Properties of Σ_c and Λ_c baryons in quark-diquark model

Ajay Majethiya[1], Kaushal Thakkar, and P. C. Vinodkumar
Department of Physics, Sardar Patel University, Vallabh vidhyanagar-388120, India

Study of the heavy flavour hadrons containing either a charm quark or a beauty quark has become a subject of recent interest due to the observations reported by the experimental groups at Belle, BABAR, DELPHI, CLEO, CDF etc;. Most of the new states observed in these experimental facilities are within the heavy flavour sector with one or more heavy flavour quark composition.

In the quark-diquark model, the Hamiltonian of the baryon is expressed in terms of a diquark Hamiltonian (H_{jk}) plus qurk-diquark Hamiltonian ($H_{i,jk}$) as [1]

$$H = H_{jk} + H_{i,jk} \tag{1}$$

The diquark(jk) Hamiltonian and Hamiltonian of the relative motion of the diquark(jk) and the third quark(i) is described by $H_d = H_{jk} = \frac{p^2}{2m_{jk}} + V_{jk}(r_{jk})$ and $H_{i,d} = H_{i,jk} = \frac{q^2}{2m_{i,jk}} + V_{i,jk}(r_{i,jk})$ respectively. Where, p and q are the relative momenta of the quarks within the diquark and within the quark-diquark systems respectively. Here, the inter-quark potential (V_{jk}) and the quark-diquark potential ($V_{i,jk}$) are taken as $V_{jk} = -\frac{2}{3}\alpha_s\frac{1}{r_{jk}} + b\ r^{\nu}_{jk}$ and $V_{i,jk} = -\frac{4}{3}\alpha_s\frac{1}{r_{i,jk}} + b\ r^{\nu}_{i,jk}$ respectively. Employing the numerical method using mathematica notebook, we get the spin average mass of the system (ie. without spin contribution) as $M_{Qqq} = \Sigma m_i + E(\overline{\mu})$ where, $E(\mu)$ is the total binding energy obtained from Eqn.1. The spin dependent interactions among the diquark and among the quark-diquark structure have been included perturbatively by considering the spin dependent potential provided by [2]. The potential parameters of the model are fixed to yield the spin average mass of the ground state of $\Sigma_c^*(2518) - \Sigma_c(2454)$ baryon. The mass spilting has been studied for different choices of the quark mass parameters, m_c for each case of the potential exponent (ν) with the different choice of the running strong coupling constant α_s. It is found that the choices of heavy quark mass parameter, m_c and α_s plays a decisive role in the mass splitting of the ground state baryons. The model parameters thus extracted here for the choices of $\alpha_s = 0.20$, $\alpha_s = 0.25$ and $\alpha_s = 0.30$ are listed in Table 1. With these sets of input values we have predicted the ground state mass of Λ_c. The three parameter sets deduced from the spectroscopy are being used to compute the magnetic moments, radiative decay and strong decay widths of Σ_c and Λ_c baryons with no additional parameters. The magnetic moments are computed by considering spin-flavor wave function of the baryonic state as well as by defining an effective bound state mass for the constituting quarks. Our results for the

[1] ajay.phy@gmail.com

Table 1: Mass, Magnetic moment and Decay width of Charm baryons

α_s	ν	m_c GeV	M_{Λ_c} GeV	$\mu_{\Sigma_c^+}$ μ_N	$\mu_{\Lambda_c^+}$ μ_N	$\Gamma_{\Sigma_c^+ \to \Lambda_c^+ \gamma}$ keV	$\Gamma_{\Sigma_c \to \Lambda_c \pi}$ MeV
0.20	0.4	1.100	2.346	0.312	0.429	10.15	< 0.01
	0.6	1.220	2.330	0.348	0.416	18.24	< 0.01
	0.8	1.280	2.323	0.365	0.410	24.39	<0.01
	1.0	1.320	2.317	0.377	0.407	27.96	< 0.01
0.25	0.4	1.360	2.310	0.389	0.404	34.17	< 0.01
	0.6	1.435	2.300	0.410	0.399	45.57	0.33
	0.8	1.480	2.298	0.422	0.396	49.54	0.61
	1.0	1.500	2.293	0.428	0.395	55.82	1.54
0.30	0.4	1.570	2.285	0.448	0.391	69.40	3.62
	0.6	1.615	2.280	0.460	0.388	79.21	5.26
	0.8	1.640	2.278	0.466	0.387	83.93	6.18
	1.0	1.650	2.275	0.470	0.386	89.31	7.14

choice of $\nu = 1.0$ and $\alpha_s = 0.25$ led to the fixing of charm mass parameter, m_c= 1.5 GeV to have the experimental $\Delta M_{(\Sigma_c^*(2518)-\Sigma_c(2454)}$= 64 MeV [3]. With the same model parameters, we have computed the mass of Λ_c as M_{Λ_c} = 2.293 GeV, as against the PDG2010 value of 2.286 GeV, the magnetic moment, $\mu_{\Lambda_c^+}$ = 0.395 μ_N, as against the value of 0.380 μ_N predicted in a relativistic quark model [4]. Our results for the transition decay width, $\Gamma_{\Sigma_c^+ \to \Lambda_c^+ \gamma}$ = 56.00 MeV is close to 60.00 MeV predicted by relativistic three quark model [5]. The overall agreement obtained in the present study indicates the success of the present model and the choice of the inter-quark potential for the description of the charm baryons.

References

[1] W. S. Carvalho *et al.*, arXiv:hep-ph **9404298v1**,(1994).

[2] S. S. Gershtein *et al.*, Heavy Ion Physics **9** , 133-144 (1999); Phys. Atom. Nucl., **63**; 274-286,(2000).

[3] K. Nakamura *et al.*, PDG, J. Phy. G: Nucl Part. Phy. **37**, 075021 (2010).

[4] Amand Faessler *et al.*, Phys. Rev. D **73**, 094013 (2006). Phys. **35**, 065001 (2008).

[5] M. A. Ivanov *et al.*, Phys. Rev.D **56** 348 (1998).