# ATLAS ITk Pixel Detector Overview

TIPP2021

**Francisca Muñoz Sánchez**
On behalf of the ATLAS ITk Pixel collaboration
The University of Manchester

27th May 2021

# Outline

- Introduction
- ITk pixel layout
  - Mechanics
    - Design
    - Prototypes
  - Services
- Modules flavours
- Power and data Transmission
- Demonstrators
- Next Steps

# Don’t miss them!

**Poster on the Opto system for data transmission earlier today:**

- The Opto-electrical conversion system for the data transmission chain of the ATLAS ITk Pixel detector upgrade for the HL-LHC. Laura Franconi.

**Talk on the ITk Strip detector later today:**

- The ATLAS ITk Strip Detector System for the Phase-II LHC Upgrade. Karol Krizka.

**Talk on 3D sensors and radiation hardness later today:**

- Performance of radiation hard 3D pixel sensors for the upgrade of the ATLAS Inner Tracker. Stefano Terzo.

**Talk on irradiation studies on DAQ components later in this session:**

- Irradiation studies at the Bern Cyclotron for the ATLAS ITk Upgrade. Lea Halser.

**Poster session last Tuesday:**

- RD53 wafer testing for the ATLAS ITk pixel detector. Mark Standke.

**Poster session yesterday:**

- Testbeam studies of ATLAS ITk strip modules at DESY-II testbeam facility. Marco Valente.
- Evaluation a multi-module demonstrator for the ITk Pixel Outer Barrel for the ATLAS Phase-II upgrade. Gerhard I. Brandt.
- Module development for the ATLAS ITk Pixel Detector. Abhishek Sharma.

**Poster session today:**

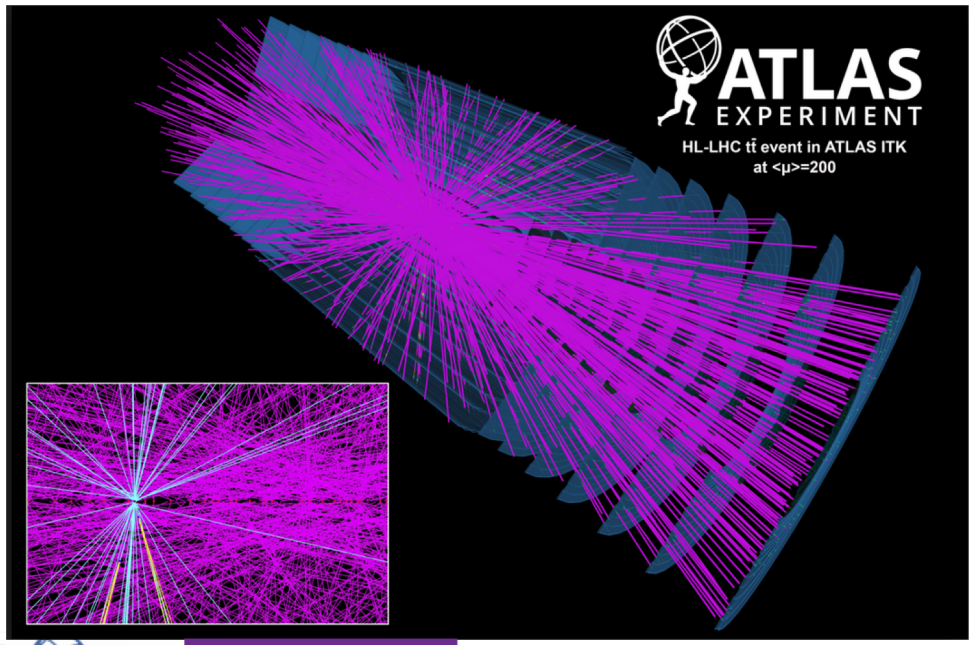
- Monitoring System of the ATLAS ITk Laboratory. Martin Sykora.
- The Monitoring of Pixel System (MOPS) chip for the Detector Control System of the ATLAS ITk Pixel Detector. Rizwan Ahmad.

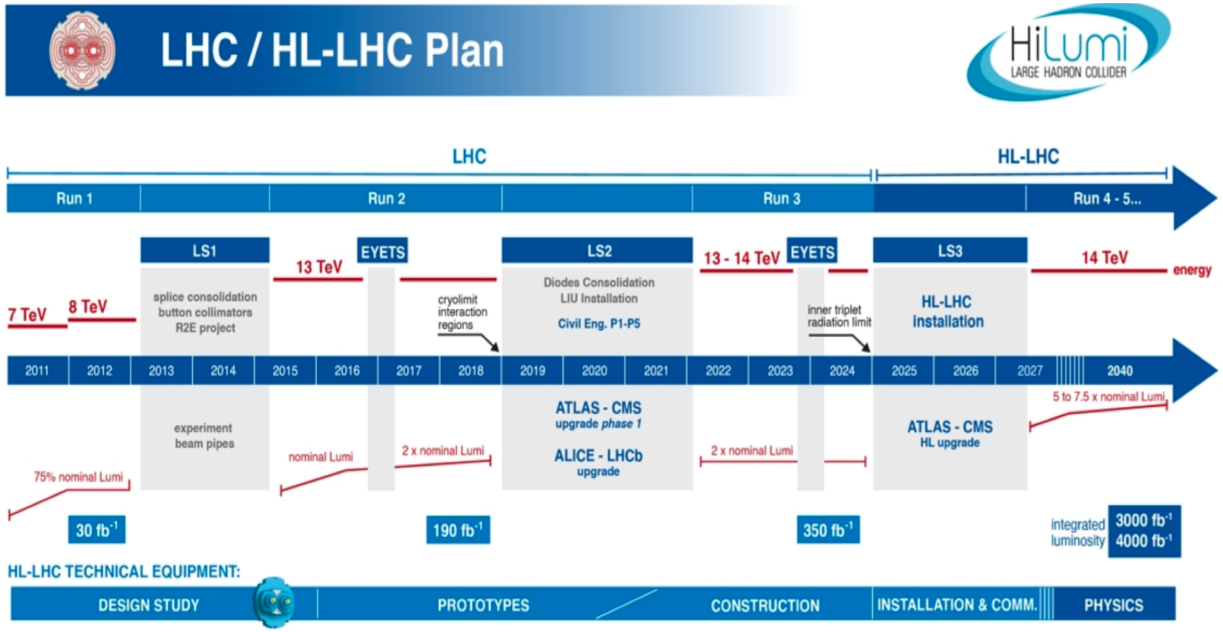
ATLAS ITk MANCHESTER 1824 The University of Manchester

# Introduction

- The LHC will upgrade to the High-Luminosity-LHC (HL-LHC) in 2027 (schedule here)

- The current **ATLAS inner detector** will upgrade to cope with:
  - The peak luminosity: $\mathcal{L}_{\text{HL-LHC}} = \mathbf{7.5} \times \mathcal{L}_{\text{LHC}} = 7.5 \times 10^{34}\ \text{cm}^{-2}\ \text{s}^{-1}$
  - The average pile-up: $\langle\mu\rangle_{\text{HL-LHC}} \sim \mathbf{8} \times \langle\mu\rangle_{\text{LHC}} \sim 200$
  - Integrated luminosity: $L_{\text{HL-LHC}} = \mathbf{10\text{-}13} \times L_{\text{LHC}} = 3000 - 4000\ \text{fb}^{-1}$
  - Radiation hardness: $\phi_{\text{HL-LHC}} = \mathbf{20} \times \phi_{\text{LHC}} = 2 \times 10^{16}\ n_{eq}/\text{cm}^2$



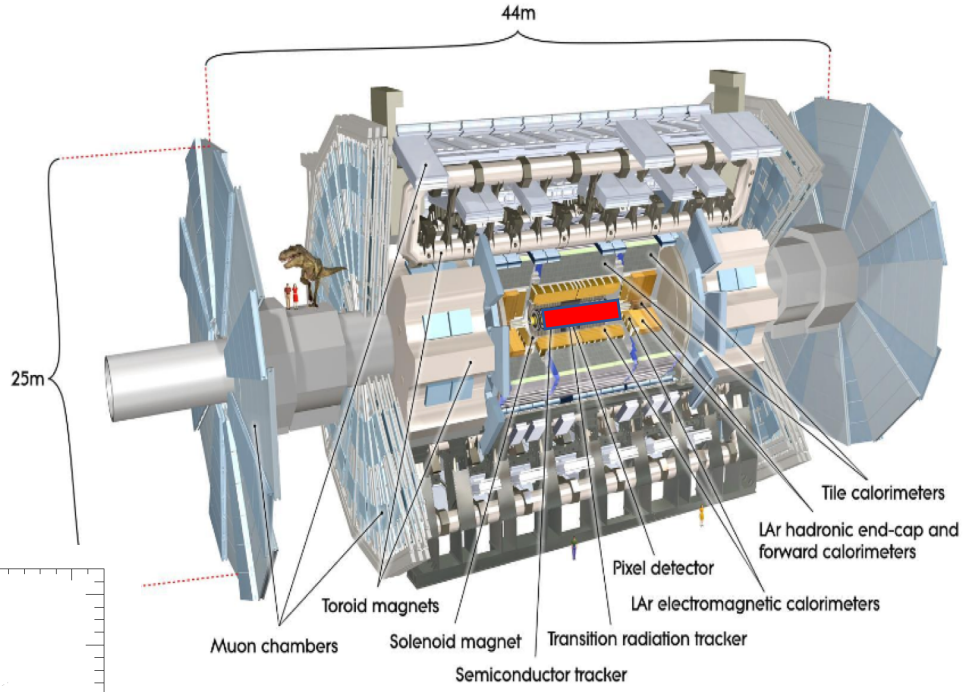

The **new ATLAS inner tracker (ITk) pixel detector** will require:

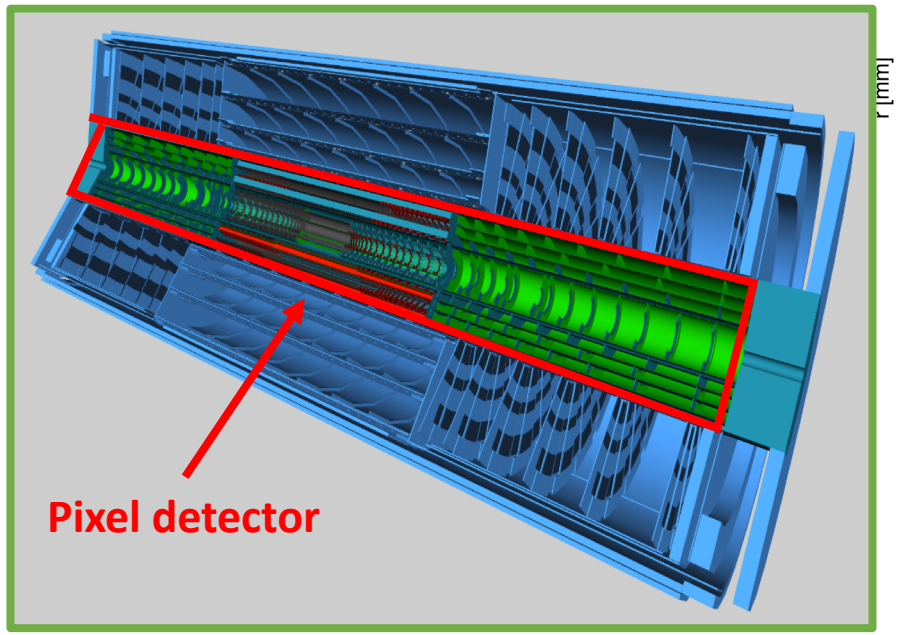
- Increased **Radiation Hardness** (sensor, chip, cables, mechanics…etc)
- Higher **Granularity** - Smaller pixel segmentation
- Higher **data rate** capabilities
- **Evaporative Cooling plant** delivering CO2 at **-35 C** to the pixel system

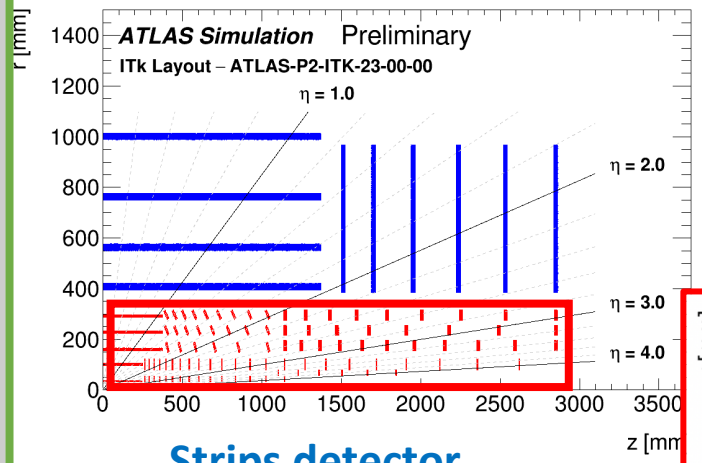
ATLAS ITk
MANCHESTER 1824
The University of Manchester

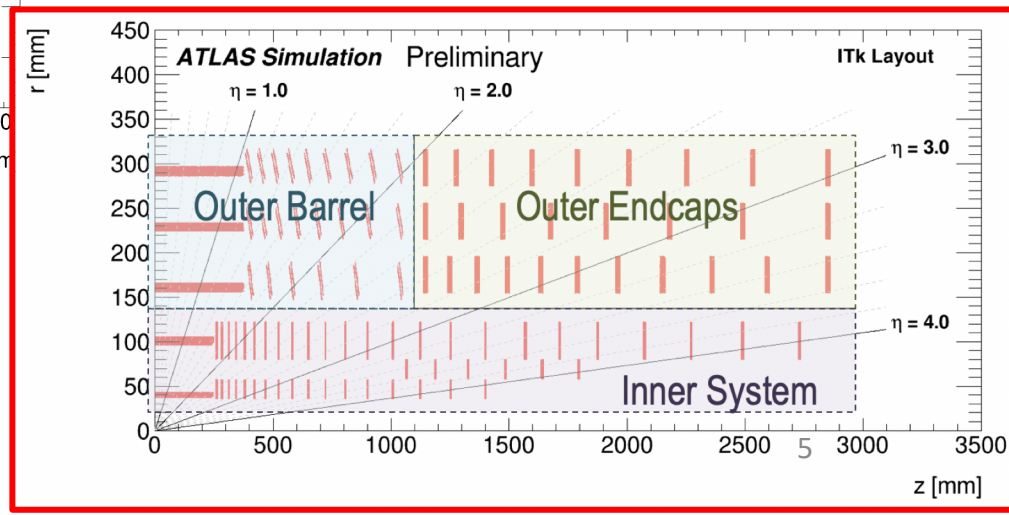
# ATLAS ITk layout

- Pixel Inner Detector - 2 layers replaceable. (Si)
- Pixel Outer detector - 3 layers (Si).
- Strips Detector - 4 layers (Si)
- coverage up to $|\eta| = 4.0$
- Details on the ITk layout and performance: ATL-PHYS-PUB-2019-01



