



中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences



河南大學
Henan University

ATLAS ITk Strip Module Site Qualification at IHEP

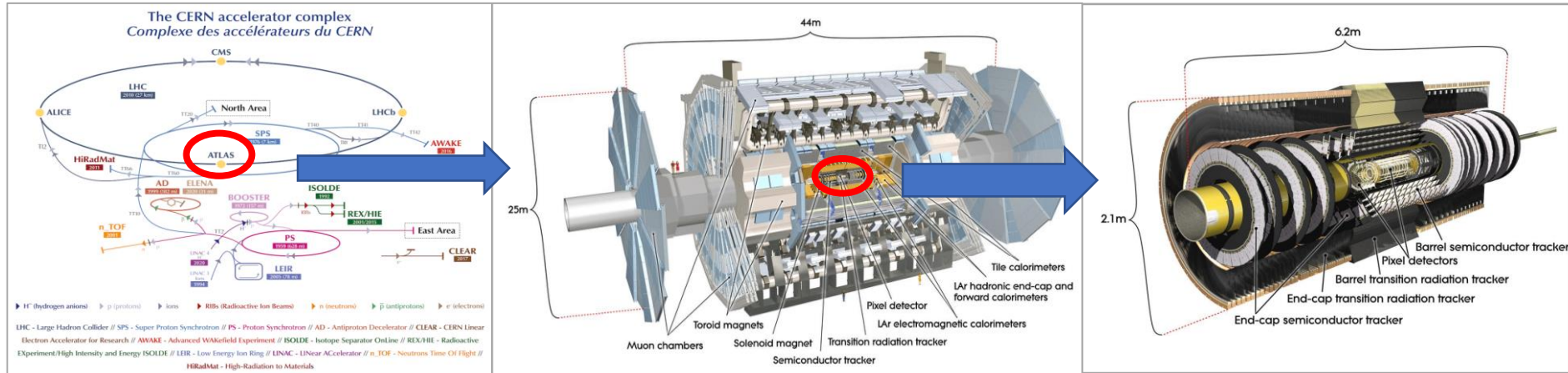
郭蕾 (Lei Guo) on behalf of China ATLAS ITk Team

CLHCP 2023, November 16-20, 2023, Shanghai, China



Introduction of ATLAS-ITk

- **ATLAS Upgrade (Phase II)** Current inner tracker to be fully replaced by all-silicon tracker ITk

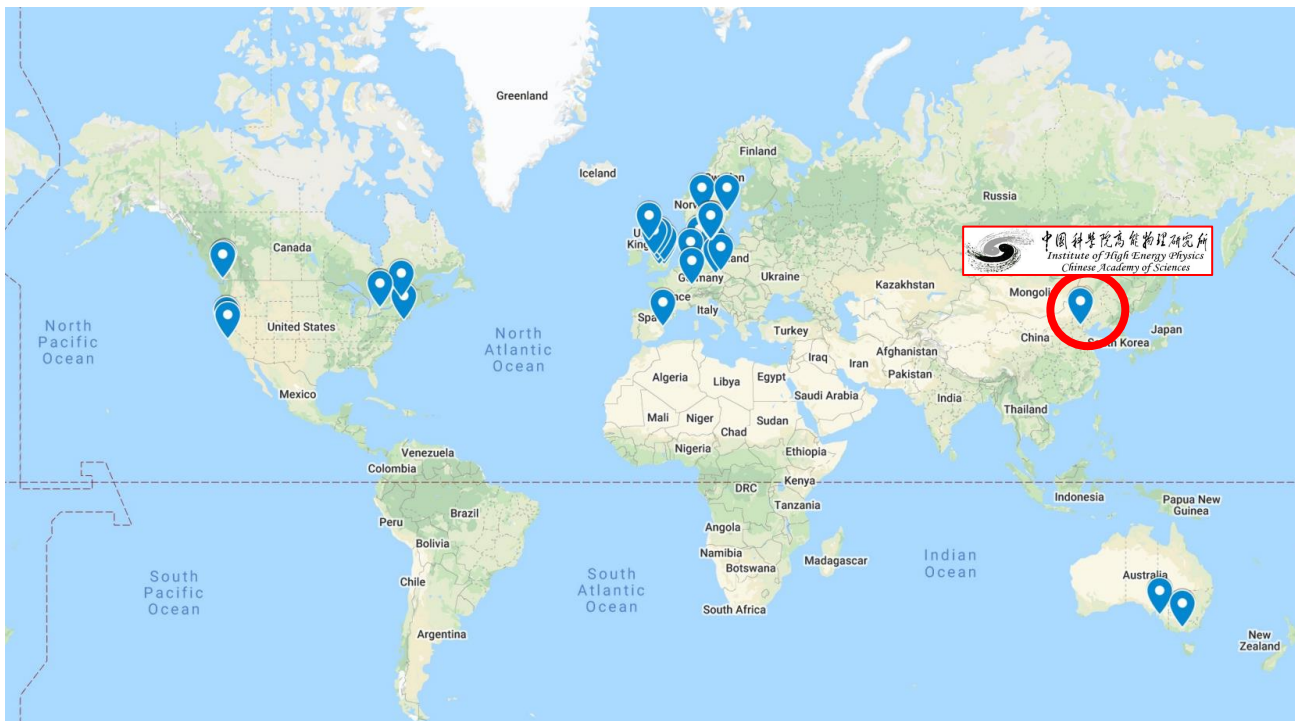


- **Motivation:**
 - Improve particle identification and search for new physics
 - It is the **first time** for China to undertake such a large area radiation hardness silicon track detector project
- **Goals:** **Sustain** and **improve** the excellent tracking performance of ATLAS Run 2 in denser environment

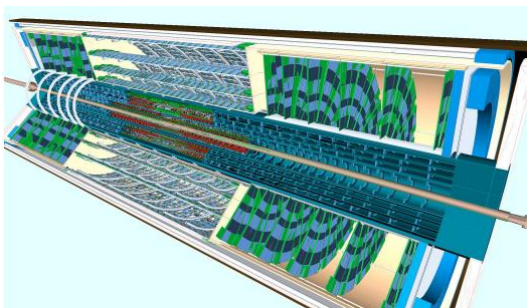
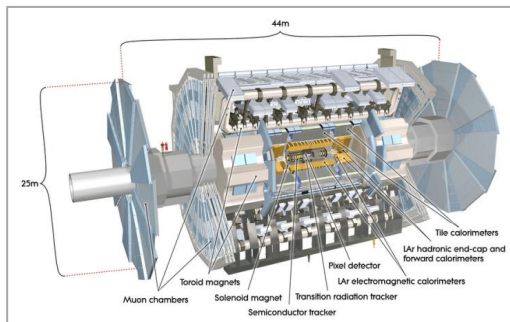
ITk Team status



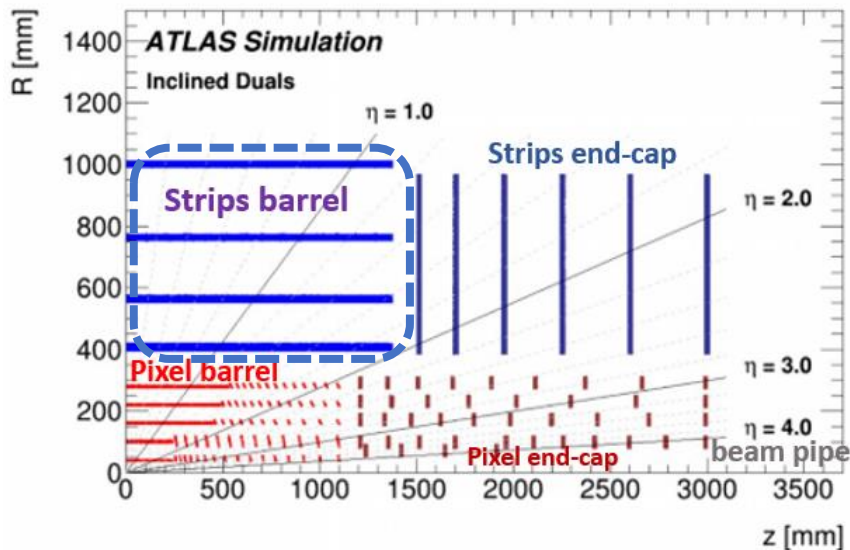
More than 200 peoples, it is shared by 50 institutions of 16 different funding agencies



