Radiation analysis and test of CMOS sensors for TEM applications

Work Package 5

24-01-2019

ESR13: Andrea Ferretti

Host Institution: Thermo Fisher Scientific (formerly FEI)

Supervisor: Luigi Mele

Smart Sensor Technologies and Training for Radiation Enhanced Applications and Measurements (STREAM) is a project funded by the European Commission under the Horizon2020 Framework Program under the Grant Agreement no 675587. STREAM began in January 2016 and will run for 4 years.

ESR13: Aims of the project

- Transmission electron microscope integration and test of HPIXEL, the KIT designed HV-CMOS particle detector
- Characterisation and assessment of HPIXEL for electron microscopy
- Radiation hardness analysis of the MALTA detector
- Identification possible fields of application or guidance for future re-design

Malta radiation test

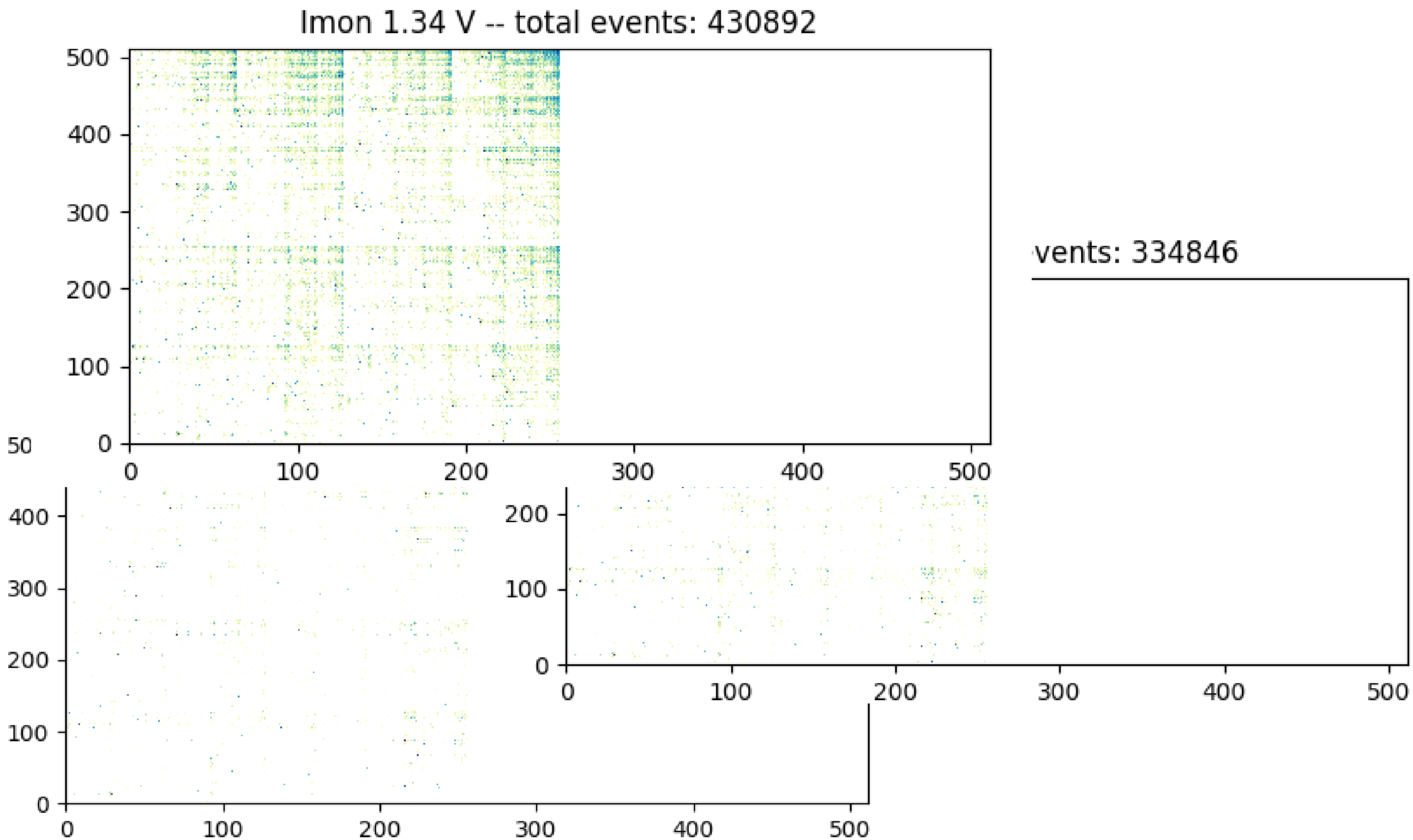
- MALTA TID(total ionizing dose) hardness tested at CERN with X-ray machine
- Measurements taken at different dose levels: 0, 5, 20 and 70 MRad

Several measurements at each stage:

1. Noise level by number of events + threshold dependency
2. Power supply analysis
3. Pixel-to-pixel threshold variation
4. Gain analysis

