Spectroscopy, photocouplings, and strong decays of the single-charm and single-bottom baryons from Quark Model

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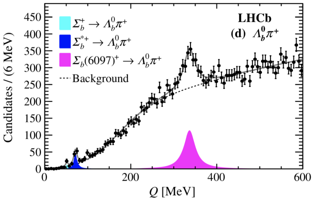
HADRON 2021, Mexico City

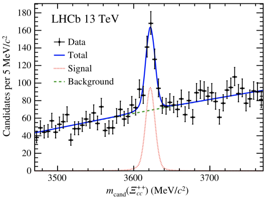
July 29, 2021

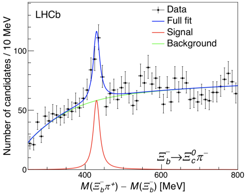
Contents

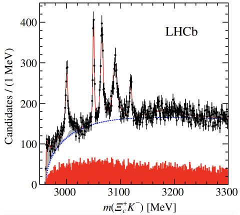
LHCb, Belle, BaBar and BESIII.

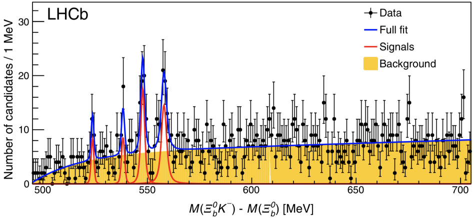
Observation of resonances with quark content c and b. [1] [2] [3]









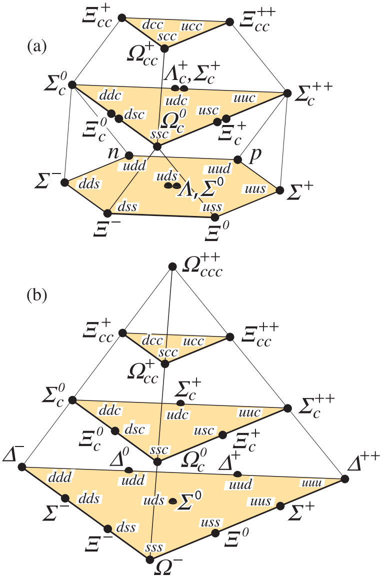


[1] R. Aaij *et al.* (LHCb Collaboration), Phys. Rev. Lett. **122**, 012001 (2019), and **119**, 112001 (2017).

[2] R. Aaij *et al.* (LHCb Collaboration), Phys. Rev. D **103**, 012004 (2021).

[3] R. Aaij *et al.* (LHCb Collaboration), Phys. Rev. Lett. **118**, 182001 (2017), and **124**, 082002 (2020).

Classification of single-charm ground state baryons



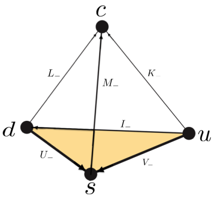
$\Longleftarrow SU(4)$ multiplets: (a) with $J^P = 1/2^+$ and (b) with $J^P = 3/2^+$, PDG.

Labels for the states:

$$\left|[f], (\alpha,\beta,\gamma), (\lambda,\mu), I, Y, Z, L^\pi, S^{\mathcal{P}}; J^P\right\rangle$$

$$|N(939)\rangle = \left|[3], (1,1,0), (1,1), \tfrac{1}{2}, 1, \tfrac{3}{4}, 0^+, \tfrac{1}{2}^+; \tfrac{1}{2}^+\right\rangle$$

Lowering operators:



Baryon wave functions

- Quark Model

Hadrons → Multiquark systems→ Degrees of freedom

$$\psi = \psi^{\mathrm{o}}\chi^{\mathrm{s}}\phi^{\mathrm{f}}\psi^{\mathrm{c}}$$

(i) Since quarks are fermions, the total baryon wave function should be antisymmetric under any permutation of the three light quarks.

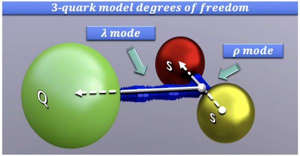
(ii) As all physical states, the color wave function is a $SU(3)$ singlet, a completely antisymmetric state.

