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η meson and hadronic interaction symmetry*

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The Zweig-Iizuka (ZI) rule for meson-meson-meson and meson-baryon-baryon interactions is stated in terms of SU(3) symmetry. The ZI rule is combined with SU(3) in order to simplify analysis of the η decay modes of the tensor mesons and spin-parity-$\frac{5}{2}^-$ baryons. The $SU(6)_W$ analysis of the preceding paper is extended to the η modes of the $\frac{1}{2}^-$ baryons. There are large contradictions between the predictions and experiment. There is no good evidence that the η modes of hadronic decays satisfy approximate SU(3) symmetry.

I. INTRODUCTION

The Zweig-Iizuka (ZI) rule states that hadronic interactions involving disconnected quark lines are weak.[1] This rule was first suggested to explain certain small interactions of the ϕ meson, assumed to have the quark structure $s\bar{s}$. (The up, down, and strange quarks are denoted by u, d, and s.) The theoretical importance of this rule has increased because of the discovery of the J/ψ and ψ' mesons.[2] In the most popular model of these particles, they are of the structure $c\bar{c}$, where c is a heavy quark. The narrow widths of the J/ψ and ψ' are then explained by the ZI rule and the assumption that the lightest hadron containing a c or $\bar{c}$ is heavier than half the ψ' mass. If this idea is correct, the ZI rule for c quarks must be valid for many processes involving P (pseudoscalar) mesons as well as V (vector) mesons. Clearly, it is important to know to what extent the rule applies to the $s\bar{s}$ component in the P mesons η and η'. The purpose of this paper is to study this question by considering η-emission decay modes of various hadrons.

There have been several analyses of SU(3) symmetry in the decays of various meson and baryon resonance multiplets.[3] However, the interpretation of the η decay modes in these analyses is ambiguous, because there are two extra parameters in the η interactions. These are the amplitude of the SU(3)-singlet component in the η wave function, and the relative interaction strengths of the singlet and octet components. Some simplification is needed. If the ZI rule and SU(3) symmetry are both valid, the rule determines the P-singlet interactions in terms of the P-octet interactions, so that the only extra parameter is the amplitude of the singlet component. I will make this kind of simplified analysis of the decays of the mesons of spin-parity 2^+ and the $\frac{5}{2}^-$ baryons in Sec. III A of this paper. The form of the ZI rule for SU(3) is given in Sec. II.

Analyses involving only SU(3) symmetry are not very useful for $\frac{1}{2}^-$ and $\frac{3}{2}^-$ baryons because of the presence of significant mixing between states of different SU(3) multiplets. However, it is shown in the preceding paper that l-broken $SU(6)_W$ is approximately valid for these states, and one can make predictions that are independent of mixing angles by summing contributions of resonances of the same spin, parity, hyperchange, and isotopic spin.[4] This technique is used in Sec. III B; it is valuable for understanding η-emission decay mode because three $\frac{1}{2}^-$ baryons have large branching ratios for η emission. Use of the ZI rule is especially appropriate, because this rule for P meson decays is satisfied automatically if l-broken $SU(6)_W$ is valid, as discussed in Sec. II C.

The ZI rule may be tested in η and $\eta'(958)$ production processes as well as in decay processes. For example, Lipkin has used the ZI rule and SU(3) symmetry for kaon-type Regge exchanges to predict the relation[5]

$$\sigma(K^-p\to\eta\Lambda)+\sigma(K^-p\to\eta'\Lambda)=\sigma(K^-p\to\pi^0\Lambda)+\sigma(\pi^-p\to K^0\Lambda)\,.$$

This equation is violated by 3.9-GeV/c data.[5] In the present paper I consider only hadronic decays involving η mesons. Studying these decays has the advantage that no assumption concerning the η' is needed, but has the advantage that the number of suitable processes is limited.

II. THE ZI RULE FOR SU(3) AND $SU(6)_W$

The main purpose of this section is to give the form of the ZI rule for MMM and MBB (meson-baryon-baryon) interactions that satisfy SU(3) symmetry and involve only the u, d, and s quarks.

A. MMM interactions

We consider the interaction of three different octets or nonets, labeled x, y, and z. If two or three of the multiplets refer to the same particles, the results are special cases of those given here.

