

ATLAS Inner Tracker Upgrade Overview

Xin Shi (IHEP)

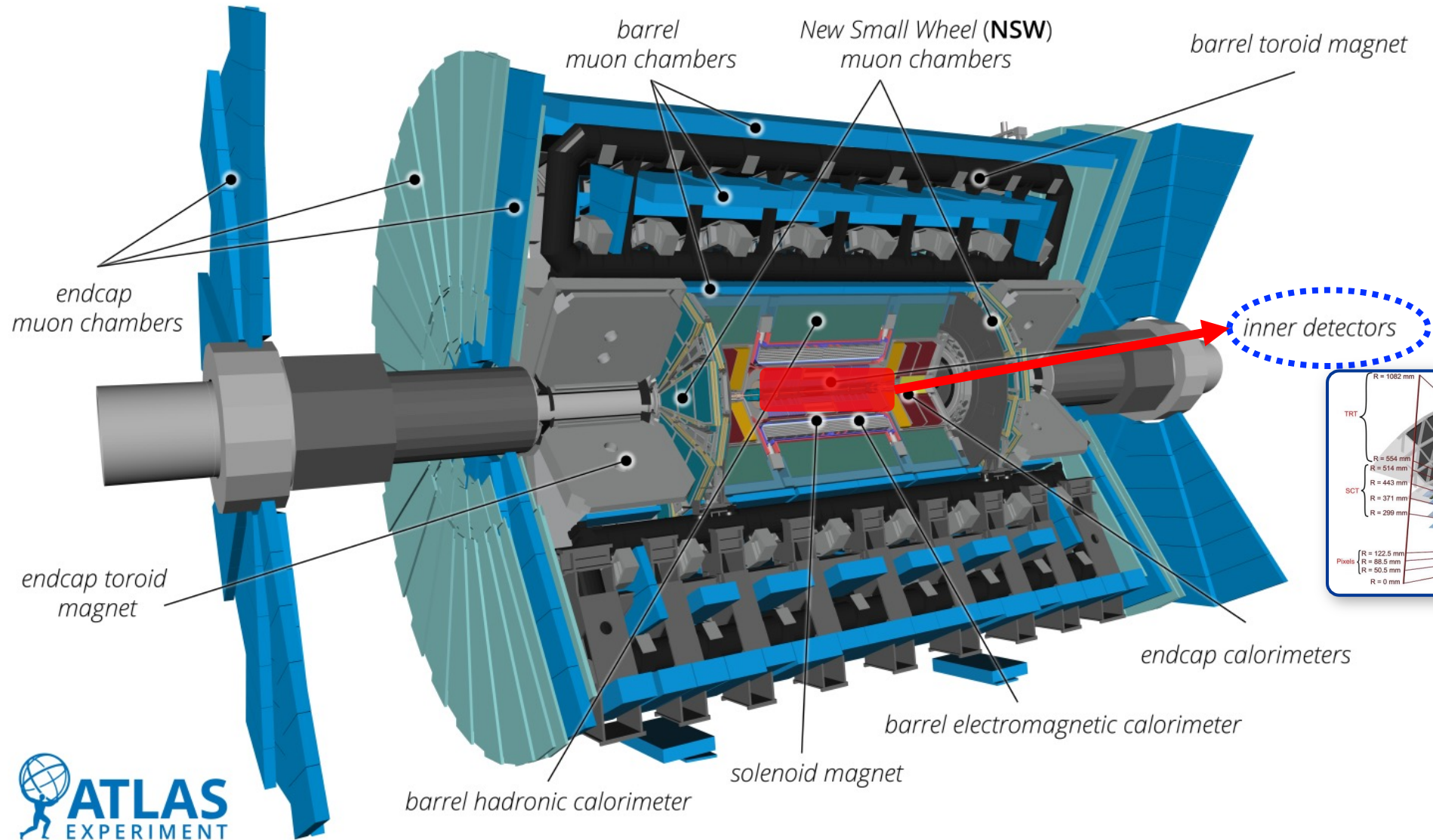
史欣 (中国科学院高能物理研究所)

On behalf of subtask 2 Team



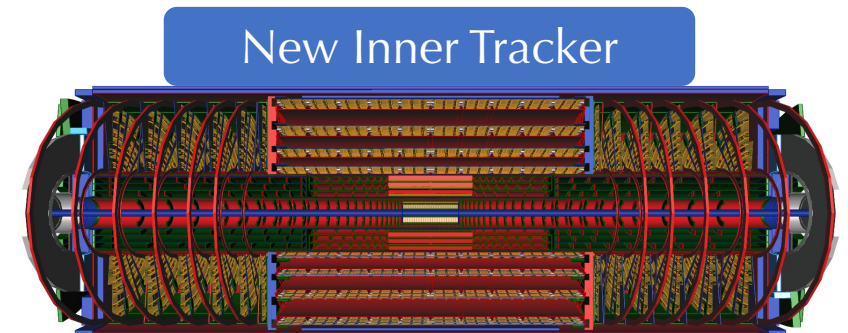
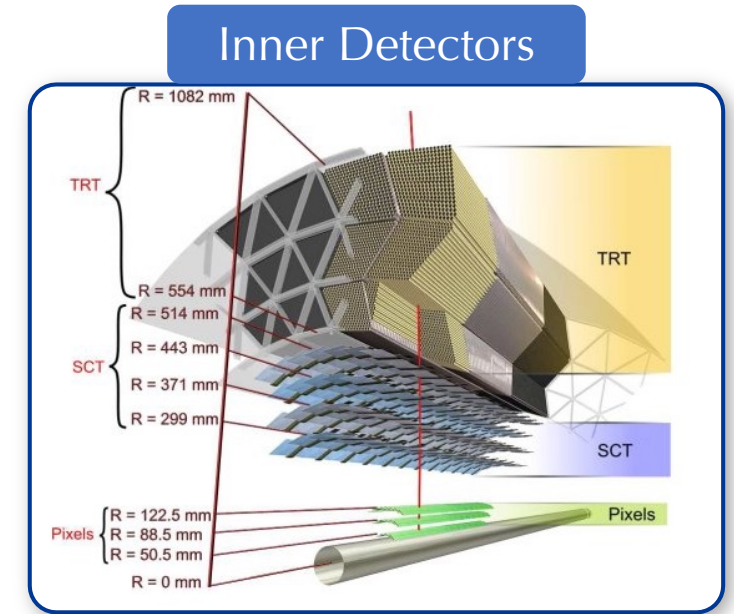
7 June 2025

