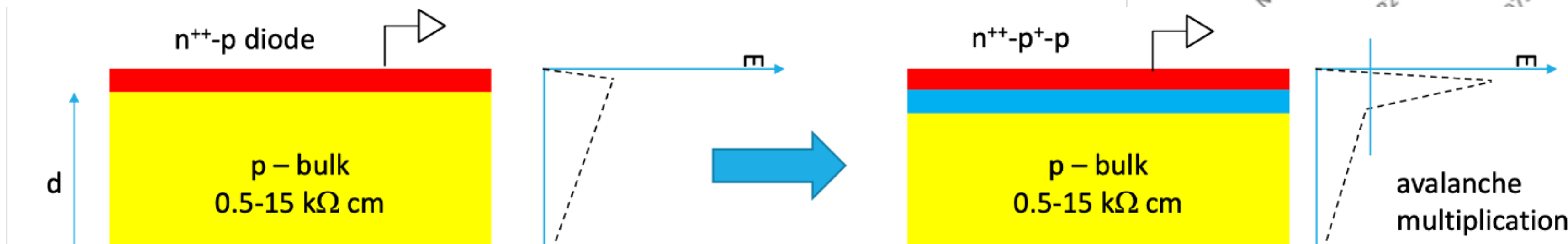
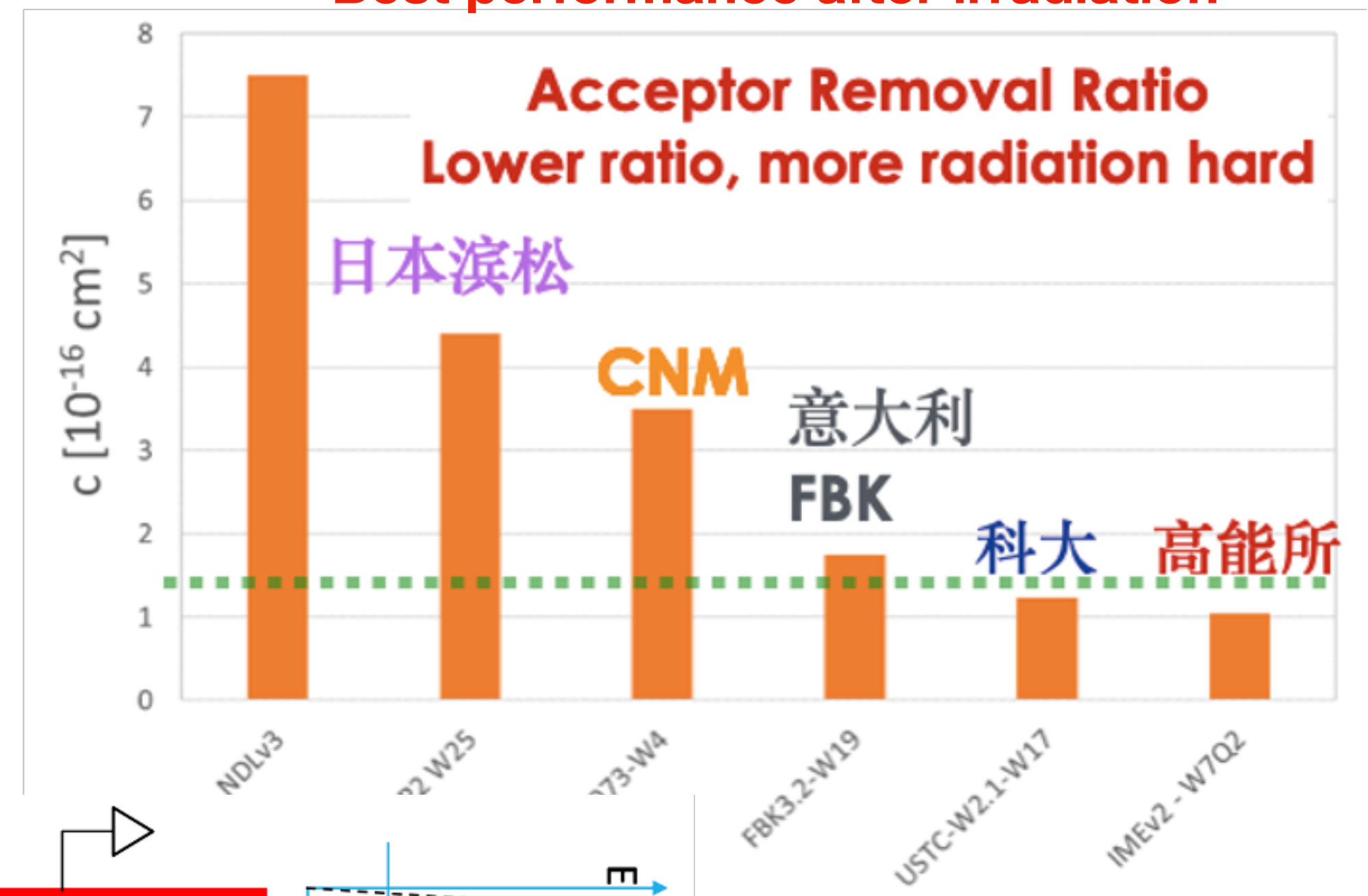
- ▶ Low-gain-avalanche-diode, provide charge collection, timing resolution ~ 30 ps
- ▶ Designed by IHEP and produced in collaboration with IME
 - ▶ First domestic sensor provided for LHC experiment
- ▶ Possibly other applications (cosmic, medical...)
- ▶ Have passed PRR and ready for production



IHEP-IME LGAD Wafer



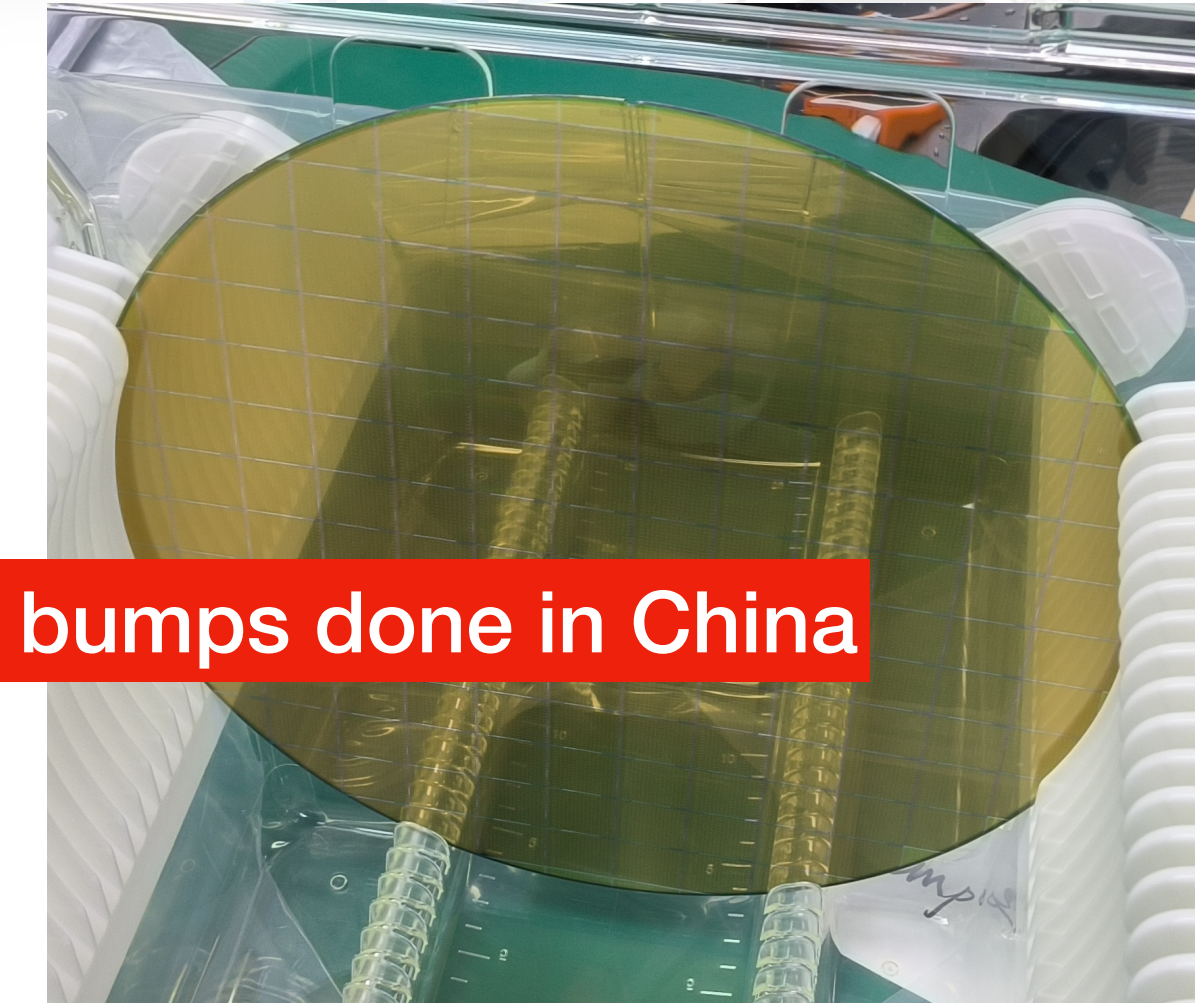
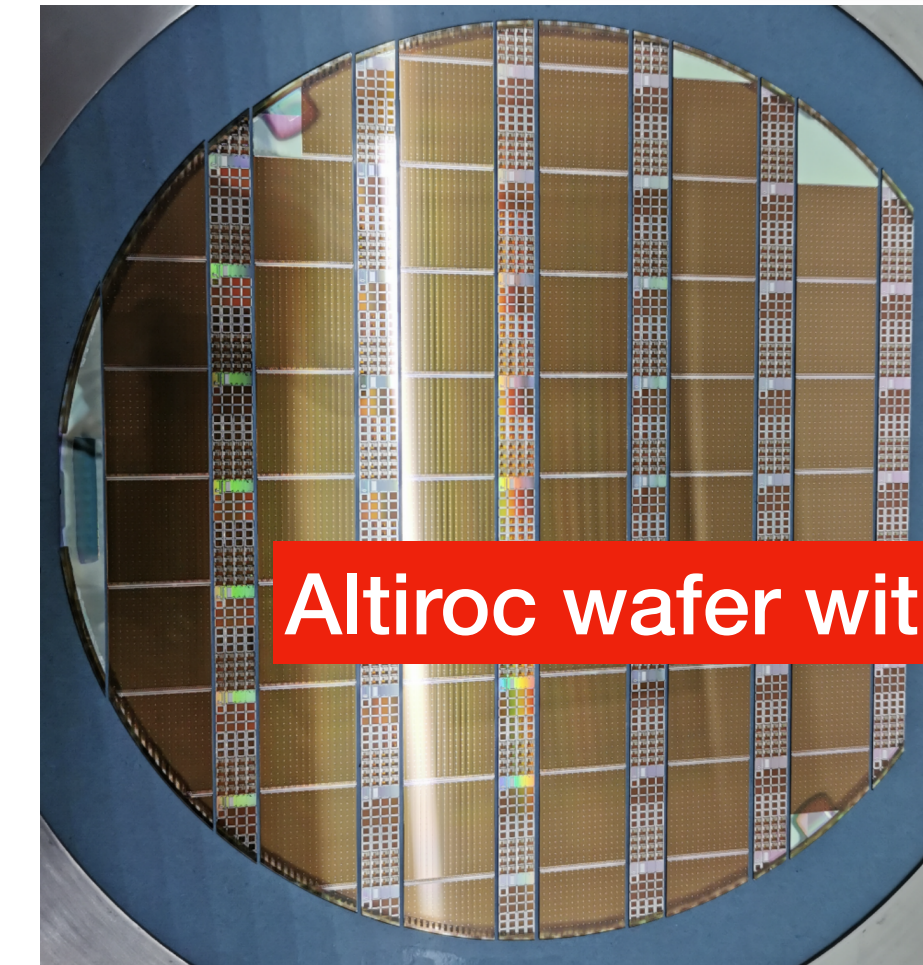
Best performance after irradiation



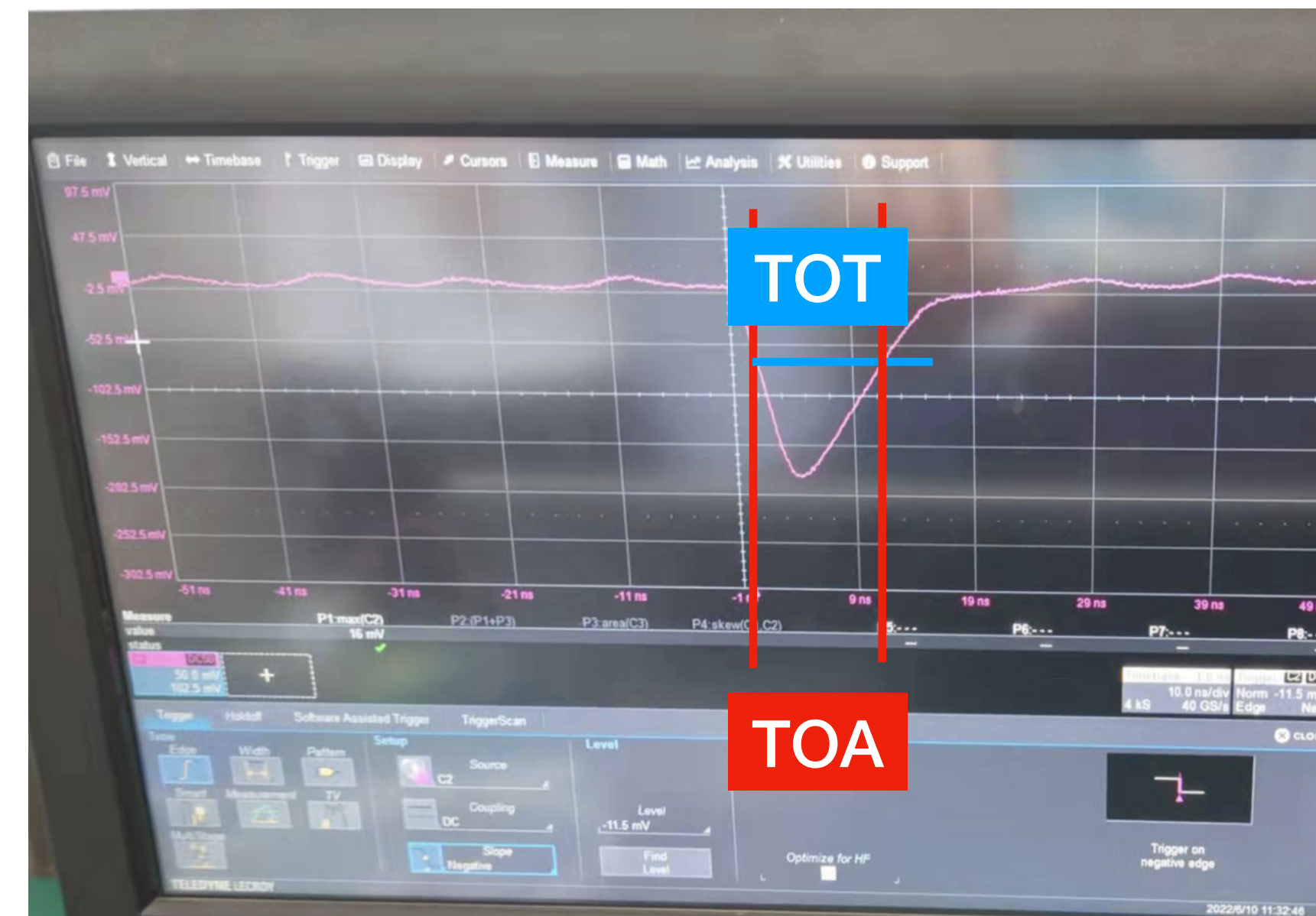
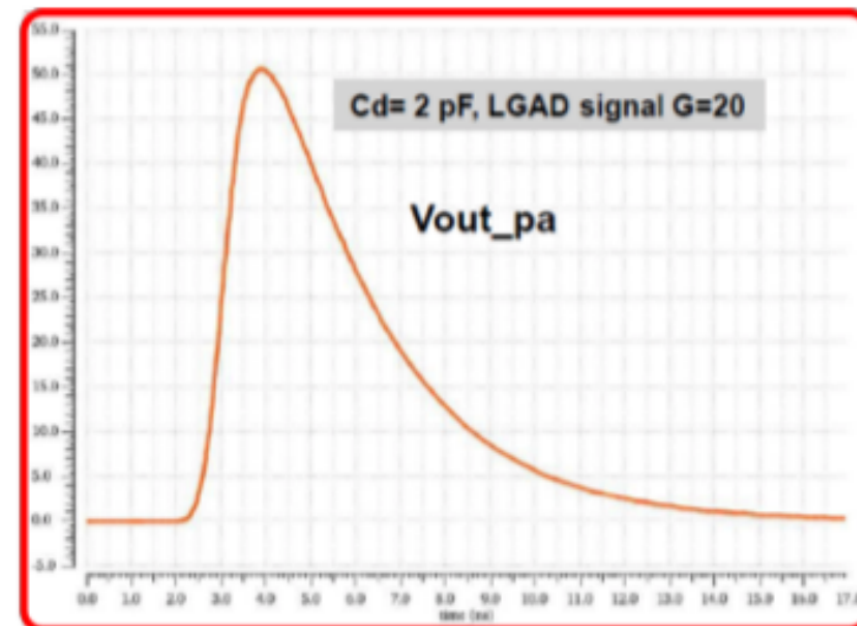
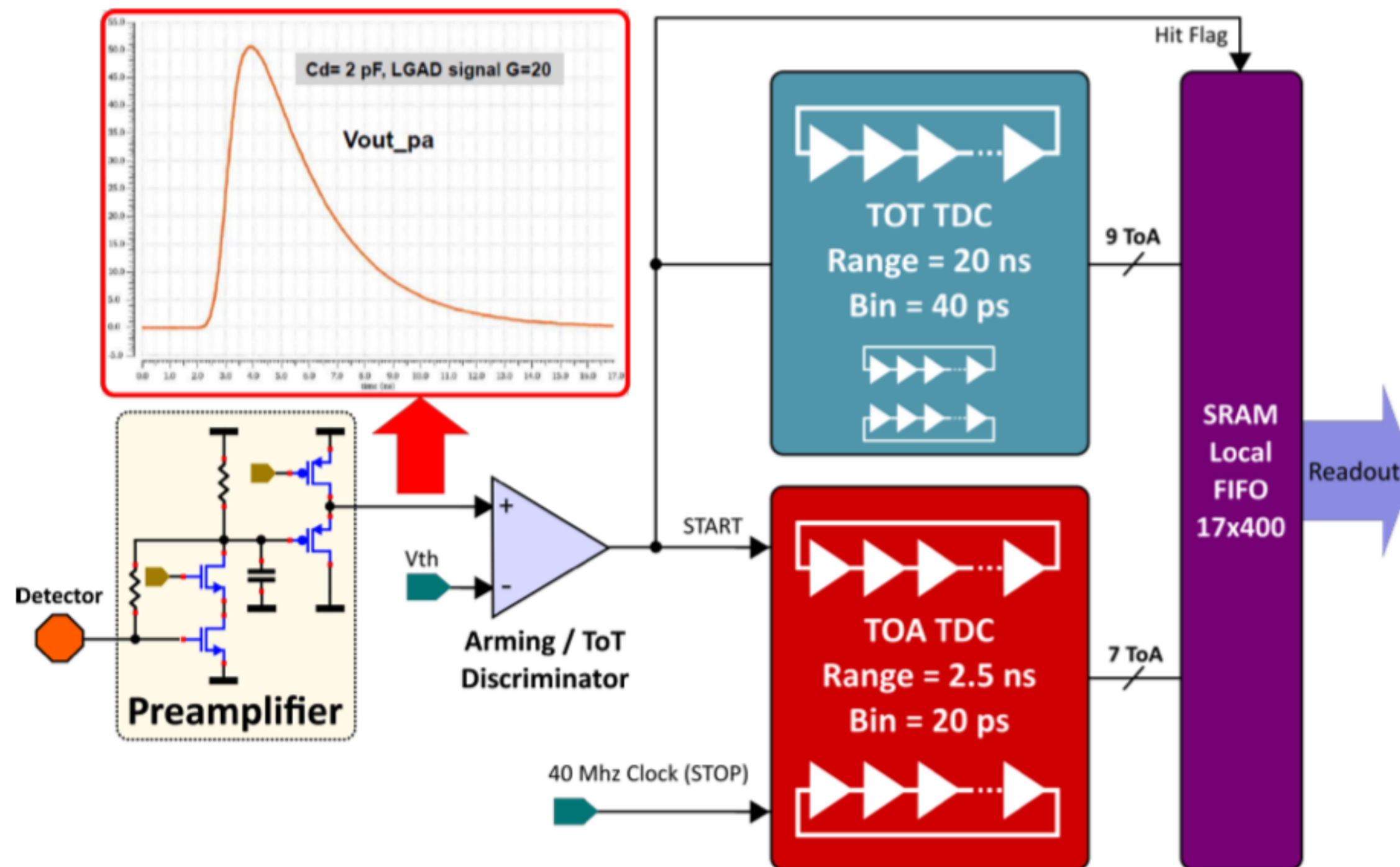
Altiroc



