Overview of the Passive CMOS Strip detectors

Marta Baselga, Spyridon Argyropoulos, Jan-Hendrik Arling, Naomi Davis, Leena Diehl, Ingrid-Maria Gregor, Fabian Hügging, Hannah Jansen, Michael Karagounis, Kevin Kröninger, Fabian Lex, Ulrich Parzefall, Arturo Rodriguez, Surabhi Sharma, Simon Spannagel, Dennis Sperlich, Niels Sorgenfrei, Jens Weingarten, Iveta Zatocilova

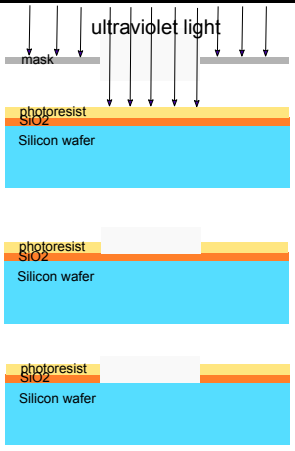
2/12/2022 - 41st RD50 Workshop, Sevilla

Motivation

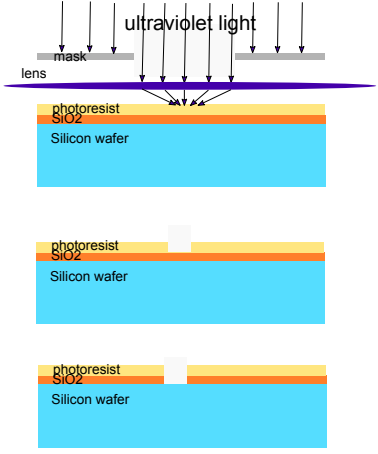
- All ATLAS and CMS upgrade strip detectors are fabricated in Hamamatsu Photonics HPK
- Seems like large area strips only are fabricated in microelectronics foundries
- Here we want to show that also CMOS foundries can fabricate strip detectors and do not have any impact in the performance

What changes regarding microelectronic foundries?

Microelectronics photolitography



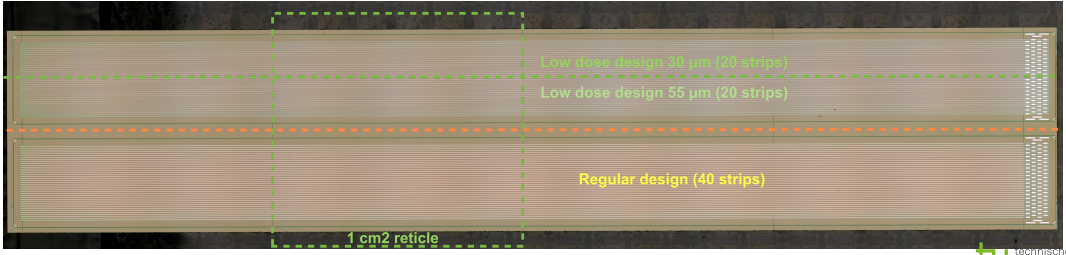
CMOS photolitography



[Image from wikipedia]

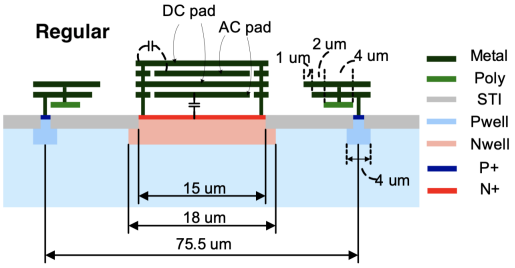
Passive CMOS Strip

- 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



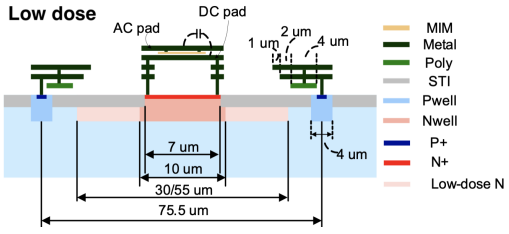
Two designs of strips: Regular design and Low Dose design

