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

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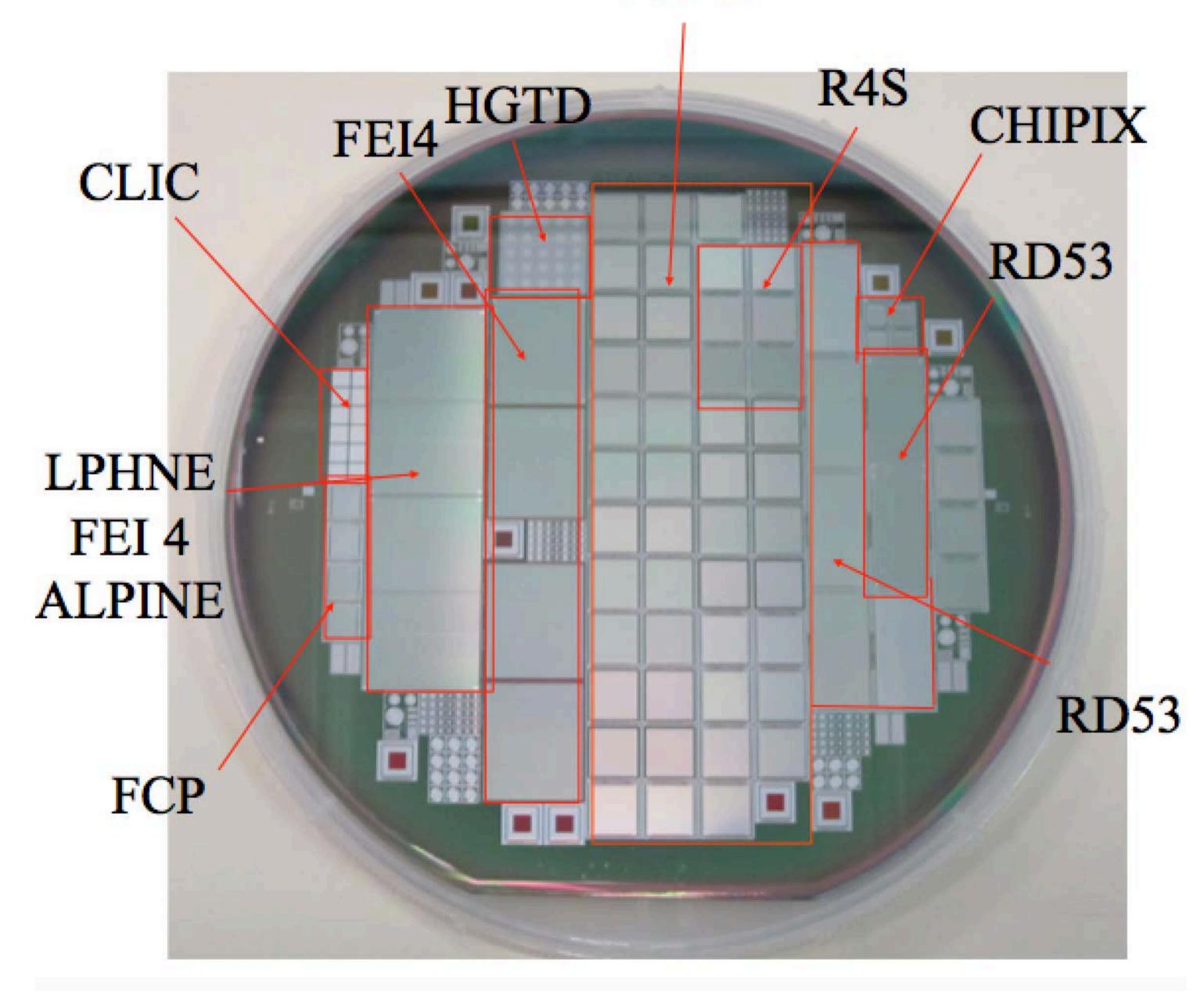
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Recent LPNHE planar pixel productions with FBK

Active edge sensor production (2018)

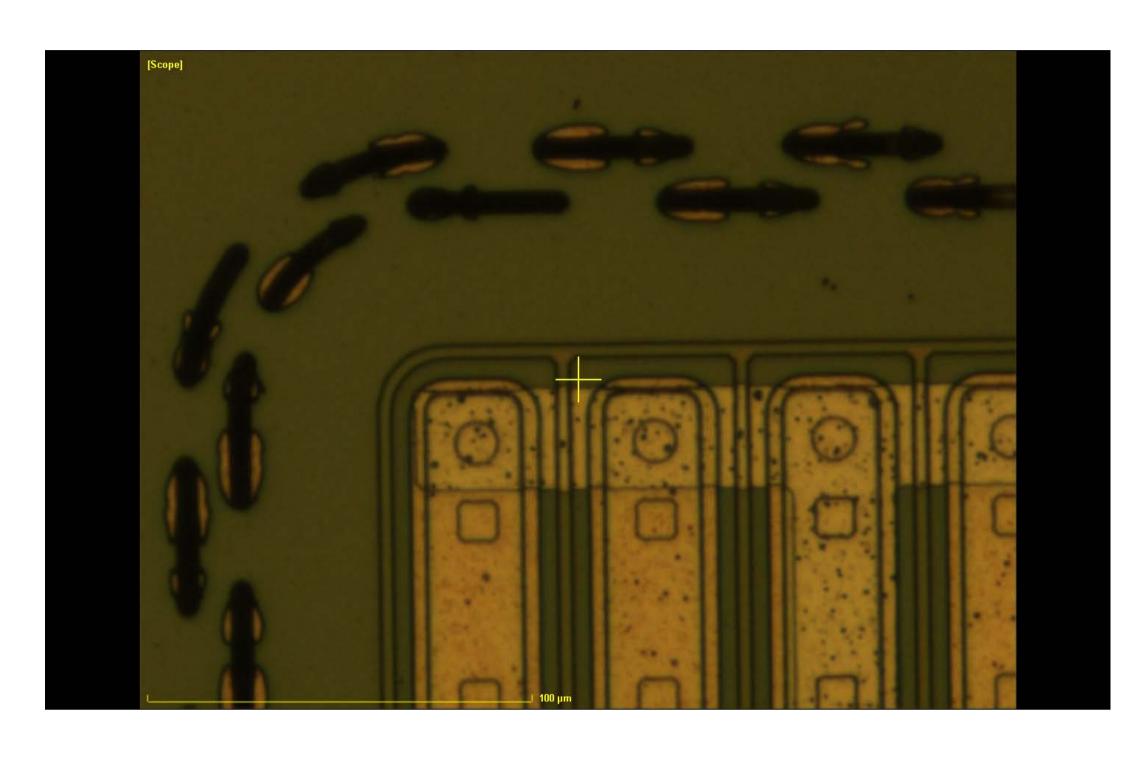**6" 100-130 μm thick n-on-p INFN ATLAS/CMS project Active Edge**

