Test Beam Characterisation of stitched CMOS Strip Sensors

Naomi Davis on behalf of the CMOS Strips Collaboration

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Fachhochschule Dortmund
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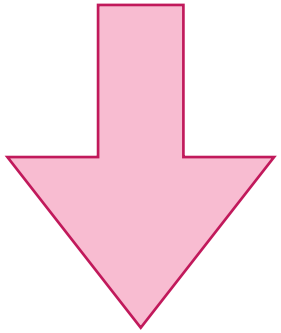
UNIVERSITÄT BONN
DESY.

Single-Vendor Problem

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

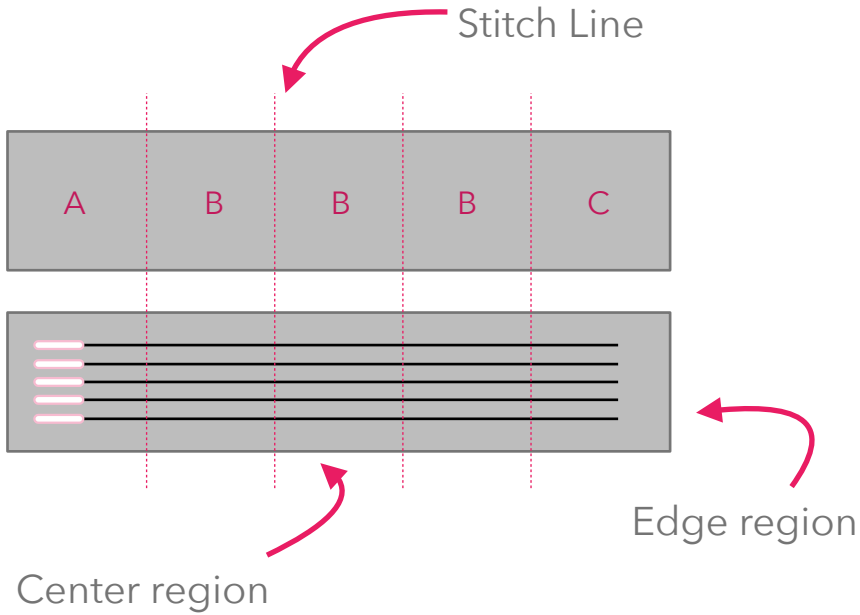


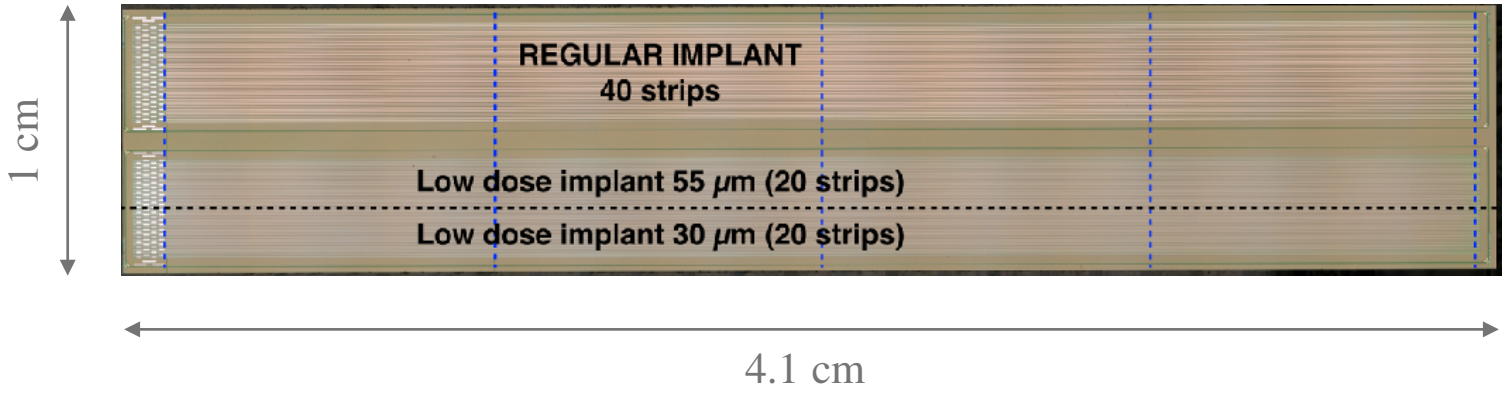
Alternative vendors ?

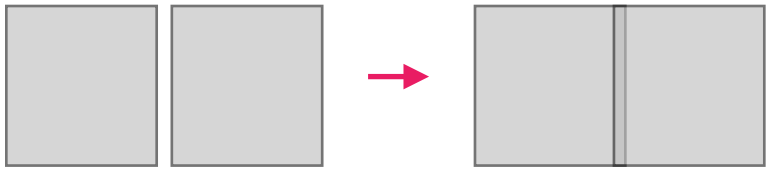
- Vendor diversification through standardised industrial CMOS process
- Fast, cheap and large-scale production

