
DESY.

“

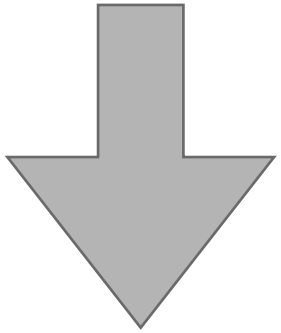
It is the part of a wise man to keep himself today for tomorrow, and not venture all his eggs in one basket.

– Miguel de Cervantes (Don Quixote, Part I)

”

Single-Vendor Problem

- Silicon sensors have become indispensable in high energy physics.
- … only available from few foundries



Alternative vendors ?

- Vendor diversification through standardised industrial CMOS process
- Fast, cheap and large-scale production

Characterisation and Simulation of stitched CMOS Strip Sensors

Naomi Davis on behalf of the CMOS Strip Detectors Collaboration

13th International "Hiroshima" Symposium on the Development and Application of Semiconductor Tracking Detectors

December 5th, Vancouver

HELMHOLTZ

technische universität dortmund

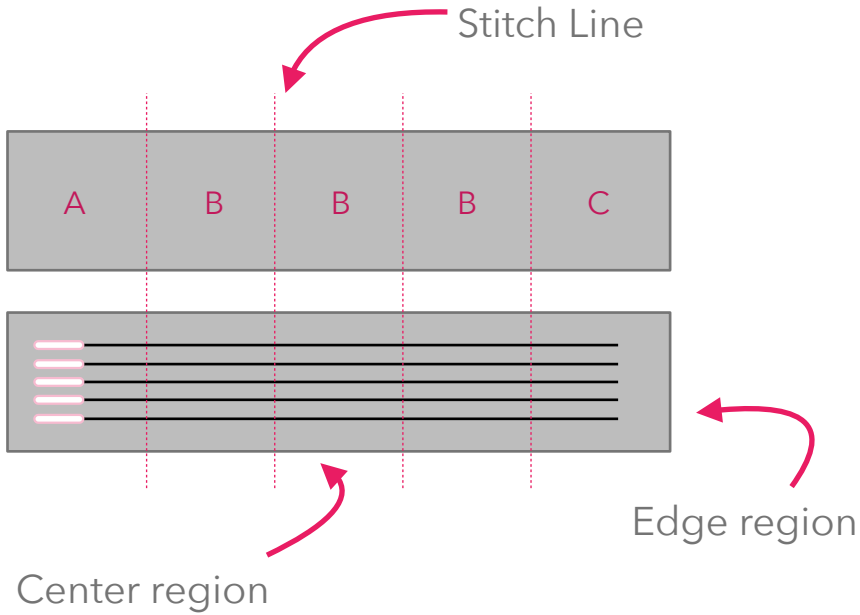
universität freiburg

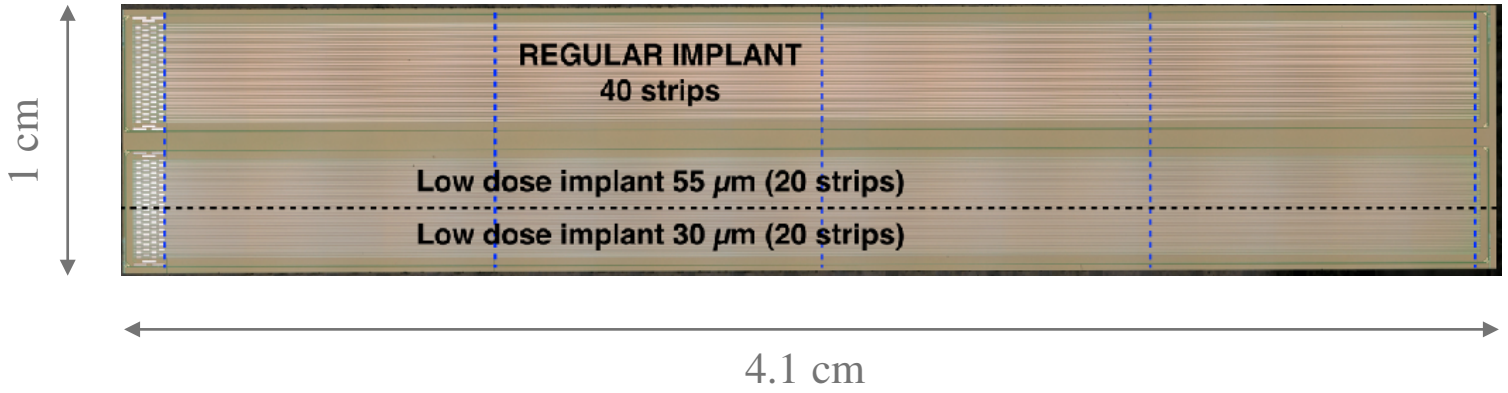
UNIVERSITÄT BONN

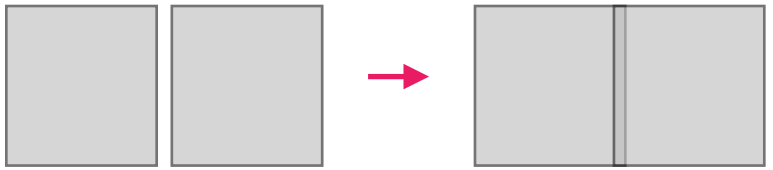
DESY.

CMOS Strip Sensors

- n-in-p sensor, 150 nm LFoundry technology
- 150 ± 10 um thickness, 75.5 um strip pitch
- Different formats through stitching technique



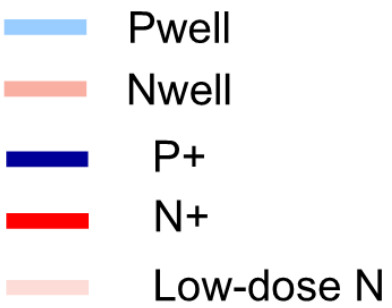




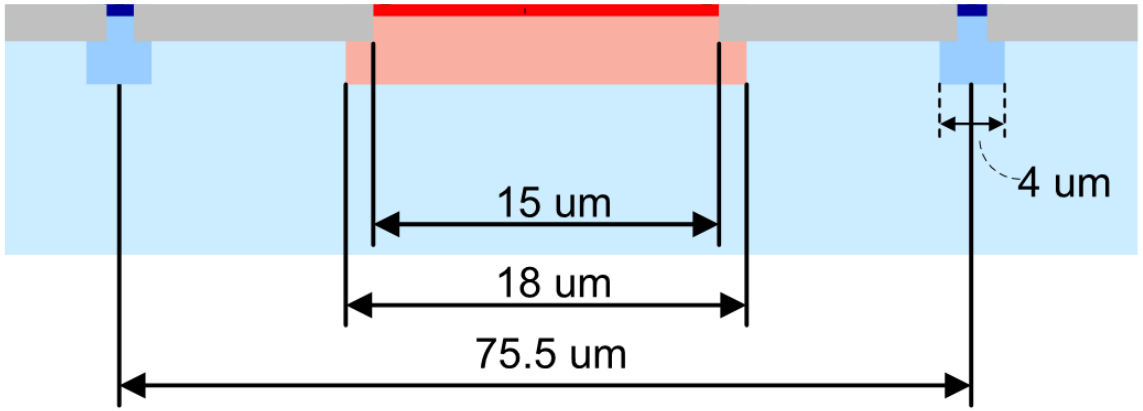
L. Diehl et al., *"Characterization of Passive CMOS Strip Sensors"*, NIMA, Vol 1022 (2022) https://doi.org/10.1016/j.nima.2022.166671

Strip Sensor Layout

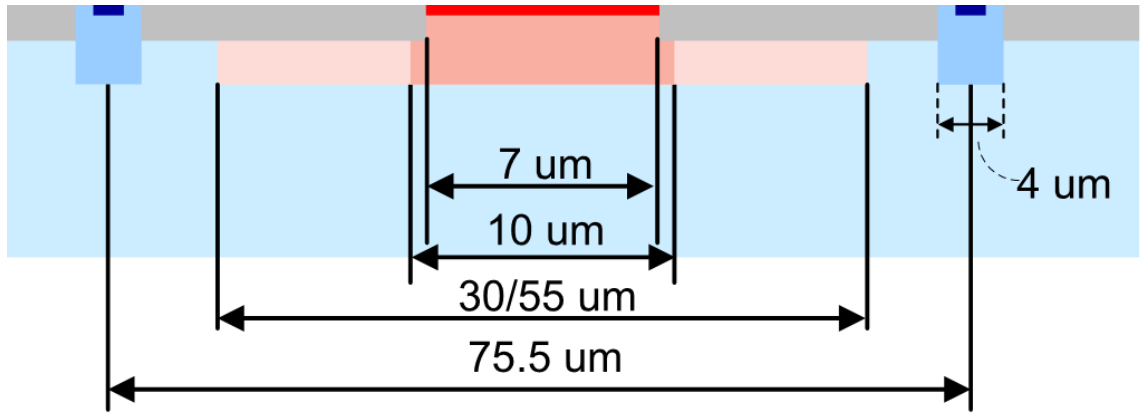
- Strip-implant varies in width and doping concentration



