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March 5, 1951

Berkeley, California

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A study of the angular distribution of photons in showers in lead has been carried out using the 322 Mev x-ray beam of the Berkeley synchrotron.¹ The experimental arrangement is shown in Fig. 1. The x-ray beam, collimated to 1/4 inch, produced showers in a target which usually was a slab of lead. The shower photons emerging from the target at various angles with the incident beam were detected by the radioactivity induced in copper foils. The 16-mil thick foils were 3-inch squares used whole or cut into halves or fourths and mounted as cylindrical segments with the beam as their axis. The mount was 21 cm from the target for angles $< 31^\circ$. For data at angles $> 31^\circ$ the mount was 11 cm from the target and only the outer four foil positions were used.

The reaction employed was $\text{Cu}^{63}(\gamma, n)\text{Cu}^{62}$, the Cu^{62} undergoing decay with a ten-minute half-life. The excitation curve of this reaction has a peak at 17.5 Mev and a full width at half-maximum of about 5-1/2 Mev;² hence the photons detected are those of energy near 17.5 Mev. After a 20-minute bombardment the fractional foils at a given angle were scotch-taped together to form "standard" 3-inch square foils and were counted along with the monitor foil for 15 minutes using Victoreen 1B85 aluminum walled Geiger tubes.

Primarily this work was carried out with a target of 2.8 shower units of lead (taking 1 s.u.=0.52 cm of pb). 2.8 shower units is roughly the depth in

¹ Reported at the Los Angeles Meeting of the American Physical Society, December 28-30, 1950.

² Diven and Almy, Phys. Rev. 80, 407 (1950).

lead at which there are a maximum number of gammas which can produce the reaction $\text{Cu}^{63}(\gamma, n)\text{Cu}^{62}$, and also it is about the depth at which maximum ionization occurs. Distributions at the shower maximum are easiest to calculate theoretically. The experimental results for 2.8 shower units are shown in curve 1, Fig. 2. The background, which is the relative activity observed when the target was absent, ranged between 15 percent at small angles to 10 percent at large angles. There was no straight forward way of subtracting off this background, but the relative error introduced is probably less than 10 percent. Points on the theoretical curve as calculated by Eyges and Fernbach³ are indicated by the X's. The two curves are arbitrarily set equal at 9° . The agreement in shape seems good. To further compare the two curves the total flux was integrated experimentally between 0° and $5\text{-}1/2^\circ$ using a copper disk intercepting these angles and normalized to the same geometry as the other detectors. For the curves equal at 9° the experimental integral is 1.3 times the integral from the theoretical curve. This agreement is not bad since the method used by Eyges and Fernbach gives unreliable results at small angles.

Measurements were also made with 1.3 shower units of lead (curve 2) and 0.85 shower units of copper (curve 3). The curves have been set equal to the 2.8 shower unit curve at $7\text{-}1/2^\circ$. No theoretical curves were available for comparison. For curves normalized in this manner the experimental integrals of the total flux between 0° and $5\text{-}1/2^\circ$ have the following relative values:

0.85 s.u. Cu	1.75 ± 10 percent
1.3 s.u. Pb	1.59 ± 10 percent
2.8 s.u. Pb	1.00 ± 10 percent
5.9 s.u. Pb	0.70 ± 10 percent

(Curve for 5.9 s.u. taken at small angles only.)

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³ Reported at the New York Meeting of the American Physical Society, February 1-3, 1951.

Fig. 1. Schematic diagram of the experimental arrangement (side and front views).

Fig. 2. Relative photon flux per steradian vs. angle with the incident x-ray beam.