THE UPGRADED MICROSTRIP SILICON SENSOR CHARACTERISATION FACILITY OF THE UNIVERSITY OF SHEFFIELD

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Introduction

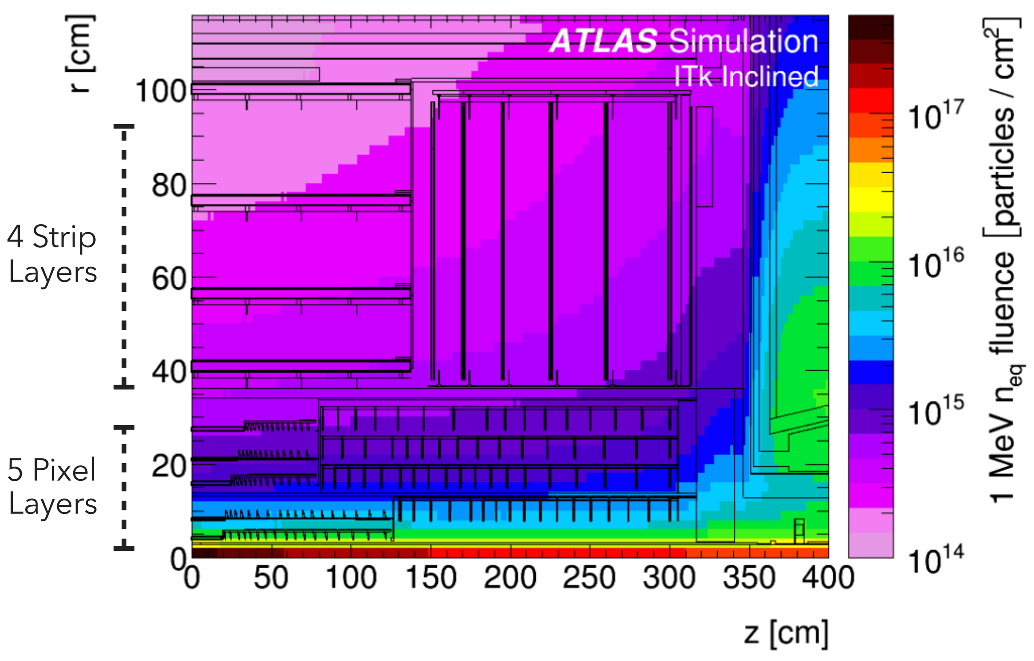
INNER TRACKER

In 2024 the Inner Detector of the ATLAS experiment [1] at CERN is foreseen a major upgrade in accordance with the High-Luminosity LHC [2]. The current system is going to be replaced by an all-silicon tracker, the Inner Tracker (ITk) [3], and this is essential to:

- maintain the tracking performance on the future high-occupancy environment,
- handle the about an order of magnitude increasement of the integrated radiation dose.

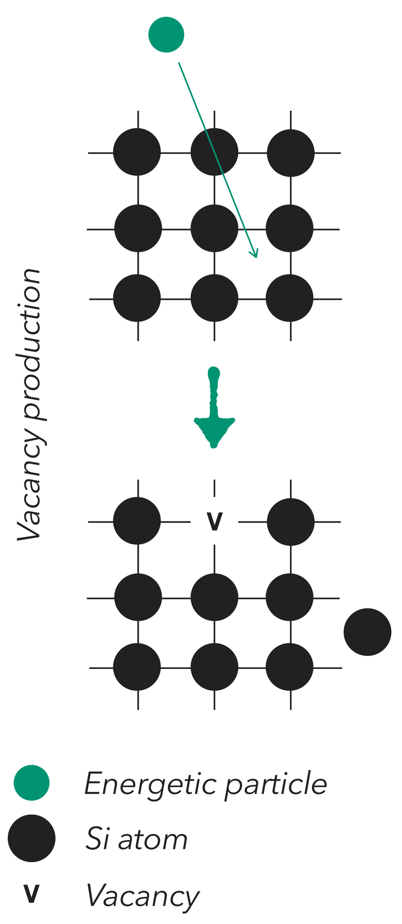
Simulation studies have shown that fluences up to **10^{15} 1 MeV n_{eq}/cm²** are expected at the inner layer of the strip detectors after a decade of operation.