- 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
- In the RD53 part: two pixel geometries, 50x50 and 25x100 μm^2
- Different biasing schemes:
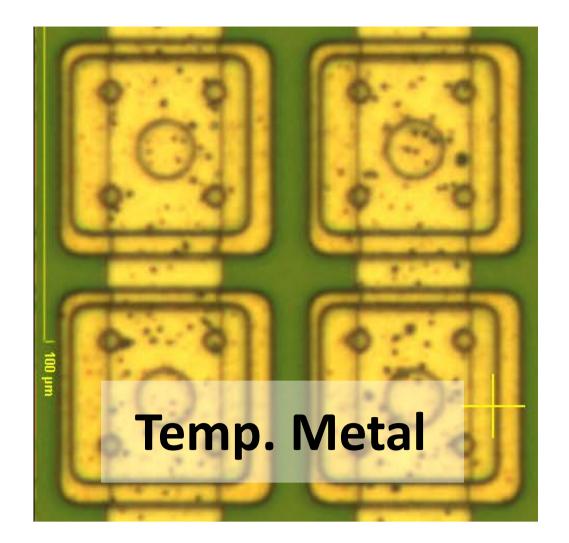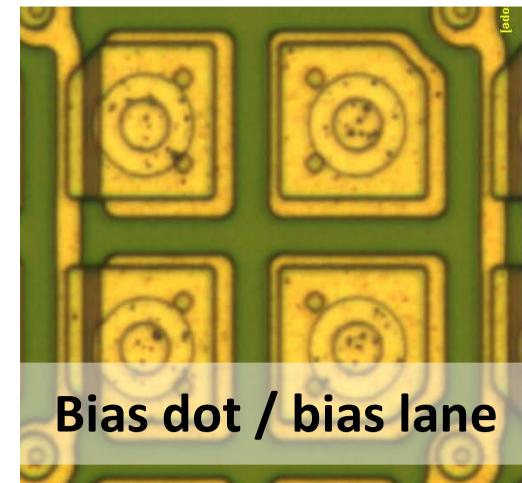 - Temporary Metal
  - Punch through (with different designs)
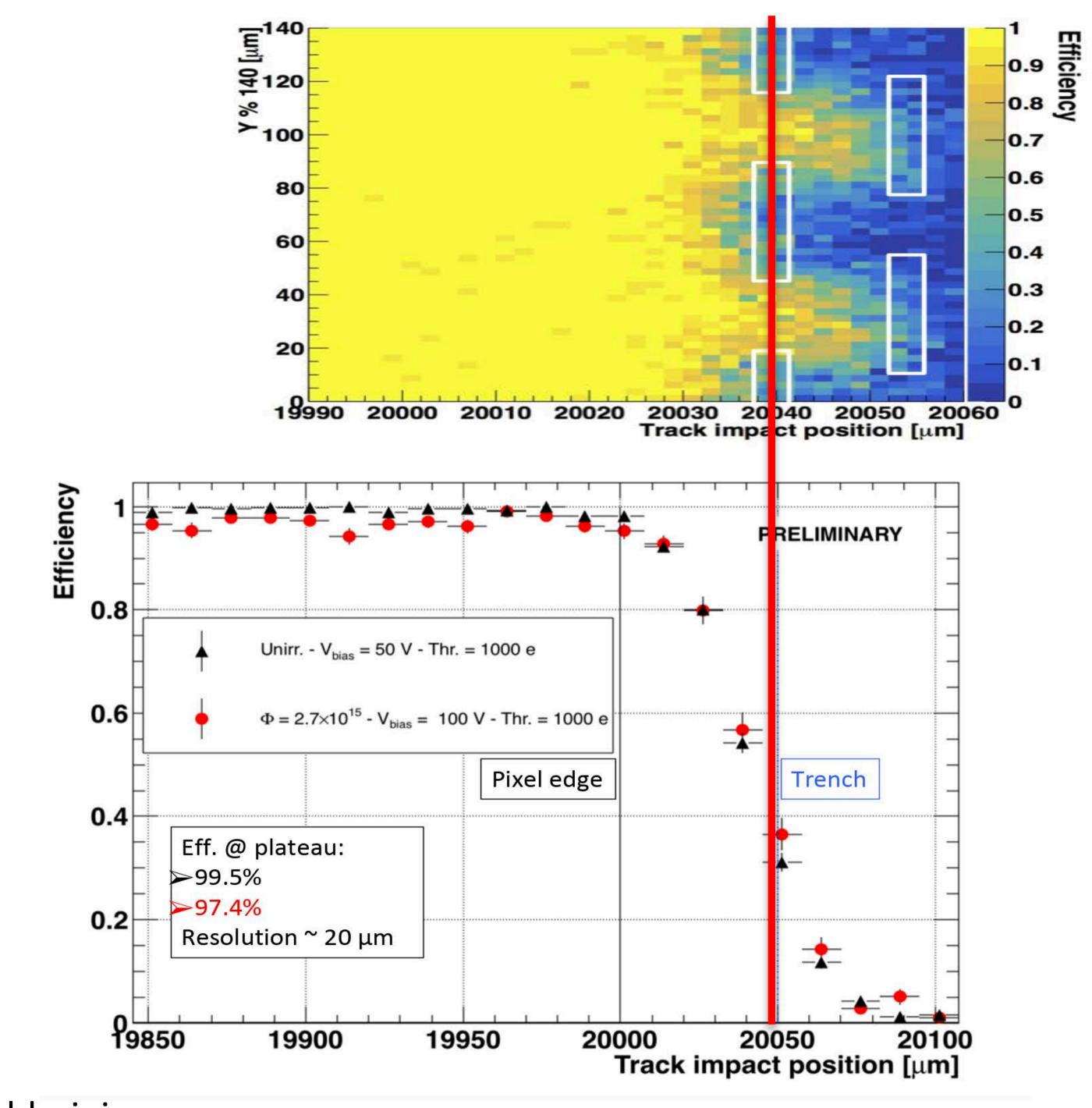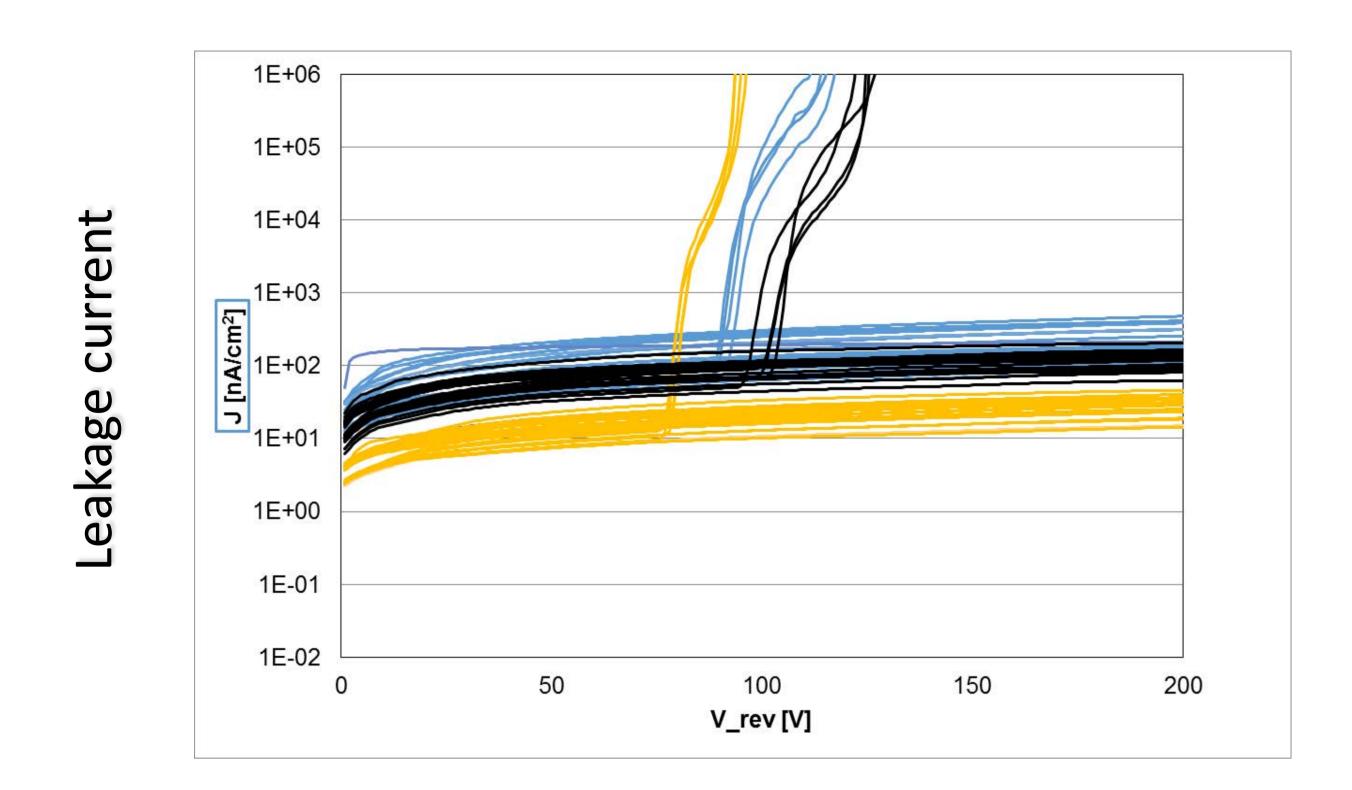
Sensors with different bias networks