Baryon wave functions

$$H = \frac{{p_1}^2}{2m} + \frac{{p_2}^2}{2m} + \frac{{p_3}^2}{2m'} + \frac{1}{2}C\sum_{i<j}^{3} |\vec{r_i} - \vec{r_j}|^2$$

- Jacobi coordinates

$$\begin{cases} \vec{\rho} = \frac{1}{\sqrt{2}}(\vec{r_1} - \vec{r_2}), \\ \vec{\lambda} = \frac{1}{\sqrt{6}}(\vec{r_1} + \vec{r_2} - 2\vec{r_3}) \\ \vec{R} = \frac{m(\vec{r_1}+\vec{r_2})+m'\vec{r_3}}{2m+m'} \end{cases}$$

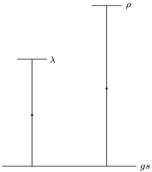


$$H = \frac{{P_{CM}}^2}{2M} + \frac{{p_\rho}^2}{2m_\rho} + \frac{{p_\lambda}^2}{2m_\lambda} + \frac{3}{2}C\rho^2 + \frac{3}{2}C\lambda^2$$

$$M = 2m + m', \quad m_\rho \equiv m, \quad m_\lambda \equiv \frac{3mm'}{2m+m'}$$

$$\alpha_i^2 = (3Cm_i)^{\frac{1}{2}}, \quad \omega_i = \sqrt{\frac{3C}{m_i}}, \quad i = \{\rho, \lambda\}.$$

$$m' > m \Rightarrow m_\lambda > m_\rho \Rightarrow \omega_\lambda < \omega_\rho$$



Baryon wave functions

- **The orbital wave function**: Ground ψ_0 and excited ψ_ρ, ψ_λ states.

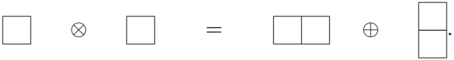
$$\psi_B(\vec{r}_1,\vec{r}_2,\vec{r}_3) = \frac{1}{(2\pi)^{3/2}} e^{\vec{P}_{CM}\cdot\vec{R}} \psi^{rel}(\vec{\rho},\vec{\lambda}) \quad \Rightarrow \quad \begin{cases} \psi^{rel}_{gs}(\vec{\rho},\vec{\lambda}) = \frac{1}{\sqrt{3\sqrt{3}}}\psi_{0,0,0}(\vec{\rho})\psi_{0,0,0}(\vec{\lambda}) \\ \psi^{rel}_{\rho}(\vec{\rho}\ \vec{\lambda}) = \frac{1}{\sqrt{3\sqrt{3}}}\psi_{1,1,m_\rho}(\vec{\rho})\psi_{0,0,0}(\vec{\lambda}) \\ \psi^{rel}_{\lambda}(\vec{\rho}\ \vec{\lambda}) = \frac{1}{\sqrt{3\sqrt{3}}}\psi_{0,0,0}(\vec{\rho})\psi_{1,1,m_\lambda}(\vec{\lambda}) \end{cases}$$

- **The spin wave functions** with maximum projection

$$\begin{aligned} \chi_{E_\rho} &= (\uparrow\downarrow - \downarrow\uparrow)\uparrow/\sqrt{2} \\ \chi_{E_\lambda} &= (2\uparrow\uparrow\downarrow - \uparrow\downarrow\uparrow - \downarrow\uparrow\uparrow)/\sqrt{6} \\ \chi_{A_1} &= \uparrow\uparrow\uparrow\,. \end{aligned}$$

Baryon wave functions

- The **flavor wave functions** can be found by choosing Q in the third position and symmetrizing the remaining two flavors.



