Neutron detection by Pulse Shape Discrimination and Time of Flight techniques

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Introduction

Uncharged radiations like gamma-rays, x-rays, and neutrons are indirectly ionizing radiation [1]. Neutrons lose energy most effectively by collisions with matter having similar mass. In hydrogen based organic liquid scintillators, the entire neutron energy can be transferred at once. These scintillators are cheap and resistant against radiation damage. However, the neutron-sources usually emit gamma rays also, to which these detectors are sensitive. So we need to distinguish neutron events from the gammas by a convenient and effective method.

In the present work we shall discuss some of these methods adopted by us while looking for the most effective one to characterize a liquid scintillator BC501A (Bicron) by detecting the gammas and neutrons emitted by a ^{252}Cf fission source .

n/γ discrimination with PSD method

Usually neutron interacts with the liquid scintillator by hitting a proton of the hydrogen nucleus, while a gamma Compton scatters off an electron. The proton-like pulse has a relatively longer tail due to long-lived scintillation components. On the other hand, an electron-like pulse decays out quickly. These differences of pulse shapes are useful for discriminating neutrons from gammas. Historically a number of pulse shape discrimination (PSD) techniques [2] have been used. For our experiment we have used the zero-crossing method or the rise-time method which determines the time at which the integrated light output reaches a certain fraction of its maximum.

We have used two PSD modules, *viz.*, FAST COMTEC (2160A) and MESYTEC MPD4, and have compared their performances by optimising them to get the best possible PSD spectrum. Studies were conducted on the different aspects of the n and n+g modes of the modules to understand their effect on the PSD spectra.

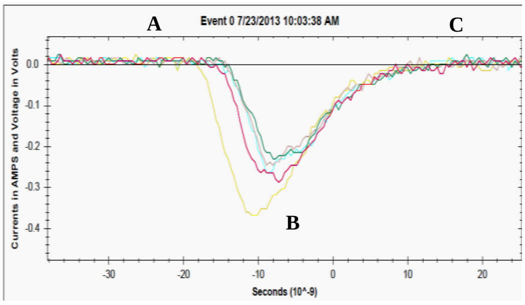

Fig. 1 A few typical pulses recorded in the oscilloscope (1000 points: 0.8 ns/bin)

As an alternative to using off-the-shelf, commercially available PSD modules, a digital oscilloscope (Tektronix DPO4032) has been used to record pulses in nanosecond detail (Fig.1). The use of a fast digitization unit to store the pulses is known to provide opportunities in developing and testing different pulse shape analysis algorithms during post-experiment data re-processing along with several other advantages over analog processing of pulse shapes [3,4]. Simplest possible analysis by plotting short integral (integral of the falling edge of the pulse: BC in Fig.1) with long integral (integral of the entire pulse ABC in Fig.1) is shown in Fig. 2. Even with this simplest method the gamma and neutron bunches are clearly separated, especially for pulses with larger long integrals. Further improvements in the algorithms shall be tried to have better discrimination.

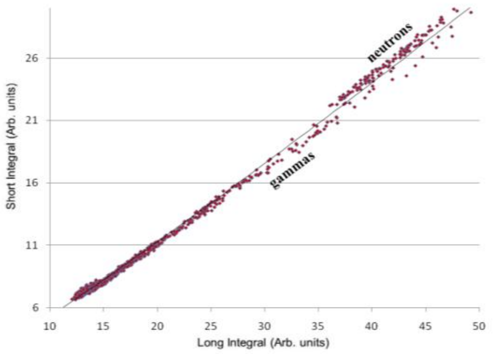

Fig. 2 A simple pulse shape discrimination plot

Time-of-Flight technique

As a complementary method of the n/γ discrimination, the Time-Of-Flight (TOF) technique [4] was also used with $LaCl_3$ detector as the starting detector and BC501A as the stop detector, as shown in Fig. 3.

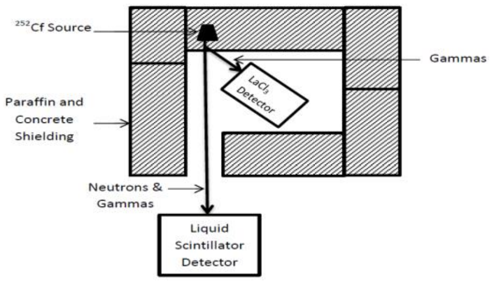

Fig.3. The TOF setup

The characteristic neutron and gamma peaks were obtained and the neutron peak was confirmed by placing the BC501A at different distances and observing the shift in the neutron peak alone (Fig.4).

The 2-D plot of the Time-of-Flight (y) vs. BC501A energy spectrum (x) (Fig.5) and PSD vs. Time-of-Flight spectrum were analysed to identify the energy regions corresponding to the gamma and neutron events.

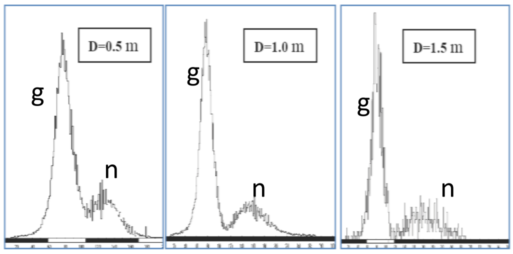

Fig.4. The shift in the neutron TOF peak with increasing source-detector distances (D=0.5, 1.0 and 1.5 m).

Furthermore the kinetic energies of the neutrons were calculated by converting the counts vs. time TOF spectrum into counts vs. energy spectrum by the use of relativistic energy formula [4]. This value of energy agreed with the theoretical value of the neutron energy from the fission source.

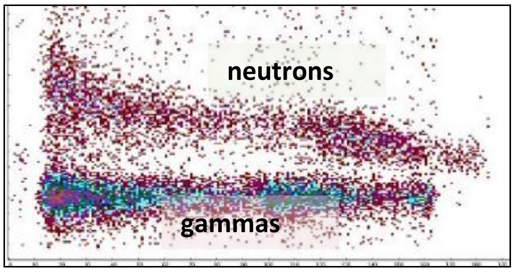

Fig.5 . The TOF vs energy plot

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