



On behalf of the IHEP ATLAS ITk Strip team

ATLAS ITk Strip Module Production at IHEP

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Outline

1. Introduction

- HL-LHC Motivation
- ATLAS ITk and Strip Module Overview

2. Module Production and Quality Control at IHEP

- Module Assembly
- Metrology
- Wire Bonding
- Single-Module Electrical Testing
- Thermal Cycling

3. HV-Tab Mechanical Testing

4. Summary and Outlook

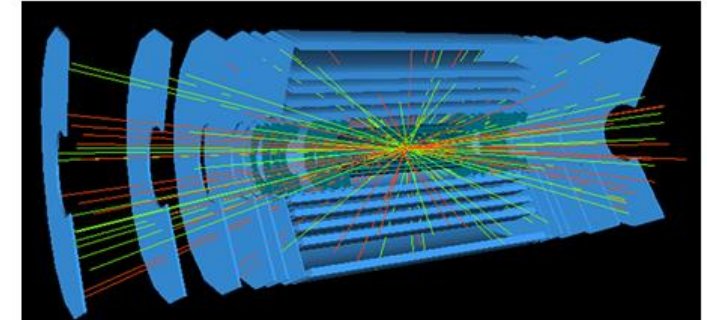
- Shipment to RAL
- Planned Study of Limbo-State Modules



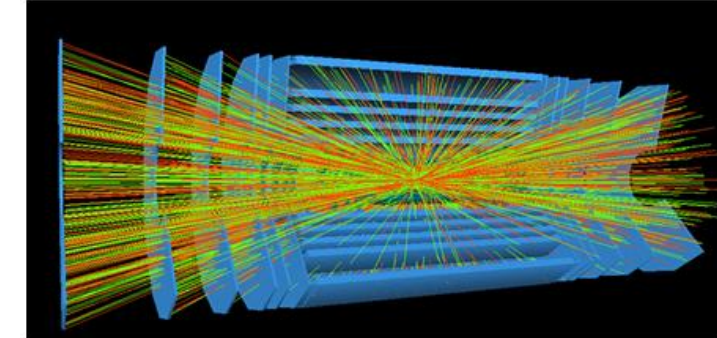
Motivation: The HL-LHC Environment

- ❖ An upgrade of the Large Hadron Collider (LHC) to the High-Luminosity LHC, foreseen in **2030**. The HL-LHC will provide much larger datasets, improving our sensitivity to rare processes.
- **Instantaneous luminosity:** up to $7.5 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$.
 - Higher trigger rate and increased event sizes (**100 kHz $\rightarrow$ 1 MHz**).
 - **Integrated luminosity:** 4000 fb^{-1} .
- **More simultaneous interactions** per bunch crossing.
 - Pile-up increasing **Up to approximately 200 interactions per bunch crossing**.
 - Limit occupancy to **1%**.
- **High particle fluences.**
 - Required radiation tolerance up to $1.3 \times 10^{16} \text{ n}_{\text{eq}}/\text{cm}^2$ for the **innermost pixel layer**.
 - **$\times 1.5$ safety factor**.
- **Low material budget.**
 - Reduction in scattering and fluences from secondary interactions.

[\[Link\]](#)



23 interactions per bunch crossing(LHC)

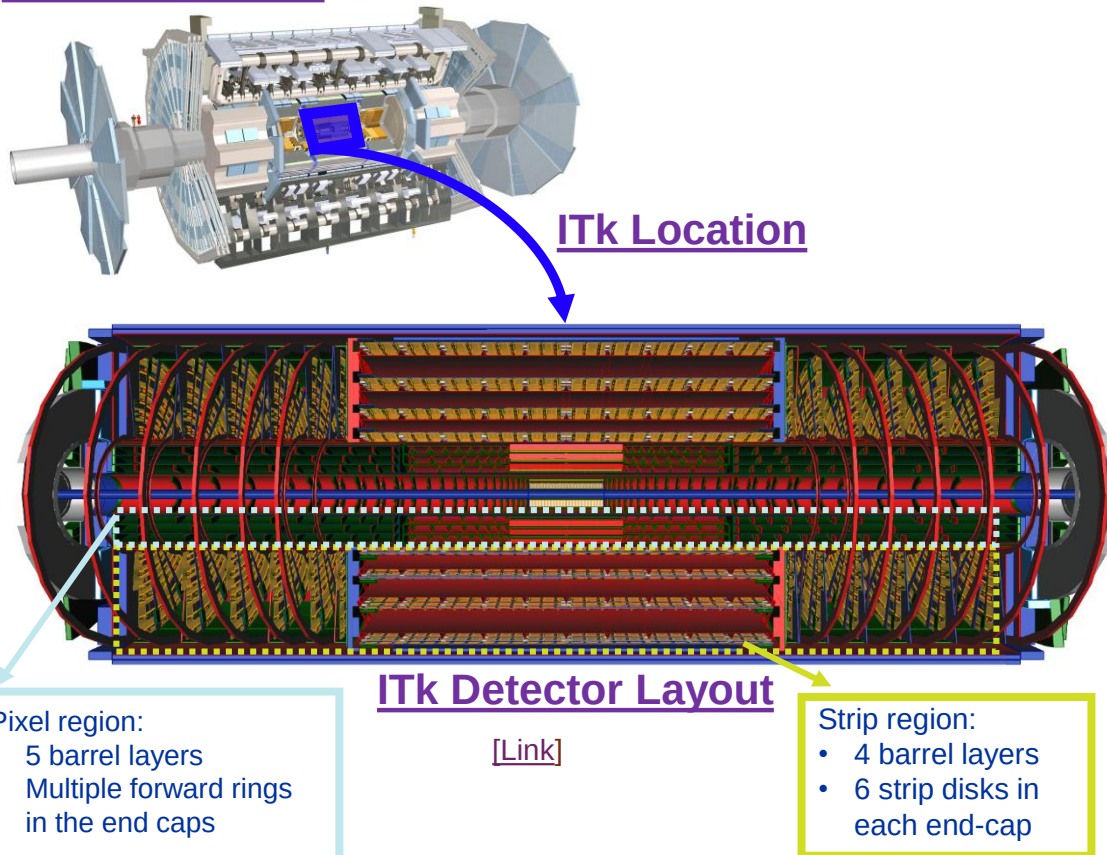


230 interactions per bunch crossing (HL-LHC)

ATLAS Inner Tracker

The ATLAS Inner Tracker (ITk) is a new all-silicon detector for the **HL-LHC**, replacing the current Pixel detector, SCT and TRT. It will reconstruct charged-particle trajectories in a higher-radiation, higher-pile-up environment.

