Synthesis of Deuterated Benzene(C_6D_6) Liquid Scintillator for nuclear and high energy physics experiments

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(Deuterated Liquid Scintillator(DLS) collaboration)

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Introduction

Liquid scintillation detectors are widely employed in both nuclear physics and high energy physics experiments for neutron and neutrino spectroscopy due to their relatively high light-output, fast time response, pulse shape discrimination and possibility of loading metals of suitable isotopes for rare event searches [1, 2]. Depending on the application, the liquid scintllators are synthesised using suitable solvent of high flash point like phenyl-o-xylyl ethane (PXE), linear alkylbenzene (LAB) and di-isopropylnaphthalene (DIN) and fluores like PPO (2,5-Diphenyloxazol) and bis-MSB (4-bis-(2-Methyl-styryl) benzene). The synthesis of an indigenous LAB based scntillator and its characterisation was reported earlier [3]. The main objective of the DLS collaboration is to develop liquid scintillator(LS), metal loaded LS for the measurement of neutrons and neutrinos from various sources(solar, reactor, supernovae etc) and planning to make 1 ton detector as prototype and subsequently develop 1 kton LAB or deuterated LS for neutrino physics. A deuterated liquid scintillator(DLS) is sensitive to both Charge Current from both ν_e and $\bar{\nu}_e$ and Neutral Currents events from all flavors [4]. It has ability to measure the low energy neutrino spectrum.

We present results of a deuterated benzene(C_6D_6) based LS detector using C_6D_6, which to our knowledge has been done for the first time in the country. We also characterised this detector in terms of its scintillation light yield and pulse shape discrimination response.

Synthesis of C_6D_6 based LS

The liquid scintillator is made using the C_6D_6 as main organic liquid solvent. The high pure solvent C_6D_6 was synthesised by HWB with 99.8% Deuterium. The solute and wavelength-shifters were PPO and bis-MSB respectively dissolved in the solvent. The LS is synthesised using homogeneous mixture of solvent C_6D_6(>97%) and fluores, PPO (<3%) and bis-MSB (<0.1%).

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C_6D_6 scintillation detector and its testing

An Aluminum cell of size 6 cm × 6 cm × 6 cm with one-end closed and other end viewed by 1.3cm thick glass port fabricated in house. A total of 500 cc of C_6D_6 LS was synthesized at BARC. About 250 cc of the sample was used to fill the LS cell in an inert environment and rest used for chemical analysis by spectroscopic technique. After sealing the liquid cell, a 5 cm diameter PMT coupled to the glass port. A photograph of the C_6D_6 LS detector is shown in Fig 1. The detector is tested using radio-active sources for gamma-rays (^{137}Cs) and neutrons (Am-Be source).

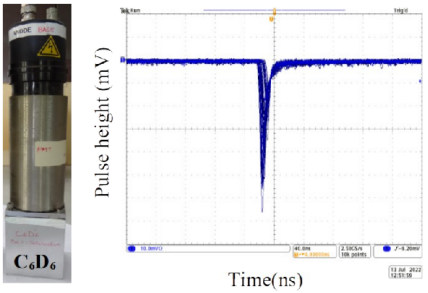

FIG. 1: A photograph of the C_6D_6 LS Cell couple to PMT and a typical Raw signal profile at -1000 V (anode signal from the PMT) for ^{60}Co source.

Results and Discussion

A typical signal as seen in the oscilloscope is shown in Fig 1 for the applied voltage at -ve 1000 V on the cathode. The rise and fall times of the signal are found to be about 5 ns and 40 ns, respectively. A VME digitizer (500M/S, CAEN make) was used for data acquisition. The pulse height spectrum from the C_6D_6 LS has been acquired by using DPP-PSD firmware in the digitizer. The measured pulse height spectra for ^{137}Cs and Am-Be Sources are shown in Fig 2(a). The Pulse shape discrimination(PSD) is obtained as the ratio of integrated charges for short gate(Q_S) to long gate (Q_L) and used to discriminate neutrons from gamma-rays. The PSD versus energy spectra for ^{137}Cs and Am-Be Sources are shown in Fig 2(b). The PSD shows very good discrimination of neutrons from the gamma-rays for the Am-Be neutron source. The PSD can be improved by further purifying the fluores and also continuous purging with N_2. The first indigenously developed C_6D_6 LS could be a precursor for the development of water based liquid scintillators and useful for R&D for metal loaded LS. The C_6D_6 LS shows promising results and can

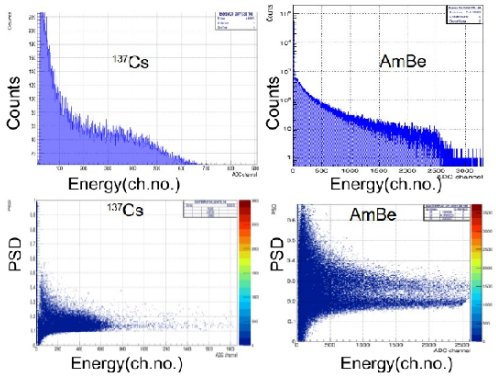

FIG. 2: (a)Measured pulse height spectrum of C_6D_6 using ^{137}Cs and Am-Be Sources(upper panel), (b) the PSD versus energy spectra for gamma-rays and neutrons with the same sources(bottom panel).

also be used in neutron measurement for low energy nuclear physics experiment. It offers pulse height analysis for energy information, PSD for particle discrimination and also fast response for time of flight measurement.

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References

[1] P. C. Rout et al., JINST 13, P01027 (2018)
[2] M. Yeh et al., NIM A 578 (2007) 329
[3] P.C. Rout et.al, Proceedings of the DAE Symp. on Nucl. Phys. 65 (2021) 772
[4] Bhavesh Chauhan, Basudeb Dasgupta, Vivek Datar, J. Cosm. Astroparticle Phys. 11, 005 (2021)