technische universität dortmund

DESY.

UNI BONN

UNI FREIBURG

Passive CMOS Strip: Lab measurements

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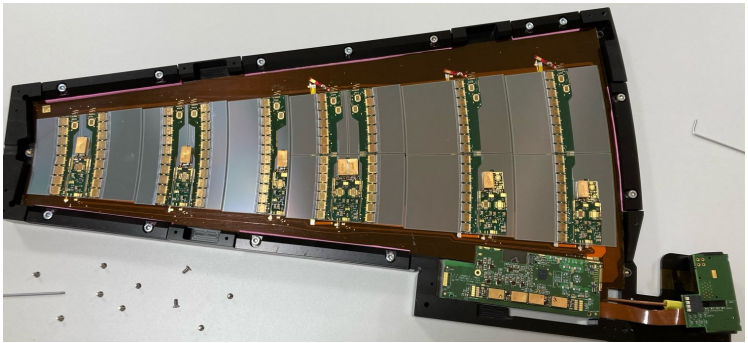
27/2/2023 Heidelberg - Verbund CMOS meeting

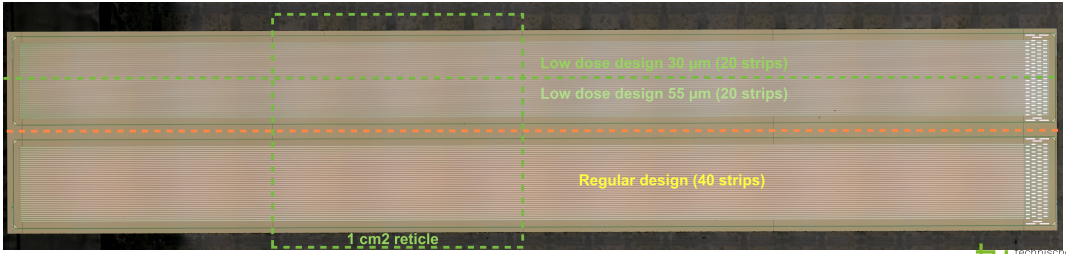
Motivation

- All ATLAS and CMS upgrade strip detectors are fabricated in Hamamatsu Photonics HPK
- Seems like large area strips only are fabricated in microelectronics foundries
- Here we want to show that also CMOS foundries can fabricate strip detectors and do not have any impact in the performance



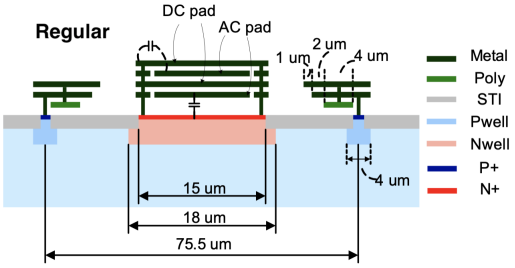
Passive CMOS Strip

- Fabrication in LFoundry with a 150 nm production
- NO electronics included $\rightarrow$ therefore Passive
- FZ 150 µm thick wafer
- We 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
- We want to demonstrate that stitching does not affect the performance of the strips



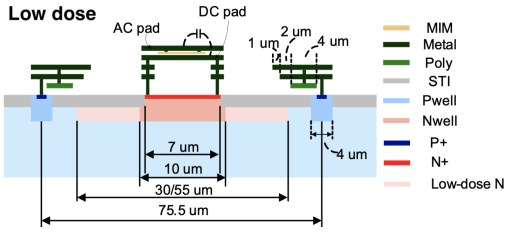
Two designs of strips: Regular design and Low Dose design

