Test Beam and Lab Results of ATLAS Sensors with Modified Pixel Implantations

8th Beam Telescopes
and Test Beams Workshop

Mareike Wagner

F. Barth, A. Gisen, V. Hohm, K. Kröninger, J. Lönker,
M. Muschak, J. Weingarten, F. Wizemann

GEFÖRDERT VOM
Bundesministerium
für Bildung
und Forschung

ATLAS EXPERIMENT

AIDA 2020

REINER Pixel Design

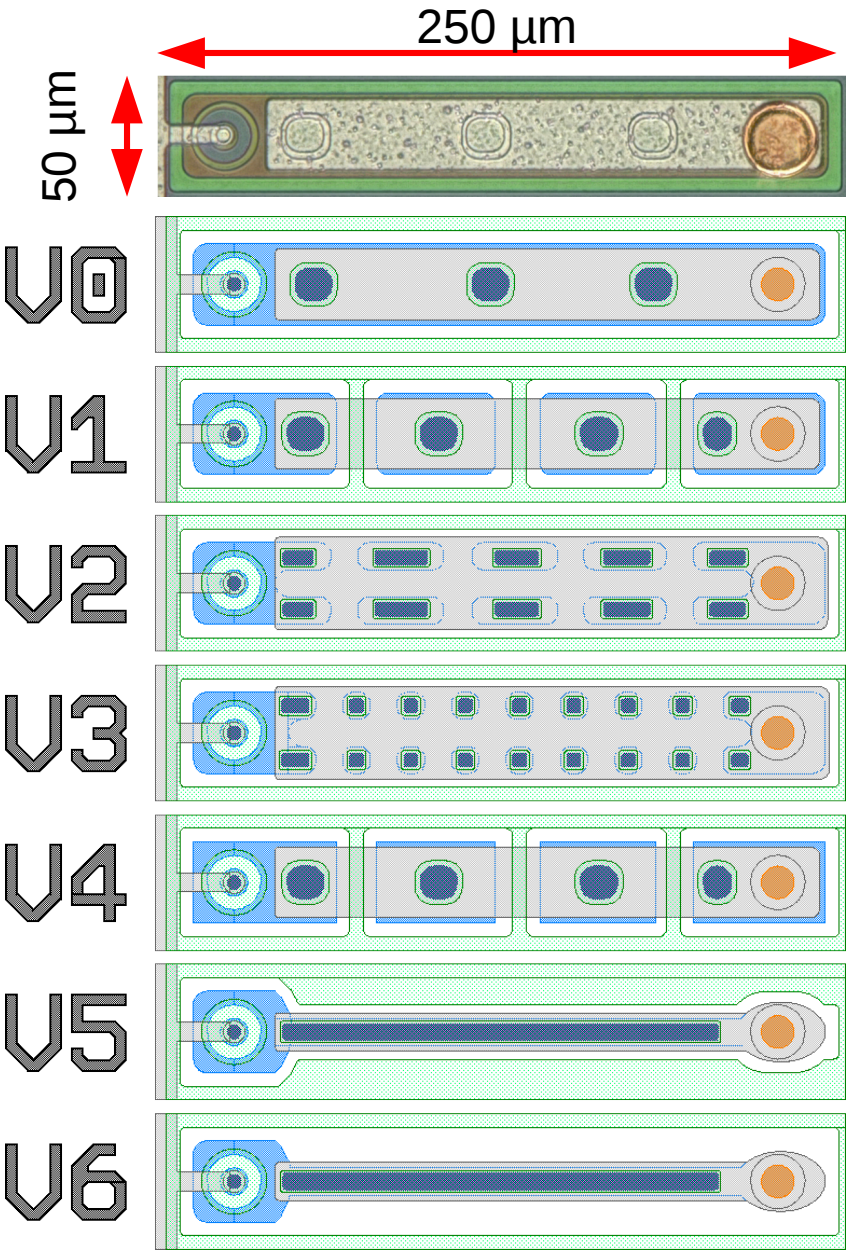
REdesigned, INnovative, Exciting and Recognizable

technische universität dortmund

- Pixel size: 250 µm x 50 µm (same as for IBL, innermost detector of the ATLAS Experiment)
- N-in-n wafer process
- Sensor thickness 200 µm
- Moderated p-spray
- Six modified designs
  - Three divided in 4/10/18 sub implants
  - One with rectangular corners
  - Two with narrowed n^+ implant

V0: IBL-standard
V1-V6: modified

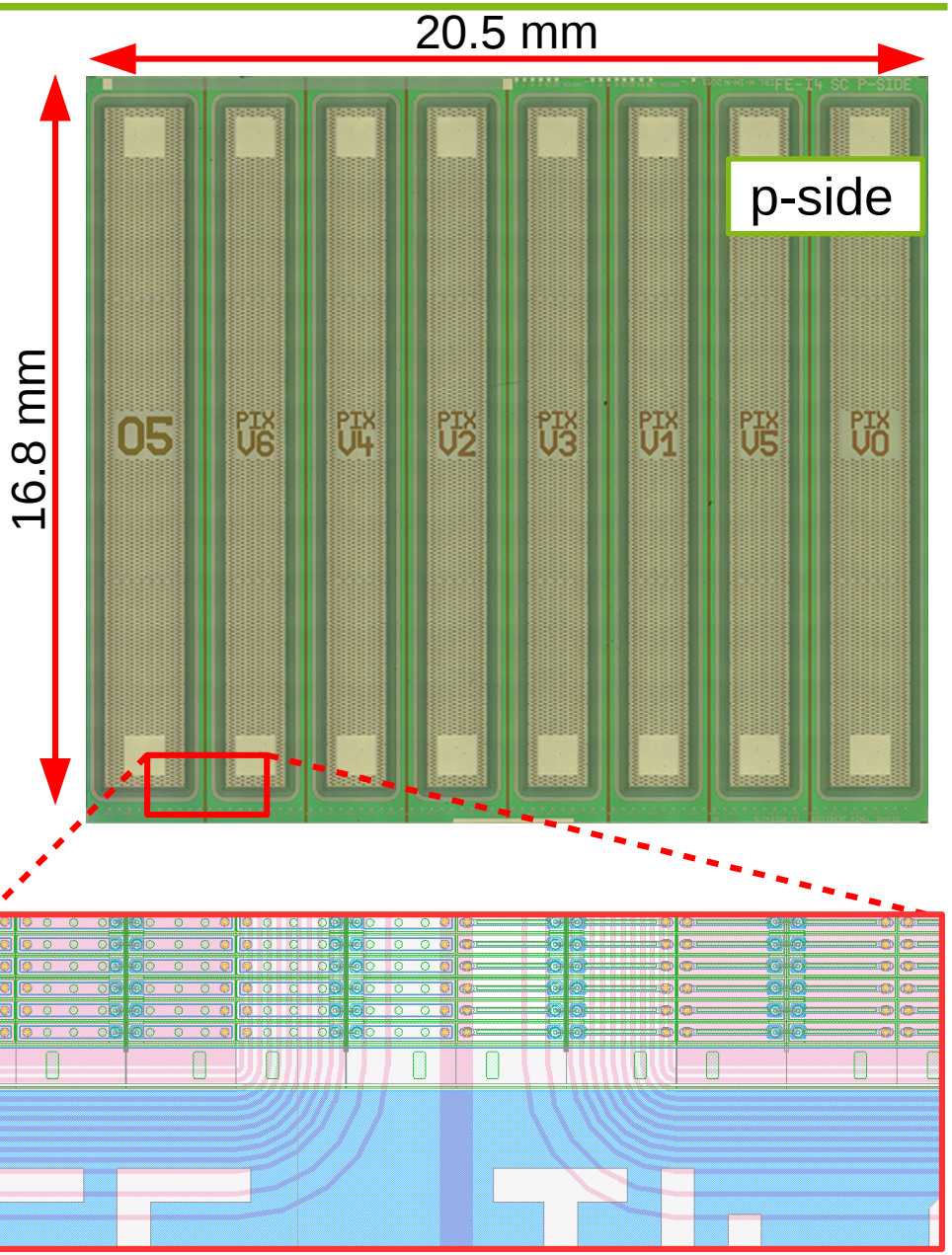
Blue: n^+
Grey: metal
Green: Nitride openings



