JOINT INSTITUTE FOR NUCLEAR RESEARCH

Dzhelepov Laboratory of Nuclear Problems

FINAL REPORT ON THE INTEREST PROGRAMME

"Radiation Protection and the Safety of Radiation Sources"

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Abstract:

The usage of ionizing radiation has a lot of applications and benefits, but it is necessary to deal with it in a good wise manner, so this course aims to establish some basic knowledge in radiation protection and detectors.

Using different software like ROOT, DppMCA, SRIM and Excel to make experimental work like fitting, integrate, simulate or plot data help to reach good results and we take data from JINR laboratories.

This report includes calibration and resolution of BGo. NaI, CdTe detectors using ROOT software and determine unknown sources according to calibration then determining attenuation coefficients for Al& Cu and the last experiment is alpha particles range in air.

Introduction:

Dealing with detectors in the radiation protection field is so important because it determines radiation doses received which can be harmful to health, environment and property.

We will use software programs and the data from JINR laboratories to find calibration and resolution of some detectors and determine some unknown sources then find attenuation coefficients and alpha particles range.

And we find that the resolution of each detector in this course. But the resolution of CdTe detector is better than NaI detector and the resolution of NaI detector is better than BGo detector. And increasing the shield thickness decreases the counts then we can find attenuation coefficient. After that for 5 MeV alpha particle in air we determine its range and it is equal to 3.51 cm.

Task 1: Effect on Resolution of BGo Detectors due to Voltage change

We do an experiment to show the impact of changing voltage of BGo detectors to the resolution of the detector.

First, we do fit to the peaks of the graphs and get sigma and mean, then we substitute in the formula $R\% = \frac{sigma}{mean} \times 2.355 \times 100$ Equation 1.

After that we plot volts in x-axis and resolution in y-axis to show the relation between them.

Attached figures to show the fitting and a graph to show the relation.

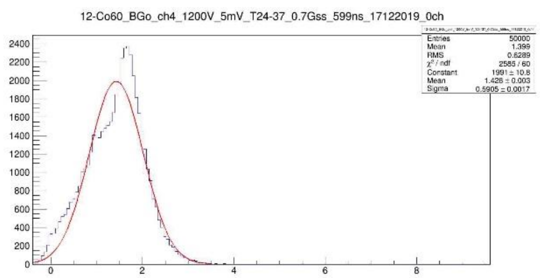

Figure 2: 1200v fitting and parameters

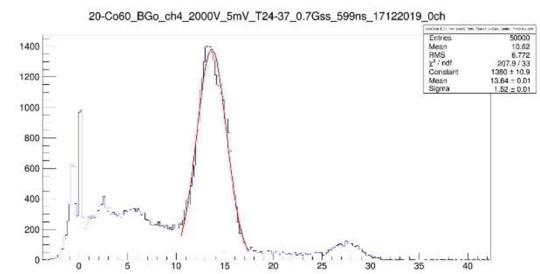

Figure 1: 2000v fitting and parameters

Table 1: parameters, volts and resolution

sigma	mean	volt (V)	resolution %
0.590538	1.42843	1200	97.3598279
0.278664	1.39098	1300	47.1792348
0.294677	1.92408	1400	36.0673327
0.465285	2.984	1500	36.7207163
0.666556	4.40053	1600	35.6715982
0.791	6.11167	1700	30.4794761
1.25192	10.656	1900	27.667714
1.52027	13.6361	2000	26.2555705

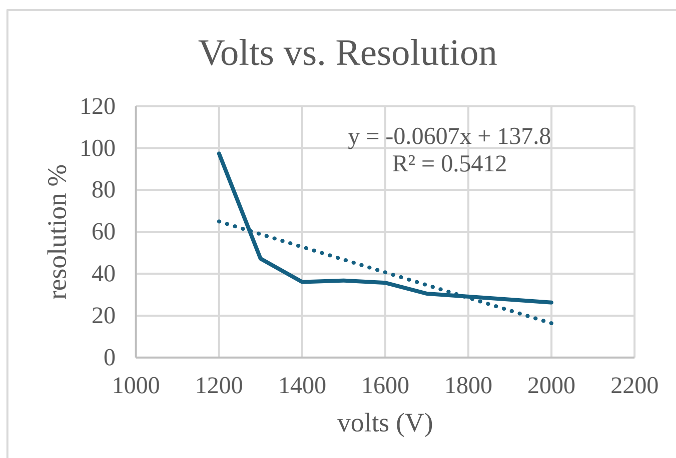

figure 3:Volts vs Resolution

Conclusion:

Increasing voltage reduces resolution.