Regular design



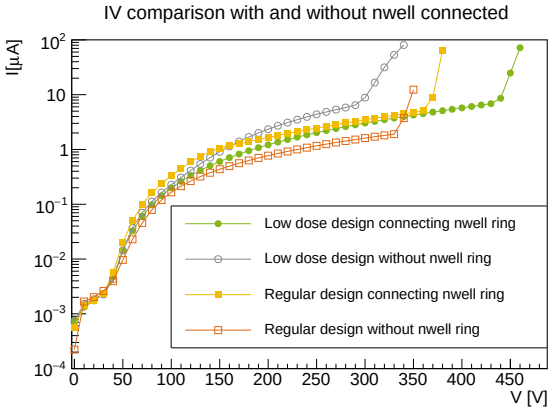
- Similar to the ATLAS strip design

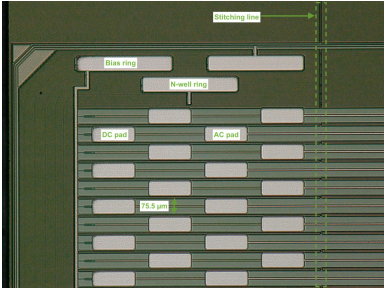
Low dose design



- Using low dose implant and a MIM capacitor

Electrical characterization: IV

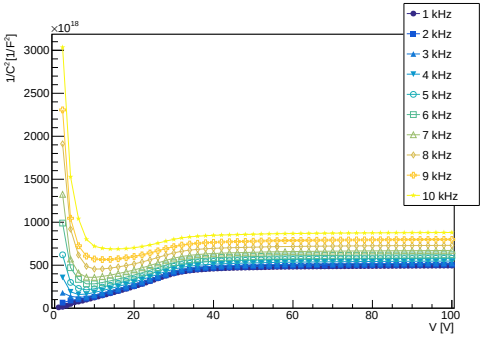




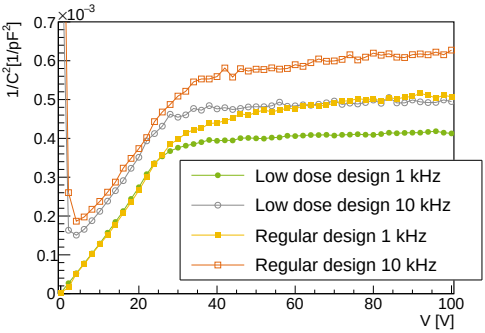
- IV curve shows an improvement when biasing the bias and the nwell ring together
- Probably the break down is happening to the edge of the detector

Electrical characterization: CV

CV with the bias pad



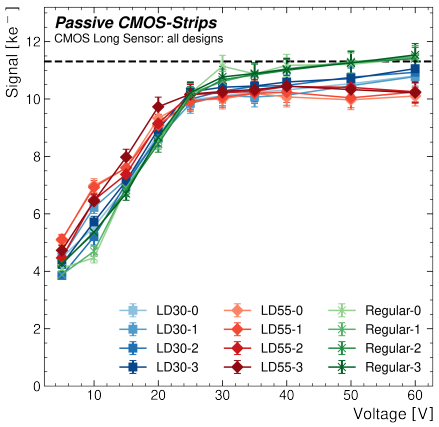
CV with the bias pad and nwell ring

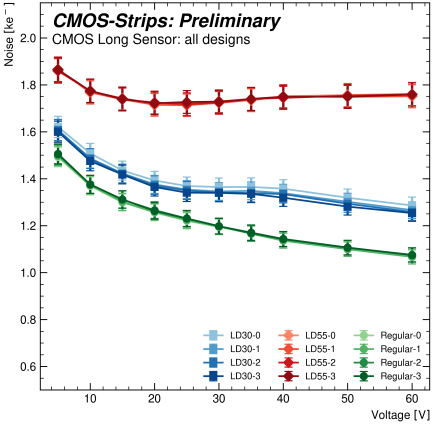


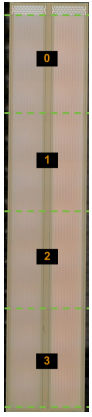
- Decrease of capacitance when increasing the frequency (small discrepancy with the results presented by S. Mägdefessel)
- The effect decreases biasing the nwell ring → some edge effect

