Progresses in the design of LGAD sensors

AIDA 2020 WP7

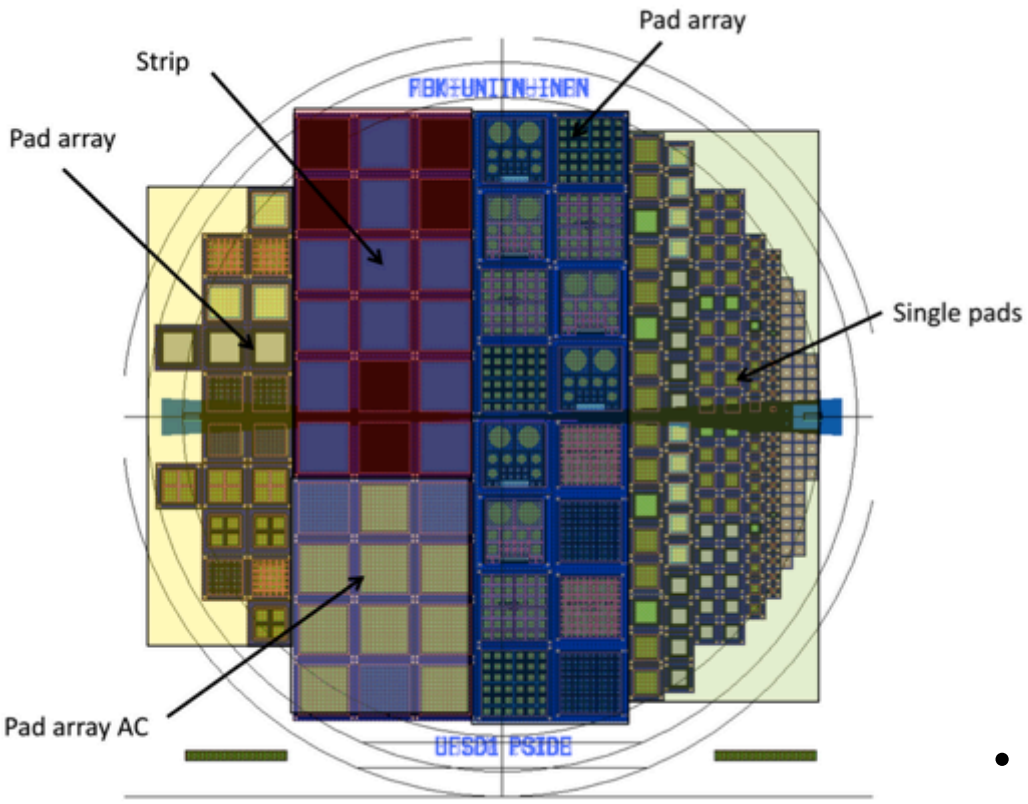
Highlights

- First LGAD and reversed-LGAD production at FBK on 300 micron sensors
- First LGAD SOI production on 50 micron sensor at CNM
- First iLGAD production at CNM
- Good signals from segmented LGADs

Ideas to be exploited soon:

- Reduce the thickness
- Use Gallium instead of Boron
- Carbon Rich Gain layer
- Compensation of gain layer decrease

