ITk strip hybrid and module production

Weiguo Lu（陆卫国）

On behalf of the ATLAS ITk China group

MOST ATLAS Detector Upgrade Project
2025 Annual meeting

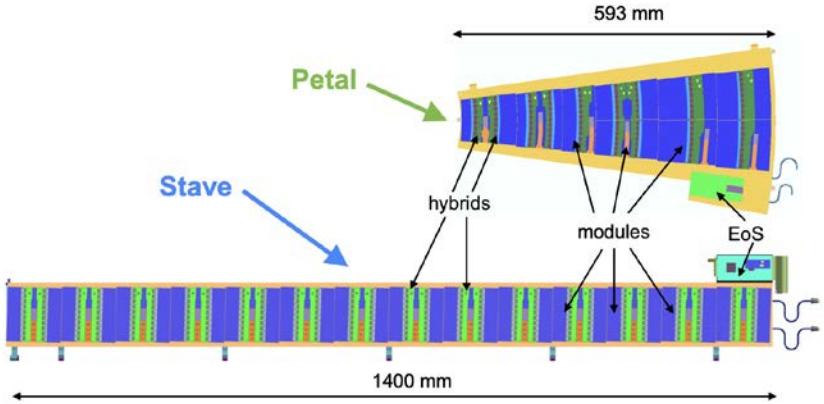
IHEP, 7 June 2025

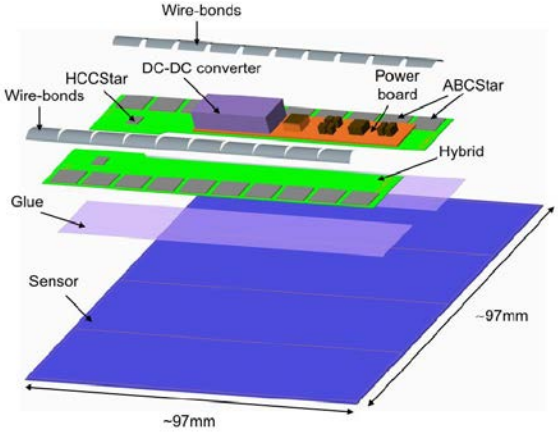
Outline

- Introduction
- Production Flow
  - Assembly
  - Qualification Control
  - Wire-bonding
  - Electrical test
- Progress and Status
- Summary

ITk Detector

- HL-LHC upgrade
- All silicon tracker
- Barrel-Stave-SS/LS module
- Endcap-Petal-R0/R1/R2/R3/R4/R5 module

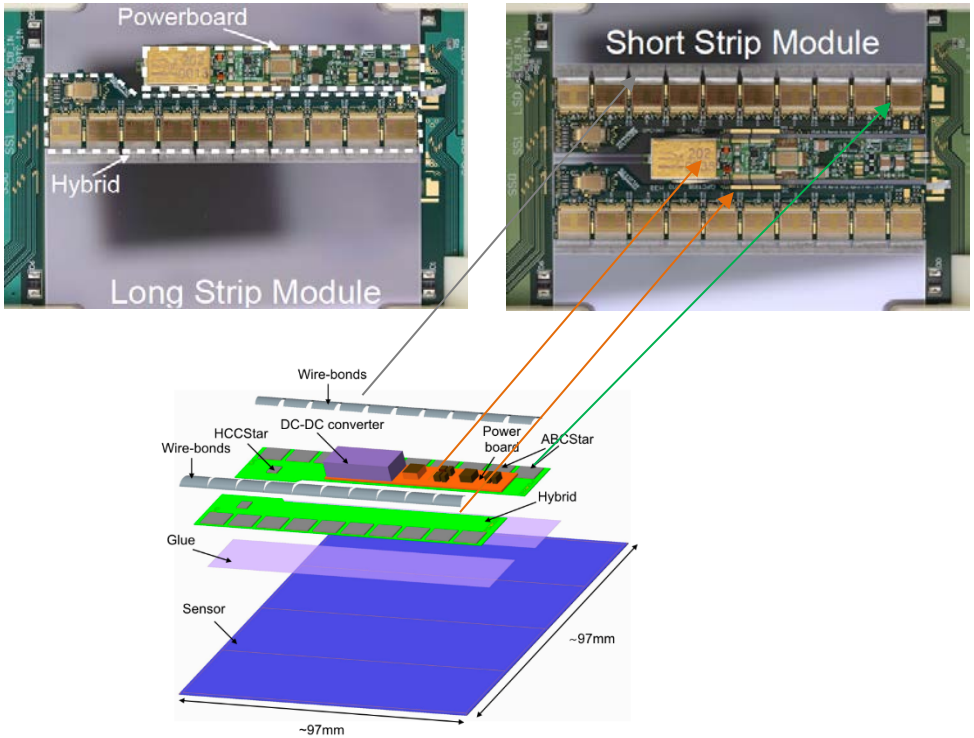




SS module

Barrel Module

- Sensor
  - Size : 97mm✖97mm
  - Strip length LS: 48.2 mm / SS: 24.1 mm
  - Pitch :75.5um
- Hybrid
  - ABCStar: ATLAS front-end Binary read-out Chip
  - HCCStar: Hybrid Controller Chip
- Powerboard
  - AMAC: monitor and control
  - bPOL12V: low-voltage regulation
  - linPOL12V: both voltages for AMAC
  - HVmux: high-voltage switching
- Glue for mechanical fixing
- Wire-bonding for electrical connection