Charge in the ALiBaVa setup

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



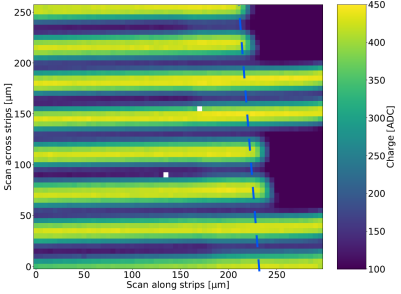




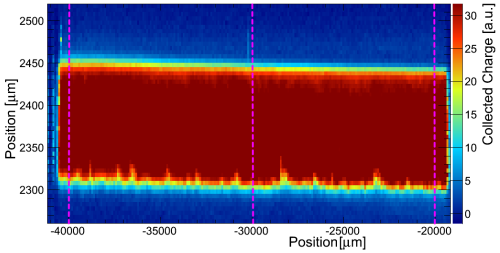
[NIMA 1033 (2022) 166671]

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]

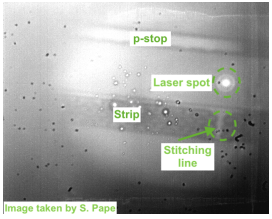


Edge TCT charge from a short LD30 sensor at 100 V (fully depleted). Stitching does not change the collected charge. [N. Sorgenfrei, 40th RD50, CERN]

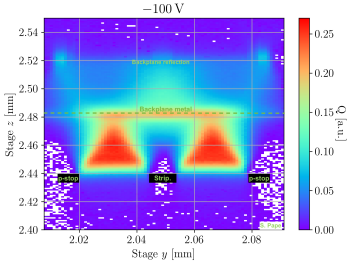
Two Photon Absorption Transient Current Technique measurements

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

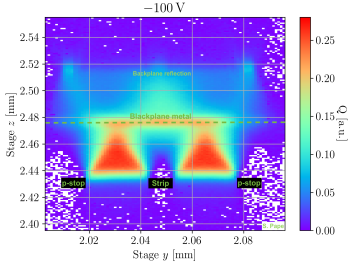
IR image



TPA-TCT in the stitch area



TPA-TCT outside the stitch

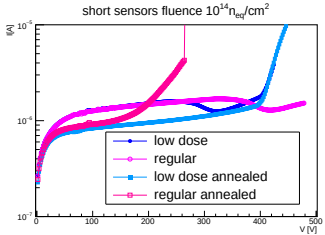


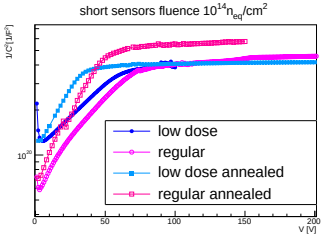
- Thanks to Sebastian Pape, Michael Moll, Marcos Fernandez Garcia, and Esteban Curras for the TPA-TCT measurements (ask them the questions about TPA-TCT)
- Check Sebastian's talk about the setup and measurements

Irradiated: IVs and CVs

Irraidated with protons at KIT

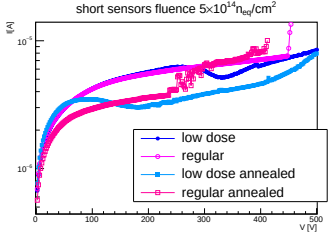
- 23 MeV protons at fluence 1×10^{14} n_{eq}/cm^2

