Radiation damages in the MIMOSA 5 detector and tests of the MIMOSTAR 2 chip

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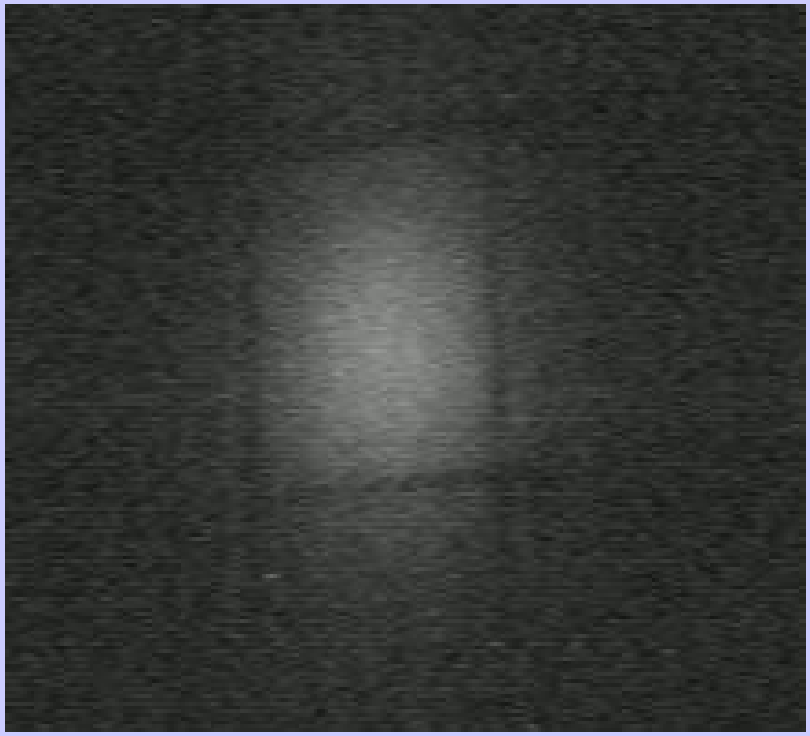
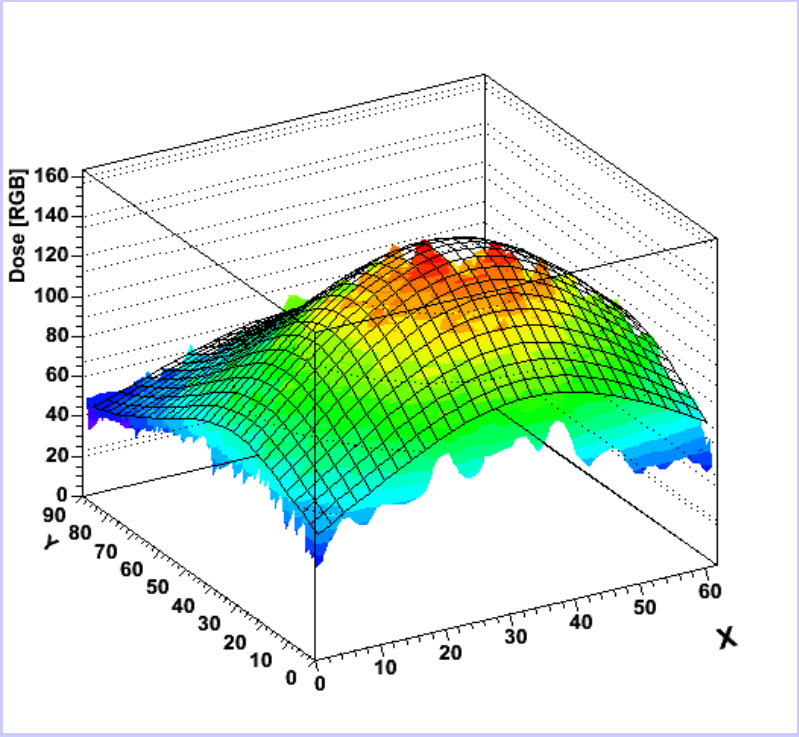
Image from a CCD camera

