Study of Neutron Flux Source Variation for Boron Neutron Capture Therapy (BNCT) Using Proton Accelerator

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Abstract. One of the deadly diseases is a cancer disease. Many ways to cure cancer are surgery or radiotherapy, and a combination of them. One treatment or cure for cancer is by radiotherapy a BNCT (Boron Neutron Capture Therapy). BNCT is harnessing beams of neutrons to be captured by Boron particles to produce lithium and alpha rays, that kill cancer cells. Viewing the vital function of the neutron beam, in this study we will compare the neutron energy and flux generated by the target materials as a result of shooting a beam of protons to the target material. The target materials consisting of beryllium, Tantalum, and Tungsten was used to produce beams of neutrons with the provisions of the parameters of the IAEA (International atomic Agency). By harnessing Monte Carlo MCNPX code, it can be seen that beams of neutrons that are generated from these three materials.

INTRODUCTION

Ideal therapy for cancer is by destroying cancer cells without destroying normal tissues around. Most of the cancer cells should be destroyed through the therapy and with the aid of immune system [1]. Otherwise, a potential tumor is formed by itself to be greater. Even through standard therapy treatment like surgery, radiation, and chemotherapy have been successful to cure various cancer diseases, however, there are still some failures [2]. Recently, cancer therapy which is more promising and is continuously developed by scientists is BNCT method [3].

BNCT is an innovative cancer treatment process without doing manual surgery and suppress pain that provides minimal side effects. BNCT is simply interpreted to destroys only cancer cells by using alpha particles as a result of the reaction of boron – neutron [6].

$$^{10}B + n \rightarrow {}^{7}Li + {}^{4}He \quad (1)$$

The nuclear reaction of boron element with neutron produced lithium and alpha rays which were He^4 particles that will kill cancer cells [9].

Boron as instead of metal is a key element in the IIIA in the periodical table, that has two materials stable isotopes, namely ^{11}B and ^{10}B, which are both relatively abundant in nature, so it is convenient to be used as neutron capture. By radiating boron with neutrons, alpha particles that kill cancer cells are generated [4].

In the study of BNCT, neutron tracing in the process of therapy is an important part [8]. Figure 1 shows the sketch of BNCT that is used for cancer therapy.

Mechanism BNCT Therapy [13]

1) Boron injection to a patient with dosimetric dose (a boron-containing drug that selectively accumulates in cancer cells is used).
2) Neutron irradiation (The affected site is irradiated with an energy-adjusted neutron beam)
3) Neutron react with boron (emitted alpha beam and lithium particles destroy cancer cells)
4) Cancer cells are destroyed (these particles only travel a distance of one cell width (about 1O μm), allowing for cell-level treatment).

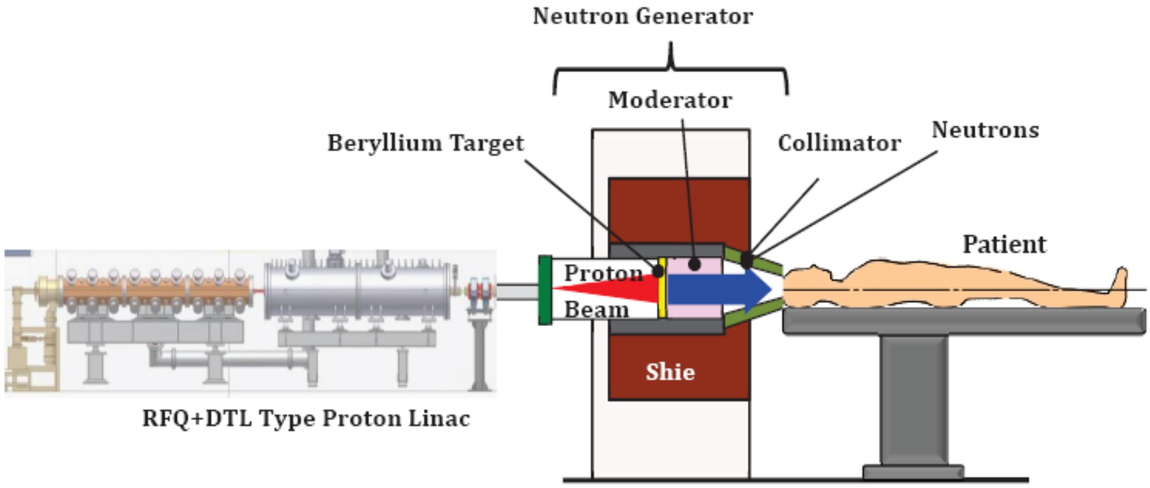

FIGURE 1. BNCT diagram and sketch of its usage [9]

Target position that will produce neutrons is in a neutron generator, which specifically shown in Figure 2.

