ATLAS Inner Tracker Upgrade Overview

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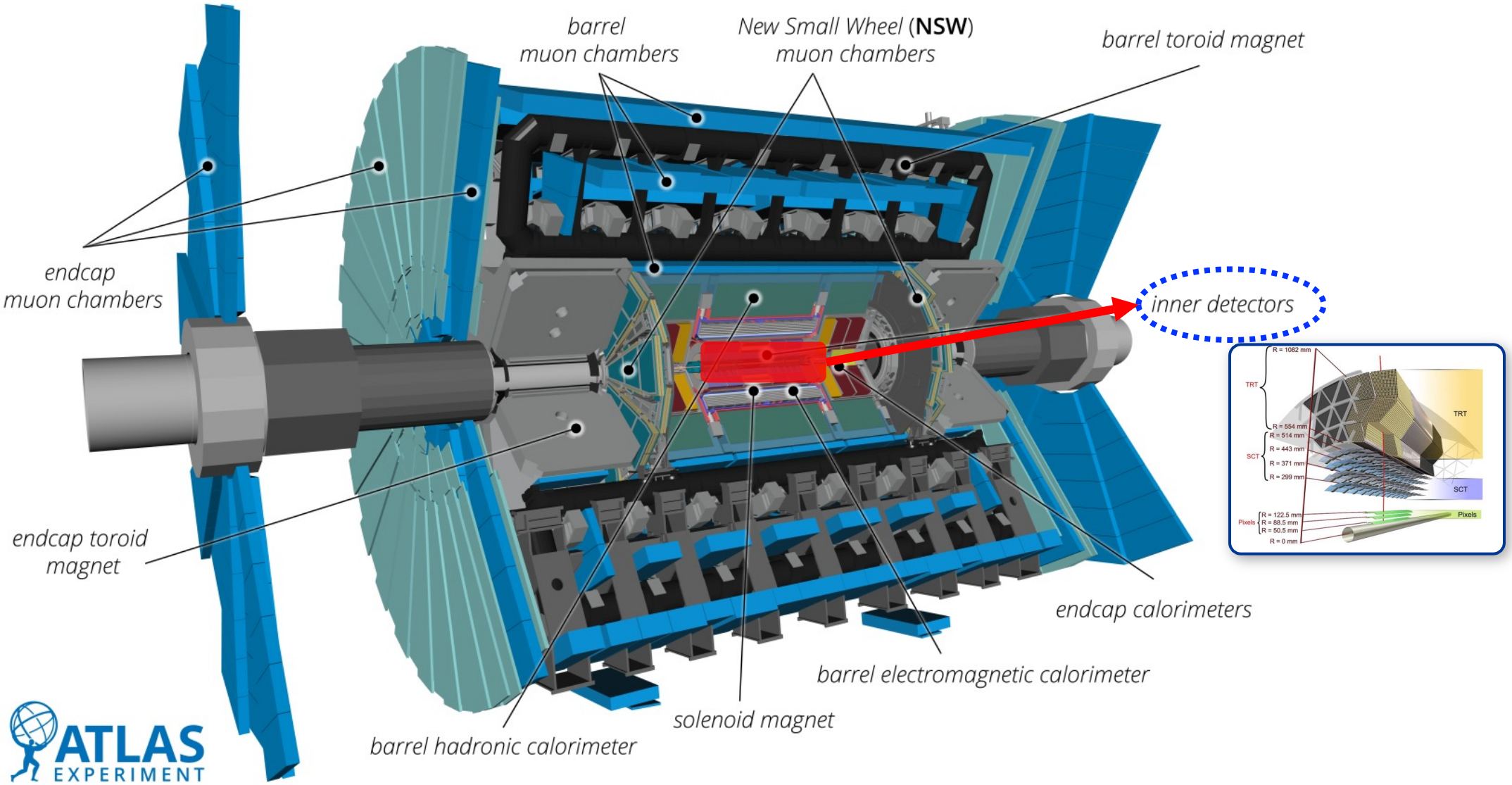
On behalf of subtask 2 Team

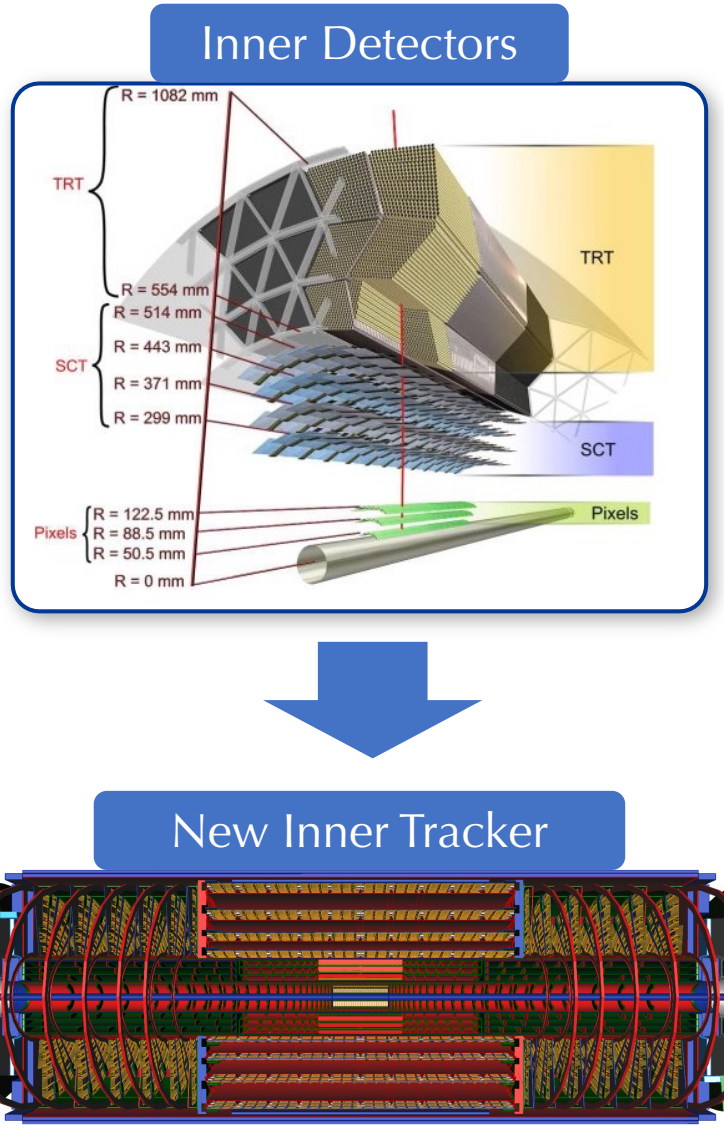
7 June 2025

Current ATLAS Detector

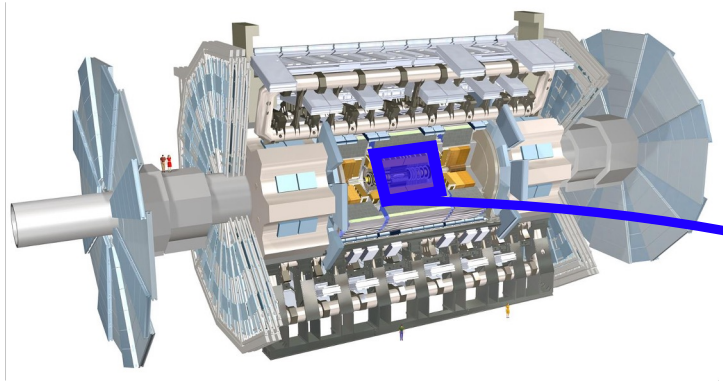


Motivation of Inner Tracker Upgrade

- 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 7.5×10^{34} $cm^{-2}s^{-1}$, <PU>200
    Pixel and SCT: 2×10^{34} $cm^{-2}s^{-1}$, <PU>50
- Detector Occupancy
  - TRT occupancy will reach 100%

