THERMAL VACUUM TESTING OF TIMEPIX3 DETECTOR

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Introduction

This poster presents the results of the thermal vacuum testing of the Timepix3 (TPX3) detector with respect to the effects on its properties and sensitivity. Timepix3 represents the new generation of Timepix chips of the Medipix family. It is equipped with Event-base mode of detection which allows measuring the position, time and energy of an incident particle at the same time. Due to their properties, TPX3 detectors are very suitable for space applications. Given that this is a relatively new device, the influence of temperature is not described in detail yet, especially for use in space, where the operation in a broad range of temperatures (e.g. QB50 mission on LEO from -20°C to +50°C) is required. Up to now, the Timepix detectors were used in space like e.g. VZLUSAT-1 (Fig.1), LUCID or SATRAM missions. In these cases, thermal cycling of the detectors occurs, for example, due to orbiting and thus distortion of the measurement results either by changing the noise edge (threshold) but also the energy spectra can emerge.

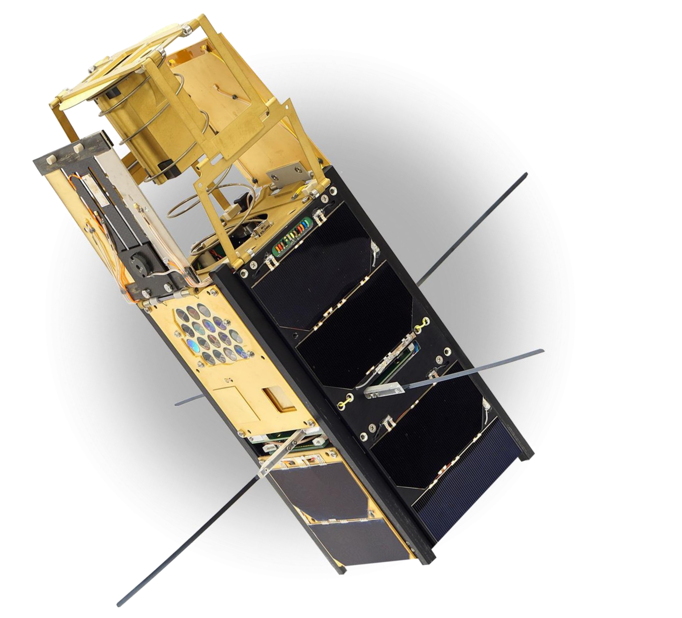

Fig.1: VZLUSAT-1 nanosatellite with a Timepix onboard

The experiments were performed on a detector equipped with a 300 μm thick Si sensor. Results of this testing help to strengthen the knowledge regarding the behaviour of the essential part of the detector under extreme conditions. They can be used to improve results and minimise external influences, for example in space applications but also in other fields where temperature stabilisation of the detector is very difficult or energy-consuming.

Experimental setup

This experiment was performed on the Timepix3 detector with AdvaPIX TPX3 read-out interface. The radiation-sensitive chip was uncovered and its back-side (with bump-bonded ASIC chip) was attached on the aluminium block (see Figure 2). This block was thermally coupled with the chip itself and thermally stabilised by three stage Peltier element with temperature feedback consists of Pt1000 thermometer. The whole arrangement was placed inside the vacuum chamber and waste heat was removed by external water cooling system. The TPX3 chip was temperature stabilized with a Peltier element and let at a stable temperature for at least 10 minutes before each measurement. The whole test was performed in the vacuum chamber under reduced pressure of approximately 3.4*10^{-6} hPa.

