

First 50 μ m thick LGAD fabrication at CNM for the HGTD and CT-PPS

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Work done in the framework of the RD50 CERN collaboration

Outline

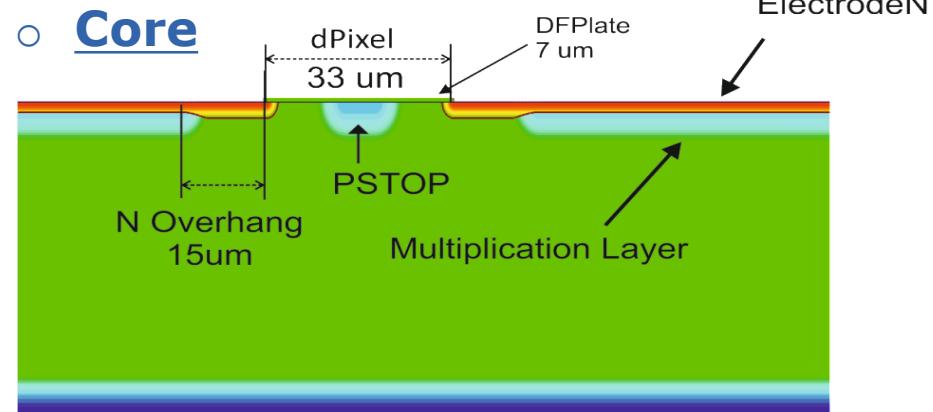
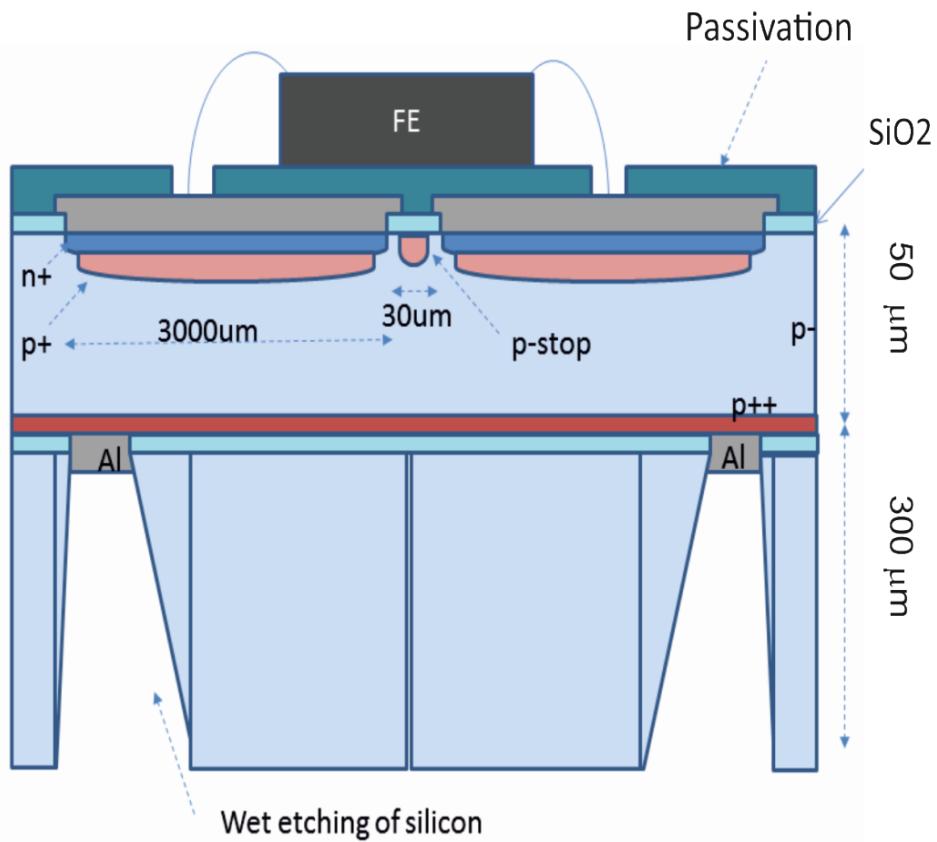
- **Motivation**
- **HGTD & CT-PPS Structure Simulation**
- **HGTD & CT-PPS Electrical Performance Simulation**
- **HGTD & CT-PPS Mask set**
- **HGTD & CT-PPS Fabrication Run**
- **First Measurements**
- **Conclusions**

50 μm thick LGAD Motivation

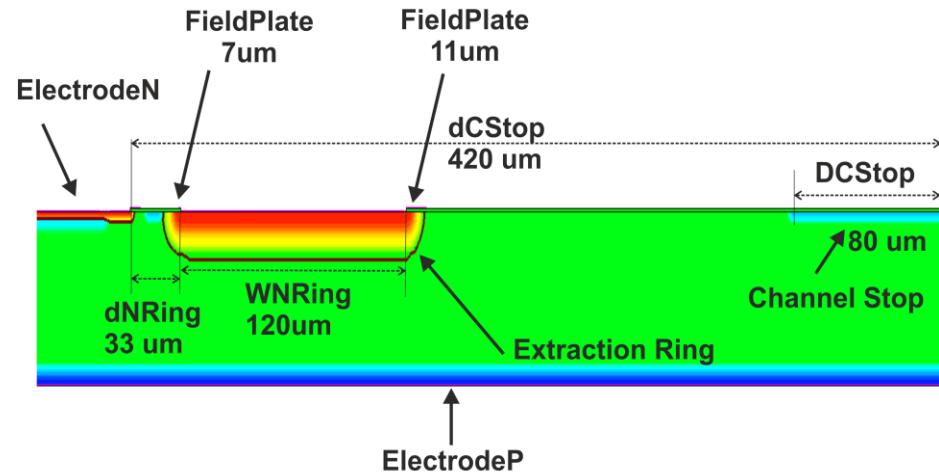
- Integrate a small gain (5-10) in a sensor while maintaining similar noise levels and avoiding readout front-end saturation & pile-up effects.
- A reduction of substrate thickness from 300um to 50um will reduce the Bulk Radiation Effects and will decrease the collection time.
- ATLAS is proposing Ultra Fast Silicon Detector based on LGAD as one of the technical options for the High Granularity Timing Detector (HGTD)
- CMS-TOTEM are considering UFSD to be the timing detectors for the high momentum- high rapidity Precision Proton Spectrometer (CT-PPS)

High Granularity Timing Detector (HGTD)

- Pixel 3000x3000 μm^2 and 2000x2000 μm^2
- High Resistivity P-type 50 μm SOI Wafers
- New Run in progress with 75 μm & 50 μm Epitaxial Wafers

