RADIATION PROTECTION AND SAFETY OF RADIATION SOURCES

INTEREST- International Remote Student Training at JINR

Wave 4

STUDENT:

Emmanuel Opoku Sevordzie

Tomsk Polytechnic University

Tomsk, Russia

PROJECT SUPERVISOR:

Dr. Said M. Shakour

Dzhelepov Laboratory of Nuclear Problems

JINR, Dubna

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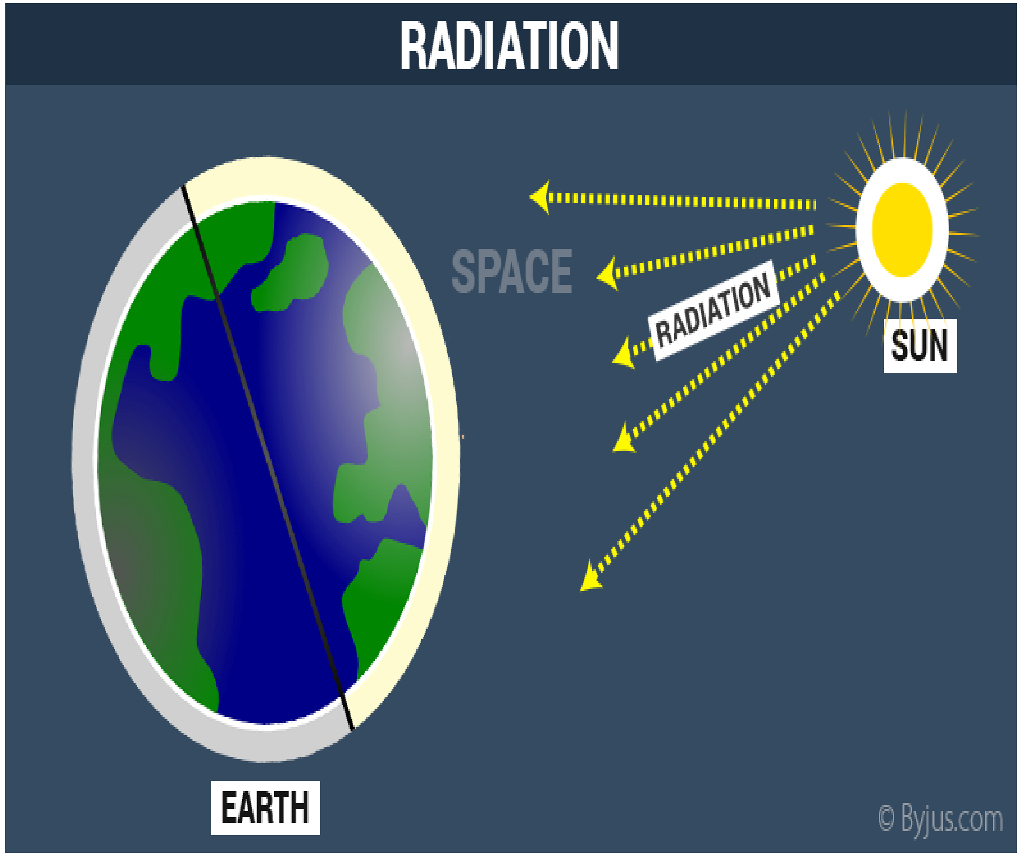
Introduction

We are under the showers of cosmic radiation which includes all types of radiations. There are artificial sources of radiation produced by specific human activity.

Inspite of its consequencies it has many beneficial applications ranging from power generation to uses in medicine, industry, agriculture and many more.



Introduction

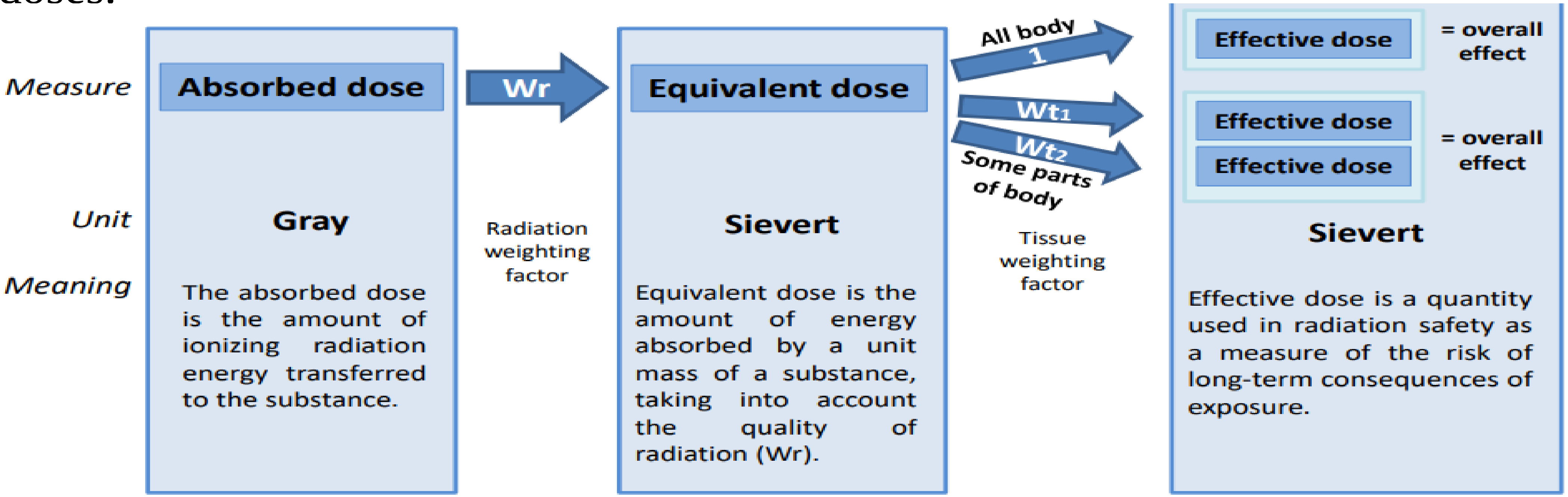
This radiation is invisible and is omnipresent. Its effect has a dire consequences. It cannot be felt, smelt, seen, heard or tasted.

However, with the use of appropriate device, it can be monitored.

Radiation monitoring involves the measurement of radiation doses, detection of radionuclide contamination, control of exposure to radiation or radioactive substances, and the analysis of the results from aforementioned activities.

Radiation Dosimetry

Radiation dosimetry is the measurement, calculation and assessment of radiation dose received by a body as a result of exposure to ionizing radiation. They are measured by dosimeters. These dosimeters can measure both delayed and real time doses.



Experimental setup and scintillation detector

Technology has made it possible to detect and measure radiation as part of monitoring it. In this project, scintillation detectors like NaI and BGO were used.

