Status of LGAD production at CNM

G. Pellegrini, M. Carulla, D. Flores, S. Hidalgo, D. Quirion

Outline

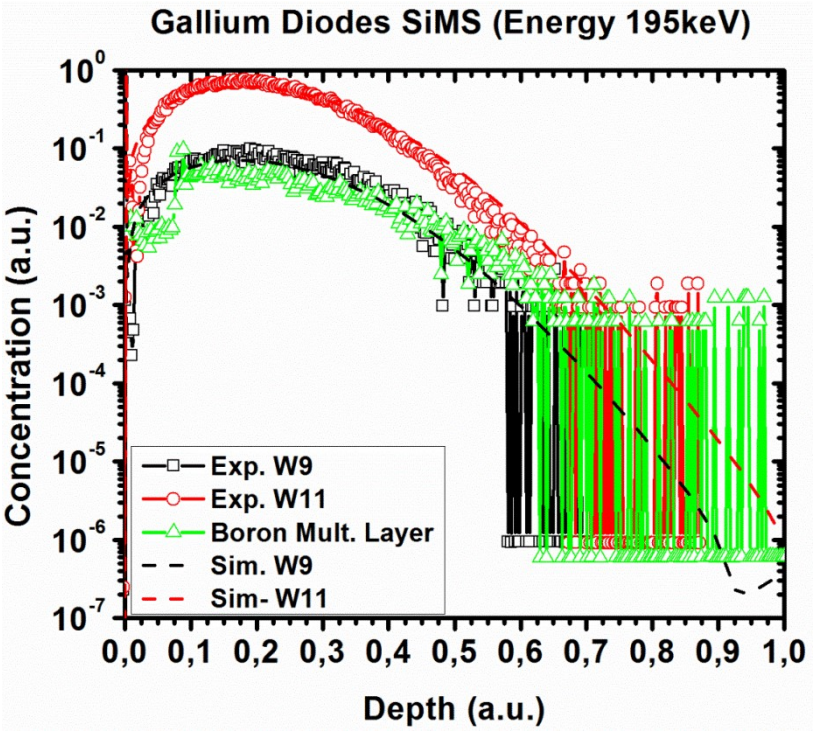
- LGAD with Ga multiplication layer
- LGAD with C spray
- HGTD production status
- HGTD assembly activities
- Conclusions

Gallium project (radiation hardness studies)

Adjustment of Silvaco Simulation from SIMS doping profiles

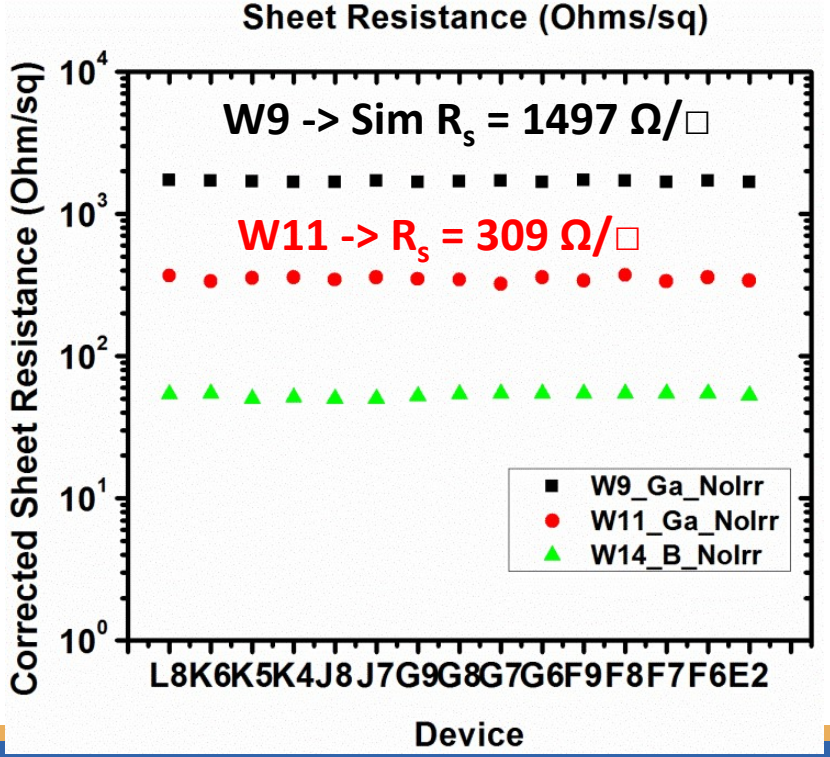
- Simulation was adjusted to reproduce the same peak and junction depth of gallium

SIMS and Simulation



Experimental

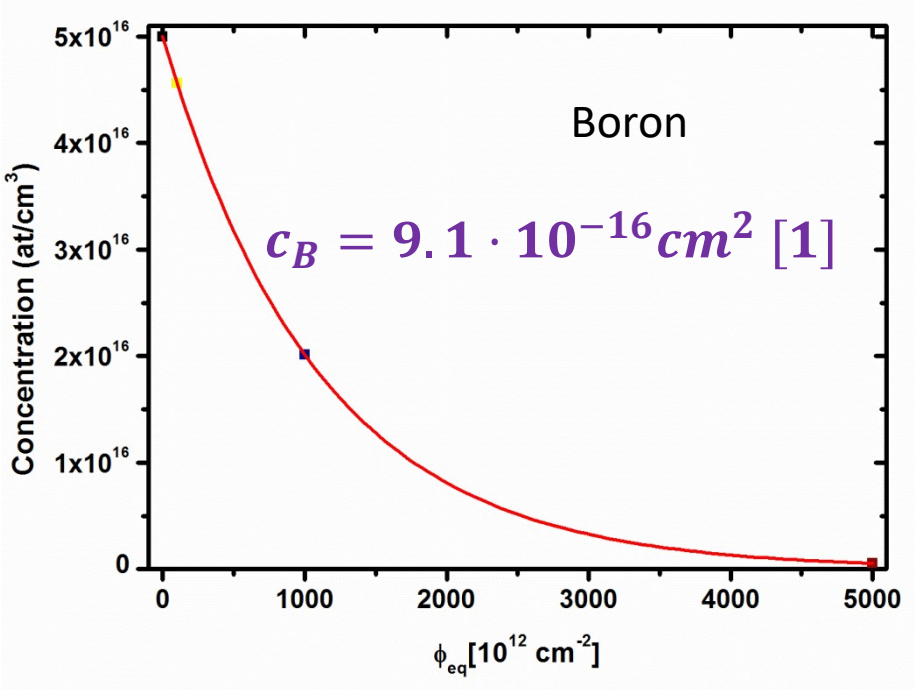
- Using this adjustment the sheet resistance was:
- Imp. Dose 1e14 atoms/cm^2 W11-> **$R_{\square}$= 1540 Ω/□**
- Imp. Dose 1e15 atoms/cm^2 W9 -> **$R_{\square}$ = 314 Ω/□**

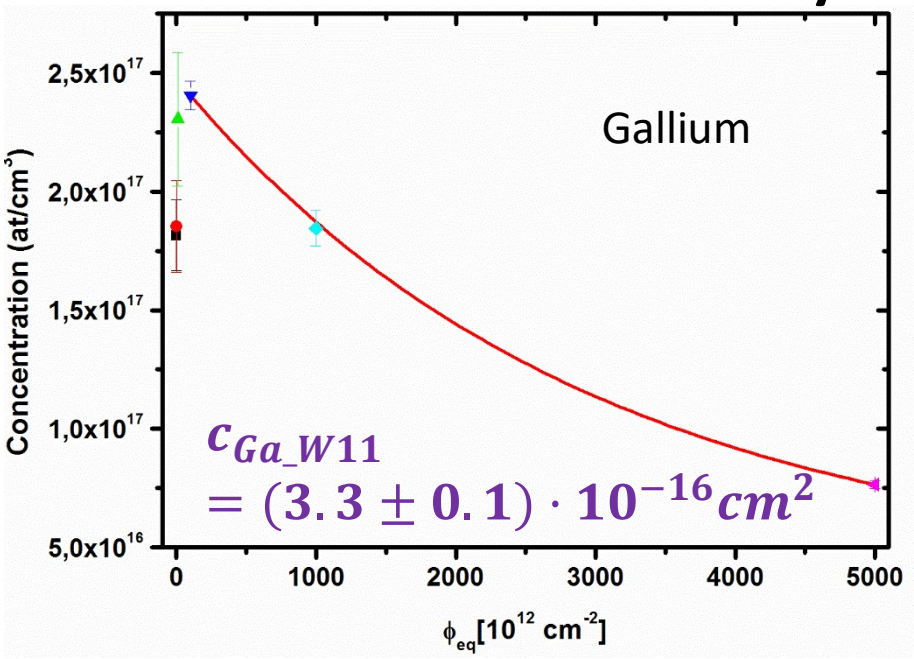


Comparing B and Ga

- Measure resistivity vs fluence to extract acceptor removal constant for neutrons. See M. Carulla Talk at the Trento Workshop 2017.
- Irradiations with electrons to compare with previous results.

