Quark Model Review of Baryon Dynamics

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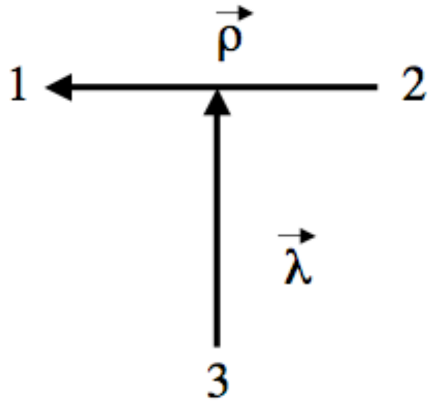
different CQMs for bayons

	Kin. Energy	SU(6) inv	SU(6) viol	date
Isgur-Karl	non rel	h.o. + shift	OGE	1978-9
Capstick-Isgur	rel	string + coul-like	OGE	1986
U(7) B.I.L.	rel M^2	vibr+L	Guersey-R	1994
Hyp. O(6)	non rel/rel	hyp.coul+linear	OGE	1995
Glozman Riska	non rel/rel**Plessas**	h.o./linear	GBE	1996
Bonn	rel	linear 3-body	instanton	2001

See also the nice talk by J.M. Richard !

Jacobi coordinates



Hyperspherical Coordinates

$$(\rho, \Omega_\rho, \lambda, \Omega_\lambda) \Rightarrow (x, t, \Omega_\rho, \Omega_\lambda)$$

$$x = \sqrt{\rho^2 + \lambda^2}$$ hyperradius

$$t = arctg\frac{\rho}{\lambda}$$ hyperangle

$$L^2(\Omega) Y_{[\gamma]}(\Omega) = -\gamma(\gamma+4) Y_{[\gamma]}(\Omega)$$

$$L^2(\Omega) \Leftrightarrow C_2(O(6))$$

γ grand angular quantum number

$$\gamma = 2n + l_\rho + l_\lambda$$

$Y_{[\gamma]}(\Omega)$ Hyperspherical harmonics

$$\sum_{i<j} V(\mathbf{r}_{ij}) \approx V(x) + \ldots$$

$$\gamma = 2n + l_\rho + l_\lambda$$

Hasenfratz et al. 1980:

$\Sigma\, V(r_i, r_j)$ is approximately hypercentral

Hypercentral Hypothesis

$$V = V(x)$$

Factorization

$$\psi(x, t, \Omega_\rho, \Omega_\lambda) = \psi_{\nu\gamma}(x) \quad Y_{[\gamma, l_\rho, l_\lambda]}$$

("dynamics") ("geometry")

Only one differential equation in x (hyperradial equation)

.

Hypercentral Model Giannini, Santopinto, Tiator, Phys. Lett. B, 1995

$V(x) = -\tau/x + \alpha\, x$

Hypercentral approximation of $V = -\, b/r + c\, r$

Two analytical solutions

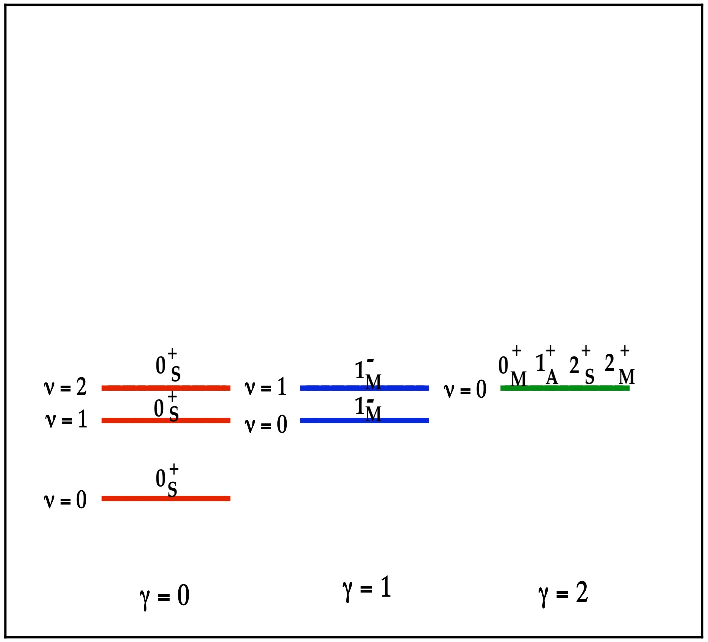
hyperCoulomb - τ/x

$$H = -\frac{\tau^2 m}{2\left[C_2(O(7)) + \frac{25}{4}\right]}$$

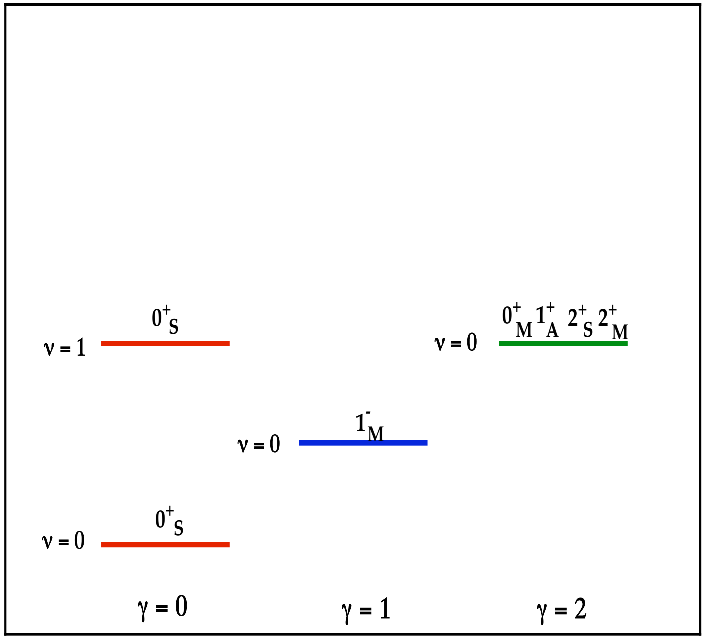
h. o. $\Sigma_{i<j}\, 1/2\, k\, (r_i - r_j)^2 = 3/2\ k\, x^2$

Algebraic approach to the hypercoulomb problem
Santopinto, E; Giannini, M, Iachello, F,
SYMMETRIES IN SCIENCE VIII, 445(1995)
Exactly solvable models of baryon spectroscopy
Santopinto, E; Iachello, F, Giannini, MM,
NUCLEAR PHYSICS A 623,100(1997)

a) HYPERCOULOMB



b) H. O.



Examples of exactly|algebraic solvable models for baryon spectroscopy

An O(7) algebraic model

Exactly solvable models of baryon spectroscopy,
Santopinto, Iachello Giannini, Nucl. Phys.A 623,100(1997)

$$H = -\frac{\tau^2 m}{2\left[C_2(O(7)) + \frac{25}{4}\right]} + \beta \left[C_2(O(7)) + \frac{25}{4}\right]^{\frac{1}{4}}$$

The eigenvalues of this Hamiltonian are given exactly by

$$E = -\frac{\tau^2 m}{2n^2} + \beta n^{\frac{1}{2}} \quad , \qquad n = \omega + \frac{5}{2} \quad , \quad \omega = 0, 1, 2, \ldots \quad .$$

Or one can use a linear confinement of the form βx

treated in perturbation theory

$$E_{n,\gamma} = -\frac{\tau^2 m}{2n^2} + \frac{\beta}{2m\tau}[3n^2 - \gamma(\gamma+4) - \frac{15}{4}] , \quad n = \omega + \frac{5}{2} \ .$$

that observation gave origin to a completely analyical version of the hypercentral model in E. Santopinto, F. Iachello, M. Giannini, Eur. Phys. J. A **1**, 307 (1998)

Comparison

- H.O.
- W.fs $e^{-\alpha r2}$
- F.F. $e^{-\alpha r2}$
- Transition form factor :
- Polinomial $\times e^{-\alpha r2}$

- Hypercoulomb.
- W.fs Polinomial e^{-br}
- F.F. :$1/(1+Q^2{}_{/b\hat{}2})^{7/2}$
- Transition f.f.:

Polinomial transition f.f.

$1\,/(1+Q^2{}_{/b\hat{}2})^{(7+n)/2}$

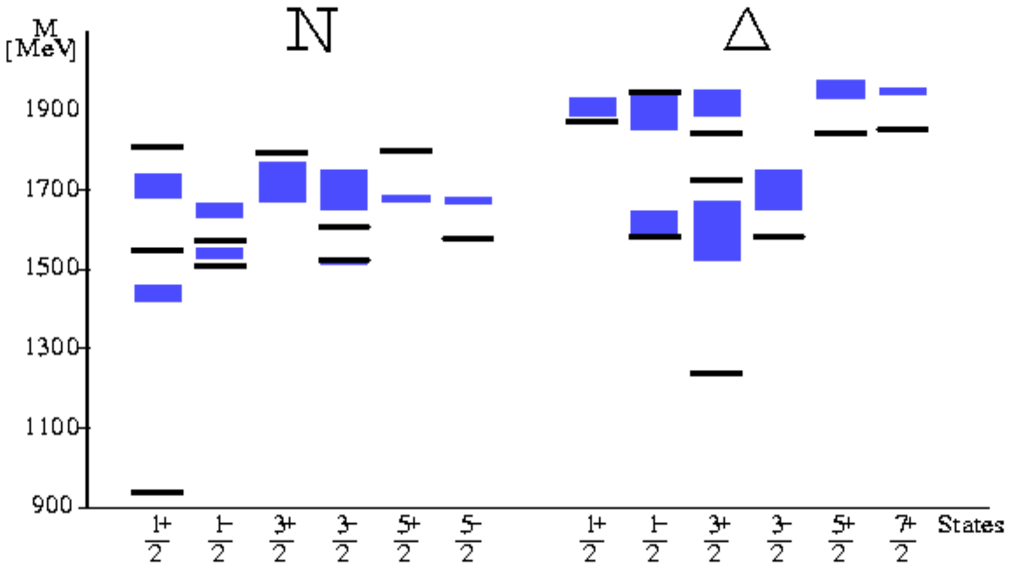
F Iachello, E Santopinto, J. Phys. A: Math. Gen. 31 (1998) 9041–9054
Algebraic treatment of the hyper-Coulomb problem

Hypercentral Model (1)

$$H_{3q} = 3m + \sum_{i=1}^{3} \frac{\mathbf{p}_i^2}{2m} + V(x) + H_{hyp}$$

M. Ferraris, M. M. Giannini, M. Pizzo, E. Santopinto, L. Tiator, Phys. Lett. B364 (1995), 231

- $V(x) = -\frac{\tau}{x} + \alpha x;$ $\qquad H_{hyp} = A \left[\sum_{i<j} V^S(\mathbf{r}_i, \mathbf{r}_j) \;\; \boldsymbol{\sigma}_i \cdot \boldsymbol{\sigma}_j + \text{tensor} \right]$
- 3 parameters τ α A ← fixed to the spectrum, $m = \frac{M}{3}$



$\tau = 4.59$

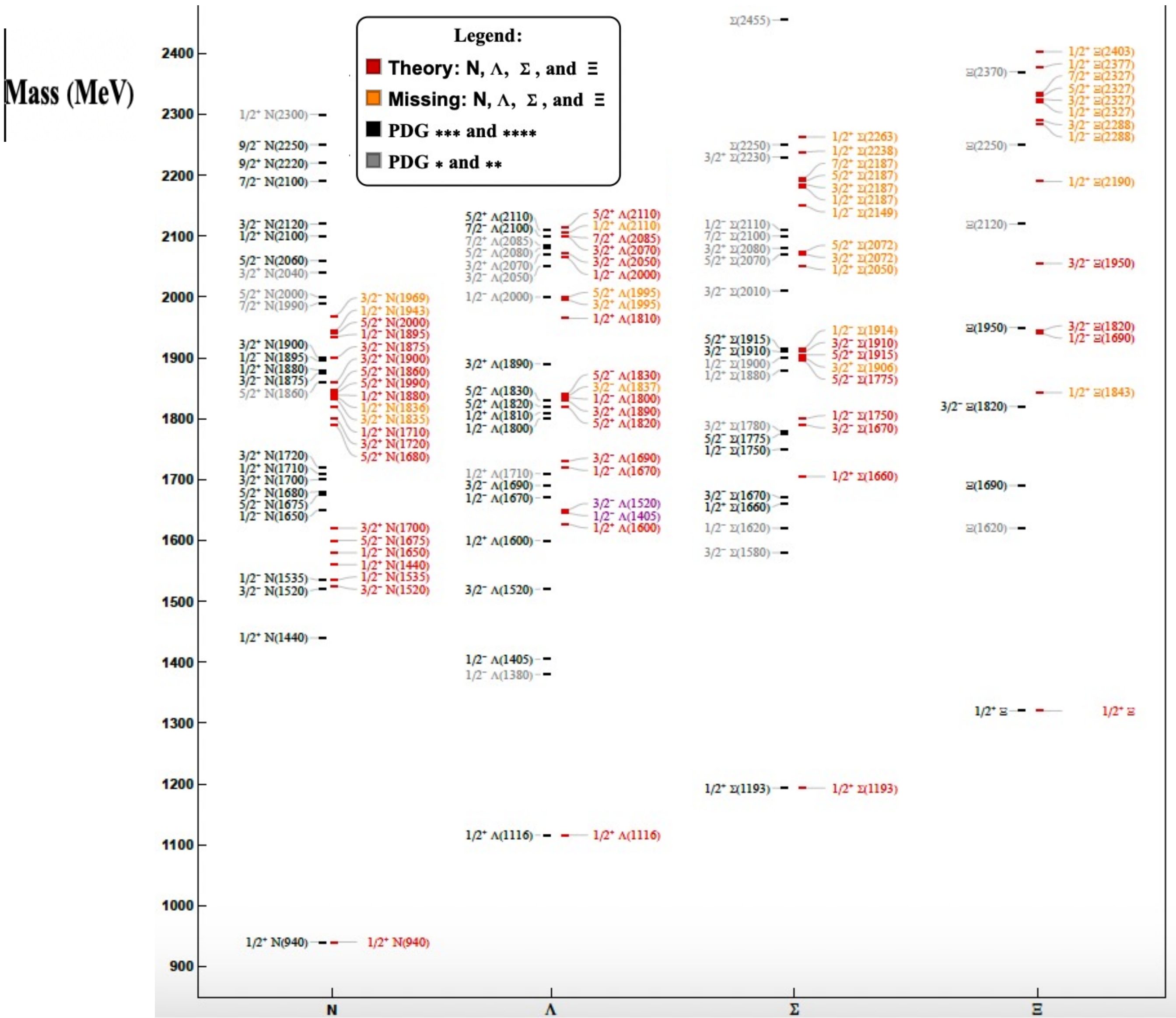
$\alpha = 1.61 \text{ fm}^{-1}$

A $\Leftarrow (N - \Delta)$

$$x = \sqrt{\rho^2 + \lambda^2}$$

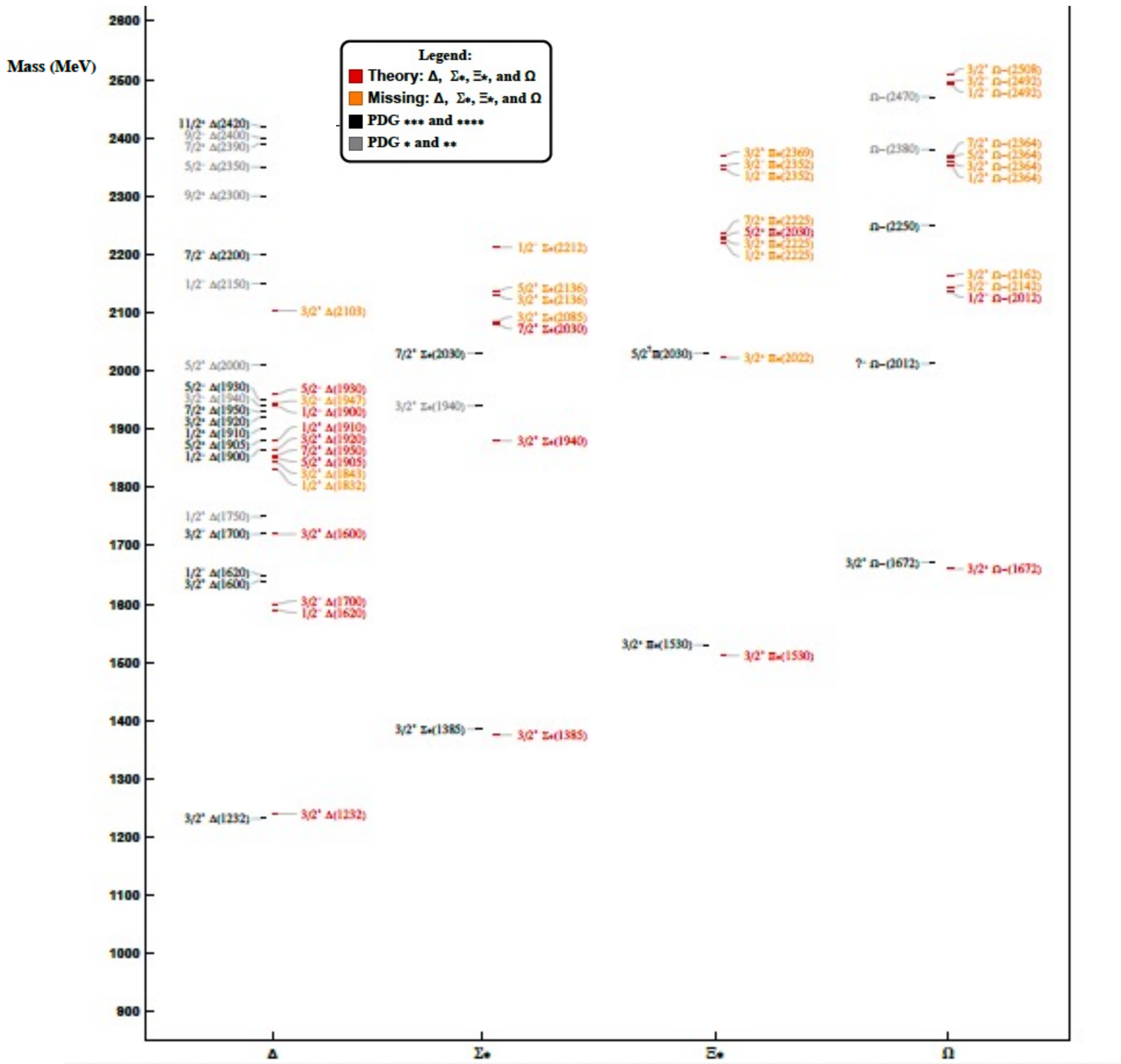
hyperradius

Hypercentral Model predictions for the Octect, Singlet and PDG 2022 results



Giannini,Santopinto 2005, Eur.Phys.J.A 25 (2005) 241-247

Hypercentral Model predictions for the Decuplet and PDG 2022 results



Strong decay

Pair-creation model

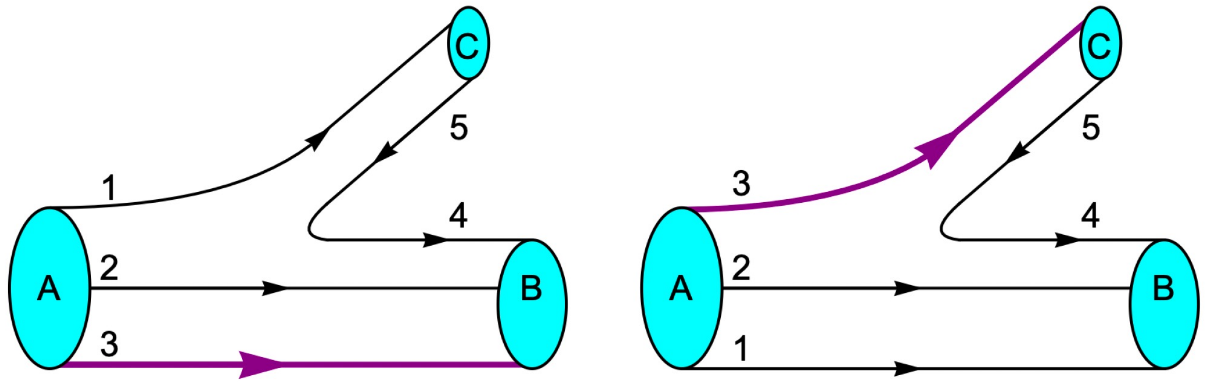


TABLE III. Strong decay widths of three- and four-star nucleon resonances (in MeV), calculated with the $U(7)$ algebraic model and the hypercentral QM. For the $U(7)$ model the calculation is done for the relativistic and the effective phase space factors of Eqs. (21) and (22), respectively, in combination with the parameters of Table II (RPSF and EPSF). For the hypercentral QM we present the results for the relativistic phase space factor (RPSF) in combination with the parameters of Table XVII. The experimental values are taken from Ref. [1]. Decay channels labeled by three dots are below threshold or forbidden by selection rules. The symbols (S) and (D) stand for S- and D-wave decays, respectively.

Model	Resonance	Status	Mass (MeV)	$N\pi$	$N\eta$	ΣK	ΛK	$\Delta\pi$	$N\rho$	$N\omega$	
	$N(1440)P_{11}$	****	1430–1470	110–338	0–5			22–101			Exp.
$U(7)$	$^{2}8_{1/2}[56,0_2^+]$		1444	85	…	…	…	13	…	…	RPSF
$U(7)$	$^{2}8_{1/2}[56,0_2^+]$		1444	108	…			22			EPSF
hQM	$^{2}8_{1/2}[56,0_2^+]$		1550	105	…	…	…	12	…	…	RPSF
	$N(1520)D_{13}$	****	1515–1530	102	0			342			Exp.
$U(7)$	$^{2}8_{3/2}[70,1_1^-]$		1563	134	0	…	…	207	…	…	RPSF
$U(7)$	$^{2}8_{3/2}[70,1_1^-]$		1563	102	0			342			EPSF
hQM	$^{2}8_{3/2}[70,1_1^-]$		1525	111	0	…	…	206	…	…	RPSF
	$N(1535)S_{11}$	****	1520–1555	44–96	40–91			<2			Exp.
$U(7)$	$^{2}8_{1/2}[70,1_1^-]$		1563	63	75	…	…	16	…	…	RPSF
$U(7)$	$^{2}8_{1/2}[70,1_1^-]$		1563	106	86			14			EPSF
hQM	$^{2}8_{1/2}[70,1_1^-]$		1525	84	50	…	…	6	…	…	RPSF
	$N(1650)S_{11}$	****	1640–1680	60–162	6–27		4–20	0–45			Exp.
$U(7)$	$^{4}8_{1/2}[70,1_1^-]$		1683	41	72	…	0	18	…	…	RPSF
$U(7)$	$^{4}8_{1/2}[70,1_1^-]$		1683	71	83			15			EPSF
hQM	$^{2}8_{1/2}[70,1_2^-]$		1574	51	29	…	0	4	…	…	RPSF
	$N(1675)D_{15}$	****	1670–1685	46–74	0–2		<2	65–99			Exp.
$U(7)$	$^{4}8_{5/2}[70,1_1^-]$		1683	47	11	…	0	108	…	…	RPSF
$U(7)$	$^{4}8_{5/2}[70,1_1^-]$		1683	29	7			79			EPSF
hQM	$^{4}8_{5/2}[70,1_1^-]$		1579	41	9	…	…	85	…	…	RPSF
	$N(1680)F_{15}$	****	1675–1690	78–98	0–1			6–21			Exp.
$U(7)$	$^{2}8_{5/2}[56,2_1^+]$		1737	121	1	…	0	100	…	…	RPSF
$U(7)$	$^{2}8_{5/2}[56,2_1^+]$		1737	63	0			99			EPSF
hQM	$^{2}8_{5/2}[56,2_1^+]$		1798	91	0	0	0	92	…	…	RPSF
	$N(1700)D_{13}$	***	1650–1750	7–43	0–3		<8	10–225 (S) <50 (D)			Exp.
$U(7)$	$^{4}8_{3/2}[70,1_1^-]$		1683	9	3	…	0	561	…	…	RPSF
$U(7)$	$^{4}8_{3/2}[70,1_1^-]$		1683	5	2			657			EPSF
hQM	$^{2}8_{3/2}[70,1_2^-]$		1606	0	0	0	0	0	…	…	RPSF
	$N(1710)P_{11}$	***	1680–1740	3–50	5–75		3–63	8–100	3–63		Exp.
$U(7)$	$^{2}8_{1/2}[70,0_1^+]$		1683	5	9	0	3	56	…	…	RPSF
$U(7)$	$^{2}8_{1/2}[70,0_1^+]$		1683	11	9			58			EPSF
hQM	$^{2}8_{1/2}[70,0_1^+]$		1808	18	12	0	14.1	70	…	…	RPSF
	$N(1720)P_{13}$	****	1650–1750	12–56	5–20		2–60	90–360	105–340		Exp.
$U(7)$	$^{2}8_{3/2}[56,2_1^+]$		1737	111	7	0	14	36	5	0	RPSF
$U(7)$	$^{2}8_{3/2}[56,2_1^+]$		1737	123	7			28			EPSF
hQM	$^{2}8_{3/2}[56,2_1^+]$		1797	141	8	0	12	30	77	5	RPSF
	$N(1875)D_{13}$	***	1820–1920	3–70	0–22	0–4		48–192 (S) 11–86 (D)	0–38	22–90	Exp. Exp.
$U(7)$	$^{4}8_{3/2}[70,2_1^-]$		1975	0	0	0	0	0	0	0	RPSF
$U(7)$	$^{4}8_{3/2}[70,2_1^-]$		1975	0	0			0			EPSF
hQM	$^{4}8_{3/2}[70,1_1^-]$		1899	14	8	2	0	560	80	82	RPSF
	$N(1900)P_{13}$	***	1875–1935	20–37	24–44	6–26	0–37			75–120	Exp.
$U(7)$	$^{2}8_{3/2}[70,2_1^+]$		1874	11	12	1	13	63	64	24	RPSF
$U(7)$	$^{2}8_{3/2}[70,2_1^+]$		1874	17	11			33			EPSF
hQM	$^{2}8_{3/2}[70,2_1^+]$		1853	15	12	1	13	70	53	23	RPSF

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TABLE VIII. Strong decay widths of missing nucleon resonances (in MeV) calculated in the $U(7)$ model of Sec. II A and Refs. [39,40] (top) and the hypercentral QM of Sec. II B and Refs. [41,46] (bottom). The calculations are carried out using the model parameters of Table II (second column) and Table XVII, respectively, in combination with the relativistic phase space factor of Eq. (21). Tentative assignments of one and two star resonances are labeled by ‡.

