Liquid scintillation detector array for fast neutron spectroscopy

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Introduction

The measurement of fast neutron emission in a nuclear reaction is an important probe for the study of basic nuclear reaction dynamics and its application in nuclear energy and nuclear astrophysics. Hydrogenous materials *viz.* plastic and liquid scintillators are used for fast neutron measurement and detection [1]. The slow component of the scintillation light of the liquid scintillator is responsible for discriminating neutrons from γ-rays on the basis of pulse shape discrimination (PSD) whereas the fast component is used for timing measurements. Since the neutron detection efficiency is very small unlike the charges particles detection, its measurement with a meaningful statistics requires solid angle coverage. An array consisting 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 section as low as $\sim 1\ \mu$b/sr and will complement the existing array of plastic scintillators [2].

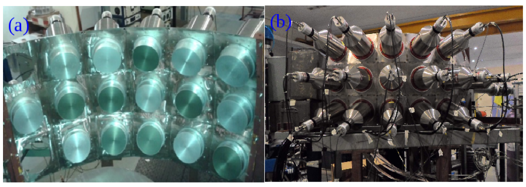

FIG. 1: Photograph of mini array of liquid scintillator, (a) front view shows the liquid cells and (b) rare view shows the PMTs coupled to the individual liquid cells.

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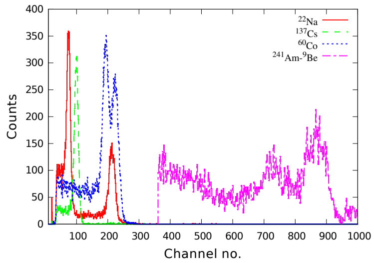

FIG. 2: Pulse height response of liquid scintillator up to ∼4MeV electron equivalent energy.

Details of scintillator array

The array consisting of 18 liquid scintillators (LS) has been set up for fast neutron spectroscopy at the PLF. Each of the LS (EJ301 and procured from SCIONIX, Holland) is cylindrical in shape with 12.7 cm diameter and 5 cm thickness. 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 spectral sensitivity of the PMT peaks at 420 nm, with a quantum efficiency of $\sim$ 22 %, and matches the emission spectrum of the liquid scintillator. The PMT has a fast response time (rise time $\sim$1.3 ns) and a gain of $\sim 10^7$ at about 2 kV bias voltage. The PMTs are powered by a 48 channel programmable high voltage power supply developed in-house. These scintillators are mounted on a mechanical stand, placed at a flight path of 75 cm with an angular separation of 16° among the detectors. Fig. 1 shows a photograph of the array of LS displaying the aluminium cells for liquid scintillator and the PMTs with mu-metal shield. Each aluminium cell can accommodate about 5% volume expansion of the liquid scintillator. The read out signals from each LS are processed using analogue electronics and stored

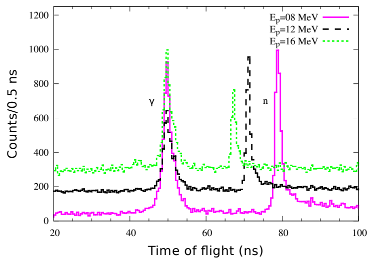

FIG. 3: Measured neutron TOF spectra at various beam energies. The neutrons peaks are well separated from γ rays.

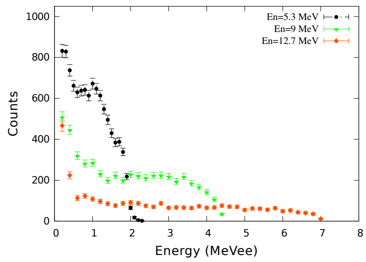

FIG. 4: Measured Pulse height responses of the liquid scintillator at E_n=5.3, 9, 12.7 MeV using (p,n_1) reaction.

using a multi-parameter VME based data acquisition system.

Characterisation of LS

The electron response of the LS was obtained by measuring the recoil electrons tagged with the backscattered γrays in a Compton scattering experiment. The recoil electrons were measured by a LS in coincidence with back scattered γ rays detected in a BaF_2 detector using ^{137}Cs, ^{22} Na, ^{60}Co and Am-Be radioactive sources. A typical electron spectrum of the LS is shown in Fig. 2 and the electron response found to be linear up to 4.1 MeV. The pulse height response to monoenergetic neutron, TOF and PSD have been measured using ^{7}Li(p,n_1)^{7}Be reaction for proton energies 8,12 and 16 MeV [3]. The measured TOF and pulse height response for En=5.3, 9.3, 12 MeV are shown in Fig. 3& 4, respectively. The continuum neutron spectra were also measured from ^{7}Li induced reaction from ^{159}Tb at 27 MeV beam energy [4]. The typical TOF spectrum with respect to the pulsed beam is shown in Fig. 5. The neutron energy spectrum can be derived from the neutron TOF spectrum.

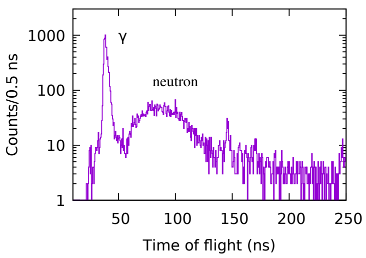

FIG. 5: Measured neutron TOF spectrum with respect to the pulsed beam in ^{7}Li induced reaction from ^{159}Tb.

Summary and Conclusion

The electron response and also the response to discrete and continuum neutrons of the the LS have been measured. The observed electron response of the LS is linear while the pulse height response to discrete neutrons is non-linear. The set up has been used for the study of damping of shell effect, rotational enhancement of nuclear level density, prompt fission neutron spectrum and neutron multiplicity for the study of fusion-fission dynamics at the PLF.

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References

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