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Charm Heavy Baryons Mass Spectrum

Dhirendra Singh
Department of Physics, D. B. S. (P. G.) College
C. S. J. M. University, Kanpur, U. P., India
e-mail: dhirendradbs@gmail.com

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Abstract: Mass spectra of baryons consisting of one or two heavy quarks and light quark are calculated in the framework of a constituent quark model. Here, we have computed the masses of low-lying baryonic states with one or two charm quarks with different choices p. The masses of single or double heavy charmed baryons are found to be in accordance with the existing experimental value and with other theoretical predictions. It is found that the baryons mass for single charm do not change appreciably for potential index p>1.0 . Our predictions on double charm baryons are compared with other theoretical model predictions found larger disagreement among the different model predictions.
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1. Introduction

Heavy baryons masses have been extensively investigated by experimental and theoretical approaches[1-9]. In recent years, experimental facilities at Belle, CLEO, CDF, DELPHI, etc. have been succsessful in discovering heavy baryon states along with other heavy flavor mesonic states[5,7,8,9] and many new states are expected in near future. This has prompted us to look for the several aspects of the constituents quark model particularly the baryon constituting one or two charm quarks.

2. Theoretical Methodology : A potential Scheme

Quark model description of baryons is a simple three body system of interest. The Jacobi coordinates to describe baryon as a bound state of three constituents quarks are given by[10]

(2.1) $$\vec{\rho} = \frac{1}{\sqrt{2}}(\vec{r}_1 - \vec{r}_2);\ \vec{\lambda} = \frac{1}{\sqrt{6}}(\vec{r}_1 - \vec{r}_2 - 2\vec{r}_3)\ .$$

Such that

(2.2) $$m_\rho = \frac{2m_1 m_2}{m_1 + m_2};\; m_\lambda = \frac{3m_3(m_1+m_2)}{2(m_1+m_2+m_3)}$$

Here m_1, m_2 and m_3 are the constituent quark masses. Further, we introduce the hyper spherical coordinates which are given by the angles.

(2.3) $$\Omega_\rho = (\theta_\rho, \phi_\rho);\; \Omega_\lambda = (\theta_\lambda, \phi_\lambda),$$

together with the hyper-radius, x and hyper angle ξ respectively defined by

(2.4) $$x = \sqrt{\rho^2 + \lambda^2};\; \xi = \arctan\left(\frac{\rho}{\lambda}\right).$$

As the model Hamiltonian for baryons can be written as

(2.5) $$H = \frac{p_\rho^2}{2m_\rho} + \frac{p_\lambda^2}{2m_\lambda} + V(\rho,\lambda) = \frac{p^2}{2m} + V(x).$$

Here the potential V(x) is not purely a two-body interaction but it contains three-body interactions also. If the interaction potential is hyper central symmetric such that the potential depends on the hyper-radius *x* only, then the hyper-radial Schrodinger equation corresponds to the Hamiltonian given by eq. (2.5), and can be written as

(2.6) $$\left[\frac{d^2}{dx^2} + \frac{5}{x}\frac{d}{dx} - \gamma(\gamma+4)\right]\phi_\gamma(x) = -2m[E - V(x)]\phi_\gamma(x),$$

where γ is the grand angular quantum number and m is the reduced mass[11] which is defined as

(2.7) $$m = \frac{2m_\rho m\lambda}{m_\rho + m\lambda}$$

and potential V (*x*) is taken as[12]

(2.8) $$V(x) = -\frac{\gamma}{x} + \beta x^p + K + V_{hyp}(x).$$

Here the hyperfine part of the potential $V_{hyp}(x)$ is given by [3]

(2.9) $$V_{hyp}(x) = Ae^{-\alpha x} \sum_{i \neq j} \sigma_i . \sigma_j ,$$

where τ, β, A, κ *and* α are potential parameters. The energy eigen value corresponding to eq. (2.6) is obtained using virial theorem for different choices of the potential index p. The trial wave function is taken as the Coulomb radial wave function given by[3].

(2.10) $$\psi_{\omega\gamma} = \left[\frac{(\omega-\gamma)!(2g)^6}{(2\omega+5)(\omega+\gamma+4)!}\right]^{1/2}(2gx)e^{-gx}.$$

The baryon mass in this model is given by

(2.11) $$M_B = \sum_{i=1}^{3} m_i + \langle H \rangle.$$

The constituent quark mass parameters employed in our calculations are m_c = 1396 MeV; m_u = 338 MeV; m_s = 402 MeV; m_d = 350 MeV; b=13.6, $\frac{\beta}{m\tau}$ =1(MeV)^p , A=140.7 MeV. α = 850 MeV along with other potential parameters. Here κ is found to be proportional to the reduced mass, the flavor-color degree of freedom (N_f N_c) as well as the strong coupling constant α_s as

(2.12) $$\kappa \propto N_c N_f m \alpha_s (1 + O(\alpha_s^2).$$

It is found that the proportionality constant is equal to 0.41 for the qqQ systems and 0.32 for the QQq systems. The computations are repeated for different choices of p from 0.5 to 2.0 and the hyperfine interaction energy is treated perturbatively.

