The ATLAS ITk Strip Detector for the LHC Phase-II Upgrade

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on behalf of China ATLAS-ITk

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中国科学院高能物理研究所

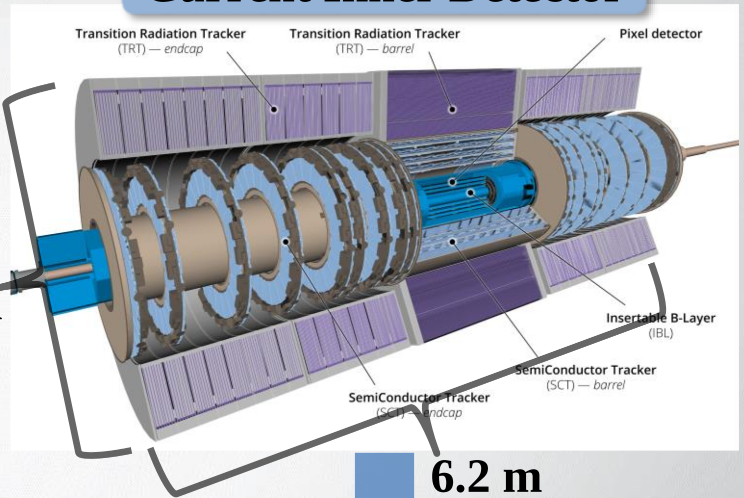
Institute of High Energy Physics, Chinese Academy of Sciences

ATLAS EXPERIMENT

ATLAS-ITk in LHC Phase-II

- **LHC Phase-II (HL-LHC) upgrade**
  - ➢ Instantaneous **luminosity** up to $7.5 \times 10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$
  - ➢ Integrated **luminosity** up to $3000 \sim 4000\ \mathrm{fb}^{-1}$
  - ➢ Collision center-of-mass energy up to $\sqrt{s} = \mathbf{14\ TeV}$
  - ➢ Up to 200 inelastic pp collision per beam crossing (**pileup**)
  - ➢ **10 times** higher **radiation**
- **All-silicon Inner Tracker (ITk)**
  - ➢ Higher granularity / Larger coverage / Faster response
  - ➢ Higher radiation tolerance
  - ➢ Reduced material budget

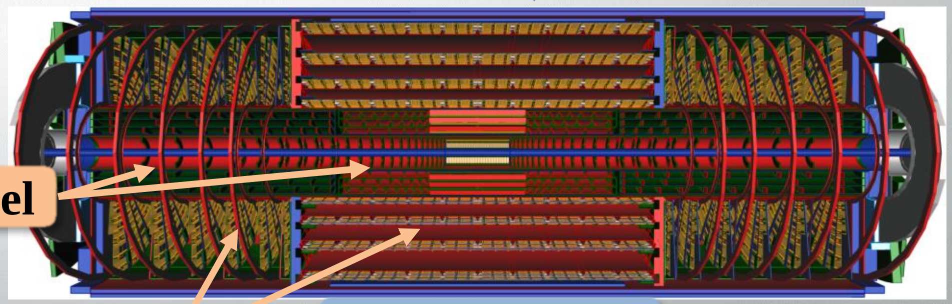
Current Inner Detector



2.1 m

6.2 m

Same envelope



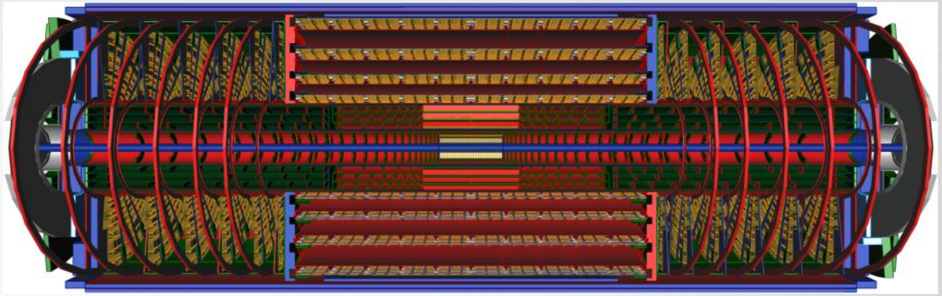
Pixel

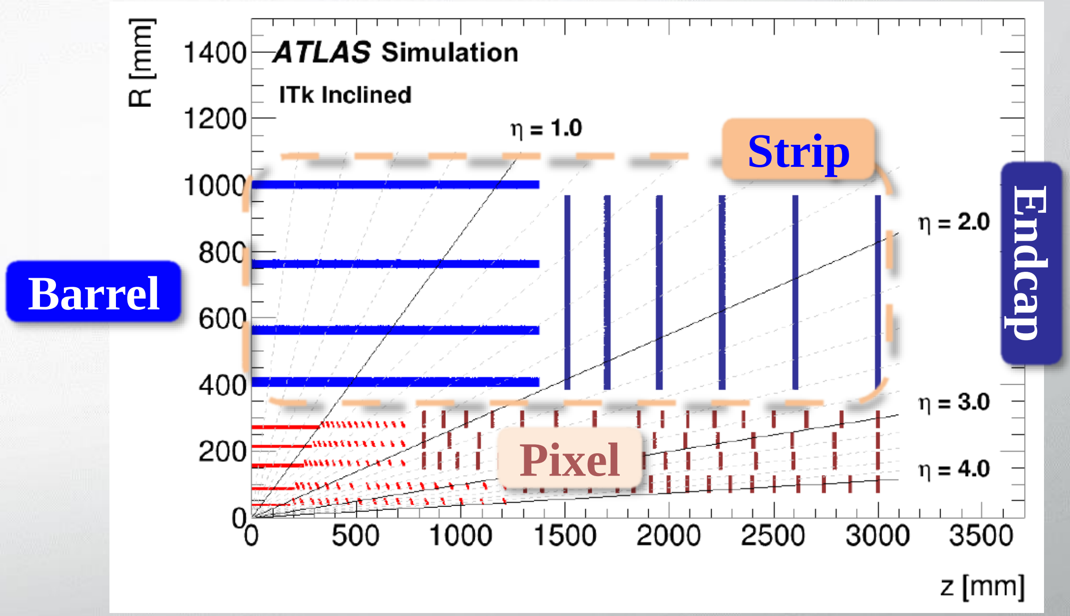
Strip

Upgrade ITk

ITk Strip Layout

- **Barrel — IHEP site**
  - 4 layers (each double sided)
  - L0 / L1 (inner) with **short strip (SS) staves**
  - L2 / L3 (outer) with **long strip (LS) staves**
- **Endcap**
  - 6 disks (double sided) at each end
  - 32 identical **petals** on each disc

