Test Beam Characterisation of Passive CMOS Strip Sensors

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11th Beam Telescopes and Test Beams Workshop, Hamburg

April 18th

HELMHOLTZ

Passive CMOS Technology

The need for alternative silicon sensor designs

- Silicon sensors have become indispensable in high energy physics.

- They are…

… main tracking devices

… immense cost-driver

… only available from few foundries

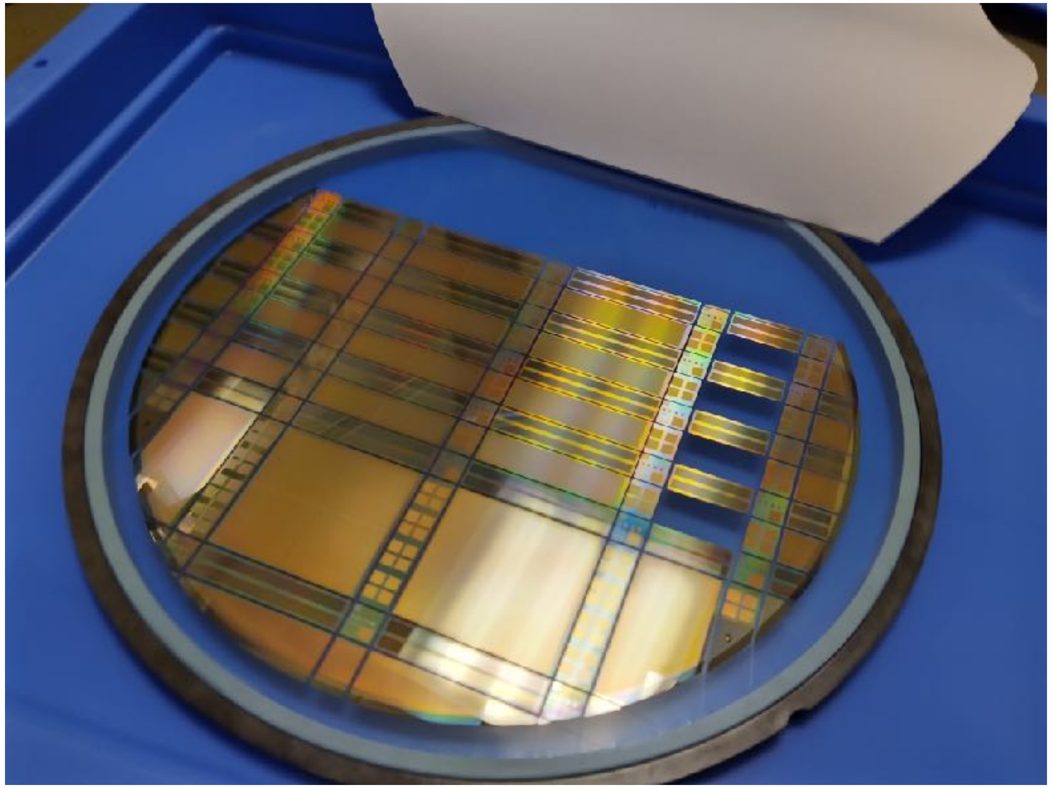
Alternative concepts ?

Alternative vendors ?

Passive CMOS Technology

A promising candidate

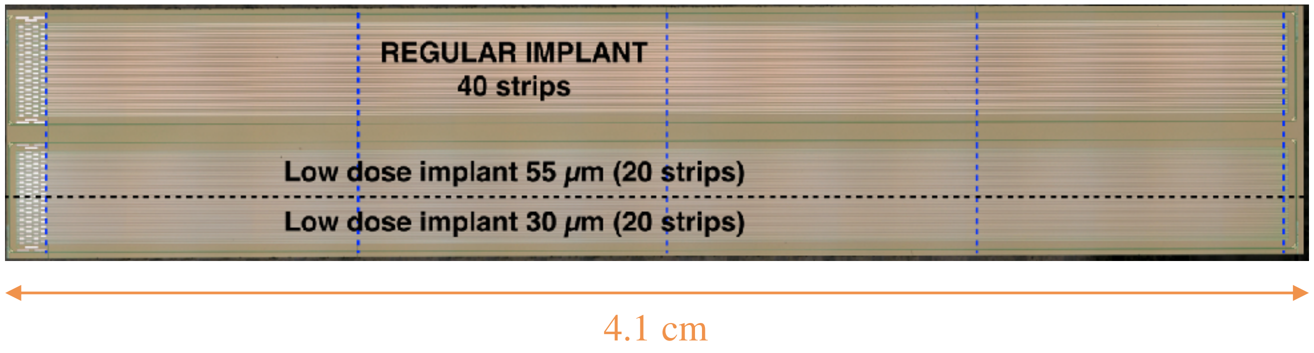
- CMOS imaging process
- Possible cost reduction
- Fast, large-scale production
- Wafer-scale industrial production
- Large vendor choice