Expected radiation levels on ITk assuming 3000fb^{-1} of p-p collisions at $\sqrt{14}$ TeV [3].

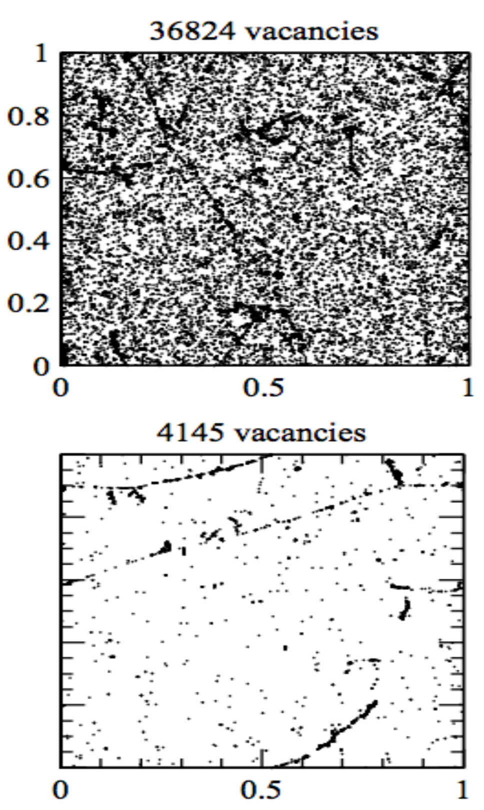


RADIATION DAMAGE

A flux of particles can generate defects on the surface and bulk material of a silicon detector. Focusing on the bulk damage, it's caused by non-ionising energy loss (NIEL) of energetic particles crossing the *depletion region* where nuclear interactions knock-out atoms from the crystal lattice, creating point or cluster vacancies.



Simulated distributions of vacancies by 10 MeV (up) and 24 GeV (down) protons of 10^{14} cm^{-2} fluence, transverse view [4].



The radiation damage in the bulk leads to:

1. **Increase of the leakage current** as defects act as generation/recombination centres. This is seen as excess heat that should be dissipated by cooling the sensors to keep this current low.
2. **Increased depletion voltage** by the change of the effective doping–donor removal/acceptor creation.
3. **Reduced charge collection efficiency** (CCE) by increasement of the charge trapping centres' density.

Characterisation Facility

ALIBAVA SYSTEM

The portable ALiBaVa system [5] is used to acquire the signal for detector performance measurements. The core of the system is the Beetle ASIC chip that readouts the micro-strip sensor providing an analogue output, where the peak of the pulse is proportional to the collected charge.
To excite the sensor, β-radiation from a radioactive source (^{90}Sr) is facilitated.
The setup is composed by tree hardware parts:

Daughterboard

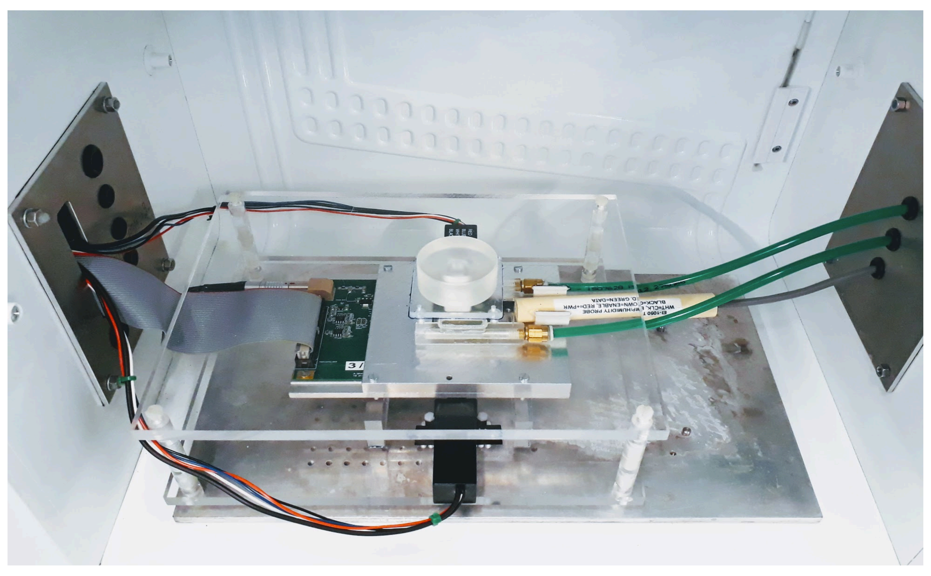
- Sensor mounting
- Beetle readout chips
- HV power supply
- Controlled environment