	N	Mass (MeV)	$N\pi$	$N\eta$	ΣK	ΛK	$\Delta\pi$	$\Sigma^* K$	$N\rho$	$N\omega$	ΣK^*	ΛK^*	$\Delta\rho$
							$U(7)$ Model						
	$^2 8_J[20, 1_1^+]$	1713	0	0	0	0	0	…	…	…	…	…	…
	$^4 8_{3/2}[70, 0_1^+]$	1796	0	3	5	0	65	…	7	7	…	…	…
	$^2 8_{5/2}[70, 2_1^+]$	1874‡	106	10	0	3	79	…	161	8	…	…	…
N(1895)1/2- , ****	$^2 8_J[70, 2_1^-]$	1874	0	0	0	0	0	…	0	0	…	…	…
N(1880)1/2+ , ***	$^4 8_{1/2}[70, 2_1^+]$	1975‡	1	8	23	0	19	1	9	9	…	…	…
N(1900)3/2+ , ****	$^4 8_{3/2}[70, 2_1^+]$	1975‡	0	4	11	0	109	5	14	14	…	…	…
N(1860)5/2+ , **	$^4 8_{5/2}[70, 2_1^+]$	1975‡	6	3	1	0	176	6	16	16	…	…	…
N(1990)7/2+ , **	$^4 8_{7/2}[70, 2_1^+]$	1975‡	25	13	4	0	99	0	5	4	…	…	…
	$^4 8_J[70, 2_1^-]$	1975‡	0	0	0	0	0	0	0	0	…	…	…
	$^2 8_{1/2}[56, 1_1^-]$	2094	5	1	1	5	3	2	48	6	2	2	14
	$^2 8_{3/2}[56, 1_1^-]$	2094‡	27	0	0	1	23	1	53	11	0	2	13
	$^2 8_{1/2}[70, 1_2^-]$	1829‡	42	7	0	1	38	…	0	0	…	…	…
	$^4 8_{1/2}[70, 1_2^-]$	1933	8	12	3	0	0	0	0	0	…	…	…
	$^4 8_{3/2}[70, 1_2^-]$	1933	0	0	3	0	0	0	0	0	…	…	…
N(2060)5/2- , ***	$^4 8_{5/2}[70, 1_2^-]$	1933	0	2	5	0	1	0	0	0	…	…	…
							hQM						
	$^4 8_{3/2}[70, 2_1^+]$	1835	4	8	7	0	97	…	8	7	…	…	…
N(1880)1/2+ , ***	$^2 8_{1/2}[20, 1_1^+]$	1836	0	0	0	0	0	…	0	0	…	…	…
	$^2 8_{3/2}[20, 1_1^+]$	1836	0	0	0	0	0	…	0	0	…	…	…
	$^4 8_{1/2}[70, 2_1^+]$	1839‡	8	16	15	0	27	…	6	5	…	…	…
N(1990)7/2+ , **	$^4 8_{7/2}[70, 2_1^+]$	1840‡	12	4	0	0	25	…	0	0	…	…	…
N(1860)5/2+ , **	$^4 8_{5/2}[70, 2_1^+]$	1844‡	3	1	0	0	137	…	9	8	…	…	…
	$^4 8_{5/2}[70, 2_1^+]$	1851‡	3	1	0	0	137	…	9	9	…	…	…
N(1900)3/2+ , ****	$^4 8_{3/2}[70, 0_1^+]$	1863‡	0	4	22	0	83	…	12	12	…	…	…
N(1895)1/2- , ****	$^4 8_{1/2}[70, 1_1^-]$	1887‡	0	22	119	0	87	…	32	32	…	…	…
	$^4 8_{1/2}[70, 1_2^-]$	1937	0	0	0	0	0	…	0	0	…	…	…
N(2060)5/2- , ***	$^4 8_{5/2}[70, 1_2^-]$	1942‡	0	0	0	0	0	0	0	0	…	…	…
	$^2 8_{1/2}[56, 0_3^+]$	1943‡	0	0	0	0	0	0	0	0	…	…	…
	$^4 8_{3/2}[70, 1_2^-]$	1969	0	0	0	0	0	0	0	0	…	…	…

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TABLE IV. As Table III, but for Δ resonances. The symbols (*S*), (*P*), (*D*), and (*F*) stand for *S*-, *P*-, *D*-, and *F*-wave decays, respectively.

Model	Resonance	Status	Mass (MeV)	$N\pi$	ΣK	$\Delta\pi$	$\Delta\eta$	$\Sigma^* K$	$N\rho$	
	$\Delta(1232)P_{33}$	****	1230–1234	114–120						Exp.
$U(7)$	$^4 10_{3/2}[56, 0_1^+]$		1246	71	…	…	…	…	…	RPSF
$U(7)$	$^4 10_{3/2}[56, 0_1^+]$		1246	115		…	…			EPSF
hQM	$^4 10_{3/2}[56, 0_1^+]$		1240	63	…	…	…	…	…	RPSF
	$\Delta(1600)P_{33}$	***	1550–1700	22–105		88–294			<88	Exp.
$U(7)$	$^4 10_{3/2}[56, 0_2^+]$		1660	17	…	65	…	…	…	RPSF
$U(7)$	$^4 10_{3/2}[56, 0_2^+]$		1660	24		74	…			EPSF
hQM	$^4 10_{3/2}[56, 0_2^+]$		1727	31	…	69	…	…	…	RPSF
	$\Delta(1620)S_{31}$	****	1615–1675	26–45		39–90			9–38	Exp.
$U(7)$	$^2 10_{1/2}[70, 1_1^-]$		1649	5	…	76	…	…	…	RPSF
$U(7)$	$^2 10_{1/2}[70, 1_1^-]$		1649	10		61	…			EPSF
hQM	$^2 10_{1/2}[70, 1_1^-]$		1584	9	…	59	…	…	…	RPSF
	$\Delta(1700)D_{33}$		1670–1770	20–80		50–200 (*S*) 10–60 (*D*)	6–28		48–165	Exp.
$U(7)$	$^2 10_{3/2}[70, 1_1^-]$		1649	46	…	311	…	…	…	RPSF
$U(7)$	$^2 10_{3/2}[70, 1_1^-]$		1649	27		343	…			EPSF
hQM	$^2 10_{3/2}[70, 1_1^-]$		1584	40	…	333	…	…	…	RPSF
	$\Delta(1905)F_{35}$	****	1855–1910	24–60		<100			>162	Exp.
$U(7)$	$^4 10_{5/2}[56, 2_1^+]$		1921	31	1	188	19	0	99	RPSF
$U(7)$	$^4 10_{5/2}[56, 2_1^+]$		1921	14		139	14			EPSF
hQM	$^4 10_{5/2}[56, 2_1^+]$		1844	26	0	182	15	…	88	RPSF
	$\Delta(1910)P_{31}$	****	1860–1910	33–102	9–48	70–299				Exp.
$U(7)$	$^4 10_{1/2}[56, 2_1^+]$		1921	26	38	32	4	…	64	RPSF
$U(7)$	$^4 10_{1/2}[56, 2_1^+]$		1921	39		27	3			EPSF
hQM	$^4 10_{1/2}[56, 2_1^+]$		1871	49	38	34	4	…	60	RPSF
	$\Delta(1920)P_{33}$	***	1900–1970	9–60	3–7	18–102 (*P*) 45–195 (*F*)	13–69		0	Exp.
$U(7)$	$^4 10_{3/2}[56, 2_1^+]$		1921	7	23	132	22	5	105	RPSF
$U(7)$	$^4 10_{3/2}[56, 2_1^+]$		1921	14		96	15			EPSF
hQM	$^4 10_{3/2}[56, 2_1^+]$		1856	17	22	137	20	…	102	RPSF
	$\Delta(1930)D_{35}$	***	1920–1970	11–75						Exp.
$U(7)$	$^2 10_{5/2}[70, 2_1^-]$		1946	0	0	0	0	0	0	RPSF
$U(7)$	$^2 10_{5/2}[70, 2_1^-]$		1946	0		0	0			EPSF
	$\Delta(1950)F_{37}$	****	1940–1960	82–151	1–2	47–101			<34	Exp.
$U(7)$	$^4 10_{7/2}[56, 2_1^+]$		1921	172	5	92	1	0	22	RPSF
$U(7)$	$^4 10_{7/2}[56, 2_1^+]$		1921	72		40	1			EPSF
hQM	$^4 10_{7/2}[56, 2_1^+]$		1851	146	3	70	1	…	16	RPSF

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TABLE IX. As Table VIII, but for missing Δ resonances.

	Δ	Mass (MeV)	$N\pi$	ΣK	$\Delta\pi$	$\Delta\eta$	$\Sigma^* K$	$N\rho$
				$U(7)$ Model				
	$^2 10_{1/2}[70, 0_1^+]$	$1764^{\ddagger}$	0	1	70	...	...	23
	$^2 10_{3/2}[70, 2_1^-]$	1946	0	0	0	0	0	0
	$^2 10_{3/2}[70, 2_1^+]$	1947	1	3	106	5	1	80
Δ (2000)5/2+ , **	$^2 10_{5/2}[70, 2_1^+]$	$1947^{\ddagger}$	18	1	107	18	4	32
Δ (1900)1/2- , ***	$^2 10_{1/2}[70, 1_2^-]$	$1904^{\ddagger}$	0	0	0	0	0	0
Δ (1940)3/2- , **	$^2 10_{3/2}[70, 1_2^-]$	1904	0	0	0	0	0	0
				hQM				
	$^2 10_{1/2}[70, 0_1^+]$	$1832^{\ddagger}$	0	2	89	7	...	57
	$^2 10_{3/2}[70, 2_1^+]$	1843	4	1	43	1	...	51
Δ (1900)1/2- , ***	$^2 10_{1/2}[70, 1_2^-]$	$1947^{\ddagger}$	0	0	1	0	0	0
Δ (1940)3/2- , **	$^2 10_{3/2}[70, 1_2^-]$	$1947^{\ddagger}$	0	0	1	0	0	0
Δ (2000)5/2+ , **	$^2 10_{5/2}[70, 2_1^+]$	$1859^{\ddagger}$	10	0	97	7	...	13
	$^4 10_{3/2}[56, 0_3^+]$	2103	0	0	0	0	0	0

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TABLE V. As Table III, but for Σ and Σ^* resonances.

Model	Baryon	Status	Mass (MeV)	$N\bar{K}$	$\Sigma\pi$	$\Lambda\pi$	$\Sigma\eta$	ΞK	$\Delta\bar{K}$	$\Sigma^*\pi$	$N\bar{K}^*$	$\Sigma\rho$	$\Lambda\rho$	$\Sigma\omega$	
	$\Sigma(1660)P_{11}$	***	1630–1690	4–60	Seen	Seen									Exp.
$U(7)$	$^2 8_{1/2}[56, 0_2^+]$		1604	3	38	14	…	…	…	7	…	…	…	…	RPSF
hQM	$^2 8_{1/2}[56, 0_2^+]$		1704	4	45	18	…	…	…	6	…	…	…	…	RPSF
	$\Sigma(1670)D_{13}$	****	1665–1685	3–10	12–48	2–12									Exp.
$U(7)$	$^4 8_{3/2}[70, 1_1^-]$		1711	5	78	8	…	…	…	36	…	…	…	…	RPSF
hQM	$^2 8_{3/2}[70, 1_1^-]$		1799	4	62	7	…	…	…	29	…	…	…	…	RPSF
	$\Sigma(1750)S_{11}$	***	1730–1800	6–64	<13	Seen	9–88								Exp.
$U(7)$	$^4 8_{1/2}[70, 1_1^-]$		1711	3	109	3	28	…	…	9	…	…	…	…	RPSF
hQM	$^2 8_{1/2}[70, 1_1^-]$		1799	5	151	6	27	…	…	7	…	…	…	…	RPSF
	$\Sigma(1775)D_{15}$	****	1770–1780	39–58	2–7	15–27				8–16					Exp.
$U(7)$	$^4 8_{5/2}[70, 1_1^-]$		1822	101	17	38	0	…	4	11	…	…	…	…	RPSF
hQM	$^4 8_{5/2}[70, 1_1^-]$		1914	79	13	30	0	…	2	7	…	…	…	…	RPSF
	$\Sigma(1915)F_{15}$	****	1900–1935	4–24	Seen	Seen				<8					Exp.
$U(7)$	$^2 8_{5/2}[56, 2_1^+]$		1872	6	58	33	2	1	96	23	6	…	2	…	RPSF
hQM	$^2 8_{5/2}[56, 2_1^+]$		1906	4	44	26	1	0	88	22	5	…	2	…	RPSF
	$\Sigma(1940)D_{13}$	***	1900–1950	<60	Seen	Seen			Seen	Seen	Seen				Exp.
$U(7)$	$^2 8_{3/2}[56, 1_1^-]$		1974	0	0	0	0	0	0	0	0	…	0	…	RPSF
hQM	$^4 8_{3/2}[70, 1_1^-]$		1914	31	6	11	0	0	554	99	251	…	0	…	RPSF
	$\Sigma^*(1385)P_{13}$	****	1383–1385		30–32	4–5									Exp.
$U(7)$	$^4 10_{3/2}[56, 0_1^+]$		1382	…	3	27	…	…	…	…	…	…	…	…	RPSF
hQM	$^4 10_{3/2}[56, 0_1^+]$		1372	…	3	24	…	…	…	…	…	…	…	…	RPSF
	$\Sigma^*(2030)F_{17}$	****	2025–2040	26–46	8–20	26–46		<4	15–40	8–30					Exp.
$U(7)$	$^4 10_{7/2}[56, 2_1^+]$		2012	54	37	75	8	1	30	37	7	0	4	0	RPSF
hQM	$^4 10_{7/2}[56, 2_1^+]$		2085	44	30	62	6	1	22	27	5	0	2	0	RPSF

TABLE X. As Table VIII, but for missing Σ resonances.

Σ	Mass (MeV)	$N\bar{K}$	$\Sigma\pi$	$\Lambda\pi$	$\Sigma\eta$	ΞK	$\Delta\bar{K}$	$\Sigma^*\pi$	$\Sigma^*\eta$	$\Xi^* K$	$N\bar{K}^*$	$\Sigma\rho$	$\Lambda\rho$	$\Sigma\omega$	$\Delta\bar{K}^*$
							U(7) Model								
$^48_{1/2}[70,1_1^-]$	1822	24	11	6	20	10	5	4	…	…	…	…	…	…	…
$^48_{3/2}[70,1_1^-]$	1822	22	4	8	0	0	602	98	…	…	…	…	…	…	…
$^28_{1/2}[70,0_1^+]$	$1822^‡$	1	20	1	1	0	33	9	…	…	…	…	…	…	…
$^28_J[20,1_1^+]$	$1849^‡$	0	0	0	0	0	0	0	…	…	0	…	…	…	…
$^28_{3/2}[56,2_1^+]$	1872	4	62	19	23	12	17	6	…	…	12	…	…	…	…
$^48_{3/2}[70,0_1^+]$	1926	0	0	0	5	1	65	12	…	…	25	…	3	…	…
$^28_{3/2}[70,2_1^+]$	1999	1	31	1	7	14	28	8	1	…	26	11	6	1	…
$^28_{5/2}[70,2_1^+]$	1999	4	76	6	1	1	60	13	4	…	7	13	21	3	…
$^28_{5/2}[70,2_1^-]$	1999	0	0	0	0	0	0	0	0	…	0	0	0	0	…
$^48_{1/2}[70,2_1^+]$	2095	4	2	1	3	4	18	4	4	1	23	5	9	7	…
$^48_{3/2}[70,2_1^+]$	2095	2	1	1	2	2	84	18	13	2	39	7	14	11	…
$^48_{5/2}[70,2_1^+]$	$2095^‡$	15	3	5	1	0	128	29	18	3	45	8	15	11	…
$^48_{7/2}[70,2_1^+]$	2095	69	13	24	2	1	54	15	1	0	17	0	3	1	…
$^48_J[70,2_1^-]$	2095	0	0	0	0	0	0	0	0	0	0	0	0	0	…
$^28_{1/2}[70,1_2^-]$	$1957^‡$	0	0	0	0	0	0	0	0	…	0	…	0	…	…
$^28_{3/2}[70,1_2^-]$	1957	0	0	0	0	0	0	0	0	…	0	…	0	…	…
$^48_{1/2}[70,1_2^-]$	2055	0	0	0	0	0	0	0	0	…	0	0	0	0	…
$^48_{3/2}[70,1_2^-]$	2055	0	0	0	0	0	1	0	0	…	0	0	0	0	…
$^48_{5/2}[70,1_2^-]$	2055	0	0	0	0	0	0	0	0	…	0	0	0	0	…
							hQM								
$^28_{3/2}[56,2_1^+]$	1906	4	69	22	19	20	20	7	…	…	21	…	…	…	…
$^48_{1/2}[70,1_1^-]$	1914	9	7	3	17	22	22	9	…	…	100	…	…	…	…
$^28_{1/2}[56,0_3^+]$	$2050^†$	0	0	0	0	0	0	0	…	…	0	…	…	…	…
$^28_{3/2}[70,2_1^+]$	2072	1	31	1	7	16	39	11	…	…	29	…	…	…	…
$^28_{5/2}[70,2_1^+]$	2072	5	89	7	3	3	66	15	…	…	11	…	…	…	…
$^28_{1/2}[70,1_2^-]$	2149	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$^48_{1/2}[70,2_1^+]$	2187	3	2	1	3	4	16	3	5	1	21	6	9	2	16
$^48_{3/2}[70,2_1^+]$	2187	1	1	1	1	2	91	21	17	5	40	10	15	3	18
$^48_{5/2}[70,2_1^+]$	2187	19	3	6	1	0	147	34	23	6	52	10	18	3	49
$^48_{7/2}[70,2_1^+]$	2187	83	15	29	2	1	83	21	3	0	30	2	7	1	159
$^28_J[20,1_1^+]$	2238	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$^48_J[70,1_2^-]$	2263	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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TABLE VII. As Table III, but for Ξ and Ξ^* resonances.

Model	Baryon	Status	Mass (MeV)	$\Sigma\bar{K}$	$\Lambda\bar{K}$	$\Xi\pi$	$\Xi^*\pi$	
	$\Xi(1690)S_{11}$	***	1680–1700					Exp.
$U(7)$	$^28_{1/2}[70,1_1^-]$		1828	58	85	14	0	RPSF
hQM	$^28_{1/2}[70,1_1^-]$		1938	55	86	15	0	RPSF
	$\Xi(1820)D_{13}$	***	1818–1828	2–18	3–12	0–8	2–18	Exp.
$U(7)$	$^28_{3/2}[70,1_1^-]$		1828	38	26	6	55	RPSF
hQM	$^28_{3/2}[70,1_1^-]$		1938	29	21	5	55	RPSF
	$\Xi^*(1530)P_{13}$	****	1531–1532			9–10		Exp.
$U(7)$	$^410_{3/2}[56,0_1^+]$		1524	…	…	11	…	RPSF
hQM	$^410_{3/2}[56,0_1^+]$		1511	…	…	9	…	RPSF

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TABLE XIV. As Table VIII, but for missing Ξ resonances.

	Ξ	Mass (MeV)	$\Sigma\bar{K}$	$\Lambda\bar{K}$	$\Xi\pi$	$\Xi\eta$	$\Sigma^*\bar{K}$	$\Xi^*\pi$	$\Lambda\bar{K}^*$	$\Sigma\bar{K}^*$	$\Xi\rho$	$\Xi\omega$
						$U(7)$ Model						
Ξ (1950) ***	$^2 8_{1/2}[70, 0_1^+]$	1932	36	6	1	11	7	13	…	…	…	…
	$^4 8_{1/2}[70, 1_1^-]$	1932	43	20	69	0	0	4	…	…	…	…
	$^4 8_{3/2}[70, 1_1^-]$	1932	4	7	22	0	216	152	…	…	…	…
	$^4 8_{5/2}[70, 1_1^-]$	1932	23	39	132	0	2	19	…	…	…	…
	$^2 8_J[20, 1_1^+]$	1957	0	0	0	0	0	0	…	…	…	…
	$^2 8_{3/2}[56, 2_1^+]$	1979	198	7	6	47	4	7	…	…	…	…
	$^2 8_{5/2}[56, 2_1^+]$	1979	59	5	4	1	20	27	…	…	…	…
	$^4 8_{3/2}[70, 0_1^+]$	2031	2	1	3	0	24	19	2	…	…	…
	$^2 8_{1/2}[56, 0_2^+]$	1727	26	4	3	…	…	2	…	…	…	…
						hQM						
Ξ (1950) ***	$^2 8_{1/2}[56, 0_2^+]$	1843	125	6	5	…	…	15	…	…	…	…
	$^4 8_{3/2}[70, 1_1^-]$	2053	8	11	37	0	223	154	…	…	…	…
	$^2 8_{1/2}[56, 0_3^+]$	2190	0	0	0	0	0	0	0	0	0	0
	$^2 8_{1/2}[70, 1_2^-]$	2288	0	0	0	0	0	0	0	0	0	0
	$^2 8_{3/2}[70, 1_2^-]$	2288	0	0	0	0	0	0	0	0	0	0
	$^4 8_{1/2}[70, 2_1^+]$	2327	3	1	8	1	6	5	8	10	40	1
	$^4 8_{3/2}[70, 2_1^+]$	2327	2	1	4	0	35	32	16	16	62	1
	$^4 8_{5/2}[70, 2_1^+]$	2327	6	7	24	0	57	53	20	18	69	1
	$^4 8_{7/2}[70, 2_1^+]$	2327	26	33	108	1	33	33	11	5	16	0
	$^2 8_J[20, 1_1^+]$	2377	0	0	0	0	0	0	0	0	0	0
	$^4 8_J[70, 1_2^-]$	2403	0	0	0	0	0	0	0	0	0	0

TABLE XV. As Table VIII, but for missing Ξ^* resonances.

	Ξ	Mass (MeV)	$\Sigma\bar{K}$	$\Lambda\bar{K}$	$\Xi\pi$	$\Xi\eta$	$\Sigma^*\bar{K}$	$\Xi^*\pi$	$\Lambda\bar{K}^*$	$\Sigma\bar{K}^*$	$\Xi\rho$	$\Xi\omega$
						$U(7)$ Model						
	$^2 10_{1/2}[70, 1_1^-]$	1869	17	10	7	7	…	7	…	…	…	…
	$^2 10_{3/2}[70, 1_1^-]$	1869	5	10	9	0	…	61	…	…	…	…
	$^2 10_{1/2}[70, 0_1^+]$	1971	2	1	1	2	51	14	…	…	…	…
	$^4 10_{3/2}[56, 0_2^+]$	1878	19	16	13	1	…	12	…	…	…	…
						hQM						
	$^4 10_{3/2}[56, 0_2^+]$	2022	19	12	13	12	…	24	…	…	…	…
	$^4 10_{1/2}[56, 2_1^+]$	2225	33	19	23	35	33	7	40	34	31	16
	$^4 10_{3/2}[56, 2_1^+]$	2225	17	10	12	17	133	29	61	50	44	23
Ξ^* (2030) 5/2 ***	$^4 10_{5/2}[56, 2_1^+]$	2225	14	19	16	3	194	44	66	51	45	24
	$^4 10_{7/2}[56, 2_1^+]$	2225	64	87	70	13	56	16	13	3	2	1
	$^2 10_{1/2}[70, 1_2^-]$	2352	0	0	0	0	0	0	0	0	0	0
	$^2 10_{3/2}[70, 1_2^-]$	2352	0	0	0	0	1	0	0	0	0	0
	$^4 10_{3/2}[56, 0_3^+]$	2369	0	0	0	0	0	0	0	0	0	0

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TABLE XVI. As Table VIII, but for missing Ω resonances.

	Ω	Mass (MeV)	$\Xi\bar{K}$	$\Xi^*\bar{K}$	$\Omega\eta$	$\Xi\bar{K}^*$
			$U(7)$ Model			
	${}^2 10_{1/2}[70, 1_1^-]$	1989	68	…	…	…
	${}^2 10_{3/2}[70, 1_1^-]$	1989	20	…	…	…
	${}^2 10_{1/2}[70, 0_1^+]$	2085	8	32	…	…
Ω(2250)?, ***	${}^4 10_{3/2}[56, 0_2^+]$	1998	79	…	…	…
			hQM			
	${}^2 10_{1/2}[70, 1_1^-]$	2142	26	48	…	…
Ω (2250)?, ***	${}^2 10_{3/2}[70, 1_1^-]$	2142	68	403	…	…
	${}^4 10_{3/2}[56, 0_2^+]$	2162	68	102	…	…
Ω(2380)?, **	${}^4 10_{1/2}[56, 2_2^+]$	2364	109	34	27	155
	${}^4 10_{3/2}[56, 2_2^+]$	2364	55	137	88	225
	${}^4 10_{5/2}[56, 2_2^+]$	2364	69	199	117	234
	${}^4 10_{7/2}[56, 2_2^+]$	2364	308	58	4	23
Ω(2470)?, **	${}^2 10_{1/2}[70, 1_2^-]$	2492	0	0	0	0
	${}^2 10_{3/2}[70, 1_2^-]$	2492	0	1	0	0
	${}^4 10_{3/2}[56, 0_3^+]$	2508	0	0	0	0

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TABLE VI. As Table III, but for Λ and Λ^* resonances.

