Neutron Shielding Properties of EuB_6 Europium based complexes - GEANT4 Simulations

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Introduction

Neutron shielding is essential for safety in nuclear reactors, medical facilities, and particle accelerators. Europium hexaboride (EuB_6) stands out as a strong candidate for neutron shielding due to its unique composition of europium and boron. Europium, especially the isotope ^{151}Eu, has a high ability to capture neutrons, with a thermal neutron absorption cross-section of around 9051 barns [1]. Boron, known for absorbing thermal neutrons efficiently, adds to EuB_6's shielding power with its cross-section of about 749 barns [2]. These properties make EuB_6 highly effective across a wide energy range. Additionally, its high density, thermal stability, and chemical inertness make it durable and reliable in challenging environments. This study uses simulations to explore how well EuB_6 absorbs neutrons from an AmBe source and evaluates its effectiveness by varying its thickness. The results aim to show its potential as both a shielding material and a neutron moderator.

Methods

In order to assess the neutron shielding capability of the EuB_6 material, the Geant4.10.03 toolkit was utilized. The density of the EuB_6 material was set to 4.91 g/cm^3 using the "G4MaterialDefinition" class available in Geant4. The simulation setup involved placing an unmoderated AmBe source at the center of a spherical geometry composed of EuB_6 material. The AmBe source was declared as an Energy-based histogram in the input file using the "General Particle Source" (GPS) feature of Geant4, allowing for the isotropic emission of neutrons. The spherical geometry enabled the investigation of neutron attenuation by EuB_6 as a function of material thickness. By varying the thickness of the EuB_6 material, the effectiveness of neutron absorption was assessed. Neutrons emitted from the outer surface of the spherical EuB_6 geometry were scored to determine the neutron absorption efficiency of the material. Geant4 simulations were conducted with varying thicknesses of the EuB_6 material to comprehensively evaluate its neutron shielding capabilities.

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Results and Discussion

The absorption efficiency of EuB_6 was calculated by comparing the incident neutron flux with the emitting neutron flux, expressed as a percentage. It was observed that as the thickness of the EuB_6 material increased, the absorption efficiency also increased. This trend is depicted in Figure 1 , where it can be seen that the absorption efficiency reaches its peak at approximately 100 cm, achieving a value of around 98.5%. The high value of the R-square coefficient (0.99) indicates a strong correlation between material thickness and absorption efficiency, validating the observed trend. Furthermore, the variation of the thermal neutron spectrum for various thicknesses of the EuB_6 material was studied as shown in Figure 2 . It was observed that at approximately 30 cm, the thermal neutron flux reaches its maximum, suggesting optimal moderation effects at this thickness. However, beyond this point, the thermal neutron flux starts to decrease, indicating a diminishing moderation capability of the material. Prior to 6 cm, the shielding capability of EuB_6 is no longer effectively retained, as evidenced by the declining thermal neutron flux. These results

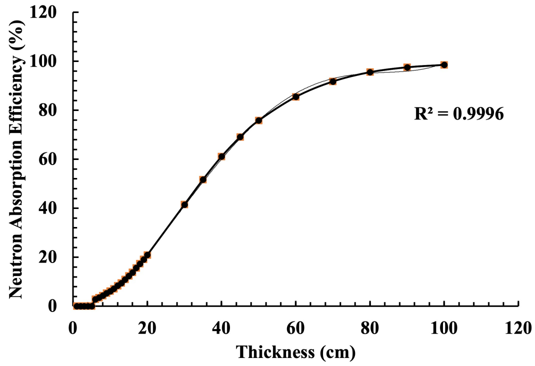

FIG. 1: Neutron Absorption Efficiency vs Thickness(cm) for EuB_6 shield

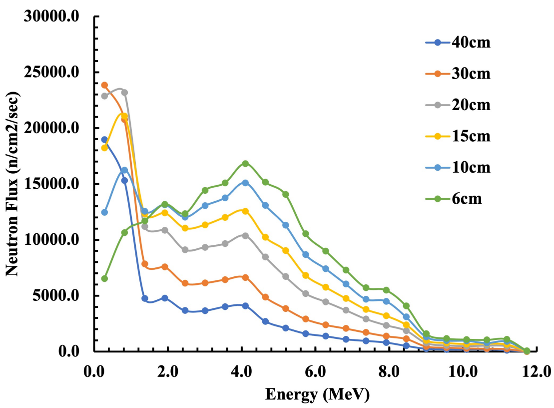

FIG. 2: Neutron energy spectrum for various thickness of EuB_6 shield

underscore the importance of optimizing the thickness of EuB_6 for neutron shielding applications. While thicker layers exhibit higher absorption efficiency, there is a trade-off between absorption and moderation capabilities. The observed trends provide valuable insights for the design and optimization of EuB_6-based neutron shielding systems, aiming to maximize protection while minimizing material usage and associated costs. Further experimental validation of these findings would enhance confidence in the suitability of EuB_6 for practical neutron shielding applications.

Conclusion

This study used Geant4 simulations to explore the neutron shielding and moderation abilities of EuB_6. The results showed that as the material thickness increased, so did its neutron absorption, peaking at 98.5% efficiency at around 100 cm. The strong correlation between thickness and absorption ($R^2 = 0.99$) highlights its effectiveness. The study also found that thermal neutron flux was highest at 30 cm, indicating optimal moderation at this point, but declined beyond that, suggesting reduced moderation. Thicknesses below 6 cm were ineffective for shielding. These findings demonstrate EuB_6's potential as a neutron shielding material, combining both absorption and moderation properties. Further experimental work will help confirm its practical use in nuclear environments, contributing to improved radiation protection and safety strategies.

References

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