For the two symmetric sextets $\mathbf{6}$,

$$\begin{aligned} \Sigma_Q &= uuQ \\ \Xi'_Q &= (us+su)Q/\sqrt{2} \\ \Omega_Q &= ssQ, \end{aligned}$$

and the antisymmetric antitriplet $\bar{\mathbf{3}}$

$$\begin{aligned} \Lambda_Q &= (ud-du)Q/\sqrt{2} \\ \Xi_Q &= (us-su)Q/\sqrt{2}. \end{aligned}$$

Since the flavor part for the hyperons of the sextet $\mathbf{6}$ is symmetric, then the spin and orbital combinations must be coupled symmetrically. Here notation ${}^{2S+1}L(B_Q)_{J^P}$ is used.

$$\begin{aligned} {}^2\Sigma_Q &= uuQ[\psi_0 \times \chi_{E_\lambda}]_{J=1/2} \\ {}^4\Sigma_Q &= uuQ[\psi_0 \times \chi_{A_1}]_{J=3/2} \\ {}^2\rho(\Sigma_Q)_J &= uuQ[\psi_\rho \times \chi_{E_\rho}]_J \\ {}^2\lambda(\Sigma_Q)_J &= uuQ[\psi_\lambda \times \chi_{E_\lambda}]_J \\ {}^4\lambda(\Sigma_Q)_J &= uuQ[\psi_\lambda \times \chi_{A_1}]_J. \end{aligned}$$

Mass spectra

$$H = \sum_{i=1}^{3}(m_i + \frac{p_i^2}{2m_i}) + \frac{1}{2}C\sum_{i<j}^{3}|\vec{r_i} - \vec{r_j}|^2 + A\,S^2 + B\,\vec{S}\cdot\vec{L} + E\,I^2 + G\,C_{2SU_f(3)}$$

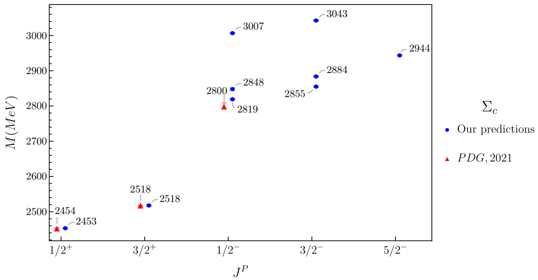
- **Parameters:** [4] [5]
  Quark masses → $\Omega_c(2695)$, $\Omega_c^*(2765)$, $\Xi_{cc}(3621)$ and $\Sigma_b(5812)$.
  $C \to \Lambda_b(5919)$, $\Lambda_b(5619)$ and $\Xi_c(2790)$, $\Xi_c(2469)$, $A \to \Sigma_c^*(2520)$, $\Sigma_c(2454)$,
  $B \to \Lambda_c(2595)$-$\Lambda_c(2625)$, $E \to \Sigma_c$ and Λ_c, $G \to \Xi_c(2469)$ and $\Xi_c'(2578)$.

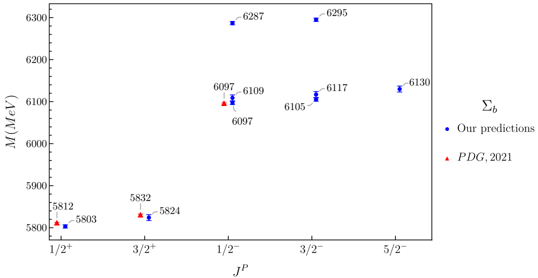
	$Q = c$	$Q = b$	
$m_u = m_d$	295	295	MeV
m_s	450	450	MeV
m_Q	1605	4920	MeV
C	0.0328	0.0235	GeV^3
A	21.54 ± 0.37	6.73 ± 1.63	MeV
B	23.91 ± 0.31	5.15 ± 0.33	MeV
E	30.34 ± 0.23	26.00 ± 1.80	MeV
G	54.37 ± 0.58	70.91 ± 0.49	MeV

[4] E. Ortiz-Pacheco, R. Bijker, H. García-Tecocoatzi, A. Giachino, and E. Santopinto, J. Phys.: Conf. Ser. **1610**, 012011 (2020).

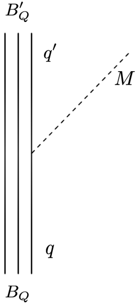
[5] E. Santopinto, *et al*, Eur. J. Phys. C 79, 1012 (2019).

