15th Trento Workshop on Advanced Silicon Radiation Detectors

LPNHE - FBK thin n-on-p pixels for HL-LHC upgrades and beyond

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Outline

- Tracking at HL-LHC and beyond
- Recent LPNHE planar pixel productions at FBK
- Testbeam results
- Conclusions and outlook

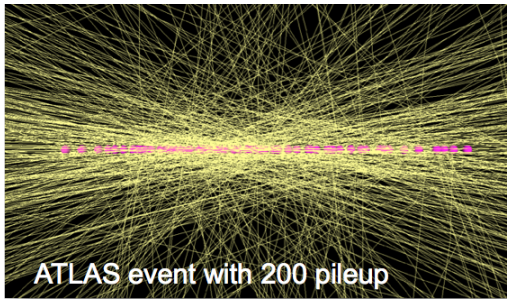
Challenges for the future ATLAS tracker

- Instantaneous luminosity : L_{inst} = 5-7x10^{34} $cm^{-2}s^{-1}$
  - x3-5 more than today
- Events-pile up: μ ≈ 140 – 200 events/*Bunch Crossing*
  - x4-6 more than today

➢ **Need to increase the pixel granularity**

  - Actual pixel size: 50x(250-400) μm^2

- Expected fluence: ϕ = 1-2x10^{16} n_{eq}/cm^2
  - 2-3x10^{15} n_{eq}/cm^2 for planar sensors



➢ **Need radiation-hard detectors**

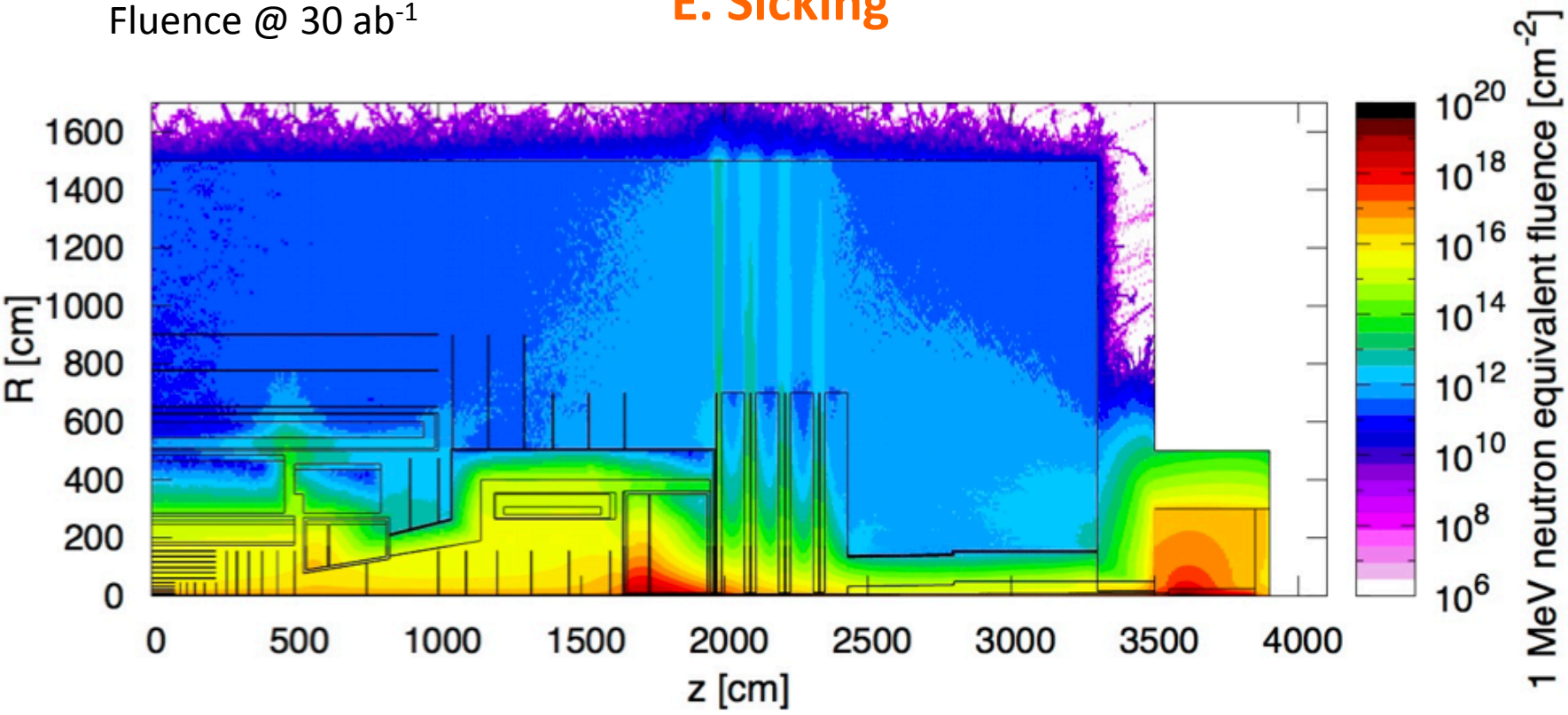
➢ **Goal: better performance in a harsher environment!**

See talks by Q. Buat and J. Lange

Tracking at FCC-hh

Fluence @ 30 ab^{-1}

E. Sicking

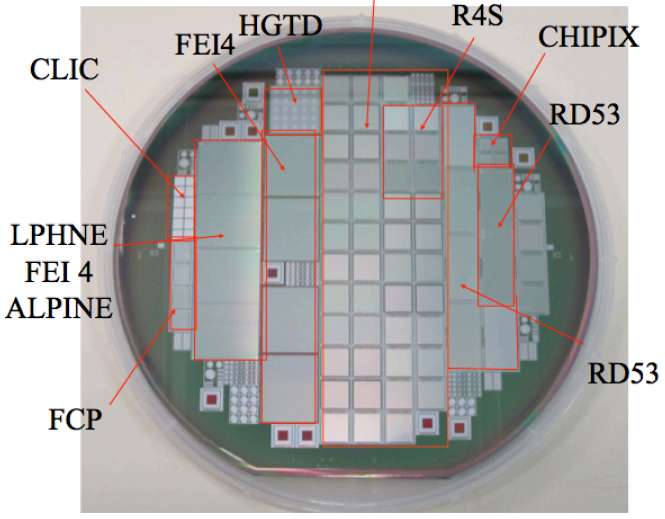


Fluence up to 5x10^{17} n_{eq}/cm^2 => need **thin** detectors

Very low material budget => need **thin** detectors

Recent LPNHE planar pixel productions

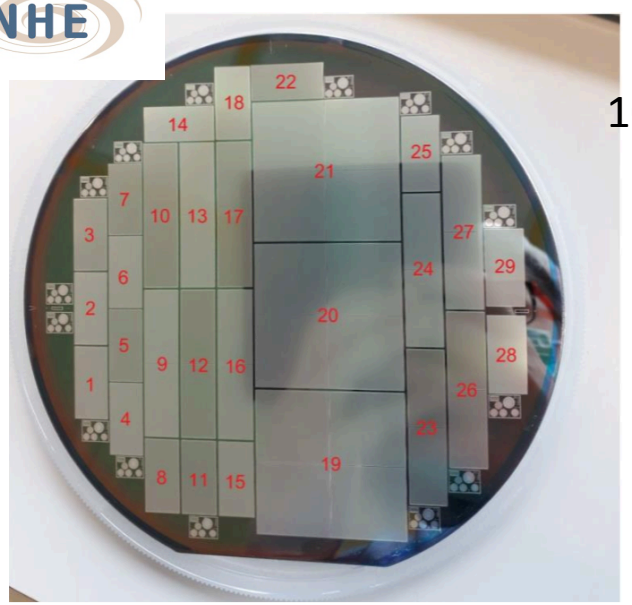
PAE3



6” 130 µm thick n-on-p
INFN ATLAS/CMS project
Active Edge technology
Pixel-to-edge down to 50 µm
RD53a compatible sensors
Measured on beam,
after irradiation too

JINST 14 (2019) no. 07, C07001

P4



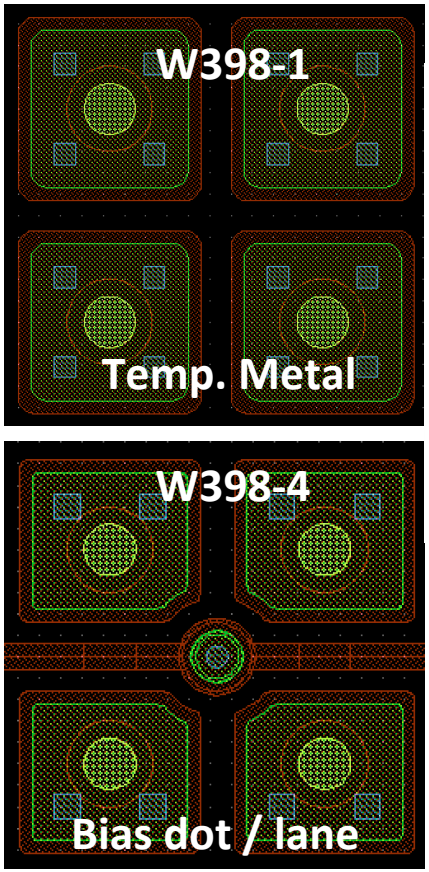
16 singles
10 doubles
3 quads

6” **50 µm thick**, ~ kΩ/cm p-type sensor wafer with 500 µm support wafer (SOI)
Single, double and quad RD53a compatible chip sensors
Split on: biasing structure and guard ring (GR) design
Measured on beam