CMOS Strip Sensors

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





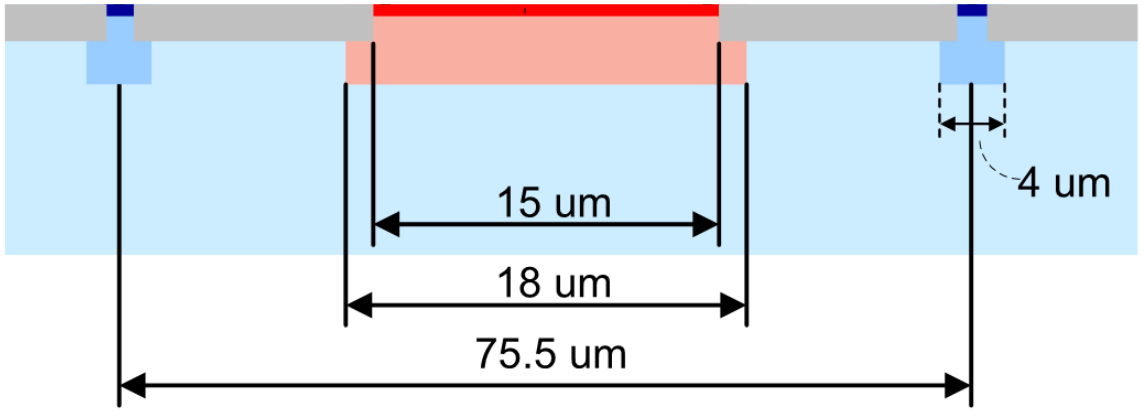


L. Diehl et al., NIMA, Vol 1022 (2022), https://doi.org/10.1016/j.nima.2022.166671

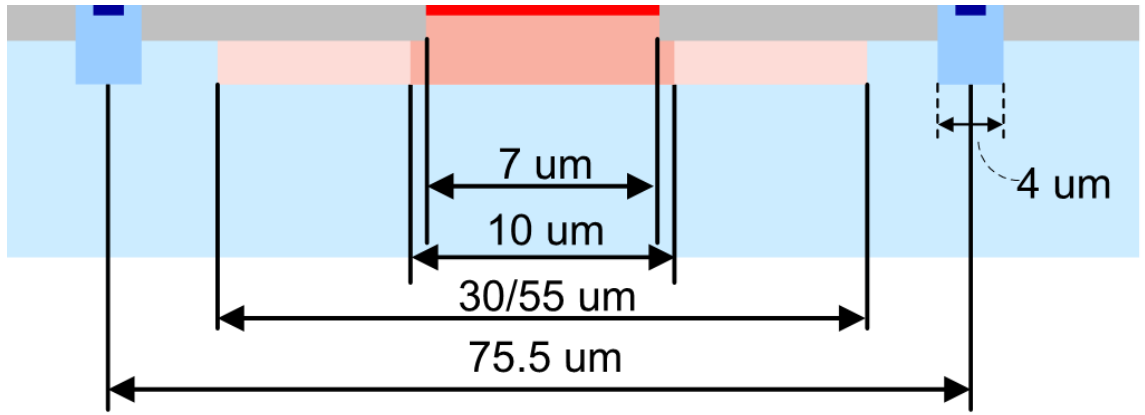
CMOS Strip Sensors

- Strip-implant varies in width and doping concentration

Regular strip implant



Low Dose (LD) 30/55 strip implant



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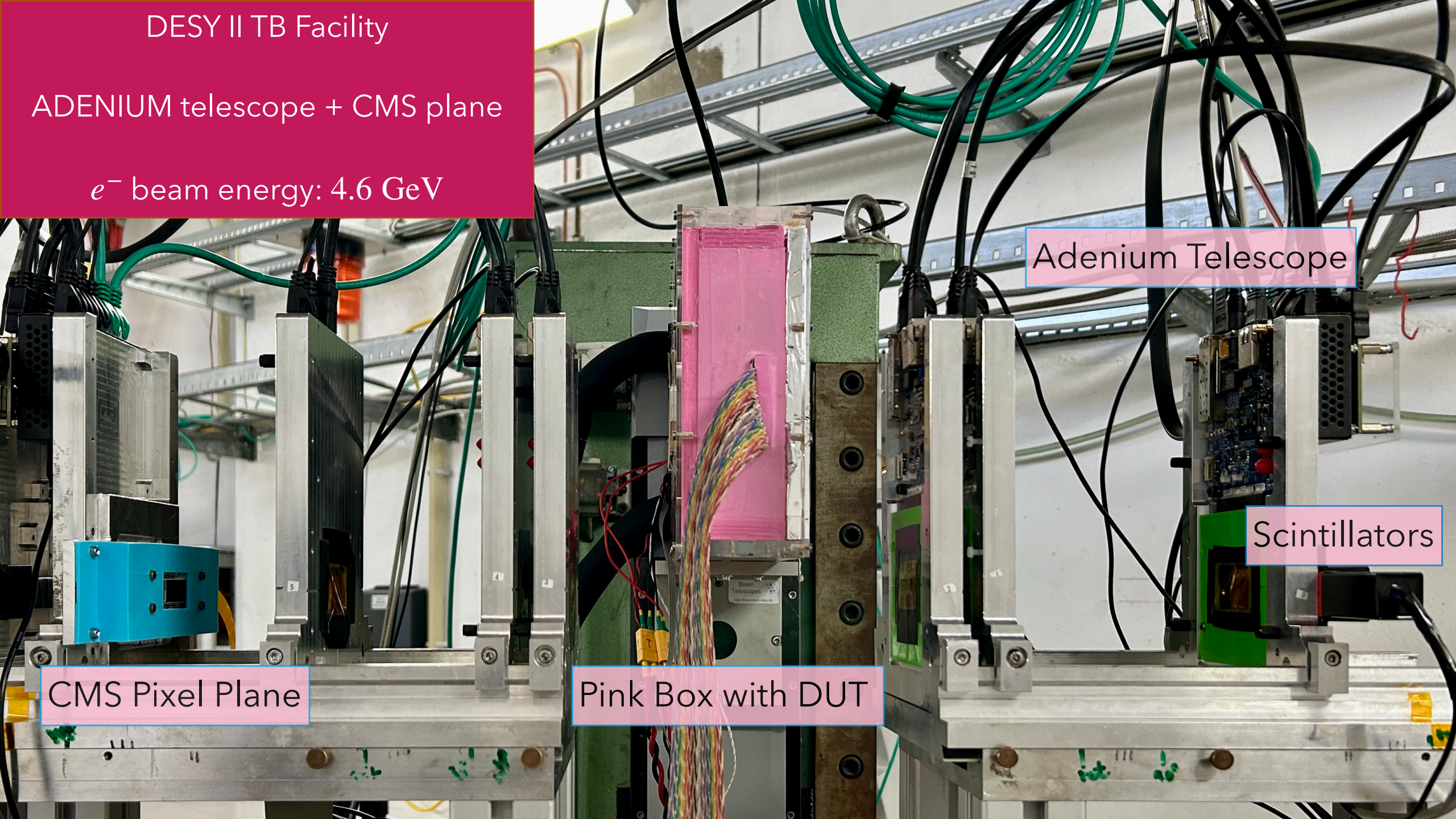
DESY II TB Facility