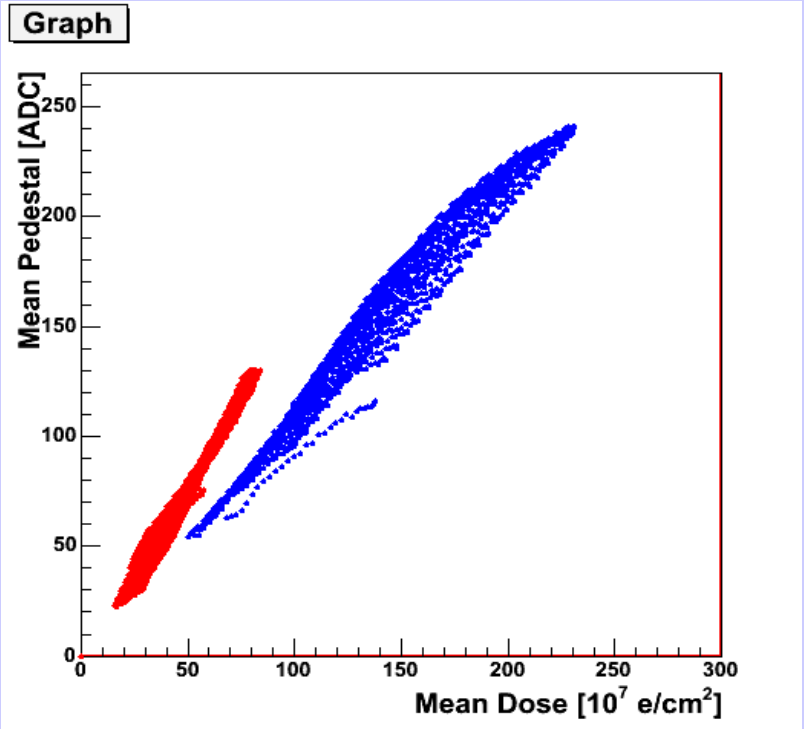


Beam profile 3D

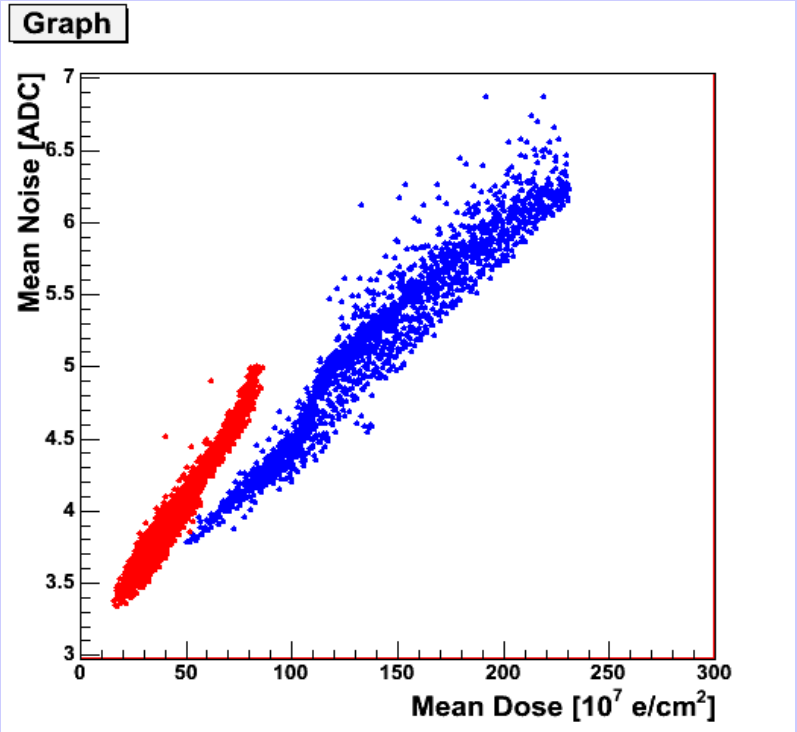


- Irradiations were done at GSI in Darmstadt – Devis Contarato
- Beam of 9.4 MeV electrons was used
- Two MIMOSA 5 submatrices were irradiated with two different fluences
  - Matrix B02 - 3×10^{12} e/cm^2
  - Matrix T02 – 10^{13} e/cm^2