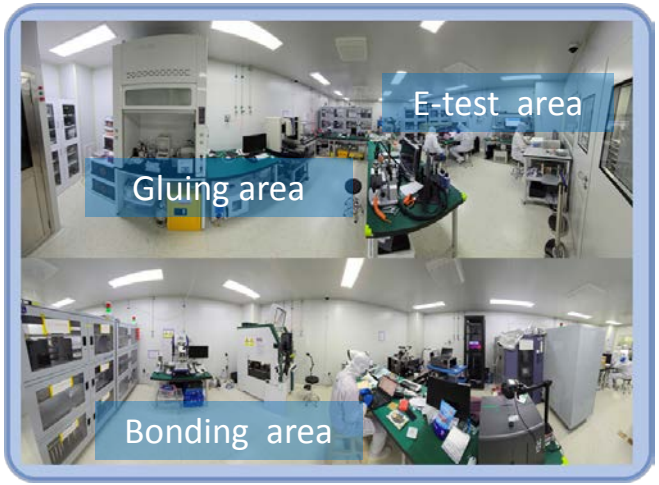


Outline

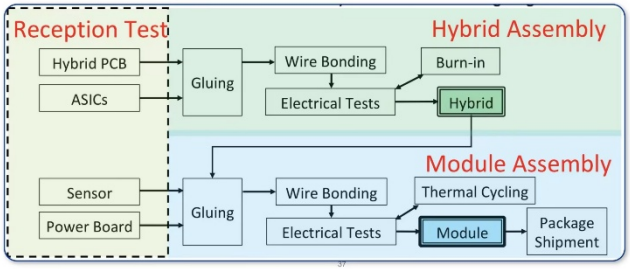
- Introduction
- Production Flow
  - Assembly
  - Qualification Control
  - Wire-bonding
  - Electrical test
- Progress and Status
- Summary

Production Flow

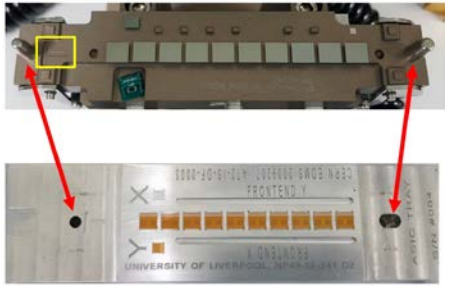
- Module Production
  - Hybrid Assembly
  - Module Assembly
  - Quality Control (QC)
- Site Qualifications
  - IHEP have been qualified for all 29 QC steps in barrel module production
  - Got the approval for Pre-Production



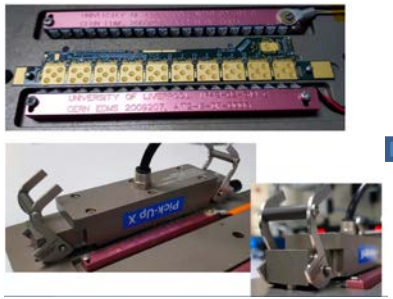
PoI		Step Number	Qualification Step
Sensor Reception	TRUE	3.2	Sensor Storage
	TRUE	6.1	PB Reception
	TRUE	6.2	PB E tests
	TRUE	6.3	PB Vis Insp
PB Reception	TRUE	6.4	PB Storage
	TRUE	8.2	Storage + shipping of glue
	TRUE	8.3	Assembling hybrids
	TRUE	8.4	Glue weight measurements
	TRUE	8.5	Bonding procedures: hybrids
	TRUE	8.6	Metrology: hybrids
	TRUE	8.7	Visual inspection: hybrids
	TRUE	8.8	Hybrid Burn-In
	TRUE	8.10	Hybrid Storage
	TRUE	8.11	hybrid QC: single panel testing
	TRUE	11.1	Storage of modules
	TRUE	11.2	Cleaning module jigs
	TRUE	11.4	Storage + shipping of glue
	TRUE	11.5	Removing hybrids from panel
Module Assembly/Testing	TRUE	11.6	Module Assembly
	TRUE	11.7	Metrology: modules
	TRUE	11.8	Bonding procedures: modules
	TRUE	11.9	Visual inspection: modules
	TRUE	11.10	Module Thermal Cycling
	TRUE	11.11	Single Module Electrical Test
Module Shipping	TRUE	12.1	Shipping modules
	TRUE	13.1	Cleanroom standards
General	TRUE	13.2	ASIC Compliance & Handling
	TRUE	13.3	Bond Pulling Procedures
Module Reception	TRUE	14.1	Module Reception



