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

Student

Danijela Rajić
Faculty of Technology,
University of Novi Sad, Serbia

Supervisor

Said M. Shakour
Dzhelepov Laboratory of
Nuclear Problems
JINR, Dubna, Russia

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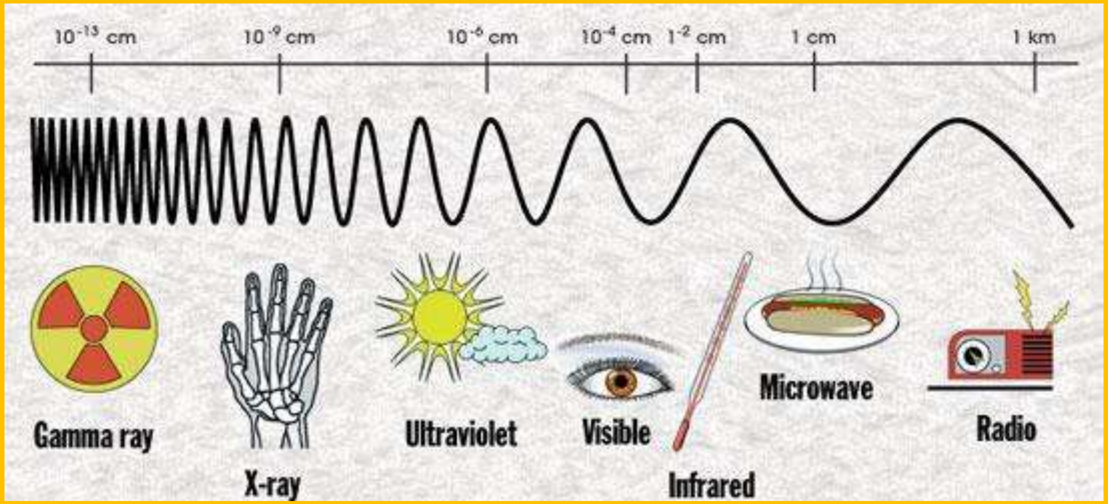
RADIATION

Radiation is the emission or transmission of energy in the form of waves or particles through space or through a material medium.

This includes:
- **electromagnetic radiation,**
- **particle radiation,**
- **acoustic radiation,**
- **gravitational radiation**

Radiation Spectrum



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

Lectures

- **Activity**
- **Radiation dose terminology and units**
- **Occupational dose limits for radiation workers**
- **Deterministic and stochastic effects**
- **Types of dosimeters**
- **Radiation sources used in laboratory and theri spectrum**

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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.

Scintillator properties of crystals

Scintillator	Light output	Decay (ns)	Wavelength (nm) max	Density (g/cm2)	Hygroscopic
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	4.57	no

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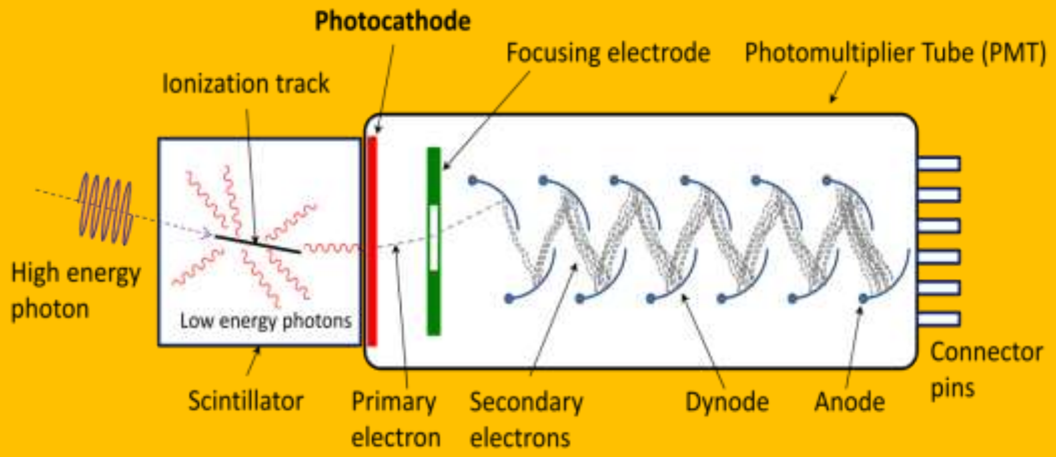
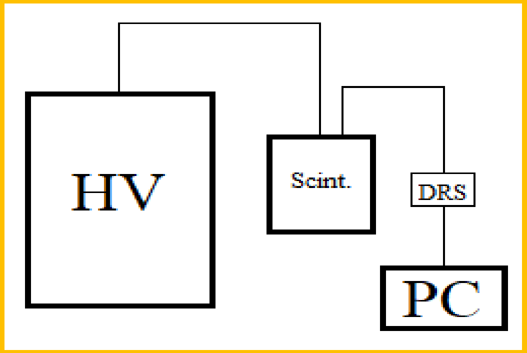
Photomultipliers Tubes (PMT)





Experimental setup

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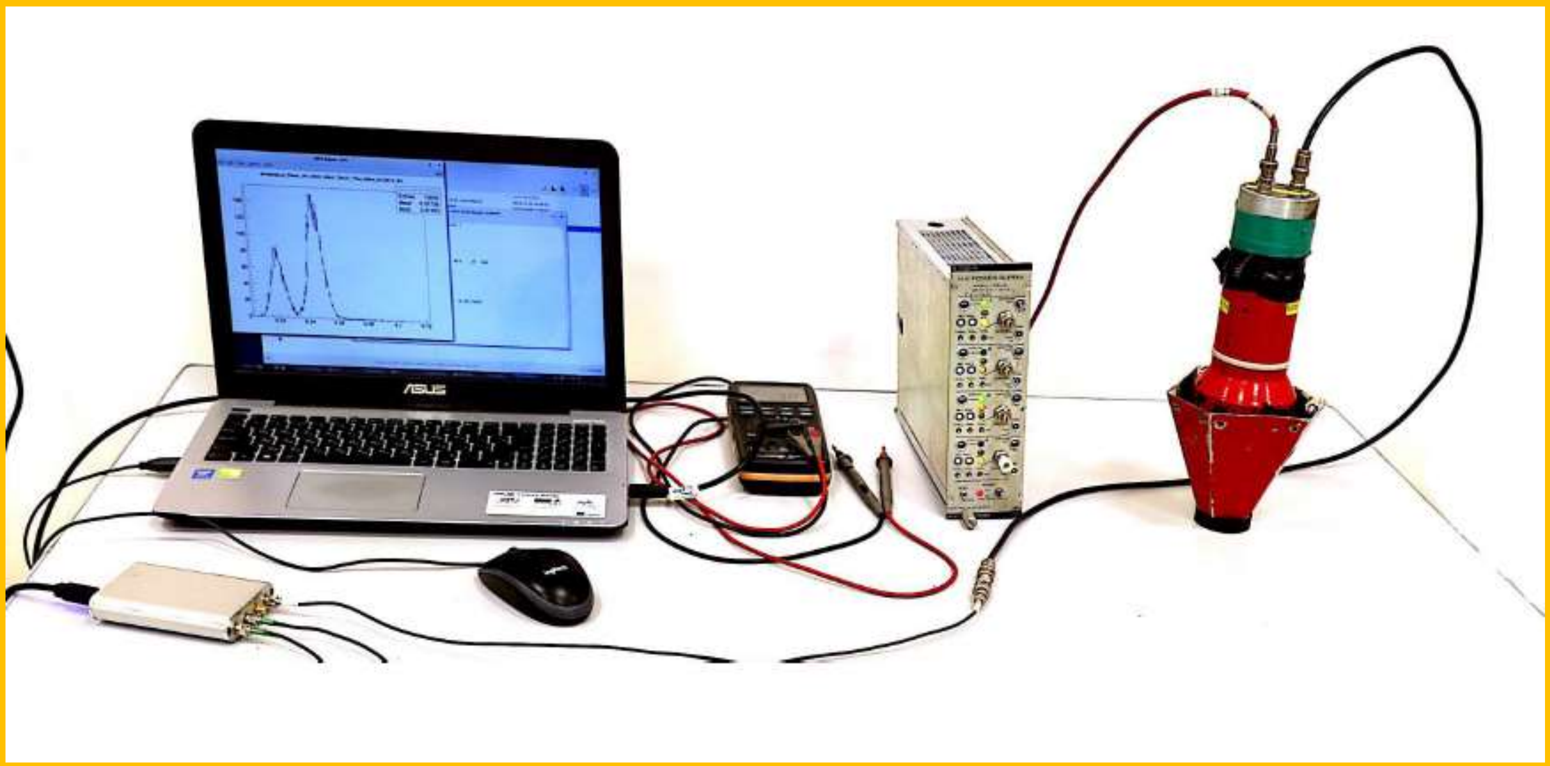

