with

$$\alpha = -1/3 \text{ for } 1_+ \to 2_+ \to 0_+,$$
$$= 1 \text{ for } 2_+ \to 2_+ \to 0_+,$$
$$= 1/7 \text{ for } 3_+ \to 2_+ \to 0_+,$$

and

$$X = (|C_T|^2 - |C_A|^2)/(C_T|^2 + |C_A|^2).$$

Here we assume $C_T = -C_T'$, $C_A = C_A'$, and $M_F = 0$. The last assumption comes from the selection rule of the isotopic spin. Therefore, if the decay scheme is $2_+ \to 2_+ \to 0_+$, this experiment is a more sensitive determination of $|C_T/C_A|^2$ than the electron-neutrino angular correlations of He^6 and Ne^{23}, because the anisotropy for the former is one while that of the latter is only one-third. If M_F is not equal to zero, αX for $2_+ \to 2_+ \to 0_+$ should be replaced by $[(-|C_S|^2+|C_V|^2)M_F^2+(|C_T|^2-|C_A|^2)M_{GT}^2]/[(|C_S|^2+|C_V|^2)M_F^2+(|C_T|^2+|C_A|^2)M_{GT}^2]$. In the case of $2_+ \to 2_+ \to 0_+$, Eq. (3) coincides with Eq. (1) in reference 4. Since the value of $d = \alpha X$ is large and negative with certain experimental error,[4] we can conclude not only that the axial vector is predominant, but also that the spin of Li^8 is 2+ and not 1+ or 3+.

Formulas for more complicated decay schemes involving alpha, beta, and gamma transitions will be derived easily from several formulas in reference 1 with the rule in reference 3.

The author would like to express his sincere thanks to Professor K. H. Lauterjung for a valuable discussion at Columbia University.

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[2] M. Morita, Nuclear Phys. 6, 132 (1958).

[3] The beta-alpha directional correlation for the forbidden transitions was given by M. Morita, Progr. Theoret. Phys. Japan 15, 445 (1956), especially p. 456, and M. Morita and R. S. Morita, Phys Rev. 110, 461 (1958), especially p. 464. That for the allowed beta transitions was given by M. Morita and M. Yamada, Progr. Theoret. Phys. Japan 13, 114 (1955), taning into account higher order corrections.

[4] Lauterjung, Schimmer, and Maier-Leibnitz, a post-deadline paper presented at the Ithaca Meeting of the American Physical Society, 1958, and Z. Physik (to be published).

LARGE-ANGLE ELECTRON PAIR PRODUCTION FROM HYDROGEN*

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In this experiment, 70-Mev positrons produced in a liquid hydrogen target are detected at 90° to a 137-Mev peak energy bremsstrahlung beam made by passing the electron beam from the Stanford Mark III linear accelerator through a tantalum radiator. Figure 1 shows the two main Feynman diagrams for the process. It is important to note here that uncertainties in the pair-production calculation due to the influence of proton structure on the rescattering of the virtual intermediate lepton can be uniquely removed from the problem. The results of the electron-proton scattering experiments can be used to predict the effect of the proton in pair production. The e-p scattering form factors depend only on the four-momentum transfer and can be introduced phenomenologically into the pair-production calculation. This leaves the electrodynamics as the only source of error in the calculation. A complete calculation of the pair production cross section from protons with form factors including radiative corrections and Compton terms has been carried out by Bjorken, Drell, and Frautschi.[1]

In Fig. 1(a) a photon of momentum k produces a pair, and a positron of momentum p_+ comes directly out. For the conditions of this experiment the four-momentum transfer q at the pair vertex is given by $q^2 = 2kp_+$. In Fig. 1(b) the electron comes directly out and q is of the order of m_ec. The mean value of q for diagram 1(a)

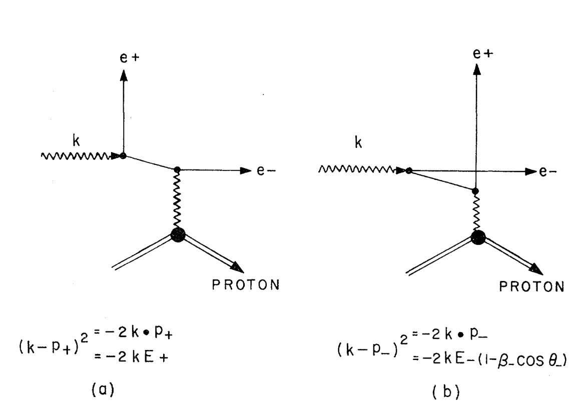

FIG. 1. Principal Feyman diagrams for pair production from a proton.