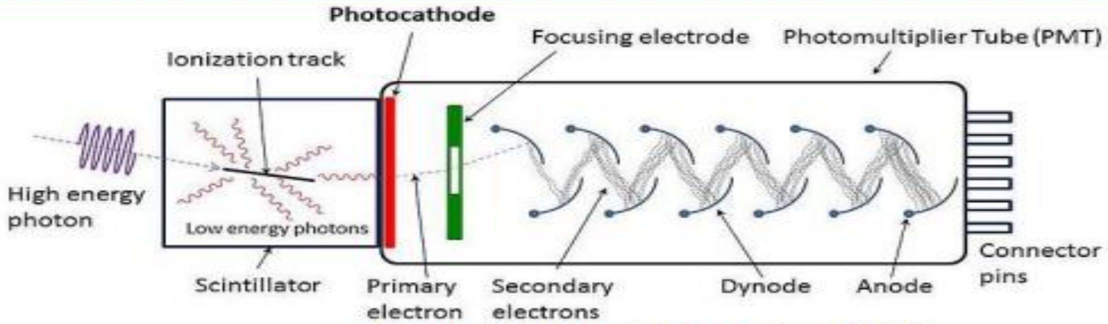


Figure.2. *Photomultipliers Tubes (PMT)*

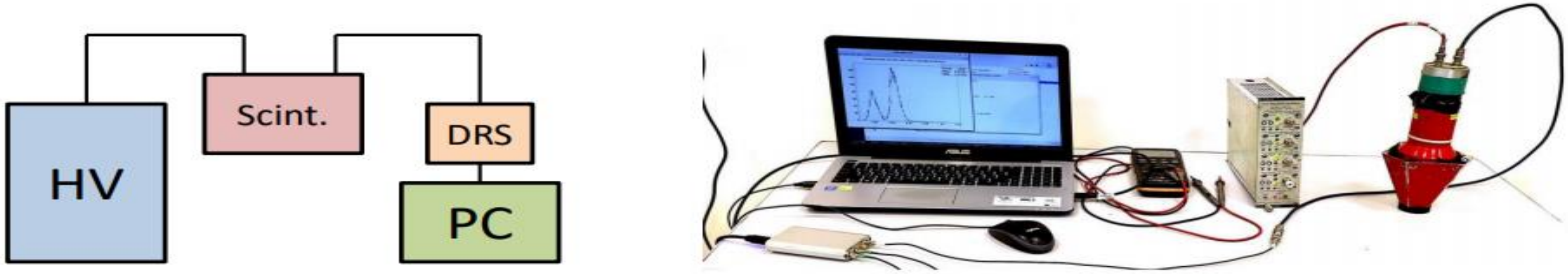


Figure.3. *Experimental set-up*

Advantages and disadvantages of the scintillation detector.

A scintillation counter is an instrument for detecting and measuring ionizing radiation by using the excitation effect of incident radiation on a scintillating material, and detecting the resultant light pulses.

Advantages

- The ability to accommodate samples of any type, including liquids, solids, suspensions and gels.
- The ease of sample preparation.
- Much higher counting efficiencies particularly for low energy β-emitters
- The ability to count separately different isotopes in the same sample, which means dual labelling experiments can be carried out
- Scintillation counters are highly automated, hundreds of samples can be counted automatically

Disadvantages

- At the high voltages applied to the photomultiplier, electronic events occur in the system that are independent of radioactivity but contribute to a high background count.
- The cost per sample of scintillation counting
- The use of pulse height analyser can be set so as to reject, electronically, most of the noise pulses that are of low energy. The disadvantage here is that this also rejects the low energy pulses resulting from low energy radioactivity

Task 1: The relationship between Resolution and Applied voltage for BGO detector

$$R = \frac{Sigma}{Mean} \, x \, 2.35$$

No	mean	Sigma	Resolution, R (%)	Applied Volts
12	1.408	0.591	98.640	1200
13	1.380	0.273	46.489	1300
14	1.920	0.295	36.106	1400
15	2.980	0.465	36.669	1500
16	4.420	0.609	32.379	1600
17	6.093	0.828	31.935	1700
19	8.744	1.248	33.540	1900
20	10.620	1.581	34.984	2000

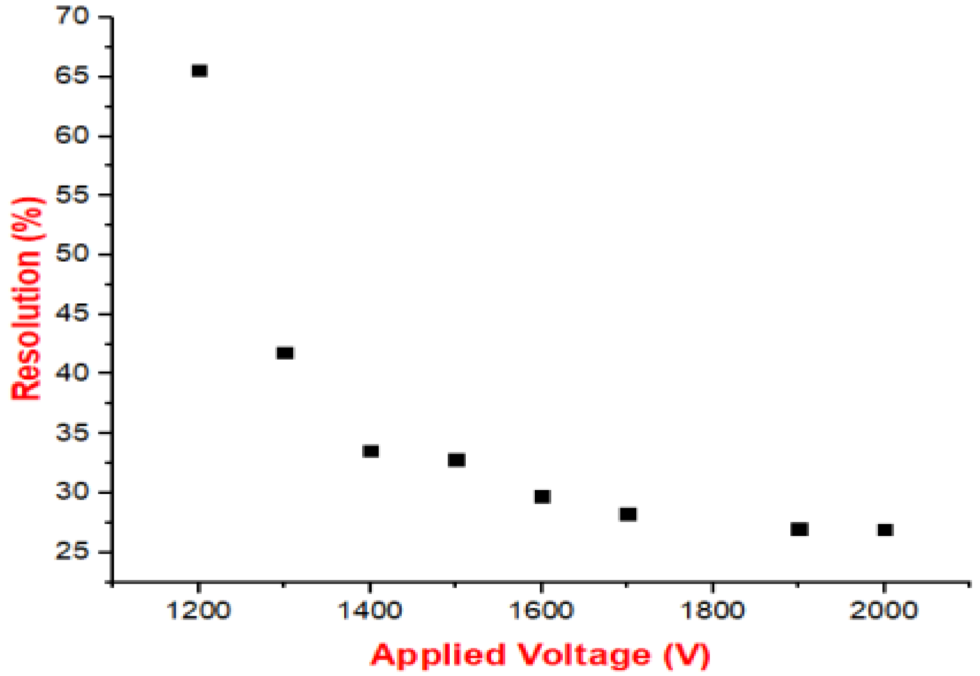


Figure.4. *The relation between the resolution and applied voltage for BGO detector*

