NEUTRON AND PHOTON SKYSHINE FROM FM CYCLOTRON

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The long-distance propagation of neutrons and photons due to skyshine effect from the FM cyclotron has been measured in order to estimate the dose level of the surrounding environment. The 52 MeV proton beams were stopped by a carbon drop probe covered with iron magnet 0.7 m far from the beam exit of the cyclotron Dee. The beam stopper becomes a neutron and photon source with removing two concrete blocks (1 m wide, 9 m long and 0.9 m thick) just above the stopper. The measurements were carried out around the source and in the vast field about 30 m to 430 m far from the cyclotron as shown in fig. 1. In the field, four directions, A, B, C and D were selected to do the skyshine measurements. The A and B directions are faced to the window of the cyclotron room and the C and D directions to its wall in order to investigate the contribution of the leakage component through the window. The counts were normalized to the beam currents at the beam stopper.

The source neutron spectra at the stopper $\phi_S(E)$ and on the 30 cm thick concrete roof just above the source (point O in fig. 1) $\phi_0(E)$ measured with a NE-213 scintillator are shown in fig. 2. The measurements with a neutron rem counter in the cyclotron room found that the source neutron leaks almost perpendicularly upward and its dose distribution upward from the source is approximated by an inverse square law. The neutrom spectrum at Point O can be estimated by

$$\phi_o(E) = \phi_S(E) \frac{e^{-\Sigma_R(E)t}}{4\pi r^2}$$

where t = concrete thickness,
r = distance from the source to Point O,
$\Sigma_R(E)$ = removal cross section.
The estimated value of $\phi_0(E)$ is in rather good agreement with the measured value of $\phi_0(E)$ as shown in fig. 2.

Figures 3 and 4 shows the neutron and photon energy spectra at several field points, respectively. These neutron spectra are quite soft compared with the source spectrum and both neutron and photon spectra in the A direction are harder than those in the D direction due to the leakage through the window. The neutron dose distribution in the field D(r) is shown in fig. 5 as a function of the distance from the source r and may be fitted to

$$D(r) = D_0\, r^{-n}.$$

The value of n is given as follows;

Direction		Total	Thermal
Window-side	A,B	~ 2.6	~ 3.1
Wall-side	C,D	~ 2.0	~ 2.0

The absolute values of neutron and photon doses in the window-side

direction A and B are about a factor 2 larger than those in the wall-side direction C and D at r = 80 m and bocome nearly equal together at r = 150 m. This discrepancy can be attributed to the direct leakage component through the window of the cyclotron room.

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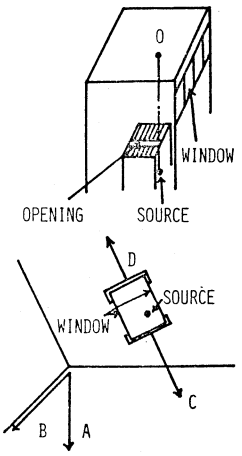


Fig. 1. Schematic diagram of skyshine experiment.

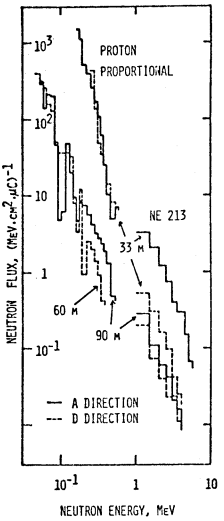


Fig. 3. Neutron energy spectrum at some field points (Distance from source is shown in m.)

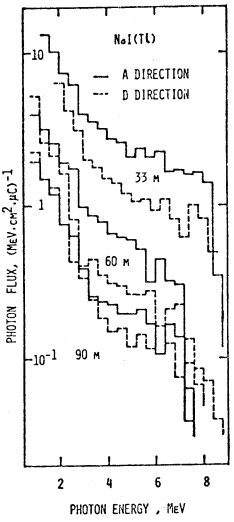
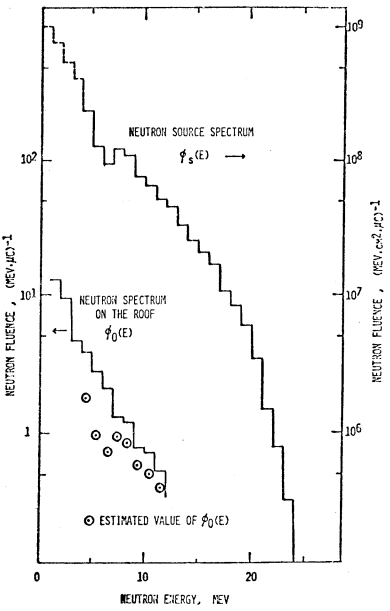


Fig. 4. Photon energy spectrum at some field points (Distance from source is shown in m.)



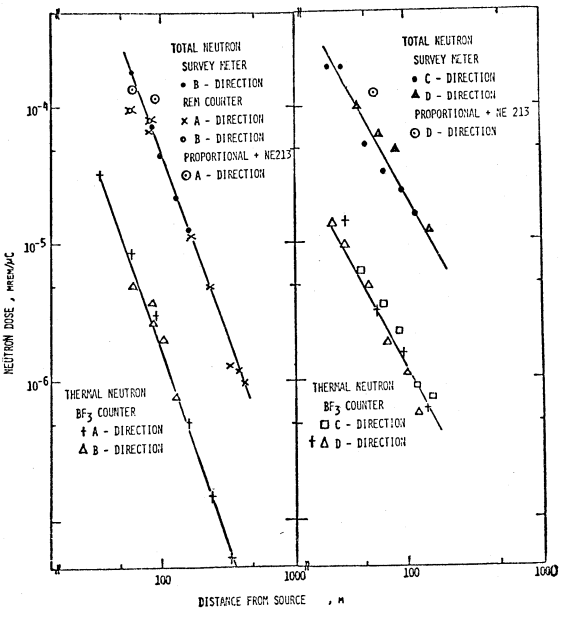


Fig. 5 Surface distribution of neutron dose in the field

Fig. 2 Neutron spectra around the source