CHARACTERISATION OF SINGLE-DIODE SILICON SENSORS FOR THE CMS HGCAL PROJECT

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Who Am I?

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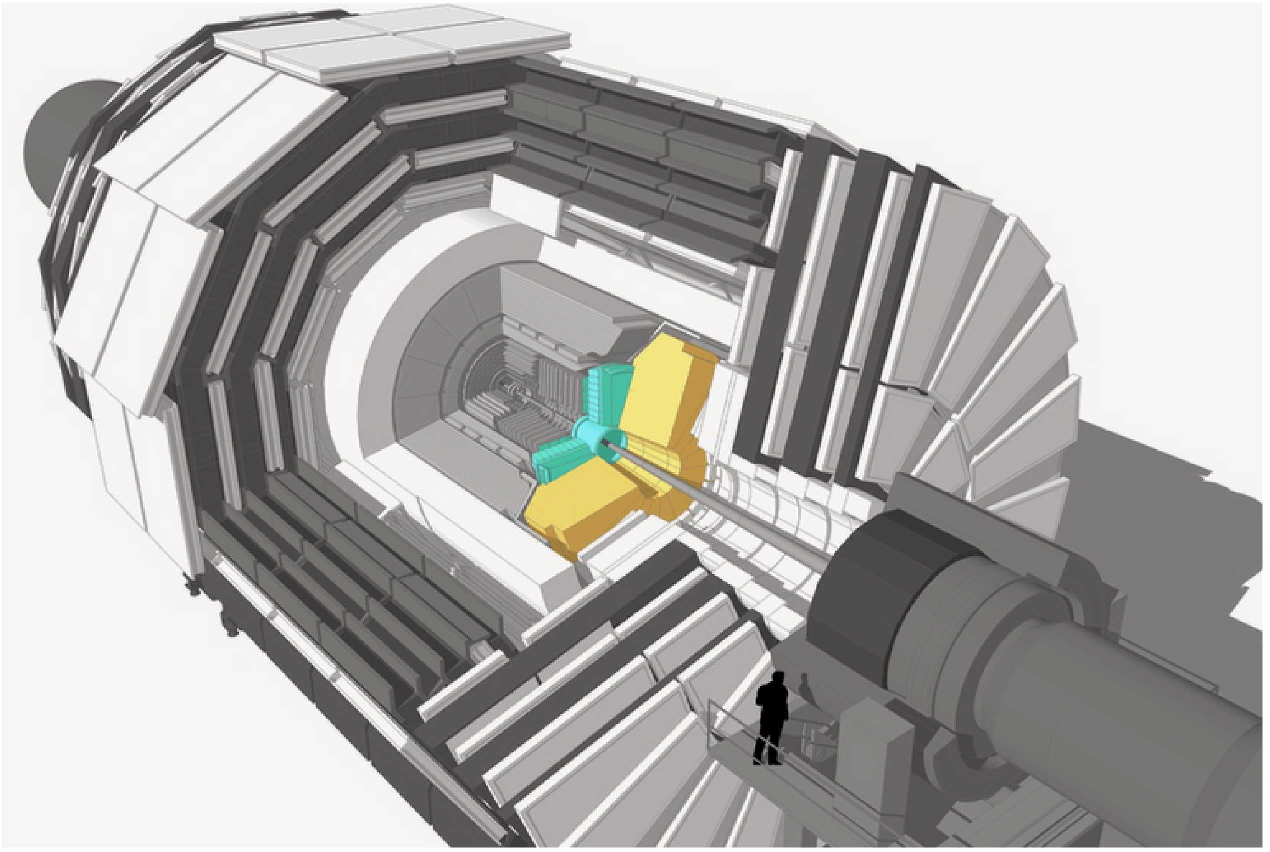
OUTLINE

- Introduction.
  - The LHC upgrade and CMS.
  - What is HGCAL?
- My Work
  - Silicon sensors.
  - Electrical characterization of single diodes.
  - Results.
- Conclusion and ongoing work.

THE LHC UPGRADE AND OUR MOTIVATION



CMS is a general purpose detector.

LHC → HL-LHC ~ 200 pileups per bunch crossing.

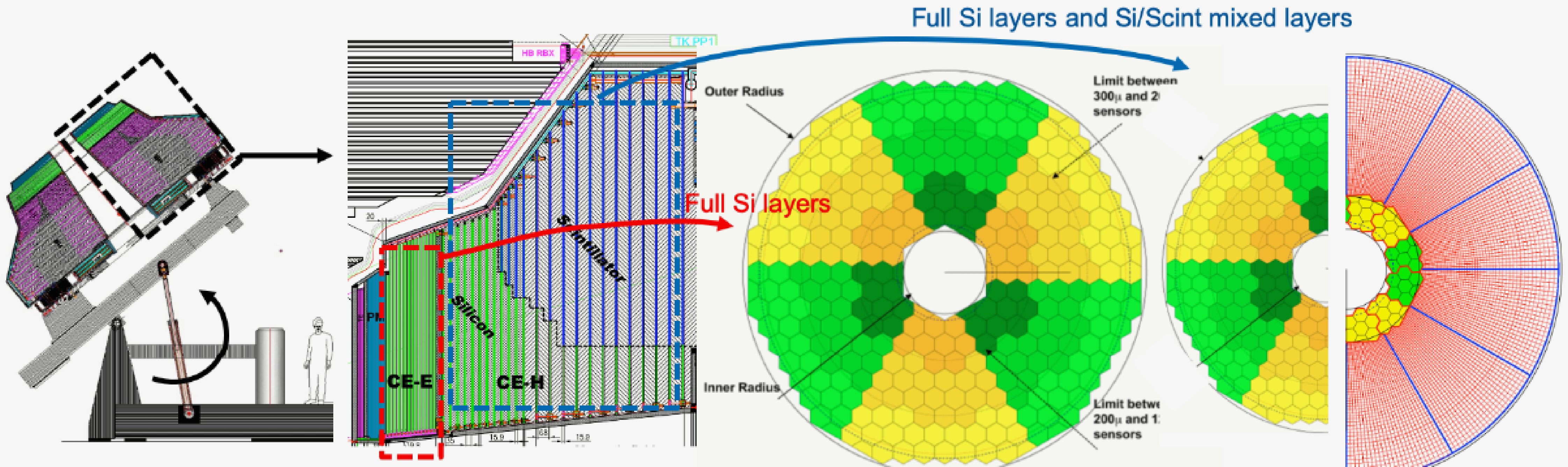
CMS Endcap Calorimeter will be replaced by the High Granularity Calorimeter (HGCAL) for the HL-LHC

What is HGCAL?

HGCAL will use ~620 m² silicon sensors produced on 8-inch wafers.

Three different thicknesses:
300 µm, 200 µm (Float zone) and 120 µm (Epitaxial).