Model	Baryon	Status	Mass (MeV)	$N\bar{K}$	$\Sigma\pi$	$\Lambda\eta$	ΞK	$\Sigma^*\pi$	$N\bar{K}^*$	$\Sigma\rho$	$\Lambda\omega$	
	$\Lambda(1600)P_{01}$	***	1560–1700	8–75	5–150							Exp.
$U(7)$	$^2 8_{1/2}[56, 0_2^+]$		1577	79	40	…	…	19	…	…	…	RPSF
hQM	$^2 8_{1/2}[56, 0_2^+]$		1627	93	46	…	…	18	…	…	…	RPSF
	$\Lambda(1670)S_{01}$	****	1660–1680	5–15	6–28	3–13						Exp.
$U(7)$	$^2 8_{1/2}[70, 1_1^-]$		1686	217	33	9	…	7	…	…	…	RPSF
hQM	$^2 8_{1/2}[70, 1_1^-]$		1722	267	39	0	…	5	…	…	…	RPSF
	$\Lambda(1690)D_{03}$	****	1685–1690	10–21	10–28							Exp.
$U(7)$	$^2 8_{3/2}[70, 1_1^-]$		1686	150	16	0	…	168	…	…	…	RPSF
hQM	$^2 8_{3/2}[70, 1_1^-]$		1722	119	23	0	…	168	…	…	…	RPSF
	$\Lambda(1800)S_{01}$	***	1720–1850	50–160	Seen			Seen				Exp.
$U(7)$	$^4 8_{1/2}[70, 1_1^-]$		1799	0	67	85	…	13	…	…	…	RPSF
hQM	$^4 8_{1/2}[70, 1_1^-]$		1837	0	98	90	…	10	…	…	…	RPSF
	$\Lambda(1810)P_{01}$	***	1750–1850	10–125	5–100			Seen				Exp.
$U(7)$	$^2 8_{1/2}[70, 0_1^+]$		1799	16	4	2	…	40	…	…	…	RPSF
hQM	$^2 8_{1/2}[56, 0_3^+]$		1973	0	0	0	…	0	…	…	…	RPSF
	$\Lambda(1820)F_{05}$	****	1815–1825	39–59	6–13			4–9				Exp.
$U(7)$	$^2 8_{5/2}[56, 2_1^+]$		1849	78	31	1	0	73	…	…	…	RPSF
hQM	$^2 8_{5/2}[56, 2_1^+]$		1829	57	22	0	0	66	…	…	…	RPSF
	$\Lambda(1830)D_{05}$	****	1810–1830	2–11	21–83			> 9				Exp.
$U(7)$	$^4 8_{5/2}[70, 1_1^-]$		1799	0	99	9	0	82	…	…	…	RPSF
hQM	$^4 8_{5/2}[70, 1_1^-]$		1837	0	84	7	0	64	…	…	…	RPSF
	$\Lambda(1890)P_{03}$	****	1850–1910	12–70	2–20			Seen				Exp.
$U(7)$	$^2 8_{3/2}[56, 2_1^+]$		1849	96	69	31	2	30	28	…	…	RPSF
hQM	$^2 8_{3/2}[56, 2_1^+]$		1829	120	79	11	1	24	27	…	…	RPSF
	$\Lambda(2110)F_{05}$	****	2090–2140	8–63	15–100			Seen				Exp.
$U(7)$	$^4 8_{5/2}[70, 2_1^+]$		2074	0	14	3	1	136	0	38	16	RPSF
hQM	$^2 8_{5/2}[70, 2_1^+]$		1995	167	20	0	3	69	15	79	25	RPSF
	$\Lambda^*(1405)S_{01}$	****	1402–1410		48–52							Exp.
$U(7)$	$^2 1_{1/2}[70, 1_1^-]$		1641	…	230	…	…	…	…	…	…	RPSF
hQM	$^2 1_{1/2}[70, 1_1^-]$		1658	…	222	…	…	…	…	…	…	RPSF
	$\Lambda^*(1520)D_{03}$	****	1518–1520	6–8	6–7			1				Exp.
$U(7)$	$^2 1_{3/2}[70, 1_1^-]$		1641	10	17	…	…	…	…	…	…	RPSF
hQM	$^2 1_{3/2}[70, 1_1^-]$		1658	8	13	…	…	…	…	…	…	RPSF

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$\Lambda(1116)$	$1/2^+$	****
$\Lambda(1380)$	$1/2^-$	**
$\Lambda(1405)$	$1/2^-$	****
$\Lambda(1520)$	$3/2^-$	****
$\Lambda(1600)$	$1/2^+$	****
$\Lambda(1670)$	$1/2^-$	****
$\Lambda(1690)$	$3/2^-$	****
$\Lambda(1710)$	$1/2^+$	*
$\Lambda(1800)$	$1/2^-$	***
$\Lambda(1810)$	$1/2^+$	***
$\Lambda(1820)$	$5/2^+$	****
$\Lambda(1830)$	$5/2^-$	****
$\Lambda(1890)$	$3/2^+$	****
$\Lambda(2000)$	$1/2^-$	*
$\Lambda(2050)$	$3/2^-$	*
$\Lambda(2070)$	$3/2^+$	*
$\Lambda(2080)$	$5/2^-$	*
$\Lambda(2085)$	$7/2^+$	**
$\Lambda(2100)$	$7/2^-$	****
$\Lambda(2110)$	$5/2^+$	***
$\Lambda(2325)$	$3/2^-$	*
$\Lambda(2350)$	$9/2^+$	***
$\Lambda(2585)$		*

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TABLE XII. As Table VIII, but for missing Λ reso

Λ	Mass (MeV)	$N\bar{K}$	$\Sigma\pi$	$\Lambda\eta$	ΞK	$\Sigma^*\pi$	$\Xi^* K$	$N\bar{K}^*$	$\Sigma\rho$	$\Lambda\omega$
					$U(7)$ Model					
$^4 8_{3/2}[70, 1_1^-]$	1799	0	15	1	...	447	...	...	...	...
$^2 8_J[20, 1_1^+]$	1826	0	0	0	0	0	...	...	...	...
$^4 8_{3/2}[70, 0_1^+]$	1904	0	3	4	2	54	...	0	...	0
$^2 8_{3/2}[70, 2_1^+]$	1978	27	6	4	10	31	...	56	1	4
$^2 8_{5/2}[70, 2_1^+]$	1978	109	12	2	1	58	...	123	3	16
$^2 8_J[70, 2_1^-]$	1978	0	0	0	0	0	...	0	0	0
$^4 8_J[70, 2_1^-]$	2074	0	0	0	0	0	0	0	0	0
$^4 8_{1/2}[70, 2_1^+]$	2075	0	13	11	12	17	1	0	20	9
$^4 8_{3/2}[70, 2_1^+]$	2075	0	6	6	6	82	4	0	28	13
$^4 8_{7/2}[70, 2_1^+]$	2075	0	51	10	2	57	0	0	1	2
$^2 8_J[70, 1_2^-]$	1936	0	0	0	0	0	...	0	...	0
$^4 8_{1/2}[70, 1_2^-]$	2034	0	0	0	0	0	0	0	0	0
$^4 8_{3/2}[70, 1_2^-]$	2034	0	0	0	0	1	0	0	0	0
$^4 8_{5/2}[70, 1_2^-]$	2034	0	0	0	0	0	0	0	0	0
					hQM					
$^4 8_{3/2}[70, 1_1^-]$	1837	0	15	2	...	477	...	...	...	...
$^2 8_{3/2}[70, 2_1^+]$	1995	38	8	0	10	29	...	55	2	4
$^2 8_{1/2}[70, 1_2^-]$	2072	0	0	0	0	0	...	0	...	0
$^2 8_{3/2}[70, 1_2^-]$	2072	0	0	0	0	0	0	0	0	0
$^4 8_{3/2}[70, 0_1^+]$	2110	0	0	1	4	35	11	0	41	8
$^4 8_{1/2}[70, 2_1^+]$	2110	0	18	13	12	35	2	0	23	9
$^4 8_{3/2}[70, 2_1^+]$	2110	0	10	6	2	87	7	0	33	14
$^4 8_{7/2}[70, 2_1^+]$	2110	0	50	10	2	19	0	0	2	2
$^2 8_J[20, 1_1^+]$	2160	0	0	0	0	0	0	0	0	0
$^4 8_{1/2}[70, 1_2^-]$	2186	0	0	0	0	0	0	0	0	0
$^4 8_{3/2}[70, 1_2^-]$	2186	0	0	0	0	1	0	0	0	0
$^4 8_{5/2}[70, 1_2^-]$	2186	0	0	0	0	0	0	0	0	0

Bijker, Garcia-Tecocoatzi, Santopinto, PRD 94, 0704040 (2016)

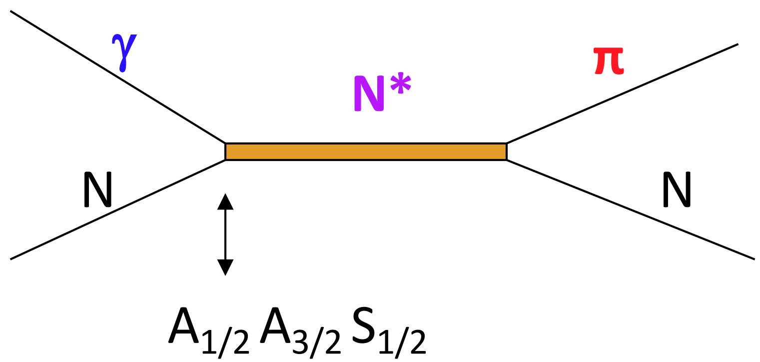
TABLE XIII. As Table VIII, but for missing Λ^* resonances.

Λ	Mass (MeV)	$N\bar{K}$	$\Sigma\pi$	$\Lambda\eta$	ΞK	$N\bar{K}^*$	$\Sigma\rho$	$\Lambda\omega$
				$U(7)$ Model				
$^2 1_{1/2}[70, 0_1^+]$	1756	29	44	14	...	...	...	...
$^4 1_J[20, 1_1^+]$	1891	0	0	0	0	0	...	...
$^2 1_{3/2}[70, 2_1^+]$	1939	35	66	36	17	39	...	6
$^2 1_{5/2}[70, 2_1^+]$	1939	88	85	10	0	94	...	15
$^2 1_J[70, 2_1^-]$	1939	0	0	0	0	0	...	0
$^2 1_J[70, 1_2^-]$	1896	0	0	0	0	0	...	0
				hQM				
$^2 1_{1/2}[70, 1_2^-]$	2008	0	1	0	0	1	...	0
$^2 1_{3/2}[70, 1_2^-]$	2008	0	0	0	0	0	...	0

Singlet Λ^*

HELICITY AMPLITUDES

Extracted from electroproduction of mesons

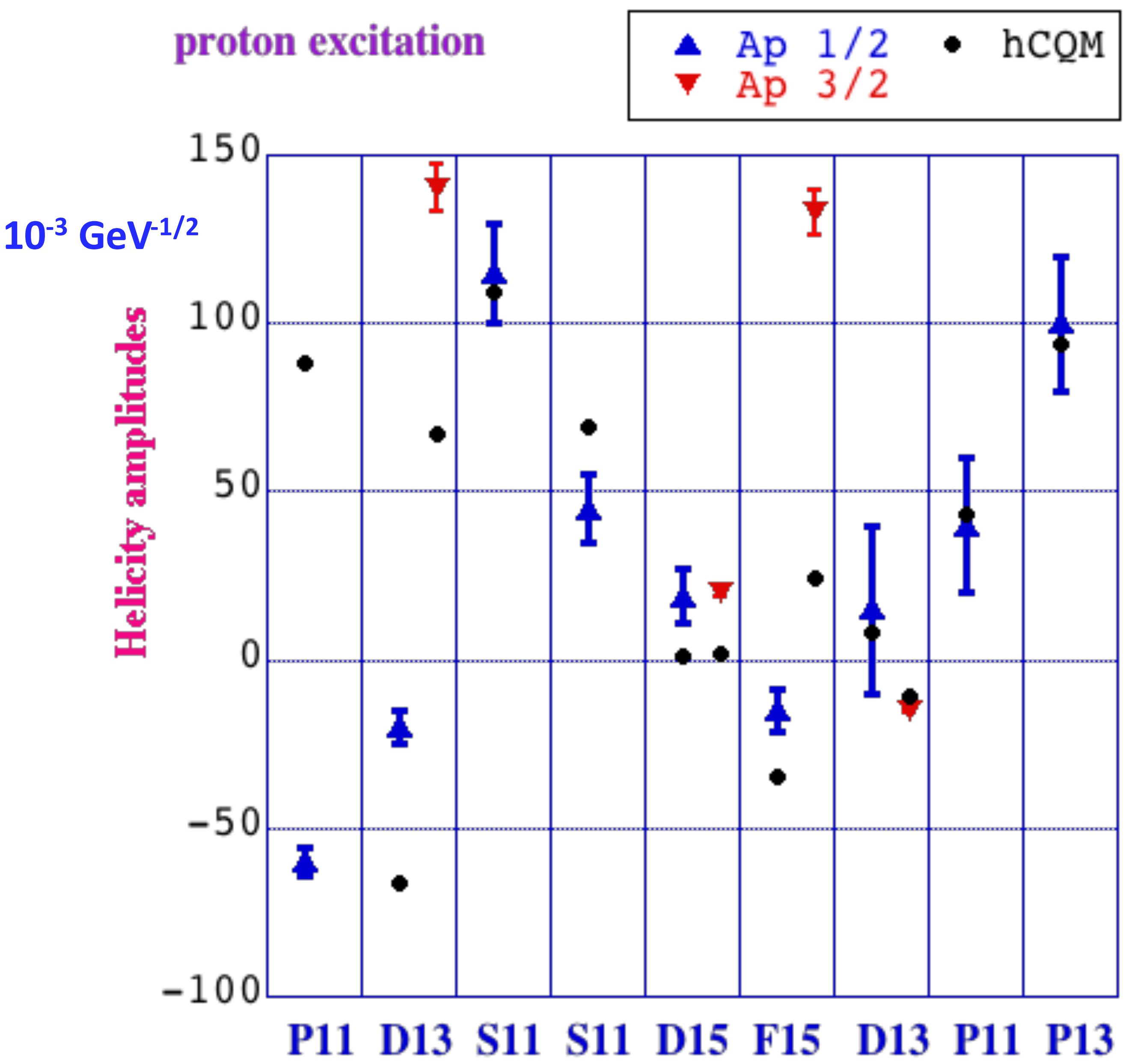


results for the negative parity resonances at Q^2 =0:
M. Aiello, M.G., E. Santopinto J. Phys. G24, 753 (1998)

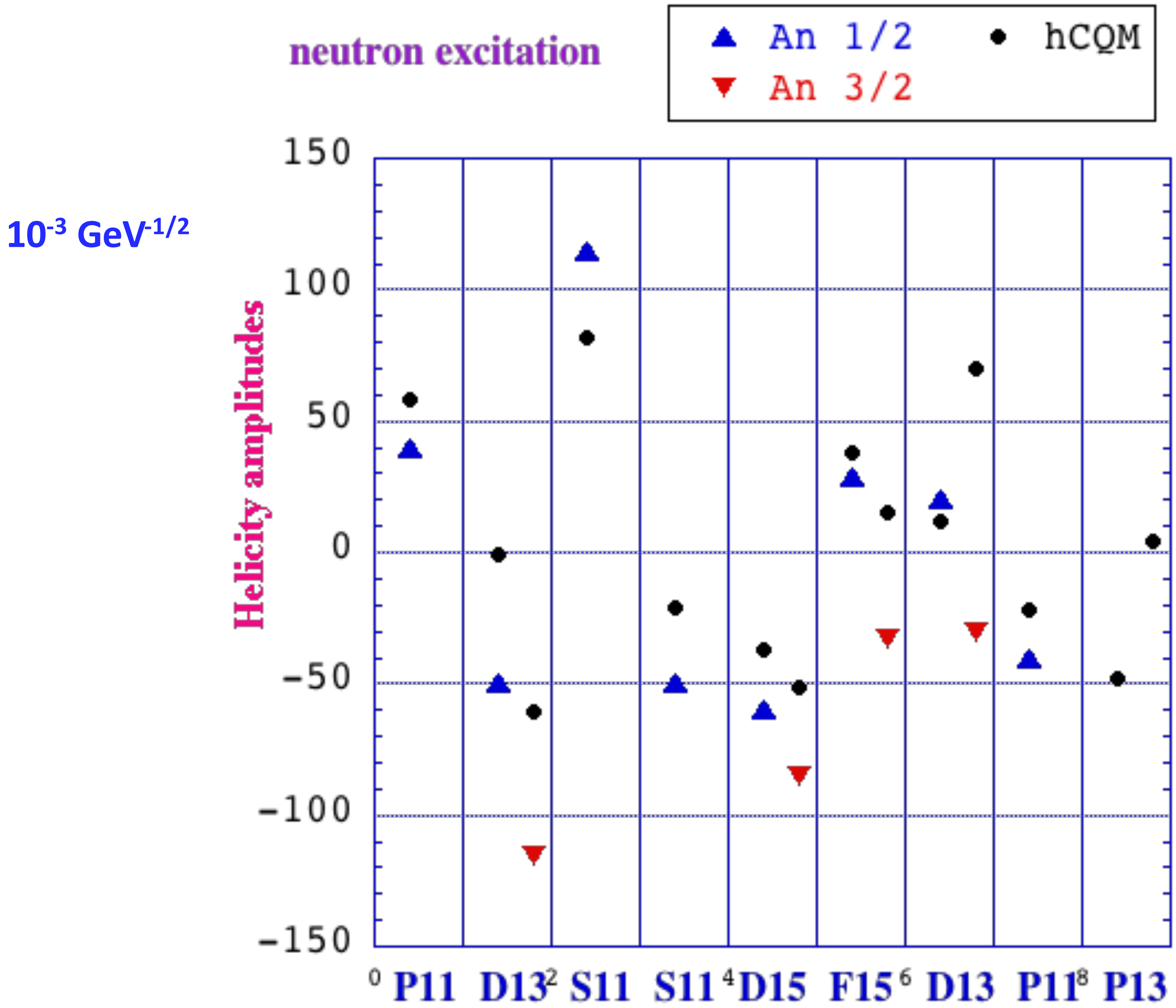
Systematic predictions for transverse and longitudinal amplitudes as a function of Q^2
E. Santopinto et al. , Phys. Rev. C86, 065202 (2012)

Proton and neutron electro-excitation to 14 resonances

The photocouplings

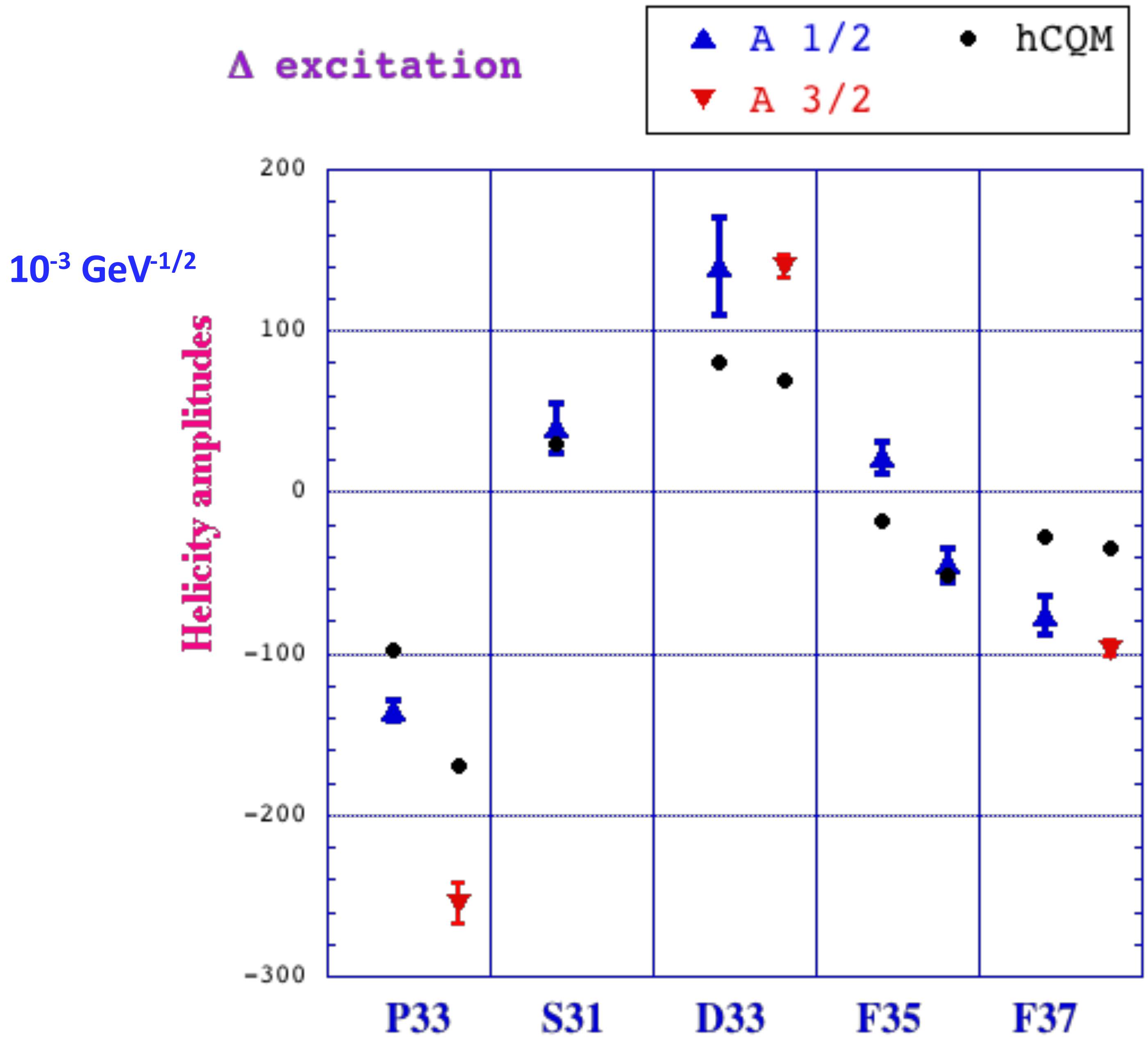


M. Aiello et al., Phys. Lett. B387, 215 (1996)
E. Santopinto, M.Giannini, Phys. Rev. C86, 065202 (2012)



M. Aiello et al., Phys. Lett. B387, 215 (1996)

E. Santopinto, M.Giannini, Phys. Rev. C86, 065202 (2012)

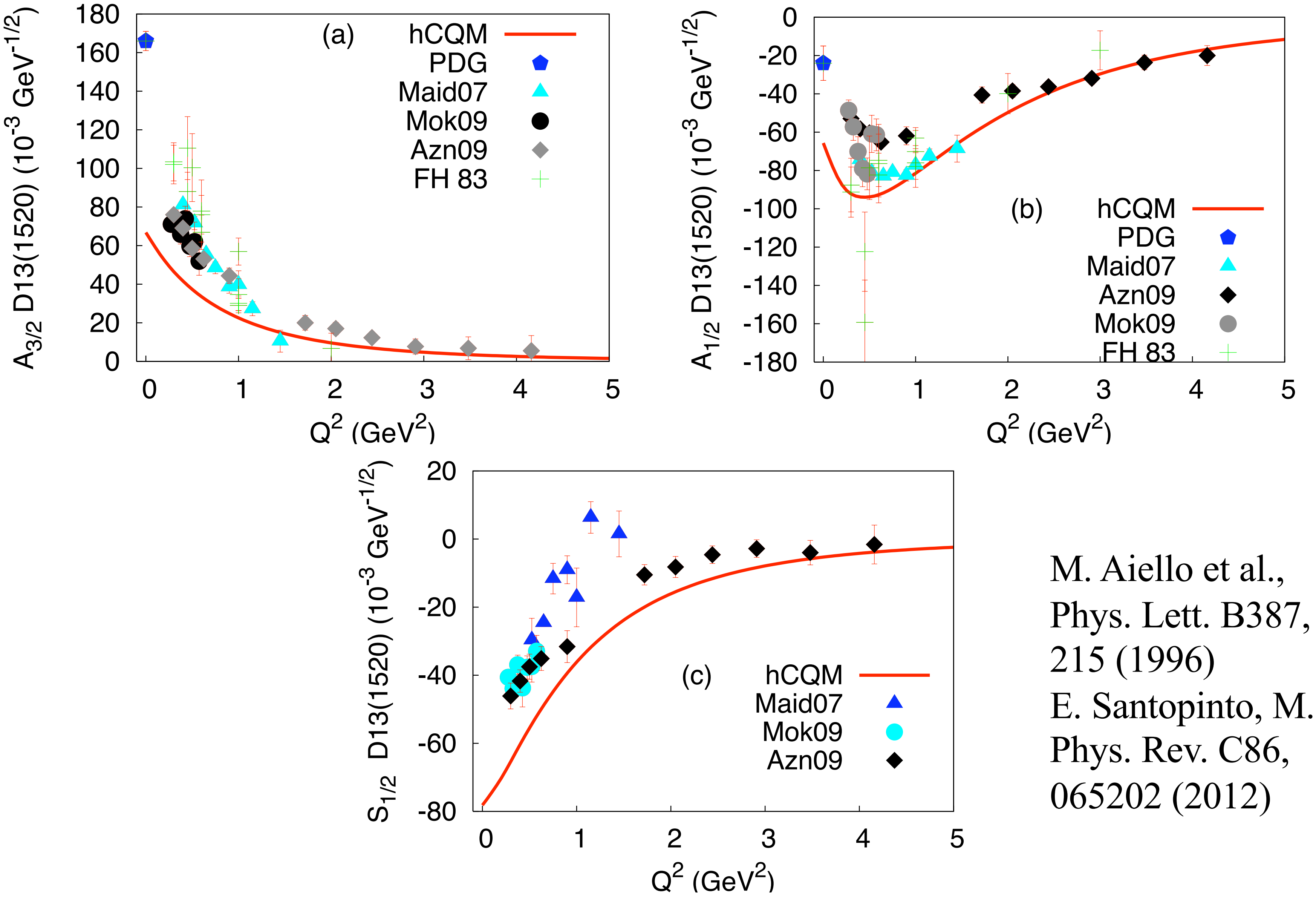


M. Aiello et al., Phys. Lett. B387, 215 (1996)

E. Santopinto, M.G., Phys. Rev. C86, 065202 (2012)

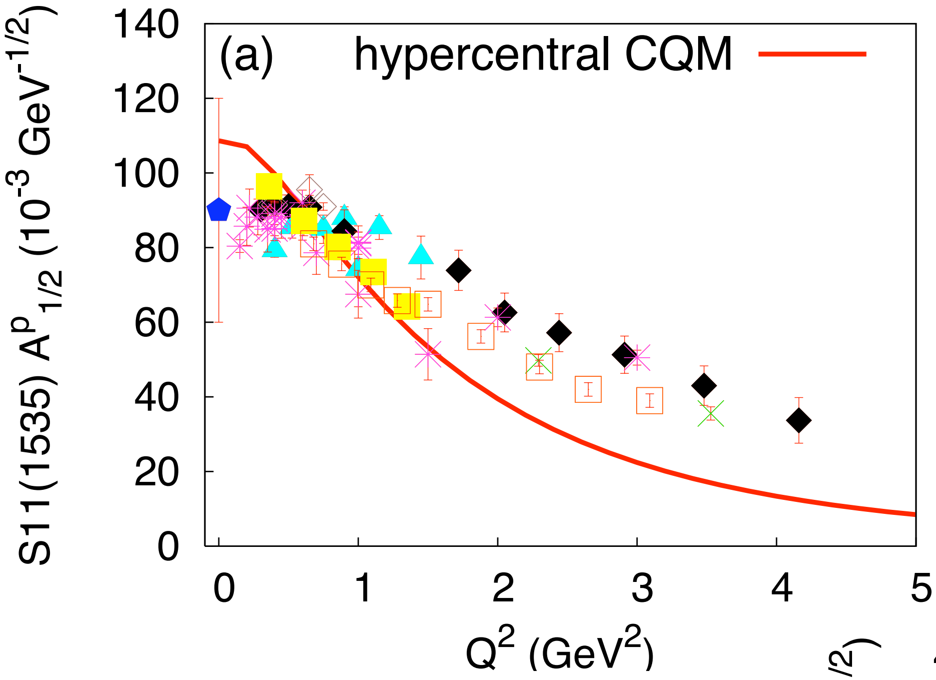
Q^2 dependence

N(1520) 3/2⁻ transition amplitudes



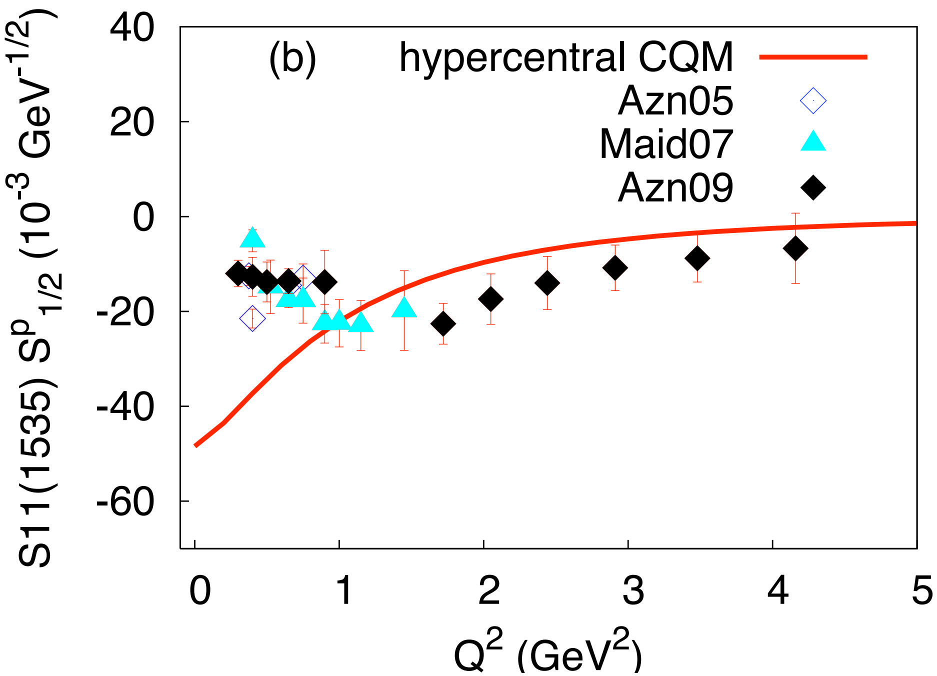
M. Aiello et al., Phys. Lett. B387, 215 (1996)

