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ELASTIC π^+p SCATTERING THROUGH 90° ANGLE AND CONTRIBUTION OF Δ_δ REGGE TRAJECTORY IN THE s-CHANNEL

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We develop in this paper the idea developed in [1], that resonances of the direct channel make a decisive contribution to the amplitude of elastic πp scattering through angles close to 90°. Attmepts to realize this idea in describing s-channel resonances by means of a sum of Breit-Wigner terms does not lead to the observed exponential decrease of the differential cross section for πp scattering through 90° with increasing energy, unless one resorts to additional assumptions which have no theoretical justification [1]. We used in this paper a different approach to this problem. The sum of the Breit-Wigner resonances was replaced by Regge's formula, which unifies in one term the contribution of the entire Regge trajectory on which the sequence of resonances lies.*

We consider elastic π^+p scattering through 90°. In this reaction, exchange is possible for resonances lying only on two Regge trajectories (Δ_δ: I = 3/2, P = +, σ = -; Δ_β: I = 3/2, P = -, σ = +). At the present time there is no confirmation of the recurrence of Regge poles for the Δ_β trajectory (only one resonance with mass 160 MeV is known). Consequently, in calculating the scattering amplitude

$$T(s,z) = f(s,z) + i\,\frac{\sigma\cdot[\mathbf{q}\times\mathbf{q}']}{q^2}\,\tilde{f}(s,z) \tag{1}$$

(q and q' are 3-momenta in the c.m.s. before and after scattering), we take into account only the contribution of the Δ_δ trajectory:

$$f(s,z) = \frac{\pi}{2q}\,\frac{\alpha(s)+1/2}{\cos\pi\alpha(s)}\,r_\alpha(s)\,[P_{\alpha(s)-1/2}(-z) - P_{\alpha(s)-1/2}(z)], \tag{2}$$

$$\tilde{f}(s,z) = -\frac{\pi}{2q}\,\frac{r_\alpha(s)}{\cos\pi\alpha(s)}\,[P'_{\alpha(s)-1/2}(-z) + P'_{\alpha(s)-1/2}(z)]. \tag{3}$$

Here $\alpha(s) = \alpha_1(s) + i\alpha_2(s)$ is the Regge Δ_δ trajectory, $r_\alpha(s)$ is its residue, and $z = \cos\theta$. The trajectory is described by the Chew-Frautschi line:

$$\alpha_1(s) = \alpha_1(0) + \alpha_1' s; \qquad \alpha_1(0) = 0.15, \quad \alpha_1' = 0.9\ \text{GeV}^{-2} \tag{4}$$

Near the resonant value $s = M^2$ (M is the resonance mass), at which Re $\alpha(M^2) = J$, the corresponding pole contribution to the partial amplitude f_J should be written with equal success in the Regge or in the Breit-Wigner form:

$$f_J = \frac{r_\alpha(s)}{J - \alpha(s)} \to \frac{X}{\epsilon - i} \quad \text{as} \quad s \to M^2, \tag{5}$$

where $\epsilon = M^2 - s/M\Gamma$, and Γ and X are the width and elasticity of the resonance. From (5) it follows directly that $\alpha_2(M^2) = \alpha_1' M\Gamma$ and $|r_\alpha(M^2)| = \alpha_2(M^2)X$. Using these relations, we can determine, from the experimental values of the parameters of the individual resonances, the particular values of the functions $\alpha_2(s)$ and $r_\alpha(s)$ at the resonance points, after which the form of these functions is determined by extrapolation. From the plot in Fig. 1 it follows that (sufficiently far from the reaction threshold) the function $\alpha_2(s) = \alpha_1' \sqrt{s}\,\Gamma(s)$ is well approximated by the relation

$$\alpha_2(s) = 0,9\sqrt{s}\,[(0,0288 \pm 0,0050) + (0,0426 \pm 0,0033)\,s]. \tag{6}$$

It must be emphasized that this empirical expression and the Chew-Frautschi formula (4) are in agreement far from threshold when substituted into the dispersion relation for the Regge trajectory.