The interaction constants referring to the antisymmetric and symmetric octet-octet-octet interactions are labeled g_a and g_s, g_{111} is the strength of the singlet-singlet-singlet interaction, and the singlet-octet-octet interaction constants are g_{188}, g_{818}, and g_{881}. Here the subscripts refer to the x, y, and z multiplets, respectively. The normalization is such that g_a^2 (or g_s^2) is the sum over all pairs of particles in two of the octets of the square of the constant of interaction with any one particle of the other octet. The constants involving a singlet are equal to the interaction of the singlet with a pair of appropriate particles in the other two multiplets. If x and y are the same nonet, then $g_{188}=g_{818}$.

In any meson octet or nonet, the charge-conjugation parities of the $Y=I_z=0$ states are the same; this is called the C parity of the multiplet. If the product of the C parities of the three multiplets is odd, only the g_a interaction is possible. In this case, no singlet can interact, and it is easy to show that the ZI rule is satisfied. Henceforth, we will consider only the case where the product of the C parities is even, and the possible interactions are g_s, g_{111}, g_{188}, g_{818}, and g_{881}. If the y and z multiplets are only octets, then the only interactions are g_s and g_{188}.

Since the results are independent of the permutations of the quark "flavors" u, d, and s, I will denote these three flavors by the general labels a, b, and c. If a multiplet is a nonet, there are two types of states, $a\bar{a}$ and $a\bar{b}$. If a multiplet is an octet, states of the type $a\bar{a}$ are not possible, but states of the type $(a\bar{a}-b\bar{b})/\sqrt{2}$ are possible.

If the mesons are all octets, it is easy to see that no interaction violates the ZI rule. However, if exactly one of the multiplets (taken to be the x multiplet) is a nonet, then the ZI rule requires that interactions of the following types vanish:

$$g[(a\bar{a}), (b\bar{c}), (c\bar{b})]=0\,, \tag{1}$$

$$g[(a\bar{a}, (b\bar{b}-c\bar{c})/\sqrt{2}, (b\bar{b}-c\bar{c})/\sqrt{2}]=0. \tag{2}$$

The convention in Eqs. (1) and (2) is that all three mesons are being annihilated at the vertex. These equations may be translated into SU(3) notation.[6] For this purpose one may use the quark-structure equations for $Y=I_z=0$ members of a meson nonet, i.e.,

$$\begin{aligned}\pi_0&=(u\bar{u}-d\bar{d})/2^{1/2}\,,\\ \eta_8&=(u\bar{u}+d\bar{d}-2s\bar{s})/6^{1/2}\,,\\ \eta_1&=(u\bar{u}+d\bar{d}+s\bar{s})/3^{1/2}\,,\end{aligned} \tag{3}$$

where the P-meson symbols π and η can represent corresponding states of any meson nonet. Equations (1) and (2) are equivalent to the SU(3) relation

$$g_{188}=(\tfrac{2}{5})^{1/2}g_s\,. \tag{4}$$

If the multiplets x and y are nonets and z is an octet, the only additional SU(3) condition is $g_{188}=g_{818}$. If all three multiplets are nonets, the ZI rule implies Eqs. (1) and (2) plus the conditions

$$g[(a\bar{a}), (b\bar{b}), (c\bar{c})]=0\,, \tag{5}$$

$$g[(a\bar{a}), (b\bar{b}), (b\bar{b})]=0\,, \tag{6}$$

plus the other two permutations of the states in Eq. (6). In terms of SU(3) these conditions are equivalent to Eq. (4) plus the conditions

$$g_{188}=g_{818}=g_{881}=g_{111}\,. \tag{7}$$

B. *BBM* interactions

I continue to assume SU(3) symmetry. The ZI rule for *BBM* interactions is satisfied if the following two conditions are satisfied:

$$g[(bbc), (bbc), (a\bar{a})]=0\,, \tag{8}$$

$$g[(bbb), (bbb), (a\bar{a})]=0\,, \tag{9}$$

where a, b, and c are the three flavors of light quark. The convention here is that of the decay $B'\to BM$, i.e., the first baryon B' is annihilated and the second baryon B created at the vertex. The interaction in Eq. (9) is possible only if both baryons are decuplet members. Because of the SU(2) symmetry of the b and c flavors, Eq. (8) implies Eq. (9), so it is sufficient if Eq. (8) is satisfield. The meson multiplet must be a nonet.