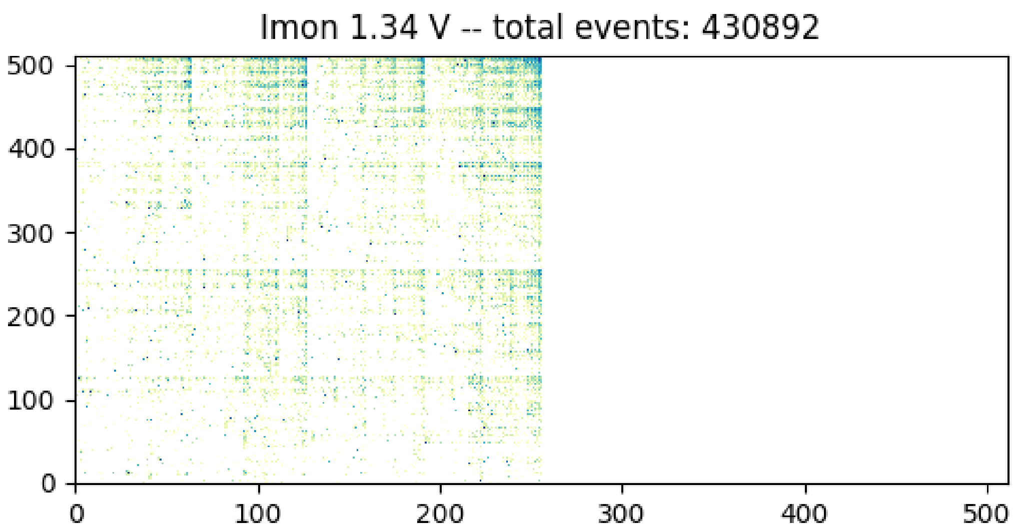
Malta radiation test

Total noisy events: 5 Mrad level

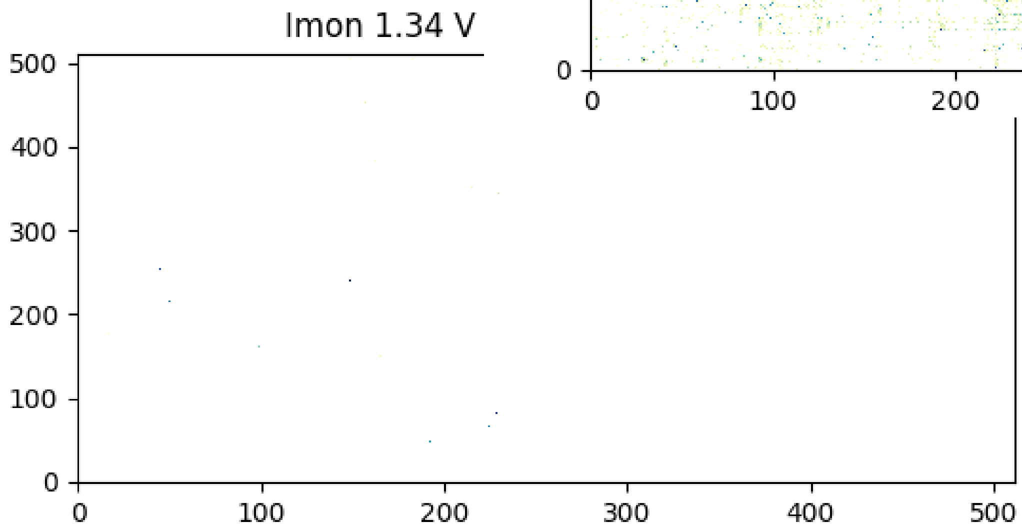


Malta radiation test

Total noisy events: Example: 0 to 5 MRad



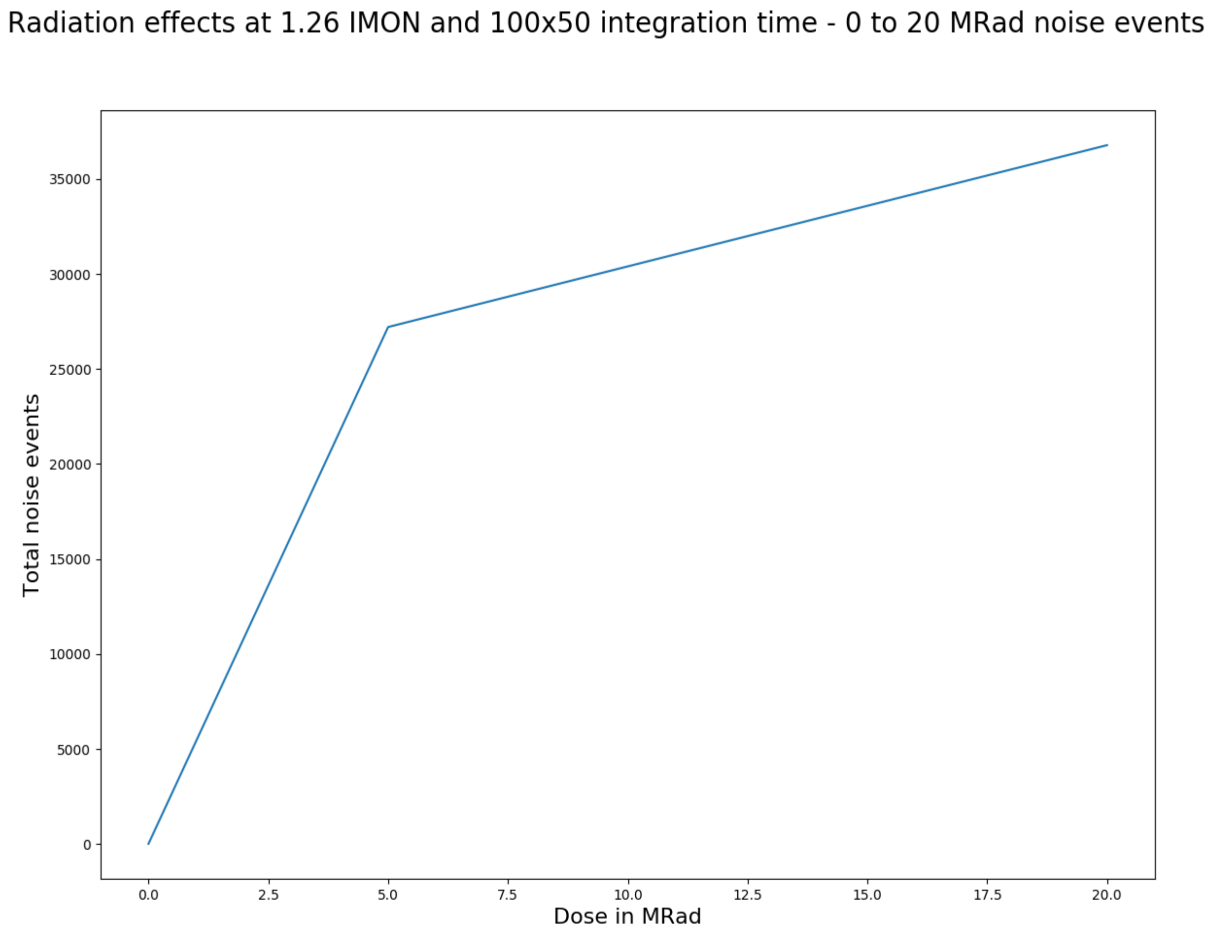
0 MRad dose



5 MRad dose

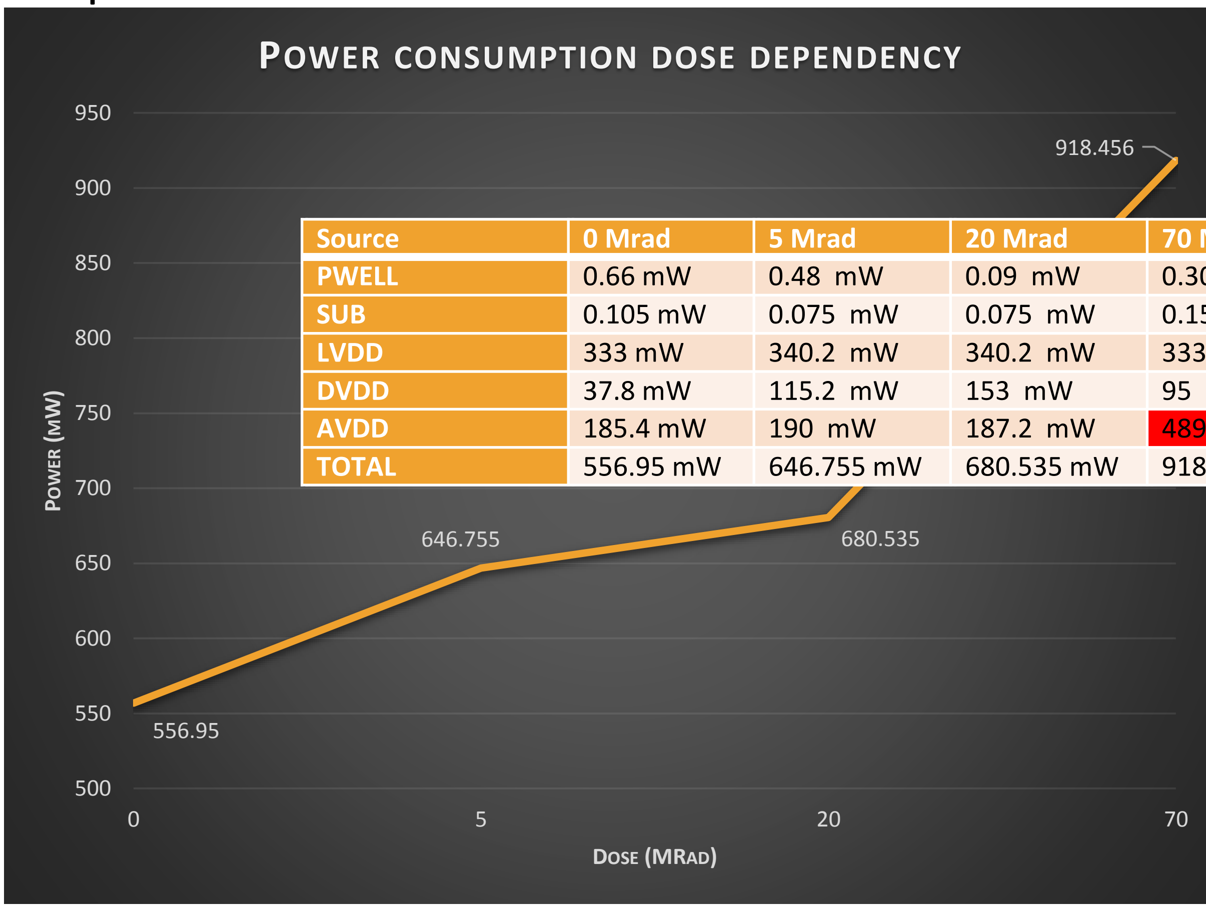
Malta radiation test

Total noisy events: 0, 5, 20 MRad points (sensor breakdown at 70 MRad)



