PIMEGA detectors on Sirius Synchrotron

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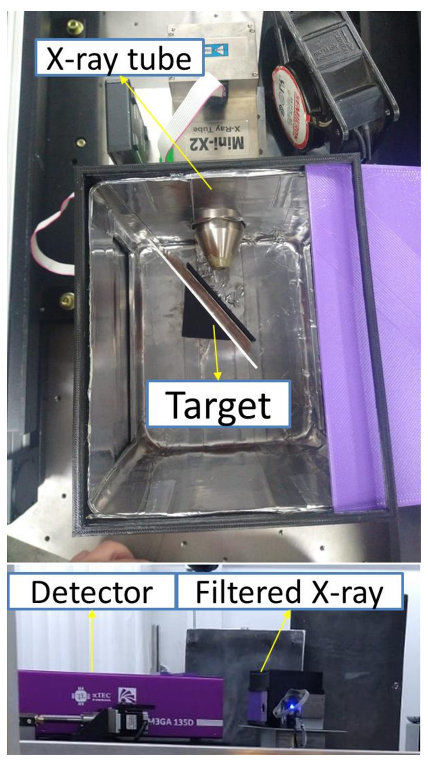
Introduction

At Sirius Synchrotron the PIMEGA series of hybrid pixels detectors are present in beamlines, using Medipix3RX [1] Application Specific integrated Circuit (ASIC), 256 x 256 squared pixels with 55 µm pitch. In this work, we continue characterization of these detectors [2] and present data that correlates different configurations of bias voltage, threshold energy, incident energy and modes of operation Single Pixel Mode (SPM) and Charge Summing Mode (CSM). We also propose a new procedure in order to select operation relative threshold energy, minimizing the effects of charge sharing.

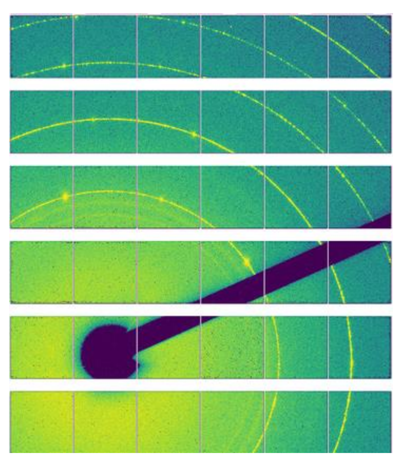
Experimental conditions & PIMEGA detectors

Experimental conditions

- PIMEGA 135D with 300µm thickness silicon sensor and 1536x1536 pixels of active area.
- Threshold scans in different conditions of fluorescence target and bias voltage and operation mode (SPM and CSM).
- Portable X-ray tube (Amptek Mini-X2) operating in 50kV/200uA (High Voltage/Current).
- Fluorescence targets of Mn ($K\alpha_1$ 5.898keV), Ni ($K\alpha_1$ 7.478keV) and Cu ($K\alpha_1$ 8.047keV).
- Noise based equalization.
- Flatfield correction applied (created with 9.8 keV)
- Normal temperature and pressure (NTP) conditions.



The PIMEGA series of hybrid pixels detectors has different models and employs many Medipix3RX chips, for multiple imaging techniques, using either 300 or 675µm thickness silicon sensors, and achieving high framerates (up to 2000fps).



