Monte Carlo simulations of target and moderator for accelerator-based boron neutron capture therapy

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1. Introduction

Boron neutron capture therapy (BNCT) is binary radiation treatment modality. It treats tumor cell using ^{10}B compound and neutron beam. The ^{10}B nuclei which have high neutron capture cross-section, release α particle and ^{7}Li ion in $^{10}B(n, \alpha)^{7}Li$ reaction. These products have high linear energy transfer characteristics and their ranges are around single cell diameter (~10 μm). Therefore, BNCT can selectively treat the tumor cell by the targeted boron drug delivery [1]. In the South Korea, accelerator-based BNCT (A-BNCT) facility is under construction aiming to make epithermal neutron source. A-BNCT has advantages over reactor based BNCT, i.e. comfortable accessibility, cheap maintenance costs, simple operation and neutron beam characteristics [2].

The primary objective of this study was to characterize the neutron beam from the newly designed beryllium target and moderator assembly. We calculated the neutron energy spectrum, radial flux and directionality using Monte Carlo simulations.

2. Materials and Methods

2.1 Target and moderator design

The target and moderator assembly (Figure 1) were fully designed by Pohang Accelerator Laboratory, PAL. The target is composed of beryllium, palladium and copper and is around 3 mm thick. The various materials of moderator, beam shaper, collimator and shielding are also marked on the Figure 1.

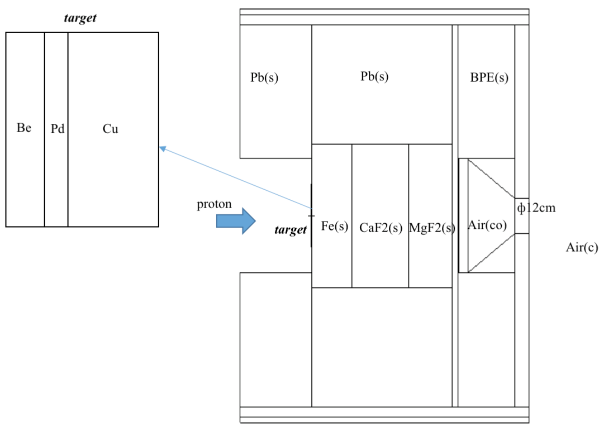

Fig. 1. The target and moderator assembly (designed by PAL).

2.2 Monte Carlo Simulations

Monte Carlo simulations are done using Geant4 version 10.3 [3]. The entire assembly geometry was imported to Geant4 geometry. We used physics list named "QGSP_BIC_AllHP" which uses evaluated nuclear data sets from TENDL-2014 and ENDF/B-VII.1 for the precise simulations of neutron and proton.

The incident proton beam to the beryllium target was assumed as uniform field (13 x 13 cm^2) and mono-energy (10 MeV). All neutrons that passed through the moderator and filter were collected.

3. Results

3.1 Neutron beam characteristics

The neutrons are produced by $^{9}Be(p, n)$, nuclear reaction. Then, they pass through the moderator and filter before they collected. Figure 2 shows the neutron beam spectrum. Over 85% of neutrons are in the epithermal range. Figure 3 shows the radial flux at the aperture whose final radius is 6 cm. The flux also steeply decreased after 6 cm apart. Figure 4 shows the angular distribution of the neutron beam. The directionality is defined as the ratio of beam direction to forward direction, which means the closer to unity the more forwarded beam. The beam directionality was calculated to be 0.86 which means almost forward direction.

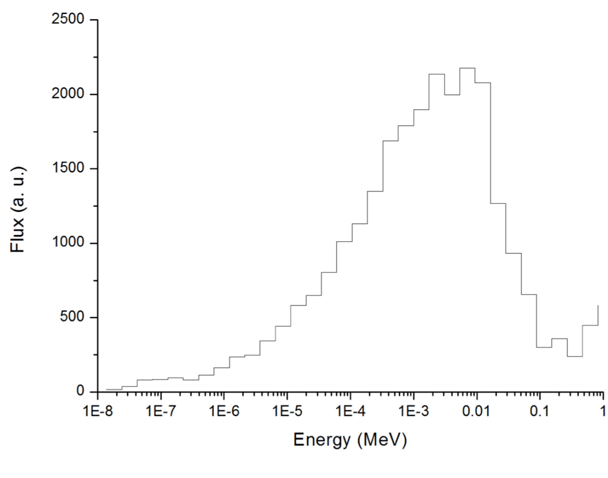

Fig. 2. The energy spectrum of neutron beam

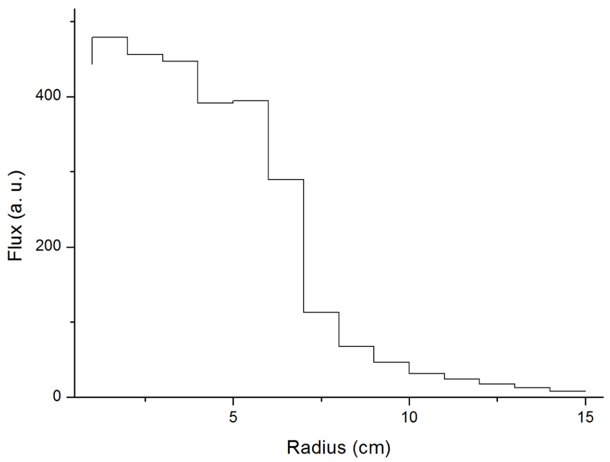

Fig. 3. The radial flux of neutron beam

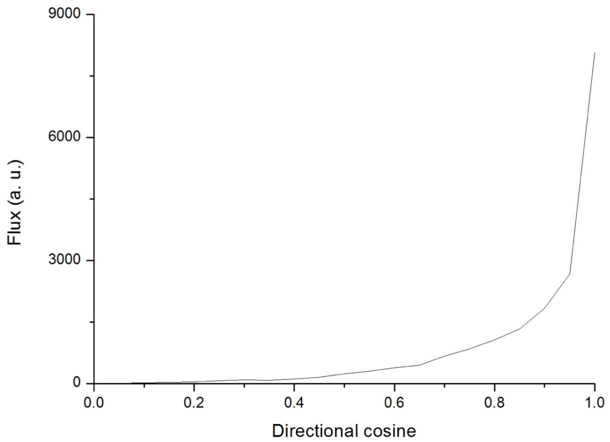

Fig. 4. The angular distribution of neutron beam

4. Conclusions

Better therapeutic effects could be achieved by precise neutron dosimetry. The calculated neutron beam data from this study is the first step of getting better therapeutic effects. These data could be used for not only in the treatment planning system but also in the clinical research area in the near future.

5. Acknowledgements

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