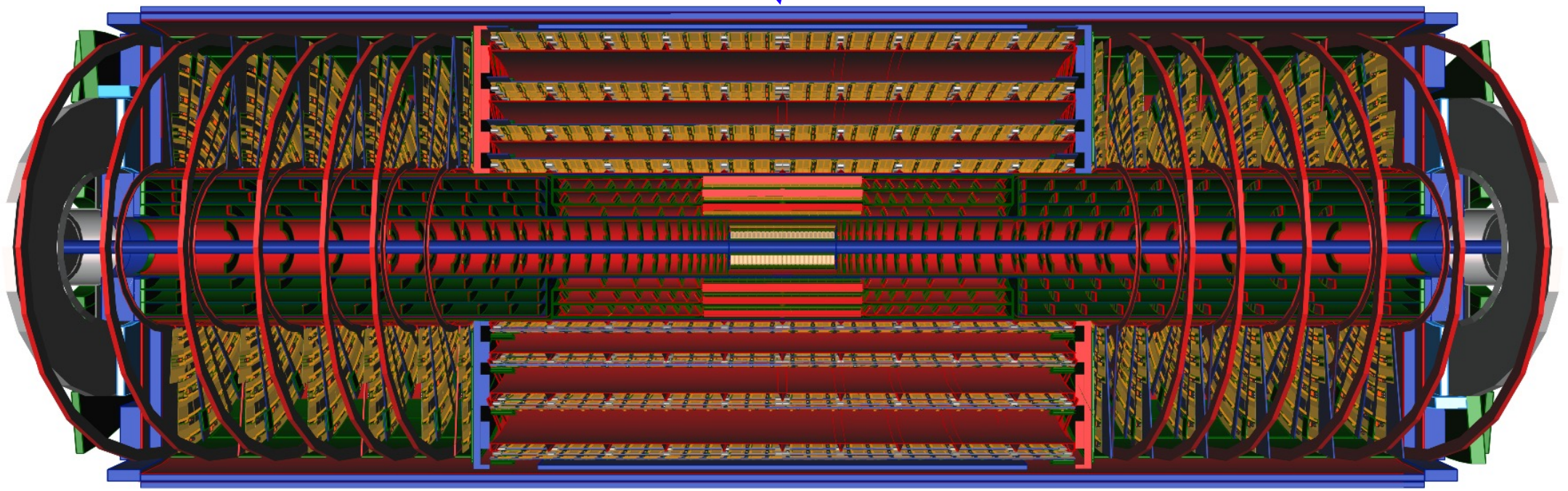


ATLAS Inner Tracker (ITk) Upgrade

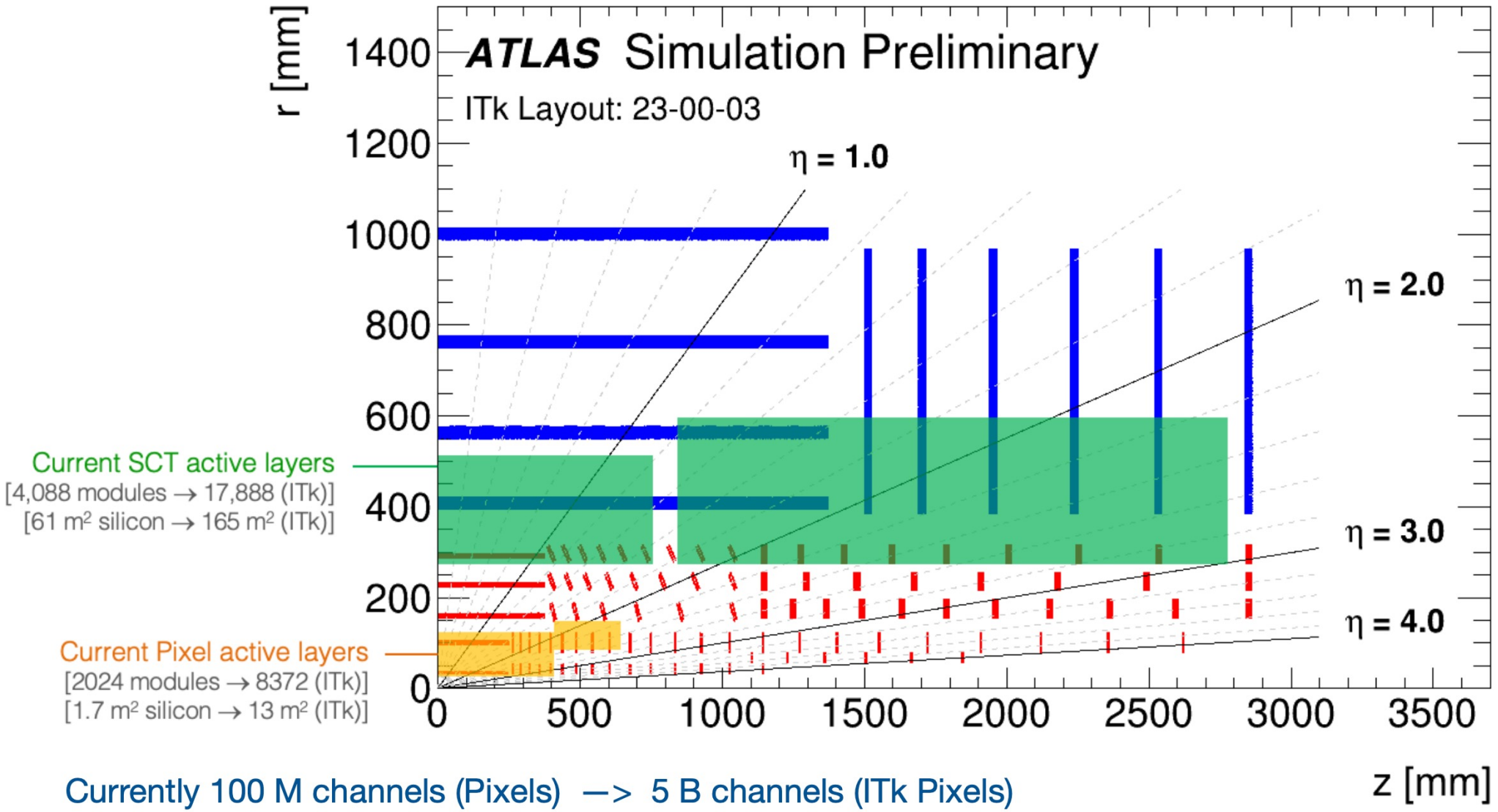


Inner Tracking Detector (ITk)

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

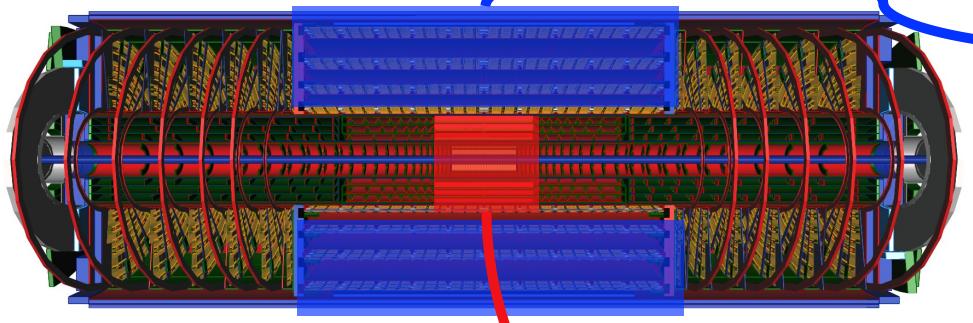


ATLAS New Inner Tracker (ITk)



