DRD3 CERN 2024

WP2 Proposal IMB-CNM

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Project 1: Trench Isolated inverse LGAD for fill factor optimization

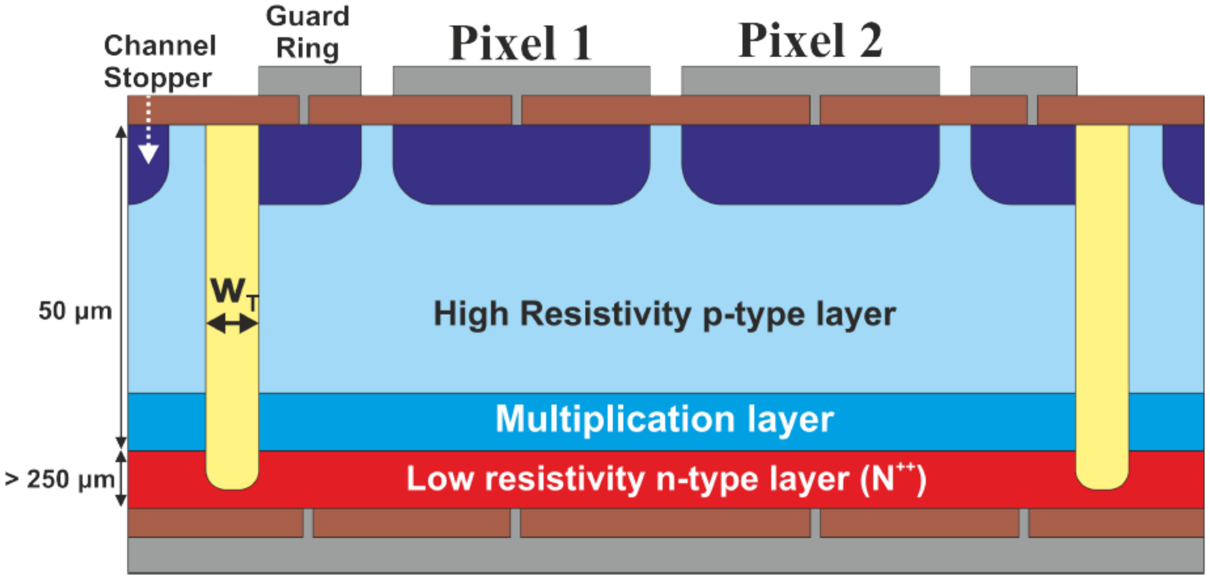
Project 2: AC-LGAD for low penetrating radiation

Project 3: Deep junction LGAD, stabilization of the technology at IMB-CNM

Project 4: Double sided 3D detectors for ultra-radiation hard timing applications.

TiLGAD: Trench Isolated inverse LGAD for fill factor optimization

- Enhancing the fill factor is essential to maximize the LGAD time and spatial resolution and improves detection efficiency
- New design: Trench isolated inverse LGAD targets at achieving 100% FF by design.