Regular strip implant



Low Dose 30/55 strip implant



L. Diehl et al., *"Characterization of Passive CMOS Strip Sensors"*, NIMA, Vol 1022 (2022) https://doi.org/10.1016/j.nima.2022.166671

Test Beam at DESY II

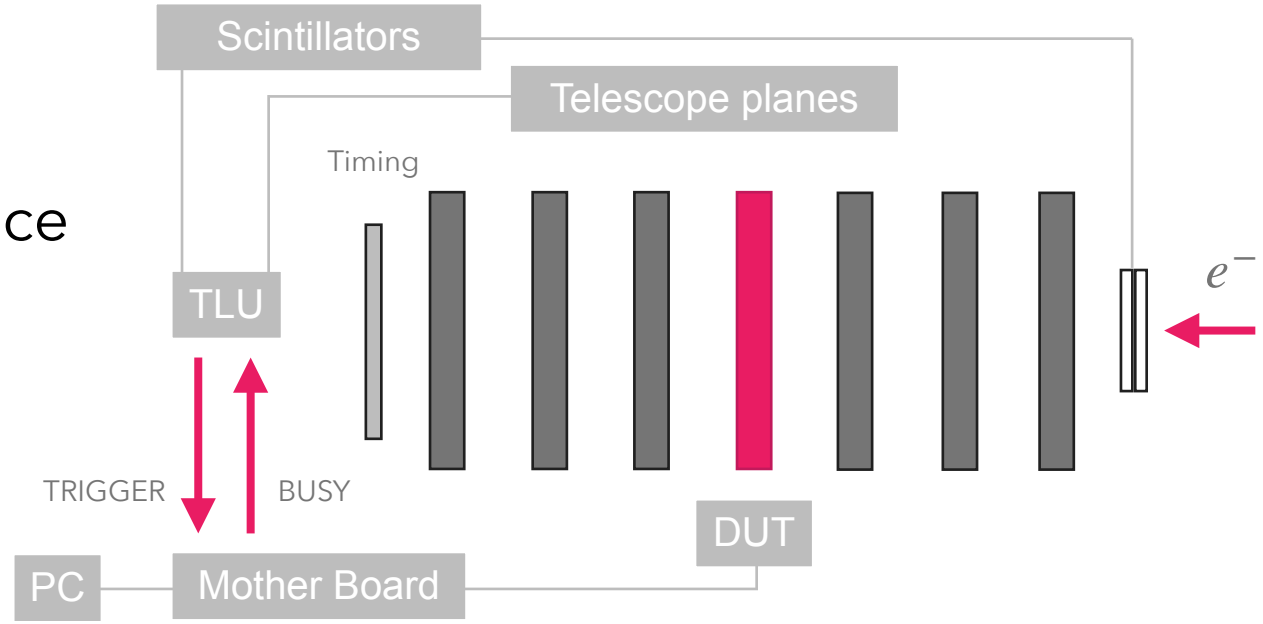
- TB campaigns in May22, Mar23 at DESY-II TB Facility
- ADENIUM telescope with 6 ALPIDE planes as reference (+ timing plane in Mar23)
- e^- beam energy: 3.4 GeV, 4.2 GeV
- Styrofoam cold box, cooling with dry ice

TB Mar23:
Unirradiated Sample

@100V bias, short

TB May22:
Irradiation with reactor neutrons in **Ljubljana**

3e14 n_{eq}/cm^2 @250V bias,



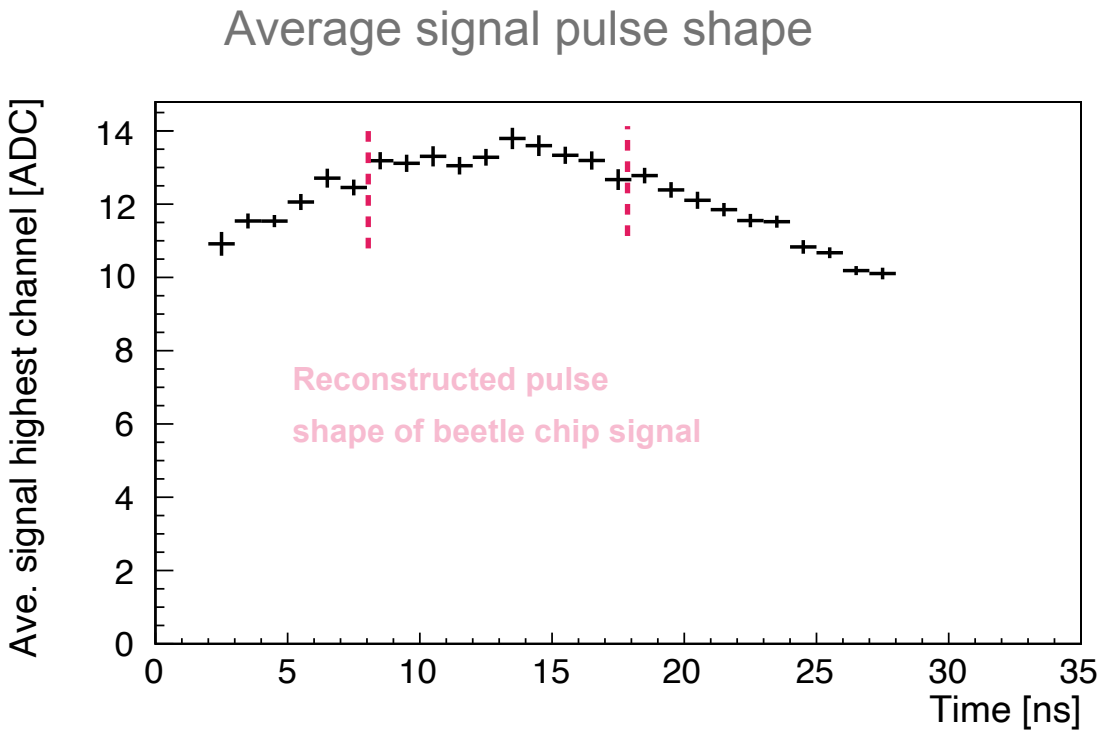
J. Dreyling-Eschweiler et al., *"The DESY II test beam facility"*, NIMA, Vol 922 (2019) https://doi.org/10.1016/j.nima.2018.11.133
H. Jansen et al., *"Performance of the EUDET-type beam telescopes"*, EPJ Techn Instrum 3, 7 (2016) https://doi.org/10.1140/epjti/s40485-016-0033-2

