The ATLAS ITk Strip Detector System for the Phase-II LHC Upgrade
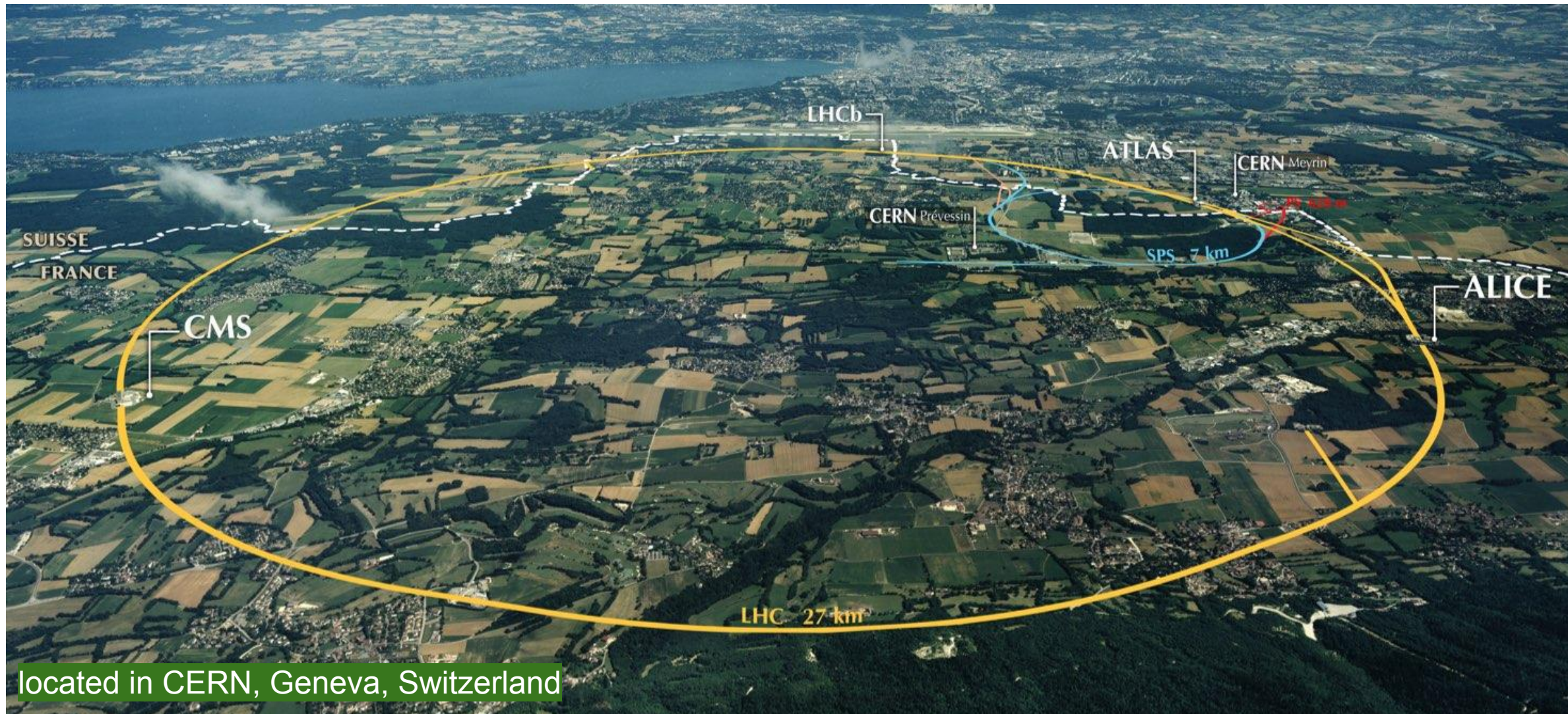
Elizaveta Sitnikova on behalf of the ATLAS ITk Collaboration
DIS 2024
09.04.2024
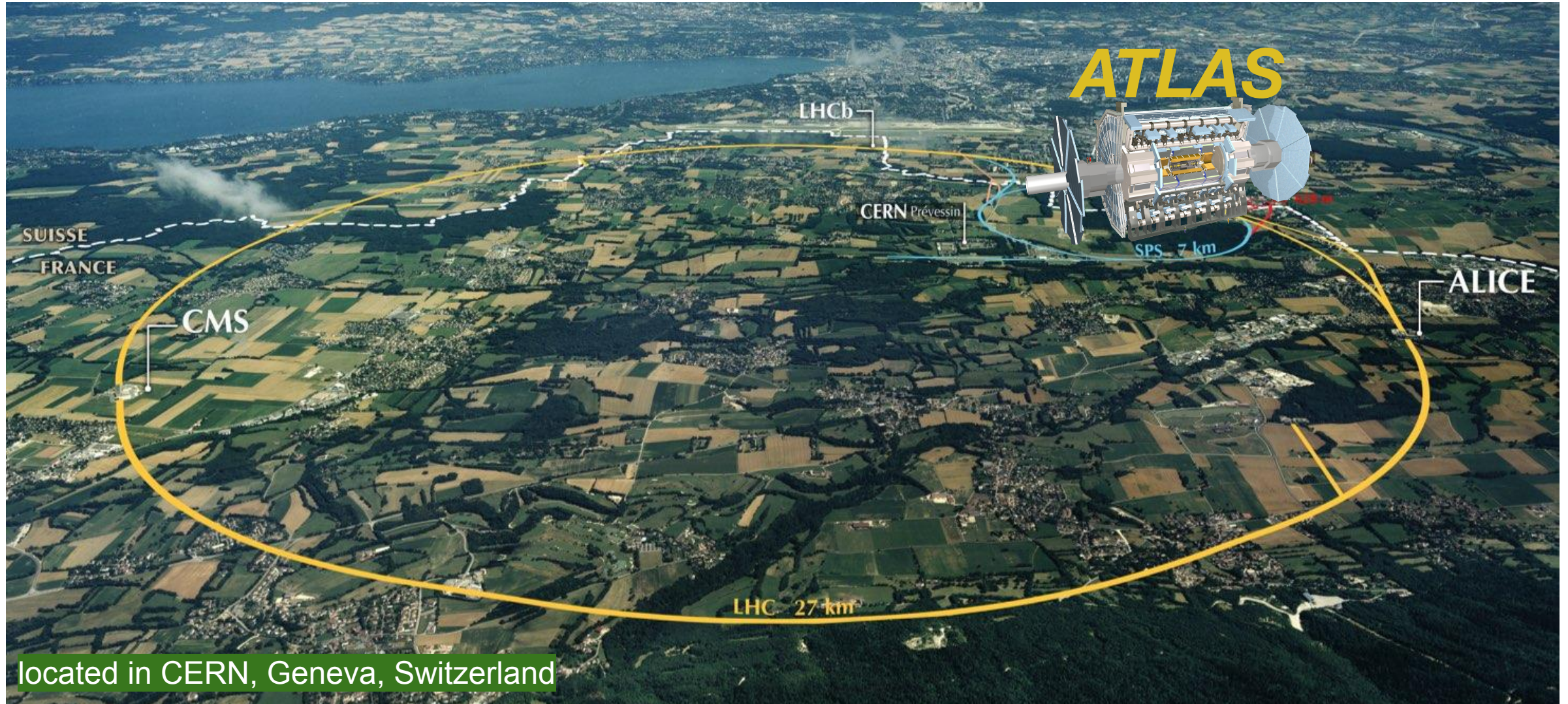
The ATLAS experiment at the LHC
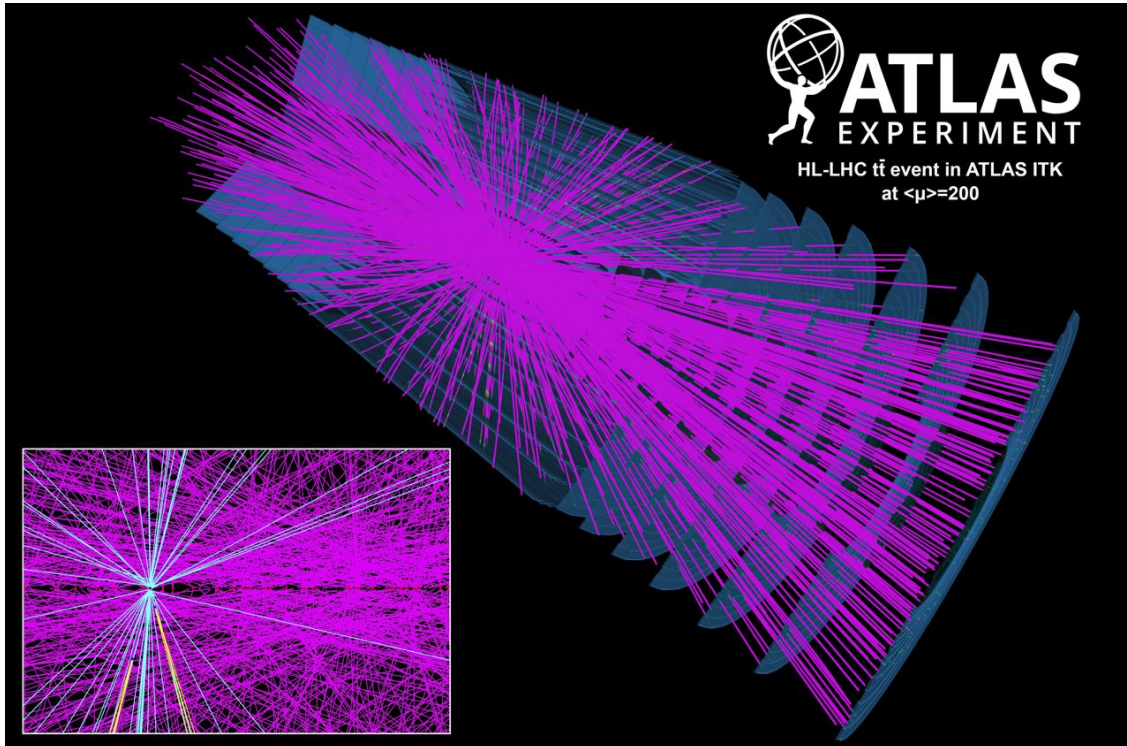
One of the two multipurpose detectors

located in CERN, Geneva, Switzerland

The ATLAS experiment at the LHC

One of the two multipurpose detectors

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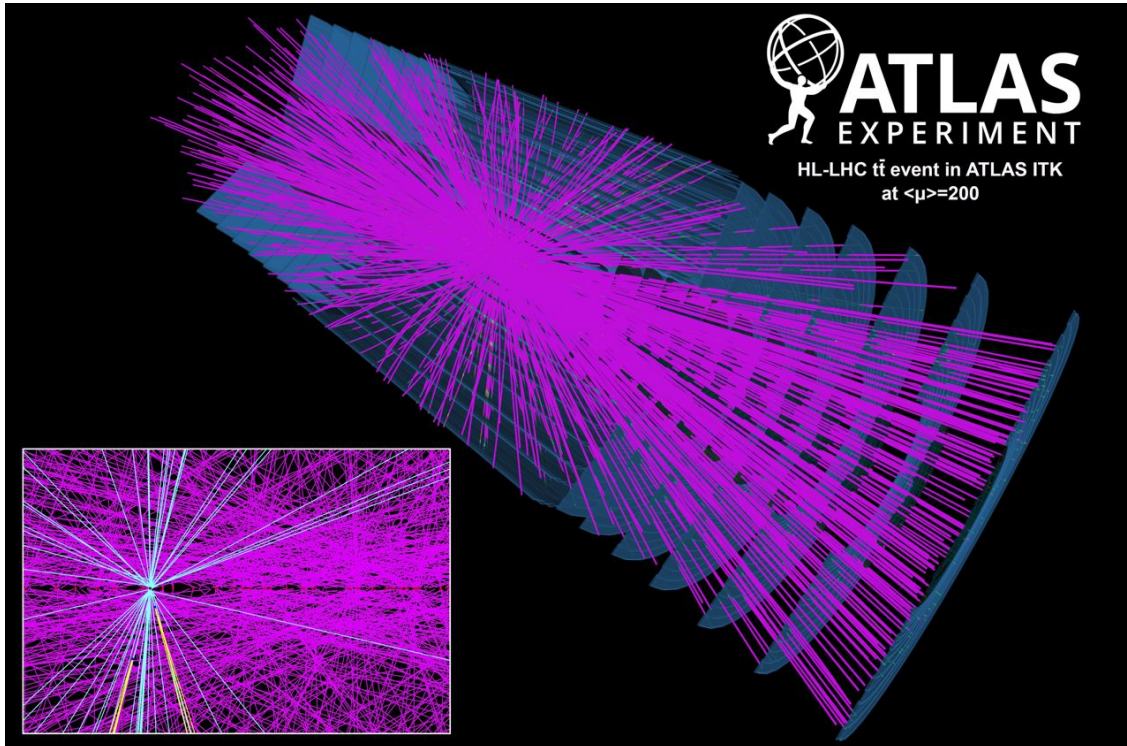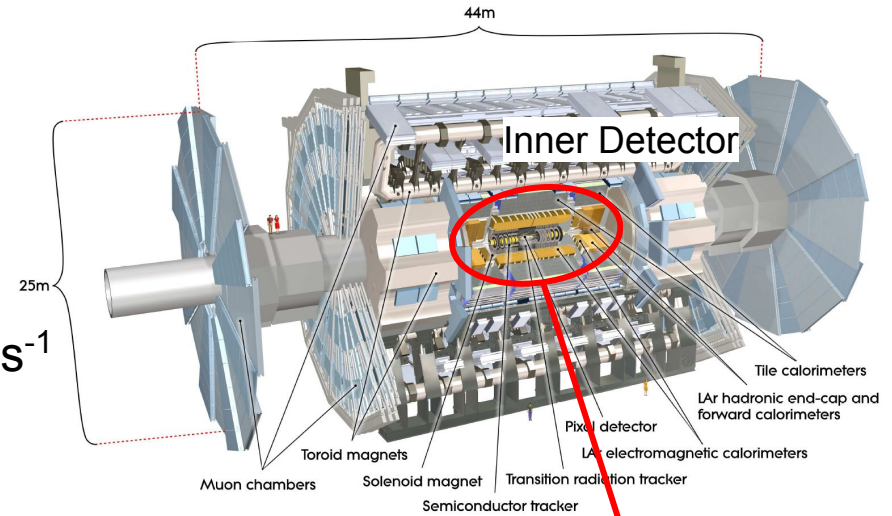
High Luminosity LHC

Tracker upgrade is necessary

- Up to 200 simultaneous proton-proton collisions

- Instantaneous luminosity increased to 5-7.5 $\cdot$ 10^{34} cm^{-2}s^{-1}

- Integrated luminosity up to 3000-4000 fb^{-1}

High Luminosity LHC

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Inner Detector

Tile calorimeters

LAr hadronic end-cap and forward calorimeters

Pixel detector

LAr electromagnetic calorimeters

Transition radiation tracker

Solenoid magnet

Semiconductor tracker

Toroid magnets

Muon chambers

- Increased granularity
- Higher radiation hardness
- Fully silicon – pixel and strip

Inner Tracker (ITk)

ATLAS EXPERIMENT

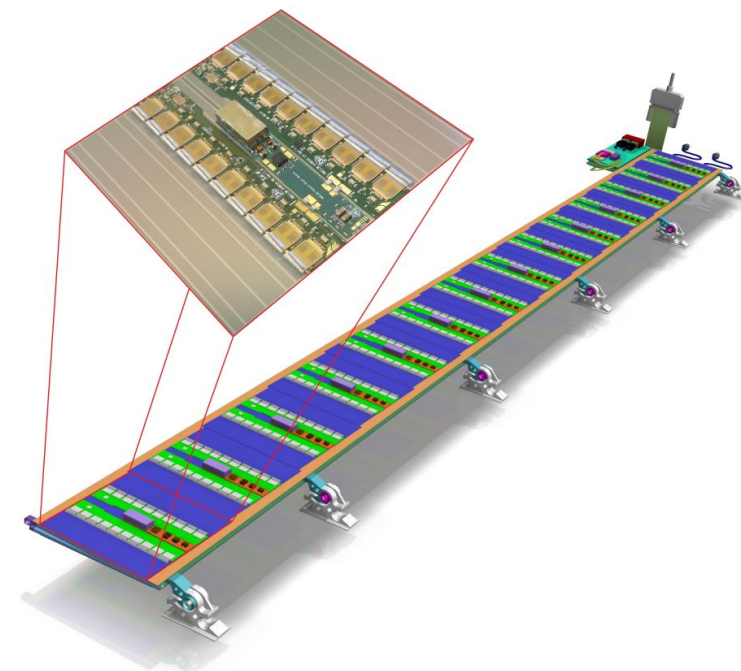HL-LHC $t\bar{t}$ event in ATLAS ITK at <μ>=200
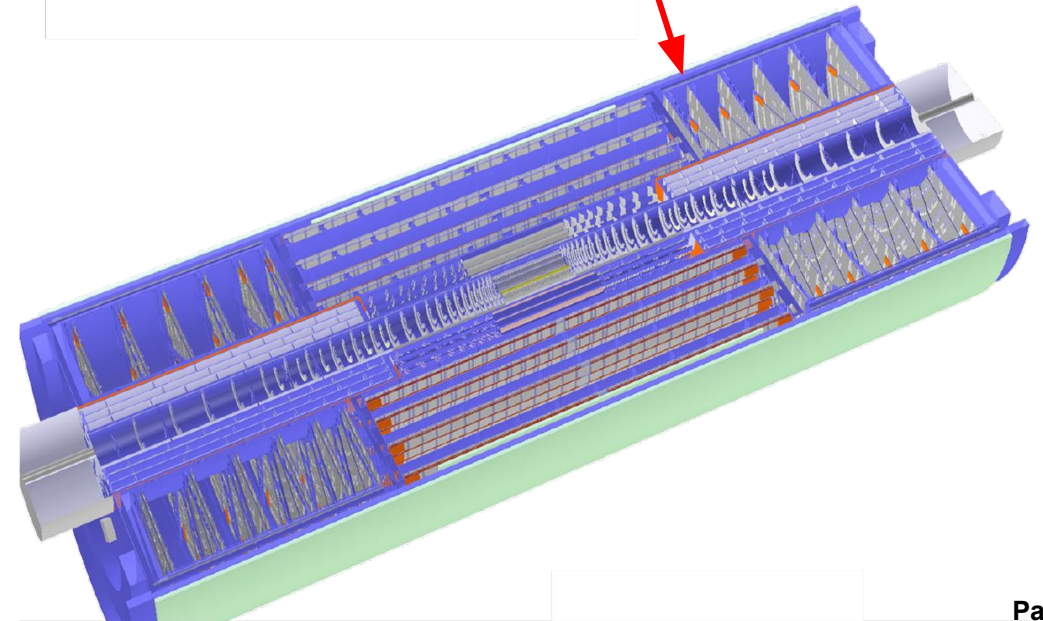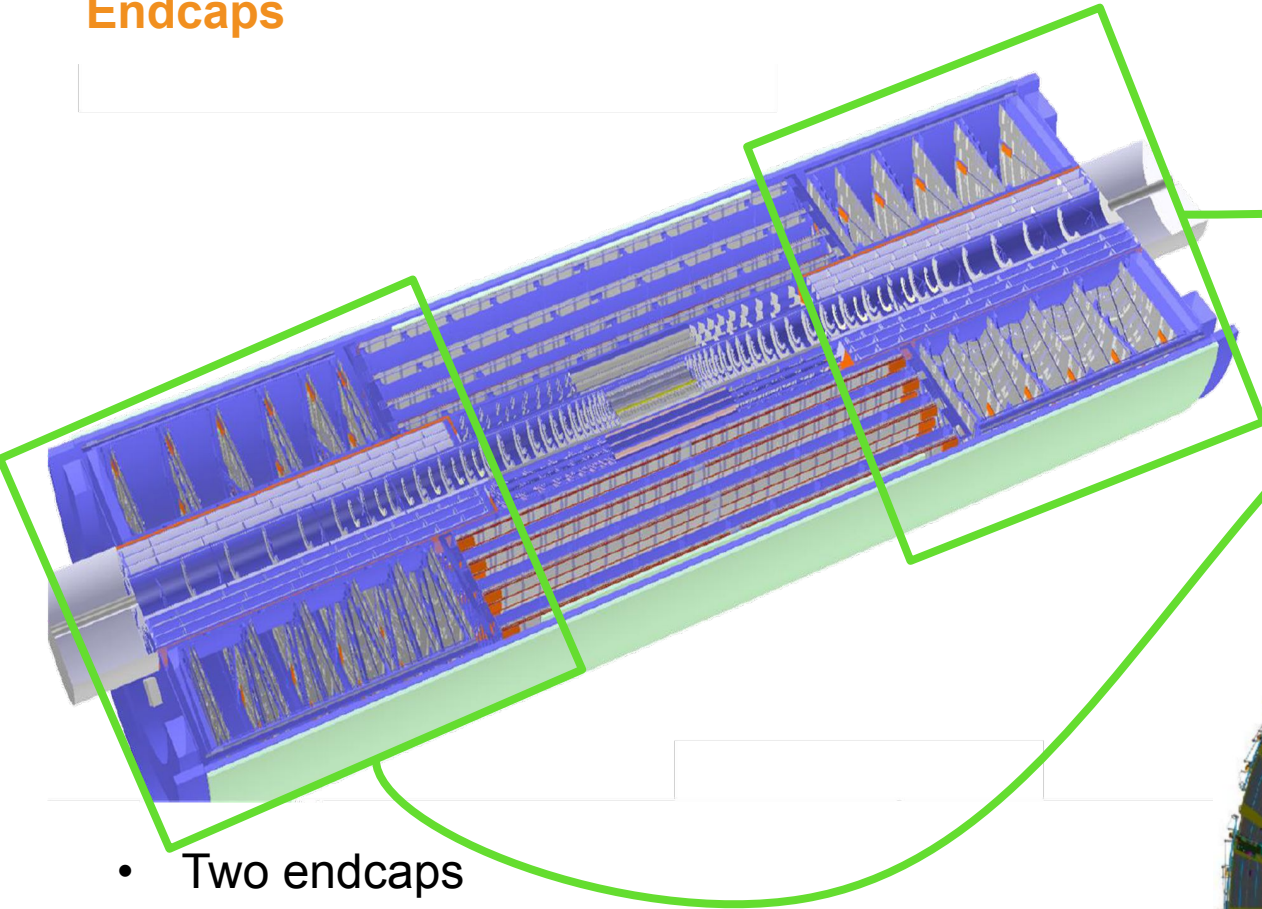
ITk strips structure