Schematic layout of the ITk for the HL-LHC phase of ATLAS

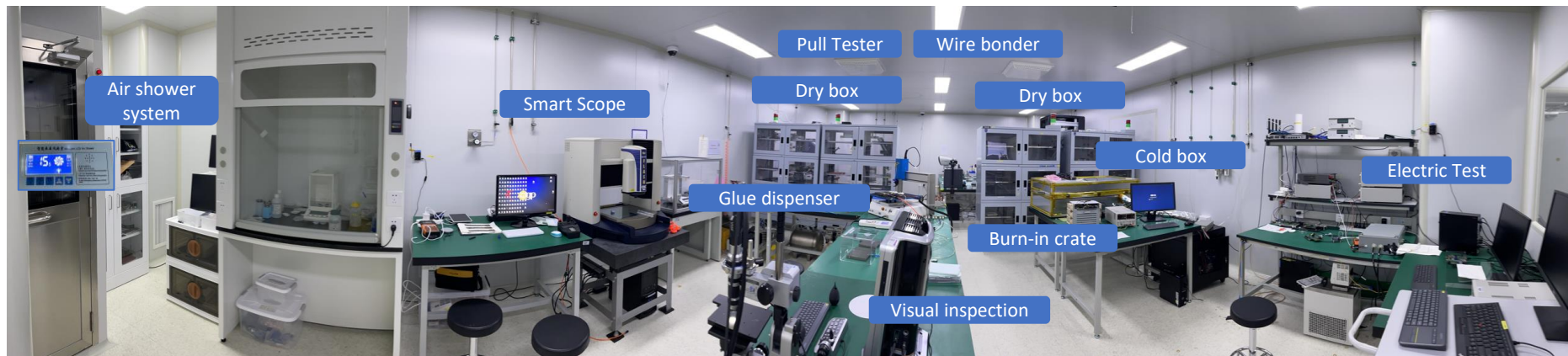


	<u>Pixel</u>	<u>Strips</u>
Silicon area	13 m ²	160 m ²
Nb channels	580 millions	50 millions



- Undertake the development of 1,000 **barrel silicon strip detector modules** (silicon sensor surface is about 10 square meters, accounting for 10% of the total)

Clean room ISO Class 7 (10000)

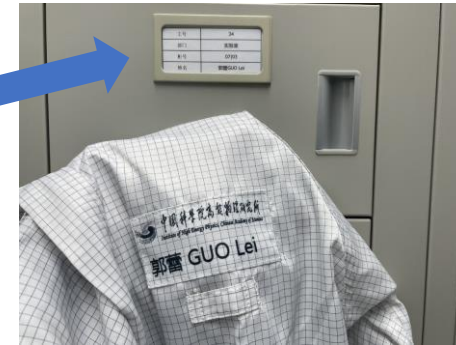


Fingerprint verification



2023/11/16

Change into clean clothes



CLHCP 2023

SOP and PDB



IHEP ATLAS-ITk Standard Operating Procedure

IHEP ATLAS-ITk

Standard Operating Procedure

Powered by Itkdb

Select theme:

- ☒ Overview
- ☐ Hybrid
- ☐ Module
- ☐ PullTest
- ☐ Shipment

Select page:

- ☒ Homepage
- ☐ Inventory
- ☐ Production Monitoring
- ☐ PDB Report
- ☐ Project Plan
- ☐ Broom Cupboard

Standard Operating Procedure

Bulletin Board

- Yuqing Wang, please work on ASSEMBLY of IHEP-Hybrid-X-PPB-6 (VPK32425-W327) and finish before 2023-06-14
- Lei Guo, please work on ASSEMBLY of IHEP-Hybrid-X-DUMMY-11 (GPC2150_X_014_B_H4_Dummy) and finish before 2023-10-11

Get Your Ticket!

2023-10-31 @ 10:52

Username

Password

ITk Production Database

ATLAS ITk Production Database

My Institute Component List

Filters: Strips, Dummy, Trashed, Add filter

Sorting: Add sorting

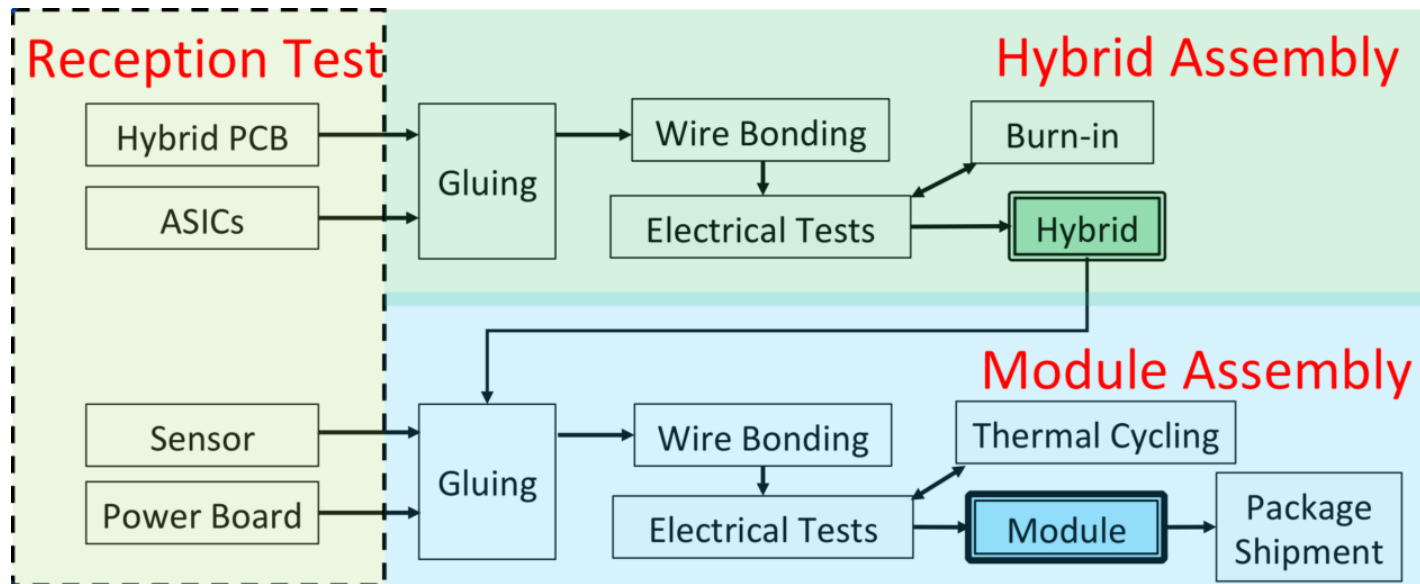
Showing 883 of 989

Component	Serial Number	Current stage	Current location	Registered
<input type="checkbox"/> STAR Hybrid Assembly - X Assembly iHEP-X-0124	20USBHX2001617	ASIC Attachment	Institute of High Energy Physics, Chinese Academy of Sciences	2023/9/1 17:04
<input type="checkbox"/> Blue - Locite 3525	20USBGL0000030	In Use	Institute of High Energy Physics, Chinese Academy of Sciences	2023/8/24 19:31
<input type="checkbox"/> STAR Hybrid Assembly - X Assembly iHEP-X-0124	20USBHX2001462	Finished Hybrid	Institute of High Energy Physics, Chinese Academy of Sciences	2023/7/13 20:29
<input type="checkbox"/> STAR Hybrid Assembly - X Assembly iHEP-X-0123	20USBHX2001455	Finished Hybrid	Institute of High Energy Physics, Chinese Academy of Sciences	2023/7/11 14:28
<input type="checkbox"/> STAR Hybrid Assembly - X Assembly iHEP-X-0122	20USBHX2001455	Finished Hybrid	Institute of High Energy Physics, Chinese Academy of Sciences	2023/7/11 12:43