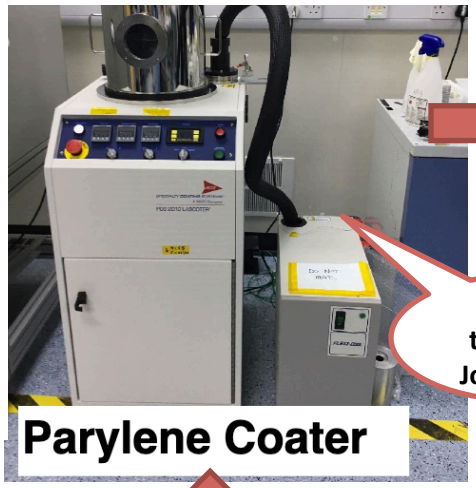
PAE3, 130 µM THICK MODULES: RESULTS

2 modules assembled

UNIVERSITY OF BIRMINGHAM



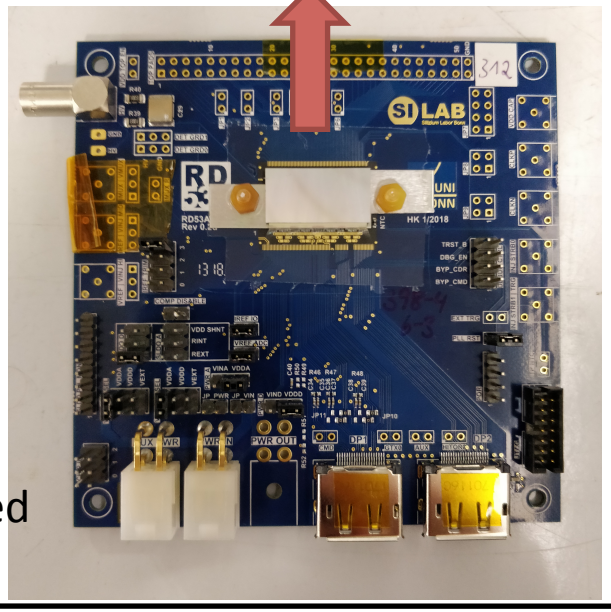
UNIVERSITY OF LIVERPOOL

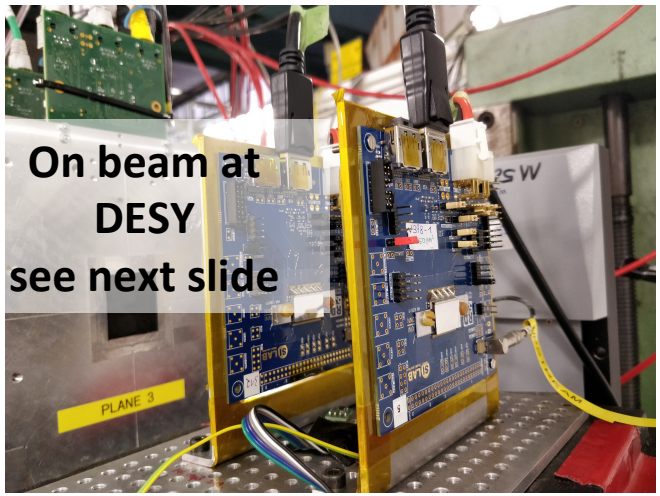


Many thanks to Jon Taylor!

Irr. w/ 27 MeV protons @ Birmingham, $\Phi=1.7\times10^{15}$ (plans to re-irr.)

Many thanks to Amelia Hunter and Laura Gonella!

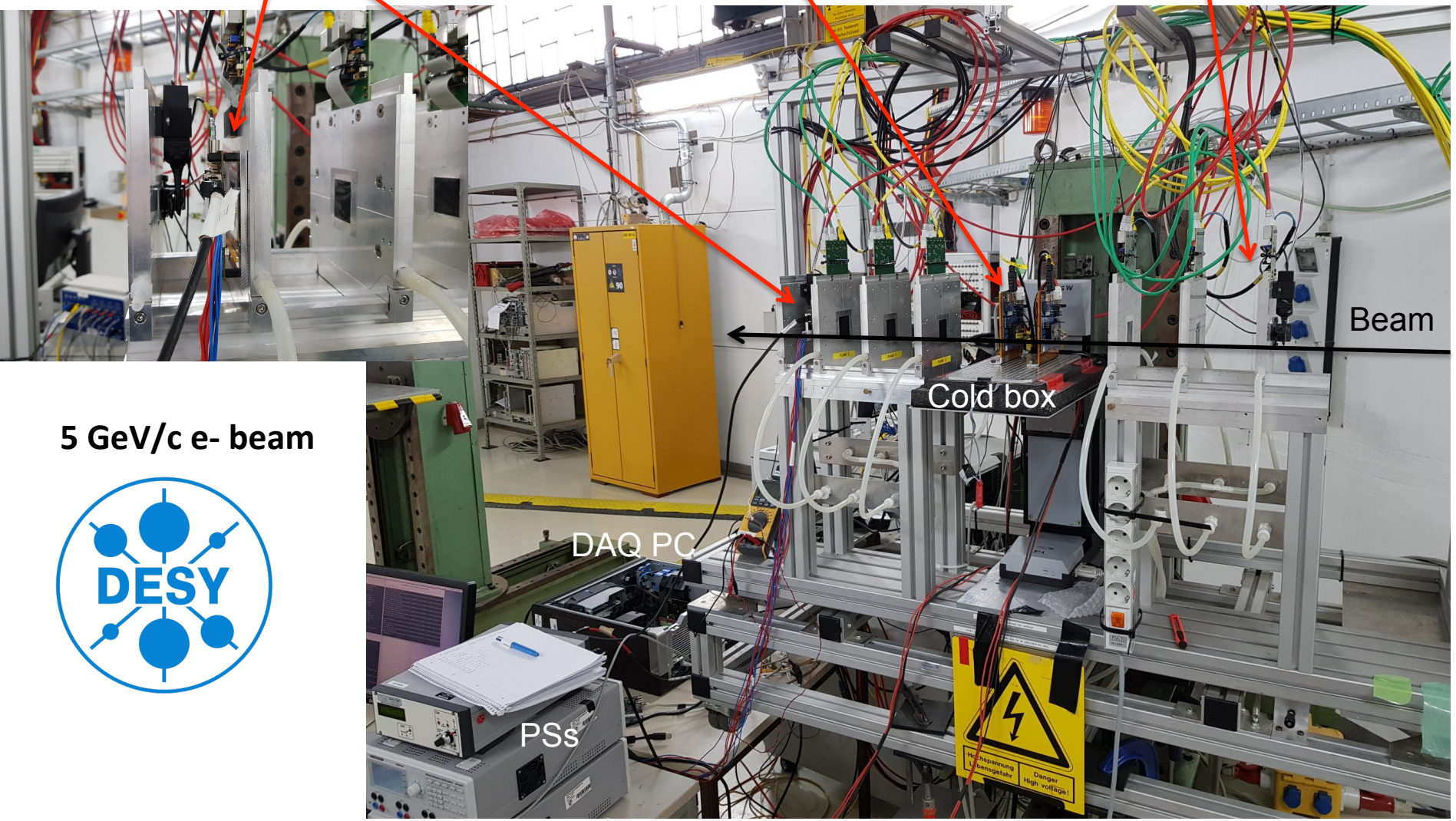




(W398-4 to be reworked as unresponsive)

