

Energy calibration of GaAs:Cr-based Timepix detector with alpha particles

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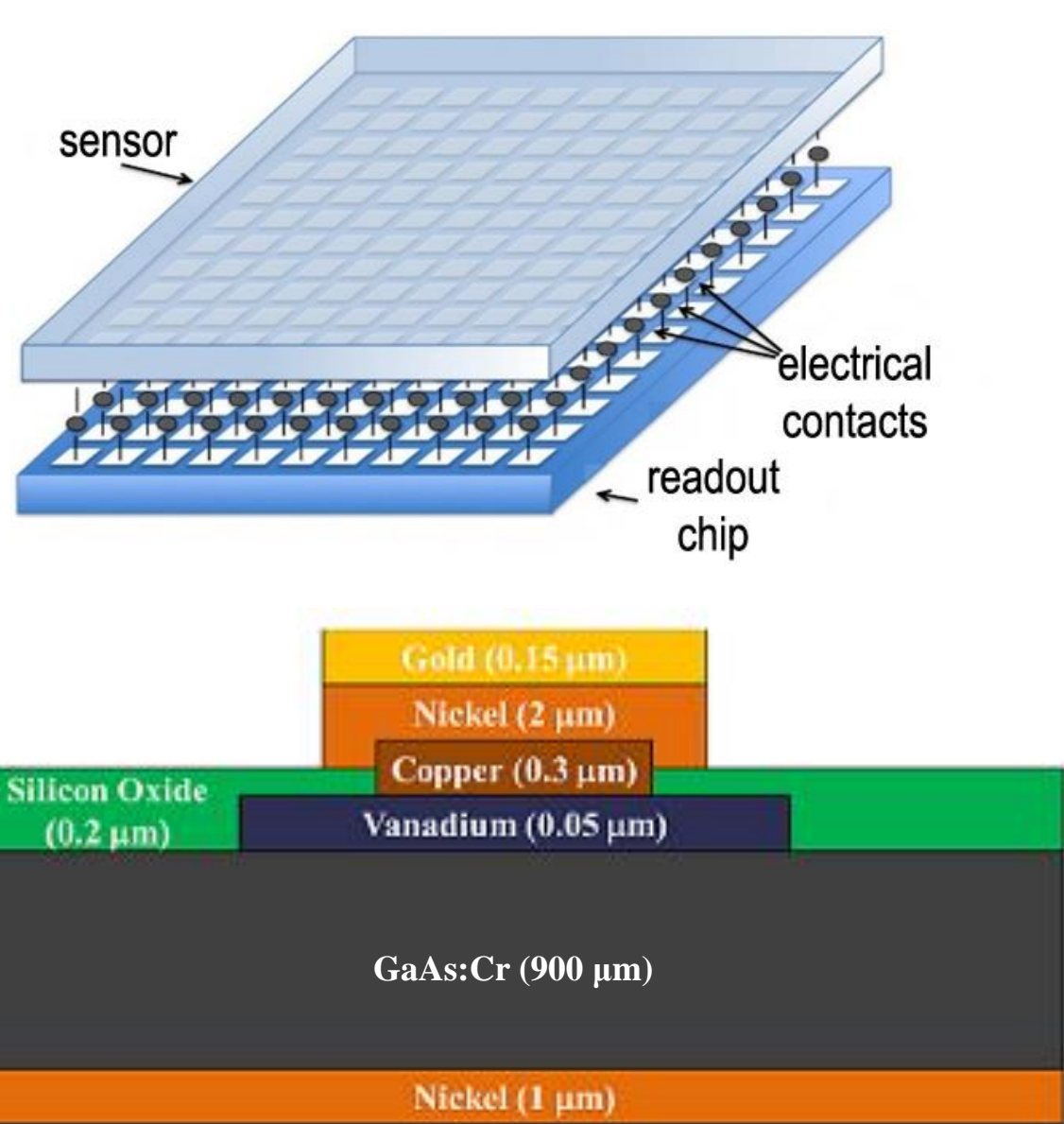
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Abstract

The advanced GaAs:Cr material for radiation detection is in the scope of many scientific and technological institutions in the world, as consequences of its proved superior properties and economic advantages. Experiments made at the JINR Dzhelepov Laboratory of Nuclear Problems for the energy calibration of a hybrid GaAs:Cr-based Timepix detector with alpha particles reaffirm that this device is able to register this particle in energy range from 3140 keV to 7687 keV. The mathematical simulation was used to calculate the transmitted energy, making possible the experimental calibration with the use of Mylar as absorbent. By calibrating the detector with characteristic X rays of some target materials and using a two steps fitting procedure was determined the relationship between the photon energies and the registered by the detector TOT counts. The energy calibration with alpha particles was performed according to linear function $y = 362.08 + 2.41 x$, with $R^2 = 0.99$, and verified with the measurement of the ²¹⁸Po line of radon in air.

