LPNHE-FBK thin n-on-p pixel sensors for HL-LHC upgrade and beyond

G. Calderini[1], M. Bomben[1], R. Camacho[1], F. Crescioli[1], G. Marchiori[1], R. Taibah[1], M. Boscardin[2], G. Borghi[2], F. Ficorella[2], S. Ronchin[2], N. Zorzi[2], L. Bosisio[3], G.F. Dalla-Betta[4], G. Giacomini[5]

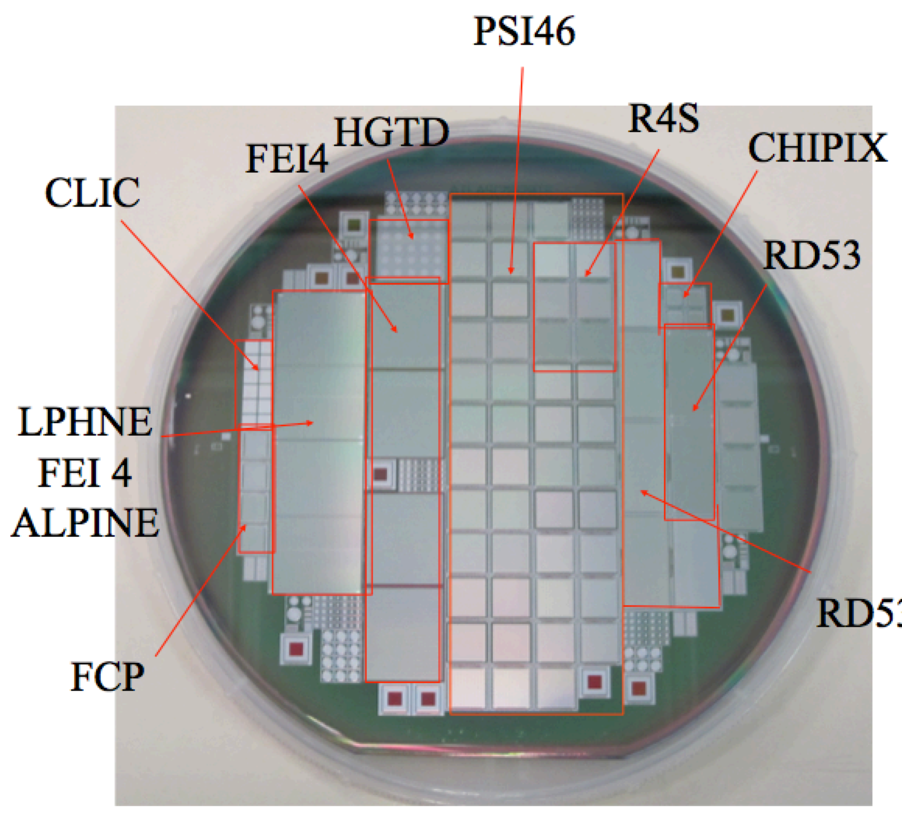
[1]LPNHE Paris, France; [2]FBK, TIFPA - INFN, Trento, Italy; [3]Università di Trieste – INFN Trieste, Italy; [4]Università di Trento, TIFPA – INFN Trento, Italy; [5]Brookhaven Natl. Lab. U.S.

