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ANALYTICITY AND DUALITY IN THE OZI RULE VIOLATION*

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ABSTRACT

Mutual relationship between the Steinmann decomposition and different contributions to certain OZI rule violating Reggeon couplings is discussed. It is shown that only the mixing term contributes to the decay coupling constant when the Reggeon is on shell.

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The OZI rule [1] violating production processes like $\pi^- p \rightarrow \phi n$, $\pi^- p \rightarrow \psi n$ etc. are conventionally described by the quark diagram of Fig. 1. Asymptotically this diagram corresponds to the ρ -Regge pole exchange with the OZI rule violating coupling. The dual properties of this coupling are not however fully understood. More precisely, it is not clear whether the mixing term (Fig. 2b) is already included in a dual sense in the triangle Reggeon diagram of Fig. 2a or whether it should be added as a separate contribution. (In the phenomenological analysis only the triangle diagram was included with the intermediate states on their mass shell [2].) A closely related problem is a continuation of this vertex to the decay region i. e., to the particle pole of the ρ -Regge pole. The discussion of the OZI rule violating for decays is based usually on the mixing mechanism [3,4]. It has, however, been suggested that the triangle diagram contribution alone may give a complementary description of the decay vertex [5] and again the mutual relation between those two contributions is not clear. Needless to say, a clarification of those problems related to duality of the OZI rule violating vertex is very important for the complete understanding of the OZI rule violation.

The purpose of this note is to show that this problem can be clarified in a rather rigorous way provided that the analytic structure of the corresponding multiparticle amplitudes which define the vertex is carefully taken into account. Two different mechanisms of the OZI rule violation appear simply as a manifestation of the

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appropriate Steinmann decomposition [6]. The main consequence of this relation is the fact that if the vertex is continued to a decay region (i. e., if the ρ -Regge pole is put on the angular momentum shell) then only this term which corresponds to the mixing mechanism remains different from zero. Its dependence on the mass of the decaying particle is similar to that used in the ref. [3] and corresponds to a Regge cut for large masses.

In order to demonstrate a relevance of Steinmann decomposition for revealing different contributions to the OZI rule violating vertex, let us consider the hybrid Feynmann diagram of Fig. 3. It is similar to the diagram of Fig. 2a and for simplicity we treat the lines with crosses as single particle propagators. (This approximation should not be relevant for the final result and simplifies the discussion substantially).

The amplitude corresponding to the diagram of Fig. 3 is given by the following expression:

$$A \sim \frac{1}{i} \int d^4 k_1 T_5(s + i\epsilon, M^2 + i\epsilon, s_1 = m^2 + i\epsilon, t_1) \times \\ \times \frac{\beta(t) g(m^2)}{(m_2^2 - (k_1 + p_1)^2 - i\epsilon)(m_3^2 - (k_1 - \delta)^2 - i\epsilon)} \quad (1)$$

where T_5 is the five point function with its kinematics defined in the Fig. 3 and $\beta(t)$ and g are the corresponding couplings.

In the double Regge limits T_5 takes the form [6]:

$$T_5 = (-s)^{\alpha_1} \Gamma(-\alpha_1) (-M^2)^{\alpha-\alpha_1} \Gamma(\alpha_1 - \alpha) G_1(t_1, t, \frac{s_1 M^2}{s}) \\ (-s)^{\alpha} \Gamma(-\alpha) (-s_1)^{\alpha_1-\alpha} \Gamma(\alpha - \alpha_1) G_2(t_1, t, \frac{s_1 M^2}{s}) \quad (2)$$

which reflects its Steinmann decomposition*.

