

Test Beam Characterisation of stitched CMOS Strip Sensors

Naomi Davis on behalf of the CMOS Strip Detectors Collaboration

Detector Platform Retreat

January 19th, Hamburg

HELMHOLTZ

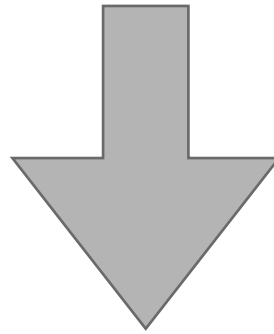
tu technische universität
dortmund

universität freiburg



Single-Vendor Problem

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

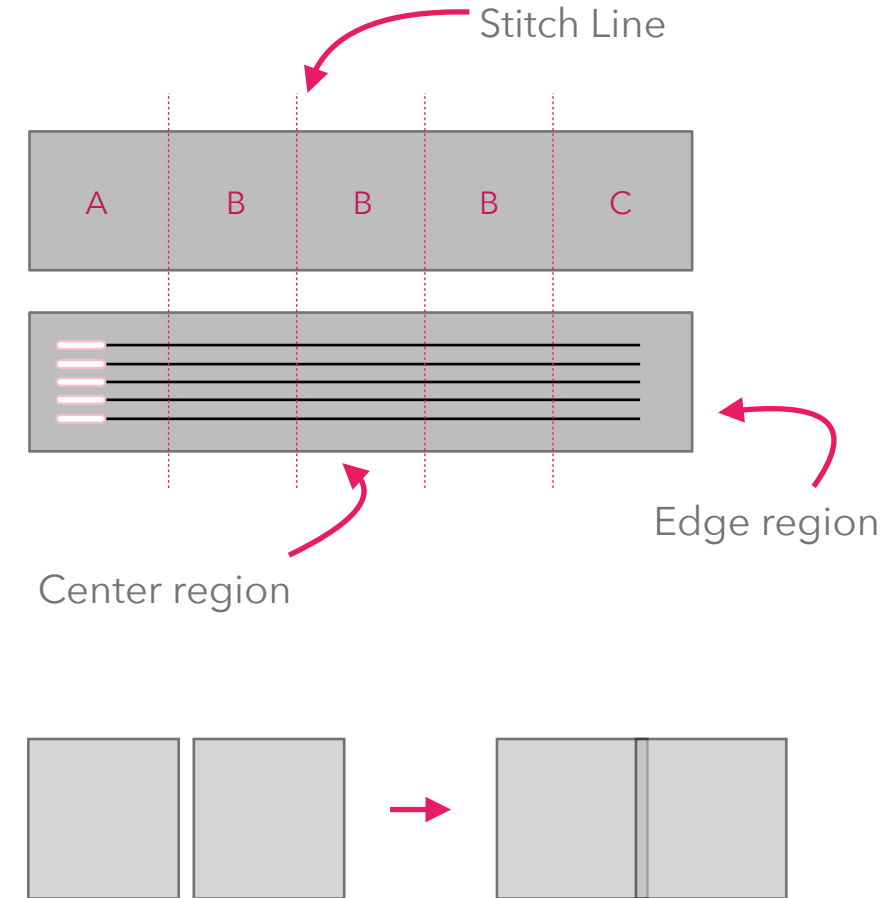
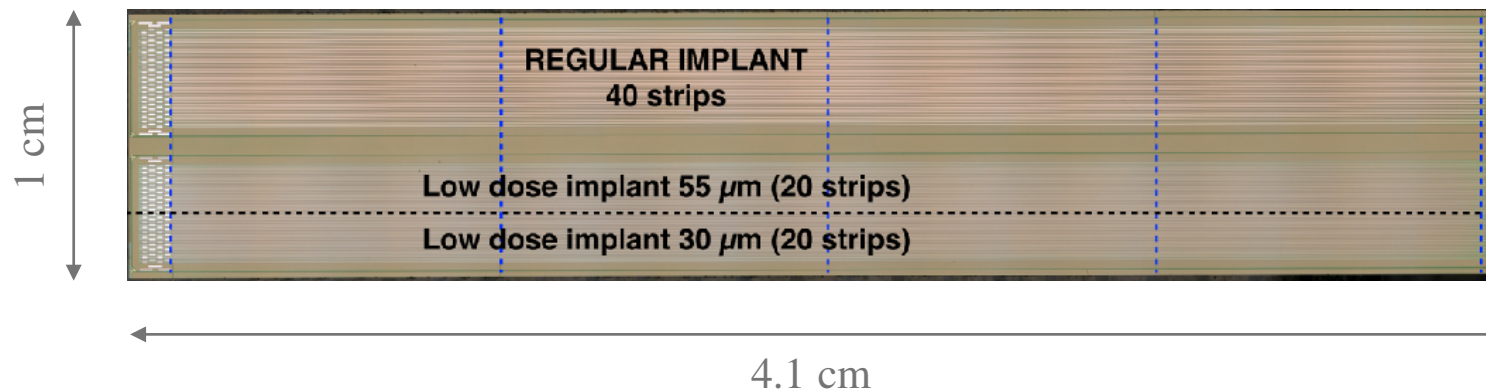


Alternative vendors ?

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

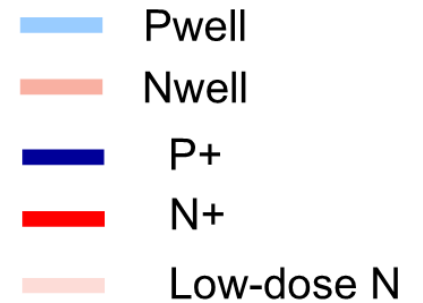
CMOS Strip Sensors

- n-in-p sensor, 150 nm LFoundry technology
- $150 \pm 10 \text{ }\mu\text{m}$ thickness, 75.5 μm strip pitch
- Different formats through stitching technique

