HIGHER SYMMETRIES AND BARYON RESONANCES*

by

J. L. Rosner†

Institute for Advanced Study
Princeton, New Jersey 08540

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

* Appendix to "Baryon Resonances and Related Phenomenology,"
rapporteur's talk by C. Lovelace at XVI International Conference
on High Energy Physics, Batavia, Ill., Sept. 6 - 13, 1972.
Work supported in part by the U. S. Atomic Energy Commission,
Contract No. AT (11-1) - 2220.

† Alfred P. Sloan Foundation Research Fellow, 1971-3. Permanent
address: School of Physics and Astronomy, University of
Minnesota, Minneapolis, Minnesota 55455.

MASTER

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

The quark model continues to provide us with the most economical framework for classifying the hadrons, and enjoys some measure of success in describing their interactions as well. The predictions which are particularly "clean" are those which do not depend on detailed dynamical details. The symmetry $SU(6)_W \otimes O(2)_{L_z}$, for example, while not always expected to hold,¹ makes some predictions which are expected to be valid, and which have been borne out by data at this conference.²⁻⁷ These are summarized briefly in Table I.

Since $[SU(6)_W \otimes O(2)_{L_z}]$ has not been discussed widely for a while, it seems worthwhile to review its calculational rules; its theoretical basis and its limitations are discussed at greater length elsewhere.¹

Consider a decay $A \rightarrow B+C$, with λ_i = helicity of particle i . The partial width may be written as follows in $SU(6)_W \otimes O(2)_{L_z}$:^{1, 8}

$$\Gamma = p M_N \tilde{\Gamma} / M_R \quad (1)$$

where p is the CM 3-momentum, M_R is the resonance mass, and M_N is the nucleon mass (inserted for dimensional purposes). $\tilde{\Gamma}$ is a reduced width which may be expressed in terms of helicity

amplitudes $M_{\lambda_B \lambda_C}$:

$$\tilde{F} = \frac{1}{2J_{A+1}} \sum_{\lambda_B \lambda_C} |M_{\lambda_B \lambda_C}|^2 \quad (2)$$

In turn, the helicity amplitudes may be related to one another for decays involving different A, B, C in the same multiplets of $[U(6)]_{\text{quarks}}$

$\otimes [U(6)]_{\text{antiquarks}} \otimes O(3)_L$. For example, we may calculate all $M_{\lambda_B \lambda_C}$ for decays

$$(\underline{70}, \underline{1}, L=1) \rightarrow (\underline{56}, \underline{1}, L=0) + (\underline{6}, \underline{6}^*, L=0) \quad (3)$$

in terms of a single parameter $a[\alpha]$, where α denotes the collection of multiplets. The relation is

$$M_{\lambda_B \lambda_C} = \sum_i \left(\underline{A} \mid \underline{B} \quad \underline{C} \right)_i \left(\alpha \mid \beta \quad \gamma \right)_i X_{\lambda_B \lambda_C}; \quad (4)$$

$$X_{\lambda_B \lambda_C} = \left(S_{\lambda_B \lambda_C}^{A A} \mid J_{\lambda_B \lambda_C}^{A A} \right) \left(W_{\lambda_B \lambda_C}^{B B} W_{\lambda_C \lambda_C}^{C C} \mid W_{\lambda_B \lambda_C}^{A A} \right) a[\alpha]. \quad (5)$$

In Eq. (4) the first term is an SU(3)-scalar factor,⁹ with $\underline{A}$, $\underline{B}$, $\underline{C}$ denoting dimensions of SU(6) multiplets and (α, a) , (β, b) , (γ, c) denoting dimensions of $SU(3) \otimes SU(2)$ multiplets. The SU(2), it should be noted, denotes W-spin W and not quark spin S, a distinction which will be clarified below. The second term is the

MASTER

usual isoscalar factor,¹⁰ with A, B, C denoting specific isomultiplets. Clebsch-Gordan coefficients of isospin are omitted; their squares would sum to 1 in any event when calculating partial widths of resonances. For specific charge states, they may be inserted at will. The index i in Eq. (4) refers to summation over d- and f-type coupling when α, β, γ are all octets; it may be omitted otherwise.

