tivistic values of the velocities v_π. The maximum of the angular distribution for this process lies in the plane perpendicular to the line of impact.

The corresponding differential cross-sections in the center-of-mass system are:

$$d\sigma(e^+ + e^- \to \mu^+ + \mu^-) = F_\mu^2 F_e^2 \frac{r_0^2}{16\gamma^2}\left\{1 + \left(\frac{\mu}{E}\right)^2 + \frac{p_\mu^2}{E^2}\cos^2\vartheta\right\} d\Omega,$$

$$d\sigma(e^+ + e^- \to \pi^+ + \pi^-) = F_\pi^2 F_e^2 \frac{r_0^2}{32\gamma^2}\frac{p_\pi^3}{E^3}\sin^2\vartheta\, d\Omega,$$

$$d\sigma(\mu^+ + \mu^- \to e^+ + e^-)$$

$$= F_\mu^2 F_e^2 \frac{r_0^2}{8\gamma^2}\frac{1}{v_{\mathrm{rel}}}\left\{1 + \left(\frac{\mu}{E}\right)^2 + \frac{p_\mu^2}{E^2}\cos^2\vartheta\right\} d\Omega,$$

$$d\sigma(\pi^+ + \pi^- \to e^+ + e^-) = F_\pi^2 F_e^2 \frac{r_0^2}{\gamma^2}\frac{v_\pi}{32}\sin^2\vartheta\, d\Omega,$$

$r_0 = 2.8 \times 10^{-13}$ cm; $\gamma = E/m$; μ and m are the masses of meson and electron; E is the energy of a particle; $v_{rel} = 2v_\mu$ is the relative velocity of the mesons in the beam; v_π, p_π are the velocity and momentum of a π meson; ϑ is the angle between the colliding and emerging particles; $q^2 = -4E^2$; $\hbar = c = 1$.

In the limit v_π, $v_\mu \approx c$ we get for the cross sections integrated over the angles

$$\sigma(e^+ + e^- \to \mu^+ + \mu^-) / \sigma(e^+ + e^- \to \pi^+ + \pi^-) = 4F_\mu^2 / F_\pi^2.$$

We note that the probability for decay of the bound system $\mu^+\mu^-$ into e^+e^- is given by

$$w = |\psi(0)|^2 (v_{\mathrm{rel}}\sigma)_{v_{\mathrm{rel}}=0} = 4 \cdot 10^{11}\ \mathrm{sec}^{-1} \approx w_{\mu^+ + \mu^- \to 2\gamma}.$$

Because of the small velocities v_π the corresponding probability $w(\pi^+ + \pi^- \to e^+ + e^-)$ is vanishingly small.

If for an estimate we set F = 1 for all particles, the largest values of the total cross-sections are of the order $10^{-30} - 10^{-31}$ cm^2.

Finally we note that if in the process $\pi + N \to N + e^+ + e^-$ the angular characteristics of the pair do not differ strongly from those for the process $\pi^+ + \pi^- \to e^+ + e^-$, then it may be possible to distinguish it experimentally, in spite of the very large background of pairs from the decay $\pi^0 \to e^+ + e^- + \gamma$.

In conclusion I express my gratitude to I. Ya. Pomeranchuk, I. L. Rozental', and E. L. Feĭnberg for fruitful discussions.

*It is possible that this bears a relation to the fact that the average multiplicity of the mesons from the annihilation of antinucleons is somewhat larger than the value given by the statistical theory with $R = 1.4 \times 10^{-13}$ cm.[1]

†The production of meson pairs by the annihilation of positrons was first discussed by I. Ya. Pomeranchuk and V. B. Beresterskiĭ.[2] In their paper a factor 4 is omitted from the expression for $\sigma(e^+ + e^- \to \mu^+ + \mu^-)$.

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ON PAIR PRODUCTION BY THE COLLISION OF TWO CIRCULARLY POLARIZED GAMMA-RAY QUANTA

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THE present note presents the results of a calculation of the electron-positron pair production in the collision of two circularly polarized γ-ray quanta, with account taken of the longitudinal polarization of the pair particles. An examination of this problem is of definite interest, since beams of γ-rays of high energy are now available ($E_\gamma \sim 0.5 - 1$ Bev).[1,2] The circularly polarized γ-rays are produced in the deceleration radiation of longitudinally polarized high-energy electrons,[3] and also in nuclear β-decay processes.[4]

The equation that describes the process $\gamma + \gamma' \to e^- + e^+$ is of the form

$$D\psi_2 = \{U(\varkappa) D^{-1} U(\varkappa') + U(\varkappa') D^{-1} U(\varkappa)\} \psi_0, \qquad (1)$$

where ψ_0 is the wave function of the initial state and ψ_2 that of the final state, D is the Dirac operator, and $U(\kappa)$ and $U(\kappa')$ are the operators for the interaction of electrons with the quanta having the momenta $\hbar\boldsymbol{\kappa}$ and $\hbar\boldsymbol{\kappa}'$. The polarization vectors $\mathbf{a}_l \equiv \mathbf{a}_l(\boldsymbol{\kappa})$ and $\mathbf{a}'_{l'} \equiv \mathbf{a}_{l'}(\boldsymbol{\kappa}')$ of the quanta are taken in the form[5,6]

$$\mathbf{a}_l = (\boldsymbol{\beta} + il[\boldsymbol{\varkappa}^0\boldsymbol{\beta}]) / \sqrt{2}, \quad \mathbf{a}'_{l'} = (\boldsymbol{\beta} + il'[\boldsymbol{\varkappa}'^0\boldsymbol{\beta}]) / \sqrt{2}. \quad (2)$$

