Indigenously developed gamma spectrometer

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Introduction

Undergraduate level nuclear physics laboratory experiments for gamma spectroscopy in India most commonly include Geiger Counters, and a selection of low-activity gamma sources. Spectroscopy experiments however, are not as frequently available due to the expensive design of the existing solutions which rely on photo-multiplier tubes and a series of signal processing modules.

We present the design and characterisation of a gamma spectrometer that is extremely compact, and has been kept very cost-effective, bearing in mind the limited resources available with universities. The detection unit is designed using a scintillator coupled photodiode detector, and the entire signal processing electronics inclusive of a 1K multi-channel analyzer is mounted in a durable aluminium enclosure measuring a mere $112 * 60 * 31mm^3$.

A mylar shielded entry window is provided on one end, and the other end has a USB communications port and a BNC socket for monitoring the $0 - 3.3V$ shaper output. The spectrometer is USB powered, and interfaced to a PC. Our cross-platform software written in Python, which we have licensed under open-source terms, has built-in features to fit, calibrate, and perform various analysis of acquired spectra.

The instrument is designed to detect gamma ray energies in a full scale range of 2 MeV with a resolution of around 80 keV for the 1.33 MeV peak of the spectrum from ^{60}Co. The two photopeaks in this spectrum have well known energies and are employed for two-point calibration of the MCA. Identification of the backscatter peak and compton edges in this spectrum as well as the one from a $1\mu C$ ^{137}Cs source showed a high degree of accuracy & linearity.

Hardware Design

The $10mm^3$ detector is composed of a Cesium Iodide(Thallium doped) scintillation crystal mated to a silicon PIN photodiode with matching surface area. The various stages of processing the signal to obtain the final spectrum reflective of the number of charge carriers deposited at various energies is outlined in the form of a block diagram in Figure 1 which is discussed below:

Signal Processing

The output of the detector is only of the order of picoCoulombs, and is directly fed to a charge to voltage preamplifier whose design has been adapted from [1]. False triggers attributed to electronic noise are rejected using a threshold setting of 150mV. The combination of peak detector and Analog to Digital Converter (ADC) is designed to convert the peak height (i.e. proportional to detected gamma energy) into a digital number, and the histogram data of energy vs number of counts is generated with the help of a Multi Channel Analyzer (MCA).

The MCA has been developed using a 64MHz microcontroller with a built-in 12-bit ADC. 2 LSBs of the digitized pulses are truncated, and the resultant 10-bit code has been used to construct 1024 channel(1K) resolution. The MCA does not use list mode, and instead the histogram data is stored in the volatile memory. Each channel is alloted 4 Bytes corresponding to over 4 billion counts, and an overflow event is unlikely to occur. This information can be transferred into a computer via the USB communications port in order to visualize, analyse, and interpret the data.

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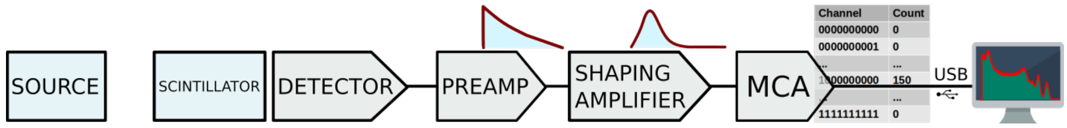

FIG. 1: Signal Processing Electronics: Flow diagram of conversion of gamma energy into a measurable quantity such as voltage pulse that maintains a predictable proportionality, followed by statistical analysis by the Multi-Channel Analyzer

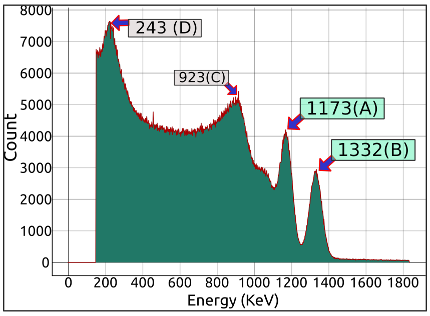

FIG. 2: a) $^{60}Cobalt$ gamma spectrum calibrated using the known photopeaks labelled A & B . The compton edge corresponding to 1173keV photopeak and backscatter peak calculated with this calibration are also labelled as C & D respectively.

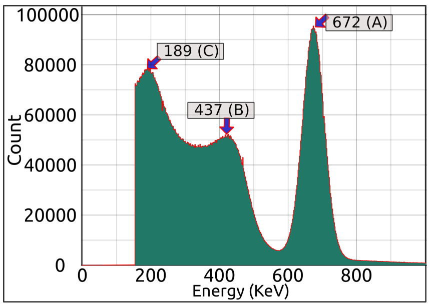

FIG. 3: a) $^{137}Cesium$ gamma spectrum showing the photopeak(A), Compton edge(B), and Backscatter Peak(C).

Calibration and linearity checks

The known photopeak energies of $^{60}Cobalt$ as obtained from ENSDF were used to apply a 2 point calibration. The calibrated spectrum was then analyzed to calculate the compton edges, and backscatter peaks as shown in Fig.2. An FWHM of $78keV$ for the 1332keV peak was observed. Two overlapping compton edges are expected at 926.5 keV and 1097 keV, and the edge corresponding to the lower energy photopeak at 1773 keV should be more well defined. Backscatter peak energies at 204 keV and 208 keV will be merged into a single peak due to resolution limits. A well-defined compton edge was obtained at 923keV(0.37% error).

A 2-point calibration based on the known photopeak energies of ^{60}Co was used to calculate the energies for photopeak, the backscatter peak, and the Compton edge for the single photopeak source ^{137}Cs in Fig.3, and the errors are determined to be 1.5%, 2.7%, and 8.5% respectively.

Conclusion

The compactness and performance of this design, coupled with its cost-effectiveness makes it a viable candidate for advanced undergraduate labs dealing with nuclear physics. This design will be extrapolated to develop coincidence experiments subsequently.

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