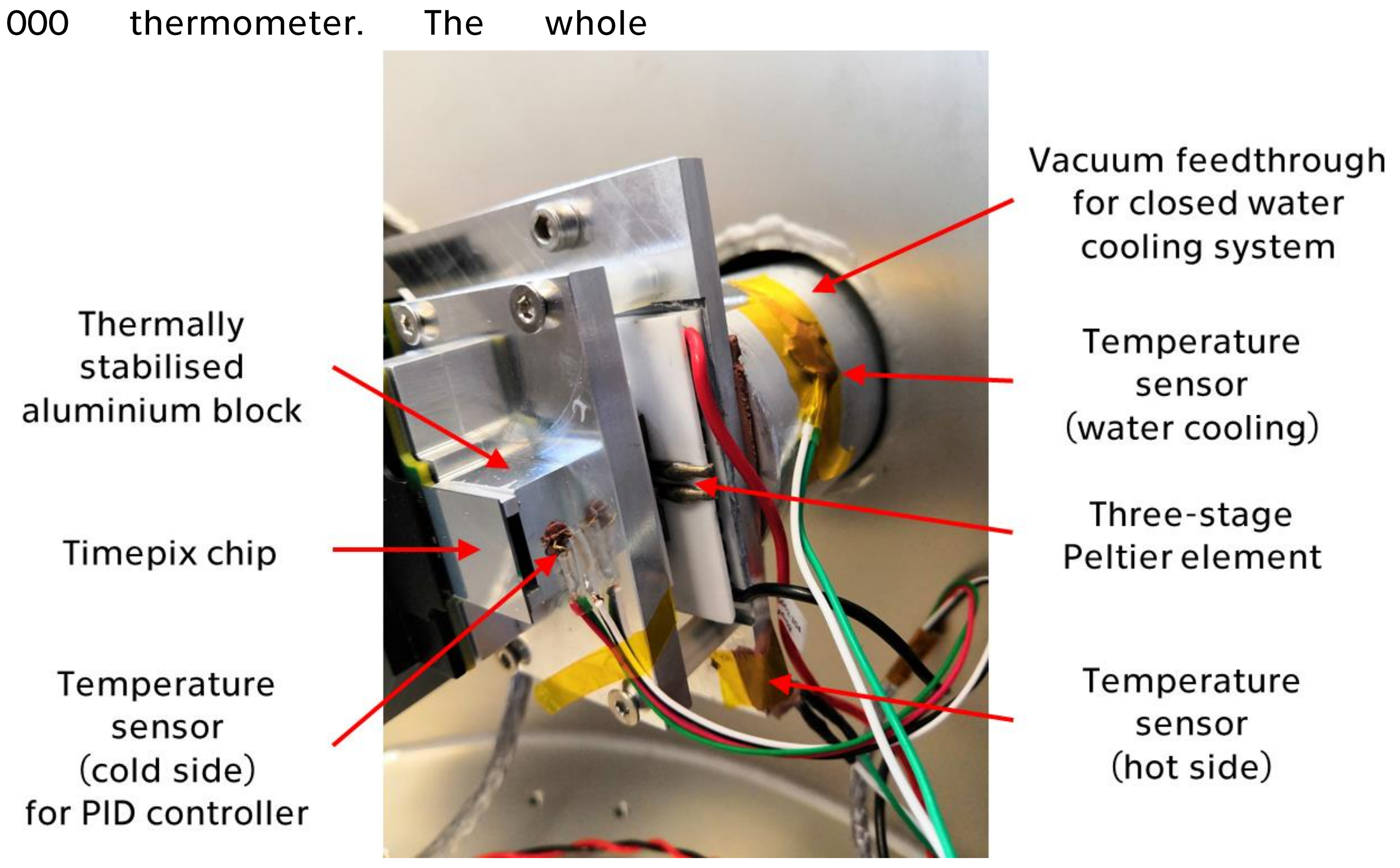

Fig.2: Detail of the detector's thermal stabilisation arrangement in the vacuum chamber

Equalization

Threshold equalization is a procedure which exploits 4-bits threshold (THL) adjustment to make overall threshold as homogenous as possible. It finds a distribution of thresholds for each adjustment value and selects for each pixel such adjustment that its threshold is as near as possible to an average of means of threshold distributions. THL is scanned in the range around the noise edges.

