in accord with prediction.[1]

A more complete description of this analysis including detailed predictions of the polarization and azimuthal correlations, together with excitation function and proton angular distribution data, will be presented in a later more extensive publication where compound-system direct-interaction interference effects will also be discussed.

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[1]Huby, Refai, and Satchler, Nuclear Phys. 9, 94 (1958).

[2]Biedenharn, Boyer, and Charpie, Phys. Rev. 88, 517 (1952); L. J. Gallaher and W. B. Cheston, Phys. Rev. 88, 684 (1952); G. R. Satchler and J. A. Spiers, Proc. Phys. Soc. (London) A65, 980 (1952).

[3]Allen, Collinge, Hird, Maglić, and Orman, Proc. Phys. Soc. (London) A69, 705 (1956).

[4]G. McCallum (private communication); G. McCallum and A. E. Litherland, Bull. Am. Phys. Soc. 5, 56 (1960).

ELECTRON PAIR PRODUCTION AT HIGH ENERGY IN A SILICON SINGLE CRYSTAL

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The cross sections for bremsstrahlung and electron pair production by high-energy primaries, interacting with the nuclei in a single crystal, have been calculated by Überall[1,2] in the Born approximation, and critically examined by Schiff.[3]

Experiments concerning the bremsstrahlung from single crystals have been performed by Panofsky and Saxena[4] and by Frisch and Olson.[5]

In this Letter we present the preliminary results of an experiment on electron pair production in a silicon single crystal using the Frascati 1-Gev electron synchrotron γ-ray beam.

The γ-ray beam from the electron synchrotron passes through a lead collimator, whose aperture is 0.8×10^{-3} radian; the beam, enclosed in a vacuum pipe, then passes through the gap of a broom magnet. The beam then enters the vacuum chamber of a pair spectrometer, at the entrance of which is located the silicon single crystal in the form of a plate 18 mm in diameter and 0.08 mm thickness (corresponding to 8.5 $\times10^{-4}$ radiation length). The crystal axis [100] is perpendicular to the plate within $\pm1°$; the crystal is used at room temperature.

The symmetrical electron pairs produced in the crystal by photons of central energy 910 Mev are selected by the pair spectrometer and detected by means of two plastic scintillators viewed by two 6810A phototubes placed outside the spectrometer at the distance of 1 m from the pole edge.

The signals are taken in prompt and delayed coincidence with a resolving time of 6×10^{-9} sec.

The momentum range accepted by the scintillators is 60 Mev/c.

The experiment consists in measuring the number $N(\theta)$ of symmetrical pairs per fixed number of monitor units as a function of the angle θ between the crystal axis [100] and the photon direction.

The energy in the beam is monitored by means of a Wilson quantameter.[6] We use 6×10^{10} equivalent quanta for each period of counting. The beam intensity after the extreme collimation used in this experiment is 3×10^{9} equivalent quanta/minute.

Under these conditions the number of prompt coincidences in each measurement is of the order of $N\simeq 50\,000$ counts of which about 3.5% are random coincidences.

In Figs. 1(a) and 1(b) are represented the experimental results relative to rotation of the single crystal about the horizontal and the vertical axis, respectively.

The points of the figures are given by

$$\xi(\theta)=[N(\theta)-N(0)]/N(0), \qquad (1)$$

where

$$N(\theta)=N_p(\theta)-[N_d(\theta)+(N_{bp}-N_{bd})], \qquad (2)$$

$N_p(\theta)$ and $N_d(\theta)$ being the number of prompt and delayed coincidences due to the single crystal and N_{bp}, N_{bd} the same quantities due to the background without crystal.