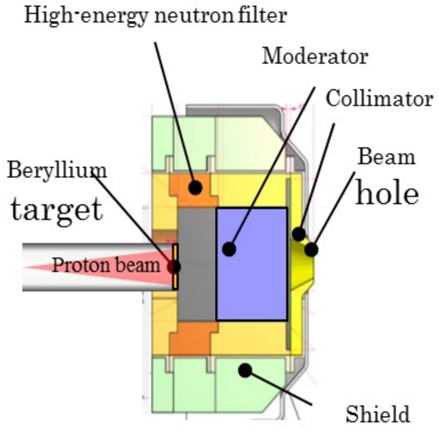

Figure 2. Material Target Position [11]

The material targets that was used to generate neutrons were Be, W, and Ta. The neutrons energy generated by these three targets were compared and then these neutrons were used to radiate boron to lead nuclear reaction so that produced alpha particles.

RESEARCH METHOD

Figure 2 shows the neutron generator scheme with material target of Be, W, Ta whose its properties are listed in Table 1.

TABLE 1. Material Target properties [12]

Target	**Proton Energy**	**Melting Point**	**Boiling Point**	**Thermal Conductivity**	**Neutron Yield**	**Gamma ray Yield**	**Gamma ray yield**
	(MeV)	**(0C)**	**(0C)**	**(W/m/K)**	**(/s/mA)**	**(/s/mA)**	**per one neutron**
Be	30	1278	2970	201	1.90E+14	3.35E+12	0.02
Ta	30	3017	5458	57.5	1.27E+14	1.18E+14	0.93
W	30	3422	5555	174	9.65E+13	1.35E+14	1.4

By using Montecarlo modeling, the simulation was conducted to study the energy of neutron flux generated from three materials Be, W, and Ta whose its properties were shown in Table 1.

The use of software Monte Carlo with MCNPx version, which is common to use as an approximation calculation of radiation transfer analysis of the materials tested above. Standard units used in MCNPX are as follows: [5]

- The length in centimeters
- Energy Flux in MeV/cm^2
- Density Atom in atoms / barn-cm
- Mass Density in g / cm^3
- Time in Shakes (10^{-8} second)
- The temperature in MeV (kT)
- Looks latitude in barns (10^{-24} cm^2)

DISCUSSION AND RESULT

The result of Montecarlo simulation that was used to simulate the neutrons produced by a generator with the variation of target materials was shown in figure 3-5. Variations target material used there are 3 materials, such as in Table 1. It is passed as the third material is used in several countries that have developed BNCT. Example KURRI Japan, BMMR United States of America, FiR 1 Finland, dan juga HFR Nederland. Proton beam that was produced by cyclotron at a content energy of 30 MeV was used to bombard the target material of Be, W, Ta that is installed in Neutron Generator to produce neutrons [10].

The result of neutron generated from neutron generators is shown in figure 3, 4, and 5. Figure 3 show the Grafik of neutron flux as a function of proton energy for Tungsten.