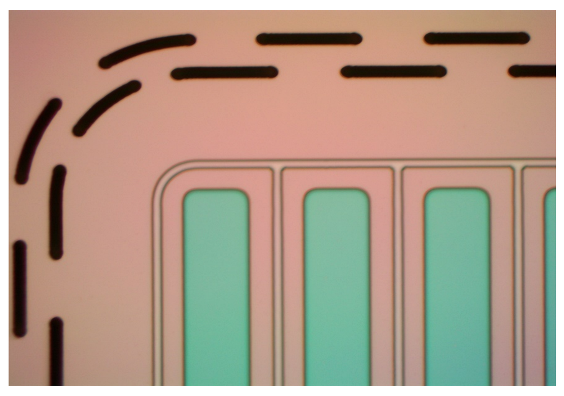
In view of the LHC upgrade phases towards the High Luminosity LHC (HL-LHC), the ATLAS experiment plans to upgrade the Inner Detector with an all-silicon system. The n-on-p silicon technology is a promising candidate to achieve a large area instrumented with pixel sensors, since it is radiation hard and cost effective. The paper reports on the last productions of n-on-p pixel productions made in collaboration between the FBK-CMM and the LPNHE in Paris, with some focus on the latest production of thin sensors bump-bonded to the RD53A prototype chip, featuring a 100x25 and 50x50 μm^2 pixel cells. An overview of 2019-2020 test-beam results of the produced devices will be given, with a special perspective to the sensor design for the ATLAS ITk pixel construction. Preliminary results for new 50 um thick n-on-p pixel sensors, still produced by LPNHE at FBK-CMM will be also presented.

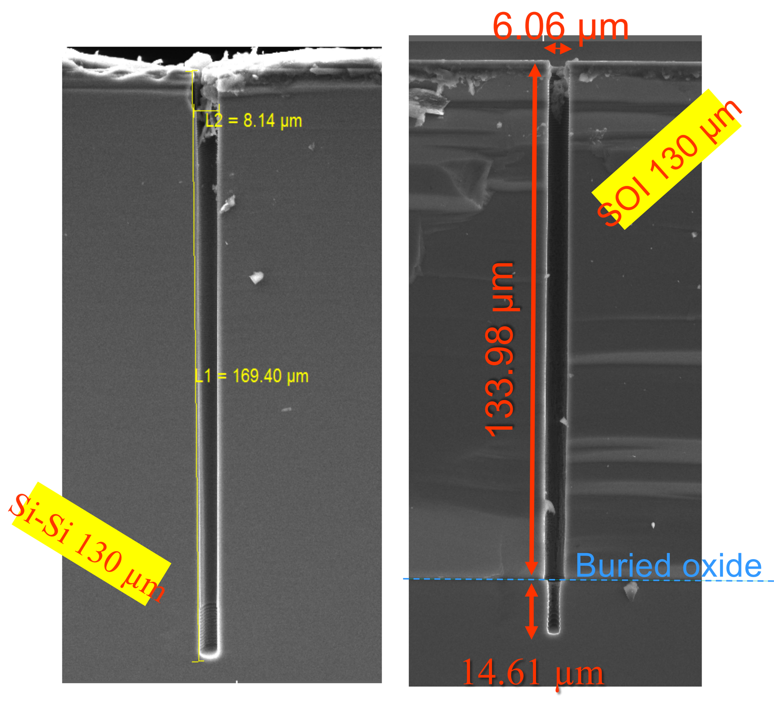
RECENT LPNHE PIXEL PRODUCTIONS AT FBK

The 2018 Active Edge

Active Edge (2018)

