ELECTROMAGNETIC AND WEAK CORRECTIONS TO THE SCATTERING OF HIGH-ENERGY HADRONS

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Unlike the strong interaction, the electromagnetic and weak interactions are taken into account with the aid of perturbation theory. As a consequence, in the partial amplitudes of purely hadronic processes there appear immobile singularities resulting, for example, from diagrams with exchange in the t-channel of two photons (two W mesons). These are the Gribov-Pomeranchuk singularities [1], shifted toward $j = 1$ as a result of the spin of the photon (W) [2]. The absence of Reggeization of these particles leads to a growth of the electromagnetic and weak corrections to hadron scattering with increasing energy.

Let us consider the contribution of the vacuum pole to the t-channel partial amplitude of the process $\gamma + p \to \gamma + p$

$$f_j(t) = \frac{\alpha r(t)}{\sqrt{j-1}\,[j-\beta(t)]}. \qquad (1)$$

Here $\alpha = e^2/4\pi$ and $\beta(0) = 1$ (the spin indices have been omitted for simplicity). The singularity $1/\sqrt{j-1}$ should be present in the partial sense-nonsense amplitude with incorrect-signature, owing to the existence of the spectral function $\rho(s, u)$ [1 - 3]. (If $r(t) \equiv 0$, then the total photon-hadron scattering cross section decreases with increasing energy [4].) By investigating two-photon exchange with the aid of the t-channel unitarity condition, we obtain the hadron-hadron partial amplitude:

$$\phi_j(t) = \frac{\alpha^2 R(t)}{[j-1]\,[j-\beta(t)]^2}. \qquad (2)$$

Let us calculate the asymptotic form of the corresponding amplitude:

$$A(s, t) = i\,\alpha^2 s R(0) \ln^2(s/s_0), \quad \beta' t \ln(s/s_0) << 1, \qquad (3)$$

$$A(s, t) = \frac{\alpha^2 R(t)\, s \exp\left[i\frac{\pi}{2}\beta(t)\right]}{[1-\beta(t)]^2 \sin\left[\pi/2\, \beta(t)\right]}. \qquad (4)$$

If the vacuum pole is quasistable [5], the multi-reggeon exchange cannot cancel out (3).

For the electromagnetic corrections (see Eq. (4)) there is no cancellation of the diffraction cone with energy, i.e., (4) comes from the impact parameters $\rho \sim 1/\mu$. The s-channel partial amplitudes of strong processes are small at such distances, owing to the cancellation of the diffraction cone with increasing energy (e.g., for exchange of a vacuum pole, $\ell_p \sim 1/\ln(s/s_0)$ [6]).

It is just for this reason that strong interactions cannot cancel out the contribution from an immobile singularity. We started the analysis with a second-order correction in α, for in this case there appear additional arguments connected with the existence of $\rho(s, u)$. Actually, the first-order corrections in α are more important, since the analysis of the reggeon diagrams shows that they also survive at high energies.

The concepts developed in the article can be verified experimentally. Let us consider, for example, reactions with non-vacuum quantum numbers in the t-channel, whose cross sections at the present time decrease rapidly with energy, such as $\gamma + p \to \pi^0(\Delta) + p$, $p + p \to p + \Delta^+$, etc. With increasing energy the region of t in which the single-photon exchange predominates should increase.

So far we have not used anywhere the fact that the photon has no rest mass, and therefore the arguments developed above are applicable also to weak interactions. Owing to the vector character of W, all the amplitudes of the weak processes of second order should be of the order of $G^2 s s_0$ (G is the Fermi constant). The real effect, however, can be much larger. For example, the weak correction to the elastic-scattering amplitude is $\sim(Gs)^2$. In calculating the s-channel imaginary part of the diagram corresponding to exchange of two W mesons in the t-channel, the amplitude of the process $W + N \to W + N$ is assumed to be equal to the Compton scattering amplitude. The enhancement is due to the large mass of W (we assume here $m_W^2 \gtrsim s$) and due to scaling for $A_{\gamma p}$ [7]. Processes of first order in the weak interaction, as argued above, should be described by the simplest Feynman diagram with exchange of one W meson, and consequently their cross sections tend to constant values in the high-energy limit. Examples are the reactions $\pi^- + p \to k^0 + n$, $p + n \to \Sigma^0(\lambda) + p$, etc. The simplest estimate shows that the cross sections of these processes are of the order of 10^{-40} cm^2. (In the calculation, the form factors of all the hadrons are assumed to be equal to the form factor of the proton, and account was taken also of the additional smallness due to the Cabibbo angle.) The effect of spatial-parity nonconservation, due to the possible interference of the weak and strong amplitudes, is larger in magnitude. By way of an example, let us estimate the longitudinal polarization of the neutron in the reaction $\pi^- + p \to \pi^0 + n$, using as the strong amplitude the exchange of ρ with a reggeon [8]. At $E_\pi = 25$ GeV we can expect $P_\ell \sim 10^{-5}$. However, at $E_\pi = 400$ GeV, P_ℓ increases to 10^{-4}. Parity nonconservation is apparently easy to observe by studying the dependence of the cross section on the polarization of the initial particles.

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