Transactions of the Korean Nuclear Society Spring Meeting
Taebaek, Korea, May 26-27, 2011

Monte Carlo Simulation on Proton-Induced Fast Neutron Source

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1. Introduction

PEFP (Proton Engineering Frontier Project) has developed a 100 MeV / 20 mA proton linear accelerator, proton beam utilization technology and accelerator applications, in order to acquire core technologies which are essential to develop future science and secure the industrial competitiveness. In the experimental hall, 10 target rooms will be constructed and the target room, TR105, will be utilized for thermal or fast neutron source for material irradiation (Fig. 1).

In order to verify optimum condition for fast neutrons, we performed the Monte Carlo N-particle Transport X (MCNPX) code [1] simulation that proton beam bombarded at target materials of lithium, beryllium, and tungsten to generate fast neutrons by (p, n) reaction. As the results, we calculated neutron energy and yield for various incident proton energy and thickness of target.

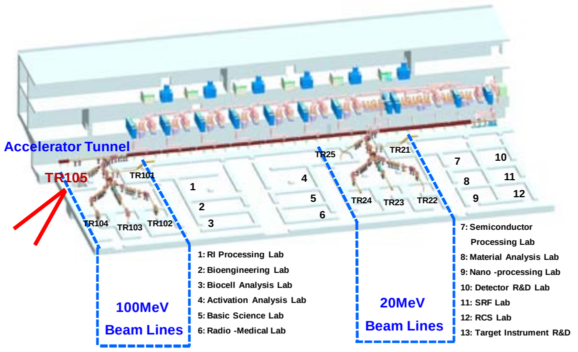

Fig. 1, Layout of accelerator tunnel & experimental hall.

2. Methods and Results

The PEFP's linear accelerator will provide a current of 20 mA, repetition rate of 1 Hz, pulse width of 50 usec, and 20/100 MeV proton beam. In worldwide, many groups are already investigating a neutron source using spallation process or nuclear reactions between several tens of MeV protons and heavy materials such as lead, tungsten and tantalum [2,3], and a sufficient neutron yield obtained. PEFP's 20 mA proton beam could obtain a sufficient neutron yield comparing with other accelerator-based neutron sources.

In order to select a suitable target material, it is important to consider the characteristics such as neutron yield, neutron energy, thermal properties and the activation on proton irradiation in terms of the maintenance of a target. The neutron yield and neutron energy were calculated by MCNPX v. 2.5, and the geometry (fig. 2) is simple because of basic research of fast neutron source. Table I shows the characteristics and nuclear cross-section data of lithium, beryllium, and tungsten as target materials [4]. The cross-section data of LA150 are based on ENDF/B-VI and provided the proton energy range within 100MeV but cross-section data of some nuclides are missing [5].

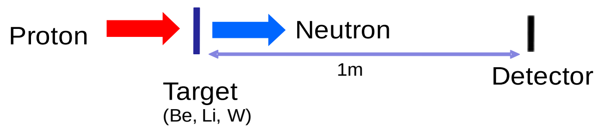

Fig. 2, Geometry for calculation.

Table I, Characteristic of Li, Be, and W

	Melting pt.(°C)	Boiling pt.(°C)	Density	XS data
Li	181	1342	0.53	La150
Be	1278	2470	1.85	ENDF/B-VII
W	3410	5660	19.3	ENDF/B-VII

2.1. 20 MeV Proton Beam

Fig. 3 shows the results of 20 MeV proton beam bombardment at a beryllium, and lithium target. In the result of a lithium target, neutron intensity was almost constant when thickness of a lithium target was increased. In case of a beryllium target, optimum target thickness is about 3 mm when 20 MeV proton beam bombard. Calculated neutron yields of beryllium and lithium target were about 4.0×10^{13} n/mA/sec and 2.0×10^{13} n/mA/sec, respectively.

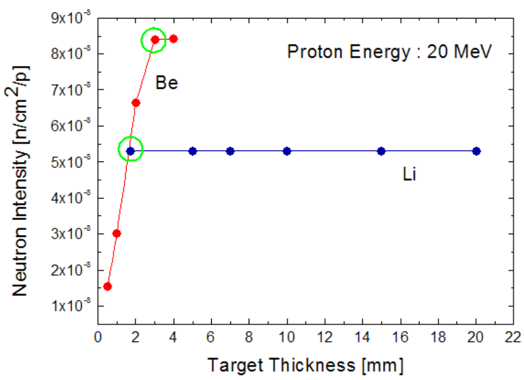

Fig. 3, Neutron intensity of lithium and beryllium target with 20 MeV proton beam.

2.2. 100 MeV Proton Beam

When 100 MeV proton beam bombarded at lithium and tungsten target, maximum neutron yield of a lithium target is about 1.20×10^{15} n/mA/sec with a peak in the neutron energy range of 0.7~0.9 MeV. In case of tungsten target, we calculated just few case and its maximum neutron yield is about 1.50×10^{15} n/mA/sec for 4 mm thickness of tungsten.