- SOP implements local production operation guidance and statistical production information
- SOP can upload the data to the official PDB of the ATLAS collaboration

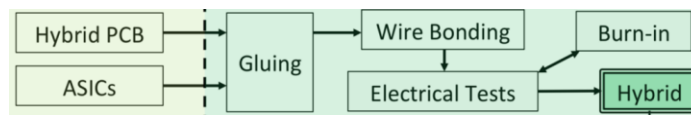
Module production and test

- Detailed quality control process to ensure that the detector module production meets the requirements

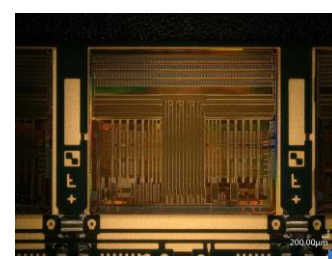
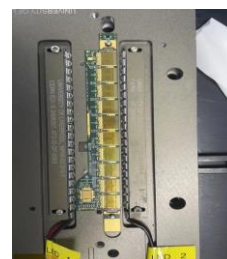
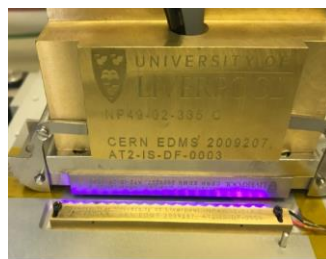
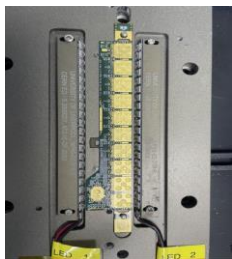
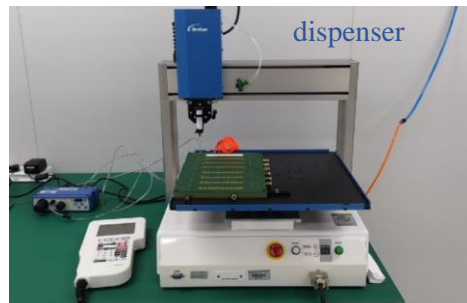
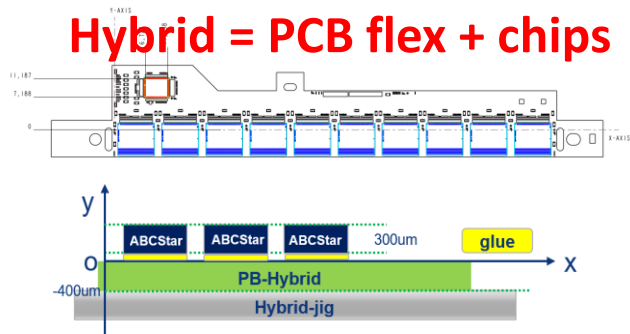


Step Number	Qualification Step
3.2	Sensor Storage
6.1	PB Reception
6.2	PB E tests
6.3	PB Vis Insp
6.4	PB Storage
8.2	Storage + shipping of glue
8.3	Assembling hybrids
8.4	Glue weight measurements
8.5	Bonding procedures: hybrids
8.6	Metrology: hybrids
8.7	Visual inspection: hybrids
8.8	Hybrid Burn-In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

Hybrid



Hybrid = PCB flex + chips



Gluing

Ship chips

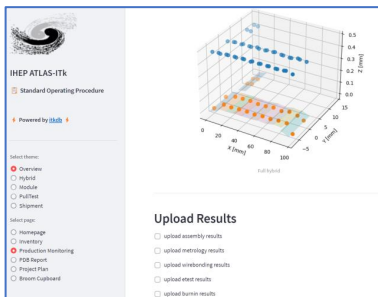
UV curing

assembled

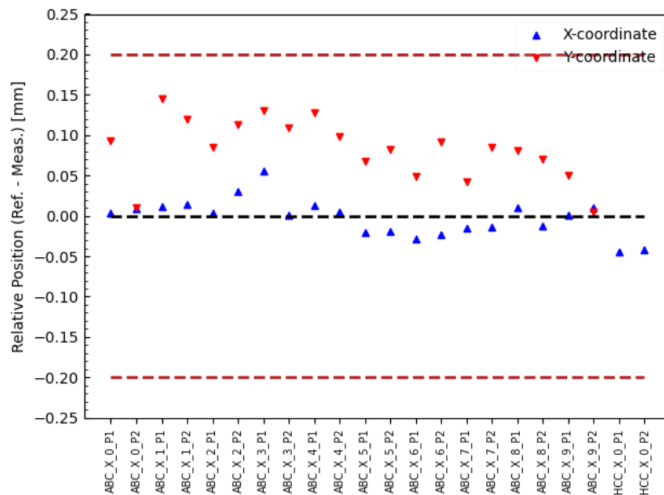
Visual inspection

→ After Hybrid assembly, metrology test is needed to guarantee the quality.