Malta radiation test

Power dissipation - 70MRad value mainly due to AVDD going to compliance.

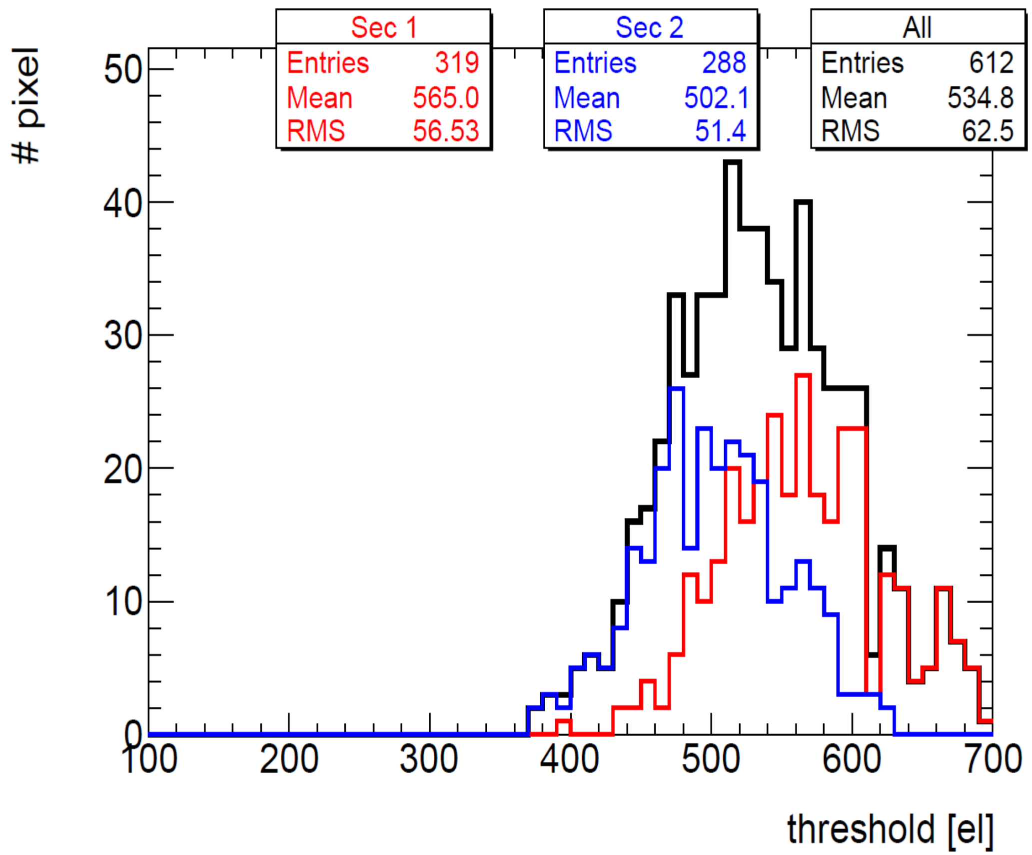


Source	0 Mrad	5 Mrad	20 Mrad	70 Mrad
PWELL	0.66 mW	0.48 mW	0.09 mW	0.306 mW
SUB	0.105 mW	0.075 mW	0.075 mW	0.15 mW
LVDD	333 mW	340.2 mW	340.2 mW	333 mW
DVDD	37.8 mW	115.2 mW	153 mW	95 mW
AVDD	185.4 mW	190 mW	187.2 mW	489.6 mW
TOTAL	556.95 mW	646.755 mW	680.535 mW	918.456 mW