Task 2: Energy Calibration of BGo detectors & Determine Unknown sources

Knowing the energy of Co-60 and Cs-137 and their channel number using ROOT program we will get a relation between them.

Table 2: Energy Calibration of BGo detector

channel no.	energy (MeV)
6.46	0.66
12.22	1.2
24.37	2.4

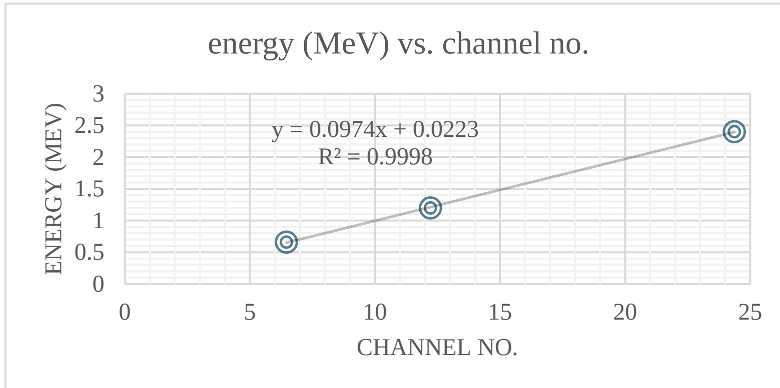

figure 4: Energy Calibration of BGo detector

And for determining the unknown sources we can substitute in calibration equation and determine the energy of the peak then determine the source.

Table 3: determining of unknown source

mean(x)	equation	energy(y) (MeV)	source	peak
0.2881	y = 0.0974x + 0.0223	0.05036094	Rh-104m	peak 1
0.3812	y = 0.0974x + 0.0223	0.05942888	Te-127m	peak 2
0.477	y = 0.0974x + 0.0223	0.0687598	Ta-182 or Ti-44	peak 3
0.5674	y = 0.0974x + 0.0223	0.07756476	Pt-197 or Hg-197	peak 4
1.033	y = 0.0974x + 0.0223	0.1229142	Co-57 or Eu-152	peak 5

Task 3: Calibration, Resolution and Find Unknown Sources for NaI Detector

1.calibration:

We made an experiment to show the relation between channel number (mean) and energy of photons detected and the result can be generalized for all elements that can be detected with NaI detectors. Attached figures for fitting.