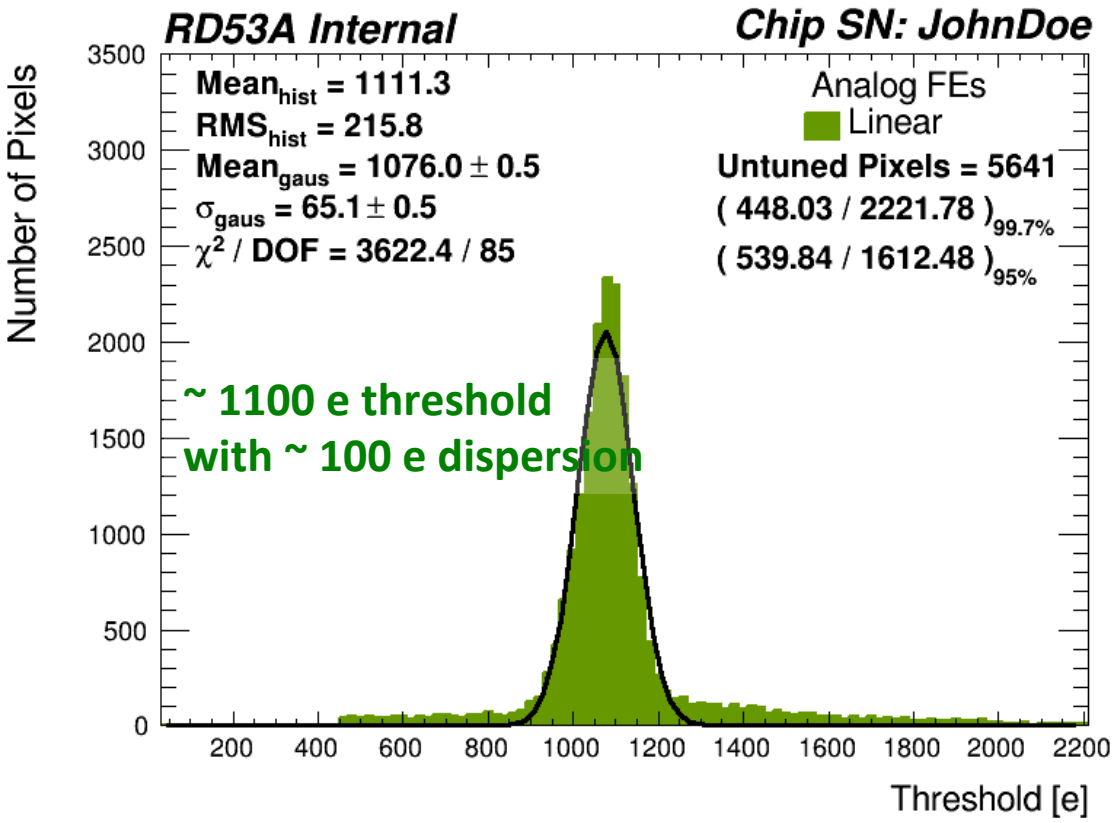
Testbeam setup

1 FEI4 reference (MMC3) + 2 RD53A DUTs (Yarr) + EUDET telescope



5 GeV/c e- beam

Threshold tuning

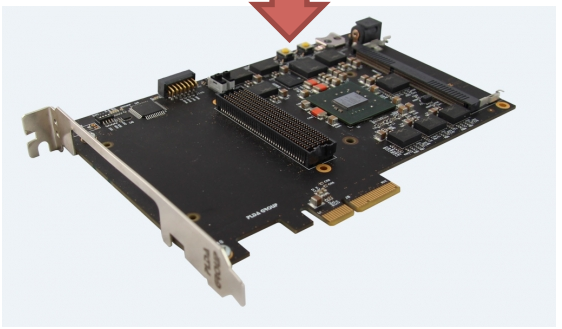


Results obtained using YARR DAQ system

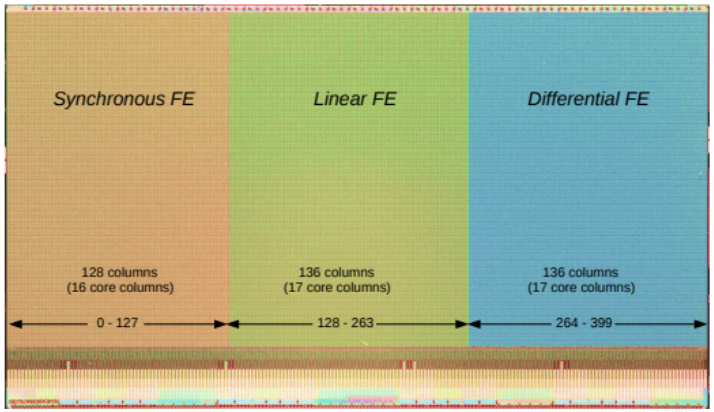
T. Heim 2017

J. Phys.: Conf. Ser.898 032053

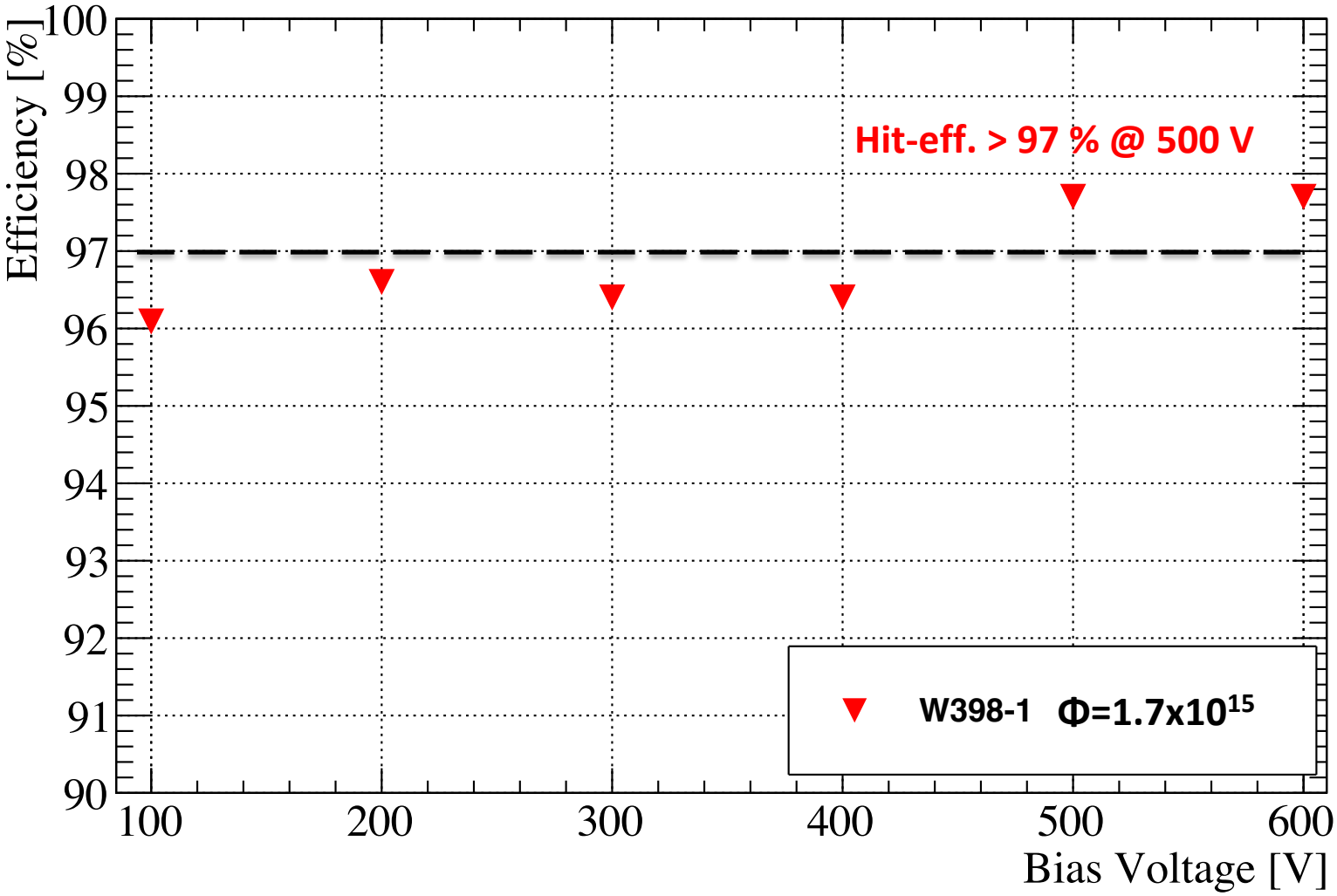
https://yarr.readthedocs.io/



RD53a chip: prototype roc for ATLAS ITk pixels
400 cols x 192 rows, 50 µm x 50 µm pitch
Three analog FE flavours implemented
Here we show results only for the Linear FE