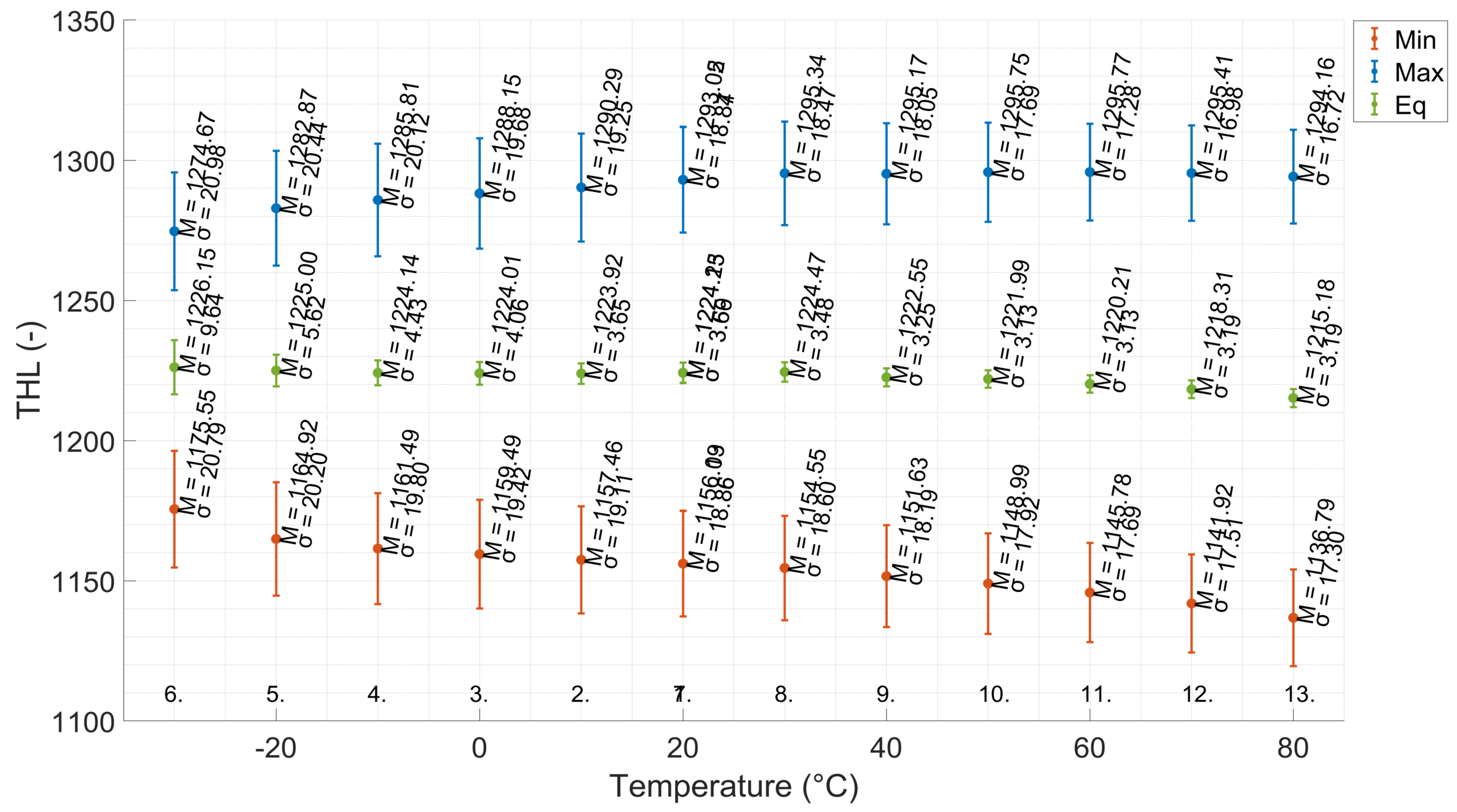

Fig.3: Changing the results of equalization according to the temperature

- **Min M** - mean of distribution of thresholds when thl. adj. is minimal (0)
- **Min σ** - standard deviation of distribution when thl. adj. is minimal (0)
- **Max M** - mean of distribution of thresholds, thl. adj. is maximal (15)
- **Max σ** - standard deviation of distribution, thl. adj. is maximal (15)
- **Equal. M** - mean of distribution of thresholds after equalization
- **Equal. σ** - standard deviation of distribution after equalization

