Alpha Calibration of the Timepix Pixel Detector Exploiting Energy Information Gained from a Common Electrode Signal

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Abstract

An alternative calibration method of pixel detector Timepix has been developed. Unlike a standard per-pixel calibration method where just single pixel tracks of low energy gammas and fluorescence roentgens are used as an input, the new method is based on the evaluation of charge distribution within multi pixel tracks of energetic alpha particles.

The new method gets practicable if energy of interacting alpha particles is precisely known. The Timepix pixel detector allows a simultaneous run of measurement in the pixel part as well as in the common electrode when a specialized read-out interface FITPix COMBO is used. The common electrode, opposite one to the pixel electrode, provides a natural sum of energy of all affected pixels among which the particle deposited charge has been shared.

The distribution of energy between pixels belonging into alpha tracks has been evaluated and dependency between partial energy and time over threshold value counted in individual pixels has been solved. Knowing the energetical dependency, it is possible to form a matrix of calibration parameters. The method has been proved for alpha particles of regular energies. The energy resolution of the pixel detector after calibration is comparable to the resolution of common electrode signal.

Timepix Detector Introduction

The single quantum counting semiconductor pixel detector Timepix [1] is of the Medipix family. Timepix is a hybrid device consisting of a radiation sensitive sensor bump bonded to a readout chip. The Timepix ASIC (fig. 1) chip can be combined by the bump-bonding technology with different semiconductor sensors (i.e. different materials — e.g. Si, GaAs, CdTe; thickness — e.g. 300, 700, 1000 μm and area of 1.4×1.4 cm^2). The sensor consists of 256×256 square pixels with a 55μm pitch. The pixel detector incorporates an independent electronic circuit in the readout chip for each pixel of the sensor. This circuit has an analogue and a digital part. The analogue part contains a preamplifier and a discriminator. The discriminator output is connected to the Timepix Synchronization Logic in the digital part. This unit controls the measurement mode and feeds a 14-bit counter/shift register.

The counter in each pixel can be independently used in one of three modes: a counting mode that counts the number of detected particles, a Time-over-Threshold mode (TOT) that measures the energy deposited per pixel, and a Timepix mode that registers the interaction particle time. Timepix provides two possibilities for the readout of the chip [2]. The first is the serial readout through LVDS lines and the second is the parallel readout through a 32-bit wide CMOS bus.

Other additional way of event acquisition is processing of a signal from the common electrode[3]. It provides naturally summarized charge of all pixels that are hit. It is operated like a standard spectroscopy chain with a regular single pad diode sensor. The fig. 2 bellow demonstrates equivalency between events acquired on the side of the pixel electrode and on the side of the common electrode.

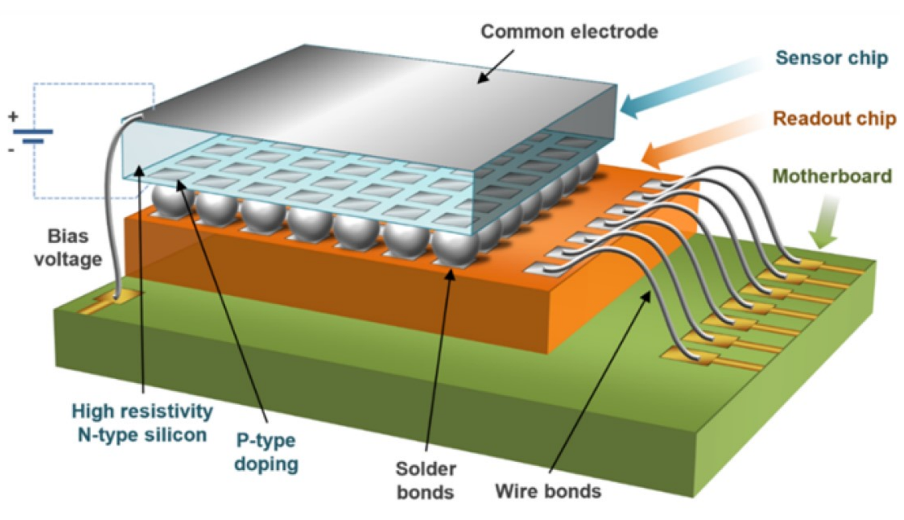

Fig. 1. – Timepix – hybrid pixel detector (read-out chip and sensor assembled together wire bonded to a mother board)

