The Upgrade of ATLAS ITk Strip Detector at IHEP

Dengfeng Zhang(Tsinghua University)

On behalf of THU/IHEP ATLAS ITk Group

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CLHCP2020@Tsinghua

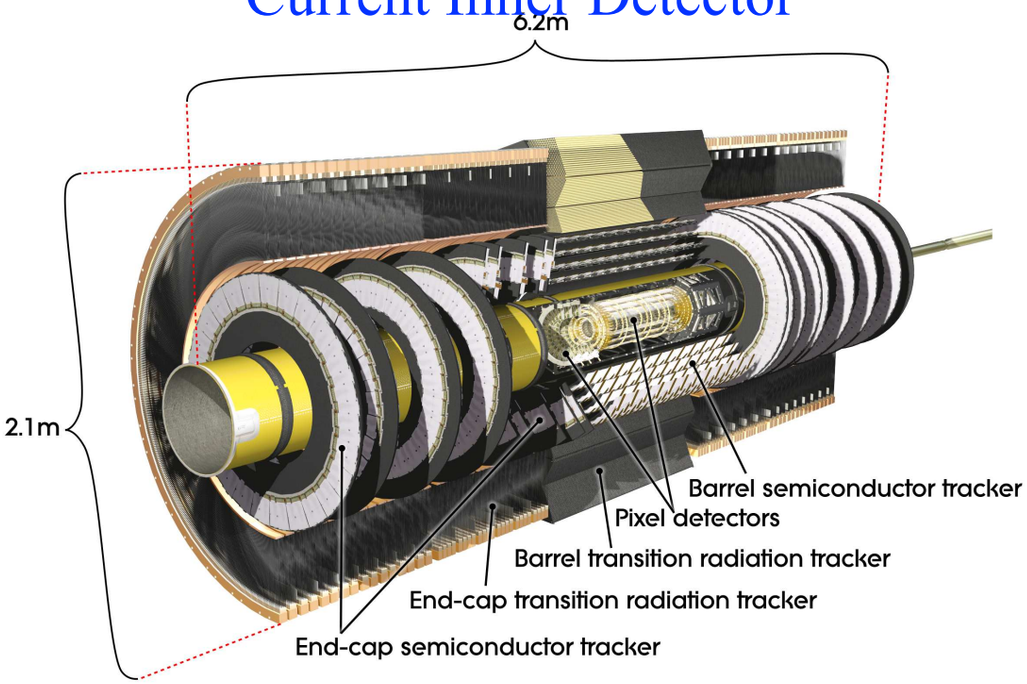
Outline

- Introduction to ATLAS ITk Strip Detector
- Hybrid and Module Assembly and their QC
- Beam Test on Strip Module
- Mini Sensor Studies
- Summary and Plan

ATLAS ITk Strip Upgrade

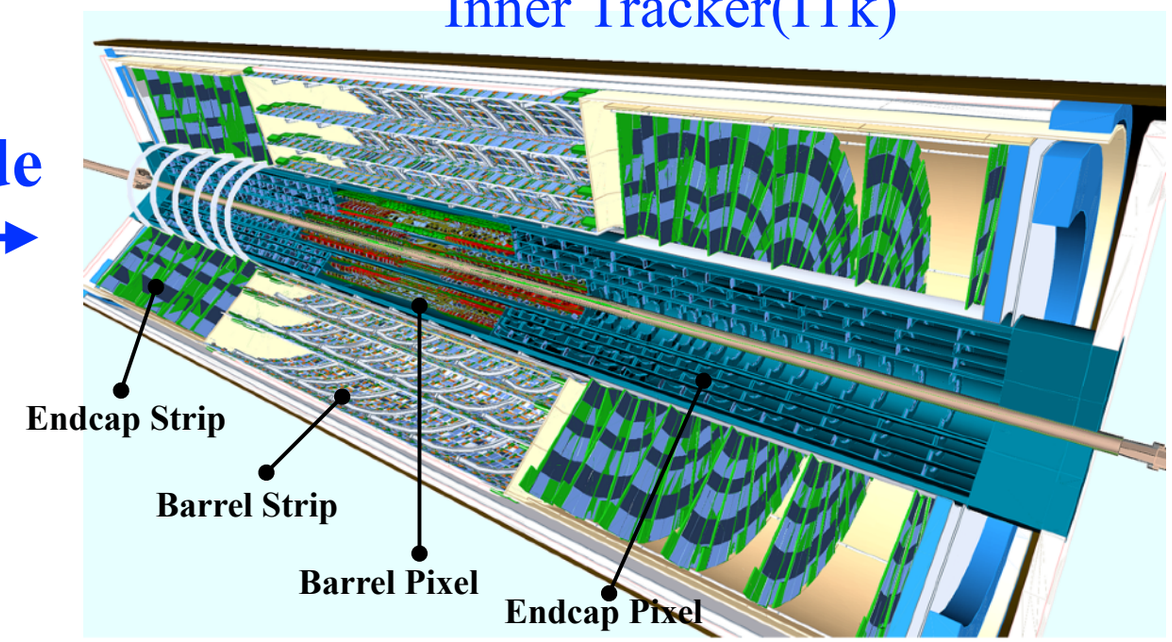
Tsinghua University

Current Inner Detector

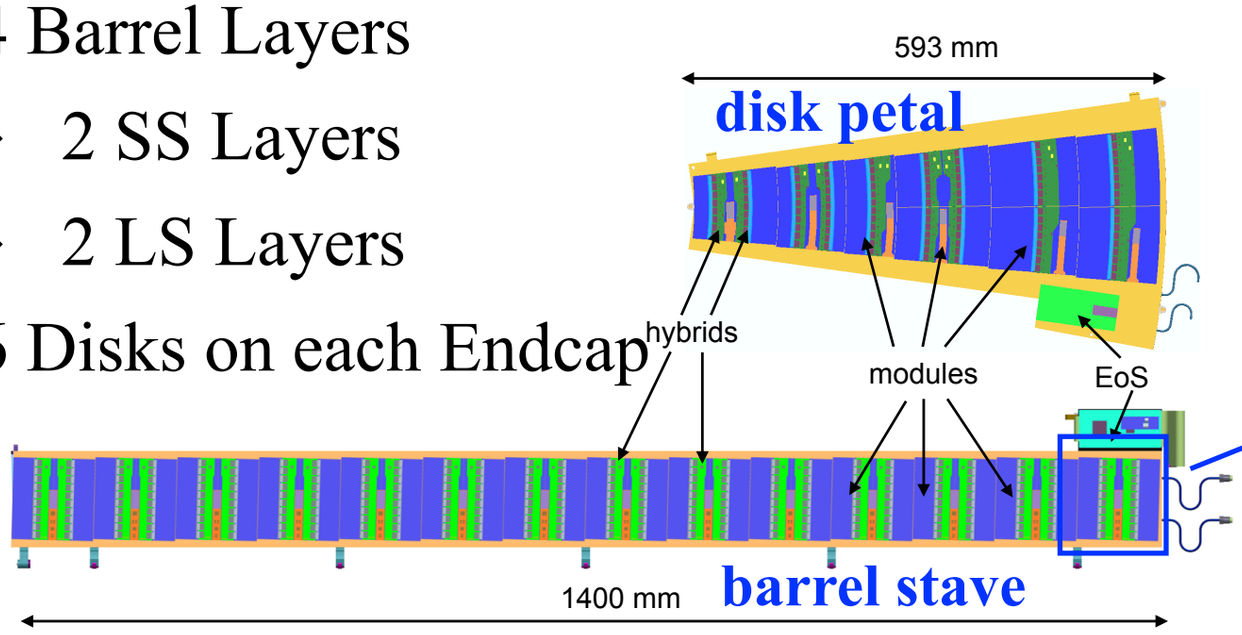


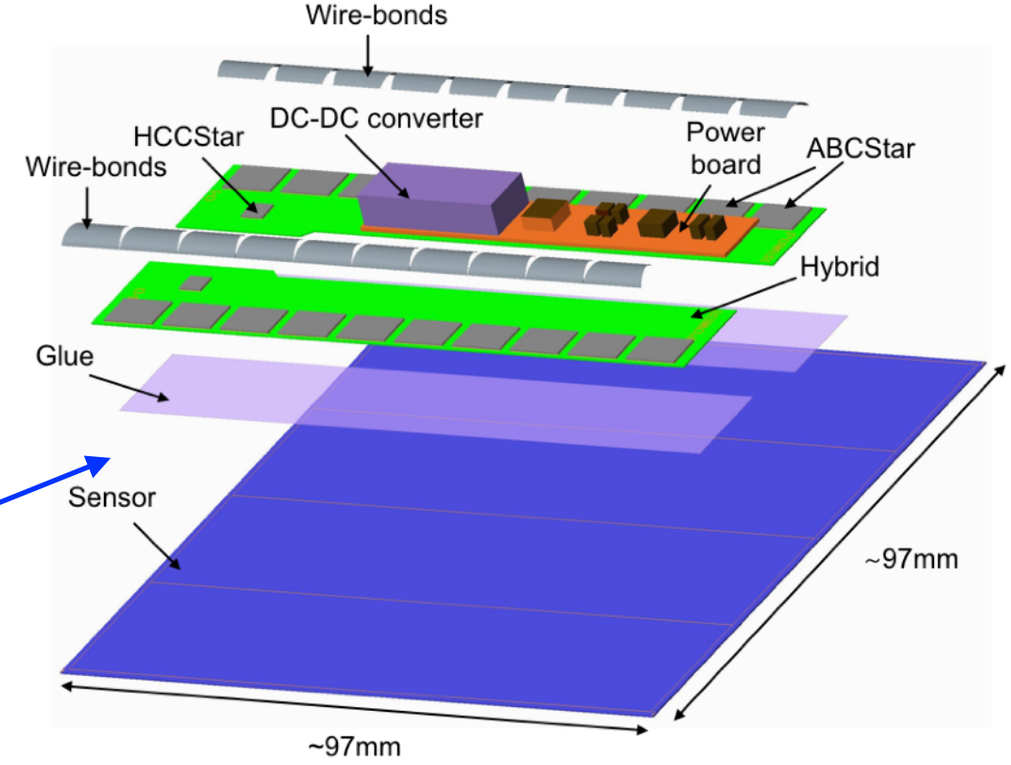
Upgrade

Inner Tracker(ITk)



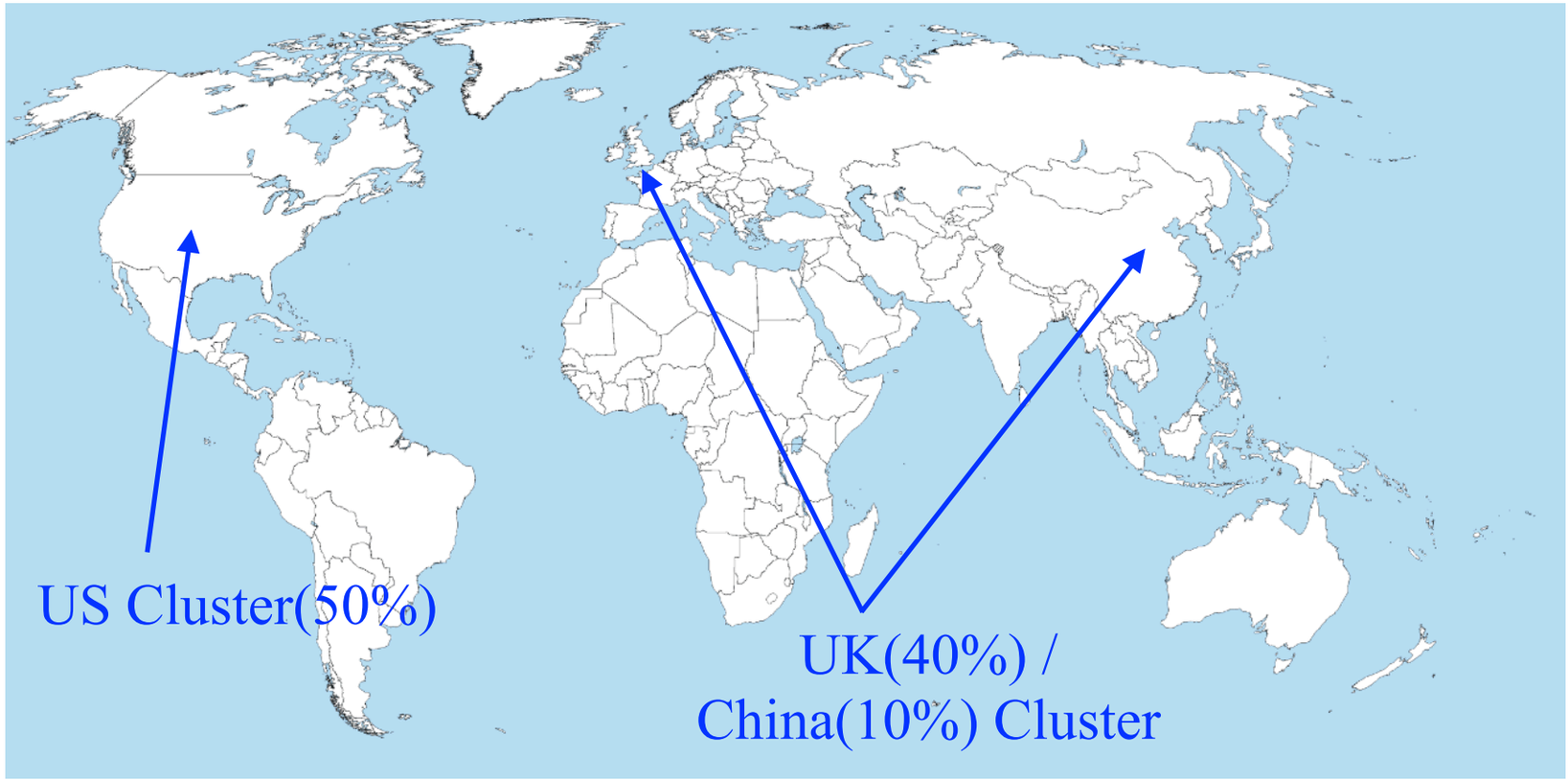
- 4 Barrel Layers
  - 2 SS Layers
  - 2 LS Layers
- 6 Disks on each Endcap





THU/IHEP joined the ITk Barrel Strip Detector Upgrade.