STREAM

Malta radiation test

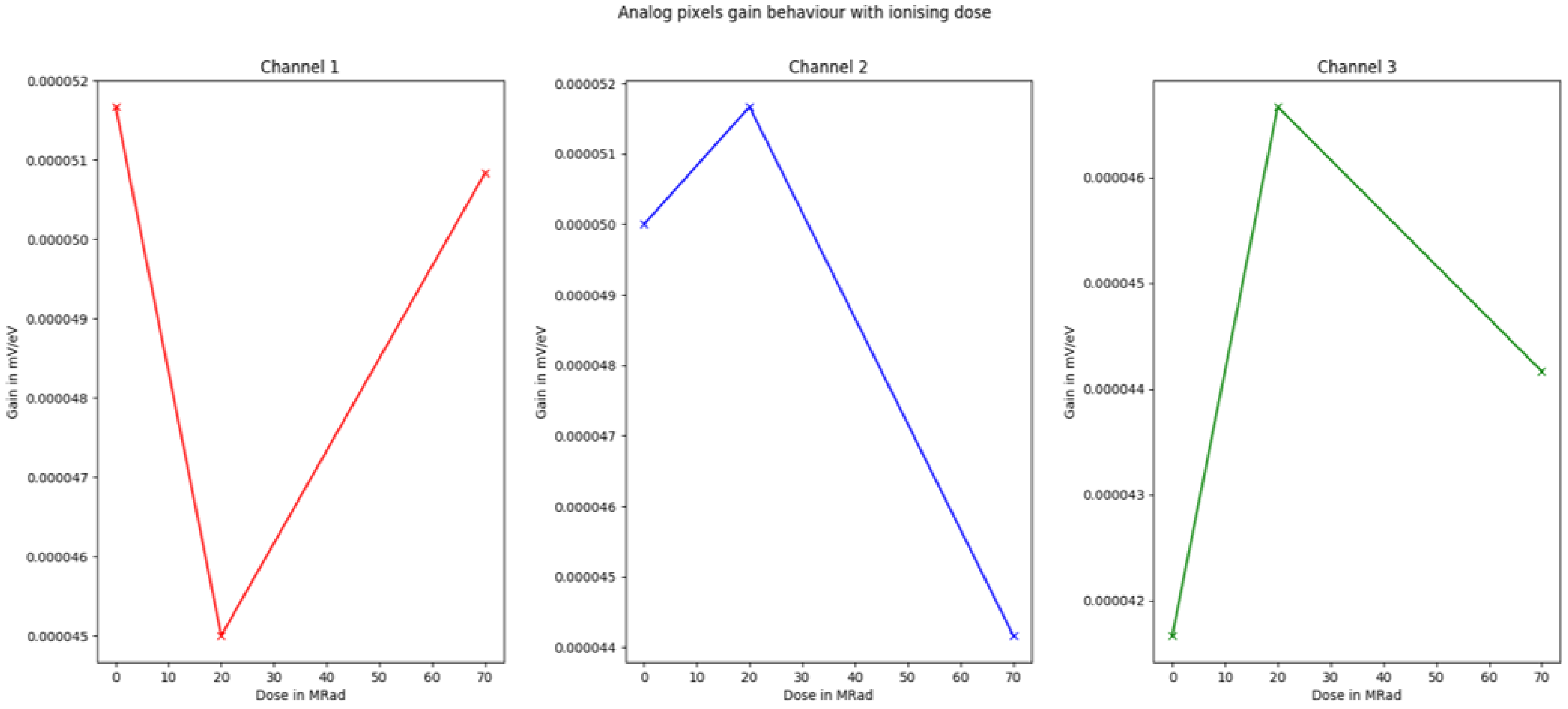
Threshold dispersion - weak increase in standard deviation: from 48 RMS unirradiated to 62.5 at 70 MRad



Malta radiation test

Gain variation – test with Fe55 source

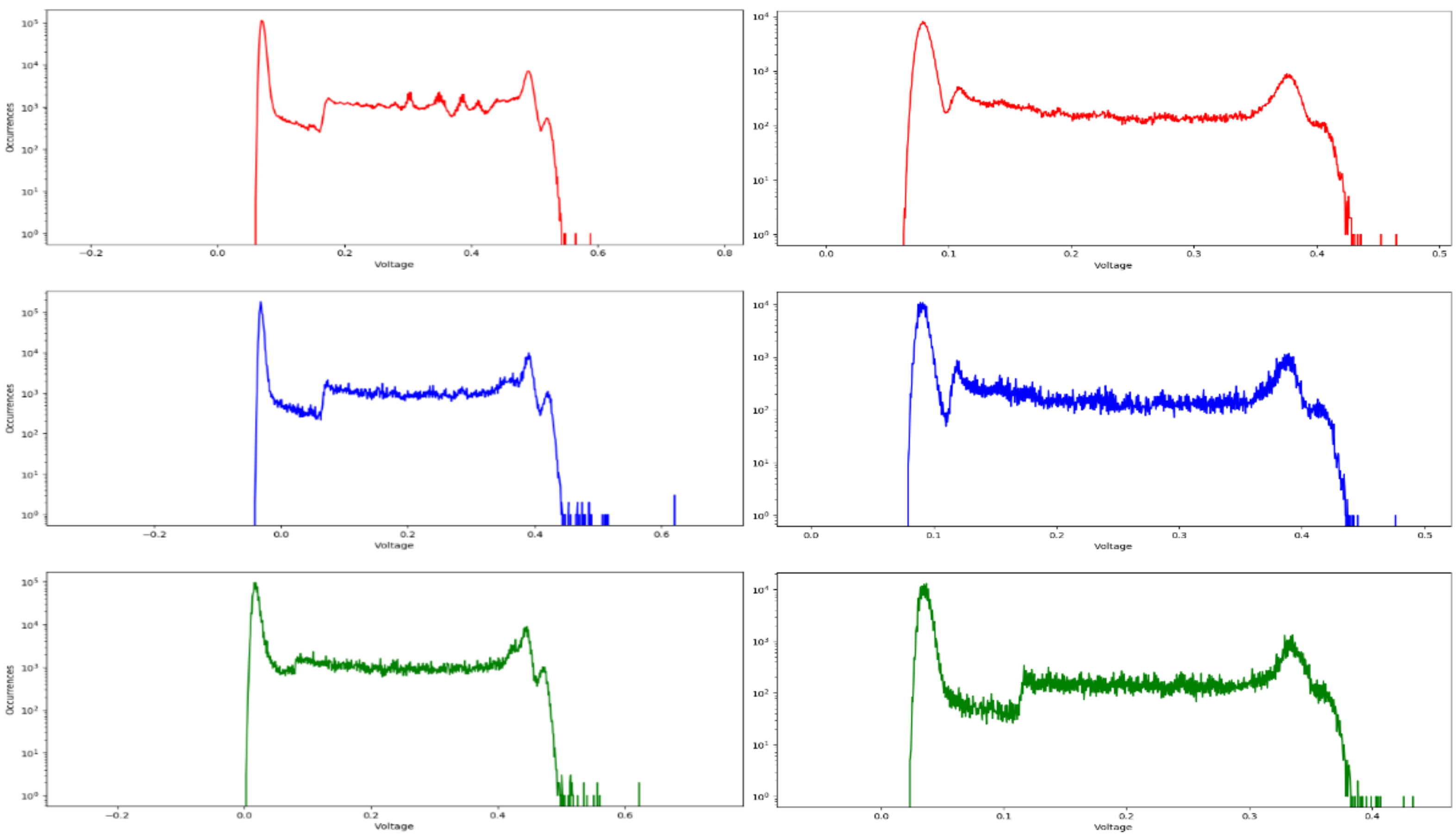
- No substantial variation



Malta radiation test

Gain variation – Peaks width doubled: chip is noisier – more events!

