Pulse height response function of different neutron energies in the LAMBDA spectrometer

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The BaF_2 material has been used as an efficient inorganic scintillator because of its very good timing properties, arising due to two components in the light output with decay times of 0.6 and 630 ns, as well as large detection efficiency owing to high density (4.8 g/cc). Utilizing these excellent properties of BaF_2, the LAMBDA spectrometer (consisting of 162-element BaF_2 detectors) [1] has been used recently as a neutron detector, apart from its usual employment as a high-energy gamma spectrometer. The energy dependent neutron detection efficiencies of the spectrometer were estimated using a ^{252}Cf source and compared with that of an organic liquid scintillator based neutron detector (BC501A) and GEANT4 simulation [2]. Interestingly, the average interaction length of neutrons in BaF_2 was also measured using the gamma multiplicity filter [3] to estimate the neutron time of flight (TOF) energy resolution. For the LAMBDA detector, the TOF energy resolution was estimated as 0.4 MeV at E_n = 4.0 MeV when kept at a distance of 80 cm from the source. Finally, the spectrometer was also applied to measure the neutron evaporation spectrum in an in-beam experiment to extract the inverse level density parameter [2].

In the recent past years, several groups have measured the neutron detection efficiency of BaF_2 detectors (different size detectors) for the neutron energy range 0.5-22 MeV [4]. The efficiencies are estimated by measuring the neutron spectrum via time of flight technique and dividing with the expected spectrum from the source. It is known that the neutrons of energy < 11 MeV interact mainly via (n, γ) and (n, n' γ) while above 11 MeV energy, more complicated reactions are involved producing charged hadrons [5]. However, the pulse height spectra of different energy neutrons are very rarely measured in the BaF_2 detector. In general, the pulse height response of the detector is an important property as it can be measured experimentally. The measured response can be effectively used to validate the simulations since the accuracy of any simulation depends on the proper modeling of the involved process and the correctness of different libraries used for the simulation.

In order to measure the pulse height spectra of the neutrons, four BaF_2 detectors (a small part of the LAMBDA spectrometer [2]), arranged in 2x2 matrix, were kept at a distance of 80 cm from the ^{252}Cf source. The detectors were gain matched and equal thresholds were applied to all of them. The start trigger for time of flight measurement was taken from the 50-element multiplicity filter [3] arranged in two 5x5 blocks. Apart from the time spectrum, the energy spectrum of all the four detectors was also measured by integrating the output pulse from the PMT in a QDC for a gate width of 2μs.

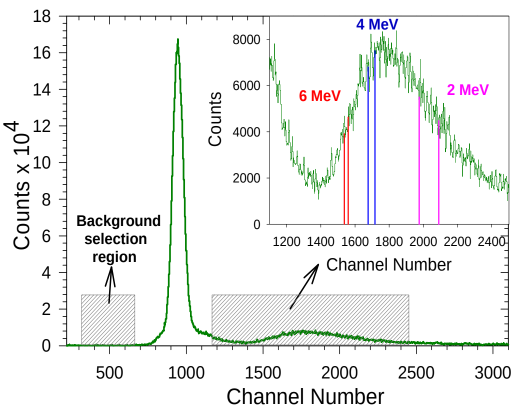

Fig. 1. The time of flight spectrum as obtained in one of the BaF_2 detectors using the ^{252}Cf source. The selection of the different energy regions in the TOF spectrum for generating the pulse height of particular energy is also indicated along with the area for background subtraction.

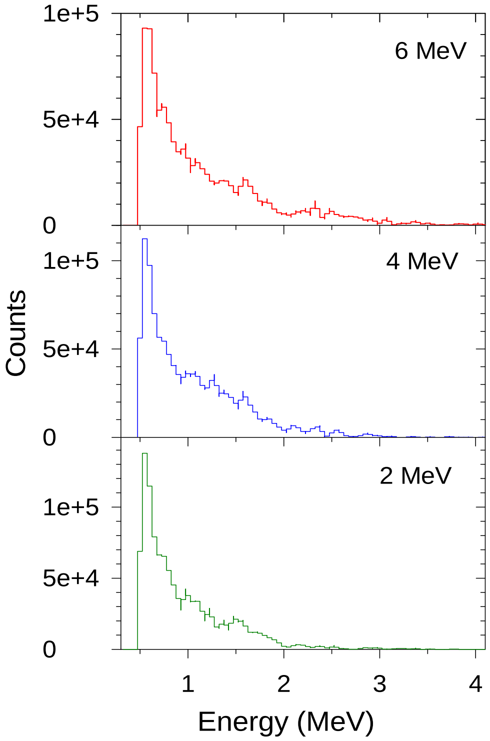

Fig.2. Background-corrected pulse height spectra measured with the BaF_2 detector for three neutron energy bins for ^{252}Cf source. The energy scale corresponds to electron-equivalent energy.

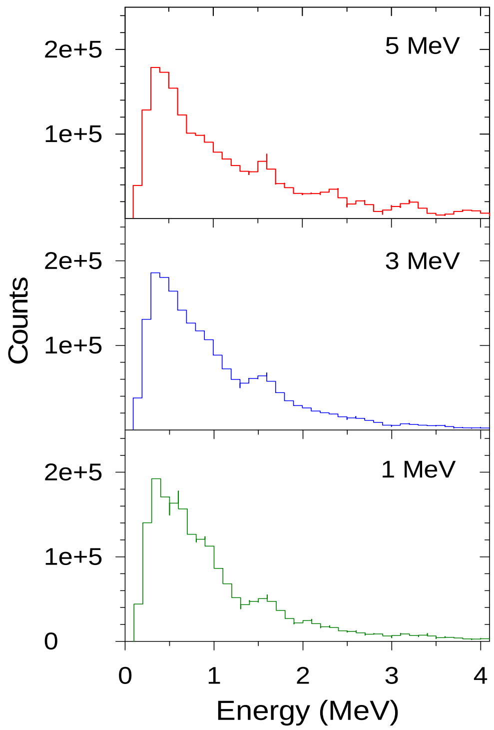

Fig. 3. Background-corrected pulse height spectra measured with the BaF_2 detector for three neutron energy bins for in beam experiment. The energy scale corresponds to electron-equivalent energy.

The typical TOF spectrum in one of the detectors of LAMBDA spectrometer is shown in Fig. 1. The TOF spectrum was converted to energy spectrum using the prompt gamma peak as a time reference. The selection of the different energy regions in the TOF spectrum for generating the pulse height of particular energy is also shown in Fig. 1. The selection for background subtraction is also indicated in the Fig. 1. Apart from the source, the same set was also used in an in-beam experiment with the K-130 cyclotron in the reaction $^{4}He + {}^{93}Nb \rightarrow {}^{97}Tc$ at E_{lab} = 35 MeV. The light output spectra of the single BaF_2 detector were determined for three bins of neutrons energies by setting appropriate gates in the time-of-flight spectra. The spectra were background-corrected and are shown in Fig. 2 and Fig. 3 for ^{252}Cf and in-beam experiment, respectively. It is very interesting to note that they all display an exponential shape. Apart from the continuous spectrum, one can notice that there are some pronounced peaks below 3 MeV and in particular at 1.5 MeV at all energies. A detailed GEANT4 simulation is underway to understand this pulse height spectra and the origin of different peaks which will be discussed during the conference.

References

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