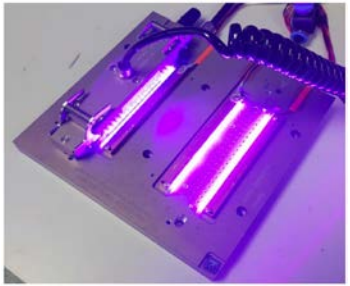
Hybrid Assembly



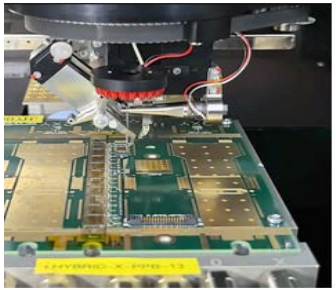
Pick up ASICs and alignment



Apply UV glue on hybrid and ASIC attachment



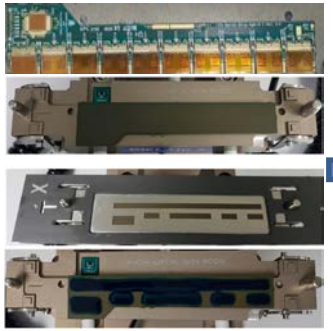
UV glue curing



Wire bonding

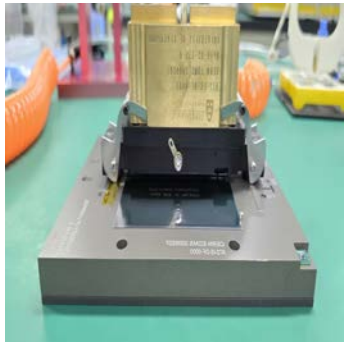
- Procedures
  - ASICs attachment
    - ASICs adhesive: UV-curable glue (Loctite 3525)
    - Glue coverage controlled by weight and thickness
  - Wire-bonding
    - Hesse Bondjet BJ820
    - 25µm diameter aluminum wires
    - Electrical connection between ASICs and hybrid flex (as well as hybrid and test panel)

Module Assembly

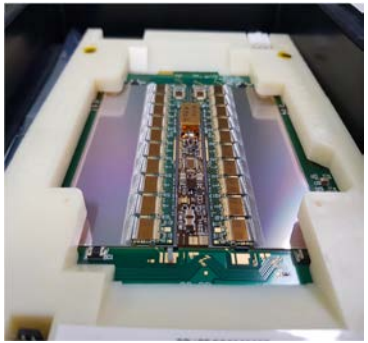


Dispense glue on stencil for hybrid

Dispense glue on stencil for PB



Glue curing for hybrid and PB



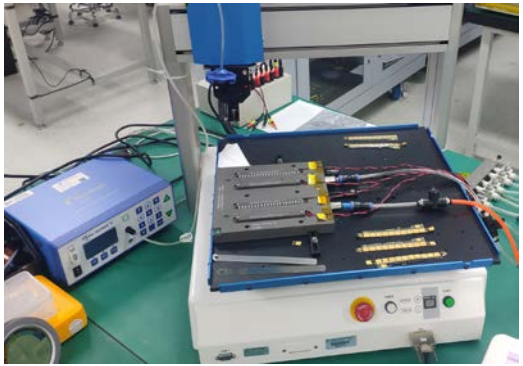
Wire bonding

- 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

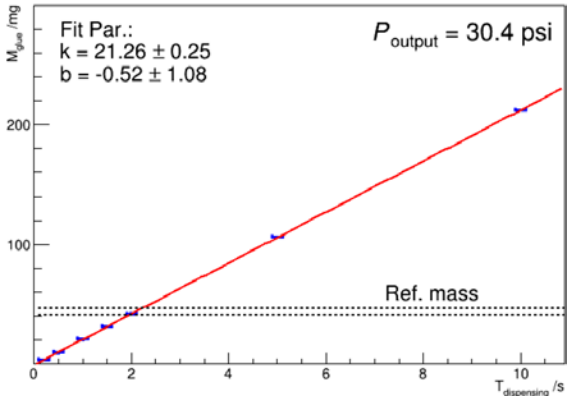
Qualification Control

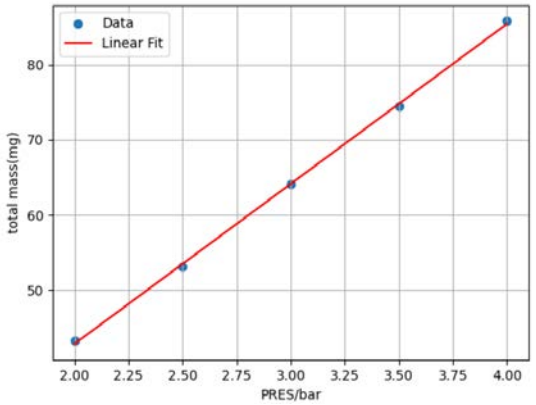
- Glue Weight
  - ASICs-to-hybrid glue dispensing by a 3-Axis E Series Automated Fluid Dispensing Robot
  - Weighting with a digital scale
  - 43.80±2.62 mg for ASIC adhesive weight
  - Calibration with dispensing time and air pressure

A Mettler digital scale



A Norson dispenser + JANOME robot

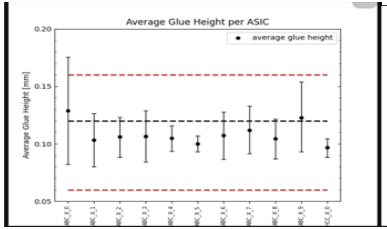




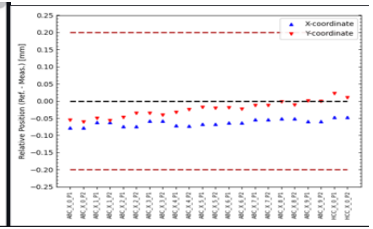
Qualification Control

- Metrology
  - Geometric positioning of characteristics
    - ASIC glue height: 120 +40/-60µm
    - ASIC xy-placement: within +/-200µm
    - ASIC flatness: Tilt ≤ 0.025
    - Hybrid package thickness: 0.84±0.04mm
    - Module bow between -50µm and +150µm

