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ЛАБОРАТОРИЯ ТЕОРЕТИЧЕСКОЙ ФИЗИКИ

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Accelerators with colliding e^+e^- and e^-e^- beams which are now being constructed will give an interesting possibility /1,2/ of measuring the absorptive part of the forward $\gamma\gamma$-scattering amplitude (which is due to the production) as a function of S and of the photon "masses" q_i^2 . This possibility is based on the fact that for the beam energies E higher than 1-2 GeV the principal mechanism of the hadron production is the "condensation" of photons (Fig. 1). The cross section for this process increases as $\ln E^2/S$ with the growth of E and at fixed S . The information on $\gamma\gamma$-scattering can be extracted from this process by the same method as the information on γp-scattering from the deep inelastic ep-process. What kind of behaviour for the $\gamma\gamma$-cross section could be expected when S , q_1^2 and q_2^2 are large?

The absorptive part of the $\gamma\gamma$-scattering amplitude $W^{\mu\nu\mu'\nu'}$ contains 8 invariant functions /2,3/

$$W^{\mu\nu\mu'\nu'} = G^{\mu\mu'} G^{\nu\nu'} W_{TT} + G^{\mu\mu'} R_{22}^{\nu\nu'} W_{TS} + G^{\nu\nu'} R_{11}^{\mu\mu'} W_{ST} +$$

$$+ R_{11}^{\mu\mu'} R_{22}^{\nu\nu'} W_{SS} + \frac{1}{2} [G^{\mu\nu} G^{\mu'\nu'} + G^{\mu\nu'} G^{\mu'\nu} - G^{\mu\mu'} G^{\nu\nu'}] W_{TT}^{\tau} + \qquad (1)$$

$$+[G^{\mu\nu}R_{12}^{\mu'\nu'}+G^{\mu\nu'}R_{12}^{\mu'\nu}+(\mu\nu\to\mu'\nu')]W_{TS}^{\tau}+$$

$$+[G^{\mu\nu}G^{\mu'\nu'}-G^{\mu\nu'}G^{\mu'\nu}]W_{TT}^{a}+[G^{\mu\nu}R_{12}^{\mu'\nu'}-G^{\mu\nu'}R_{12}^{\mu'\nu}-(\mu\nu\to\mu'\nu')]W_{TS}^{\tau a}, \qquad (1)$$

where

$$G^{\mu\nu}=-g^{\mu\nu}+\frac{(q_1q_2)(q_1^{\mu}q_2^{\nu}+q_1^{\nu}q_2^{\mu})-q_1^2q_2^{\mu}q_2^{\nu}-q_2^2q_1^{\mu}q_1^{\nu}}{(q_1q_2)^2-q_1^2q_2^2} \qquad (2a)$$

is the metric tensor of the space orthogonal to the photon momenta q_i,

$$R_{ij}^{\mu\nu}=\frac{k_i^{\mu}k_j^{\nu}}{(k_ik_j)};\ k_1=q_2-q_1\frac{(q_1q_2)}{q_1^2};\ k_2=q_1-q_2\frac{(q_1q_2)}{q_2^2} \qquad (2b)$$

and W are functions of S, q_1^2 and q_2^2 free of kinematical singularities. The first four of them are simply connected with the $\gamma\gamma$-cross section Gab (a = S or T for the scalar and transversal photons correspondingly)

$$W_{ab}=2\sqrt{(q_1q_2)^2-q_1^2q_2^2}\,G_{ab}. \qquad (3)$$

The last four functions are not positive definite and must vanish when $S\to\infty$ in comparison with the first four ones /3,5/. The expression for the differential cross section of the process on Fig. 1 in terms of W's is found in /2/.

As compared with the γp -scattering here there is a new possibility of investigating the dependence of W_{ab} on S, q_1^2 and q_2^2 in the limit of the Bjorken type

$$S\to\infty,\ |q_1^2|\to\infty,\ S\gg -q_1^2>0,\ (2\sqrt{(q_1q_2)^2-q_1^2q_2^2}\approx S). \qquad (4)$$

We are interested in the hadron part of the four amplitudes $W_{ab}^{(h)}$ in the Regge region.

