Strong decay of charmed baryons using quark-diquark Model

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Introduction

Some new excited charmed baryons observed by Belle, BABAR and CLEO [1–3] have initiated a great interest in the study of heavy baryons in both experiment and theory. The experimental information is still limited. So, it is important to understand the structures, spin-parity, decay, production and their interactions with other particles of new heavy flavour baryons theoretically. As adequate experimental data are available in the charm sector, our efforts would be to understand their properties based on the phenomenological description using the quark-diquark model [4, 5]. In this paper, we report the spectroscopy and strong decay of the charmed baryons. By studying the strong decay modes, one expects to extract information about their structures and the low energy dynamics of heavy baryons *vis a vis* interaction with pion and other pseudoscalar mesons.

Methodology

The Hamiltonian of the baryon, in the quark-diquark model, can be written in terms of diquark Hamiltonian plus quark-diquark Hamiltonian as [4, 5]

$$H = H_{jk} + H_{i,jk} \quad (1)$$

The internal motion of the diquark(jk) is described by

$$H_d = H_{jk} = \frac{p^2}{2m_{jk}} + V_{jk}(r_{jk}) \quad (2)$$

where, p is the relative momentum of the quarks within the diquark. The Hamiltonian of the relative motion of the diquark(jk) and the third quark(i) is given by

$$H_{i,d} = H_{i,jk} = \frac{q^2}{2m_{i,jk}} + V_{i,jk}(r_{id}) \quad (3)$$

where, q is the relative momentum between the diquark and the third quark, $m_{jk} = \frac{m_j m_k}{m_j+m_k}$ and $m_{i,jk} = \frac{m_i(m_j+m_k)}{m_1+m_2+m_3}$.
In the diquark model, the potential energy can be written, as

$$V = V_{jk}(r_{jk}) + V_{i,jk}(r_{id}) \quad (4)$$

Where, the diquark potential as well as the quark-diquark potential are assumed to be, [4, 5]

$$V_{jk} = -\frac{2}{3}\alpha_s \frac{1}{r_{jk}} + b\ r_{jk}^{\nu}; V_{i,jk} = -\frac{4}{3}\alpha_s \frac{1}{r_{id}} + b\ r_{id}^{\nu} \quad (5)$$

respectively. Here, ν is the potential exponent, r_{id} is the quark-diquark separation distance, α_s the running strong coupling constant, b is the model parameter corresponding to the confining part of the potential, which is assumed to be same for the di-quark interaction as well as between the quark-diquark interaction.

The numerical approach using the Runge-Kutta method in a mathematica note book has been used to solve the Schrodinger equation corresponds to the Hamiltonian as given in Eq.2 and 3.
The degeneracy of the states are removed by introducing the spin dependent interaction potential given by [6].

Strong decay of charmed baryons

The strong decay is computed as [7]

$$\Gamma(\Sigma_c^*, \Sigma_c \to \Lambda_c \pi) = \frac{g_2^2}{2\pi f_\pi^2} \frac{m_{\Lambda_c}}{m_{\Sigma_c}} p_\pi^3 \quad (6)$$

TABLE I: Strong decay width of the Σ_c^* and Σ_c Baryons in terms of MeV.

α_s	ν	b	m_c	M_{Λ_c}	$\Gamma_{(\Sigma_c\to\Lambda_c\pi)}$	$\Gamma_{(\Sigma_c^*\to\Lambda_c\pi)}$
	0.4	0.1604	1.100	2.346	<0.01	1.92
	0.6	0.0912	1.220	2.330	<0.01	4.17
0.20	0.8	0.0562	1.280	2.321	<0.01	5.77
	1.0	0.0355	1.320	2.317	<0.01	6.55
	0.4	0.1036	1.360	2.310	<0.10	8.030
	0.6	0.0581	1.435	2.300	0.25	10.40
0.25	0.8	0.0342	1.480	2.298	0.37	10.90
	1.0	0.0217	1.500	2.293	0.72	12.22
	0.4	0.0598	1.570	2.285	1.46	14.95
0.30	0.6	0.0325	1.615	2.280	2.02	16.00
	0.8	0.0190	1.640	2.278	2.26	16.63
	1.0	0.0117	1.650	2.275	2.65	17.59
Exp	[8]				2.23	14.90
[9]					1.51	11.27
[10]					2.85	21.99
[11]					2.50	8.20
[12]					2.41	17.52

where, g_2 is related to the axial vector coupling and is taken as 0.61 [7]. Here, $f_\pi = 132$ MeV and p_π is the momentum carried by the pion. It is computed as $\sqrt{(\frac{m_{\Sigma_c}^2 - m_{\Lambda_c}^2}{2m_{\Sigma_c}})^2 - m_\pi^2}$

Results and Discussions

For the description of the charm baryon, we employ the quark-diquark model with two body color coulomb plus power potential. The potential parameters of the model are fixed to yield the spin average mass as well as the mass difference, $\Sigma_c^*(2518) - \Sigma_c(2454)$ [8]. The mass spiltting has been studied for different choices of the quark mass parameter, m_c for each case of the potential exponent (ν) and with different choices of α_s. It is found that the value of heavy quark mass parameter and choice of α_s plays a decisive role in the mass splitting of the ground state baryons. The resulting quark mass parameters for the different choice of the potential exponent ν are listed in TableI along with the predicted mass of Λ_c. Using the spectroscopic mass parameters, we have computed the strong decay of $\Sigma_c(1/2, 3/2) \to \Lambda_c\pi$ baryons. The predicted widths for the choice of potential exponent $0.4 \le \nu \le 0.8$ and $\alpha_s = 0.3$ lie well within the experimental results with the error bar. So, we may expect that the quark-diquark model with the inter quark interaction reflects the physical reality and is applicable to all processes where baryons are involved.

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