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TPU – NPI Monthly seminar

«Software design for a detector of ionizing radiation»

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28th April
2017

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Presentation overview

1. Transfer to the computer and graphical visualization of energy spectra;
2. Comparison of two methods of obtaining energy spectra;
3. Implementation of false signal filtration;
4. Dosimetric calibration of the detector using alpha particles from radiation sources ^{252}Cf, ^{241}Am, ^{239}Pu;
5. Next steps and conclusion.

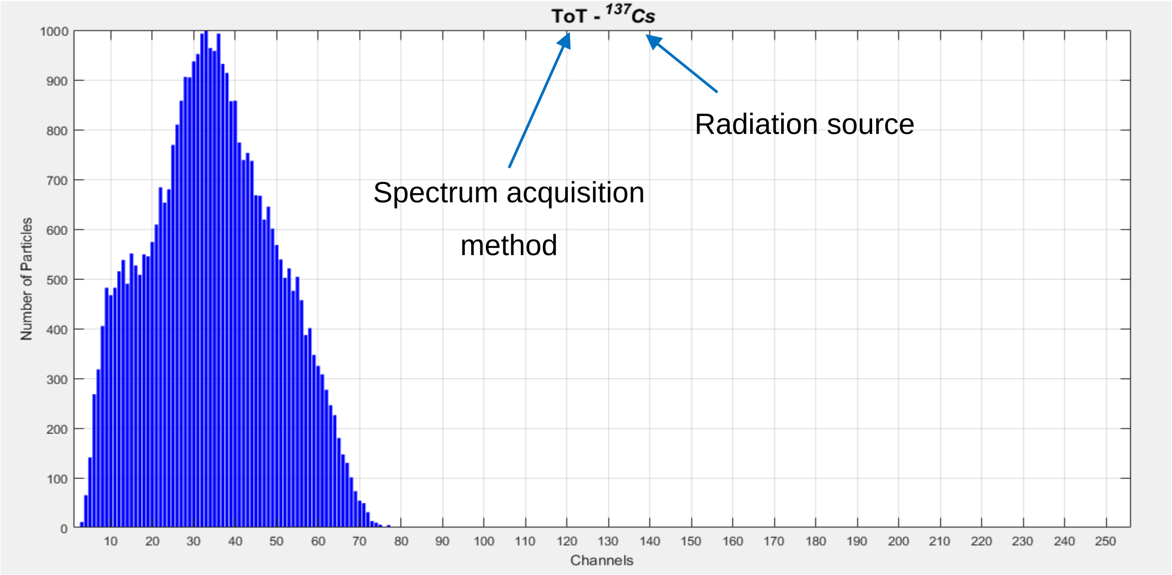
Transfer to the computer of energy spectra

Transmission stages:

1. UART of the STM32L053 board
2. UART-USB converter model CP2102
3. Putty.exe program
4. Matlab 2016b application package

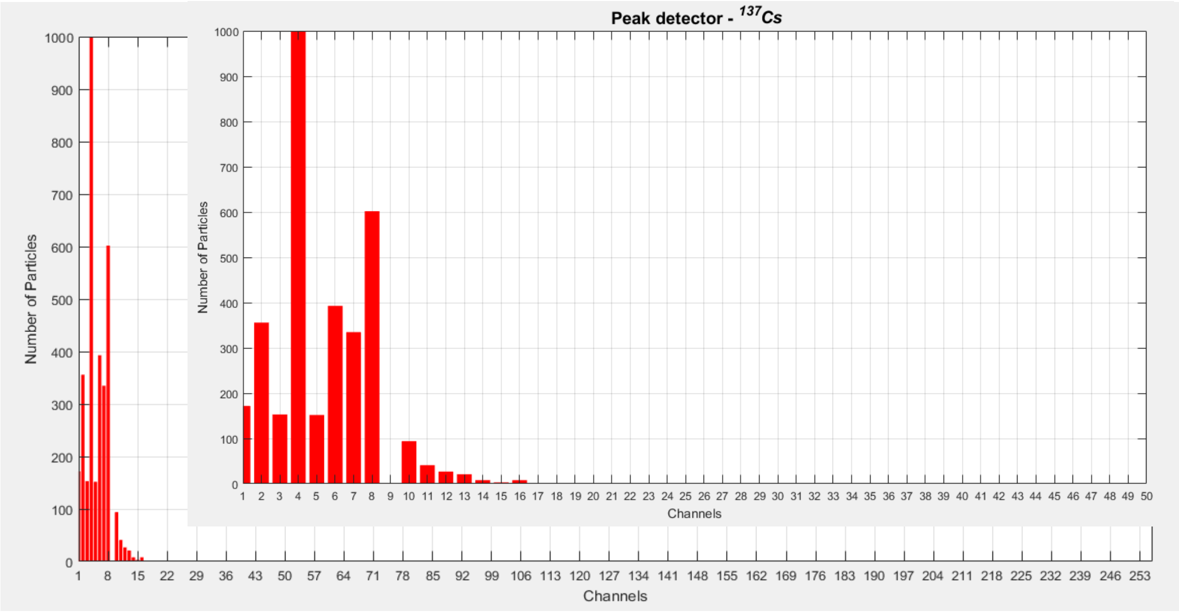
Appearance of the UART-USB converter model CP2102

