Neutron Chareacterization of BNCT Water Phantom Based on 30 MeV Cyclotron Using PHITS Computational Code

Okti Dyah Rahayuningsih[1*], Susilo[2], Yohannes Sardjono[1,2]

[1]*Department of Physics, Faculty of Mathematics and Siences, State University of Semarang, Semarang 50229, Indonesia*
[2]*Pusat Sains dan Teknologi Akselerator - Badan Tenaga Nuklir Nasional (PSTA-BATAN), Yogyakarta 55281, Indonesia*

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A B S T R A C T

Cancer is the second leading cause of death globally and was responsible for 8,8 million deaths in 2015. Approximately 70% of deaths from cancer occur in low- and middle-income countries. The war on cancer has been fought with three tools – surgery (cut), radiation therapy (burn) including radiotherapy and bracytherapy, and also chemotherapy (poison). Cancer therapy has increased life expectancy of patients but each treatment modality has its own effects, complications and toxicity. Moreover we have found a new effective method to fight cancer, that is, Boron Neutron Capture Therapy (BNCT). Boron Neutron Capture Therapy (BNCT) has for many decades been advocated as an innovative form of radiotherapy that, in principle, has the potential to be the ideal form of treatment for many types of cancers. This research's aim is the characterising neutron of BNCT water phantom based on 30 MeV cyclotron using PHITS computational code. The result from the simulation is that thickness of the water phantom, related to flux neutron.

1. INTRODUCTION

Cancer is the second leading cause of death globally and was responsible for 8,8 million deaths in 2015. Globally, nearly 1 in 6 deaths is due to cancer. Not only it in the same year cancer also be a leading causes of death worldwide. Approximately 70% of deaths from cancer occur in low and middle-income countries. The most common causes of cancer death are cancers of the lung (1.69 million deaths) , liver (788 000 deaths), colorectal (774 000 deaths), stomach (754 000 deaths) and breast (571 000 deaths).[1] Meanwhile 14.1 million new cancer cases and 8.2 million cancer deaths occured in 2012 worldwide, with the most common cancer death from lung cancer (1.6 million deaths), liver cancer (745 000 deaths), stomach cancer (723 000 deaths), colorectal cancer (693 000 deaths), and breast cancer (522 000 deaths).[2]

The data shows that there had been increased cancer causes in the world. Although Indonesia is not included in the 50 biggest countries whith the highest cancer death rate, but in 2012 Indonesia had high enough cancer deaths for 1.551 million of the total Indonesian population of 247 million. [3] The prevalence of Indonesian cancer causes was 1,4 ‰, with the highest prevalence in DI Yogyakarta (4,1 ‰), following Central Java (2,1 ‰), Bali (2 ‰), Bengkulu and DKI Jakarta at 1,9 ‰. [4]

Cancer is a group of diseases characterized by the uncontrolled growth and speread of abnormal cells. If the spread is not controlled, it can result in death. [5] But there is no type of cancer from which some people have not recovered. The road to recovery generally is not very easy and requires real determination.[6]

The war on cancer has been fought with three tools – surgery (cut), radiation therapy (burn) including radiotherapy and bracytherapy, and also chemotherapy

*E-mail: dyahokti@gmail.com

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(poison).[7] Cancer therapy has increased life expectancy of patients but Each treatment modality has its own effects, complications and toxicity ; [8] such as cardiac toxicity following radiotherapy that can manifest itself as arrhythmias, pericarditis, congestive heart disease, ischemic heart disease (myocardial infarctions), or valvular disease with the pathogenesis of these entities suggested to be fibrosis/damage of the AV node and conduction system, inflammation, fibrosis, accelerated atherosclerosis, and fibrosis respectively.[9] In collon cancer operations can cause difficult lymphatic to drainage after surgery [10] and laryngectomy is often required, which inevitably results in permanent tracheostomy and loss of the natural voice. [11] Furthermore, some cancer therapy can change be a more chronic disease. For example a benign tumor can be malignant. Moreover a new effective method to fight cancer, that is, Boron Neutron Capture Therapy (BNCT). [12] Boron Neutron Capture Therapy (BNCT) has for many decades been advocated as an innovative form of radiotherapy that, in principle, has the potential to be the ideal form of treatment for many types of cancers.[13]

1.1. Boron Neutron Capture Therapy (BNCT)

Boron neutron capture therapy (BNCT) is an emerging cancer treatment modality that utilizes the neutron capture reaction of boron-10 (10B) and subsequent nuclear fission reaction to produce cellular death. [14] The result of this reaction is 10 B (n,α)7Li which has high LET (Linier Energy Transfer) with α particle 150 keVμm-1 and the 7Li 175 keVμm-1 . [17][18]

Dosimetry of BNCT is very complicated because of the presence of different dose components including oron dose (DB): The dose from 10B(n,α)7Li reaction; gamma dose (Dg): The dose from the neutron beam and 1H(nth,γ)2H reaction; thermal neutron dose (Dth): The dose resulting from thermal neutron capture in nitrogen 14N(nth, p)14C; fast neutron dose (Df): The dose from the 1H(n, n')2H reaction.[15] Besides the dose delivered to the target organ in a BNCT treatment, the doses deposited in the remaining organs may induce secondary cancer risk.[16] Moreover, we have to calculate more about the neutron fluks. Because of calculation of the fluks we have to make a simulation using Particle and Heavy Ion Transport Code System (PHITS).

