Results on Irradiated 3D Pixel Sensors Interconnected to RD53A Readout Chip

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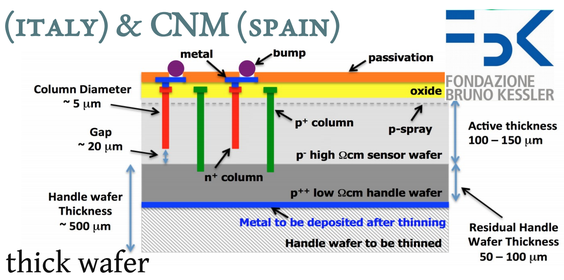
3D COLUMNAR PIXEL SENSORS

3D sensors[1] fabricated at FBK (Italy) & CNM (Spain)

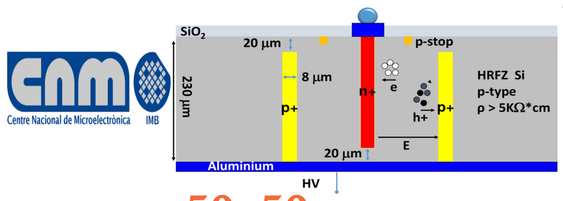
Subtrates: p-type

Single sided (Si-on-Si, FBK)
Double sided (CNM)
Implanted on Float Zone (FZ)
- High resistivity (>3 kΩ cm)
- 130 μm (FBK)/230 μm (CNM) thick wafer

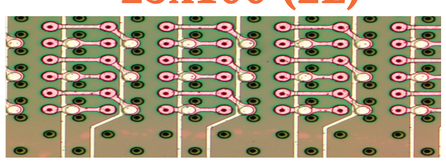


Pixel layout

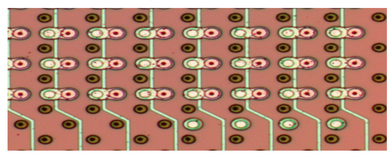
- 25x100 with two junction electrodes (2E)
- 25x100 1E
- 50x50

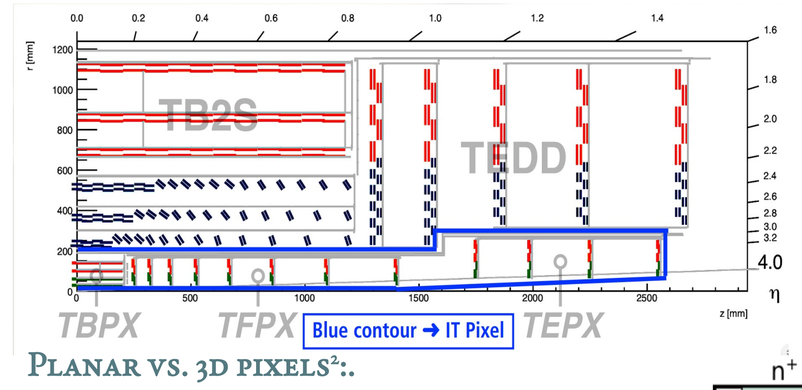


25x100 (2E)



50x50





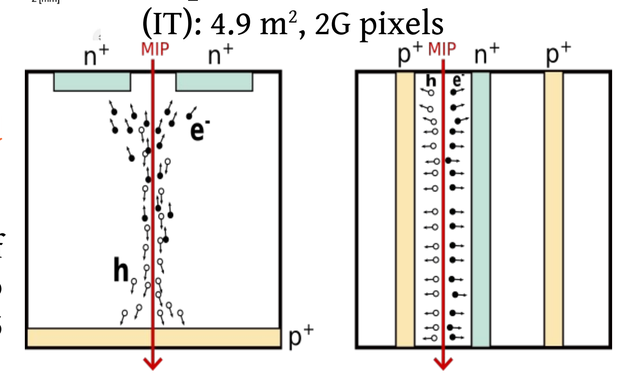
CMS Upgrade for HL-LHC.

