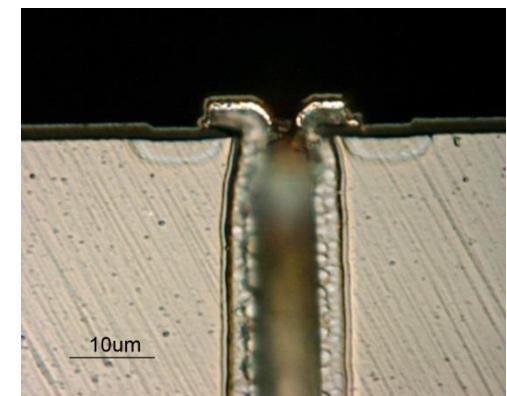
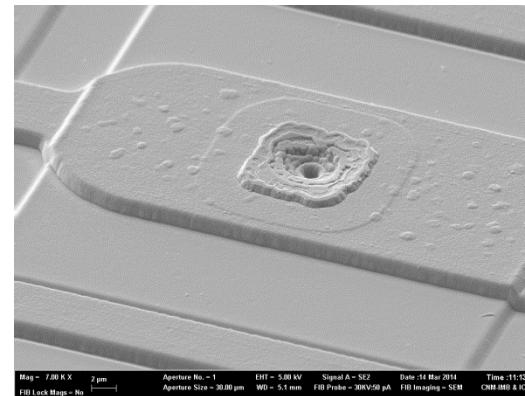


Status of 3D detector activities at CNM

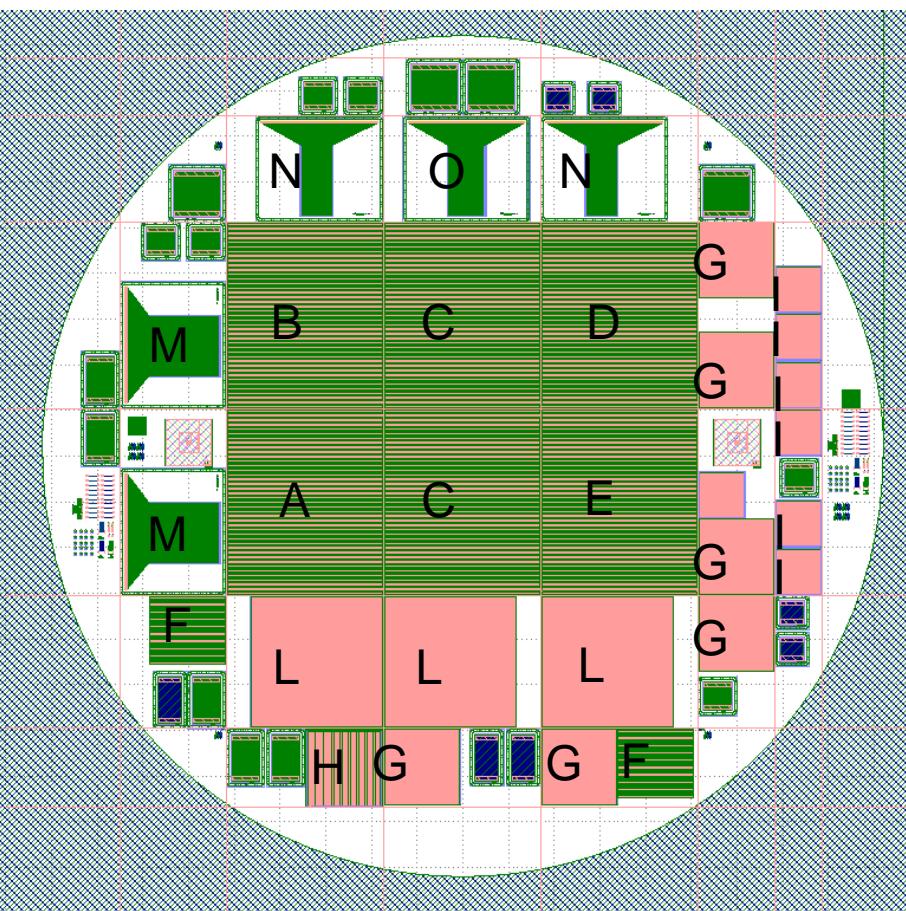
**Giulio Pellegrini
RD50 funded project**



Outline

- **Processes under fabrication**
- **New process to get thin 3D detectors with biasing on the back surface.**
- **Planar detectors activity at CNM.**
- **New developments in LGAD and iLGAD.**

Standard double sided 3D- Joint 3D MPW pixel run (Atlas, CMS, LHCb)



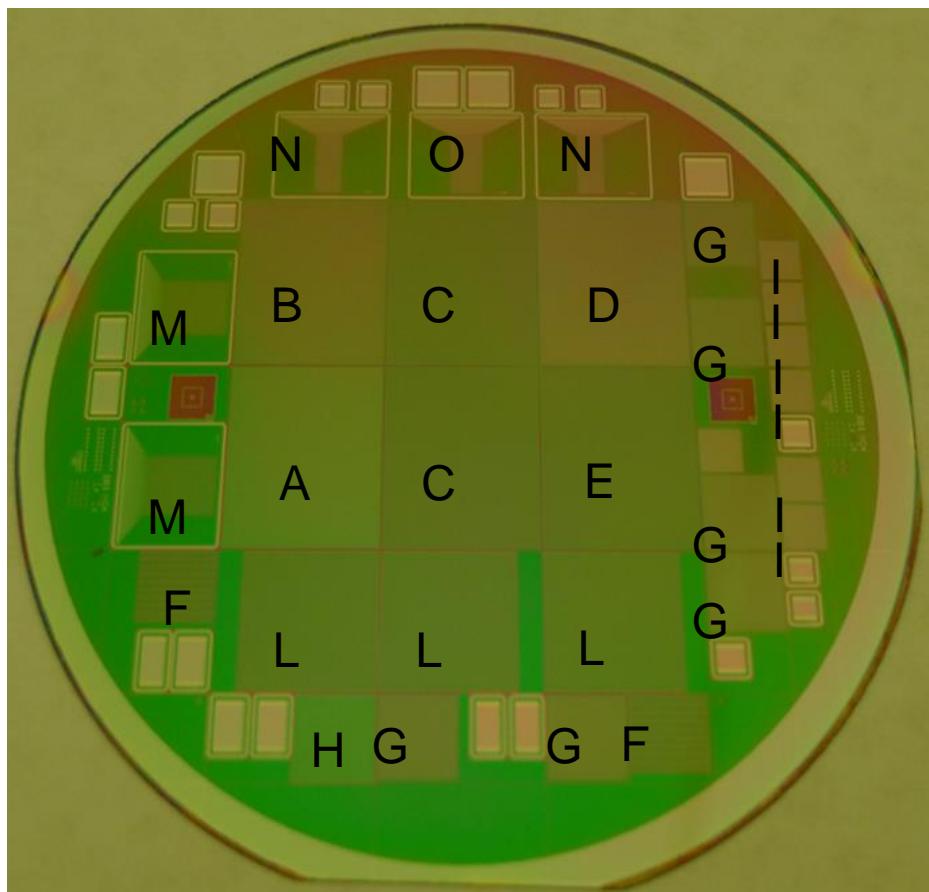
- A: standard Fe-I4
- B:25x100um2 ("25x500" 1E, with 3DGR - a la GP).
- C:50x50um2 with the rest connected to GND with 3DGR
- D:25x100um2 (2E - version 4x100+grid to GND - a la GF)
- E:50x50um2 with the rest connected to GND without 3DGR
- F:FEI3 device: x 50x50um2 with rest to GND with 3D GR
- G: ROC4sens 50x50um2
- H: PSI46dig
- I FERMILAB RD ROC 30x100um2
- L: Velopix 55x55um2
- M: Strip 50x50um2
- M Strip 25x100um2
- O Strip 30x100um2f

