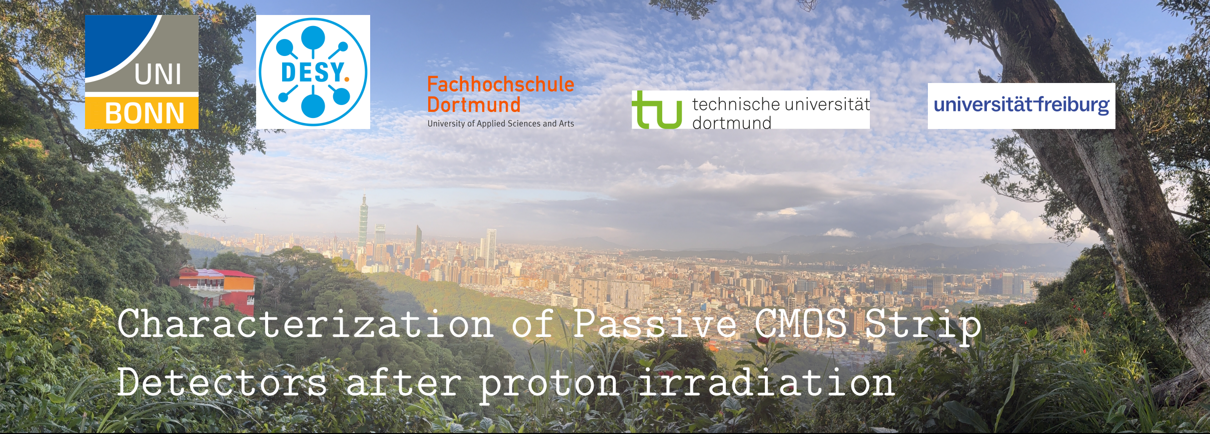


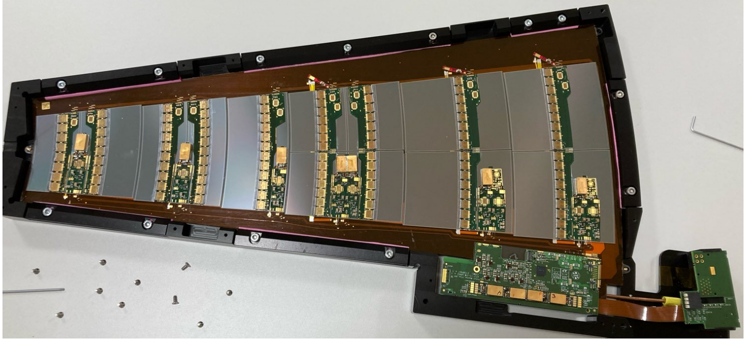
Characterization of Passive CMOS Strip Detectors after proton irradiation

Marta Baselga,J.-H. Arling, N. Davis, J. Dingfelder, I.-M. Gregor, M. Hauser, F. Hügging, K. Jakobs, M. Karagounis, R. Koppenhöfer, K. Kröninger, F. Lex, U. Parzefall, S. Spannagel, D. Sperlich, J. Weingarten, I. Zatocilova

21/11/2025 - 14th HSTD, Taipei

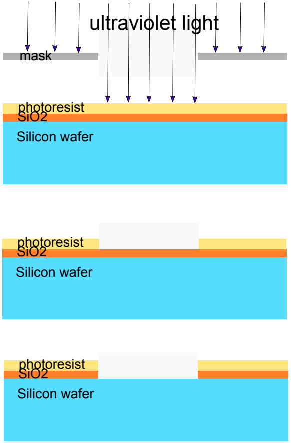
Motivation - Strip detectors

- All ATLAS and CMS upgrade strip detectors are fabricated in same foundry
- So far, large area strips are only fabricated in "microelectronics" foundries
- Here we want to prove that CMOS foundries can fabricate strip detectors and do not have any impact in the performance

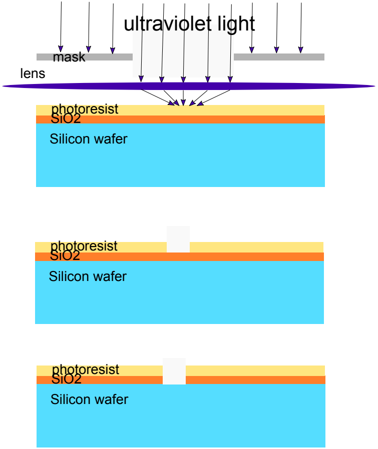


What changes regarding microelectronic foundries?

