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Radiative M1 Decays of Heavy Flavor bottom Baryons in Effective Mass Scheme

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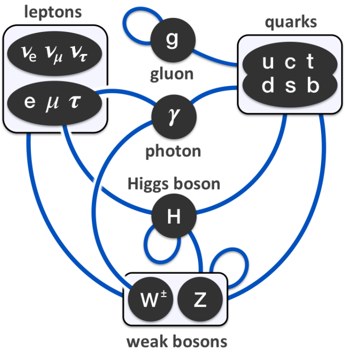
Outline

The Standard Model of particle physics is, by far, the most successful application of quantum field theory (QFT). It accurately describes all experimental measurements involving strong, weak, and electromagnetic interactions with gauge group $SU_c(3) \otimes SU_L(2) \otimes U_Y(1)$ and fermion fields for the leptons and quarks, realized in nature.



Introduction

- Despite the fact that the Standard Model is a well established framework to study interactions of fundamental particles, significant discrepancies can be seen between theoretical predictions and experimental results. However, within the past few decades, several theoretical approaches have been put forth to diminish the inconsistency between theory and experiments.
- In the present work, we have calculated magnetic and transition moments, and M1 decay widths of ground-state singly, doubly, and triply heavy bottom baryons. Also, we have given the estimates for the magnetic moments in an improved manner by determining one gluon exchange hyperfine interaction terms for $s-$, $c-$, and $b-$flavors from precise experimental values of baryon masses within the same flavor sector.
- Following the EMS [1, 2, 3], we have calculated the constituent and effective masses of quarks inside a baryon for both $J^P = \frac{1}{2}^+$ and $J^P = \frac{3}{2}^+$ baryons.

Theoretical Frame Work (EMS)

- In the EMS, the baryon mass can be written as the sum of the constituent quark masses and the spin-dependent hyperfine interaction among them [1, 2, 3],

$$M_{\mathcal{B}} = \sum_i m_i^{\xi} = \sum_i m_i + \sum_{i<j} b_{ij} s_i . s_j, \tag{1}$$

where, m_i^{ξ} represents the effective mass of the quark inside the baryon; s_i and s_j denote the spin operators of the i^{th} and j^{th} quark, respectively.

- The b_{ij} for baryons $\mathcal{B}(qqq)$, is given by

$$b_{ij} = \frac{16\pi\alpha_s}{9m_i m_j} < \psi_0|\delta^3(\vec{r})|\psi_0 >, \tag{2}$$

where, ψ_0 is the baryon wave function at the origin.

Theoretical Frame Work (Continues)

- For (112)- type $J^P = \frac{1}{2}^+$ baryons, we can write

$$m_1^{\xi} = m_2^{\xi} = m + \alpha b_{12} + \beta b_{13}, \quad m_3^{\xi} = m_3 + 2\beta b_{13}, \tag{3}$$

where, $m_1 = m_2 = m$ and $b_{13} = b_{23}$. The α and β parameters are to be determined as follows:

$$M_{\mathcal{B}_{\frac{1}{2}^+}} = 2m + m_3 + \frac{b_{12}}{4} - b_{13}, \tag{4}$$

for

$$s_1.s_2 = \frac{1}{4}, s_1.s_3 = s_2.s_3 = -\frac{1}{2}, \tag{5}$$

thus giving

$$\alpha = \frac{1}{8} \text{ and } \beta = -\frac{1}{4}. \tag{6}$$

Theoretical Frame Work (Continues)

- Therefore, equation (1) may be generalized for $J^P = \frac{1}{2}^+$ baryons as

$$M_{\mathcal{B}_{\frac{1}{2}^+}} = m_1 + m_2 + m_3 + \frac{b_{12}}{4} - \frac{b_{23}}{2} - \frac{b_{13}}{2}. \tag{7}$$

- By using equation (3), we will obtain more general expressions for effective masses of the quarks inside the baryon, as follows:
  1. For (112)-type $J^P = \frac{1}{2}^+$ baryons with quarks 1 and 2 being identical,

$$m_1^{\xi} = m_2^{\xi} = m + \frac{b_{12}}{8} - \frac{b_{13}}{4}, \tag{8}$$

and

$$m_3^{\xi} = m_3 - \frac{b_{13}}{2} \text{ for } 1 = 2 \neq 3. \tag{9}$$

Theoretical Frame Work (Continues)