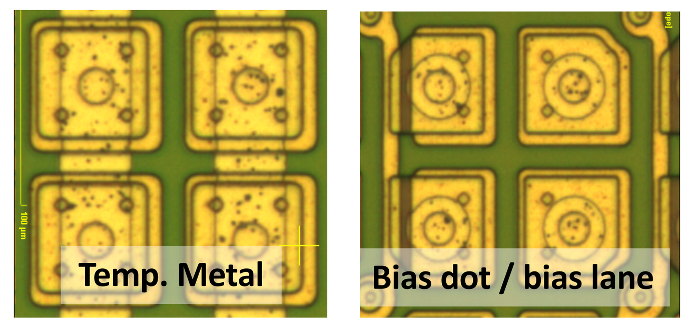




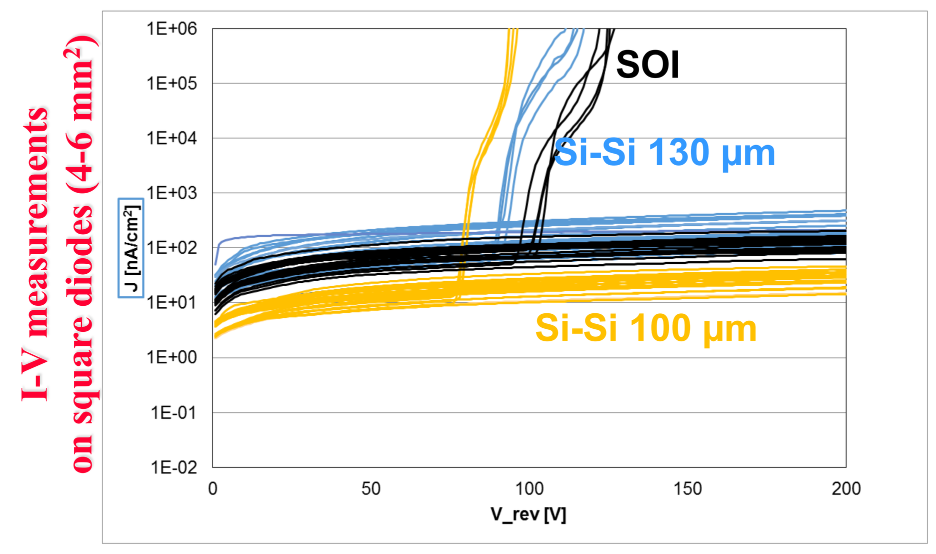


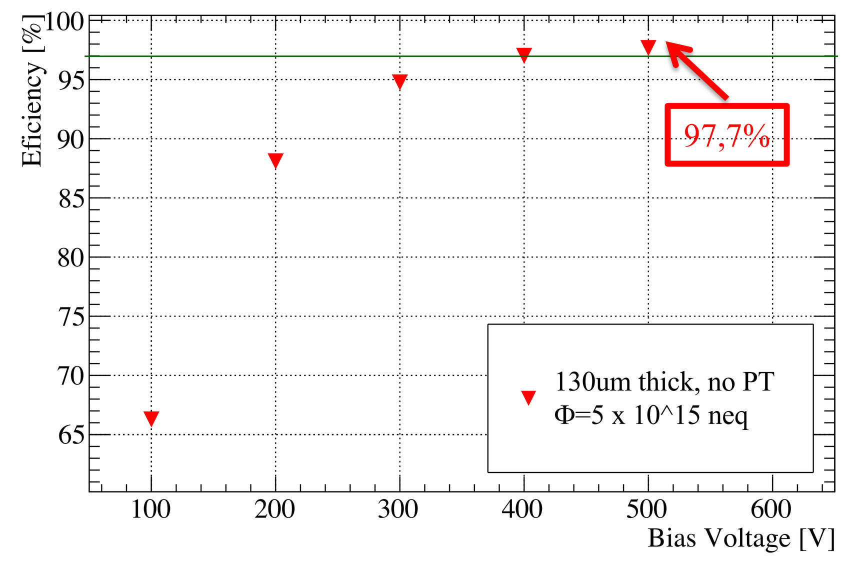
6” 100-130 µm thick n-on-p INFN ATLAS/CMS project Active Edge

- Staggered trench, doped with BBr_3 gas source and filled with poly
- Pixel-to-edge down to 50 µm
- RD53a compatible sensors + many other designs
- RD53 part: two pixel geometries, 50x50 and 25x100 μm^2
- Different biasing schemes:
  - Temporary Metal
  - Punch through (with different designs)