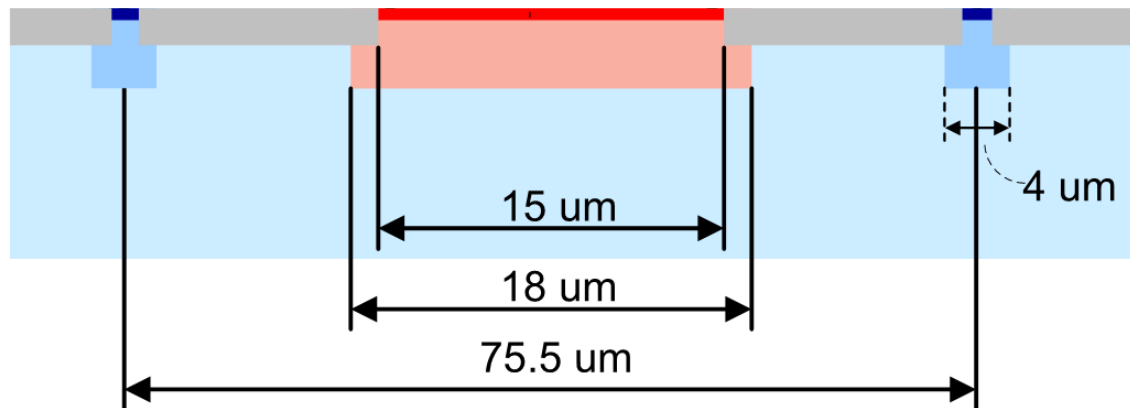


Strip Sensor Layout

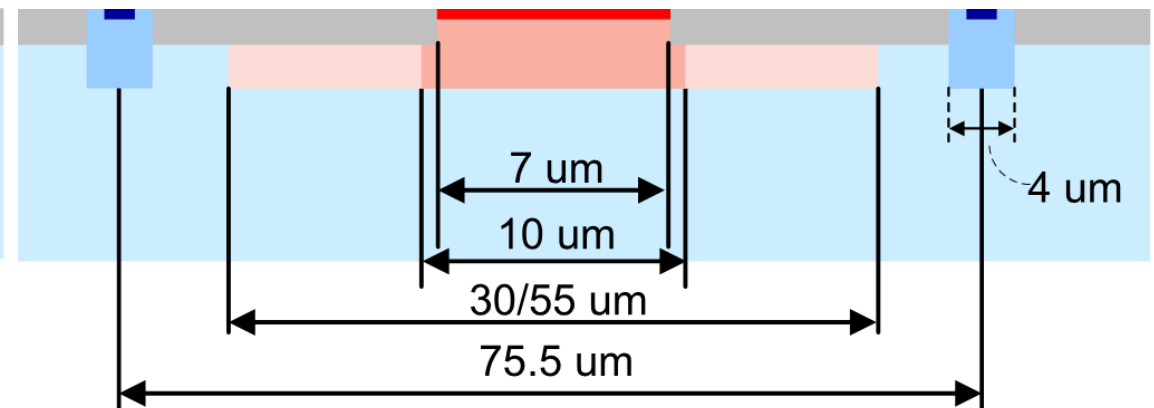
- Strip-implant varies in width and doping concentration



Regular strip implant



Low Dose 30/55 strip implant

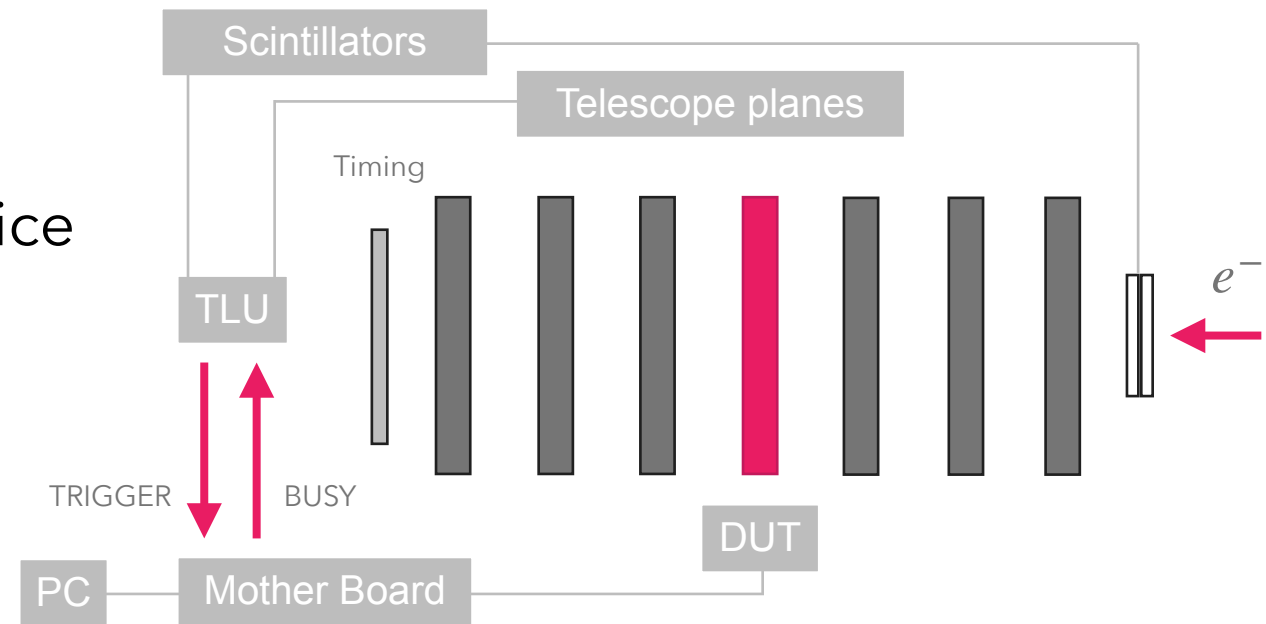


Test Beam at DESY II

- 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, $3e14 \text{ n}_{eq}/\text{cm}^2$
@250V bias, long