ATLAS Detector



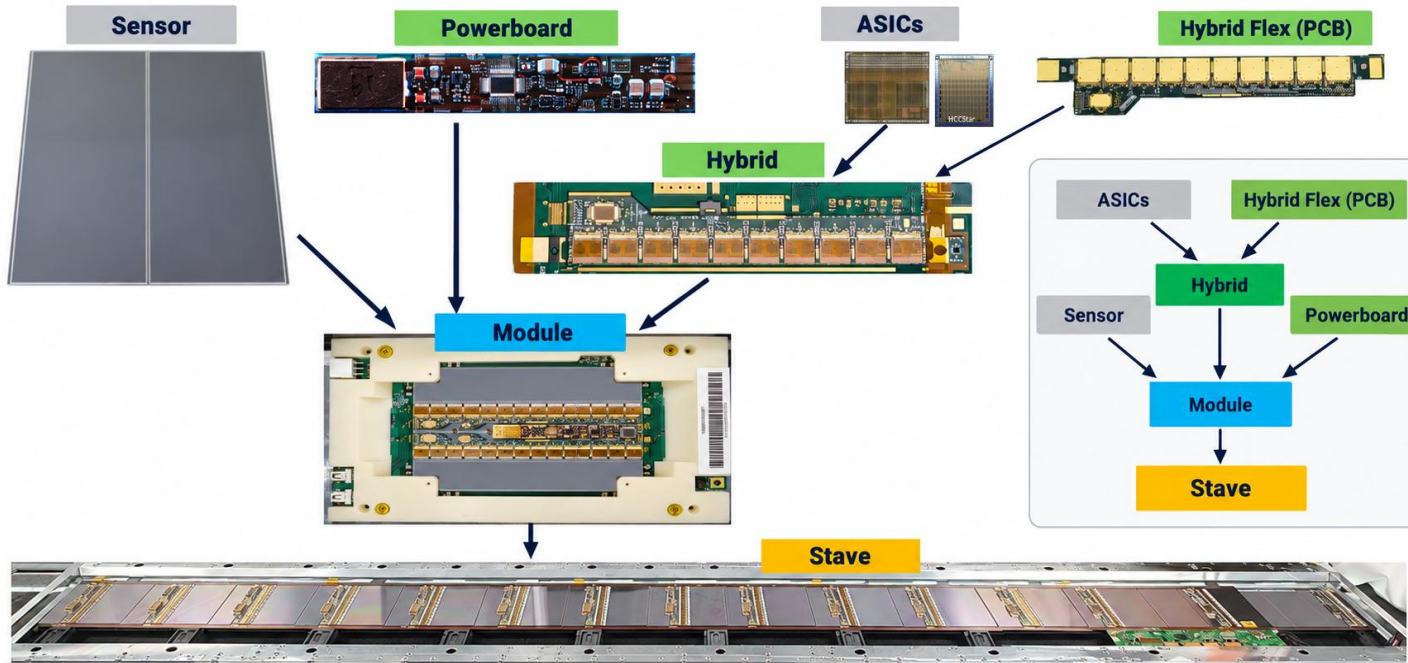
- **Strip barrel:** 392 staves; 10,976 modules.
- **Strip endcaps (both):** 192 petals; 3,456 modules

[\[Link\]](#)

- ❖ It combines an inner pixel system with an outer strip system
- ❖ Operates in a **2 T magnetic field**, with an approximate length of **6 m** and radius of **1 m**.
- ❖ Extends tracking coverage from $|\eta| < 2.5$ to $|\eta| < 4$.
- ❖ **Pixel detector:** five barrel layers and multiple forward rings.
- ❖ **Strip detector:** four barrel layers and six disks in each endcap, covering $|\eta| < 2.7$.

ITk Strip Module Components and Assembly

From Components to Stave



A **module** consists of a

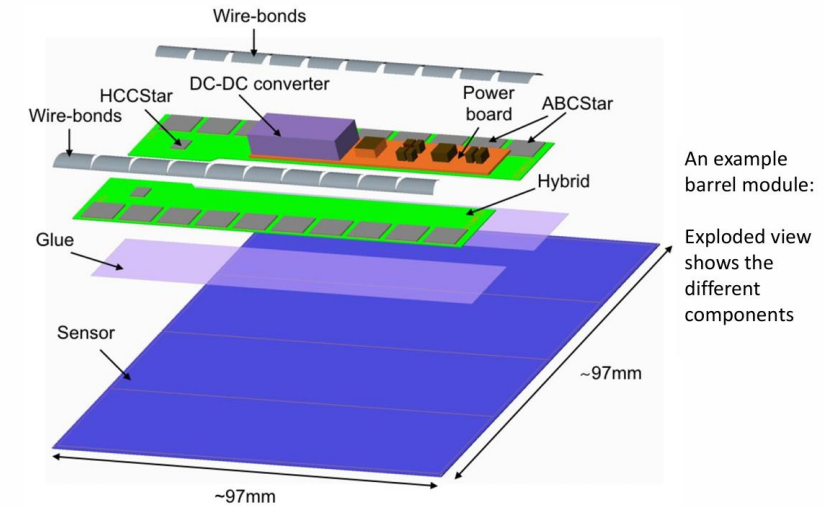
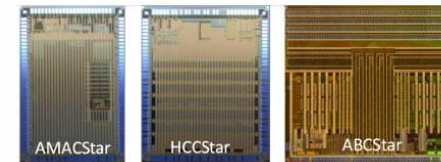
- Silicon strip sensor,
- Hybrids,
- Powerboard.

❖ The **hybrid** carries the

- ABCStar
- HCCStar.

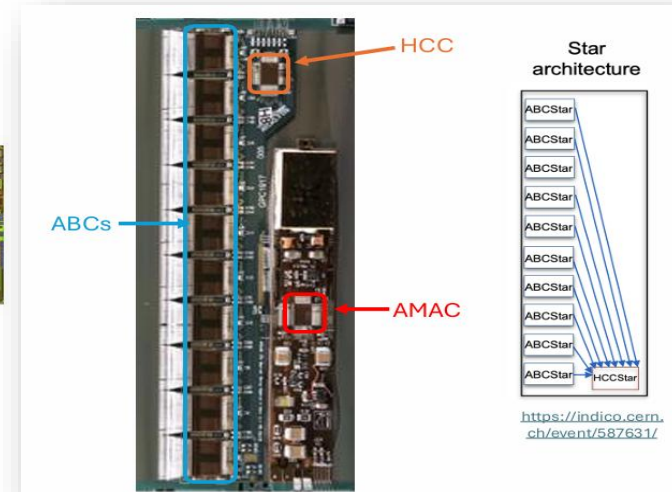
- **Sensor:** Detects charged particles.
- **Hybrid:** Carries ASICs for sensor-signal readout.
- **Powerboard:** Provides power conversion, monitoring and control.

Exploded View of a Barrel Strip Module



Standard Barrel Hybrid

- 10 × ABCStar
- 1 × HCCStar
- 2,560 readout channels

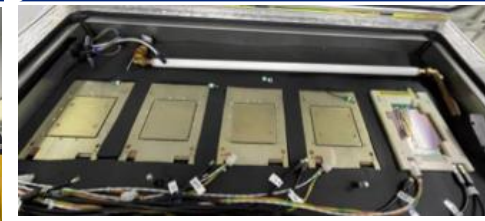


ITk Strip Module Production Facility at IHEP

- ❖ Completed all 29 Site Qualification (SQ) steps for module production.
- ❖ Produced dummy hybrids and modules during qualification to validate assembly procedures and production readiness.



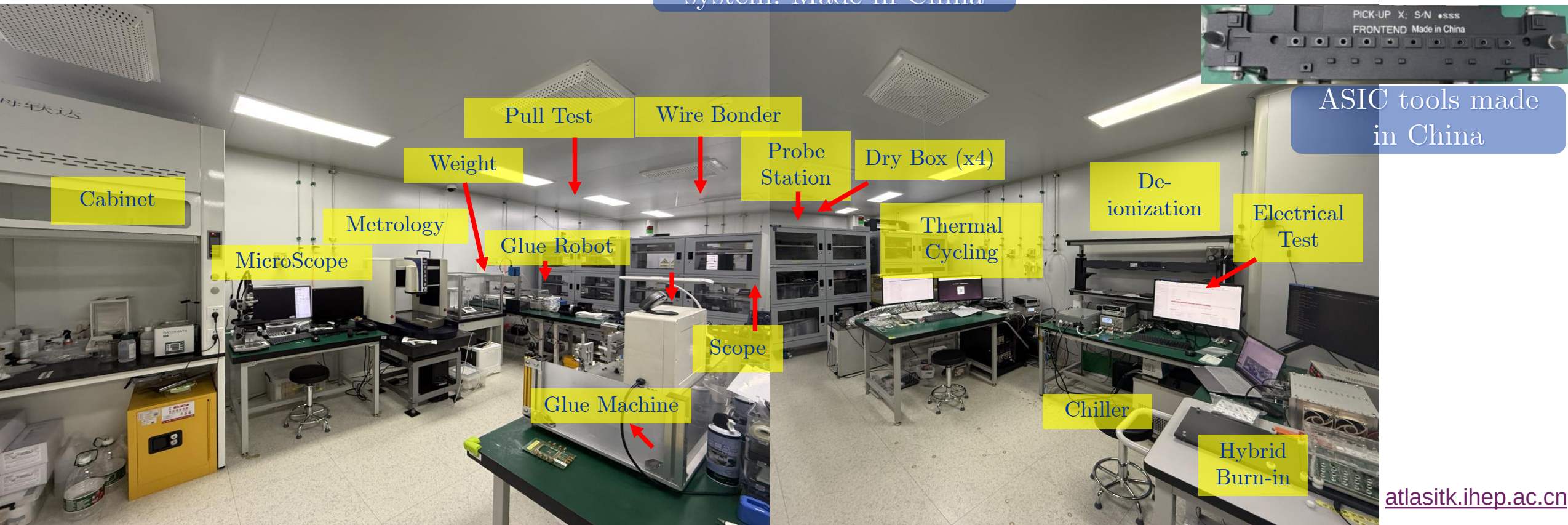
Adhesive-dispensing system. Made in China