Temp. Metal

Bias dot / bias lane

Temporary Metal
Punch-Trough
 - Straight
 - Wiggled

Significant hit efficiency even in proximity of the trench edge: >50% at 10μm distance

Unirr. - V_{bias} = 50 V - Thr. = 1000 e

$\Phi = 2.7 \times 10^{15}$ - V_{bias} = 100 V - Thr. = 1000 e

Pixel edge

Trench

PRELIMINARY

Eff. @ plateau:
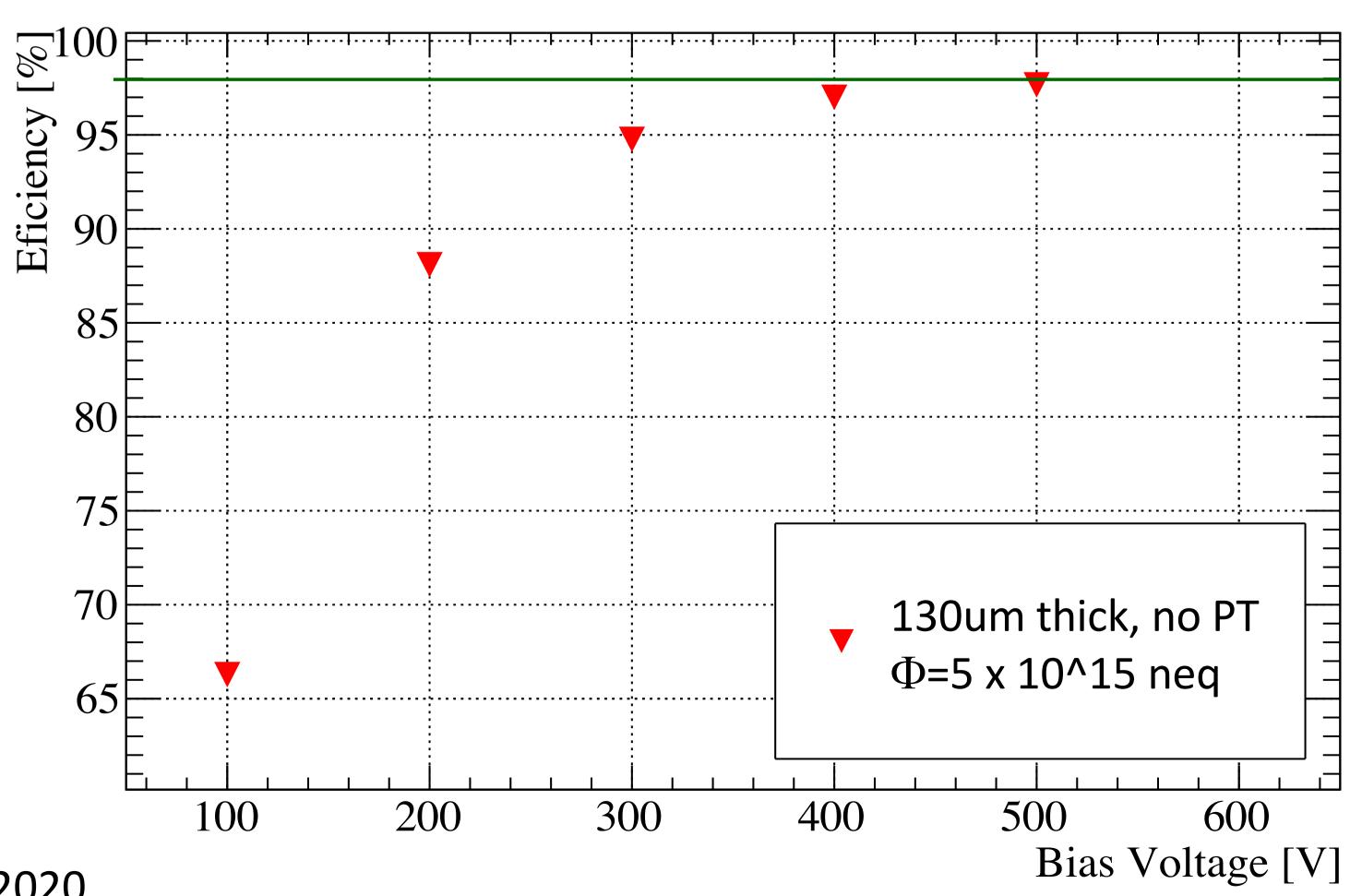➤ 99.5%
➤ 97.4%
Resolution ~ 20 μm

