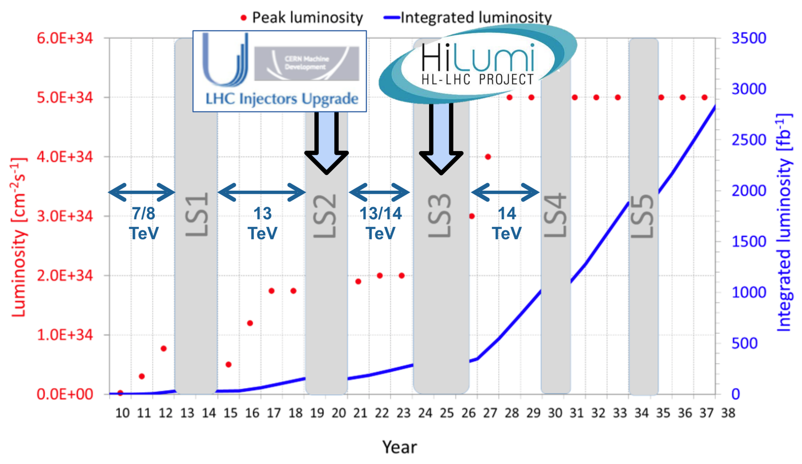
Testbeam studies of the ATLAS ITk strip modules at the DESY-II testbeam facility

Marco Valente (TRIUMF), on behalf of the ATLAS ITk Strip Testbeam Group

International Conference on Technology and Instrumentation in Particle Physics (TIPP 2021)

Introduction

The High Luminosity LHC (HL-LHC) is the upgrade of the LHC envisaged to be ready in 2026 targeting instantaneous luminosities at least a factor of five larger than the LHC design value. In order to deal with the unprecedentedly high levels of radiation and pile-up of the HL-LHC, the ATLAS experiment will replace its current tracking device with the *Inner Tracker* (ITk), a new all-silicon tracker for which new radiation-hard sensors and front-end chips have been developed. A vital task for this upgrade is the continuous testing of prototype silicon modules at dedicated testbeam facilities. Recent testbeam results of the ITk strip modules using the DESY-II testbeam facility are summarized below.