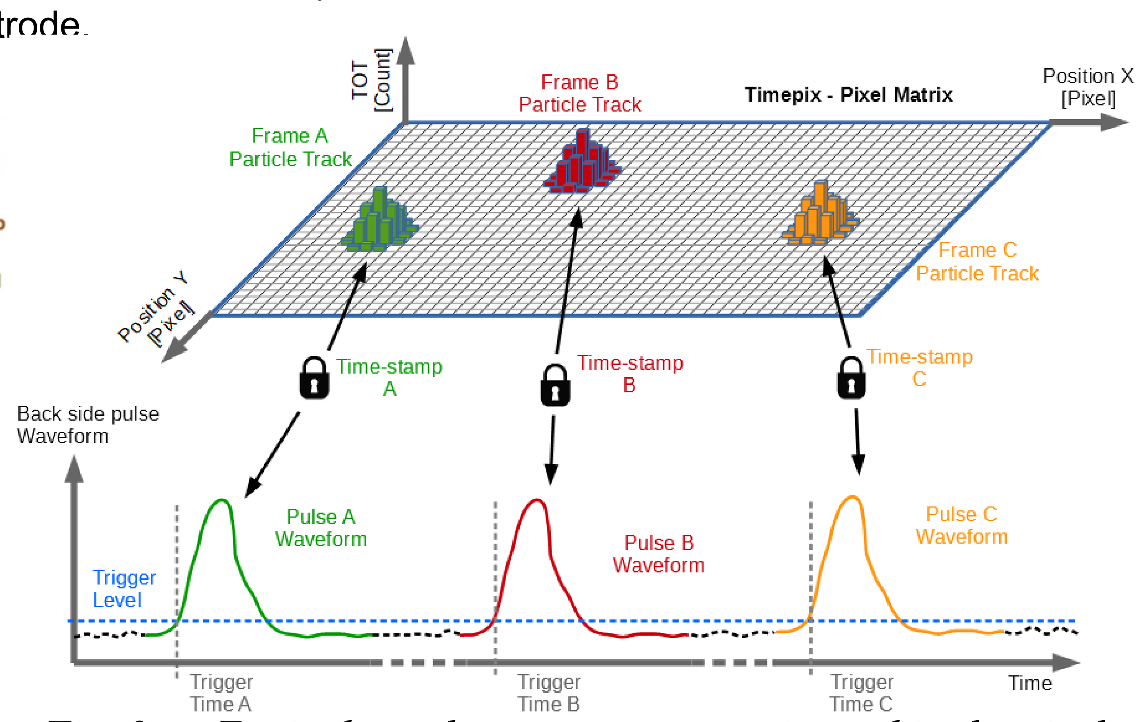

Fig. 2. – Equivalence between events registered in the pixel electrode and the common electrode of the Timepix detector

Calibration Method Procedure Description

The presented calibration method depends on two main inputs as indicated in the introductory part above. The first input is a detector response on hitting particles registered on the pixel side. It is obtained in a form of data matrices. Raw data has to be processed to extract clusters that represent tracks left by interacting particles. Clusters provide information about distribution of energy between a set of pixels. However, it does not provides precise information about absolute value of the deposited energy. Only TOT volume is obtained when all pixel counts are integrated. Therefore other reference input is needed. Precise information about absolute value of deposited energy can be simply gained from the common electrode signal after pulse processing of waveforms and performing of single pad sensor calibration procedure (see fig.4). Each event (in this case alpha hit) provides multiple calibration points (i.e. number of hit pixels in cluster). Dependency of a pixel TOT value on energy can be reconstructed after collection of sufficient amount of calibration points. Finally, generation of calibration coefficients is done by fitting of calibration function on previously obtained calibration points (to be seen in fig. 6).