Thermal Cycle Box



Burn-in Crate

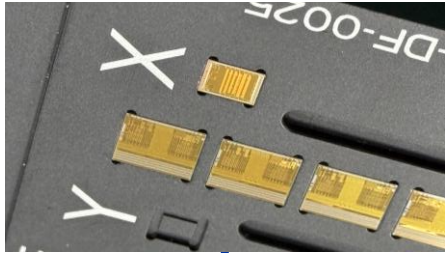


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Hybrid Preparation and Module Assembly

Hybrid Production

Readout ASICs



Adhesive Dispensing

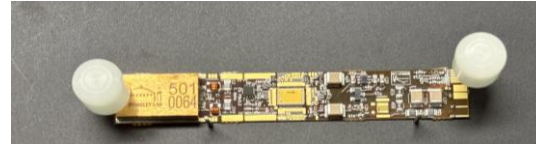


Assembled Hybrids



Assembly Component Placement Setup

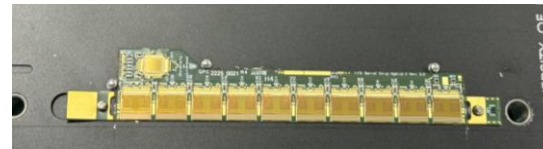
Powerboard



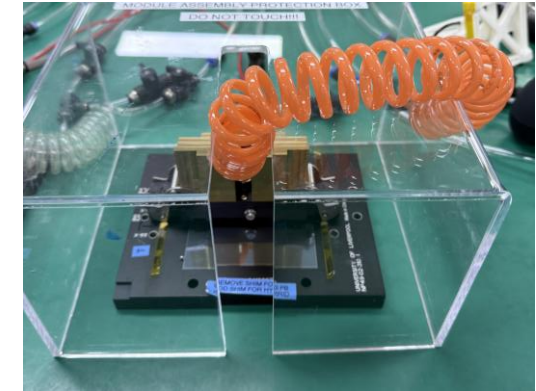
Adhesive Applied to Powerboard



Hybrid

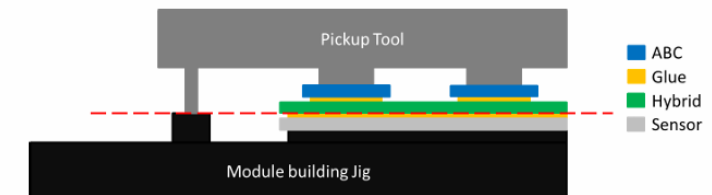


Hybrid Pickup Tools



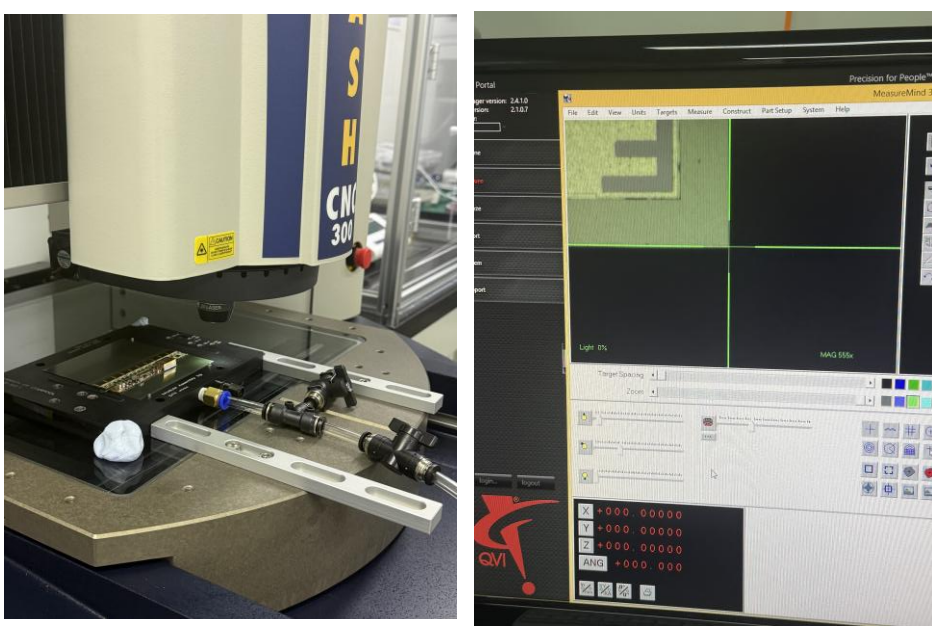
Module in Assembly Jig

- ❖ **Preparation:** Position the sensor in the assembly jig.
- ❖ **Adhesive application:** Apply glue to the hybrid and powerboard using the specified patterns.
- ❖ **Placement:** Use dedicated pickup tools to align and place components on the sensor.
- ❖ **Curing:** Allow the adhesive to cure according to the SOP.

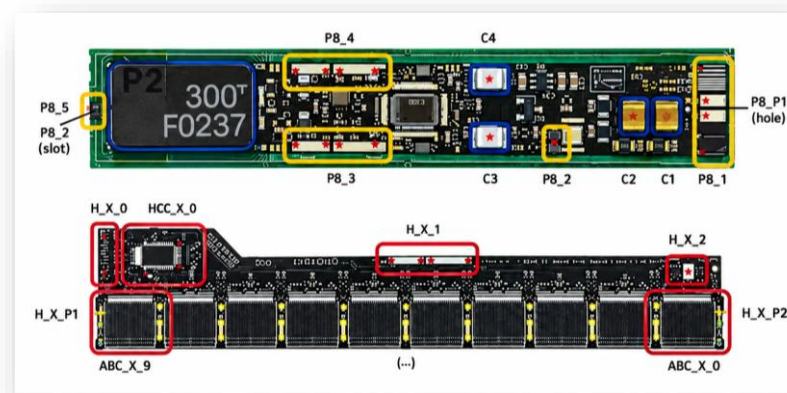


Metrology of Modules

- ❖ Metrology measures component positions and heights to assess assembly accuracy and adhesive thickness.
- ❖ Measured glue heights are compared with the specified acceptance limits to identify deviations requiring review.

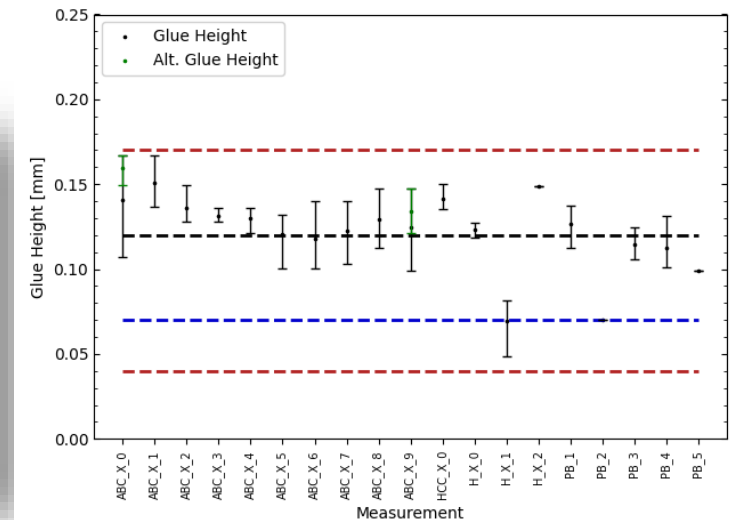


Metrology Setup



Measurement Locations

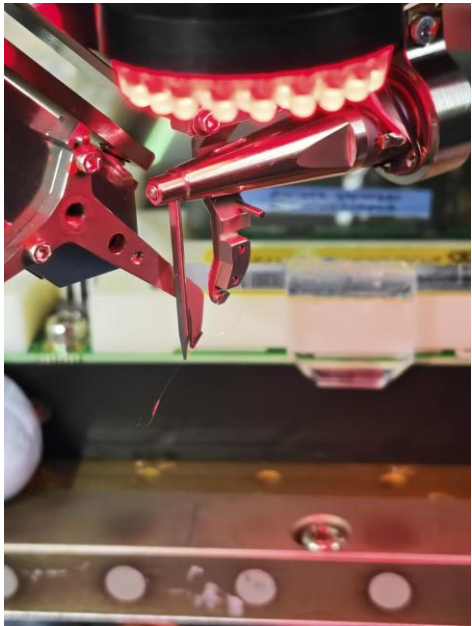
Glue-Height Results



Metrology measurements assessed **glue-height uniformity** across the assembled module, with most values close to **0.12 mm**. The results were reviewed and accepted for further processing.