Σ_Q Mass spectrum





Strong couplings



- Interaction Hamiltonian [6]

$$H_s^{eff} = \int d^3x \frac{g_{qq'M}}{2m} \bar{q}(\vec{x})\gamma^\mu\gamma_5\tau^a q(\vec{x})\partial_\mu\varphi^a(\vec{x}).$$

Non-relativistic approximation in the Elementary Meson Emission model (EME): [7] [8]

$$H_s = \frac{1}{(2\pi)^{3/2}(2k_0)^{1/2}} \sum_{j=1}^{3} X_j^M \left[2g(\vec{s_j}\cdot\vec{k})e^{-i\vec{k}\cdot\vec{r_j}} + h\vec{s_j}\cdot\left(\vec{p_j}e^{-i\vec{k}\cdot\vec{r_j}} + e^{-i\vec{k}\cdot\vec{r_j}}\vec{p_j}\right)\right].$$

[6] A. Le Yaouanc *et al. Hadron Transitions in the Quark Model* (Gordon and Breach, NY, USA, 1988).

[7] R. Koniuk and N. Isgur, Phys. Rev. D **21**, 1868 (1980).

[8] R. Bijker, F. Iachello, and A. Leviatan, Annals of Physics **284**, 89 (2000).

Strong couplings

- Decay width

$$\Gamma(B_Q \to B'_Q + M) = 2\pi\rho \frac{2}{2J+1} \sum_{\nu>0} |\mathcal{A}_\nu(k)|^2,$$

Where the phase space factor and momentum of the meson are

$$\rho = 4\pi \frac{E_{B'_Q} E_M k}{m_{B_Q}}, \qquad k^2 = -m_M^2 + \frac{(m_{B_Q}^2 - m_{B'_Q}^2 + m_M^2)^2}{4m_{B_Q}^2}.$$

$E_{B'_Q} = \sqrt{m_{B'_Q}^2 + k^2}$ and $E_M = \sqrt{m_M^2 + k^2}$ are the energies from the resulting baryons and mesons.

$$\begin{aligned}\mathcal{A}_\nu(k) &= \langle \psi_{B'_Q}; 1/2, \nu | H_s | \psi_{B_Q}; J, \nu \rangle, \qquad \nu = 1/2,\ 3/2.\\ &= \frac{1}{(2\pi)^{3/2}(2k_0)^{1/2}} \Bigg\{ \langle L0S\nu | J\nu \rangle \sum_{j=1}^{3} \zeta_{j,0} \underbrace{Z_{j,0}(k)}_{\text{orbital matrix elements}} \\ &+ \frac{1}{2} \langle L1S\nu - 1 | J\nu \rangle \sum_{j=1}^{3} \underbrace{\zeta_{j,+}}_{\text{spin-flavor matrix elements}} Z_{j,-}(k) + \frac{1}{2} \langle L-1S\nu+1 | J\nu \rangle \sum_{j=1}^{3} \zeta_{j,-} Z_{j,+}(k) \Bigg\}\end{aligned}$$

Strong couplings

Flavor matrix elements $\langle \phi' | X_j^M | \phi \rangle$

$(20) \longrightarrow (20) \oplus (11)$

$$\begin{pmatrix} \Sigma_Q \\ \Xi'_Q \\ \Omega_Q \end{pmatrix} \longrightarrow \begin{pmatrix} & \Sigma_Q\pi & \Sigma_Q\eta_8 & \Xi'_Q K \\ \Sigma_Q \bar{K} & \Xi'_Q\pi & \Xi'_Q\eta_8 & \Omega_Q K \\ & \Xi'_Q\bar{K} & \Omega_Q\eta_8 & \end{pmatrix} = \frac{1}{\sqrt{40}} \begin{pmatrix} & 24 & -4 & 12 \\ 18 & 9 & 1 & 12 \\ & 24 & 16 & \end{pmatrix}^{1/2}$$

$(20) \longrightarrow (01) \oplus (11)$

$$\begin{pmatrix} \Sigma_Q \\ \Xi'_Q \\ \Omega_Q \end{pmatrix} \longrightarrow \begin{pmatrix} & \Xi_Q K & \Lambda_Q\pi \\ \Xi_Q\eta_8 & \Xi_Q\pi & \Lambda_Q\bar{K} \\ & \Xi_Q\bar{K} & \end{pmatrix} = \frac{1}{\sqrt{8}} \begin{pmatrix} & -4 & 4 \\ -3 & 3 & 2 \\ & 8 & \end{pmatrix}^{1/2}$$