In Eq. (5) the first Clebsch-Gordan coefficient refers to the coupling of quark spin and orbital angular momentum to total angular momentum in hadron A. The assumption that L_z , the third component of L, is equal to zero corresponds to the assumption that the decay conserves the component of quark angular momentum (and hence of quark spin) along the decay axis z. It is this assumption which leads to the symmetry $SU(6)_W \otimes O(2)_{L_z}$. Certain simple ways of relaxing this assumption based on the quark model^{1, 11, 12} preserve many of the relations of the above symmetry.

The second Clebsch-Gordan coefficient in Eq. (5) reflects W-spin¹³ conservation. The group $[SU(2)]_W$ is that subgroup of $[SU(2)]_{\text{quarks}} \otimes [SU(2)]_{\text{antiquarks}}$ whose generators commute with boosts in the z direction. Physically it arises as an attempt to salvage conserved quantities from the fact that when we move past any system, the numbers of quarks and antiquarks are no

longer separately conserved. The rule¹³ for constructing W-spin multiplets from S-spin multiplets is simple: for quarks, $\bar{W} = \bar{S}$, while for antiquarks, $W_z = S_z$, $W_{x,y} = -S_{x,y}$. For the baryons, $\bar{W} = \bar{S}$; for the mesons,

$$|11\rangle_S = |11\rangle_W \quad (6a)$$

$$|10\rangle_S = -|00\rangle_W \quad (6b)$$

$$|1-1\rangle_S = -|1-1\rangle_W \quad (6c)$$

$$|00\rangle_S = -|10\rangle_W \quad (6d)$$

Eq. (6b), for example, tells us that a vector meson with helicity zero belongs to a W-spin singlet, and (6d) implies that a pseudoscalar meson belongs to a W-spin triplet.

Taking process (3) as an example, angular momentum and parity conservation imply that it may involve (a priori) decays in which the final particles are in $\ell=0$, $\ell=2$, or even (for $5/2^- \rightarrow 3/2^+ 0^-$ and various processes involving vector mesons) $\ell=4$. It turns out that all the $\ell=4$ amplitudes vanish in $SU(6)_W \otimes O(2)_{L_z}$. The $\ell=0$ (S wave) and $\ell=2$ (D wave) amplitudes, on the other hand, are related to one another. This constraint is unphysical and its relaxation is desirable. This may be achieved phenomenologically by expanding decay helicity amplitudes for any given process in terms of contributions from S waves and D waves, whose normalizations

will then be specified for the process at hand in the $SU(6)_W \otimes O(2)_{L_z}$ limit. A prescription for breaking this symmetry then consists of defining separate S wave and D wave amplitudes such that in the symmetry limit,

$$S = D = a [\alpha] , \quad (7)$$

and retaining the coefficients of S and D in each helicity amplitude that were specified in the symmetry limit. This procedure turns out to be equivalent to some recent quark model approaches.^{1, 11, 12} Even if such specific models are incorrect, it is useful to isolate S and D wave predictions since there is reason to believe that the latter might be considerably more reliable.² This is because in $SU(6)_W \otimes O(2)_{L_z}$, the S wave amplitudes, being proportional to the D wave ones, must acquire a p^2 factor not demanded on more general grounds. Any breaking leading to properly behaved S wave amplitudes will consequently swamp those of $SU(6)_W \otimes O(2)_{L_z}$.

Consequently, we may introduce separate amplitudes normalized as in Eq. (7); the resulting predictions for the "reduced widths" $\tilde{\Gamma}$ (see Eq. (1)) are shown in Table II. The comparison of these predictions with experiment requires an assumption about barrier factors; we have used zero-radius forms:

$$\left. \begin{matrix} S \\ P \\ D \\ F \end{matrix} \right\} = \left\{ \begin{matrix} \tilde{S} \\ \tilde{P} p \\ \tilde{D} p^2 \\ \tilde{F} p^3 \end{matrix} \right. \quad (8)$$

where $\tilde{S}$, $\tilde{P}$, $\tilde{D}$, and $\tilde{F}$ are taken to be constant. These quantities are estimated from the partial widths of single states. While this is probably inferior to performing an overall fit, it gives an idea of the quality of the predictions. The rules for choosing the input widths are as follows:

- (a) We use elastic πN widths.
- (b) We use $I = 3/2$ states since they can be isolated cleanly from $\pi^+ p$ data.
- (c) Where possible, we use states which are not expected to mix with one another on the basis of the quark model. This is true for $S_{31}(1620)$ and $D_{33}(1700)$, which are unique $N = 1$ states, and $F_{37}(1920)$, which is a unique $N = 2$ state. It turns out to be impossible to find an unmixed state for which one can obtain P ; the best we can do is to choose a state which may mix with one other and hope that it does not. One may see that $P_{31}(1900)$ is the unique choice. We shall assume, as is usual, that this state belongs to $\underline{56}$, $N = 2$, $L = 2$.