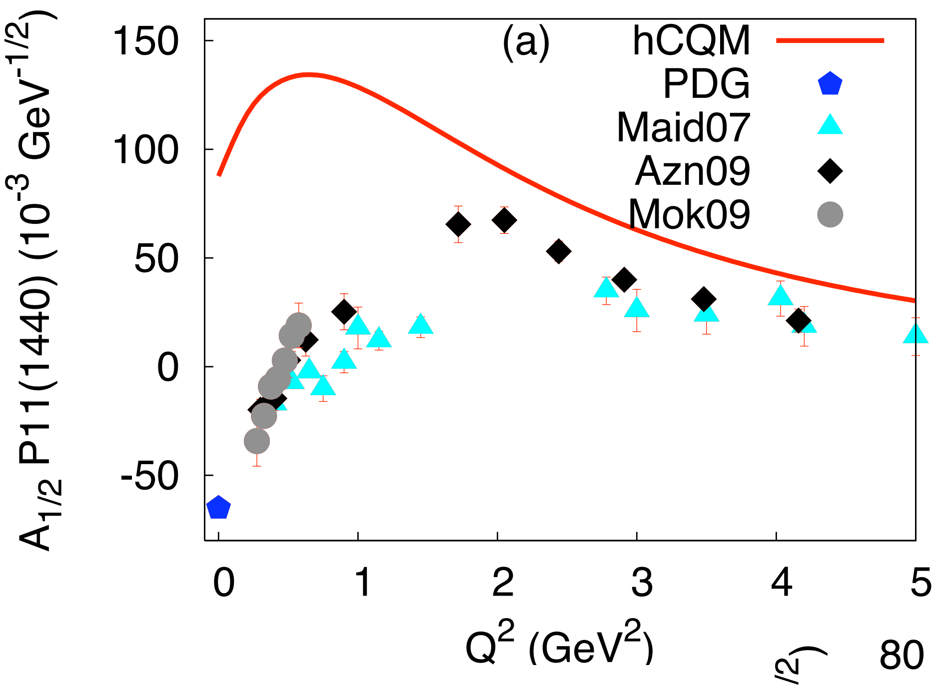
E. Santopinto, M.G. Phys. Rev. C86, 065202 (2012)



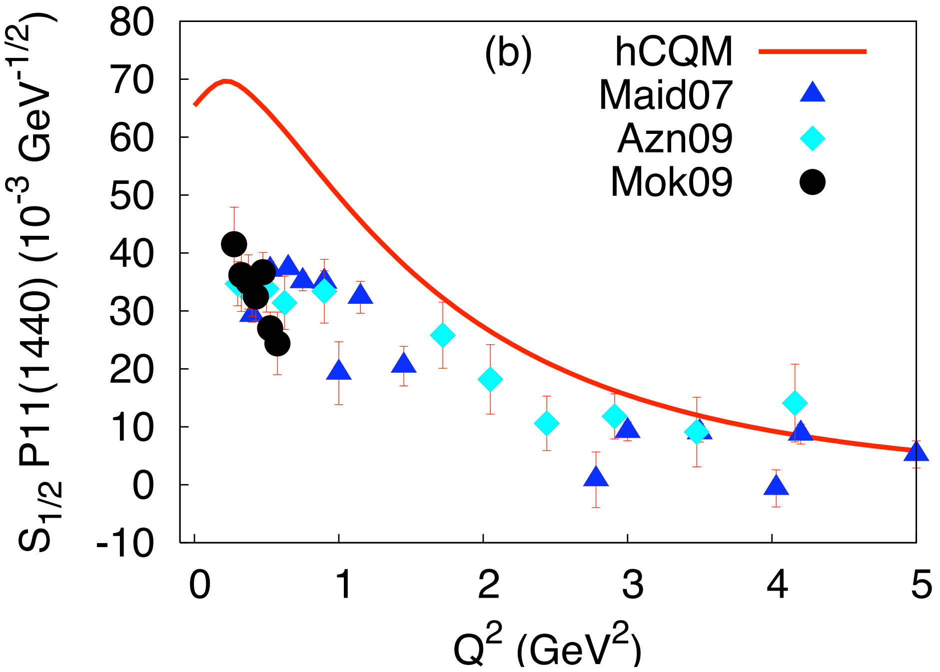
N(1535) ½ ⁻ transition amplitudes

M. Aiello et al., Phys. Lett. B387, 215 (1996)
E. Santopinto, M.G. Phys. Rev. C86, 065202 (2012)





N(1440) ½ $^{+}$ (Roper) transition amplitudes



E. Santopinto, M.G.
Phys. Rev. C86,
065202 (2012)

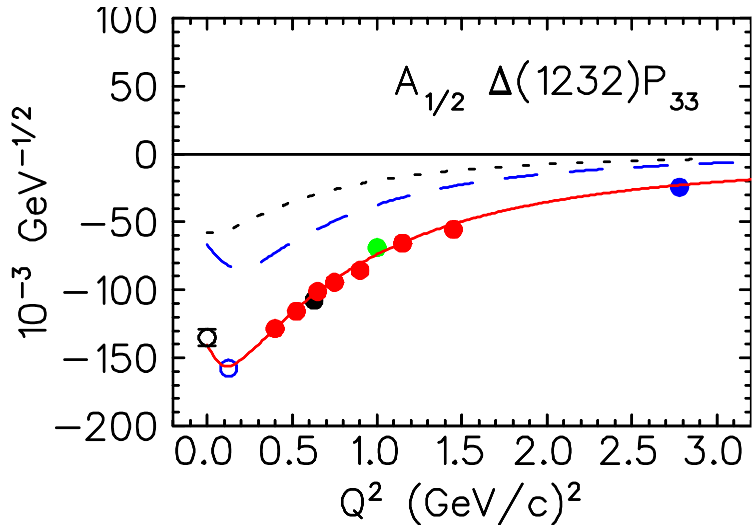
There is missing strength at low Q^2

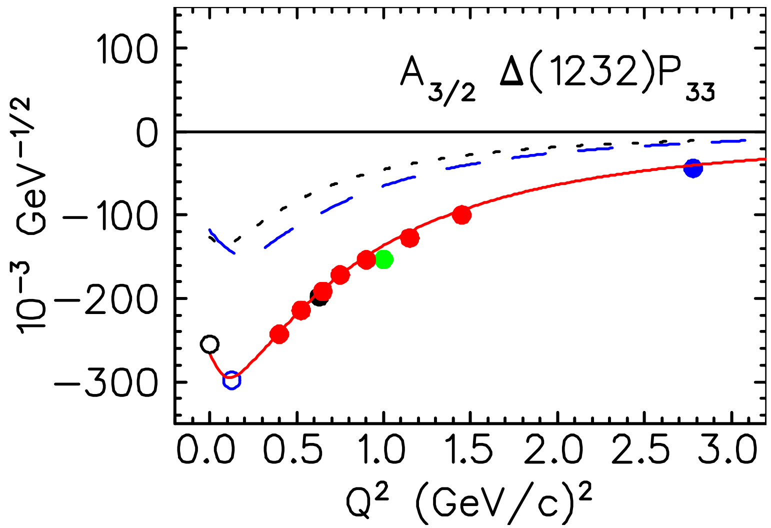
The reason is attributed to the lack of

Quark-antiquark pair mechanisms

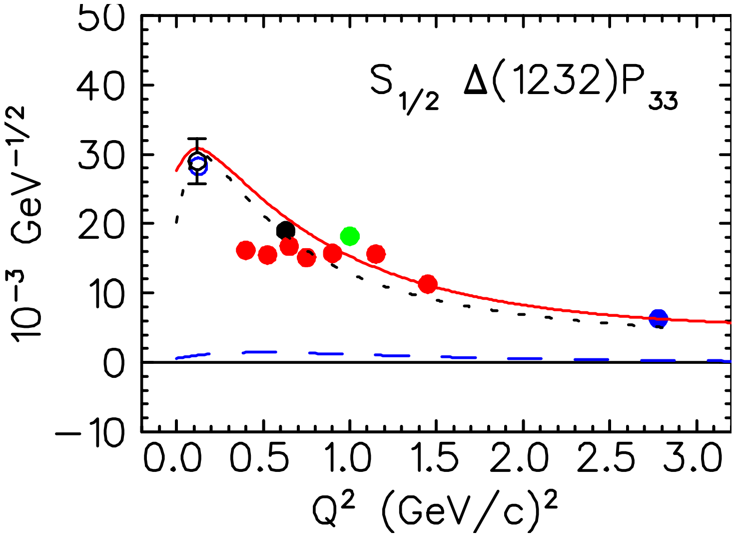
not present in a three-quark model

E. Santopinto, Ph. D. Thesis (Genova 1996).
M. Aiello et al., Phys. Lett. B387, 215 (1996)





solid: MAID
dotted: dynamical model
dashed: hCQM predictions



L. Tiatot et al., Eur. Phys. J. A19, 55 (2004).

Necessity of unquenching the quark model

Unquenched Quark Model for Baryons (Formalism)

R. Bijker, E. Santopinto, Phys.Rev.C80:065210, 2009

$$| \psi_A \rangle = \mathcal{N} \left\{ | A \rangle + \sum_{BClJ} \int d\vec{K}\, k^2 dk \; | BC\vec{K}\, k\, l J \rangle \frac{\langle BC\vec{K}\, k\, l J \mid T^\dagger \mid A \rangle}{M_A - E_B - E_C} \right\}$$

Three-quark configuration

B/C = intermediate baryon/meson

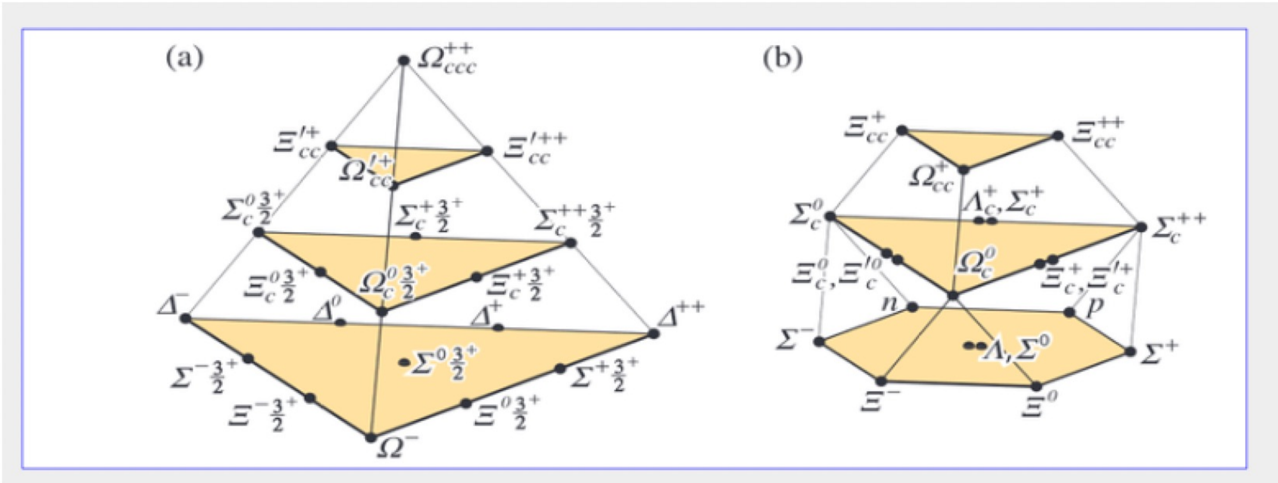
Pair-creation operator: $T^\dagger = T^\dagger(^3P_0)$

L=S=1, J=0, color singlet, flavor singlet

It is a couple channel model, in the language of the quark model

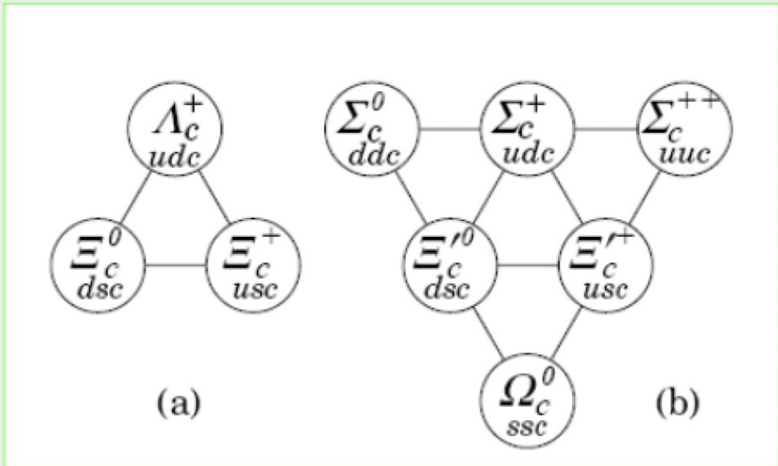
Heavy Baryons

Heavy baryon with charm quarks



Wave function $\Psi = \sum \omega\psi\phi\chi$
Three particles of spin 1/2
$1/2 \times 1/2 \times 1/2 = 1/2 + 1/2 + 3/2$

Heavy baryon with a single charm quark



$$\Xi_c^0 := \frac{1}{\sqrt{2}}(|dsc\rangle - |sdc\rangle)$$
$$\Xi_c^+ := \frac{1}{\sqrt{2}}(|usc\rangle - |suc\rangle)$$
$$\Lambda_c^+ := \frac{1}{\sqrt{2}}(|udc\rangle - |duc\rangle)$$

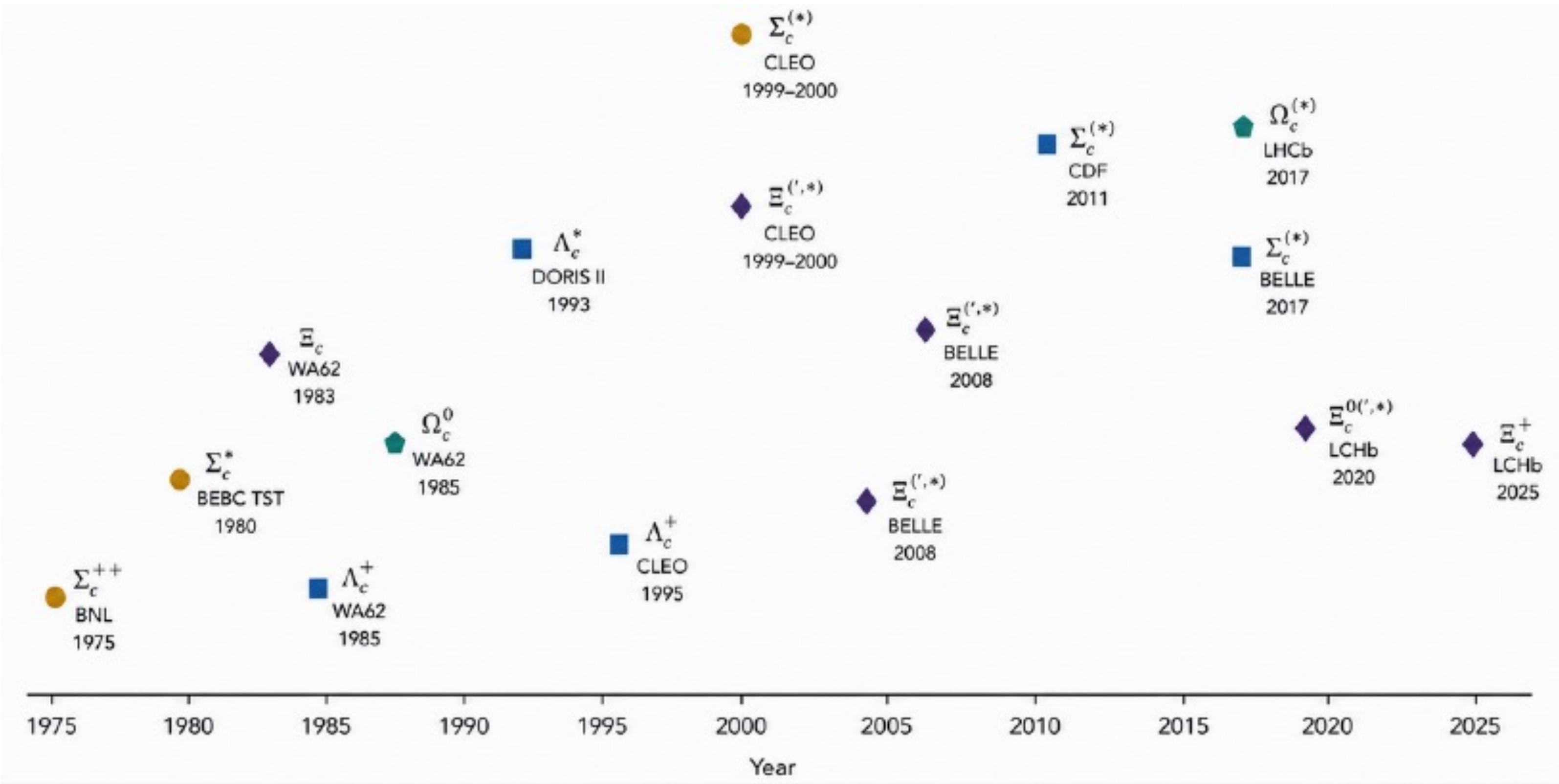
$$\Omega_c := |ssc\rangle$$
$$\Xi_c'^0 := \frac{1}{\sqrt{2}}(|dsc\rangle + |sdc\rangle)$$
$$\Xi_c'^+ := \frac{1}{\sqrt{2}}(|usc\rangle + |suc\rangle)$$
$$\Sigma_c^{++} := |uuc\rangle$$
$$\Sigma_c^0 := |ddc\rangle$$
$$\Sigma_c^+ := \frac{1}{\sqrt{2}}(|udc\rangle + |duc\rangle)$$

Wave function $\Psi = \sum \omega\psi\phi\chi$

Three particles of spin 1/2

$1/2 \times 1/2 \times 1/2 = 1/2 + 1/2 + 3/2$

The Experimental Evolution of Singly Charmed Baryons



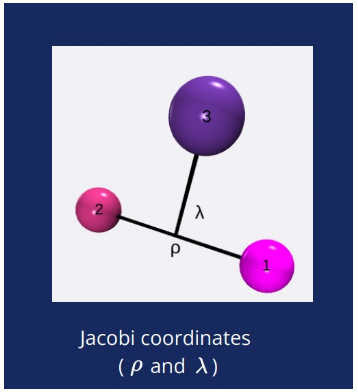
Phenomenological model I

- The masses of the heavy single baryon states are calculated as the eigenvalues of the Hamiltonian , E. Santopinto, A. Giachino, J. Ferretti, H. Garcia-Tecocoatzi, M.A. Bedolla, R. Bijker, E. Ortiz-Pacheco, EPJC 79(12), 1012 (2019), which is modeled as:

$$H = H_{\mathrm{h.o.}} + P_s\, \mathbf{S}^2 + P_{sl}\, \mathbf{S}\cdot\mathbf{L} + P_I\, \boldsymbol{I}^2 + P_f\, \mathbf{C_2}(\mathrm{SU}(3)_{\mathrm{f}}), \qquad (1)$$

  $\mathbf{S}, \mathbf{L}, \boldsymbol{I}$ and $\mathbf{C_2}(\mathrm{SU}(3)_{\mathrm{f}})$ are the spin, orbital momentum, isospin and Casimir operators, respectively.
- We describe the observed excited states of Ω_c, Σ_c, Λ_c, Ξ_c, and Ξ'_c at the same time, PRD107 034031 (2023)
- We recently study the Ω_b, Σ_b, Λ_b, Ξ_b, and Ξ'_b states
- We work within the quark-model framework H. Garcia-Tecocoatzi, A. Giachino, A. Ramirez-Morales, A. Rivero-Acosta, E. Santopinto, and C. Vaquera e-Print: 2307.00505 [hep-ph] (2023)

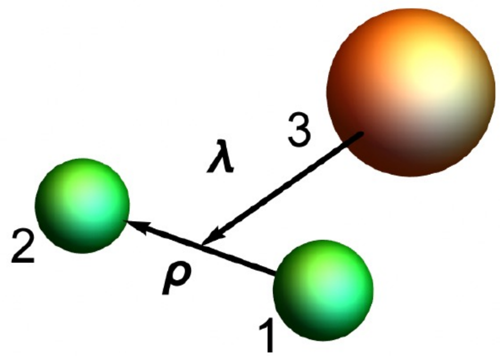
PRD 107, 034031 (2023)



Mass formula

Algebraic Model for Heavy Baryons

$$H = H_{\mathrm{h.o.}} + a_S \mathbf{S}^2_{\mathrm{tot}} + a_{SL} \mathbf{S}_{\mathrm{tot}} \cdot \mathbf{L}_{\mathrm{tot}} + a_I \mathbf{I}^2 + a_F \hat{\mathbf{C}}_2(SU(3))$$



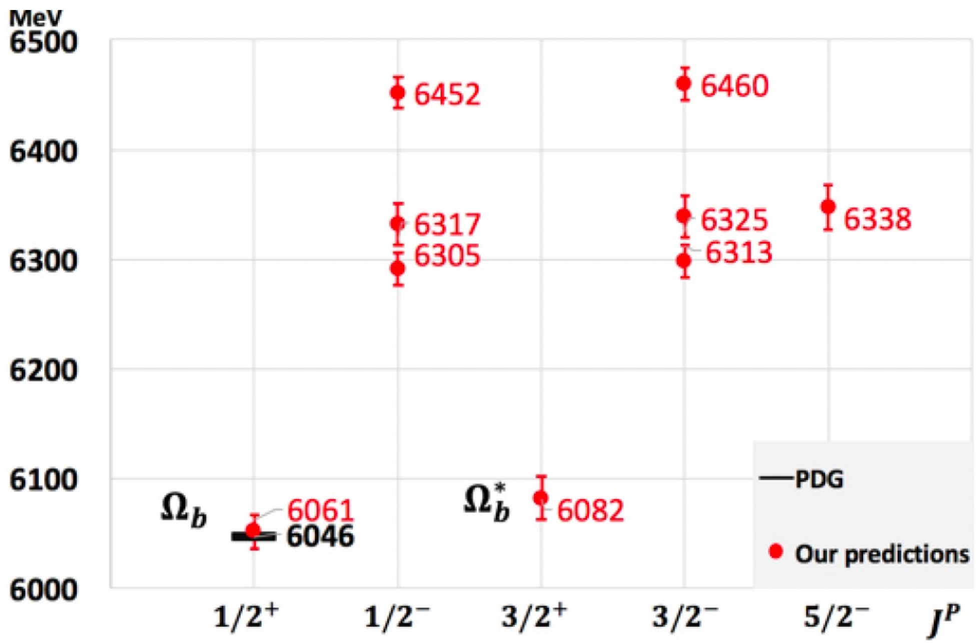
$$\begin{aligned} E^{3q} &= \sum_{i=1}^{3} m_i + \omega_\rho n_\rho + \omega_\lambda n_\lambda + a_S [S_{\mathrm{tot}}(S_{\mathrm{tot}}+1)] \\ &+ a_{SL} \frac{1}{2} \left[J(J+1) - L_{\mathrm{tot}}(L_{\mathrm{tot}}+1) - S_{\mathrm{tot}}(S_{\mathrm{tot}}+1) \right] \\ &+ a_I [I(I+1)] + a_F \frac{1}{3} [p(p+3) + q(q+3) + pq] \end{aligned}$$ (

