Development of proto-type neutron detector for MONSTER

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The structure of neutron rich nuclei has immense importance in nuclear structure physics, astrophysics as well as from nuclear technology point of view. Decay of neutron rich nuclei is often associated with abundant emission of neutron. The neutron rich nuclei generally associated with a high Q_β value and their daughter nuclei have relatively low neutron separation energy. Therefore these nuclei are often associated with delayed neutron emission from the populated unbound levels after the initial β decay. So in order to establish full decay strength, neutron measurement up to 10 MeV with good detection efficiency and high energy resolution is required. Moreover highly neutron rich system may decay through the emission of multiple neutrons, so a detector system with multiple neutron detection capability and having minimum cross talk is desirable.

A neutron detector array MONSTER (MOdular Neutron SpectromeTER) [1] has been proposed for the measurement of the beta decay properties of neutron rich isotopes at the DESPEC (decay spectroscopy) experiment at FAIR. The spectrometer will be sensitive to β-delayed neutron with energies ranging from 300 keV to several MeV and allow reconstructing its energy by time of flight. The MONSTER will consist of ~ 100 numbers of BC501A liquid scintillator based neutron detectors. Part of the proposed MONSTER is being built in INDIA and part of it in SPAIN. Here we report performance of the first indigenously developed MONSTER module at VECC which has been shown in Fig.1. The detector consists of a cylindrical aluminium chamber with 8 inch diameter and 2 inch thickness filled with BC501A liquid scintillator. The liquid sealing is done with a 9 mm thick quartz glass. The liquid chamber is coupled with a conical shape acrylic light guide. The light guide is finally connected with a Hamamatsu photomultiplier tube R4144, which convert the scintillation light into electrical signal.

Fig. 1 Photograph of the MONSTER cell.

The detector was thoroughly tested using standard γ and neutron sources. The pulse shape discrimination (PSD) property of the detector was studied by the zero cross over (ZCO) technique [2] using a ^{241}Am-^{9}Be neutron source. The pulse shape discrimination property can be described quantitatively by the figure of merit defined as $M = \Delta/(\delta_n + \delta_\gamma)$, where Δ is the separation between the γ peak and the neutron peak, δ_γ , δ_n are the full width at half maximum of γ and neutron peaks respectively. Fig. 2 shows the measured figure of merit as a function of pulse height threshold. The figure of merit gradually improves with detector threshold and it finally saturates to a value 1.6 at around 160 keVee threshold. A typical ZCO spectrum showing the n-γ spectrum at a threshold of 200keVee has been shown in Fig. 3.

The pulse height response of the detector has been measured using a ^{137}Cs γ-ray source. The same has also been estimated using Monte Carlo simulation. The Compton edge in the calculated spectrum was then folded with a Gaussian distribution to match the experimental spectra.

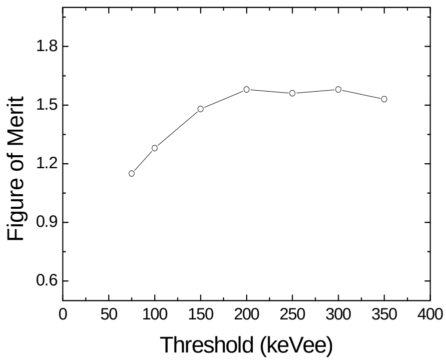

Fig. 2 Figure of merit vs pulse height threshold.

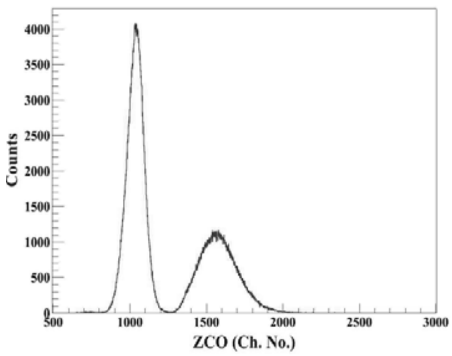

Fig. 3 n- gamma spectra at 200 keVee threshold.

Fig. 4 shows the measured pulse height response compared with theoretical prediction. The width of the Gaussian distribution which gives the pulse height resolution at the Compton edge, was found to be around 10% at 477 keV in the present case.

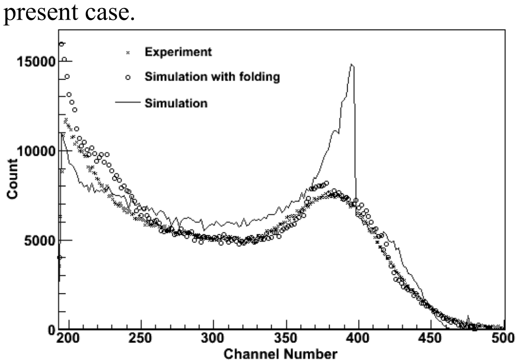

Fig. 4 Pulse height response of γ-rays from ^{137}Cs source.

Intrinsic time resolution of the detector was measured using by the time of flight (TOF) technique. Where the start of the TOF was taken from a 3.5x3.5x5 cm^3 of BaF_2 detector and the stop signal was taken from the liquid scintillator neutron detector. The intrinsic time resolution of the neutron detector was found to be ~ 0.635 nsec at a threshold of 100 keVee.

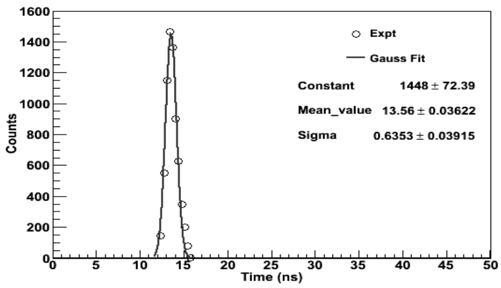

Fig. 5 Timing spectra between BaF_2 detector and MONSTER cell.

The more detail testing such as pulse height resolution in a wider energy range and neutron detection efficiency of the MONSTER cell is presently underway. The details will be presented during the symposium.

References:

[1] A. R. Garcia et. al. JINST 7, C05012, 2012.
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