It is seen from (7) that E^0 vanishes as $H_0 \to 0$ and $H_0 \to H_{cr}$, and E^0 is maximal at $H_0 = H_{cr}/2$.

There are two alternatives: 1) measure E^0 with z given, and 2) measure $\langle E^0 \rangle$ (E^0 averaged over the length) in the direction of the helix axis. If the axis spans an integer number of turns, then calculation shows that $\langle E^0 \rangle = 0$. If the number of turns is not integer, then the results of the two alternatives are of the same order of magnitude, equal to

$$E^0 \approx \frac{32\pi\delta I^0}{cH_{cr}\sqrt{\epsilon}(1+2\sqrt{\epsilon}+\epsilon)} \equiv \gamma_\epsilon I^0 .$$

In conducting media we have, in order of magnitude,

$$E^0 \approx \frac{\sqrt{2\pi\mu}}{L\omega c}\sqrt{\frac{\sigma}{\omega}}\, I^0 \equiv \gamma_\sigma I^0$$

(μ and σ are the mobility and the conductivity and L is the length of the sample in the flux direction. Here $\sigma \ll \omega$ and both are much lower than the carrier relaxation frequencies. In other cases γ_σ is even smaller.) We see that γ_ϵ is always much larger than γ_σ. We note that the weak damping of the waves in a dielectric makes it possible for E^0 to appear in bulky samples, unlike conducting media in which the field is weak if L exceeds greatly the skin layer.

In conclusion, let us estimate the radioelectric field. At $H_0 \simeq 10^3$ Oe, $\delta \simeq 0.2$, $\epsilon \simeq 4$, and $I^0 = 1$ kW/cm^2 we have $E^0 \simeq 0.1$ V/cm.

[1] H. E. Barlow, Proc. IRE 46, 1411 (1958).
[2] L. E. Gurevich and A. A. Rumyantsev, Fiz. Tverd. Tela 9, 75 (1967) [Sov. Phys.-Solid State 9, 55 (1967)].
[3] A. A. Grinberg, Zh. Eksp. Teor. Fiz. 58, 989 (1970) [Sov. Phys.-JETP 31, 531 (1970)].
[4] E. I. Kats, ibid. 59, 1854 (1970) [32, 1004 (1971)].
[5] P. G. de Gennes, Solid State Comm. 6, 163 (1968).
[6] P. G. de Gennes, J. de Physique 30, Supl. II, Col. C4 (1969).

COLLIDING POLES AND GROWING CROSS SECTIONS

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The growth of the total cross sections and other features of pp scattering, observed in high-energy experiments, are discussed on the basis of the assumption of colliding complex Regge poles.

We discuss in the present article the possibility of describing the regularities observed in pp scattering at high energies [1 - 6], namely: (a) the growth of the total cross section $\sigma_{tot}(s)$ in the region $s \sim 500 - 3000$ GeV^2, (b) the change of the sign of $\sigma(s)$ = ReT(s, 0)/ImT(s, $\sigma(s)$ = ReT(s, 0)/ImT(s, 0) in the region $s \sim 5\times10^2$ GeV^2, and (c) the slowing down of the growth of the diffraction-peak slope parameter b(s) under the assumption [7] that the leading singularities in the j-plane of the partial amplitude of the crossing channel are complex-conjugate poles. Denoting the contribution of the other singularities by F(s, t), we express the scattering amplitude in the form

$$T(s,t) = \beta s^{\alpha} e^{-i\pi\alpha/2} + \beta^* s^{\alpha^*} e^{-i\pi\alpha^*/2} + F(s,t), \tag{1}$$

where $\alpha = \alpha_R = i\alpha_I$ and $\beta = |\beta|e^{i\phi}$ are the trajectory and residue of the complex pole.

