PAPER • OPEN ACCESS

ATLAS ITk Pixel Detector Overview

To cite this article: J. Francisca *et al* 2022 *J. Phys.: Conf. Ser.* **2374** 012061

ATLAS ITk Pixel Detector Overview

Francisca J. Muñoz Sánchez on behalf of the ATLAS collaboration
Department of Physics and Astronomy, Faculty of Science and Engineering,
University of Manchester,
Oxford Road, M13 9PL
United Kingdom.

E-mail: fmunoz@cern.ch

Abstract. In this work an overview of the layout and current status of development of the ITk Pixel detector is given. For the HL-LHC upgrade the current ATLAS Inner Detector is replaced by an all-silicon system. The Pixel Detector will consist of 5 barrel layers and a number of rings, resulting in about 14 m^2 of instrumented area. Due to the huge non-ionising fluence (1×10^{16} neq/cm^2) and ionising dose (5 MGy), the two innermost layers, instrumented with 3D pixel sensors (L0) and 100 μm thin planar sensors (L1) will be replaced after about 5 years of operation. All hybrid detector modules will be read out by novel ASICs, implemented in 65 nm CMOS technology, with a bandwidth of up to 5 Gb/s. Data will be transmitted optically to the off-detector readout system. To save material in the servicing cables, the ASICs are serially powered. Large-scale prototyping programs are being carried out by all sub-systems.

1. Introduction

The upgrade of the Large Hadron Collider (LHC) to the High Luminosity LHC (HL-LHC) will increase peak and integrated luminosities by factors 7.5 and 13 respectively [1]. The mean pile-up will average up to 200 events and the radiation fluence reaches values up to 1×10^{16} neq/cm^2 in some areas of the detector. The current inner detector cannot successfully perform under those conditions and it will be upgraded to an all-silicon tracker, the **I**nner **T**rac**k**er (ITk).

The ATLAS-ITk consists of a strip detector [2] in the outermost layers and a pixel detector [3] in those layers closer to the interaction point (shown in Figure 1 -left)). The pixel detector is divided in three different sub-detectors' covering up to $\eta = 4$, the Inner System (IS), the Outer Barrel (OB) and two Outer Endcaps (OEs), see Figure 1 -right).

2. ITk Pixel layout

In this section a brief description of the three sub-detectors mechanical designs is given. Some prototypes used to qualify the designs are also shown.

2.1. Inner System

The IS is formed by a barrel and an endcap section and it will follow a quarter-shell integration structure. Each quarter shell has a barrel section where staves and rings are local support structures. It also has an endcap section where flavours of rings will support the pixel modules. (see Figure 2).

The IS has built several prototypes to qualify the mechanical design and to exercise the assembly of local supports. In Figure 3 different prototypes are shown.

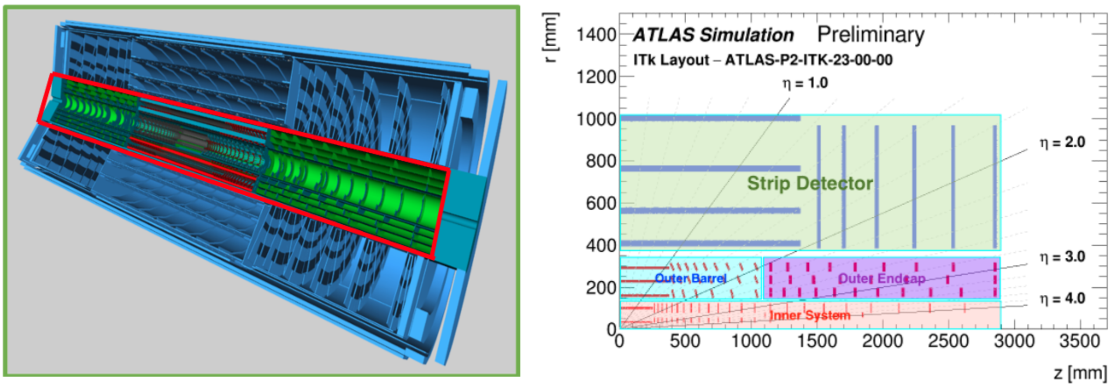

Figure 1. ITk layout. Strip detector in blue and pixel detector inside the red rectangle on the left image [3], while the pixel detector quadrant coverage where the three sub-detectors are distinguishable is shown at the right [4].

