Characterization of CLYC detector

Balaram Dey[1],* H. Krishnamoorthy[2], S. Pal[3],
M.S. Pose[1], V. Nanal[1], and R.G. Pillay[1]
[1]*DNAP, Tata Institute of Fundamental Research, Mumbai - 400005, India*
[2]*INO, Tata Institute of Fundamental Research and Homi*
Bhabha National Institute, Mumbai - 400085, India and
[3]*PLF, Tata Institute of Fundamental Research, Mumbai - 400005, India*

Recently, the development of new scintillators from elpasolite crystal family for the simultaneous detection of γ-rays and neutrons [1] has attracted much attention. In particular, CLYC (Cs_2LiYCl_6:Ce) detector is found to be suitable for a wide range of applications involving high energy neutrons (1-10 MeV), thermal neutrons and γ-rays. Thermal neutrons are detected via capture reaction ^{6}Li(n,α)^{3}H, which produces a peak at ~3.2 MeVee in the energy spectrum [2]. The presence of ^{35}Cl in CLYC detector enables the measurement of fast neutrons through the reaction ^{35}Cl(n,p)^{35}S [3]. The light yield of CLYC detector for γ-ray and thermal neutron excitation is ~20000 photons/MeV and ~ 70500/neutron, respectively [4]. Due to high light output, the energy resolution of CLYC detector is ~ 4% at 662 keV [2–4], which is better than the commonly used scintillators such as BaF_2 and NaI. Further, the CLYC detector output signal has an ultrafast scintillation decay component (~ 2 ns) only for γ-ray induced interactions, which enables n-γ separation through the pulse shape discrimination (PSD). Therefore, the CLYC detector, with its very good energy resolution and high neutron capture efficiency, is ideally suited for the simultaneous measurement of neutrons and γ-rays. In this paper, the characterization of two CLYC detectors for neutron spectroscopy is reported.

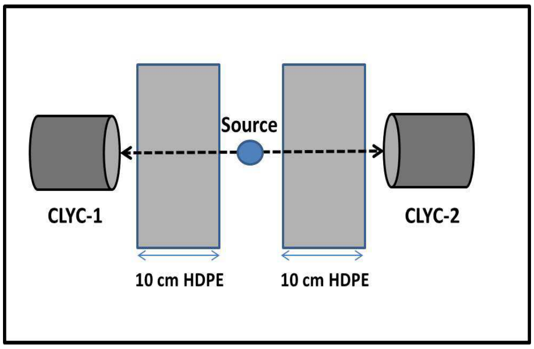

FIG. 1: A schematic of experimental set-up.

Measurements were carried out at TIFR, Mumbai using two cylindrical $1'' \times 1''$ CLYC detectors procured from M/S Scionix, Netherlands. Each detector was coupled to a $2''$ Hamamatsu R13089 photo multiplier tube (PMT), which was operated at -850 V. Different radioactive sources, namely, ^{137}Cs, ^{60}Co, ^{241}Am-^{9}Be and ^{252}Cf were used for γ-rays ($\sim 0-5$ MeV) and neutrons (upto ~10 MeV). A schematic diagram of the experimental setup is shown in Fig. 1. Two detectors were placed opposite to each other at a distance of 10 cm from the source. A 10 cm thick high density poly-ethylene (HDPE) brick was used to thermalize the fast neutrons from the source. The data was acquired using a CAEN make V1730 digitizer (16 channel, 14 bit, 500 MS/s, 2 Vpp) and digiTES-4.2.6 data acquisition software [5]. This digitizer has an in-built constant fraction discrimination (CFD) algorithim and gives the time stamp, PSD and energy information. The anode output of detector was integrated in two different gates of 50 ns (Q_S) and 900 ns (Q_L) for n-γ discrimination using PSD technique and energy measurement, respectively. The energy vs PSD spectra with