Hit-efficiency

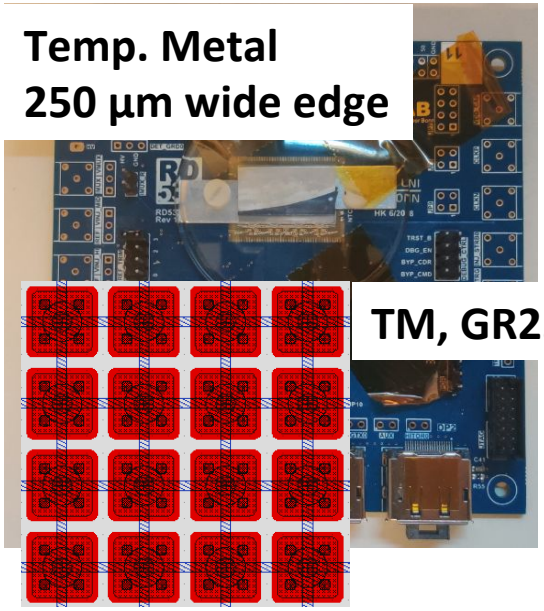


P4, 50 µM THICK MODULES: RESULTS

5 modules assembled on Single Chip Card

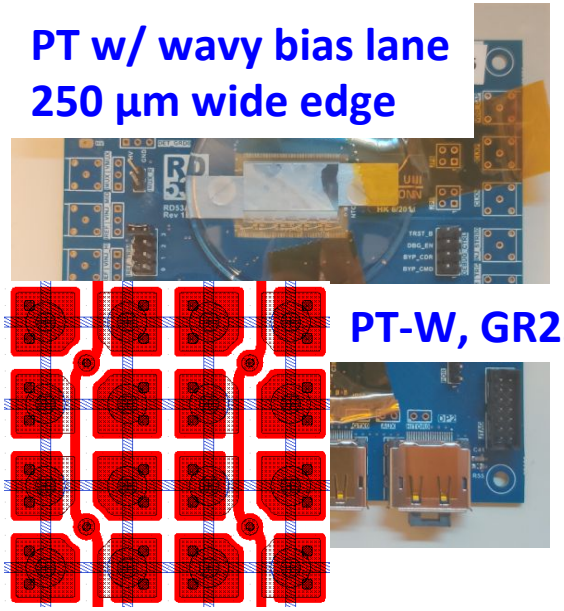
All 50x50 µm^2, bump-bonded at Leonardo, wirebonded at CERN