Regular design



- Similar to the ATLAS strip design

Low dose design

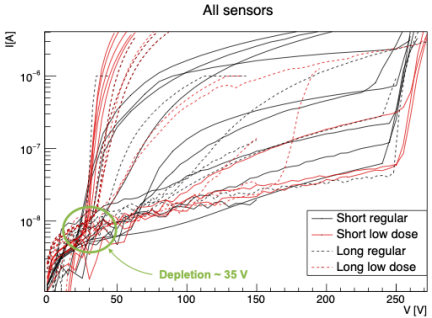


- Using low dose implant and a MIM capacitor

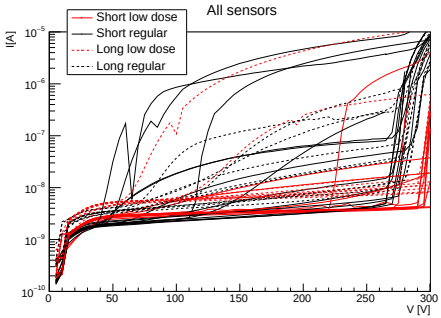
Electrical characterization: IV

- Two different back processing:
  1. First had very often an early break down voltage when reaching the depletion the backplane
  2. Second had an improvement with the break down voltage

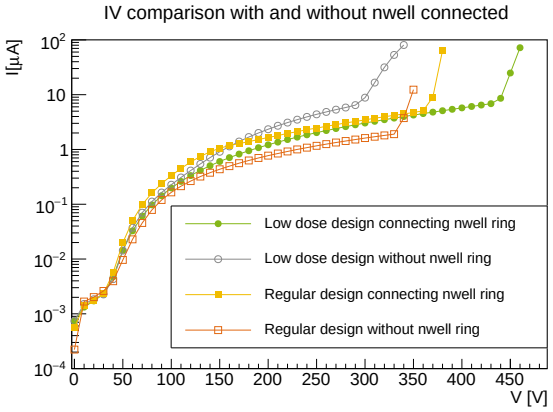
First back processing

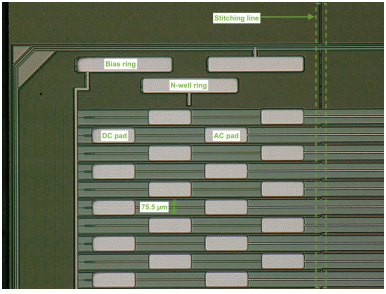


Second back processing



Electrical characterization: IV with nwell ring

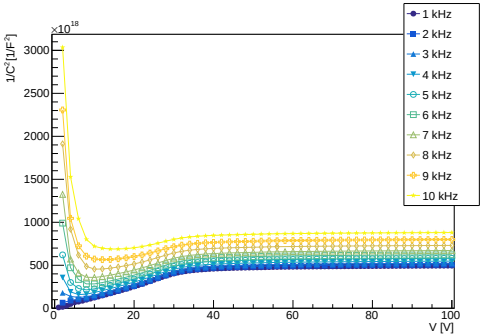




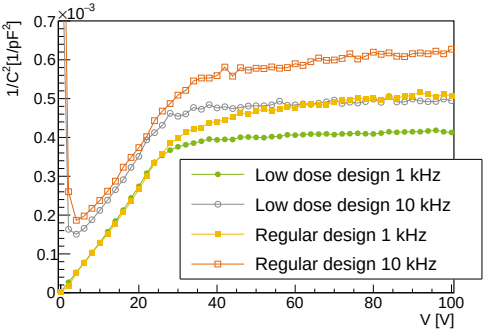
- IV curve shows an improvement when biasing the bias and the nwell ring together
- Probably the break down is happening to the edge of the detector

Electrical characterization: CV

CV with the bias pad



CV with the bias pad and nwell ring

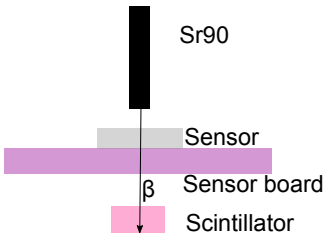


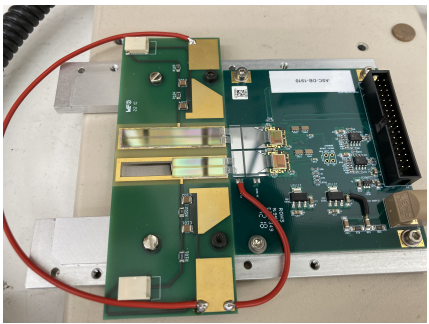
- Decrease of capacitance when increasing the frequency
- The effect decreases biasing the nwell ring → some edge effect