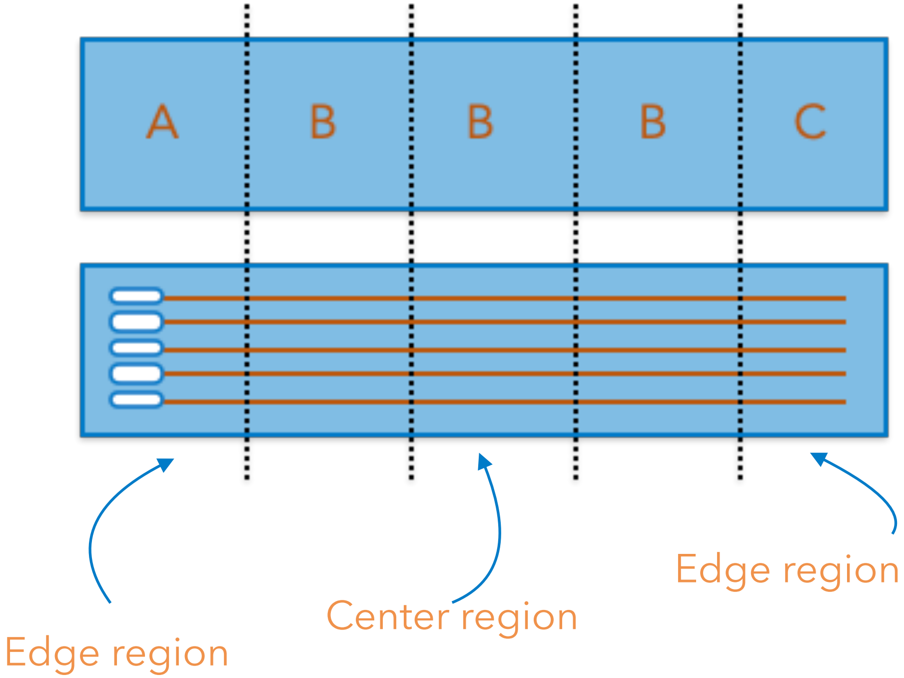
Sensor Design

Stitched strip sensors

- n-in-p sensor in $150\ \mathrm{nm}$ LFoundry technology
- Float-Zone wafer with $3 - 5\ \mathrm{k\Omega \cdot cm}$ resistivity
- $150 \pm 10\ \mathrm{um}$ thickness, $75.5\ \mathrm{um}$ strip pitch
- Connection of neighbouring reticles (Stitching)



Stitching is possible in both dimensions



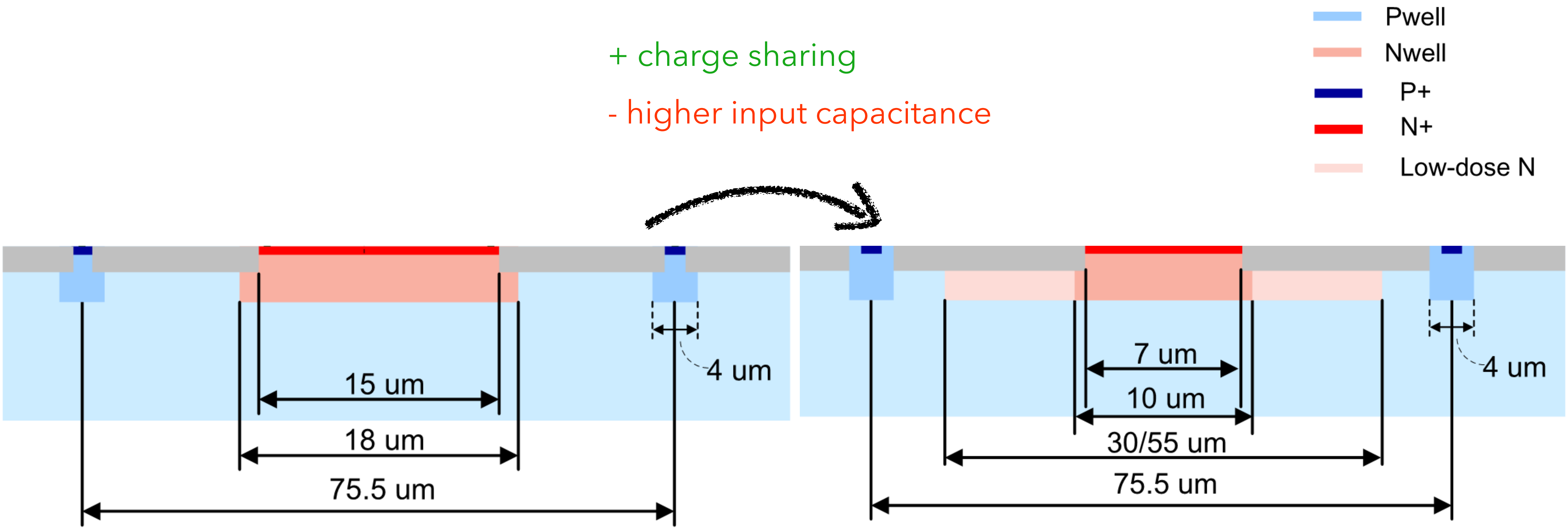
L. Diehl et al., *"Characterization of Passive CMOS Strip Sensors"*, NIMA, Vol 1022 (2022) https://doi.org/10.1016/j.nima.2022.166671

Sensor Design

Varying n-well characteristics

+ charge sharing

- higher input capacitance



Regular implant strip design

Low Dose (LD) implant strip design

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 Setup

Testing the sensor performance

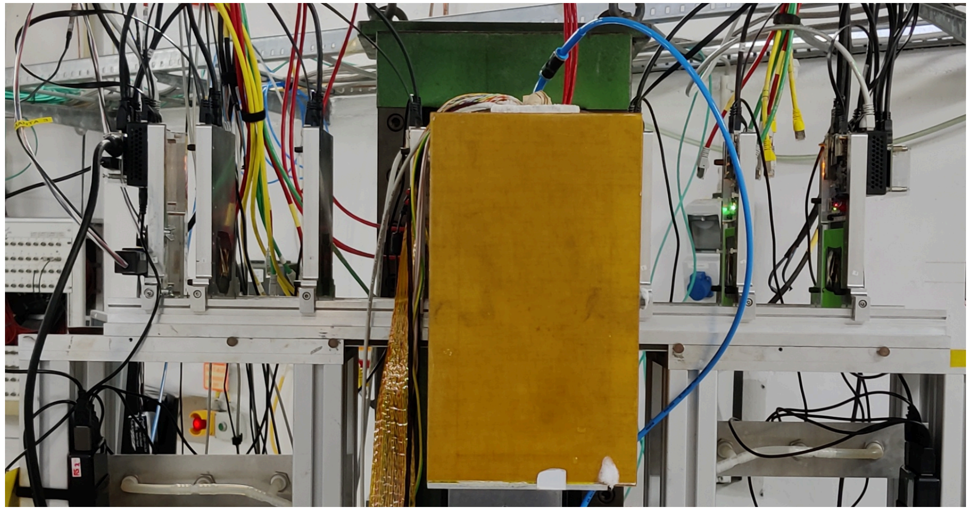
- TB campaigns in Nov21, May22 at DESY-II
- EUDET telescope with 6 ALPIDE planes as reference
- e^- beam energy: $3\ \mathrm{GeV}$, $3.4\ \mathrm{GeV}$
- Styrofoam cold box, cooling with dry ice

