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Characterizing a Mini Gamma Detector

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ABSTRACT

There are several types of gamma radiation detectors, which have different characteristics depending on its use. We designed and instrumented a gamma detector for low energies of a small and portable size to obtain spectrum from radioactive sources and from that analyze each spectrum. This instrument basically consists of a scintillator crystal coupled to a SiPM this in turn coupled to a PCB card designed with capacitors and resistors for a better signal, a voltage source of 29 volts. For signal acquisition the system must be connected to an oscilloscope this in turn is controlled by a script developed in Python. For the calibration radioactive isotopes with the same dimensions were used, caesium-137 (Cs-137), cobalto-60 (Co-60), sodium-22 (Na-22) and manganese-54 (Mn-54) as gamma ray emission.

1. Introduction

The equipment to use gamma rays every day are of more interest to society necessary not only for industrial, medical or security use, but we need to continue developing instruments to investigate more characteristics and behavior of gamma rays and thus optimize all existing equipment and make them more sensitive and reliable in measurements. In the market there are several types of detectors for measuring radiation that are high-cost, large and expensive to maintain, although there are Geiger detectors that are inexpensive and compact but these do nothing more than measure ionizing radiation without more.

Gamma radiation is nothing more than usually very high energy photons, emitted by unstable nuclei or other processes. The nucleus does not change its identity but only loses energy. Gamma rays emitted by radioactive sources have specific energies that it is possible to know what type of source it is [1]. Due to the fact that photons have a high penetrating power as they have neither charge nor mass, they are part of the ionizing radiation. Ionizing radiation causes neutral atoms or molecules to acquire an electrical charge, either positive or negative.

The system under development has several advantages over the scintillation radiation detectors available on the market, as this mini gamma detector would not only provide us with the amount of radiation, but would also function as a gamma radiation spectrophotometer as it would provide characteristics such as the spectrum of the source it is emitting, the energy resolution and the deposited charge.

Basically, a scintillator detector converts the wavelength of a gamma ray into the wavelength of a photon in the visible region, then transforms that optical signal into an electronic signal using a silicon photomultiplier (SiPM) [2]. When a gamma ray interacts with the scintillator, electrons charged by three fundamental interactions photoelectric effect, compton scattering and pair production are produced.

Usually gamma radiation spectroscopes based on scintillators use NaI:Tl [1, 3], which has a high efficiency and good energy resolution but in question of the effective atomic number (i.e., the number Z) the crystal is relatively lower than other inorganic scintillating crystals, such as the German bismuth (BGO) [1, 4], the latter has the advantage of being mechanically resistant and not hygroscopic which allows us to develop a mini detector that allows us to make measurements in real time, efficient, economical and less expensive.

2. Materials and experimental configuration

2.1 *Description of the Instrument or Detector*

The instrument under development consists of a scintillator crystal for our system we use a BGO (6.3mmx6.3mmx6.3mm) for its property of being mechanically and chemically

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resistant in addition to not being hygroscopic, the crystal is shielded with a reflective layer to prevent light leaks, as a sensor we use a SiPM (6.1x6.1mm effective area) SensL MicroFC-60035-SMT [6], we designed a PCB with resistors and capacitors that have the function of filters to avoid noise in the signal, also inside the PCB is mounted the SiPM, we use a voltage source of 29V and an oscilloscope DPO-7054.

Table 1: Properties of common scintillators [1].

Scintillator	Type	ρ[g/cm³]	Photons/MeV	τ_{decay}	λ_{max} [nm]
NaI(Tl)	inorganic	3.67	38 10^3	230	410
CsI(Tl)	inorganic	4.51	65 10^3	1300	560
BGO	inorganic	7.13	8.2 10^3	300	480
NE104	plastic	1.03	10 10^3	1,8	406
NE224	liquid	0.88	12 10^3	2,5	425

The coupling of the scintillator to the SiPM is done with optical grease, this to ensure that the light generated in the crystal reaches the SiPM and prevent light losses collected by the crystal; to isolate the system from ambient light, we covered the system with a thick and dark commercial plastic tape, the entire instrument was contained in a hermetic box.