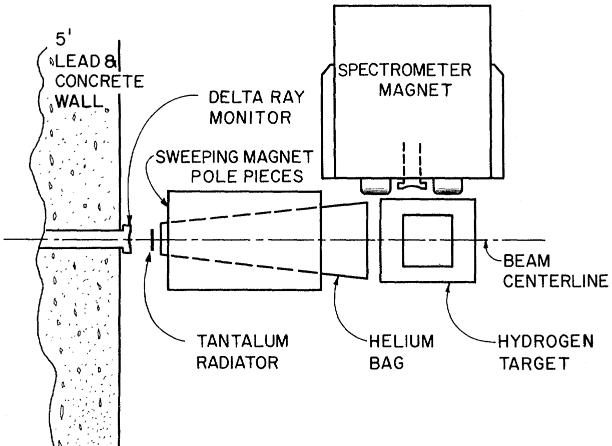

FIG. 2. Top view of experimental arrangement.

is ~ 115 Mev/c, making the experiment useful as a test of the small-distance (large-momentum-transfer) behavior of quantum electrodynamics. Diagram 1(a) contributes about 30% to the cross section.

Figure 2 shows a top view of the experimental setup. The energy-analyzed electron beam passes through a delta-ray monitor, a 0.1-radiation-length tantalum converter, and a magnet which sweeps charged particles from the beam, and then hits a Styrofoam liquid hydrogen target. The positrons are momentum-analyzed by a double-focusing magnetic spectrometer and detected by two Plexiglas Cerenkov counters in coincidence.

The main source of background in the experiment comes from events wherein a pair is produced either in the target walls or in the hydrogen, and the positron is then scattered into the spectrometer by a nucleus other than the one which produced it. About 50% of the counting rate comes from this source. The data were normalized by measuring the yield of elastically scattered electrons from the liquid hydrogen target using exactly the same setup as was used in measuring the positron yield, and using the measurements of Hofstadter and co-workers[2] of the proton form factor in the Rosenbluth cross section to determine the normalization factor.

The result to date is that the ratio of the experiment to the prediction of Bjorken, Drell, and Frautschi is 0.96 ± 0.14 where most of the error comes from counting statistics. The question now is, What does it mean? There is no good way to characterize a deviation from the point interaction theory of quantum electrodynamics without having constructed another theory to replace it. Lacking a theory, all one can do is make a guess. If the electron propagator is modified,[3]

$$(p^2-m_0^2c^2)^{-1} \to \{(p^2-m_0^2c^2)^{-1} - [p^2-m_0^2c^2-(\hbar^2/\Lambda_e)]^{-1}\},$$

one obtains a form factor for the electrodynamic interaction that looks like $F^2(q^2) = 1 - 2q^2\Lambda_e^2 + \ldots$.

This expression has no fundamental theoretical significance: it is merely a way to characterize a deviation from the point interaction theory. Figure 3 shows a plot of the cutoff distance *vs* the ratio of the yield predicted by a theory with cutoff to that by the point-interaction theory. It has been assumed that diagram 1(b), which contributes 70% of the cross section but involves only a small momentum transfer, will agree with the point theory. The result of this experiment is indicated on Fig. 3. The experimental error (standard deviation) intersects the curve at a value of Λ_e of about 0.9 fermi. This might be an upper limit to the distance at which the present theory of quantum electrodynamics breaks down.

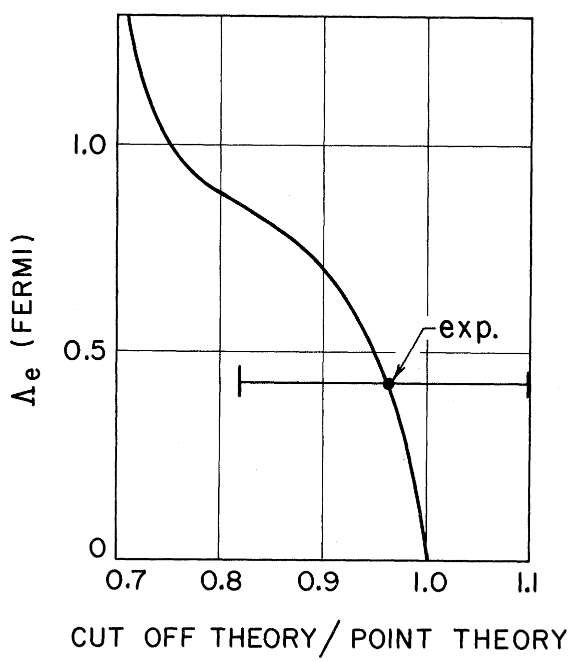

FIG. 3. Cutoff parameter as a function of the ratio of the predicted yield of a cutoff theory to that of the point interaction theory for the conditions of this experiment.