The (bbc) baryon state can be part of an octet or decuplet, so we need consider only these two baryon multiplets. If one of the baryons is a decuplet member and the other an octet member, SU(2) symmetry of the bc subgroup implies that Eq. (8) vanishes, so that the ZI rule is satisfied. (For example, a Δ cannot decay into a nucleon and an isosinglet meson.) If the baryons are both octet members, Eq. (8) is equivalent to the relation

$$g_1=(\tfrac{1}{2})^{1/2}g_a-(\tfrac{1}{10})^{1/2}g_s\,. \tag{10}$$

The normalization here is the same as that used in discussing *MMM* interactions. If the baryons are both decuplet members, the corresponding relation is

$$g_1=-\tfrac{1}{2}g_8\,. \tag{11}$$

The normalization is such that g_8^2 is the sum of the squares of the couplings of all *BM* states to a particular state of the B' multiplet.

C. The ZI rule for $SU(6)_W$

Before relating the ZI rule and $SU(6)_W$, we review briefly a few basic properties of this symmetry.[7] $SU(6)_W$ is formed by combining SU(3) generators with the quark "W-spin" operators σ_z, $\beta\sigma_x$, and $\beta\sigma_y$. It is applied to three-hadron vertices by taking the z axis to be the interaction direction and assuming that the x and y components of the momenta of all the initial and final quarks are zero. The spin and W spin of a quark are the same. The effect of the β in W_x and W_y is to change the phase relation between the spin-up and spin-down states of antiquarks. Consequently, in $q\bar{q}$ states, a spin singlet is part of a W-spin triplet, and a W-spin singlet is part of a spin triplet.

The following theorem is known to many physicists, but, as far as I know, it is not stated simply in the journals: If $SU(6)_W$ symmetry or l-broken $SU(6)_W$ is valid the ZI rule applies automatically to $B'BP$ interactions and to the P-singlet parts of MMM interactions. A simple proof has been given by Lipkin.[8] $SU(6)_W$ symmetry implies that the W spin of each of the three quark flavors is conserved separately. If a P meson is of the structure $a\bar{a}$ (where a is any of the three flavors), and the other hadrons contain no a or $\bar{a}$ quarks, W-spin conservation of the a flavor implies that W spin of the P meson is zero. This is a contradiction, since a P meson is part of a W-spin triplet. This is sufficient to imply the ZI rule for all $B'BP$ interactions, since the satisfaction of Eq. (8) implies the rule. In Sec. III we shall be concerned also with PP decays of tensor mesons. If the tensor meson is an octet member, the above argument implies the ZI rule. That is, Eq. (4) must be satisfied, where the singlet is the P singlet.

If the different interactions that must be related by the ZI rule correspond to different SU(6) representations, then the $SU(6)_W$ symmetry does not imply the rule, in general. For example, if one considers the $B'BV_0$ interactions, where V_0 is a vector meson with helicity zero in the decay direction, the SU(3)-singlet component of the V nonet is an SU(6) singlet in the $SU(6)_W$ classification. In this case the ZI rule is not guaranteed by $SU(6)_W$ symmetry, but requires a relation between the interactions of the meson multiplets $\underline{35}$ and $\underline{1}$.

III. COMPARISON OF THEORY AND EXPERIMENT FOR η EMMISSION

A. SU(3)-symmetric analysis

The physical η meson may be written in terms of SU(3)-octet and -singlet terms as

$$\eta = \cos\theta\, \eta_8 - \sin\theta\, \eta_1\,, \tag{12}$$

where the quark structures of η_8 and η_1 are given by Eq. (3). The sign convention is the usual one, in which the component of $s\bar{s}$ in the η is smaller for negative θ than for zero θ. The absolute magnitude of θ that results from application of the quadratic Gell-Mann–Okubo mass formula[9] is 10.4°, while the $|\theta|$ corresponding to the linear mass formula is 23.7°. The analysis of Bolotov *et al.* of $\pi^- p \to \eta n$ and $\pi^- p \to \eta' n$ cross sections provides evidence that θ is negative.[10]

The partial width for every two-hadron decay mode of a resonance is written in the form used in R1, i.e.,

$$\Gamma_{ri} = g_{ri}^2 p_i^{2l_i+1}/M_r^2\,, \tag{13}$$

where M_r is the mass of the resonance, p_i is the decay momentum, l_i is the orbital angular momentum of the decay, and g_{ri} is the interaction constant. It is assumed that the g_{ri} corresponding to the same l_i and same particle multiplets are related by SU(3) symmetry or (in Sec. III B) by $SU(6)_W$ symmetry. If the decay mode includes one or two η's, the factor $F_{ri}(\theta)$ is defined by

$$g_{ri}^2 = g_{ri8}^2 F_{ri}\,, \tag{14}$$

where g_{ri8} is the coupling constant that would apply if the η were pure octet.