Breakdown 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

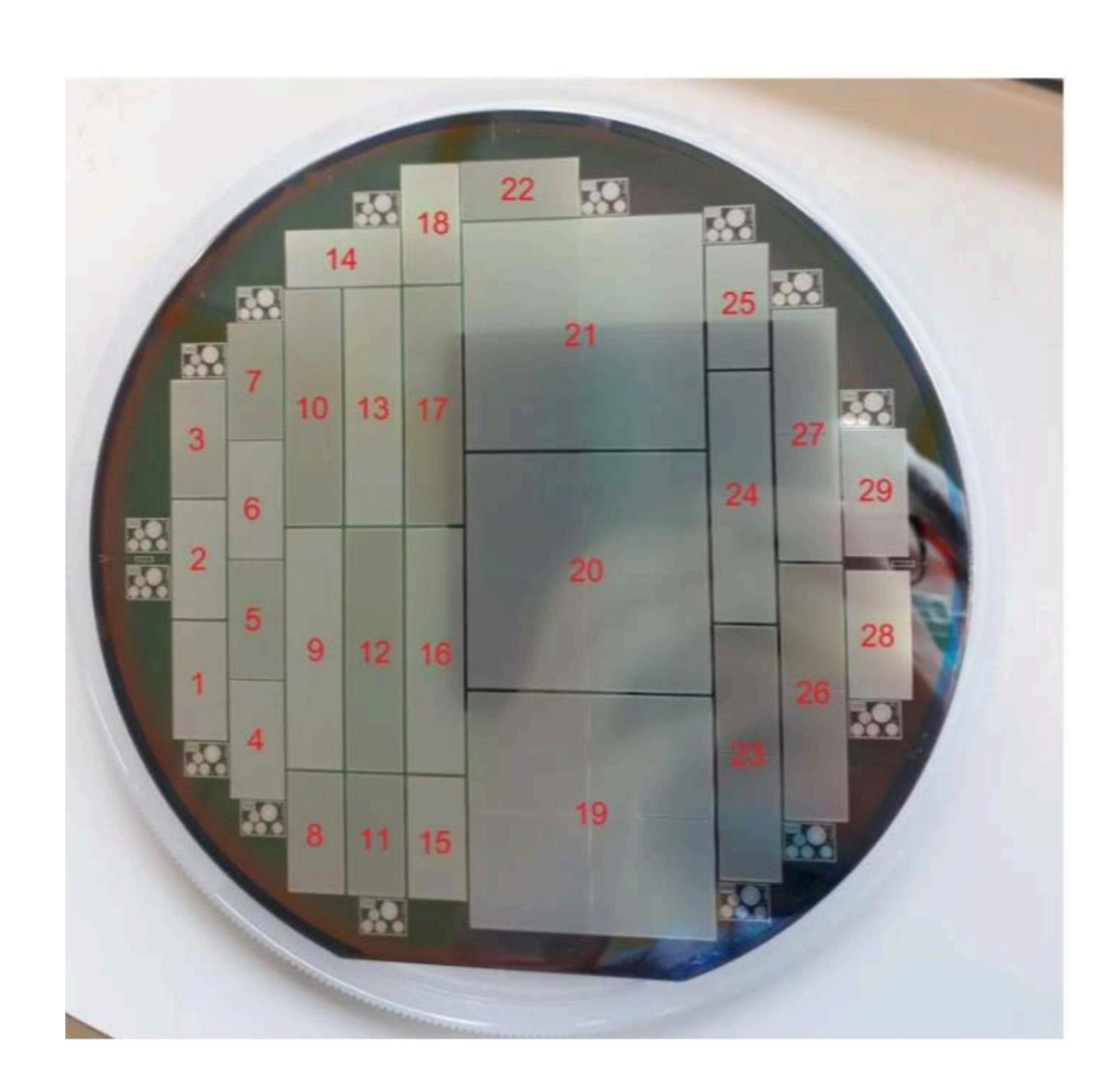## Characterization at test-beams after irradiation
Hit-efficiency well above 97%

130um thick, no PT
Φ=5 x 10^15 neq

G.Calderini

Standard edge (2019) – ATLAS Inner Tracker (ITk) oriented

Good electrical properties

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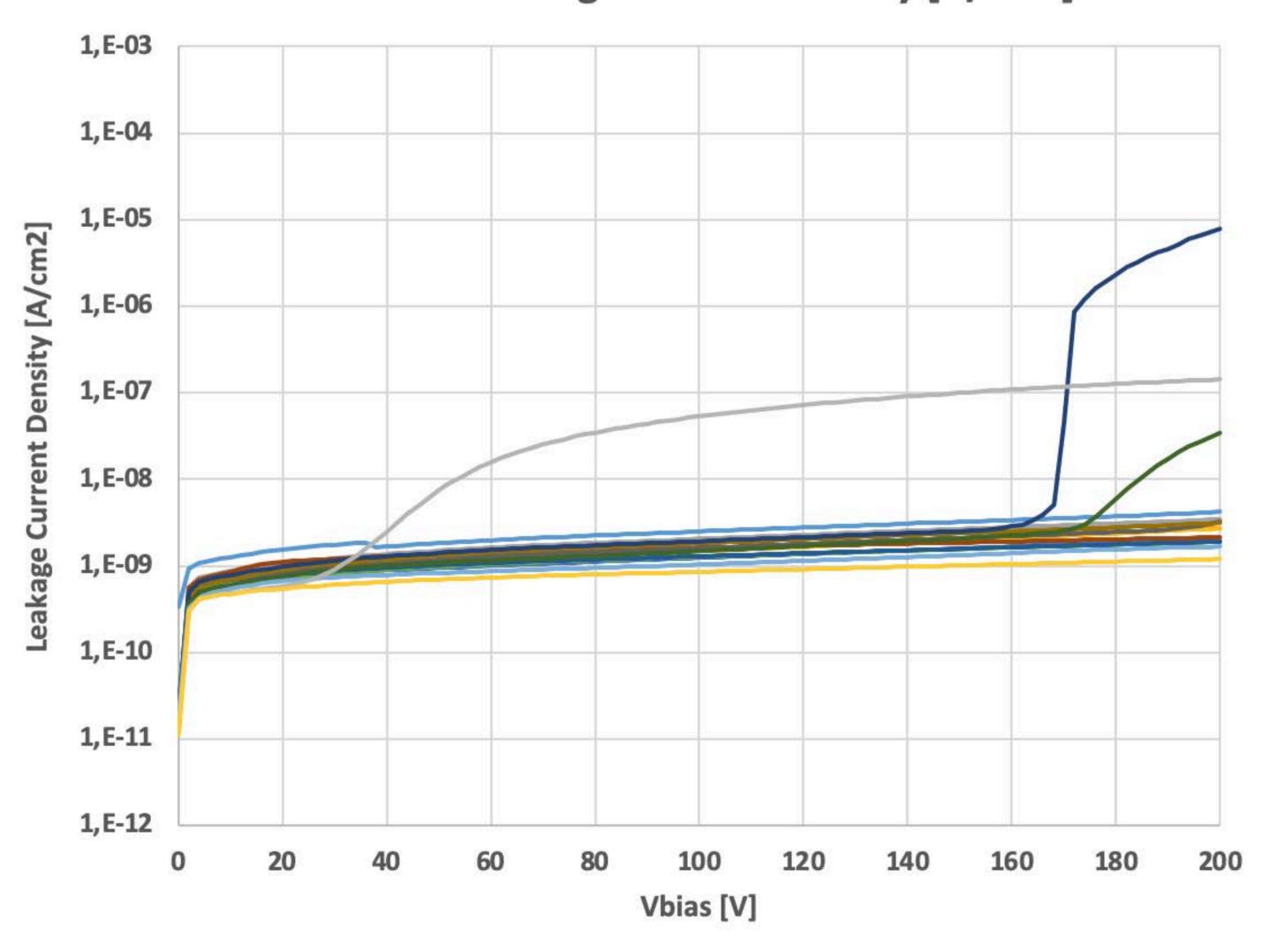- Depletion voltage in the 10-15V (for 100µm) and 20-30V range (for 150 µm)