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>

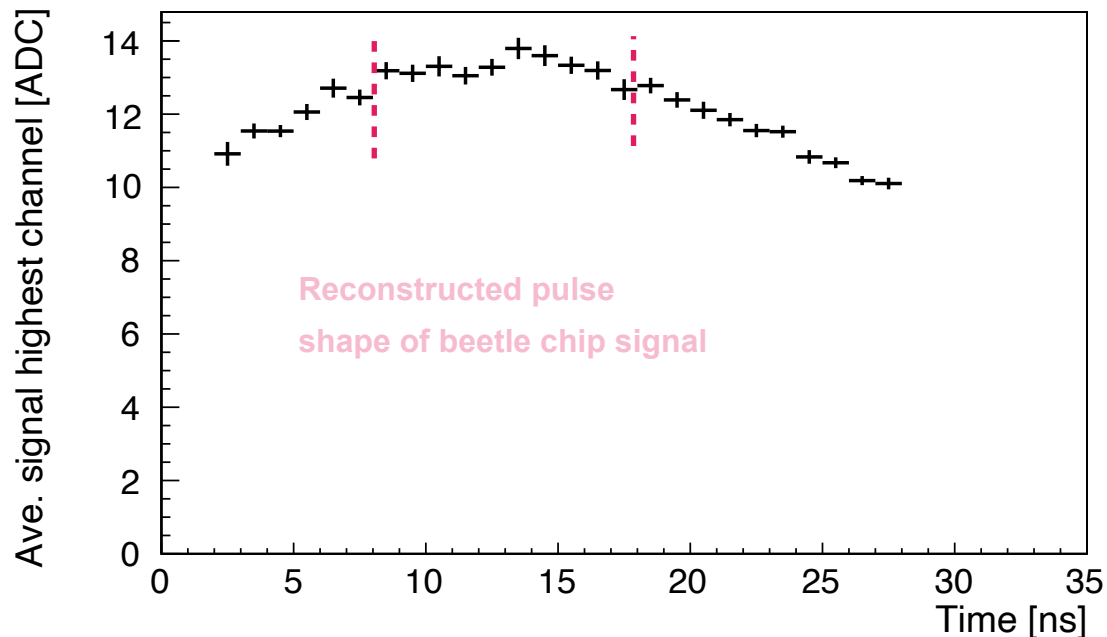
Strip Sensor Readout

Unirradiated Sample

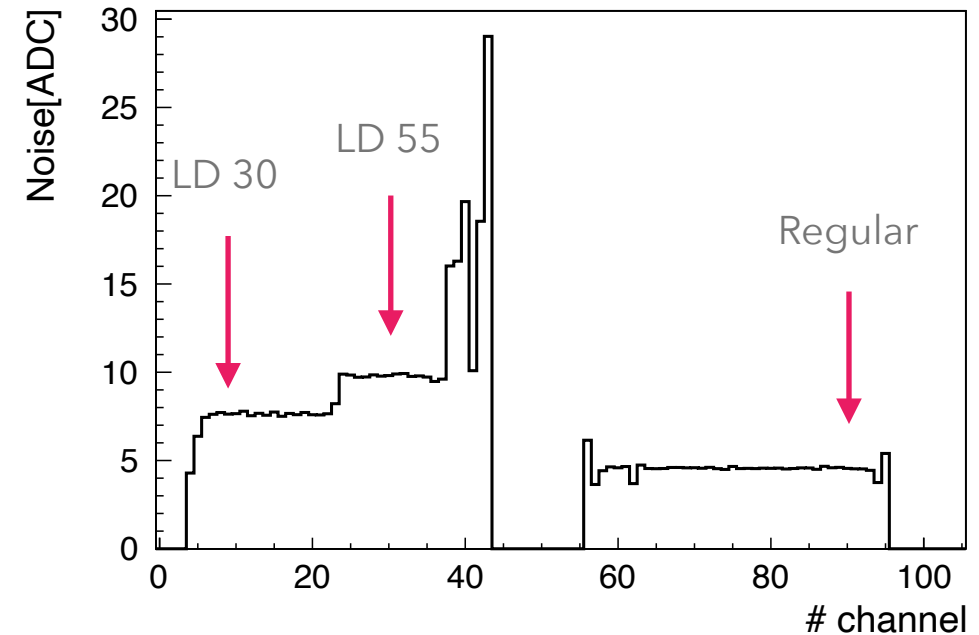
@100V bias, short

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

Average signal pulse shape



Sensor noise per r/o channel



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>

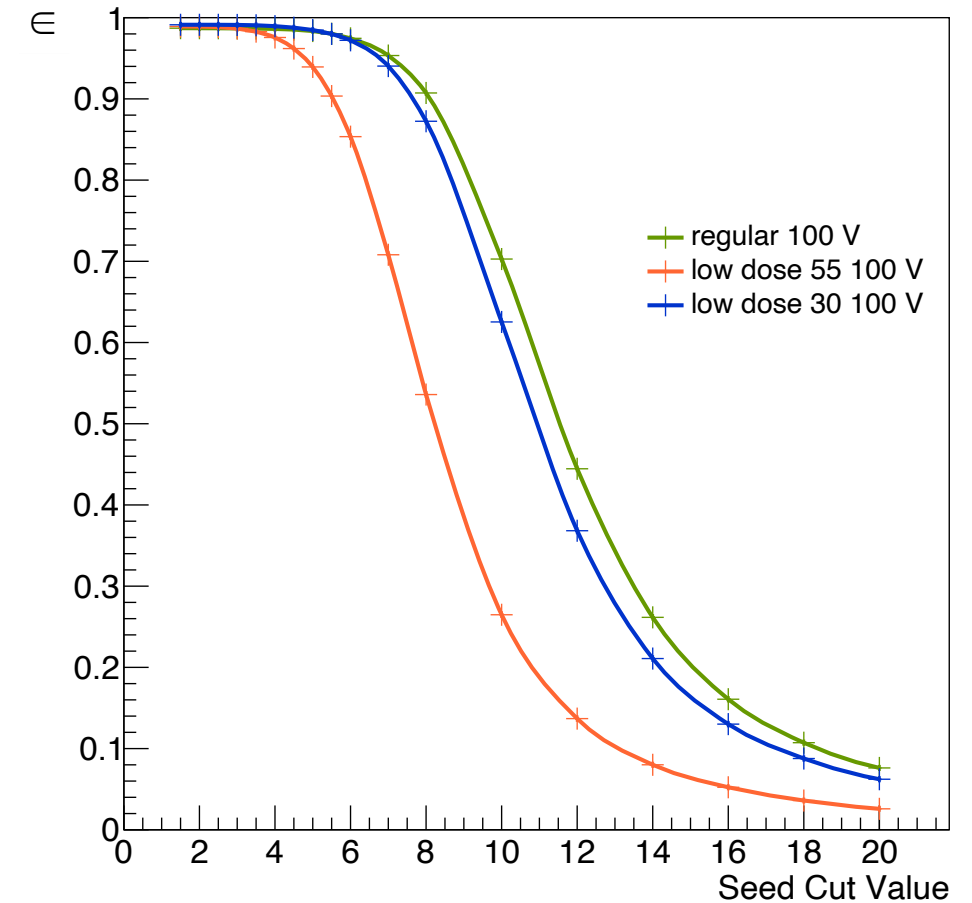
Total Hit Detection Efficiency

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

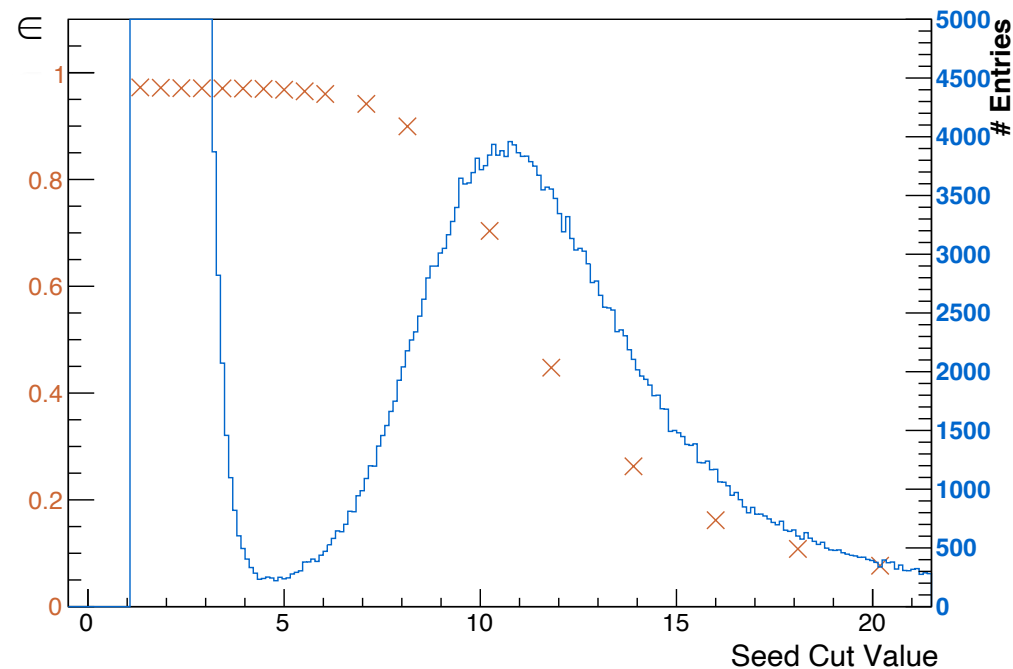
Signal distribution of an unirradiated sample