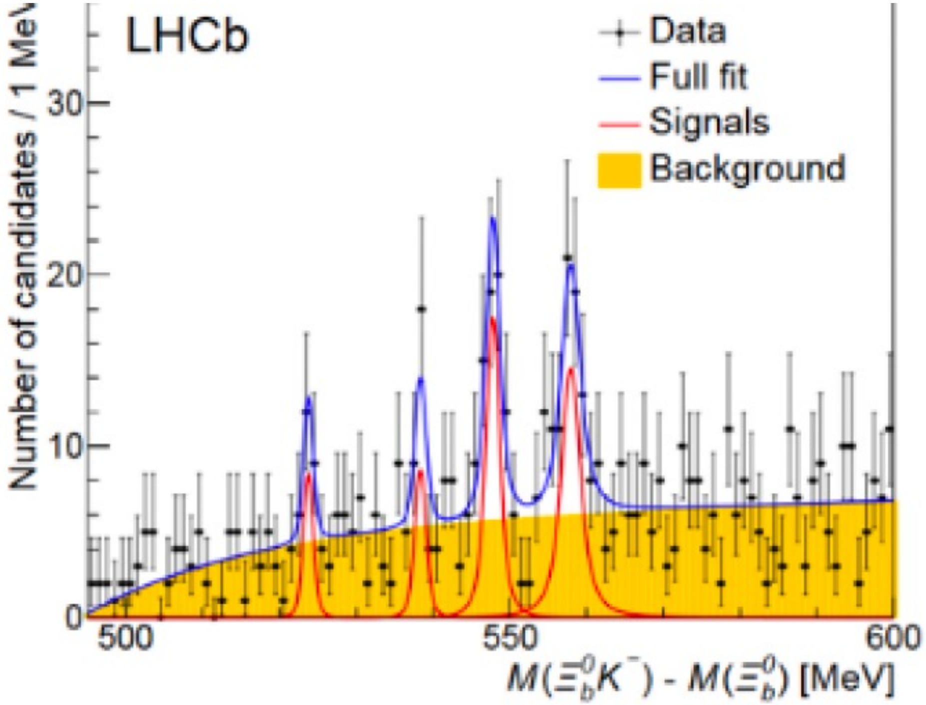
It gives origin/ it is equivalent to a mass formula

E. Santopinto et al., EPJC 79(12), 1012 (2019)

Predictions of Ω_b excited states

First Observation of Excited Ωb States by LHCb collaboration, PRL 124, 082002 (2020)
In agreement with our predictions





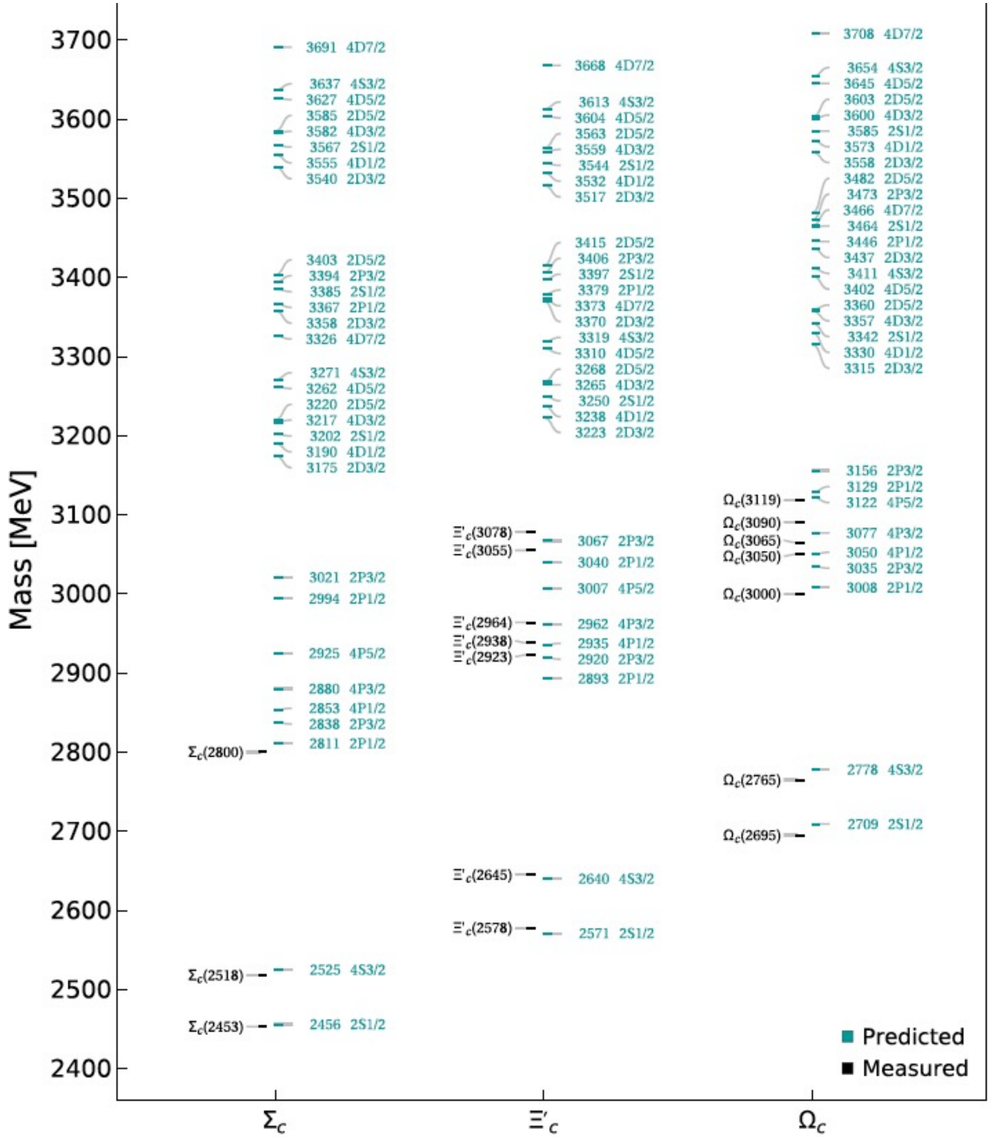
Eur.Phys.J. C79 (2019) no.12, 1012

LHCb results in MeV:

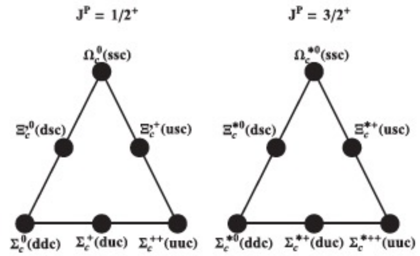
Mass	Width	$Mass_{th.}$	$Width_{th}$
6316	< 2.8	6313	0.50
6330	< 3.1	6317	2.79
6340	< 1.5	6325	1.14
6350	< 2.8	6338	0.62

Singly Charmed Baryon Spectrum

H. García-Tecocoatzi, A. Giachino, J. Li, A. Ramirez-Morales,E. Santopinto, PRD 107, 034031 (2023)

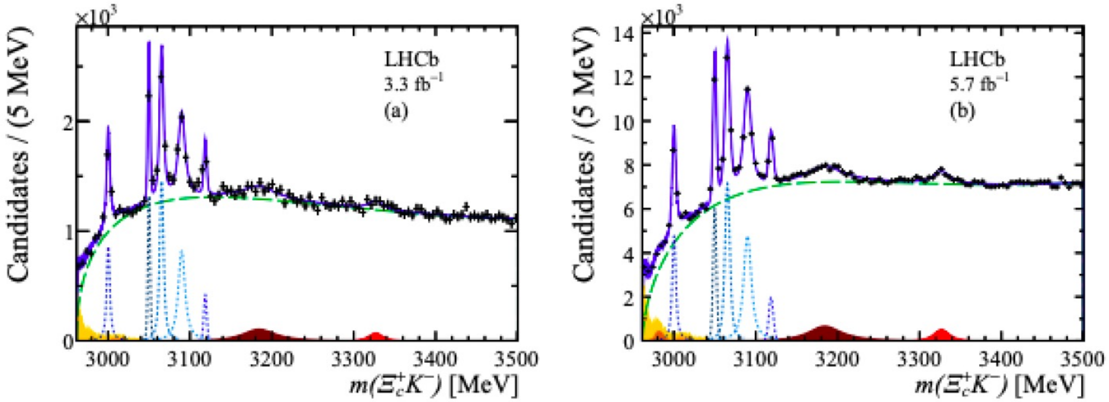


The sextect



New Ω_c states observed by LHCb, PRL131 131902(2023)

New state $\Omega_c(3327)$ with mass$=3327.1 \pm 1.2$ MeV and $\Gamma = 20 \pm 5$ MeV

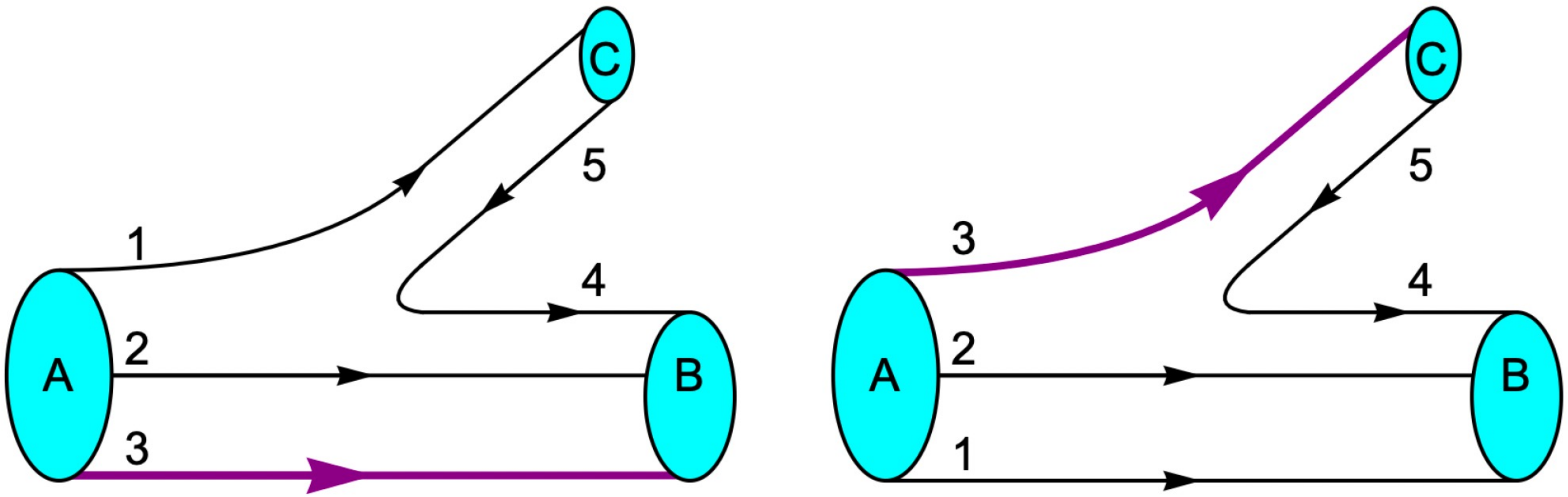


$\vert l_\lambda = 2, l_\rho = 0, k_\lambda = 0, k_\rho = 0\rangle$	$^2D_{3/2}$	3315^{+15}_{-14}	3306^{+14}_{-14}	†	11^{+5}_{-5}
$\vert l_\lambda = 2, l_\rho = 0, k_\lambda = 0, k_\rho = 0\rangle$	$^2D_{5/2}$	3360^{+17}_{-16}	3348^{+17}_{-17}	†	24^{+12}_{-12}
$\vert l_\lambda = 2, l_\rho = 0, k_\lambda = 0, k_\rho = 0\rangle$	$^4D_{1/2}$	3330^{+25}_{-25}	3328^{+24}_{-23}	†	16^{+8}_{-8}
$\vert l_\lambda = 2, l_\rho = 0, k_\lambda = 0, k_\rho = 0\rangle$	$^4D_{3/2}$	3357^{+18}_{-19}	3354^{+17}_{-17}	†	30^{+15}_{-15}
$\vert l_\lambda = 2, l_\rho = 0, k_\lambda = 0, k_\rho = 0\rangle$	$^4D_{5/2}$	3402^{+13}_{-13}	3396^{+12}_{-12}	†	62^{+31}_{-31}

H. Garcia-Tecocoatzi, A. Giachino, J. Li, A. Ramirez-Morales, and E. Santopinto, PRD107 034031 (2023)

Strong decay

Pair-creation model

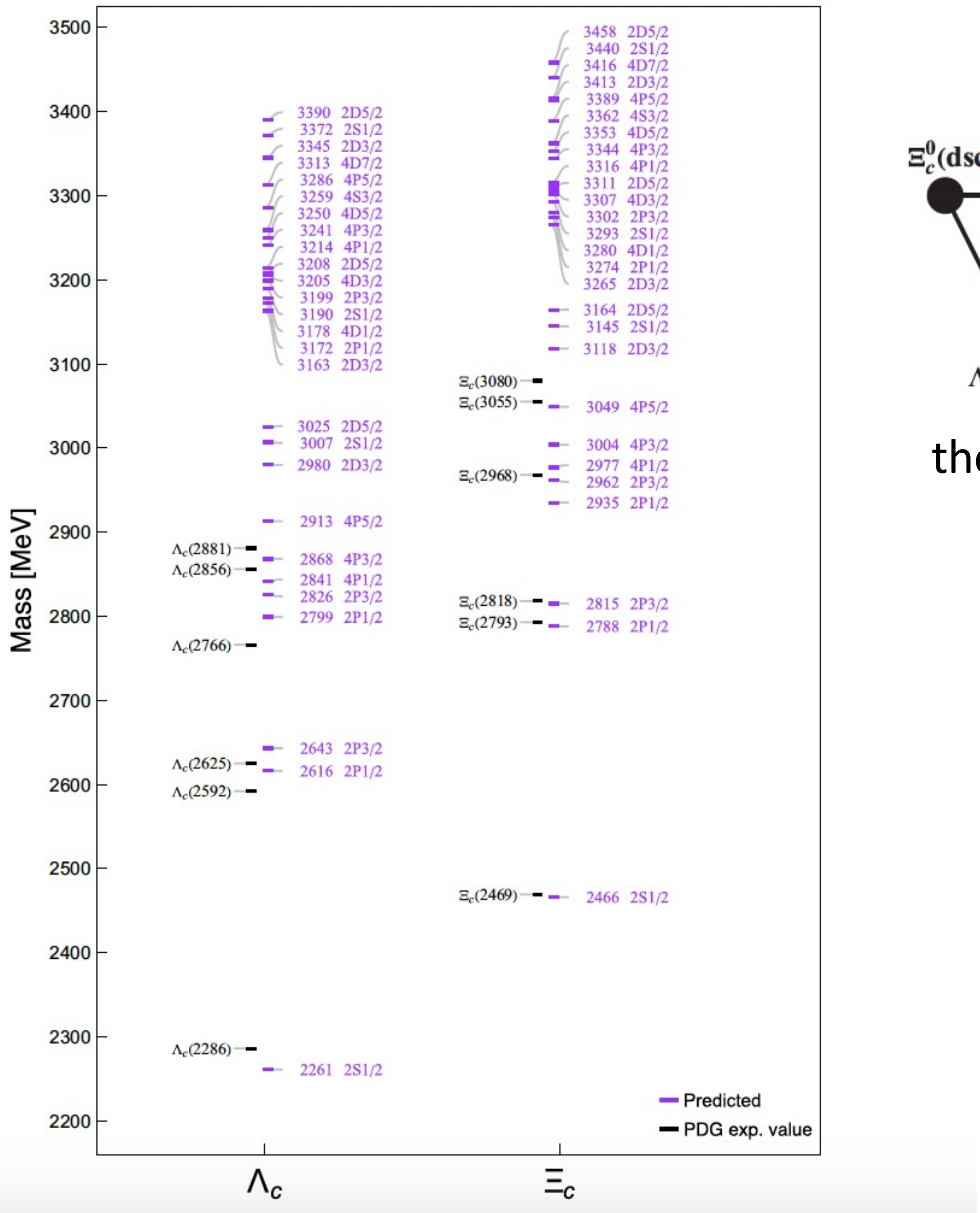


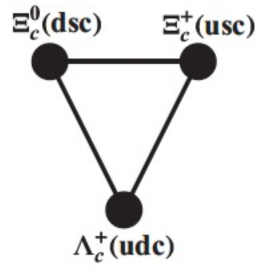
Results, partial-decay widths PRD107 034031 (2023)

$\Omega_c(ssc)$ $\mathcal{F}=\mathbf{6}_{\rm f}$	$\Xi_c K$	$\Xi_c' K$	$\Xi_c^* K$	$\Xi_c K^*$	$\Xi_c' K^*$	$\Xi_c^* K^*$	$\Omega_c \eta$	$\Omega_c^* \eta$	$\Omega_c \phi$	$\Omega_c^* \phi$	$\Omega_c \eta'$	$\Omega_c^* \eta'$	$\Xi_8 D$	$\Xi_{10} D$	Predicted $\Gamma_{\rm tot}$
$\Omega_c(2709)^2S_{1/2}$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$\Omega_c(2778)^4S_{3/2}$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$\Omega_c(3008)^2P_{1/2}$	4.1	0	0	0	0	0	0	0	0	0	0	0	0	0	4.1
$\Omega_c(3050)^4P_{1/2}$	7.5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	7.6
$\Omega_c(3035)^2P_{3/2}$	26.3	0	0	0	0	0	0	0	0	0	0	0	0	0	26.3
$\Omega_c(3077)^4P_{3/2}$	6.3	0.4	0	0	0	0	0	0	0	0	0	0	0	0	6.7
$\Omega_c(3122)^4P_{5/2}$	40.9	8.9	0.3	0	0	0	0	0	0	0	0	0	0	0	50.1
$\Omega_c(3129)^2P_{1/2}$	—	8.9	5.5	0	0	0	0	0	0	0	0	0	0	0	14.4
$\Omega_c(3156)^2P_{3/2}$	—	61.1	10.5	0	0	0	0	0	0	0	0	0	0	0	71.6
$\Omega_c(3315)^2D_{3/2}$	1.9	1.8	2.3	0	0	0	0.3	—	0	0	0	0	4.3	0	10.6
$\Omega_c(3360)^2D_{5/2}$	5.4	5.1	0.5	0	0	0	1.2	—	0	0	0	0	12.2	0	24.4
$\Omega_c(3330)^4D_{1/2}$	0.2	0.2	3.3	0	0	0	0.1	0.1	0	0	0	0	12.3	0	16.2
$\Omega_c(3357)^4D_{3/2}$	2.0	0.5	5.2	0.2	0	0	0.2	0.6	0	0	0	0	21.7	0	30.4
$\Omega_c(3402)^4D_{5/2}$	5.0	1.2	5.0	1.6	0	0	0.3	1.2	0	0	0	0	46.9	1.1	62.3
$\Omega_c(3466)^4D_{7/2}$	7.8	2.0	5.0	2.6	0	0	0.8	0.9	0	0	0	0	83.2	20.9	123.2
$\Omega_c(3342)^2S_{1/2}$	0.2	0.3	0.1	0	0	0	0.1	—	0	0	0	0	0.5	0	1.2
$\Omega_c(3411)^4S_{3/2}$	0.2	0.1	0.4	0.2	0	0	—	0.1	0	0	0	0	2.1	0.2	3.3
$\Omega_c(3585)^2S_{1/2}$	0.3	1.0	0.7	3.0	11.6	0.1	1.1	0.5	0	0	0	0	—	—	18.3
$\Omega_c(3654)^4S_{3/2}$	0.1	0.1	1.2	2.8	1.0	17.2	0.2	1.4	0	0	—	0	—	—	24.0
$\Omega_c(3437)^2D_{3/2}$	—	6.5	107.0	53.5	0	0	4.0	27.0	0	0	0	0	—	—	198.0

H. Garcia-Tecocoatzi, A. Giachino, J. Li, A. Ramirez-Morales, and E. Santopinto, PRD107 034031 (2023)

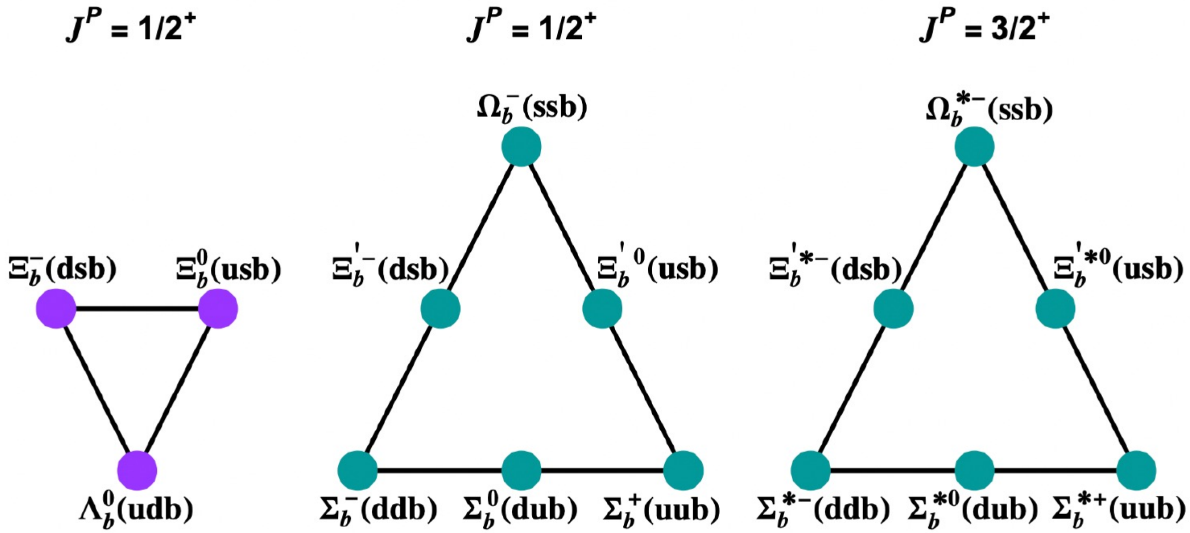
R. Gamboa-Goni, et al., PRD 114, 036020 (2026)





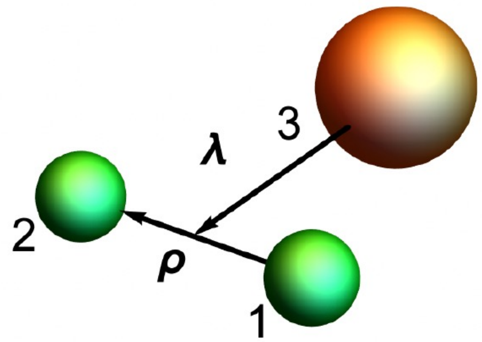
the anti-triplet

Ground state bottom baryons



Mass formula

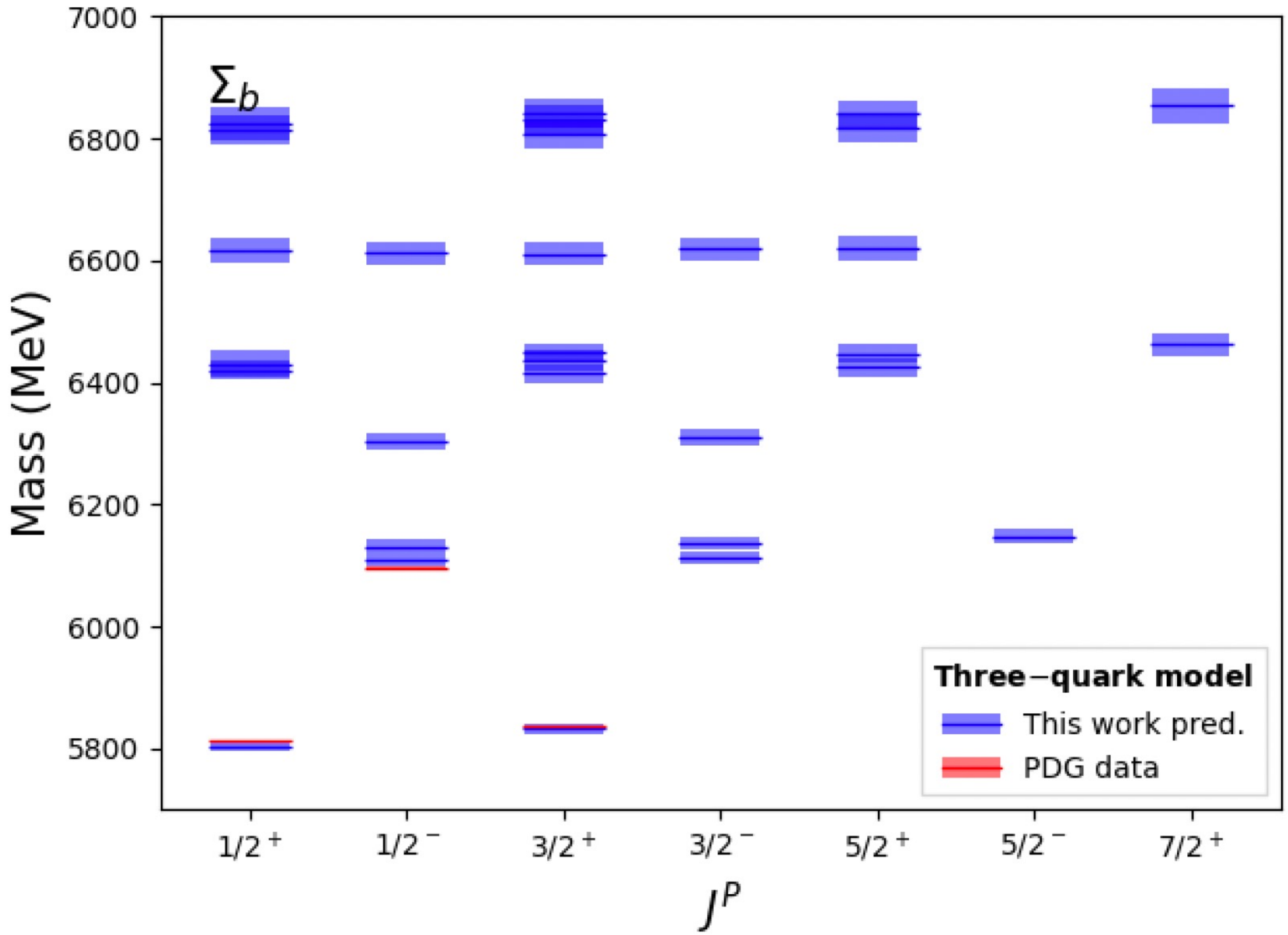
$$H = H_{\text{h.o.}} + a_S \mathbf{S}^2_{\text{tot}} + a_{SL} \mathbf{S}_{\text{tot}} \cdot \mathbf{L}_{\text{tot}} + a_I \mathbf{I}^2 + a_F \hat{\mathbf{C}}_{2(SU(3)}$$



$$\begin{aligned} E^{3q} &= \textstyle\sum_{i=1}^{3} m_i + \omega_\rho n_\rho + \omega_\lambda n_\lambda + a_S [S_{\text{tot}}(S_{\text{tot}}+1)] \\ &+ a_{SL} \tfrac{1}{2} \Big[J(J+1) - L_{\text{tot}}(L_{\text{tot}}+1) - S_{\text{tot}}(S_{\text{tot}}+1) \Big] \\ &+ a_I [I(I+1)] + a_F \tfrac{1}{3} [p(p+3) + q(q+3) + pq] \end{aligned}$$ (

