Concerning the possibility of explaining the Argonne experiment on the reaction $\pi^- p \to \omega n$ at 6 GeV/c as being due to two-reggeon exchanges

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The anomalous polarization phenomenon observed in Argonne in the reaction $\pi^- p \to \omega n$ at 6 GeV/c is attributed to a Regge πA_2 cut. The appearance of a dip in $\rho_{00} d\sigma/dt$ at $t \approx 0$ and a stronger manifestation of the $\rho^0 - \omega$ interference in $\rho_{00} d\sigma/dt$ are predicted for the reactions $\pi^+ N \to \omega N$ with increasing energy.

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1. Recently published data, with large statistics, obtained in Argonne on the reaction $\pi^- p \to \omega n$[1] at $q_L = 6$ GeV/c, cannot be understood by using the known Regge trajectories. In the experiment, $\rho_{00} d\sigma/dt$ does not vanish at very small transfers, $|t| \sim 0.02$ (GeV/c)^2, as expected theoretically (exchange of Regge B pole). This means that the amplitude without helicity flip in the c. m. s. $M_{0\,1/2,1/2}$, is significant. This amplitude is described at high energies by Z-exchange in the t-channel with quantum numbers $(\tau, P, G, I) = (+1, -1, +1, 1)$, where τ is the signature. The observed phenomenon can in principle be attributed to Z exchange.[2] It must be emphasized that an explanation with the aid of simple Regge poles is possible only under conditions of "conspiracy" of the Z trajectory with its daughter trajectory $Z_d(-1, +1, +1, 1)$.[3] In the opposite case, it follows from the analyticity of the invariant amplitudes that $M_{0\,1/2,1/2} \sim t$.

Thus, we need two new trajectories. However, the existence of such trajectories is doubtful, since we do not know of any heavy particles with $I^G(J^P) = 1^+(2^-)$ and $1^+(1^+)$ lying on the Z and Z_d trajectories, respectively.

2. We propose in this paper an alternate explanation with the aid of two-reggeon branching.[4]

Let us first determine which cuts contribute to the amplitude $M_{0\,1/2,1/2}$. It was shown in[5] that the signature of the Regge cut is equal to the product of the signatures of the Regge poles that make up the cut. An important role is therefore played only by two-reggeon cuts from poles with identical signature

$$\tau_{cut} = \tau_1 \tau_2 = +1. \tag{1}$$

It can be shown that contributions to the amplitude $M_{0\,1/2,1/2}$ are made only by cuts from poles with natural ($\tau P = +1$) and unnatural ($\tau P = -1$) parities. Indeed, P-parity conservation yields

$$M_{0\,1/2,\,1/2} = -M_{0\,-1/2,\,-1/2} \tag{2}$$

The contribution of the cut of the amplitudes, see Fig. 1, is

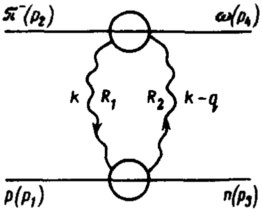

FIG. 1.

$$M_{o\ \pm 1/2,\ \pm 1/2} \sim \sum_\lambda \left\langle \pm\frac{1}{2} \middle| R_2(\mathbf{q}-\mathbf{k}_\perp) \middle| \lambda \right\rangle \left\langle \lambda \middle| R_1(\mathbf{k}_\perp) \middle| \pm\frac{1}{2} \right\rangle, \quad (3)$$

$$\mathbf{q} = \mathbf{p}_3 - \mathbf{p}_1, \quad t = -\mathbf{q}^2.$$

Here λ are the helicities of the intermediate state, it being implied that summation is carried out over all the intermediate states and integration is carried out with respect to $\mathbf{k}_\perp$ and $s_1 = (p_1 + k)^2$ along the right-hand (or left-hand, since these integrals are equal) cut of the reggeon-production amplitude.[5-7] For simplicity we have also left out the upper block of Fig. 1, which is common to both amplitudes, inasmuch as in this place it is of no importance for our discussion. From P-parity conservation it follows, obviously, that

$$M_{o\ -1/2,\ -1/2} \sim \sum_\lambda \left\langle -\frac{1}{2} \middle| R_2(\mathbf{q}-\mathbf{k}_\perp) \middle| \lambda \right\rangle \left\langle \lambda \middle| R_1(\mathbf{k}_\perp) \middle| -\frac{1}{2} \right\rangle$$

$$= (r_1 P_1)(r_2 P_2) \sum_\lambda \left\langle \frac{1}{2} \middle| R_2(\mathbf{q}-\mathbf{k}_\perp) \middle| \lambda \right\rangle \left\langle \lambda \middle| R_1(\mathbf{k}_\perp) \middle| \frac{1}{2} \right\rangle. \quad (4)$$

It follows from (2) that the observed effect can explain the cuts only from poles with

$$(r_1 P_1)(r_2 P_2) = -1. \quad (5)$$

From among the Regge poles known to us, only the pairs $\pi A_2, B\rho, A_1\omega$ satisfy conditions (1) and (5). All these cuts result in approximately the same energy behavior of $M_{0\,1/2,1/2} \sim s^{-1/2}$, under the normalization $d\sigma/dt \sim |M|^2/s^2$. The cut $A_1\omega$ will not be considered, since the A_1 pole does not appear anywhere. In addition we disregard contributions from exchange of two strange poles. Their contribution to $M_{0\,1/2,1/2}$ is $\sim s^{-1}$.