Pedestal versus dose

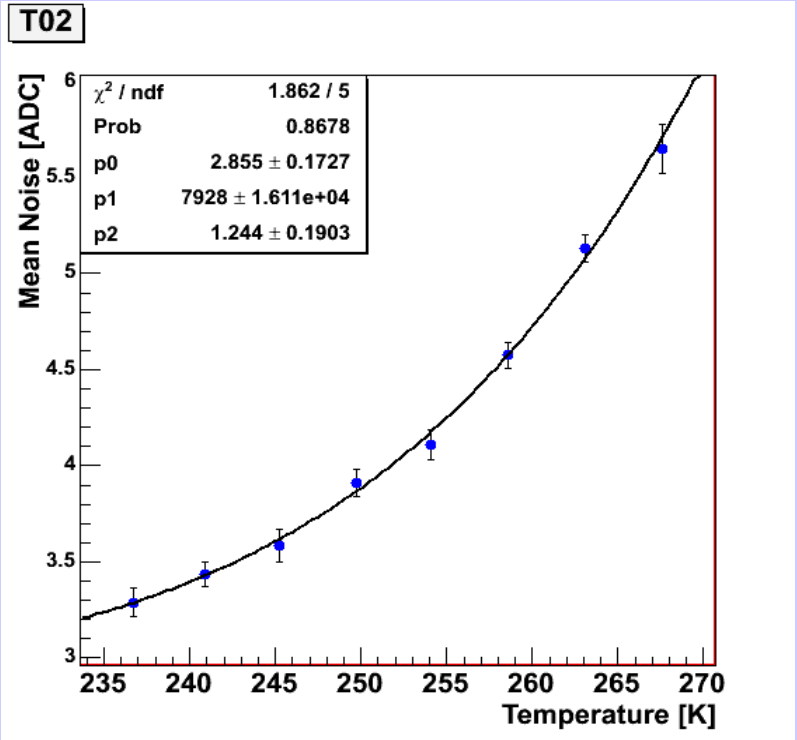


Noise versus dose

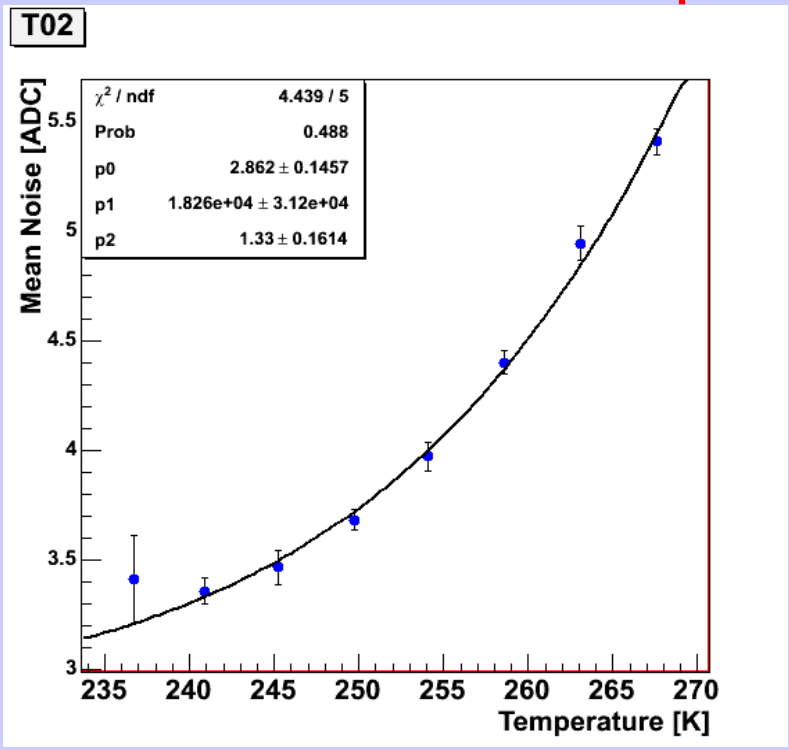


- Red points correspond to the matrix B02 and blue points to the matrix T02
- Pedestal and noise grow with an absorbed dose
  - After absorption of about 2×10^9 e/cm^2, pedestal grew more than order of magnitude and noise about factor of 2

Mean noise vs temp.



Mean noise vs temp.



- Experimental points follow theoretical prediction (energy gap in the formula was set as a third fit parameter)

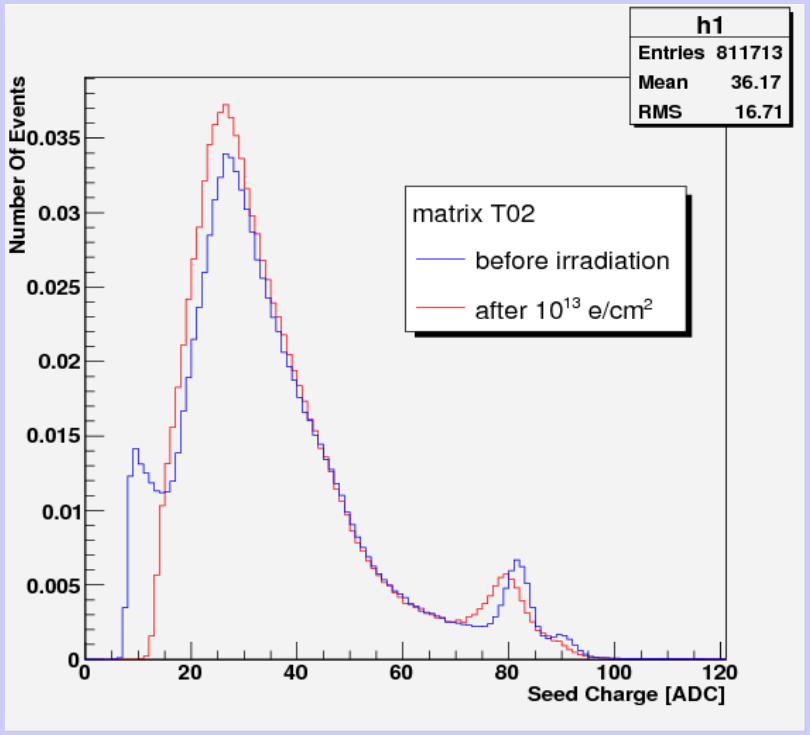
$$\text{noise} = \text{p0} + \text{p1} \cdot \text{T} \cdot \sqrt{\exp\left(-\frac{\text{E}_g}{(2\text{k}_B\text{T})}\right)}$$

(energy gap in a silicon E_g = 1.12 eV)

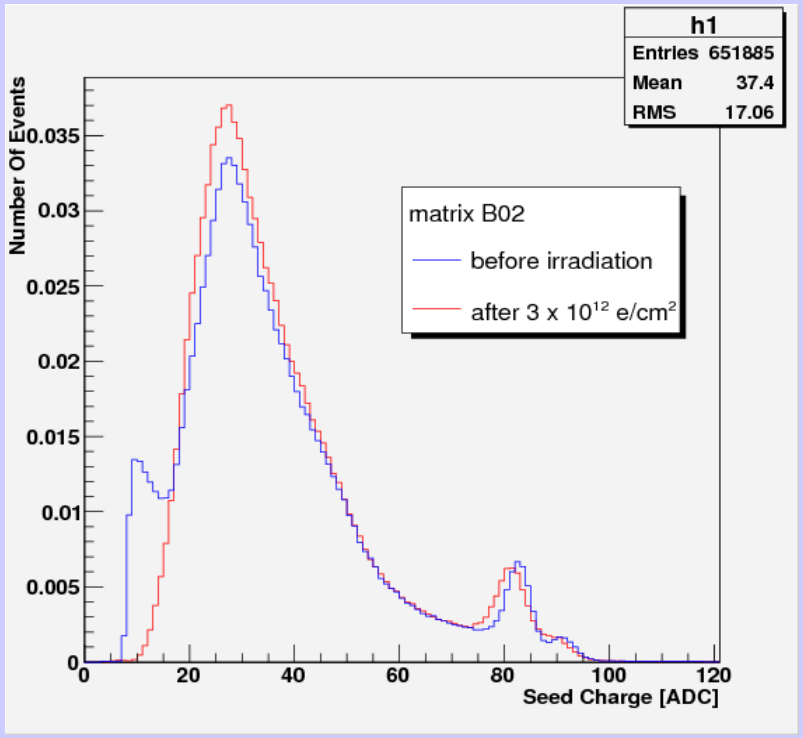
Energy gap received from the fit:

- E_g = 1.24 ± 0.19 eV
- E_g = 1.33 ± 0.16 eV

^{55}Fe signal (T02)



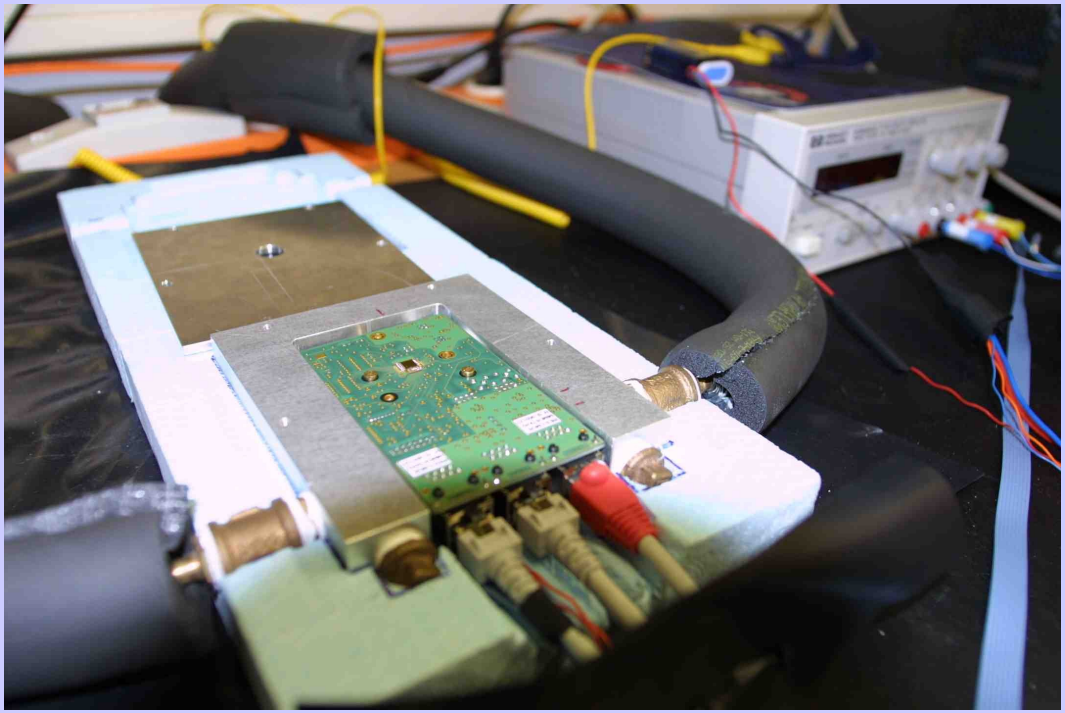
^{55}Fe signal (B02)



- Blue line corresponds to the measurements done before irradiation and red one to the measurements done after irradiation
- Peak of the 5.9 eV photons is slightly shifted to the lower values
  - Radiation-induced trapping levels are responsible for charge looses in signal
  - Effect is more significant for the matrix T02, which was exposed to higher dose

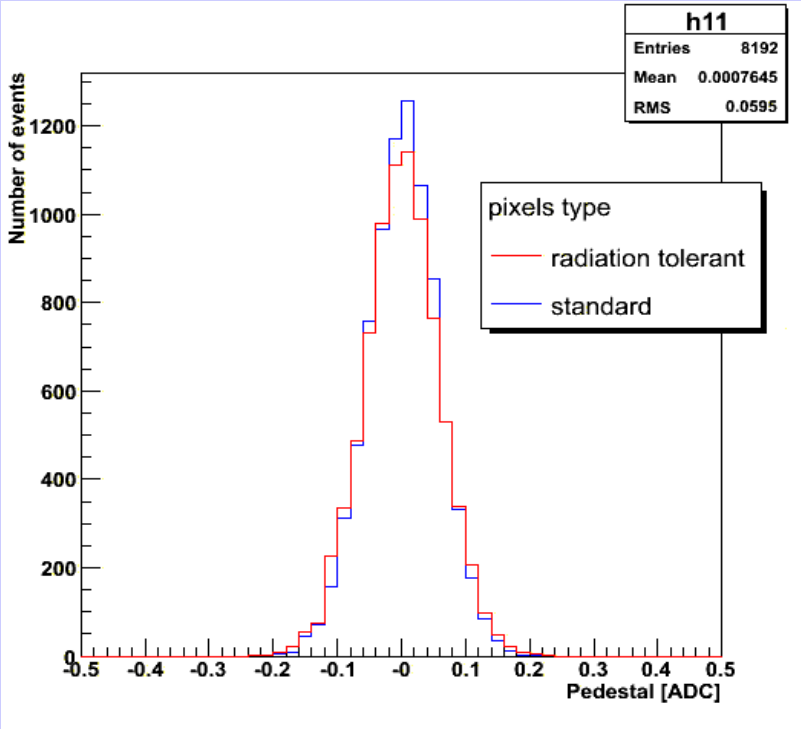
- MIMOSTAR 2 consists of 2 sub-matrices, 64 columns by 128 raws each (but the data stream shows 66 columns per matrix – two dummy pixels are added at the beginning of each line)
  - Matrix 0 is equipped with radiation tolerant pixels
  - Matrix 1 is equipped with standard pixels
    - All pixels are self biased diodes with 30 µm pitch
- MIMOSTAR 2 – DESY setup
  - MIMOSTAR 2 is controlled by a Windows PC
  - JTAG protocol is used for the software configuration of the chip operation modes (PC parallel port)
  - MIMOSTAR 2 is assembled on a PCB board controlled by the IreS USB ADC Imager board (it provides digital signals to drive the chip and to acquire analogue outputs)
  - The PCB board with the MIMOSTAR 2 is placed in a cooling box

