NAL-THY-43
1971

No-Exotics-NoGo Theorems and Inclusive Reactions

A Comment Presented to the Rochester DPF Meeting

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ABSTRACT

The process $a + E \to a + E$, where E is an exotic baryon, is relevant to the inclusive reaction $a + b \to c + X$, with E representing the $(\bar{c}b)$ system. The theorem proves that an amplitude which vanishes when (aE) is exotic and which also vanishes for exotic exchanges in the $(\bar{a}a)$ channel must vanish for any octet meson a, even when (aE) is not exotic. Thus in a kinematic region where the inclusive reaction is described by coupling the conventional Regge trajectories to the $(\bar{a}a)$ channel and exotic exchanges are forbidden, an amplitude which vanishes when $(ab\bar{c})$ is exotic will also vanish when $(b\bar{c})$ is exotic and $(ab\bar{c})$ is not exotic; i.e. whenever the fragmentation vertex $b \to c$ involves an exotic exchange.

*Work done under the auspices of the U. S. Atomic Energy Commission.

The assumption that certain "exotic" amplitudes vanish in inclusive reactions[1] has been shown to lead under certain reasonable assumptions to the conclusions that certain other amplitudes must also vanish, even though they are not normally considered exotic.[2] The exact implications and the validity of this result have been questioned. We present here a theorem which provides a concise and systematic statement of which non-exotic amplitudes must also vanish when the criterion of Chan _et al_ is assumed.[1] We do not enter into the dynamical discussion of which criterion of exoticity is the proper one to use for inclusive reactions. This is a matter to be settled by experiment.

Consider the reaction

$$a + E \rightarrow a + E \tag{1}$$

where E is a baryon state having exotic isospin and hypercharge quantum numbers: (i.e., either $Y \geqslant 2$, $Q \leqslant -2$, or $Q \geqslant 2 + Y$.)

The reaction (1) is relevant to the analysis of the inclusive reaction

$$a + b \rightarrow c + \text{anything} \tag{2}$$

where the exotic baryon E in equation (1) represents the $(b,\bar{c})$ system in equation (2). It has been suggested that the energy-dependent part of the cross section (2) should vanish for the case when the quantum numbers of the $(a,b,\bar{c})$ complex are exotic.[1] The validity of this criterion has been questioned[2,3] in the kinematic region where the inclusive reaction (2) described by a 6 point function has conventional Regge trajectories coupled to the $(\bar{a}a)$ channel. The precise nature of this difficulty can be described more precisely by examining the reaction (1). We prove the following theorems.

Theorem 1. If the amplitude for the reaction (1) vanishes whenever the aE system has exotic quantum numbers and it also is required to vanish whenever the $(a,\bar{a})$ channel has exotic quantum numbers, then the amplitude must vanish whenever a is a pion, even when the aE system is not exotic.

Theorem 2. If the conditions of Theorem 1 are assumed and SU(3) symmetry is also assumed the amplitude (1) must vanish when a is any octet meson even when (aE) is not exotic.

Theorem 3. If the conditions of Theorem 1 are assumed, a non-vanishing amplitude can be obtained when a is a kaon only by breaking SU(3) in a generally unacceptable manner; namely by introducing exchanges in the $(a\bar{a})$ channel which are coupled only to kaons and not to pions and which have peculiar couplings not found in any known trajectories nor in any normal SU(3) multiplets.

The proofs of these theorems are straightforward.

Theorem 1. πE scattering.

If a is a pion, there are three independent amplitudes for the reaction (1) corresponding to the three charge states of the pion or to the three possible isospins in the $(a,\bar{a})$ channel, which we call the t channel. We denote the three isospin amplitudes by $I_t = 0$, $I_t = 1$ and $I_t = 2$. The $I_t = 2$ amplitude vanishes because I = 2 is an exotic exchange. The

$I_t = 0$ and $I_t = 1$ amplitudes correspond to the f^o and ρ trajectories in the conventional Regge exchange models.

The case where a is a π^o is always exotic since the $\pi^0 E$ system has the same Q, Y as E. The $\pi^o E$ amplitude has contributions only from $I_t = 0$ and $I_t = 2$. Since the latter already vanishes the I = 0 amplitude must also vanish, i.e. in the conventional Regge description the f^o contribution vanishes.