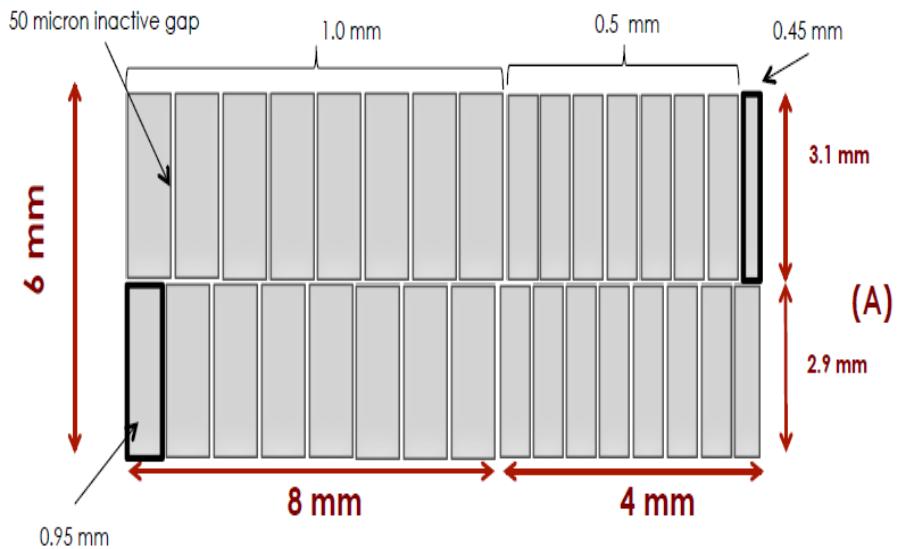


○ Termination

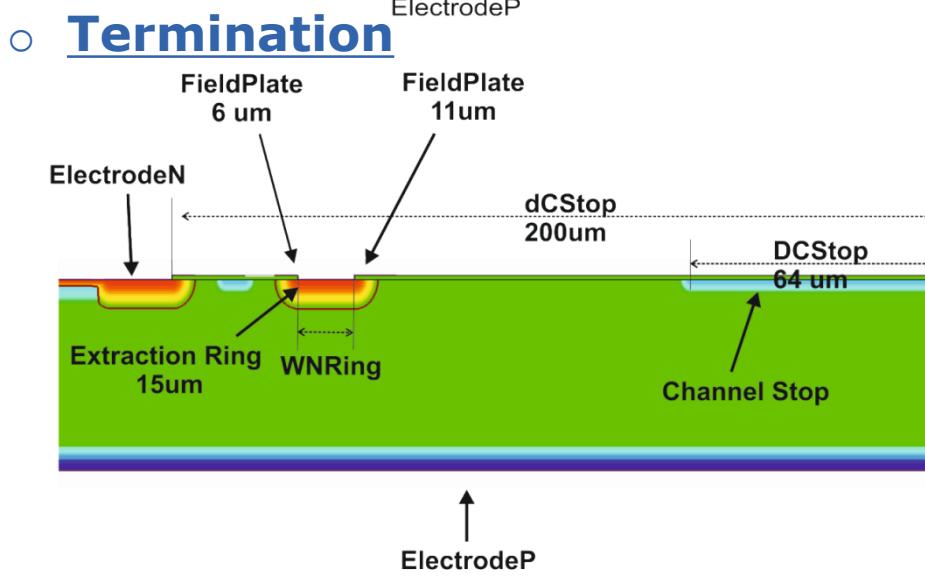
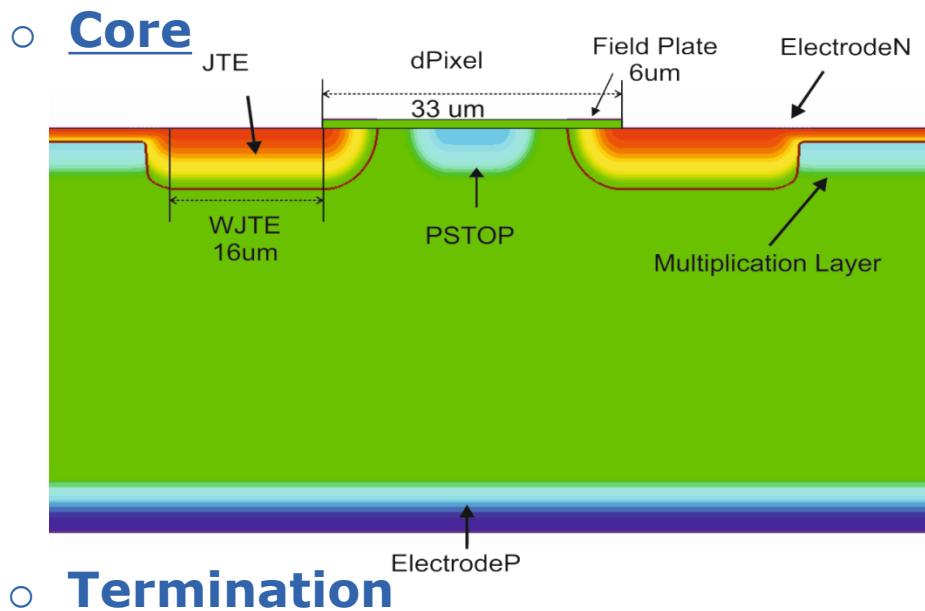


CMS-TOTEM Precision Proton Spectrometer (CT-PPS)

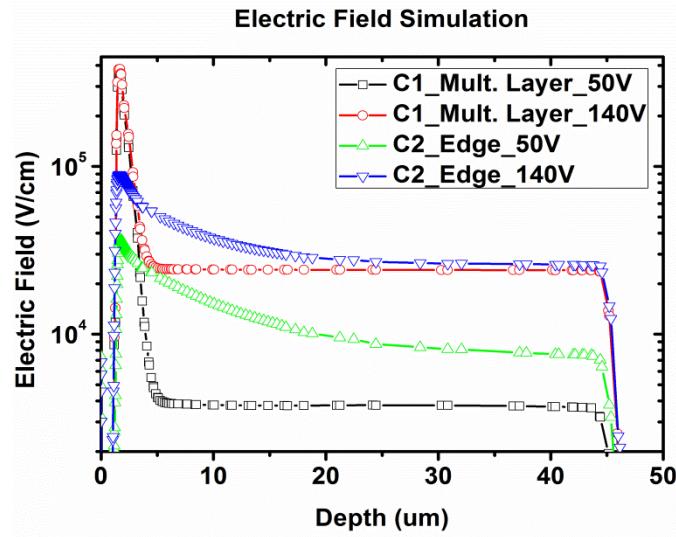
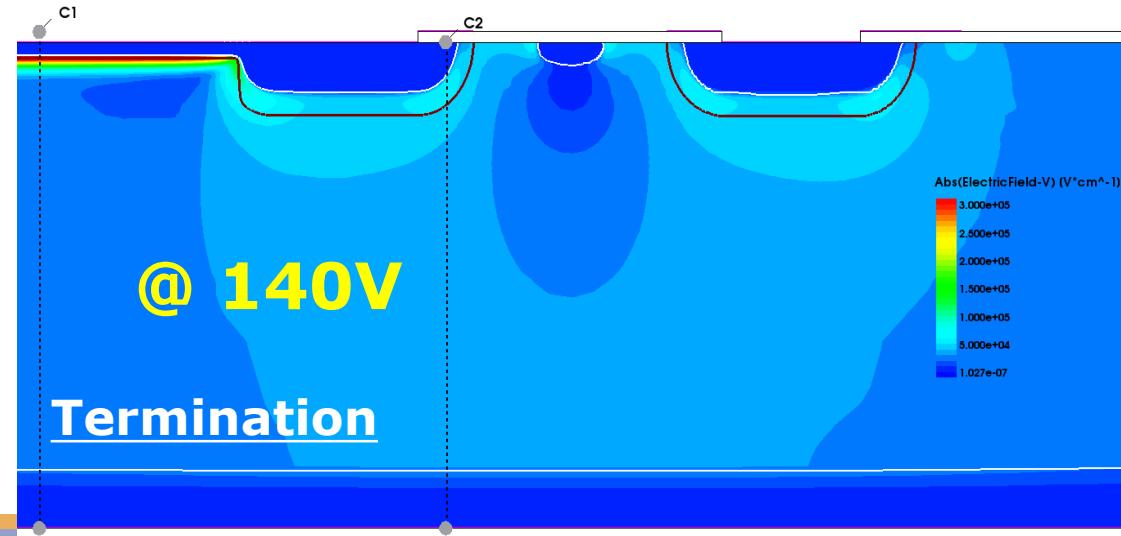
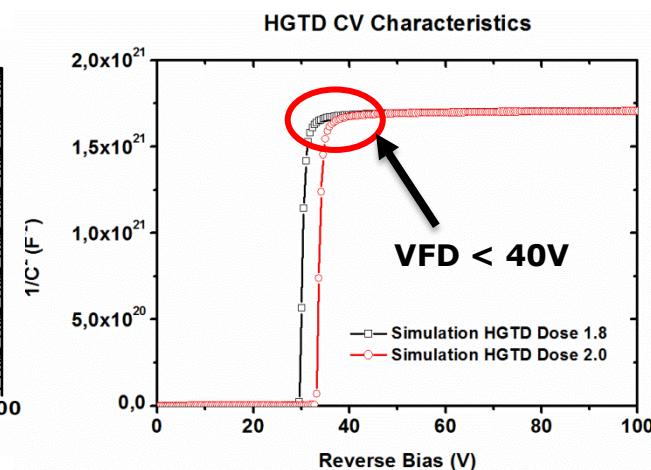
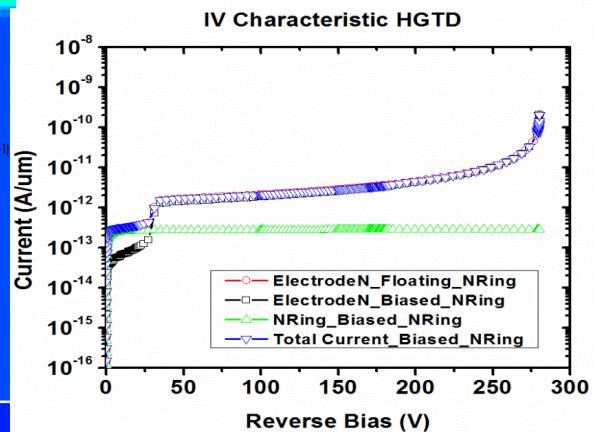
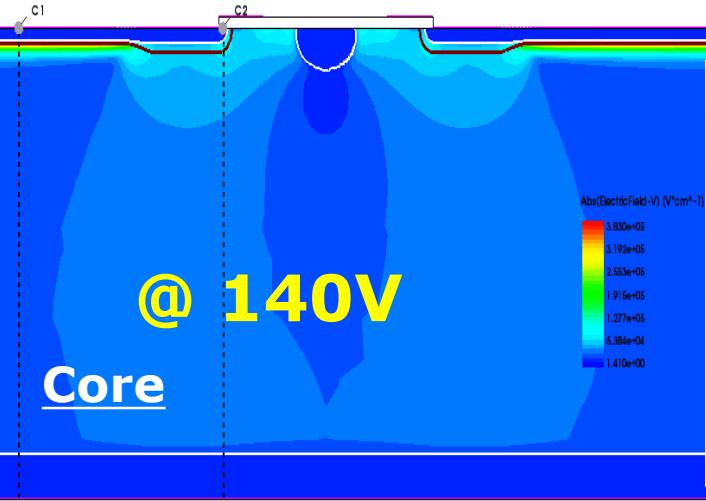
CT-PPS proposed sensor geometry



