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International Student Practice - Radiation Protection and the Safety of the Radiation Sources -

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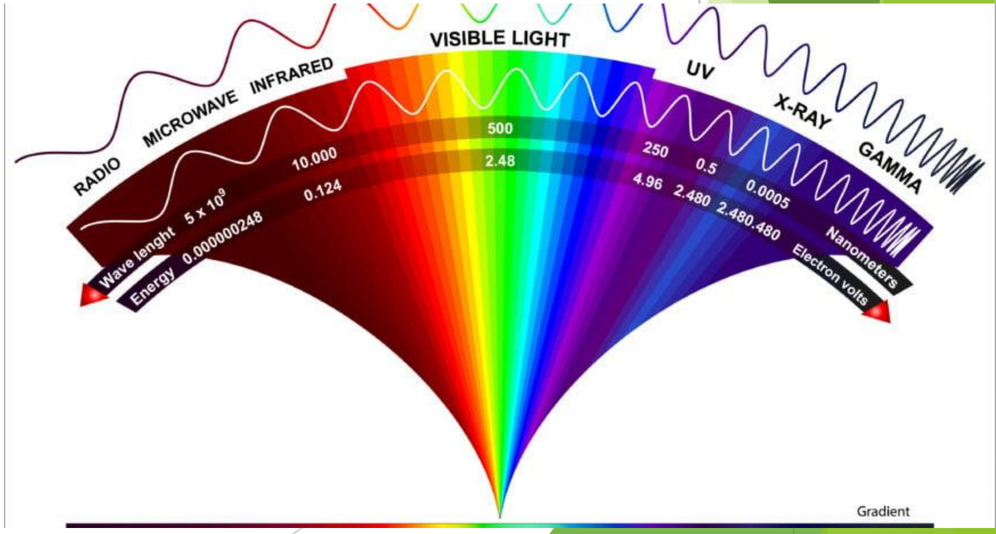
Radiation

Radiation is energy in the form of waves or streams of particles. There are many kinds of radiation all around us. When people hear the word radiation, they often think of atomic energy, nuclear power and radioactivity, but radiation has many other forms.

A radioisotope is an isotope of an element that undergoes spontaneous decay and emits radiation as it decays. There are three main types of radioactive decay:

- Alpha decay
- Beta decay
- Gamma decay

Electromagnetic Spectrum



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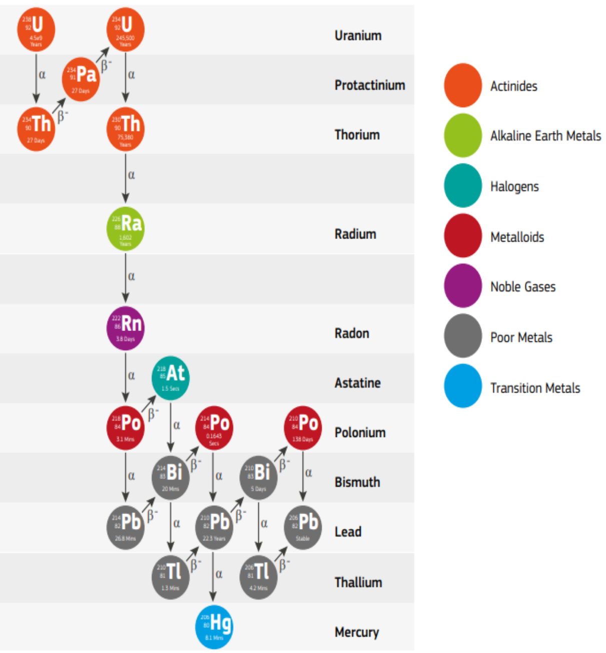
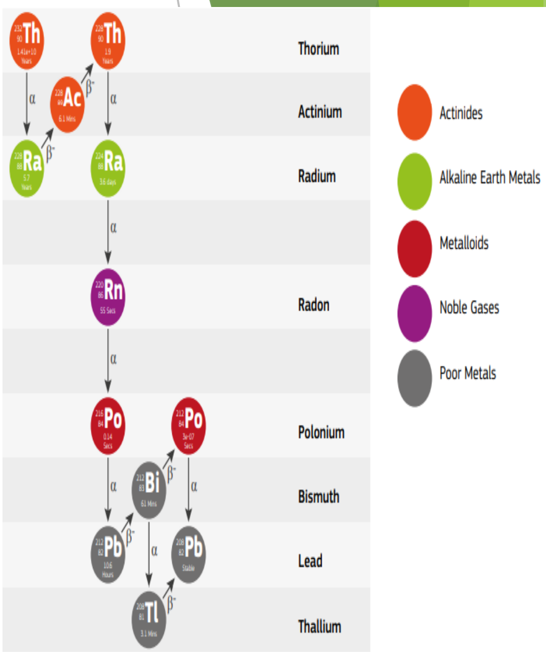
Nature Radioactive Decay Series





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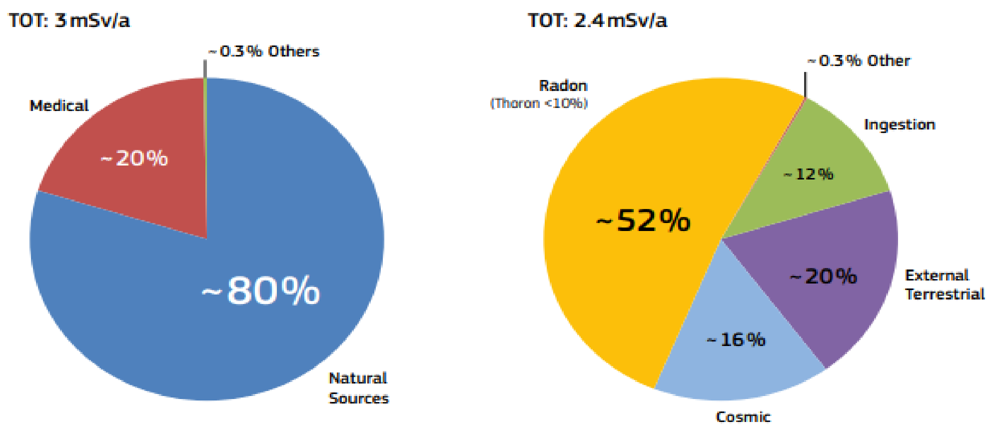
Dose assessment

There are a number of factors that must be taken into consideration in calculating the quantity, or dose, of radiation a person has received, including

- the nature of the ionizing radiation
- the strength of the source
- the biological sensitivity of the area exposed, and exposure factors such as time, distance, and shielding from the source.

Sources of Radiation



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Scintillation detectors

BGO – Bismuth Germanate ($Bi_4Ge_3O_{12}$)

- Highly effective gamma ray absorber;
- Diverse applications: PET, HEP, NP, space and medical physics;
- Crystals: 75 mm max diameters; 300 mm max lengths;
- Wavelength range: 375-650 nm.

NaI (Tl) – Sodium Iodide (Tl)

- A well established and the most extensively used scintillator;
- Used for detection of gamma rays of low and intermediate energies;
- Have an optical output well match to the maximum sensitivity of commonly available PMTs and it is independent of temperature;
- Crystals: 150 mm max diameters; 400 mm max lengths;
- Wavelength range: 325-550 nm.