Four types of radioactive sources of the same dimensions were used as gamma ray emitters: cesium-137 (Cs-137), cobalto-60 (Co-60), sodium-22 (Na-22) and manganese-54 (Mn-54).

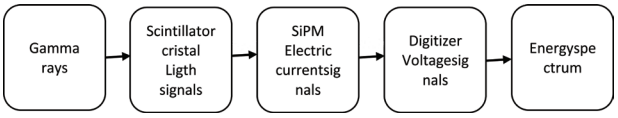

Figure 1: Schematic diagram of the detector and electronics.

Table 2: Characteristics of gamma emitting sources.

SOURCES	GAMMA (KeV)	$t_{1/2}$	Radioactivity (μCi)
Co-60	315, 1173.2, 1332.5	5.27 years	1
Cs-137	661.64	30.2 years	5
Na-22	511, 1274.5	2.60 years	1
Mn-54	834	313.1 days	1

2.2 *Data Acquisition*

The analogical input signals to SiPM are acquired by means of a digital oscilloscope controlled by a Python script which allows us to acquire each one of the pulses, to later process them with another script, the processed data are analyzed with the ROOT program [5], in which we can see the deposited load, source spectrum (pulse histogram) and energy resolution (FWHM).

2.3 *Calibration*

The energy calibration of the gamma radiation detector is important to correctly locate the photopeaks [7] associated with the correct energy according to which channel of the corresponding multichannel system.

If we consider that the peaks tend to a Gaussian distribution, the width of the peak is given by:

$$FWHM = 2\tilde{A}\sqrt{2log2} \approx 2.355\tilde{A} \quad (1)$$

And for the resolution we calculate it with the following expression:

$$R(\%) = \frac{FWHM}{H_0} \times 100 \quad (2)$$

Where, H_0 is where the greatest amplitude of the photopeak is found.

It is immediate to note that the better the resolution of a measurement system [1] (or, what is the same, the lower the FWHM) the more capable the system of discriminating between energy events will be.

3. Results and Discussion

The first characterization of the instrument was to measure the radiation spectra of each gamma ray emitting source. Within each spectrum we can observe the physical processes such as the photopeaks preceded by the compton edge, the interaction of production of pairs is not observed, the photopeaks correspond to each of the sources. It is observed in each of the spectra an adjustment was made to each photopeak this was obtained from the deposited charge. In the case of the ^{60}Co source we were able to observe the double photopeak, since an exhaustive analysis was made with the ROOT program to have more definition.

The difference between the heights of the photopeaks points out the low efficiency of the BGO crystal as it is not long enough to stop the gamma radiation of higher energy.

The deposited load per source was calculated from the height spectra. Figure 3 shows the deposited load for a ^{60}Co source. In order to calculate the load only the integration of the pulse height was done, by means of a Python script.

The instrument was then calibrated to determine the relationship between the channel number and the incident

photon energy value of each gamma ray emitting source. In order to determine with precision the position of the emission maxima, a non-linear adjustment of a Gaussian was made to each one by means of the ROOT program. Figure 4a) shows the linear adjustment made to make the calibration in energies corresponding to the channels of our software, also calculated the full width to half the maximum (FWHM) of the photopeaks.

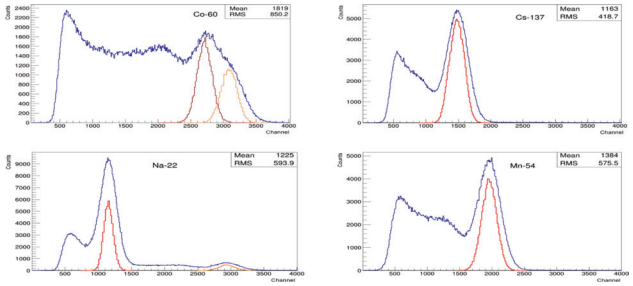

Figure 2: Gamma radiation spectrum measured for source of a) ^{60}Co, b) ^{137}Cs, c) ^{22}Na, d) ^{54}Mn.

