Characterization of $CeBr_3$ detectors

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Nuclear physics plays an important role to achieve the Sustainable Development Goals (SDGs) by contributing to clean energy (SDG 7), healthcare (SDG 3) and climate change (SDG 13). Nuclear energy provides a low-carbon, reliable source for combating climate change and ensuring energy requirements. Radiation techniques, especially in medical diagnostics and cancer treatment, becoming important part of the nuclear medicine. Radiation detection and monitoring safeguard the public health, protect the environment, and ensure the secure use of nuclear technologies. As nuclear applications expand, security systems are crucial to prevent misuse and protect facilities, radiation detectors play a key role in monitoring the radioactivity. Apart from all these applications, radiation detectors play key role in understanding the basic nuclear physics and related phenomena. Among radiation detectors, Cerium Bromide ($CeBr_3$) scintillator stand out for their high efficiency, fast response, and cost-effectiveness, making them essential tools in science, technology, and security [1–3].

The characterization of radiation detectors is of paramount importance for any measurement, and it becomes more important for numerous basic nuclear physics, industrial, and medical applications. It involves assessing the performance parameters of detectors, such as operating voltage, linearity & stability, energy resolution, efficiency, and minimum detectable activity (MDA) to ensure accurate and reliable measurements of ionizing radiation. Precise characterization of radiation detectors not only enables the detailed study of radioactive materials, explaining the nuclear reaction mechanism, and nuclear structure, thus contributing to the advancements in fundamental nuclear physics, but also require for the diagnostics and treatment for accurate imaging and precise dosimetry, ensuring effective and safe patient care in medical science. Additionally, in environmental monitoring and nuclear security, characterized detectors ensure the effective detection of radioactive contaminants and the prevention of illicit trafficking of nuclear materials.

FIG. 1: (a) Typical $CeBr_3$ detector with PMT, (b) $CeBr_3$ detector with Osprey, (c) $CeBr_3$ detector with 2007P, (d) PIN side of PMT, (e) socket side of 2007P and Osprey tube base, (f & g) connection side of Osprey and 2007P, respectively.

In the present work, the detailed characterization of 4 $CeBr_3$ scintillator detectors (1.5"x1.5": height and diameter - cylindrical geometry), coupled with the 8-stage Hamamatsu PMT R6231-100-01 have been performed (see Fig.1). The detector assembly, supplied by Scionix, Holland, was subjected to various characterization and measurements of energy linearity, energy resolution, time resolution, and absolute efficiency measurements. Notably, this study reports such detailed charaterization along with the abso-

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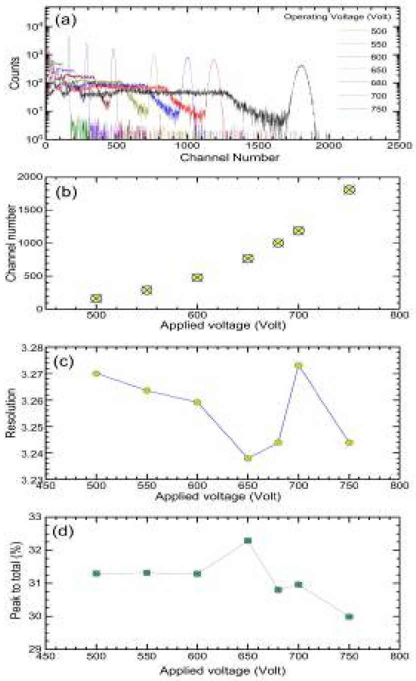

FIG. 2: (a-d) Typical γ-ray spectra acquired for ^{137}Cs standard γ-source at different operating voltages, (b) The variation of peak position of 662 keV γ-ray with the operating voltages, (c) The variation of detector resolution with the operating voltages have shown.

lute efficiency measurements and comparison of two different types of set-ups comprises of (*i*) 2007P pre-amplifier cum PMT base and (*ii*) Osprey-fully integrated multi-channel analyzer (MCA) tube base. Overall, the aim is to provide valuable insights into the characterization of $CeBr_3$ scintillation detectors and their practical implications for nuclear research, environmental monitoring, and nuclear security. Through detailed experimental investigations and performance evaluations, we aim to elucidate the capabilities and limitations of $CeBr_3$ detectors in different operational scenarios.

In scintillation detector's performance the operating voltage is a critical parameter, which directly influences the detector's efficiency, energy resolution, and signal-to-noise ratio (see Fig.2). For these detectors, an optimal voltage ensures that the photomultiplier tube (PMT) or photodiode operates within its ideal range, thereby producing the highest possible light yield and the best spectral resolution. In order to understand the behaviour of $CeBr_3$ detectors under varying applied voltages, count rate measurements were conducted in a fixed geometry. The rise time and flat top time were set to 1.0 μs each using the ProSpect software. The gamma-ray spectrum for a standard ^{137}Cs source was recorded for 180 seconds at each voltage from 500 to 750 volts, and results are shown in Fig.2. As can be seen from this Fig.2(c-d) that the resolution and peak-to-total are best at 650 volt applied voltage, thus can be inferred as the operating voltage for this detector. Further, the experiments for the optimization of rise and flat top time, for shift and drift of PMT gain, energy calibration and absolute efficiency measurements have been performed. Apart from these measurements a detailed comparison of both commercially available signal processing systems, the 2007P pre-amplifier cum PMT base with Lynx-II and Osprey-fully integrated multi-channel analyzer (MCA) tube base, have also been performed. The details of analysis and results will be presented during the symposium.

Authors thank the TAMU-DTRA-ORNL collaboration for providing financial support to establish the state of art radiation detector laboratory at Amity University Uttar Pradesh.

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