Barrel
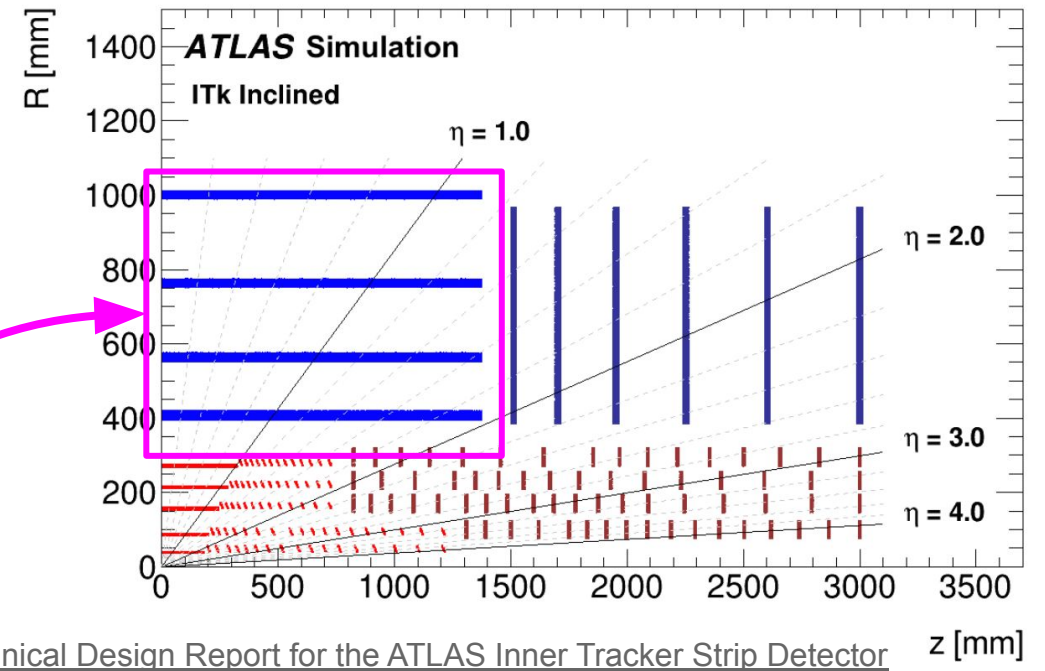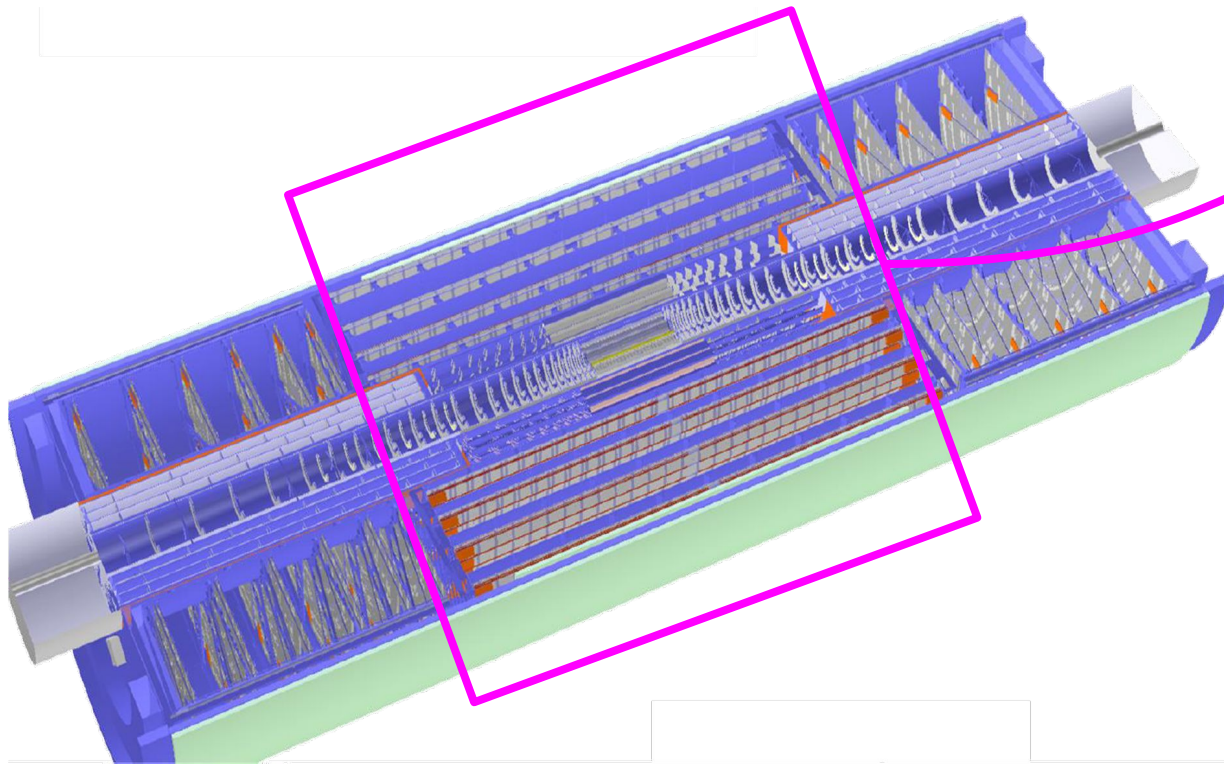
Technical Design Report for the ATLAS Inner Tracker Strip Detector

- Two layers with short strip modules
- Two layers with long stip modules
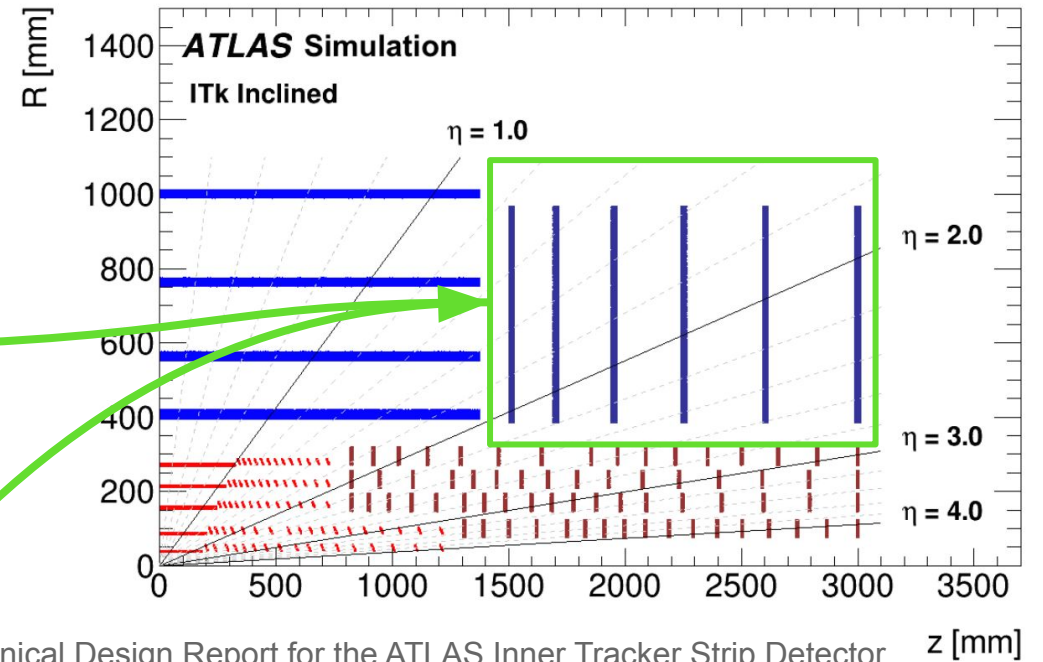- 392 staves in total
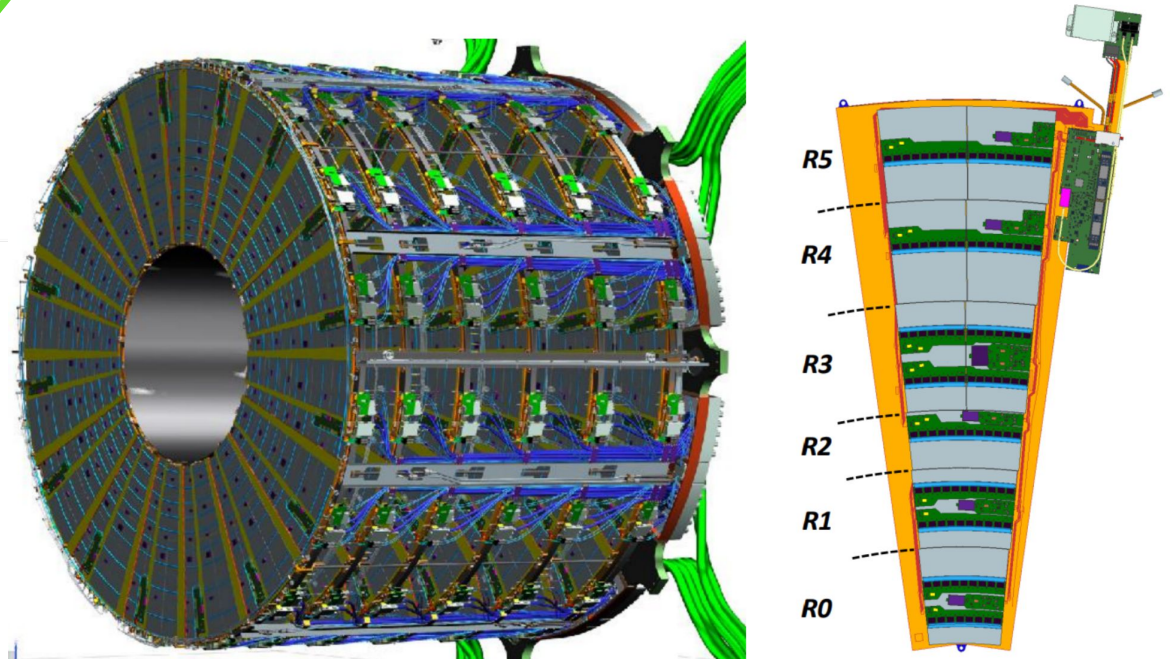- 28 modules per stave

ITk strips structure

Endcaps

Technical Design Report for the ATLAS Inner Tracker Strip Detector

- Two endcaps
- 6 wheels in each
- 32 petals in a wheel – 192 petals per endcap
- 12 modules per petal