Unirradiated | 70 MRad



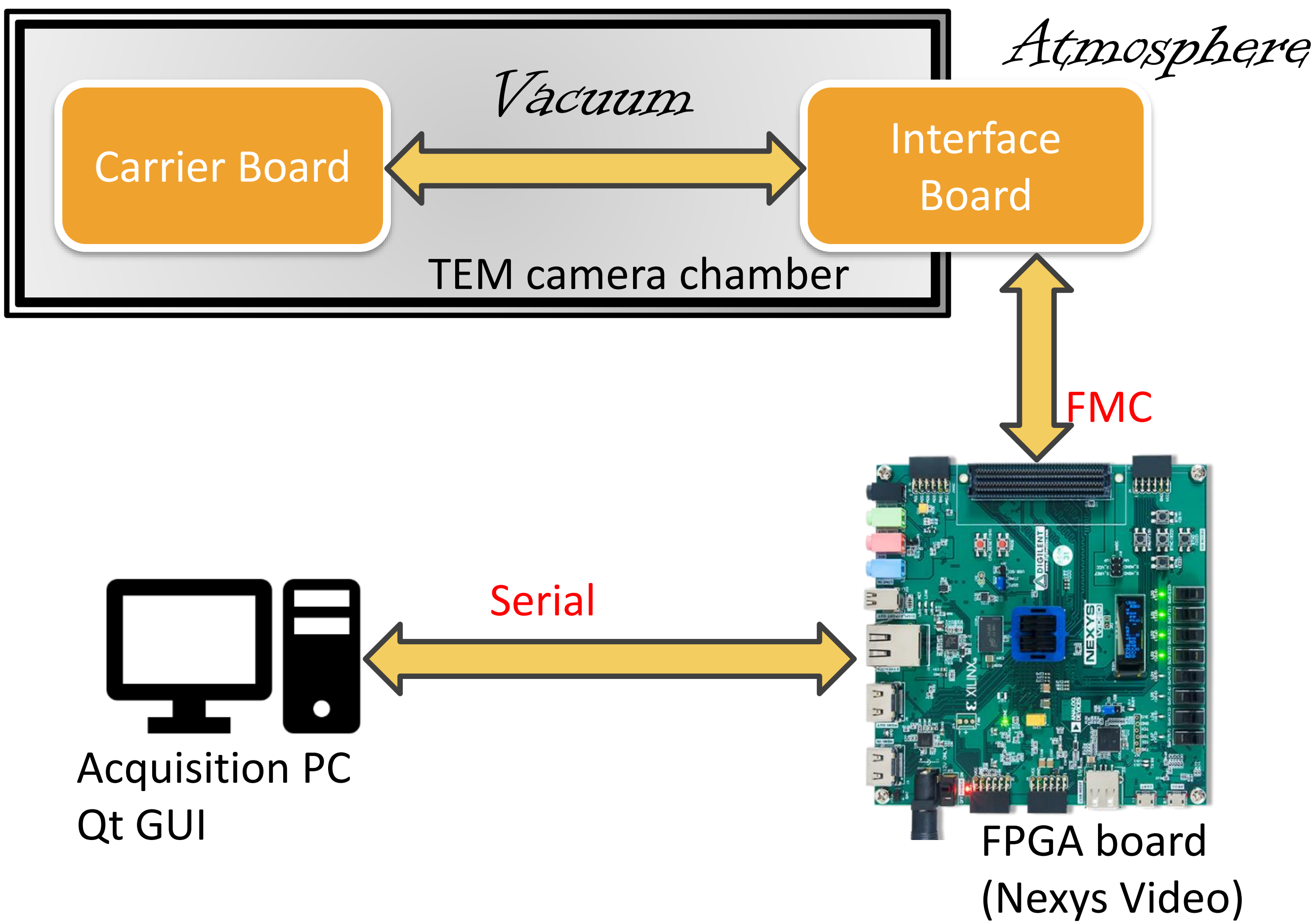
Malta radiation test

Summary

- Actual chip non-usable for low-threshold applications with doses of 70 MRad and higher due to strong noise activity and power dissipation
- Digital electronics and LVDS drivers seem to withstand ionizing dose, so does analogue front-end as gain does not seem to change with radiation

Hpixel progress – System setup

Measurement system setup with Nexys Video board

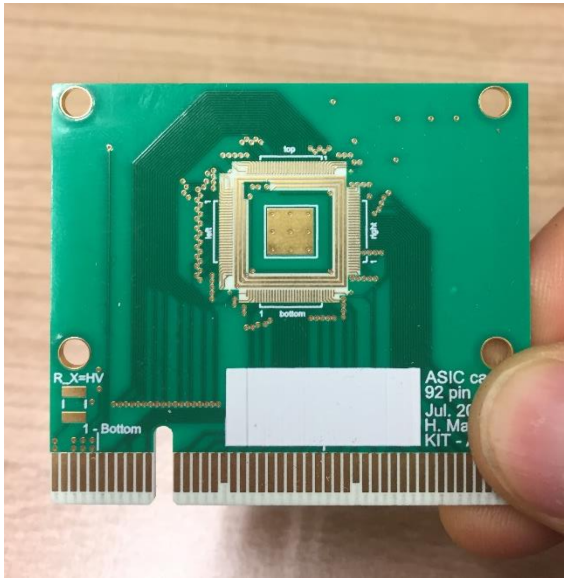


HPixel integration

Power plugs were on carrier board: inaccessible

New compact PCBs designed

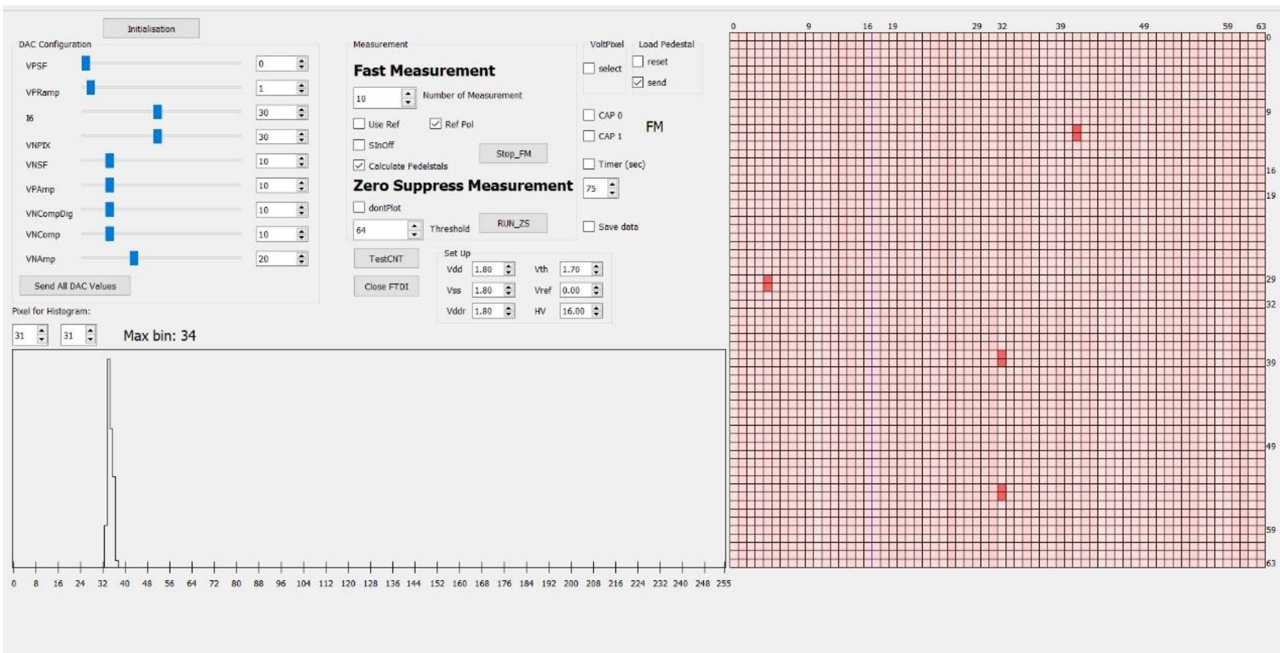
- Interface PCB broader, with power plugs and trim control connector
- 90 degree connector to sensor board: saves internal space
- Smaller carrier PCB: few components and sensor directly bonded on the board