Task 1.2 Energy calibration for BGO

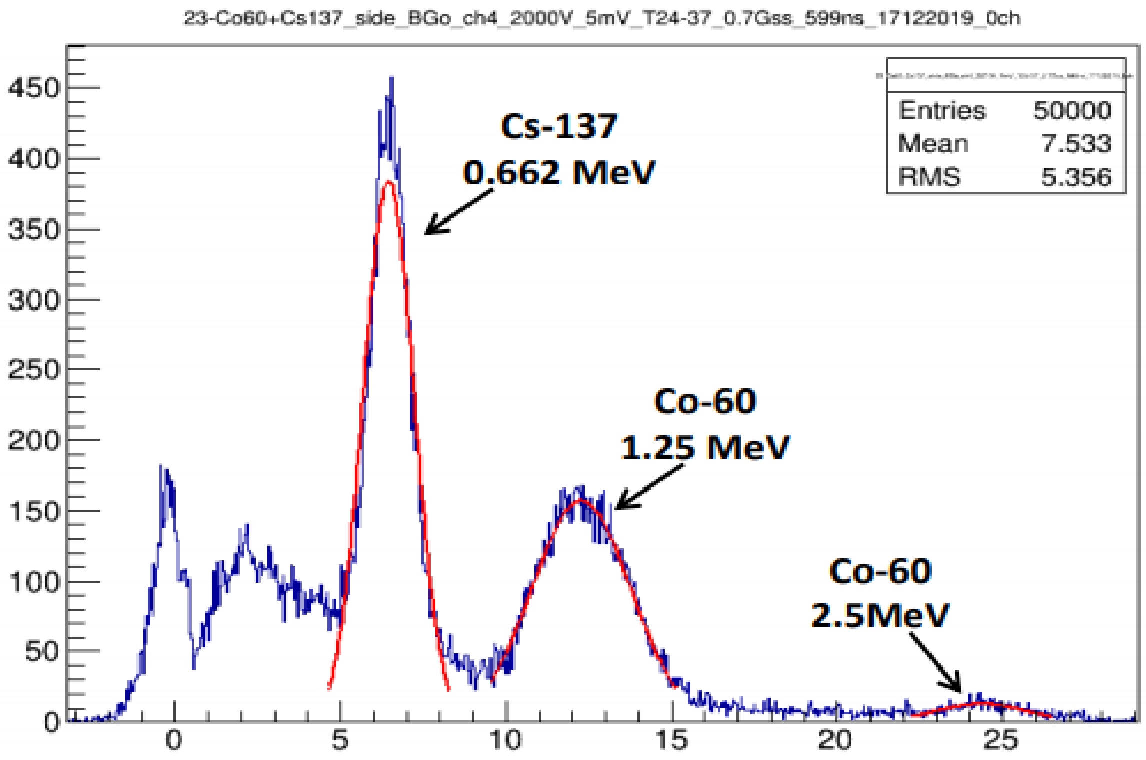


Figure.5. *Cs-137 and Co-60 spectrum from measurements with BGO detector at 2000 V*

Equation of calibration:

y=0.05179+9.73835x ,

where y = PMT signal A.U,

x = Energy of unknown source

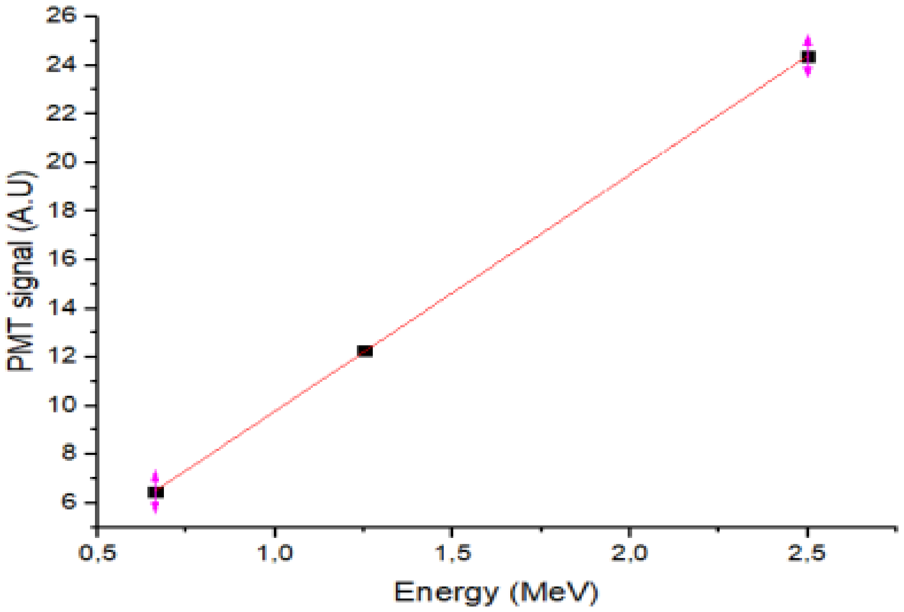


Figure.6. *Energy calibration function*

Task 2.1 The relation between resolution and applied voltage for NaI detector

$$R = \frac{Sigma}{Mean} \; x \; 2.35$$

№	Sigma	Mean	Resolution	Applied Voltage
2	0,626	23,66	6,2176669	900
3	1,043	40,61	6,0355824	1000
4	1,516	65,78	5,4159319	1100
5	2,035	98,76	4,8422945	1200

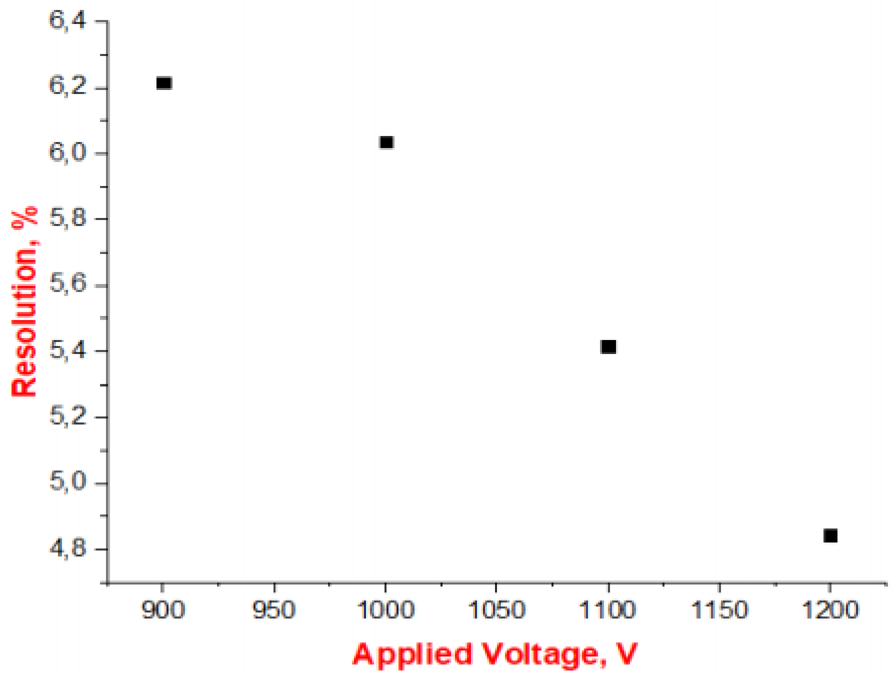


Figure.7. *The relation between the resolution and applied voltage for NaI detector*