- ▶ Transform analog signal to digital signal and readout to PEB
 - ▶ Pre-amplifier: amplify analog signal
 - ▶ Two TDC: TOT, TOA
 - ▶ SRAM: store data stream in one clock
- ▶ IHEP will do 50% wafer probing->going to start next month
- ▶ Wafer processing by IHEP in collaboration with Chinese company



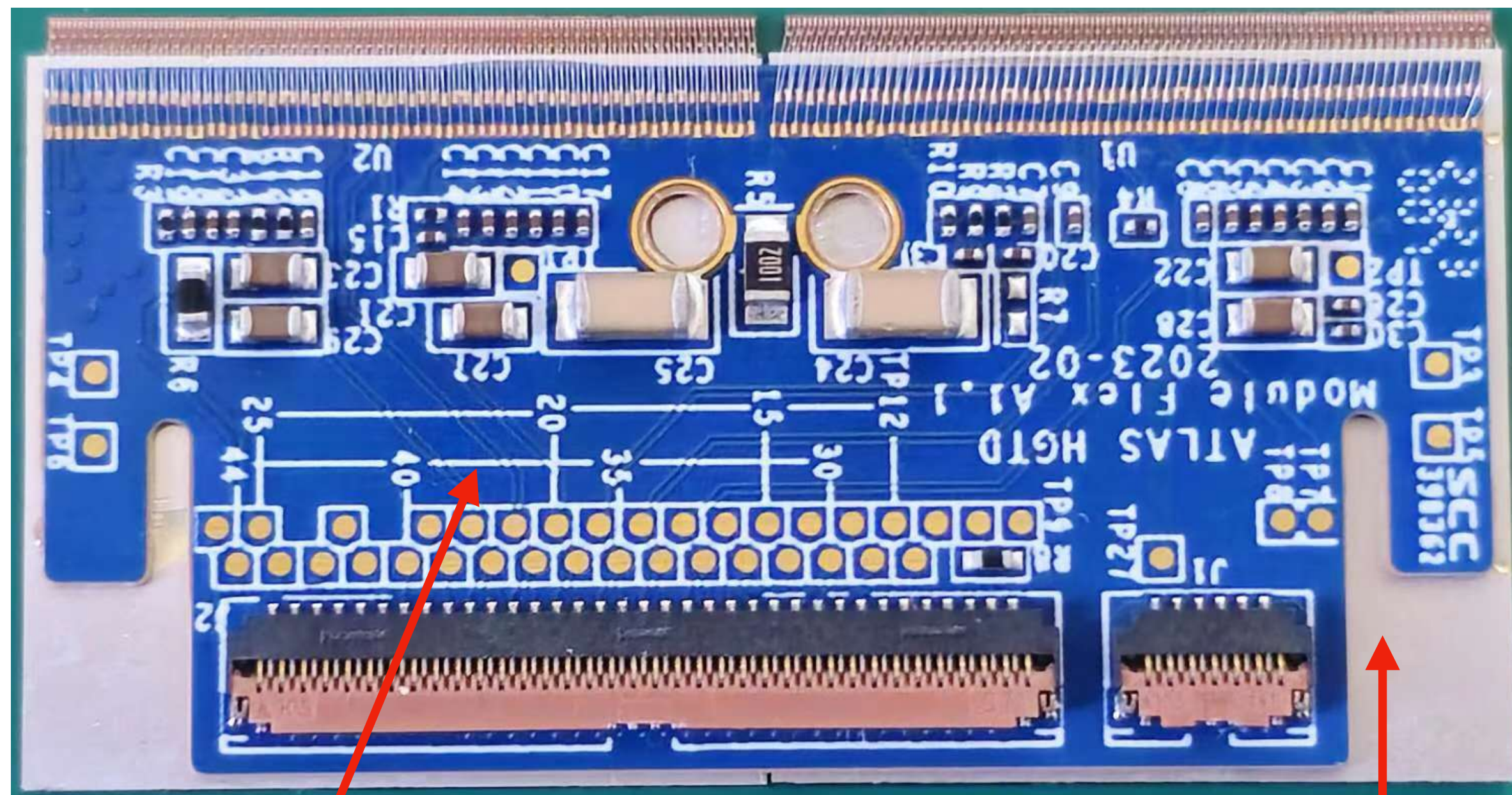
Altiroc wafer with bumps done in China



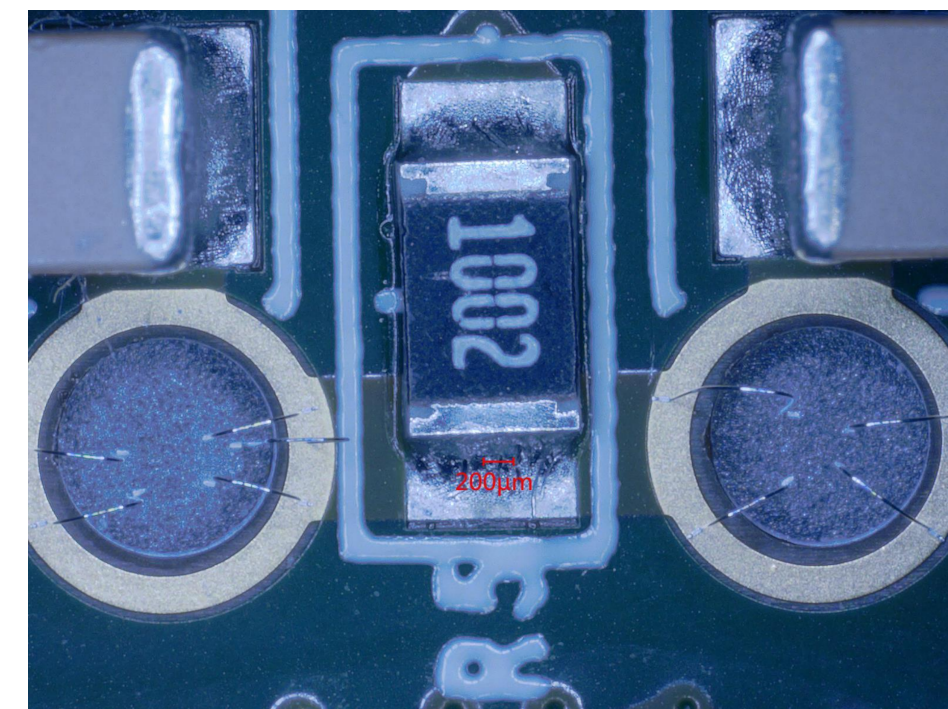
HGTD Module Assembly



- ▶ Bare module consists of flex pcb and two hybrids:
 - ▶ Hybrids are glued under the flex pcb, **thickness and weight of glue must be within specification**
 - ▶ Electrical connection and HV bias for LGAD sensor through wire-bonding
- ▶ Bump bonding is easy to break, **need to design a safe assembly method with high efficiency**