- Started in December, 2014 (To be finish in end of 2015)
- 8um holes, 200um thick wafers. Aspect ratio 25:1.
- Radiation hardness of strips with different geometries.
- 4 sides slim edges, 100um and 200um.

**Status= 90% of the fabrication process done.
Temporal metal deposited and wafers are being tested at CNM. 5 wafers.**

RD50 collaboration project

Standard double sided 3D- Joint 3D MPW pixel run (Atlas, CMS, LHCb)



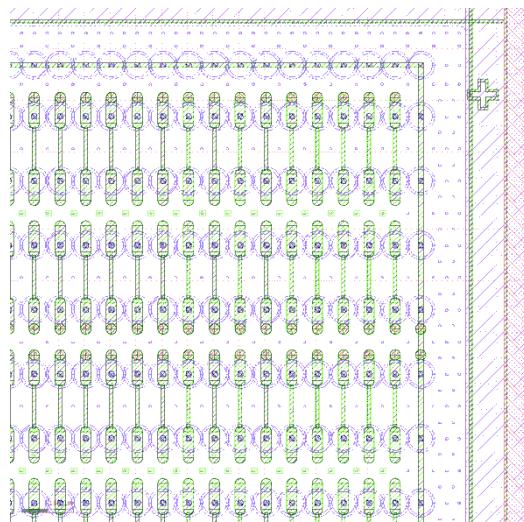
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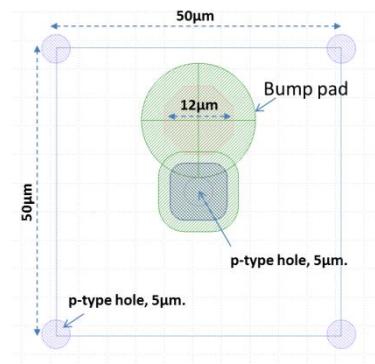
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RD50 collaboration project

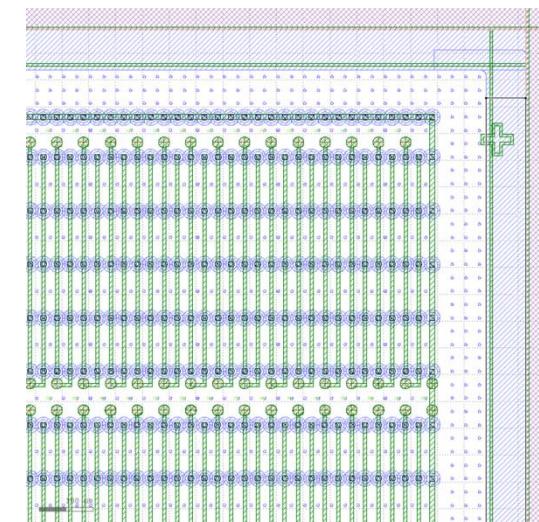
Sensor Layouts- Atlas



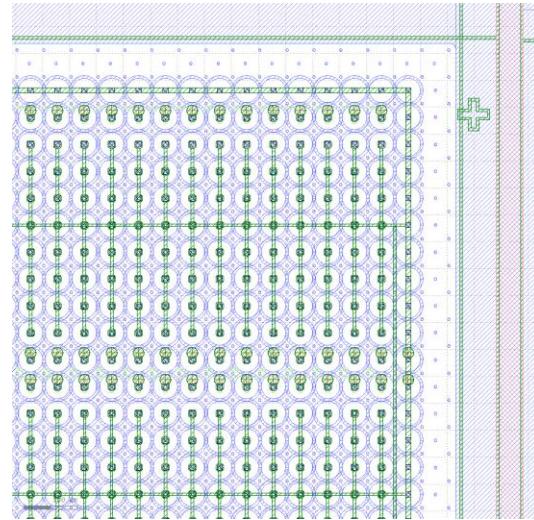
Standard Fe-I4
w/3DGR
 $50 \times 125 \mu\text{m}^2$



$50 \times 50 \mu\text{m}^2$
with the rest
connected to
GND with
3DGR



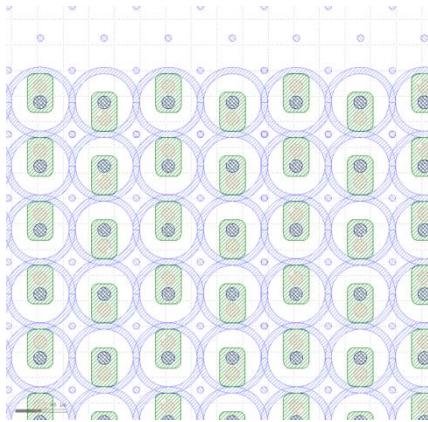
$25 \times 100 \mu\text{m}^2$
("25x500" 1E,
with 3DGR)



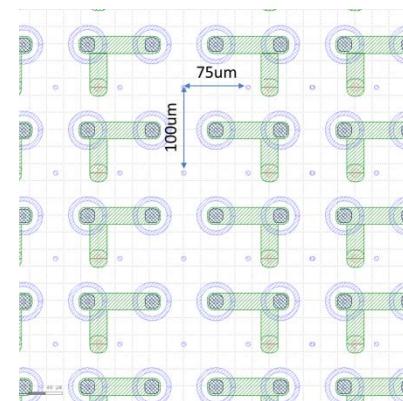
Sensor Layouts- CMS

- **Underlying motivation: small size pixel sensors bonded with ROCs expected to be available in 2016 (signal routing lines where needed).**