"Microelectronics" photolitography

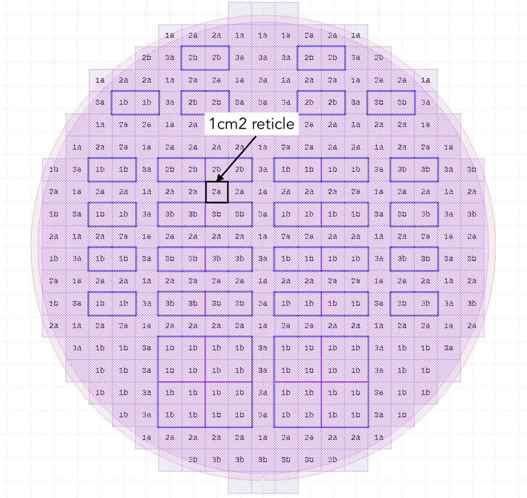


CMOS photolitography

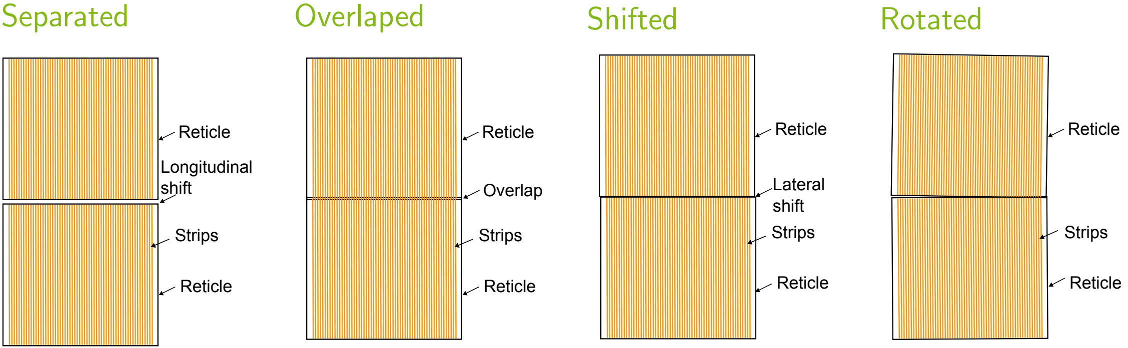


[From wikipedia]

Mask design



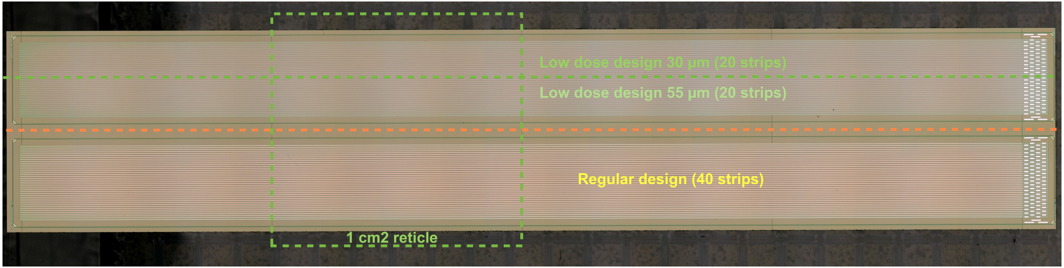
Stitching



- Simulations in JINST 20 C01027 2025

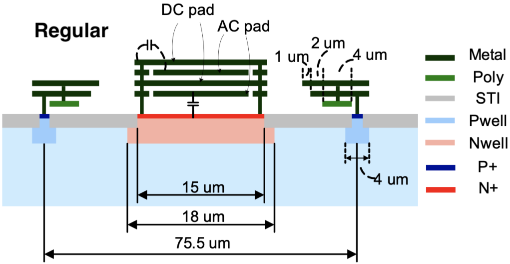
Passive CMOS Strip

- Fabrication in LFoundry with a 150 nm production
- NO electronics included → therefore Passive
- FZ 150 µm thick wafer, with resistivity 3-5 kΩ
- Fabricated 2.1 cm and 4.1 cm long strips:
    1. 1 cm^2 reticle used (2 set of masks used)
    2. The strips had to be stitched 3 or 5 times
- Goal→ to show that stitching does not affect the performance of the strip