FBK LGAD production layout

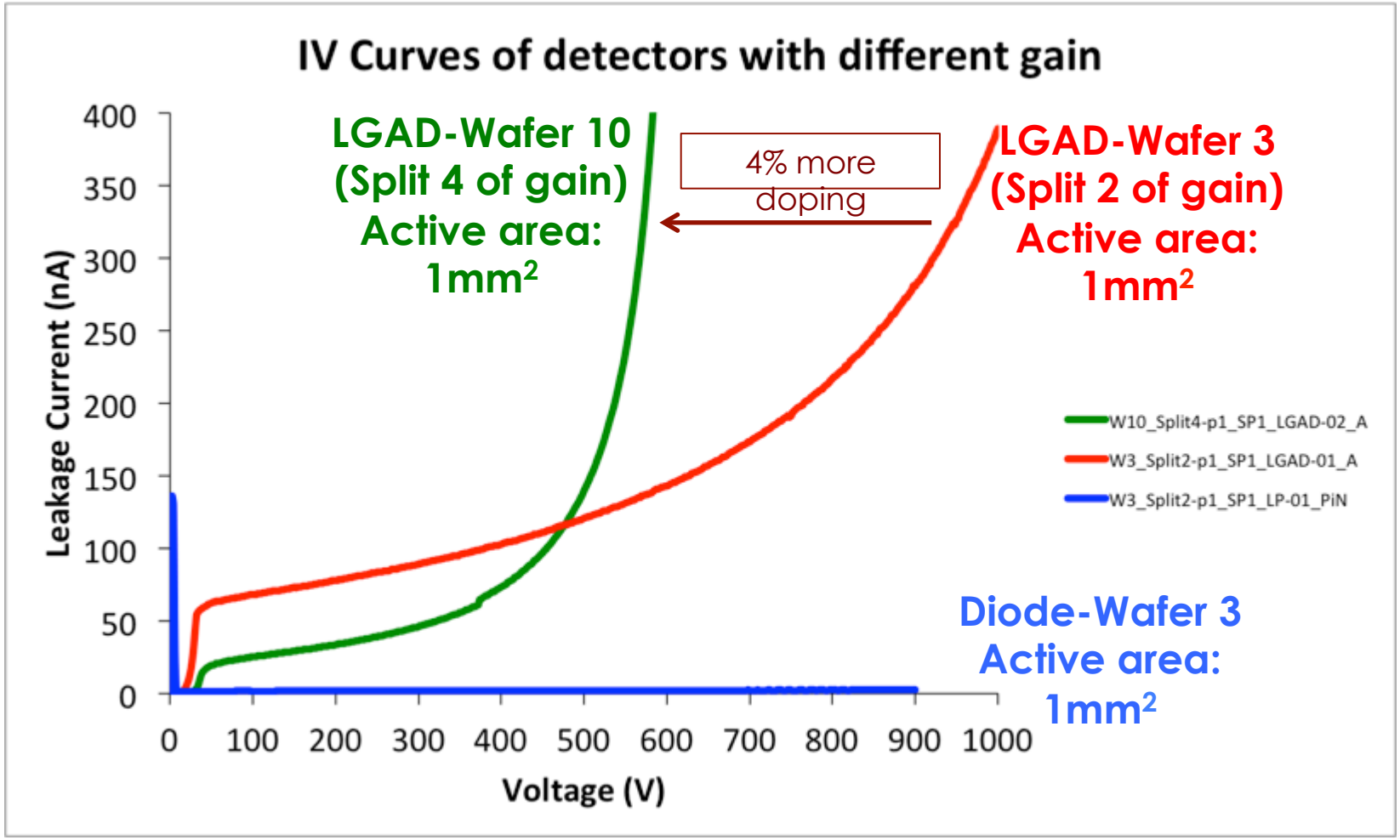


Wafer Layout

Characteristics:
- Thickness 300µm;
- 13 Wafers produced;
- 5 Splits of gain in 2% steps;
- Multiple structures (single pad, multi-pad, array, strip);
- n-side segmentation;
- p-side segmentation;

Goals of this production:
- **Investigate the gain layer**
- **Demonstrator of LGAD technology at FBK**