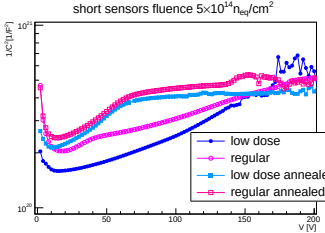




CV at 1 kHz

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

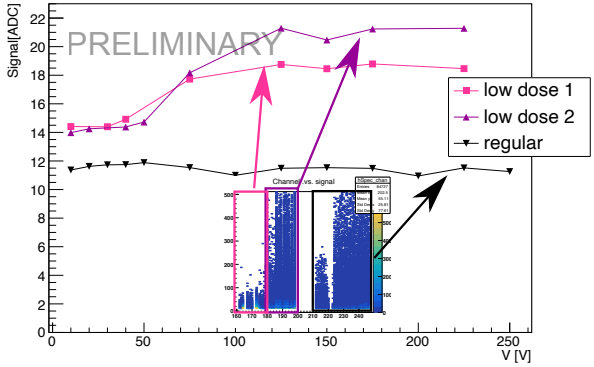




CV at 1 kHz

Irradiated: ALiBaVa setup with Sr^{90}

Irraidated with protons at KIT (23 MeV and annealed)

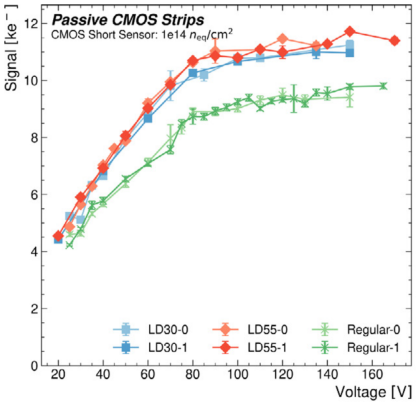


- Data not calibrated
- Regular design seems to stop working after irradiation

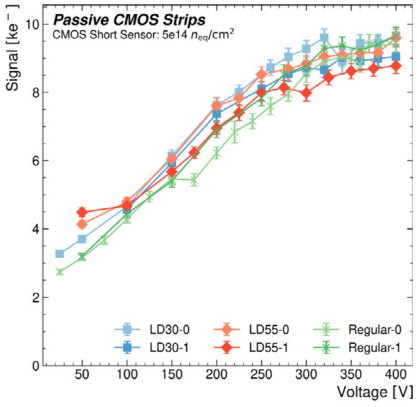
[12th PSD 2021 Birmingham]

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

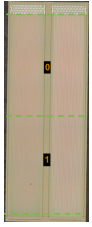
Signal of a short detector with Sr^{90} source irradiated



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



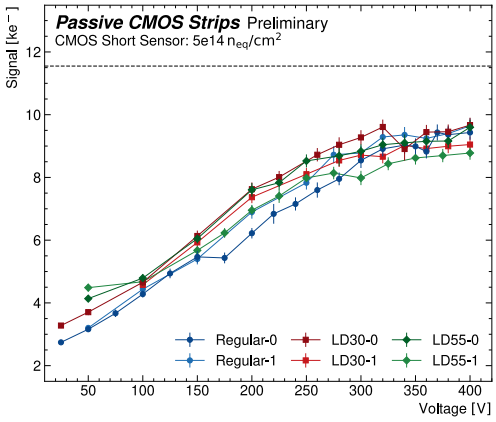
Neutrons fluence 5×10^{14} n_{eq}/cm^2



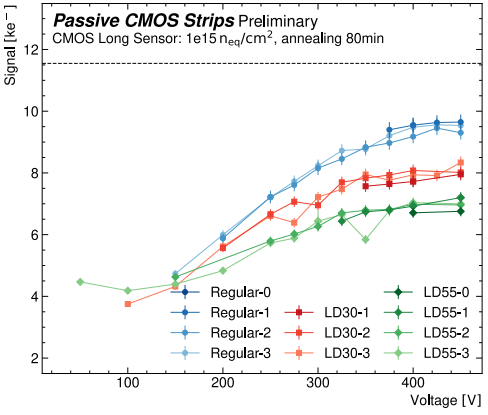
[NIMA 1039 (2022) 167031]

