MALTA Total Ionizing Dose irradiation tests

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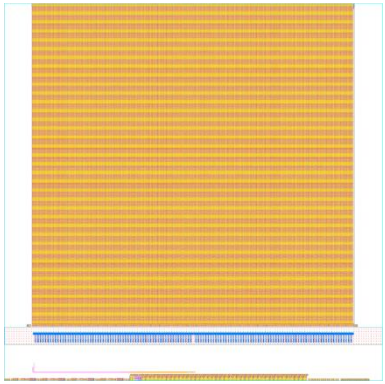
Outline

- Introduction: MALTA Chip
- Introduction: X-ray facility
- MALTA TID irradiation setup
- MALTA TID irradiation plan
- MALTA TID irradiation results
- Conclusions

Introduction: Malta chip

MALTA chip:

- Prototype for the ATLAS ITK upgrade
- Towerjazz 180nm MAPS technology
- Full ATLAS size demonstrator
  - 20x20 mm^2 ⇨ 36x36 um^2 pixel size, 512x512 pixels
- Asynchronous digital output
  - 37 parallel signals, 1ns width
- 8 different flavours in this matrix (sections)



Expected performance:

- Radiation hardness up to **80Mrad**, 10^{15} Mev neq/cm^2
- Response time of 25 ns
- Operating threshold of 300 e (from simulations, I. Berdalovic presentation)

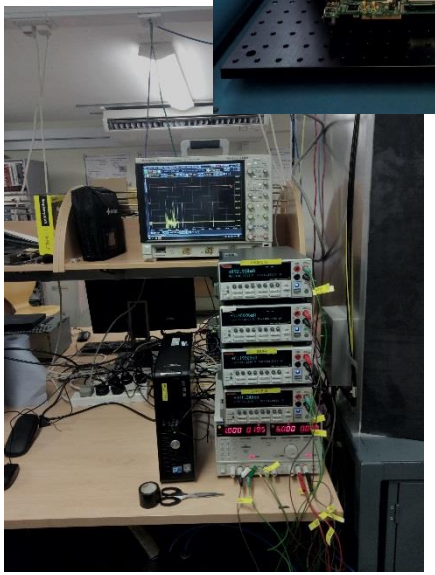
Introduction: X-ray facility

Setup overview:

- Gulmay 3.2kW HV generator
- Thales 100 kVp tungsten X-Ray tube
- Gulmay MP1 integrated controller
- 150x120x120 cm^3 lead lined box
- Laser sample alignment system
- 35x25x6 cm^3 cold sample box (down to -30 °C with Peltier cooling)
- Dry air supply
- Automated ambient temperature and humidity logging, DUT temperature logging
- Maximum dose rate of 3.8 MRad/h

Malta setup

- 6 Power supply channels:
  - Digital (1.8V)
  - Analog (1.8V)
  - Substrate and Pwell (6V)
  - **Low voltage for pulsing** (1.2 – 1.6V)
  - DAC and LVDD (1.8V)
  - **Threshold** (0.6 – 1.5V)
- MALTA mounted inside a polyester box to maintain environment with low humidity (1%) and low temperature (0°C)
- Analog signal from monitor pixel measured with oscilloscope
- Connected to MALTA readout (virtex7 FPGA) for Slow Control communication and signal acquisition