2. The baryonic states with three different quarks flavor (123) can have both anti-symmetric $\Lambda_{[12]3}$-type and symmetric $\Sigma_{\{12\}3}$-type flavor configuration under the exchange of quarks 1 and 2. (a) For (123) Λ-type, $J^P = \frac{1}{2}^+$ baryons,

$$m_1^{\xi} = m_1 - \frac{3b_{12}}{8}, \quad m_2^{\xi} = m_2 - \frac{3b_{21}}{8}, \tag{10}$$

and

$$m_3^{\xi} = m_3 \text{ for } 1 \neq 2 \neq 3. \tag{11}$$

(b) For (123) Σ-type, $J^P = \frac{1}{2}^+$ baryons,

$$m_1^{\xi} = m_1 + \frac{b_{12}}{8} - \frac{b_{13}}{4}, \quad m_2^{\xi} = m_2 + \frac{b_{12}}{8} - \frac{b_{23}}{4}, \tag{12}$$

and

$$m_3^{\xi} = m_3 - \frac{b_{23}}{4} - \frac{b_{13}}{4} \text{ for } 1 \neq 2 \neq 3. \tag{13}$$

Theoretical Frame Work (Continues)

- Following the similar procedure described for $J^P = \frac{1}{2}^+$ baryons, the generalized mass formula for different flavor configuration of $J^P = \frac{3}{2}^+$ baryons is given by

$$M_{\mathcal{B}_{\frac{3}{2}^+}} = m_1 + m_2 + m_3 + \frac{b_{12}}{4} + \frac{b_{23}}{4} + \frac{b_{13}}{4}, \quad \text{for } \alpha = \beta = \frac{1}{8}. \tag{14}$$

Throughout the above discussions 1, 2, 3 represents u, d, s, c, and b quarks.
1. For (112)-type $J^P = \frac{3}{2}^+$ baryons,

$$m_1^{\xi} = m_2^{\xi} = m + \frac{b_{12}}{8} + \frac{b_{13}}{8}, \tag{15}$$

and

$$m_3^{\xi} = m_3 + \frac{b_{13}}{4} \text{ for } 1 = 2 \neq 3. \tag{16}$$

Theoretical Frame Work (Continues)

2. For (123)-type $J^P = \frac{3}{2}^+$ baryons,

$$m_1^{\xi} = m_1 + \frac{b_{12}}{8} + \frac{b_{13}}{8},$$
$$m_2^{\xi} = m_2 + \frac{b_{23}}{8} + \frac{b_{12}}{8}, \quad (17)$$

and

$$m_3^{\xi} = m_3 + \frac{b_{13}}{8} + \frac{b_{23}}{8}. \quad (18)$$

3. For (111)-type $J^P = \frac{3}{2}^+$ baryons,

$$m_1^{\xi} = m_2^{\xi} = m_3^{\xi} = m + \frac{b_{12}}{4}, \quad (19)$$

and

$$b_{12} = b_{23} = b_{13}. \quad (20)$$

Theoretical Frame Work (Continues)

- The values of constituent quark masses and hyperfine interaction terms b_{ij} are obtained from the experimentally observed baryon masses [4]. In order to obtain the effective quark masses, especially in the charm and bottom sector, we have calculated the interaction contribution of single gluon exchange term from the corresponding flavor sector. We proceed to obtain,

$$\begin{gathered} m_u = m_d = 362\ MeV, m_s = 538\ MeV, \\ b_{uu} = b_{ud} = b_{dd} = 195\ MeV. \end{gathered} \tag{21}$$

from N, Δ, and Λ up to strange sector.
In the charm sector, from Ω_c and $\Xi_c^{(*)}$, we obtain:

$$m_c = 1646\ MeV, b_{us} = b_{ds} = 153\ MeV,$$

$\mathrm{b}_{ss} = 81\ MeV, (22) \Sigma_c^{(*)}$ will gives

$$b_{uc} = b_{dc} = 43\ MeV, \tag{23}$$

and $\Omega_c^{(*)}$, and Ξ_{cc}^{++} yields

$$b_{sc} = 47\ MeV, \tag{24}$$

Theoretical Frame Work (Continues)

and

$$b_{cc} = 40\ MeV. \tag{25}$$

In the bottom sector, Λ_b, $\Sigma_b^{(*)}$, and $\Xi_b^{(*)}$ leads to

$$m_b = 5043\ MeV, b_{ub} = b_{db} = 13\ MeV, b_{sb} = 17\ MeV. \tag{26}$$

For the first time we have estimated b_{cb} and b_{bb} from the hyperfine interaction terms b_{sc} and b_{sb} that are obtained from the experimentally known masses. We use the symmetry relations [1, 2, 3] to get,

$$b_{cb} = \left(\frac{m_s}{m_b}\right) b_{sc} = 5.0\ MeV, \text{ and } b_{cb} = \left(\frac{m_s}{m_c}\right) b_{sb} = 5.4\ MeV, \tag{27}$$

since both the values are roughly same, we use

$$b_{cb} \cong 5\ MeV. \tag{28}$$

Furthermore, we get

$$b_{bb} = \left(\frac{m_s m_c}{m_b m_b}\right) b_{sc} = 1.6\ MeV, \text{ and } b_{bb} = \left(\frac{m_s m_b}{m_b m_b}\right) b_{sb} = 1.8\ MeV. \tag{29}$$

which is approximated to

$$b_{bb} \cong 2\ MeV. \tag{30}$$

Theoretical Frame Work (Continues)

