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INTERRELATION BETWEEN THE BACKGROUND AND RESONANCES IN
INCLUSIVE DISTRIBUTIONS *

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ABSTRACT

It is argued that in inclusive reactions the diffractive resonance excitation of the projectile (target) is dual to part of the background in the target (projectile) excitation spectrum. Accelerator data show that diffraction models can not saturate the magnitude of the observed spectra.

It is becoming increasingly apparent that the study of inclusive reactions provides a very powerful analytical tool to probe the underlying dynamics of high-energy multiparticle production.¹ The complex multiparticle final states reached at accelerator energies have been elegantly summarized by the work of Benecke et al.² and Feynman.³ The subsequent development by Mueller⁴ of a Regge language for inclusive spectra based on a generalization of the optical theorem has led to a greater understanding of the spectra in terms of some familiar concepts borrowed from two-body scattering.

Near the kinematical boundaries, the application of two component duality to reggeon-particle absorptive amplitudes⁵ has revealed the relative importance of the various triple reggeon couplings in controlling the spectrum. In the presence of a weak triple Pomeranchuk coupling,⁶ these data have been interpreted in terms of diffractively produced resonances (pomeron-pomeron-reggeon couplings) superposed on a smooth background which is dominantly produced by the exchange of ordinary reggeons (reggeon-reggeon-pomeron couplings).

In this paper, we reintroduce the Deck mechanism⁷ to interpret the diffractively produced resonances. As a consequence, there arises naturally a dual correspondence between resonance bumps on one side of the spectrum⁸ ($x > 0$) and the background structure on the opposite side ($x < 0$), which previously went by the title of kinematical "reflections." This dual correspondence allows models which propose diffractively produced resonances as the dominant mechanism⁹ for particle production to have a nonresonant background spectrum in addition to the resonance bumps as is indicated by the existing

accelerator data.¹⁰ However, as we shall see, if our interpretation is correct, only the shapes of the spectra will be correct, with the magnitude of the predicted background much too small to account for the total hadronic cross section.

Cast in the language of triple reggeon couplings, the Deck interpretation of diffractively produced resonances when coupled with duality dictates that the pomeron-pomeron-reggeon (PPR) couplings set the scale for the reggeon-reggeon-pomeron (RRP) couplings in all models in which diffraction dissociation plays the dominant role in multiparticle production. In this way, the background spectrum is normalized by that of the resonances. As we shall see below, the data rule out any such possibility.

To make these ideas more concrete, let us discuss a simple example. Consider the process,

$$p_a + p_b \rightarrow p'_a + N^* \quad (1)$$

$$\downarrow$$

$$p + \pi^0$$

and its corresponding Deck interpretation (Figs. 1a and 1b). Here p_a , p_b , and p'_a refer to the projectile, target, and outgoing (fast in the lab. system) protons, as well as to their momenta, respectively. Such a mechanism (Fig. 1b) is capable of producing the resonance structures (on the average) in the invariant mass of the $p\pi^0$ system, as well as the overall energy independence of the differential cross section $\frac{d\sigma}{dt}[p_a + p_b \rightarrow p'_a + (N^* \rightarrow p + \pi^0)]$. Such an exclusive process will represent a finite fractional contribution to the resonant structure observed in the inclusive process $p_a + p_b \rightarrow p'_a + \text{anything}$ for fast protons in the lab frame ($x > 0$). This mechanism can be

generalized to include the higher multiplicity decays of the N^* 's and in this way one can build up the entire diffractively produced resonant spectrum for the inclusive process $p_a + p_b \rightarrow p'_a + (\text{Resonances})$.

On the other hand, if we now examine the spectrum of fast protons in the projectile frame ($x < 0$), such a mechanism (Figs. 1b and 1c) will yield a distribution of the form

$$\frac{d^2\sigma}{dt dM^2/s} \sim \frac{\beta(t)}{s} \left(\frac{s}{M^2} \right)^{2\alpha_R(t)} \frac{(M^2)^{2\alpha_P(0)-1}}{\ln M^2} \quad (2)$$

where $s = (p_a + p_b)^2$, $t = (p - p_b)^2$, and $M^2 = (p'_a + p_{\pi^0})^2$. If we choose $\alpha_P(0) = 1$, this distribution scales in the sense of Feynman³ up to factors of $\log M^2$. The shape of this spectrum is the same as that predicted for the background proton spectrum in the $x < 0$ region on the basis of a dominant RRP coupling. We see therefore that the Deck mechanism for the diffractive production of resonances makes an immediate correspondence between the resonance contributions on one side of the inclusive spectrum ($x > 0$) and the background structure on the other side ($x < 0$).