Lab Setup: Alibava board

- Readout is done with ALiBaVa system, it contains a mother board and a daughter board populated with two Beetle readout chip (from LHCb)
- It allows an analogue readout of the signal of 258 channels (two Beetle chips)

Sketch of the β source setup

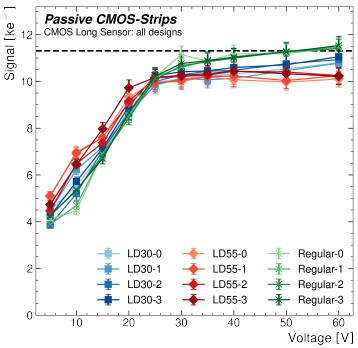


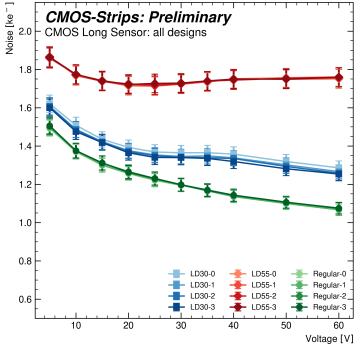


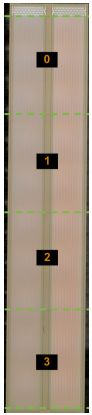
→ Daughter board (with two beetle chips) bonded to the passive CMOS strips

Charge in the ALiBaVa setup: Long detector with Sr^{90} source

- Sr^{90} source located on top of 4 different positions (shown in right image)





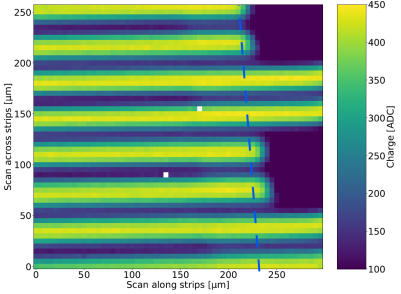


[NIMA 1033 (2022) 166671]

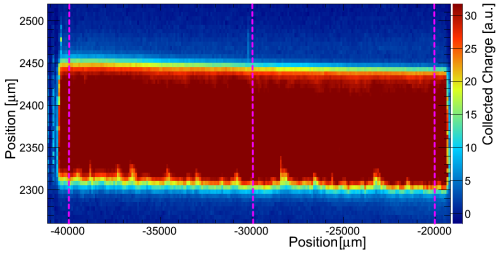
- The three different flavours have similar signal (expected $\sim$ 11500 electrons)
- Low Dose 55 µm has higher noise $\rightarrow$ it has higher inter strip capacitance

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]

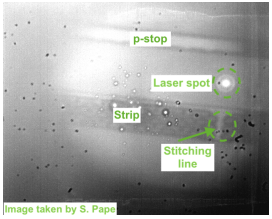


Edge TCT charge from a short LD30 sensor at 100 V (fully depleted). Stitching does not change the collected charge [N. Sorgenfrei, 40th RD50, CERN]

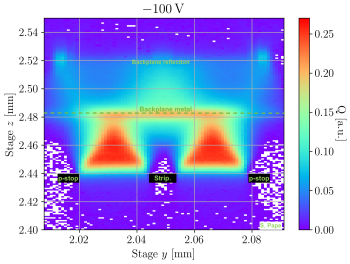
Two Photon Absorption Transient Current Technique measurements

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

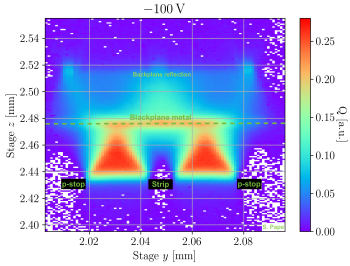
IR image



TPA-TCT in the stitch area



TPA-TCT outside the stitch



- Measurements from Sebastian Pape, Michael Moll, Marcos Fernandez Garcia, and Esteban Curras. More details about this technique in this talk

Irradiated samples

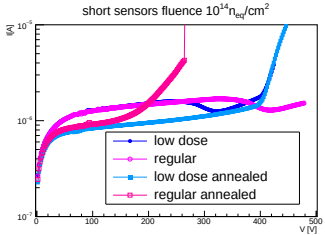
We wanted to test the sensors under irradiation, we shipped samples to:

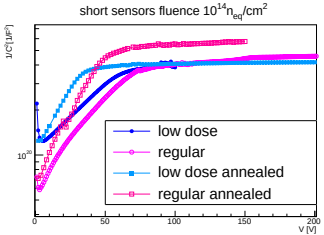
- 23 MeV protons @ KIT
- Neutrons at Ljubljana
- 24 GeV protons @ IRRAD (CERN)

Irradiated: IVs and CVs

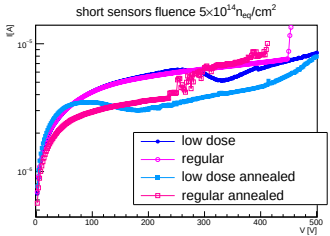
Irraidated with protons at KIT

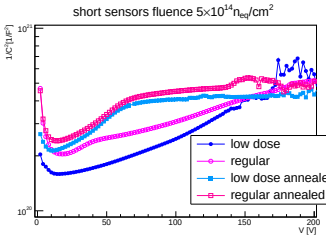
- 23 MeV protons at fluence 1×10^{14} n_{eq}/cm^2
- 23 MeV protons at fluence 5×10^{14} n_{eq}/cm^2





CV at 1 kHz

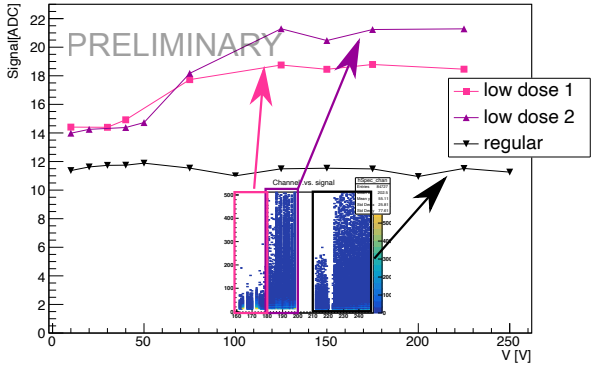




CV at 1 kHz

Irradiated: ALiBaVa setup with Sr^{90}

Irraidated with protons at KIT $5 \times 10^{14}\,n_{eq}/cm^2$ (23 MeV and annealed)

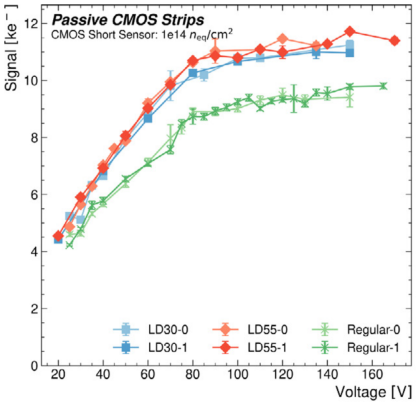


- Data not calibrated
- Regular design seems to stop working after irradiation

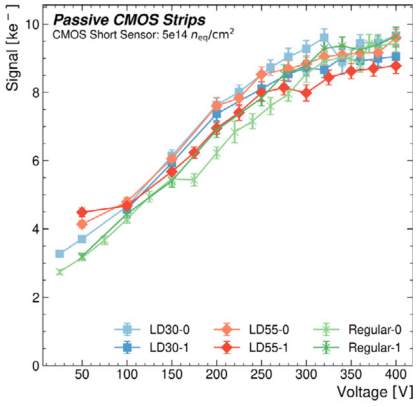
[12th PSD 2021 Birmingham]

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

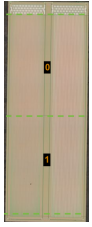
Signal of a short detector with Sr^{90} source irradiated