Module Wire Bonding

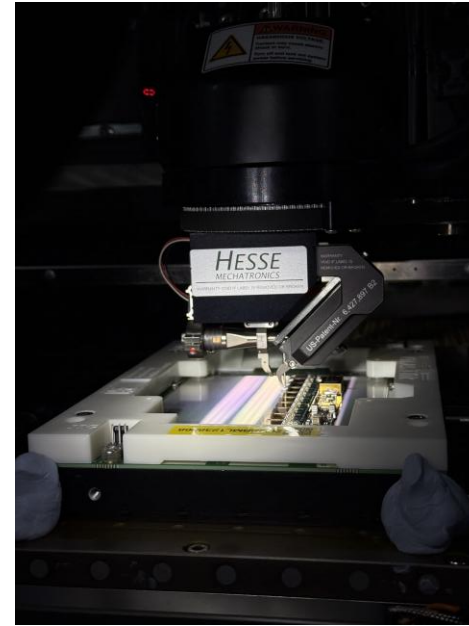
- ❖ After gluing and acceptance of metrology results, the module is secured in a dedicated frame for wire bonding.
- ❖ **Purpose:** To provide electrical connections that transfer charge signals from the silicon sensor strips to the readout ASICs for hit detection.
- ❖ The frame supports and protects the module while providing access to the bonding areas.
- ❖ Inspect bond placement, loop geometry and connections around the HCC.



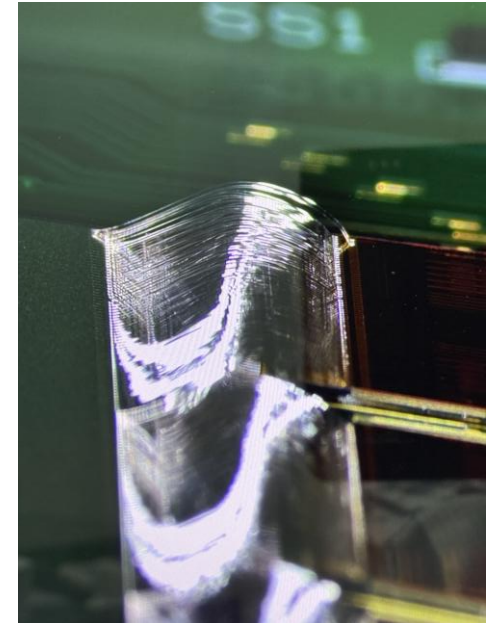
Bonding Tool



Wire Bonding at IHEP



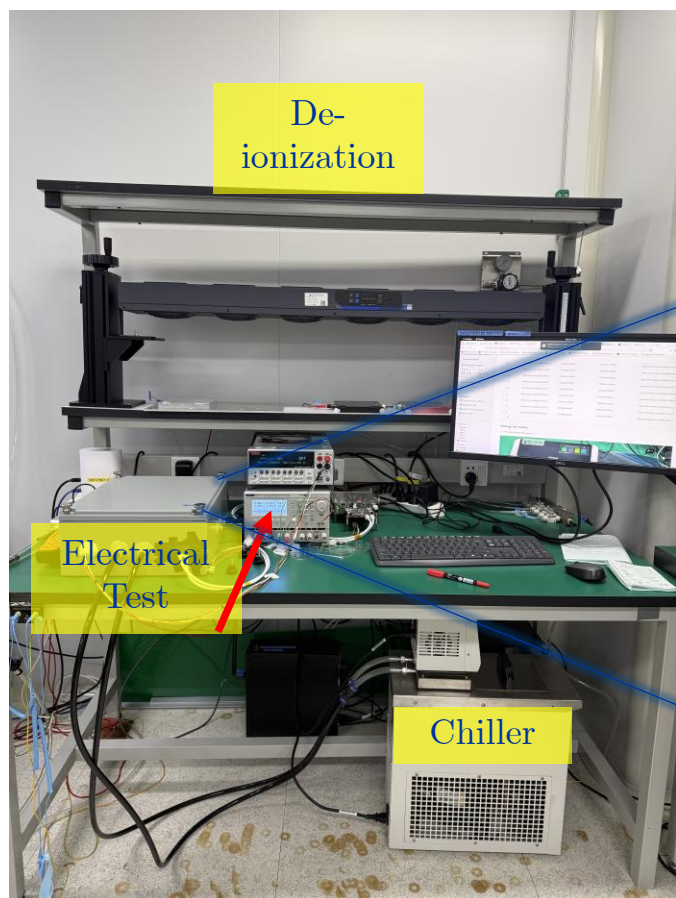
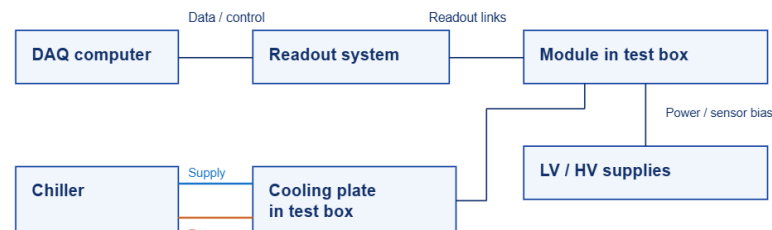
Module Positioned for Wire Bonding



Wire-Bond Loops

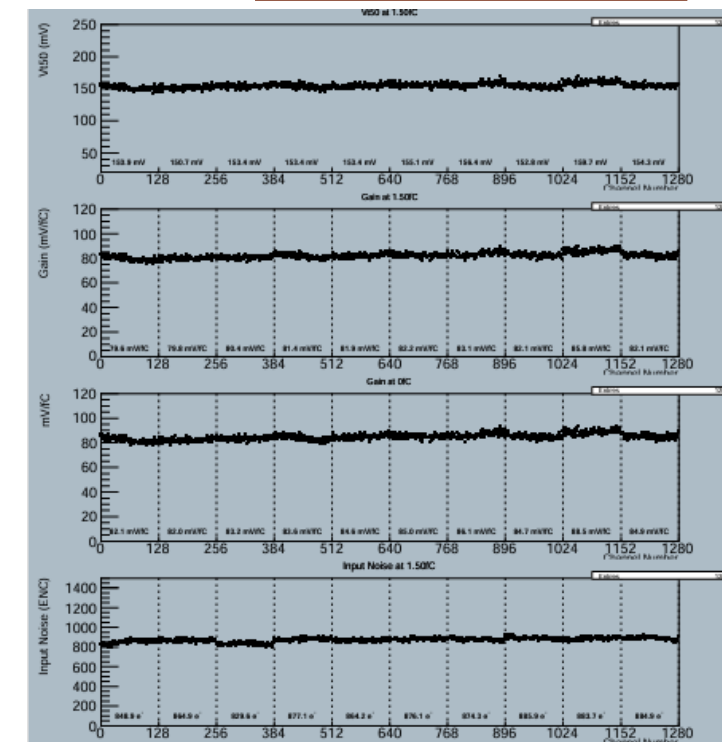
Single Module E-test

- ❖ Electrical tests verify module readout functionality after wire bonding.
- ❖ **Readout testing:** Measures channel-by-channel threshold response, gain and noise to assess readout performance.
- ❖ **IV scan:** Measures sensor leakage current as a function of reverse-bias voltage to check for excessive current or early breakdown.