Temp. Metal
250 µm wide edge



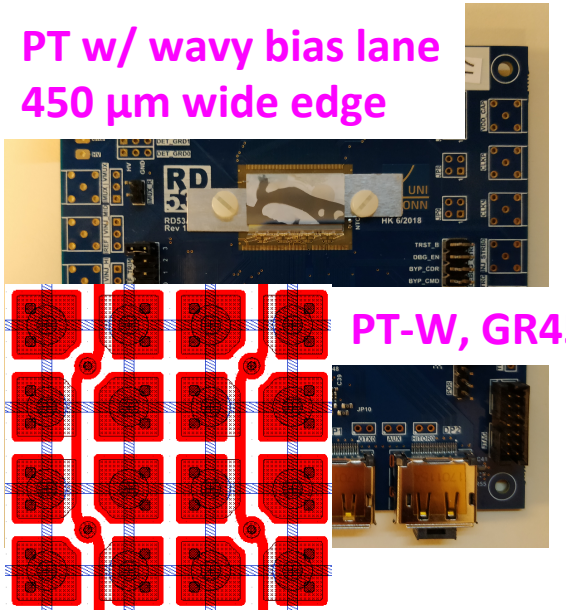
TM, GR250

PT w/ wavy bias lane
250 µm wide edge



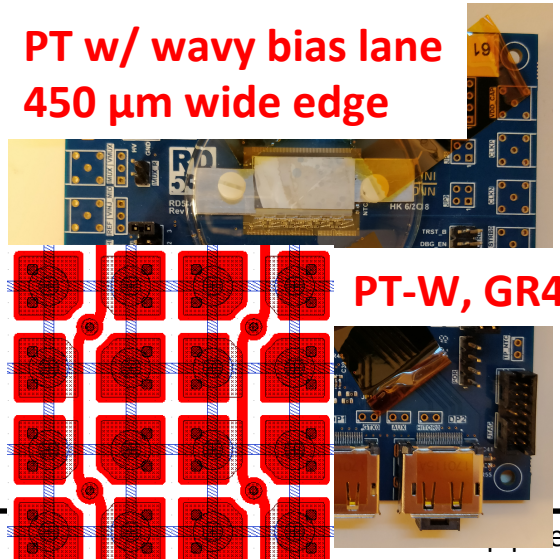
PT-W, GR250

PT w/ wavy bias lane
450 µm wide edge



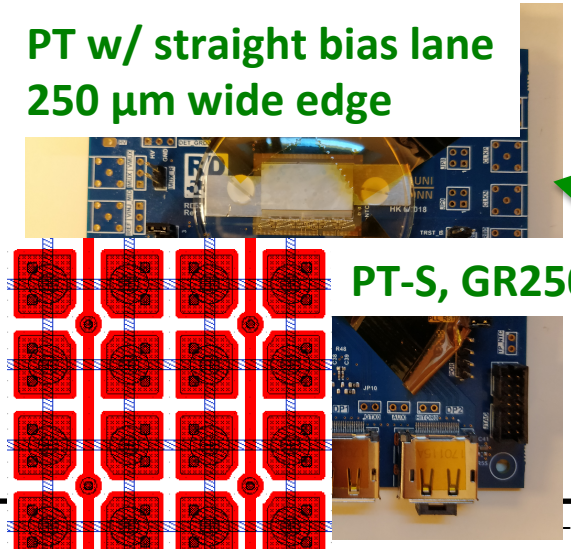
PT-W, GR450

PT w/ wavy bias lane
450 µm wide edge



PT-W, GR450

PT w/ straight bias lane
250 µm wide edge

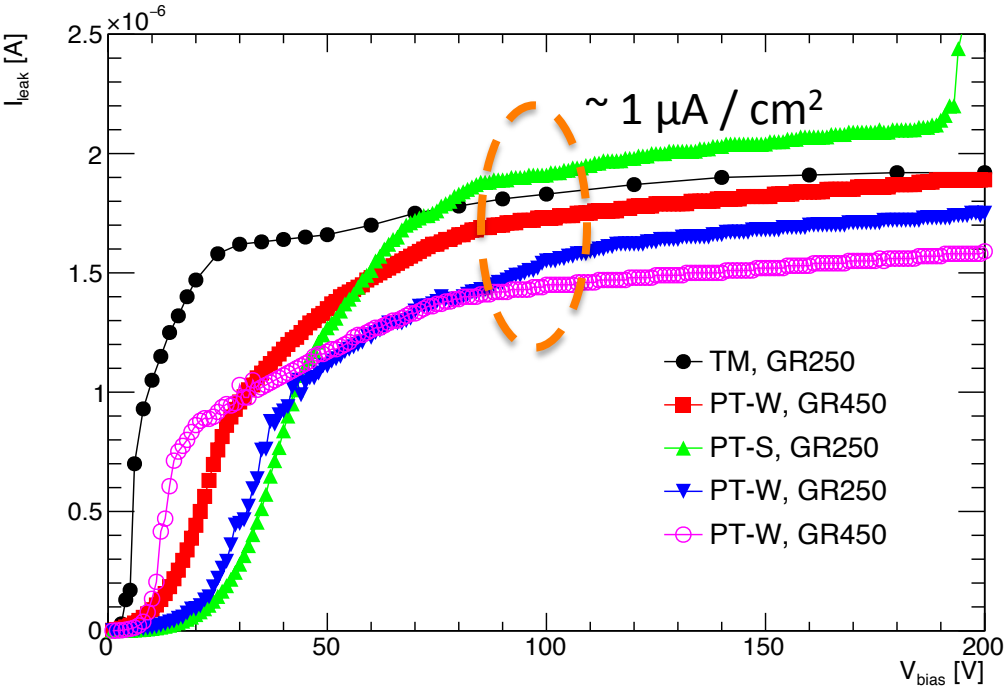


PT-S, GR250

Unfortunately roc unresponsive so no data for this design

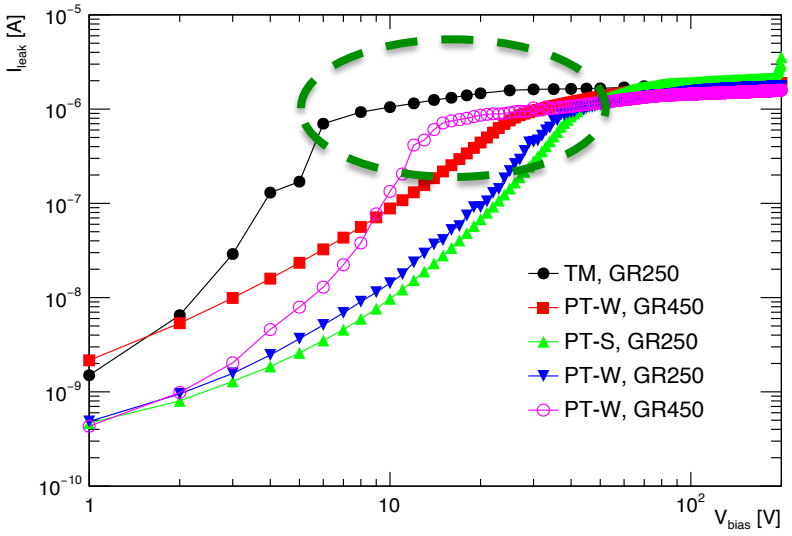
IV curves

Modules mounted on SCC, roc configured, in climate chamber at 20 C

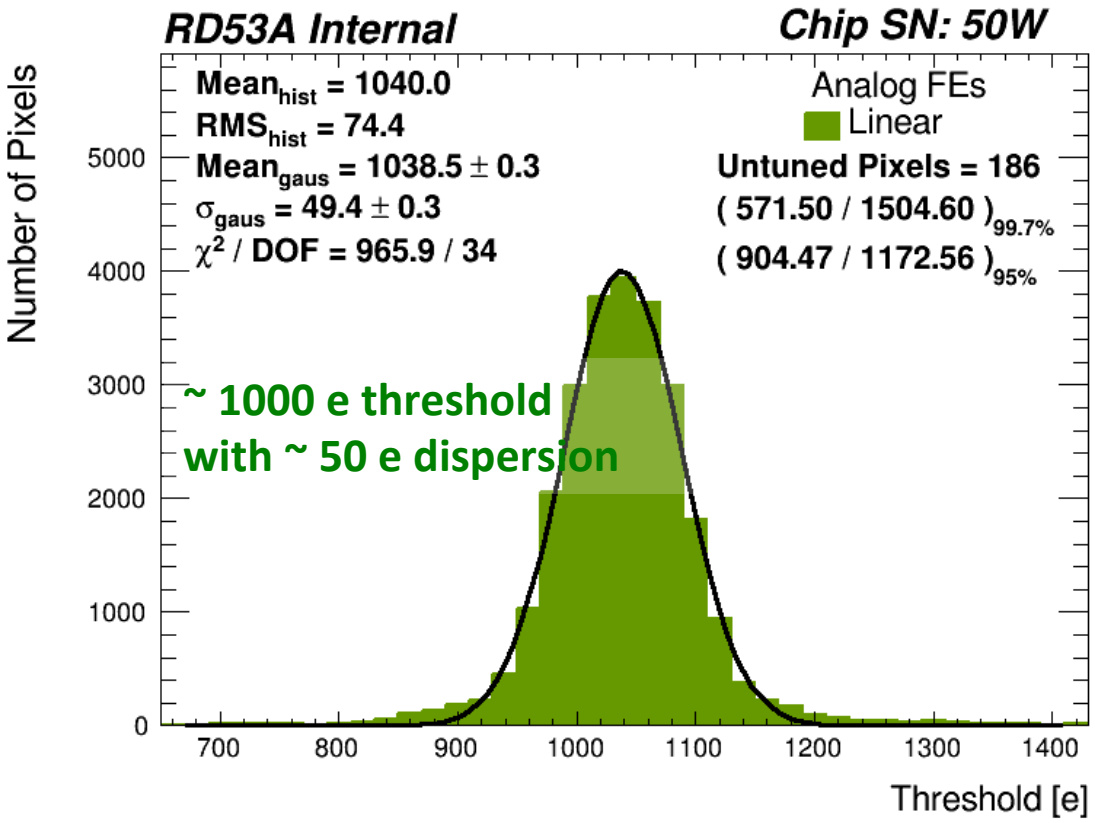


V_{BD} >~ 200 V

V_{depl} ~ 10-30 V

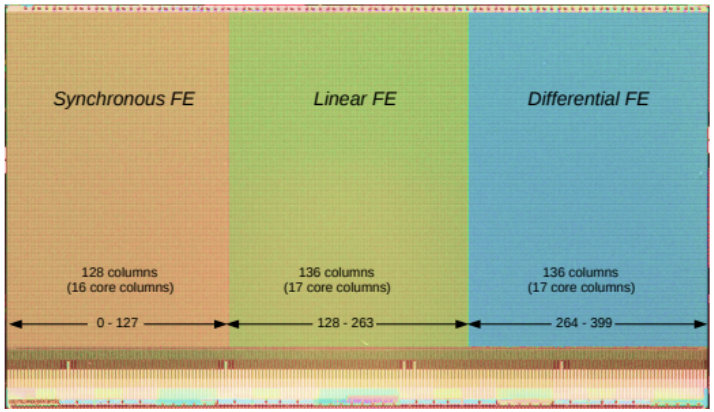


Threshold tuning

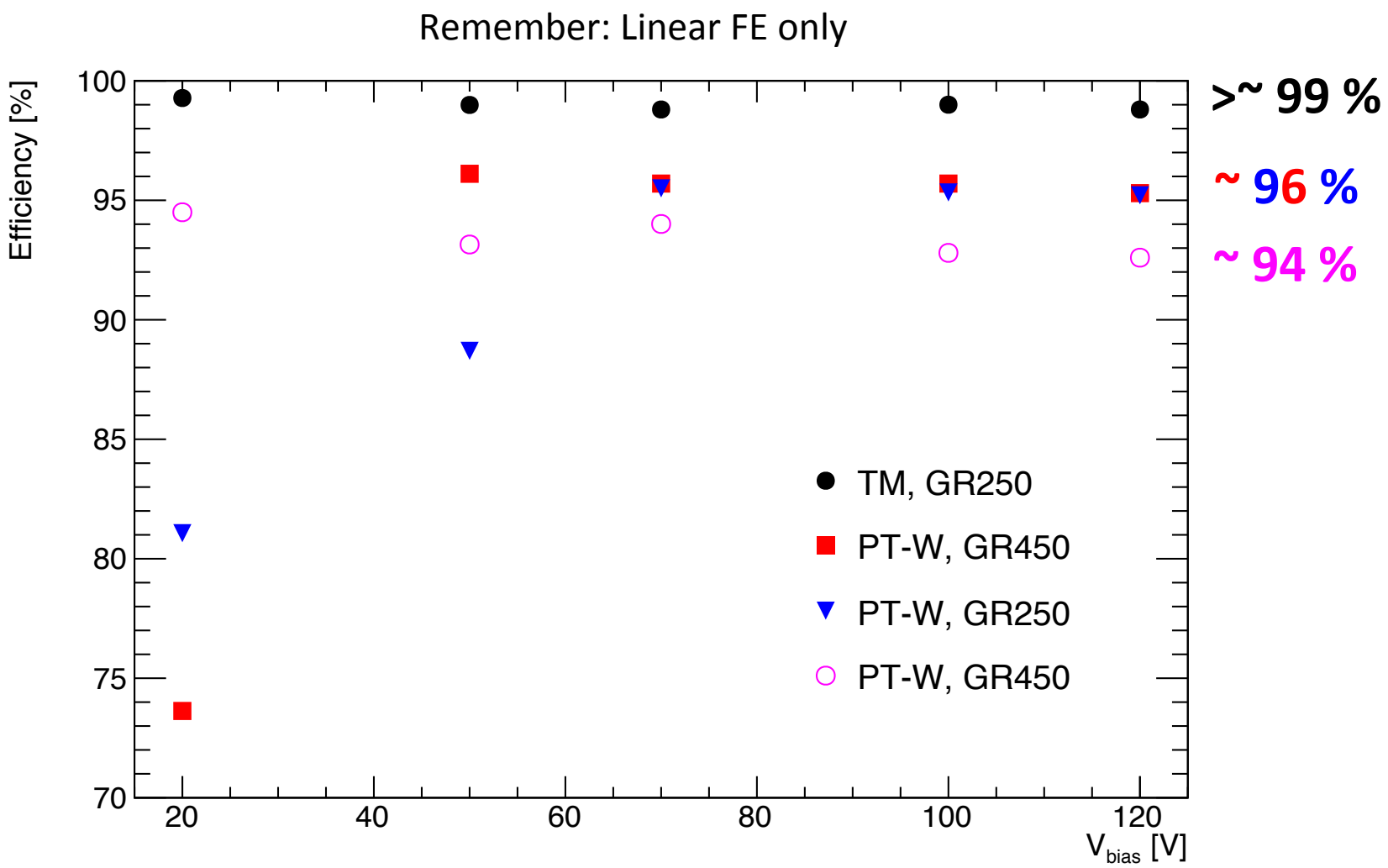


We show results only for the Linear FE

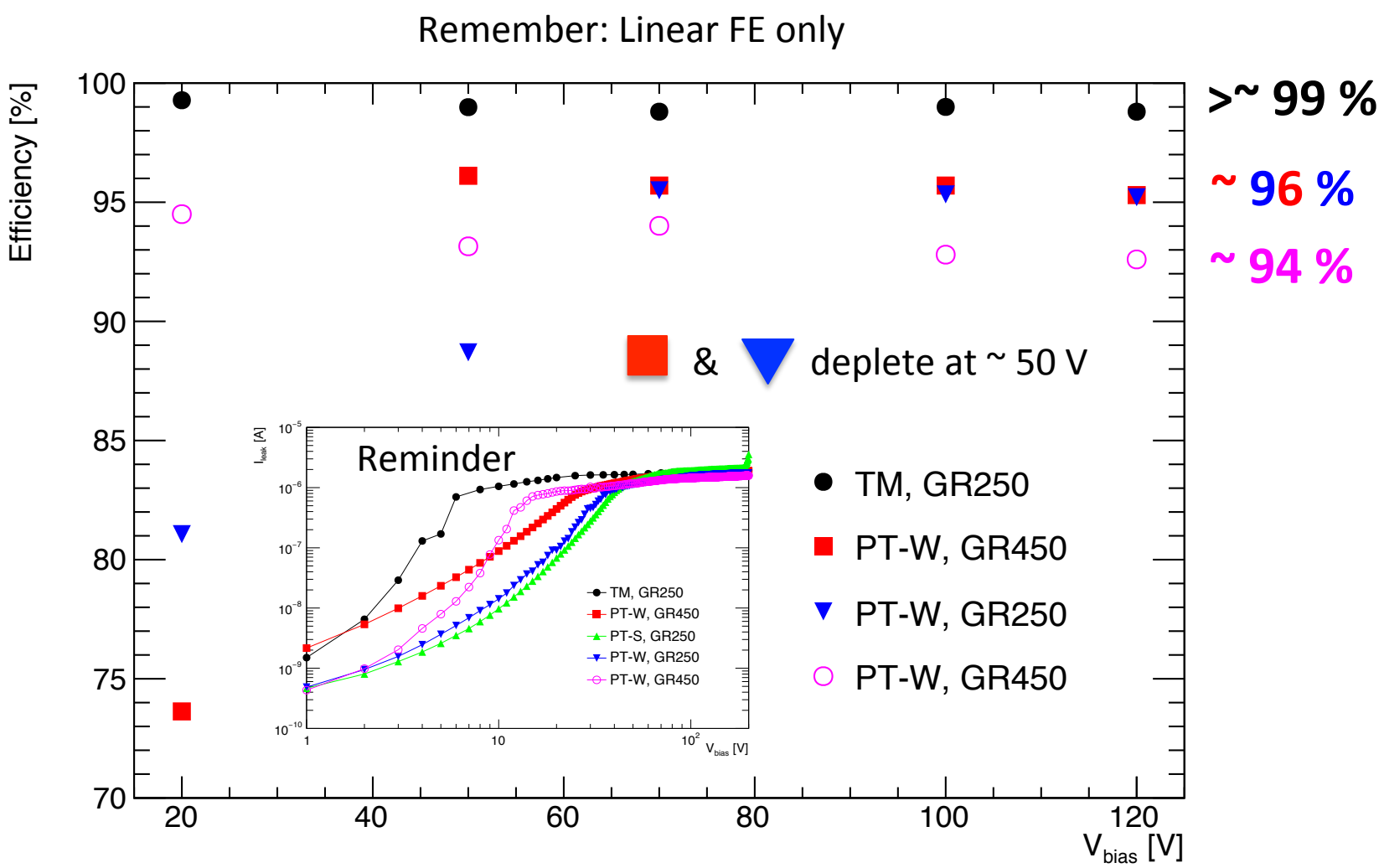
Results obtained using YARR DAQ system



Hit-efficiency



Hit-efficiency

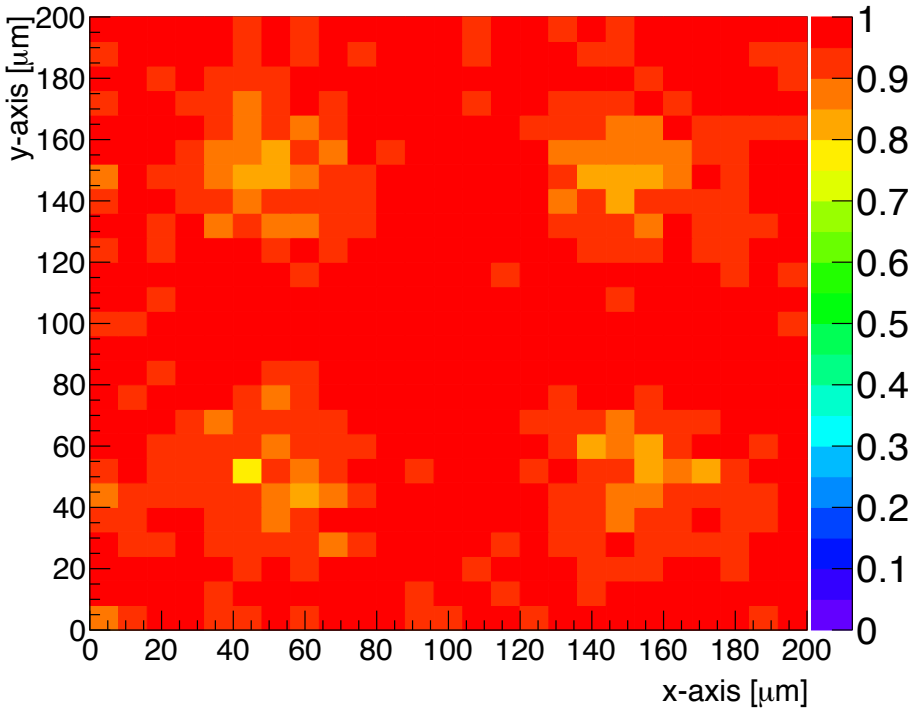