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

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



Neutrons 5×10^{14} n_{eq}/cm^2

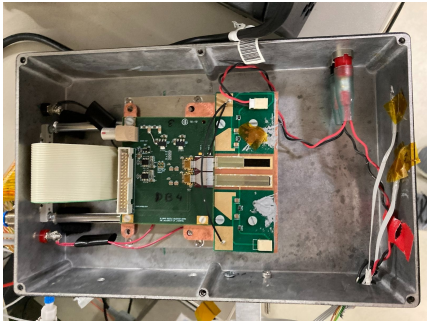


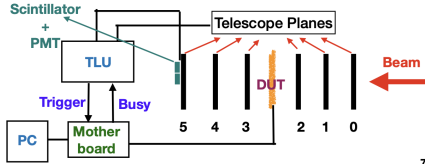
Neutrons 1×10^{15} n_{eq}/cm^2

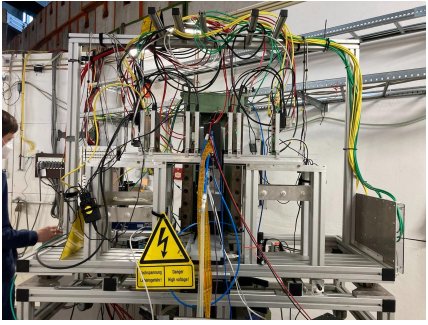
[N. Sorgenfrei, 40th RD50, CERN]

Testbeam campaigns

- Several Testbeams were done at DESY
- Electrons between 3 GeV and 3.4 GeV were used
- DAQ with ALiBaVa



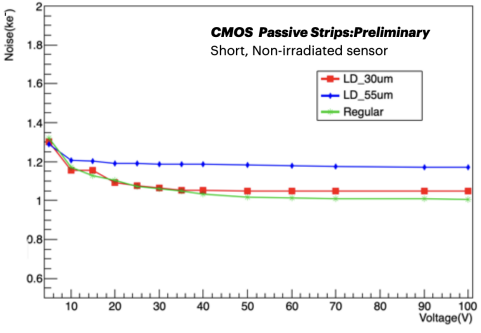


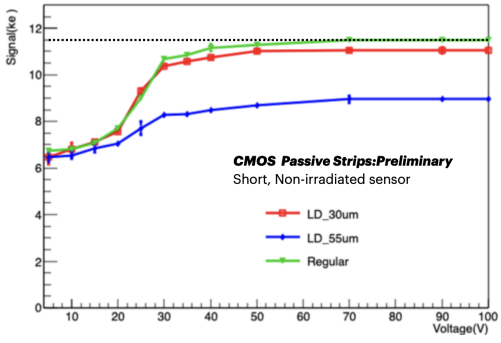


Testbeam results

Unirradiated sensor data @ 100 V bias voltage

All measurements are performed at 18° C



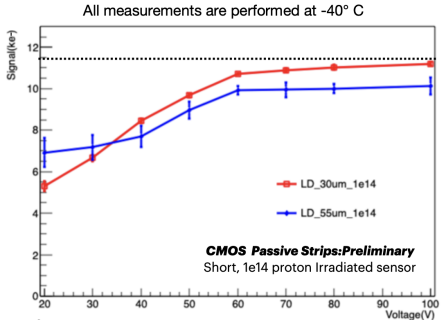


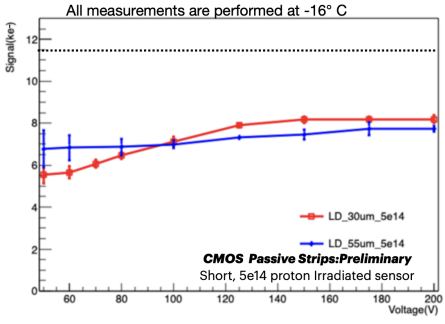
- The charge is similar as the lab tests
- Low Dose 55 µm design shows lower charge related to the Beettle chip configuration

[10th BTTB 2022, Lecce, Italy]

Testbeam Irradiated samples

Sensors irradiated with 23 MeV protons @KIT





- Regular design does not show charge, still to be investigated
- The sensors are still working after irradiation with protons
- Implementation of ALiBaVa data to Corryvreckan ongoing

[10th BTTB 2022, Lecce, Italy]