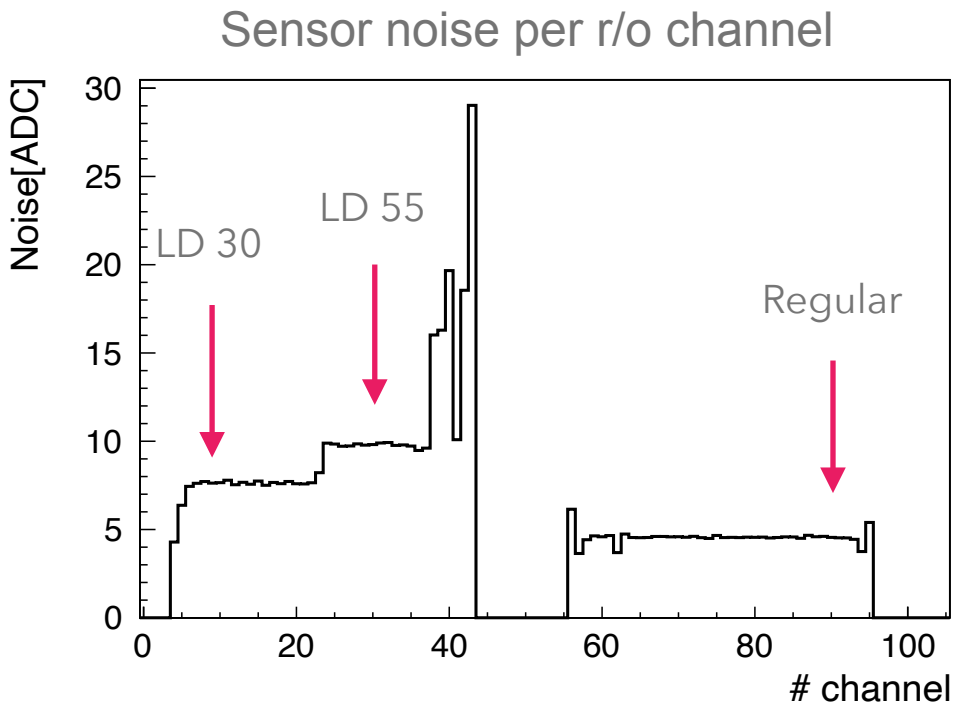
Strip Sensor Readout

Unirradiated Sample

@100V bias, short

- ALiBaVa readout system uses 128-channel Beetle r/o chips
- Reconstruction and Analysis with Corryvreckan: [EventLoaderALiBaVa]





D. Dannheim et al., *"Corryvreckan: a modular 4D track reconstruction and analysis software for test beam data"*, J. Instr. 16 (2021) https://doi.org/10.1088/1748-0221/16/03/P03008

R. Marco-Hernandez et al., *"ALIBAVA: A portable readout system for silicon microstrip sensors"*, NIMA, Vol 623 (2010) https://doi.org/10.1016/j.nima.2010.02.197

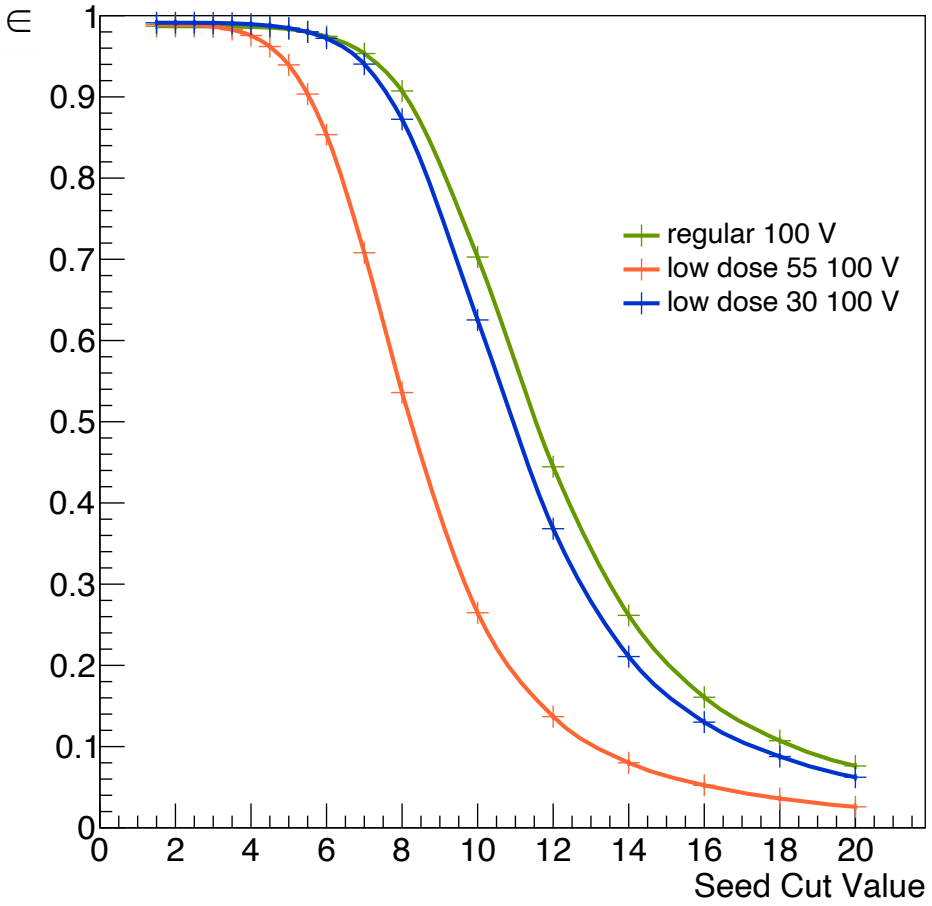
Total Hit Detection Efficiency

Hit detection efficiency of an unirradiated sample

Unirradiated Sample

@100V bias, short

- Seed Cut Value:
  - Clustering Algorithm based on SNR distribution
  - Threshold: cut in SNR distribution for definition of seed and neighbour strip
- High efficiency region at low seed cuts



Total Hit Detection Efficiency

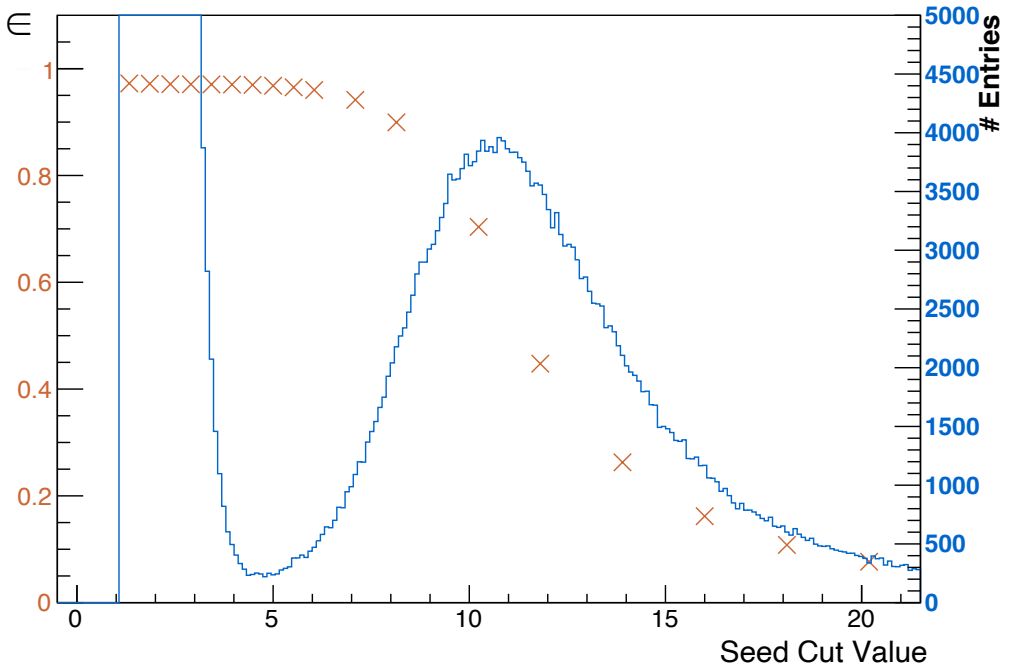
Signal distribution of an unirradiated sample

Unirradiated Sample

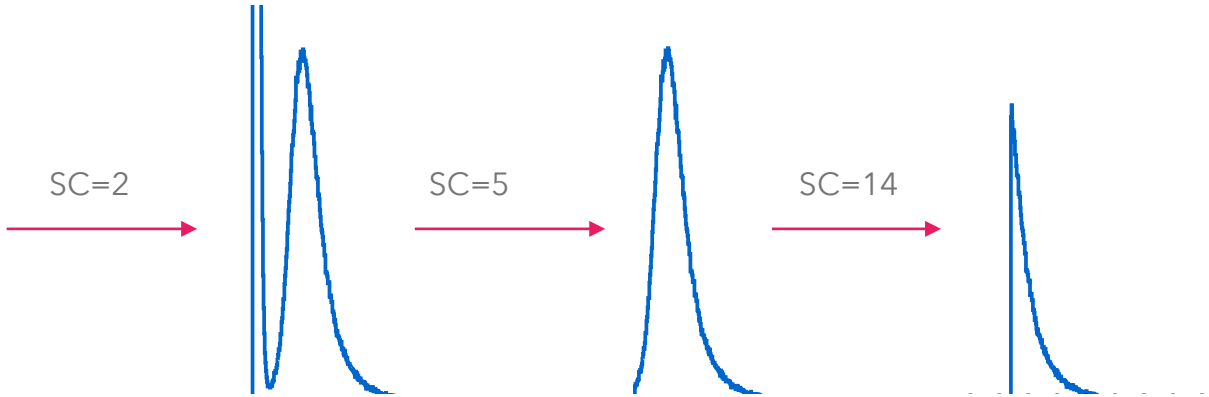
@100V bias, short

- Efficiency decline with threshold cuts within the signal distribution

SNR-distribution (Regular)



