Spectra and Decay Properties of singly beauty Baryons

Zalak Shah

in collaboration with: Amee Kakadiya, Ajay Kumar Rai

Department of Physics,
Sardar Vallabhbhai National Institute of Technology, Surat, India

9^{th} November, 2022.

The Model I

The relevant degrees of freedom for the relative motion of the three constituent quarks are provided by the relative Jacobi coordinates ($\vec{\rho}$ and $\vec{\lambda}$) given in the Hypercentral Constituent Quark Model

$$\vec{\rho} = \frac{1}{\sqrt{2}}(\vec{r_1} - \vec{r_2}) \qquad \vec{\lambda} = \frac{m_1\vec{r_1} + m_2\vec{r_2} - (m_1 + m_2)\vec{r_3}}{\sqrt{m_1^2 + m_2^2 + (m_1 + m_2)^2}} \tag{1}$$

The hyper radius x is a collective coordinate and therefore the hypercentral potential contains also the three-body effects. The Hamiltonian of three body baryonic system expressed as

$$H = -\frac{\hbar^2}{2m}\left(\frac{\partial^2}{\partial x^2} + \frac{5}{x}\frac{\partial}{\partial x} + \frac{L^2(\Omega)}{x^2}\right) + V_{SD}(x) + V_{SI}(x) \tag{2}$$

R. Bijker, F. Iachello, A. Leviatan, Annals Phys. 284, 89 (2000)
M. M. Giannini and E. Santopinto, Chin. J. Phys. **53**, 020301 (2015)
E. Santopinto, Phys. Rev. C72, 022201 (2005)

The spin dependent part of potential $V_{SD}(x)$ have three terms; spin-spin, spin-orbit and tensor term.

$$V_{SD}(x) = V_{SS}(x)(\vec{S_\rho}\cdot\vec{S_\lambda}) + V_{\gamma S}(x)(\vec{\gamma}\cdot\vec{S}) + V_T(x)\left[S^2 - \frac{3(\vec{S}\cdot\vec{x})(\vec{S}\cdot\vec{x})}{x^2}\right]$$

The spin independent part of potential is,

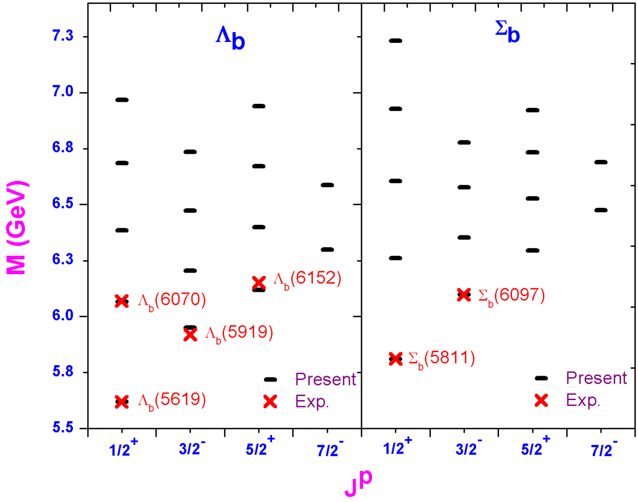
$$V_{SI}(x) = V_{conf}(x) + V_{Col}(x)$$

The screened potential is incorporated as confining potential with the color-Coulomb potential, which can be expressed as,

$$V_{conf}(x) = a\left(\frac{1-e^{-\mu x}}{\mu}\right) \quad and \quad V_{Col}(x) = -\frac{2}{3}\frac{\alpha_s}{x} \qquad (3)$$

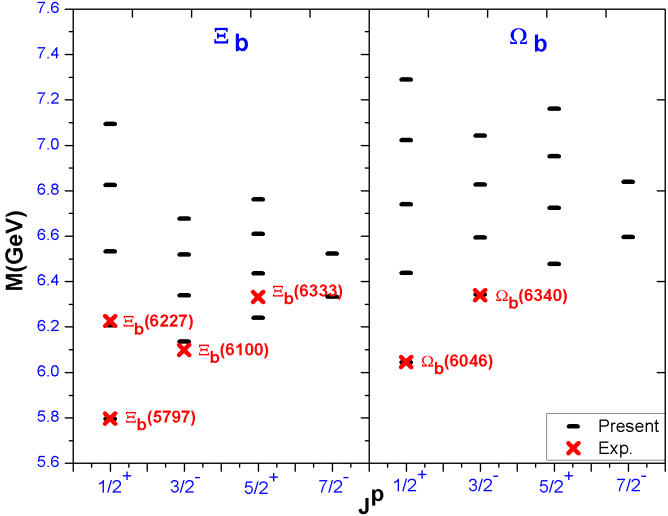
Phys. Rev. Lett **97**, 122003 (2006).
Prog. Part. Nucl. Phys. **51**, 455 (2008).
Int. J. of Ther. Phys. 59, 1129 (2020)

Mass Spectra



Few-Body Syst (2022) 63:29; Phys .Rev. Lett.123,152001(2019); Phys.Rev.Lett.122,012001(2019)

Mass



IJMPA 37, 2250053 (2022); PRD 103 1, 012004 (2021); PRL 124 8, 082002 (2020); PRL 121, 072002 (2018).