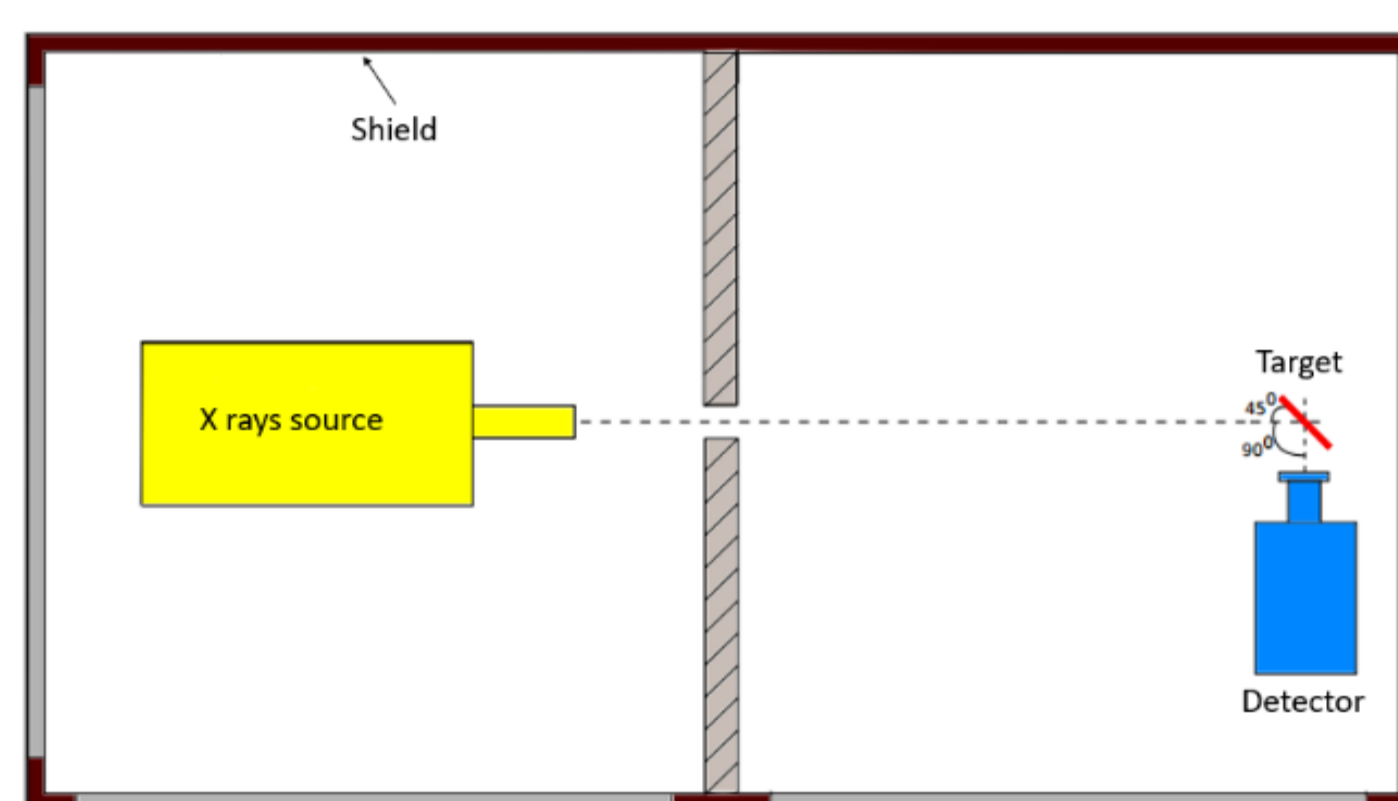
Materials and methods

General scheme of the hybrid detector and graphical representation of the single pixel basic structure



GaAs:Cr sensor of 900 μm
256 x 256 array of 45 μm anode pixels
with 10 μm spacing

Schematic representation of reflection geometry used for characteristic X-rays measurements