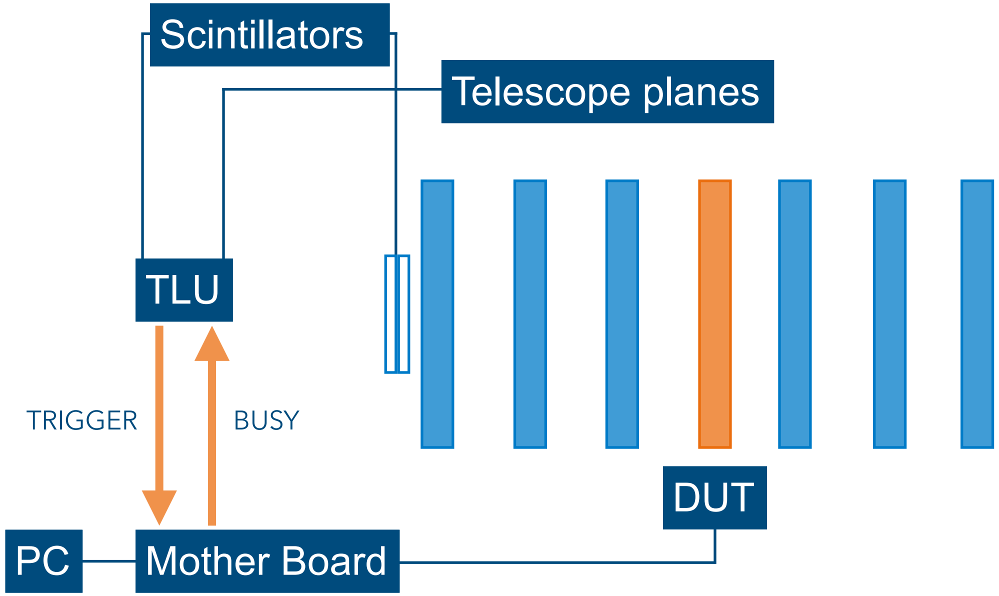
NOV21:
Unirradiated,

@100V bias, short

MAY22:
Irradiation with reactor neutrons in **Ljubljana**

3e14 @250V bias, short





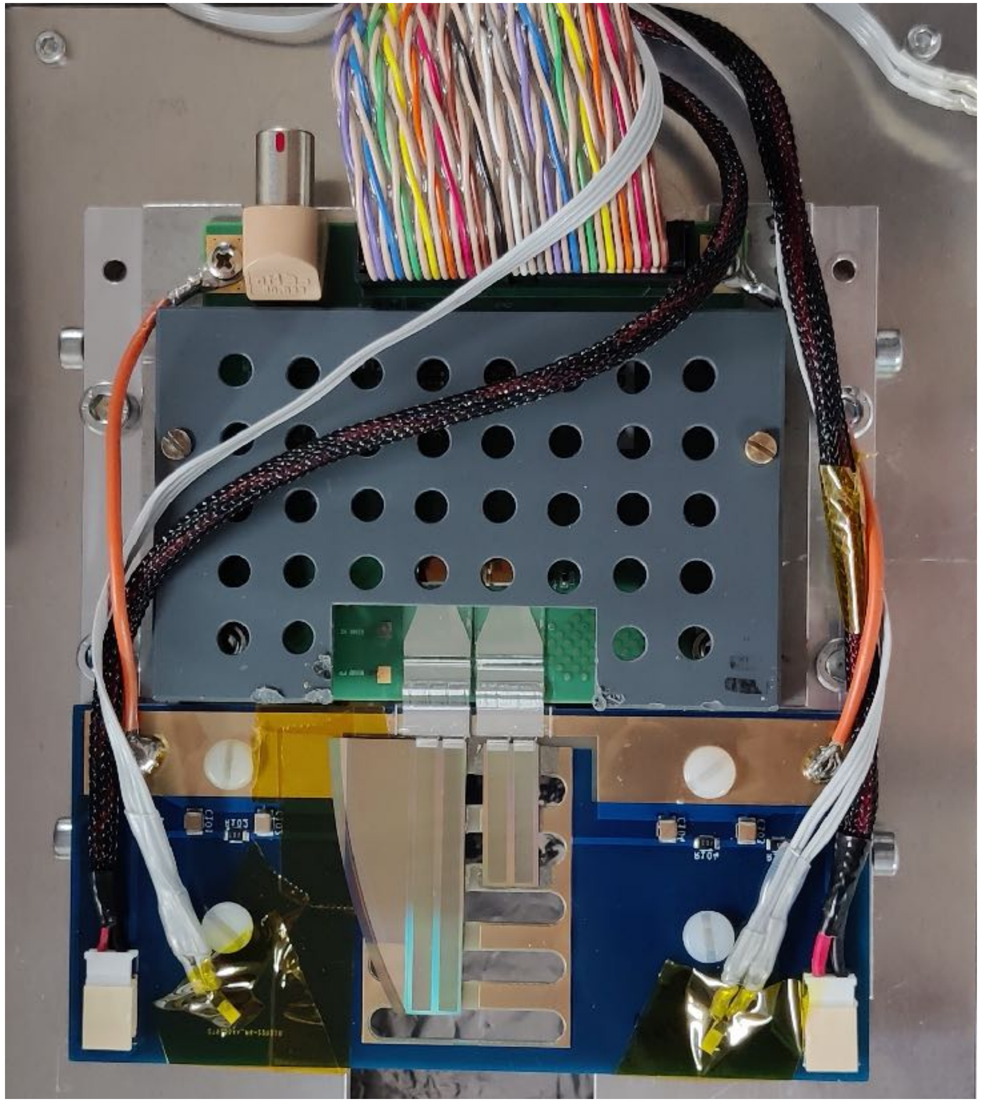
J. Dreyling-Eschweiler et al., *"The DESY II test beam facility"*, NIMA, Vol 922 (2019)
https://doi.org/10.1016/j.nima.2018.11.133
H. Jansen et al., *"Performance of the EUDET-type beam telescopes"*, EPJ Techn Instrum 3, 7 (2016)
https://doi.org/10.1140/epjti/s40485-016-0033-2

ALiBaVa Readout System

ALiBaVa Daughterboard

- ALiBaVa readout system for DUT data acquisition
- 128-channel Beetle Chip
- Reconstruction and Analysis with Corryvreckan
- [EventLoaderALiBaVa] for DUT