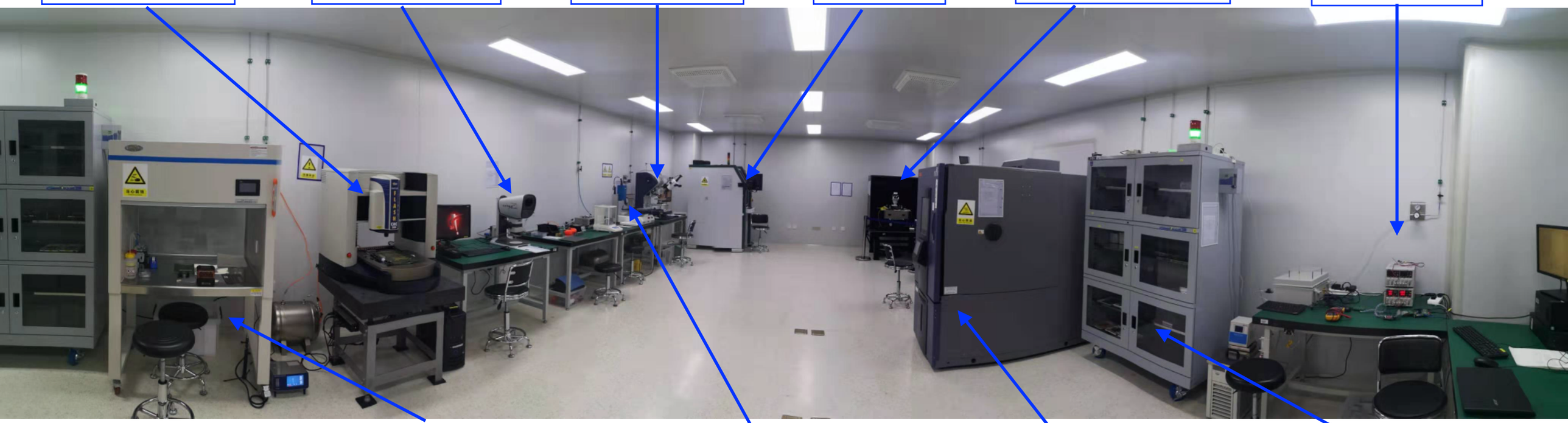
ATLAS ITk Strip Upgrade



- ITk Strip Barrel Region: ~11000 barrel modules in total:
  - US and UK/China Clusters
- **Tsinghua/IHEP committed 1000 Modules(~10 m²):**
  - **500 produced at IHEP**
  - **500 produced at RAL**
- **IHEP committed 2 FTEs at RAL**

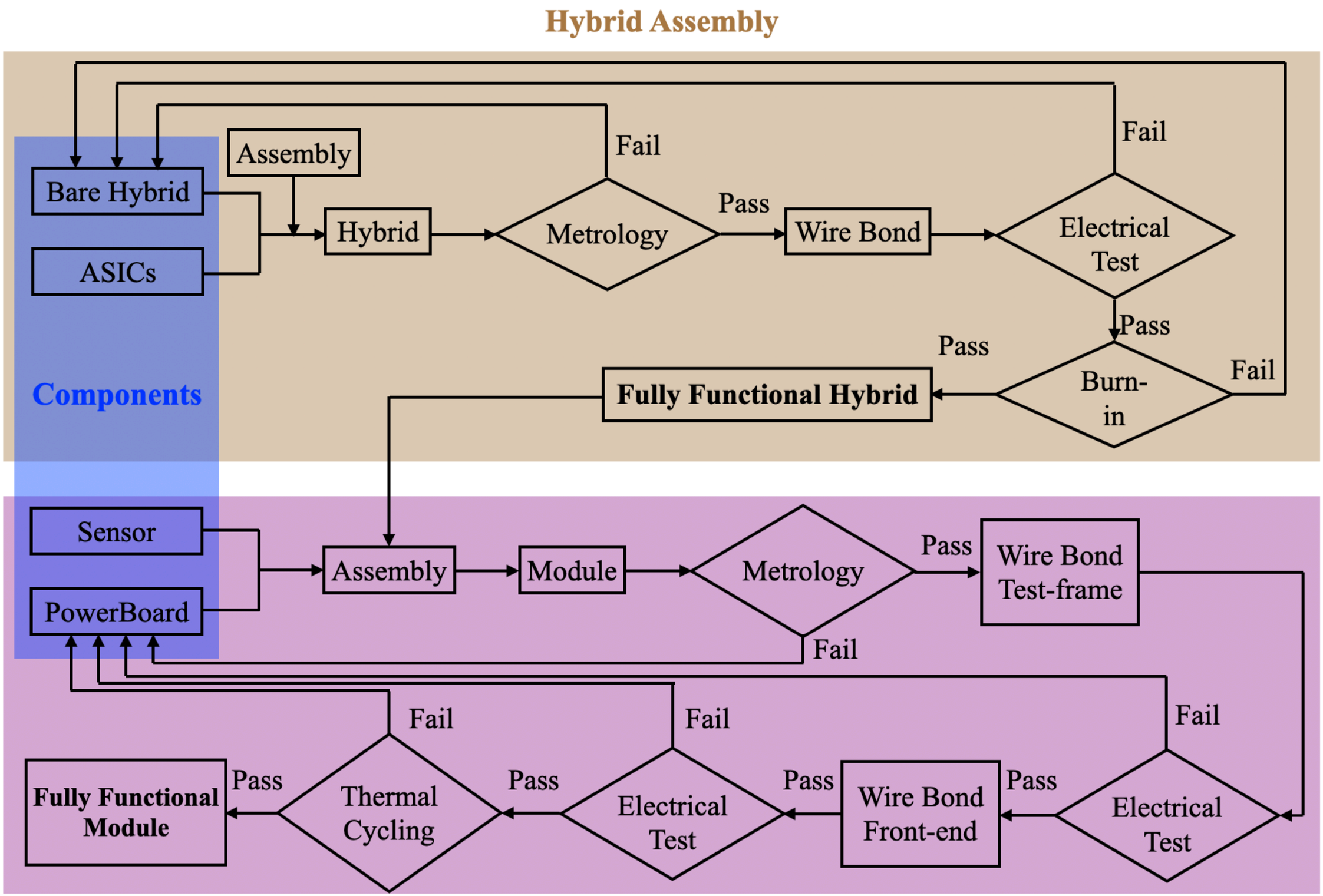
Science & Technology Facilities Council
Rutherford Appleton Laboratory

Lab for Production at IHEP



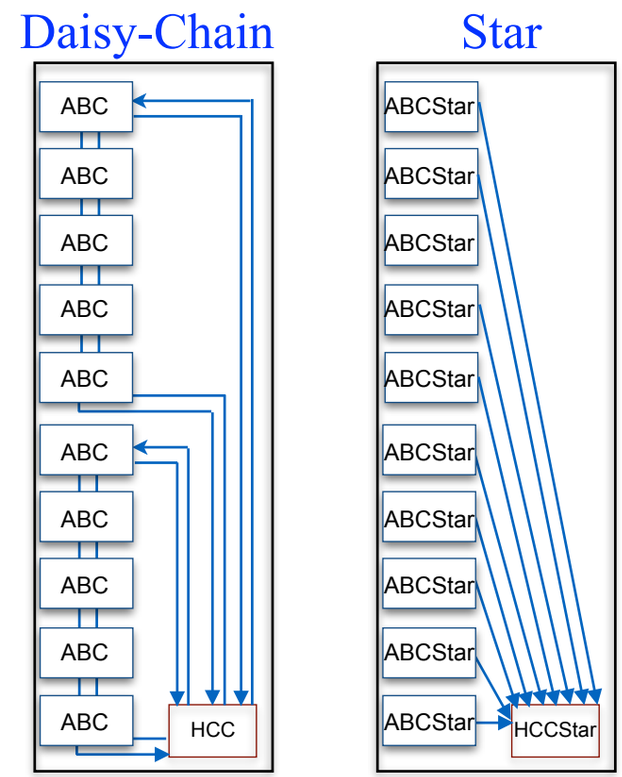
- ~85 m² IOS Class 7 cleanroom at IHEP
- Operational since April of 2019

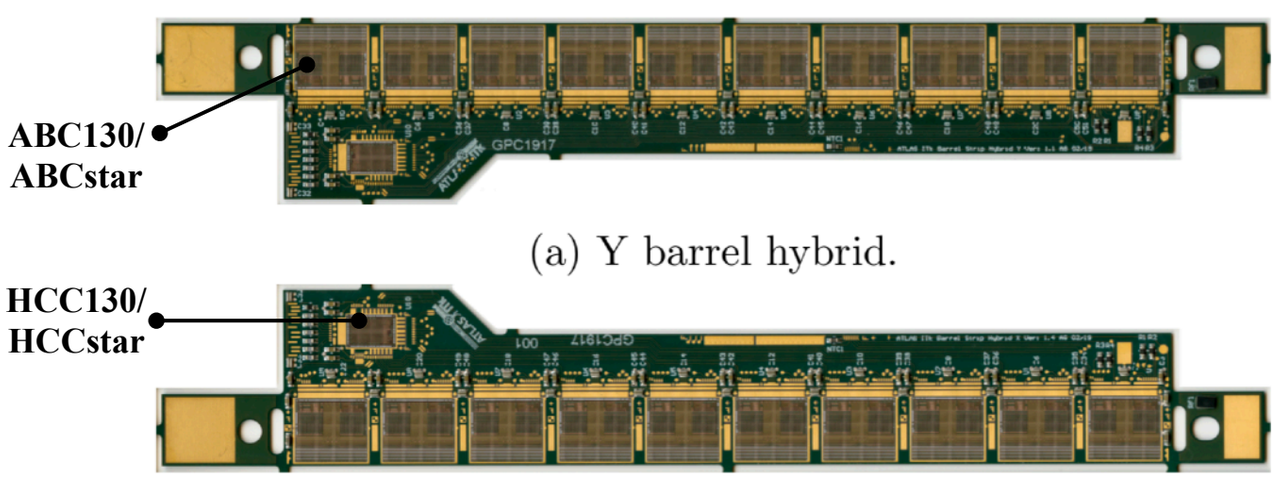
Module Production Flow



Hybrid

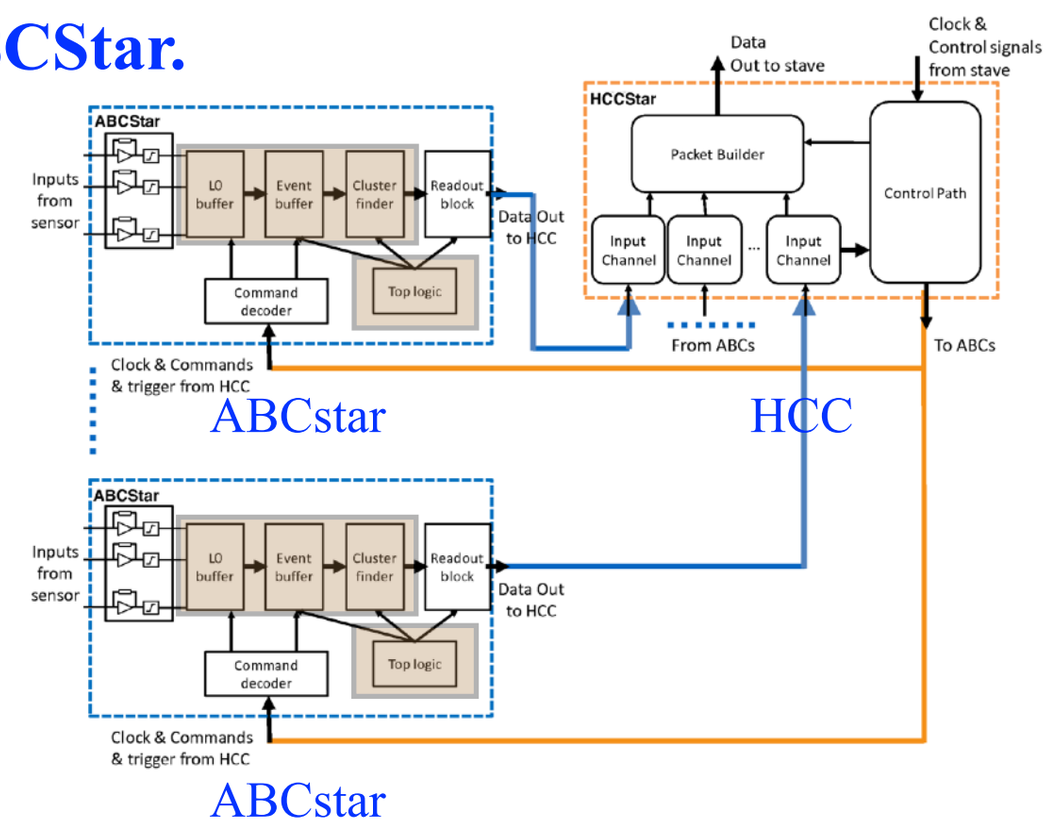
- A flexible PCB retaining the required circuitry/ASICs to read-out signal,
- Two types: X-Type, Y-Type,
- Two types of custom ASICs: 10 ABCs and 1 HCC:
  - HCC/ABC130(prototype), daisy-chain architecture,
  - HCC/ABCstar(production), star architecture.
- **IHEP contributed to the digital part of ABCStar.**



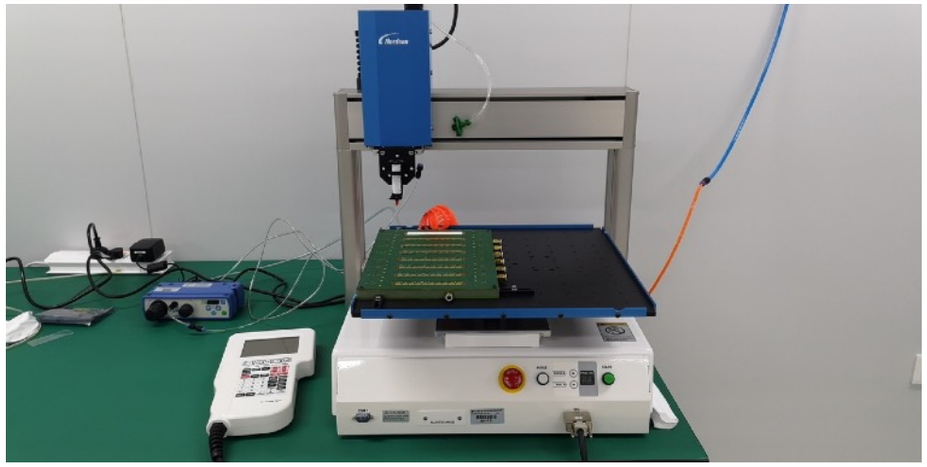


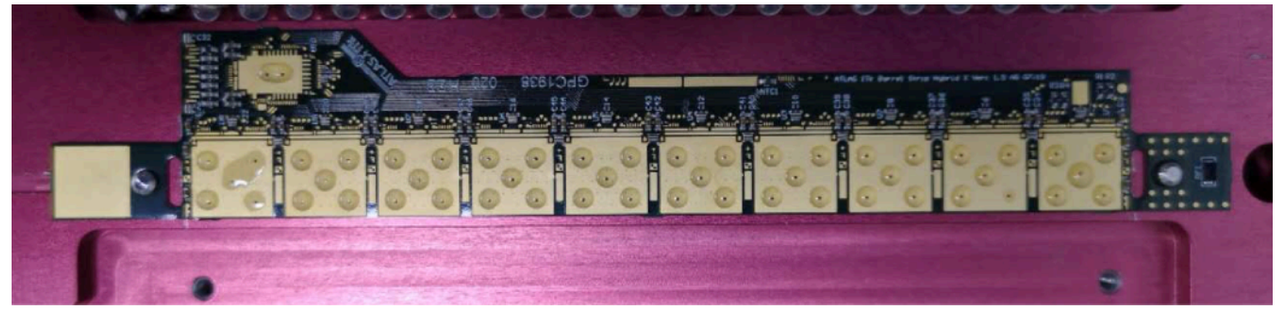
(a) Y barrel hybrid.

(b) X barrel hybrid.

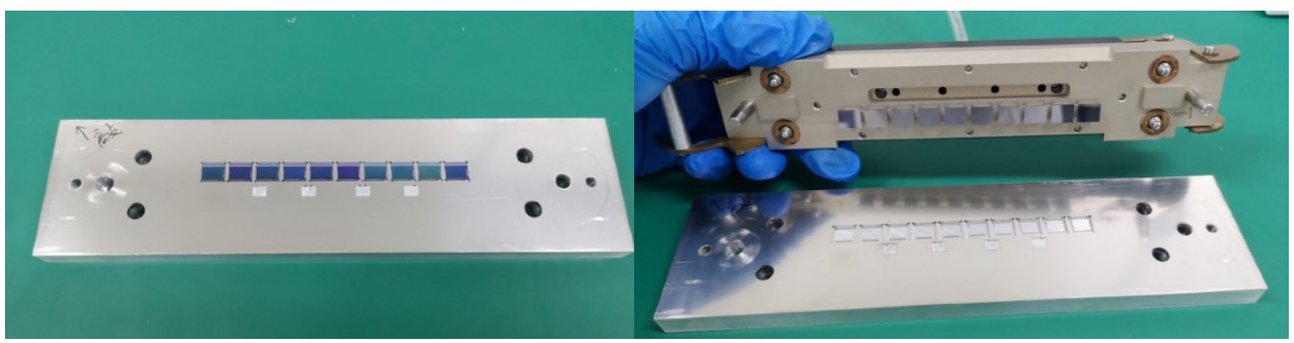


Hybrid Assembly

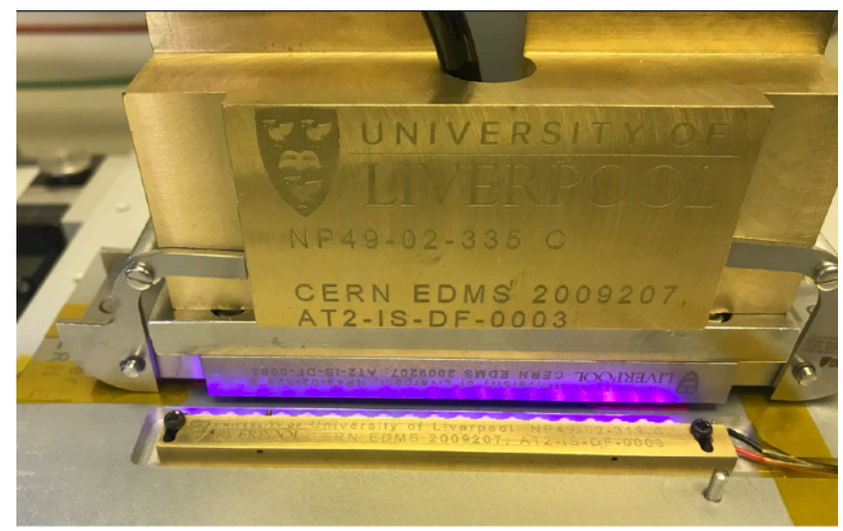




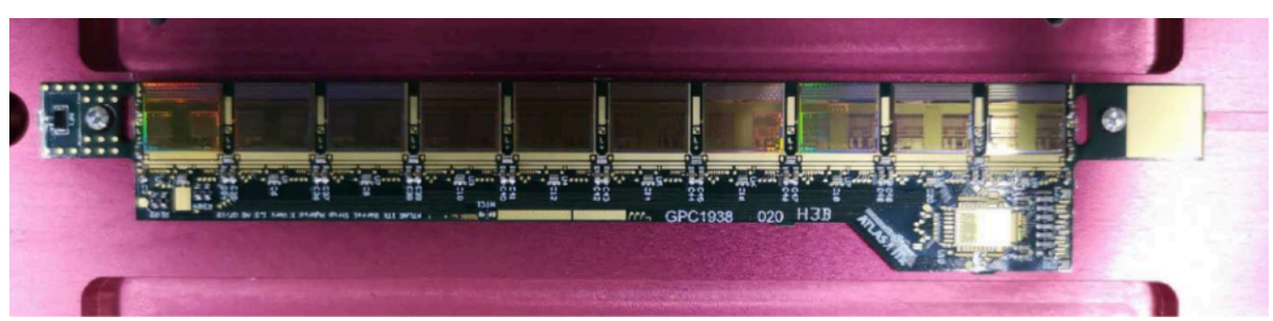
- Calibrate glue(4.03 mg/ABC) and dispense UV Glue