The loop integral in (s) can be easily performed using the Sudakov (i. e., light cone) variables [7]:

$$k = -x\tilde{p}_1 + y\tilde{p}_2 + k_\perp \quad (3)$$

where

$$p_{1,2} = p_{1,2} - \frac{m_{1,2}^2}{s} \quad (4)$$

Closing the y integration contour around the pole at $(k_1 + p_1)^2 = m_2^2$ we obtain:

$$A \sim g(m^2) \beta(t) \int_0^1 dx d^2 k_1 T_5(s + i\epsilon, M^2 + i\epsilon = xs + i\epsilon, s_1 = m^2 + i\epsilon, t_1) \times \\ \times \frac{1}{(1-x) [m_3^2 - (k_1 - \delta)^2 - i\epsilon]} \quad (5)$$

* The coupling G which controls M^2 discontinuity in the helicity pole limit [6] is given by $G = G_1(t_1, t; 0)$.

The finite limit of integration comes from the condition that the singularity in y coming from the pole $(k + p_1)^2 = m_1^2$ lies on the opposite side of the contour than those generated by the (right hand cut) singularities in k_1^2 , $(k_1 + \delta)^2$ and M^2 [8].

The analytic structure of A is thus the reflection of the corresponding singularity structure of the auxiliary five point function in its physical region. From the Steinmann decomposition of T_5 in the double Regge limit given by the formula (2) we obtain finally:

$$A \sim \beta(t) g(m^2) \Gamma(-\alpha)(-s)^\alpha \left\{ \int_0^1 \frac{dx}{1-x} \int d^2 k_\perp \frac{1}{[m_3^2 - (k_1 - \delta)^2 - i\epsilon]} \times \right. \\ \times \left[\frac{\Gamma(-\alpha_1)}{\Gamma(-\alpha)} x^{\alpha-\alpha_1} \Gamma(\alpha_1 - \alpha) G_1(t_1, t; x s_1) + \right. \\ \left. + (-s_1)^{\alpha_1-\alpha} \Gamma(\alpha - \alpha_1) G_2(t_1, t; x s_1) \right] \Bigg\} = \\ = \Gamma(-\alpha)(-s)^\alpha [V_1(t) + V_2(t)] \beta(t) .$$

(The signaturised ρ exchange amplitude corresponds, of course, to $A_\rho = \frac{1}{2} [A(s) - A(-s)]$). The following properties of the coupling V can be read from the representation (6):

- (1) The "mixing" contribution to the OZI rule violating coupling (Fig. 2b) is unambiguously identified with the term V_2 in (6). This term is related to that part of the auxiliary five point function T_5 which carries singularities in s_1 and the double Regge

expression represents simply the asymptotic form of this singularity. It is this term which is dual to resonance contributions in the s_1 channel (like those shown in the Fig. 2b) and this duality may even be formulated in the form of the FESR for the five point amplitude [9]. They relate the resonance contributions in the s_1 channel to the coupling G_2 i. e. to that part of the double Regge amplitude which has singularities in s_1^* . (In the kinematical configuration relevant for the integral (6) we have, of course, $s_1 = m^2$ where m is the mass of the external particle.)

- (2) The two terms V_2 and V_1 appear as two independent contributions and are not, in general, simply related. Asymptotic behaviour of the mixing term V_2 as the function of external mass m^2 ($s_1 = m^2$) is controlled mainly by the term $(-s_1)^{\alpha_1}$. It is this factor which is mainly responsible for suppression of the coupling for large values of s_1 and low values of the intercept α_1^{**} .

* Strictly speaking the FESR receive also contributions from certain kinematical singularities which vanish in the helicity pole limit ($x = 0$).

** If the external mass is also Reggeised one obtains a Regge cut behaviour which was used in the ref. [3]. In our simplified model the loop integral introduces an extra factor $\log s_1$ which should disappear provided that sufficient details of the analytic structure related to the twisted lines are taken into account [10].

The term V_2 has similar asymptotic behaviour for large values of s_1 (i. e., $V_2 \sim |s_1|^{\alpha_1}$) because the important region of integration over x in the formula (6) is $x \sim 0(1/s_1)$ if the amplitude T_5 is strongly damped for large values of $|(k_1 - \delta)|^2$.

