Variation of Ground state B_c and B_c^* meson masses for various n values

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Introduction

One of the most challenging field in theoretical particle physics is heavy quark physics. The huge amount of data available on hadrons needs to be explained in order to explore this field. Experimentally if one finds the need of high energy particles that can probe quark level physics, theoretically a suitable model is required to explain the properties such as mass spectrum, decays, reaction mechanism and bound state behaviours of those mesons which involve these quarks. In this line B_c meson is of significance when compared to flavour symmetric $c\bar{c}$ and $b\bar{b}$ meson states because it is the only meson composed of a b-quark and $\bar{c}$ quark and is the first particle containing both b and c quarks. The B_c is the lowest mass bound state of c and b quarks which is expected to be a pseudo scalar meson predicted by the Standard Model.

The B_c meson was first discovered by the CDF collaboration [1] in $p\bar{p}$ collisions. The mass and lifetime of B_c meson have been measured by CDF [2, 3] and D0 [4, 5] in decays of $B_c \to J/\psi\pi$ and $B_c \to J/\psi l$. They measured the mass to be 6.4±0.4 GeV. The PDG mass of B_c meson is 6.277±0.006 GeV [6]. Experimental studies of the B_c mesons are planned for B-Physics both at TEVATRON [7] and LHC [8].

A sound theoretical understanding of experimental data available for B_c mesons is of greater importance for several reasons. Some decay channels of B_c mesons show that bound state effects are significant in B_c decays. Masses of the constituents of B_c meson are considerably large. The lighter c quark has a decay rate which is larger than heavier b quark. The flavour antisymmetry of B_c meson unlike in symmetric quarkonium, forbids the annihilation of B_c meson into gluons. The pseudo scalar $c\bar{b}$ state decays only weakly. The B_c is unique in that either one of its quarks can decay, leaving the other as a spectator.

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Theory

In this work for the study of the B_c meson mass spectra, we have considered the following non relativistic Hamiltonian [9–11],

$$H = K + V_{CONF}(\vec{r}_{ij}) + V_{OGEP}(\vec{r}_{ij}) \quad (1)$$

where $V_{CONF}(\vec{r}_{ij})$ is the confinement potential

$$V_{CONF}(\vec{r}_{ij}) = -a_c r_{ij} \vec{\lambda}_i \cdot \vec{\lambda}_j \quad (2)$$

K is the kinetic energy term

$$K = \left[\sum_{i=1}^{2} M_i + \frac{P_i^2}{2M_i} \right] - K_{CM} \quad (3)$$

with M_i and P_i as the mass and momentum of the ith quark, respectively.

The central part of the two body potential due to OGEP [12] is given by

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

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.

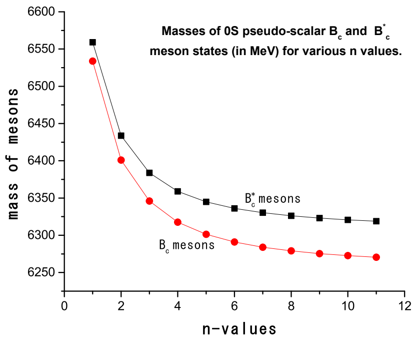

FIG. 1: Ground state masses (in MeV) of B$_c$ and B_c^* for different n values.

TABLE I: **Masses of 0S vector B_c^* and pseudo-scalar B_c meson states (in MeV) for various n values.**

n values	B_c^* mass	B_c mass
1	6559.05	6533.76
2	6433.69	6400.89
3	6383.69	6345.93
4	6358.89	6317.68
5	6344.92	6301.25
6	6336.13	6290.95
7	6330.27	6284.03
8	6326.07	6279.02
9	6323.04	6275.38
10	6320.75	6272.63
11	6318.96	6270.47

Results and Conclusions

The main objective of this work is to study the variation of ground state B$_c$ and B_c^* meson masses for various n values within the framework of NRQM formalism. There are five parameters in our model. These are the mass of charm quark M_c, the mass of the bottom quark M_b, the confinement strength a_c, the harmonic oscillator size parameter b and the quark-gluon coupling constant α_s. We use the following set of parameter values. $M_c = 1.4$ GeV; $M_b = 4.645$ GeV; $\alpha_s = 0.3$; $a_c = 260.0$ MeV fm^{-1}; $b = 0.325$ fm.

To start with, we construct a 11 × 11 Hamiltonian matrix for both pseudo-scalar and vector mesons in the harmonic oscillator basis. In our calculation, the product of the quark-antiquark oscillator wave functions are expressed in terms of oscillator wave functions corresponding to the relative and centre of mass coordinates.

In computing the meson masses we have diagonalised the Hamiltonian matrix in the relative space for S wave mesons. Table I gives the values of the mass for 0S state for various bases, by constructing 1 to 11th order matrices which justifies the perturbative effects in calculating the mass of pseudo scalar and vector mesons. The graph (fig 1) gives the variation of mass with different n values, for B_c and B_c^* mesons. For higher n values the variation of mass is almost negligible.

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