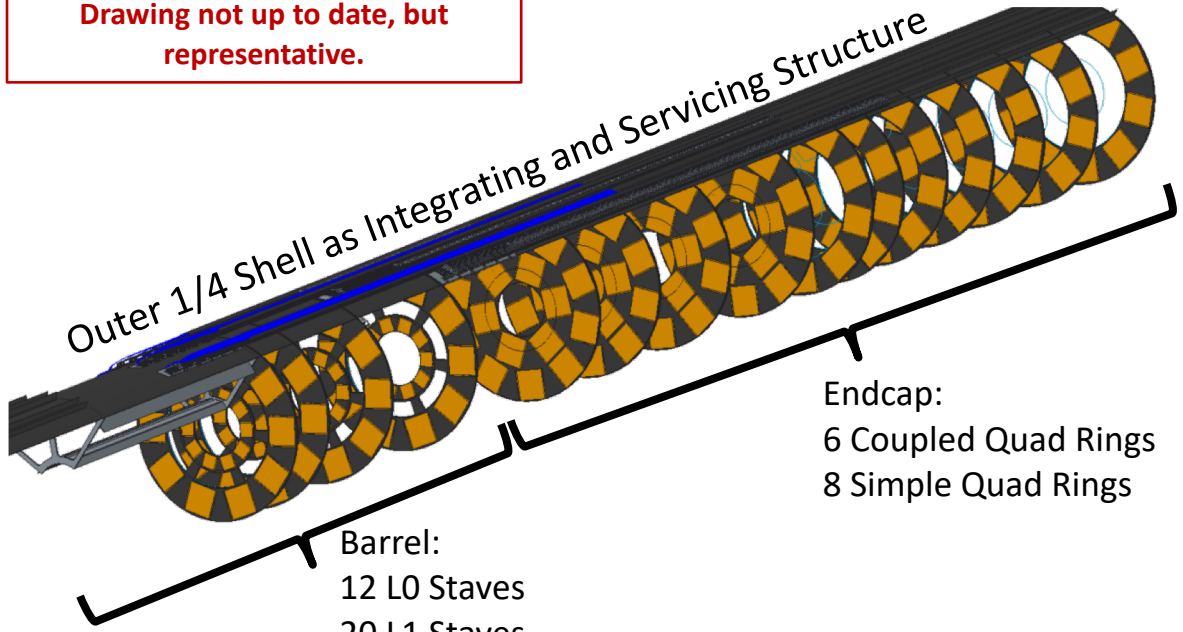






MANCHESTER 1824
The University of Manchester

# ATLAS ITk Pixel supports: IS design

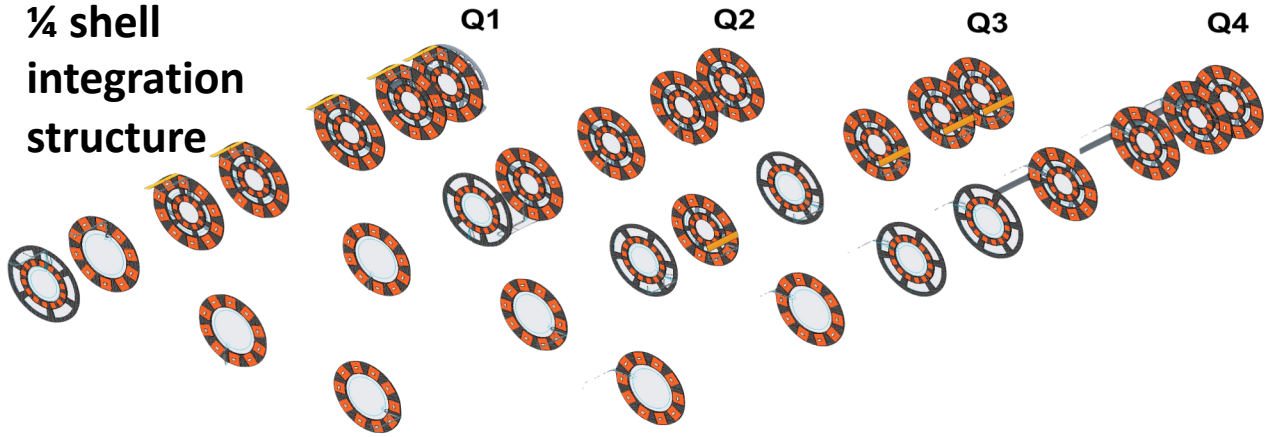
**Drawing not up to date, but representative.**

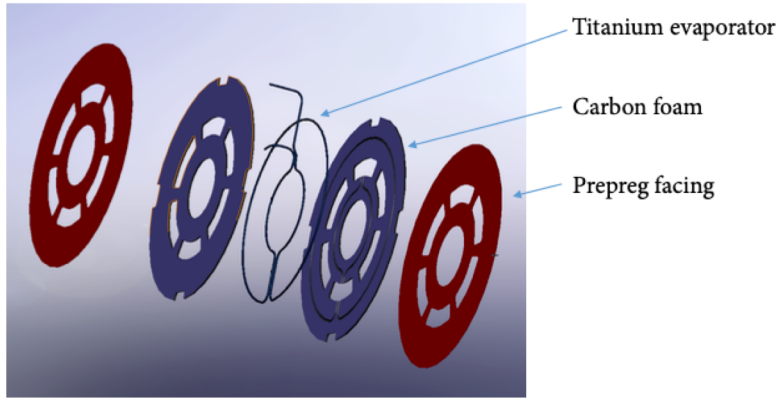


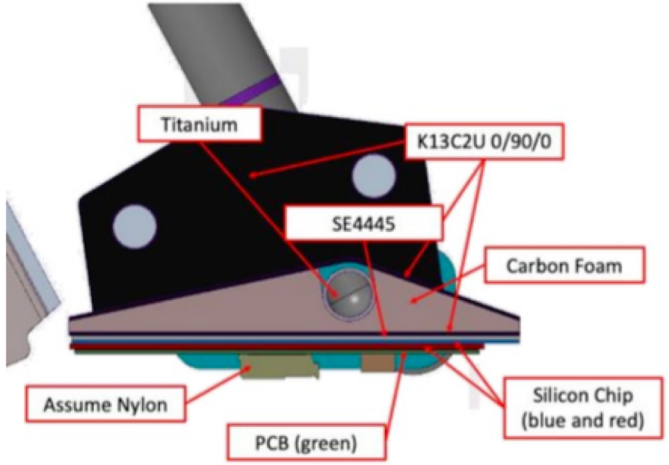

Endcap:
6 Coupled Quad Rings
8 Simple Quad Rings

Barrel:
12 L0 Staves
20 L1 Staves
15 L0/L1 Coupled Rings *(4 shown here for clarity)*

**¼ shell integration structure**

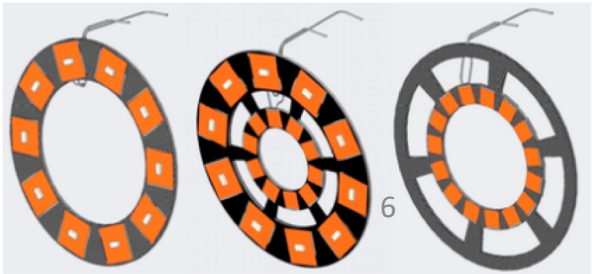


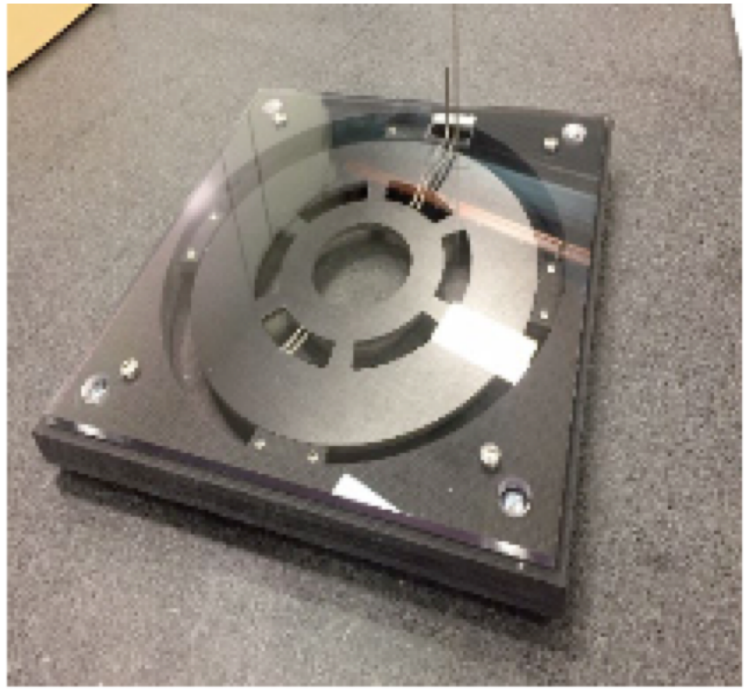

**Two flavours of staves**

**29 rings**
**Three flavours**

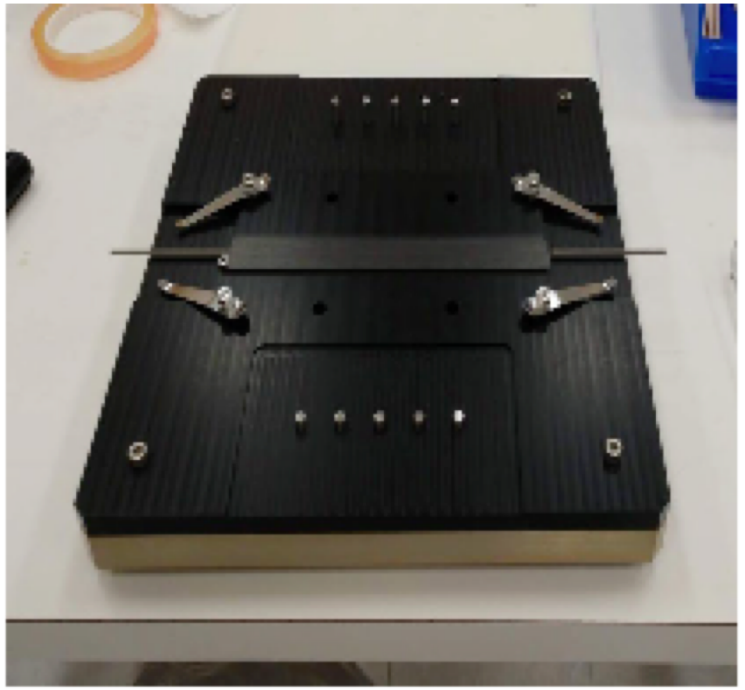


# ATLAS ITk Pixel supports: IS prototypes

Prototype 0



Prototype 19-0 (R0/1)

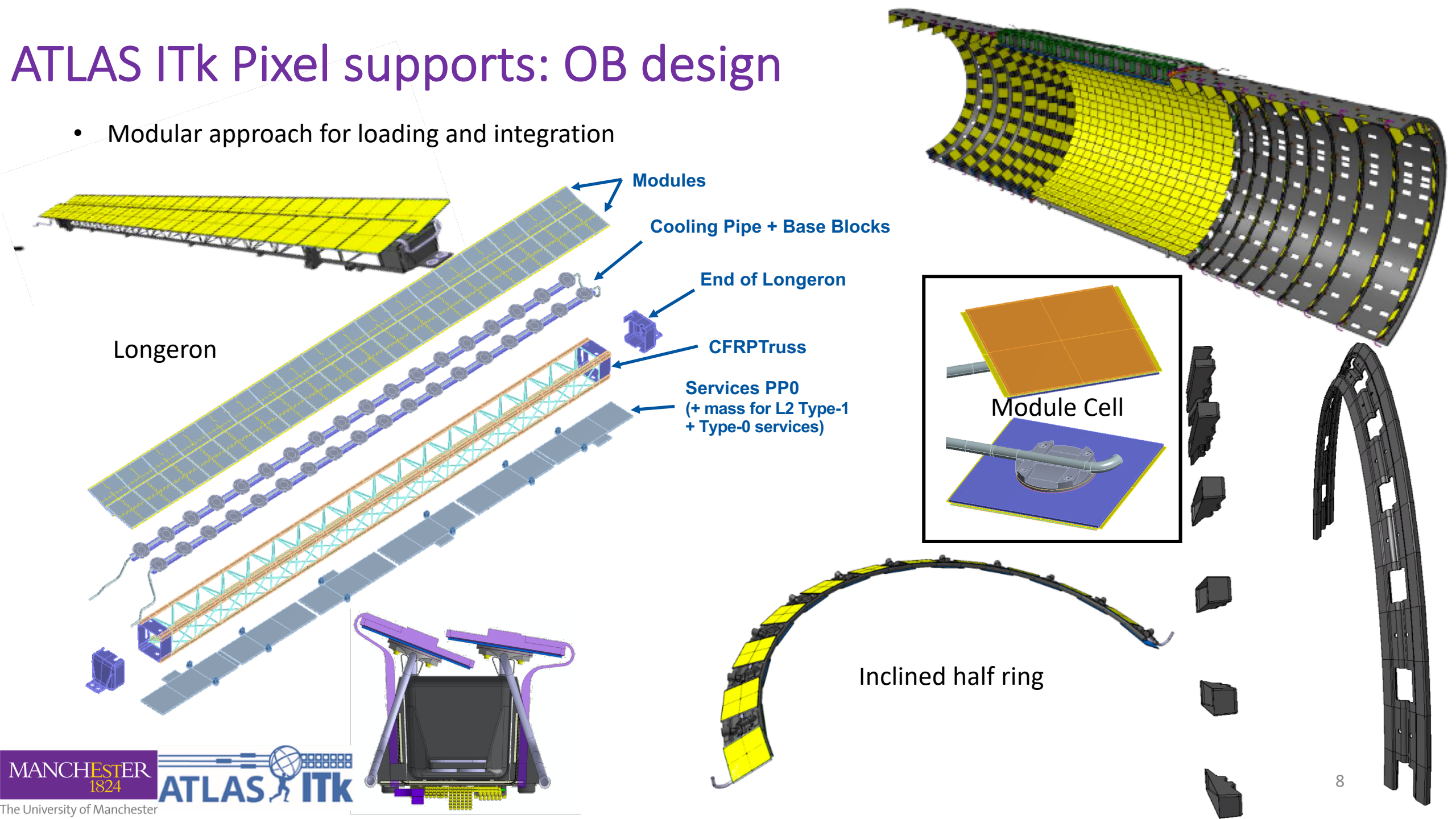


Prototype 19-0 (L0)

