CAP Meeting 2022

AREA-X
Active Region Extension Assessment with X-rays

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ATLAS ITk

Sensor characterisation

Sensors for new experiments (especially new tracking detectors) keep evolving

- Finer granularity
- Better timing resolution
- Higher radiation hardness
- Thinner silicon
- New technologies

More and more detailed understanding of sensors is required before/after irradiation

New methods needed for characterisation

Current methods

Of interest here: mapping of the depleted area/volume of sensors to measure shape and diagnose defects

Standard ways to perform this measurement:

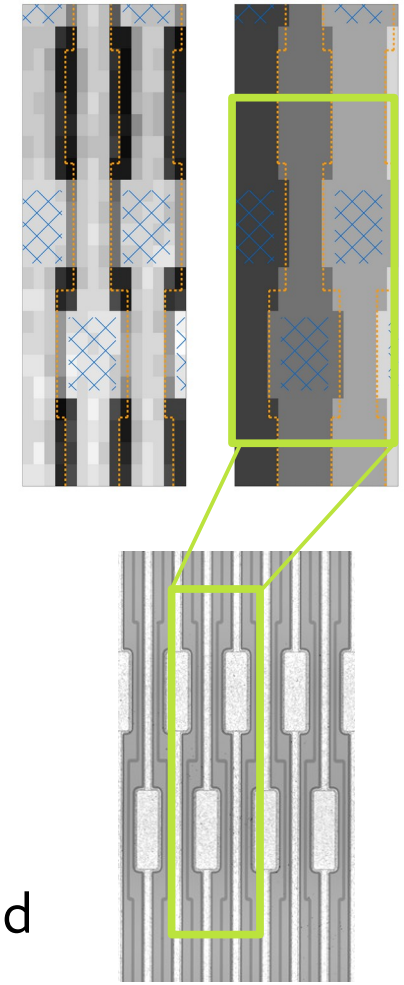
- **Particle beam measurements**

Complex setup, very slow readout, complex reconstruction

- **Laser setup measurements**

Require light transmission – metallised surfaces need to be etched, which affects the performance and limits options for sensor irradiation, assembled devices, …