Applying Seed Cuts on the SNR-distribution



Global Hit Detection Efficiency

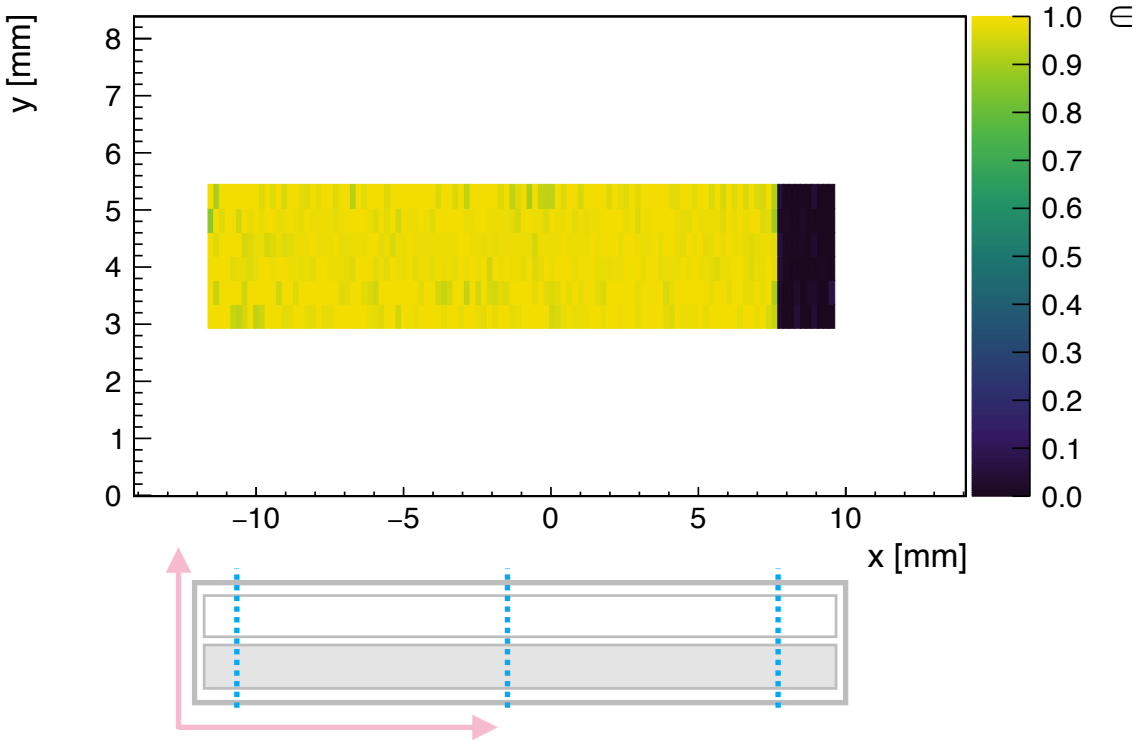
Efficiency along the Regular design in the bond-pad region @SC=3

Unirradiated Sample

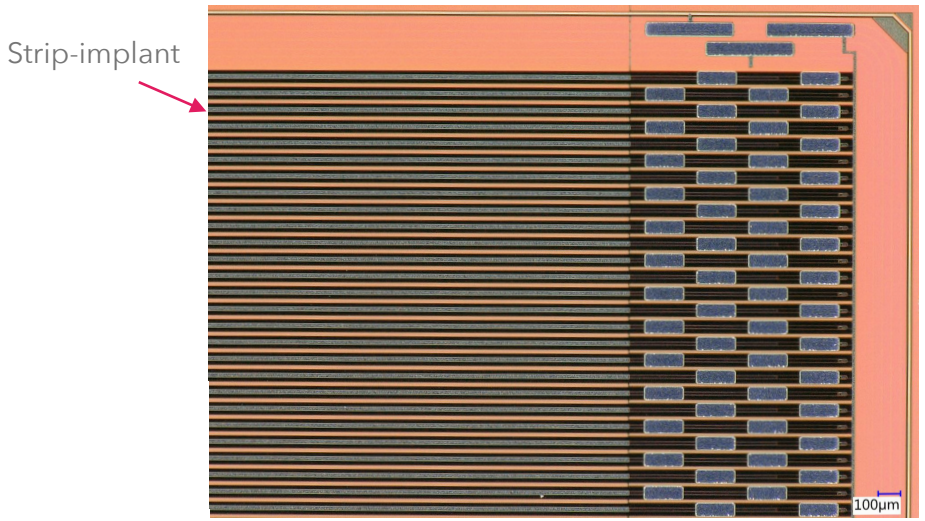
@100V bias, short

- Efficiency drop at bond-pad region

Strip length with bond pad region (Regular)



Regular strip implants



Focus on the bond-pad region in recent TB

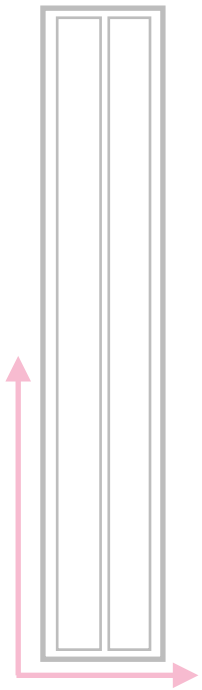
In-Strip Hit Detection Efficiency

Efficiency within the strip of an unirradiated sample @SC=3

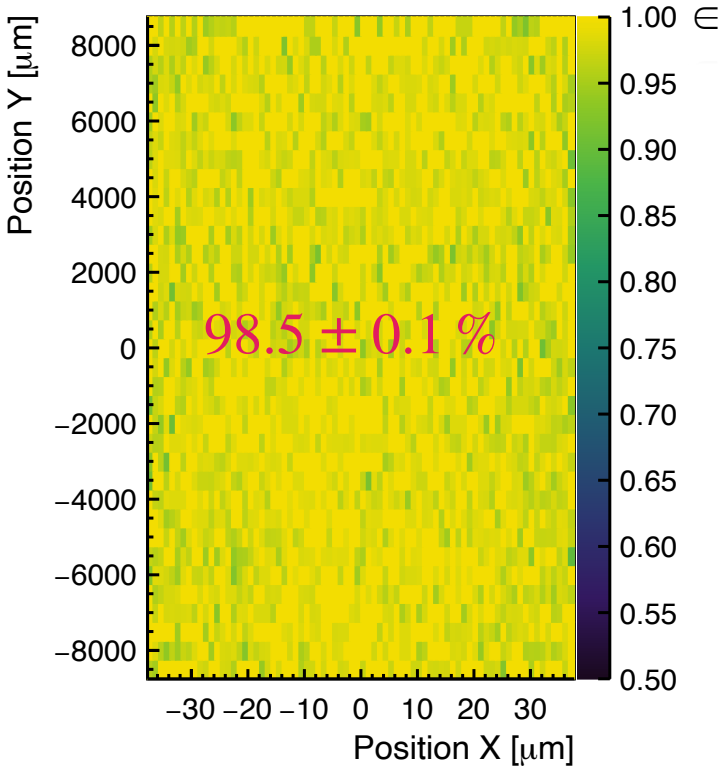
Unirradiated Sample

@100V bias, short

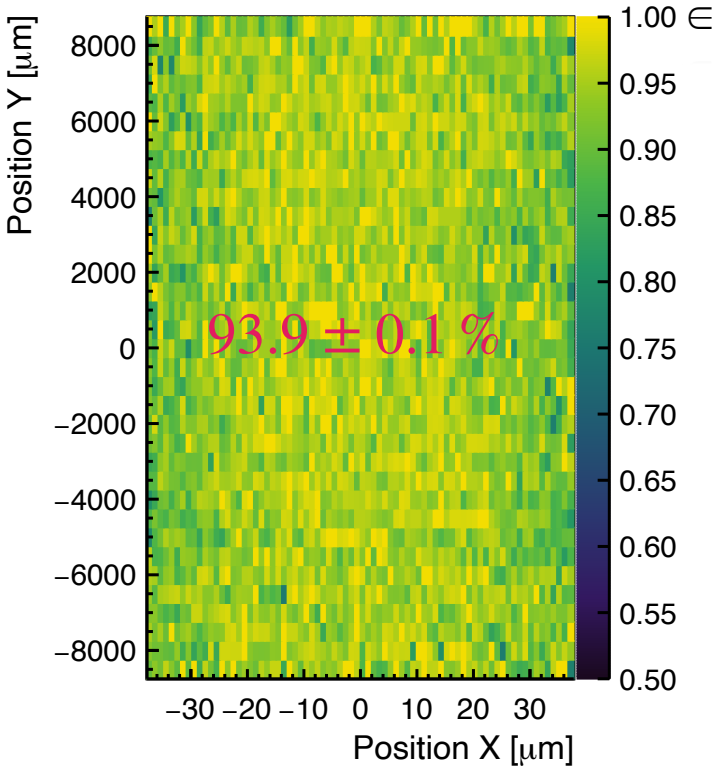
- Homogeneous distribution along strip length



