High intensity irradiation influence on gain, noise and offset uniformity of a pixel detector readout designed in 130nm CMOS

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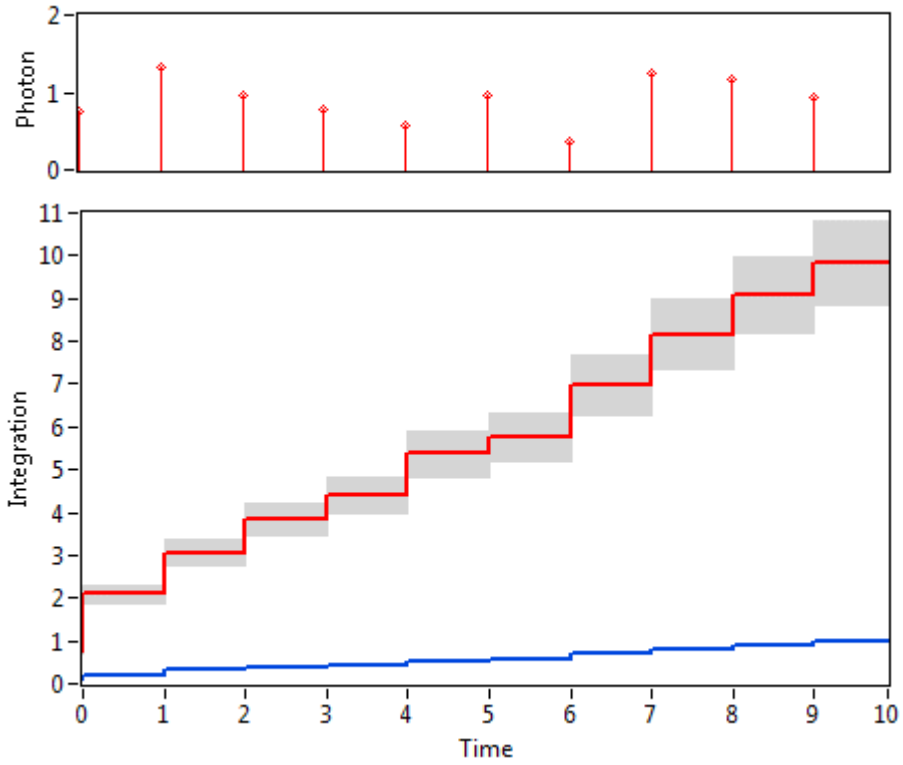
Outline

