Studying the sensor response in the punch-through-protection region

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Punch-through protection

The punch-through protection (instrumented gap between strip implant and **bias ring**) protects readout electronics from beam splashes inducing high currents. This area (16.2 µm x 9.5 cm per sensor strip row) makes up a combined area of 800 cm^2 (eight modules) in the ATLAS ITk strip tracker. It is thus important to know whether charge can be collected in this region.

High precision

Studying this sensor region requires µm level position resolution, which was achieved by using a micro-focused X-ray beam (2 x 3 μm^2) and µm precision positioning stages.
Given the dimensions of the implant width (16 µm) and the strip pitch (75.5 µm), the micro-focused beam is well suited to study the strip responses in different areas.

Sensors

Two n-on-p type ATLAS R0* mini sensors (1 cm^2, thickness 300 µm) were tested in comparison:
one unirradiated
(operated fully depleted at -400 V)
one irradiated
at JSI with thermal neutrons to $1 \cdot 10^{15}$ n_{eq}/cm^2
(operated under-depleted at -800 V)
Both sensors were tested at -20 °C
and 0% humidity.

* C. Lacasta et al., "Design of the first full size ATLAS ITk Strip sensor for the endcap region", HSTD11

Charge deposition

The Diamond Light Source provides photons every 2 ns. Using only monochromatic 15 keV photons reduces the flux to 1.2±0.2 photons arriving within 10 ns.

Each arriving photon has a 51% probability to react within a 300 µm of silicon, so that an average of 1.4±0.3 react inside the sensor volume within the sampling time of each event.

Data was taken continuously without triggering.

Readout and Data analysis

Sensors were wire bonded to an analogue readout board (ALiBaVa).

For each event, the charge registered in each readout channel was compared to the channel noise and pedestal value. A hit was registered if the read out charge exceeded the channel noise by a factor of 1.6.

The number of hits obtained per channel were used to map the responding sensor region.

Positioning

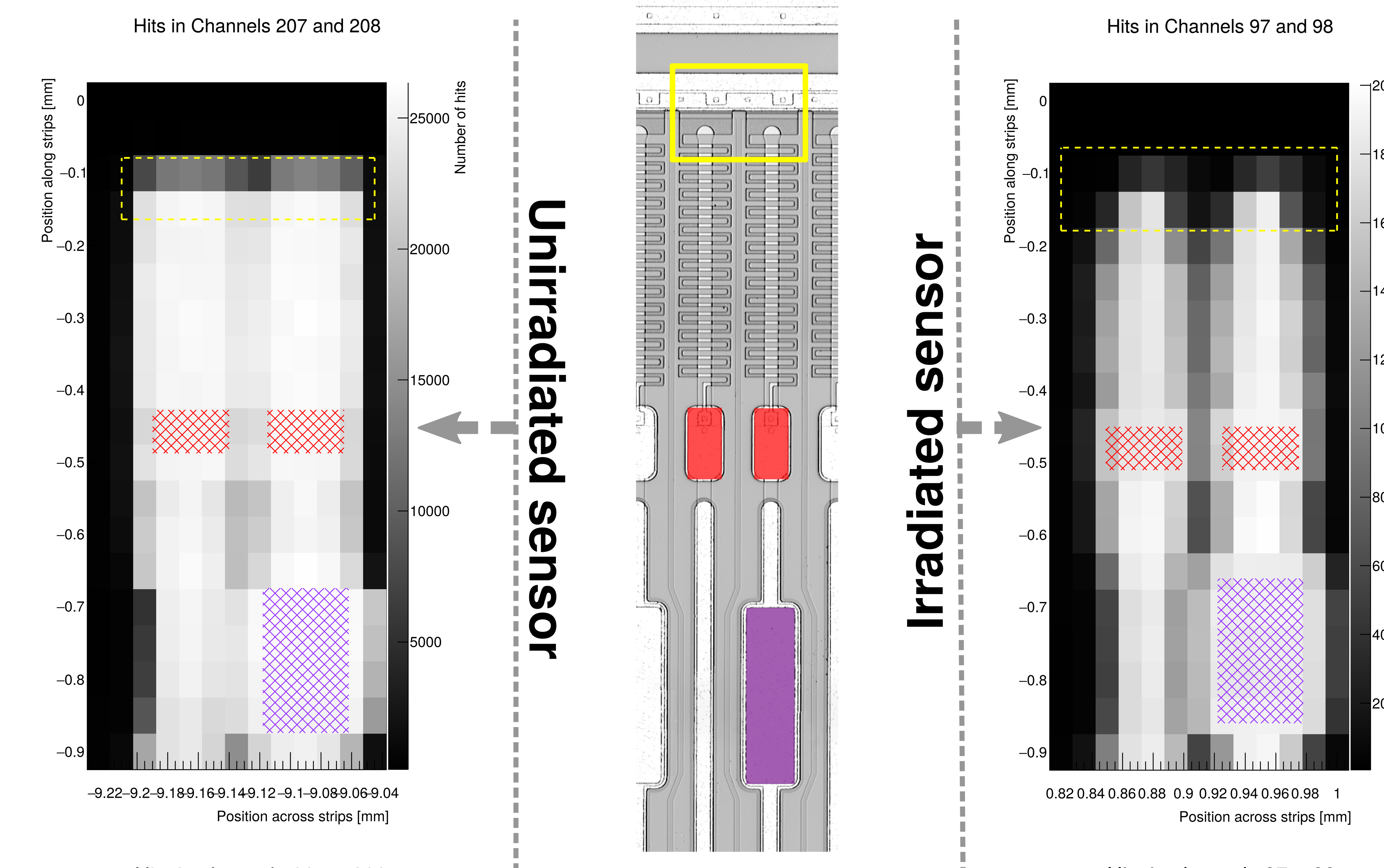
The beam was positioned on the sensor using a positioning laser with a width of 0.5 mm.

