

Development of a medium-sized photon counting UFXC-demonstrator at SOLEIL synchrotron

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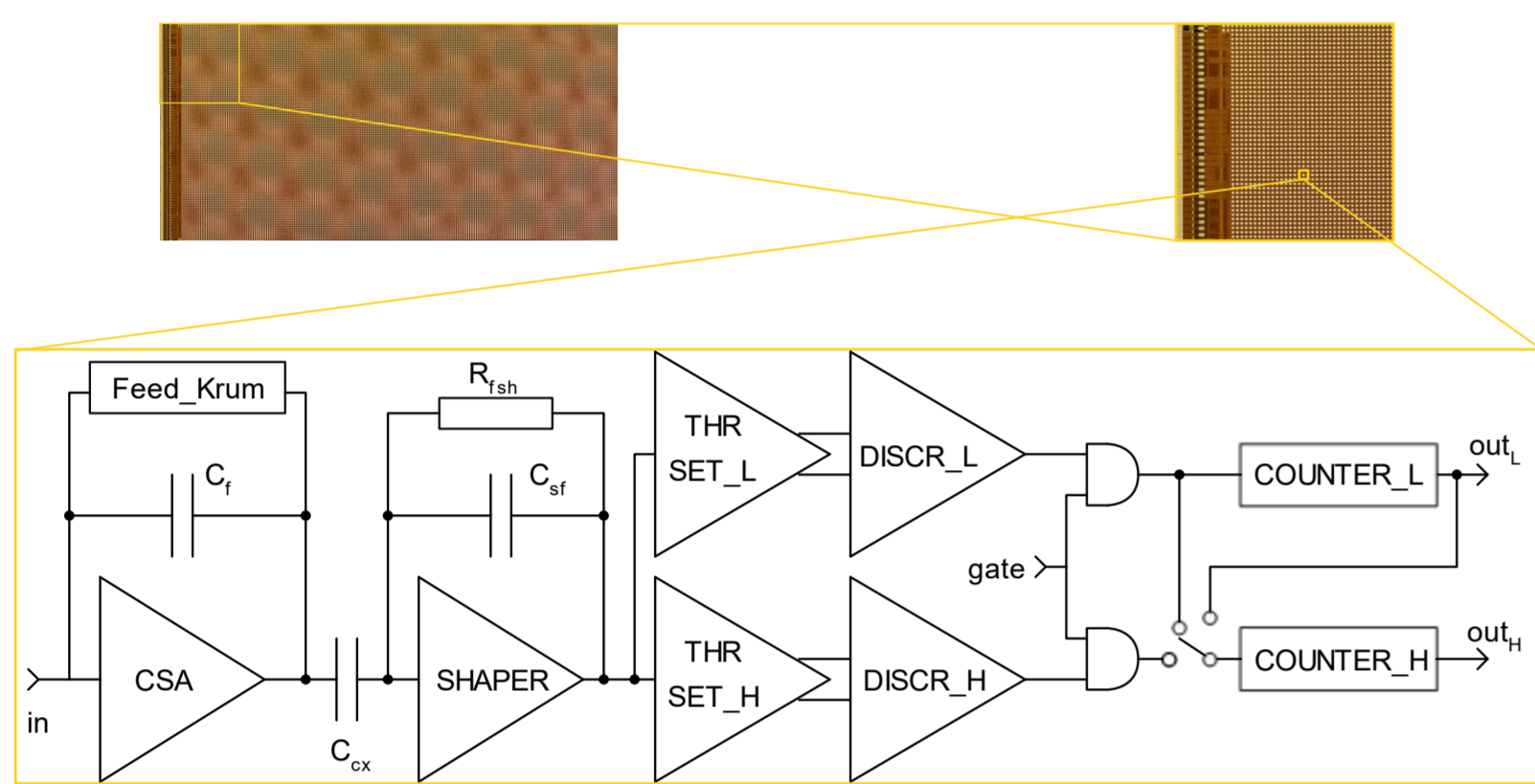
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ULTRA FAST X-RAY CAMERA DEMONSTRATOR with 8 CHIPS

A hybrid photon-counting pixel detector of medium size with very high frame rate, high count rate capability and short gating time for time-resolved pump-probe experiments and other new or existing applications

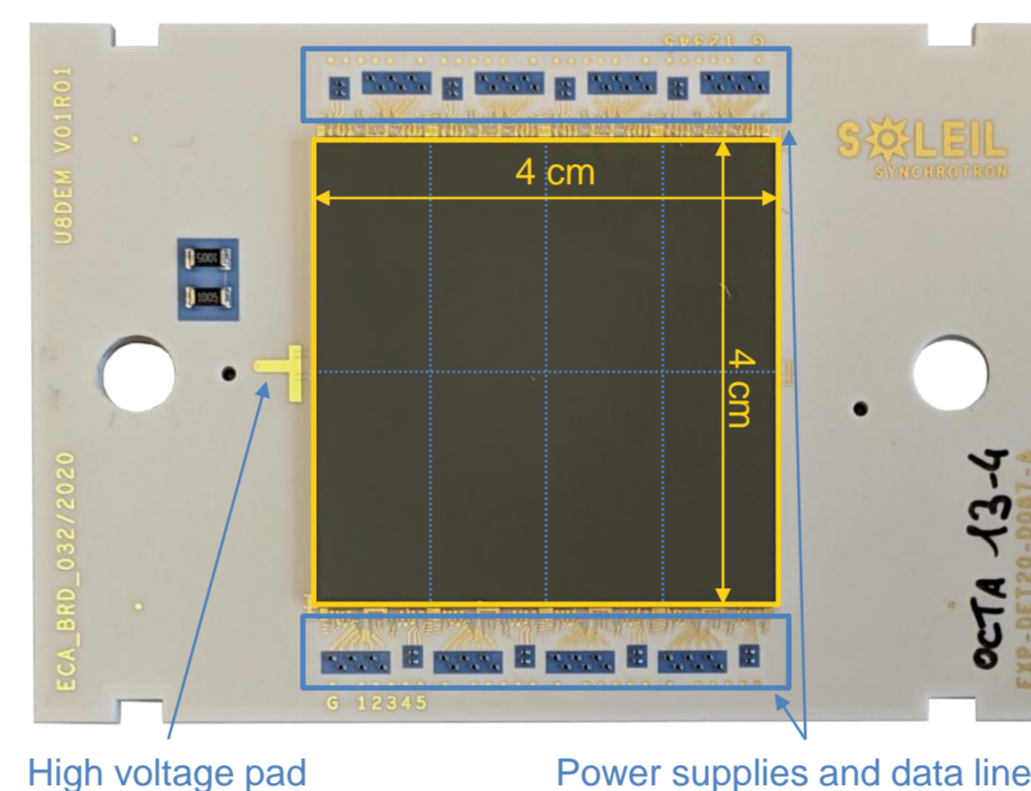
UFXC32k readout chip designed at AGH-UST, Krakow

