



中國科學院高能物理研究所  
*Institute of High Energy Physics, Chinese Academy of Sciences*

# Development of ATLAS ITk Strip Detector for LHC Phase-II Upgrade

**Speaker: Chengwei Wang 王成伟**

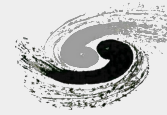
**On behalf of China ATLAS ITk Group**

**November 16, 2024**

*The 10th China LHC Physics Conference (CLHCP2024), November 14~17, 2024, Qingdao*



# LHC Phase-II Upgrade & ATLAS ITk



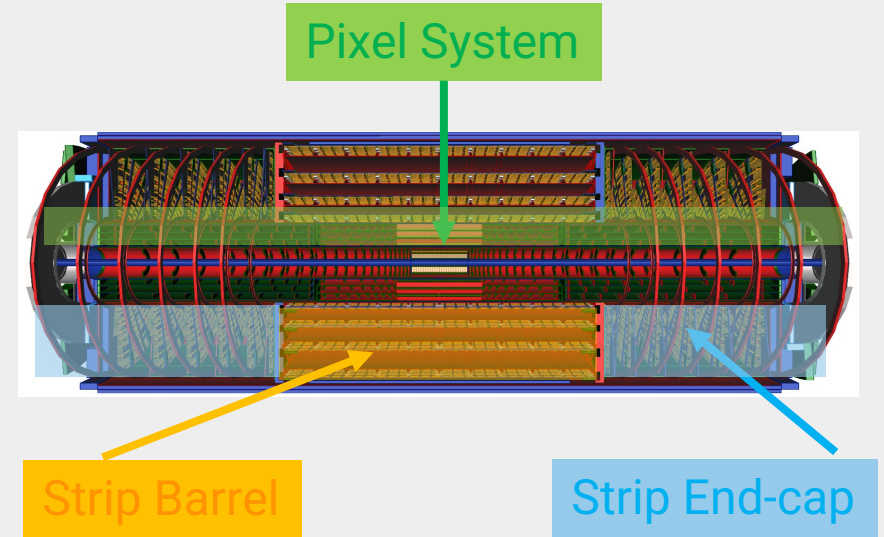
中国科学院高能物理研究所  
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## ✓ LHC Phase-II (HL-LHC) upgrade

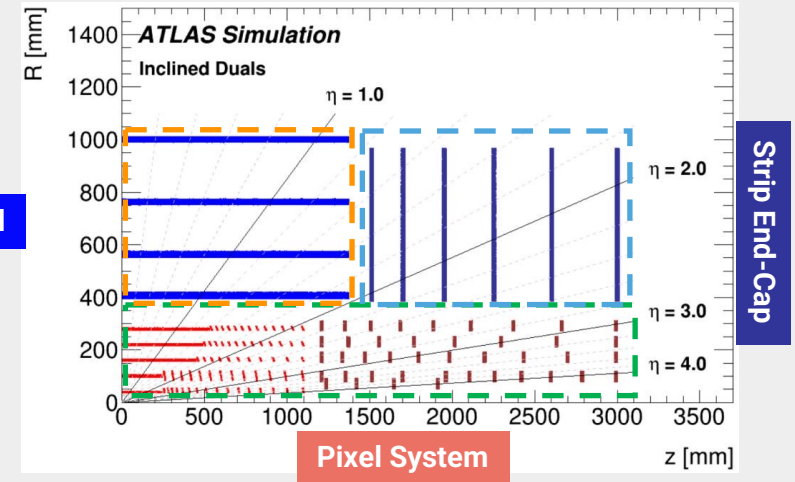
- Instantaneous luminosity up to  $7.5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$
- Integrated luminosity up to 3000 ~ 4000  $\text{fb}^{-1}$
- Up to 200 p-p collision per bunch crossing (**pileup**)
- 10 times higher radiation

## ✓ All-silicon New Inner Tracker (ITk)

- Higher radiation tolerance to deal with ionization from 300K Gy (ID) to 10M Gy
- Higher granularity to keep occupancy below 1%
- Faster response
- Reduced material budget



Strip Barrel

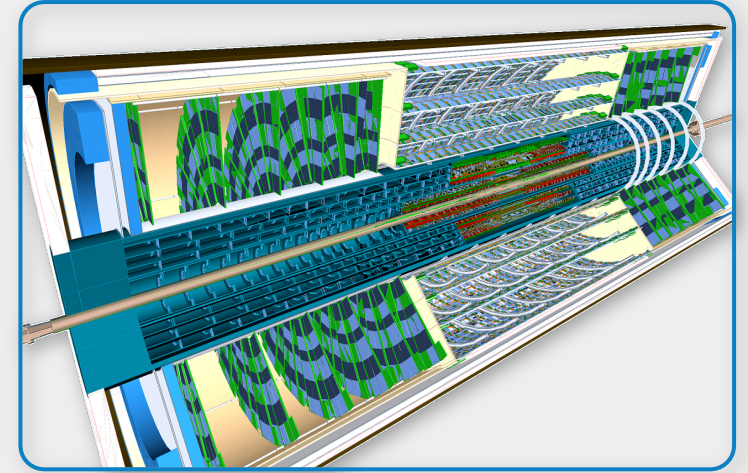




# LHC Phase-II Upgrade & ATLAS ITk

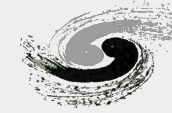
## ✓ IHEP Objectives

- Radiation hard sensor and readout ASIC study
  - Check Yingjun's presentation: [ATLAS ITk Strip Sensor Irradiation at CSNS](#)
  - Check Yan & Weiguo's presentation: [Radiation effects of ASICs for ATLAS ITk strip upgrade](#)
- High performance strip detector module production
  - IHEP and THU committed to deliver ~1000 strip barrel modules (10 m<sup>2</sup> of sensor surface)
  - 10% of total strip barrel modules (US 50% + UK 40%)
- Complex silicon detector system integration