Current ATLAS Detector

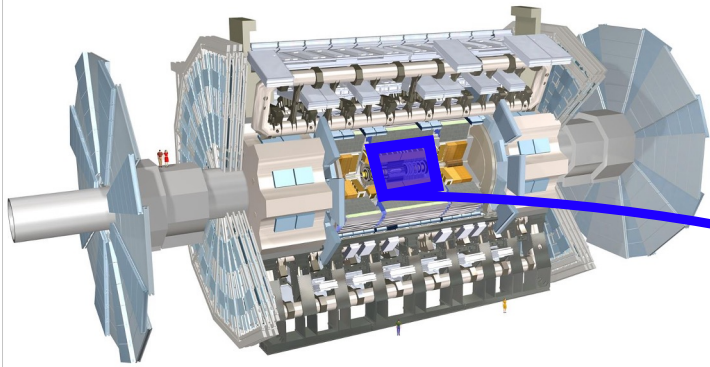


Motivation of Inner Tracker Upgrade

- Radiation Damage
 - Current tracking detector can not meet the HL-LHC:
4000 /fb
Pixels (400 /fb), SCT (700/fb), IBL (850/fb)
 - Above the design fluences, the intrinsic hit efficiencies drop and leakage currents exceed power supplies limits, affect on-detector power and cooling system
- Bandwidth Saturation
 - Current front-end electronics can not handle
luminosity $7.5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$, $\langle \text{PU} \rangle > 200$
Pixel and SCT: $2 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$, $\langle \text{PU} \rangle > 50$
- Detector Occupancy
 - TRT occupancy will reach 100%

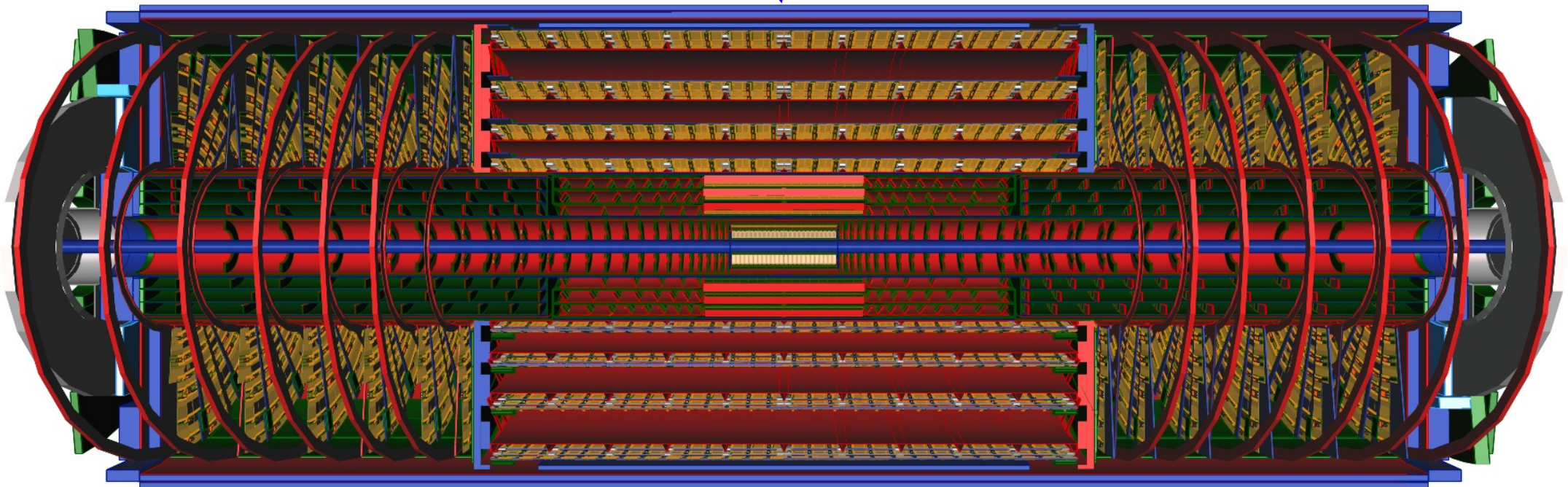


ATLAS Inner Tracker (ITk) Upgrade

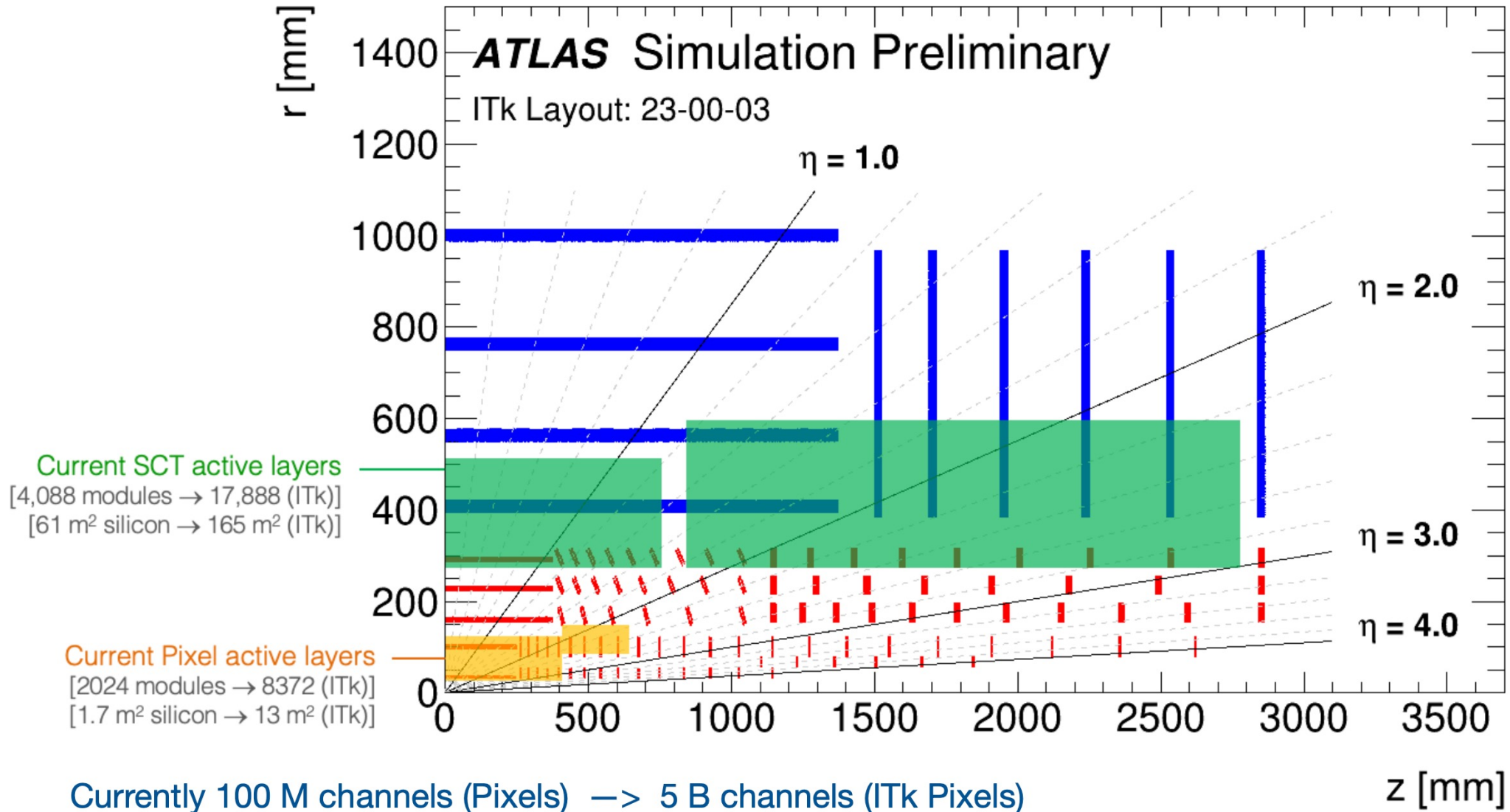


Inner Tracking Detector (ITk)

