JOINT INSTITUTE
FOR NUCLEAR RESEARCH

Radiation Protection and the Safety of the Radiation Sources

INTEREST - INTErnational REmote Student Training at JINR
Wave 3

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Radiation Protection and Dosimetry

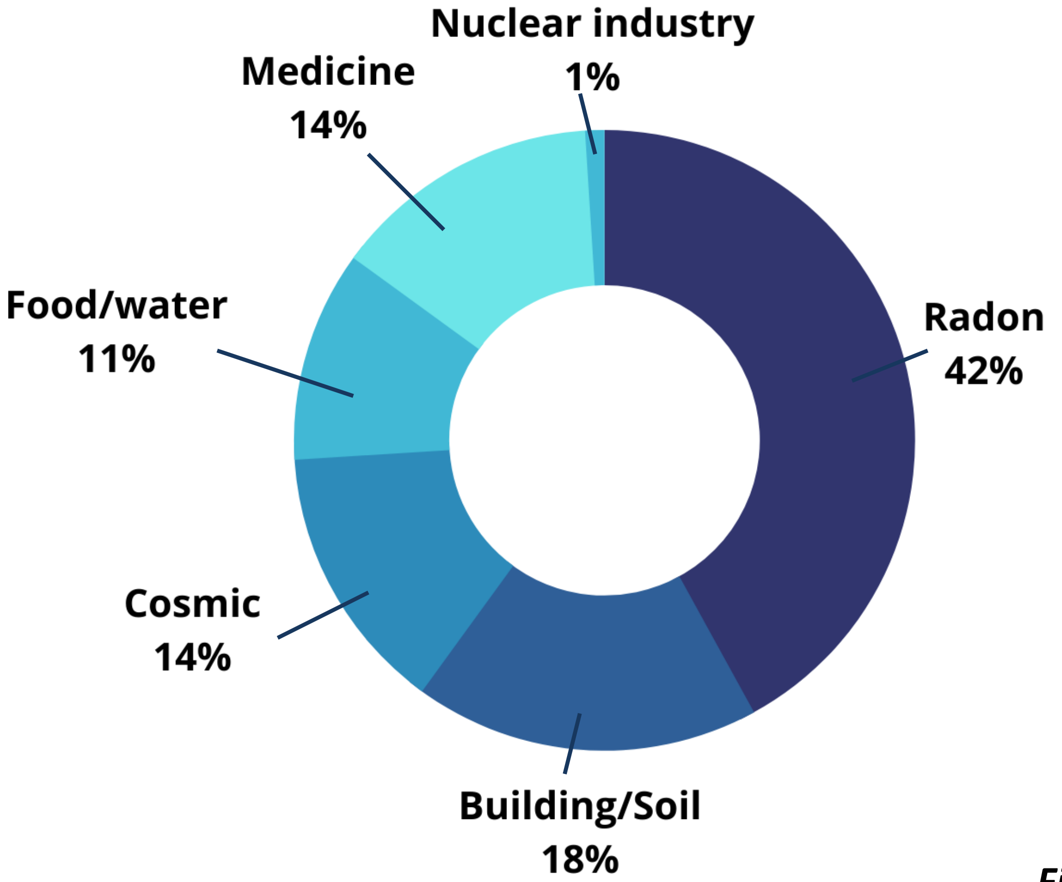


Figure 1. *Sources of Radiation*

Radiation Protection and Dosimetry

Measure	**Absorbed dose**	**Wr** →	**Equivalent dose**	**All body 1** → / **Wt1** → **Wt2** → **Some parts of body**	**Effective dose** = overall effect; **Effective dose** + **Effective dose** = overall effect
Unit	**Gray**	Radiation weighting factor	**Sievert**	Tissue weighting factor	**Sievert**
Meaning	The absorbed dose is the amount of ionizing radiation energy transferred to the substance.		Equivalent dose is the amount of energy absorbed by a unit mass of a substance, taking into account the quality of radiation (Wr).		Effective dose is a quantity used in radiation safety as a measure of the risk of long-term consequences of exposure.

Scintillation detectors and experimental set-up

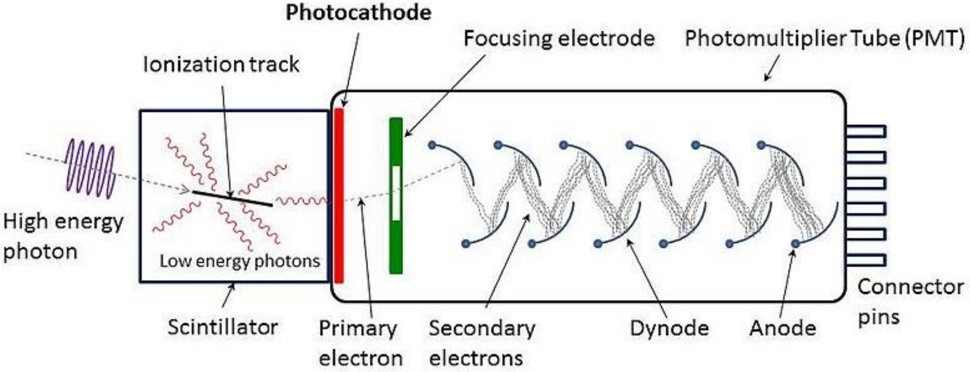
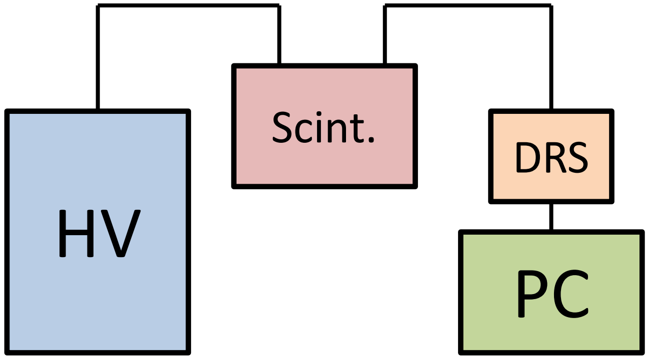