Fluences of up to 1e16 neq/cm²



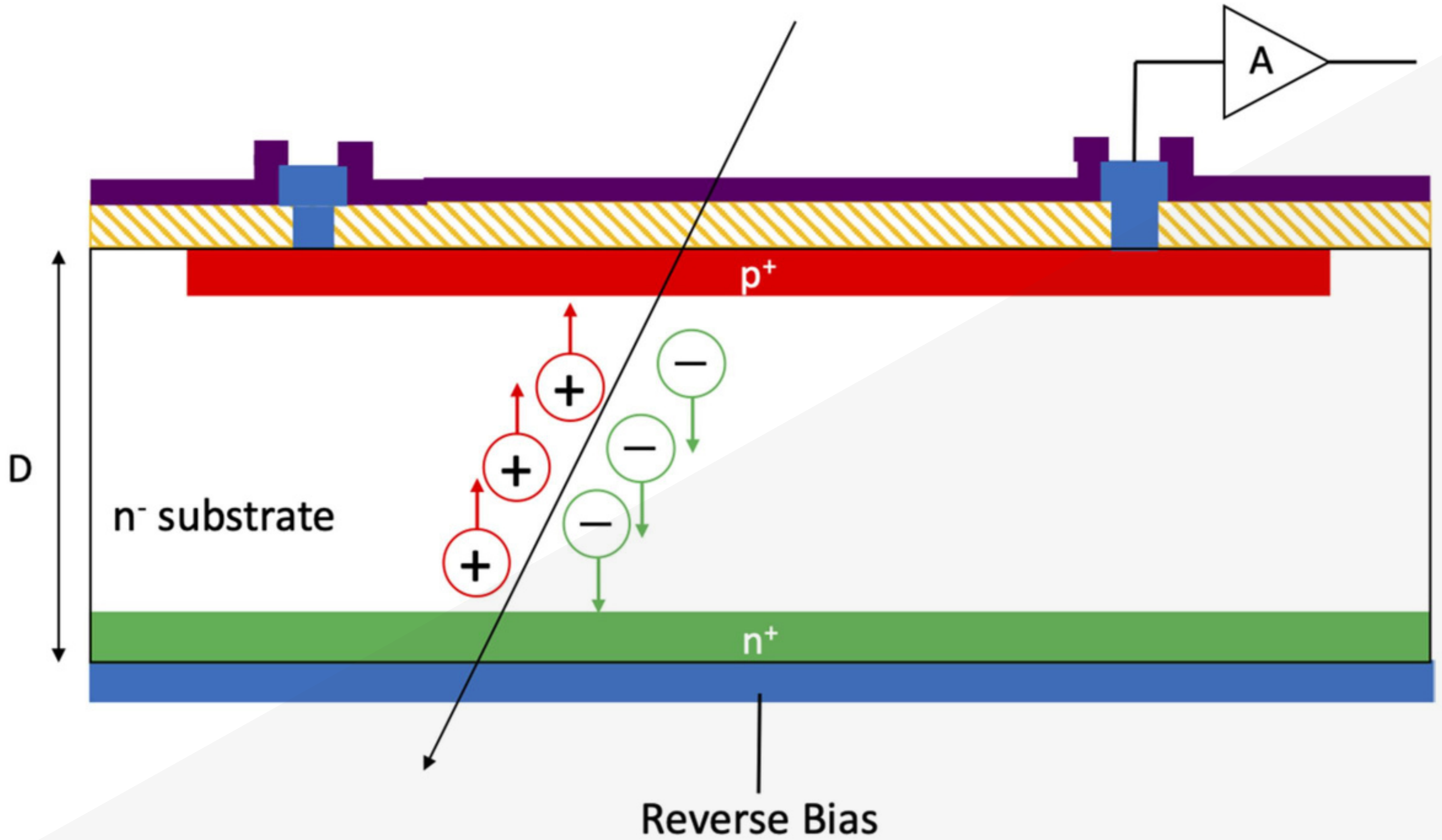
WHY SILICON SENSORS?

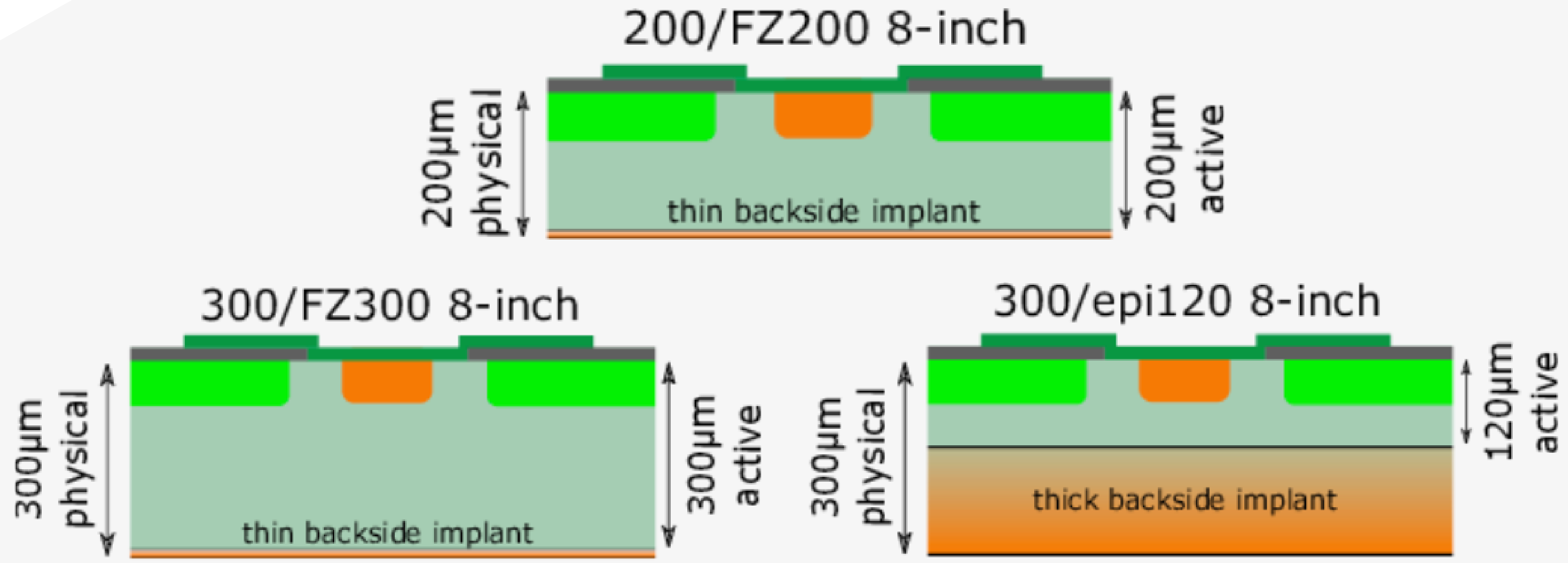
- Radiation hardness
- Extremely precise position measurement
- High readout speed
- Simultaneous measurement of energy, position and arrival time
- Possibility of integrating detector and readout electronics on a common substrate

HOW SILICON SENSORS WORK?

- Charged particles traversing the detector create electron-hole pairs.