If there is just one η in the decay, and the other final hadron and the resonance are composed only of u and d quarks and antiquarks, F has a simple form, denoted by F_{ud},

$$F_{ud} = (\cos\theta - \sqrt{2}\sin\theta)^2\,. \tag{15}$$

This applies, for example, if the baryon resonance is nonstrange or if the meson resonance is an isotriplet. Equation (15) may be derived from the formulas of Sec. II, but follows more simply from Eqs. (3) and (12) and the condition that the $s\bar{s}$ component of the η does not interact. The factor F_{ud} is expected to be significantly different from unity. The values corresponding to the θ's of the quadratic and linear mass formulas are

$$F_{ud}(-10.4°) = 1.53\,, \quad F_{ud}(-23.7°) = 2.20\,. \tag{16}$$

One of the most accurately known decay widths involving the η is the $\eta\pi$ partial width of the tensor meson $A_2(1310)$. If one uses SU(3) symmetry and Eq. (4), the predicted $\eta\pi/K\bar{K}$ interaction ratio of the A_2 is

$$g_{\eta\pi}^2/g_{K\bar{K}}^2 \text{ (theory)} = \tfrac{2}{3} F_{ud}\,.$$

The experimental data and the phase-space formula of Eq. (13) yield the experimental value[11]

$$g_{\eta\pi}^2/g_{K\bar{K}}^2 \text{ (exp)} = 1.10 \pm 0.15\,.$$

This is in agreement with the prediction, since F_{ud} is expected to be on the order of the values of Eq. (16).

Next we consider the $J^P = \frac{5}{2}^-$ baryon resonance octet. The predicted $\eta\pi/\pi N$ coupling ratio of the

$N_{5/2^-}(1665)$ is given by

$$\frac{g_{\eta N}^2}{g_{\pi N}^2}=\frac{1}{9}\left[\frac{1-3(f/d)}{1+(f/d)}\right]^2 F_{ud},$$

where f/d is related to the g_a and g_s of Eq. (10) by

$$(f/d)=(\tfrac{5}{9})^{1/2}g_a/g_s.$$

If $f/d=-\frac{1}{3}$, as predicted by $SU(6)_W$ for the quark-spin $\frac{3}{2}$ octet of the $\underline{70}$,[12] then $g_{\eta N}^2/g_{\pi N}^2=1$ and the predicted value of $\overline{g_{\eta N}}^2$ is

$$g_{\eta N}^2\ (\text{theory})=(3.51\pm 0.5)F_{ud}\ \text{GeV}^{-2},$$

where the experimental value and error used in R1 for $N\to\pi N$ have been used in the computation. The corresponding experimental value is

$$g_{\eta N}^2\ (\text{exp})<0.64\ \text{GeV}^{-2}.$$

Here I have used a conservative upper limit of 1% for the ηN branching ratio, as opposed to the limit 0.5% listed in Ref. 12. If one had used the value $f/d=-0.138$ obtained from an SU(3) analysis of the $\frac{5}{2}^-$ resonances,[3] the prediction would have been

$$g_{\eta N}^2\ (\text{theory})=(1.05\pm 0.15)F_{ud}\ \text{GeV}^{-2}.$$

This is somewhat better, but there is still a conflict, since one expects F_{ud} to be at least as large as 1.5.

These comparisons are significant because SU(3) works very well for the non-η decay modes of the 2^+ mesons and the $\frac{5}{2}^-$ baryons. In order to make this clear I will show the results of SU(3) analyses of these multiplets, although the experimental numbers have not changed much from those used in earlier analyses.[3] The tensor-meson results, with η modes included, are shown in Table I; the experimental partial widths, phase-space factors, and errors are determined by the same procedure used in R1. The overall normalization of the theoretical values was chosen to minimize the sum $\sum_i[g_i^2\ (\text{exp})-g_i^2\ (\text{th})]^2$ over the decays $A_2\to K\overline{K}$, $f\to\pi\pi$, and $K^*\to\pi K$. The F factors of the η-emission modes are listed below:

$$F(A_2\to\eta\pi)=F_{ud}=(\cos\theta-\sqrt{2}\sin\theta)^2,$$

$$F(f\to\eta\eta)=(\cos\theta-\sqrt{2}\sin\theta)^4,$$

$$F(f'\to\eta\eta)=[\cos\theta+(\tfrac{1}{2})^{1/2}\sin\theta]^4,$$

$$F(K^*\to\eta K)=[\cos\theta+\sqrt{8}\sin\theta]^2.$$

Table II shows the comparison between theory and experiment for the $\frac{5}{2}^-$ decays, with the f/d ratio taken as the value of Ref. 3. The experimental errors are the same in Table I of R1. The normalization of the theoretical numbers was chosen to minimize the sum $\sum_i[g_i^2\ (\text{exp})-g_i^2\ (\text{th})]^2$ over those modes with experimental errors in g_i^2 smaller than 1 GeV^{-2}.

B. $SU(6)_W$ symmetry

We next consider ηN, $\eta\Lambda$, and $\eta\Sigma$ decay modes of $\frac{1}{2}^-$ and $\frac{3}{2}^-$ resonances. In these cases there is mixing between different SU(3) multiplets. Therefore, I will follow the procedure of R1 and sum g_{ri}^2 over resonances of the same spin, parity, hypercharge, isotopic spin, and (presumably) the same quark-model level. The result is then compared with l-broken $SU(6)_W$, and is independent of mixing angles.[4] It is shown in R1 that the predictions are satisfied fairly well for π- and K-emission modes.

The η modes of the $\frac{3}{2}^-$ resonances have not been seen. However, the $N_{3/2^-}(1512)$, $\Lambda_{3/2^-}(1519)$, and $\Sigma_{3/2^-}(1582)$ are close to or below η-emission threshold. Therefore, appreciable η couplings of these resonances may exist and may have escaped detection, so that no violation of the predictions is implied.

We turn to the $\frac{1}{2}^-$ resonances. The $\Lambda_{1/2^-}(1405)$ and $\Sigma_{1/2^-}(1620)$ are also below the η-emission thresholds. However, the measured η-emission rates of other baryons of this spin parity are large. The decays are S-wave decays. The ex-

TABLE I. Experimental and theoretical values of g_{ri}^2 [in (GeV)$^{-2}$] for the PP decays of the tensor mesons.

Decay	g^2 (exp)	g^2 (theory)
$A_2(1310)\to K\overline{K}$	0.57 ± 0.07	0.84
$A_2(1310)\to\eta\pi$	0.63 ± 0.06	$0.56F$
$f(1271)\to\pi\pi$	2.57 ± 0.29	2.53
$f(1271)\to K\overline{K}$	0.82 ± 0.21	0.84
$f(1271)\to\eta\eta$	<1.7	$0.09F$
$f'(1516)\to K\overline{K}$	1.50 ± 0.53	1.69
$f'(1516)\to\eta\eta$	<0.8	$0.75F$
$K^*(1421)\to\pi K$	1.38 ± 0.14	1.27
$K^*(1421)\to\eta K$	<0.35	$0.14F$

TABLE II. Experimental and theoretical values of g_{ri}^2 in (GeV)$^{-2}$ for PB decays of $J^P=\frac{5}{2}^-$ resonances. The f/d for g^2 (theory) is -0.138.

Decay	g^2 (exp)	g^2 (theory)
$N(1665)\to\pi N$	3.51	3.74
$N(1665)\to\eta N$	<0.64	$1.12F_{ud}$
$\Lambda(1827)\to\overline{K}N$	0.37	0.38
$\Lambda(1827)\to\pi\Sigma$	4.63	6.71
$\Sigma(1768)\to\overline{K}N$	4.99	4.34
$\Sigma(1768)\to\pi\Lambda$	1.37	2.24
$\Sigma(1758)\to\pi\Sigma$	0.16	0.26

perimental and theoretical values of $G_i^2 = \Sigma_r g_{ri}^2$ for the η modes of this multiplet are shown in Table III. The experimental numbers and errors are determined as in R1, and the overall normalization of the theoretical G_i^2 is that of Table II of R1. The F factors are

$$F_{\eta N} = F_{ud} = (\cos\theta - \sqrt{2}\sin\theta)^2 ,$$

$$F_{\eta\Lambda} = \cos^2\theta - (2\sqrt{2}/7)\sin\theta\cos\theta + (\tfrac{8}{7})\sin^2\theta ,$$

$$F_{\eta\Sigma} = \cos^2\theta + (2\sqrt{2}/3)\sin\theta\cos\theta + (\tfrac{8}{3})\sin^2\theta .$$

The experimental value of G^2 for the $\Sigma \to \eta\Sigma$ is not included in Table III because the errors in the mass and $\eta\Sigma$ branching ratio of the $\Sigma_{1/2^-}(1750)$ are so large that the G^2 would not be very meaningful. The contributions to the ηN and $\eta\Lambda$ couplings come entirely from the $N_{1/2^-}(1516)$ and $\Lambda_{1/2^-}(1672)$.

