Space engineering
Radiation detectors

1. Timepix detector

„The Timepix detector is a pixel-particle-counting detector which can be used for measurements of energies of radiation and particle imaging (photons above approx. 5 keV, neutrons, electrons,…). It is a kind of hybrid pixel semiconductor detector. As a hybrid pixel detector, it has the readout chip and the sensor manufactured separately. Each part has the same matrix of contact electrodes for mechanical and electrical contact through small spherical bonds. The important advantage of this concept is the possibility to use a combination of different materials for the sensor (Si, GaAs, CdTe) with the same readout chip.

Detection layer is divided into 256 x 256 square pixels with 55 µm pitch. Each pixel has its own charge sensitive preamplifier, threshold discriminator and 14-bit counter in bump-bonded CMOS readout circuit. This arrangement allows operation of each pixel in one of three modes: particle counter (Medipix mode), energy measurement (Time over Threshold – ToT mode) and measurement of the interaction time (Timepix mode).“ [1]. The principal scheme is in the Fig.1.

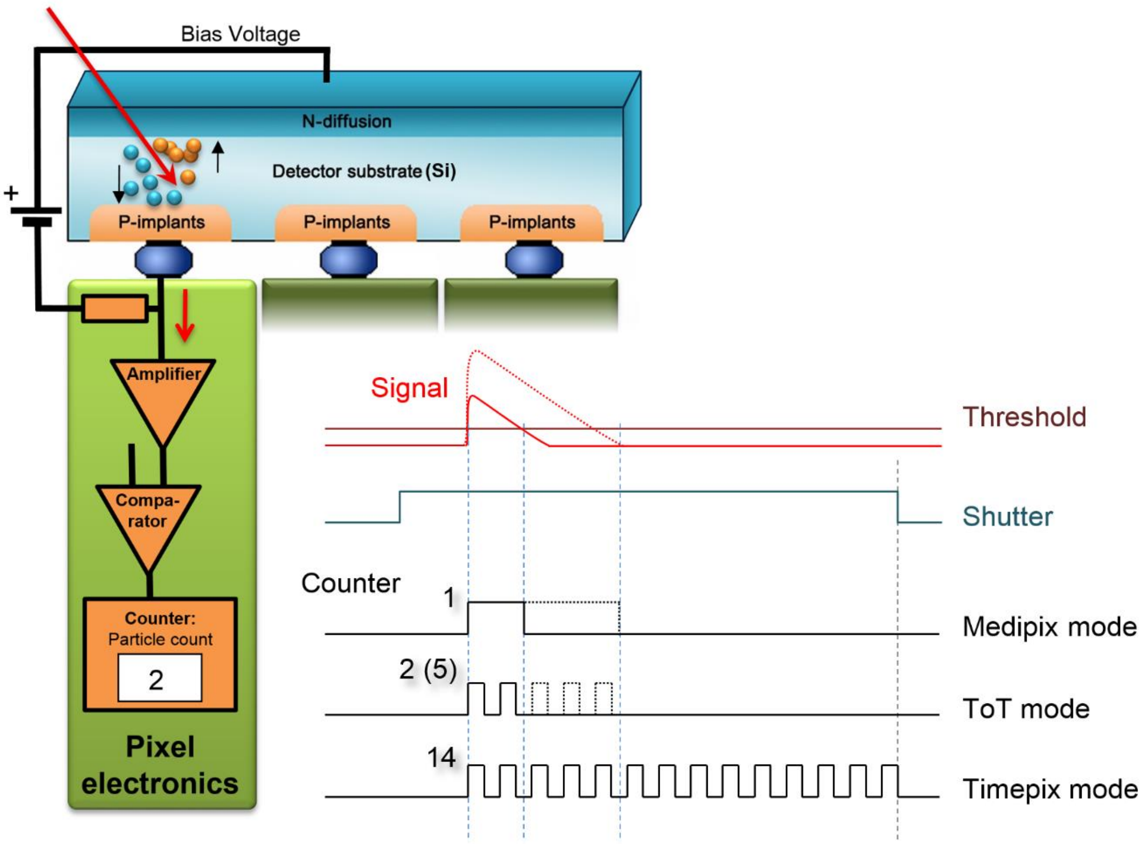

Fig.1: Scheme of principle of signal acquisition of the Timepix detector [2]