In-pixel efficiency

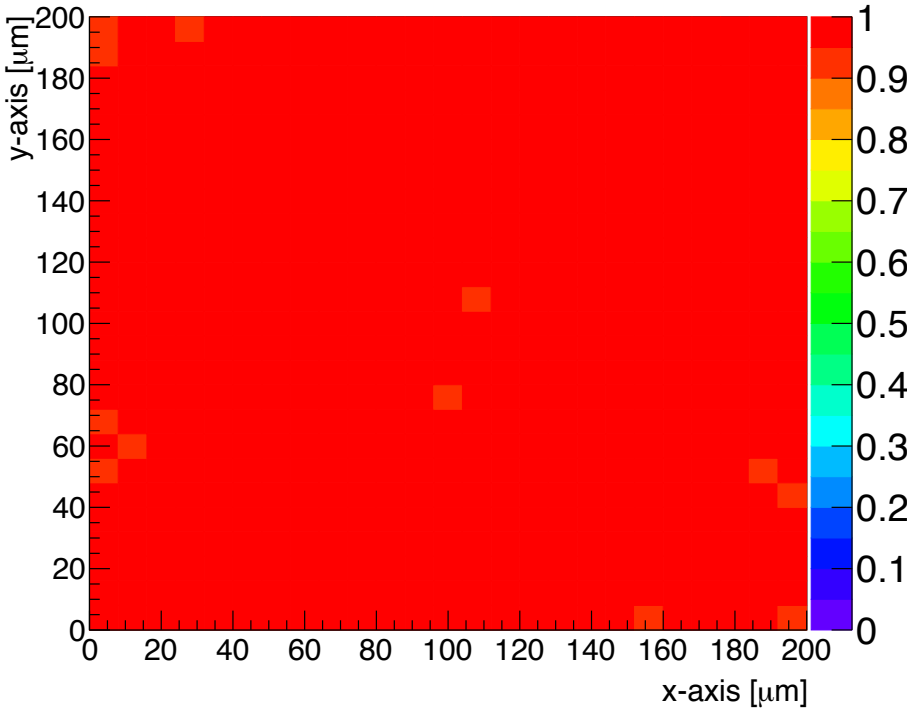
Remember: Linear FE only

N.B. tracks at normal incidence

Hit-eff. folded in a 4x4 pixel map



PT-W, GR250



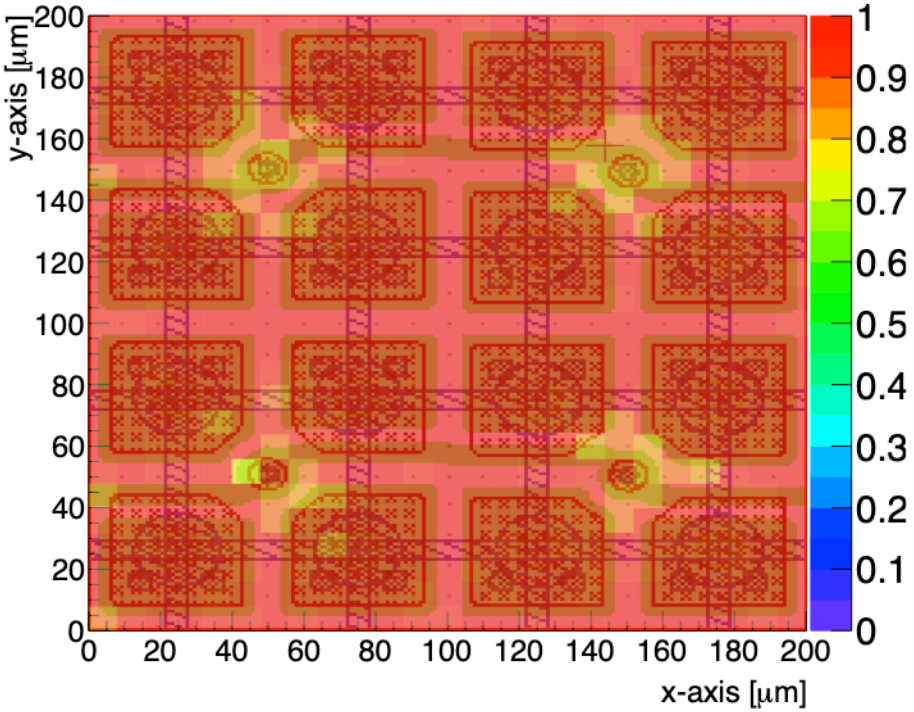
TM, GR250

In-pixel efficiency

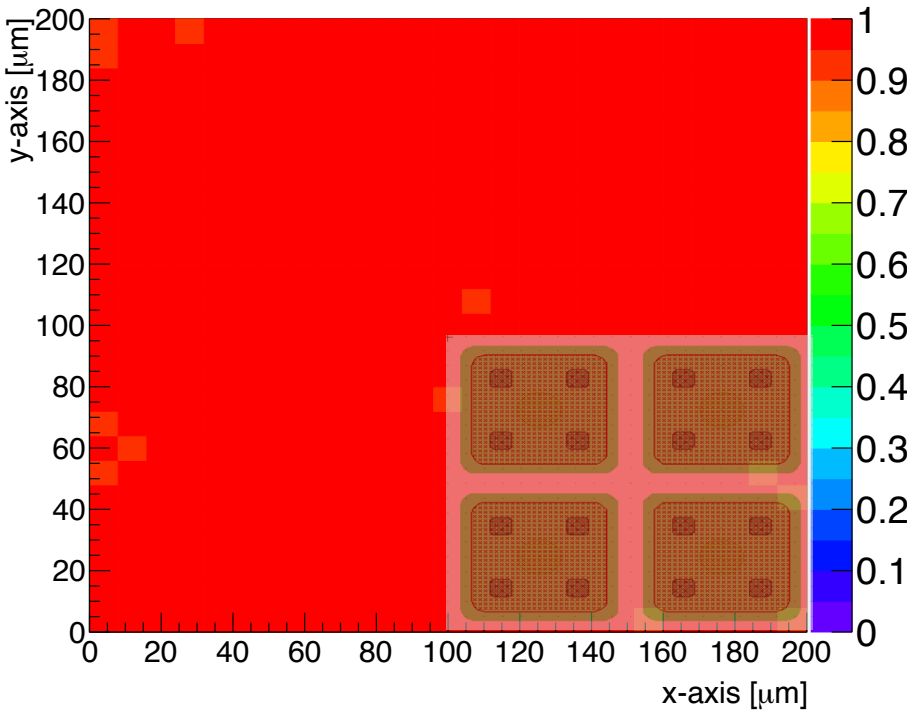
Remember: Linear FE only

N.B. tracks at normal incidence

Hit-eff. folded in a 4x4 pixel map



PT-W, GR250



TM, GR250

About 3-4% hit-eff. loss in bias dot region

Module w/o permanent biasing structure shows uniform eff.

Conclusions and Outlook

- New hadronic colliders impose light and high efficient silicon sensors for tracking in unprecedented harsh environments
- Thin n-on-p pixels are promising candidates
- Small pitches are becoming available
- LPNHE and FBK produced thin (130 µm) sensors which proved to be radiation hard for HL-LHC
- Very thin sensors (50 µm) show promising results before irradiation and two of them will be tested in DESY in ~ 1 month after irradiation to $5x10^{15}$ n_{eq}/cm^2

