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Abstract

It is pointed out that the twist parameter which governs the breaking of exchange degeneracy, Zweig rule violation, exotic exchange, and the relative production of vector and tensor mesons, is J-dependent. A simple model for this dependence reconciles the smallness of exotic exchange with the large ratio of vector to tensor production, and successfully predicts the sign and magnitude of $\alpha_\rho(o)-\alpha_{A_2}(o)$.

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There have been several attempts recently (1,2,3) to calculate, within the multiperipheral dual topological expansion, quantities such as exotic exchange, violation of the Zweig rule, and the breaking of exchange degeneracy between the ρ and A_2 trajectories. These quantities have been calculated by evaluating diagrams with twists on produced meson lines, and so have been expressed in terms of a "twist parameter," usually denoted by ϵ, which gives the relative strengths of intermediate-state mesons with and without a twist; a small value of ϵ (corresponding to suppression of twisted lines) would then account for the smallness of the above-mentioned quantities.

However, as has been pointed out in Ref. (1), ϵ is also related to the relative production of states of even and odd charge conjugation C: a small value of ϵ corresponds to approximately equal production of states with $C = +$ and with $C = -$. This leads to an apparent paradox; The fact that vector mesons are produced much more copiously than are tensor mesons might seem to indicate that ϵ is not small, while, for example, approximate ρ-A_2 exchange degeneracy would indicate that it is small.

In this note we wish to point out that this twist parameter ϵ is in reality dependent upon the value of J, so that it will not in general have the same numerical value when used to describe particle production (which corresponds to $J \approx 1$) as it will when used to describe the breaking of ρ-A_2 exchange degeneracy (which occurs at $J \approx \frac{1}{2}$). We will also consider a simple model for particle production in which the J-dependence of ϵ turns out to be quite pronounced, and which is able to account for phenomena occuring at different values of J.

The J-dependence of ϵ arises from the fact that the mass spectra for $C = +$ and for $C = -$ are not in general the same, even in a model of production of clusters, because of the existence of prominent low-mass resonances. The multiperipheral production of a state (cluster or resonance) with coupling g which occupies an amount Δ of rapidity contributes to the multiperipheral kernel a term of the form $g^2 \exp[-\Delta J]$. (See Refs. 4,5,6.) States of even and of odd C contribute with the same sign to the untwisted produced line, and with opposite sign to the twisted produced line, so that (writing for simplicity one state of each value of C):

$$\epsilon \equiv \frac{\text{twisted line}}{\text{untwisted line}}$$

$$= \frac{g_+^2 e^{-\Delta_+ J} - g_-^2 e^{-\Delta_- J}}{g_+^2 e^{-\Delta_+ J} + g_-^2 e^{-\Delta_- J}} \qquad (1)$$

where $g_\pm$ and $\Delta_\pm$ denote the coupling and rapidity spread of $C = \pm$ states; in general one should of course sum over states of each C in the numerator and denominator of Eq. (1). The analysis of Zweig rule violation, the breaking of exchange degeneracy, and exotic exchange in terms of ϵ can now proceed exactly as in Refs. (1,2,3), except that one must remember to evaluate ϵ at the appropriate value of J.

We now consider the following simple model for a production process: the multiperipherally-produced states are the vector and tensor mesons, produced with the same basic coupling g; essentially the same model is considered in Refs. (1,2,3). We also use the relation $\Delta = \ln(M^2/T)$, [valid for $T \ll M^2$]* where

* Otherwise use $\cosh \Delta = 1 + M^2/2T$

M is the mass of the produced state and T is related to a typical value of the momentum transferred. (See Ref. 4.) If we denote $M_\pm$ the tensor and vector masses, then we find from Eq. (1) that

$$\epsilon(J) = \frac{(M_-^2)^J - (M_+^2)^J}{(M_-^2)^J + (M_+^2)^J} , \qquad (2)$$

where we have used the assumption $g_+^2 = g_-^2$; note that all dependence on T has dropped out. Using $M_- = M_\rho = 765$ MeV/c^2 and $M_+ = M_{A_2} = 1310$ MeV/c^2 , we find from Eq. (2) the following representative values for ϵ :

$$\epsilon(0) = 0 \; ; \; \epsilon(\tfrac{1}{2}) = -0.26; \; \epsilon(1) = -0.49 \qquad (3)$$

We now proceed to discuss various quantities which depend on ϵ .

