Studies in $LaBr_3$:Ce Detectors: Experiments and Simulations

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Introduction

The recent discovery of Lanthanum-halide (LaX_3:Ce) crystals seems to be a major step forward in the continuing quest for an ideal scintillator for nuclear radiation detection. The production and marketing of the $LaCl_3$:Ce and $LaBr_3$:Ce crystals have resulted in a flurry of activities in further developmental work and also testing and characterisations. The very attractive and superior properties of $LaBr_3$:Ce, namely, energy and timing resolution, stability, high efficiency etc. over most of the other scintillators open up a very wide usage of these scintillators in nuclear spectroscopy, astronomy, medical imaging, geological applications etc. As far nuclear spectroscopy is concerned the $LaBr_3$:Ce and $LaCl_3$:Ce scintillators demonstrate the capabilities to be used for the detection of both low and high energy gamma rays.

Measurements with small and large $LaBr_3$ crystals

We have carried out extensive measurements and realistic GEANT4 simulations to study the important properties of $LaBr_3$:Ce crystals [1]. The measurements have been carried out using two small cylindrical crystals of 1" diameter and 1" length and one large crystal of 3.5" diameter and 6" length. Gamma rays spectra have been recorded using a host of low energy gamma ray sources and also using in-beam reactions covering energies from tens of keV to 22.5 MeV.

The properties studied in-depth are, energy and timing resolutions, detection efficiencies (both photo-peak and total), uniformity of the crystals, internal radioactivity, neutron response, linearity, neutron-gamma separation in heavy-ion induced in-beam reactions etc. We have carried out comprehensive simulations using GEANT4 for all the detectors and have been able to produce the measured energy spectra on absolute scale. Detailed comparative studies have been carried out for efficiencies and other relevant properties of detection for the $LaBr_3$:Ce, NaI(Tl) and BaF_2 crystals. Close geometry efficiency calibration and coincidence summing correction have been performed for the $LaBr_3$:Ce crystals [2]. The uniformity of the large volume crystal has been tested over its entire surface using gamma ray sources of ^{137}Cs and ^{60}Co. The internal radioactivity of the large $LaBr_3$:Ce crystal has been extracted and the rate of activity estimated. The neutron response of the large crystal has been measured using radioactive source and also in in-beam measurements using heavy-ion fusion reactions.

Inspite of its high efficiency of detection, the currently available largest size of $LaBr_3$ may not be maximally suited for detection of high energy gamma rays, say, up to 50 MeV or so. In addition, the internal activity of $LaBr_3$:Ce that increases with the volume of the detector also poses a problem for large volume $LaBr_3$:Ce detectors. While research in this direction continues, it is worth exploring other possible and effective alternatives. We have proposed compact assembly of scintillators of different types and simulated the detection efficiencies for such configurations over wide energy range. Assemblies of the cylindrical $LaBr_3$:Ce crystal of presently available size within annular crystals of NaI(Tl) and BaF_2

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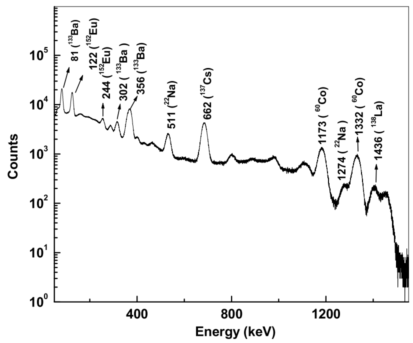

FIG. 1: .The typical spectrum recorded in the 1" × 1" $LaBr_3$:Ce using five different low energy gamma sources.

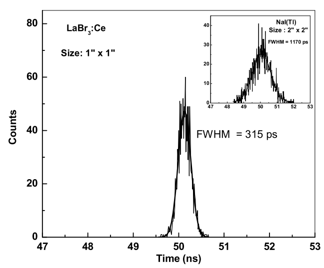

FIG. 2: . Comparison of energy gated time spectra for $LaBr_3$ and NaI(Tl) of similar sizes.

to provide a much larger combined volume. The performance of such assemblies have been compared with performances of NaI(Tl) and BaF_2 crystals of equivalent volumes. In addition, we have also considered a compact geometry of a cylindrical $LaBr_3$:Ce inside a well shaped NaI(Tl) and BaF_2 to provide a rather large detection volume. The result of these simulations show that even in absence of larger volumes of lanthanum halides, at least for the time being, the combinations of lanthanum halides with other scintillators available in bigger volumes and different shapes are superior to NaI(Tl) or BaF_2 of equivalent sizes.

All the results mentioned so far will be presented in the meeting.

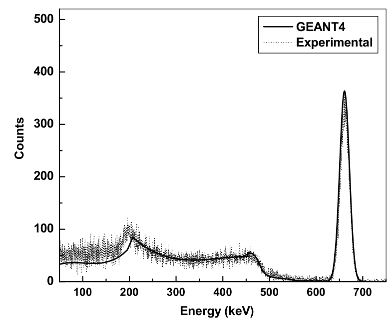

FIG. 3: .The background subtracted energy spectrum of 661 keV gamma rays from calibrated ^{137}Cs source compared with the simulated spectrum (solid line) using GEANT4 on absolute scale.

References

[1] G. Anil Kumar, I. Mazumdar, D.A. Gothe, Nucl. Instr. Meth. A**610**, 522 (2009) and references therein.

[2] G. Anil Kumar, I. Mazumdar, D.A. Gothe, Nucl. Instr. Meth. A**609**, 183 (2009).