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Scintillator properties of crystals

Scintillator	Light output	Decay (ns)	Wavelength (nm)	Density (g/cm2)	Hydroscopic
Na (Tl)	100	250	415	3.67	Yes
CsI	5	16	315	4.51	Slightly
BGO	20	300	480	7.13	No
BaF2 (f/s)	3/16	0.7/630	220/310	4.88	Slightly
CaF2	50	940	435	3.18	No
CdWO4	40	14000	475	7.9	No
LaBr3(Ce)	165	16	380	5.29	Yes
LYSO	75	41	420	7.1	No
YAG(Ce)	15	70	550	4.75	No

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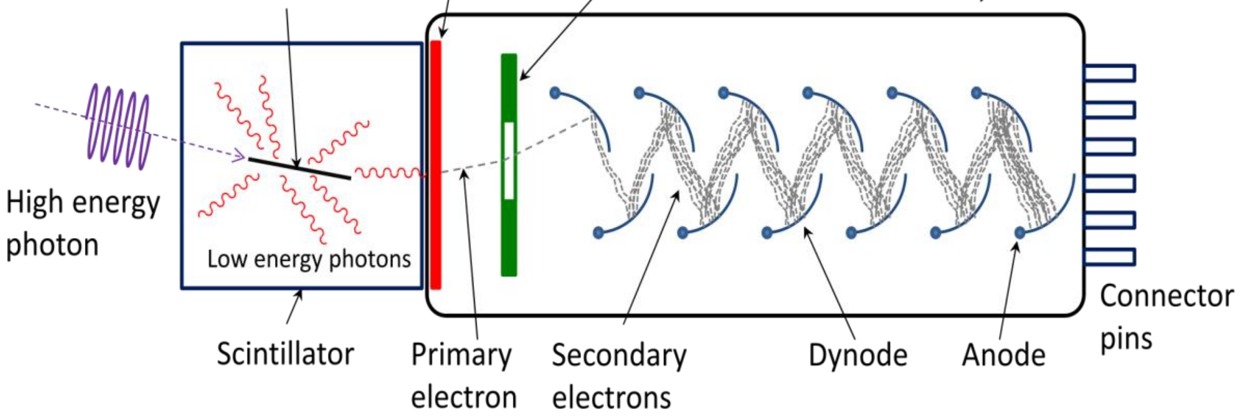
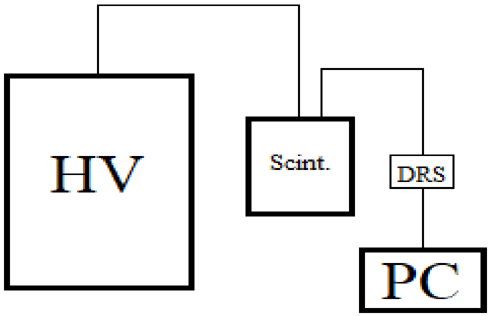
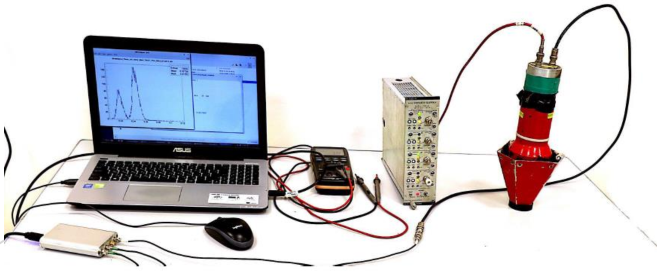
Photomultipliers Tubes



Experimental setup





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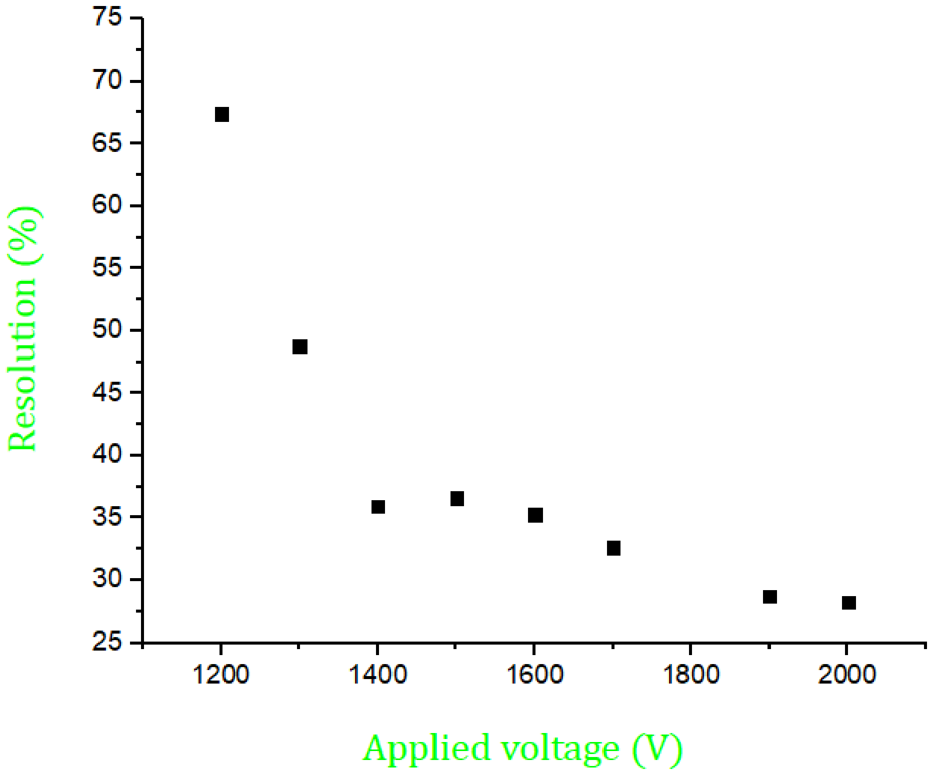
Task 1. The relation between the resolution and applied Voltage for BGO detector

N°	Sigma	Mean	Resolution [%]	Applied Voltage [V]
12	0,462	1,610	67,43	1200
13	0,289	1,393	48,75	1300
14	0,294	1,924	35,91	1400
15	0,465	2,984	36,62	1500
16	0,661	4,402	35,29	1600
17	0,845	6,083	32,64	1700
19	1,299	10,634	28,71	1900
20	1,633	13,570	28,28	2000

