[9] J.K. Foley et al., Phys. Rev. Lett. 19, 397 (1967); E.W. Anderson et al., Phys. Rev. Lett. 25, 699 (1970).
[10] F.J. Gilman et al., Phys. Lett. 31B, 307 (1970).

SPLITTING OF A_2 MESON

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Considerable interest attaches to the question of the nature of the experimentally observed [1] splitting of the maximum of the A_2 resonance [2]. Attempts to explain this phenomenon with the aid of two closely-lying resonances with identical quantum numbers [1, 3] or a dipole [1, 4] encounter certain difficulties in view of the recently reported experiments [5], in which no splitting of the A_2 meson was observed. We note in the present paper that the available experimental data can be explained if it is assumed that there exists a strong destructive interference between the A_2 resonance and the background.

When the A_2 meson is produced in the reactions $\pi^{\pm}p \to A_2^{\pm}p \to \rho^0\pi^{\pm}p$, (1), the mass spectra of the $\rho^0\pi^{\pm}$ systems indicate the existence of a considerable background under the A_2 peak (see Fig. 1). The A_2 meson has quantum numbers $I^P = 2^+$ [6], i.e., it corresponds to the d-wave of the $\rho\pi$ system, and the greater part of the background is apparently in other partial waves - for example, the s-wave. There are no grounds at all, however, for assuming that the background in the d-wave is not small. In this connection, we write down the amplitude for the production of the $\rho\pi$ system in the reaction (1) in the form (we can consider in similar fashion the production of A_2 in other processes and its transitions to the channels $K\bar{K}$ and $\eta\pi$)

$$T(M, s_i, t_i) = g(M, s_i, t_i)\left[\frac{\Gamma/2}{M_{A_2} - M - i\frac{\Gamma}{2}} + \alpha(M, s_i, t_i) + i\beta(M, s_i, t_i)\right], \qquad (1)$$

where

$$M = s_{\rho\pi}^{1/2} = \sqrt{(E_\rho + E_\pi)^2 - (\mathbf{p}_\rho + \mathbf{p}_\pi)^2}$$

is the invariant mass of the $\rho\pi$ system, and s_i and t_i are the other invariant variables, on which the amplitude of the reaction may depend. The form of this relation is thus far immaterial to us.

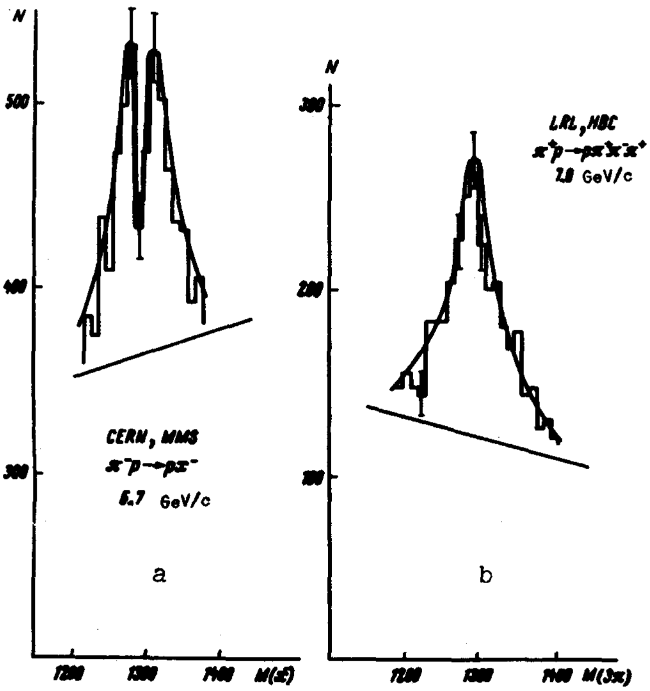

Fig. 1. Mass distributions in the region of the A_2 resonance: a - $\pi^-p \to p x^-$ at $p_{\pi^-} = 6.7$ GeV/c [1], b - $\pi^+p \to p\pi^+\pi^-\pi^+$ at $p_{\pi^+} = 7.0$ GeV/c [5].