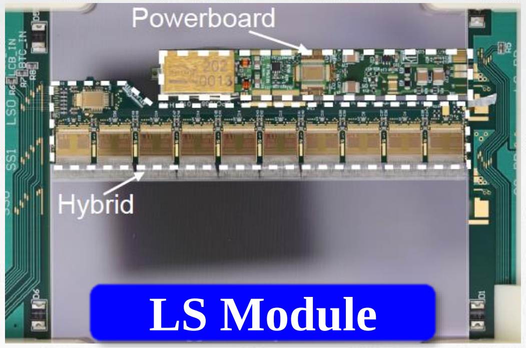


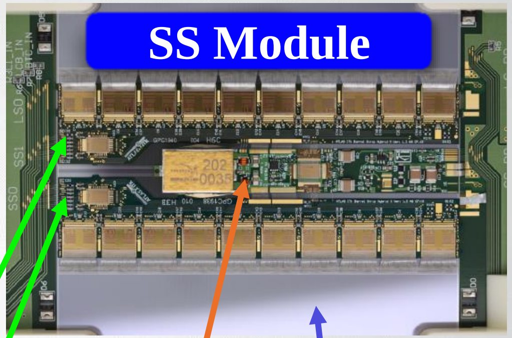


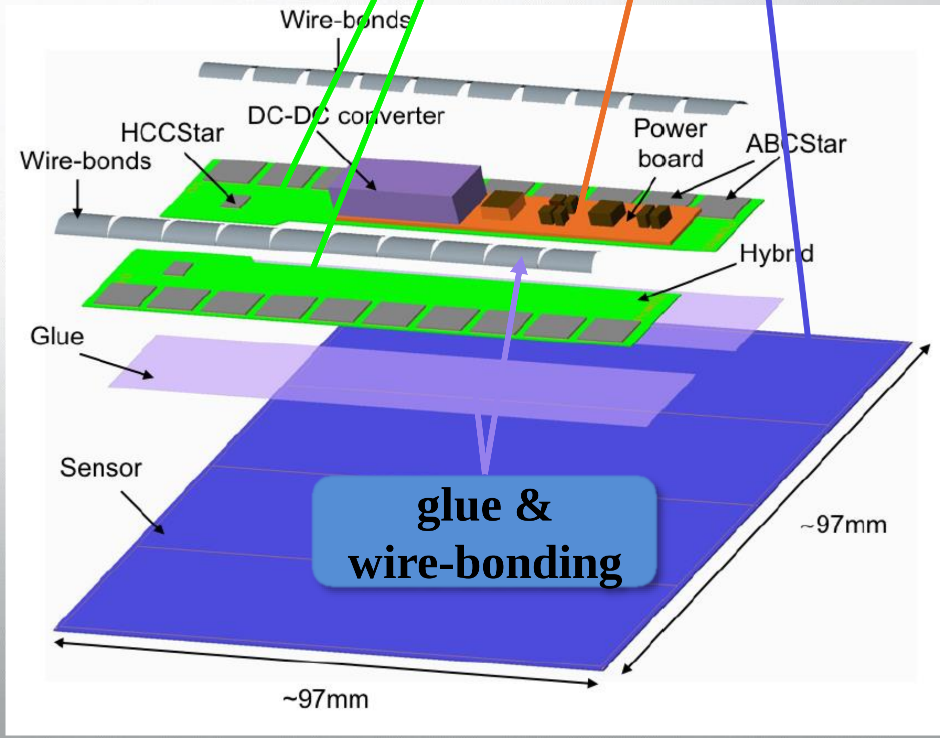
ITk Strips	Layers	Staves/Petals	Modules	Surface [m^2]	Channels [M]	Strip pitch [μm]	Strip length [mm]
Barrel	4	392 Staves	10976	104.86	37.85	75.5	24.1 – 48.2
Endcap	6	384 Petals	6912	60.4	22.02	69.0 – 85.0	19.0 – 60.0

Detector Element

- **Module**
  - ➢ **Sensors**
    - ➢ LS: 48.2 mm strip / SS: 24.1 mm strip
  - ➢ **Hybrid**
    - ABCStar — frontends binary readout chip
    - HCCStar — hybrid controller chip
  - ➢ **Powerboard**
    - AMACStar — monitoring & controller
    - HVMux — HV switch and multiplexer
    - DCDC

