Event-Resolved Analysis of Neutron Detection by Organic Scintillators: Simulation and Analytical Solution

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Organic scintillators are commonly used in systems for the detection of nuclear materials in nonproliferation and homeland security applications. Neutron detection in this type of detector occurs by multiple scatterings on hydrogen and carbon, the main constituents of the scintillator. Analysis of the neutron collision statistics is important to an understanding of the mechanism of neutron detection and for performing subsequent unfolding procedures aimed at determining the incident neutron spectrum.

This paper describes the Monte Carlo simulation of neutron interaction with the detector material for varying detector sizes and varying incident neutron energies. The simulations are performed using the code MCNP-PoliMi, which allows event-resolved predictions of the interactions of neutrons with the detector material. A subsequent postprocessing of the simulation results allows us to determine the number of elastic collisions with hydrogen and carbon that the neutrons undergo, together with the amount of energy that is deposited as a function of the number of collisions. The light output generated by the hydrogen and carbon recoils is also modeled, and the total detector efficiency is determined as a function of the incident neutron energy. When the neutron energy is above 4.4 MeV, inelastic scattering on carbon can occur, and subsequent gamma rays can be generated. This effect is taken into account and its contributions to the light output are discussed.

An analytical model is developed to describe the amplitude probability distribution of the light output generated in the scintillator for a monoenergetic flux of neutrons. This model takes into account the multiple collisions and the conversion to light pulses of the deposited energy per collision. The analytical model can be solved quantitatively by numerical quadrature. The possibility of including in the model neutron inelastic scattering and light generation by inelastic gamma rays is also investigated.

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