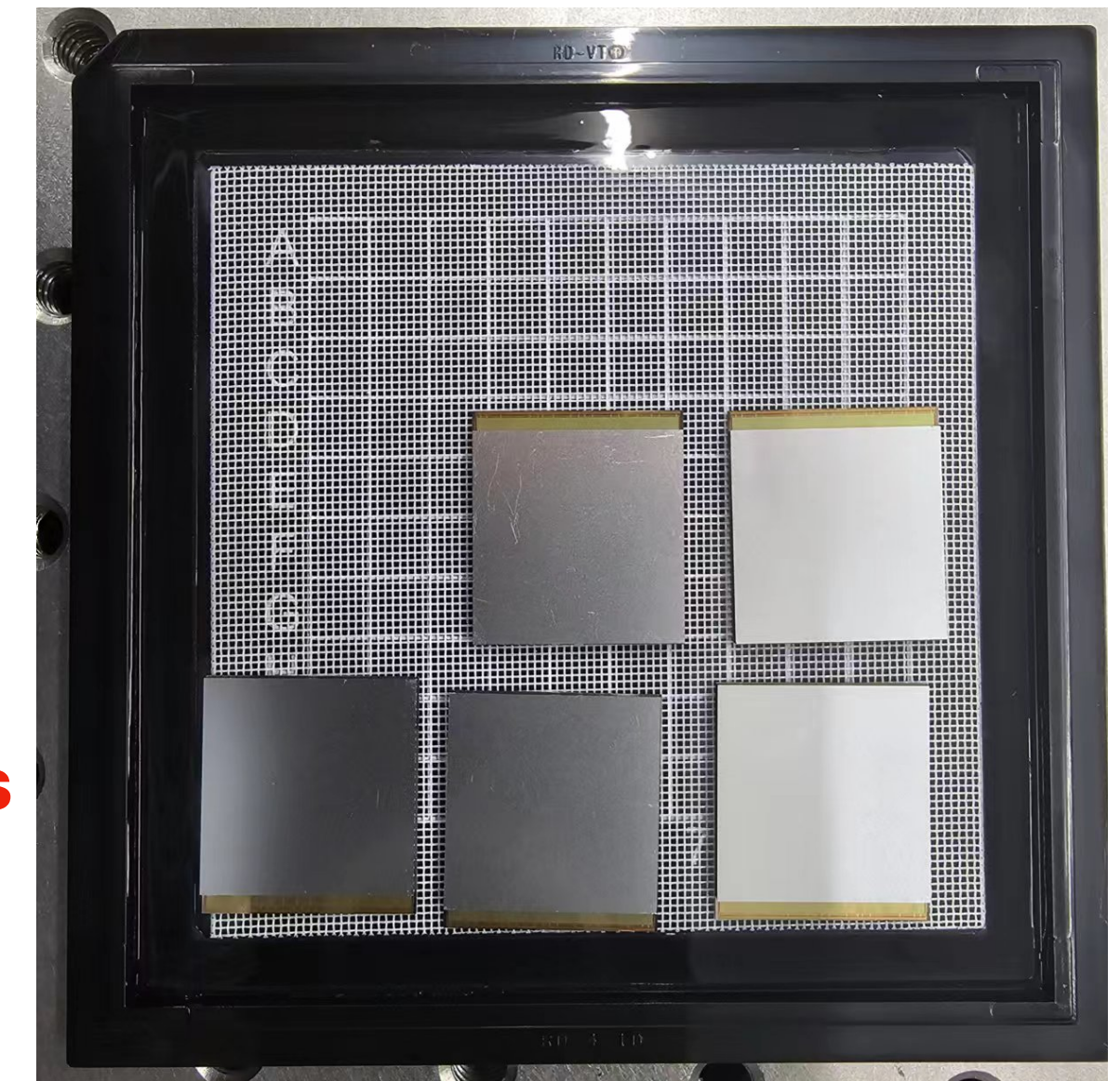


Flex PCB designed by IHEP



HV wires through the holes

Hybrids glued under pcb



Prototype hybrids produced by Chinese company

Assembly Sharing

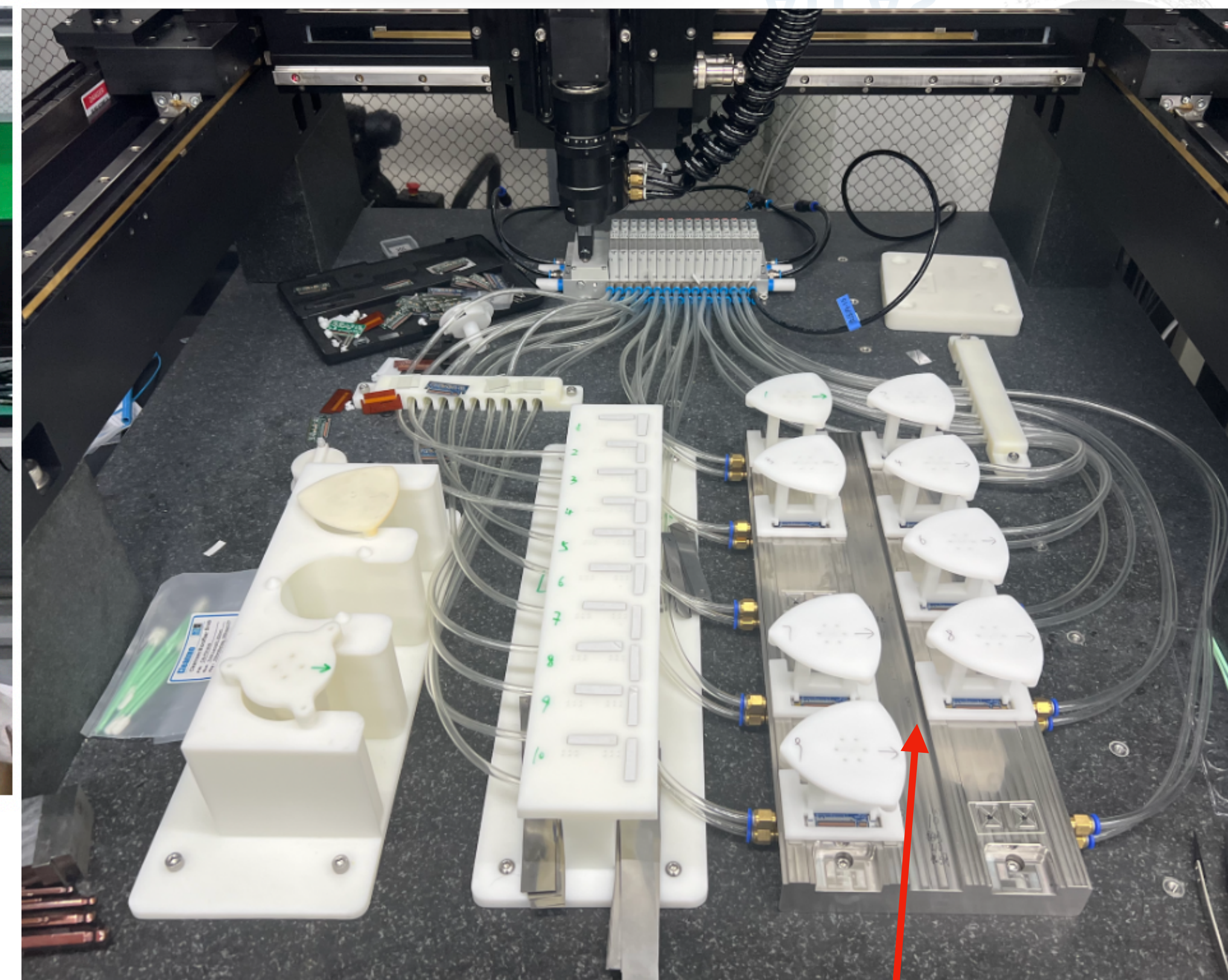
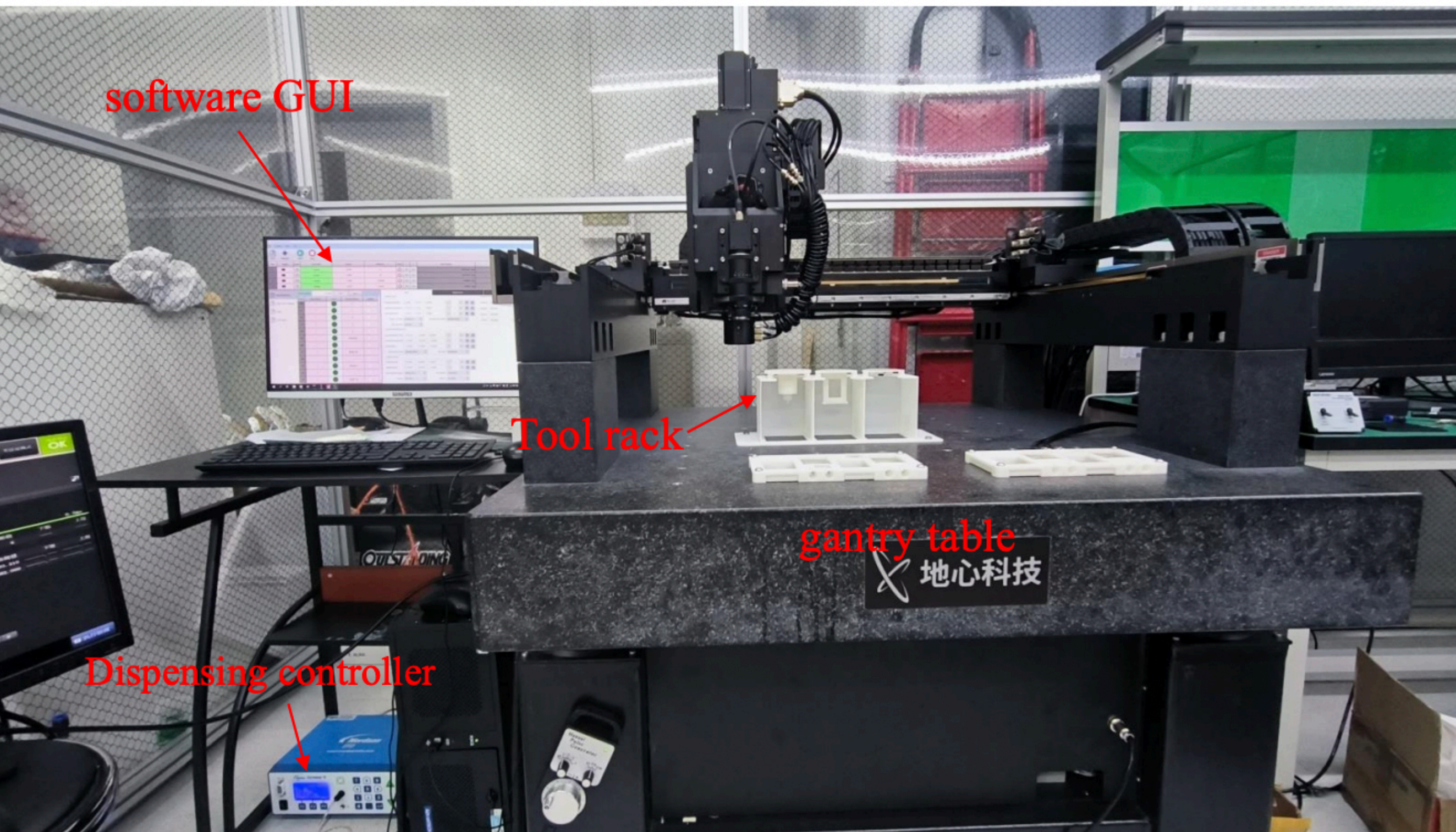


Site	IHEP	IJCLab	Morocco	IFAE	Mainz	USTC
Production share	34%	20%	16%	10%	10%	10%
# of modules	2731	1607	1285	803	803	803
# of modules (74% yields)	3691	2172	1737	1086	1086	1086
Production rate per week	57.6	34	27.2	17.1	17.1	17.1

IHEP will produce the most modules (~4000) across the collaboration.

About 60 modules need to be assembled per week -> 20 per day considering 3 work days every week for assembly, 2 work days for loading.

Gantry system

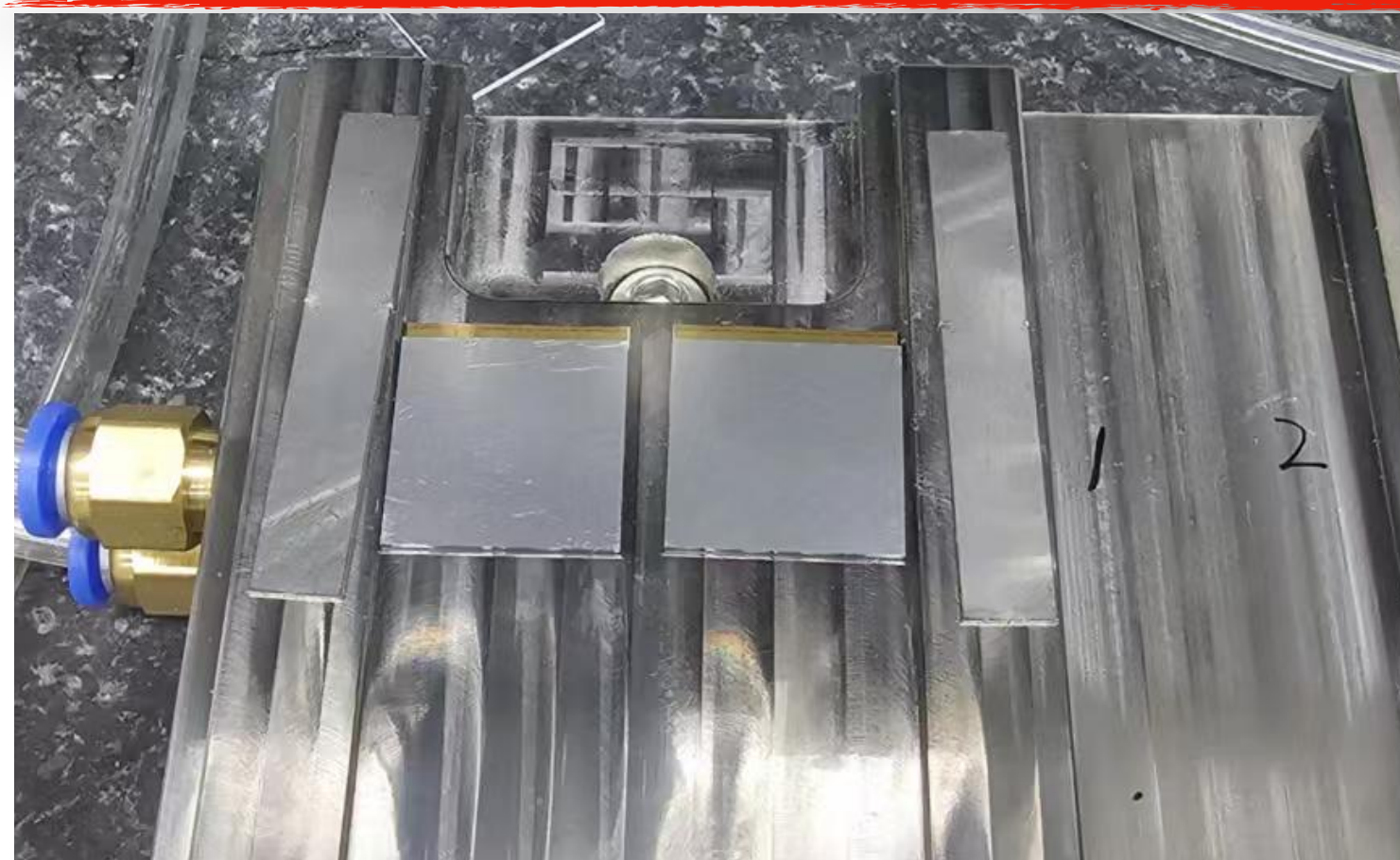


- ▶ Domestic gantry
 - ▶ Fix hybrids by vacuum
 - ▶ Image recognition to detect position
 - ▶ Automatical glue dispensing
 - ▶ Automatically placement and assembly

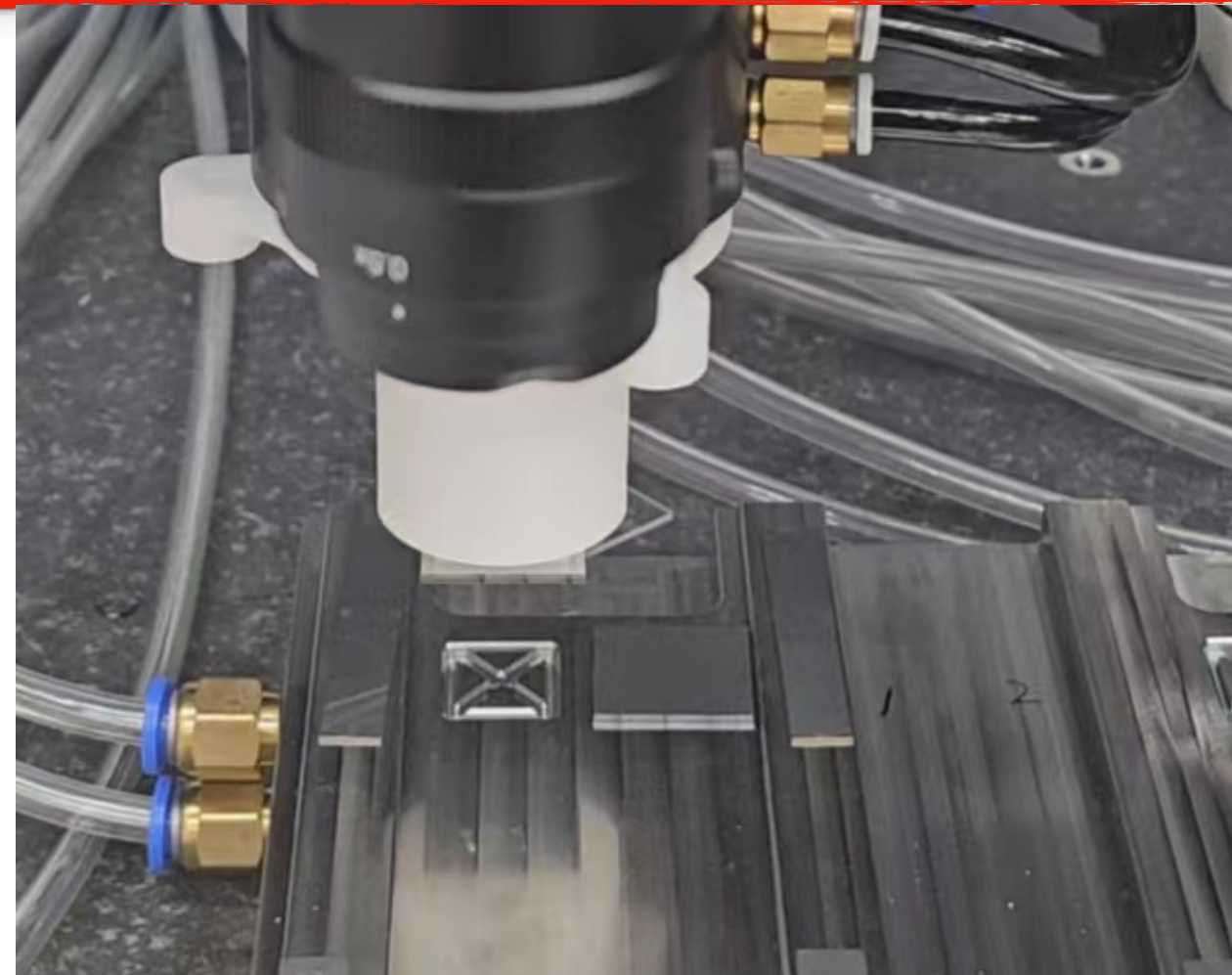
Successfully tested with a batch of 5 modules

Module assembly platform, 20 modules per day, meet the requirement of production rate.

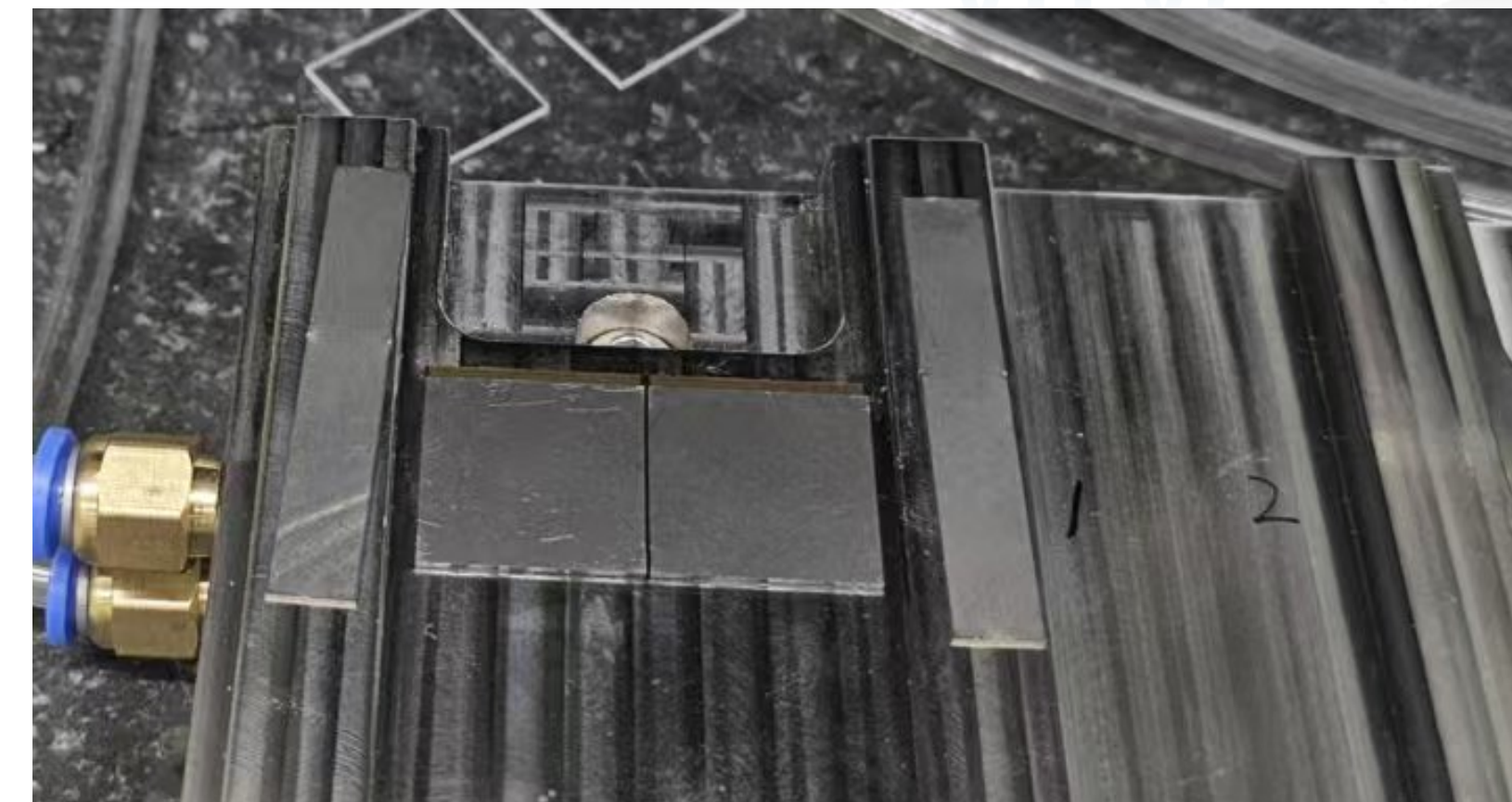
Assembly procedure



① put hybrids on the platform



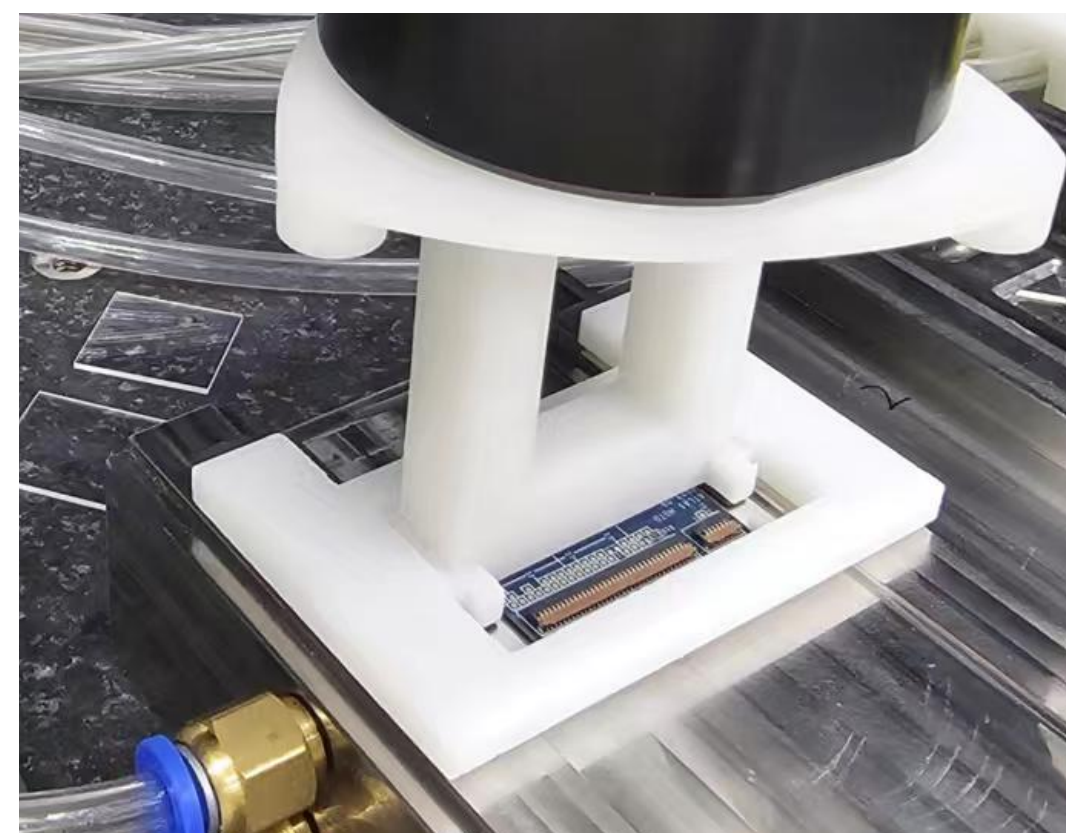
② gantry automatically tuning the position