ADENIUM telescope + CMS plane

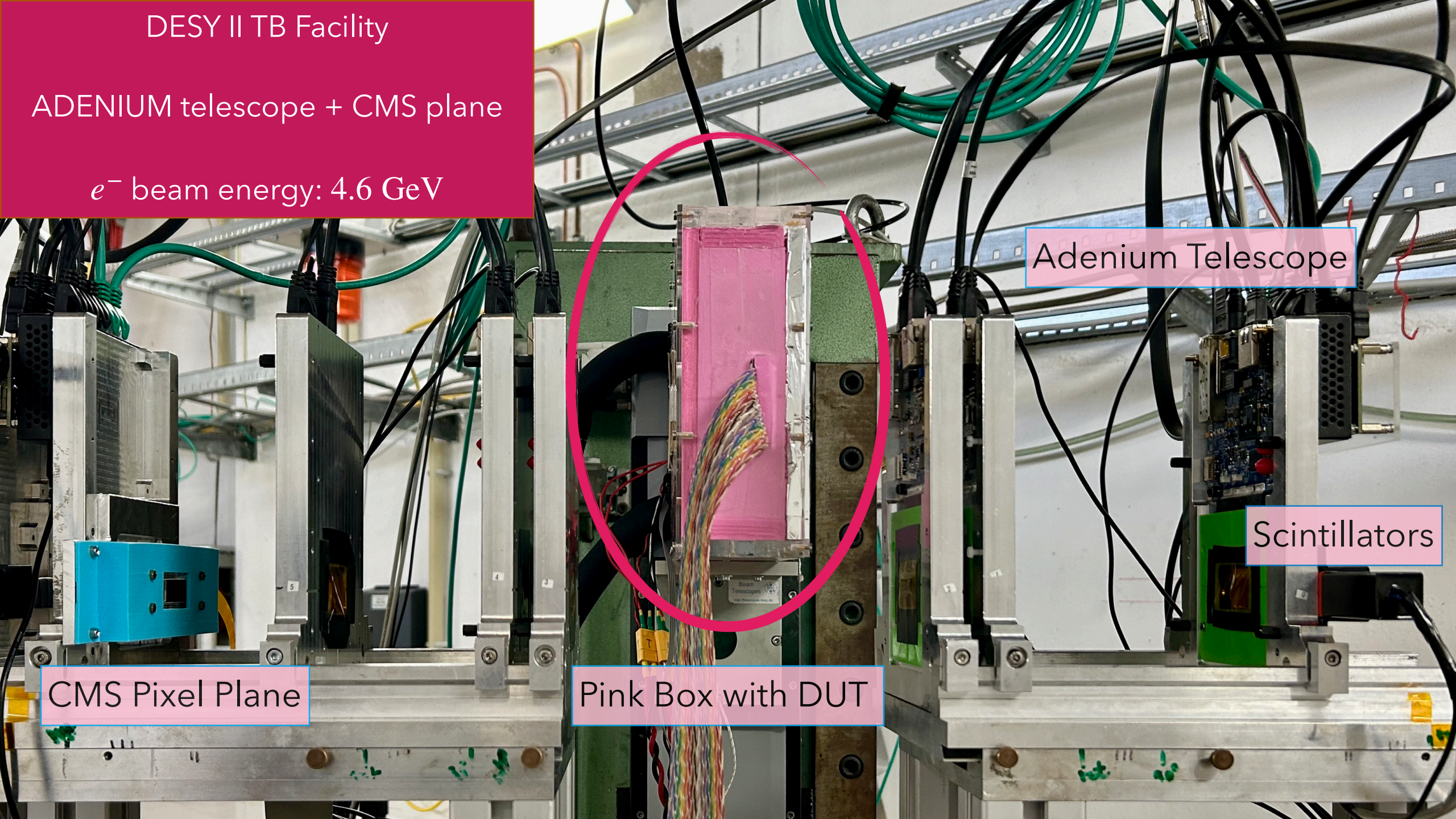
e^- beam energy: 4.6 GeV



DESY II TB Facility

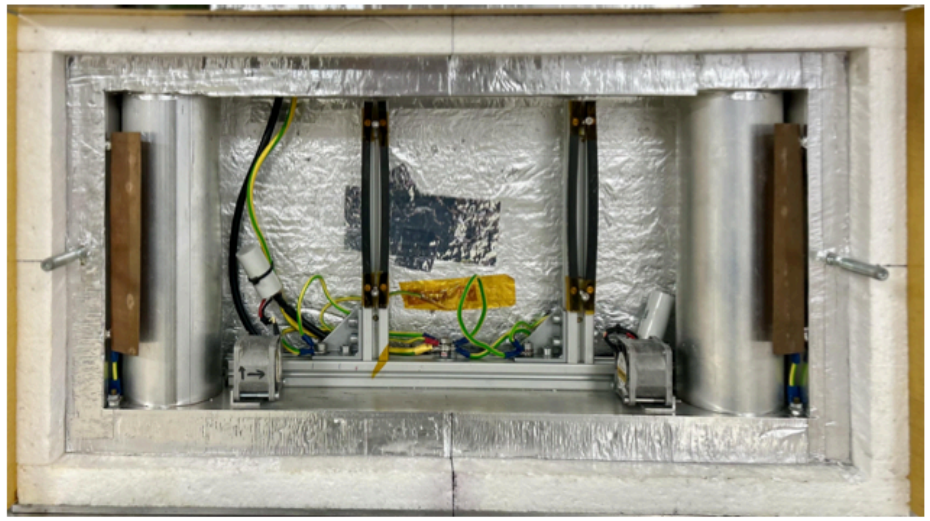
ADENIUM telescope + CMS plane

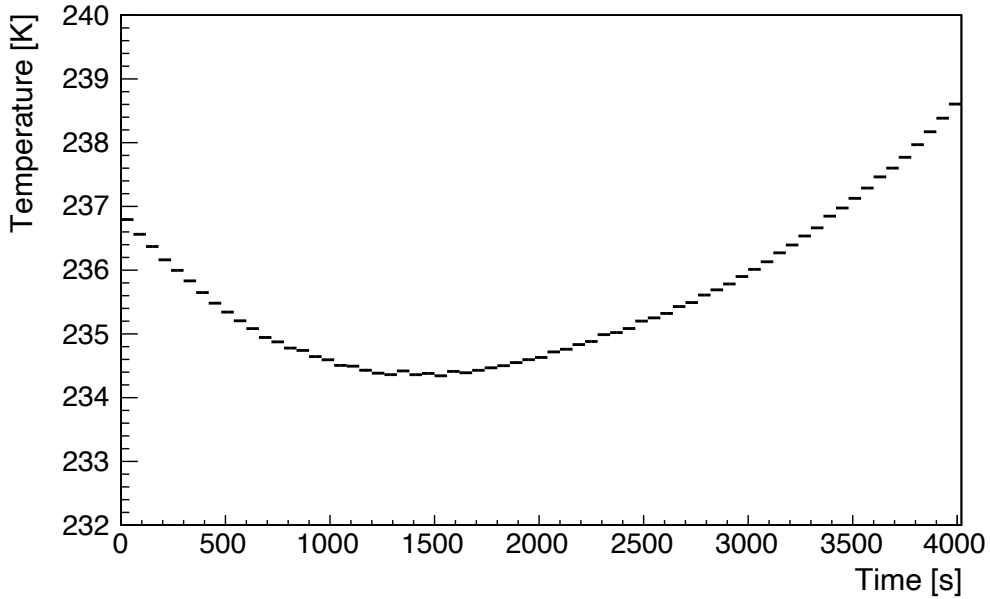
e^- beam energy: 4.6 GeV



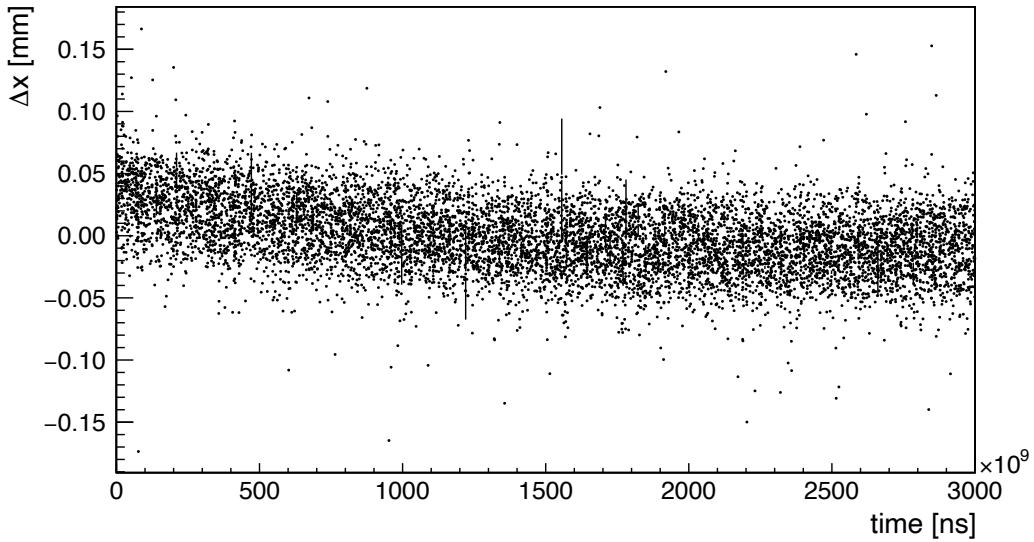
DUT Cooling – ITk Box

- Cooling with dry ice pellets to $-45°C$
