Ground State Charmed Meson Spectra in a Non Relativistic Quark Model

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Introduction

D mesons are particles made of a charm and a lighter antiquark or an anticharm and a lighter quark. They are short-lived and decay in multiple ways, which makes them an interesting object of research. The neutral K,D,B_d and B_s mesons are the only hadrons which mix with their antiparticles. These meson states are flavour eigenstates and the corresponding antimesons have opposite flavour quantum numbers. A light-heavy quark structure composed of the charm and the strange quark is Ds meson.It requires a relativistic treatment Recently some of the higher excited states such as the $D_{s1}(2710)$, $D_{sJ}(2860)$ and $D_{sJ}(2040)$ have been experimentally measured Since the D meson is the lightest meson which contains a charm quark, it must change that charm quark to some other quark in order to decay. The D mesons were discovered by the Mark I detector at the Stanford Linear Accelerator Center. Measurements of D meson masses and mass differences have been performed using pp collision data, corresponding to an integrated luminosity of 1.0 fb^{-1}collected at a centreofmass energy of $\sqrt{s}$ = 7TeV with the LHCb detector. The Compressed Baryonic Matter (CBM) experiment at the Facility for Antiproton and Ion Research (FAIR) will provide new possibilities for charm-quark (D-meson) observables in heavy-ion collisions at low collision energies and high baryon[1].

Theoretical Background

The Hamiltonian employed in our model [2, 3] includes kinetic energy part, confinement potential and one gluon potential (OGEP) [4].

$$H = K + V_{CONF} + V_{OGEP} \tag{1}$$

The kinetic energy part (K) is the sum of the kinetic energies including the rest mass minus the kinetic energy of the center of mass motion (CM) of the total system, i.e.,

$$K = \left[\sum_{i=1}^{2} M_i + \frac{P_i^2}{2M_i}\right] - K_{\rm cm}, \tag{2}$$

with M_i and P_i as the mass and momentum of the ith quark, respectively. K_{CM} is the kinetic energy of the centre of mass motion.

For our model we have chosen the linear confinement potential which represents the non perturbative effect of QCD that confines quarks within the color singlet system [3].

$$V_{CONF}(\vec{r}_{ij}) = -a_c r_{ij} \vec{\lambda}_i \cdot \vec{\lambda}_j \tag{3}$$

where a_c is the confinement strength and λ_i and λ_j are the generators of the color SU(3) group for the ith and jth quarks. The one gluon exchange potential is given by

$$V_{OGEP} = -\frac{4}{3}\frac{\alpha_s}{r} + V_{SD}(r) \tag{4}$$

where the spin dependent potential V_{SD} is introduced as an additional term to the potential to take into the account the spin-orbit and spin-spin interactions, causing the splitting of the nL levels (n is the principal quantum number, L is the orbital momentum), so it has the form [4]

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$$V_{SD}(r) = \left(\frac{L \cdot S_c}{2m_c^2} + \frac{L \cdot S_b}{2m_b^2}\right)\left(-\frac{dV(r)}{rdr} + \frac{8}{3}\alpha_s \frac{1}{r^3}\right) + \frac{4}{3}\alpha_s \frac{1}{m_c m_b}\frac{L \cdot S}{r^3} + \frac{4}{3}\alpha_s \frac{2}{3m_c m_b} S_c \cdot S_b 4\pi\delta(r) + \frac{4}{3}\alpha_s \frac{1}{3m_c m_b}\left[3(S_c \cdot n)(S_b \cdot n) - S_c \cdot S_b\right]\frac{1}{r^3} \tag{5}$$

The central part of the two-body potential due to OGEP is [4],

$$V_{OGEP}(\vec{r}_{ij}) = \frac{\alpha_s}{4}\vec{\lambda}_i \cdot \vec{\lambda}_j \left[\frac{1}{r_{ij}} - \frac{\pi}{M_i M_j}(1 + \frac{2}{3}\vec{\sigma}_i \cdot \vec{\sigma}_j)\delta(\vec{r}_{ij})\right] \tag{6}$$

where the first term represents the residual Coulomb energy and the second term is the chromo-magnetic interaction leading to the hyperfine splitting. σ_i is the Pauli spin operator and α_s is the quark-gluon coupling constant.

The non$-$central part of OGEP is zero gound state mass spectra ($L = 0$).

Results and Conclusion

TABLE I: Masses of D meson in GeV

$n\ ^{2S+1}L_J$	Our model	Ref.[5]
$1\ ^1S_0$	1.869	1.875
$2\ ^1S_0$	2.455	2.579
$3\ ^1S_0$	2.946	
$4\ ^1S_0$	3.410	
$5\ ^1S_0$	3.860	
$1\ ^3S_1$	2.014	2.009
$2\ ^3S_1$	2.567	2.629
$3\ ^3S_1$	3.067	
$4\ ^3S_1$	3.543	
$5\ ^3S_1$	4.006	

We have calculated S wave mass spectrum of D meson in a non relativstic model. Meson masses after diagaonalization 5×5 Hamiltonian matrix are listed in I. The calculated masses are in good agreement with the other theoretical model and also with the experiment.

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