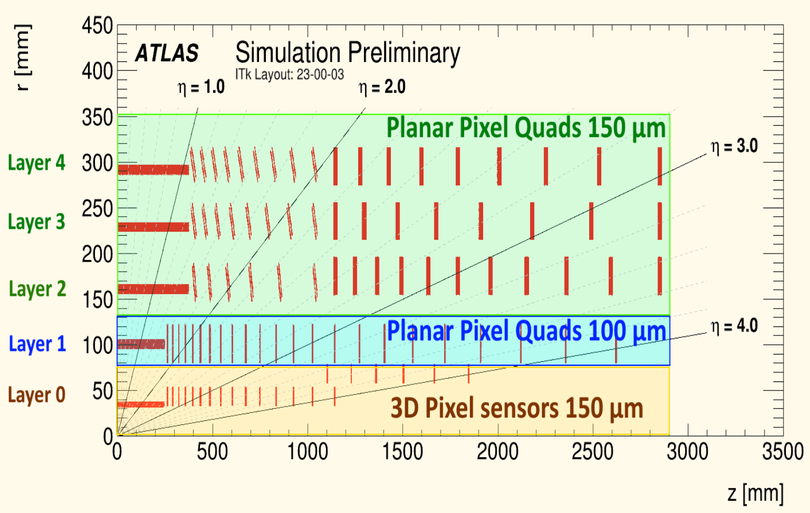
Test beam results of ITk pixel sensors for the new ATLAS ITk detector

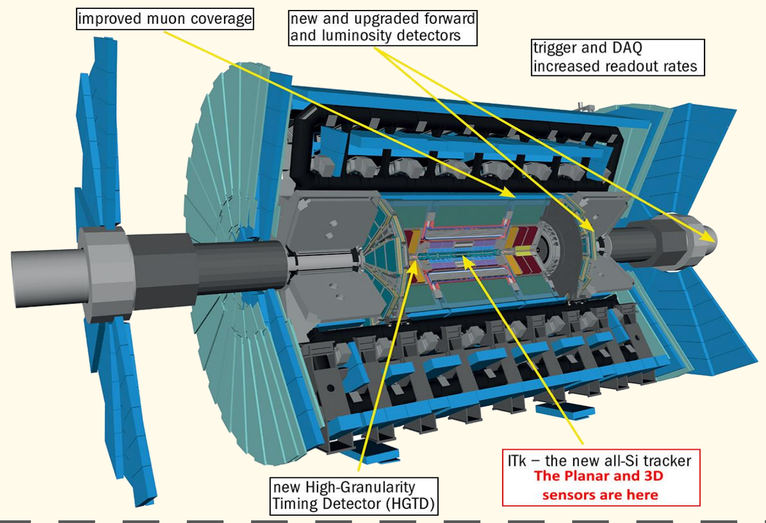
Presenter : Thibaud Carcone - On behalf of the ATLAS ITk Collaboration - Thanks to the efforts of the ATLAS ITk test beam team

This project has received funding from the European Union's Horizon Europe Research and Innovation programme under the Grant Agreement No 101057511 – Many thanks to the Eurolab project.