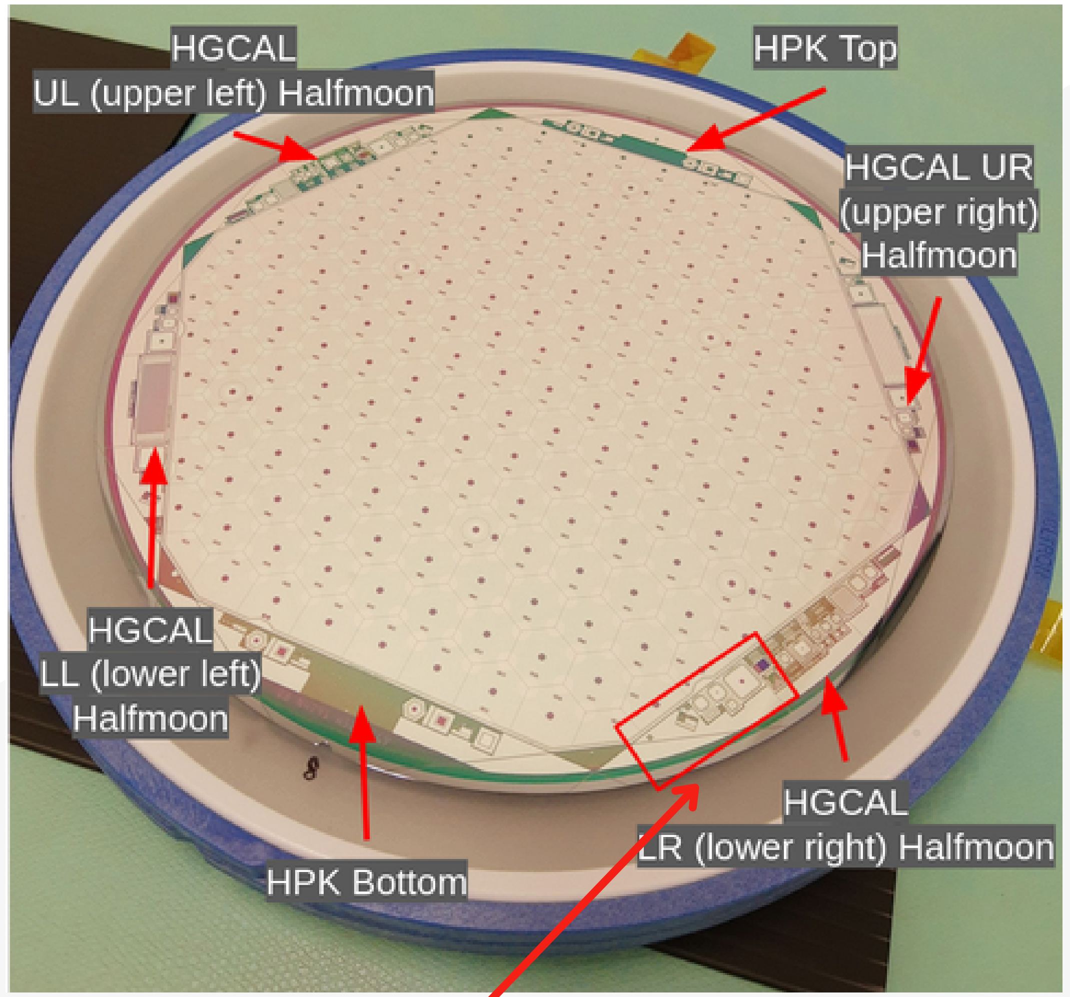
- The electron-hole pairs are separated by an electric field and drift to the electrodes. This is the signal we are looking for.



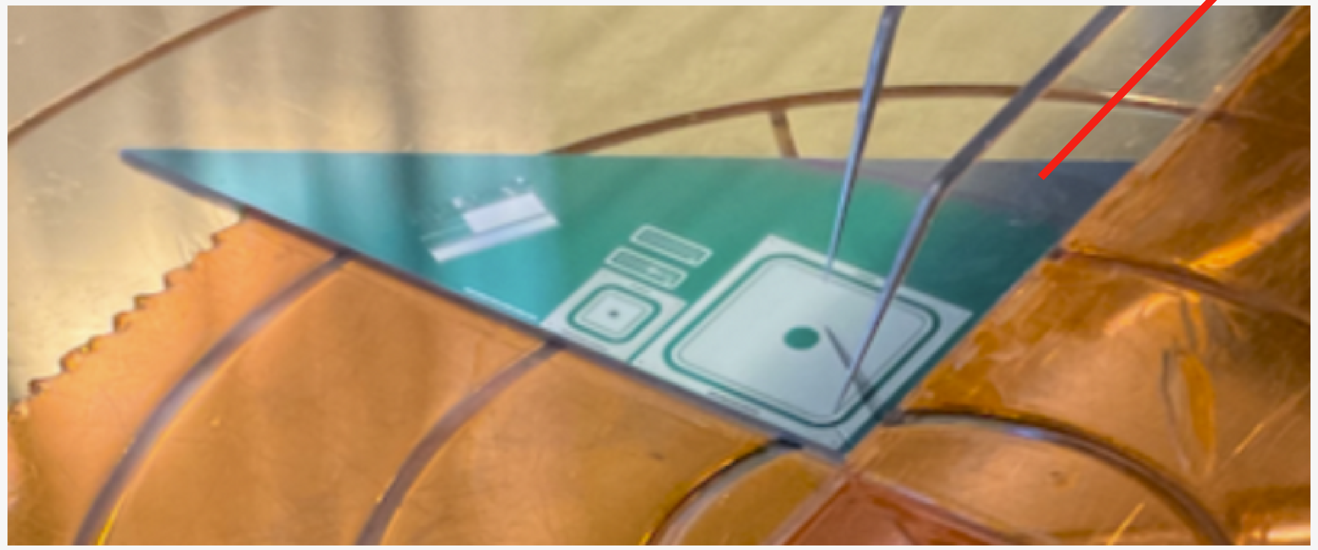


Sensors cross section (not to scale):
300, 200 and 120 µm; FZ denotes float zone process and epi – epitaxial process

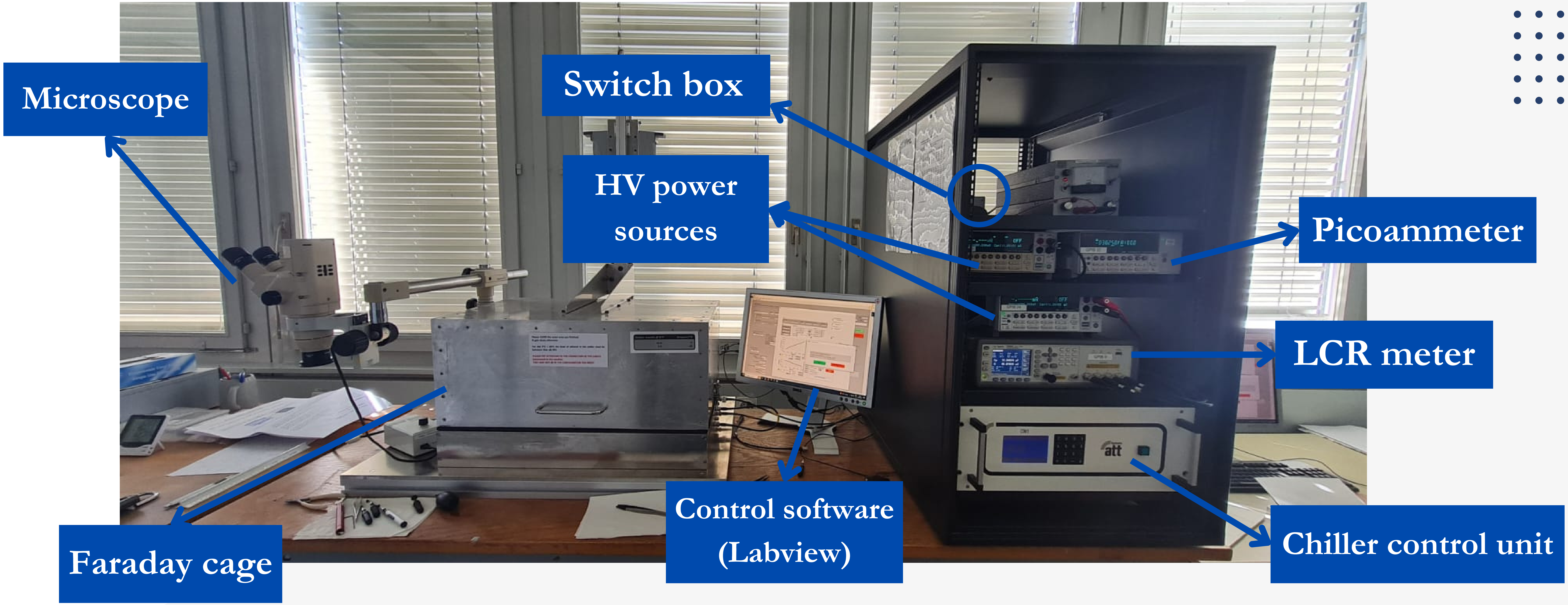
FULL SENSORS AND DIODE TEST STRUCTURES



- Circular wafers are cut into Hexagonal full sensors.
- Remaining space is used for the small diode test structures.
- Set of pre-series and pre-production diodes were irradiated at JSI (Jozef Stefan Institute) in June 2023
- Electrical characterization through CV/IV measurements is performed on the diodes.