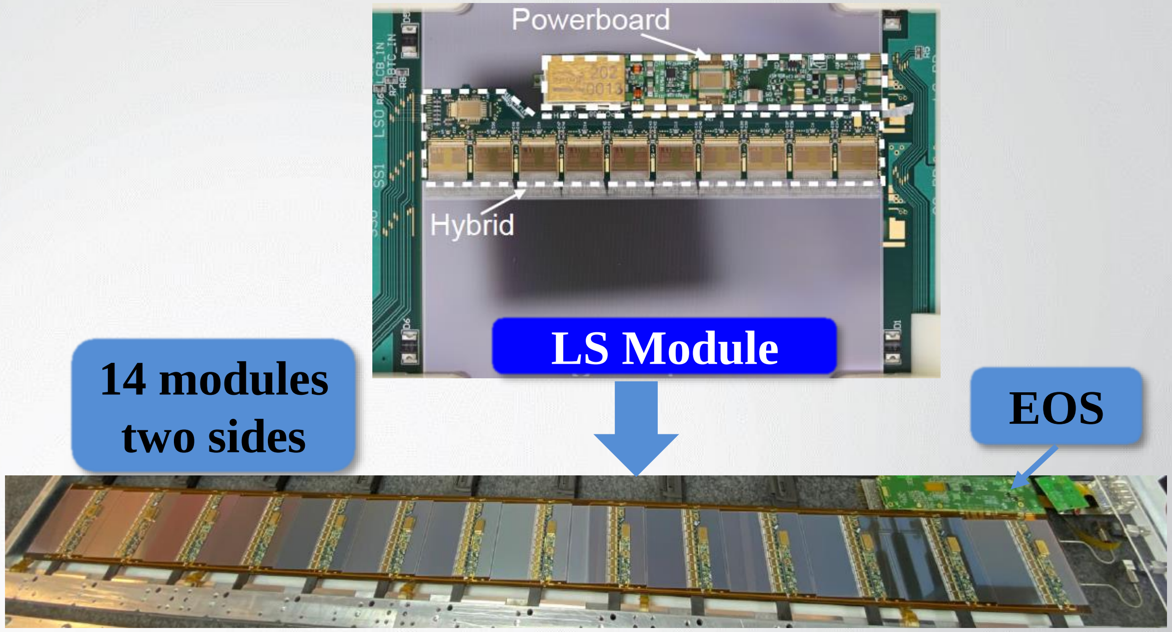


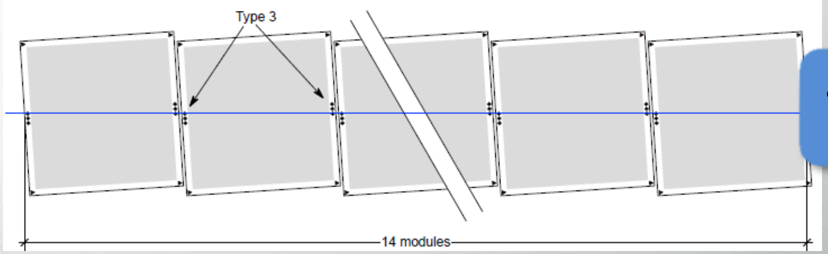


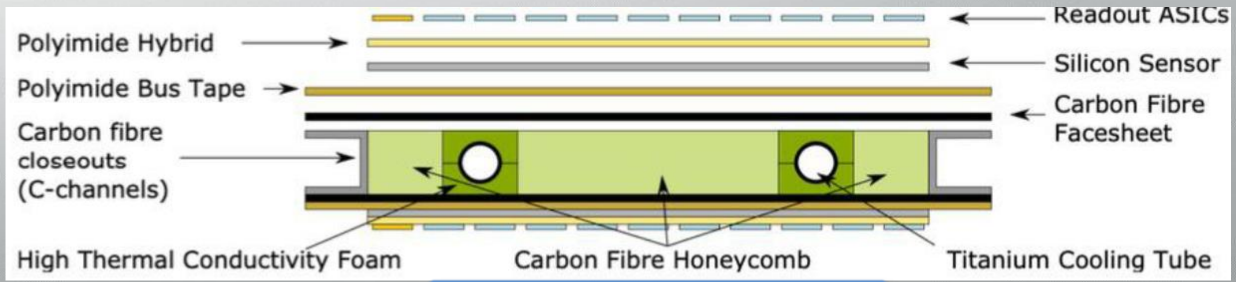


Detector Element

- **Staves**
  - Modules are loaded to **Staves**
    - Carbon-fibre **mechanical support**
    - Copper-Kapton **bus tape** (pow. / com.)
    - Titanium **cooling tubes** (evaporative CO_2)
  - **End-of-Substructure (EOS) Card**
    - **Interface** between **stave** and **off-detector**
    - lpGBTx (Low Power GigaBit Transceiver)
    - VTRx+ (optical transceiver module)





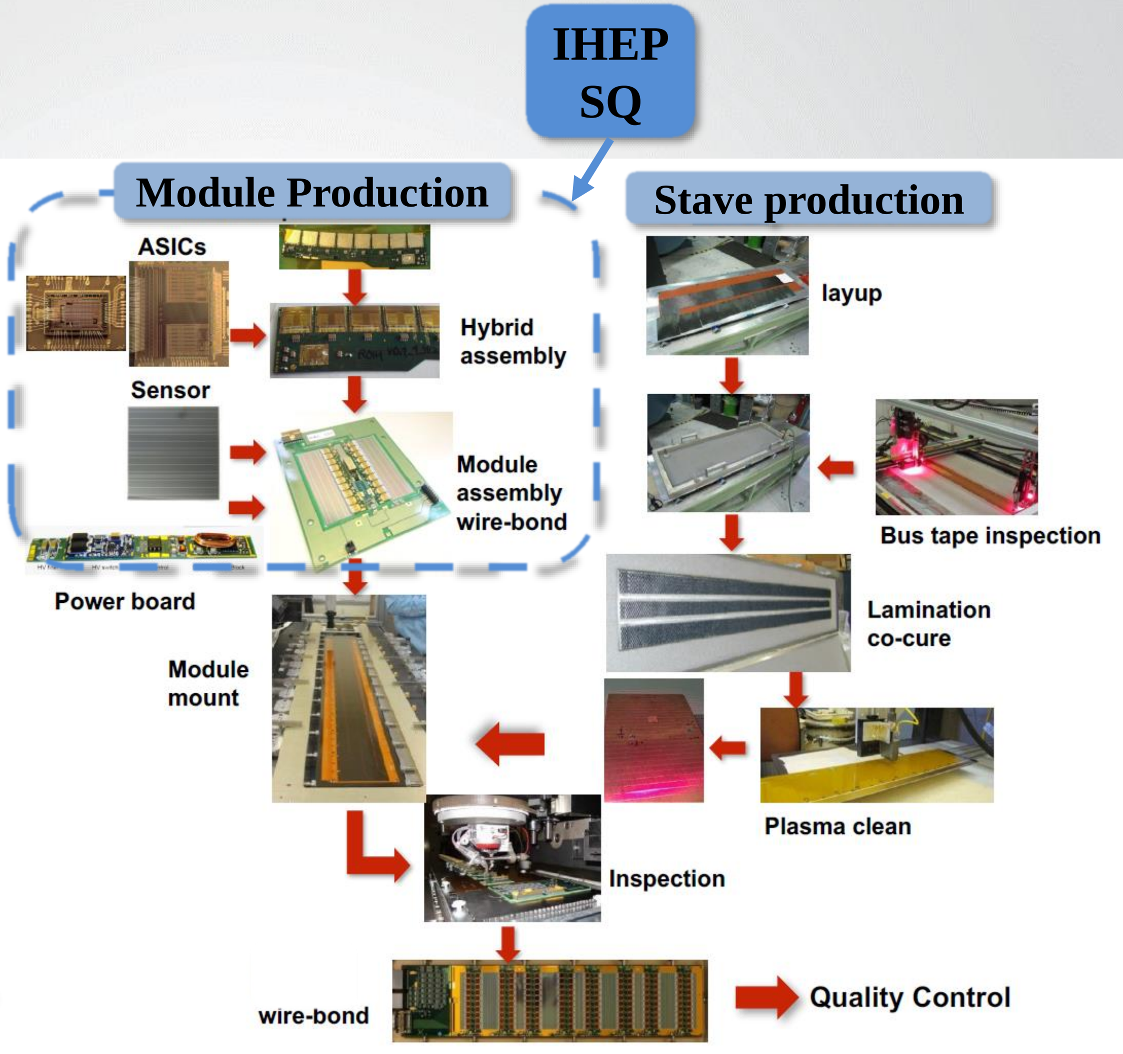


stave cross section

Production Flow

- **For Module Production**
  - Hybrid Assembly
  - Module Assembly
  - Quality Control