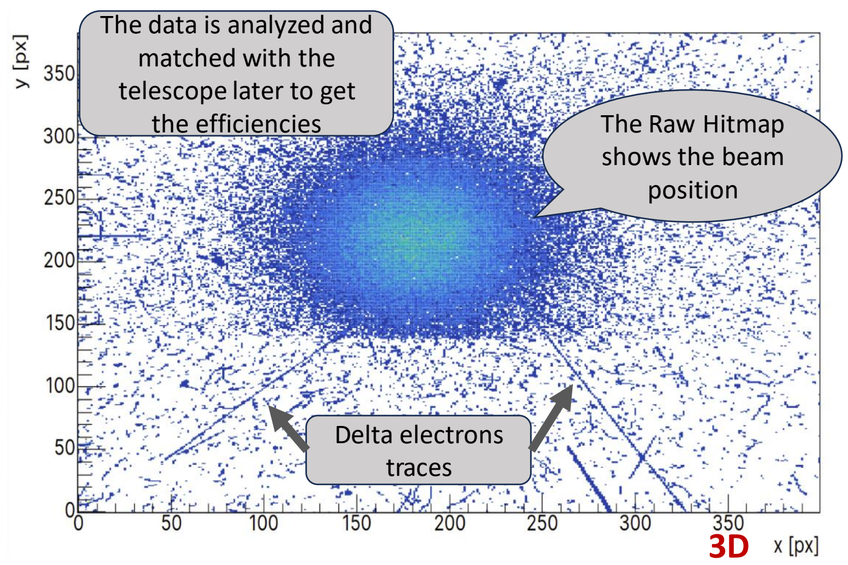
Introduction

In the future the entire tracking detector of the ATLAS experiment must be replaced. The new Inner Tracker (ITk) must withstand extreme radiation conditions at the High Luminosity LHC (HL-LHC). The ITk will be equipped with sensors provided by MICRON (planar 100 & 150 µm thick), SINTEF (3D 150 µm thick with 50x50 µm² pixel cell), HPK (planar 150 µm thick) and FBK[3] (planar 100 µm thick and 3D 150 µm thick with 25x100 µm² and 50x50 µm² pixel cell). In this poster, we present efficiency results of SINTEF 3D[2] and HPK planar[1] sensors. Such sensors were tested at fluences above 1.0×10^{16} n_{eq}/cm^2 (SINTEF 3D) and 4.31×10^{15} n_{eq}/cm^2 (HPK planar).





Hitmap



3D and Planar Pixel Sensors

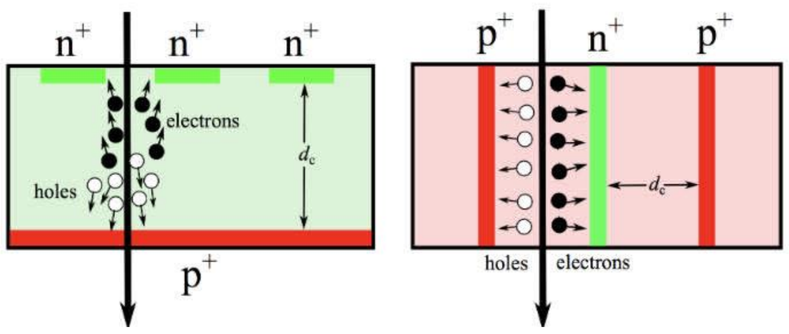
Both sensors are filled with n-type and p-type electrodes vertically or horizontally into the silicon bulk. When a charged particle goes through the active volume, charges move to the electrodes, and we cab gather the signal on each pixel.

PLANAR:

- Cheaper
- Collection of the charges depends on the thickness

3D:

- Fast charge collection
- Better radiation hardness

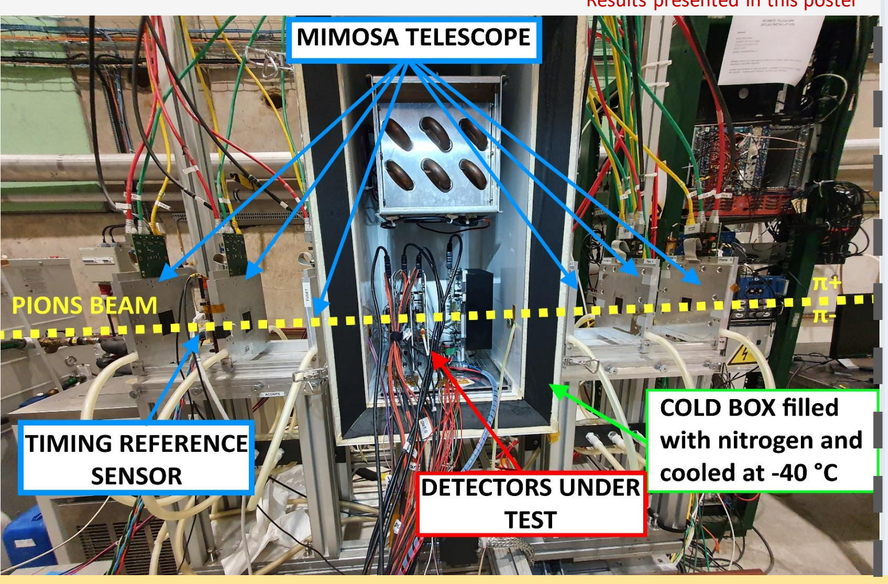


Test Beam Setup

The EUDET Pixel Telescope

- At the CERN SPS North Area H6 test beam line
- Tracking capabilities of 6 MIMOSA26 (MAPS) planes for track reconstruction
- Beam of 120 GeV pions (π^+ and π^-)
- Tested sensors: planar 100 µm by FBK, planar 150 µm by HPK*, 150 µm 3D by SINTEF (50x50 µm²)* and FBK (50x50 and 25x100 µm²).