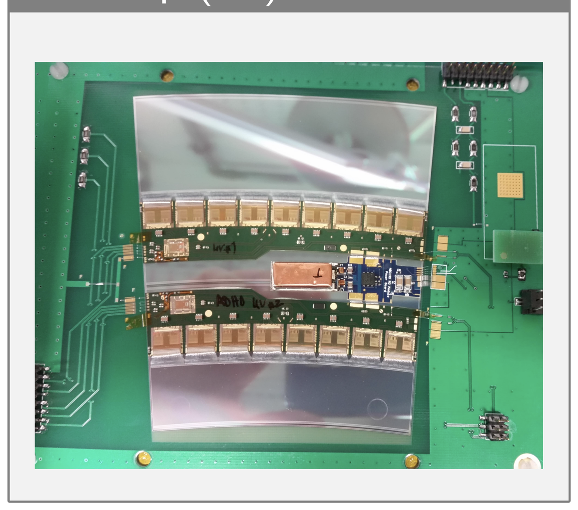


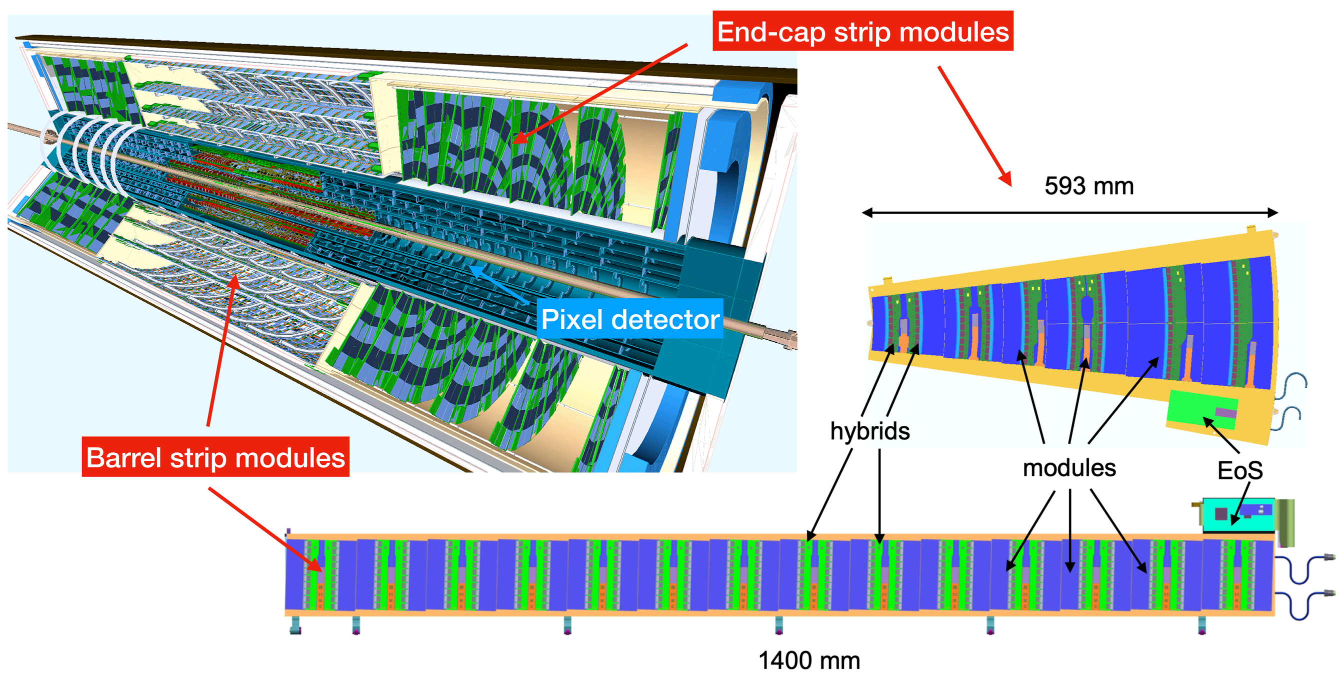
The ATLAS Inner Tracker (ITk) Strip Detector

The ATLAS ITk will be composed of 12.7 m^2 of pixel detectors located in the innermost part of the detector, and 165 m^2 of strip detectors in the outermost part of the tracking device. The strip detector [1] will be composed of:

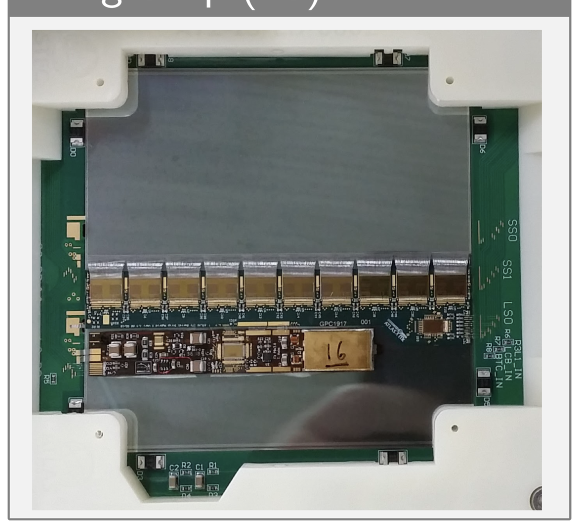
- A **barrel sector**, made of four layers of *staves* with rectangular modules and provided with 2.4 cm strips in the innermost two layers (Short Strip), and 4.8 cm strips in the outermost two layers (Long Strip). For both module types, a strip pitch of 75.5 µm and a stereo angle of 52 mrad will be used.
- Two **end-cap sectors**, located on each sides of the barrel, and composed of six rings made of six different types (R0-5) of trapezoidal-shaped strip modules assembled into *petals*. The sensors are provided with radial strips of different lengths and radii, varying from 1.9 to 6 cm.