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 the implementation of ALiBaVa in Corryvreckan is ongoing (great work from Fabian Lex)
- Finishing some pending measurements (such as Corryvreckan reconstruction or irradiation with high energy protons measurements)

Future work

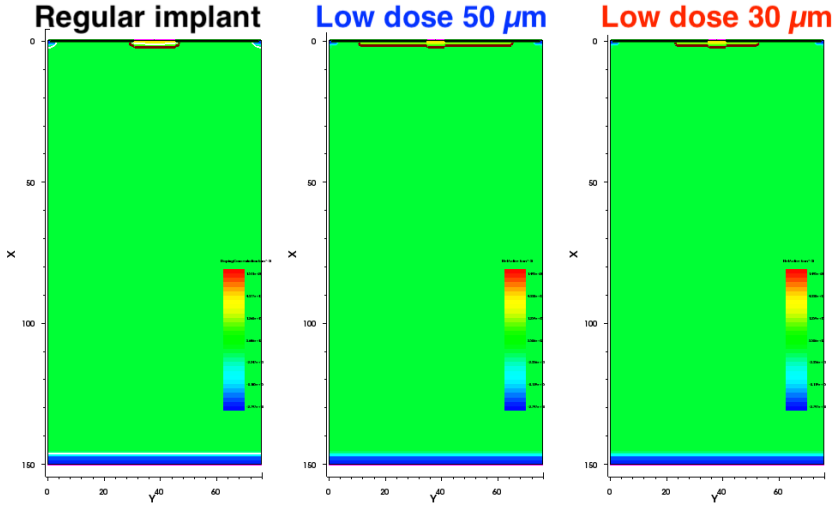
- Planning a new production with the electronics implemented in the strips is ongoing $\rightarrow$ that would allow to avoid all the bondings of the strips to the chips
- Production of a full wafer size strip detector with a CMOS foundry

Acknowledgements

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

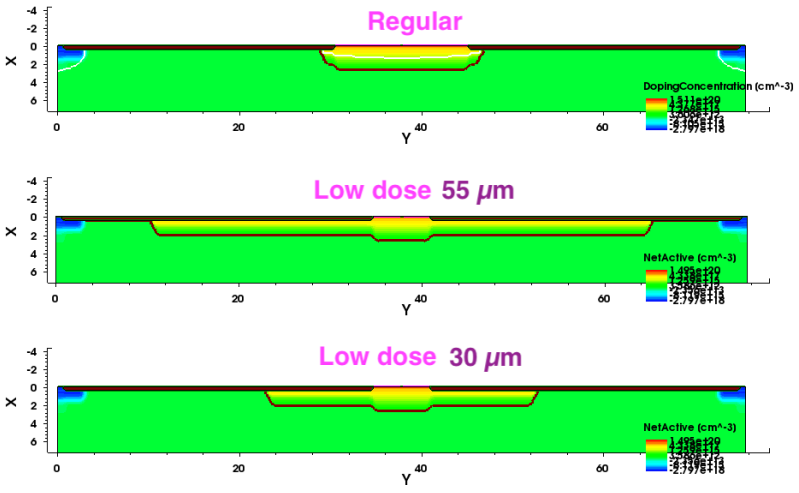
Backup

TCAD simulations: Simulated device



38th RD50 Workshop (On Line), June 2021

TCAD simulations: Simulated device zoom



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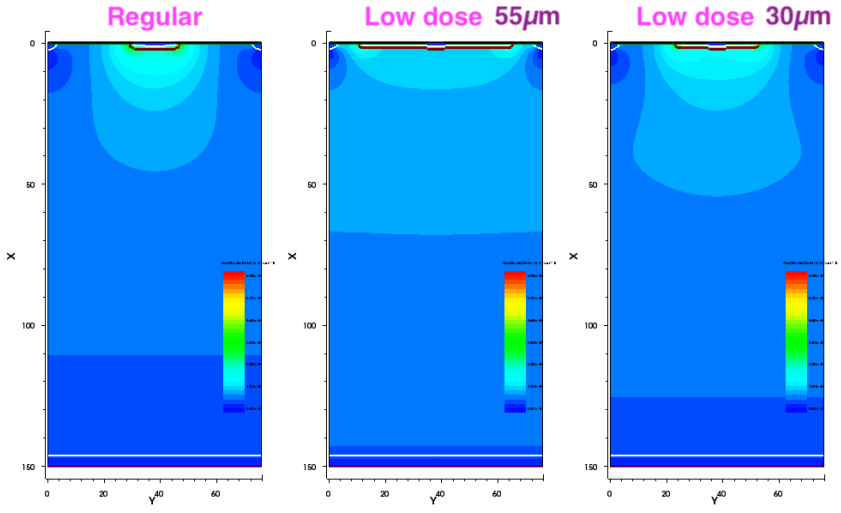
TCAD simulations: Simulated Electric field at 100 V