Extensive Thermo-mechanical FEA and tests are ongoing

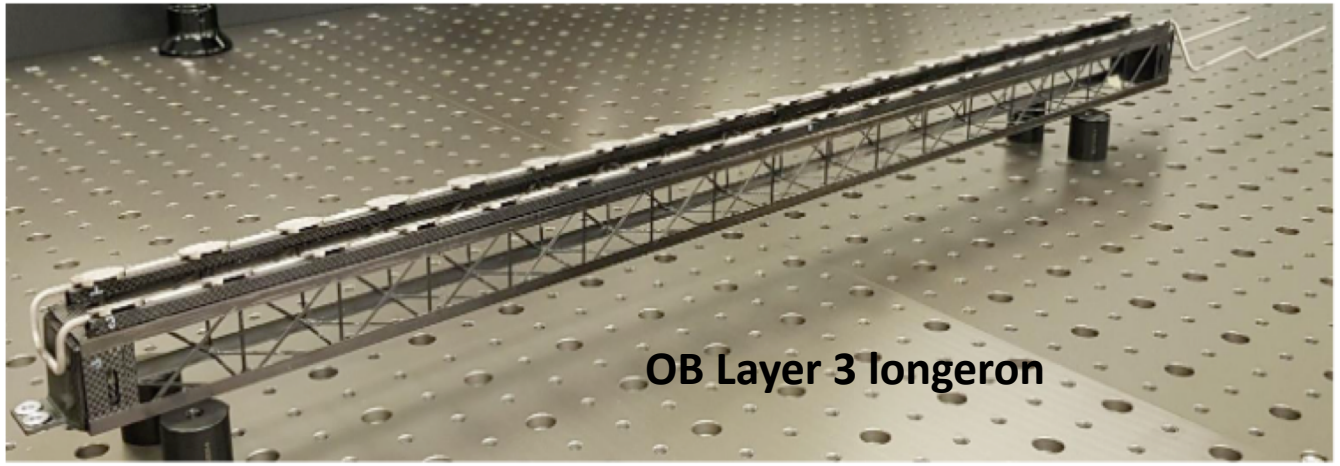
# ATLAS ITk Pixel supports: OB design

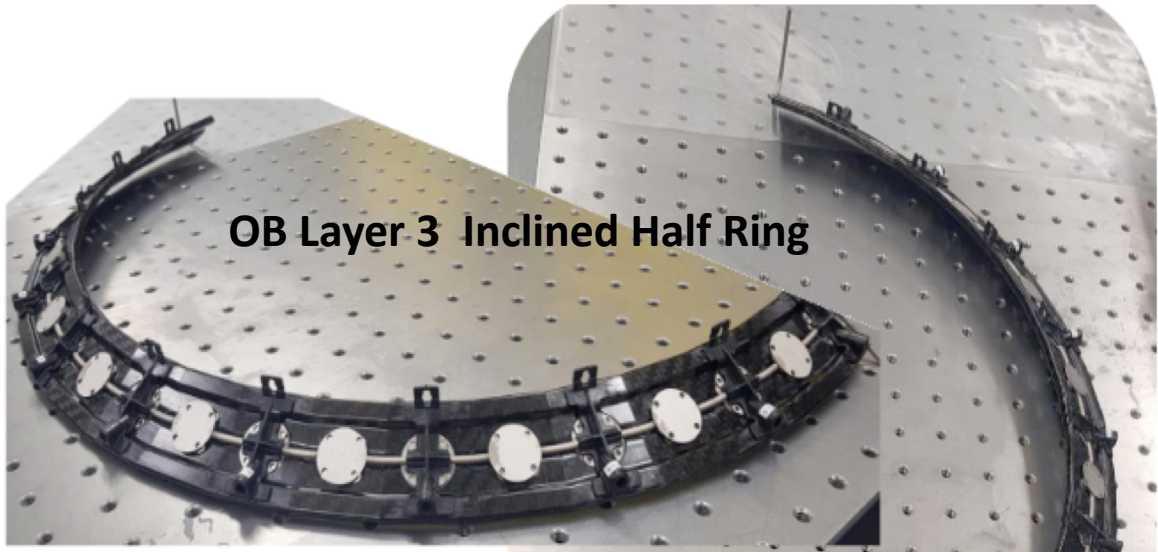
- Modular approach for loading and integration

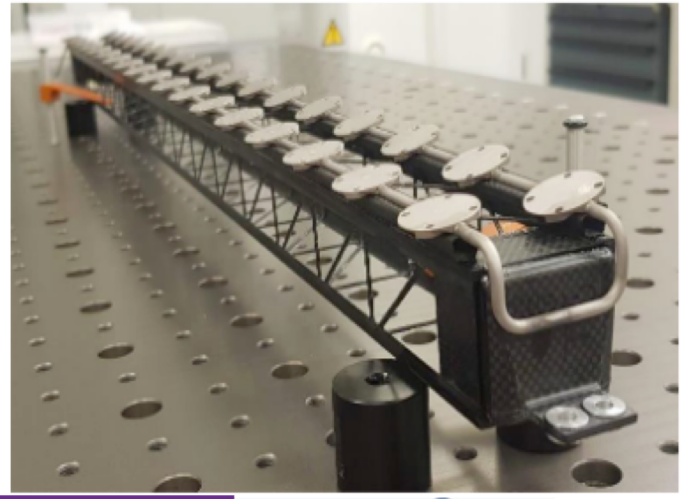


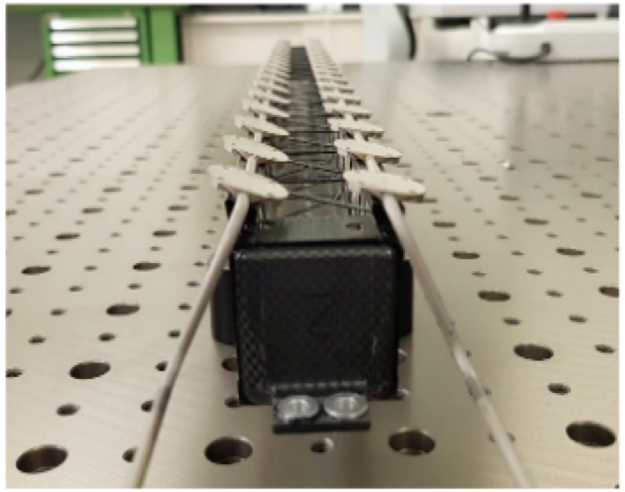
# ATLAS ITk Pixel supports: OB prototypes

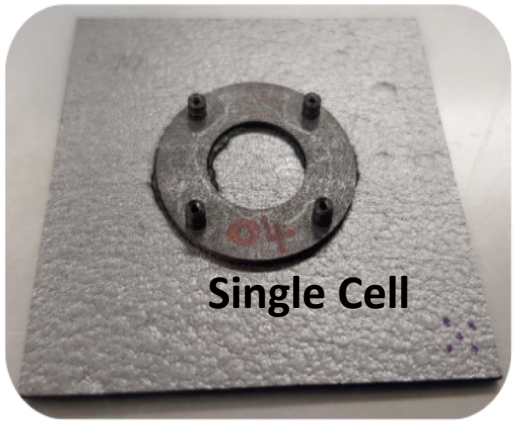
Full size Layer- 3 longeron and Inclined half ring for the outer barrel. Modular approach for the local support, it allows total re-workability by replacing single cell

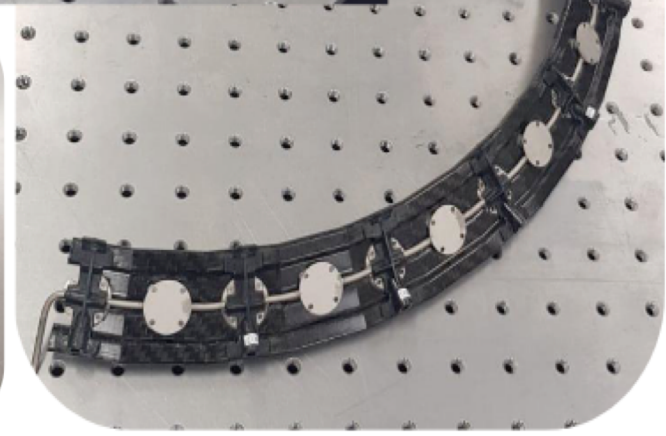






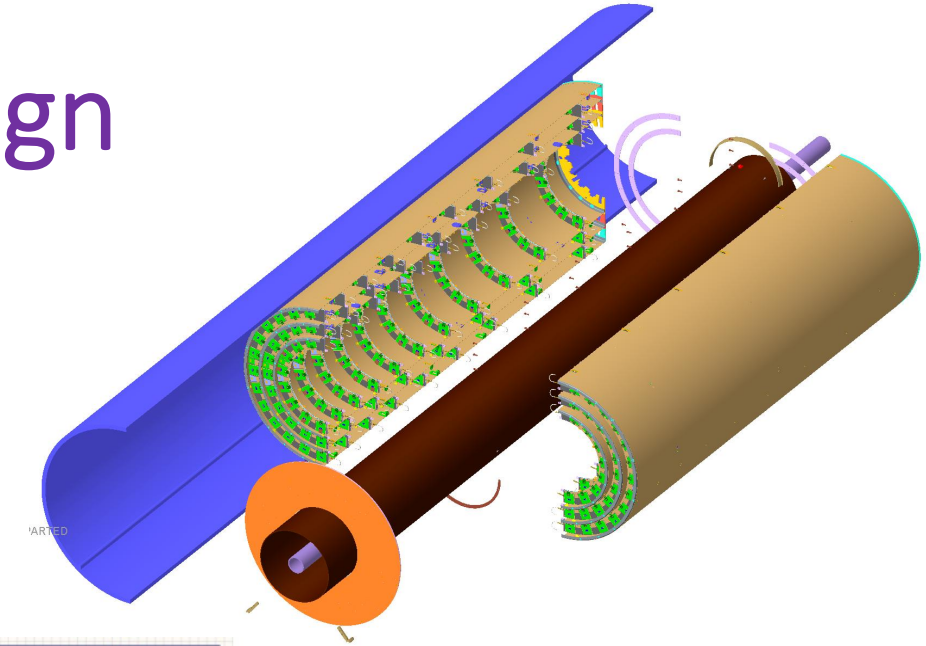



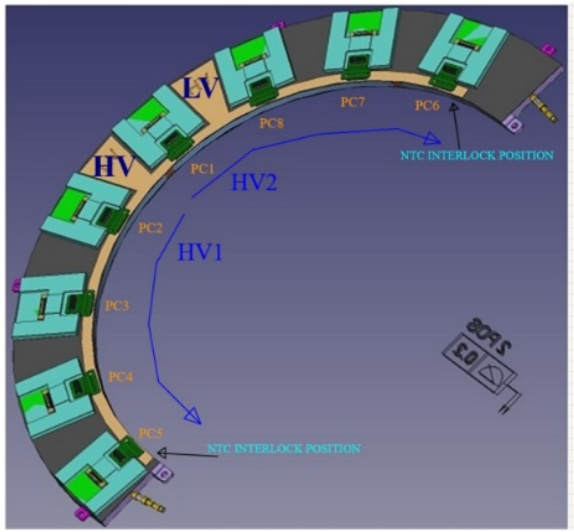
Extensive Thermo-mechanical FEA and tests are ongoing

# ATLAS ITk Pixel supports: OEC design

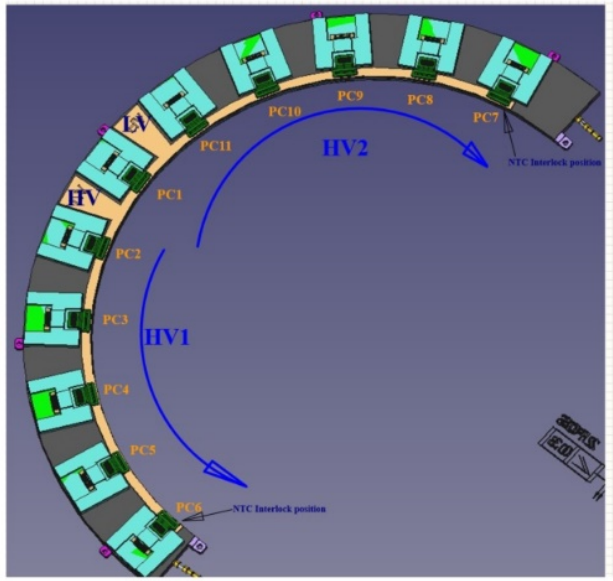
Same design there different sizes of local supports.