BGO Scintillation detector

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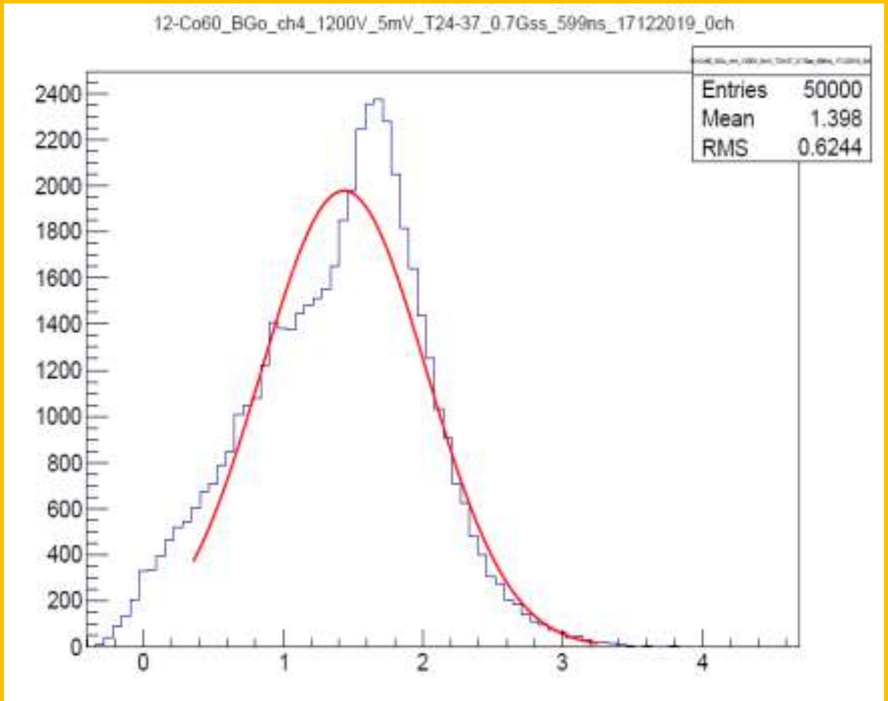
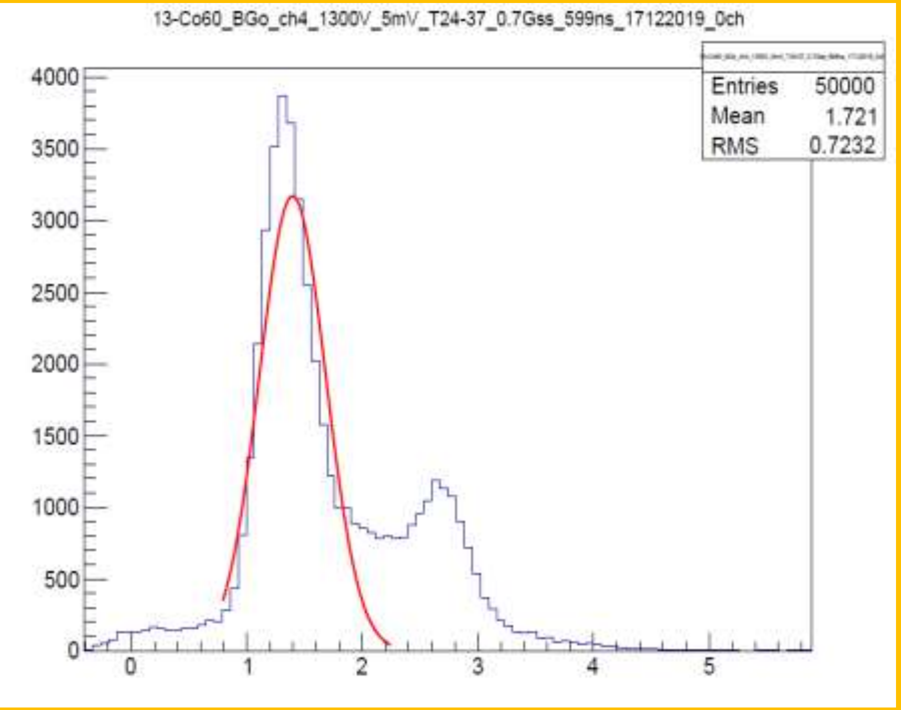
Dependence of resolution on applied voltage for BGO detector

1200V



1300V



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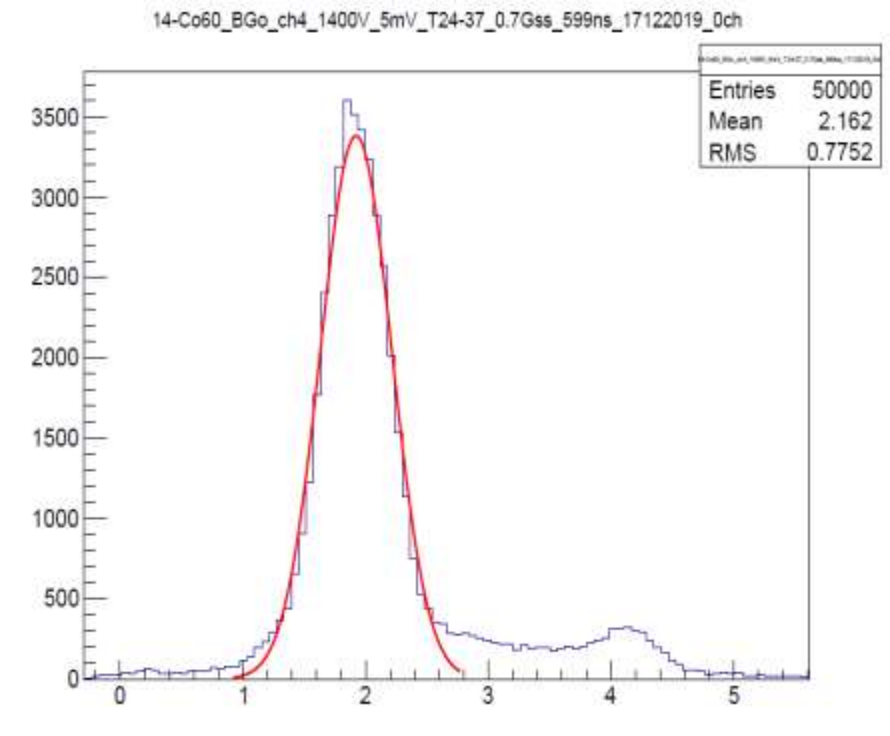
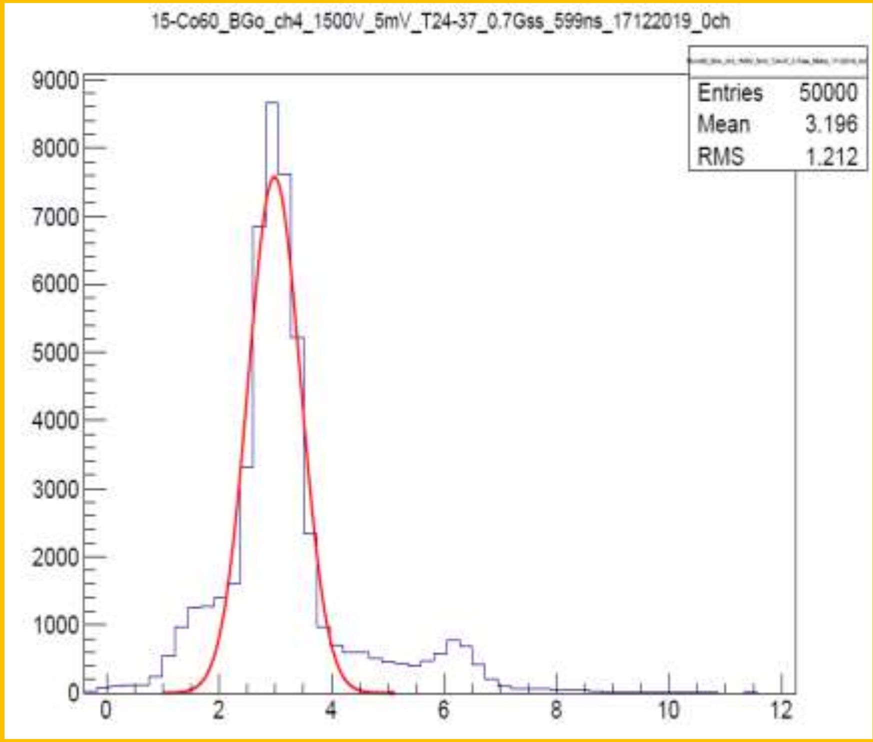
1400V



1500V



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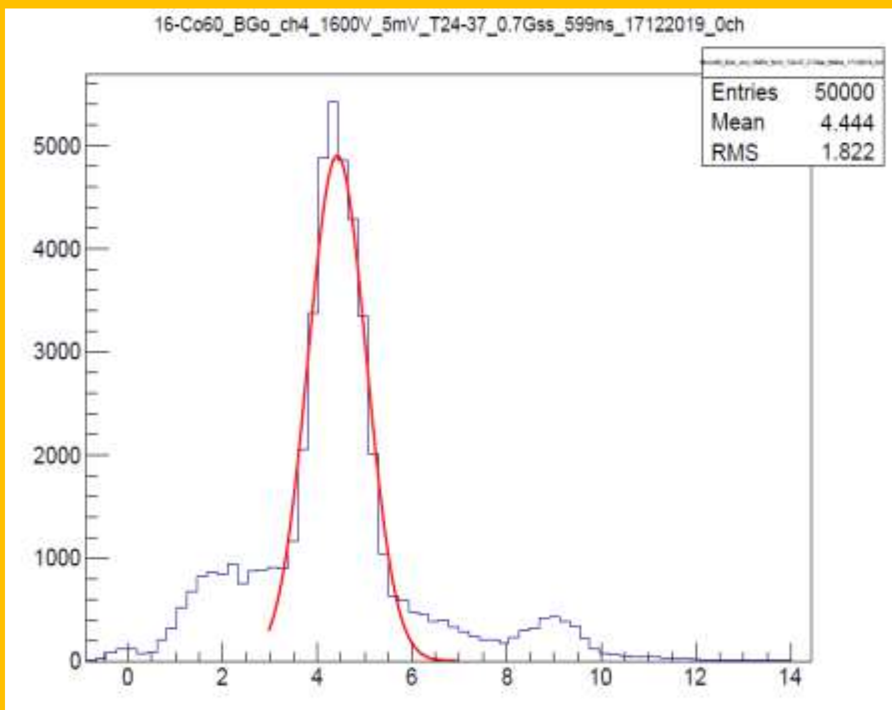
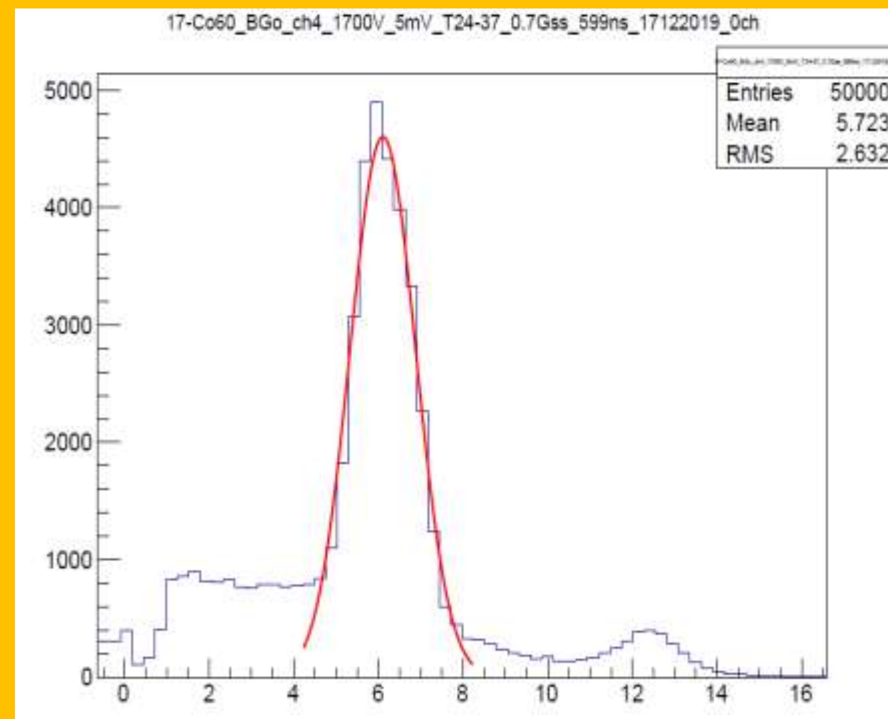
1600V