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)

Device SINGLE - Leakage Current Density [A/cm2]

Characterisation of 100/150 μm thick sensors

Tested at DESY after irradiation
- 2×10^{15}
- 5×10^{15}

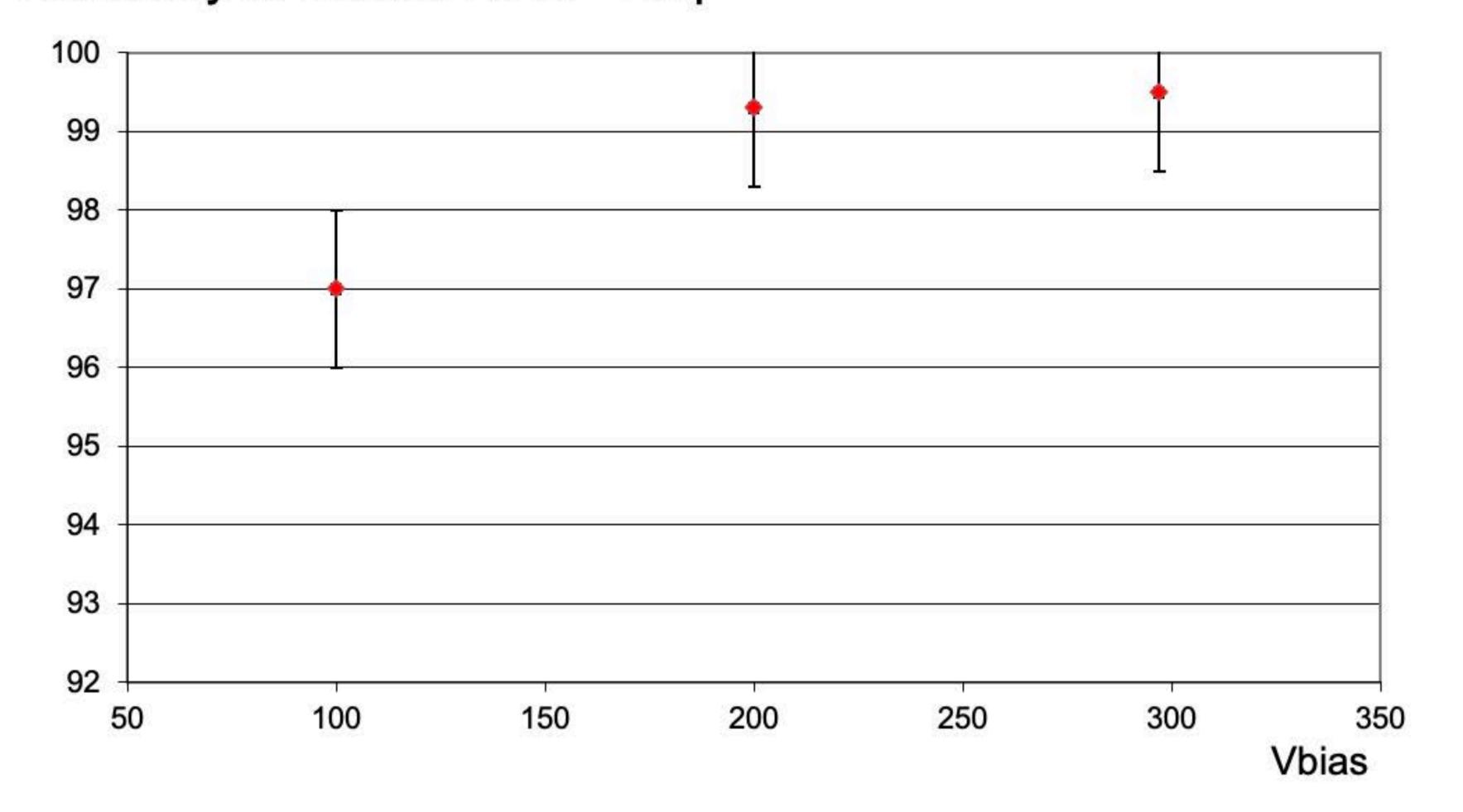Lack of time has prevented to apply parylene protection for HV
- HV limited to 400V after irradiation