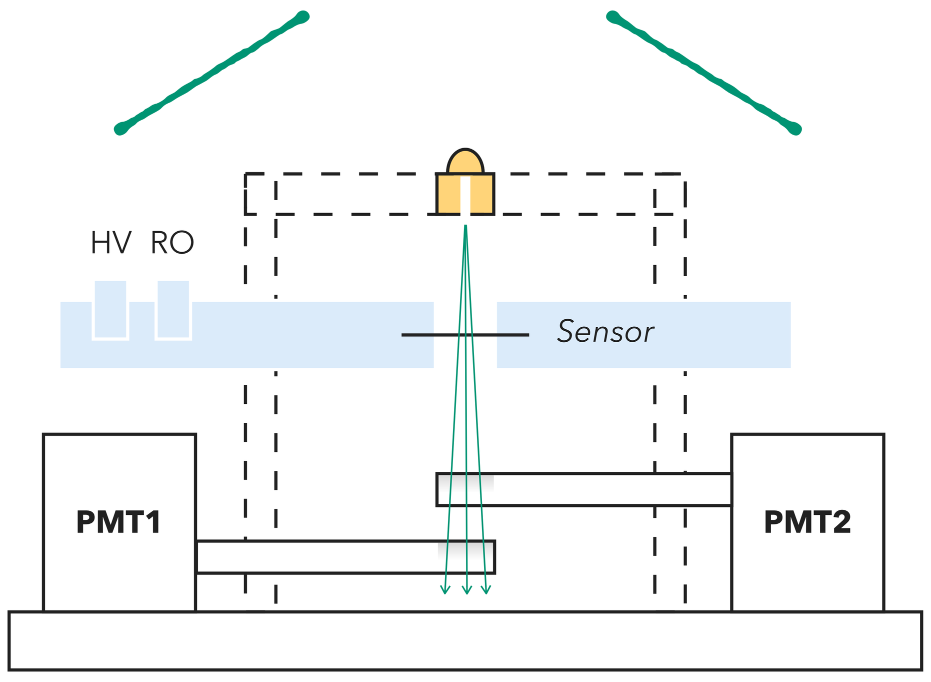
Motherboard

- FPGA based
- Analogue data processing
- Trigger signal handling
- PC communication

The Fridge

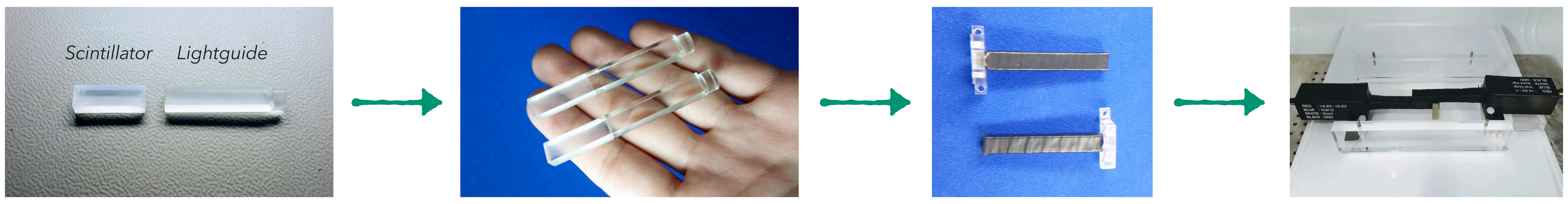
In order to take measurements in an environment that closely resembles the operational one, the **radioactive source**, the **daughterboard** and the **triggering system** are placed inside a fridge that can reach temperature and humidity down to **-30°C** and **10% RH** respectively.