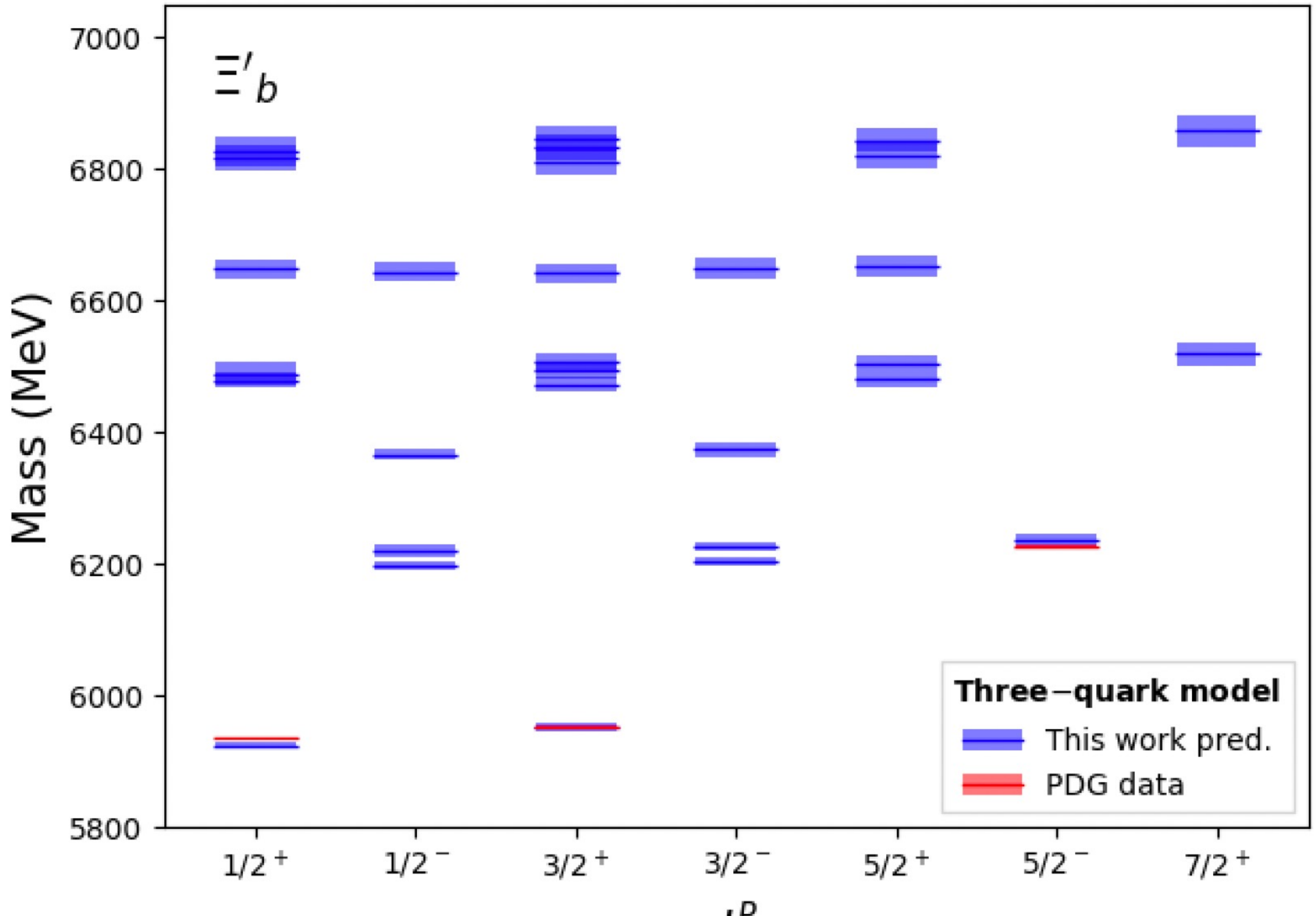
bases on the algebraic model introduced in E. Santopinto et al., EPJC 79(12), 1012 (2019)

Mass spectra of Σ_b



H. García-Tecocoatzi, A. Giachino, A. Ramirez-Morales, A.Rivero-Acosta, E. Santopinto, C. A. Vaquera-Araujo, Phys. Rev. D **110**, 114005 (**2024**)

Mass spectra of Ξ'_b



H. García-Tecocoatzi, A. Giachino, A. Ramirez-Morales, A.Rivero-Acosta, E. Santopinto, C. A. Vaquera-Araujo, Phys. Rev. D **110**, 114005 (**2024**)

Strong decay widths for Λ_b resonances

$\mathcal{F}=\bar{3}_F$				$\Sigma_b\pi$	$\Sigma_b^*\pi$	$\Lambda_b\eta$	$\Sigma_b\rho$	$\Sigma_b^*\rho$	$\Lambda_b\eta'$	$\Lambda_b\omega$	Ξ_bK	$\Xi_b'K$	Ξ_b^*K	Ξ_bK^*	$\Xi_b'K^*$	$\Xi_b^*K^*$	NB	Γ^{Strong}
$\Lambda_b(nnb)$	$\mathbf{J}^P$	$\vert l_\lambda,l_\rho,k_\lambda,k_\rho\rangle$	${}^{2S+1}L_J$	MeV	MeV	MeV	MeV	MeV	MeV	MeV	MeV	MeV	MeV	MeV	MeV	MeV	MeV	
$N=0$																		
$\Lambda_b(5613)$	$\frac{1}{2}^+$	$\vert 0,0,0,0\rangle$	${}^2S_{1/2}$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$N=1$																		
$\Lambda_b(5918)$	$\frac{1}{2}^-$	$\vert 1,0,0,0\rangle$	${}^2P_{1/2}$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$\Lambda_b(5924)$	$\frac{3}{2}^-$	$\vert 1,0,0,0\rangle$	${}^2P_{3/2}$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$\Lambda_b(6114)$	$\frac{1}{2}^-$	$\vert 0,1,0,0\rangle$	${}^2P_{1/2}$	9.3	57.5	0	0	0	0	0	0	0	0	0	0	0	0	66.8
$\Lambda_b(6137)$	$\frac{1}{2}^-$	$\vert 0,1,0,0\rangle$	${}^4P_{1/2}$	4.2	31.3	0	0	0	0	0	0	0	0	0	0	0	0	35.5
$\Lambda_b(6121)$	$\frac{3}{2}^-$	$\vert 0,1,0,0\rangle$	${}^2P_{3/2}$	76.9	7.8	0	0	0	0	0	0	0	0	0	0	0	0	84.7
$\Lambda_b(6143)$	$\frac{3}{2}^-$	$\vert 0,1,0,0\rangle$	${}^4P_{3/2}$	4.2	123.6	0	0	0	0	0	0	0	0	0	0	0	0	127.8
$\Lambda_b(6153)$	$\frac{5}{2}^-$	$\vert 0,1,0,0\rangle$	${}^4P_{5/2}$	26.4	47.9	0	0	0	0	0	0	0	0	0	0	0	0	74.3
$N=2$																		
$\Lambda_b(6225)$	$\frac{3}{2}^+$	$\vert 2,0,0,0\rangle$	${}^2D_{3/2}$	1.4	8.3	-	0	0	0	0	0	0	0	0	0	0	3.3	13.0
$\Lambda_b(6235)$	$\frac{5}{2}^+$	$\vert 2,0,0,0\rangle$	${}^2D_{5/2}$	3.1	1.2	-	0	0	0	0	0	0	0	0	0	0	13.2	17.5
$\Lambda_b(6231)$	$\frac{1}{2}^+$	$\vert 0,0,1,0\rangle$	${}^2S_{1/2}$	0.2	0.4	-	0	0	0	0	0	0	0	0	0	0	0.5	1.1
$\Lambda_b(6624)$	$\frac{1}{2}^+$	$\vert 0,0,0,1\rangle$	${}^2S_{1/2}$	0.3	0.8	-	0.9	0.1	-	1.6	-	0.4	0.2	0	0	0	-	4.3
$\Lambda_b(6421)$	$\frac{3}{2}^+$	$\vert 1,1,0,0\rangle$	${}^2D_{3/2}$	11.4	48.7	1.3	0	0	0	3.2	2.5	0	0	0	0	0	-	67.1
$\Lambda_b(6431)$	$\frac{5}{2}^+$	$\vert 1,1,0,0\rangle$	${}^2D_{5/2}$	81.4	8.0	8.3	0	0	0	0.7	9.4	0.3	0	0	0	0	-	108.1
$\Lambda_b(6438)$	$\frac{1}{2}^+$	$\vert 1,1,0,0\rangle$	${}^4D_{1/2}$	2.2	23.5	1.1	0	0	0	3.3	4.3	0.1	0	0	0	0	-	34.5
$\Lambda_b(6444)$	$\frac{3}{2}^+$	$\vert 1,1,0,0\rangle$	${}^4D_{3/2}$	2.8	75.5	1.2	0	0	0	12.5	2.9	0.1	0	0	0	0	-	95.0
$\Lambda_b(6454)$	$\frac{5}{2}^+$	$\vert 1,1,0,0\rangle$	${}^4D_{5/2}$	9.0	95.1	3.7	0	0	0	15.6	4.5	0.1	0	0	0	0	-	128.0
$\Lambda_b(6468)$	$\frac{7}{2}^+$	$\vert 1,1,0,0\rangle$	${}^4D_{7/2}$	29.1	59.4	12.1	0	0	0	4.8	16.3	0.7	0	0	0	0	-	122.4
$\Lambda_b(6423)$	$\frac{1}{2}^-$	$\vert 1,1,0,0\rangle$	${}^2P_{1/2}$	-	0.5	-	0	0	0	-	-	0	0	0	0	0	-	0.5
$\Lambda_b(6429)$	$\frac{3}{2}^-$	$\vert 1,1,0,0\rangle$	${}^2P_{3/2}$	1.2	0.3	0.1	0	0	0	-	0.1	0	0	0	0	0	-	1.7
$\Lambda_b(6446)$	$\frac{1}{2}^-$	$\vert 1,1,0,0\rangle$	${}^4P_{1/2}$	-	0.3	-	0	0	0	-	-	-	0	0	0	0	-	0.3
$\Lambda_b(6452)$	$\frac{3}{2}^-$	$\vert 1,1,0,0\rangle$	${}^4P_{3/2}$	0.1	1.0	-	0	0	0	0.1	-	-	0	0	0	0	-	1.2
$\Lambda_b(6462)$	$\frac{5}{2}^-$	$\vert 1,1,0,0\rangle$	${}^4P_{5/2}$	0.4	1.3	0.2	0	0	0	0.2	0.2	-	0	0	0	0	-	2.3
$\Lambda_b(6456)$	$\frac{3}{2}^+$	$\vert 1,1,0,0\rangle$	${}^4S_{3/2}$	2.3	14.1	1.1	0	0	0	8.2	5.8	0.3	0	0	0	0	-	31.8
$\Lambda_b(6427)$	$\frac{1}{2}^+$	$\vert 1,1,0,0\rangle$	${}^2S_{1/2}$	12.2	7.0	1.5	0	0	0	3.5	5.2	0	0	0	0	0	-	29.4
$\Lambda_b(6618)$	$\frac{3}{2}^+$	$\vert 0,2,0,0\rangle$	${}^2D_{3/2}$	21.5	53.1	-	9.3	0.1	-	40.7	-	3.1	3.6	0	0	0	-	131.4
$\Lambda_b(6628)$	$\frac{5}{2}^+$	$\vert 0,2,0,0\rangle$	${}^2D_{5/2}$	52.9	93.0	-	1.0	1.1	-	29.2	-	7.5	0.5	0	0	0	-	185.2

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TABLE XIII. Comparison of our predicted $\Xi_b(snb)$ strong decay widths with those of other theoretical studies (in MeV). The flavor multiplet is indicated by the symbol $\mathcal{F}$. The first column contains the three-quark model state, $|l_\lambda, l_\rho, k_\lambda, k_\rho\rangle$, where $l_{\lambda,\rho}$ are the orbital angular momenta and $k_{\lambda,\rho}$ the number of nodes of the λ and ρ oscillators. The second column displays each state's spectroscopic notation $^{2S+1}L_J$. In the third column, our predicted strong decay widths, computed within the $^3P_0$ model and the baryon-meson channels included in the calculation, are shown. Our results are compared with those of Refs. [66] (fourth column), [68] (fifth column), [67] (sixth column), [73] (seventh column), [75] (eighth column), and [100] (ninth column). The experimental widths, as from PDG [1], are reported in the tenth column. The symbol "..." indicates that there is no prediction for that state. The "†" indicates that there is no reported experimental decay width for that state up to now.

$\Xi_b(snb)$ $\|l_\lambda, l_\rho, k_\lambda, k_\rho\rangle$	$\mathcal{F} = \bar{3}_F$ $^{2S+1}L_J$	This work Γ (MeV)	[66] Γ (MeV)	[68] Γ (MeV)	[67] Γ (MeV)	[73] Γ (MeV)	[75] Γ (MeV)	[100] Γ (MeV)	Experimental Γ (MeV)
Channels		$\Lambda_b K, \Xi_b\pi, \Xi'_b\pi$ $\Xi^*_b\pi, \Sigma_b K, \Sigma^*_b K$ $\Xi_b\eta, \Lambda_b K^*, \Xi_b\rho$ $\Xi'_b\rho, \Xi^*_b\rho, \Sigma_b K^*$ $\Sigma^*_b K^*, \Xi'_b\eta, \Xi^*_b\eta$ $\Xi_b\eta', \Xi'_b\eta', \Xi^*_b\eta'$ $\Xi_b\omega, \Xi'_b\omega, \Xi^*_b\omega$ $\Xi_b\phi, \Xi'_b\phi, \Xi^*_b\phi$ $\Lambda_8 B, \Lambda_8 B^*, \Sigma_8 B$ $\Lambda^*_8 B$	$\Xi_b\pi, \Xi'_b\pi$	$\Xi'_b\pi, \Xi^*_b\pi$ $\Sigma_b K, \Sigma^*_b K$	$\Xi'_b\pi, \Xi^*_b\pi$	$\Xi'_b\pi, \Xi^*_b\pi$ $\Sigma_b K, \Sigma^*_b K$	$\Xi_b\pi, \Xi'_b\pi$ $\Xi^*_b\pi$	$\Sigma_b\bar{K}, \Xi'_b\pi$ $\Sigma^*_b\bar{K}, \Xi^*_b\pi$ $\Lambda_b\bar{K}, \Xi_b\pi$ $\Xi_b\eta$	
$N = 0$									
$\|0,0,0,0\rangle$	$^2S_{1/2}$	0	...	...	...	...	...	0	≈0
$N = 1$									
$\|1,0,0,0\rangle$	$^2P_{1/2}$	0	11	...	3	18	4	0	†
$\|1,0,0,0\rangle$	$^2P_{3/2}$	1	≈0	...	3	16	3	0	<1.9
$\|0,1,0,0\rangle$	$^2P_{1/2}$	9	223	...	...	...	...	0.55	†
$\|0,1,0,0\rangle$	$^4P_{1/2}$	6	10	...	...	...	...	0.36	†
$\|0,1,0,0\rangle$	$^2P_{3/2}$	66	...	...	...	...	...	1.90	†
$\|0,1,0,0\rangle$	$^4P_{3/2}$	26	...	...	...	...	...	1.90	†
$\|0,1,0,0\rangle$	$^4P_{5/2}$	68	...	...	...	...	...	2.16	†
$N = 2$									
$\|2,0,0,0\rangle$	$^2D_{3/2}$	2	...	7	...	7	...	0.19	<2.2
$\|2,0,0,0\rangle$	$^2D_{5/2}$	2	...	7	...	6	...	0.10	<1.6
$\|0,0,1,0\rangle$	$^2S_{1/2}$	5	...	...	...	7	16	...	†
$\|0,0,0,1\rangle$	$^2S_{1/2}$	179	...	...	...	...	...	...	†
$\|1,1,0,0\rangle$	$^2D_{3/2}$	46	...	...	...	...	...	...	†
$\|1,1,0,0\rangle$	$^2D_{5/2}$	108	...	...	...	...	...	...	†
$\|1,1,0,0\rangle$	$^4D_{1/2}$	20	...	...	...	...	...	...	†
$\|1,1,0,0\rangle$	$^4D_{3/2}$	67	...	...	...	...	...	...	†
$\|1,1,0,0\rangle$	$^4D_{5/2}$	100	...	...	...	...	...	...	†
$\|1,1,0,0\rangle$	$^4D_{7/2}$	114	...	...	...	...	...	...	†
$\|1,1,0,0\rangle$	$^2P_{1/2}$	0	...	...	...	...	...	...	†
$\|1,1,0,0\rangle$	$^2P_{3/2}$	2	...	...	...	...	...	...	†
$\|1,1,0,0\rangle$	$^4P_{1/2}$	0	...	...	...	...	...	...	†
$\|1,1,0,0\rangle$	$^4P_{3/2}$	1	...	...	...	...	...	...	†
$\|1,1,0,0\rangle$	$^4P_{5/2}$	2	...	...	...	...	...	...	†
$\|1,1,0,0\rangle$	$^4S_{3/2}$	33	...	...	...	...	...	...	†
$\|1,1,0,0\rangle$	$^2S_{1/2}$	31	...	...	...	...	...	...	†
$\|0,2,0,0\rangle$	$^2D_{3/2}$	127	...	...	...	...	...	...	†
$\|0,2,0,0\rangle$	$^2D_{5/2}$	98	...	...	...	...	...	...	†

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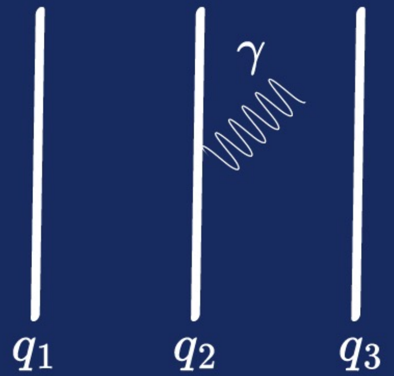
Electromagnetic decays

$$B \longrightarrow B' + \gamma$$



- Electromagnetic Hamiltonian: Spin Flip + Orbit Flip

$$H_{em} = 2\sqrt{\frac{\pi}{\mathrm{k}_0}}\sum_{j=1}^{3}\hat{\mu}_j\left[\mathrm{k}\,\vec{\mathrm{s}}_{j,-}\,e^{-i\vec{k}\cdot\vec{r}_j} - \frac{1}{2}\left(\vec{\mathrm{p}}_{j,-}\,e^{-i\vec{k}\cdot\vec{r}_j} + e^{-i\vec{k}\cdot\vec{r}_j}\,\vec{\mathrm{p}}_{j,-}\right)\right]$$

- Transition Amplitude

$$A_{M_{J_B}} = \langle J'_B, M_{J_B} - 1|H_{em}|J_B, M_B\rangle.$$

- Electromagnetic Decay Width

$$\Gamma_{em}(B \to B'\gamma) = \Phi_{B\to B'\gamma}\frac{1}{(2\pi)^2}\frac{2}{(2J_B+1)}\sum_{M_{J_B}>0}|A_{M_{J_B}}|^2$$

We introduced a new method to calculate the convective term in H. García-Tecocoatzi ,A. Ramirez-Morales, A. Rivero-Acosta, E. Santopinto, C.A. Vaquera-Araujo, Phys. Lett. B 868 (2025) 139666, without replacing $\mathbf{p}_j/m_j$ with $i\mathrm{k}\mathbf{r}_j$ (Close-Copley replacement) as done previously

Results: Electromagnetic decays

A. Dávila-Rivera, H. García-Tecocoatzi, A. Ramirez-Morales, A. Rivero-Acosta, E. Santopinto, and C. A. Vaquera-Araujo, **Phys. Rev. D 113, 093001** (2026), doi:10.1103/srjs-mrs3.

$\mathcal{F}=\mathbf{6}_{\mathrm{F}}$				$\Omega_c\gamma$	$\Omega_c^*\gamma$	
$\Omega_c(ssc)$	$\mathbf{J^P}$	$\lvert l_\lambda,l_\rho,k_\lambda,k_\rho\rangle$	$^{2S+1}L_{x,J}$	$^2S_{1/2}$	$^4S_{3/2}$	
$N=0$						
$\Omega_c(2709)$	$\frac{1}{2}^+$	$\lvert 0,0,0,0\rangle$	$^2S_{1/2}$	0	0	
$\Omega_c(2778)$	$\frac{3}{2}^+$	$\lvert 0,0,0,0\rangle$	$^4S_{3/2}$	$1{,}4^{+1,6}_{-1,0}$	0	
				0.89	...	[211]
				1	...	[212]
$N=1$						
$\Omega_c(3007)$	$\frac{1}{2}^-$	$\lvert 1,0,0,0\rangle$	$^2P_{\lambda,1/2}$	212^{+15}_{-14}	$0{,}1^{+0,0}_{-0,0}$	
				200-360	$\sim$10	[211]
				135.7	0	[212]
$\Omega_c(3049)$	$\frac{1}{2}^-$	$\lvert 1,0,0,0\rangle$	$^4P_{\lambda,1/2}$	$0{,}3^{+0,2}_{-0,2}$	37^{+4}_{-4}	
				...	...	[211]
				0.2	17.5	[212]
$\Omega_c(3034)$	$\frac{3}{2}^-$	$\lvert 1,0,0,0\rangle$	$^2P_{\lambda,3/2}$	320^{+22}_{-22}	$0{,}1^{+0,1}_{-0,1}$	
				350	0.568	[211]
				251.6	0.1	[212]
$\Omega_c(3077)$	$\frac{3}{2}^-$	$\lvert 1,0,0,0\rangle$	^4P [illegible]	$1{,}2^{+0,7}$ [illegible]	142^{+8} [illegible]	