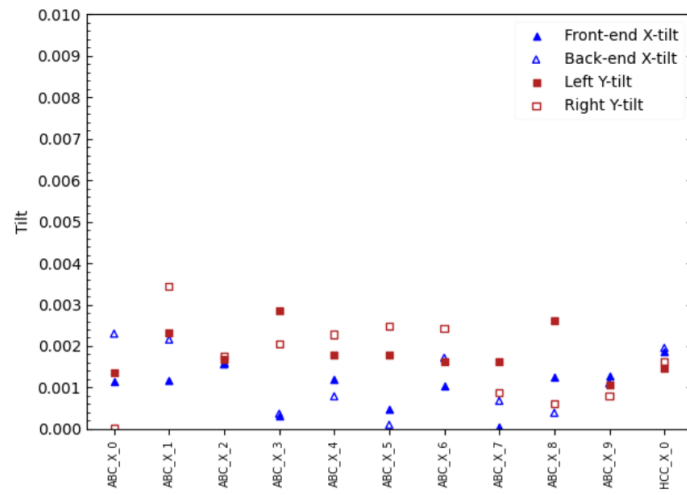
Metrology test for Hybrid



Requirement: $-0.25 \sim 0.2$ mm

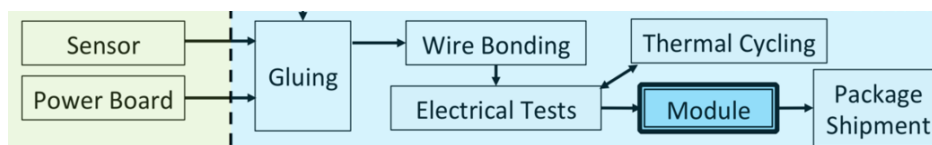


Requirement: $\text{tilt} \leq 0.025$



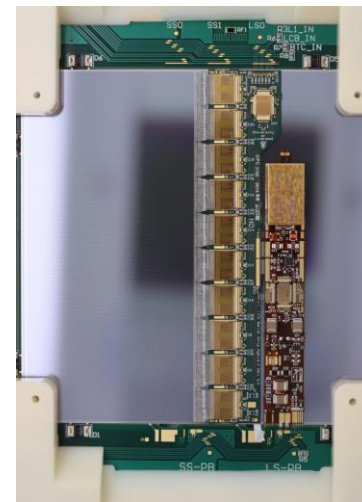
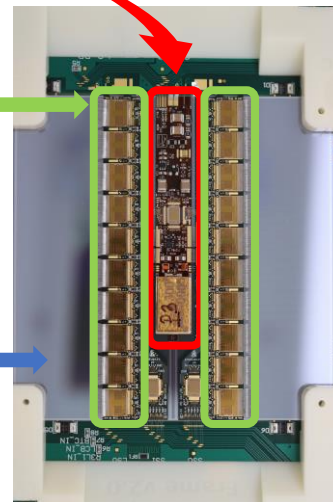
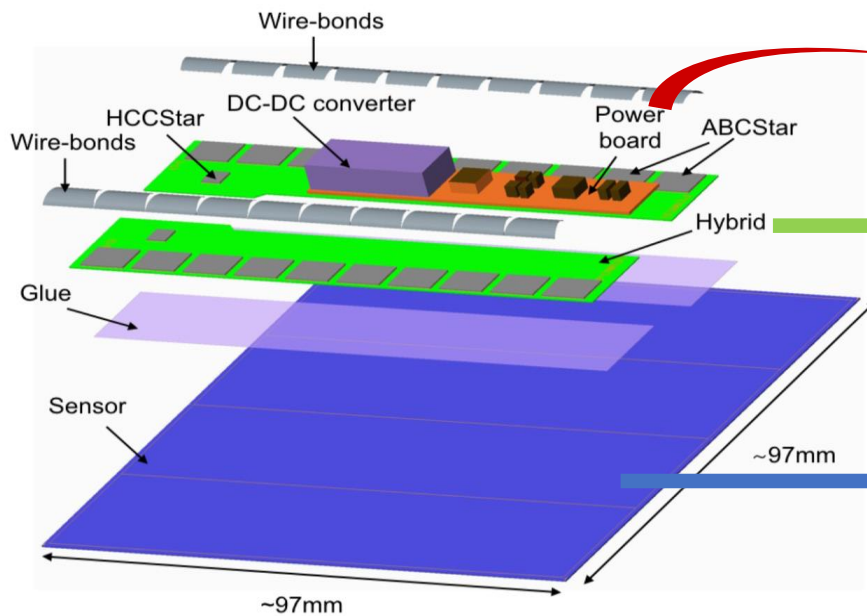
- SOP for more convenient visualization
- Metrology results meet the requirements

Module



Module = Hybrid + sensor + power board

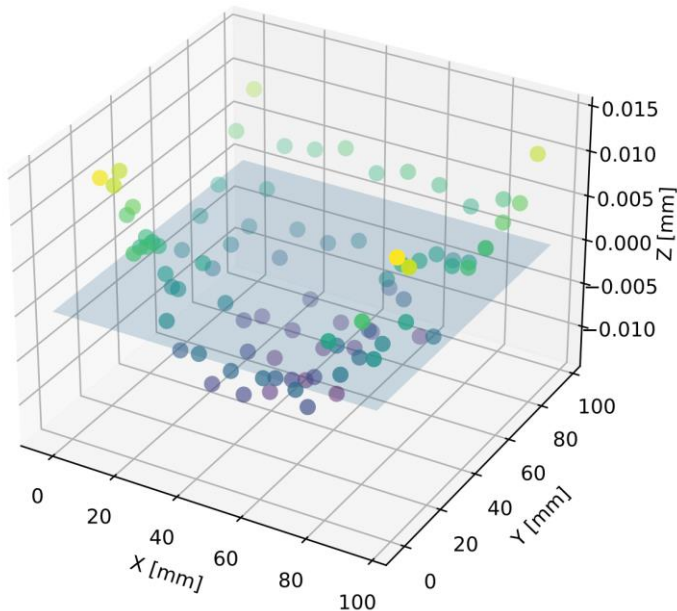
- Left: **Short-strip** barrel module.
- Right: **Long-strip** barrel module.



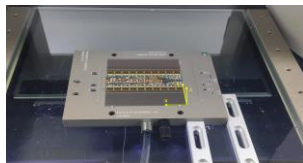
Metrology test for module



Module metrology result

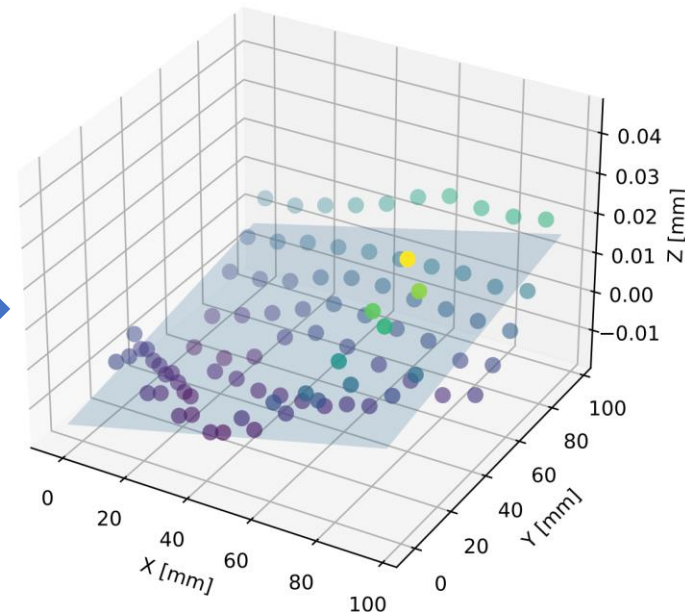


within $-10/+10\ \mu\text{m}$



Remove vacuum

Bow test result

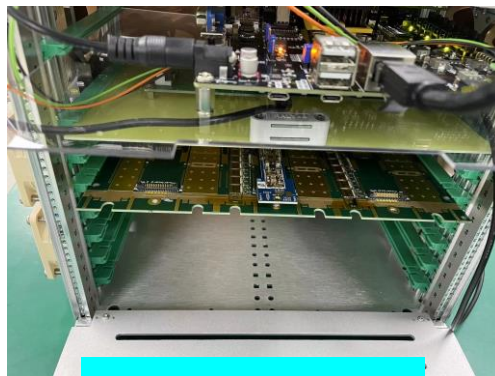


$-50/+150\ \mu\text{m}$ requirement
ensured the surface below is sufficiently flat