Preliminary



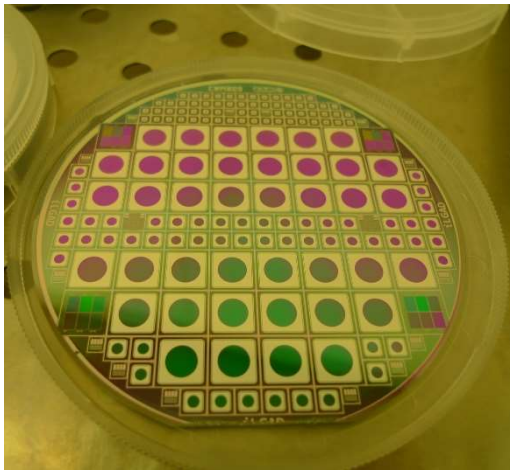


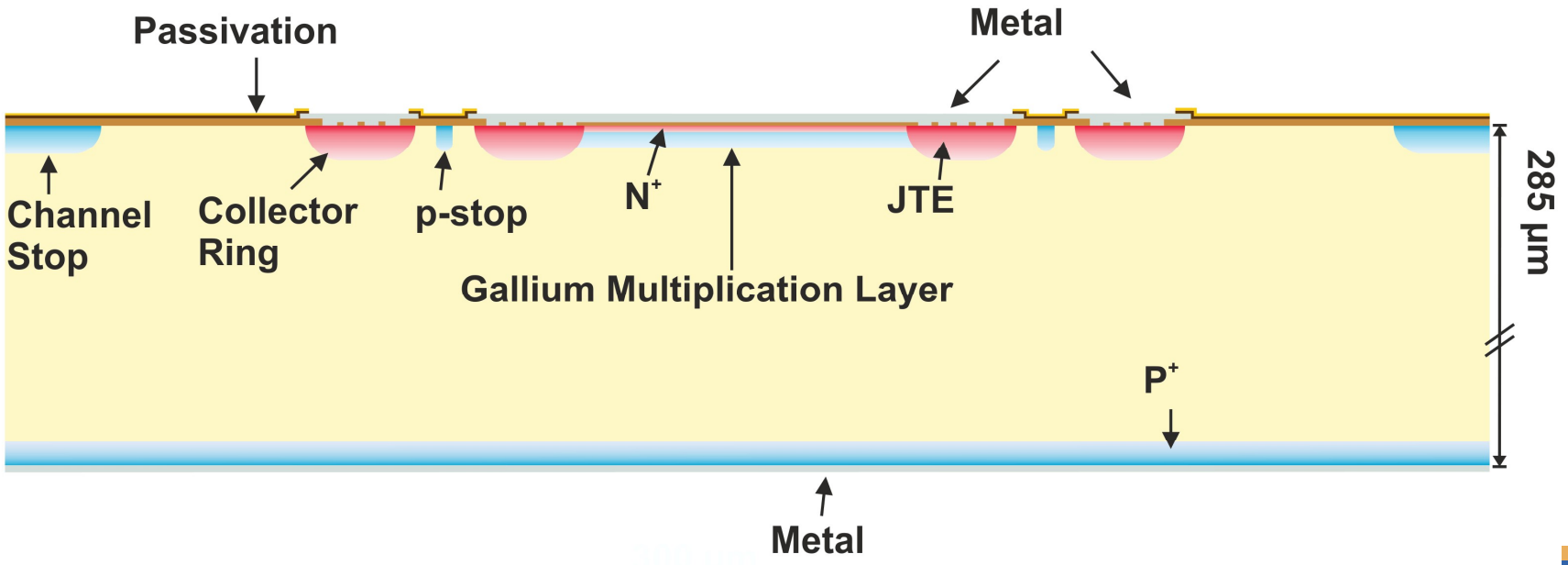
[1] G. Kramberger, 2015 JINST 10 P07006

LGAD with Ga (run 10628)

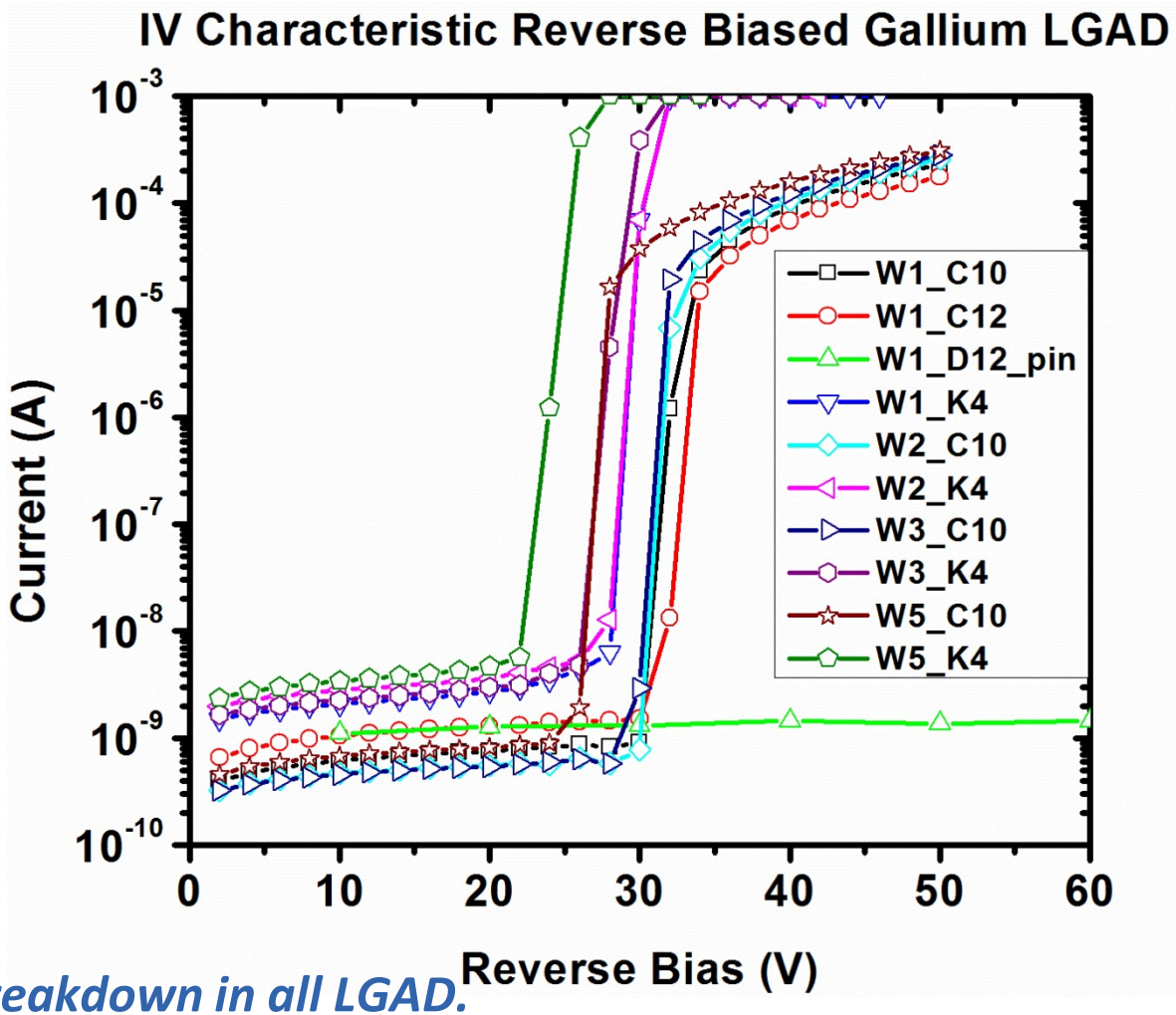
- ✓ 300 µm high resistivity p-type FZ wafers
- ✓ Gallium implant at multiplication layer
- ✓ 5 different implant doses
- ✓ LGAD with pad size 1.2x1.2 mm², 3.2x3.2 mm², 8.2x8.2 mm²

Size	Dose	Wafer	Device
1.2x1.2 mm²	Dose_1	W1	52
3.2x3.2 mm²	Dose_1	W1	49
8.2x8.2 mm²	Dose_1	W1	36
1.2x1.2 mm²	Dose_2	W2	52
3.2x3.2 mm²	Dose_2	W2	49
8.2x8.2 mm²	Dose_2	W2	36
1.2x1.2 mm²	Dose_3	W3	52
3.2x3.2 mm²	Dose_3	W3	49
8.2x8.2 mm²	Dose_3	W3	36
1.2x1.2 mm²	Dose_4	W5	52
3.2x3.2 mm²	Dose_4	W5	49
8.2x8.2 mm²	Dose_4	W5	36





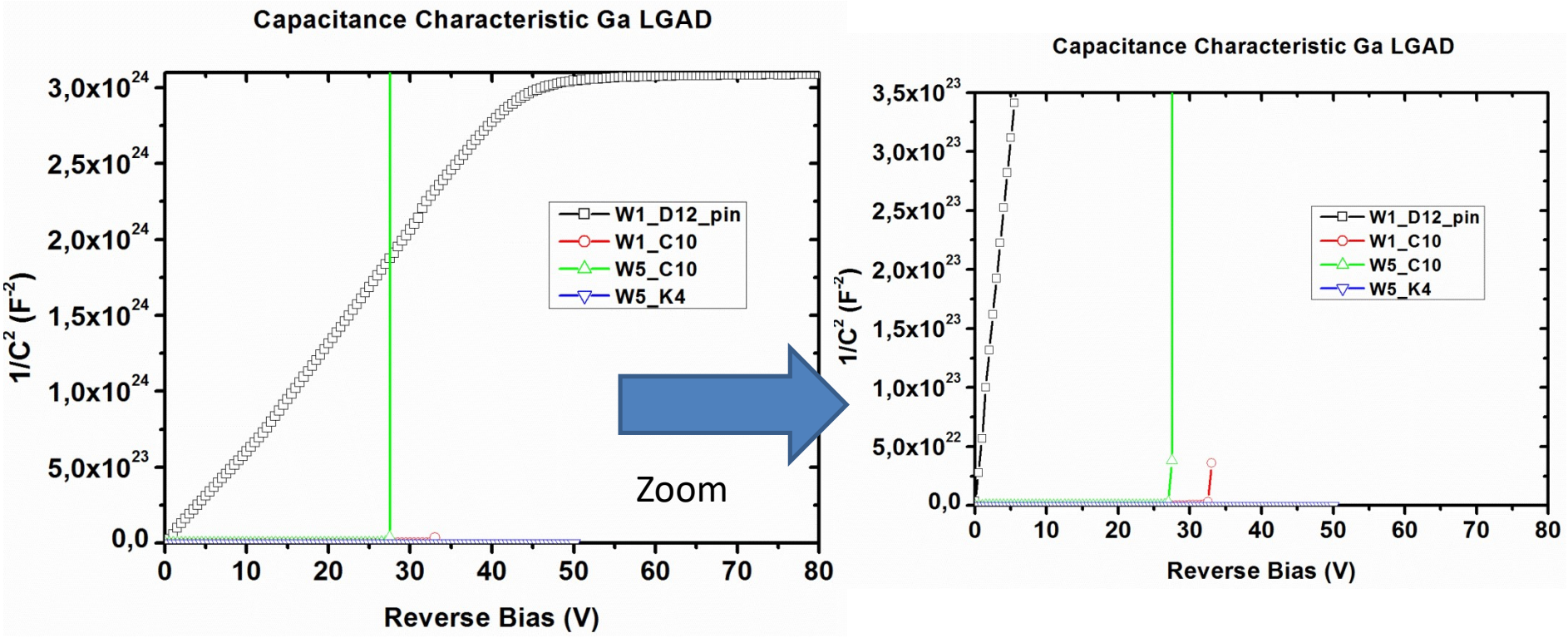
IV Measurements



Premature breakdown in all LGAD.