Let us assume that the behaviour in this region is defined by the Regge poles only /4/, i.e. the contribution of the cuts and standing singularities are nonessential. Then, the factorization theorem is valid for the contribution of each of the Regge trajectories a to the cross section

$$W_{ab}^{a}=S\sigma_{ab}^{a}(S,q_1,q_2)=S\frac{\sigma_{aa}^{\gamma p}(S,q_1^2)\sigma_{ba}^{\gamma p}(S,q_2^2)}{\sigma_a^{pp}(S)}, \qquad (5)$$

$$\sigma_{ab}=\sum_a\sigma_{ab}^{a};\ \sigma_a^{\gamma p}=\sum\sigma_{aa}^{\gamma p};\ (a,b=T,S). \qquad (6)$$

The experimentally observed scaling law means

$$S\sigma_{Ta}^{\gamma p}(S,q^2)\approx\left(\frac{S}{-q^2}\right)^{a}. \qquad (7)$$

Substitution of (7) to (5) together with $S\sigma_a^{pp}(S)\approx\left(\frac{S}{S_0}\right)^{a}$ gives immediately for $\gamma\gamma$-scattering

$$W_{TT}^{a}\approx\left(\frac{SS_0}{q_1^2q_2^2}\right)^{a}. \qquad (8)$$

For the presently available energies it is necessary to take into account several Regge poles, i.e. in view of (6) $S\sigma_T^{\gamma p}\approx\phi\left(-\frac{S}{q^2}\right)$. Thus,

$$S\sigma_{TT}^{h}\approx\phi\left(-\frac{S}{q_1^2q_2^2}\right). \qquad (9)$$

The present experimental situation gives no possibility of revealing scaling law for the scalar phonon scattering. But if the scaling law is revealed it will lead to the dependence (9) for the remaining functions W_{ab} .

In other words, the scaling law for γp -scattering (7) means that the Regge pole residue $C^{\gamma}_{aa}(q^2)$ is proportional to $(-q^2)^{a/2}$. Thus, for the Regge pole contribution to $\gamma\gamma$ -scattering, $W^{a}_{ab} \approx C^{\gamma}_{aa}(q^2)P_a\left(\frac{S}{\sqrt{q_1^2 q_2^2}}\right)C^{\gamma}_{ba}(q_2^2)$ we obtain again in the region (4) the expression (8).

The attempts [7,8] to find the dependence (7) in summation of the ladder diagrams in the ϕ^3 -theory with the minimal photo-hadron interaction have led [8] to the scaling law for $W_S \approx \left(\frac{S}{-q^2}\right)^a$,

It appears also that the ratio

$$\frac{G_T}{G_S} \approx \frac{2q^2}{\ln|q^2|} \to \infty \quad \text{when } q^2 \to \infty. \qquad (10)$$

A similar result gives us the same model for $\gamma\gamma$-scattering. Namely,

$$W_{SS} \approx \left(\frac{S}{q_1^2 q_2^2}\right)^a, \quad \text{but}$$

$$\frac{\sigma_{SS}}{G_{TT}} \approx \frac{4q_1^2 q_2^2}{\ln|q_1^2|\ln|q_2^2|} \to \infty \quad \text{and} \qquad (11)$$

$$\frac{\sigma_{ST}}{\sigma_{TT}}, \frac{\sigma_{SS}}{\sigma_{ST}} \approx \frac{2q_2^2}{\ln|q_2^2|}; \quad \frac{\sigma_{SS}}{\sigma_{TS}}, \frac{\sigma_{ST}}{\sigma_{TT}} \to \frac{2q_1^2}{\ln|q_1^2|}. \qquad (12)$$

These results are also valid when going beyond the framework of the ladder model, by summing all the logarithms of the diagrams in ϕ^3- theory.