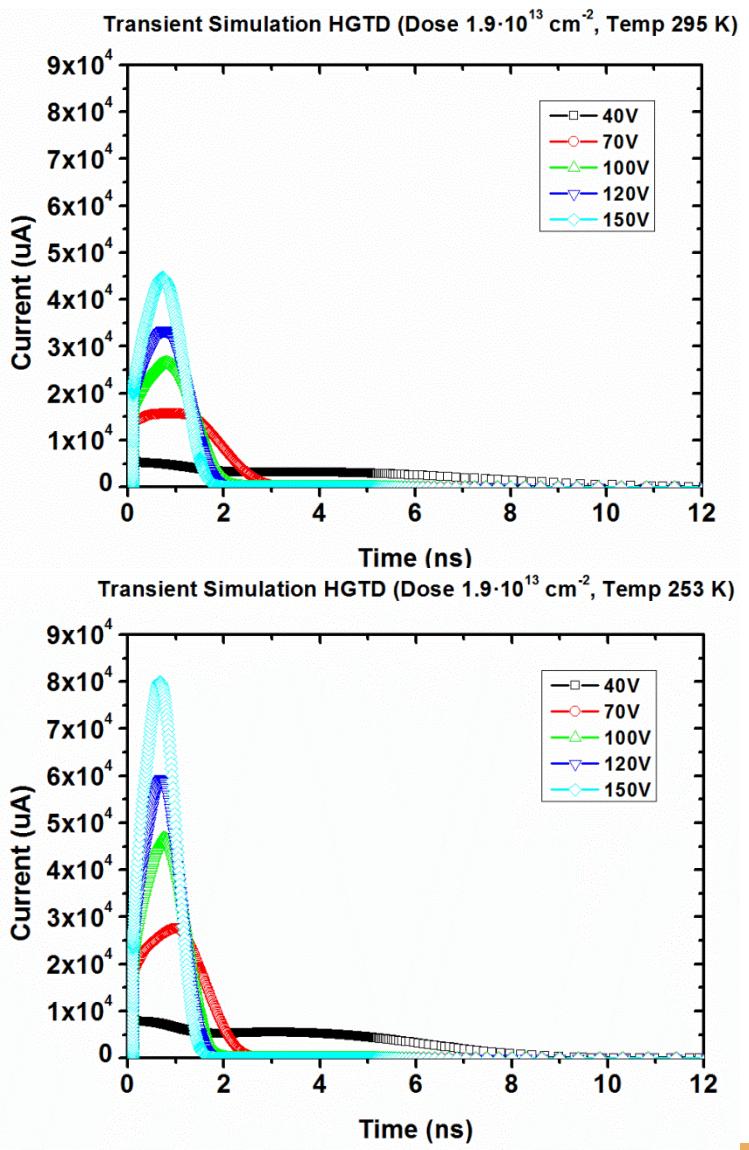
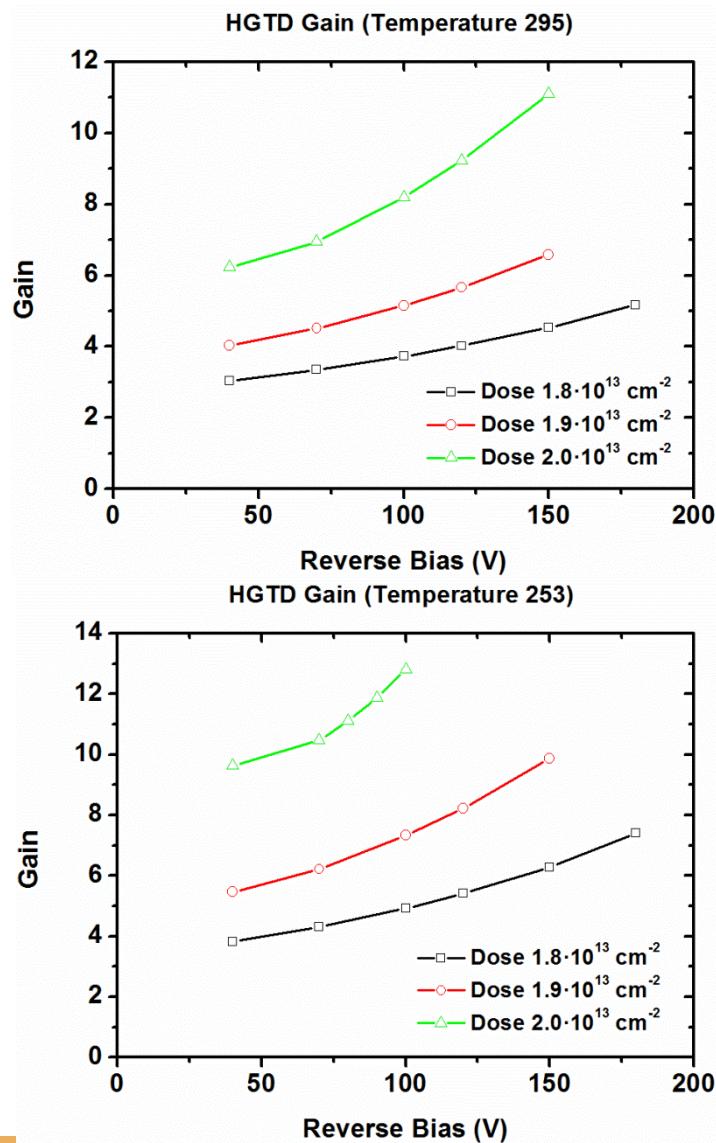
- Asymmetric design. Segmented accordingly to the hit density distribution
- Area = 12mm X 6mm
- Thickness = 50 μ m
- Slim edge of 200 μ m on the side facing the beam
- Gain \sim 15
- Radiation Hard
- Specifications proposed by Nicolo Cartiglia