Who will be building this?
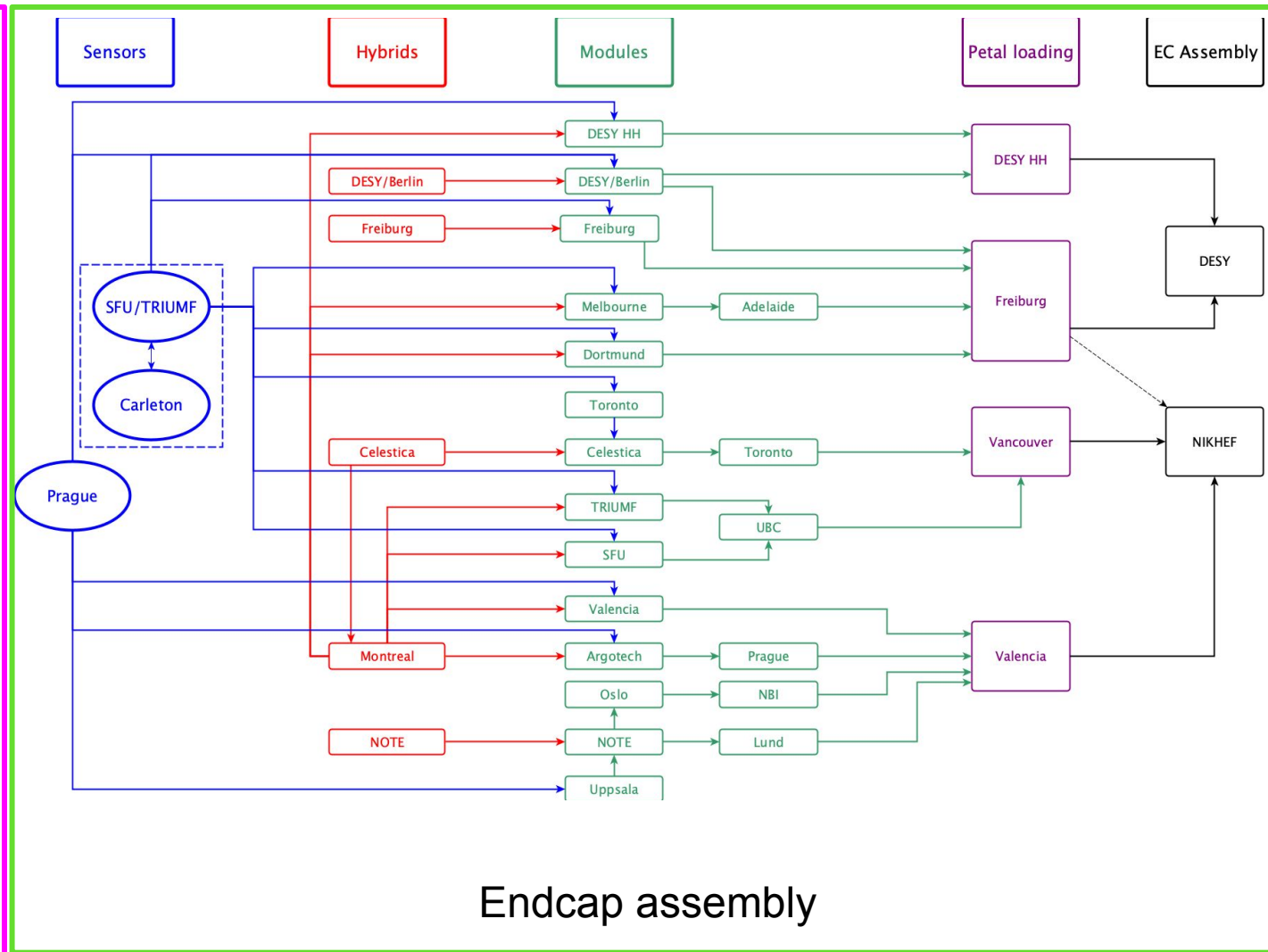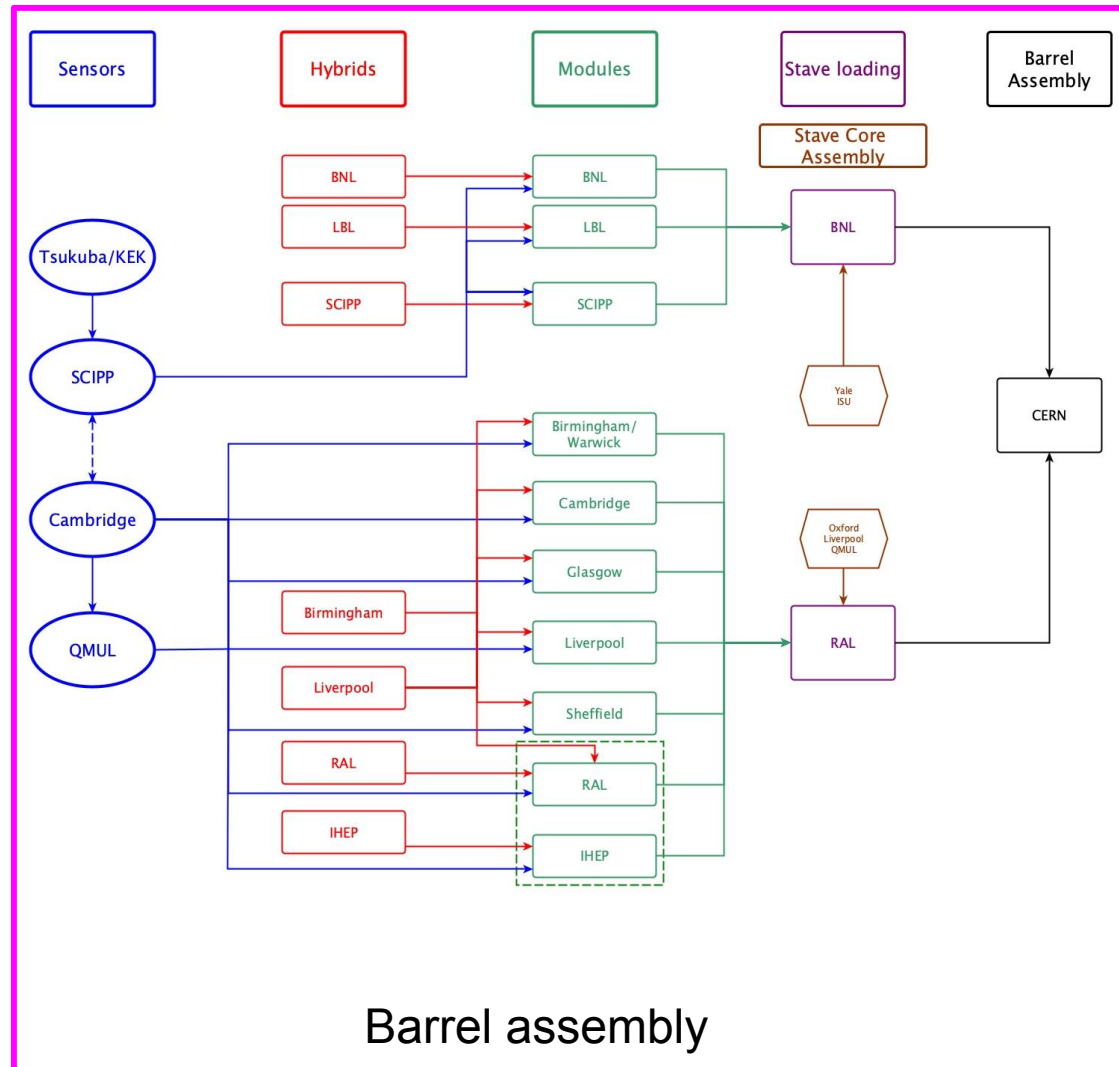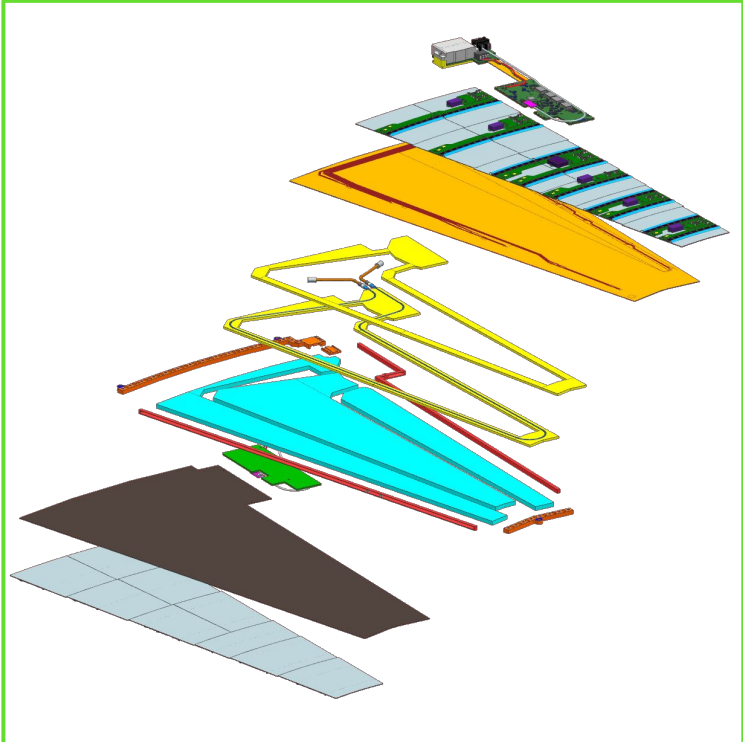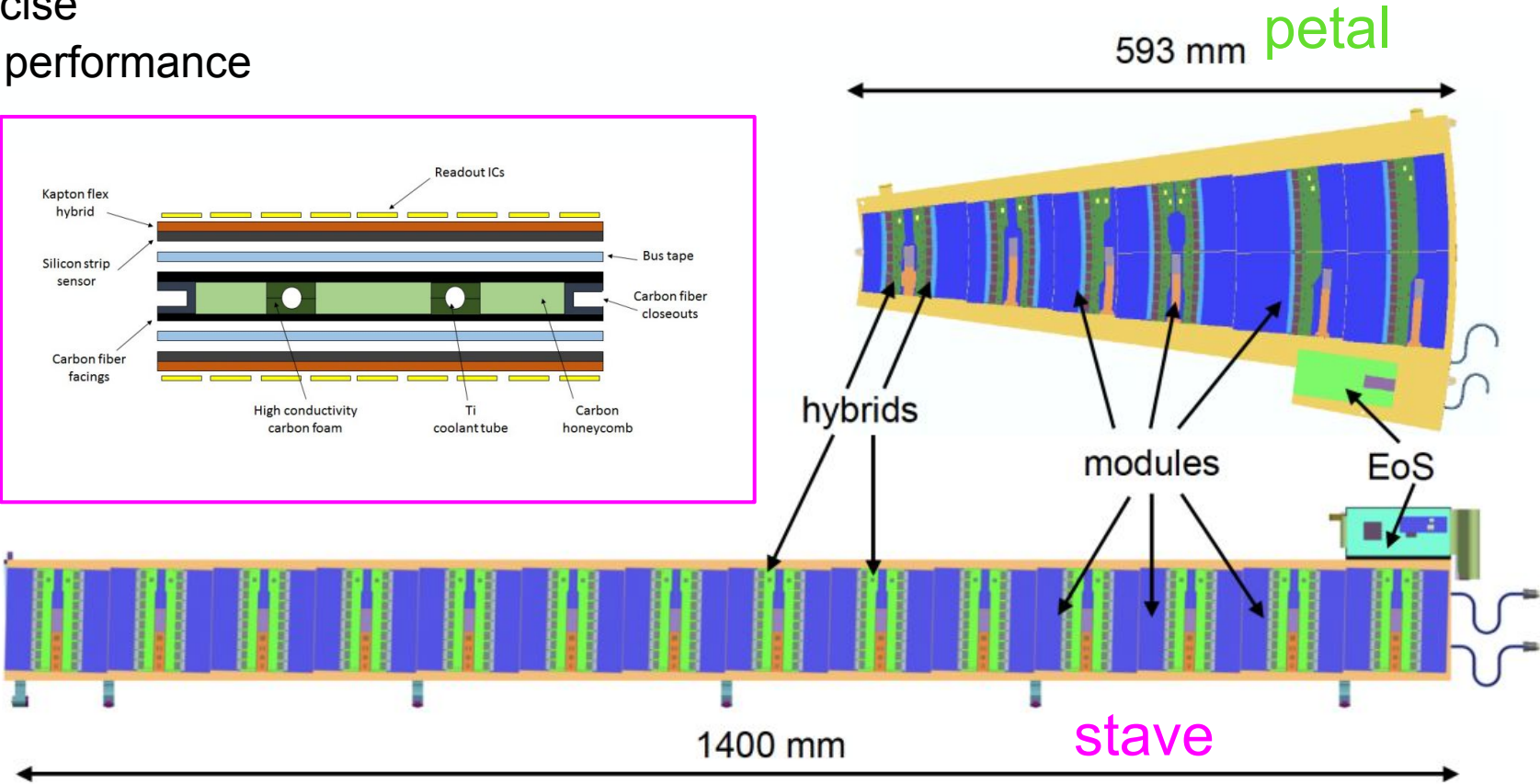
Production workflow

Barrel assembly

Endcap assembly

Local support structures

Staves and petals

Stave and petal cores are layered carbon fiber based structures:

- Low mass
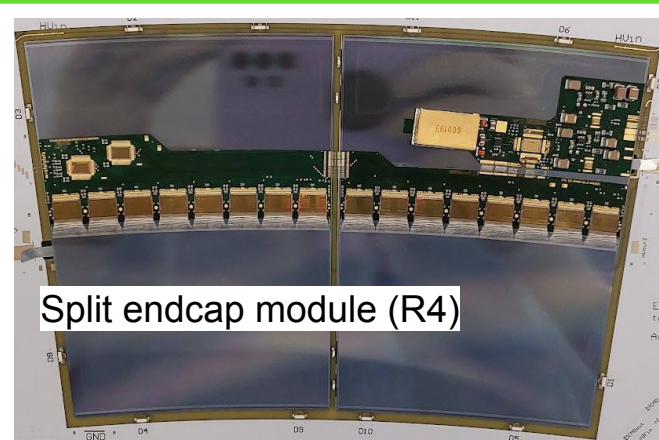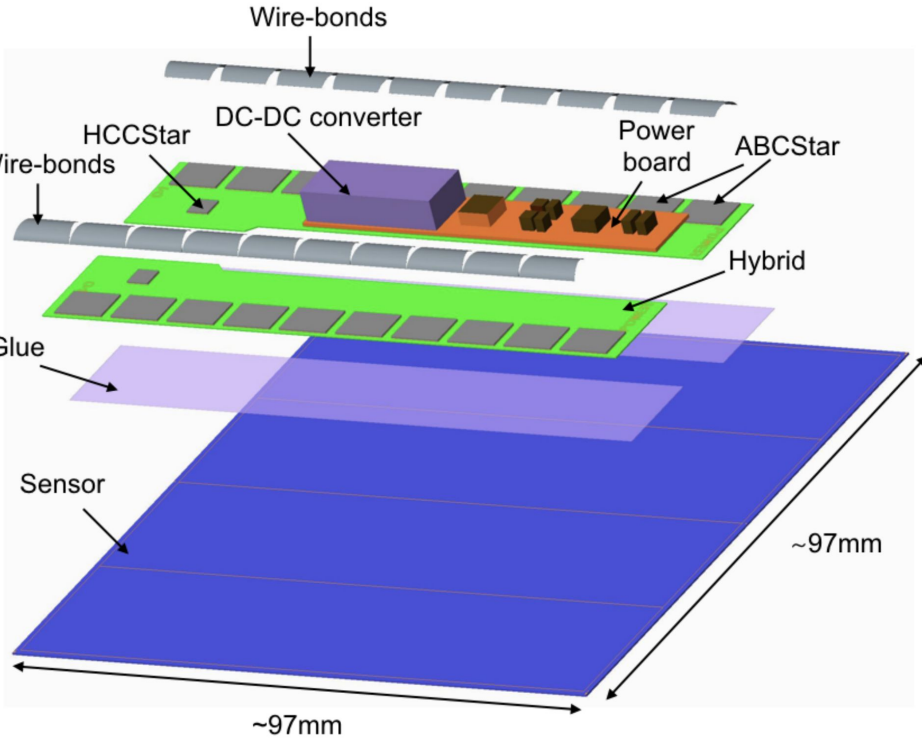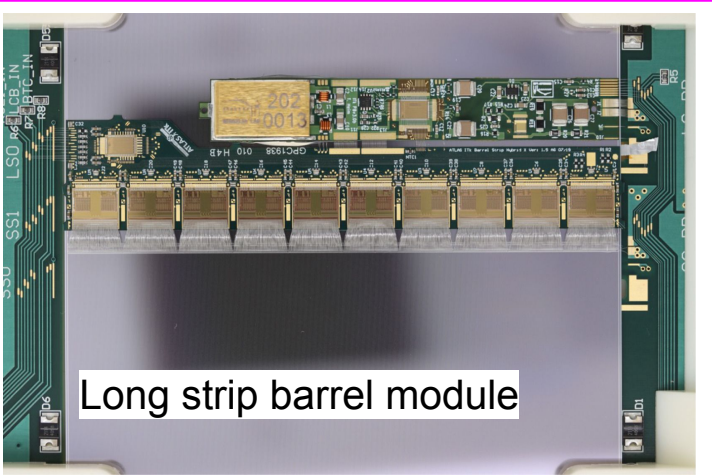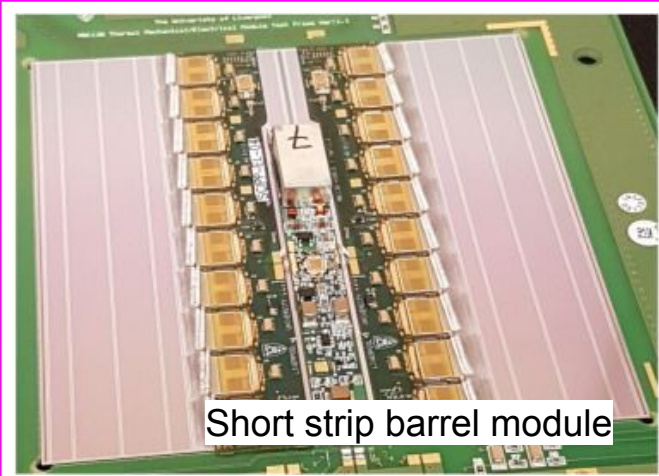- Mechanically stable and precise
- Good thermal and electrical performance
- Integrated cooling

Modules

- Electronics is glued on top of the sensor
- Electrical connections are established using thin wirebonds
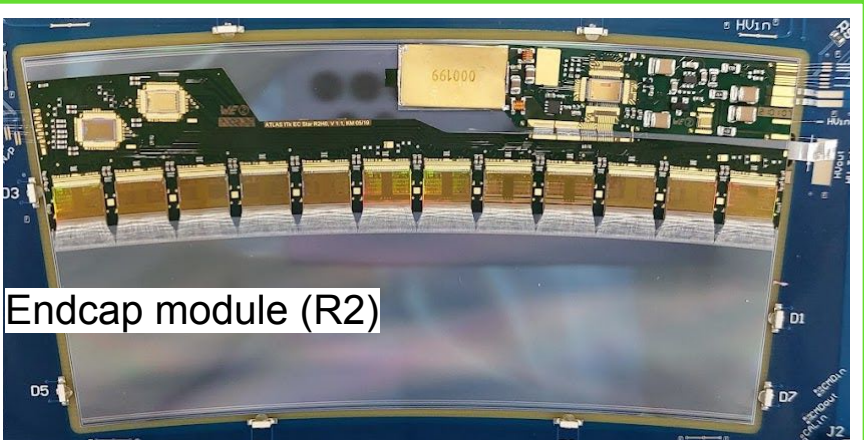
Short strip barrel module

Long strip barrel module

Split endcap module (R4)

Endcap module (R2)

Wire-bonds

HCCStar

Wire-bonds

DC-DC converter

Power board

ABCStar

Hybrid

Glue

Sensor

~97mm

~97mm

Sensors

6" wafers, 8 different types

- Two types of rectangular barrel sensors - with long and short strips
- Six types of arc-segment-shaped endcap sensors of different sizes
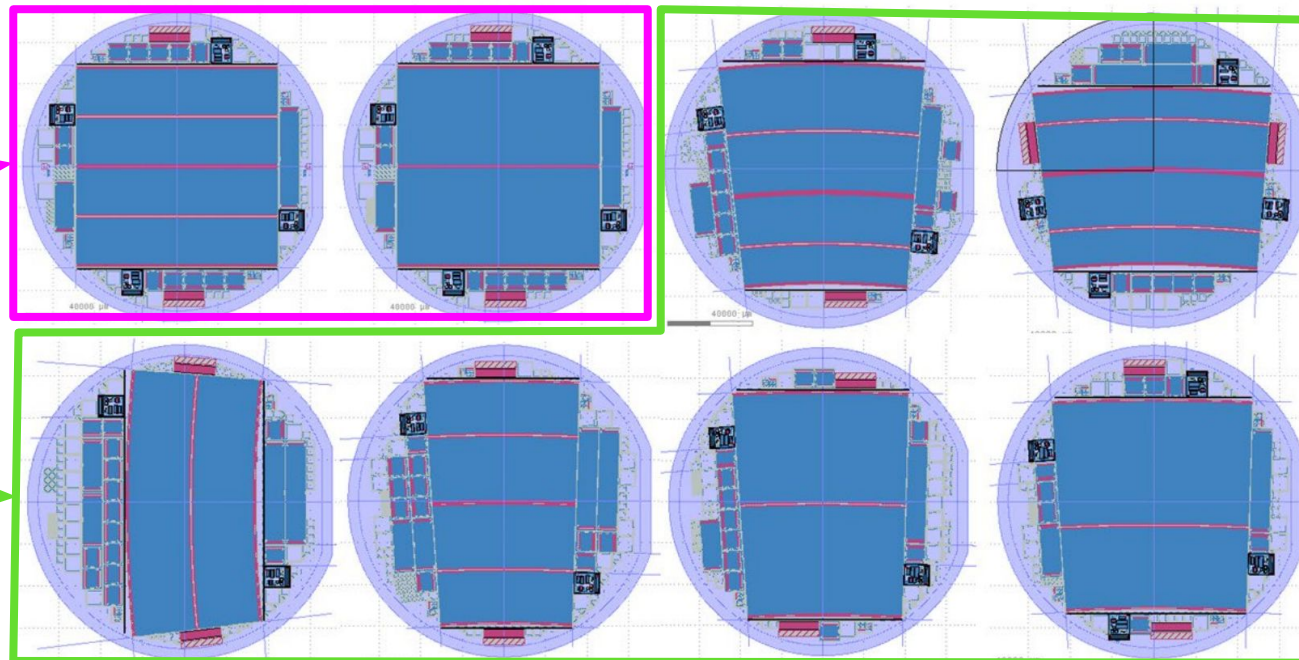
Sensors

6" wafers, 8 different types
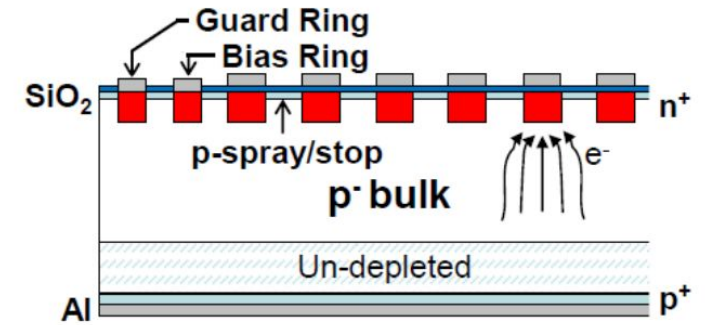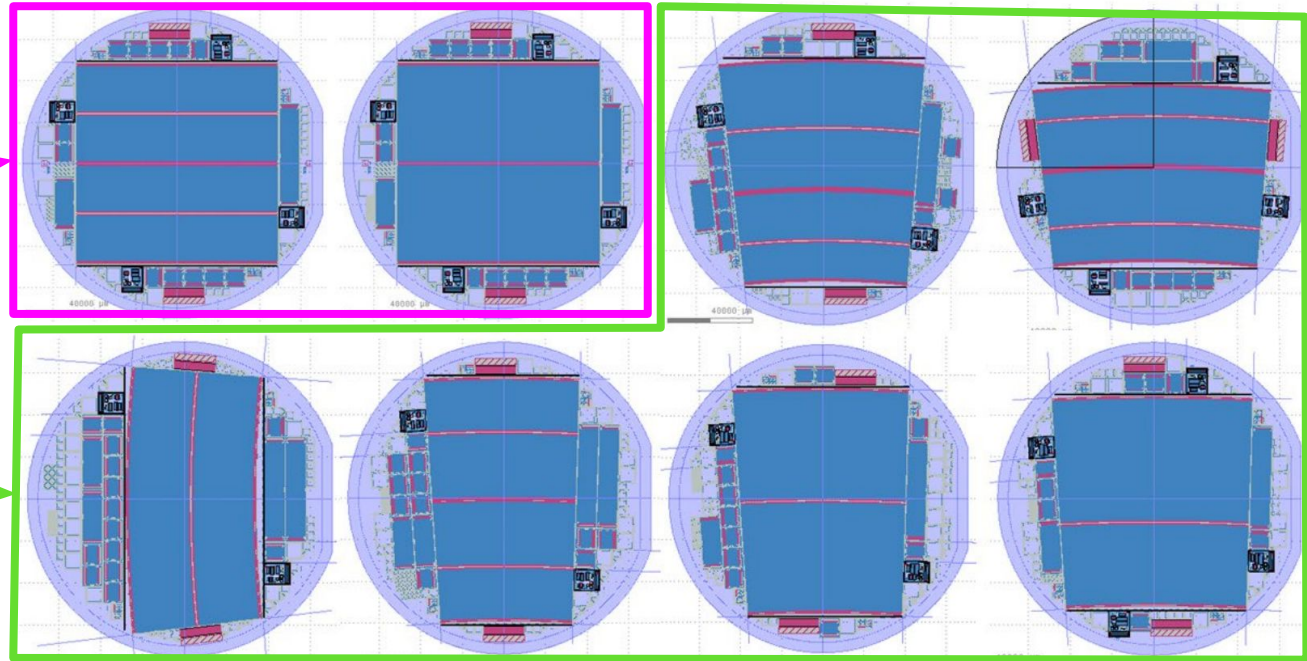
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n-in-p sensors:
- better speed and radiation hardness than p-in-n
- good signal even in underdepleted sensors

