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Recent work on the state of polarization of bremsstrahlung beams has been reported by several authors;[1, 2, 3, 4] the results of each paper are somewhat at variance with the others and with the theory.[5, 6, 7] We have attempted to investigate this polarization effect, both because of interest in the phenomenon and because of possible application. In practically all the experiments on nuclear reactions an average has been taken over the possible states of polarization of the incident photons. It is apparent that if one were able to use polarized photons, additional information could be obtained.

In this work, the fractional polarization observed at angle $\theta$ in the laboratory system is defined by

$$P(\theta, E, k) = \frac{d\sigma_{\perp}(\theta, E, k) - d\sigma_{\parallel}(\theta, E, k)}{d\sigma_{\perp}(\theta, E, k) + d\sigma_{\parallel}(\theta, E, k)},$$

where $d\sigma_{\perp}(\theta, E, k)$ is the bremsstrahlung cross section per unit solid angle with the following parameters: The incident electron has energy E; the energy of the emergent photon is in a band (defined below) about k; and the electric vector is perpendicular to the plane containing the paths of the electron and the photon. Let $d\sigma_{\parallel}(\theta, E, k)$ be similarly defined for a photon with its electric vector parallel to the plane. The angle $\theta$ is shown in Fig. 1. Note that the value of polarization does not depend upon the azimuthal angle about the center of the bremsstrahlung beam, but the significance of $d\sigma_{\perp}$ and $d\sigma_{\parallel}$ does.

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[1] K. Phillips, Phil. Mag. 44, 169 (1953).

[2] E. G. Muirhead and K. B. Mather, Australian Journal of Physics 7, 527 (1954).

[3] Christophe Tzara, Compt. rend. 239, 44 (1954).

[4] J. W. Motz, Bull. Am. Phys. Soc. II, 1, No. 1, Abstract AB8 (1956).

[5] M. May and G. C. Wick, Phys. Rev. 81, 628 (1951); Michael M. May, Phys. Rev. 84, 256 (1951).

[6] R. L. Gluckstern, M. H. Hull, Jr., and G. Breit, Phys. Rev. 90, 1026 (1953); R. L. Gluckstern and M. H. Hull, Jr., Phys. Rev. 90, 1030 (1953).

[7] Robert Karplus and Alfred Reifman, "Polarization of Bremsstrahlung" UCRL-2686, Sept. 1954.

For the case in which the electron is relativistic both before and after the collision, the bremsstrahlen electric vectors are predicted to be predominantly in the angular range labeled "⊥" in Fig. 1. The calculations indicate that nearly the entire energy spectrum is partially polarized over a relatively large range of $\theta$ in the beam; however, the polarization is predicted to be rather sharply peaked about an angle $\theta_0$ such that $\sin \theta_0 \cong \theta_0 \cong mc^2/E$ for all energies in the bremsstrahlung spectrum. The peak is broadened, and displaced to larger values of $\theta$ by multiple scattering of the electrons in the radiator.

Three earlier experiments attempting to verify the theory in the energy region of interest to us have been published. All used deuterium photodisintegration detection in one form or another, and all used betatrons as sources of photons. Phillips[4] obtained results that indicated a second direction of prominent polarization as well as that predicted by the theory; Muirhead and Mather[5] observed no polarization; Tzara[6] reports observing a polarization in excess of 50% (under the definition above). Motz[7] has very recently reported an experiment verifying polarization in a lower energy region.

It is evident that if the polarization is to be detected, or if this property of the bremsstrahlung beam is to be used, the incident electrons must be very well collimated, and the possibility of multiple scattering in the target must be sharply restricted. The first requirement was met by the use of the 35-Mev electron linear accelerator at Stanford University. The second requirement was met by the use of a very thin radiator of low atomic number (described below).

24-Mev electrons emergent from the linear accelerator traveled down an evacuated tube and struck a 1-mil aluminum radiator in which the bremsstrahlen were produced. The electrons that passed through the radiator were then deflected by a magnetic field in the evacuated region and caught in a thick carbon beam stopper. The latter was heavily shielded with iron and paraffin. The bremsstrahlen emerged from the evacuated system through an aluminum window and a thin lead filter (which was introduced to reduce low-energy background), and passed through the intervening air to the detector. A portion of the deflecting field for the main beam of electrons was used to remove secondary electrons produced in the window and filter.

The detector was constructed as follows: six 200μ Ilford C.2 emulsions on 1-by-3-inch glass supports were arranged side by side to form a 3-by-6-inch rectangle. A second set of six plates was arranged identically. A double-decker sandwich of three thin stainless steel foils and these two sets of plates was mounted perpendicular to the axis of the beam of photons, with the emulsion side of each set of plates faced toward the radiator. The set of six plates that was to be nearer the radiator was soaked for several hours prior to exposure in $D_2O$; the set directly behind it in the sandwich was similarly loaded with $H_2O$. During exposure, the plates in both sections of the plate holder were kept wet. The entire plate holder was cooled with ice water during exposure, to reduce fading and to preserve the emulsion.

Detection was by means of the electric dipole photodisintegration of the deuterons in the heavy-water-loaded plates. The maximum of the cross section for this process occurs for incident photons of roughly 5 Mev, at and above which energy the magnetic dipole photodisintegration cross section is small. The useful proton tracks in the heavy-water-loaded plates were found to have ranges corresponding to photon energies between 4 and 8 Mev. The ordinary-water-loaded plates were exposed simultaneously in order to evaluate the background of protons due to all other effects. The 5% background they indicated has been subtracted from the results we quote below.