- Double sided half rings
- 1 SP chain per side
- Layer 4 SP chain is of 13 modules

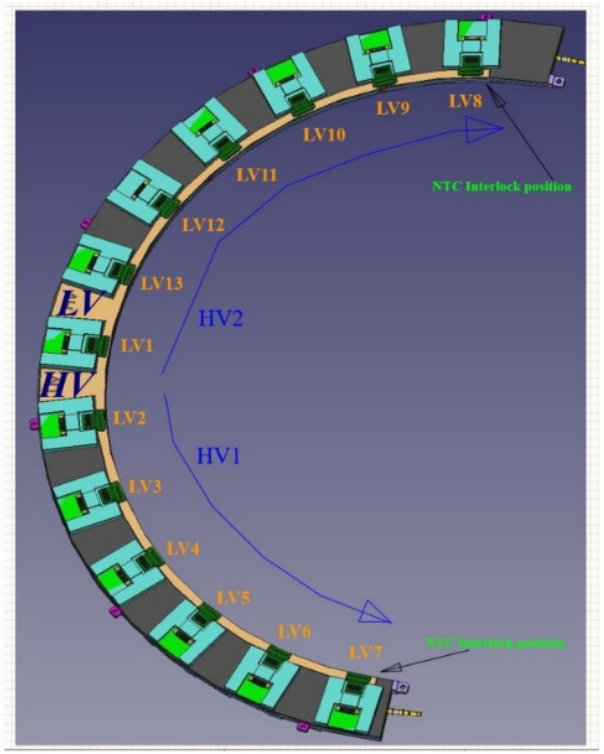




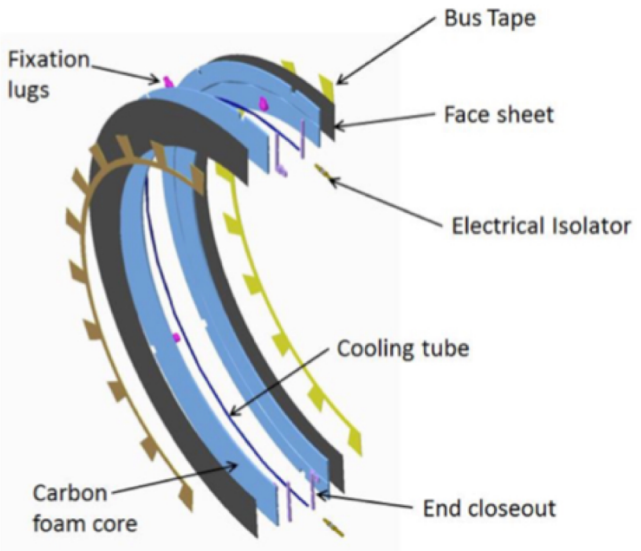

L2



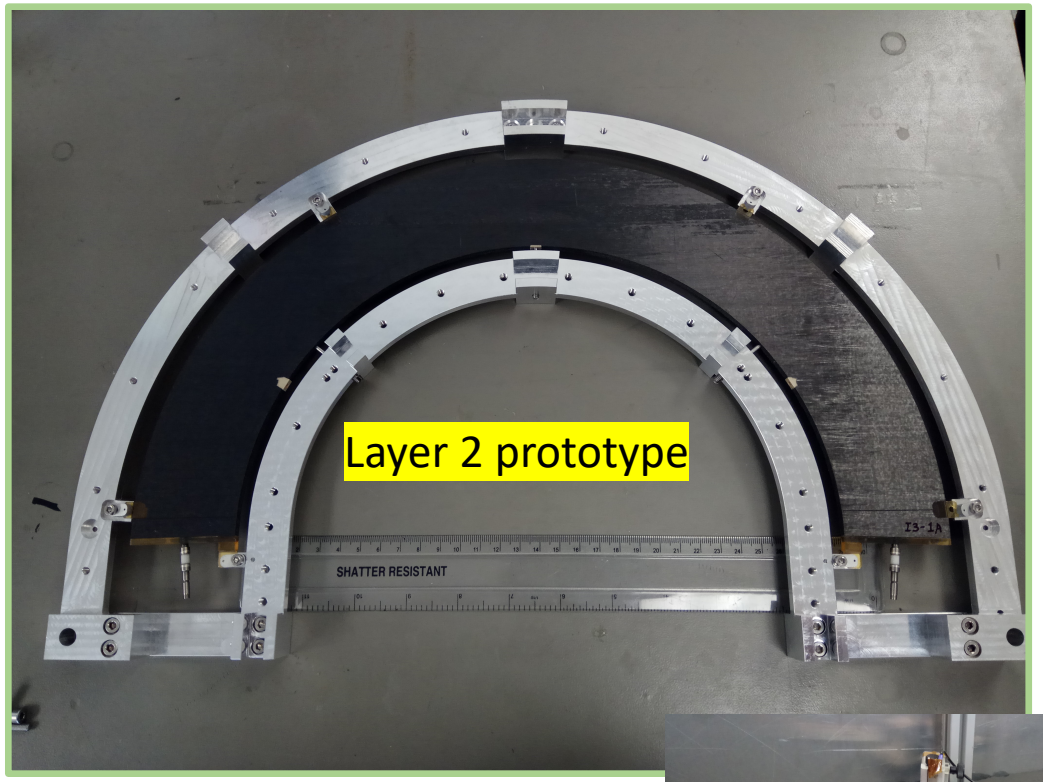

L3



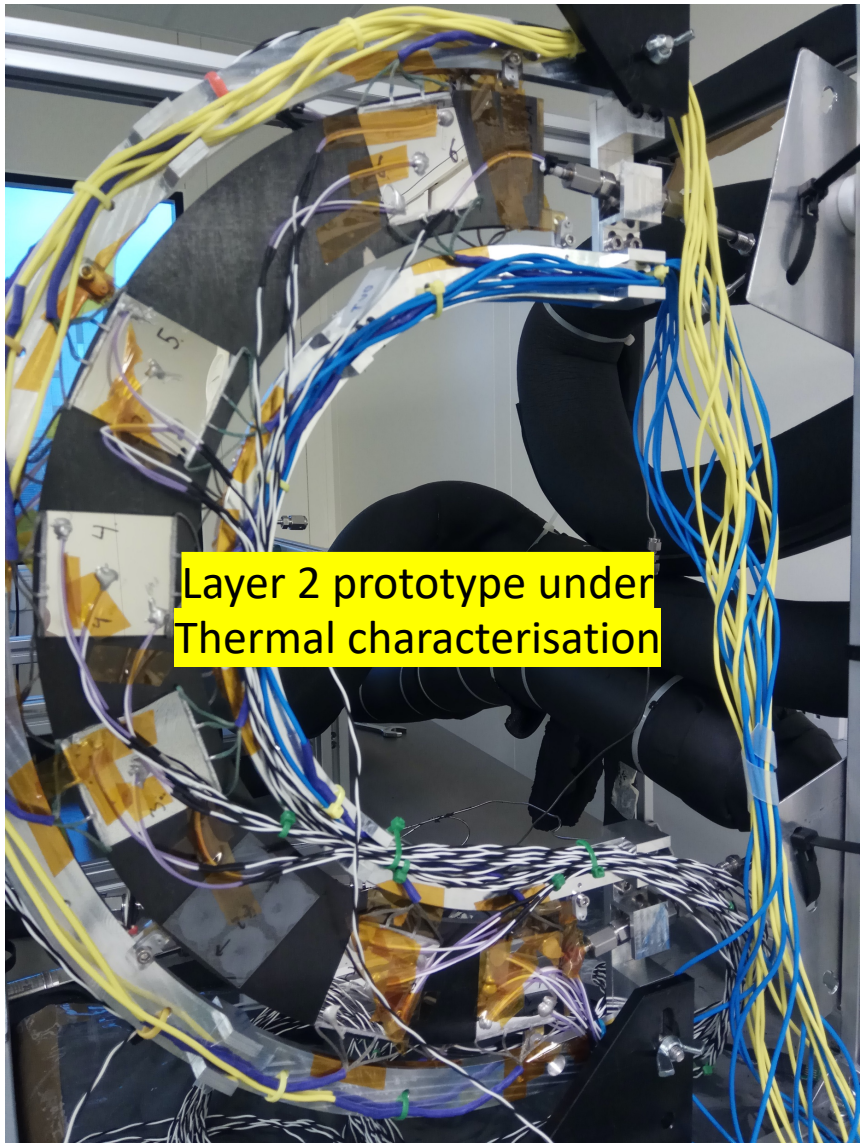

L4



# ATLAS ITk Pixel supports: OEC prototypes

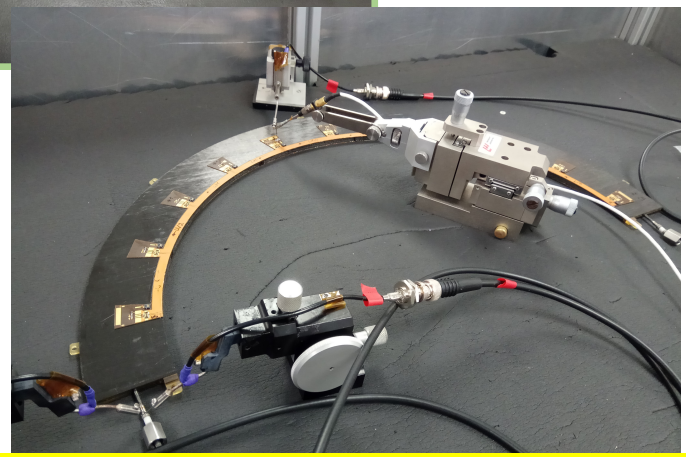



Layer 2 prototype



Layer 2 prototype under Thermal characterisation

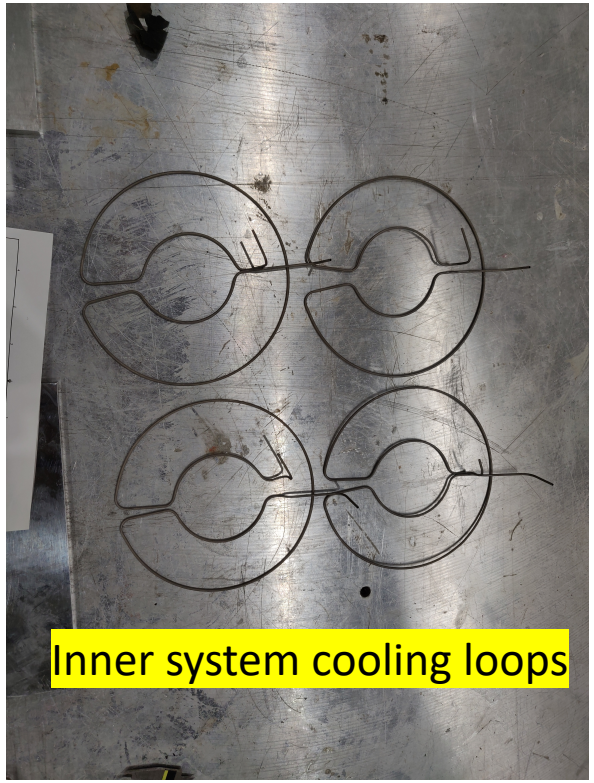
Extensive Thermo-mechanical FEA and tests are ongoing



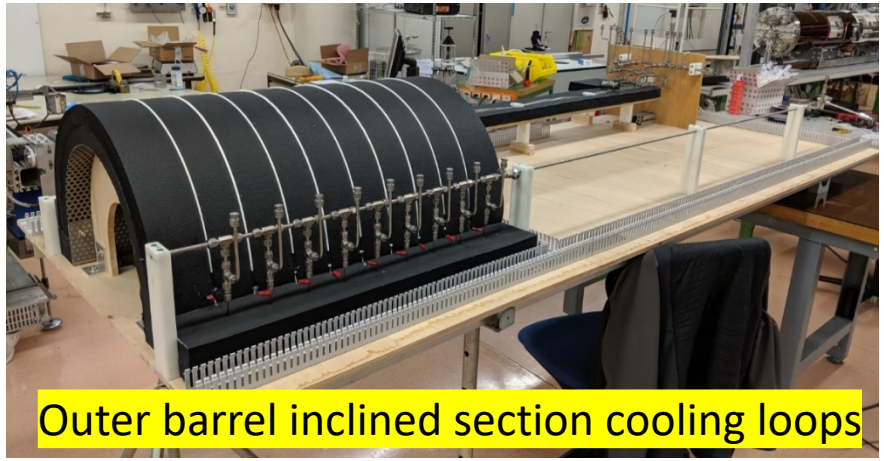
Layer 3 prototype. Ring 1 under electrical QC

# ATLAS ITk pixel cooling: real scale thermo-mechanical mockups

- All subsystems are now developing their final mockups, including realistic services



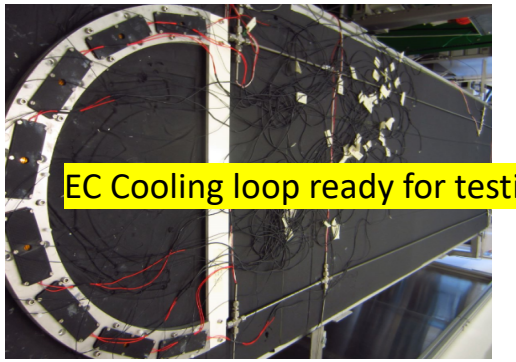
Inner system cooling loops



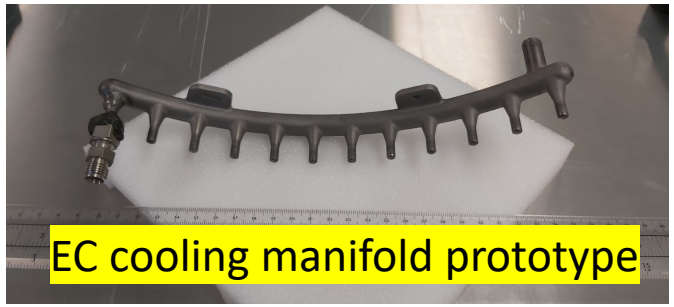
Outer barrel inclined section cooling loops

100mm OB half shell prototype

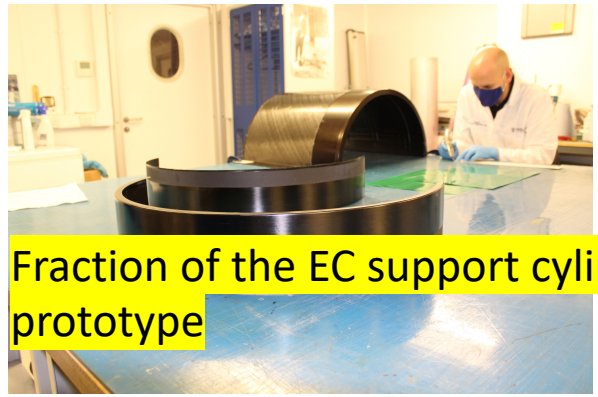
Extensive Thermo-mechanical FEA have been done and tests are planned in realistic conditions