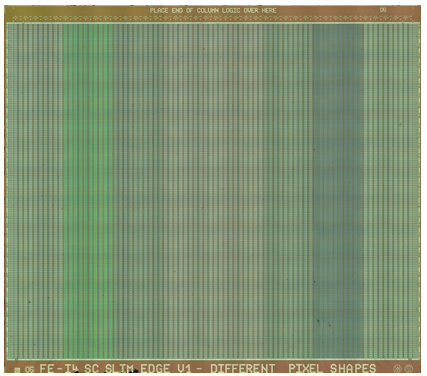
REINER Pixel Sensors

technische universität dortmund

- Eight structures on one sensor
  - Two IBL designs (V0 & 05)
  - Six modified designs
- Each structure consists of 10 columns x 336 rows with the same design
- Separate HV pads
- Individual guard rings
- Readout by one FE-I4



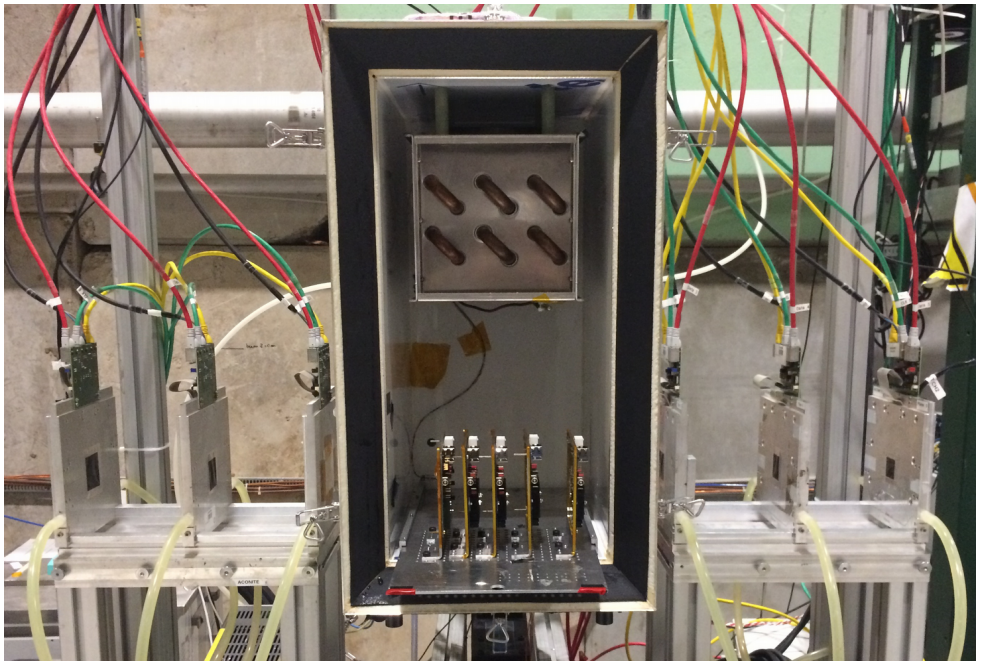
n-side



Measurements

Test Beam:

- DESY and CERN
- 5GeV Electron or 120GeV Pion Beam
- EUDET-type telescope
- Cooled setup
- Irradiated REINER sensors measured at different tuning, positions and voltages

