Measurements of Secondary Neutron and Photon Yield from Several-Tens-MeV Light Ions

by

Kazuo SHIN*, Kouki HIBI*, Masahiko Fujii** and Takashi Nakamura***

* Department of Nuclear Engineering, Kyoto University

** Nippon Atomic Industry Group Co., Ltd.

*** Institute for Nuclear Study, University of Tokyo

Measurements were made of secondary neutron and photon emission spectra from several-tens-MeV light ions by using SF cyclotron in Institute for Nuclear Study of University of Tokyo. Thick targets were used in the measurements to stop the incident ions completely in the targets, and the emerged neutrons and gamma rays were measured in various directions.

Fig. 1 shows experimental arrangement. The incident particles, their energy, and used targets are listed up in Table I. The electron emission from the target by the ion bombardment was suppressed with suppression vias of about 100 V supplied between the target and the suppressor grid. The emerged neutron and photons were measured simultaneously by a 3" by 3" NE-213 scintillator set at the position 4 m away from the target and at angles of 0°, 15°, 30°, 45°, 75°, and 135°. The background run was made by locating a shadow shield between the target and the detector. The obtained pulse-height distributions were unfolded by FERDO method with the aid of response functions obtained by the Monte Carlo method.

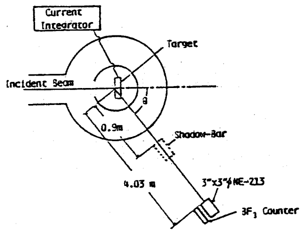

Fig. 1 Experimental arrangement.

Table I. Experimental Conditions.

	Target		
	Nuclide	Density (g/cm^3)	Thickness (mm)
30-MeV proton	C	1.7	9.0
	Fe	7.36	3.0
	Cu	8.93	3.0
	Pb	11.34	3.0
65-MeV alpha particle	C	1.7	6.0
	Fe	7.86	2.0
	Cu	8.93	2.0
	Pb	11.34	2.0
33-MeV deuteron	C	1.7	9.0
	Fe	7.86	3.0
	Cu	8.93	3.0
	Pb	11.34	3.0
65-MeV helium-3 particle	C	1.7	9.0
	Fe	7.86	3.0
	Cu	8.93	3.0
	Pb	11.34	3.0

Examples of the obtained double differential neutron and photon production data are shown in Figs. 2 and 3 for 33-MeV deuteron incidence on the Cu target. The dotted line in Fig. 2 shows neutron emission spectrum at 0° given by Meulders et al.(1) by the time of flight method. His data agree very well with our data in absolute value.

The neutron spectra as shown in Fig. 2 were integrated with the neutron energy over the neutron energy range higher than 2 MeV, to obtain the diffrential neutron yield data per unit steradian. The obatined differential neutron yield at 0° direction of the C target from the 33-MeV deuterons are compared with other experimental data (1,2) in Fig. 4. The discri level of the neutron energy, used to get the yield data, is different among the three data; 2 MeV for ours, 0 MeV for Weaver's data and 4 MeV for Meulder's data. Taking this fact into account, we can say that the agreement among the three data in Fig. 4 is very good.

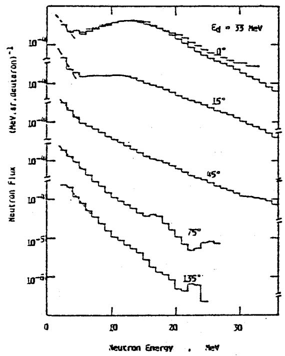

Fig. 2 Double differential neutron yield from 33-MeV deuterons for C target.

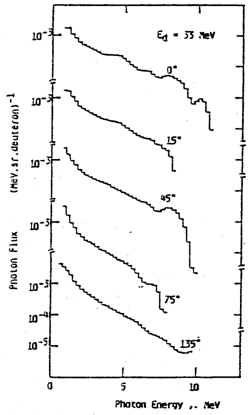

Fig. 3 Double differential photon yield data from 33-MeV deuterons for C target.

Our measured neutron spectrum at each angle was extrapolated to lower energy range ($E_n \leq 2$ MeV) by assuming evaporation spectrum in this energy region. For deuteron incidence, this extrapolation dose not give so much effect to the total neutron yield as was shown by Fig. 4. But for alpha particle incidence, neutron in this low energy range give more contribution to total neutron yield. The obtained total neutron yield by the above method for 4π steradian of the alpha particle incidence is compared with other data(3,4) in Fig. 5 for C and Cu targets. Our data agree very well with Wadman's ones for the C target. For the Cu target, though the number of experiments is insufficient to test the accuracy of our data exactly, we can imagine as the dotted line that our data are consistent with Stelson's data.

We can conclude that our experimental data for double differential neutron yield have good accuracy.

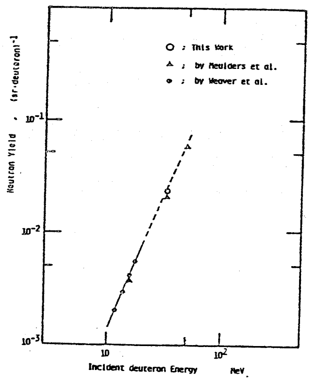

Fig. 4 Secondary neutron yield at 0° of Cu target from 33-MeV D$^+$.

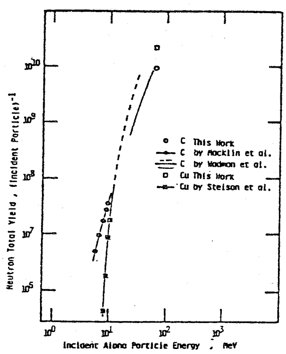

Fig. 5 Total neutron yield from alpha particles for C and Cu targets.

1) J.P.Meulders et al., Phys. Med. Biol., 20, 235 (1975).
2) K.A.Weaver et al., Nucl. Sci. Eng., 52, 35 (1973).
3) D. H. Stelson and F. K. McGown, Phys. Rev., 133, 24 (1964).
4) L.D.Stephens and A.J.Miller, CONF-691101, p459 (1969).