EC Cooling loop ready for testing



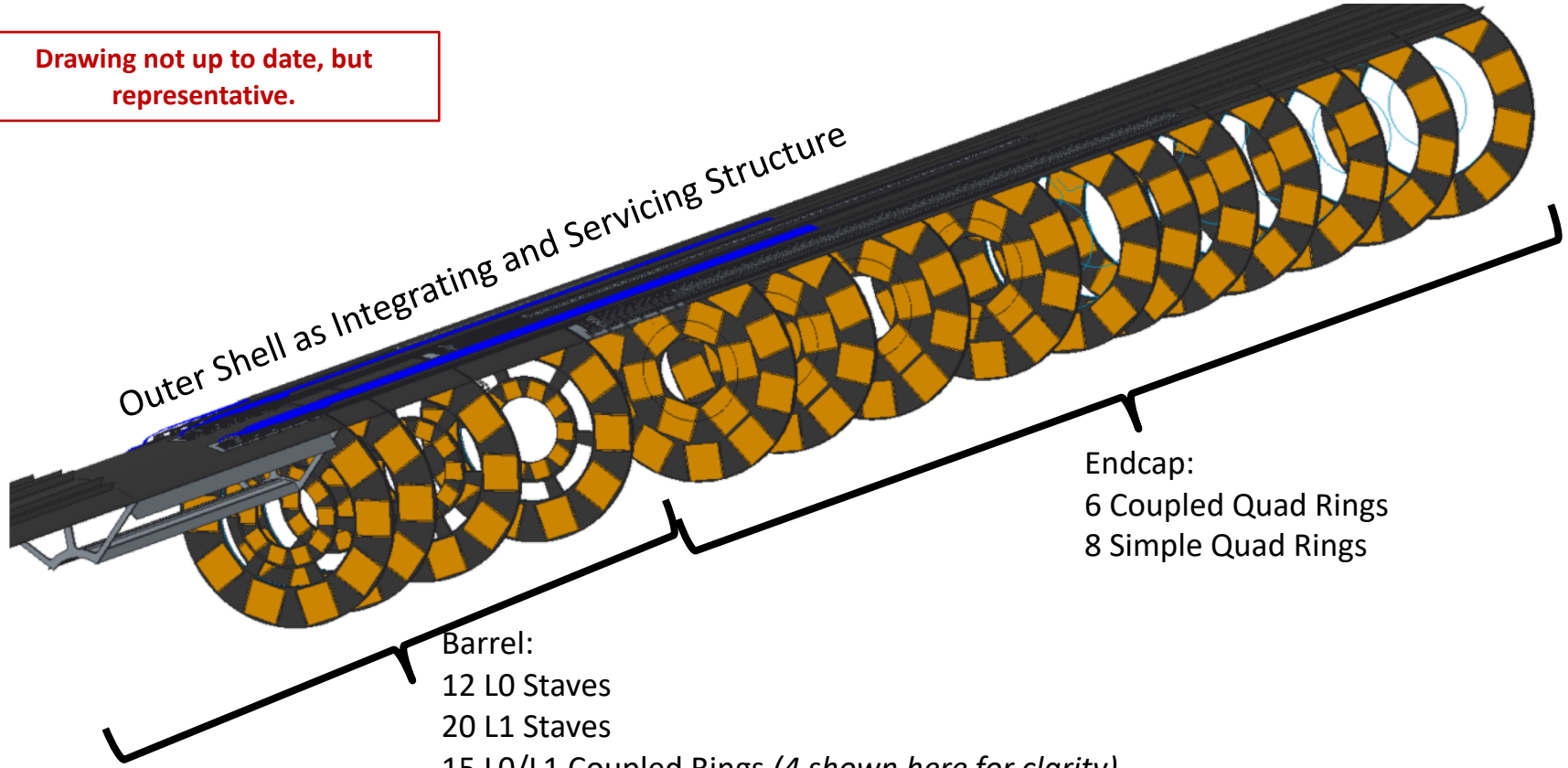
EC cooling manifold prototype



Fraction of the EC support cylinder prototype

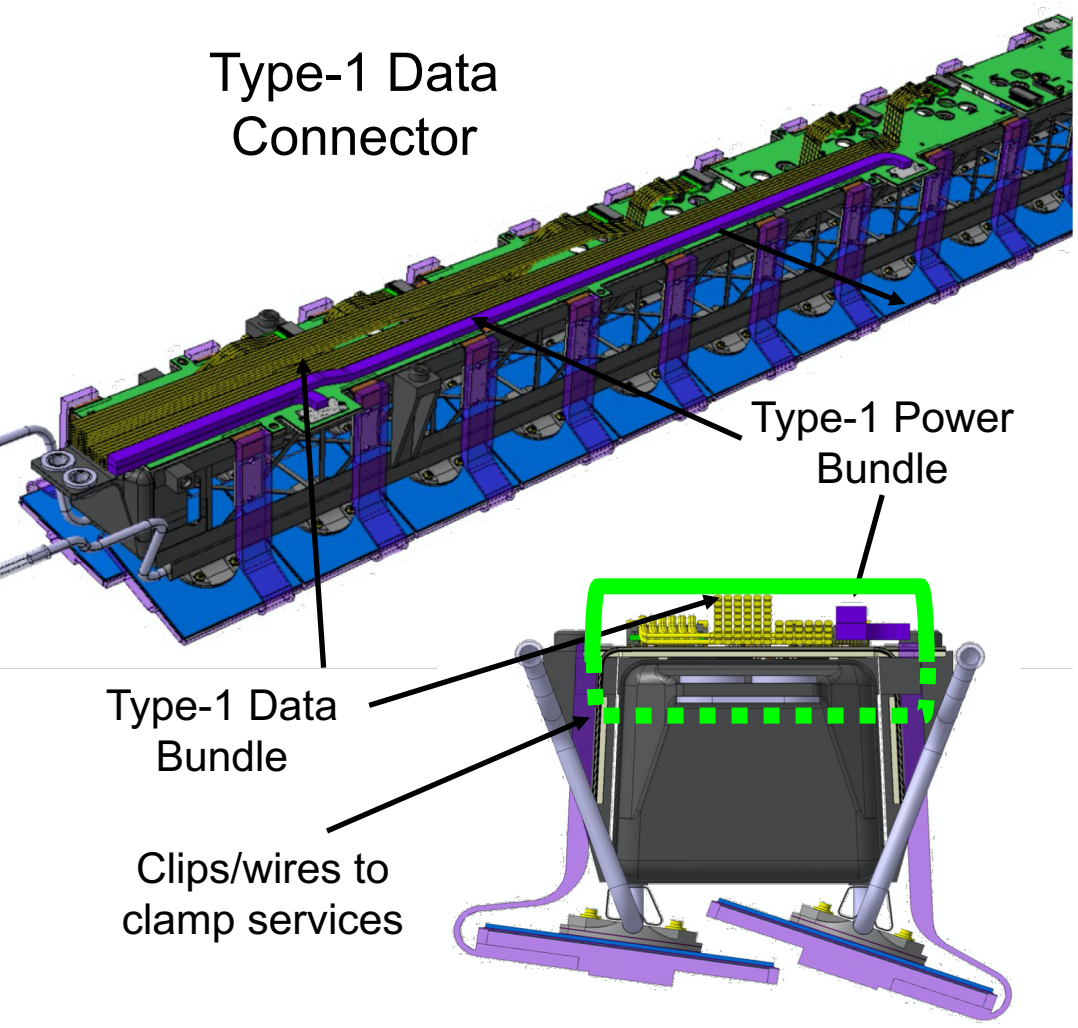
# ATLAS ITk pixel electrical services: Data and Power cables

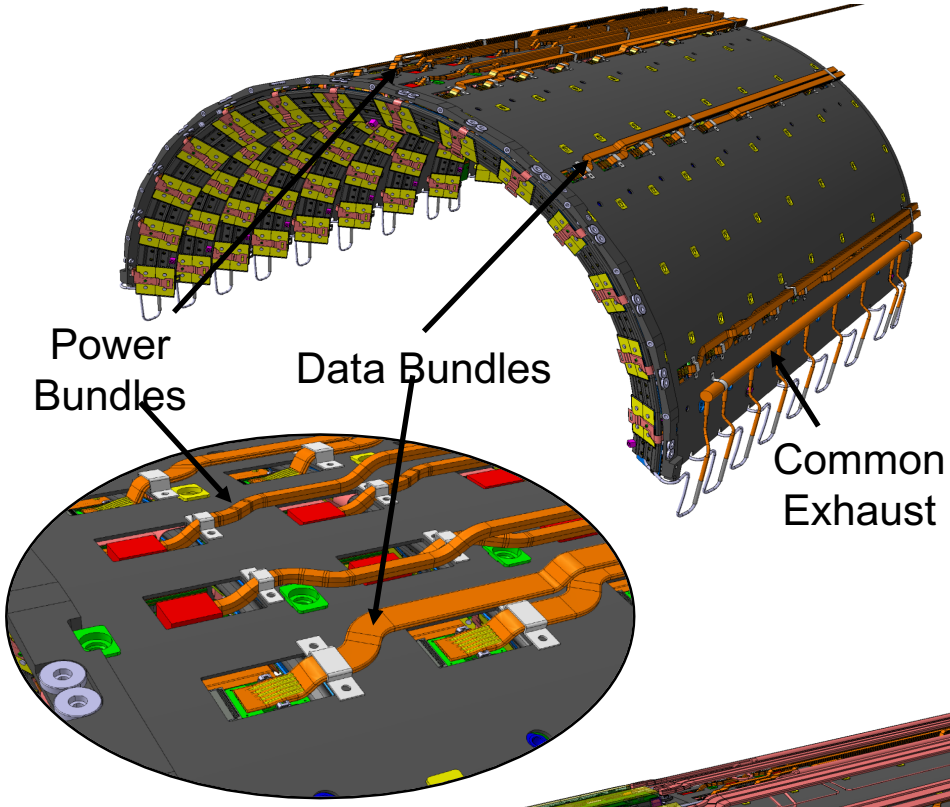
**Drawing not up to date, but representative.**