- Effective quark masses for $J^P = \frac{1}{2}^+$ baryons
  1. For singly heavy baryons,

$$m_u^{\Lambda_b} = m_d^{\Lambda_b} = 289\ MeV, m_b^{\Lambda_b} = 5043\ MeV;$$
$$m_u^{\Xi_b} = m_d^{\Xi_b} = 305\ MeV, m_s^{\Xi_b} = 481\ MeV, m_b^{\Xi_b} = 5043\ MeV;$$
$$m_s^{\Omega_b} = 544\ MeV, m_b^{\Omega_b} = 5035\ MeV;$$
$$m_u^{\Sigma_b} = m_d^{\Sigma_b} = 383\ MeV, m_b^{\Sigma_b} = 5036\ MeV;$$
$$m_u^{\Xi'_b} = m_d^{\Xi'_b} = 378\ MeV, m_s^{\Xi'_b} = 553\ MeV, m_b^{\Xi'_b} = 5036\ MeV.$$

Theoretical Frame Work (Continues)

1. For doubly heavy baryons,

$$m_u^{\Xi_{cb}} = m_d^{\Xi_{cb}} = 346\ MeV, m_c^{\Xi_{cb}} = 1630\ MeV, m_b^{\Xi_{cb}} = 5043\ MeV;$$

$$m_s^{\Omega_{cb}} = 520\ MeV, m_c^{\Omega_{cb}} = 1628\ MeV, m_b^{\Omega_{cb}} = 5043\ MeV;$$

$$m_u^{\Xi'_{cb}} = m_d^{\Xi'_{cb}} = 364\ MeV, m_c^{\Xi'_{cb}} = 1650\ MeV, m_b^{\Xi'_{cb}} = 5038\ MeV;$$

$$m_s^{\Omega'_{cb}} = 540\ MeV, m_c^{\Omega'_{cb}} = 1651\ MeV, m_b^{\Omega'_{cb}} = 5038\ MeV;$$

$$m_u^{\Xi_{bb}} = m_d^{\Xi_{bb}} = 355\ MeV, m_b^{\Xi_{bb}} = 5040\ MeV;$$

$$m_s^{\Omega_{bb}} = 530\ MeV, m_b^{\Omega_{bb}} = 5039\ MeV.$$

2. For triply heavy baryons,

$$m_c^{\Omega_{ccb}} = 1650\ MeV, m_b^{\Omega_{ccb}} = 5040\ MeV;$$

$$m_c^{\Omega_{cbb}} = 1644\ MeV; m_b^{\Omega_{cbb}} = 5042\ MeV.$$

Theoretical Frame Work (Continues)

- Effective quark masses for $J^P = \frac{3}{2}^+$ baryons
  1. For singly heavy baryons,

$$m_u^{\Sigma_b^*} = m_d^{\Sigma_b^*} = 388\ MeV, m_b^{\Sigma_b^*} = 5046\ MeV;$$

$$m_u^{\Xi_b^*} = m_d^{\Xi_b^*} = 383\ MeV, m_s^{\Xi_b^*} = 559\ MeV, m_b^{\Xi_b^*} = 5047\ MeV;$$

$$m_s^{\Omega_b^*} = 550\ MeV, m_b^{\Omega_b^*} = 5047\ MeV.$$

  2. For doubly heavy baryons,

$$m_u^{\Xi_{cb}^*} = m_d^{\Xi_{cb}^*} = 369\ MeV, m_c^{\Xi_{cb}^*} = 1652\ MeV, m_b^{\Xi_{cb}^*} = 5045\ MeV;$$

$$m_s^{\Omega_{cb}^*} = 546\ MeV, m_c^{\Omega_{cb}^*} = 1652\ MeV, m_b^{\Omega_{cb}^*} = 5046\ MeV;$$

$$m_u^{\Xi_{bb}^*} = m_d^{\Xi_{bb}^*} = 365\ MeV, m_b^{\Xi_{bb}^*} = 5045\ MeV;$$

$$m_s^{\Omega_{bb}^*} = 542\ MeV, m_b^{\Omega_{bb}^*} = 5045\ MeV.$$

  3. For triply heavy baryons,

$$m_c^{\Omega_{ccb}^*} = 1652\ MeV, m_b^{\Omega_{ccb}^*} = 5044\ MeV;$$

$$m_c^{\Omega_{cbb}^*} = 1647\ MeV, m_b^{\Omega_{cbb}^*} = 5044\ MeV;$$

$$m_b^{\Omega_{bbb}^*} = 5044\ MeV.$$

Magnetic Moments of Heavy Flavor Baryons

- Magnetic Moments of ($J^P = \frac{1}{2}^+$) and ($J^P = \frac{3}{2}^+$) Baryons