We consider first the case when the poles α and α^* collide at t = 0 in such a way that a second-order pole is produced at j = 1.[1)] Since the collision of two poles leads to a root singularity for the trajectory and the residue, we assume that as $t \to 0$ we get $\alpha_I = a\sqrt{-t}$ and arg $h(t) = b\sqrt{-t}$, where $h = 2i\alpha_I\beta$ and $|h(0)| \equiv h \neq 0$. To describe the low-energy region

($s \lesssim 10^2$ GeV^2) we take into account also the contribution of the secondary trajectories in the form $F = As^{1/2}$, where A is a complex quantity that takes into account the deviation of the contributions of the $i = \rho$, f, ω, and A_2 poles from exact degeneracy, and all the $\alpha_i(0)$ are assumed equal to 1/2. In this case we have

$$\sigma_{tot}(s) = h\frac{b}{a} + h\ln s + \mathrm{Im}As^{-1/2},$$

$$a(s) = a_{tot}^{-1}(s)\left(\frac{\pi}{2}h + \mathrm{Re}\,As^{-1/2}\right),$$

$$b(s) = b_0 + b_1 \ln s + \xi R(s),$$

where ξ is connected with the ratio of the slope parameters of the secondary poles and the pole α, while R(s) can be calculated explicitly if the parameters that enter in (2) and (3) are known. The seven unknown parameters of the model were determined by us by fitting successively to the experimental data on $\sigma_{tot}(s)$ [1 - 3], $\sigma(s)$ [1, 2, 4], and b(s) [2, 4 - 6]. The values of χ^2_α were $\chi^2_\alpha = 23.7$ (41 degrees of freedom), $\chi^2_\alpha = 32.5$ (20 degrees of freedom), and $\chi^2_b = 52.4$ (33 degrees of freedom) at h = 4.1, h(b/a) = 25.0, ImA = 39.9, ReA = -82.8, $b_0 = 10.9$, $b_1 = 0.24$, and $\xi = -3.2$. The comparison with experiment is shown in Figs. 1, 2, and 3 (solid curves). It must be emphasized that the logarithmic growth of the cross section as obtained in our model agrees well with the data in the region $s \simeq 500 - 3000$ GeV^2. The fact that the theoretical values on Fig. 1 increase somewhat more slowly than the experimental ones is connected with our desire to describe the entire aggregate of the experimental data, up to p = GeV/c, for a concrete choice of F with $\alpha_i(0) = 1/2$.

We mention here also a problem on which the double-pole model can have a bearing. We have in mind the different values of the effective ρ-trajectory obtained from measurements of $\Delta\sigma \equiv \sigma(\pi^- p) - \sigma(\pi^+ p)$ ($\alpha_\rho(0) = 0.67 \pm 0.06$ [9]) and $(d\sigma/dt)_{t=0}(\pi^-_p \to \pi^0 n)$ ($\alpha_\rho(0) = 0.58 \pm 0.02$ [10]). In our model, at $\ln s \sim \ln s_0 \equiv |b/a|$ and $b/a < 0$ we have

$$\Delta\sigma = 2hs^{\alpha_R^\rho - 1}(b/a + \ln s) \sim s^{\alpha_R^\rho - 1}\ln s/s_0,$$

$$\left(\frac{d\sigma}{dt}\right)_{t=0} = \frac{1}{8\pi}h^2 s^{2\alpha_R^\rho - 2}\left[\frac{\pi^2}{4} + (b/a + \ln s)^2\right] \sim s^{2\alpha_R^\rho - 2}$$

