MASTER

Level Shift and Charm Mass: A Test of Asymptotic Planarity*

William F. Palmer, Stephen S. Pinsky, and Chin-Chue Shi

Department of Physics
The Ohio State University
Columbus, Ohio 43210

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Abstract

Level shifts and mixings away from exact exchange degeneracy are examined with respect to the "Asymptotic Planarity" predictions of Chew and Rosensweig. It is found that the data in the $J^P = 0^-, 1^-, \text{ and } 2^+$ multiplets support neither the general shape nor the special relation proposed by Chew and Rosenzweig for the tensor and vector "cylinder" corrections.

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Recently several groups^{1,2,3} have attempted to correlate deviation from exact exchange degeneracy [ideal mixing mass formula (IMMF) and nonet vertex coupling as given by the Okubo Ansatz] with deviation from the Okubo-Zweig-Iizuka⁴ (OZI) rule for decays. This has been done in several frameworks, including that of the Veneziano topological expansion (TE).^{5,6}

The key principle of the TE, supported by a specific model, is that there is an expansion of the n -point function in increasing orders of complexity of the quark line topology. The leading term, yielding planar graphs, gives rise to exchange degenerate trajectories, IMMF, and exact OZI rules. The next term, with the topology of a cylinder, breaks exchange degeneracy, IMMF, and the OZI rule. A major problem is to calculate these cylinder corrections and to understand, at least qualitatively, their physical effects.

At present there are several fundamentally different approaches to this problem. In this note we would like to comment on the approach of Chew and Rosenzweig (CR). They have concluded, from their Reggeon analysis, that (1) the cylinder is a monotonic smoothly decreasing function of t and (2) there is a special relation between the cylinders that contribute in the tensor and vector channels; i.e., using $K(t)$ to represent the cylinder correction, with T, V, P to indicate channels with $J^{PC} = 2^{++}, 1^{--}, 0^{-+}$, they propose

$$K_T(t) = -K_V(T) \quad (1)$$

with the general shape for $|K_{V,T}(t)|$ shown in Fig.1. These results can easily be tested by direct comparison to data involving deviation from IMMF and OZI rule violation.

We briefly review the basic calculation of cylinder effects, and establish our notation.¹ Since we are only interested in t -dependence, we work at fixed J . We use ρ , ω , ϕ , and ψ to generically represent quark model states, independent of J^{PC} . The planar isoscalar propagator in the ideally mixed basis is

$$P^{-1} = \begin{pmatrix} t - m_{\omega}^2 & 0 & 0 \\ 0 & t - m_{\phi}^2 & 0 \\ 0 & 0 & t - m_{\psi}^2 \end{pmatrix} \quad (2)$$

where we denote ideally mixed masses by m and shifted, cylinder corrected masses by μ . The $SU(4)$ cylinder correction is given by

$$Q = K(t) \begin{pmatrix} 2 & \sqrt{2} & 1 \\ \sqrt{2} & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix} \quad (3)$$

and the "dressed" propagator satisfies

$$\pi = P + P Q \pi \quad (4)$$

yielding

$$\pi = (P^{-1} - Q)^{-1} \quad (5)$$

which is conveniently written in terms of the eigenvectors V_{α} and eigenvalues μ_{α} of π^{-1} ,

$$\pi \approx \sum_{\alpha} \frac{V_{\alpha} V_{\alpha}^T}{S - \mu_{\alpha}} \quad (6)$$

where μ_α^2 are given by

$$\mu_\alpha^2 = M_\alpha^2 (\mu_\alpha^2) \quad (7)$$

with $M_\alpha^2(t)$ the roots of the characteristic equation

$$\begin{aligned} (M_\omega^2 - m_\omega^2) (M_\varphi^2 - m_\varphi^2) (M_\psi^2 - m_\psi^2) - K(t) \{ (M_\omega^2 - m_\omega^2) (M_\varphi^2 - m_\varphi^2) \\ + (M_\omega^2 - m_\omega^2) (M_\psi^2 - m_\psi^2) + 2 (M_\varphi^2 - m_\varphi^2) (M_\psi^2 - m_\psi^2) \} = 0. \end{aligned} \quad (8)$$