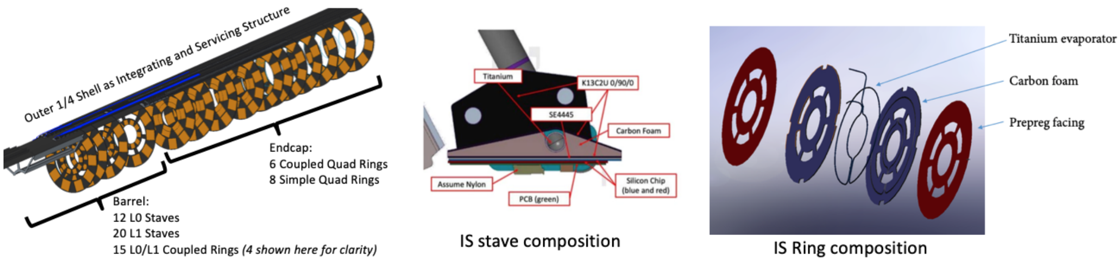

Figure 2. Inner System layout. Left: Quarter shell layout with the barrel and endcap sections. Middle: stave local support composition. Right: ring local support composition.

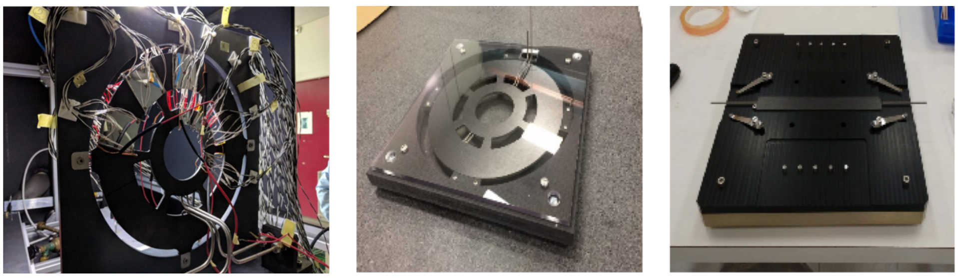

Figure 3. IS prototypes. Left: ring prototype for thermal qualification where some silicon heaters can be identified. Middle: Bare ring prototype. Right: Bare stave prototype.

2.2. Outer Barrel

The OB layout has two different sections, flat and inclined. The local supports in the flat section supports are called *longerons* while those in the inclined section are called *inclined rings*. In the OB, modules are loaded on *module cells*, which are screwed to *base blocks* on the local supports at a later integration stage, see details in Figure 4. Any of those cells can be integrated in both local support structures. Prototypes of layer-3 OB local supports are shown in Figure 5 together

Journal of Physics: Conference Series **2374** (2022) 012061 doi:10.1088/1742-6596/2374/1/012061