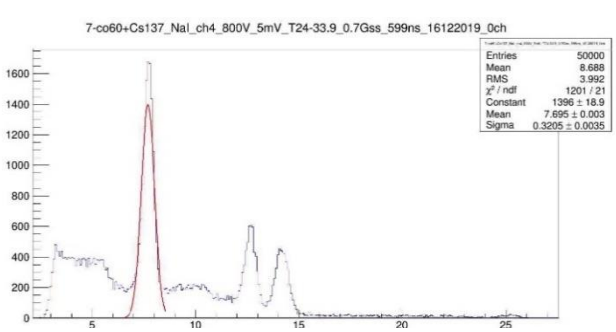

figure 5: first peak fitting

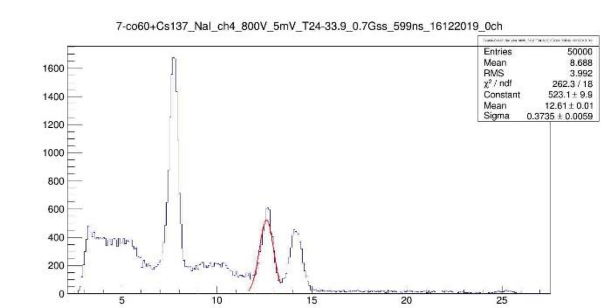

figure 6: second peak fitting

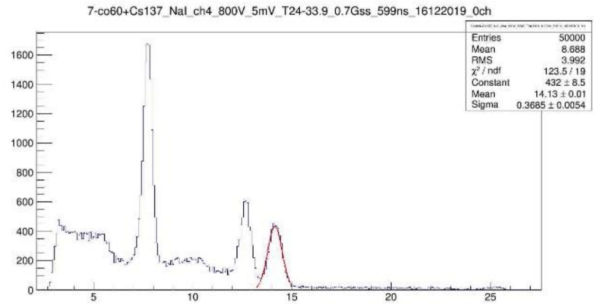

figure 8: third peak fitting

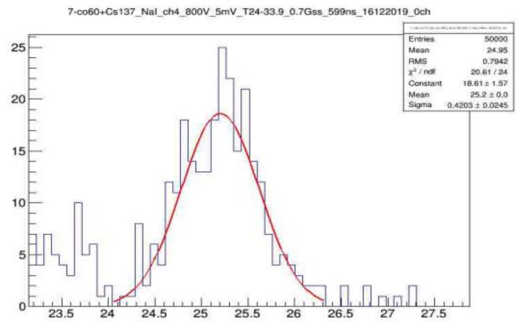

figure 7: fourth peak fitting

conclusion:

As shown from the curves the NaI detector can separate between Co-60 two peaks than BGo detector which means better resolution.

Table 4: channel no. vs. energy

channel no.	*energy (MeV)*
7.695	0.66
12.61	1.173
14.13	1.332
25.2	2.505
0	0

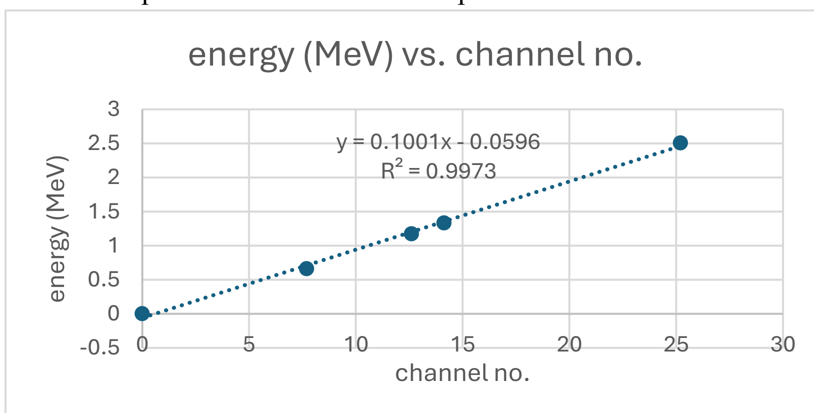

figure 9: energy vs. channel no. for NaI detector

2. Resolution:

We did an experiment to show the impact of changing voltage of NaI detector to the resolution of the detector.

First, we do fit to the peaks of the graphs and get sigma and mean, then we substitute in the formula: $R\% = \frac{sigma}{mean} \times 2.355 \times 100$ Equation 2.

After that we plot volts in x-axis and resolution in y-axis to show the relation between them.

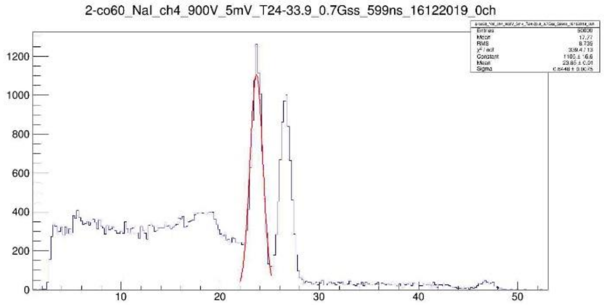

figure 11: fitting for 900 v

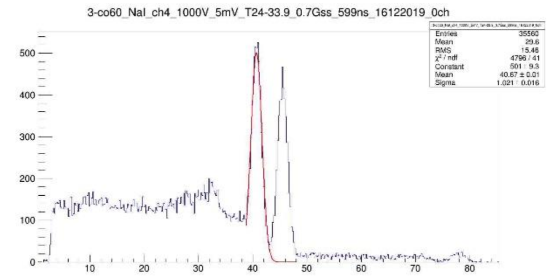

figure 10: fitting for 1000 v

Attached figures to show the fitting and a graph to show the relation.