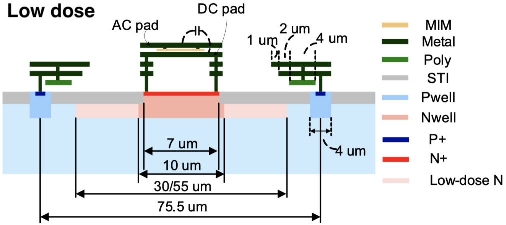
Two designs of strips: Regular design and Low Dose design

Regular design



- Similar to the ATLAS strip design

Low dose design



- Using low dose implant and a MIM capacitor

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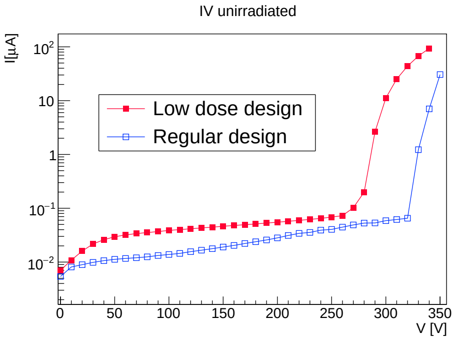
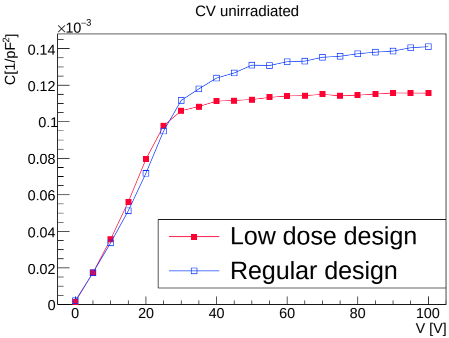
Electrical characterization: unirradiated



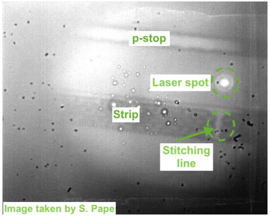


- No break down before 250 V
- Depletion around 35 V
- More in NIMA 1033 (2022) 166671

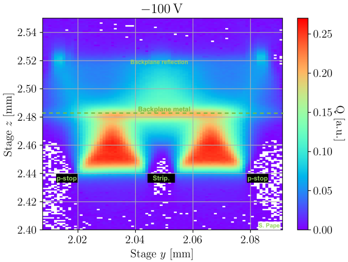
Two Photon Absorption Transient Current Technique measurements

- TPA-TCT measurements were performed at CERN SSD
- The charge in stitching and outside stitching does not show any difference

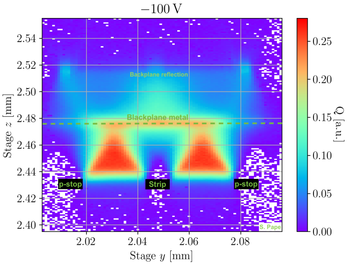
IR image



TPA-TCT in the stitch area



TPA-TCT outside the stitch



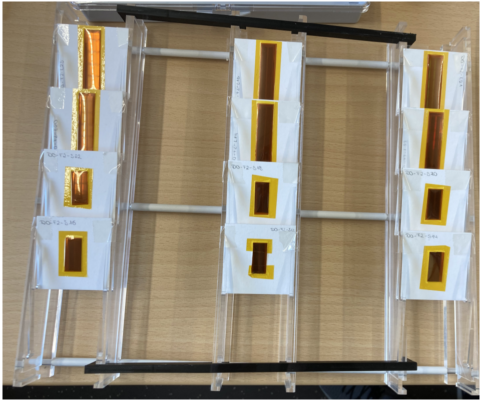
* Measurements taken by to Sebastian Pape, Michael Moll, Marcos Fernandez Garcia, and Esteban Curras