Figure 2. *Photomultipliers Tubes (PMT)*



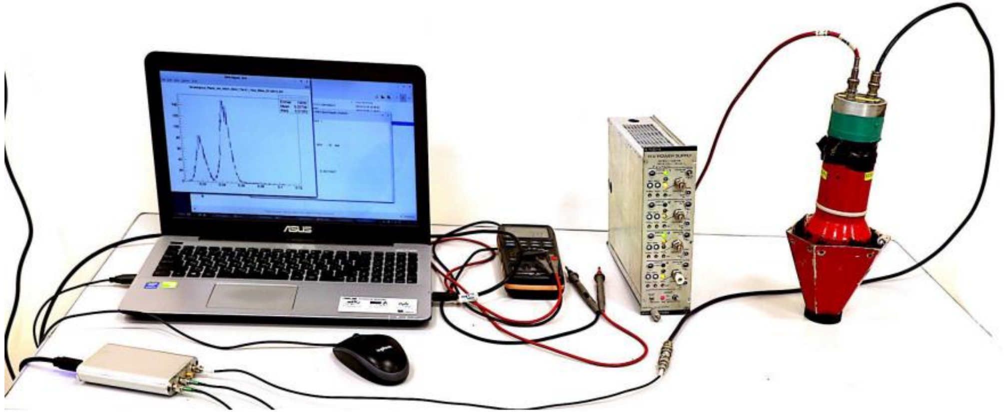


Figure 3. *Experimental set-up*

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

Task 1.1. The relation between the resolution and applied Voltage for BGO detector

$$R = \frac{Sigma}{Mean} \times 2.35$$

№	Sigma	Mean	Resolution	Applied Voltage
12	0,4518	1,618	65,620	1200
13	0,2412	1,356	41,801	1300
14	0,2738	1,917	33,564	1400
15	0,4178	2,989	32,848	1500
16	0,5595	4,418	29,761	1600
17	0,7352	6,11	28,277	1700
19	1,227	10,67	27,024	1900
20	1.562	13.61	26.971	2000

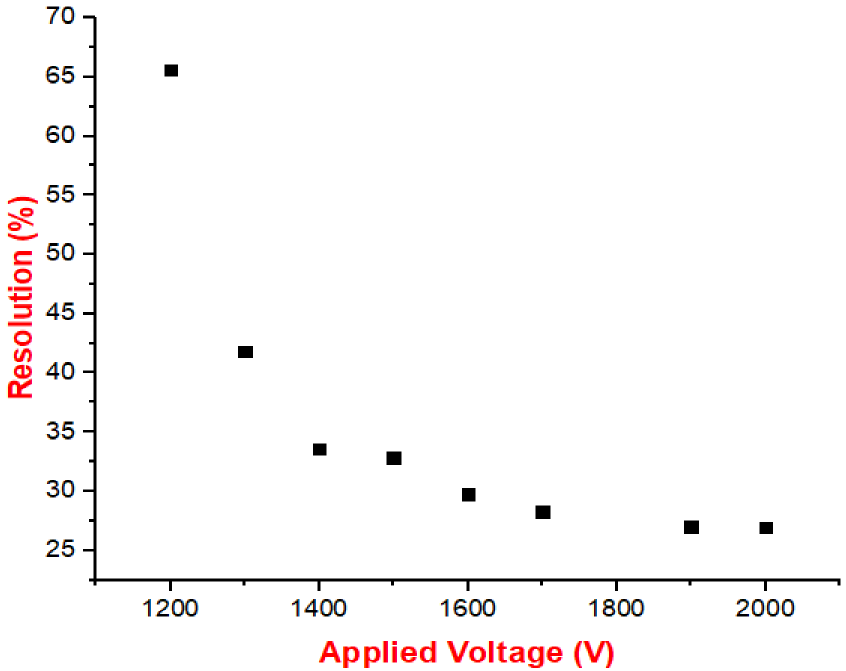


Figure 4. *The relation between the resolution and applied voltage for BGO detector*

Task 1.2. Energy calibration for BGO

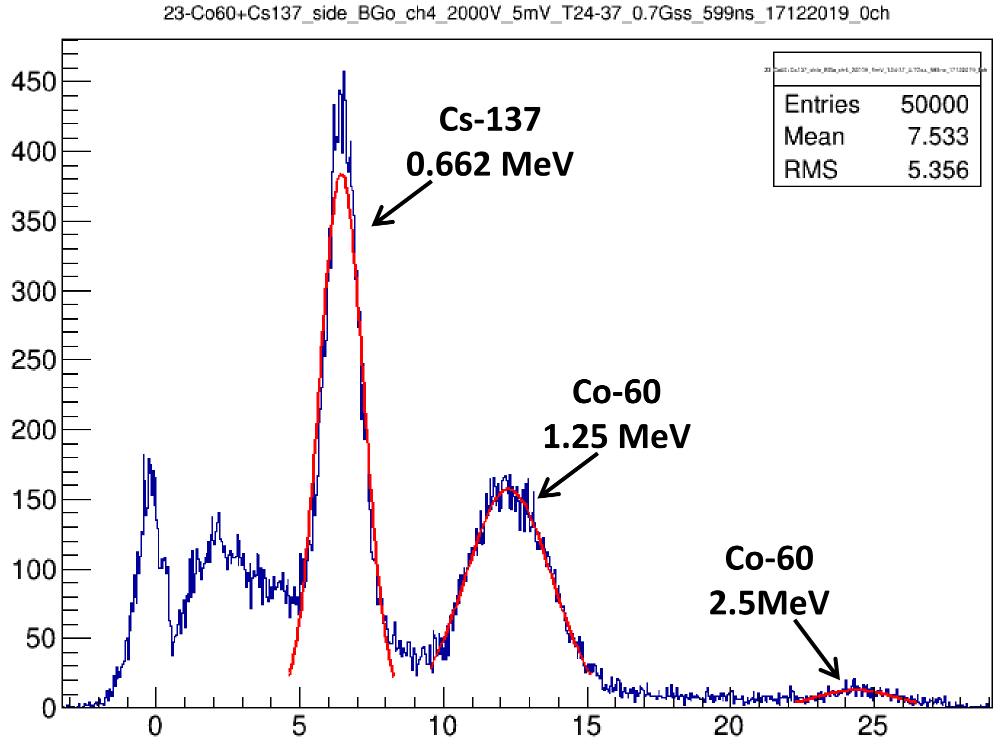


Figure 5. *Cs-137 and Co-60 spectrum from measurements with BGO detector at 2000 V*