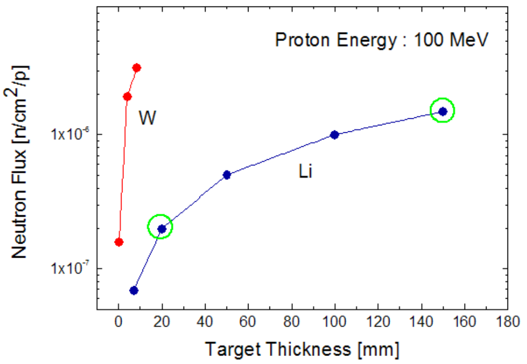

Fig. 4, Neutron intensity of lithium and tungsten targets with 100MeV proton beam.

2.3. Fast neutron with variable proton energy and target thickness

Table II shows the parameters of incident proton energy, and thickness of a lithium target. The ion range and the thickness of ΔE=2MeV are calculated by SRIM and TRIM code [6]. In this simulation, target thickness was set the thickness at ΔE=2MeV for all the incident proton energy because the Q-value of (p, n) is about 2 MeV [7].

Table II, Parameters of

Proton Energy [MeV]	Ion Range [mm]	Target Thickness @ ΔE=2 MeV	Peak Neutron Energy [MeV]
20	9.5	1.7	13.09
33	23.6	2.6	24.51
45	41.4	3.4	35.05
57	63.6	4.0	46.97
69	89.8	4.7	59.23
80	117.1	5.3	71.82

Fig. 5 shows that peak neutron energy is linearly increased with incident proton beam energy. The neutron fluence is increased then maximized at proton energy of 80 MeV with about 1.0×10^{13} n/mA/sec.

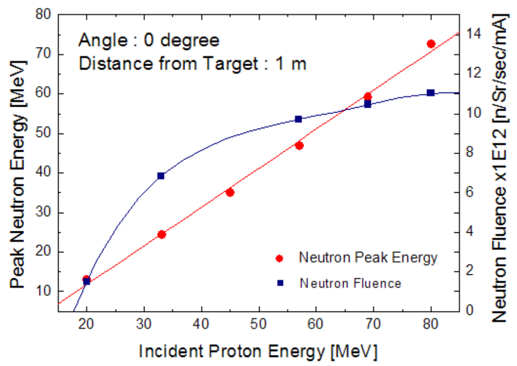

Fig. 5, Peak neutron energy and fluence when proton bombarded at lithium target.

4. Conclusion

In this article, we presented basic study of neutron source. By means of Monte Carlo simulations the target thickness of lithium and beryllium have been optimized for the high energy neutrons emitted from the (p,n) reaction with a 20/100 MeV proton beam. The target materials, that we investigated, are well known for neutron source, and we need to study other material for neutron source.

5. Acknowledgement

This work was conducted as a part of the Proton Engineering Frontier Project supported by the Ministry of Education Science & Technology of Korea Government.

REFERENCES

[1] D.B. Pelowitz, MCNPX user’s manual—version 2.5.0. Los Alamos National Laboratory Report LA-CP-05-0369., 2005.

[2] S. Yonai, T. Aoki, T. Nakamura, H. Yashima, M. Baba, H. Yokobori, Y. Tahara, Feasibility study on epithermal neutron field for cyclotron-based boron neutron capture therapy, Medical Physics, Vol. 30 (8), p. 2021, 2003.

[3] Y. Tahara, Y. Oda, T. Shiraki, T. Tsutsui, H. Yokobori, S. Yonai, M. Baba, T. Nakamura, Engineering design of a spallation reaction-based neutron generator for boron neutron capture therapy, Journal of Nuclear Science and Technology, Vol. 43 (1), p. 9, 2006.

[4] H. Tanaka, Y. Sakurai, M. Suzuki, T. Takata, S. Masunaga, Y. Kinashi, G. Kashino, Y. Liu, T. Mitsumoto, S. Yajima, H. Tsutsui, M. Takada, A. Maruhashi, K. Ono, Improvement of dose distribution in phantom by using epithermal neutron source based on the Be(p,n) reaction using a 30MeV proton cyclotron accelerator, Applied Radiation and Isotopes, Vol. 67, p. s258, 2009.

[5] H. Tanaka, Y. Sakurai, M. Suzuki, S. Masunag, Y. Kinashi, G. Kashino, Y. Liu, T. Mitsumoto, S. Yajima, H. Tsutsui, A. Maruhashi, K. Ono, Characteristics comparison between a cyclotron-based neutron source and KUR-HWNIF for boron neutron capture therapy, Nuclear Instruments and Methods in Physics Research B, Vol. 267, (2009) 1970−1977

[6] James F. Ziegler, SRIM 2003, 2003, [Online available]; http://www.srim.org/.

[7] Q-value Calculator, Brookhaven National Laboratory, [Online]; http://nndc.bnl.gov/.