- Align and pick up ASICs



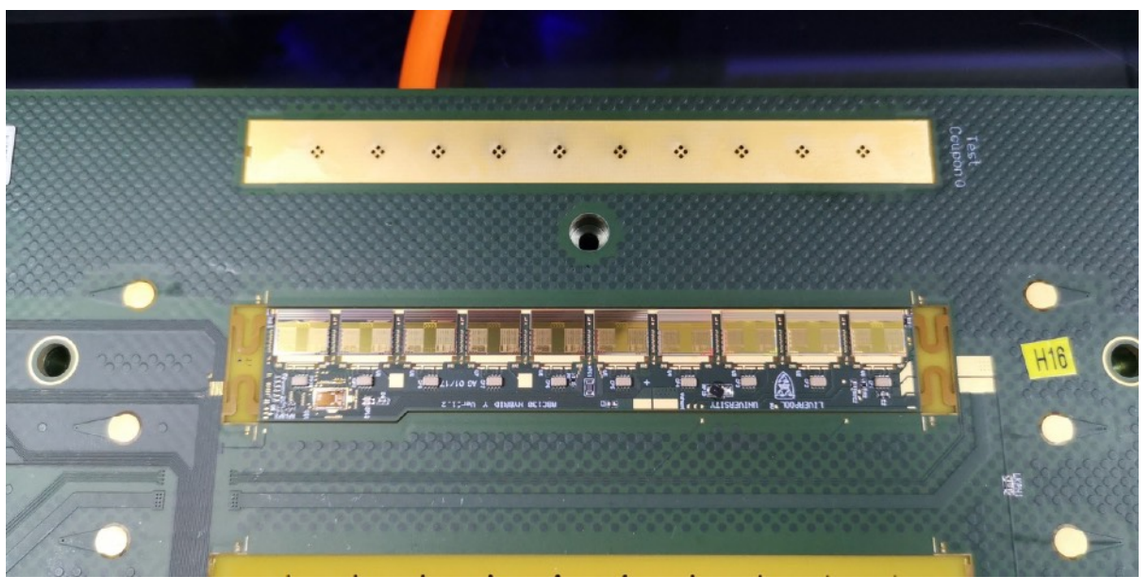
- Glue ASICs and Hybrid together



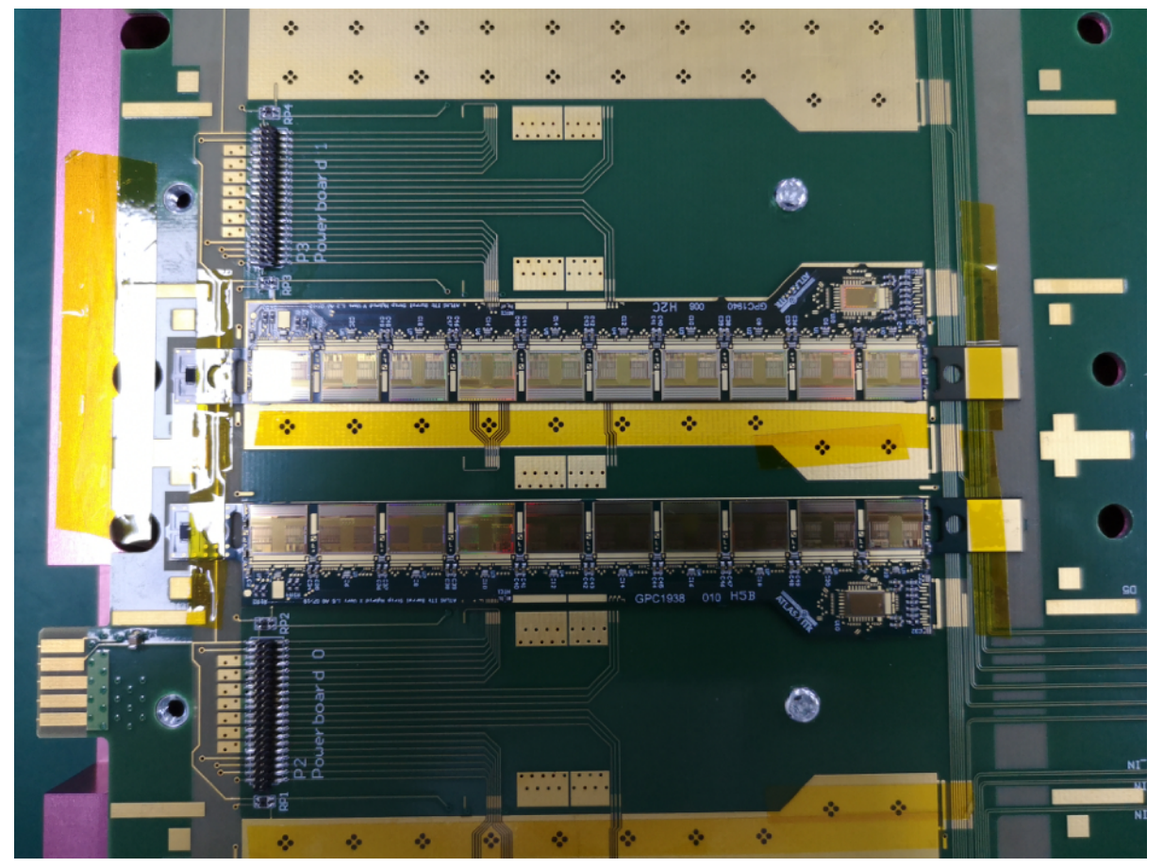
Hybrid Assembly at IHEP

- Two X-Hybrids and two Y-Hybrids with ABC/HCC130,
- Five X-Hybrids and one Y-Hybrid with ABC/HCCStar.

Hybrid with ABC/HCC130

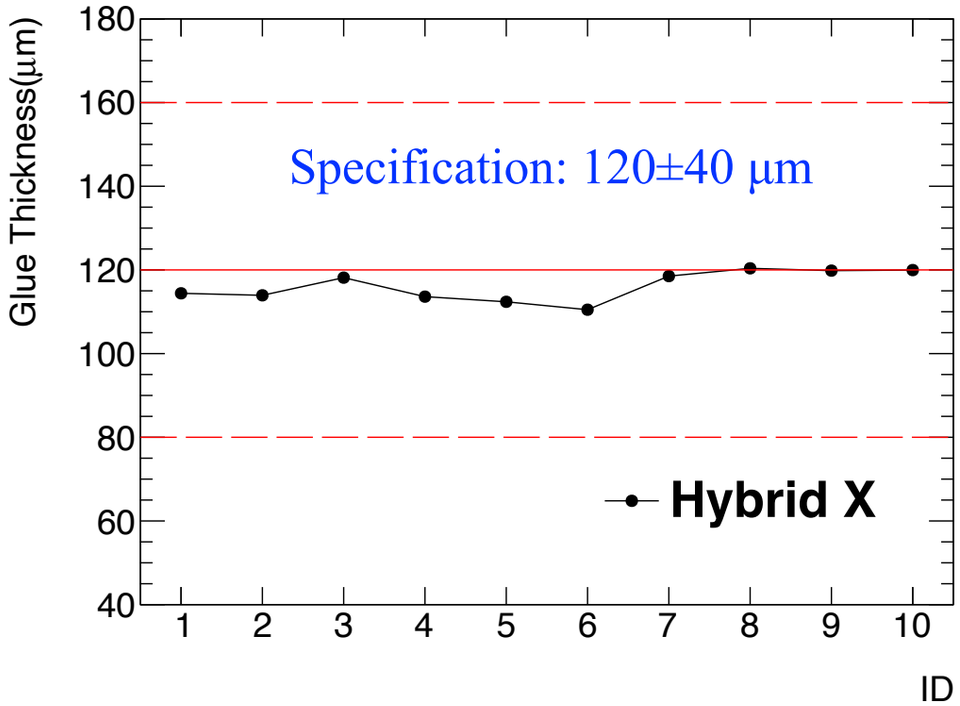


Hybrid with ABC/HCCStar



Hybrid QC-Metrology

- Hybrid Metrology: position, rotation, tilt of ASICs, glue thickness:
  - Crucial to wire bonding, heat dissipation, ASIC attachment, etc.
- Wrote the program for common Data Format for Database.

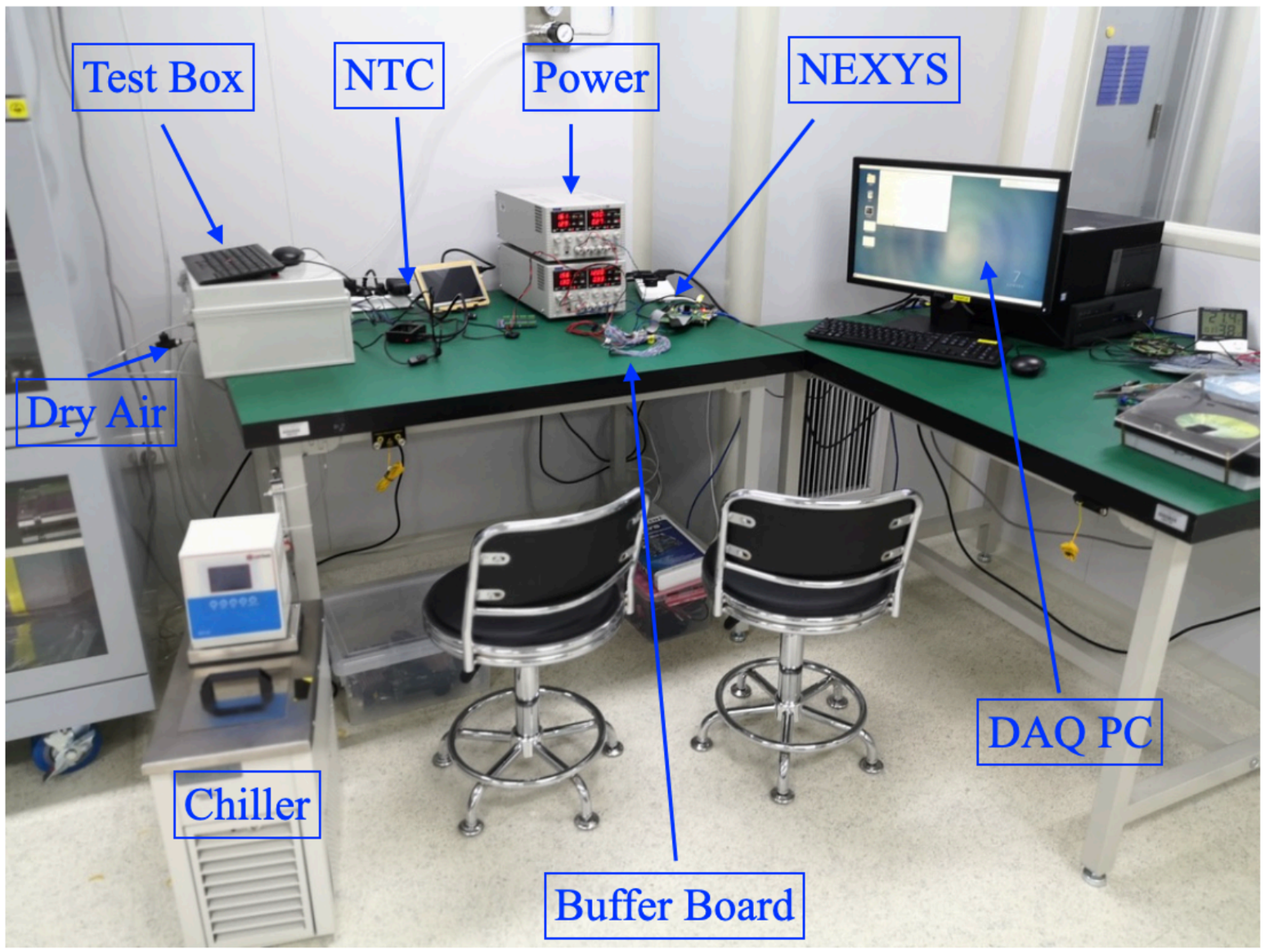


Electrical Test

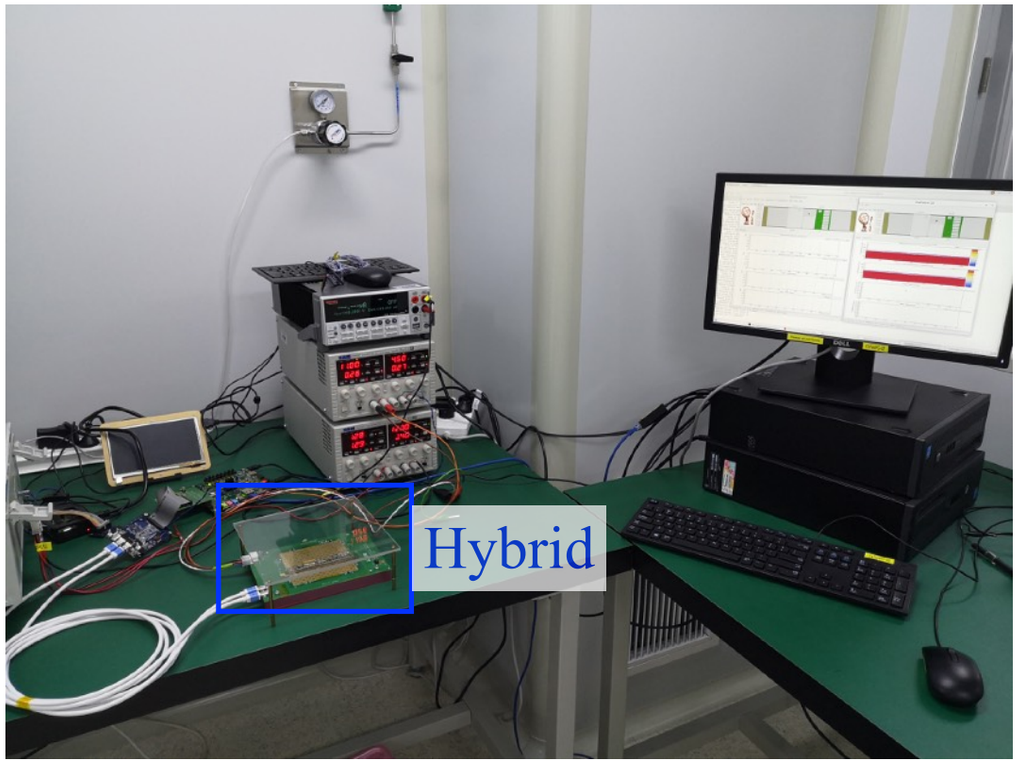
- Check for front-end chip functionality: Chip Communication, Gain, Noise and Noise Occupancy of the FEE, etc.

