POSSIBILITY OF ELECTROMAGNETIC DOMINANCE NEAR THE KINEMATIC LIMIT OF A HADRON SPECTRUM

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Submitted 8 July 1972
ZhETF Pis. Red. 16, No. 7, 406 - 410 (5 October 1972)

It is of interest, in the theory of inelastic hadronic processes, to study the asymptotic distributions near the boundary of phase space, for in this region, by using the quasi-two-particle phenomenology, it is possible to reduce the problem to a determination of several unknown parameters - three-reggeon constants. Thus, for the particle-beam production processes illustrated in the figure, in which vacuum exchange is possible, the following three-reggeon formulas are valid in the limit $-t \lesssim m^2$; $s \gg M^2, M_1^2, M_2^2 \gg m^2$:

$$\frac{d\sigma_{st}^{(a)}}{dt\,dM^2} \approx \frac{\gamma_a(t)}{s^2}\left(\frac{s}{M^2}\right)^{2\alpha_P(t)}(M^2)^{\bar{\alpha}(0)}\underset{t\to 0}{\approx}\frac{\gamma_a(0)}{(M^2)^{2-\bar{\alpha}(0)}}, [1] \tag{1a}$$

$$\frac{d\sigma_{st}^{(b)}}{dt\,dM_1^2dM_2^2} \approx \frac{\gamma_b^2(t)}{s^2}\left(\frac{s}{M_1^2M_2^2}\right)^{2\alpha_P(t)}(M_1^2M_2^2)^{\bar{\alpha}(0)}\underset{t\to 0}{\approx}\frac{\gamma_b^2(0)}{(M_1^2M_2^2)^{2-\bar{\alpha}(0)}}, [2] \tag{1b}$$

$$\frac{d\sigma_{st}^{(c)}}{dt_1\,dt_2\,dM^2} \approx \frac{\gamma_c^2(t_1t_2)}{s^2}\int\frac{ds_1}{s_1}\left(\frac{s_1}{M^2}\right)^{2\alpha_P(t_1)}\left(\frac{s_2}{M^2}\right)^{2\alpha_P(t_2)}(M^2)^{\bar{\alpha}(0)}\underset{t\to 0}{\approx}$$

$$\approx\frac{\gamma_c^2(0)\ln\eta}{(M^2)^{2-\bar{\alpha}(0)}}; \tag{1c}$$

$$\eta = \frac{s\sqrt{t_1t_2}}{M^2m_1m_2} > 1.$$

In (1a - 1c) we have retained only the terms that do not vanish as $s \to \infty$ and correspond to exchange of a Pomeranchuk pole, $\bar{\alpha}$ is a certain effective trajectory that determines the behavior of the total cross sections σ_{tot}^{pP} and σ_{tot}^{PP}, and $\gamma(t)$ are the effective three-reggeon constants and include the residues and the signature and kinematic factors.

It was shown in a number of papers [3, 4] that the three-pomeron constant is small ($\sim\alpha' t$ as $t \to 0$), and consequently the contribution of the three-pomeron mechanism (PP, P) to (1a) is $(d\sigma_{st}^{(a)}/dtdM^2)_{t\to 0} \approx (t\gamma'/M^2)$. In the language of two-component duality this means that the production of the background dies out asymptotically, and contributions to the processes in question are made only by resonances, or, which is the same, the trajectory dual to them $P'(\bar{\alpha}(0) = 1/2)$. The experimental data [5], however, point apparently to an even faster decrease with respect to M^2 [4]. We note that this decrease can be attributed to the 2π-cut corresponding to $\bar{\alpha}(0) = -1$, which effectively takes into account the contribution made to the matrix element of the process $NN \to NN\pi$ by one-pion exchange [6], which is appreciable in the mass region $M \sim 1.2 - 1.4$ GeV and fades out rapidly with increasing M^2. We note in this connection that as $t \to 0$ the contribution of electromagnetic effects becomes appreciable (and even dominant).

Namely, as $t \to m^2$, the expressions for the cross sections of the electromagnetic processes described by the diagrams of the figure, with P replaced by a gamma quantum, take in the region under consideration the form

$$\frac{d\sigma_{em}^{(a)}}{dt\,dM^2} = \frac{\alpha}{\pi}\,\frac{\sigma_T^{\gamma P}(M^2)}{|t|\,M^2}\left[1 - \frac{t_{min}}{t}\right]; \quad |t_{min}| = \frac{m_1^2 M^4}{s^2}, \tag{2a}$$

$$\frac{d\sigma_{em}^{(b)}}{dM_1^2\,dM_2^2\,dt} = \frac{\sigma_T^{\gamma P}(M_1^2)\,\sigma_T^{\gamma P}(M_2^2)}{8\pi^3 M_1^2 M_2^2}\left[1 + \left(1 - \frac{t_{min}}{t}\right)^2\right]; \tag{2b}$$

$$|t_{min}| = \frac{M_1^2 M_2^2}{s},$$

$$\frac{d\sigma_{em}^{(c)}}{dt_1\,dt_2\,dM^2} = \frac{\alpha^2\sigma_T^{\gamma\gamma}(M^2)}{\pi^2 M^2 t_1 t_2}\left[(\ln\eta)(1 + \eta^{-2}) - (1 - \eta^{-2})\right], \tag{2c}$$

