PRODUCTION OF NEUTRONS AND PHOTONS FROM THICK TARGETS BOMBARDED BY 52 MEV PROTONS

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In carrying out neutron and photon transport calculations for shielding accelerators, it is necessary to get the accurate information on secondary neutron and photon yields by nucleon-nucleus nonelastic collisions when the accelerating particles strike a beam stopper. We measured the energy and angular distributions of neutrons and photons from thick carbon, iron, copper and lead targets exposed to 52 MeV protons with a NE-213 scintillator and activation detectors of Al and Fe. The neutron and photon pulse height distributions measured by use of n-γ pulse shape discrimination technique were converted to the neutron and photon energy spectra by the FERDO unfolding code[1] with the aid of response functions and were normalized to one incident proton. In order to get more accurate absolute values, all neutron and photon spectra were renormalized by using experimental saturated activities of Al and Fe detectors.

The neutron energy spectra $\phi_n(E,\theta)$ at several θ values are shown for C target in fig. 1 as an example. Figure 1 shows that the neutron energy spectra become soft with the neutron emission angle θ. The neutron angular distribution $\phi_n(\theta)$

$$\phi_n(\theta) = \int_{5\,MeV}^{\infty} \phi_n(E,\theta)\,dE ,$$

is shown in fig. 2. The experimental results for neutrons were used for the integral check of neutron production cross section data by Alsmiller et al.[2] which have never been evaluated. They gave analytic representation of nonelastic cross sections and nucleon-emission spectra in the energy range 25 to 400 MeV on a variety of targets based upon the intranuclear-cascade-evaporation data by Bertini[3]. The neutron spectra calculated by assuming the continuous slowing down model for proton in a thick target are also shown in fig. 1. From the comparison of the calculated spectra in 0°-30°, 30°-60° and 60°-90° with the experimental ones at 15°, 45° and 75°, respectively, it is found that the spectrum shapes between experiment and calculation resemble well each other at all angles, but the absolute values of calculated neutron spectra are 2$\sim$3 times larger than the experimental results at θ = 15° and 45°, and the former shows rather good agreement with the latter at 75°. The calculated neutron angular distributions were normalized to the experimental results at 15° as shown in fig. 2 and the former gives larger variation of secondary neutron emission with the angle than the experimental results for every target. This large discrepancy at small emission angles reveals a poor accuracy of the calculational model by Bertini in the energy range below $\sim$50 MeV.

The measured photon energy spectra, $\phi_\gamma(E,\theta)$ are shown for C target in fig. 3 as an example. Differently from the neutron spectra, it is clear that the photon spectra do not change so much with the emission angle. Figure 4 shows the photon angular distribution, $\phi_\gamma(\theta)$ integrated above ~ 2 MeV. For photons, there have been no systematic photon-production cross section data. We could only compare with the photon spectra emitted at $\Theta = 135°$ from thin carbon target bombarded by 50.3 MeV protons[4], as shown in fig. 4. Despite of the difference of the target thickness and the emission angle, the relative photon spectra between two experimental results are close to each other.

References

1) W. R. Burrus and V. V. Verbinski, ANS-SD-2, 148 (1964).
2) R. G. Alsmiller, Jr. et al., ORNL-4046 (1967).
3) H. W. Bertini, ORNL-3383 (1963); Phys. Rev., 131 (1963) 1801.
4) W. Zobel et al., Nucl. Sci. Eng., 32 (1968) 392.

Fig. 1

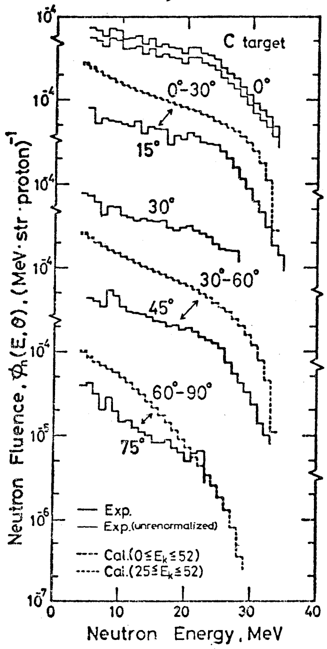

Fig. 3

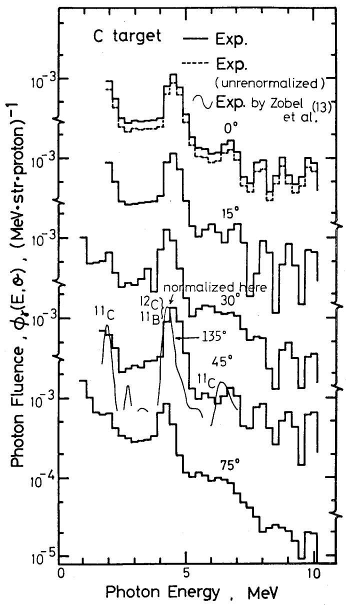

Fig. 2

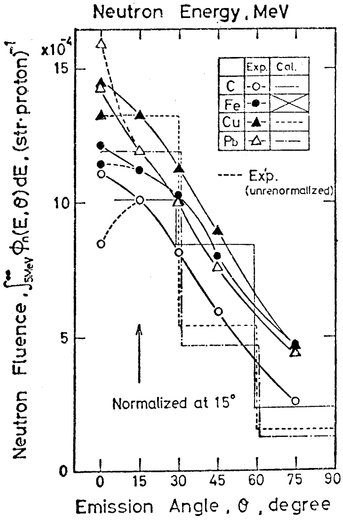

Fig. 4