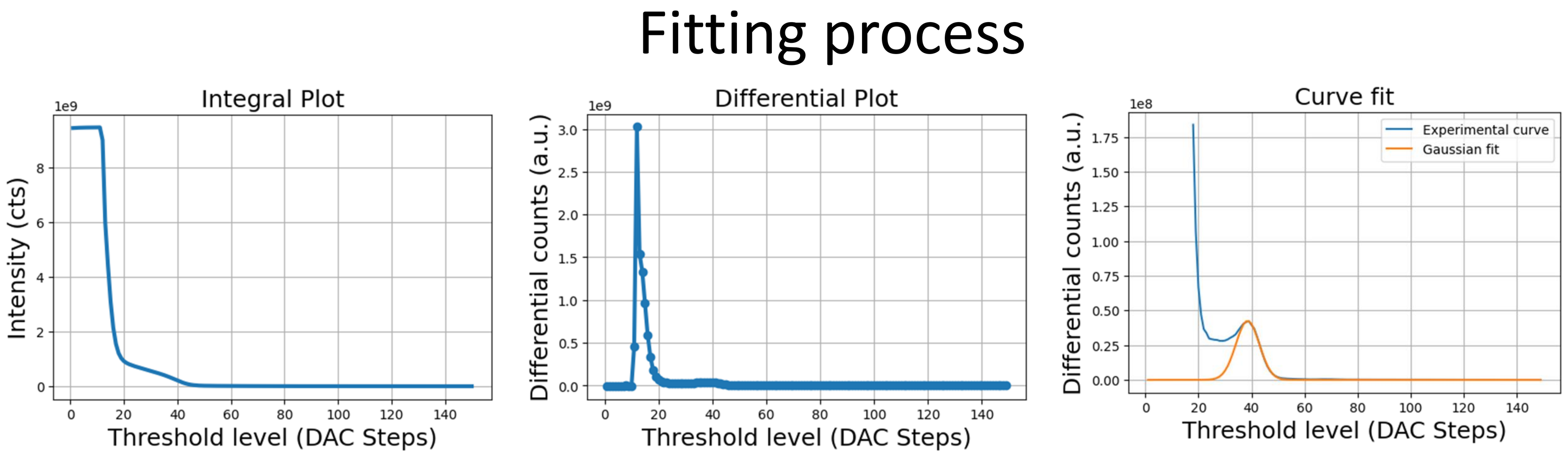
As example, PIMEGA 135D(36 Medipix3RX) and diffraction of CeO_2

Characterization

Energy Calibration

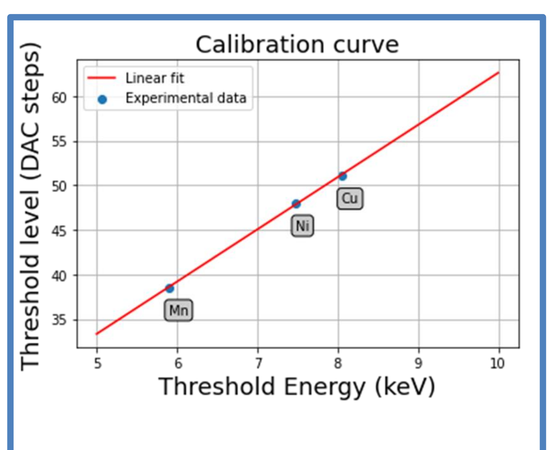
Starting from threshold scans, alongside with bias voltage scans in SPM and CSM modes, we were able to fit the differential curve with a gaussian. The scans were obtained using a fluorescence setup with energies from Kα of Mn, Ni and Cu. From the gaussian fit, we were able to create calibration curves between Threshold level (DAC Steps) and Energy level (keV).