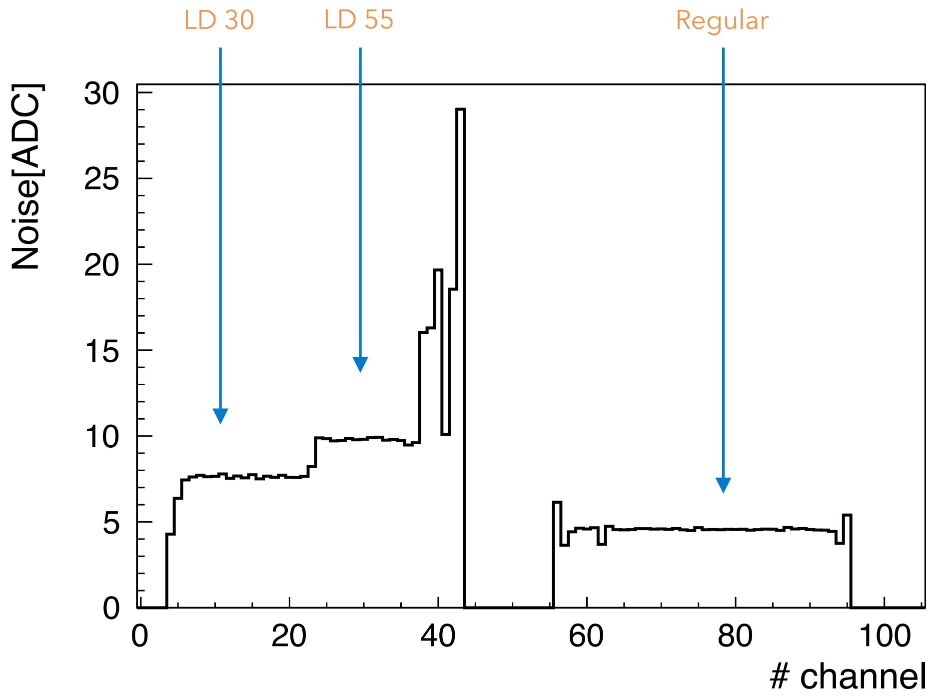
ALiBaVa Daughterboard



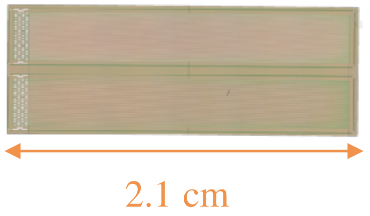
D. Dannheim et al., *"Corryvreckan: a modular 4D track reconstruction and analysis software for test beam data"*, J. Instr. 16 (2021) https://doi.org/10.1088/1748-0221/16/03/P03008
R. Marco-Hernandez et al., *"ALIBAVA: A portable readout system for silicon microstrip sensors"*, NIMA, Vol 623 (2010) https://doi.org/10.1016/j.nima.2010.02.197