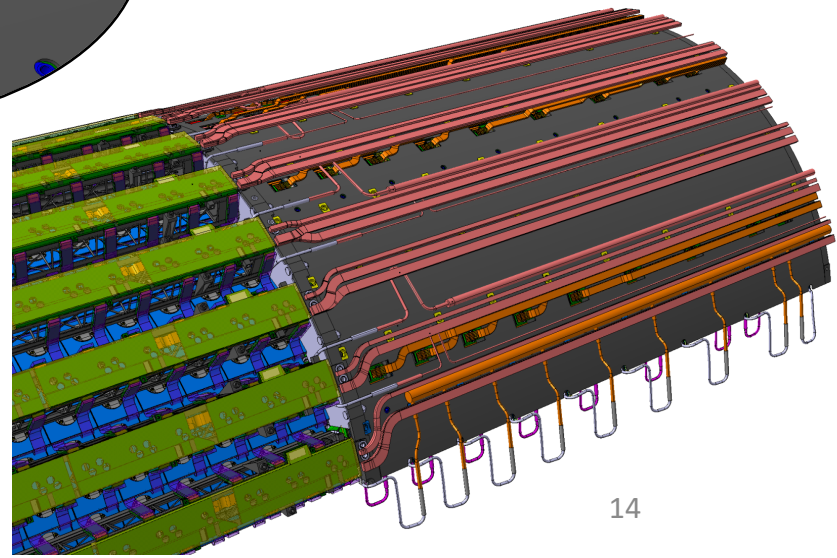



CAD modelling of services routing is ongoing

# ATLAS ITk pixel electrical services: Data and Power cables

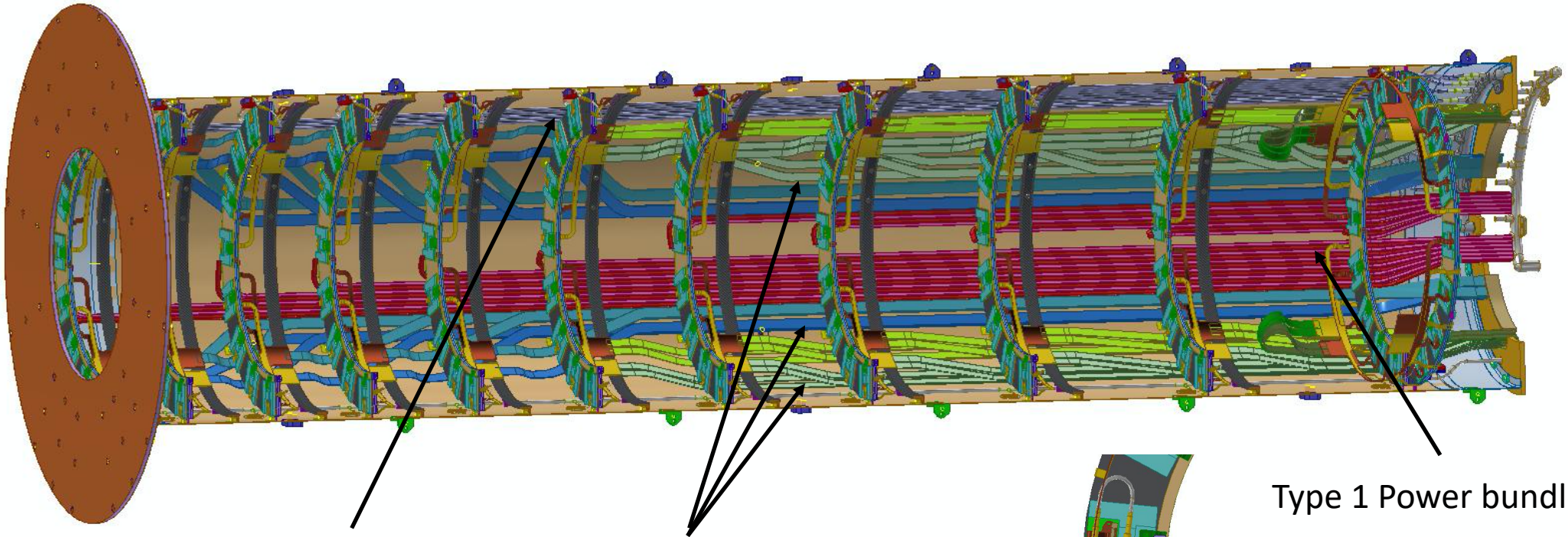


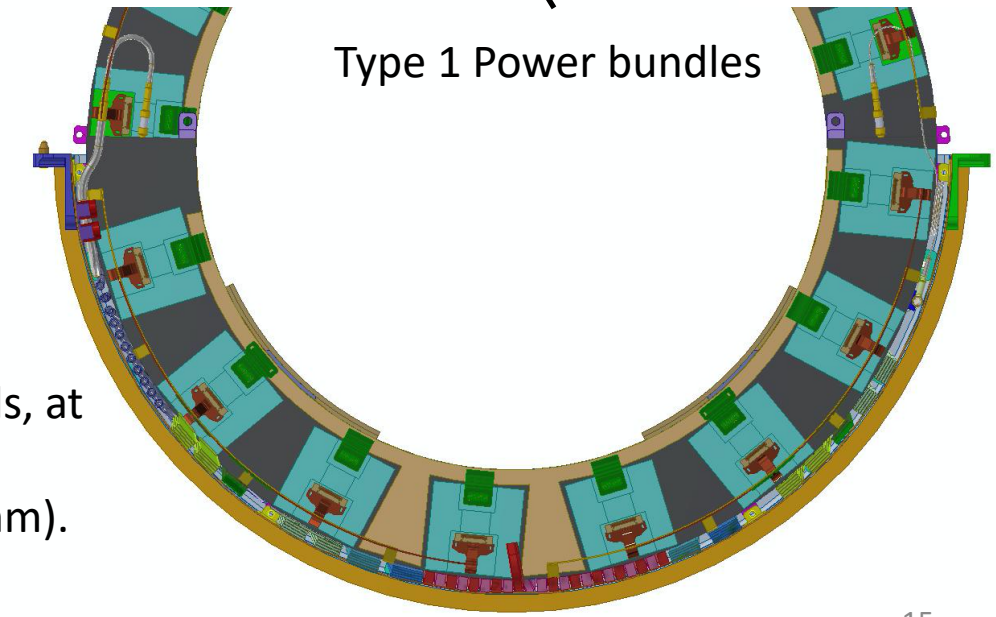



- Longeron type 1 services run over the Inclined section

# ATLAS ITk pixel electrical services: Data and Power cables



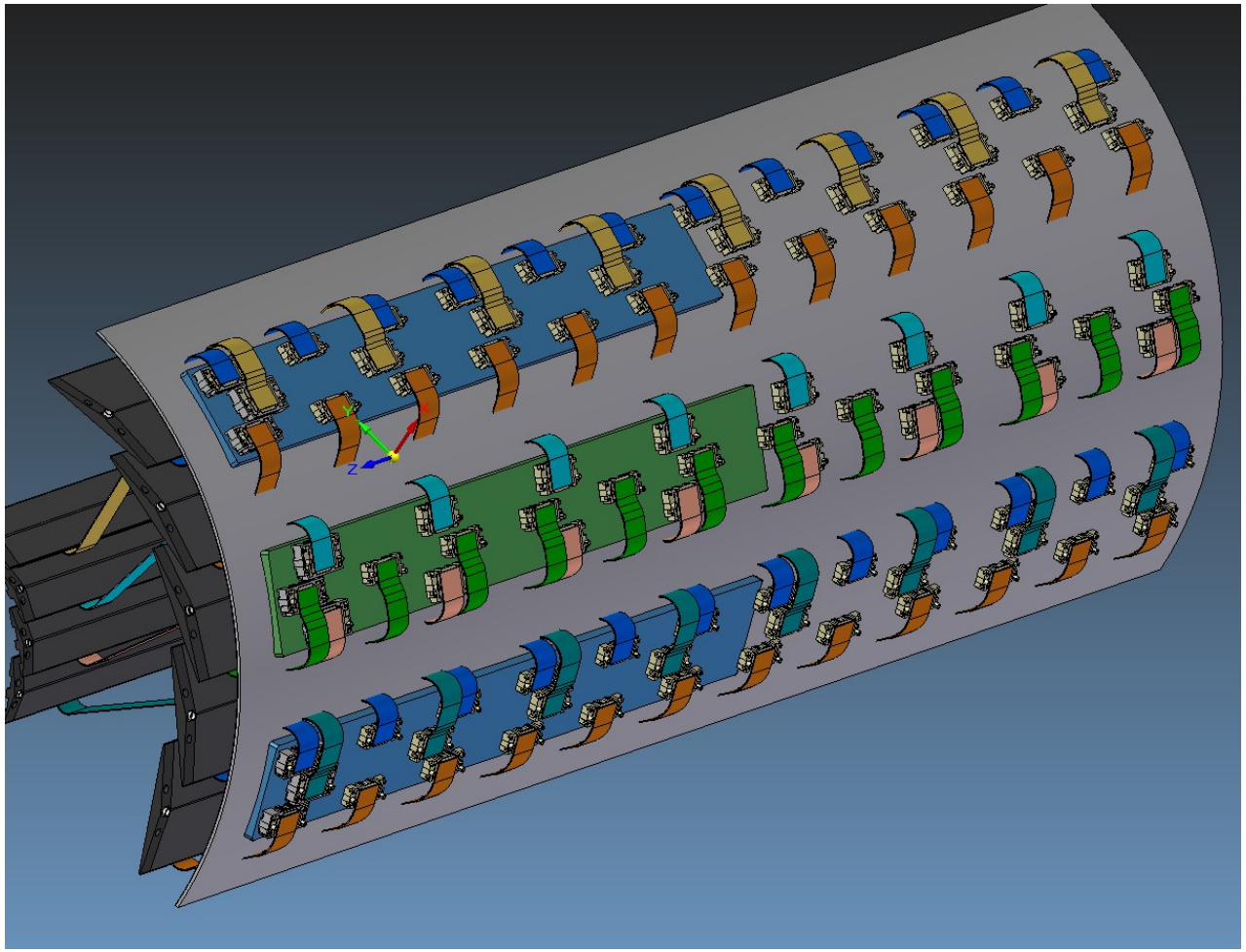



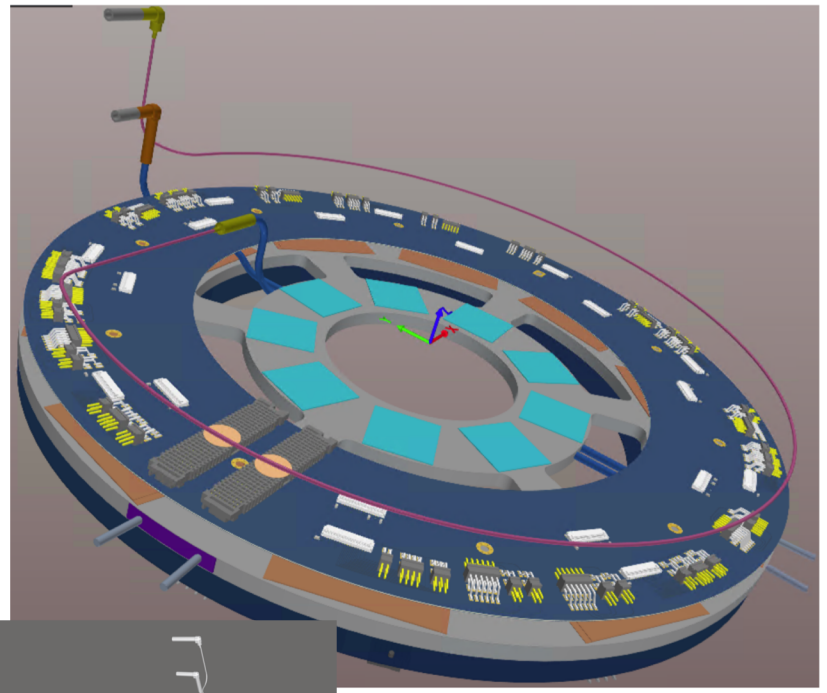

- In the Outer Endcaps, all services are routed along the support shells, at the outer rim of the half rings.
- All the services fit in the worst scenarios Layer 2 last half ring (6.6 mm).

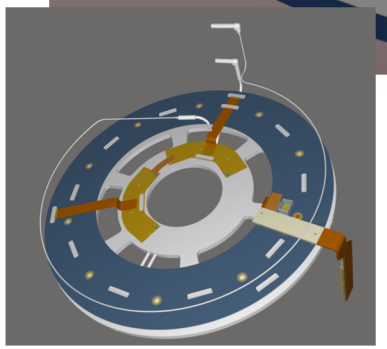
ATLAS ITk MANCHESTER 1824 The University of Manchester

# ATLAS ITk pixel electrical services: IS On detector services

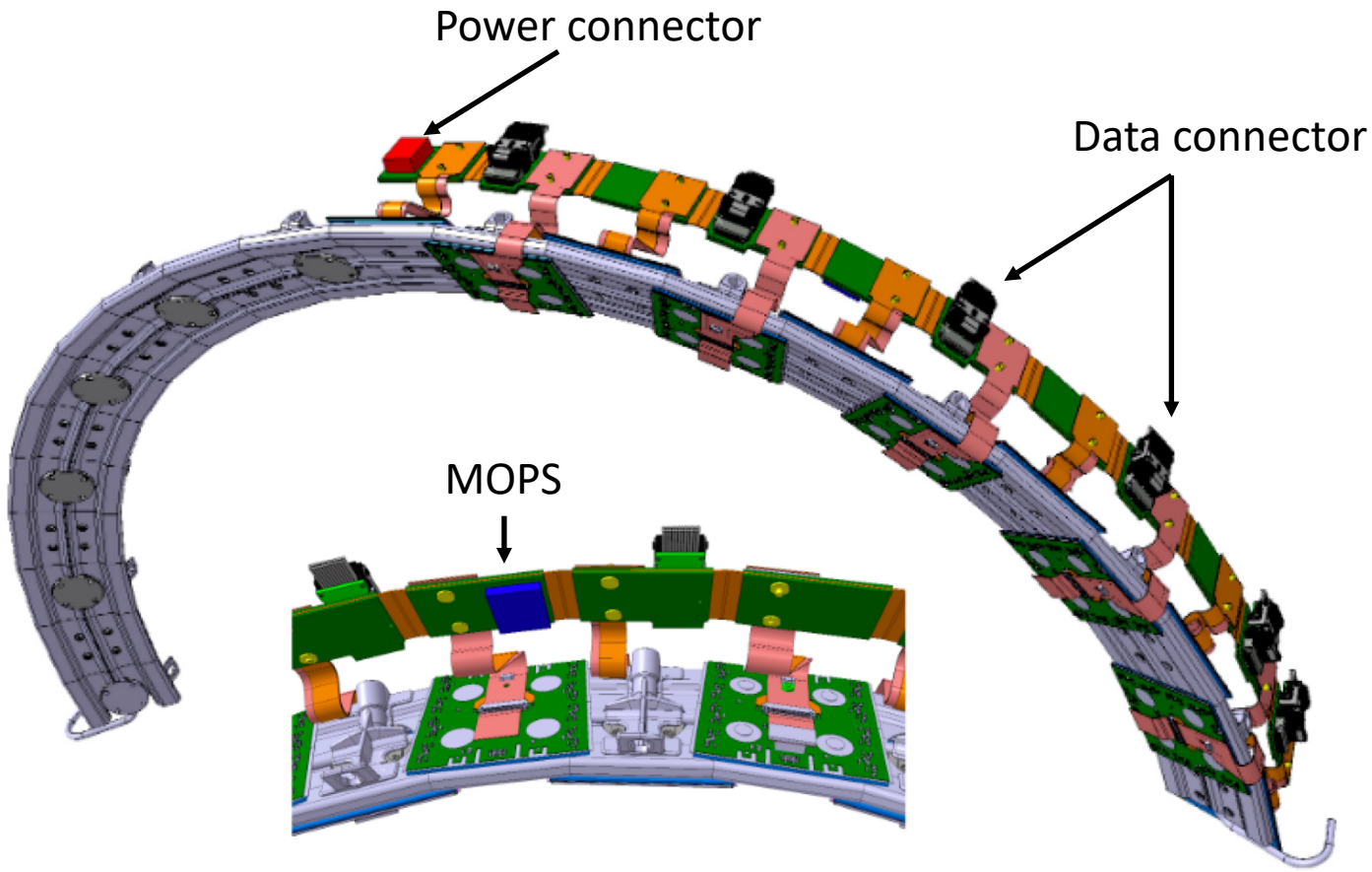
Data and power are integrated in a Patch Panel for the inner system