1700V



BGO DETECTOR

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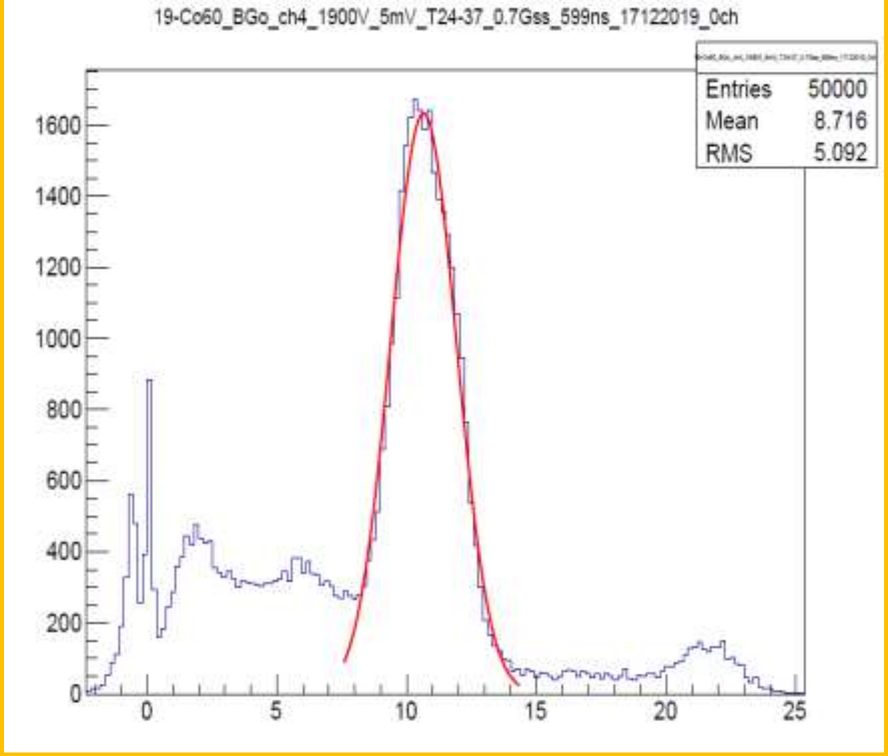
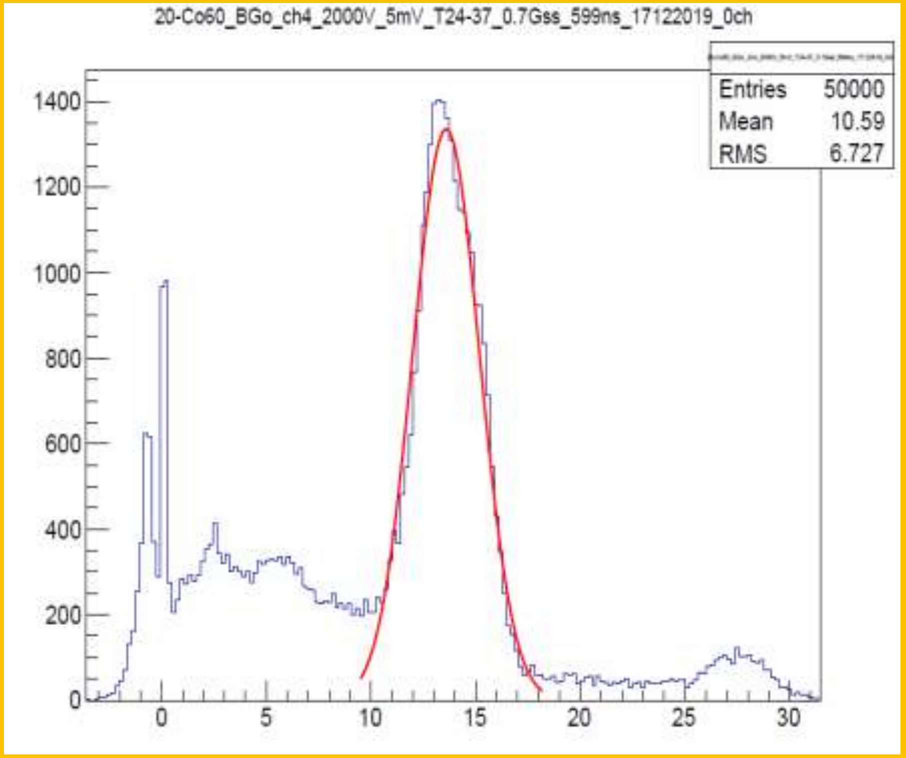
1900V



2000V



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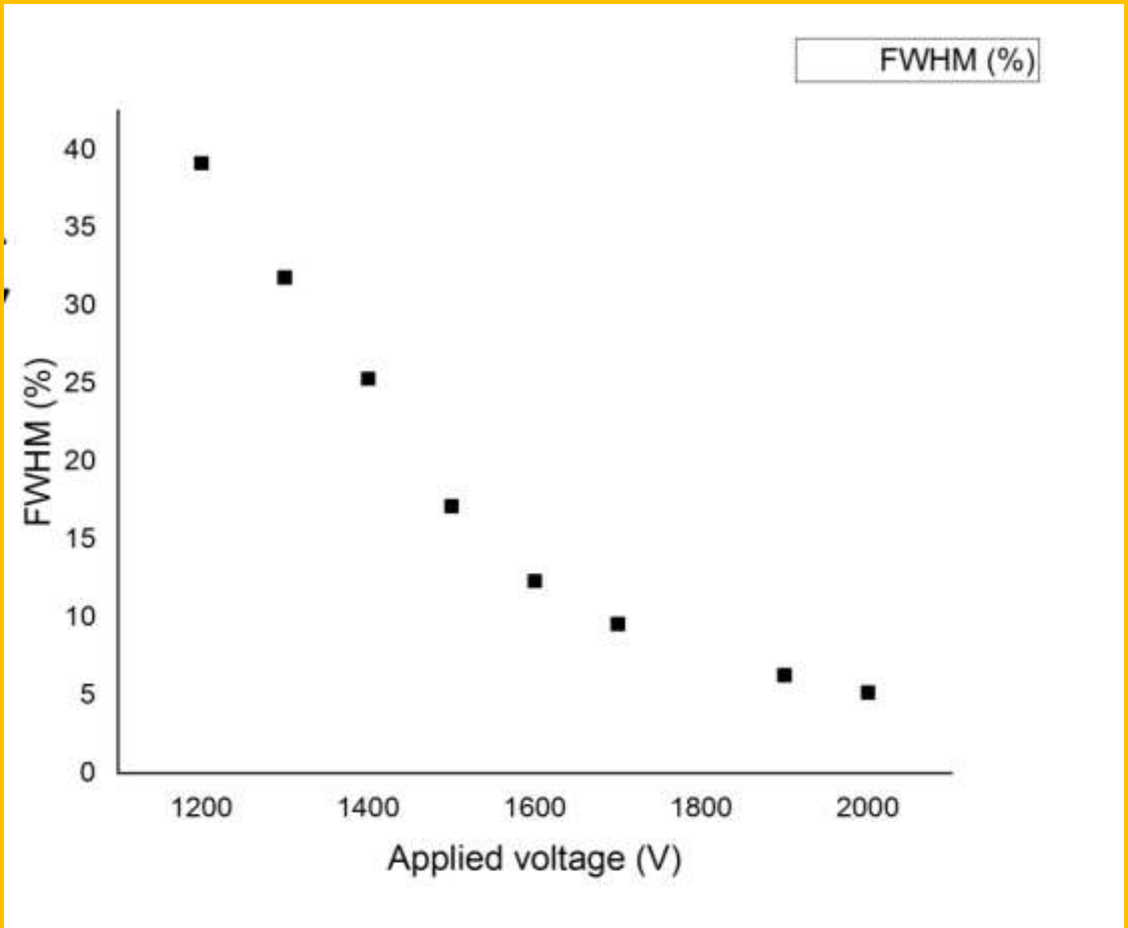