$\mathcal{F}=\mathbf{6}_{\mathrm{F}}$				$\Omega_c\gamma$	$\Omega_c^*\gamma$	$\Omega_c\gamma$	$\Omega_c\gamma$	$\Omega_c\gamma$	$\Omega_c\gamma$	$\Omega_c\gamma$	$\Omega_c\gamma$	$\Omega_c\gamma$	
$\Omega_c(ssc)$	$\mathbf{J^P}$	$\lvert l_\lambda,l_\rho,k_\lambda,k_\rho\rangle$	$^{2S+1}L_{x,J}$	$^2S_{1/2}$	$^4S_{3/2}$	$^2P_{\lambda,1/2}$	$^4P_{\lambda,1/2}$	$^2P_{\lambda,3/2}$	$^4P_{\lambda,3/2}$	$^4P_{\lambda,5/2}$	$^2P_{\rho,1/2}$	$^2P_{\rho,3/2}$	
$N=2$													
$\Omega_c(3315)$	$\frac{3}{2}^+$	$\lvert 2,0,0,0\rangle$	$^2D_{\lambda\lambda,3/2}$	$1{,}9^{+1,0}_{-1,0}$	$0{,}4^{+0,1}_{-0,1}$	384^{+29}_{-29}	$0{,}3^{+0,1}_{-0,1}$	44^{+4}_{-3}	$0{,}1^{+0,0}_{-0,0}$	0	0	0	[213]
				...	...	91,8	0,13	18.4	0.2	0.03	...	...	
$\Omega_c(3360)$	$\frac{5}{2}^+$	$\lvert 2,0,0,0\rangle$	$^2D_{\lambda\lambda,5/2}$	20^{+8}_{-8}	$0{,}6^{+0,1}_{-0,1}$	7^{+2}_{-2}	$0{,}1^{+0,0}_{-0,0}$	564^{+42}_{-47}	$0{,}2^{+0,1}_{-0,1}$	$0{,}1^{+0,1}_{-0,0}$	0	0	[213]
				...	...	9,79	0,008	39.7	0.09	0.14	...	...	
$\Omega_c(3330)$	$\frac{1}{2}^+$	$\lvert 2,0,0,0\rangle$	$^4D_{\lambda\lambda,1/2}$	$0{,}8^{+0,3}_{-0,3}$	$0{,}8^{+0,5}_{-0,5}$	$0{,}4^{+0,2}_{-0,2}$	315^{+21}_{-22}	0	24^{+4}_{-4}	$0{,}1^{+0,1}_{-0,1}$	0	0	[213]
				...	...	0,03	70,3	0.04	27.5	2.44	...	...	[175]
				0.2	11.4	...	...	...	...	...	...	...	
$\Omega_c(3357)$	$\frac{3}{2}^+$	$\lvert 2,0,0,0\rangle$	$^4D_{\lambda\lambda,3/2}$	$2{,}0^{+0,6}_{-0,5}$	$2{,}0^{+0,9}_{-1,0}$	$1{,}3^{+0,8}_{-0,7}$	206^{+17}_{-18}	$0{,}1^{+0,0}_{-0,0}$	142^{+9}_{-10}	$4{,}8^{+0,7}_{-0,7}$	0	0	[213]
				...	...	0,49	34,7	0.02	54.1	7.95	...	...	
$\Omega_c(3402)$	$\frac{5}{2}^+$	$\lvert 2,0,0,0\rangle$	$^4D_{\lambda\lambda,5/2}$	$3{,}7^{+0,9}_{-0,7}$	$4{,}3^{+1,9}_{-2,0}$	$0{,}8^{+0,4}_{-0,4}$	6^{+2}_{-2}	$1{,}4^{+0,7}_{-0,7}$	378^{+27}_{-28}	71^{+5}_{-5}	0	0	[213]
				...	...	0,19	5,56	0.17	39.8	19.6	...	...	
$\Omega_c(3466)$	$\frac{7}{2}^+$	$\lvert 2,0,0,0\rangle$	$^4D_{\lambda\lambda,7/2}$	$3{,}6^{+0,9}_{-0,8}$	20^{+9}_{-9}	0	$0{,}3^{+0,2}_{-0,1}$	$2{,}5^{+1,4}_{-1,3}$	10^{+4}_{-3}	637^{+70}_{-75}	0	0	[213]
				...	...	0	1,07	0.13	5.62	23.1	...	...	[175]
				0.4	3.9	...	...	...	...	...	...	...	
$\Omega_c(3342)$	$\frac{1}{2}^+$	$\lvert 0,0,1,0\rangle$	$^2S_{1/2}$	13^{+4}_{-3}	$1{,}2^{+0,3}_{-0,3}$	344^{+38}_{-40}	0	16^{+7}_{-6}	0	$0{,}4^{+0,3}_{-0,2}$	0	0	[175]
				3	0.2	...	...	...	...	...	...	...	
$\Omega_c(3412)$	$\frac{3}{2}^+$	$\lvert 0,0,1,0\rangle$	$^4S_{3/2}$	7^{+2}_{-2}	8^{+3}_{-3}	$4{,}0^{+1,9}_{-2,0}$	125^{+12}_{-12}	10^{+5}_{-4}	153^{+12}_{-13}	5^{+3}_{-2}	0	0	[175]
				5.4	1.9	...	...	...	...	...	...	...	
$\Omega_c(3585)$	$\frac{1}{2}^+$	$\lvert 0,0,0,1\rangle$	$^2S_{1/2}$	57^{+12}_{-11}	5^{+1}_{-1}	$0{,}9^{+1,0}_{-0,6}$	0	21^{+11}_{-9}	0	$0{,}4^{+0,3}_{-0,2}$	55^{+16}_{-14}	132^{+42}_{-37}	
$\Omega_c(3655)$	$\frac{3}{2}^+$	$\lvert 0,0,0,1\rangle$	$^4S_{3/2}$	18^{+3}_{-4}	51^{+10}_{-11}	$3{,}2^{+1,9}_{-1,5}$	$0{,}8^{+0,1}_{-0,1}$	7^{+4}_{-3}	$1{,}8^{+0,6}_{-0,5}$	11^{+7}_{-5}	85^{+20}_{-19}	214^{+56}_{-53}	
$\Omega_c(3436)$	$\frac{3}{2}^+$	$\lvert 1,1,0,0\rangle$	$^2D_{\lambda\rho,3/2}$	14^{+4}_{-4}	$4{,}7^{+1,6}_{-1,4}$	$2{,}6^{+0,7}_{-0,7}$	6^{+2}_{-2}	$2{,}6^{+0,7}_{-0,6}$	$1{,}5^{+0,5}_{-0,5}$	$0{,}1^{+0,0}_{-0,0}$	194^{+13}_{-14}	28^{+2}_{-2}	
$\Omega_c(3482)$	$\frac{5}{2}^+$	$\lvert 1,1,0,0\rangle$	$^2D_{\lambda\rho,5/2}$	19^{+5}_{-5}	6^{+2}_{-2}	7^{+2}_{-2}	$0{,}9^{+0,4}_{-0,3}$	5^{+1}_{-1}	$3{,}4^{+1,2}_{-0,9}$	$2{,}0^{+0,8}_{-0,6}$	$1{,}8^{+0,7}_{-0,6}$	245^{+19}_{-19}	
$\Omega_c(3445)$	$\frac{1}{2}^-$	$\lvert 1,1,0,0\rangle$	$^2P_{\lambda\rho,1/2}$	0	0	0	8^{+3}_{-3}	0	$4{,}6^{+1,5}_{-1,3}$	$0{,}7^{+0,3}_{-0,2}$	192^{+16}_{-15}	24^{+2}_{-2}	
$\Omega_c(3473)$	$\frac{3}{2}^-$	$\lvert 1,1,0,0\rangle$	$^2P_{\lambda\rho,3/2}$	0	0	10^{+3}_{-2}	$3{,}3^{+1,3}_{-1,1}$	$3{,}8^{+1,1}_{-0,9}$	$3{,}6^{+1,1}_{-0,9}$	$0{,}9^{+0,4}_{-0,3}$	57^{+5}_{-6}	165^{+13}_{-14}	

[175] Yu-Xin Peng, Si-Qiang Luo, and Xiang Liu. Refining radiative decay studies in singly heavy baryons. Phys. Rev. D, 110(7):074034, 2024.

[213] Ya-Xiong Yao, Kai-Lei Wang, and Xian-Hui Zhong. Strong and radiative decays of the low-lying D-wave singly heavy baryons. Phys. Rev. D, 98(7):076015, 2018.

[211] Kai-Lei Wang, Li-Ye Xiao, Xian-Hui Zhong, and Qiang Zhao. Understanding the newly observed Ωc states through their decays. Phys. Rev. D, 95(11):116010, 2017. 119, 123

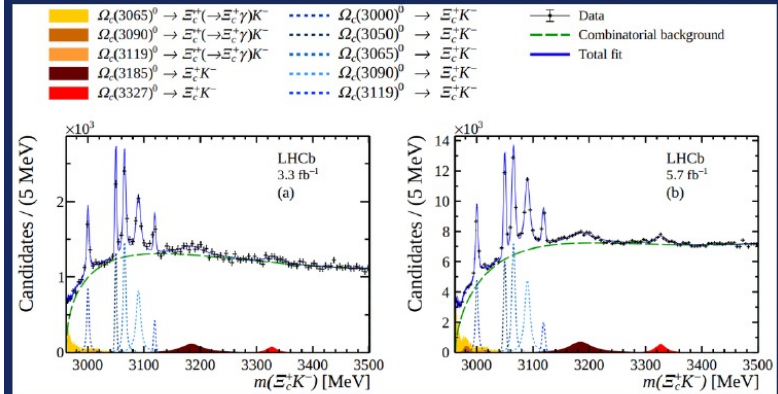
see also

R. Gamboa-Goni, H. García-Tecocoatzi, Ailier Rivero-Acosta, A. Gutierrez-Rodriguez, A. Ramirez-Morales, Santopinto, Carlos Alberto Vaquera-Araujo, PRD 114, 036020 (2026)

Why Electromagnetic Decays?

Case 1: $\Omega_c(3327)$

$$M = 3327.1 \pm 1.2^{+0.1}_{-1.3} \pm 0.2 \text{ MeV}, \quad \Gamma = 20 \pm 5^{+13}_{-1} \text{ MeV}.$$



R. Aaij et al. Observation of New Ωc0 States Decaying to the Ξc+K- Final State. Phys. Rev. Lett., 131(13):131902, 2023. 127

- Strong decay: In the 3315–3330 MeV region, the theory predicts two possible λ-mode

$$\Omega_c(2D_{\lambda\lambda},, J^P = 3/2^+) \quad M \approx 3315 \text{ MeV}, \quad \Gamma_{\text{strong}} \approx 11 \text{ MeV}$$

$$\Omega_c(4D_{\lambda\lambda},, J^P = 1/2^+) \quad M \approx 3330 \text{ MeV}, \quad \Gamma_{\text{strong}} \approx 16 \text{ MeV}$$

H. Garcia-Tecocoatzi, A. Giachino, J. Li, A. RamirezMorales, and E. Santopinto. Strong decay widths and mass spectra of charmed baryons. Phys. Rev. D, 107(3): 034031, 2023. doi: 10.1103/PhysRevD.107.034031.

Both compatible with $\Omega_c(3327)$

- EM decay:

$$\Gamma_{\text{em}}[\Omega_c(3315) \to \Omega_c(3008)\gamma] = 384 \pm 29 \text{ keV}$$

$$\Gamma_{\text{em}}[\Omega_c(3330) \to \Omega_c(3008)\gamma] = 0.4 \pm 0.2 \text{ keV}$$

Branching ratio

3315: $\dfrac{\Gamma_{em}(\Omega_c(3315) \to \Omega_c(3008)\gamma)}{\Gamma_{em}(\Omega_c(3315) \to \Omega_c(3050)\gamma)} = 1280^{+437}_{-437}$

3330: $\dfrac{\Gamma_{em}(\Omega_c(3330) \to \Omega_c(3008)\gamma)}{\Gamma_{em}(\Omega_c(3330) \to \Omega_c(3050)\gamma)} = 0.0013^{+0.0006}_{-0.0006}$

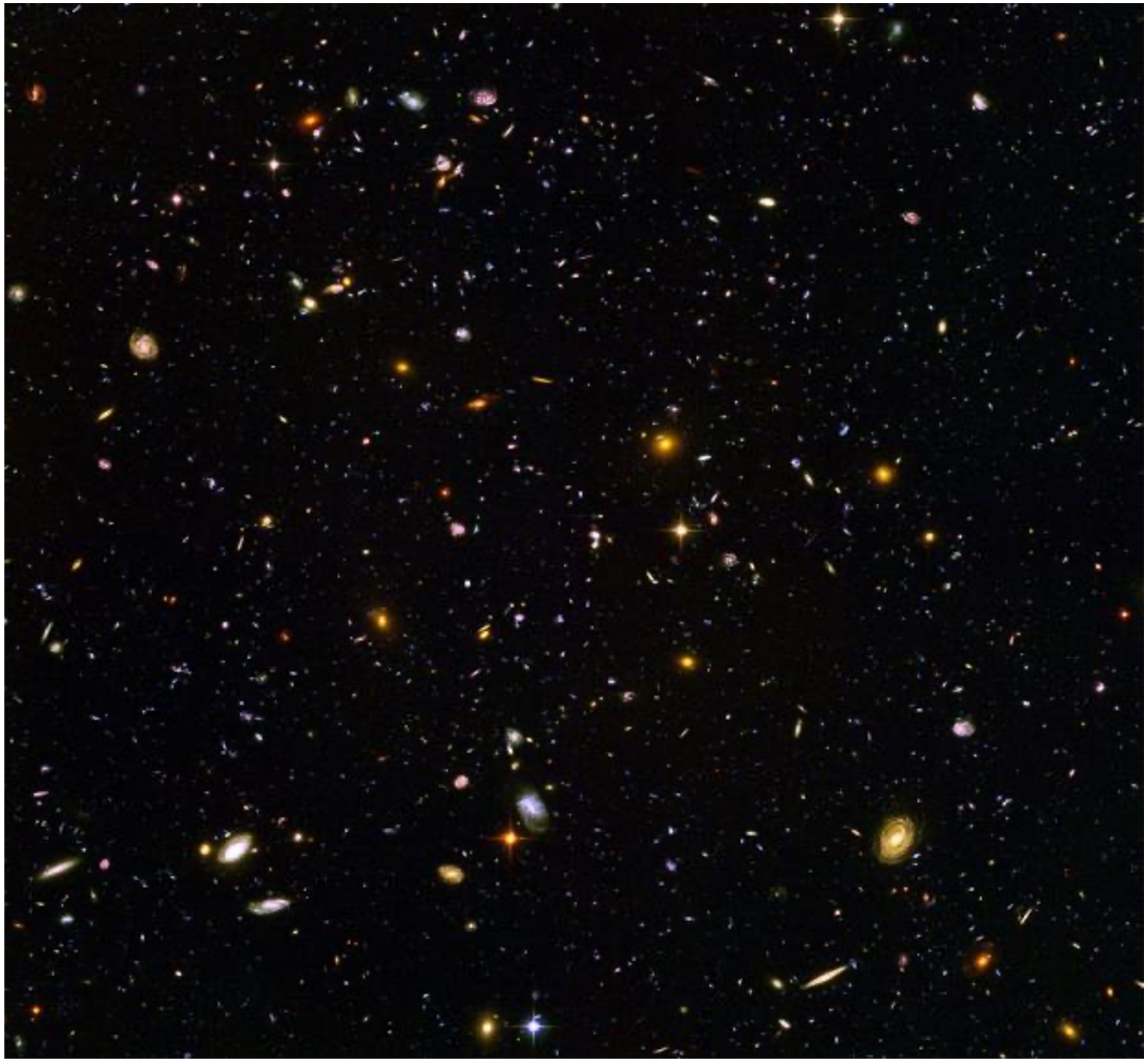
Six orders of magnitude

A. Dávila-Rivera, H. García-Tecocoatzi, A. Ramirez-Morales, A. Rivero-Acosta, E. Santopinto, and C. A. Vaquera-Araujo, Radiative decays of the Σc, Ξ′c and Ωc charmed baryons, arXiv:2512.03008 [hep-ph] (2025).

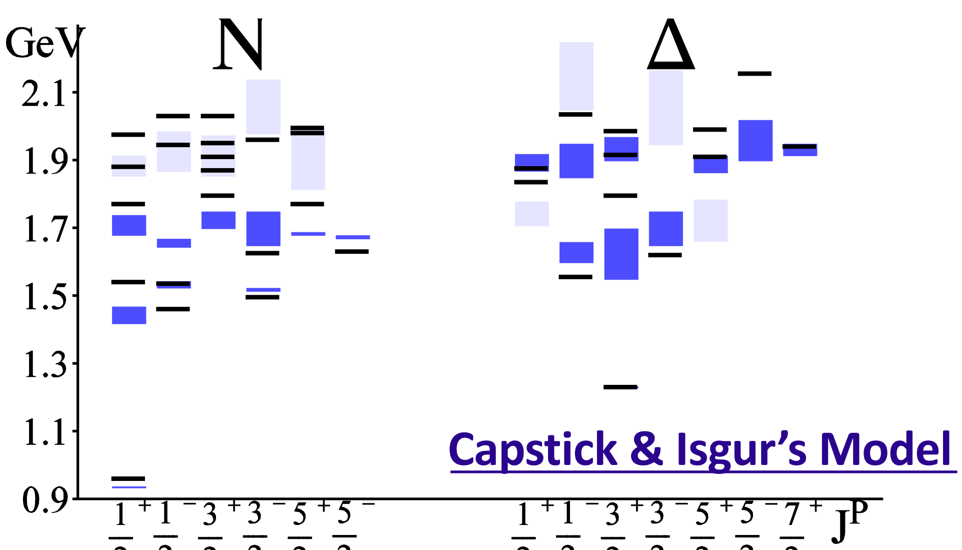
A. Dávila-Rivera, H. García-Tecocoatzi, A. Ramirez-Morales, Ailier Rivero-Acosta, E. Santopinto, Carlos Alberto Vaquera-Araujo, D 113, 093001 (2026)

- Electromagnetic decays prove decisive in distinguishing between possible quantum-number assignments, even when masses and strong decays cannot differentiate them.
- Showed that electromagnetic decays act as a fingerprint of singly charmed baryons, providing complementary information for quantum-number assignments.

Thanks for your attention!

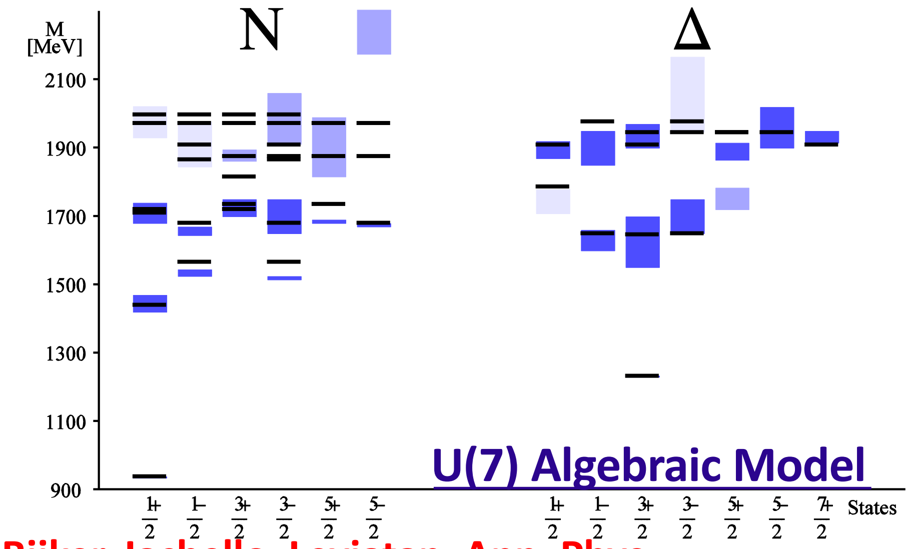


Non strange spectrum



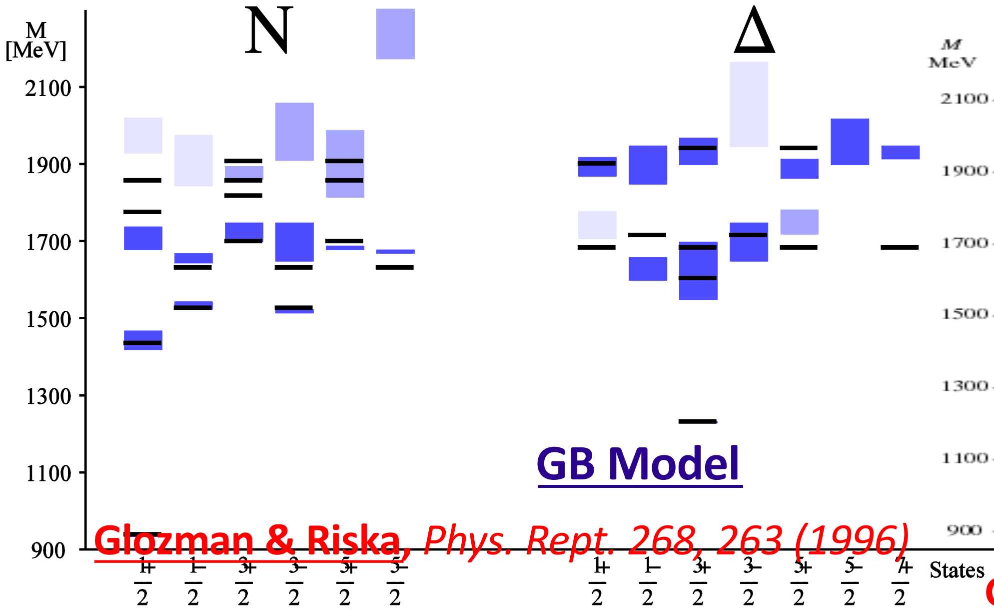
Capstick & Isgur's Model

Capstick and Isgur, *Phys. Rev. D34, 2809.*



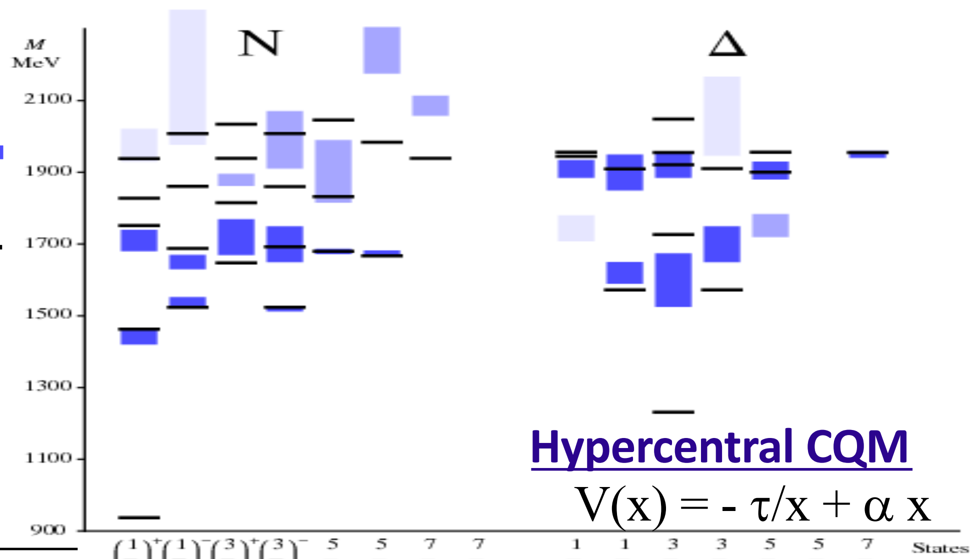
U(7) Algebraic Model

Bijker, Iachello, Leviatan, Ann. Phys. 236, 69 (1994)



GB Model

Glozman & Riska, *Phys. Rept. 268, 263 (1996)*



Hypercentral CQM

$V(x) = -\tau/x + \alpha x$

Giannini, Santopinto, Vassallo, *Eur. Phys. J .A12:447*

SU(6) configurations for three quark states

6 X 6 X 6 =	20	+	70	+	70	+	56
	A		M		M		S

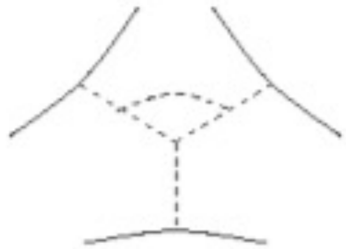
Notation

(d, L^{π})

d = dim of SU(6) irrep
L = total orbital angular momentum
π = parity

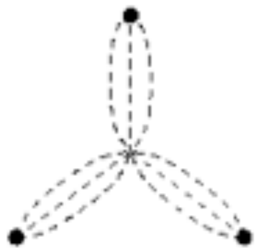
- QCD fundamental mechanism

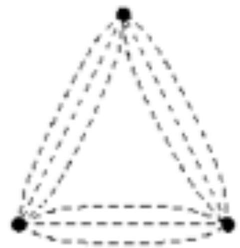
3-body forces



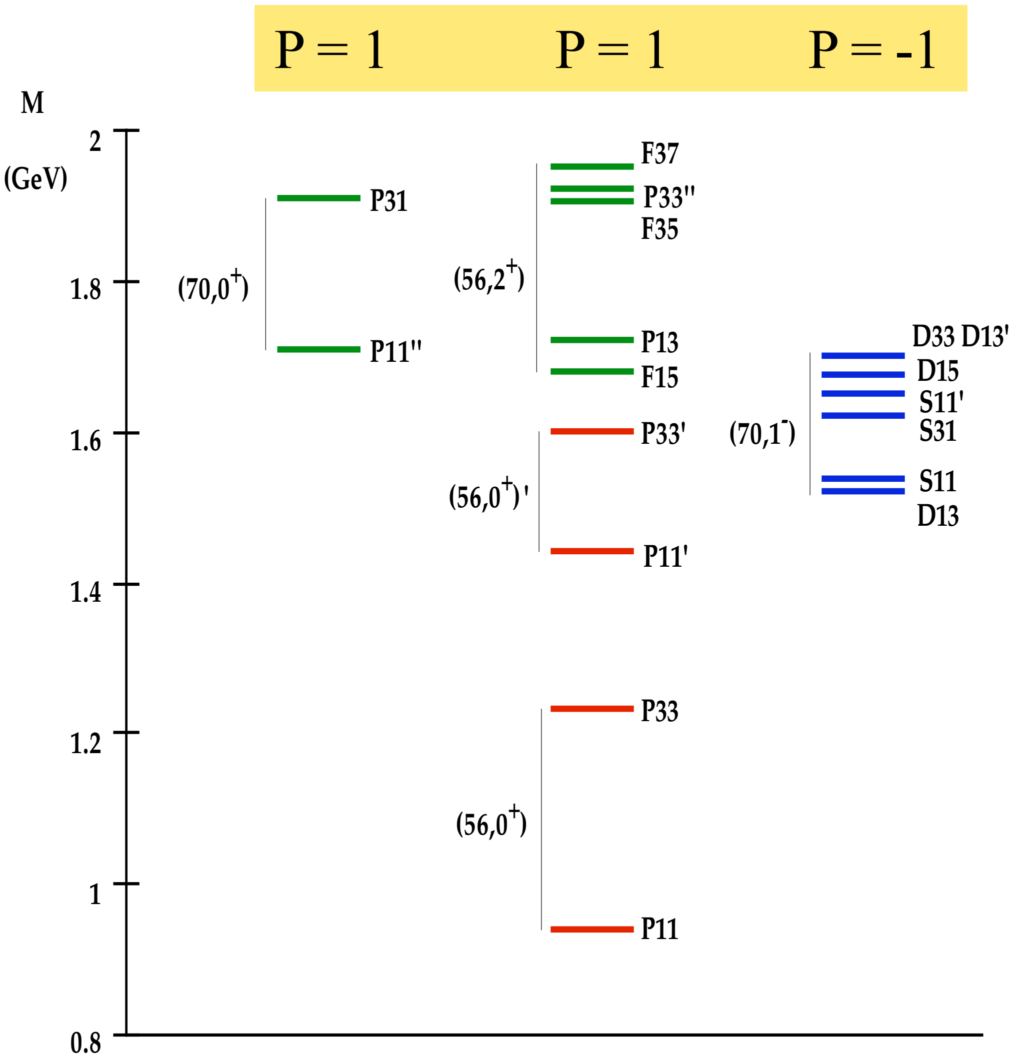
Carlson et al, 1983
Capstick-Isgur 1986
hCQM 1995