$$\begin{aligned} \mu(\mathcal{B}) &= \frac{1}{3}(4\mu_1^\xi - \mu_2^\xi), \\ \mu(\mathcal{B}) &= \mu_3^\xi, \\ \mu(\mathcal{B}') &= \frac{1}{3}(2\mu_1^\xi + 2\mu_2^\xi - \mu_3^\xi), \\ \mu(\mathcal{B}^*) &= \mu_1^\xi + \mu_2^\xi + \mu_3^\xi. \end{aligned} \tag{31}$$

where, $\mu_i^\xi = \frac{e_i}{2m_i^\xi}$ denote the effective magnetic moments of first, second and third quarks, respectively. We adopt the convention that $[q_1 q_2]$ denotes anti-symmetric (S = 0) and $\{q_1 q_2\}$ denote symmetric (S = 1) combinations of quark flavor indices (with respect to the interchange of q_1 and q_2):

$$\begin{aligned} |\mathcal{B}\rangle &= \left|[q_1 q_2]^{S=0} q_3, J = \frac{1}{2}\right\rangle \\ |\mathcal{B}'\rangle &= \left|\{q_1 q_2\}^{S=1} q_3, J = \frac{1}{2}\right\rangle \\ |\mathcal{B}^*\rangle &= \left|\{q_1 q_2\}^{S=1} q_3, J = \frac{3}{2}\right\rangle . \end{aligned} \tag{32}$$

Transition Moments of Heavy Flavor Baryons

- Transition Moments Relations

$$\begin{aligned}
\mu_{\frac{1}{2}'^+ \to \frac{1}{2}^+} &= \sqrt{\frac{1}{3}}\left[\mu^{\xi}(2) - \mu^{\xi}(1)\right], \\
\mu_{\frac{3}{2}^+ \to \frac{1}{2}^+} &= \sqrt{\frac{2}{3}}\left[\mu^{\xi}(1) - \mu^{\xi}(2)\right], \\
\mu_{\frac{3}{2}^+ \to \frac{1}{2}'^+} &= \frac{\sqrt{2}}{3}\left[\mu^{\xi}(1) + \mu^{\xi}(2) - 2\mu^{\xi}(3)\right].
\end{aligned} \quad (33)$$

To evaluate $\mu_{\frac{1}{2}'^+ \to \frac{1}{2}^+}$ and $\mu_{\frac{3}{2}^+ \to \frac{1}{2}^+}$ transition moments, we take the geometric mean of effective quark masses of the constituent quarks of initial and final state baryons.

$$m_i^{\xi}(\mathcal{B}_J'^{(*)} \to \mathcal{B}_J) = \sqrt{m_i^{\xi}(\mathcal{B}_J'^{(*)})m_i^{\xi}(\mathcal{B}_J)}, \quad (34)$$

where, symbols have their usual meaning.

Transition Moments of Heavy Flavor Baryons (Continues)

- Using the Eqs. (8) - (13) and (15) - (20), we calculate the transition masses of baryons as follows:
  1. For singly heavy bottom baryons,

$$m_u^{\Lambda_b} = m_d^{\Lambda_b} = 335\ MeV, m_b^{\Lambda_b} = 5045\ MeV;$$

$$m_u^{\Xi_b} = m_d^{\Xi_b} = 341\ MeV, m_s^{\Xi_b} = 518\ MeV, m_b^{\Xi_b} = 5045\ MeV;$$

$$m_s^{\Omega_b} = 547\ MeV, m_b^{\Omega_b} = 5041\ MeV;$$

$$m_u^{\Sigma_b} = m_d^{\Sigma_b} = 386\ MeV, m_b^{\Sigma_b} = 5041\ MeV;$$

$$m_u^{\Xi'_b} = m_d^{\Xi'_b} = 380\ MeV, m_s^{\Xi'_b} = 556\ MeV, m_b^{\Xi'_b} = 5041\ MeV.$$

Transition Moments of Heavy Flavor Baryons (Continues)

1. For doubly heavy baryons,

$$m_u^{\Xi_{cb}} = m_d^{\Xi_{cb}} = 357\ MeV, m_c^{\Xi_{cb}} = 1641\ MeV, m_b^{\Xi_{cb}} = 5044\ MeV;$$

$$m_s^{\Omega_{cb}} = 533\ MeV, m_c^{\Omega_{cb}} = 1640\ MeV, m_b^{\Omega_{cb}} = 5044\ MeV;$$

$$m_u^{\Xi'_{cb}} = m_d^{\Xi'_{cb}} = 366\ MeV, m_c^{\Xi'_{cb}} = 1651\ MeV, m_b^{\Xi'_{cb}} = 5042\ MeV;$$

$$m_s^{\Omega'_{cb}} = 543\ MeV, m_c^{\Omega'_{cb}} = 1652\ MeV, m_b^{\Omega'_{cb}} = 5042\ MeV;$$