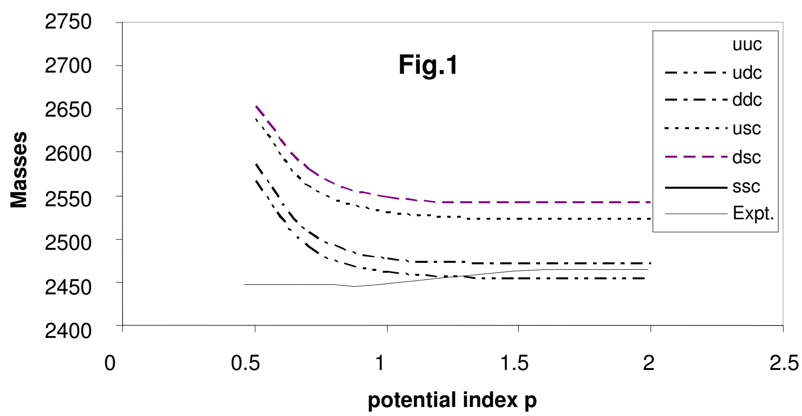

Fig.1. Variation of spin average mass with potential index p for single charm baryons

3. Results and discussions

The computed masses of the ground states of single or double charm baryons are listed in table 1 and 2. It is important to see that the baryon mass is not change appreciably beyond the potential index p>1.0. It may be due to the saturation of effective inter quark interaction within the baryon at potential index p>1.0. (see fig.1) The masses of single heavy flavor baryons are found to be in accordance with other model predictions.

Table 1: Single charm baryons masses in MeV (*indicates $J^P = \frac{3}{2}^+$ states)

Baryon	Content	Potential index P					Expt. [6]	Others
		0.5	0.7	1.0	1.5	2.0		
Σ_c^{++}	uuc	2548	2472	2443	2436	2436	$2454 \pm .18$	2453[13]
Σ_c^{*++}		2617	2537	2505	2498	2498	2518 ± 0.6	-
Σ_c^{+}	udc	2567	2490	2461	2453	2453	2453 ± 0.4	2451[13]
Σ_c^{*+}		3637	2556	2524	2519	2518	2518 ± 2.3	2505[14]
Σ_c^{0}	ddc	2585	2507	2476	2470	2470	2454 ± 0.18	2452[13]
Σ_c^{*+}		2658	2576	2542	2536	2537	2518 ± 0.5	-
Ξ_c^{+}	usc	2640	2560	2531	2522	2522	2468 ± 0.4	2466[13]
Ξ_c^{*+}		2721	2636	2603	2596	2596	2647 ± 1.4	2633[14]
Ξ_c^{0}	dsc	2652	2579	2547	2542	2542	2471 ± 0.4	2472[13]
Ξ_c^{*0}		2735	2755	2621	2617	2617	2646 ± 1.2	-
Ω_c^{0}	ssc	2721	2652	2618	2613	2613	2698 ± 2.6	2698[13]
Ω_c^{*0}		2811	2737	2705	2698	2698	-	2759[14]

Table 2: Double charm baryons masses in MeV (*indicates $J^P = \frac{3}{2}^+$ states)

Baryon	Content	Potential Index P					Expt.[16]	Others
		0.5	0.7	1.0	1.5	2.0		
Ξ_{cc}^{++}	ccu	3840	3762	3732	3725	3725	3541	3480[15]
Ξ_{cc}^{*++}		3914	3834	3802	3790	3790	-	3610[15]
Ξ_{cc}^{+}	ccd	3864	3788	3757	3746	3746	3443	3480[15]
Ξ_{cc}^{*+}		3946	3860	3829	3820	3820	3520	3610[15]
Ω_{cc}^{+}	ccs	3961	3890	3856	3851	3851	-	3590[15]
Ω_{cc}^{*+}		4051	3976	3945	3935	3935	-	3690[15]

Our predictions on the doubly charm baryons are compared with other theoretical predictions in Table 2. The predicted values from this model is found to be far from the experimental values as well as other theoretical models. Only future experiments would be able to test the validity of the theoretical model predictions.

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