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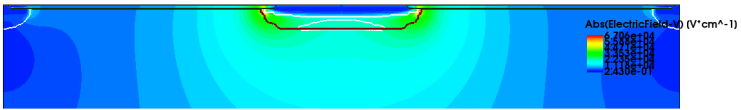
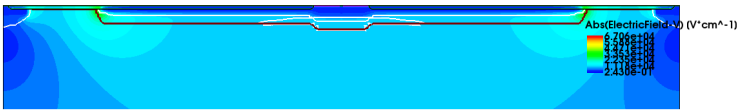
TCAD simulations: Electric field zoom

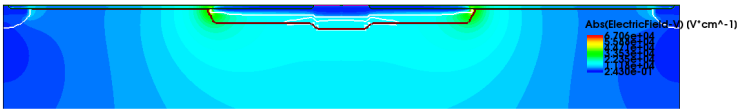
Regular implant



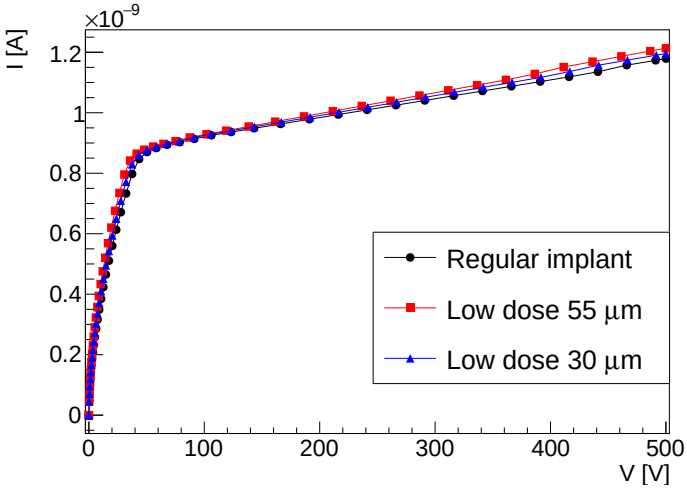
Low dose 55 μm



Low dose 30 μm



TCAD simulation: Current voltage curve



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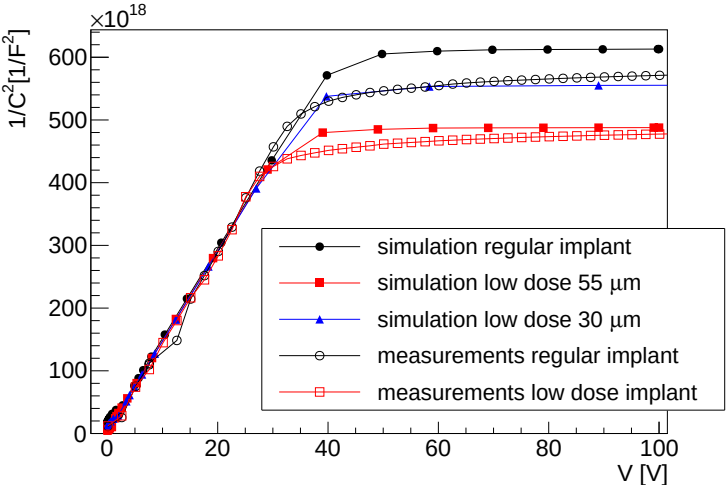
TCAD simulation compared with data: capacitance voltage curves