$$m_u^{\Xi_{bb}} = m_d^{\Xi_{bb}} = 360\ MeV, m_b^{\Xi_{bb}} = 5042\ MeV;$$

$$m_s^{\Omega_{bb}} = 536\ MeV, m_b^{\Omega_{bb}} = 5042\ MeV.$$

2. For triply heavy baryons,

$$m_c^{\Omega_{ccb}} = 1651\ MeV, m_b^{\Omega_{ccb}} = 5042\ MeV;$$

$$m_c^{\Omega_{cbb}} = 1645\ MeV; m_b^{\Omega_{cbb}} = 5043\ MeV.$$

Radiative Decay Widths of Heavy Flavor Baryons

- We will continue our presentation with the analysis for M1 partial widths of the ground state heavy baryons. We ignore the transition of type E2 which is expected to be much smaller in magnitude [5, 6] when compared to M1. The radiative decay widths of the decay type $\mathcal{B}_J'^{(*)} \rightarrow \mathcal{B}_J\gamma$ (Ref. [7, 8]) is given by

$$\Gamma(\mathcal{B}_J'^{(*)} \rightarrow \mathcal{B}_J\gamma) = \frac{\alpha\omega^3}{m_p^2}\frac{2}{(2J+1)}|\mu(\mathcal{B}_J'^{(*)} \rightarrow \mathcal{B}_J)|^2, \tag{35}$$

where,

$$\omega = \frac{M^2_{\mathcal{B}'^{(*)}} - M^2_{\mathcal{B}}}{2M_{\mathcal{B}'^{(*)}}}, \tag{36}$$

is the photon momentum in the center-of-mass system of the initial baryon states. Here, $\mu(\mathcal{B}_J'^{(*)} \rightarrow \mathcal{B}_J)$ is the transition magnetic moment (in μ_N), J is the spin quantum number for parent state, and $M_{\mathcal{B}'^{(*)}}$ and $M_{\mathcal{B}}$ are the masses of initial and final baryon state, respectively.

Numerical Results

Table: I. Magnetic moments (in nuclear magneton, μ_N) of $J^P = 1/2^+$ bottom baryons.

Baryons	EMS	[9, 10]	[11]	[9]	[8]	[13]
Λ_b^0	−0.062	−0.060	-	−0.066	−0.060	-
Σ_b^+	2.197	2.500	2.575	1.622	2.250	1.590
Σ_b^0	0.565	0.640	0.659	0.422	0.603	0.390
Σ_b^-	−1.068	−1.220	−1.256	−0.778	−1.150	−0.810
Ξ_b^0	−0.062	−0.110	-	−0.100	−0.106	0.400
Ξ_b^-	−0.062	−0.050	-	−0.063	−0.056	−0.730
$\Xi_b^{\prime 0}$	0.747	0.900	0.930	0.556	0.782	-
$\Xi_b^{\prime -}$	−0.908	−1.020	−0.985	−0.660	−0.968	-
Ω_b^-	−0.746	−0.790	−0.714	−0.545	−0.806	−0.650

Numerical Results (Continues)

Table: II. Magnetic moments (μ_N) of $J^P = 1/2^+$ bottom baryons.

Baryons	EMS	[9, 10]	[11]	[12]	[9]	[8]
Ξ_{cb}^{+}	-0.062	-0.250	-	-0.475	-0.157	-0.222
Ξ_{cb}^{0}	-0.062	0.130	-	0.518	0.068	0.102
$\Xi_{cb}^{\prime +}$	1.419	1.710	1.525	1.990	1.093	1.460
$\Xi_{cb}^{\prime 0}$	-0.299	-0.530	-0.390	-0.993	-0.236	-0.452
Ω_{cb}^{0}	-0.062	0.080	-	0.368	0.034	0.058
$\Omega_{cb}^{\prime 0}$	-0.113	-0.270	-0.119	-0.542	-0.106	-0.275
Ξ_{bb}^{0}	-0.669	-0.700	-0.722	-0.742	-0.432	-0.581
Ξ_{bb}^{-}	0.210	0.230	0.236	0.251	0.086	0.171
Ω_{bb}^{-}	0.114	0.120	0.100	0.101	0.043	0.112
Ω_{ccb}	0.526	0.540	0.476	-	0.505	0.455
Ω_{cbb}	-0.210	-0.210	-0.197	-	-0.205	-0.187

Numerical Results (Continues)

Table: III. Magnetic moments (in μ_N) of $J^P = 3/2^+$ bottom baryons.