Strong decays using Heavy Hadron Chiral Perturbation Theory (HHChPT)

$$\Gamma_{\Sigma_b^+ \to \Lambda_b^0 \pi^+} = \frac{a_1^2}{2\pi f_\pi^2} \frac{M_{\Lambda_b^0}}{M_{\Sigma_b}^+} p_\pi^3; \quad a_1 = 0.612 \tag{4}$$

$$\Gamma_{\Lambda_b^0(1^2P_{\frac{1}{2}}) \to \Sigma_b^+ \pi^-} = \frac{b_1^2}{2\pi f_\pi^2} \frac{M_{\Sigma_b^+}}{M_{\Lambda_b^0(1^2P_{\frac{1}{2}})}} E_\pi^2 p_\pi; \quad b_1 = 0.572 \tag{5}$$

$$\Gamma_{\Sigma_b^+(1^2P_{\frac{1}{2}}) \to \Lambda_b^0 \pi^+} = \frac{b_2^2}{2\pi f_\pi^2} \frac{M_{\Lambda_b^0}}{M_{\Sigma_b^+(1^2P_{\frac{1}{2}})}} E_\pi^2 p_\pi; \quad b_2 = \sqrt{3} \cdot b_1 \tag{6}$$

$$\Gamma_{\Lambda_b^0(1^2P_{\frac{3}{2}}) \to \Sigma_b^+ \pi^-} = \frac{2b_3^2}{9\pi f_\pi^2} \frac{M_{\Sigma_b^+}}{M_{\Lambda_b^0(1^2P_{\frac{3}{2}})}} p_\pi^5; \quad b_3 = 3.50 \times 10^{-3} \tag{7}$$

$$\Gamma_{\Sigma_b^+(1^2P_{\frac{1}{2}}) \to \Lambda_b^0 \pi^+} = \frac{4b_4^2}{15\pi f_\pi^2} \frac{M_{\Lambda_b^0}}{M_{\Sigma_b^+(1^2P_{\frac{3}{2}})}} p_\pi^5; \quad b_4 = 0.4 \times 10^{-3} \tag{8}$$

Phys.Rev. D **56**, 5483 (1997), Eur. Phys. J. Plus 133, 512 (2018),

Strong decay widths(in MeV) [4]

	Decay mode	Present	[1]	[2]	[3]
P-wave	$\Sigma_b^+(1^2S_{\frac{1}{2}}) \rightarrow \Lambda_b^0\pi^+$	7.08	7.1	4.35	5.08
	$\Sigma_b^{*+}(1^2S_{\frac{1}{2}}) \rightarrow \Lambda_b^0\pi^+$	12.80	12.4	8.50	9.71
	$\Xi_b^{*0} \rightarrow \Xi_b^0 + \pi$	0.339			
S-wave	$\Lambda_b^0(1^2P_{\frac{1}{2}}) \rightarrow \Sigma_b^+\pi^-$	10.95			
	$\Sigma_b^+(1^2P_{\frac{1}{2}}) \rightarrow \Lambda_b^0\pi^+$	71.01			
	$\Omega_b^-(1P) \rightarrow \Xi_b^0 + \bar{K}$	445.1			
D-wave	$\Lambda_b^0(1^2P_{\frac{3}{2}}) \rightarrow \Sigma_b^+\pi^-$	0.0003			
	$\Sigma_b^+(1^2P_{\frac{3}{2}}) \rightarrow \Lambda_b^0\pi^+$	12.02			
	$\Sigma_b^{*+}(1^4P_{\frac{5}{2}}) \rightarrow \Lambda_b^0\pi^+$	11.64			
	$\Sigma_b^+(1^2P_{\frac{3}{2}}) \rightarrow \Sigma_b^{*+}\pi^0$	0.42			
	$\Omega_b^-(1P) \rightarrow \Xi_b^0 + \bar{K}$	0.489			

[1] A.Limphiratetal.,arXiv:0710.3942[hep-ph]

[2] Eur. Phys. J. C50,793(2007)

[3] Phys. Rev. D 100, 054013 (2019)

[4] Phys. Rev. D 75, 014006 (2007)

Conclusion

- In this work, the masses of the radial and orbital states of singly bottom baryons are calculated using Hypercentral Constituent Quark Model (hCQM) with the screened potential. The predicted masses are in accordance with the experimental observations and we also assign the J^P value to the unknown states.
- The strong decay width of various channels (P-wave, S-wave and D-wave of singly heavy bottom-strange baryons) are analyzed in the heavy hadron chiral perturbation theory (HHChPT), in absence of any experimental result we have compared our results to other references.