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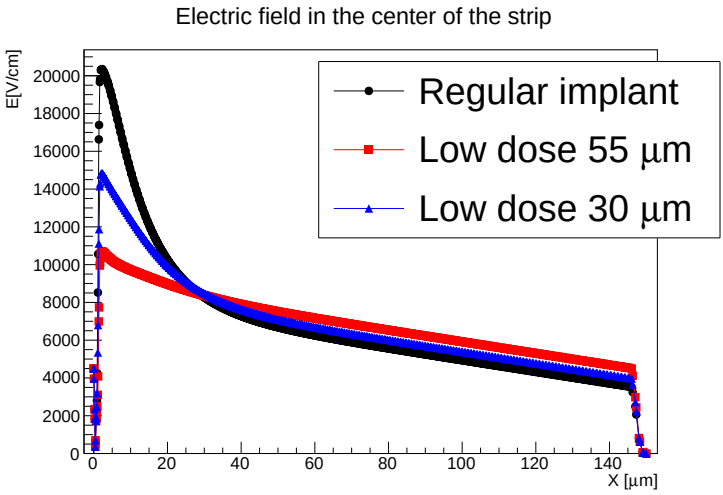
TCAD simulation: Electric field 100 V at the center of the strip



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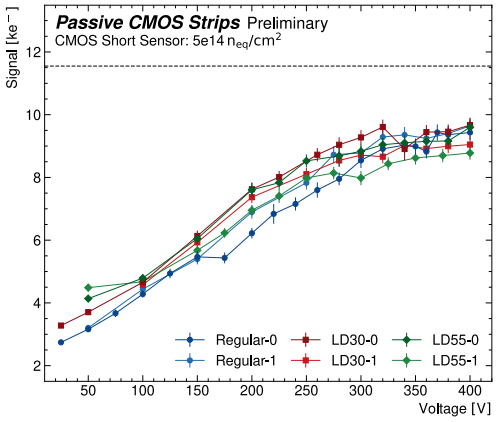
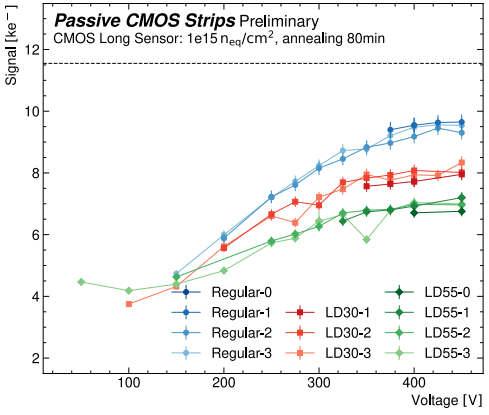
Irradiated: Charge in the ALiBaVa setup with Sr^{90}

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



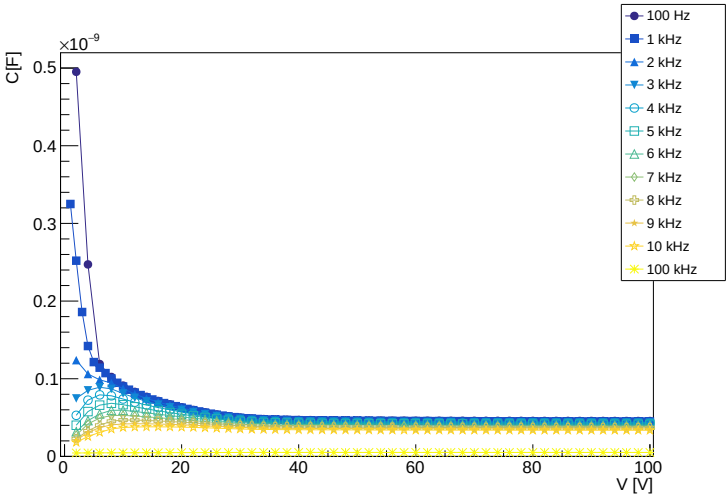
Neutrons 5×10^{14} n_{eq}/cm^2



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]