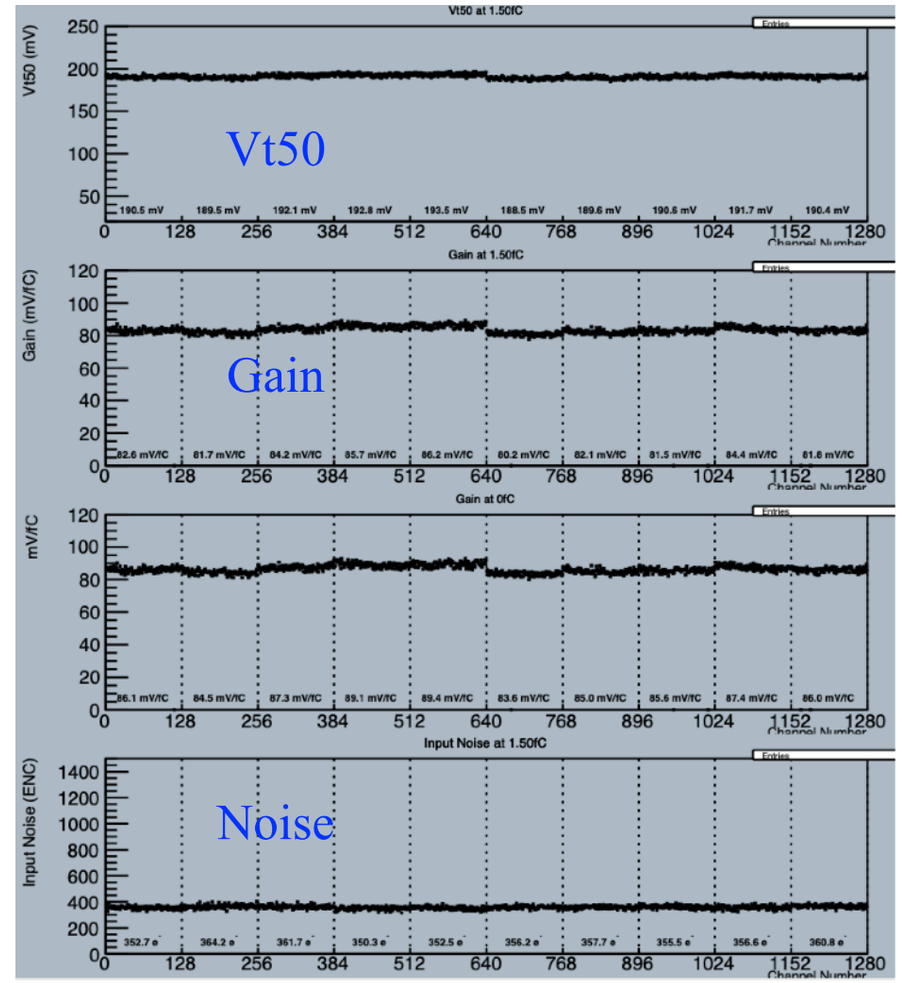
- Setup for Hybrid and Module Electrical Test:

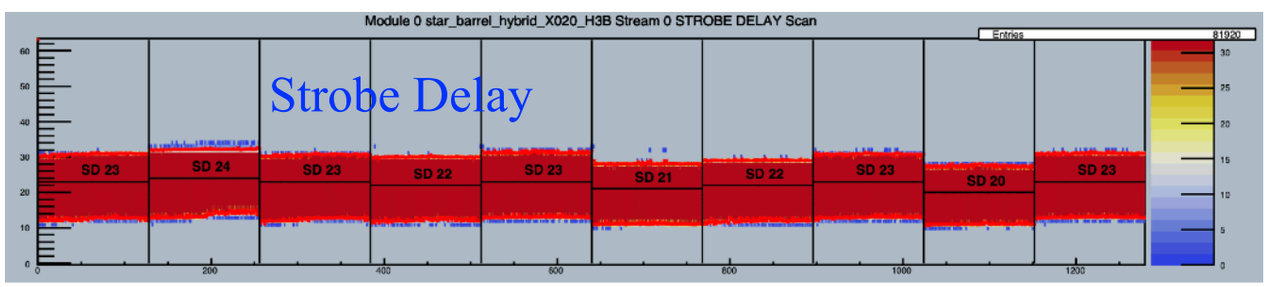
More in Kai's Talk

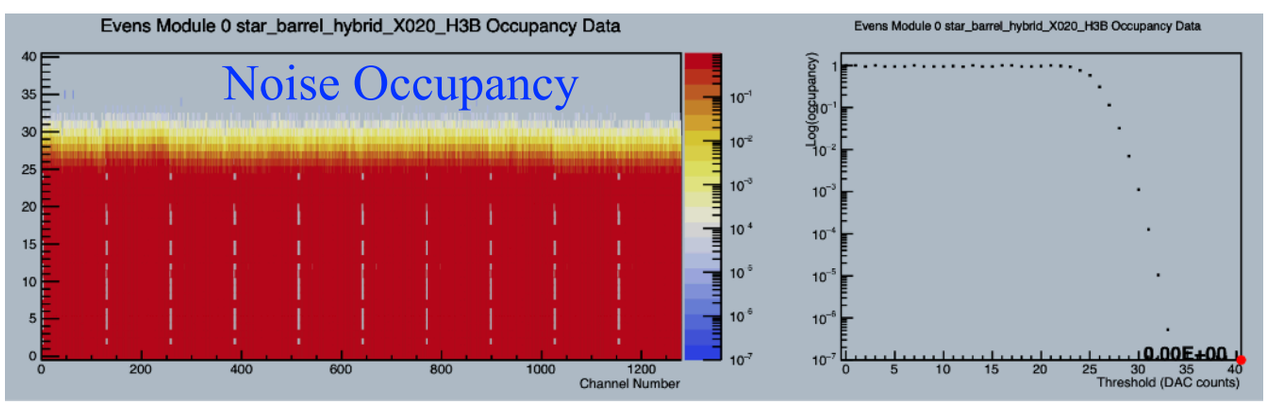


Hybrid QC-Electrical Test



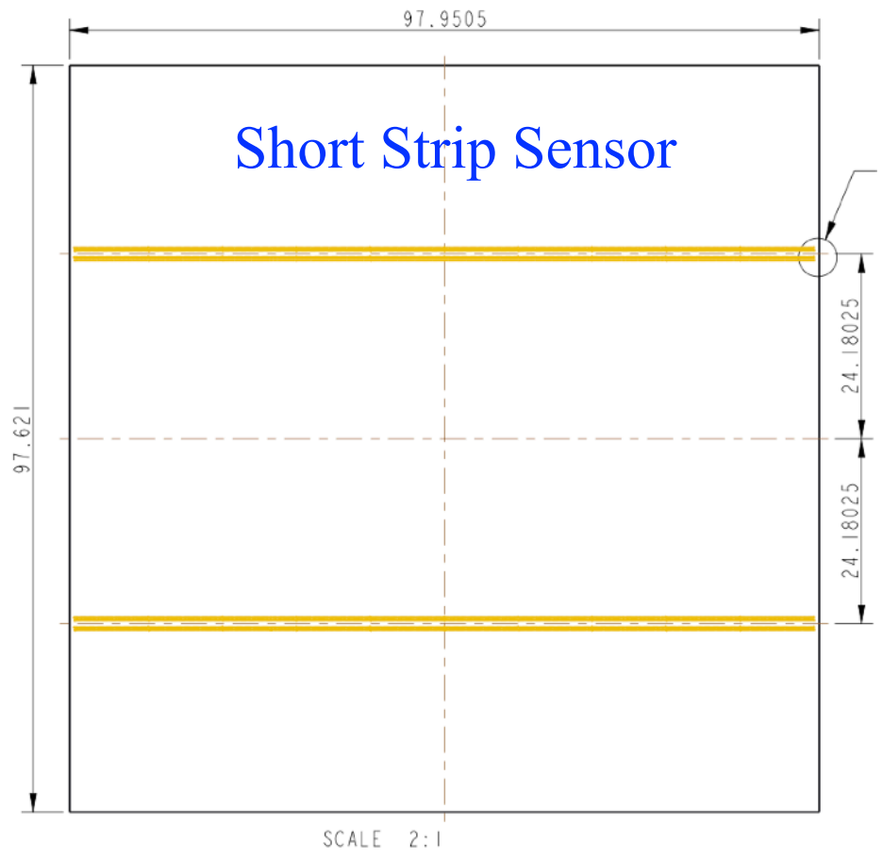


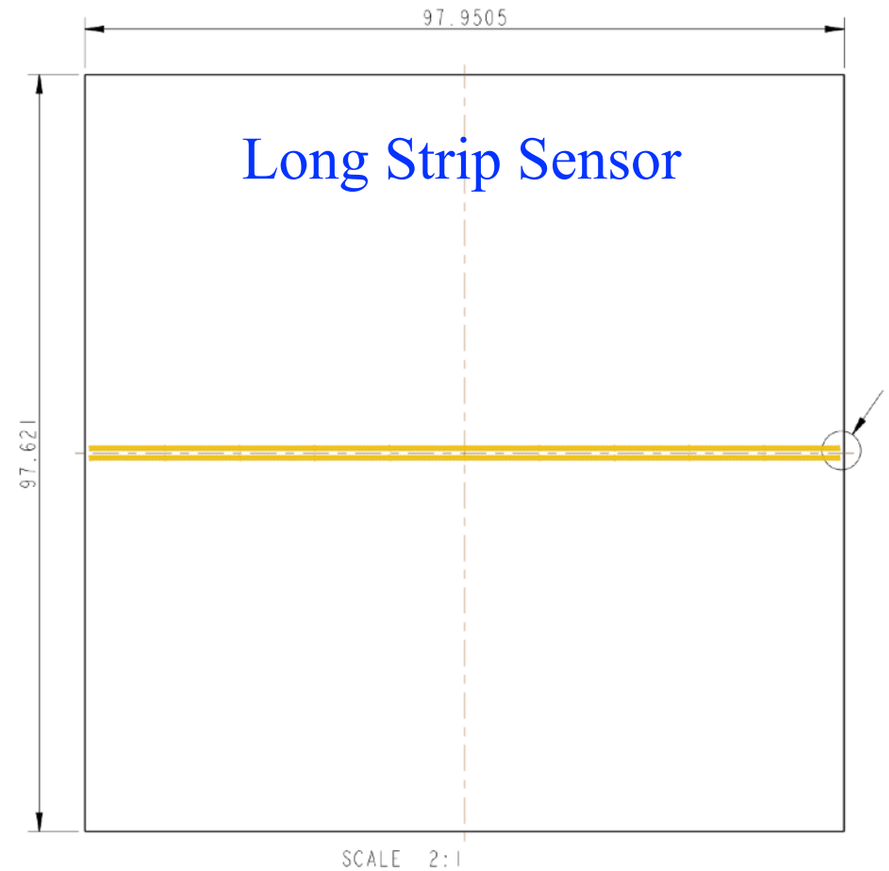




- Noise Occupancy:
  - <1×10-3
  - at least one order less than the hit occupancy(1%)

Sensor



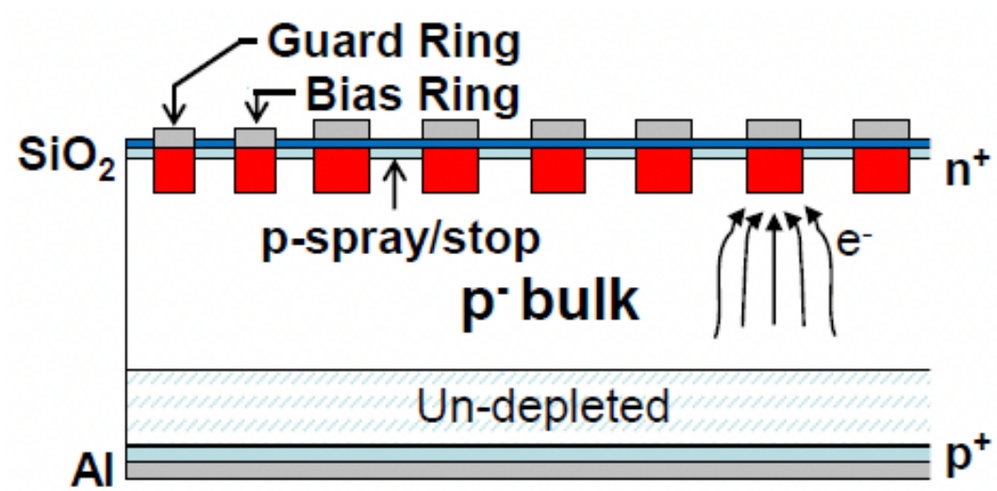


Short Strip Sensor:

- Four Segments(Two Hybrid)
- Strip Length: 2.4 cm
- 5120 read-out strips
- Pitch: 75.5 μm

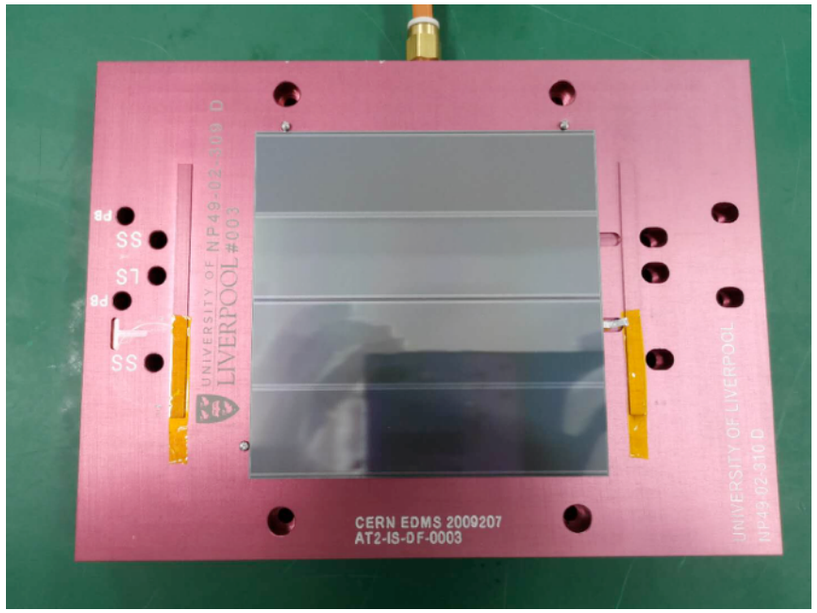
Long Strip Sensor:

- Two Segments(one Hybrid)
- Strip Length: 4.8 cm
- 2560 read-out strips
- Pitch: 75.5 μm

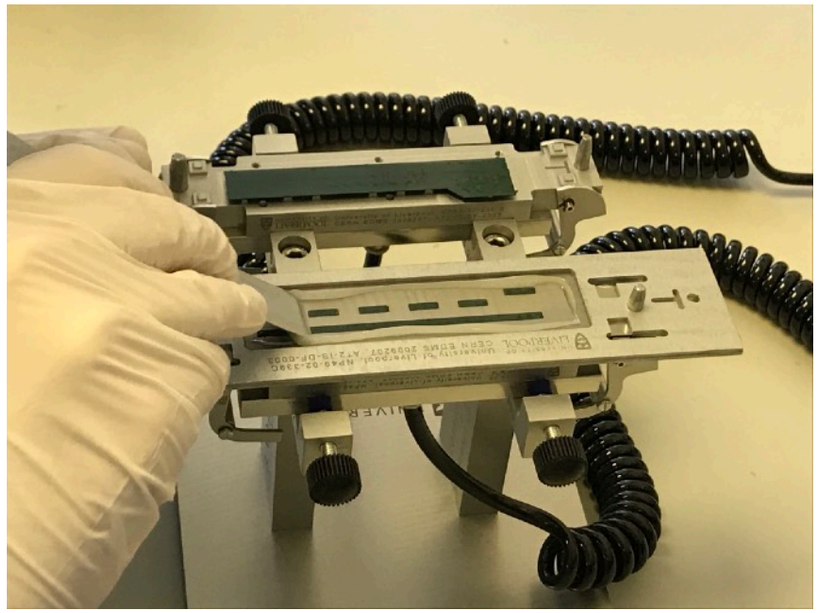


Module Assembly

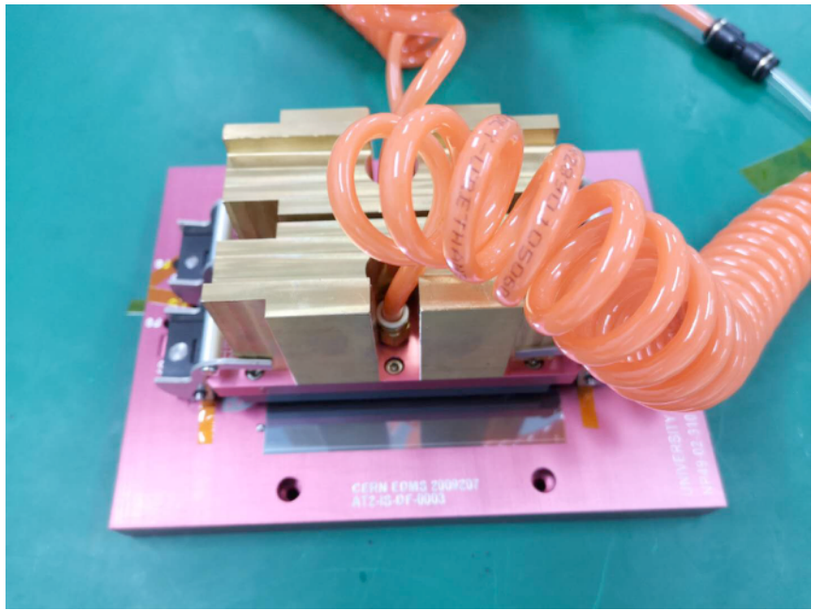
- Align Sensor on sensor plate



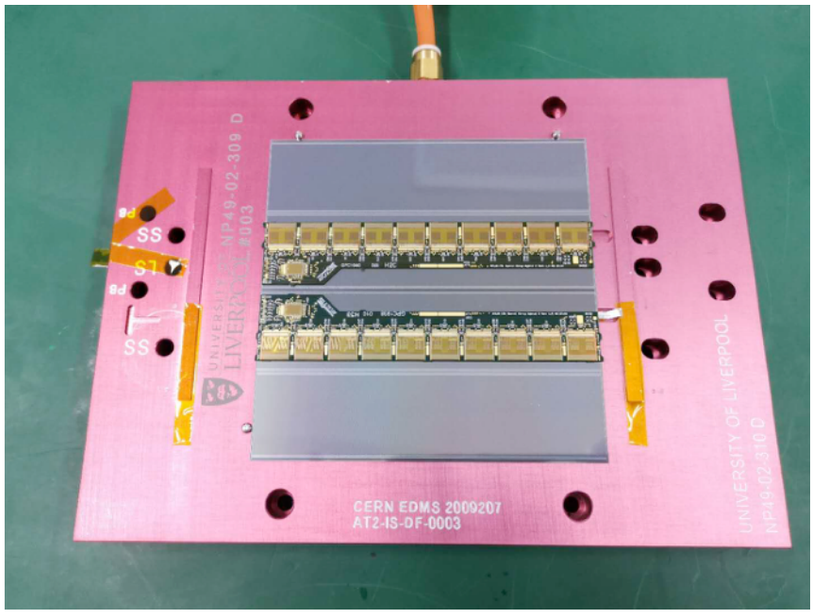
- Dispense glue on Hybrid through Stencil