L. Poley *et al* 2017 *JINST* **12** P07006

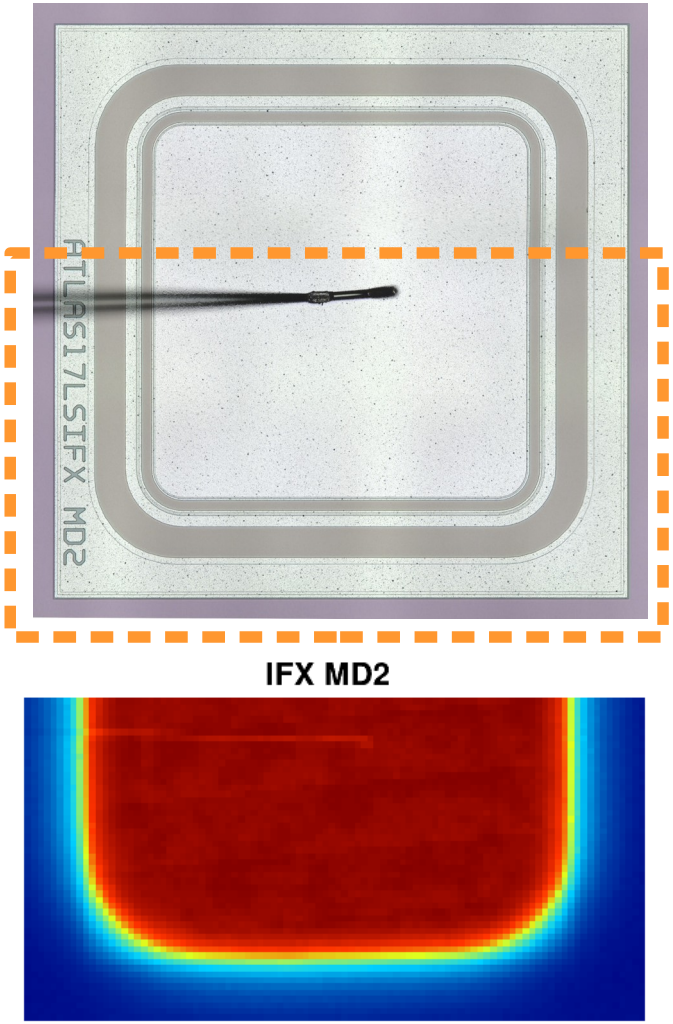


AREA-X

But what if we have access to a micro-focused X-ray beam?

- Method to map different types of sensors
- Up to high levels of irradiation
- Full or partial depth
- Use current measurement to assess depth of depleted sensor volume for fast readout

Similar to laser setup
No limits by surface requirements



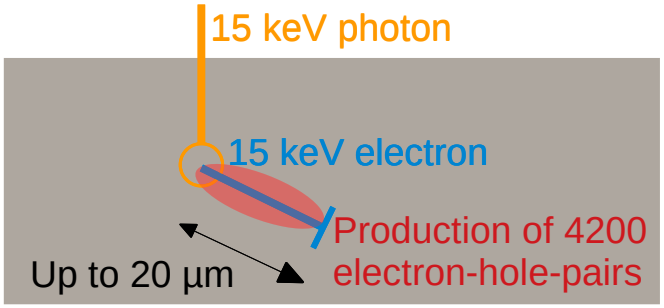
Mechanism

X-rays between 10-20 keV: production of one single keV electron, which then travels up to 20 um in silicon, i.e. very local interaction at random depth

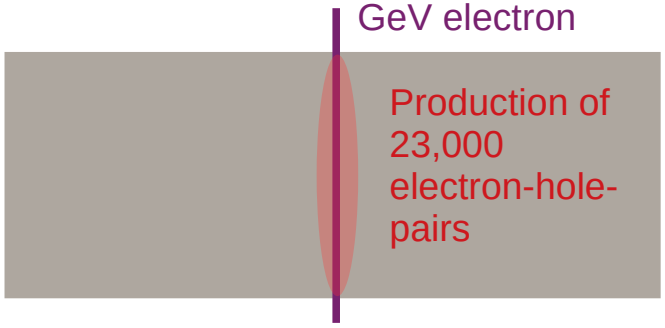
When traversing depleted sensor volume, the induced photo current is measured as increased leakage current

Sufficient to map depletion

X-ray beam measurement



Operation in LHC

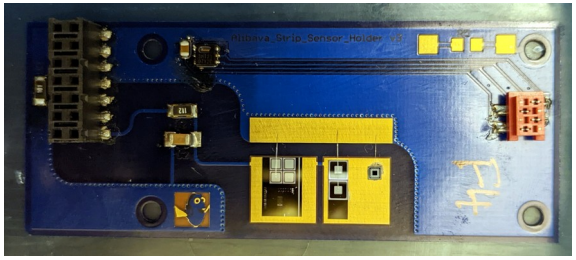


Setup

Only minimal setup required
- PCB to apply bias voltage to sensors and measure current
- Included temperature/humidity sensor for environmental monitoring

Housing to accommodate biased tests of irradiated sensors
- Chiller-cooled cold plate with peltier elements
- Inlet for nitrogen/dry air to prevent condensation

Minimalistic setup!

