Mass spectra of B_c meson using Woods-Saxon potential

Antony Prakash Monteiro[1*] and Manjunath Bhat[1]
[1] *P.G Department of Physics, St Philomena College, Darbe, Puttur-574202,India*

Introduction

The B_c meson, the ground state of $\bar{b}c$ system is an intermediate between charmonium ($c\bar{c}$) and bottomonium ($b\bar{b}$) systems. The B_c meson provides a window for studying the heavy-quark dynamics that is very different from those provided by ($c\bar{c}$) and ($b\bar{b}$) quarkonia, because B_c meson consists of quarks of different flavours. 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].

QCD motivated potential models have played an important role in understanding quarkonium spectroscopy. QCD motivated Coulomb plus linear confining potential with colour magnetic spin dependent interactions have described the bottomonium and charmonium states successfully. Mesons composed of valence heavy (b and c) quarks are relatively simple because they are non relativistic systems and a potential model may be expected to work reasonably well. Hence we use the NRQM formalism for the study of B_c meson states.

Theory

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

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

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

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

where a_c is the confinement strength and $\boldsymbol{\lambda}_i$ and $\boldsymbol{\lambda}_j$ are the generators of the color SU(3) group for the ith and jth quarks. The confinement potential is entirely central in nature.
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 following central part of two-body potential due to Woods-Saxon potential is employed,

$$V_{WS}(\vec{r}_{ij}) = -\frac{V_0}{1 + exp\left(\frac{r_{ij}-R}{a}\right)} \quad (4)$$

where V_0 (having dimension of energy) represents the potential well depth for the $q\bar{q}$ system, R and a are the parameters. In order to determine these parameters we solved Schroedinger equation numerically for Woods-Saxon potential using matrix Numerov method. We developed a mathematica code for the numerical solution of Schroedinger equation.

In this work we have considered the Woods-Saxon potential, since it satisfies the short range behaviour of strong force.

Results and Discussions

There are eight parameters in our model. These are the mass of charm quark M_c, the

*Electronic address: `aprakashmonteiro@gmail.com`

TABLE I: Masses of pseudo-scalar B_c meson states(in MeV).

Meson states $^1S_0$	Calculated masses
0S	6275.41
1S	6640.71
2S	6986.59
3S	7273.98
4S	7581.36
5S	7856.58
6S	8135.95
7S	8427.72
8S	8746.91
9S	9114.69
10S	9570.97

TABLE II: B_c meson mass for various potentials (GeV).

PDG	6.277±0.006
Logarithmic[14]	6.266
QCD[15]	6.264
Cornell[16]	6.254
Powerlaw[17]	6.248
Our model	6.275

mass of the bottom quark M_b, the confinement strength a_c, the harmonic oscillator size parameter b ,the quark-gluon coupling constant α_s, potential depth V_0, R and a. These parameters were obtained by solving the Schroedinger equation numerically for Woods-Saxon potential using matrix Numerov method [13].

$V_0 \approx 50$ MeV; $a \approx 0.6$ fm; $R = 8$ fm;
$M_c = 1.4$ GeV; $M_b = 4.645$ GeV;
$a_c = 135.0$ MeV fm^{-1}; $b = 0.5$ fm.

We construct a 11×11 Hamiltonian matrix for pseudo-scalar meson 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. The masses of the pseudo scalar B_c meson after diagonalization for successive values of n_{max} are listed in table I.

Conclusion

We have calculated the masses for ground state and orbital excitations of B_c meson. We compare our calculated value of mass with PDG and three other potential models as listed in table II. We find our value closer to the present experimental value.

References

[1] F. Abe et al., (CDF Collaboration) Phys. Rev. D**58**, 112004 (1998).

[2] A. Abulencia et al. (CDF Collaboration), Phys. Rev. Lett. **96**, 082002 (2006).

[3] A. Abulencia et al. (CDF Collaboration), Phys. Rev. Lett. **97**, 012002 (2006).

[4] V. M. Abazov et al. (D0 Collaboration), Phys. Rev. Lett. **101**,012001 (2008).

[5] V. M. Abazov et al. (D0 Collaboration), Phys. Rev. Lett. **102**,092001 (2009).

[6] J. Beringer et al. (Particle Data Group), Phys. Rev. D**86**, 010001 (2012).

[7] K. Anikeev et al., arXiv:hep-ph/0201071.

[8] I. P. Gouz, V. V. Kiselev, A. K. Likhoded, V. I. Romanovsky and O. P. Yuschenko, arXiv:hep-ph/0211432.

[9] K. B. Vijaya Kumar, B. Hanumaiah and S. Pepin, Eur. Phys. J. A**19**, 247 (2004).

[10] Bhavyashri, S. Sarangi, Godfrey Saldhana and K. B. Vijaya Kumar, Pramana J. Phys. **70**, 75(2008).

[11] K. B. Vijaya Kumar, Bhavyashri, Yong-Ling Ma and A. P. Monteiro, Int. J. Mod. Phys. A**22**, 4209 (2009).

[12] R. D. Woods and D. S. Saxon, Phys. Rev. **95**, 577 (1954).

[13] Mohandas Pillai, Joshua Goglio and Thad G. Walker, Am. J. Phys. **80**, 1017(2012).

[14] C.Quigg and J. L. Rosner, Phys. Lett. B **71**, 153 (1977).

[15] W. Buchmuller and S.H.H. Tye, Phys. Rev. D **24**, 132 (1981).

[16] E. Eichten, K. Gottfried, T. Kinoshita, K. D. Lane, T. M. Yan, Phys. Rev. D **17**, 3090(1978).

[17] A. Martin, Phys. Lett. B **93**, 338 (1980).