Penetration of 33 MeV Neutrons through Iron and Concrete

V. 2. Penetration of 33 MeV Neutrons through Iron and Concrete

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Introduction

The shielding of high energy neutrons is quite important to the radiation safety of high energy accelerator facilities, due to their strong penetrability. The shielding studies on neutrons above 20 MeV have, however, been scarcely reported hitherto. A few experiments on the neutron penetration through the shield have been done using continuous energy neutron sources.[1,2] In these experiments, the measured neutron energy range was limited only above about 1 MeV which could be measured by the NE-213 liquid scintillation counter, coupled with the n-γ discrimination technique.

We aimed to measure the neutrons penetrated through iron and concrete shielding materials with the 33 MeV quasi-monoenergetic neutron source by the Li(p,n) reaction and also the penetrated neutron energy spectra from 35 MeV down to 0.4 eV epithermal energy.

Measurement

The neutron penetration experiment was performed in the No. 5 target room and in the TOF room at the Cyclotron and Radioisotope Center, Tohoku University (CYRIC). Figure 1 shows the cross sectional view of the experimental arrangement along the neutron beam axis.

A 35-MeV proton beam extracted from the AVF cyclotron, was stopped on the thin lithium target in the No. 5 target room, in order to produce quasi-monoenergetic neutrons. The thickness of the lithium target was 103 mg/cm^2 which corresponds to the 1.76 MeV proton energy loss. Through two collimators, neutrons were incident to the shield which was set at the hole (50 cm in height, 100 cm in width and 283 cm in length) in the concrete wall between the No. 5 target room and the TOF room. The neutrons penetrated through the shield were measured with the 5.1 cm-diametric by 5.1 cm-long NE-213 liquid

scintillation counter, the 7.0 cm-diametric spherical proton recoil proportional counter (hydrogen 4.5 atm. and methan 0.5 atm.), and the multi-moderator spectrometer with a 10 atm. ^{3}He counter, i.e., Bonner Ball.

On the other hand, the most part of the proton beam stops at the Faraday cup through the thin lithium target and produces much more neutrons which come into background of the measurements. Therefore, we injected the proton beam to the Li target at an angle of 10° to the horizontal axis by the beam swing magnet, in order to prevent these neutrons from the direct incidence into the collimator. We repeated the same measurements when the lithium target was taken off from the proton beam axis, in order to estimate the background components due to neutrons scattering on the concrete surface in the No. 5 target room.

The source neutron energy spectrum produced from the lithium target without the shield was measured with the NE-213 by the TOF method. The spectrum had a quasi-monoenergy whose averaged energy was 32.6 MeV and fwhm was 1.4 MeV, as shown in Fig. 2.

Shielding materials used in the experiments were iron (10, 20, 30 and 40 cm in thickness) and concrete (25, 50, 75 and 100 cm in thickness).

The neutron spectra penetrated through the shielding materials were obtained by subtracting the background and unfolding the measured data with the FERDOU code[3] for the NE-213, the FERDOR code[4] for the proportional counter and the SAND-II code[5] for the Bonner Ball.

Results and Discussion

The neutron energy spectra measured for 30 cm thick iron are shown in Fig. 3, and those for 75 cm thick concrete are shown in Fig. 4.

In these figures, the measured neutron energy ranges were above 2 MeV for the NE-213, from 200 keV to 2 MeV for the proportional counter and above 0.4 eV for the Bonner Ball. The energy spectra obtained with these three detectors agree pretty well each other. There can be seen a peak of direct neutrons uncollided through shield near 33 MeV. Figure 3 clearly gives a broad peak around several hundred keV, which corresponds to the valley of the iron elastic scattering cross section near 600 keV and the linear decrease of spectrum with decreasing of energy below 600 keV. In Fig. 4, the neutron energy spectrum below 100 keV is nearly constant, namely, the 1/E slowing down spectrum because of the hydrogen content in the concrete. The 33 MeV peak by the Bonner Ball gives larger value than that by the NE-213 and the spectrum by the Bonner Ball gives rough but gross spectral shapes in the wide energy range from 0.4 eV to 33 MeV.

Fig. 5 shows the attenuation curves of the direct neutrons from the target, that is, the 33 MeV peak as a function of the shielding thickness. In Fig. 5, the exponential function

curves are shown whose attenuation coefficients are the macroscopic total cross sections in the 35~30 MeV energy group in the cross section library DLC-87.[6] The curves calculated by the Monte Carlo code MORSE-CG[7] with DLC-87 are also shown. It was concluded from Fig. 5 that the MORSE-CG calculation gave the values below the experimental results both for the iron and the concrete and the measured attenuation coefficient of 33 MeV neutrons are much smaller than the macroscopic total cross sections in the DLC-87.

