tensor over the time keeps the energy dependence linear in the expression for the average force.

The use of expression (10) for the force in the equation of the elastic oscillations of the target (2) makes it possible to determine the amplitude of the acoustic oscillations generated by relativistic particles in a solid. According to (10), the amplitude of the acoustic oscillations increases linearly with the energy of the incident particles. The total force due to passage of a beam of charge particles in proportional to the number of particles in the pulse, as is observed in experiment [1 - 2].

The expression (10) obtained for the force exerted by the passing particle on the target, at a fixed target thickness L, can exceed, with increasing energy, the force due to the ionization loss [6]

$$F_{\text{ion}} = \frac{4\pi e^4 N_e}{mv^2} \frac{L}{(a\kappa)^4} \ln \frac{m^3}{\pi N_e e^2} \quad . \tag{11}$$

The linear energy dependence of the acoustic-oscillation amplitude makes it possible to use the indicated mechanism to register the energy of high-energy particles.

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SPECTRUM OF PHOTONS EMITTED AT LARGE ANGLES IN e^+e^- COLLISIONS AT HIGH ENERGIES

V.S. Fadin and V.A. Khoze
B.P. Konstantinov Institute of Nuclear Physics, USSR Academy of Sciences
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In view of reported designs of installations with colliding beams of high-energy leptons (up to 10^2 - 10^3 GeV; see, e.g., [1, 2]), possible physical experiments with such accelerators have been under discussion recently (e.g., [3]).

Great interest attaches here to the possibility of investigating weak interactions by measuring the process

$$e^+e^- \rightarrow \nu\bar{\nu}\gamma \tag{1}$$

at large photon emission angles (e.g., [4]).

However, the question of identifying this process is quite complicated, since only one photon is registered in the final state. It is therefore necessary to examine in detail the background processes, when all the final particles with the exception of the photons are not registered for some reason. In addition, it may turn out that the apparatus transmission required to register such rare events as (1), and also a number of other processes discussed in [3], may be attained only in the regime of rare collisions of bunches with high particle densities [2] (when everything takes place within a time $\sim 10^{-9}$ sec). This makes the background situation much worse, and such processes as photon emission (even at low frequencies of the order of $\sim m_e$) lead to a number of additional difficulties in the registration of the investigated physical processes. Therefore knowledge of the cross sections of such background processes is essential in the analysis of the background situation in concrete physical experiments with such installations. As is well known, the cross sections of such quantum-electrodynamics processes as $e^+e^- \rightarrow 2\gamma$, $e^+e^- \rightarrow e^+e^-\gamma$, $e^+e^- \rightarrow 3\gamma$, $e^+e^- \rightarrow e^+e^-\gamma\gamma$, etc. decrease like $1/s$ with increasing $s = (2E)^2$ at high electron energies E and at large photon-emission angles θ_k ($\sin\theta_k \sim 1$). At large values of s the photon emission process in electroproduction of the e^+e^- pair,

$$e^+e^- \rightarrow e^+e^-e^+e^-\gamma , \tag{2}$$

becomes very important (and in a number of cases, decisive), since the cross section of this process is determined only by the transverse momentum K of the emitted quantum and increases with increasing s (like $\ln^2[s/m_e^2]$). In the lower order (α^5) of perturbation theory, the main contribution to the cross section of the process (2) is made by the "block" diagram (see the figure). This contribution can be calculated in the doubly-logarithmic approximation ($\sim\ln^2(s/m_e^2)$ with the aid of the Weizsacker-Williams (WW) method applied to both virtual photons. In the WW approximation, the cross section of the process (2) in the c.m.s. (at a quantum frequency $\omega \ll E$) is written in the form

$$d\sigma = \frac{\alpha^2}{\pi^2} L^2 \int \frac{d\omega_1}{\omega_1} \frac{d\omega_2}{\omega_2} d\sigma_{\gamma\gamma}(\omega_1, \omega_2, \omega, \theta_k), \tag{3}$$

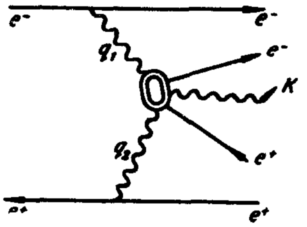
where $L = \ln(s/m_e^2)$, $\omega_{1,2}$ are the frequencies of the virtual photons, and $d\sigma_{\gamma\gamma}$ is the cross section of the photoprocess $\gamma\gamma \rightarrow e^+e^-\gamma$.

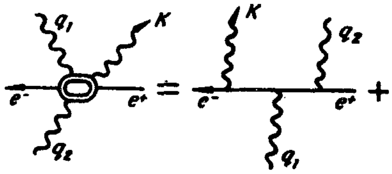
We consider first the case $\omega \ll m_e$, when the cross section $d\sigma_{\gamma\gamma}$ can be obtained by the classical-current method (e.g., [5]). Integrating in (3) with respect to ω_1 and ω_2 at fixed ω and θ_k($\sin\theta_k \sim 1$), we obtain

$$d\sigma = \frac{\alpha^5}{m_e^2} \frac{1}{2\pi^3} L^2 \frac{1}{\sin^2\theta_k} \left[\frac{128\pi^2}{105} - 6\right] \frac{d\omega}{\omega} d\Omega_k . \tag{4}$$

Comparing (4) with the corresponding formulas for the angular distributions of the soft photons in the processes $e^+e^- \rightarrow e^+e^-\gamma$, $e^+e^- \rightarrow 3\gamma$, etc., we can readily see that at $\theta_k = 90°$, starting with an electron energy $E \gtrsim 100$ MeV, the process (2) becomes the main source of photons of energy $\omega < m_e$.