Innermost layers of the future HL-LHC experiments will have to survive with high tracking efficiency up to a **fluence** in excess of **1x10[16] neq/cm²**. CMS Inner tracker (IT): 4.9 m², 2G pixels

Planar vs. 3D pixels[2]:.

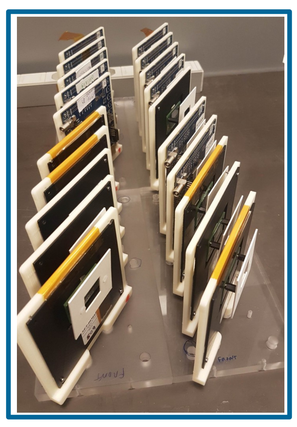
- **Full depletion at lower bias voltages**
- **Less impacted by trapping, higher collected charge**
- **Fast response time**

Same pitch and thickness → same number of electron-hole pairs, but less max. distance to travel before being collected (51μm 25x100 1E, 35 μm 50x50, 28 μm 25x100 2E)

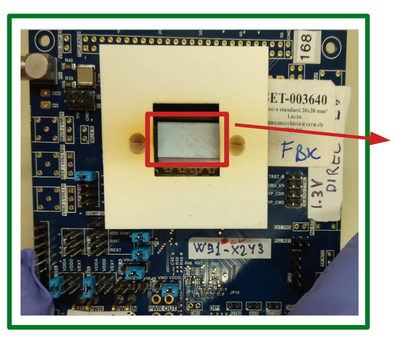


irradiation & Test Beam setup

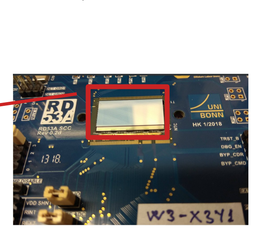
Irradiation performed at CERN IRRAD in high intensity 24 GeV/c proton beam with a FWHM of 12 mm in x and y direction. **Target fluence** was **1x10[16] neq/cm²**. Modules tilted on beam at an angle of 55 deg. to irradiate the 2.4x1 cm² sensor area. Under investigation maximum fluence reached depending on sensor area. Results shown here are preliminary, based on the assumption of the target requested equivalent fluence.



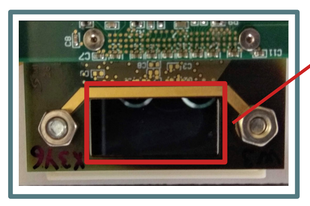
Modules mounted on the tilted supports before installation on IRRAD



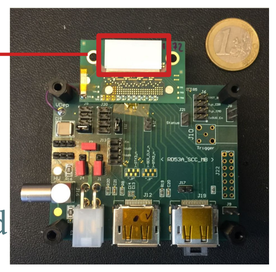
Pixel sensors and RD53A chip on a **SCC Bonn** card