- 128 × 256 pixels with 75 μm pitch
- Two discriminators with 7 trimitbits each and two 14-bit counters per pixel
- Adjustable gain and frontend speed
- Selectable readout counter depth (2, 4, 8, 14 or 28-bit)
- Minimum exposure time < 100 ns
- High count rate linearity > 10⁶ ph/pix/s (at 90 % counting efficiency)



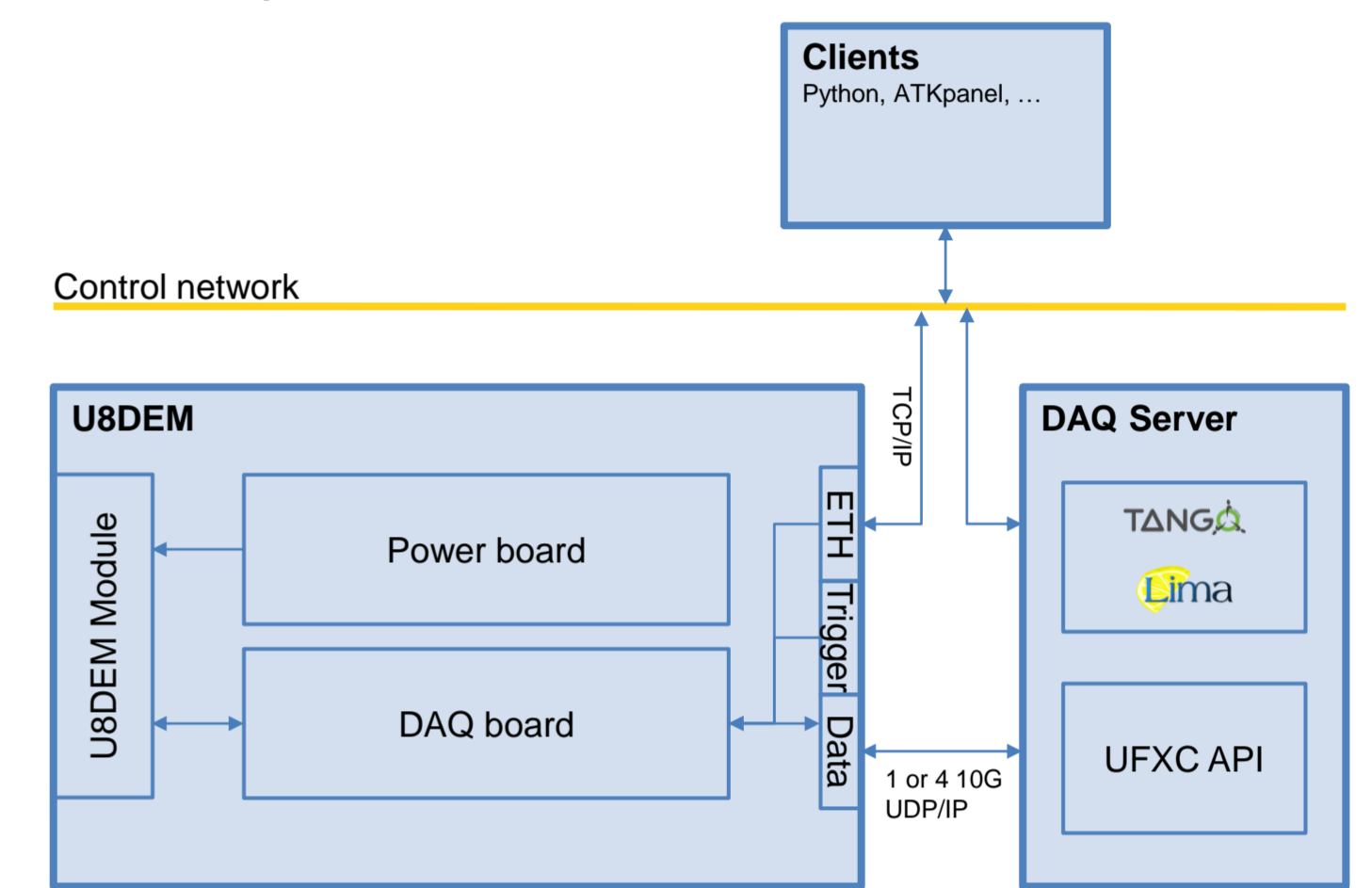
U8DEM module

- Evolution of the existing 2-chip system tested at SOLEIL
- Single Si-sensor (320 μm or 450 μm thickness), bump bonded to eight UFXC32k readout chips
- Detection area: 4 × 4 cm² (250k pixels with 75 μm pitch, including single pixel inter-chip spacing)
- Ceramic PCB (LTCC, 88 × 60 mm²)
- Single high-density connector on the backside