- Limited run time of 1.5h
- Temperature and position fluctuations





Box temperature fluctuation



Sensor position fluctuation

DUT Cooling – 'Pink' Box

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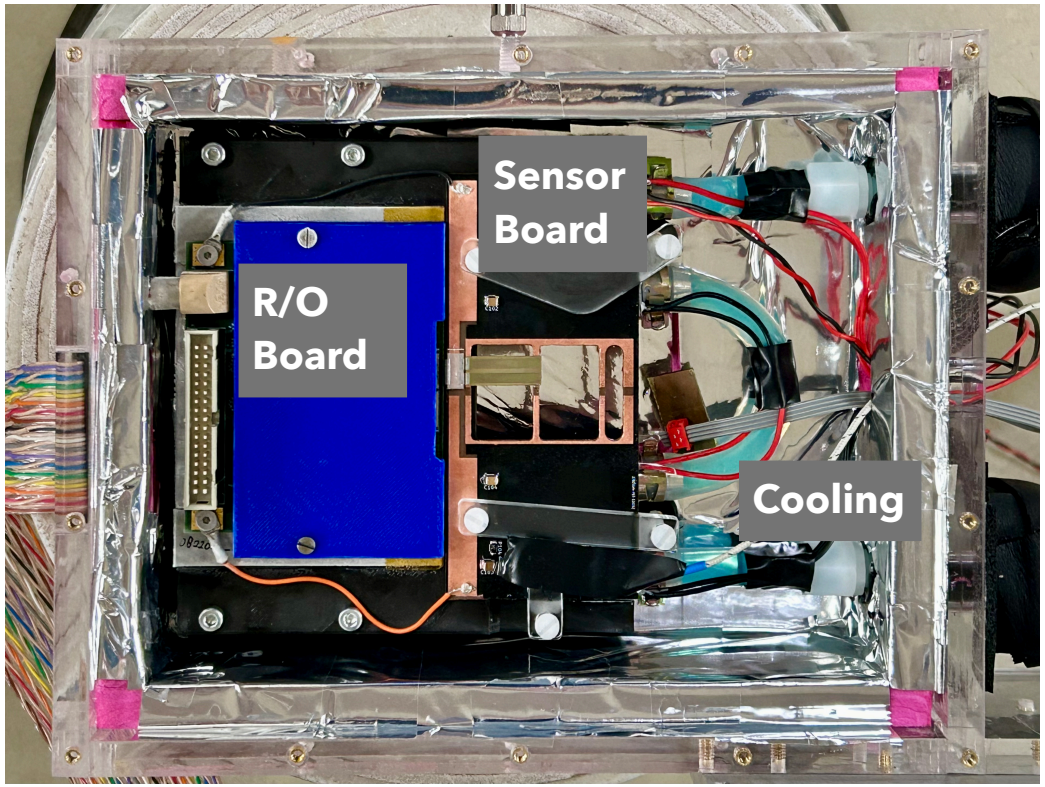
- Reduced box dimensions
- Cooling with stacked Peltier elements connected to chiller