Unirradiated Sample

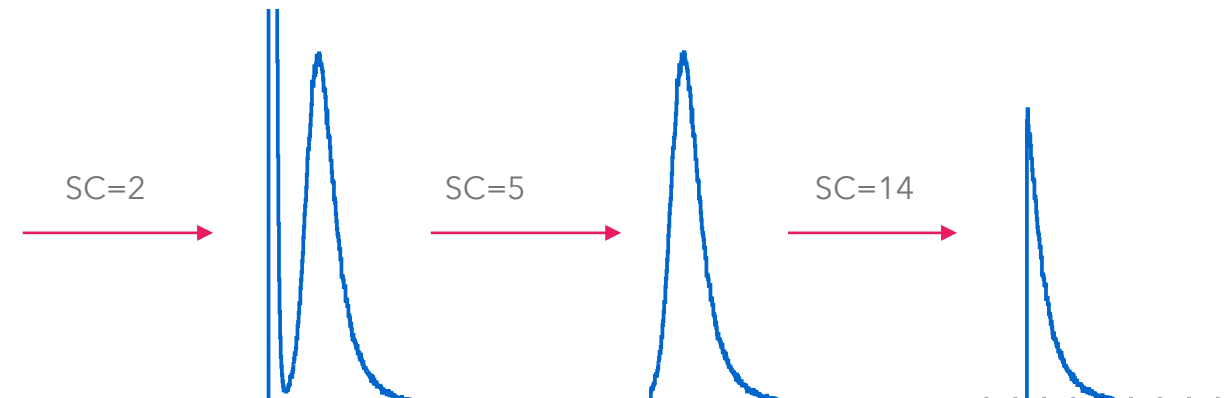
@100V bias, short

- Efficiency decline with threshold cuts within the signal distribution

SNR-distribution (Regular)



Applying Seed Cuts on the SNR-distribution



Global Hit Detection Efficiency

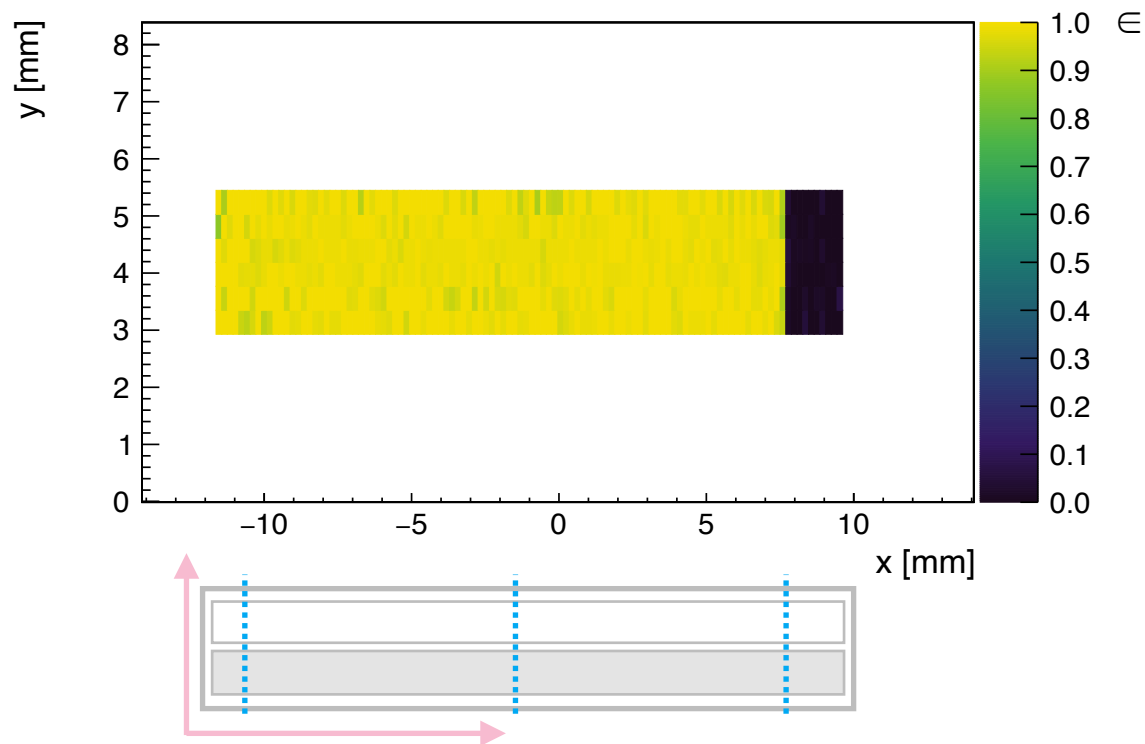
Efficiency along the Regular design in the bond-pad region @SC=3