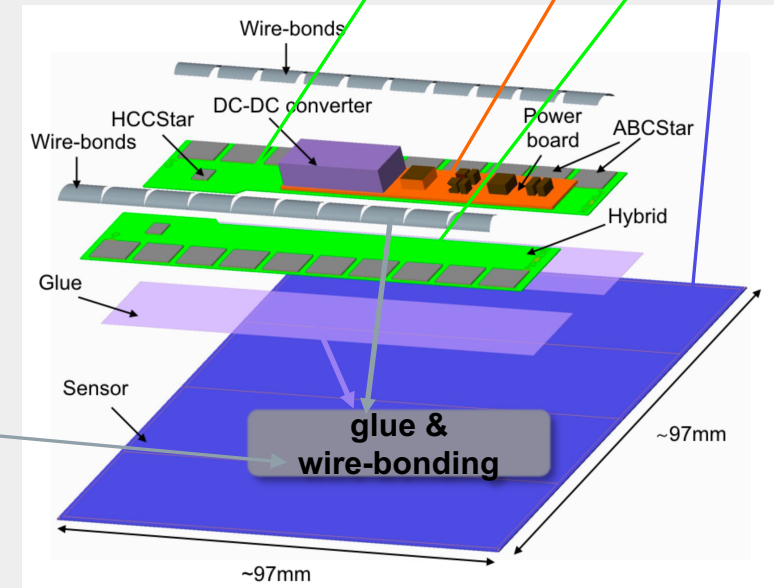
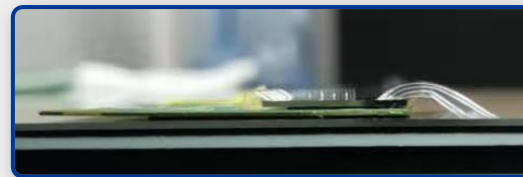
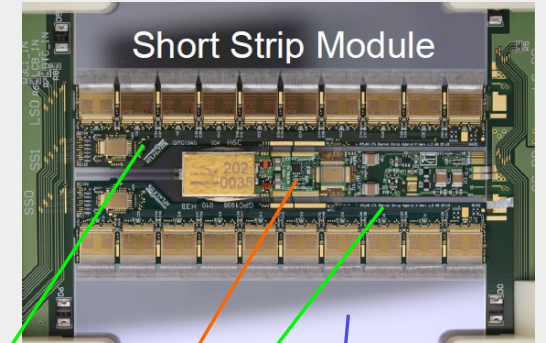
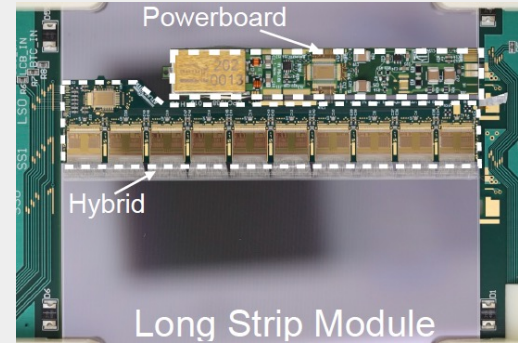


# ITk Detector Element



## ✓ Module

- **Sensor**
  - LS: 48.2 mm / SS: 24.1 mm strip
- **Hybrid**
  - ABCStar: **A**TLAS front-end **B**inary read-out **C**hip
  - HCCStar: **H**ybrid **C**ontroller **C**hip
- **Powerboard**
  - AMAC: monitor and control
  - bPOL12V: low-voltage regulation
  - linPOL12V: both voltages for AMAC
  - HVmux: high-voltage switching







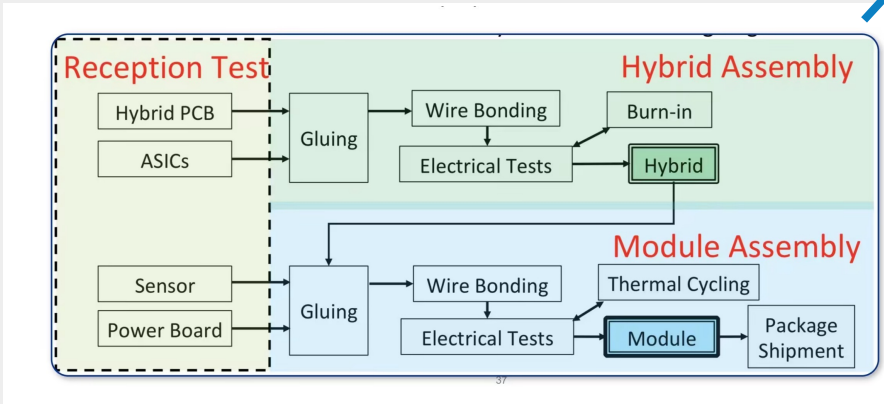
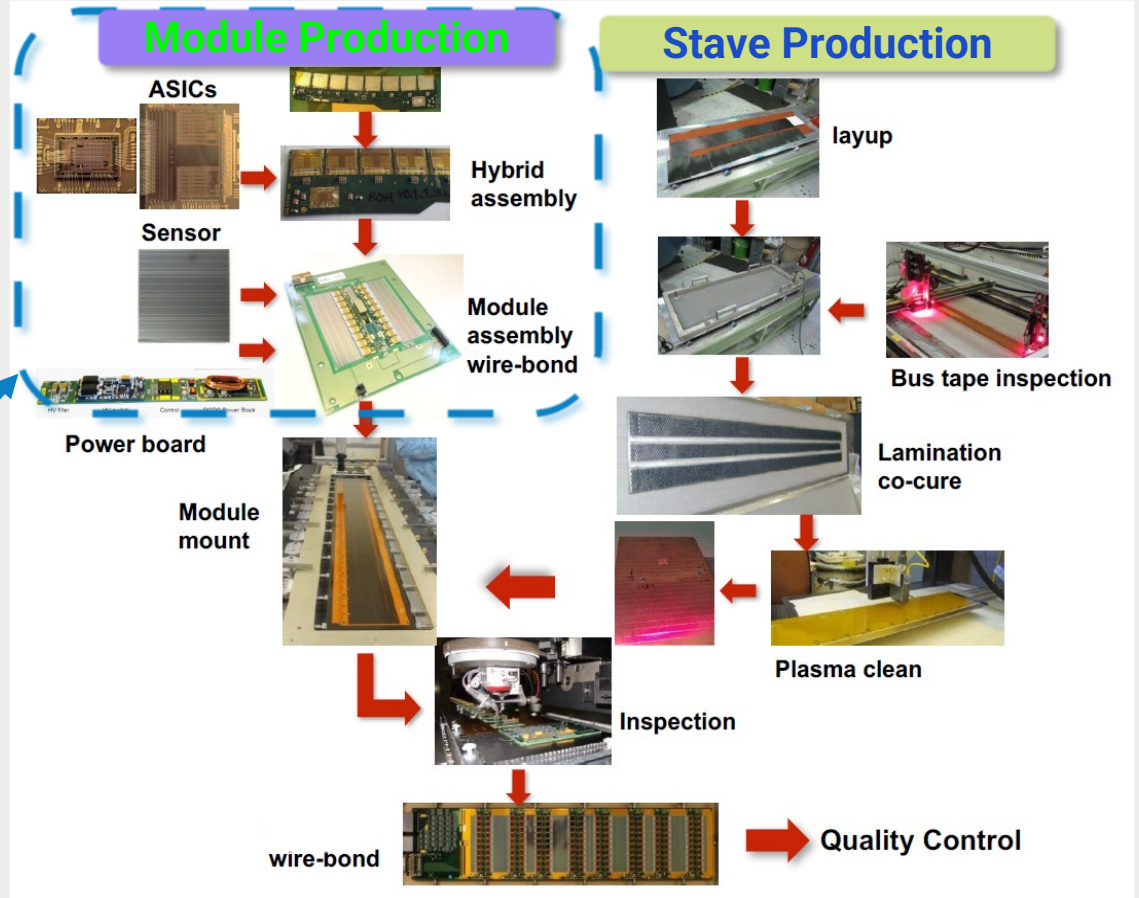
# Production Flow

