Intrinsic Efficiency of Neutron Detectors of NAND Array at IUAC

N. Saneesh[1]*, A. Jhingan[1] and P. Sugathan[1]
[1]*Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi - 110067, INDIA*
. * *email: saneesh@iuac.res.in*

Introduction

National Array of Neutron Detectors (NAND) [1] is a multi detector array for the detection of fast neutrons from heavy ion induced nuclear reactions. The facility has been used for exploring the dynamical aspects of heavy ion induced fusion-fission reaction around Coulomb barrier based on neutron multiplicity measurements. NAND facility consists 100 organic liquid scintillators (BC501A) of size 5”x5” coupled to R4144 photomultiplier tube (PMT) providing excellent neutron gamma discrimination. For experiments aiming to extract neutron multiplicity, the precise knowledge of detector efficiency is essential as it will be used for correcting observed counts. Other features such as neutron-gamma discrimination, linearity in response to different energies, etc. also should be understood. So, a detailed study on detector characteristics is very important to understand the detector response to different kind of radiations at different energies.
This article briefly reports some of the important characteristics of detector. The method adopted for deriving the intrinsic efficiency of BC501A detectors will be discussed in details. Finally the experimentally measured efficiency has been compared with a Monte Carlo simulation code.

Detector Characteristics

The BC501A detectors were tested with different radioactive sources for fixing their response characteristics. Detector bias voltages were decided according to the amplitude of timing signal from the the PMT. Voltages found to be varying between -1400V and -1800V for different detectors and the individual detector bias value was fixed by maintaining anode signal amplitude ~ 500 mV for 662 keV gamma rays from ^{137}Cs. The light output linearity response to different energies were tested using gamma rays from radioactive sources like ^{137}Cs, ^{60}Co, ^{22}Na and Am-Be. In low energy range, the response was found to be quite linear. Pulse shape discrimination (PSD) property of the scintillator has been exploited for neutron gamma separation. Custom made (PSD) modules based on conventional zero cross method was used for neutron-gamma discrimination. The PSD performance, given by its Figure Of Merit (FOM) was found to be better than 1.6 at 120 keVee detection threshold. Also the FOM was found to be improving with increasing threshold promising better discrimination.

Experiment setup

The intrinsic efficiency of BC501A has been determined by time of flight (TOF) technique. A spontaneous fission source, ^{252}Cf, was placed at the centre of the reaction chamber of NAND. A large area position sensitive Multi Wire Proportional Counter (MWPC) of size 20 cm x 10 cm was kept very close to ^{252}Cf to capture maximum number of fission fragments (FF). The MWPC timing signal provided the START for TOF and BC501A provided the STOP signal. The source and detectors were mounted in such a way that they are collinear. The detection threshold for BC501 detector was set around 100keVee for better count rate and appreciable neutron-gamma separation. The TOF, PSD and light output information were collected in list mode data acquisition systems triggered by fission signals from MWPC detector.

Theory

^{252}Cf decay by spontaneous fission (3.1%) emits on an average 3.76 neutron per fission. The theoretical neutron energy spectrum from spontaneous fission of ^{252}Cf in center of mass (CM) frame is well described by Maxwell's equation [2],

$$f(E)dE = \frac{2\sqrt{E}}{\sqrt{\pi}\,T^{3/2}}\; e^{-E/T} dE$$

where E is neutron energy and T is the temperature of the neutron source which is considered to be 1.42 MeV [2]. Knowing the number of fission F_n, neutron multiplicity M_n, solid angle subtended by the neutron detector to the source position Ω and distribution function $f(E)$, the number of neutrons impinging the detector in the CM frame can be calculated as,

$$\frac{dN}{dE} = F_n \times M_n \times \frac{\Omega}{4\pi} \times f(E)dE$$

Since the fission detector could cover a wide range of angles, the consequence of kinematic focusing on energy and counts can be neglected in the energy spectrum though it is present for individual events. Assuming the fission detector detects fission fragments emitted in all the directions, the laboratory energy distribution of neutrons will coincide with CM energy distribution, and then the ratio of the two will give intrinsic efficiency.

Data Analysis

The light output spectrum from neutron detector has been used for threshold settings. It was initially calibrated using known gamma ray from ^{137}Cs. Neutron energy was derived from TOF considering gamma peak as the time reference, and two dimensional gate (PSD v/s TOF) was applied to select neutron triggered events which is shown in the Fig. 1.

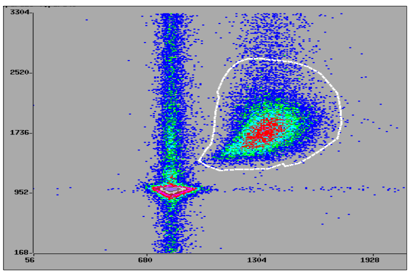

Fig. 1 Two dimensional plot showing PSD against TOF. Events in the marked region are neutrons

The derived energy spectrum was further gated with MWPC positions and energy loss signal to emphasis that the events triggered in BC501A are of fission origin. A small correction to number of fission has been applied based on position data. Finally, the intrinsic efficiency of the neutron detector for 100 keVee threshold was derived by taking the ratio of measured energy to Maxwell's prediction corrected for excess fission. It is shown in the Fig. 2.

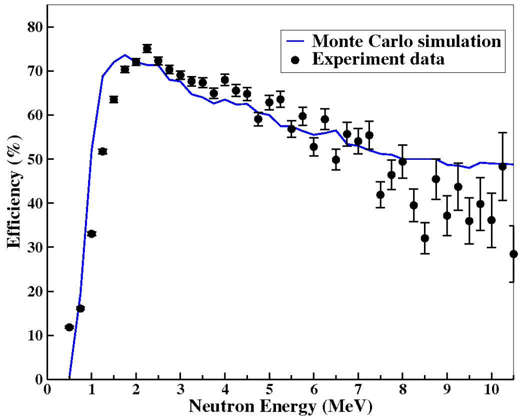

Fig. 2 Variation of Neutron detection efficiency as a function of energy

Conclusion

We have performed the intrinsic efficiency measurement of BC501A detector of size 5"x 5" at 100 keVee threshold. The data shows fairly good agreement with Monte carlo simulation for energies upto 7 MeV and beyond that theory over predicts the efficiency.

Acknowledgment

We gratefully acknowledge the support by Department of Science and Technology (DST) under grant no IR/S2/PF-02/2007.

References

[1] P. Sugathan et al., Pramana Journal of Physics, **83** (2014) 807

[2] "Proc. Advisory Group Mtg. Properties of Neutron Sources", IAEA-TECDOC-410, International Atomic Energy Agency (1987)