- Flux tube model

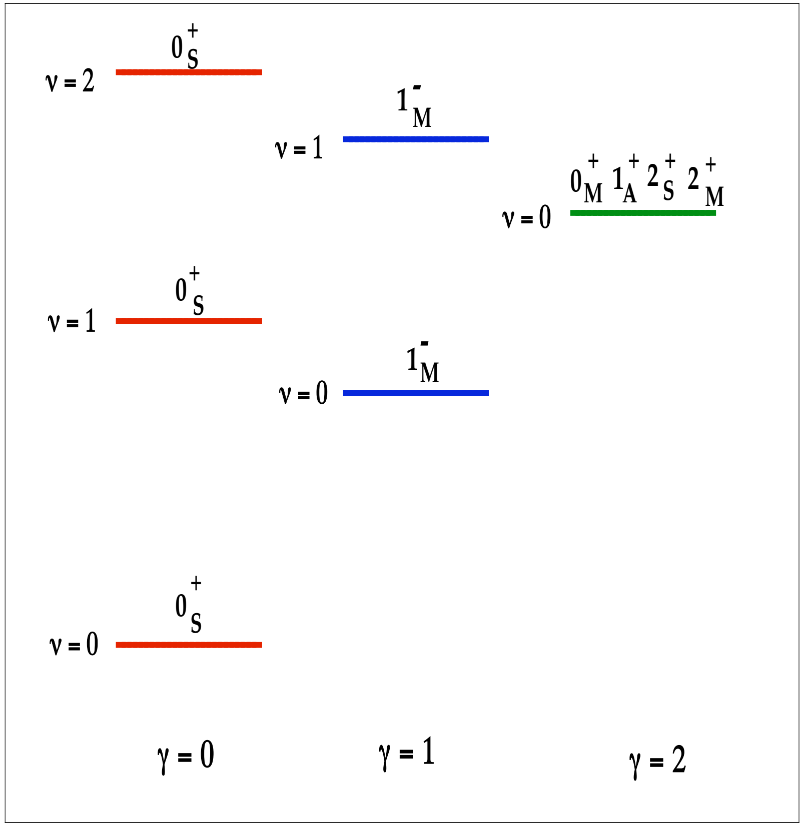




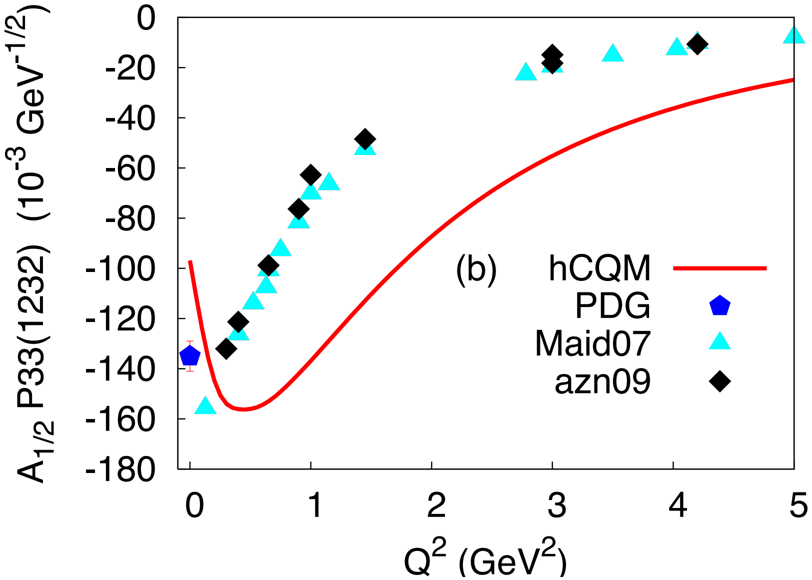
PDG 4* & 3*

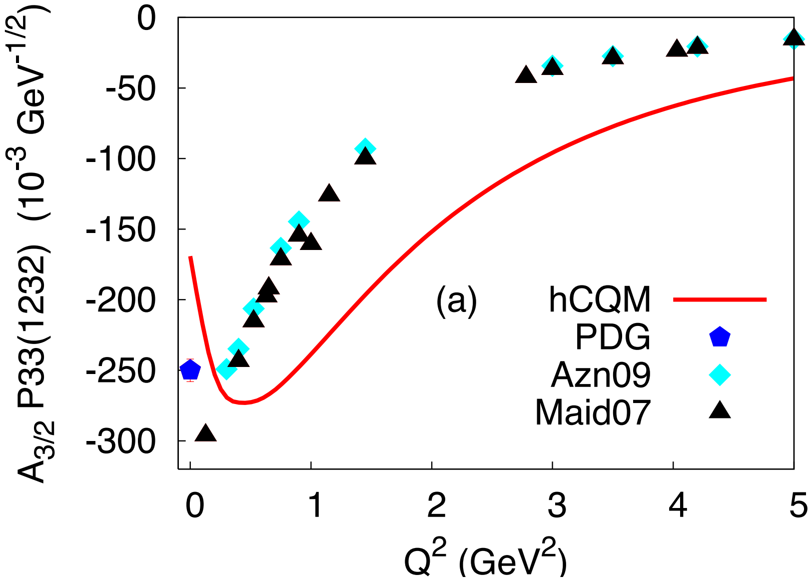


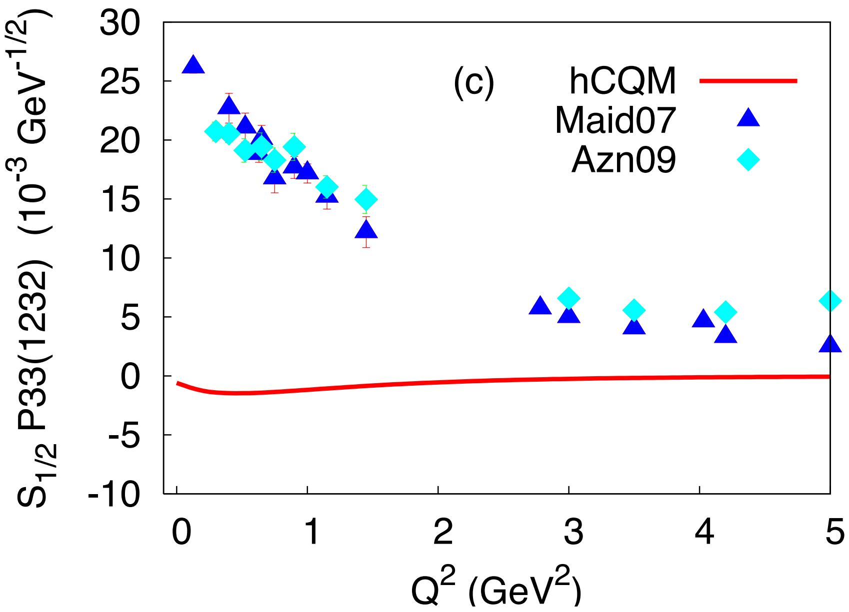
$V(x) = - \tau/x + \alpha\, x$



Δ(1232) $3/2^+$ transition amplitudes

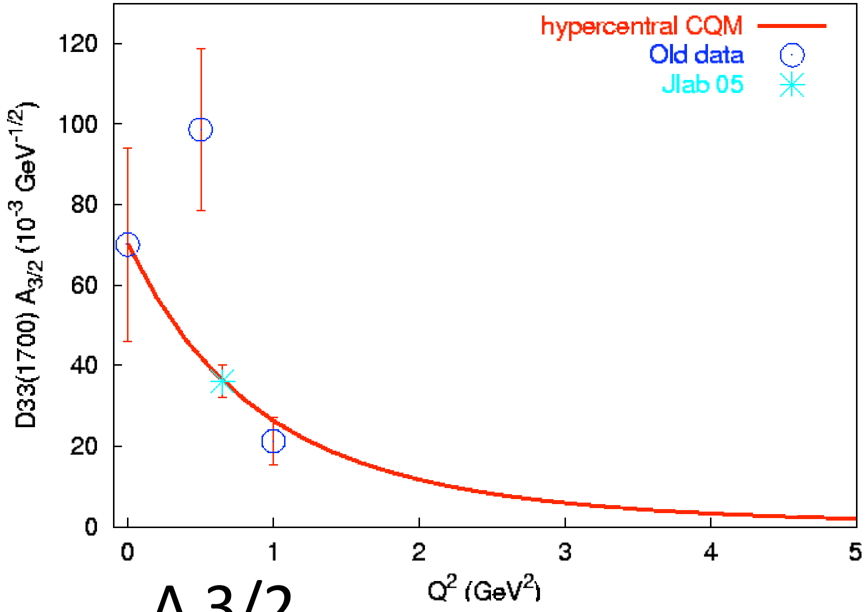






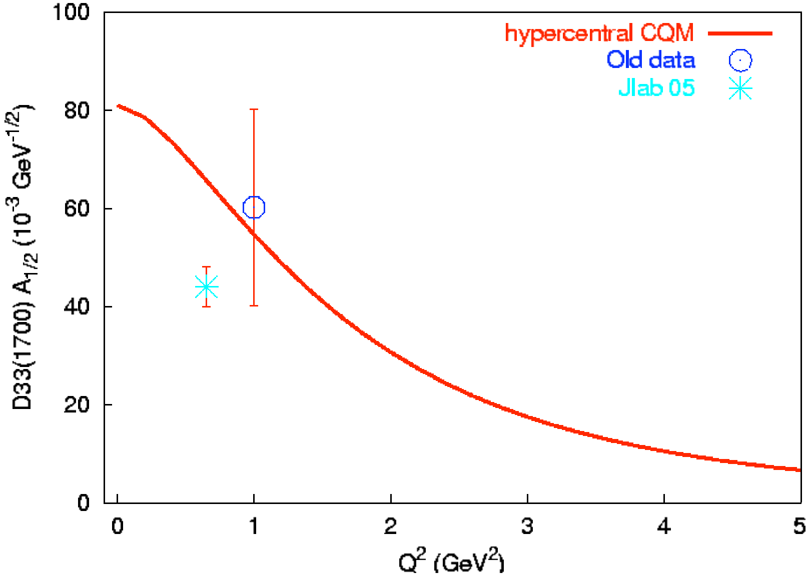
E. Santopinto, M.G.
Phys. Rev. C86,
065202 (2012)

D33(1700)



A 3/2

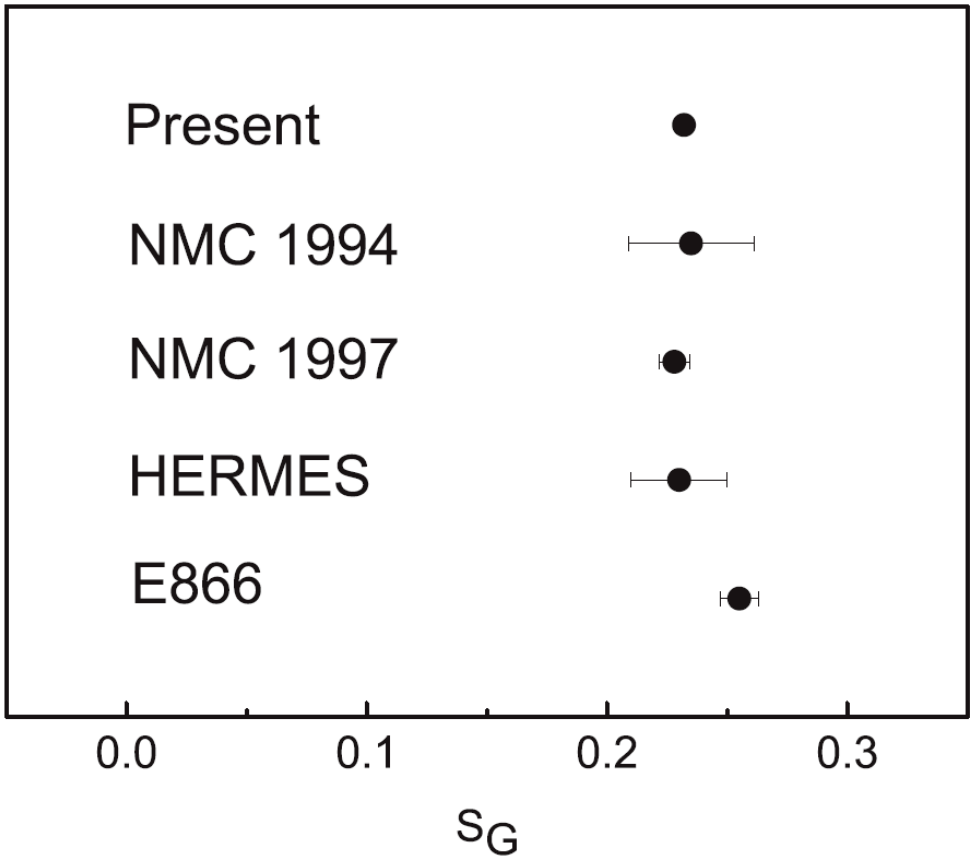
A 1/2

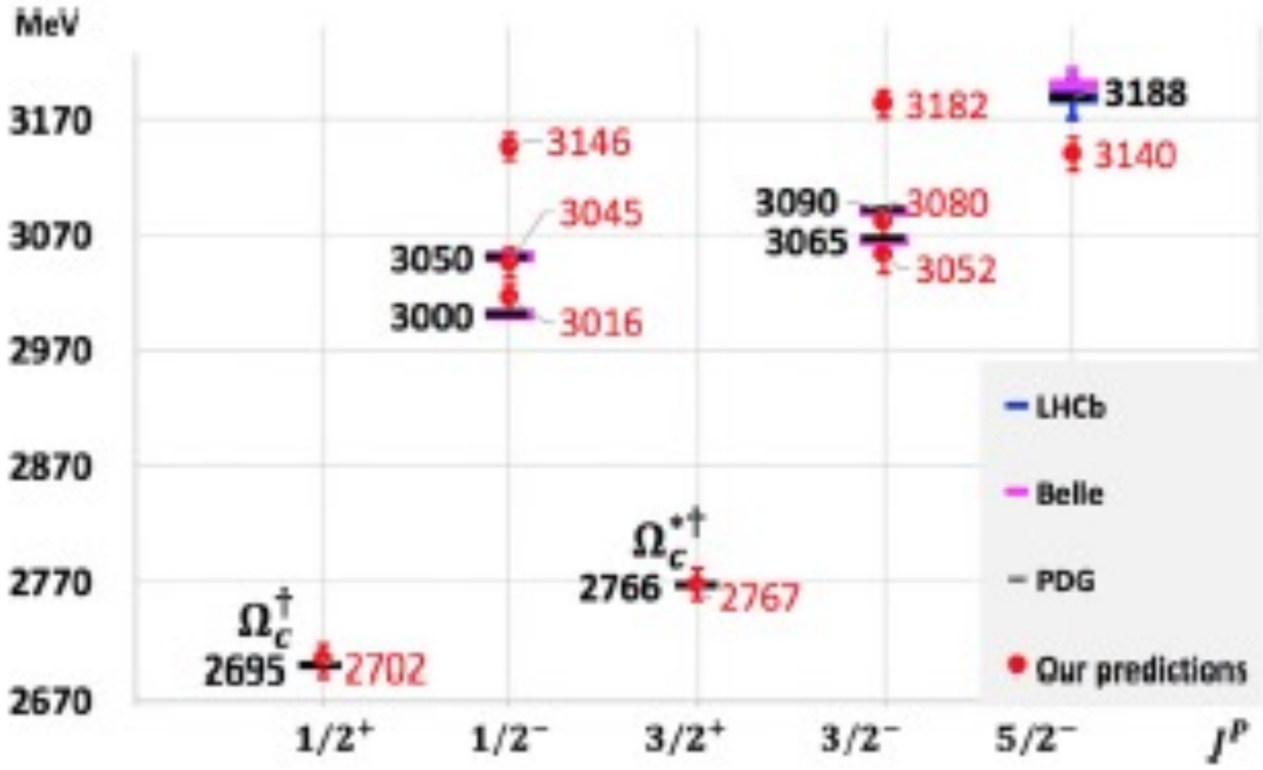


E. Santopinto, M.Giannini,Phys. Rev. C86, 065202 (2012)

Proton Flavor asymmetry

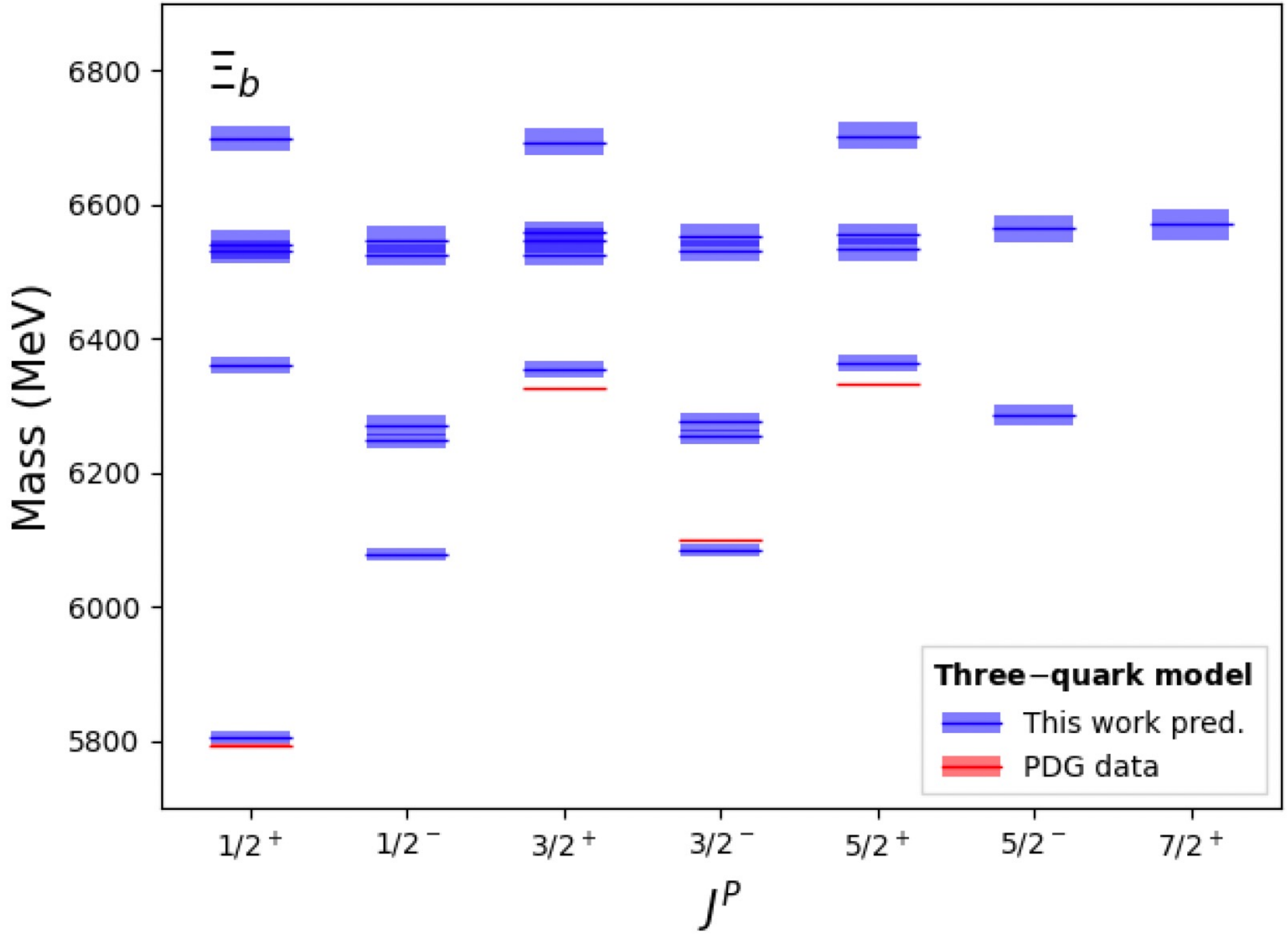
Santopinto, Bijker, PRC 82,062202(R) (2010)





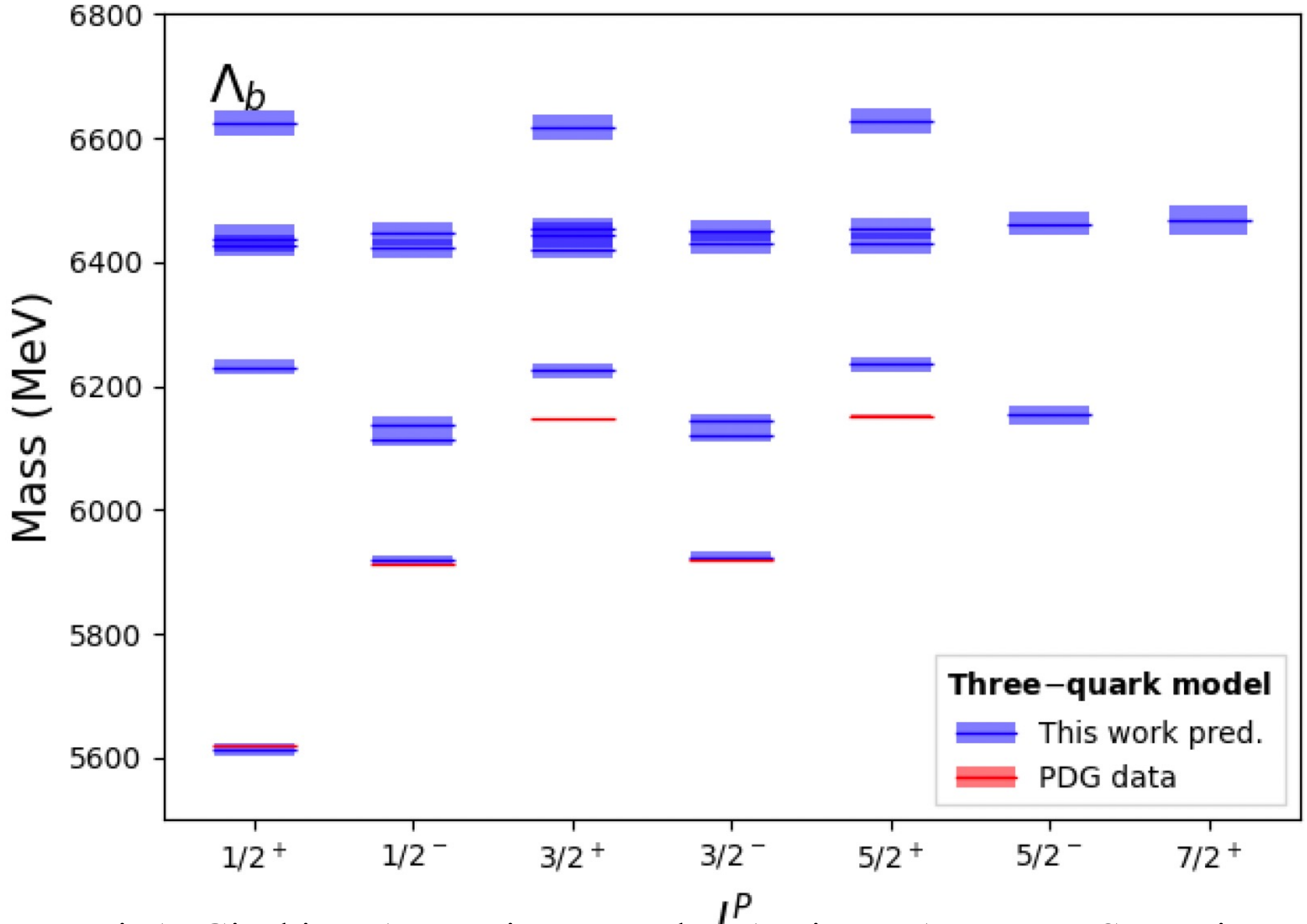
MeV
3170
3070
2970
2870
2770
2670
3146
3045
3050
3000
3016
3090
3080
3065
3052
3182
3188
3140
$\Omega_c^\dagger$
2695
2702
$\Omega_c^{*\dagger}$
2766
2767
1/2+
1/2−
3/2+
3/2−
5/2−
J^P
LHCb
Belle
PDG
Our predictions

Mass spectra of Ξ_b



H. García-Tecocoatzi, A. Giachino, A. Ramirez-Morales, A.Rivero-Acosta, E. Santopinto, C. A. Vaquera-Araujo, Phys. Rev. D **110**, 114005 (**2024**)

Mass spectra of Λ_b



H. García-Tecocoatzi, A. Giachino, A. Ramirez-Morales, A.Rivero-Acosta, E. Santopinto, C. A. Vaquera-Araujo, Phys. Rev. D **110**, 114005 (**2024**)

Case 2: $\Xi_c(2923)^+$

In 2025, LHCb reported the state $\Xi'_c(2923)^+$: $M = 2922.85$ MeV, $\Gamma = 5.3$ MeV.

Both measurements are consistent with previous predictions.

H. Garcia-Tecocoatzi, A. Giachino, J. Li, A. RamirezMorales, and E. Santopinto. Strong decay widths and mass spectra of charmed baryons. Phys. Rev. D, 107(3): 034031, 2023. doi: 10.1103/PhysRevD.107.034031.

* Strong decay:

The state is identified as an excited state

P_λ

It belongs to the flavor sextet, within the states

$\Xi'_c(1P)$

Possible quantum numbers

$J^P = \frac{1}{2}^-, \quad S = \frac{2}{3}$

A. Dávila-Rivera, H. García-Tecocoatzi, A. Ramirez-Morales, A. Rivero-Acosta, E. Santopinto, and C. A. Vaquera-Araujo, Radiative decays of the Σc, Ξ′c and Ωc charmed baryons, arXiv:2512.03008 [hep-ph] (2025).

* EM decay:

$\Xi'_c(2923)^+$

$\Gamma_{\rm em}\left[\Xi'_c(2923)^+ \to \Xi_c^+\gamma\right] = 73$ keV

$\Gamma_{\rm em}\left[\Xi'_c(2923)^+ \to \Xi_c'^+\gamma\right] = 49$ keV

$\Gamma_{\rm em}\left[\Xi'_c(2923)^+ \to \Xi_c^{*+}\gamma\right] = 0.8$ keV

$\Xi'_c(2923)^0$

$\Gamma_{\rm em}\left[\Xi'_c(2923)^0 \to \Xi_c^0\gamma\right] = 1.6$ keV

$\Gamma_{\rm em}\left[\Xi'_c(2923)^0 \to \Xi_c'^0\gamma\right] = 449$ keV

$\Gamma_{\rm em}\left[\Xi'_c(2923)^0 \to \Xi_c^{*0}\gamma\right] = 0.4$ keV

A. Dávila-Rivera, H. García-Tecocoatzi, A. Ramirez-Morales, Ailier Rivero-Acosta, E. Santopinto, Carlos Alberto Vaquera-Araujo, D 113, 093001 (2026)