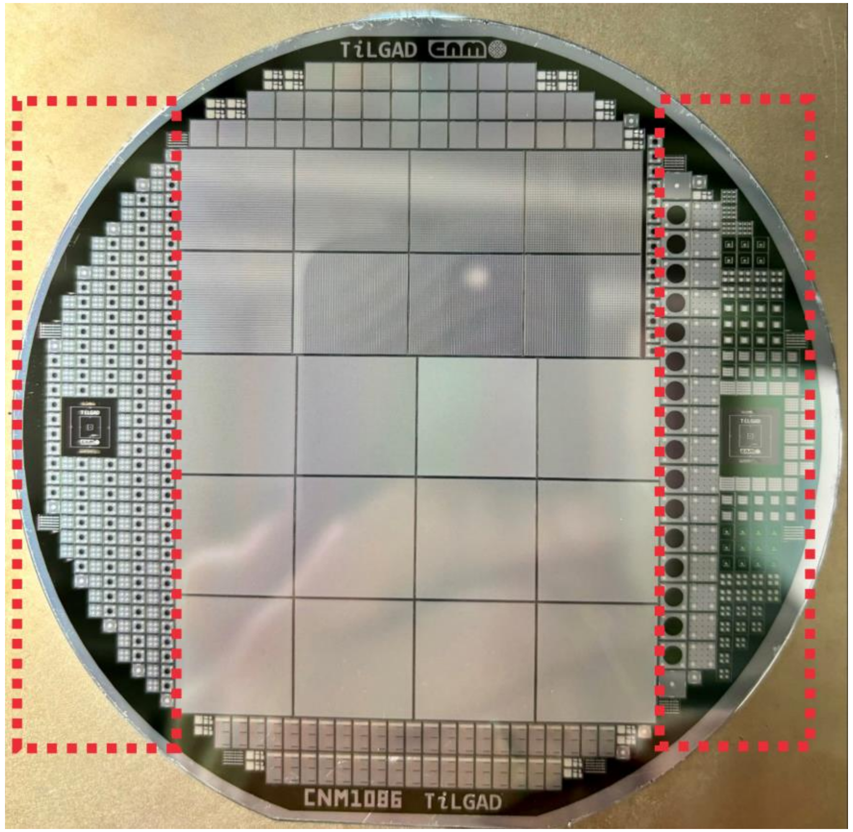


Reference: Jairo Villegas: PhD Thesis (soon available)

- Designed and fabricated at IMB-CNM
- Multiplication region fabricated over a thick low resistivity n-type handle wafer
- Two techniques:
  - Epitaxial growth of Multiplication and High resistivity p-type layer
  - Si-Si wafer bonding (multiplication layer implanted on a high resistivity p-type wafer)
- Single-side photolithographic process:
  - Deep trench isolation of the junction
  - Inverse LGAD (pixilation on the P^+ Ohmic contact)

TiLGAD: Trench Isolated inverse LGAD for fill factor optimization

- First fabrication at IMB-CNM



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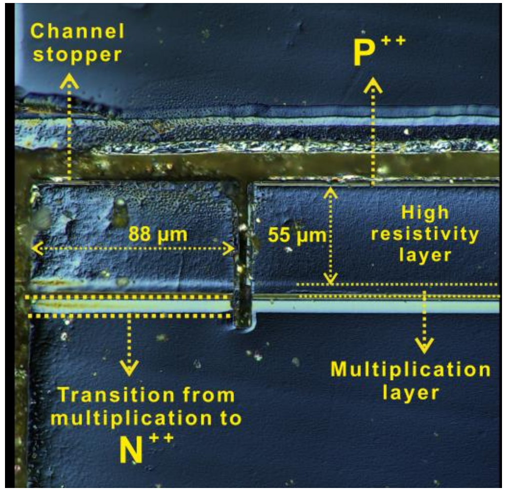
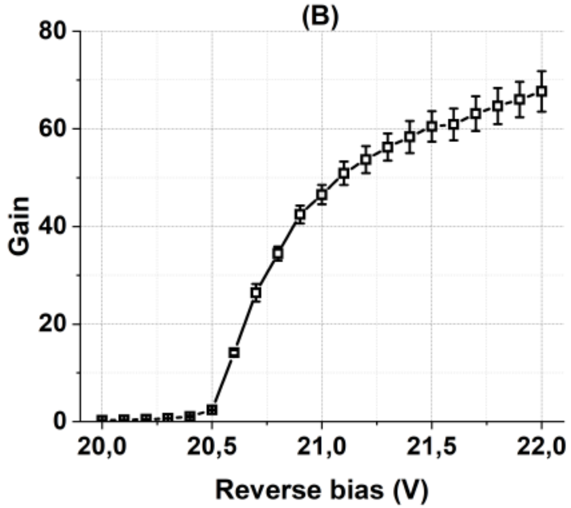
- 6 Wafers:
  - W1-W3 on Si-Si wafers
  - W4-W6 Epitaxial wafer
- Main outcomes of the first fabricated devices:
  - Excellent trench isolation
  - High dependence on the accuracy of the Epi or Si-Si substrates (so far, not enough precise: APD behaviour)