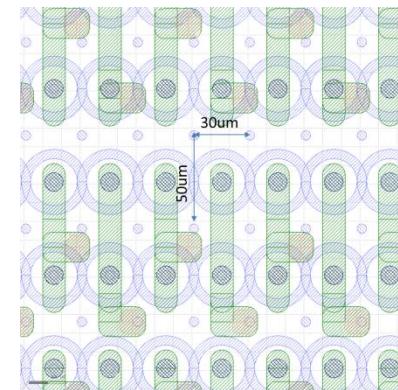
ROC4sens 50x50um²



PSI46dig 2E 75x100um²



FERMILAB FCP130 2E 30x50um²

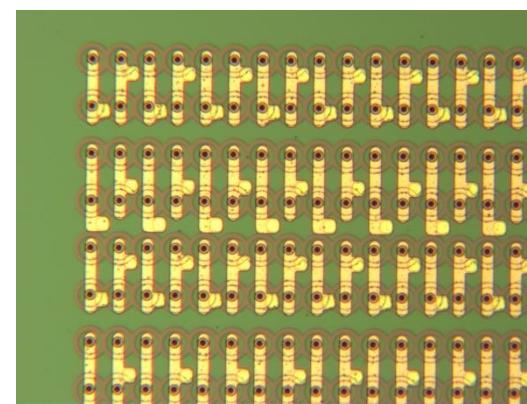
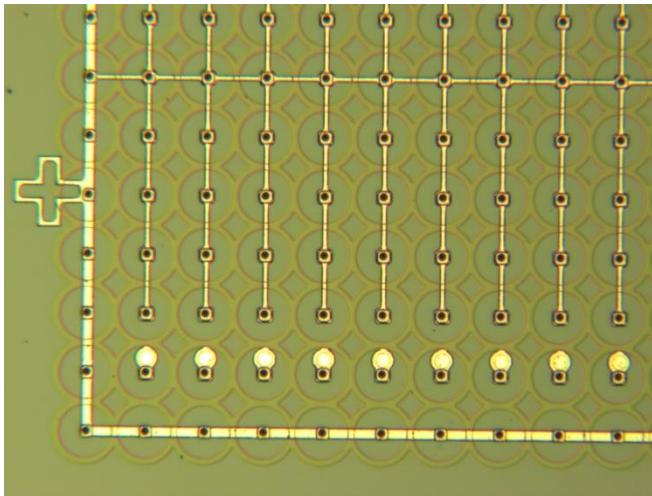


- Design criteria (educated guess for 2E16neq/cm²) :
 - 50x50 um² → 1E layout (à la ROC4Sens).
 - 25x 100 um² → 2E layout (à la FCP130).

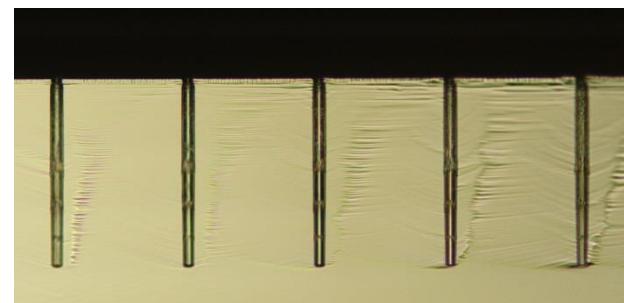
Technology tests

- Increase aspect ratio, 25:1
- Reducing sidewall damage in deep holes.
- Reducing wafer breaking during process. New fabrications.

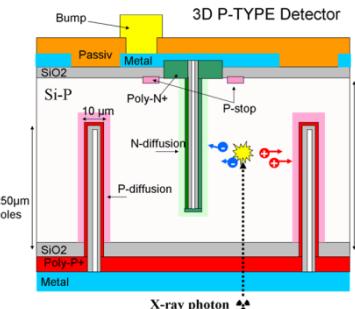
50x50 μm^2 with the rest connected to GND.