1. Readout type
2. Chip architecture
3. Measurement setup & modules
4. Methodology
5. Results
6. Conclusions

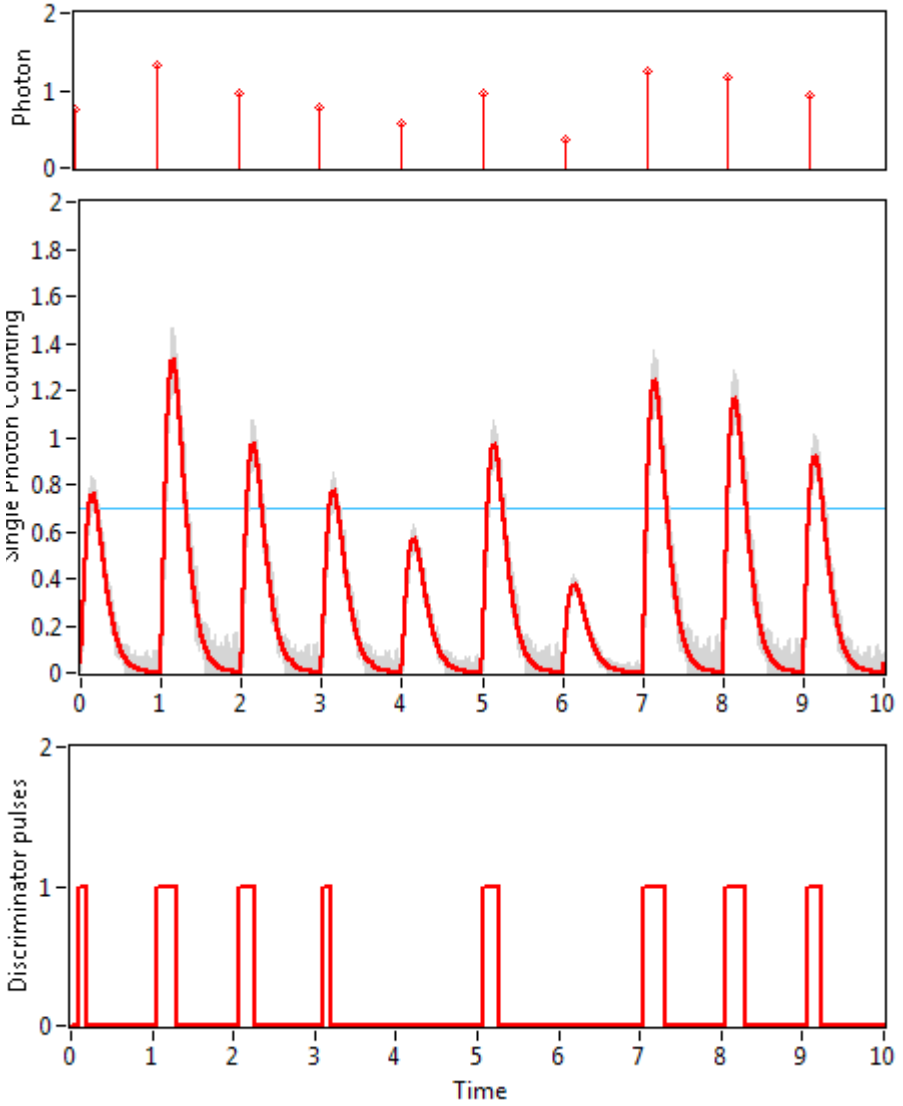
Readout type: Integration vs. Single Photon Counting

Integration type detector

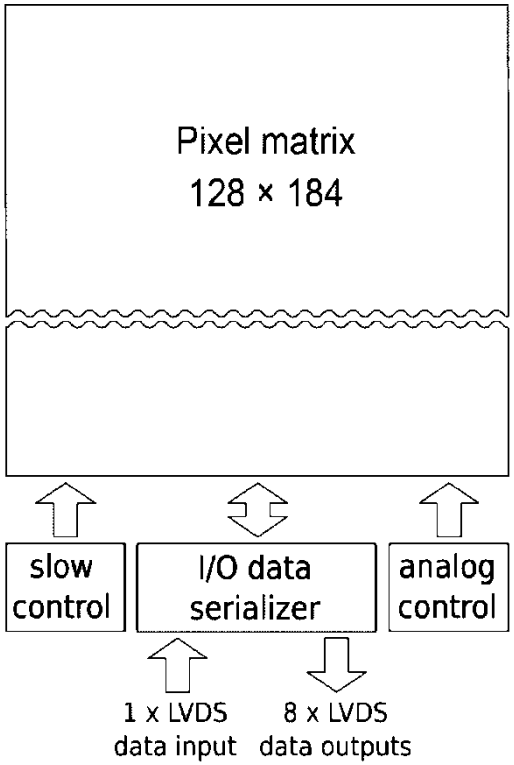


+ essentially infinite dynamic range,
+ noiseless imaging
+ possibility of counting photons only within a given energy window.