Equation of calibration:

y=0.05179+9.73835x ,

where y = PMT signal A.U,

x = Energy of unknown source

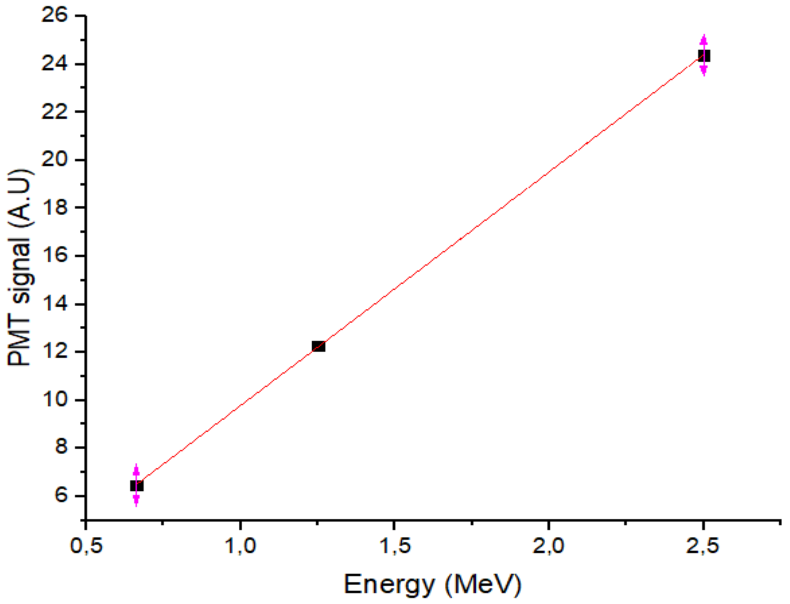


Figure 6. *Energy calibration function*

Task 2.1. The relation between the resolution and applied Voltage for NaI detector

$$R = \frac{Sigma}{Mean} \times 2.35$$

№	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

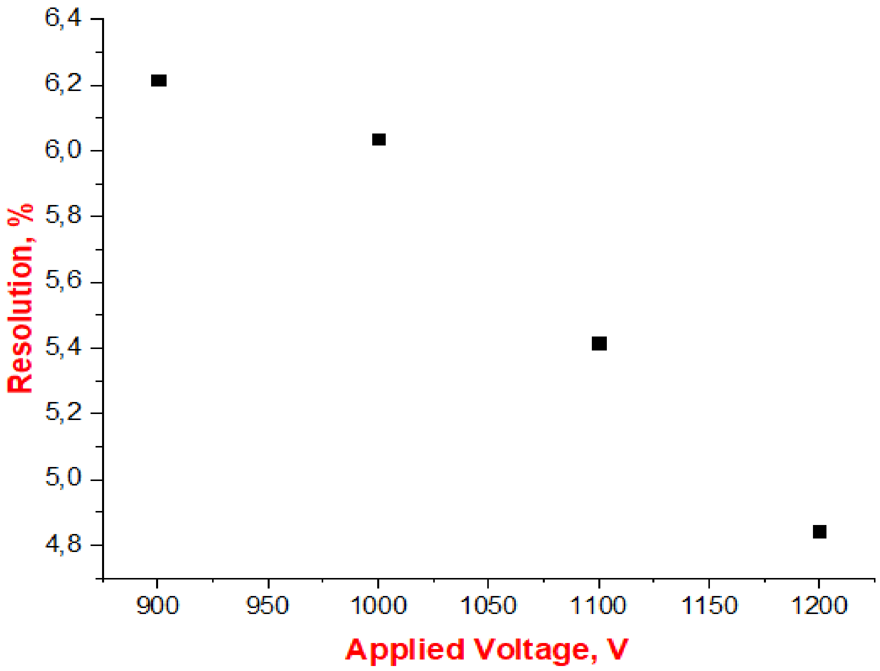


Figure 7. *The relation between the resolution and applied voltage for NaI detector*