HPixel integration

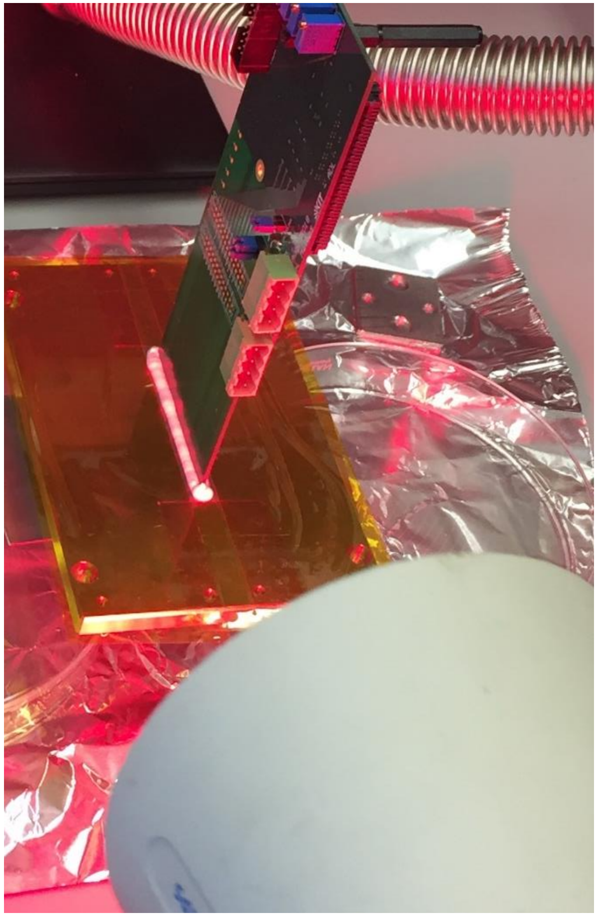
Example of desk test to verify functionality - repeated at different stages

Noise floor standing around 34 DN best-case (digital numbers)



HPixel integration

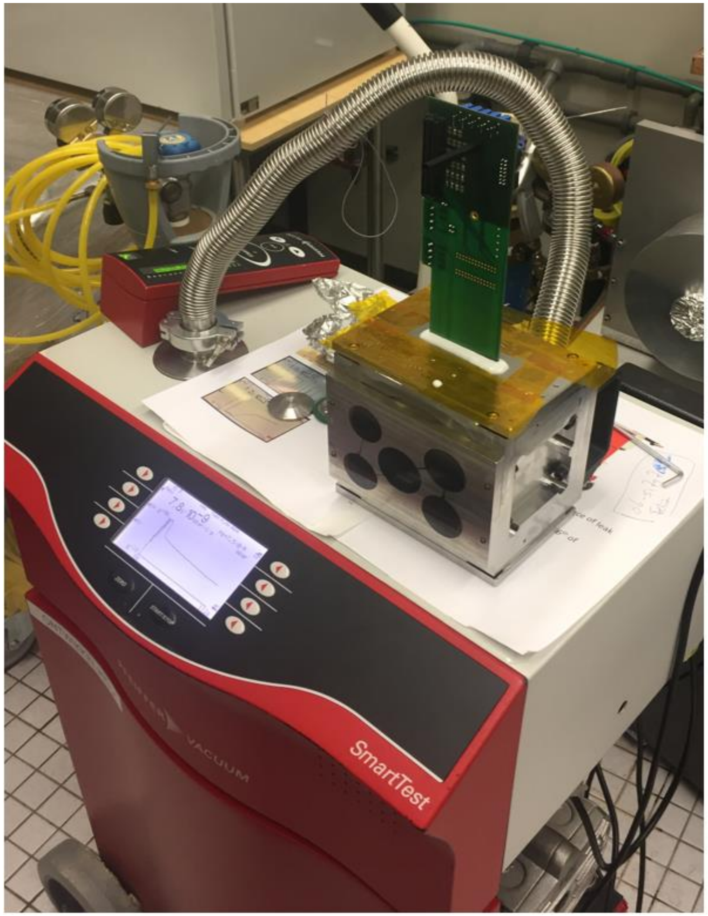
Vacuum compatibility: epoxy resin application on the flange slot



STREAM

HPixel integration

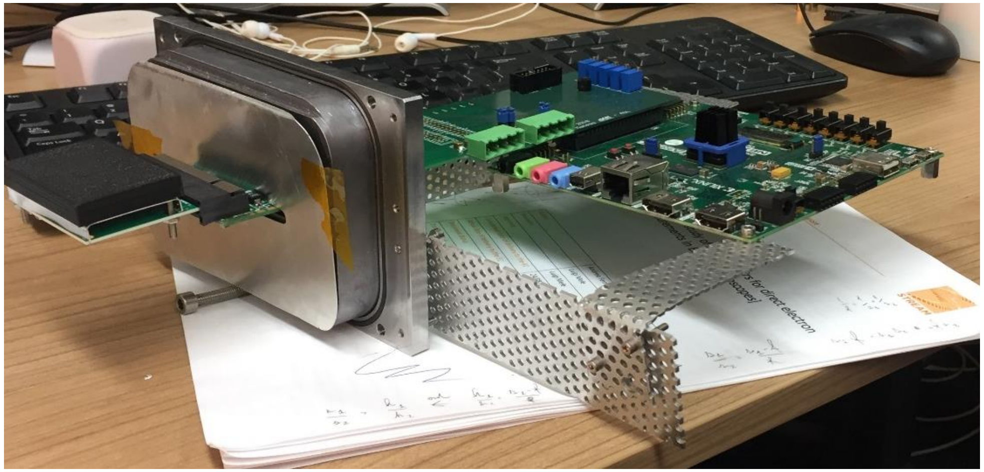
Vacuum compatibility: test with vacuum pump