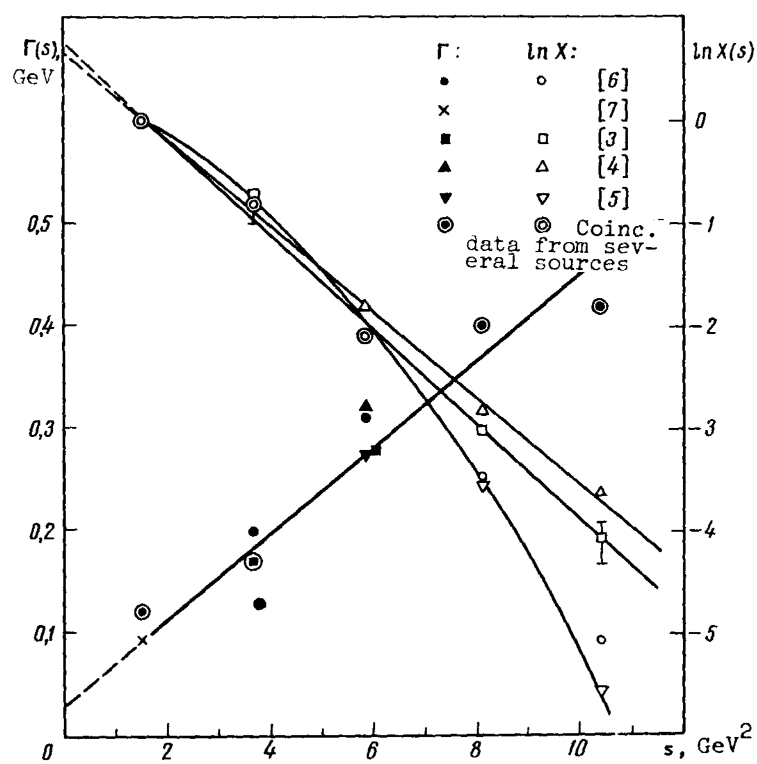

Fig. 1

Unfortunately, the presently available sets of elasticities of the Δ_δ resonances [3-6] do not make it possible to establish uniquely the dependence of the residue of the Regge trajectory on s. In accordance with the plots of $\ln X(s) \equiv \ln|r_\alpha(s)|/\alpha_2(s)$, which are given in Fig. 1, we have

$$[3]: \quad r_a(s) = a_2(s)\exp(0{,}7 - 0{,}46\,s),$$

$$[4]: \quad r_a(s) = a_2(s)\exp(0{,}65 - 0{,}42\,s),$$

$$[5,6]: r_a(s) = a_2(s)\exp(0{,}45 - 4{,}2\;a_2(s)).$$

According to (2) and (3), the energy dependence of the cross section for elastic π^+p scattering through 90° is of the form:

$$\left.\frac{d\sigma}{d\Omega}\right|_{90^\circ} = \left|\tilde{f}(s,0)\right|^2 = \frac{\pi}{q^2}\left|\frac{r_a(s)}{\cos\dfrac{\pi\lambda(s)}{2}}\;\frac{\Gamma[1+(\frac{\lambda(s)}{2})]}{\Gamma[\frac{(1+\lambda(s))}{2}]}\right|^2 . \tag{10}$$

Here $\lambda(s) = \alpha(s) - (1/2)$ and Γ is the Euler gamma function. The approximation of the residue by means of formula (9) leads to a decrease of the Regge contribution of the Δ_δ trajectory

