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QUARK-GLUON STRUCTURE OF DIFFRACTIVE BUMPS

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The diffractive dissociation of hadrons is interpreted as production of the gluonic excitations of incident particles. Regge trajectories of such gluonic excitations are calculated in the bag models and in the dual model. Good agreement is found with the observed spectra of diffractive bumps.

1. Introduction

In this paper we continue the discussion [1] of the enhancements in the mass distribution of the diffractively produced systems [2]. These enhancements, called D-resonances [3], are difficult to interpret theoretically: they have neither the clean Breit-Wigner shape [4], nor are they explained by pure kinematical effects [5]. It was proposed in Ref. [1] that these objects are gluonic excitations of the incoming particles without any change in the quark configuration. This hypothesis accounts for such features of diffractive dissociation as internal quantum numbers of D-resonances and Gribov-Morrison rule [6]. We thus find worthwhile to continue the investigation of this hypothesis.

In the present paper this problem is reconsidered in the framework of the bag models [7,8] and in the dual model [9]. It is argued that these models imply a specific quark-gluon structure of diffractive bumps. Taking into account this specific structure, described below, it is possible to estimate the corresponding Regge trajectories, at least in the high angular momentum limit. The slope of these trajectories turns out to be substantially smaller than that of normal ones. For example, in the MIT bag model one obtains Regge slope $\alpha' \simeq 0.6 \text{ GeV}^{-2}$. This seems to agree quite well with the existing data.

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2. *The structure of diffractively excited systems*

Let us start by recalling the mechanism for elastic diffraction in the bag model [10]. The first step is the one gluon exchange between the incident hadrons. The subsequent separation of the colour octet states creates a cigar-shaped tube with incident quarks at both ends and a complicated quark-gluon structure inside. The decay of this intermediate state gives rise to the multiple production. The elastic scattering is obtained as shadow effect of this production process. Thus it can be represented as neutralisation of the colour octets by exchange of the second gluon between the incident quarks.

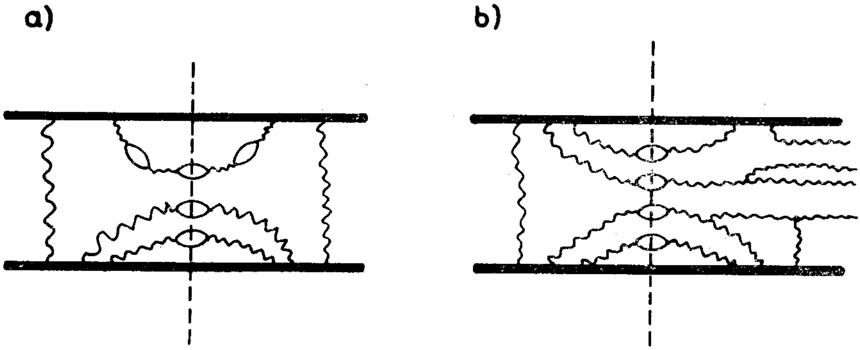

Fig. 1. (a) Elastic and (b) inelastic diffraction in the bag model

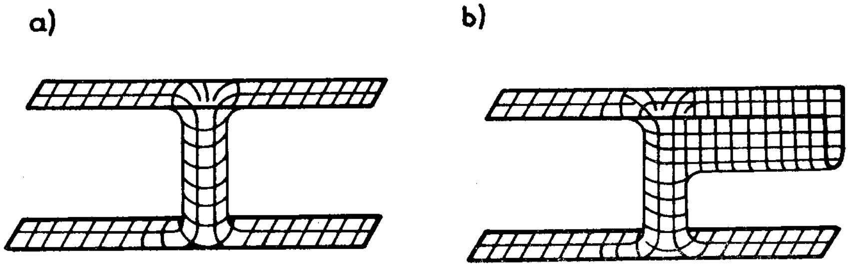

Fig. 2. (a) Elastic and (b) inelastic diffraction in the dual model

The generalisation of this mechanism to include the inelastic diffraction is straightforward: inelastic diffraction occurs if the second gluon connects the target quark not with the quark of the beam, but with the system of quarks and gluons (including the beam quarks). The situation is shown graphically in Fig. 1, where also the shadow nature of inelastic diffraction is explicitly displayed. As seen from Fig. 1, the diffractively excited state obtained from this mechanism is a gluonic tube with the incident quarks at one end. The quantum numbers of quarks remain unchanged in the collision.

Although our considerations were based on one specific model, the resulting picture seems to be more general. For example, similar conclusions can be reached in the dual model [9]. Here the elastic scattering is described by cylinder-shaped diagram (Fig. 2a) whereas the inelastic diffraction occurs when the string connecting two quarks is "not strained" after the collision (Fig. 2b). The structure of the diffractive state dictated by this mechanism is thus similar to that of the bag model.

3. Estimate of Regge trajectories

To calculate the Regge trajectories of the diffractive states we used the method proposed by Johnson and Thorn [11]. They have shown that, in the very high angular momentum limit, the Regge trajectory describing a cigar-like object is a straight line with the slope α' depending on the value of the colour quantum number situated at the ends of the tube. As seen from the previous discussion, the diffractive states of high angular momentum are elongated bags with colour octets at the ends. The expected slope is thus different from that describing normal $q\bar{q}$ resonances which are represented by elongated bags with colour triplets at the ends. Using the formulae from Ref. [11], one obtains

$$\alpha'_{\mathrm{D}} = \sqrt{\frac{C_3}{C_8}}\,\alpha'_{\varrho} = \tfrac{2}{3}\,\alpha'_{\varrho}, \tag{1}$$

where C_3 and C_8 are expectation values of the SU_3 Casimir operators in triplet and octet states, respectively. α'_{D} and α'_{ϱ} are slopes of diffractive and normal $q\bar{q}$ trajectories, respectively.