Pending further scanning and improvement of statistics, we report values of $P(\theta)$, for $E = 24$ Mev and $k = 4$ to 8 Mev, calculated from total photoproton track counts in the quadrants centered on the directions $\perp$ and $\parallel$ in Fig. 1. On the basis of 922 tracks we find

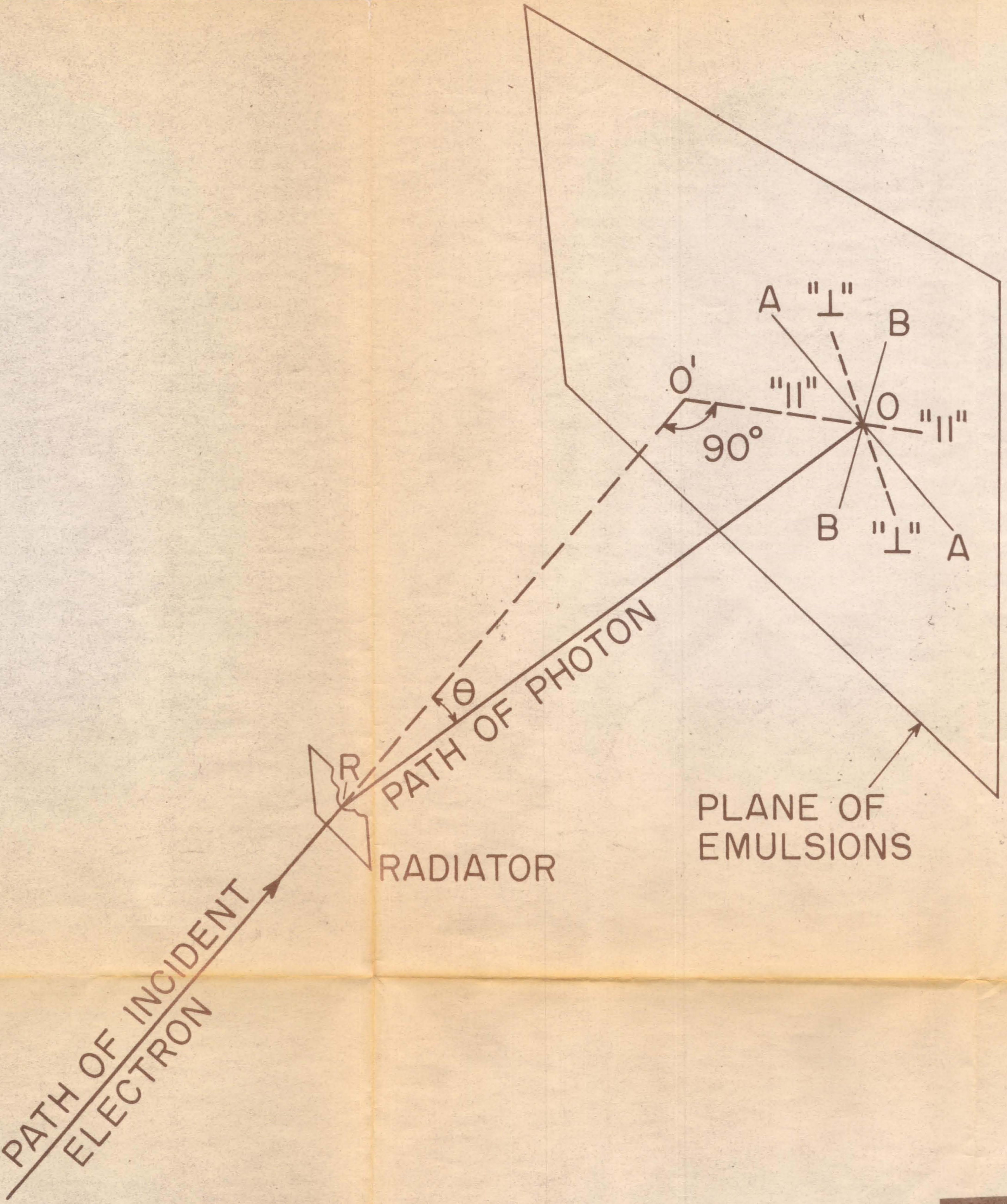
$P(\theta_0) = 0.242 \pm 0.081$ (from 396 tracks),
$P(1.6\ \theta_0) = 0.157 \pm 0.095$ (from 260 tracks),
$P(2.5\ \theta_0) = 0.123 \pm 0.102$ (from 255 tracks).

The errors quoted are standard deviations.

We wish to thank the members of the Hansen High Energy Physics Laboratory at Stanford University, particularly Dr. W. C. Barber, for the use of and help with the accelerator, and Drs. Walter H. Barkas and A. C. Helmholz of this laboratory for helpful guidance. This work was done under the auspices of the U. S. Atomic Energy Commission.

# FIGURE CAPTION

Fig. 1. Geometry of bremsstrahlung event and deuterium photoproton tracks. The intersection of the Plane of Emulsions, which is perpendicular to the path of the incident electron, with the Plane of Emission(O'RO) is along (OO'). The quadrants (AOB) in the Plane of Emulsions are centered on the two mutually perpendicular directions "$\perp$" and "$\parallel$". RO' is the extended path of the incident electron.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