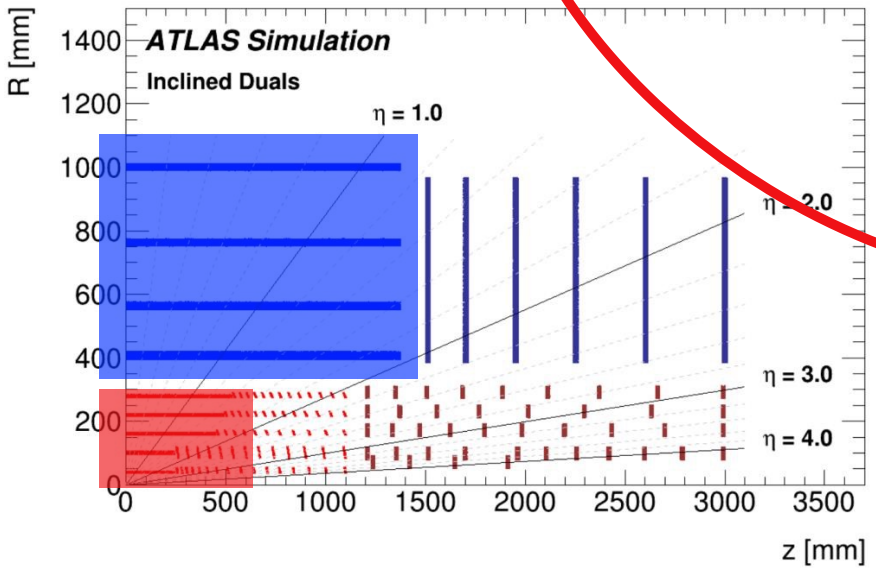
Currently 100 M channels (Pixels) —> 5 B channels (ITk Pixels)

Subtask 2: Inner Tracker (ITk) Upgrade



2.1 ITk Strip Barrel Detector

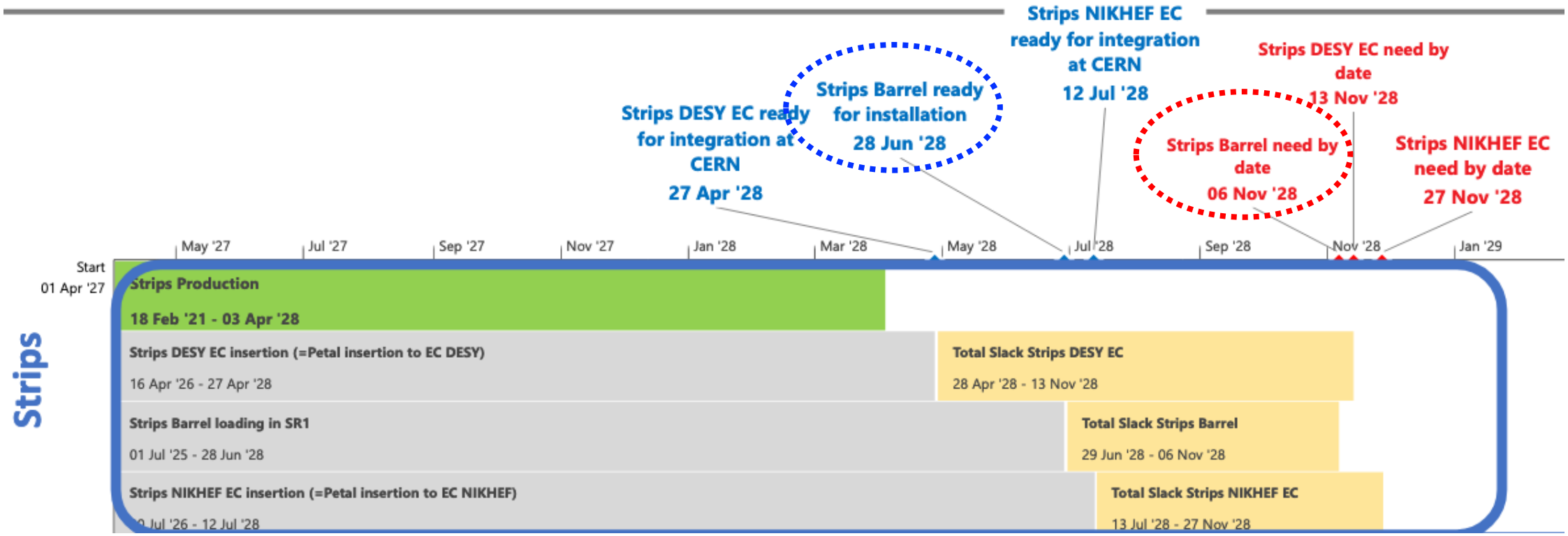
- Radiation hard sensor and ASIC study
- Strip detector module production
- Complex silicon tracker system integration