## ✓ Module Production

- Hybrid Assembly
- Module Assembly
- Quality Control (QC)

## ✓ Site Qualifications

- IHEP have been qualified for all 29 QC steps in barrel module production
- Got the approval for **Pre-Production C (PPC) phase**





# Hybrid Assembly



## ✓ Procedures

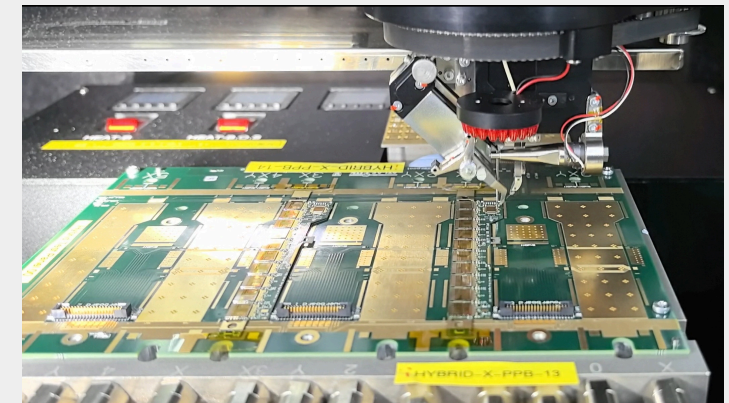
- ASICs attachment
  - ASICs adhesive: UV-curable glue (Loctite 3525)
  - Glue coverage controlled by weight and thickness
- Wire-bonding
  - Hesse Bondjet BJ820
  - 25 $\mu$ m diameter aluminum wires
  - Electrical connection between ASICs and hybrid flex (as well as hybrid and test panel)
- Hybrid Electrical Testing
  - Single panel testing
  - Multi-panel testing / Burn-in
- QC
  - Glue weight, metrology, visual inspection, burn-in



Pick up ASICs and alignment

Apply UV glue on hybrid using dot pattern

UV glue cured for 5 minutes



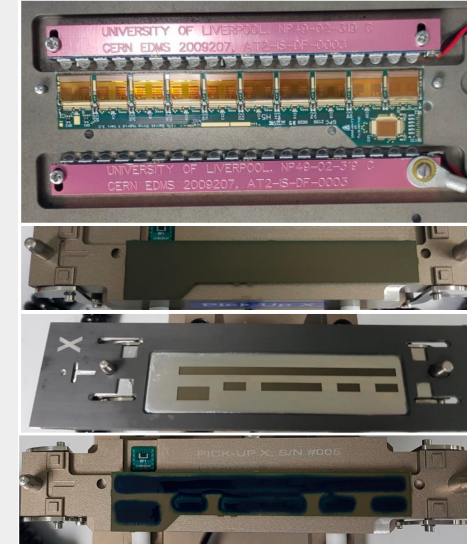
Wire-bonding



# Module Assembly

## ✓ Procedures

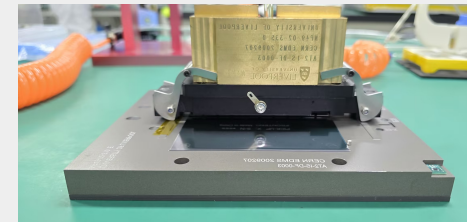
- Hybrid / Powerboard attachment
  - Hybrid and PB adhesive: Epoxy (True Blue)
- Wire-bonding
  - Hesse Bondjet BJ820
  - 256 Al wires in 4 rows per ABCStar chip at Front-end
  - Hybrid to powerboard wire-bonding
  - Module to test frame wire-bonding
- Module Electrical Testing
  - Single Module Testing
  - Multi-module testing / Thermal Cycling
- QC
  - Glue weight, metrology, visual inspection, thermal cycle