DUT Cooling – 'Pink' Box

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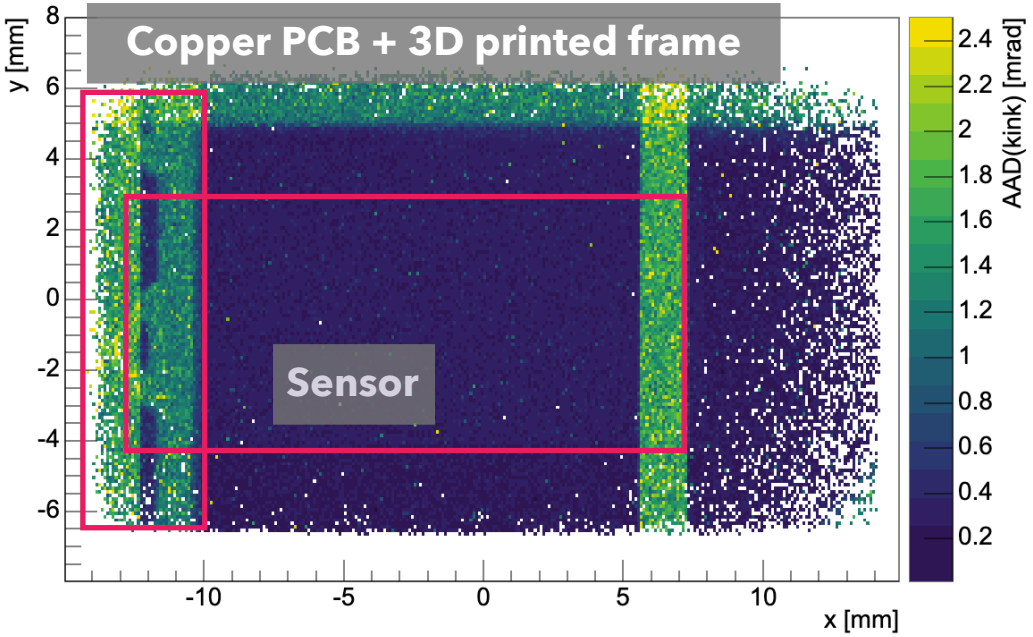
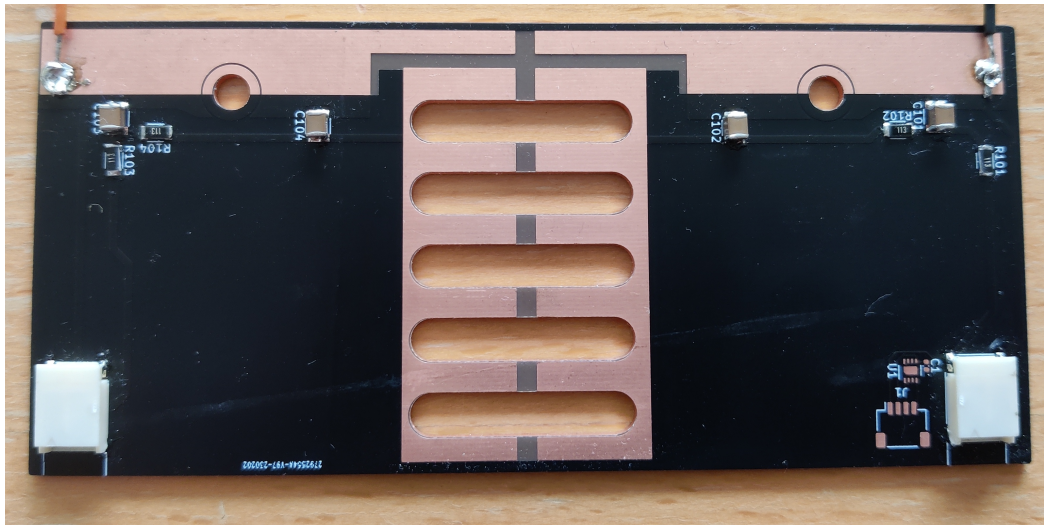
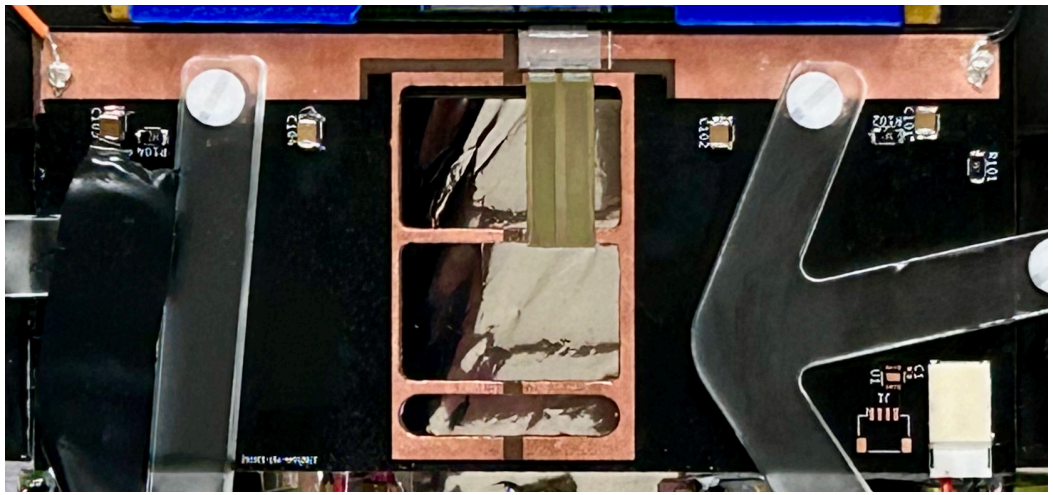
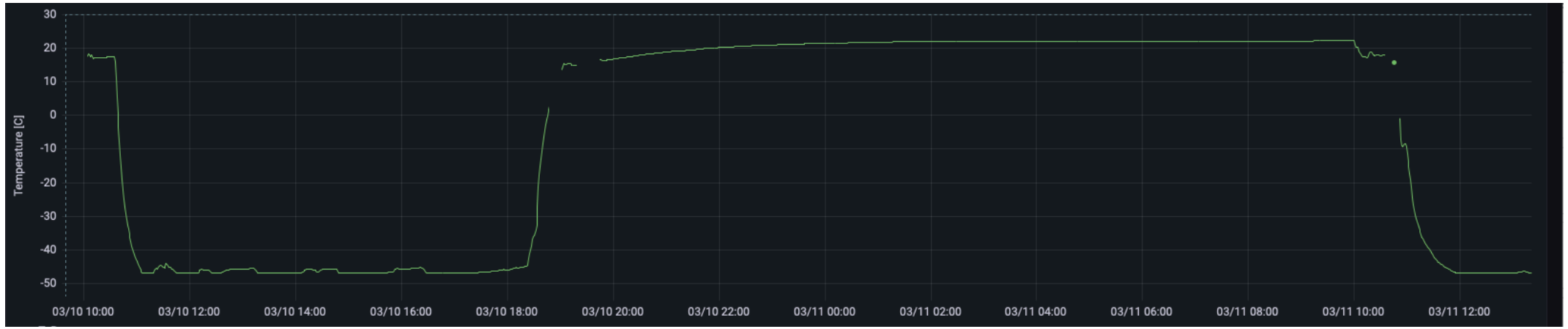
- Sensor held by copper PCB (cooling)
- Reduced material budget