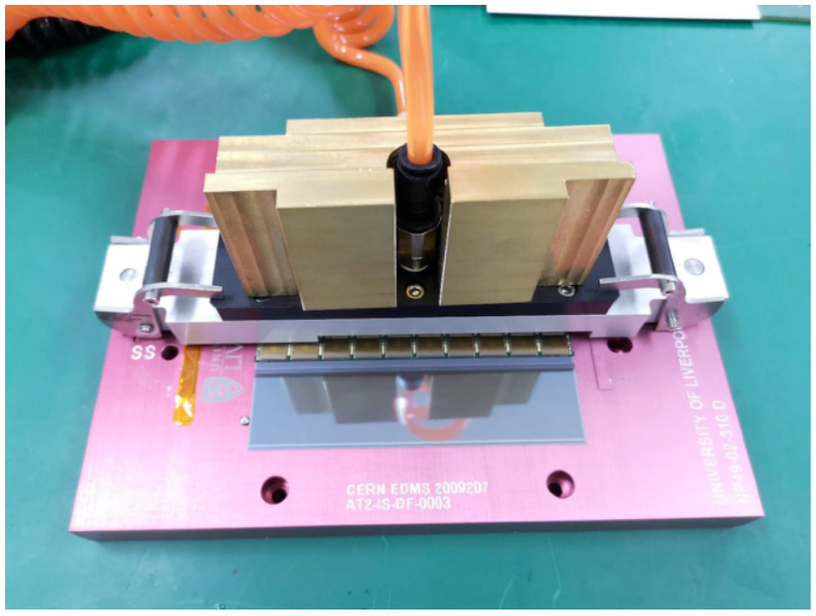
- Glue Hybrids on sensor



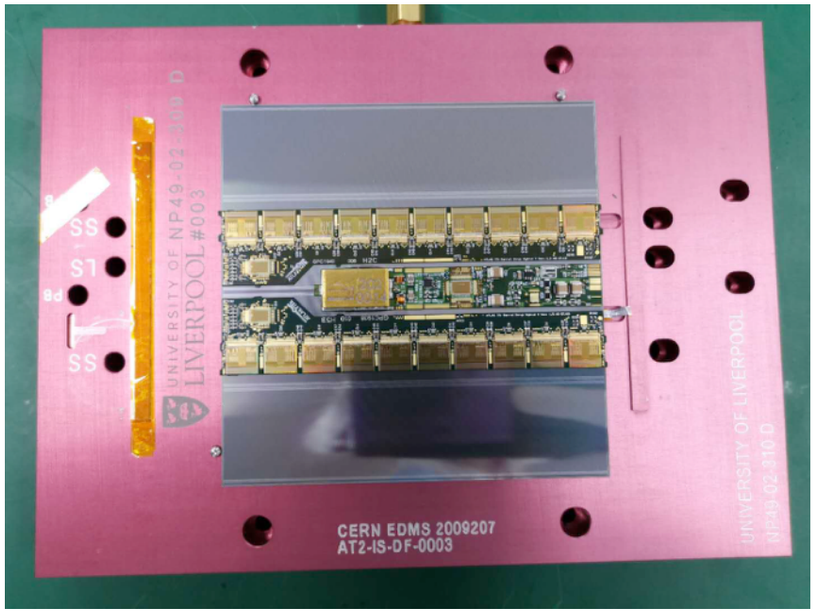
- Module without Powerboard



- Glue Powerboard to sensor

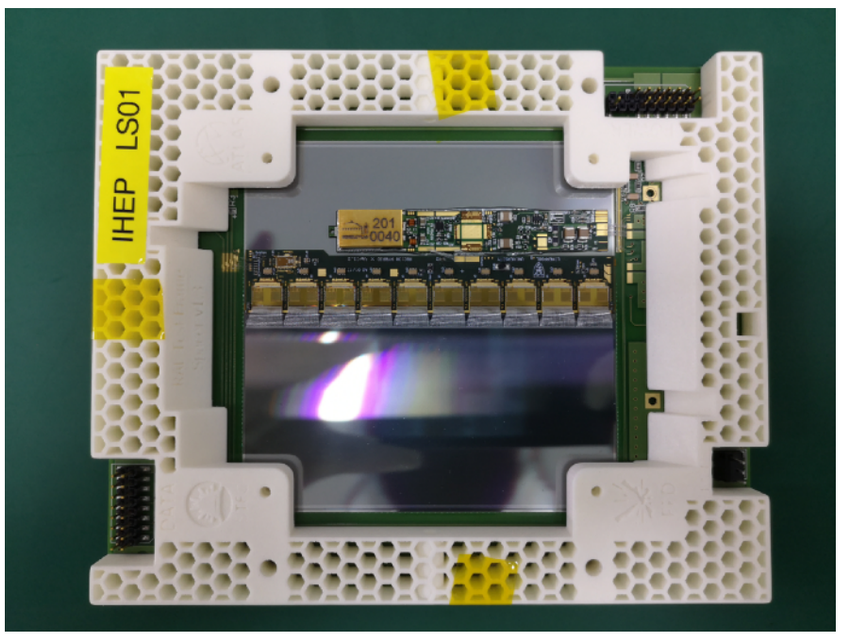


- Assembled Module

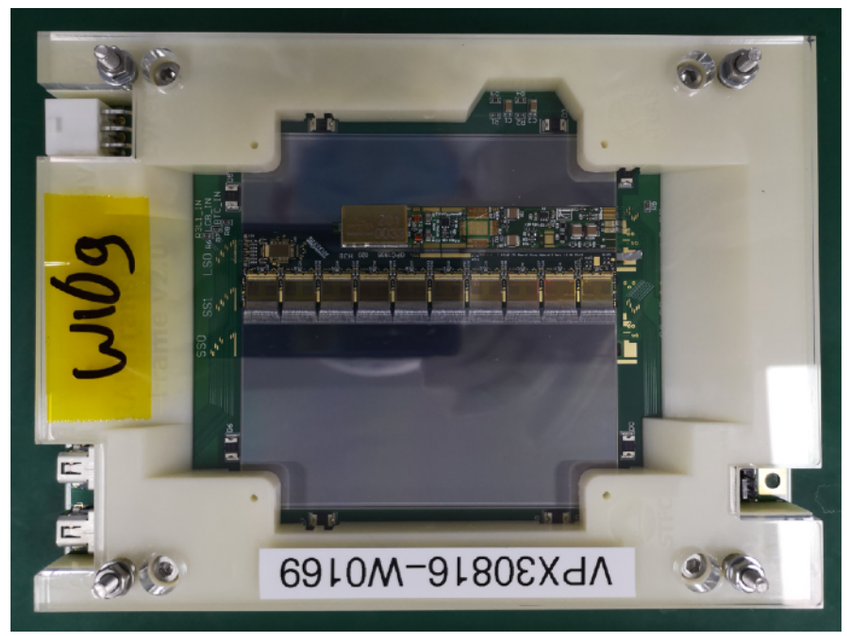


Module Assembly at IHEP

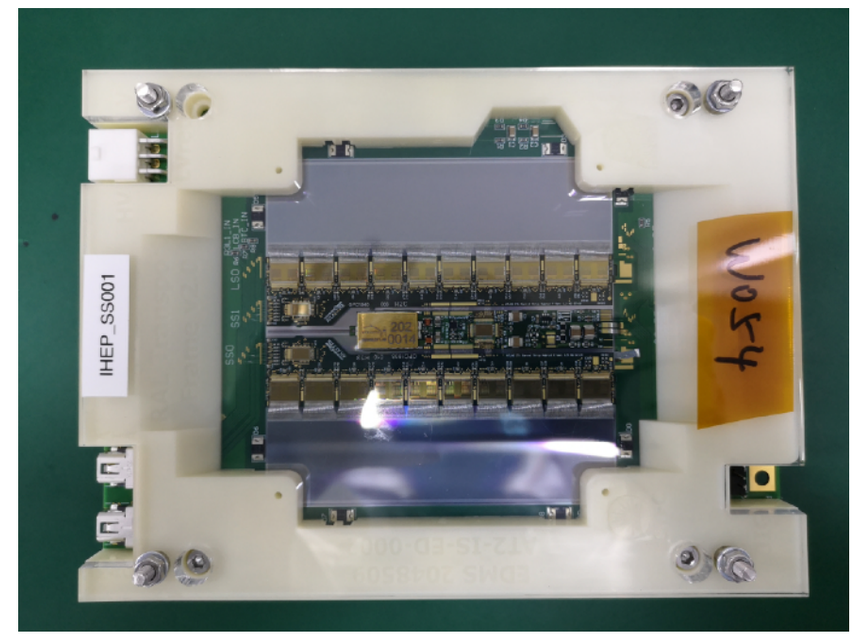
- Two LS Modules with ABC/HCC130,
- Three LS Modules with ABC/HCCStar,
- One SS Module with ABC/HCCStar.