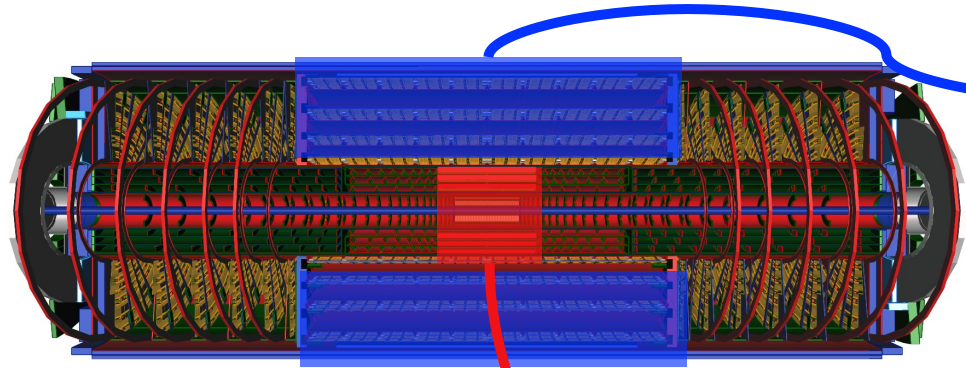
- All silicon with at least 9 layers up to $|\eta| = 4$
- Less material, finer segmentation



ATLAS New Inner Tracker (ITk)

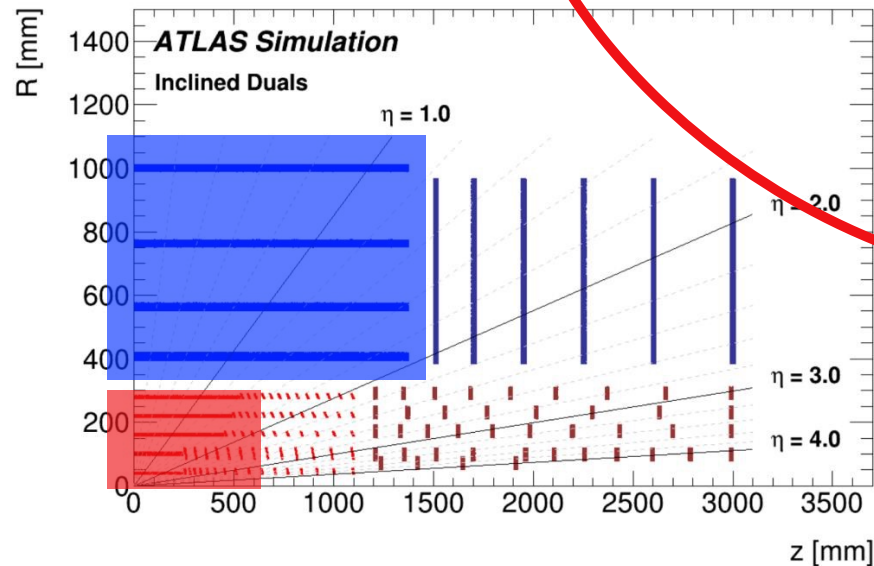


Subtask 2: Inner Tracker (ITk) Upgrade



2.1 ITk Strip Barrel Detector

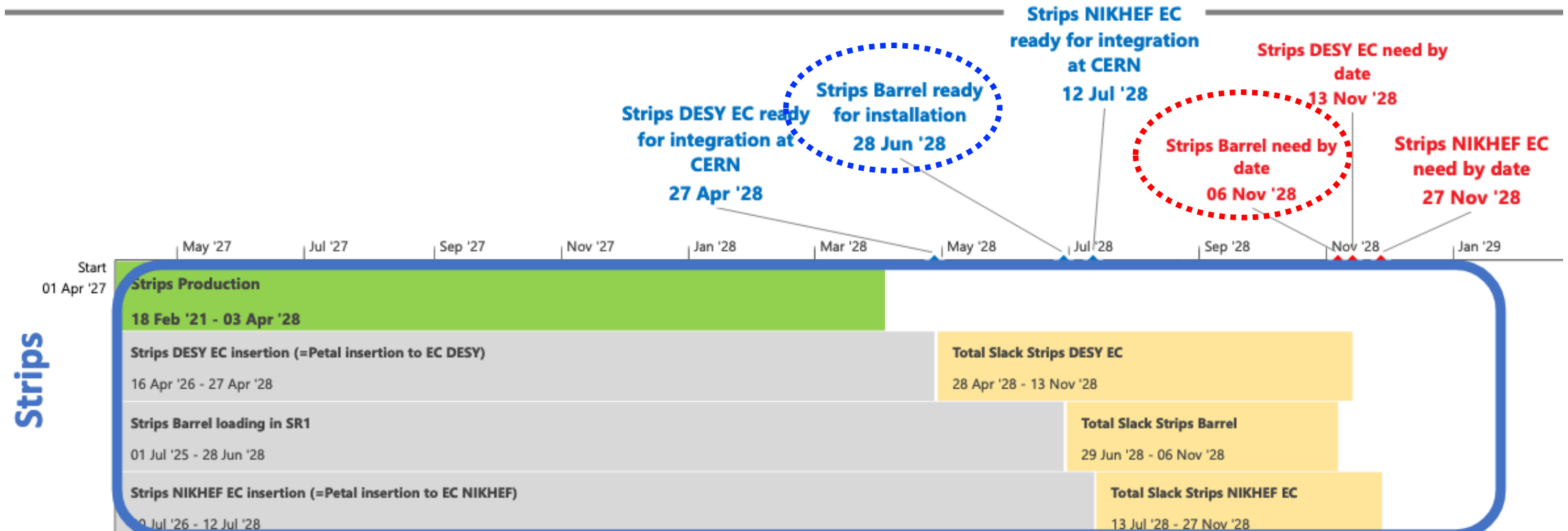
- Radiation hard sensor and ASIC study
- Strip detector module production
- Complex silicon tracker system integration



2.2 Timing Pixel Detector

- Pixelated LGAD sensor R&D
- Fast front-end electronics R&D

ATLAS ITk Strip schedule



- ITk Strips Barrel **ready for installation**: 28 June 2028
- ITk Strips Barrel **need-by date**: 06 November 2028

ATLAS ITk Strip Project World Wide

16 Funding Agencies and 50 Institutes

China: IHEP, THU, SYSU, TDLI, SDU
1000 Modules (10m² Silicon Surface Area)