Neutrons fluence 1×10^{14} n_{eq}/cm^2



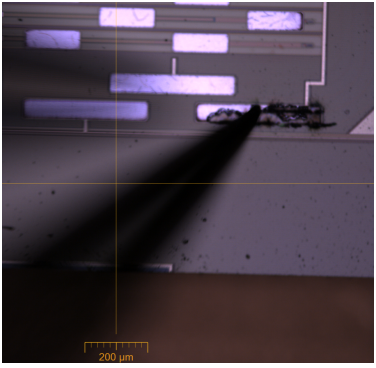
Neutrons fluence 5×10^{14} n_{eq}/cm^2

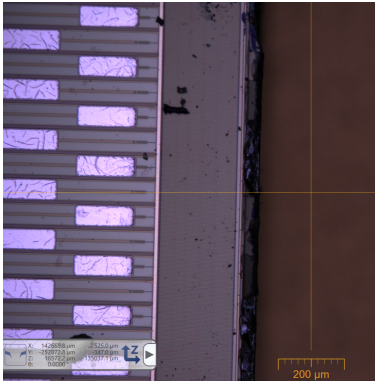


[NIMA 1039 (2022) 167031]

Electrical stress to some sensors

- Sensors irradiated at CERN we tried to reach the break down voltage (not reached at 800 V)
- Some burned damage was inflicted in the sensors (slide 6 shows a non burned edge detector)





Conclusions and future work

Conclusions

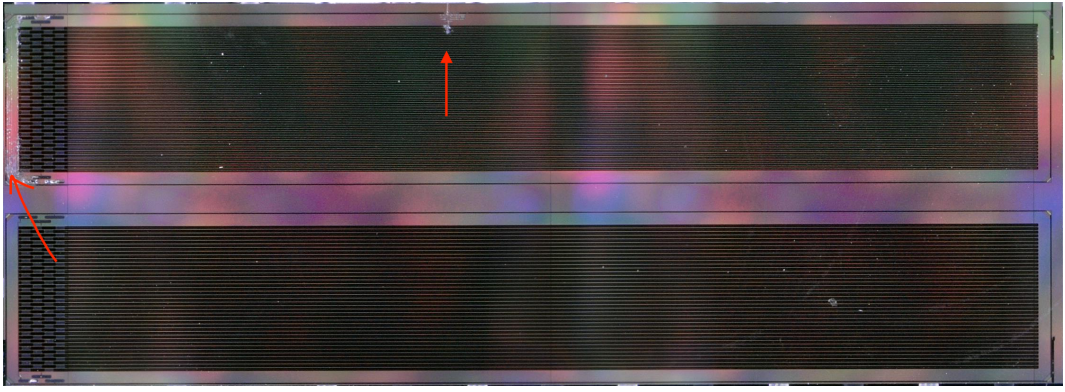
- So far, stitching does not have any impact in the performance of the strip detectors before and after irradiation
- Currently wrapping up the irradiated measurements, finishing the testbeam analysis and studying if there is a problem with the burning detectors

Future work

- 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
- Production of a full wafer size strip detector with a CMOS foundry