Baryons	EMS	[12]	[9]	[8]	[13]	[15]	[17]
Σ_b^{*+}	3.161	-	2.346	3.460	2.140	2.52 ± 0.50	-
Σ_b^{*0}	0.744	-	0.537	0.820	0.400	0.50 ± 0.15	-
Σ_b^{*-}	-1.674	-	-1.271	-1.820	-1.350	-1.50 ± 0.36	-
Ξ_b^{*0}	1.013	-	0.690	1.030	0.540	0.50 ± 0.15	-
Ξ_b^{*-}	-1.438	-	-1.088	-1.550	-1.170	-1.42 ± 0.35	-
Ω_b^{*-}	-1.199	-	-0.919	-1.310	-0.970	-1.40 ± 0.35	-
Ξ_{cb}^{*+}	2.012	2.270	1.414	1.880	-	-	2.630
Ξ_{cb}^{*0}	-0.531	-0.712	-0.257	-0.534	-	-	-0.960
Ω_{cb}^{*0}	-0.256	-0.261	-0.111	-0.329	-	-	-1.110
Ξ_{bb}^{*0}	1.588	1.870	0.916	1.400	-	-	2.300
Ξ_{bb}^{*-}	-0.980	-1.110	-0.652	-0.880	-	-	-1.390
Ω_{bb}^{*-}	-0.701	-0.662	-0.522	-0.697	-	-	-1.560
Ω_{ccb}^{*+}	0.695	-	0.659	0.594	-	-	-
Ω_{cbb}^{*0}	0.256	-	0.225	0.204	-	-	-
Ω_{bbb}^{*-}	-0.186	-	-0.194	-0.178	-	-	-

Numerical Results (Continues)

Table: IV. Magnetic $\mu_{\frac{1}{2}'^{+}\to\frac{1}{2}^{+}}$ transition moments (in μ_N) of bottom baryons.

Transition	EMS	[22]	[9]	[8]	[23]	[6]
$\Sigma_b^0 \to \Lambda_b^0$	-1.628	-	1.052	-1.430	-1.370	$-1.54 \pm 0.0.6$
$\Xi_b'^- \to \Xi_b^-$	0.182	-	0.082	0.109	0.210	-0.21 ± 0.03
$\Xi_b'^0 \to \Xi_b^0$	-1.415	-	0.917	-1.300	-0.750	1.19 ± 0.06
$\Xi_{cb}'^0 \to \Xi_{cb}^0$	0.729	-	0.508	0.598	-	-
$\Xi_{cb}'^+ \to \Xi_{cb}^+$	-0.797	-	0.277	-0.531	-	-
$\Omega_{cb}'^0 \to \Omega_{cb}^0$	0.561	-	0.443	0.508	-	-

Numerical Results (Continues)

Table: V. Magnetic $\mu_{\frac{3}{2}^+ \to \frac{1}{2}^+}$ transition moments (in μ_N) of bottom baryons.

Transition	EMS	[8]	[23]	[6]
$\Sigma_b^{*0} \to \Lambda_b^0$	2.288	2.020	1.960	-2.18 ± 0.08
$\Sigma_b^{*-} \to \Sigma_b^-$	−0.706	−0.760	−0.580	0.87 ± 0.03
$\Sigma_b^{*0} \to \Sigma_b^0$	0.441	0.464	0.300	-0.33 ± 0.02
$\Sigma_b^{*+} \to \Sigma_b^+$	1.588	1.690	1.170	-1.52 ± 0.07
$\Xi_b^{*-} \to \Xi_b^-$	−0.255	−0.182	−0.300	-0.29 ± 0.04
$\Xi_b^{*0} \to \Xi_b^0$	1.988	1.830	1.060	1.69 ± 0.08
$\Xi_b^{*-} \to \Xi_b^{\prime -}$	−0.594	−0.623	−0.490	0.74 ± 0.03
$\Xi_b^{*0} \to \Xi_b^{\prime 0}$	0.569	0.521	0.330	-0.43 ± 0.02
$\Omega_b^{*-} \to \Omega_b^-$	−0.480	−0.523	−0.380	0.60 ± 0.04

Numerical Results (Continues)

Table: VI. Magnetic $\mu_{\frac{3}{2}^+ \to \frac{1}{2}^+}$ transition moments (in μ_N) of bottom baryons.

Transition	EMS	[8]
$\Xi_{cb}^{*0} \to \Xi_{cb}^{0}$	−1.026	−0.919
$\Xi_{cb}^{*+} \to \Xi_{cb}^{+}$	1.118	1.120
$\Xi_{cb}^{*0} \to \Xi_{cb}^{\prime\,0}$	−0.165	−0.042
$\Xi_{cb}^{*+} \to \Xi_{cb}^{\prime\,+}$	1.042	0.814
$\Omega_{cb}^{*0} \to \Omega_{cb}^{0}$	−0.790	−0.748
$\Omega_{cb}^{*0} \to \Omega_{cb}^{\prime\,0}$	−0.034	0.017
$\Xi_{bb}^{*-} \to \Xi_{bb}^{-}$	0.760	0.643
$\Xi_{bb}^{*0} \to \Xi_{bb}^{0}$	−1.695	−1.450
$\Omega_{bb}^{*-} \to \Omega_{bb}^{-}$	0.492	0.478
$\Omega_{ccb}^{*+} \to \Omega_{ccb}^{+}$	0.416	0.362
$\Omega_{cbb}^{*0} \to \Omega_{cbb}^{0}$	−0.417	−0.352

Numerical Results (Continues)

Table: VII. Photon momenta, ω of bottom baryons.