Acknowledgments

- PAE3 planar pixel production presented in this paper are supported by the Italian National Institute for Nuclear Research (INFN), Projects ATLAS, CMS, RD-FASE2 (CSN1)

- Many thanks to Laura and Amelia for taking care of irradiations

- Many thanks to Jon for parylene coating deposition on our modules

- Authors received support for irradiation and testbeam campaigns via the H2020 project AIDA-2020, GA no. 654168

- Some of the measurements leading to these results have been performed at the Test Beam Facility at DESY Hamburg (Germany), a member of the Helmholtz Association (HGF)

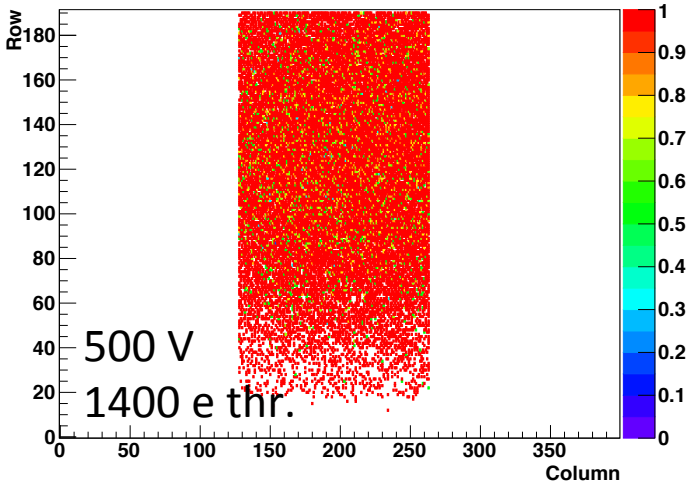
- Many thanks to the ATLAS ITk Pixels testbeam community

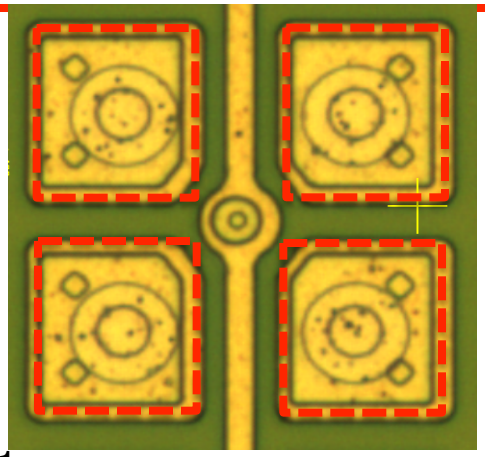

THANK YOU FOR YOUR ATTENTION!

Backup

PAE3 - Performance of irradiated RD53A

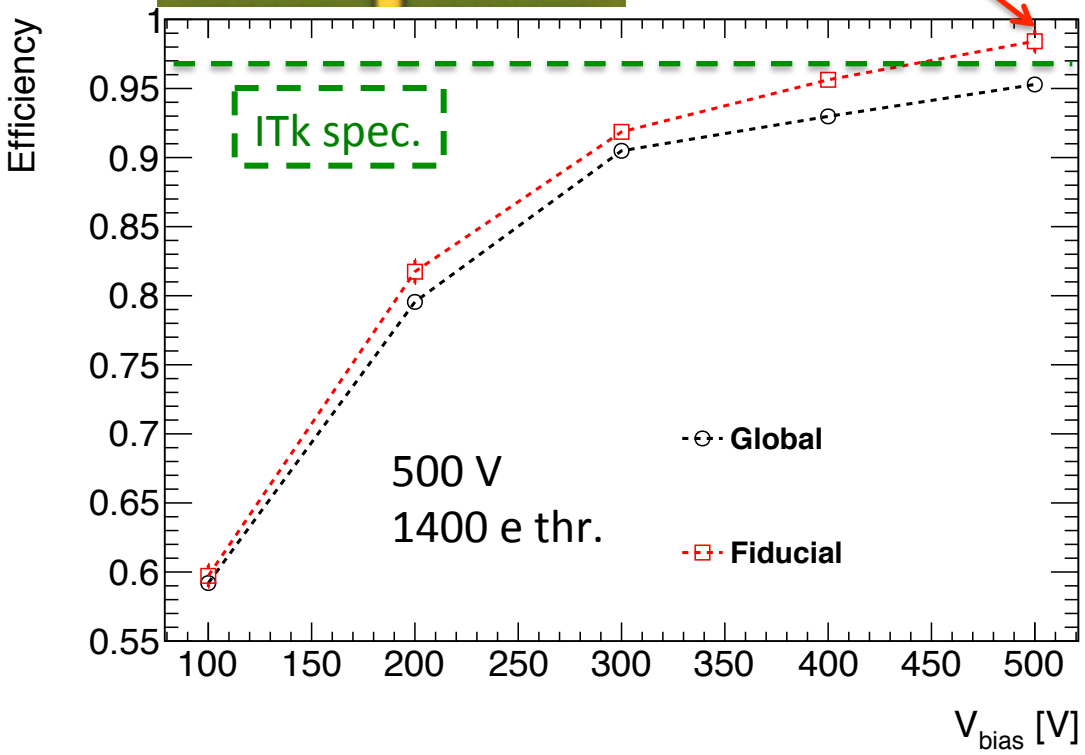
Irr. at CERN IRRAD @ **<Φ> = 3.5x10^{15} n$_{eq}$/cm^2**





