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PAIRED SPECTRA OF PARTICLES IN COLLIDING BEAMS AT HIGH ENERGIES

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The experimental data [1 - 3] show that the total (so-called "inclusive") cross section for particle production $d\sigma_1 = \sum_H d\sigma(a + b \to 1 + H)$, with a specified momentum $\vec{P}_1 = (P_\ell, \vec{P}_\perp)$, where H is a certain multiparticle hadron state, has at high energy $E_0 = E_{1ab}$ a unique self-similar property - it depends only on $x = P_\ell/E$ and $P_\perp{}^2$, i.e., $d\sigma_1 = \rho(x, P_\perp{}^2)(d^3P_1/2E_1)$, $P_\ell \simeq E$, $P_\perp << E$. The theory of complex angular momenta defines the function ρ in the region $m^2/s << 1 - x << 1$ in the form [4 - 6]

$$\rho(x, P_\perp^2) = \sum_a B_a(t) - (1-x)^{1-2\alpha_a(t)}, \tag{1}$$

where

$$t = (P_a - P_1)^2 = (1-x)\left(m_0^2 - \frac{m_1^2}{x}\right) - \frac{P_\perp^2}{x}$$

$\alpha_a(t) = \alpha_0(0) + t\alpha_a'$ is the trajectory of one of the possible reggeons,

$$B_a(t) = \frac{1}{\pi^2}|g_a(t)\eta_a(t)|^2\sigma_2(t). \tag{2}$$

The parametrization $B_a(t) = B_a^0\exp(2R_a^2t)$ results in a good description of spectra of the $\pi^\pm$, $K^\pm$, P, and $\bar{P}$ obtained in PP collisions [7, 8].

In connection with the startup of the storage rings at CERN, it has now become possible to study experimentally the analogous total cross section for the production of two particles, $d\sigma_{12} = \sum_H d\sigma(a + b \to 1 + 2 + H)$. If $1 - x_1 << 1$ and $1 - x_2 << 1$, where $x = P_{1\ell}/E_0 \simeq E_1/E_0$, $x_2 = P_2/E_0 \simeq E_2/E_0$, $E_0 = P_a = P_b$, and the transverse momenta $P_{1\perp}$ and $P_{2\perp}$ are small, then the process $a + b \to 1 + 2 + H$ corresponds[1)] to the diagram of Fig. 1 and to an amplitude in the form [9]

$$T = 8\pi g_1(t_1)g_2(t_2)\eta_1(\alpha_1)\eta_2(\alpha_2)T_H'(t_1, t_2, s')\left(\frac{s}{s_2}\right)^{\alpha_1(t_1)}\left(\frac{s}{s_1}\right)^{\alpha_2(t_2)} \tag{3}$$

where g_1 and g_2 are the Regge vertices, η_1 and η_2 the signature factors, T_H' the amplitude for the production of a beam of hadrons, $s_1/s = 1 - x_2$ and $s_2/s = 1 - x_1$, i.e., [9], $s_1s_2 = s(s' + P'^2)$.

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1)The ratios $s/s_1 = 1/(1 - x_2)$ and $s/s_2 = 1/(1 - x_1)$ are large in this case, this being the condition [9] for the applicability of the multireggeon description.

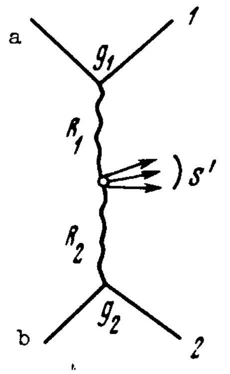

Fig. 1

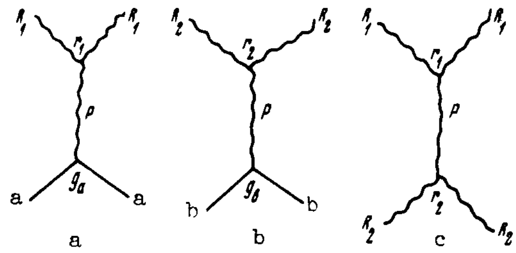

Fig. 2

Since

$$d\sigma_{12} = \sum_H \frac{|T|^2}{2s} d\tau \text{ where } d\tau = \frac{d^3P_1 d^3P_2}{(2\pi)^6 2E_1 2E_2} d\tau_H',$$