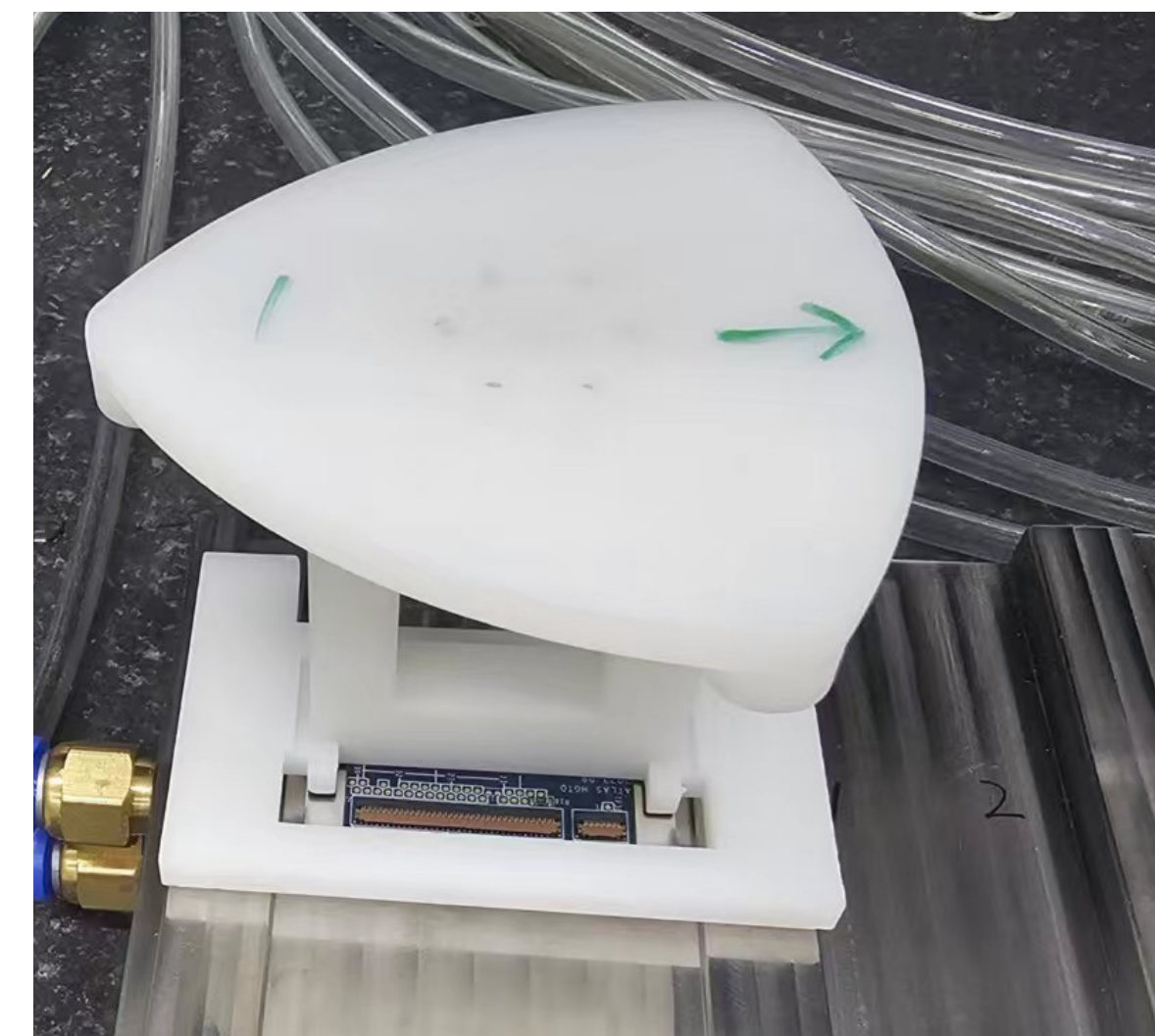
③ hybrids on the correct position



④ glue dots based on pre-defined weight and shape



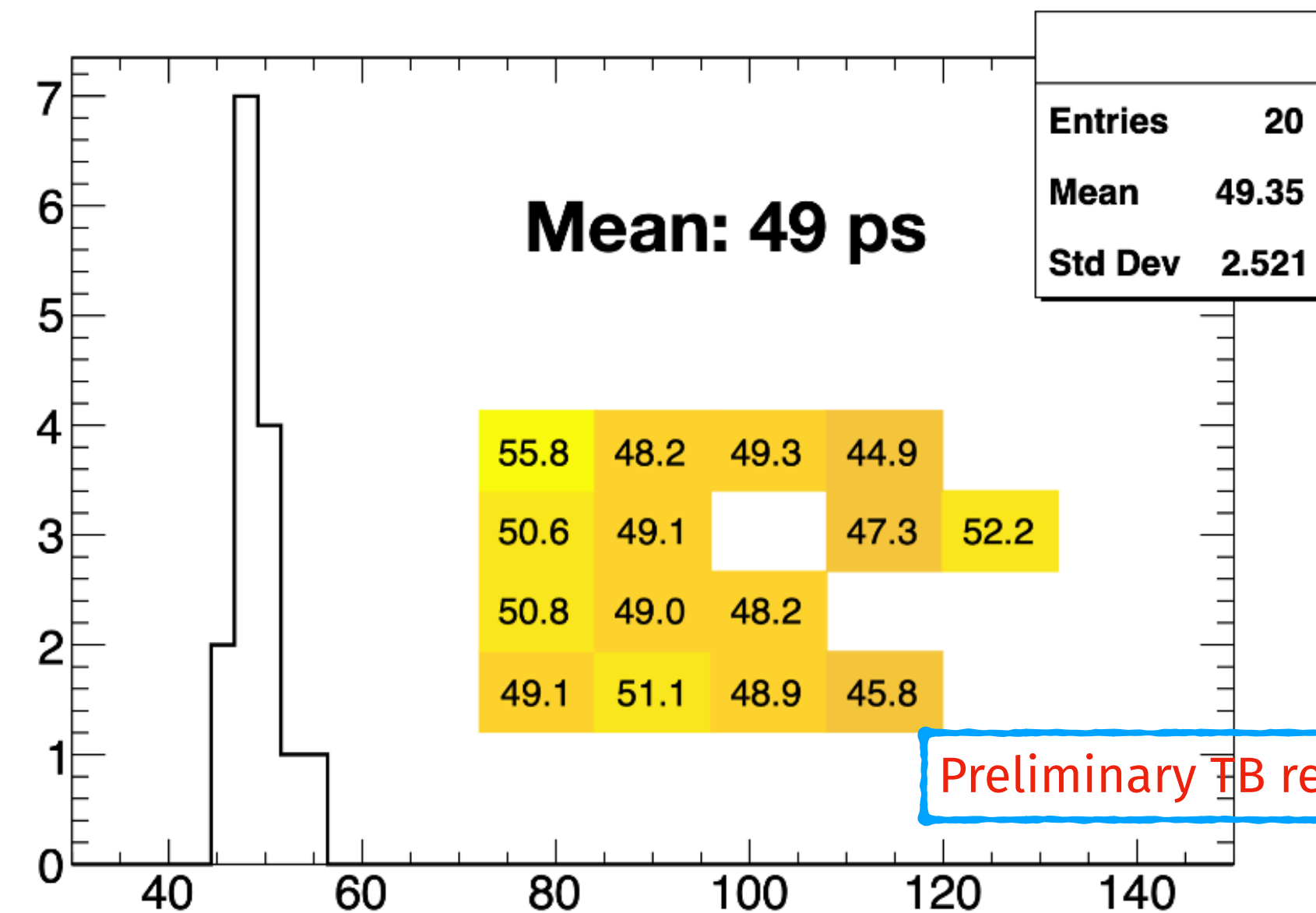
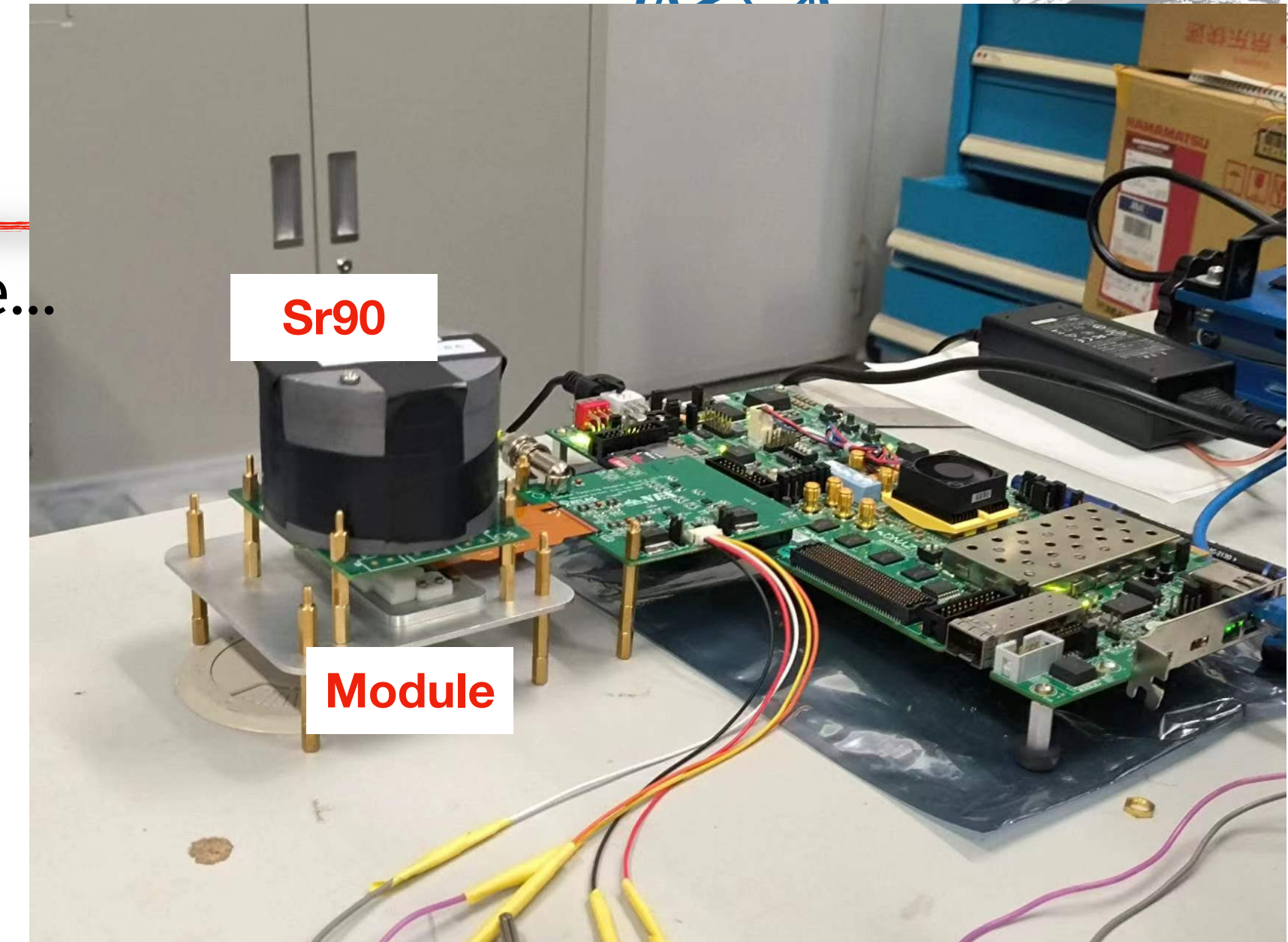
⑤ automatically find the position of flex pcb



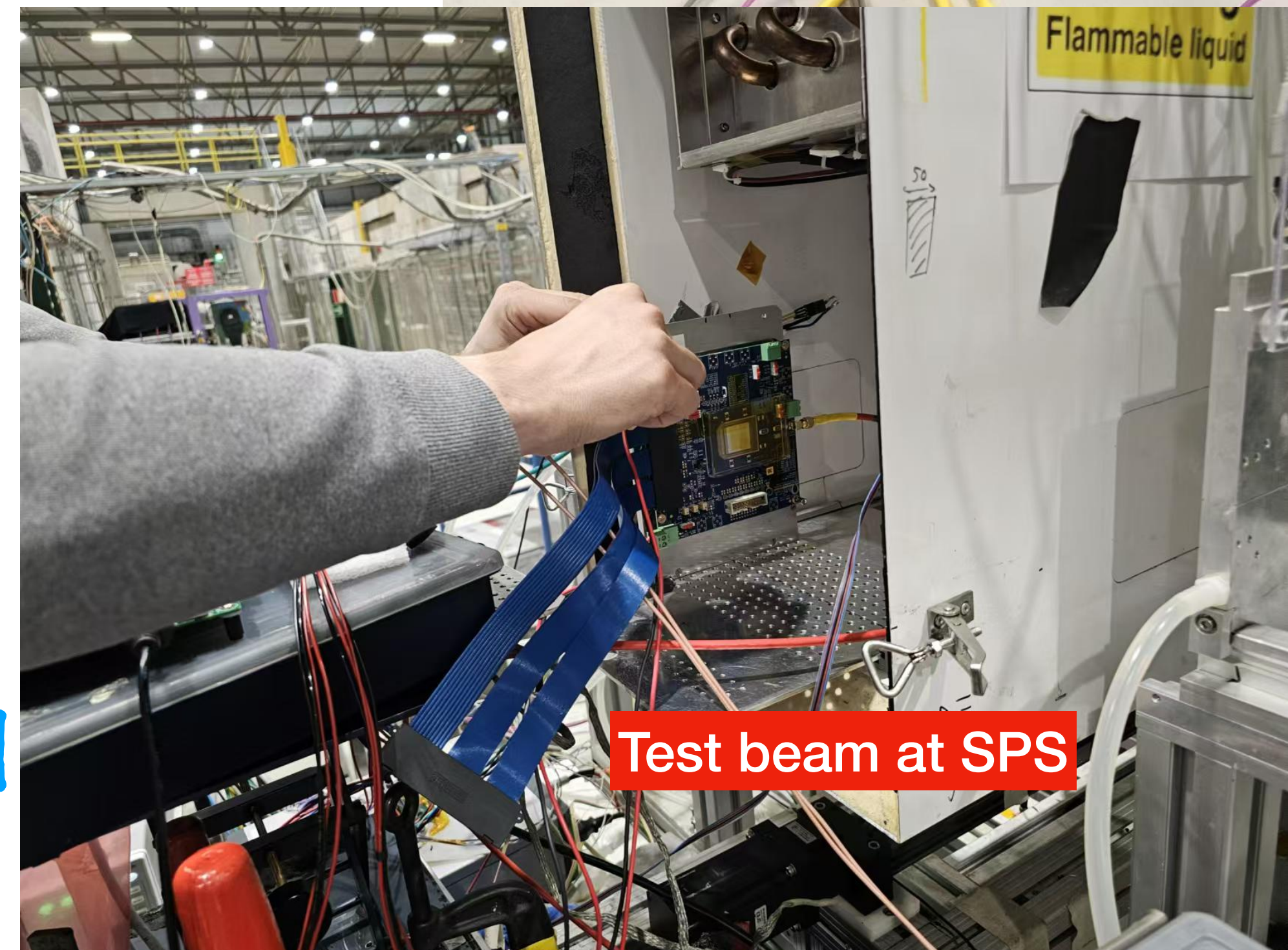
⑥ one module done, wait for glue curing

Module test

- ▶ Important performance specifications: timing resolution, lowest detectable charge...
- ▶ First module test setup in the collaboration at IHEP
- ▶ Provide most module/test boards for demonstrator/Test beam, etc
- ▶ Tuning with self-injection of Altiroc
 - ▶ Tuning TDC, threshold, etc
- ▶ Source test: Sr90, test beam
 - ▶ Validate timing resolution, etc



