Evaluation of a Neutron Beam Generation Facility for the Accelerator-Based BNCT

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1. Introduction

The important things in designing facilities for BNCT are to obtain neutron beams with appropriate energy spectrum and intensity for efficient treatment. In recent years, at several universities, accelerator-based BNCT facilities were designed, which are composed of target and beam shaping assembly to generate epithermal neutron beams[1].

As a previous study, target system[2][3] and a beam shaping assembly design[4] with good neutron beam quality and high intensity for BNCT have been researched in Hanyang University. Neutrons are generated from the lithium target through $^{7}Li(p,n)^{7}Be$ reaction, and moderated to suitable energy spectrum for BNCT.

In this study, to evaluate the beam shaping assembly which has been manufactured, neutron spectrum from the lithium target system and beam shaping assembly was measured with He-3 counter, and the results are compared with those from MCNPX.

2. Methods and Materials

Beam shaping assembly as shown in Figure 1 is composed with three moderators surrounded by reflector. First and secondary moderators are composed of AlF_3 whose density is 2.78 g/cm^3. Added moderator and reflector are respectively made from aluminum (ρ=2.78 g/cm^3) and graphite (ρ=1.85 g/cm^3).

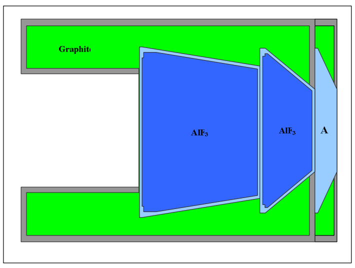

Fig. 1 The Beam Shaping Assembly

A proton beam from MC-50 cyclotron was used to evaluate neutron beams in KIRAMS (Korea Institute of Radiological and Medical Sciences). Experiments are carried out for measuring a background signal and neutrons from the lithium target system.

Average energy of proton beam was 18.3 MeV and experiment environment was shown in Figure 2. Since neutron beams with acceptable energy spectrum are generated from the proton energy of 2.5 MeV, 0.61 mm aluminum was set just in front of the lithium target to degrade the proton beam energy to 2.5 MeV. Beam current used in this experiment was 20 nA whose uncertainty is about 10%, and 3 cm of beam diameter was used. Proton beam was irradiated in order to induce sufficient number of neutrons for 1200 seconds.

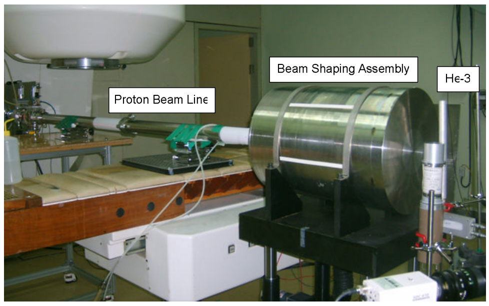

Fig. 2 Configuration of BNCT Experiment

A He-3 proportional counter was located at 8 cm away from the beam shaping assembly to measure a neutron beam. This detector is widely used as a neutron spectrometer for low energy neutrons up to 1 MeV.

The BNCT experiment was simulated with MCNPX [5] by modeling the lithium target system, beam shaping assembly, and He-3 proportional counter as shown in Figure 3. Neutron energy spectrum was calculated using pulse height tally (F8 tally).

The results were compared with experimental pulse height spectrum normalized within 1 MeV.

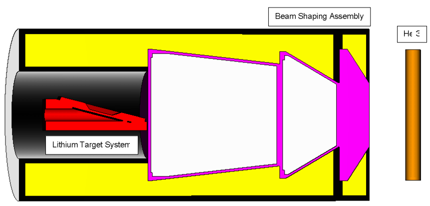

Fig. 3 MCNPX Modeling for Neutron Beam Facility and He-3 Counter

3. Results and Discussions

Figure 4 shows the compared results between experiment and calculation. Experimental neutron pulse spectrum is agreed well with the calculation result in the energy ranges from 200 keV to 1 MeV. However, some discrepancies in the compared results were found in the energy range below 200 keV which is the most important energy range for BNCT, especially near 40keV. These discrepancies seem to be occurred by two major reasons. First, proton beam current was continually fluctuated during experiment. Second, since neutron yield through (p,n) reaction is so low that various variance reduction techniques were employed in the simulation, which might cause the results biased.

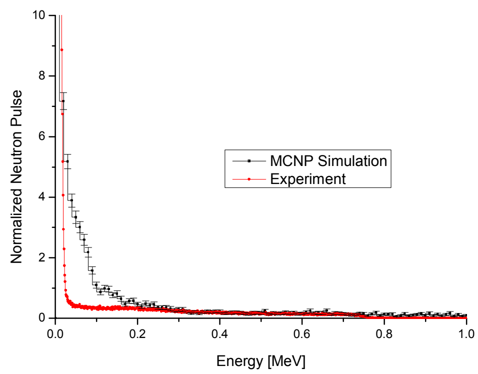

Fig. 4 The Comparison of the Experiment and Simulation

4. Conclusions

An evaluation of a neutron beam generation facility was made experimentally and theoretically for accelerated-BNCT. The experimental results are not matched with the calculated results by MCNPX in the important energy regions for BNCT, while in other energy range, those are comparatively well matched.

It seems to be caused by the fact that the experiment condition was not stable due to the fluctuating current of proton beam, use of aluminum degrader which disperses the proton beam, and so on.

It is needed to carry out an additional experiment using 2.5 MeV mono energy of proton beam with stable beam current. In addition, a technique for accurate calculation of neutron spectrum by MCNP should be devised in this kind of problem which involves low neutron yield.

Acknowledgement

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