Calculation of Fast Neutron Calibration Fields by Using an Accelerator at the Neutron Therapy Room of KIRAMS

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1. Introduction

The MCNPX[1] code was used to calculate the neutron fluence spectra at the neutron therapy room of KIRAMS (Korea Institute of Radiological & medical Sciences) in a series of the quantification of neutron fields. The Be target of thickness 1.0 mm was bombarded by two kinds of proton of different energies, 20 MeV and 35 MeV to produce neutron and these geometrical configurations were simulated. Neutron spectra with an intense yield and broad energy would be available for high energy sources when neutron detectors and dosimeters need to be calibrated over an energy range of 10 MeV. Because the mean energy of the neutrons produced at the MC50 facility is greater than that of a ^{252}Cf source, it can be a useful calibration source. Also, the most effective method for producing a monoenergetic neutron fields is to use an accelerator is stated by ISO (International Organization for Standardization) [2]

2. Methods and Results

2.1 Production Condition of the Fast Neutron Fields

For an effective production of the fast neutron calibration fields using the accelerator, calculation was carried out using MCNPX (ver. 2.4.0) which is a general purpose Monte Carlo radiation transport code with two different proton energies, 20 MeV and 35 MeV. The accelerated protons generate neutrons by bombarding the Be target with a 1 mm thickness in a beam porter. The neutron fields were generated by the addition of several beam stoppers and moderators on the fixed Be target. A photograph of the fast neutron facility of the MC50 and the structure of the horizontal beam porter are presented in Fig.1.

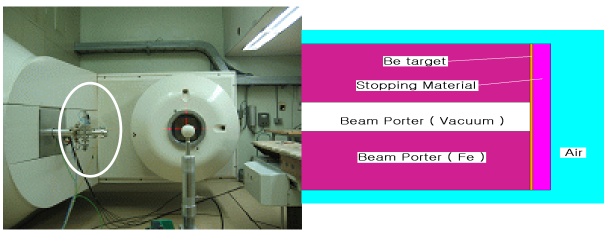

Fig. 1. Photograph of neutron production facility of the MC50 (left, horizontal beam porter in white circle line) and structure of horizontal beam porter (right)

Materials of the stopper are Pb, Cu, Al, Fe and the thickness of those is 6 mm. Two different moderators have been applied for the calculation of the neutron spectra; one is a cylindrical type PolyEhylene moderator, 10 cm thickness, covered with 0.5 mm thickness of Cd, the other is a spherical type D_2O moderator, 32 cm diameter, covered with 1 mm thickness of Cd and 1 mm thickness of stainless steel. The D_2O moderator was located at 3 cm from the end of the horizontal beam porter on line between beam porter and center of the D_2O moderator

2.2 Summary of the Calculation for the Fast Neutron Spectra

The MCNPX code was used to obtain the neutron fluence spectra of two kinds of neutron sources. Nuclear physics mode for neutron production using the p + Be reaction was the Bertini Intranuclear Cascade (INC) model[3] which is one of the models prepared in the MCNPX code for high energy particle physics. Proton energy was 35 MeV and 20 MeV. Both neutron transport and photonuclear reaction also in the Be target and its surrounding materials were considered when proton interacted with them. But the contribution of photoneutron to neutron production was negligible because quantity of neutron production is very small ($<10^{-6}$) under 35 MeV. Cut-off energies of proton, neutron and photon were set as 1 MeV, 10^{-9} MeV and 1 keV to save time for the calculation. Neutron fluence was transported to the reference position of geometry, 90 cm from the Be target, and the radius of tally surface is 13 cm.

2.3 Effects of the Stopper and Moderator on the Production of the Fast Neutron Calibration Fields

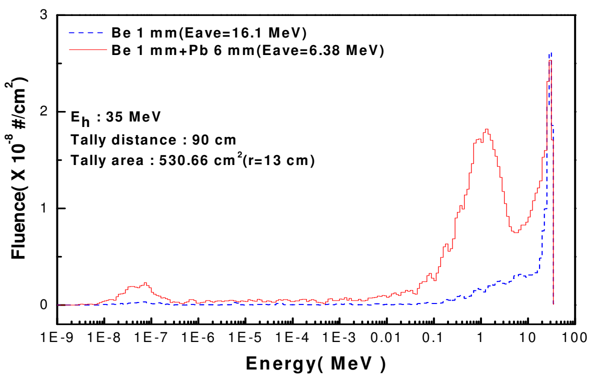

Fig. 2. Difference of neutron fluence spectra with the the Pb stopper and without the Pb stopper (35 MeV proton)

Fig. 2 is the neutron fluence spectra made from the Be target and attached the Pb stopper of 6 mm thickness. When the Pb stopper is attached, the neutron yield increased and an evaporation peak appeared remarkably at around 1 MeV.