2.2 Timing Pixel Detector

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

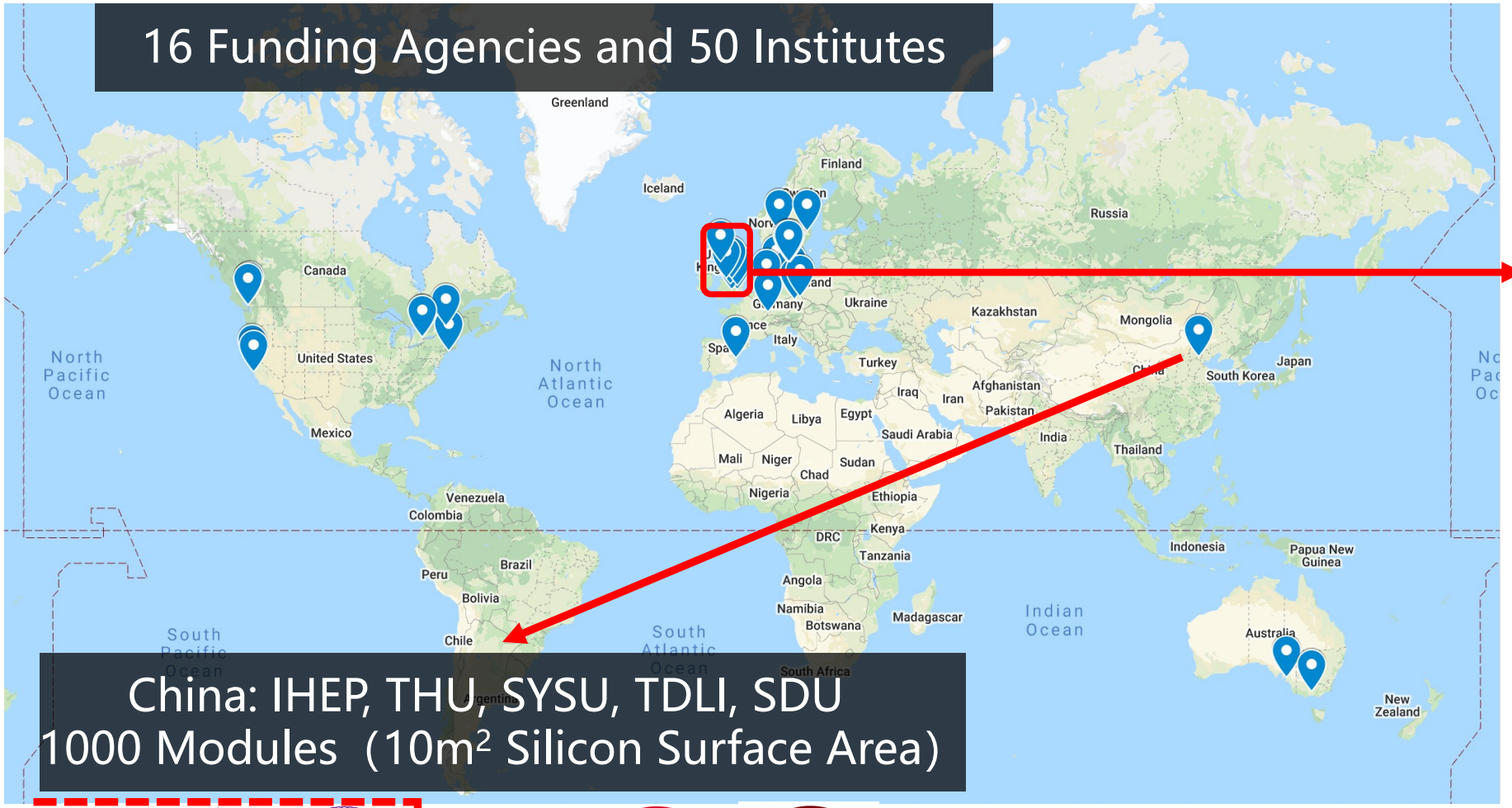
ATLAS ITk Strip schedule



- 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



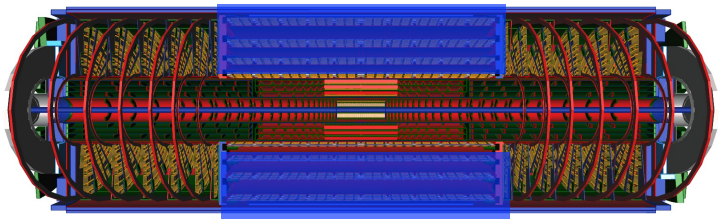
China: IHEP, THU, SYSU, TDLI, SDU
1000 Modules (10m² Silicon Surface Area)