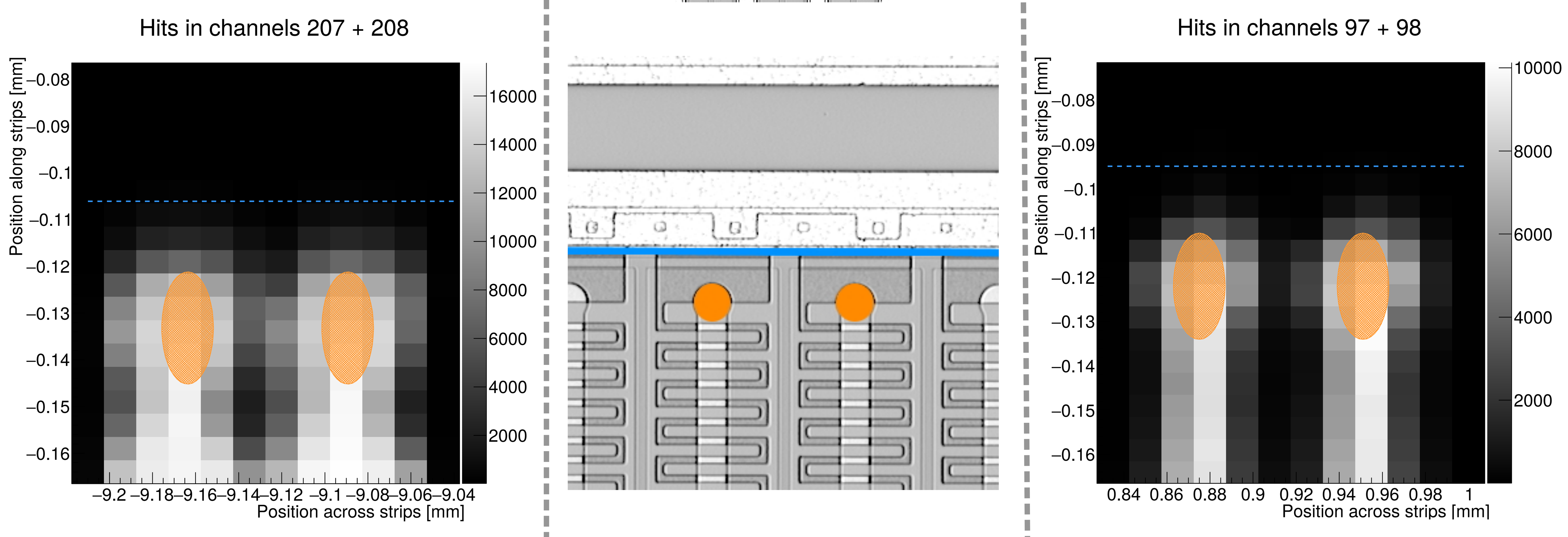
For sufficient statistics, data needed to be taken for 2.5 minutes per beam position. With 48 hours of beam time available, the position of the punch-through protection had to be known with a precision of ±20 µm, which could not be achieved with the used position laser.