Unirradiated Sample

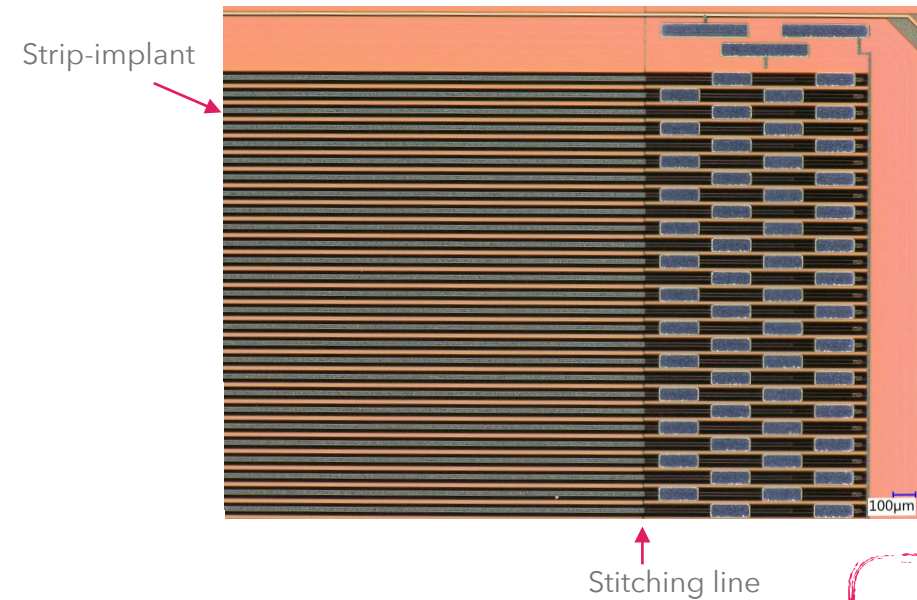
@100V bias, short

- 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

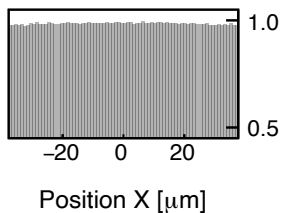
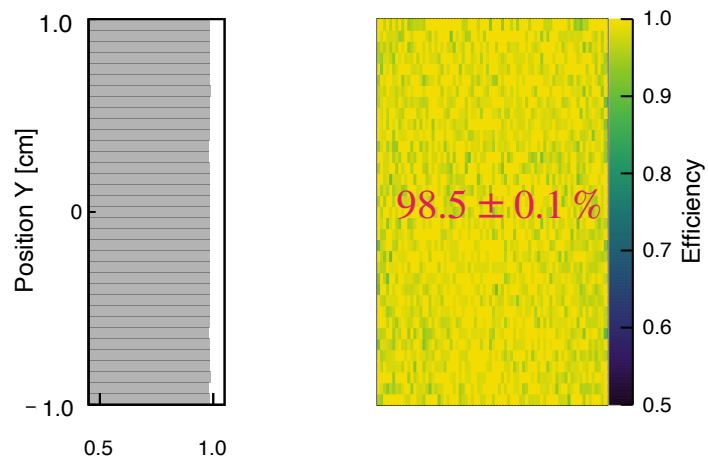
Efficiency within the strip of an unirradiated sample @SC=3

Unirradiated Sample

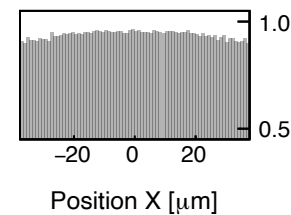
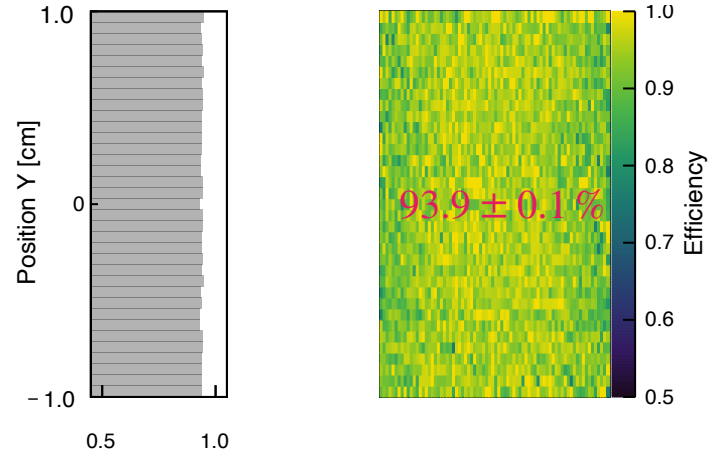
@100V bias, short

- Homogeneous distribution along strip length

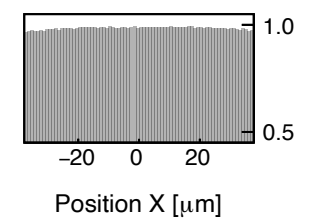
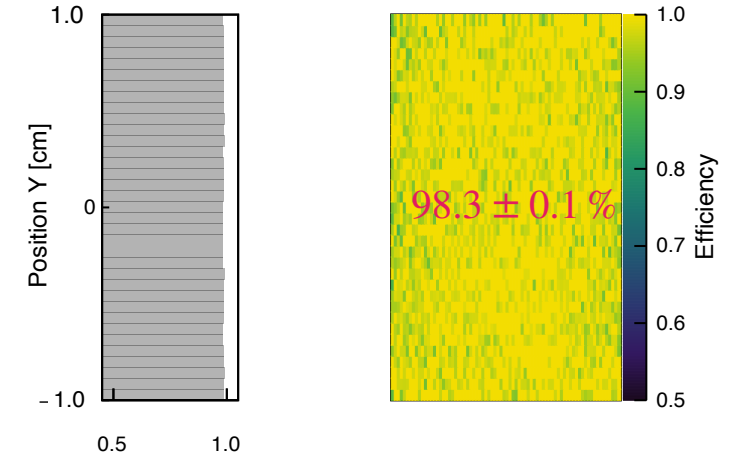
Regular



Low Dose 55



Low Dose 30



In-Strip Hit Detection Efficiency

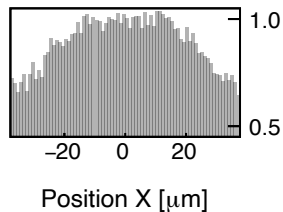
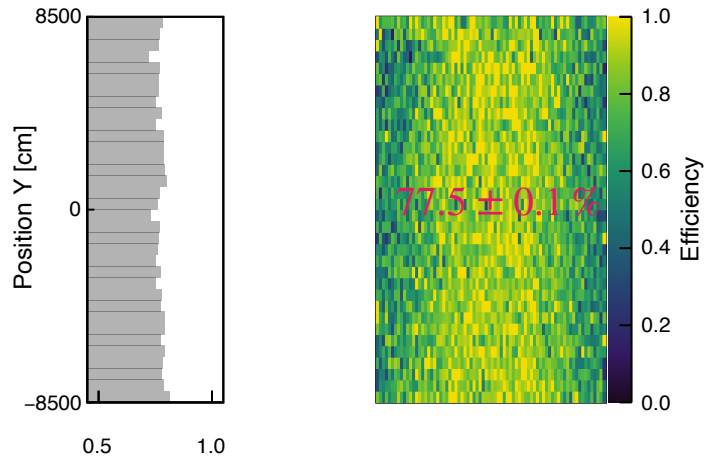
Efficiency within the strip of an irradiated sample @SC=3

Irradiation with reactor
neutrons in Ljubljana

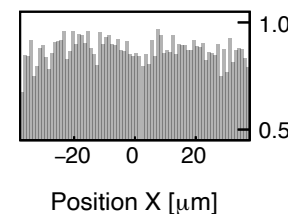
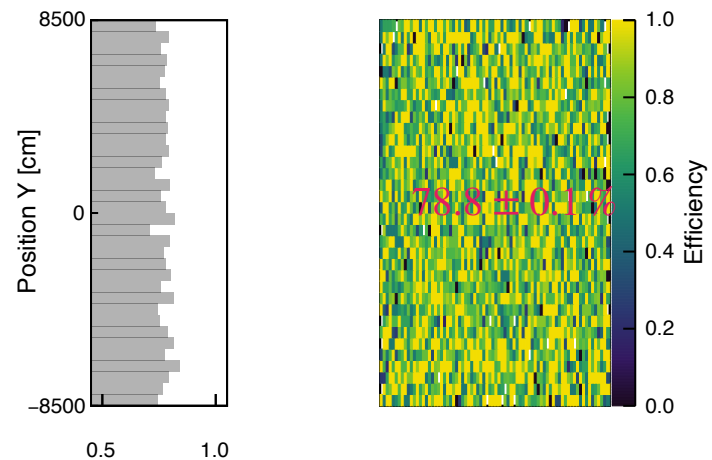
$3e14$ n_{eq}/cm² @250V bias,
long