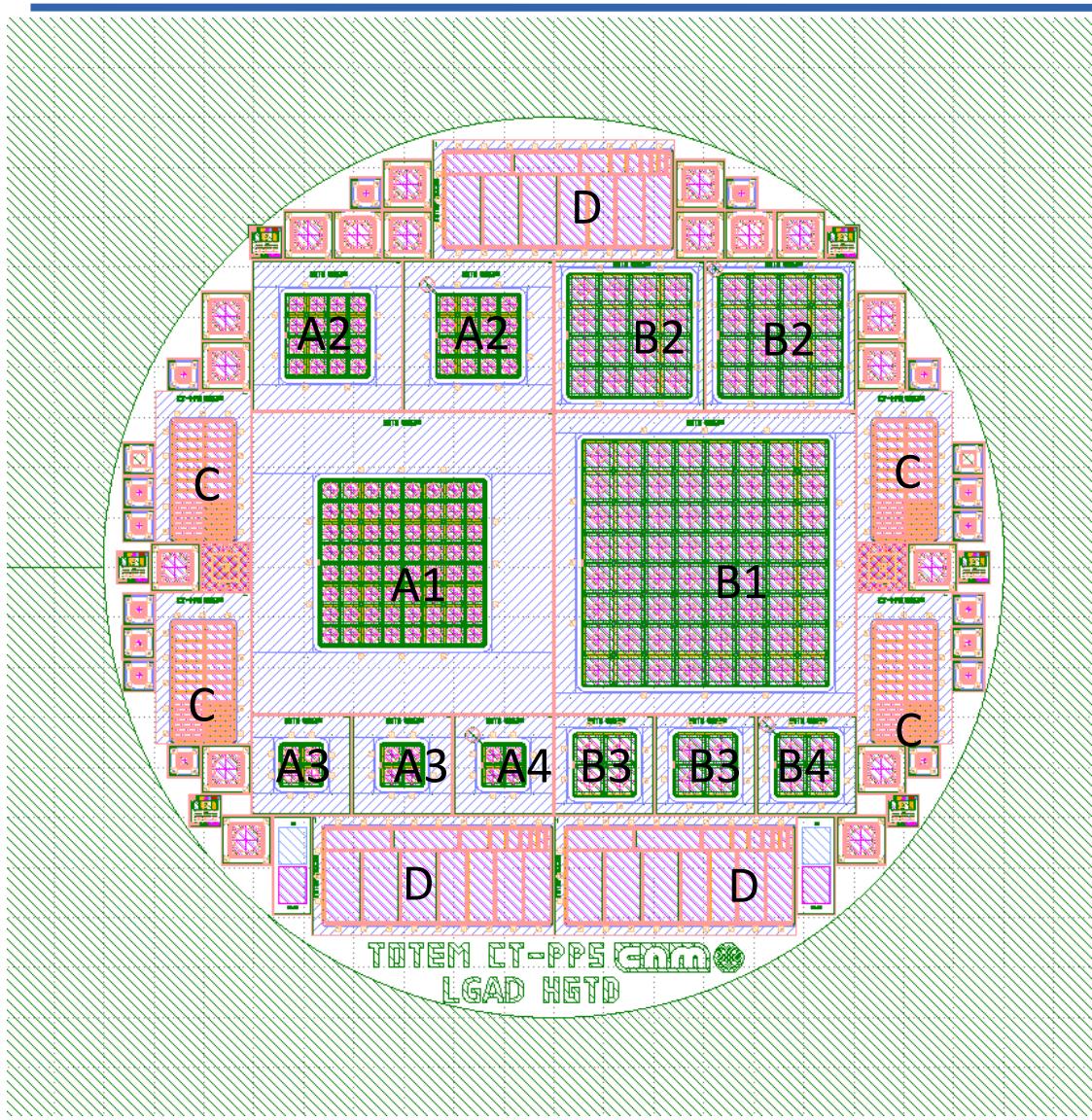
Electrical Performance Simulation (Dose $1.8 \cdot 10^{13} \text{ cm}^{-2}$)



MIP Simulation and Gain.



HGTD – CTPPS detectors (mask design)

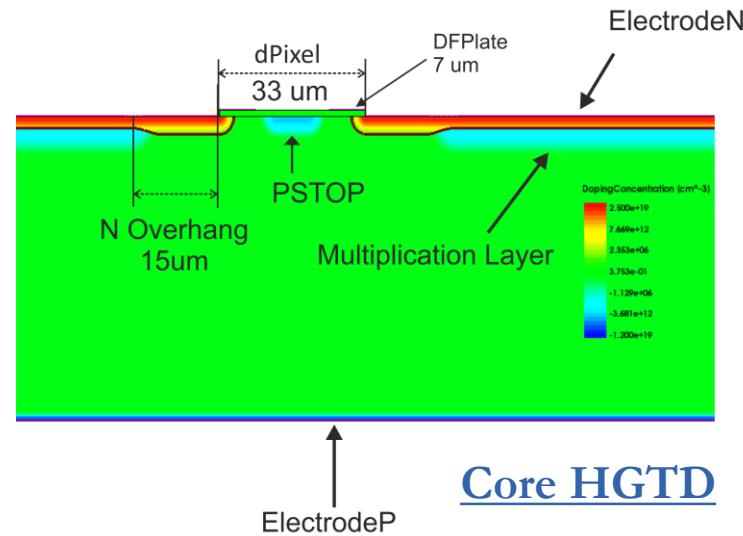


A1=8x8 matrix, 3mm pad
 B1=8x8 matrix, 2mm pad
 A2=4x4 matrix, 3mm pad
 B2=4x4 matrix, 2mm pad
 A3=2x2 matrix, 3mm pad
 B3=2x2 matrix, 2mm pad
 A4=2x2 matrix, 3mm pad, PIN
 B4=2x2 matrix, 2mm pad, PIN

C=CT-PPS

D=TOTEM detector

Different diodes and test structures.



Summary of Wafers fabricated

Wafers

#	10x SOI HPR 50um 3x FZ HRP 285um 1 Dummy (gluing test)		
14	W3-W12	W1; W2 & W14	W13

Multiplication

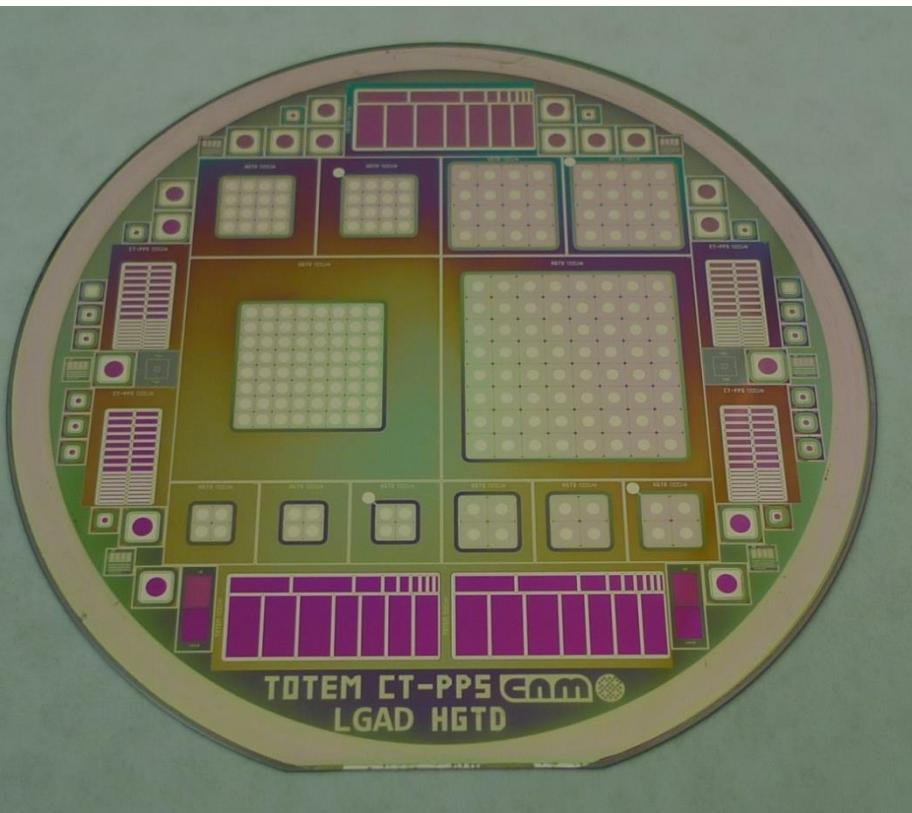
Ion	Energy (keV)	Dose (atm/cm²)	Wafer
B	100	1,90E+13	W1-W2; W5-W10
B	100	1,80E+13	W3 & W4
B	100	2,00E+13	W11 & W12
-	No Multiplication	No Multiplication	W14

- W6 & W10 were broken during fabrication.
- 8 SOI wafers + 3 FZ 300um wafers + 1 dummy are ok.
- 4 SOI wafers + dummy ready for testing.