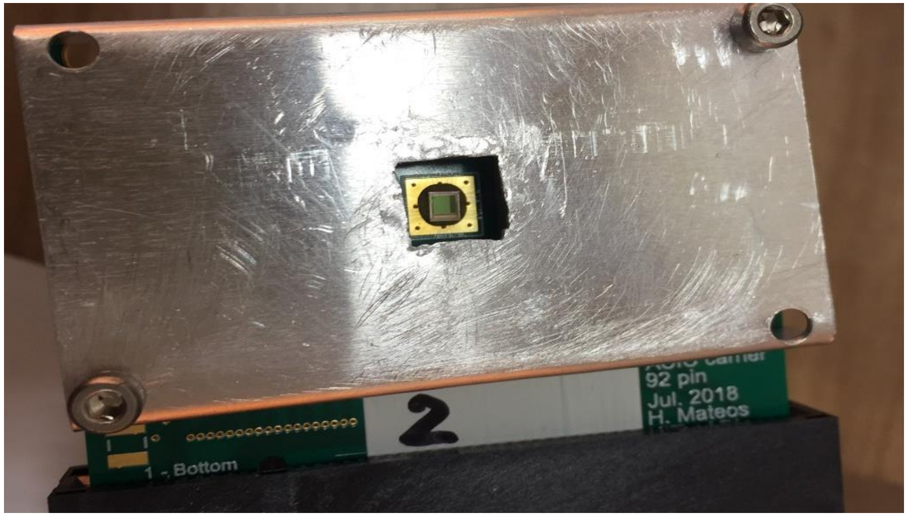


STREAM

HPixel integration

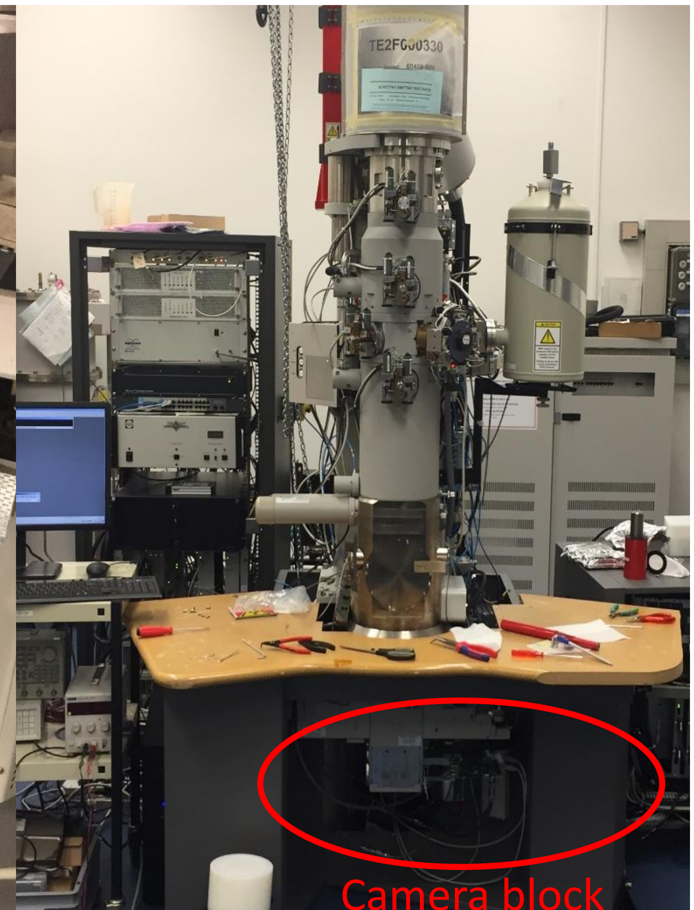
Mechanical support and shielding for the system





HPixel integration

TEM integration



HPixel test

First tests on the TEM in mid December 2018

- HPIXEL detector exposed to a 200keV electron beam

- Broke down with a beam current of ~9nA (probably latch-up event in readout electronics) -> further investigation on radiation hardness needed

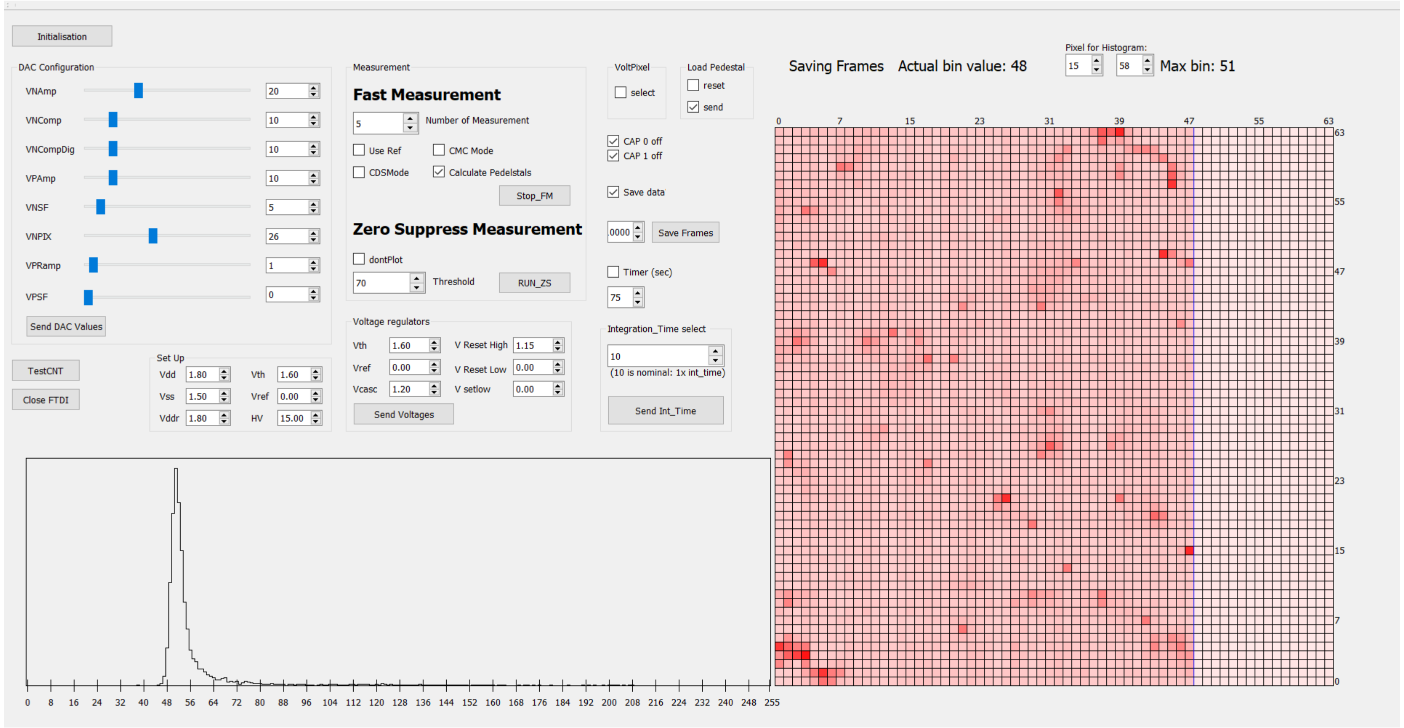
HPixel test

January 2019 tests at the Thermo Fisher Scientific facility:

- Supported by ESR4 from KIT
- Measurements at very low currents, single electron events
- Characterization of the detector at different High Voltage levels: gain, blob size.