Sensors

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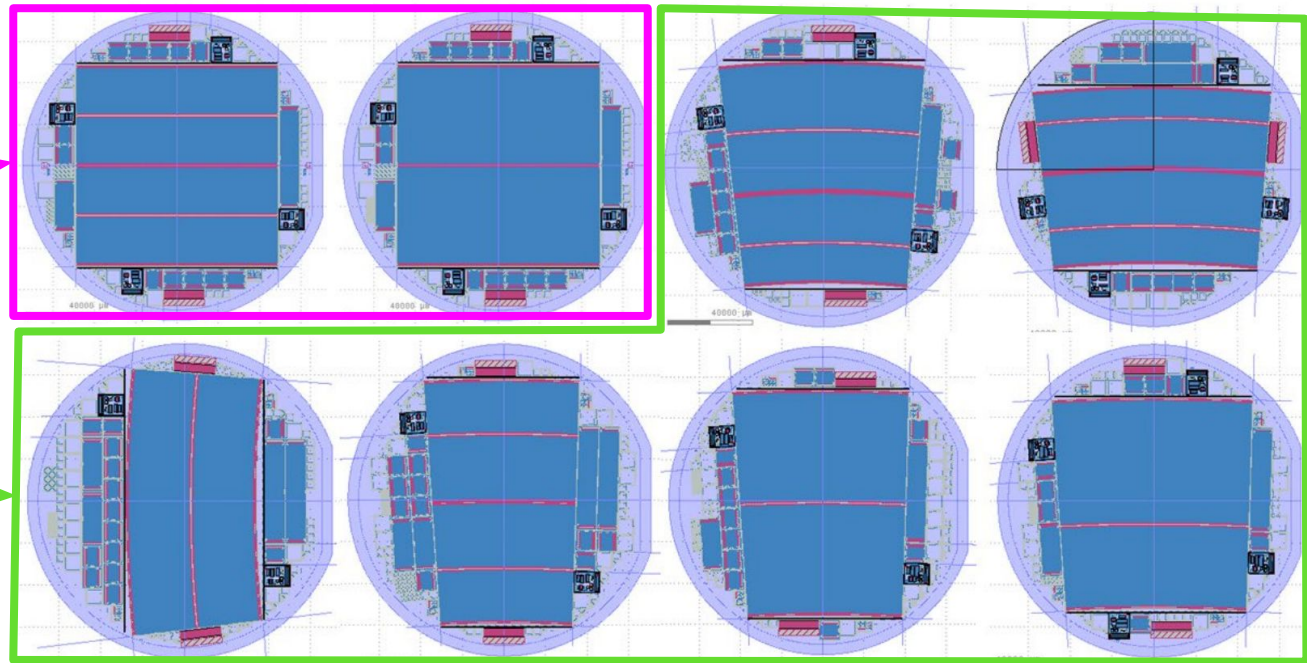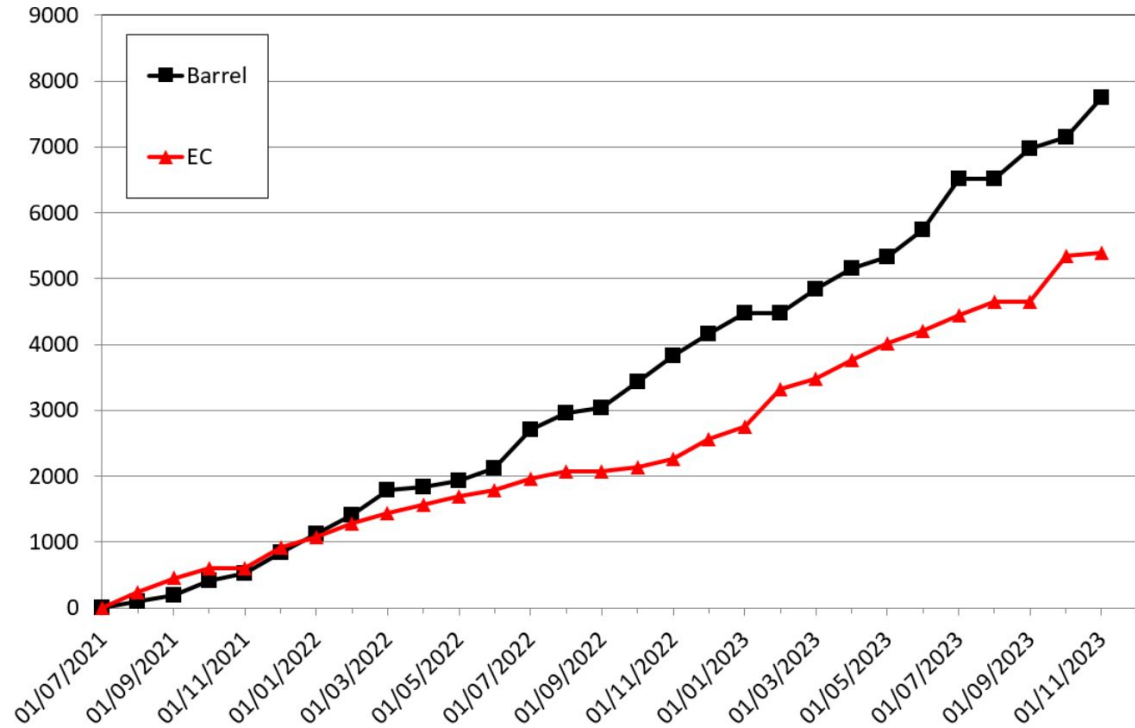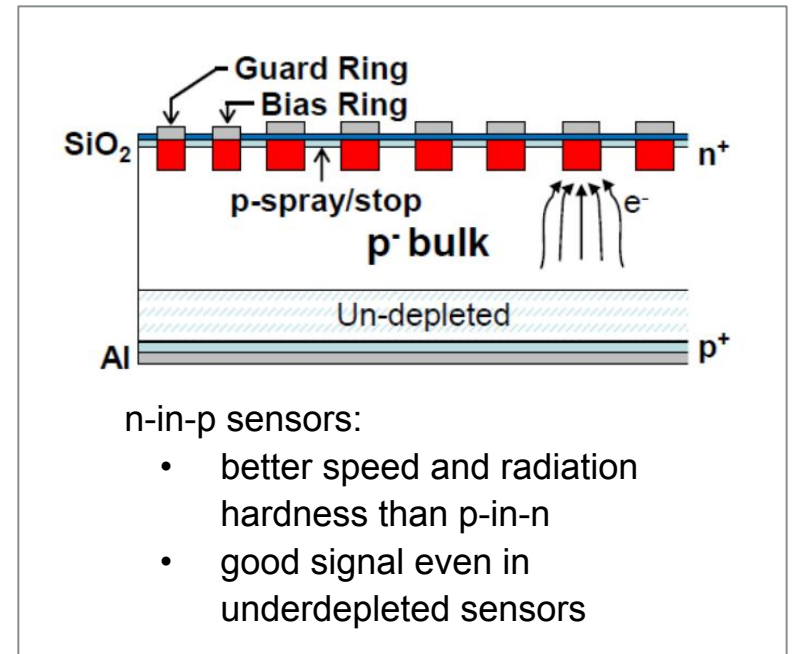- Six types of arc-segment-shaped endcap sensors of different sizes
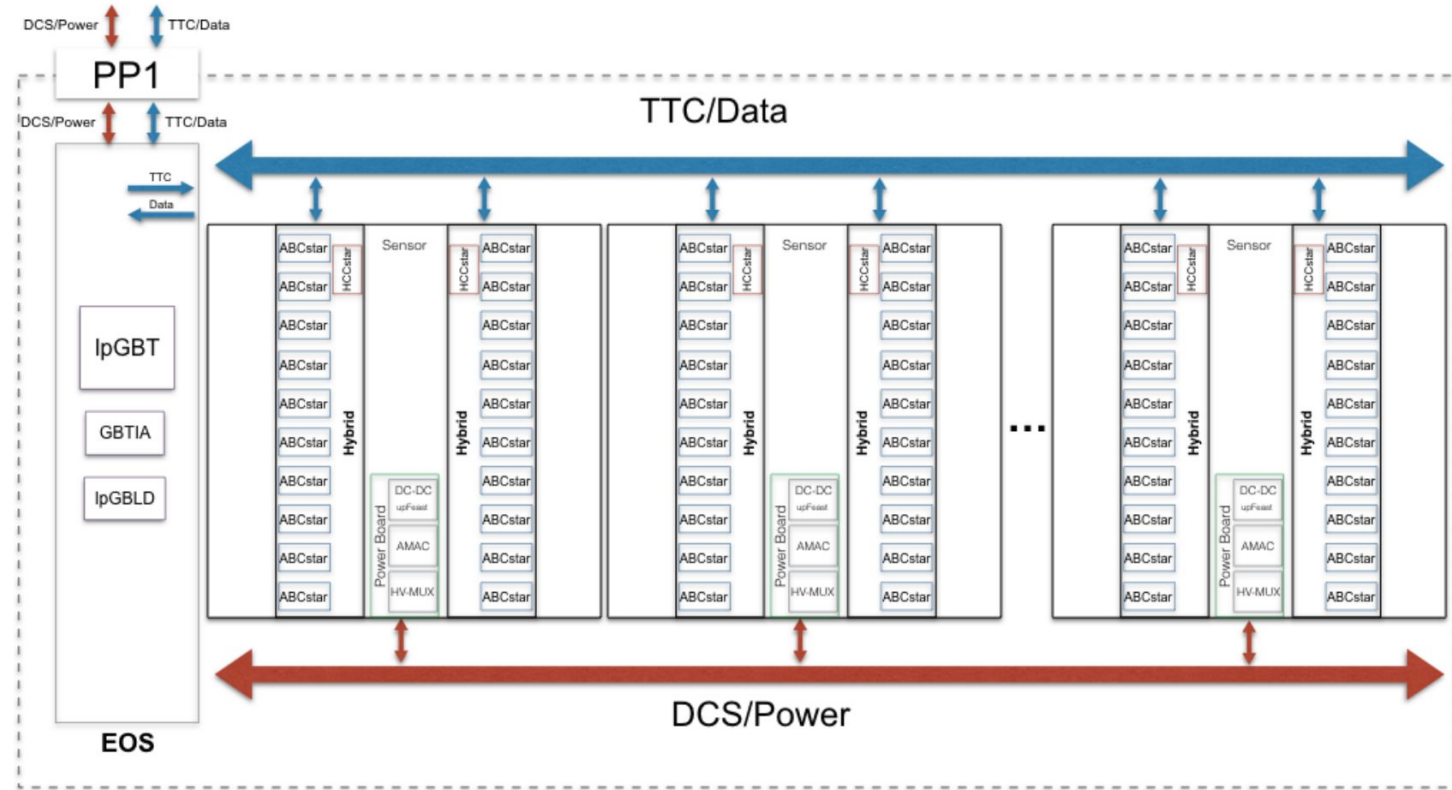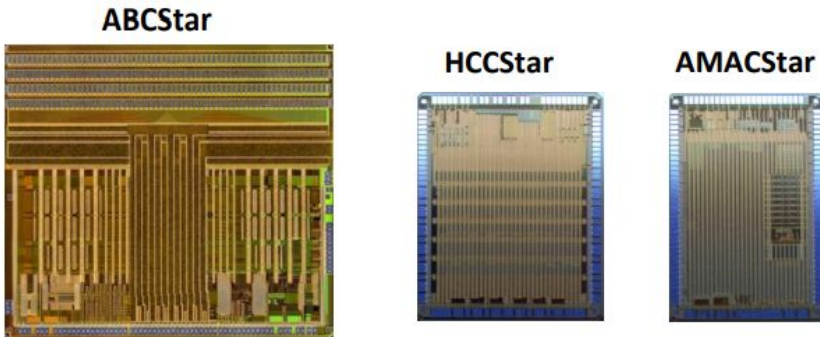

Accumulated number of sensors received

Received ~15 000 sensors - ~71% of the total

n-in-p sensors:
- better speed and radiation hardness than p-in-n
- good signal even in underdepleted sensors

Electronics

Single chipset for all module types

- ABCStar – frontend chips, readout from all channels
- HCCStar – repackaging ABCStar data per hybrid and sending it out
- AMACStar – module control and power

Electronics

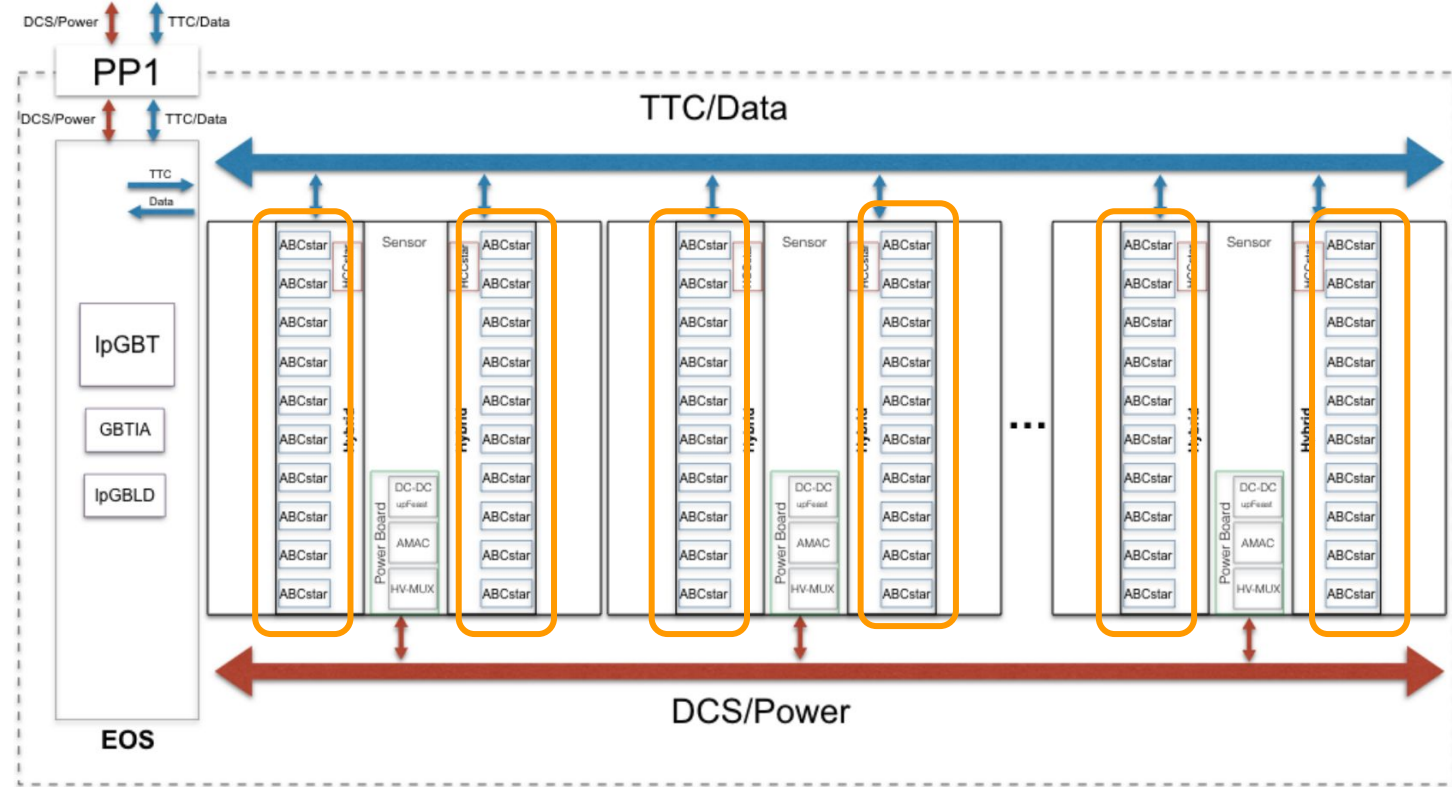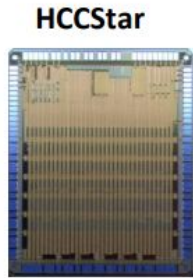## Single chipset for all module types

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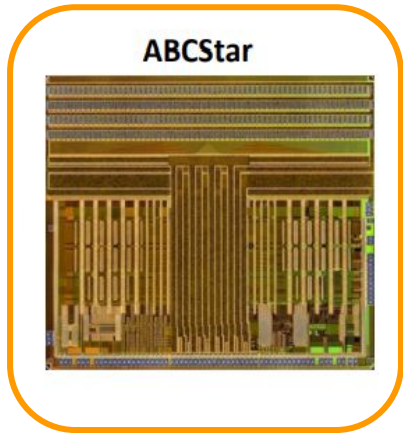## Single chipset for all module types