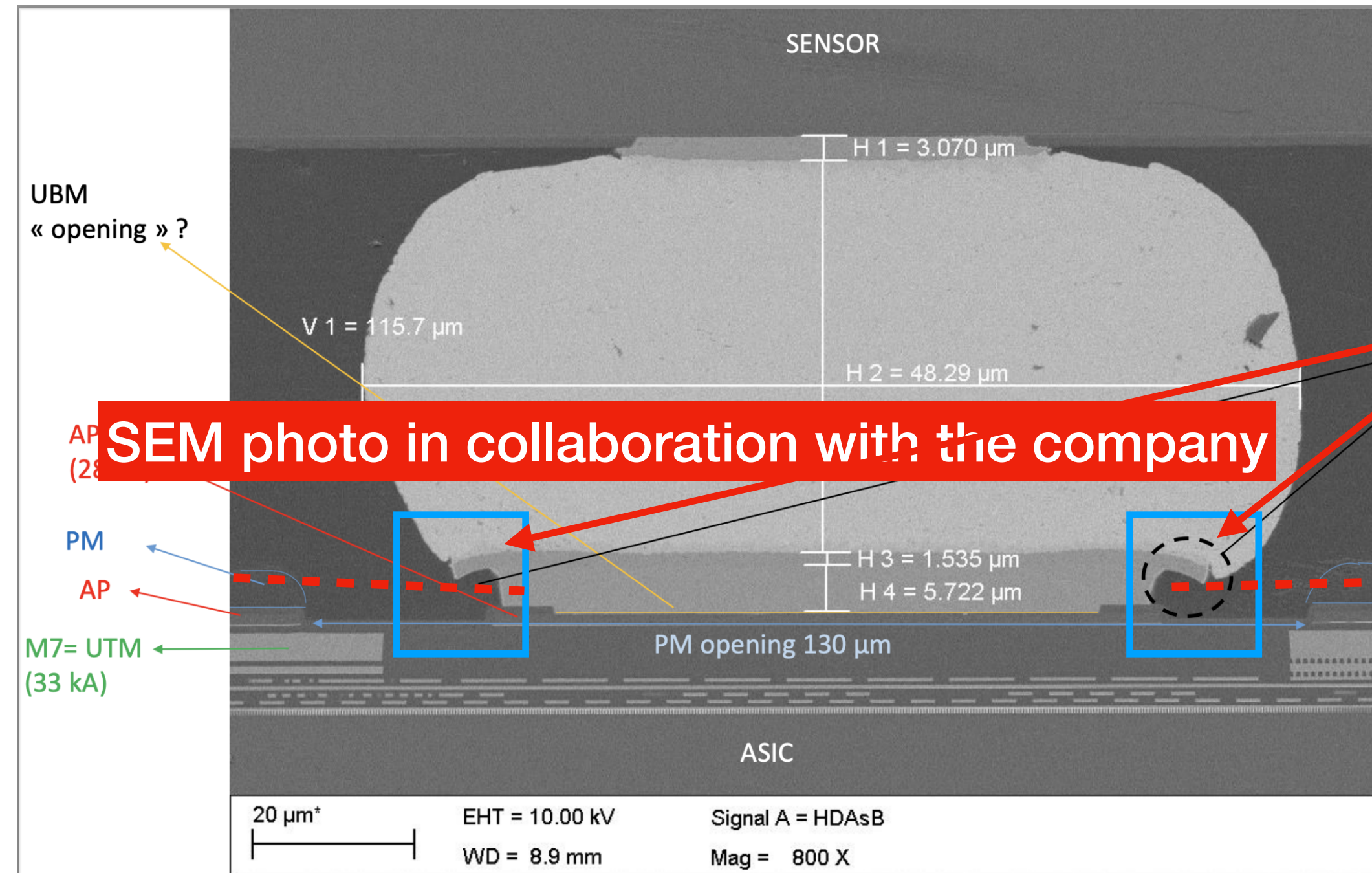
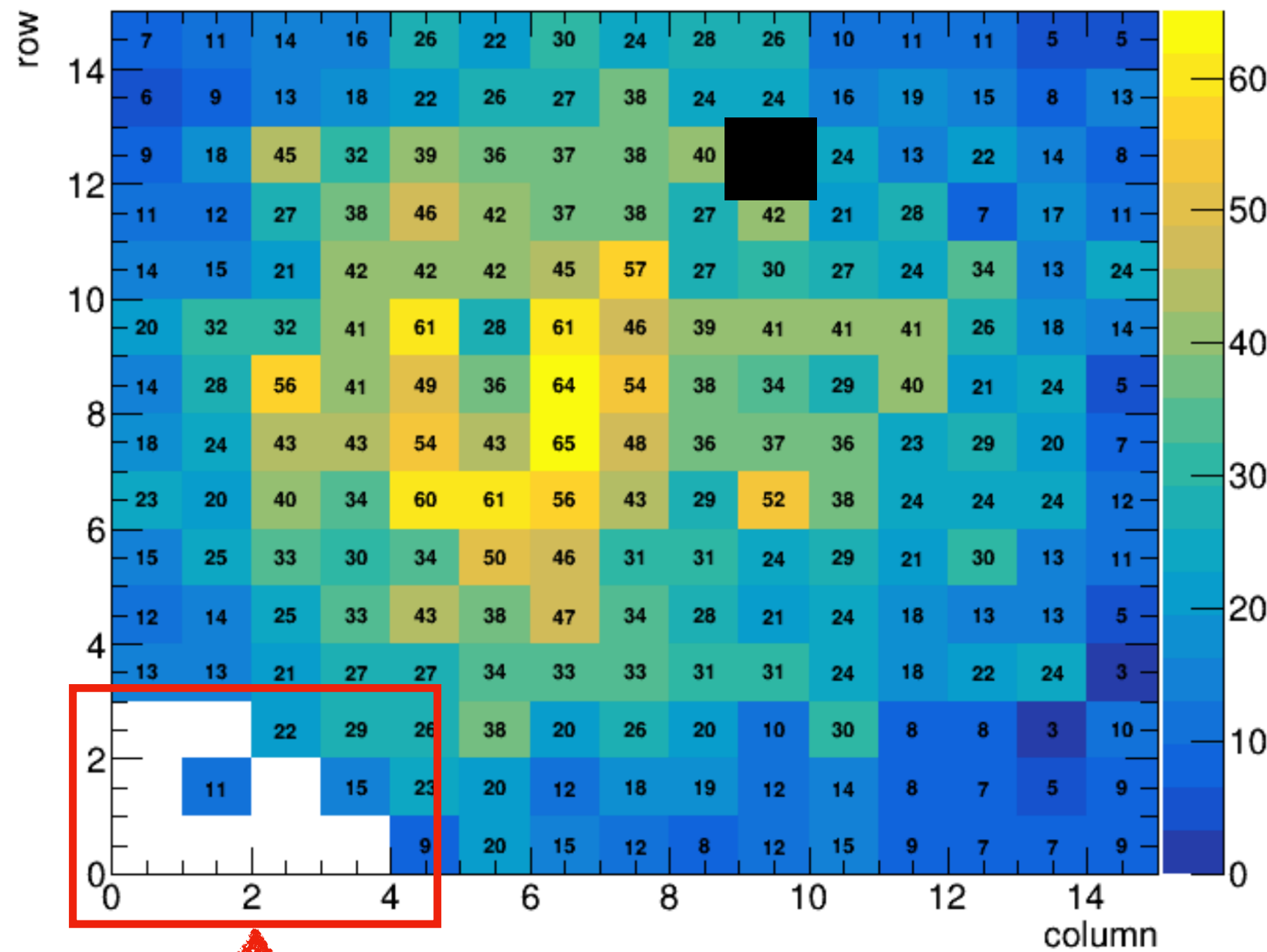
Preliminary TB result of Altiroc3 hybrid



Hybrid Quality



Occupancy

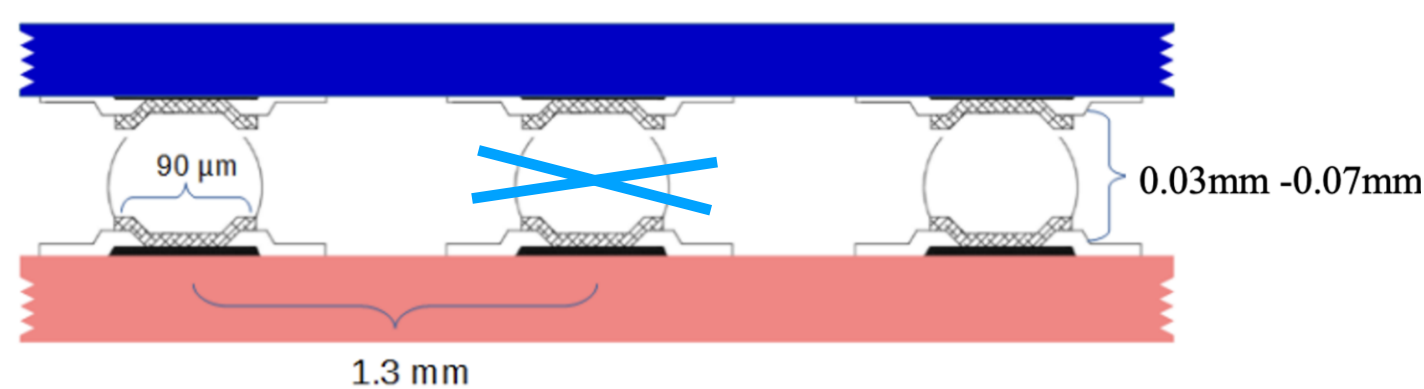


Polyamide layer should cover here

SEM photo in collaboration with the company

Observed that bumps will be destroyed after thermal cycling, one of the most critical problem towards module FDR

- Key factors leading to the issue:
- ▶ **Wrong polyamide layer deposited by TSMC**
 - ▶ TSMC only deposit their default design of polyamide layer (larger size than our requirement)
 - ▶ **Thickness of sensor, thinner sensor leads to larger remaining stress after reflow**



Hybrid Quality

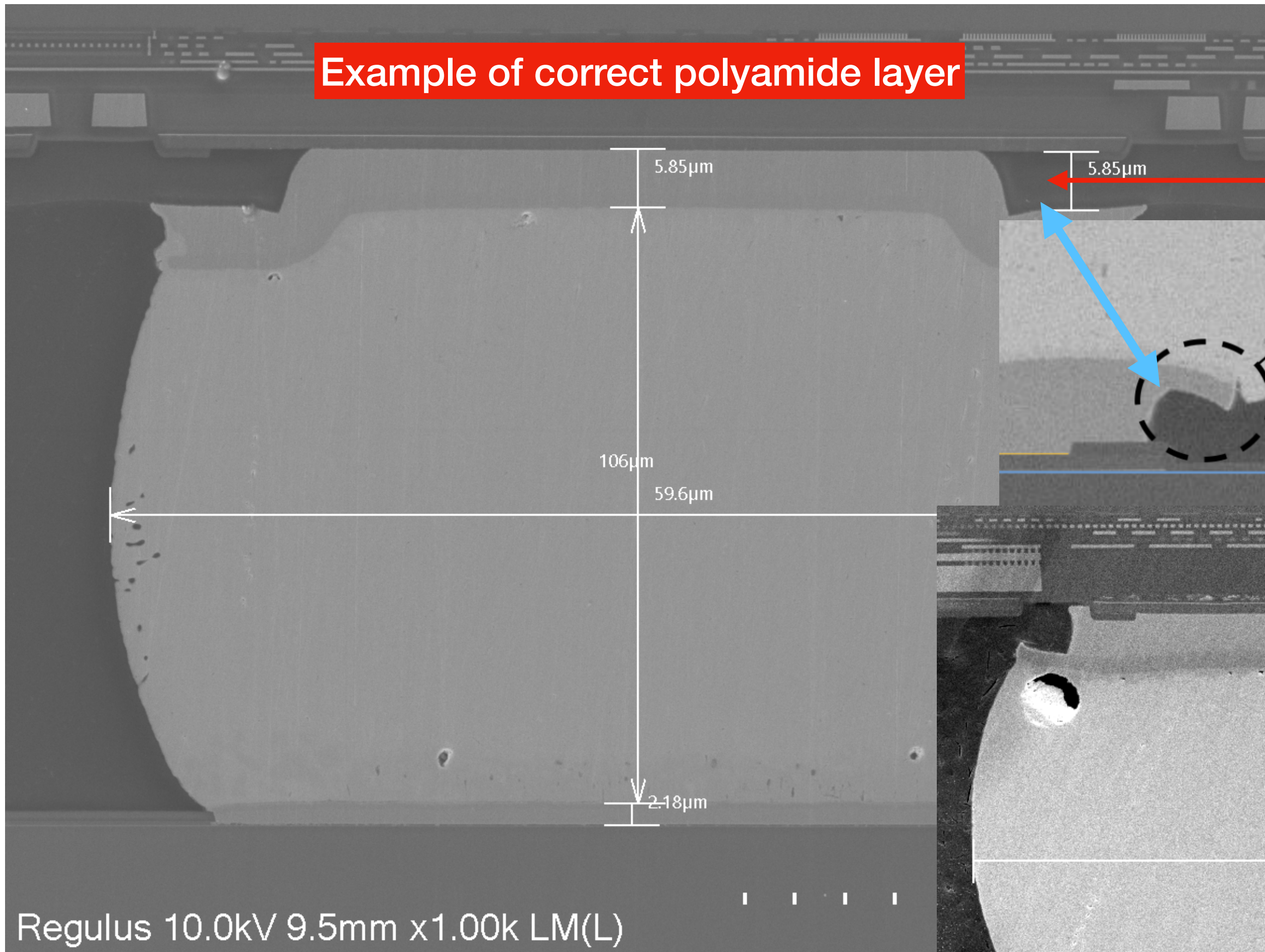


Details about thermal cycle studies in Yulong's presentation

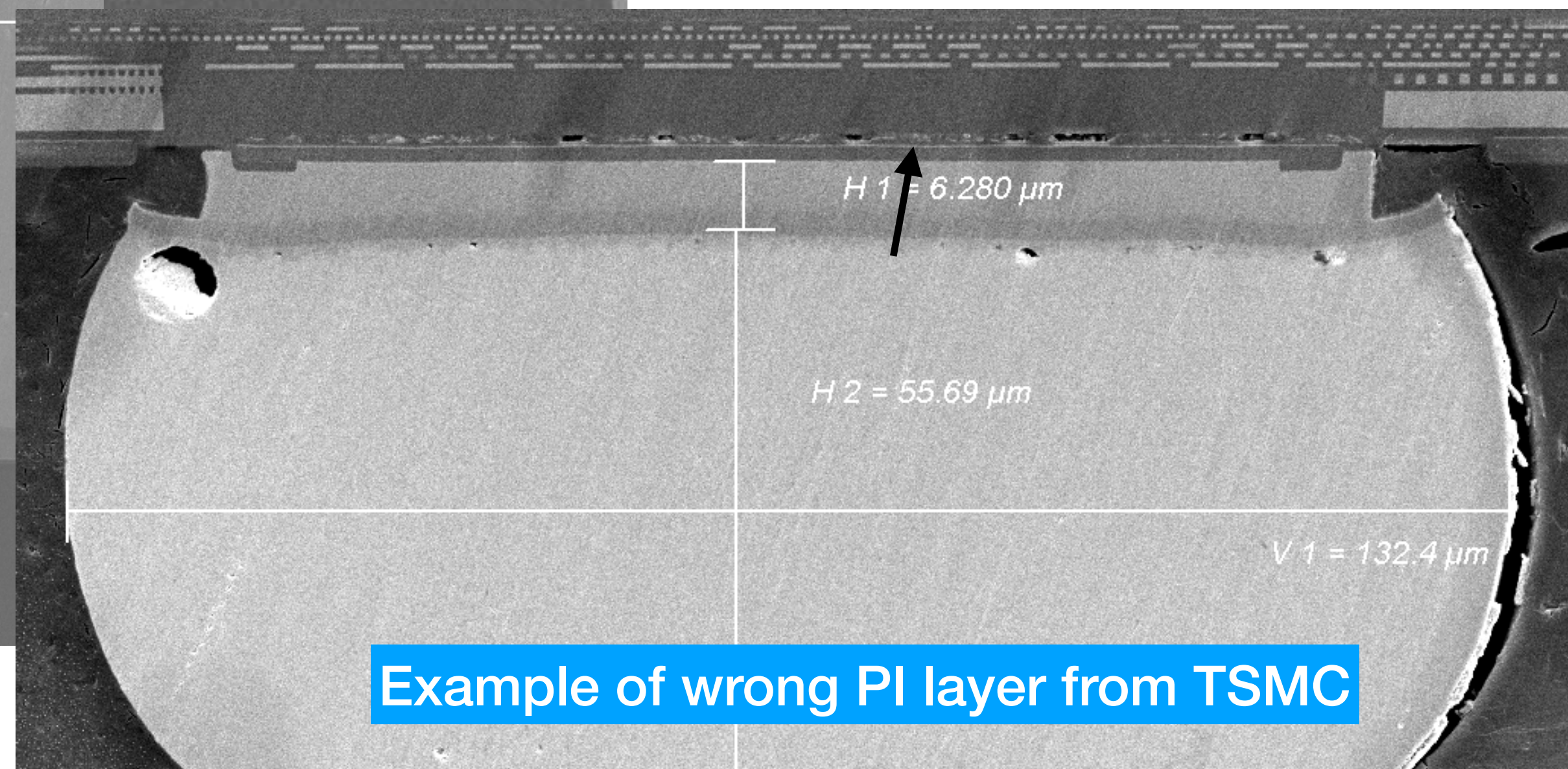
Correct PI layer can provide enough support for bump balls, making hybrid more robust.

