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# Commissioning of an X-ray irradiation facility to test HPGe sensors and to irradiate CMOS electronics

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## Context

X-ray generators are a proven test method to determine the vulnerability or hardness of electronic components with respect to ionizing radiation effects.

X-ray generators offer a relatively high dose rate, offering reduced testing time in comparison to most cobalt-60 sources.

X-ray generators provide radiation of sufficiently low energy (~10 keV) such that it can be readily collimated. As a result, it is possible to irradiate a localised area in a device or on a wafer.

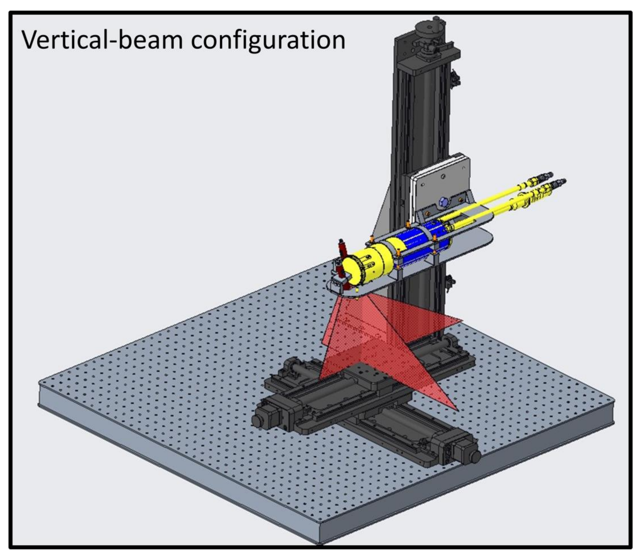

Radiologically shielded chamber with the X-ray tube
Internal volume: 1m x 1m x 2 m (H x D x W)

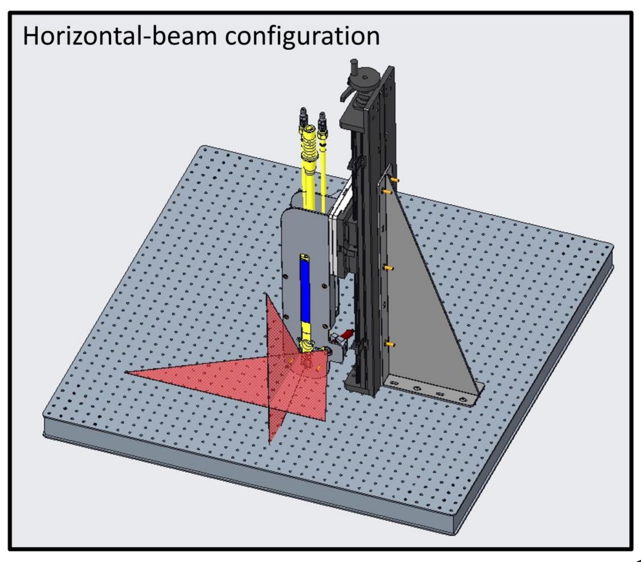
The X-ray irradiation facility at the UKRI-STFC Daresbury Laboratory (UK) supports the in-house development of :

High Purity Germanium systems for accelerator based light sources.

Radiation-hard electronics like CMOS sensors for particle collider experiments.

The X-ray beam can be configured vertically or horizontally depending on the test requirements.



