Synthesis of LAB based liquid scintillator for nuclear and high energy physics experiments

P.C Rout[1,12],* D. Goswami[2,12], T Santhosh[1,12], S.Santra[1,12], V.M. Datar [3], S. Dey[4,12], A. Verma [5], J. Ajish [6], B. Dasgupta [7], S. Malhotra [8], T.K. Ghanty [9,12], S.M. Yusuf [10,12], A.K. Tyagi [11,12], J. Srivastava [5], and S.K. Nayak [5]
[1]*Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA*
[2]*Bio-Organic Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA*
[3] *IMSc, Chennai - 600113 INDIA*
[4] *Chemistry Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA*
[5] *Heavy Water Board, Mumbai - 400085, INDIA*
[6] *RPCD, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA*
[7] *DTP, Tata Institute of Fundamental Research, Mumbai- 400005, INDIA*
[8] *EmA&ID, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA*
[9] *Bio Science Group, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA*
[10] *Physics Group, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA*
[11] *Chemistry Group, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA and*
[12]*Homi Bhabha National Institute, Anushaktinagar, Mumbai- 400094, INDIA*

Introduction

Organic scintillators, particularly liquid scintillors have high light yield, good timing($\lesssim$ ns) and pulse shape discrimination for particle identification. These detectors have been used for fast neutron spectroscopy [1]. Metal-loaded liquid scintillators are the detectors of choice for various experiments such as measurement of thermal neutrons, neutrinos and also search for rare events[2, 3]. The most common organic compound used in liquid scintillators (LS) are Xylene, Toluene and Pseudocumene. These scintillators offer good light yield and pulse shape discrimination. However, these scintillators have a low flash point which for large detectors($>$ 1 ton) is a fire safety concern. In addition these solvents are not environment friendly. Nevertheless, new scintillator solvents particularly, phenyl-o-xylyl ethane (PXE), linear alkylbenzene (LAB) and di-isopropylnaphthalene (DIN) are biodegradable, relatively safe solvents, with a high flash point and very low toxicity compared to traditional liquid scintillator solvents.

*Electronic address: prout@barc.gov.in

TABLE I: properties of molecule used with optical absorption/emission peak.

Molecule	density	flash point	λ^{abs}_{max}	λ^{em}_{max}
LAB	0.87	140^{o}C	260 nm	284 nm
PPO			303 nm	358 nm
bis-MSB			345 nm	418 nm

We present results of a LAB based LS detector prepared at BARC, 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. We also plan to measure the time response. We then compare these responses with those of a plastic scintillation (with PSD property) and a xylene based detector.

Formulation of LAB based scintillation detector

The liquid scintillator generally consists of a mixture of an organic liquid solvent and one or two wavelength-shifters as solutes. The solvent LAB (98% purity) has been chosen for the present study because of its high light yield and low risk properties. The wavelength-shifters dissolved were PPO

(2,5-Diphenyloxazol) and bis-MSB (4-bis-(2-Methyl-styryl) benzene). Important parameters of solvent and solute are given in Table I. The solution is made with the concentration of 2.5 g/l of PPO and 0.25 g/l of bis-MSB.

LAB based scintillation detector and its testing

An Aluminum cell of dimension 6 cm × 6 cm ×6 cm was designed and fabricated in house. One-end of the liquid cell is closed and other-end is viewed by 1.3cm thick glass port for coupling the photo multiplier tube (PMT) for signal readout. About 400 cc of LAB based scintillator has been synthesized at BARC. About 250 cc of the sample was used to fill the LS cell in an inert environment. 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).

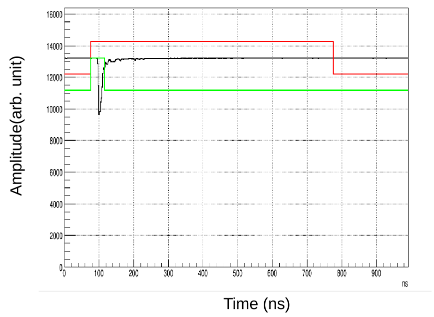

FIG. 1: Raw signal profile at -1100 V (anode signal from the PMT)

Results and Discussion

A CAEN 500M/S desktop digitizer was used for data acquisition. The pulse profile is started seeing at an applied voltage of -800 V. A typical signal as seen in the oscilloscope is shown in Fig 1 for the applied voltage at -ve 1100 V on the cathode. The rise and fall times of the signal are found to be about 5 ns and 150 ns, respectively. The pulse height from the LAB based LS detector is compared with that of a 5 cm diameter and 5 cm thick cylindrical plastic scintillator(PS) and a 12.5 cm diameter and 5 cm thick cylindrical xylene based LS (at -1300 V applied high voltage). The light yield of LAB is higher than that of the LS and similar to that of PS and the comparison is shown in Fig 2. The PSD of the LS and LAB are also shown in Fig 2. The poor PSD is found for the synthesized LAB scintillator. However the PSD can be tailored by varying concentration of fluors and wavelength-shifters. The first indigenously developed LAB scintillator shows promising results and provides motivation for the R&D on metal loaded and D2O based LS detectors. Generally, Xylene based scintillators are good for neutron measurement and not suitable for large scale detectors due to small attenuation length. LAB based detectors have large attenuation length and suitable for neutrino measurement using even a kiloton LS detector.

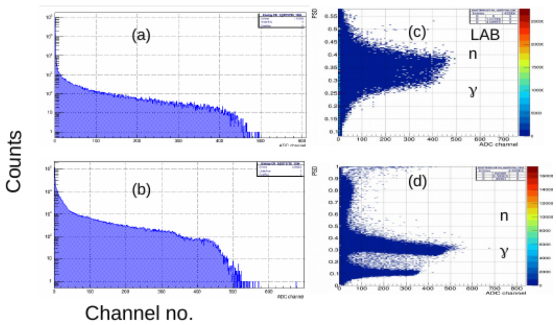

FIG. 2: Comparison of pulse height spectrum between LAB (a)and Xylene (b) based scintillators and the pulse shape discrimination versus energy spectra are (c) and (d) respectively.

Acknowledgments

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References

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