- Efficiency drop towards inter-strip region for Regular design

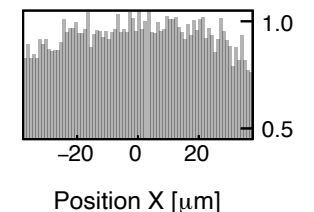
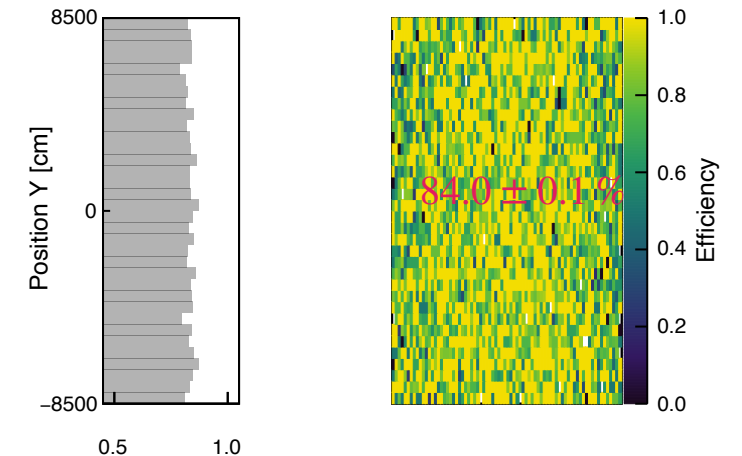
Regular



Low Dose 55



Low Dose 30



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:
 - **Proton** and neutron irradiation, **Bond-pad** region
- TB data comparison with **simulation**
- **Active** sensor submission under discussion

Thank you, Questions?

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Deutsches Elektronen-Synchrotron DESY

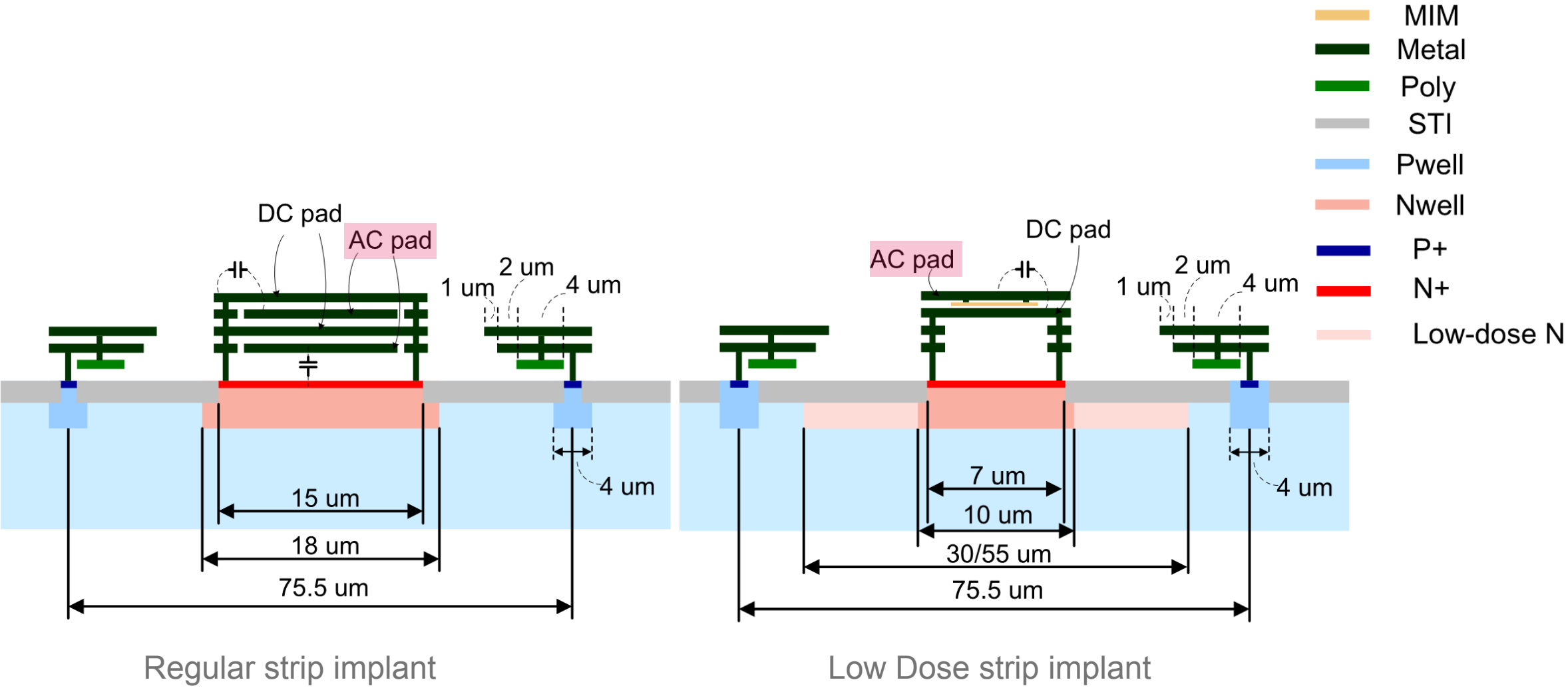
The measurements leading to these results have been performed at the Test Beam Facility at DESY Hamburg (Germany), a member of the Helmholtz Association (HGF)

Authors

Jan-Hendrik Arling, Marta Baselga, Naomi Davis, Leena Diehl,
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Backup

Full Sensor Layout



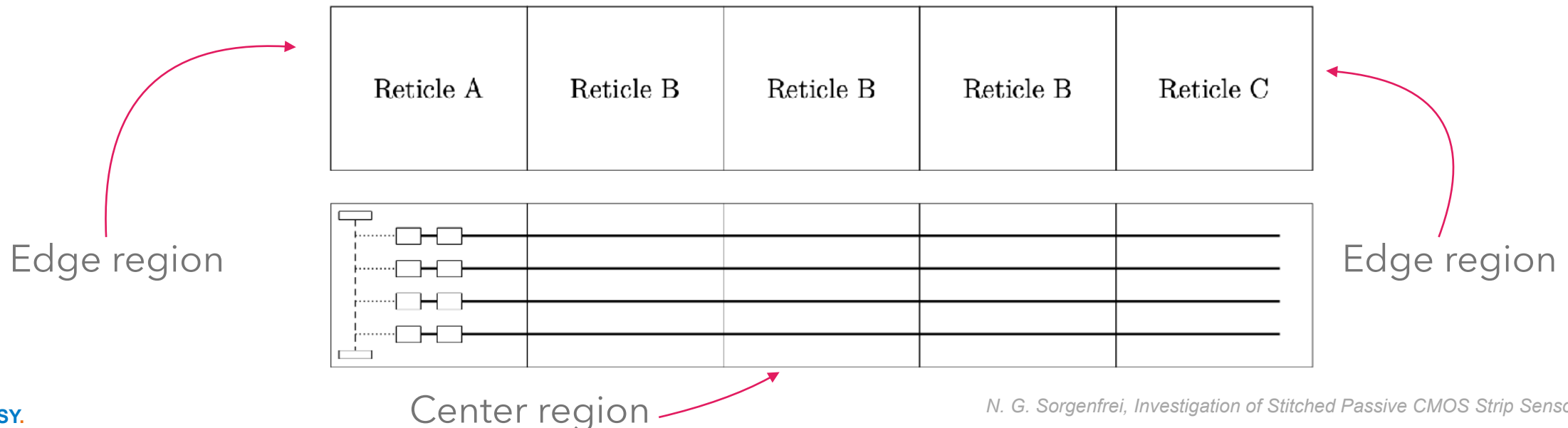
L. Diehl et al., "Characterization of Passive CMOS Strip Sensors", NIMA, Vol 1022 (2022)
<https://doi.org/10.1016/j.nima.2022.166671>

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!