MIMOSTAR 2 – DESY setup

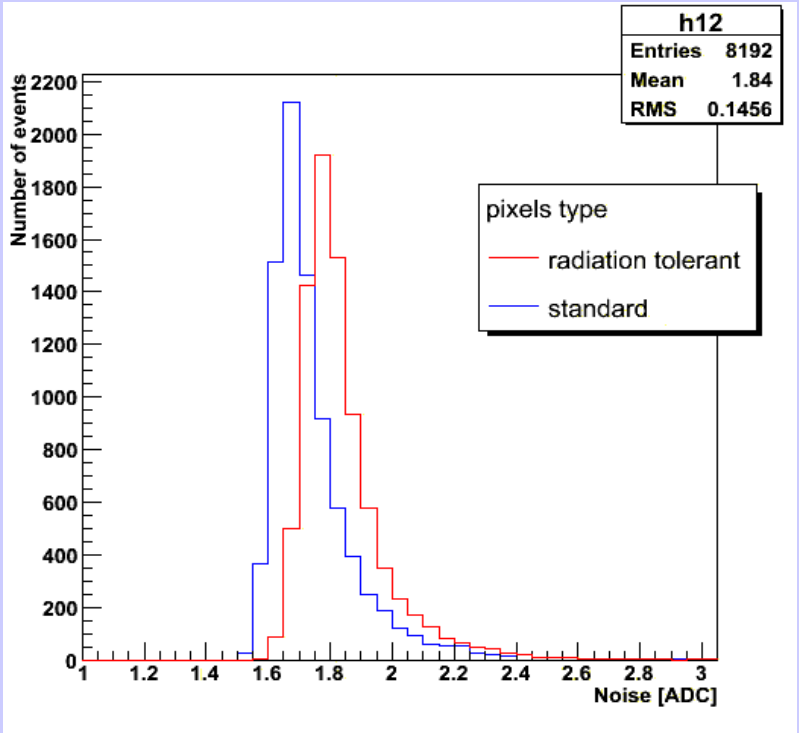


- DESY setup enables measurements of the pedestal and the noise distributions and their dependences on a temperature. Measurements with ^{55}Fe source were also performed.