Back side: Al plate for support and thermal contact

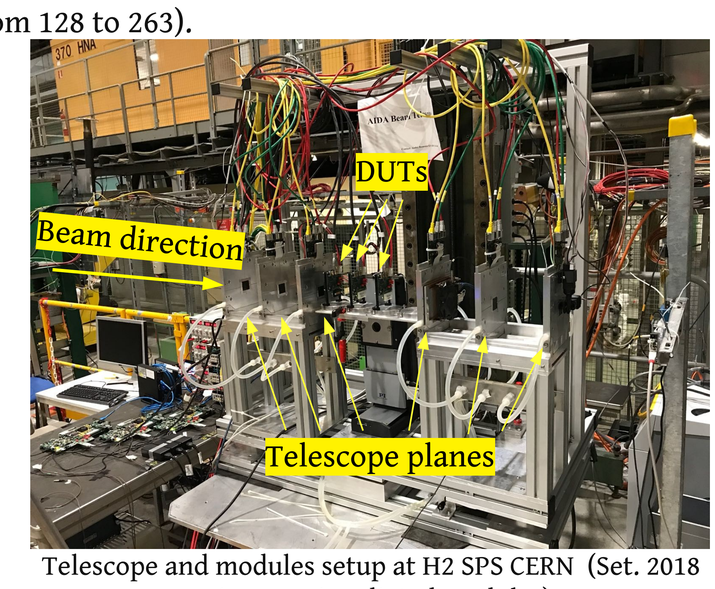


Pixel sensors and RD53A chip on a CMS irradiation **RICE** card



RICE adapter board

TEST BEAMs at CERN : pixels sensors were bump-bonded with RD53A prototype readout chips[3] in units with 76800 single pixel cells (400 rows, 192 columns). The modules were tested on 120 GeV/c proton beam both **before** and **after** irradiation. Preliminary results presented here were obtained with the Linear Front-End of the RD53A chip (136 columns, from 128 to 263).

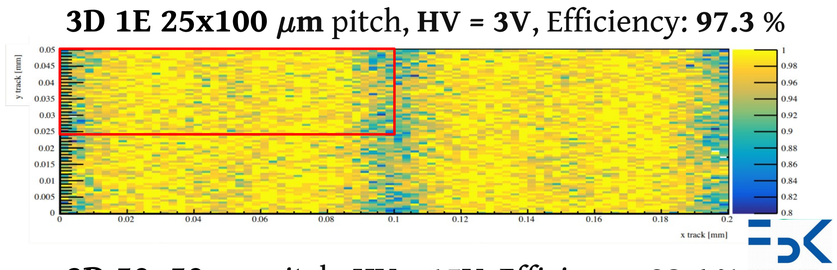


Telescope and modules setup at H2 SPS CERN (Set. 2018 using non-irradiated modules)

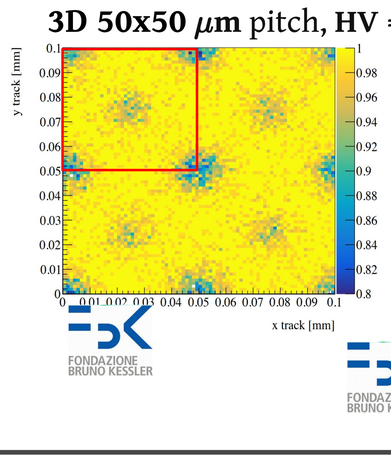
Sensor Response (target fluence 1x10[16] neq/cm²)

Hit Efficiency for 3D sensor BEFORE irradiation.
- 0 deg. tilt angle

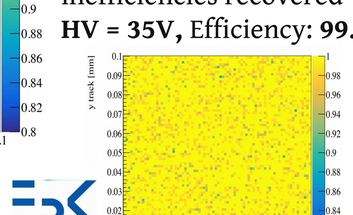
3D 1E 25x100 μm pitch, **HV = 3V**, Efficiency: **97.3 %**



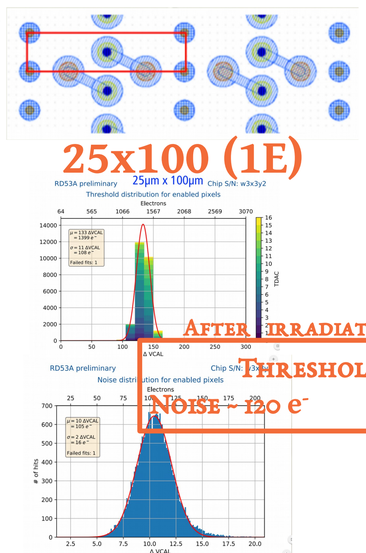
3D 50x50 μm pitch, **HV = 15V**, Efficiency: **98.6 %**



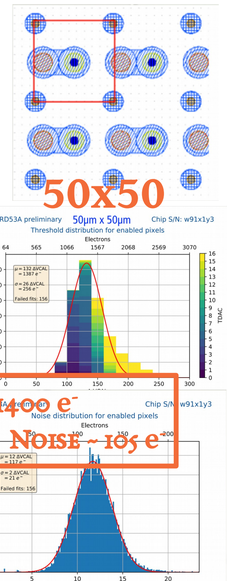
34 deg. tilt angle, geometrical inefficiencies recovered
HV = 35V, Efficiency: **99.3 %**