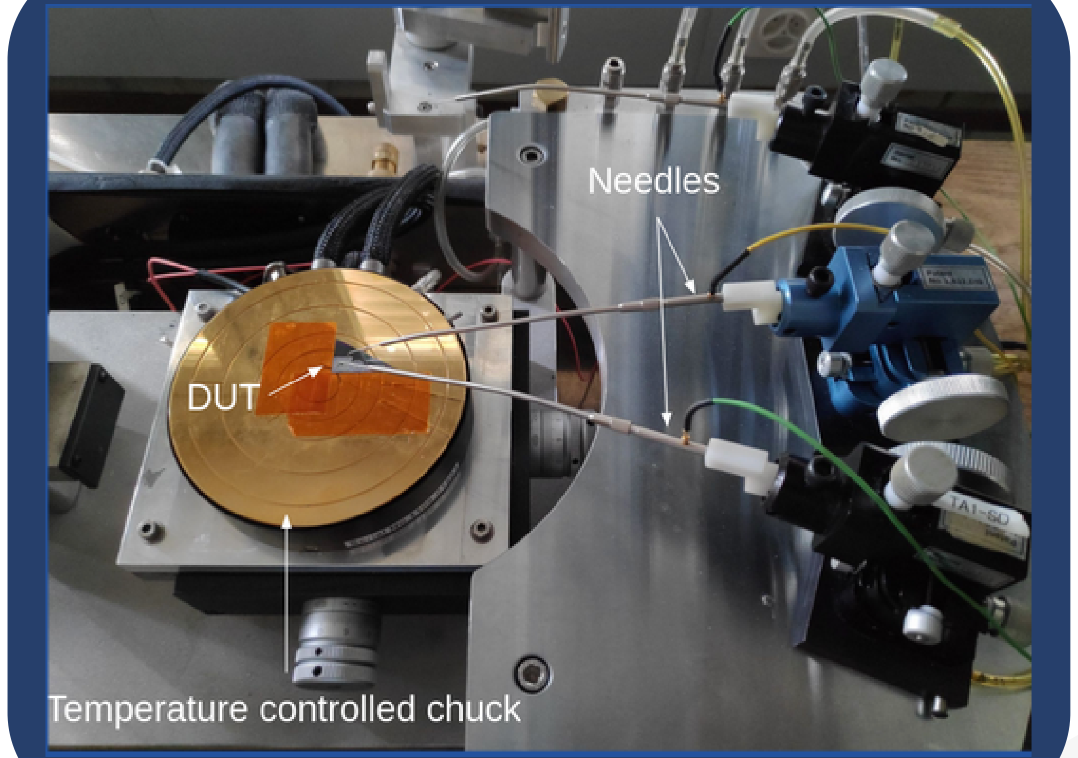


SETUP

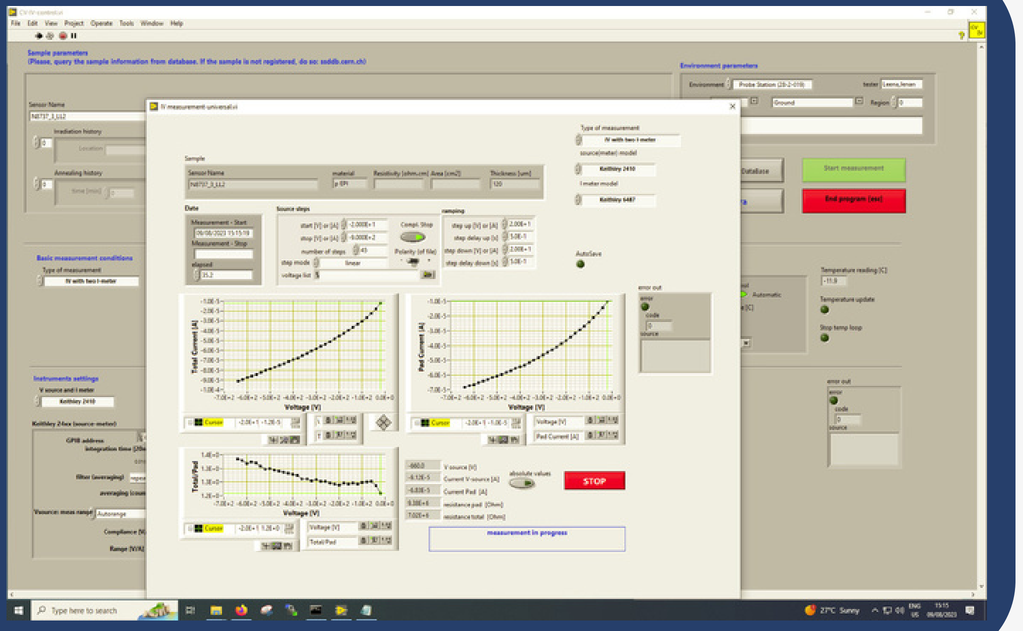


CERN EP-DT-DD SSD group IVCV probestation

ELECTRICAL CHARACTERIZATION PROCESS

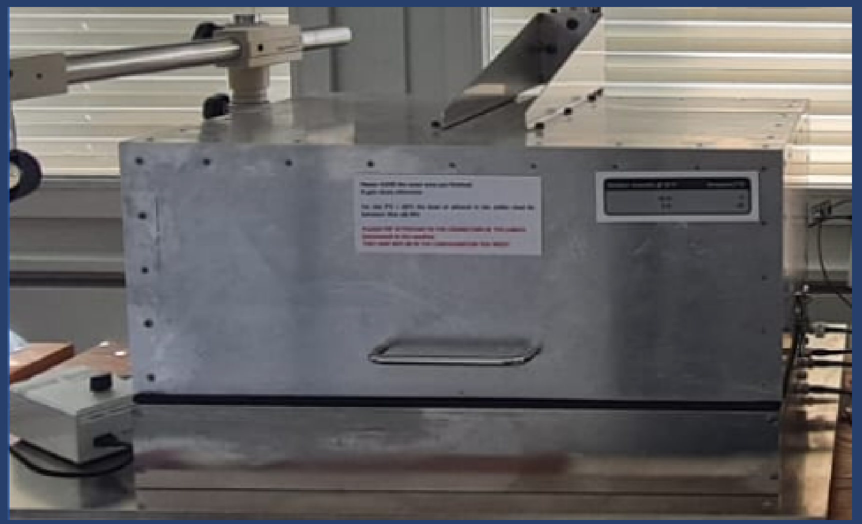


CV and IV Measurements done on a temperature controlled chuck