Requiring the observed masses of the known particles to satisfy these equations yields $K(t)$ at corresponding t , in terms of the ideally mixed masses,

$$K(\mu_\alpha^2) = \left[\frac{1}{(\mu_\alpha^2 - m_\psi^2)} + \frac{1}{(\mu_\alpha^2 - m_\varphi^2)} + \frac{2}{(\mu_\alpha^2 - m_\omega^2)} \right]^{-1} \quad (9)$$

where as a result of IMMF and the fact that only isoscalars suffer mass shift from the cylinder, we have

$$m_\omega^2 = \mu_\rho^2 \quad (10)$$

$$m_\varphi^2 = 2\mu_K^{*2} - \mu_\rho^2 \quad (11)$$

$$m_\psi^2 = 2\mu_D^{*2} - \mu_\rho^2. \quad (12)$$

Thus m_ω^2 and m_φ^2 are determined by observed physical masses. Unfortunately, the charmed state masses are not yet well known; fortunately, $K(\mu_\omega^2)$ and $K(\mu_\varphi^2)$ are not very sensitive to m_ψ^2 provided, as required by the narrowness of the ψ , $m_\psi^2 \approx \mu_\psi^2$. This allows us to determine two points on each of the functions $K_V(t)$, $K_T(t)$ and $K_P(t)$. To proceed further and determine m_ψ^2 and $K(\mu_\psi^2)$ [verifying $m_\psi^2 \approx \mu_\psi^2$ and the insensitivity of $K(\mu_{\omega,\varphi}^2)$ to allowed m_ψ^2

variation] we can either consider OZI forbidden rates or, in the case of the pseudoscalars, to identify the recently reported 1.87 GeV $K^\pm \pi^\mp$ bump as the $D(0^-)$. There are reliable OZI violation data for both the vectors and the pseudoscalars. The model makes predictions for these, which in turn fix $(\mu_\psi^2 - m_\psi^2)^2$. In particular,

$$\Gamma(\psi \rightarrow \rho \pi) = P_\rho^3 \frac{G^2 \omega \rho \pi}{4\pi} R_{\omega\omega}^\psi \quad (13)$$

where

$$R_{\omega\omega}^\psi = \frac{2}{(\mu_\psi^2 - m_\omega^2)^2} \left[\frac{2}{(\mu_\psi^2 - m_\omega^2)^2} + \frac{1}{(\mu_\psi^2 - m_\phi^2)^2} + \frac{1}{(\mu_\psi^2 - m_\psi^2)^2} \right]^{-1}. \quad (14)$$

Similarly, the rate $\psi' \rightarrow \psi \eta$ determines $(\mu_\eta^2 - m_{\eta_c}^2)^2$. For details of these calculations, see Ref.1. However, a more sensitive determination for the pseudoscalars is afforded by the speculation $\mu_D = 1.87$ GeV, yielding from Eq.(12), $m_{\eta_c} = 2.64$. This enables us to calculate a third point of $K(t)$. (A sign ambiguity results in two choices for this high point in the case of the vectors.) In Figs.1a, 1b, and 1c, we tabulate our results for the V, P, and T cylinders. In the case of the tensor multiplet we cannot as yet supply the high point.

Commentary and Conclusions

- (1) $K_V(t)$, it would appear, does not have the monotonic decreasing shape proposed by CR.
- (2) Their relation $K_T = -K_V$ fails to hold.
- (3) The more thoroughly mixed pseudoscalar multiplet also does seem to be described by the qualitative behavior proposed by CR.

We find it interesting to note that from a gluon exchange picture the failure of the CR behavior is not totally surprising. Here the vector transitions proceed via three gluons and the tensor via two gluons. Thus different shapes, especially in the lower t -range, as well as a different asymptotic scale, are not unexpected.

Qualitatively, the results of Figs. 2a, 2b, and 2c reflect the picture suggested by gluon dynamics, with the relative order of decreasing purity, $P:T:V$. (A rough calculation - see Ref. 1, C00-1545-180 - yields the T OZI violation intermediate between P and V .) K_V , moreover, suggests a bulge between low and high T possibly related to resonating or near-resonating glue in an energy range intermediate between the $SU(3)$ states and the bound charm system. For developments on this possible mechanism, see Ref. 1, C00-1545-180.

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Figure Captions

Fig.1a. "Asymptotic Planarity" prediction for $K(t)$; see Ref.2.

Fig.2b. $K(t)$ as determined by pseudoscalar data, using $\mu_D = 1.87$ GeV.

Fig.2c. $K(t)$ as determined by vector and tensor data. The error on the lowest vector point reflects the ρ -mass uncertainty.