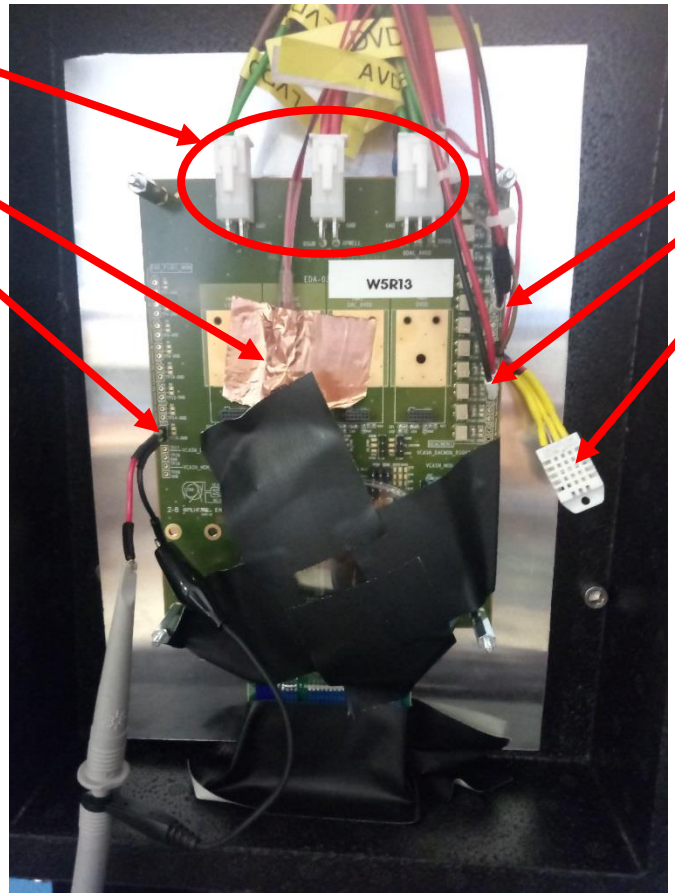


Malta setup

Powering

Temperature sensor

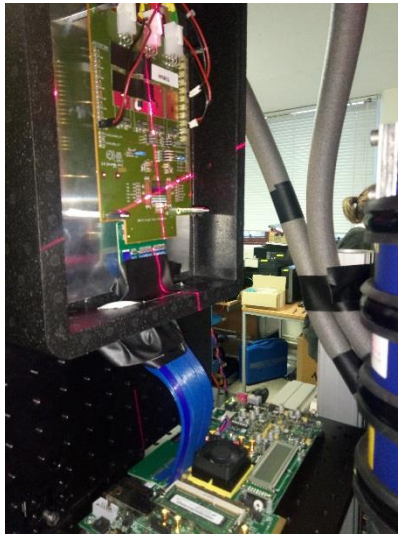
Analog pixel



Pulsing signal

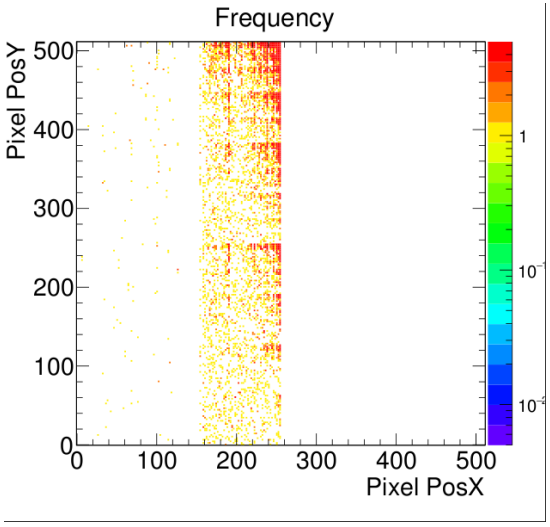
Threshold

Humidity sensor



TID irradiation plan

- Irradiate the chip up to a dose of 80Mrad
- Monitor Noise, Threshold, Charge collected and internal pulsing at different irradiation steps
  - Expecting huge impact at low irradiation doses → Planning more measurements from 0 to 5Mrad
- Monitor currents over the whole process (AVDD, DVDD, LVDD, SUB, PWELL)
- Current consumption is proportional to pixel activity. We tried to minimize this by masking the maximum number of pixels possible
- Low dose rate: 0.25MRad/h
- Aim to irradiate the closest to ATLAS conditions as possible
  - Minimum temperature achieved: 0C
  - Chip powered during irradiation
- **TID plan was discussed with STREAM members based at CERN**

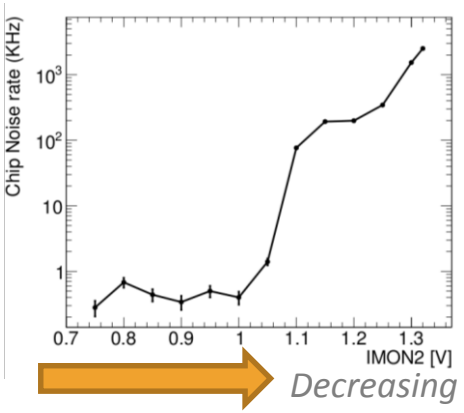


Pixel hit-map during X-ray irradiation

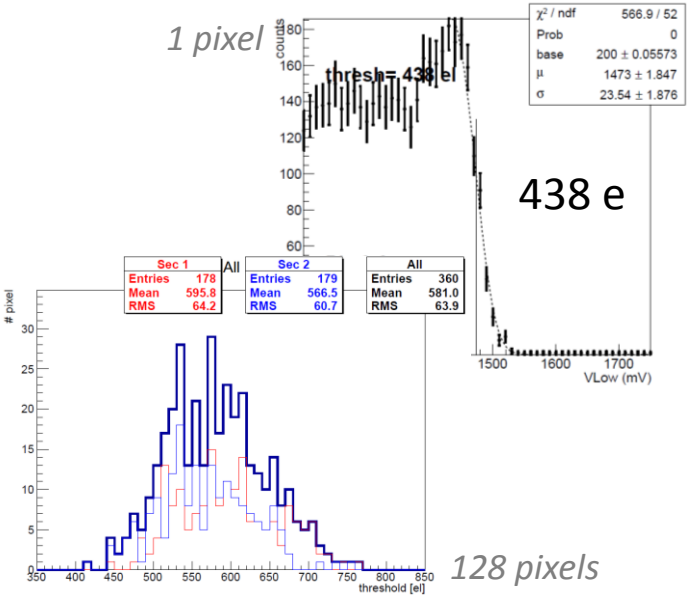
TID irradiation plan

Scans description:

- Noise scan:
  - Sweeping threshold voltage and recording noise for a fixed period of time
  - Duration of the scan ~15min



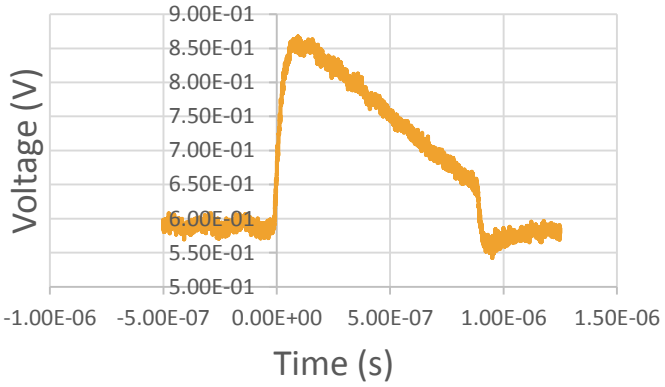
- Threshold scan:
  - Fixed Th. voltage (1.0V) and injecting different amounts of charge pixel by pixel by changing pulsing voltage
  - Duration of the scan ~12h



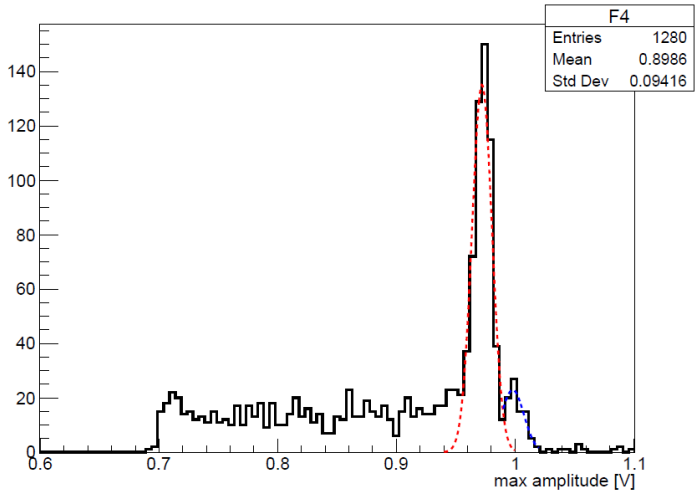
TID irradiation plan

Scans description:

- Pulsing scan:
  - Sending a fixed pulse in the monitoring pixel and measuring the analog output in the oscilloscope
  - Duration of the scan ~5min



- Charge calibration:
  - Inducing charge from a known source (Iron fluorescence) and measuring signal peak of the monitoring pixel
  - Duration of the scan ~5h (not automatized)



TID irradiation plan

Overriding ICASN voltage in order to increase the threshold even more

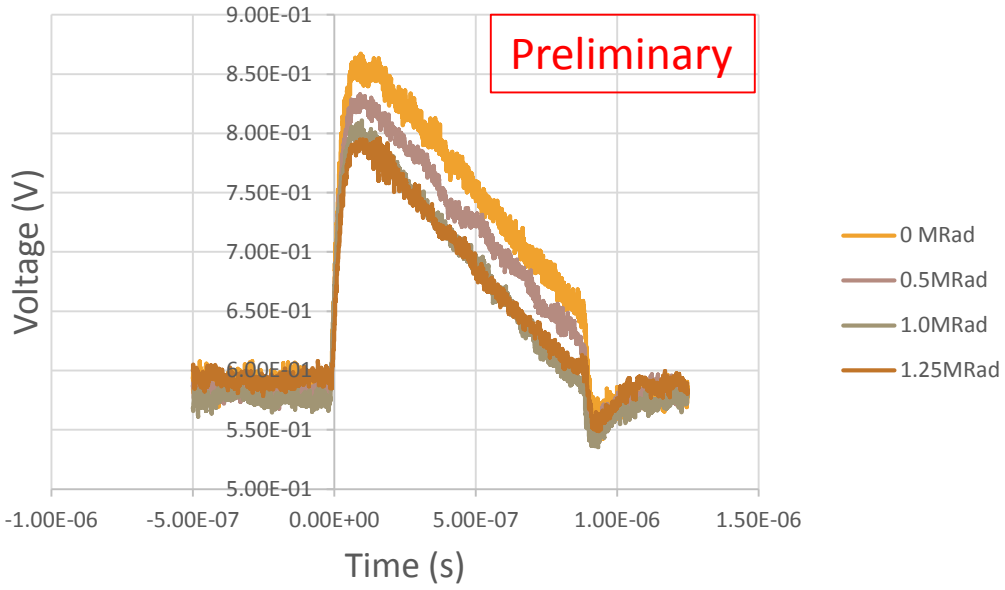
Current measurements performed:

Dose	0	0.125	0.25	0.375	0.5	0.625	0.75	0.875	1.0	1.125	1.25
Noise											
Pulse											
Thr.											
C.C											

Dose	1.375	1.5	1.75	1.875	2.0	2.125	2.25	2.375	2.5
Noise									
Pulse									
Thr.									
C.C									

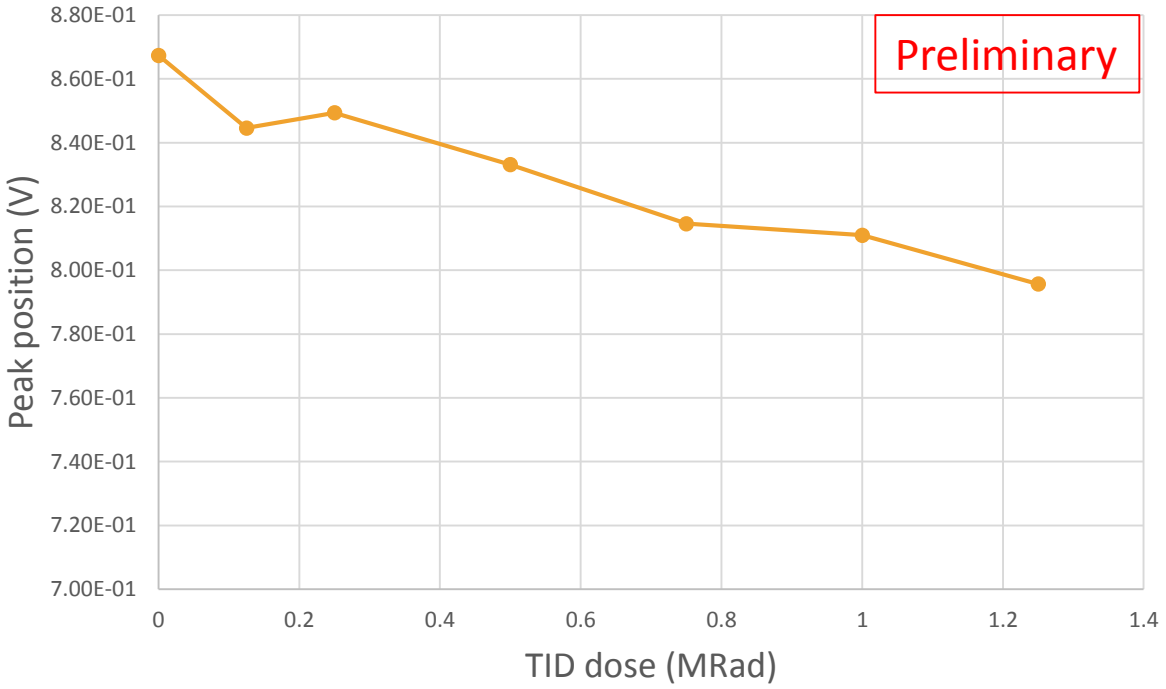
Not shown in this presentation

Test pulse scans results



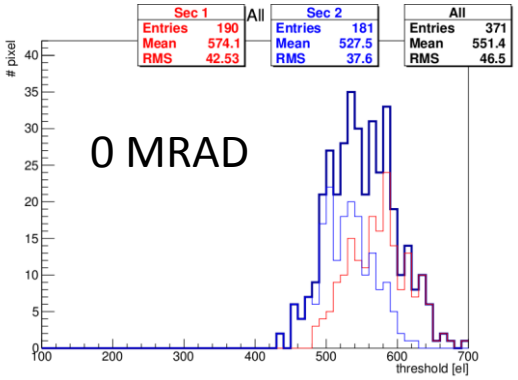
- Planning to plot baseline, amplitude and peak to peak value as a function of the irradiation dose