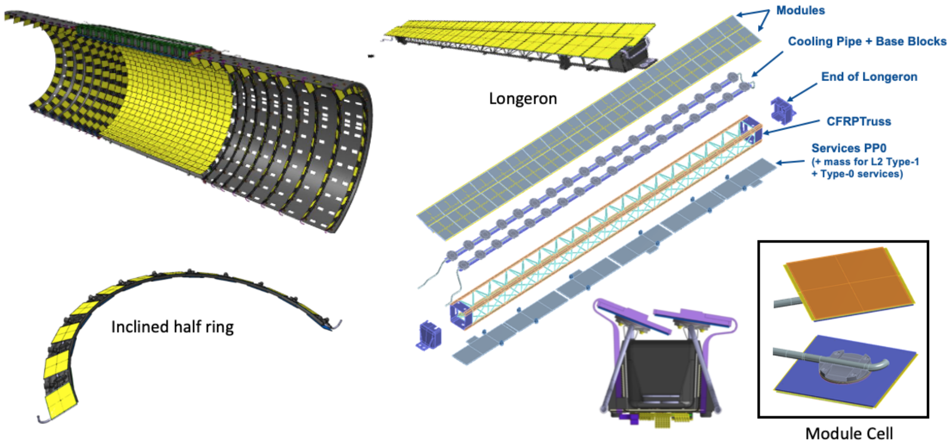

Figure 4. OB mechanics. Top Left: OB layer layout. Top right: longeron breakdown. Bottom left: inclined ring drawing. Bottom right: longeron cross section and module cell.

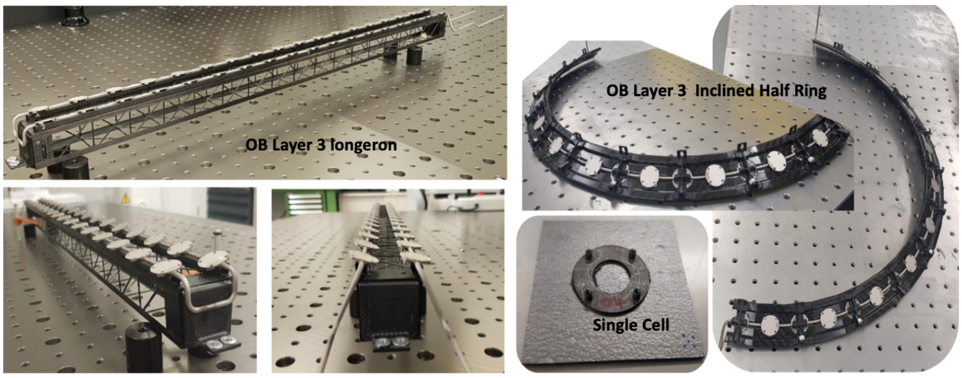

Figure 5. Layer 3 OB local support prototypes.

with a prototype of a single cell where modules will be loaded. These prototypes are used to test the production and assembling chains as well as to qualify their design.

2.3. Outer Endcap

In the case of the OE, the local supports are carbon-based half-ring structures where a titanium pipe is embedded. Pixel modules will be loaded on both sides of half-rings where a flex PCB will also be loaded to route power and monitoring signals to each module.

Each OE will consist of three layers of local supports, see Figure 6, which shows the complete layout of one endcap, together with the composition of a local support, and one of the prototypes used to qualify the design, test the production and assembly chains, and validate simulations.

Though only local supports prototypes are shown in this proceeding, some prototypes of full-scale global support structures are already under test for the different subsystems as well. In addition to the support structures, the services routing (comprising power and monitoring cables, cooling pipes and data lines) is currently in the latest stage of the design for all subsystems.

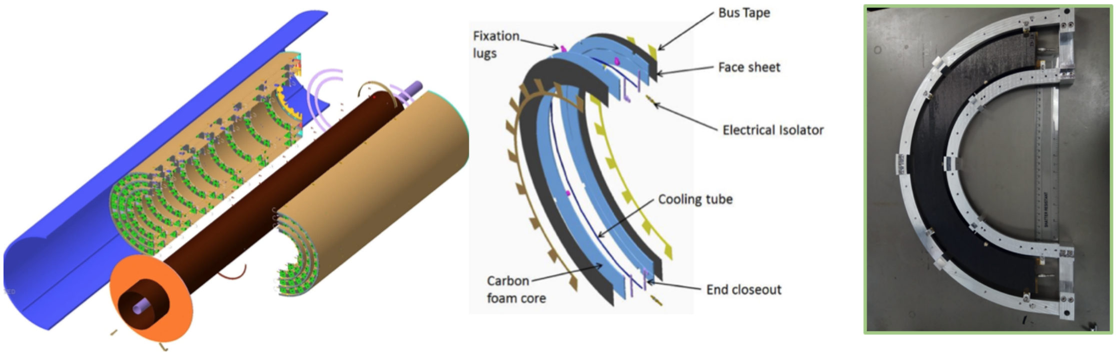

Figure 6. OE mechanics layout. Left: one endcap layout. Centre: A half-ring local support breakdown. Right: Layer 2 half-ring prototype.