Treshold scan depending on the temperature and the radiation energy

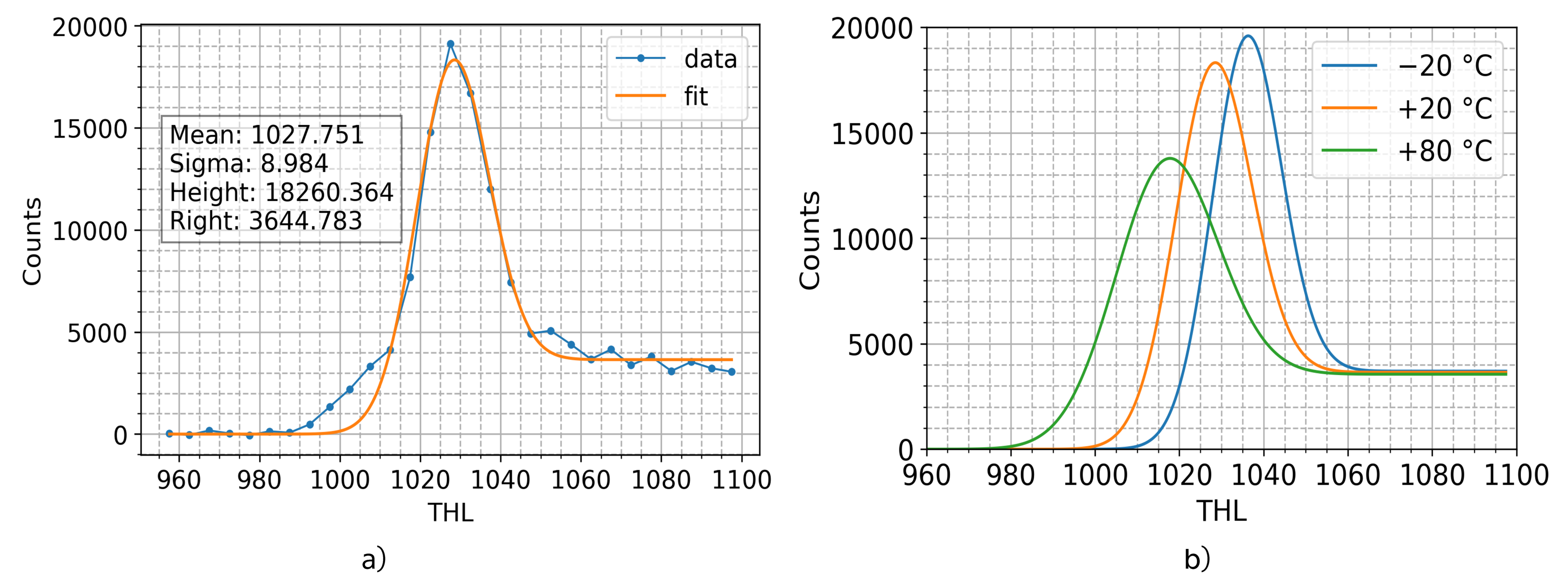

Fig.4: **a)** Data and fit for an energetic calibration of XRF radiation (Cu) at 20 °C. A decrease in THL means an increase in the value of XRF energy. The offset in the right part of the plot is caused by the charge sharing effect. **b)** Fits of THL scans based on characteristic radiation of Cu at the different temperatures -20 °C, +20 °C and +80 °C

The measured data for the TPX3 THL scan from each temperature step and each fluorescence characteristic radiation energy (XRF) were fitted by a combination Gauss and Error function (gerf). Figure 4 a) is an example of this plot for copper (Cu) radiation at 20 °C on the chip with the valid equalization for 20 °C as well.