Inner (fiducial) region

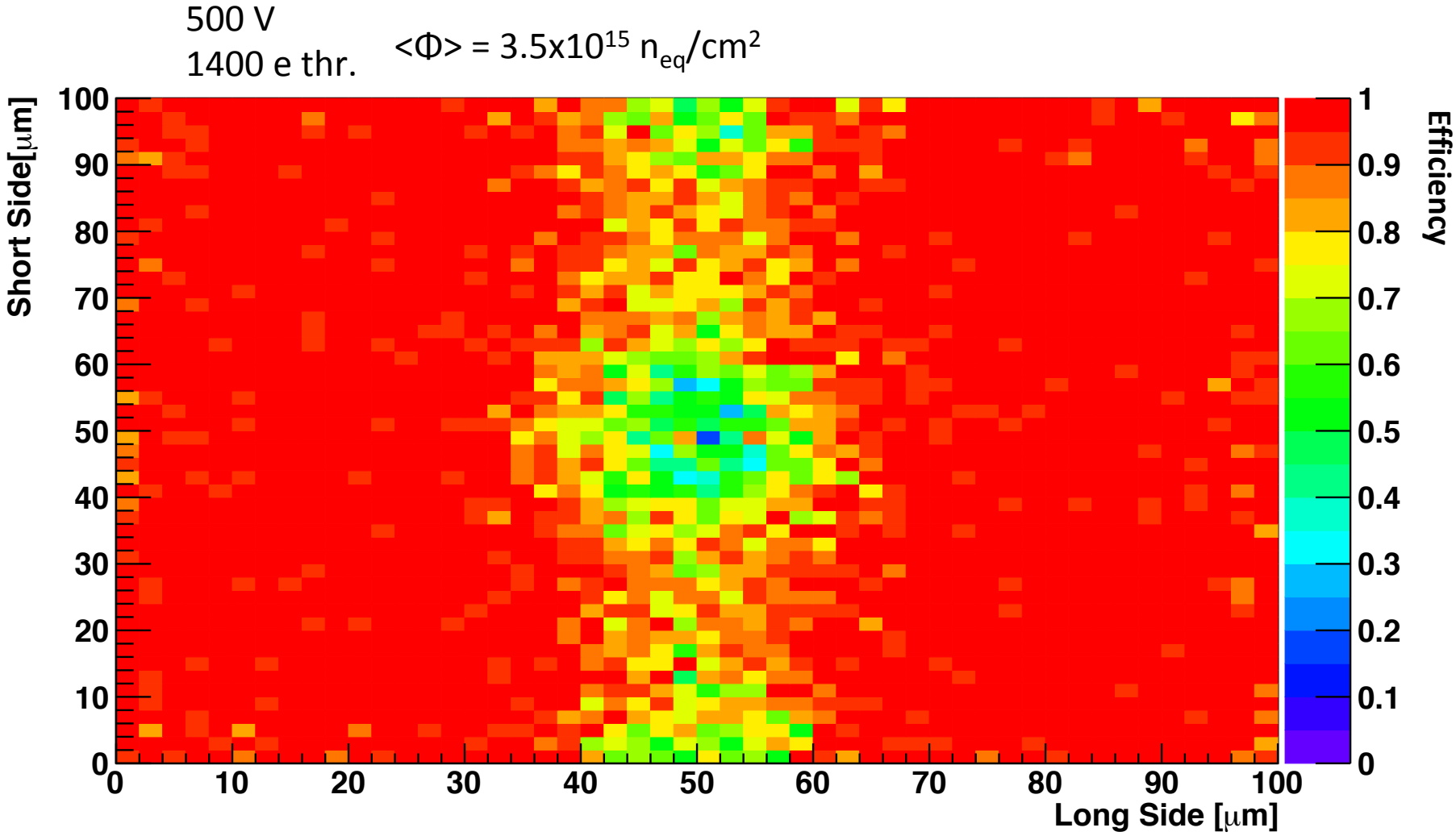
98.4% @ 500 V



Significant efficiency loss when whole matrix is considered

Restricting analysis to the inner part of the cell brings back > 97% hit efficiency

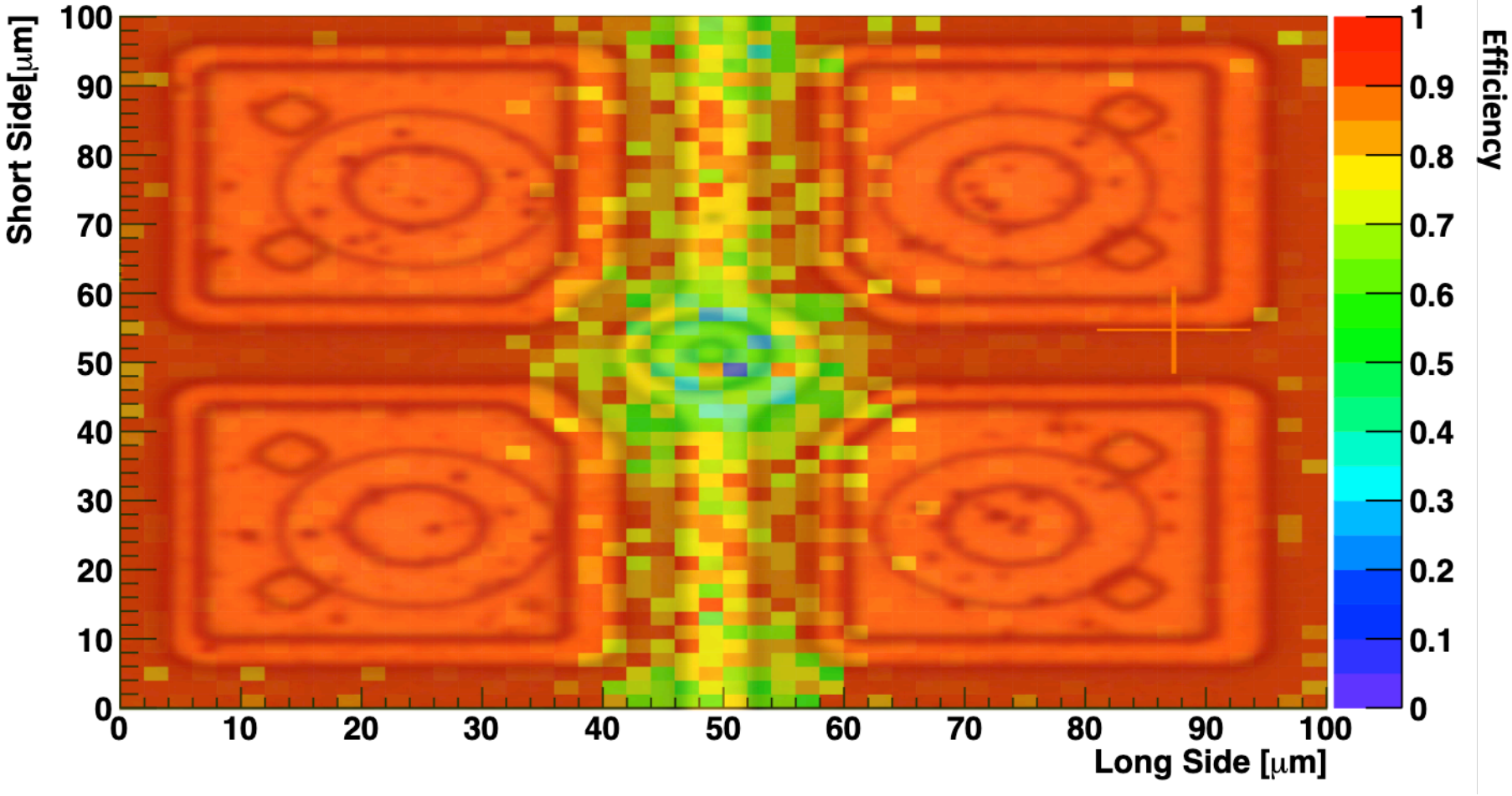
PAE3 - Hit efficiency map



PAE3 - Hit efficiency map

500 V
1400 e thr.

$\langle\Phi\rangle = 3.5\times10^{15}\ n_{eq}/cm^2$



New thin n-on-p wafer map