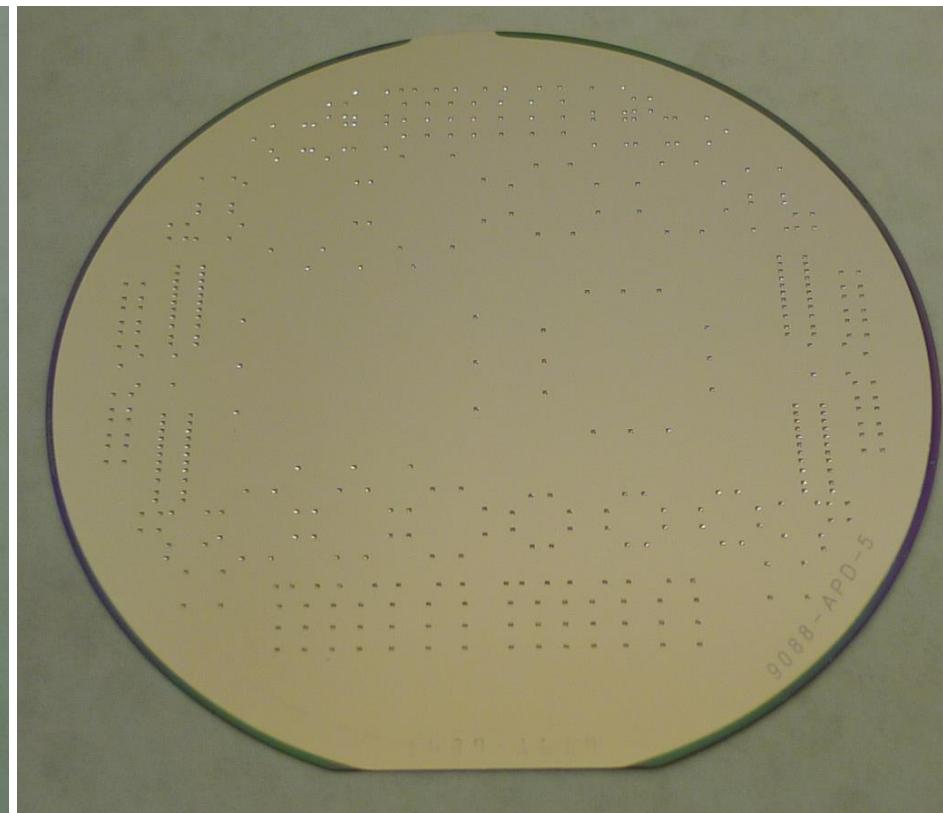
First 50um thick LGAD

- 4 wafers with different doses were finished last Thursday

Front Surface

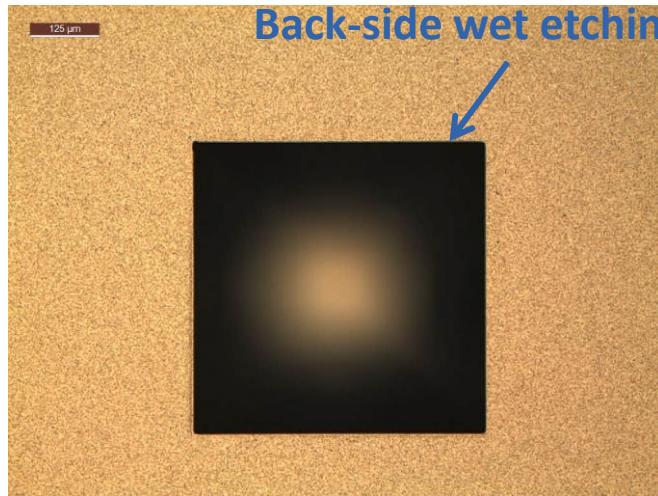


Back Surface

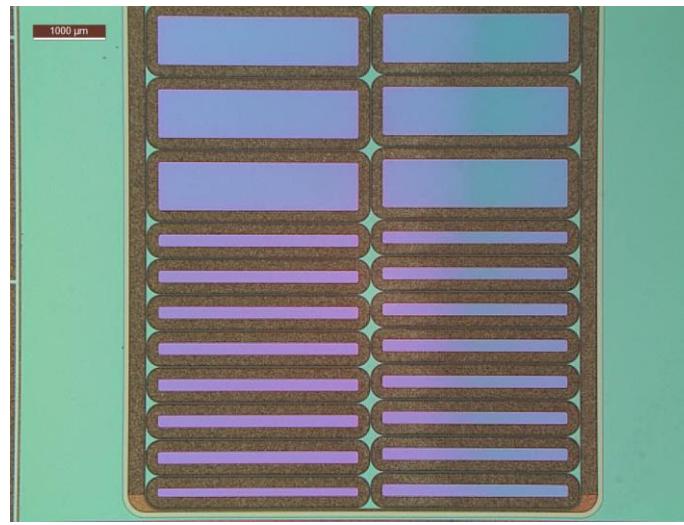
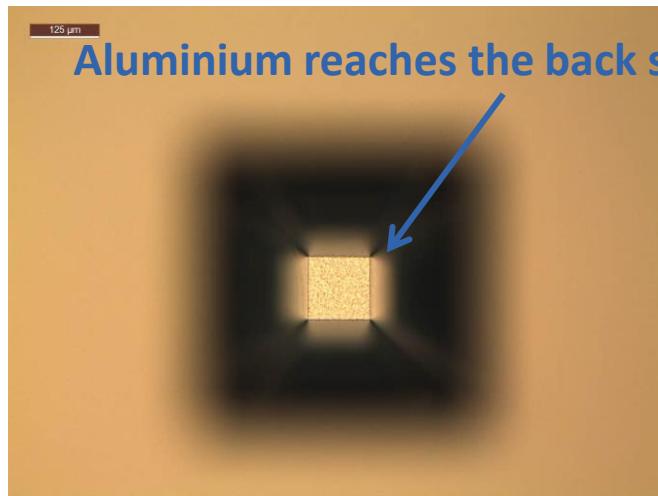
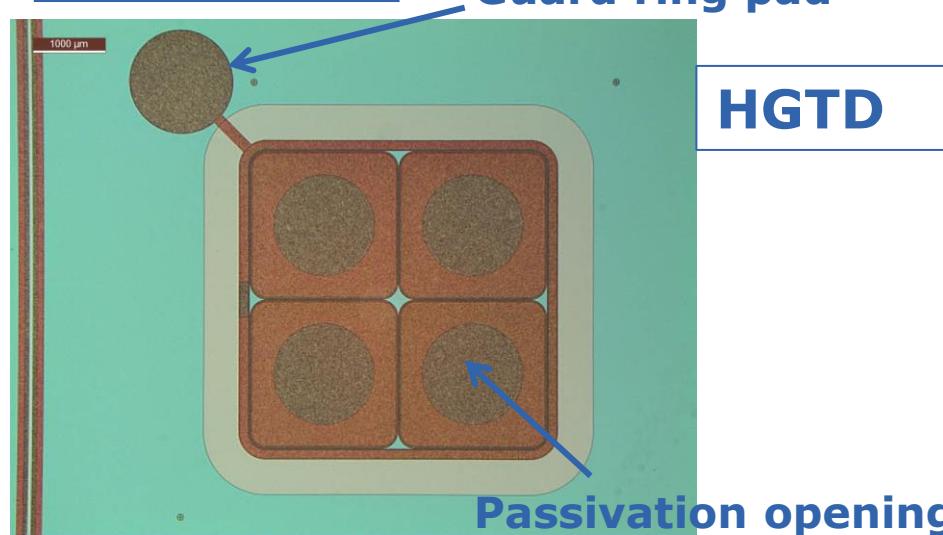