Dependence of resolution on applied voltage for BGO detector

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

BGO DETECTOR

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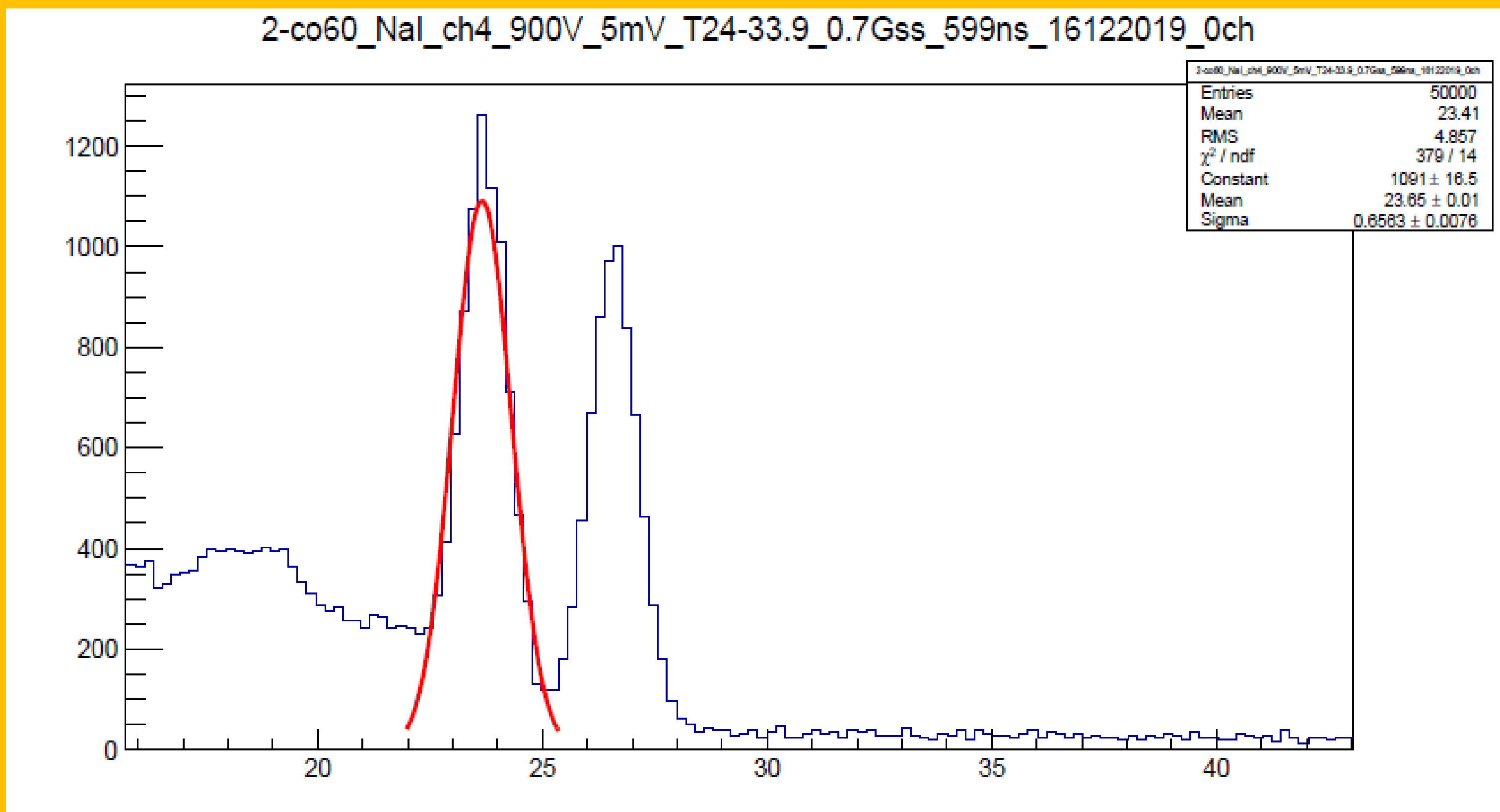
Dependence of resolution on applied voltage for NaI detector

900V



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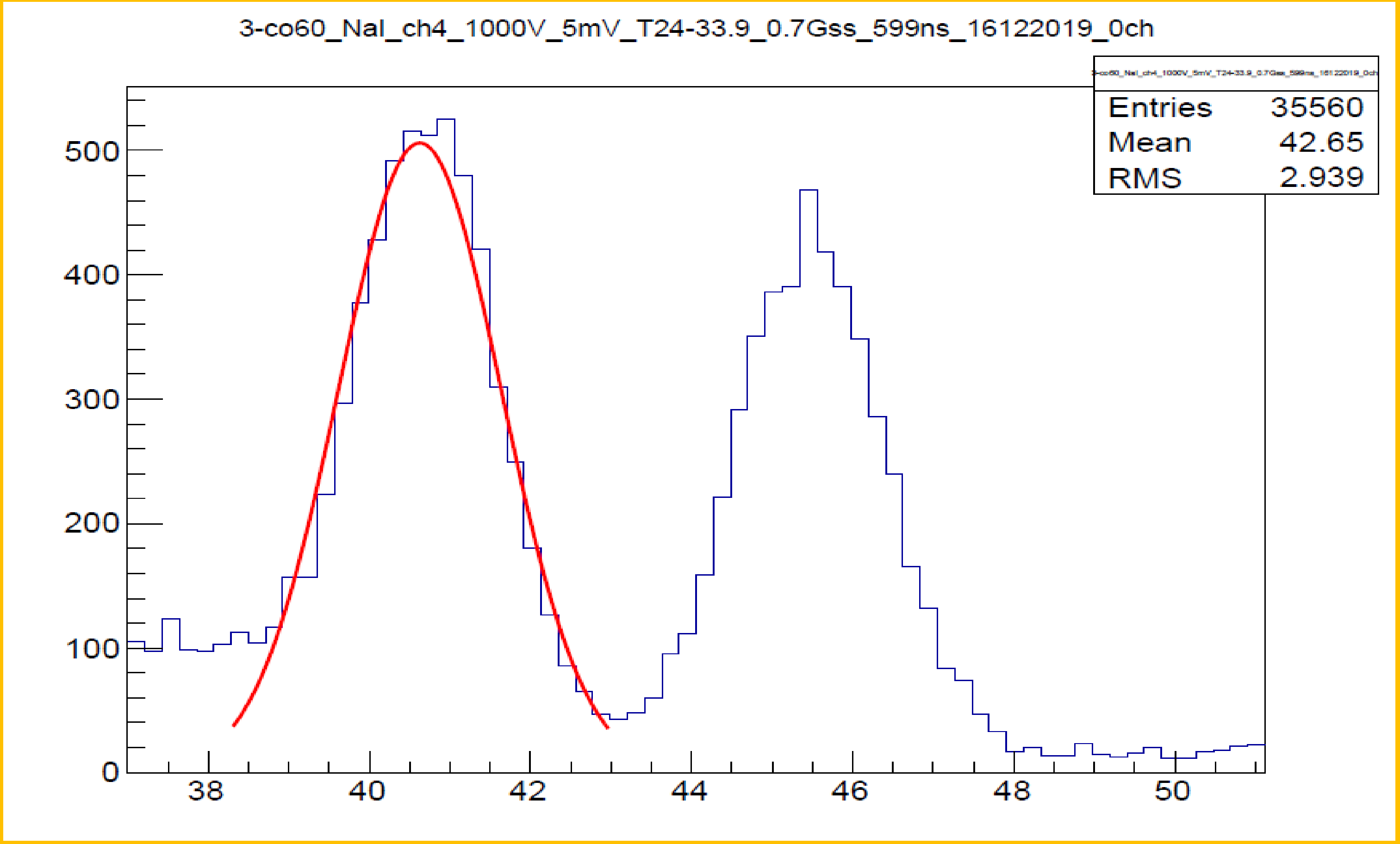
1000V



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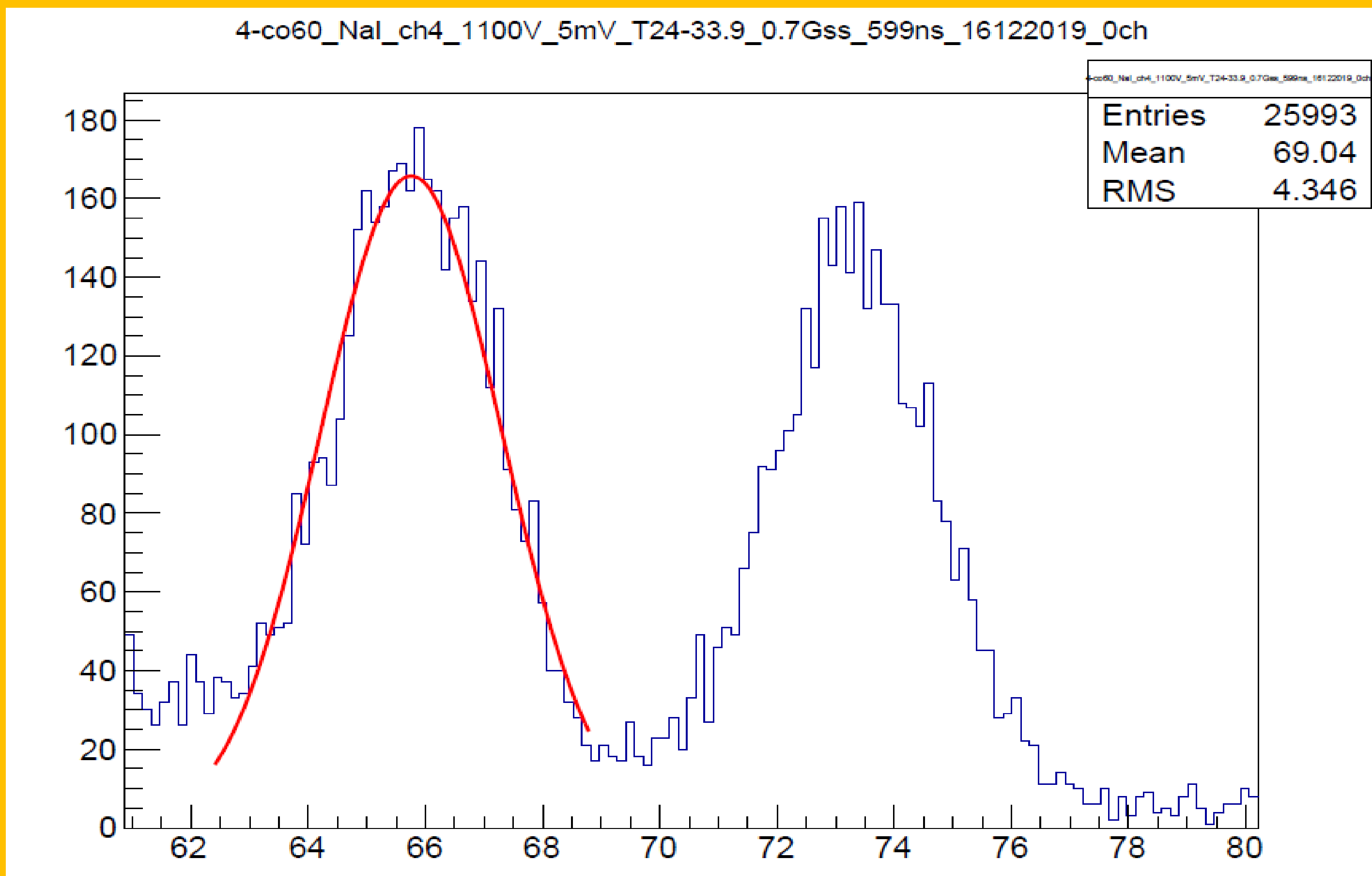
1100V