It is assumed that the functions $g(M, s_i, t_i)$, $\alpha(M, s_i, t_i)$, and $\beta(M, s_i, t_i)$ change little when M changes by an amount $\sim\Gamma$, i.e., the strong dependence on M is contained only in the usual Breit-Wigner form of the A_2 resonance. If, however, the amplitudes α and β of the background are comparable in magnitude with the resonant part, then their interference may strongly distort the shape of the maximum in the distribution of $d\sigma/dM$ with respect to M. The real part of the resonant term (curve I on Fig. 2[1]) reverses sign at $M = M_{A_2}$ and its square has two maxima at $M = M_{A_2} \pm (\Gamma/2)$. Together with the square of the imaginary part (curve II), it gives the usual form of the resonance maximum. If, however, the contribution of the background term decreases the imaginary part of the amplitude by more than a factor of 2, then we get at $M = M_{A_2}$ not a maximum but a minimum. The real part of the background causes, in general, the resonance structure to become asymmetrical with respect to the point $M = M_{A_2}$. Since the experimental distributions of $d\sigma/dM$ in the reaction (1) are symmetrical to a considerable degree, it follows that $\alpha(M, s_i, t_i)$ is small. To describe the experimental data on the splitting of the maximum of $d\sigma/dM$, we choose $\beta(M)$ in the form shown in Fig. 2 (curve III). To describe correctly the experimental distributions on the wings of the resonance, it is necessary that the function $\beta(M)$ decrease on both sides of the resonance. At a distance $\sim\Gamma$, the value of $\beta(M)$ changes by 15 - 20%. Such a behavior of the background as a function of M can be understood by recognizing that in the region $M < M_{A_2}$ the amplitude is near the threshold of the $\rho\pi$ system, and should decrease like $k^{2\ell} \sim (M - (m_\rho + \mu))^2$. In the region of large masses, $s_{\rho\pi} = M^2 > 2\ (\mathrm{GeV})^2$, and at sufficiently high energies of the colliding particles we can expect the amplitude to be determined by the two-reggeon diagrams shown in Fig. 3. In this case the amplitude corresponding to a definite partial wave decreases like $\sim(s_{\rho\pi})^{\alpha_1(t_1) - \alpha_2(t_2) - 1}$. Since α_2 can be a vacuum pole and α_1 can be π, R (for Fig. 3a) and ρ, P', P trajectories (for Fig. 3b), the amplitude decreases more rapidly than $s_{\rho\pi}^{-1}$. Consequently the background part of the amplitude should actually have a maximum in the region $s_{\rho\pi} = 1.5 - 2\ (\mathrm{GeV})^2$, i.e., in the region of the A_2 resonance.

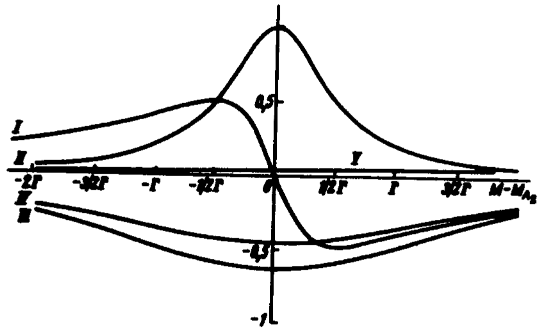

Fig. 2. I - real part of resonant amplitude, II - imaginary part of resonant amplitude, III - imaginary part of background amplitude for π^-p interaction at 6.7 GeV/c, IV - π^+p interaction at 7.0 GeV/c, V - $\alpha(M)$.

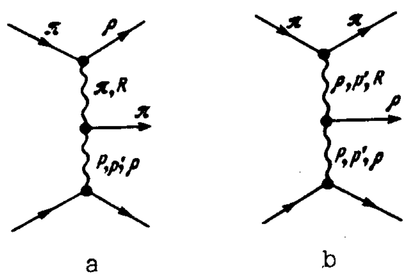

Fig. 3. Two-reggeon diagrams corresponding to the background part of the amplitude

We note that the form of the peak is exceedingly sensitive to the value of $\beta(M_{A_2})$. At $|\beta(M_{A_2})| < 1/2$, the two-hump structure in