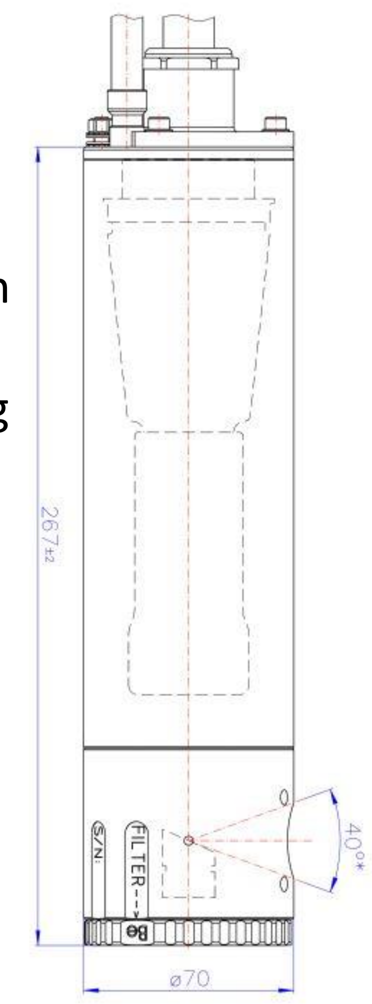




## X-ray generator properties

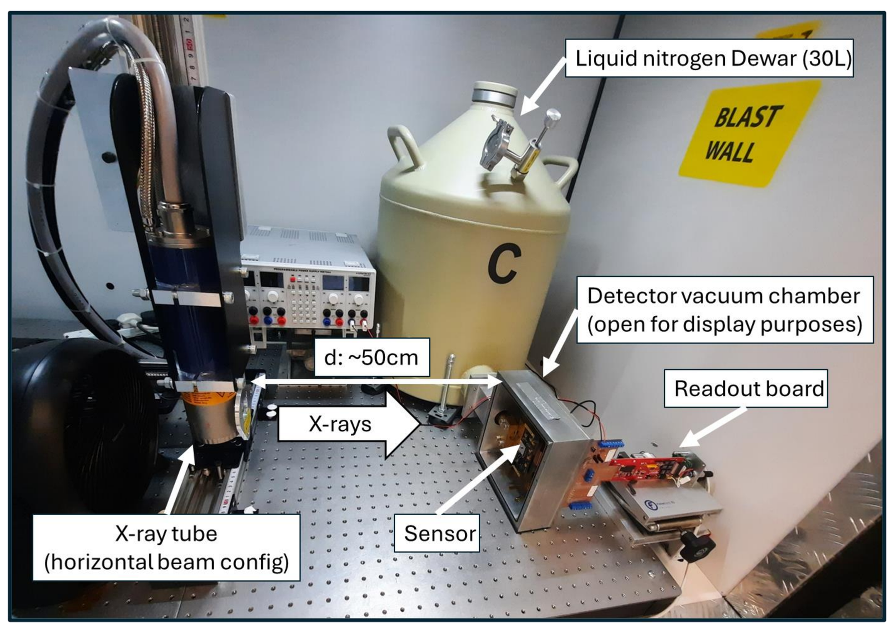
The X-ray generator can produce up to 3kW of power and it features an anode grounded X-ray tube limited to 60kV. The tube is X-ray shielded and the whole vacuum vessel is water cooled to achieve high stability X-ray emissions.
The target material is tungsten because it is most used to test ionizing radiation effects. Tungsten provides emission lines at ~10keV.

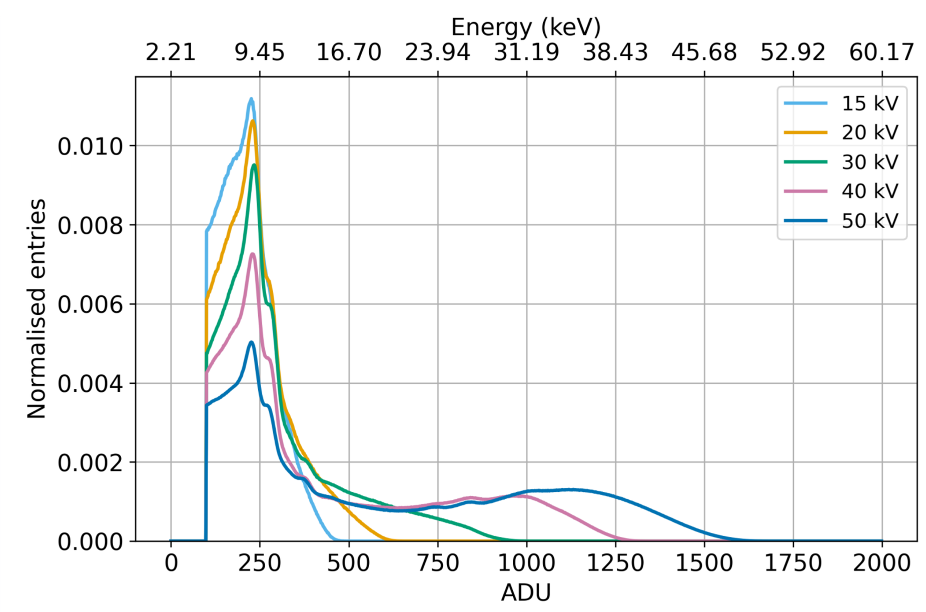
| Tungsten X-ray tube specifications | |
|---|---|
| Tube Voltage | 0 – 60 kV |
| Tube Current | 0 -50 mA |
| Total max power | 3 kW |
| Beam divergence | 40 deg |
| Inherent flirtation | 1mm Be |
| Additional filters | 2mm Al; 4mm Pb |