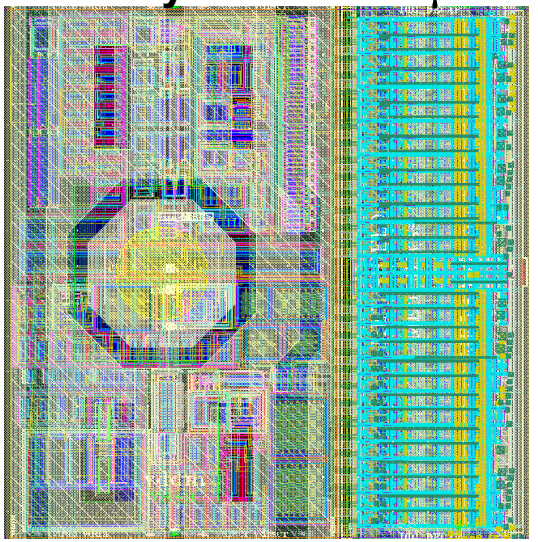
Single Photon Counting

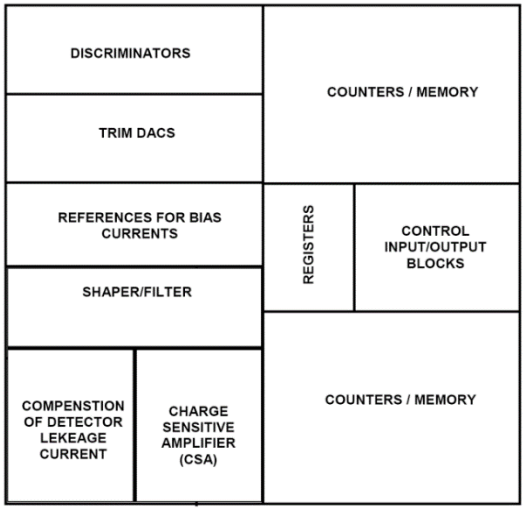


Chip Architecture



Pixel layout: 75 x 75 μm²





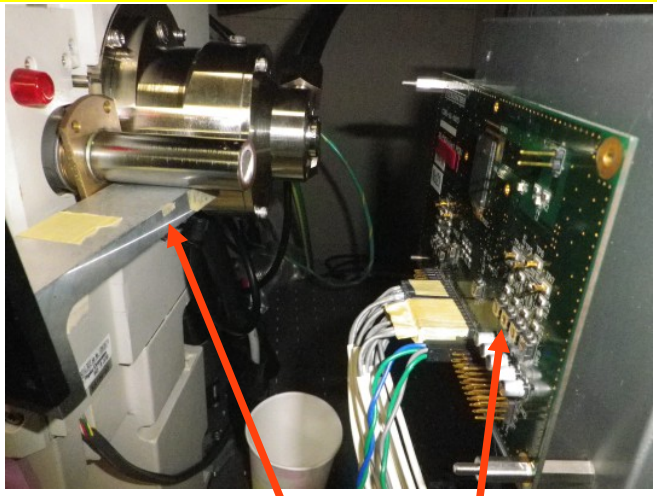
TSMC 130nm

Chip 10 x 15 mm²

Measurement Setup

ultraX-18 18kW

One of the most powerful
X-ray generator in the world



Power and
shutter control

ASIC control

Rigaku

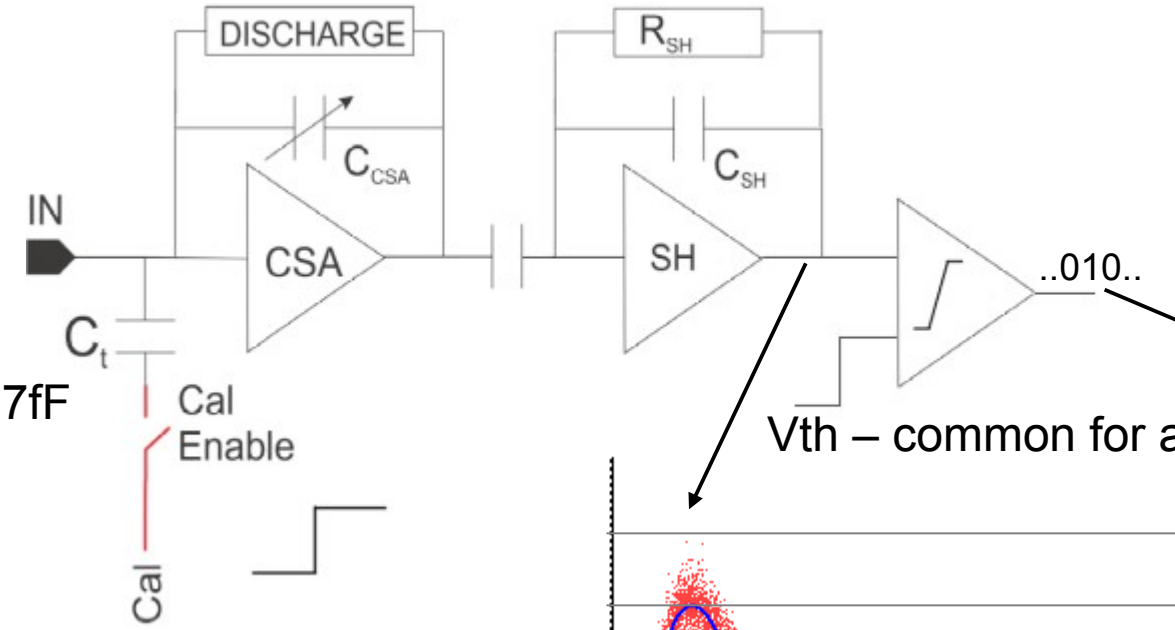
Measured modules

- 2 modules measured
- The X-ray Mo anode (17.4keV)
- Two different cases:

  a. Intensity: 5 Mcps/pixel → for 25 hours

  b. Intensity: 5 Mcps/pixel → silicon detector → for 222 hours
- Our idea was to monitor the main parameters (offsets, gain and noise) changing with irradiation
- The frequency of monitoring:
  - First 5 hours = every few mins,
  - Next hours = every half hour

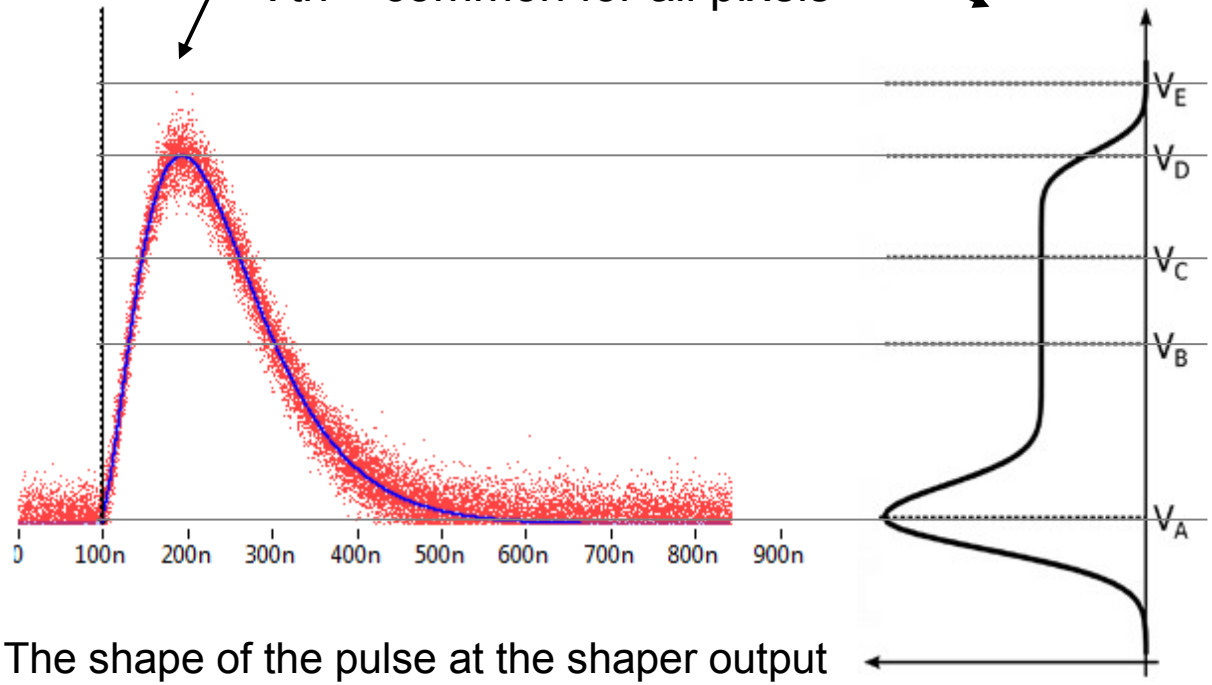
Methodology - threshold scan using calibration pulse