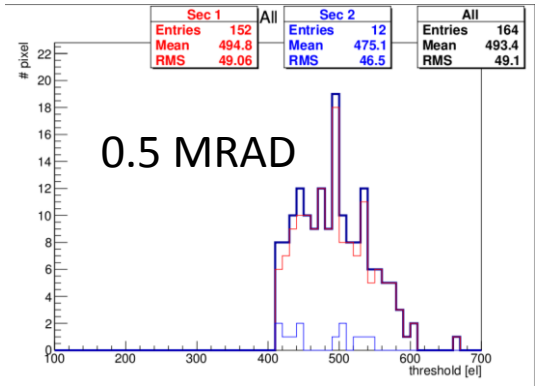
Test pulse scans results

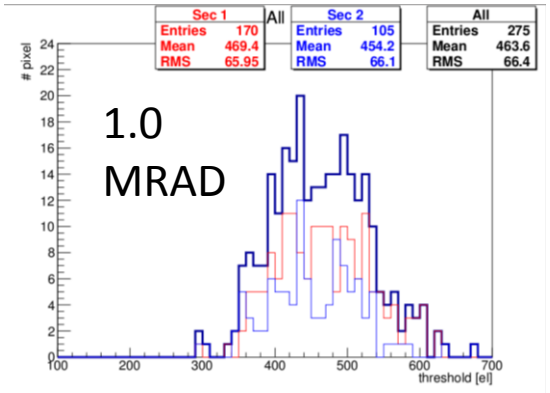


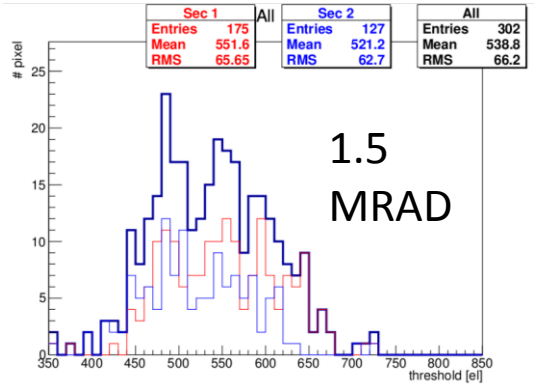
- Peak position of pulsing waveform decreases as a function of dose
- However, correction needs to be made due to corresponding decrease of the baseline

