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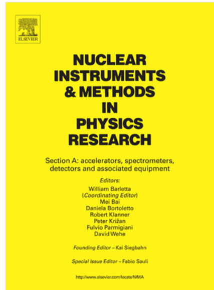

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Material optimisation in dual particle detectors by comparing advanced scintillating materials using two Monte Carlo codes

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Abstract

A new generation of scintillating materials have been recently developed in the radiation-imaging field offering very promising dual particle detection abilities. Here, four different scintillating materials (Cs_2LiYCl_6:Ce (CLYC), 95% ^{6}Li enriched Cs_2LiYCl_6:Ce (CLYC-6), natural Li-glass scintillator (GS10) and liquid scintillator EJ-309) have been characterized for their abilities to attenuate thermal neutrons, fast neutrons and gamma-rays. Recent studies regarding these materials overlook these fundamental characteristics, which can directly affect the design process of advanced imaging systems such as Compton cameras and dual particle imaging systems. The response of each featured material to these three types of radiation fields was simulated with two different Monte Carlo codes, MCNP6 and Geant4. The results indicated that among these four materials, natural Li-glass scintillator (GS10) has the highest thermal neutron detection efficiency and the highest elastic scattering efficiencies. However, the attenuation of fast neutrons was found to be the most severe in EJ-309 liquid scintillator. When gamma-rays are considered, it was found that the mass attenuation coefficient of CLYC and CLYC-6 is the highest of the four materials considered when energies lower than 1 MeV are incident. It is intended that this work will lead to the design and the build of an advanced prototype three stage Compton Camera which will be sensitive to both neutrons and Gamma rays.

Key words: Neutron imaging; gamma-ray imaging; MCNP6; Geant4; Cs2LiYCl6:Ce (CLYC), 95% ^{6}Li enriched Cs2LiYCl6:Ce (CLYC-6), natural Li-glass (GS10) and EJ-309 liquid scintillator.

Areas of Novelty: This work compares and contrasts how four different scintillators from four different families interact with thermal neutrons, fast neutrons and gamma-ray using two different simulations toolkits, MCNP6 and Geant4. The work characterizes the materials in terms of their ability to interact favorably with neutrons and gamma-rays.

1. Introduction

Accurate localization and characterization of radiation sources is essential in many fields including border security, nuclear security, counter-terrorism, medical imaging as well as within nuclear site decommissioning. There are a number of materials and detectors used in localizing and characterizing radiation sources that emit single mode radiation fields [1-3]. However, the real challenge in radiation detection research field is the development of an optimal detecting material that is capable of detecting both highly penetrating neutrons and gamma-rays.

In the last two decades, the search for high performance scintillators has led to the discovery of new scintillating materials [3, 4], some of which are sensitive to both neutrons and gamma-rays. Examples are Elpasolite scintillators [5-10], lithium based glass scintillators [11-16], some classes of liquid scintillators [11, 17-19] and plastic scintillators [20, 21]. An interesting example from the Elpasolite family is the Cs_2LiYCl_6:Ce (CLYC) scintillator, considered to be one of the most promising inorganic scintillators with an excellent energy resolution of less than 5% at 662 keV [4, 22]. The light yield photons of CLYC (with a Ce dopant concentration of 0.1%) is estimated to be 20,000 photons/MeV for gamma-rays and 70,000 photons/n for thermal neutrons. In addition, the crystal is sensitive to both thermal and fast neutrons [4, 23, 24]. Enriching the crystal with the ^{6}Li isotope can tone the sensitivity of the detector towards thermal neutrons. 95% ^{6}Li enriched CLYC is commonly known as CLYC-6 [6, 25]. Within CLYC, thermal neutron detection is mainly due to ^{6}Li(n,t)α interactions (thermal neutron $\sigma_{capture}$~940barns, Q~4.8 MeV, negligible gamma emission). Fast neutrons mainly interact through elastic and inelastic scattering although capture reactions are possible as well via the ^{35}Cl(n,p)^{35}S and ^{35}Cl(n,α)^{35}P reactions. Interaction of gamma-rays in CLYC crystals results in a unique Core to Valence