$d\tau_H'$ is the phase volume of the particles in the H beam, and $d\sigma_H' = [|T_H'|^2/2s']d\tau_H'$ is the cross section for the production of this beam by collision of two reggeons, we have

$$d\tau_{12} = B_{12}(1-x_1)^{1-2\alpha_1(t_1)} (1-x_2)^{1-2\alpha_2(t_2)} \frac{d^3P_1}{2E_1} \frac{d^3P_2}{2E_2} = \rho_{12} \frac{d^3P_1}{2E_1} \frac{d^3P_2}{2E_2}, \quad (4)$$

where

$$B_{12} = \frac{1}{\pi^4} |g_1(t_1)\eta_1 g_2(t_2)\eta_2|^2 \sigma'(t_1, t_2, s') \quad (5)$$

and $\sigma' = \sum_H \int d\sigma_H'$ is the total cross section for the interaction of two reggeons at an energy $\sqrt{s'}$. Similarly, expression (2) for the single spectrum contains the reggeon-particle interaction cross section σ_2. At large s' these cross sections are independent of the energy. If the optical theorem is satisfied for reggeon-reggeon scattering (it was proved for the scattering of a reggeon by a particle by V.N. Gribov and A.A. Migdal in [10]), then it can be readily seen that (see Figs. 2a, b, c)

$$\begin{aligned} \sigma_1 &= \sigma(a + R_1) = 8\pi g_a r_1(t_1), \\ \sigma_2 &= \sigma(b + R_2) = 8\pi g_b r_2(t_2), \\ \sigma' &= \sigma(R_1 + R_2) = 8\pi r_1(t_1) r_2(t_2), \end{aligned} \quad (6)$$

where $r_1(t_1)$ and $r_2(t_2)$ are the vertices of the P-reggeon interaction with reggeons R_1 and R_2 in Figs. 2a and 2b, and g_a and G_V are the vertices for the P-reggeon interaction with particles a and b, we therefore have $\sigma' = \sigma_1\sigma_2/8\pi g_a g_b$ in the region $s' \gg m_i^2$, and formulas (2) and (5) yield

$$\rho_{12}(x_1, x_2, P_{1\perp}^2, P_{2\perp}^2) \doteq \frac{\rho_1(x_1, P_{1\perp}^2)\rho_2(x_2, P_{2\perp}^2)}{8\pi g_a g_b} . \qquad (7)$$

If the optical theorem is not satisfied for reggeon-reggeon scattering at large s', but σ' assumes a constant value at the same time, then B_{12} in (5) is a certain decreasing function of the variables t_1 and t_2, and can be represented at small $|t_1|$ and $|t_2|$ in the form $B_{12} = B_{12}^0 \exp[2(R_1^2 t_1 + R_2^2 t_2)]$.

If the particles a and 1 (or b and 2) are identical, then the main contribution in Figs. 2a and 2b is made by the P reggeon (R = P). It can be shown in this case [10] that the vertex $r_1(t_1)$ or $r_2(t_2)$ should annihilate, respectively, as $|t_1| \to 0$ or $|t_2| \to 0$. An experimental investigation of this effect, and also of the optical theorem for reggeon-reggeon scattering, is of great interest to the theory.

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CONCERNING RESONANCES IN A THREE-NUCLEON SYSTEM AT LOW ENERGIES

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A considerable number of recent experimental papers report observation of a resonant behavior of the differential corss sections, say, in the process $\pi^- + {}^3He \to \pi^+ + (3n)$ [1] or $p + {}^3He \to n + (3p)$ [2], as functions of the kinetic energy of the three-nucleon system. The authors conclude for the most part from the obtained data that a three-particle resonance or an excited state of ^3He exists [1 - 3]. Such conclusions based on the observation of only the energy behavior of the cross sections may be too hasty. Phillips [4] was the first to call attention to the fact that in the reaction

$$\pi^- + {}^3\mathrm{He} \to \pi^+ + 3n \qquad (1)$$

the resonant behavior of the cross section may be due to interaction of two neutrons in the final state. The results obtained in [4], however, are based in essence on a large number of approximations connected with dynamics of the process (1), and cannot be simply generalized to cover other reactions of similar type.

It seems to us that in the study of process (1) or of (p, n) reactions on ^3He and ^3H [2] it is necessary to separate first (after comparison with the four-particle phase volume) the contribution made to the cross sections of