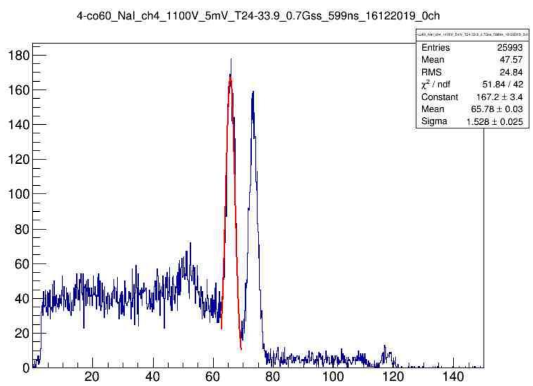

figure 12: fitting for 1100 v

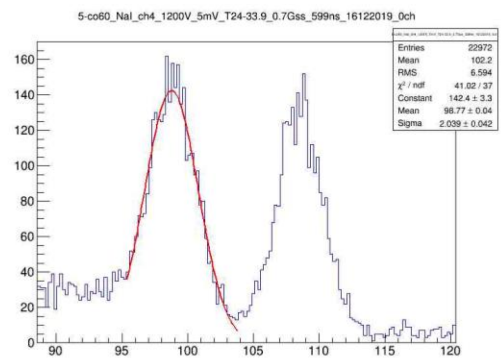

figure 13: fitting for 1200 v

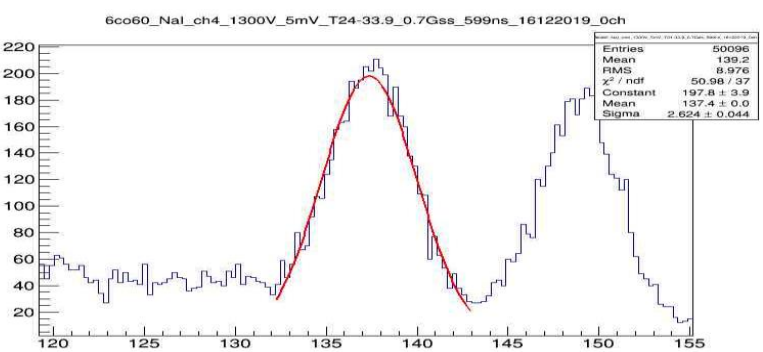

figure 14: fitting for 1300 v

Table 5: parameters used for resolution

sigma	*mean*	*volts (V)*	*resolution %*
0.6448	23.65	900	6.42073573
1.021	40.67	1000	5.91210966
1.528	65.78	1100	5.47041654
2.039	98.77	1200	4.86164321
2.624	137.4	1300	4.49746725

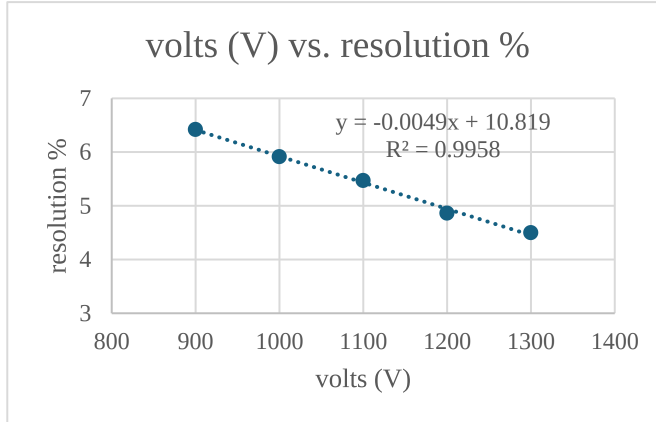

figure 15: volts vs. resolution

3. Unknown sources identification:

from calibration we get energy vs. channel number so when we know the channel number, we can predict the energy and also the source of radiation.