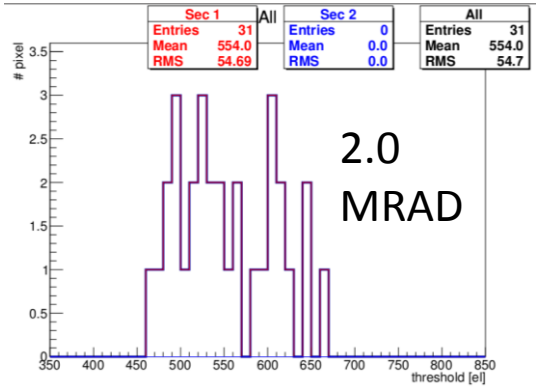
Threshold scan results



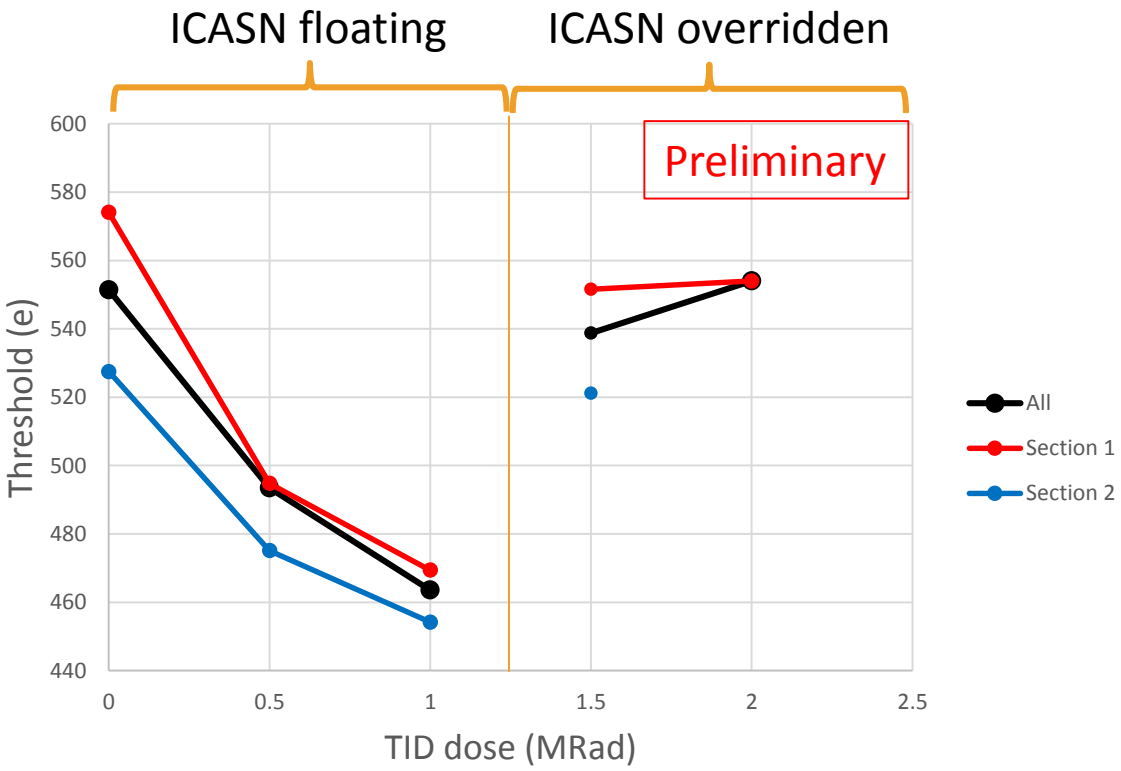








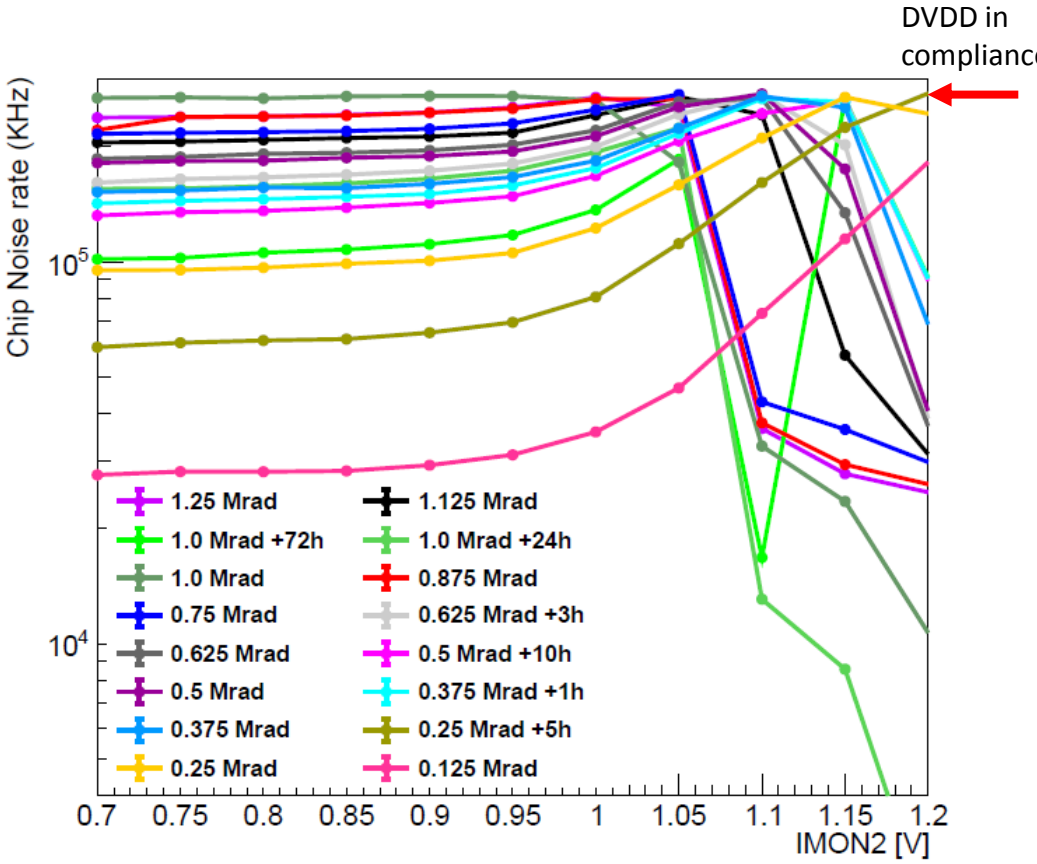
Threshold scan results



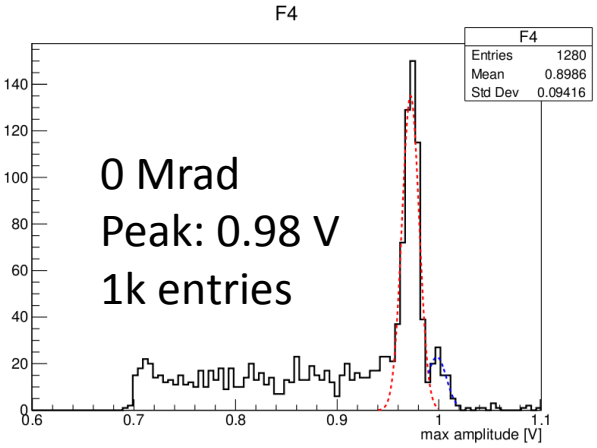
- Number of pixels measured in every point is **different**!!!
- Threshold voltage (IMON2) fixed at 1.0 V
- This measurement has to be corrected due to the dependence of the pulsing signal with the TID dose