Task 2.2. Energy calibration for NaI

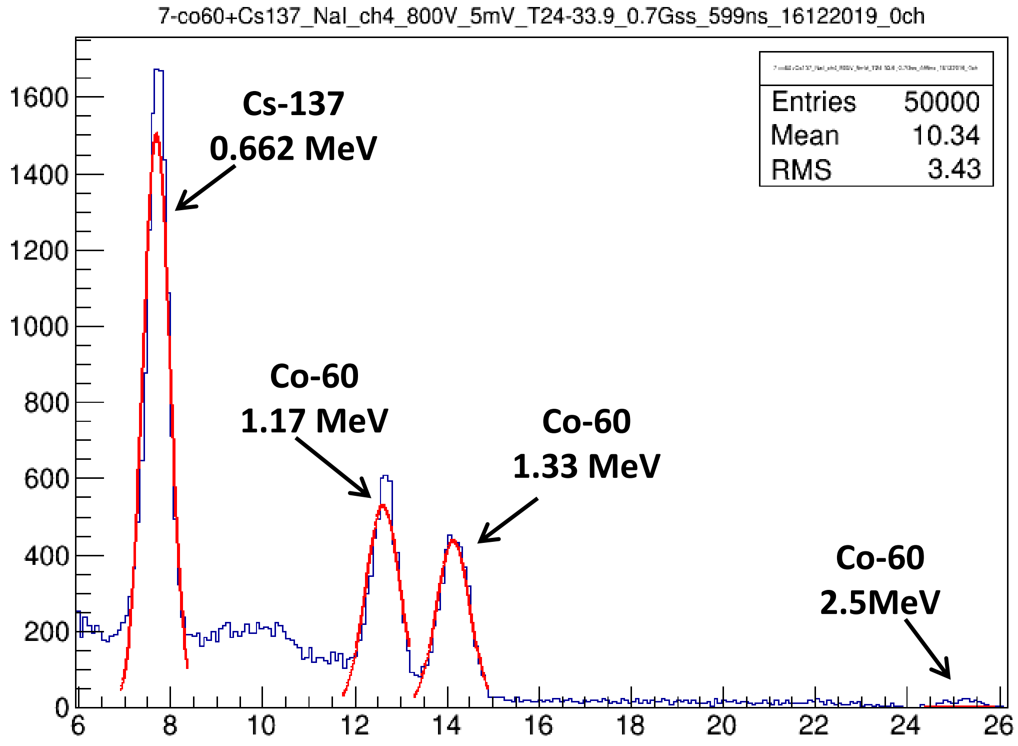


Figure 8. *Cs-137 and Co-60 spectrum from measurements with NaI detector at 2000 V*

Equation of calibration:

y = 1.45953 + 9.50263x

where y = PMT signal A.U,
x = Energy of unknown source

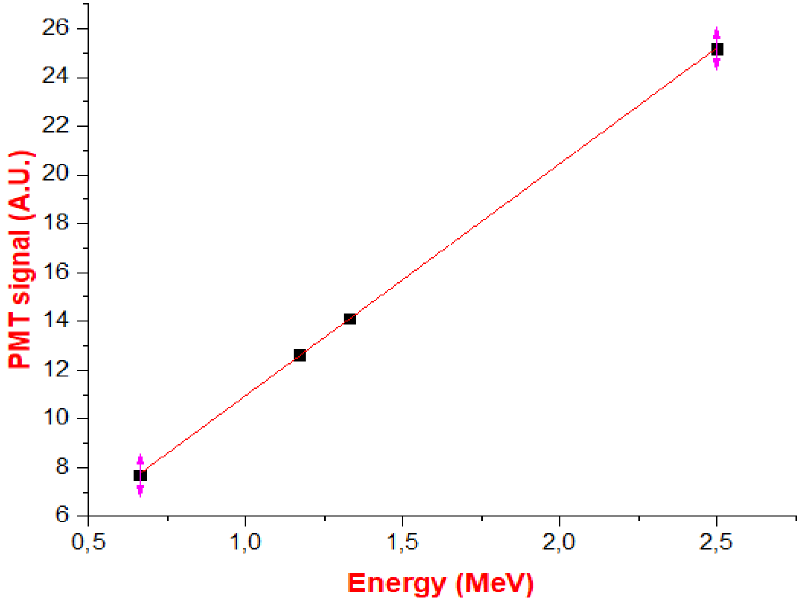


Figure 9. *Energy calibration function*

Task 2.3. Identification of unknown sources

- 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:

$$y = 1.45953 + 9.50263x,$$

where y = PMT signal A.U,

x = Energy of unknown source

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

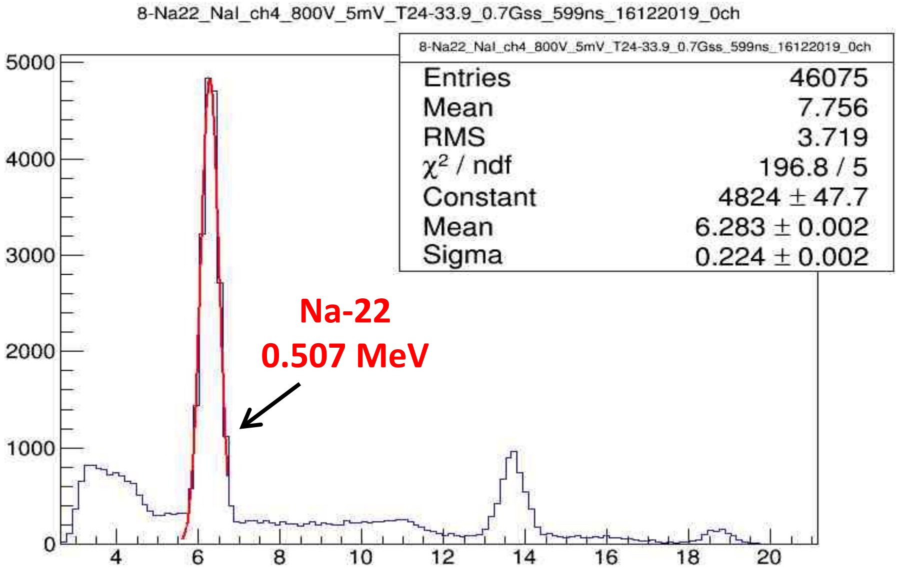


Figure 10. *Na-22 spectrum*

Unknown sources 2

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

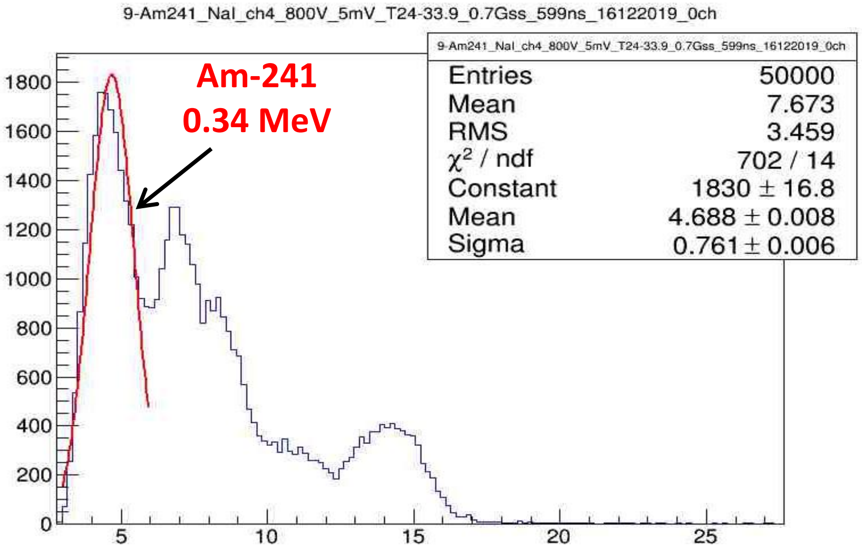


Figure 11. *Am-241 spectrum*

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

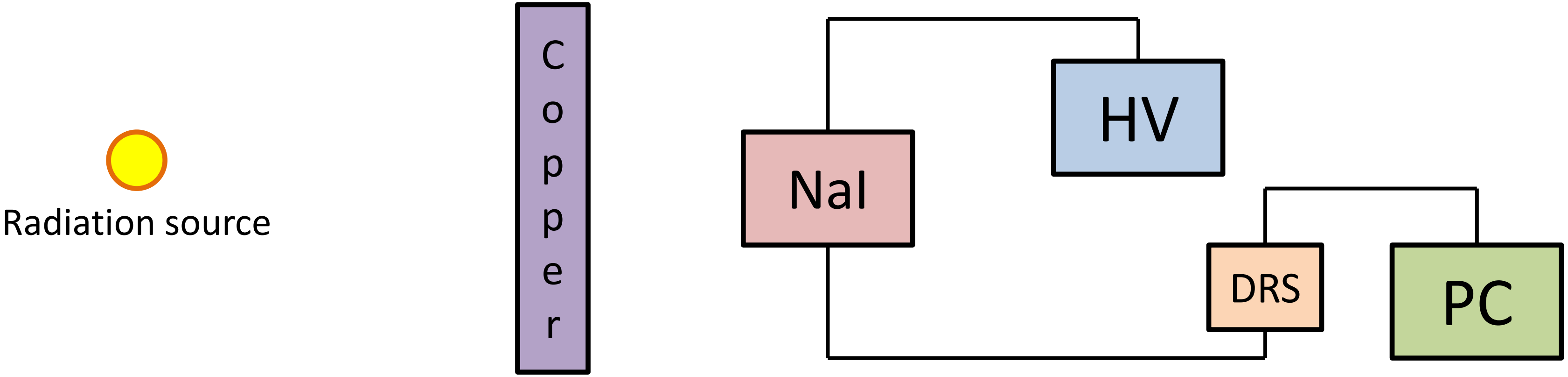