Single-Module Test Setup

Readout Test Results



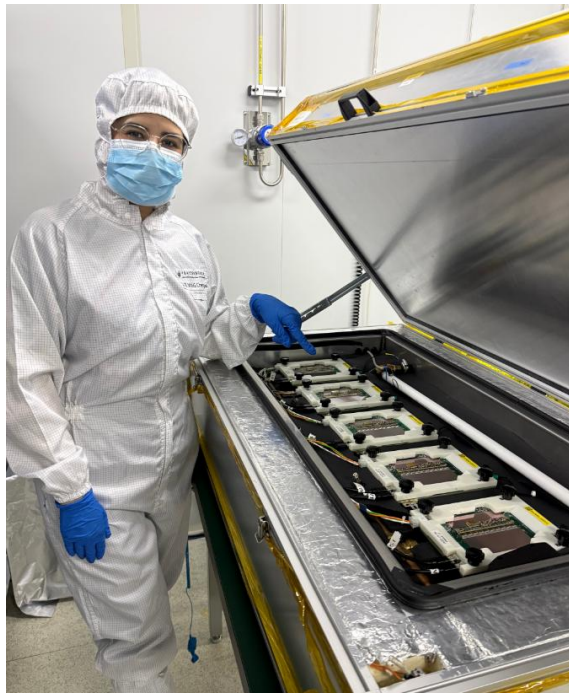
- Threshold response and gain are broadly uniform across the measured channels.
- Input noise is around 900 e^- ENC.
- Readout status: **PASS**

Module Thermal Cycling

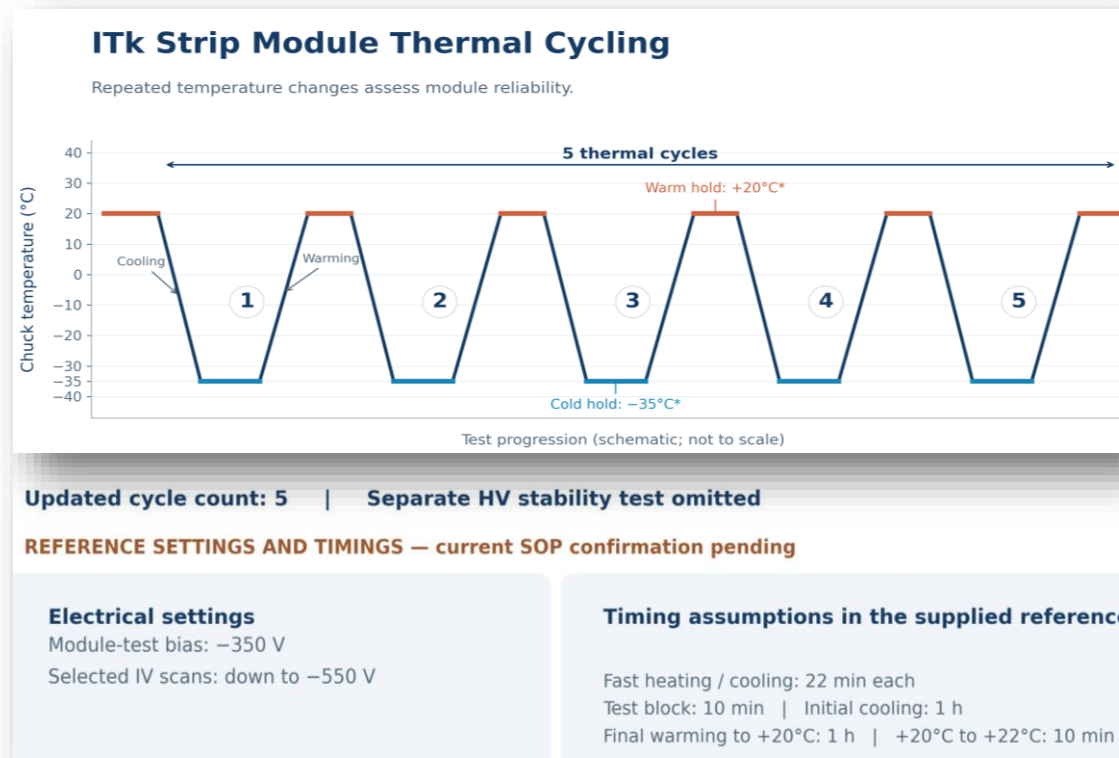
Purpose: Assess module reliability under repeated temperature changes and check for changes in electrical performance.

- **Cold chuck temperature:** -35°C
- **Warm chuck temperature:** $+20^{\circ}\text{C}$
- **Thermal cycles:** 5
- **Module-test bias:** -350 V
- **Selected IV scans:** down to -550 V

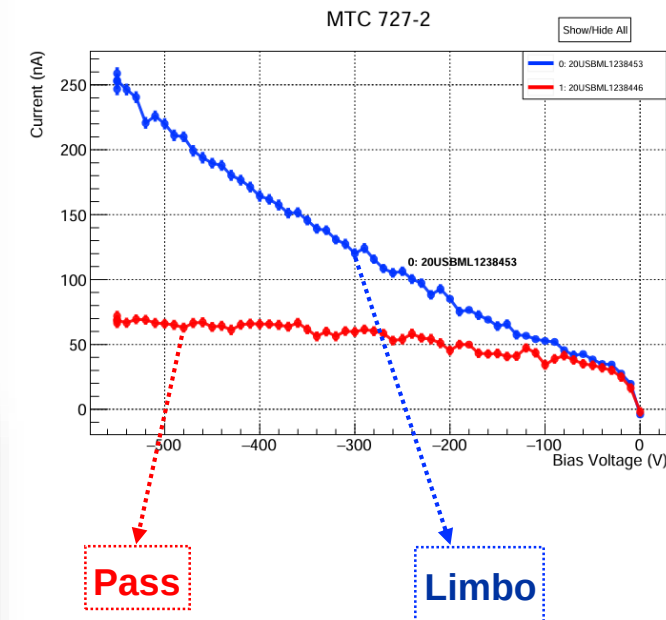
Thermal-Cycling Protocol



Thermal-Cycling Setup at IHEP



Illustrative thermal-cycling sequence with electrical checks at warm and cold stages; chuck temperature shown.



IV Response of Two Modules

HV Tab Bonding and Mechanical Testing at IHEP

Purpose

- HV tabs provide the electrical connection to the sensor backplane for high-voltage biasing. cds.cern.ch
- Pull tests assess the mechanical strength of the HV-tab bond.

Work at IHEP

- Evaluate HV-tab bond strength using pull tests on half-moon sensor samples.
- Improve the pulling fixture to reduce movement at the loading point and improve test reproducibility.

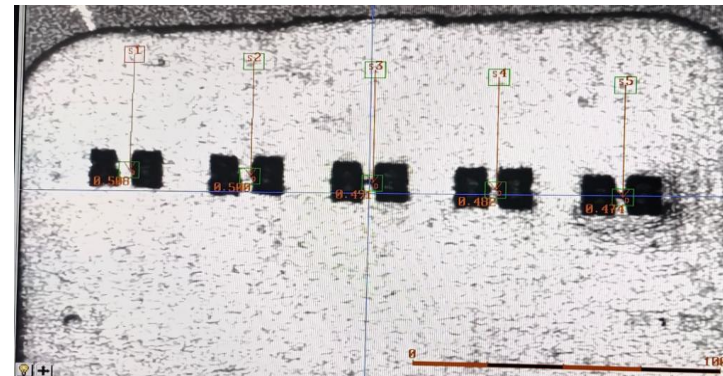
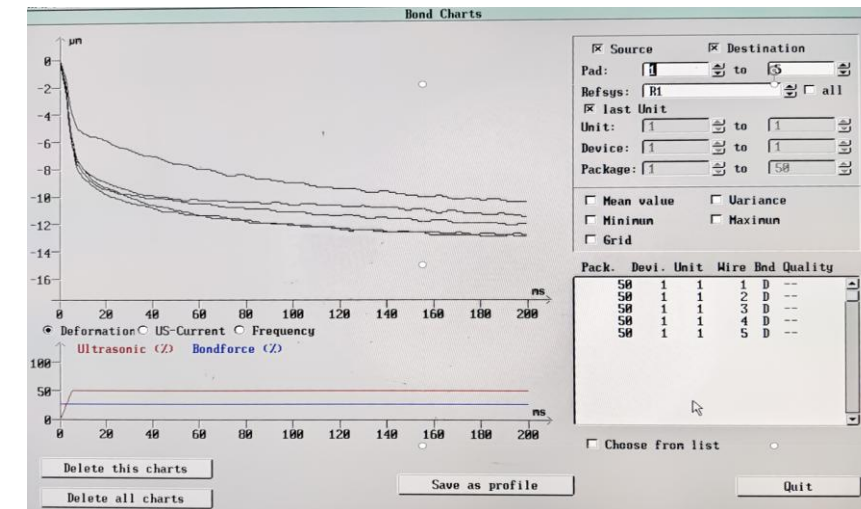