UK/China Cluster
50% Barrel Strip Detector

IHEP

- Xin Shi as UK/China Cluster Manager since 2022

2.1 ITk Strip Barrel Detector

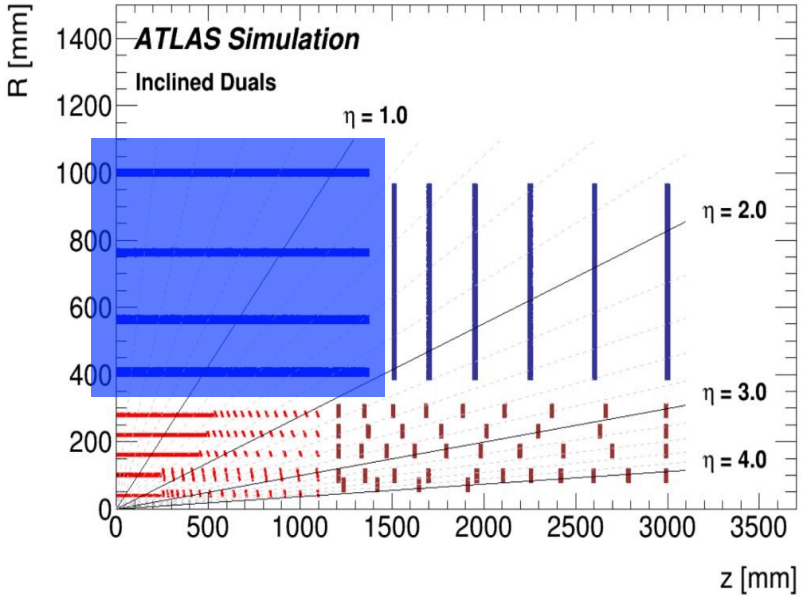


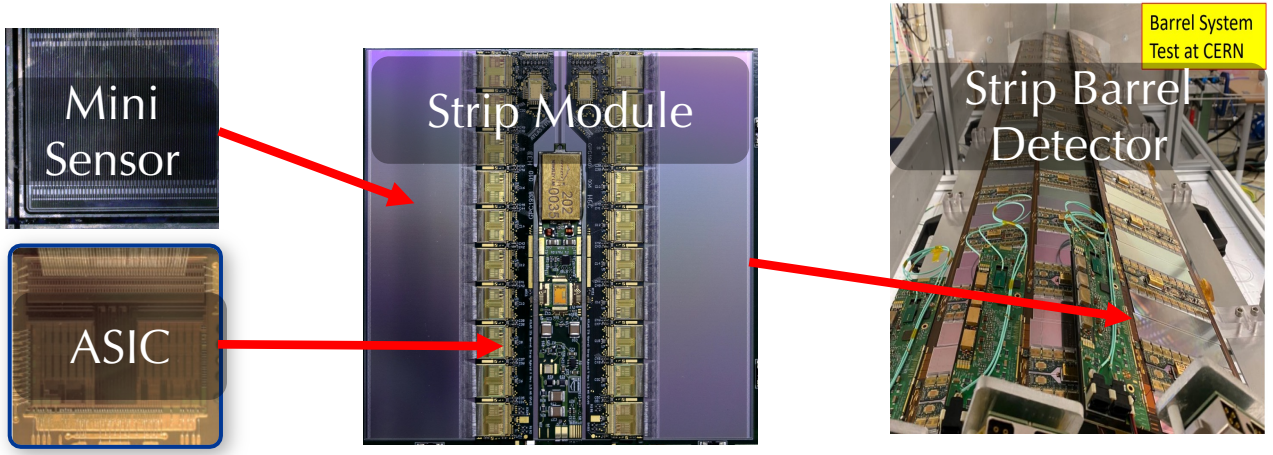
Deliverables

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

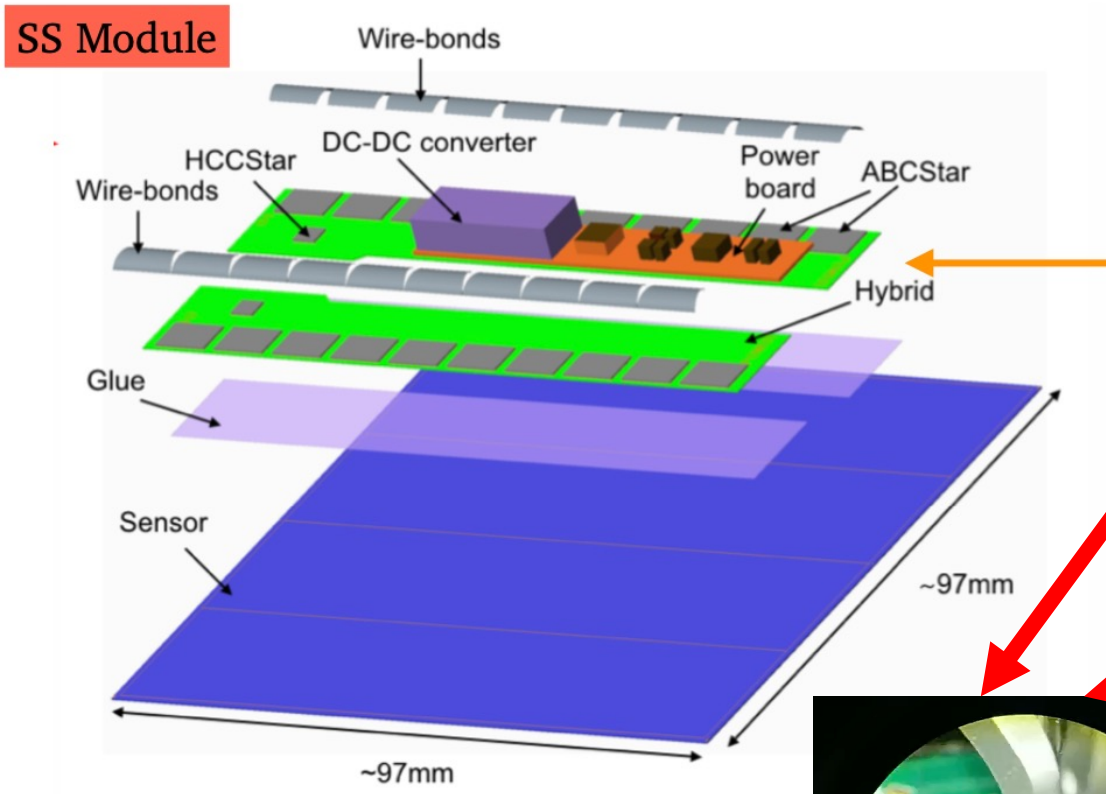
Contents

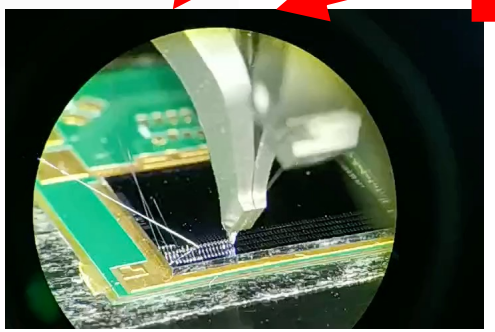
- Radiation hard sensor and readout ASIC study
- High performance strip detector module production
- Complex silicon detector system integration

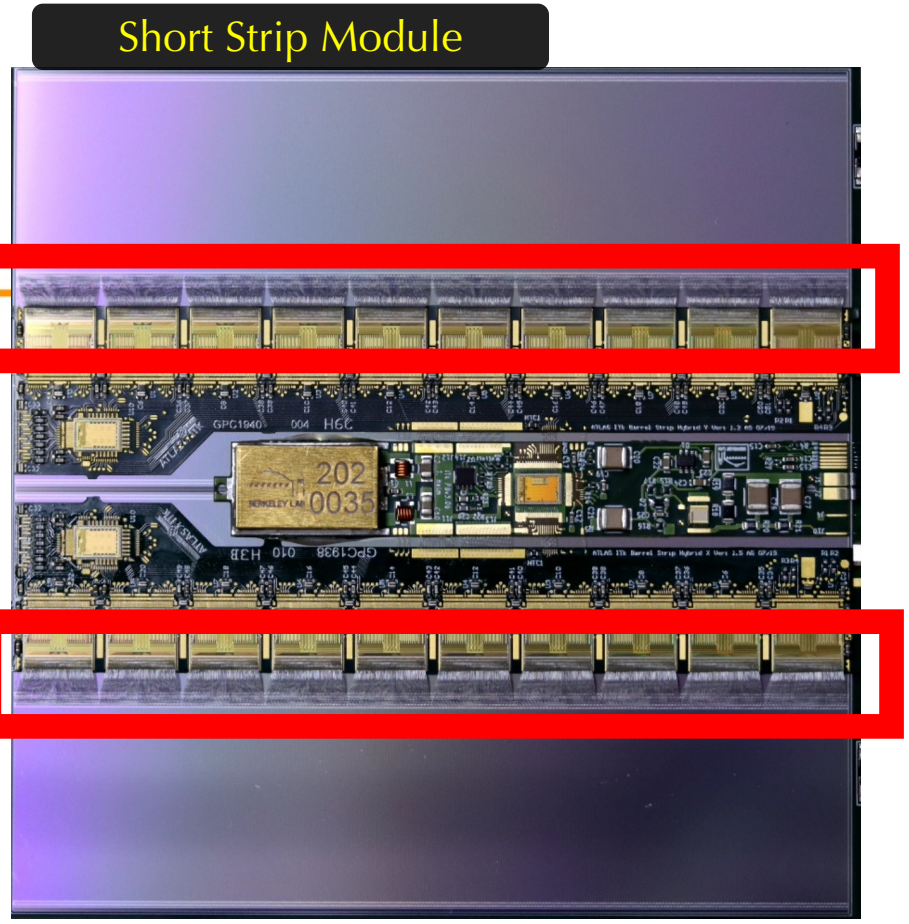




Strip Module Component

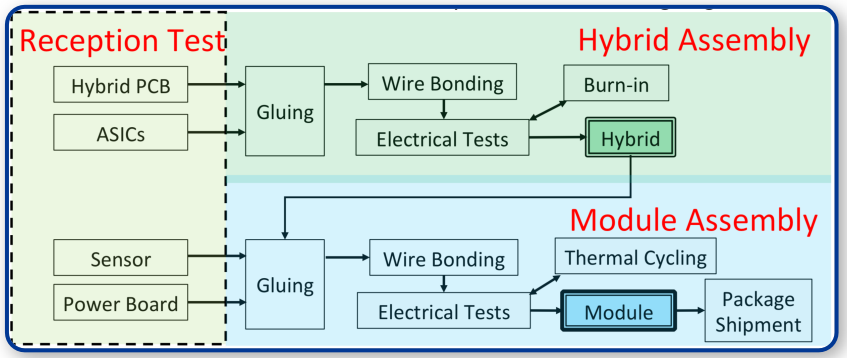






ITk Strip Module Production Procedure

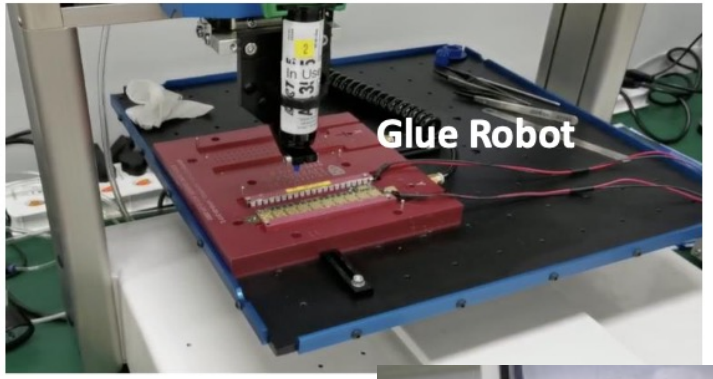
- Well defined module production steps to ensure High Quality Modules



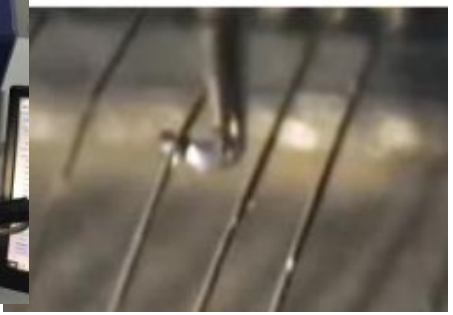
Step Number	Qualification Step	Review End Date
3.2	Sensor Storage	finished: 2021-06-17
6.1	PB Reception	finished: 2022-01-11
6.2	PB E tests	finished: 2022-07-14
6.3	PB Vis Insp	finished: 2021-12-16
6.4	PB Storage	finished: 2021-06-17
8.2	Storage + shipping of glue	finished: 2021-08-26
8.3	Assembling 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