TiLGAD: Trench Isolated inverse LGAD for fill factor optimization

List of already interested institutions

Country	Collaborating Institution	Town	Institution Code	Contact
Spain	IMB-CNM, CSIC	Barcelona	CNM	**Pablo Fernández Martínez***
Spain	IFCA, CSIC	Santander	IFCA	Iván Vila Álvarez
Spain	CNA	Sevilla	CNA	Mª Carmen Jiménez Ramos
Spain	ITA	Zaragoza	ITA	Fernando Arteche
Scotland	University of Glasgow	Glasgow		Richard Bates
Montenegro	University of Montenegro	Podgorica		Gordana Lastovicka-Medin
Czech Rep.	Czech Technical University	Prague	Czech Tech. University	Peter Svirha

Potential links to other WG:

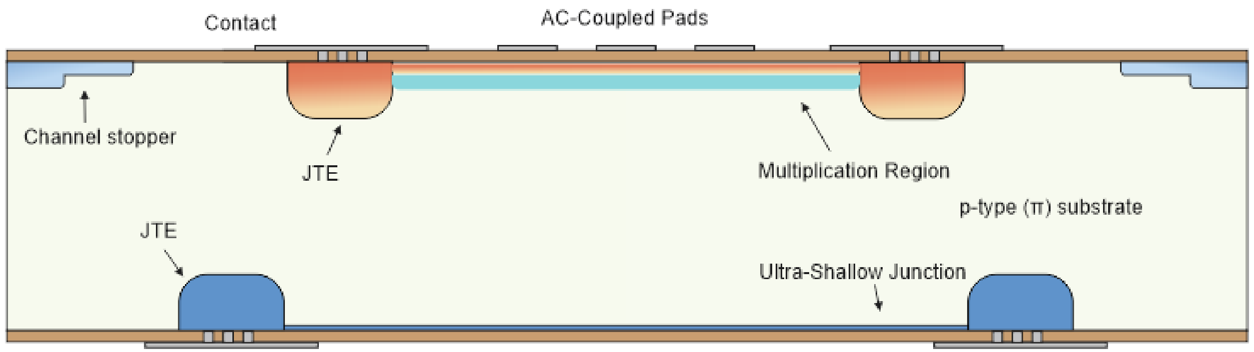
- WG3 for radiation damage characterization
- WG5 for characterization with test beams
- WG4 for simulation
- DRD7 for readout and interconnection

List of missing topics/not covered activities

- Irradiation campaigns
- Test beam characterization at CERN
- Simulation of radiation damage
- Timing studies

AC-Coupled LGAD.

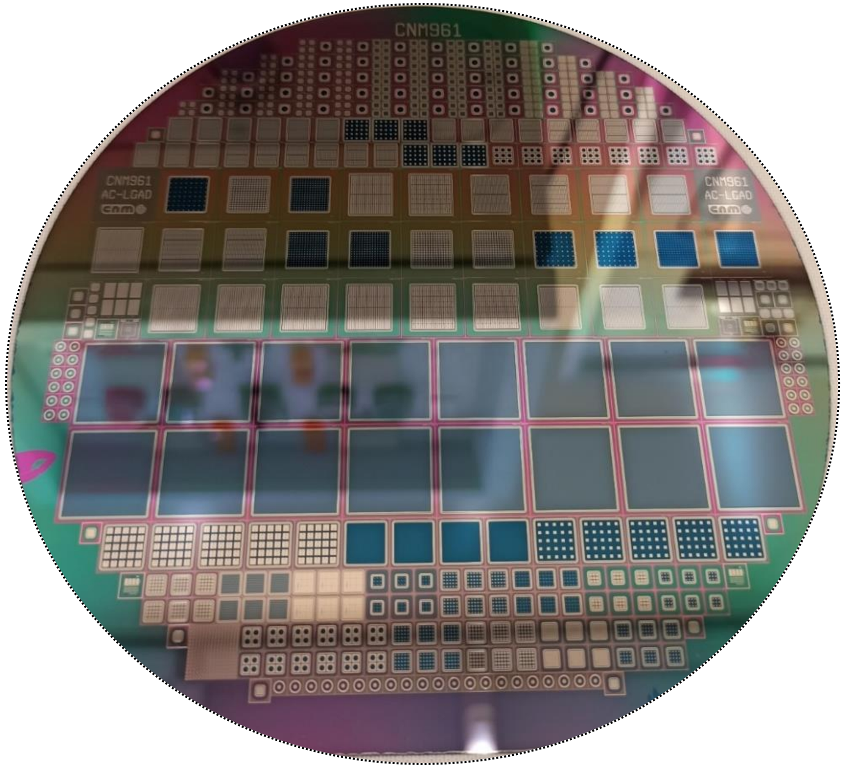
- Enhancing the fill factor is essential to maximize the LGAD time and spatial resolution and improves detection efficiency
- New design: AC-LGAD targets at achieving 100% FF by design with capability of detecting low penetrating radiation from backside illumination