UK/China Cluster
50% Barrel Strip Detector

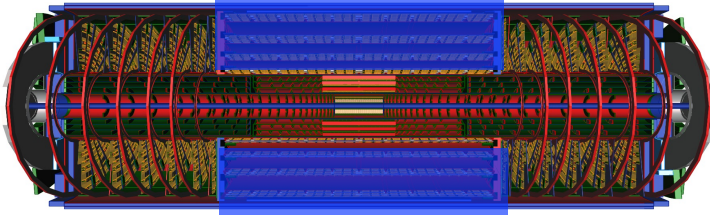


IHEP



- Xin Shi as UK/China Cluster Manager since 2022

2.1 ITk Strip Barrel Detector

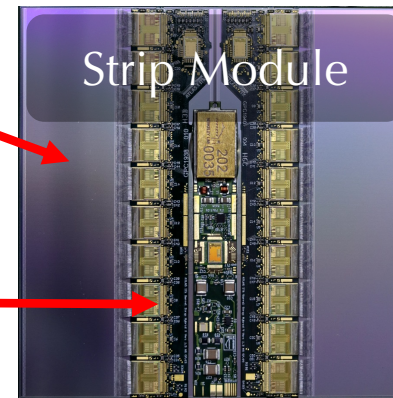
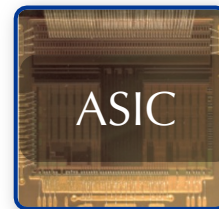
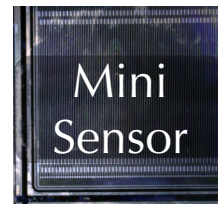
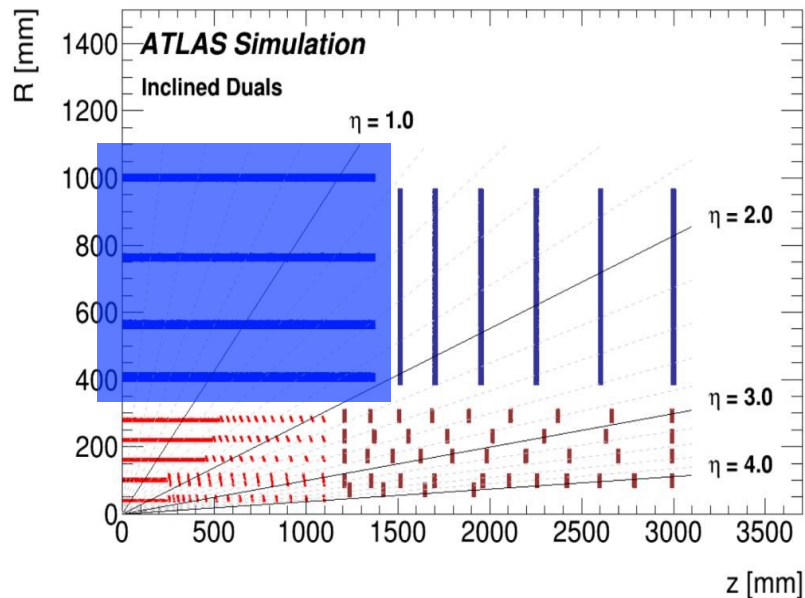


Deliverables

- Complete strip barrel detector with 25 μ m spacial resolution
- Provide strip module spacial resolution evaluation report

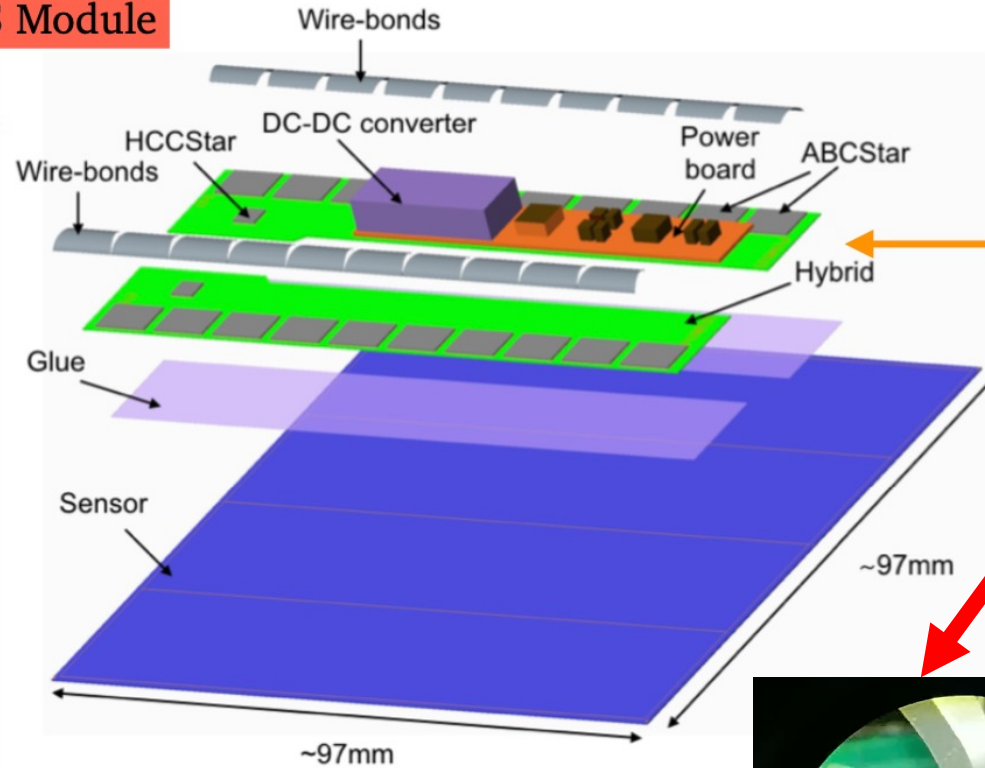
Contents

- Radiation hard sensor and readout ASIC study
- High performance strip detector module production
- Complex silicon detector system integration

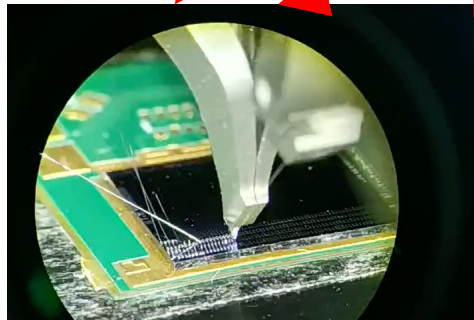
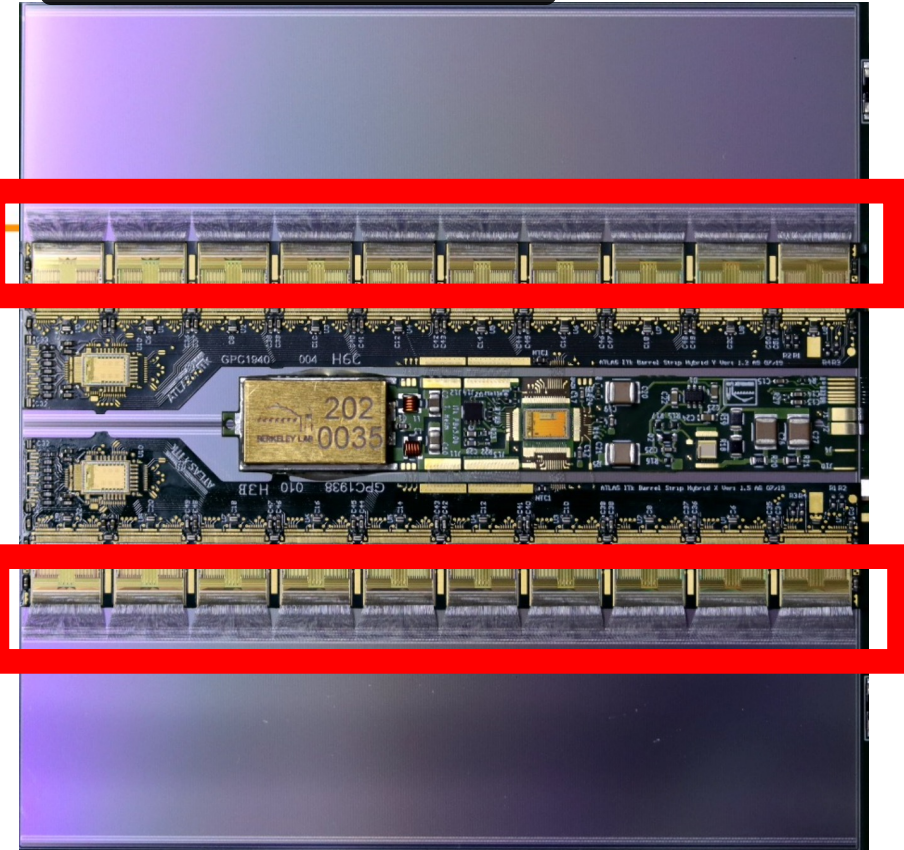