Graphical visualization of energy spectra



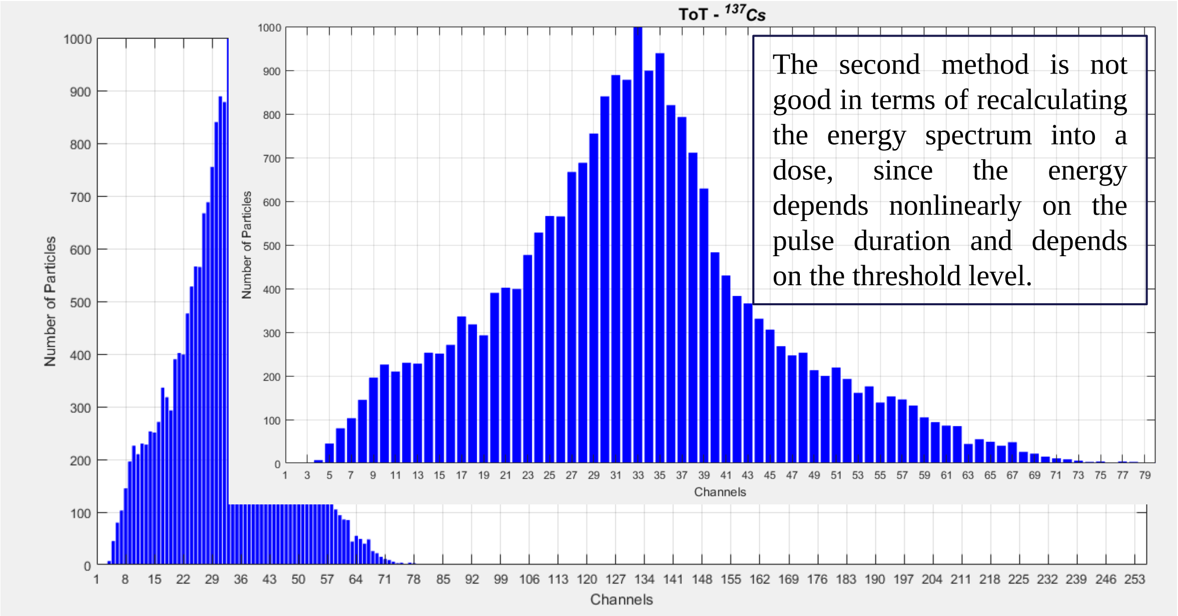
Example of the energy spectrum

Comparison of two methods of obtaining energy spectra



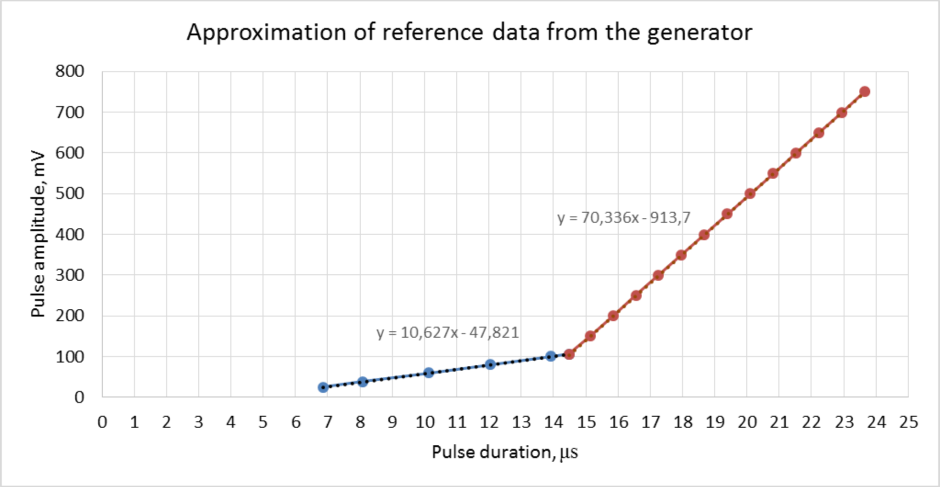
Spectrum of the photons from ^{137}Cs (peak detector)