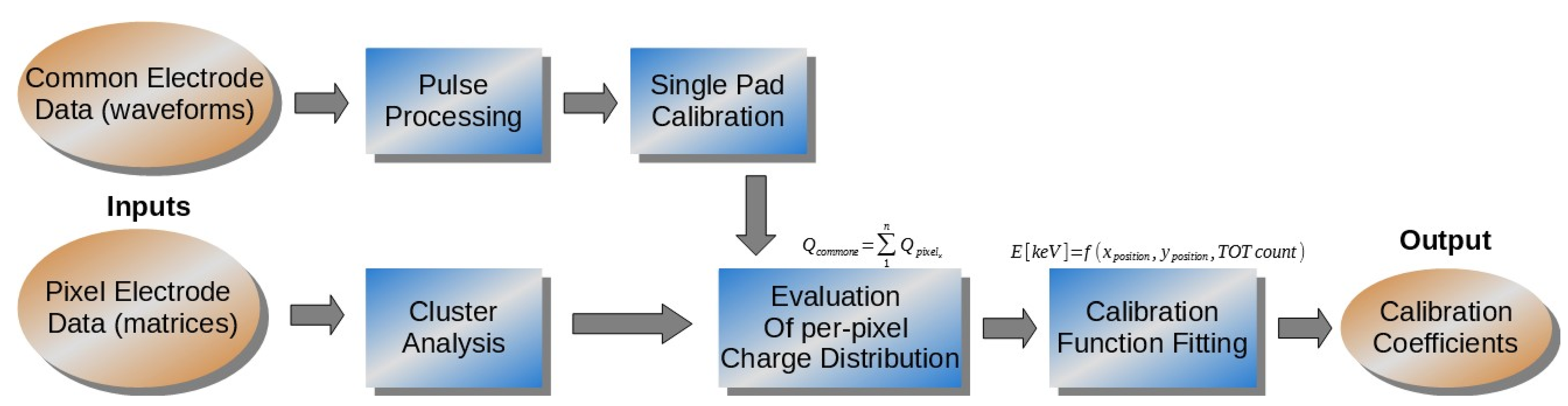

Fig. 3. – Calibration procedure and obtaining response function of individual pixels – TOT value vs Energy

REFERENCES

[1] X. Llopart, R. Ballabriga, M. Campbell, L. Tlustos and W. Wong, Timepix, A 65 k programmable pixel readout chip for arrival time, energy and/or photon counting measurements, Nucl. Instrum. Meth. A 581 (2007) 485

[2] V Kraus, M Holik, J Jakubek, M Kroupa, P Soukup and Z Vykydal, “FITPix — fast interface for Timepix pixel detectors”, 2011 JINST 6 C01079

[3] M. Holik, V. Kraus, V. Georgiev, C. Granja “FITPix COMBO—Timepix detector with integrated analog signal spectrometric readout” 2016 JINST 11 C02032

[4] Holik M., Ahmadov G., Berikov D., Ahmadov F., Kopatch Yu., Nuruyev S., Akbarov R., Abbaszada N., Telezhnikov S., Broulim J., Siroky J., Mora Y., “A synchronization and data acquisition system for silicon detectors “, 2018 JINST 13 C11019

[5] Jan Jakubek, Precise energy calibration of pixel detector working in time – over - threshold mode, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, Volume 633, Supplement 1, May 2011, Pages S262 - S266, ISSN 0168 - 9002

Experimental results

A test measurement has been done using the Timepix detector with 300 um thick silicon sensor while applying 60 V bias voltage. Radiation source Rn266 providing alpha particles with various energies: 4784.34, 5304.33, 5489.48, 6002.35, 7686.82 keV (Ra226, Po210, Rn222, Po218, Po214) was used as a stimulus. The test measurement has been performed in vacuum chamber. Acquired events [4] have been used as an input data set for the presented calibration method.

Partial steps of the calibration procedure are illustrated in the figures bellow. Fig.4 shows a result of energy calibration of common electrode part of the Timepix detector. Result of evaluation of per-pixel charge distribution and fitting of calibration functions is shown in the fig.6. Finally, demonstration of application of obtained calibration coefficients onto raw pixel data is presented in the fig. 7 and fig 8.