| Tungsten K and L shell emission lines | |
|---|---|
| Kα1 | 59.3 keV |
| Kα2 | 58.0 keV |
| Kβ1 | 67.2 keV |
| Lα1 | 8.4 keV |
| Lα2 | 8.3 keV |
| Lβ1 | 9.7 keV |
| Lβ2 | 9.9 keV |
| Lγ1 | 11.3 keV |
| Mα1 | 1.8 keV |



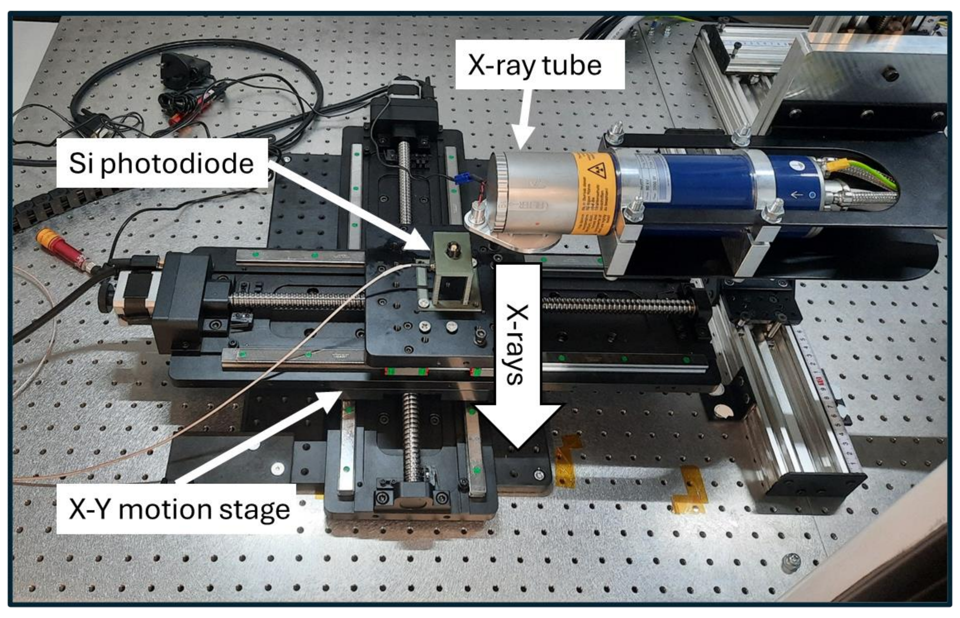

## X-ray energy spectra

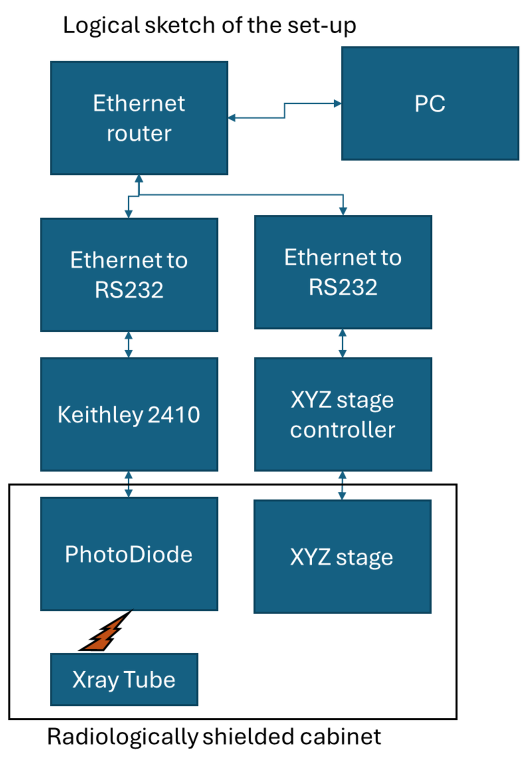



Different spectra were measured with the HEXITEC detector system featuring a 2mm tick CZT sensor. The maximum energy in each spectrum is proportional to the peak kilovoltage of the X-ray tube. The characteristic lines of tungsten at ~10keV are visible in all the spectra.