Fitting process

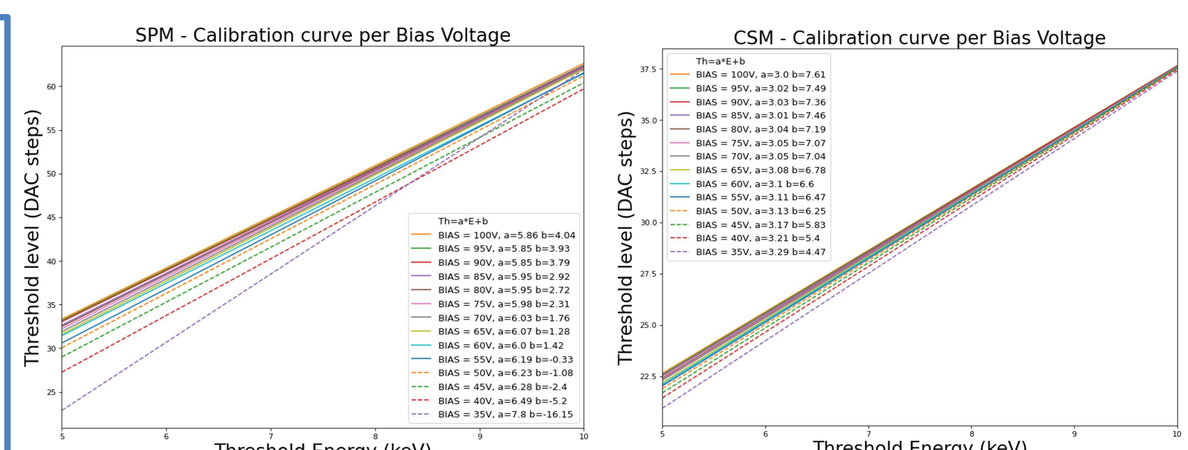


Fitting of Mn peak ($K\alpha_1$ 5.898keV), with bias voltage 100V and SPM mode.