Correct PI layer deposited by domestic company, significantly improved quality of hybrids

Example of correct polyamide layer



Example of wrong PI layer from TSMC



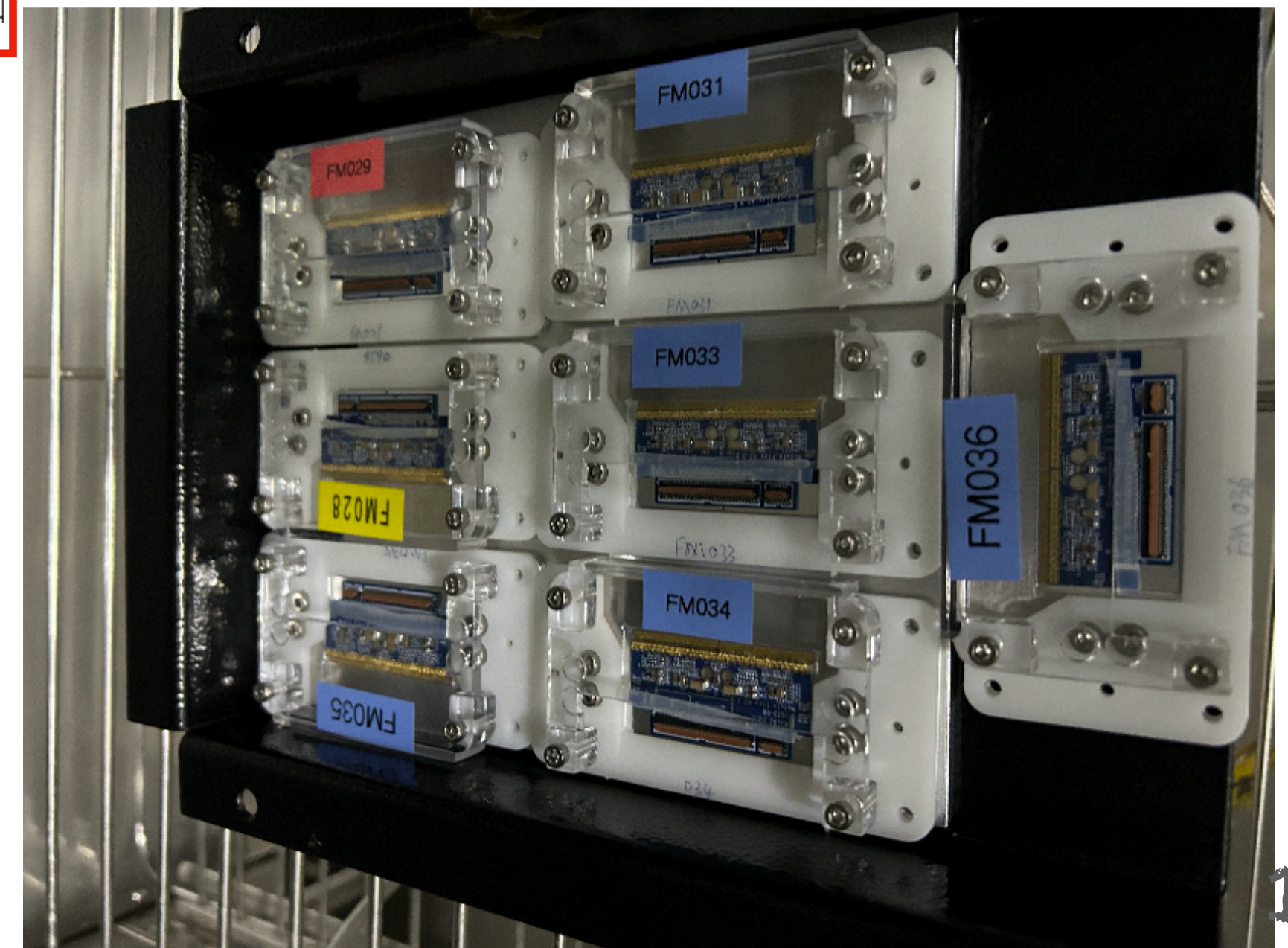
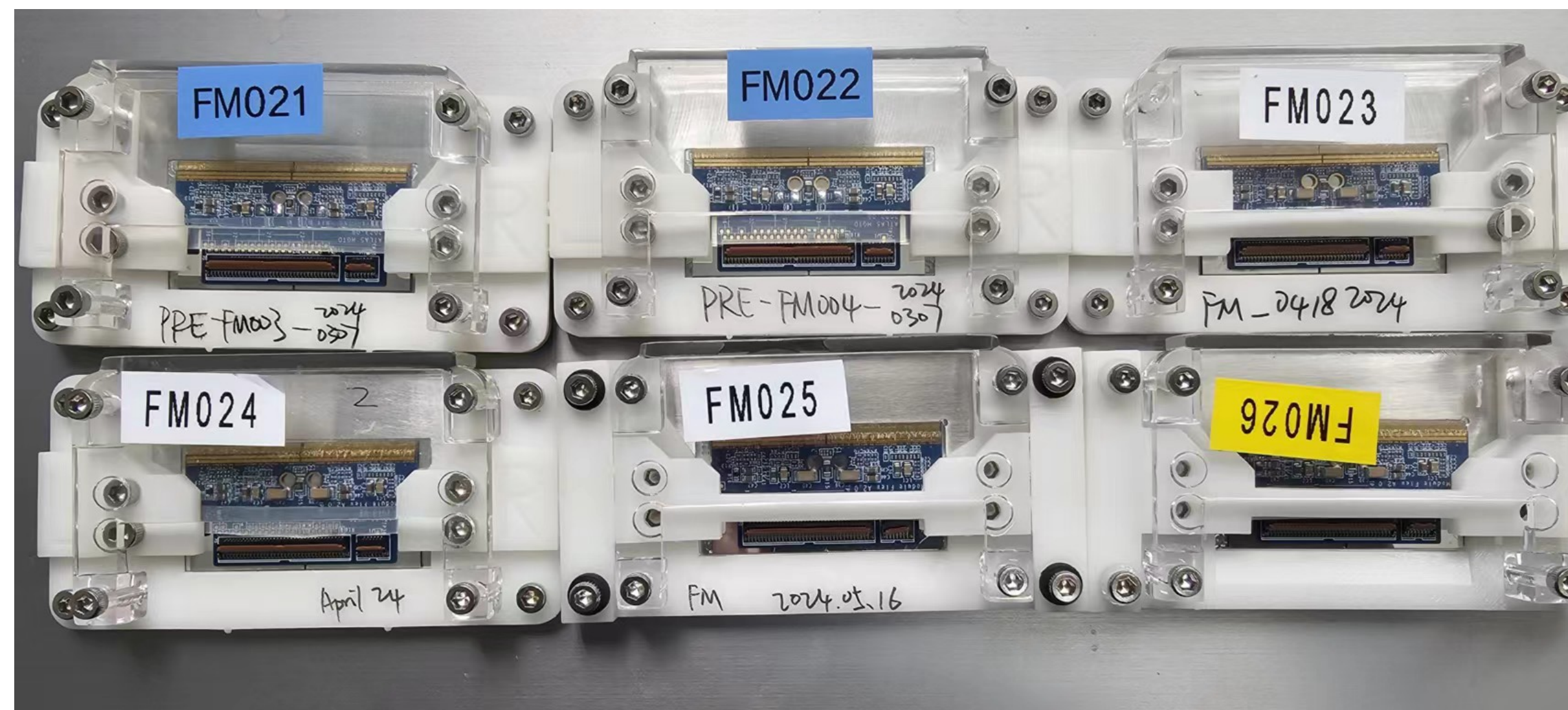
Module Assembled at IHEP



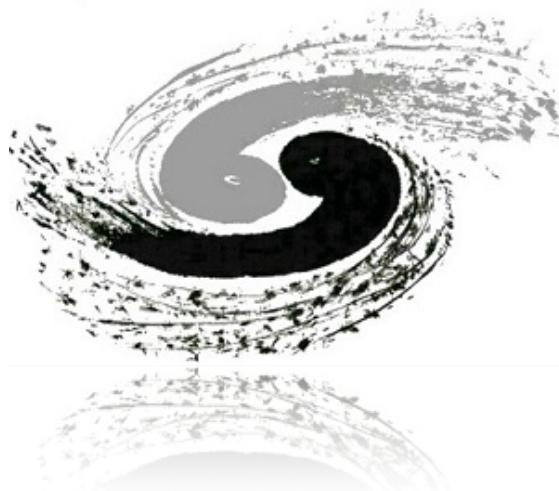
	ASIC Version	ASIC UMB/Balling	LGAD Size	WB	Functionality	Bump status
FM028	ALTIROC3	PWCHIP	Thick	OK	Both chip working	All connected (after 30 cycles)
FM029	ALTIROC3	PWCHIP	Thick	OK	Both chip working	All connected (after 30 cycles)
FM031	ALTIROC3	PWChip	Thick	OK	Both chip working	All connected (after 30 cycles)
FM033	ALTIROC3	PWChip	Thick	OK	Both chip working	All connected (after 30 cycles)
FM034	ALTIROC3	PWChip	Thick	OK	Both chip working	All connected (after 30 cycles)

We have been able to produce small amounts of prototype bare modules with good quality using the gantry system, which is a milestone towards the production

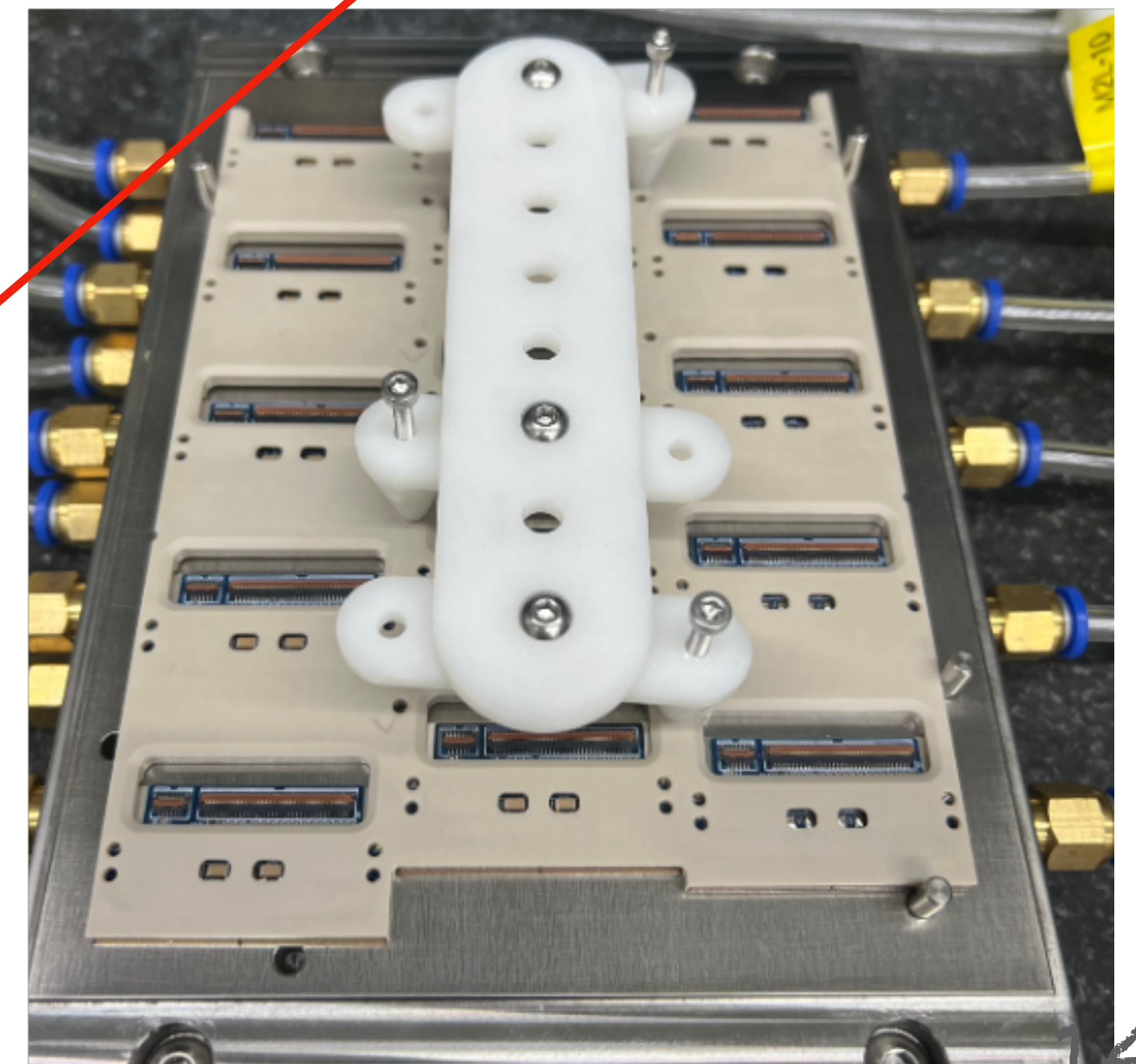
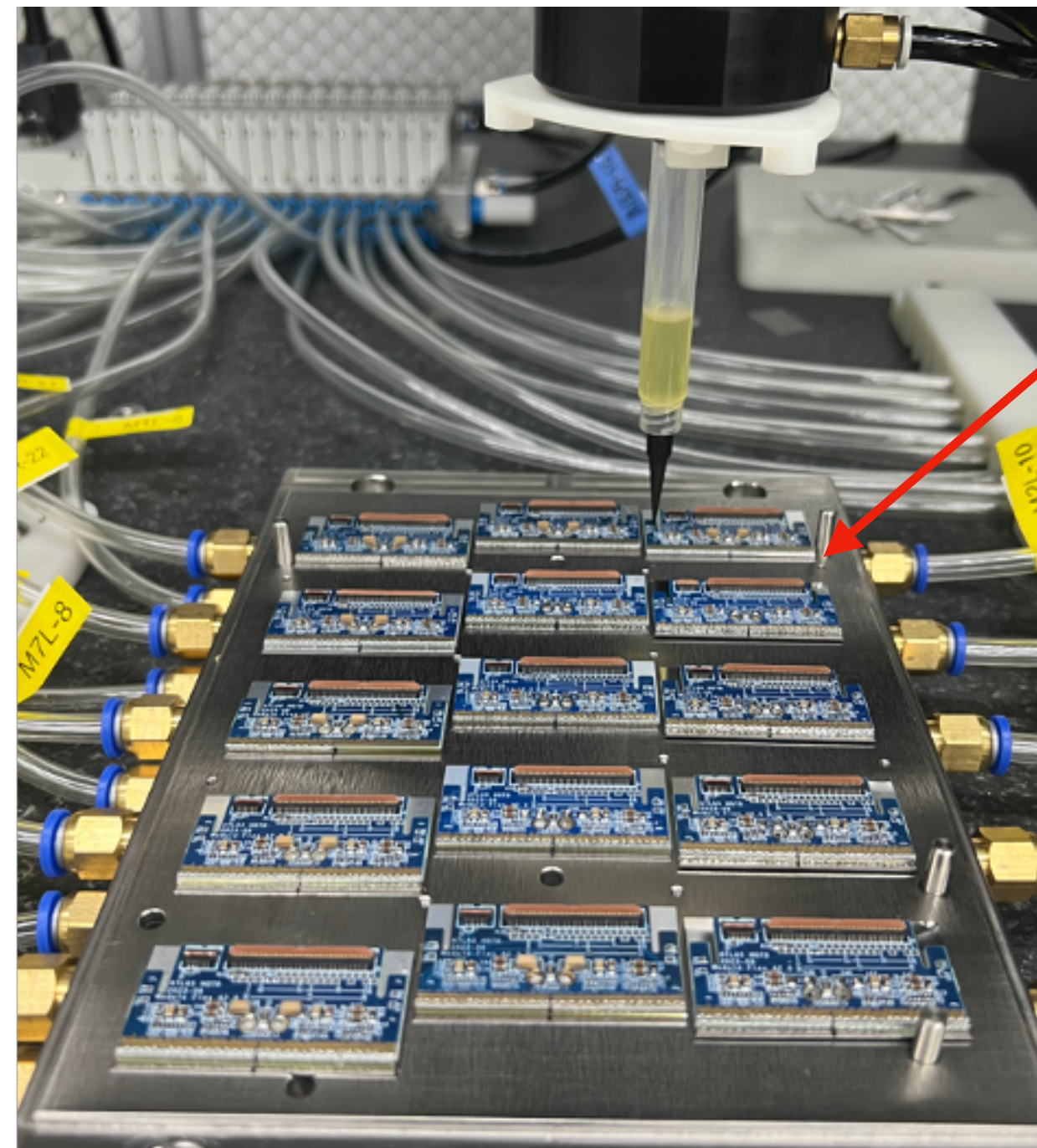
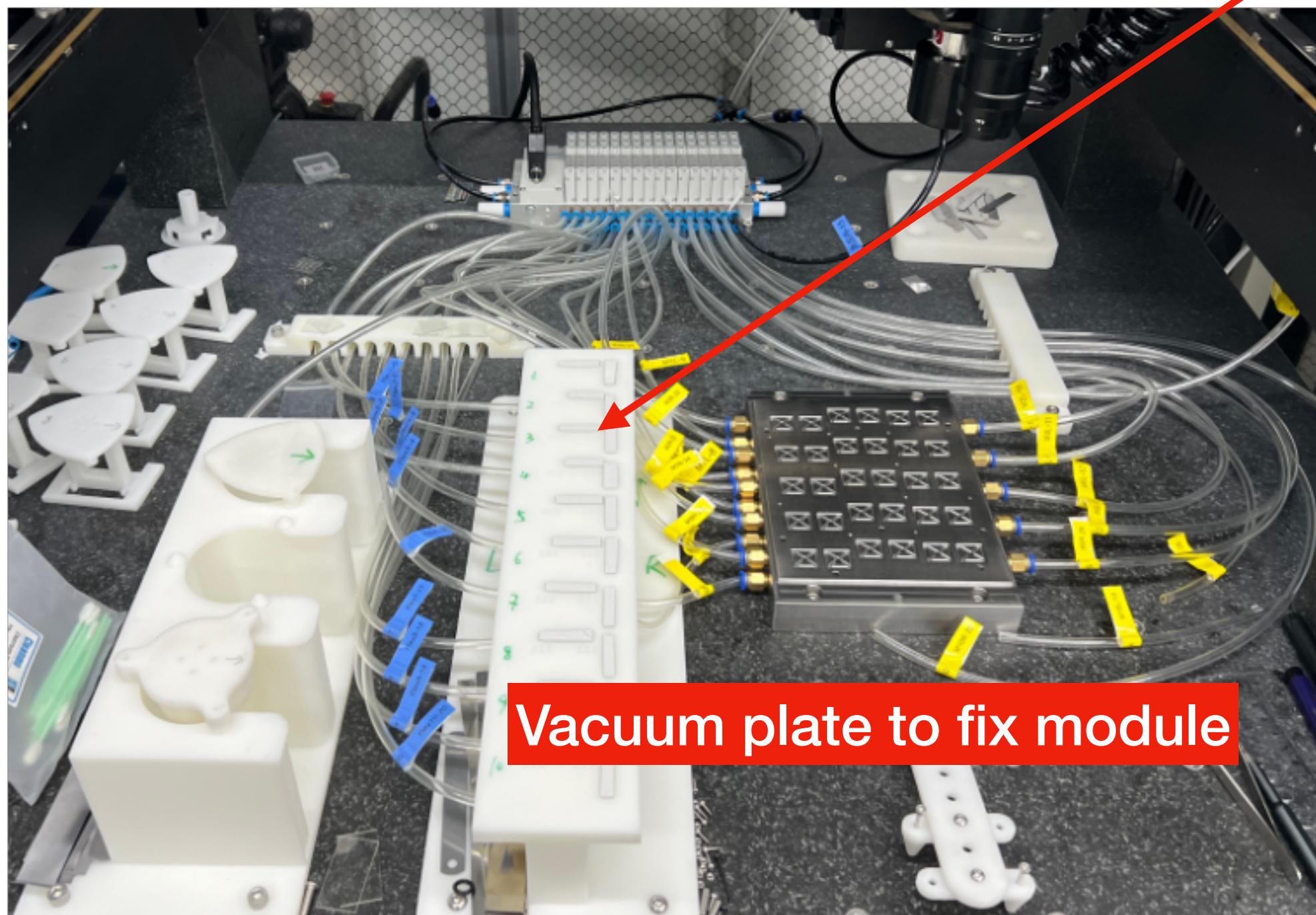
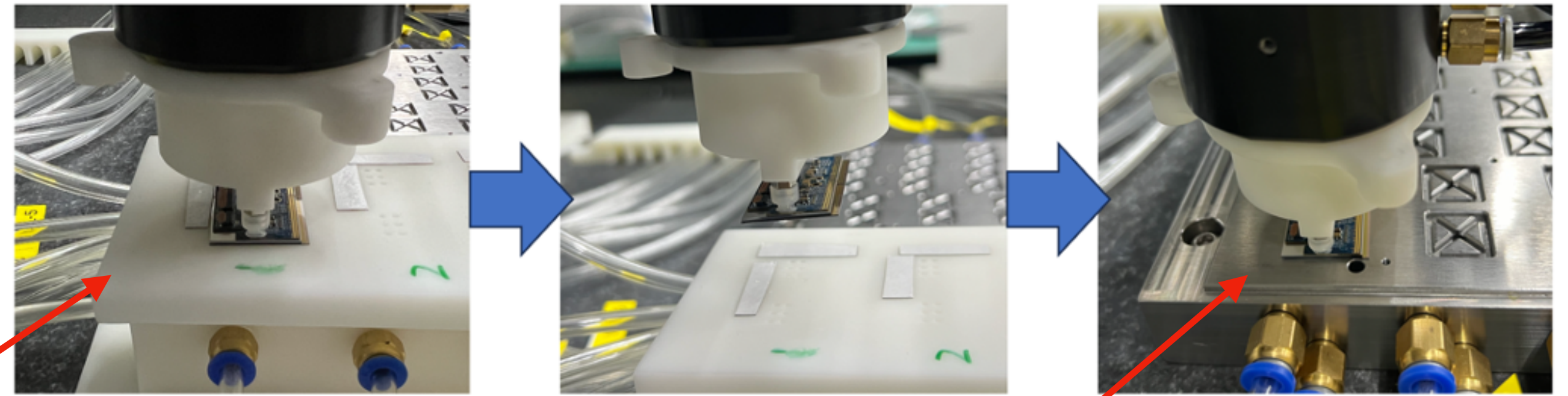
More than 50 modules assembled, leading in the collaboration