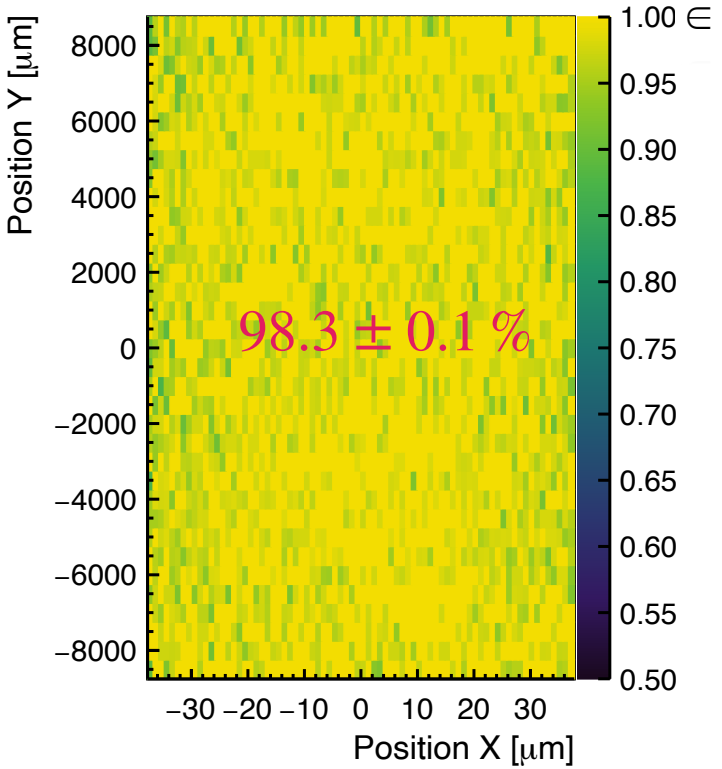
Regular



Low Dose 55



Low Dose 30



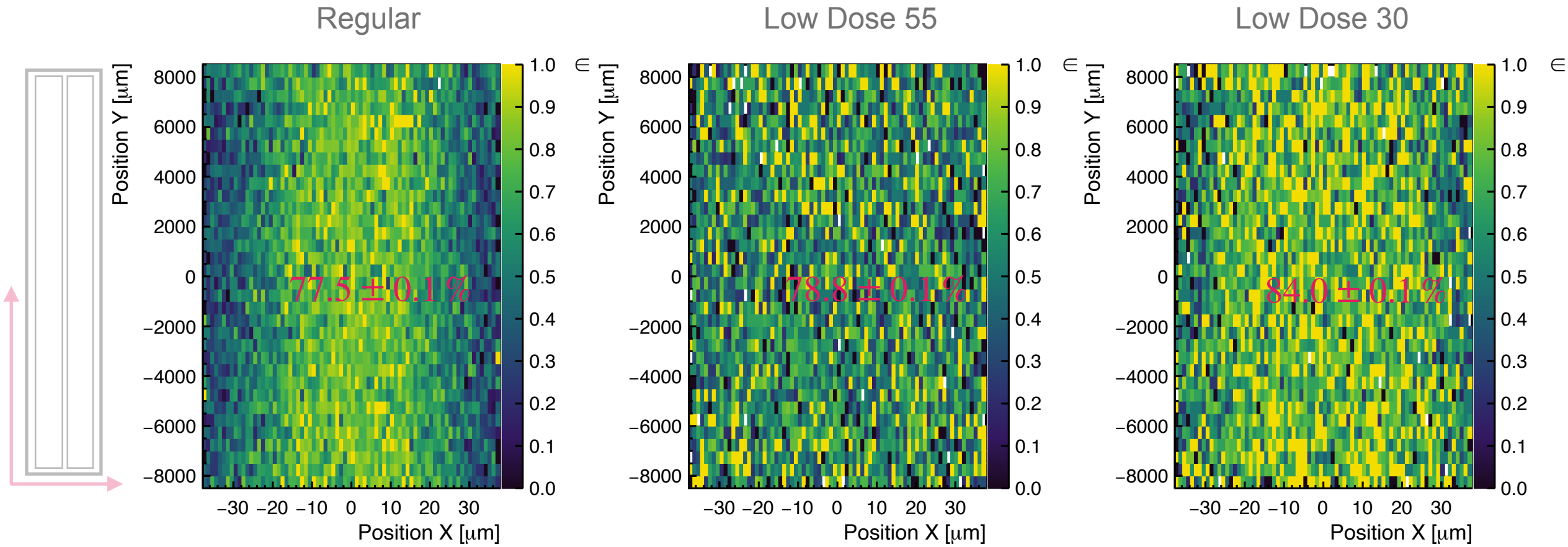
In-Strip Hit Detection Efficiency

Efficiency within the strip of an irradiated sample @SC=3

Irradiation with reactor neutrons in **Ljubljana**

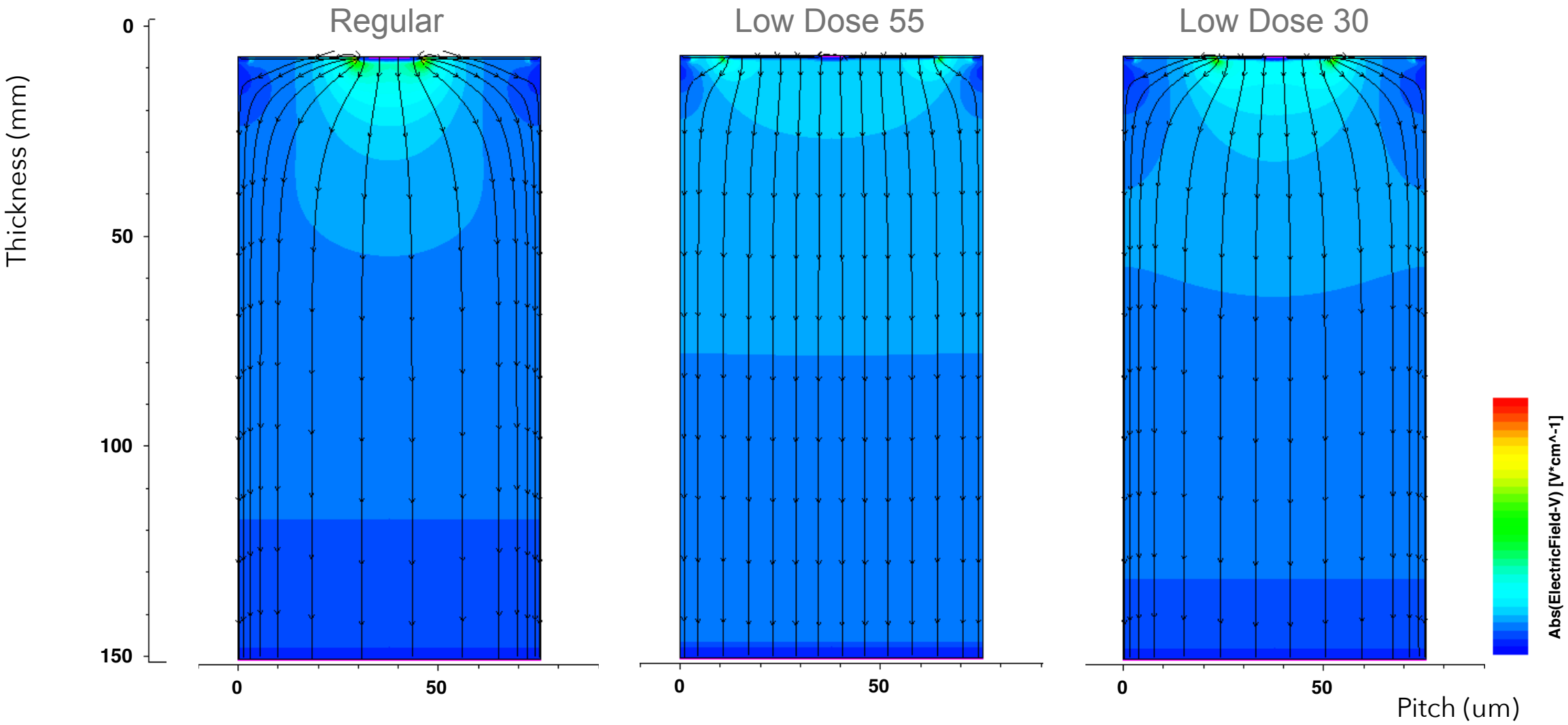
3e14 n_{eq}/cm^2 @250V bias, long

- Efficiency drop towards inter-strip region for Regular design



Electric Field Strength

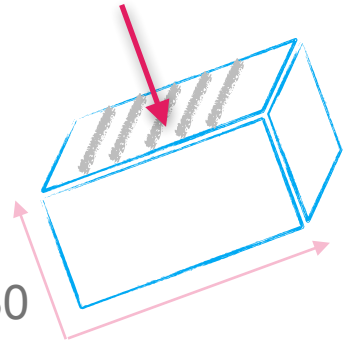
TCAD: Simulation of the electric field within the sensor @100 V

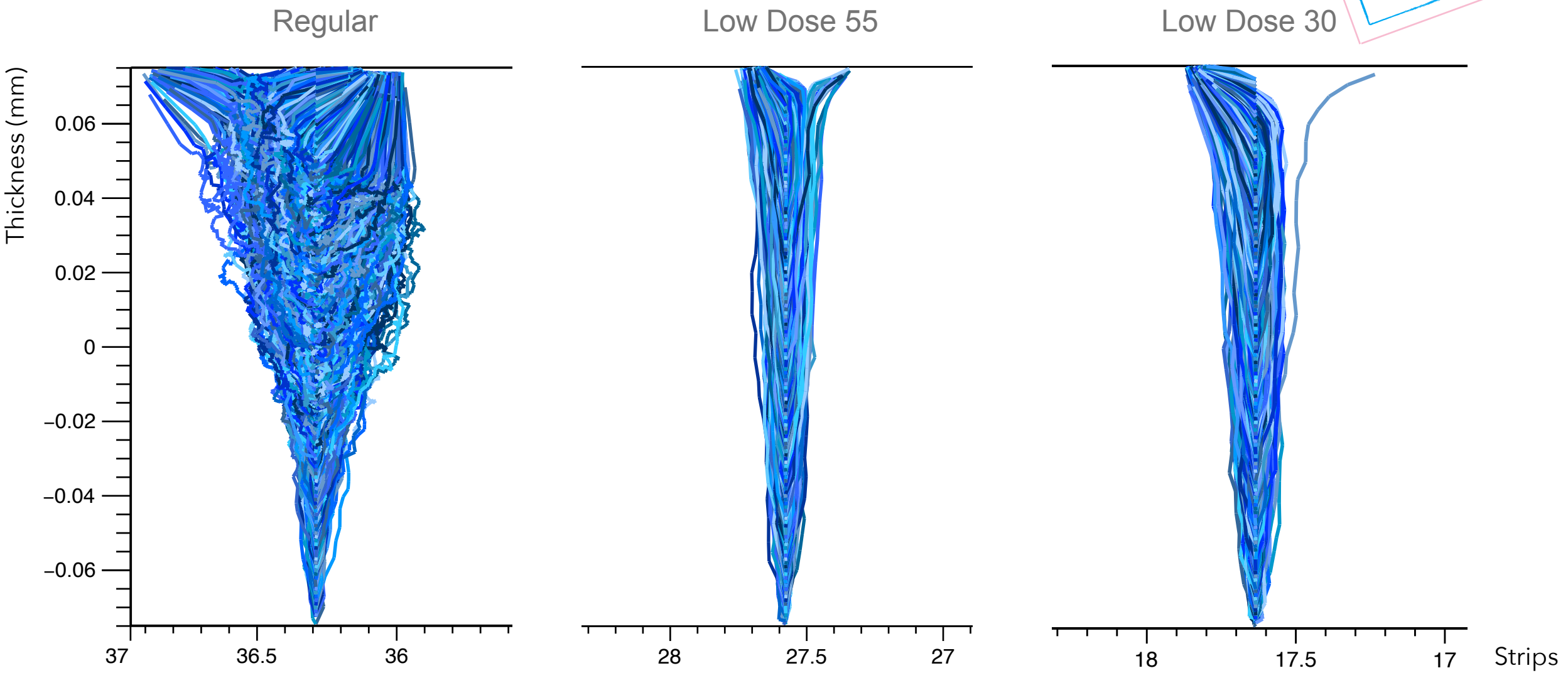


By I. Zatocilova

Charge Carrier Propagation

Allpix²: Simulation of the charge carrier path within the sensor