Energy calibration curves

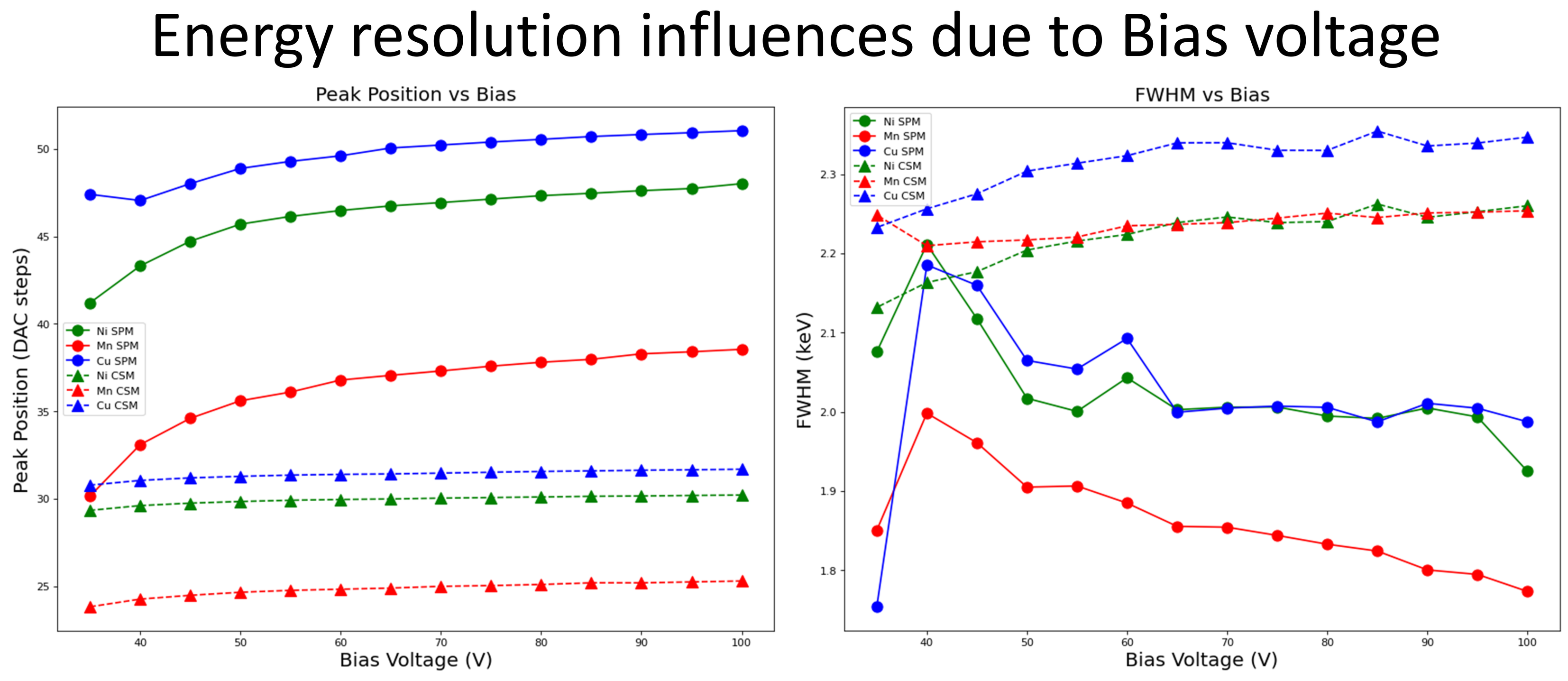


Example of calibration curve



Each line is one energy calibration curve , for a fixed Bias Voltage value, using $K\alpha_1$ of Mn, Ni and Cu.

Energy resolution influences due to Bias voltage



References

[1] R. Ballabriga et al. "The Medipix3RX: A high resolution, zero dead-time pixel detector readout chip allowing spectroscopic imaging," (2013), J. Inst, 8(02), C02016.

[2] R.B. Campanelli et al., Large area Hybrid Detectors Based on Medipix3RX: Commissioning and Characterization at Sirius Beamlines, 2022 [Manuscript submitted for publication]

[3] T. Koenig et al., "Charge Summing in Spectroscopic X-Ray Detectors With High-Z Sensors" (2013),IEEE Transactions on Nuclear Science, 60(6), pp. 4713-4718.

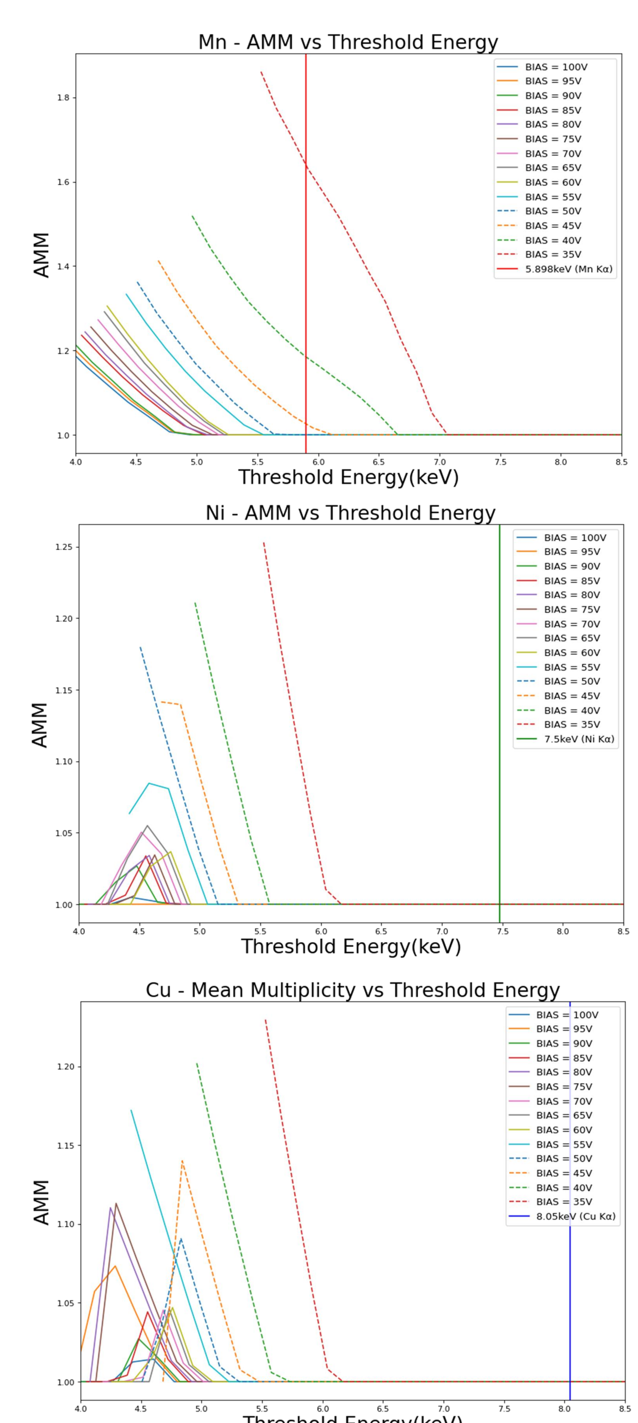
[4] T. Michel et al., "Investigating the DQE of the Medipix detector using the multiplicity concept" (2006), IEEE Nuclear Science Symposium Conference Record, pp. 1955-1959.