---

*Electronic address: `dey.balaram@gmail.com`

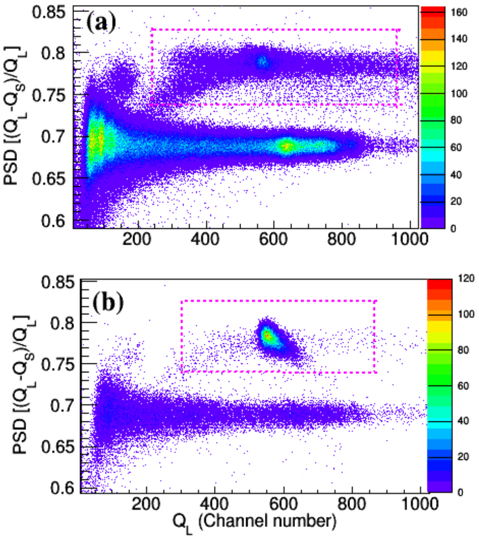

FIG. 2: PSD spectra (a) without HDPE and (b) with HDPE brick using ^{241}Am-^{9}Be source. Neutron events are indicated by rectangular box in both panels.

^{241}Am-^{9}Be source are shown in Fig. 2.

A clear n-γ separation is evident from Fig. 2. The neutron events can be divided into two groups based on the interaction of thermal and fast neutrons with the CLYC crystal, as discussed earlier. The fast neutrons with varying energy are seen scattered within the band while the thermal neutron capture results in an intense peak. It can be seen that with 10 cm HDPE brick, most of the neutrons are thermalized and only a narrow peak is visible in the neutron band [Fig. 2(b)]. The γ-ray energy spectra for different sources are shown in Fig. 3. Energy resolution of both the detectors were measured and found to be $\sim$ 5 % at 662 keV. In Fig. 3(d), a peak at $\sim$ 2.2 MeV arising due to thermal neutron capture in HDPE brick is also clearly visible. Further, the intrisic neutron detection efficiency is found to be $\sim$ 6 % in the energy region of 1 - 6 MeV and $\sim$ 25 % for thermal neutrons.

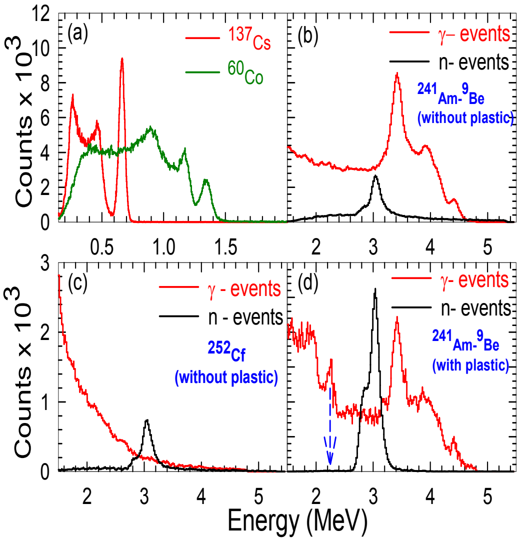

FIG. 3: Energy spectra using [a] ^{137}Cs and ^{60}Co [(b) & (c)] ^{241}Am-^{9}Be and ^{252}Cf without HDPE absorber, and [d] ^{241}Am-^{9}Be with HDPE absorber.

Thus, with this excellent n - γ discrimination, good energy resolution and neutron capture capabilities, the CLYC detectors are ideal for the neutron spectroscopy. It is proposed to use these detectors for neutron measurements in connection with radiation background studies for rare decays at TIFR, Mumbai.

Acknowledgments

We would like to thank Mr. K.S. Divekar for assistance during the setup.

References

[1] Jarek Glodo *et al.*, IEEE. Tranc. Nucl. Sci. **59**, 2328 (2012).
[2] M.M Bourne *et al.*, NIM A **736**, 124 (2014).
[3] M.B Smith *et al.*, NIM A **784**, 162 (2015).
[4] Li Kui-Nian *et al.*, arXiv:1608.08696
[5] http : //www.caen.it