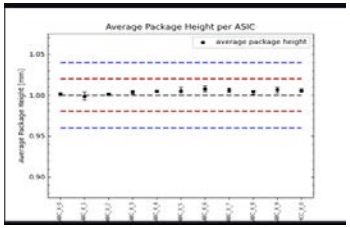
Glue height



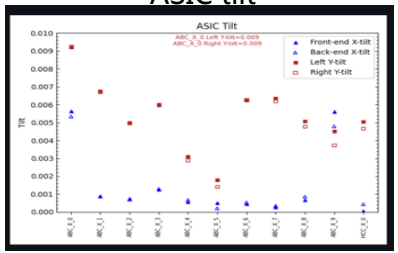
ASIC relative position



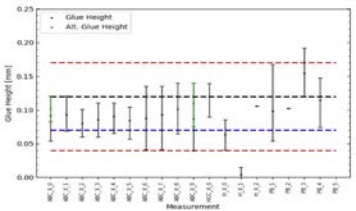
Total package height



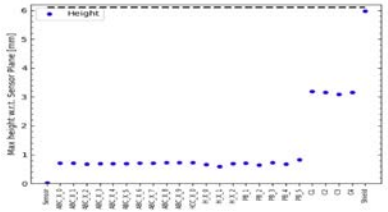
ASIC tilt



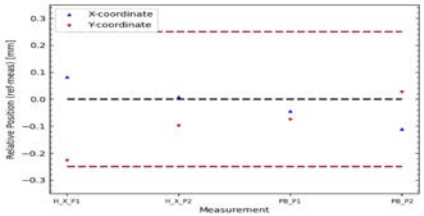
Glue height



Maximum height



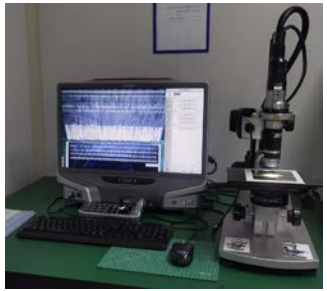
Relative position



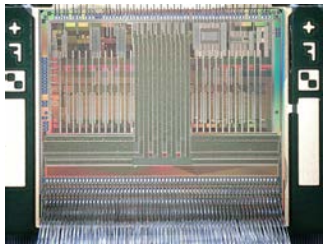
Qualification Control

- 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

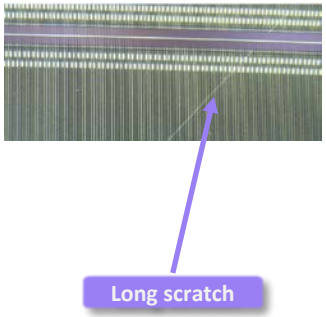


ASICs



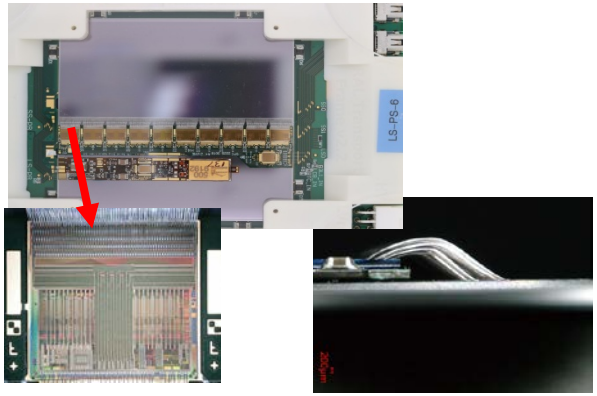
FE wire-bondings

sensor



Wire Bonding

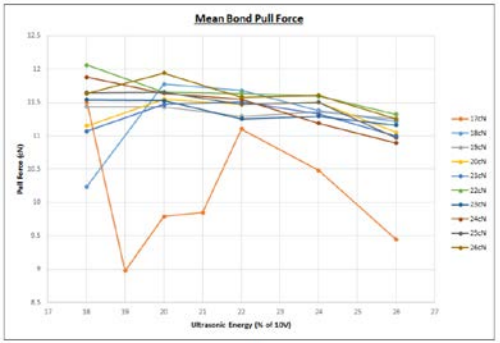
- Module wirebonding
  - Front end – four columns of pads with 75.5um pitch
  - Yield of the electronics channel >99%