Photo results of 5 tab tool welds using the Bondjet BJ820 automatic wedge bonder(wire bonder)



High Speed Fully Automatic Fine Wire Wedge Bonder

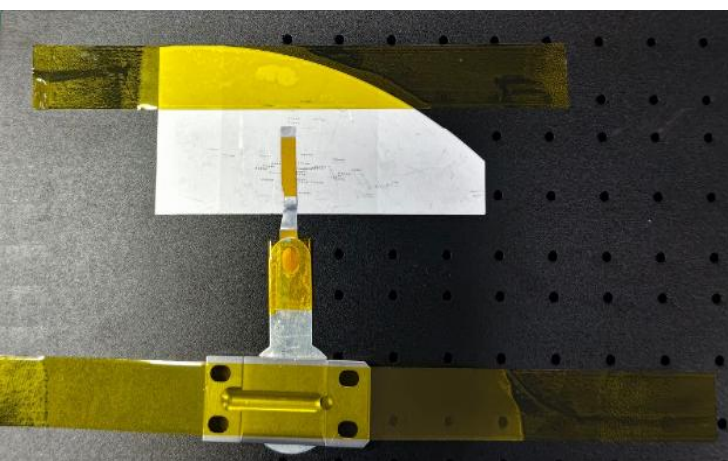
- Bonder: BondJet BJ820 automatic wedge bonder (wire bonder)
- Tab Tool: Micro-Point Pro Tab Tool MP-45102-1014-159-604
- Tab tool footprint: ~200x200 μm , allowing for 5 welds along tab width.
- Manual placement pitch: 340-374 μm .

- The figure above shows the Bond Charts interface for real-time process monitoring. The upper graph displays the Z-axis deformation (μm) over time (ms) for multiple welds.
- The lower graph plots applied ultrasonic power percentage (red line) and bond force percentage (blue line) over time.

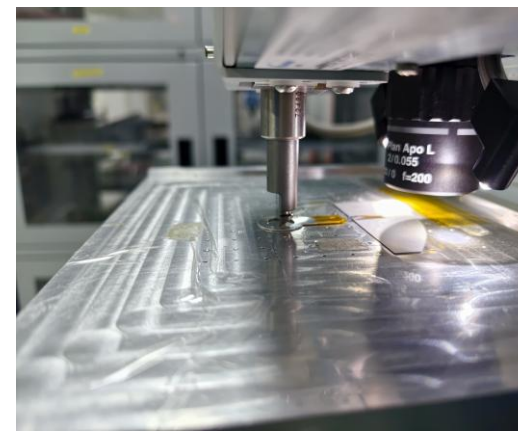
HV Tab Bonding and Mechanical Testing at IHEP

Tab pull testing

- Tab weld strength is measured using our Nordson DAGE 4000Plus bond test system equipped with an S50KG cartridge.
- For test reliability, the sensor halfmoons are placed on the test platform and secured by vacuum suction, providing a level surface for the shear tool to travel along.
- Solder tags are attached to the short tab segments using tape to enable the shear tool to engage. The tabs are held in place with tape during bonding, which is removed prior to testing.



As shown in the figure, a single short tab segment with a solder tag attached is prepared for testing, the sensor halfmoon is also secured with tape. After these components are fixed, the wire bonding process is performed. After bonding, the tape is removed, and the shear testing is subsequently carried out on the DAGE 4000Plus.



Shear test setup for the Tab sample using the S50KG cartridge, and a close-up of the custom tool insert.

Parameter	Halfmoon
Pull strength Test 1 (g)	464.67
Pull strength Test 2 (g)	318.92
Pull strength Test 3 (g)	451.49
Pull strength Test 4 (g)	418.19
Pull strength Test 5 (g)	334.67
Mean pull strength (g)	397.6
Stdev. pull strength (g)	67.0
Maximum pull strength (g)	464.67
Minimum pull strength (g)	318.92
Failure mode	All tabs pulled off from Halfmoon

Summary and Outlook

Production Results

- ✓ 50 Modules has been completed from IHEP site.
- ✓ Contribution of 14 long-strip (LS) modules assembled and tested.
- ✓ All 14 modules passed the required QC tests.

Next Steps

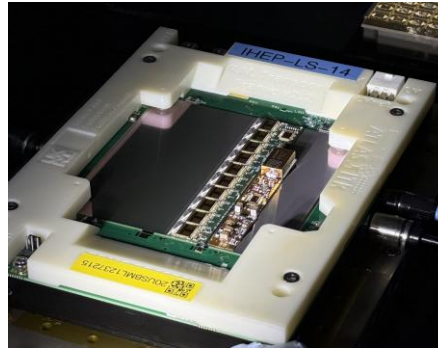
- ❖ Ship the accepted modules back to Rutherford Appleton Laboratory (RAL).
- ❖ Investigate limbo-state modules to understand their electrical behavior and assess recovery procedures.
- ❖ Start working on the Limbo state modules (6 out of 50 modules).

14

LS modules completed
through defined
production steps

100%

Final QC acceptance
14/14 modules



Examples of Accepted LS Modules



Acknowledgements

I would like to thank our collaborators from the other universities for their contributions and support.



史欣

Overall



张希媛

Modules



陆卫国

Thermal Cycling



庄霄爱

Special thanks to my supervisors Professor Xin Shi and the IHEP ITk team for their guidance, technical training and support throughout module assembly and testing.



李瞻

SOP



蔡祺

Hybrids



李航

Modules



赵森

Wirebonding



米欣然

SOP



符晨曦

Modules



Thank You

Backup

Overview

A **module** consists of a

- ❖ **Silicon strip sensor,**
- ❖ **Hybrids,**
- ❖ **Powerboard.**

- ❖ The **hybrid** carries the
 - ABCStar
 - HCCStar.

The hybrid performs readout and communication; the separate powerboard performs power conversion and module monitoring

Application-specific integrated circuits (ASICs)

- used for readout and control
- Custom developed in 130 nm CMOS technology
- STAR architecture used to deal with 1 MHz trigger rate