Exotic exchange. Since in models of the type we consider the leading exotic Regge singularity has an intercept near zero, the strength of exotic exchange is governed by $\epsilon(J)$ for J near zero, which in our model is very small. In Ref. (1), it is estimated that the observed level of exotic exchange implies a value of $|\epsilon| \approx 0.2$ to 0.25. However, the relation obtained in Ref. (1) was really $|\epsilon\epsilon_B| \approx (0.2)^2$ to $(0.25)^2$; where ϵ_B measures the strength of a twisted produced baryon line; Ref. (1) then made the assumption $|\epsilon_B| \approx |\epsilon|$ to arrive at the estimate $|\epsilon| \approx 0.2$ to 0.25. If on the other hand we assume $|\epsilon_B| \approx |$, we obtain $|\epsilon| \approx 0.04$ to 0.06; in our model ϵ takes this value for $|J| \approx 0.1$. In any case, since exotic exchange amplitudes are so very small, they could easily arise from effects not considered in these models (e.g. double baryon exchange, for which no twist on a produced meson line is needed), and so it is possible that $|\epsilon\epsilon_B| \ll 0.2$.

Breaking of exchange degeneracy. In the calculation of the splitting of the ρ and A_2 trajectories at $t = 0$, the relevant value of J is the ρ-A_2 intercept, which implies $J \approx \frac{1}{2}$. From Eq. (3), $\epsilon(\frac{1}{2}) = -0.26$, which is approximately the same value as found in Ref. (2) and (3) to fit the experimental splitting $\alpha_\rho(0) - \alpha_{A_2}(0) = 0.11$. This fact means that both the sign and the magnitude of $\alpha_\rho(0) - \alpha_{A_2}(0)$ are successfully predicted by our model.

Production of vector and tensor mesons. If we denote by $n_\pm$ the average multiplicities of A_2 and of ρ, and use the parametrization $n_\pm = a_\pm + b_\pm \ln s$, then to a good approximation [see Ref. (3)]

$$\frac{b_-}{b_+} = \frac{1-\epsilon}{1+\epsilon} + 0.7 \tag{4}$$

where the last term arises from the fact that 70% of the produced A_2's decay into ρ's. Since in Eq. (4) we must use $\epsilon(1)$, we obtain from our model $b_-/b_+ = 3.6$, which is to be compared with the experimental value (Ref.7) $b_-/b_+ \gtrsim 4$. Note that if we had used $\epsilon(\frac{1}{2})$ in Eq. (4), we would have predicted $b_-/b_+ = 2.4$, corresponding to not enough suppression of tensor meson production.

Violation of Zweig rule. The amplitude for $\pi^- p \rightarrow \phi n$ is governed by ϵ evaluated at the ρ intercept, roughly $J = \frac{1}{2}$. Thus we predict here that ϵ should be about -0.26, in agreement with the analysis of Ref. (1). One can also discuss "Zweig-violating Pomeron couplings" [see Ref. (3)], which require ϵ to be evaluated at the P intercept, roughly $J = 1$. An analysis of these terms which contribute to ωp but not to ρp scattering, leads to the relation[3]

$$\sigma_T(\omega p) / \sigma_T(\rho p) \xrightarrow[s \to \infty]{} 1 + \epsilon(J=1) \cos \pi\alpha , \tag{5}$$

where α is the value of the planar ρ trajectory at an average value of t.

In the approximation $\alpha = 0.5$ the interesting term in Eq. (5) disappears; however, $\epsilon(1)$ is so big that even for $\alpha = 0.4$ our model predicts $\sigma_T(\omega p) / \sigma_T(\rho p) \rightarrow 0.85$.

In a comparison of $d\sigma/dt$ for ω and for ρ photoproduction, the ratio in (5) is squared, and so its predicted deviation from unity might be more readily apparent.

Restoration of the ω. It was pointed out in Ref. (2 and 3) that diagrams with twists on produced lines can generate an ω exchange, thus alleviating the "ω catastrophe."[(8)] When we take into account the fact that ϵ is J-dependent, it may still be possible to generate an ω with a reasonable intercept, but this possibility depends sensitively on the precise values of the average momentum transfers T.

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