- **IHEP Site Qualifications**
  - 29 steps qualified for **barrel module** production
  - **10 %** of production (**~ 1k modules**) allocated to IHEP

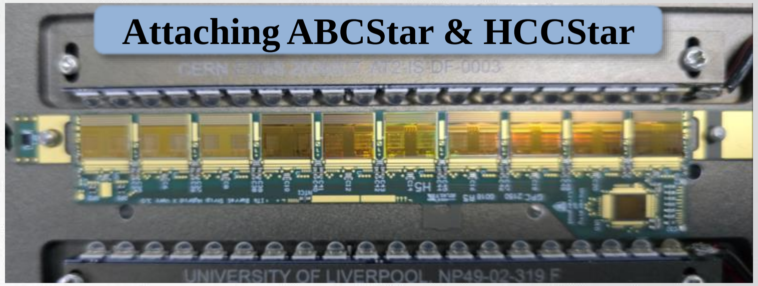


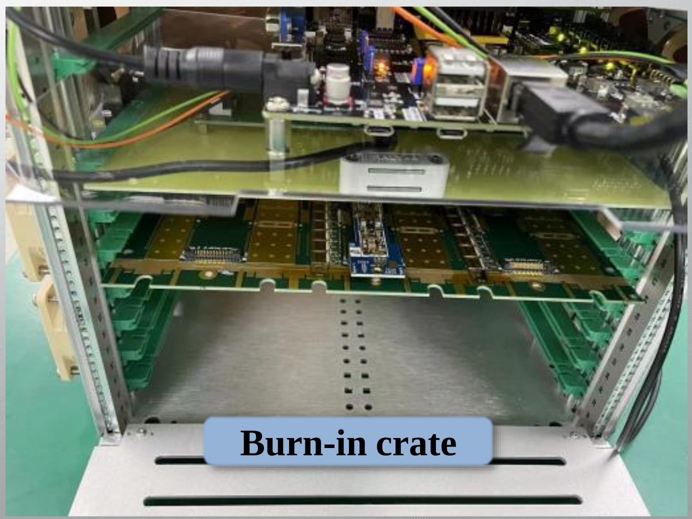
Hybrid Assembly

- **Procedure**
  - **ASICs** attachment and **wire-bonding**
    - ASICs adhesive: **Acrylic UV glue**
    - Glue coverage controlled by weight and thickness
    - Wire-bonding with a Hesse Bondjet
    - Examine wire-bonding flaws by visual inspections
  - Electrical performance test and **Burn-in**
    - E-test under heat stress — 100 hour at 40 ± 5℃

Check C. Wang's Poster about E-testing in ITk, No. 5-23

- **Quality control**
  - Glue weight, metrology, visual Inspection, burn-in





Module Assembly

- **Procedure**
  - ➢ **Hybrid** / **Powerboard** attachment and **wire-bonding**
    - ➢ Hybrid & PB adhesive: **Epoxy**
    - ➢ Bond 256 Al wires in 4 rows per ABCstar chip FE
    - ➢ Examine module envelope, positions of hybrid & PB, sensor bow
  - ➢ Electrical performance test and **Thermal cycling**
    - Ten ‘$-35 \rightarrow 20 \rightarrow -35$ °C’ thermal cycles with E-tests

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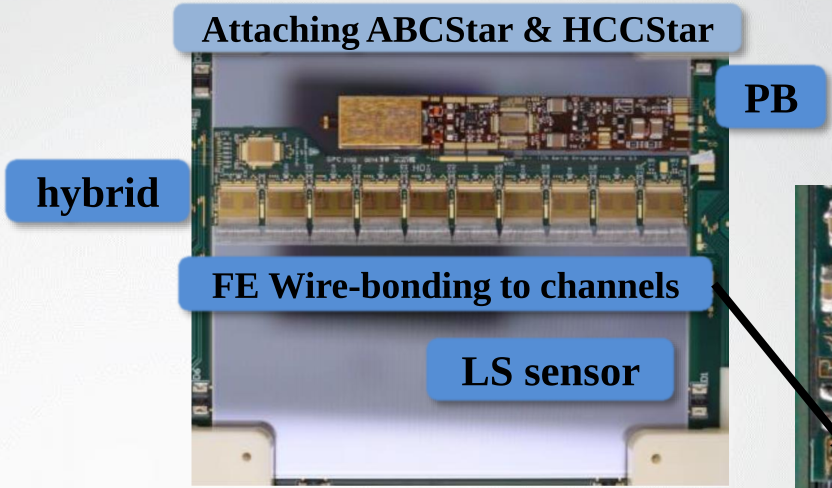
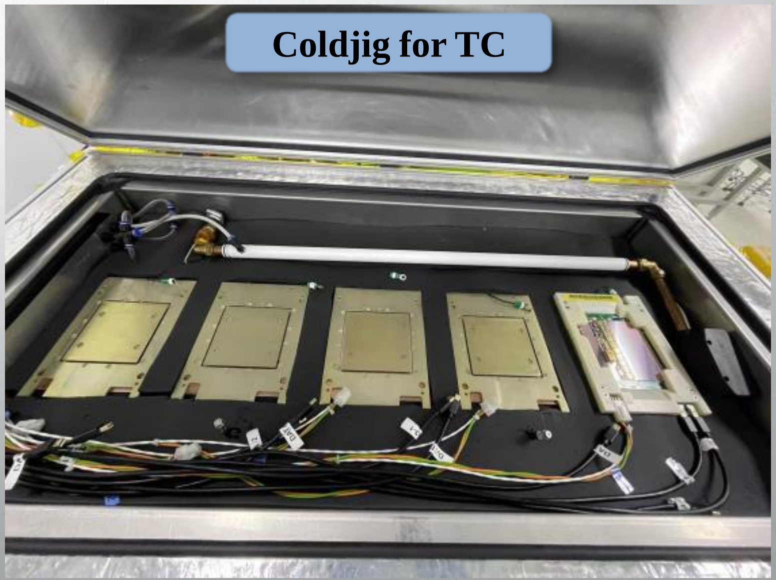
- **Quality control**
  - ➢ Glue weight, metrology, visual inspection, thermal cycle