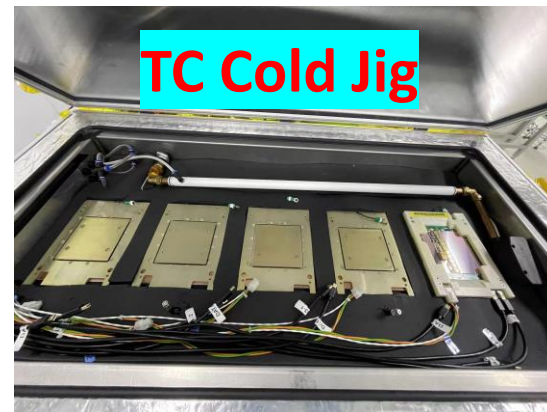
E-test & Burn-in & Thermal cycle



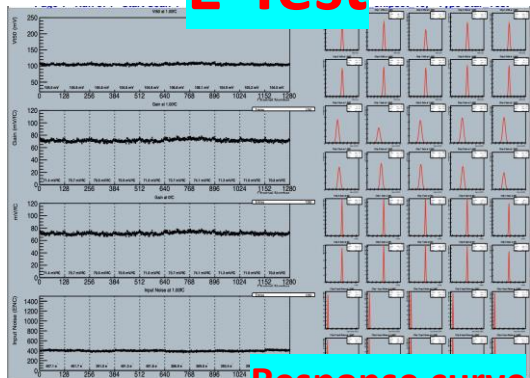
E-Test



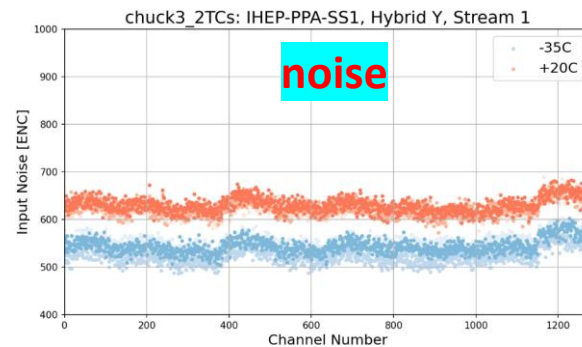
Burn-in crate



TC Cold Jig



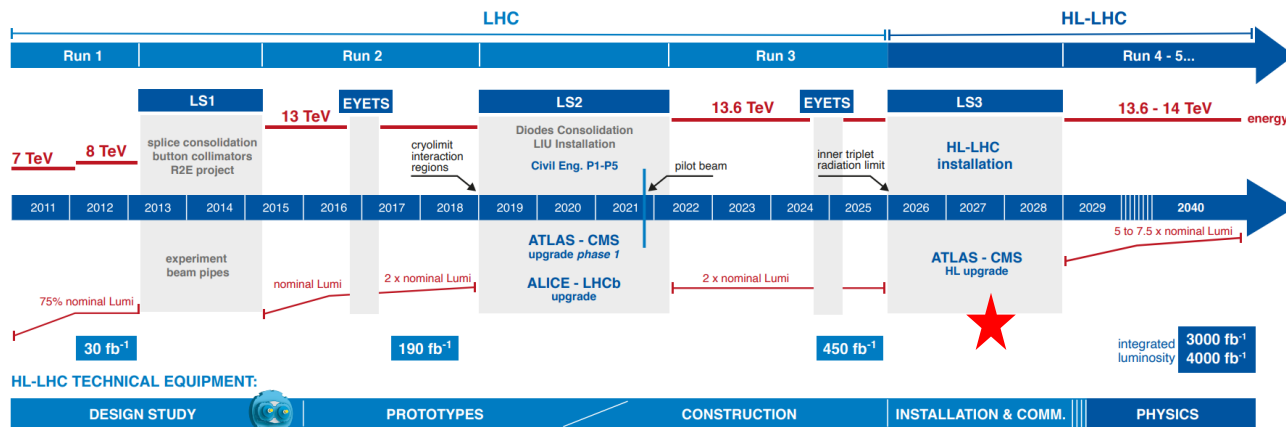
Response curve



noise

Summary

- Module production status at IHEP site
 - Qualified all the 29 steps
 - The SOP webpage should be in “production-ready” stage
- Quickly enter the formal production stage. Steadily advance to reach the peak production



Thank you !



- <https://cds.cern.ch/record/2257755/files/ATLAS-TDR-025.pdf>
- [ATLAS硅径迹探测器升级模块样机预制完成---中国科学院 \(cas.cn\)](https://cas.cn)

ATLAS 内径迹探测器升级

- 升级后的内径迹系统全部由硅探测器构成
- 磁场2T, 长约6米, 半径约1米
- 顶点探测器包括5层桶部和若干层端盖
- 硅微条探测器包括4层桶部和6层(x2)端盖
 - 约18000 个模块
 - 约6千万道读出
 - 硅微条覆盖面积165m²
 - 由16个不同的资助机构的50个单位共同承担
 - 高能所/清华 承担 1000 个模块制造 (10m² 硅探测器)

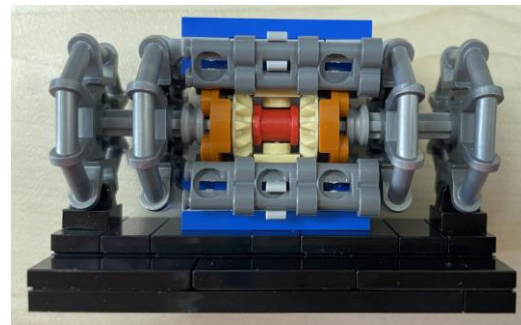
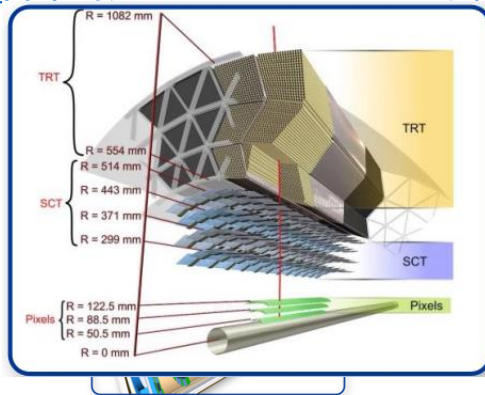
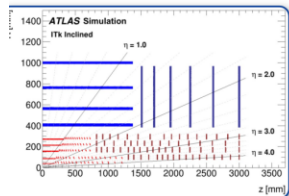


Table 6.3: Overview of the custom made ASICs for the ITk Strip Detector.



Strip detector comparisons	Current Inner strip tracker (SCT)	Future ITK strip tracker
Radial distance	300-560mm	400-1000mm
Channels	~8 millions	~100 millions
Modules	4 thousands	~20 thousands (165m ² silicon)

Acronym	Full Name	Basic functionality	Prototype	Production Chip
ABC	ATLAS Binary Chip	Converts incoming charge signal into hit information	ABC130	ABCStar
HCC	Hybrid Controller Chip	Interface between ABC130 and bus-tape	HCC130	HCCStar
AMAC	Autonomous Monitor and Control Chip	Provides monitoring and interrupt functionality	AMAC-I	AMAC-II
FEAST	FEAST	Synchronous Step-Down Buck DC/DC converter	FEAST	upFEAST

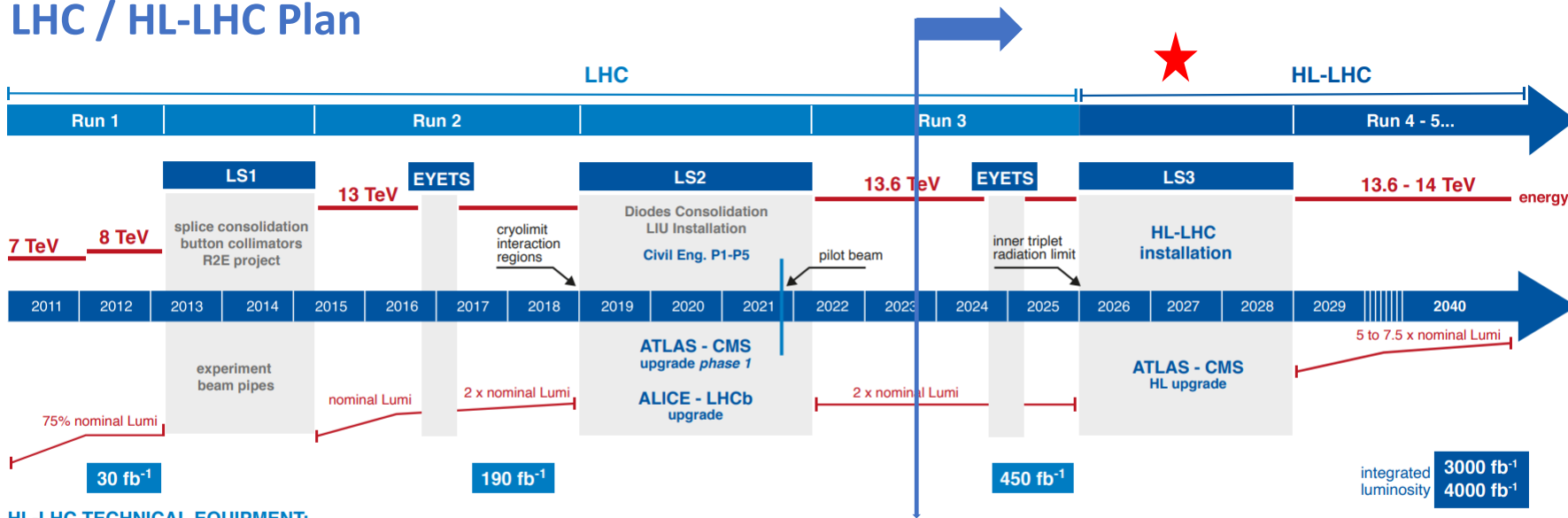
Outline



- ATLAS-ITk and China ATLAS ITk team at IHEP
- SOP(Standard Operating Procedure) and PDB(Production Database)
- Module production
- Summary