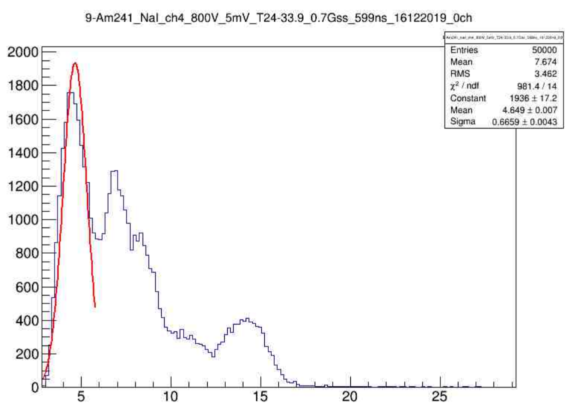

figure 18: first peak for unknown source

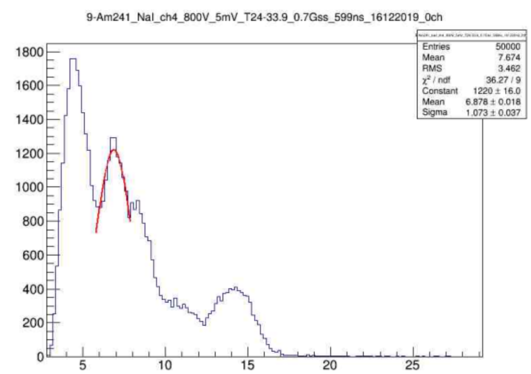

figure 17: second peak for unknown source

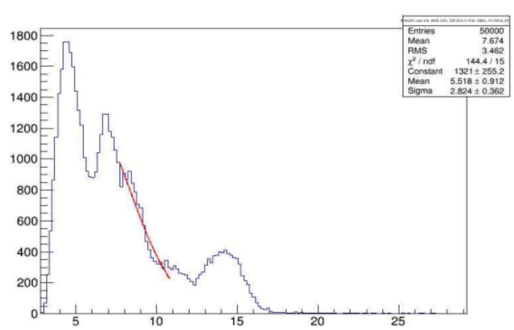

figure 16: third peak for unknown source

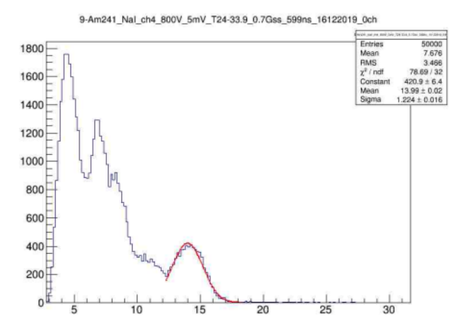

figure 19: fourth peak for unknown source

Table 6: determining unknown sources

peak	*sigma*	*mean (x)*	*equation*	*energy (MeV) (y)*	*source*
1	0.6659	4.649	y=0.1001x-0.0596	0.4057649	Pb-211
2	1.073	6.878	y=0.1001x-0.0596	0.6288878	Ru-106 or Rh-106 or I-131
3	5.518	2.824	y=0.1001x-0.0596	0.2230824	Hf-180m or Ru-97 or Te-132
4	1.224	13.99	y=0.1001x-0.0596	1.340799	Co-60

Task 4: Calibration, Resolution for CdTe Detector

Introduction:

in this task we will treat with a new detector which is CdTe detector, and it is required to determine as usual its resolution and make calibration.

1. Calibration:

We made an experiment to show the relation between channel number (mean) and energy of photons detected and the result can be generalized for all elements that can be detected with CdTe detectors. Attached table and chart for calibration results.