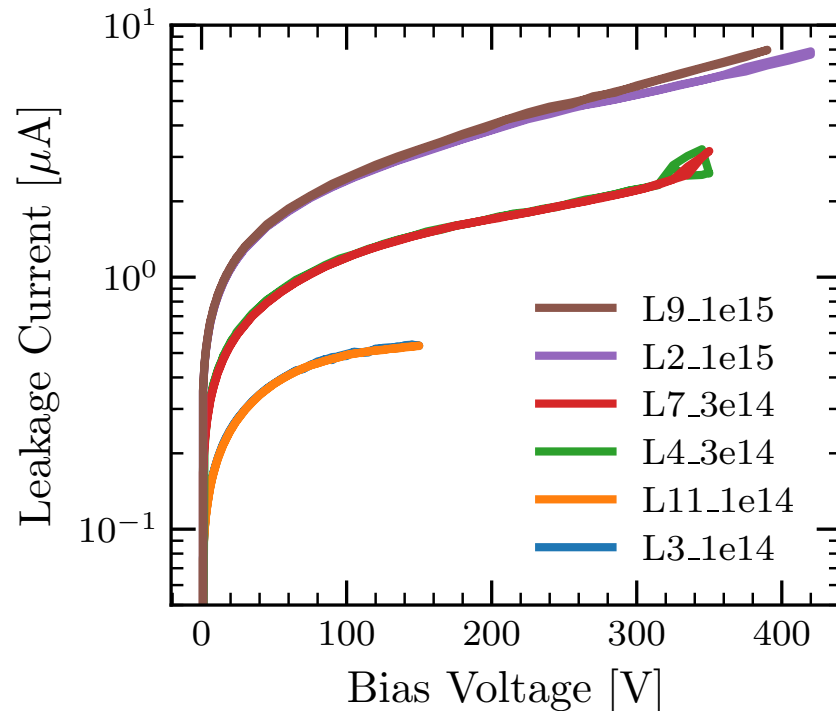


IV-Measurements

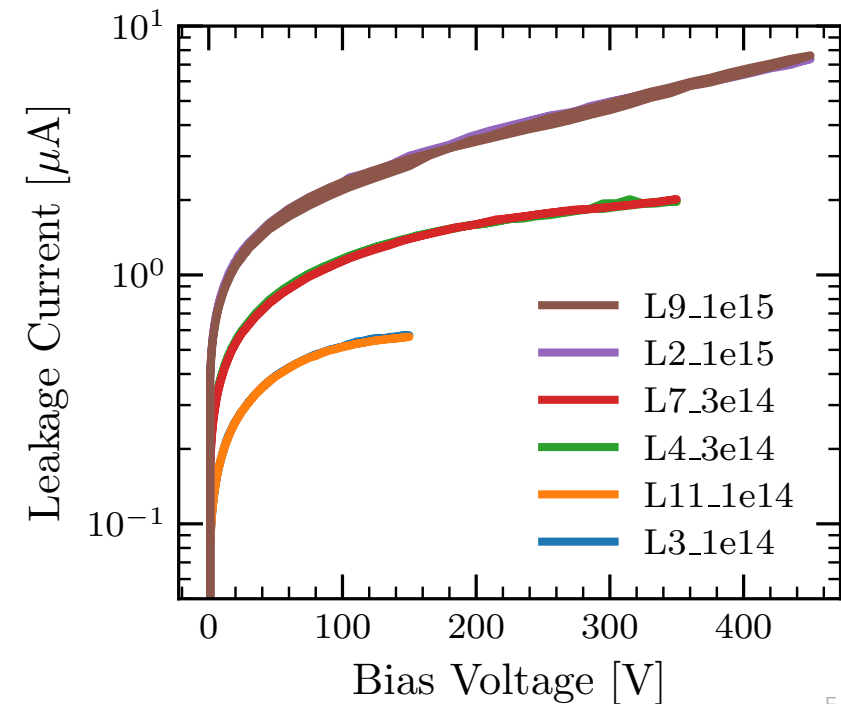
Characterising the sensor

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

Low Dose



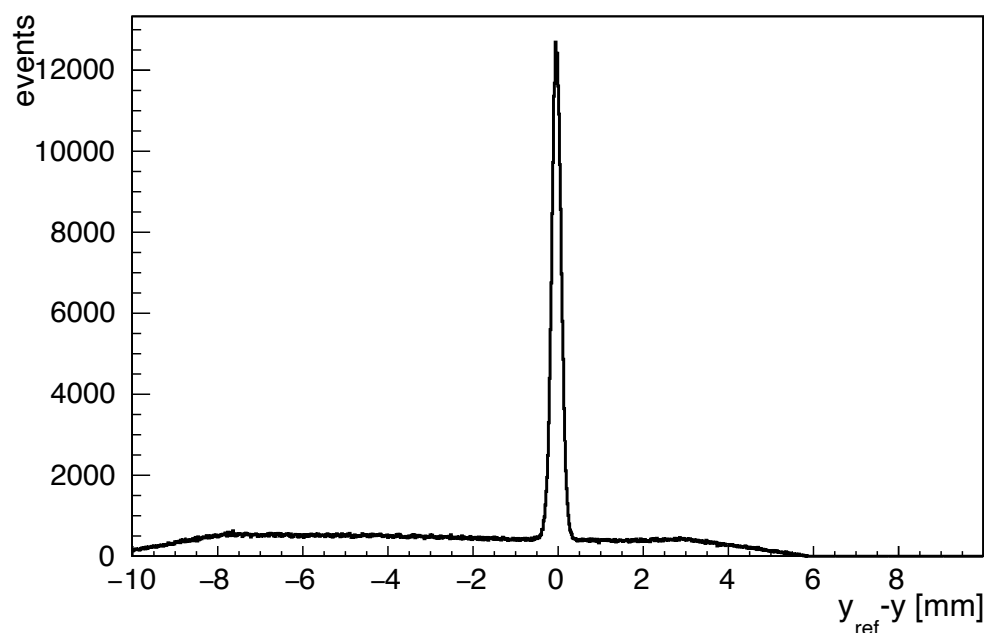
Regular



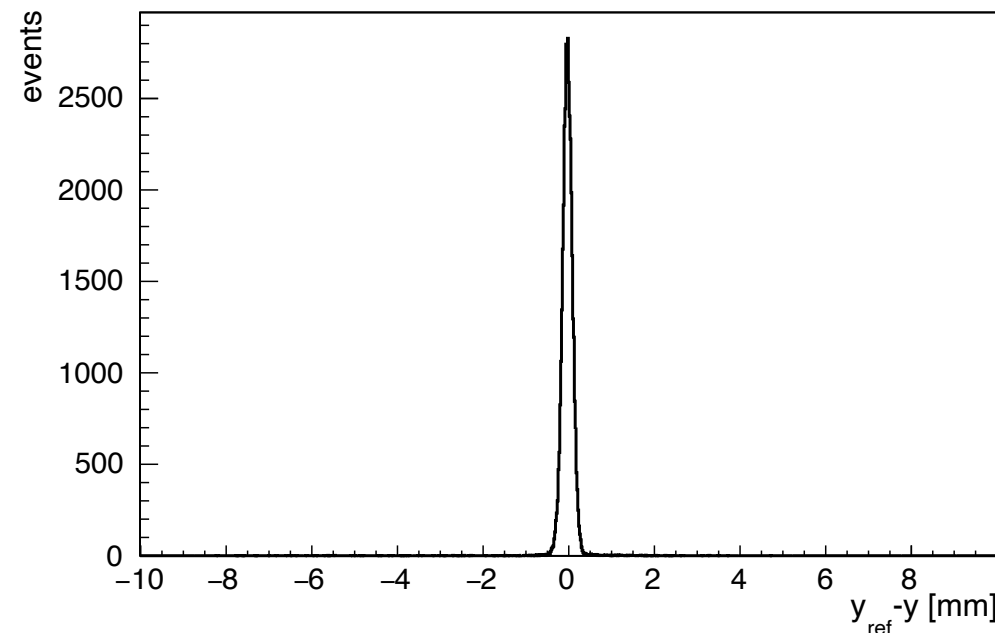
Integration Times

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 μ s)
