Diffractive dissociation and “fine structure” of diffraction peak

N. I. Starkov and V. I. Tsarev

P.N. Lebedev Physics Institute, USSR Academy of Sciences
(Submitted February 17, 1976)
Pis'ma Zh. Eksp. Teor. Fiz. **23**, No. 7, 403–407 (5 April 1976)

It is shown that the peripheral contributions of the inelastic diffraction processe produce in the elastic-scattering cross section a large-scale and a small-scale periodic structure in t. In pp scattering this structure is revealed by a "kink" $t \approx -0.15(\mathrm{GeV}/c)^2$, by large-scale oscillations observed at large t $(1 \lesssim \sqrt{|t|} \lesssim 4$ GeV/c), and by small-scale oscillations in the region of small $t(\lesssim 0.4\ (\mathrm{GeV}/c)^2$

PACS numbers: 13.80.Dh

We show in this paper that the three singularities observed in the cross se tion of elastic p-p scattering, namely the "kink" at $t = -0.15\ (\mathrm{GeV}/c)^2$, [1] the small-scale oscillations with period $\Delta t \approx 0.1$—$0.3\ (\mathrm{GeV}/c)^2$ separated from t ta at $0.1 \lesssim |t| \lesssim 0.4$ (GeV/c)^2,[2] and the large-scale oscillations with Δt 1.5–2 (GeV/c)^2, obtained at $1 \lesssim |t| \lesssim 4$ (GeV/c)^2,[3] can be explained as a anifestation of one and the same mechanism, which is connected with diffrac- 're dissociation. We confine ourselves here to a simple semiquantitative alysis which yields, nevertheless, without introducing any free parameters, reasonable quantitative description of all the indicated effects. A more de- iled discussion will be presented in a subsequent article. The proposed model close in spirit to the model of Henyey *et al.*,[4] proposed for the explanation the "kink." The essential difference lies in the fact that we are using a more alistic description of diffraction dissociation and consider also oscillatory 'ects, besides the "kink."

We neglect the possible small contributions of spin-flip effects and the real rt of the elastic-scattering amplitude is T_{el}. We then get from the s-channel itarity in the impact-parameter representation

$$T_{el}(\rho) = 2i\left(1 - \sqrt{1 - G(\rho)}\right), \qquad (1)$$

iere $G(\rho) \equiv \sum_n |T_n(\rho)|^2$ is the inelastic overlap function, which takes into ac- unt the contribution of all the inelastic processes. We represent G as a sum $+\Delta G$, where G_0 has by assumption a central character and is responsible r the principal part of the elastic peak, including the structure at $t \approx -1.4$ eV/c)^2. ΔG takes into account the contribution of the inelastic diffraction ocesses. To calculate ΔG, we use the peripheral model with absorption,[5] iich describes adequately all the main features of diffractive dissociation at iall t. We consider first the excitation of a nucleon in states with small mass. ie main contribution is made here by the transition $N \to N + \pi$ with small change the s-channel helicity $\Delta\lambda = 0$ is given by

$$T_d(\rho) = \frac{iA}{2}\left\{\frac{\exp\left[\frac{-\rho^2}{2(B+B_1)}\right]}{B+B_1} - \frac{\sigma b(B+B_1)\exp\left[-\frac{\rho^2(B+B_1+b)}{2b(B+b)}\right]}{4\pi(B+B_1+b)^2}\right\} \qquad (2)$$

in the t-representation

$$T_d(t) = iA\left\{\exp\left[\frac{(B+B_1)t}{2}\right] - \frac{\sigma\exp\left[\frac{(B+B_1)bt}{2(B+B_1+b)}\right]}{4\pi(B+B_1+b)}\right\}. \qquad (3)$$