$$R = \left(\frac{Sigma}{Mean}\right) x2.35$$



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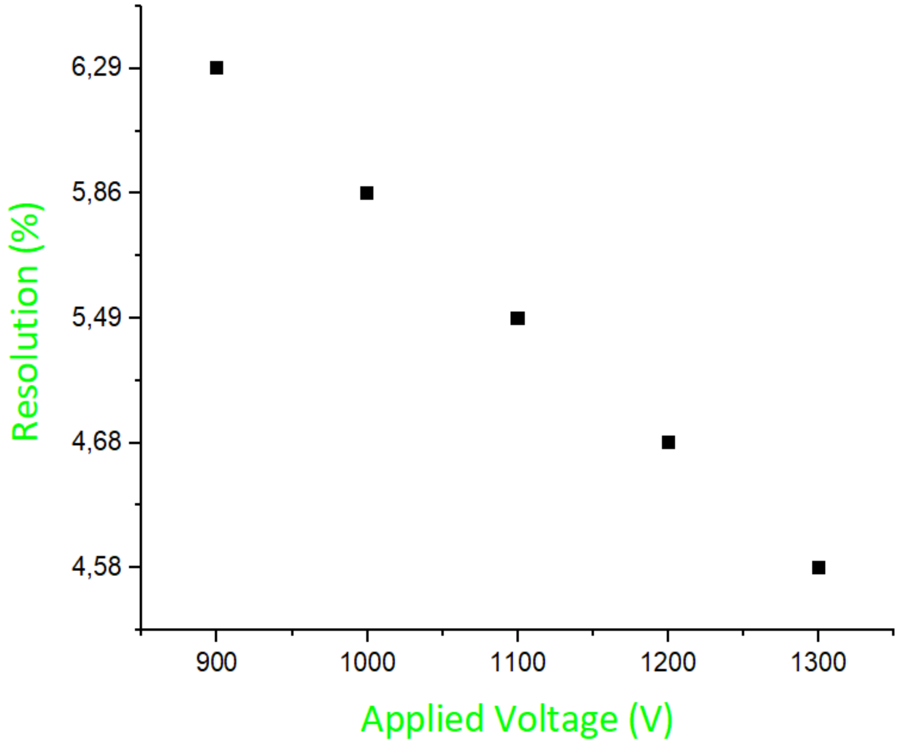
Task 2. The relation between the resolution and applied Voltage for NaI detector

Nº	Sigma	Mean	Resolution [%]	Applied Voltage [V]
1	0,634	23,669	6,29	900
2	1,013	40,626	5,86	1000
3	1,536	65,768	5,49	1100
4	1,968	98,733	4,68	1200
5	2,679	13,349	4,58	1300

$$R = \left(\frac{Sigma}{Mean}\right)x2.35$$



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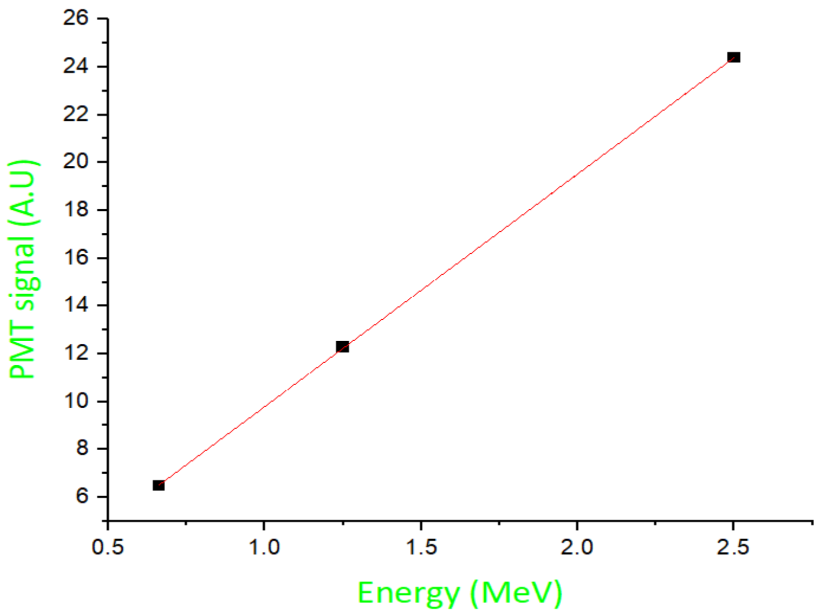
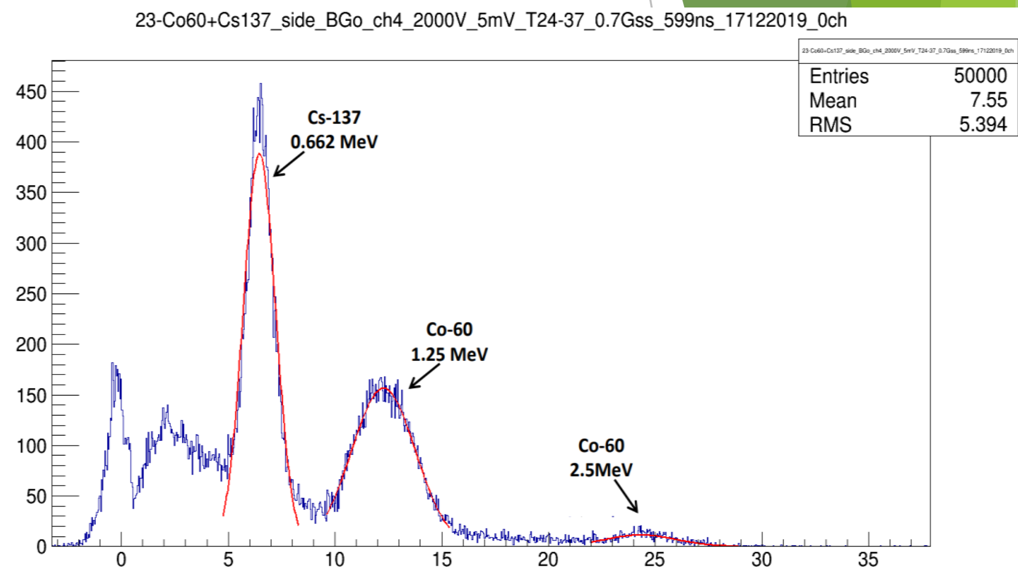
Task 3. Energy calibration for BGO

PMT signal (A.U.)	Energy (MeV)
6,478	0,662
12,282	1,25
24,390	2,5





Equation of calibration:

$$y = 0,06471 + 9,73614 \cdot x$$

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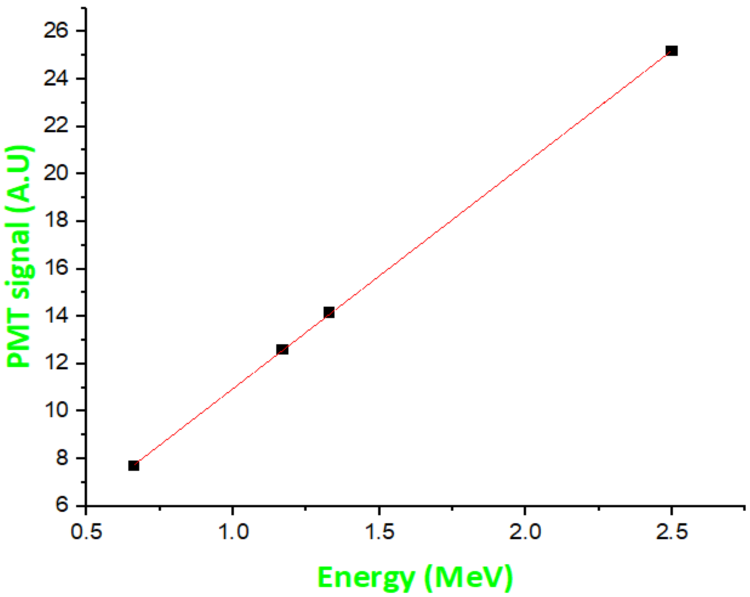
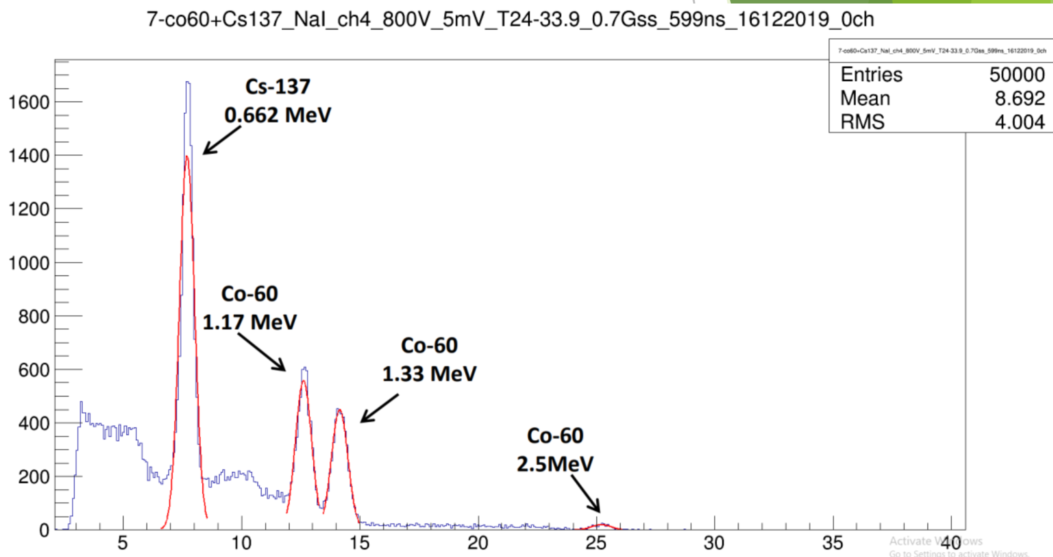
Task 4. Energy calibration for NaI

PMT signal (A.U.)	Energy (MeV)
7,694	0,662
12,597	1,17
14,141	1,33
25,19	2,5





Equation of calibration:

$$y = 1,45011 + 9,50575 \cdot x$$

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Task 5. Identification of unknown sources

- We get the spectrum of unknown source
- We make GAUS FIT and find Mean
- From energy calibration we can determine energy peak of unknown source by using equation from calibration of NaI detector:

$$y = 1,45011 + 9,50575 \cdot x$$

where y = PMT signal A.U,

x = Energy of unknown source

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Task 5. Identification of unknown sources

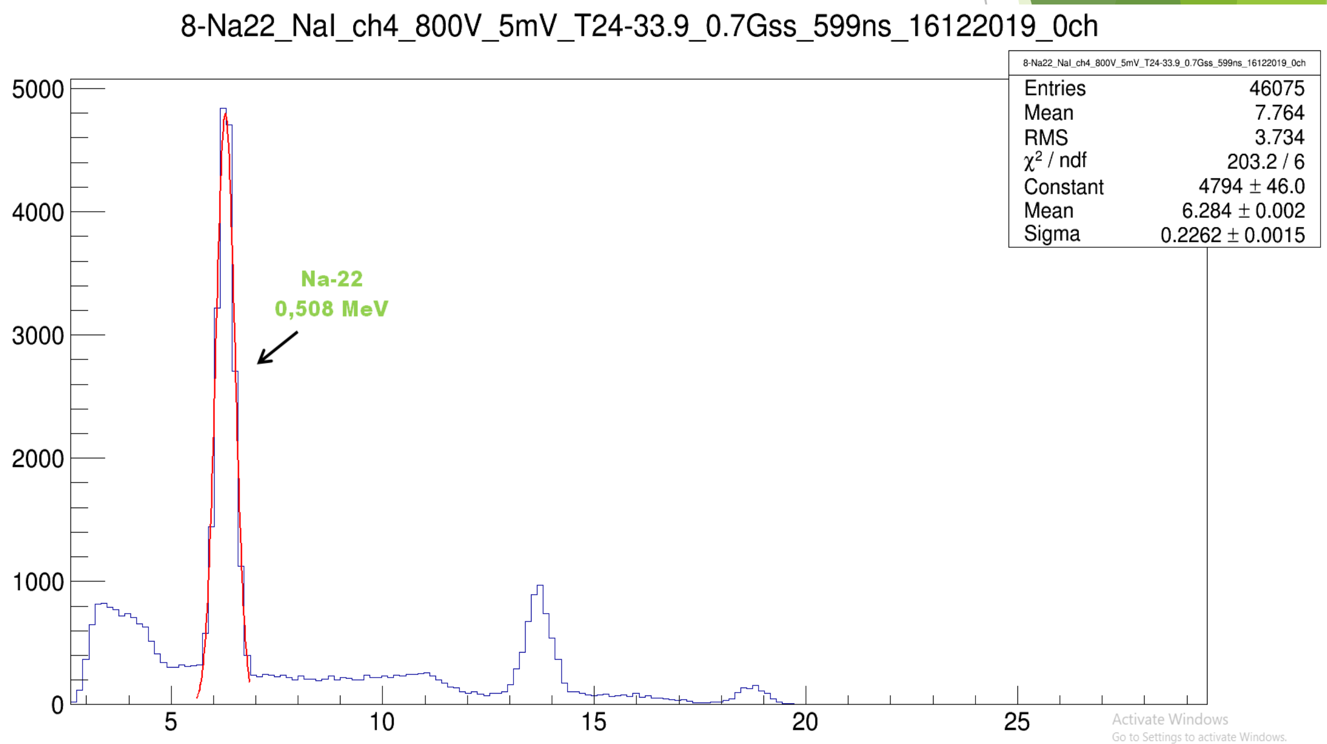
Unknown sources 1

$$y = 1,45011 + 9,50575 \cdot x$$

$$y = 6,284$$

$$6,284 = 1,45011 + 9,50575 \cdot x$$

$$x = 0,508$$



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Task 5. Identification of unknown sources

