POSSIBILITY OF BARYON-ANTIBARYON ENHANCEMENTS WITH UNUSUAL QUANTUM NUMBERS

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Arguments are presented in favor of $B=0$ enhancements in the $\underline{10}$, $\underline{10}^*$, and $\underline{27}$ representations of SU(3) which decay mainly into a baryon and an antibaryon.

The observed connection between low-energy direct-channel resonances (DCR) and energy dependence of total cross sections σ_t at higher energies has recently been expressed[1,2] in the language of finite-energy sum rules (FESR).[3] Trajectories other than the Pomeranchukon (P) are assumed to be "built" from DCR, while the P is assumed to arise from nonresonant background. This separation explains both the constancy of $\sigma_t(K^+p)$, $\sigma_t(K^+n)$, $\sigma_t(pp)$, and $\sigma_t(pn)$, and the decrease with increasing energy of other measured total cross sections.

We show here that (i) the above connection can be maintained in the conventional Regge model for MM, Mb, and bb scattering ($M=0^-$ meson; $b=\frac{1}{2}^+$ baryon $[B]$ or $\frac{3}{2}^+$ baryon $[D]$); (ii) the connection then appears to break down for $\bar{b}b$ systems in a very definite pattern. Specifically, we predict energy dependence in the $\underline{10}$, $\underline{10}^*$, and $\underline{27}$ $\bar{b}b$ channels despite their apparent lack of resonances.

This difficulty is resolved if we assume the existence of $B=0$ resonances in the $\underline{10}$, $\underline{10}^*$, and $\underline{27}$ which couple mainly to $\bar{b}b$. Such resonances then will not affect $\sigma_t(MM)$ much, and may well have been missed in mesonic spectra.[4] While no such selection rule is known at present, a direct check of $\bar{b}b$ mass spectra for such resonances nonetheless seems desirable.

The simplest Regge-pole model fitting all $t=0$ MB and BB data involves exchange of P and tensor and vector nonets.[5] The flatness of $\sigma_t(K^+p)$, $\sigma_t(K^+n)$, $\sigma_t(pp)$, and $\sigma_t(pn)$ comes in this model from P'-ω and A_2-ρ degeneracy in couplings and intercepts. If this degeneracy is not exact, then flatness is predicted only in a restricted energy range.

If σ_t is to be flat in all those MM, Mb, and bb channels thought to lack resonances,[6] the Regge-pole model is more restricted. The P', A_2, ω, and ρ must all have the intercept α_0, while the f' and φ must have the intercept α_1. Moreover, additional coupling relations must hold: For example, in order that $\sigma_t(\pi^+\pi^+)$ be flat, the P' and ρ must couple to the π with equal strength.[1]

A self-consistent set of couplings of the tensor and vector nonets to M and b has been found such that all appropriate $\sigma_t(MM)$, $\sigma_t(Mb)$, and $\sigma_t(bb)$ will be flat. This set is shown in Table I. σ_t is related to these couplings for large $\nu=\frac{1}{2}(s-u)$ by

$$\sigma_t(AB)=(8\pi/\nu)\times\sum_E \eta_E(E\bar{A}A)(E\bar{B}B)(\nu/\nu_0)^{\alpha_E}, \tag{1}$$

where $(E\bar{A}A)$ and $(E\bar{B}B)$ are the $t=0$ couplings of the trajectory E to particles A and B, $\nu_0=1$ GeV^2, and

$$\eta_E=+1 \text{ for } P,\ P',\ f', \text{ and } A_2,\quad =-1 \text{ for } \omega,\ \varphi, \text{ and } \rho; \tag{2}$$

$$\alpha_E=\alpha_0 \text{ for } P',\ A_2,\ \omega, \text{ and } \rho,\quad =\alpha_1 \text{ for } f' \text{ and } \varphi. \tag{3}$$

Table I. Couplings $(E\bar{A}A)$ of trajectories E to particles A at $t=0$. Other couplings are related by charge conjugation or isospin. Pomeranchukon couplings are arbitrary.

A \ E	P'	f'	A_2	ω	ϕ	ρ
π^+	2a	0	0	0	0	2a
η	2b/3	$-4c\sqrt{2}/3$	0	0	0	0
K^+	d	$-e\sqrt{2}$	d	d	$e\sqrt{2}$	d
p	3f	0	g	3f	0	g
Σ^+	2h	$-i\sqrt{2}$	2h	2h	$-i\sqrt{2}$	2h
Λ	2j	$-k\sqrt{2}$	0	2j	$-k\sqrt{2}$	0
Ξ^0	m	$-2n\sqrt{2}$	m	m	$-2n\sqrt{2}$	m
Δ^{++}	3p	0	3p	3p	0	3p
Δ^+	3p	0	q	3p	0	q
Y^{*+}	2r	$-v\sqrt{2}$	2r	2r	$-v\sqrt{2}$	2r
Ξ^{*0}	w	$-2x\sqrt{2}$	w	w	$-2x\sqrt{2}$	w
Ω^-	0	$-3y\sqrt{2}$	0	0	$-3y\sqrt{2}$	0