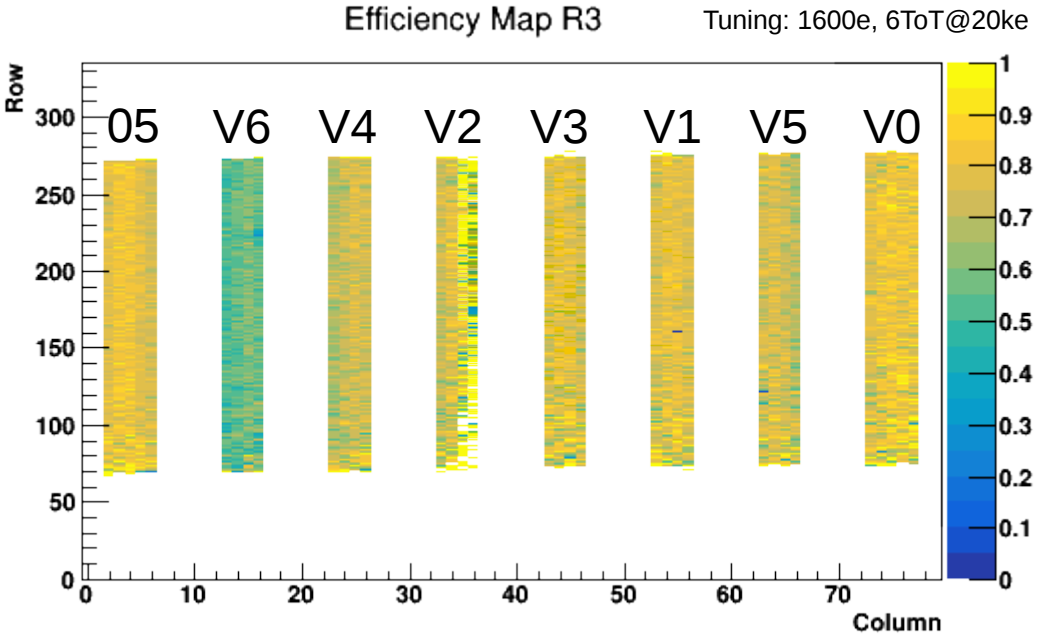


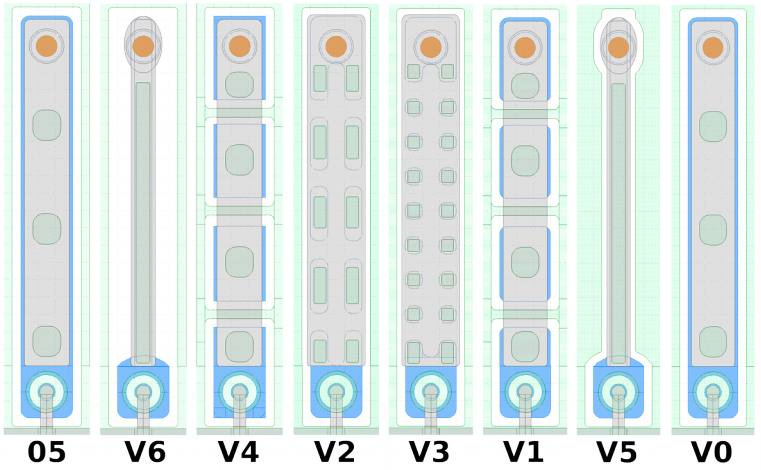
This talk focuses on the results of the irradiated Sensor R3: neutron irradiated to 5e15n_{eq}/cm² in Ljubljana

TB Results for irrad. Sensor R3

technische universität dortmund

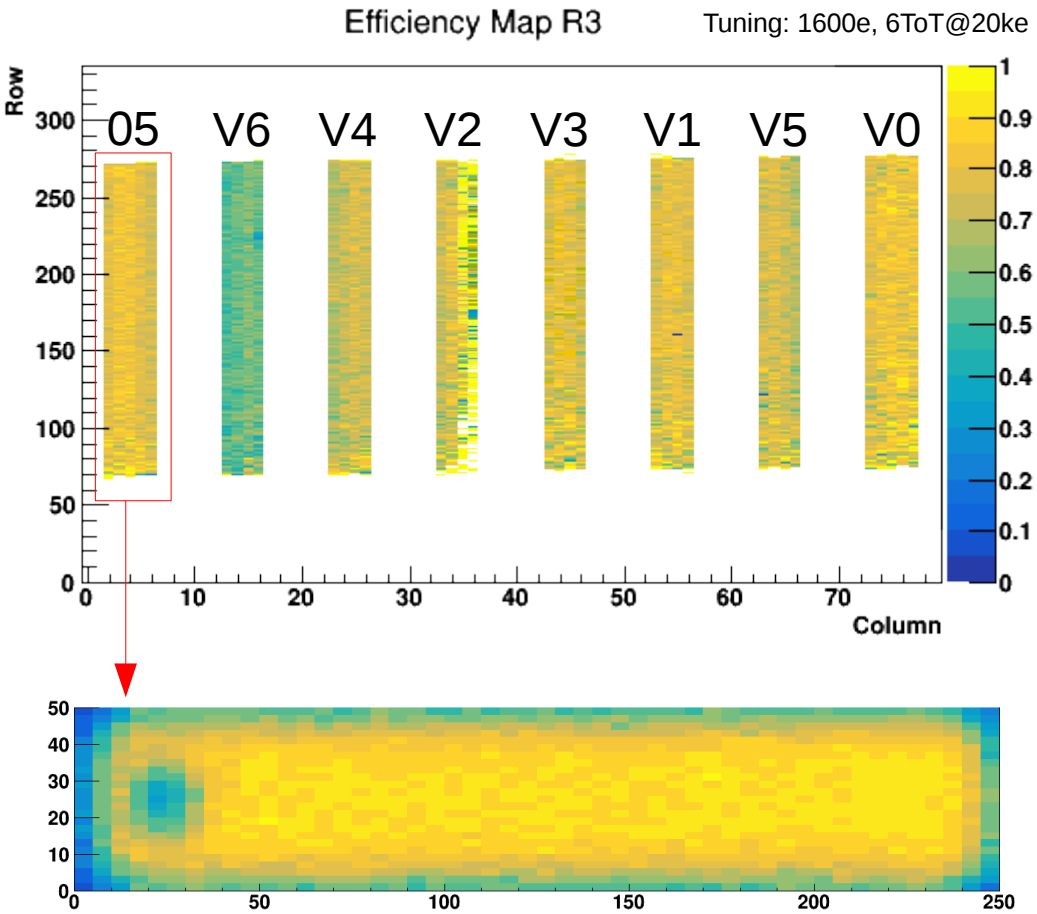
- To prevent influence of guard rings:
  Only four innermost columns of each pixel design
- When sensor fully depleted:
  No differences in the efficiency between voltage steps
- ➔ To observe differences of the pixel designs use lower voltages (here: 300V)



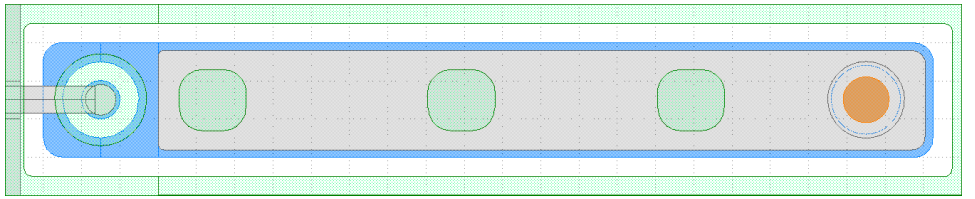


TB Results for irrad. Sensor R3

- To prevent influence of guard rings:
  Only four innermost columns of each pixel design
- When sensor fully depleted:
  No differences in the efficiency between voltage steps
- ➔ To observe differences of the pixel designs use lower voltages (here: 300V)