S. Spannagel et al., "Allpix²: A Modular Simulation Framework for Silicon Detectors", NIMA, Vol 901 (2018) http://dx.doi.org/10.1016/j.nima.2018.06.020

Conclusion & Outlook

What we have learned and what's next …

- Stitching does not impact hit detection efficiency!
  - Efficiency drop for LD designs and irradiated samples

- Further investigation of:
  - Bond-pad region, proton and neutron irradiation
- TB data comparison with simulation
- Active sensor submission under discussion

Thank you,
Questions?

Naomi Davis

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Deutsches Elektronen-Synchrotron DESY

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).

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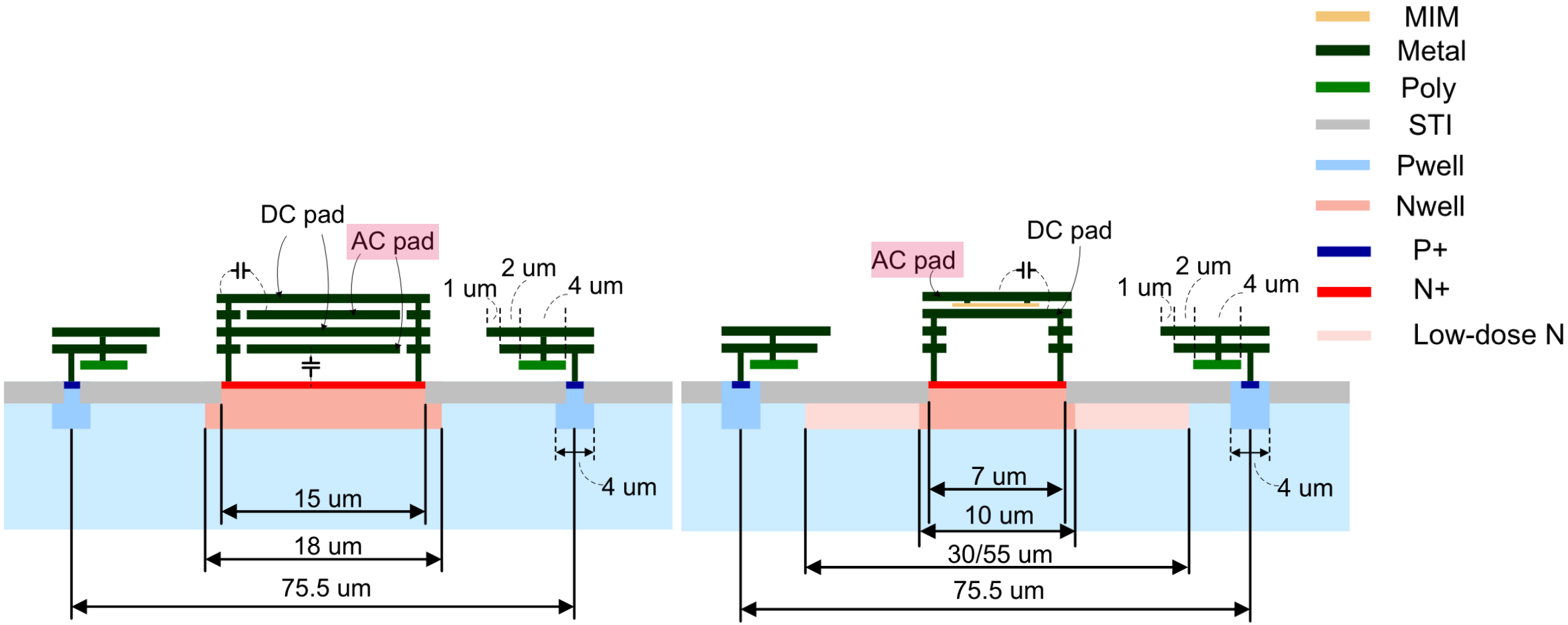
Jens Weingarten, Iveta Zatocilova