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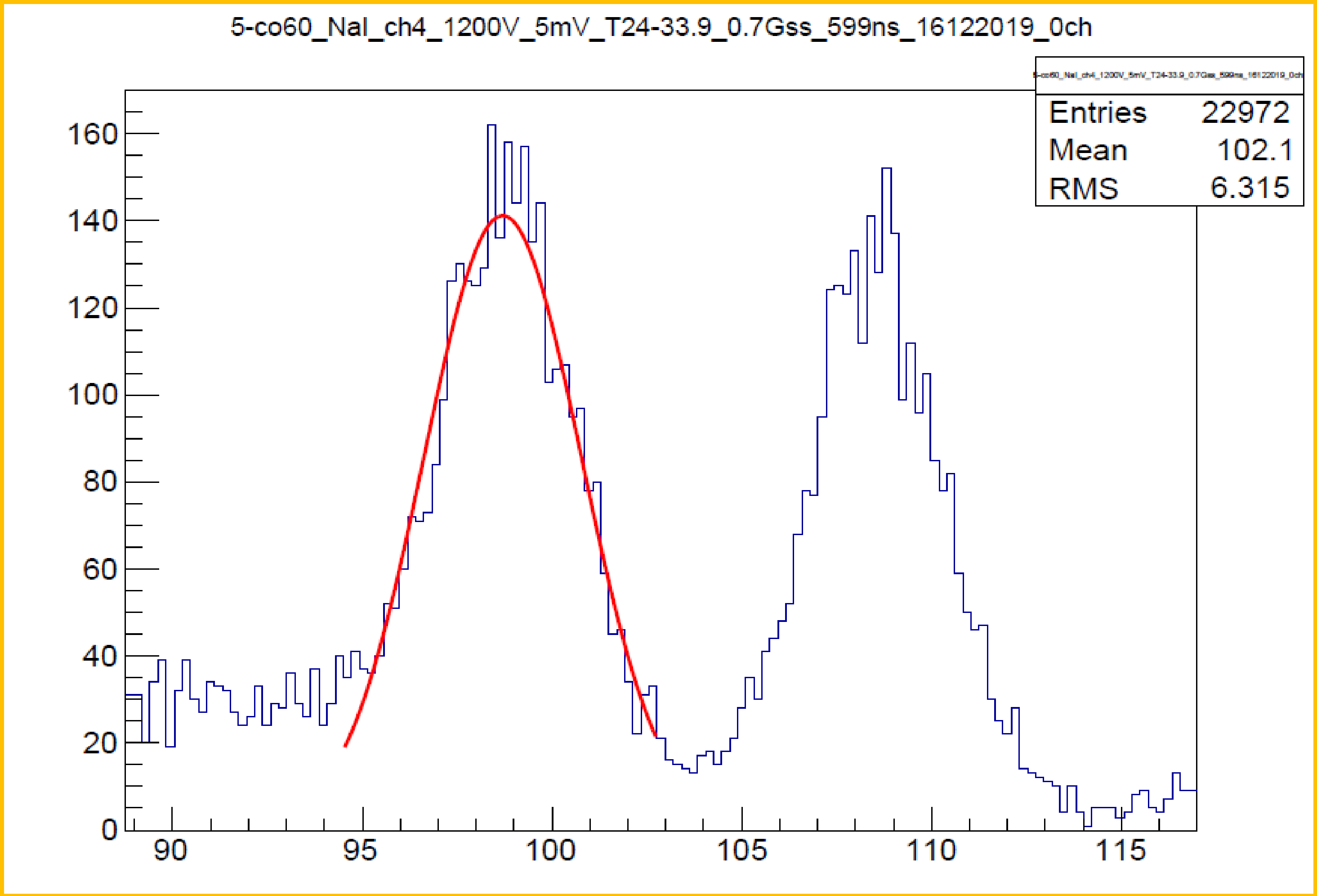
1200V



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NaI DETECTOR

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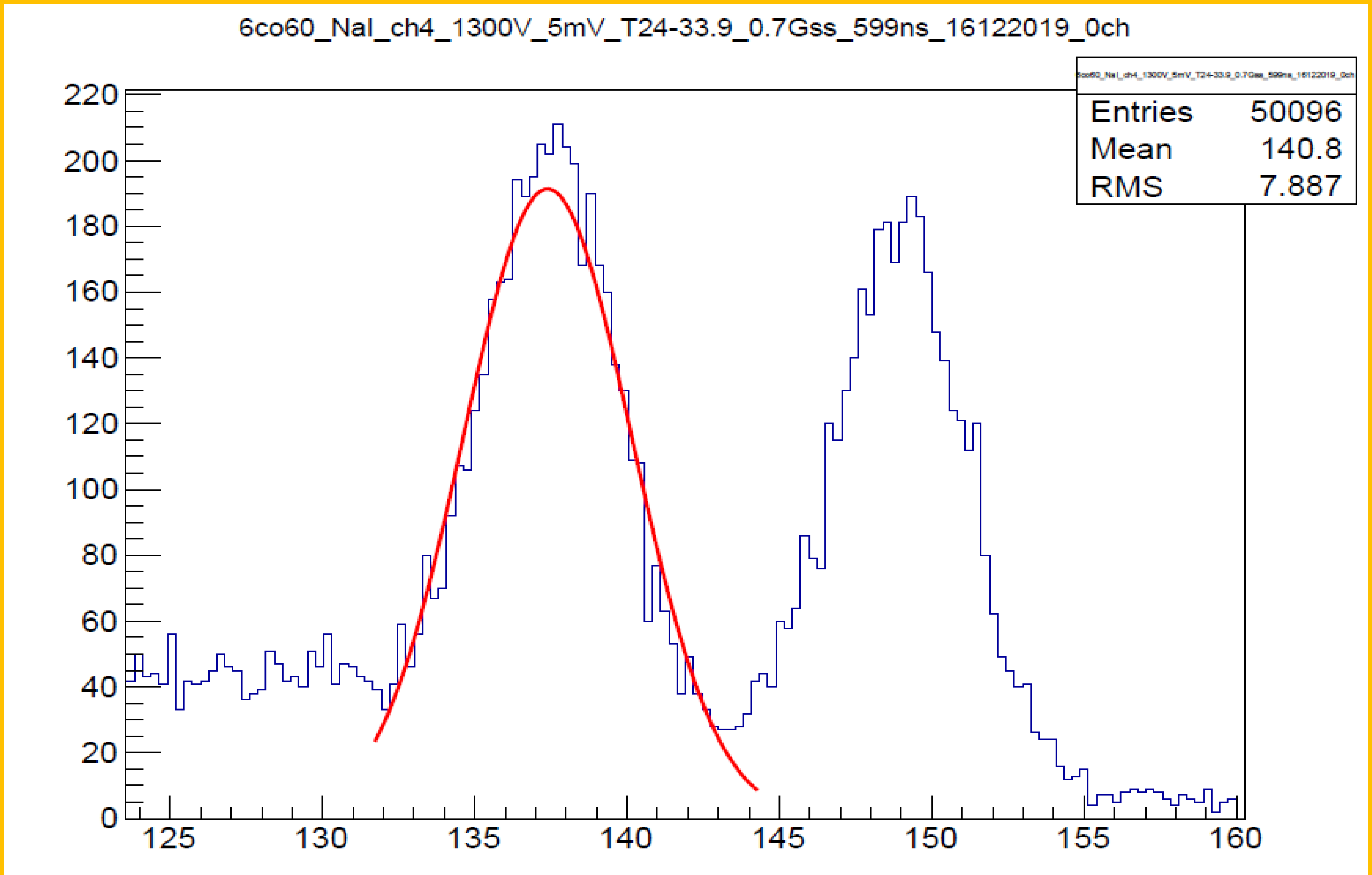
1300V



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NaI DETECTOR

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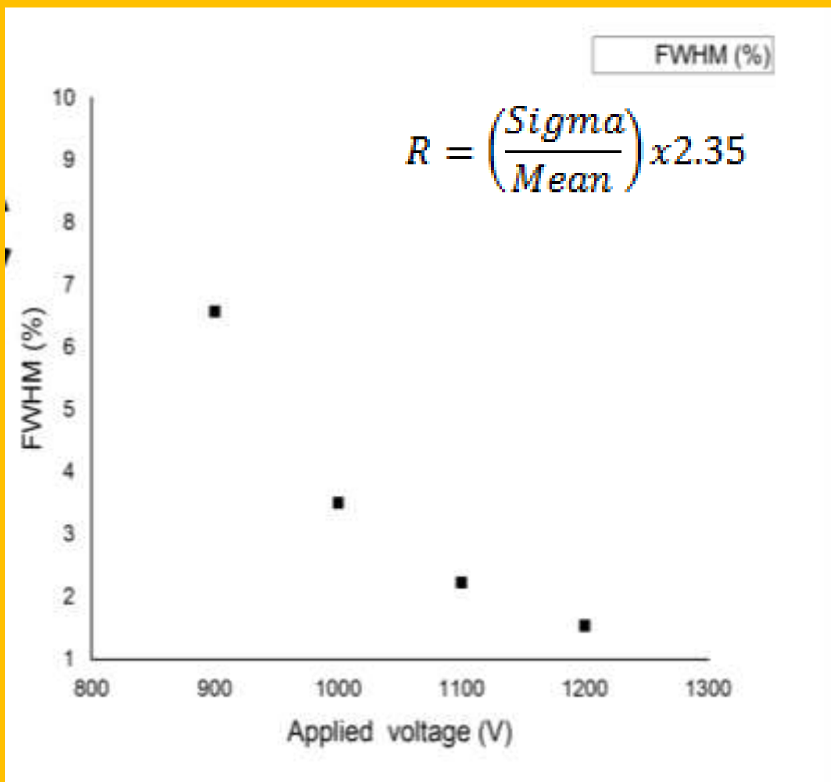