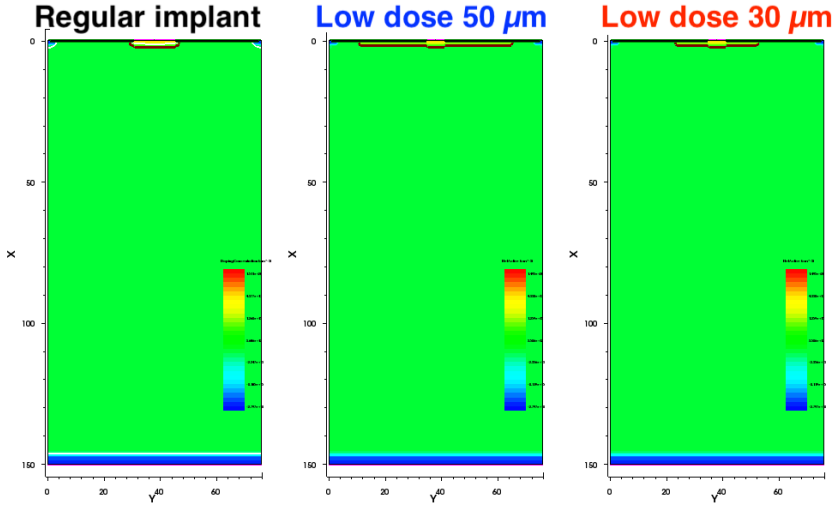
Backup

Irradiated with 23 MeV protons



- some burned guard rings after some electrical stress

TCAD simulations: Simulated device



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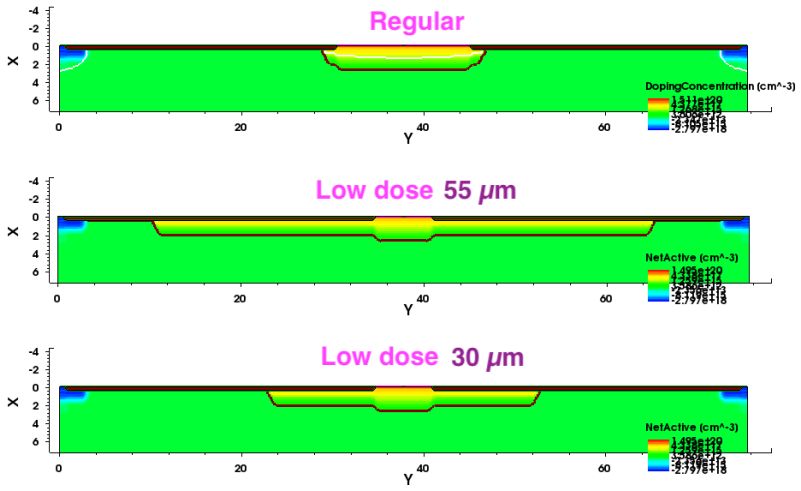
TCAD simulations: Simulated device zoom



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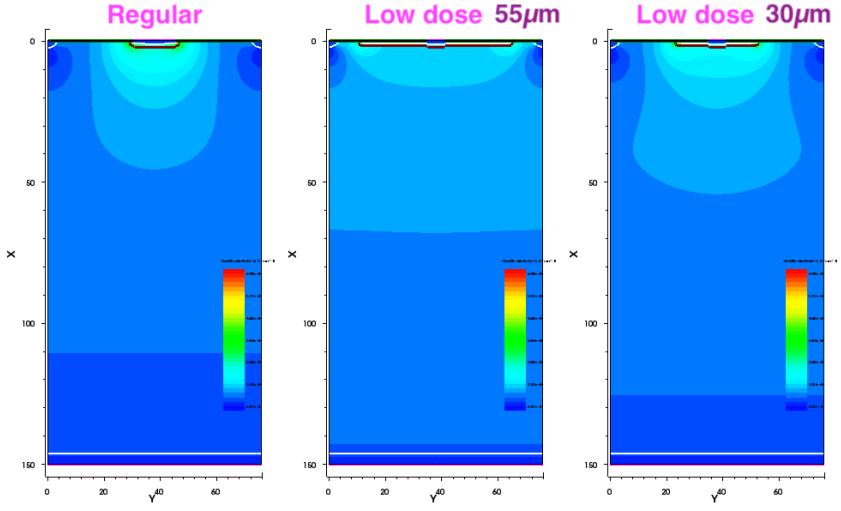
TCAD simulations: Simulated Electric field at 100 V



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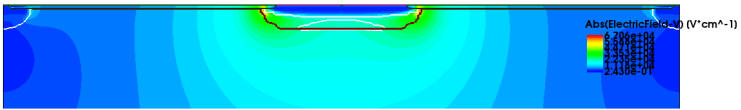
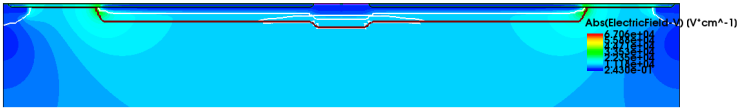
TCAD simulations: Electric field zoom