3. Modules

The pixel modules in the ITk pixel detectors are made using a hybrid technology, where silicon sensors are bump-bonded to the readout ASICs. The readout chip is based on the 65 nm technology developed by the RD53 collaboration [5].

In order to optimise the performance of the ATLAS experiments an extensive study [6] was done by the collaboration to decide which sensor technology is used in different parts of the detector. This study showed that best compromise between performance, yield and cost is achieved by having planar pixel sensors in layers 1 to 4, with 100 μm thick sensors in layer 1 and 150 μm thick sensors in layers 2, 3 and 4. In Layer 0, 3D silicon pixel sensors will be used due to their higher resistance to radiation. However, it was also found that different pixel geometries in layer 0 provide a better resolution. Therefore, 50 $\times$ 50 μm^2 pixels will be used on the rings while 25 $\times$ 100 μm^2 will be used in the central staves.

4. Power and data transmission

The pixel system will be powered using a serial powering scheme [7] where up to thirteen pixel modules will be powered in the longest chain in the OEs. The use of the serial powering decreases significantly the amount of material needed by reducing the number of required cables for powering. A Monitor Of the Pixel System (MOPS) chip will be used to monitor the temperature and the voltage drop in every module. Relative to the data transmission approach [8], the electrical signals will be transmitted at 1.28 Gbps from the module through twinax cables up to the opto-electrical conversion system outside of the pixel detector. This custom-designed system will equalise and aggregate the signals to 10.24 Gb/s and perform the conversion into optical signals.

5. Demonstrators

In order to test the performance of the pixel detectors and to investigate possible issues in the final system, every sub-system is building realistic demonstrators from the local support up to patch panel 1, which is located at end of the pixel detector.

These demonstrators will be real scale local supports prototypes populated with the nearly-final modules, electronics, cooling and interfaces. Working with these prototypes will give the collaboration experience at operating a representative part of the detector in realistic conditions. Complete serial power chains will be tested while they are being cooled down to the operating temperatures and modules will be read out with full-length cables and realistic data acquisition

Journal of Physics: Conference Series **2374** (2022) 012061 doi:10.1088/1742-6596/2374/1/012061

systems. Demonstrators will provide the possibility to completely understand the system, validate simulations, and test the production plans.

6. Summary and outlook

The ATLAS pixel community is facing the latest phase of R&D of the different components and pre-production is expected to start in 2022-2023 (depending on the components). Intensive work is being carried out in order to understand complex systems in terms of cooling, power, data and supports that need to be integrated and fully operational in the ATLAS experiment in 2027.

References

[1] High Luminosity LHC project, https://hilumilhc.web.cern.ch/.
[2] ATLAS Collaboration, *Technical Design Report for the ATLAS Inner Tracker Strip Detector*, CERN-LHCC-2017-005, 2017.
[3] ATLAS Collaboration, *Technical Design Report for the ATLAS Inner Tracker Pixel Detector*, CERN-LHCC-2017-021, 2017.
[4] ATLAS Collaboration, https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PLOTS/ITK-2020-002, 2020
[5] RD53 Collaboration, https://rd53.web.cern.ch/
[6] ATLAS Collaboration, *Expected Tracking Performance of the ATLAS Inner Tracker at the HL-LHC*, ATL-PHYS-PUB-2019-014, 2019.
[7] L Gonella et al., *A serial powering scheme for the ATLAS pixeldetector at sLHC*, 2010 JINST5 C12002.
[8] L Franconi, *The Opto-electrical conversion system for the data transmission chain of the ATLAS ITk Pixel detector upgrade for the HL-LHC*, TIPP 2021 poster presentation, proceeding included in this conference publication.