- (3) In the decay region, i. e., for the ρ -Regge pole on the angular momentum shell ($\alpha = 1$) only the mixing term V_2 contributes while the term V_1 decouples from the vertex. This is a straightforward consequence of Steinmann relations and may be easily seen to follow from the formula (6).
- (4) The absorptive part $\text{Abs}_s A(s, s_1 + i\epsilon)$ receives two contributions generated by two independent cuttings of the diagram [8]:

$$\begin{aligned} \frac{1}{2i} \text{disc}_s A(s, s_1 + i\epsilon) &\equiv (V_1 + V_2) \frac{s^\alpha}{\Gamma(\alpha+1)} \beta(t) = \\ &= \frac{s^\alpha}{\Gamma(\alpha+1)} \left\{ V_1^{(a)} + V_1^{(b)} + V_2^{(b)} \right\} \beta(t). \end{aligned} \quad (7)$$

The contributions $V_1^{(a)}$ and $V_1^{(b)}$ correspond to two different cuttings and are related to $\text{disc}_{M^2} T_5 \cdot (s + i\epsilon, M^2, s_j + i\epsilon)$ (a) and $\text{disc}_s T_5(s, M^2 - i\epsilon, s_1 + i\epsilon)$ (b) respectively. In the double Regge limit the functions $V_1^{(a,b)}$ take the form:

$$\begin{aligned} V_1^{(a,b)} &= g(m^2) \int_0^1 \frac{dx}{1-x} \int d^2 k_1 F_1^{(a,b)}(x, t_1, t) \times \\ &\times \frac{1}{(m_3^2 - (k_1 - \delta)^2 - i\epsilon)} \end{aligned} \quad (2)$$

where $F_1^{(a,b)}$ are related in the following way to the couplings G_i :

$$F_1^{(a)} = \Gamma(\alpha + 1) \Gamma(-\alpha_1) e^{-i\pi\alpha_1} x^{\alpha-\alpha_1} \frac{1}{\Gamma(\alpha-\alpha_1+1)} G_1(t_1, t; xs_1) \quad (9a)$$

$$F_1^{(b)} = \Gamma(\alpha + 1) \frac{x^{\alpha-\alpha_1}}{\Gamma(\alpha_1+1)} \Gamma(\alpha_1 - \alpha) e^{i\pi(\alpha-\alpha_1)} G_1(t_1, t; xs_1) \quad (9b)$$

$$F_2^{(b)} = \Gamma(\alpha - \alpha_1) e^{-i\pi(\alpha_1 - \alpha)} s_1^{\alpha_1 - \alpha} G_2(t_1, t; xs_1) \quad (9c)$$

It follows from (9a) - (9c) that $(F_1^{(a)} + F_1^{(b)})$ is real and vanishes for α on the angular momentum shell although it is not true for individual terms separately. The function $F_2^{(b)}$ is complex due to singularities in s_1 of the vertex. The loop integration (8) introduces also some additional singularities in $V_1^{(a,b)}$. The vanishing of $(F_1^{(a)} + F_2^{(b)})$ at the particle pole implies that the estimates of the decay amplitude

based on the extrapolation of $F_1^{(a)}$ alone
as advocated for instance in the ref. [5] may not be
valid because in general $F_2^{(b)} \neq F_1^{(a)}$.

The sum up we have demonstrated the importance of
Steinmann decomposition for understanding the dual properties of the
OZI rule violating coupling. The so-called "mixing term" was
identified with that term which had singularities in s_1 in the
double Regge limit and is dual to resonance contributions in the
 s_1 channel. It is an independent contribution to the vertex
and should be added to a term which is related to the missing
mass discontinuity. In a decay region only the mixing term gives
a non-vanishing contribution.

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FIGURE CAPTIONS

Fig. 1: The quark diagram describing the OZI rule violating production process.

Fig. 2a: The triangle diagram corresponding to the quark diagram of Fig. 1.

Fig. 2b: The diagram corresponding to "mixing" contribution.

Fig. 3: The hybrid Feynmann diagram model corresponding to the quark diagram of Fig. 1.

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Fig. 1

(a)

(b)

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Fig. 2

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Fig. 3

1 4 7 0 1 7 4 0 0 0 0

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