It is interesting to note that in the peculiar limit

$$|q_1|^2 \ll S \ll q_1^2 q_2^2 / S_0$$

the Regge terms (8) vanish and the behaviour of the amplitudes is described [5] by the sea-gull diagrams of Fig. 3 with asymptotics $\ln S$.

The account of the nucleon spin leads in the simplest case to the interaction $g\bar{\psi}\gamma_5\psi\phi + h\phi^4$ and changes the above-mentioned results. It can be shown that the ladder approach gives the same qualitative results as the summation of all the logarithms of all the diagrams within the assumption of the finite renormalization of coupling constants g and h and wave functions. In this case we have instead of (7) and (8)

$$S\sigma^{\gamma p}_{aa} \approx \left(\frac{S}{-q^2}\right)^a(-q^2)^b; \quad S\sigma^{a}_{ab} \approx \left(\frac{S}{q_1^2 q_2^2}\right)^a (q_1^2 q_2^2)^b. \qquad (13)$$

In addition we predict that the cross-sections of the scalar photon scattering on the proton and neutron are equal to each other in constant to the transversal photon scattering, i.e.

$$G_T^{\gamma p} \neq G_T^{\gamma n} \quad \text{but} \quad G_S^{\gamma p} = G_S^{\gamma n}.$$

Instead of the ratios (10) and (11) we find

$$\sigma_S^{\gamma p}/G_T^{\gamma p} \approx g_0^2$$

$$\sigma_{SS}/\sigma_{TS}, \sigma_{ST}/\sigma_{TT}, \sigma_{TI}/\sigma_{TT} \approx g_0^2; \qquad (14)$$

where g_0 is the bare coupling constant. The value of this constant defines the position of the j-plane standing square-root branch point in the elastic scattering which was obtained [9,10] in addition to the Regge poles, in the same theory under the same assumptions and by similar method as the result (13), (14). If the Pomeranchuk singularity is just this branch point, then $3(\frac{g_0}{4\pi})^2 \approx 0{,}14$ and the formulae (13) have to be multiplied by $\ln(S/\sqrt{q^2})^{-3/2}$ and $\ln(S/\sqrt{q_1^2 q_2^2})^{-3/2}$ correspondingly. The condition of its validity in this case is $(\ln|q^2|)^2 < 8\ln S/\sqrt{-q^2}$.

The restoration of gauge invariance, which was destroyed by the finite renormalization assumption leads, most likely to the condition $b=0$. (The last experimental data on the deep inelastic ep-scattering gives $\sigma_S/\sigma_T \approx 0.18, |b|<0.1$). At present this question is being investigated and the details will be published elsewhere.

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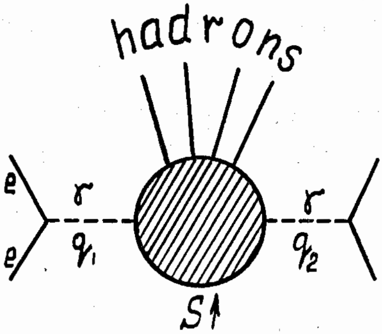

Fig. 1.

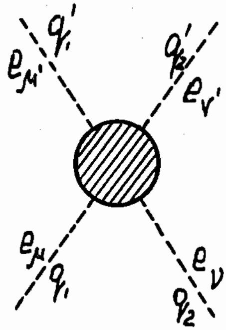

Fig. 2.

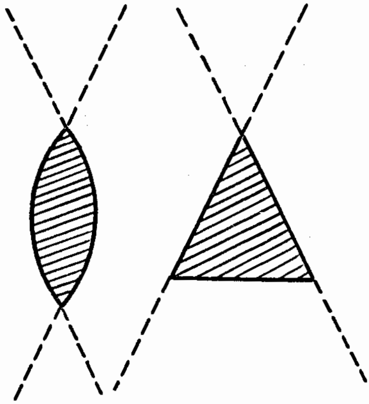

Fig. 3.