*Results presented in this poster



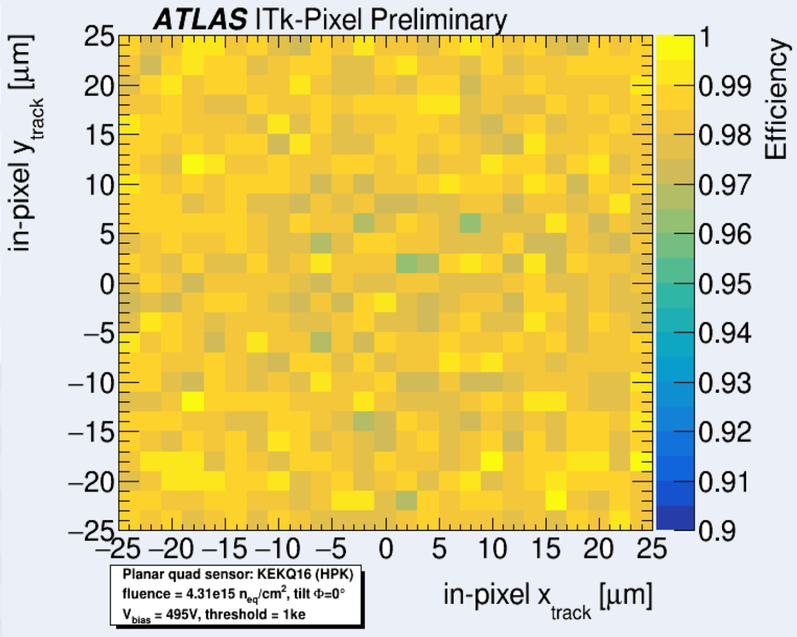
In-Pixel Efficiency Maps

Telescope tracks crossing the detector under test (DUT) are matched with hits on the DUT. The efficiency is defined as the ratio between matched tracks and total tracks. The efficiency is then plotted as a function of the relative position in the pixel for all pixels

Overall efficiency is >96 % (required performance for perpendicular configuration). In-pixel efficiency map highlights the internal structure of each pixel:

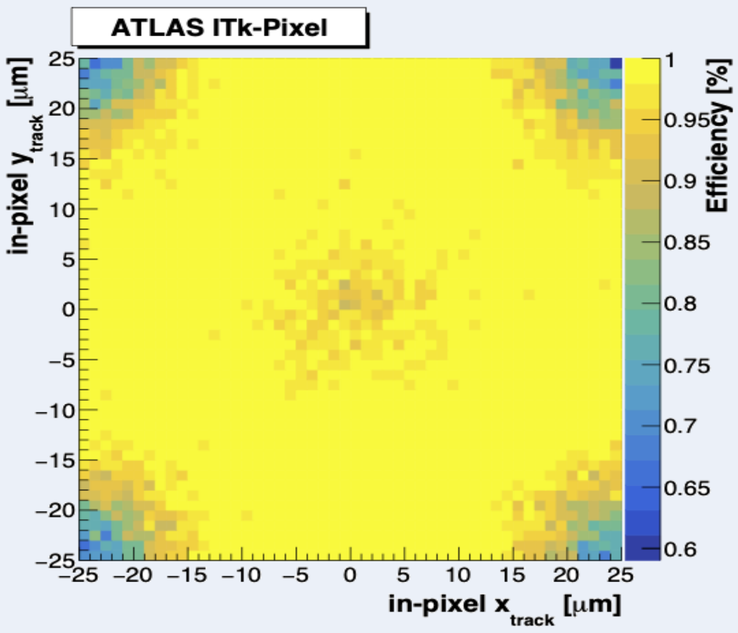
Planar [1]

- In the planar sensor at ~500 V no structure is visible even after irradiations.