29 Steps

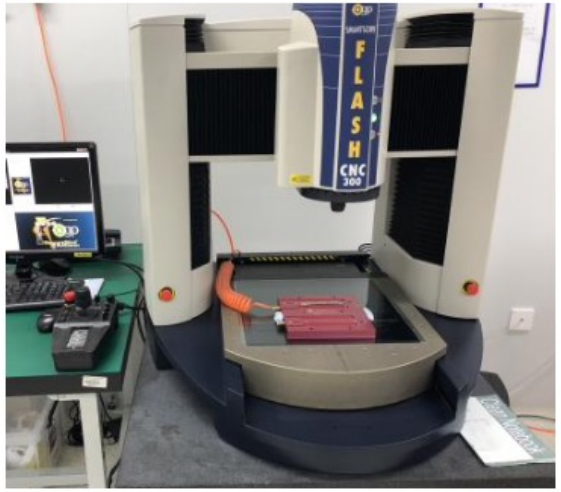
Calibration of glue amount



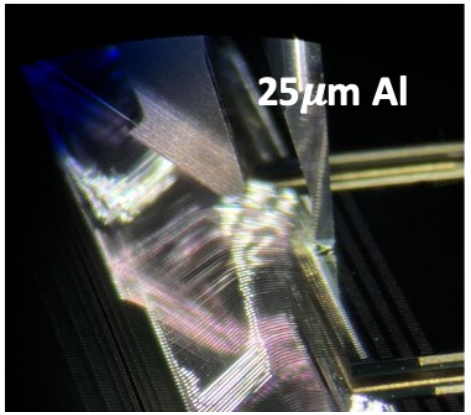
Pull force test



Metrology of glue thickness



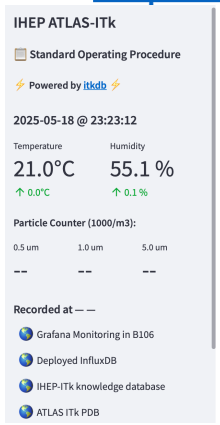
Wire bonding

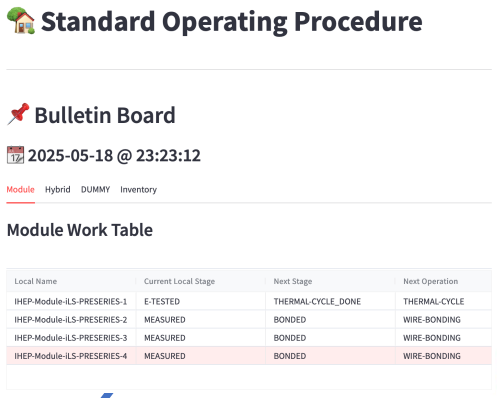


Standard Operating Procedure (SOP)

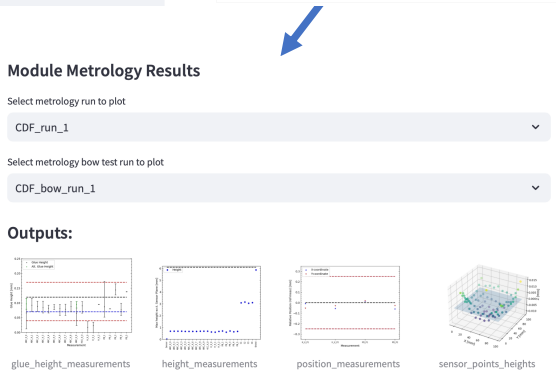
- Developed at IHEP for local production
  - Accessible to PC and Tablets with internal network
  - All SQ 29 steps have been implemented in SOP