Bonder Hesse BJ 820

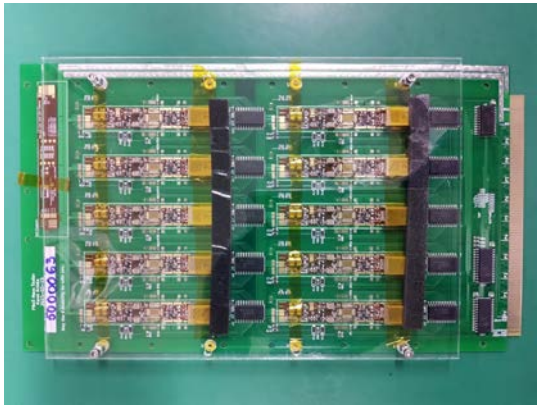
Nordson Dage 4000Plus

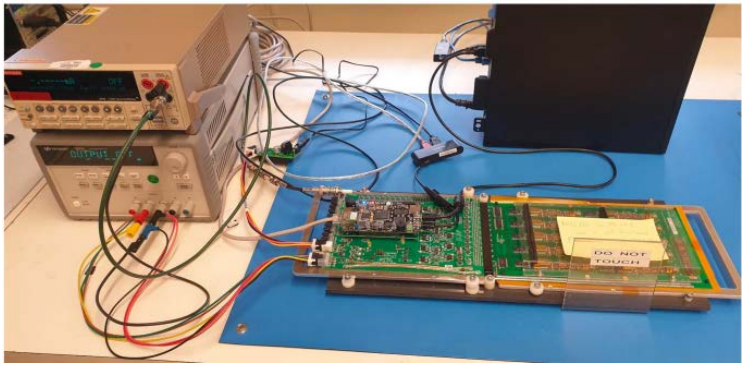
- Pull test every month to optimize the bonding parameters
  - Pull force > 8g
  - Peel break (4/5) < 10%
  - Variation of different surfaces



Electrical Test

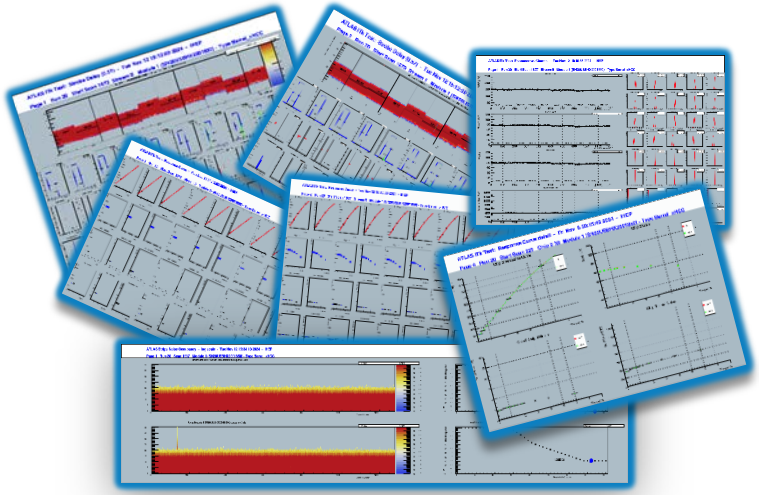
- Reception of sensor and powerboard
  - Required to ensure the quality
  - Powerboard
    - alive and functionality test
  - Sensor
    - IV test based on single module test system





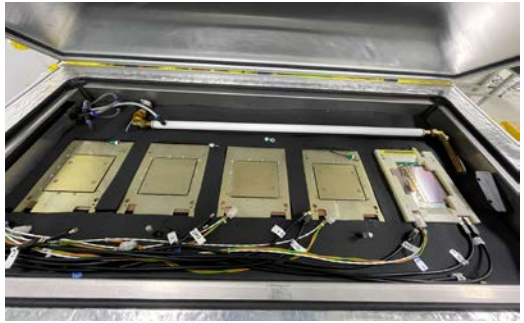
Electrical Test

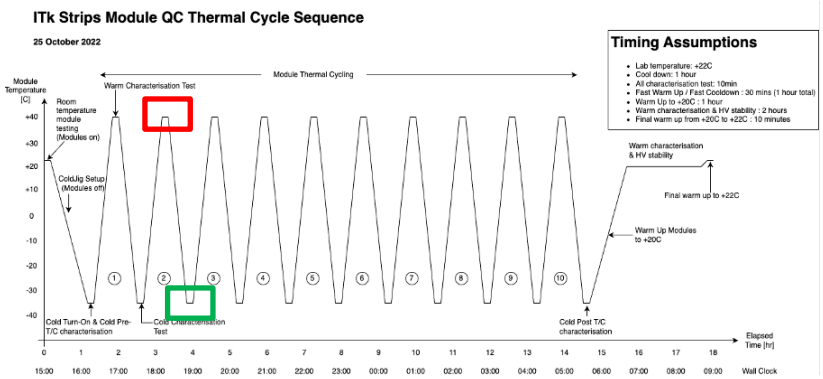
- Hybrid Burn-in
  - The hybrids are required to be burned in before using for module assembly
  - 100（20）hours running to check hybrid operation stability at ~40 ℃
  - Voltage and current of AMAC, temperature of AMAC and hybrid are monitored by InfluxDB/Grafana
- Hybrid burn-in performs cycles of ITSDAQ Full Test
  - Pedestal Trim
  - Strobe Delay
  - Three Point Gain
  - Response Curve
  - Noise Occupancy

