Characterization of liquid scintillators for NAND facility at IUAC

N. Saneesh[1],* Meenu Takur[2], Ruchi Mahajan[2], Gurpreet Kaur[2], R. Dubey[1], S. Venkataramanan[1], A. Jhingan[1] and P. Sugathan[1]

[1]Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi - 110067, INDIA
[2]Physics Department, Punjab University
. * email: saneesh@iuac.res.in

Introduction

The upcoming neutron detector array facility at IUAC will have 100 individual neutron detectors installed in a fixed radius semi sphere configuration. Currently in its first phase of installation, the array consist 50 detectors mounted on a metallic geodesic dome structure at a radial distance of 1.75 m from the target. The detectors are of 5”x5” organic liquid scintillator cell BC501-A coupled to 5” photo multiplier tube (PMT). The BC501-A liquid organic scintillators have the best pulse shape discrimination properties giving good neutron-gamma discrimination. The detectors are coupled to Hamamatsu R4144 PMT which, according to the manufacturer, has good timing characteristics and from comparative study made by Moszynski et.al [1], it was found to be the second best recommended tube for liquid scintillators.

Total 50 organic liquid scintillators are presently mounted on the array. All the 50 detectors for the first phase have been tested for its performance characteristics using standard gamma ray as well as neutron sources. From each detector cell, the light output, pulse shape discrimination and time of flight are recorded using standard NIM electronics. The anode signal from PMT is used for timing as well as pulse shape discrimination whereas the dynode signal is used for energy (light output) information . Though the detectors and PMTs are all identical, the operating voltage varied slightly among detectors. Nominal operating voltage on each detector was determined by keeping the anode signal amplitude for 662 keV (^{137}Cs source) gamma rays around 450 mV for best timing and zero-cross separation. Typical operating voltage ranged between 1400 – 1600 V which gives good timing characteristics and a good dynamic range for typical neutron measurements at our beam energies.

N-gamma discrimination module

The neutron-gamma (n-γ) discrimination test was carried out with home made Pulse Shape Discrimination (PSD) electronics and compared with commercial electronics. A custom made PSD module [2] has been used for the signal readout. This module contains the integrated electronics for neutron-gamma discrimination, time of flight and energy. It is a single width NIM module having two independent channels that can accept signals from two detectors. For each detector, the anode and dynode (through a charge sensitive pre-amplifier) signals are fed to the inputs of the PSD module which process them and provide energy, constant fraction timing and a time to amplitude signal corresponding to zero-crossing time distribution for n -γ separation at its outputs. Other logic signals and monitoring signals are also provided on its front panel. Total 50 channels of PSD modules have been fabricated and tested for its performance.

Detector performance

To check the linearity of the PMT output, we have measured the light output for different gamma sources (like ^{137}Cs, ^{60}Co, ^{22}Na, etc) and determined the corresponding Compton edges. In figure 1, we show a typical light output spectrum obtained with a ^{22}Na source showing peaks due to the Compton edge of the two emitted gamma rays (of energies 511 keV and 1275keV respectively). We observe a good linear relationship between the deposited energy and the light output. Excellent timing property of the detector can be exploited for the time of flight (TOF) study of fission neutrons. The timing performance of the detector set up has been tested using ^{22}Na source. A typical TOF spectrum recorded between a BC501-A detector and a BaF2 detector is shown in Fig 2. An FWHM of 1.56 ns has been observed. Figure 3 shows the two dimensional histogram displaying the light output plotted against the zero cross time distribution for one detector using neutrons and gamma radiations from ^{252}Cf source. Distinct separation between neutron and gamma events from the source is clearly visible illustrating the performance of the pulse shape discrimination of the setup. The PSD performance at a given energy threshold is quantified by using a figure of merit (FOM), defined as the ratio of peak separation to the sum of full width at half maximum (FWHM) of the peaks. The typical FOM for the detector and electronics combinations is found to be 1.62 at 120keV recoil electron energy. Figure 3 also shows the enhancement in FOM as the threshold energy is increased. Neutron-gamma discrimination at thresholds in the range between 250 and 500 keV ee were found for all the 50 detectors tested. These threshold values are good enough for most of the reaction-mechanism studies.

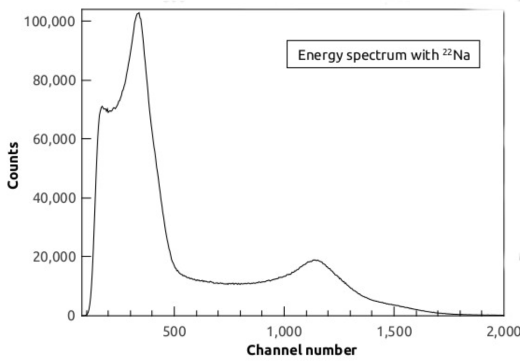

Fig. 1 Light output from ^{22}Na

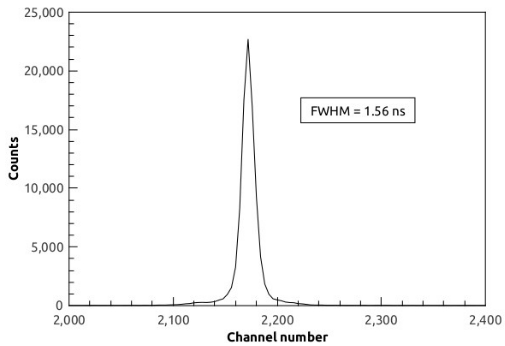

Fig. 2 Time of flight spectrum of gamma rays from ^{22}Na having FWMH of 1.56 ns.

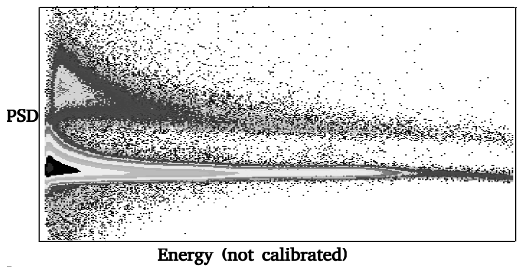

Fig. 3 Neutron-gamma discrimination using home made PSD module based on zero-cross timing.

Acknowledgment

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References

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