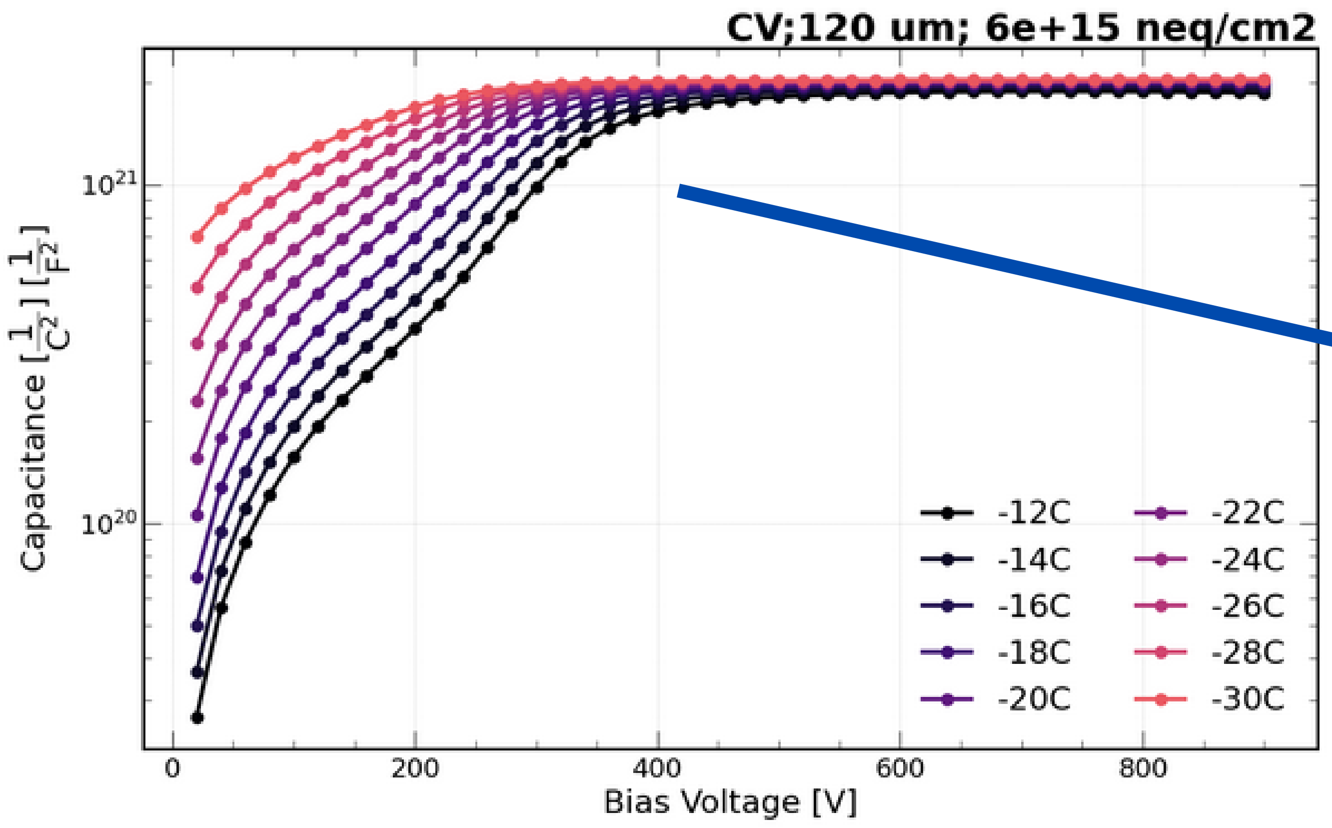
Measurements controlled by Labview

Inside the Faraday cage is where the test area is

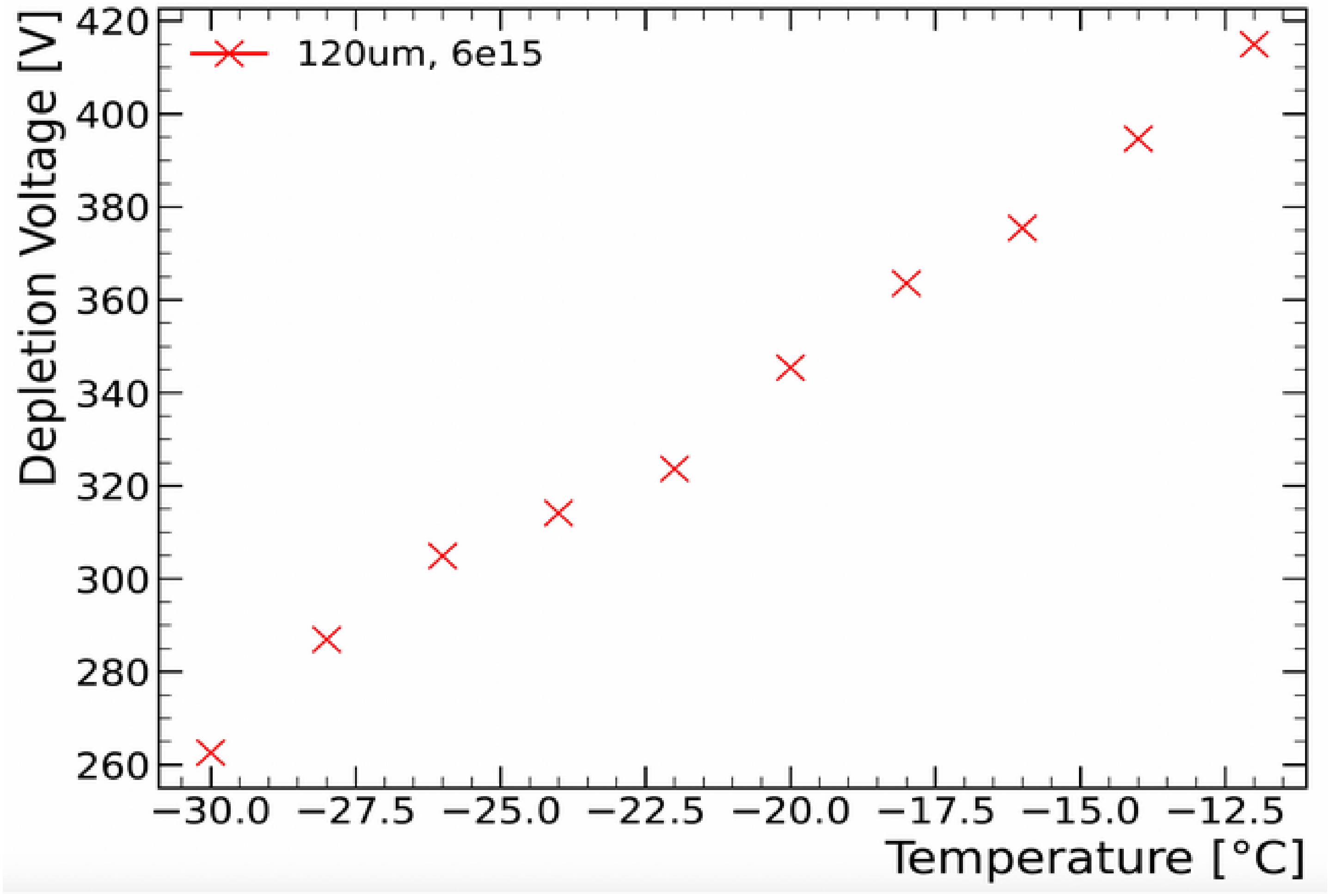


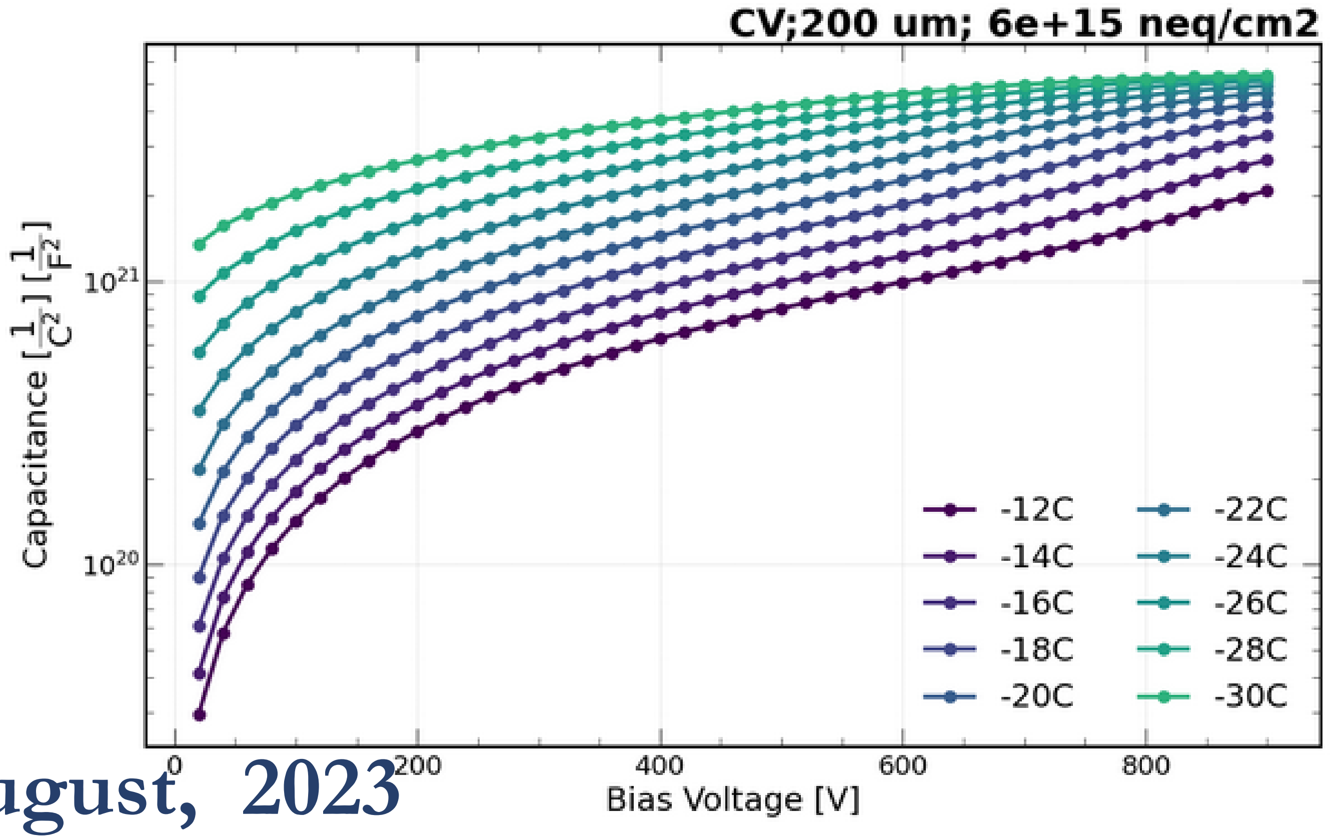
Contact is done with the DUT at the pad and at the guard ring

