Radiation Protection and the Safety of the Radiation Sources

INTEREST - **INTE**rnational **RE**mote **S**tudent **T**raining at JINR

Wave 9

JOINT INSTITUTE
FOR NUCLEAR RESEARCH

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Abstract:

Since the early beginning of the discovery of radioactivity, humans strived desperately to control the powers of radiation by the deep study of the nature of these living rocks, and tried hard to benefit from radioactivity through many applications in industrial, medical, and power production fields. In today's world, the use of radioactivity can be seen almost everywhere and areas where radioactivity can be a very good tool is growing rapidly.

This rapid growth of nuclear field gave rise of the importance of radiation protection in order to protect the workers in the field being exposed to ionizing radiation and the public from the hazardous effects of the ionizing radiation. The interest in radiation protection field is held by many universities and institutes all over the world in order to provide students with the essential information considering safety and protection in various applications of radiation.

In order to provide wide understanding of radiation nature, some types of detectors must be covered. In this course we studied the BDO and NaI detectors, considering the signal provided by each one, resolution, and calibration curves of each one of them, then used the results to recognize unknown radioactive source. (first three tasks)

Then, we used plastic detector to define the range of alpha particle in air. (Forth task)

Also, we managed to define the attenuation coefficient of gamma rays in aluminium, and copper. (Task five)

Finally, we covered the pixel detector in brief details considering its structure and could use it to define the range of alpha particles in air.

All data in this report are shown and analysed using the ROOTS software, tables and graphs are plotted using Microsoft excel.

Task 1: BGO detectors

In this task we study the BGO detectors in details, determining the relation between the applied voltage and both resolution and signal produced by the detector while detecting radiation emitted be the Co-60 which is known to have two peak at energies of 1173.2 and 1332.5 KeV

The resolution of a detector is defined as the ability of the detector to distinguish between two peaks at two different energies. It can be determined from the relation:

$$\%R=\frac{\sigma}{mean} * 2.35 * 100$$

In this experiment, the applied voltage is changed and produced signal is recorded using the multichannel analyser DRS as follows:

Volt (v)	**1200**	**1300**	**1400**	**1500**	**1600**	**1700**	**1900**	**2000**
Mean	**1.4285**	**1.4159**	**1.9240**	**2.984**	**4.401**	**6.0835**	**10.621**	**13.548**
Segma	**0.5906**	**0.3187**	**0.2949**	**0.4653**	**0.6648**	**0.8477**	**1.3179**	**1.6377**
R %	**97.170**	**52.903**	**36.028**	**36.641**	**35.500**	**32.745**	**29.159**	**28.407**

The mean and sigma can be easily provided using ROOTS software:

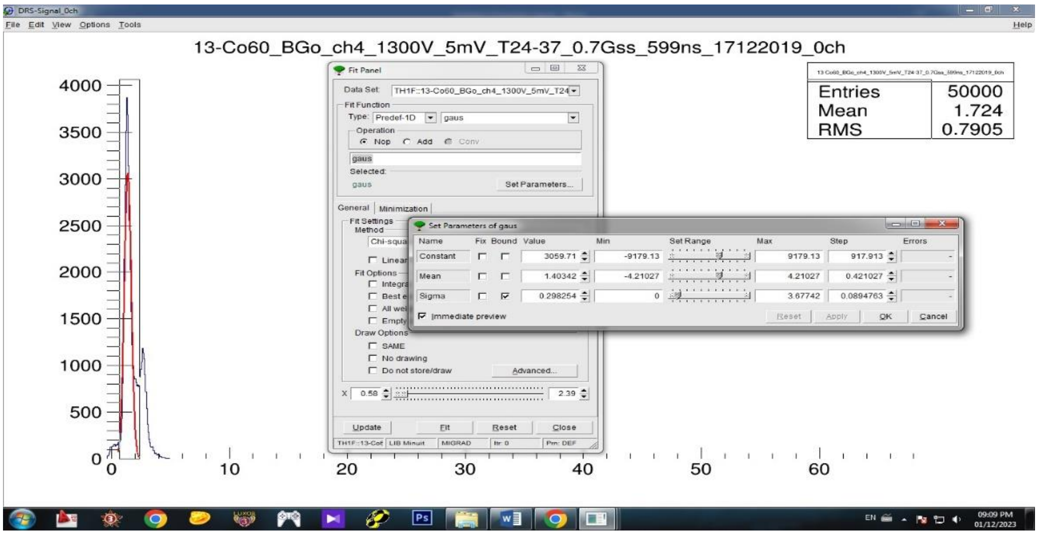

Figure1: signal produced by BGO detector using Co-60 standard source at 1300v

Also, using two standard sources Co-60 and Cs-137, we managed to plot the

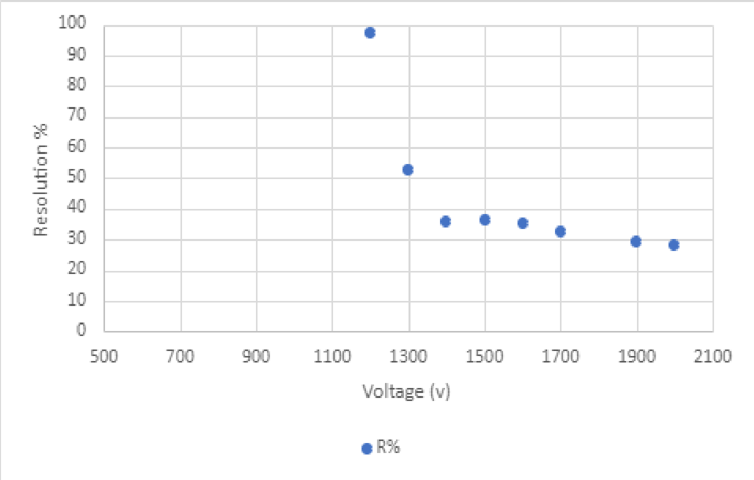

Figure 2: relation between the applied volt and resolution

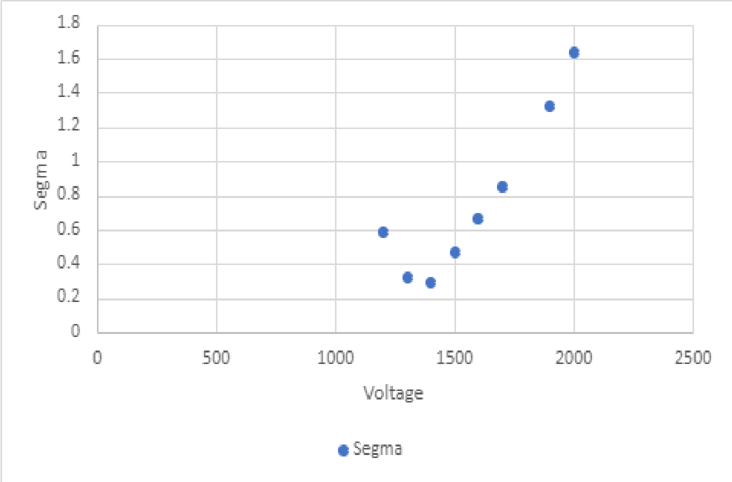

Figure 3: relation between the applied volt and signal

calibration curve of the detector by
plotting the relation between channel number and corresponding peak energies:

Channel number	**6.45536**	**12.2687**	**24.3794**
Energy (Kev)	**662**	**1253**	**3000**