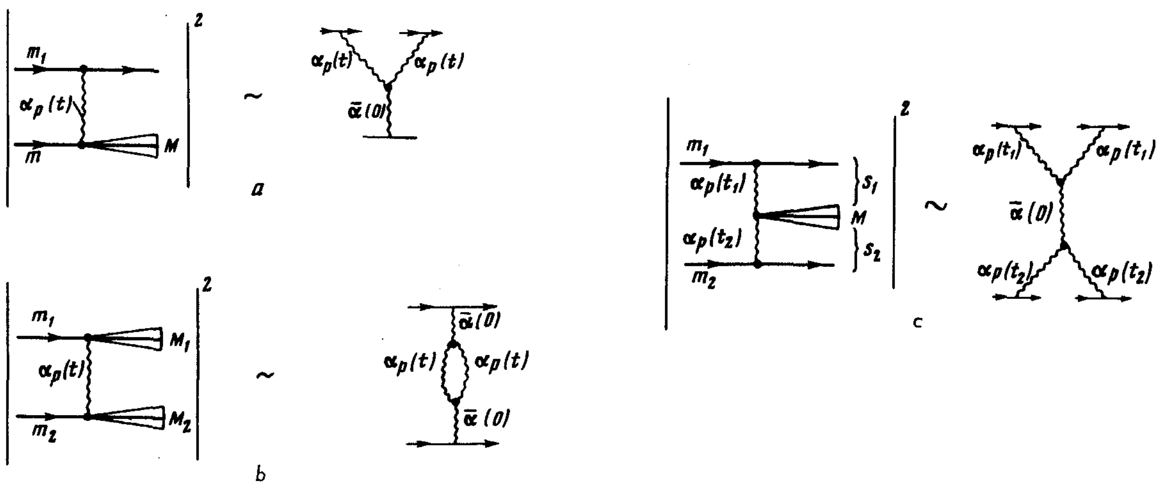
Here $\sigma_T^{\gamma P}(M^2) \approx 110$ μb and $\sigma_T^{\gamma\gamma}(M^2) = (\sigma_T^{\gamma P})^2/\sigma_T^{PP} \approx 0.3$ μb. The results (2a - 2c) were obtained in analogy with [7]. Comparison of (1a) and (2a) yields

$$\frac{d\sigma_{em}^{(a)}}{d\sigma_{st}^{(a)}} = C_{\bar{\alpha}}\,\frac{(M^2)^{1-\bar{\alpha}(0)}}{|t|}\left[1 - \frac{t_{min}}{t}\right], \tag{3}$$

(M^2, t, and s are henceforth given in GeV^2).

For the processes $pp \to pX$ and $\pi p \to \pi X$ [4, 5], assuming $\bar{\alpha}(0) = 1/2$, we obtain $C^{(p)} = (5 \pm 2.5) \times 10^{-5}$ and $C^{(\pi)} \sim 2C^{(p)}$.

Actually, however, the region where the electromagnetic effects become noticeable is much broader, owing to the interference of the hadronic and electromagnetic mechanisms.



Namely, the contribution from the interference, for example for the process (1a) at large s, is

$$\frac{d\sigma_{int}^{(a)}}{dt\,dM^2} \approx \frac{\bar{\gamma}(t)\,\alpha}{s^2}\left(\frac{s}{M^2}\right)^{\alpha_P(t)} \frac{s\sqrt{1-\frac{t_{min}}{t}}}{M^2\sqrt{-t}} \mathrm{Re}\,[\eta(t,s,M)\,\mathrm{Im}\,A_{\gamma p \to Pp} \times$$

$$\times (M^2, t, 0)]_{t\to 0} \approx \frac{\alpha\bar{\gamma}(0)}{(M^2)^{2-\bar{\alpha}(0)}}\left[\frac{\sqrt{|t-t_{min}|}}{|t|}\,\mathrm{Re}\,\eta(t,s,M)\right]_{t\to 0}, \tag{4}$$

where $\eta(t, s, M)$ is the effective signature factor. Re $\eta(t, s, M)$ indicates the contributions of the branch cuts, the secondary trajectories, and the real part of the contribution of the Pomeranchuk pole, which as $t \to 0$ are respectively proportional to $1/\ln^2(s/M^2)$, $[(M^2)^{3/2-\bar{\alpha}(0)}]/\sqrt{s}$, and t. Consequently, the contribution of the interference can be neglected in the dominance region.