CV temperature Scans



The behavior of the depletion voltage with temperature

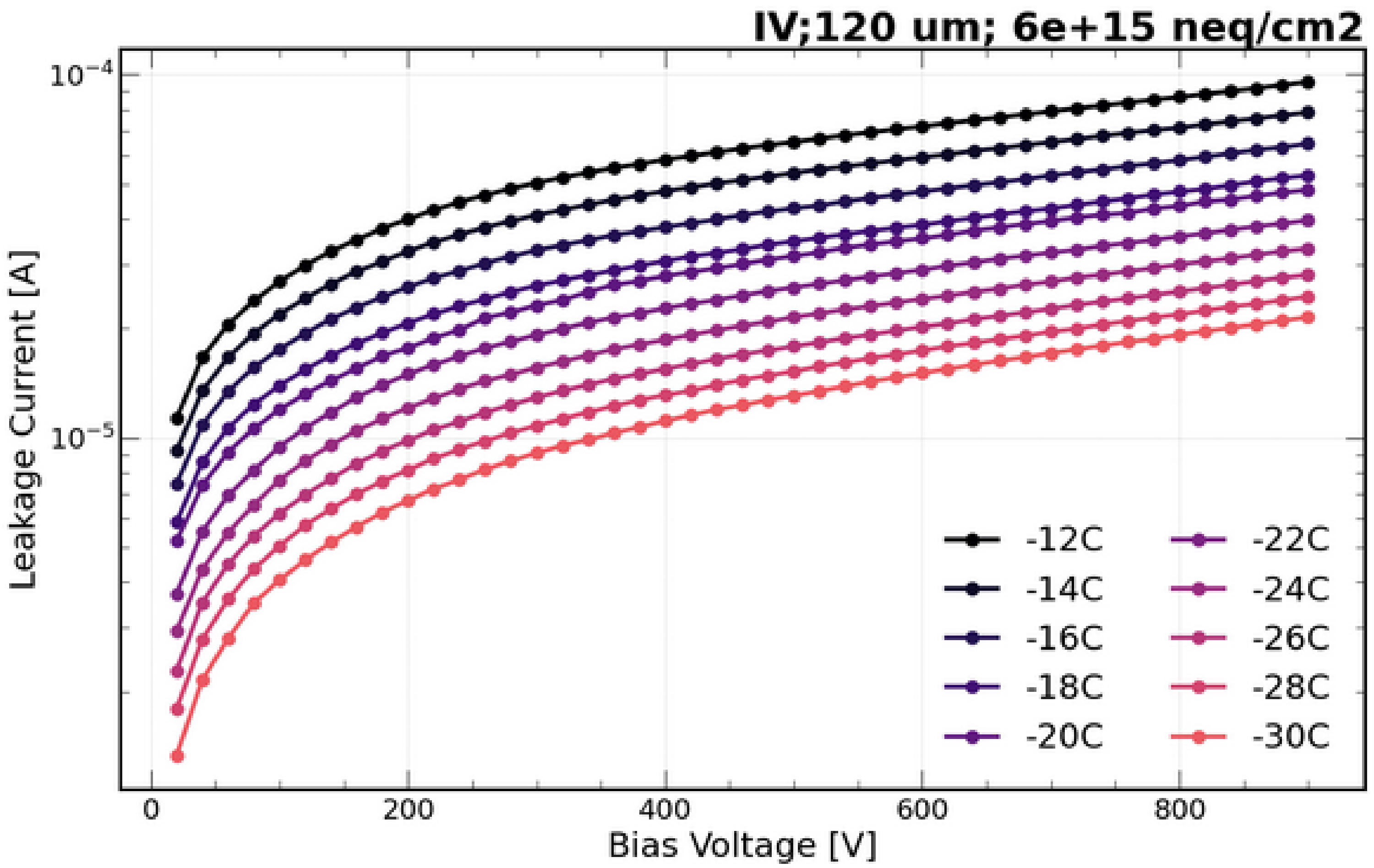


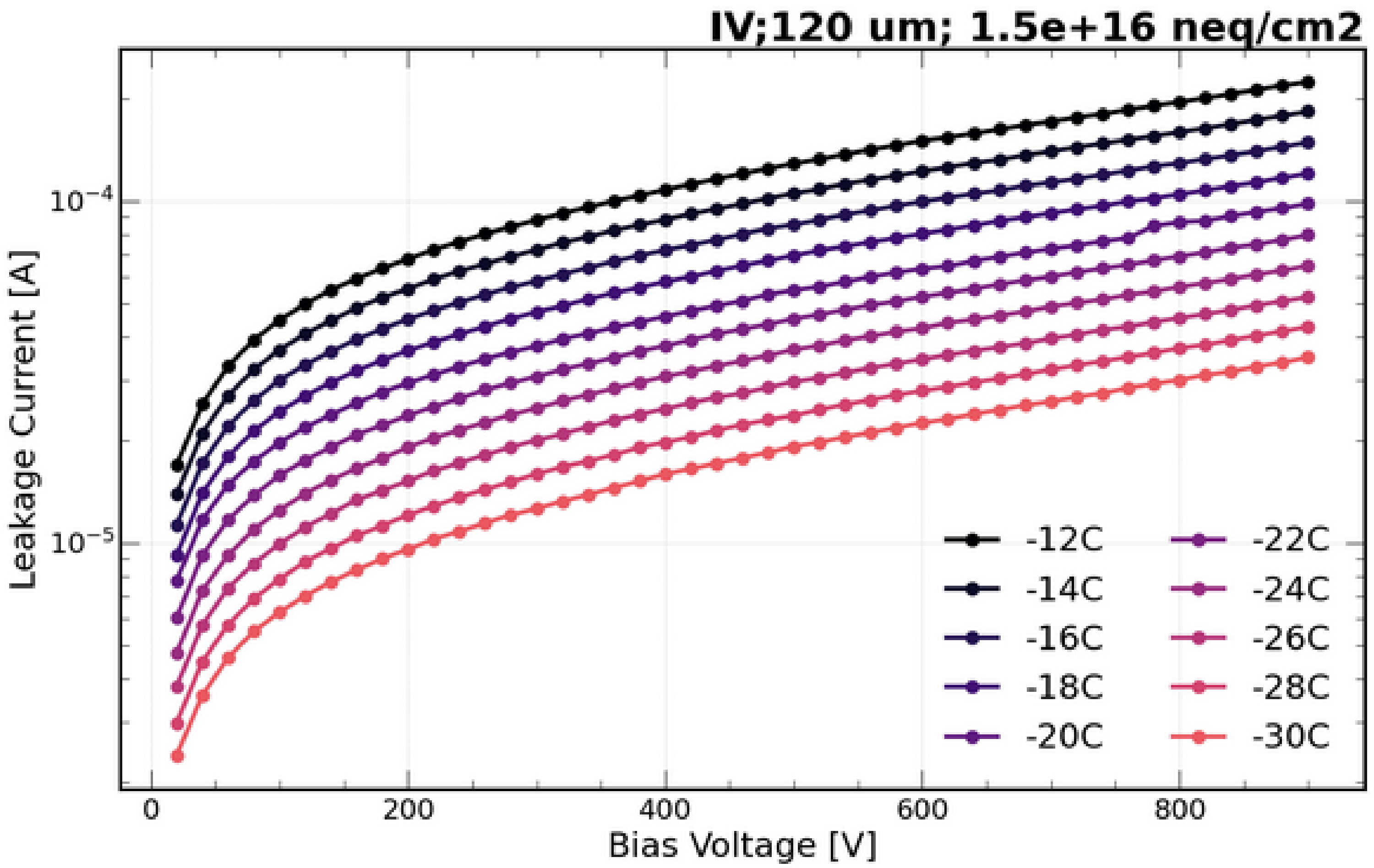


Temperature increase → depletion voltage increase

Diodes with higher thickness don't reach full depletion until applied voltage of 900V