- Designed and fabricated at IMB-CNM
- Modelled using TCAD and PSPICE
- AC-LGAD replaces the segmentation of the pad implants into continuous sheets of multiplication layer and n+ layer
  - Resistive n+ layer
  - 100% fill factor
  - Only metal is pixelated
  - Careful design of coupling oxide/resistive layer and metal pads required.

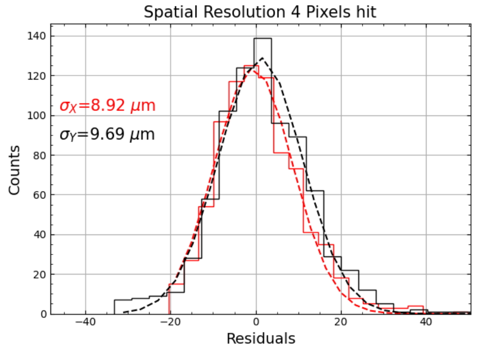
AC-Coupled LGAD for low penetrating radiation.

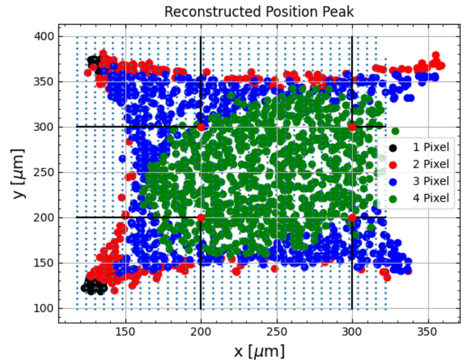
- 2nd fabrication at IMB-CNM



1st run fabricated in 2022
- Showed low gain (1.5-2).
- High Leakage current (10s of µAs)
- Good spatial resolution ≈10 µm

2nd Run - 5 Wafers:
- 300µm p-type substrate
- 5 multi implant doses to tune gain
- Shallow back contact
- Range of pixel arrays (3x3-656x656)
- Range of pixel sises (30um-500um)
- Run will finish **February 2025**





1. *Goal is to produce an AC-LGAD with excellent timing resolution, excellent spatial resolution with 100% fill factor.*
2. *In parallel produce a detector capable of detecting low penetrating particles*
3. *Produce a detector for low energy X-rays for synchrotron applications.*

AC-Coupled LGAD for low penetrating radiation.