Ct = 1.7fF

Cal Amp = 150 mV/175mV

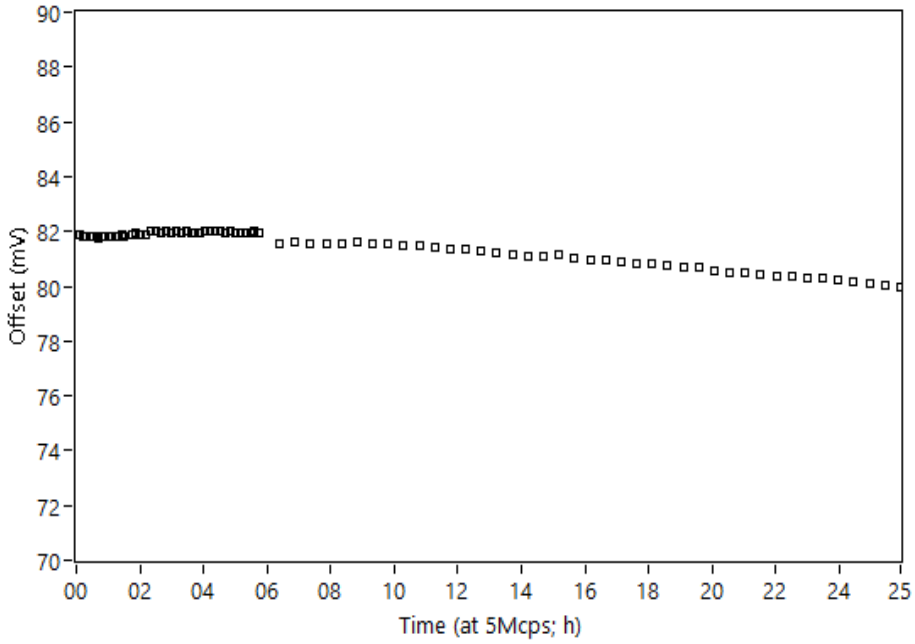
Vth – common for all pixels



The shape of the pulse at the shaper output

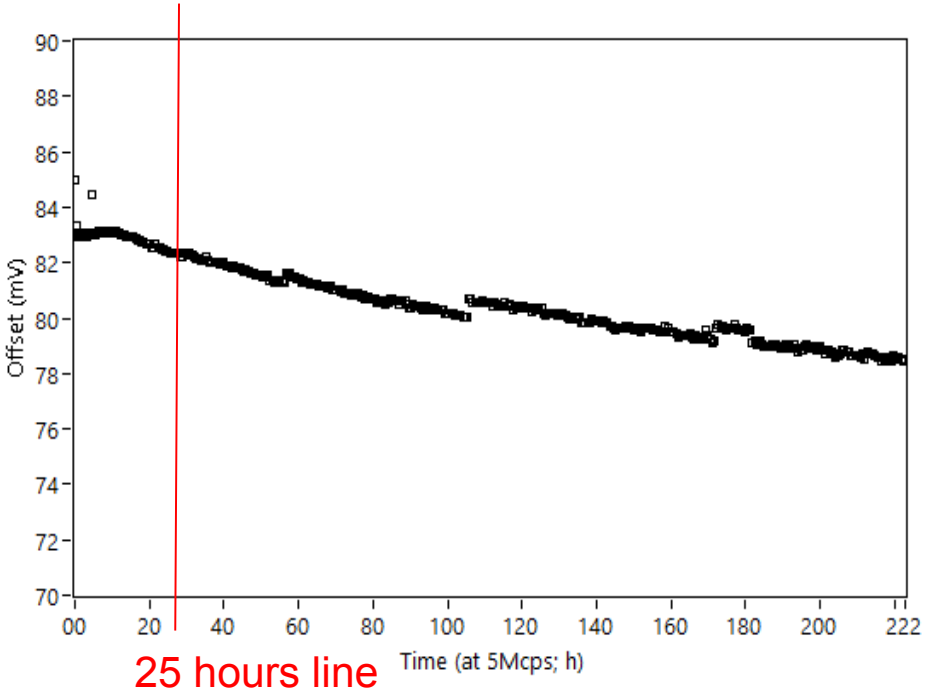
Offsets

Module A = 25 hours



DC Shift = -2 mV

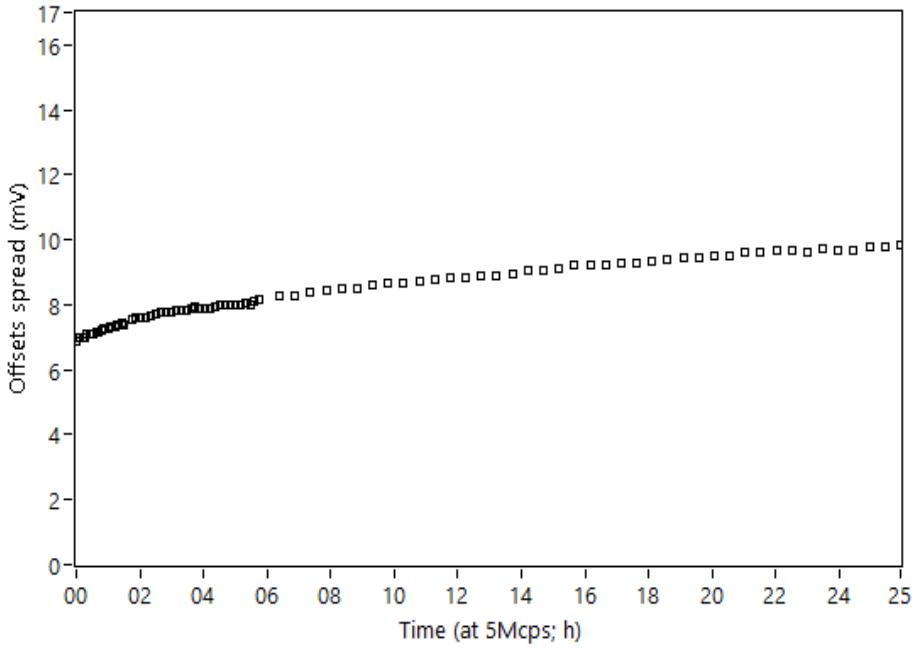
Module B = 222 hours



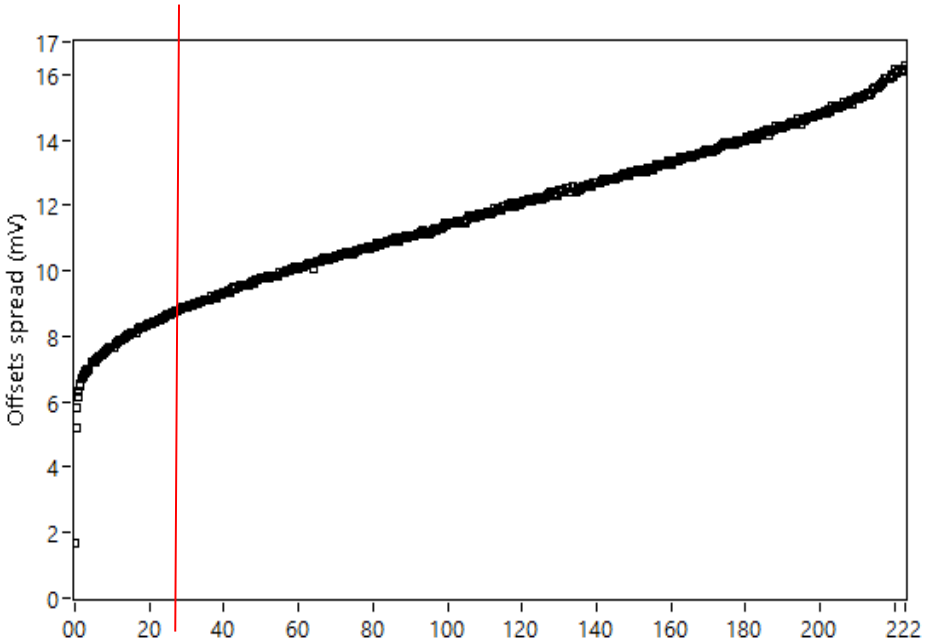
DC Shift = -5 mV

Offsets spread

Module A = 25 hours



Module B = 222 hours