ABCs – ATLAS Binary Readout Chips

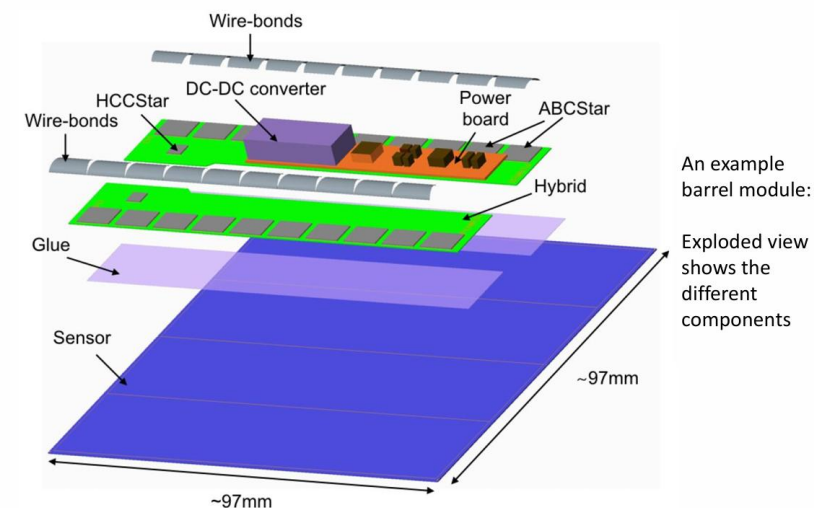
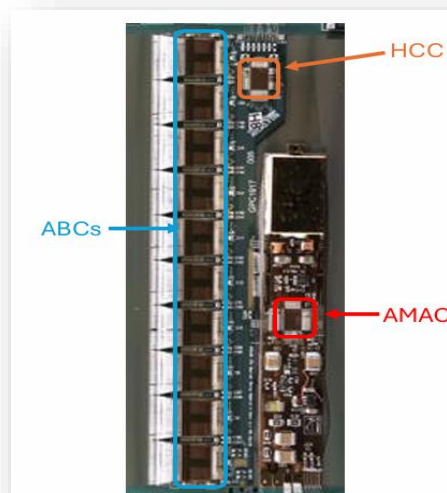
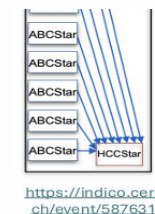
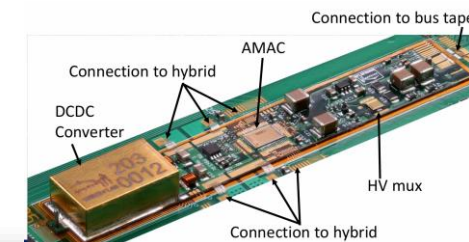
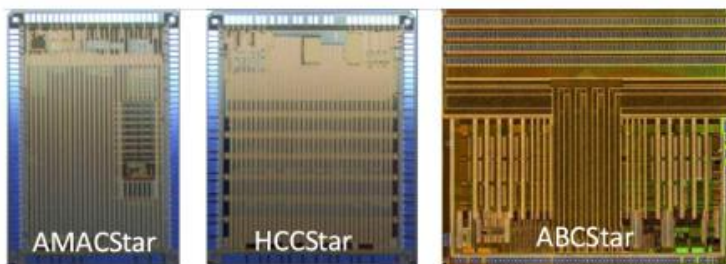
- Readout analogue signal from sensors into binary data (hits)
- Wire-bonded to the sensors

HCCs – Hybrid Controller Chips

- Collect data from ABCs (10 ABCs per HCC) for output to off-detector
- Glued to the hybrids (the readout PCBs)

AMAC – Autonomous Monitor And Control

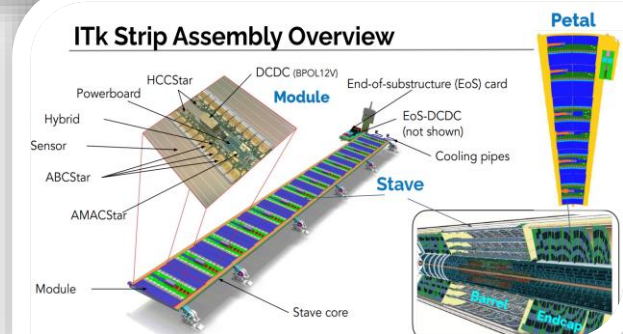
- chip to control and monitor the module



Standard Barrel Hybrid

- 10 × ABCStar
- 1 × HCCStar
- 2,560 readout channels

ITk Strip Assembly Overview



Hybrid Status:

❑ ASICs & HCC Gluing

ABCStar readout ASICs and the HCCStar controller are precisely positioned and glued onto the hybrid PCB.

❑ Metrology for hybrid

Component positions and heights are measured to verify alignment and assembly geometry.

❑ Wire-bonding

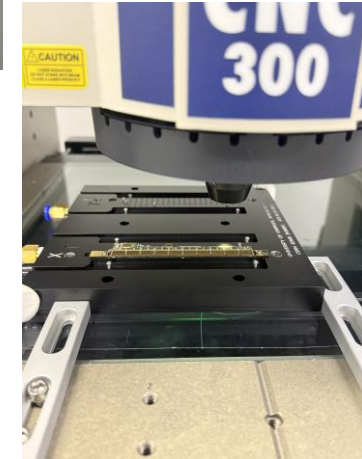
Fine wire bonds connect the ASICs to the hybrid circuitry, providing power, control and data connections.

❑ Burn-in test

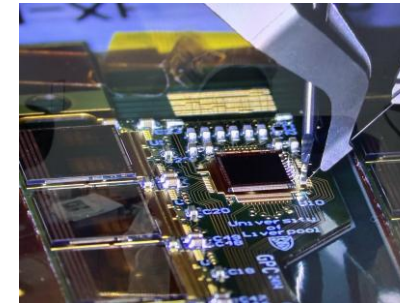
The assembled hybrid operates under controlled conditions for an extended period to check stability and identify early failures.



Assembly



Metrology



Wire bonding

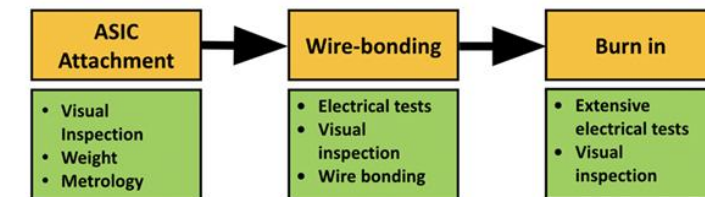
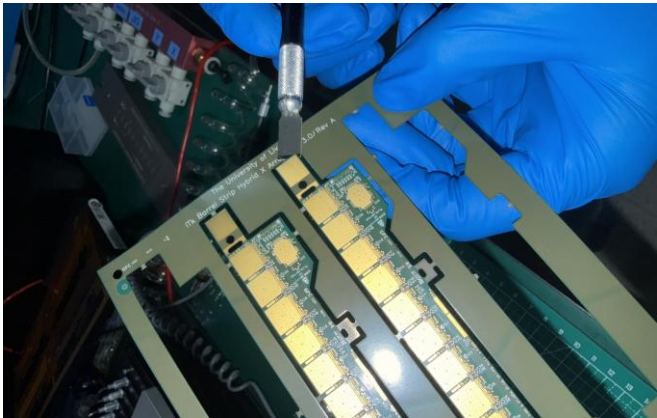


Figure 4: Hybrid assembly and QC steps.