$(20) \longrightarrow (20) \oplus (00)$

$$\begin{pmatrix} \Sigma_Q \\ \Xi'_Q \\ \Omega_Q \end{pmatrix} \longrightarrow \begin{pmatrix} \Sigma_Q\eta_1 \\ \Xi'_Q\eta_1 \\ \Omega_Q\eta_1 \end{pmatrix} = \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}$$

$(01) \longrightarrow (01) \oplus (11)$

$$\begin{pmatrix} \Lambda_Q \\ \Xi_Q \end{pmatrix} \longrightarrow \begin{pmatrix} & \Xi_Q K & \Lambda_Q\eta_8 \\ \Xi_Q\pi & \Xi_Q\eta_8 & \Lambda_Q\bar{K} \end{pmatrix} = \frac{1}{\sqrt{16}} \begin{pmatrix} & -12 & 4 \\ -9 & -1 & 6 \end{pmatrix}^{1/2}$$

$(01) \longrightarrow (20) \oplus (11)$

$$\begin{pmatrix} \Lambda_Q \\ \Xi_Q \end{pmatrix} \longrightarrow \begin{pmatrix} & \Xi'_Q K & \Sigma_Q\pi & \\ \Omega_Q K & \Xi'_Q\eta_8 & \Xi'_Q\pi & \Sigma_Q\bar{K} \end{pmatrix} = \frac{1}{\sqrt{16}} \begin{pmatrix} & -4 & -12 & \\ 4 & -3 & 3 & -6 \end{pmatrix}^{1/2}$$

$(01) \longrightarrow (01) \oplus (00)$

$$\begin{pmatrix} \Lambda_Q \\ \Xi_Q \end{pmatrix} \longrightarrow \begin{pmatrix} \Xi_Q\eta_1 \\ \Lambda_Q\eta_1 \end{pmatrix} = \begin{pmatrix} 1 \\ 1 \end{pmatrix}$$

Strong couplings

State	Present	ChQM	Exp	$\Gamma^{\text{exp}}_{\text{tot}}$(MeV)
$^{2}(\Sigma_c)_{1/2^+}$	**0.57**	$\cdots$	$\Sigma_c(2455)$	1.86 ± 0.19
$^{4}(\Sigma_c)_{3/2^+}$	**3.36**	$\cdots$	$\Sigma_c(2520)$	15.04 ± 0.45
$^{2}\lambda(\Sigma_c)_{1/2^-}$	**3.55**	22.65	$\Sigma_c(2800)$	69.67 ± 41
$^{4}\lambda(\Sigma_c)_{1/2^-}$	**6.80**	17.63		
$^{2}\lambda(\Sigma_c)_{3/2^-}$	**11.82**	36.5		
$^{4}\lambda(\Sigma_c)_{3/2^-}$	**6.76**	24.69		
$^{4}\lambda(\Sigma_c)_{5/2^-}$	**17.08**	33.22		
$^{2}\rho(\Sigma_c)_{1/2^-}$	**19.40**	$\cdots$		
$^{2}\rho(\Sigma_c)_{3/2^-}$	**21.34**	$\cdots$		
$^{2}(\Xi_c)_{1/2^+}$	–	$\cdots$	$\Xi_c(2469)$	
$^{2}\lambda(\Xi_c)_{1/2^-}$	**0.02**	3.61	$\Xi_c(2790)$	9.5 ± 2.0
$^{2}\lambda(\Xi_c)_{3/2^-}$	**0.22**	2.11	$\Xi_c(2815)$	2.48 ± 0.5
$^{2}\rho(\Xi_c)_{1/2^-}$	**2.87**	$\cdots$		
$^{4}\rho(\Xi_c)_{1/2^-}$	**4.95**	$\cdots$		
$^{2}\rho(\Xi_c)_{3/2^-}$	**9.69**	$\cdots$		
$^{4}\rho(\Xi_c)_{3/2^-}$	**4.62**	$\cdots$		
$^{4}\rho(\Xi_c)_{5/2^-}$	**16.64**	$\cdots$		
$^{2}(\Omega_c)_{1/2^+}$	–	$\cdots$	$\Omega_c(2695)$	$< 10^{-7}$
$^{4}(\Omega_c)_{3/2^+}$	–	$\cdots$	$\Omega_c(2770)$	
$^{2}\lambda(\Omega_c)_{1/2^-}$	**1.92**	4.38/4.28	$\Omega_c(3000)$	4.6 ± 0.6
$^{4}\lambda(\Omega_c)_{1/2^-}$	**0.8***	–	$\Omega_c(3050)$	0.8 ± 0.2
$^{2}\lambda(\Omega_c)_{3/2^-}$	**3.5***	4.96	$\Omega_c(3066)$	3.5 ± 0.4
$^{4}\lambda(\Omega_c)_{3/2^-}$	**1.05**	0.94	$\Omega_c(3090)$	8.7 ± 1.0
$^{4}\lambda(\Omega_c)_{5/2^-}$	**16.83**	9.53	$\Omega_c(3188)$	60 ± 26
$^{2}\rho(\Omega_c)_{1/2^-}$	**6.28**	$\cdots$		
$^{2}\rho(\Omega_c)_{3/2^-}$	**7.04**	$\cdots$		