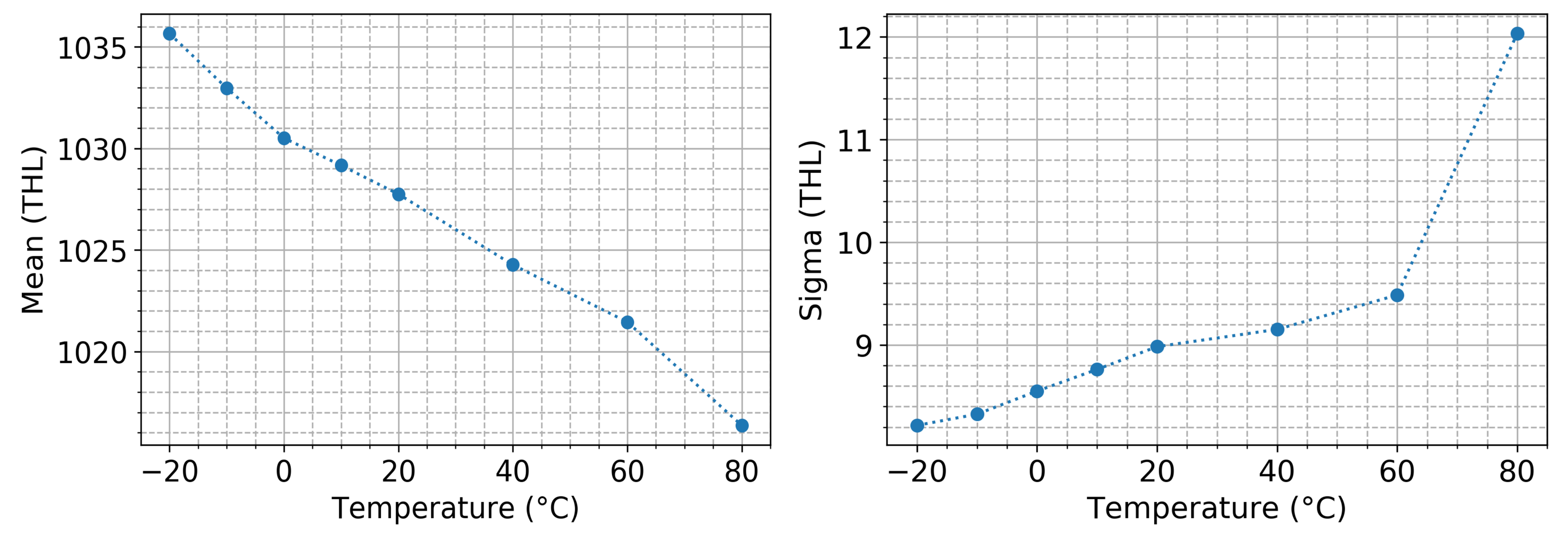

Fig.5: Temperature dependence of measured values for characteristic (Cu) radiation especially Mean and Sigma of fits

The data set consists of measurements for several temperatures and elements (energies). Figure 4 b) shows the dependency of the whole fit for one element (Cu) on the detector temperature. The evolution of its dependence through the whole temperature range is shown in Figure 5. The shift of THL mean and its sigma from the reference temperature (20 °C) is shown in Figure 6. This figure contains curves for several energies.

The characteristic lines of elements:

- **Ti** Titanium **4,508 keV**
- **Fe** Iron **6,398 keV**
- **Cu** Copper **8,046 keV**
- **Mo** Molybdenum **17,48 keV**
- **Cd** Cadmium **23,106 keV**