The expression for the angular distribution of the photons at $\sin\theta_k \sim 1$ in the process (2) can be obtained in analytic form also in the case when $E \gg K_\perp = \omega\sin\theta_k \gg m_e$.



where  + all photon-line permutations

To find the cross section $d\sigma_{\gamma\gamma}$, we can use the results of [6] and, carrying out rather cumbersome calculations, we obtain

$$d\sigma = \frac{4\alpha^5}{\pi^3 (K_\perp)^4} L^2 \left[\frac{7}{12} L_0 - C\right] \frac{d^3k}{\omega},$$

$$C = \frac{1565}{216} - 6\zeta(3) \approx 0{,}03, \quad L_0 = \ln \frac{K_\perp^2}{m_e^2}.$$

Formula (5) is valid at $L \gg L_0$; on the other hand, if $L \sim L_0$ (but $s \gg K_\perp^2$) then we get

$$d\sigma = \frac{4\alpha^5}{\pi^3 (K_\perp)^4} L \left[L - \frac{1}{3} L_0\right] \frac{7}{12} L_0 \frac{d^3k}{\omega}. \qquad (6)$$

It follows from (5) and (6) that at $\sin\theta_k \sim 1$ the cross section $d\sigma$ exceeds the cross section of the process $e^+e^- \to e^+e^-\gamma$ at values of $K_\perp$ up to $K_\perp \lesssim 2 \times 10^{-3} EL$. At E = 100 GeV and $\theta_k = 90°$, $d\sigma$ becomes comparable with the cross section of the process (1) at $\omega \sim 10$ GeV, so that to reduce the background from the process (2) when (1) is registered it is necessary to choose a photon-detection threshold substantially above this value. We note, however, that the main contribution to (5) and (6) is determined by the kinematics, when at least one of the charged particles is emitted at a large angle. Registration of this particle would make it possible to separate the process (2) from (1).

Let us also make a few remarks concerning the angular distributions of the photons (at $\sin\theta_k \sim 1$) connected with the processes of hadron production in e^+e^- collisions.

Since the cross section for the production of a C-odd hadron system in one-photon annihilation of an e^+e^- pair apparently decreases like α^2/s with increasing s (e.g., [7]), the angular distribution of the photons produced in the decay of this system should behave similarly.

In the doubly-logarithmic approximation it is easy to obtain an expression for the angular distribution of the photons produced in the electroproduction of C-even resonances (e.g., [8]) $e^+e^- \to e^+e^-R$, where $R = \pi^0, \eta, x^0, \varepsilon$, etc., integrated over the photon frequencies.

At $s \gg M_R^2$ we obtain for resonances with zero spin

$$d\sigma_R = \frac{8\alpha^2}{\pi \sin^2\theta_k} \frac{\Gamma_{\gamma\gamma}}{M_R^3} \left(\frac{\Gamma_{\gamma\gamma}}{\Gamma_{tot}}\right) L^2 d\Omega_k, \qquad (7)$$

where $\Gamma_{\gamma\gamma}$ is the partial width of the decay $R \to \gamma\gamma$, and M_R is the resonance mass. The main contribution to (7) is made by the frequencies $\omega \sim \omega_{max} = M_R/2\sin\theta_k$.

As to the photons produced in the decays of a C-even hadron system resulting from the reaction $e^+e^- \to e^+e^-$ + hadrons [9], in this case $\langle K_\perp \rangle$ does not exceed several hundred MeV if, as is usually assumed, the cross sections of the hadronic processes have an exponential dependence [$\sim \exp(-bP_\perp)$ on the transverse momentum $P_\perp$ of the produced hadron.

For $P_\perp \gg \mu_\pi$, however, the situation is at present uncertain, in connection with the experimental data recently obtained at CERN (ISR) in the measurement of the cross section of the reaction $pp \to \pi^0 + X$ at large $P_\perp$ [10]. It may turn out that the dependence of the cross sections of the inclusive hadronic processes on P will be not exponential but power-law [11], and that in the range of values $E \gg K_\perp \gg \mu_\pi$ the two-photon mechanism of hadron production may in principle become a rather substantial source of photons emitted at large angles in e^+e^- collisions.

A detailed exposition of the group of questions considered here will be published.

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SUM RULES IN ELECTRON SCATTERING BY NUCLEI

V.D. Efros
I.V. Kurchatov Institute of Atomic Energy
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New sum rules are formulated for the scattering of electrons by nuclei. Some of these sum rules are independent of the model in the single-particle approximation for the nuclear current. Such sum rules are attractive for an experimental determination of the contributions of the non-single-particle currents.

1. Let $q_\mu = (\vec{q}, i\omega)$ be the 4-momentum transferred by the electron to the nucleus, and let θ and $\varepsilon_{i(f)}$ be the electron scattering angle and its initial