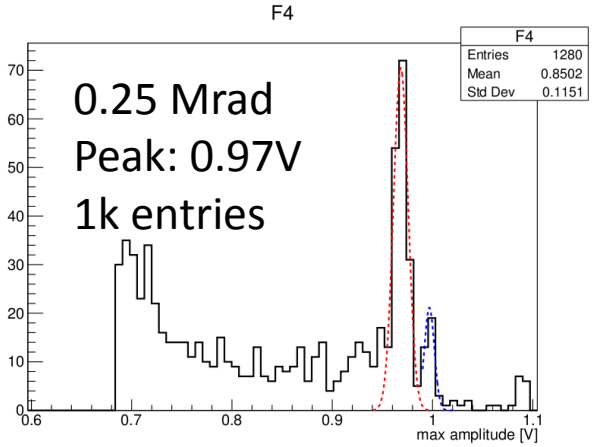
Noise scans results

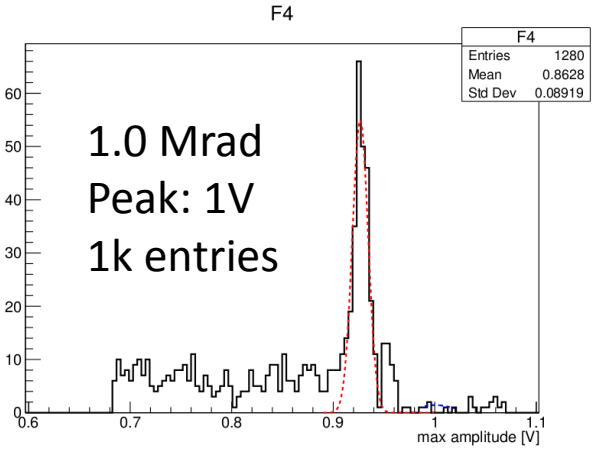
- Noise at 0MRad was negligible (<1Hz)
- After the first irradiation step (0.125MRad) the noise increased a lot
- Noise significantly goes down when leaving the chip for annealing for a few hours
- This plot needs to be correlated with real value of the threshold, since it changes as a function of TID