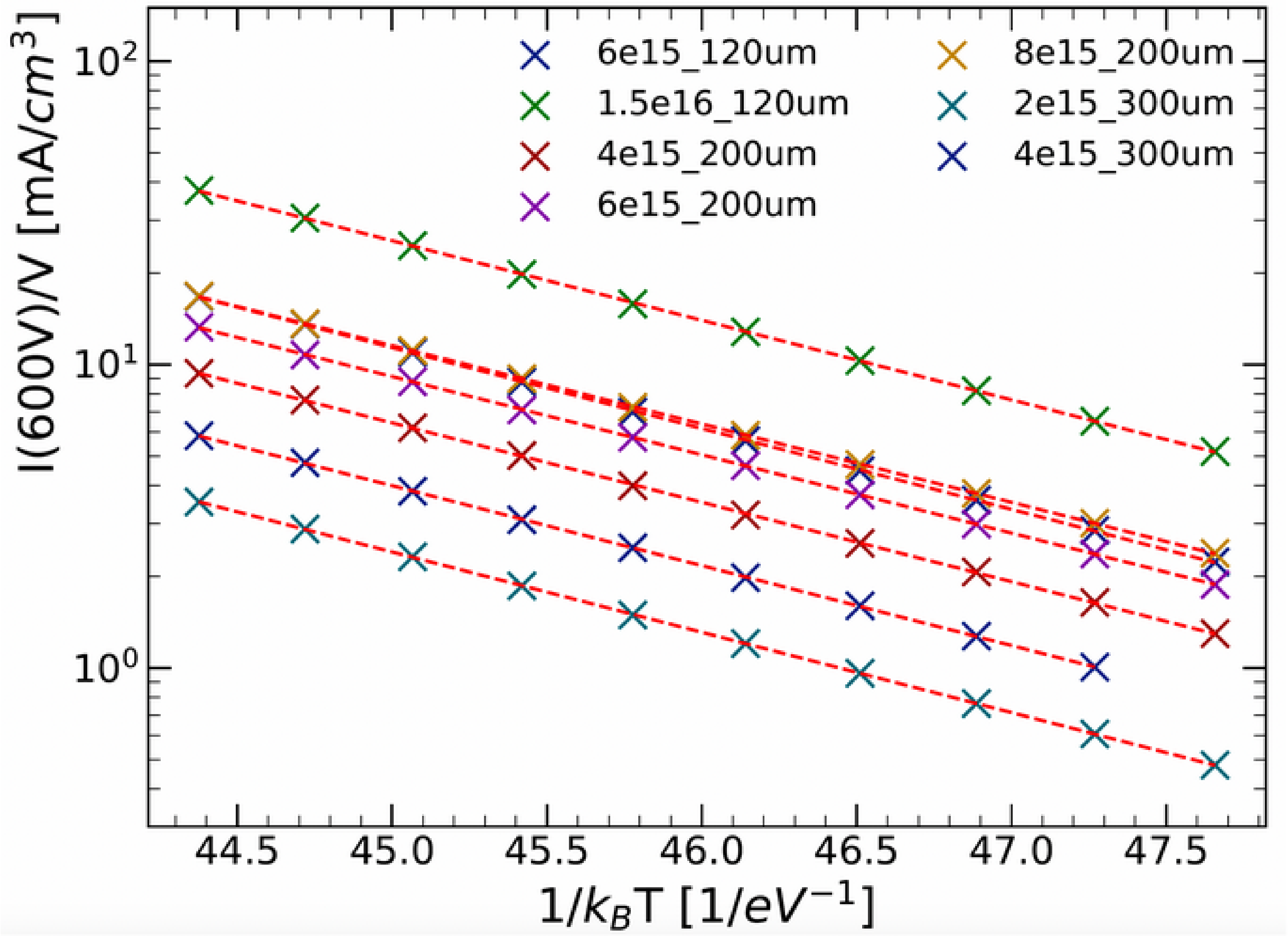
IV temperature scans





- **For the same thickness of diodes the leakage current increases for higher fluences.**
- **The value of the leakage current also increases exponentially for the irradiated diodes as the temperature is increased.**