First 50um thick LGAD

Back Surface

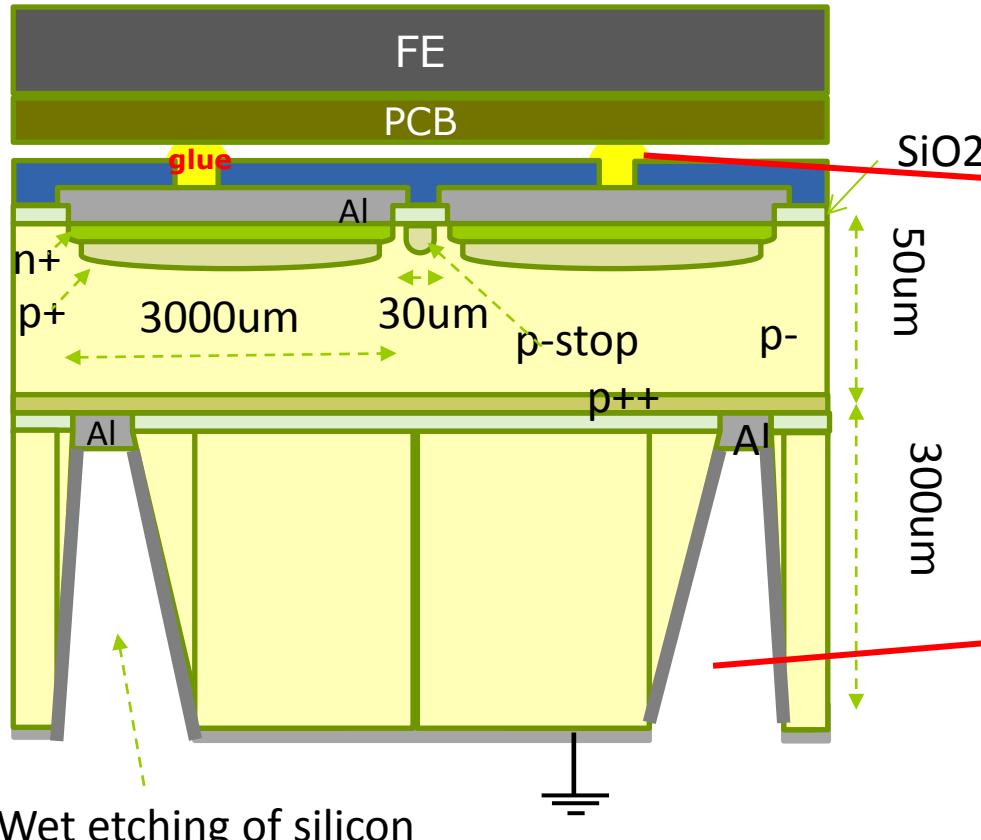


Front Surface



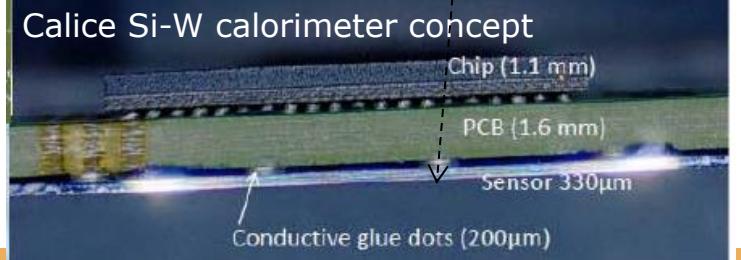
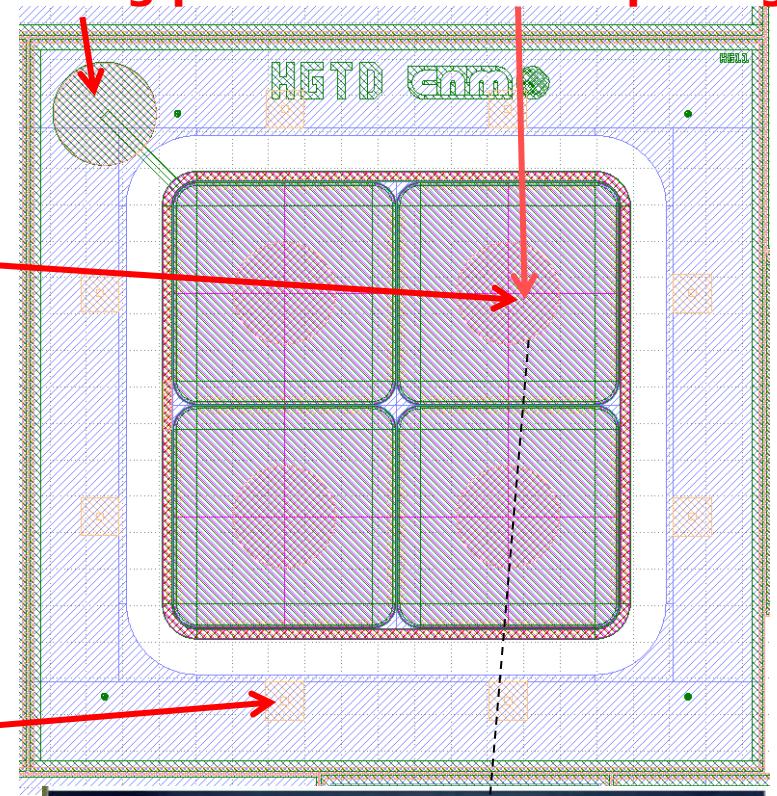
Connections to FE