The symmetry predictions of this scheme ("T-broken-SU(6)_W") are shown in Table II. The Clebsch-Gordan coefficients are actually of some interest, since they vary greatly. For example, the $N\pi$ partial width of $D_{13}(1730)$ is predicted to be $1/40$ that of $D_{13}(1520)$, modulo phase space corrections. Qualitatively, this conclusion is borne out.

It is clear that one can hope for only very qualitative success from Table II. One of the most glaring discrepancies in comparison with experiment² is the prediction of large partial widths for the sum of the two S_{11} states. No matter what the mixing, one predicts $\Sigma \tilde{\Gamma} = 5S^2/216$; depending on whether the lower or upper peak carries most of this strength, the sum of partial widths is predicted to be $\sim 350 - 420$ MeV. This is five times too large. Earlier analyses which permitted the upper state to be broad are apparently in disagreement with later data.

Many of the other predictions do not fare badly, if we take them as qualitative guides:

(a) Large $\Delta\pi$ mode of S_{31} . This can be ascribed to the relative size of the $N\pi$ and $\Delta\pi$ Clebsch-Gordan coefficients. Experimentally, the $\Delta\pi$ partial width is large. In fact, the coefficient for S-wave $N\rho$ decay is also large, and indeed this is observed despite the fact that the state is below $N\rho$ threshold.

(b) P_{33} state with large $\Delta\pi$ mode. This state is expected to be most easily seen when decaying to $\Delta\pi$. Note that one expects a non-negligible F-wave $\Delta\pi$ decay. Experimentally, this state is indeed seen decaying to $\Delta\pi$,⁴ but the predicted F-wave admixture is not detected.

(c) Large $\Delta\pi$ mode of $D_{33}(1700)$. This prediction is probably an overestimate. Note that it depends on S^2 , which may indeed have been overestimated as many of our S-wave predictions turn out quite large.² Nonetheless, it explains the considerable inelasticity of this state quite nicely.

(d) Suppression of $\Delta\pi$ mode of $P_{13}(1850)$. The assignment of this state to a multiplet with quark spin 1/2 suffices to predict that 9/10 of the expected $SU(6)_W \Delta\pi$ partial width goes via the higher partial wave. When $SU(6)_W$ is broken by centrifugal barriers, whereby F-wave decays are suppressed, the whole $\Delta\pi$ mode will be reduced in importance. We do expect a detectable F-wave $\Delta\pi$ decay with the assignment shown. Evidence from N_p decay to be discussed below favors this assignment. Experimentally, the decay $P_{13}(1850) \rightarrow \Delta\pi$ is simply not observed.

(e) Large $\Delta\pi$ mode of $D_{13}(1730)$. The predicted partial width is very large. As mentioned quite early and often by quark model enthusiasts, this could at least explain why this state has not been seen conclusively before. It is the one nonstrange state of the quark model in 70, $L = 1$ that was missing when this subject was reviewed in 1968. The fact that SLAC-Berkeley see a much narrower effect than what we predict is reminiscent of our difficulties with $S_{11}(1670)$.

We should mention one further difficulty:

(f) The experimental predominance of F-wave $\Delta\pi$ decay^{4,14} of $F_{35}(1875)$ is not explained.¹⁵ The $N\pi$ decay is also larger than expected. Does this mean the state is a mixture of 70 and 56 (both $L = 2$)? If so, where is the orthogonal state? Does it decouple altogether from $N\pi$? A similar question can be asked for $F_{15}(1688)$, whose experimental $N\pi$ width is also larger than that predicted.

To summarize, the quark model provides some limited insights into inelastic decays of N^* 's and Δ 's. It must probably be augmented with further dynamical understanding and overwhelmingly better-statistics experiments (to pin down mixing problems) if more progress is to be made in understanding partial widths.

There is a tendency in analyzing final states with two or more partial waves to keep only the dominant one. In all cases except $F_{35}(1875) \rightarrow \Delta\pi$, the lowest possible orbital angular momentum ℓ is thus selected. This is a trivial consequence of barrier effects. On the other hand, one cannot choose a priori the dominant spin of the $N\pi$ system when both spins ($1/2$ and $3/2$) are allowed for the lowest ℓ .

