Development of Organic Scintillation Detectors for Nuclear Physics Experiments

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Introduction

The measurement of neutron energy spectrum is useful for the study the thermodynamic properties of excited compound nucleus and also have applications in nuclear energy production based on fusion and fission reactions. However the detection is difficult unlike charged particle. Interaction of neutrons with matter involve the production of secondary charged particles through nuclear reactions. Transfer of a substantial fraction of fast neutron energy by scattering off a light nucleus is the most common mechanism for the fast neutron detection. Hydrogenous materials *viz.* plastic and liquid scintillators are used for fast neutron measurement and detection. The fast component of the scintillation light of the detector is used for timing measurement and the slow component is used for discriminating neutrons from γ-rays on the basis of pulse shape discrimination (PSD). Plastic scintillators offer very good timing property and therefore are used for the neutron measurement employing time of flight technique [1], whereas the liquid scintillators (LS) have both PSD and very good timing properties.

A mini array of 18 liquid scintillators has been set up for the fast neutron spectroscopy at the Pelletron-LINAC Facility (PLF), Mumbai. The set up will be extended to an array of 80 liquid scintillators (EJ-301) to measure neutron cross sections as low as $\sim 1\ \mu$b/sr and will complement the existing array of plastic scintillators [1]. The setup will be useful for the study of washing out of shell effect and damping of rotational enhancement of nuclear level density with excitation energies, the measurement of the prompt fission neutron spectrum in the fast neutron induced fission of actinides, neutron multiplicity for the study of fusion-fission dynamics and also for coincidence measurements involving neutrons.

In this paper, we shall describe a mini array of LS along with the measured response and a few experimental results utilizing the array. We also highlight the development of new types scintillation detectors, as a part of Deuterated liquid Scintillators (DLS) collaboration, which can be used for the measurements involving neutrons, neutrinos and rare event searches.

LS array and experiments

A mini array of 18 liquid scintillators (LS) [2] has been set up for the study of fast neutron spectroscopy in the energy range from 0.5 MeV to 20 MeV by pulse shape discrimination and time of flight technique (TOF). Each of the LS (EJ301 equivalent to NE213 and procured from SCIONIX, Holland) is cylindrical in shape with 12.7 cm diameter and 5 cm thickness. The scintillator has a light output of $\sim$ 78% compared to that of anthracene and a bulk attenuation length $>$ 2.5 m. The mean scintillation decay times of the scintillator are $\sim$3.2 ns (fast), 32.3 ns and 270 ns (slow). Each LS is coupled to a fast linear focused, 12.7 cm diameter Hamamatsu R1250 (14 stage) photo-multiplier tube (PMT) for signal readout. The anode signal of each LS is processed for generating the time using a constant fraction discrimination (CFD) and for deriving the energy and the PSD with a Mesytech MPD4 electronics module. The data are stored using a multi-

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parameter VME based data acquisition and offline analysis carried out with Linux Advanced MultiParameter System (LAMPS). The array has been used for the study of collective enhancement and fade out in A∼170 and A∼170 via novel techniques and observed large collective enhancement for the first time, used for the coincidence experiments to study the structure of ^{9}Be and ^{5}He in addition to other measurements involving fast neutrons. Recently the array has been used to study the pairing re-entrance phenomenon.

Synthesis of novel LS

The scintillators used described earlier section are Xylene based scintillator.However 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 diisopropylnaphthalene (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 [3] shows excellent timing without pulse shape discrimination. The main objective of the Deuterated Liquid Scintillator(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. It has ability to measure the low energy neutrino spectrum. 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%).

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. The detector is tested using radio-active sources for gamma-rays (^{137}Cs) and neutrons (Am-Be source).

The rise and fall times of the signal are found to be about 5 ns and 40 ns, respectively. 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 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 C_6D_6 LS shows promising results and can 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. The first indigenously developed LS could be a precursor for the development of water based liquid scintillators and useful for R&D for metal loaded LS.

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References

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