Measurement of Neutron Spectrum and Yield for the Lithium Target System in Accelerator-Based BNCT

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1. Introduction

^{7}Li(p,n)^{7}Be reaction is prevalently used as a neutron source for accelerator-based BNCT. This reaction allows users to get epithermal neutron beams for BNCT with less moderation than those of higher energy produced other reactions such as ^{9}Be(p,n)^{9}B, ^{9}Be(d,n)^{10}C, and ^{13}C(d,n)^{14}O. While ^{7}Li(p,n)^{7}Be reaction is neutronically excellent in BNCT, the melting point of pure lithium metal is very low (181 °C) and its thermal conductivity is also poor (85 W/m-K at 300 K).

To overcome these defects, university of Birmingham, BINP(Budker Institute of Nuclear Physics), and LANL(Lawrence Berkeley National Laboratory), and so on, have developed each original cooling system of lithium target.

In the previous study [1], a lithium target system had been designed to be maintained up to 1 mA proton beam. In this study, the lithium target system was fabricated and spectrum and yield of neutrons produced from the lithium target system were investigated experimentally, and compared with the result of simulation using MCNPX code.

2. Experiment and Simulation

2.1 Lithium Target System

Figure 1 shows the design of the lithium target system. To reduce the heat flux generated from the ^{7}Li(p,n)^{7}Be reaction within the permitted limit, the proton beam spot size on the target should be expanded up to a few centimeters in diameter. The lithium target was tilted with the normal direction of its surface meeting the incident direction of proton beam at the angle of 70 degree. To efficiently remove heat generated from the ^{7}Li(p,n)^{7}Be reaction, the copper backing between lithium and coolant channel was employed and then the coolant channel was laid to be in direct contact with the copper backing. Finally, it was predicted that the maximum temperature of the lithium target system for 1 mA proton beam was only about 50 °C.

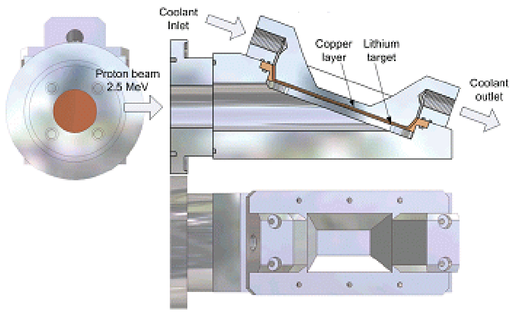


Figure 1. Lithium Target System

2.2 Proton Beam

MC50 cyclotron in KIRAMS(Korea Institute of Radiological and Medical Sciences) was used for the proton beam. In the experiment, the average proton beam energy was 18.3 MeV, the beam current was 0.36 nA (beam current uncertainty was 12.3%), and beam diameter was about 8 mm. The exposure time was 600 seconds.

To obtain average 2.5 MeV proton beam, a 0.61 mm thick aluminum degrader was put on the lithium target and 18.3 MeV proton beam from MC50 was retarded by the aluminum degrader. The thickness of aluminum degrader was decided by ion transport code, SRIM (Stopping and Range of Ions in Matter).

2.3 Measurement

Figure 2 shows the equipments used in this experiment to measure the neutron source. A He-3 counter, that has shown good efficiency in detecting low energy neutron up to 1 MeV, was used to obtain neutron spectrum and yield produced from the lithium target. The absolute efficiency of the He-3 counter is 0.0054. The neutron spectrum of lithium target was indirectly measured through ^{3}He(n,p)^{3}H reaction within the He-3 counter.

In case of neutron yield measurement, a polyethylene block was additionally laid between the lithium target hydrogen having large scattering cross section for neutron, so that neutrons moderated by polyethylene have energies (< 1 MeV) adequate to be detected by the He-3 counter and then detecting efficiency is increased.

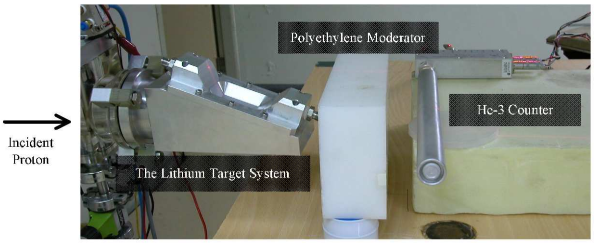


Figure 2. Experiment for Measurement of Neutron Source

2.4 MCNPX Simulation

For simulation of the neutron spectrum measurement using the He-3 counter, the same experimental environment, including the He-3 counter, was modeled using MCNPX, as shown in Figure 3.

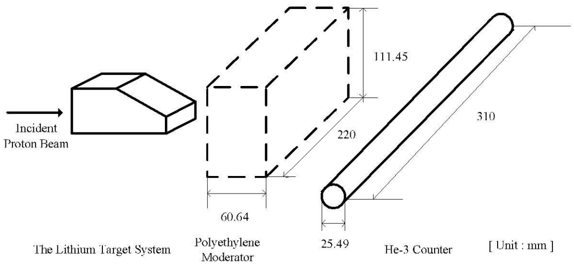


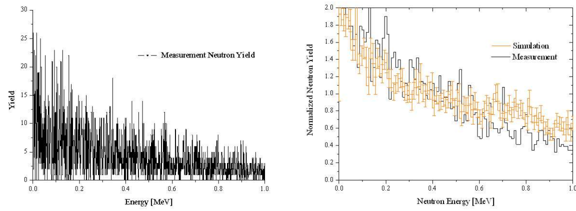
Figure 3. MCNPX Modeling of Experiment for Neutron Yield Measurement

3. Result and Discussion

3.1 Neutron Spectrum

Figure 4-(a) shows the pulse height spectrum in the He-3 counter by neutrons produced from the lithium target system. The neutron spectrum due to only the lithium target was obtained by removing background neutrons produced from other target structure materials (e.g., neutrons produced by incident proton in aluminum degrader) except the lithium target.

As considering the detecting efficiency of He-3 counter, the experimental result of neutron spectrum was presented only for pulses less than 1 MeV and normalized to compare with the MCNPX calculation result as shown in Figure 4-(b). It is shown that the neutron spectrum calculated by MCNPX has a good agreement with the measured neutron spectrum.



(a) Measured (b) Measured and Calculated

Figure 4. Comparison of Neutron Spectrum

3.2 Neutron Yield

Table 1 shows neutron yield from the lithium target system. The measured neutron yield is $9.3\pm1.1\times10^5$ [n/mA]. This result is a little higher than the theoretical neutron yield [2].

Table 1. Comparison of Neutron Yield

	Theoretical	Measured
Neutron Yield [n/mA]	9.0×10^5	$9.3\pm1.1\times10^5$

4. Conclusions

The lithium target system endurable against 1mA proton beam was fabricated firstly in Korea for accelerator-based BNCT. The neutron spectrum and yield from the target were also measured experimentally using MC50 cyclotron in KIRAMS. The experimental results validated the MCNPX calculation and the theoretical calculation results.

In the next step, a prototype of the lithium target system will be designed in detail and fabricated for the purpose of the link with an epithermal neutron beam assembly [2].

Acknowledgement

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References

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