Prospect

LHC / HL-LHC Plan

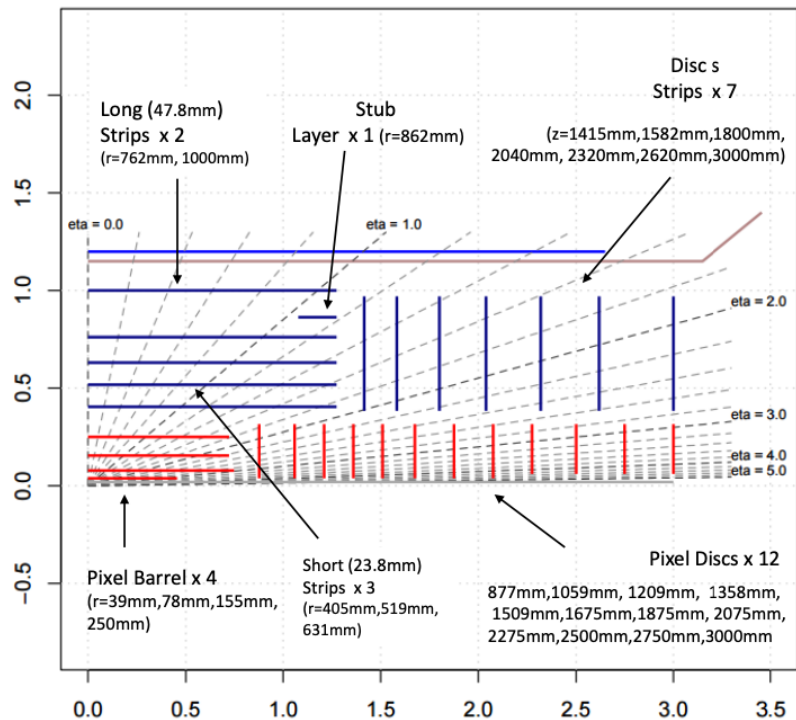


HL-LHC TECHNICAL EQUIPMENT:



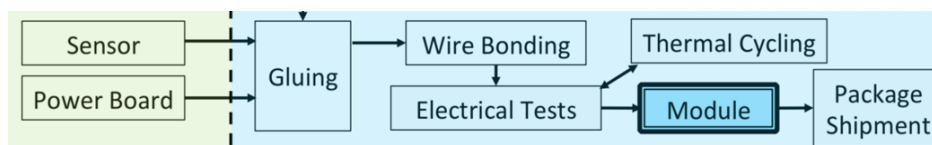
- in 2015, Long Shutdown 1 (LS1) was completed to prepare the accelerator for operation at 13 TeV and its design luminosity;
- for Long Shutdown 2 (LS2) in 2019/20 further improvements of the LHC are foreseen, accompanied by significant detector upgrades (Phase-I);
- ★ Long Shutdown 3 (LS3) starting at the end of 2023 will include major performance upgrades of the accelerator for the high-luminosity phase (HL-LHC) which requires replacement of several major detector components (Phase-II).

SS & LS module

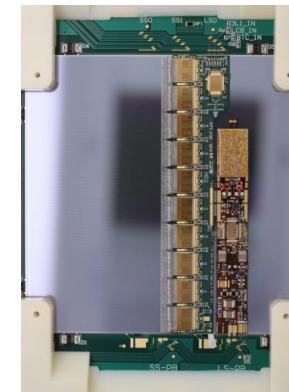
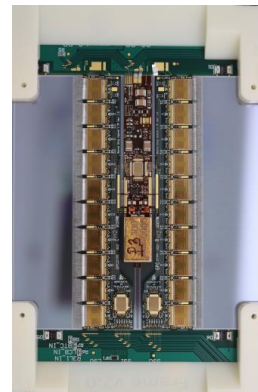
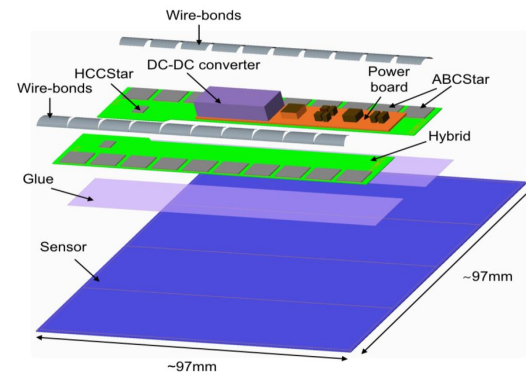
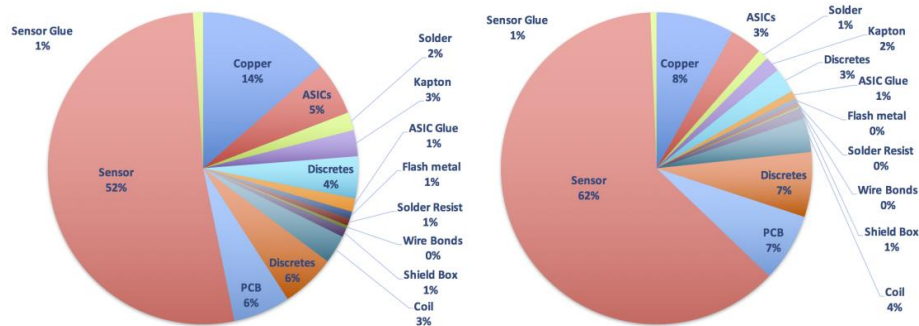


The ITk Strip modules are constructed by directly gluing kapton flex hybrids to silicon sensors with electronics-grade epoxy. Various different strip lengths and geometries are foreseen, depending on the planned location of the module within the detector. For the barrel, two strip lengths are used: long strips are suitable in the lower occupancy region at larger radii (layers L2 and L3), whereas further subdivision with shorter strips is required at lower radii (layers L0 and L1). Therefore two different module types are required for the barrel section: the so-called short-strip and long-strip barrel modules where "short" and "long" refers to the strip length.

Module




Module = Hybrid + sensor + power board



- Fractional contributions for different materials to the radiation length of the barrel modules.
- Left: **Short-strip** barrel module.
- Right: **Long-strip** barrel module.