Strip Module Component

SS Module

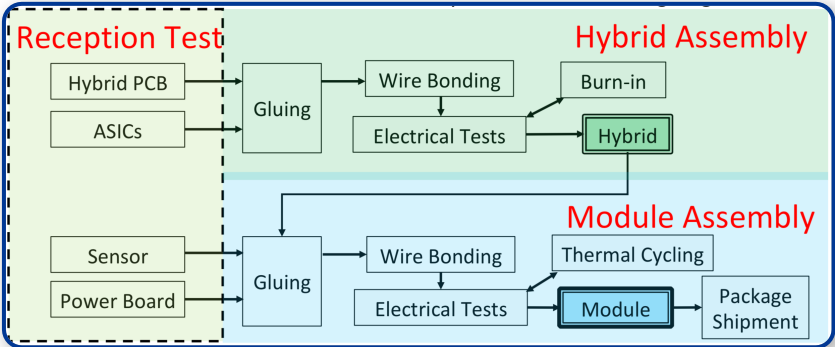


Short Strip Module



ITk Strip Module Production Procedure

- Well defined module production steps to ensure High Quality Modules



Calibration of glue amount

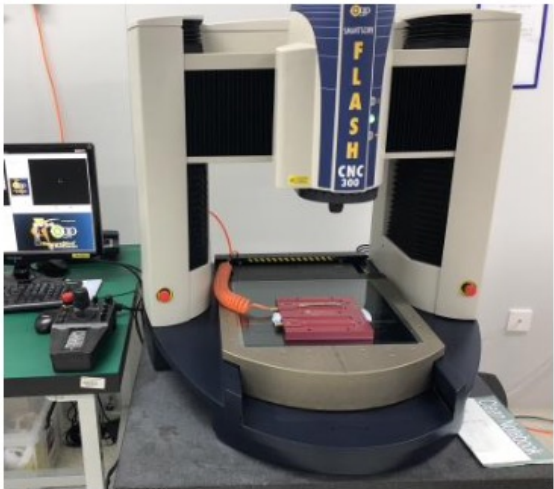


Pull force test

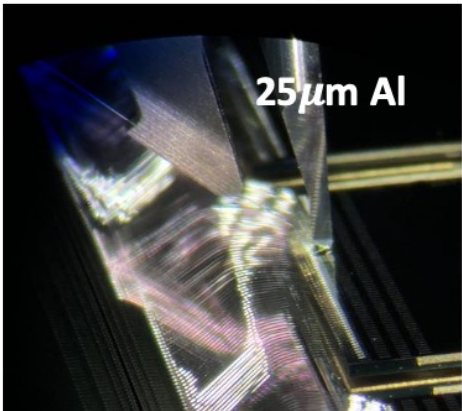


Step Number	Qualification Step	Review End Date
3.2	Sensor Storage	finished: 2021-06-17
6.1	PB Reception	finished: 2022-01-11
6.2	PB E tests	finished: 2022-07-14
6.3	PB Vis Insp	finished: 2021-12-16
6.4	PB Storage	finished: 2021-06-17
8.2	Storage + shipping of glue	finished: 2021-08-26
8.3	Assembling hybrids	finished: 2021-11-20
8.4	Glue weight measurements	finished: 2021-11-21
8.5	Bonding procedures: hybrids	finished: 2022-05-31
8.6	Metrology: hybrids	finished: 2023-03-07
8.7	Visual inspection: hybrids	finished: 2021-08-06
8.8	Hybrid Burn-in	finished: 2023-05-25
8.10	Hybrid Storage	finished: 2021-06-17
8.11	Hybrid QC: single panel testing	finished: 2022-08-25
11.1	Storage of modules	finished: 2021-06-17
11.2	Cleaning module jigs	finished: 2021-06-16
11.4	Storage of modules	finished: 2021-11-29
11.5	Removing hybrids from panel	finished: 2021-12-09
11.6	Module Assembly	finished: 2022-02-25
11.7	Metrology: modules	finished: 2023-07-10
11.8	Bonding procedures: modules	finished: 2022-05-25
11.9	Visual inspection: modules	finished: 2021-07-19
11.10	Module Thermal Cycling	finished: 2023-10-29
11.11	Single Module Electrical Test	finished: 2022-10-23
12.1	Shipping modules	finished: 2022-04-25
13.1	Cleanroom standards	finished: 2021-11-25
13.2	ASIC Compliance & Handling	finished: 2021-06-03
13.3	Bond Pulling Procedures	finished: 2021-12-03
14.1	Module Reception	finished: 2022-01-25

Metrology of glue thickness



Wire bonding



Standard Operating Procedure (SOP)

- Developed at IHEP for local production
 - Accessible to PC and Tablets with internal network
 - All SQ 29 steps have been implemented in SOP

<http://atlasitk.ihep.ac.cn>

IHEP ATLAS-ITk

Standard Operating Procedure

Powered by

2025-05-18 @ 23:23:12

Temperature

Humidity

21.0°C

55.1 %

↑ 0.0°C

↑ 0.1 %

Particle Counter (1000/m3):

0.5 um

1.0 um

5.0 um

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Recorded at --

Grafana Monitoring in B106

Deployed influxDB

IHEP-ITk knowledge database

ATLAS ITk PDB

Standard Operating Procedure

Bulletin Board

2025-05-18 @ 23:23:12

Module Hybrid DUMMY Inventory

Module Work Table

Local Name	Current Local Stage	Next Stage	Next Operation
IHEP-Module-ILS-PRESERIES-1	E-TESTED	THERMAL-CYCLE_DONE	THERMAL-CYCLE
IHEP-Module-ILS-PRESERIES-2	MEASURED	BONDED	WIRE-BONDING
IHEP-Module-ILS-PRESERIES-3	MEASURED	BONDED	WIRE-BONDING
IHEP-Module-ILS-PRESERIES-4	MEASURED	BONDED	WIRE-BONDING

Module Metrology Results

Select metrology run to plot

CDF_run_1

Select metrology bow test run to plot

CDF_bow_run_1

Outputs:

glue_height_measurements

height_measurements

position_measurements

sensor_points_heights

Connect to
ITk
Production
Database

Reception

Select task:

☐ Receive new components

☐ Receive new bulk shipments

☒ Test received components

Select the category of component to test:

BareModule

Select the Type, BareModule of the BareModule:

LS

Select the Version, BareModule of the BareModule:

PP

Please select the component you want to work on:

IHEP-BareModule-LS-PP-3 (NFK32425-W523)

Shipping Reception Checklist

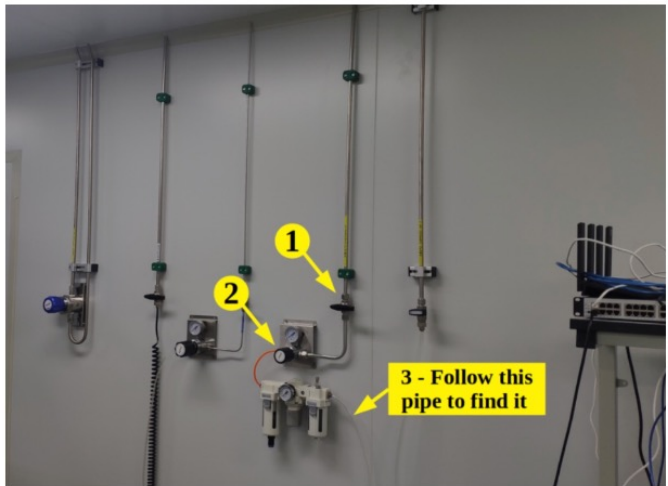
☒ Start to fill reception shipping checklist

Shipment Checklist

- ☐ Shipment was properly packaged
 - ☐ Outer box intact
 - ☐ Inner box intact
 - ☐ ESD state bag used
 - ☐ Humidity barrier bag used
 - ☐ Vacuum sealed bag used
 - ☐ 50g shock watch present
 - ☐ 50g shock watch was not triggered
 - ☐ 25g shock watch present
 - ☐ 25g shock watch was not triggered
 - ☐ Desiccant present
 - ☐ Humidity indicator present
- Humidity indicator triggered up to percentage

Check compressed air flow

- ☒ Turn on the air compressor in 107
- ☒ Check the wall-mount air pipe system, turn on each valves in 1,2,3



FigName: Fig_Reception_bareModule_IV_AirPipeSystem.png

- ☒ Check if air pressure on the meters 4,5 are correct
- ☐ Find airmeter attached to the table leg. Rotate red knob counter-clockwise to turn on the air flow. If the indicator red ball floats, the

Run IV scan

- ☒ IV scan for the installed module inside TestBox is automatically performed by programs of ITSDAQ. Make sure the pow. / com. cable are connected, and temp. / humid. are achieved!
- ☒ Go to penguin-1. Switch to ITSDAQ GUI "BurstData on penguin1", click DCS panel, open the interface "Configure IV Scan(700V, module output format)" by clicking "Module (bare) IV scan (700V)".
- ☒ This interface controls the auto IV scanning and record the input informations:
- ☒ Set "vStop" to -50V for a quick test run. Click on "OK" to start a scan. If it prompts a scanned IV curve at the end, set "vStop" to -700, and repeat last checkbox for the real scan.
- ☐ Click on "OK" to start a scan. Find the prompt output of the current status on terminal.
- At each step, terminal should prompt the present scanning voltage and current.
- If it prompts "Warning! Incorrect component format entered...", Check the input SN of HV-tab module.

☒ Start to do Reception IV

Expand to show the REWORK button

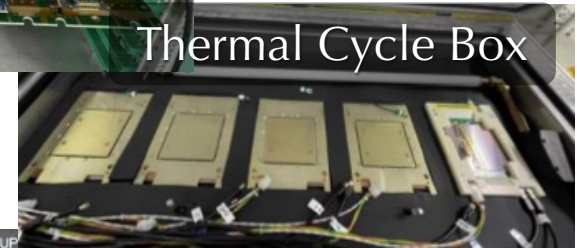
--- Bare Module Reception IV Done! 🎉🎉🎉🎉🎉🎉

IHEP Site Module Production Status

- Passed **all** 29 SQ Steps for Module production
- Produced 16 pre-production modules
 - PPA x3 , PPB x9 , PPC x4
- Produced 17 PRESERIES hybrids and 7 Modules



Burn-in Crate

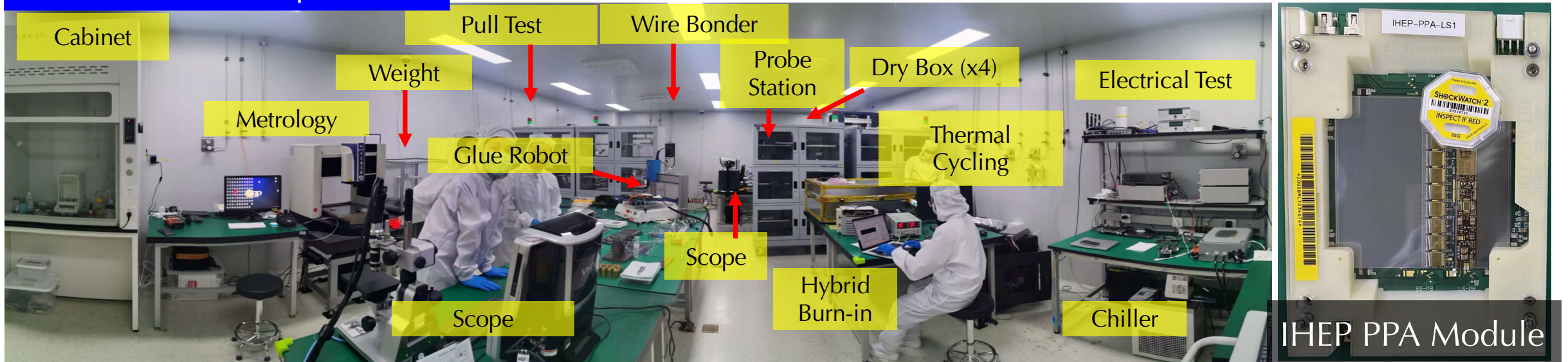


Thermal Cycle Box



ASIC tools made in China

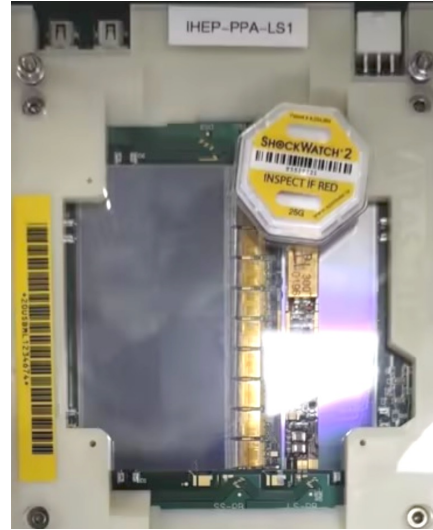
IHEP Site for ITk Strip Module



IHEP PPA Module

Modules @ IHEP

- 8 prototype modules
- 16 Pre-Production Modules
- 17 PRESERIES hybrids
- 7 PRESERIES modules



More details in Weiguo's talk.