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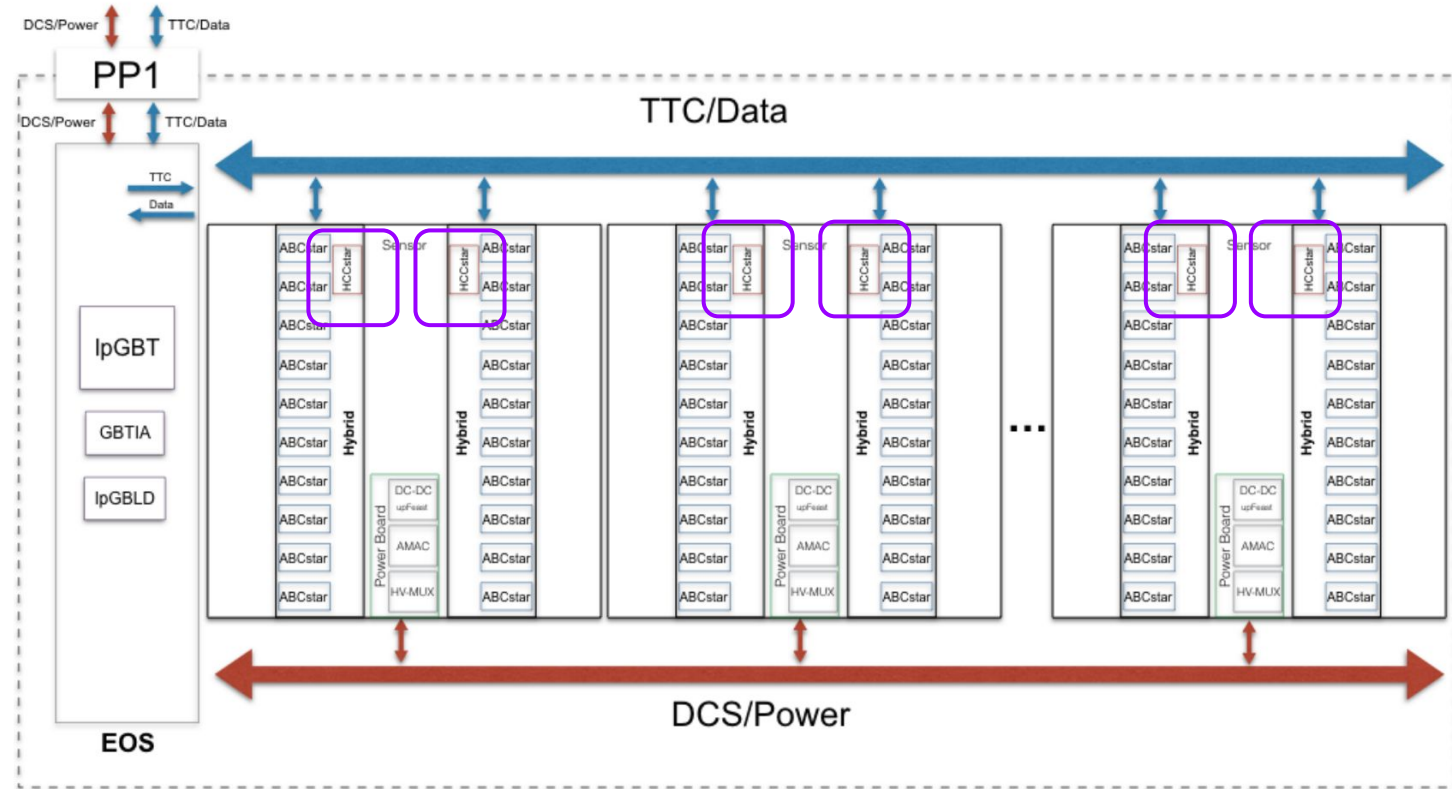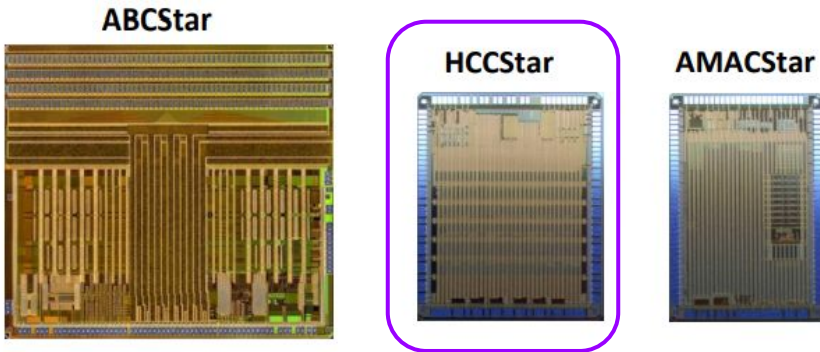
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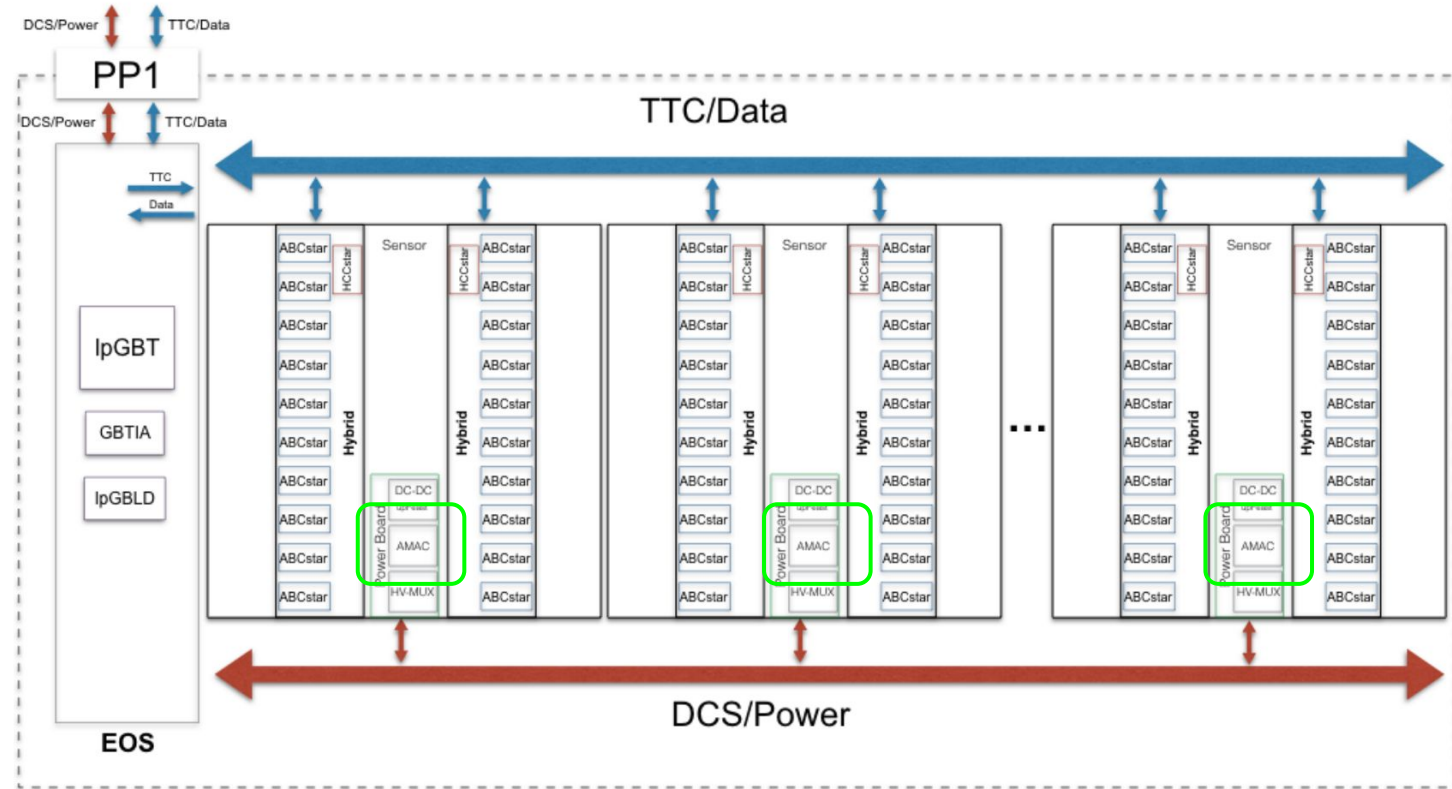
Electronics

Single chipset for all module types
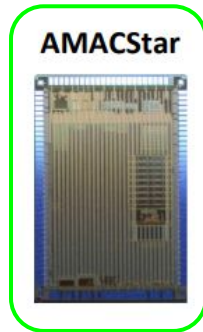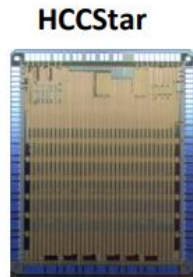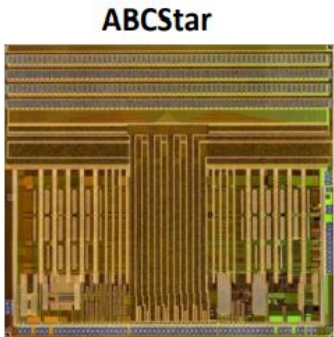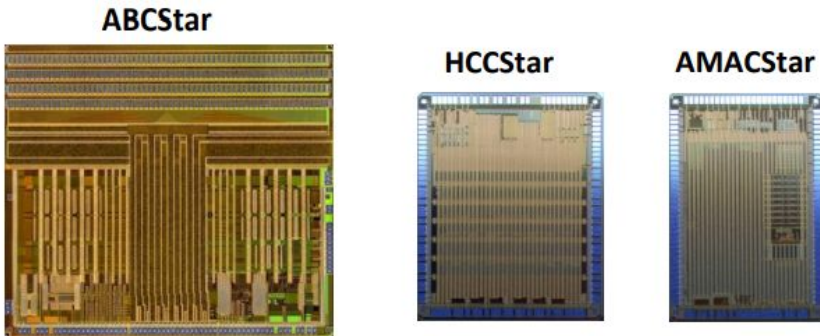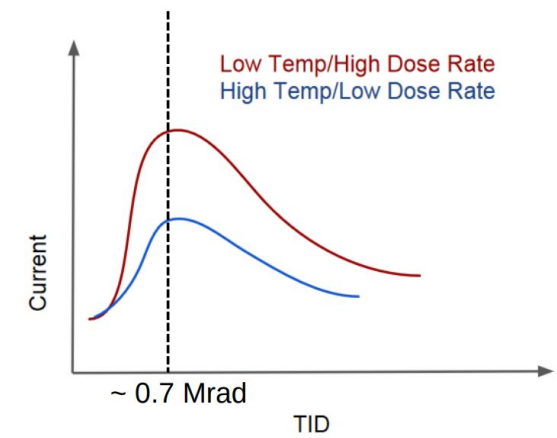
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ASIC	Manufactured	Probed	Diced	Pre-irradiated	Distributed
ABCStar	354 380 (101%)	321 480 (92%)	175 701 (56%)	134 136 (43%)	14 716 (5%)
HCCStar	43 446 (121%)	38 433 (107%)	35 599 (105%)	23 185 (68%)	2 020 (6%)
AMACStar	37 986 (167%)	37 986 (167%)	29 650 (144%)	19 517 (95%)	5 899 (29%)
Overall	107%	98%	66%	48%	6%

production flow

Module building

Highlights

Module building

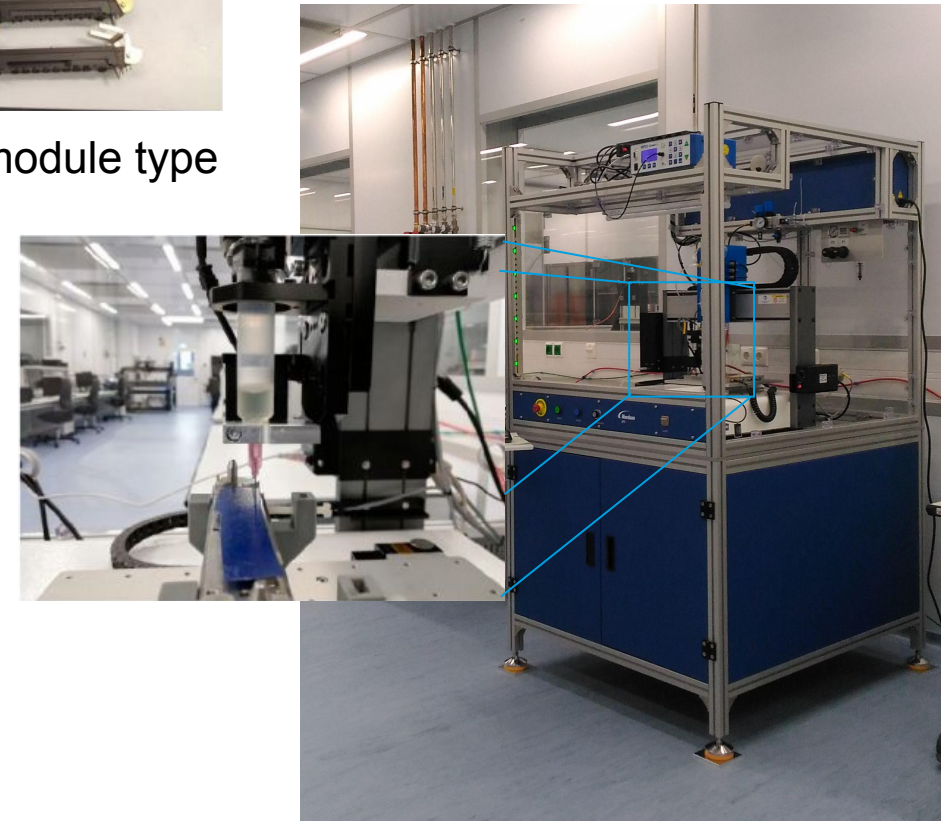## Highlights

Dedicated tools for each module type

Module building

Highlights

Dedicated tools for each module type

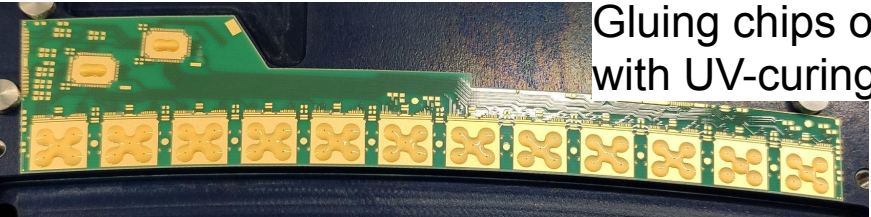Automated glue application using programmable robots

Module building

Highlights

Dedicated tools for each module type

Automated glue application using programmable robots

Gluing chips onto hybrids with UV-curing glue

UV lights

R4H0 ABCs (AT2-IS-DF-0011 v 3.7)
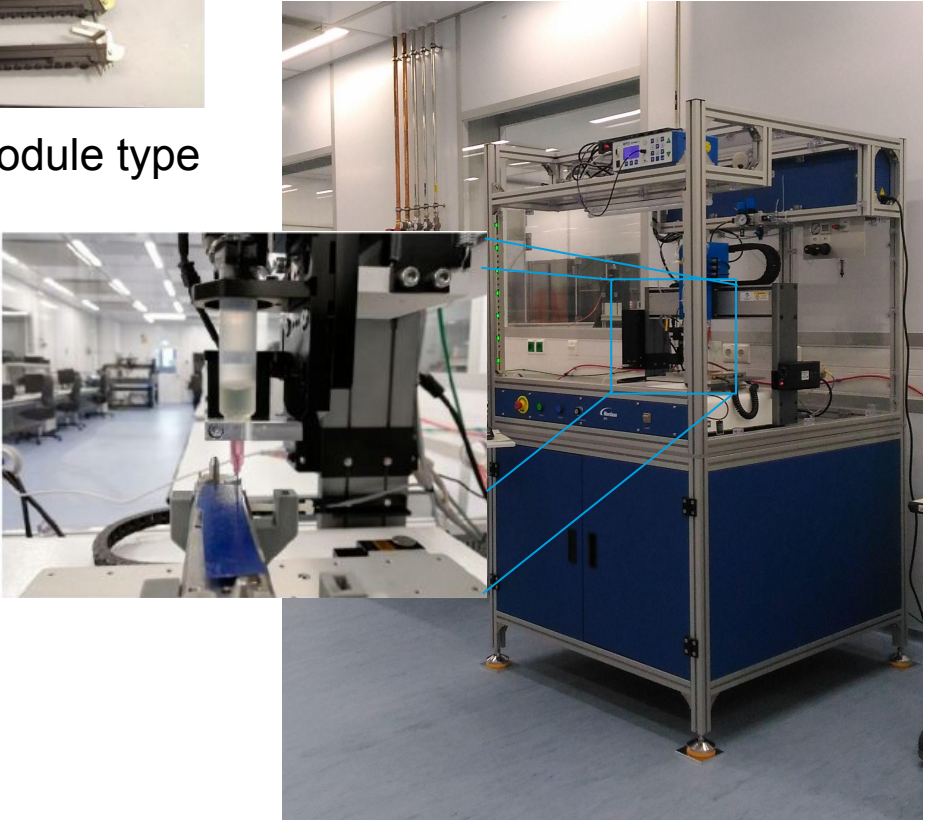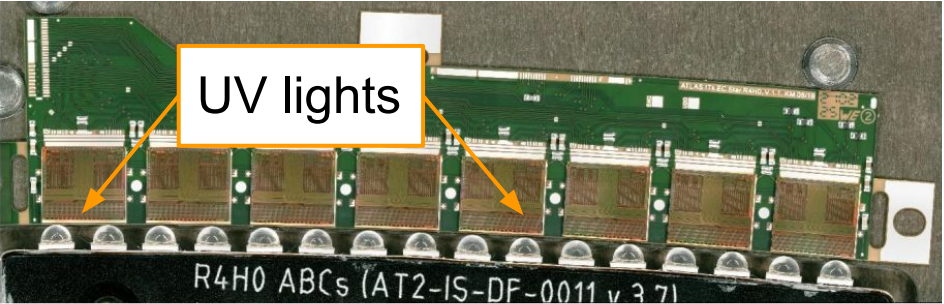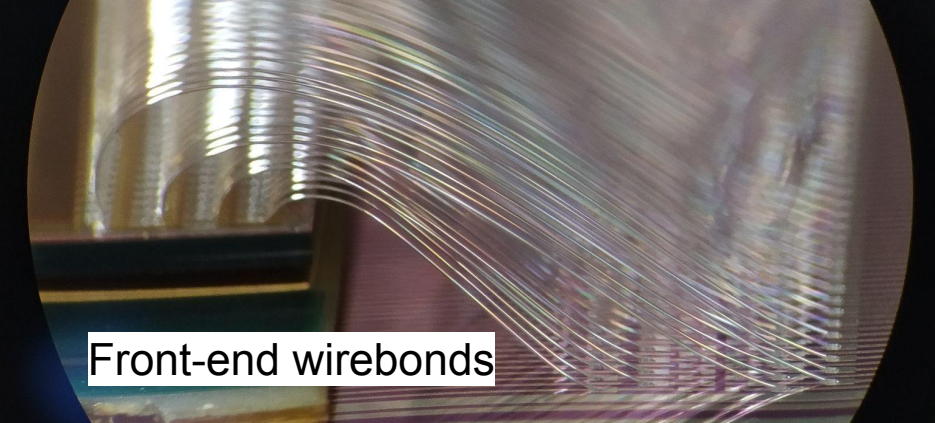
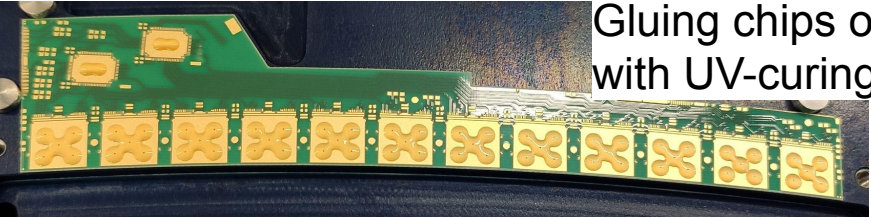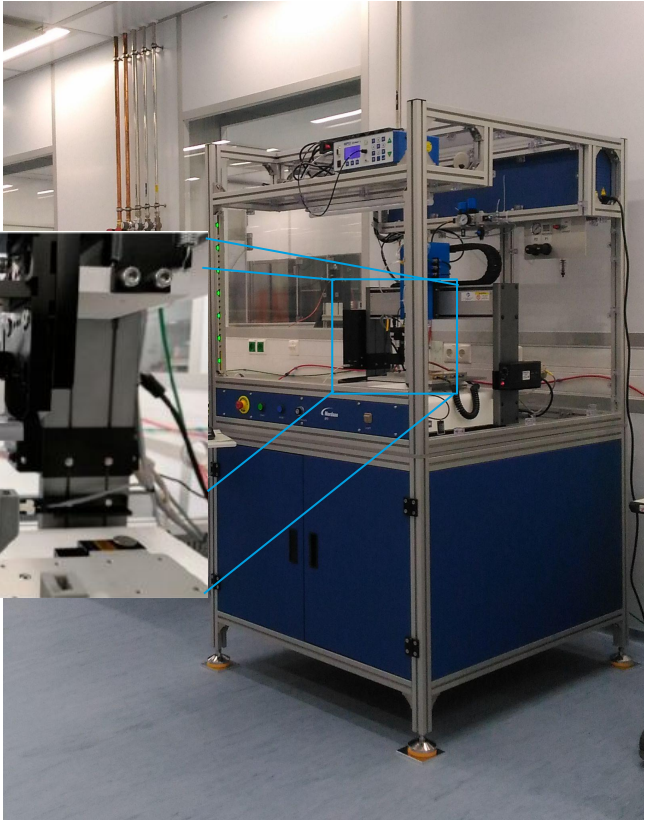# Module building