Good voltage capability of pin diodes (> 1000V)

CV Measurements



LGAD breaks before multiplication layer has been depleted.
All doses are too high.

CV Profiling

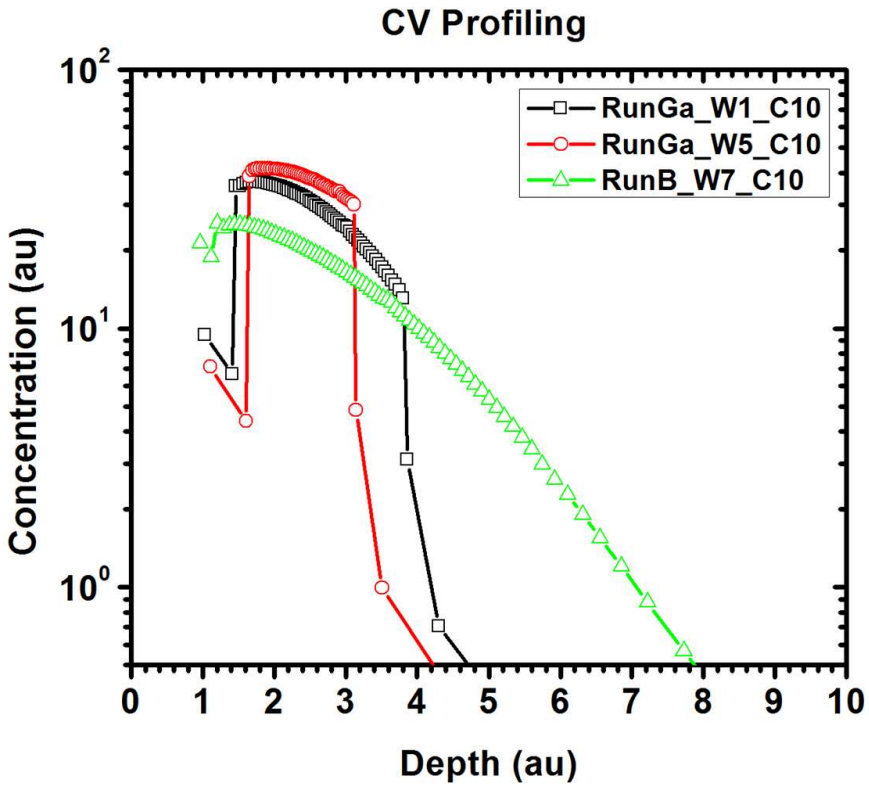


Figure shows the differences between Boron and Ga profiles.

Boron peak much **lower** than Gallium.

Boron diffusion seems **deeper** than Gallium diffusion.

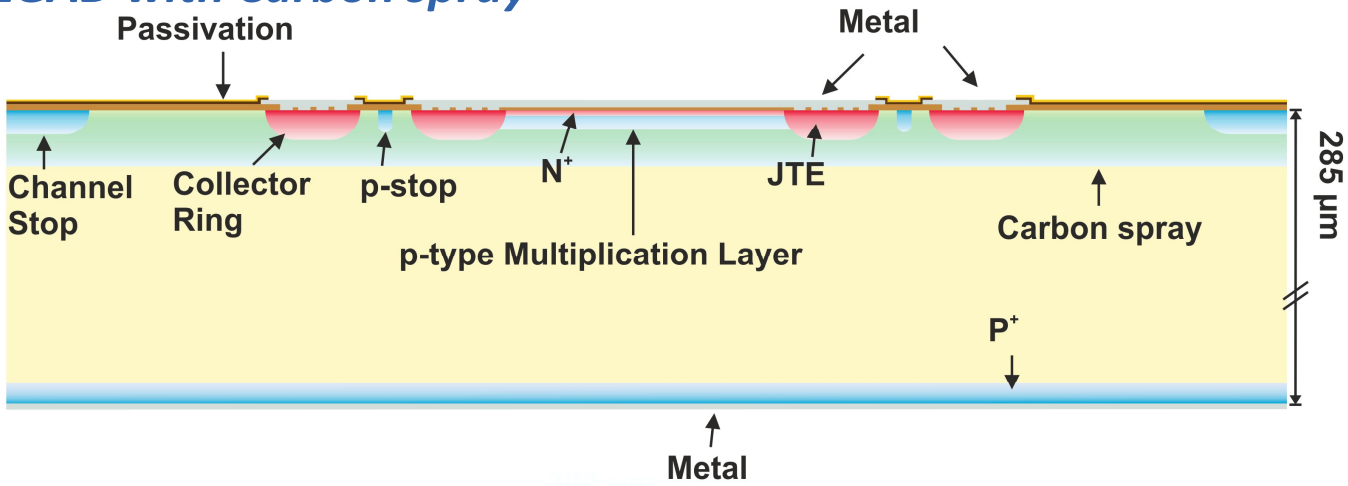
Diffusion model of Ga still to be optimized. Necessary for the simulation.

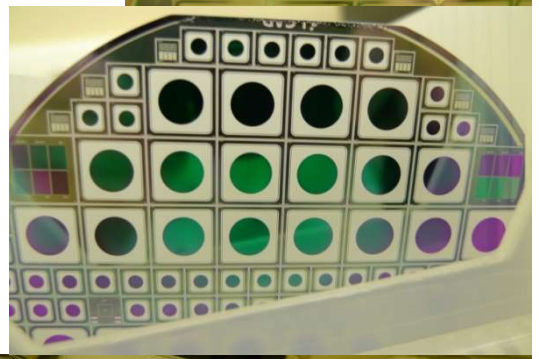
Waiting for results from **SIMS**

Radiation hard studies results in Gregor´s talk at this workshop

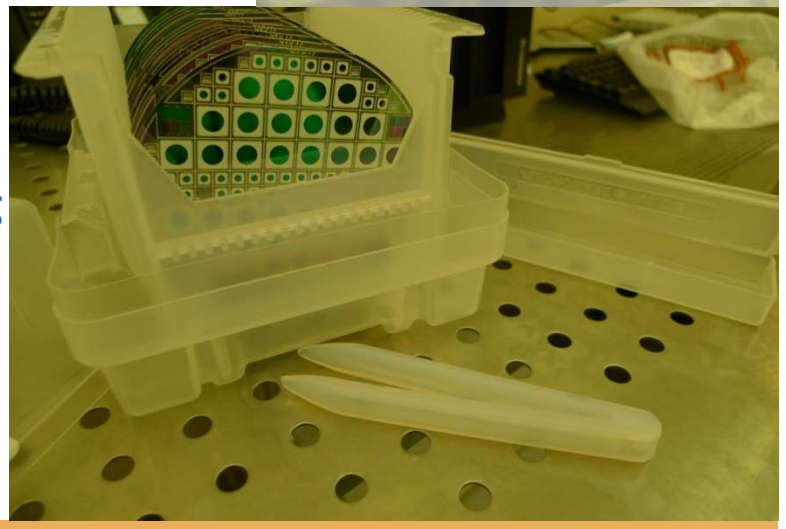
First measurements on LGAD with Carbon spray (run 9889)

LGAD with Carbon spray





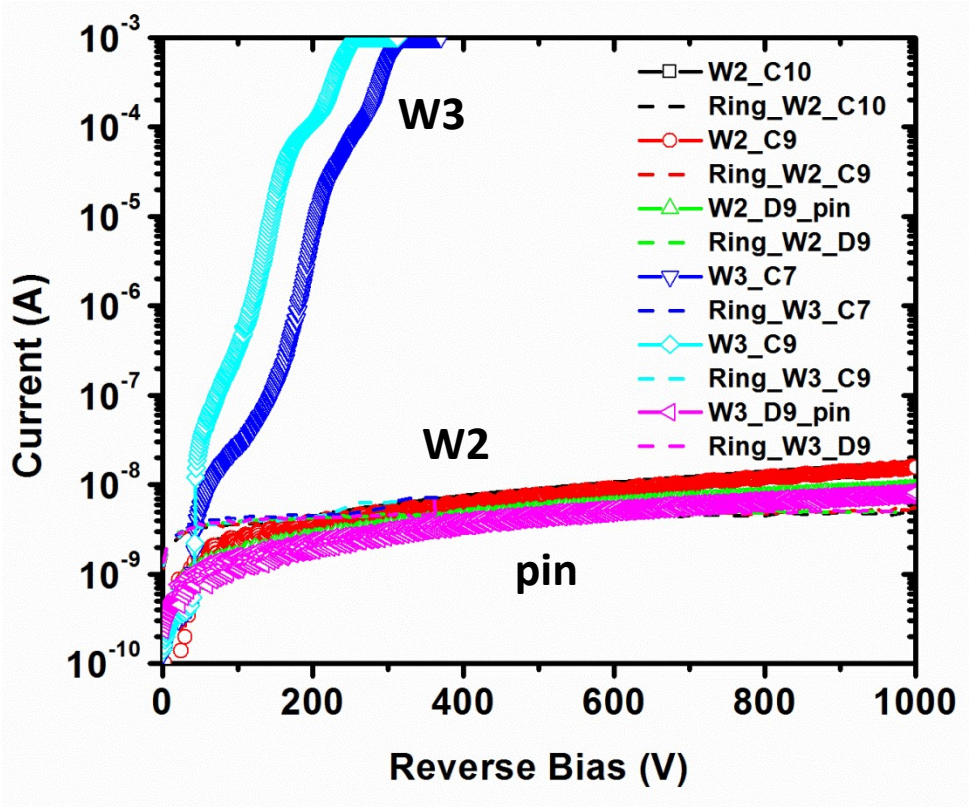
- 300 µm high resistivity p-type wafers
- 5 PWell Implantation Dose
  - ✓ Co-diffusion of Boron, Phosphorous and Carbon will introduce some difference in the final doping profile. Carbon can reduce the Boron and Phosphorus diffusion. Because that variation, 5 Pwell imp. Doses have been implanted.