Comparison of two methods of obtaining energy spectra



Spectrum of the photons from ^{137}Cs (time over threshold detector)

Implementation of the false signal filtration



Two filtration equations are obtained: for pulses with a duration less than 14.5 μs - equation (1), and more than 14.5 μs - equation (2).

$$V = 10.63 * T - 47.82, \quad (1)$$

$$V = 70.34 * T - 913{,}7, \quad (2)$$

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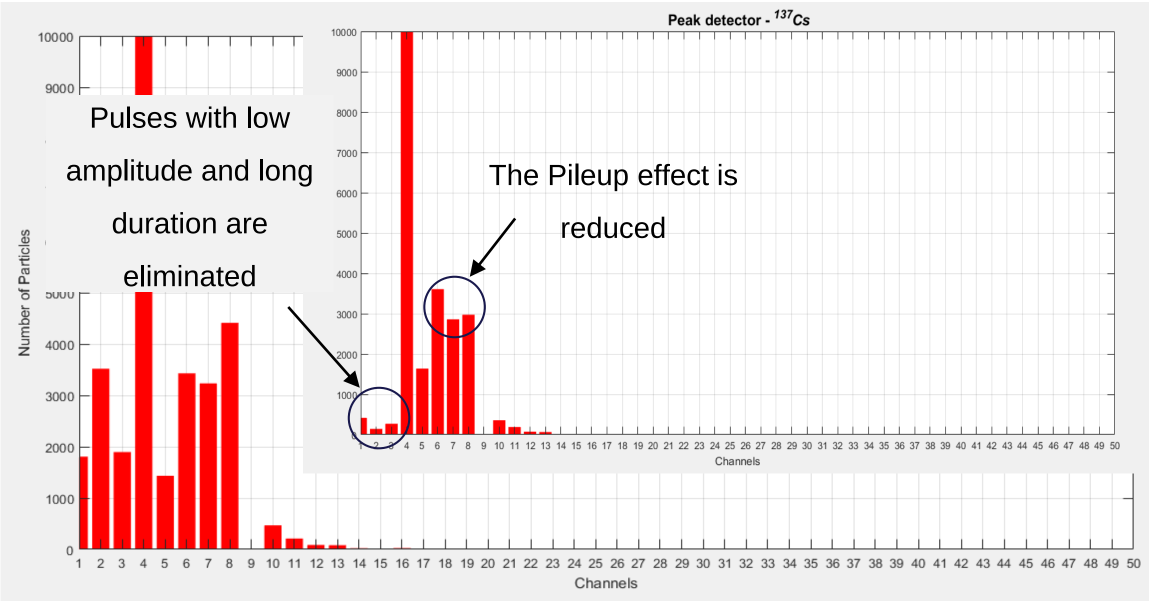
Result of the false signal filtration



Result of the filtration for the radiation source ^{137}Cs

Filtration characteristics

Type of experiment	N_{TOTAL}, particles	N_{LOST}, particles	δ_{LOST}, %
Without filtration	34456	0	0
With filtration	28406	5776	20,33

The quality of pulse recording has been significantly improved. This plays an important role in recalculating the energy spectrum into radiation dose.