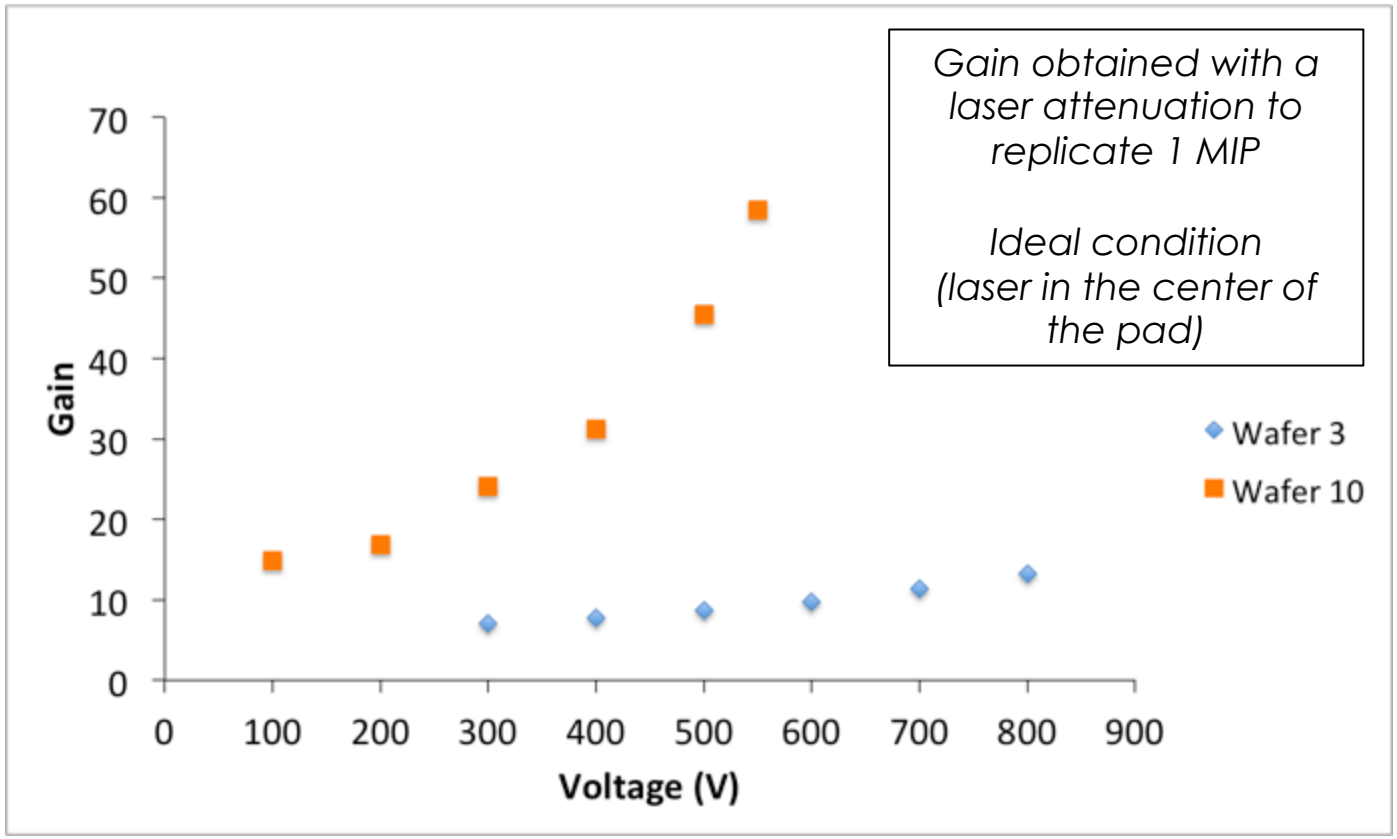
IV measurements



The Breakdown Voltage decreases with the increasing gain

Breakdown in simulation:
- wafer 3 is about 880 V
- Wafer 10 is about 500 V

Gain measurements



Gain = LGAD area signal/DIODE area signal

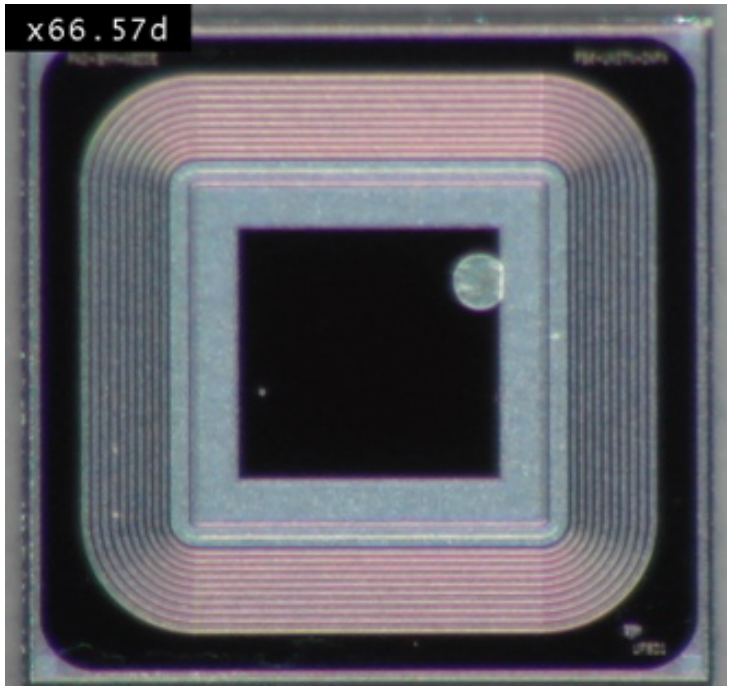