ALiBaVa Readout System

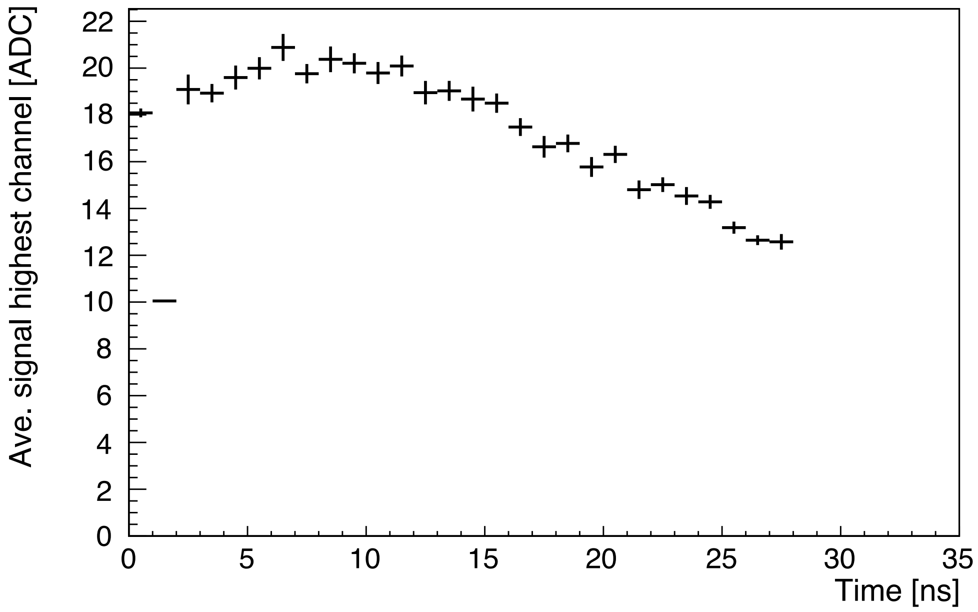
EventLoaderALiBaVa



Sensor noise per beetle chip channel



NOV21:
Unirradiated,
@100V bias, short



Average signal pulse waveform

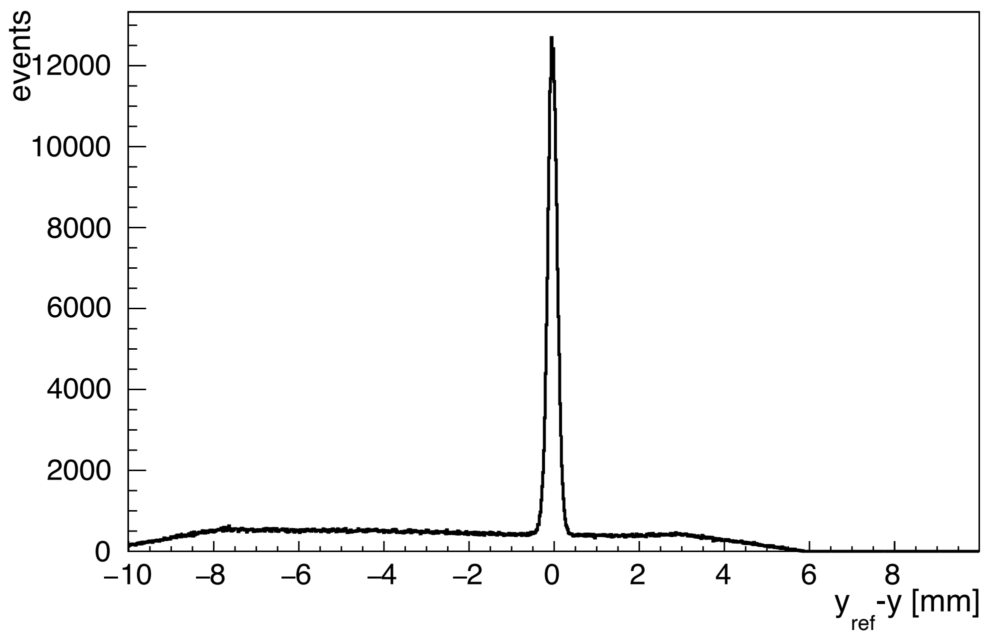
Correlations

Beam particle track rate

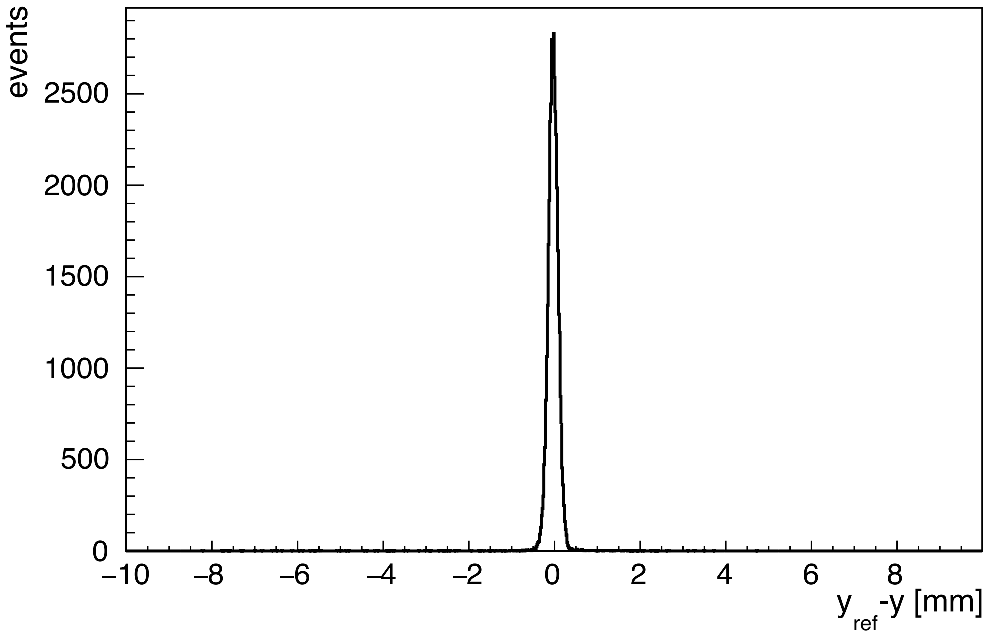
- High particle track rate in TB Nov 21 and May 22
- Issue: different integration times of DUT and telescope (~75 ns vs ~30 us)
- `[FilterEvents]` module: restriction to one cluster per event

Additional timing plane in TB March 23

NOV21: Unirradiated, @100V bias, short



Correlation Y between telescope and DUT



Correlation Y between telescope and DUT (Filter)

In-Strip Efficiency

Efficiency within the strip of an unirradiated sample

$\epsilon_{reg} > \epsilon_{ld30} > \epsilon_{ld55}$

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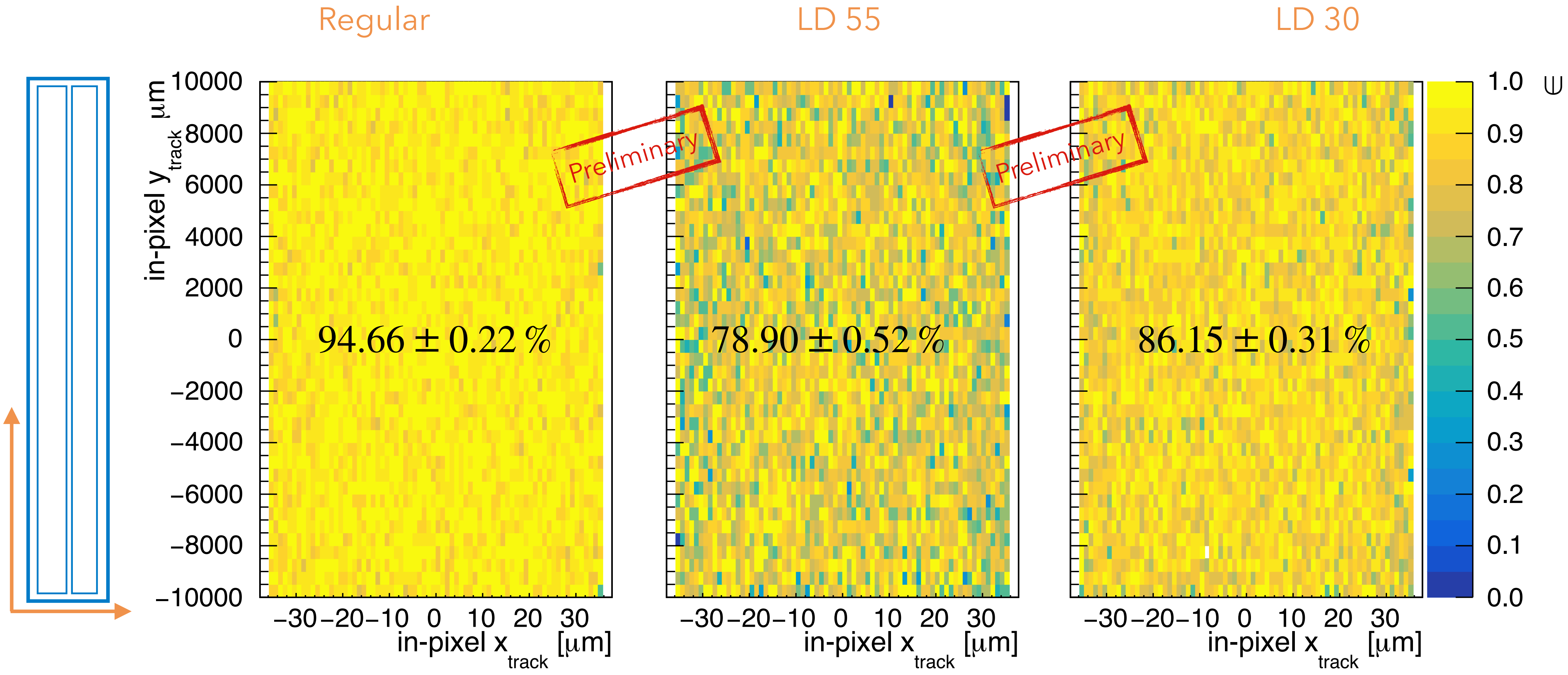