End-cap (R0) module

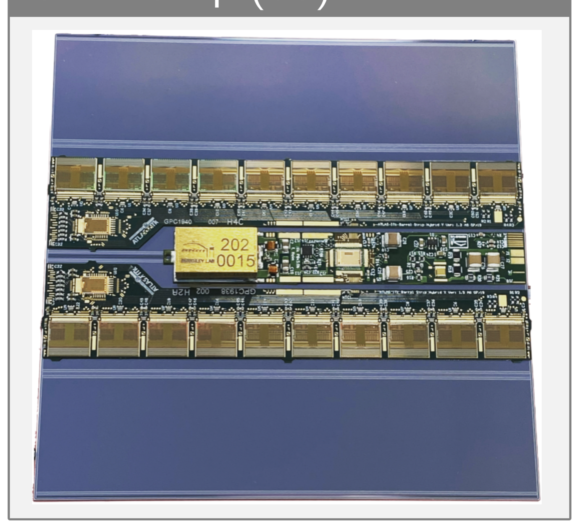




Long Strip (LS) module



Short Strip (SS) module

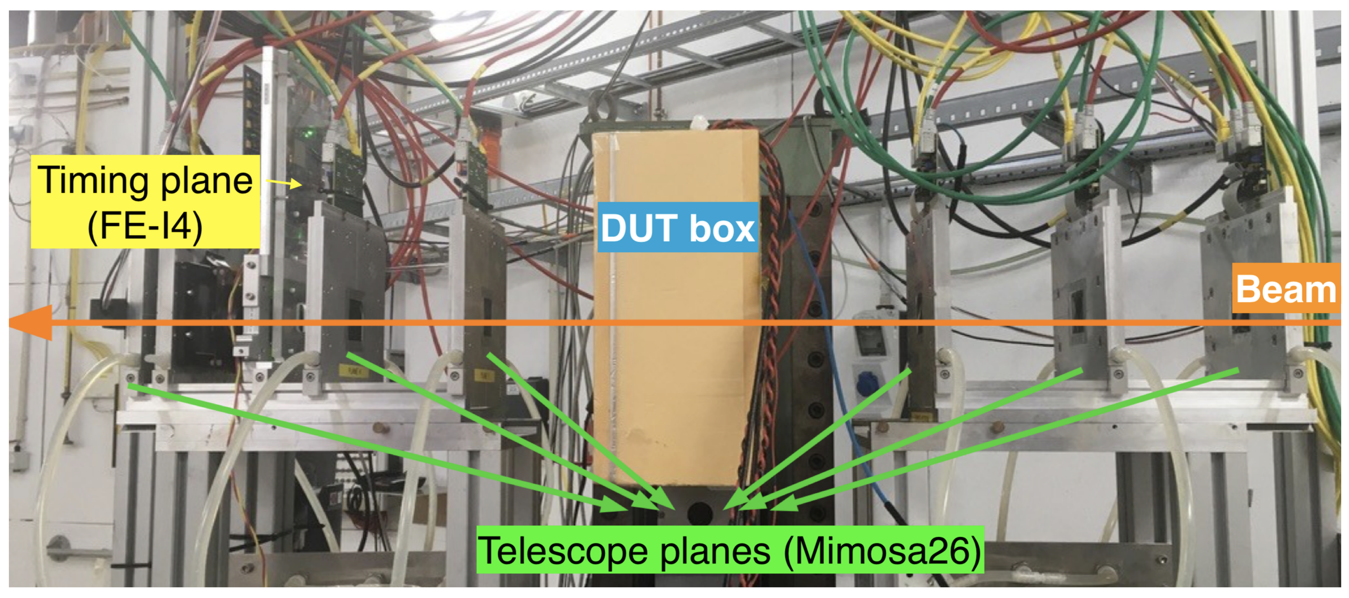


DESY-II Testbeam

DESY II is a synchrotron in the DESY campus (Hamburg, DE) which accelerates electrons up to 6.3 GeV and serves as injector for the PETRA III synchrotron. Using a system of collimators and photon/e^-e^+ converters, a tunable electron beam with momentum of 1-6 GeV can be provided for testbeam purposes. The testbeam telescope is based on a EUDET-type telescope and it consists of:

- Six *Mimosa26* silicon pixel planes, with a pitch of 18.4 µm and a total active area of 1×2 cm^2.
- A *Device Under Test (DUT)*, placed in the center of the telescope (between the Mimosa26 planes), for which spacial and other physical properties want to be studied.
- A *timing-plane (FE-I4)*, to compensate the large time integration of the pixel planes ($\sim$ 115 µs) with respect to the DUT ($\sim$ 25 µs) through precise measurement of the particle arrival time.

The telescope-DUT alignment and track reconstruction is performed using the *EUTelescope* framework. The more flexible *Corryvreckan* framework, more common within pixel testbeams, is now under implementation.