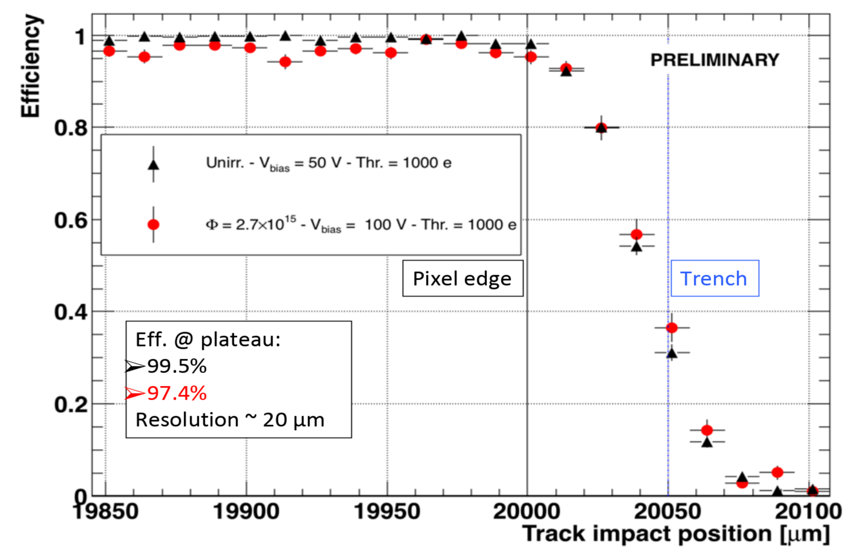


Breakdown voltage typically larger than 200V
Very aggressive design:
0-1-2 guard rings (0-1 for active edge)
Distance from pixel to trench: 60 to 80 µm





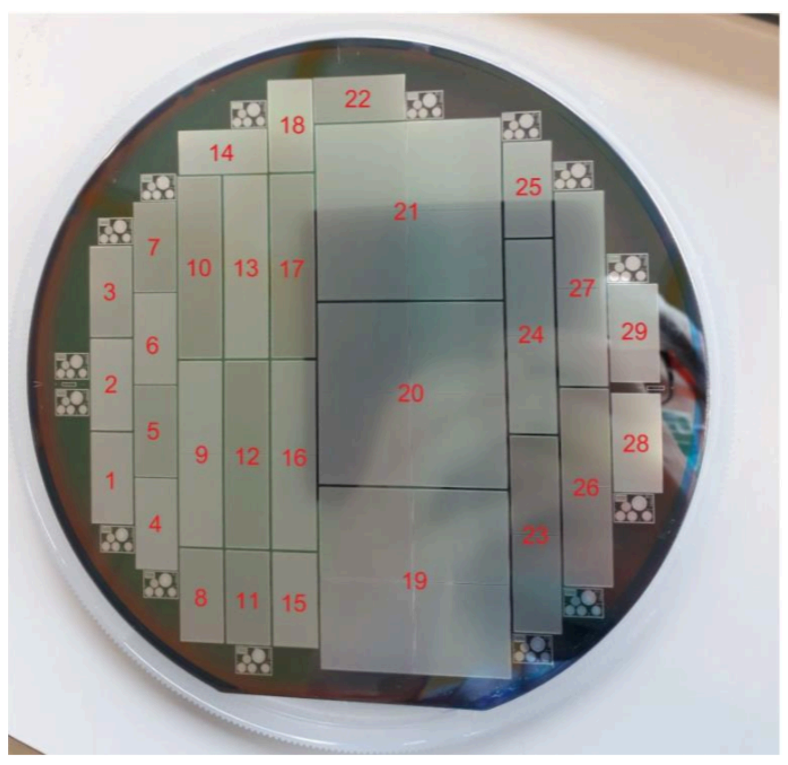
Characterization at testbeams after irradiation
Hit efficiency well above 97%



Hit efficiency remains high (>80%) even in proximity of trench

Production 2019 (ATLAS-oriented)

Standard Edge (2019) - ITk oriented



6” 50-100-150 µm thick n-on-p sensors (no active edge)

- Single RD53a sensors, Double RD53a, Quad ITk sensors
- Different biasing schemes:
  - Temporary Metal
  - Punch through (with different designs)

Study of 100µm thick devices (ATLAS specs)