Backup

Full Sensor Layout



Regular strip implant

Low Dose strip implant

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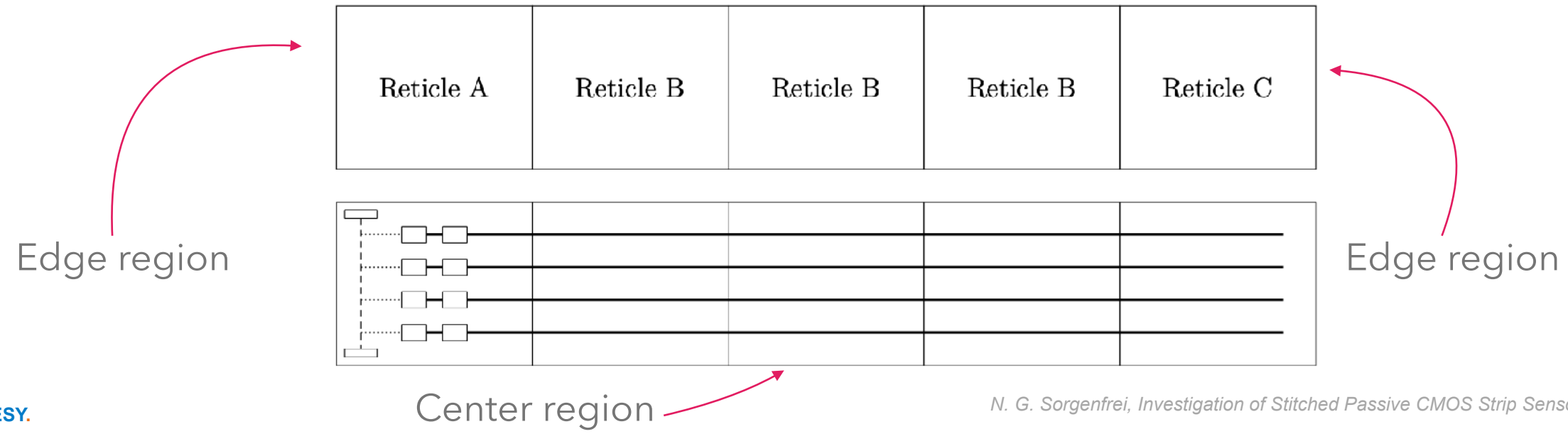
https://doi.org/10.1016/j.nima.2022.166671

Stitching for Silicon Sensors

Connection of neighbouring reticles

- Sensor is divided into small(er) parts
- Different reticles used to imprint these parts
- Reticle B: is imprinted, moved, imprinted…

Stitching is possible in both dimensions!



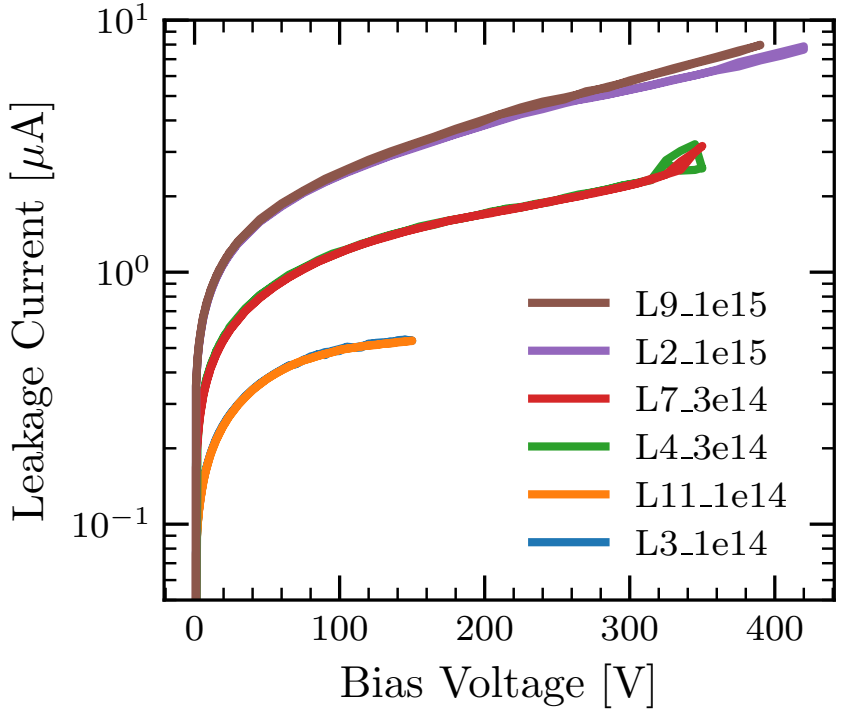
N. G. Sorgenfrei, Investigation of Stitched Passive CMOS Strip Sensors

IV-Measurements

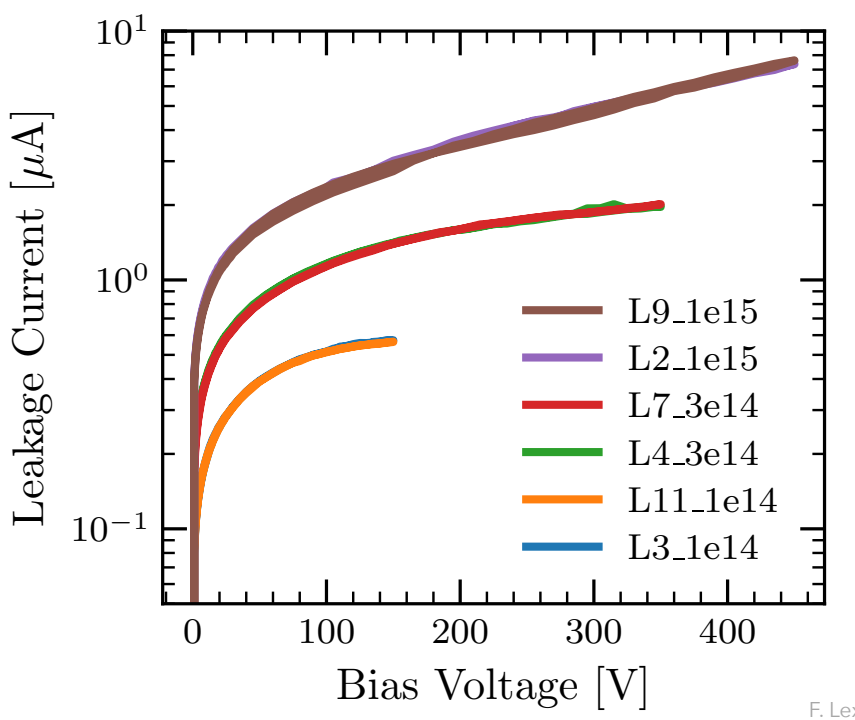
Characterising the sensor

- Depletion Voltage:
  - 30 - 40 V unirradiated
  - 160V irradiated (beneficially annealed for 80min at 60◦C)