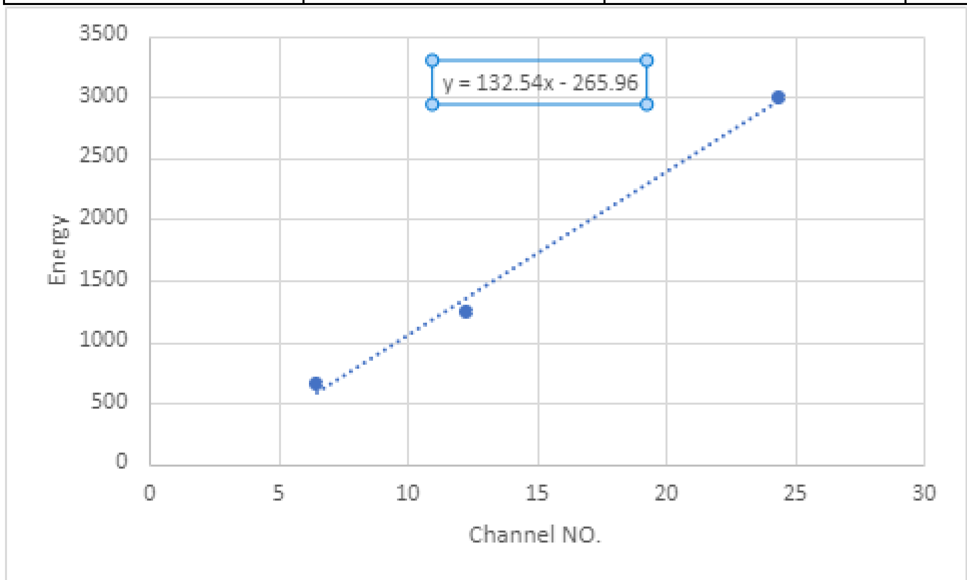

Figure 4: calibration curve of the BGO detector.

Task 2: Sodium iodide detector (NaI)

Again, we determine the relation between the applied voltage and both resolution and signal produced by NaI detector using standard Co-60 source having two peaks at 1173.2 and 1332.5 KeV. It is notable that resolution of sodium iodide detector is considerably higher than that of BGO detector although both are scintillation detectors, since NaI crystal has higher efficiency.

Voltage (v)	900	1000	1100	1200	1300
Mean	23.6396	40.6248	65.7819	98.7029	137.471
Segma	0.655425	1.01022	1.52299	2.08313	2.56895
R %	6.5115	5.84376	5.4407	4.9596876	4.3915

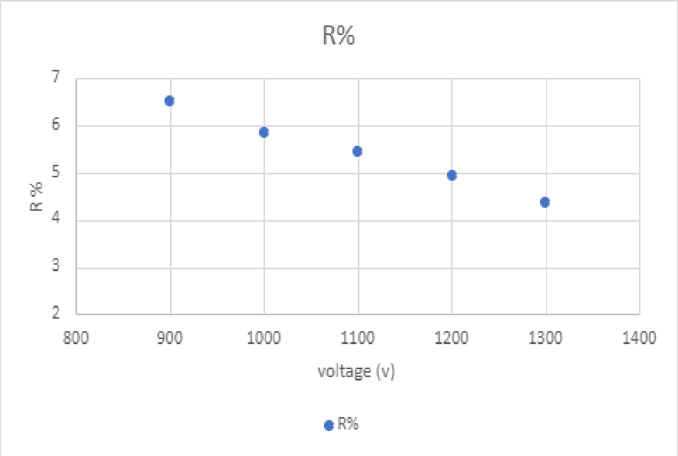

Figure 5: relation between resolution and the applied volt

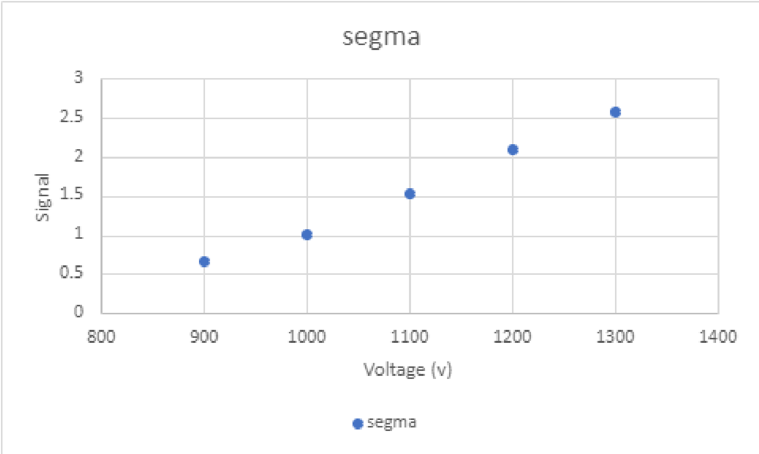

Figure 6: relation between signal and the applied volt

Also managed to plot the calibration curve using two standard sources Co-60 and Cs-137 as follows:

Channel No.	7.6992	12.6112	14.1384	25.1948
Energy (Kev)	662	1173.2	1332.5	2614

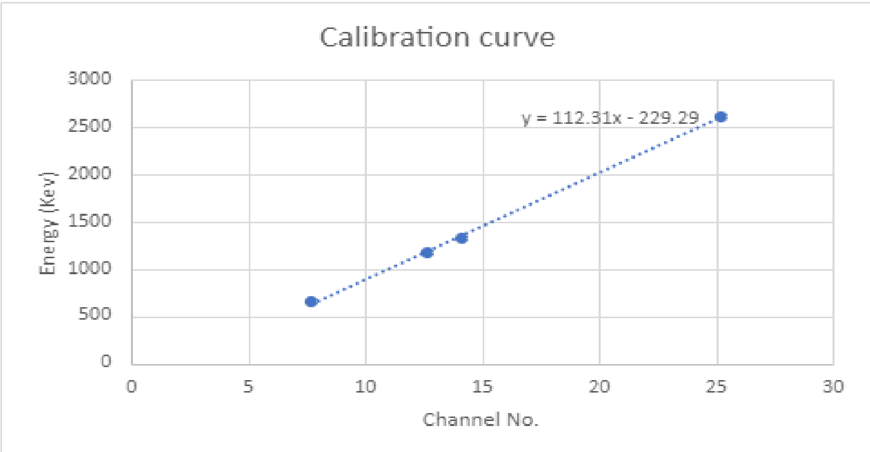

Figure 7: calibration curve of the detector relating channel number and energy

The multichannel analyser provides the signal with respect to the channel number, and using the calibration curve, it is possible to find the energy corresponding to a certain channel number. As a result, peak energy for any radioactive source can be defined.

As an application, we picked up an unknown source in order to define its peak energy using this detector. Using ROOTs we managed to define channel number corresponding to source peaks as:

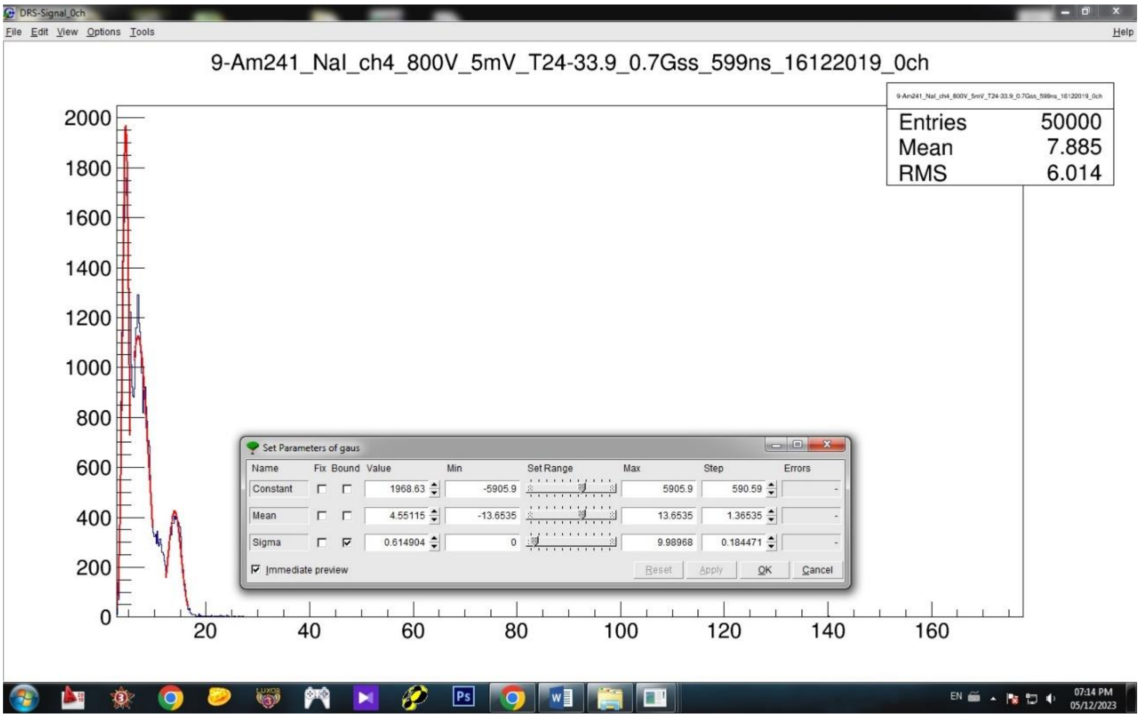

Figure 8: peaks of an unknown source

Channel no.	6.68599	13.9953	4.55115
Energy (KeV)	521.6135	1342.522143	281.85

Task 3: Determining the range of alpha particles in the air

A radioactive material can undergo radioactive decay by the emission of one of three particles: alpha, beta, or gamma. The alpha particle consists of two neutrons and two protons bound together (nucleus of helium) travels in matter with the excess energy that gets out of the nucleus.

In this experiment, we determine the range of alpha particles emitted from a standard Pu-239 source which has a peak energy of 5MeV using a plastic detector. The reason why we do not use crystal detector is that the alpha particles are totally stopped in the aluminium foil layer before they reach the detector. The range of alpha is defined as the distance at which almost no counts reach the detector.

Counts	0	5	10	15	20	25	30	35
Distance(mm)	440	390	360	340	320	300	280	240

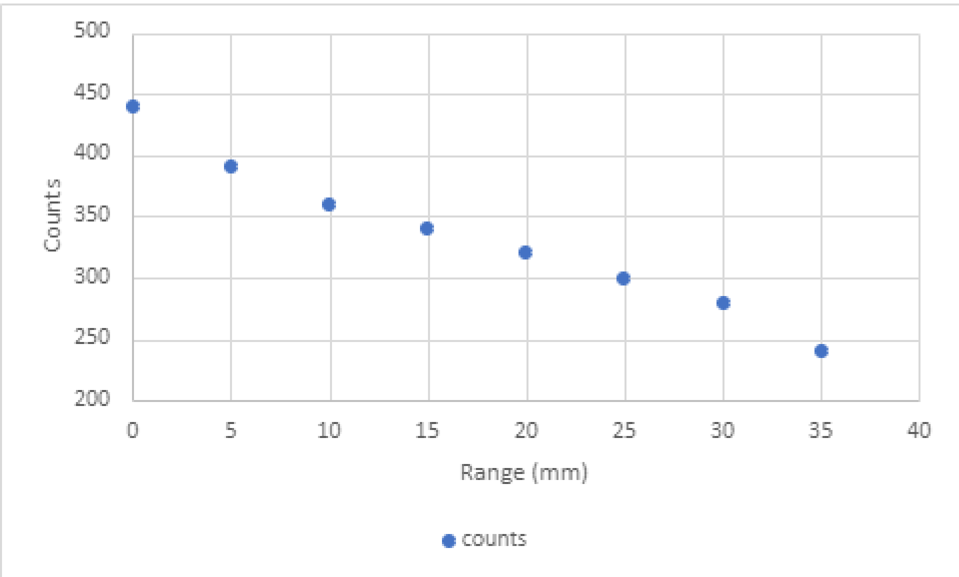

Figure 9: range of the alpha particles in air

From the graph the range of alpha particles in air is almost 35mm or 3.5cm

Task 4: determining the attenuation coefficient of gamma rays in both aluminium and copper

Gamma rays are known to be very penetrating since they do not have any rest mass which make it easier to go through matter. That's why it is very important to determine the attenuation coefficient of gamma rays in material so as to determine the suitable candidates in shielding applications in fields involving the use of high energetic gamma rays. In this experiment we determine the attenuation coefficient of aluminium and copper by shooting a target of the desired material with a defined thickness by gamma rays, then repeating the process several times. The attenuation coefficient can be determined through the relation:

$$I/_{Io} = e^{-\mu t}$$

For the aluminium:

Thickness (cm)	0	0.15	0.3	0.45	0.75	0.9	1.08	1.26
I/Io	1	0.75573	0.71623	0.70509	0.68596	0.67155	0.66103	0.63939

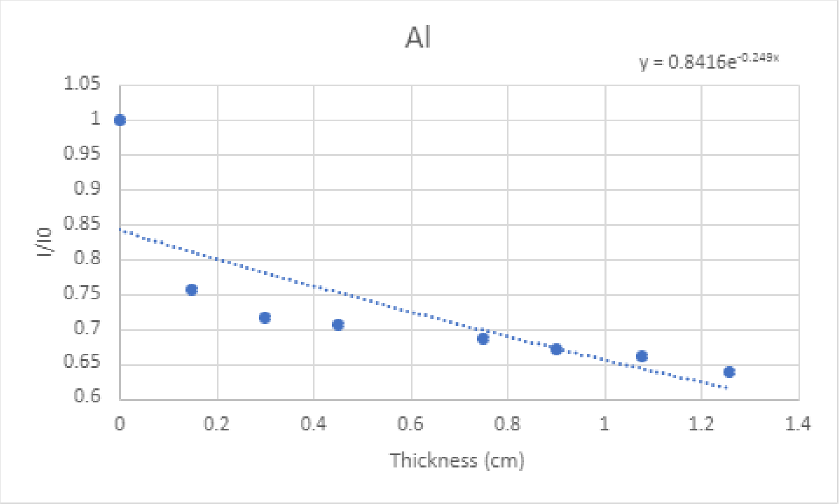

Figure 10: the attenuation coefficient of gamma rays in aluminium

From the graph: the attenuation coefficient μ =0.249

For the copper:

Thickness (cm)	0	0.2	0.25	0.4	0.8	1	1.2
I/Io	1	0.73931	0.7357	0.68065	0.58611	0.53827	0.48042

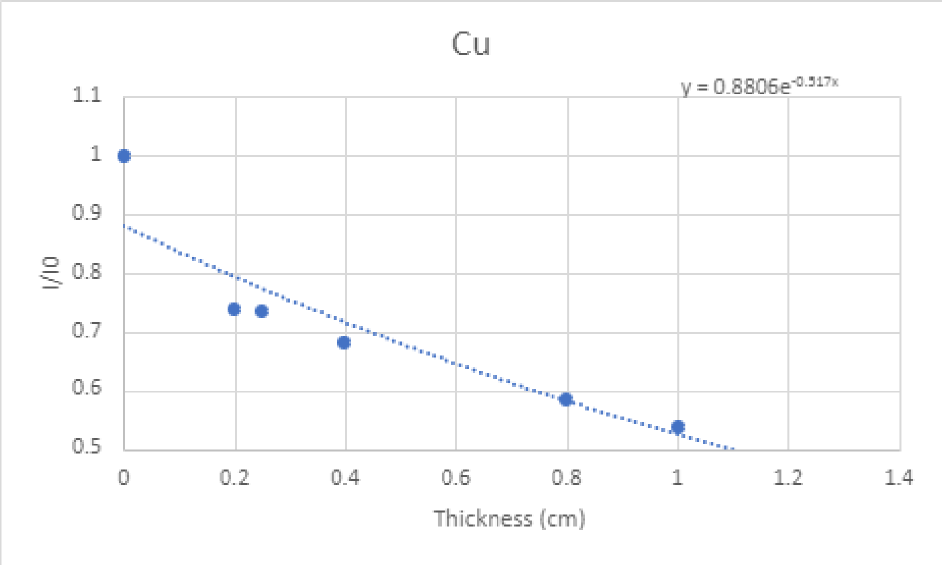

Figure 11: attenuation coefficient of gamma rays in copper

From the graph: the attenuation coefficient $\mu = 0.517$