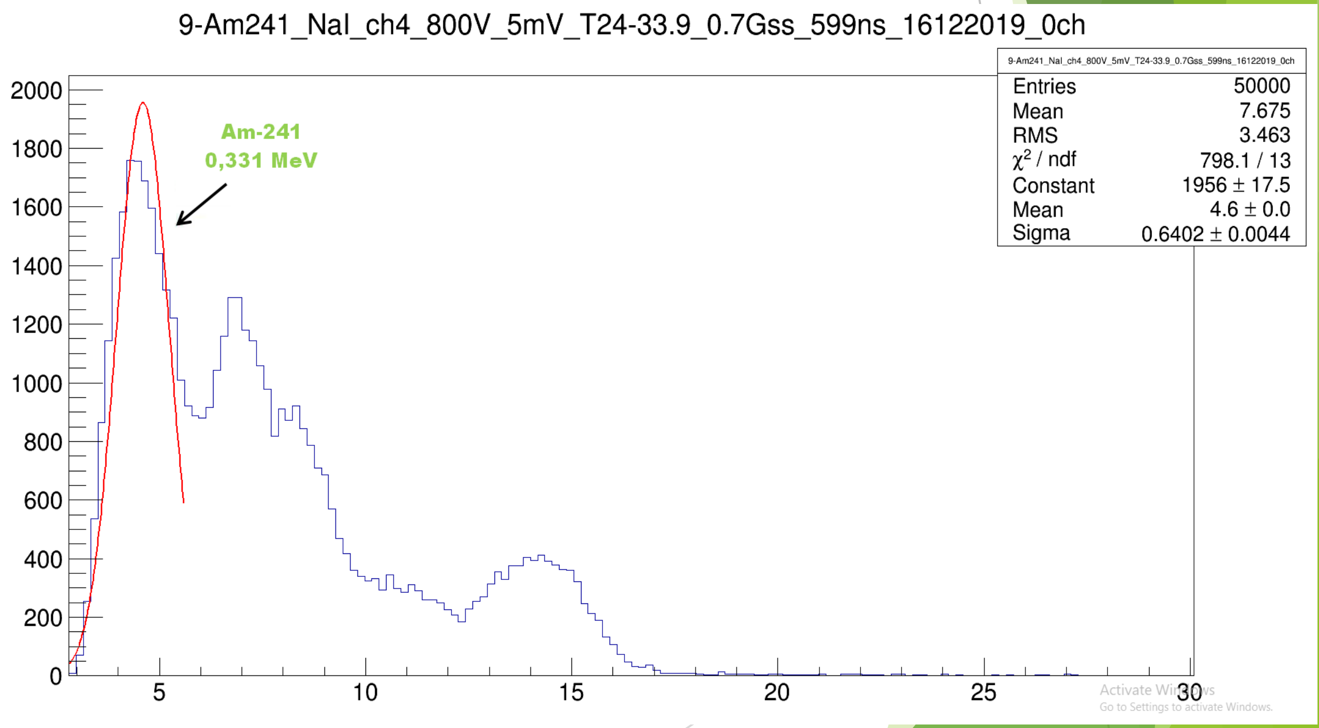
Unknown sources 2

$$y = 1,45011 + 9,50575 \cdot x$$

$$y = 4,600$$

$$4,600 = 1,45011 + 9,50575 \cdot x$$

$$x = 0,331$$



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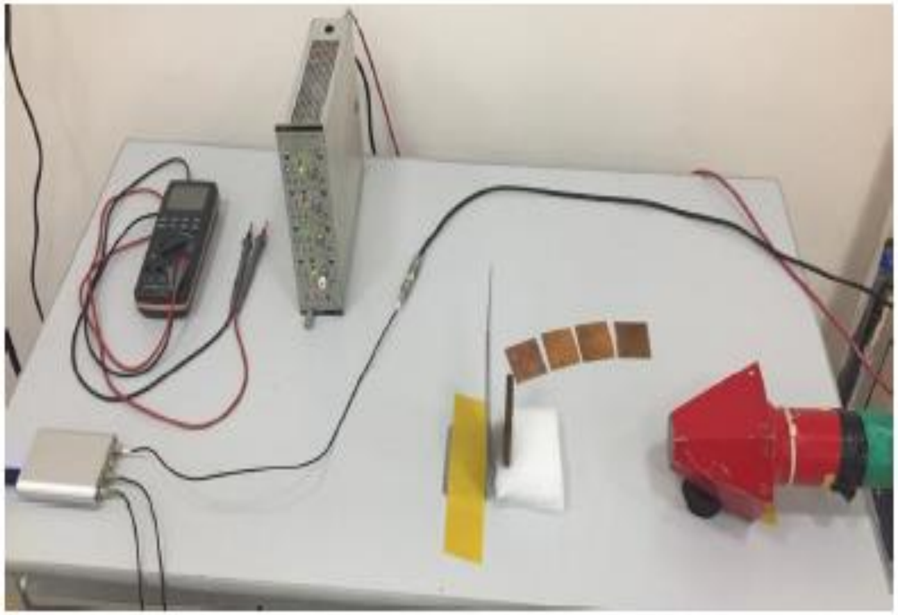
Task 6. Attenuation coefficient

Determination of attenuation coefficient

Experiment equipment:

- BGO scintillation detector
- operating volt 2000V
- Gamma Source Cs137 with energy 661 KeV

$$I = I_0 e^{-\mu x}$$



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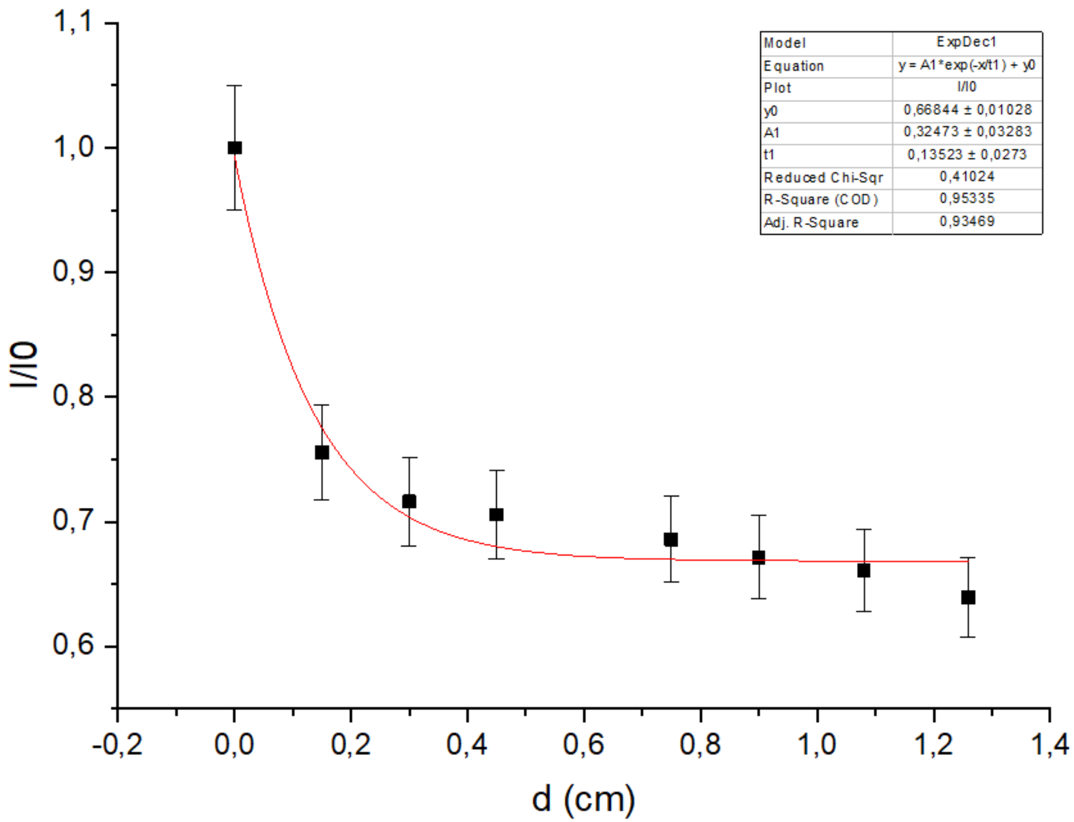
Task 6. Attenuation coefficient