Low Dose



Regular

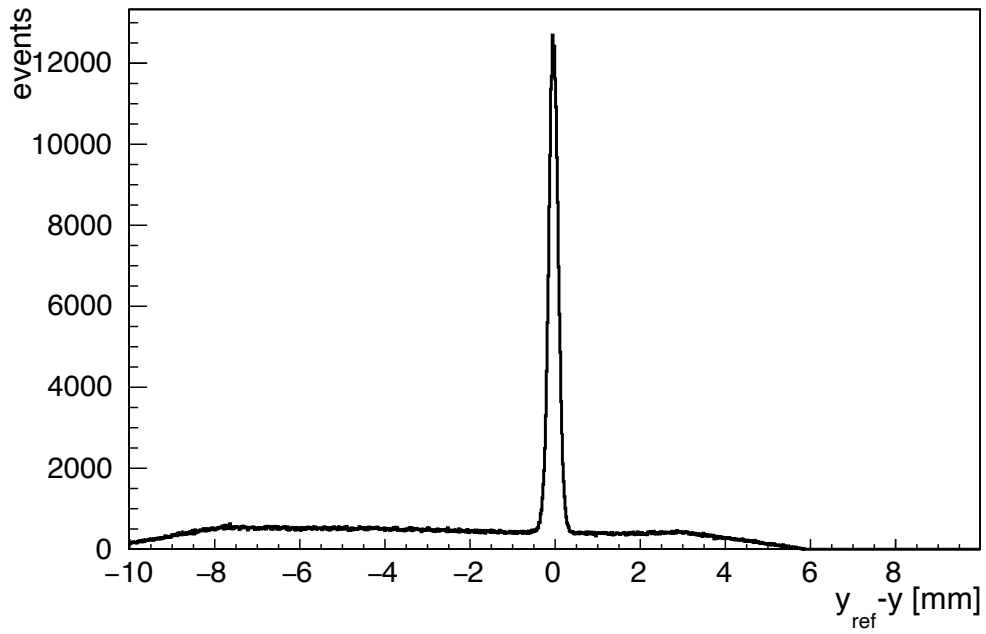


F. Lex

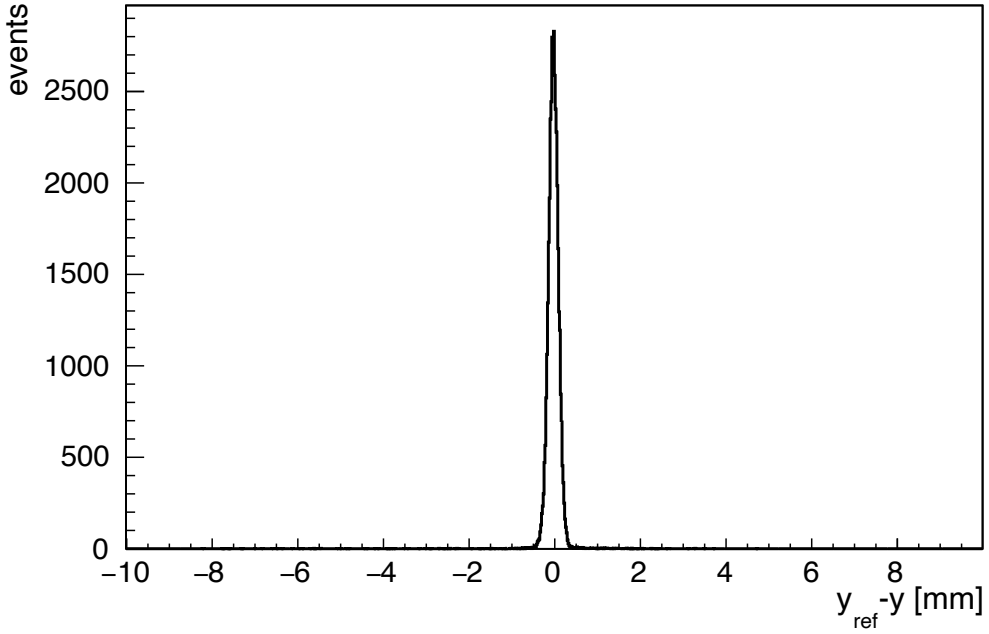
Integration Times

Beam particle track rate

- High particle track rate in TB Nov 21 and May 22
- Issue: different integration times of DUT and telescope (~75 ns vs ~30 us)
- `[FilterEvents]` module: restriction to one cluster per event



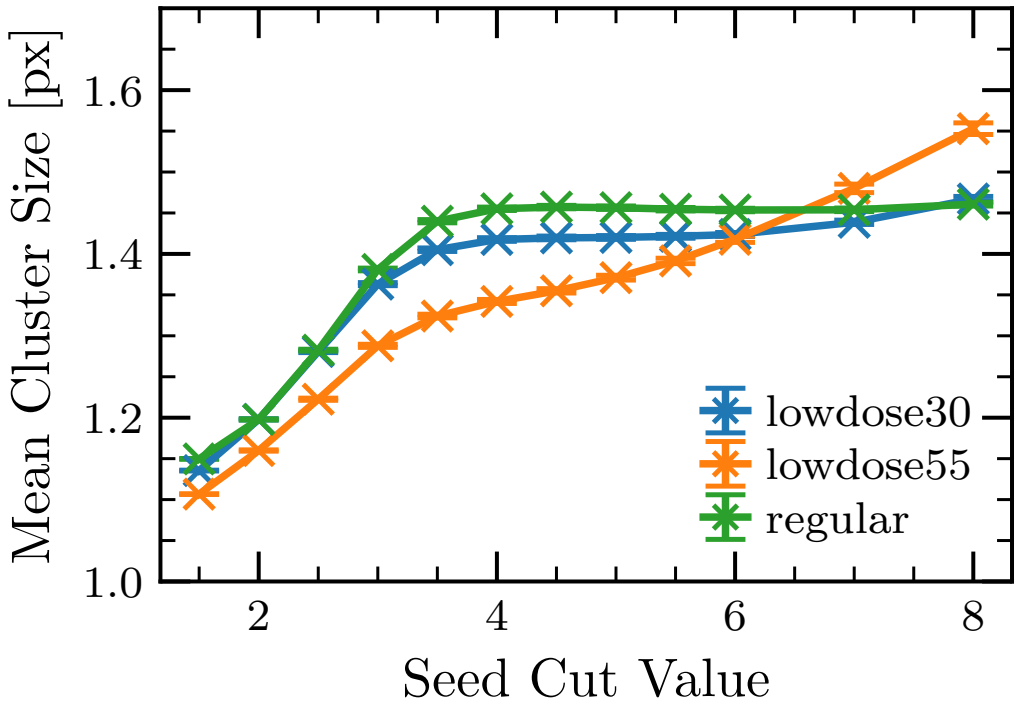
Correlation Y between telescope and DUT



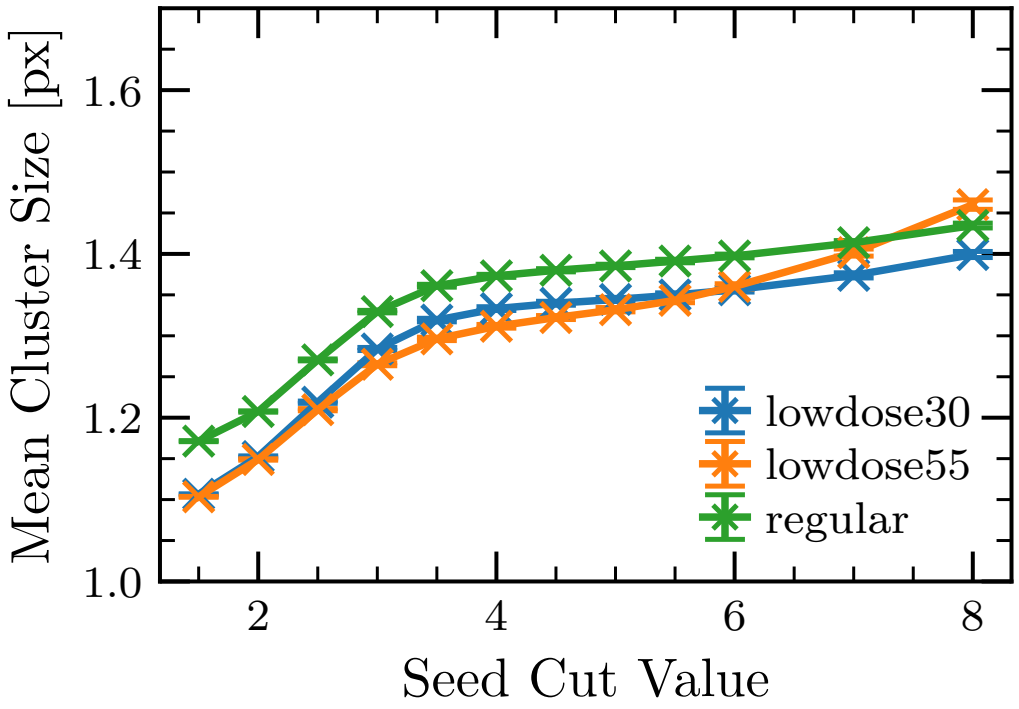
Correlation Y between telescope and DUT (Filter)

Cluster Size

Unirradiated



Irradiated



Fake-Cluster Rate