DUT Cooling – ‘Pink’ Box



Temperature in ITk Box (on sensor board)

Temperatur in Pink Box (air)

In-Strip Mean Absolute Deviation (MAD)

MAD within the strip @threshold[SNR] = 5

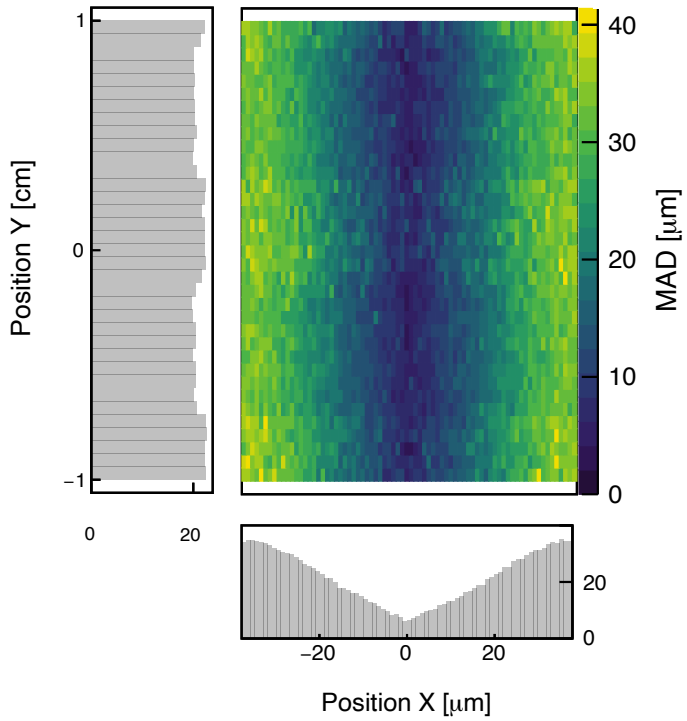
Unirradiated Short Sample

@100V bias

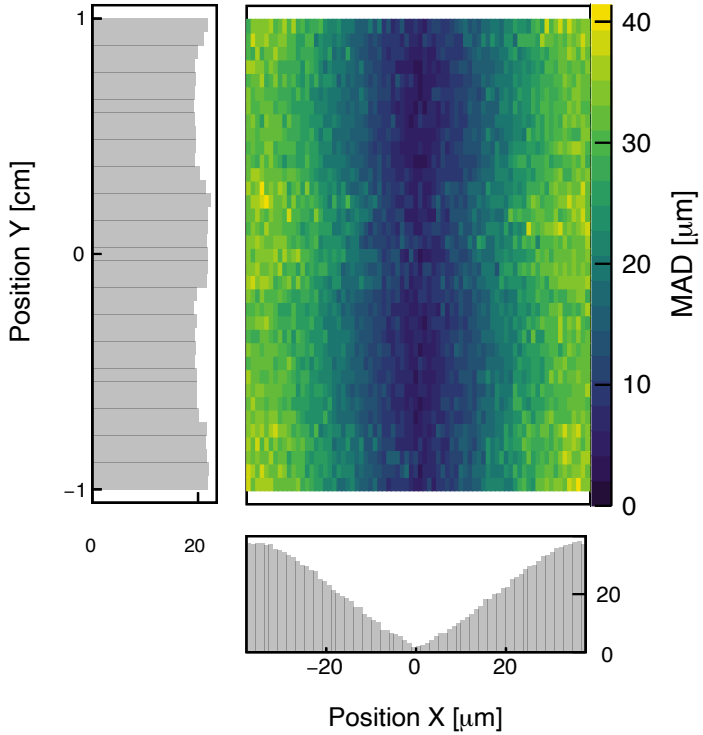
- Hit position residual $\mathrm{MAD} = \frac{\sum |x_{track} - x_{cluster}|}{n}$
- PCB support visible