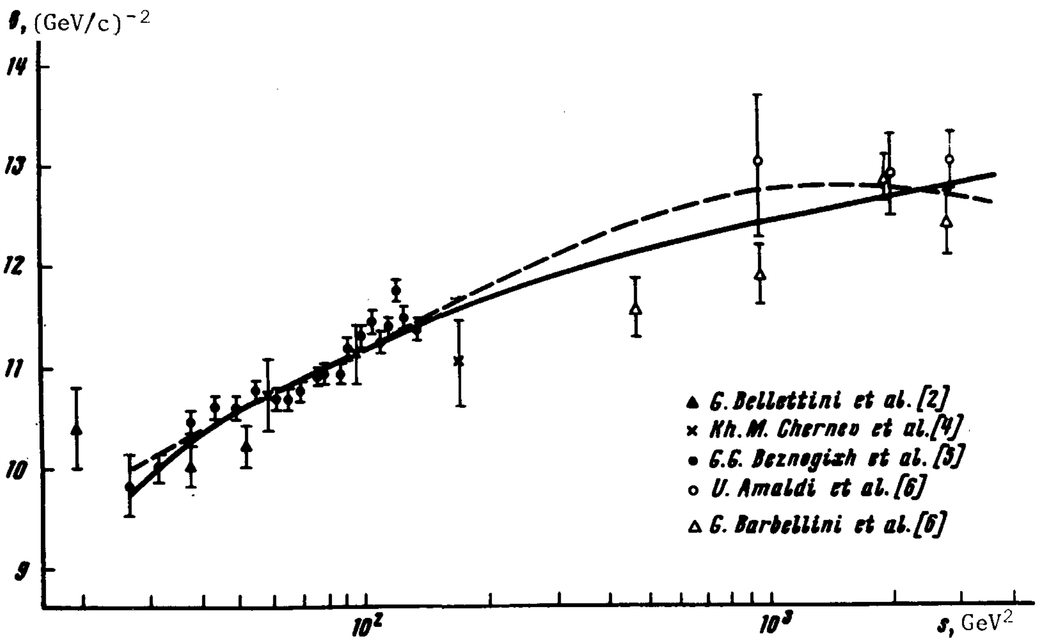

Fig. 1. Total pp-scattering cross section: solid — "double pole" model, dashed — complex-Regge pole model.

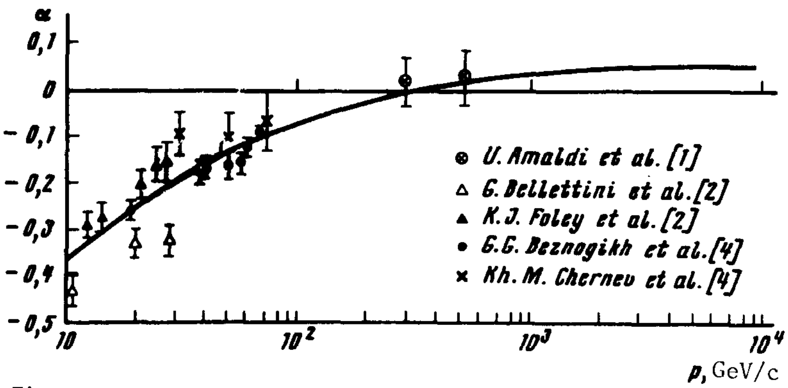

Fig. 2. The ratio $\alpha(s) \equiv \mathrm{Re}T(s, 0)/\mathrm{Im}T(s, 0)$ of pp scattering in the "double pole" model.

so that the effective trajectory is higher in $\Delta\sigma$ than in $d\sigma/dt$, owing to the factor $\ln s/s_0$.[2] We consider now another case, when the pole collision occurs at $t > 0$. Then $\alpha_I \neq 0$ at $t = 0$ (we assume, as before, $\alpha_R(0) = 1$), and the condition $\sigma_{tot}(s) \geq 0$ means that it is necessary to take into account, besides the complex pair, also the usual Pomeranchuk pole with $\alpha_P = 1$, i.e., $F = \alpha s^{\alpha_P} \exp(-i\alpha_P\pi/2)$. Then:

$$\sigma_{tot}(s) = \gamma + 2|\beta|\,\mathrm{ch}\,\frac{\pi\alpha_I}{2}\cos(\phi + \alpha_I \ln s),$$

$$\alpha(s) = -2|\beta|\,\mathrm{sh}\,\frac{\pi\alpha_I}{2}\sin(\phi + \alpha_I \ln s)\,\sigma_{tot}^{-1}(s),$$