Triggering

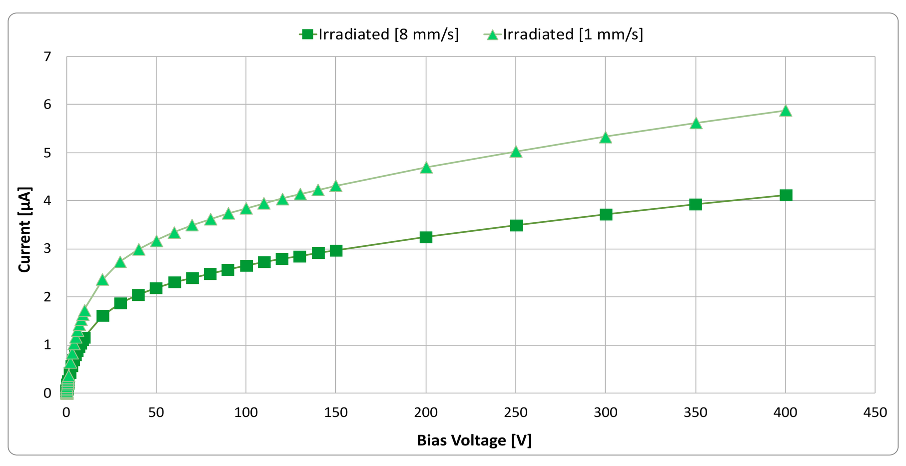
For triggering purposes an assembly of two plastic scintillators glued to lightguides and mounted to Photomultipliers (PMTs) is manufactured. The two PMTs can operate in **coincidence** to reduce the environmental background.



Commissioning Measurements

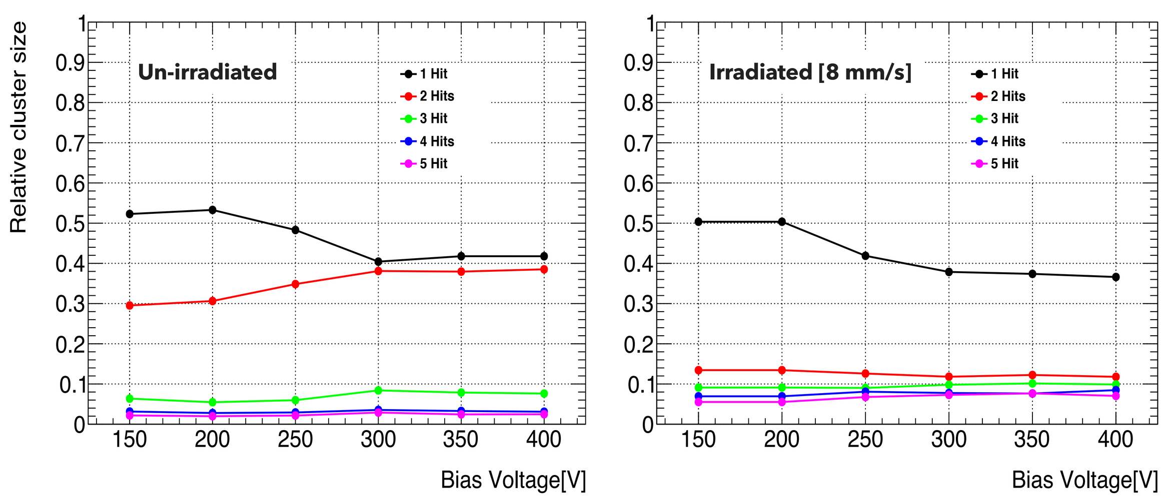
To gauge the operation of the facility, commissioning measurements **compare** the performance of an **un-irradiated** sensor with **irradiated** ones. N^{+}-in-p miniature (1 x 1 cm²) micro-strip sensors of the ATLAS12A design [3] irradiated to fluence of 10^{15} 1 MeV n_{eq}/cm² at the Birmingham MC40 irradiation facility [6] using a proton beam of energy 27 MeV. The sensors were scanned through the beam with **two different scanning speeds** to also study the effect of the thermal annealing.