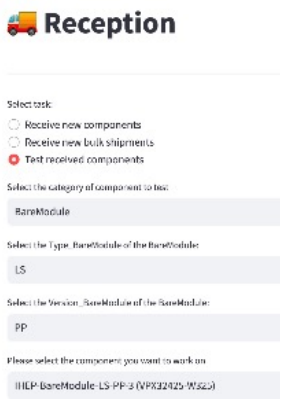
http://atlasitk.ihep.ac.cn

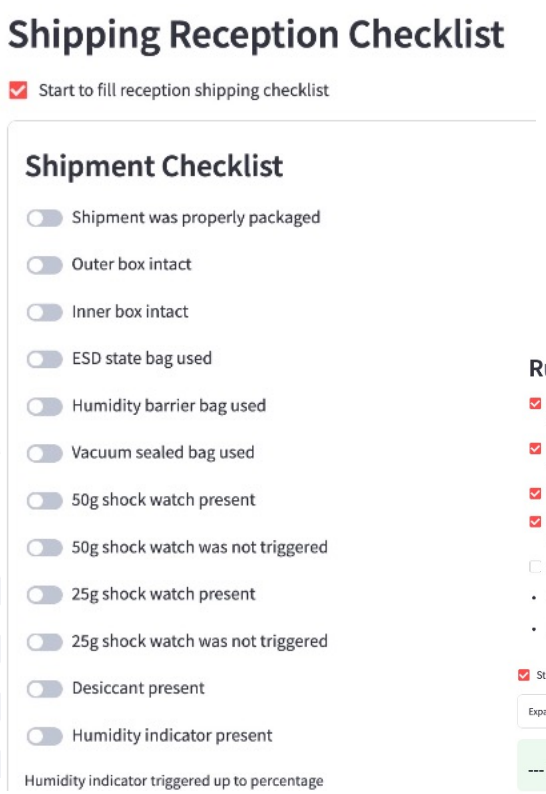


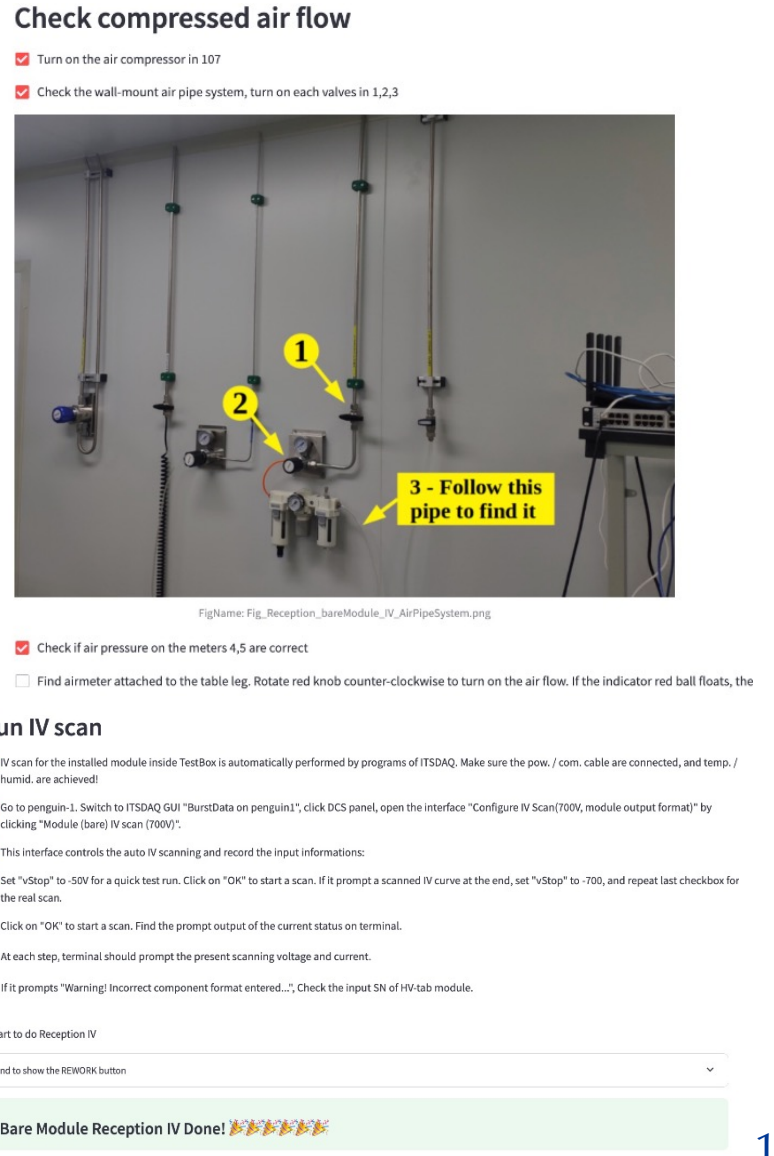


Connect to ITk Production Database



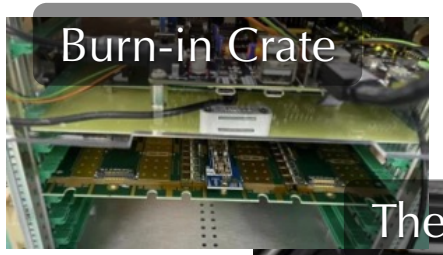


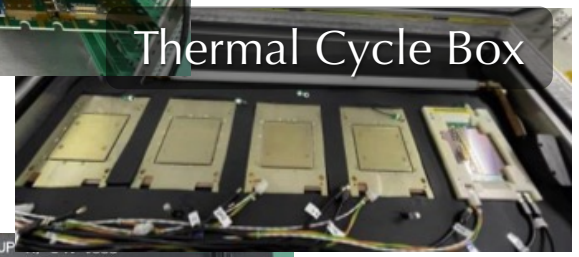




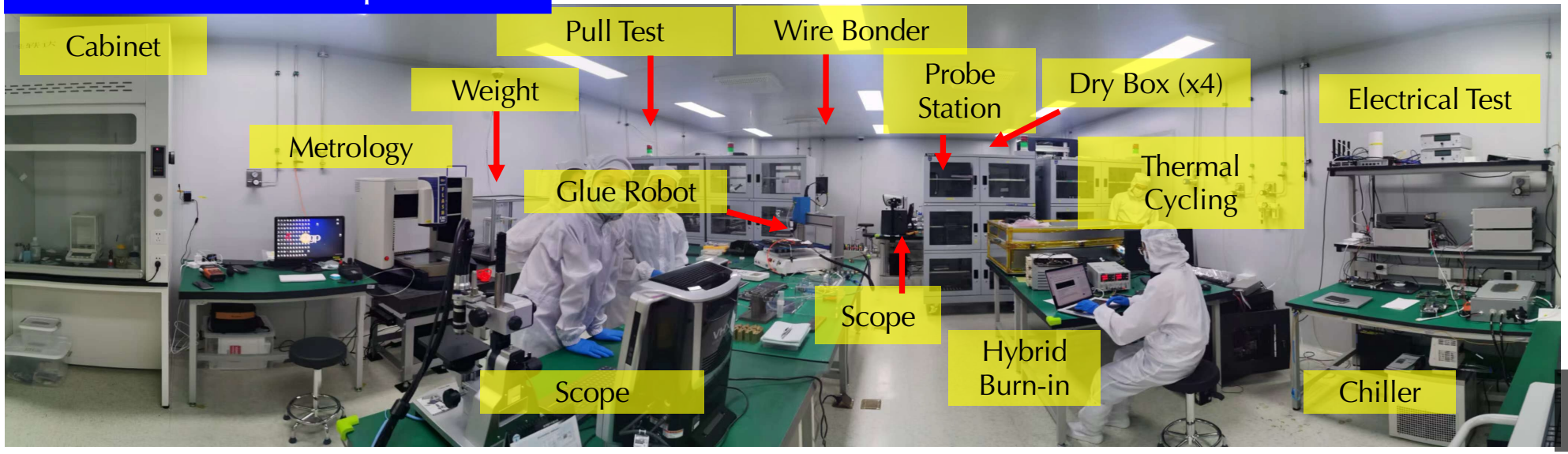
IHEP Site Module Production Status

- 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





IHEP Site for ITk Strip 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

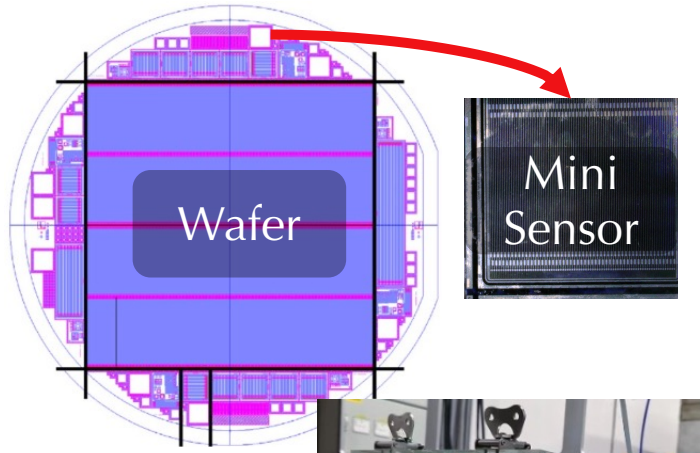
- Two FTEs from China based at RAL
  - Contribute the 50% of China module production

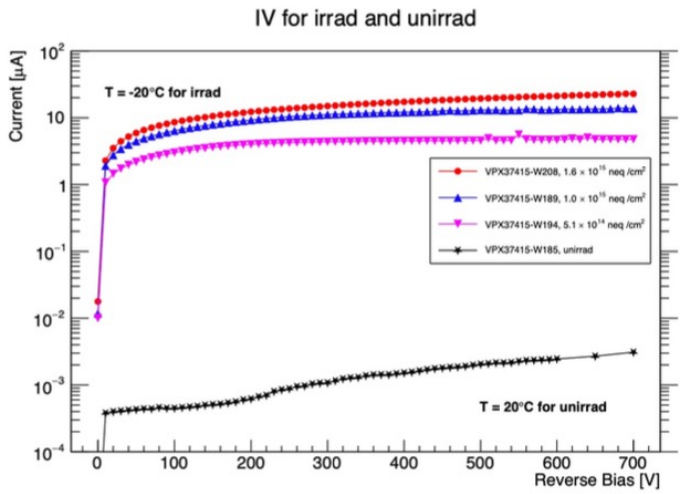
- Contributed to RAL site module production and stave loading
  - Assembled and tested over 20 prototype modules at RAL
  - Receive modules from other production sites and perform visual inspection and electrical testing to prepare for subsequent stave assembly

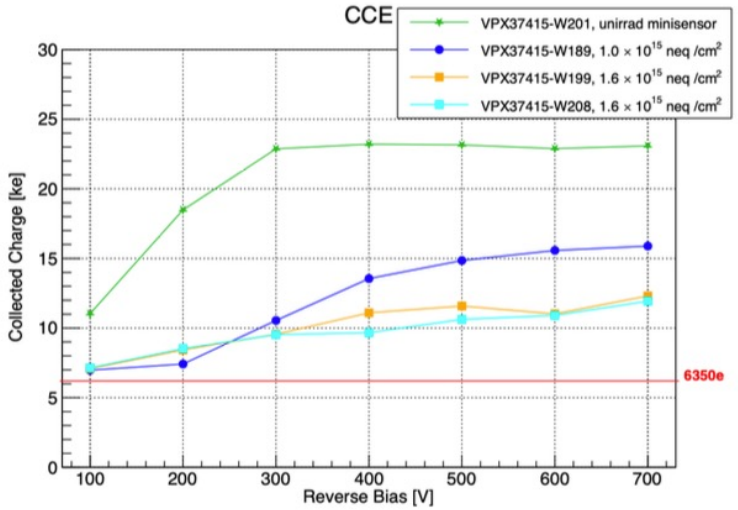
- Coordinate ASIC and power board distribution