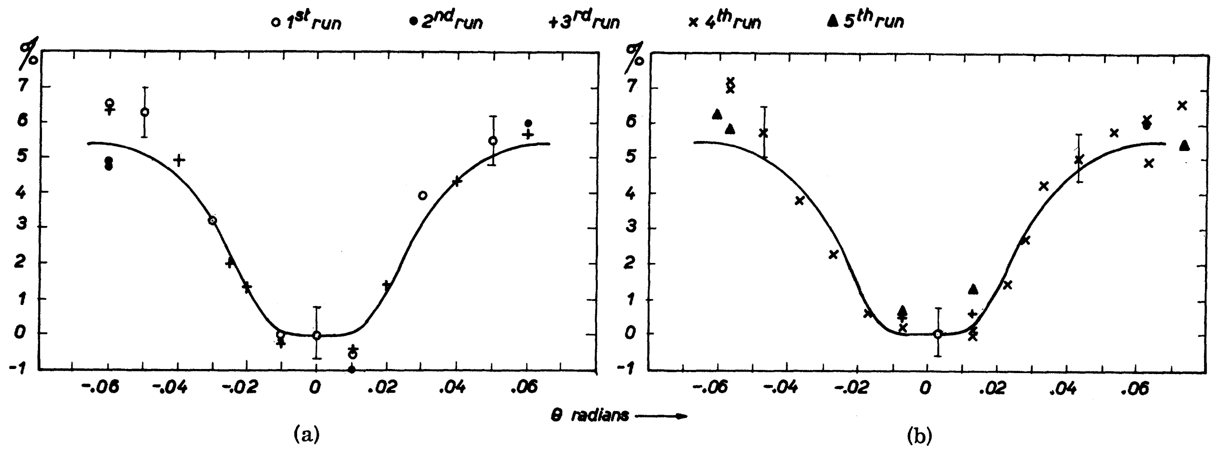

FIG. 1. Relative variation of the electron pair production cross section in silicon single crystals ($T=293°K$), versus θ (the angle between the γ-ray beam and the crystal axis [100]). The electron energy (for equipartition) is $E_\pm = 455 \pm 30$ Mev. The continuous curves of the figures represent $\eta(\theta)$ given by (3), while the experimental points represent $\xi(\theta)$ given by (1), expressed in percent. The statistical error of each measurement is $\pm 0.7\%$; this is also indicated for some points. The different runs are indicated by the legend in the figures. Figures 1(a) and 1(b) refer to rotation of the angle θ about the horizontal axis and vertical axis, respectively.

The continuous curves in Figs. 1(a) and 1(b) are given by

$$\eta(\theta) = \frac{[\Phi_n(\theta)+\Phi_e](1+\frac{1}{2}\theta^2) - [\Phi_n(0)+\Phi_e]}{\Phi_n(0)+\Phi_e}, \tag{3}$$

$\Phi_n(\theta)$ and Φ_e being quantities proportional to the pair production cross section in the field of the nucleus and electron, respectively. We have

$$\Phi_n(\theta) = [y^2+(1-y)^2][\psi_1{}^C + \psi_1{}^0(\theta/\delta)] + \tfrac{2}{3}y(1-y)[\psi_2{}^C + \psi_2{}^0(\theta/\delta)], \tag{4}$$

where $y = E_\pm/K = 0.5$, $E_\pm = 455$-Mev central energy (for equipartition) of the electrons, and $K = 910$-Mev central energy of the photons.

The functions $\psi_1{}^C$, $\psi_2{}^C$, $\psi_1{}^0$, $\psi_2{}^0$ are given by Überall[2] in the complete screening approximation; their numerical value has been calculated from the following data:

$Z = 14$ = atomic number;

$p = 5.42$ A = lattice spacing along the axis [100];

$T = 293°K$ = room temperature;

$\Theta_T = 645°K$ = Debye temperature[7];

$\delta = (mc^2/2K)[1/y(1-y)]$ = minimum momentum transferred to the nucleus in units of mc (mc^2 is the electron rest mass).

As far as the contribution of the atomic electrons is concerned, we obtain from the Wheeler-Lamb formula[8]:

$$\Phi_e = (1.33/Z)\Phi_{BH},$$

Φ_{BH} being proportional to the Bethe-Heitler pair production cross section[9] in the field of the nucleus. We then take Φ_e as given by a noncrystalline target.

In (3) the factor $(1+\frac{1}{2}\theta^2)$ is considered to take into account the variation of the number of pairs with the variation of the effective crystal thickness due to the rotation of the angle θ (< 0.07 radian).

As we can see, the experimental results are in good agreement with the Überall calculation. Measurements concerning dependence of the effect on the photon energy are also in progress.

[1]H. Überall, Phys. Rev. 103, 1055 (1956).
[2]H. Überall, Phys. Rev. 107, 223 (1957).
[3]L. I. Schiff, Phys. Rev. (to be published).
[4]W. K. H. Panofsky and A. N. S. Saxena, Phys. Rev. Letters 2, 219 (1959).
[5]O. R. Frisch and D. H. Olson, Phys. Rev. Letters 3, 141 (1959).
[6]R. R. Wilson, Nuclear Instr. 1, 101 (1957).
[7]P. Flubacher, A. J. Leadbetter, and J. A. Morrison, Phil. Mag. 4, 273 (1959).
[8]J. A. Wheeler and W. E. Lamb, Phys. Rev. 55, 858 (1939).
[9]H. Bethe and W. Heitler, Proc. Roy. Soc. London A146, 83 (1943).