Figure 12. *Experimental set-up for determining the attenuation coefficient*

Task 3. Attenuation coefficient

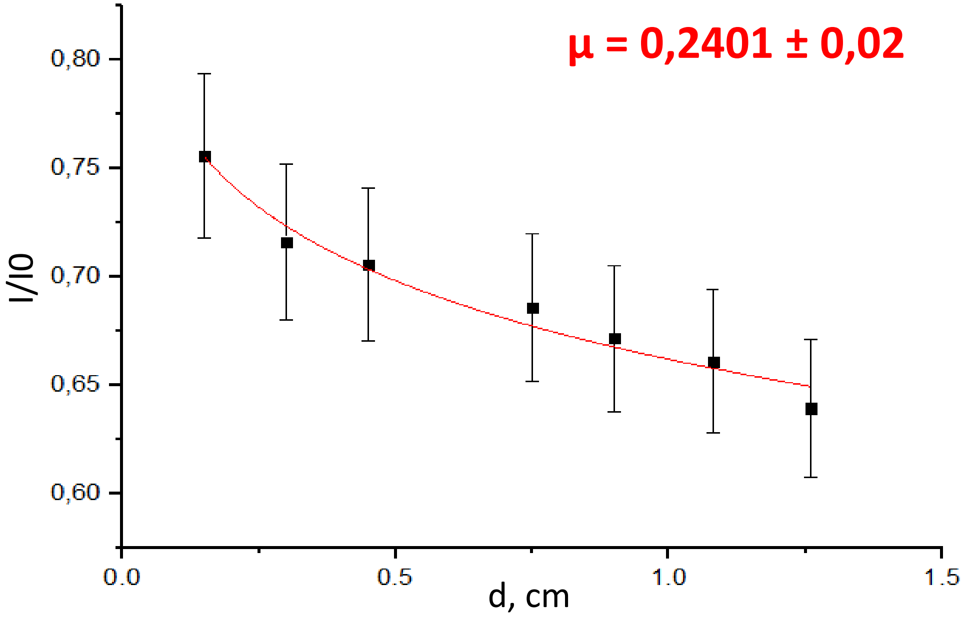


Figure 13. *Determination of attenuation coefficient for Al*

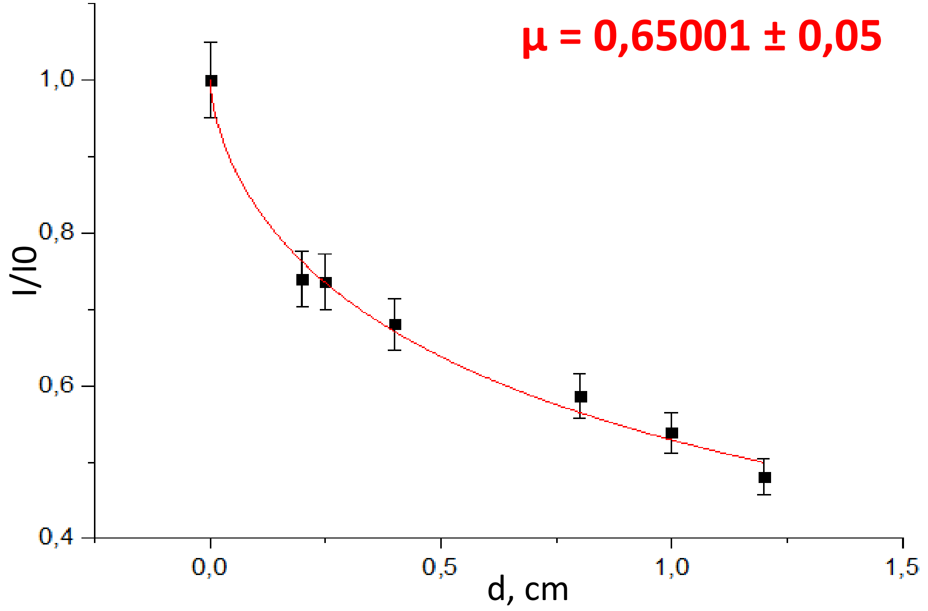


Figure 14. *Determination of attenuation coefficient for Cu*

Task 4. SRIM Simulation

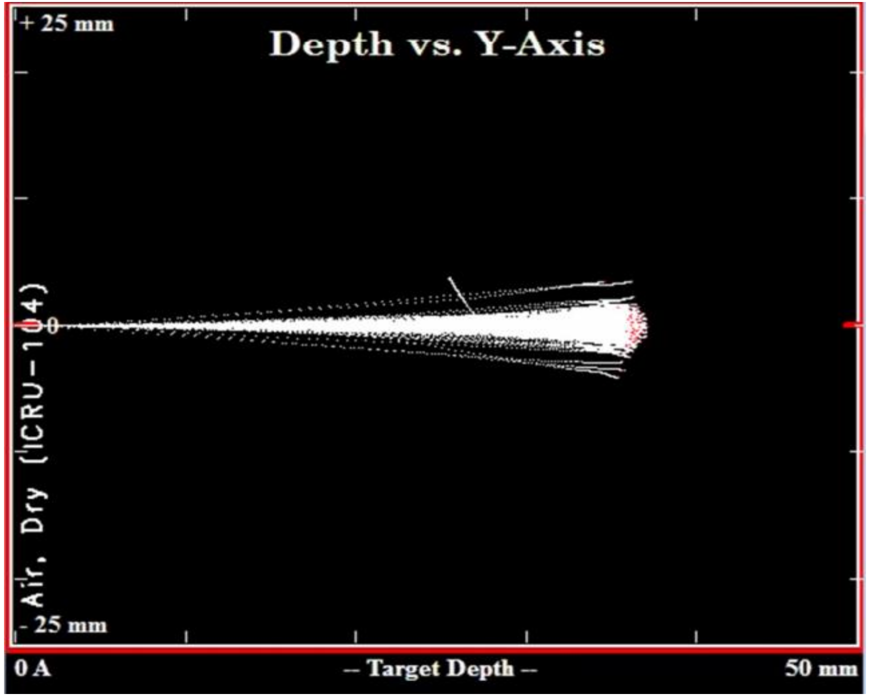


Figure 15. *Depth for α-radiation in air*