CERN irradiation with 24 GeV/c protons (IRRAD)

- Several samples were irradiated at different fluences from IRRAD

Fluence
$1 \times 10^{14}\, n_{eq}/cm^2$
$5 \times 10^{14}\, n_{eq}/cm^2$
$1 \times 10^{15}\, n_{eq}/cm^2$

- Annealed at 80 min 60 °C



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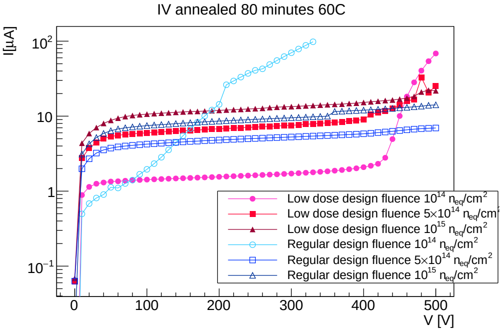
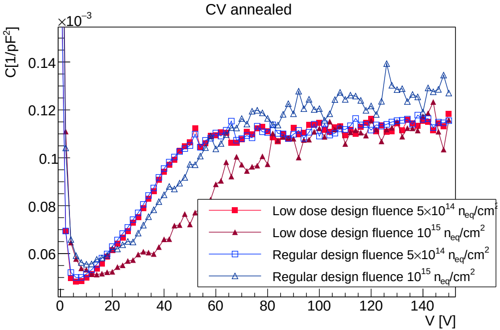
Electrical characterization: irradiated and annealed



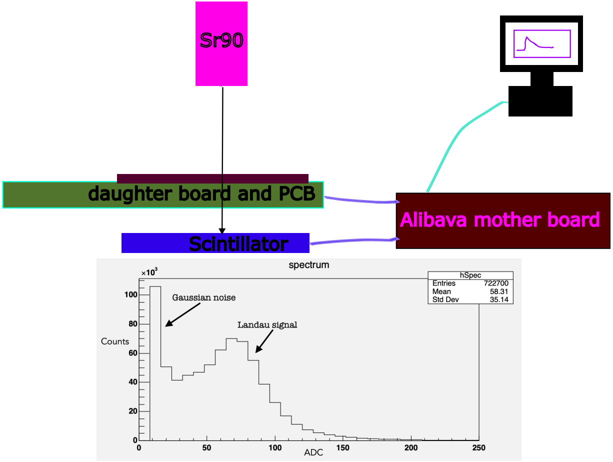


- No break down before 400 V
- Depletion around 60 V or lower

Alibava setup

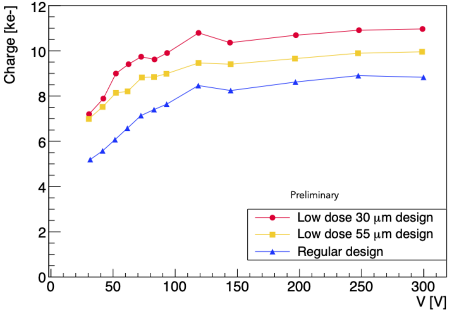
- Alibava readout system
- Analog readout of the strips
- Using Beattle chip from LHCb
- Charge investigated using electrons from a Sr90 source

Sketch of the setup

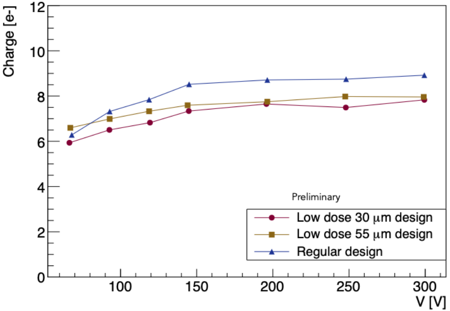


Alibava measurements

Fluence $5 \times 10^{14}\ n_{eq}/cm^2$



Fluence $1 \times 10^{15}\ n_{eq}/cm^2$



- Measurements talken at $-20\,^\circ$C
- Close to non irradiated values
- Inverted performance for the three geometries