Highlights

Front-end wirebonds

Dedicated tools for each module type
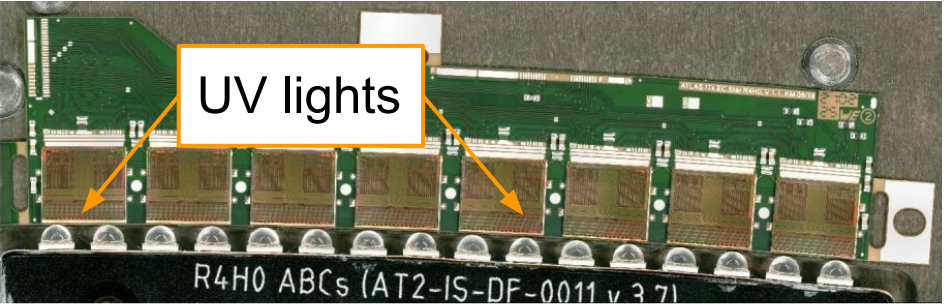
Automated glue application
using programmable robots

Gluing chips onto hybrids
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UV lights
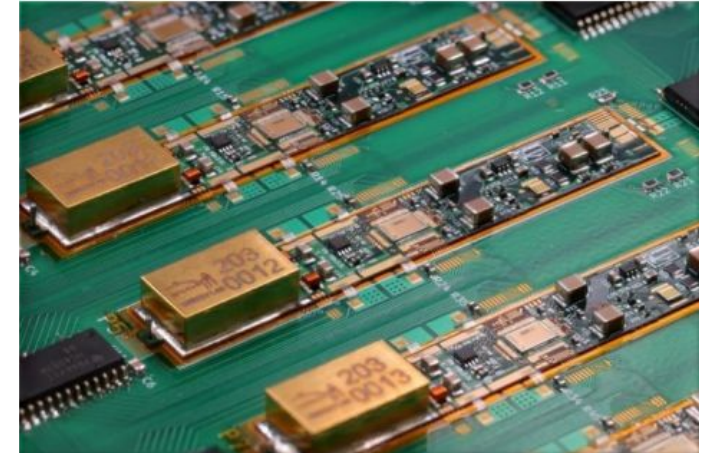
R4H0 ABCs (AT2-IS-DF-0011 v 3.7)

Module QA/QC

Some highlights

Module QA/QC

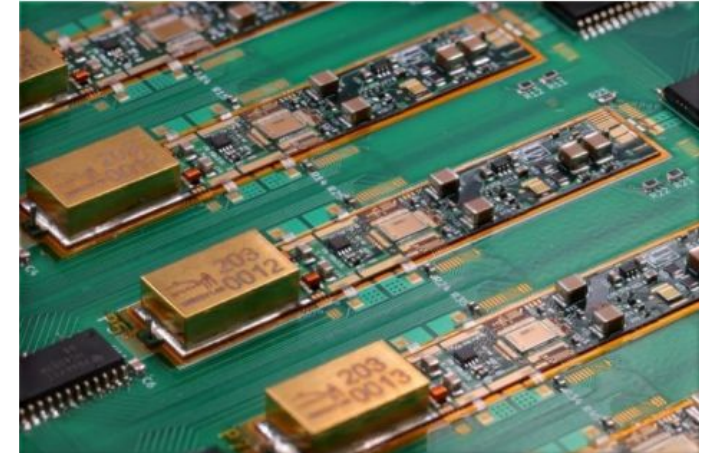## Some highlights

Testing of barrel powerboards on a test panel

Module QA/QC

Some highlights

Testing of barrel powerboards on a test panel

Hybrid testing and burn-in panel

Module QA/QC
Some highlights

Module metrology after the gluing to see that the components are glued in the right places
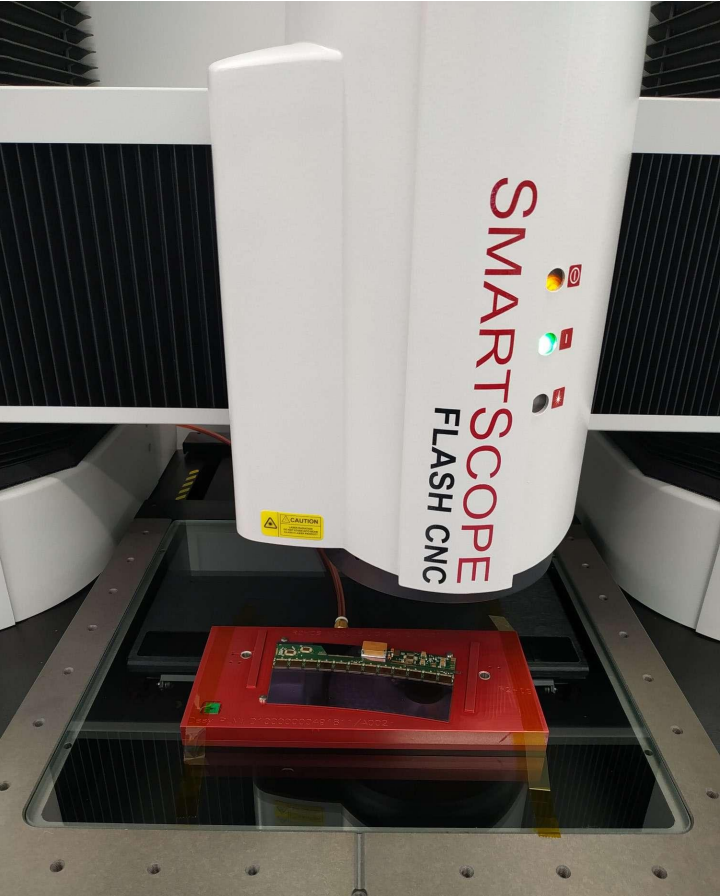

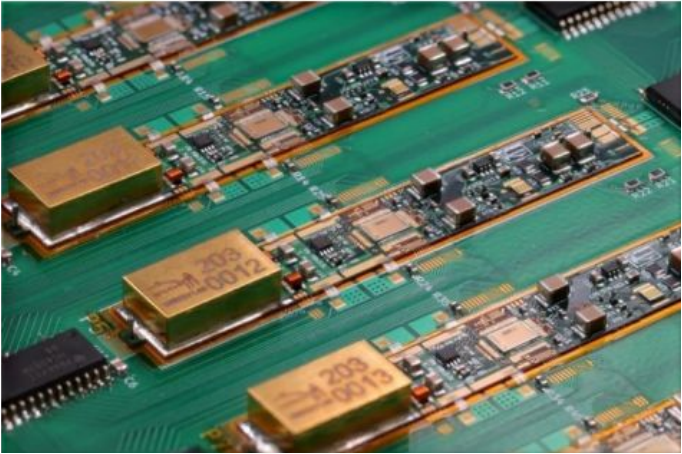Testing of barrel powerboards on a test panel

Hybrid testing and burn-in panel
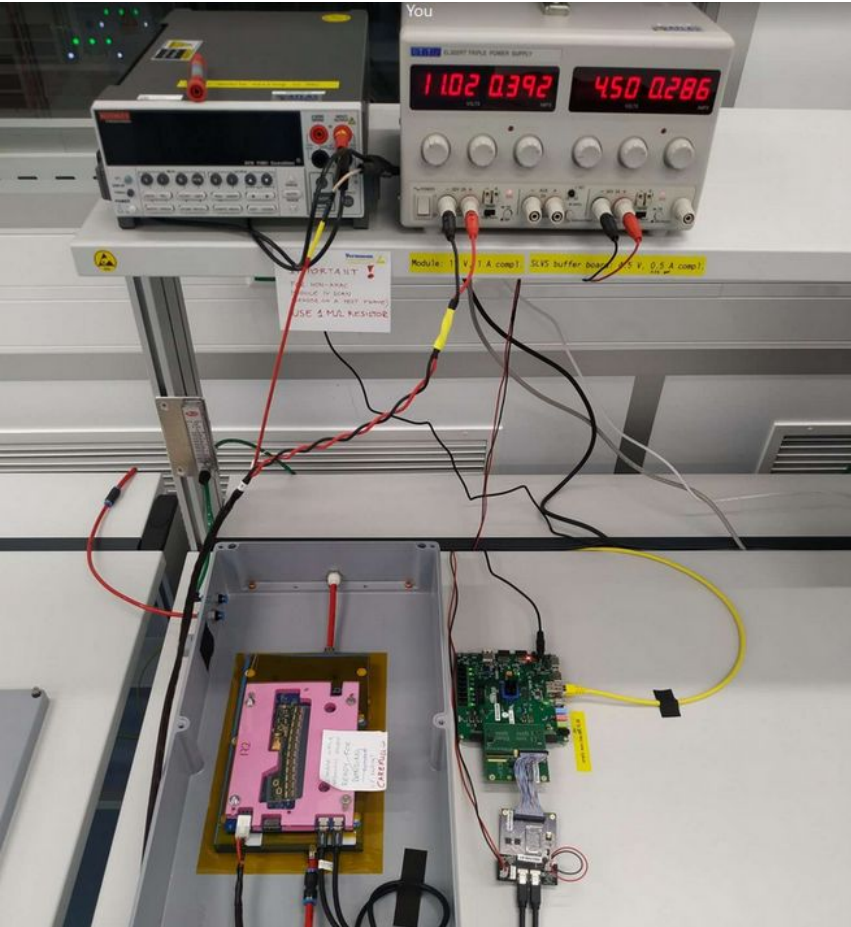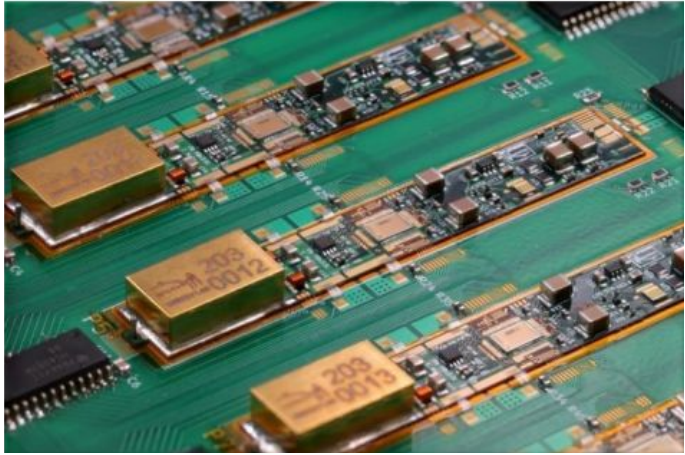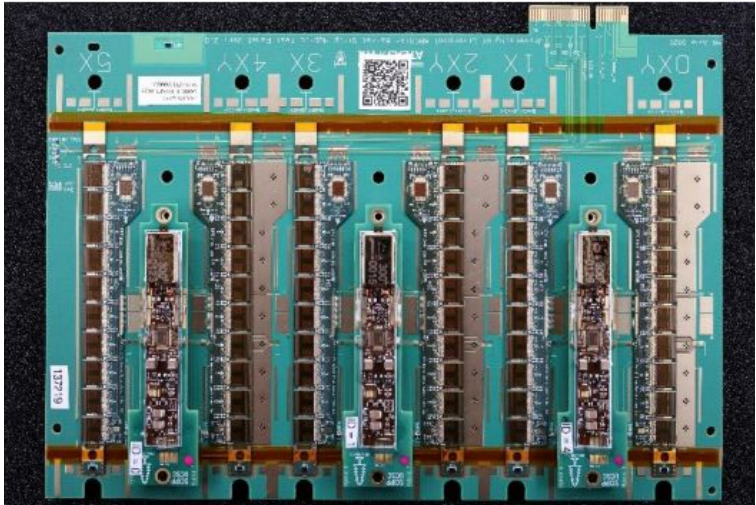
Module QA/QC

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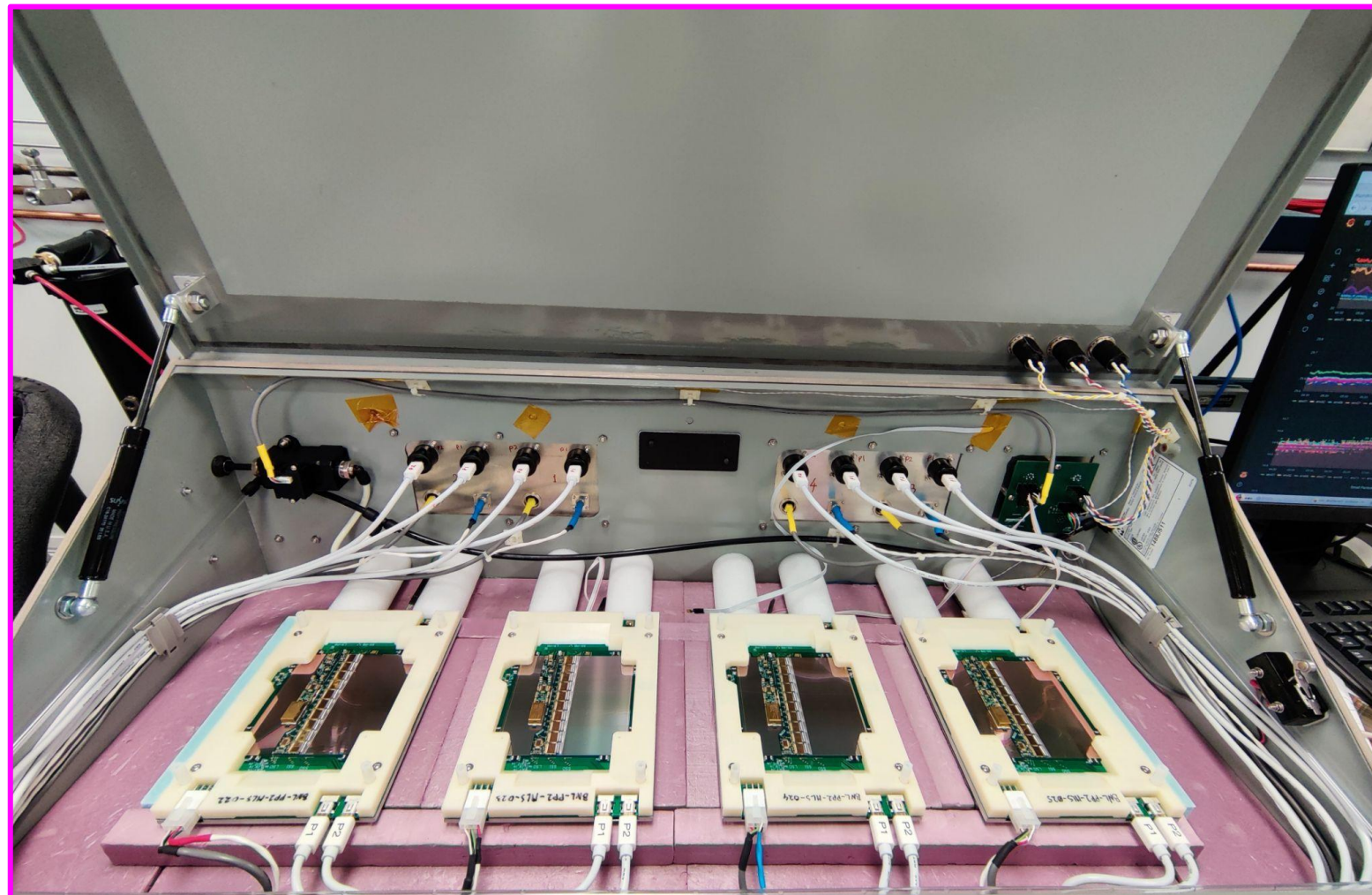Single module testing is done in a light-tight box