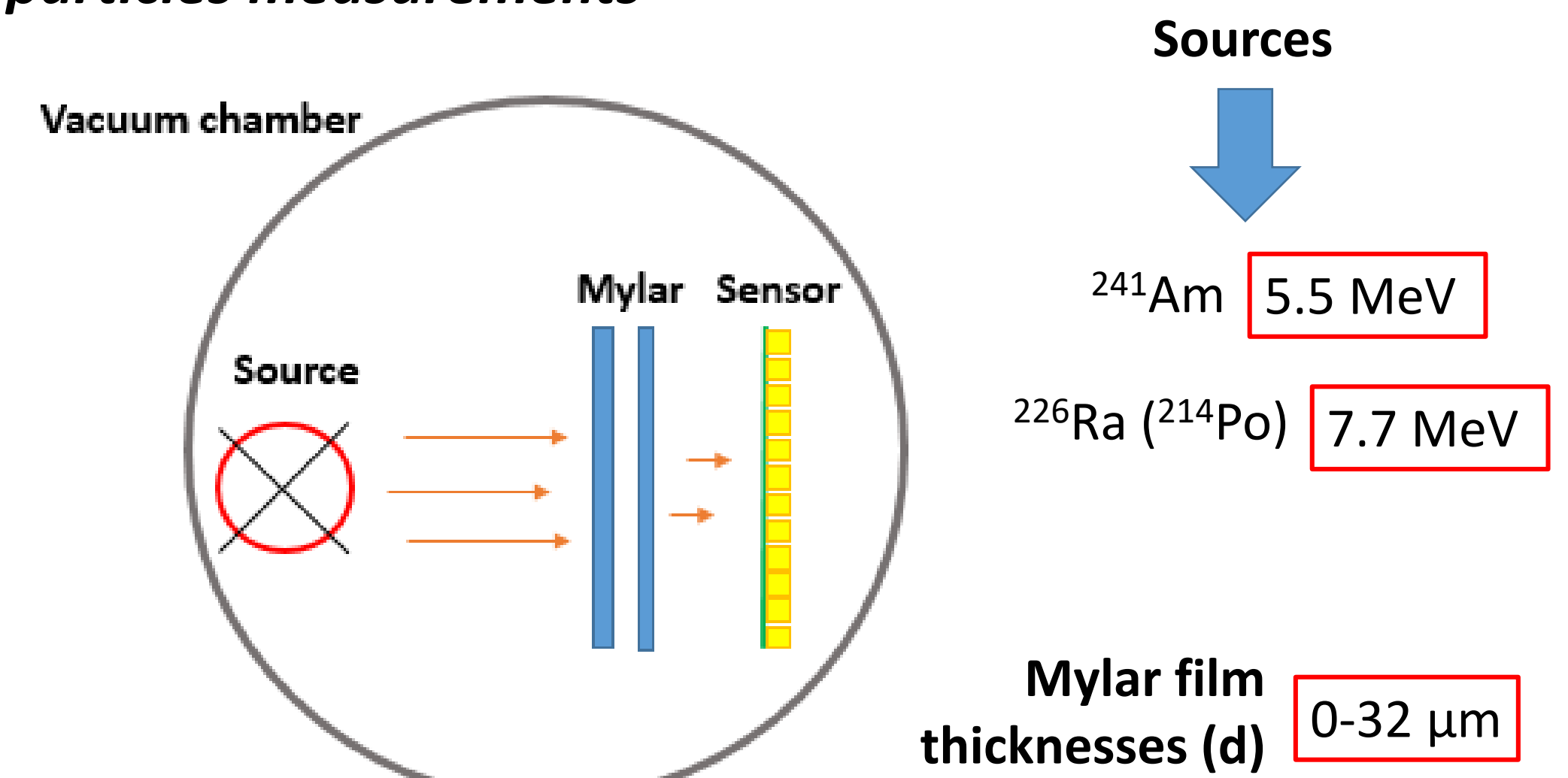
Element	$K_{\alpha 1}$ (keV)
²⁸ Ni	7.48
²⁹ Cu	8.04
³⁰ Zn	8.64
⁴⁰ Zr	15.78
⁴² Mo	17.48
⁴⁵ Rh	20.22
⁴⁸ Cd	23.17
⁴⁹ In	24.2
⁵⁰ Sn	25.27
⁷³ Ta	57.54

$K_{\alpha 1}$ lines of characteristic fluorescence X-rays emission energies of different targets used for preliminary calibration.