3D[2]

- In the 3D sensor at 60 V the inefficiency due to p+ columns is visible, this is expected for a DUT mounted perpendicular to the beam.



Results

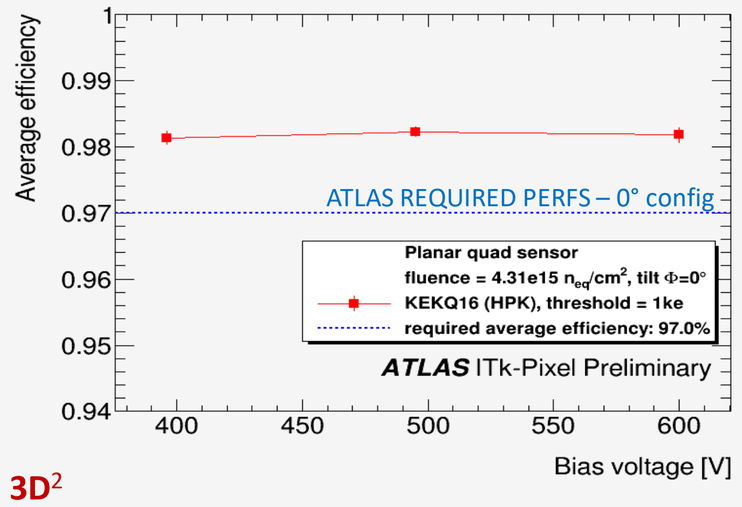
The plots below shows the average pixel efficiency as a function of the bias voltage for some irradiated sensors.

- 3D SINTEF sensor was irradiated at 1.0×10^{16} n_{eq}/cm^2
- Planar HPK sensor was irradiated at 4.31×10^{15} n_{eq}/cm^2

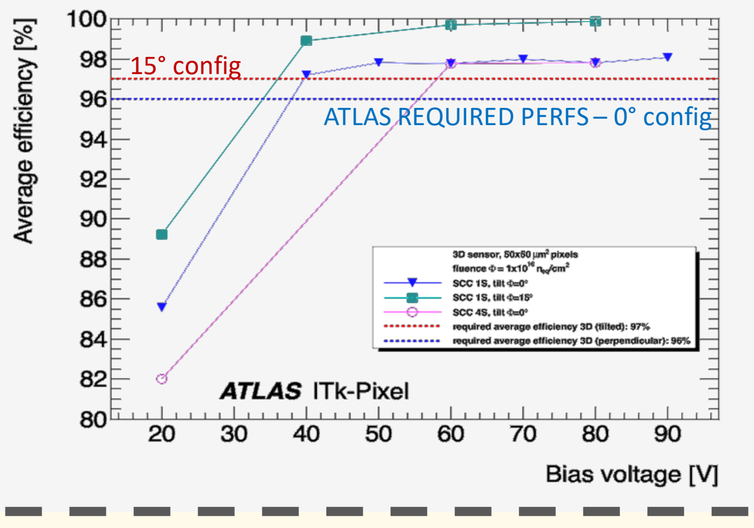
For both sensor types :

- We find an efficiency above specifications
- As expected, the inefficiency shown in the in-pixel hitmap for the 3D sensor perpendicular to the beam is not visible at an angle giving a higher average efficiency.

Planar [1]



3D[2]



Conclusion

We present an efficiency analysis and sensors from Run 6. The sensors meet ATLAS ITk specifications:

- ❑ SINTEF 3D[2] :
  - >97 % efficiency in 0° perpendicular configuration
  - >98 % efficiency at 15° tilted configuration
- ❑ HPK Planar quad[1]
  - >98 % efficiency in 0° perpendicular configuration
- ❑ FBK 3D[3] sensors also above >96 % (not shown here)

[1] ATLAS ITk Collaboration. 2023. Test Beam Results of Planar HPK Pixel Silicon Sensors. CERN, Geneva. https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PLOTS/ITK-2023-005/

[2] ATLAS ITk Collaboration. 2023. Test Beam Results of SINTEF 3D Pixel Silicon Sensors. CERN, Geneva. https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PLOTS/ITK-2023-004/

[3] Simone Ravera. 2023. Qualification of irradiated 3D pixel sensors produced by FBK for the pre-production of the ATLAS ITk detector. PoS (VERTEX2023)072. https://cds.cern.ch/record/2884604