Detector

- Compact (16 × 28 × 11 cm³) and light (~3 kg) mechanics
- Efficient water cooling (up to 50 W)
- Power board
- Acquisition board with FPGA
- 1 or 4 × 10G QSFP connections for data transfer
- Power consumption of the detector head < 25 W



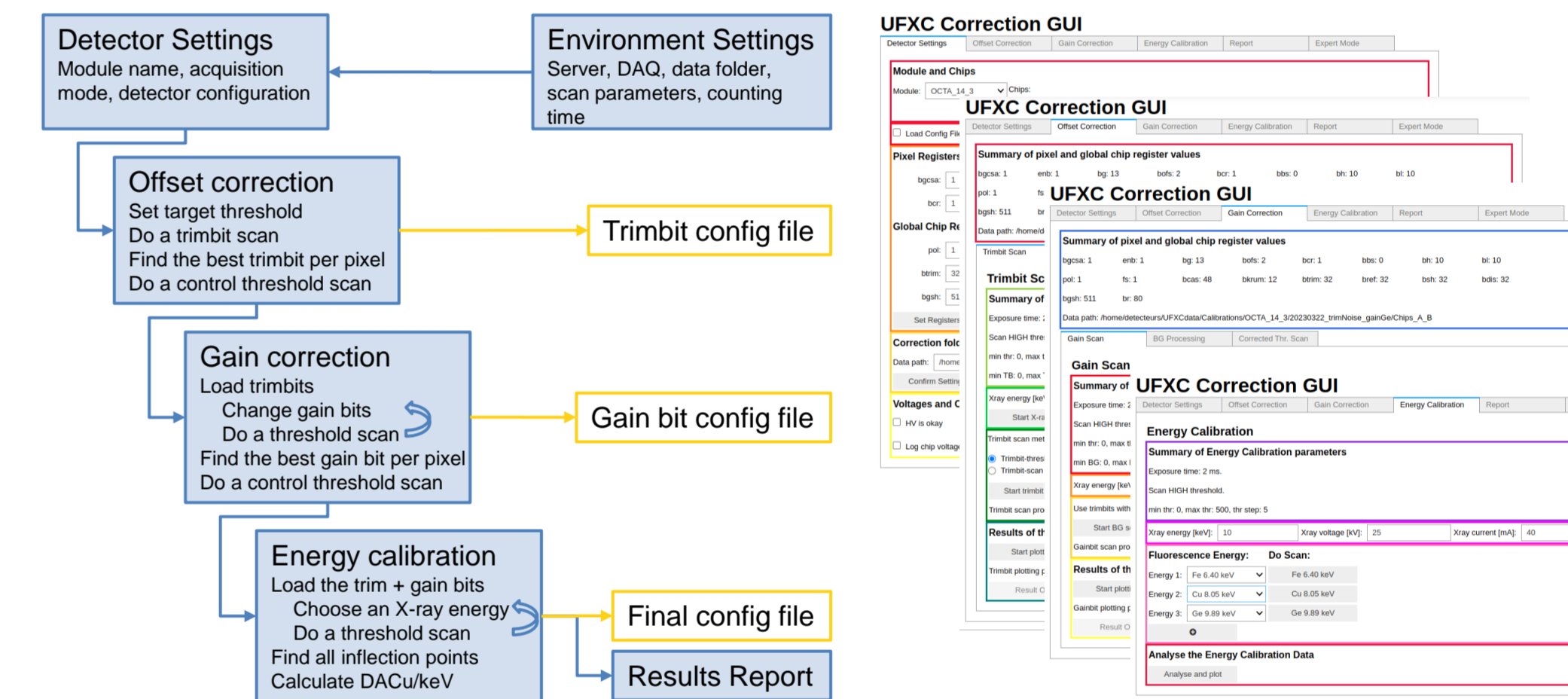
FIRMWARE AND SOFTWARE STATUS

Firmware + Library developed for U8DEM

- Based on firmware + decoding library made for the 2-chip system
- Interface to TANGO and LIMA to ease integration into the SOLEIL beamline control system
- Controls 8 chips simultaneously
- Frame rate between 3.4 kHz and 23 kHz (depending on the acquisition mode)
- Based on FEM-II acquisition board (Virtex 6 FPGA + Zynq SoC)
- Under finalization