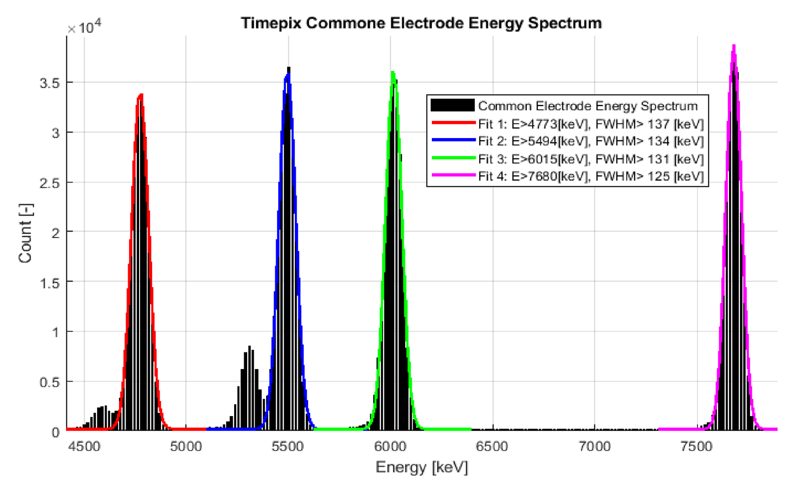

Fig. 4 - Energy spectrum of alpha source obtained by processing common electrode signals (Energy measured is used as a reference in the evaluation process of charge distribution among cluster pixels)

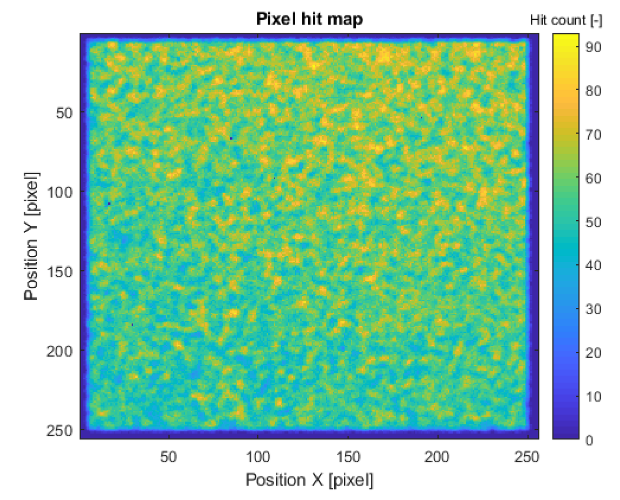

Fig. 5 - Distribution of hits within the Timepix matrix collected during acquisition of calibration data (border region pixels are intentionally masked)