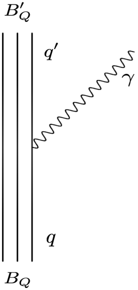
State	Present	*ChQM*	Exp	$\Gamma^{\text{exp}}_{\text{tot}}$(MeV)
$^{2}(\Lambda_c)_{1/2^+}$	–	$\cdots$	Λ_c	
$^{2}\lambda(\Lambda_c)_{1/2^-}$	**0.05**	$\cdots$	$\Lambda_c(2595)$	2.6 ± 0.6
$^{2}\lambda(\Lambda_c)_{3/2^-}$	**0.06**	$\cdots$	$\Lambda_c(2625)$	< 0.97
$^{2}\rho(\Lambda_c)_{1/2^-}$	**4.27**	$\cdots$		
$^{4}\rho(\Lambda_c)_{1/2^-}$	**3.31**	$\cdots$		
$^{2}\rho(\Lambda_c)_{3/2^-}$	**12.24**	$\cdots$		
$^{4}\rho(\Lambda_c)_{3/2^-}$	**13.90**	$\cdots$	$\Lambda_c(2940)$	20 ± 6
$^{4}\rho(\Lambda_c)_{5/2^-}$	**18.40**	$\cdots$		
$^{2}(\Xi'_c)_{1/2^+}$	–	$\cdots$	$\Xi'_c(2578)$	
$^{4}(\Xi'_c)_{3/2^+}$	**0.70**	$\cdots$	$\Xi_c(2645)$	2.25 ± 0.41
$^{2}\lambda(\Xi'_c)_{1/2^-}$	**0.96**	21.67		
$^{4}\lambda(\Xi'_c)_{1/2^-}$	**2.01**	37.05	$\Xi_c(2923)$	7.1 ± 2.0
$^{2}\lambda(\Xi'_c)_{3/2^-}$	**6.55**	20.89	$\Xi_c(2939)$	10.2 ± 0.14
$^{4}\lambda(\Xi'_c)_{3/2^-}$	**2.12**	12.33	$\Xi_c(2965)$	14.1 ± 1.6
$^{4}\lambda(\Xi'_c)_{5/2^-}$	**12.28**	20.2		
$^{2}\rho(\Xi'_c)_{1/2^-}$	**6.13**	$\cdots$	$\Xi_c(3055)$	7.8 ± 1.9
$^{2}\rho(\Xi'_c)_{3/2^-}$	**12.14**	$\cdots$	$\Xi_c(3080)$	4.6 ± 3.3