Transition	ω (in MeV)	[8]
$\Sigma_b^0 \to \Lambda_b^0$	193	190
$\Xi_b'^0 \to \Xi_b^0$	141	135
$\Xi_b'^- \to \Xi_b^-$	136	138
$\Sigma_b^{*0} \to \Lambda_b^0$	209	210
$\Sigma_b^{*0} \to \Sigma_b^0$	17	20
$\Sigma_b^{*-} \to \Sigma_b^-$	19	20
$\Sigma_b^{*+} \to \Sigma_b^+$	20	20
$\Xi_b^{*0} \to \Xi_b^0$	158	155
$\Xi_b^{*-} \to \Xi_b^-$	156	158
$\Xi_b^{*0} \to \Xi_b'^0$	17	20
$\Xi_b^{*-} \to \Xi_b'^-$	20	20
$\Omega_b^{*-} \to \Omega_b^-$	39	20

Numerical Results (Continues)

Table: VIII. Photon momenta, ω of bottom baryons.

Transition	ω (in MeV)
$\Xi_{cb}^{\prime 0} \rightarrow \Xi_{cb}^{0}$	16
$\Xi_{cb}^{\prime +} \rightarrow \Xi_{cb}^{+}$	16
$\Omega_{cb}^{\prime 0} \rightarrow \Omega_{cb}^{0}$	34
$\Xi_{cb}^{*0} \rightarrow \Xi_{cb}^{0}$	42
$\Xi_{cb}^{*+} \rightarrow \Xi_{cb}^{+}$	42
$\Xi_{cb}^{*0} \rightarrow \Xi_{cb}^{\prime 0}$	26
$\Xi_{cb}^{*+} \rightarrow \Xi_{cb}^{\prime +}$	26
$\Omega_{cb}^{*0} \rightarrow \Omega_{cb}^{0}$	61
$\Omega_{cb}^{*0} \rightarrow \Omega_{cb}^{\prime 0}$	27
$\Xi_{bb}^{*-} \rightarrow \Xi_{bb}^{-}$	35
$\Xi_{bb}^{*0} \rightarrow \Xi_{bb}^{0}$	35
$\Omega_{bb}^{*-} \rightarrow \Omega_{bb}^{-}$	35
$\Omega_{ccb}^{*+} \rightarrow \Omega_{ccb}^{+}$	30
$\Omega_{cbb}^{*0} \rightarrow \Omega_{cbb}^{0}$	34

Numerical Results (Continues)

Table: IX. The radiative decay widths (in KeV) of bottom baryons.

Transition	EMS	[29]	[8]	[23]	[6]‡	[24, 25, 26]	[30]
$\Sigma_b^0 \to \Lambda_b^0\gamma$	157.1	58.90	116.0	108.0	138.6	152.0	130.0
$\Xi_b^{'-} \to \Xi_b^-\gamma$	0.697	0.118	0.357	1.000	0.912	3.300	0000
$\Xi_b^{'0} \to \Xi_b^0\gamma$	46.91	14.70	36.40	13.00	32.96	47.00	84.60
$\Sigma_b^{*0} \to \Lambda_b^0\gamma$	198.3	81.10	158.0	142.1	180.0	114.0	335.0
$\Sigma_b^{*-} \to \Sigma_b^-\gamma$	0.014	0.010	0.019	0.010	0.021	0.110	0.060
$\Sigma_b^{*0} \to \Sigma_b^0\gamma$	0.004	0.005	0.008	0.003	0.002	0.028	0.020
$\Sigma_b^{*+} \to \Sigma_b^+\gamma$	0.080	0.054	0.110	0.050	0.073	0.460	0.250
$\Xi_b^{*-} \to \Xi_b^-\gamma$	1.030	0.278	0.536	1.400	1.332	1.500	0000
$\Xi_b^{*0} \to \Xi_b^0\gamma$	64.93	24.70	55.30	17.20	46.92	135.0	104.0
$\Xi_b^{*-} \to \Xi_b^{'-}\gamma$	0.012	0.005	0.014	0.008	0.019	0.303	15.00
$\Xi_b^{*0} \to \Xi_b^{'0}\gamma$	0.007	0.004	0.010	0.002	0.004	0.131	5.190
$\Omega_b^{*-} \to \Omega_b^-\gamma$	0.056	0.006	0.009	0.031	0.088	0.092	0.100

‡The values given in the column are calculated from the transition magnetic moments given by G. S. Yang and H. C. Kim in their results.

Numerical Results (Continues)

Table: X. The radiative decay widths (in KeV) of bottom baryons.

