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Analysis of Neutron-Induced Gamma-ray Background for BNCT Dose Evaluation System Using a LaBr3 Detector/$LaBr_3$ 検出器を用いた BNCT 線量評価システムの中性子誘起ガンマ線バックグラウンドの解析

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Currently, several approaches have been investigated for dose evaluation in the boron neutron capture therapy (BNCT). (1) In clinical practice, the absorbed dose is typically evaluated using the gold wire activation technique combined with pre-treatment PET scans, which provide both the neutron flux and boron concentration. (2) Another approach introduces MRI-sensitive structures, such as Gd-containing compounds, into boron agents, allowing boron concentration to be inferred from MRI [1]. (3) A more direct method, known as PG-SPECT (Prompt Gamma SPECT) [2], detects the 478 keV prompt gamma rays emitted from the ^{10}B(n, α)^{7}Li reaction, thereby estimating the actual reaction rate and corresponding dose. The advantage of PG-SPECT is that it eliminates the need for gold wire activation measurement, providing a direct and online assessment of the treatment dose.

In our previous studies, PG-SPECT has faced several challenges. One major issue is the large neutron-induced gamma-ray background. Because the neutron fluence in BNCT experiments in the lab system can reach the order of 10^9 n/cm^2/s, extensive neutron interactions occur within the detection system, producing a substantial and complex gamma-ray background that interferes with the measurement of the 478 keV gamma-ray signal. Our previous findings suggest that these secondary gamma rays are mainly generated by neutron interactions within the material inside the PMT. Therefore, in this study, we employ PHITS simulations to investigate and validate this hypothesis.

Another challenge lies in the trade-off between lightweight system design and background shielding. Conventional clinical SPECT systems typically detect the 140 keV gamma rays emitted by ^{99m}Tc, requiring only a few millimeters of lead shielding. In contrast, PG-SPECT must detect 478 keV prompt gamma rays, which necessitates significantly thicker shielding layers. This results in increased system volume and weight, making compact and clinically practical designs more difficult. Therefore, an optimal balance must be achieved between shielding performance and mechanical lightweighting.

In this study, PHITS simulations are conducted to clarify the origin of neutron-induced gamma-ray background and to explore optimized shielding and collimator configurations that reduce these backgrounds while minimizing overall system weight. This work aims to support the development of a clinically feasible PG-SPECT system for BNCT dose monitoring.

References:

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