Wafer 3 → Gain between 7 and 13

Wafer 10 → Gain between 14 and 60

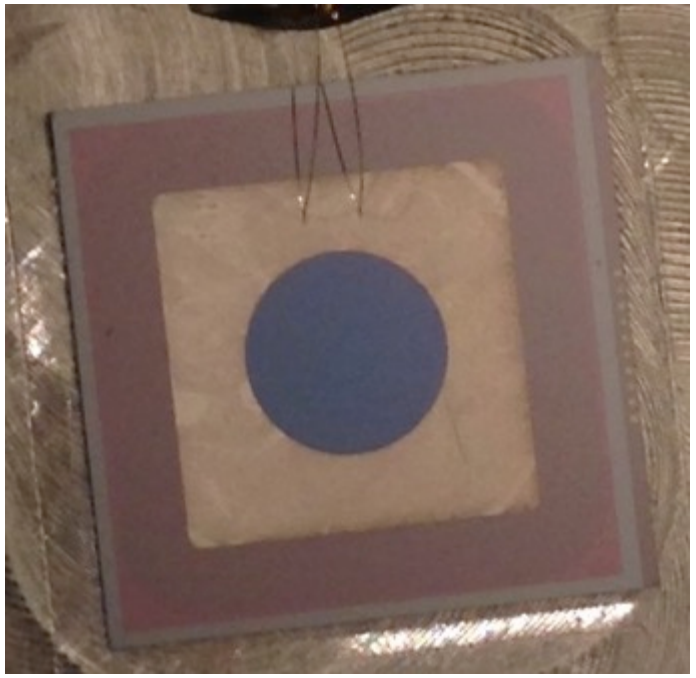
Measurements of gain in agreement with the simulation

The mystery of guard rings

Two clearly smart groups designed the guard rings for their respective LGAD
Can you spot any difference?