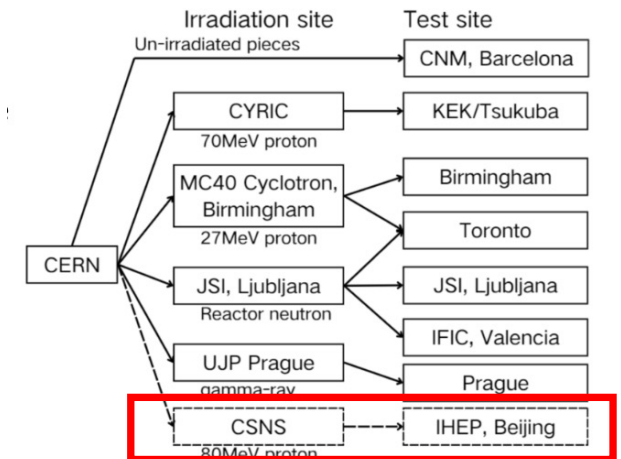
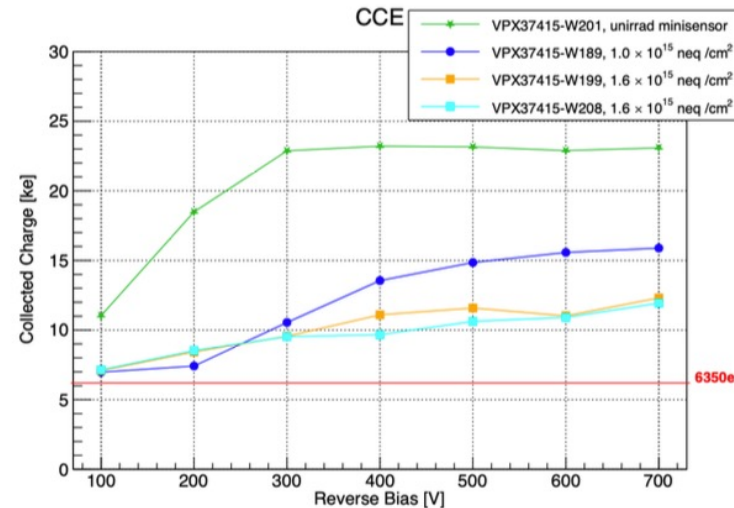
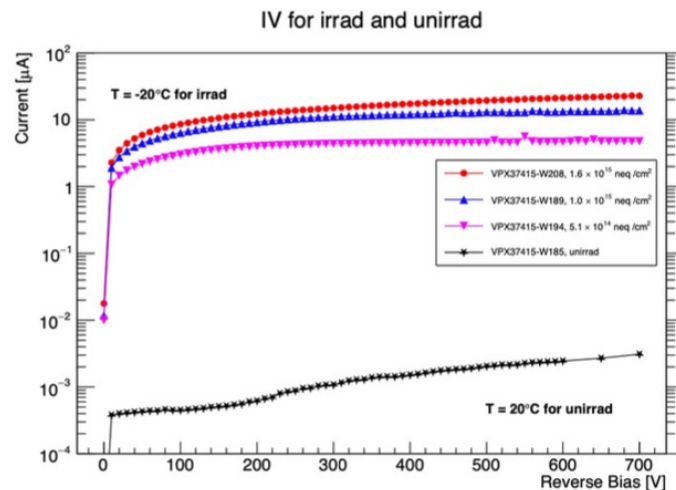
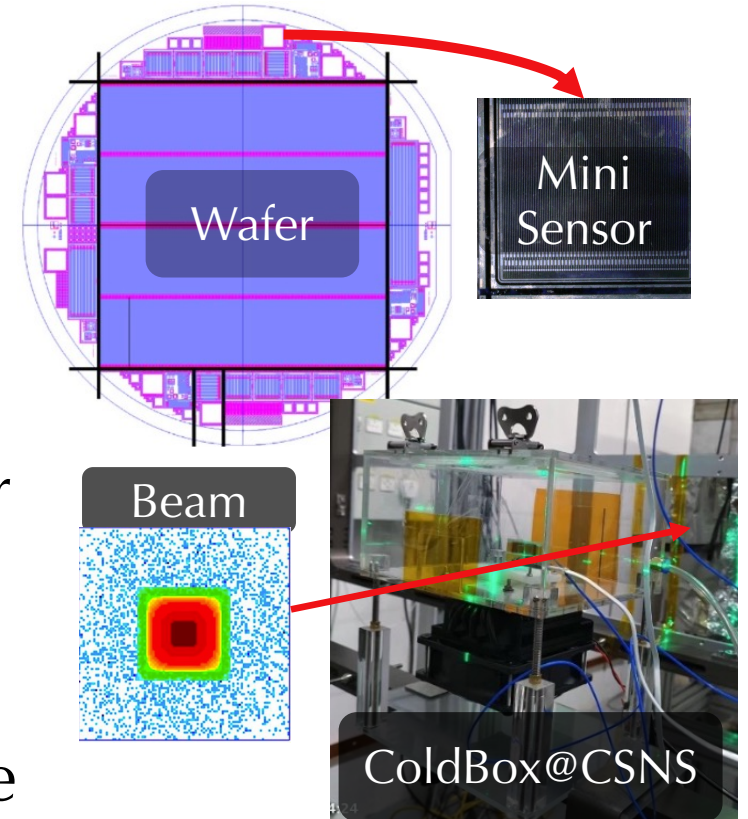
RAL Site Contribution

- Two FTEs from China based at RAL
 - Contribute the 50% of China module production
- Contributed to RAL site module production and stave loading
 - Assembled and tested over 20 prototype modules at RAL
 - Receive modules from other production sites and perform visual inspection and electrical testing to prepare for subsequent stave assembly
- Coordinate ASIC and power board distribution



Strip Sensor Irradiation Study

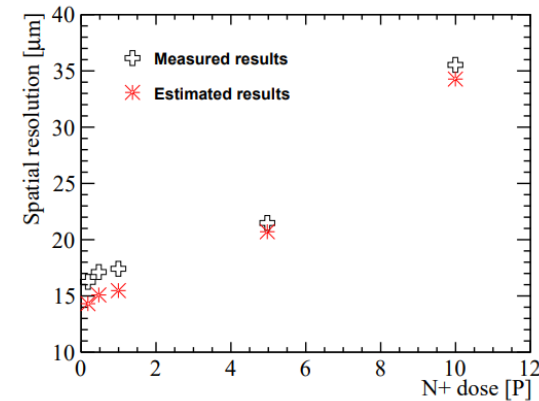
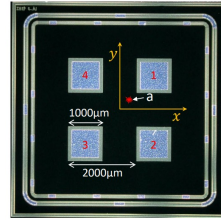
- Proton irradiation of strip mini-sensor at CSNS for quality assurance (QA) site
 - 80 MeV proton fluence up to $1.6 \times 10^{15} \text{ n}_{\text{eq}}/\text{cm}^2$
 - Developed temperature and humidity control chamber
- Sensor characterization at IHEP
 - I-V, C-V, CCE (Charge Collection Efficiency)
- CSNS and IHEP have been qualified as sensor QA site



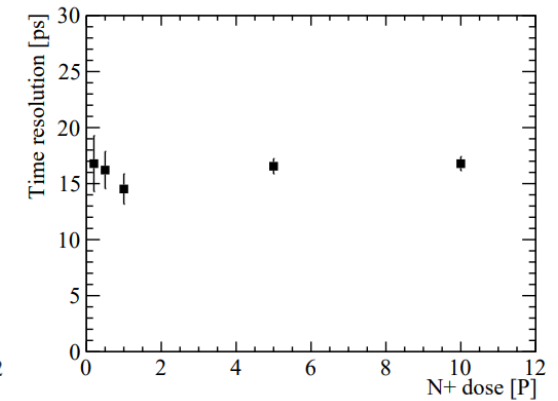
More details in Peilian's talk.