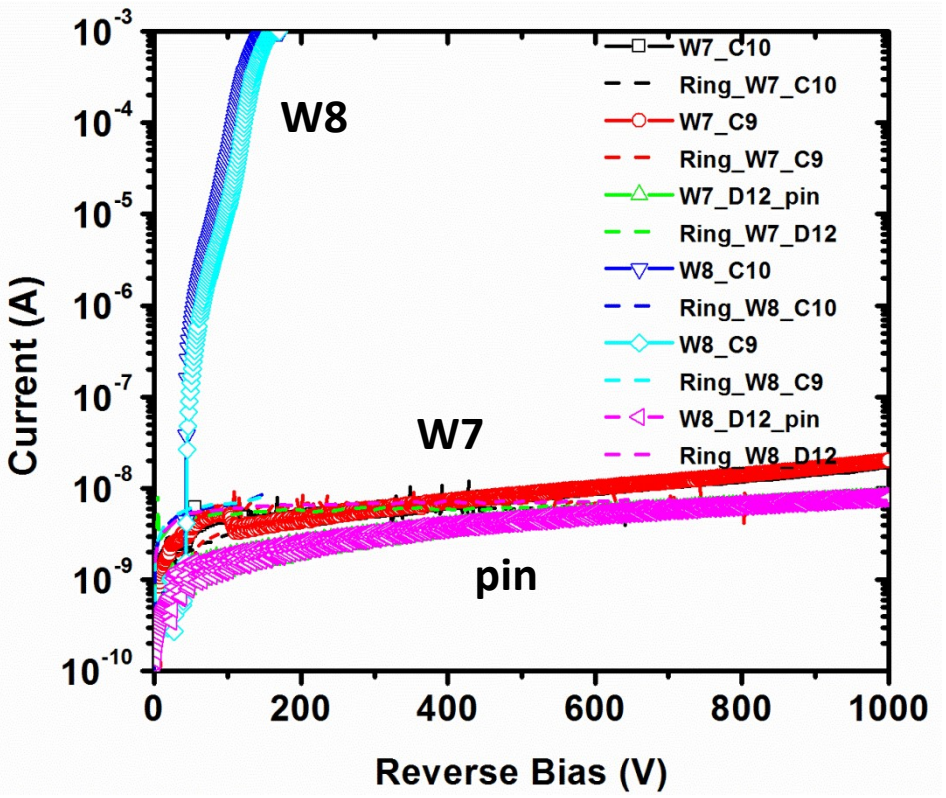
First measurements on LGAD with Carbon spray

Electrical characteristic of LGAD with Carbon spray

Dose 1 & 2 with Carbon spray



Dose 1 & 2 without Carbon spray



First measurements on LGAD with Carbon spray

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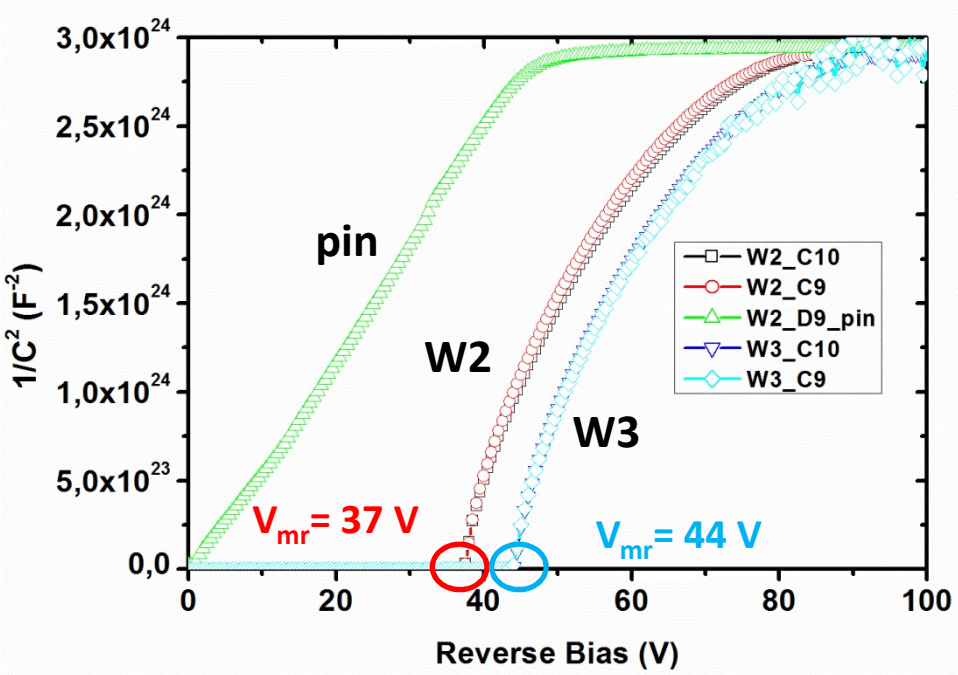
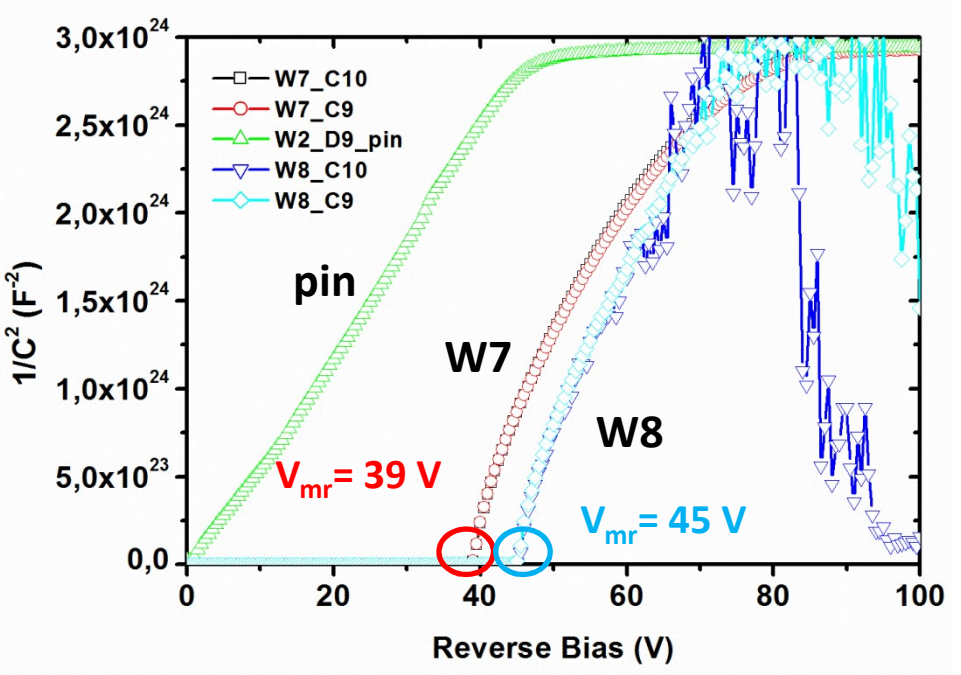


Dose 1 & 2 without Carbon spray

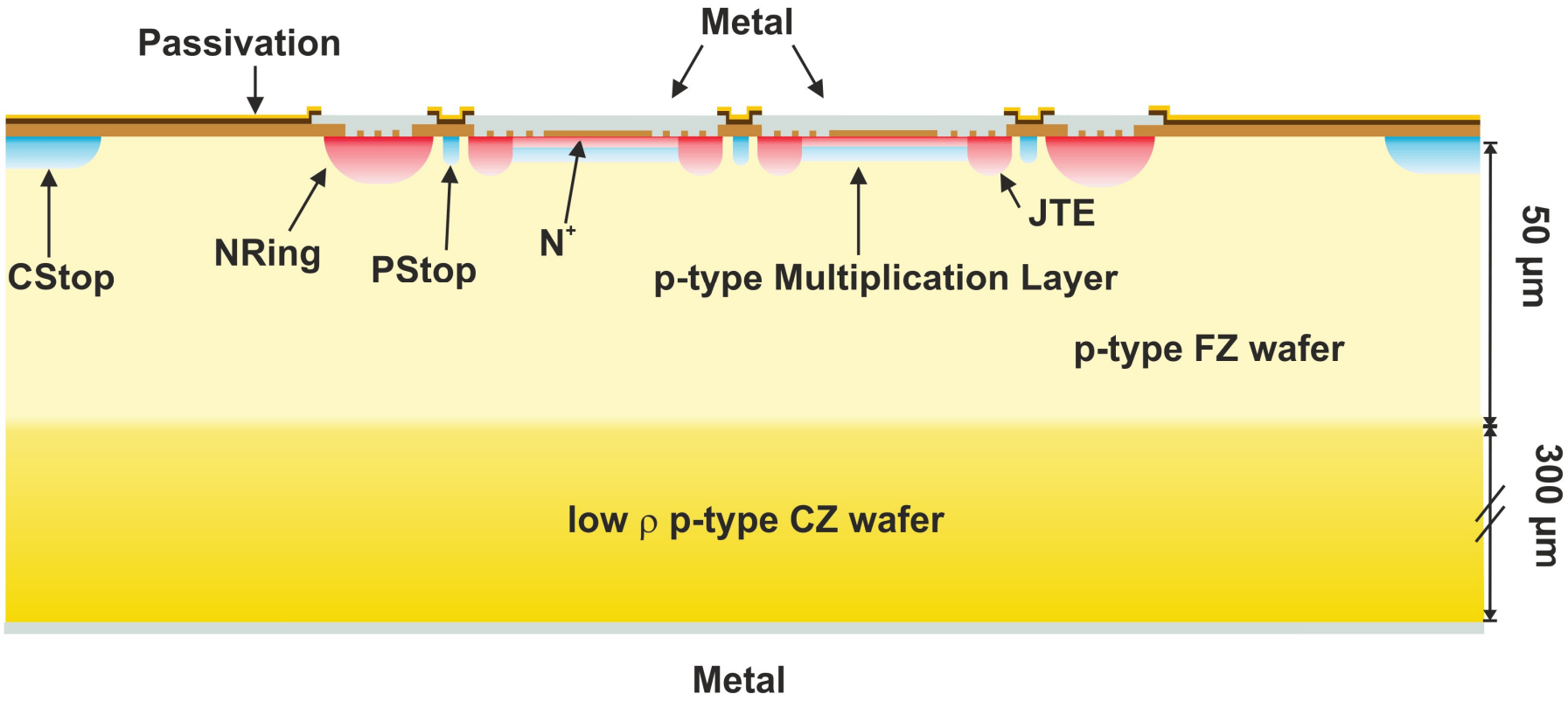


As expected Carbon doesn't change the electrical characteristics of devices. Devices of wafers with higher implant doses break before the multiplication layer is full depleted.

