Diffraction-minimum mechanism in elastic hadron scattering

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We discuss the mechanism of diffraction minimum in elastic scattering of hadrons. The dip is the result of unitary effects of the dipole-pomeron model and corresponds to absorption at small values of the impact parameter. Absorption is characterized by the constant $\kappa = \lambda - 1/b$, where λ is determined from the total cross section and b is the slope parameter of the diffraction peak. The use of this connection as well as of the results of the quark model enables us to predict the position of the diffraction minimum in K^+p scattering.

The presence, in the high-energy region, of a characteristic diffraction minimum in the pp-scattering cross section raises the natural question whether such a minimum exists also in other hadronic processes. We show in this article that a diffraction minimum exists also in meson-baryon scattering processes, and that the position of the minimum is determined by the slope parameter b of the diffraction cone and by the parameter λ characterizing the growth of the total cross section.

Our model is a generalization of the dipole-pomeron model used successfully in [1] to describe pp scattering. Attractive properties of the dipole-pomeron model are the presence of geometric similarity[2] and the self-reproducibility when account is taken of rescattering. The scattering amplitude is given in the dipole-pomeron model by[1]

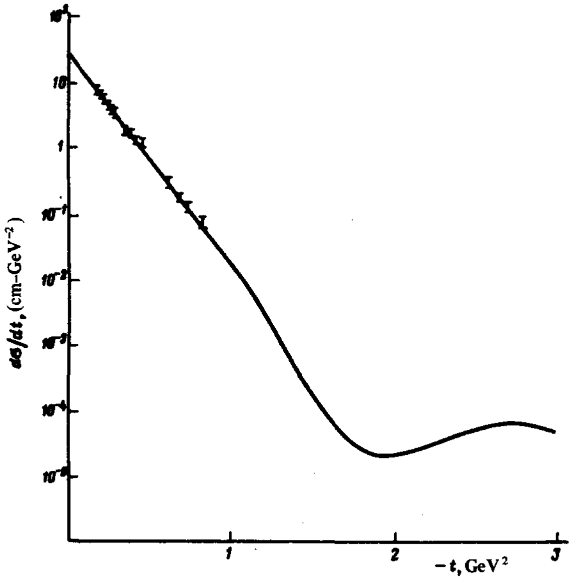
$$A(s,t) = \frac{d}{da}\left[e^{-i\frac{\pi a}{2}}\left(\frac{s}{s_0}\right)^{a} G(a)\right]$$

$$= e^{-i\frac{\pi a}{2}}\left(\frac{s}{s_0}\right)^{a} G'(a)\left[1 + \phi(a)\ln\frac{s}{s_0} - i\frac{\pi}{2}\phi(a)\right],$$

where

$$\phi[a(t)] = \frac{1}{b}(1 - e^{-b a' t}) + \lambda e^{-b a' t} . \qquad (1)$$

Here b is the slope parameter of the diffraction cone, the parameter λ determines the logarithmic growth of the cross section $\sigma_t = \sigma_0[1 + \lambda \ln(s/s_0)]$, and α' is the slope of the Pomeranchuk-pole trajectory. The position of



the minimum in the differential cross section is determined by the condition

$$1 + \phi(t)\ln\frac{s}{s_0} = 0. \qquad (2)$$

It can be easily seen that this equation has a solution only if $\kappa = \lambda - 1/b < 0$. Reduction of the experimental pp-scattering data yields the following parameter values:

$$b = 10, \ \lambda = 0.07, \ \alpha' = 0.2\,\mathrm{GeV}^{-2}, \ s_0 = 100\,\mathrm{GeV}^2 .$$

The model makes use of a minimum number of free parameters. In particular, the differential cross section is determined by one parameter b in the region of the diffraction peak. The behavior of the differential cross section outside of the peak, and in particular the position of the diffraction minimum, is predicted by the model. The position of the minimum is given by[1]

$$t_{dip} = \frac{1}{\alpha' b}\ln\left(\frac{1-\lambda b}{1 + b/\ln\frac{s}{s_0}}\right). \qquad (3)$$

It follows therefore that the minimum in the differential pp-scattering cross section, say at $s = 3000$ GeV^2, occurs at $t = -1.3$ GeV^2, in accord with the experimental data.

We consider now the meson-baryon scattering. To describe these processes we use, as before, an amplitude of the type (1). Let us first estimate the parameter $\kappa = \lambda - 1/b$. The behavior of the diffraction-peak slope parameter in the processes πN, KN, and NN was investigated experimentally up to the maximum Serpukhov accelerator energies (there are also ISR data on pp).

The behavior of the slope parameter is similar in many respects to the behavior of the corresponding cross sections, namely, for all processes (except pp scattering, where the contribution of secondary trajectories is still appreciable), a tendency to approach an asymptotic logarithmic growth is observed. Approximating the known experimental data in the ISR energy region, we obtain the empirical ratio $b_{MB}/b_{BB} = \frac{4}{5}$. This ratio can be obtained also on the basis of the factorizing-quark model,[3] where it is assumed that the quarks participating in the reaction are scattered independently by some common effective potential produced by hadrons that repel one another. Consequently, the number of independent scatterings in the system is one less than the number of the quarks in the two-hadron system. Assuming, as usual, an exponential parametrization of the quark-scattering amplitude, we obtain the sought ratio of the diffraction-cone parameters. (Indeed, in the meson-baryon and baryon-baryon systems there are 4 and 5 independent scatterings, respectively.)

The experimental data on the total cross section do not make it possible to determine the parameter λ with high accuracy. Nonetheless, these data allow us to state that $\lambda_{BB} \approx \frac{4}{5}\lambda_{MB}$. This yields $\kappa_{MB} \approx \frac{5}{4}\kappa_{BB}$.

Thus, the parameter κ_{MB} is also a small negative number, and a dip will be observed in the meson-baryon differential scattering cross section. Using the obtained values of the parameters, we find that in K^+p scattering, at NAL energies, $p_L = 200$ GeV/c, the minimum will be observed at $t \approx -1.93$ GeV^2.

The figure shows a plot of the differential K^+p scattering cross section at the indicated energy. Simple calculations show that the amplitude (1) leads to the existence of a diffraction maximum. The position of the maximum is given by

$$t_{max} = -\frac{1}{b\alpha'}\ln\frac{\left(\ln\frac{s}{s_0} - b\right)^2 + \pi^2/4}{(1-\lambda b)\left(\ln^2\frac{s}{s_0} + \frac{\pi^2}{4}\right)} .$$

At the parameters indicated above, the maximum of the differential K^+p scattering cross section occurs at $t \approx -2.68$ GeV^2.

In conclusion, we wish to emphasize once more that the existence of diffraction minima in the considered model is connected with the fact that the parameter κ is negative. This means physically that absorption is introduced into the amplitude (1) in the region of small impact parameters. This is seen directly from the Eq. (1) is rewritten in the impact-parameter representation

$$T(s,\rho) = e^{-\frac{m\alpha_0}{2}}\left\{\frac{1}{b}\exp\left[-\frac{\rho^2}{4\left(b\alpha' + \alpha'\ln\frac{s}{s_0} - i\frac{\pi\alpha'}{2}\right)}\right] + \kappa\exp\left[-\frac{\rho^2}{4\left(\ln\frac{s}{s_0} - i\frac{\pi}{2}\right)\alpha'}\right]\right\},$$

It is precisely the absorption in the region of small ρ which leads to the existence of the diffraction minimum.

An experimental investigation of the differential cross section in the region considered by us is scheduled to be performed at NAL this fall.

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