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Scotland	University of Glasgow	Glasgow		Richard Bates

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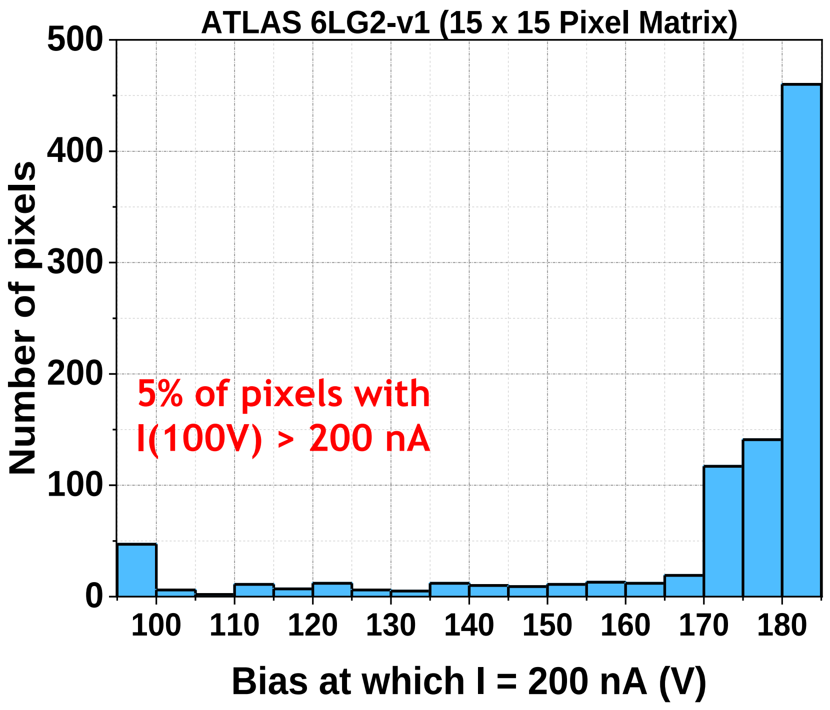
List of missing topics/not covered activities

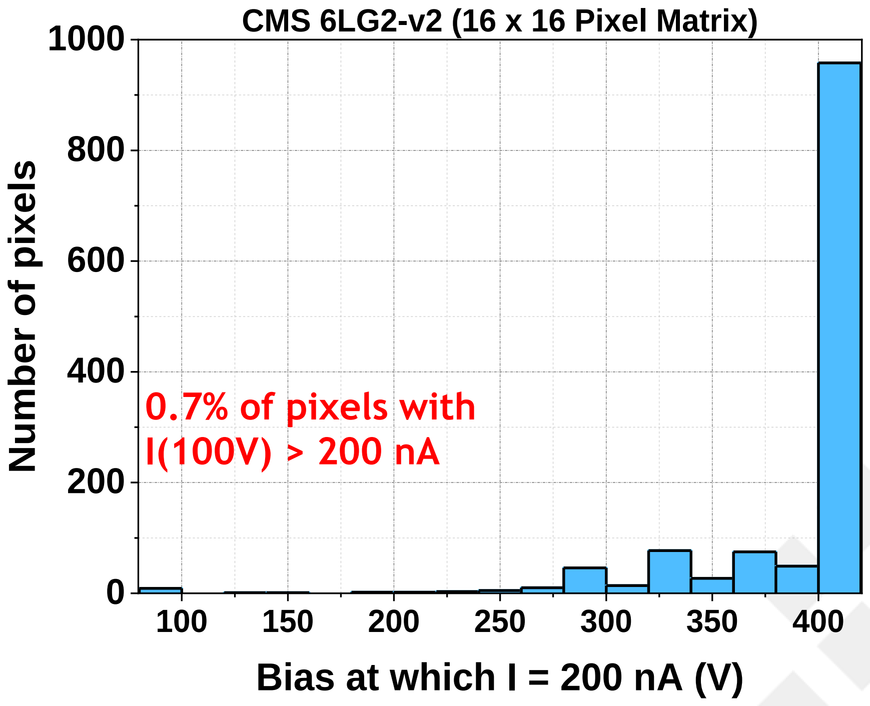
- Irradiation campaigns
- Test beam characterization at CERN and/or Diamond Light Source/ALBA (Synchrotrons)
- Simulation of radiation damage (X ray and NIEL)
- Timing/Spatial Resolution studies