Task 2.2 Energy calibration for NaI

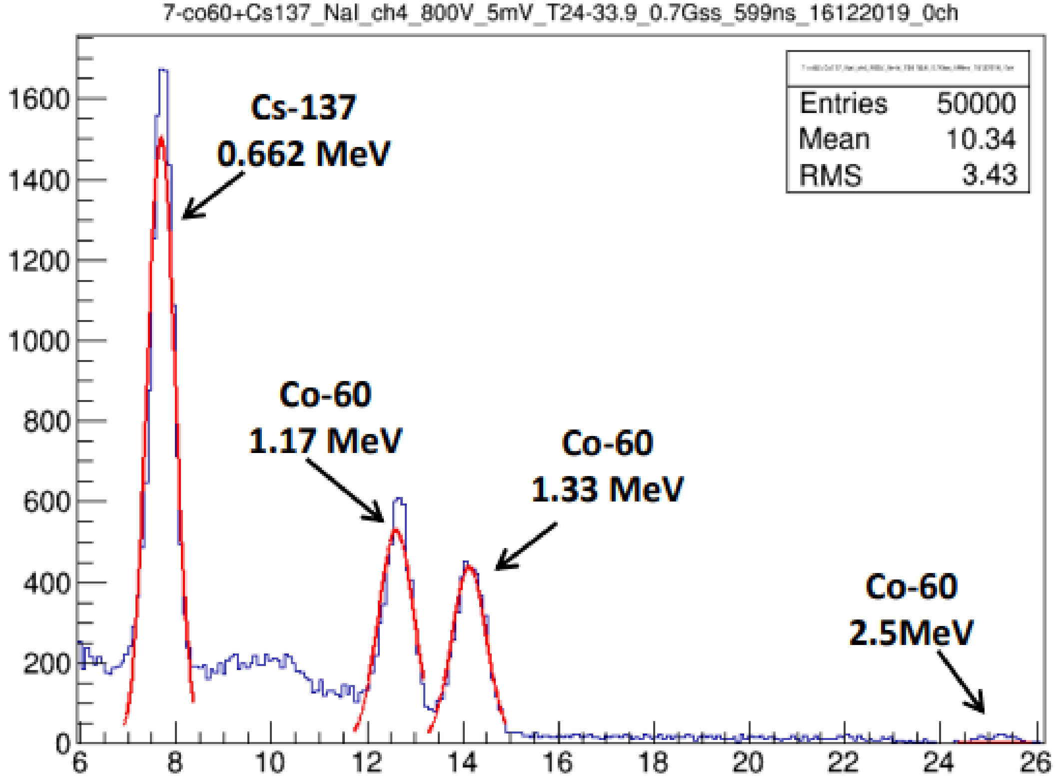


Figure.8. *Cs-137 and Co-60 spectrum from measurements with NaI detector at 2000 V*

Equation of calibration:

y = 1.45953 + 9.50263x

where y = PMT signal A.U,

x = Energy of unknown source

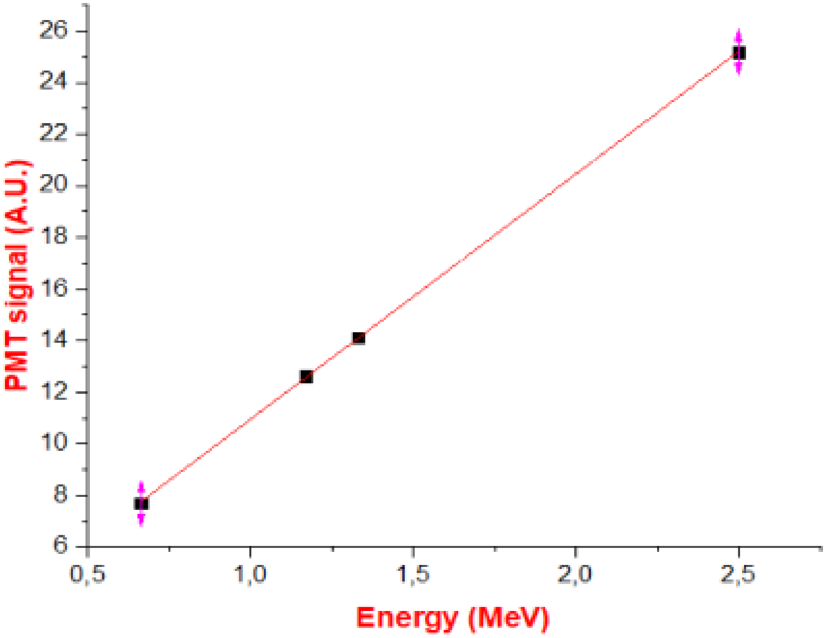


Figure.9. *Energy calibration function*

Task 2.3 Identification of unknown sources

Unknown sources 1

y = 1.45953 + 9.50263x
y = 6.283
6.283 = 1.45953 + 9.50263x
x = 0.507

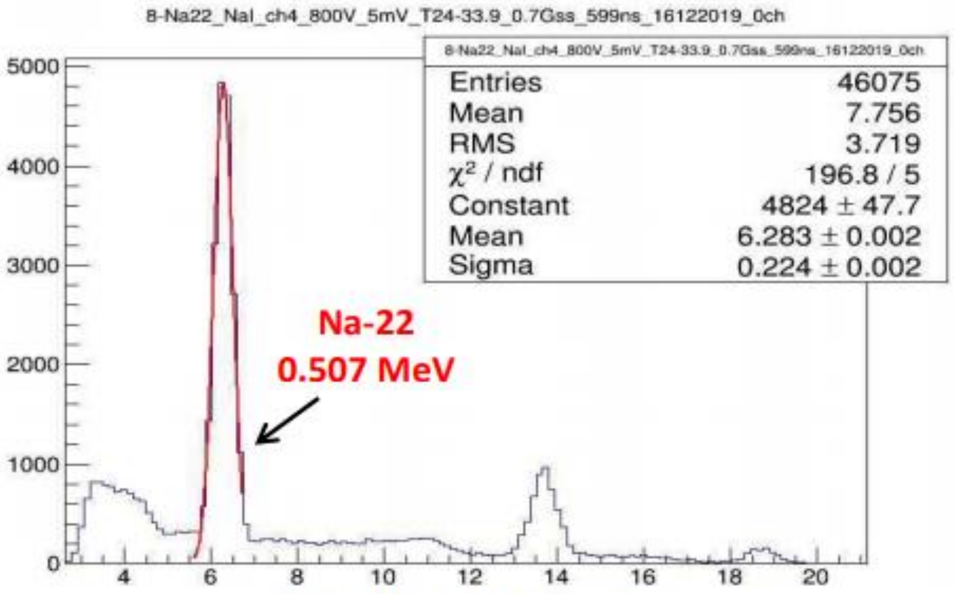


Figure.10. *Na-22 spectrum*

Unknown sources 2

y = 1.45953 + 9.50263x
y = 4.488
4.688 = 1.45953 + 9.50263x
x = 0.34

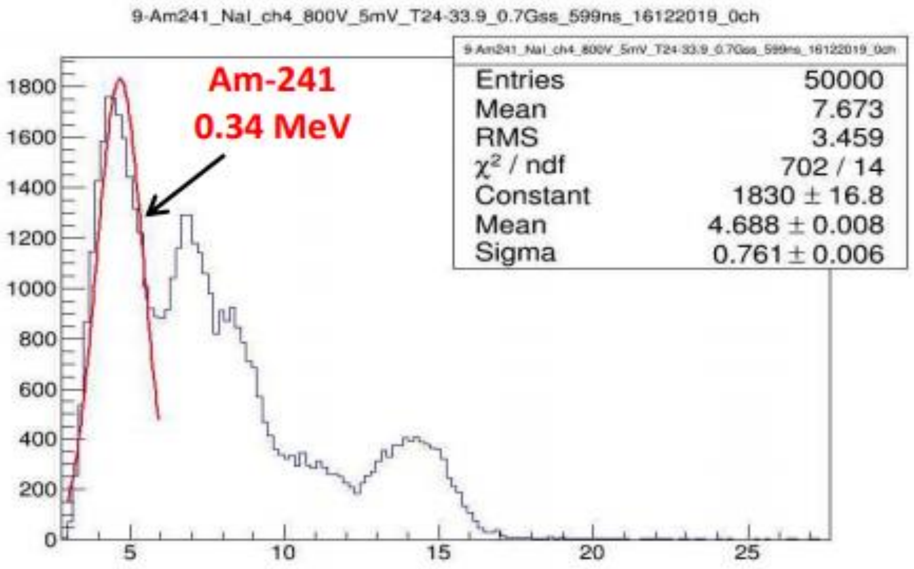
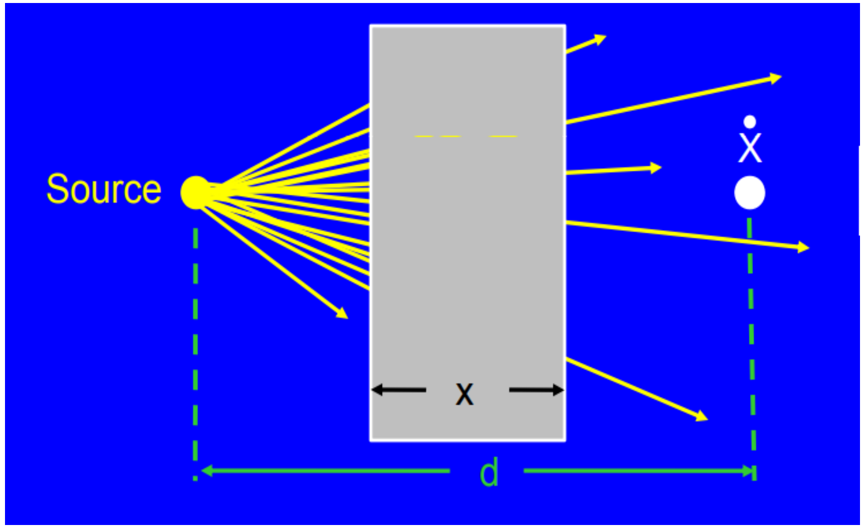


Figure.11. *Am-241 spectrum*

Task 3 Attenuation coefficient

Attenuation coefficient describes the fraction of a beam that is absorbed or scattered per unit thickness of the absorber.

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



where μ is attenuation coefficient

I -is the exposure rate with the shield in place

I_0 -is the exposure rate without the shield

x - is the thickness of the shield

The equation assumes a narrow beam of radiation penetrating a thin shield (a situation usually referred to as "good geometry").