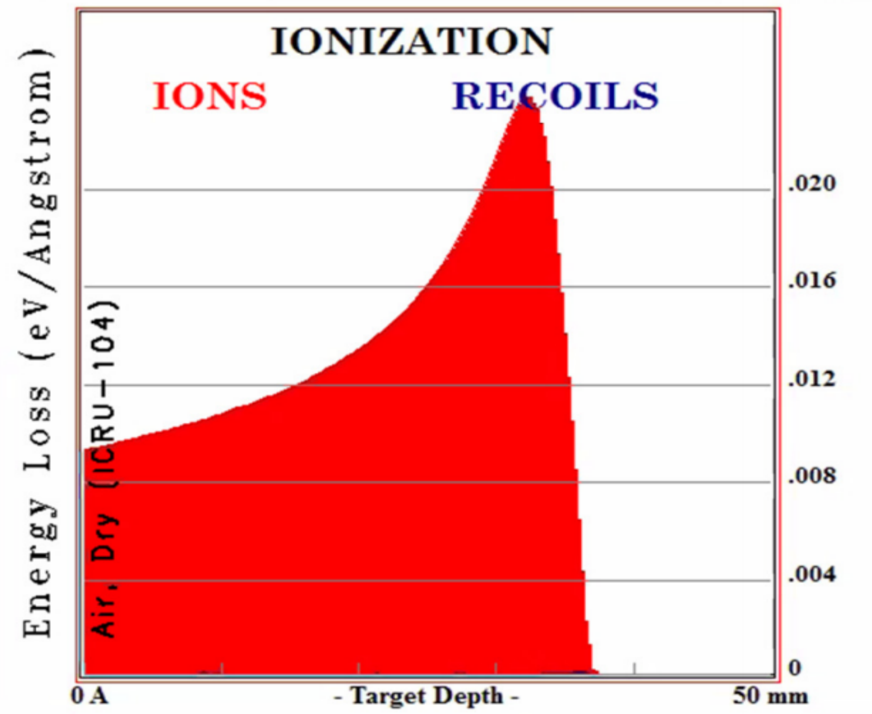


Figure 16. *Ionization*

Task 4. Alpha range in air

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

R = 3.5

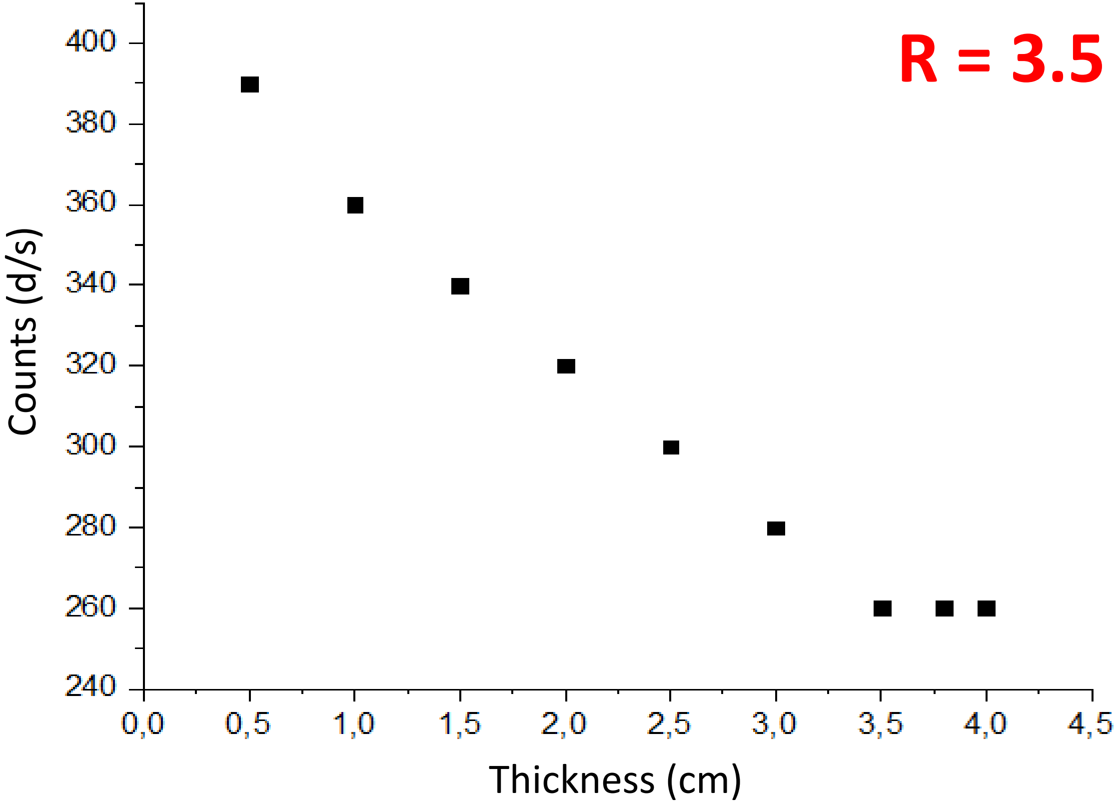


***Figure 17.** The range of alpha particles*

Task 5. Pixel detectors (PD)

- 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.

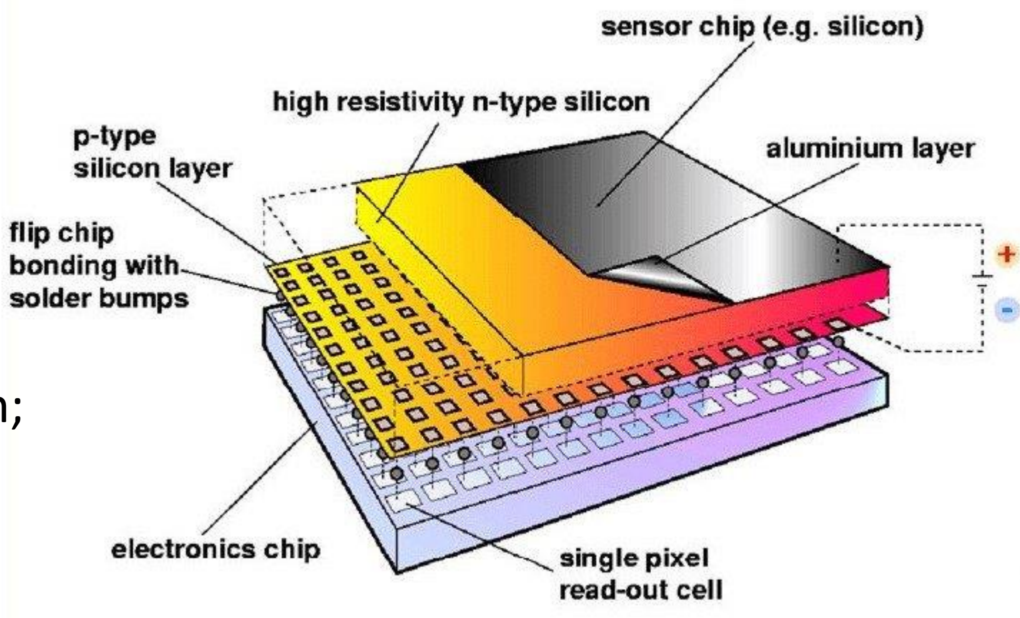


Figure 18. *Pixel detectors*

Task 5. Pixel detectors (PD)