Good electrical properties

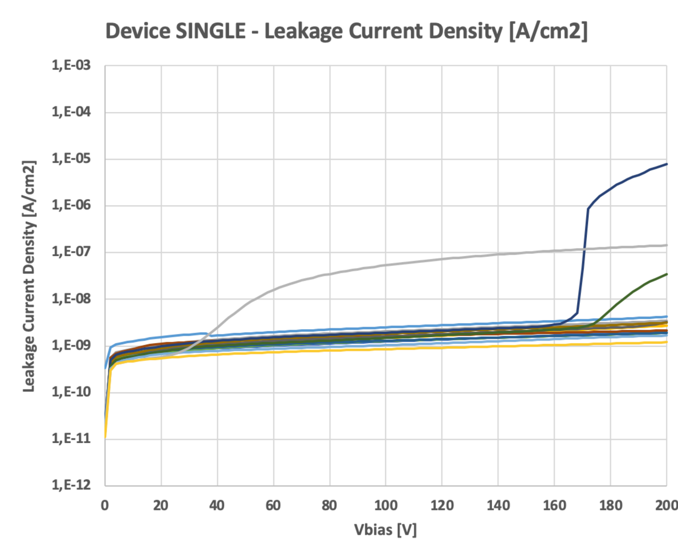
- Breakdown voltage before irradiation typically larger than 200V
- Guard-ring regions of 250 and 450 µm
- Depletion voltage in the 10-15V (for 100um) and 20-30V range (for 150um)