The remaining $I_t = 1$ amplitude (ρ exchange in the conventional description) now provides the only contribution to $\pi^+ E$ and $\pi^- E$ scattering. However for any E either $\pi^+ E$ or $\pi^- E$ or both must be exotic. Therefore the $I_t = 1$ or ρ exchange amplitude vanishes and all the πE amplitudes vanish.

Theorem 2. Octet meson scattering with SU(3) symmetry

The proof of Theorem 1 is extended to any octet meson by SU(3) rotations which replace isospin by U spin and V spin. The pion isospin vector is rotated into meson states which are U spin or V spin vectors and again all three amplitudes are shown to vanish.

Theorem 3. KE scattering without SU(3)

If SU(3) symmetry is not assumed, KE amplitudes can be defined which vanish only when KE is exotic and do not vanish when KE is not exotic. Consider first the case when E has electric charge Q = -2. The K^+E amplitude is not exotic but the three other KE amplitudes are exotic and must vanish. Let us label the four independent amplitudes by the t channel quantum numbers as isoscalar and isovector with even and odd signature; i.e. with the quantum numbers of f, A_2, ω and ρ. All four amplitudes must be present, corresponding in a Regge picture to four exchange-degenerate trajectories with couplings arranged to add constructively for the K^+E case but to cancel for all other three. However, Theorem 1 shows that these amplitudes cannot be present for πE scattering. The set of four KE amplitudes thus includes two amplitudes with quantum numbers of the ρ and f respectively, which are coupled to kaons but decoupled from pions. The isoscalar amplitude can be identified with f^* exchange and causes no difficulty. However, an isovector trajectory coupled to kaons and not to pions is very peculiar. Such states do not exist in SU(3) nonets and have not been found experimentally.

The case where E has $Q = 2 + Y$ is obtained from the previous case $Q = -2$ by an isospin reflection and gives similar results. The case where E has $Y = 2$ has two exotic amplitudes K^+E and K^oE and two non-exotic amplitudes K^-E and $\overline{K^o}E$. An amplitude which vanishes for the exotic cases and does not vanish for the non-exotic cases is obtainable by introducing an exchange-degenerate pair of isoscalar amplitudes which have opposite signature, such as those corresponding to the ϕ and f^* trajectories. This possibility was overlooked in the treatment of Ellis <u>et al</u>.[2] The possible existence of such ϕ and f^* isoscalar trajectories coupled only to kaons and not to pions cannot be disregarded in a systematic consideration of duality constraints.[4] For example, an apparent contradiction arises in meson-meson scattering if only the ρ, ω, A2 and f trajectories are considered. The contribution of these four trajectories all cancel in K^oK^- scattering even though the s channel is not exotic.[3] The situation is saved only by the introduction of the isoscalar trajectories which are coupled to kaons and decoupled from pions.

For the case of the reaction (1) where E is a Y = 2 baryon the isoscalar trajectories coupled to kaons are required to be a bit more peculiar than the conventional f^* and ϕ trajectories. Since the ηE and $\eta' E$ systems are also exotic the new isoscalar trajectories which are coupled to kaons are required to be decoupled not only from pions but also from the η and the η' as well. This again is inconsistent with simple nonet schemes and is probably not in agreement with nature, although there is as yet no definite evidence from η and η' experimental scattering.

These theorem can be extended in a straightforward manner to the case where E is an exotic two-meson system and a is a baryon. The case where E is an exotic two-pion system and a is a nucleon or antinucleon is simplest and the analog of Theorem 1 holds without any SU(3) assumptions. For other cases different types of peculiar SU(3) symmetry breaking are required to obtain non-vanishing amplitudes, as in Theorem 3. For example, in the case where E is an exotic $K\pi$ or KK system and a is a nucleon, non-vanishing amplitudes are obtained only by introducing trajectories coupled to both kaons and nucleons but decoupled from the two-pion system.

These theorems show that if the contribution from normal Regge exchange to the inclusive reaction (2) must vanish whenever the quantum numbers of $(ab\bar{c})$ are exotic, as suggested by Chan *et al*,[1] then the contribution from normal trajectories must also vanish when $(b\bar{c})$ is exotic and there are no exotic exchanges allowed in the $(a\bar{a})$ channel, even if $(ab\bar{c})$ is not exotic.

These theorems may help to decide whether the conjecture by Chan _et al_.[2] indeed agrees with experiment. A comparison with the data will be published elsewhere.

We wish to thank G. Veneziano for stimulating and clarifying discussions.

References

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