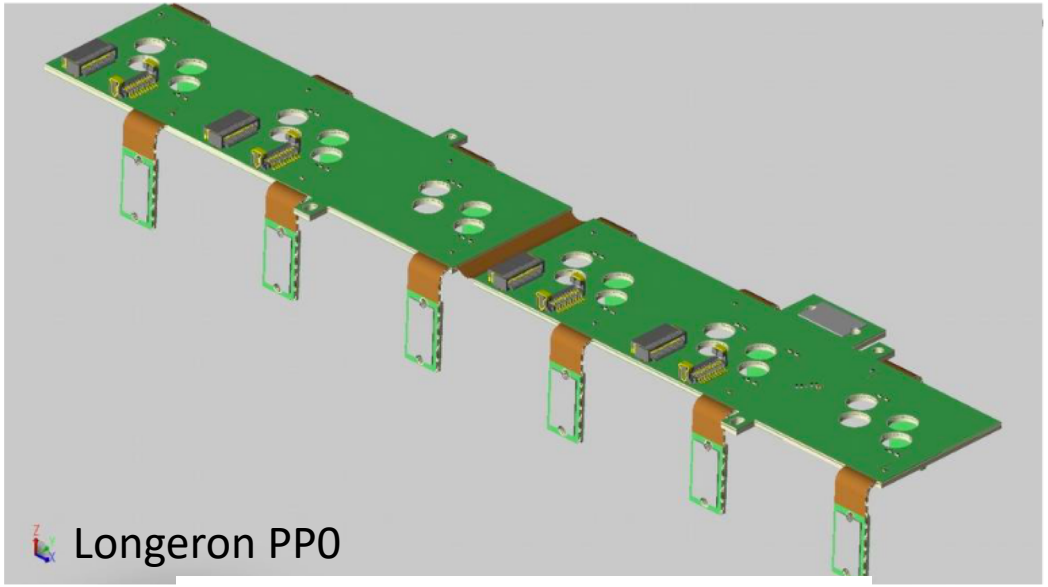


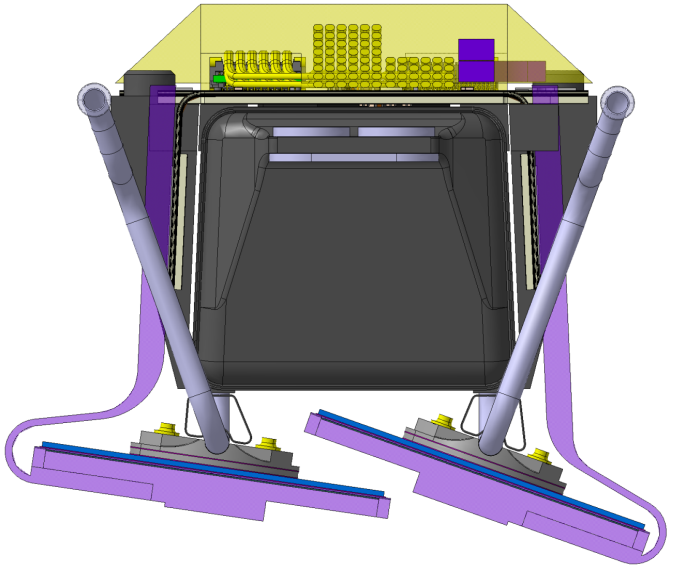




# ATLAS ITk pixel electrical services: OB On detector services



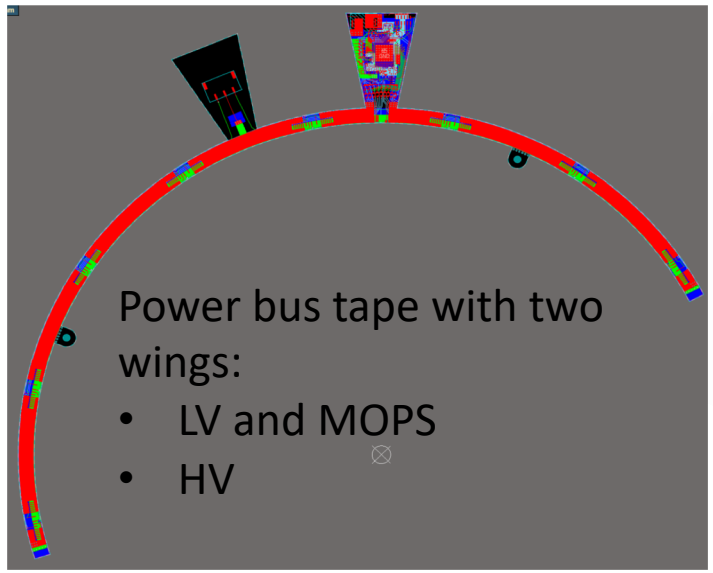



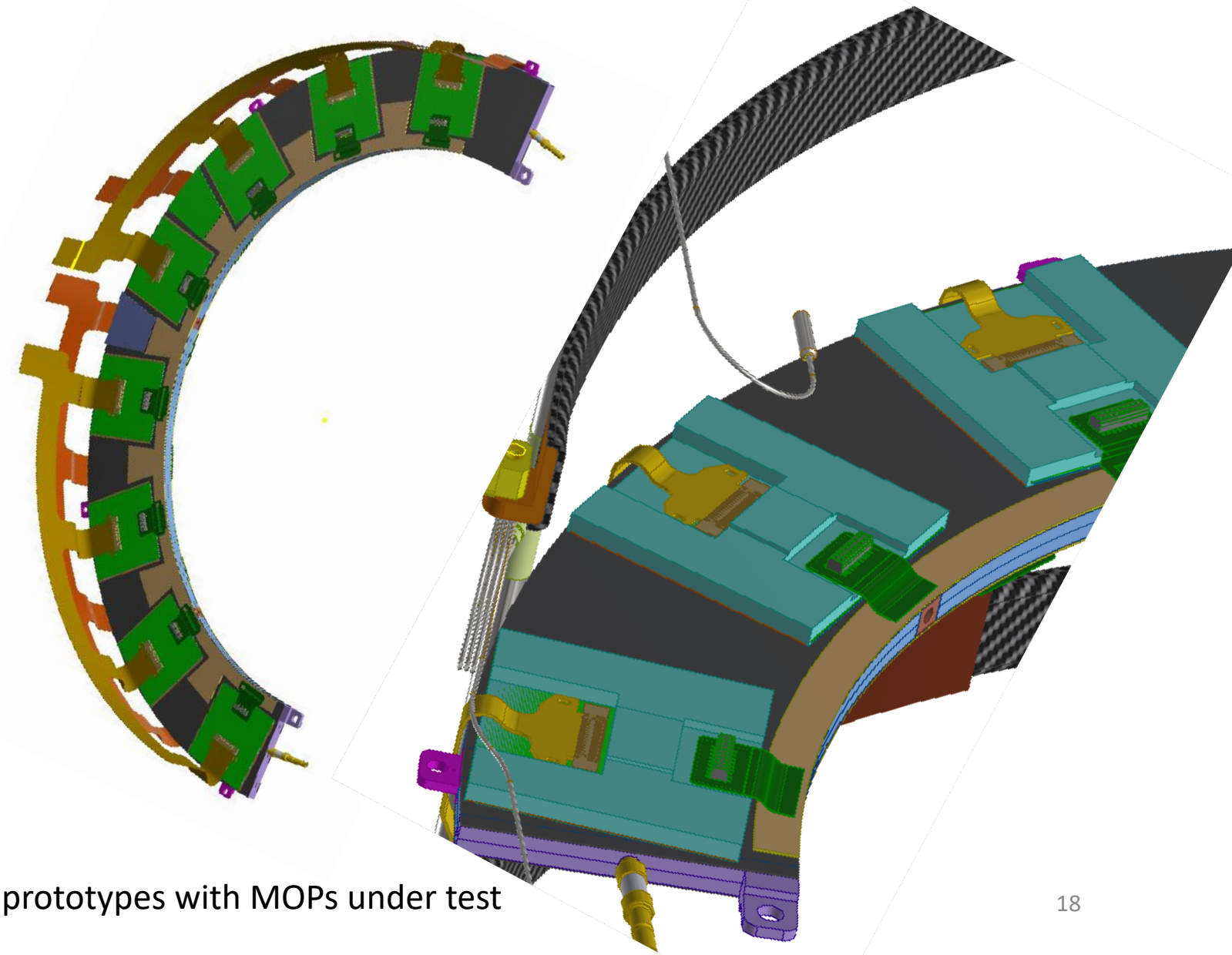



# ATLAS ITk pixel electrical services: OEC On detector services

Power and data PP0 are separated in the OEC approach:

- Power bus tape loaded in the ring and power pigtails connect to modules
- Data PP0s to route data lines from several modules to the same cable bundle

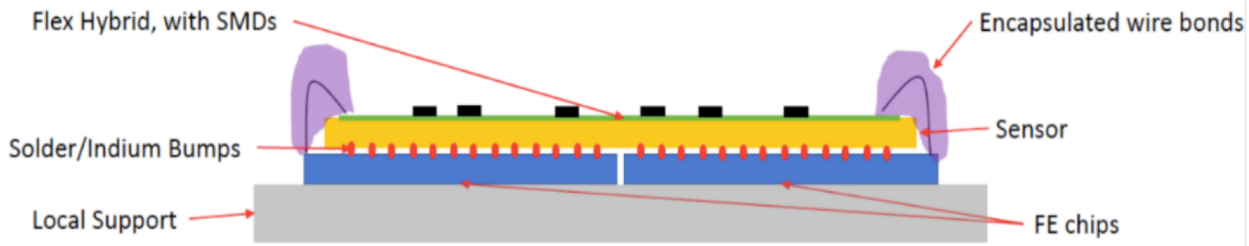


Bus tapes prototypes with MOPs under test

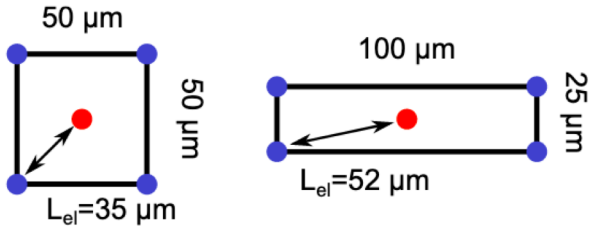
# ATLAS ITk pixel detector: Modules

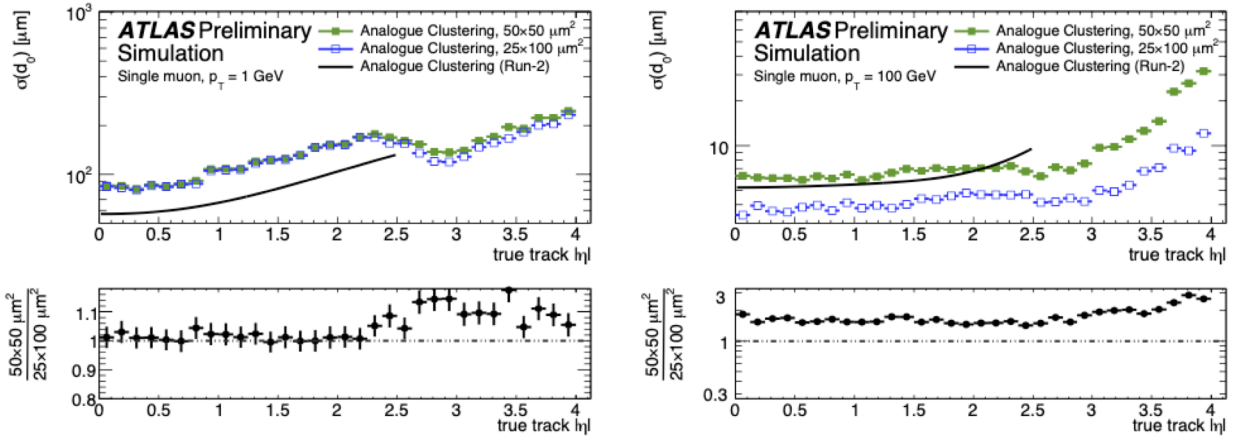
- Modules flavours:
  - 3D triplets (three Front-Ends) in the innermost layer (Layer-0):
    - 25 x 100 $um^2$ in the barrel staves
    - 50 x50 $um^2$ in the rings
  - Planar Quads (four Front-Ends) in layers 1 to 4. 50 x50 $um^2$. n-in-p sensors:
    - 150 um for Layers 2 to 4
    - 100 um for layer 1




**FE chip ITkPix readout based on the developed RD53 65nm technology**

- Dedicated **task force** evaluating several combinations of pixel sizes in the inner system in terms of radiation hardness, production yield and performance. Note on the tracking performance: ATL-PHYS-PUB-2019-014
  - 25x100 um2 in the barrel stave improves the performance, the impact parameter resolution: d0 (e.g. low $P_T$, b-tagging)



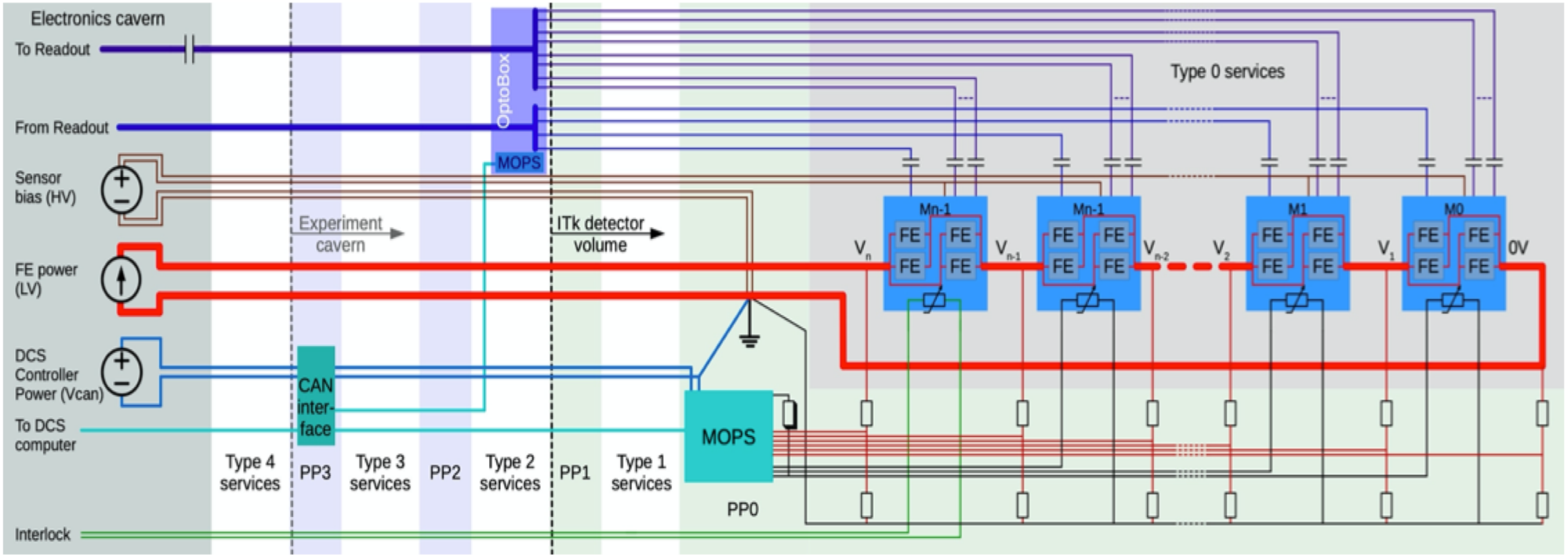




RD53 wafer testing for the ATLAS ITk pixel detector. Mark Standke.

Performance of radiation hard 3D pixel sensors for the upgrade of the ATLAS Inner Tracker. Stefano Terzo.

Module development for the ATLAS ITk Pixel Detector. Abhishek Sharma.

# ATLAS ITk pixel detector: Power and data transmission




- Serial powering chains up to 13 quad modules.
- One Monitor Of Pixel System (MOPS) chip per SP-chain to monitor:
  - Temperature
  - Voltage drops
- A Detector Control System (DCS)
- Twinax cables will drive data at 1.28 Gbps from PP0 (Patch panel) to the optoboxes

**Poster session today:**

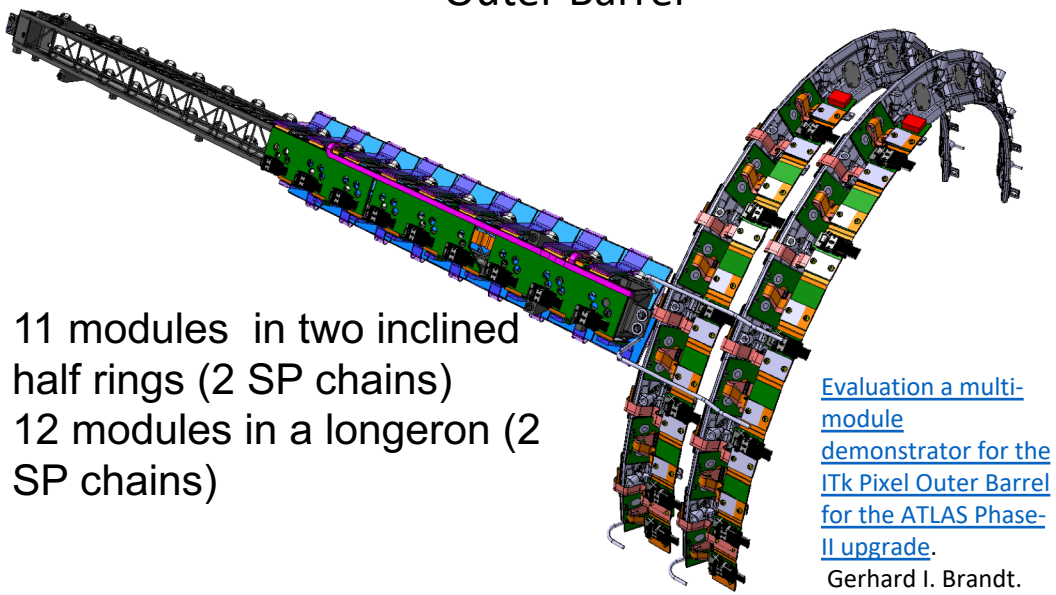
- Monitoring System of the ATLAS ITk Laboratory. Martin Sykora.
- The Monitoring of Pixel System (MOPS) chip for the Detector Control System of the ATLAS ITk Pixel Detector. Rizwan Ahmad.
- The Opto-electrical conversion system for the data transmission chain of the ATLAS ITk Pixel detector upgrade for the HL-LHC. Laura Franconi.