X-ray tube SB120

60 kV and 20 μA

Schematic representation of the experimental configuration inside of the vacuum chamber for alpha particles measurements



Sources

²⁴¹Am 5.5 MeV
²²⁶Ra (²¹⁴Po) 7.7 MeV

Mylar film thicknesses (d) 0-32 μm



SRIM-2013.0

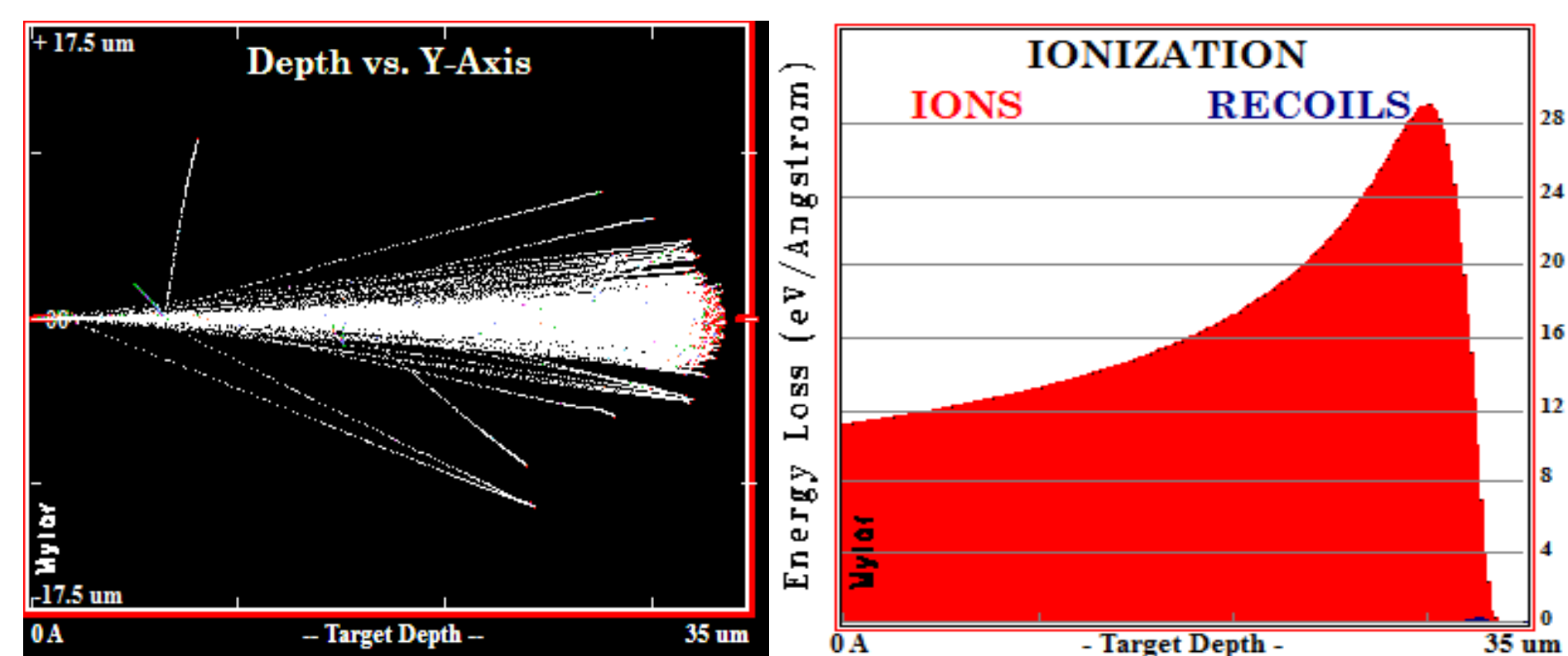
Energy loss of 5.5 MeV alpha particles (²⁴¹Am source) crossing Mylar film