[1] The common scale on Fig. 2 was chosen such that the imaginary part of the resonant term equals unity at the point $M = M_{A_2}$. Unlike elastic scattering, the unitarity condition does not fix the value of the imaginary part of the amplitude at $M = M_{A_2}$. The function $g(M, s_i, t_i)$ is arbitrary and is generally complex.

the distribution with respect to M disappears, and there is one maximum. Therefore on going from the reaction $\pi^- p \to \pi^- \rho^0 p$ to $\pi^+ p \to \pi^+ \rho^0 p$ a small change of the resonance to background ratio (curves III and IV respectively on Fig. 2) suffices to cause the minimum at the center to disappear. Figure 1 shows a description of the experimental data based on formula (1) with $\beta(M)$ as represented in Fig. 2, M_{A_2} = 1298 MeV, and Γ = 32 MeV. The straight lines in Fig. 1. which characterize the nonresonant background, were taken from [6]. We note that the model predicts the characteristic form of the curve in the presence of a minimum, namely a sharp dip in the center and a relatively slow decrease on the wings of the resonance, and describes well the mass distribution in both reactions.

In order to make more detailed predictions concerning the character of the mass distributions at different energies and in different processes, it is necessary to specify some model for the description of the production of the A_2 resonance and the background. We shall assume that at high energies the A_2 meson is produced as a result of exchange of P, P', and ρ Regge poles, and the background is connected mainly with two-reggeon diagrams of the type shown in Fig. 3. We note that such a model is not dual but interferential. One can choose the residues of the poles in such a way as to describe the existing experimental data on the production of the A_2 resonance. The model predicts the following properties of particle production in the region of the A_2 resonance:

a) The form of the mass distributions should generally speaking depend on the angle of emission of the $\rho(K, \eta)$ meson relative to the incident pion in the rest system of A_2. This property should be particularly strongly pronounced in the reactions $\pi^- p \to \rho^+ \pi^- n$ (2), $\pi^- p \to \rho^- \pi^+ n$ (3), and $\pi^- p \to K^+ K^- n$ (4). If ρ^+ in reaction (2), π^+ in (3), and K^+ in (4) move in the direction of the incident π^-, then in this kinematics there are no diagrams of the type of Fig. 3, since exchange of a charge Q = 2 takes place in the t_1 channel. Therefore there is no background and the splitting of the A_2 meson should not be observed. On the other hand, if ρ^+, π^+, and K^+ travel in opposite directions, then the background corresponding to the two-reggeon diagrams exists, and a minimum should occur in the mass distribution.

b) With increasing energy, the splitting of the A_2 produced in $\pi^- p$ collisions should vanish. This is connected with the fact that at very high energy only the vacuum pole makes a contribution and the amplitude of the reaction $\pi^- p \to A_2^- p$ is the same as for the reaction $\pi^+ p \to A_2^+ p$, in which no splitting of the A_2 meson is observed.

An experimental verification of these predictions, aimed at clarifying the mechanism of the splitting of the A_2 resonance, is of considerable interest.

[1] G.E. Chikovani, M.N. Focacci, W. Kienzle, et al., Phys. Lett. 25B, 44 (1967); H. Benz, G.E. Chikovani, G. Damgard, et al., Phys. Lett. 28B, 233 (1968); R. Baud, H. Benz, B. Bosnjakovic, et al., Phys. Lett. 31B, 397 (1970).

[2] P. Schubelin, Phys. Today 23, 32 (1970).

[3] C. Rebbi and R. Slansky, Phys. Rev. 185, 1838 (1969); J.V. Beaupre, T.P. Coleman, K.E. Lassila, and P.V. Ruuskanen, Phys. Rev. Lett. 21, 1849 (1968).

[4] K.E. Lassila and P.V. Ruuskanen, Phys. Rev. Lett. 19, 762 (1967).

[5] M. Alston-Garnjost, A. Barbaro-Galtieri, W.F. Buhl, et al., Phys. Lett. 33B, 607 (1970); K.J. Foley, W.A. Love, S. Ozaki, et al., Phys. Rev. Lett. 26, 413 (1971).

[6] M. Roos, C. Brickman, A. Barbaro-Galtieri, et al., Phys. Lett. 33B, 1 (1970).