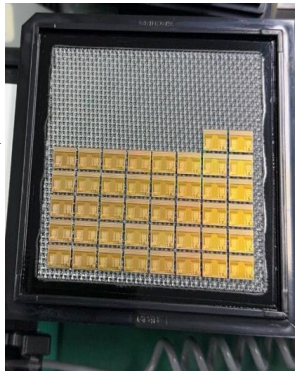
Assembly steps



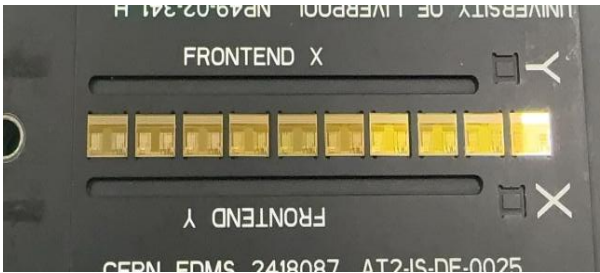
Hybrid Flex Preparation



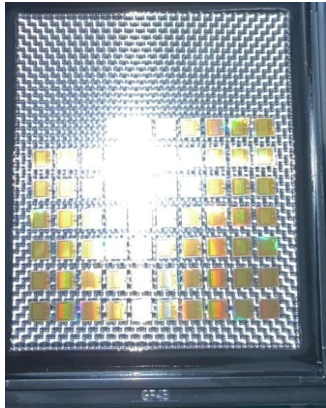
Assembly Jig Preparation



ASIC Reception & Inspection



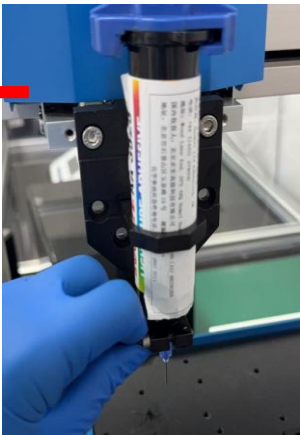
ASIC Loading into Jig



HCC inspection Check



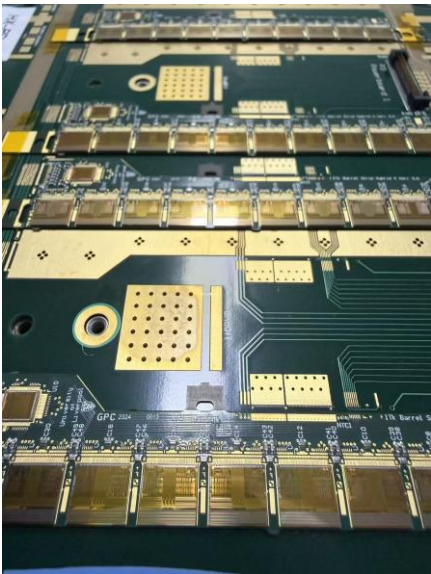
HCC loading into Jig



Preparation of Glue



Controlled Glue used

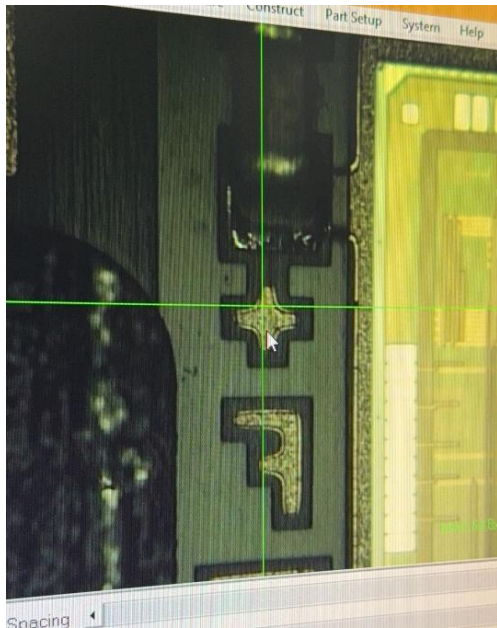
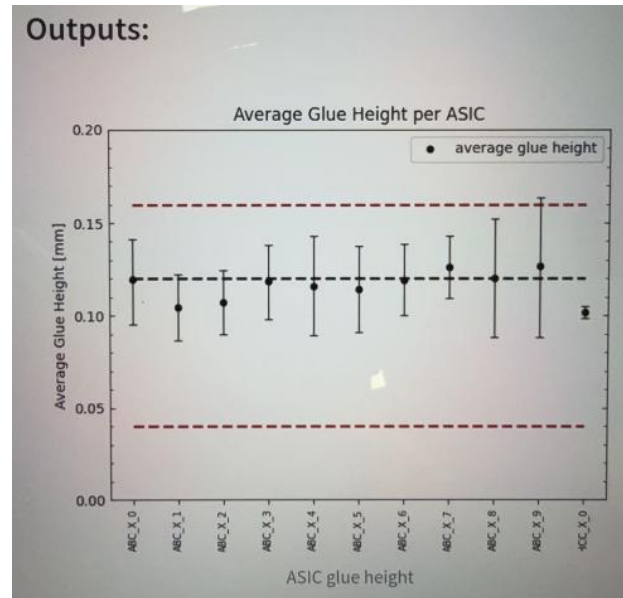


Completed Hybrid

Metrology and Wirebonding of Hybrid

Metrology

Metrology confirms the mechanical accuracy of ASIC attachment

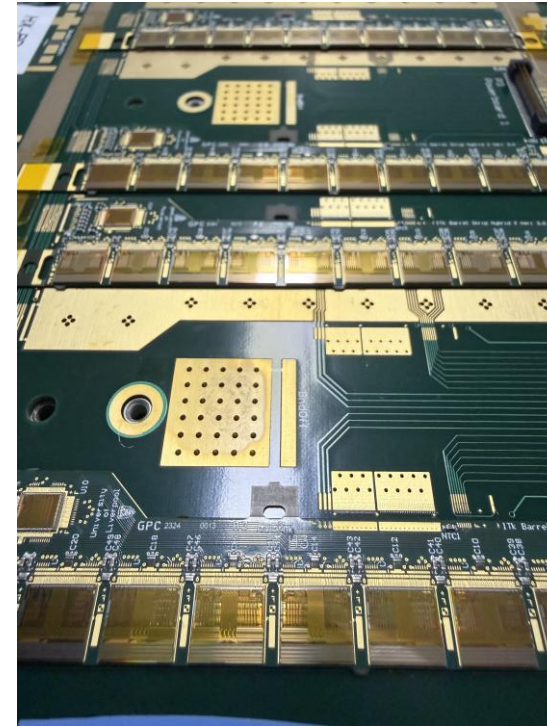


Metrology Results:

- Verifies ASIC position, alignment and glue height.
- Average glue height remains within the defined limits.
- Consistent height indicates controlled adhesive deposition.

Wire bonding

- Connects ABCStar and HCCStar ASICs to the hybrid flex.
- Provides power, control and data connections.
- Bond placement and loop geometry are visually inspected.
- Bond quality is verified through process-control pull tests.



Wire bonding establishes reliable electrical connections. Both checks are essential before the hybrid is released for module assembly."

Standard values

Sensor parameter	Typical/reference value
Technology	n+-in-p, AC-coupled strip sensor
Footprint	~98 mm × 98 mm
Thickness	~320 μm physical; ~300 μm active
Strip pitch	~75.5 μm
Long-strip length	~48 mm
Estimated sensor mass	~7.0–7.1 g (from Si density)

Readout / power	Typical/reference information
ABCStar	256 channels per chip
LS hybrid	~10 ABCStar → 2560 channels
HCCStar	1 per hybrid; controller/data concentrator
Powerboard	AMACStar + DC-DC + HV switching
Bond wire	~25 μm Al wire
Module bow reference	–50 μm to +150 μm in public IHEP material

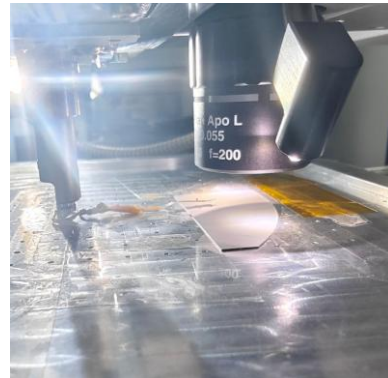
HV Tab Bonding and Mechanical Testing at IHEP

Purpose

- HV tabs provide the electrical connection to the sensor backplane for high-voltage biasing. cds.cern.ch
- Pull tests assess the mechanical strength of the HV-tab bond.

Work at IHEP

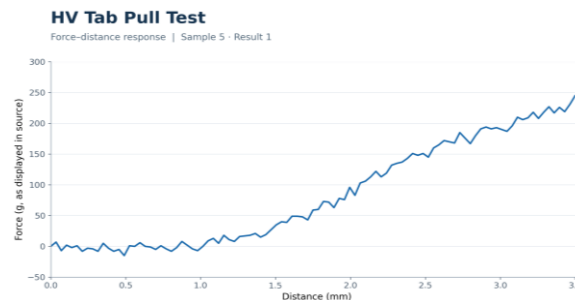
- Evaluate HV-tab bond strength using pull tests on half-moon sensor samples.
- Improve the pulling fixture to reduce movement at the loading point and improve test reproducibility.



The 250g HV TAB has disconnected from the halfmoon.



- We use a ring made of braided metal wire to secure the solder tab. The solder tab is bonded to the HV TAB with adhesive and then fixed with tape.
- This method has a drawback: the contact point between the ring and the solder tab is movable, which directly affects the test.



We plan to use a larger ring with a diameter of 10.2 mm, so the braided ring is no longer needed. Instead, the S50KG will be inserted directly into the solder tab and then moved, which avoids the previous problem.