The $SU(6)_W$ predictions of the dominant $N\pi$ spin for a given ℓ are expected to hold, of course, even in ℓ -broken $SU(6)_W$. These predictions are easily tested, and all appear to work, as shown in

Table III. They support the assignment of $P_{13}(1850)$ to 56, $L = 2$ (if this state is indeed unmixed). An amusing corollary of this assignment is that the dominant P-wave N_ω decay of this state should have spin 3/2: $\Gamma_{P_{3/2}} > \Gamma_{P_{1/2}}$.

By methods similar to those described above, one predicts

$$\tilde{\Gamma} | P_{13}(1850) - N_\omega | = \frac{7P^2}{2250} + \frac{8F^2}{375}, \quad (9)$$

leading to

$$\Gamma_{P,F} = 2.2, 1.5 \text{ MeV} \quad (10)$$

Since the two values of f are of comparable importance, a study of

$$\pi^- p \rightarrow n \omega \quad 1700 \leq E_{\text{cm}} \leq 2000 \text{ MeV} \quad (11)$$

might prove very interesting in determining the sign of P/F [given the 56, $L = 2$ assignment for $P_{13}(1850)$] or in determining whether P_{13} states other than the 56, $L = 2$ one are present (by the spin-ratio test described above).

One final application of the present method, as yet untested, is the study of relative signs of two partial-wave amplitudes using $\Delta\pi$ decays.¹

Table II implies that $D_{33}(1700)$ should have a detectable D wave $\Delta\pi$ decay.⁸ The phase of this amplitude relative to the (dominant)

S wave is then of interest. Its effect will show up as unequal rates for helicity $3/2$ and $1/2$ Δ production in $D_{33} \rightarrow \Delta\pi$. We distinguish the two cases:

(i) $\Gamma(\lambda=3/2) < \Gamma(\lambda=1/2)$: "SU(6)_W-like" (SU(6)_W predicts complete suppression of $\lambda=3/2$).

(ii) $\Gamma(\lambda=3/2) > \Gamma(\lambda=1/2)$: "anti-SU(6)_W". The sign of D/S in this case is opposite to that predicted by SU(6)_W.

The above example should be a particularly "clean" test, as it involves a state which should not undergo mixing with any other $N = 1$ state. The SLAC-Berkeley group does not claim evidence for any D-wave $\Delta\pi$ decay of $D_{33}(1700)$, however. Similar tests have been suggested for $D_{13}(1520) \rightarrow \Delta\pi$ and $F_{15}(1690) \rightarrow \Delta\pi$.¹

The field of experimental resonance spectroscopy has taken a qualitative turn in recent years from "bump-hunting" toward detailed analysis of production and decay properties. The ability of the quark model to keep pace with such developments indicates that this model is likely to provide a very useful guide in the formulation of any realistic theory of the hadrons.

I am grateful to W. P. Petersen for help in checking the entries of Table II, and to F. Halzen for numerical assistance in calculating the numbers, based on this table, quoted in Ref. 2. It is a pleasure to acknowledge discussions with C. Lovelace.

REFERENCES

- ¹W.P. Petersen and J. L. Rosner, papers nos. 364 (Phys. Rev. D6, 820 [1972]) and 790; J. Rosner, paper no. 365 (Phys. Rev. D6, Sept. 1972), these proceedings.
- ²C. Lovelace, rapporteur's talk, these proceedings.
- ³R. Ayed et al., 1972 Saclay phase shift analysis, quoted in Ref. 2; S. Almehed and C. Lovelace, Nucl. Phys. B40, 157 (1972).
- ⁴R. J. Cashmore, et al., paper no. 289, these proceedings.
- ⁵W. Langbein and F. Wagner, paper no. 305, these proceedings.
- ⁶W. F. Baker, et al., paper no. 525, these proceedings.
- ⁷F. Wagner, paper no. 393, these proceedings.
- ⁸D. Faïman and D. Plane, paper no. 650, these proceedings.
- ⁹C. L. Cook and G. Murtaza, Nuovo Cimento 39, 531 (1965).
- ¹⁰Particle Data Group, Phys. Letters 39B, 1 (1972).
- ¹¹R. Feynman, M. Kislinger, and F. Ravndal, Phys. Rev. D3, 2706 (1971).
- ¹²J. Rosner, Parallel Session F3, these proceedings.
- ¹³See, e.g., H. J. Lipkin and S. Meshkov, Phys. Rev. Letters 14, 670 (1965).
- ¹⁴U. Mehtani, et al., paper no. 666, these proceedings.
- ¹⁵See, however, S. Y. Fung and A. Kernan, paper no. 667, these proceedings.