Metrology test for Hybrid



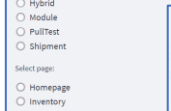
Production Monitoring

Select component type:
Hybrid

Select component:
IHEP-Hybrid-X-DUMMY-10

Component current local stage: **MEASURED**

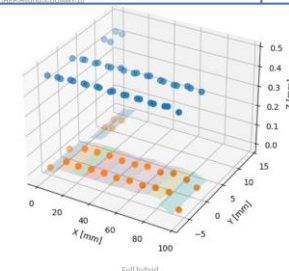
Component basic info:



Production Monitoring

Select theme:
Overview
Hybrid
Module
PullTest
Shipment

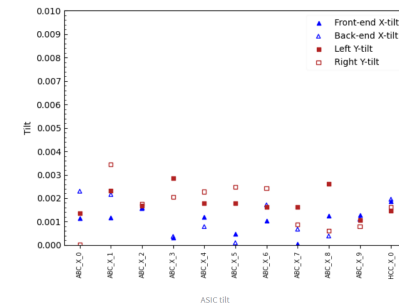
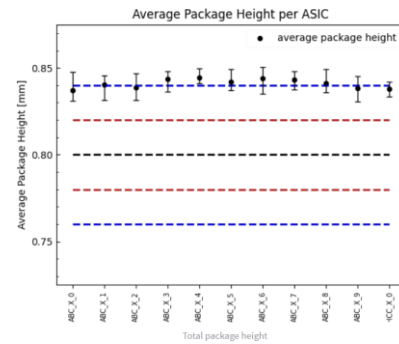
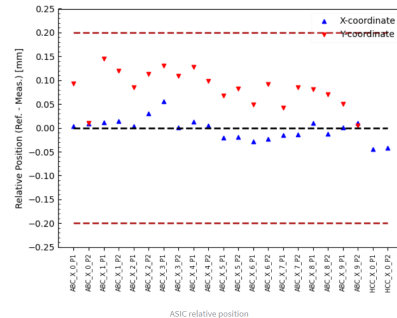
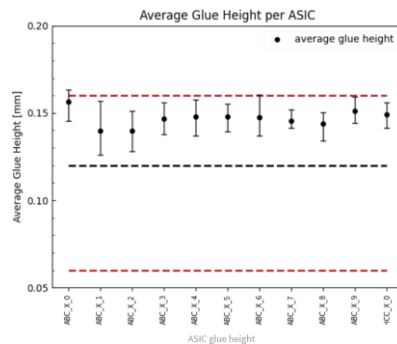
Select page:
Homepage
Inventory
Production Monitoring
PDB Report
Project Plan
Broom Cupboard



Full Hybrid

Upload Results

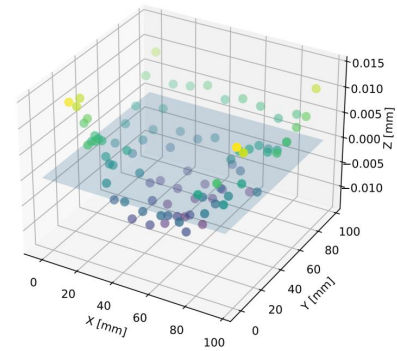
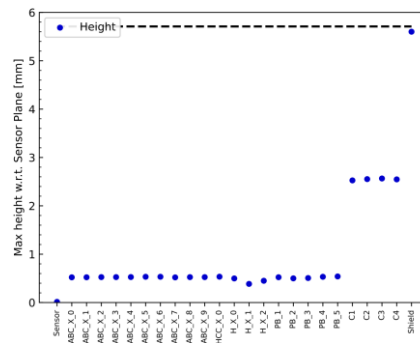
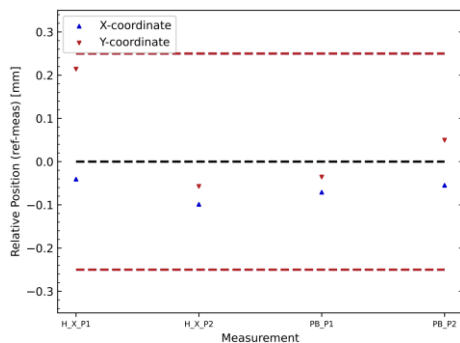
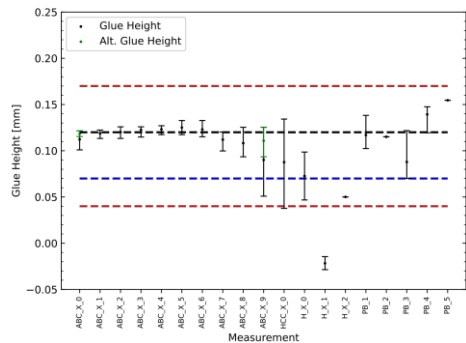
- ☐ upload assembly results
- ☐ upload metrology results
- ☐ upload wirebonding results
- ☐ upload etest results
- ☐ upload burnin results



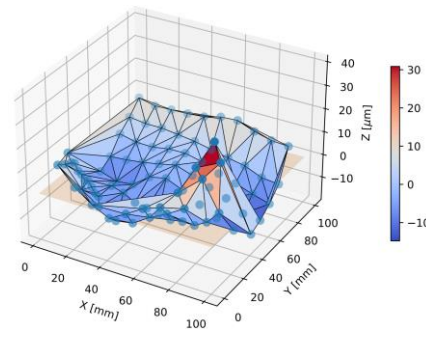
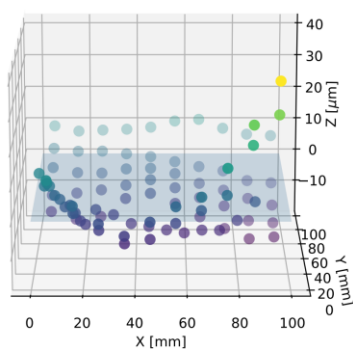
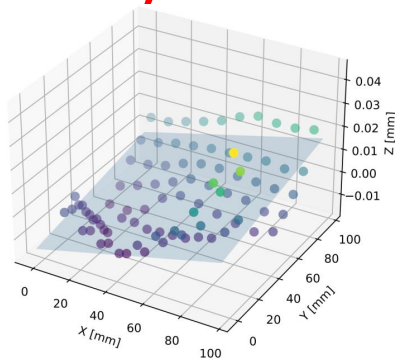
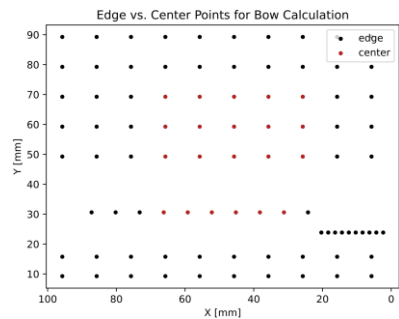
- SOP for more convenient visualization
- Metrology results meet the requirement

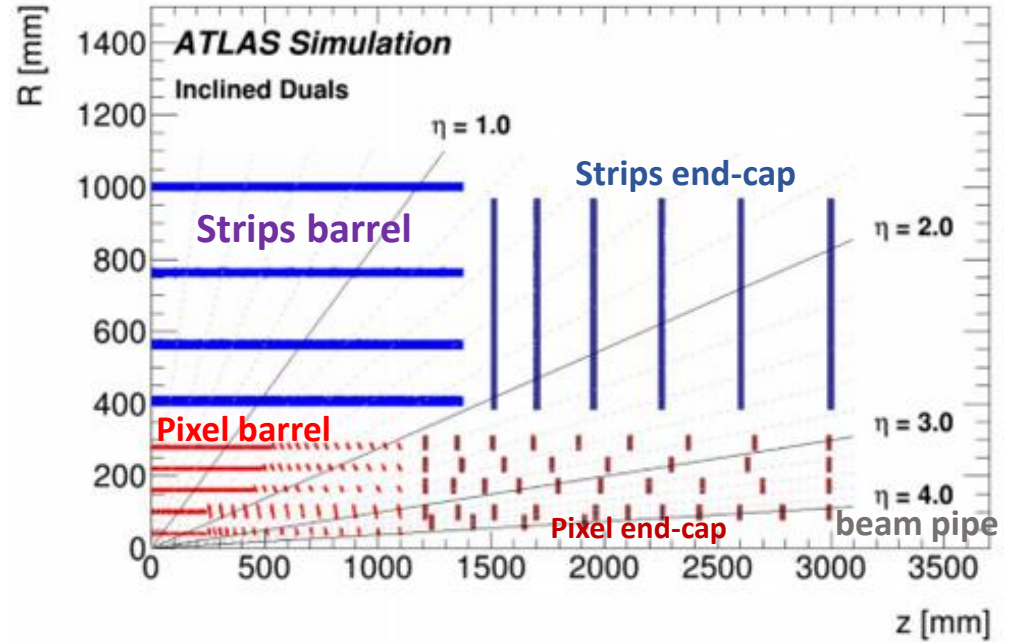
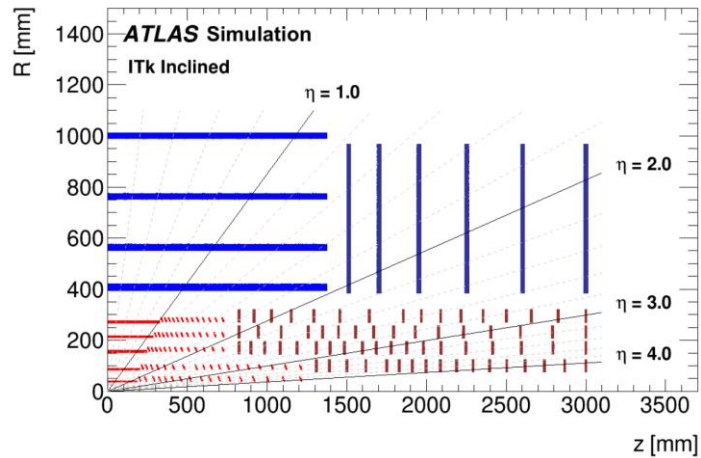
Metrology test for module