$$b(s) = b_0 + b_1 \ln s + A\sin(\phi + \alpha_I \ln s),$$

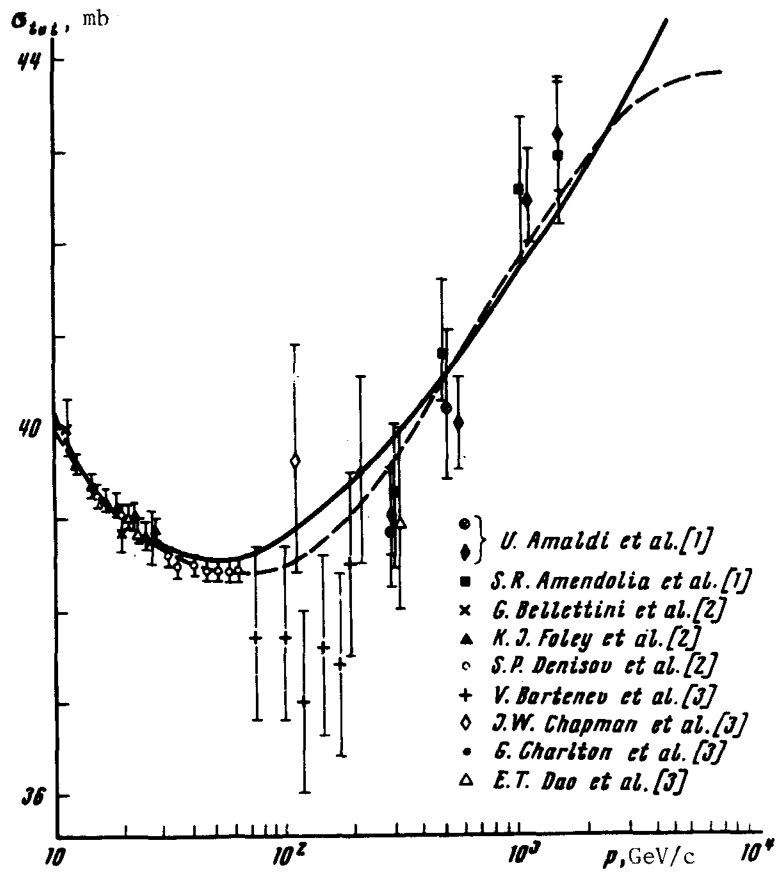

Fig. 3. Slope parameter of pp scattering: solid — "double pole" model, dashed — complex Regge pole model.

where the parameter A depends on $d\phi/dt$ (we assume for simplicity $\alpha_I(t)$ = const at $t \simeq 0$). By fitting to the experimental data on σ_{tot} and b we obtained the following values of the parameters: $\alpha_I = 0.66$, $\phi = 0$, $\gamma = 41.1$, $|\beta| = 0.85$, $b_0 = 10.9$, $b_1 = 0.096$, and $A = -1.2$ ($\chi^2 = 16.4$, $\chi_b^2 = 56.6$). The behavior of $\alpha(s)$ agrees qualitatively with the experimental data. A quantitative agreement can be obtained by taking into account the secondary trajectories. The growth of the cross section in the region $s > 500\ \mathrm{GeV}^2$ is connected in this case with the increase of the cosine (like $\alpha_I^2 \ln^2 s$) after passing through the minimum at $\phi + \alpha_I \ln s = \pi/2$. The maximum σ_{tot}, equal to 43.8 mb, is reached at $s = 1.5\times10^4\ \mathrm{GeV}^2$. The oscillations that arise in this model can be made to attenuate slowly by choosing $\alpha_R(0) = 1 - \varepsilon$ ($\varepsilon \gtrsim 0$) or by considering complex branch points instead of poles.

Thus, both models enable us to describe the existing experimental data on pp scattering, but lead to different behaviors at high energies, viz., a growth of σ_{tot} in the case of the double pole and oscillations in the case of the complex-pair model.

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1) A similar phenomenon takes place, for example, in the quasipole model [8] in the case when the point of pole collision does not coincide with the branch point "screening" the poles.

2) Other possibilities of obtaining different effective trajectories were discussed by us in [11].