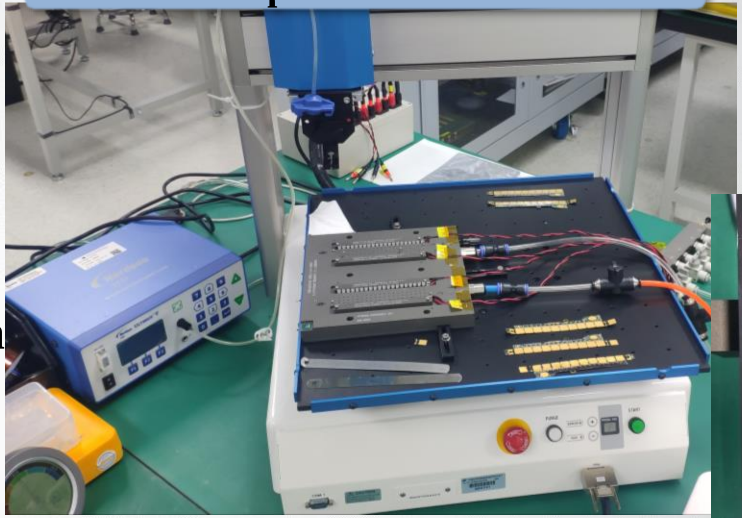




Quality Control

- **Glue weights**
  - ASICs-to-hybrid glue dispensing by a **CNC dispensing system**
    - weighting with a digital scale
    - 43.8 ± 2.62 mg for ASIC adhesive weight
  - Hybrid / PB -to-sensor gluing by **stencils**
- Metrology
  - Geometric positioning of characteristics
    - Hybrid package thickness, ASIC positions, tilts
    - Module envelope, sensor bowing

A Norson dispenser + JANOME robot



stencil

A Mettler digital scale

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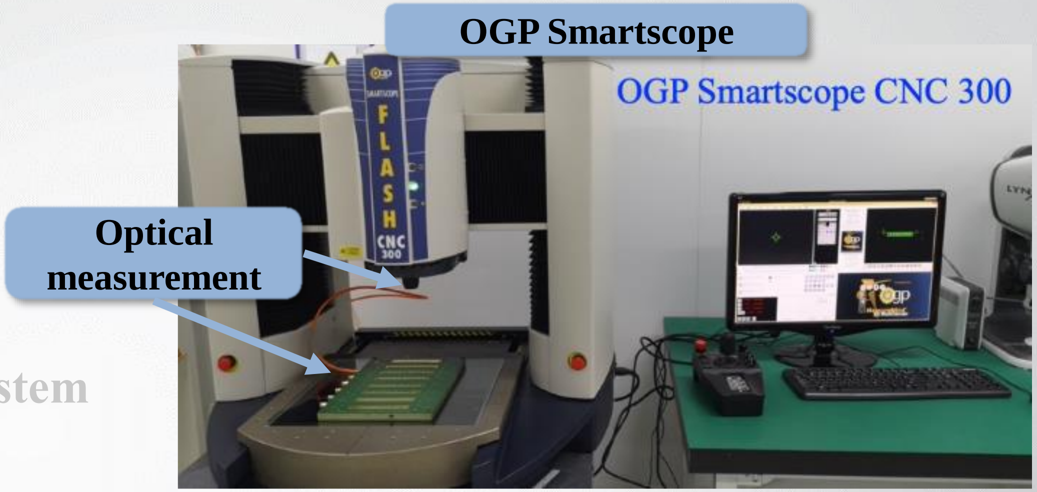
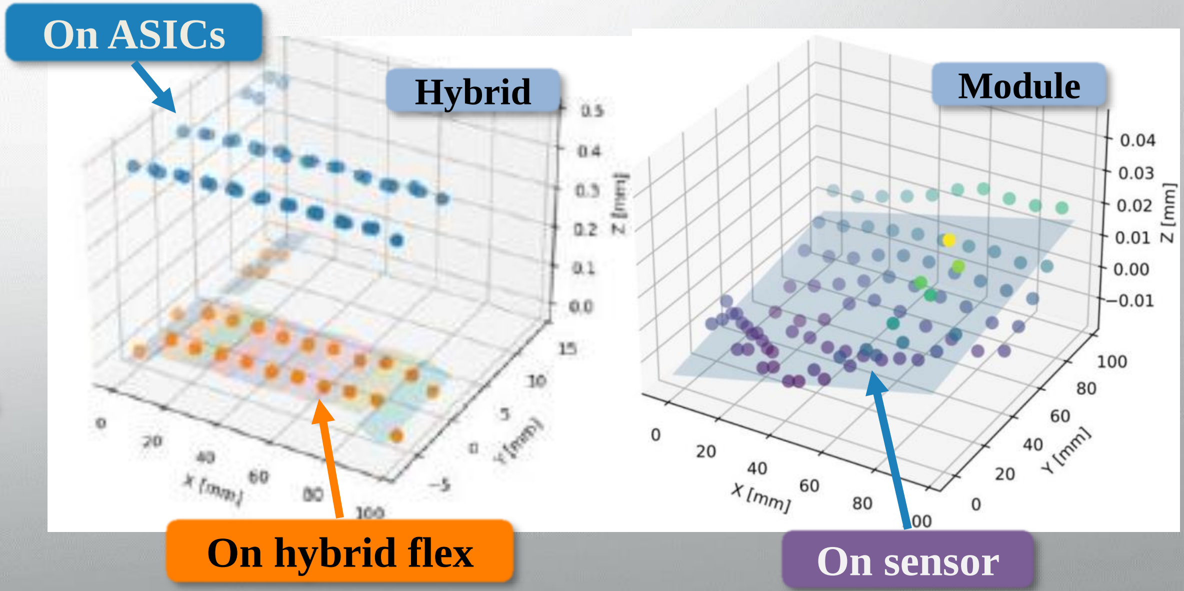
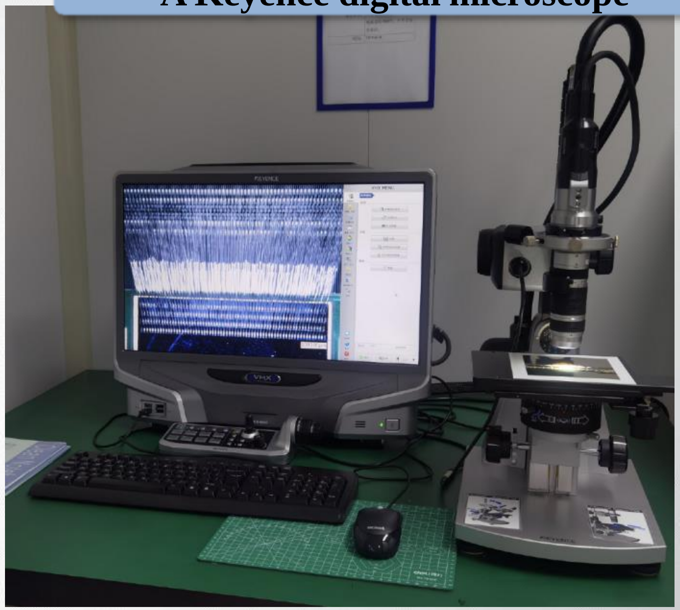