Table 7: CdTe detector calibration

channel no. (mean)	*energy (KeV)*	*element*
95	13.18	*Am-241*
141	17.7	*Am-241*
172	20.7	*Am-241*
195	26.34	*Am-241*
318	59.54	*Am-241*
652	122.4	*Co-57*
6239	1173	*Co-60*
7090	1332	*Co-60*

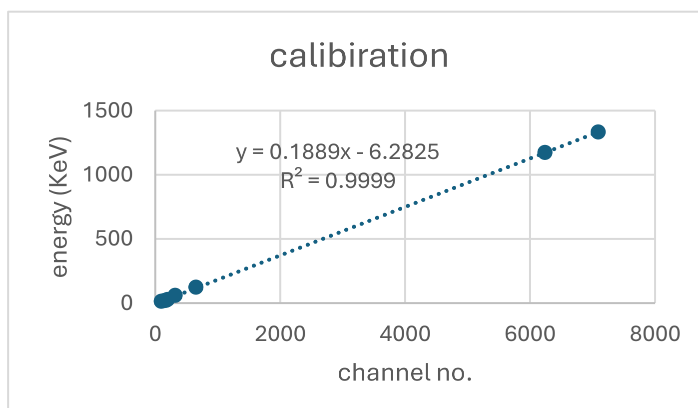

Figure 20: CdTe detector calibration chart

1.1. Conclusion:

As shown from the curve the CdTe detector can separate between Co-60 two peaks than BGo detector which means better resolution.

2. ***Resolution:***

We know the mean (channel no.) and get FWHM then we substitute in equation 1 to get the resolution of the CdTe detector.

$R\% = \frac{FWHM}{mean} \times 100$ Equation 3.

Table 8: CdTe detector resolution

FWHM	mean	Resolution	element
4.8182	318	***1.515157***	*Am-241*
7.4	652	***1.134969***	*Co-57*
97.33	6239	***1.560026***	*Co-60*
126.35	7090	***1.782087***	*Co-60*

2.1. conclusion:

Less values of resolution means that this detector is efficient and its separation between peaks is better.

Task 5: Attenuation Coefficients Using Am-241source and Registration efficiency

Objective:

The goal is to determine the attenuation coefficient for aluminum and copper using Am-241 source. According to $I = Ioe^{-\mu x}$ Equation 2, we will plot a relation between I/Io vs. thickness x and the slope will be $e^{-\mu x}$ so we can determine μ

Noting that background=29 and will be subtracted from all values of Io. And time for experiment is 100 seconds.

AL: For Al Io=2933.

Table 9: determining attenuation coefficient for Al

x (cm)	I	I/Io
0.52	2189	0.746335
1.1	2893.5	0.986533
1.6	2562.5	0.873679
2.2	2595	0.88476
2.81	2506.5	0.854586
3	2353	0.80225
5	2072.5	0.706614
8	1607	0.547903

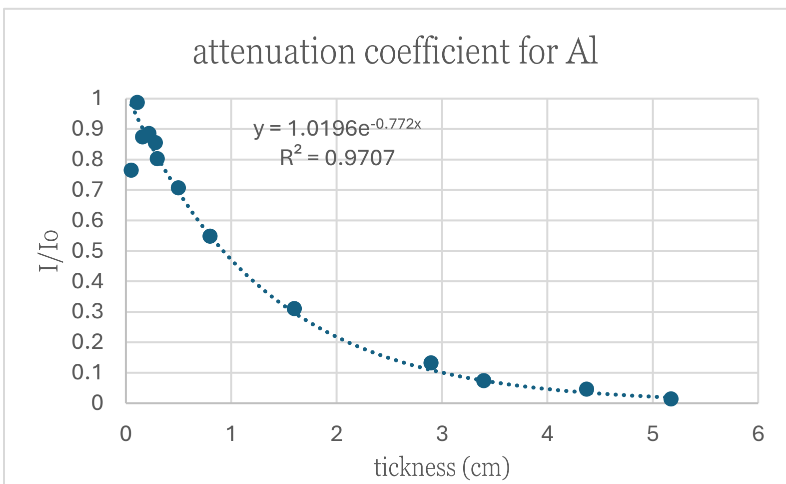

Figure 21: attenuation coefficient for Al

16	909	0.309922
28.97	386	0.131606
33.97	215.5	0.073474
43.74	134	0.045687
51.74	39	0.013297

It is obvious that $\mu = 0.772$ cm^{-1} for Al.