In-Strip Efficiency

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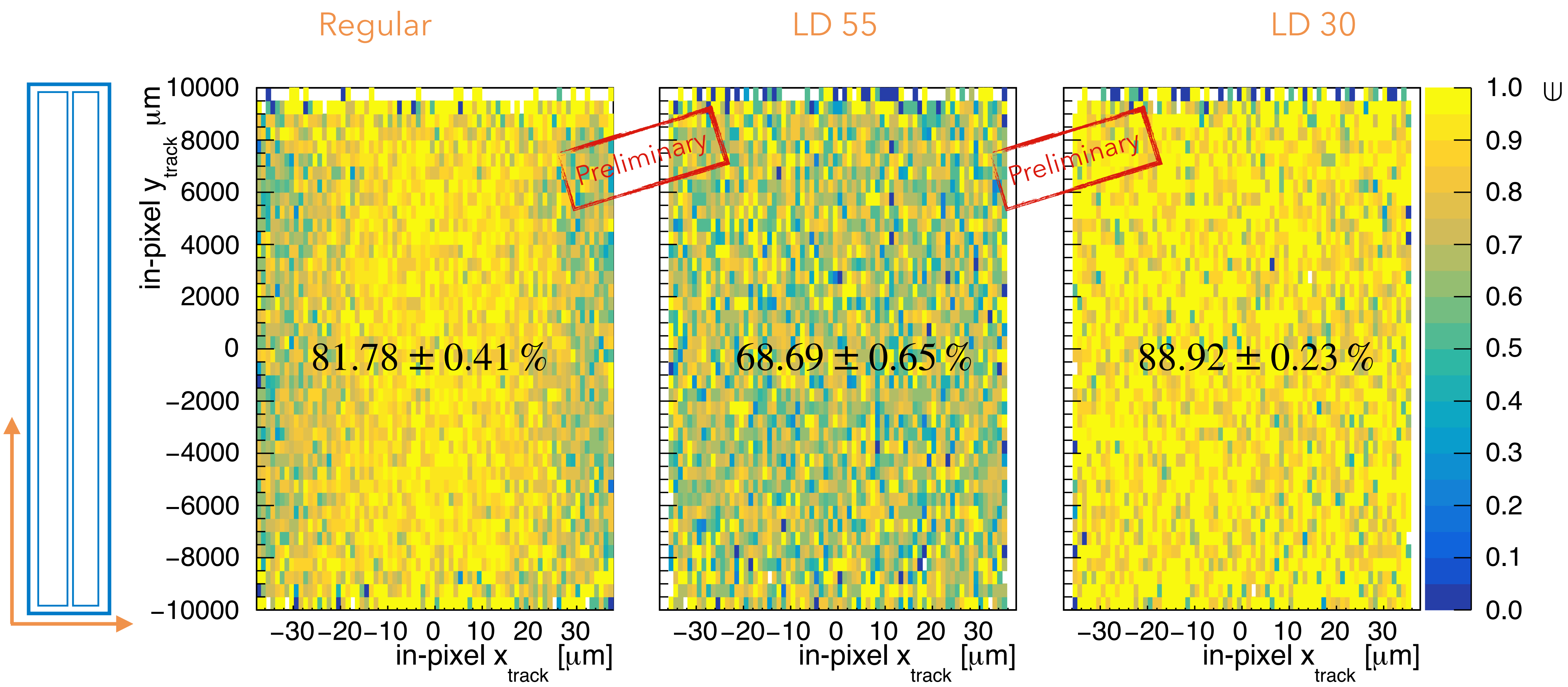