re σ is the total cross section of the pp interaction; b, B, and B_1 are the pe parameters of the NN- and πN-scattering cross sections and functions t describe the vertex and the propagator of the emitted pion. Just as in[5], put $b \approx B \approx B_1 = 10$ (GeV/c)^2 and $\sigma \approx 40$ Mb. Expression (3) vanishes at -0.2 (GeV/c)^2, leading to the minimum recently observed in the cross sec- ı of the reaction $pp \to \pi^+ np$.[6] It is seen from (2) that $T_d(\rho)$ has a peripheral file—a "ring" with radius $R \sim 1$ F. Recognizing that $G \ll 1$ at $\rho \gtrsim 1$ F, we can roximately write down (1) in the form $T_{el} \approx T_0 + \Delta G$, where according to (2)

$$\Delta G(t) = i\frac{A^2}{2}\left\{\frac{\exp\left[\frac{t(B+B_1)}{4}\right]}{B+B_1} + \frac{\sigma^2\exp\left[\frac{tb(B+B_1)}{4(B+B_1+b)}\right]}{16\pi^2 b(B+B_1)(B+B_1+b)}\right.$$ (

$$\left. - \frac{\sigma\exp\left[\frac{tb(B+B_1)}{2(B+B_1+b)}\right]}{\pi(B+B_1)(B+B_1+2b)}\right\}.$$

As expected from (1), $\Delta G(t)$ behaves like a Bessel function

$$\Delta G(t) \sim i f(t) J_0(R\sqrt{-t})$$ (

with $R \sim 1$ F (see Fig. 1). The elastic-scattering differential cross section ca be expressed in terms of T_0 and ΔG in the form

$$\frac{d\sigma}{dt} = (|T_0|^2 + 2T_0^* \Delta G) + |\Delta G|^2 .$$ (

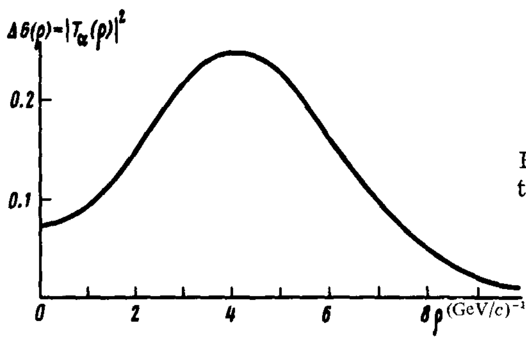
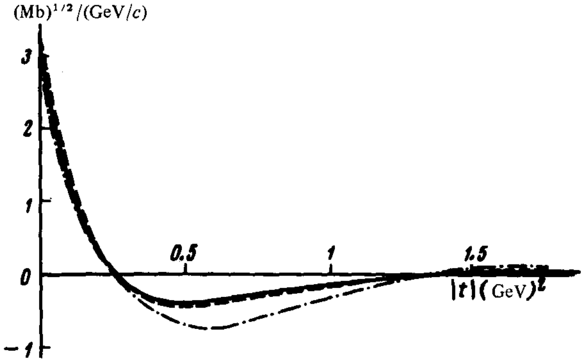


FIG. 1. Profile of $\Delta G(\rho) \equiv |T_d(\rho)|^2$ i the impact-parameter representatic

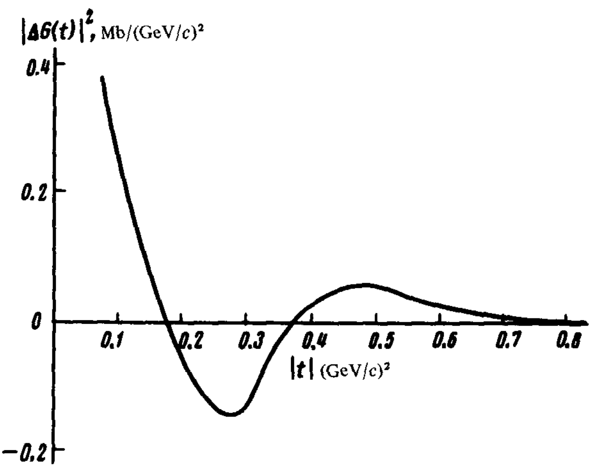
Assuming that $T_0(t)$ at small $|t|$ can be described by a simple exponential or l the function $\exp(B_0 t) J_1(R_1\sqrt{-t})/R_1\sqrt{-t}$, which appears in many geometrical models, and taking (4) into account, we see immediately that the expression i the brackets in (6) describes a diffraction peak with a kink due to the term $2T_0^*\Delta G$. At the same time the quadratic term $|\Delta G|^2$ yields small-scale oscil lations about the average value of the cross section (Fig. 3). One can expect the "ring" effect to be manifest also at larger $|t|$. Continuing (5) into the regi of large $|t|$, we obtain large-scale oscillations with a period $\Delta\sqrt{|t|} \sim 1.5$ (GeV/c), similar to those observed recently in[3], and small-scale oscillatior with $\Delta t \sim 0.7$ (GeV/c)^2.