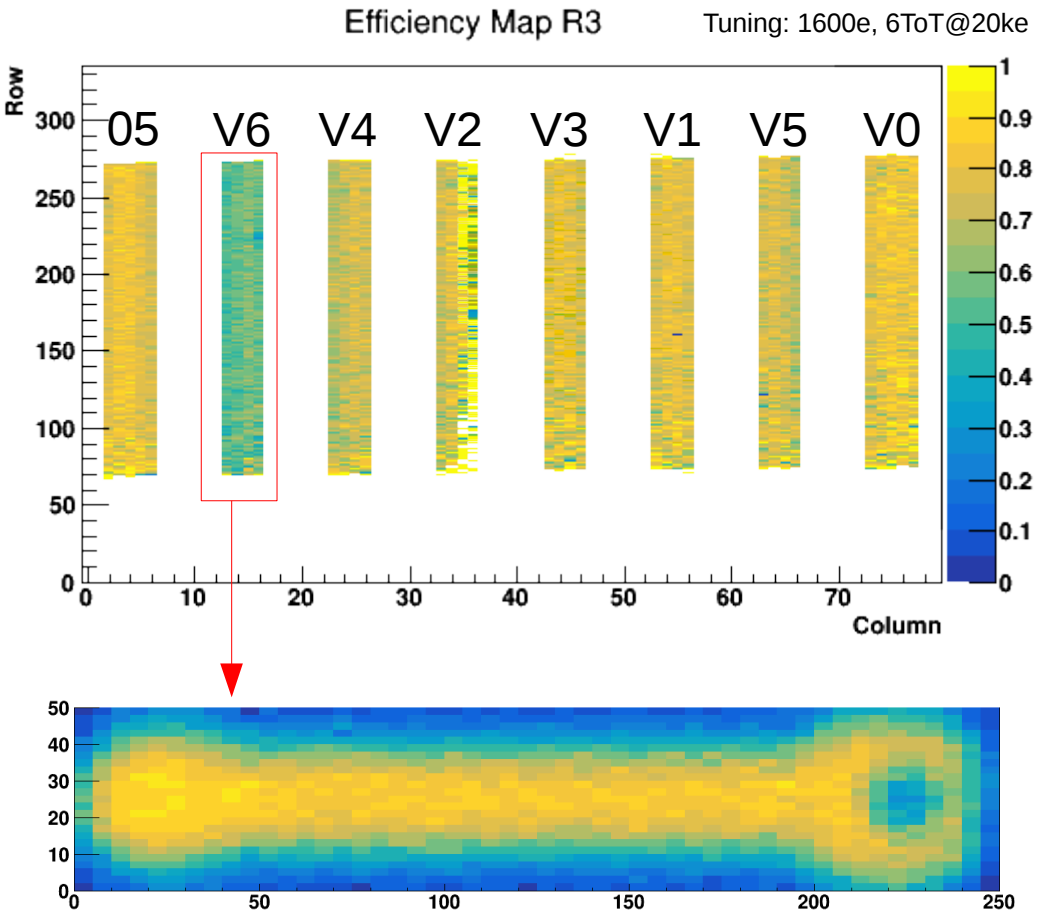
- Projection of the track position into one pixel: In-Pixel Maps



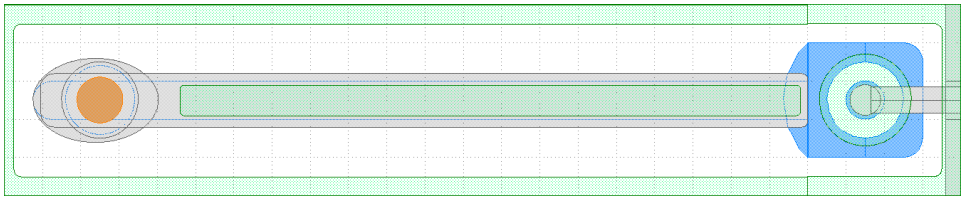
TB Results for irrad. Sensor R3

technische universität dortmund

- To prevent influence of guard rings:
  Only four innermost columns of each pixel design
- When sensor fully depleted:
  No differences in the efficiency between voltage steps
- ➔ To observe differences of the pixel designs use lower voltages (here: 300V)