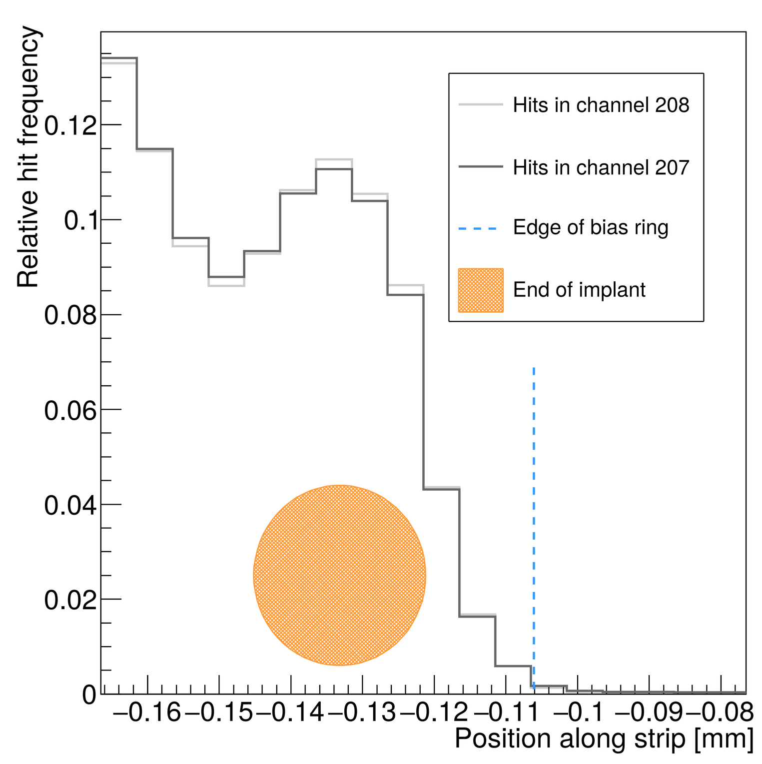
Orientation using sensor layout

Sensor strips respond differently in sensor areas with and without aluminium pads:

around AC and DC aluminium pads, strips collect charges over a wider area. By finding bond pads in a coarse scan, approximate positions of the punch-through protection region can be derived from bond pad positions.

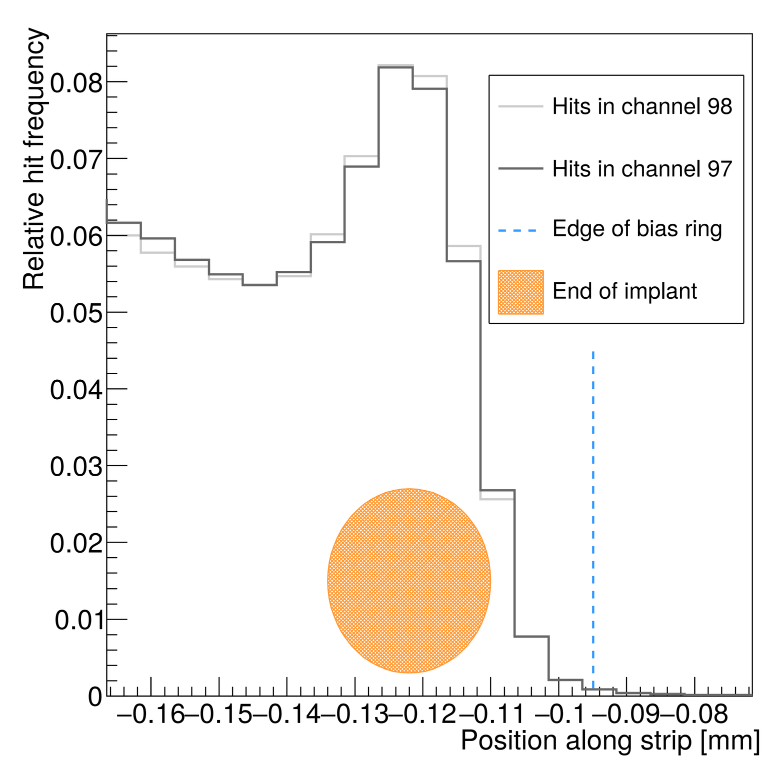






Results

Charge collection decreases rapidly beyond the **end of the implant**. Hits in the punch-through protection region can not be collected, neither using an unirradiated nor an irradiated sensor.



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