Operations Parameters:
-300 V bias voltage, 16 MHz frequency and THL = 180 DAC

Results

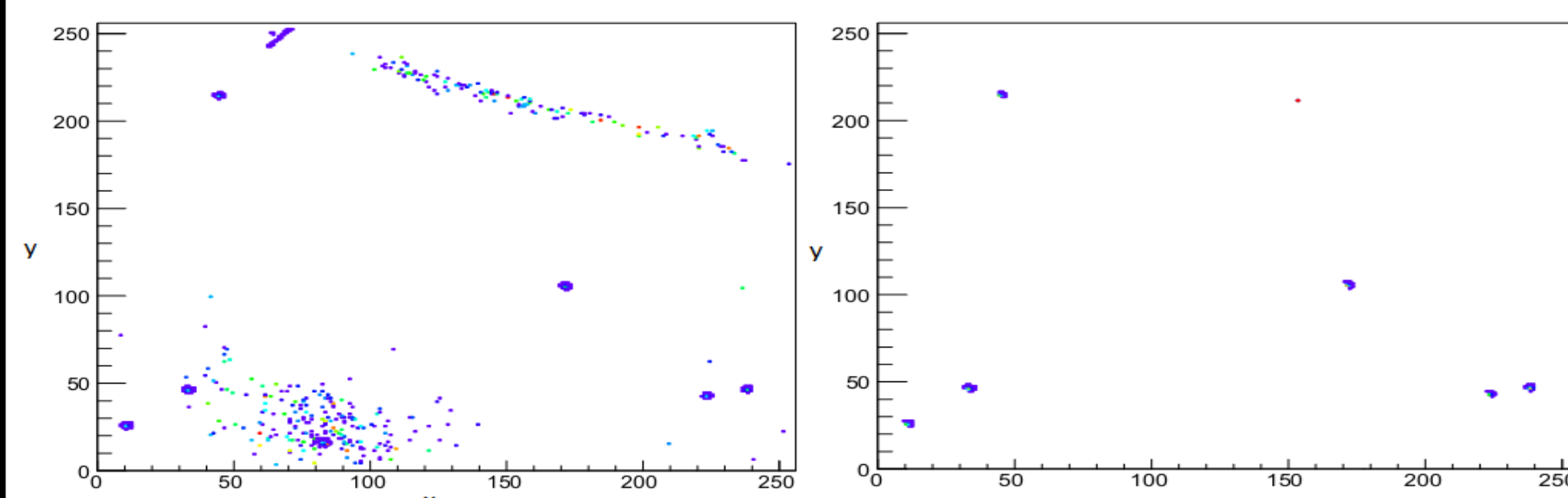
Representations of ion tracks projected in plane and ionization profiles in depth produced by particles crossing 35 μm of Mylar film



d(μm)	Ed (eV)	E'(keV)
0	0	5500
6	695225,33	4800
12	1468092,04	4030
15	1889793,89	3610
18	2355595,83	3140
32	5401103,36	100

Relationship of Mylar film thicknesses, mean energy loses within the material and the output alpha particle energies.

Energy calibration of detector with alpha particles

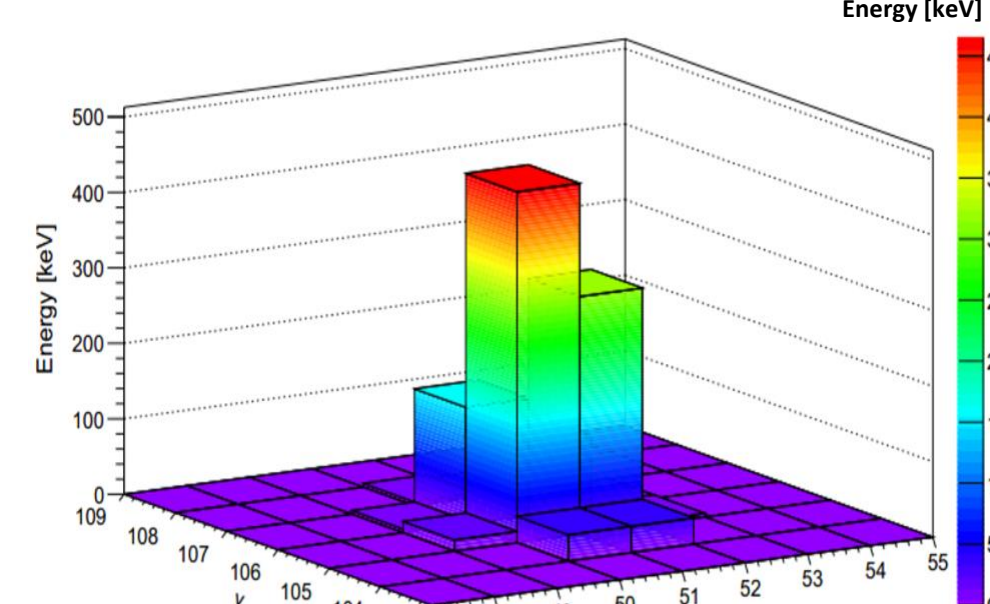


Detector illumination for 5 frames (left) and α cluster for α particles with 5.5 MeV after cluster selection (right)

