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Exotics and Rapid Scaling in Inclusive Reactions

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Abstract

We consider the criteria for rapid scaling in $ab \rightarrow c+x$ where c is a fragment of a. The assumption that the exoticity of $ab\bar{c}$ implies rapid scaling is shown to lead to rapid scaling if $a\bar{c}$ only is exotic. Experimentally, in one such case rapid scaling does not take place, indicating that the exoticity of $ab\bar{c}$ may not be a sufficient condition.

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The role of duality and exotics in implying rapid scaling in inclusive reactions has been the subject of recent discussions. When considering the reaction

$$a+b \rightarrow c+x \qquad (1)$$

where c is a fragment of a , several criteria for rapid scaling have been proposed. Chan et al.[1] suggest that a sufficient condition for rapid scaling is:

(i) $ab\bar{c}$ is exotic.

Ellis et al.[2] have argued that criterion (i) is insufficient and that the sufficient condition is:

(ii) ab and $ab\bar{c}$ exotic.

ab should be exotic in order to eliminate non-scaling contributions due to s-channel resonances. Einhorn et al.[3] have argued on the basis of dual models that the sufficient condition is:

(iii) ab and $\bar{c}b$ exotic.

Tye and Veneziano[4] considered the planar dual model and reached the conclusion that rapid scaling is present only if:

(iv) all channels are exotic.

We do not think that present understanding of duality suffices to decide between the proposed criteria. It is thus useful to extract all possible consequences of the proposals in order to confront them with experiment.

An additional condition has been shown to follow under certain reasonable assumptions[5,6] as a logical consequence of the condition (i); namely

(v) $a\bar{c}$ exotic regardless of whether or not $ab\bar{c}$ is exotic.*†

We present below experimental evidence that condition (v) disagrees with experiment in the case of the reactions

$$K^- + p \rightarrow \pi^+ + x \tag{2a}$$

$$K^+ + p \rightarrow \pi^- + x \tag{2b}$$

Thus, if condition (v) is indeed required by condition (i), the experimental disagreement with condition (v) for the reactions (2) implies that condition (i) is not valid. We therefore examine in detail the general arguments presented[5)] to relate these conditions for the specific case of the reactions (2) in order to see whether there may be any loopholes in the proofs.

We consider the reactions (2) in the beam fragmentation region, where they are described by fig. 1, and assume that only the standard vector and tensor trajectories contribute to the nonscaling part of the inclusive cross section. We require that these contributions must vanish or cancel one another whenever condition (i) is satisfied, and apply this requirement to a number of reactions similar to (2). We obtain too many constraints and prove that the only solution is the null solution in which all the standard trajectories are decoupled from the $K^-\pi^-$ system. We examine the proofs for three sets of assumptions in detail.

(a) Exact SU_3. Consider the V spin couplings. The $K^-\pi^-$ is a member of a $V = 3/2$ state. The p belongs to $V = 1$. In the $ab\bar{c}$, the missing mass M^2, channel we have $V = 1/2$; $3/2$ and $5/2$ two of which are exotic. In the t-channel we have only $V = 0$ and $V = 1$ exchanges. The two non-vanishing t-channel amplitudes must satisfy two independent homogeneous equations insuring that the two exotic amplitudes in the M^2 channel vanish. The only solution in this case implies that all contributions vanish. Thus the amplitude in which $V = 1/2$ in the M^2 channel vanishes as well.

(b) Factorization of Regge Trajectories.[††] Consider an auxiliary reaction $a = K^-$ $\bar{c} = \pi^-$ $b = \pi^o$. The only t-channel exchange is the f^o. $ab\bar{c}$ is exotic therefore the f^o contribution vanishes. Since the f^o couples to pions it should decouple from the $K^-\pi^-$ bubbles.

Consider now $b = p, n, \bar{p}$, and $\bar{n}$. We assume that the ϕ and f' do not couple to nucleons as is standard in duality arguments. Let the contributions of the standard ρ, ω, f^o and A_2 trajectories to a given reaction be denoted by $\rho^{(b)}$, $\omega^{(b)}$, $f^{(b)}$, and $A_2^{(b)}$ respectively. Then

$$A(p) = \rho^{(p)} + \omega^{(p)} + A_2^{(p)} + f^{(p)} \tag{3}$$

$$A(n) = \rho^{(n)} + \omega^{(n)} + A_2^{(n)} + f^{(n)} = -\rho^{(p)} + \omega^{(p)} - A_2^{(p)} + f^{(p)} \tag{4}$$

$$A(\bar{p}) = \rho^{(\bar{p})} + \omega^{(\bar{p})} + A_2^{(\bar{p})} + f^{(\bar{p})} = -\rho^{(p)} - \omega^{(p)} + A_2^{(p)} + f^{(p)} \tag{5}$$

$$A(\bar{n}) = \rho^{(\bar{n})} + \omega^{(\bar{n})} + A_2^{(\bar{n})} + f^{(\bar{n})} = \rho^{(p)} - \omega^{(p)} - A_2^{(p)} + f^{(p)} \tag{6}$$

Since condition (i) requires that the left hand sides of eqs. (4) (5) and (6) should vanish, we obtain:

$$\rho^{(p)} = \omega^{(p)} = A_2^{(p)} = f^{(p)} \tag{7}$$

Since the f^o decouples, eq. (7) must vanish and therefore $A(p)$ vanishes as well as $A(n)$, $A(\bar{p})$ and $A(\bar{n})$.