25x100 (1E)



50x50



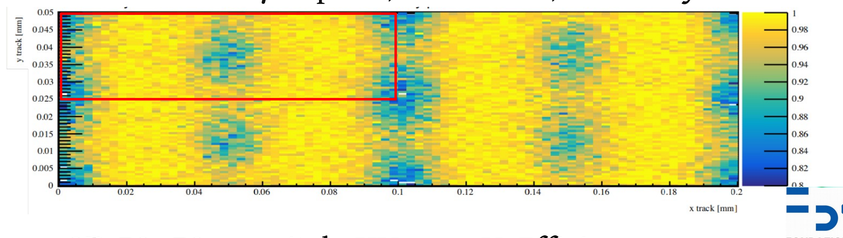
After irradiation
Threshold ~1400 e⁻
Noise ~ 120 e⁻
Noise ~ 105 e⁻

Hit Efficiency Summary Table 3D Pixel-RD53A

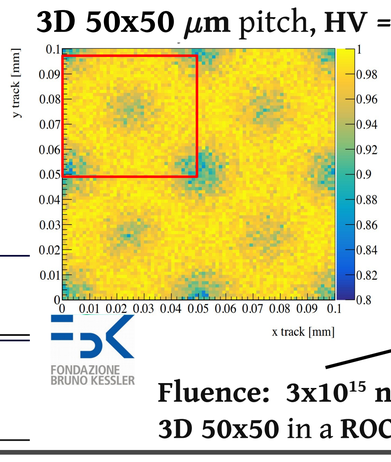
	25x100 μm (0 deg. tilt)	50x50 μm (0 deg. Tilt)
BEFORE irradiation	97.3	98.6
AFTER irradiation	96.6	97.5

Hit Efficiency for 3D sensor AFTER irradiation.
- 0 deg. tilt angle

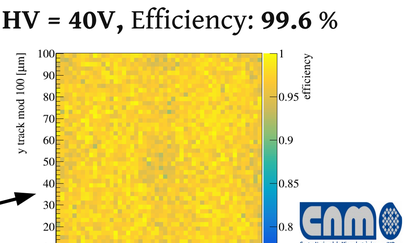
3D 1E 25x100 μm pitch, **HV = 120V**, Efficiency: **96.6 %**



3D 50x50 μm pitch, **HV = 150V**, Efficiency: **97.5 %**



12 deg. tilt angle, geometrical inefficiencies recovered
HV = 40V, Efficiency: **99.6 %**



Fluence: **3x10[15] neq/cm²**
3D 50x50 in a **ROC4SENS**[4]

Conclusions & Outlook

Preliminary Test Beam results obtained with **3D pixel sensors** show **no significant degradation after irradiation** at bias voltages below 200V. New data is currently being analyzed from the CERN 2018 test beam campaign as well as Fermilab and DESY test beams, in order to confirm and extend this study. A new 3D sensors batch is in progress at **FBK** and a 3D sensor new batch with 25x100 and 50x50 pitch sensors just finished at **CNM**, which is expecting to be tested and characterized during this year.

Acknowledgements

RD53 Collaboration for the RD53A chip; we remind our results are not on chip performance but on sensor performance
RD50 Collaboration for its support
Bonn ATLAS group for SCC cards and support for flip-chipping
Nuria Castello-Mor for providing the elegant template
This work has been partially supported by the EU project AIDA-2020, GA nº 654168

References

1) Small pitch 3D devices, G.F Dalla Betta, PosVertex2016 (2017) 028
2) 3D: A New architecture for solid state radiation detectors, S. Parker et. al. NIMA 395 (1997) 328
3) The RD53A Integrated Circuit, Garcia-Sciveres, Maurice - CERN-RD53-PUB-17-001
4) ROC4SENS – a generic readout chip for sensor studies, https://indico.cern.ch/event/663851/contributions/2788211