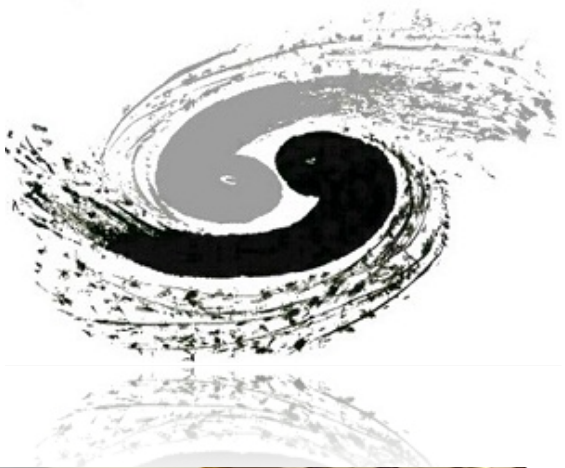
Detector Loading



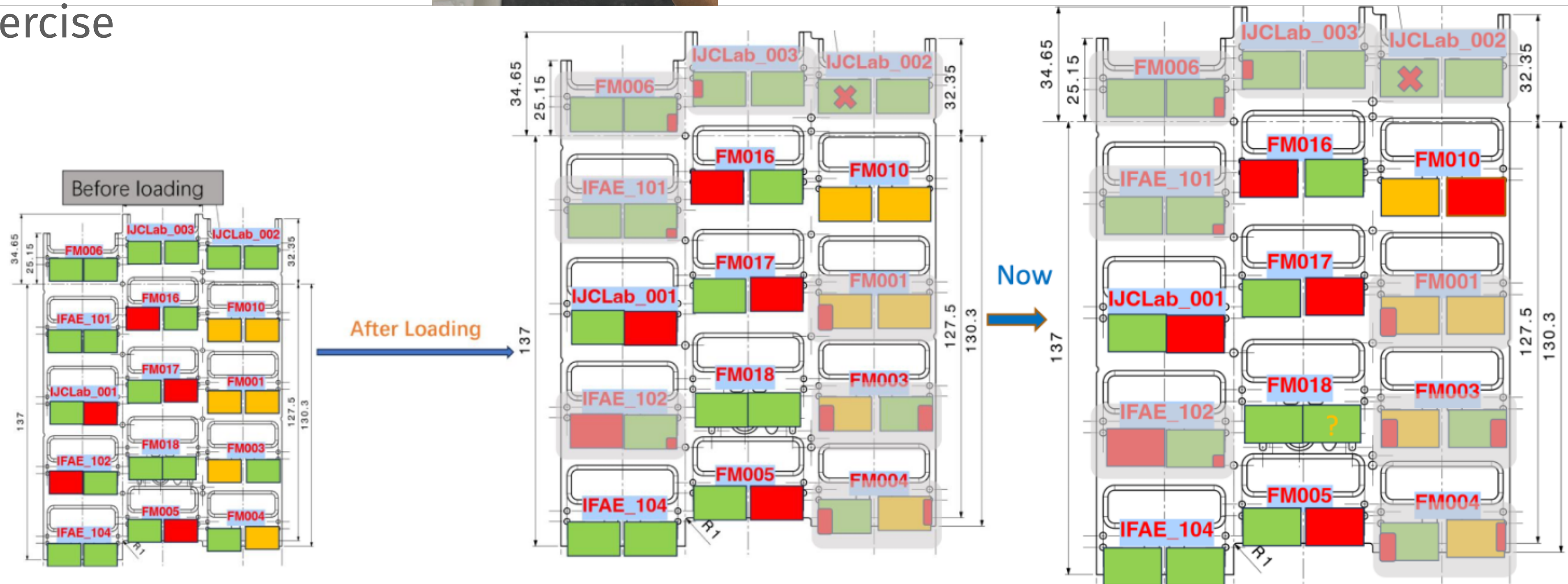
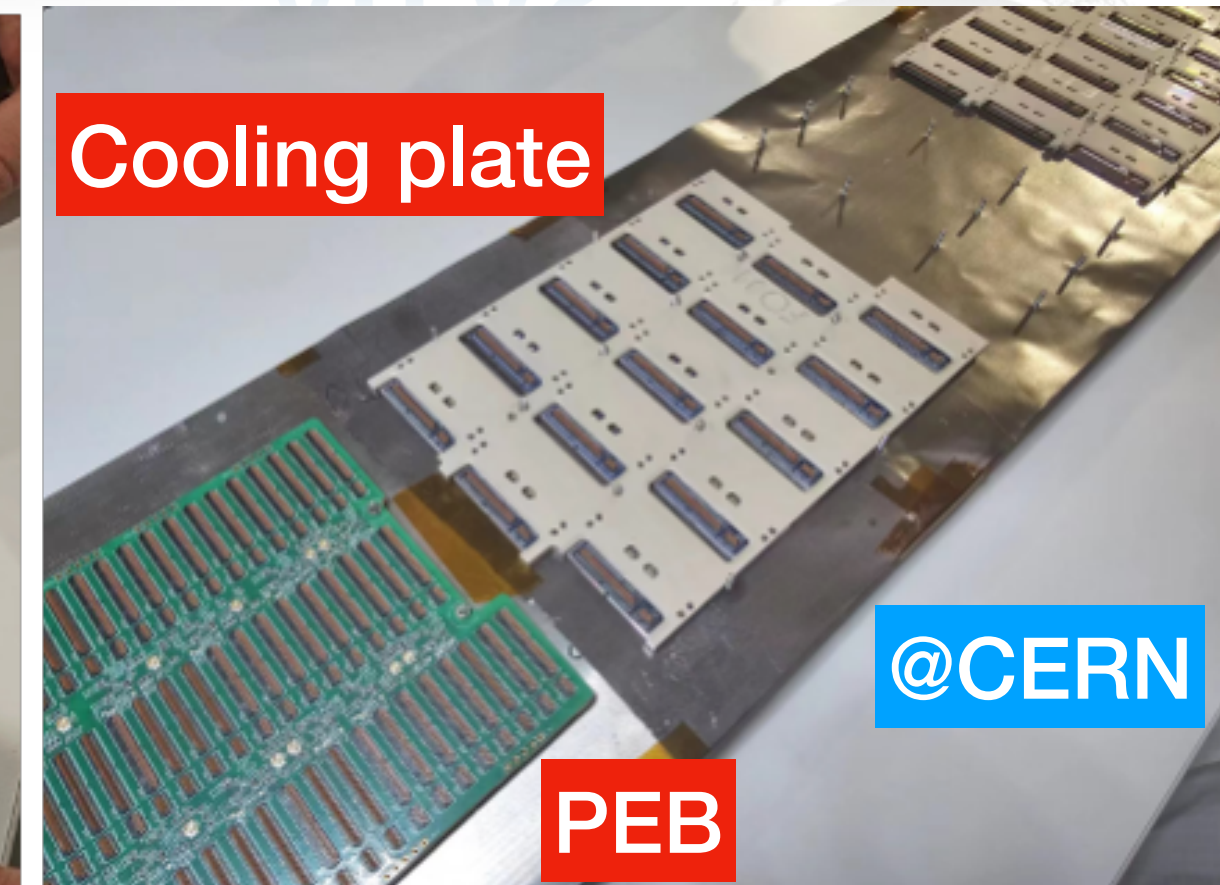
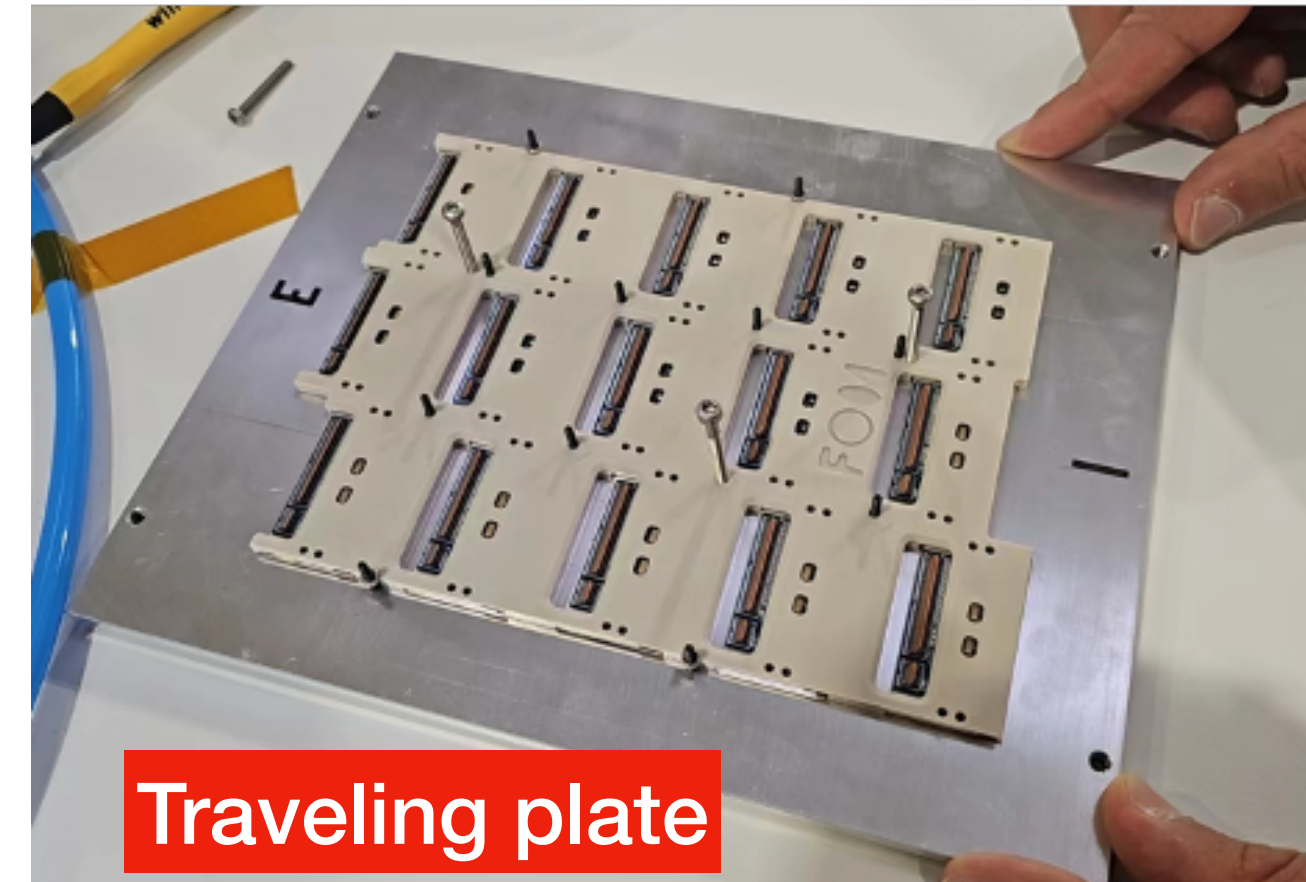
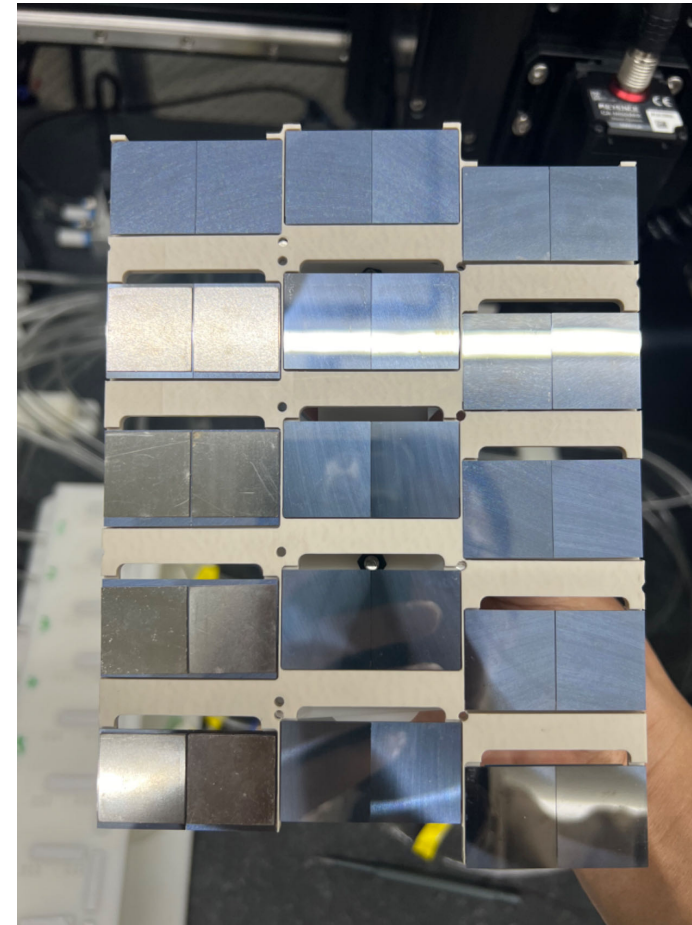
- Detector unit loading is another important task at the assembly site
- 2~3 DU loaded per week at IHEP
- Using the same gantry system, but changing the relevant tools



