Characterization of prototype detectors for MIni Neutron deTector (MINT) Array

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Introduction

The measurement and detection of neutrons are important for fundamental and applied sciences, including nuclear physics, reactor monitoring, radiation protection, astrophysics and medical physics. The organic scintillators are essentially used for the detection of fast neutrons because they consist of hydrogeous atoms that help neutrons lose energy by elastic scattering. Unlike charged particles, the neutron detection efficiency is small. Therefore, a large solid angle coverage is required with high granularity (angular resolution) for statistically significant measurements. A large area plastic scintillation detector array [1] has been set up for fast neutron spectroscopy using the time-of-flight technique. Another array of liquid scintillators [2] has been used for the measurement of fast neutrons, using both the fast timing and pulse shape property (PSD) of the liquid scintillators (LS). These arrays have been used for the study of shell effect on nuclear level density, collective enhancement and its fade-out, pre-scission neutron multiplicity, and transfer reactions involving neutrons in the exit channel. In many experiments, it is also demanded that the detectors remain in a forward angle for efficient detection of neutrons to study the transfer reactions or inverse kinematics reactions.

In this paper, we present briefly the proposed mini-neutron detector array along with the pulse height responses of the prototype detectors measured using radioactive sources as well as an in-beam experiment using ^{7} Li(p,n) reaction.

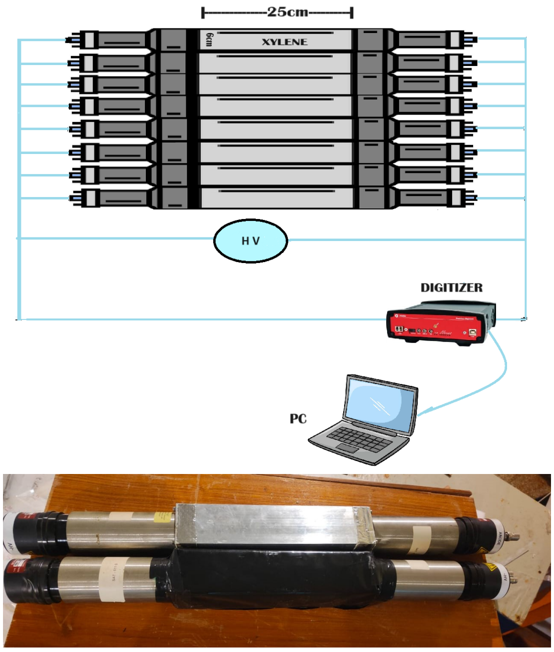

FIG. 1: Schematic of MINT array (top panel) along with a photograph of two prototype detectors (bottom panel), liquid scintillator filled in Al Cell and plastic scintillator covered with black sheet.

MIni Neutron deTector (MINT) array

An array of eight plastic scintillator (PS) bars (Eljen PS with PSD, EJ-299-33) or Xylene based LS is proposed to develop for

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the measurement of neutrons in transfer reaction studies and will be placed in forward direction with angular coverage from 20° to 35°. Each detector bar has dimension of 6 cm×6 cm×25 cm and is coupled to two 5 cm diameter fast PMTs, one each at either end. A schematic of the array along with indigenously made two prototype detectors based on LS and PS for the array is shown in Fig. 1. For LS prototypes, an Aluminum cell of size 6 cm × 6 cm × 25 cm with glass port viewer on either end fabricated in house. Xylene based LS (EJ-301) was used to fill the LS cell in an inert environment and subsequently sealed. Two 5 cm diameter PMT coupled to the glass port as shown in bottom panel of Fig 1. And for the PS prototype, the Scintillator (EJ-299-33M, 6 cm×6 cm×25 cm) wrapped with TYVEK paper for total reflection of photons and then covered with black HDPE (high-density polyethylene) sheet to prevent light-leak. Then, PMTs coupled either end of the PS using Si optical grease. The prototype detectors are tested using radio-active sources for gamma-rays (^{137}Cs) and neutrons (Am-Be source).

Experimental Details

Mono-energetic neutrons were produced by bombarding a $\sim$ 2 mg/cm^2 thick ^{nat}Li metal target with proton beams of energies 8, 10, 12, 16 and 20 MeV from the Mumbai Pelletron Linac Facility. The neutrons produced in the reaction ^{7}Li(p,n$_1$)^{7}Be* were detected by the prototype detectors placed at 1m from the target and 45° with respect to beam direction. The mono-enegetic neutrons are detected in respective detectors in coincidence with the 429 keV γ-ray emitted from the first excited state of ^{7}Be, measured using a 4 inch diameter and 6 inch thick LaBr$_3$ detector. The detector signal is processed using a sixteen channel 500MS/s digitizer (CAEN-V1730) and data acquired in event-by-event mode using CoMPASS software for further analysis.

Results and Discussion

The Pulse Shape Discrimination(PSD) is obtained as the ratio of integrated charges for short gate(Q$_S$) to long gate (Q$_L$) and is used to discriminate neutrons from gamma rays. The data is analyzed using the CERN root. In the PSD versus energy spectra, the neutrons are well separated from the gamma rays. Thus, for the neutron PSD gate, the projected pulse height spectra for proton beam of 16 and 20 MeV is shown in Fig 2 and similar nonlinear response has been reported for quasimonoenergetic neutrons [1, 2]. It is also observed that

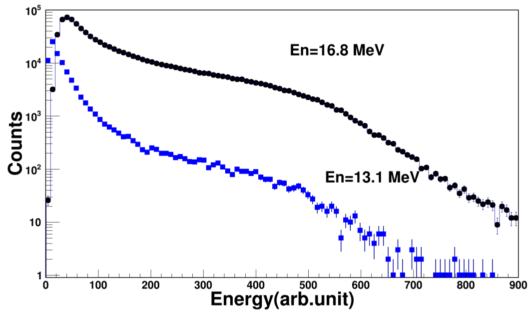

FIG. 2: Measured pulse height spectrum of LS detector for neutron PSD gate for E^n=13.1 MeV and 16.8 MeV for 16 MeV and 20 MeV proton, respectively.

the PSD property of long PS is not as good as the small size PS. The Long PS has poor PSD compared to the LS of the same dimension. The energy, time of flight, and position information can be derived in addition to the PSD property of these detectors. Therefore, these detectors are suitable for unambiguous measurement of neutron amid gamma-ray background.

Acknowledgments

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References

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[2] P. C. Rout et al., JINST 13, P01027 (2018)