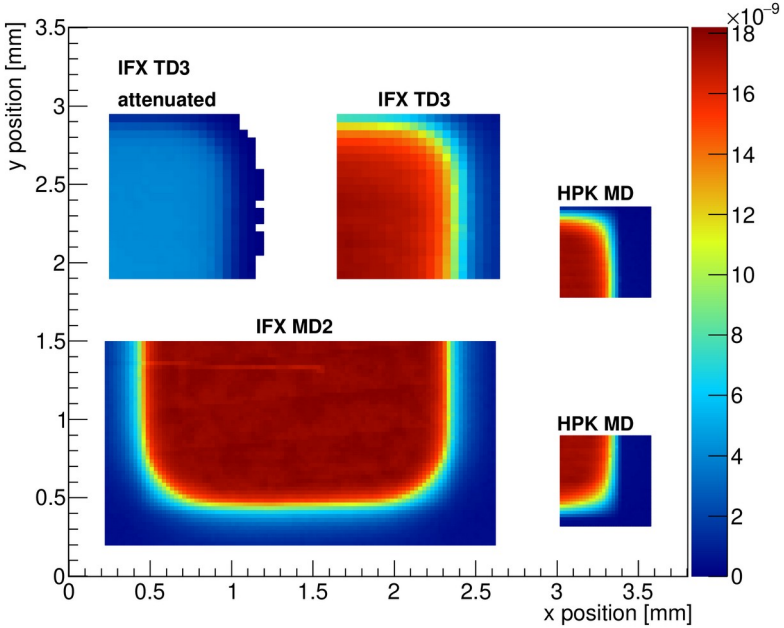


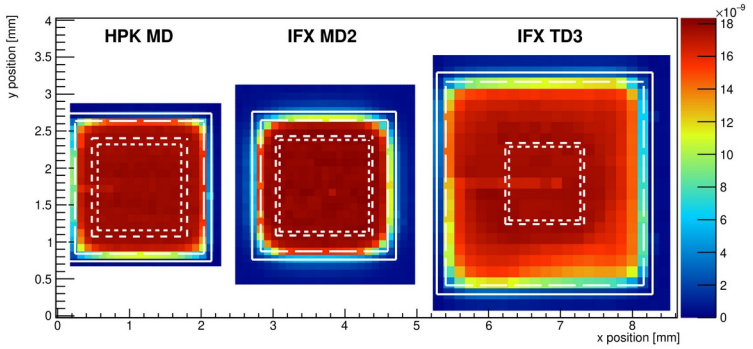
Initial results

Proof of concept measurements using ATLAS test diodes:

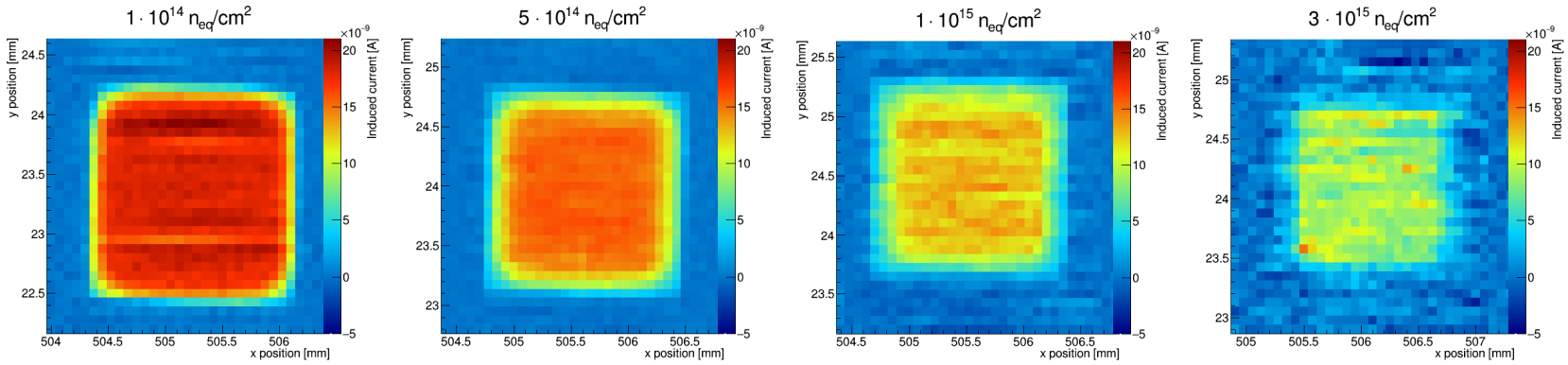
L. Poley et al 2019 JINST 14 P03024

- Mapping area, depleted volume of diodes to compare to diode geometry
- Tests with attenuated and unattenuated beam
- Comparison of maps with different bias voltages