Radiation hard studies results in Gregor´s talk at this workshop

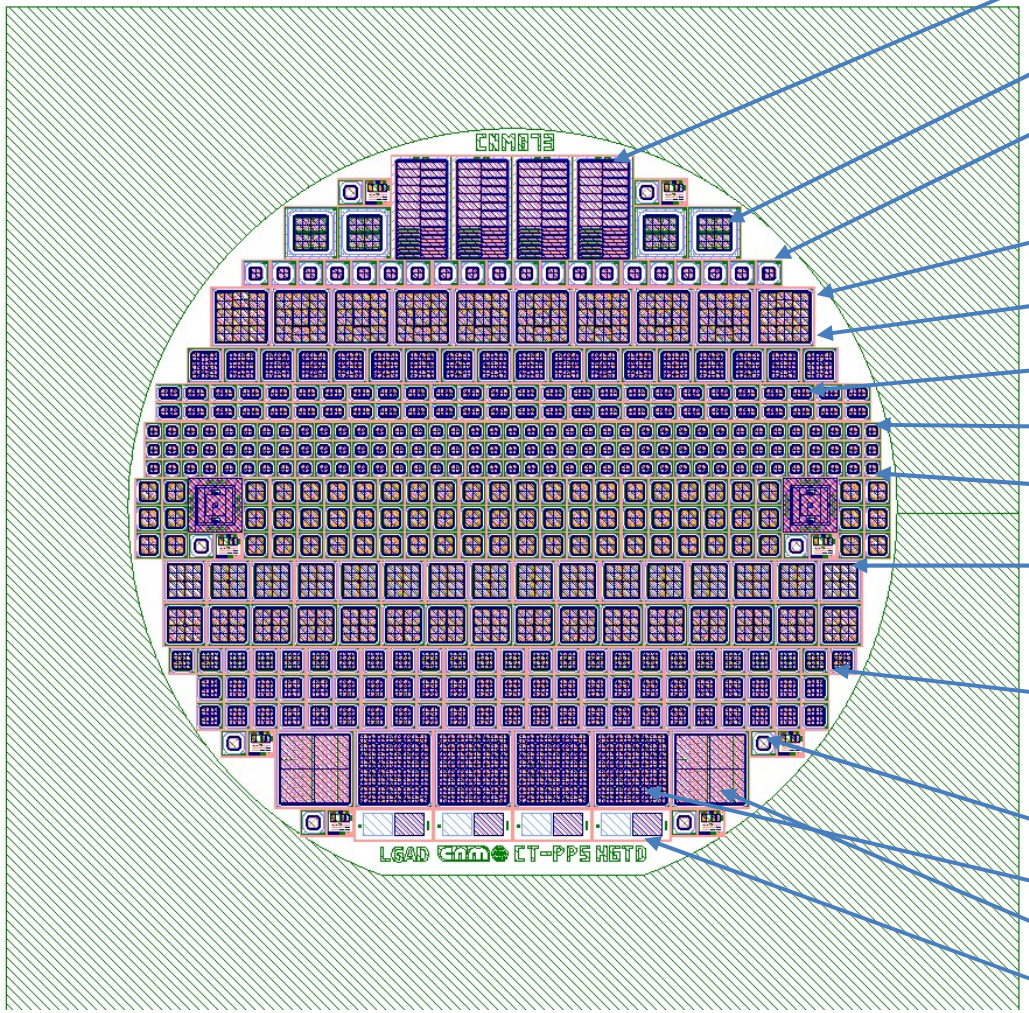
HGTD on Si-Si direct wafer bonding

- **HGTD technology:**
  - ✓ **Wafer to wafer bonding (1 mask step and process less than SOI wafers)**
  - ✓ **50 µm high resistivity p-type FZ wafer + 300 µm low resistivity p-type CZ wafer**
  - ✓ **JTE in all structures**



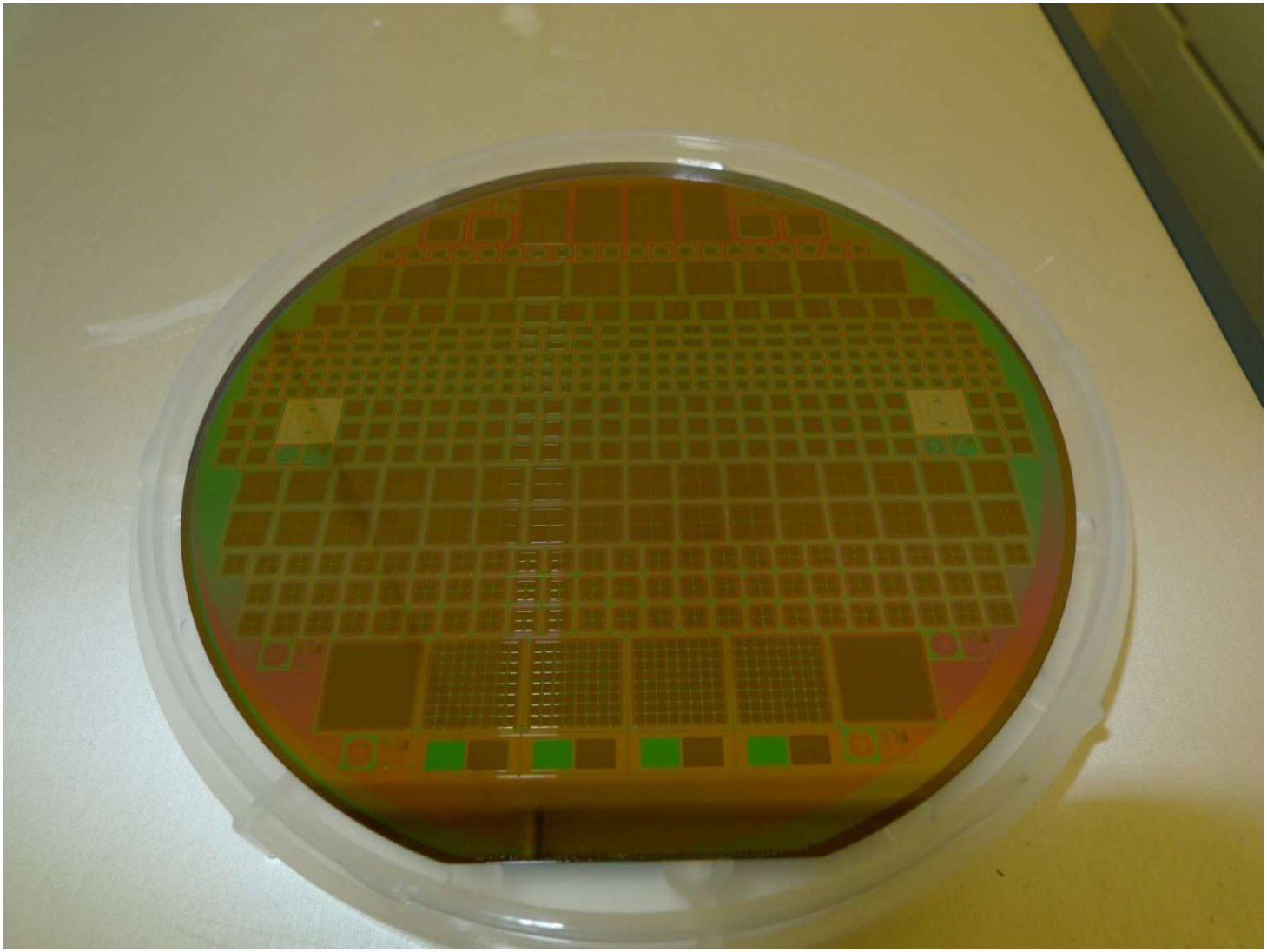
HGTD on wafer to wafer bonding

New 4'' mask set up



- CT-PPS detectors (4)
- 2x2 matrix, 2x2 mm pads. 1000um edge (4)
- 1.2 mm LGAD diodes. 800um edge (18 lgad +2 pin)
- 3x3 matrix. 2mm pads (8 lgad +2 pin)
- 3x3 matrix. 1mm pads (16 lgad +2 pin)
- Epitaxial Lgad structures (TBD)
- 1 mm LGAD diodes. 500um edge (111 lgad + 6pin)
- 2 mm LGAD diodes. 500um edge (66 lgad + 6pin)
- 2x2 matrix, 2 mm pads. 500um edge (28 lgad + 4pin)
- 2x2 matrix, 1 mm pads. 500um edge (63 lgad + 8pin)
- AC coupled LGAD. 500um edge (2)
- 8x8 matrix, 1 mm pads. 500um edge (4)
- AltiRoc dummy structures (4)
- SIMS test structures (4)

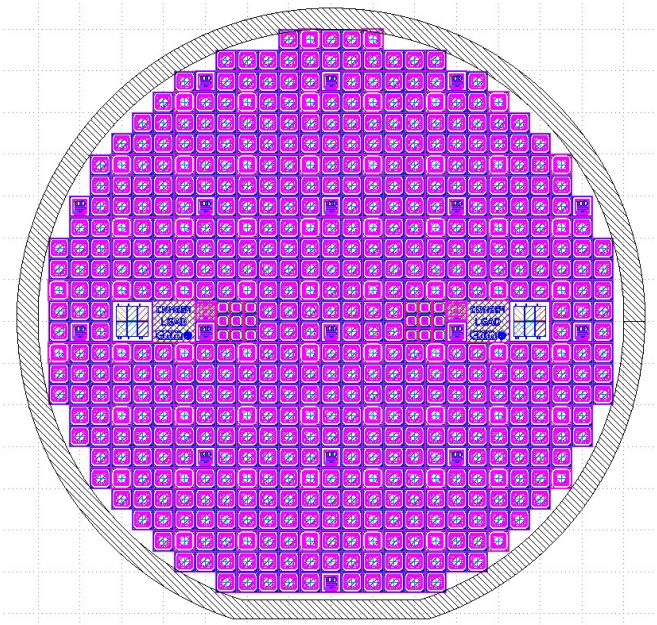
HGTD on wafer to wafer bonding

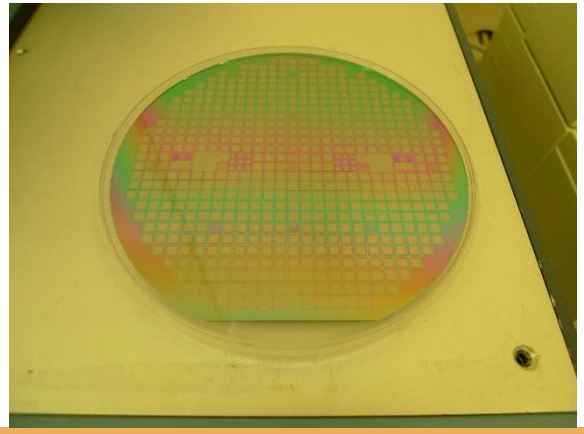


LGAD on 6'' wafers (In process)

- **Previous pin diodes fabrication on 6'' wafers show a good performance**

- **New LGAD batch on 6'' wafers:**
  - ✓ **6'' wafers have to be processed in a different ion implanter and furnace**
  - ✓ **Re-calibrated Drive-in**
  - ✓ **Re-calibrated Implantation Energy and Dose**
  - ✓ **Pad size 1.2x1.2 mm^2, 3.2x3.2 mm^2**
  - ✓ **6 different multiplication layer implant doses**





Multiplication layer implantation done . We expect to finish the fabrication in June.