Results

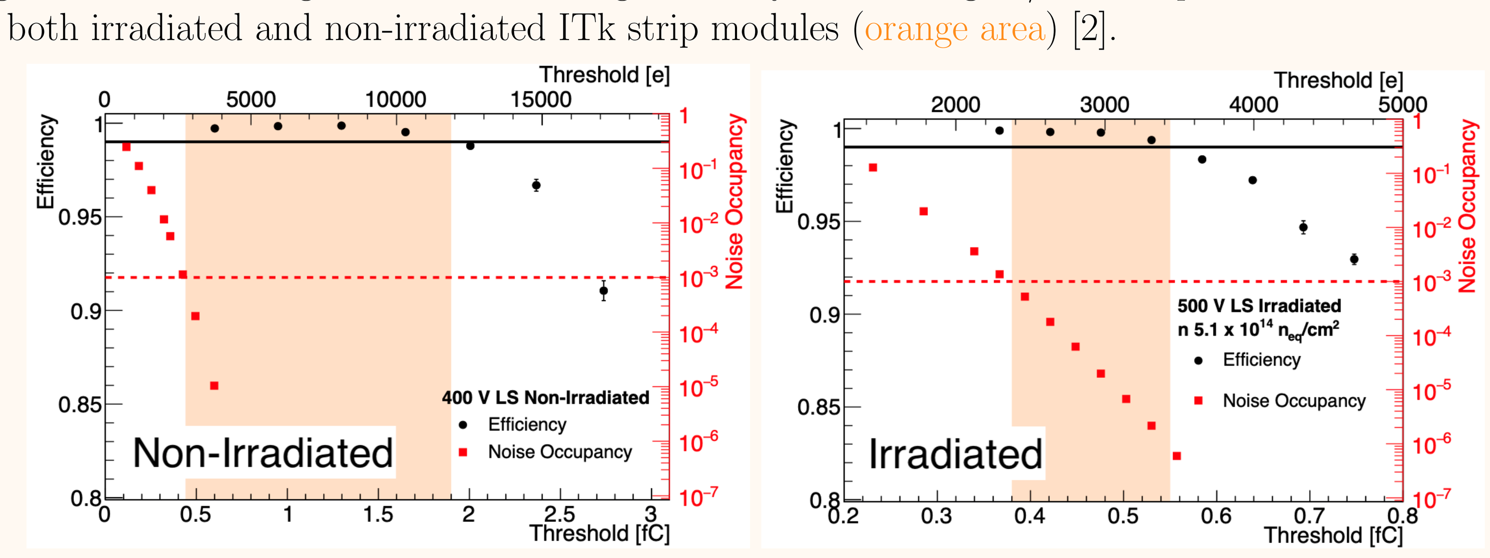
It is important to continuously test ITk strip module prototypes to ensure optimal tracking performance, even when the maximal irradiation dose expected from the HL-LHC (1.1×10^{15} n_{eq}/cm^2) is achieved. In order to meet the ATLAS ITk tracking standards, strip modules are expected to satisfy the following requirements through their entire lifetime:

- Efficiency > 99%
- Noise-occupancy < 0.1%
- Signal-to-noise ratio > 10

Currently, results obtained with both irradiated and non-irradiated strip modules show that **all these requirements can be satisfied by both barrel and end-cap modules**. Additional sensor properties such as dependency of detection efficiency on module temperature or position of the beam on the sensor have also been studied using 2019 testbeam data.

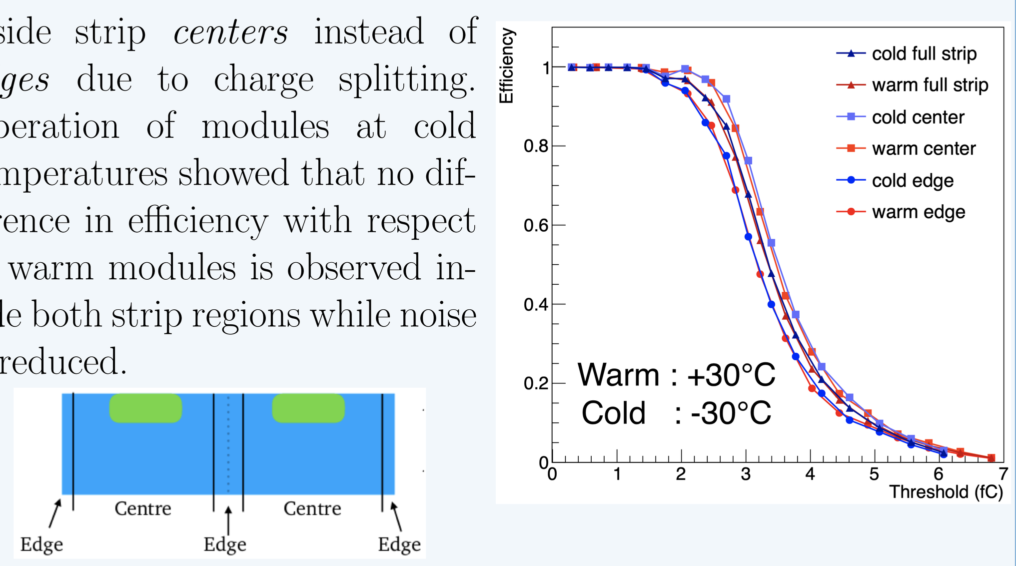
Irradiated vs non-irradiated signal/noise performance

A good collected charge threshold allowing to satisfy the ITk signal/noise requirements can be found for both irradiated and non-irradiated ITk strip modules (orange area) [2].