Correction + Calibration Software

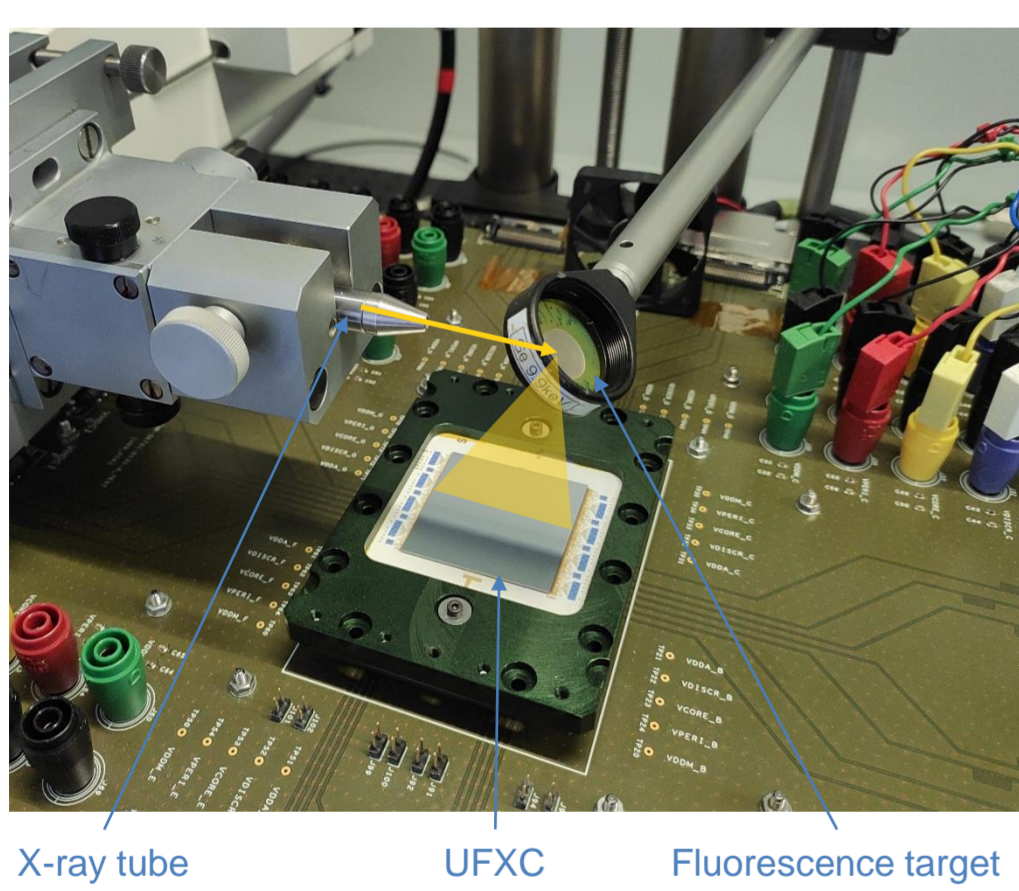
- Semi-automatised offset and gain correction and energy calibration
- Control of the detector and X-ray generator (via TANGO devices)
- Generates the configuration files and pixel mask
- Displays and saves all resulting plots and data
- GUI based on Jupyter-Notebook widgets
- Under finalization



FIRST CHARACTERISATION MEASUREMENTS

All presented measurements have been acquired with the existing 2-chip readout system and in the laboratory X-ray setup using fluorescence photons. The data of all 8 chips are presented.