Deep junction LGAD, stabilization of the technology at IMB-CNM

Pixel yield on standard CNM LGADs

- Even if the current levels and the pixel yield was overall good, there was a dispersion in V_{BD} higher than desirable for large area pixelated devices

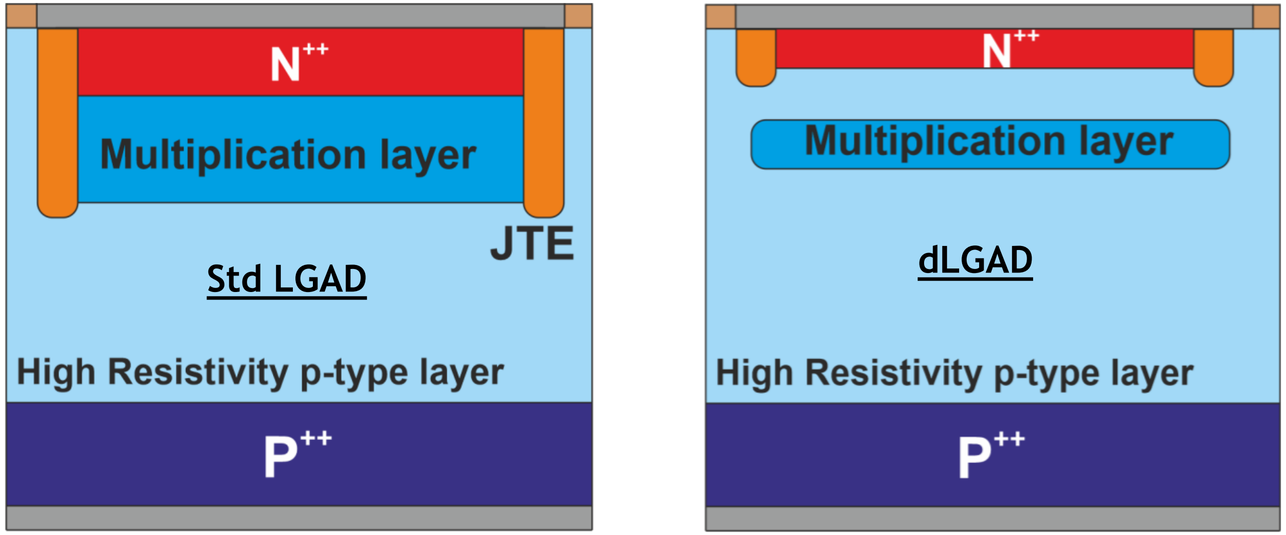


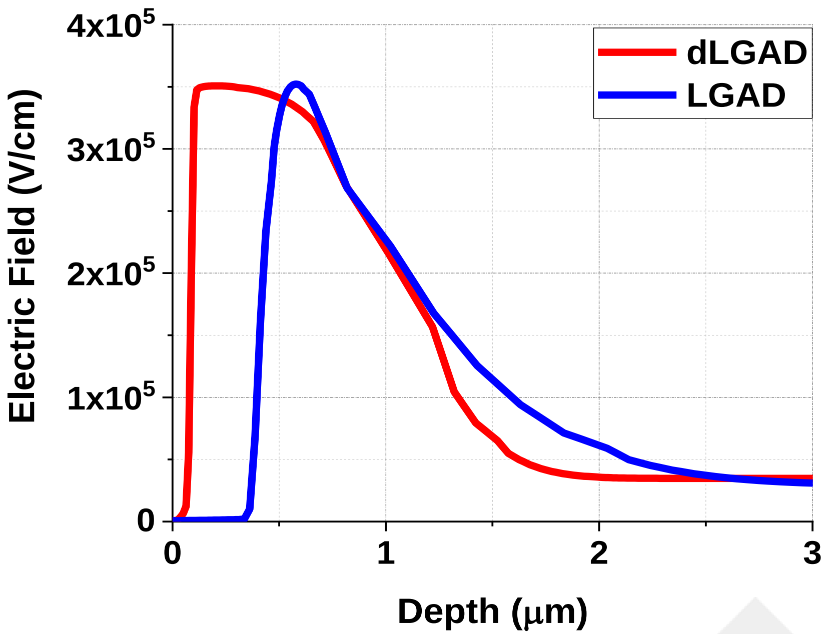


Reference: Jairo Villegas: https://doi.org/10.1016/j.nima.2024.169424

Deep junction LGAD, stabilization of the technology at IMB-CNM

- This project aims at improving the yield of large area pixelated LGAD through a more stable technological process, which includes an optimized doping profile and uniform response across a large area sensor.