During the runs at 5×10^{15} neq a cooling problem had a large impact on the leakage current of all the tested modules The effective Vbias was significantly different from the provided tension due to some voltage drop in resistances
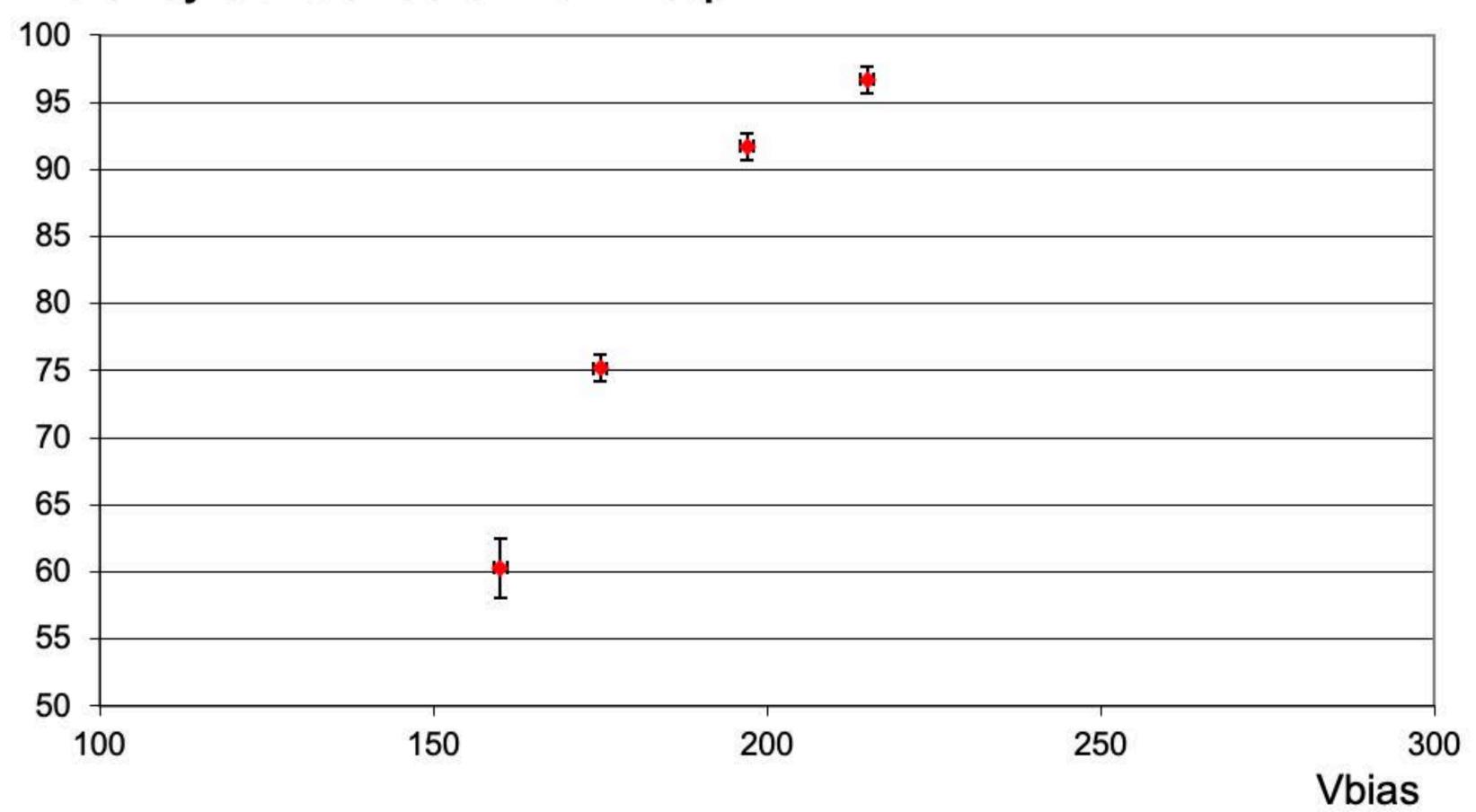
The effective Vbias has been carefully evaluated

Even at a fluence of 5×10^{15} neq, the hit efficiency reaches a value well above 97% (the ITk standard for that dose) already at (effective) Vbias < 250V
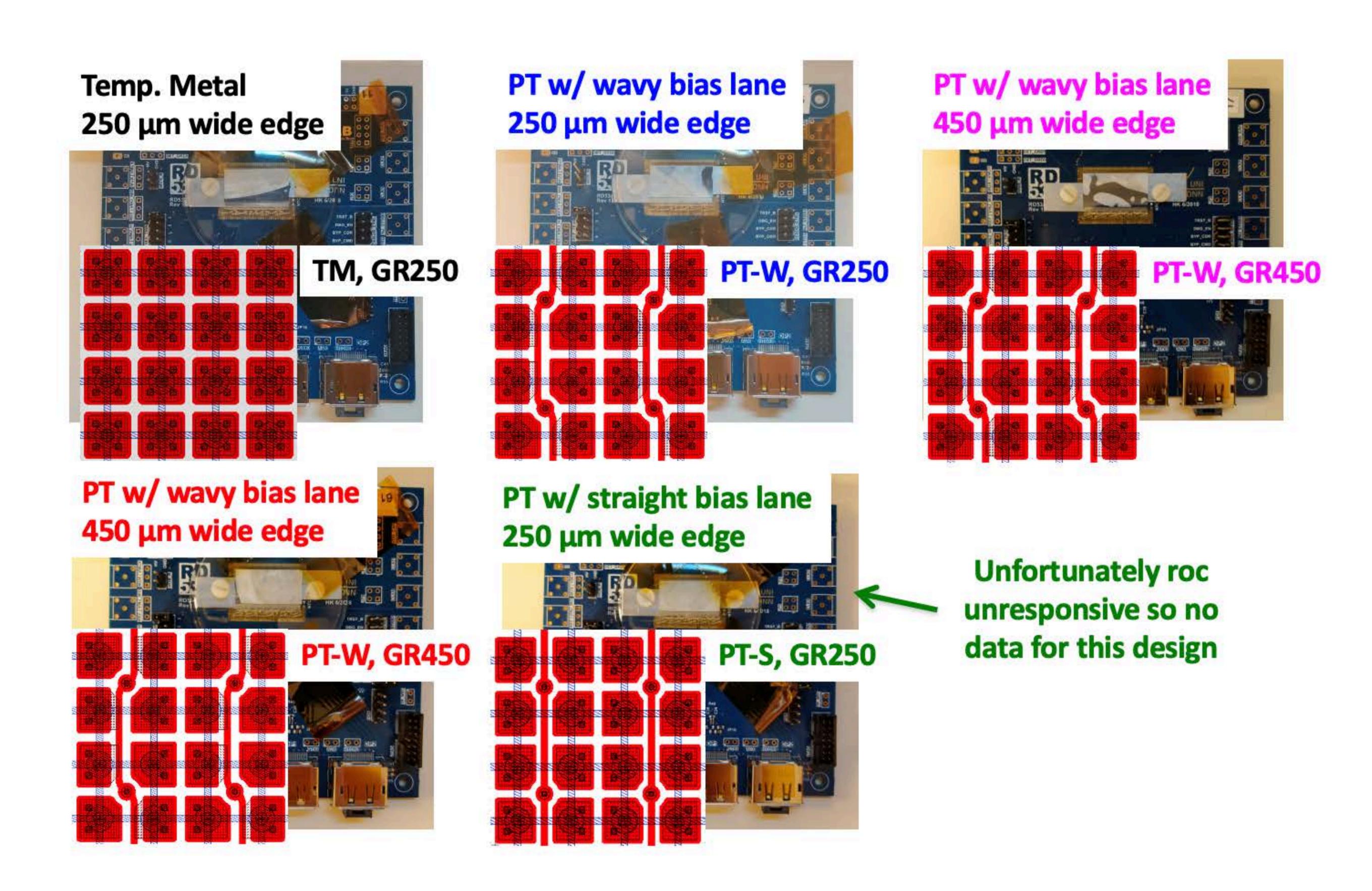