Attenuation coefficient for AL

$\mu = 0,2401 \pm 0,02$



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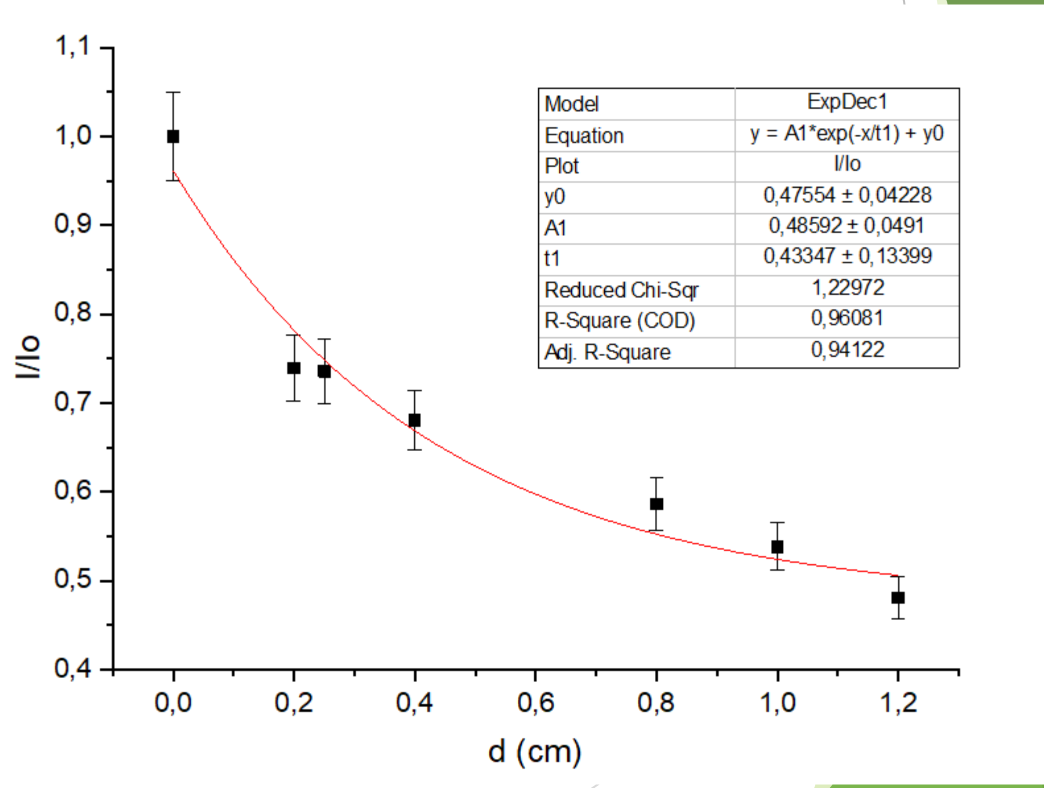
Task 6. Attenuation coefficient

Attenuation coefficient for Cu

$\mu = 0,650001 \pm 0,05$



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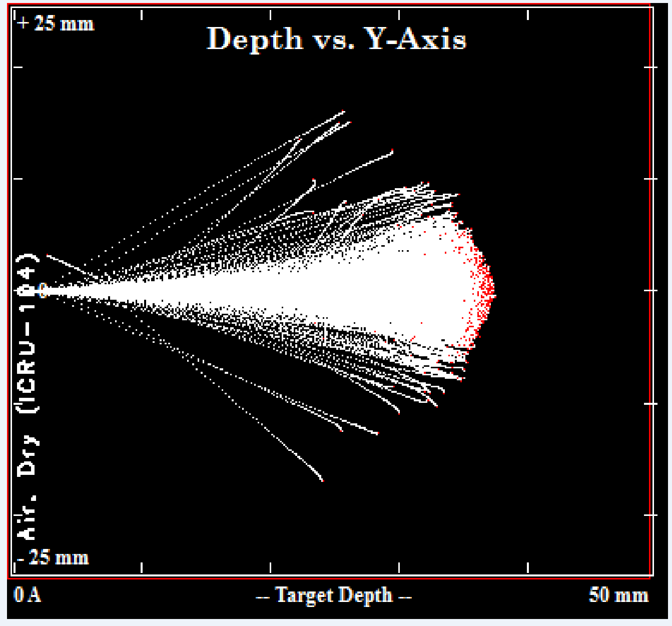
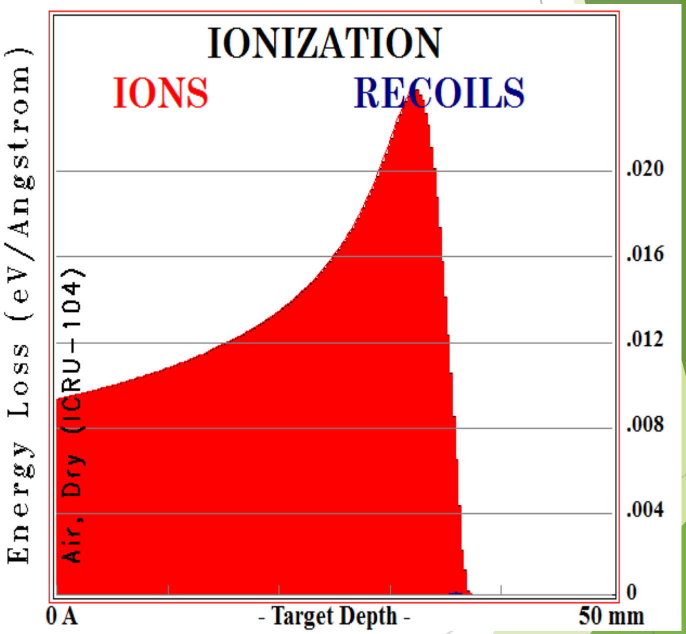
Task 7. SRIM Simulation