2. Particle types

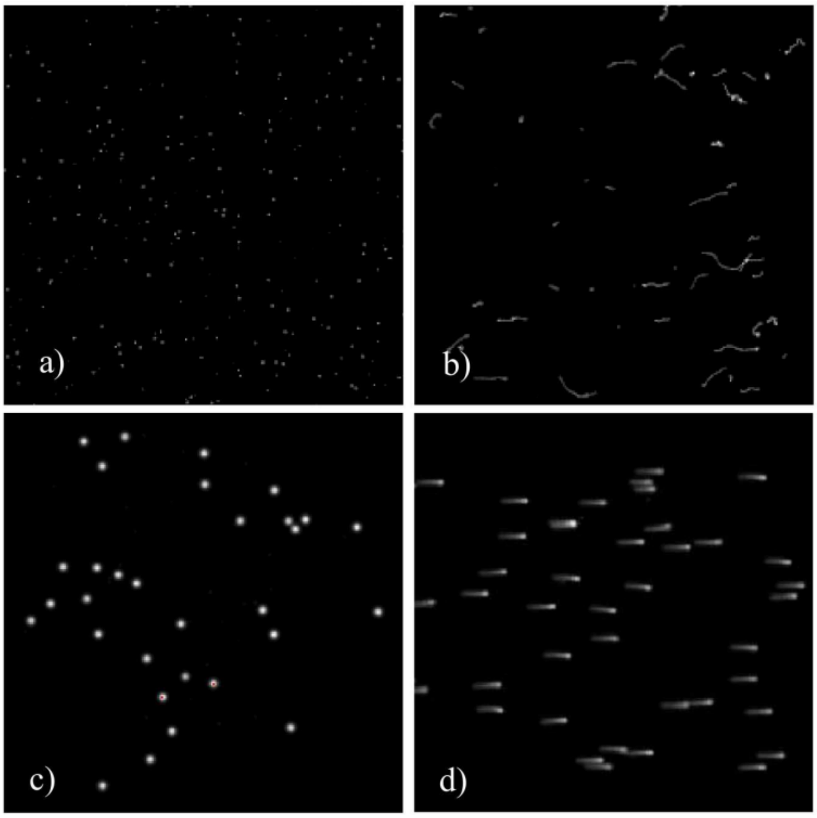

Fig.2.: Typical tracks recorded by Timepix device in TOT mode for different particle types:

a) are tracks of gammas (60 keV) and X-rays (26 keV) from ^{241}Am,

b) are tracks of electrons emitted by ^{90}Sr source,

c) are clusters created by 5.5 MeV alpha particles from ^{241}Am and

d) are traces of 11 MeV protons entering to detector under angle of 85 degrees (coming from left side).[3]

3. Energy calibration

"The device is irradiated by monoenergetic radiation recording a spectrum for each pixel using single pixel clusters only. The spectral peaks are then fitted with Gaussians and four parameters of a surrogate function *f(x)* describing the energy response of each pixel are computed by another fit. This procedure requires the measurement of at least 4 spectral lines and performance of at least five least-squares fits for each pixel." [4]

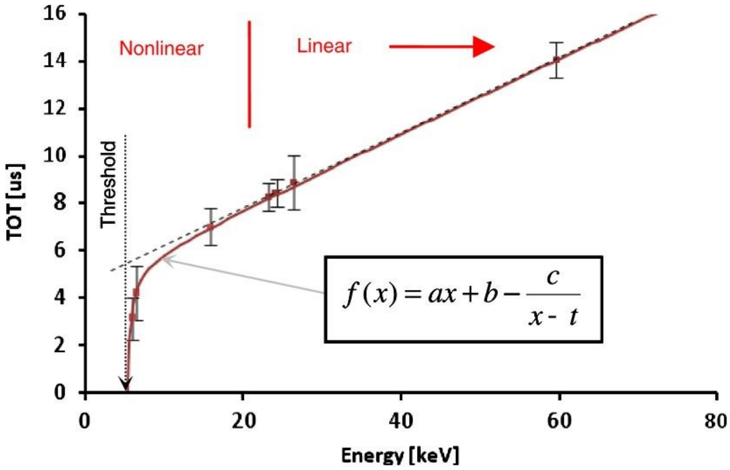

Fig.3:. Dependence on particle energy of the time-over-threshold signal measured by a single Timepix pixel. [4]

Acquired TOT frames have to be calibrated per pixel to energy using inverted form of surrogate function *f(x)*, then radiation energy can be determined.

Inverted surrogate function f^{-1} transforming TOT (*y*) to energy (*x*):

$$x = \frac{ta + y - b + \sqrt{(b + ta - y)^2 + 4ac}}{2a}$$

Tab.1.: Examples of Elements with X-ray Energies

Element	Energy (keV)
Aluminium (Al)	1,486
Iron (Fe)	6,405
Copper (Cu)	8,046
Americium (Am)	59,5409 (gamma)
Zirconium (Zr)	15,775
Cadmium (Cd)	23,173

4. Task

- Perform the evaluation of data measured in ToT mode using calibration matrixes *a, b, c* and *t*. Implement a function f^{-1} and plot radiation spectra. According to the obtained energy spectra, specify the element type from the Tab.1.
- Implement single-photon filtration and compare the results.

References

[1] M. Urban, "*New methods of environment monitoring for space applications*", Doctoral thesis proposal (2017)
[2] M. Platkevič, "*Signal Processing and Data Read-Out from Position Sensitive Pixel Detectors*", PhD thesis (2014)
[3] J. Jakůbek, "*Semiconductor Pixel Detectors and their Applications in Life Sciences*", 2009 JINST 4 P03013 doi:10.1088/1748-0221/4/03/P03013
[4] J. Jakubek, "*Precise energy calibration of pixel detector working in time-over-threshold mode*", Nucl. Instrum. Methods A, 633 (2011), doi: 10.1016/j.nima.2010.06.183