Cu:

For Cu Io=2750.

Table 10: attenuation coefficient for Cu

X(cm)	*I/Io*
0.02	0.783091
0.05	0.561273
0.07	0.464545
0.1	0.280545
0.15	0.155091
0.2	0.075636
0.25	0.042364
0.3	0.020727
0.35	0.009091
0.4	0.002545
0.45	0.003273
0.5	0.001455
0.55	0.000727
0.6	0.000727
0.65	0
0.8	0

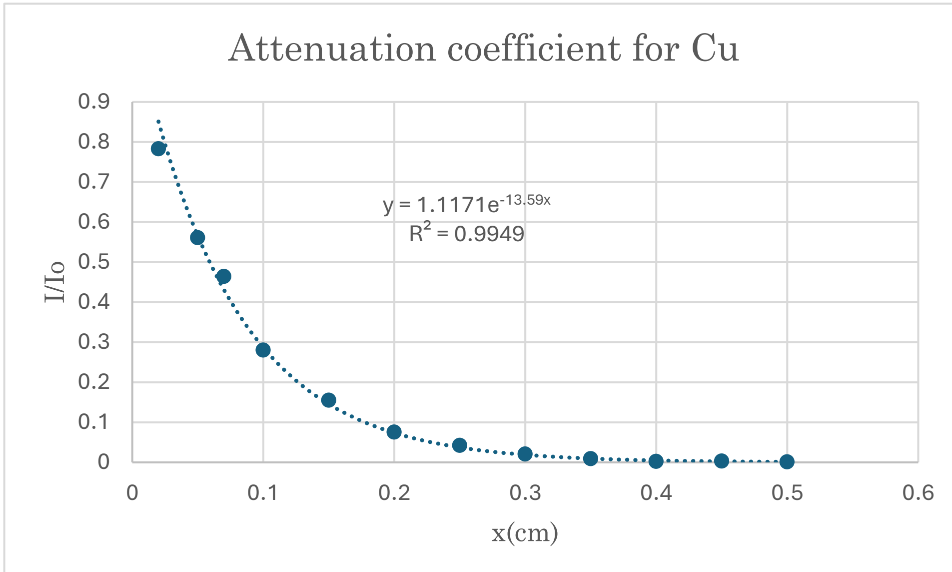

figure 22: attenuation coefficient for Cu

It is obvious that $\mu = 13.59$ cm^{-1} for Cu

Registration efficiency:

To calculate regeneration efficiency, we need to determine how much the detector count to how much the sample emits particles so we calculate the total counts for Am-241, Co-57 and Co-6o and we know the detectors counts so we will divide and plot a relation with the energy.

Table 11: registration efficiency

channel no.	***measured counts***	***total counts***	***energy (KeV)***	***R.E***	***element***
318	33894	397838	59.54	0.0851955	Am-241
652	3371	56822	122.4	0.0593256	Co-57
6239	2630	42643959	1173	6.167E-05	Co-60
7090	1378	42643959	1332	3.231E-05	Co-60