Transition	EMS	[29]	[8]	[27]	[28]
$\Xi'^0_{cb} \to \Xi^0_{cb}\gamma$	0.018	0.125	0.204	-	-
$\Xi'^+_{cb} \to \Xi^+_{cb}\gamma$	0.022	0.037	0.161	-	-
$\Omega'^0_{cb} \to \Omega^0_{cb}\gamma$	0.102	0.053	0.170	-	-
$\Xi^{*0}_{cb} \to \Xi^0_{cb}\gamma$	0.320	0.612	0.876	0.520	-
$\Xi^{*+}_{cb} \to \Xi^+_{cb}\gamma$	0.381	0.533	1.310	0.520	-
$\Xi^{*0}_{cb} \to \Xi'^0_{cb}\gamma$	0.002	3×10^{-4}	7.6×10^{-5}	7.190	-
$\Xi^{*+}_{cb} \to \Xi'^+_{cb}\gamma$	0.079	0.031	0.029	26.20	-
$\Omega^{*0}_{cb} \to \Omega^0_{cb}\gamma$	0.580	0.239	0.637	0.520	-
$\Omega^{*0}_{cb} \to \Omega'^0_{cb}\gamma$	1×10^{-4}	5×10^{-4}	1.3×10^{-5}	7.080	-
$\Xi^{*-}_{bb} \to \Xi^-_{bb}\gamma$	0.102	0.022	0.027	5.170	0.210
$\Xi^{*0}_{bb} \to \Xi^0_{bb}\gamma$	0.508	0.126	0.137	31.10	0.980
$\Omega^{*-}_{bb} \to \Omega^-_{bb}\gamma$	0.043	0.011	0.015	5.080	0.040
$\Omega^{*+}_{ccb} \to \Omega^+_{ccb}\gamma$	0.019	0.004	0.010	-	-
$\Omega^{*0}_{cbb} \to \Omega^0_{cbb}\gamma$	0.028	0.005	0.013	-	-

Summary and Conclusion

- In the present work, we have primarily focused on the prediction of magnetic properties of heavy flavor baryons in the framework of EMS. The EMS takes into account the modification based on hyperfine interaction between constituent quarks via one gluon exchange inside the baryon. Another unique feature of EMS is that it is parameter independent and, in addition, we have also incorporated symmetry breaking (through masses), which is a desirable feature for consistent predictions of baryon properties.
- We have calculated the magnetic and transition moments involving low-lying heavy baryons containing up to three heavy quarks, and consequently, have predicted M1 radiative decay widths for $\frac{1}{2}' \rightarrow \frac{1}{2}$ and $\frac{3}{2} \rightarrow \frac{1}{2}$ baryon states. Also, we have compared our results with existing predictions from other theoretical models. In order to make robust predictions, we have utilized precisely measured experimental values of baryon masses, and have used LQCD estimates in the case of unobserved baryons.

Summary and Conclusion (Continues)

- Following the current approach, we have accomplished two improvements. Firstly, symmetry breaking (through masses and interaction terms) is partially incorporated, and secondly, a more reliable calculation of effective masses has been achieved. In addition, we have tried to limit the uncertainties in photon momenta by mostly relying on experimental information. In the light of preceding arguments, it is therefore expected that our results would provide reasonably accurate predictions of magnetic (transition) moments and M1 radiative decay widths.
- We hope that our results prove to be useful in future experimental as well as theoretical ventures concerning heavy baryons.

Thanks for your attention! Any questions?

Hope you all are well during this pandemic!

Bibliography

- S. Kumar, R. Dhir and R. C. Verma, J. Phys. G **31**, no.2, 141-147 (2005) doi:10.1088/0954-3899/31/2/006
- R. Dhir and R. Verma, Eur. Phys. J. A **42**, 243-249 (2009) doi:10.1140/epja/i2009-10872-8 [arXiv:0904.2124 [hep-ph]].
- R. Dhir, C. S. Kim and R. C. Verma, Phys. Rev. D **88**, 094002 (2013) doi:10.1103/PhysRevD.88.094002 [arXiv:1309.4057 [hep-ph]].
- P. A. Zyla *et al.* [Particle Data Group], PTEP **2020**, no.8, 083C01 (2020) doi:10.1093/ptep/ptaa104
- H. Bahtiyar, K. U. Can, G. Erkol, M. Oka and T. T. Takahashi, Phys. Rev. D **98**, no.11, 114505 (2018) doi:10.1103/PhysRevD.98.114505 [arXiv:1807.06795 [hep-lat]].
- G. S. Yang and H. C. Kim, Phys. Lett. B **801**, 135142 (2020) doi:10.1016/j.physletb.2019.135142 [arXiv:1909.03156 [hep-ph]].
- J. Dey, V. Shevchenko, P. Volkovitsky and M. Dey, Phys. Lett. B **337**, 185-188 (1994) doi:10.1016/0370-2693(94)91466-4
- V. Simonis, arXiv:1803.01809 [hep-ph].
- A. Bernotas and V. Simonis, arXiv:1209.2900 [hep-ph].