FBK

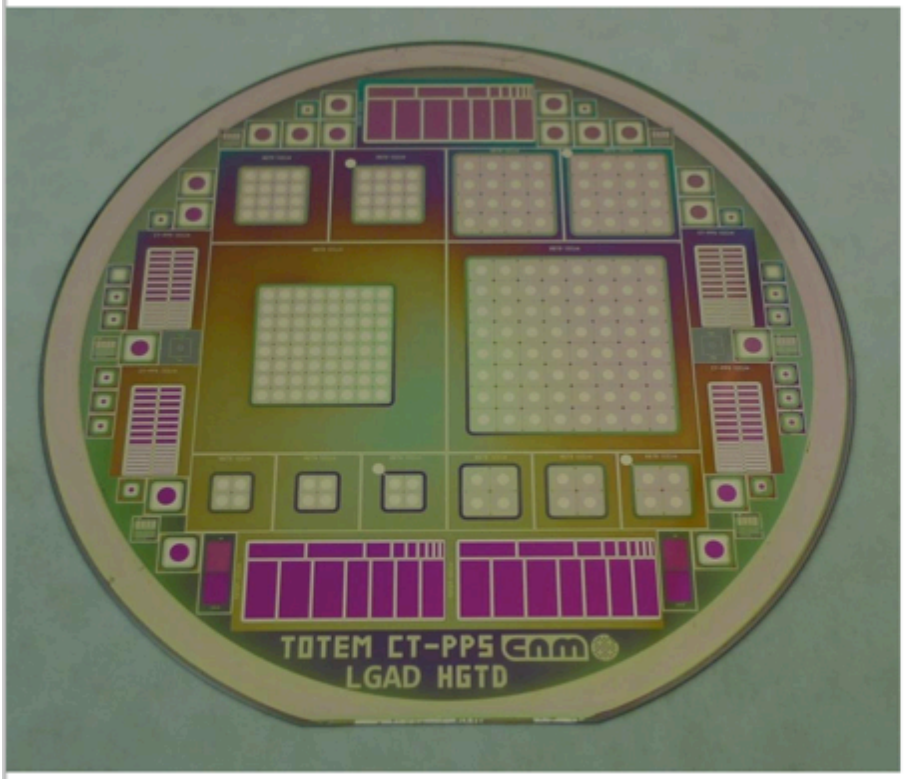


CNM

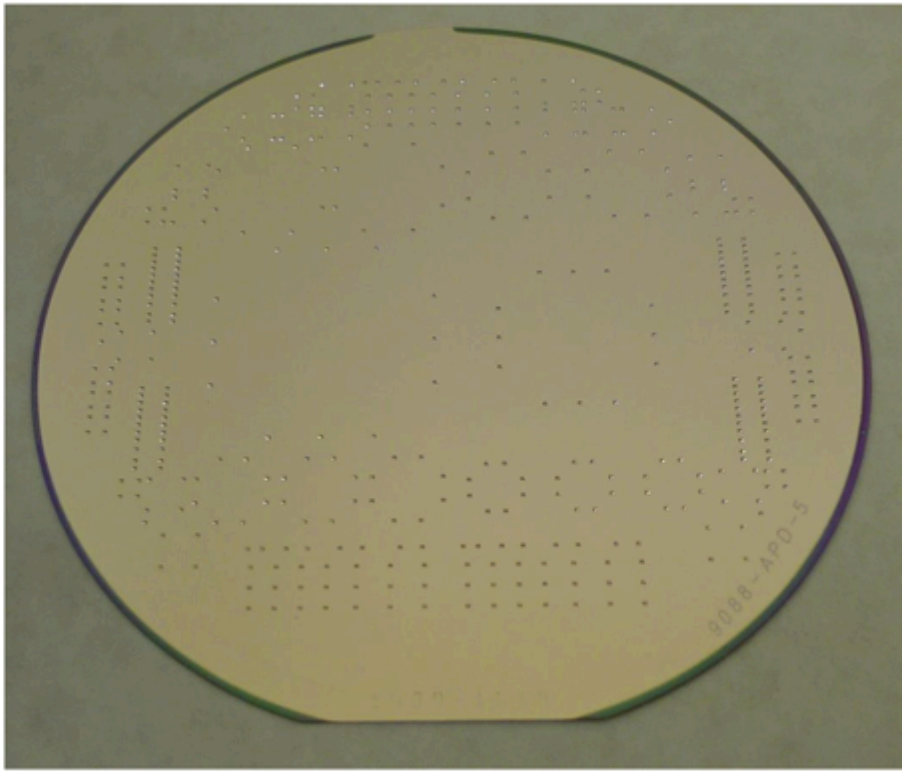
I find it very interesting the two different solutions, both motivated by simulations.