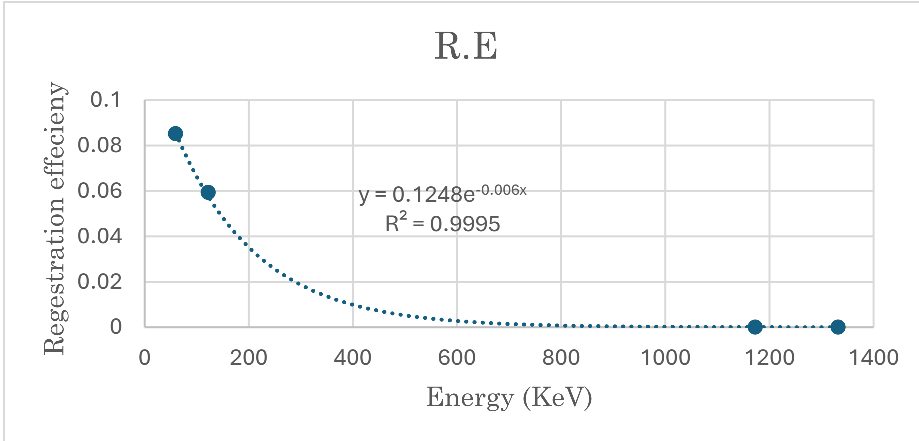

Figure 23: Registration efficiency vs. Energy

Task 6: Alpha Particle (α) Range in Air and Energy Loss

The objective of this task is to determine the range of alpha particles in air and their energy loss. Due to its positive charge alpha has good ionizing power but its high mass lead to low penetration. It will be seen in results the accuracy of this information.

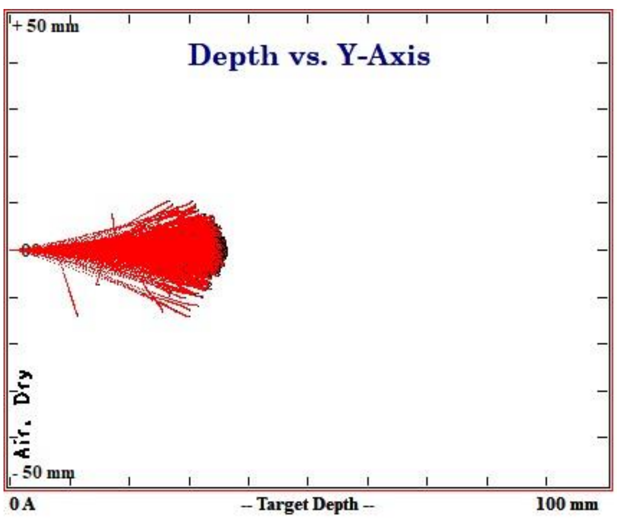

figure 25: range of alpha particle in air using SRIM

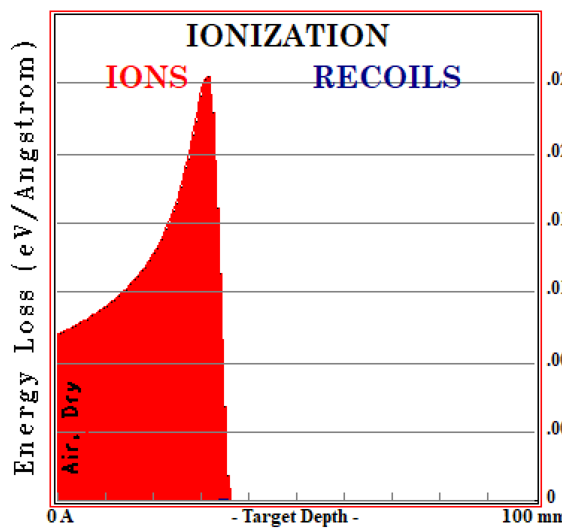

figure 24: energy loss due to ionization of alpha particles using SRIM

The results show that alpha has little range about 3.51cm in air and also has a great ionization power.

Conclusion:

In this course the main objective was dealing with different types of detectors like BGo, NaI, CdTe and the last detector was pixel detector by making calibration, calculating resolution and defining unknown sources. In addition to determining attenuation coefficients and compuying alpha particles range.

In this course we deal with different software like ROOT, DppMCA, SRIM and Excel to make the experimental work like fitting, integrate, simulate or plot data.

The results show that increasing voltage decreases the resolution of each detector in this course. But the resolution of CdTe detector is better than NaI detector and the resolution of NaI detector is better than BGo detector.

And then for attenuation coefficient we use Am-241 source and different thickness of aluminum and copper shields plotting the thickness against I/Io we get the attenuation coefficients = 0.772 and 13.59 cm^{-1} for aluminum and copper respectively.

At the end we use SRIM simulation to determine 5 MeV energy alpha particle range in air and we find the range = 3.51 cm this short range due to high charge and mass of alpha particles.