Clustering

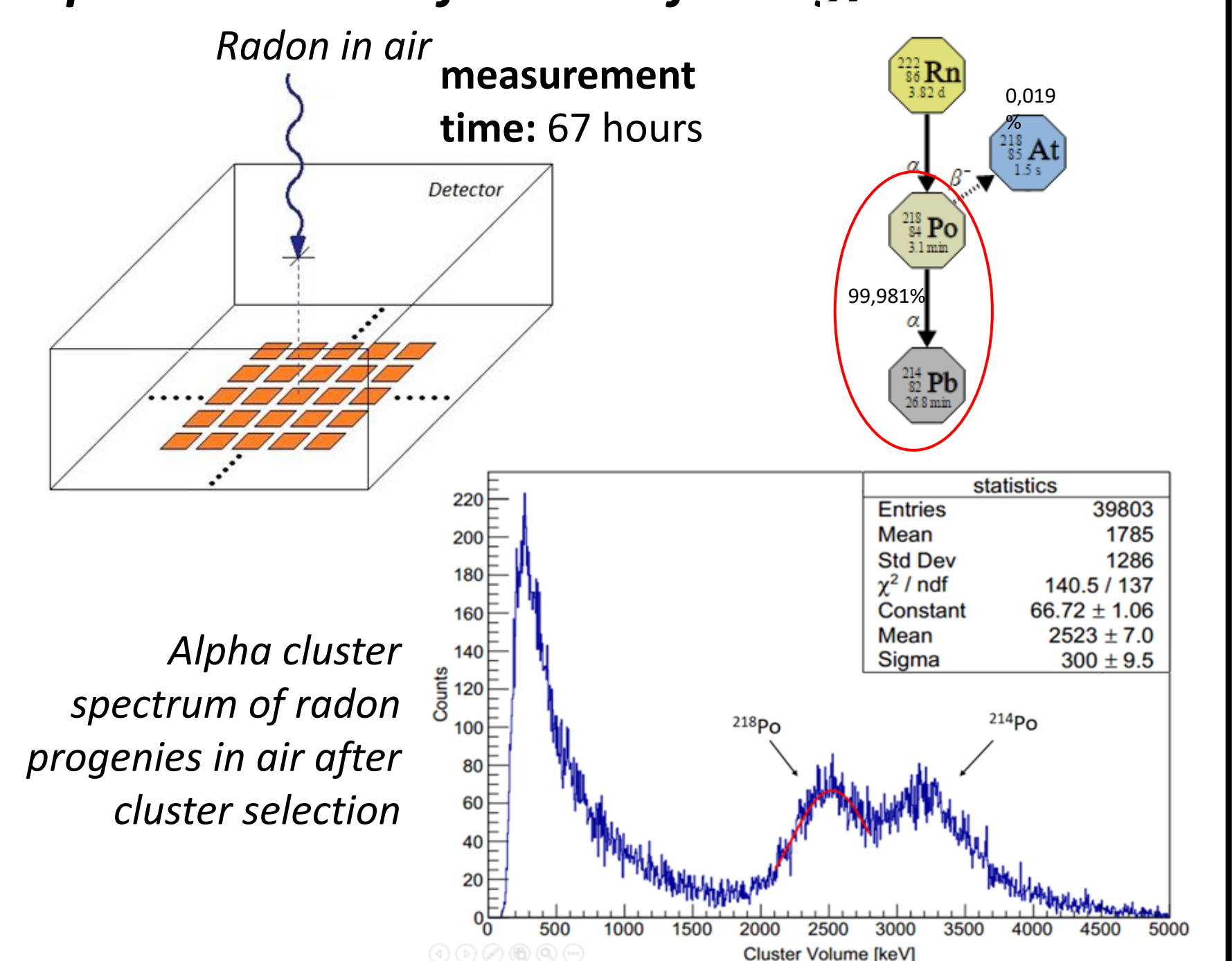
Cluster height: 80 - 1700 keV
Cluster size: 10 - 10000 pixels

Cluster volume [TOT] ↔ Cluster volume [eV]