The significance of understanding how the diffractively produced resonances can yield a part of the spectrum consistent with the triple regge hypothesis was first clarified by Kugler and his collaborators.¹¹ Note, however, that the estimate achieved in their analysis represents only a lower bound on the background spectrum and does not determine the magnitude. There must be other mechanisms which contribute to build up the background spectrum besides the mechanism of diffractively produced resonances in order that the unique correspondence between PPR couplings and RRP couplings suggested by such models be broken.¹²

The incompatibility of this unique correspondence with the experimental data can be most easily seen within the framework of energy-momentum conservation as applied to inclusive distributions. As such, the constraint imposed by energy conservation assumes the form of a sum rule for the total hadronic cross section¹³

$$\sigma_T^{ab} = \frac{1}{2} \sum_c \int_{-1}^1 |x| \frac{d\sigma^{ab \rightarrow c+X}}{dx} dx \quad (3)$$

where the sum runs over all types of "stable" particles produced. For the particular case of p-p scattering which we shall examine, the symmetry in the center of mass system simplifies our sum rule to the form,

$$\sigma_T^{pp} = \sum_c \int_0^1 x \frac{d\sigma^{pp \rightarrow c+X}}{dx} dx \quad (4)$$

We distinguish three main contributions to the sum rule (4) in line with our previous remarks concerning the inclusive distributions. The first two are the elastic peak and discrete resonance contributions, which we designate by σ_{el} and $\sigma_{s.d.d.}$ (single diffractive dissociation) respectively. Everything left over is considered background (BG);

$$\sigma_T^{pp} = \sigma_{el}^{pp} + \sigma_{s.d.d.}^{pp} + \int_0^1 x \frac{d\sigma}{dx} BG dx \quad (5)$$

Now, if the matrix elements which gave rise to the background spectra for $x > 0$, were dual to resonant part of the proton spectrum for $x < 0$, then we are allowed to replace the last term in the sum rule (5), by $\sigma_{s.d.d.}^{pp}$ and we arrive at the familiar simple form,

$$\sigma_T^{pp} = \sigma_{el}^{pp} + 2 \sigma_{s.d.d.}^{pp} \quad (6)$$

In this approach, the simultaneous dissociation of the target and projectile protons was assumed to be a negligibly small contribution to σ_T^{pp} .

We turn now to a comparison of (6) with experimental results on p-p scattering. From the data of E. W. Anderson et al.¹⁰ at 30 GeV/c lab momentum we find that the cross section to produce the prominent N^* resonances (diffractively) is roughly $\sigma(1400) \approx 0.744 \pm 0.350$ mb, $\sigma(1520) \approx 0.166 \pm 0.042$ mb, $\sigma(1690) \approx 0.576 \pm 0.084$ mb, and $\sigma(2190) \approx 0.108 \pm 0.036$ mb; $\sigma_{el} \approx 8-10$ mb while $\sigma_T \approx 39-40$ mb. Altogether, the right-hand side of Eq. (6) represents approximately only 1/3 of the left-hand side or total cross section.¹⁴

This inadequacy has its basis in the unique correspondence between PPR couplings (resonances) and RRP couplings (background) implied by any model based exclusively on the diffractive excitation of resonances. As our analysis shows, this unique correspondence is severely broken and that other mechanisms are largely responsible for producing the large background spectrum observed in the data. Consequently, it is these other mechanisms which give rise to the majority of the total cross section ($\sim 2/3$) and not the diffractive resonance production.

We conclude with a survey of the main points. We have shown that "reflections" play a minor role ($\sim 10\%$ for pp collisions) in building up the background in inclusive spectra. Consequently, diffraction models highly underestimate the magnitude of the background, although they can account for the shapes of the spectra. Finally, we

remark that reflections in high-energy missing-mass experiments should not be considered as extraneous contributions to be subtracted from the overall spectrum, but through duality, must be considered as "diffractive background."

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FOOTNOTES AND REFERENCES

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 - ‡ Participating guest, Lawrence Berkeley Laboratory. Research supported in part by the Air Force Office of Scientific Research, Office of Aerospace Research, USAF, under contract number F44690-70-C-0028.
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14. Our results agree with those of A. B. Kaidalov, Sov. Journ. of Nuclear Physics 13, 226 (1971), who finds that the importance of pomeron exchange for inelastic processes in p-p collisions is roughly at the 10% level. The same conclusion has been reached also by A. I. Sanda and S. D. Ellis (private communication) and by M. B. Einhorn, M. B. Green, and M. Virasoro (to be published), on the basis of a triple-regge analysis of the inclusive spectra.

FIGURE CAPTIONS

- Fig. 1. (a) The amplitude contributing to the resonating spectrum of the inclusive distribution of p'_a (fragment of the projectile) from diffractively produced N^* 's. Generalization to high multiplicity processes is obtained by replacing π^0 by a set of hadrons:
- (b) The Deck interpretation of the amplitude in Fig. 1a.
- (c) The amplitude in 1b generates part of the background in the inclusive spectrum of p (fragment of the target).

(a)

(b)

(c)

Fig. 1

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