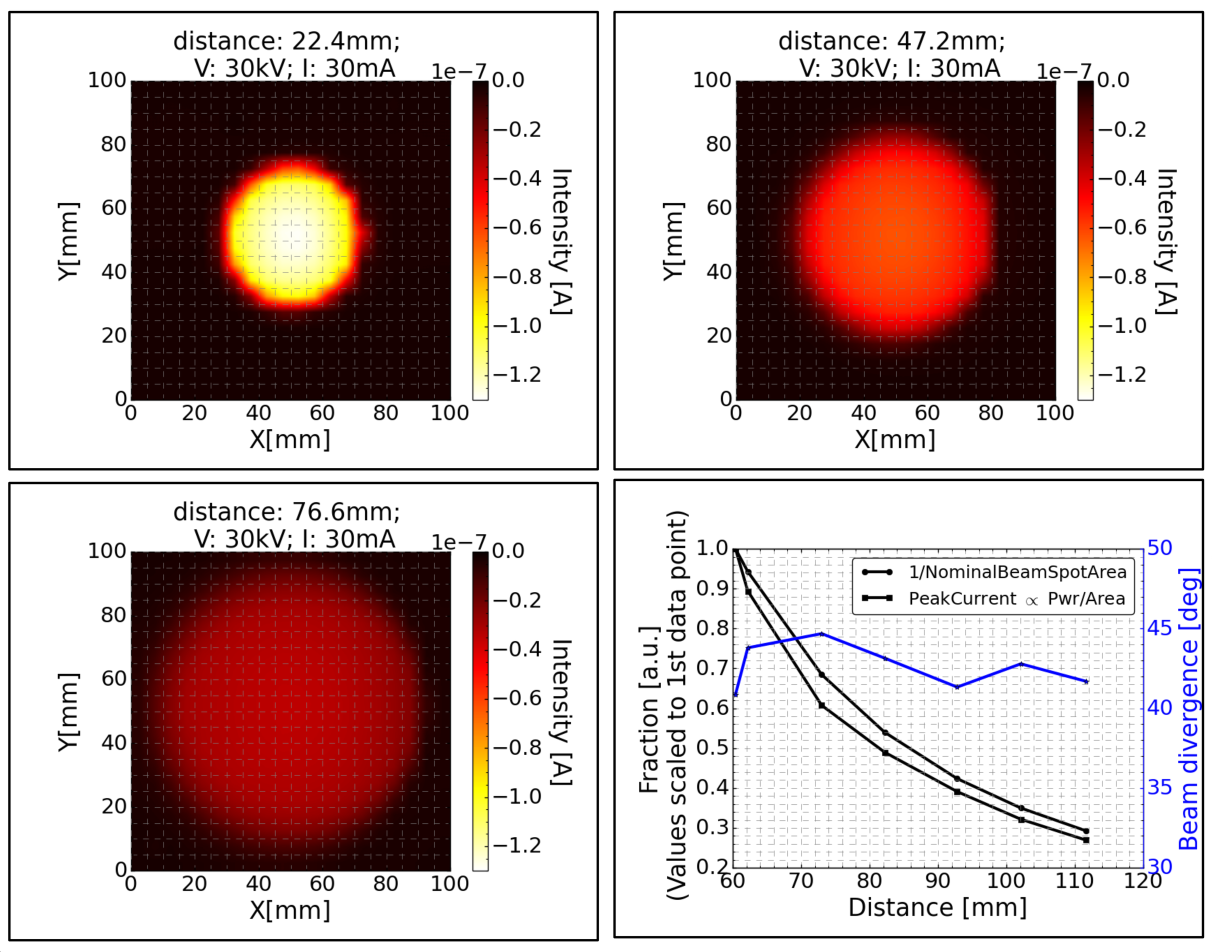
## Set-up for beam spot measurements




A series of tests were performed with a commercial off-the-shelf photodiode to measure the intensity and the width of the beam spot.
The position of the Si photodiode was changed systematically with an XY motion stage and the signal current recorded at each position.