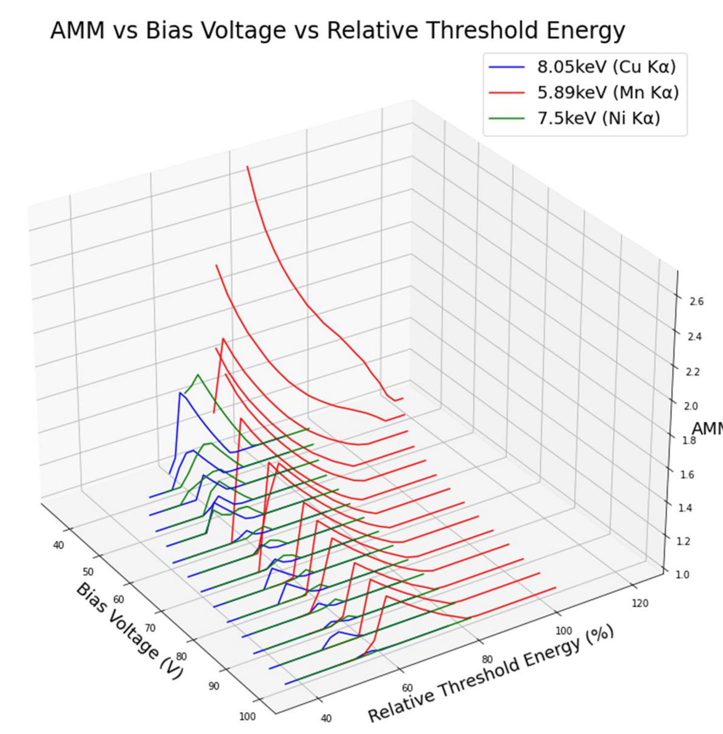
Aproximated Mean Multiplicity

CSM operation mode[1,3] was created in order to minimize charge sharing effects, consenquently reducing the mean multiplicity <m>[4]. Ideally we can consider that CSM would bring <m> = 1. Considering this assumption, we define the Aproximated Mean Multiplicity (AMM) as it follows in the equation:

$$AMM\left(\frac{SPM_{Counts}}{CSM_{Counts}}\right) = \begin{cases} \frac{SPM_{Counts}}{CSM_{Counts}}, if \ \frac{SPM_{Counts}}{CSM_{Counts}} \geq 1 \\ 1, if \ \frac{SPM_{Counts}}{CSM_{Counts}} < 1 \end{cases}$$

We can evaluate AMM in relation to the Energy Threshold (keV), Bias Voltage (V) and Incident Energy (keV) . In the 3D Figure we can see this relation, the Threshold Energy axis is changed to Relative Threshold Energy by dividing each curve in Threshold Energy axis by the Incident Energy. Also we can correlate AMM directly to the threshold energy, pointing an optimal choose of operation relative threshold energy (keV), as it is shown in the curves below.





Conclusions

- Calibration curve in CSM has less variations in relation to bias voltage.
- Kα Peak position slightly varies for the right (increase energy) with the increase of bias voltage.
- As expected[3] CSM has a worse energy resolution compared to SPM.
- Bias Voltage has greater influence on energy resolution when operating in SPM.
- AMM can define a new procedure to choose the operation relative threshold energy value in order to minimize the charge sharing effect and improve spatial resolution[2].

Future perspectives

- Improve the AMM confiability by exploring the limitations of CSM mode, in order to evaluate how good is the assumption of <m> = 1 in CSM mode.
- Perform spatial resolution experiments exploring its relation with BIAS and the choose of threshold via AMM.

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