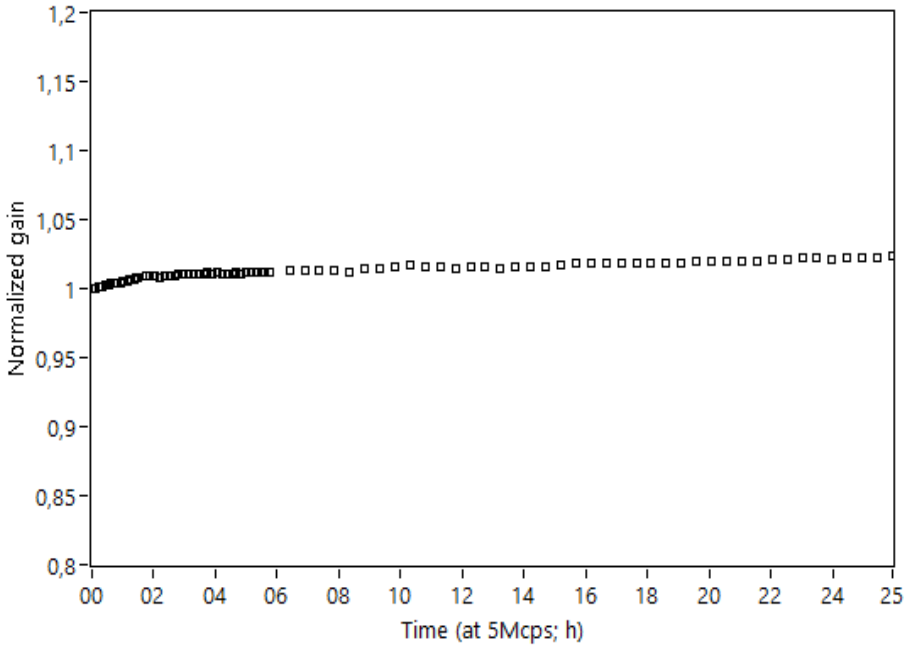


25 hours line

	Before	After	New Correction After
Mod3	8.37	11.98	3.67
Mod7	2.02	16.93	6.13

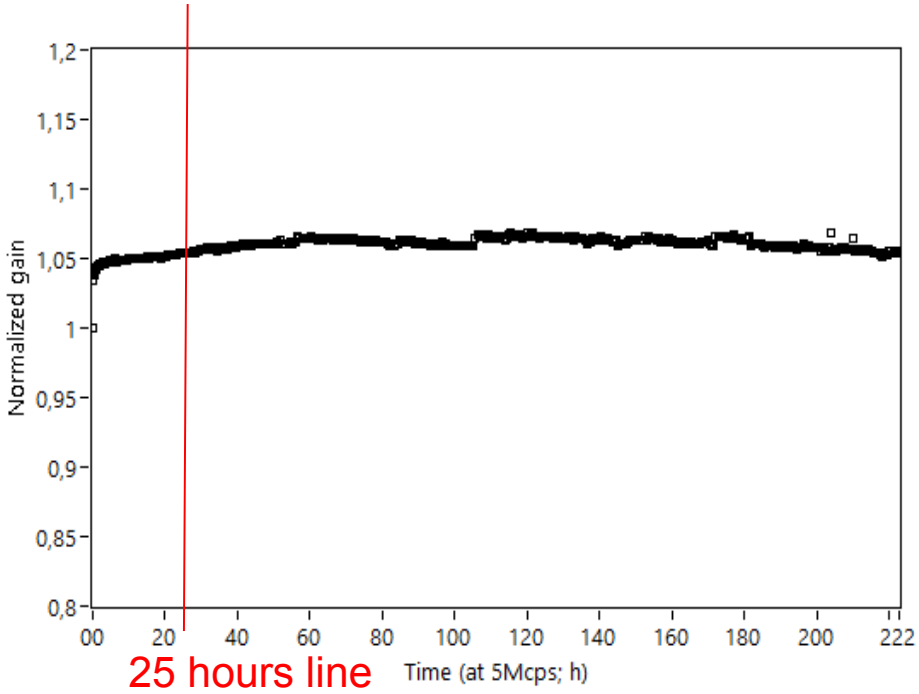
Gain

Module A = 25 hours



Difference = 2%

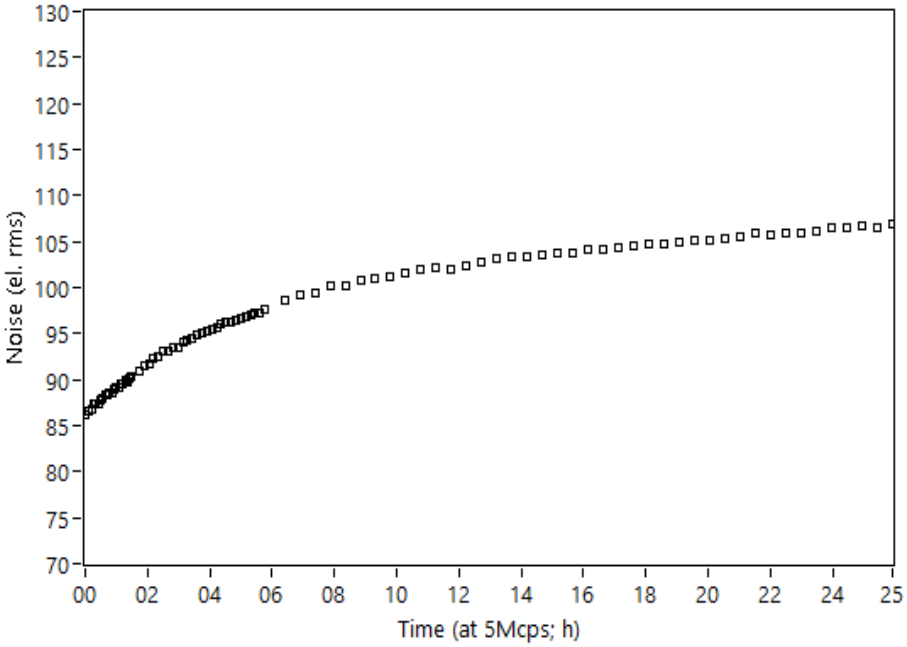
Module B = 222 hours



Difference = 5%

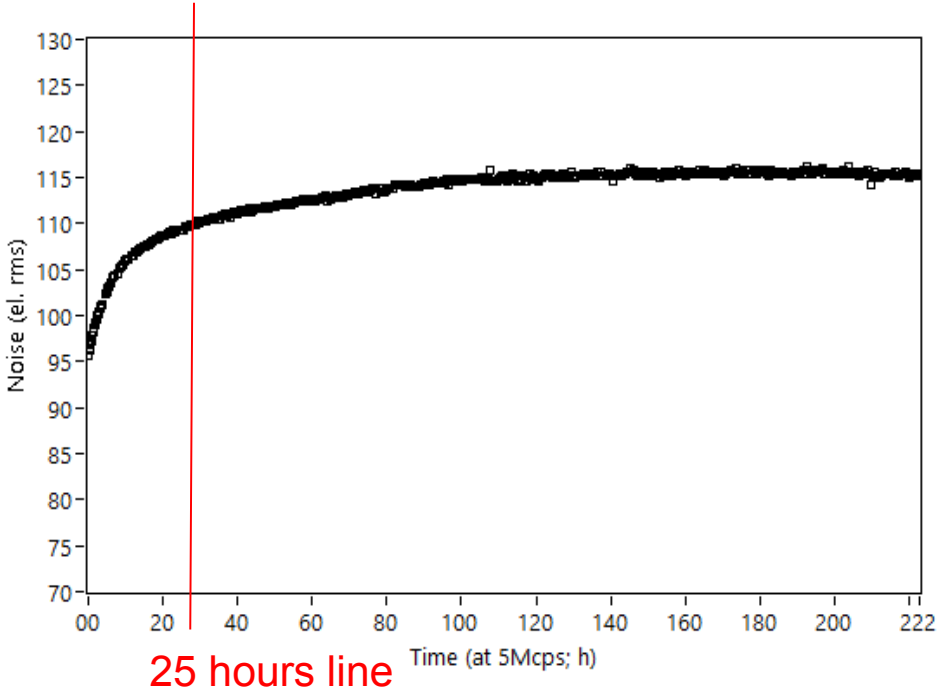
Noise

Module A = 25 hours



Noise increase = 24%

Module B = 222 hours



Noise increase = 19%

Summary

1. Today X-ray generators can be effectively used to study the radiation damage (constant monitoring of parameters is possible)

2. The pixel readout chip working in single photon counting mode, fabricated in CMOS 130 nm was tested, irradiated for the 25 hours and for 222 hours (about 5Mcps/pixel)

3. Observed changes (25 h / 222 h):
   - offset shifts of single mV (2 / 5 mV)
   - offset spread increase up to 6 times, but we are able to re-correct the whole pixel matrix
   - noise increase about 24% / 19%
   - gain changes up to 5%
4. New sets of tests are planned shortly, but:
   - improved fast correction algorithm
   - correcting offsets during irradiation
   - speed of digital communication and power supply vs radiation dose

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