HGTD assembly activities at IFAE and CNM

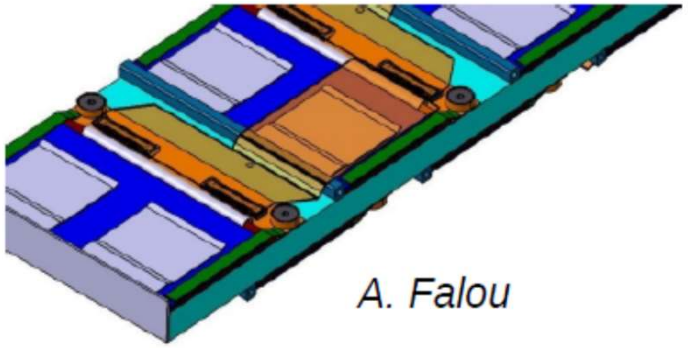
M. Chmeissani, J. Garcia, J. Lange, V. Gkougkousis, S. Grinstein (IFAE-Barcelona)

HGTD preliminary stave design presented in IDR: https://cds.cern.ch/record/2239738

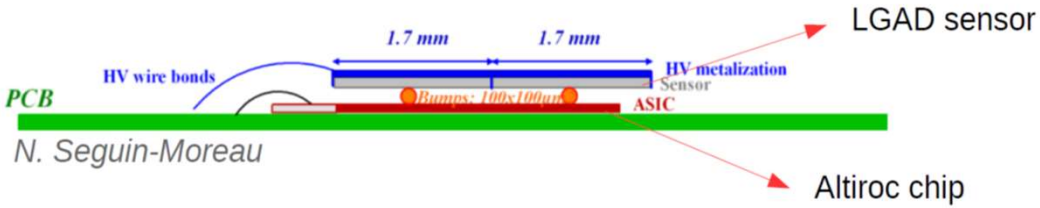
HGTD preliminary stave design presented in IDR: https://cds.cern.ch/record/2239738

- Core of detector:
- LGAD sensor bump-bonded to “Altiroc” ASIC
- Compact layout:
- Up to 4 sensing layers in ΔZ~6cm
- Also see details in **L. Serin** talk:

https://indico.cern.ch/event/613355/
and Aboud Falou's slides:
https://indico.cern.ch/event/634325/



Prototype design for testing:
hybrid detector mounted on dedicated PCB:

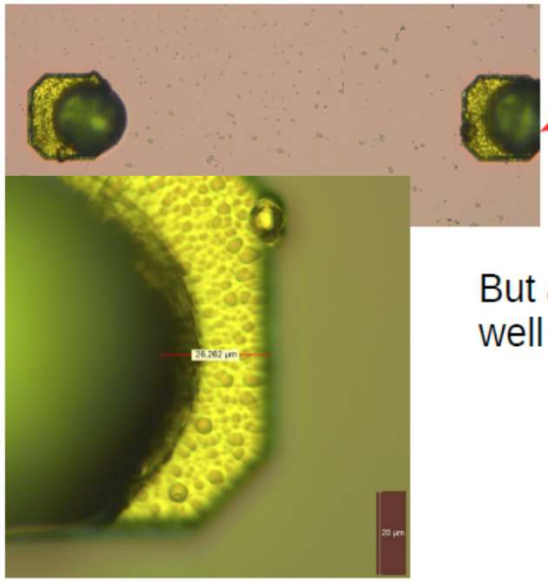


Bump deposition

- Pactech laser soldering system
- 80um SnAg balls deposited on Altiroc dummy
  - Preparation time: 1 day
    - Program: ½ day
    - Head change: ½ day (250 um default head)
  - Did low and high energy deposition of balls
  - Deposition time: 5 sec/sample (20 bumps)
  - 6 Altiroc dummies bumped

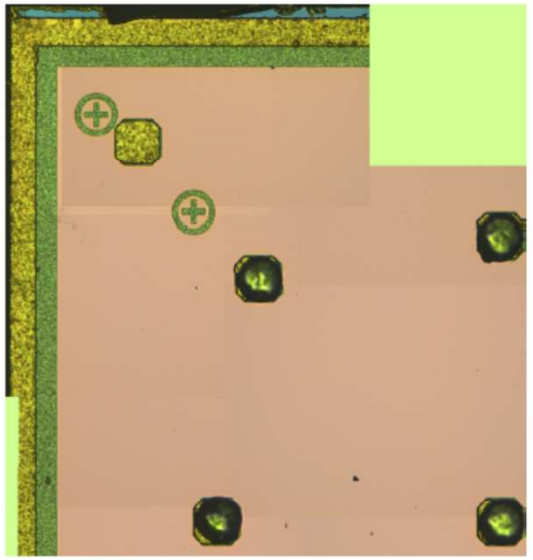
- Inspection:

Solder bump deposition on UBM



Some alignment offset observed in one sample (low energy deposition)

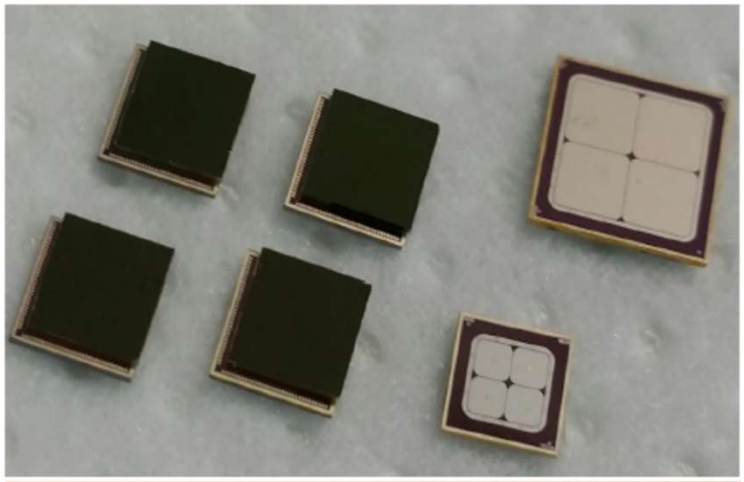
But after reflow balls mostly well aligned



S. Grinstein, IFAE - HGTD meeting

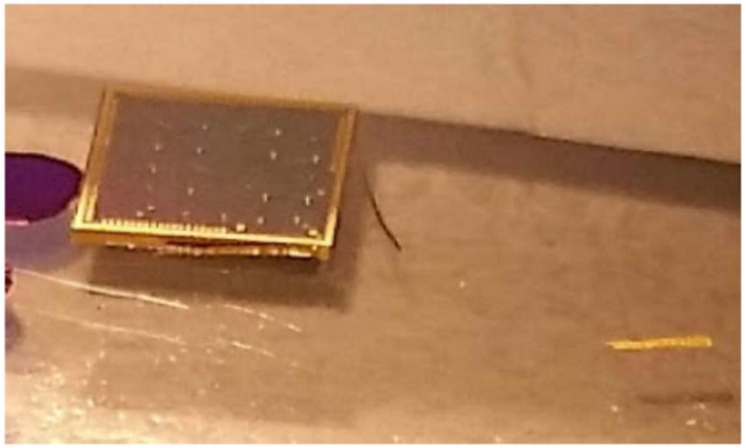
Flip-chip

- Flip-chipped four samples, all cycles were successful
- Decided not to try the 2 mm pads
  - Not a priority

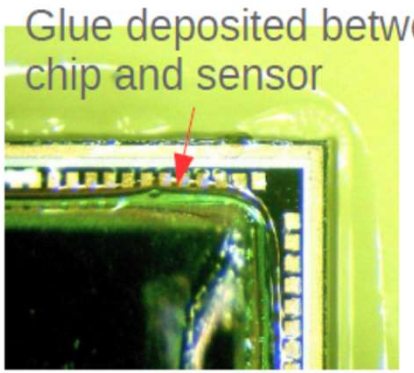


Observed that UBM from the side of the chip became lose during handling prior to flip-chip

- Very problematic
  - Don't want this material floating around during flip-chip/reflow cycles...
- Can be removed “by hand”, since loosely attached
- Can be altogether avoided by dicing after UBM!