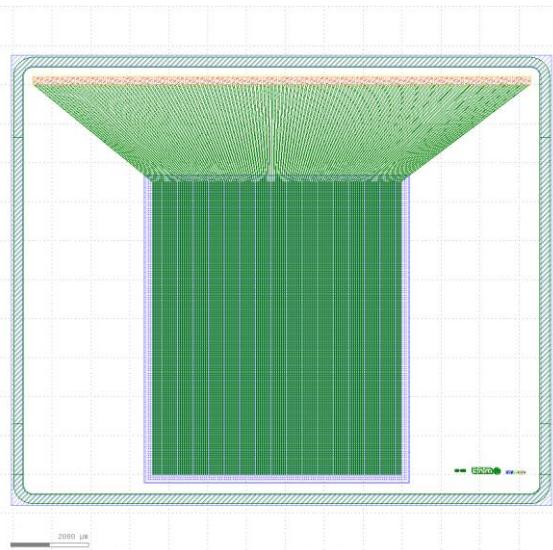
FERMILAB FCP130 2E 30x50 μm^2



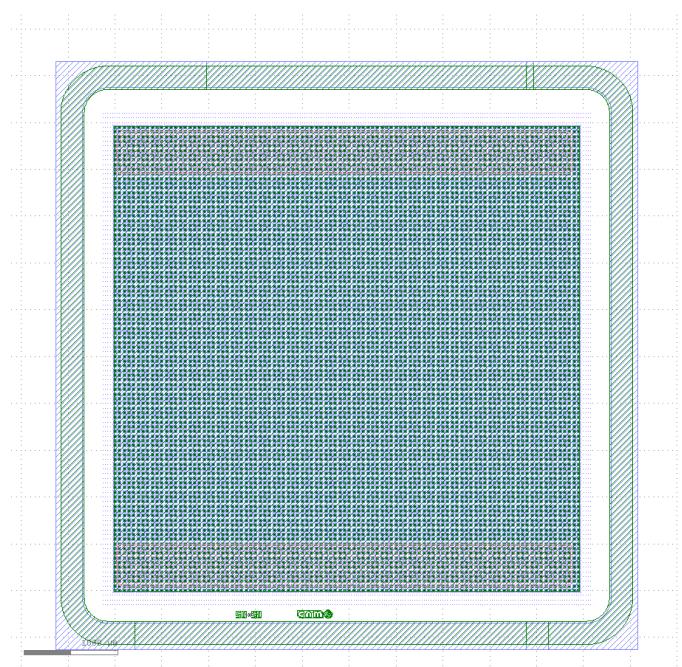
Strips geometries 50x125 μm^2



Diodes and strips



Strips geometries: 50x50, 25x100,
30x120 μm^2

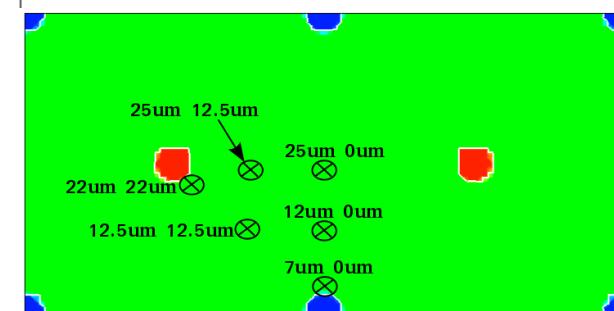
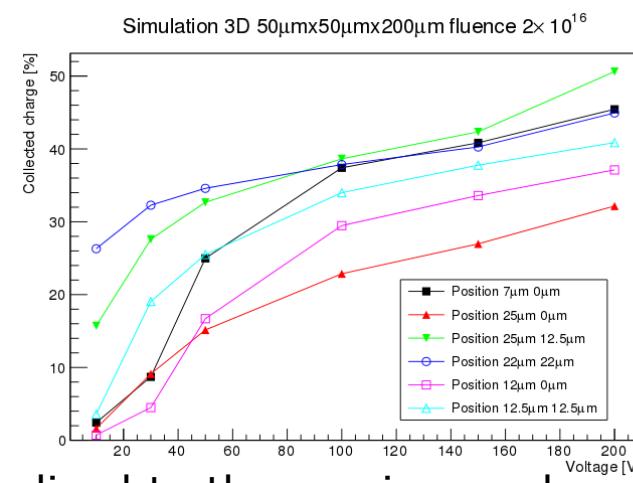
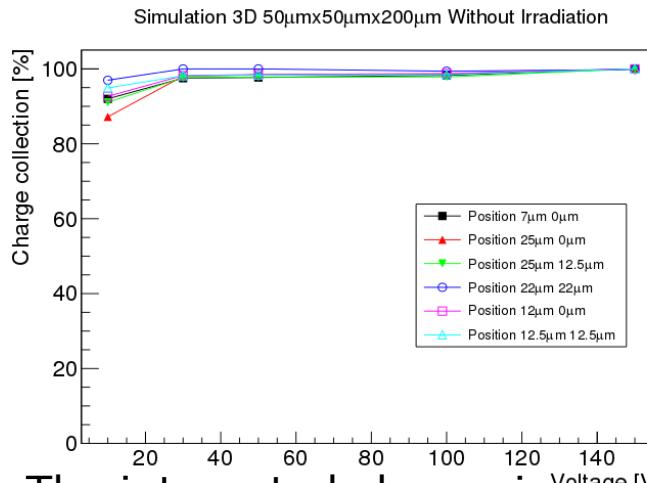
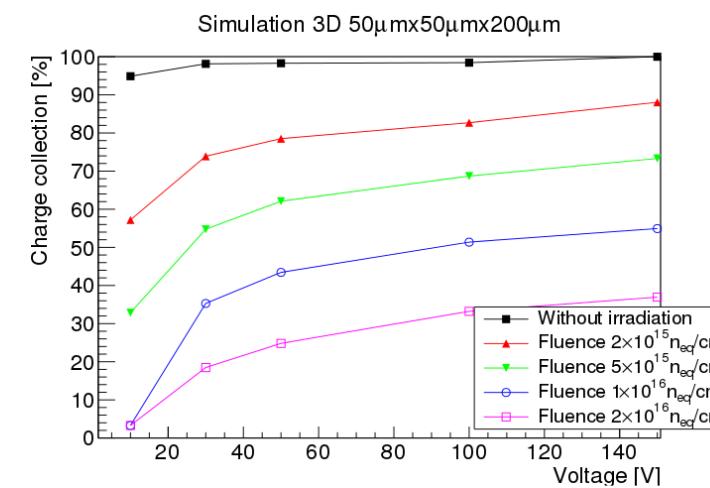
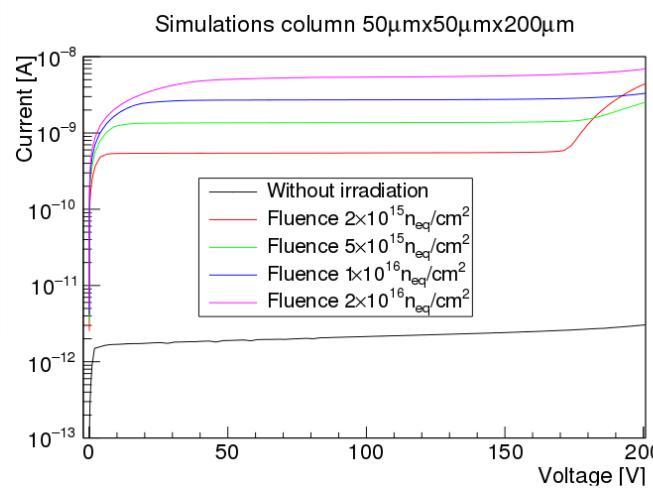
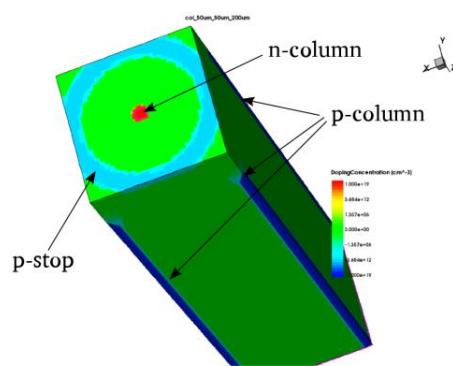


Pad geometries: 25x25, 25x50, 30x30,
30x50, 50x50 μm^2

No guard ring.
Useful to study radiation hardness.
Test current density vs holes density
Metal routing to fit 80 μm pitch electronics (**Alibaba Systems**).
May be connected through our AC fan ins.

Simulations 50x50x200um³

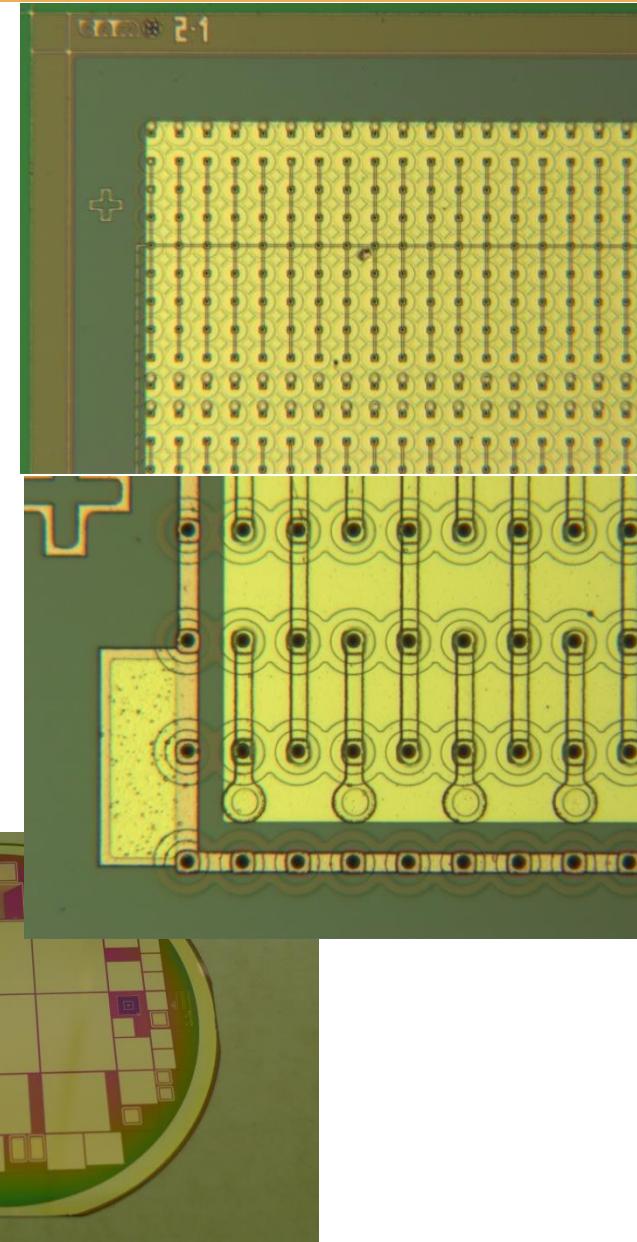
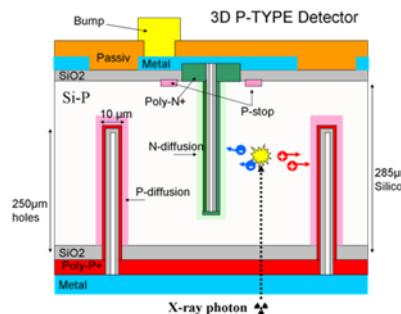
M. Baselga