It should be borne in mind that if the $\eta\Lambda$ coupling of the $\Lambda_{1/2^-}(1405)$ were known and included, the experimental $G^2(\eta\Lambda)$ would be larger. For θ in the range $-24°$ to 0, $F_{\eta\Lambda}$ is in the range 1 to 1.2. Since F_{ud} is expected to be in the range 1.5 to 2.2 [see Eq. (16)], a large violation of the $SU(6)_W$ prediction is present for the ηN couplings

TABLE III. Experimental and theoretical values of G_i^2 (in GeV^2) for η-emission modes of $J^P = \frac{1}{2}^-$ baryons.

Decay	G_i^2 (exp)	G_i^2 (theory)
$N \to \eta N$	106 ± 40	$15F$
$\Lambda \to \eta\Lambda$	43.5 ± 23	$26F$
$\Sigma \to \eta\Sigma$	uncertain	$11.1F$

IV. CONCLUDING REMARKS

There are hadronic decays involving the η other than those considered here. However, in those cases where fairly accurate measurements have been made, various difficulties obscure the question of the applicability of SU(3) to the η vertices. An example is the $\eta\gamma$ partial width of the ϕ meson. This can be compared with other $V \to P\gamma$ interactions, if one assumes SU(3) symmetry and vector dominance.[13] Unfortunately, these assumptions are in conflict with some $VP\gamma$ interaction ratios that do not involve η's. If one accepts the $\omega \to \pi\gamma$ width as a standard, the predicted $\rho \to \pi\gamma$ and $K^{*0} \to K^0\gamma$ widths are more than twice too large.[13] This cannot be explained as a ZI violation for the P or V mesons, since the only P- or V-singlet component involved is that in the ω, and the known small $\phi \to \pi\rho/\omega \to \pi\rho$ interaction ratio supports the ZI rule for the V nonet. The discrepancy cannot be explained by attributing an SU(3)-singlet component to the γ, because a singlet component of such sign to decrease the $\rho \to \pi\gamma$ interaction will increase the $K^{*0} \to K^0\gamma$ interaction.[14] Because of this difficulty, $V \to P\gamma$ decays are not very suitable for studying the SU(3) properties of the η.

My main conclusion is that the two assumptions of SU(3) symmetry and the Zweig-Iizuka rule lead to contradictions with experimental measurements of η-emission decay modes of various hadrons. The measured $A_2 \to \eta\pi$ width is in agreement with predictions for a reasonable value of the η-η' mixing angle. On the other hand, an appreciable ηN decay of the $N_{5/2^-}(1665)$ is predicted, in contradiction with experiment. The large observed ηN decay width of the $N_{1/2^-}(1516)$ is in violation of the combination of the ZI rule and l-broken $SU(6)_W$, although this symmetry works fairly well for non-η decay modes of the odd-parity baryon resonances. There is no good evidence from hadronic decays that η interactions satisfy approximate SU(3) symmetry.

The large η modes of the $J^P = \frac{1}{2}^-$ baryons $N(1516)$, $\Lambda(1672)$, and $\Sigma(1750)$ are sometimes called "threshold effects" since these resonances are close to the η-emission thresholds. It is conceivable that the η-emission reaction is crucial in whatever dynamics determines the masses of these resonances, and that their locations near the thresholds are not coincidential. If this is so, it is another way in which the η is different from other hadrons. No such striking threshold effects have been observed for pion or kaon emission, or for $\pi\Delta$ decays. In this connection, it is interesting to note that the quark-model assignments of these three baryons are quite different in most analyses. In the analysis of Hey, Litchfield, and Cashmore, for example,[15] the largest components in the wave functions for the $\frac{1}{2}^-$ baryons $N(1516)$, $\Lambda(1672)$, and $\Sigma(1750)$ are of quark-spin and SU(3) multiplicities $^2 8$, $^4 8$, and $^2 10$, respectively.

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