**Talk on irradiation studies on DAQ components later in this session:**

- Irradiation studies at the Bern Cyclotron for the ATLAS ITk Upgrade. Lea Halser.

# ATLAS ITk pixel detector: Demonstrators

## Outer Barrel

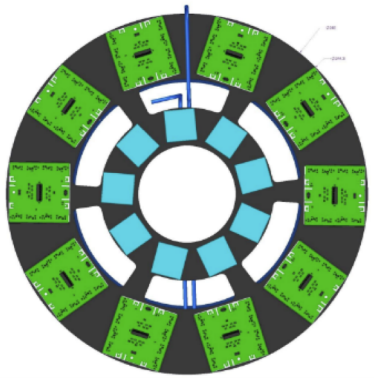


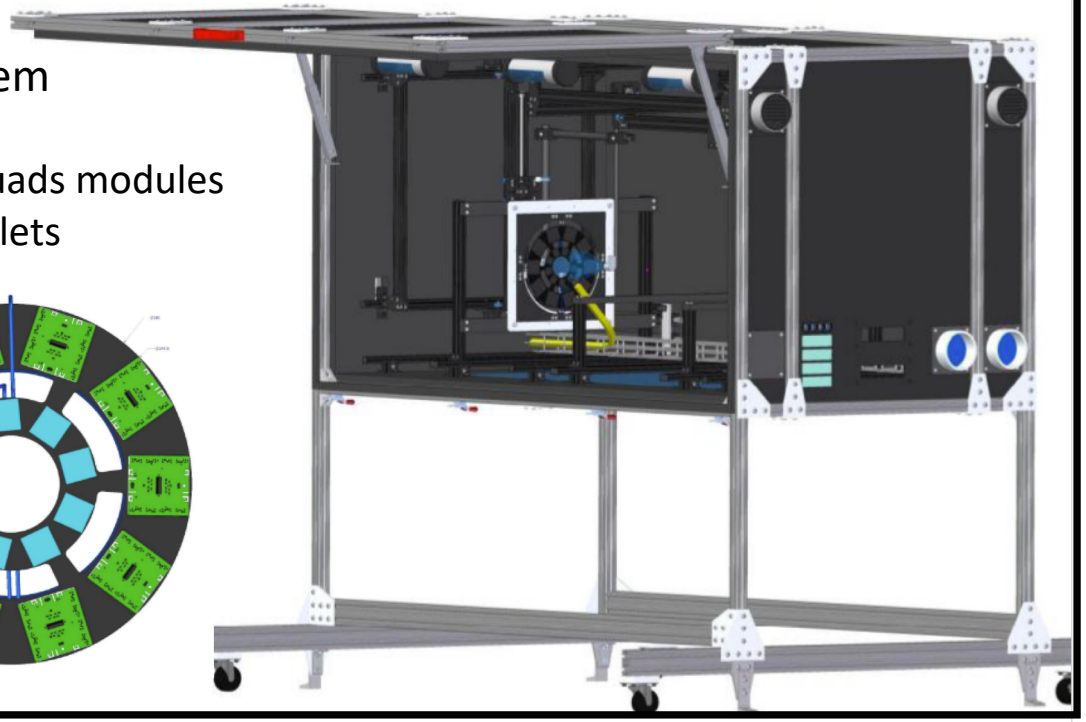
- 11 modules in two inclined half rings (2 SP chains)
- 12 modules in a longeron (2 SP chains)

Evaluation a multi-module demonstrator for the ITk Pixel Outer Barrel for the ATLAS Phase-II upgrade.
Gerhard I. Brandt.

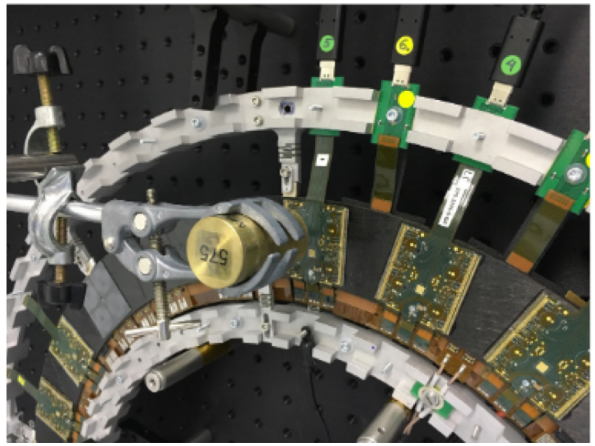
## Inner System

- 10+10 quads modules
- 3 + 3 triplets

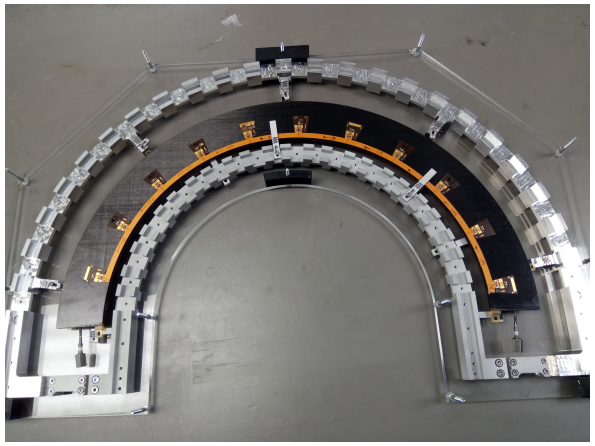




## Outer Endcaps



- FEI4 demonstrator (left)
- Layer 3 local support prototype ready (right) to be loaded with 22 RD53A modules (2 SP chains)



# Summary

- Pixel ITk layout
  - Local supports: design and prototypes
  - Off detector Services Routing
  - On detector services
- Module flavours overview
- Power and data transmission
- Demonstrators: production chain and system test

# Next steps

- Final design review for local supports and services
- RD53A Demonstrators loading and testing (system test from local support up to the DAQ)
- Itkpix_vx module testing
- Preparation for module production
  - Loading
- Integration

# Don’t miss them!

**Poster on the Opto system for data transmission earlier today:**

- The Opto-electrical conversion system for the data transmission chain of the ATLAS ITk Pixel detector upgrade for the HL-LHC. Laura Franconi.

**Talk on the ITk Strip detector later today:**

- The ATLAS ITk Strip Detector System for the Phase-II LHC Upgrade. Karol Krizka.

**Talk on 3D sensors and radiation hardness later today:**

- Performance of radiation hard 3D pixel sensors for the upgrade of the ATLAS Inner Tracker. Stefano Terzo.

**Talk on irradiation studies on DAQ components later in this session:**

- Irradiation studies at the Bern Cyclotron for the ATLAS ITk Upgrade. Lea Halser.

**Poster session last Tuesday:**

- RD53 wafer testing for the ATLAS ITk pixel detector. Mark Standke.

**Poster session yesterday:**

- Testbeam studies of ATLAS ITk strip modules at DESY-II testbeam facility. Marco Valente.
- Evaluation a multi-module demonstrator for the ITk Pixel Outer Barrel for the ATLAS Phase-II upgrade. Gerhard I. Brandt.
- Module development for the ATLAS ITk Pixel Detector. Abhishek Sharma.

**Poster session today:**

- Monitoring System of the ATLAS ITk Laboratory. Martin Sykora.
- The Monitoring of Pixel System (MOPS) chip for the Detector Control System of the ATLAS ITk Pixel Detector. Rizwan Ahmad.

ATLAS ITk

MANCHESTER 1824

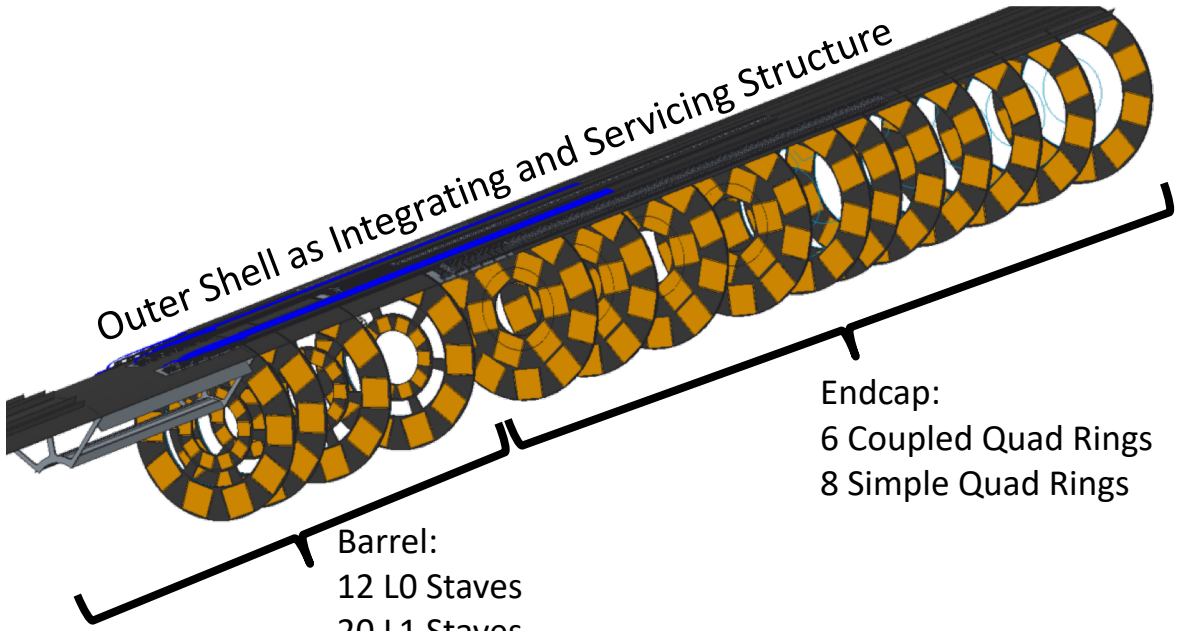
The University of Manchester

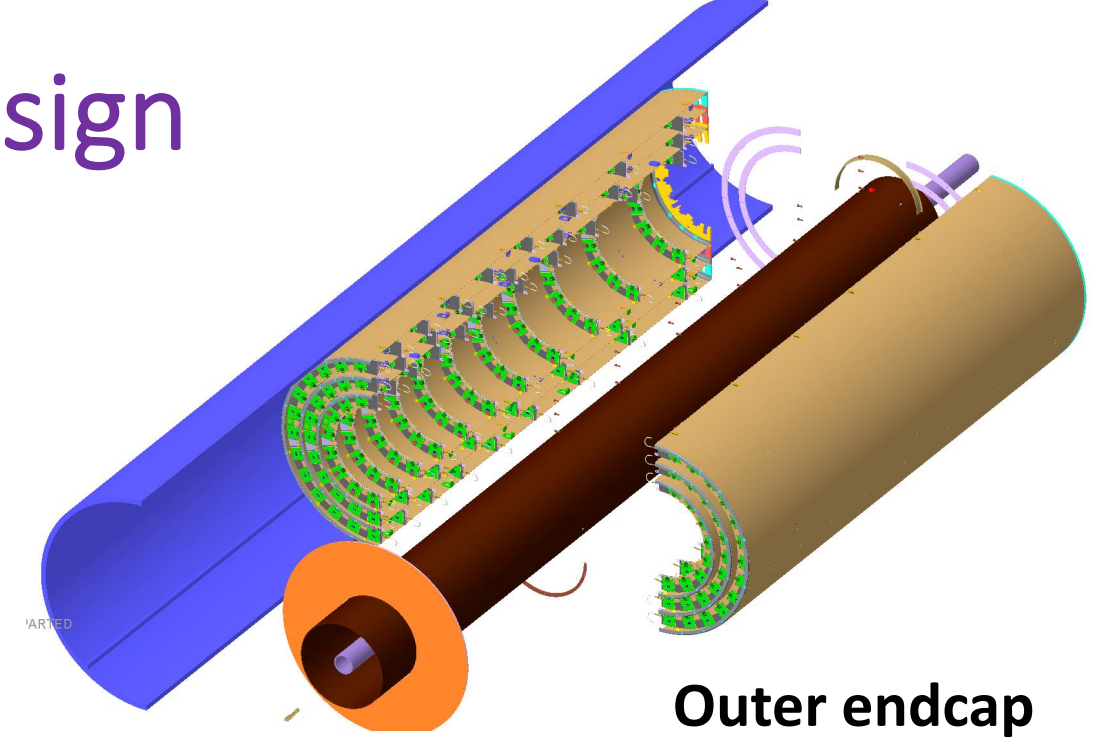
# Thank you for your attention.

# Questions?

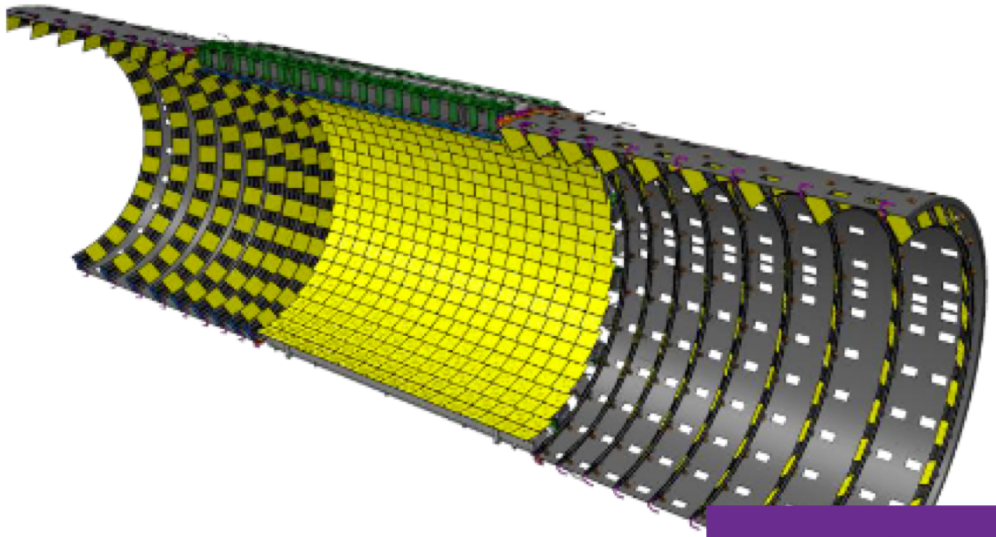
# ATLAS ITk pixel: mechanics design

- ITk pixel detector is divided in three different subsystems with different support structures:
  - Outer Barrel: Longerons and inclined rings
  - Outer Endcaps: Half-rings
  - Inner System: Staves and rings



**Outer endcap**



**Half Layer Outer Barrel**