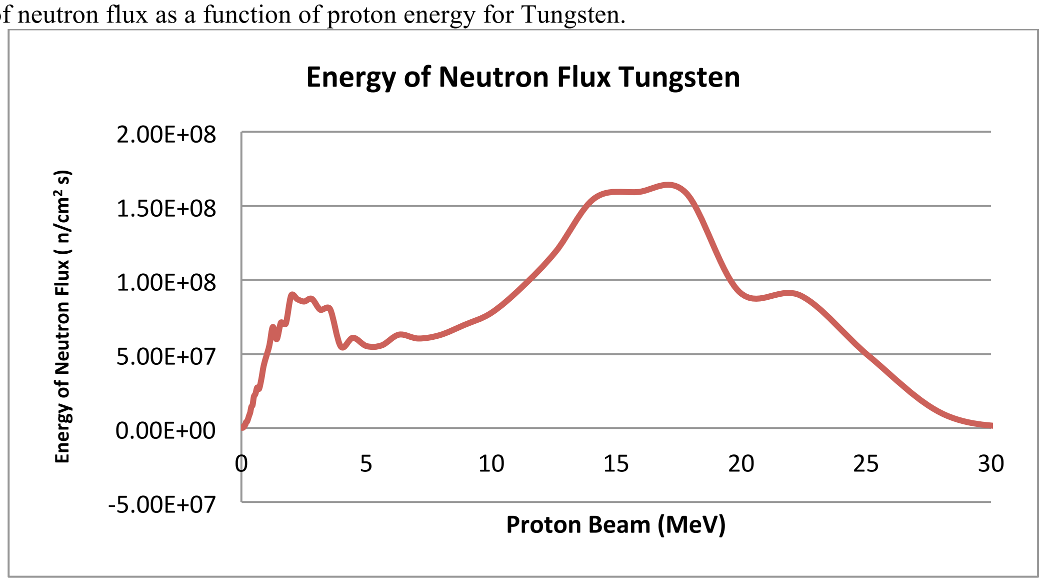

FIGURE 3. Graphic Neutron Flux as a function of proton energy for Tungsten

Tungsten neutron flux reaches the peak at 1,6. 10^8 n/cm^2s. And then Figure 4, show the Grafik of a Neutron Flux as a function proton energy for Tantalum, Neutron Flux reaches a peak at 1,9. 10^8 n/cm^2s. Finally, Figure 5, show the Grafik Neutron Flux as a function proton energy for Beryllium, peak at 1,06. 10^9 n/cm^2s.

The Graphic of neutron flux as a function of proton energy for beryllium target with a thickness of 0,6 cm and diameter of 3 cm is shown in Figure 5. As shown in Figure 5, Chart Beryllium, can be explained beam of protons fired from 0 to 30 MeV, the target material beryllium (Be) with a thickness of 0.6 cm and a diameter of 3 cm. With 0^0 scattering angle neutron generating total Flux Neutron $1,57.10^{10}$ n/cm^2s, which exponentially until exhausted at 30 MeV proton energy sources. Also in Figure 4. The Graphic of neutron flux as a function of proton energy for Tantalum total Neutron Flux $2,99.10^9$ n/cm^2s. Finallay in Figure 3, Graphic of neutron flux as a function of proton energy for Tungsten total Neutron Flux 2,63. 10^9 n/cm^2s. Source spectra analysis from MCNPX with 10^7 nps at proton creation and proton loss is known three material targets Be, Ta, and W.

IAEA that the minimum epithermal neutron beam flux is 10^9 n / cm^2s if using a neutron beam with an intensity a smaller 10^9 n / cm^2s it will take quite a long irradiation.

TABLE 2. Source Spectra Analysis

Material	Subject		Tracks	Weight per Source particle	Energy (MeV) per Source particle
Beryllium (Be)	Proton Creation				
		Nucl. Interaction	33277	3,30E-03	2,52E-02
	Proton Loss				
		escape	9922106	0,99	2,63E+01
		Energy cutoff	60821	0,0061	6,08E-03
		Nucl. Interaction	50679	0,0051	9,92E-02
Tantalum (Ta)	Proton Creation				
		Nucl. Interaction	1290	1,29E-04	1,85E-03
	Proton Loss				
		escape	8562075	0,856	2,55E+01
		Energy cutoff	1427778	0,14278	1,43E-01
		Nucl. Interaction	11770	0,001177	2,61E-02
Tungsten (W)	Proton Creation				
		Nucl. Interaction	1235	1,24E-04	1,81E-03
	Proton Loss				
		escape	8561044	0,8561	2,55E+01
		Energy cutoff	1428863	0,14289	1,43E-01
		Nucl. Interaction	11661	0,001166	2,59E-02