Pedestal distribution

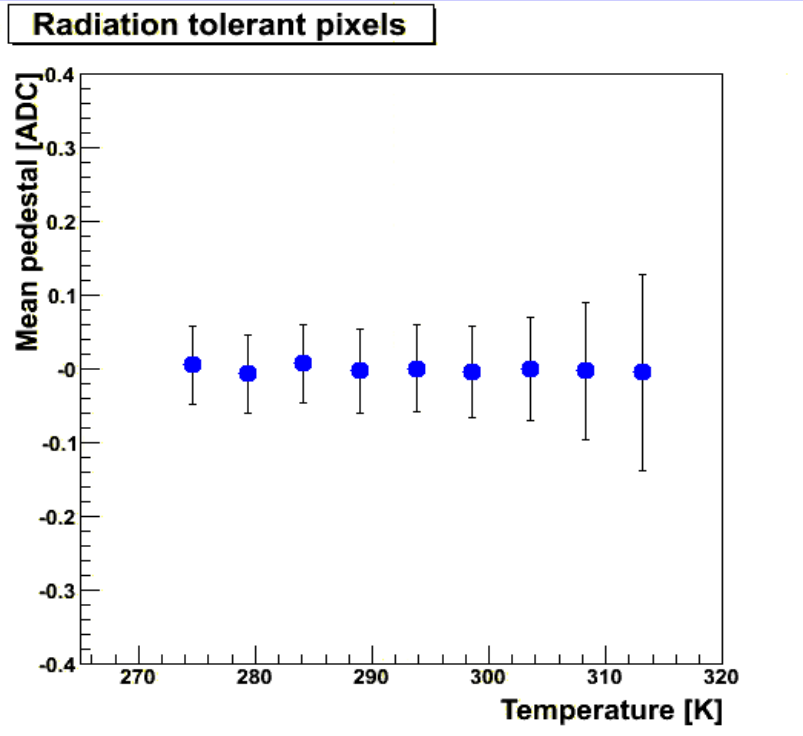


Noise distribution

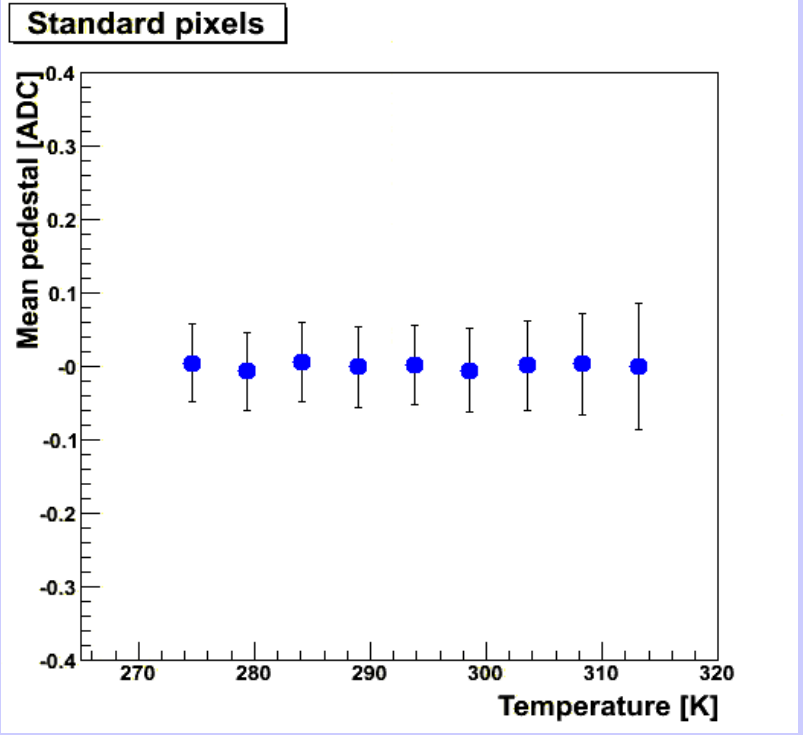


- Measurements were done at 21 °C
- Pedestal is distributed around 0 ADC – feature of the self biased diodes
- Noise in the matrix with the radiation tolerant pixels is higher than in the matrix with the standard pixels

Mean pedestal vs temp.

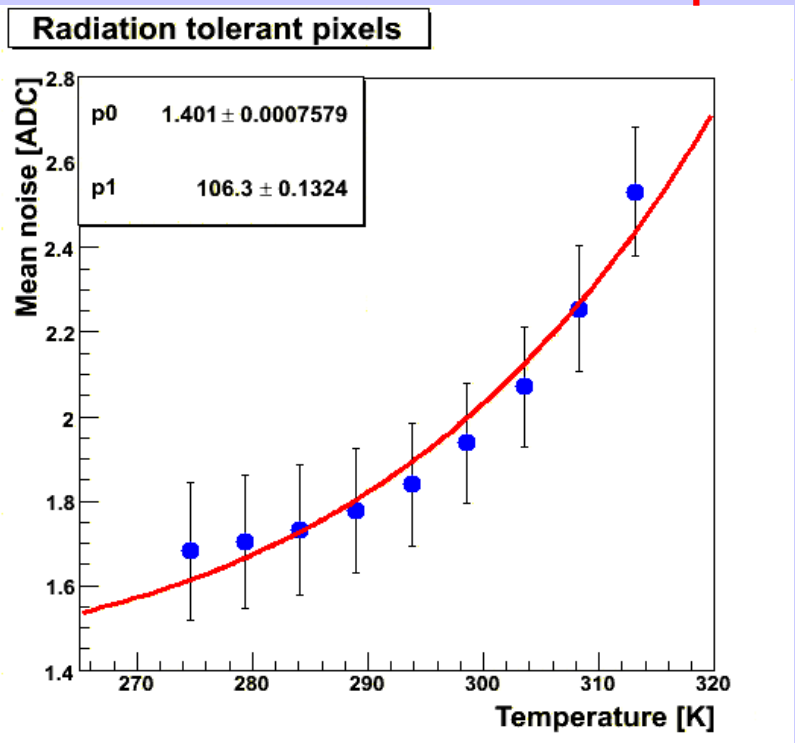


Mean pedestal vs temp.

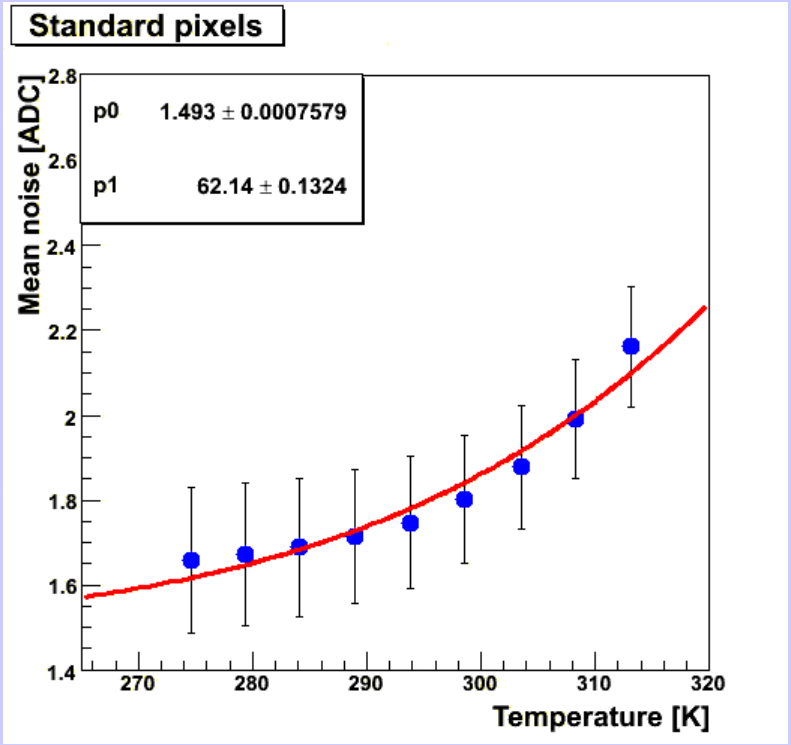


- Error bars are the RMS of the pixel pedestal distribution
- The mean value of the pixel pedestal distribution does not depend on the temperature
- The RMS of the pixel pedestal distribution grows with the temperature