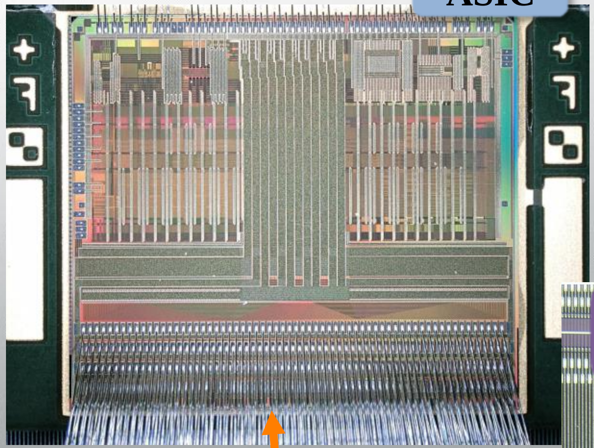
Quality Control

- **Visual Inspection**
  - Check for any defects on hybrid flex, e.g. on SMDs and bonding pads
  - Check for ASICs
    - Integrity of surface / edges for ASICs
    - cleanness on bonding pads
  - Check for sensor
    - Any scratches / marks / debris on sensor
    - Integrity of edge
    - broken sensor

A Keyence digital microscope

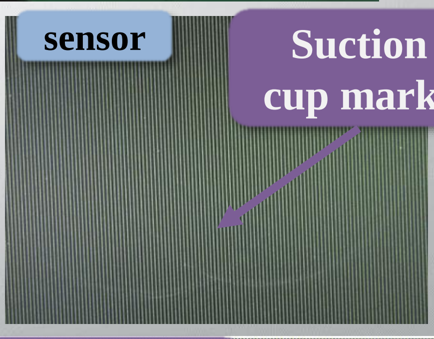


ASIC

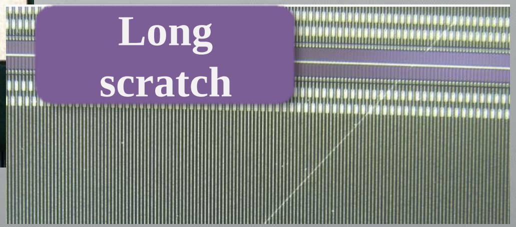


FE wire-bondings are OK

sensor



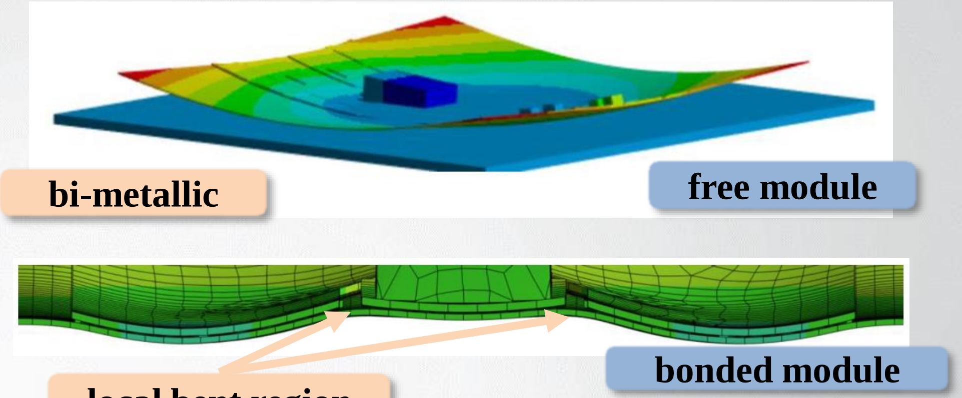
Suction cup marks

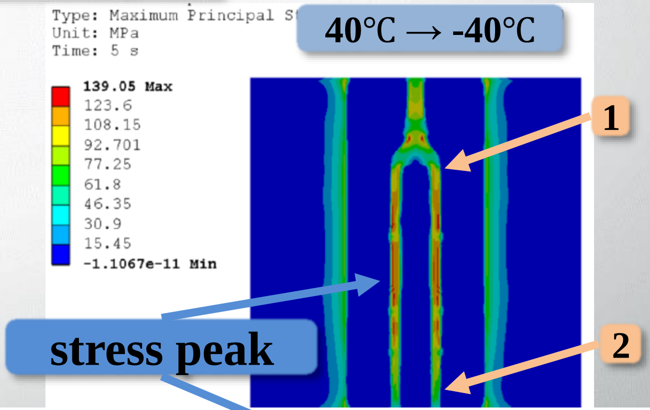


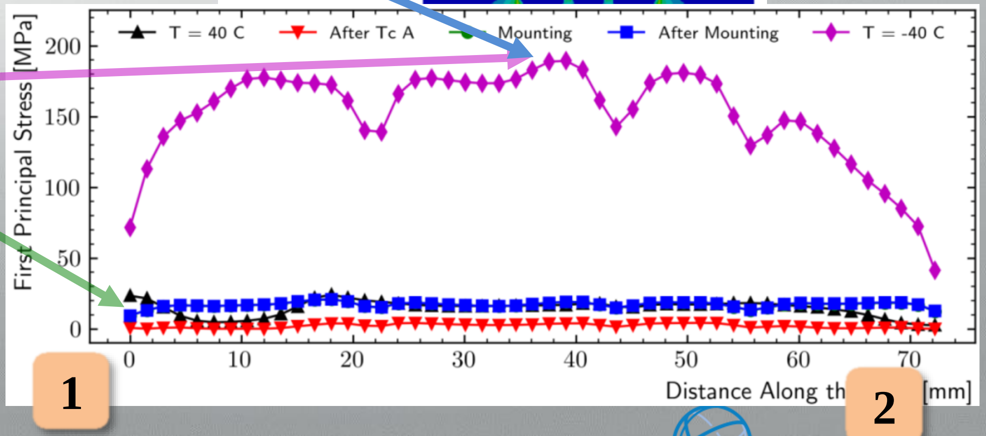
Long scratch

Towards Production

- **Sensor cracking**
  - High rate of HV-failing due to **sensor cracking**
    - mainly at interval between hybrid & PB
    - during thermal cycling
  - FEA simulation indicates a issue of **CTE mismatch**
    - different CTE — **'bi-metallic'** effect
    - bonded sensor create **local bending** — intensified stress
    - peak stress after 1st cold cycle: **150 ~ 200 Mpa**
    - stress due to 'flattening' sensor bowing: ~ 25 MPa