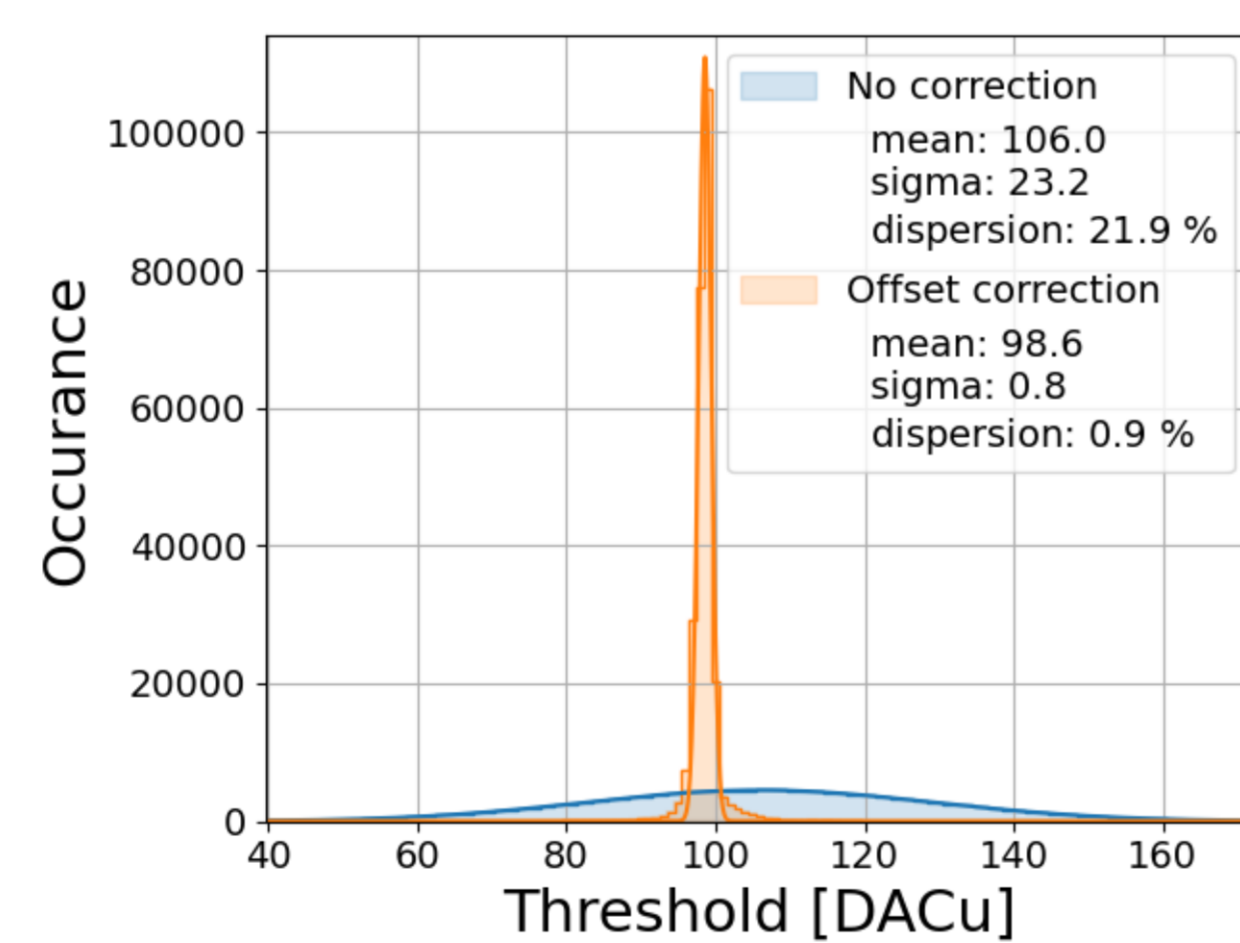
Laboratory X-ray setup



X-ray tube UFXC Fluorescence target

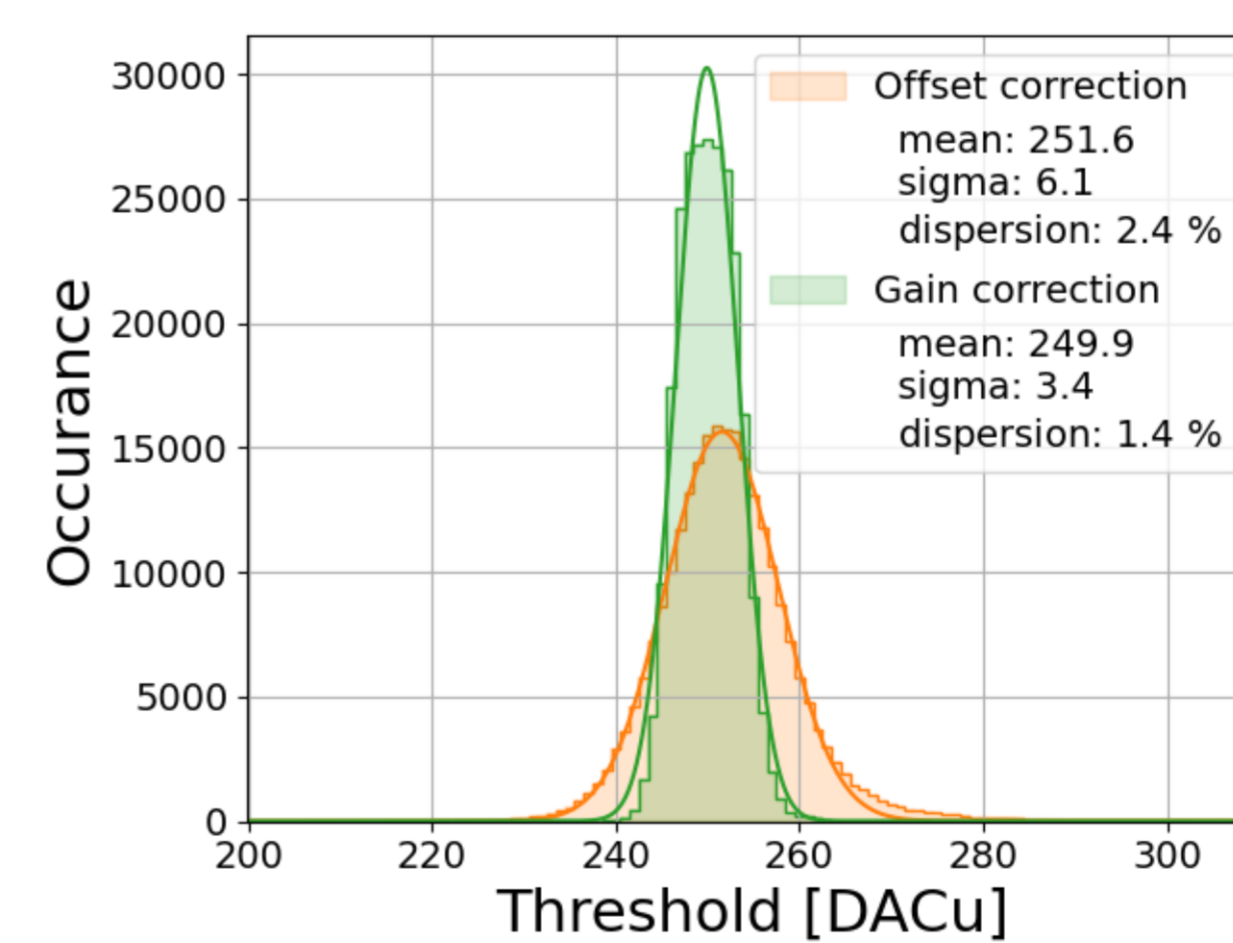
Fluorescence setup with temporary readout system