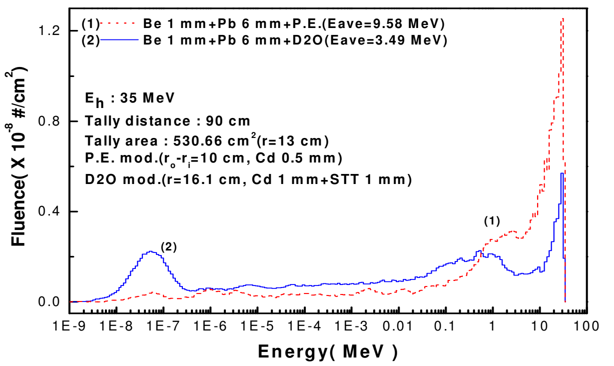

Fig. 3. Comparison of neutron fluence spectra to the case of the P.E moderator and the D_2O moderator (35 MeV proton energy)

The neutron fluence spectra made by the P.E. moderator and the D_2O moderator, originated from bombarding the Be target with 35 MeV proton beam, are presented in Fig. 3, respectively. In the case of the P.E. moderator, the part of the thermal neutron was very weak in comparison with the case of the D_2O moderator. From the comparison of the spectra in Fig. 2 and Fig. 3, it could be concluded that the P.E. moderator absorbs the thermal neutron as well as the evaporation peak produced by the Pb stopper.

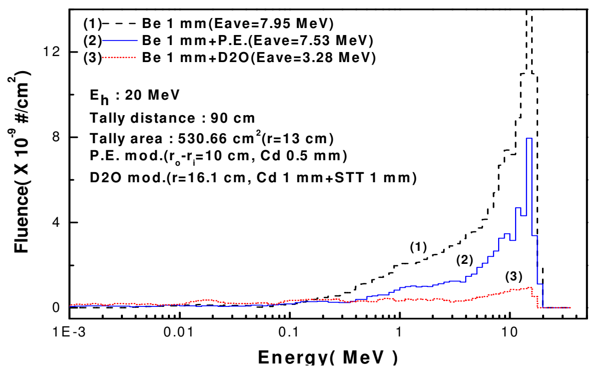

Fig. 4. Comparison of neutron fluence spectra to the case of the P.E moderator and the D_2O moderator in the case without stopper (20 MeV proton energy)

Fig. 4 shows the effect of two moderators on producing the neutrons with 20 MeV proton energy. The neutron yields and mean energies of the neutron decreased due to using the P.E. and the D_2O moderators. However, the shape of the fluence spectra were similar each other.

2.4 Results of Calculation

Calculation was carried by with changing the stopper materials and the kinds of moderator. Table 1 shows the several dosimetric quantities resulted from the calculation. As shown in Table 1, the mean energy of the neutron fluence ranges from 1.59 MeV to 16.1 MeV, while the quantities of $h^*(10)$ and $h_p(10)$ varied from around 140 pSv/cm^2 to 480 pSv/cm^2. From those results, it could be concluded that the calculated the neutron fields can be applied to establishing the calibration fields. The quantities of $h^*(10)$ and $h_p(10)$ were calculated by a dose equivalent conversion factor for the monoenergetic neutron of ICRP-74[4].

Table 1. Dosimeteric quantities of the several neutron fields produced by the different proton energies, the stoppers and the moderators

E_p (MeV)	Target (mm)	Stopper (mm)	moderator (mm)	Eave. (MeV)	$h^*(10)$ (pSv/cm^2)	$h_p(10)$ (pSv/cm^2)
35	Be(1)	-	-	16.1	445	477
	Be(1)	Pb(6)	-	6.38	351	369
	Be(1)	Cu(6)	-	7.89	370	390
	Be(1)	Al(6)	-	9.85	389	406
	Be(1)	Fe(6)	-	12.6	411	435
	Be(1)	Pb(6)	P.E(100)	9.58	357	375
	Be(1)	-	D_2O(r=161)	4.29	189	198
	Be(1)	Pb(6)	D_2O(r=161)	3.49	177	189
20	Be(1)	-	-	<7.42	<418	<440
	Be(1)	-	P.E(100)	<5.53	<345	<363
	Be(1)	-	D_2O(r=161)	1.59	141	148

Eave. : Fluence mean energy
$h^*(10)$: Ambient dose equivalent conversion factor
$h_p(10)$: Personal dose equivalent conversion factor

3. Conclusions

The effect of various stoppers and moderators on the neutron spectra was studied using the MCNPX code to find candidates for establishing the fast neutron calibration fields. When using the stoppers and the moderators, the neutron yield increased while the mean energies of the neutron decreased. The mean energies of the neutron spectra were changed from 1.59 MeV to 16.1 MeV. Although there is a difference in the intensity, the stoppers generally produced an evaporation peak at around 1 MeV. Consequently, it is concluded that several kinds of the fast neutron calibration fields can be established having different dosimetric quantities and spectra just by attaching various stoppers and moderators to the MC50 proton accelerator without any structural changes.

REFERENCES

[1] LANL, MCNPXTM User's Manual, Version 2.4.0, (RSIC-CCC-715), LA-CP-02-408,
[2] ISO, "Reference Neutron Radiation-Characteristics and Methods of Production of Simulated Workplace Neutron Field", ISO 8529-1, 20, 2001.
[3] H.W. Bertini, Phus Rev. Low-Energy Intranuclear Cascade Calculation, Vol.131, 1801, 196.
[4] ICRP, "Conversion Coefficients for Use in Radiological Protection Against External Radiation", ICRP Publication No. 74, 1997.