Global Efficiency

Efficiency in the bond pad region

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Unirradiated,

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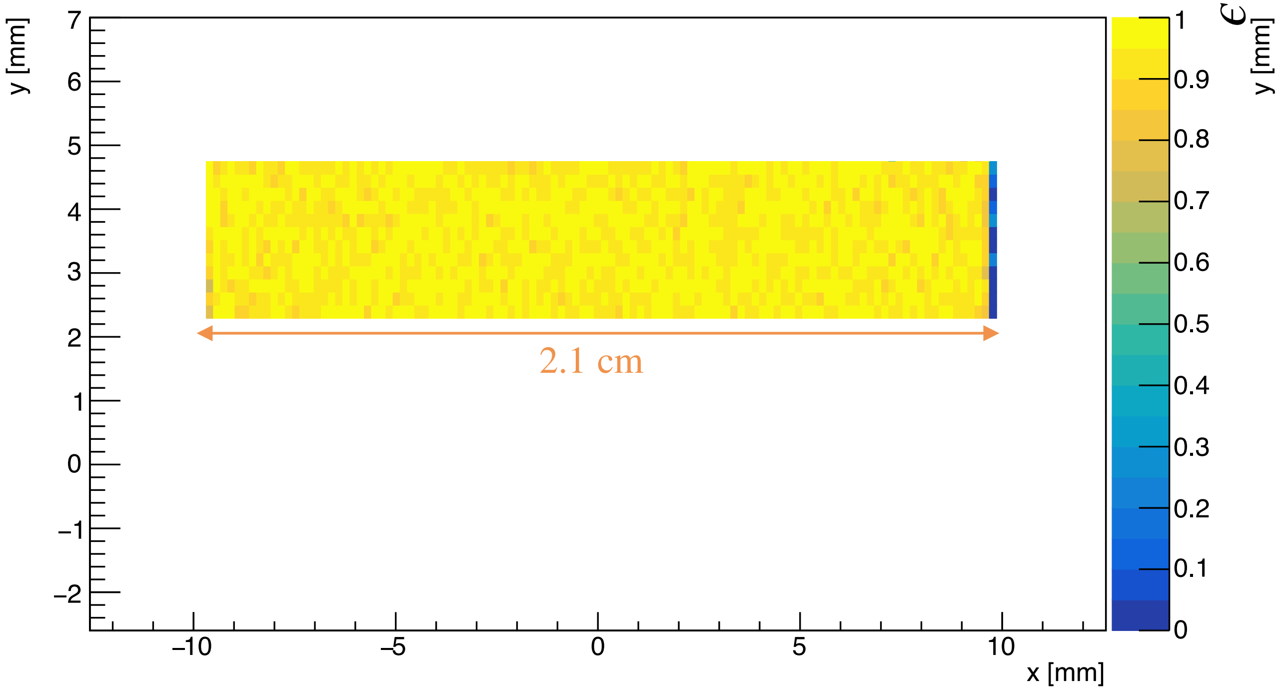
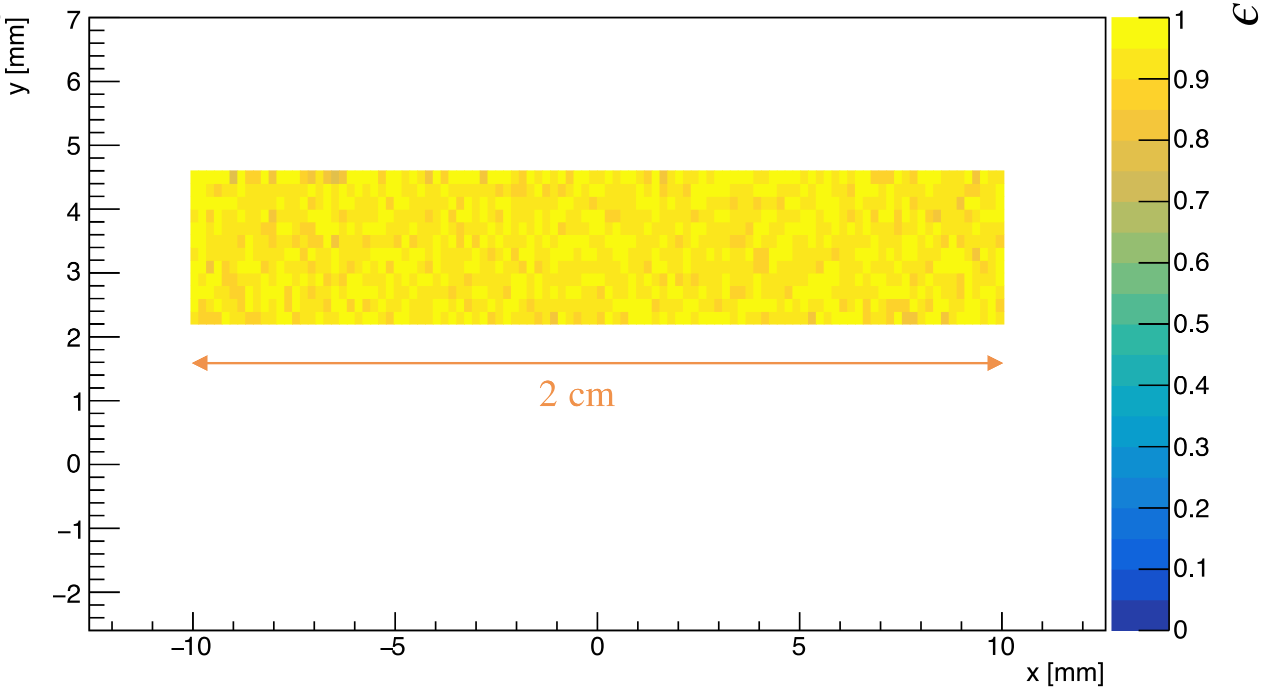


Strip length including bond pad region (regular)



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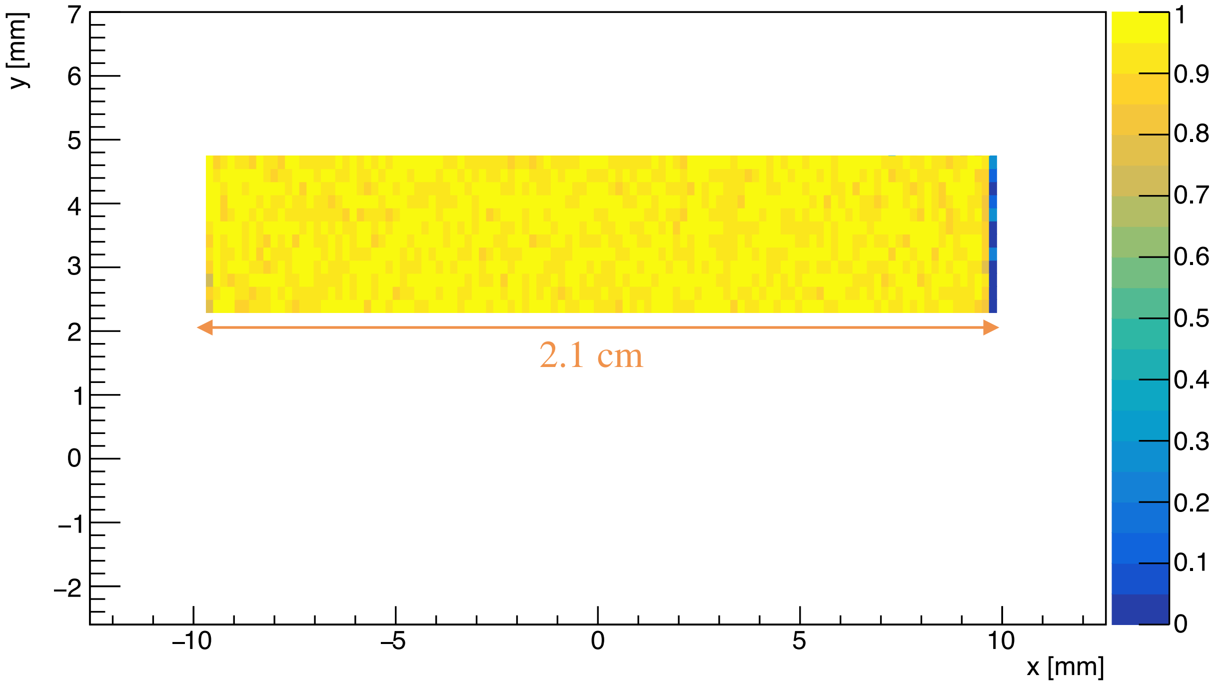
Global Efficiency