The integrated charge is normalized to the maximum charge of a non irradiated device, and the maximum collected charge is up to 50% when the detector is irradiated at 2×10^{16} n/cm² and biased at 200V bias voltage.

Technology

- p-holes= 8um
- n-holes= 8um
- Depth of the holes:210um
- FZ wafers, 230um thick, p-type
- Rho >5Kohm
- Metal2 for IV testing.
- Bumps for UBM growth at CNM (for testing).

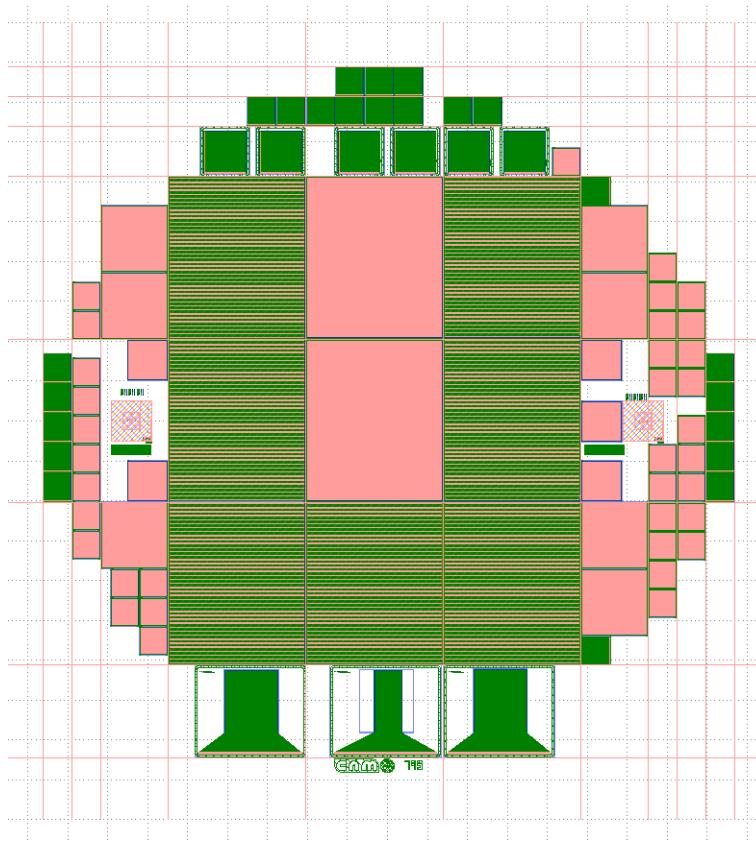


Temporary metal for IV tests.

Temporary metal deposited on the passivation layer and then removed after testing. The test can be done only on the wafer, before dicing.

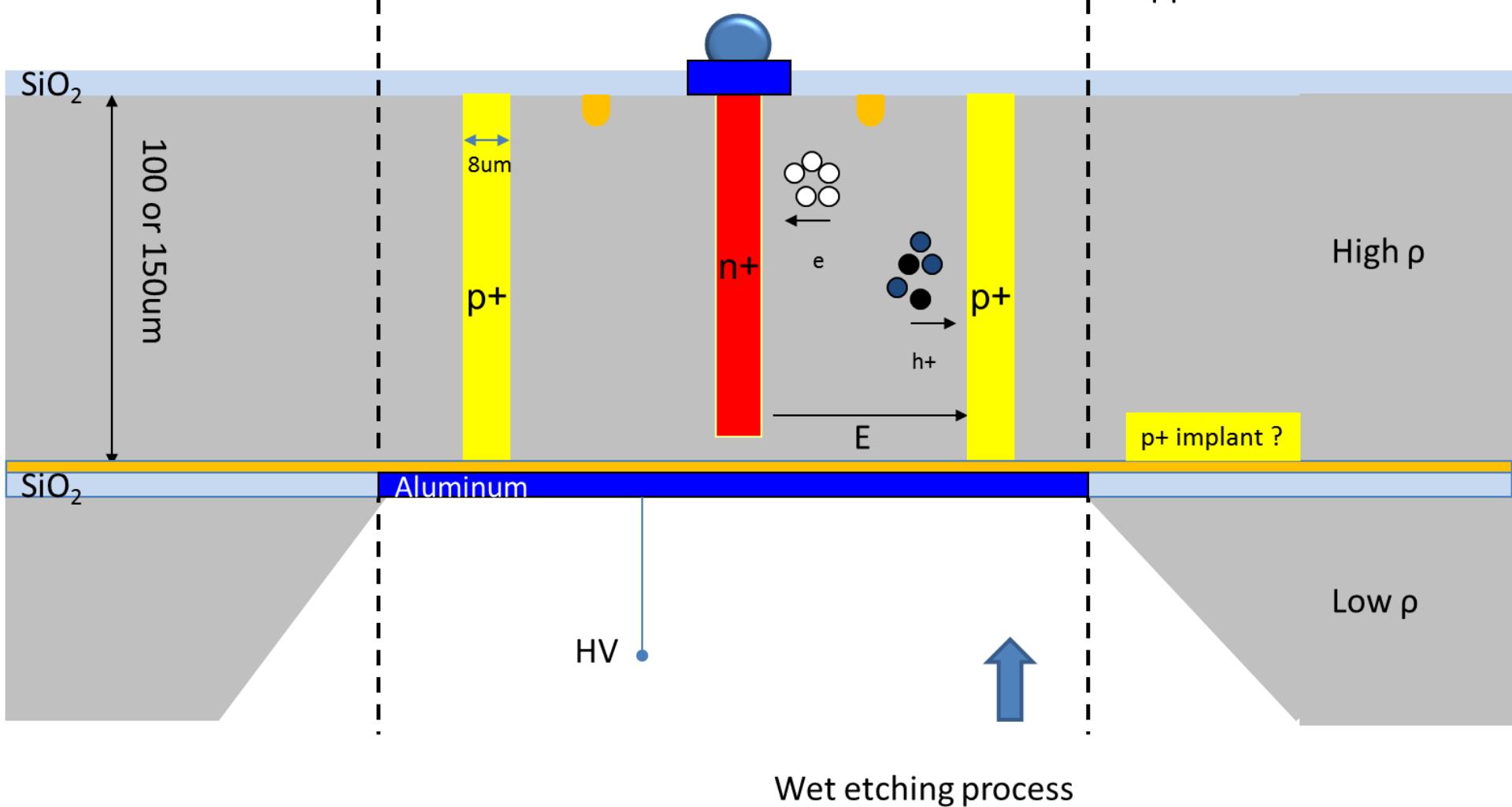
Mask set (single side, thin 3D). Joint 3D MPW pixel run (Atlas, CMS)

Objective: fabricate thin 3D detectors using single side process (very well established at CNM since many years) but with biasing on the back surface.