(c) Broken SU(3). If SU(3) symmetry is assumed only for the Reggeon-baryon vertices, the following sum rules are obtained for the octet isovector contributions

$$\rho^{(p)} = \rho^{(\Sigma^+)} + \rho^{(\Xi^-)} \tag{8}$$

$$A_2^{(p)} = A_2^{(\Sigma^+)} + A_2^{(\Xi^-)} \tag{9}$$

We can also obtain relations analogous to (7) for the coupling of the isovector trajectories to hyperons by considering the cases $b = \Sigma^0, \Sigma^-, \Xi^0$ and Ξ^- . Since these are all exotic, we obtain the relations

$$\rho^{(\Sigma^+)} = -A_2^{(\Sigma^+)} \tag{10}$$

$$\rho^{(\Xi^-)} = -A_2^{(\Xi^-)} \tag{11}$$

Relations (7), (10) and (11) are clearly inconsistent with the SU(3) sum rules (8) and (9), except for the null solution. Some insight into this inconsistency is gained by noting that the exoticity condition (i) requires the isovector trajectory contribution to cancel when b is a strange baryon or a nonstrange antibaryon, while SU(3) relates baryons to baryons and antibaryons to antibaryons. Thus, if the trajectory couplings to hyperons are defined to satisfy eqs. (10) and (11), the SU(3) relations (8) and (9) would determine the couplings to the nucleon to make the contributions cancel when b is a nucleon, rather than an antinucleon.

We are thus forced to conclude that the only trajectory contributing to reaction (2a) is the Pomeron. This implies rapid scaling for that reaction. Since the energy dependence of reaction (2a) has not yet been measured, we cannot test rapid scaling directly. However, an alternative test is to compare the reactions (2a) and (2b).

In (2b) $ab\bar{c}$ is exotic and rapid scaling should also hold. Since only the Pomeron contributes to both reactions in the beam fragmentation region, the reactions should be equal even at different energies.

Fig. 2 shows a comparison between reaction (2a) at 9 GeV/c and (2b) at 12.' GeV/c, in the beam fragmentation reagion.[9,10] The disagreement is by a factor of 2, much larger than the estimated errors in the data.

The nonscaling part of the cross section is of the same order of magnitude as the "allowed" scaling part observed in processes where either $ab\bar{c}$ or $b\bar{c}$ are non-exotics. We cannot thus blame the disagreement on, some small SU_3 symmetry breaking effects.

We are thus forced to conclude that <u>the exoticity of $ab\bar{c}$ may not be a sufficient criterion for rapid scaling</u>.

The only other cases with $a\bar{c}$ exotic measured so far are the reactions ($\pi^+p \rightarrow \pi^- + \ldots$) and ($\pi^-p \rightarrow \pi^+ + \ldots$). These show near equality within, rather large, experimental errors[10], see fig. 2. The π^+ initiated reaction also shows weak energy dependence[11]. We do not have a simple physical interpretation of the different behaviour of the two sets of reactions. A possible interpretation would be to assume that the non-scaling part is caused by s-channel resonances or ordinary Regge poles. In this case the difference between resonance couplings to π^-p and π^+p is much smaller than the difference between the couplings in K^-p and K^+p at 10 GeV/c. This is obtained from the total cross section difference. If this explanation is true, then the π^+p reaction should show faster scaling than the π^-p reaction.

A good energy dependent study of $K^-p \rightarrow \pi^+ + \ldots$ is needed to establish more clearly the lack of scaling in the reaction we discussed.

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Footnotes

* An example where condition (i) leads to rapid scaling in non-exotic channels was already given in ref. (2).

† Although in the triple-Regge limit the processes in which $a\bar{c}$ is exotic have vanishing cross sections, it is known experimentally that in the limiting fragmentation region these cross sections are comparable to processes in which $a\bar{c}$ is nonexotic.[10] We are thus not comparing a very small non-scaling part to a small scaling part.

†† This assumption may lead into some difficulties (see ref. (7)).

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Figure Captions

Fig. 1. Diagramatic representation of Regge exchanges in the reaction $a+b \to c+x$., c is a fragment of a

Fig. 2. Projectile fragmentation in the reactions:

$K^-p \to \pi^+ + x \ldots$ at 9 GeV/c [9]

$K^+p \to \pi^- + x \ldots$ at 12.7 GeV/c [10]

$\pi^-p \to \pi^+ + x \ldots$ at 7 GeV/c [10]

$\pi^+p \to \pi^- + x \ldots$ at 24.8 GeV/c [10]

Data are plotted versus $p_{\parallel}$ in the projectile frame.