Pixels cluster caused by single alpha particle with 7627 keV

Experimental verification of energy calibration



Alpha cluster spectrum of radon progenies in air after cluster selection

Reported result: $E' = 6115$ keV
Experimental result: $E' = 6434 \pm 380$ keV

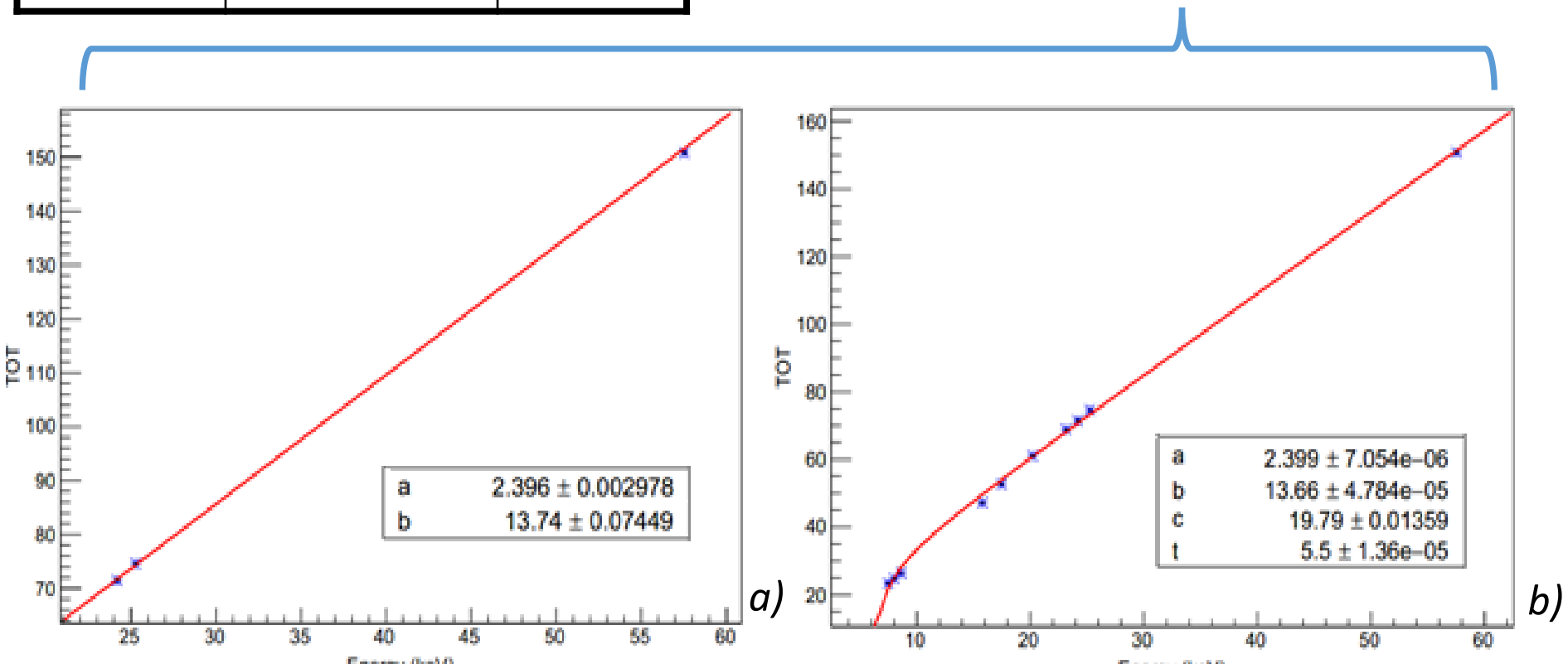
Energy calibration with characteristic X-rays

Photon energy (keV)	TOT [DAC] mean value	Sigma
7.48	23.34	7.265
8.04	24.79	7.374
8.64	26.37	8.162
15.78	47.18	9.52
17.48	52.68	9.299
20.22	61.03	8.881
23.17	68.88	9.18
24.2	71.48	9.691
25.27	74.55	9.517
57.54	150.8	21.29

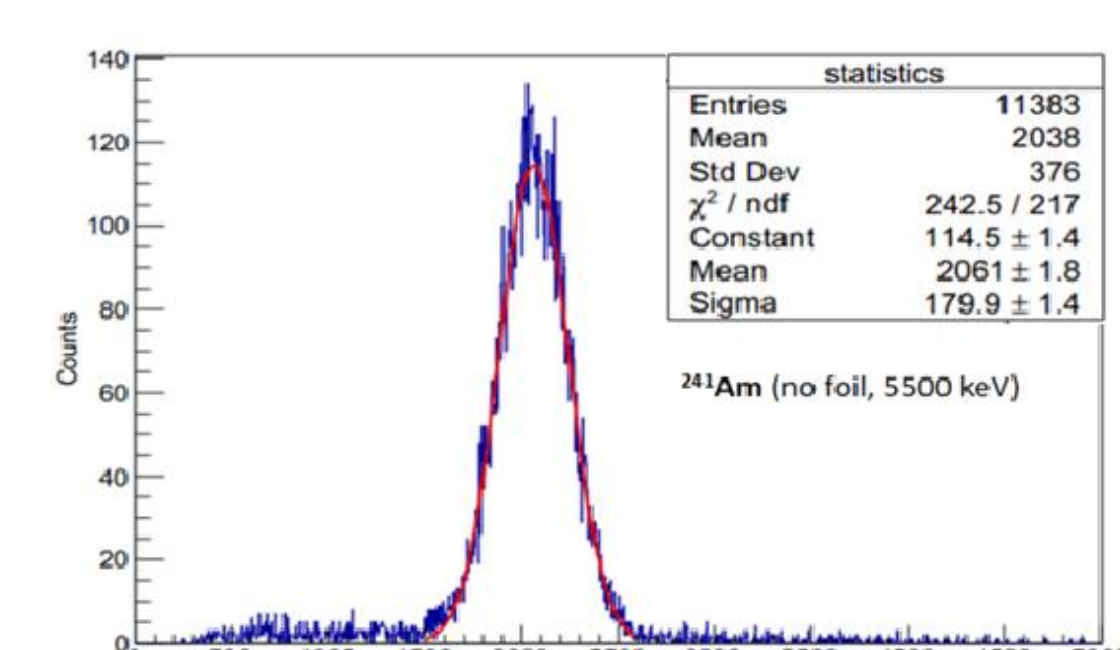
Results of the Gaussian fitting for each photon energy