Stitching

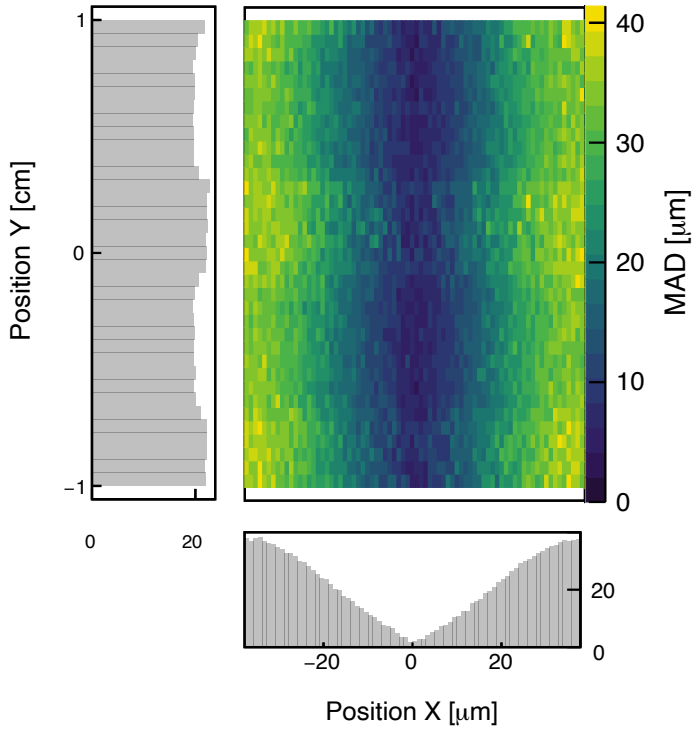
Regular



LD 55



LD 30



D. Dannheim et al., J. Instr. 16 (2021) https://doi.org/10.1088/1748-0221/16/03/P03008

In-Strip Hit Detection Efficiency

Efficiency within the strip @threshold[SNR] = 5

Unirradiated Short Sample

@100V bias

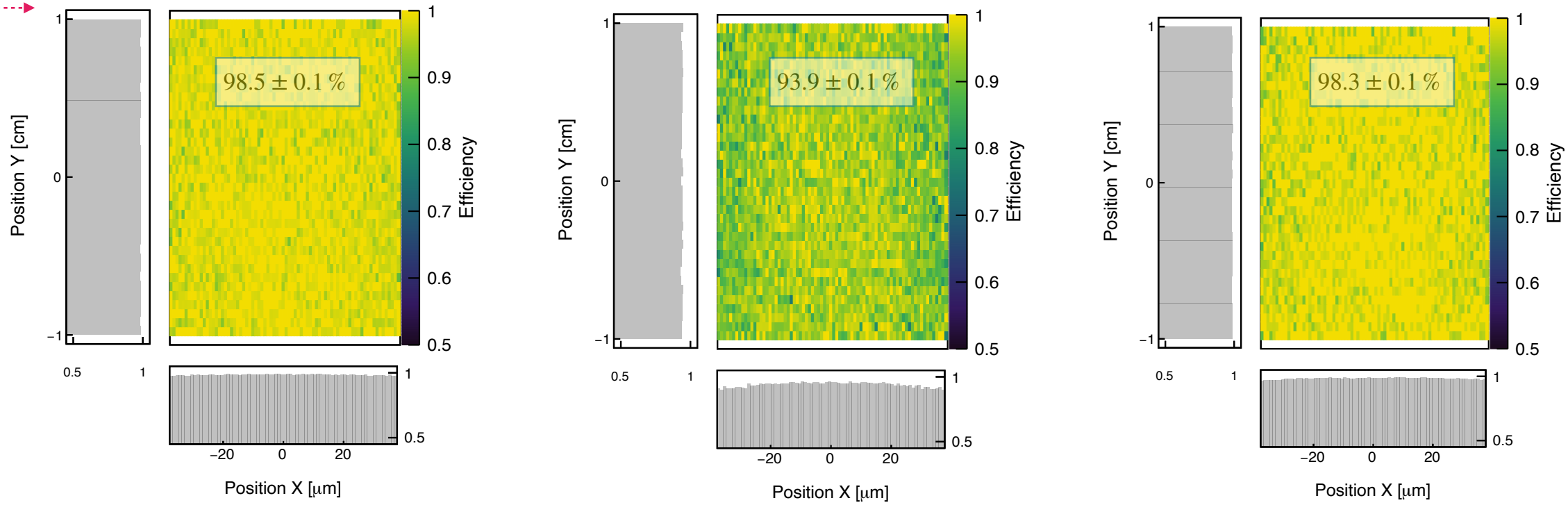
- Homogeneous efficiency along strip length

Regular

LD55

LD30

Stitching



In-Strip Mean Absolute Deviation (MAD)

MAD within the strip @threshold[SNR] = 5

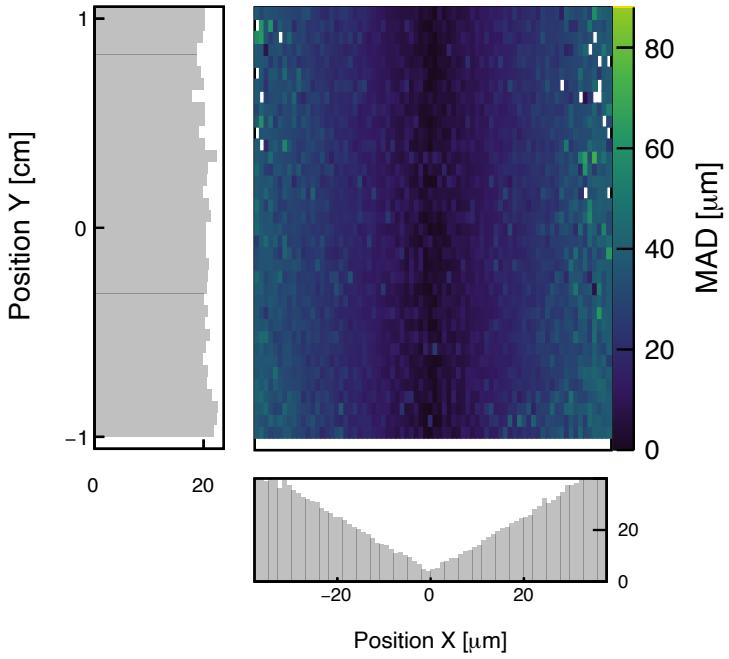
Neutron Irradiated Short Sample

1e16 n_{eq}/cm² @500V bias

- Hit position residual $\mathrm{MAD} = \frac{\sum |x_{track} - x_{cluster}|}{n}$
- Deprecated resolution towards strip edges (no full depletion)