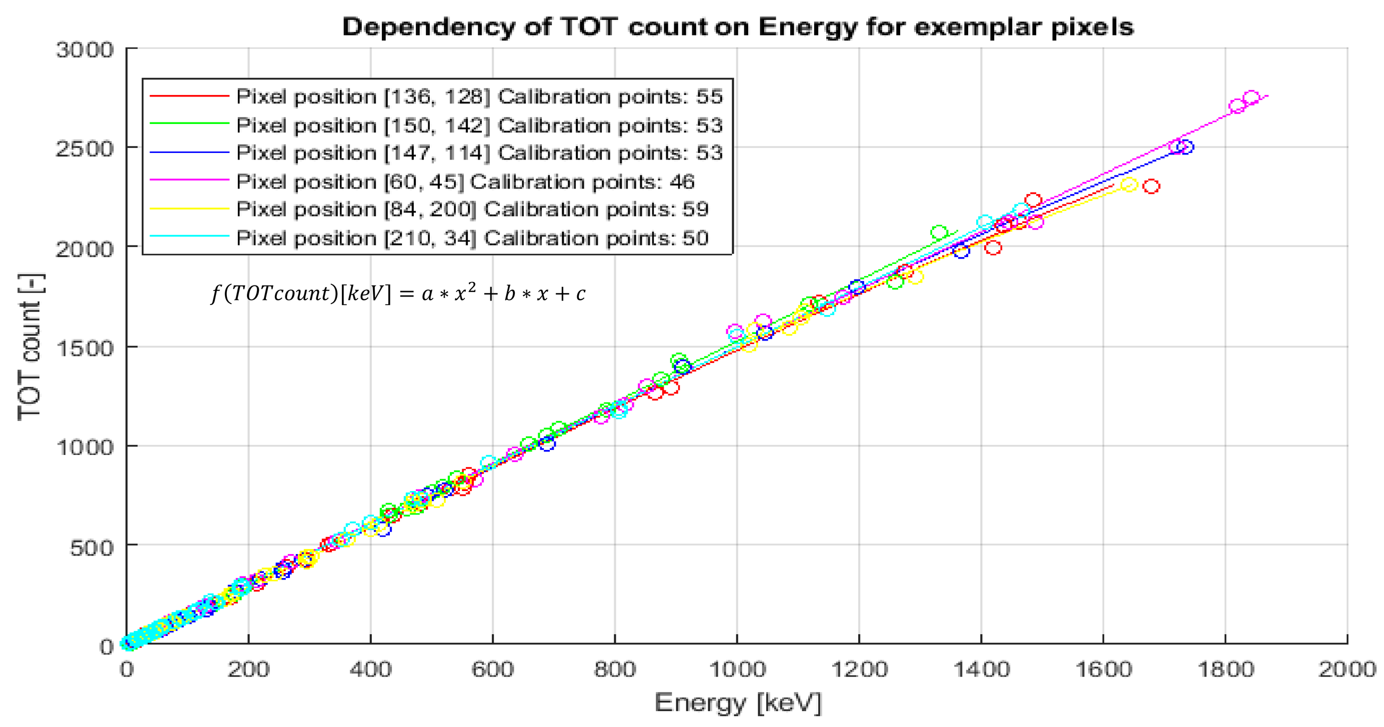

Fig. 6 - Demonstration of output obtained after evaluation of charge distribution among pixels (circle marks stand for calibration points) and calibration function fittings (solid lines stand for calibration curves). Results for several randomly selected set of pixels are shown in the plot.