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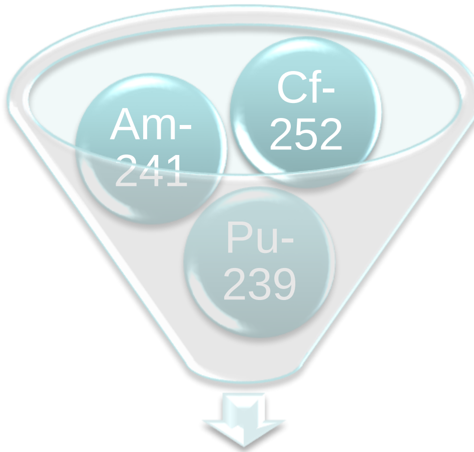
Dosimetric calibration of the detector using alpha particles

- Calibration is important for the correct conversion of the energy spectrum into **an absorbed dose D**.
- For this purpose it is necessary to determine **the channel width** of the energy spectrum.
- Since high-energy particles are present in cosmic rays, commercially available radionuclide sources of α-radiation have been chosen for this calibration: **californium-252, americium-241, plutonium-239.**



Channel width [keV/channel]

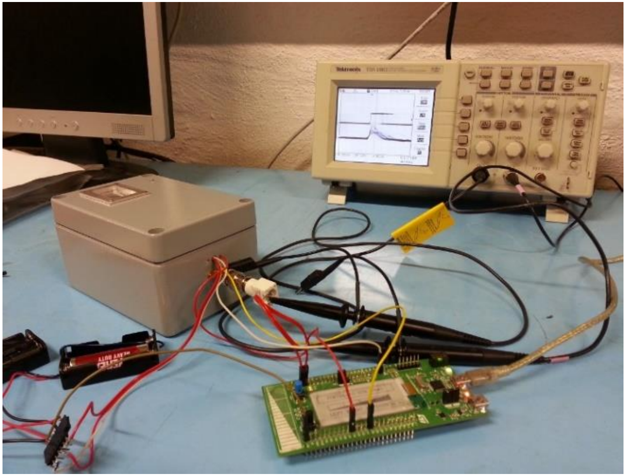
Radiation sources for calibration of the detector

General information about radiation sources

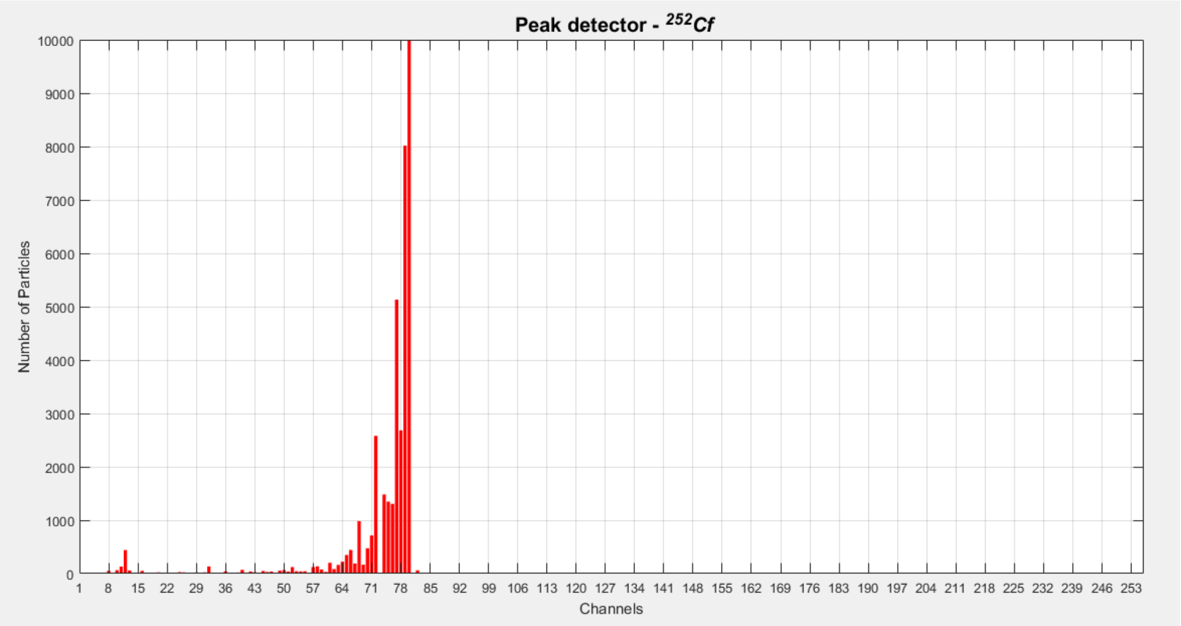
Radiation source	Particle type	Energy, keV	Intensity, %
^{252}Cf	α	6118,24	84,20
		6075,77	15,70
^{241}Am	α	5485,56	84,50
		5442,80	13,00
	γ	59,54	35,90
^{239}Pu	α	5156,59	73,30
		5144,30	15,10
		5105,50	11,50