We are now proceeding to the similar experiments using the quasi-monoenergetic neutrons from 25 MeV proton beam.

References

1) Shin K. et al., Nucl. Sci. Eng. 71 (1979) 294.
2) Uwamino Y. et al., Nucl. Sci. Eng. 80 (1982) 360.
3) Shin K. et al., Nucl. Tech. 53 (1981) 78.
4) Burrus W. R. et al., Nucl. Instr. Method 67 (1969) 181.
5) McElroy W. N. et al., AFWL-TR 67-41, I, II (1967).
6) Alsmiller R. G., Jr. and Barish J., ORNL/TM-7818 (1981).
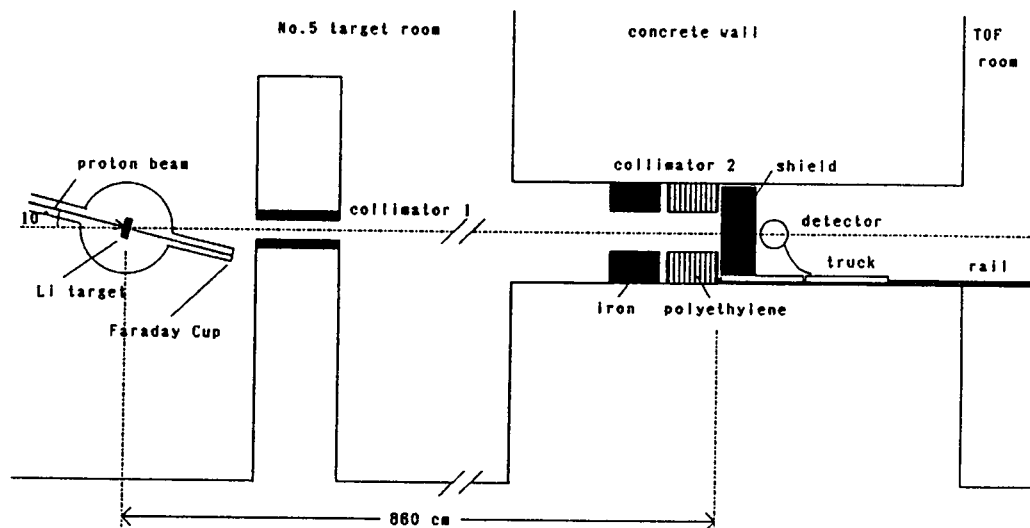7) Emmett, M. B., ORNL-4972 (1975).

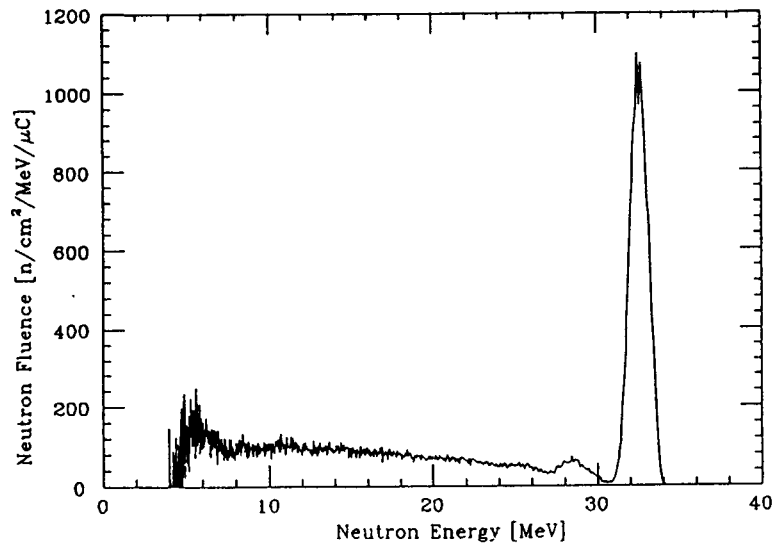Fig. 1. Cross sectional view of experimental arrangement along neutron beam axis.