Efficiency at fluence 2×10^{15} neq

Efficiency at fluence 5×10^{15} neq
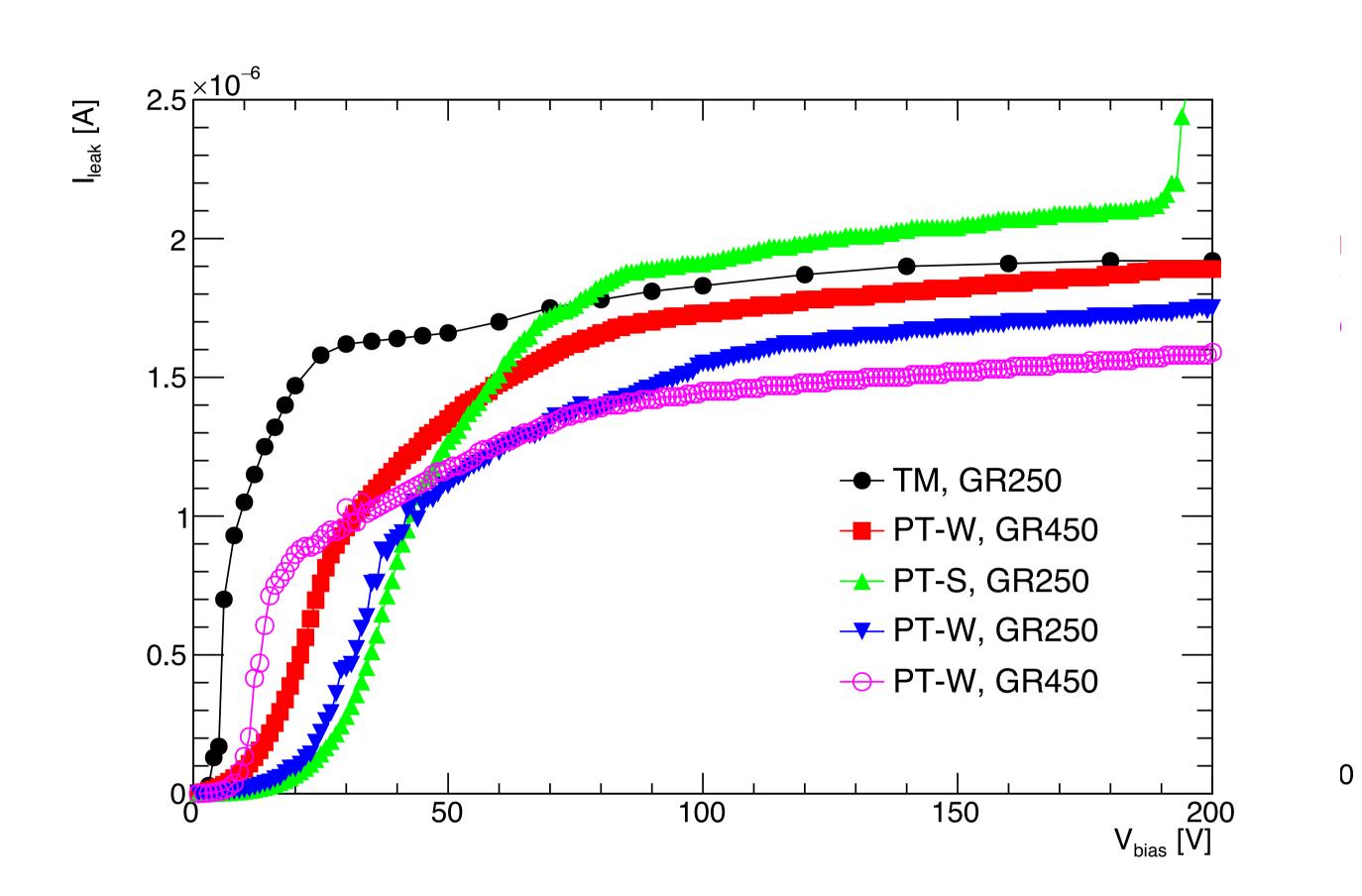
Characterisation of 50 μm thick sensors

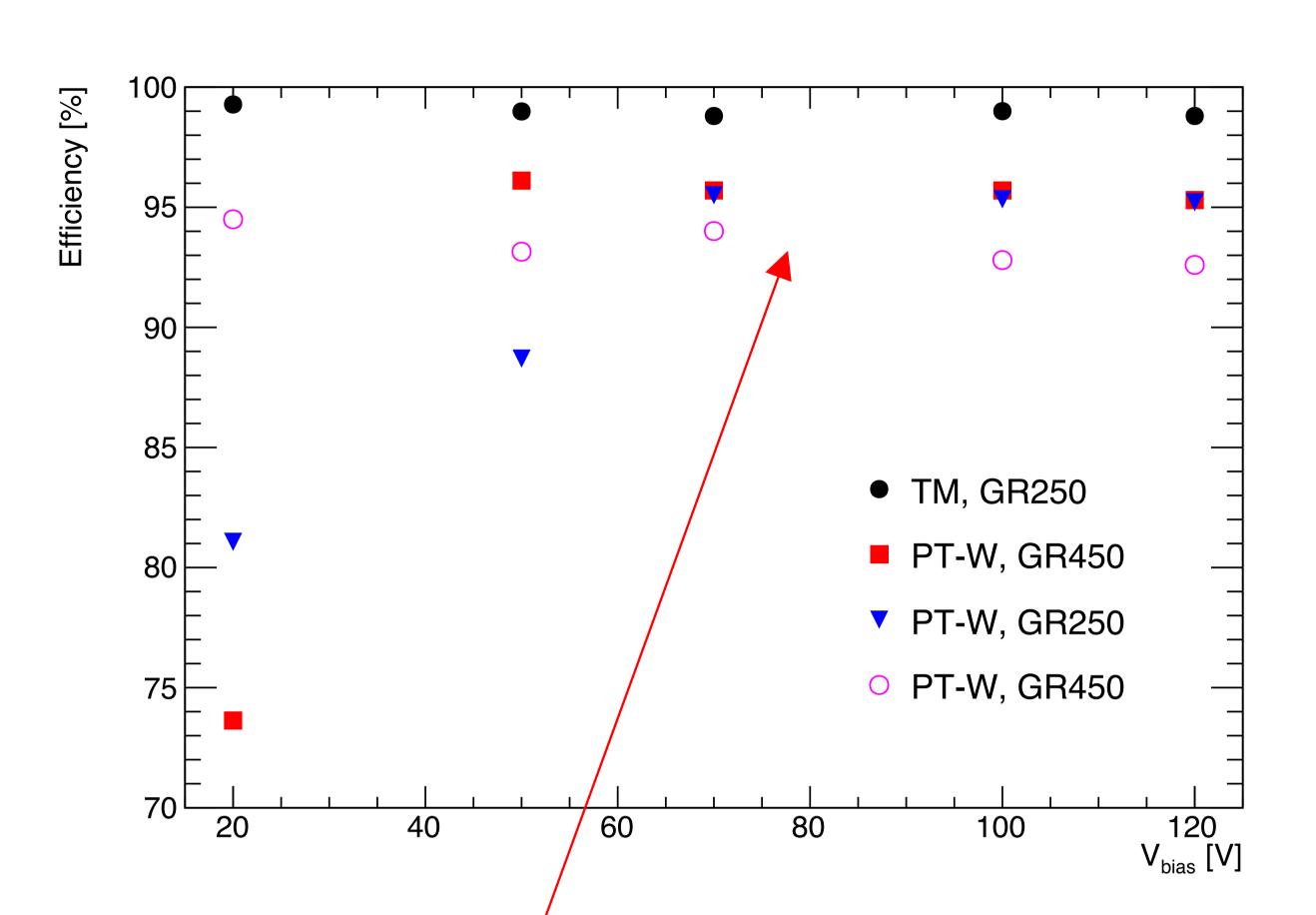The lower threshold achievable with the RD53A FE chip allowed to design and produce thinner sensors