- **[FilterEvents]** module: restriction to **one cluster per event**



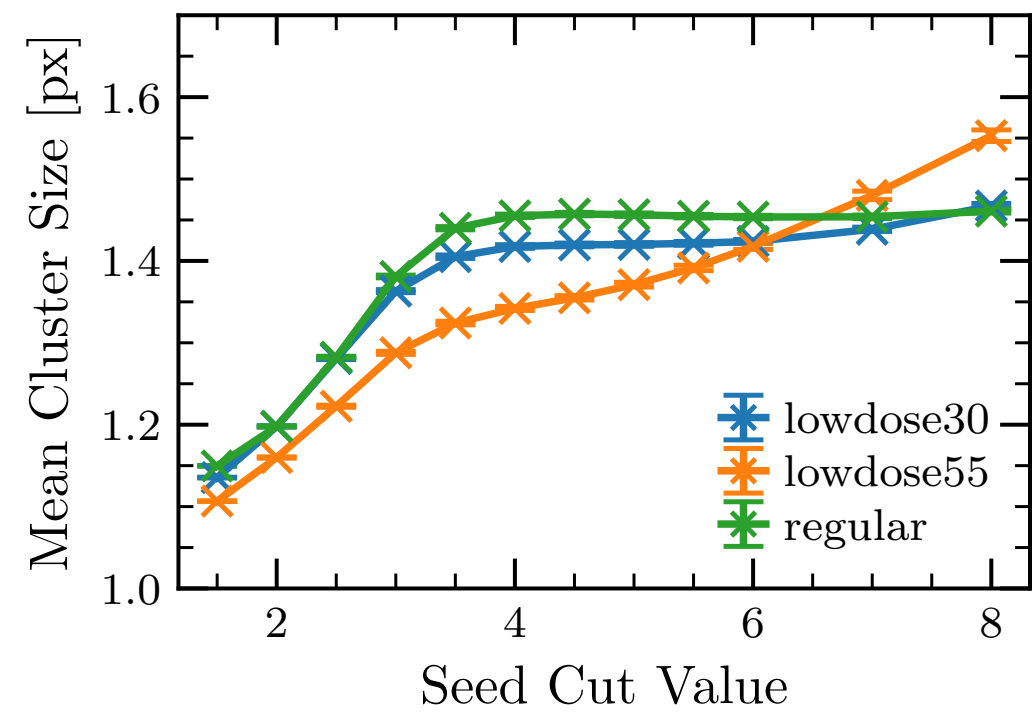
Correlation Y between telescope and DUT



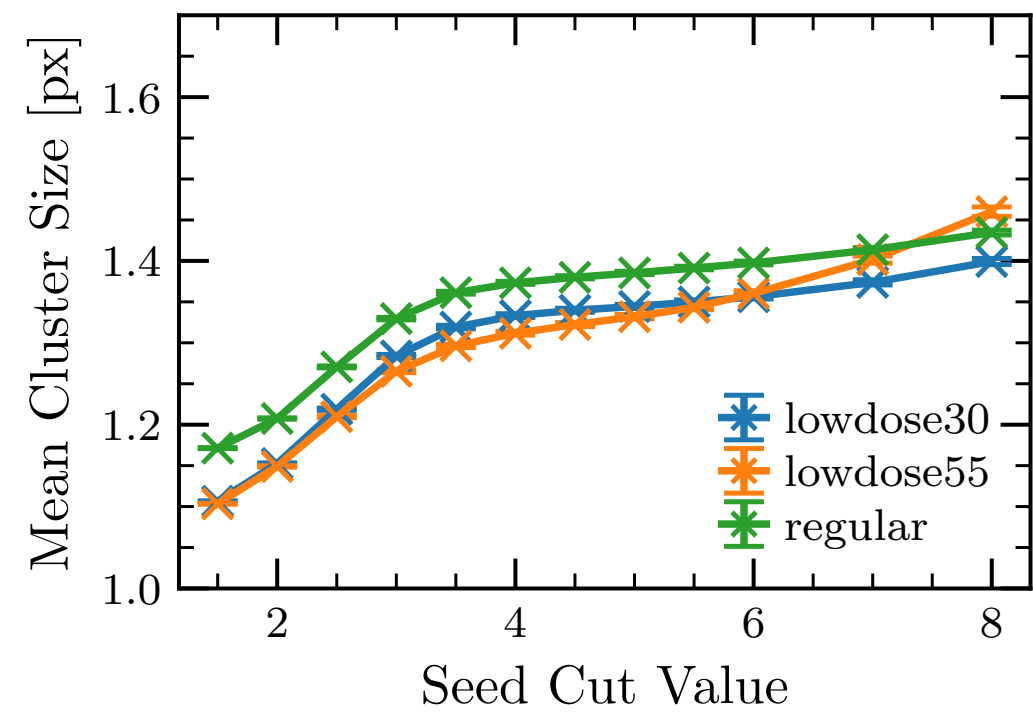
Correlation Y between telescope and DUT (Filter)

Cluster Size

Unirradiated



Irradiated



Fake-Cluster Rate