Mean noise vs temp.



Mean noise vs temp.

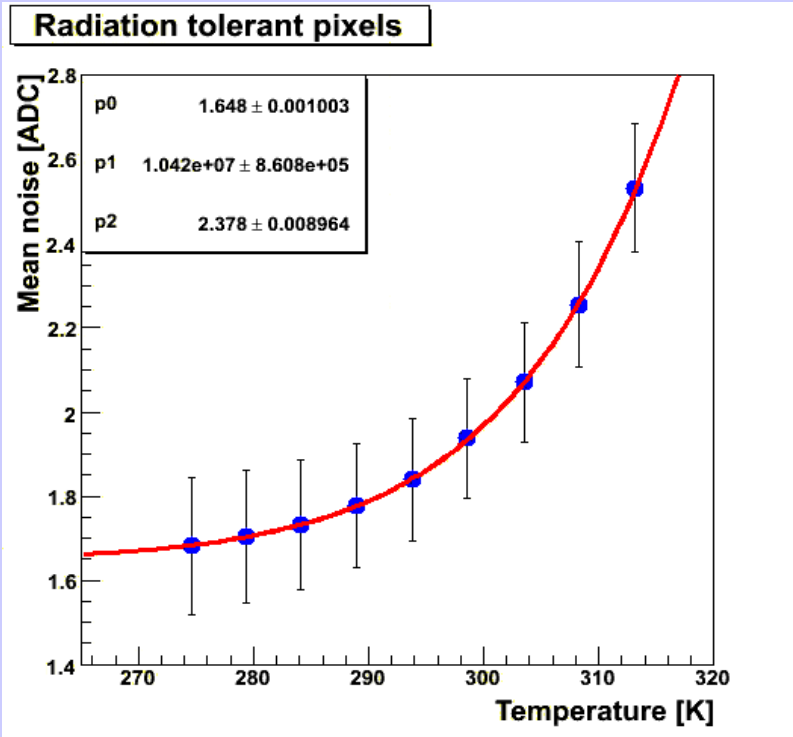


- Error bars are the RMS of the pixel noise distribution
- Experimental points do not follow theoretical prediction:

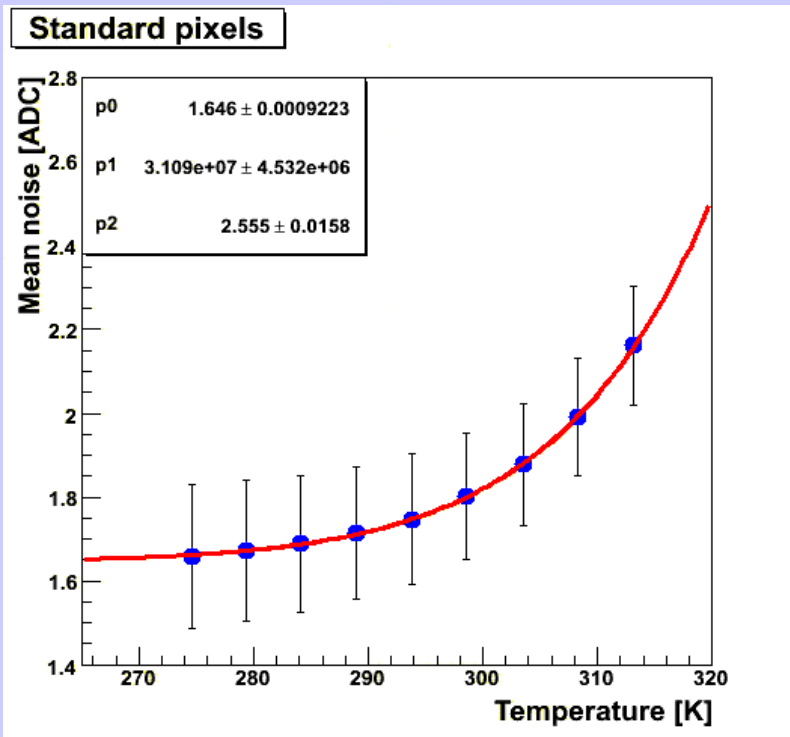
$$\text{noise} = p0 + p1 \cdot T \cdot \sqrt{\exp\left(-\frac{E_g}{(2k_B T)}\right)}$$

  - E_g = 1.12 eV (energy gap in the silicon)

Mean noise vs temp.



Mean noise vs temp.