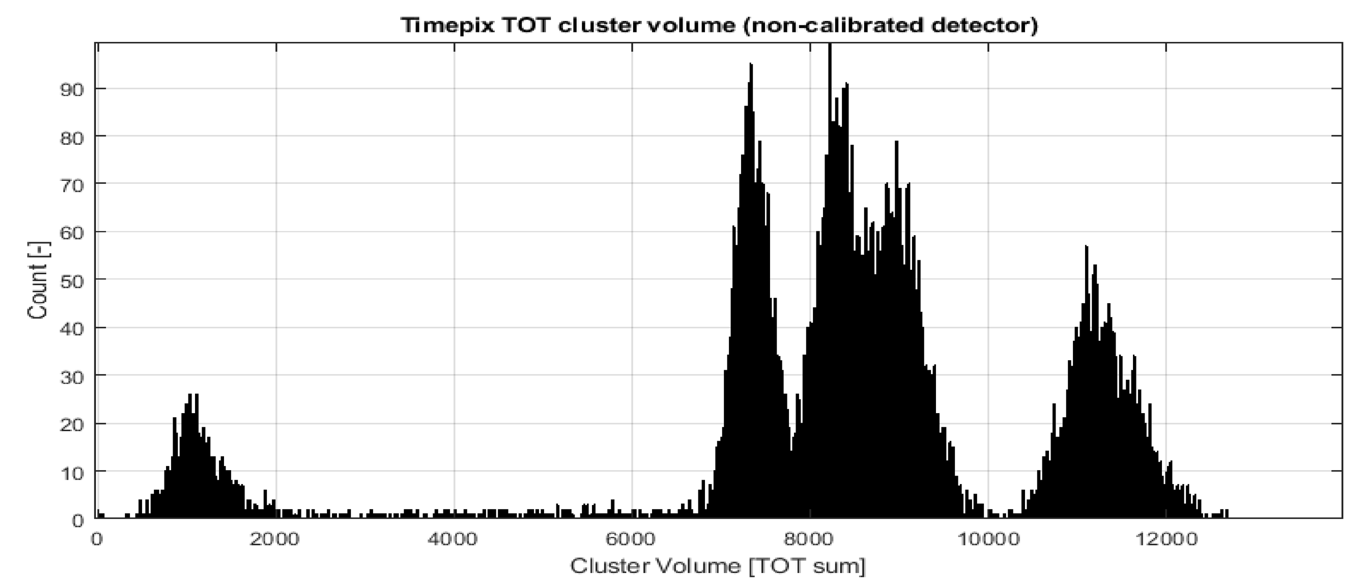

Fig. 7 - Energy spectrum of clusters gained for raw pixel data without application of calibration functions. Cluster volume is a sum of TOT values of pixels belonging into clusters.

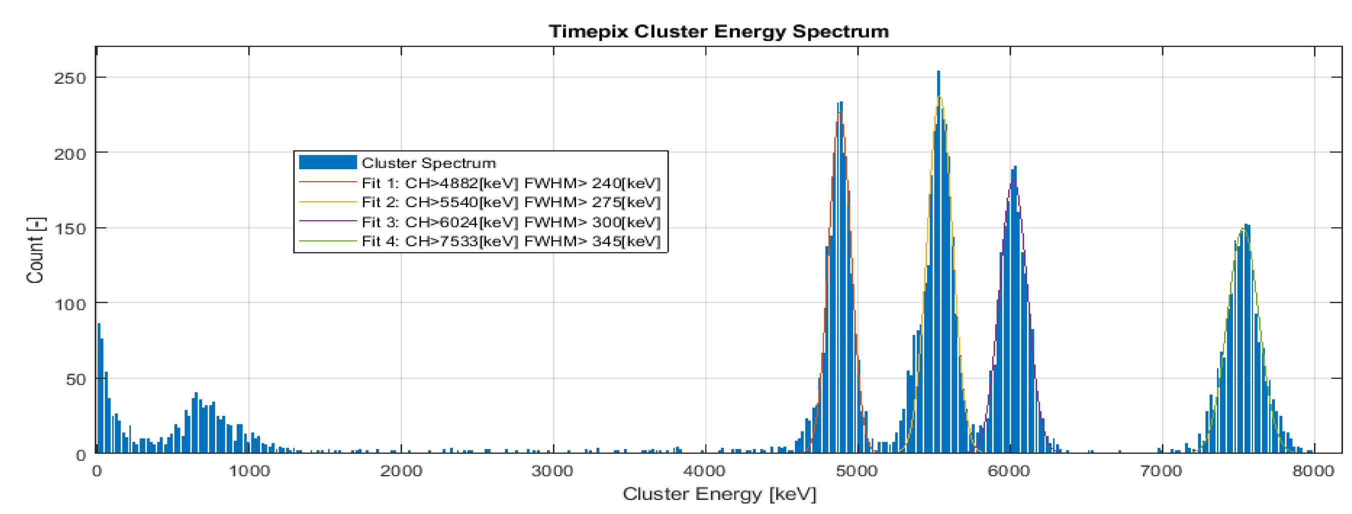

Fig. 8 - Energy spectrum of clusters gained after application of calibration functions for pixels.

CONCLUSIONS

The presented method is one of alternatives to the standard calibration method [5] that is widely used. The presented method exploits energetic ions for calibration in comparison to commonly used one where low energetic particles are used instead.

The first experimental results confirm that the presented method is a suitable for a further study. Significant improvement in resolution may be expected in the evaluation step of the per-pixel charge distribution. Other possible point of enhancement can be expected in region of low energy as the pixel characteristics (i.e. energy vs TOT) is nonlinear but this method does not reflect that fact yet. It can be expected that the method would be also applicable to different pixel detector from the Timepix family or even different one.