To obtain a kink on the order of that observed in experiment we must have $A^2 \sim 200$. The cross section oscillations due to $|\Delta G|^2$ will then be on the orde of several percent, and the increment of the slope at the "kink" will be

$[\Delta G(0)/T_0(0)]R^2 \sim 2(\mathrm{GeV}/c)^2$. Estimates show that to obtain this value of A^2 is necessary to take into account the contribution of the excitations of the ıcleon up to sufficiently large masses (> 5 GeV) under the assumption that the ɘripheral character of the profile is preserved for the different contributions. he model of[5] leads to a practically universal behavior of $\Delta G_{\Delta\lambda}(\Delta\lambda \neq 0)$, corɘsponding to a ring with $R \sim 1$ F. This is illustrated by the behavior of $G_{\Delta\lambda=1}(t)$ in Fig. 2.



IG. 2. Contribution made to the amplitude of elastic pp scattering by diffracve dissociation: solid—$\Delta G(t)$ in accordance with formula (3), dashed—in ccordance with $3.1\exp(1.7t)J_0(4.7\sqrt{-t})$; dash-dot—$\Delta G_{\Delta\lambda=1}(t)$ (arbitrary scale).



IG. 3. The contribution $|\Delta G(t)|^2$ gives the "fine structure" of the peak relative the average behavior. The averaging was over the interval $0.1 \leq |t| \leq 0.4$ GeV$/c)^2$.

We do not discuss here many important problems, such as the s-dependence the amplitude, the self-consistency of the considered pomeron model, etc. ıis will be done later. We confine ourselves here to only one remark. By plying a Mellin transformation we can obtain the t-channel partial wave corresponding to the considered amplitude. It can be shown that for a large class of the functions $R(s)$ the contribution ΔG corresponds to complex singularities. For example, for the simplest cast $R(s)=R_0 \ln s$ we obtain a pair of complex-conjugate branch points at $\alpha_{\pm}(t)=\alpha_R(t)\pm iR_0\sqrt{-t}$. We thus arrive (discarding inessential details) at the pomeron picture proposed in[2], where the small-scale structure is ascribed to complex components of the pomeron.

It is obvious that the mechanism considered above should manifest itself also in other elastic-scattering processes, as well as in inelastic reactions.

The authors are grateful to Yu. M. Antipov, A. M. Baldin, S. P. Denisov, and E. L. Feĭnberg for useful discussions.

[1]V. Amaldi *et al.*, Phys. Lett. **36B**, 504 (1971); Barbellini *et al.*, Phys. Lett **39B**, 663 (1972).
[2]V. Tsarev, FNAL Pub-74-17 (January 1974).
[3]B. Schrempp and F. Schrempp, Phys. Lett. **55B**, 303 (1975).
[4]F. S. Henyey, R. H. Tuan, and G. L. Kane, Nucl. Phys. **B70**, 445 (1974).
[5]V. Tsarev, Phys. Rev. **11D**, 1864 (1975); **11D**, 1875 (1975).
[6]Nagy *et al.*, CERN report submitted to the 17th Intern. Conf. on High Energy Physics, London, July 1974.