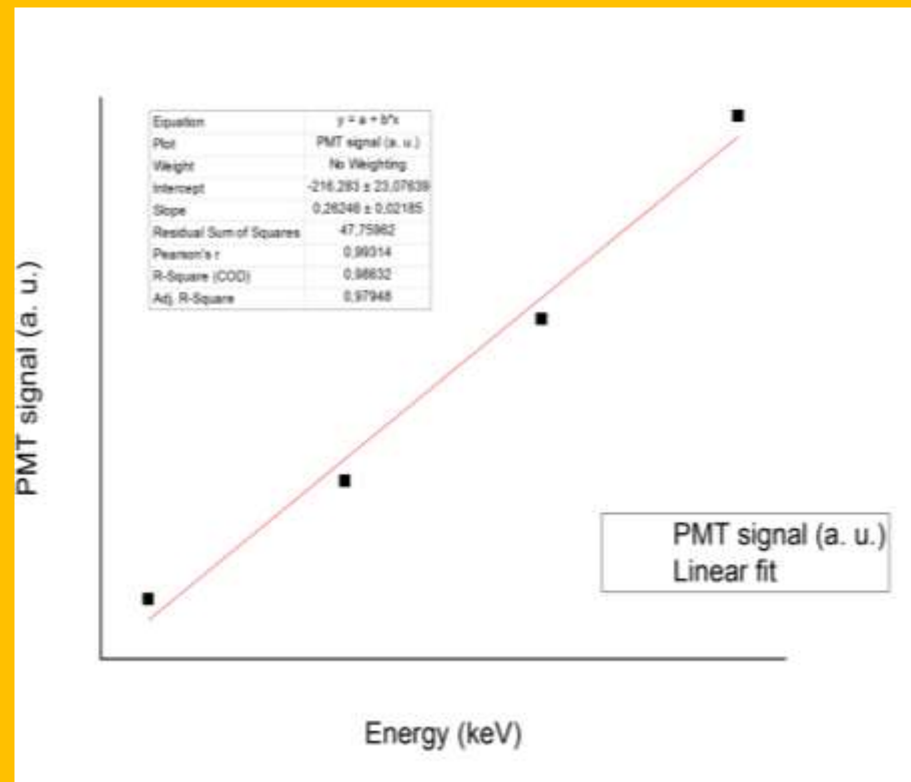

Dependence of resolution on applied voltage for NaI detector

Energy calibration for NaI detector

NaI DETECTOR

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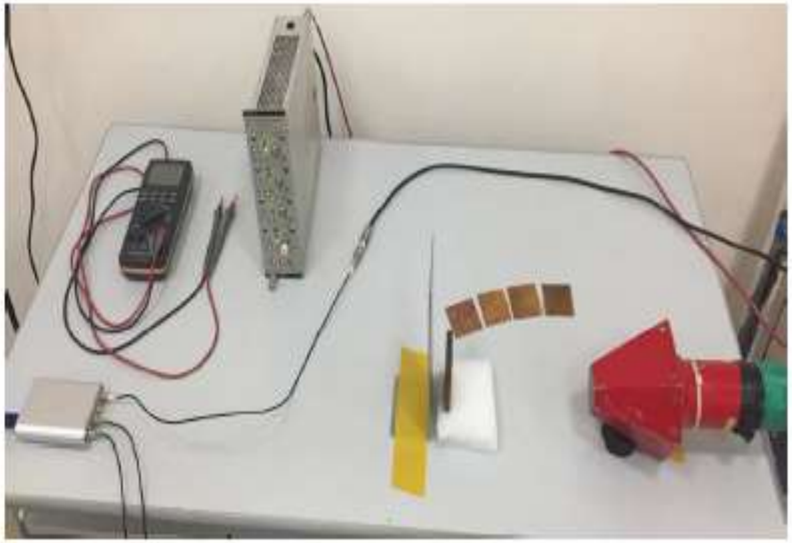
Determination of an attenuation coefficient

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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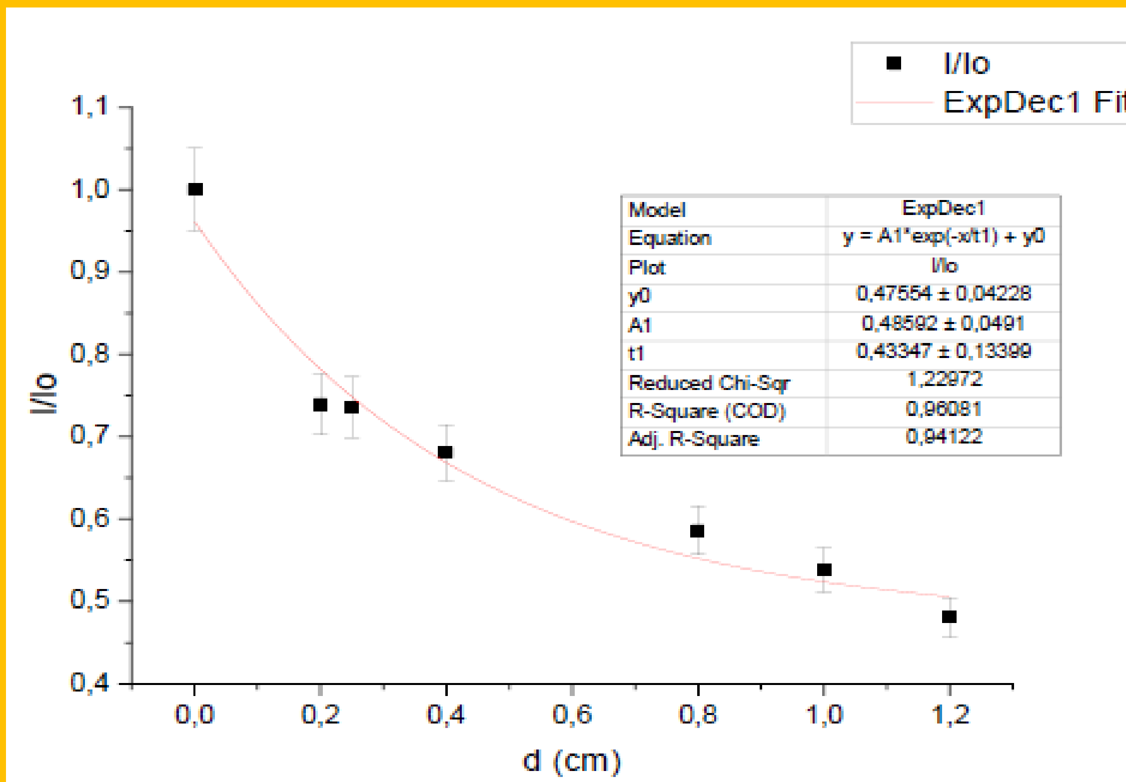

$$\mu = 0.65001 \pm 0.05$$

Attenuation coefficient for Cu

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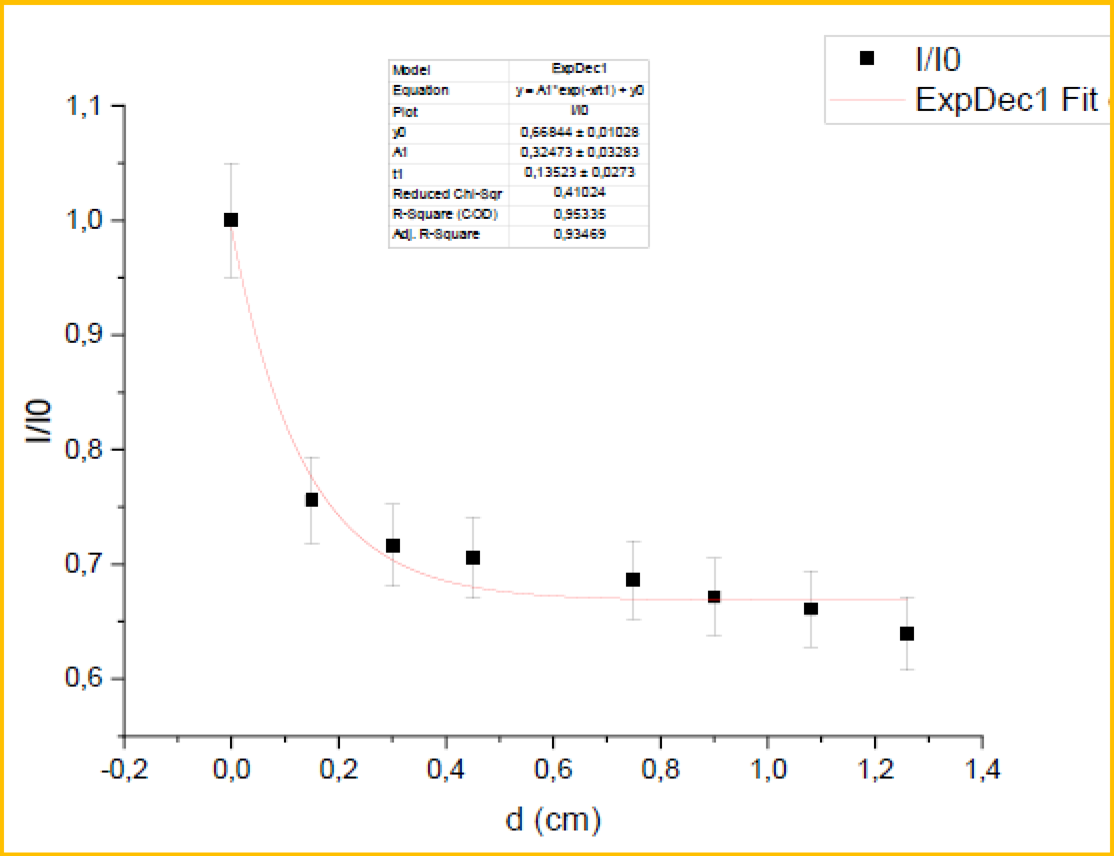