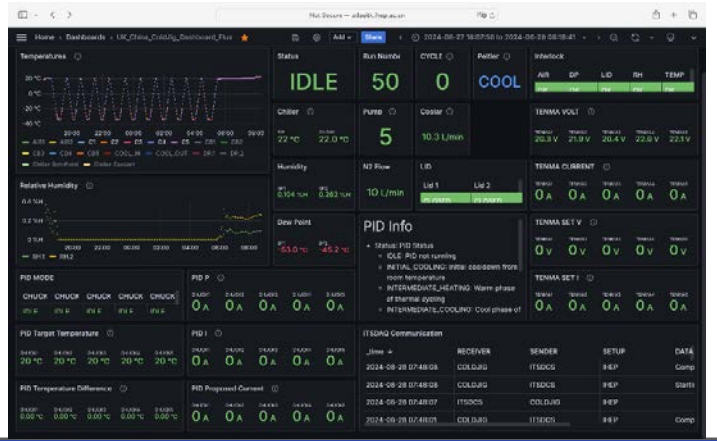


Electrical Test

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

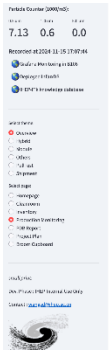


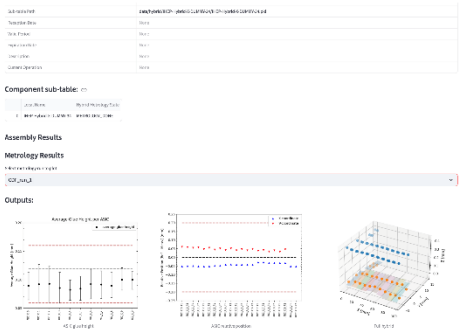


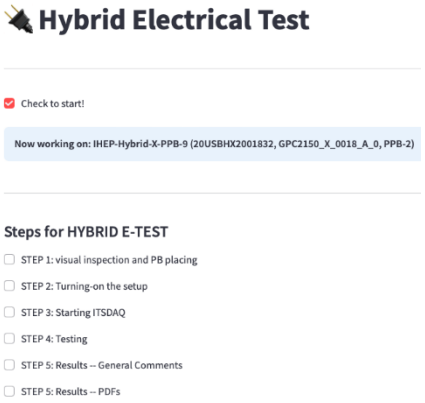


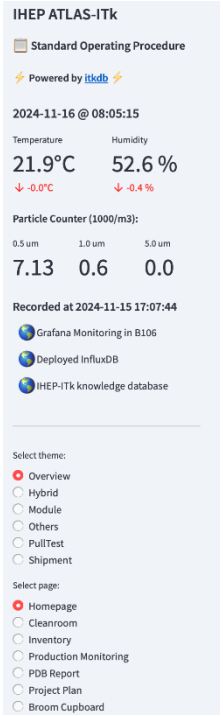
IHEP SOP

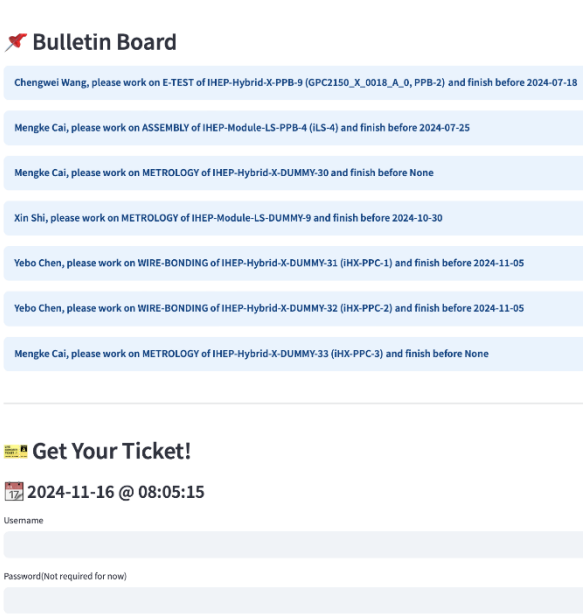
- IHEP ATLAS-ITK Standard Operating Procedure
  - Environment real time monitoring of cleanroom
    - Temperature and humidity
    - Dust Particle
  - Local production operation guidance
  - Local production statistics and report
  - Production database interaction









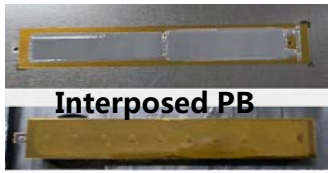


Outline

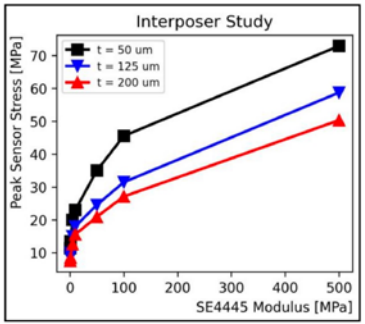
- Introduction
- Production Flow
  - Assembly
  - Qualification Control
  - Wire-bonding
  - Electrical test
- Progress and Status
- Summary

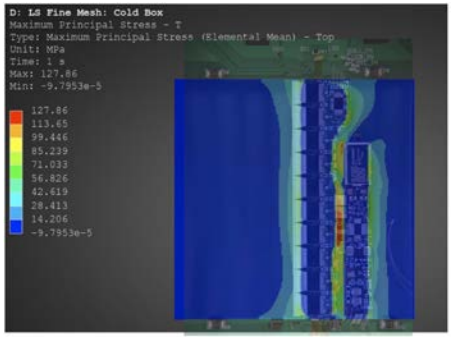
Sensor Cracking

- Sensor Cracking problem
  - 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
- Sensor Cracking Mitigation
  - Interposer
  - 50 um & soft glue reduce ~ 90% stress
  - SE4445 (silicone) as glue, Kapton as interposer