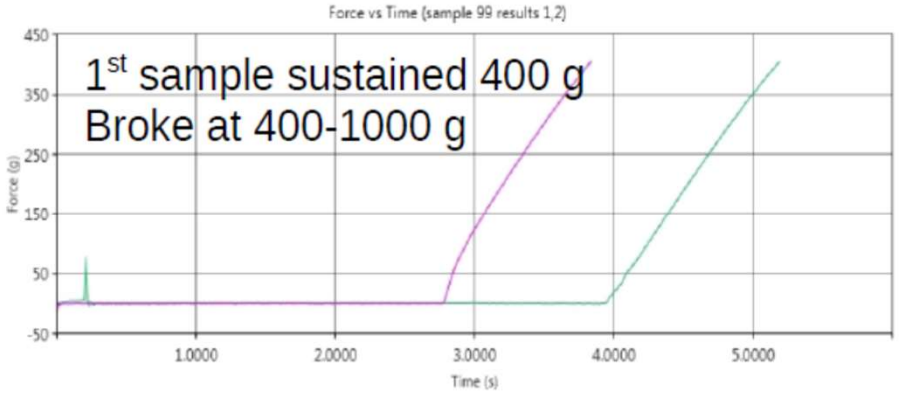


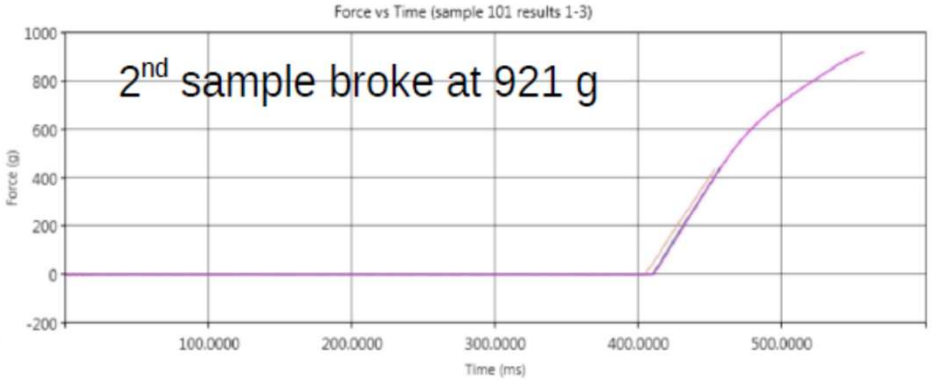
Assembly Shear Tests



Four samples available for studies

- Two lost due to poor gluing of sample to holder for shear test
- Two glued correctly and tested:
  - Little glue to hold sample to PCB
  - Two shear iterations up to 400 g failed to break device
  - Third try up to 1000g broke it, but Force vs Time plot not registered





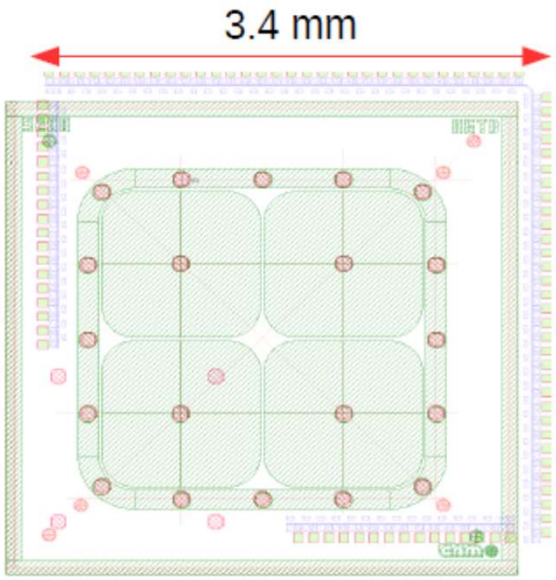
Excellent results overall:

- About 1 kg needed to break 1 mm Altiroc dummy
- Consistent with 60 g/bump observed in previous test
  - Expected that assembly test shear force < Σ (bump shear force)

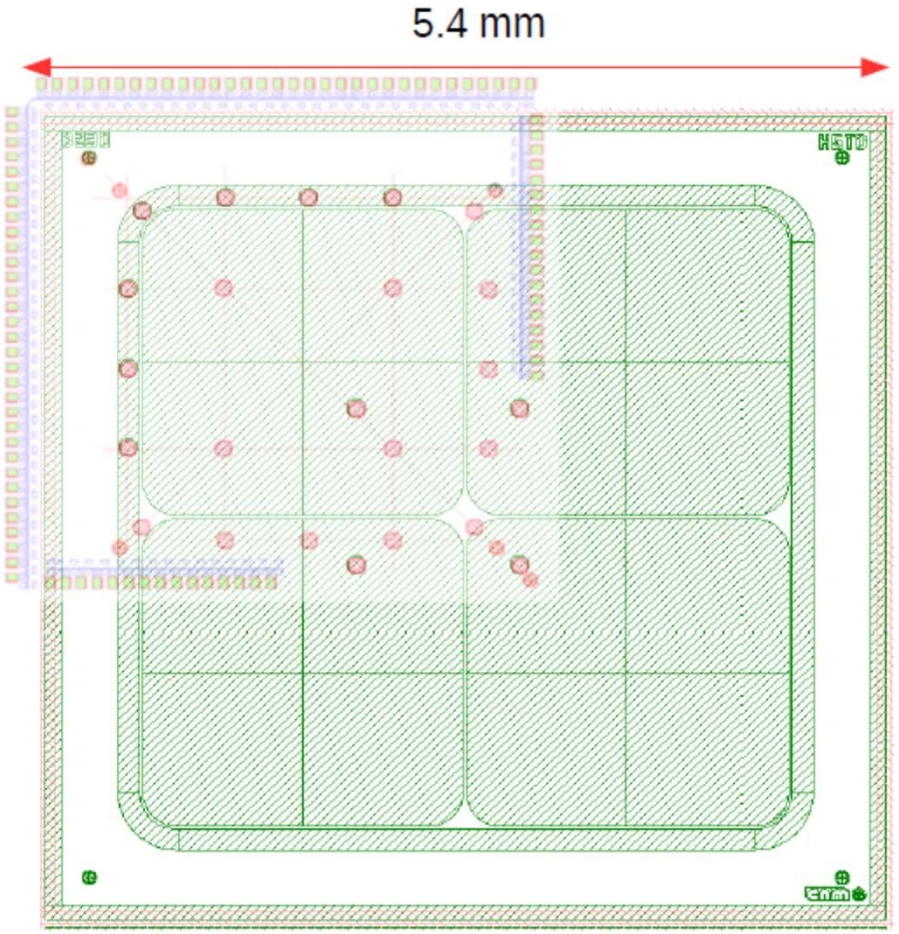
Conclusions

- Ga acceptor removal constant for neutron irradiations seems lower that B.
- Diffusion model of Ga still to be optimized. Necessary for the simulation of next productions.
- Carbon spray doesn’t change the electrical characteristics of devices. Irradiated devices will be presented in Gregor´s talk
- Overall, excellent assembly results with dummy samples for HGTD.
- UBM of Altiroc dummies at CNM successful.
- IFAE has a full assembly line for hybrid detectors for HGTD in place.

The HGTD Dummy Hybrid



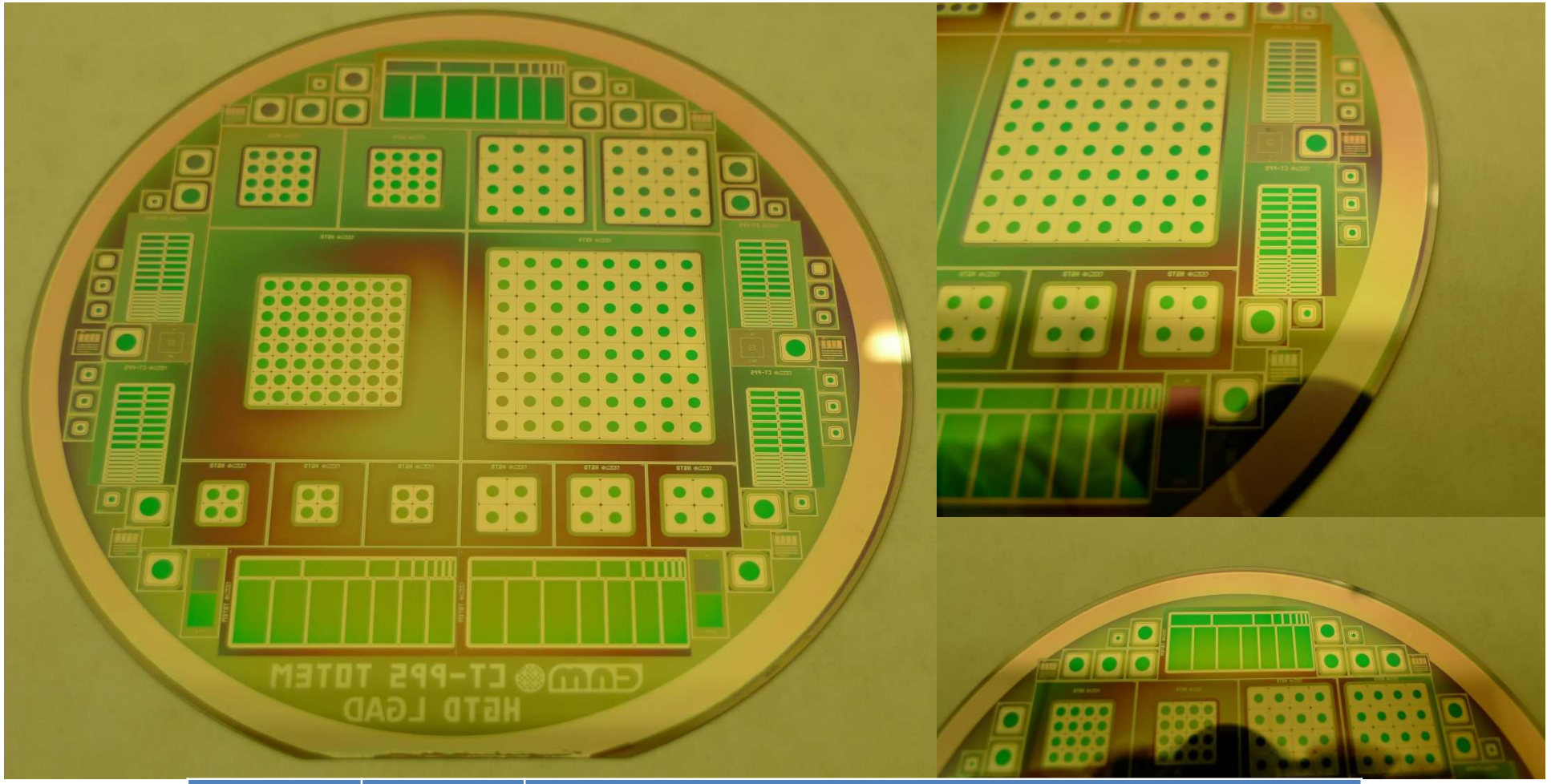
20 bumps connected



11 bumps connected

- Matching of sensor and Altiroc pads
- Note that for 2x2 mm^2 pads, structure will be more fragile
  - *Less bumps, asymmetry*
  - *Correct placing of HV wire-bond in back of sensor*