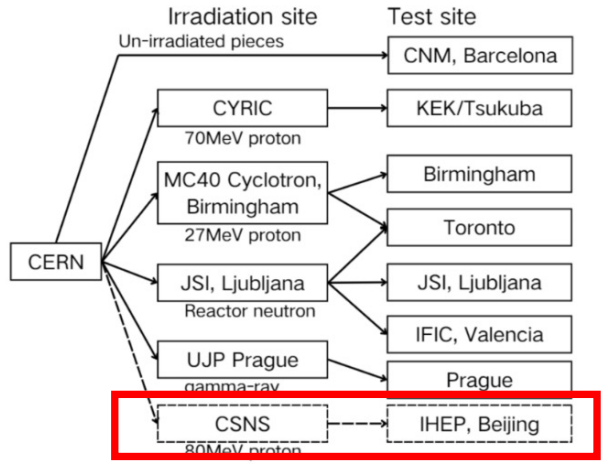
Strip Sensor Irradiation Study

- Proton irradiation of strip mini-sensor at CSNS for quality assurance (QA) site
  - 80 MeV proton fluence up to 1.6x10^{15} n_{eq}/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





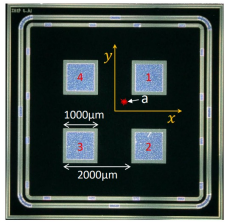


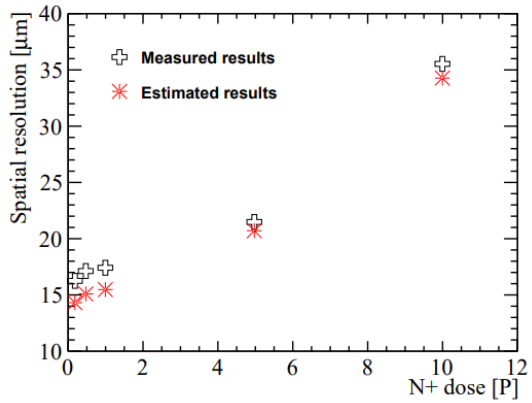


More details in Peilian's talk.

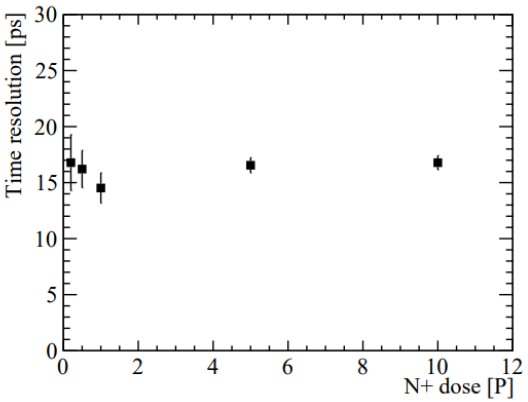
2.2 Timing Pixel Sensors – AC-LGAD R&D

- Pixelated AC-LGAD R&D
  - Large pad-pitch size: 1mm-2mm
- Spatial resoluiton study



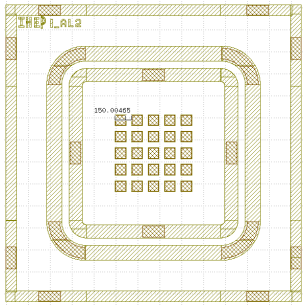


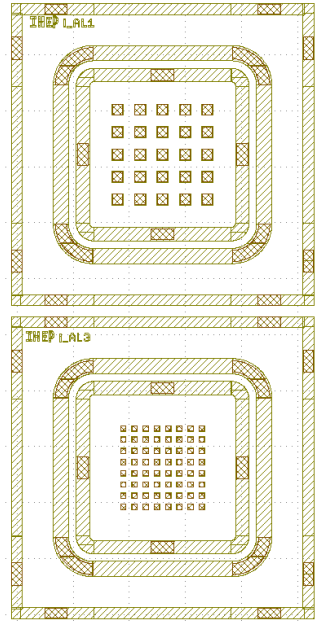
Spatial resolution: 15um



Timing resolution: 15-17ps

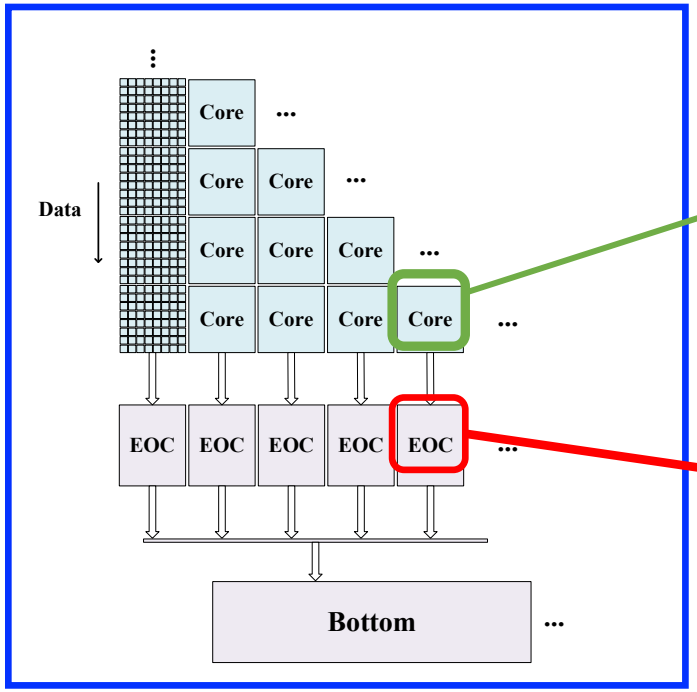
- New design with different pad-pitch size
  - 50-100um, 100-150um, 100-200um
  - Submitted in March 2025
  - Expectect to receive in August 2025

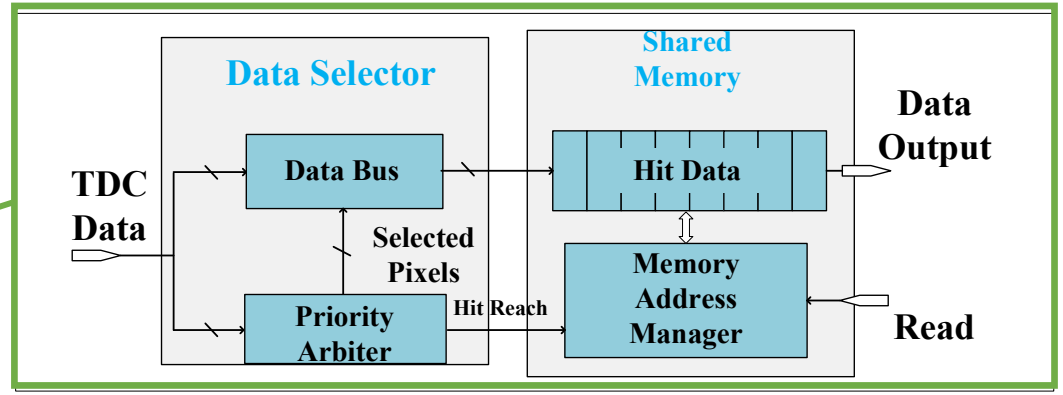


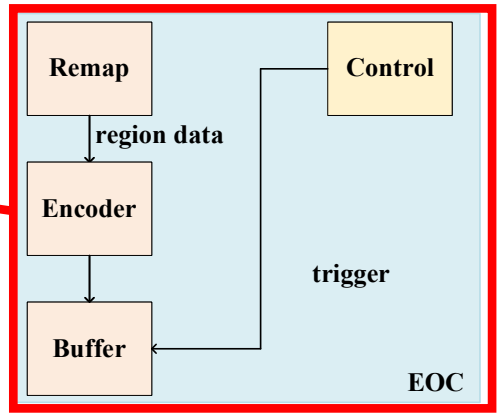


2.2 Timing Pixel Readout Electronics

- 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 25μm
  - 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!