Module metrology results (qualified)

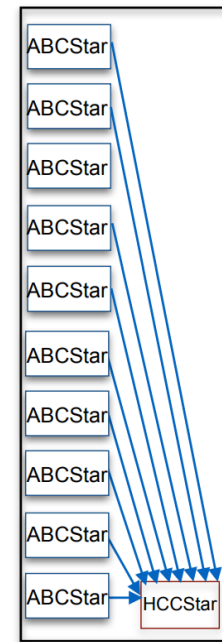
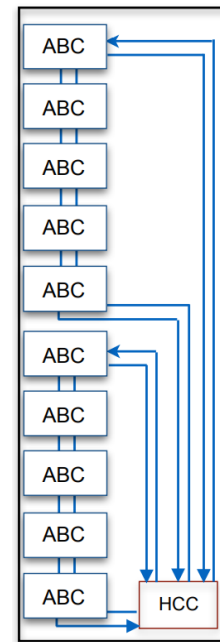
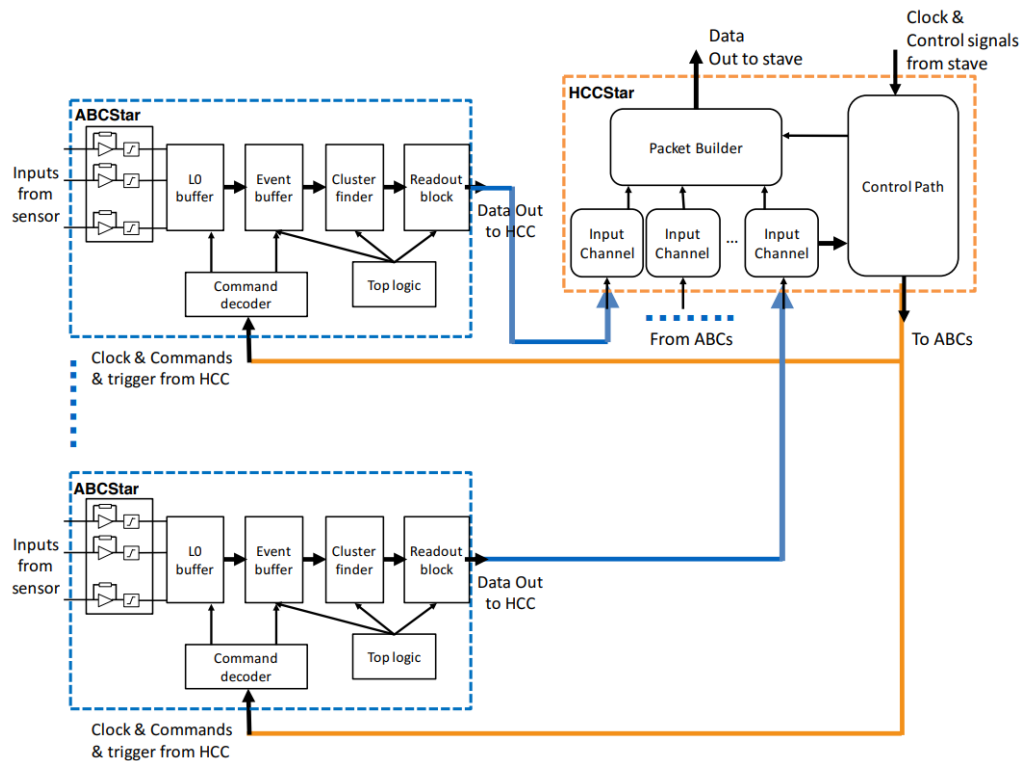


Module bow test (qualified)



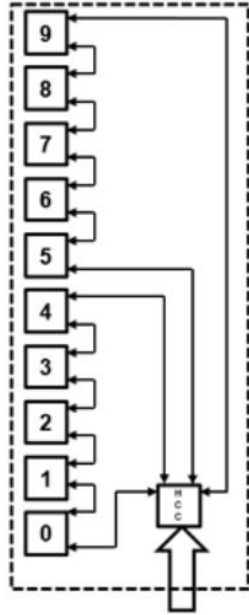


Simplistic schematic of a hybrid for the ITk strip modules

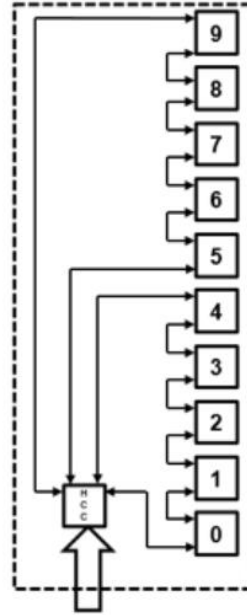




LH-Hybrid



RH-Hybrid



Stave side signalling



- Eight hybrids within a panel, four of each flavour (left-handed and right-handed).
- Hybrids are assembled in-situ with both SMDs and ASICs being attached to the circuits.
- The rigid former and vacuum holes, underneath the ASICs, providing suitable mechanical support for the Aluminium wedge wire-bonding of the bare die in-situ.
- Provision of trace routing, external to the hybrids, supplying both power and digital I/O. This enables the testing of the circuits whilst still resident on a panel. With the connections being brought to dedicated power and digital I/O connectors.

- Assuming a 320 μm thick sensor, this yields a predicted average radiation length for short-strip barrel and long-strip barrel modules of 0.65% and 0.55%, respectively.
- Reducing the copper thickness could affect the hybrid yield
- Quality Assurance (QA): Quality Assurance (QA) tests are statistical studies of quality during R&D and on a batch basis in production
- Quality Control (QC) : Quality control (QC) tests are performed on every production item

Glue step	Special Requirements	Chosen glue	Comment
ABCStar to hybrid	UV curable	Dymax 6-621 or Loctite 3525	fully qualified incl. radiation tolerance [79]
HCCStar to hybrid	higher thermal conductivity	silver-loaded epoxy adhesive TRA-DUCT 2902, BIPAX	fully qualified incl. radiation tolerance and activation
Hybrid to sensor		electronics grade epoxy Epolite FH-5313	fully qualified; availability unclear – alternative being investigated
Power board to sensor		electronics grade epoxy Epolite FH-5313	fully qualified; availability unclear – alternative being investigated
Module to Local Support	higher thermal conductivity to ensure low temperature of sensor	SE4445	qualified up to $2\text{E}15 \text{ n}_{\text{eq}}/\text{cm}^2$