Follow-up: irradiated structures



Tests of the same diodes, irradiated up to different fluences to test limits of the method

L. Poley et. al, Mapping the in-plane electric field inside irradiated diodes. NIM A 980:164509, 2020

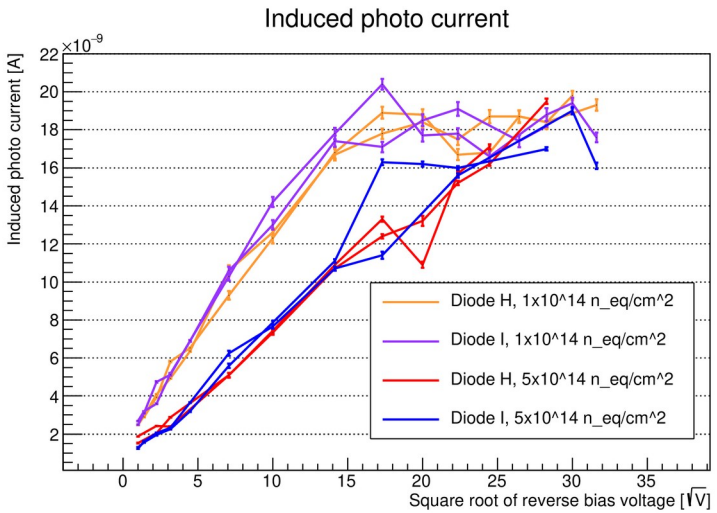
Active area can be mapped up to high levels of radiation
Possibility to map even irradiated samples without need for physical changes to samples

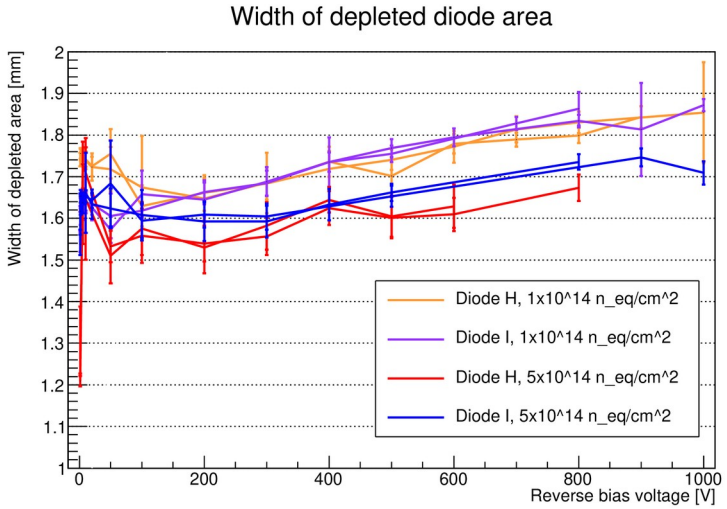
Follow-up: irradiated structures

Measurement of interest:
Does the depleted sensor volume decrease in width beyond full depletion?

1) Use induced photo current to judge depth of depleted sensor volume
2) Compare to width of depleted sensor volume

Increase of width even beyond full depletion, indication of field bulging out





Paper about AREA-X in preparation

Going forward

All measurements shown here were performed at the Diamond Light Source (RAL, UK)

Beam time scheduled at the Canadian Light Source to set up measurements at Canadian X-ray beam line:

- Timing optimisation
- Expand from 2D-mapping to 3D-mapping using different energies or bias voltages

Future measurements planned:

- Mapping the active volume of 3D pixel sensors
- Tests of large scale devices (to study uniformity across full sensors)
- Studies of breakdown mechanisms
- New devices (especially if not transparent to lasers)