Task 3 Attenuation coefficient

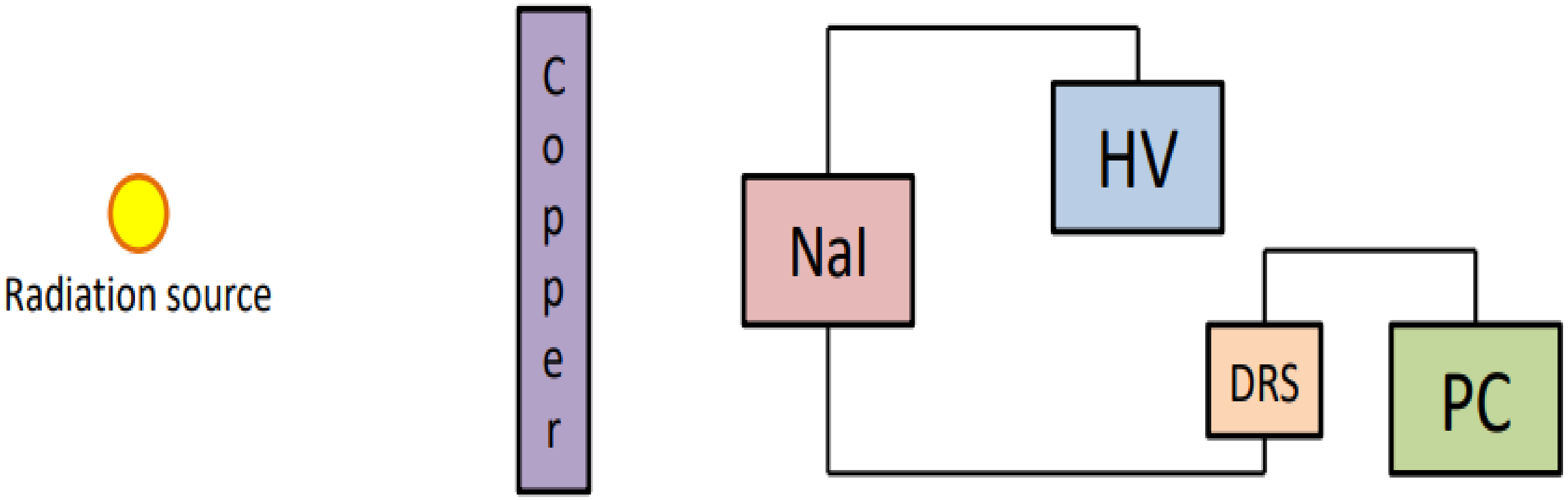


Figure.12. *Experimental set-up for determining the attenuation coefficient*

Task 3: Attenuation coefficient

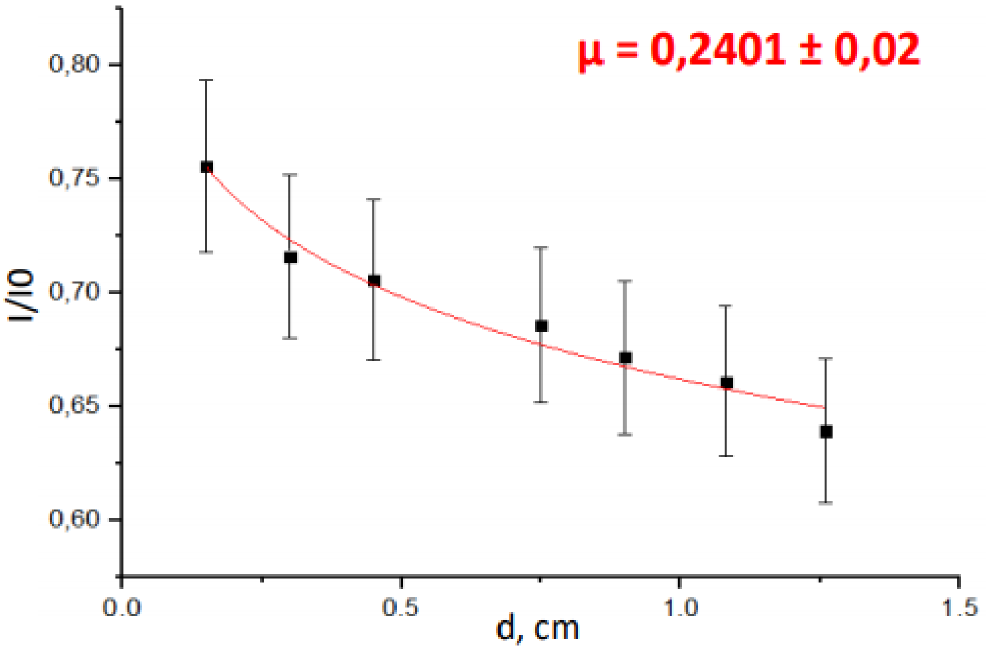


Figure.13. *Determination of attenuation coefficient for Al*

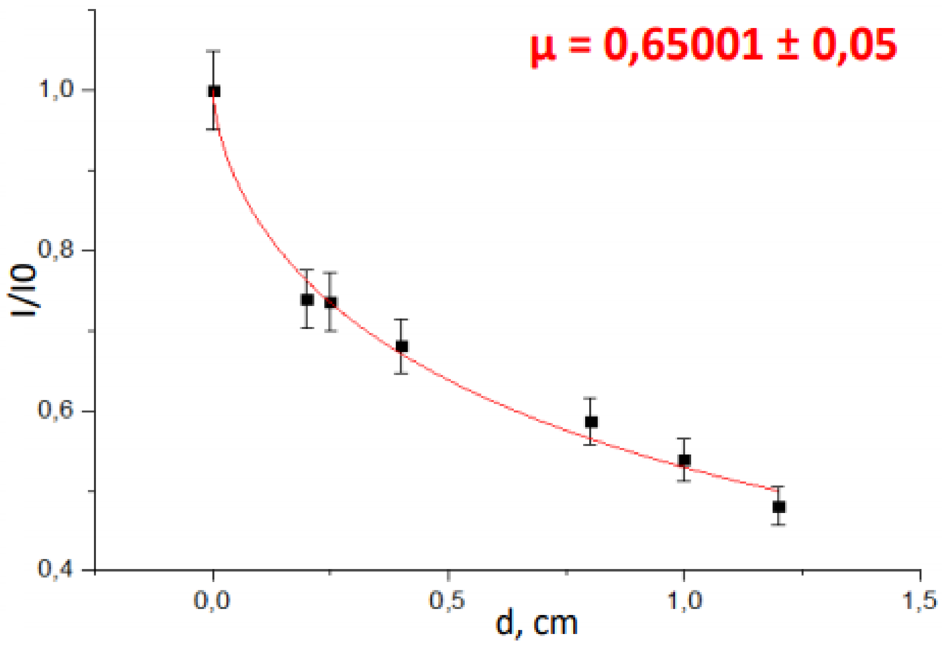


Figure.14. *Determination of attenuation coefficient for Cu*

Task 4: SRIM Simulation

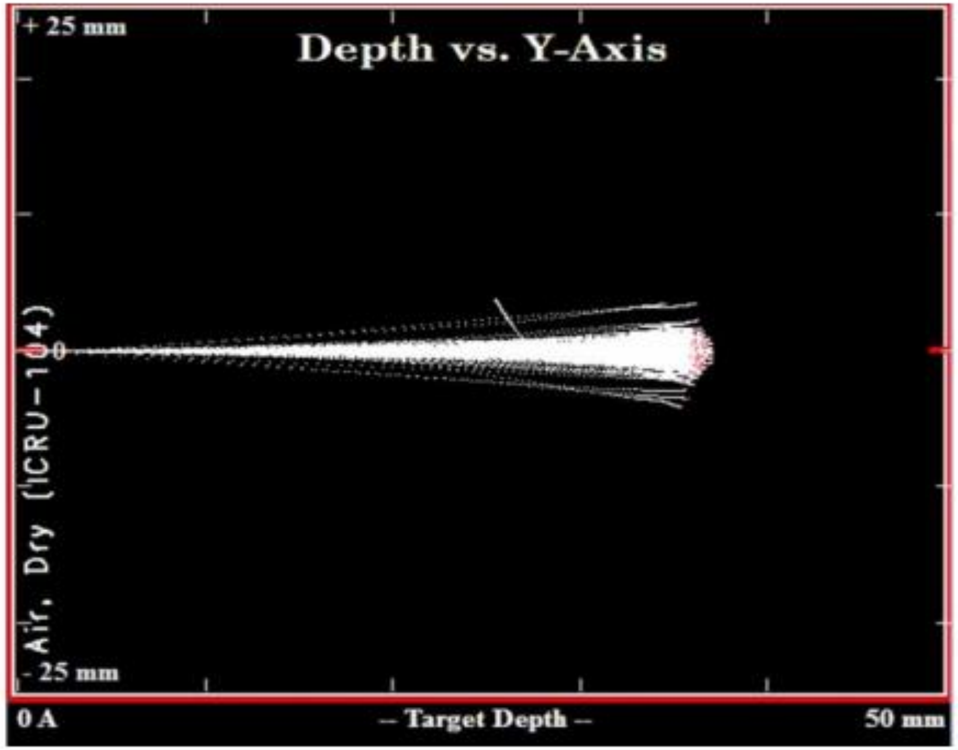


Figure.15. *Depth for α-radiation in air*