- In a LGAD, the N^{++} and the Multiplication layer are overlapped, and the electric field peaks at the PN junction
- In a dLGAD, the N^{++} and the Multiplication layer are physically separated, and the electric field is nearly flat within this gap

Deep junction LGAD, stabilization of the technology at IMB-CNM

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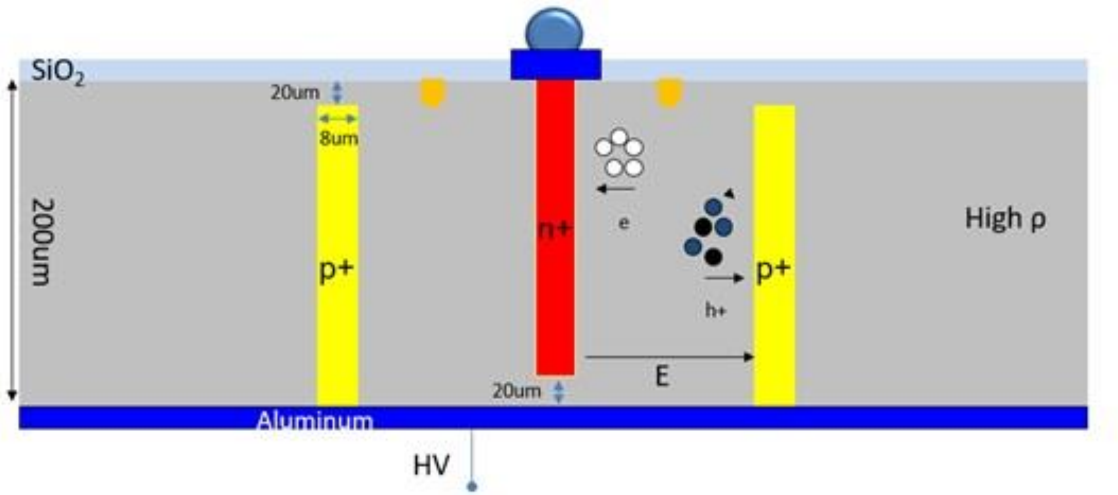
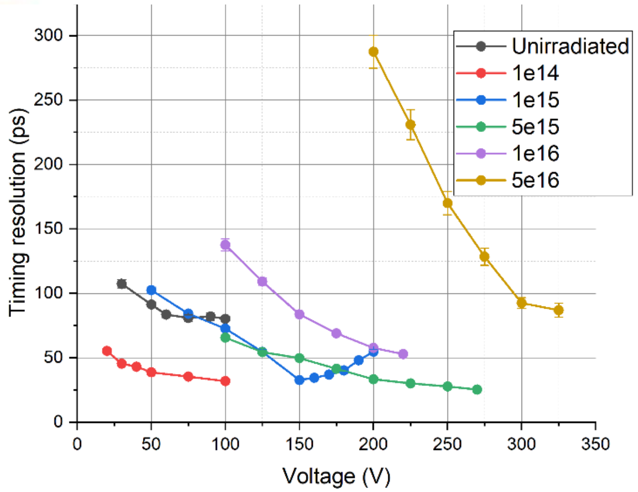
Double sided 3D detectors for ultra-radiation hard timing applications