Offset spread



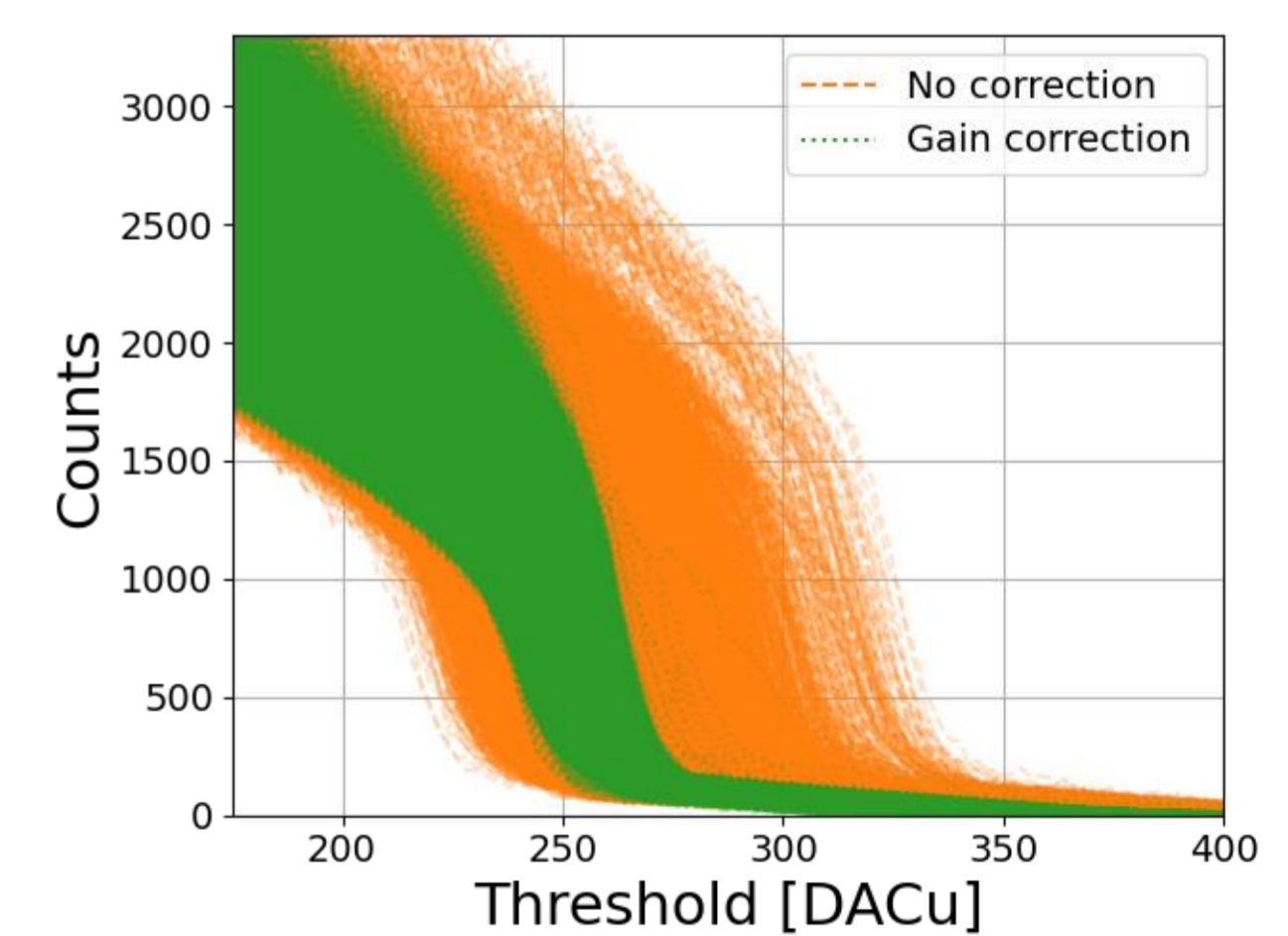
Very low offset spread after the correction

Threshold dispersion @ 10 keV



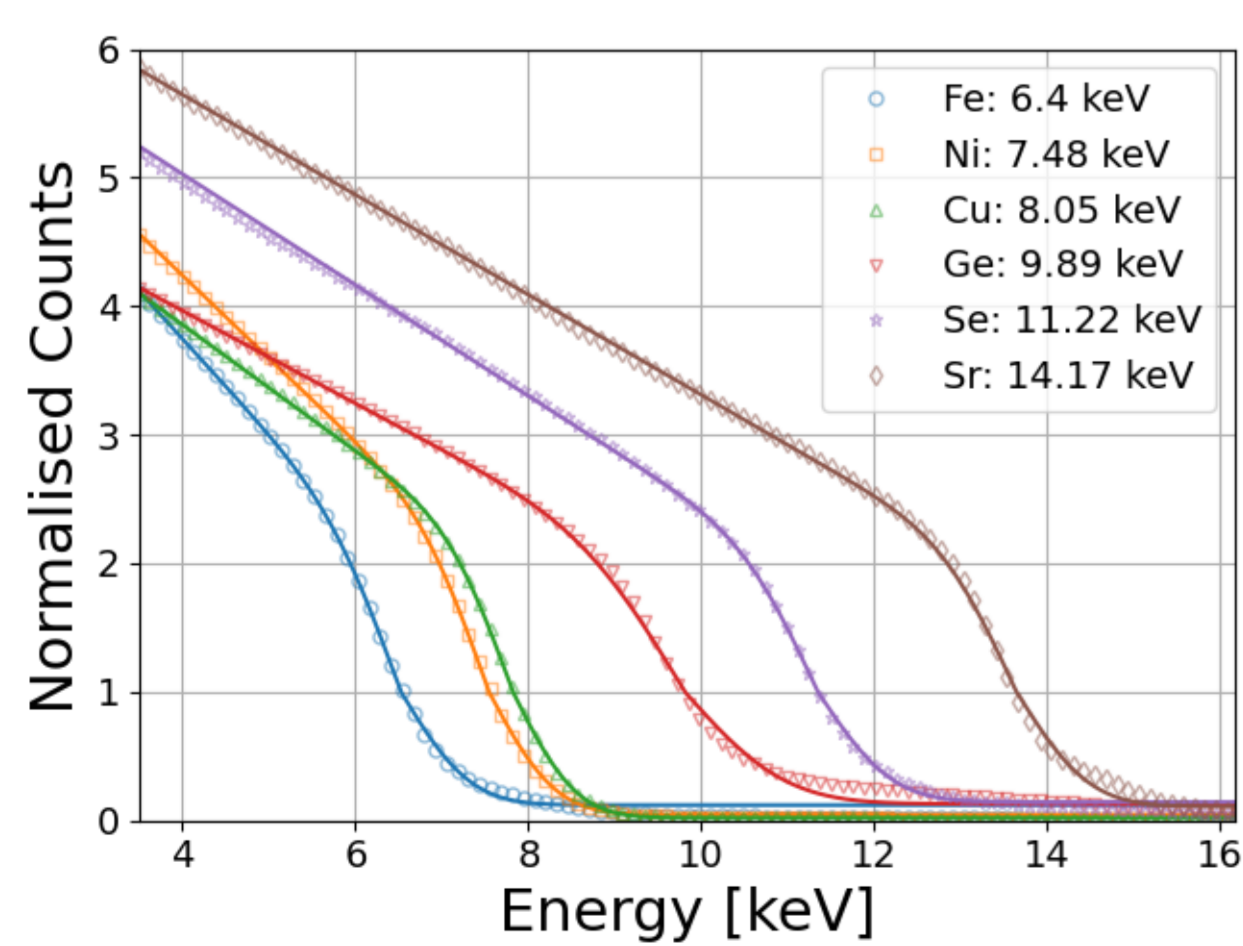
Reduced threshold dispersion < 2% after gain correction