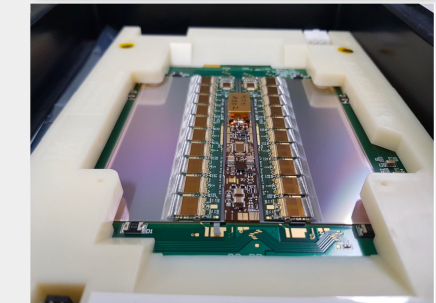
Dispense glue on stencil for hybrid



Dispense glue on stencil for powerboard



Placing hybrid and powerboard on sensor and glue curing for 6 hours



Completed wire-bonding marks the module assembly finished

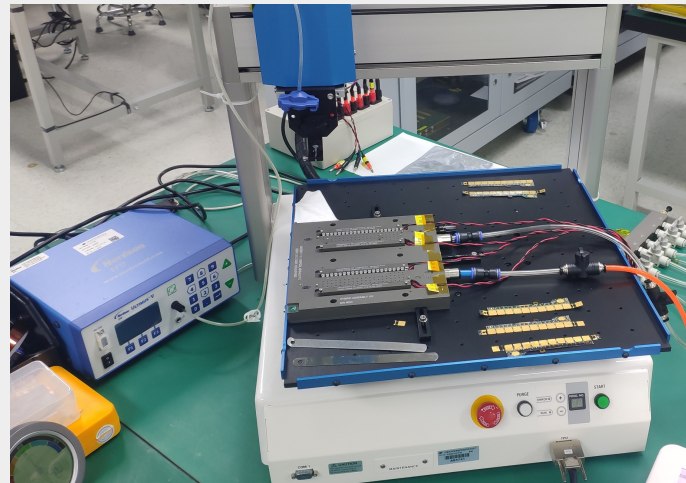




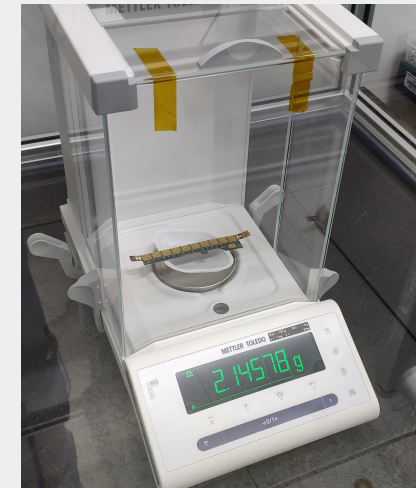
# Quality Control

## ✓ Glue Weight

- ASICs-to-hybrid glue dispensing by a 3-Axis E Series Automated Fluid Dispensing Robot
  - Weighting with a digital scale
  - $43.80 \pm 2.62$  mg for ASIC adhesive weight



A Norson dispenser + JANOME robot



A Mettler digital scale

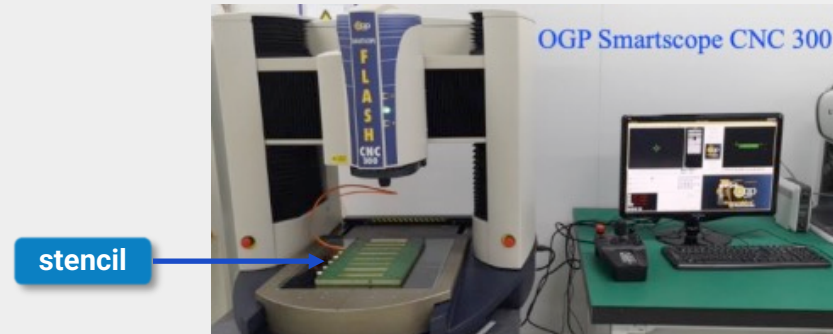


# Quality Control

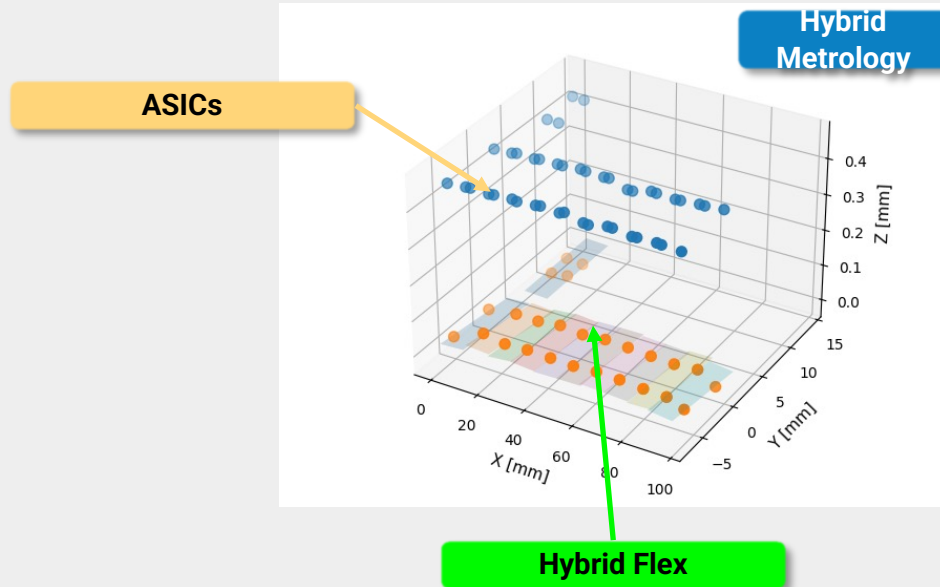
## ✓ Metrology

- Geometric positioning of characteristics
  - ASIC glue height:  $120 +40/-60\mu\text{m}$
  - ASIC xy-placement: within  $\pm 200\mu\text{m}$
  - ASIC flatness: Tilt  $\leq 0.025$
  - Hybrid package thickness:  $0.84 \pm 0.04\text{mm}$
  - Module bow between  $-50\mu\text{m}$  and  $+150\mu\text{m}$

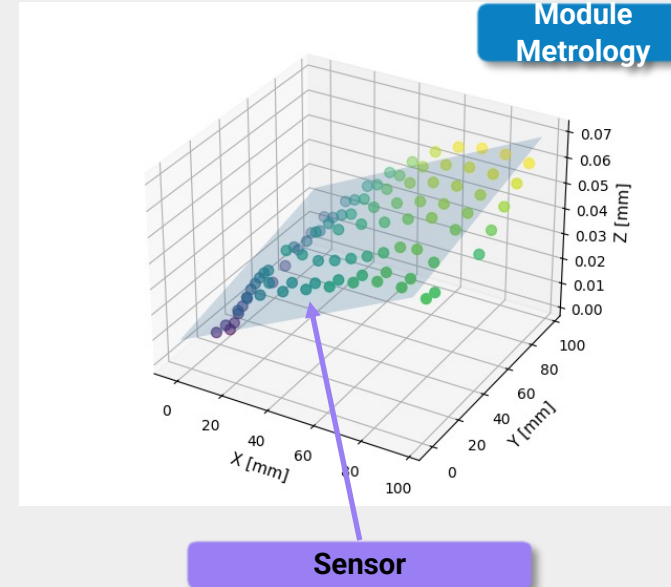
OGP Smartscope



Hybrid Metrology



Module Metrology





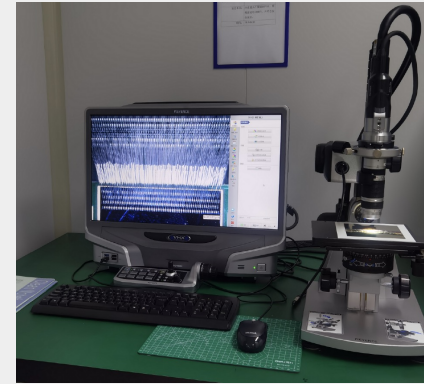


# Quality Control

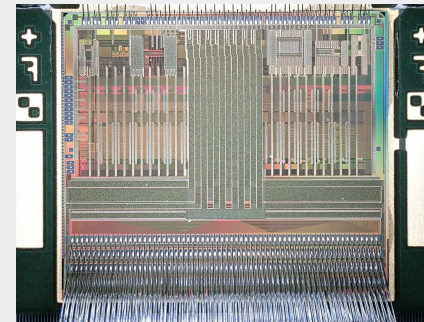
## ✓ Visual Inspection

- Check hybrid flex
  - Defects
- Check ASICs
  - Integrity of surface and edges
  - Cleanness on bonding pads
- Check Sensor
  - Any scratches, marks and debris
  - Integrity of edge
  - broken sensor
- Check bond-wires