Tested at DESY after irradiation

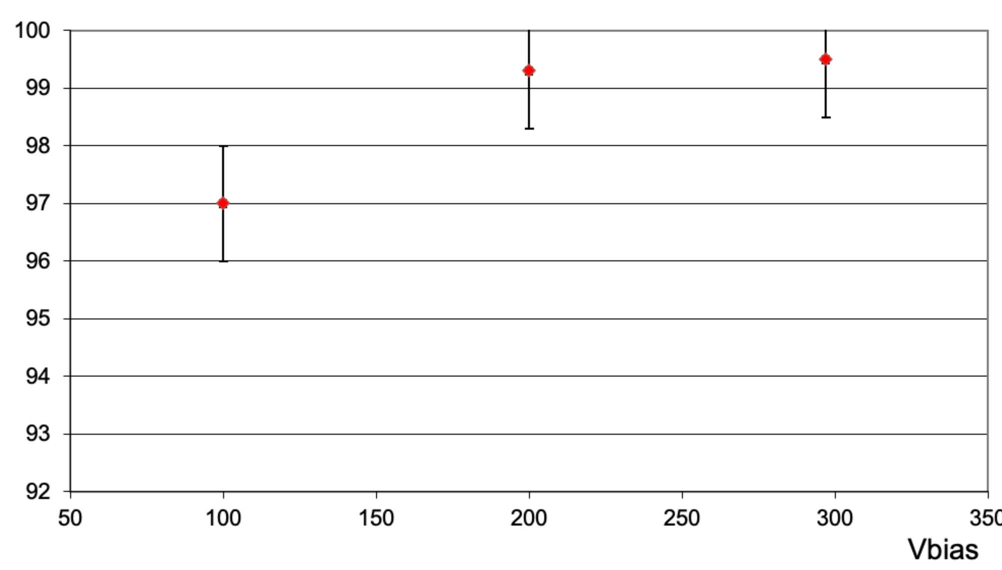
- 2 x 10^15
- 5 x 10^15

Lack of time has prevented to apply parylene protection for HV

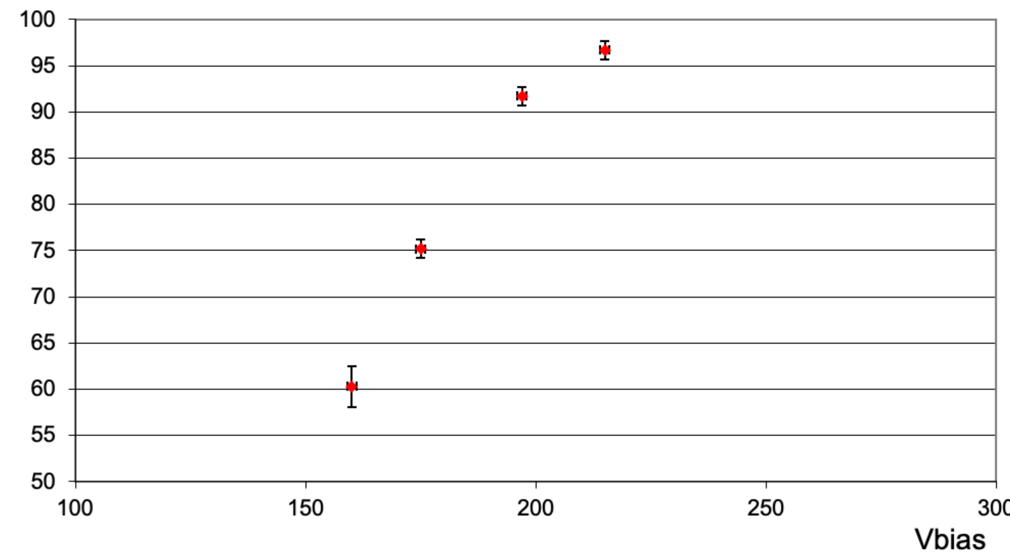
- HV limited to 400V after irradiation



Efficiency at fluence $2x10^{15}$ neq