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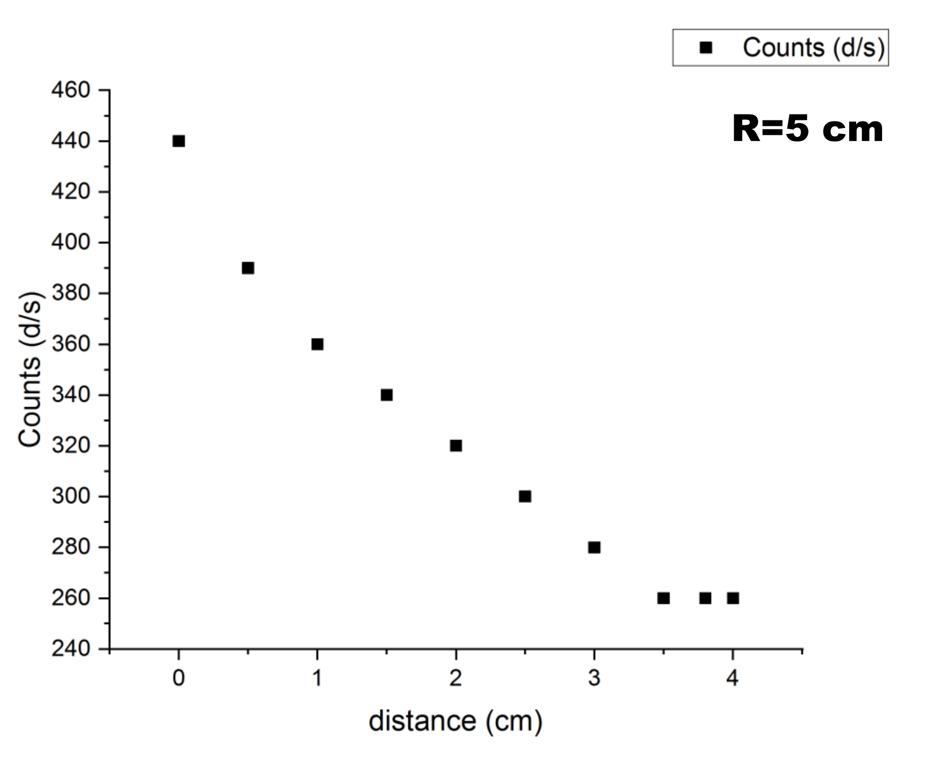
Task 7. SRIM Simulation

Rande determination of an alpha particle in air

- He range in air source : Pu239
- Energy of He : 5 MeV
- detector: plastic
- applied voltage: 2000 V



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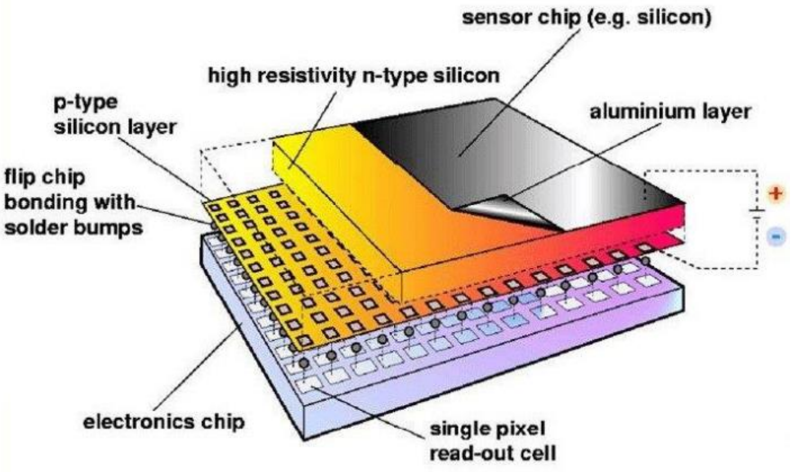
Task 8. Pixel detectors

- PD is an advanced detector like a digital camera;
- PD has high resolution;
- PD is used for registration different types of radiation

It has 3 parts:
1. Sensor (Si)
2. Electronic chip
3. USB



- The size of the sensor: 1.5x1.5 cm;
- 256 x 256 pixels (65.536 pixel);
- Pixel size: 55μm x 55μm.

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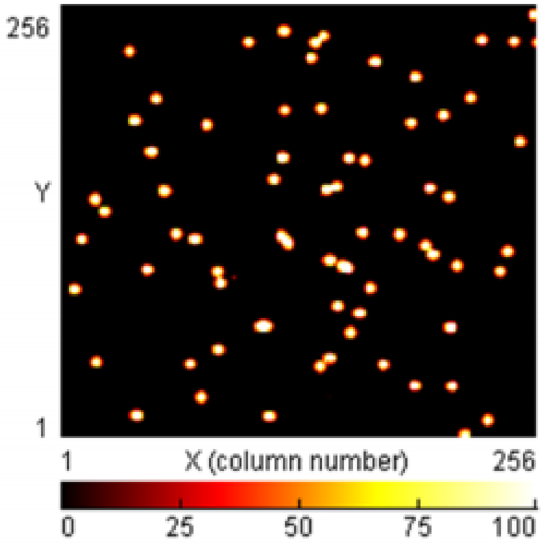
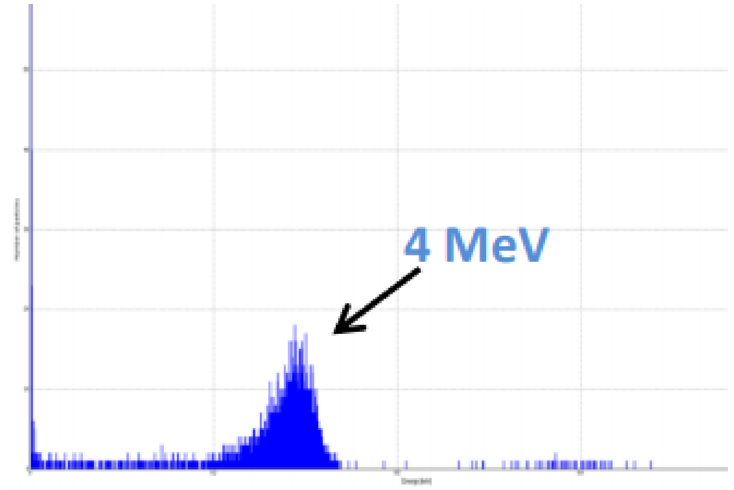
Task 8. Pixel detectors

Determination the range of Alpha particles with (Am-241) energy about 4 MeV in air using pixel detector.

Absorption of alpha particle energy in the air at 0 cm





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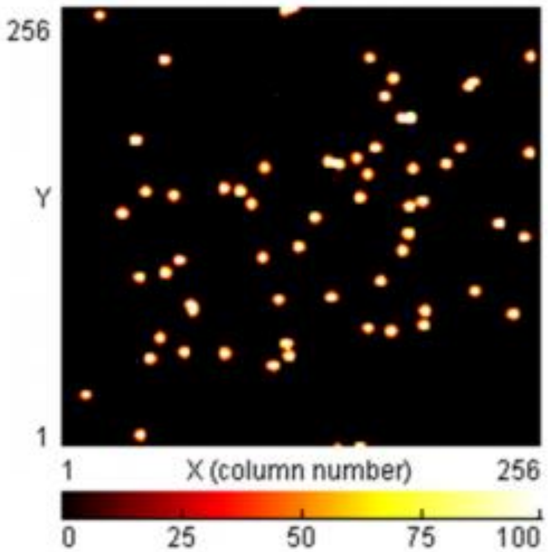
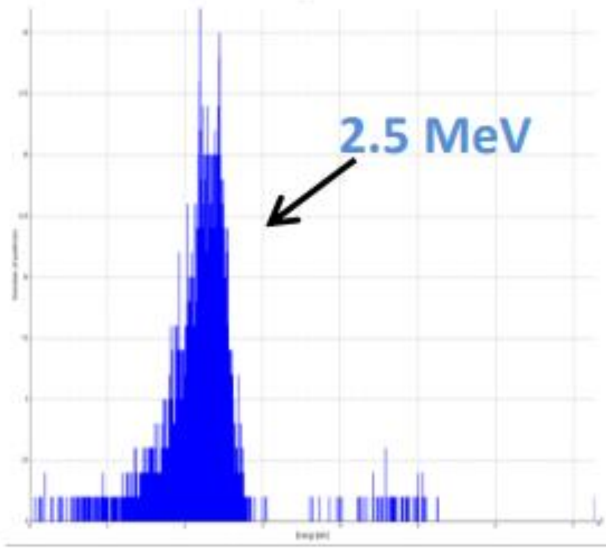
Task 8. Pixel detectors

Determination the range of Alpha particles with (Am-241) energy about 4 MeV in air using pixel detector.