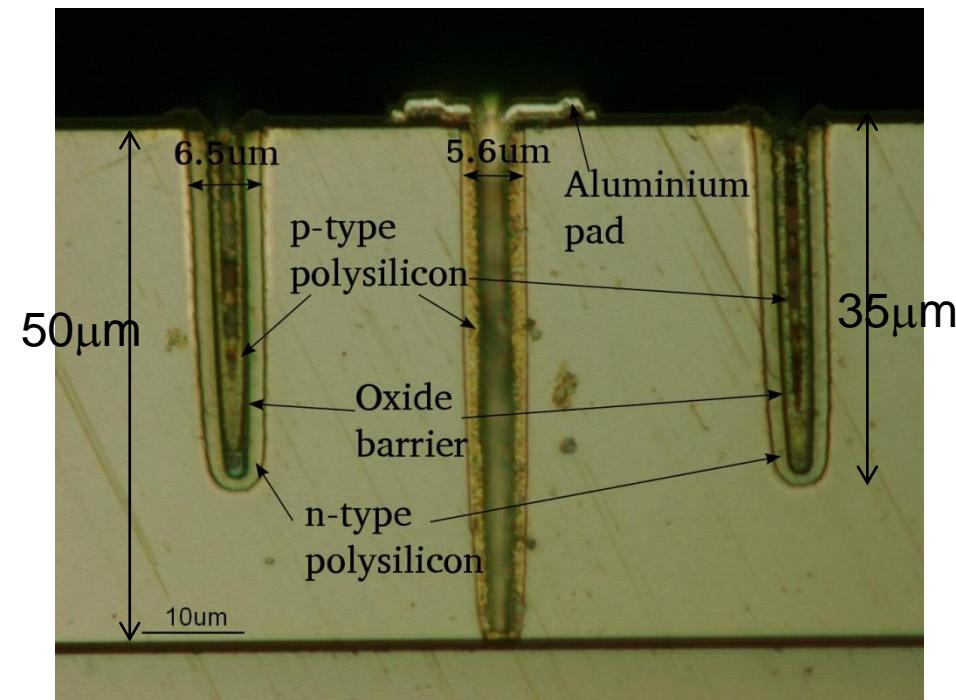
- 3 FE-I4 standard ($50 \times 125 \mu\text{m}^2$)
- 2 FE-I4 $50 \times 50 \mu\text{m}^2$
- 2 FE-I4 $50 \times 50 \mu\text{m}^2$ part of the pixel shorted.
- 2 FE-I4 $25 \times 50 \mu\text{m}^2$ part of the pixel shorted
- 7 CMS PSI $50 \times 50 \mu\text{m}^2$
- 4 Fermilab chip $30 \times 50 \mu\text{m}^2$
- 14 RD53 chip $50 \times 50 \mu\text{m}^2$, 1E (64x64)
- 13 RD53 chip $50 \times 50 \mu\text{m}^2$, 2E (64x64)
- Diodes 50×50 , 25×50 , $50 \times 125 \mu\text{m}^2$
- 3 strips 50×50 , 25×50 , $50 \times 125 \mu\text{m}^2$

Cross section



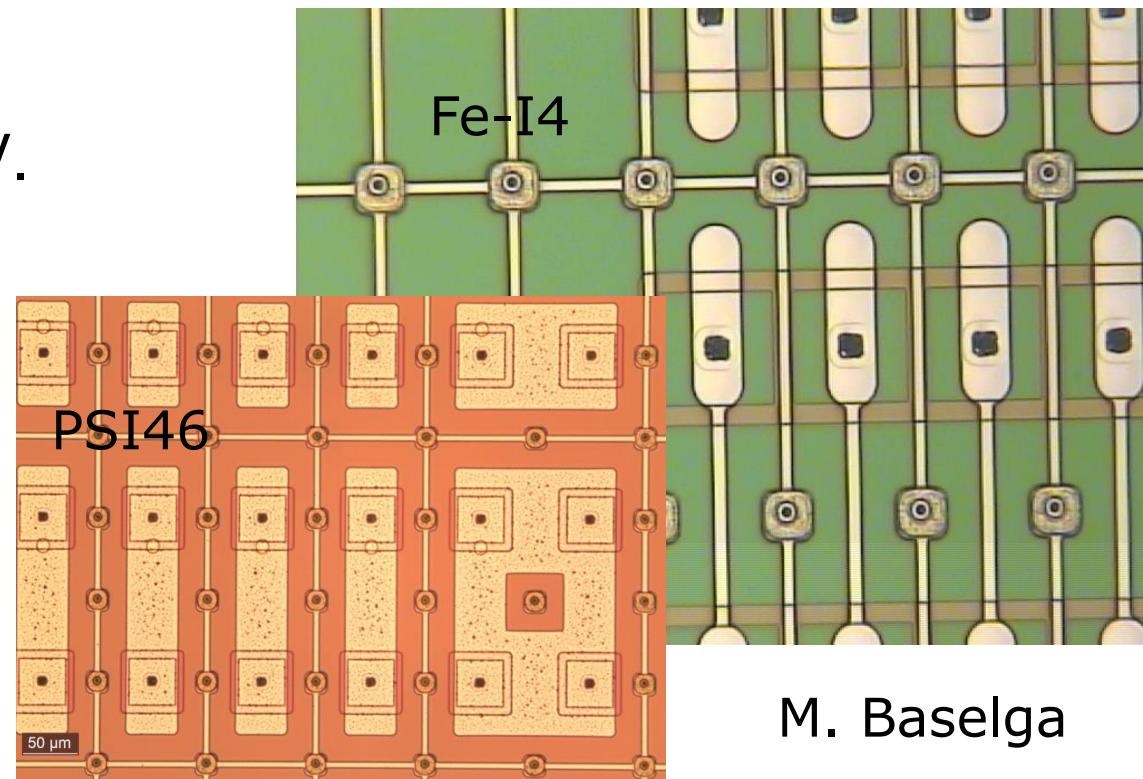
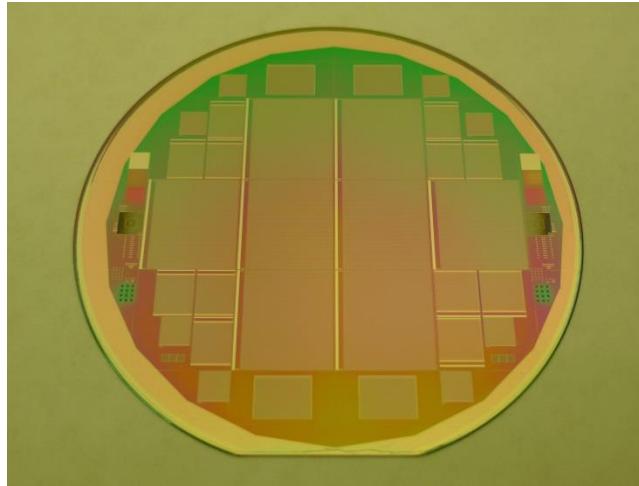
Technology (single side 3D)

- p-holes= 8um
- n-holes= 5um
- SOI wafers implanted =300 + 150um, 300 +100um.
- SOI wafers no implanted= 300 + 150um.
- Rho >1Kohm
- Metal2 for IV testing.
- Bumps for UBM growth.