[1] U. Amaldi et al., Phys. Lett. 43B, 231 (1973); 44B, 112 (1973); S. R. Amendolia et al., Phys. Lett. 44B, 119 (1973).
[2] G. Bellettini et al., Phys. Lett. 14, 164 (1965); K. J. Folet et al., Phys. Rev. Lett. 19, 857 (1967); S. P. Denisov et al., Phys. Lett. 36B, 415 (1971).
[3] V. Bartenev et al., Phys. Rev. Lett. 29, 1755 (1972); J. W. Chapman et al., Phys. Rev. Lett. 29, 1686 (1972); G. Charlton et al., Phys. Rev. Lett. 29, 515 (1972); E. T. Dao et al., Phys. Rev. Lett. 29, 1627 (1972).
[4] G. G. Beznogikh et al., Phys. Lett. 39B, 411 (1972); Kh. M. Chernev et al., Phys. Lett. 36B, 266 (1971)
[5] G. G. Beznogikh et al., Phys. Lett. 30B, 274 (1969).
[6] U. Amaldi et al., Phys. Lett. 36B, 504 (1971); G. Barbellini et al., Phys. Lett. 39B, 663 (1972).
[7] V. A. Tsarev, Kratkie soobshcheniya po fizike (FIAN), No. 8 (1973).
[8] V. A. Tsarev, Yad. Riz. 18, 425 (1973) [Sov. J. Nuc. Phys. 18, No. 2 (1974)]; FIAN Preprint No. 69, 1973.
[9] Yu. P. Gorin et al., Yad. Fiz. 17, 309 (1973) [Sov. J. Nuc. Phys. 17, No. 2 (1973)].
[10] V. N. Bolotov et al., Report at XVI Inter. Confer. on High Energy Physics, Batavia, 1972.
[11] N. I. Starkov, V. A. Tsarev, N. P. Zotov, and P. N. Lebedev, Physical Institute Preprint No. 103, 1973.

INELASTIC INTERACTIONS OF FAST HADRONS WITH NUCLEI

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The picture of the inelastic processes accompanying the interaction of a fast hadron with a nucleus is considered under the assumption that the interaction of two hadrons is described by means of a pomeron exchange and that the asymptotic total cross sections are constant in this case.

1. The physical picture of the interaction can be easily understood by starting from the parton conceptions [1, 2] of the spatial structure of the wave function of a fast hadron of energy E, namely, its stationary state constitutes in the mean an aggregate of particles (partons) with energy spectrum $d\varepsilon/\varepsilon$ ($m < \varepsilon < E$) and with bounded transverse momenta; the particles with energies $\sim \varepsilon$ are distributed in a disk of radius $\sim \sqrt{2\alpha' \ln(E/\varepsilon)}$ and thickness $\sim 1/\varepsilon$. When such a "comb" of partons is incident on a hadron at rest, then the hadron can interact only with a slow particle from the comb; after the interaction, which destroys the coherence of the system, the remaining particles of the comb also become free (after times on the order of $\varepsilon\mu^{-2}$), with the shape of the $d\varepsilon/\varepsilon$ spectrum remaining the same. The total cross section σ of this process is determined by the interaction of the slow particles, and therefore $\sigma \approx \mu^{-2}$ (μ is the meson mass).

We apply these conceptions to a nucleus consisting of A nucleons (the radius of the nucleus is R, the average distance between nucleons is $r \sim 1/\mu$, and the nucleon mass is m). It is convenient to consider the hadron-nucleus interaction in a coordinate system in which the nucleus has an energy AE and the hadron is at rest. What is the parton state in such a system? We assume at first that E is relatively small, and then start to increase it. Owing to the Lorentz contraction, the nucleus flattens gradually with increasing E, and the average longitudinal distances between the nucleons decrease like $(r/\sqrt{3})(m/E)$, while the average transverse distances remain unchanged.

Each of the nucleons of the nucleus is accompanied by a comb of partons. How do these combs interact? We consider two nucleons located a distance $[x_z, x_\perp]$ apart in the rest system of the nucleus. Obviously, their parton clouds are spatially separated if at least one of the conditions

$$x_\perp^2 > 8\alpha' \ln(E/m), \qquad (m/E)\, x_z > 1/\mu . \qquad (1)$$

is satisfied. If $x_\perp^2 \sim 8\alpha' \ln(E/M)$, the regions in which the slow partons are situated begin to