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

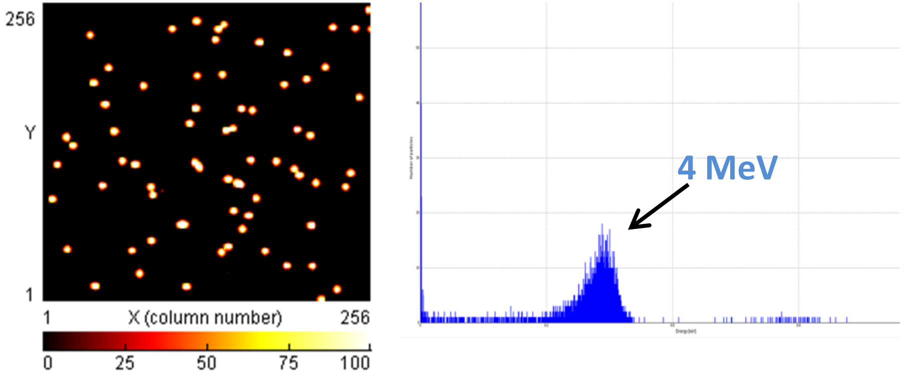


Figure 19. *Absorption of alpha particle energy in the air at 0 cm*

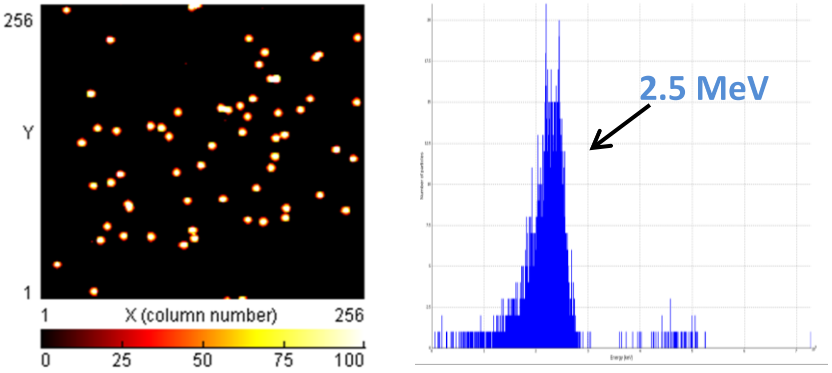


Figure 20. *Absorption of alpha particle energy in the air at 1 cm*

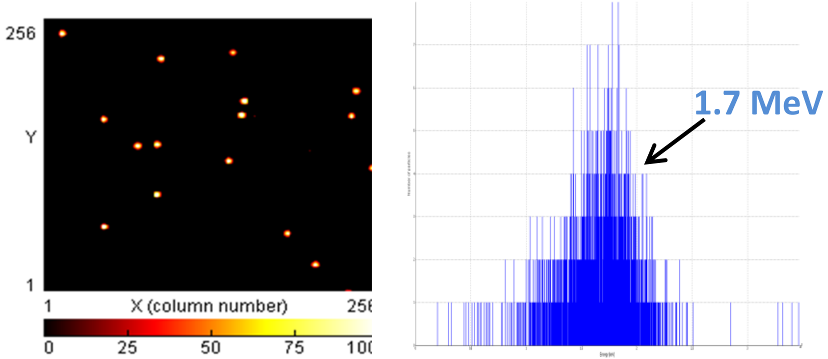


Figure 21. *Absorption of alpha particle energy in the air at 2 cm*

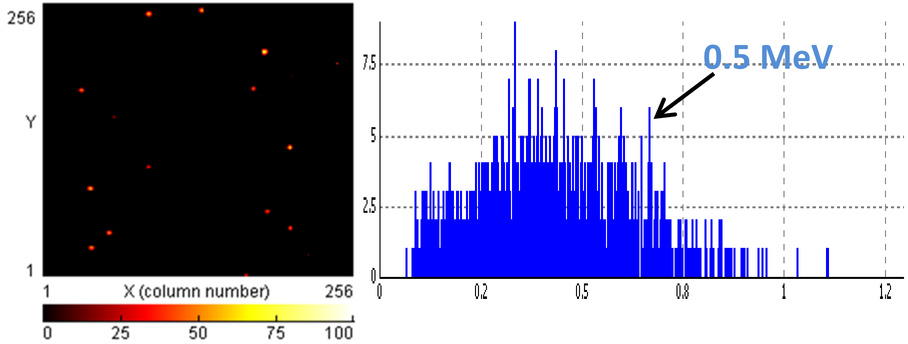


Figure 22. *Absorption of alpha particle energy in the air at 2.5 cm*

Task 5. Pixel detectors (PD)

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

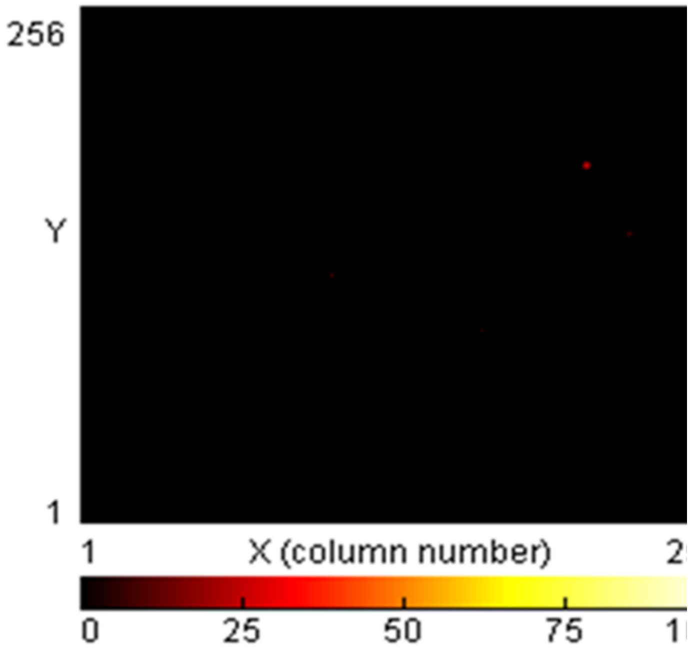


Figure 23. *Maximum range of* α-particles in air (3 cm)

There are no α-particles at 3 cm distance

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Maximum of α-particle range is 3 cm

Conclusion

- Acquiring base in radiation protection and safety;
- Evaluation of exposure, absorbed, equivalent, effective doses and recommended radiation protection protocol;
- Radioactivity and naturally occurring radioactive materials NORM;
- Evaluation of exposure, absorbed, equivalent, and effective doses;
- Providing the necessary practical skills and basic tools for:
  - Calculation of *resolution* of different scintillation detectors (BGO and NaI);
  - *Energy calibration* of some scintillation detectors by using Standard sources;
  - Identification of *unknown sources* using the energy calibration function;
  - Determination of the *attenuation coefficient*;
  - Determination of *alpha range* in air using Monte Carlo simulations via SRIM software, Plastic detector and Pixel detector.

References

1. Attix, F.H., *Introduction to Radiological Physics and Radiation Dosimetry*, Wiley, New York (1986).
2. Cember, H., *Introduction to Health Physics*, 3rd Edition, McGraw-Hill, New York (2000).
3. Knoll, G. F., *Radiation detection and measurement,* 4th Edition, Wiley (2010).
4. Martin J.E., *Physics for Radiation Protection*, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim (2013).
5. *Nuclear Radiation and Health Effects* (2019). Available at: https://www.world-nuclear.org/information-library/safety-and-security/radiation-and-health/nuclear-radiation-and-health-effects.aspx (accessed 14 March 2021)