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Signs of baryon-resonance photocouplings

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New baryon-resonance photocouplings from an analysis of Barbour, Crawford, and Parsons are analyzed from the standpoint of single-quark-transition selection rules. A previous conclusion is strengthened: The pionic decays of $\underline{56}$, $L=2$ resonances appear from this analysis to be dominated by $\Delta L_z=\pm 1$ transitions, in contrast to the conclusion that would be drawn from analysis of $\pi N\to\pi\Delta$. Both $P13(1810)$ and $F35(1890)$ photocouplings are important in drawing this conclusion.

It has been shown that the signs of baryon-resonance photocouplings are sources of valuable information about quark dynamics, both within the context of explicit models[1-5] and within a more general algebraic context.[6-10] The present note is intended to update an analysis presented earlier[10] based on single-quark-transition selection rules, in the light of new photocouplings presented by Barbour, Crawford, and Parsons.[11]

The reduced probable errors for $F35(1890)$ photocouplings quoted in Ref. 11 allow a strengthening of the result of Ref. 10: a particular relative sign of the P-wave and F-wave pionic decays of the $\underline{56}$, $L=2$ SU(6)×0(3) baryon multiplet is favored. This sign now rests on the photocouplings of both the $P13(1810)$ and $F35(1890)$ resonances, and corresponds to a dominance of $\Delta L_z=\pm1$ transitions in the pionic decays of $\underline{56}$, $L=2$ resonances. This is in accord with the predictions of a number of explicit quark models.[2-5] By contrast, the less restrictive single-quark-transition approach[6,8,12] does not predict the relative sign of P-wave and F-wave pionic decays of the $\underline{56}$, $L=2$ multiplet. From a study of the $F15(1680)$ resonant contribution in $\pi N\to\pi\Delta$ (for the most recent analysis see Ref. 13), it was concluded[8,12,13] that pionic decays of $\underline{56}$, $L=2$ resonances were dominated by $\Delta L_z=0$ transitions. Thus, a potential contradiction remains between the photocoupling and $\pi N\to\pi\Delta$ information, within the context of *any* single-quark-transition model,[1-10,12] unless significant $\underline{70}$, $L=2$ contributions also are present.

Details and notation are contained in Refs. 9 and 10. The photocouplings for $\underline{70}$, $L=1$ and $\underline{56}$, $L=2$ resonances are presented in Tables I and II, along with values fitted to the single-quark-transition picture.

The conclusions are qualitatively similar to those in Ref. 10, which were based on an earlier set of photocouplings.[14] Some of the major differences are quoted in Table III. In Tables I-IV the signs ξ, ξ' are positive or negative depending on whether $\Delta L_z=0$ transitions or $\Delta L_z=\pm1$ transitions are dominant, respectively. The notable point, and the reason for this note, is the improved distinction between $\xi'=-$ and $\xi'=+$ possible for $\underline{56}$, $L=2$ photocouplings on the basis of the new data. This can be traced to the reduced errors in Ref. 11 for the $F35$ photocouplings, relative to those quoted in Ref. 14.

In terms of multipole amplitudes, the new $F35$ couplings specify the reduced matrix element $E2$ (see Refs. 9 and 10) much more closely than before:

$$\begin{aligned}F35:\ E2&\equiv(1.16)^{-1}(A^{p}_{1/2}+\sqrt{2}\,A^{p}_{3/2})/(2\sqrt{21})\\&=(-4.6\pm9.8)\times10^{-3}\ \mathrm{GeV}^{-1/2}\,(\text{Ref. 14; old})\\&=(-4.2\pm3.0)\times10^{-3}\ \mathrm{GeV}^{-1/2}\,(\text{Ref. 11; new}).\end{aligned}\tag{1}$$

Figure 1 of Ref. 10 shows that a small negative value of $E2$ is compatible only with $\xi'=-$.

The qualitative features of the favored solutions ($\xi=\xi'=-$) are very similar to those noted in Ref. 10, as shown in Table IV. These include small values of $\overline{E1}/\overline{M2}$ and $\overline{E2}/\overline{M3}$, implying that transitions involving quark spin flip do not give rise to large electric multipoles, and a small $\Delta L_z=\pm2$ reduced matrix element for $\underline{56}$, $L=2$ photoproduction.[15]

To conclude, we find that the most recent set of baryon-resonance photocouplings supports signs for *pionic* resonance couplings[11] of $\underline{56}$, $L=2$ baryons which would follow from the dominance of $\Delta L_z=\pm1$ transitions in those couplings. This

TABLE I. 70, $L=1$ baryon resonance photocouplings in units of 10^{-3} $\text{GeV}^{-1/2}$.