Increased leakage current *measured on the sensor characteristics. Un-irradiated sensors current few nA.*

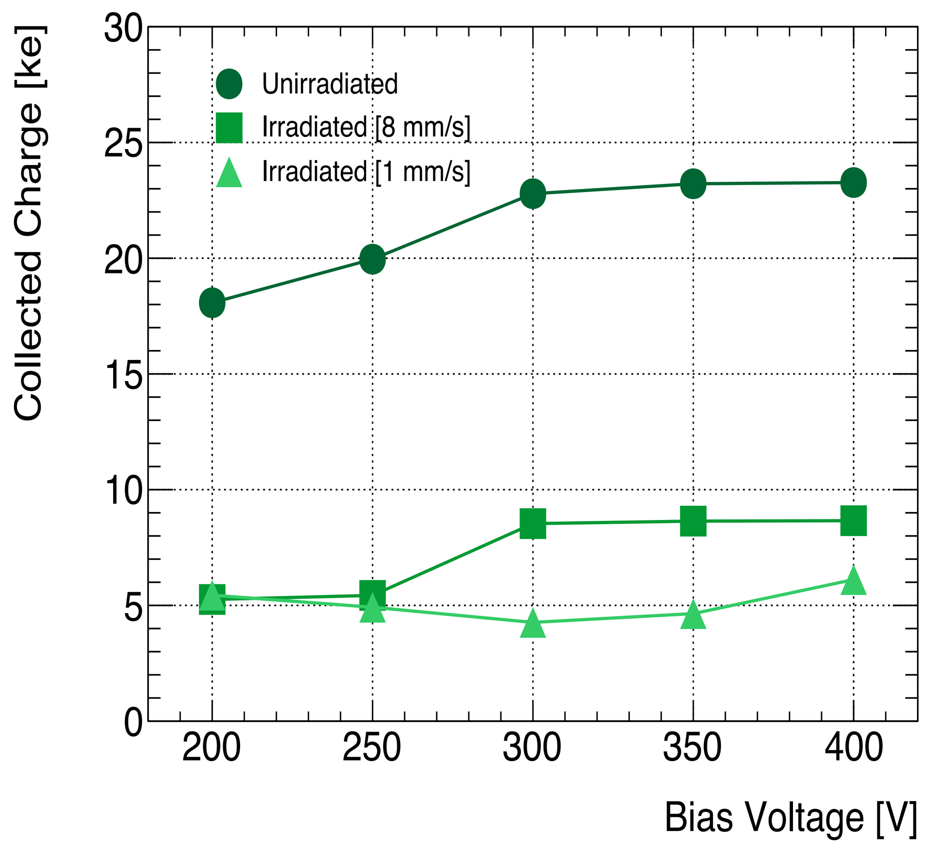


Sensor **CCEs**, **characteristic curves** and **cluster size distributions** are presented.
The results fount in agreement with measure-ments of similar facilities [6].

Decrement on the 2-strips event *as accumulated surface charge decrease the between-strips-efficiency.*



Reduced CCE *by 65 - 80% is measured on the irradiated sensors. Thermal annealing found to further degrade the performance.*



References

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3. ATLAS Collaboration. "Technical Design Report for the ATLAS Inner Tracker Strip Detector". CERN-LHCC-2017-005 (2017).
4. M. Huhtinen, "Simulation of non-ionising energy loss and defect formation in silicon". Nucl. Instrum. Meth. A 491194-215 (2002).
5. R. Marco-Hernandez. "A Portable Readout System for Microstrip Silicon Sensors (ALIBAVA)". IEEE Transactions on Nuclear Science, vol. 56, no. 3, pp. 1642-1649 (2009).
6. Allport, P., et al. "Recent results and experience with the Birmingham MC40 irradiation facility". JINST 12 C03075 (2017).

The University Of Sheffield.
IOP Institute of Physics
High Energy Particle Physics Group
ATLAS EXPERIMENT