- Pixel 3000x3000 μm^2 .
- High Resistivity P-type 50 μm SOI Wafers

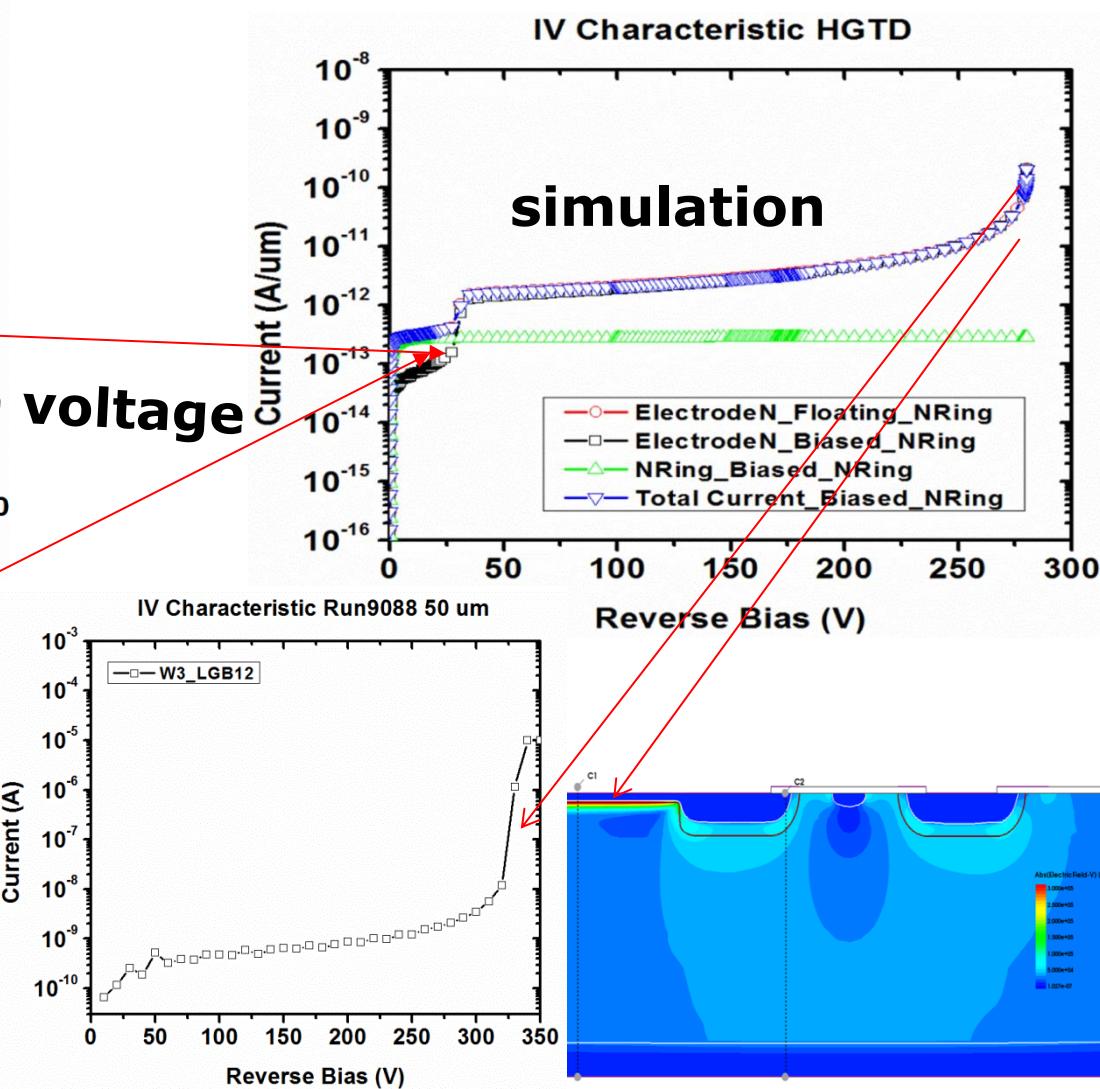
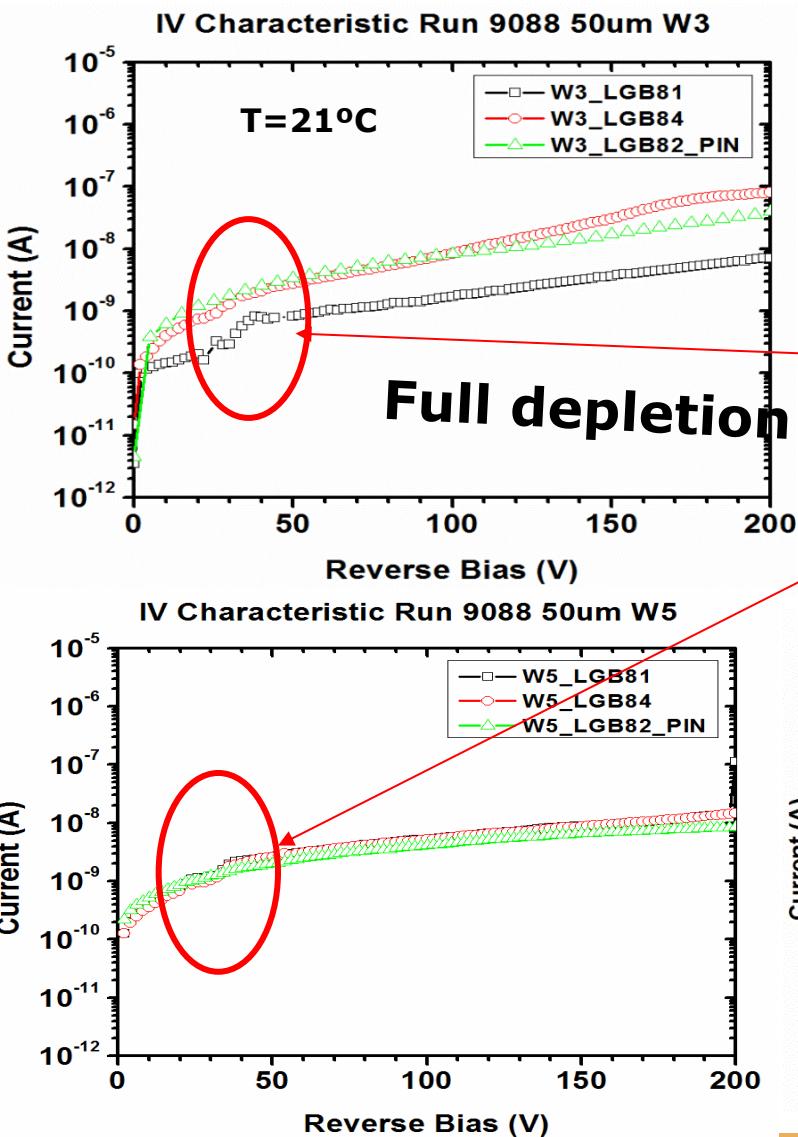


Didier Lacour for LPNHE , "Active Sensors Unit assembly process for the ATLAS High Granularity Timing Device", Santa Cruz meeting 2016.