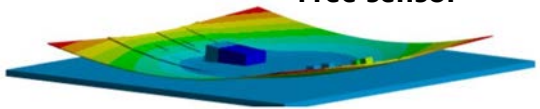


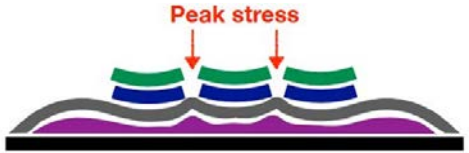
Stress vs. SE-4445 modulus





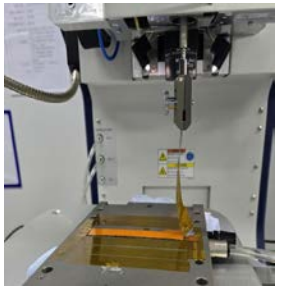
Free sensor

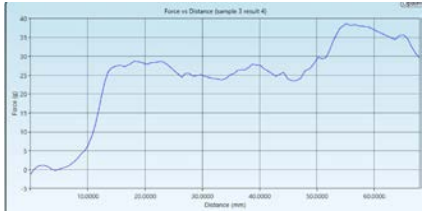




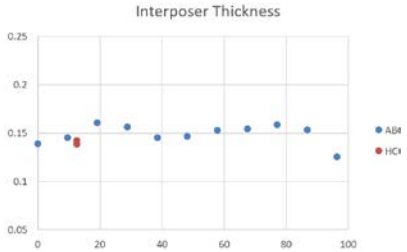
Interposing

- Interposer assembly
  - 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





Peel Force Pass

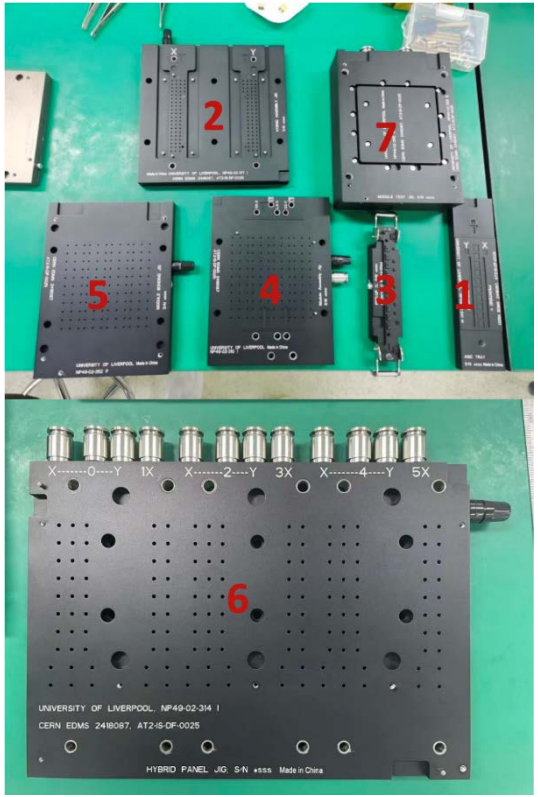


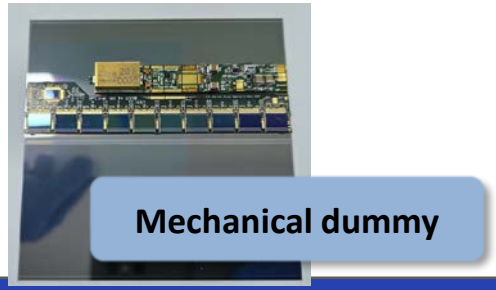
Thickness/Uniform Pass

- Peel force Pass
- Interposer thickness/uniform Pass

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
  - Training with dummy parts