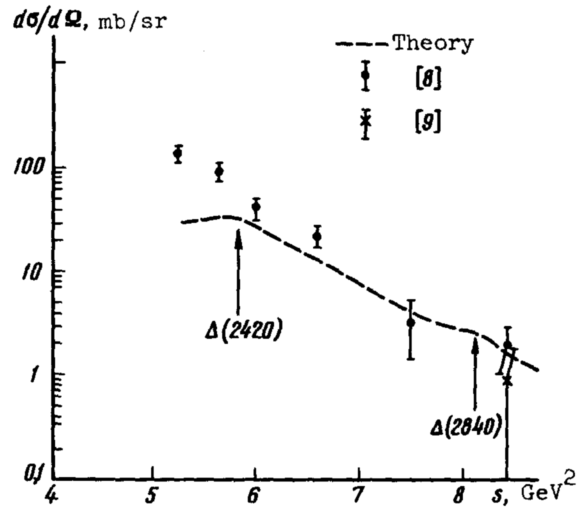

Fig. 2

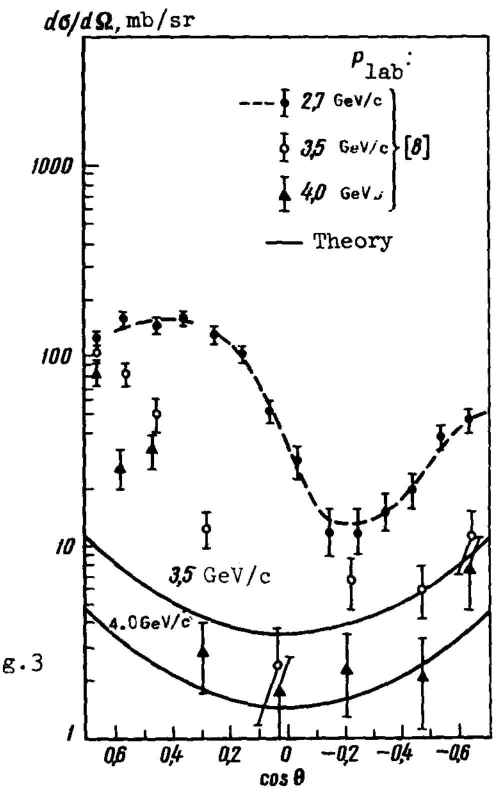

Fig.3

to $(d\sigma/d\Omega)|_{90^\circ}$, which continuously remains approximately one-fourth as large as the experimentally measured cross section of elastic π^+p scattering near 90° in the range $P_{lab} = 2.3 - 4$ GeV/c [8]. As regards formulas (7) and (8), their use leads to results that differ little from each other. Figure 2 shows that by using the variation of the residue $r_\alpha(s)$ given by

(8) or by (7) it is possible to describe satisfactorily elastic π^+p scattering through 90° at sufficiently large energies by means of the contribution of the Δ_δ trajectory.** The angular distribution of the cross section

$$\frac{d\sigma}{d\Omega} = |f(s, z)|^2 + \sin^2\theta\,|\tilde{f}(s, z)|^2 \tag{11}$$

also agrees near 90° with the experimental values for energies $P_{lab} \gtrsim 3.5$ GeV/c (Fig. 3). (In the forward hemisphere, the contribution of the t-channel is large.) We note the following important circumstance: At high energies, in spite of the presence in formulas (2) and (3) of Legendre functions with oscillating real and imaginary parts, the π^+p scattering angular distribution corresponding to the contribution of one Δ_δ Regge trajectory is described on the whole by a smooth curve which is symmetrical with respect to $z = 0$, and which has a minimum at this point. The presence of a minimum at $z = 0$ is characteristic of experiments at $P_{lab} \geq 3.5$ GeV/c [8], i.e., in the region where the plot of Fig. 2 agrees with the experimental data.

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* A similar idea was used recently by Desai et al. [2] to describe the polarization occurring during the charge-exchange process $\pi^-p \to \pi^0 n$. The authors became acquainted with a preprint of this paper after completing the present work, and are grateful to K. A. Ter-Martirosyan for supplying this preprint.

** Estimates show that if the Δ_β trajectory exists and if its residue decreases with energy more rapidly than the residue of the Δ_δ trajectory, then the contribution of the Δ_β trajectory to the cross section of the process can improve the agreement between theory and experiment at medium energies, without making the agreement worse at high energies.

MAGNETIC-GRAVITATIONAL ANALOGY AND THE POSSIBLE CONSEQUENCES FROM GENERAL RELATIVITY IN COSMOGONY

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The tensor nature of the gravitational field leads, even in the linear approximation, to additional forces that act on a moving particle and which in principle are absent in