LS Module with ABC/HCC130



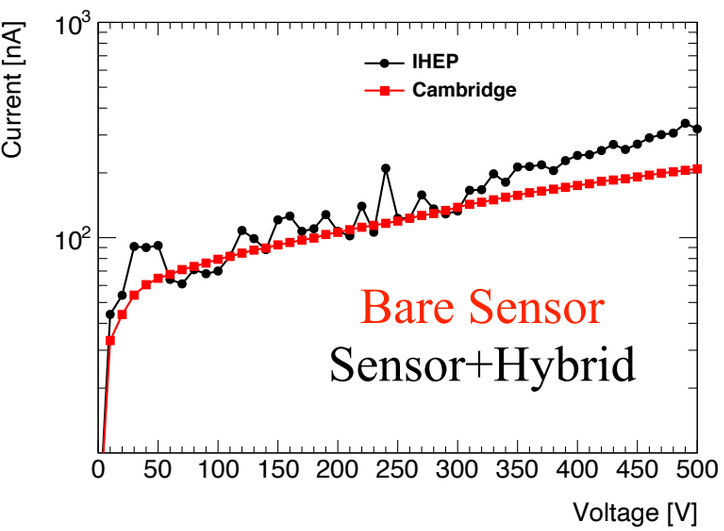
LS Module with ABC/HCCStar

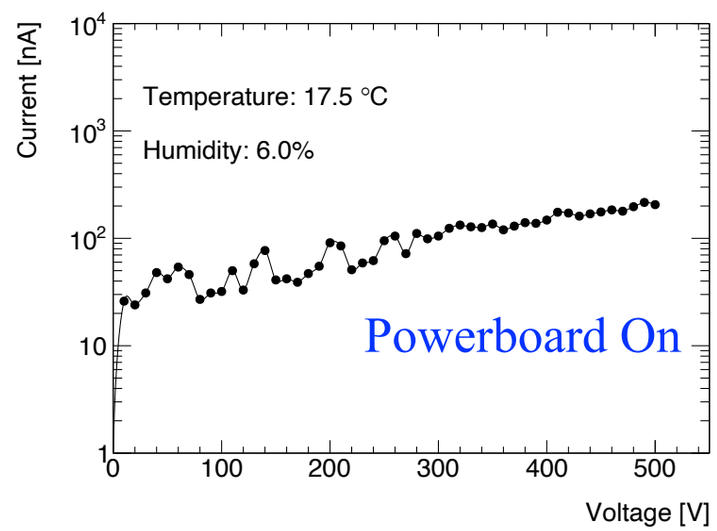


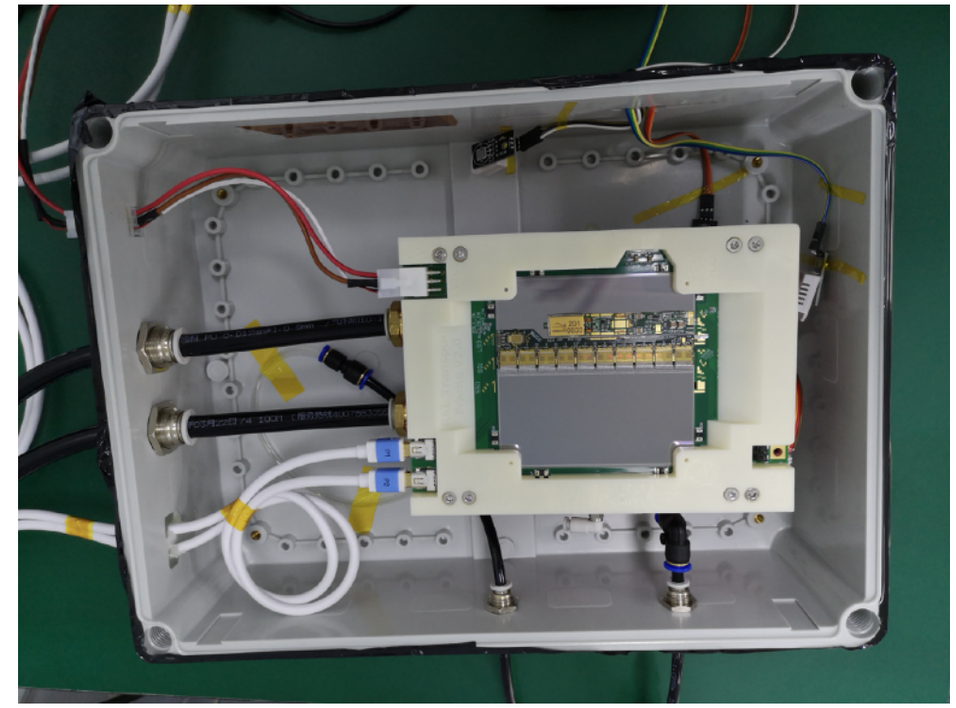
SS Module with ABC/HCCStar

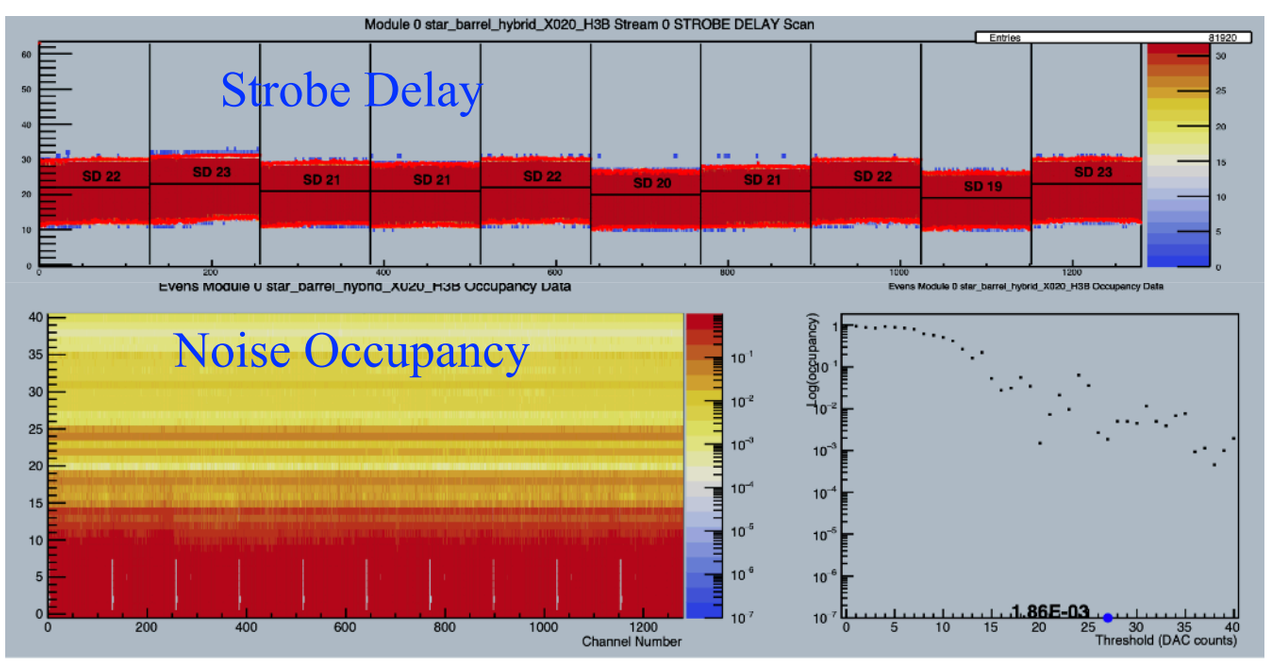
Electrical Test on Module

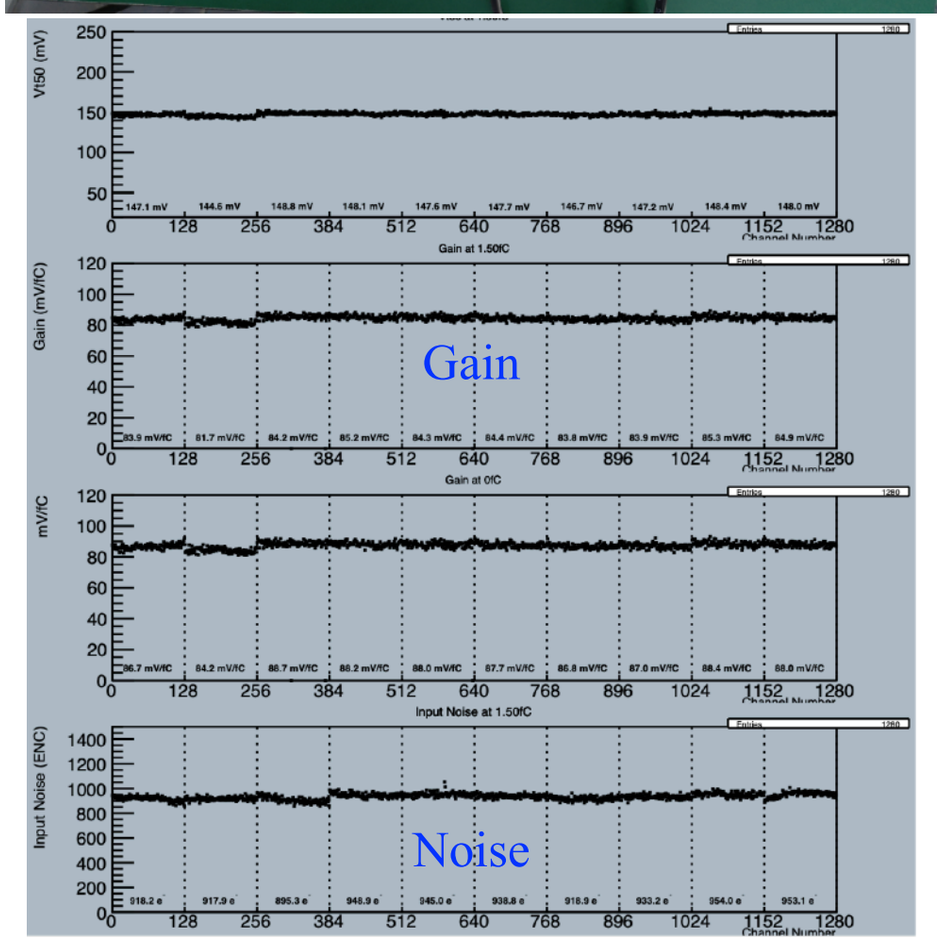
- Dark/Dry/Cool environment,
- Fully functional module for system test on stave.





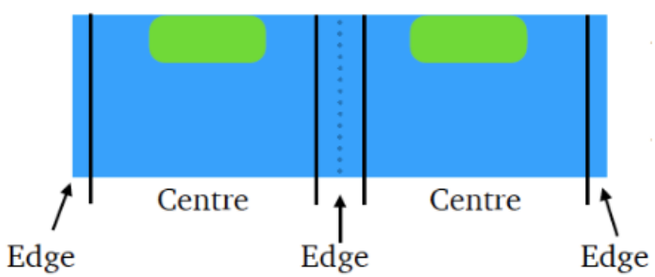


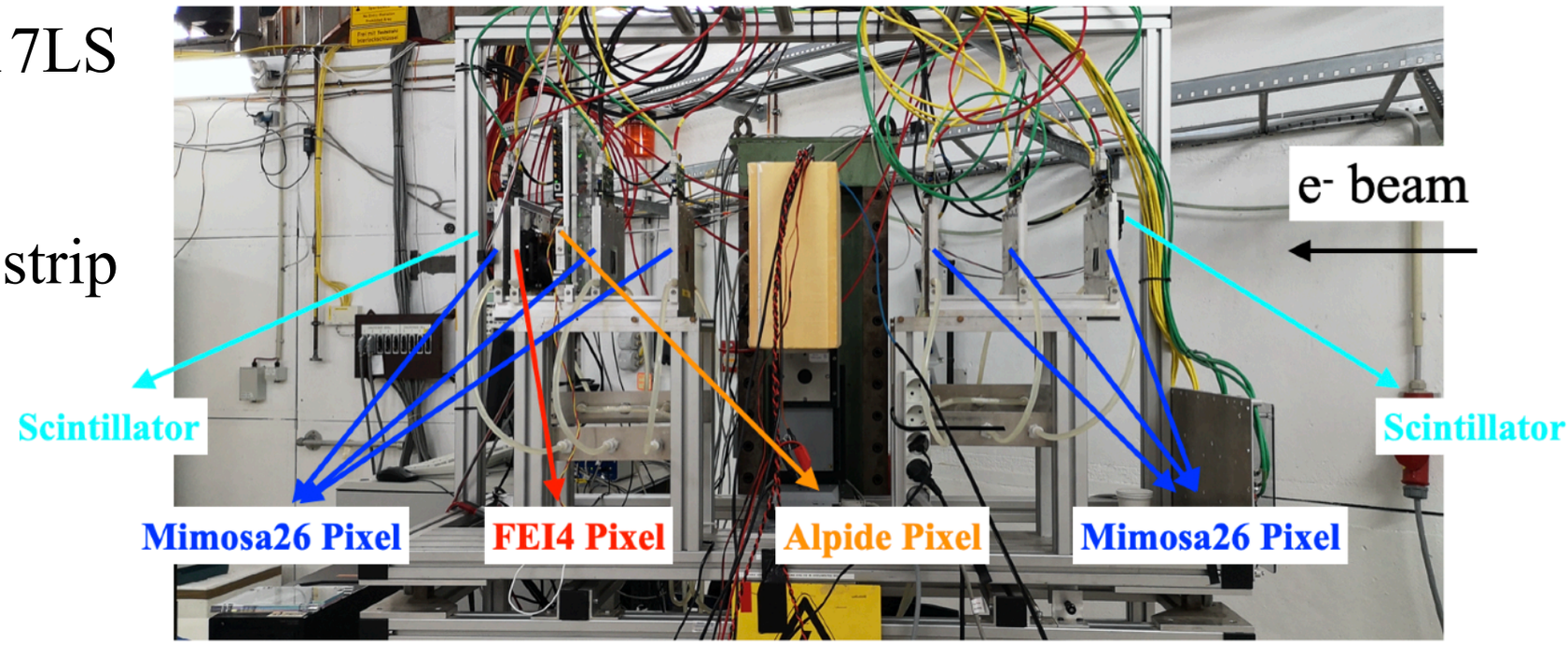




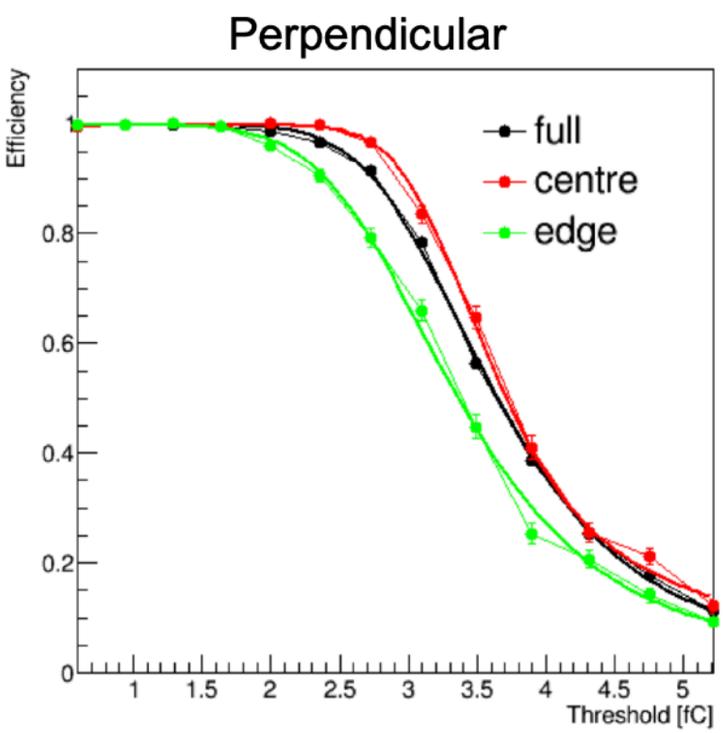
Beam Test on Module

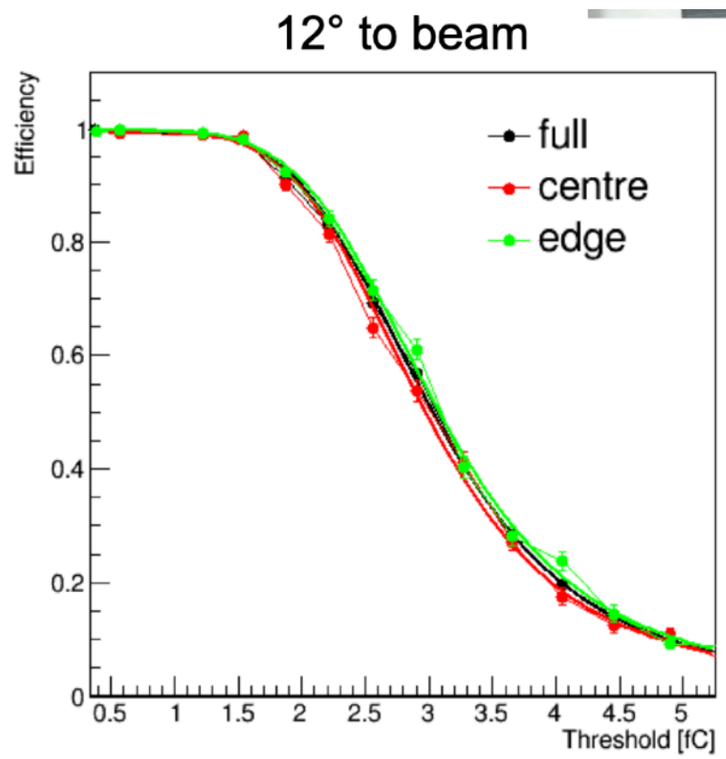
- Module built using ATLAS17LS sensor and star-chipset
- Define "edge" of strip/inter-strip region of 15 μm





EUDET-type telescope





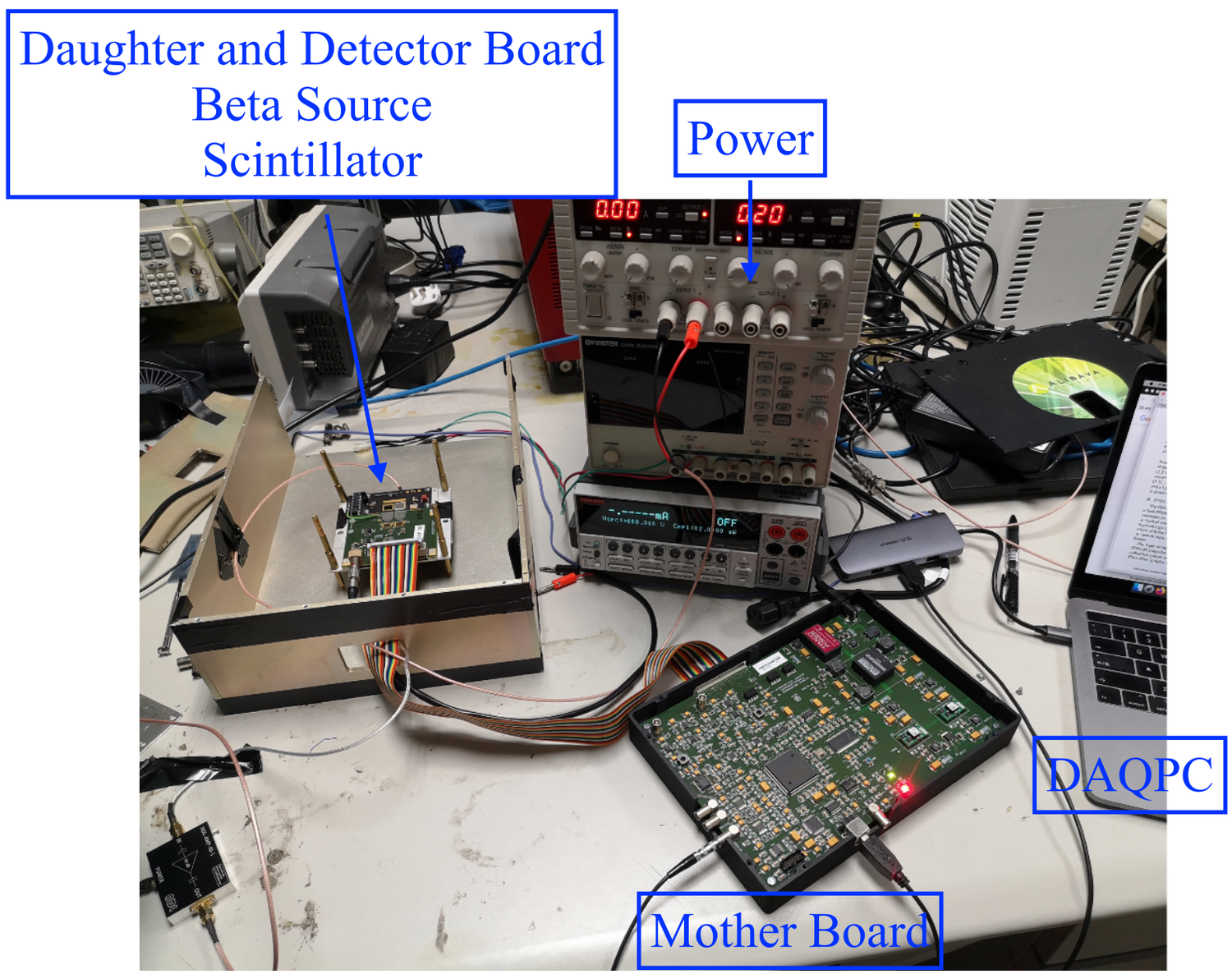
Median charge	Overall	Centre	Edge
Perpendicular to beam	3.65 fC	3.72 fC	3.37 fC
12° to beam	3.03 fC	2.97 fC	3.08 fC

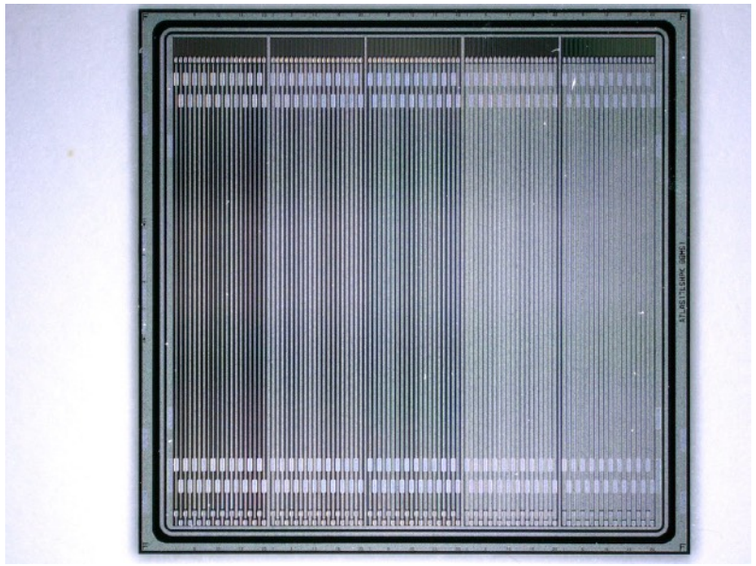
Lower efficiency for inter-strip region mainly due to charge sharing between strips