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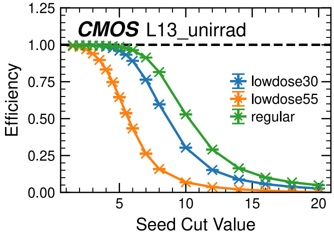
Test beam results

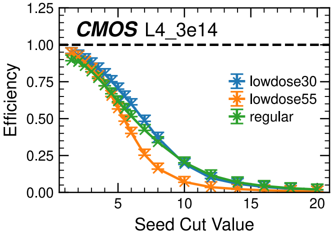
Efficiency dependency with the seed cut

Unirradiated



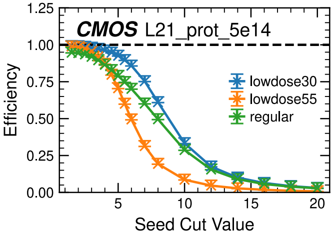
Neutron Irradiated

$\Phi_{eq} = 3 \cdot 10^{14}\ n_{eq}/cm^2$



Proton Irradiated

$\Phi_{eq} = 5 \cdot 10^{14}\ n_{eq}/cm^2$



[I. Zatocilova, CMOS Strip Sensors – Characterisation, Simulation and Test Beam Results, 2nd DRD3 week]

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Test beam results

In strip efficiency

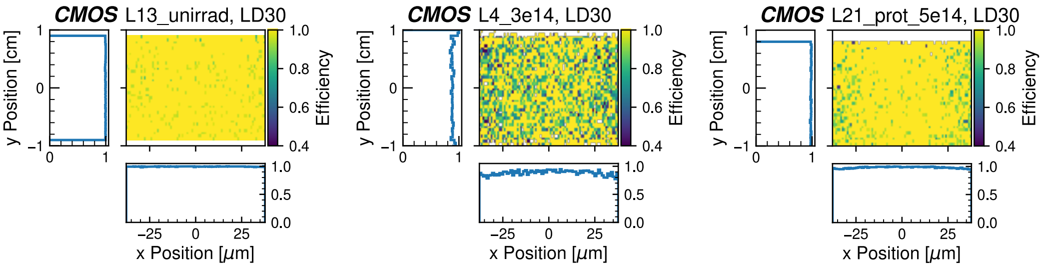
Unirradiated

Neutron Irradiated

$\Phi_{eq} = 3 \cdot 10^{14}\ n_{eq}/cm^2$

Proton Irradiated

$\Phi_{eq} = 5 \cdot 10^{14}\ n_{eq}/cm^2$

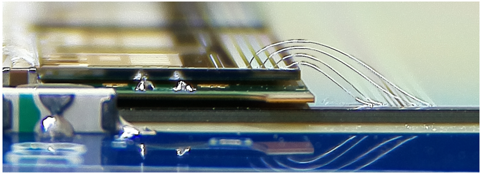


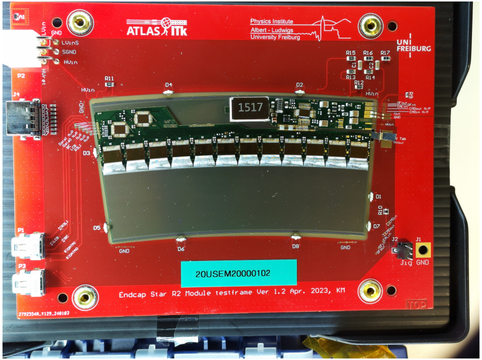
[I. Zatocilova, CMOS Strip Sensors – Characterisation, Simulation and Test Beam Results, 2nd DRD3 week]

Next steps

Monolythic Active Strip Sensors (MASS)

- Increasing number of production foundries
- No so much bonding (avoiding 1500 bonds from chip to strip)
- No gluing





Monolythic Active Strip Sensors (MASS)

Monstera (MONolithic STrip Extended Readout Architecture)

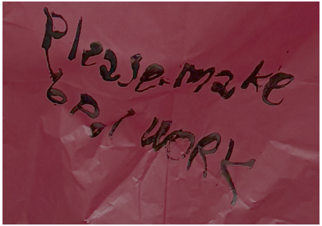
- German consortium
- In DRD3 collaboration
- Designing next submission for next year
- Each strip 75.5 µm pitch will have each own front end

Conclusions and future work

- Stitching does not have any impact in the performance of the strip detectors before and after irradiation
- Planning a new production with the electronics implemented in the strips is ongoing $\rightarrow$ that would allow to avoid all the bondings of the strips to the chips

Thanks for staying till the end of the week!