TABLE 3. Parameter IAEA

Facility	$\varphi_{epithermal}$ (10^9 n/cm^{2}s)
IAEA	> 1
Be	1,06
Ta	0,19
W	0,16

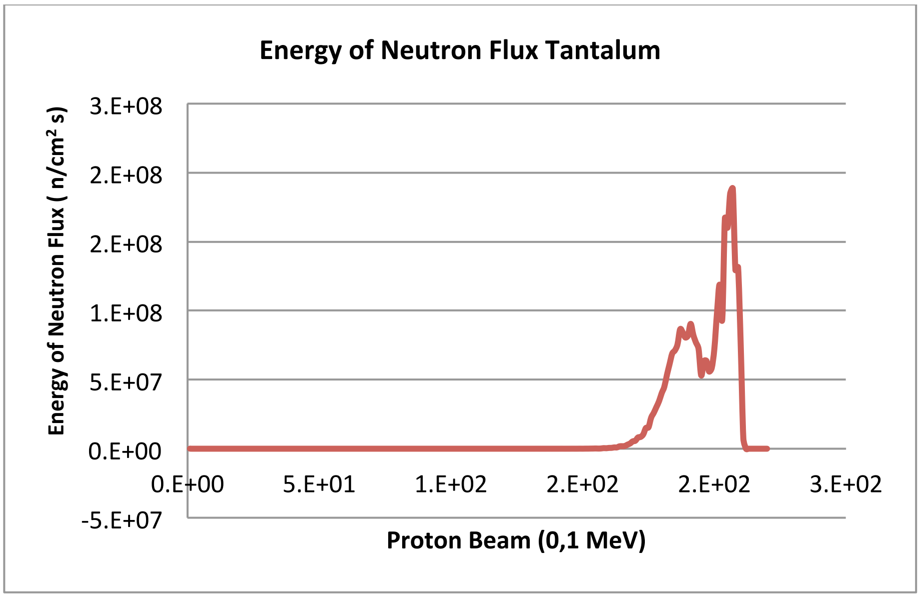

FIGURE 4. Graphic Neutron Flux of as a function of proton energy for Tantalum

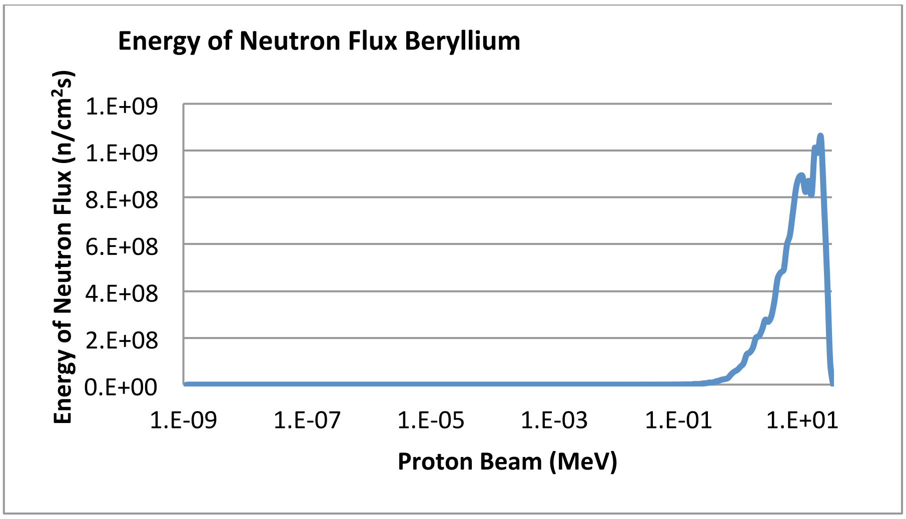

FIGURE 5. Graphic Neutron Flux as a function of proton energy for Berrylium

CONCLUSIONS

Variation of Materials target of BNCT has shown the different in the neutron flux. Beryllium, tungsten, and tantalum are usually used as target materials in Boron Neutron Capture Therapy. Among the target materials, beryllium showed greater for an energy of neutron flux. The energy of neutron flux that is produced by neutron generators depends on the kind of material target.

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