$$\mu = 0.2401 \pm 0.02$$

Attenuation coefficient for Al

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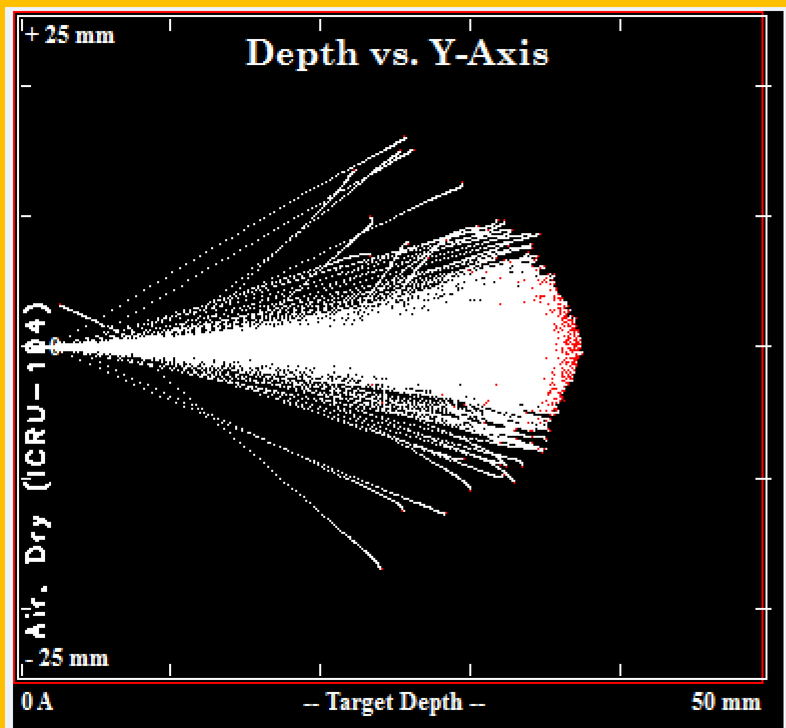
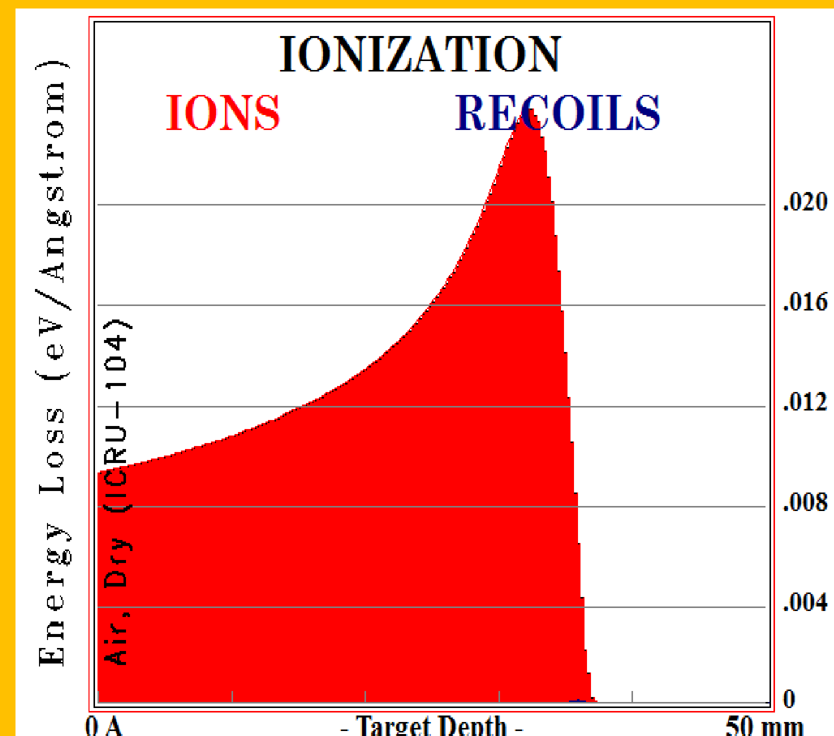
Rande determination of an alpha particle in air



Depth for α-radiation in air



Ionization

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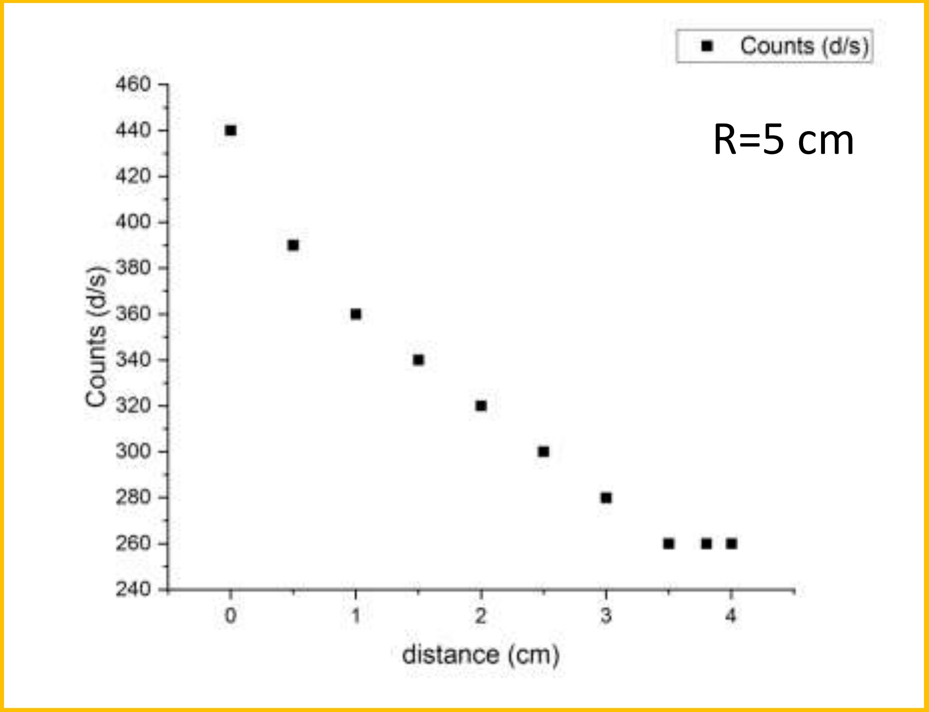
Rande determination of an alpha particle in air

CONDITIONS:

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



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Pixel Detector

Pixel detector is an advanced detector like a digital camera.
It consists of 3 parts:
-Sensor (Si)
-Electronic chip
-USB

The size of the sensor is 1.5x1.5 cm.
- It has 256 x 256 pixels (65.536 pixel).
-The pixel size is 55µm x 55µm.
- It has high resolution.
-It is used for regestration different types of radiation

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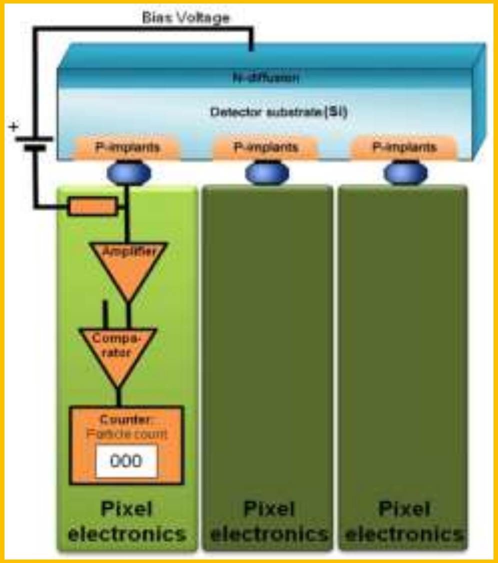

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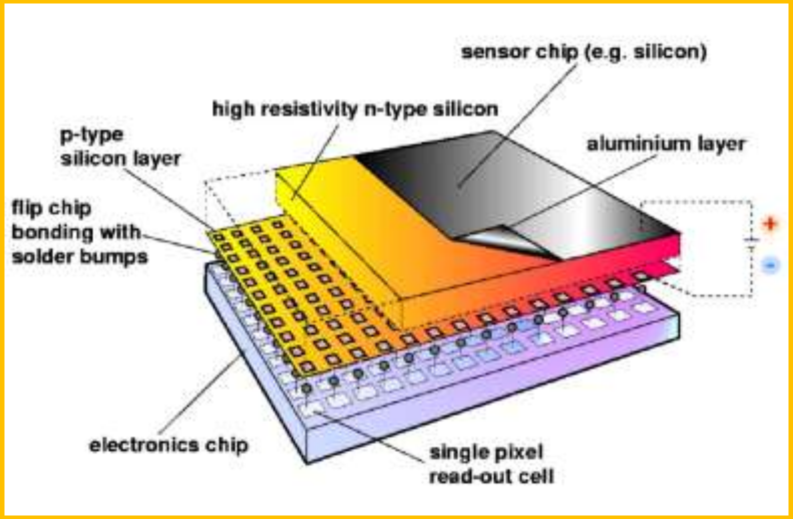
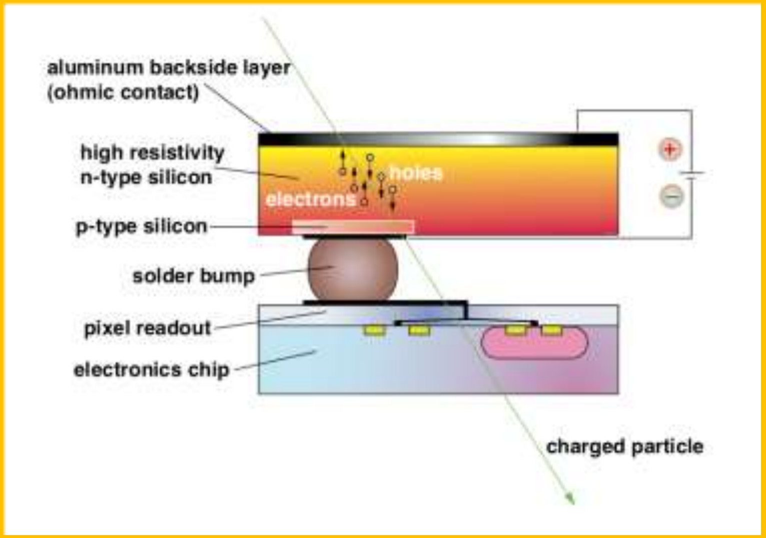
Hybrid Pixel Detector



Detector and electronics readout are optimized separately



Hybrid Pixel Detector - Cross Section

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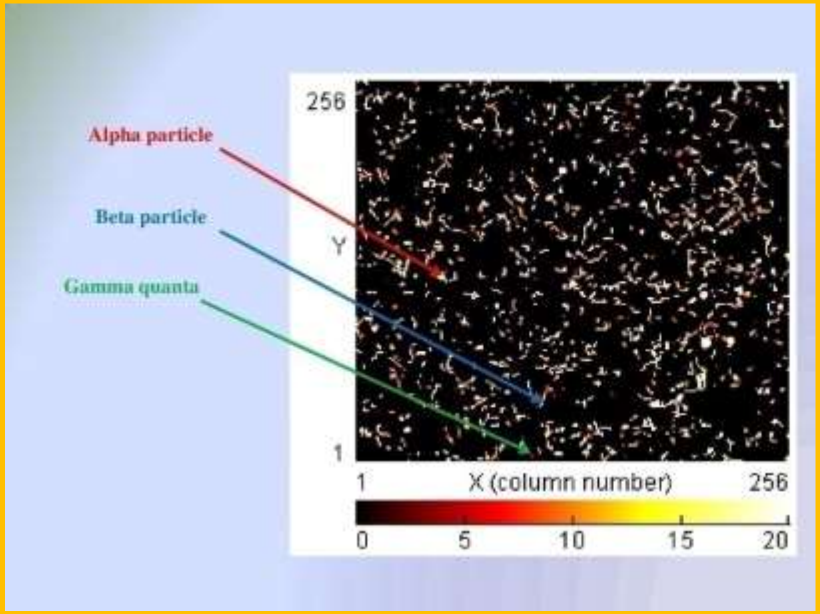
Determination the range of **Alpha** particles with (Am-241) energy about 4 MeV in air using pixel detector.