The contribution from the πA_2 cut is the most appreciable, because π exchange has a pole at $t = \mu^2$. We confine ourselves to single-particle states in the amplitudes of the produced reggeons, i.e., we operate in effect within the framework of the absorption-model approximations.[8] More concretely, we use the technique developed in[7], and carry out the integration with respect to s_1 and $s_2 = (p_2 - k)^2$ in (4) along the right-hand cut of the reggeon-production amplitudes $R_1 = \pi$ and $R_2 = A_2$. We take into account the $\rho^0 n$ and $\rho^- p$ intermediate states, $\pi^- p \to (\rho^0 n, \rho^- p) \to \omega n$. From isotopic invariance it follows that these

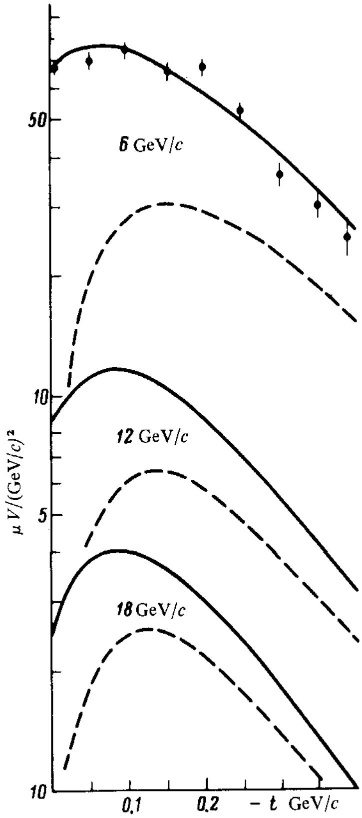

FIG. 2. $\rho_{00} d\sigma/dt(\pi^- p \rightarrow \omega n)$ with allowance for the πA_2 cut and the B pole at various energies. The dashed curves show the contribution of the B pole.

contributions are equal. Therefore the result is doubled. In the A_2NN vertex we have taken into account only the residue with spin flip, since it alone contributes to $M_{0\,1/2,\,1/2}$. We have taken into account the $\rho N \rightarrow \pi N$ amplitude with only longitudinal polarization of the ρ meson. The contribution of amplitudes with transverse polarization is smaller by a factor six—seven. Using the experimental and theoretical information on the residues of the Regge poles, we have arrived at the conclusion that the contribution of the intermediate states $\rho\Delta$, $\pi^- p \rightarrow (\rho^0\Delta^0, \rho^-\Delta^+) \rightarrow \omega n$ is five—six times smaller than the contribution of the ρN intermediate states. The $B\rho$ cut is apparently six—seven times smaller than the πA_2 cut, since the amplitude with B exchange does not contain a pole at $t = \mu^2$.

Using the experimental information on π exchange in the reaction $\pi N \rightarrow \rho N$[9] and on the residue A_2NN with spin flip from the reaction $\pi N \rightarrow \eta N$,[10] as well as the results of an analysis of the total cross section for the photoproduction of hadrons on nucleons[1] for the estimate of the amplitude $\rho N \rightarrow \omega N$, we found that at $q_L = 6$ GeV/c the πA_2 cut yields

$$\rho_{00}\, d\sigma/dt(\pi^- p \rightarrow \omega n)\big|_{t=0} \approx 43 \quad \mu b/(\mathrm{GeV}/c)^2. \tag{6}$$

To explain the experimentally observed value 65 $\mu b/(\mathrm{GeV}/c)^2$ we must assume that the contributions of the other intermediate states, and perhaps also the contributions of other cuts ($B\rho$, etc.) amount to 23%. It is difficult to judge whether this difference should be attributed to contributions of other intermediate states or to inaccuracy in the calculation of the principal contribution, especially the amplitude of the A_2 exchange in $\rho N \to \omega N$. In Fig. 2 our result for $\rho_{00} d\sigma/dt$ becomes comparable with experiment and predictions are given for different energies. We have fixed $\rho_{00} d\sigma/dt = 65\ \mu b/(\mathrm{GeV}/c)^2$ at $t=0$. The contribution of the Regge B pole was chosen in accordance with the strong $B-\pi$ exchange degeneracy. With increasing energy, the contribution of the branch cut phase away in comparison with the B exchange, and we predict the appearance of a dip in $\rho_{00} d\sigma/dt$ at $t \approx 0$, (see Fig. 2).

3. We also predict enhancement of the $\rho^0 - \omega$ interference in the reaction $\pi^{\pm} N \to \omega N$[12,13] with increasing energy.

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