1.2. Cyclotron- Based Neutron Source

In 2006 KURRI and SHI started development of the accelerator based neutron source for BNCT. In order to get high flux of epithermal neutrons, a combination of 30 MeV proton beams and a beryllium target was selected after the feasibility study. The neutron source consists of a cyclotron as the accelerator, a beam transport system and an irradiation and treatment system. Figure 1 shows the layout of the neutron source. The source was installed in December 2008 at the Innovation Research Laboratory in KURRI. The main equipments were installed in the area of 18 m long and 15 m wide excluding power supply rooms.[19]

This KURRI project has to deal with a very hard neutron spectrum. The current status have target beam energi 30 MeV, beam current 1 mA.[20]

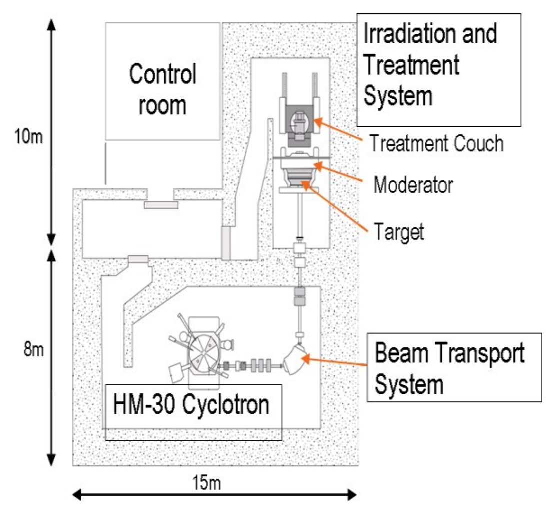

Figure 1. Layout of neutron source.

1.3. Particle Heavy Ion Transport System (PHITS)

PHITS have been used for several medicine aplications such as radiation dose therapy estimation and tomograph investigation computer based. Several reasons for using

PHITS is that it has high acuration, less computation time, less suspending file, repairing fault in MCNPX, detail investigation, can simulate all the kinds of particle transport and is used in various calculating microdosimetri applications; such as bilogy dose estimation from the multiplication betwen RBE and phisycs dose.[21][22][23]

2. MATERIALS AND METHODS

Legal Requirement

The designing to know the neutron characterization of water phantom BNCT based on 30 MeV cyclotron have been done using a set of programs PHITS.

The procedure of the reasearch implementation is formulated in a flow chart shown by figure 2.

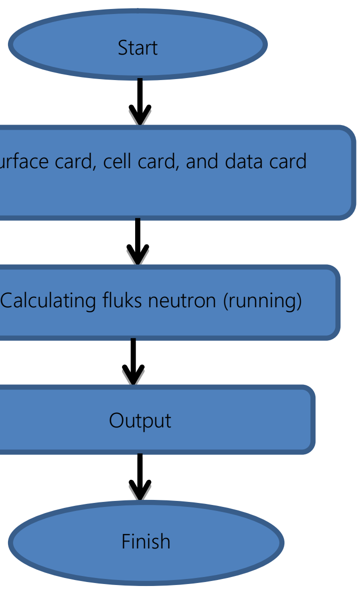

Fig 2. Fluks calculation algorithm on PHITS programs.

TABLE 1. Main specification of HM-30 cyclotron.

Accelerated Particle	Negative hydrogen ion
Extraction Energy	30 MeV
Extraction Method	Foil stripping
Maximum Beam Current	2 mA
Nominal Operation Current	1 mA
Magnet Size	3.0 m x 1.6 m x 1.7 m
Weight	60 tons

This reaserch's main specification using cyclotron 30 MeV based is shown on table 1.

3. RESULTS AND DISCUSSION

Neutron characterization has been designed using PHITS. HM-30 cyclotron succesfully accelerated the 30 MeV proton beam which is limited by the radiation regulation of the building. The cyclotron is stable.

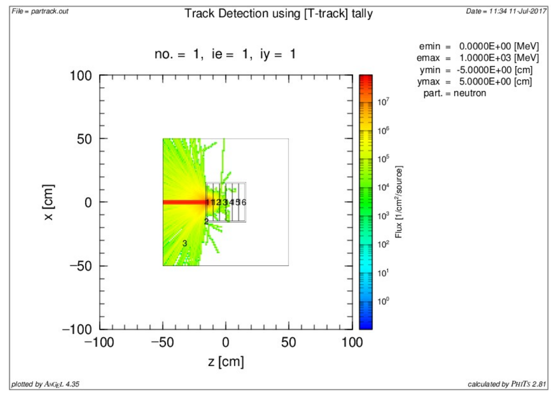

Fig 3. The design neutron characterization using PHITS.