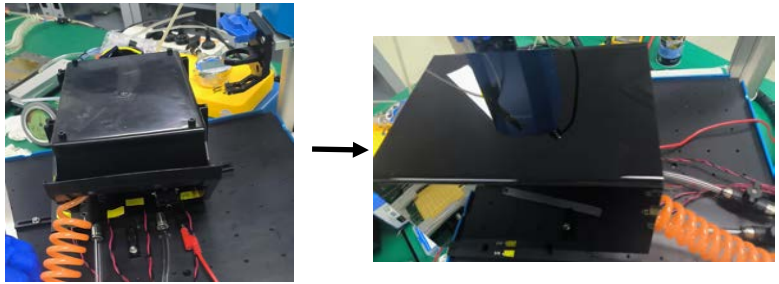


Hybrid Status

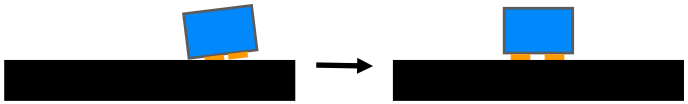
- 17 Hybrids finished

	Local Name	ASIC_ATTACHED	MEASURED	BONDED	BURN-IN_DONE	ON_MODULE
0	IHEP-Hybrid-iX-PRESERIES-1	PASS	FAIL	PASS	PASS	
1	IHEP-Hybrid-iX-PRESERIES-2	PASS	PASS	PASS	PASS	PASS
2	IHEP-Hybrid-iX-PRESERIES-3	PASS	PASS	PASS	PASS	PASS
3	IHEP-Hybrid-iX-PRESERIES-4	PASS	PASS	PASS	PASS	PASS
4	IHEP-Hybrid-iX-PRESERIES-5	PASS	FAIL			
5	IHEP-Hybrid-iX-PRESERIES-6	PASS	FAIL			
6	IHEP-Hybrid-iX-PRESERIES-7	PASS	PASS	PASS	PASS	PASS
7	IHEP-Hybrid-iX-PRESERIES-8	PASS	PASS	PASS	PASS	PASS
8	IHEP-Hybrid-iX-PRESERIES-9	PASS	PASS	PASS	PASS	PASS
9	IHEP-Hybrid-iX-PRESERIES-10	PASS	PASS	PASS	PASS	
10	IHEP-Hybrid-iX-PRESERIES-11	PASS	PASS	PASS	PASS	PASS
11	IHEP-Hybrid-iX-PRESERIES-12	PASS	PASS	PASS	PASS	
12	IHEP-Hybrid-iX-PRESERIES-13	PASS	PASS	PASS	PASS	
13	IHEP-Hybrid-iX-PRESERIES-14	PASS	PASS	PASS	PASS	
14	IHEP-Hybrid-iX-PRESERIES-15	PASS	PASS	PASS	PASS	
15	IHEP-Hybrid-iX-PRESERIES-16	PASS	PASS	PASS		
16	IHEP-Hybrid-iX-PRESERIES-17	PASS	PASS	PASS	PASS	

- 3 hybrids metrology failed
  - UV shield box press the vacuum pipe
  - The pickup tool and Assembly jig not match
  - Mis-operation
- Problem solved
  - Custom-made UV shield box



  - Made the same version pickup tool with assembly jig

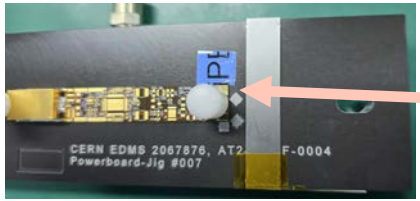


Module Status

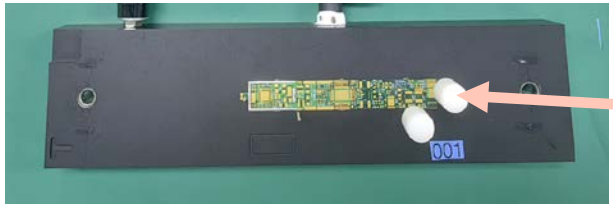
- 8 modules assembled

	Local Name	MEASURED	BONDED	E-TESTED
0	IHEP-Module-iLS-PRESERIES-1	FAIL	FAIL	FAIL
1	IHEP-Module-iLS-PRESERIES-2	FAIL		
2	IHEP-Module-iLS-PRESERIES-3	FAIL		
3	IHEP-Module-iLS-PRESERIES-4	PASS	PASS	PASS
4	IHEP-Module-iLS-PRESERIES-5	PASS	PASS	
5	IHEP-Module-iLS-PRESERIES-6	PASS	PASS	PASS
6	IHEP-Module-iLS-PRESERIES-7	PASS	PASS	
7	IHEP-Module-iLS-PRESERIES-8	PASS		

- First 3 modules metrology failed
  - PB_X/Y out of spec due to missing of the positioning holes
  - Large errors of the manually glued markers



- Problem solved
  - Made new PB tray with positioning holes



Summary

- ITk strip barrel module production is challenging
- IHEP passed site qualification and enter PS phase
- Efforts made on QC including SOP development
- Produced several modules which makes production flow much smoother

Thanks

Back up

plan

课题 2：ATLAS 实验内径迹探测器升级

1、年度：2023 年 12 月—2024 年 5 月

任务：测试硅微条传感器关键性能，掌握模块生产全部流程。开展时间像素探测器文献调研，分析明确设计需求。

考核指标：通过硅微条模块站点考核。确定时间像素探测器技术路线。

成果形式：硅微条探测器国际合作组内部评审报告，时间像素探测器内部报告。

2、年度：2024 年 6 月—2024 年 11 月

任务：测试读出芯片关键性能，开始制备长硅微条模块，在卢瑟福实验室完成多桶板小系统联调测试，在 CERN 搭建桶板接收测试系统。完成时间像素探测器传感器与前端电子学整体架构设计和功能模块划分。

考核指标：研制出合格的长硅微条探测器模块，完成时间像素探测器技术设计报告。

成果形式：长硅微条探测器模块合作组内测试报告，时间像素探测器技术设计报告。

3、年度：2024 年 12 月—2025 年 5 月

任务：测试传感器、芯片在不同辐照条件下的性能表现，制备长硅微条模块。时间像素探测器完成传感器增益层设计与第一版原型验证电路功能层级设计。

考核指标：完善长硅微条探测器模块研制流程，完成时间像素传感器增益层与验证电路功能层设计验证。

成果形式：长硅微条探测器完整流程优化合作组内报告，时间像素探测器初步设计验证