Fig. 2. Neutron energy spectrum produced by Li(p,n) reaction
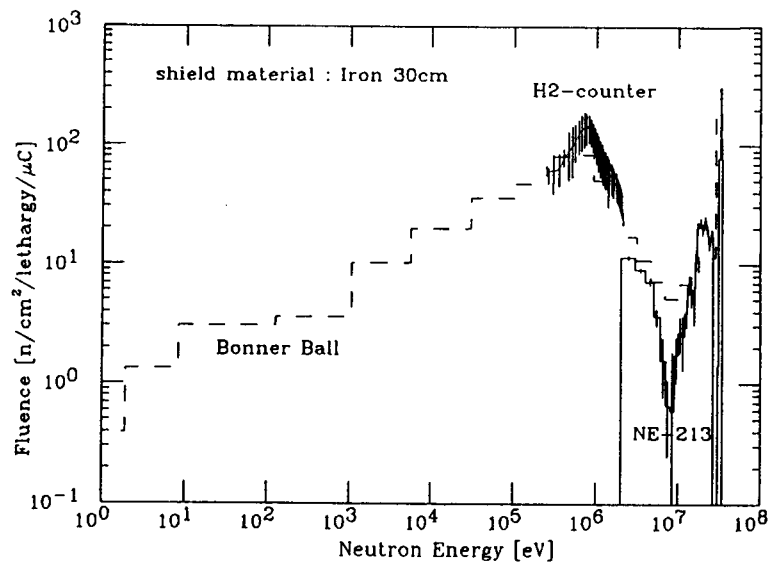measured with TOF method.

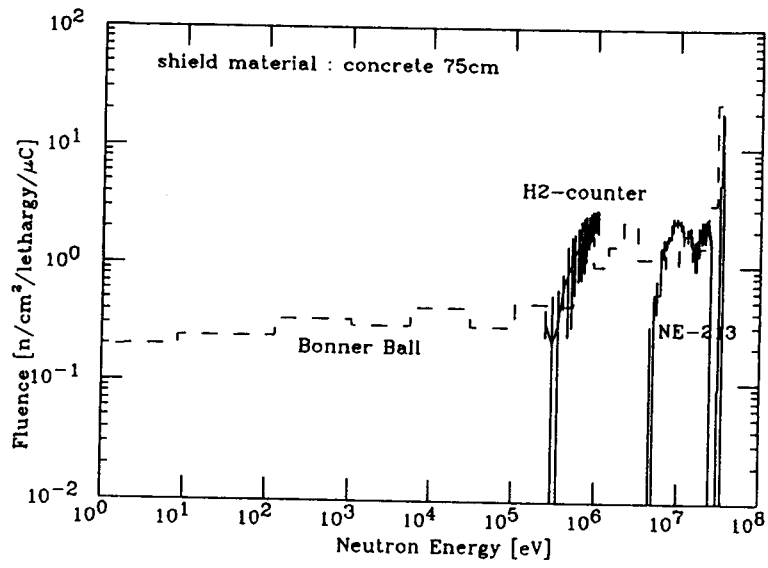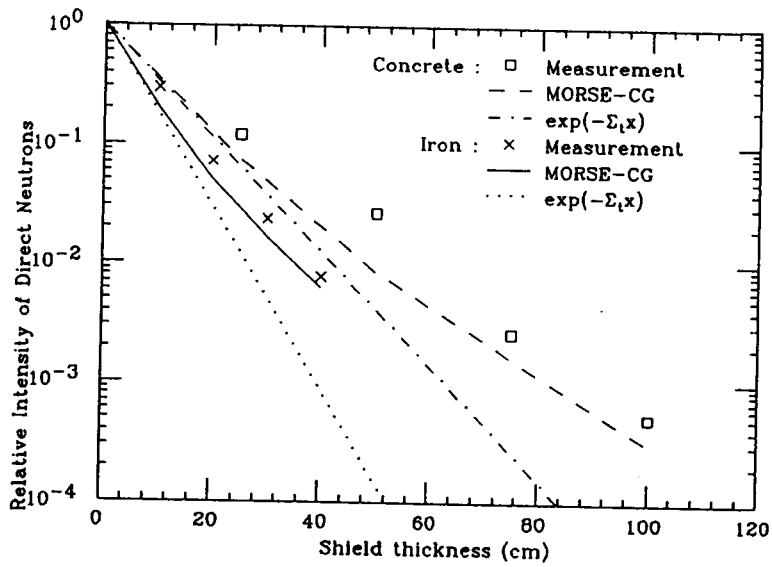Fig. 3. Neutron specrum through 30 cm thick iron.

Fig. 4. Neutron spectrum through 75 cm thick concrete.

Fig. 5. Direct neutron attenuation curve.