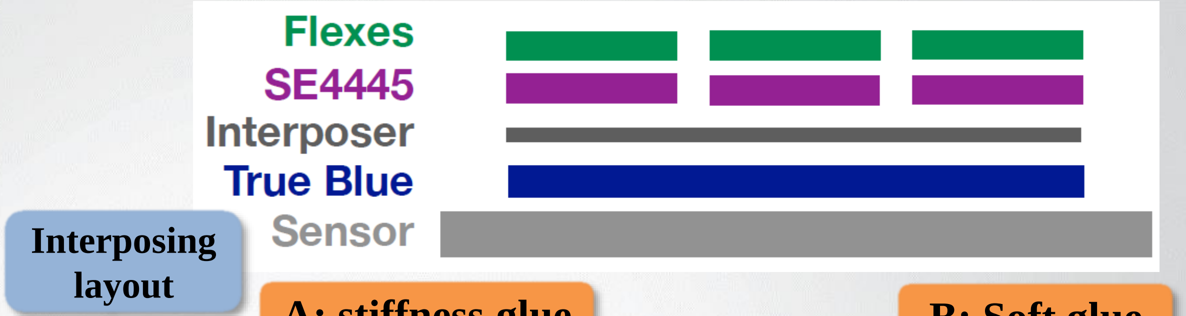


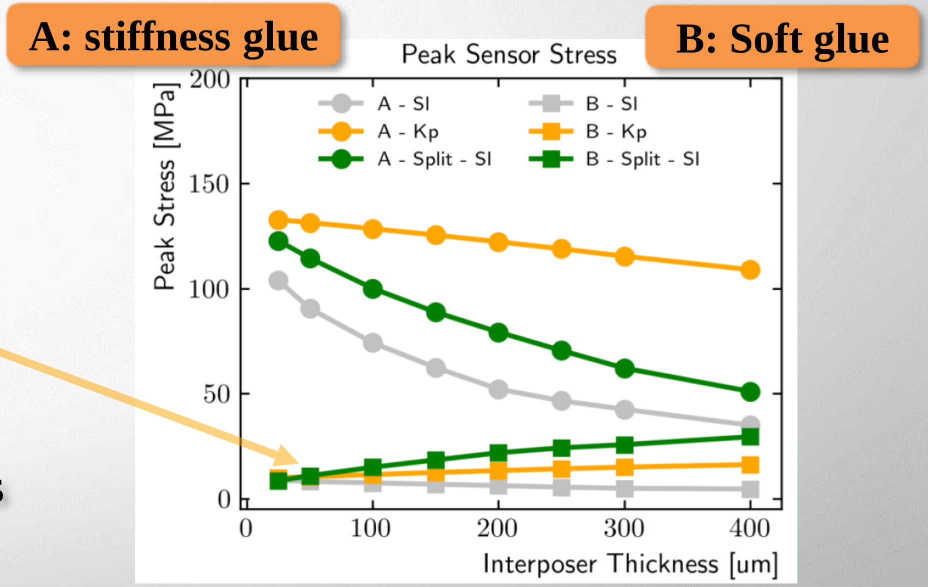


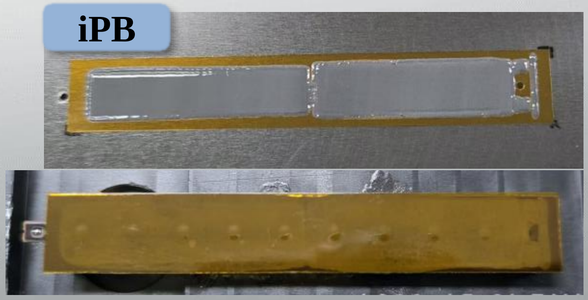


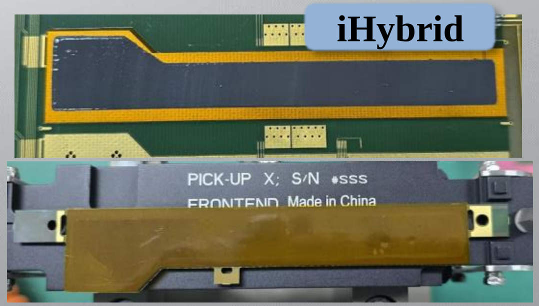
Towards Production

- **Sensor cracking — Mitigation**
  - Interposer
    - **50 um & soft glue reduce ~ 90% stress !**
    - SE4445 (silicone) as glue, Kapton as interposer
  - i-(**Interposed**)Hybrids and iPowerboards assembled at IHEP
    - Metrology measurement for monitoring interposer thickness
    - Update our pre-production phase with iModule
  - Production phase
    - Receive iHybrid / iPB from hybrid flex sites