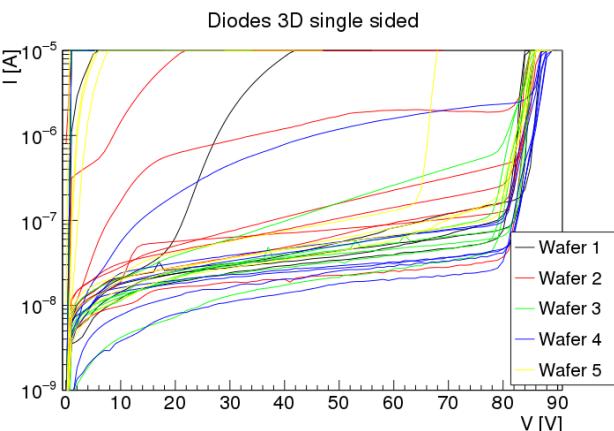
Fabrication of new 3D p-type pixel detectors with enhanced multiplication using SOI wafers (RD50 funded project).

- Single side technology, IBL mask.
- 50um thick detectors with support wafer (350um), SOI.
- Possible to thin down the detectors.
- 5um holes diameter.
- Detector tested, good IV.

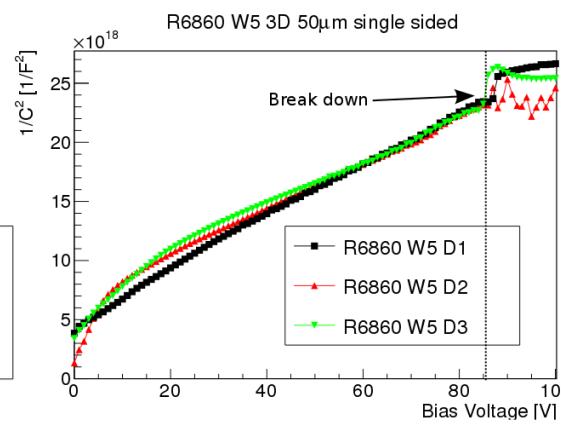


Measurements before irradiation

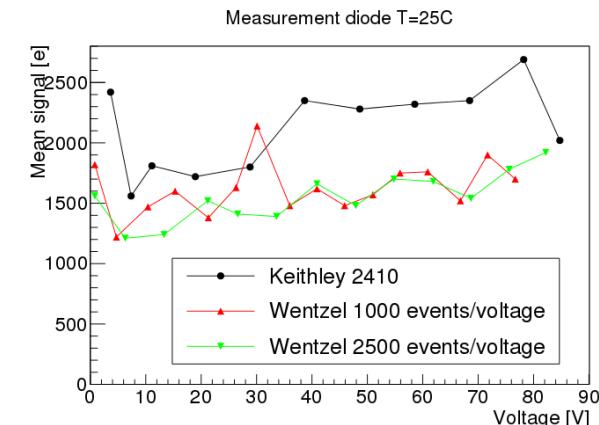
Resistivity of $150\Omega\text{cm}$ -> The detectors are not fully depleted before breakdown