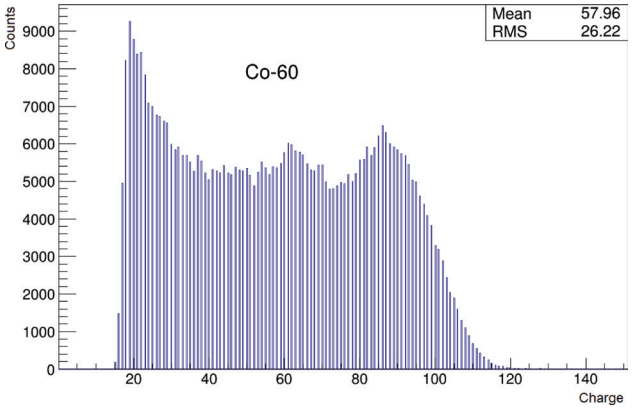

Figure 3: Histogram charge deposited ^{60}Co.

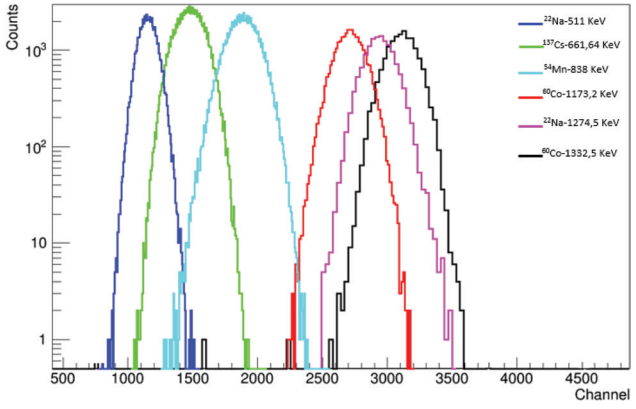

Figure 4: Photopeaks emitted from each of the radioactive sources.

Table 3: Calculation of the energies for the measured photopeak data. The FWHM is calculated from the points (FWHM = 2.335 σ).

Source	H_0 (channel)	FWHM	E (keV)	R (%)
^{54}Mn	1885	293.98	834	15.59
^{22}Na	1153	167.53	511	14.53
	2942	284.82	1274.5	9.68
^{137}Cs	1517	241.81	661.64	15.94
^{60}Co	2712	276.12	1173.2	10.18
	3084	287.64	1332.5	9.32

Conclusions

The work describes the principle of operation and the development of a new gamma-ray spectrometer working with a BGO crystal, which is well-functioning and operates under normal conditions. The instrument was characterized with low and high counting rates using gamma ray emitting sources.

The height spectra of the sources of ^{60}Co, ^{137}Cs, ^{22}Na, ^{54}Mn were obtained in which the compton effects and the photopeaks of each one of the sources could be observed; for the case of the source of ^{60}Co an analysis had to be made with the ROOT software to be able to observe the double photopeak of the source, this is done since the instrument does not have the sufficient resolution to see the double photopeak. From the height spectrum it was possible to calculate and make the histogram of the deposited load.

Finally, the device was calibrated by determining the energy value of the incident photon according to the corresponding channel. The instrument presents a linear relation for each one of the photopeaks what tells us that the device is viable as gamma ray spectrometer, without counting that it is portable, economic and the acquisition and processing of data is done with open source programs.

References

[1] Knoll, Glenn F. Radiation detection and measurement. John Wiley & Sons, 2010.

[2] V. Saveliev, and V. Golovin, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment **442**, 223 (2000). https://doi.org/10.1016/S0168-9002(99)01225-5

[3] M.T. Madsen, Journal of Nuclear Medicine **48**, 661 (2007). https://doi.org/10.2967/jnumed.106.032680

[4] O. H. Nestor and C. Y. Huang, IEEE Transactions on Nuclear Science **22**, 68 (1975). https://doi.org/10.1109/TNS.1975.4327617

[5] Root Analysis Framework, http://root.cern.ch

[6] C. Jackson et al., Proceedings 9359, Optical Components and Materials XII; 93591C (2015) https://doi.org/10.1117/12.2076898

[7] L. Schlattauer et al., European Journal of Physics **38**, 055806 (2017). https://doi.org/10.1088/1361-6404/aa7a7a

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