Efficiency at fluence $5x10^{15}$ neq



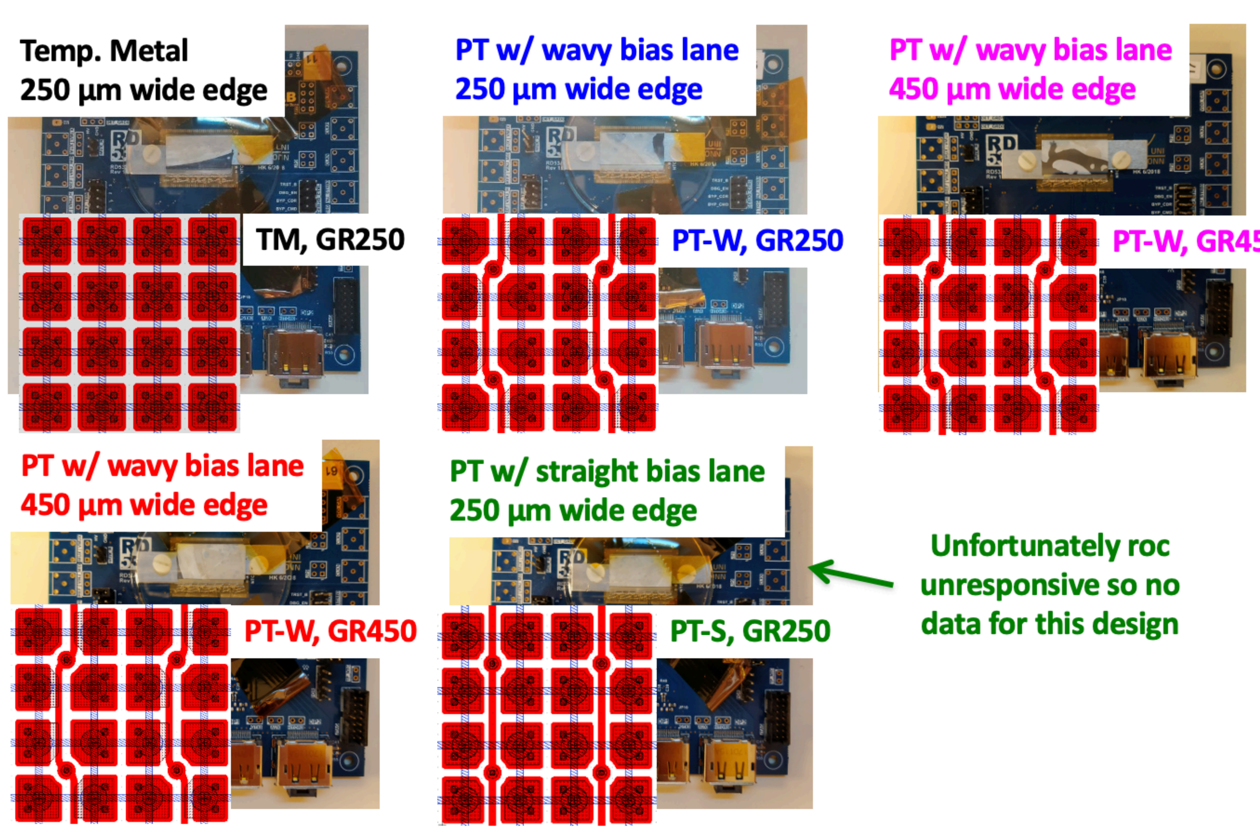
Performance of thinner sensors

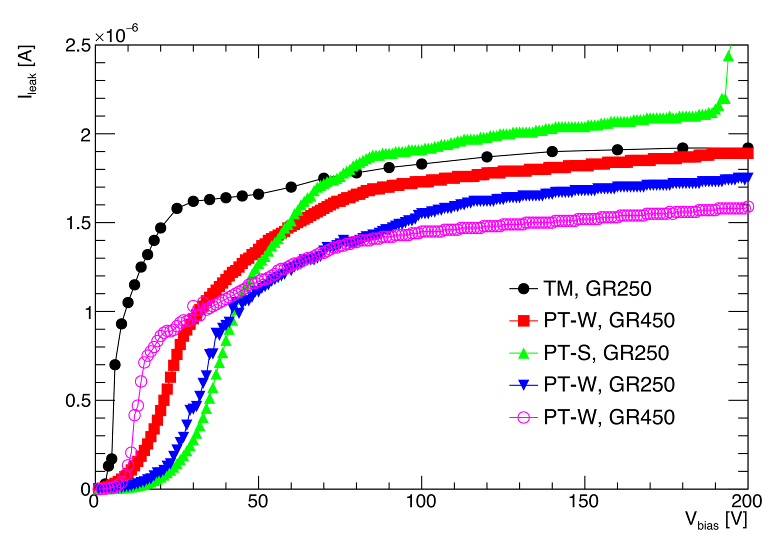
Study of 50µm thick devices

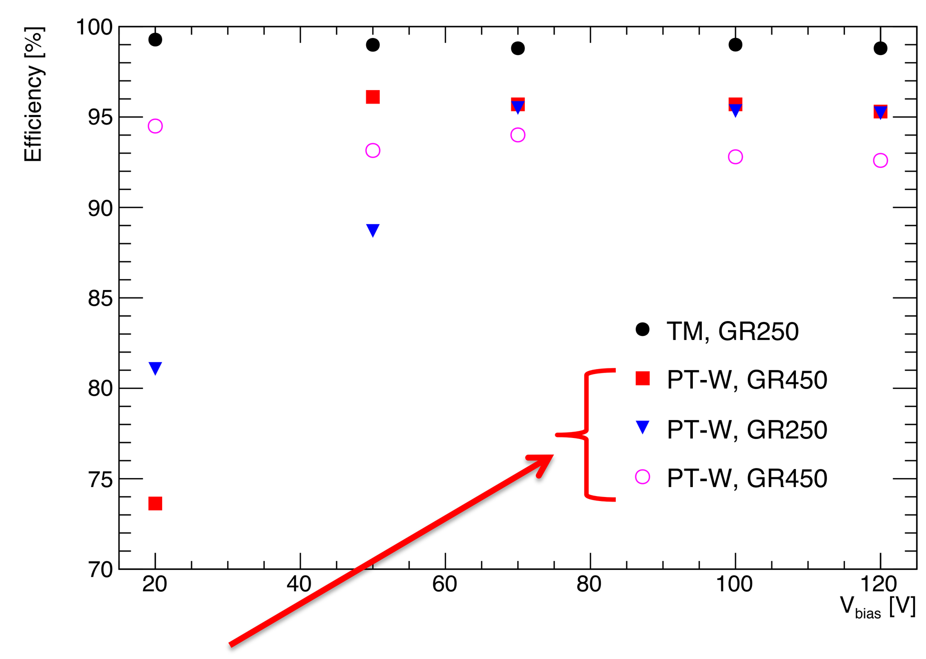
The lower threshold achievable with the RD53A FE chip allowed to design and produce thinner sensors

