Setup and characteristics of a low radioactivity background shielding hutch

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Introduction

Detectors based on single crystal scintillator are widely used for various applications in nuclear physics. Specialized scintillator detectors are being developed for rare event searches like neutrino-less double beta decay, WIMPs and Axions for dark matter etc. Due to negligible interaction cross section or rare occurrence of these events, a large volume of detectors are required. Therefore, the intrinsic radioactivity of materials has the paramount importance in these detectors. It has been shown that the required background counts of about 10^{-4} counts/kg/keV/year are required for ^{100}Mo based scintillators setup for neutrino less double beta decay experiments.

The measurements of intrinsic radioactivity of the potential scintillators and other materials require special shielding from the background radiations. Kim et al. have reported the measured intrinsic radioactivity of CsI crystals upto 3 mBq/kg for Dark matter measurements [1]. The cosmic background can be reduced by making the measurements in underground laboratories. The shielding hutch of layered materials is also required to cut various kind of radiations generated in background. As the initial screening of radio-purity of single crystals is required at the crystal growth lab, we have made a setup for measuring the intrinsic radio-purity of single crystal scintillators.

Experimental Setup

The shielding chamber was designed having about 3 ft X 1 ft empty cavity to accommodate single crystal having PMTs mounted on both side. The layers are made of (starting from inside) 1 mm Cadmium, 4 mm Copper, 50 mm Lead, 4 mm Copper, 50 mm Lead , 4 mm Copper, 50 mm Borated Polythelene (BPE, 30 % B-10 loaded) Sheet, and 4 mm thick Copper. A plug with 10 mm hole is mounted on side for power and signal cables. A plug of 3 inch dia, with similar shielding layers, is also placed on side which can be removed to place HPGe detector, as per the requirement. The total weight of hutch is around 4500 kg. The hutch is mounted on a trolley so that it can be moved for experiments at different sites. The hutch is placed at Crystal Technology Section, Technical Physics Division for initial screening of the in-house grown scintillator crystals.

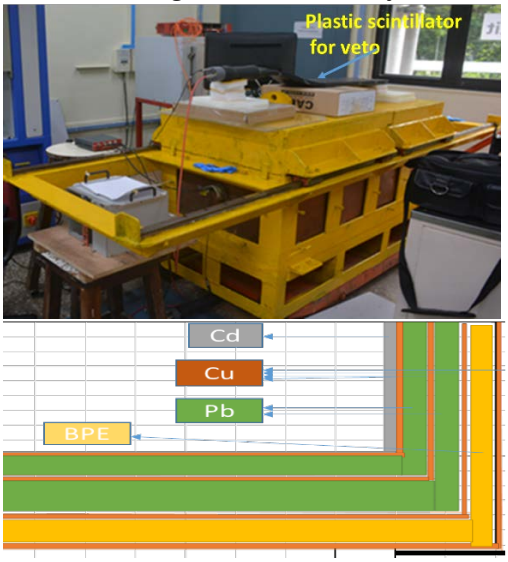

Fig 1: The photograph of low background activity shielding hutch, plastic scintillators for veto and schematics of shielding materials.

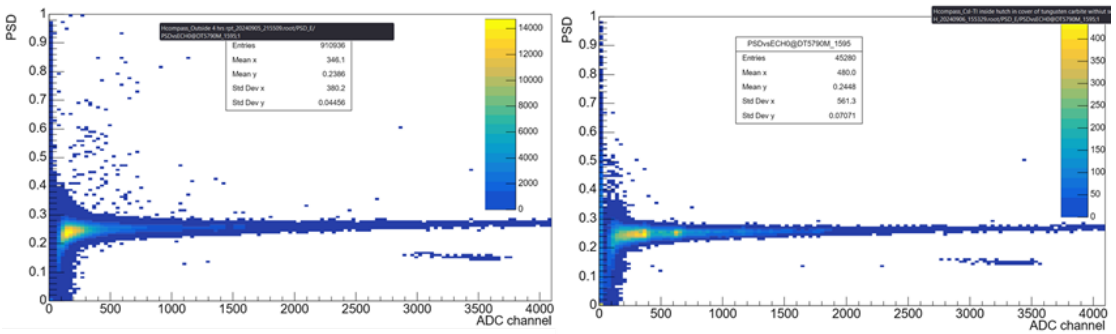

Fig 2: The pulse shape discrimination (PSD) of 2 inch X 2 inch CsI(Tl) mounted on PMT and kept (a) outside shielding hutch **(b)** inside hutch

Further refinement of particular radio-isotopes causing intrinsic background radiation can be planned accordingly. Digitizer was used for data processing and measurements.

Results & Discussions

A 2 inch X 2inch CsI(Tl) single crystal was mounted on PMT and PSD spectra were measured, for four hours, inside and outside the shielding hutch. As the alpha irradiation quench the decay time in CsI scintillators, lower band on PSD plot, shown in figure 2 can be assigned to the alpha background. The radioisotopes generated in U/Th decay chain contributes in the alpha background activity [2]

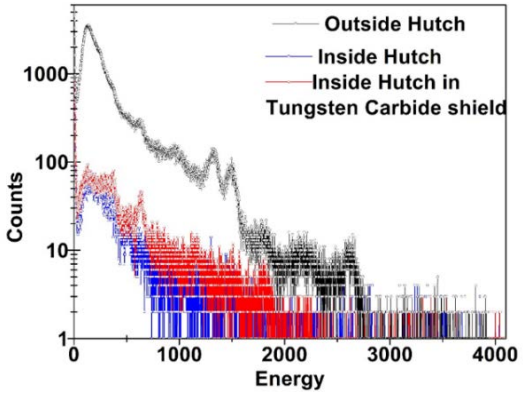

Fig 3: The measurements of pulse height spectra of CsI(Tl) mounted on PMT and kept outside and inside shielding hutch

The pulse height spectra, measured outside and inside shielding hutch are shown in figure 3. The major dominating peaks are from Bi and Tl radioisotopes from U/Th decay chain and Cs-137 from intrinsic impurity of the crystal. Tl-206 and K-40 gamma peak also decreases significantly after keeping the detector inside shielding hutch and indicates the contribution from background radiation in addition to intrinsic radioactivity. A 6 mm thick tungsten carbide shielding was also used around the detector and some peaks were observed to increase. It indicates the radio impurity present in tungsten carbide shielding, which may be confirmed by using different scintillators. More detailed investigations including background measurements of various single crystal scintillators like GGAG, $CeBr_3$, Phoswich etc., neutron background measurements using neutron sensitive scintillators, muon veto using plastic scintilaltors, and GEANT4 simulations of various backgrounds, are in progress and would be presented in the conference.

References:

[1] T.Y. Kim et al., "Study ofthe internal background of CsI(Tl) crystal detectors for dark matter search," Nuclear Instruments and Methods in Physics Research A 500 (2003) 337–344.

[2] S. K. Liu et al. "Measurements of intrinsic radioactive background from the ^{137}Cs and U/Th chains in CsI(Tl) crystals," Chinese Phys. C 39 (2015) 046002