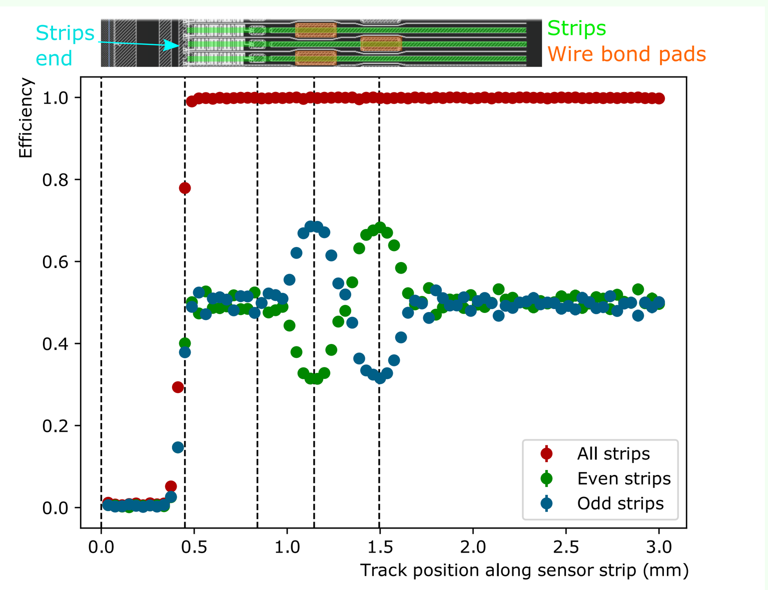
Short Strip modules temperature dependency

Particle-induced signals are expected to be better detected inside strip *centers* instead of *edges* due to charge splitting. Operation of modules at cold temperatures showed that no difference in efficiency with respect to warm modules is observed inside both strip regions while noise is reduced.



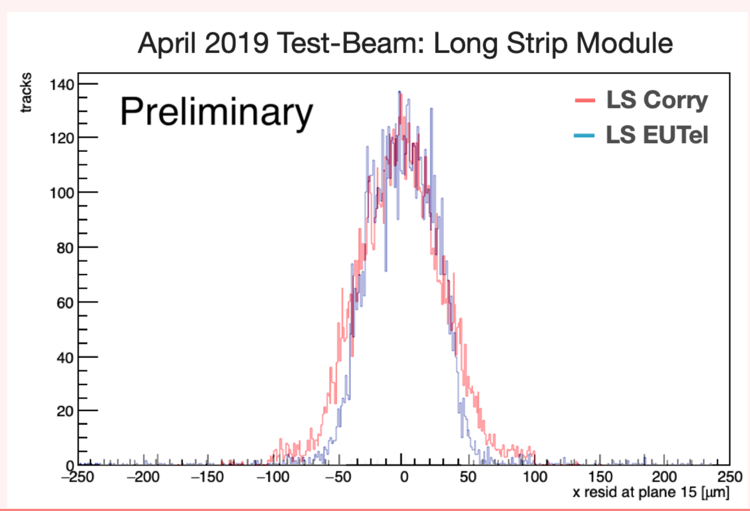
Long Strip edges studies

The maximization of the sensor active area is important for optimal ITk tracking performance. Tracking efficiency >99% is achieved through the whole LS strip length. Positions of AC pads are clearly visible when even/odd strips are selected.



Position/Reconstruction studies with Corryvreckan

Both barrel and end-cap geometries have been implemented in Corryvreckan, showing consistent results to the ones obtained using the EUTelescope alignment and track reconstruction.



Conclusions

Irradiated and non-irradiated ITk strip modules of both barrel and end-cap types are tested at DESY-II testbeam facility. Recent tests have shown that the latest prototypes (ABCStar modules) fulfil the requirements imposed for the HL-LHC tracking upgrade. Additional sensor properties (e.g. dependence of the detection efficiency on module temperature, sensor edges, etc.) have also been studied showing good detection performance. A transition of the analysis framework to the more flexible Corryvreckan is also ongoing. This new framework is foreseen to be used to analyse future ITk strip testbeams data collected during 2020-2021.

References

[1] The ATLAS Collaboration. Technical Design Report for the ATLAS Inner Tracker Strip Detector. 2017. CERN-LHCC-2017-005, ATLAS-TDR-025.

[2] E. Rossi. Characterization of Silicon Modules and Sensors for the ATLAS Inner Tracker Strip Detector, 2020. Ph.D. Thesis, Universitat Hamburg.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654168

The measurements leading to these results have been performed at the Test Beam Facility at DESY Hamburg (Germany), a member of the Helmholtz Association (HGF).