The water phantom was positioned in y axis from -5.000 cm to 5.000 cm and the energy from 0.000 MeV to 1.000 MeV.

Results after the program had been running are shown in figure 4,5,6,7,8,and 9.

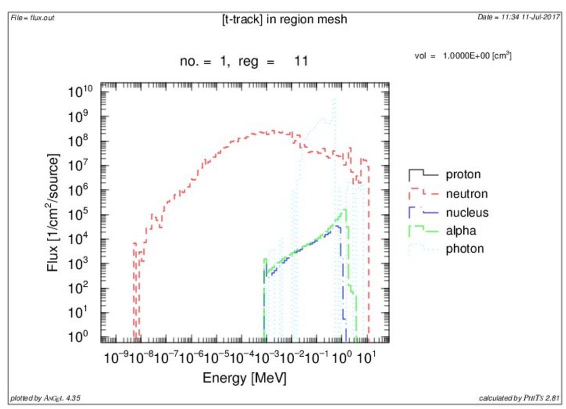

Fig 4. Fluks characterization in region 1.

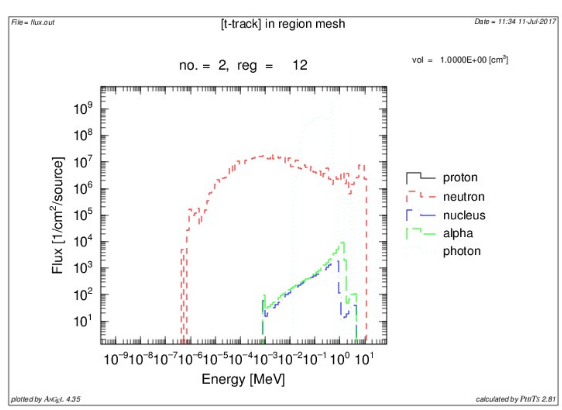

Fig 5. Fluks characterization in region 2.

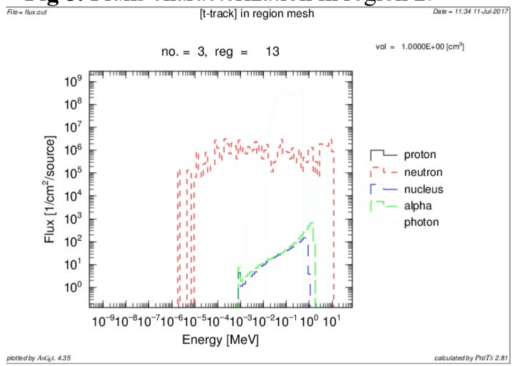

Fig 6. Fluks characterization in region 3.

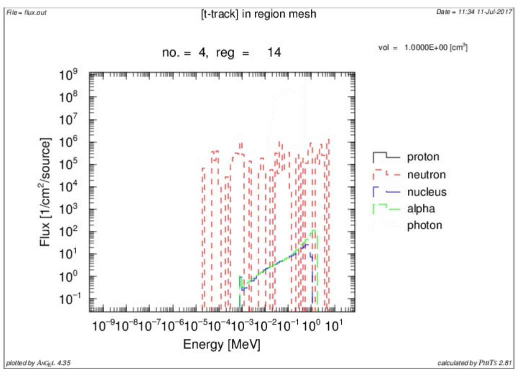

Fig 7. Fluks characterization in region 4.

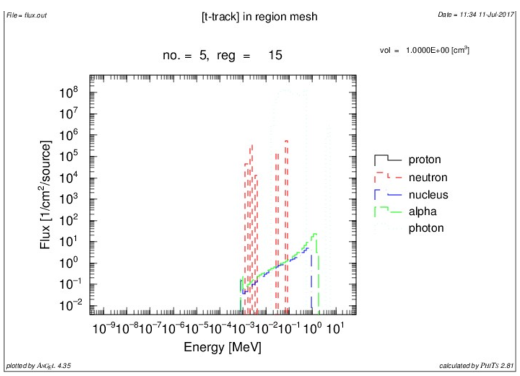

Fig 8. Fluks characterization in region 5.

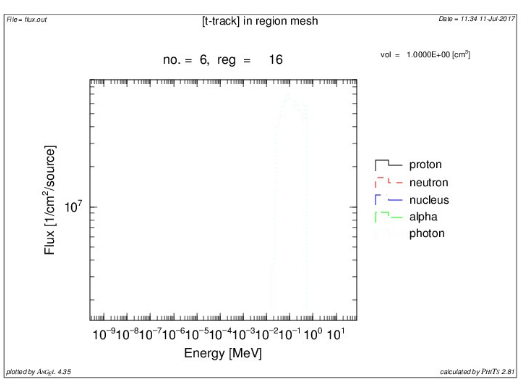

Fig 9. Fluks characterization in region 6.

4. CONCLUSION AND REMARKS

The result from the simulation is that the ticker of water phantom has smaller neutron flux.

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