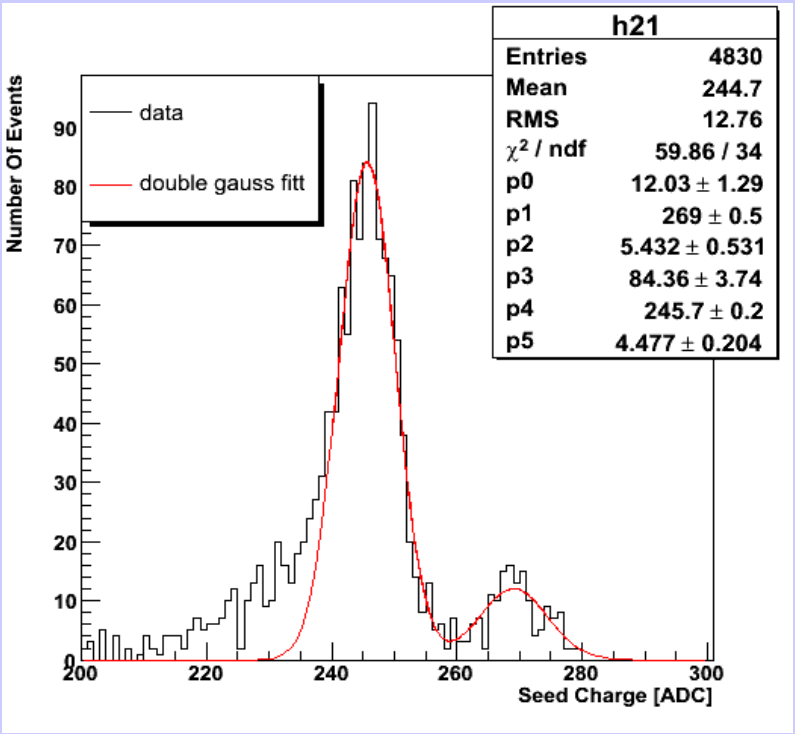


- Error bars are the RMS of the pixel noise distribution
- In order to improve the fit, energy gap in the formula was set as a third fit parameter

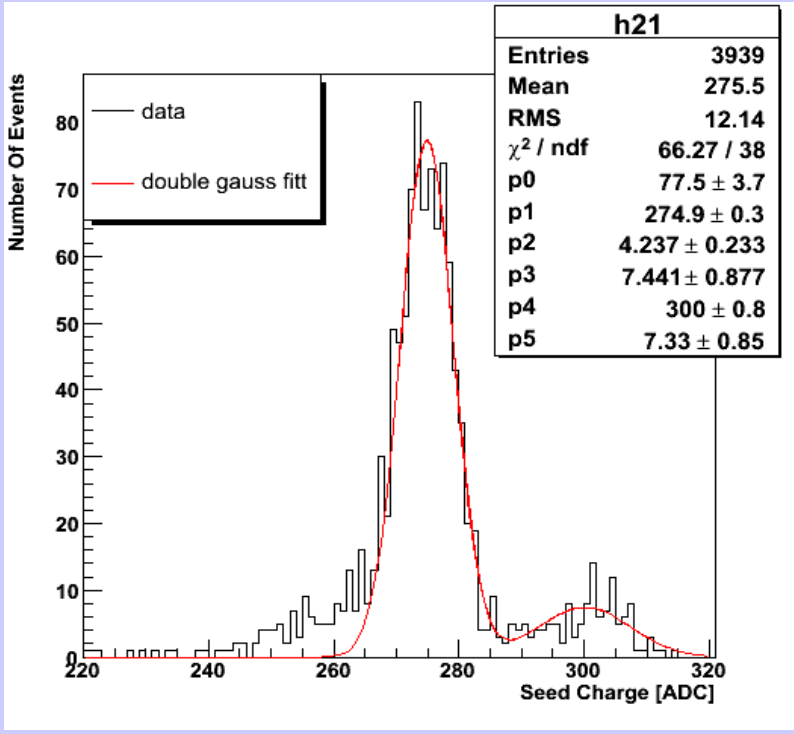
$$\text{noise} = \text{p0} + \text{p1} \cdot \text{T} \cdot \sqrt{\exp\left(-\frac{\text{p2}}{(2\text{k}_\text{B}\text{T})}\right)}$$

  - Energy gap got from the fit:
    - radiation tolerant pixels E_g = 2.38 eV
    - standard pixels E_g = 2.56 eV

Radiation tolerant pixels



Standard pixels



- Two emission lines from the ^{55}Fe source
  - Both MIMOSTAR 2 chips present good energy resolution
  - Signal measured by matrix equipped with radiation tolerant pixels is lower than signal measured by matrix with standard pixels

Summary

MIMOSA 5

- Poor knowledge of the beam profile made it impossible to establish an accurate dependence of pedestal and noise on the absorbed dose
  - After absorption of 2×10^9 e/cm^2, pedestal grew more than order of magnitude and noise about factor of 2
- Radiation-induced energy levels do not have an significant impact on the energy gap in the silicon
- Irradiated MIMOSA 5 detector is capable to measure photons from ^{55}Fe, but radiation-induced trapping energy levels make signal to decline

MIMOSATR 2

- Before irradiation the noise of the radiation tolerant pixels is higher than the noise of the standard pixels
  - This should changed after irradiation (irradiation tests should be performed)
- The noise of the pixels in both matrices grows with temperature as well as the RMS of the pedestal distribution
- Good separation of the ^{55}Fe emission lines can be seen in cases of the standard and the radiation tolerant pixels
  - Signals measured by matrix equipped with standard pixels are higher than signals measured by matrix with radiation tolerant pixels