More in Emma's Talk

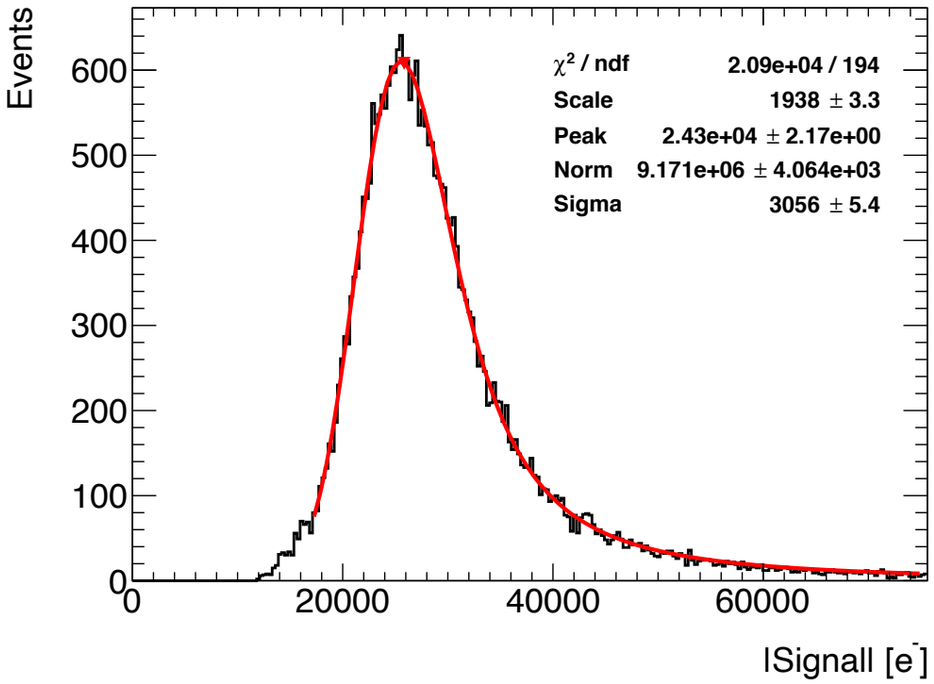
Mini Sensor Studies

- Set up the ALiBaVa system,
- Study the CCE of mini sensor w/o irradiation using beta source.



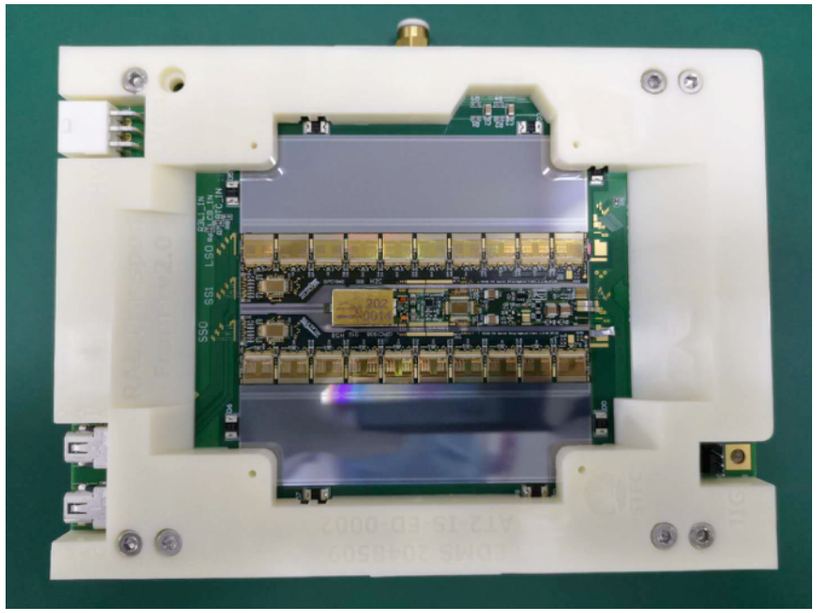


Signal Shape



Summary

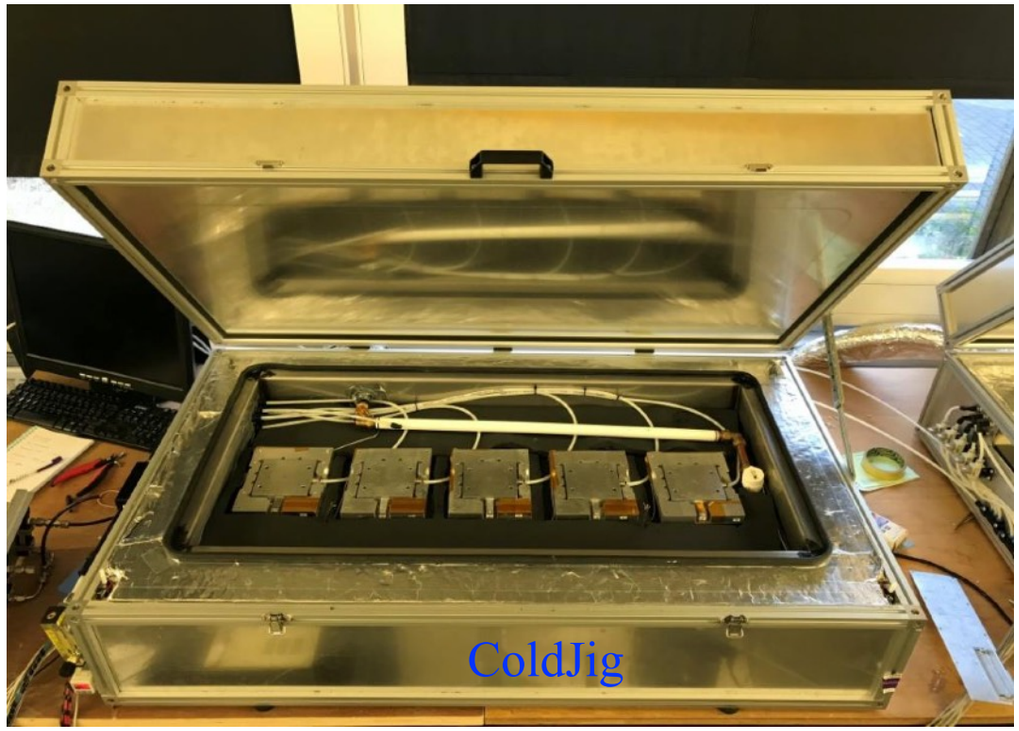
- Built cleanroom for production at IHEP,
- Assembled electrical Hybrids and Modules,
- Performed QC on Hybrids, Sensors and Modules,
- Participated in beam test activities and mini sensor studies.



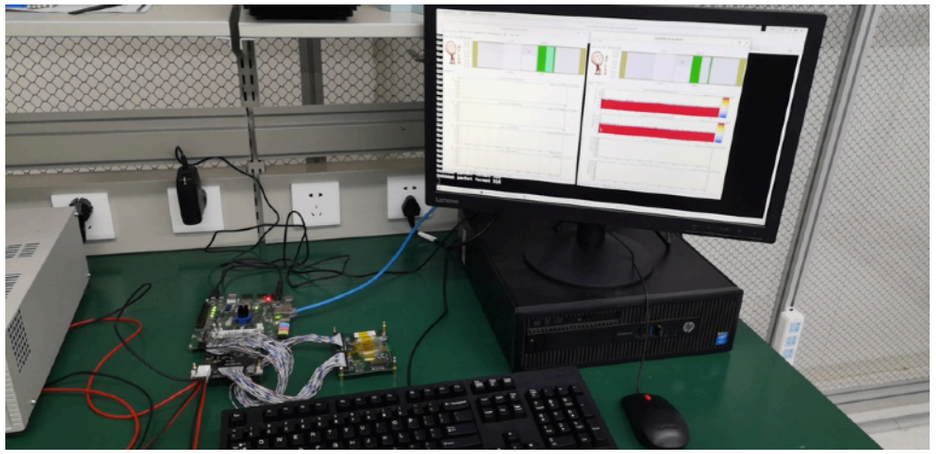
Plan

- Preparing the site qualification and pre-production,
- Request more components for module assembly,
- Setting up the single chip test(exposing to X-ray),
- Waiting for Hybrid burn-in and Module thermal cycling setups.

Hybrid Burn-in Crate



ColdJig

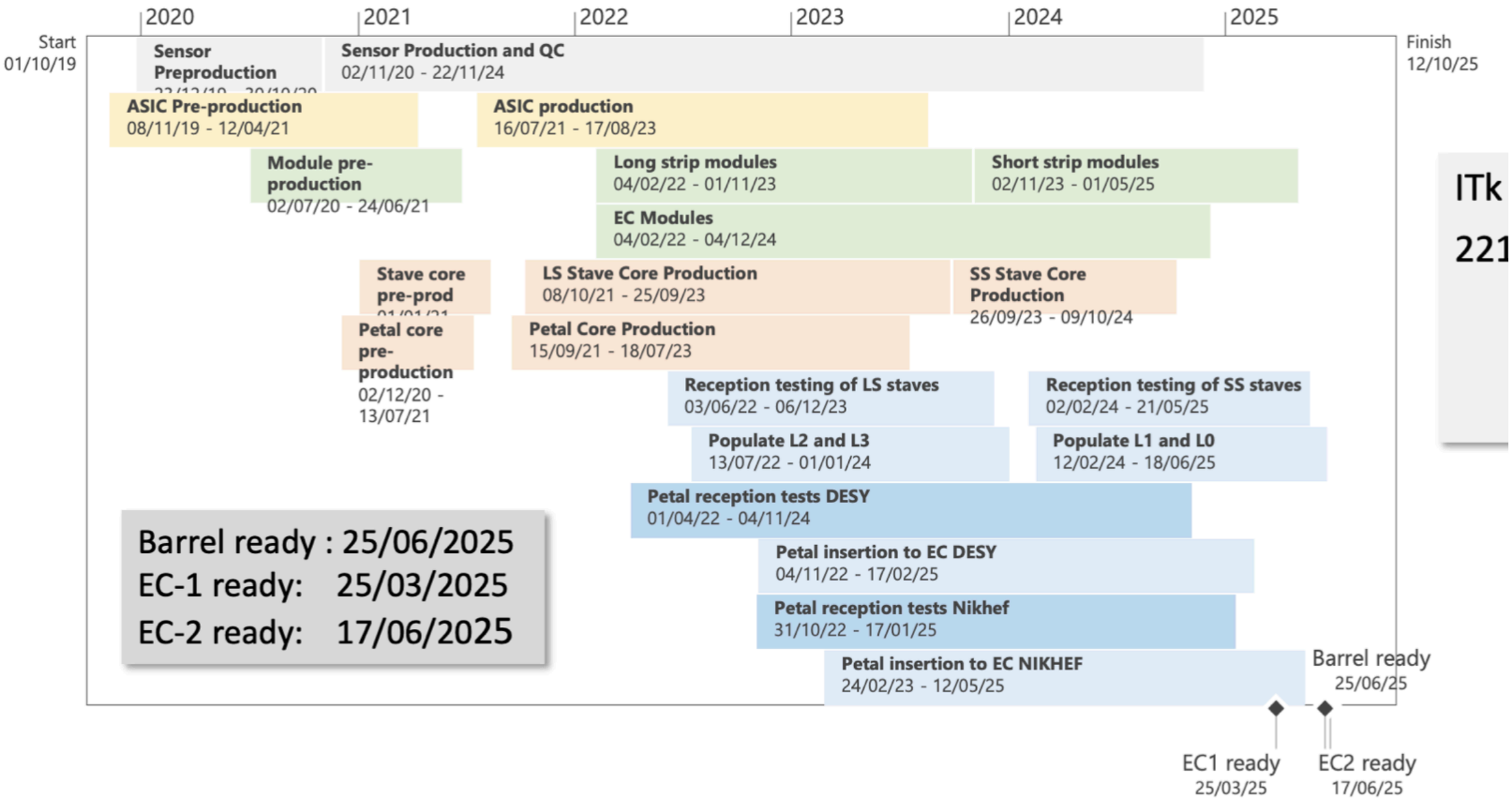


Single chip test

Thanks

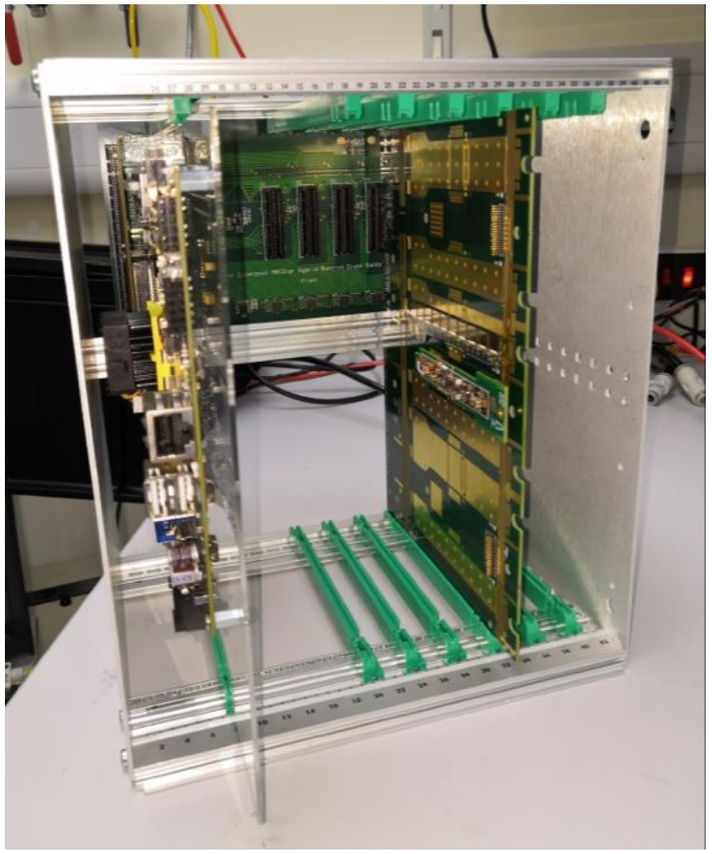
Backup

Timeline


2020
2021
2022
2023
2024
2025
Start
01/10/19
Finish
12/10/25
Sensor Preproduction
Sensor Production and QC
02/11/20 - 22/11/24
ASIC Pre-production
08/11/19 - 12/04/21
ASIC production
16/07/21 - 17/08/23
Module pre-production
02/07/20 - 24/06/21
Long strip modules
04/02/22 - 01/11/23
Short strip modules
02/11/23 - 01/05/25
EC Modules
04/02/22 - 04/12/24
Stave core pre-prod
LS Stave Core Production
08/10/21 - 25/09/23
SS Stave Core Production
26/09/23 - 09/10/24
Petal core pre-production
02/12/20 - 13/07/21
Petal Core Production
15/09/21 - 18/07/23
Reception testing of LS staves
03/06/22 - 06/12/23
Reception testing of SS staves
02/02/24 - 21/05/25
Populate L2 and L3
13/07/22 - 01/01/24
Populate L1 and L0
12/02/24 - 18/06/25
Petal reception tests DESY
01/04/22 - 04/11/24
Petal insertion to EC DESY
04/11/22 - 17/02/25
Petal reception tests Nikhef
31/10/22 - 17/01/25
Petal insertion to EC NIKHEF
24/02/23 - 12/05/25
Barrel ready
25/06/25
EC1 ready
25/03/25
EC2 ready
17/06/25
Barrel ready : 25/06/2025
EC-1 ready: 25/03/2025
EC-2 ready: 17/06/2025
ITk
221

Hybrid Burn-in

- Check for early ASIC death,
- Long term (> 100 h) tests on hybrids at ~40 °C,
- Missing the Burn-in Crate(host 6 Hybrid Panels/36 Hybrids).