And thanks to the organizers to prepare this nice Symposium

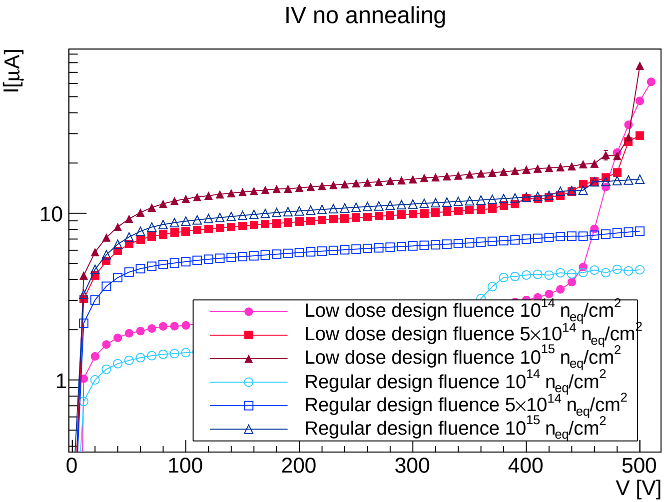


More results from passive CMOS strips

- PSD
  - Proceedings: NIMA 1061 (2024) 169132
- RD50
- Hiroshima (HSTD13)
  - Proceedings: NIMA 1064 (2024) 169407
- VERTEX23
  - Proceedings: PoS(VERTEX2023)067
- NIMA 1033 (2022) 166671
- NIMA 1039 (2022) 167031
- NIMA 1080 (2025) 170807
- 2025 JINST 20 C01027

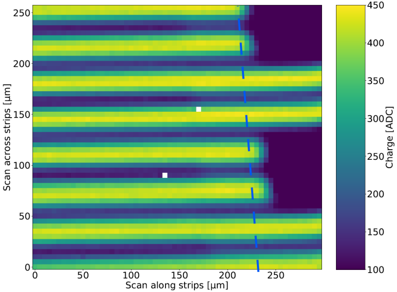
Backup

Electrical characterization: Irradiated, not annealed

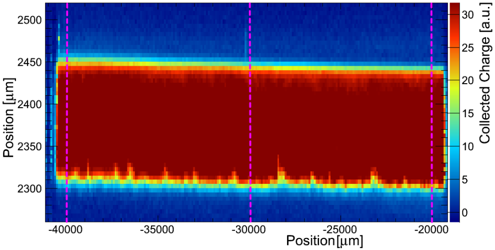


Transient Current Technique measurements

TCT and edge TCT with IR laser



Collected charge of the regular design of a long sensor as a function of the laser position at 50 V, illuminating from top. [NIMA 1033 (2022) 166671]

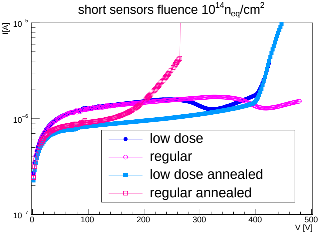


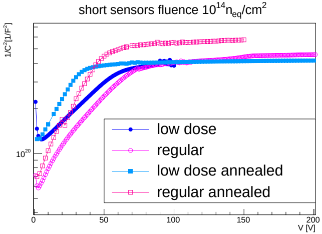
Edge TCT charge from a short LD30 sensor at 100 V (fully depleted). Stitching does not change the collected charge. [N. Sorgenfrei, 40th RD50, CERN]