Arrhenius plot

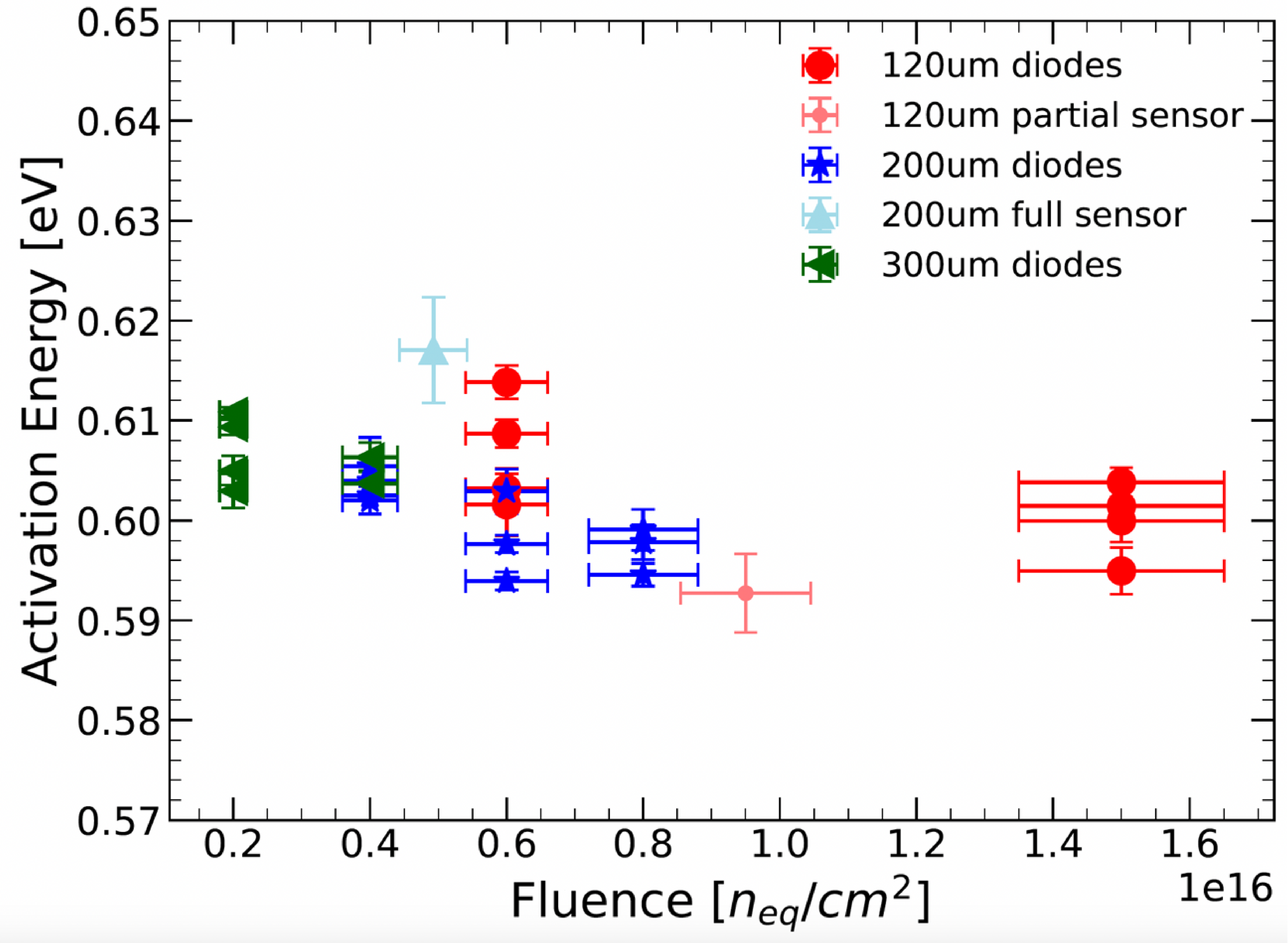


$$\frac{I(600V)}{V} = \exp\left(\frac{-A}{K_B T} + B\right)$$

Activation energy

We have roughly same slope for all measurements.
Different values for the same fluence if the thicknesses vary.
Offset between thicknesses is constant (see 4e15)

Activation energy vs the Fluence

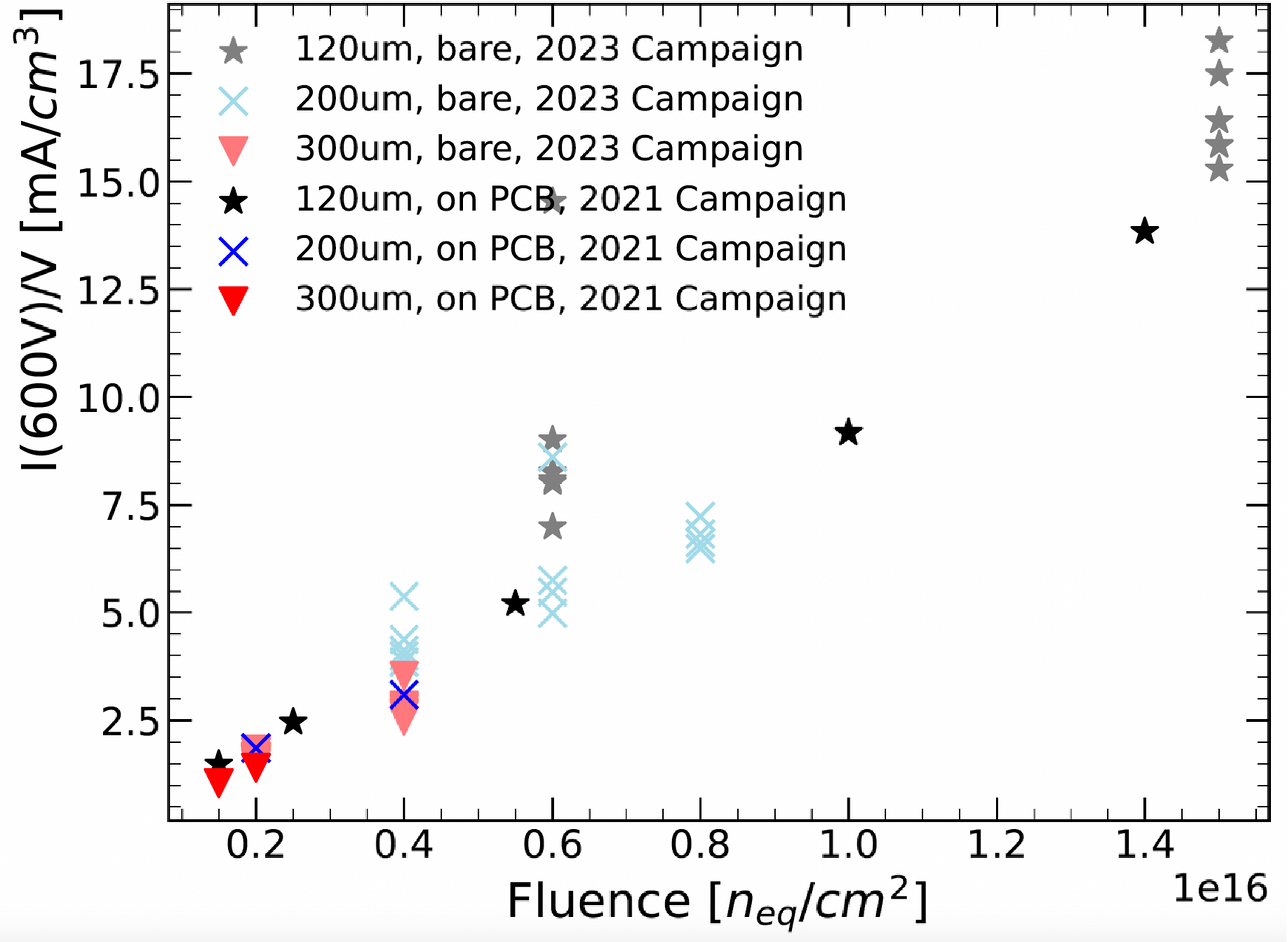


Offset between thickness

Slight fluence dependence possible

We are still investigating this possible dependance by increasing the sample of sensors tested.

I_leak/V vs fluence (alpha plot)



We have large spread for the new sensors compared to previous campaigns.

A slight difference between thicknesses for the same fluence was also observed with the old sensors

$$\frac{I}{V} = \alpha \cdot \phi$$

Conclusion

- Temperature studies were performed on seven diodes of different thicknesses and fluences.
- Results are in agreement with what we expected:
  - Exponential increase of current with temperature.
  - Shift of depletion voltage with temperature in CV measurements.

Ongoing work

Investigation of possible fluence dependencies in the activation energy, investigation of the larger spread in the alpha plot.

THANK YOU

Any questions?