Electromagnetic couplings

- Interaction Hamiltonian [9] [10]

$$H_{em}^{eff} = e \int d^3x \bar{q}(\vec{x}) e_q \gamma^{\mu} q(\vec{x}) A_{\mu}(\vec{x})$$

$$H_{em} = 2\sqrt{\frac{\pi}{k_0}} \sum_{j=1}^{3} \mu_j \left[k s_{j,-} e^{-i\vec{k}\cdot\vec{r}_j} - \frac{1}{2g} \left(p_{j,-} e^{-i\vec{k}\cdot\vec{r}_j} + e^{-i\vec{k}\cdot\vec{r}_j} p_{j,-} \right) \right]$$



$$\Gamma(B_Q \to B'_Q + \gamma) = 2\pi\rho \frac{1}{(2\pi)^3} \frac{2}{2J+1} \sum_{\nu>0} |\mathcal{A}_{\nu}(k)|^2,$$

$$\rho = 4\pi \frac{E_{B'_Q} k^2}{m_{B_Q}}, \qquad k = \frac{m_{B_Q}^2 - m_{B'_Q}^2}{2m_{B_Q}}.$$

$E_{B'_Q} = \sqrt{m_{B'_Q}^2 + k^2}$ is the energy of the resulting baryon

$$\mathcal{A}_{\nu} = \langle \psi_{B'_Q}; J', \nu - 1 | H_{em} | \psi_{B_Q}; J, \nu \rangle, \qquad \nu = 1/2,\ 3/2.$$

[9] R. Bijker, F. Iachello, and A. Leviatan, Annals of Physics **284**, 89 (2000).

[10] A. Le Yaouanc *et al. Hadron Transitions in the Quark Model* (Gordon and Breach, NY, USA, 1988).

Electromagnetic couplings

- Ground states

$B_Q \to B'_Q\gamma$	Present	LCQSR	BM[11]	VMD	$ChQM$	NRQM[12]	HBChPT[13]	RQM	hCQM[14]
${}^4\Sigma_c^{++} \to {}^2\Sigma_c^{++}\gamma$	**1.79**	2.65 ± 1.60	0.826	3.567	3.94	1.15	1.20		1.32, 0.85
${}^4\Sigma_c^{+} \to {}^2\Sigma_c^{+}\gamma$	**0.00**	0.40 ± 0.22	0.004	0.187	0.004	$< 10^{-4}$	0.04	0.14 ± 0.004	1×10^{-4}, 9×10^{-5}
${}^4\Sigma_c^{0} \to {}^2\Sigma_c^{0}\gamma$	**1.79**	0.08 ± 0.042	1.08	1.049	3.43	1.12	0.49		1.072, 1.20, 1.55
${}^4\Xi_c^{'+} \to {}^2\Xi_c^{'+}\gamma$	**0.03**	0.274	0.011	0.485	0.004		0.07		
${}^4\Xi_c^{'0} \to {}^2\Xi_c^{'0}\gamma$	**1.53**	2.142	1.03	1.317	3.03		0.42		
${}^4\Omega_c^{0} \to {}^2\Omega_c^{0}\gamma$	**1.30**	0.932	1.07	1.439	0.89	2.02	0.32		0.34, 1.44
${}^2\Sigma_c^{+} \to {}^2\Lambda_c^{+}\gamma$	**67.92**	50.0 ± 17.0	46.1		80.60	60.55	65.6	60.7 ± 1.5	71.20, 58.13
${}^4\Sigma_c^{+} \to {}^2\Lambda_c^{+}\gamma$	**137.85**	130 ± 35	126	409.3	373	154.48	161.8	151 ± 4	171.9, 143.97, 213.3
${}^2\Xi_c^{'+} \to {}^2\Xi_c^{+}\gamma$	**17.84**	8.5 ± 2.5	10.2		42.3		5.43	12.7 ± 1.5	
${}^4\Xi_c^{'+} \to {}^2\Xi_c^{+}\gamma$	**60.36**	52 ± 32	44.3	152.4	139	63.32	21.6	54 ± 3	17.48
${}^2\Xi_c^{'0} \to {}^2\Xi_c^{0}\gamma$	**0.38**	0.27 ± 0.06	0.0015		0.00		0.46	0.17 ± 0.002	
${}^4\Xi_c^{'0} \to {}^2\Xi_c^{0}\gamma$	**1.28**	0.66 ± 0.41	0.908	1.318	0.00	0.30	1.84	0.68 ± 0.04	0.45, 0.91
${}^4\Sigma_b^{+} \to {}^2\Sigma_b^{+}\gamma$	**0.10**	0.46 ± 0.28	0.054	0.137	0.25	0.08	0.05		
${}^4\Sigma_b^{0} \to {}^2\Sigma_b^{0}\gamma$	**0.01**	0.028 ± 0.02	0.005	0.006	0.02	$< 10^{-3}$	3×10^{-3}		
${}^4\Sigma_b^{-} \to {}^2\Sigma_b^{-}\gamma$	**0.02**	0.11 ± 0.076	0.01	0.040	0.06	0.01	0.013		
${}^4\Xi_b^{'0} \to {}^2\Xi_b^{'0}\gamma$	**0.01**	0.131	0.004	0.281	5.19		1.5×10^{-3}		
${}^4\Xi_b^{'-} \to {}^4\Xi_b^{'-}\gamma$	**0.01**	0.303	0.005	0.702	15.0		8.2×10^{-3}		
${}^4\Omega_b^{-} \to {}^2\Omega_b^{-}\gamma$	**0.052**	0.092	0.006	2.873	0.1	0.03	0.031		
${}^2\Sigma_b^{0} \to {}^2\Lambda_b^{0}\gamma$	**98.30**	152.0 ± 60.0	58.9		130	94.79	108.0		
${}^4\Sigma_b^{0} \to {}^2\Lambda_b^{0}\gamma$	**120.07**	114 ± 62	81.1	221.5	335	128.62	142.1		
${}^2\Xi_b^{'0} \to {}^2\Xi_b^{0}\gamma$	**35.05**	47.0 ± 21.0	14.7		84.6		13.0		
${}^4\Xi_b^{'0} \to {}^2\Xi_b^{0}\gamma$	**47.96**	135 ± 85	24.7	270.8	104	18.79	17.2		
${}^2\Xi_b^{'-} \to {}^2\Xi_b^{-}\gamma$	**0.74**	3.3 ± 1.3	0.118		0.00		1.0		
${}^4\Xi_b^{'-} \to {}^2\Xi_b^{-}\gamma$	**1.02**	1.50 ± 0.095	0.278	2.246	0.00	0.09	1.4		