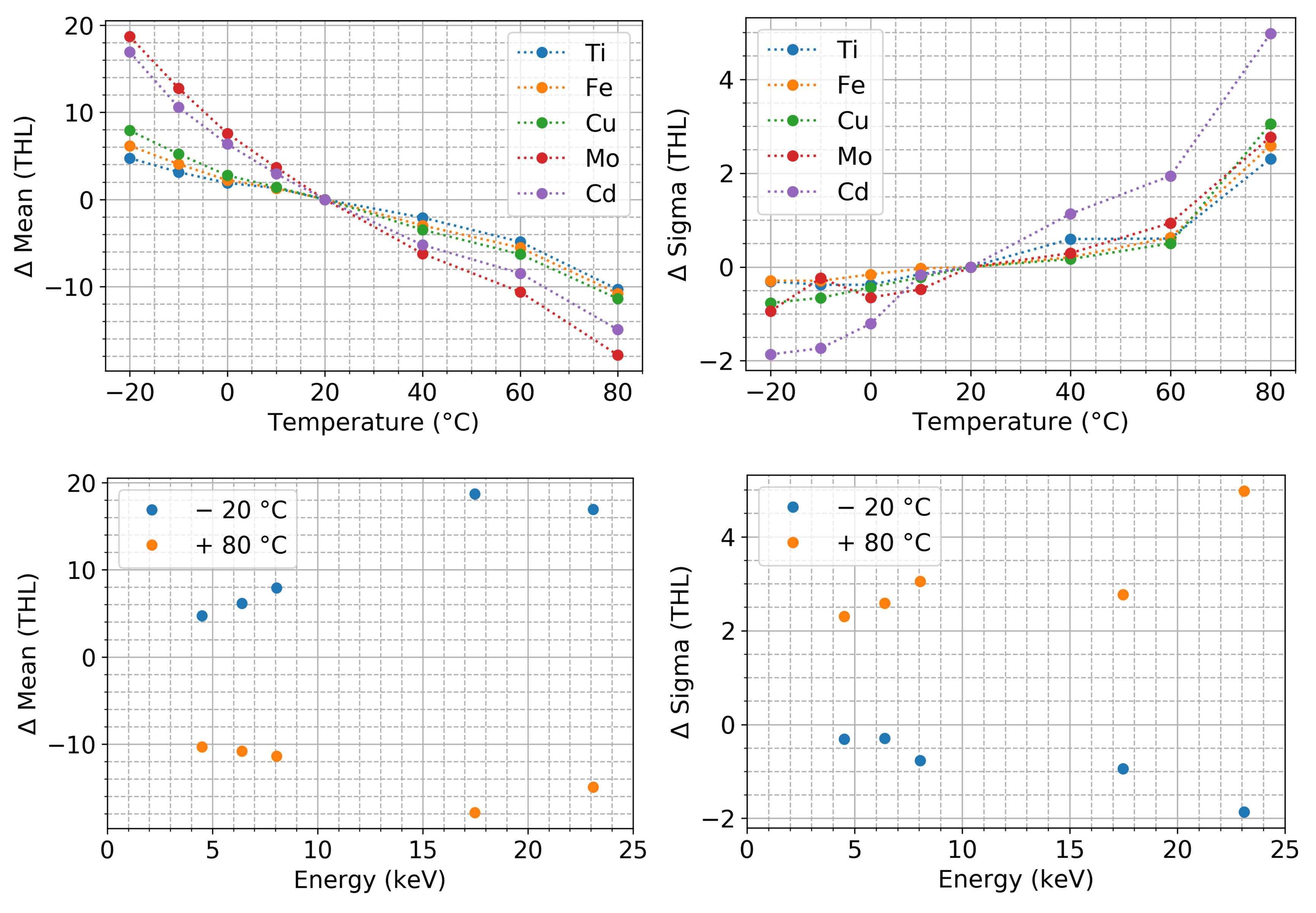

Fig.6: The shifts of measured THL Means and THL Sigmas from the reference value (at 20 °C) depending on temperature and energy of radiation (element).

Conclusion

Timepix3 detector (300 μm Si) was tested in a wide range of temperatures (from -30°C resp. -20°C to +80°C) under vacuum in order to gain the knowledge of the detector behaviour under extreme conditions, which can be essential for usage in space applications. The temperature range was chosen according to requirements for Low-Earth-Orbit satellites. The first part of the testing was performed without radiation, focusing mainly on equalization of the chip. A shift of noise level was observed with temperature change. Also, the validity of the chip normal-conditions-setting was deeply studied. In the next step, the measurement of characteristic radiation (XRF) of selected elements (Ti, Fe, Cu, Mo, Cd) was performed. Both the shift of the fluorescence peaks and the peak width were measured. The goal of the future work is to study the Time-over-Threshold calibration and its validity under specific conditions in order to get the overall knowledge necessary for the usage of Timepix3 detectors in future space missions. Based on detector behaviour knowledge, a procedure (an algorithm) can be designed to minimise this effect of distortion while maintaining the reduced requirement for temperature stabilisation and cooling.

Ack.

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