Absorption of alpha particle energy in the air at 1 cm





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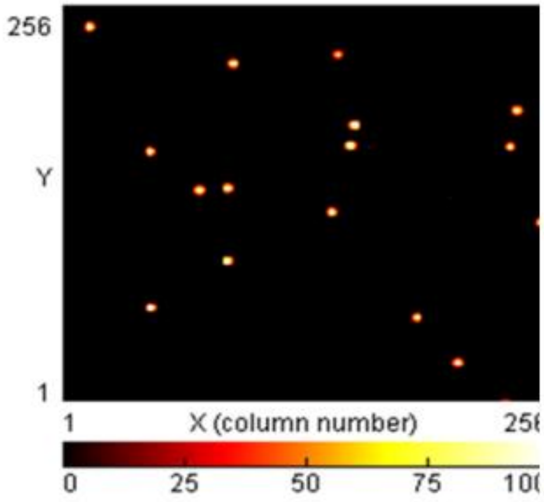
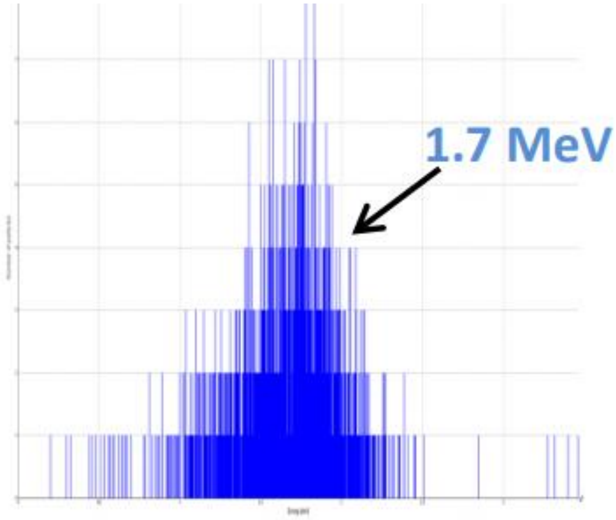
Task 8. Pixel detectors

Determination the range of Alpha particles with (Am-241) energy about 4 MeV in air using pixel detector.

Absorption of alpha particle energy in the air at 2 cm





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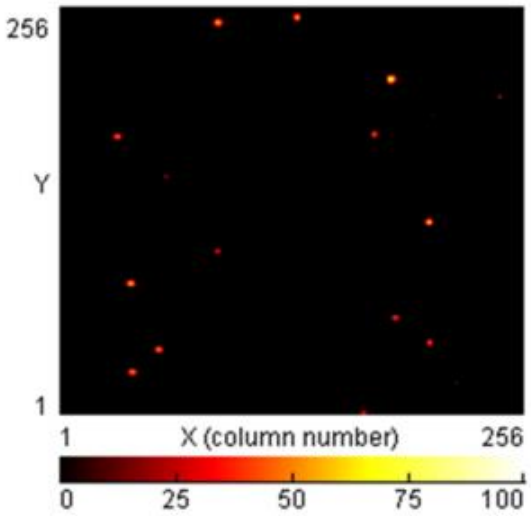
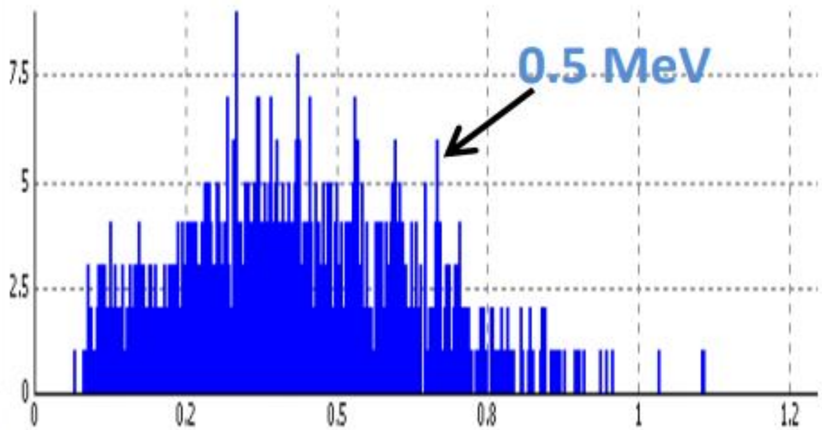
Task 8. Pixel detectors

Determination the range of Alpha particles with (Am-241) energy about 4 MeV in air using pixel detector.

Absorption of alpha particle energy in the air at 2,5 cm





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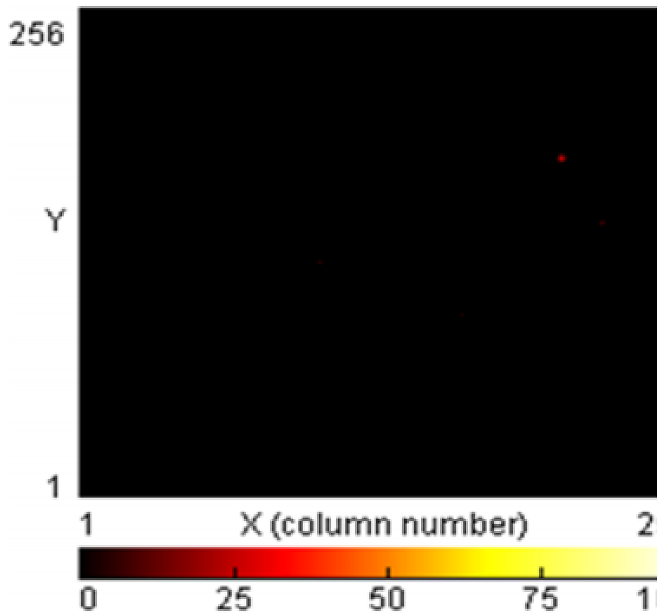
Task 8. Pixel detectors

Determination the range of Alpha particles with (Am-241) energy about 4 MeV in air using pixel detector.



There are no α-particles at 3 cm distance

↓

Maximum of α-particle range is 3 cm

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CONCLUSION-ACQUIRED KNOWLEDGE

- Radiation
- Different types of radiation sources
- Dose of radiation
- Types of dosimeters
- Radiation detectors (BGO, NaI)
- Energy calibration of some scintillation detectors by using Standard sources
- Calculation of Resolution diffrent scintillation detectors
- Determination of Attenuation coefficient for different materials
- Determination of alpha range in air using Pixel and Plastic detectors
- Assessment the ranges and energy of alpha particles using Monto Carlo simulation SRIM software

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THANK YOU FOR ATTENTION ☺

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