HPixel test

Chip tested at very low doses in TEM

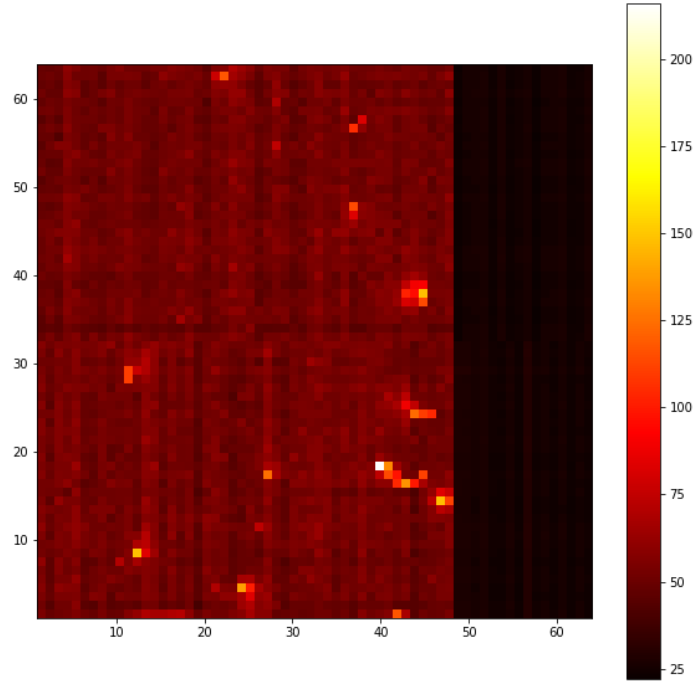


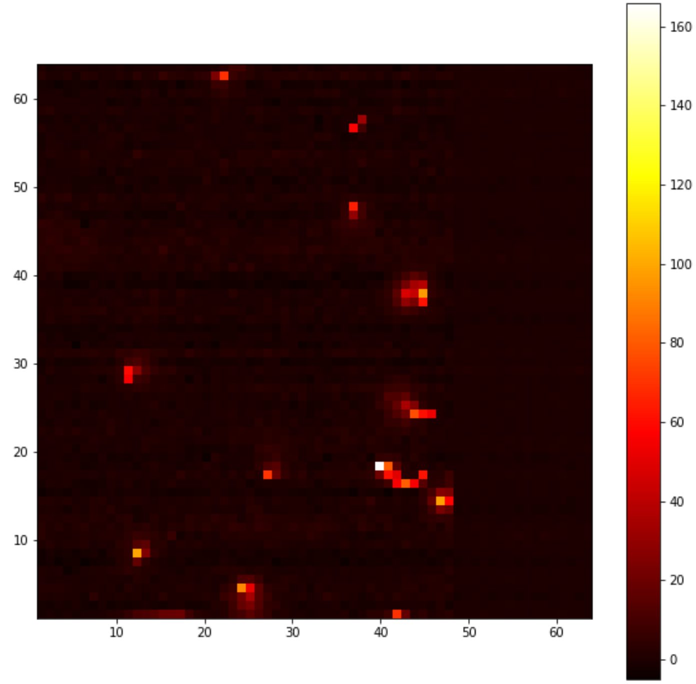
HPixel test

Blob size with HV - most of the processing to be done

At -40HV biasing, deviation of charge events around 0.18.

Laplacian of Gaussian approach to detect blobs and deviation



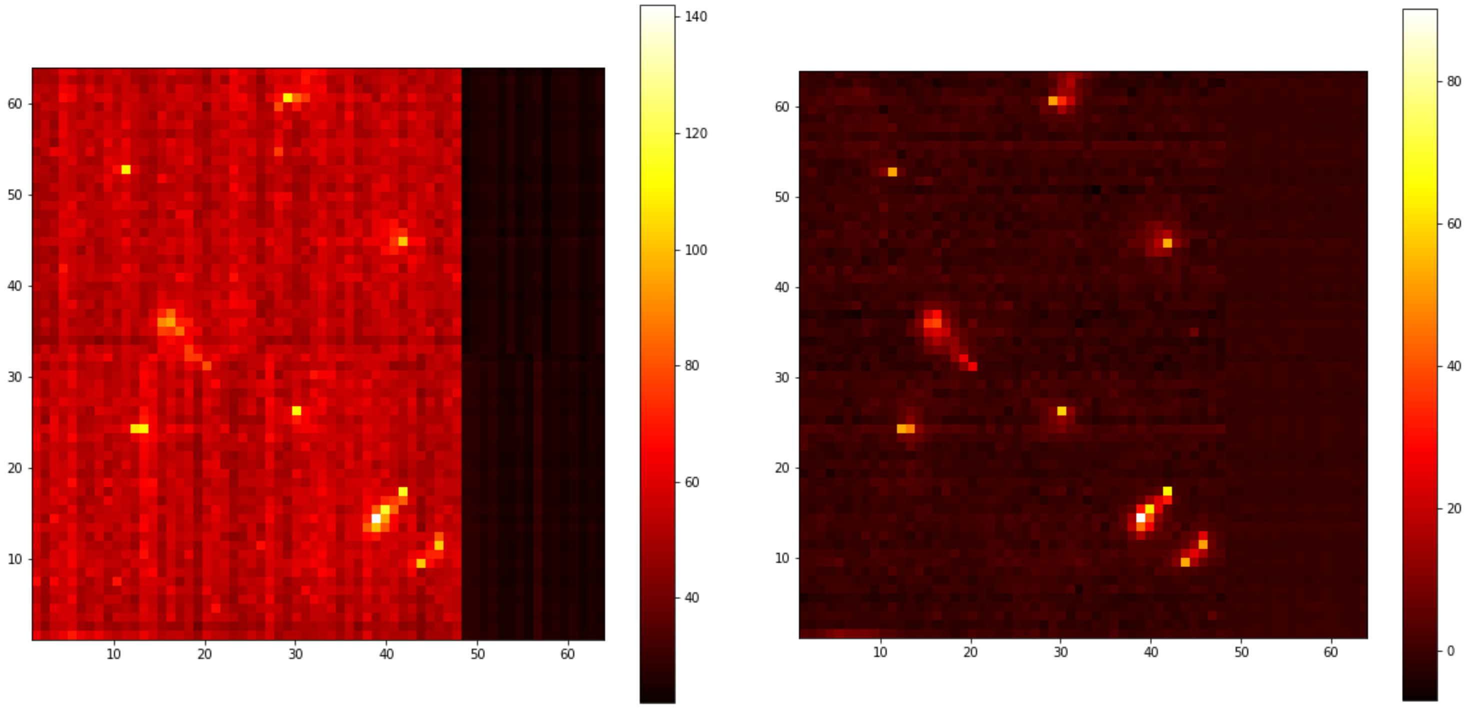


HPixel test

Blob size with HV - most of the processing to be done

At 0HV biasing, deviation of charge events around 0.177.

Why lower? -> might be low statistics or radiation effects



HPixel test

- Processing for gain analysis still to be conducted
- But chip started to break down at low radiation levels
- 2/2 chips broken: -> to investigate why HPIXEL seems not radiation tolerant to ionizing radiation?

Thanks for the attention!

Q&A