## Beam spot measurements



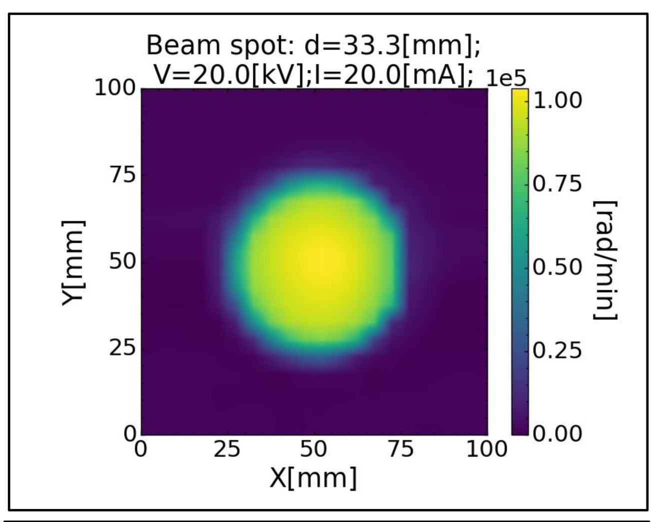

The diameter of the beam spot was measured as a function of the distance from the X-ray tube.

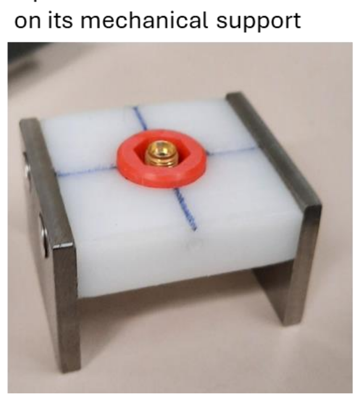
The beam divergence angle was reconstructed and in agreement with the nominal value of 40deg.

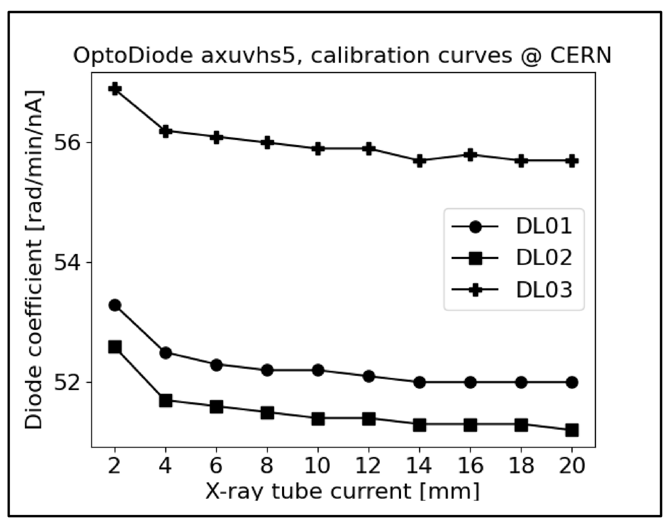
The radiation power per unit area was compared with the reciprocal of the nominal beam spot area. The two curves show similar trends.

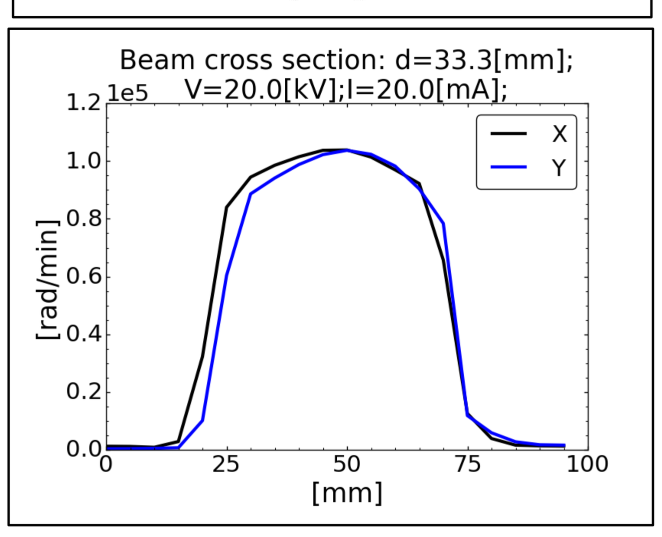
## Total Ionising Dose (TID) calibration

Three OptoDiode-axuvhs5 photodiodes were calibrated at the CERN EP department (ESE group) with the Obelix X-ray system.
The beam spot measurements were repeat at Daresbury Laboratory with the calibrated axuvhs5 photodiodes. The Daresbury system was able to deliver the same target dose rate of 100krad/min used by CERN to perform irradiations.
The dose rate is uniform within 3% over an area of ~1cm$^2$ around the peak value.



