Radiopurity Study of CsI and CsI(Tl) detectors for the mini-DINO

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Introduction

Inorganic scintillator detectors are widely used for nuclear spectroscopic studies, mainly due to high efficiency. Large arrays of NaI/CsI are employed in rare event studies like search for dark matter. In India, proposed experiment DINO to search for dark matter candidates as WIMPs, using simultaneous detection of light and phonon signals, has been initiated [1]. For this purpose, indigenous development of CsI scintillation detectors is undertaken at Technical Physics Division, BARC [2]. In rare event studies, the background reduction is of paramount importance. It is therefore pertinent to investigate the radiopurity of these detector materials. This paper reports measurements of radio-impurities in indigenously grown CsI and CsI(Tl) crystals using the TiLES (TIFR Low Background Experimental Setup). A commercial CsI(Tl) crystal is also studied for comparison.

Experimenatal Details

The TiLES consists of a low background, high efficiency HPGe detector (70% relative efficiency) [3]. The detector is shielded with 5 cm low activity OFHC Cu, 10 cm low activity Pb (^{210}Pb $<$ 0.3 Bq/kg) and an active cosmic muon veto system [4]. Further, the setup is enclosed in a Radon exclusion box (made of Perspex) and the box volume is continuously purged with boil-off N_2 at an over-pressure of $\sim$ 8 - 10 mbar to reduce the ^{222}Rn contamination. TiLES is one of the best HPGe based low backgorund setup at sea level [5] and with a senstivity of 2 mBq/g for ^{40}K.

Details of samples are given in table I. All the samples were counted in close geometry for better efficiency ($\sim$ 1 cm from detector face). Data is acquired using a commercial CAEN N6724 digitizer (14-bit, 100 MS/s). The offline anticoincidence between the HPGe detector and the plastic scintillators is perfomed using a C++ based algorithm within the timing window of $\pm$ 2.5 μs. The LAMPS [6] software and ROOT [7] framework is used for the data analysis. Energy calibration is found to be stable within 0.1 keV and a pulser (10 Hz) was also used for monitoring.

TABLE I: Sample Details

Samples	Description	Dimensions (in mm)	T_{count} (days)
1	CsI	11.0× 12.0×11.5	31
2	CsI(Tl)	10.6×10.4× 9.9	14.3
3	CsI(Tl)[a]	r = 10.9, t = 6.1	16.7

[a]Commercial.

Data analysis and result

Figure1 shows the spectra of different samples. The background spectrum is also shown for comparison. The impurities were identified by characteristic γ-rays.

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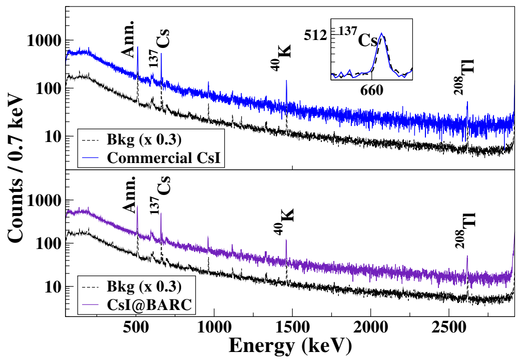

FIG. 1: The time normalised (scaled) spectra of commercial CsI(Tl) and CsI compared with background. Inset shows the ^{137}Cs photopeak counts of commercial CsI(Tl).

The impurity activity (A_γ) is estimated using

$$A_\gamma = \frac{N_\gamma - B_\gamma}{\epsilon_\gamma I_\gamma t\ m} \quad (1)$$

Where N_γ and $B\gamma$ are the area under the photopeak for the sample and background respectively, ϵ_γ is the photopeak efficiency, I_γ is the branching ratio, t is the counting time and m is mass of the sample.

TABLE II: Observed photo-peak yields of prominent γ-rays.

Energy (keV)	Bkg (/d)	Sample 1 (/d)	Sample 2 (/d)	Sample 3 (/d)
139.5	30(3)	30(4)	35(5)	33(9)
198.1	31(2)	32(2)	38(7)	26(8)
510.6	209(7)	191(8)	184(10)	201(11)
661.2	**85(3)**	**102(4)**	**97(7)**	**93(3)**
669.4	12(1)	18(2)	19(5)	15(3)
961.4	25(1)	22(3)	23(4)	25(3)
1114	12(1)	12(3)	11(3)	9(3)
1172	5(1)	6(2)	7(3)	5(2)
1459.7	32(2)	31(2)	35(2)	38(4)
2613.8	17(2)	18(2)	14(2)	19(3)

The photopeak efficiency is obtained from simulations using Geant4 based detector model [3]. The observed major gamma-rays and the resepctive yields are listed in Table II. It can be seen that all samples show a slightly higher activity ^{137}Cs (661 keV) as compared to the background. In case of crystals grown (sample 1 and 2) at BARC, all other major γ-rays corresponding to ^{60}Co, ^{40}K, ^{208}Tl etc. were similar to the background within errors. However, the sample 3 (commercial CsI crystal) showed a slightly higher content of ^{40}K ($\sim$ 18%) as compared to the background. Thus, it can be seen that the commercial CsI(Tl) has lower concentration of of ^{137}Cs but higher concentration of ^{40}K, which has a long half-life .

Conclusion

Radiopurity studies of indigenously grown CsI and CsI(Tl) crystals were carried out using the TiLES. A commercial CsI(Tl) crystal is also studied for comparison. The present results indicate that the radiopurity levels of indigenously grown crystals in BARC are comparable to commercial crystals.

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