TABLE I

Some "Clean" $SU(6)_W \otimes O(2)_{L_z}$ Predictions

Borne Out by Data at This Conference

Decaying Multiplet	Final f	Predictions	Experiment
<u>70</u> , $L = 1$	2	Some states quite inelastic.	Confirmed in $\pi N \rightarrow \pi N^3$ and $\pi N \rightarrow \pi \Delta$. ⁴
<u>56</u> , $L = 2$	3	Branching ratios for Δ (1950) decays, e.g. spin 3/2 dominant in $N\rho$.	Confirmed in $\pi N \rightarrow \pi \Delta$ and $\pi N \rightarrow \rho N$. ⁴
<u>70</u> , $L = 2$	3	Highly inelastic F_{17} πN resonance, $m \sim 2$ GeV.	Likely: new phase shifts in $\pi N \rightarrow \pi N$, ³ $K\Sigma$. ⁵
<u>56</u> , $L = 3$	4	G_{39} πN resonance, possibly narrow (small $\pi \Delta$ width).	Consistent with new backward $\pi^+ p$ data ⁶ and with πN phase shifts. ^{3, 7}
<u>56</u> , $L = 4$	5	Inelastic G_{19} πN resonance accompanying prominent G_{17} one.	Suggested by new πN elastic phase shifts. ^{3, 7}

TABLE II

Partial-Width Predictions for $N\pi$, $\Delta\pi$ and $N\rho$

State	Assignment	$\tilde{\Gamma}(N\pi)$	$\tilde{\Gamma}(\Delta\pi)$	$\tilde{\Gamma}(N\rho)$
$S_{31}(1620)$	<u>70</u> , L=2	$S^2/432$	$5D^2/108$	$\frac{25S^2}{1296} + \frac{D^2}{162}$
$P_{31}(1900)$	<u>56</u> , L=2	$8P^2/675$	$P^2/270$	$4P^2/675$
$P_{33}(1890)^d$	<u>56</u> , L=2	$4P^2/675$	$\frac{8P^2}{675} + \frac{F^2}{150}$	$\frac{28P^2}{3375} + \frac{4F^2}{1125}$
$D_{33}(1700)$	<u>70</u> , L=1	$D^2/432$	$\frac{5S^2}{216} + \frac{5D^2}{216}$	$\frac{S^2}{324} + \frac{29D^2}{1296}$
$F_{35}(1880)$	<u>56</u> , L=2	$8F^2/4725$	$\frac{7P^2}{450} + \frac{64F^2}{4725}$	$\frac{28P^2}{3375} + \frac{184F^2}{(189)(125)}$
$F_{37}(1920)$	<u>56</u> , L=2	$4F^2/525$	$F^2/70$	$16F^2/1575$
$S_{11}(1520)^a$	<u>70</u> , L=1	$S^2/54$	$D^2/27$	$\frac{S^2}{648} + \frac{25D^2}{324}$
b	<u>70</u> , L=1	$S^2/432$	$D^2/216$	$\frac{S^2}{324} + \frac{121D^2}{2592}$
$S_{11}(1670)^a$	<u>70</u> , L=1	$S^2/216$	$D^2/108$	$\frac{S^2}{648} + \frac{D^2}{1296}$
b	<u>70</u> , L=1	$S^2/48$	$D^2/24$	$D^2/32$
$P_{13}(1850)$	<u>56</u> , L=2	$P^2/54$	$\frac{16}{675} \left[\frac{P^2}{10} + \frac{9F^2}{10} \right]$	$\frac{103P^2}{6750} + \frac{32F^2}{1125}$
$D_{13}(1520)^c$	<u>70</u> , L=1	$D^2/54$	$(S^2 + D^2)/54$	$\frac{25S^2}{648} + \frac{13D^2}{324}$
$D_{13}(1730)^c$	<u>70</u> , L=1	$D^2/2160$	$\frac{5S^2}{108} + \frac{4D^2}{135}$	$\frac{5S^2}{1296} + \frac{17D^2}{6480}$
$D_{15}(1680)$	<u>70</u> , L=1	$D^2/360$	$7D^2/180$	$D^2/240$
$F_{15}(1688)$	<u>56</u> , L=2	$F^2/54$	$\frac{16}{675} \left[\frac{3P^2 + 2F^2}{5} \right]$	$\frac{128P^2}{6750} + \frac{167F^2}{6750}$