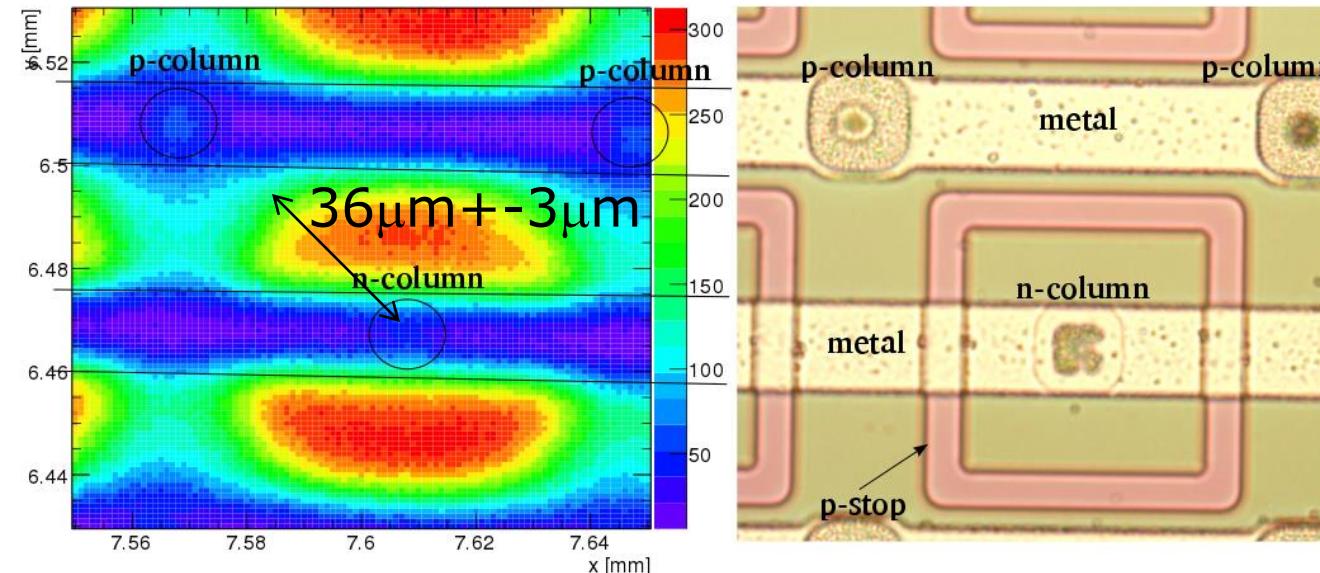
IV diodes



CV diodes



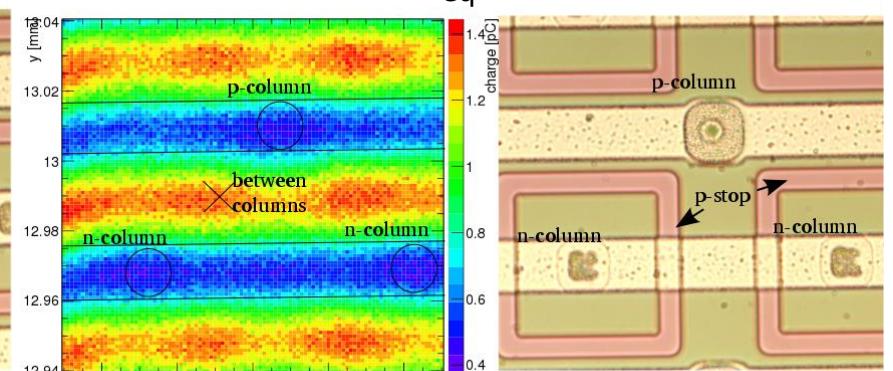
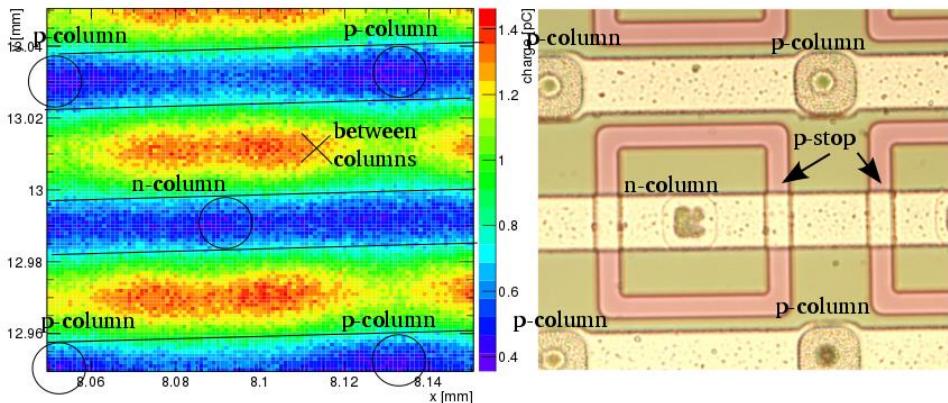
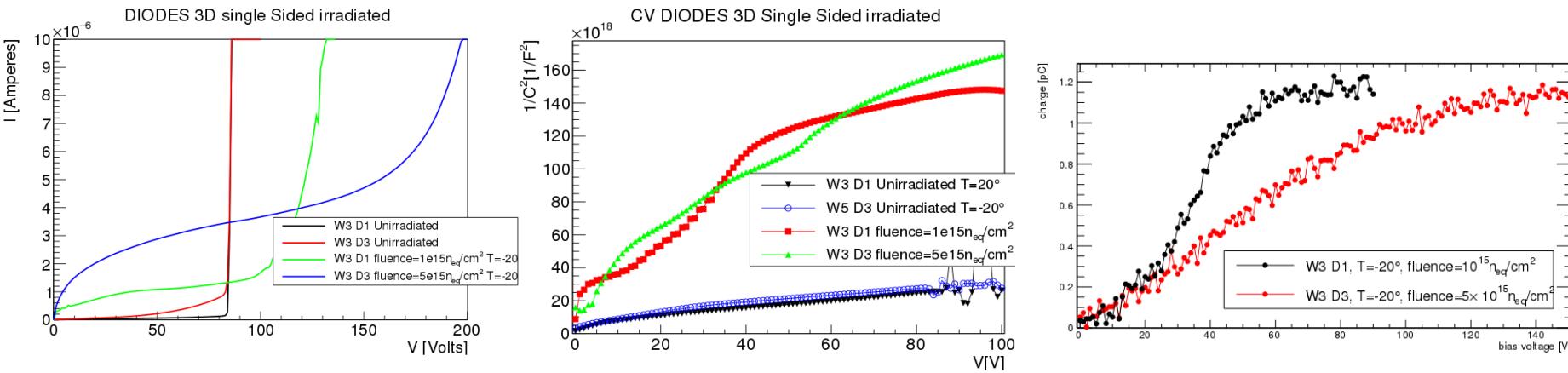
Measurements done at Ljubljana by G. Kramberger with Sr90



Irradiated sensors with neutrons (Ljubljana)

- Fluence $10^{15} n_{eq}/cm^2$
- Fluence $5 \cdot 10^{15} n_{eq}/cm^2$

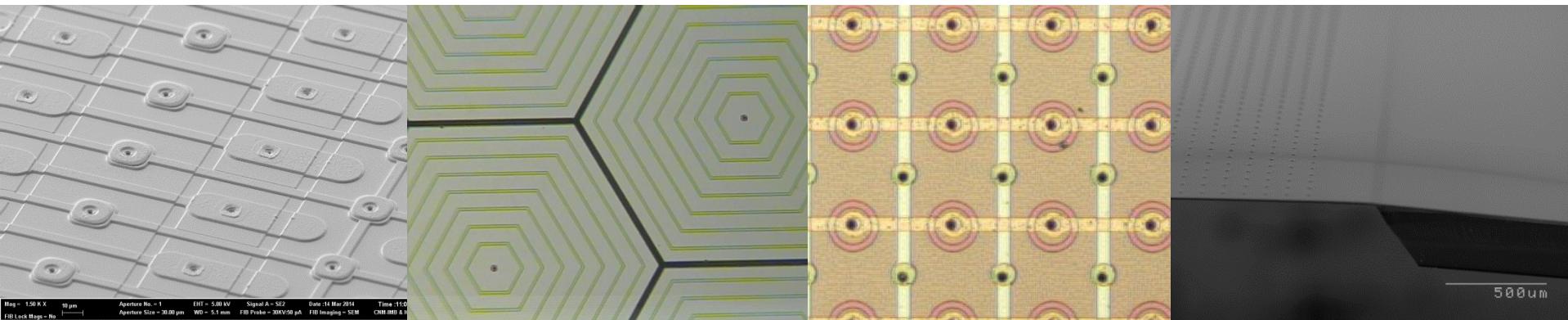
Collected charge between two columns (TCT Measurements at CERN with IR laser) C. Gallrapp



Measurements by C. Gallrapp at CERN

Conclusions on 3d Single side technology

- CNM developed this technology in 2008*.
- We used it to fabricate different detectors for various applications and geometries.
- Our experience is that single side 3D detectors are more complicate to be fabricated and the technology is more difficult to be tuned. Anyway, the yield is higher and the breaking of the wafer is negligible.



* As proposed by C. Kenney and S. Parker

Conclusions

- We are working to adapt the double side 3D technology to the new pixel geometry foreseen for the upgrade of the LHC experiments.
- A common effort in the framework of RD50 collaboration is being carried on.
- There is still place to push the limits of the 3D detector technology up to fluences of 2×10^{16} n/cm². At least simulation shows that the detectors can collect more than 50% of the charge at 200V.
- 3D detectors with 50x50um² geometry are a reliable option for the upgrade. The technology is ready and the thickness of the substrate can be adapted to the requirements of the experiments.

Thank you for your attention !!!!



Simulations 100 μm x25 μm x200 μm