The relations in Table I follow uniquely from requiring (a) factorizability, (b) decoupling of f' and φ from $S=0$ particles, (c) monotonic decrease with increasing energy of σ_t in systems with DCR, and (d) flatness of $\sigma_t(MM)$, $\sigma_t(Mb)$, and $\sigma_t(bb)$ in systems without DCR.[6,7]

From Table I one sees that, for example,

$$\sigma_t(\Sigma^+p)=32\pi h(3f-g)\nu^{\alpha_0-1}+\sigma_t(\Sigma p)|_{\nu=\infty}, \quad (4)$$

while

$$\sigma_t(\overline{\Omega}^+p)=\sigma_t(\Omega p)|_{\nu=\infty}. \quad (5)$$

Hence $\sigma_t(\overline{\Sigma}^+p)$ is energy dependent[8] while $\sigma_t(\overline{\Omega}^+p)$ is flat. In general one finds that energy dependence in $\sigma_t(\overline{b}b)$ is present in the $\underline{1}$, $\underline{8}$, $\underline{10}$, $\underline{10}^*$, and $\underline{27}$ channels but absent in other channels.[9]

As we predict $\sigma_t(\overline{b}b)$ in $\underline{10}$, $\underline{10}^*$, and $\underline{27}$ to be energy dependent but $\sigma_t(\overline{M}M)$ in these channels to be flat, we seem to lose the simple connection between DCR and energy dependence of σ_t. Consistency of Table I with FESR requires contributions to the imaginary parts of $\underline{10}$, $\underline{10}^*$, and $\underline{27}$ $\overline{b}b$ amplitudes besides those of the nonresonant background, but these contributions must not affect MM amplitudes.

It has been suggested[10] that mesonic annihilation channels must be added to DCR when saturating the integral over ν in FESR for $\overline{b}b$ scattering. Such contributions would then affect all $\sigma_t(\overline{b}b)$ including those expected here to be flat, such as $\sigma_t(\overline{\Omega}^+p)$. For this reason it may be dangerous to speculate on the special role of mesonic annihilations. When saturating FESR with DCR one is neglecting inelastic two-or-more-particle intermediate states all the time. It is certainly worth seeing if such an approximation can work for $\overline{b}b$ scattering.

We therefore suggest that one look for the missing $\underline{10}$, $\underline{10}^*$, and $\underline{27}$ contributions in the form of $B=0$ resonances coupling mainly to $\overline{b}b$. Table II summarizes these channels (others are related by charge conjugation or isospin).

Table II. Possible $\overline{b}b$ enhancements with unusual quantum numbers. Others are related by charge conjugation or isospin.

S	Q	I	Sample decay modes
2	1	0,1	$p\overline{\Xi}^0$
2	2	1	$p\overline{\Xi}^+$
1	2	$\frac{3}{2}$	$\Delta^{++}\overline{\Lambda}, p\overline{\Sigma}^+$
0	2	2	$\Delta^{++}\overline{n}, \Sigma^+\overline{\Sigma}^+$

Even in the expected $\underline{1}$ and $\underline{8}$ channels few $\overline{b}b$ resonances have been seen, as their production is usually depressed by many competing processes. Such resonances have been reported (a) as bumps in $\sigma_t(\overline{p}p)$ and $\sigma_t(\overline{p}d)$,[11] and (b) in the $\overline{\Lambda}N$ system in $K^+p\to(\overline{\Lambda}pp,\ \overline{\Lambda}n\pi^+p$, and $p\overline{\Lambda}p\pi^0)$.[12,13] These processes are unlikely to yield the resonances of Table II, however. Measurements of σ_t in the channels mentioned are impossible at present. The enhancement in (b) appears to be produced peripherally by P or meson exchange. Production of the resonances of Table II by P exchange is impossible since incident particles of the right quantum numbers do not exist, and their production by an incident meson via meson exchange would be suppressed by the rule against coupling to mesonic systems.

One does not expect to see resonances in most $\overline{b}b$ final states of $\overline{p}p$ or $\overline{p}d$ reactions because of strong competition from isobar production.[14] Whereas production of a $\overline{b}b$ resonance requires baryon exchange, double-isobar production requires only meson exchange and is therefore expected to dominate. Exceptions to this rule should occur for low energies and high multiplicities, where the peripheral picture is less valid.

As $\overline{b}b$ structure begins to be seen in $\overline{p}p$ or $\overline{p}d$ final states through analysis of high-multiplicity events, we would suggest special note be taken of any $\overline{b}b$ enhancements with unusual quantum numbers. It would probably be easiest to see a $\Delta^{--}\overline{n}$ resonance, for example, as a bump in the $(\overline{p}n\pi^-)$ spectrum of $\overline{p}p\to(\overline{p}n\pi^-)+(m\pi)^{++}$ or $\overline{p}n\to(\overline{p}n\pi^-)+(m\pi)^+$. The latter reaction may be favored as it involves less charge exchange. Similarly $S=-1, Q=-2$ resonances may appear in the $(\overline{p}\Lambda\pi^-)$ or $(\overline{p}\Sigma^-)$ spectra of the appropriate reactions initiated by antiprotons. The absence of such resonances would be significant only in the strong presence of similar resonances belonging to the $\underline{1}$ or $\underline{8}$.