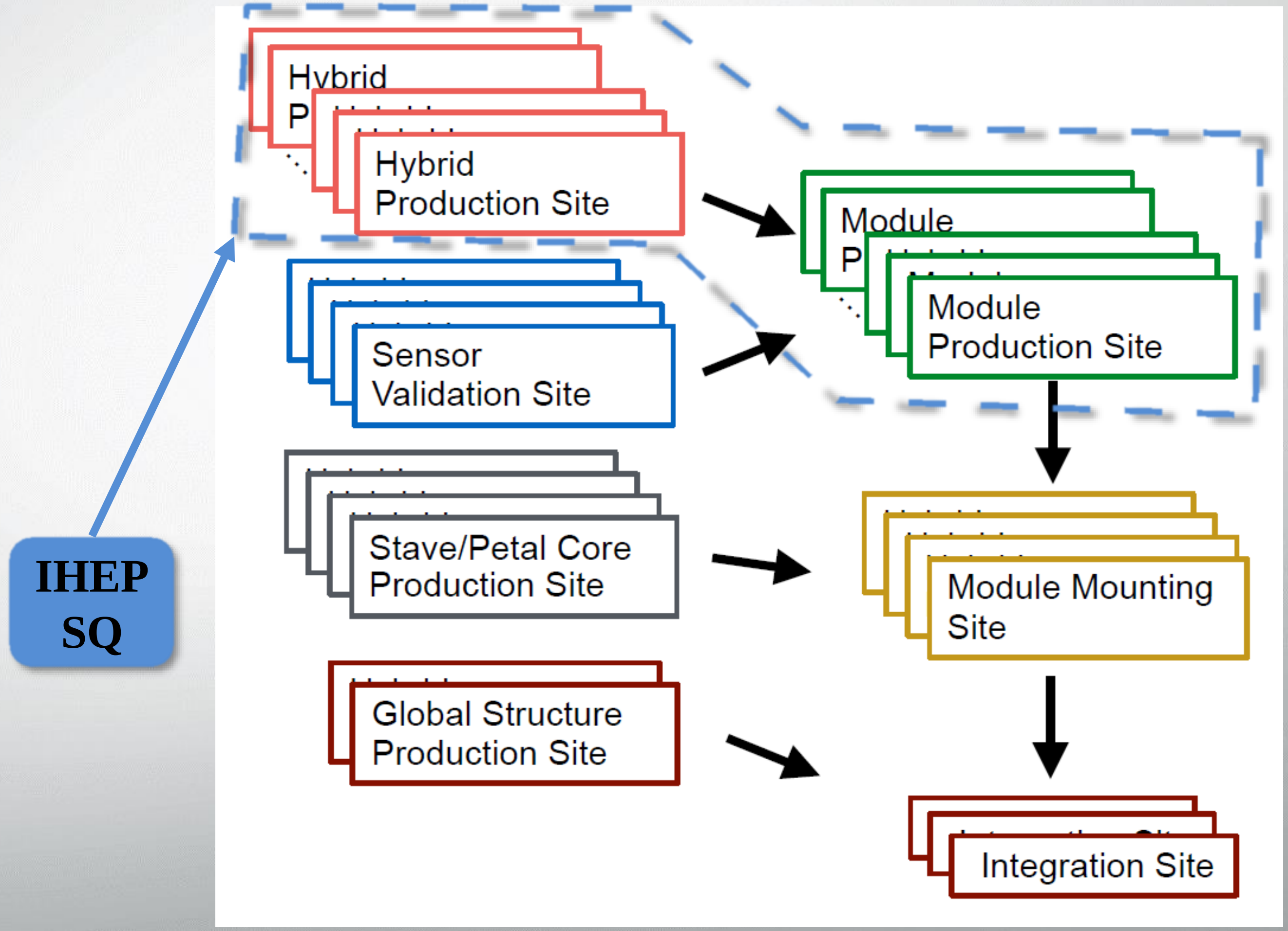


Thank you !

Backup

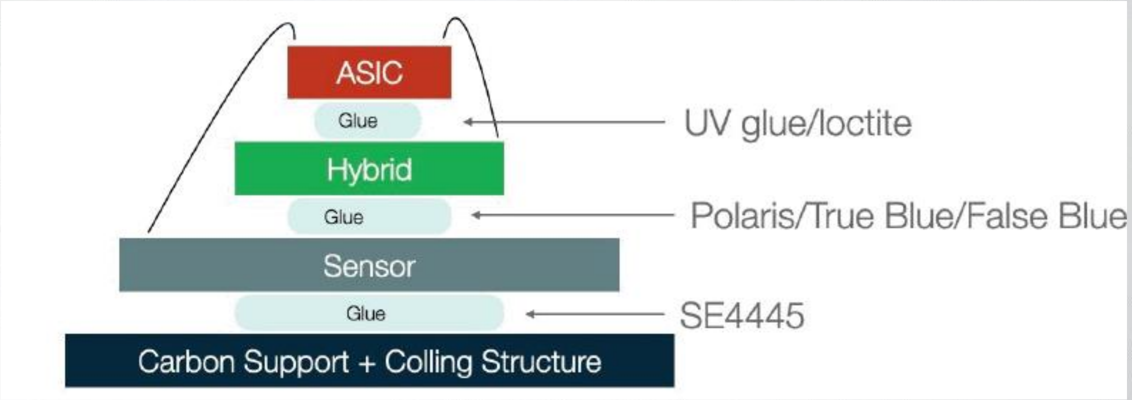
Backup

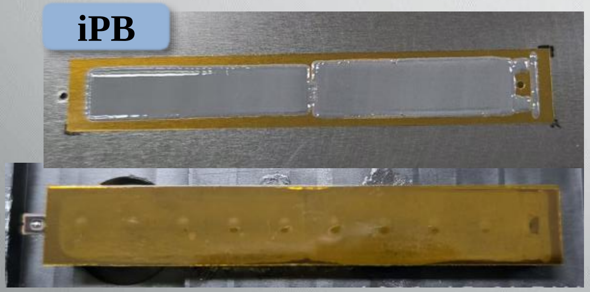
- **Logistic Flow**

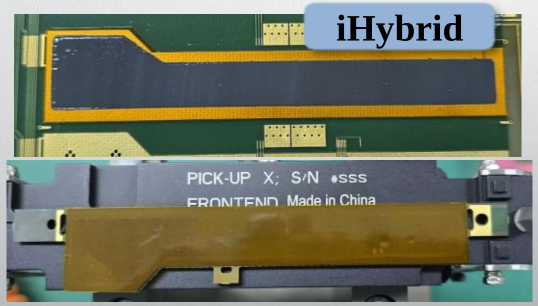


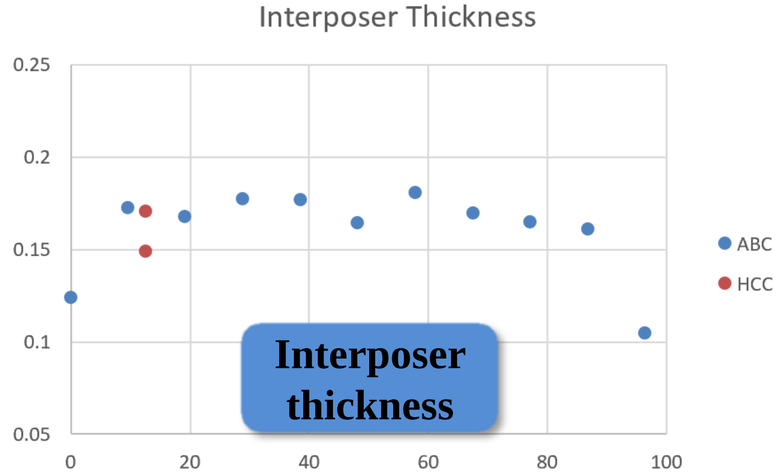
Backup

- **Interposer -- IHEP**
  - Interposed Hybrids and Powerboards assembled
    - 3 i-(**interposed**)hybrids and iPB
    - Interposer layer thickness measurement with metrology
    - Update our pre-production phase with iModule









50 um Kapton + 100um SE4445 layer