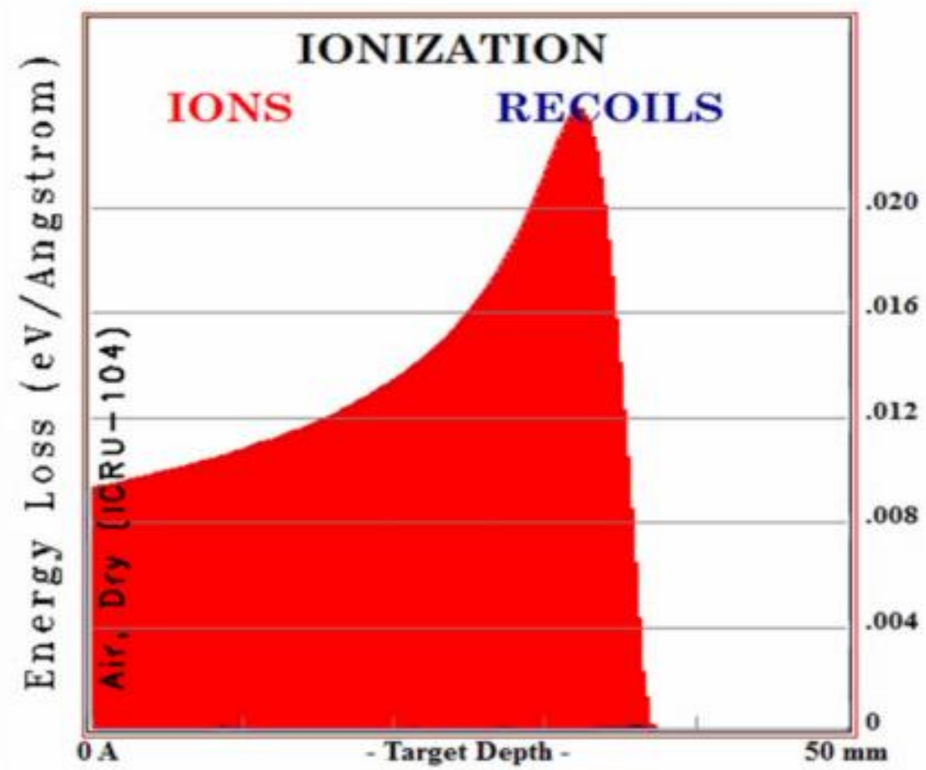


Figure.16. *Ionization*

Task 4: Alpha Range in air

Source: Pu239
Energy of He: 5 MeV
Detector: plastic
Applied volt: 2000 V

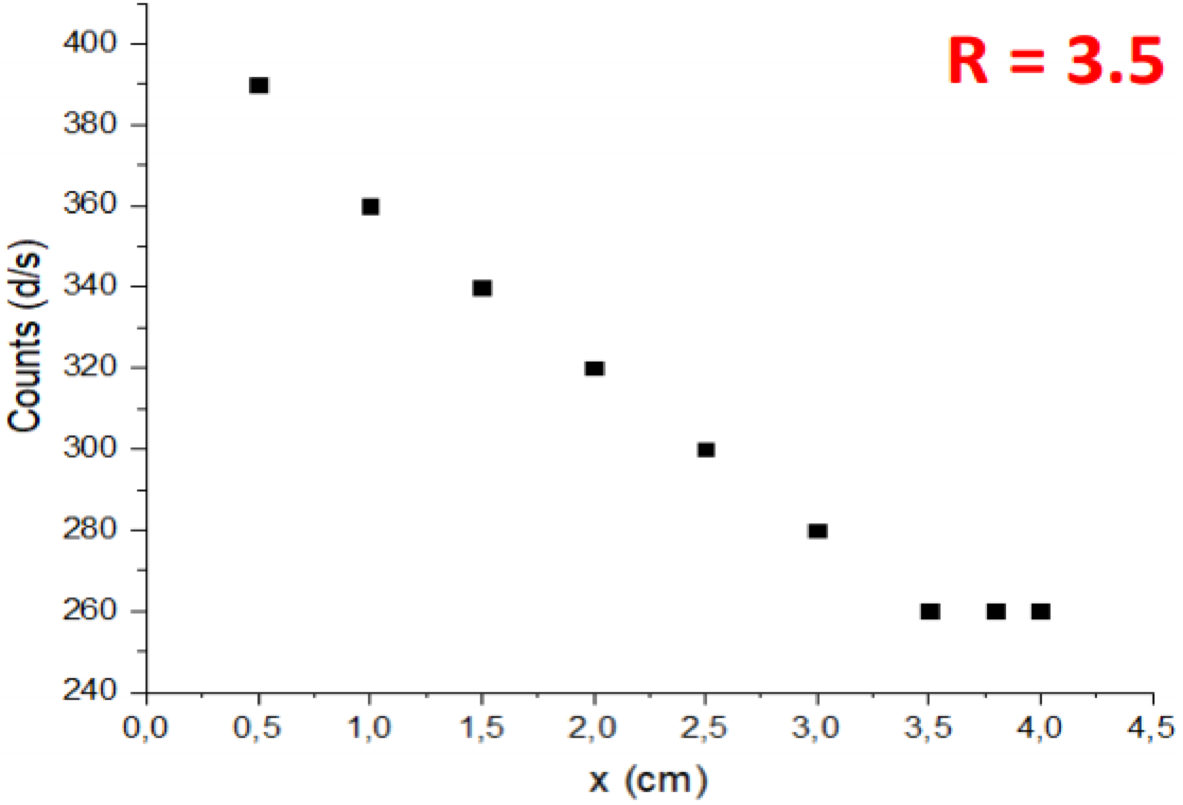


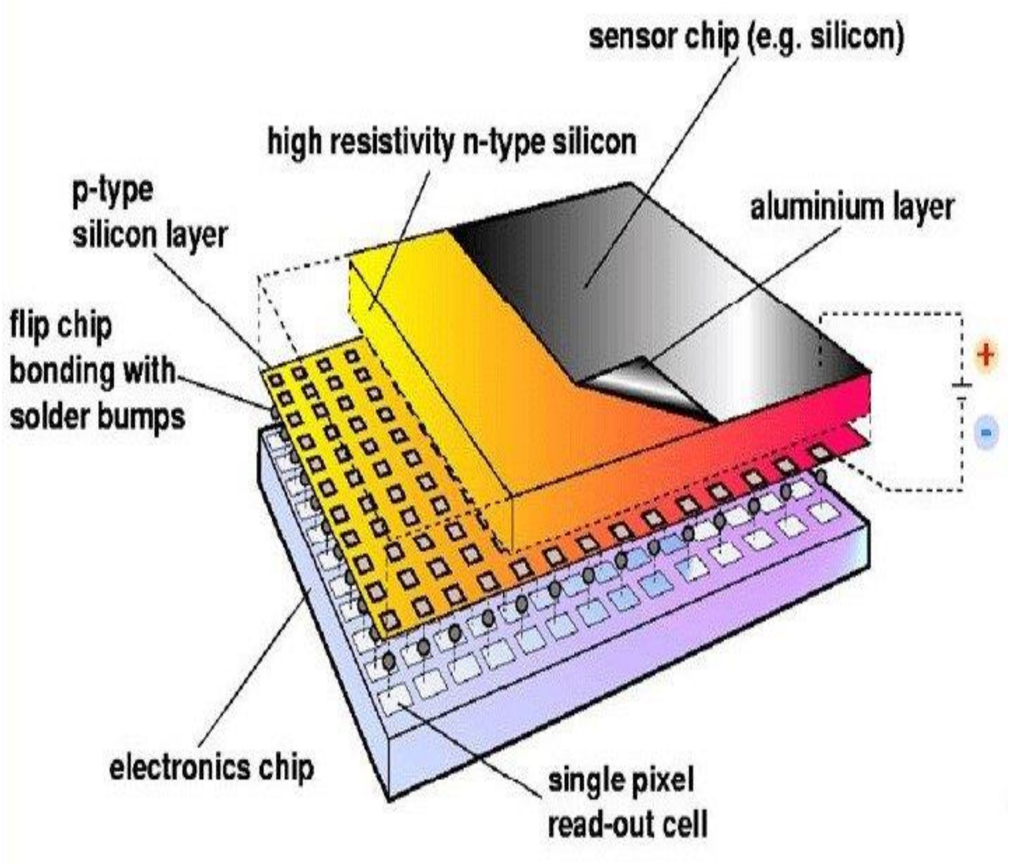
Figure.17. *The range of alpha particles*

Task 5 Pixel detectors

The pixel detector has a sensor connected to electronic chip by flip chip bonding with solder bump. It has a high resolution good for registering different types of radiation. Advance pixel detector is like a digital camera.