Stitching

Regular



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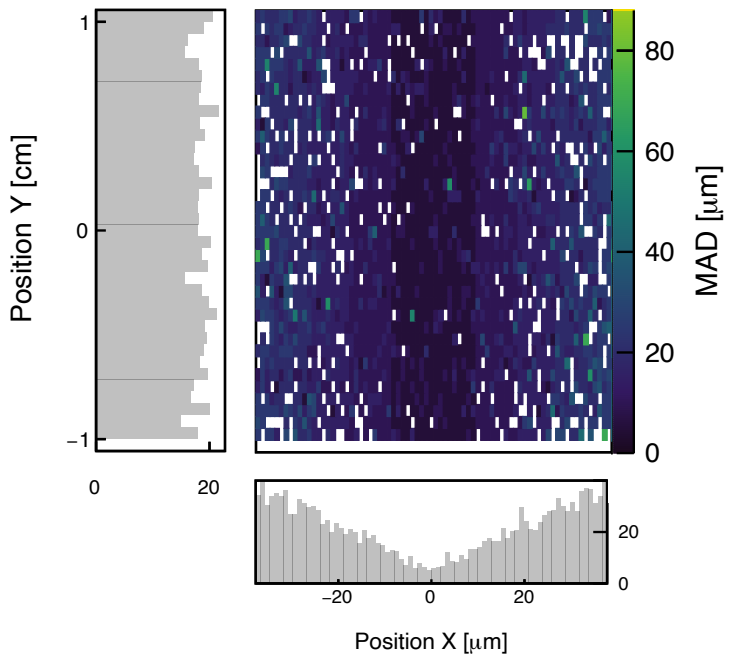
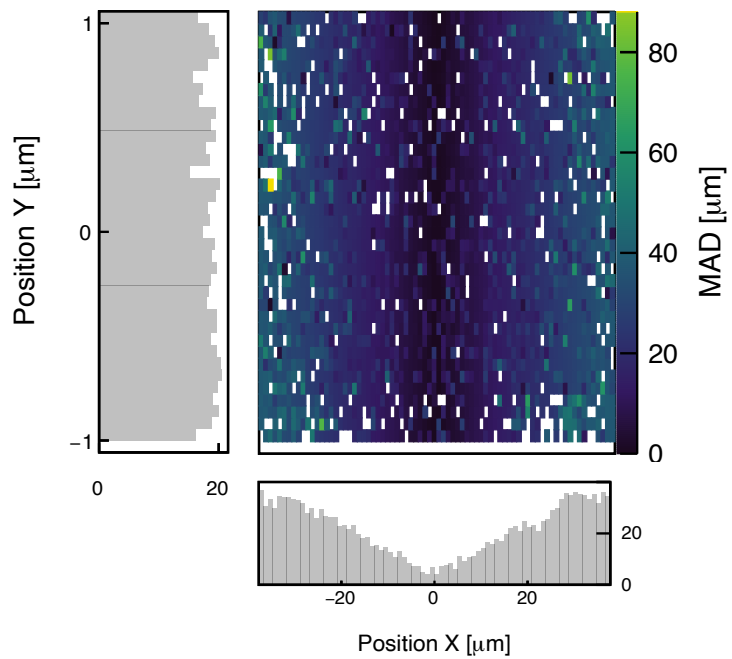


LD 30



In-Strip Hit Detection Efficiency

Efficiency within the strip @threshold[SNR] = 5

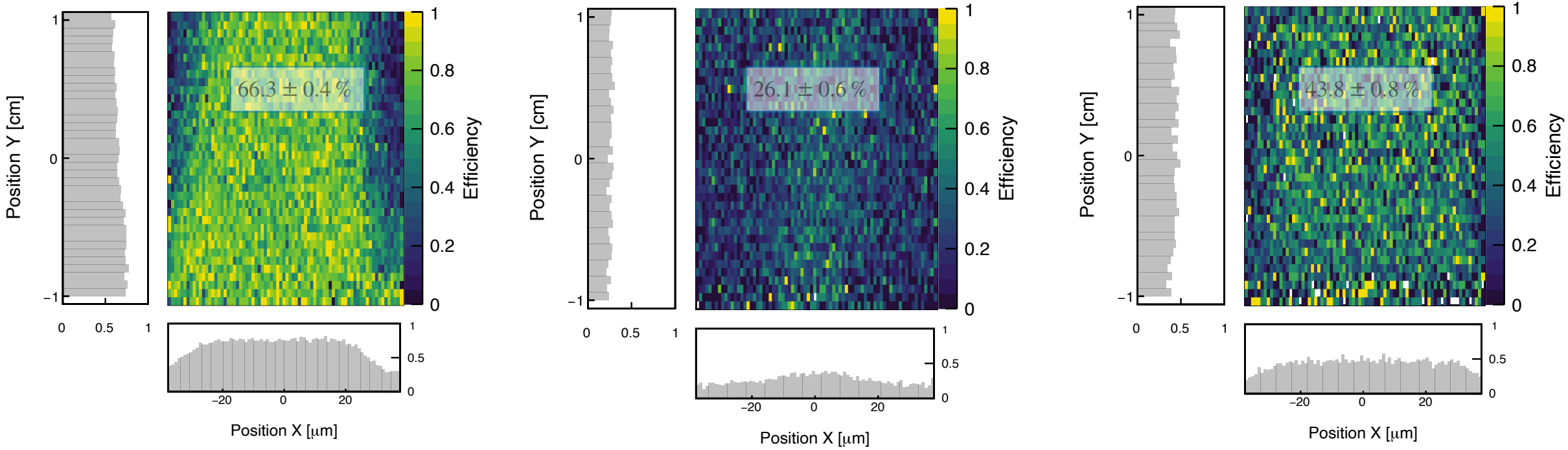
Neutron Irradiated Short Sample

1e16 n_{eq}/cm^2 @500V bias

- Strong efficiency decrease (no full depletion)
- No stitching effect at high fluences

Stitching

LD 55



Conclusion & Outlook

What we have learned and what's next …

- Stitching does not impact resolution and hit detection efficiency!
  - Efficiency drop for LD designs and irradiated samples
- Improved setup for more efficient data taking

- Further Investigations:
  - Comparison to proton irradiation, charge calibration
- Active sensor submission under discussion

Thank you,
Questions?

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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).