A similar situation obtains for the process of Fig. b. The corrections to the process of Fig. c, due to the interference of the P and γ exchanges, are determined by five-reggeon diagrams with even P and are of the order of

$$\frac{d\sigma}{dt_1\,dt_2\,dM^2} \underset{\substack{t_1\sim t_2\sim t\to 0\\ s\to\infty}}{\sim} \frac{\alpha^2}{|t|\,(M^2)^{2-\bar{\alpha}(0)}}. \tag{5}$$

The entire foregoing analysis had an asymptotic character, with $s \to \infty$ assumed. At the realistically attainable energies of the nearest future, however, it is necessary to take into account also the contributions of the secondary trajectories. In this case we obtain for the process (1a), in view of the absence of interference between the vacuum and second exchanges (PR, P) and (PR, R) [8], neglecting the term (RR, R) and putting $\bar{\alpha} = 1/2$, the formula

$$\frac{d\sigma_{st}^{(a)}}{dt\,dM^2} \approx \left[\frac{\gamma_{PPR}(0)}{M^3} + \frac{\gamma_{RRP}(0)}{s}\right]\frac{\mathrm{mb}}{(\mathrm{GeV})^4}. \tag{1a'}$$

From an analysis of the experimental data for $pp \to pX$ [4, 5] we find $\gamma_{PPR}(0) \simeq 5$ and $\gamma_{RRP}(0) \simeq 100$ with accuracy up to 50%. It follows therefore that at large but fixed s, in the region $s^{3/2} \gg M^3 > 5 \times 10^{-2}s$ the spectra are described by the second term in (6), thus greatly decreasing the region of electromagnetic dominance. The interchange of regimes in (6) occurs at $M \simeq 5.6$.

The contribution from the interference takes in the region in question the form

$$\frac{d\sigma_{int}}{dt\,dM^2} = \sum_{R=\rho,\,\omega} \frac{\alpha\gamma_{\gamma R,P}(0)}{\sqrt{-t}\,\sqrt{sM^2}}\left(1-\frac{t_{min}}{t}\right)^{1/2}. \tag{4'}$$

The contribution (4') becomes comparable with the second term of (1a) at $|t|M^2 \lesssim (10^{-5} - 10^{-6})s(1 - (t_{min}/t))$.

If the experimental data at large M permit reliable separation of the contribution of the (RR, P) background from the contribution of the resonances

(PP, R), then the corresponding electromagnetic terms ($\gamma\gamma$, P) and ($\gamma\gamma$, R), which result from putting $\sigma_T^{\gamma P} = \alpha\gamma_{\gamma\gamma P}(0) + (\alpha\gamma_{\gamma\gamma R}(0)/M)$ in (2a), will make a contribution to each of them, and at small fixed t the term ($\gamma\gamma$, P) will imitate the (PP, P) mechanism. On the other hand, if these contributions are separated only in accordance with their asymptotic behavior with respect to s, then the asymptotic analysis given above holds for the contribution that does not depend on s as $s \to \infty$.

We note that the background can be investigated by studying the process $pp \to \Delta X$ at large M, for in this case only ρ, A_2, and π exchanges are allowed, and consequently we have the formula

$$\frac{d\sigma_{str}}{dt\,dM^2} = \frac{1}{s^2}\sum_{R=\rho A_2 \pi} \gamma_{RR,P}(t)\left(\frac{s}{M^2}\right)^{2\alpha_R(t)} M^2_{t\to 0} \approx \left[\sum_{R=\rho,\,A_2} \gamma_{RR,P}(0)\right] \times \frac{1}{s} + 0\left(\frac{M^2}{s^2}\right). \quad (6)$$

For comparison, we present the corresponding electromagnetic cross section

$$\frac{d\sigma_{em}}{dt\,dM^2} = \frac{2\Gamma_{\Delta\to P\gamma}\,\sigma_T^{\gamma P}(M^2)}{\pi}\,\frac{M_\Delta^3}{(M_\Delta^2 - m^2)^3}\,\frac{1}{M^2}\left[1 + \left(1 - \frac{t_{min}}{t}\right)^2\right]. \quad (7)$$

$$\Gamma_{\Delta\to P\gamma} = 0{,}72\ \text{MeV}.$$

In conclusion, we are grateful to A.A. Ansel'm, S.G. Matinyan, and R.M. Ryndin for useful discussions.

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