CNM first 50-micron production

Front Surface



Back Surface



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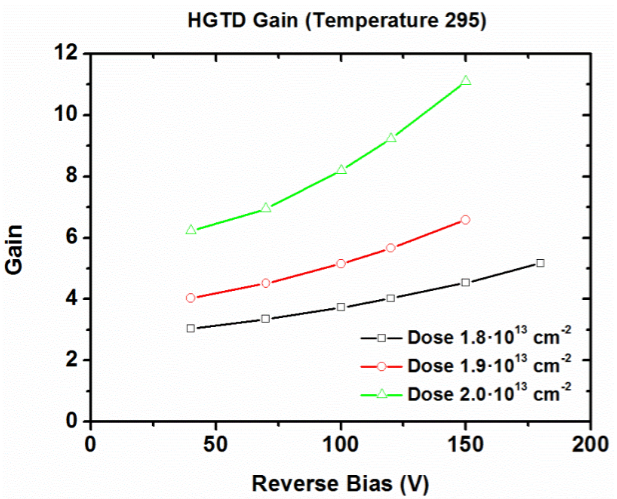
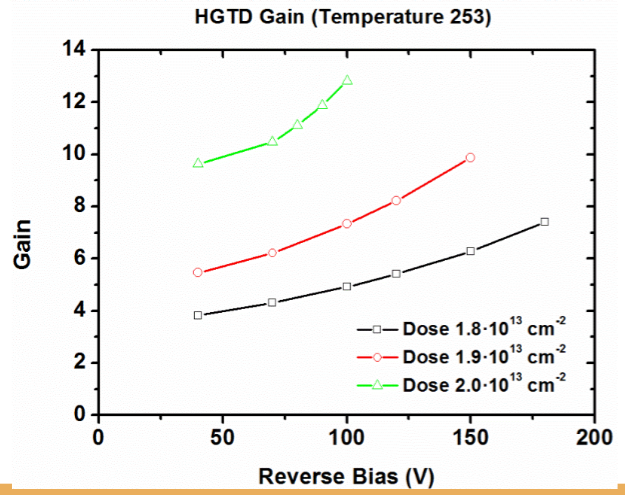
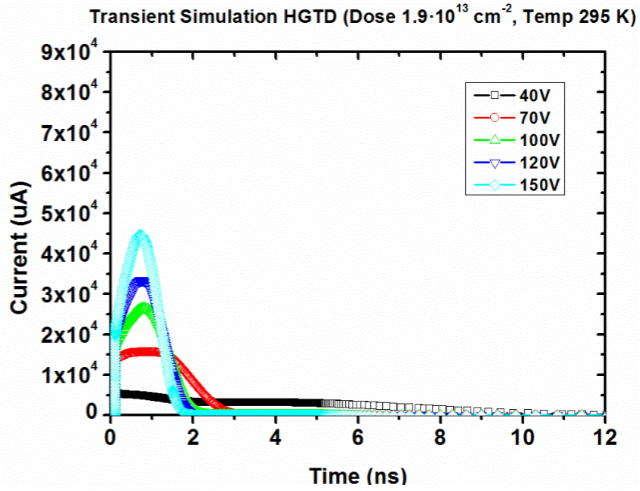
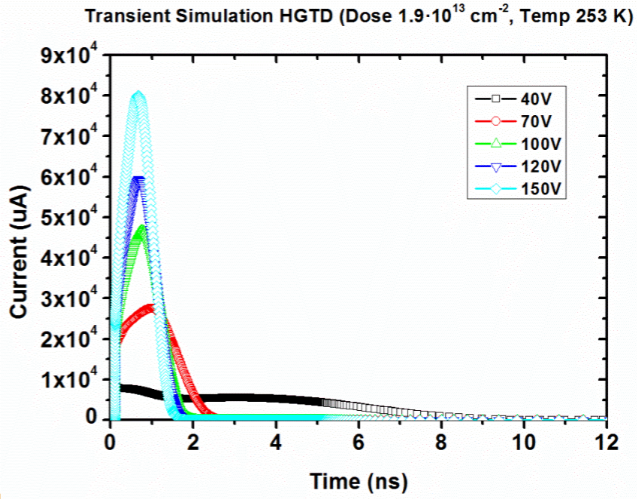
Simulation: note the differences with temperature!

MIP Simulation and Gain.









Simulation optimization at CNM

Simulation TCAD: Synopsys

1ST Step: we compare the Doping profile obtained by SiMs with the Doping Profile obtained in the Process Simulation. Our Process simulation overestimates the Phosphorus junction depth and the Boron peak. We have adjusted the models in order to reproduce the same profiles obtained by SiMs.

2nd Step: The new Simulation Model is validated by C(V) simulation & experimental data (measured at the CNM Radiation Lab). Both of them have the same multiplication layer depletion Voltage @ 30V & the same full depletion Voltage @ 70V.

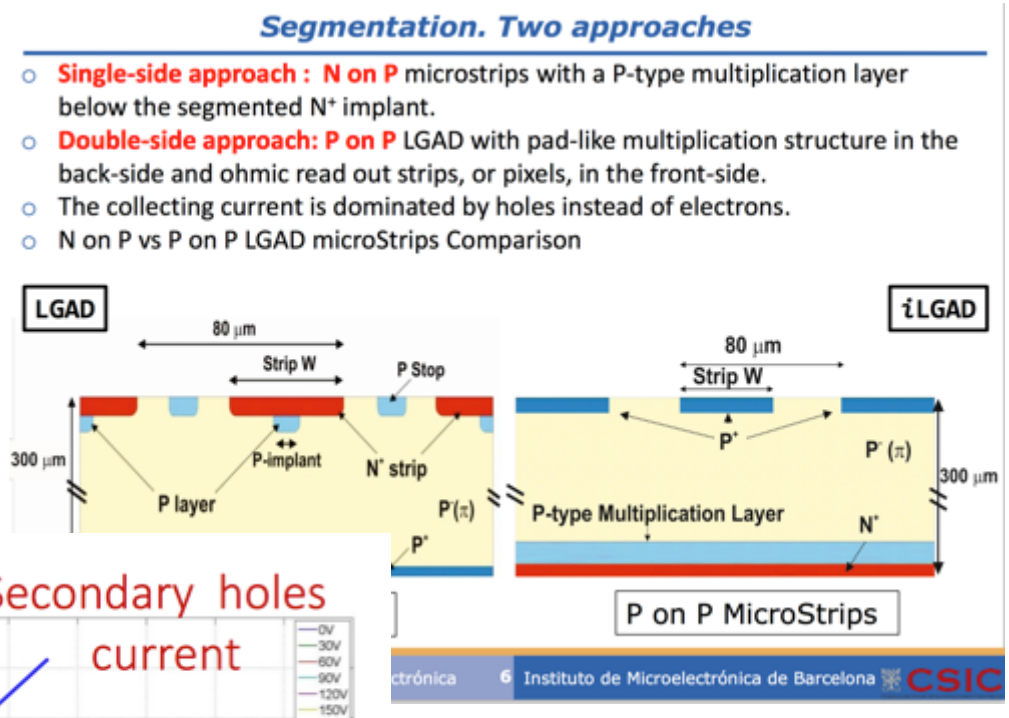
3rd Step: We compare the Gain Simulation with the experimental Gain (measured at the CNM Radiation Lab with a tri-alfa source), as well as with the experimental MIP data (measured at CERN).