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published).

[2] Hofstadter, Bumiller, and Yearian, Revs. Modern Phys. (to be published).

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POLARIZATION OF CONVERSION ELECTRONS FOLLOWING β DECAY

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The experiments (aside from the use of polarized sources) which serve to verify breakdown of parity and charge conjugation invariance in the β interaction are largely of two types: measurement of the longitudinal polarization of the β particles, and of the circular polarization of γ radiation following the β transition.[1] In addition to the demonstration of P and C breakdown, these experiments are useful as a method of testing the validity of the two-component theory. In addition, variations of this method, involving observation of the recoil could, in principle, provide information relevant to the β interaction.[2] The β-particle polarization analysis entails conversion of longitudinal to transverse polarization and the consequent loss of intensity. The β-circularly polarized γ correlation is similarly handicapped by the circumstance the only two (approximately) of the Fe electrons contribute to the magnetization of the analyzing field.

In this communication we discuss an alternative procedure which may offer some advantages particularly for β transitions followed by moderately low-energy conversion electrons. This involves the measurement of the polarization of the conversion electrons in coincidence with the β. The primary point of interest here is that these electrons are partially transversely polarized and that in many cases the polarization is fairly large. The existence of a transverse polarization in an allowed transition is made possible by the coincidence observation, defining a plane in which the polarization lies, and by the finite rest mass of the conversion electrons. These are to be understood as necessary conditions.

The (unnormalized) population of the nuclear state resulting from β decay referred to the direction of the β particle is

$$p_M = 1 + bM. \tag{1}$$

The present results apply to any process wherein a polarization of the form (1) exists.[3] If $\vec{n}'$ is a unit vector defining the direction of the polarization in the rest system, the polarization in the laboratory frame is

$$P_n = (\Psi, S_n\Psi)/(\Psi,\Psi), \tag{2}$$

where[4]

$$S_n = i\gamma_5\gamma_\mu n_\mu = -\beta\,\vec{\sigma}\cdot\vec{n} - \beta\gamma_5\,\vec{n}\cdot\vec{p}/E\,. \tag{3}$$

Here Ψ is the modified plane wave for the conversion,[5] n_μ is obtained from $\vec{n}'$ by a Lorentz transformation and $\vec{p}$, E are the momentum, total energy of the conversion electron (m, c =1). For transverse polarization $S_n = -\beta\vec{\sigma}\cdot\vec{n}$ and $\vec{n} = \vec{r}_1 \times(\vec{e}\times\vec{r}_1)/\sin\theta$ with $\vec{r}_1$ a unit vector along $\vec{p}$, $\vec{e}$ a unit vector in the direction of the β, and θ the angle between these two directions. For longitudinal polarization $\vec{n}p = E\vec{p}$, and S_n is equivalent to $\vec{\sigma}\cdot\vec{p}/p = \vec{\sigma}\cdot\vec{r}_1$.

The decay chain is defined by $J_1(\beta)\ J(c.e.)\ J_2$. The multipolarity of the conversion link is most generally a magnetic L - electric L' mixture and $L' = L\pm 1$ (rigorously). With these definitions the polarization can be written as ($q = \parallel$ or $\perp$)

$$P_q = \frac{P_q(ML) + \bar{\delta}^2 P_q(EL') + 2\bar{\delta}\,P_q(ML,EL')}{1+\bar{\delta}^2}, \tag{4}$$

where $\bar{\delta}^2$ is the ratio of intensities of EL' to ML conversion electrons:

$$\bar{\delta} = \delta(\alpha_{L'}/\beta_L)^{\frac{1}{2}}, \tag{5}$$

where δ is the parameter[6] whose square gives the relative γ-ray intensities EL' to ML and $\alpha_{L'}$ and β_L are, respectively, the electric and magnetic conversion coefficients for pure multipoles.

Then for the pure multipole longitudinal polarization one finds, for an initial $s_{\frac{1}{2}}$ electron,

$$P_\parallel(ML) = \tfrac{1}{2}bN\cos\theta \times \frac{|Q_{L+1}\exp(i\eta_{L+1}) - Q_{-L}\exp(i\eta_{-L})|^2}{(L+1)|Q_{L+1}|^2 + L|Q_{-L}|^2}, \tag{6}$$

$$N = \frac{L(L+1) + J(J+1) - J_2(J_2+1)}{2L+1}. \tag{6a}$$

η_{κ} ($\kappa = L+1, -L$) are the (Coulomb) phase shifts and the Q_κ are defined in reference 5. For co-