Low energy neutron response function of BC501A detector: comparison with GEANT4 simulation

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Organic liquid scintillator (BC501A) based neutron time-of-flight (TOF) detector arrays are widely used for neutron spectroscopic studies in mixed field of neutron (n) and γ-rays due to their superior time resolution and $n-\gamma$ discrimination properties. Generalised packages, like, GEANT4 [2], FLUKA [3], MCNP [4] are used for the estimation of overall performance of more complex geometry of detector arrays. Among them, GEANT4 is extensively used by the nuclear and high energy physics community, because of its versatile capability of large scale, comprehensive simulation over a very wide energy range.

The accuracy of any simulation in general depends on proper modelling of the processes involved, as well as the correctness of the data libraries, and it is important to critically evaluate them. The pulse-height response of the detector, which is experimentally measurable, is an important tool to directly check the correctness of the simulation process as a whole. In recent years, the response function of BC501A neutron detector have been studied using GEANT4 [5], and it was shown that for low neutron energies ($E_n \lesssim 8$ MeV), where knockout protons dominate the detection mechanism, GEANT4 simulations were in good agreement with the data; on the contrary, for higher E_n (typically, $\gtrsim 8$ MeV), the smaller pulse height region of the experimental response function could not be explained properly by GEANT4 simulations.

At low energies ($E_n \leq 20$ MeV), NeutronHP model is nowadays most widely used for precise calculation of neutron induced reactions. So, a thorough evaluation of the NeutronHP model is highly desirable. The recent work of Patronis et al. [5] has highlighted the effect of knockout protons only. Here we report a comprehensive study of neutron response functions for neutron energies up to 20 MeV to evaluate the performances of NeutronHP model which include other reactions in addition to the dominant proton knockout reaction. The GEANT4 simulated pulse height response functions have been compared with those obtained experimentally. The experimental neutron response functions have been obtained from the literature [6]. The monoenergetic neutron response functions have been simulated using the GEANT4 toolkit version 4.9.2. The neutron cross-section data have been obtained from the library G4NDL3.14, the recently updated high precision data library, generated from ENDF/B-VI library [7].

The incident neutron may undergo multiple interactions in the detector depending on the neutron energy and detector dimension, leading to the production of multiple secondary charged particles. The complete trajectory of each secondary charged particle constitutes a track in GEANT4; each neutron event may usually be made up of several tracks. The complete history of the tracks thus generated are then used to calculate the light output from the scintillator [8]. To include the wall effect, the light output of each secondary particle has been calculated as $L = L(E_K) - L(E_{KR})$, where $E_{KR} = E_K - E_{dep}$, E_K is the kinetic energy of the secondary particle produced in the scintillator material, and, E_{KR} is the residual kinetic energy, and, E_{dep} is the

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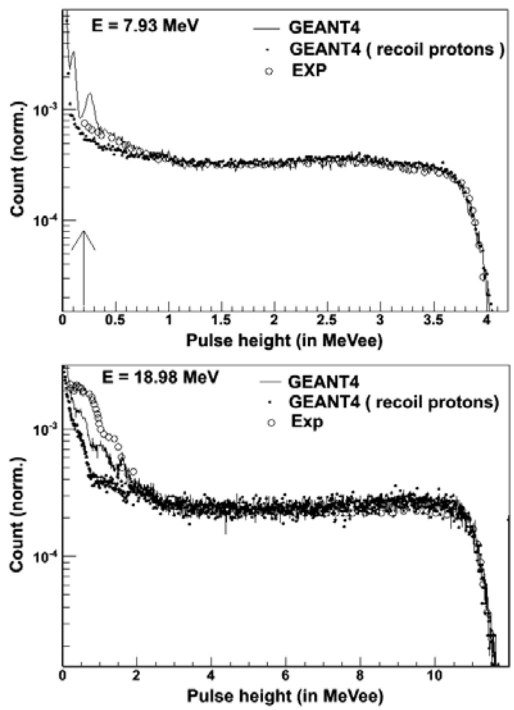

FIG. 1: Comparison of experimental and GEANT4 simulated pulse height spectra for neutron energies 7.93 and 18.98 MeV. Here line shows GEANT4 simulation considering all reaction process and dot shows recoil proton only. Detector thresholds are shown by arrows.

energy deposited by the secondary particle in the scintillator material.

The roles played by different neutron induced reactions at higher energies is evident from Fig. 1, where the experimental neutron response function has been compared with those obtained using (a) full GEANT4 simulation and (b) GEANT4 simulation considering only recoil protons (from neutron-proton scattering). It is seen (from Fig. 1 top) that at low energy ($\sim$8 MeV), only recoil proton contribution explains the spectrum quite satisfactorily over the whole region, and contributions of other mechanisms are not quite significant. However at higher energy ($\sim$19 MeV), there is significant discrepancy between the experimental and simulated recoil proton spectra in the low pulse height region (Fig. 1 bottom), which is due to the onset of other reactions at this energy; here, the inclusion of other physics processes have some effect, which however is not sufficient to explain the data. In particular, the non-inclusion of the contributions of higher order processes (i.e. (n, α), (n, 3α) reactions with ^{12}C) in their calculations in NeutronHP model might be the cause of this discrepancy. It may be noted here that the inclusion of these higher order reactions has been shown to produce better agreement in case of MCNP, NRESP7 codes. Further work is in progress.

References

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