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Electromagnetic couplings

- For the first time The Belle Collaboration reported the electromagnetic decay of the **excited charm baryons** $\Xi_c(2790)$ and $\Xi_c(2815)$.[15]

- We identify these states as λ-**exited states**.

$B_Q \to B'_Q\gamma$	Present	$\alpha_\rho, \alpha_\lambda$	$ChQM$[16]	DGCB.[17]	$LCQSR$[18]	RQM[19]	Γ^{exp}(KeV)[13]
$\Xi_c^+(2790) \to {}^2\Xi_c^+\gamma$	**0.92**	**5.28**	4.65	249.6±41.9	265(1±0.4)	$\cdots$	< 350
$\Xi_c^+(2815) \to {}^2\Xi_c^+\gamma$	**2.80**	**2.39**	2.80	$\cdots$	$\cdots$	190 ± 5	< 80
$\Xi_c^0(2790) \to {}^2\Xi_c^0\gamma$	**547.16**	**234.96**	263	119.3±21.7	2.7(1±0.3)	$\cdots$	800 ± 320
$\Xi_c^0(2815) \to {}^2\Xi_c^0\gamma$	**711.45**	**315.03**	292	$\cdots$	$\cdots$	497 ± 14	320 ± 45

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Conclusions

- There is a good agreement between our assignments in the **spectra** and the experimental data for the single-heavy baryons. In the most cases, deviations are under 0.35 %, while only for two resonances $\Lambda_c(2595)$ and $\Lambda_c(2625)$ are less than 1.7 %.
- We were able to calculate all the **strong decay widths**, allowed by the selection rules, between single heavy baryons either with c or b. From the comparison with other works, it can be concluded that the quark model, by means of the EME, is in better agreement with the current experimental data.
- For the electromagnetic couplings we found our results, for ground baryon states, in a close similarity with 4 models: $LCQSR$, $hCQM$, RQM and $NRQM$. For the BM and the calculations with the $HHChPT$ we observe widths slightly smaller than ours, while for the VMD and $ChQM$ there are a few discrepancies.
- We report the **radiative decay widths** of $\Xi_c(2790)$ and $\Xi_c(2815)$ recently observed by Belle, where we found a very good agreement with the experiment.

Thanks!