Corrected threshold scans @ 10 keV



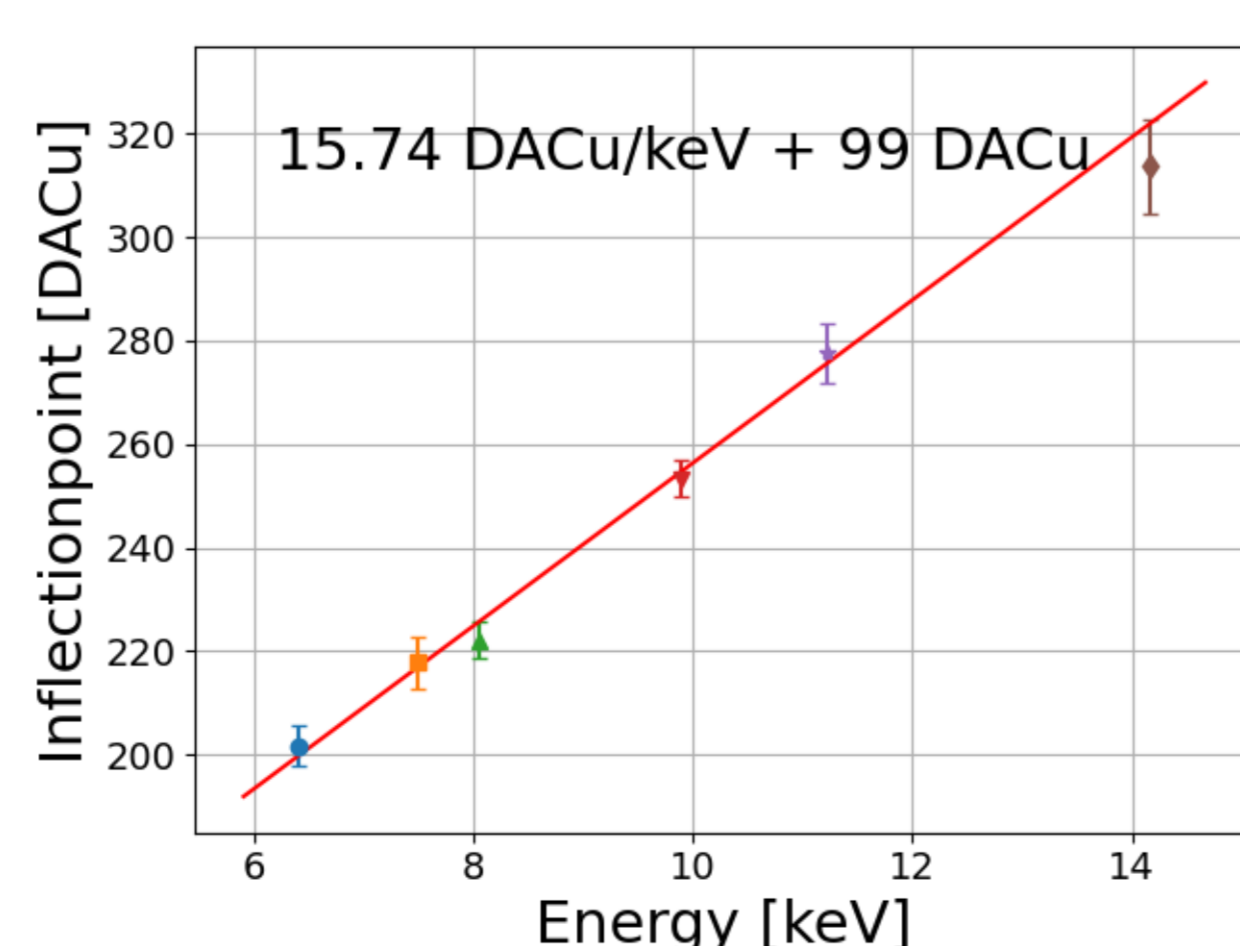
Threshold scans before and after gain correction

Threshold scans at different energies



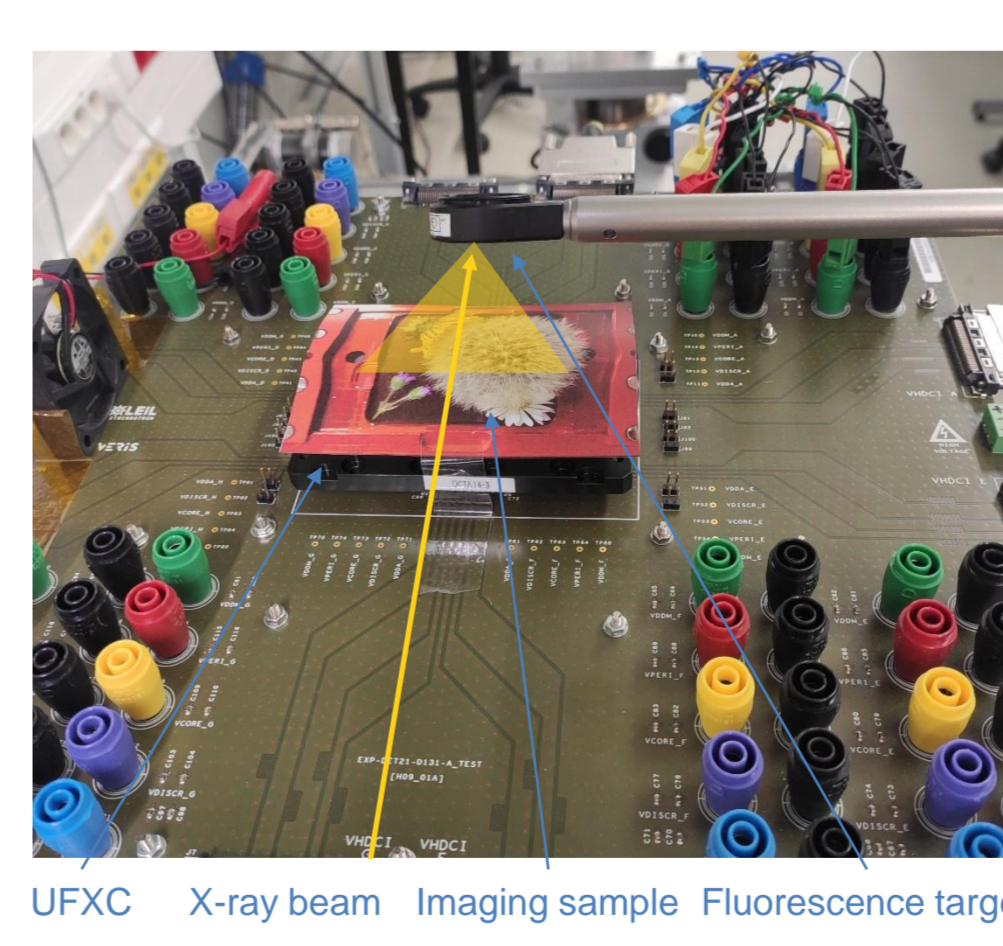
Median threshold scans after corrections at low gain
Energy resolution ~1.3 keV