We thus conclude that the MIT bag model predicts for diffractive Regge trajectory a slope significantly smaller than that observed for normal $q\bar{q}$ resonances.

Similar results are obtained also in other models. The bag model with surface tension [8] gives

$$\alpha'_{\mathrm{D}} = \sqrt[3]{\frac{C_3}{C_8}}\,\alpha'_{\varrho} = \sqrt[3]{\tfrac{4}{9}}\,\alpha'_{\varrho}, \tag{2}$$

whereas the dual model suggests the relation

$$\alpha'_{\mathrm{D}} = 0.5\alpha'_{\varrho} \tag{3}$$

because the two end points of the diffractive system are connected by two non-interacting gluon strings[1].

We thus see that, although the exact numerical value of the ratio $\alpha'_{\mathrm{D}}/\alpha'_{\varrho}$ differs slightly from one model to another, one can rather safely conclude that the slope of the diffractive trajectory is expected to be significantly smaller than that of normal Regge trajectories.

4. Comparison with the data

The comparison of Eqs (1)—(3) with the data is not straightforward, because these formulae are derived in the limit of very high angular momentum (very long bags) and it is not clear how they should be extrapolated to low angular momentum states where the

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[1] For discussion of relation between mass spectra in bag models and in dual model see Ref. [12].

experimental information is available. Also the intercept of the trajectory is not determined. Nevertheless, we attempted the comparison of the model with experimental data assuming that the linear trajectory can be continued down to the lowest angular momenta. The data for π-induced, K-induced and p-induced reactions are shown in Fig. 3.

The most complete information is available from π-induced reactions where 3 well-established A-bumps were identified [13]. It is clear from these data that the observed

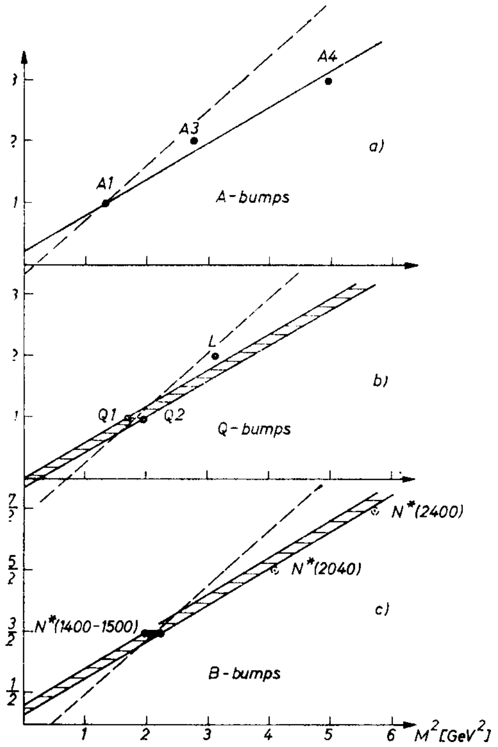

Fig. 3. Chew-Frautschi plots for diffractive trajectories. (a) A-trajectory, (b) Q-trajectory, (c) B-trajectory; full line — the trajectory with $\alpha'_D = 0.6$, dashed line — the trajectory with $\alpha'_\varrho = 0.9$

diffractive trajectory is much less steep than the normal Regge trajectory with the slope $\alpha'_\varrho = 0.9$ GeV^{-2}. The data agree quite well with the slope predicted by the MIT bag model which gives, according to Eq. (1), $\alpha'_D \approx 0.6$ GeV^{-2}. However, also the slope $\alpha'_D = 0.45$ cannot be excluded by the data of Fig. 3, particularly if one takes into account the asymptotic nature of the predictions given by Eqs (1)—(3). We thus conclude that the pion data strongly support the general prediction that the diffractive trajectory is significantly less steep than the normal one. More data on diffractive bumps with higher angular momentum will help in distinguishing between different models of quark gluon bags.

These conclusions are also compatible with the data on K-induced and p-induced diffractive reactions. In kaon data only two diffractive states were established and the situation is additionally complicated by the interference phenomena in the 1300 MeV region [14]. As seen from Fig. 3b the situation is not very conclusive, although certainly consistent with the slope smaller than 1 GeV^{-2}. In the case of nucleon induced reactions the partial wave analysis did not reveal yet any diffractive state with angular momentum higher than 3/2 [15]. Consequently one cannot derive the trajectory from the data. However, by drawing the straight line with the slope $\alpha'_D = 0.6$ through the well established diffractive bump with spin-parity $3/2^-$ and mass $1400 \div 1500$ MeV, we can find the expected positions of the higher angular momentum diffractive states. It is amusing that two diffractive bumps at 2040 MeV and 2400 MeV observed in $p\pi\pi$ decay mode [16] have masses close to the ones expected for $5/2^+$ and $7/2^-$ states, respectively. However, the spins of these states are not yet known and thus the conclusions must wait till the partial-wave analysis is performed.

To summarize, we have argued that the bag models and the dua lmodel support the idea of diffractive bumps being the gluonic excitations of the beam particles [1]. The Regge trajectories of such gluonic excitations are expected to be significantly less steep than the normal ones. The existing data are compatible with this picture.

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