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

Temp. Metal
250 μm wide edge

TM, GR250

PT w/ wavy bias lane
250 μm wide edge

PT-W, GR250

PT w/ wavy bias lane
450 μm wide edge

PT-W, GR450

PT w/ wavy bias lane
450 μm wide edge

PT-W, GR450

PT w/ straight bias lane
250 μm wide edge

PT-S, GR250

Unfortunately roc unresponsive so no data for this design

Characterisation of 50 μm thick sensors

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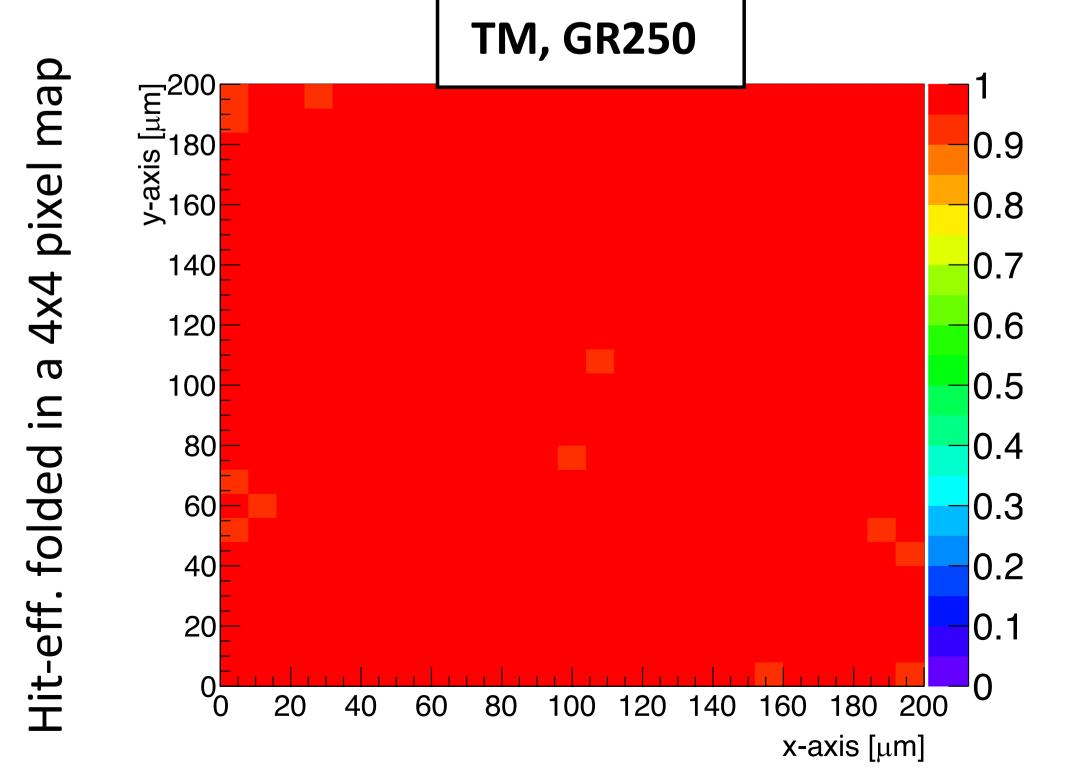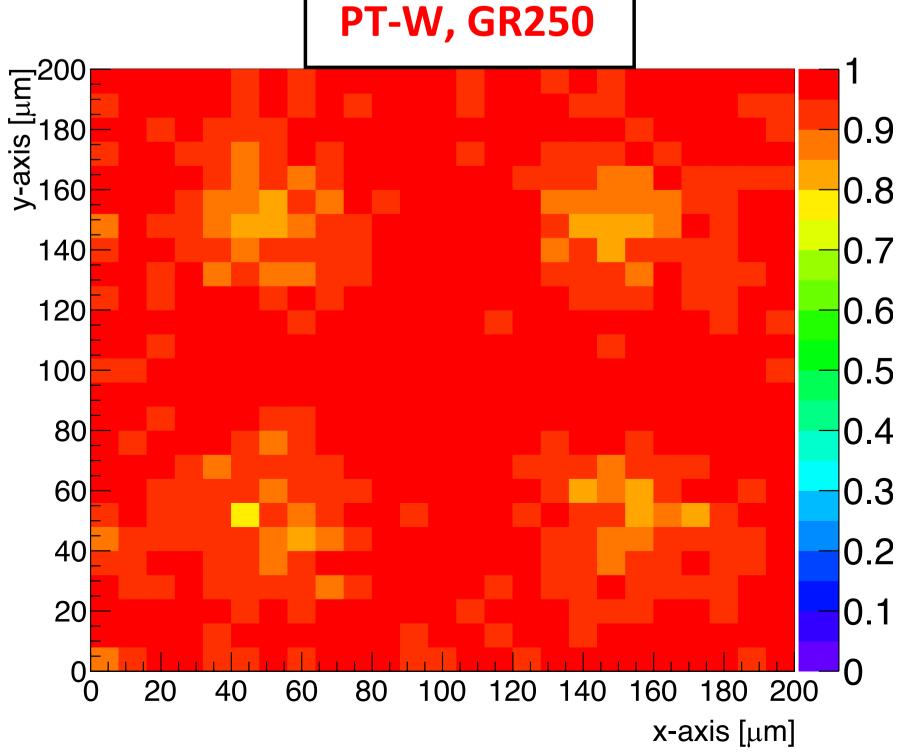(rather high values, reason for this still under investigation)

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

Efficiency for Temporary Metal is stable
around 99% even at very low bias voltage

Devices with PT networks lose a few % due to
the inefficient regions of the bias dots / lines

Sensors have been irradiated up to 5×10^{15} neq but test-beam characterization has not been possible yet due to COVID.

That will happen soon, stay tuned