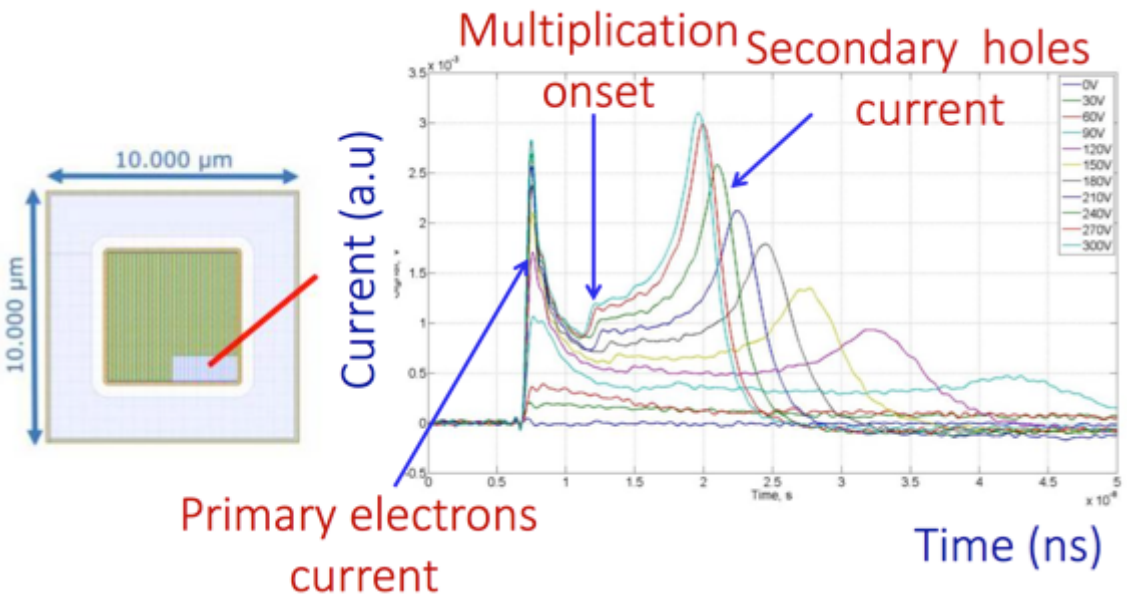
This virtual feedback mechanism is starting now at FBK

LGAD segmented on the p-side

(these devices have two names, iLGAD and reverse-LGAD… like the J/Psi… depending on what side of Sardinia you are)