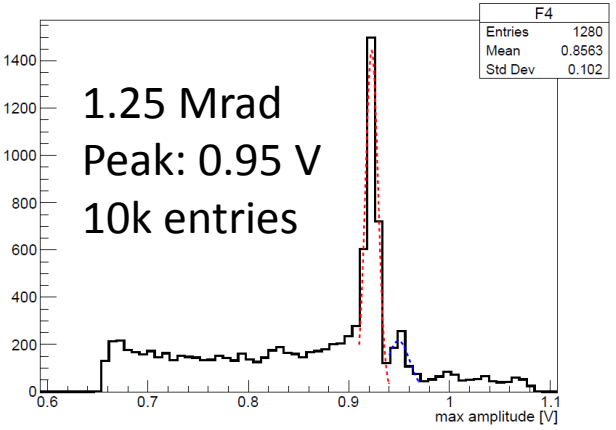


Fluorescense scan results

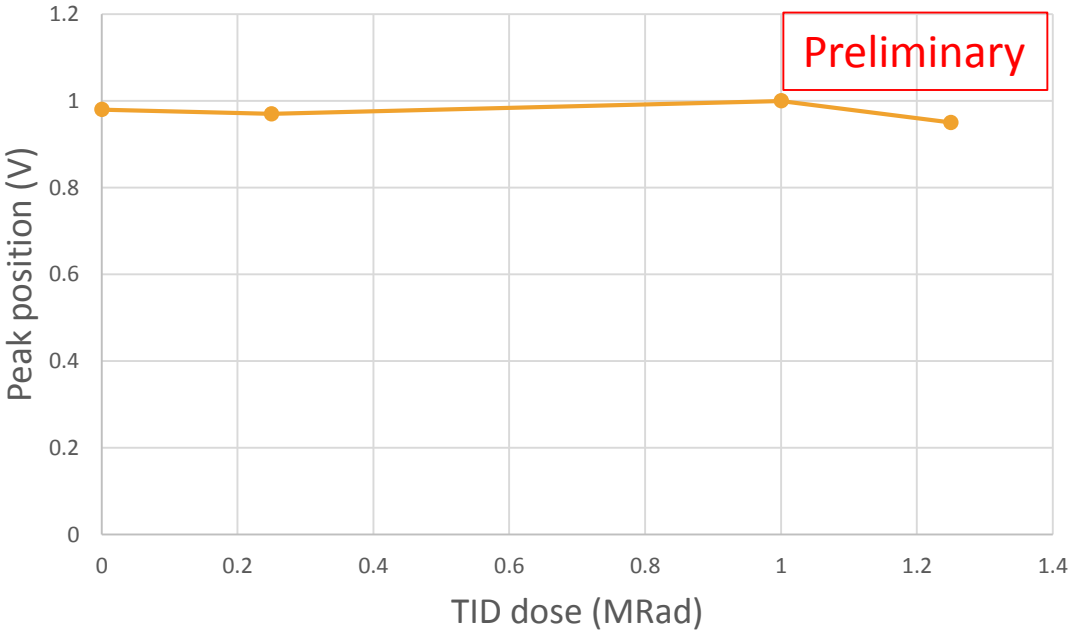






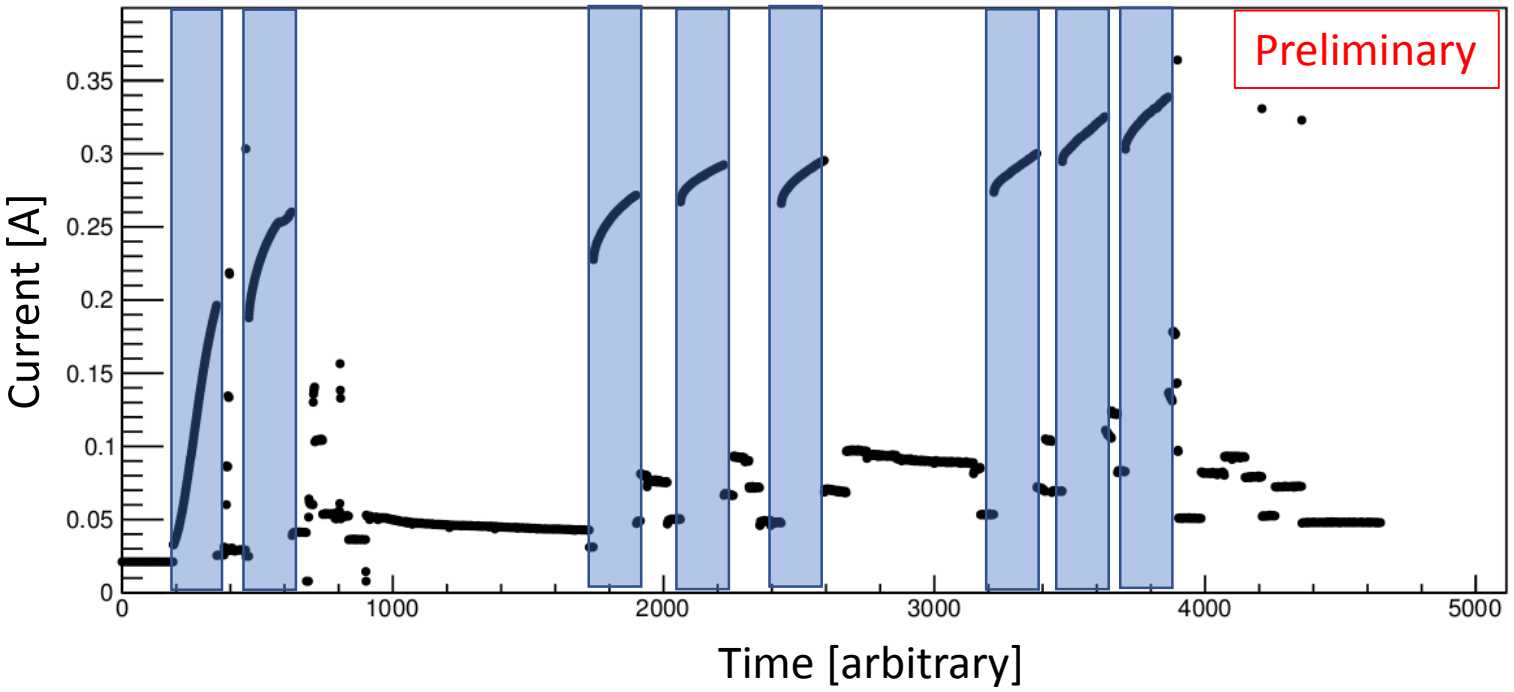


Fluorescense scan results



- Response to input charge appears to be constant at low irradiation doses

DVDD current over time



Chip being irradiated, each irradiation step is of 0.125Mrad

Conclusion

- MALTA TID irradiation has been carried out up to a dose of 2.5MRad
- Different measurements have been taken during the irradiation process:
  - Noise measurements
  - Threshold calibration
  - Charge injected calibration
  - Injected pulse signal
  - Monitor DVDD, AVDD, LVDD, DAC, SUB and PWELL currents during irradiation
- Analysis is still in progress
- First results show that low TID (up to 2.5Mrad) has a significant effect on the operation of the MALTA chip
  - Increase on the noise
  - Decrease on the threshold
  - Charge maintained constant
  - Pulse signal slightly decreases
  - DVDD, AVDD currents significantly increase
- Such effects have been seen in other processes at low dose ("TID bump") and hence, it will be important to see if the effects reflect a bump or continue even at high TIDs