Guard ring pad Passivation opening

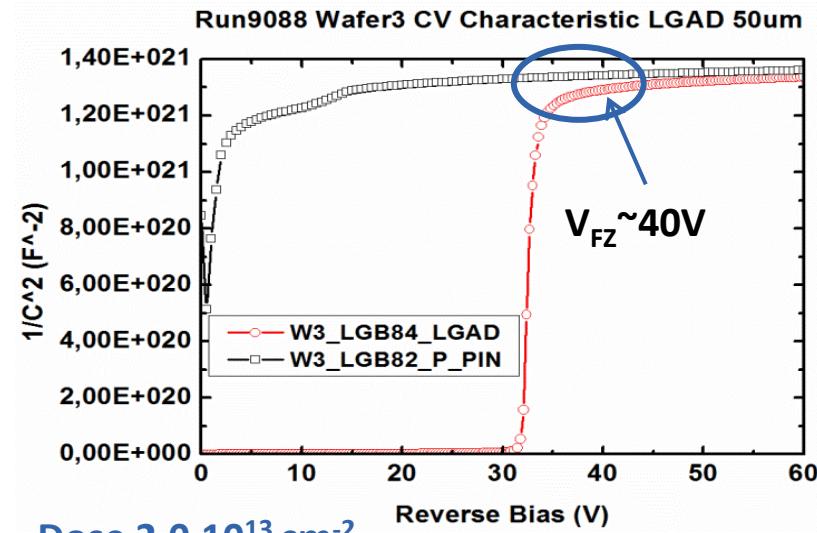


First Measurements. IV Characteristics

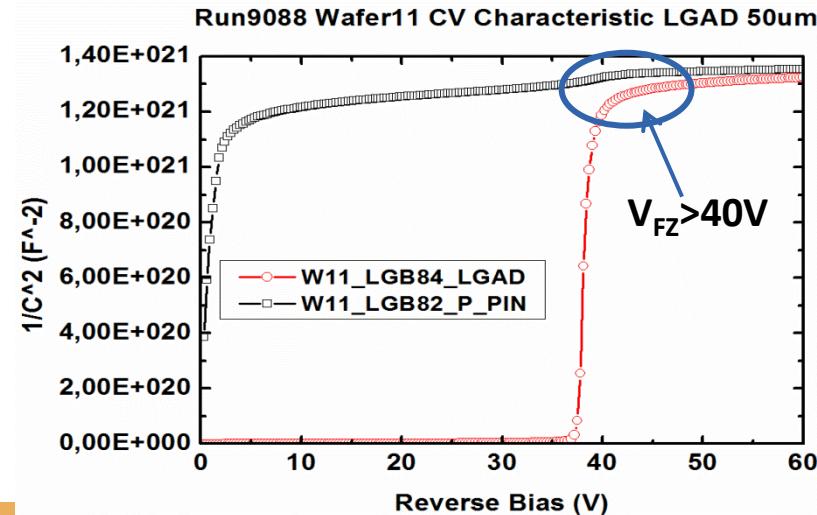


First Measurements. CV Characteristics

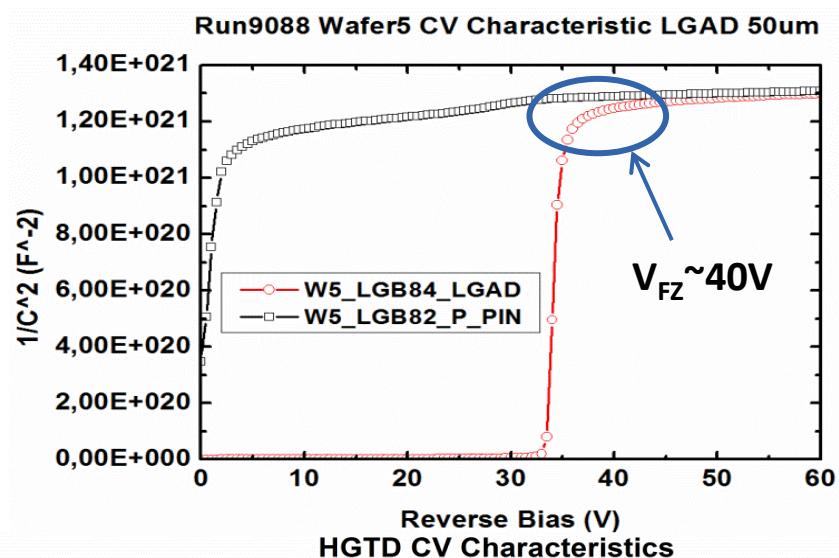
Dose $1.80 \cdot 10^{13} \text{ cm}^{-2}$



Dose $2.0 \cdot 10^{13} \text{ cm}^{-2}$

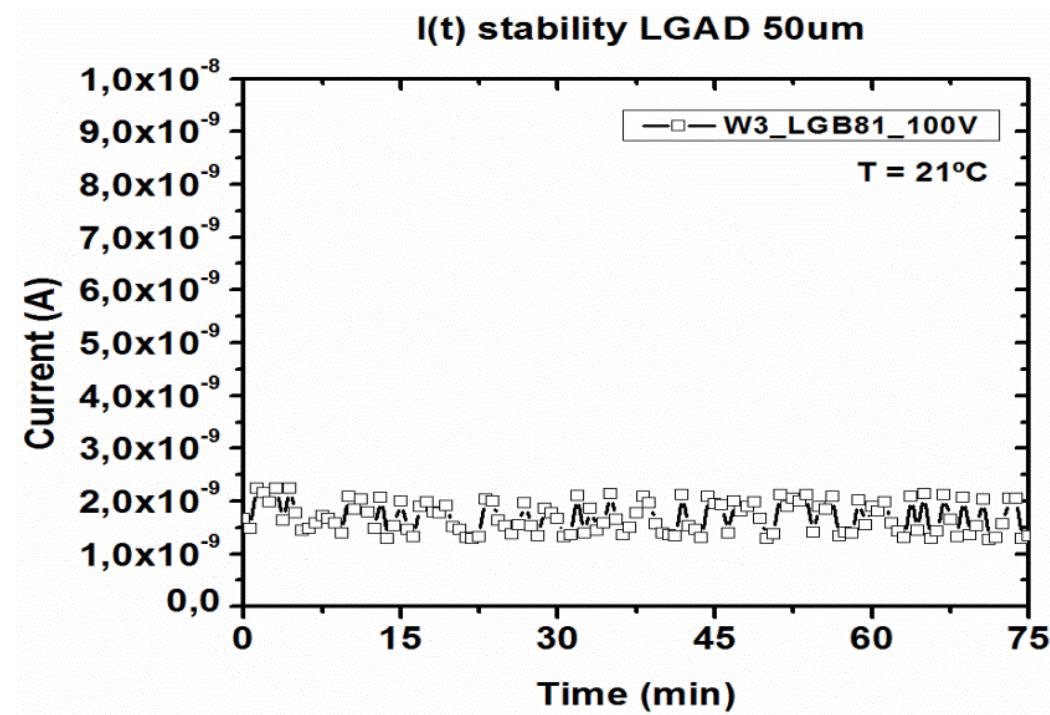


Dose $1.90 \cdot 10^{13} \text{ cm}^{-2}$



I(t) stability

- The experimental data show a good Current stability in Reverse mode (between 1.5 and 2.0 nA)



Summary

- Detectors are working as expected by simulation, at the moment we measured test pad structures
- 4 SOI wafers are ready for dicing. They will be diced during this week
- 3 FZ are already diced and 2 of them were sent to LPNHE
- All the SOI wafers will be finished this week
- Future work
 - ✓ Exhaustive electrical testing
 - ✓ Mechanical Test
 - ✓ Charge collection measurements
 - ✓ Timing measurements
 - ✓ Radiation Hardness

Thank you for your attention !!!!



Summary of LGAD Activities at IMB-CNM Clean Room

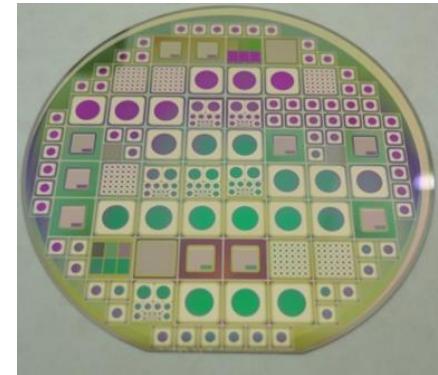
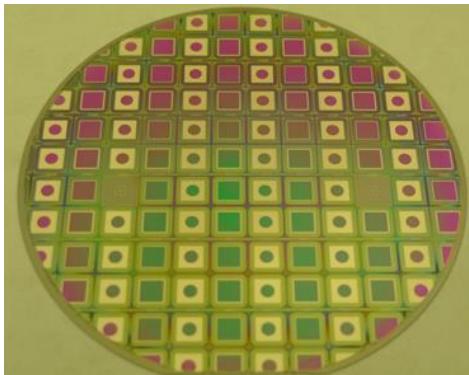
No. Run	Tipo	# Wafers	PiN Waf	Mask Set	P-Well	Drive-in	Implant Mask	Year
5176	1 st APD	8	-	CNM 458	3 Doses	Long	Photoresist	2010
5646	2 nd APD	9	2	CNM 458	6 Doses	Short	Photoresist	2010
5730	3 rd APD	4	2	CNM 458	2 Doses	Short	Oxide	2011
5870/5883	4 th APD	4	-	CNM 458	2 Doses	Short	Oxide	2011
5944/5982	5 th APD	5	1	CNM 458	3 Doses	Short	Oxide	2011
6474	1 st LGAD	11	1	CNM 652	8 Doses	Short	Oxide	2012
6884/6951	2 nd LGAD	13	1	CNM 652	3 Doses	Short	Oxide	2013
6984/7062	3 rd LGAD	7	1	CNM 652	3 Doses	Short	Oxide	2013
7509	4 th LGAD	7	1	CNM 761	3 Doses	Short	Oxide	2014
7735	1 st Gallium	3	-	CNM 761	3 Doses	Short	Oxide	2014
7782/8642	1 st 200 µm	10	-	CNM 761	5 Doses	Short	Oxide	2014

Summary of LGAD Activities at IMB-CNM Clean Room

No. Run	Tipo	# Wafers	PiN Waf	Mask Set	P-Well	Drive-in	Implant Mask	Year
7859	5 th LGAD	6	-	CNM 761	3 Doses	Short	Oxide	2015
8373	1 st SOI 6"	4	2	CNM 784	1 Dose	Short	Oxide	2015
8533	1 st iLGAD	6+3 (Ga)	-	CNM 809	2 Doses	Short	Oxide	2015
8622	6 th LGAD	6+3(Ga)	-	CNM 761	2 Doses	Short	Oxide	2016
9088	1 st SOI 50 μm	14	1	CNM 827	3 Doses	Short	Oxide	2016

- Good
- Under electrical testing
- Still in process
- Calibration run

R&D mainly financed by Spanish research project and partially by CERN RD50 collaboration



LGAD, 300 μm Substrate

- ✓ Yield improved in new fabrications, good repeatability
- ✓ Low leakage current and high breakdown voltage.