2.2 Timing Pixel Sensors – AC-LGAD R&D

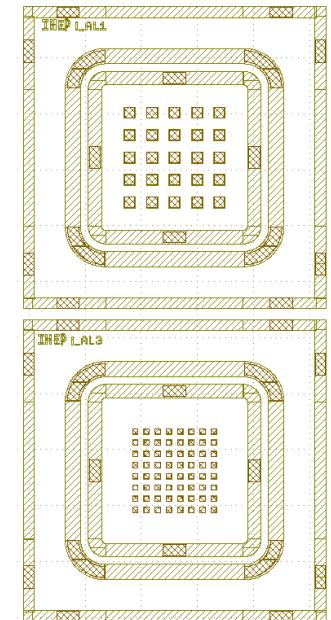
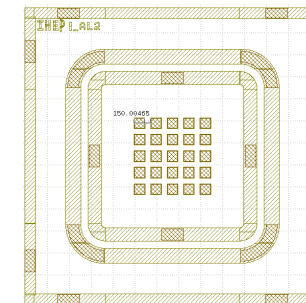
- Pixelated AC-LGAD R&D
 - Large pad-pitch size: 1mm-2mm
- Spatial resolution study
- New design with different pad-pitch size
 - 50-100 μm , 100-150 μm , 100-200 μm
 - Submitted in March 2025
 - Expectect to receive in August 2025



Spatial resolution: 15 μm

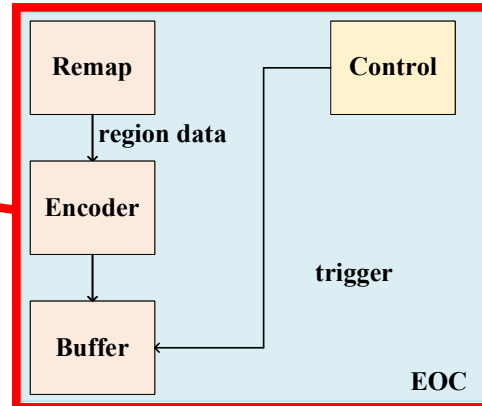
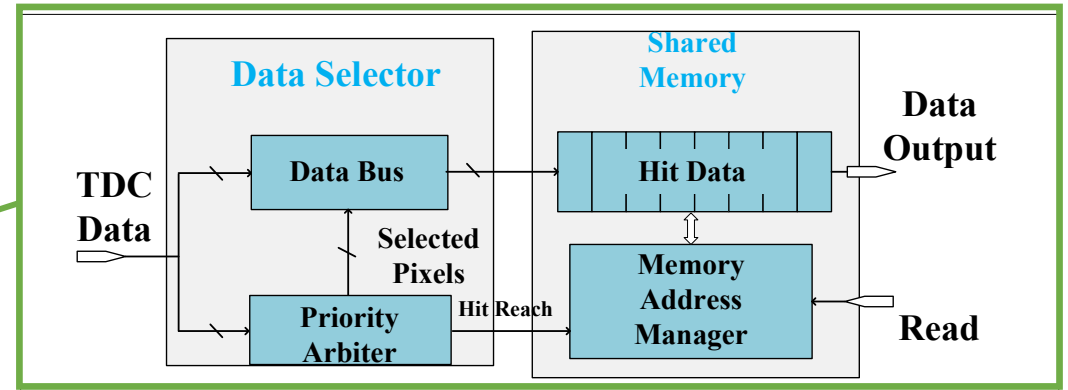
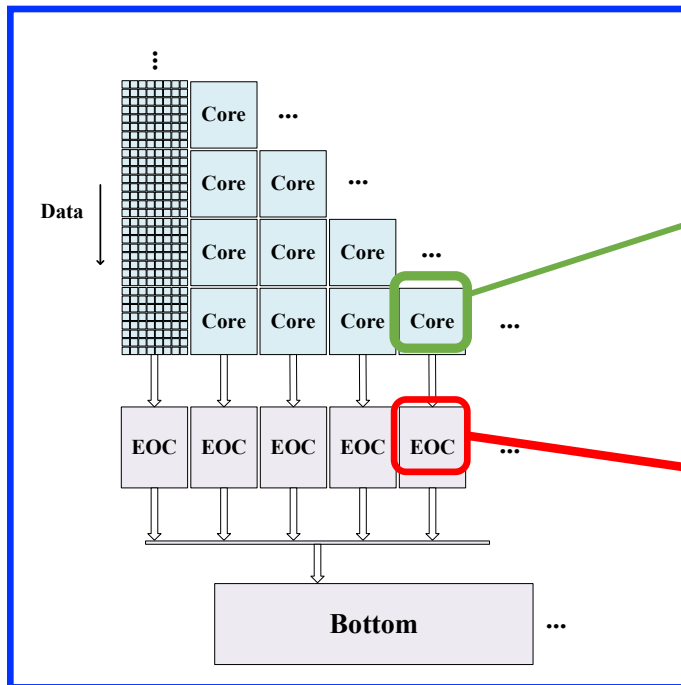


Timing resolution: 15-17ps



2.2 Timing Pixel Readout Electronics

- The scheme of the chip have been designed, including:
 - Pixel array: shared memory
 - End of Column (EOC): encoding and packaging the hit data
 - Bottom: data concentrating and trigger table management
- Next: design of the analog part



More details in Zhe's talk.

Schedule and Expected in mid-term

- 2024
 - Finish the sensor and ASICs key evaluation test; pass the site qualification, start producing long strip module; complete multi-stave small system test at RAL, start system integration such as stave reception at CERN – DONE
 - Complete literature survey, clarify the design specifications and technical path, finish the framework and functional module design of sensor and front-end electronics. – DONE
- 2025
 - Evaluate the performance of strip sensor and ASICs after irradiation, participate in the reliability test during production; produce long strip module; receive, test and ship the barrel stave to CERN, complete the workflow. - DONE
 - Complete design of the first sensor, finish the prototype design of the first front-end electronics. – DONE
- Mid-Term expectation
 - Strip module: spatial resolution $25\mu\text{m}$
 - Timing pixel: temporal resolution better than 1ns

Summary and Plan

- China is responsible to deliver 10% ITk Strip barrel modules
 - IHEP passed all 29 site qualification steps and implemented into local SOP
 - Produced 16 pre-production modules, 7 PRESERIES modules at IHEP site
- Completed strip sensor and ASICs radiation study
 - CSNS/IHEP qualified as sensor QA site
- Timing Pixel detector completed sensor gain layer design and readout ASIC functional design
- Plan
 - Strip module: move on module production
 - Timing pixel: evaluate the design of the first sensor, finish the analog design of the first front-end electronics

Thank you!