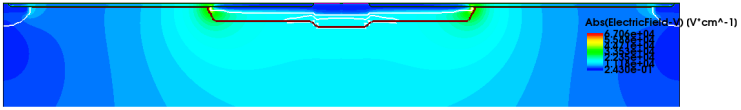
Regular implant



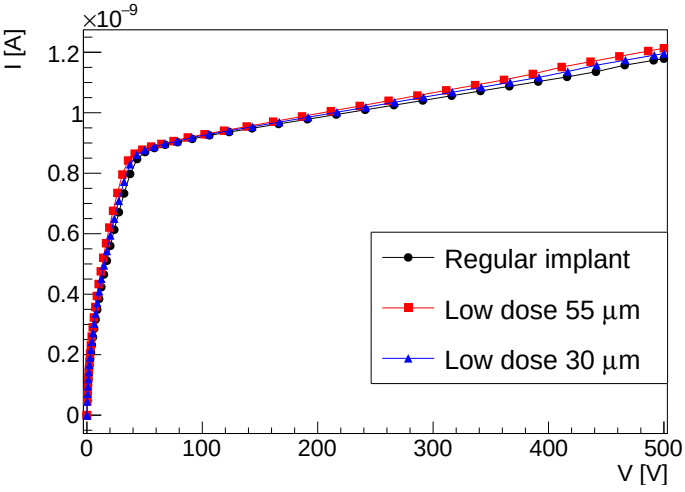
Low dose 55 μm



Low dose 30 μm



TCAD simulation: Current voltage curve



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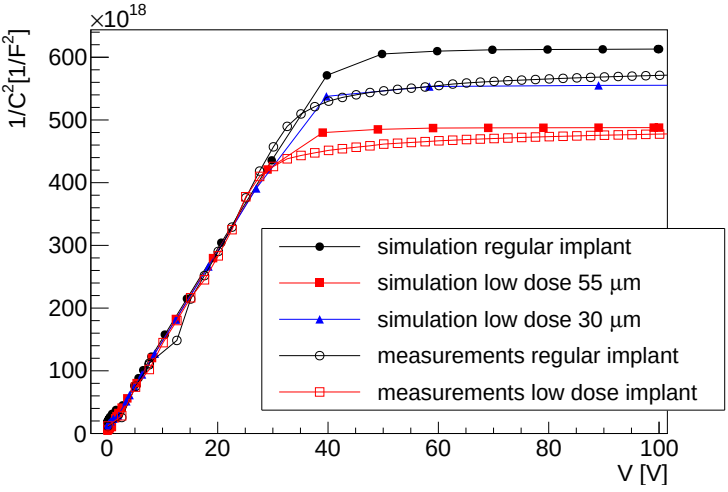
TCAD simulation compared with data: capacitance voltage curves



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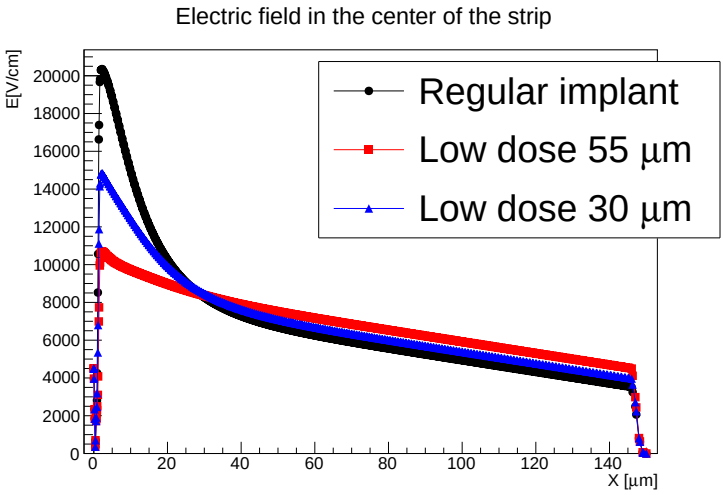
TCAD simulation: Electric field 100 V at the center of the strip