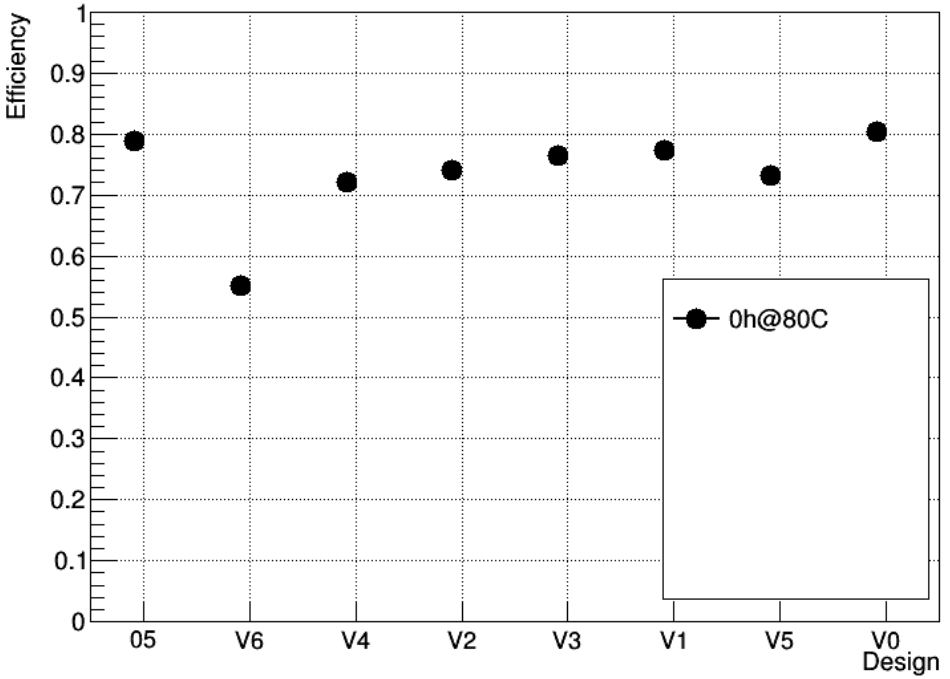


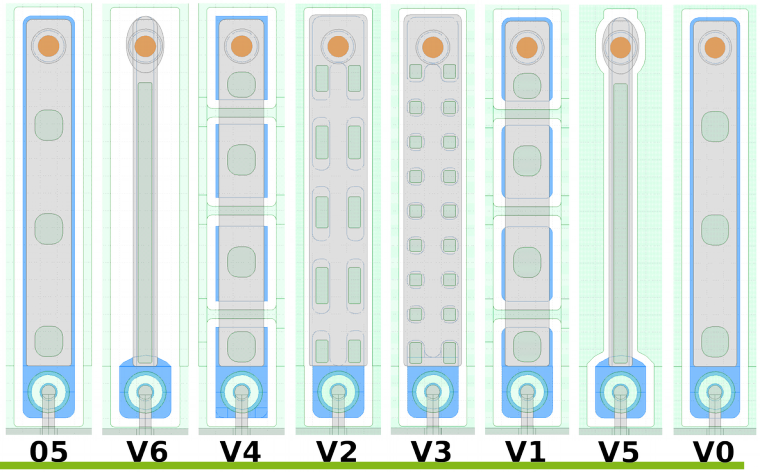
- Projection of the track position into one pixel: In-Pixel Maps



Results of R3 at 300V

Tuning: 1600e, 6ToT@20ke





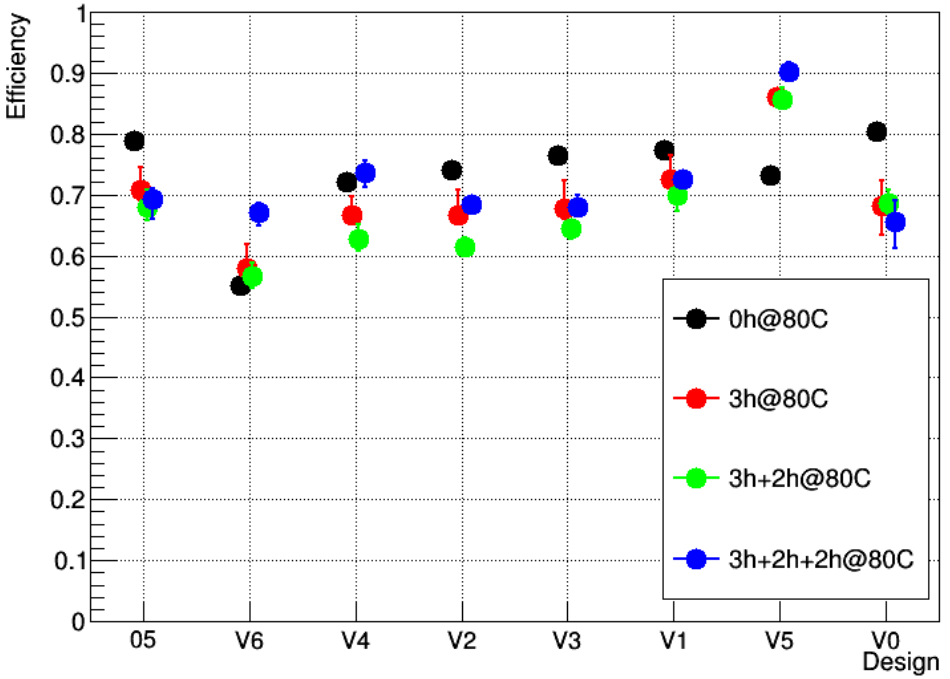
Annealing Results of R3 at 300V

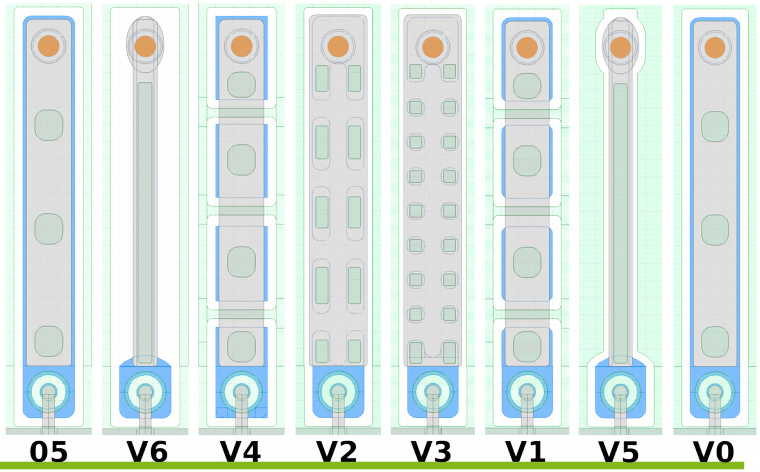
technische universität dortmund

- Annealing steps:
  3h and 2h at 80°C (long term)
- Efficiencies of standard designs dropped
- Efficiencies of pixel designs with smaller implantation (V5 and V6) increased

➔ With longer annealing times an increase in efficiency of pixel designs V5 and V6 is observed