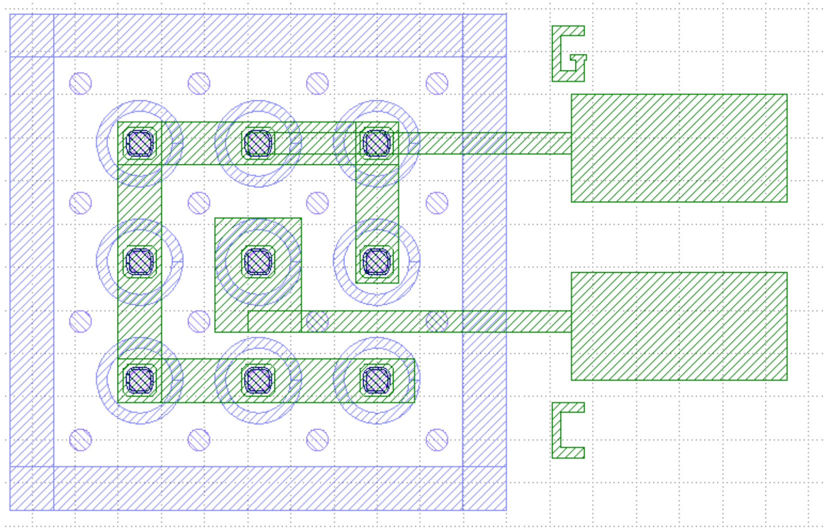


- 3D detectors were developed by implementing the junctions as columns through the sensor bulk
- This minimizes the drift distance of the created charge carriers
- Improved radiation hardness (less probability of carriers being trapped by defect points)
- And Improved timing resolution compared to standard planar sensors.

Electric field not uniform, need to design sensor for timing applications.

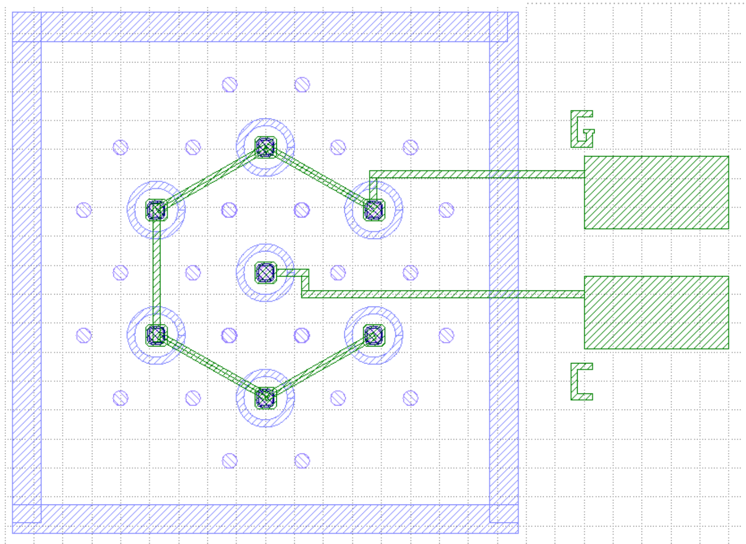
Double sided 3D detectors for ultra-radiation hard timing applications

Square pixels



Motivation and goals

1. Create an ultra-radiation hard detector for use in high luminosity environments, i.e. HL-LHC, FCC.
2. Optimise the design for timing applications
   - Extrapolate TCAD simulation to Montecarlo simulation (Garfield). First results already produced by Victor Coco.
   - What is the best thickness?
   - What is the best pixel size/shape?



Hexagonal pixels
-> Improved timing/Radiation resistance

Double sided 3D detectors for ultra-radiation hard timing applications

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Poland	AGH University of Krakow	Krakow	UGH	Tomasz Szumlak
Germany	Freiburg University	Freiburg		Ulrich Parzefall
Scotland	University of Glasgow	Glasgow		Richard Bates
Slovenia	Jožef Stefan Institute	Ljubljana	JSI	Gregor Kramberger
Switzerland	CERN, LHCb	Geneva	CERN	Victor Coco
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Acknowledegments

Acknowledgements

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