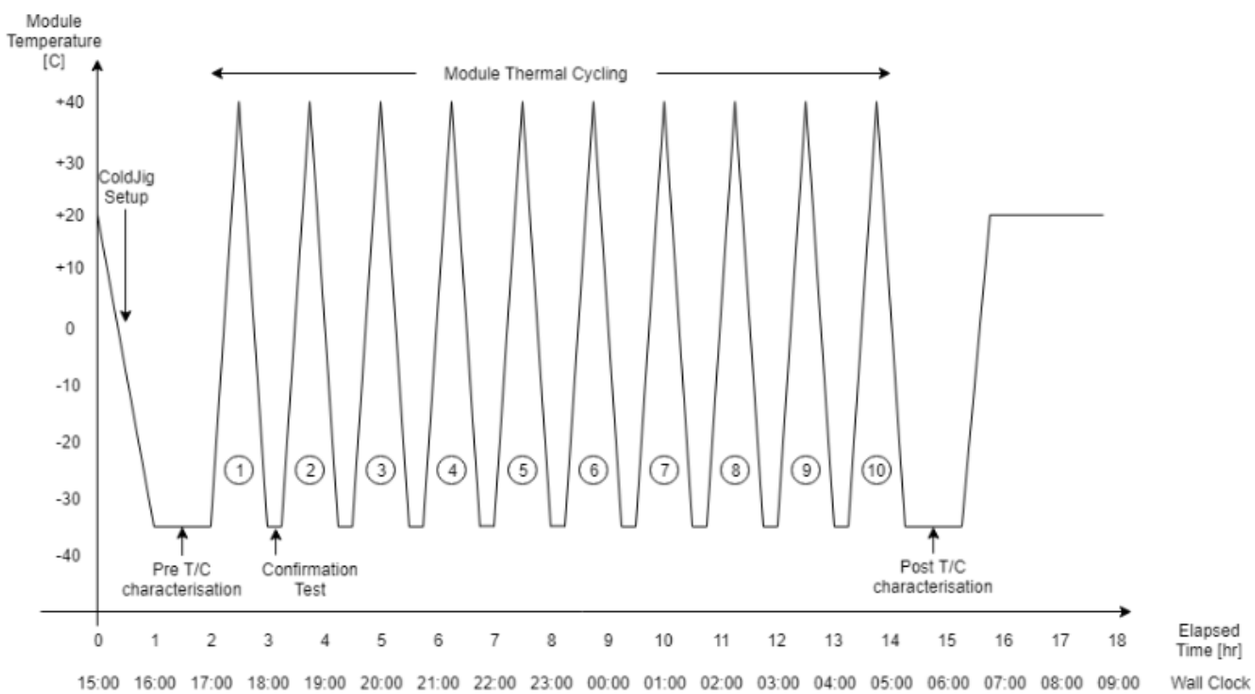


Hybrid Burn-in Crate

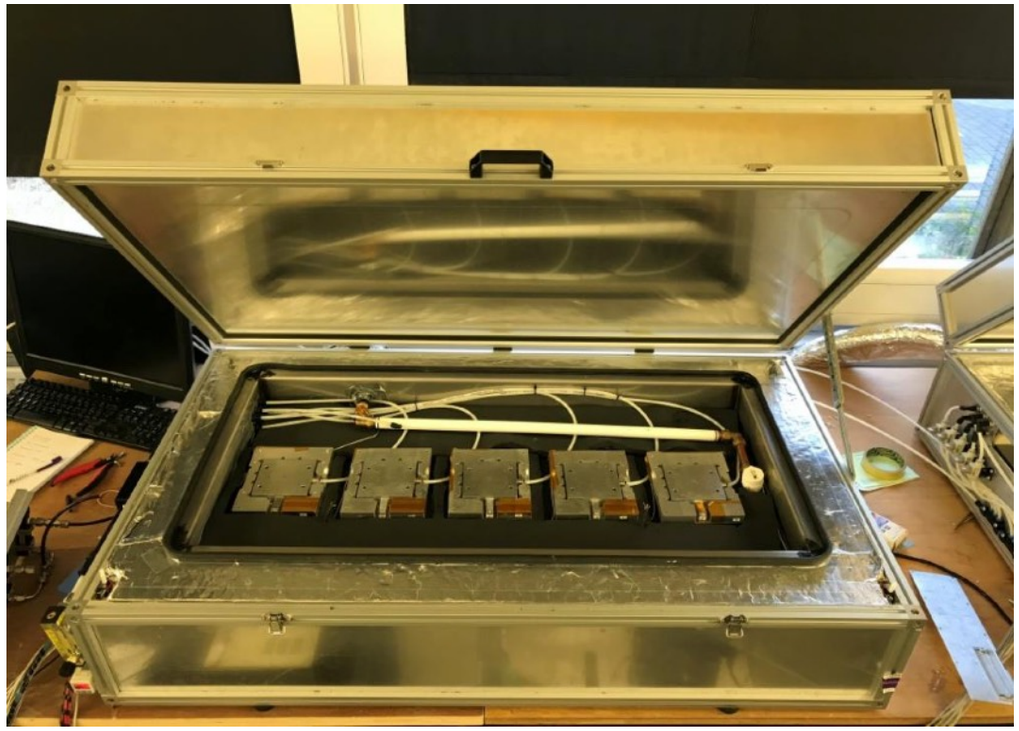
H&T Chamber at IHEP

Module Thermal Cycling

- Thermal-cycling between -35 °C to +40 °C, 10 times over 12 hours,
- Module test before and after the thermal cycling period, and between each thermal cycle,
- Expect to get ColdJig at the end of October.



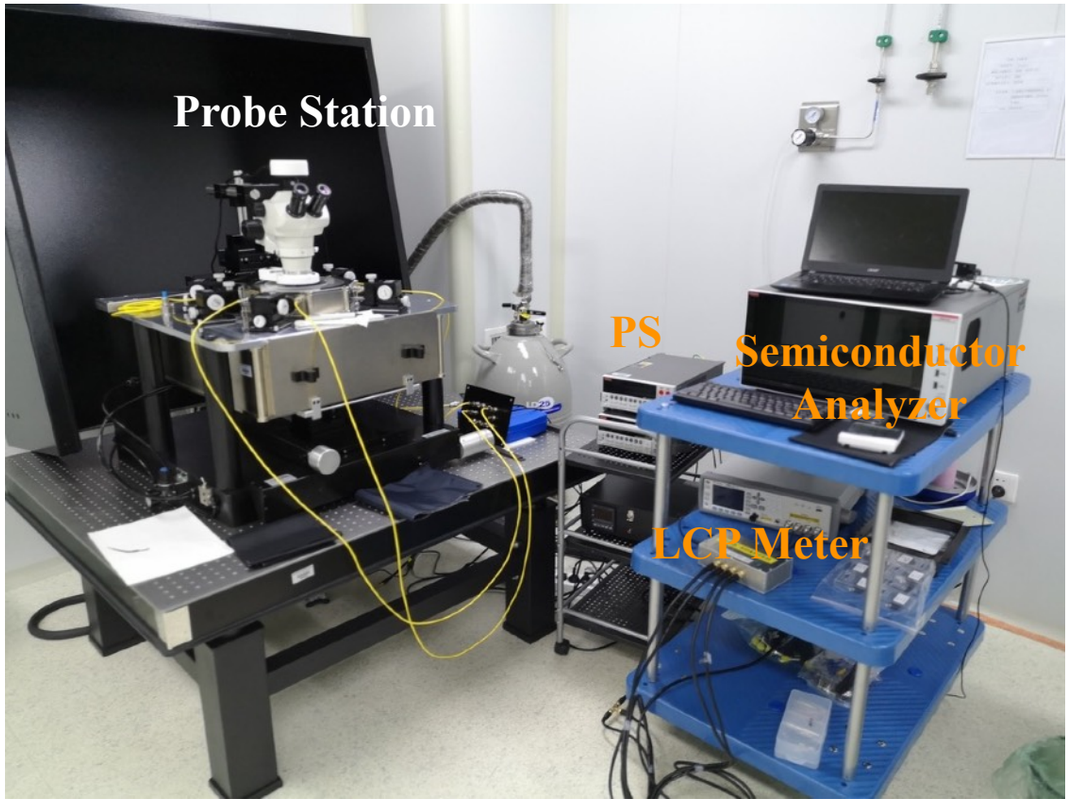
Thermal Cycling Timeline

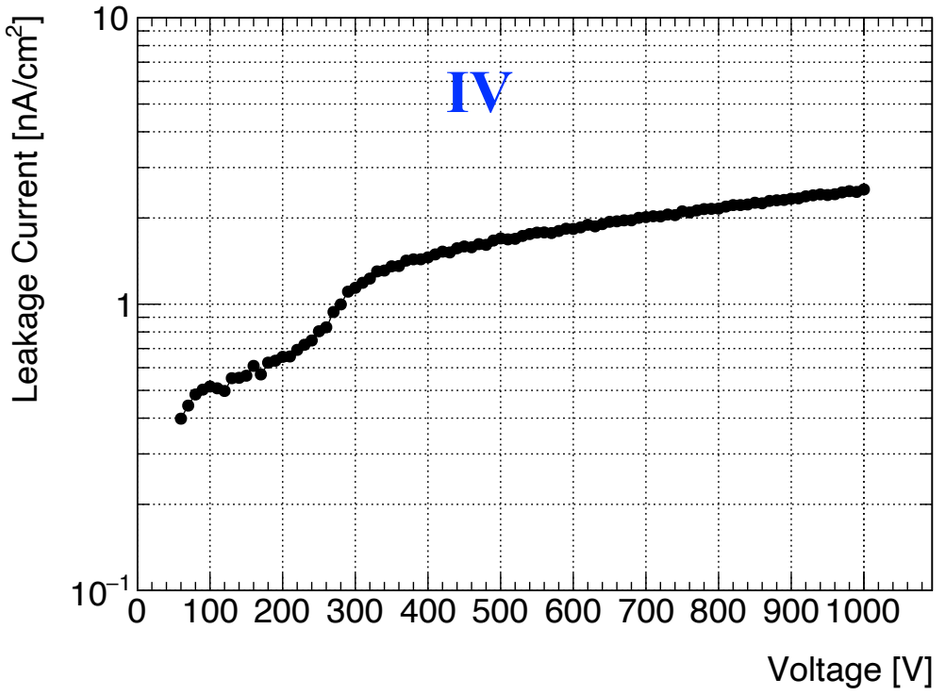


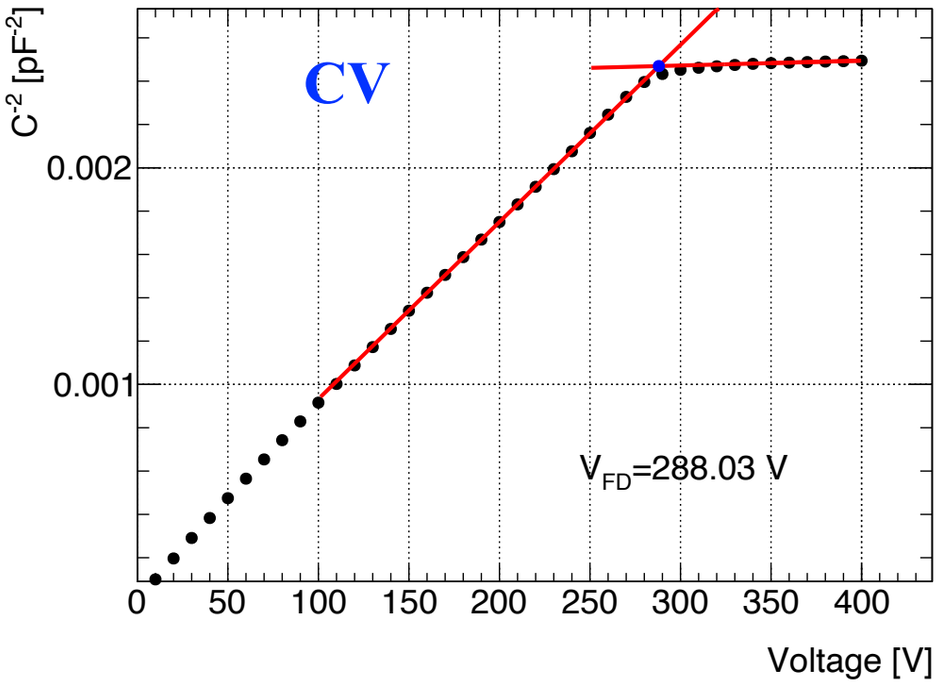
ColdJig at Warwick

Mini Sensor Studies

- Study the prosperities of sensors:
  - Leakage Current<0.1 μA/cm^2 at 500 V
  - Onset of micro-discharge Voltage>500
  - V_{FD}<350 V

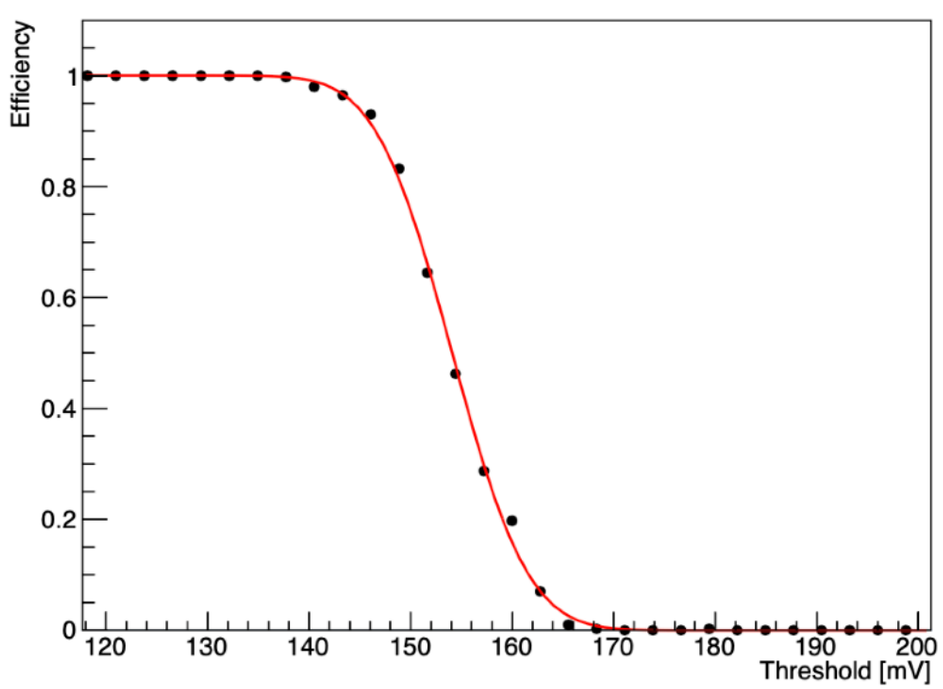




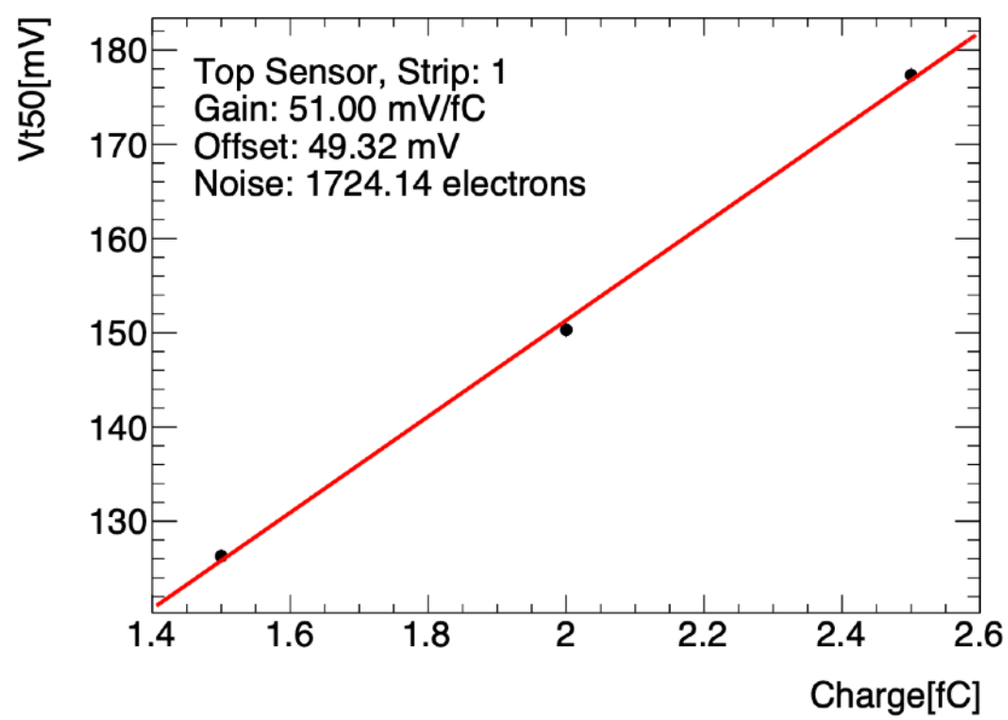


QC-Electrical Test

- Check for front-end chip functionality:
  - Chip Communication,
  - Strobe delay to determine the delay of the injecting and arrival time of signal,
  - Three Point Gain to determine discriminator offset, channel gain and input noise,
  - Noise Occupancy to measure the noise occupancy as a function of threshold.



S-Curve to determine Vt50 and ENC



Response Curve to determine offset, gain, noise