Experimental conditions

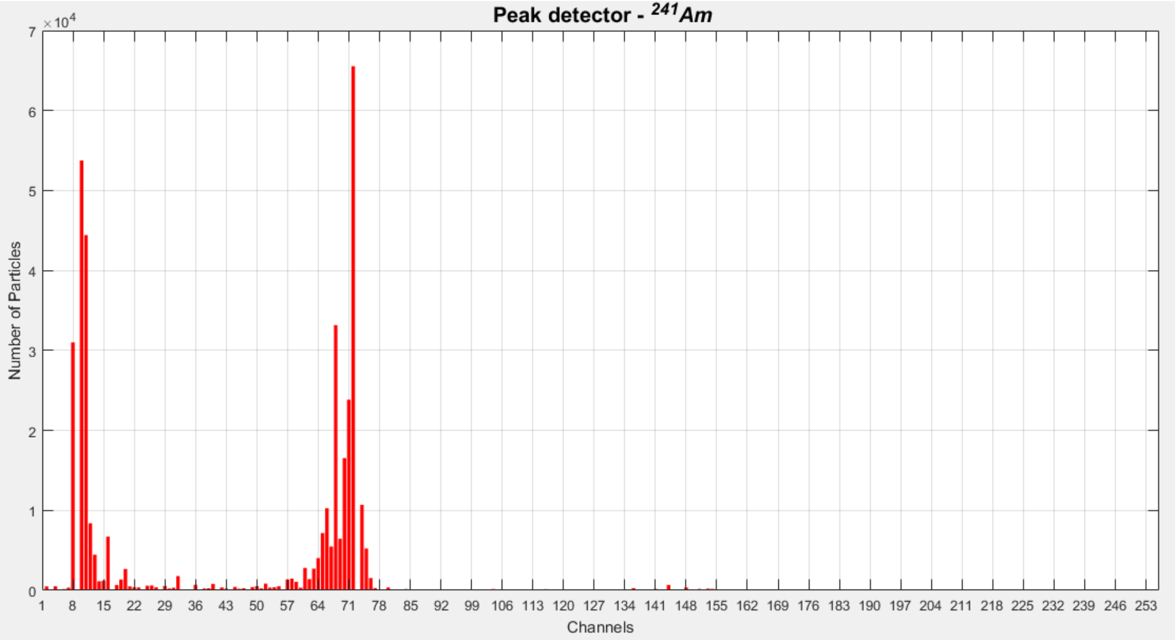
- In the detector the original photodiodes TEMD5080X01 with an epoxy layer was replaced by a photodiode S2744-09 **without a protective epoxy layer**.
- The spectra was recorded with the minimum distance between the radiation source and the photodiode.



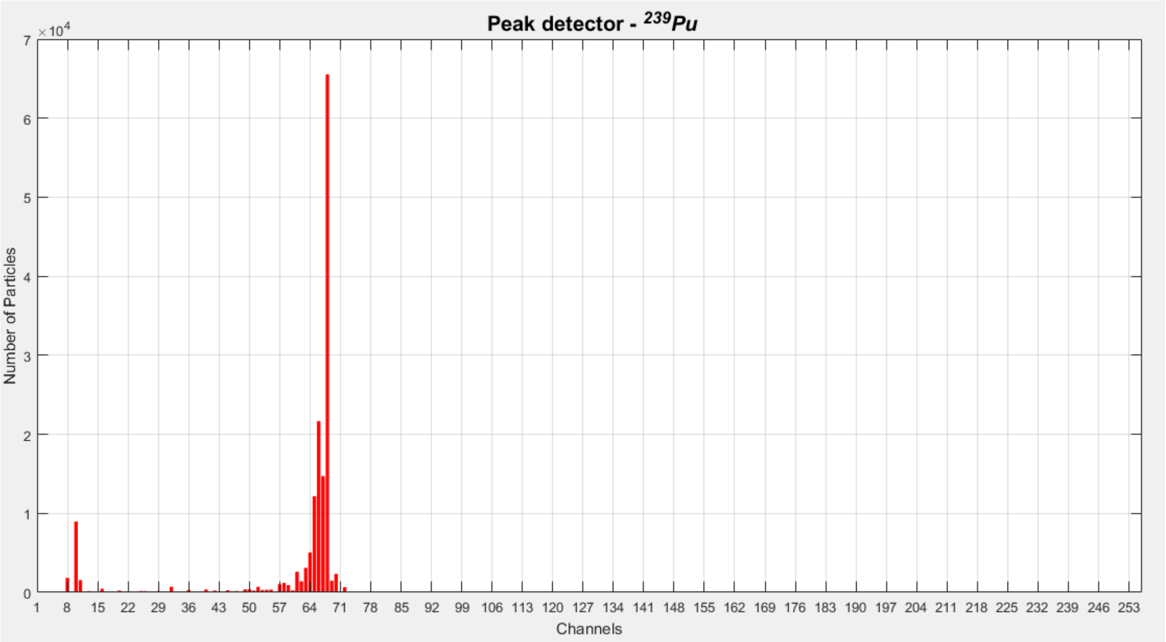
Energy spectra of α particles from the radiation source ^{252}Cf