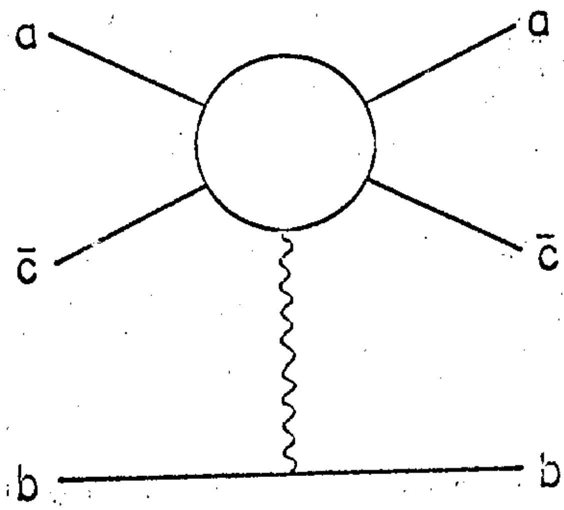

Fig. 1

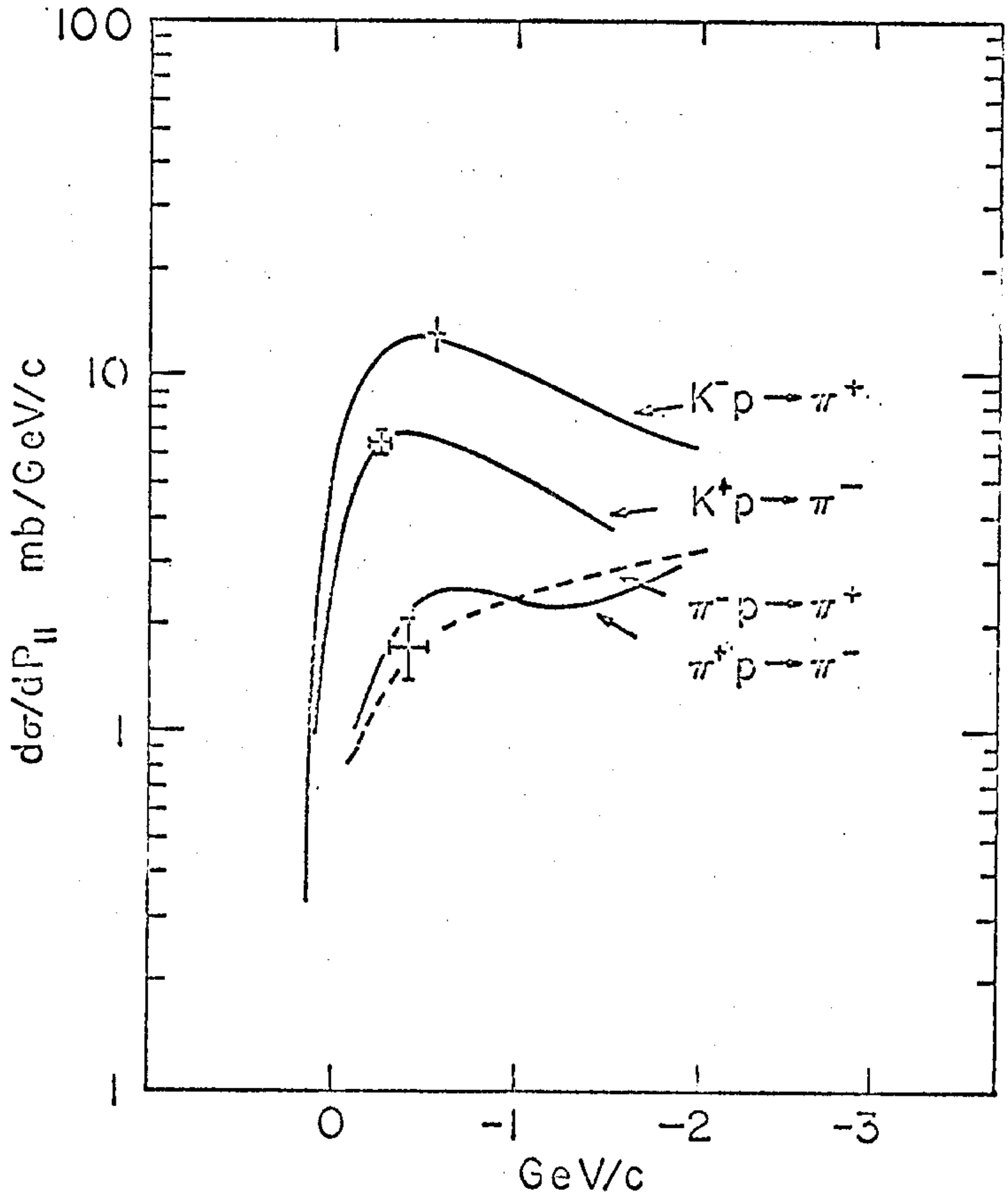

Fig. 2