Energy calibration carried out in two steps: fitting in lineal zone a) and general fitting b)

$$TOT(E) = a \cdot E + b - \frac{c}{E - t}$$

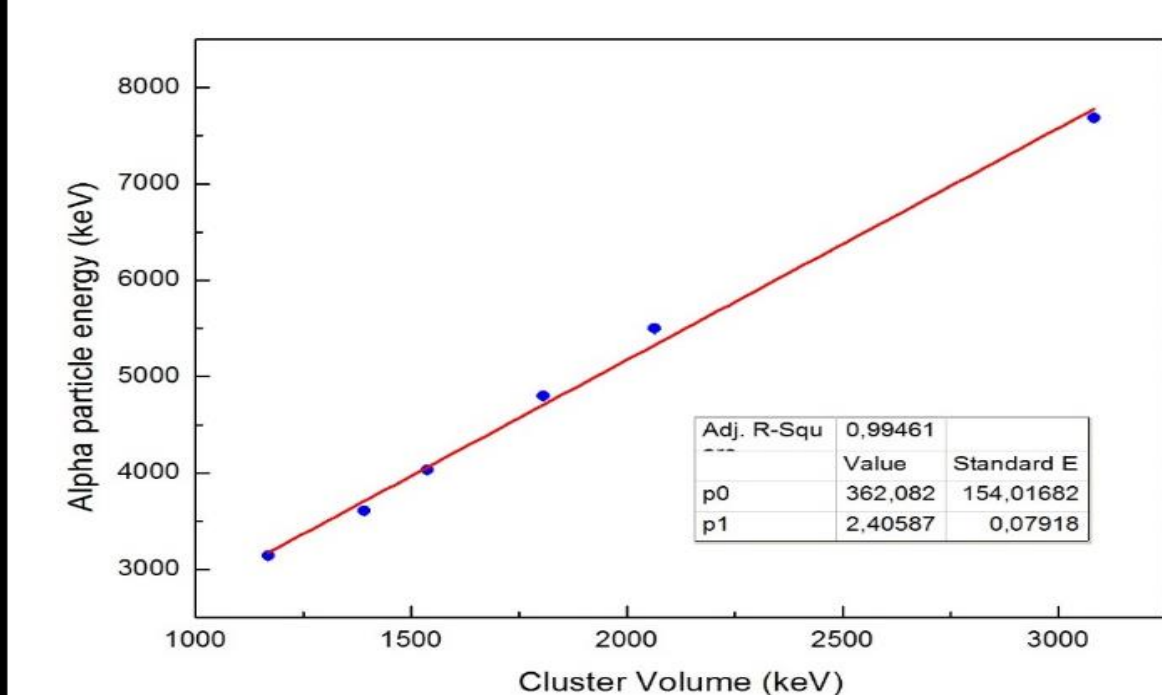


Example of spectrum obtained in TOT mode



Cluster volume (CV) [keV]	α particle energy [keV]
1170	3140
1392	3610
1538	4030
1806	4800
2061	5500
3083	7687

Results of the Gaussian fitting for each alpha particle energy



Energy calibration with alpha particles for selected DAC settings and bias

$$E'(CV) = p_0 + p_1 CV$$

Conclusions

- The measurements made in this work for the energy calibration of a hybrid GaAs:Cr-based Timepix detector with alpha particles, in the first instance, reaffirm that this device is able to register this particle in energy range from 3140 keV to 7687 keV.
- The performed mathematical simulation of the 5.5 MeV alpha particles transport through different Mylar film thicknesses, allowed to calculate the transmitted energy making possible the experimental calibration with the use of Mylar as absorbent. It was proved that 35 μm Mylar films thickness is sufficient to the total stop of the alpha particles from a ²⁴¹Am source.
- By calibrating the detector with characteristic X-rays and using a two steps fitting procedure was determined the relationship between the photon energies and the registered by the detector TOT counts.
- The energy calibration with alpha particles was performed according to linear function $y = 362.08 + 2.41 x$, with $R^2 = 0.99$, and was verified with the measurement of the ²¹⁸Po line of radon in air.

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