Resonance	Amplitude	Expt. (Ref. 11)	Predicted value $\xi=+$	χ^2	$\xi=-$	χ^2
$D13$	$A^p_{1/2}$	-16 ± 8	-18	0.0	-19	0.1
	$A^p_{3/2}$	157 ± 7	162	0.4	160	0.2
	$A^n_{1/2}$	-55 ± 14	-23	5.4	-39	1.3
	$A^n_{3/2}$	-141 ± 15	-96	9.1	-124	1.3
$S11$	$A^p_{1/2}$	82 ± 19	64	0.9	74	0.2
	$A^n_{1/2}$	-112 ± 34	-17	7.8	-76	1.1
$S31$	$A^p_{1/2}$	34 ± 28	-85	18.2	103	6.1
$D33$	$A^p_{1/2}$	130 ± 37	50	4.7	107	0.4
	$A^p_{3/2}$	98 ± 36	10	6.0	109	0.1
$S11'$	$A^p_{1/2}$	48 ± 17	43	0.1	49	0.0
	$A^n_{1/2}$	-45 ± 24	40	12.5	-54	0.1
$D13'$	$A^p_{1/2}$	-33 ± 21	-4	1.9	-4	1.9
	$A^p_{3/2}$	-14 ± 25	35	3.8	34	3.7
	$A^n_{1/2}$	50 ± 42	67	0.2	16	0.6
	$A^n_{3/2}$	35 ± 30	54	0.4	-34	5.3
$D15$	$A^p_{1/2}$	22 ± 10	0	4.8	0	4.8
	$A^p_{3/2}$	15 ± 6	0	6.3	0	6.3
	$A^n_{1/2}$	-66 ± 20	-41	1.5	-41	1.5
	$A^n_{3/2}$	-73 ± 14	-58	1.1	-58	1.1
χ^2/DF			85.0/16		36.2/16	

TABLE II. 56, $L=2$ baryon resonance photocouplings in units of 10^{-3} GeV$^{-1/2}$.

Resonance	Amplitude	Expt. (Ref. 11)	Predicted value $\xi'=+$	χ^2	$\xi'=-$	χ^2
$F15$	$A^p_{1/2}$	-5 ± 15	-20	1.0	-5	0.0
	$A^p_{3/2}$	138 ± 21	118	0.9	138	0.0
	$A^n_{1/2}$	37 ± 10	40	0.1	49	1.4
	$A^n_{3/2}$	-38 ± 18	-41	0.0	-28	0.3
$P13$	$A^p_{1/2}$	111 ± 47	-60	13.2	81	0.4
	$A^p_{3/2}$	-63 ± 32	-23	1.6	-85	0.5
	$A^n_{1/2}$	7 ± 20	5	0.0	5	0.0
	$A^n_{3/2}$	51 ± 51	35	0.1	23	0.3
$F37$	$A^p_{1/2}$	-58 ± 13	-55	0.1	-54	0.1
	$A^p_{3/2}$	-75 ± 20	-71	0.1	-70	0.1
$F35$	$A^p_{1/2}$	33 ± 18	41	0.2	22	0.4
	$A^p_{3/2}$	-55 ± 19	-2	7.8	-29	1.9
$P31$	$A^p_{1/2}$	-35 ± 21	-35	0.0	-24	0.3
χ^2/DF			25.1/9		5.5/9	

is in accord with specific predictions of a number of explicit quark models[2-5] and at variance with a conclusion based on $\pi N\to\pi\Delta$ data in the region of $F15(1680)$.[13,16] The resolution of this contradition is uncertain, but in view of the widespread success in other areas of the single-quark-transition picture,[6-10,12] we suspect that a re-examination of the $\gamma N\to\pi N$ and/or $\pi N\to\pi\Delta$ analyses[11,13] may be called for. An alternative possibility[11,10] is that a low-lying 70, $L=2$ multiplet should be taken into account in the $\pi N\to\pi\Delta$ and photoproduction analyses. The existence below 2 GeV of this multiplet will be difficult to confirm without even more precise data on inelastic channels ($\pi N\to K\Lambda, K\Sigma, \eta N$, etc.) than are available at present, since many of the πN couplings of its states are expected to be rather small.[17,18]

TABLE III. Changes in χ^2 values from Ref. 14 to Ref. 11.

70, $L=1$	$\chi^2(\xi=+)$/DF	$\chi^2(\xi=-)$/DF
Ref. 14 (old)[a]	104/16	48/16
Ref. 11 (new)	85/16	36/16
56, $L=2$	$\chi^2(\xi'=+)$/DF	$\chi^2(\xi'=-)$/DF
Ref. 14 (old)[a]	14.4/9	3.2/9
Ref. 11 (new)	25.1/9	5.5/9

[a]Babcock-Rosner (BR) analysis of Ref. 10 quoted, for comparison with new analysis.

TABLE IV. Reduced matrix elements in units of 10^{-3} GeV$^{-1/2}$. Normalization as in Ref. 9.

Multipole representation		
70, $L=1$	$\xi=+$	$\xi=-$
$\bar{E}1'/\bar{M}2$	0.69	1.59
$\bar{E}1\ /\bar{M}2$	-1.39	-0.08
$\bar{M}2$	-28.2	-28.2
56, $L=2$	$\xi'=+$	$\xi'=-$
$\bar{E}2'/\bar{M}3$	1.05	1.80
$\bar{M}1\ /\bar{M}3$	0.55	-0.37
$\bar{E}2\ /\bar{M}3$	-0.29	0.14
$\bar{M}3$	-12.6	-12.6
W, L_z representation		
70, $L=1$	$\xi=+$	$\xi=-$
$\langle\Vert D_+(W=0,L_z=1)\Vert\rangle$	-19.3	-44.7
$\langle\Vert D_+(W=1,L_z=0)\Vert\rangle$	7.8	-18.3
$\langle\Vert D_+(W=1,L_z=1)\Vert\rangle$	-47.7	-21.5
56, $L=2$	$\xi'=+$	$\xi'=-$
$\langle\Vert D_+(W=0,L_z=1)\Vert\rangle$	-13.3	-22.6
$\langle\Vert D_+(W=1,L_z=0)\Vert\rangle$	-7.6	-7.7
$\langle\Vert D_+(W=1,L_z=1)\Vert\rangle$	-6.9	-11.0
$\langle\Vert D_+(W=1,L_z=2)\Vert\rangle$	-10.7	-1.3

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