Irradiated: IVs and CVs

Irraidated with protons at KIT

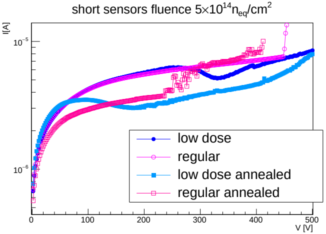
- 23 MeV protons at fluence $1 \times 10^{14}\,n_{eq}/cm^2$

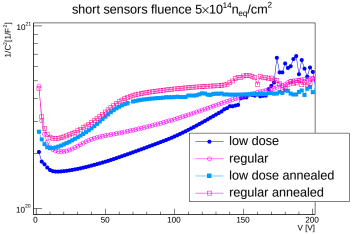




CV at 1 kHz

- 23 MeV protons at fluence $5 \times 10^{14}\,n_{eq}/cm^2$





CV at 1 kHz

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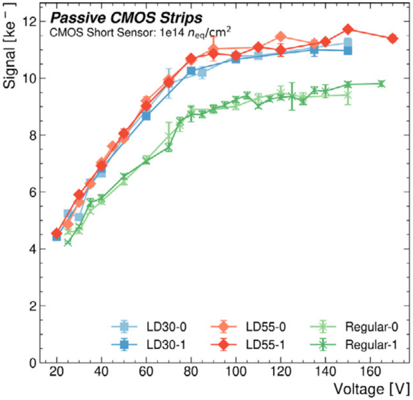
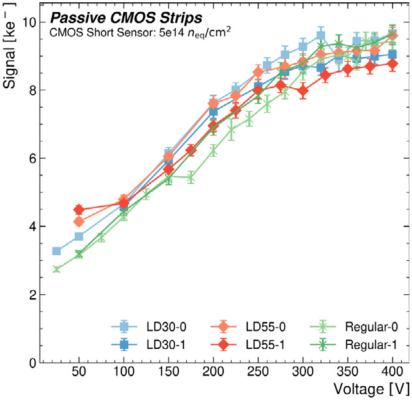
Irradiated: Charge in the ALiBaVa setup with Sr^{90}

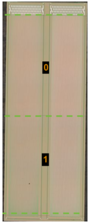
Signal of a short detector with Sr^{90} source irradiated



Neutrons fluence $1 \times 10^{14}\ n_{eq}/cm^2$



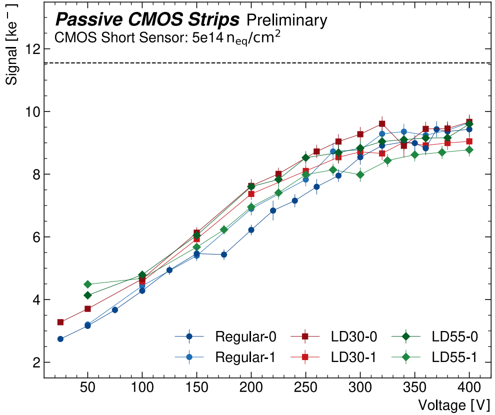
Neutrons fluence $5 \times 10^{14}\ n_{eq}/cm^2$



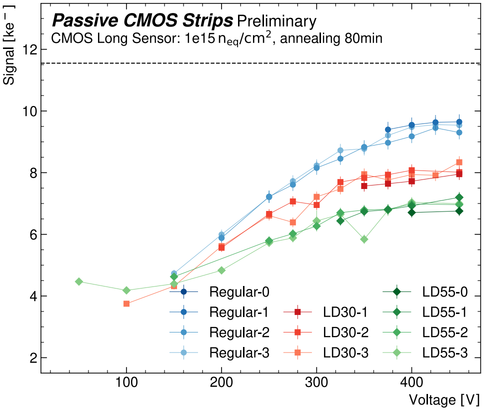
[NIMA 1039 (2022) 167031]

Irradiated: Charge in the ALiBaVa setup with Sr^{90}

Signal of a detector with Sr^{90} source irradiated



Neutrons $5 \times 10^{14}\ n_{eq}/cm^2$



Neutrons $1 \times 10^{15}\ n_{eq}/cm^2$

[N. Sorgenfrei, 40th RD50, CERN]

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