Energy spectra of α particles from the radiation source ^{241}Am



Energy spectra of α particles from the radiation source ^{239}Pu



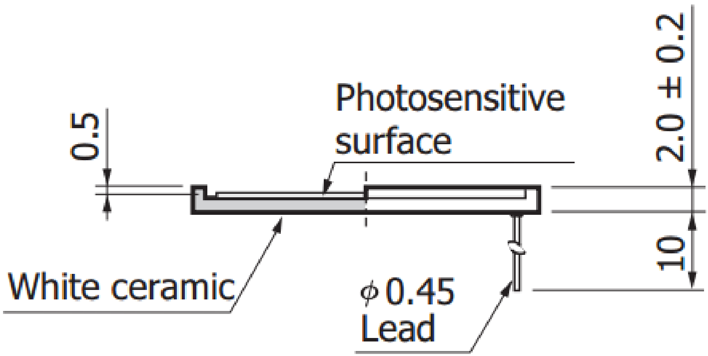
Calculation of the channel width

Comparing the energy of α particles from different sources with their peaks, it is possible to calculate the amount of energy per channel of the energy spectrum.

Radiation source	Energy, keV	Channel number of the peak	Channel width, keV/channel	Average channel width, keV/channel
^{252}Cf	6118,24	80	76,48	76,17
^{241}Am	5485,56	72	76,19	
^{239}Pu	5156,59	68	75,83	

Energy loss for air ionization by α particles

Between the radiation source and the sensitive surface of the photodiode there is a gap filled with air (0.2 mm) due to the construction of the photodiode.



Model of silicon PIN-photodiode S2744-09 - side view

Energy loss for air ionization by α particles

Using the SRIM program, the value of energy loss by α-particles (6 MeV) in air was calculated. This value equals 80.78 keV/mm. Thus, the energy loss in the gap of the photodiode can be calculated from the equation (3):

$$E_{loss} = 80{,}78\,\frac{keV}{mm} \cdot 0{,}2\,mm = 16{,}16\,keV \tag{3}$$

Subtracting the energy loss from the initial source energies, the corrected value of the average channel width of the energy spectrum was obtained.

Result of detector calibration with α particles adjusted for air ionization

Radiation source	Energy, keV	Channel number	Channel width, keV/channel	Old average channel width, keV/channel	New average channel width, keV/channel
^{252}Cf	6102,08	80	76,28	76,17	75,96 ≈ 76
^{241}Am	5469,40	72	75,96		
^{239}Pu	5140,43	68	75,60		

The relationship between the absorbed energy in photodiode and the channel number is described by the equation (4):

$$\varepsilon_i = i \cdot \Delta\varepsilon, \qquad (4)$$

where i is the channel number, $\Delta\varepsilon = 76 keV/ch$ is the channel width.

Conclusion

Progress (from 27.03 to 28.04):

- ✓ Data transfer and graphical visualization of spectra are configured.
- ✓ Two methods of measuring particles energy are compared. The second method is considered the worst.
- ✓ Filtration of the false signals is implemented and tested.
- ✓ Dosimetric calibration of the detector using 6 MeV alpha particles is carried out. The channel width of the energy spectrum equals 76 keV/channel.

Next steps:

- ➢ To calibrate the detector with 1 and 3 MeV protons in the Tandetron laboratory;
- ➢ To calculate the absorbed dose D and ambient dose equivalent H*(10);
- ➢ To carry out final experiments in the Cyclotron and Microtron laboratory.
- ➢ To compare the data with the commercially available Liulin detector with silicon diode;