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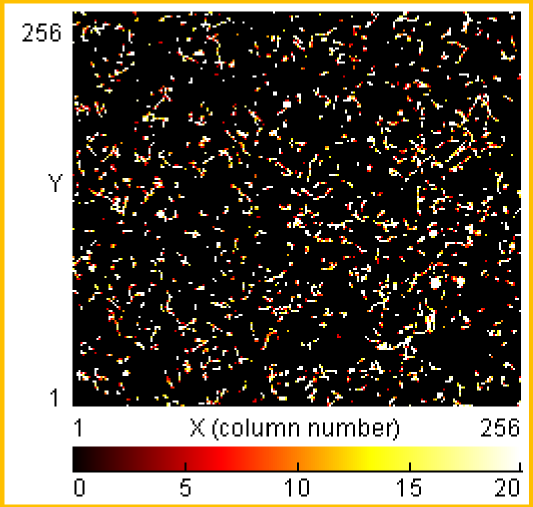
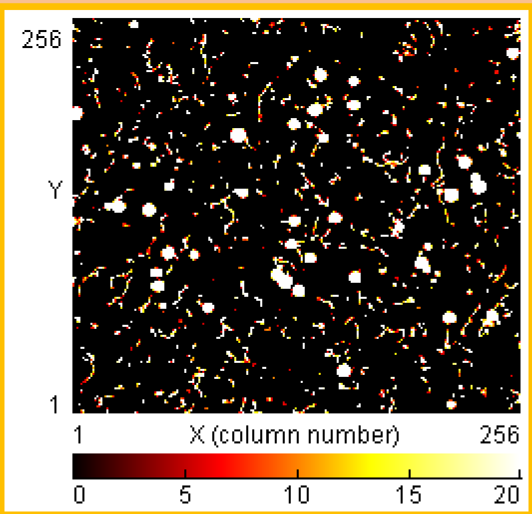
Uranium glass (U-238+U-235)



Type	Number
Alpha	5
Beta	794
Gamma	287
Total	1086

Thorium rod



Type	Number
Alpha	46
Beta	563
Gamma	116
Total	725

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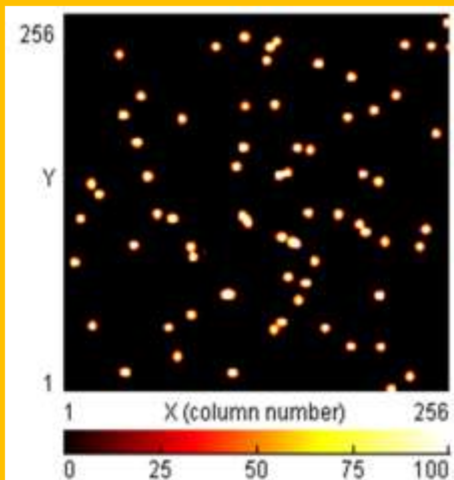

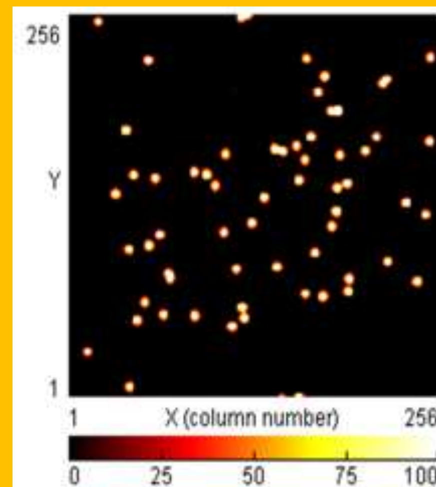

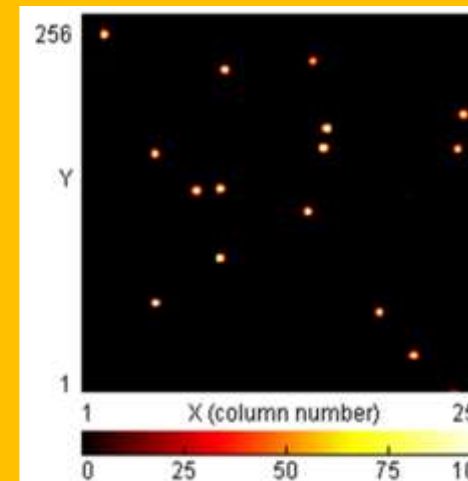

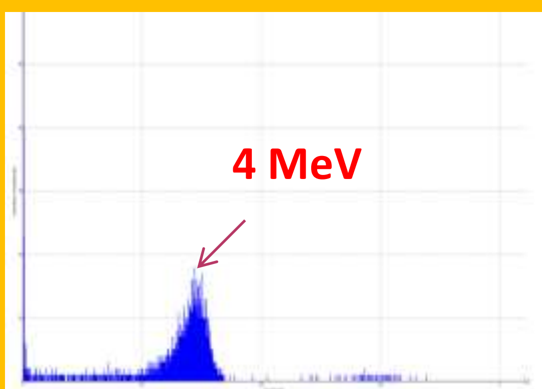

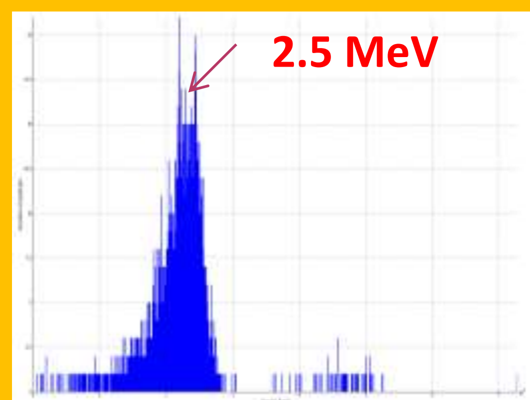

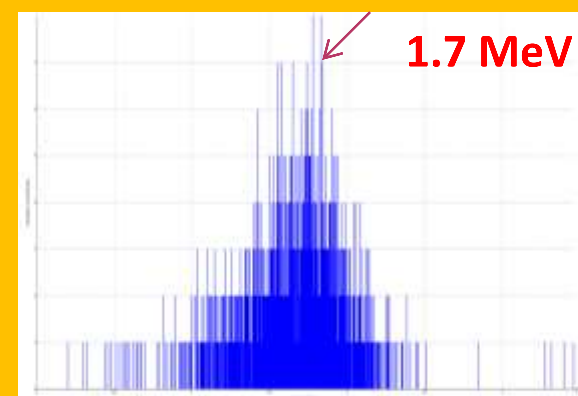

Absorption of alpha particle energy in the air at 0, 1, 2 cm

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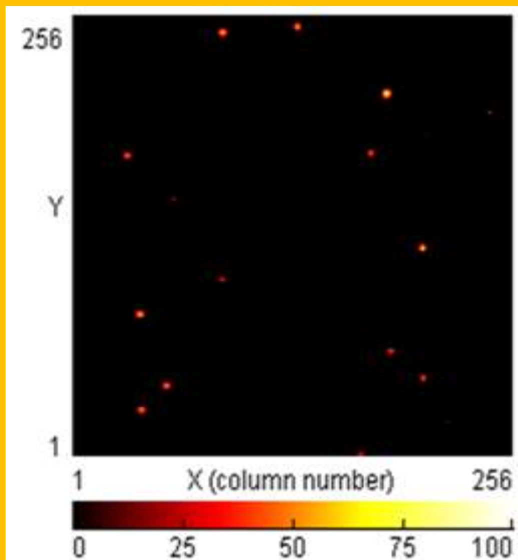
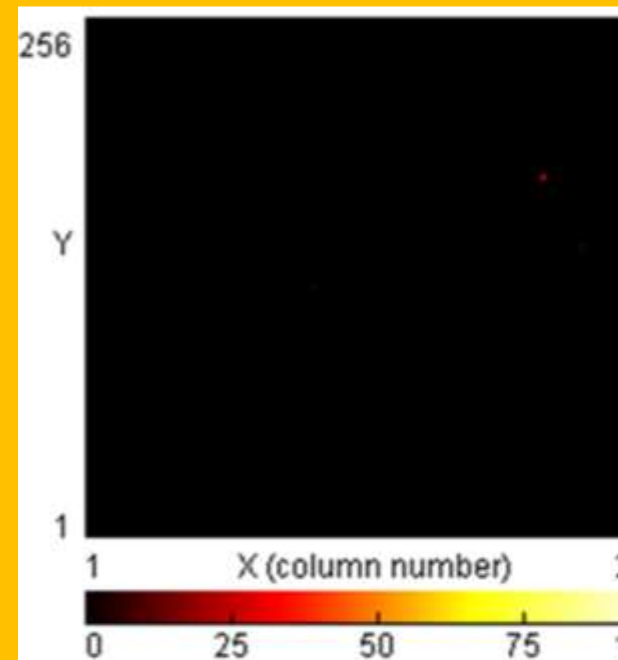
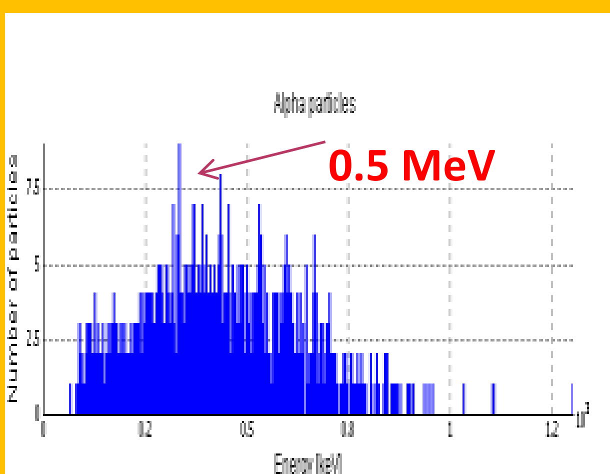


Maximum of alpha particle range is 3 cm, no alpha particles are detected





Absorption of alpha particle energy in the air by moving the alpha source away by 2.5 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

REFERENCES

-Cember, H., (2000) *Introduction to Health Physics*, 3rd Edition, McGraw-Hill, New York

-Attix, F.H., (1986) *Introduction to Radiological Physics and Radiation Dosimetry*, Wiley, New York

-Martin J.E., (2013)*Physics for Radiation Protection*, Wiley-VCH Verlag Gmbh; Co KGaA, Weinheim

-Currie, L.A. (1968). *Limits for qualitative detection and quantitative determination. Application to radiochemistry*. Anal. Chem. 40, 586-593.

-L'Annunziata M. F. (2012) *Handbook of Radioactivity Analysis*, Academic Press, 3rd edition.

-G. F.Knoll, (1987) *Techniques for Nuclear and Particle Physics Experiments* (Springer -Verlag, Berilin, Germany

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