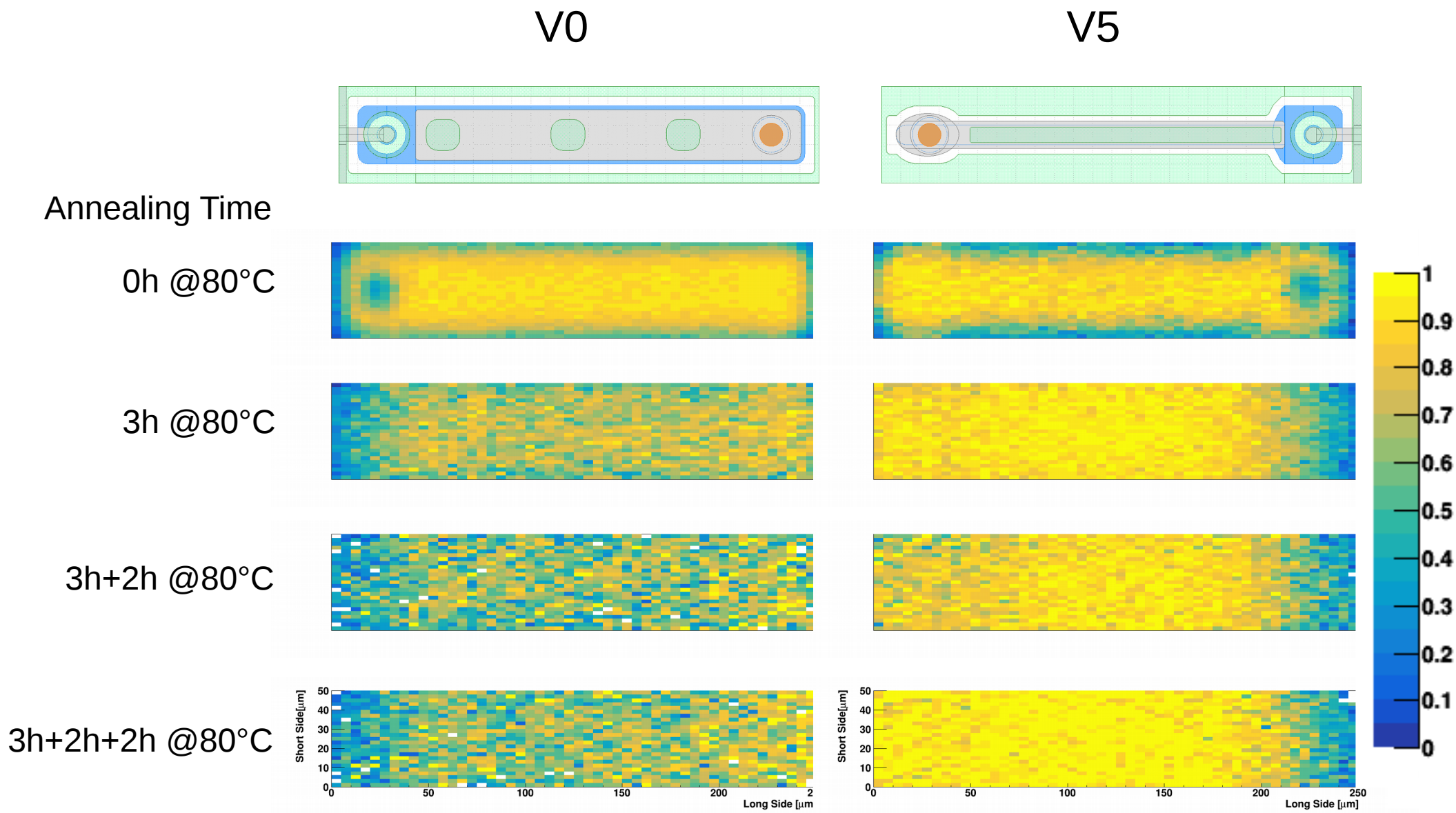
Tuning: 1600e, 6ToT@20ke





Annealing Results of R3 at 300V

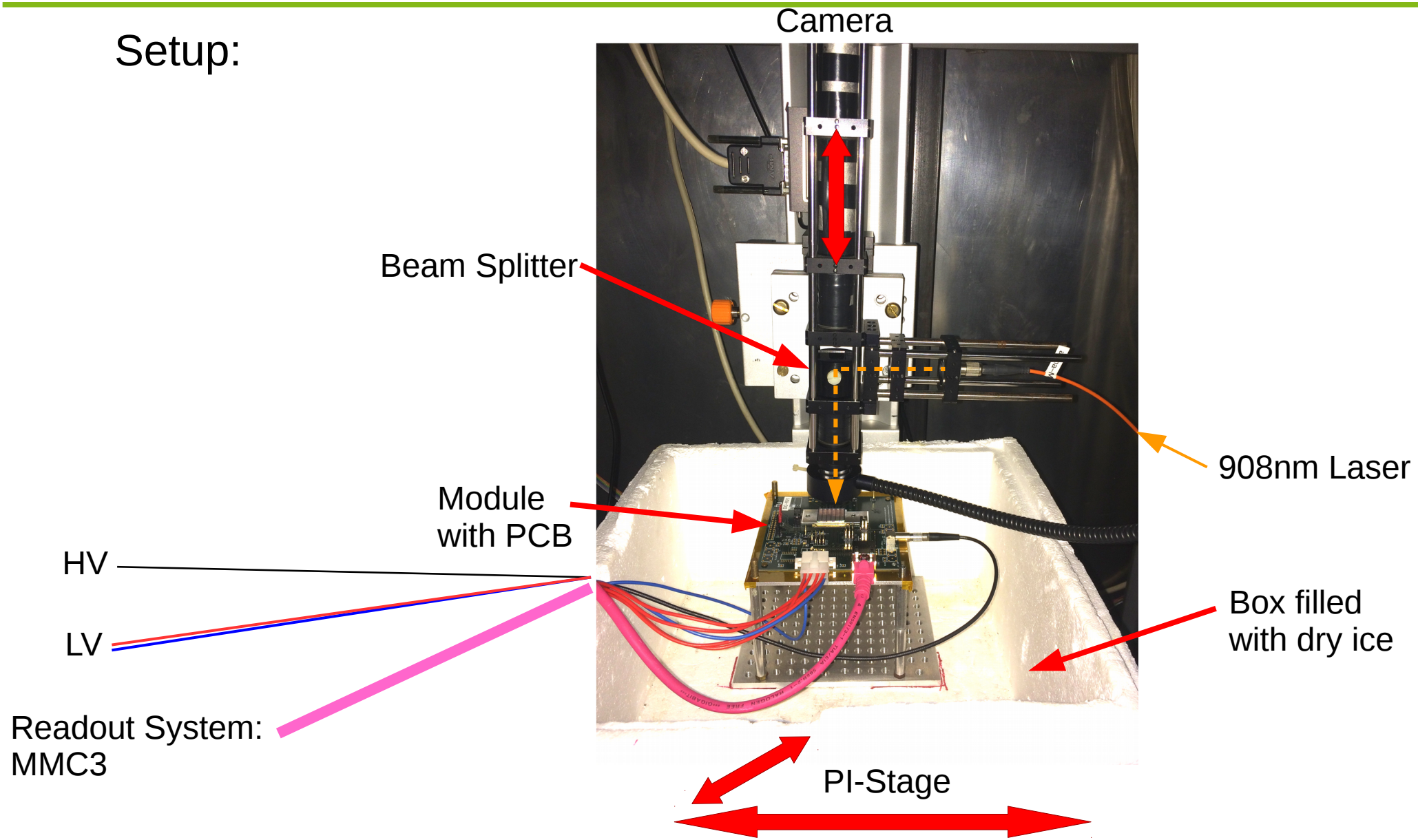
technische universität dortmund



Charge Collection Measurement

technische universität dortmund

Setup:



Module Preparation

- Target:

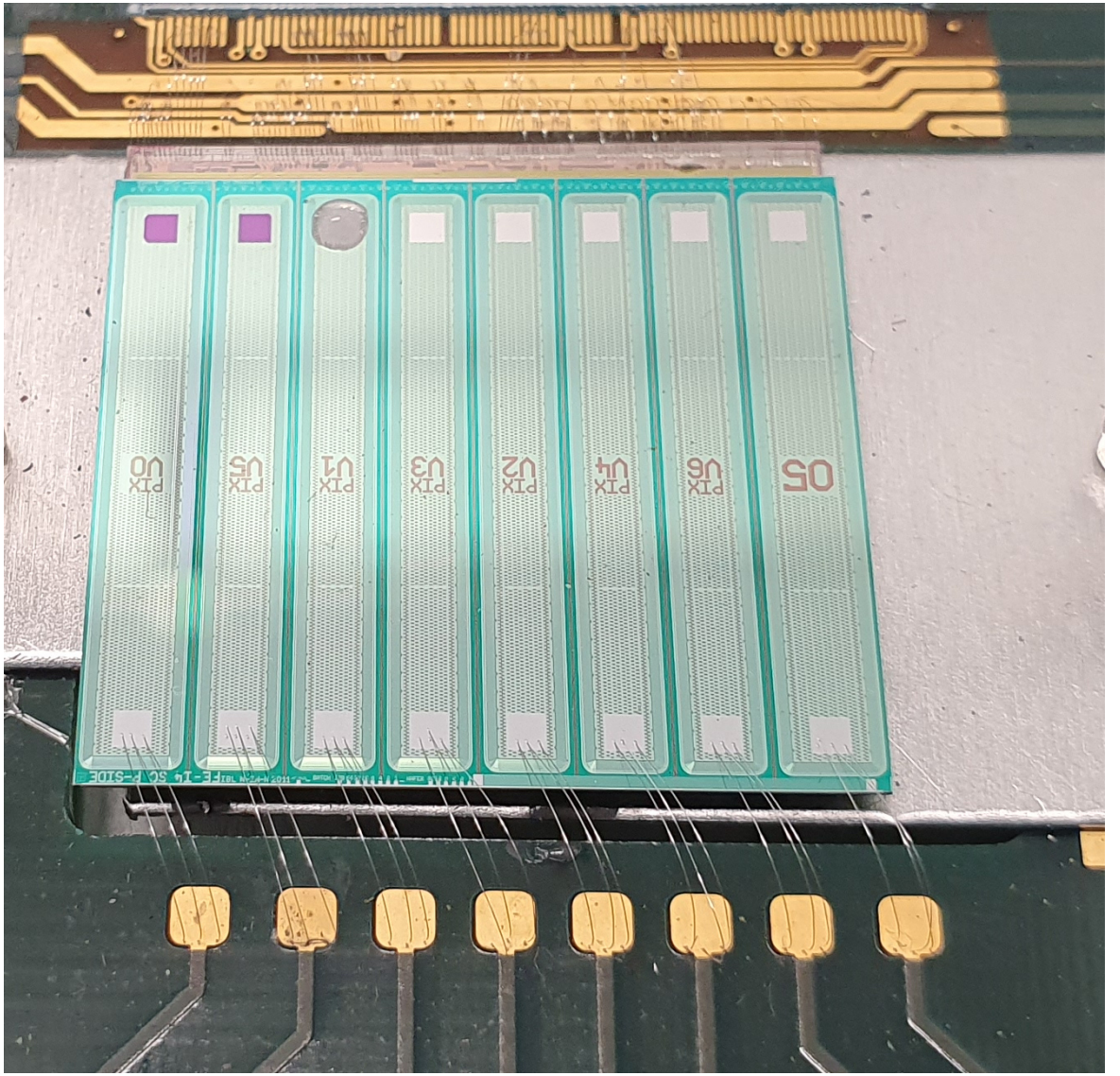
  Metal free area to inject laser

- Etch HV pad with sodium hydroxide solution:

  One drop per HV pad

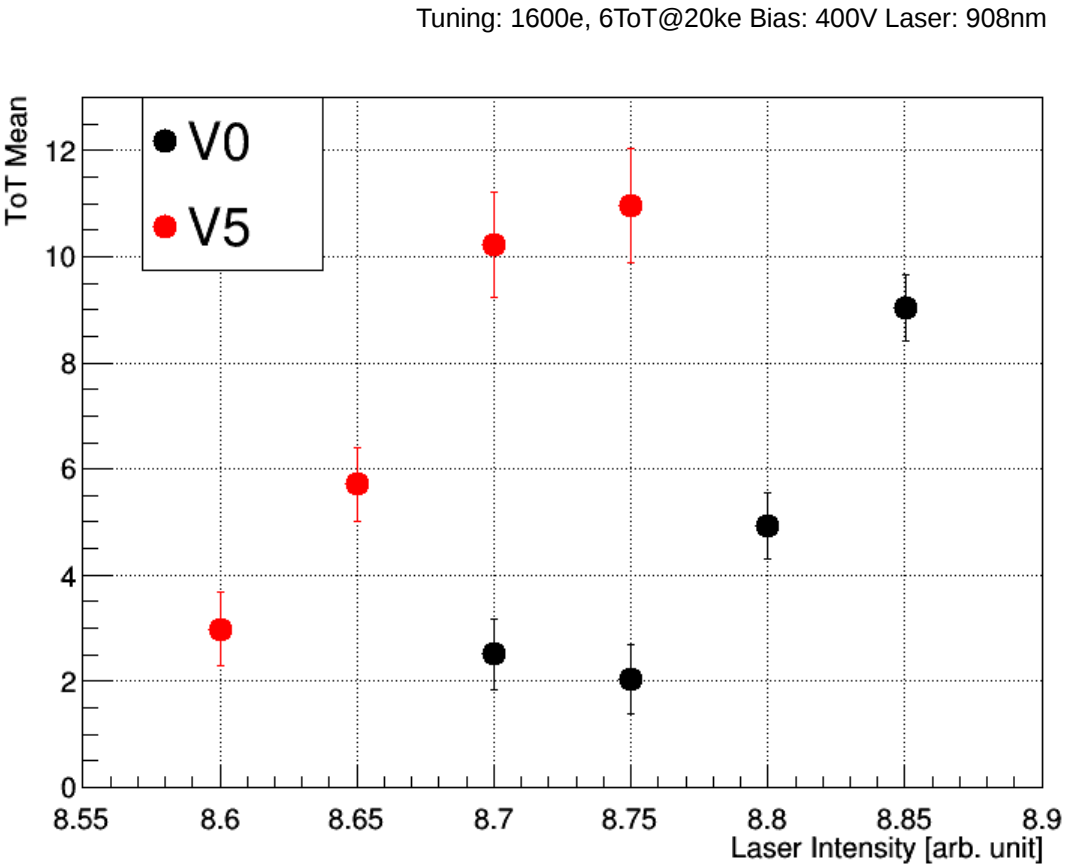
- After ~5 min metal is removed

- Rinse with water



Laser Intensity

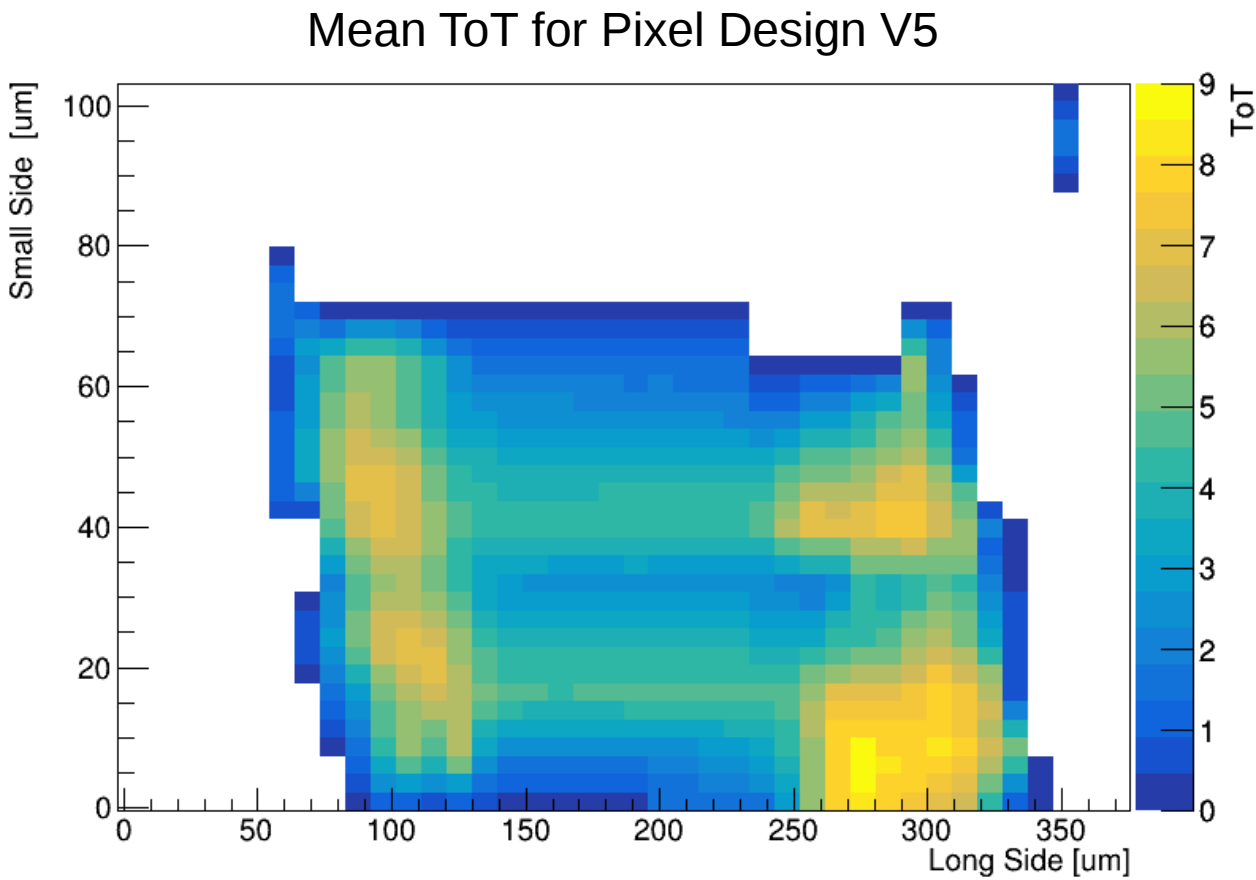
- Focused in central region of the pixel
- Depending on laser intensity the measured mean ToT changes
- Large difference between different Pixel designs
- Optimal laser intensity:
  - For V5 = 8.65
  - For V0 = 8.80-8.85



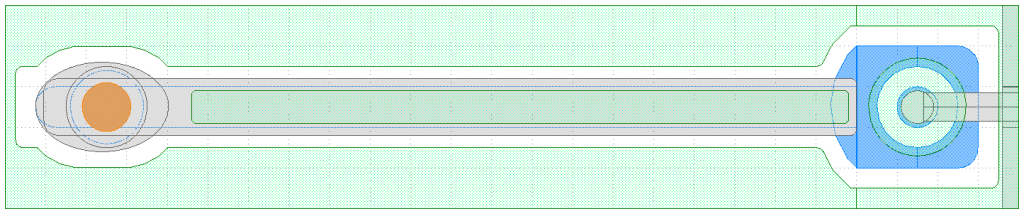
→ No common laser intensity for V0 and V5 can be found

Results Charge Collection

- 908nm laser
- Laser intensity: 8.65aU
- Trigger: 500Hz
- Scan area:
  370µm x 100µm
- Step width: 8µm
- Only cluster size 1



➔ Hot spots with higher ToT values are visible



Conclusion

- Test beam results of neutron irrad. sensor:
  Efficiencies of the pixel designs with narrowed implantation increase with annealing
- DESY TB results do not provide enough resolution to investigate the region with higher efficiency inside the pixel

→ Charge multiplication could result in higher efficiencies

→ Investigate the charge collected by the sensor after laser injection

→ Regions with higher ToT values (charge) are visible in this laser induced charge collection measurements

Outlook

- Improve the setup by fixing the module holder and insulating box to the PI-stage

- Measure the amount of photons in dependence of the laser intensity

- Measure non-annealed neutron irradiated sensors ($1e15n_{eq}/cm^2$ and $5e15n_{eq}/cm^2$) with the improved setup in small annealing steps

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654168

The measurements leading to these results have been performed at the Test Beam Facility at DESY Hamburg (Germany), a member of the Helmholtz Association (HGF)