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Note added in proof.—The observed masses of f' and φ probably imply that the $t=0$ intercepts of their trajectories lie below those of the P', A_2, ω, and ρ. Assuming this, one gets the decoupling result (b), and hence the "usual" ω-φ

and f-f' mixing, directly from the flatness criterion.

[1]Haim Harari, Phys. Rev. Letters 20, 1395 (1968).

[2]Frederick J. Gilman, Haim Harari, and Yair Zarmi, Phys. Rev. Letters 21, 323 (1968).

[3]K. Igi, Phys. Rev. Letters 9, 76 (1962); A. Logunov, L. D. Soloviev, and A. An. Tavkhelidze, Phys. Letters 24B, 181 (1967); K. Igi and S. Matsuda, Phys. Rev. Letters 18, 625 (1967); R. Dolen, D. Horn, and C. Schmid, Phys. Rev. 166, 1768 (1968).

[4]G. Alexander, A. Firestone, and G. Goldhaber, Phys. Letters 27B, 177 (1968); J. C. Berlinghieri et al., in Proceedings of the Fourteenth International Conference on High Energy Physics, Vienna, Austria, 1968 (to be published).

[5]V. Barger, Proceedings of the Topical Conference on High Energy Collisions of Hadrons, CERN, 1968 (to be published).

[6]We mean by these all channels outside the 1 or 8 of MM and the 1, 8, and 10 of Mb, and all bb channels.

[7]Table I is consistent with the SU(3) model of V. Barger, M. G. Olsson, and K. V. L. Sarma, Phys. Rev. 147, 1115 (1966), with equal F/D for coupling of tensor and vector nonets to B, when $a=b=c=d=e=\gamma_M$, $3f/(4F-1)=g=h/F=i/(2F-1)=3j/(5F-2)=3k/(2F+1)$ $=m/(2F-1)=n/F=\gamma_B$, and $p=r=v=w=x=y=\gamma_D$. The arbitrary numerical factors are based on the limit $F=1$.

[8]If $h=0$ or $3f-g\leq 0$, assumption (c) is violated in the $\pi^-\Sigma^+$ or π^+p systems, respectively.

[9]This result can also be obtained independently of Regge theory. See H. J. Lipkin, Phys. Rev. Letters 16, 1015 (1966).

[10]H. J. Lipkin, private communication.

[11]R. J. Abrams et al., Phys. Rev. Letters 18, 1209 (1967).

[12]G. Alexander, A. Firestone, G. Goldhaber, and B. C. Shen, Phys. Rev. Letters 20, 755 (1968).

[13]An experiment at 12.3 GeV/c fails to confirm the $\bar{\Lambda}N$ resonance observed in Ref. 12 at 9.0 GeV/c. See J. C. Berlinghieri et al., in Proceedings of the Fourteenth International Conference on High Energy Physics, Vienna, Austria, 1968 (to be published).

[14]For example, in $\bar{p}p\to\bar{p}p\pi^+\pi^-$ at 3.2 and 3.6 GeV/c, where double-isobar production dominates, the $\bar{p}p\pi^\pm$ spectrum shows no structure. The author thanks T. Ferbel for this information.

SMALL-Δ^2 BEHAVIOR IN $\pi^-p\to\rho^0 n$ AT 8 GeV/c; CHEW-LOW EXTRAPOLATION AND CONSPIRACY EFFECTS*

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ρ^0 production and decay are examined, particularly for $\Delta^2<\mu^2$. The implications of the results regarding Chew-Low extrapolation procedure, and regarding a conspiracy interpretation, are discussed.

The behavior of the reaction

$$\pi N\to\rho N, \tag{1}$$

at small $\Delta^2<\mu^2$, is of particular interest for two reasons:

(1) If the Δ^2 dependence of $d\sigma/d\Delta^2$ as $\Delta^2\to 0$ becomes sharply different from the OPE (one-pion-exchange) prediction, then there may be some practical difficulty in using the Chew-Low extrapolation procedure[1] to obtain $\pi\pi$ cross sections.

(2) With the recent development of the ideas of conspiracy and evasion effects[2] at $\Delta^2=0$, it has been suggested that the Δ^2 dependence both of $d\sigma/d\Delta^2$ and of individual helicity amplitudes, in Reaction (1) and in other reactions, might be of particular interest close to $\Delta^2=0$.

We have accordingly examined data by Poirier et al.,[3] giving information on the reaction

$$\pi^-p\to\rho^0 n,\quad \rho^0\to\pi^-\pi^+ \tag{2}$$

at 8 GeV/c. The similar reaction

$$\pi^+p\to\rho^+p,\quad \rho^+\to\pi^+\pi^0 \tag{3}$$

has recently been studied in a similar way, also at 8 GeV/c, by Aderholz et al.[4]

Figure 1 shows the Δ^2 distribution for two