Here $\boldsymbol{\beta}$ is a unit vector perpendicular to the momenta of the γ-ray quanta, $\boldsymbol{\kappa}^0 = \boldsymbol{\kappa}/\kappa$, and $\boldsymbol{\kappa}'^0 = \boldsymbol{\kappa}'/\kappa'$. In the case $l = l' = 1$ we have quanta with right-handed polarization (the spins of the quanta are in the direction of motion), and for $l = l' = -1$ we have left-handed polarization (spin opposite to motion). Using Eqs. (21) and (15) of reference 5 for the total cross sections for electron-positron pair production, with inclusion of the spin states of the particles, we find

$$\sigma = (\pi/8)(e^2/\hbar c)^2 \{(1+s_-s_+)(1+ll')F_1 + (1-s_-s_+)(1-ll')F_2 - (1+s_-s_+)F_3 + s_-s_+(1-ll')F_4 + (s_-+s_+)(l+l')F_5\}, \quad (3)$$

where

$$F_1 = 2k/K^3 + {}^1/_2(k^2/K^4 - 1/K^2)q,$$

$$F_2 = -k/K^3 + {}^1/_2(1/K^2 + k^2/K^4)q,$$

$$F_3 = k(3k_0^2 + 2k^2)/K^5 + (k^4/2K^6 + k^2/K^4 - 3/2K^2)q,$$

$$F_4 = (3k_0^2 + 2k^2)/kK^3 + (k^2/2K^4 + 1/K^2 - 3/2k^2)q,$$

$$F_5 = k^2/K^4 + qkk_0^2/2K^5,$$

$$q = \ln(K+k)/(K-k), \quad K = \sqrt{k^2 + k_0^2}.$$

Here $p_- = p_+ = \hbar k$ is the momentum of the electron (positron); $k_0 = m_0c/\hbar$ corresponds to the rest mass of the electron; $s_\pm = \pm 1$, with $s_- = 1$ (or $s_+ = 1$) for the state of the electron (or positron) with right-handed polarization, and $s_- = -1$ (or $s_+ = -1$) for the state of left-handed polarization.

From Eq. (3) it follows that: 1) in the collision of two right-handed ($l = l' = 1$) or two left-handed ($l = l' = -1$) quanta there can be production of an electron and positron with right-handed ($s_- = s_+ = 1$) or with left-handed ($s_- = s_+ = -1$) longitudinal polarization, the probabilities being different for the two polarizations. In such collisions, however, there cannot be production of an electron with right-handed ($s_- = 1$) and a positron with left-handed ($s_+ = -1$) polarization, or vice versa ($s_- = -1$, $s_+ = 1$), since the cross-section σ for this is zero. 2) In the collision of two quanta, one with right-handed ($l = 1$) and the other with left-handed ($l = -1$) polarization (or vice versa, $l = -1$, $l' = 1$) there can be production of: a) an electron and positron with right-handed ($s_- = s_+ = 1$) or with left-handed ($s_- = s_+ = -1$) polarization, the probabilities for the two results being equal; or b) an electron with right-handed ($s_- = 1$) and a positron with left-handed ($s_+ = -1$) polarization, or vice versa ($s_- = -1$, $s_+ = 1$), with equal probabilities.

In the ultrarelativistic case (κ and $k \gg K_0$) the expression (3) goes over into the following:

$$\sigma = \frac{\pi}{4}\left(\frac{e^2}{c\hbar}\right)^2 \frac{1}{k^2}\Big\{(1+s_-s_+)ll' + (1-ll')\Big[s_-s_+ - (1-s_-s_+)\Big(\frac{1}{2} - \ln\frac{2k}{k_0}\Big)\Big] + \frac{1}{2}(s_-+s_+)(l+l')\Big\}. \quad (4)$$

The analysis given above can also be carried through for Eq. (4).

By averaging Eq. (3) over the polarizations of the quanta and summing over the spin states of the electron and positron, we get the cross-section for pair production by the collision of two unpolarized quanta:

$$\sigma_0 = \frac{\pi}{2}\left(\frac{e^2}{\hbar c}\right)^2 \times \left\{\frac{k}{K^3} - \frac{k(2k^2+3k_0^2)}{K^5} + \left(\frac{3}{2K^2} - \frac{k^4}{2K^6}\right)\ln\frac{K+k}{K-k}\right\}. \quad (5)$$

In conclusion we express our gratitude to Professor A. A. Sokolov for his constant interest in this work and for valuable comments.

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ON THE MECHANISM OF THE LEPTONIC DECAY OF HYPERONS

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THE best confirmation of the universal V-A interaction[1] is now coming from nuclear β-decay experiments and from the study of the branching ratios for the different decay modes of the π meson.[2] This interaction also explains to a certain degree the equality of the probabilities for the K_{e3} and $K_{\mu 3}$ decays and the absence of the K_{e2} decay.[3] However, in the calculation of the leptonic decay rates of the Σ^- and Λ^0 hyperons,[4] (which, admittedly, were obtained without account of the form factor and the renormalization constant), the V-A interaction leads to values for these