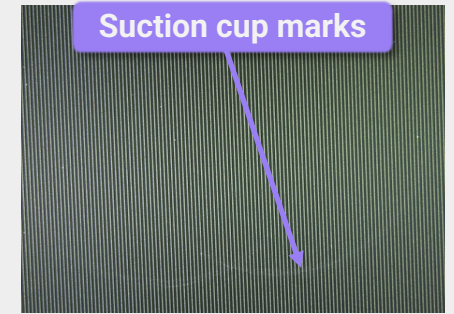
A Keyence digital microscope



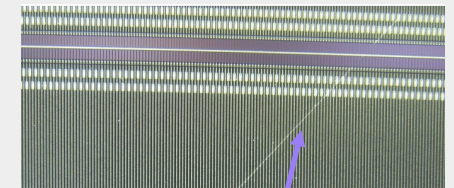
ASICs



FE wire-bondings



sensor



Long scratch

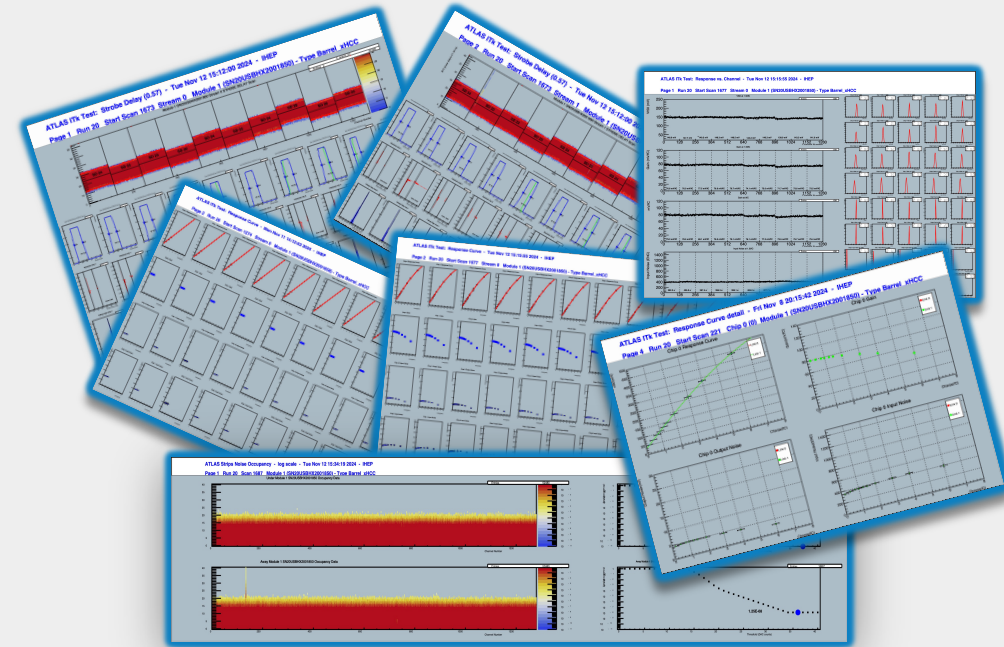
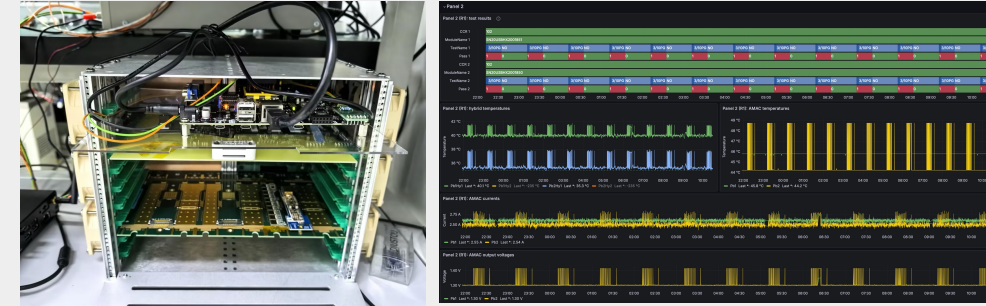


# Electrical Testing



## ✓ Hybrid Burn-in

- The hybrids are required to be burned in before using for module assembly
  - **100 hours** running to check hybrid operation stability at **~40 C°**
  - Voltage and current of AMAC, temperature of AMAC and hybrid are monitored by InfluxDB/Grafana
- Hybrid burn-in performs 100 ITSDAQ Full Test
  - Pedestal Trim
  - Strobe Delay
  - Three Point Gain
  - Response Curve
  - Noise Occupancy