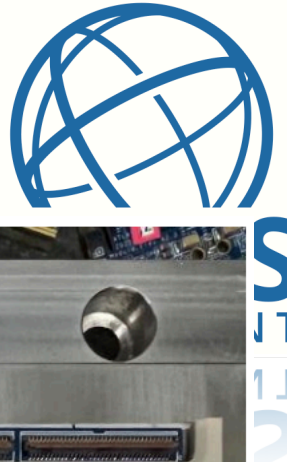
First DU Loaded at IHEP



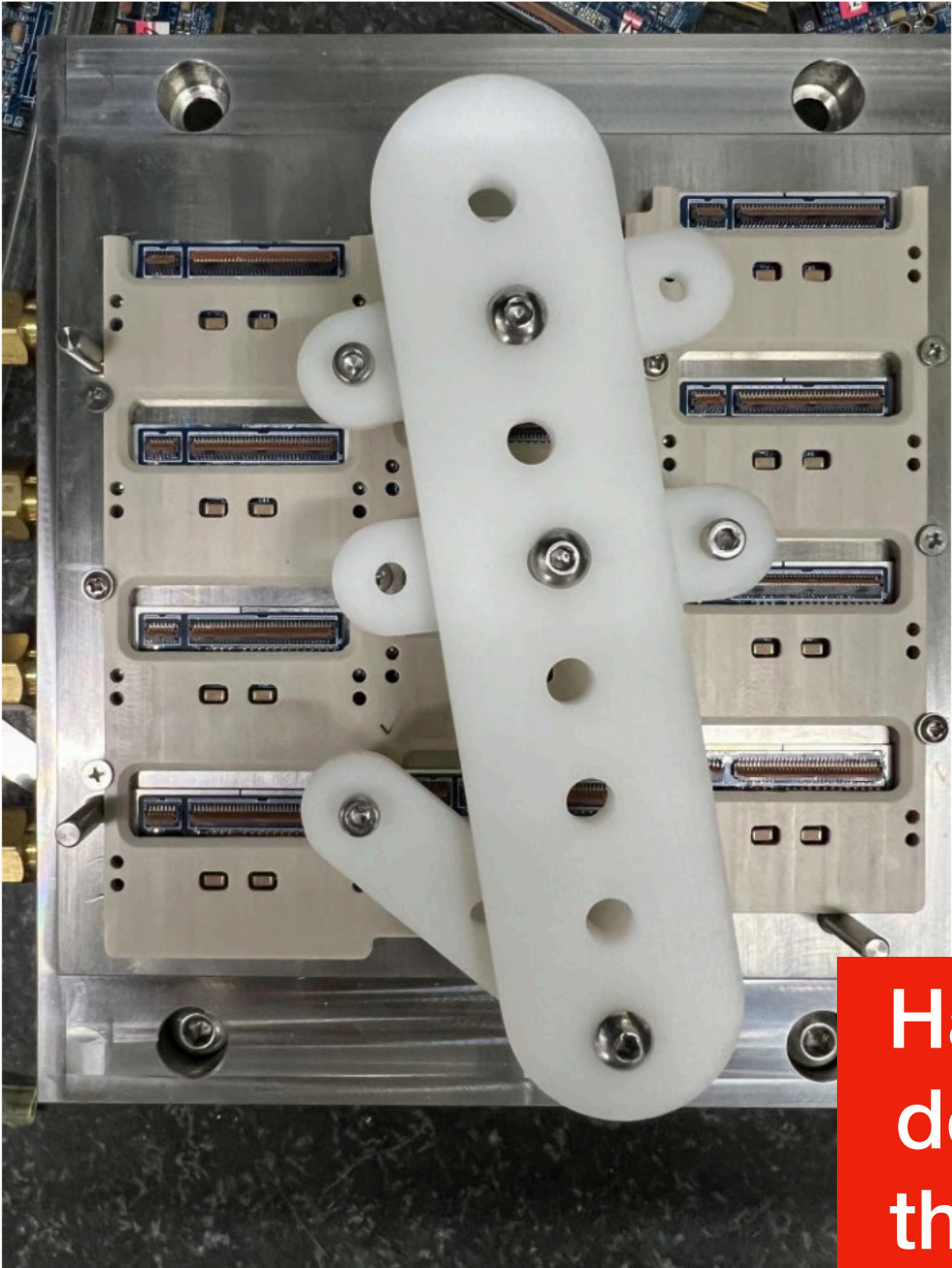
- First Altiroc3 (latest prototype) DU loaded at IHEP in April 2024.
- Brought to CERN for installation exercise, mechanic tests and PEB tests
- Quality is not ideal, but enough for a first exercise



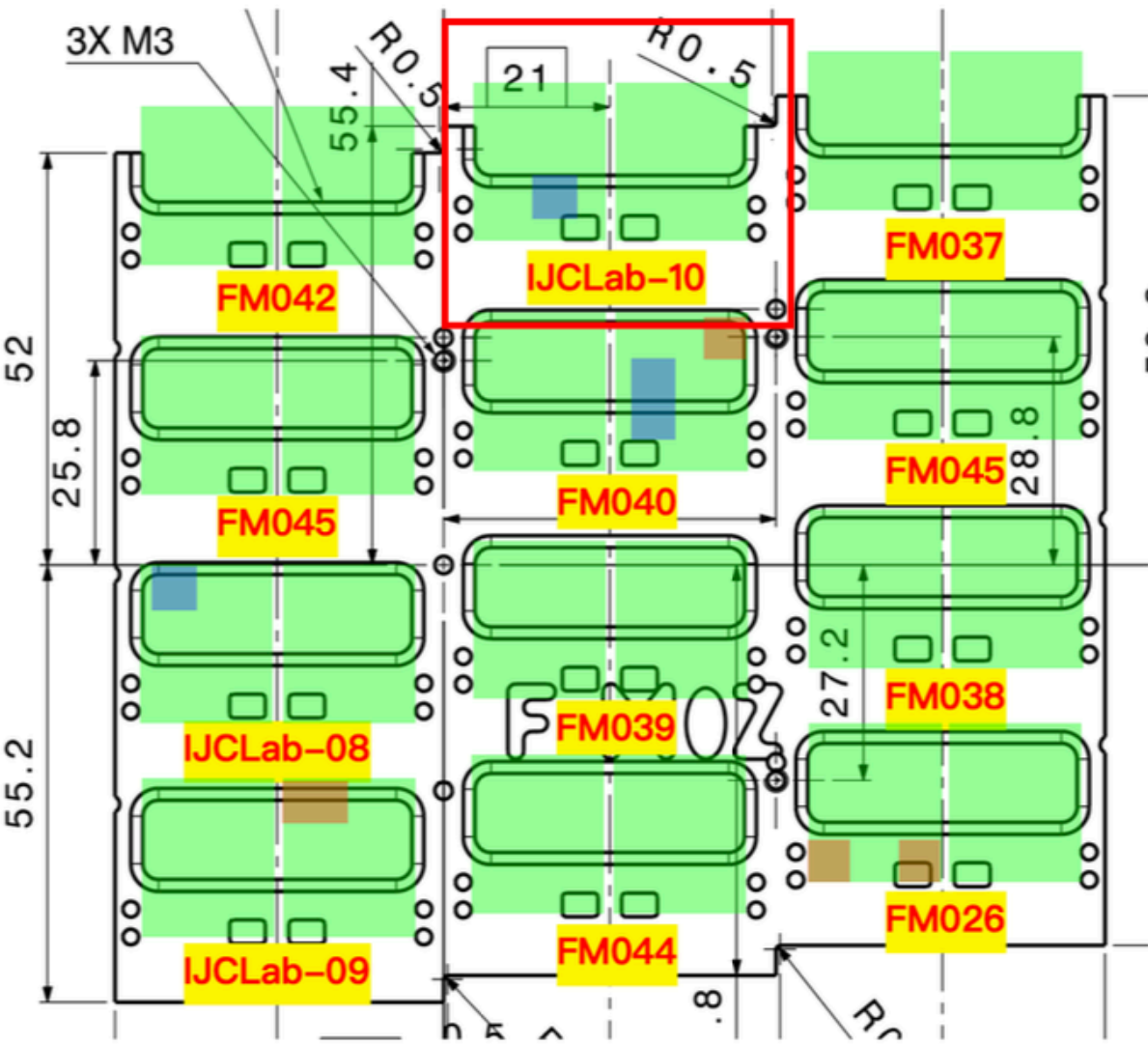
Second DU



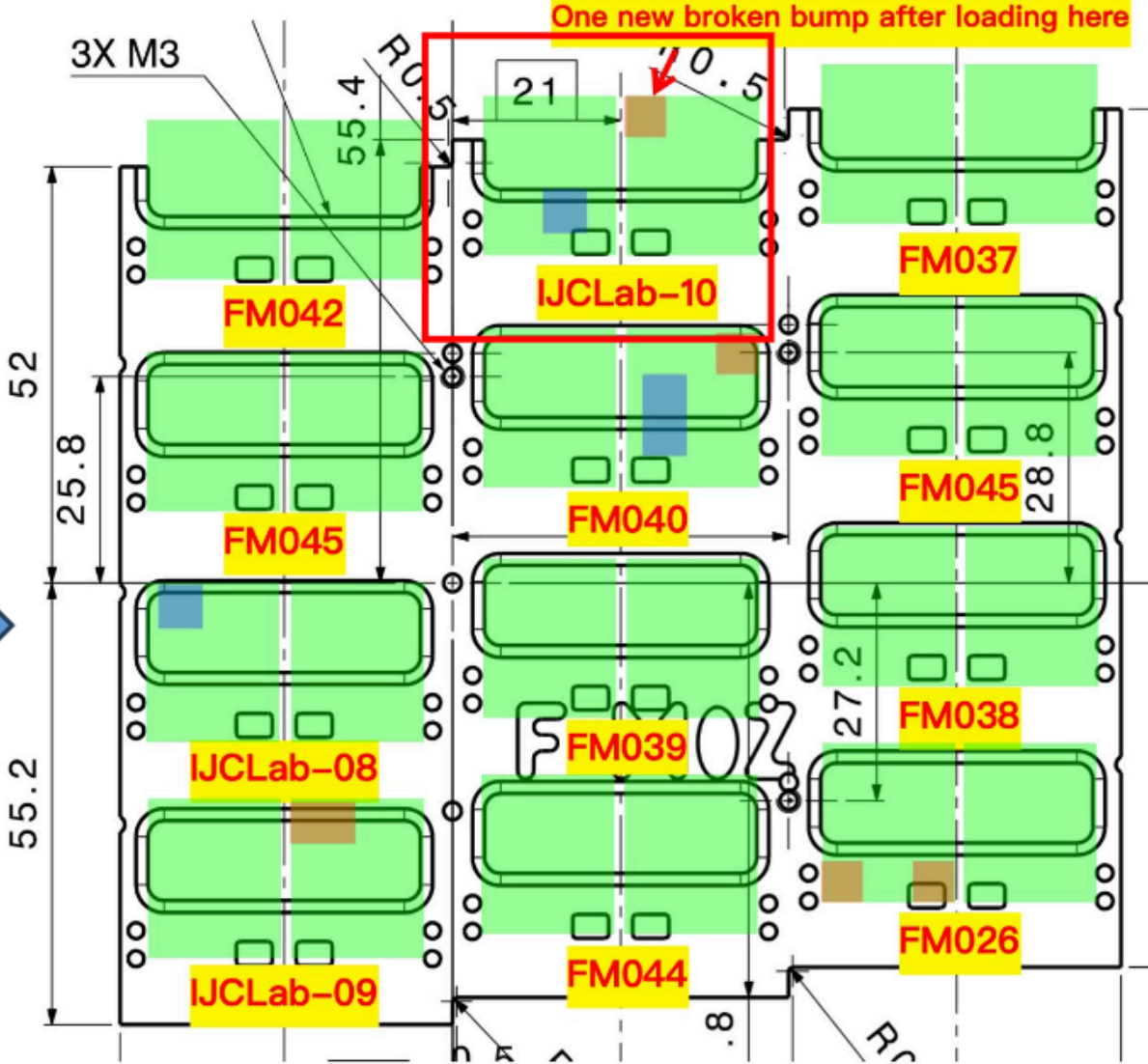
- The second DU loaded at IHEP in Nov. 2024
- Using a improved algorithm to recognize the position
- Much better position precision and metrology than the first one
- Much smaller damage to modules after loading
- Under testing at CERN by the demonstrator team



Handler to push down or pull up the support unit

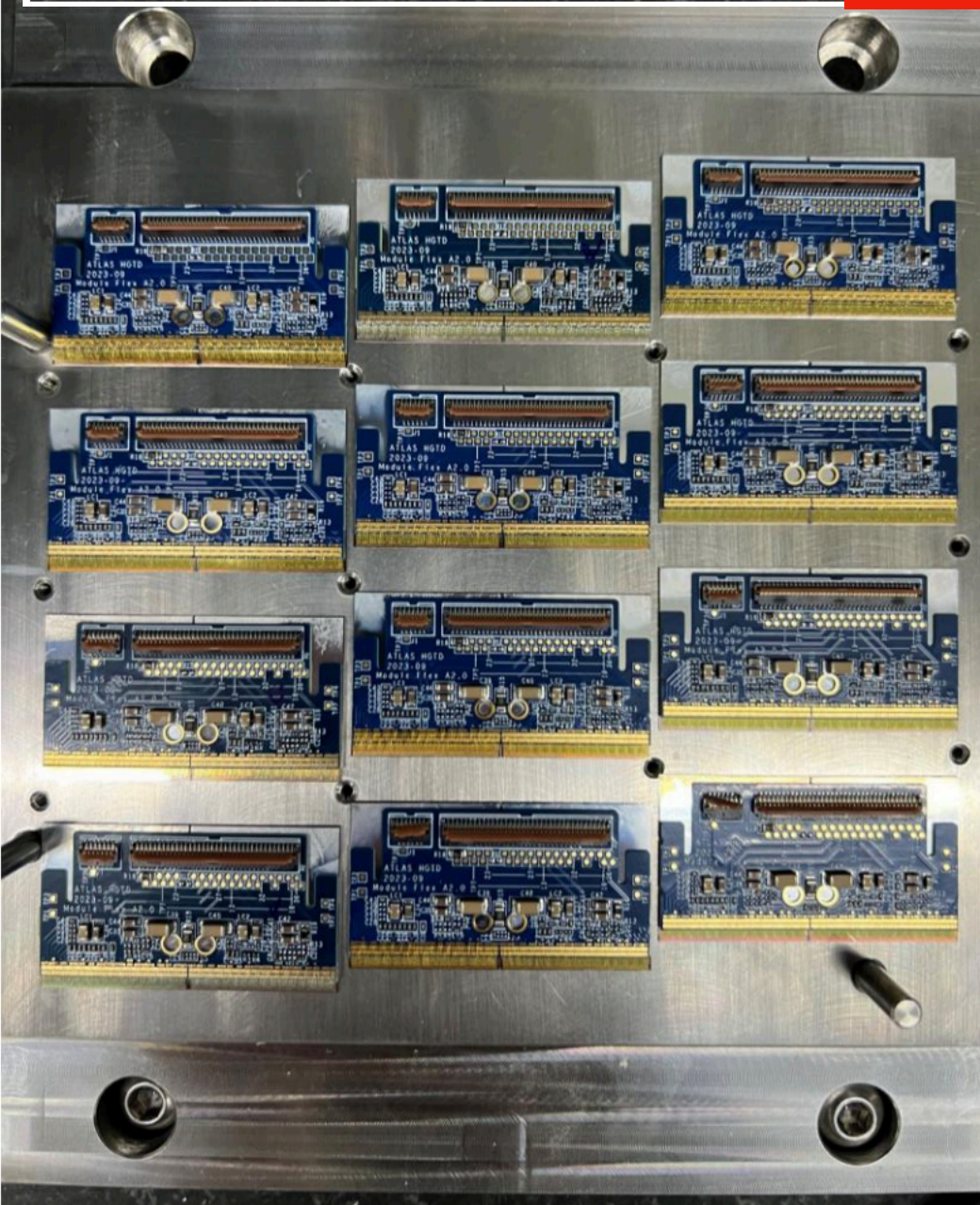


After loading



■ Good hybrid
■ Has masked pixel (only 1-2 pixel)
■ Has disconnected bump (only 1-2 pixel)

■ Good hybrid
■ Has masked pixel (only 1-2 pixel)
■ Has disconnected bump (only 1-2 pixel)



Summary



- ▶ We have developed an automatic assembly and loading system for HGTD detector production at IHEP
- ▶ We've been playing a leading role in several key tasks toward module FDR
- ▶ FDR happened in the end of October, we are now starting pre-production

	IHEP	USTC	IFAE	IJCLab / LPNHE	Mainz	MAScIR
Gluing	✓	✓	✓	✓	✓	✓
Wire bonding	✓	✓	✓	✓	✓	Partial WB (process tuning ongoing)
DAQ testing	✓	✓	✓	✓	✓	✓
Loading	✓	Tests with glass dummies	To do	✓	Tests with glass dummies	To do
STAGE 1.0 (pre-qualif.)	✓ (3/3)	✓ (3/3)	✓ (3/3)	✓ (3/3)	2/3	0/3

