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Simulation of a Compact Neutron Source with 13MeV cyclotron

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1. Introduction

Proton accelerator is valuable for neutron generator for neutron generator. This paper is aim to verify possibility to get neutron from KIRAMS-13, which is located in Pusan national university and optimize neutron target. To get nice quality of neutrons, it is necessary to study neutron flux and neutron energy spectrum. In order to get neutronic data, the simulation is conducted by using Monte Carlo method with Geant4 code. Regarding target design, which is consist of Beryllium target, metal layer and cooling system, simulation is conducted below many different combinations.

2. Target Design Process

In this system, it is consist of Be target, moderator, cooling water and aperture for imaging system like below Fig.1. (a),(b)

(a)

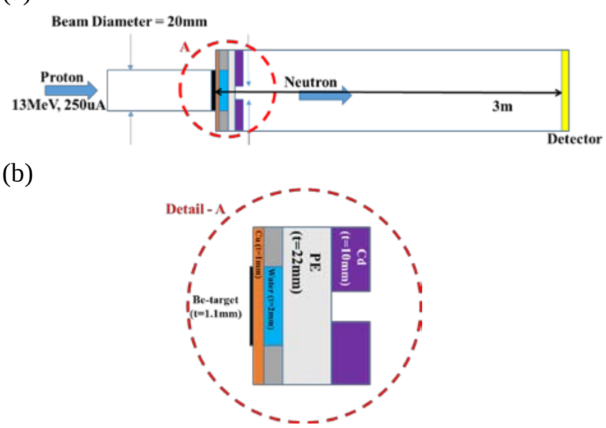

Fig. 1. (a) Concept Design of Compact Neutron Source, (b) Details of Target in Fig.1.(a)

2.1 Beryllium Target

In low energy based compact neutron generator, they mainly choose 7Li and 9Be for target material.

In order to make neutron with 13MeV proton beam, 9Be is proper material. The reaction (1) is mainly occurring, during neutron generating process. In general, this reaction has threshold energy, 2.057MeV.

9Be + proton → n + 9B - 1.850 MeV (Q-Value) (1)

In order to deciding required thickness of target, we calculated by stopping power with Geant4.

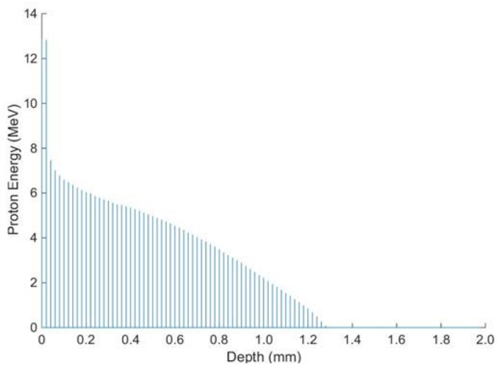

Fig. 2. Incident 13 MeV Proton Energy Distribution in Beryllium target.

2.2 Metal Layer

After proton passing through target, hydrogen ion continued to pile up in the material. Because of hydrogen, material gets brittle. It is related with life time of target. For solving this problem, we found material, which has high hydrogen diffusion coefficient and short half-life isotope after activating with neutron. They have to solder by lead or weld together. Additionally, we have to concern melting point, thermal conductivity and yield strength. However it is not related in generated neutron flux each metals, Fig.4. For all conditions, vanadium is suitable for this system. It is cited from RANS (RIKEN Accelerator-driven compact Neutron Source).

2.3 Cooling System

When accelerated-proton beam penetrate the Be-target, it generates lots of heat. Necessarily, this system has to need cooling system. We selected water cooling system for removing heat effectively, which has to be concerned about water's neutron absorption cross section. We calculated neutron flux and energy spectrum by changing water's thickness. Neutron flux had decreasing aspect as being thick water layer. Additionally, after proton passing through water, they had one more peak in energy spectrum, thermal range neutrons.

2.4 Aperture

Aperture is important part in neutron imaging system. we set up aperture in the system and changed the diameter of aperture(D). Thermal energy neutron was decreasing as diameter. If diameter size is big, it brings bad quality imaging. The smaller diameter set system, the better quality of imaging we get.

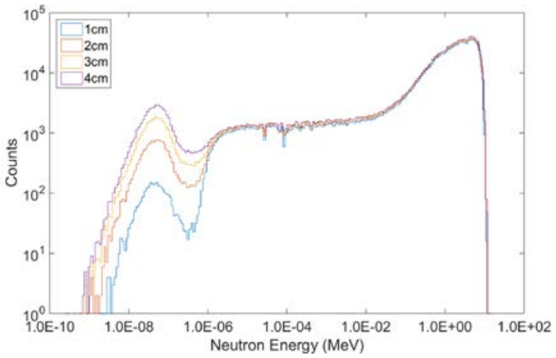

Fig. 3. Neutron Energy Spectrum as Aperture Diameter

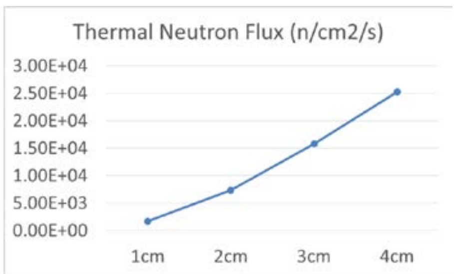

Fig 4. Thermal Neutron Flux as Aperture Diameter

3. Conclusion

In this presentation, we calculated neutron flux and neutron energy spectrum in 13MeV Cyclotron. Additionally, we found suitable design of target, metal layer and cooling system. We could find an opportunity about neutron radiography system by using cyclotron. For neutron radiography, fast neutron have to shift thermal range. We need to study this direction. Monte Carlo code is not almighty, so we need to refer to this data. This presentation can be first step to prove to operate KIRAMS-13 in Pusan National University.

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