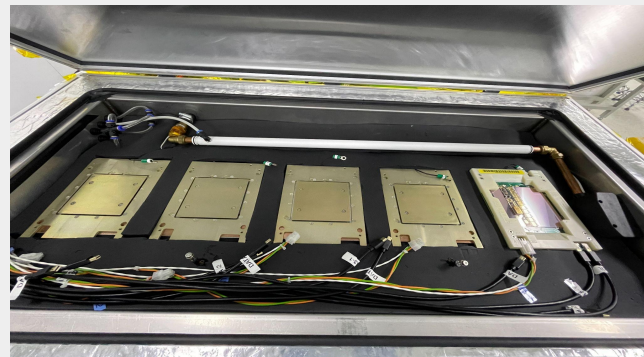
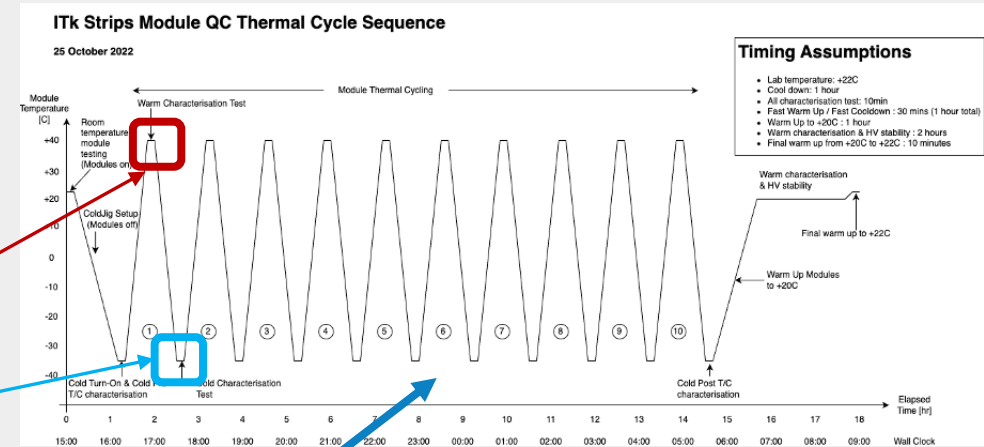


# Electrical Testing



## ✓ Module Thermal Cycling / Multi-module Testing

- Prior to Stave/Petal assembly and evaluate each module to determine if it should go forward to Stave/Petal assembly
- Each module undergoes **electrical and thermal** quality control (QC) testing
  - ▢ **Thermal-cycled** 10 times (-35°C ~ +20°C, +20°C ~ -35°C)
  - ▢ **AMAC IV scan (0, -550V)**
  - ▢ **ITSDAQ Full Test** carried at -350V performed at -35°C and +20°C each cycle
  - ▢ 2 hours **HV stability** measurement and **Open Channel Search** test is performed at -10V







# IHEP SOP Webpage

## ✓ IHEP ATLAS-ITK Standard Operating Procedure

- Environment real time monitoring of cleanroom
  - Temperature and humidity
  - Dust Particle
- Local production operation guidance
- Local production statistics and report
- Production database interaction

### IHEP ATLAS-ITK

Standard Operating Procedure

Powered by [itkdb](#)

2024-11-16 @ 08:05:15

Temperature	Humidity
21.9°C	52.6 %
↓ -0.0°C	↓ -0.4 %

Particle Counter (1000/m3):		
0.5 um	1.0 um	5.0 um
7.13	0.6	0.0

Recorded at 2024-11-15 17:07:44

- Grafana Monitoring in B106
- Deployed InfluxDB
- IHEP-ITk knowledge database

### Bulletin Board

Chengwei Wang, please work on E-TEST of IHEP-Hybrid-X-PPB-9 (GPC2150\_X\_0018\_A\_0, PPB-2) and finish before 2024-07-18

Mengke Cai, please work on ASSEMBLY of IHEP-Module-LS-PPB-4 (ILS-4) and finish before 2024-07-25

Mengke Cai, please work on METROLOGY of IHEP-Hybrid-X-DUMMY-30 and finish before None

Xin Shi, please work on METROLOGY of IHEP-Module-LS-DUMMY-9 and finish before 2024-10-30

Yebo Chen, please work on WIRE-BONDING of IHEP-Hybrid-X-DUMMY-31 (iHX-PPC-1) and finish before 2024-11-05

Yebo Chen, please work on WIRE-BONDING of IHEP-Hybrid-X-DUMMY-32 (iHX-PPC-2) and finish before 2024-11-05

Mengke Cai, please work on METROLOGY of IHEP-Hybrid-X-DUMMY-33 (iHX-PPC-3) and finish before None

### Get Your Ticket!

2024-11-16 @ 08:05:15

Username

Password(Not required for now)

## Hybrid Electrical Test

Check to start!

Now working on: IHEP-Hybrid-X-PPB-9 (20USBHX2001832, GPC2150\_X\_0018\_A\_0, PPB-2)

### Steps for HYBRID E-TEST

- STEP 1: visual inspection and PB placing
- STEP 2: Turning-on the setup
- STEP 3: Starting ITSDAQ
- STEP 4: Testing
- STEP 5: Results -- General Comments
- STEP 5: Results -- PDFs

Select theme:

- Overview
- Hybrid
- Module
- Others
- PullTest
- Shipment

Select page:

- Homepage
- Cleanroom
- Inventory
- Production Monitoring
- PDB Report
- Project Plan
- Broom Cupboard

Particle Counter (1000/m3):  
0.5 um 1.0 um 5.0 um  
7.13 0.6 0.0

Recorded at 2024-11-15 17:07:44

- Grafana Monitoring in B106
- Deployed InfluxDB
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Select theme:  
 Overview  
 Hybrid  
 Module  
 Others  
 PullTest  
 Shipment

Select page:  
 Homepage  
 Cleanroom  
 Inventory  
 Production Monitoring  
 PDB Report  
 Project Plan  
 Broom Cupboard

small print:  
Dev. Phase: IHEP Internal Use Only  
Contact: [ganqun@ihep.ac.cn](mailto:ganqun@ihep.ac.cn)

Sub-table Path: data/hybrid/IHEP-Hybrid-X-DUMMY-34/IHEP-Hybrid-X-DUMMY-34.gpd

Reception Date: None  
Valid Period: None  
Expiration Date: None  
Description: None  
Current Operation: None

Component sub-table:  IHEP-Hybrid-X-DUMMY-34 METROLOGY\_DONE

Assembly Results

Metrology Results  
Select metrology run to plot

Outputs:

Average Glue Height per ASIC

ASIC glue height

ASIC relative position

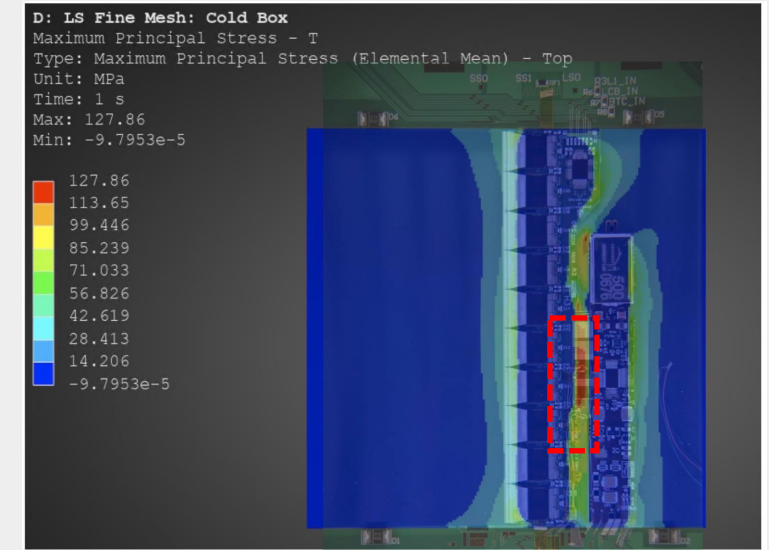
Full Hybrid



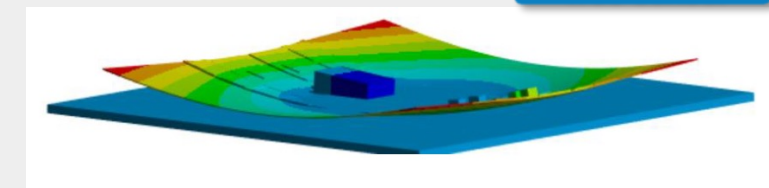
# Towards Production

## ✓ Sensor Cracking

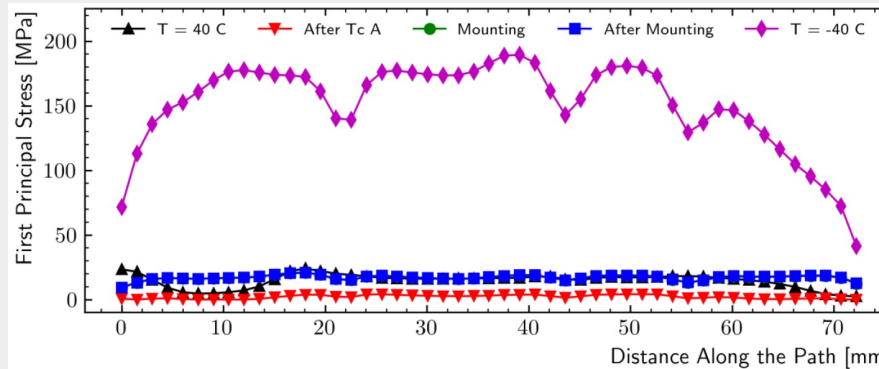
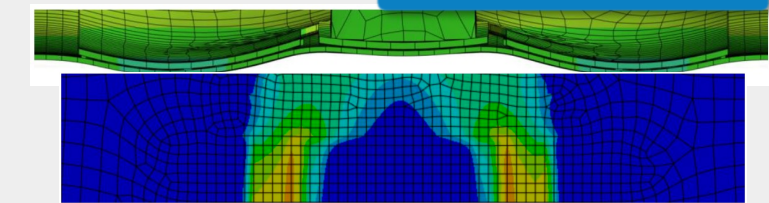
- High rate of HV breakdown due to **sensor cracking**
  - Early breakdown at less than 100V
  - Sensor receive enough stress when thermal cycled down to -35C
  - Peak stress in **gaps**
- FEA simulation indicates a issue of **CTE mismatch** from gluing powerboard and hybrid on sensor
  - Different CTE – ‘**bi-metallic**’ effect
  - Bonded sensor create **local bending** – intensified stress
  - Stress due to ‘flattening’ sensor bowing: ~ 25 MPa
  - Peak stress after 1<sup>st</sup> cold cycle: 150 ~ 200 Mpa



free sensor



sensor bonded to stave



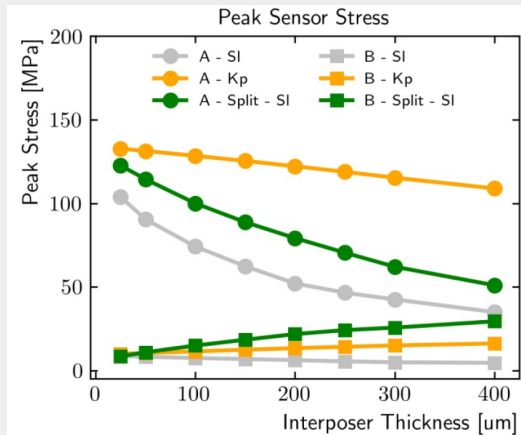




# Towards Production

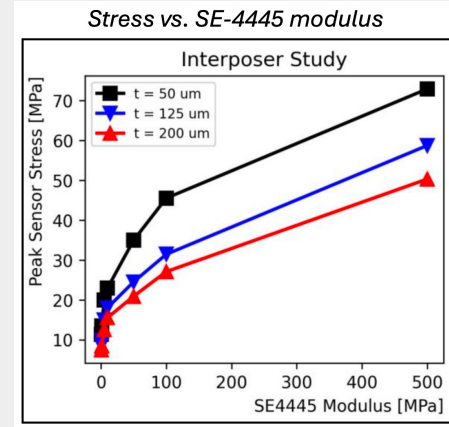
## ✓ Sensor Cracking Mitigation

- Interposer
  - 50 um & soft glue reduce ~ **90% stress** !
  - SE4445 (silicone) as glue, Kapton as interposer



**A: stiffness glue**

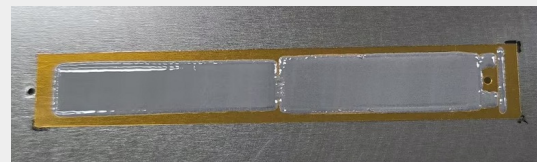
**B: soft glue**



- i-(Interposed)Hybrids and iPowerboards assembled at IHEP



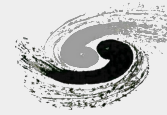
**iHybrid**



**iPB**



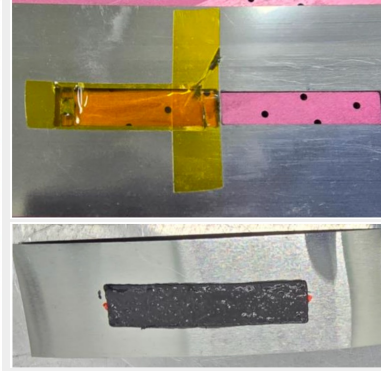
# Towards Production



## ✓ Interposer preparation at IHEP

- Interposer

- Dispense glue with AB glue gun (10g A+B) with a mixing nozzle
- Add 0.2g glass beads (50 - 100 um labeled, 2% of glue weight)
- Magnetic mixer (500+rpm) for 3 mins
- Degas with vacuum for 5 min
- Use deprecated stencils for glue brushing (200um thickness / 9mm wide)
- Attach Kapton piece to glue
- Use ASIC tray to hold it flat (optionally with additional weight)
- SE4445 (silicone) as glue, Kapton as interposer