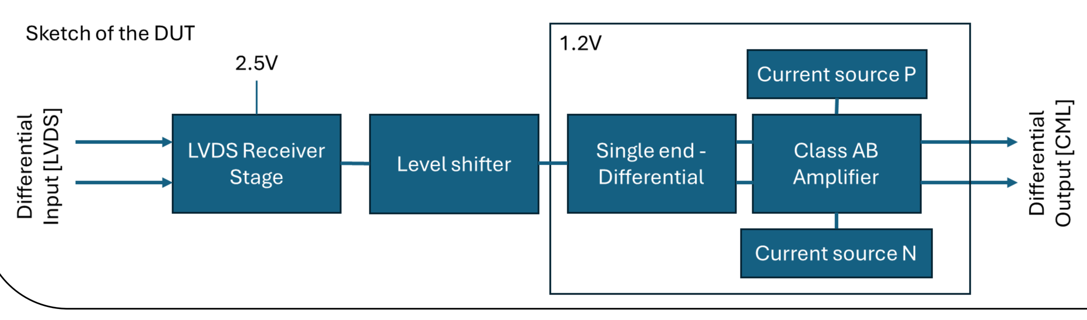



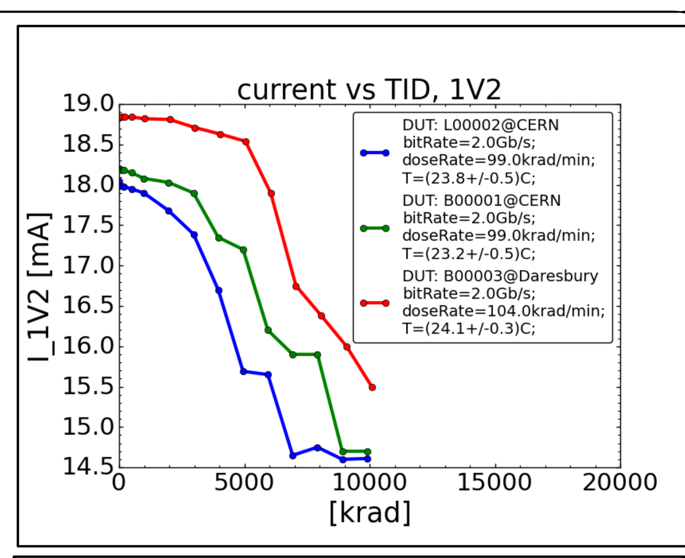



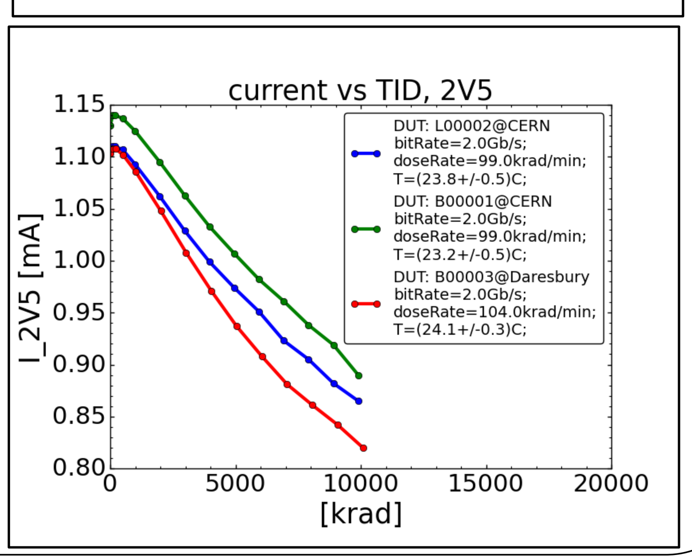




## TID irradiations with reference Device Under Test (DUT)

A comparative irradiation was performed by irradiating different samples of a reference DUT at CERN and Daresbury Laboratory.
The DUT was a data transmission block with LVDS input and CML output. The DUT was designed as part of the R&D programme for the CERN ALICE ITS3 and BNL ePIC SVT detectors.
Different samples were irradiated up to 10Mrad with a dose rate of ~100krad/min. The supply currents of the different power domains were monitored. Results for irradiations at CERN and Daresbury Laboratory show similar results.

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