Efficiency in the bond pad region

Focus on Bond pad region in TB March 23



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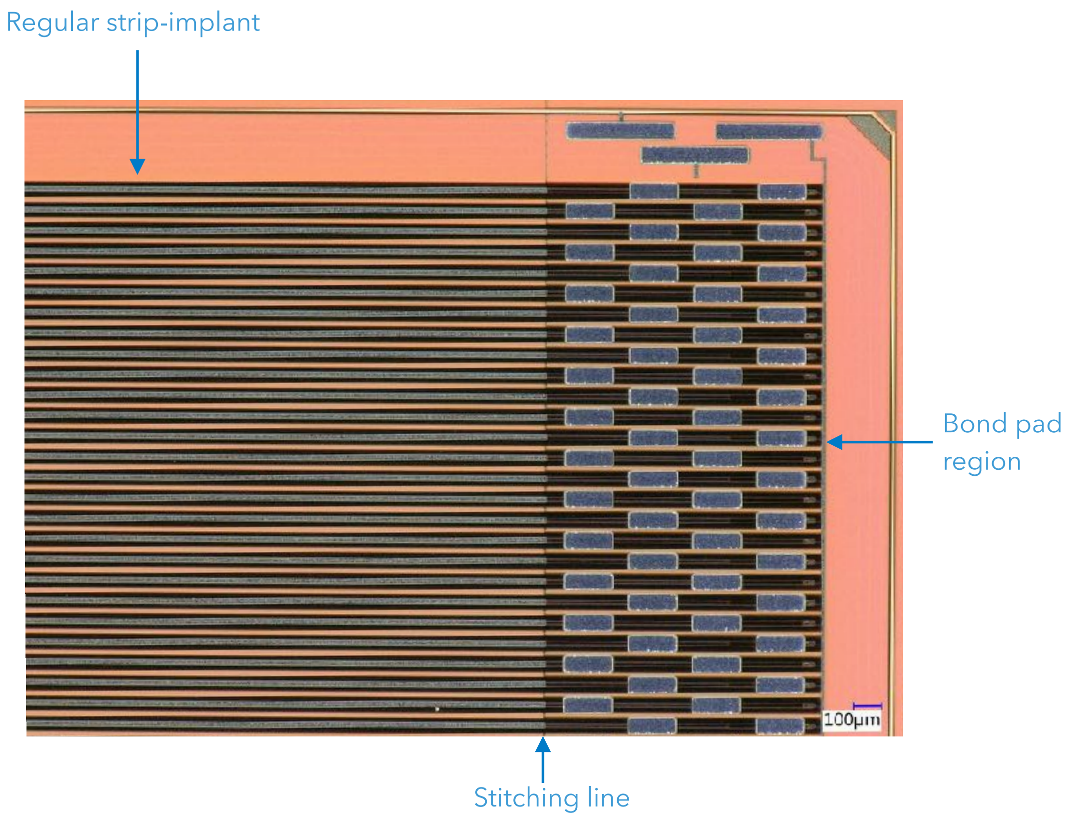

Microscopic picture of regular strip implants

Summary & Outlook

What we have learned and what's next …

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

- Analysis of Mar23 TB campaign to verify results
  - high statistic runs, timing plane, bond pad region
- New sensor submission in discussion

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Deutsches Elektronen-Synchrotron DESY

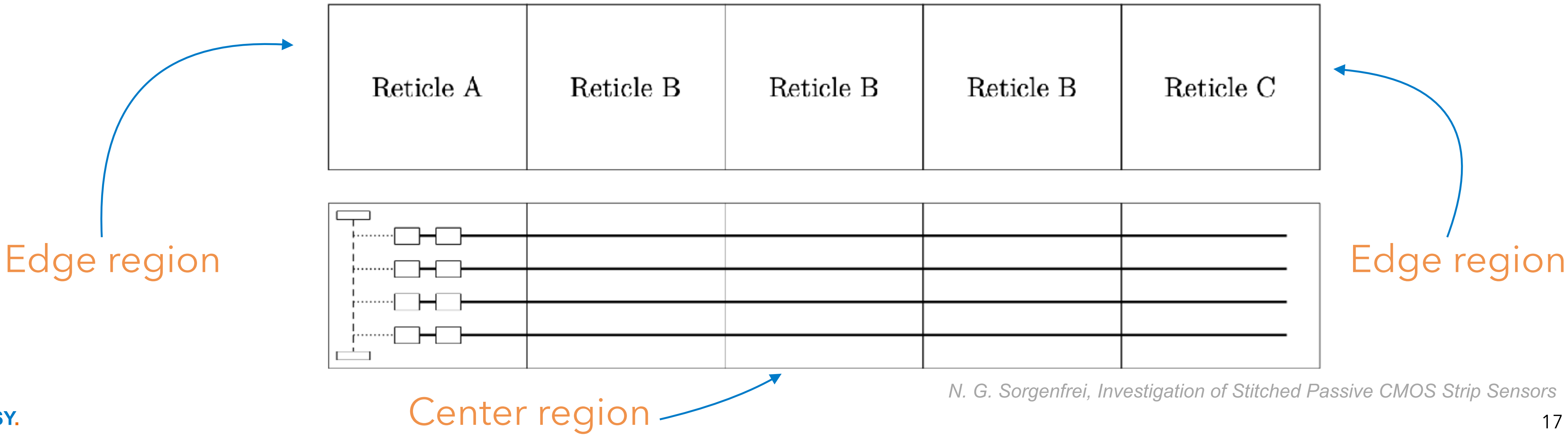
Backup

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