NOTES:

(a) $S_{11}(1500) \in (8, 2)$; $S_{11}(1670) \in (8, 4)$ (b) $S_{11}(1500) \in [(8, 2) - (8, 4)]/\sqrt{2}$ (maximum $N\eta$ coupling); $S_{11}(1670) \in [(8, 2) + (8, 4)]/\sqrt{2}$ ($N\eta$ coupling vanishes)(c) $D_{13}(1520) \in (8, 2)$; $D_{13}(1730) \in (8, 4)$

Where two numbers are shown separated by commas, the first refers to the lower partial wave and the second to the higher.

(d) Based on Ayed, et al., Ref. 3.

TABLE III

Predictions of l -Broken $SU(6)_W$
for Dominant Np Spins in Lowest Available l

J^P	State	Assignment	Lowest l , spins predicted. Underlined: dominant.	Experiment: dominant
$7/2^+$	$F_{37}(1925)$	<u>56</u> , (10, 4) $L = 2$	$F1/2$, <u>$F3/2$</u>	$F3/2$
$3/2^+$	$P_{13}(1850)$	<u>56</u> , (8, 2) $L = 2$	<u>$P1/2$</u> , $P3/2$	$P1/2$
		<u>70</u> , (8, 4) $L = 0$	$P1/2$, <u>$P3/2$</u>	
		<u>70</u> , (8, 4) $L = 2$	$P1/2$, <u>$P3/2$</u>	
		<u>70</u> , (8, 2) $L = 2$	$P1/2$, <u>$P3/2$</u>	
$1/2^+$	$P_{31}(1900)$	<u>56</u> , (10, 4) $L = 2$	<u>$P1/2$</u> , $P3/2$	$P1/2$
		<u>70</u> , (10, 2) $L = 0$	<u>$P1/2$</u> , $P3/2$	

TABLE IV

Numerical values associated with predictions of Table II.

[Not to be incorporated into proceedings; see instead Ref. 2.]

Underlined: input values. Parentheses: author's experimental estimates [may differ from Ref. 2].

State	$\Gamma(N\pi)$, MeV	$\Gamma(\Delta\pi)$, MeV ^d	$\Gamma(N\rho)$ ^d , MeV
$S_{31}(1620)$	<u>40</u>	D: 42 (~55)	-
$P_{31}(1900)$	<u>66</u>	P: 9 (~30)	P: 6, 5 (~15)
$P_{33}(1890)$	32 (22)	P: 28; F: 8	P: 8; F: 0.6
$D_{33}(1700)$	<u>40</u>	S: 280 (~125); D: 51	-
$F_{35}(1880)$	13 (45)	P: 34 (~0), F: 14 (~70)	P: 7 (~140); F: 1
$F_{37}(1920)$	<u>80</u>	F: 23 (35)	F: 33 (30)
$S_{11}(1520)$ ^a	290	D: 4.2	-
b	$\left. \begin{matrix} (13) \\ 83 \end{matrix} \right\}$	$\left. \begin{matrix} D: 15 \end{matrix} \right\} (\sim 0)$	-
$S_{11}(1670)$ ^a	36	D: 0.5	-
b	$\left. \begin{matrix} (60- \\ 370) \end{matrix} \right\} 74$	$\left. \begin{matrix} D: 68 \end{matrix} \right\} (\sim 0)$	-
$P_{13}(1850)$	90 (75)	P: 5 (~0); F: 17 (~0)	P: 11 (~240); F: 2
$D_{13}(1520)$ ^c	108 (70)	S: 147; D: 3.3 (~15)	-
$D_{13}(1730)$ ^c	9 (13)	S: 580 (~100); D: 17 (~0)	-
$D_{15}(1680)$	44 (68)	D: 72 (~70)	-
$F_{15}(1688)$	42 (91)	P: 13 (~25); F: 1.1 (~0)	-

(a) - (c) -- see Table II.

(d) -- Numbers in parentheses estimated from value of amplitude, Ref. 4.