Testing of barrel powerboards on a test panel

Hybrid testing and burn-in panel

Module QA/QC

The biggest highlight - Thermal Cycling

Module QA/QC

The biggest highlight - Thermal Cycling
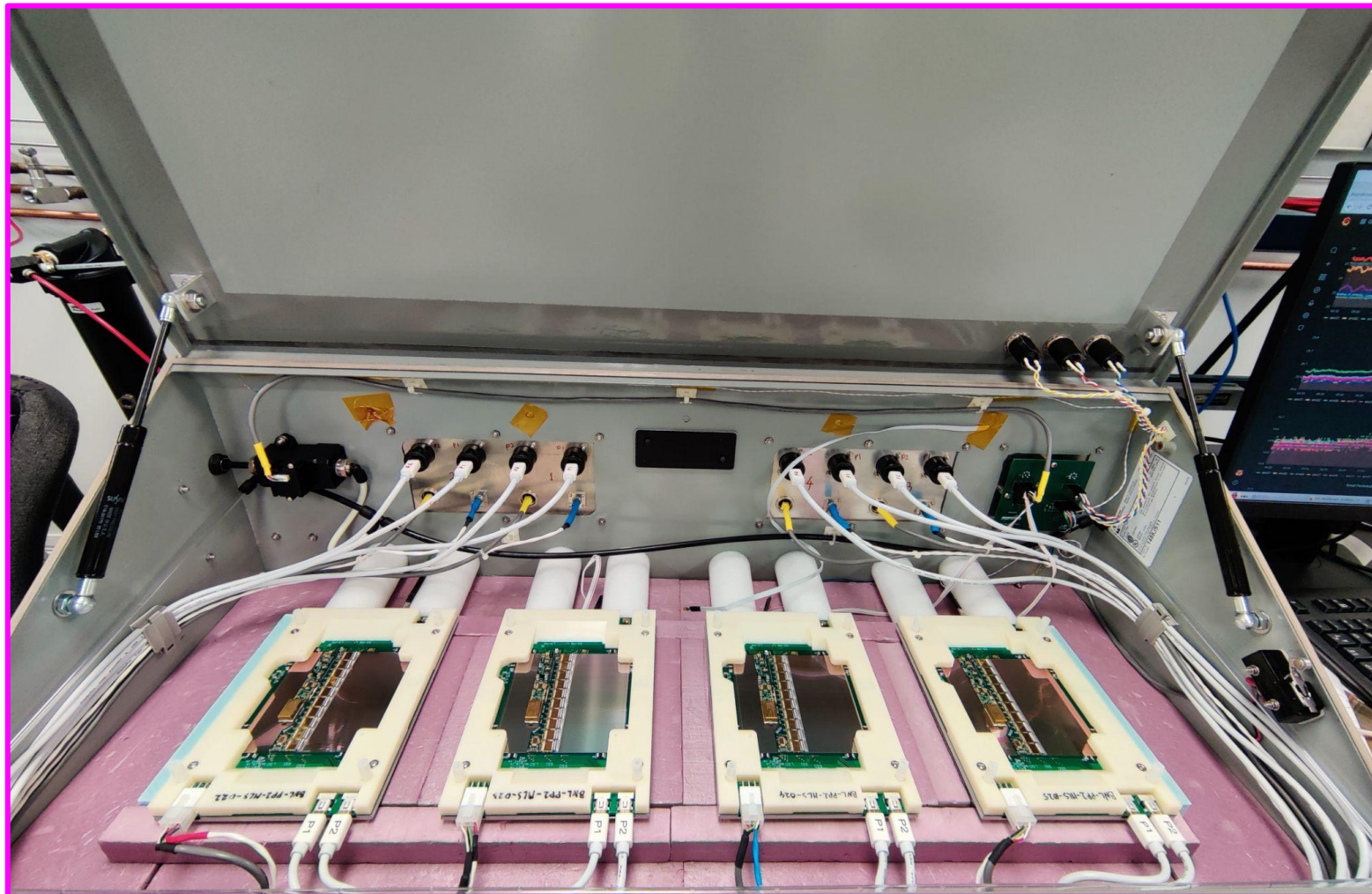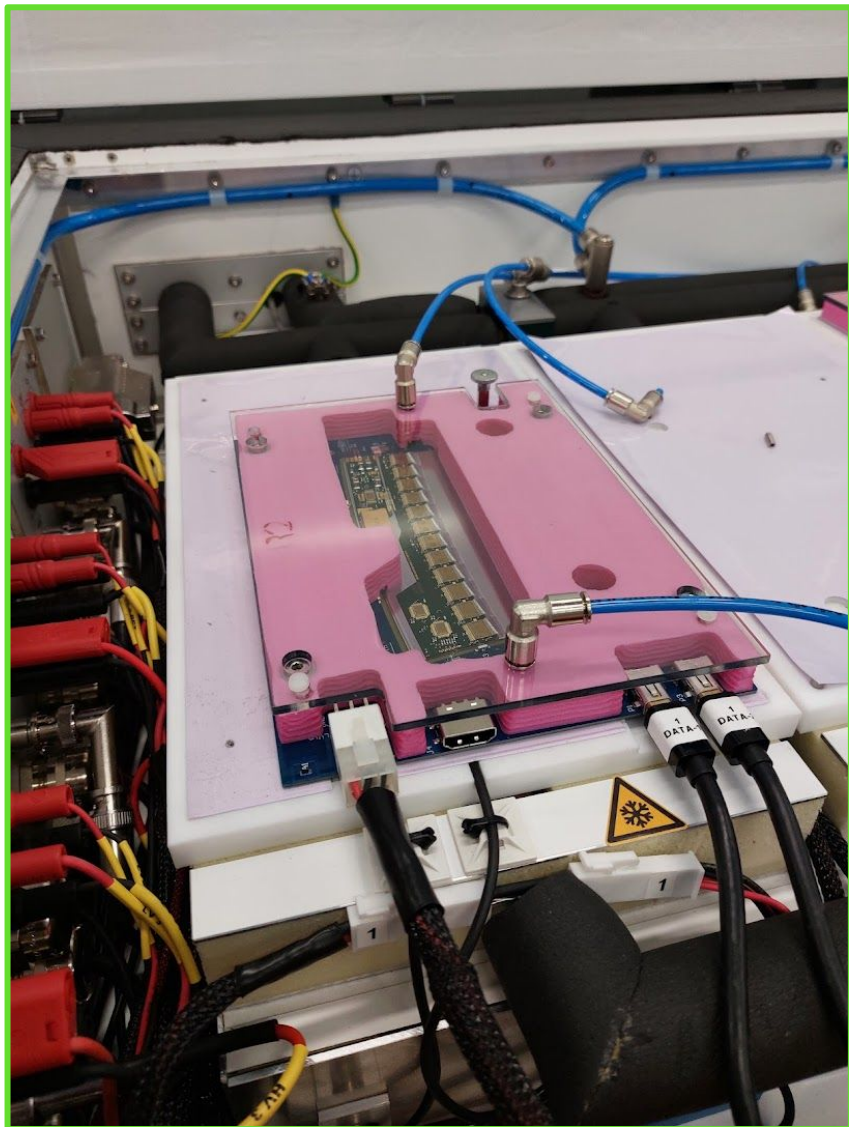
Module QA/QC

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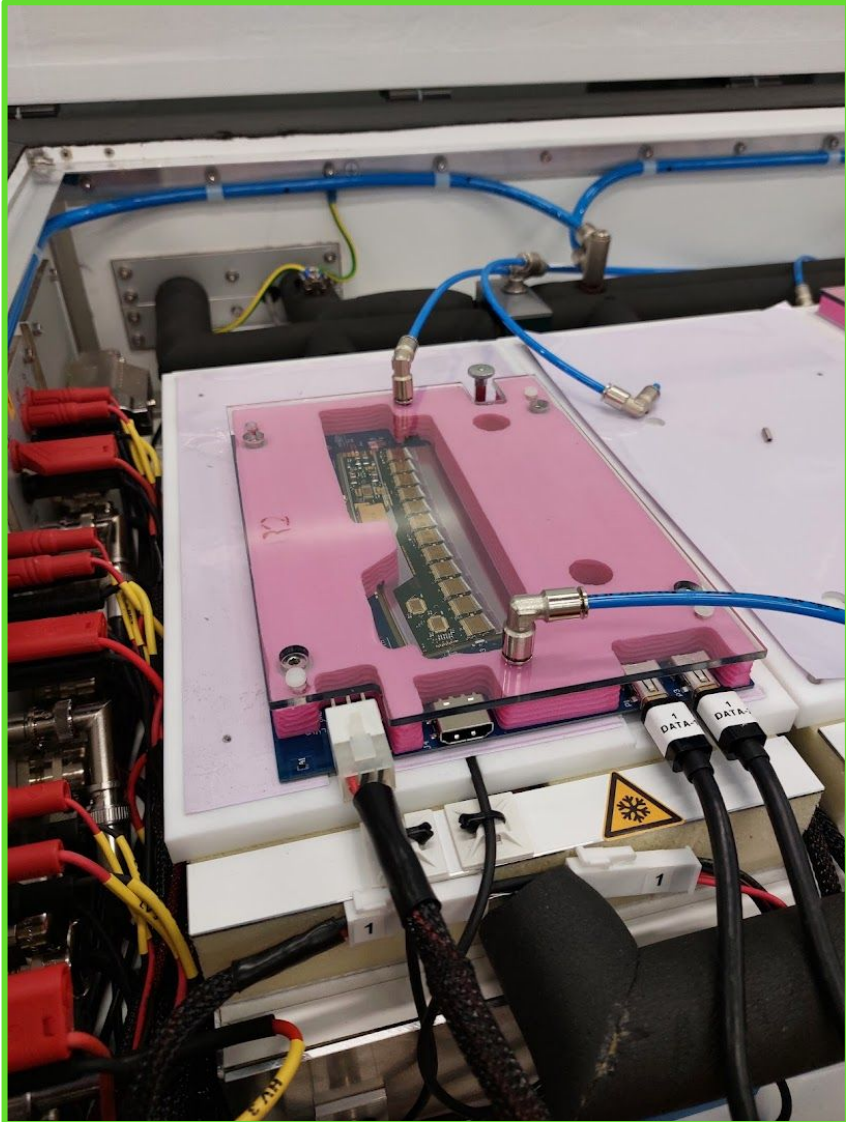
ITk Strips Module QC Thermal Cycle Sequence

12 July 2023

Timing Assumptions

- Module cycled from -35℃ to +20℃
- Fast Warm Up / Fast Cooldown : 30 mins (1 hour total)
- Module test/IV scan/Shunt Test: 10min
- Lab temperature: +22C
- Cool down: 1 hour
- Warm Up to +20C : 1 hour
- Warm characterisation & HV stability : 2 hours
- Final warm up from +20C to +22C : 10 minutes
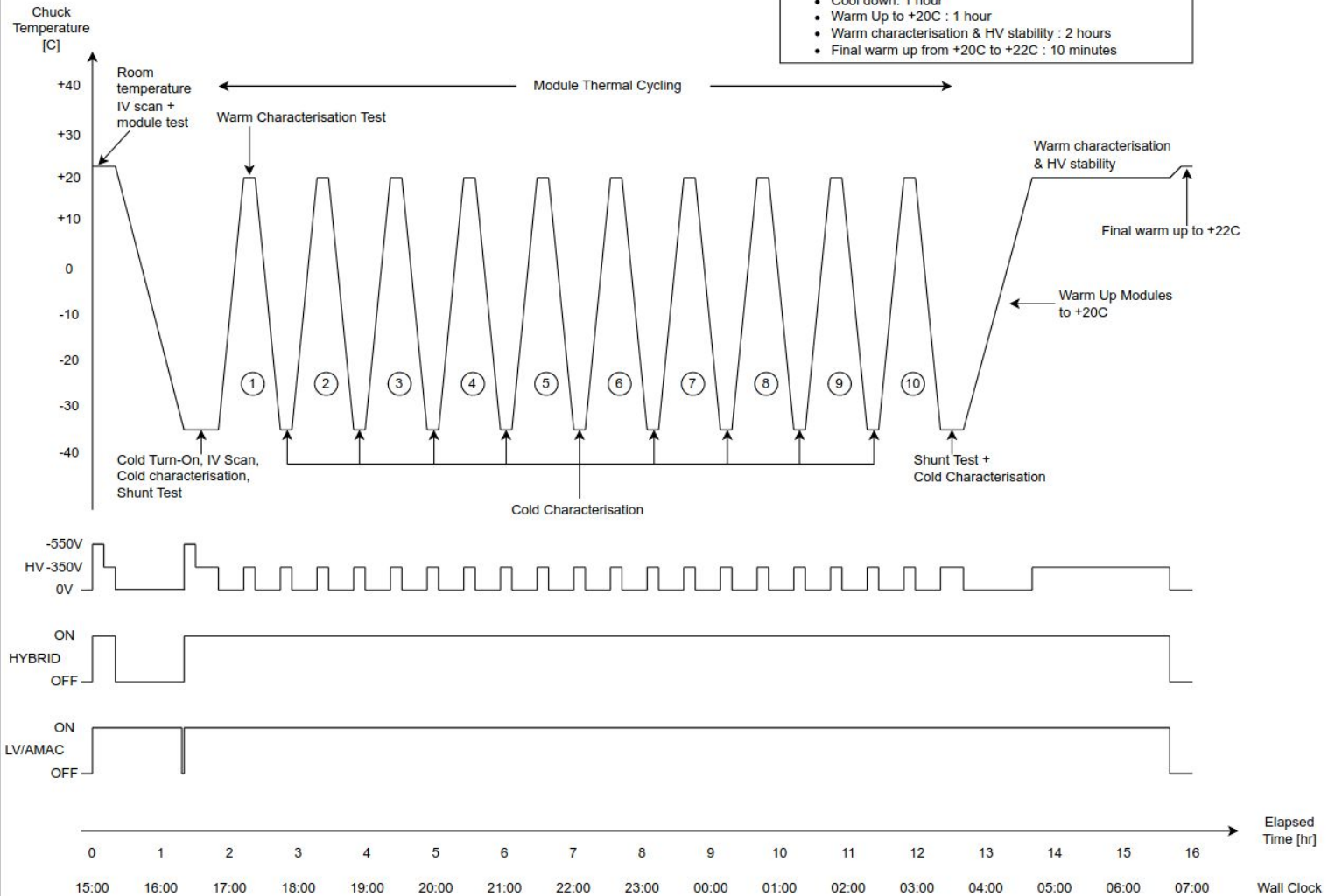
Module loading

Manual and automatic

Barrel staves – manual loading:
- Possible to load several modules at the same time

Module loading

Manual and automatic
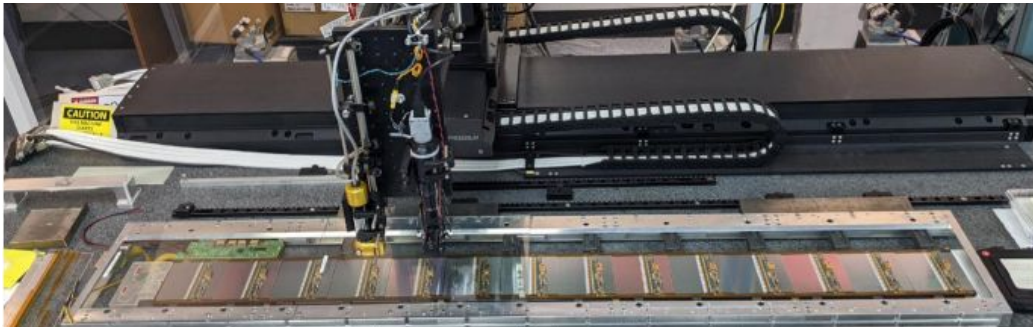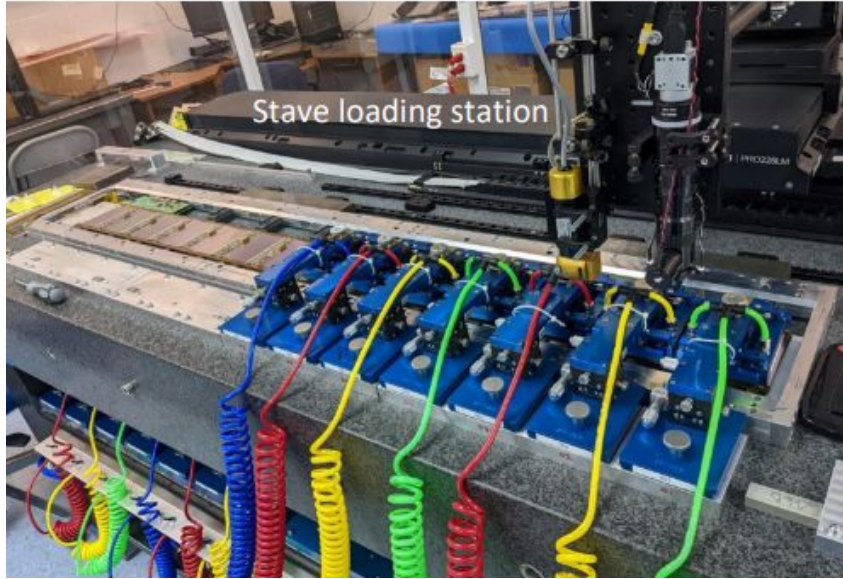
Barrel staves – manual loading:
- Possible to load several modules at the same time

Endcap petals – automated loading:
- Modules are loaded only one by one

Module loading

Manual and automatic

Stave loading station

Barrel staves – manual loading:
- Possible to load several modules at the same time

Vacuum tools

Assembly frame

Gantry Camera System
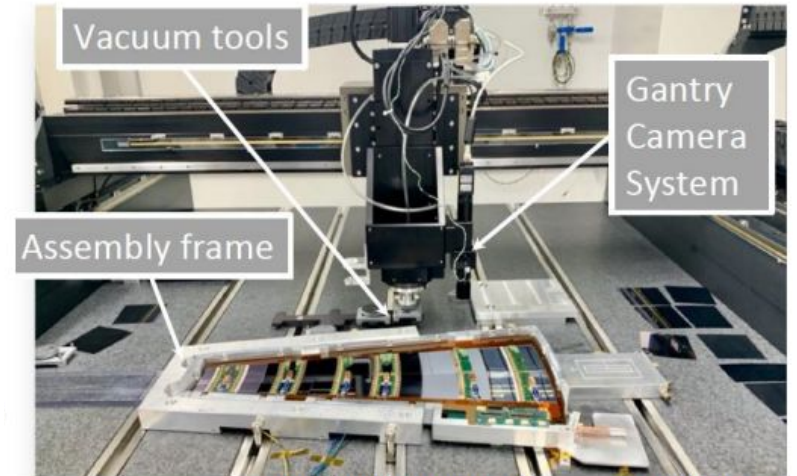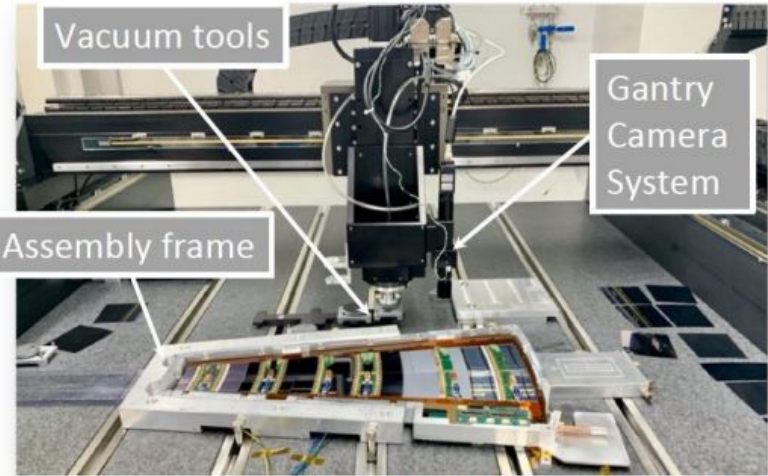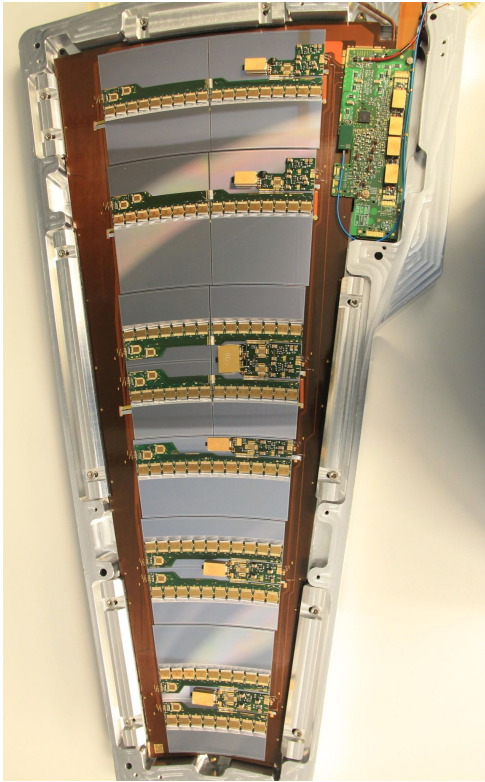
Petal loading gantry

Endcap petals – automated loading:
- Modules are loaded only one by one
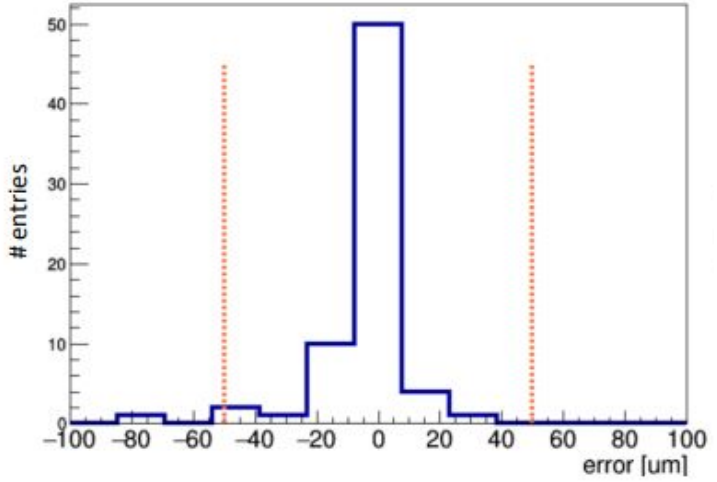
High precision achieved with both methods

Global structures and integration

Inserting staves and petals into global structures

Stave insertion tool

Petal insertion tool

- Barrel integration at CERN
- Endcap integration at DESY and Nikhef
- Insertion of staves and petals using special insertion tools

Where are we now?