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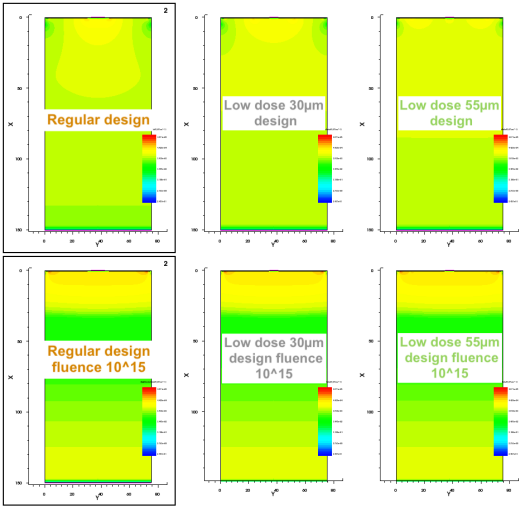
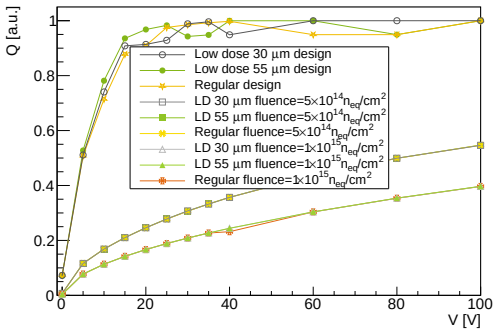
TCAD simulation: Irradiated electric field

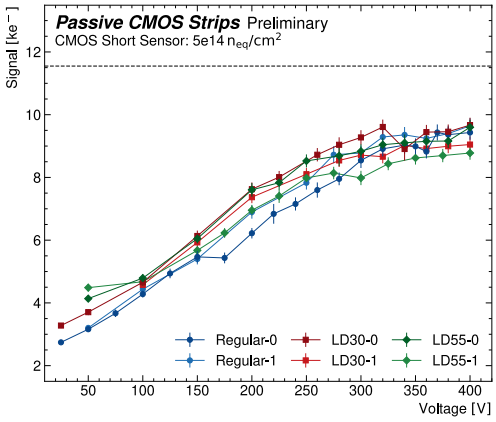


MIP particle going through center of the strip

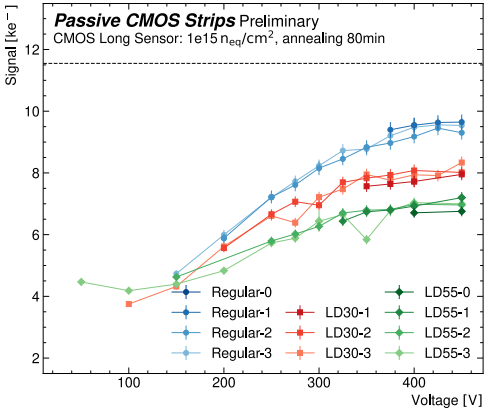


Irradiated: Charge in the ALiBaVa setup with Sr^{90}

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



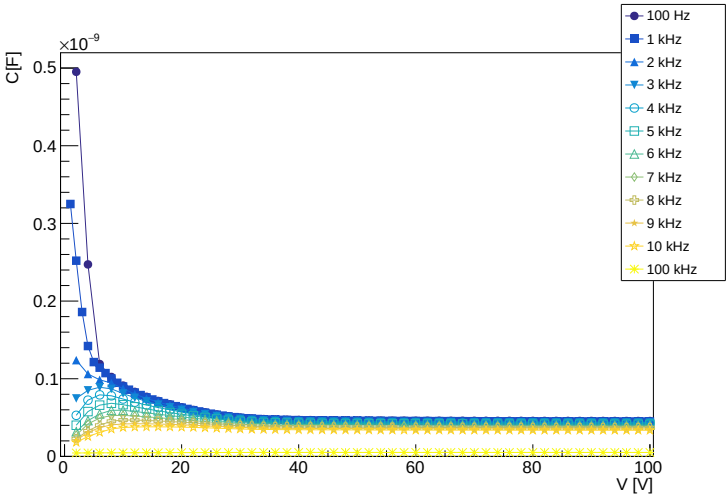
Neutrons 5×10^{14} n_{eq}/cm^2



Neutrons 1×10^{15} n_{eq}/cm^2

[N. Sorgenfrei, 40th RD50, CERN]

CV


100 Hz
1 kHz
2 kHz
3 kHz
4 kHz
5 kHz
6 kHz
7 kHz
8 kHz
9 kHz
10 kHz
100 kHz
×10⁻⁹
C[F]
0.5
0.4
0.3
0.2
0.1
0
0
20
40
60
80
100
V [V]