Energy Calibration



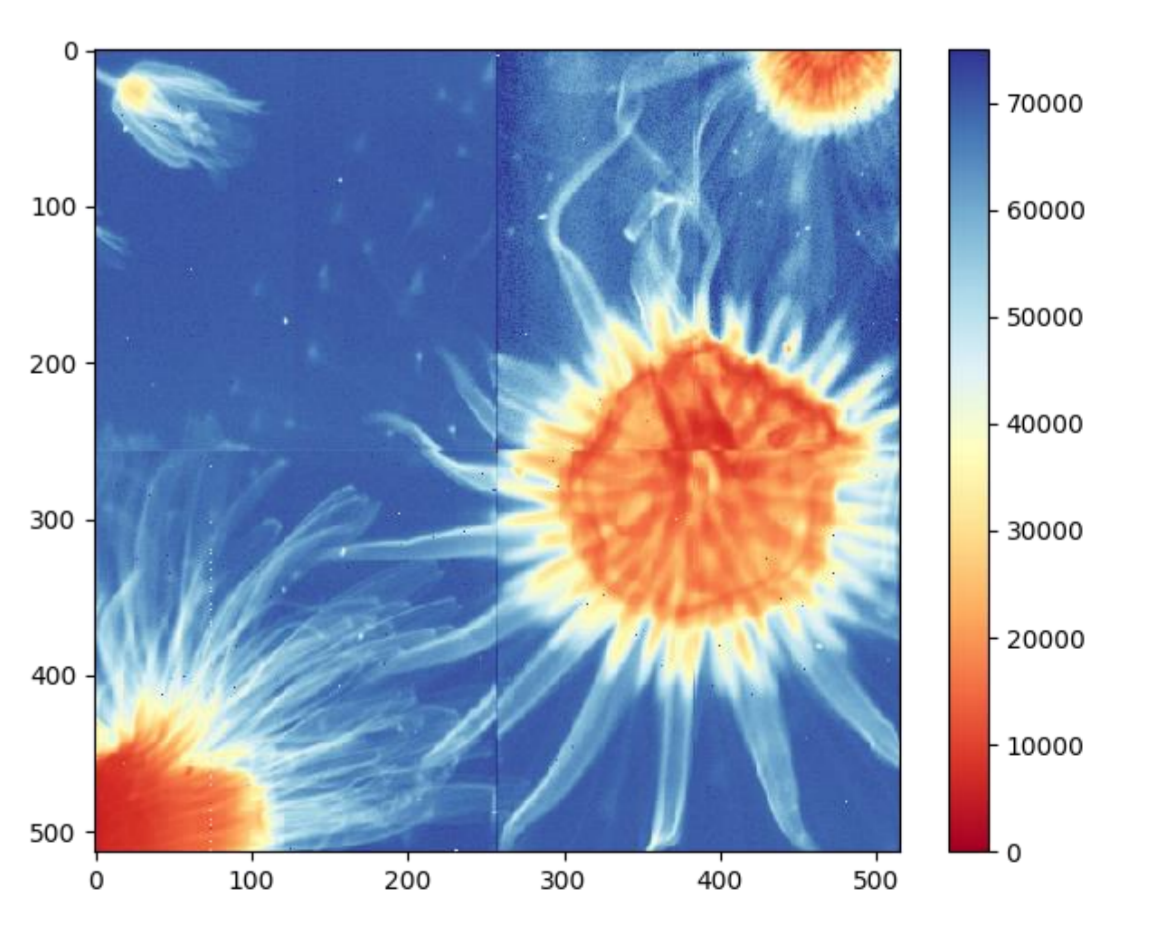
Median energy calibration at low gain
Non-linear >12 keV

Imaging setup at the beamline



UFXC with imaging sample using fluorescence photons

First imaging @ 10 keV



Flatfield and inter-chip gap correction
Shifts in the image are due to the composition of four 2-chip images taken one after the other

SUMMARY AND OUTLOOK

- ✓ An 8-chip demonstrator has been developed
- ✓ Offset, gain correction and energy calibration work as expected
- ✓ Validated good quality of several hybrid modules
- ✎ Firmware and software are in the final development stage

Goal: Have the first fully assembled and operational U8DEM detector by end 2023 / beginning 2024

REFERENCES

- A. Dawiec et al., AIP Conf. Proc. 2054, 060067, (2019)
- P. Grybos et al., IEEE Trans. Nucl. Sci. 63 1155, (2016)
- D. Bachiller-Perea et al., J. Synchrotron Rad. 27, (2020)



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