In the middle of production!

Production status:

- Sensors – <mark>ongoing</mark>
- ASICs – <mark>almost finished</mark>
- Modules – <mark>about to start</mark>
- Local supports – <mark>ongoing</mark>
- Global structures – <mark>ongoing</mark>
- Integration – <mark>ready to start</mark>

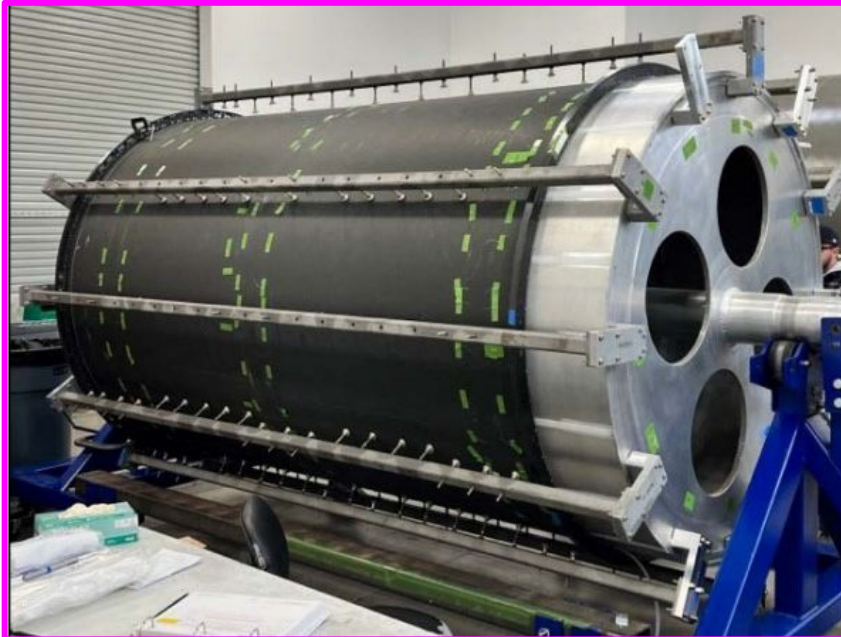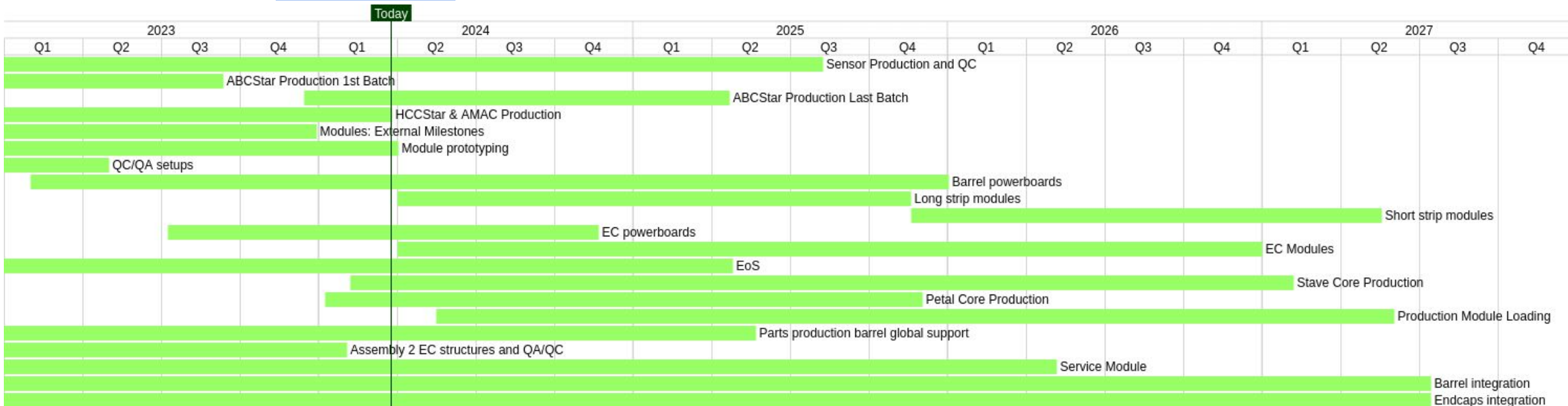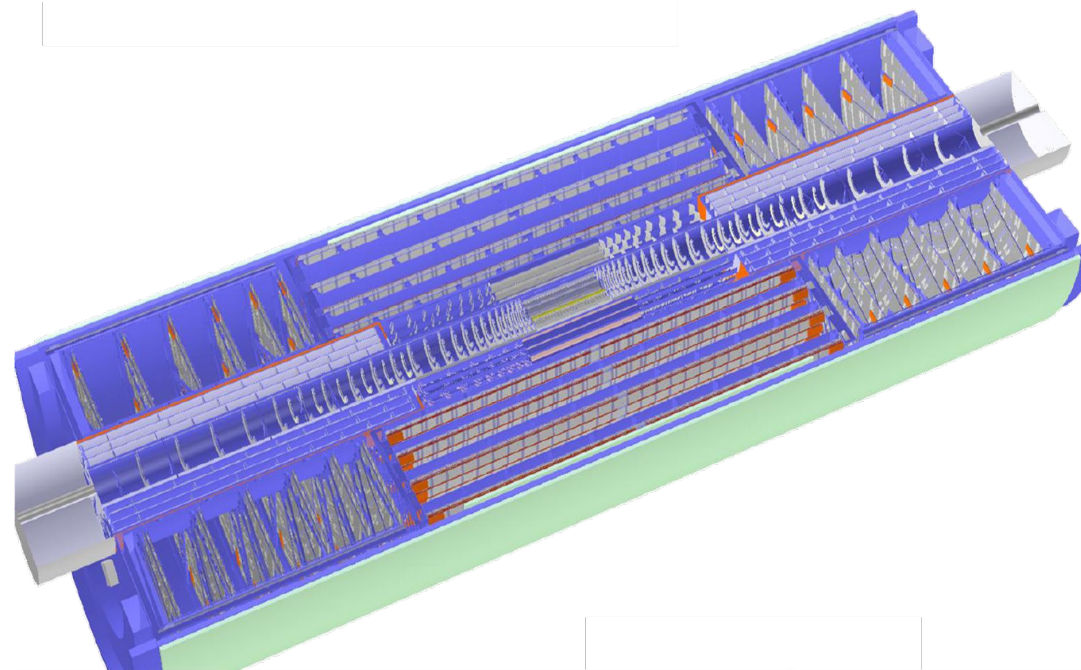

Gantt chart timeline (2023–2027):

- Sensor Production and QC
- ABCStar Production 1st Batch
- ABCStar Production Last Batch
- HCCStar & AMAC Production
- Modules: External Milestones
- Module prototyping
- QC/QA setups
- Barrel powerboards
- Long strip modules
- Short strip modules
- EC powerboards
- EC Modules
- EoS
- Stave Core Production
- Petal Core Production
- Production Module Loading
- Parts production barrel global support
- Assembly 2 EC structures and QA/QC
- Service Module
- Barrel integration
- Endcaps integration

Summary
ATLAS ITk Strips

- ATLAS ITk – fully silicon tracking detector that will replace the current Inner Detector before HL-LHC
  - High granularity
  - High radiation hardness
  - High readout speed
- ITk strips is a complex system, requiring production of multiple components, strict quality control and a lot of effort from multiple institutions worldwide
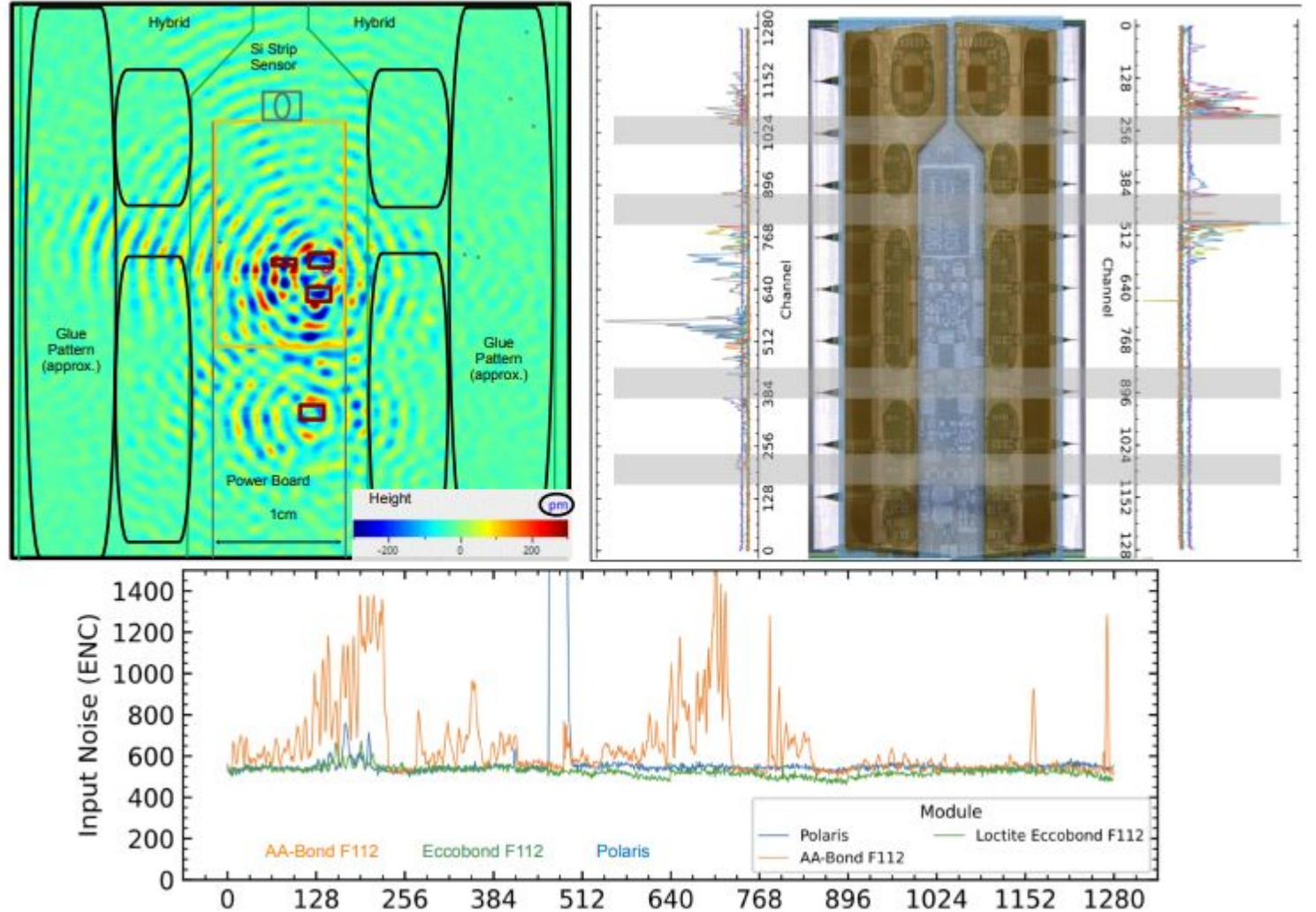- Production has already started for multiple components of the detector
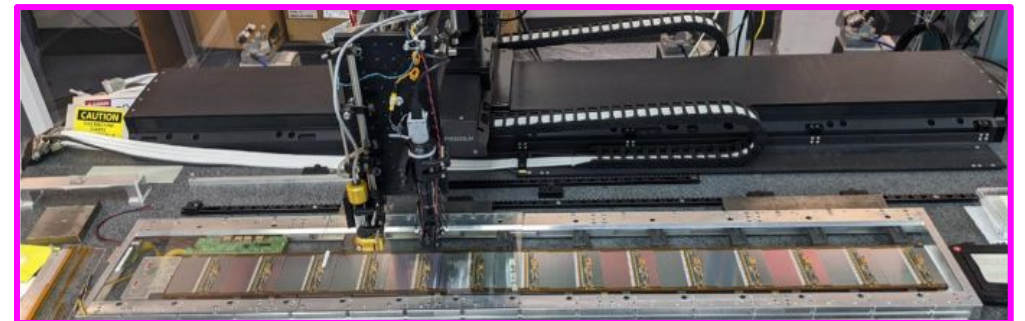
Backup

Cold noise

Mitigation already in place

- Before production some modules showed increased noise when cooled down
- The issue linked to vibrating powerboard capacitors
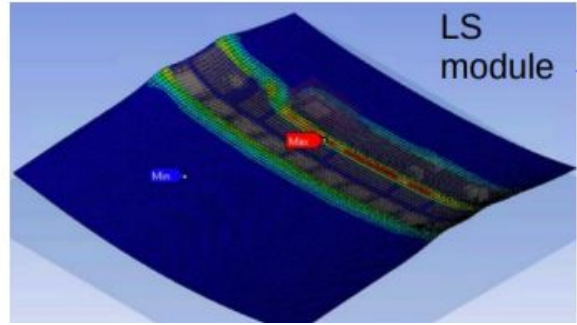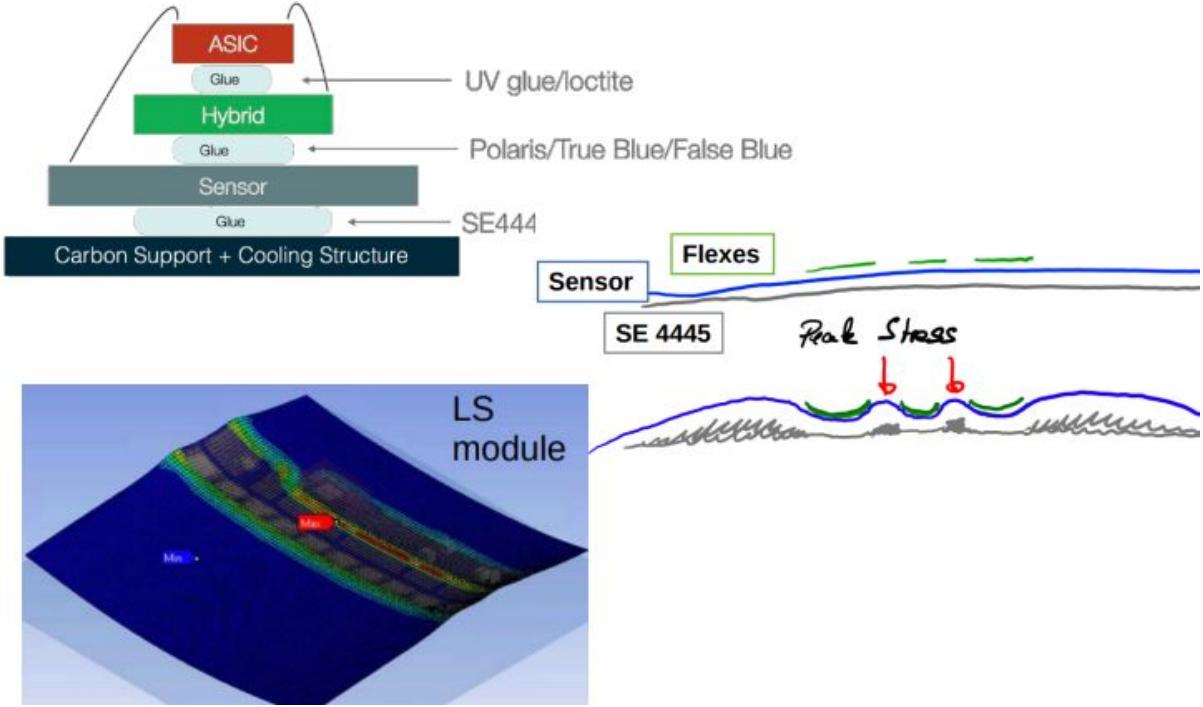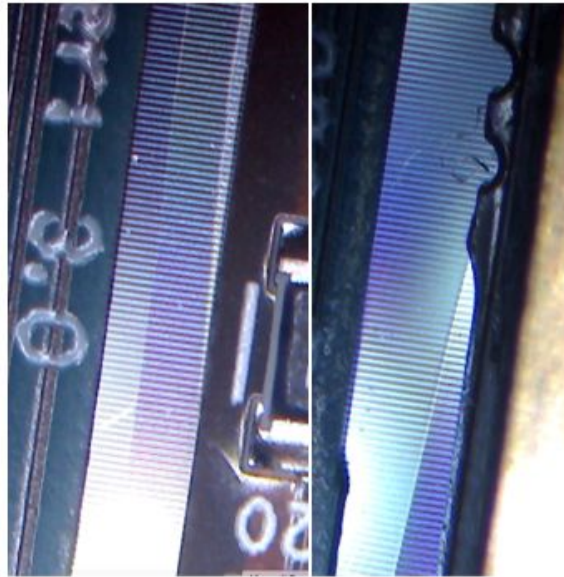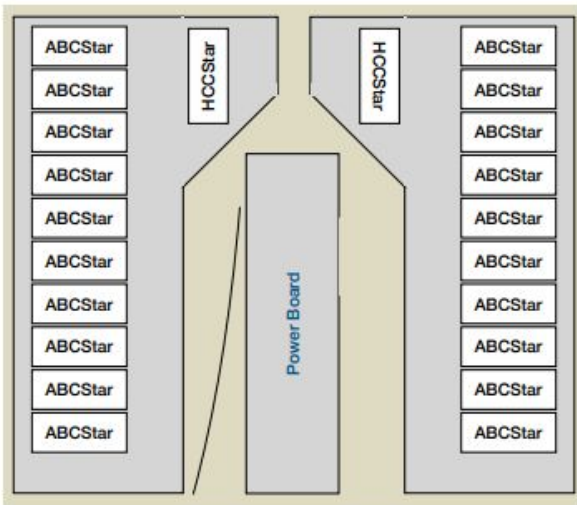- Mitigation: changing the glue to minimize vibrations that reach the sensor

Source: slides by George Iakovidis at HSTD13

Sensor cracking

Studies ongoing

- During cold tests of global structures (staves and petals) sensors crack
- Studies are ongoing, simulation indicates CTE mismatch between the components
- Different stiffness of glue below and above sensor

Source: slides by George Iakovidis at HSTD13