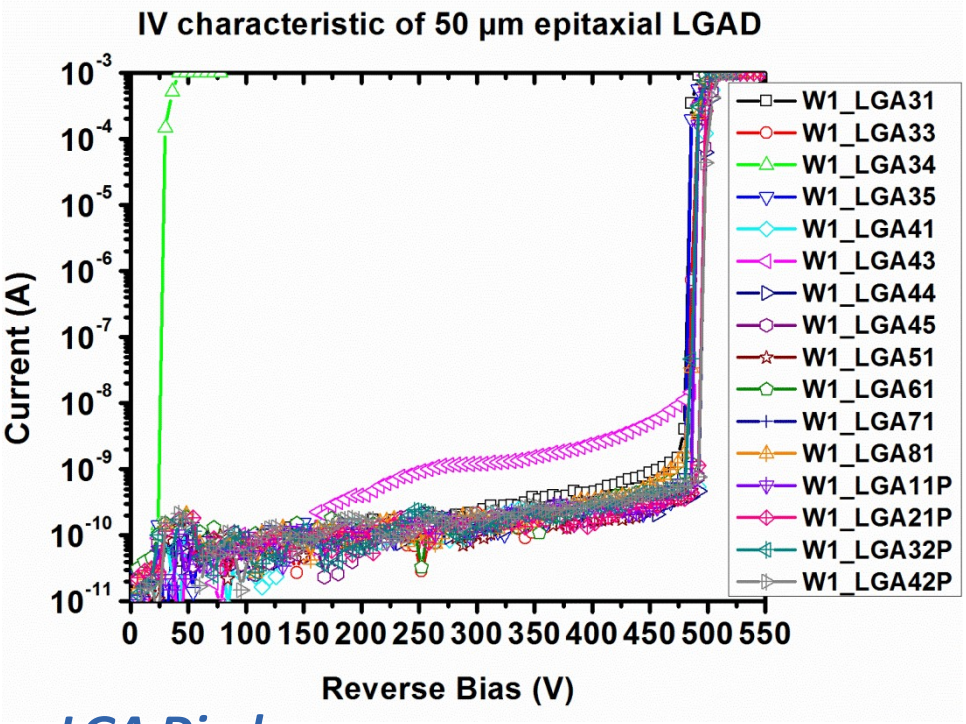
LGAD on Epitaxial wafers (9254)



Wafer 1	**Epi-Si/ Si**	**<100> 50µm-Epi 96.7 Ohms·cm /Thickness 575 µm**
Wafer 2-4	**Epi-Si/ Si**	**<100> 75µm-Epi 104.6 Ohms·cm /Thickness 600 µm**
Wafer 5	**FZ**	**<100> 285µm**

LGAD on Epitaxial wafers (9254)

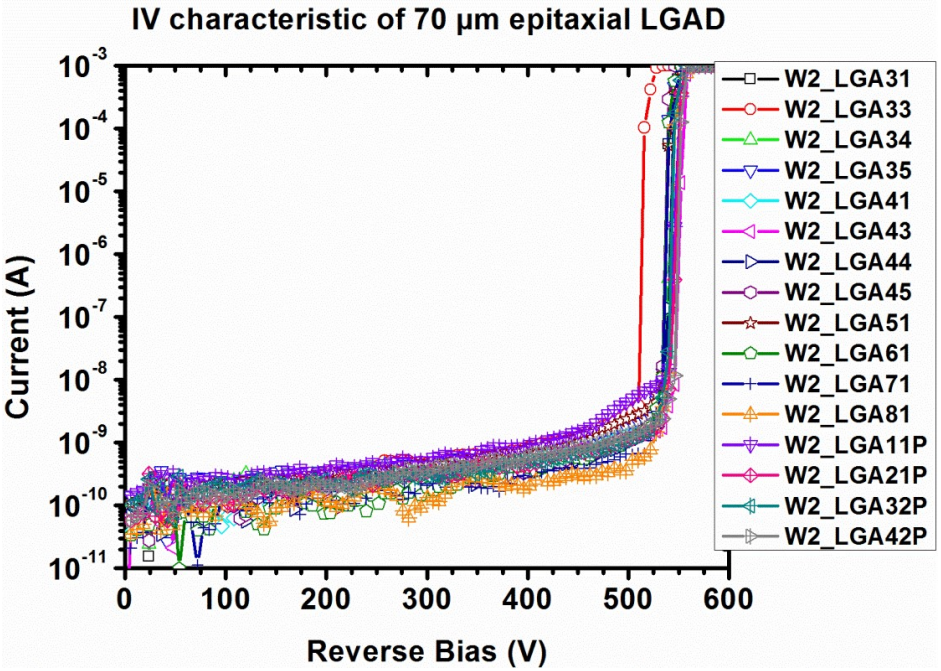
- IV Measurements (50 µm Epi)



LGA Diodes

- Active Area-> 1.3x1.3 mm²
- Breakdown voltage ~ 500V

- IV Measurements (70 µm Epi)

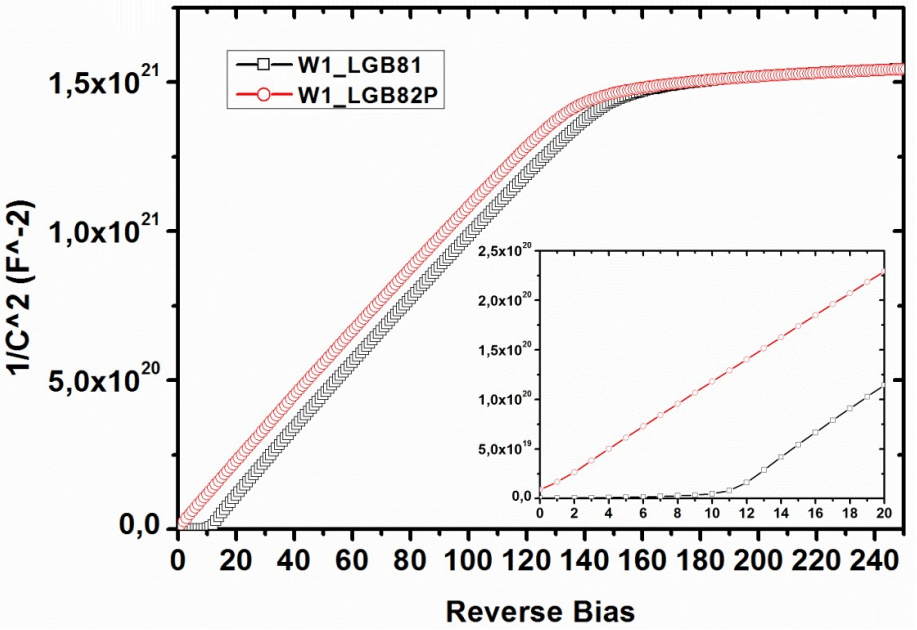


Status

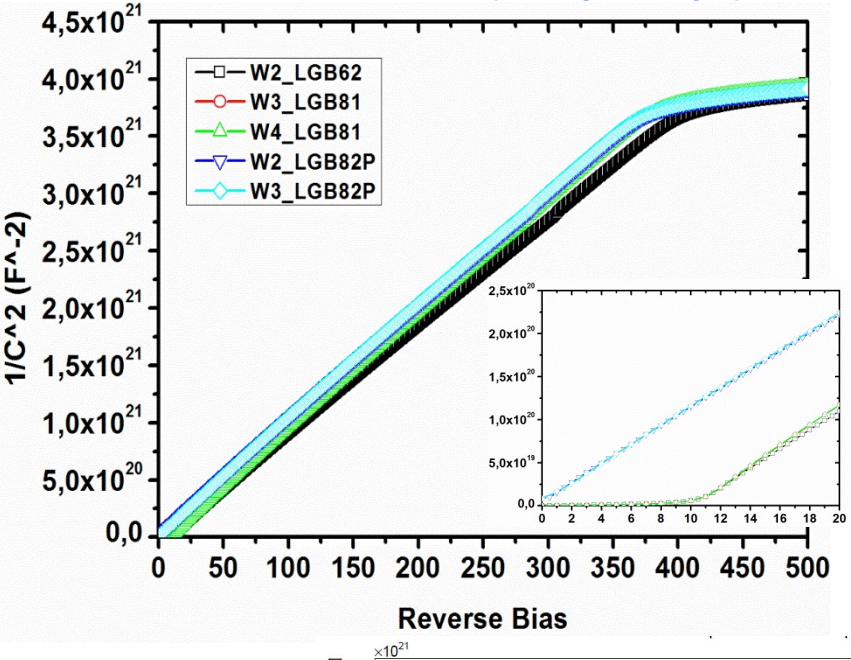
- 4 LGAD (2 x Epi 50µm and 2 x Epi 70 µm) bonded
- 2 PIN bonded
- CCE measurements with a tri-α source next week

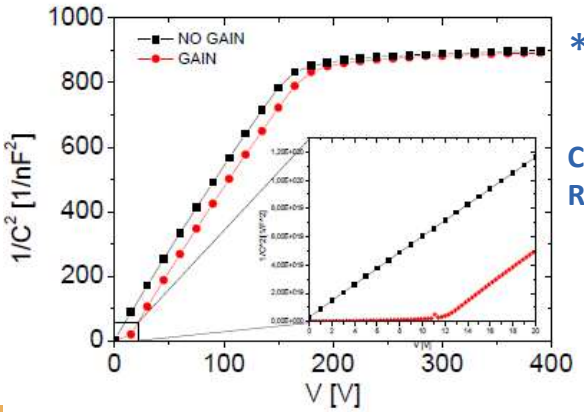
LGAD on Epitaxial wafers

○ CV Measurements (50 µm Epi)



○ CV Measurements (70 µm Epi)

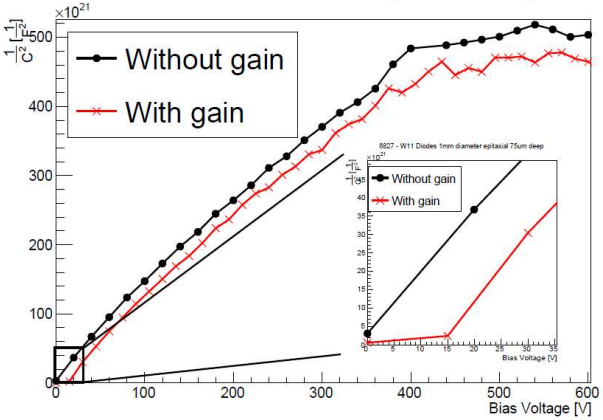




* Comparing to Martar's Ph.D. Thesis

CV measurements agrees with Marta's measurements Run 6827 :

- **V_{FD} at 150V (50 µm) / V_{FD} at 350V (70 µm)**
- **V_{mr} at 11V for both of them**



Work to do

- Wafers already diced.
- Distribute devices to participating institutes.
- No-uniform irradiation (IFAE) AFP and CT-PPS experiments.
- Test gain before and after irradiation. Preliminary results with Alpha source is Gain=2 at 400V.
- New run with new epitaxial layout under simulation.