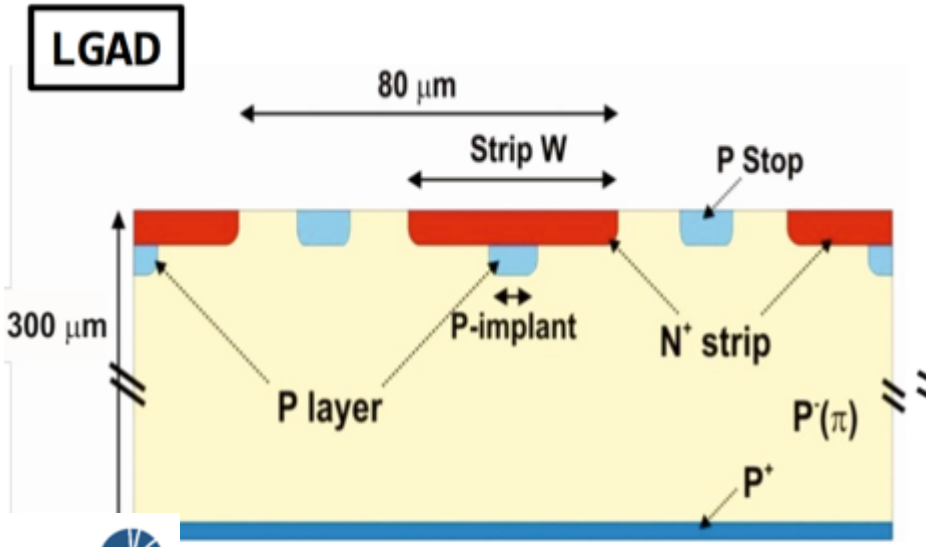
Very nice demonstration of iLGAD (west of Sardinia)



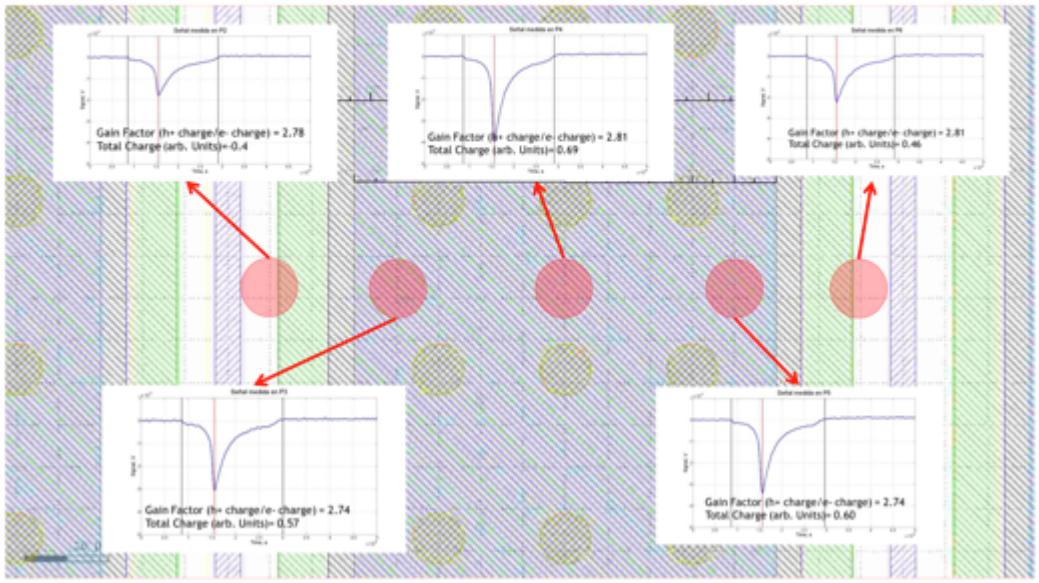


Segmented LGAD

Is the design of LGAD strip reliable?



Strip LGAD: Gain Factor Uniformity:



The elephant in the room

Would LGAD ever work at fluences above 10^{14} n_{eq}/cm^2?

We don't have a design, there are at least 4 ideas that are being explored:

1) Go thin to avoid "double junction" – related effects

2) Defect engineering: dope the gain layer with Carbon. Carbon will prevent the boron to become interstitial.

3) Replace Boron doping with Gallium doping: Gallium is supposed to be less prone to move from substitutional to interstitial

4) Design the sensor so that you can compensate the lowering of the gain
   a) Design the sensor with more gain than what you need
   b) Increase the voltage as the gain layer decreases

Outlook

There is a strong understanding of LGAD design, and there is almost a routine for their productions.

Important steps such as:

- thin sensor design,
- 6" productions,
- segmentation of the ohmic side,
- gain in highly segmented detectors,
- FZ and EPI substrates
- LGAD with thin edges
- more than one producer

have been achieved.

LGAD currently work up to a few 10^{14} n_{eq}/cm^{2}.

➔ A design to go higher in radiation has not been found yet