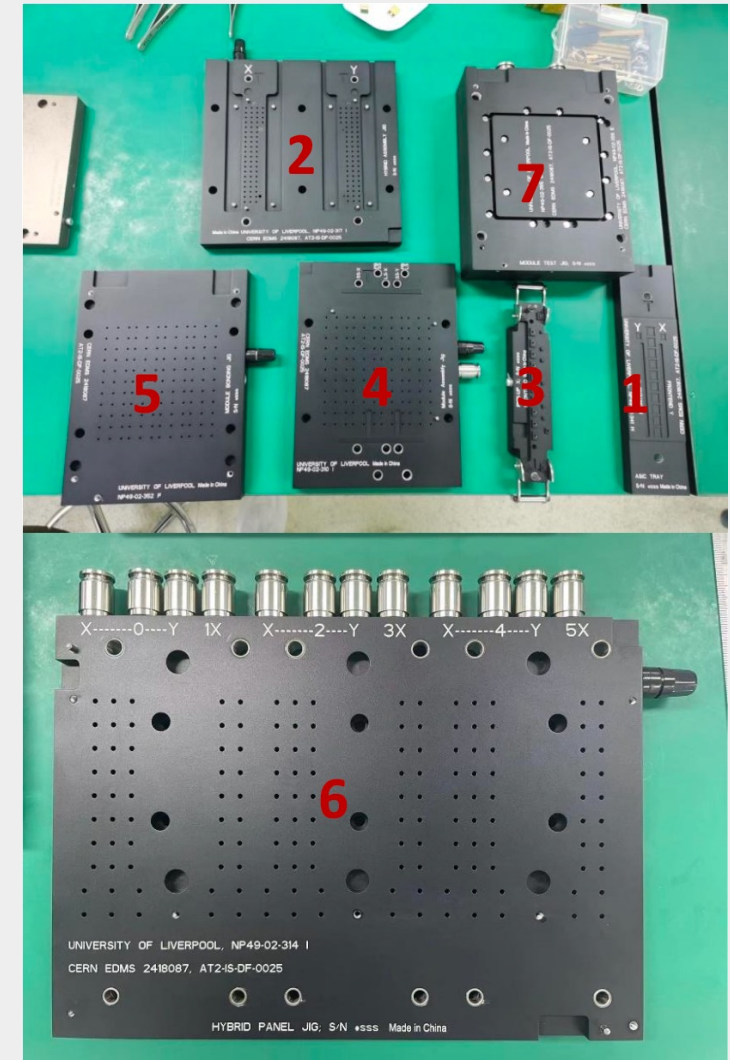




# Towards Production

## ✓ ITk production tools

- A couple of new tools made in China
  1. ASIC tray
  2. Hybrid assembly Jig
  3. Pickup tool
  4. Module assembly Jig
  5. Module bonding Jig
  6. Hybrid panel Jig
  7. Module test Jig
- Performed the quality check for all tools Ref: [Link](#)

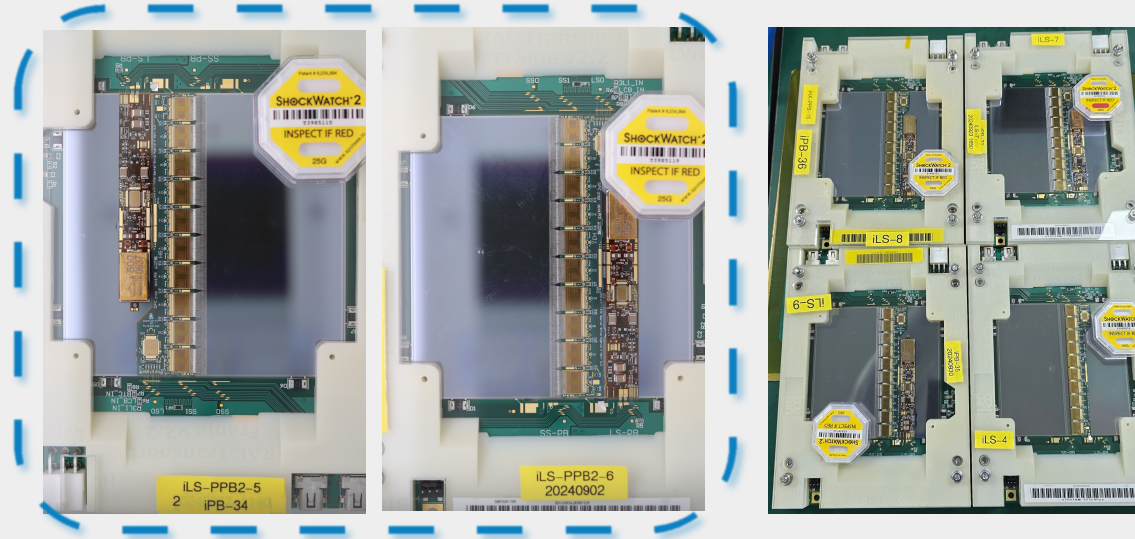






# Summary

- ✓ IHEP is working in collaboration with THU to build ~10% of strip barrel modules
- ✓ IHEP have passed all 29 steps of SQ and now enter PPC phase
  - Built 6 iLS PPB-2 barrel modules
    - **iLS-PPB2-5** and **iLS-PPB2-6** have shipped to CERN ready to load on stave at RAL
  - 4 PPC iHybrids assembled



- ✓ Focus on improvement of production procedures by developing IHEP SOP webpage

## Thank you!

# Backup





# ITk Detector Element

## ✓ Stave

- Finished modules (Electrical Testing passed) need to be loaded to Stave
  - Carbon-fiber mechanical support
  - Copper-Kapton bus tape
  - Titanium cooling tubes
- End-of-Substructure (EOS) Card
  - Interface between stave and off-detector
  - IpGBTx (Low Power GigaBit Transceiver)
  - VTRx+ (optical transceiver module)

### Stave Core