Five modules of 50µm thickness with different bias network structure and guard ring region were tested on beam and have been now irradiated. Unfortunately one is not working, data available from the remaining four

Typical depletion voltage of the order of 20V with a couple of sensors at 40V (rather high values, reason for this still under investigation)

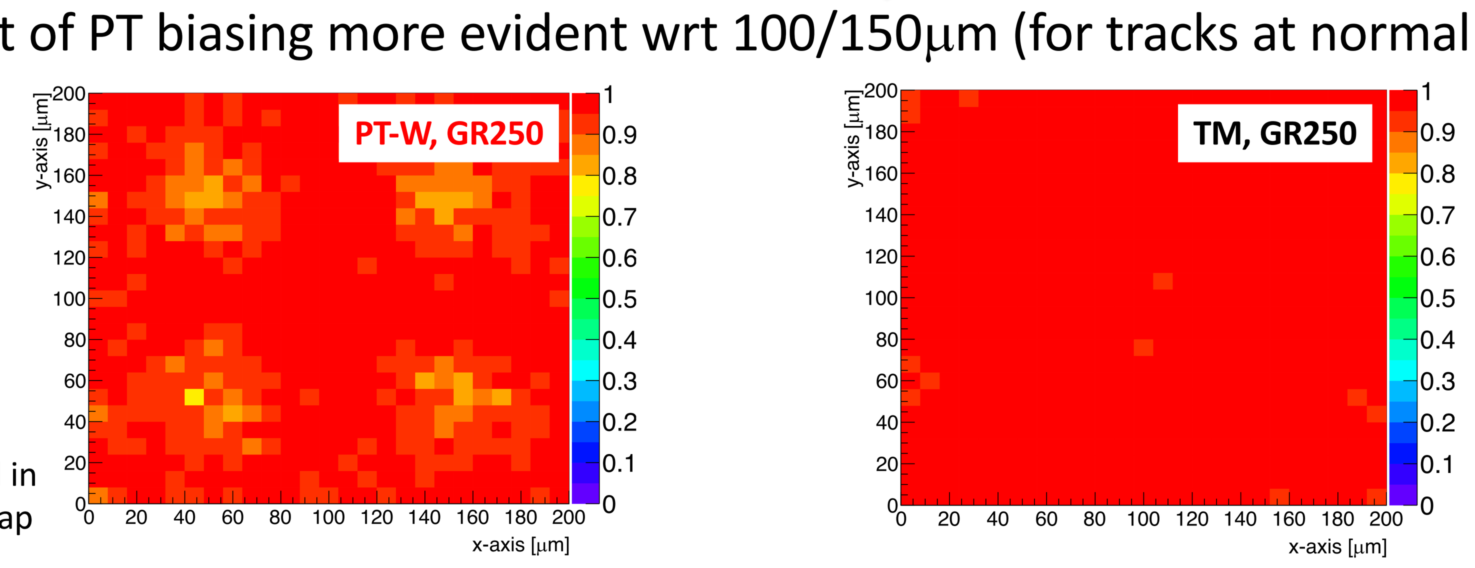






Effect of PT biasing more evident wrt 100/150µm (for tracks at normal angle)

Hit-eff. folded in a 4x4 pixel map



Stay tuned for test-beam results on recently irradiated devices !