SECONDARY NEUTRON AND PHOTON YIELD FROM SEVERAL TENS MEV IONS

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## Introduction

Accelerators of the energy of several tens MeV are lately widely used for many purposes. In these accelerators, secondary neutrons and gamma rays generated from the beam stoppers are the most important for the accelerator shielding problem. In this work, energy and angular distributions were systematically measured of the secondary neutrons and gamma rays from thick targets of C, Fe, Cu and Pb bombarded by 30-MeV protons, 35-MeV deuterons, 65-MeV $^3$He particles and 65-MeV alpha particles.

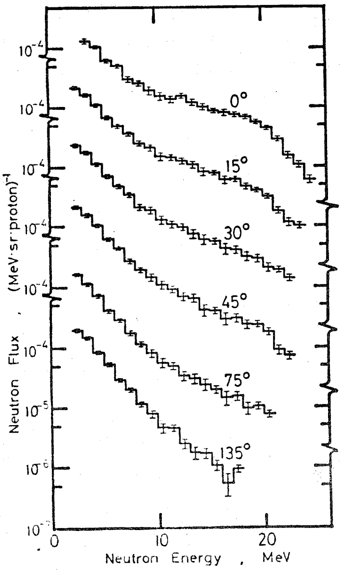


Fig. 1 Neutron spectra from thick Cu target bombarded by 30-MeV protons.

## Experiment

The particles accelerated by a SF cyclotron of Institute for Nuclear Study of University of Tokyo were injected to the C, Fe, Cu and Pb targets whose thickness were thicker than the ranges of the incident particles. The generated neutrons and gamma rays from the targets were measured simultaneously with a 3-in. dia. by 3-in. thick NE-213 using the pulse shape discrimination circuit. The measurements were done at the angles of 0°, 15°, 30°, 45°, 75° and 135° with respect to the incident beams. The obtained pulse height distributions for both neutrons and gamma rays were unfolded to energy spectrum by the FERDO code with the aid of the response functions which were calculated by the Monte Carlo method.

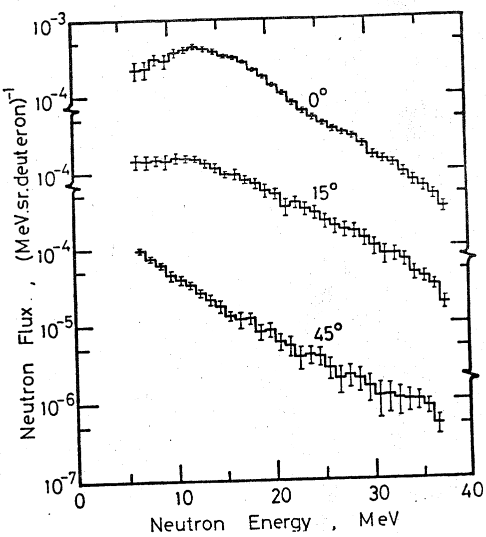


Fig. 2 Neutron spectra from thick Cu target bombarded by 35-MeV deuterons.

## Results for Secondary Neutrons

The spectra of secondary neutrons from Cu target bombarded by 30-MeV protons and 35-MeV deuterons are shown in Figs. 1 and 2, as examples. In the spectra of deuteron incidence, the broad peak around the energy of 12 MeV rapidly becomes larger with decreasing of the angle. This can be explained with the splitting reaction of the incident deuterons. Contrary to this, such broad peak can not be seen in the spectra of proton incidence. Their spectral shape becomes harder monotonically with decreasing the angle. In Fig. 3 are shown angular distributions of secondary neutrons from Cu target which were obtained by integrating the energy spectra with the neutron energy. The angular dependence of neutron flux shows a tendency to decrease with increasing angle.

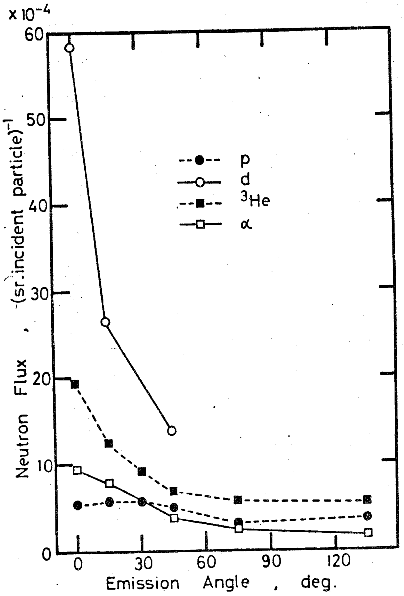


Fig. 3 Angular distribtuion of neutron flux for Cu target.

## Results for Secondary Gamma Rays

The spectra of secondary gamma rays from Cu target of 30-MeV proton incidence are shown in fig. 4, as example. Contrary to the neutrons, the spectral shape does not change with the angle. The angular distribution of secondary photon yield which was obtained from the energy spectra is shown in Fig. 5. In the case of proton and $^{3}$He incidence, the distributions seem nearly isotropic but have slight peculiar peaks at $\vartheta = 30°$ and 135°. While in the case of deuteron and alpha particle incidence, the distributions show forward peaks.

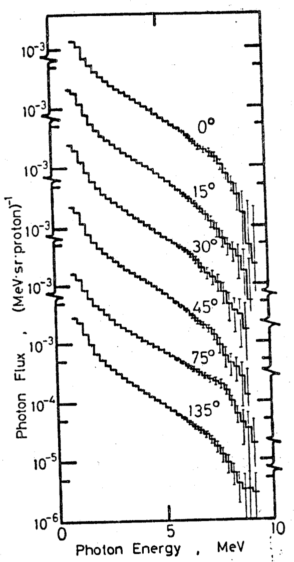


Fig. 4 Photon spectra from thick Cu target bombarded by 30-MeV protons.

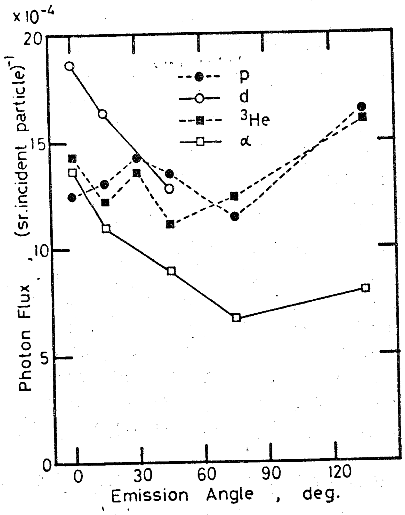


Fig. 5 Angular distribution of photon flux for Cu target.