It consists of 3 parts:

- ❖ Sensor (Si)
- ❖Electronic ship
- ❖ USB



Task 5: Pixel detectors

An alpha source is brought near the pixel detector. The number of alpha particles decreases as the source is moved away from the detector as shown below:

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

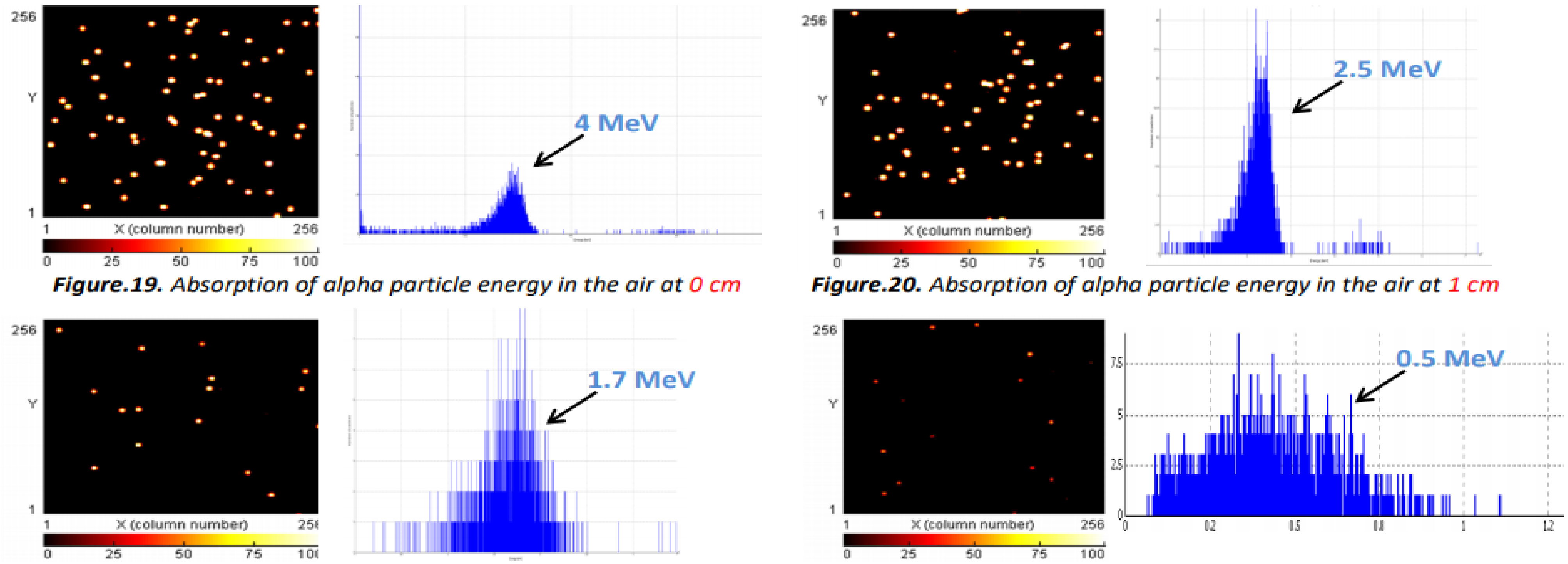


Figure.19. *Absorption of alpha particle energy in the air at 0 cm*

Figure.20. *Absorption of alpha particle energy in the air at 1 cm*

Figure.21. *Absorption of alpha particle energy in the air at 2 cm*

Figure.22. *Absorption of alpha particle energy in the air at 2.5 cm*

Task 5: Pixel detectors

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

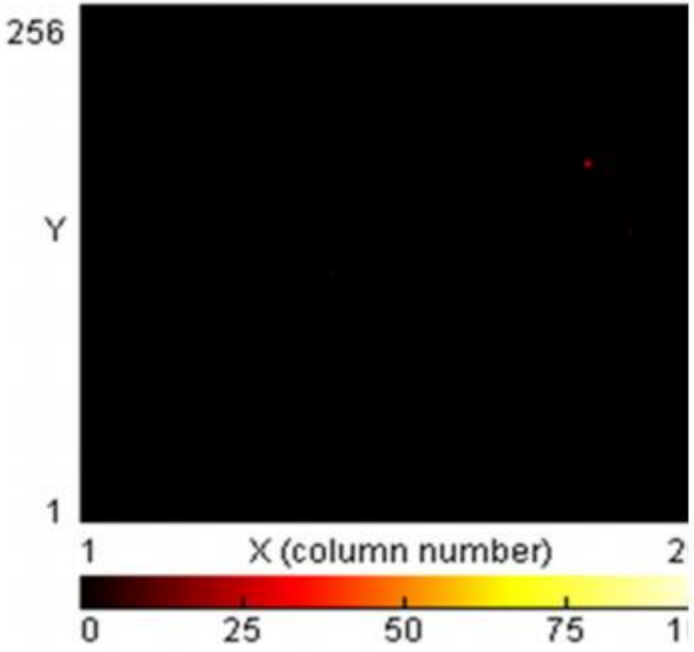


Figure.23. *Maximum range of* α-particles in air (3 cm)

There are no α-particles at 3 cm distance

↓

Maximum of α-particle range is 3 cm

Conclusion

This project has given me a fair understanding of radiation protection and safety. I have come to appreciate the fact that radiation can be measured, detected and shielded.

Basic skills in measuring and interperating results from BGO and NaI scintillation detectors were obtained.

Skills for identifying an unknown source was also obtained.

Reference

- Department of Health, https://www.rhd.gov.hk and the Hong Kong Observatory http://www.info.gov.hk/hko for more information.
- International Atomic Energy Agency (2007). *IAEA Safety Glossary: Terminology Used in Nuclear Safety and Radiation Protection* (PDF). Vienna: IAEA. ISBN 92-0-100707-8.
- *International Atomic Energy Agency (2010). Programmes and Systems for Source and Environmental Radiation Monitoring. Safety Reports Series No. 64. Vienna: IAEA. p. 234. ISBN 978-92-0-112409-8.*
- Technical Design Report of the ATLAS Pixel Detector, CERN/LHCC/98-13 (1998); N. Wermes, Design and Prototype Performance of the ATLAS Pixel Detector, Nucl. Inst. Meth. A447 (2002) 121-128.
- [2] CMS, the Tracker System Project, Technical Design Report, CERN/LHCC/98-006 (1998); W. Erdmann, The CMS pixel detector, Nucl. Inst. Meth. A447 (2000) 178-83