Mass spectrum of Orbitally Excited State of B Mesons in a Non Relativistic Quark Model with Hulthen Potential

Praveen P D'Souza [1 2],* A P Monteiro[1], and K. B. Vijaya Kumar [2]
[1]P.G Department of Physics, St Philomena College, Darbe, Puttur-574202,INDIA and
[2]Department of Physics, Mangalore University,
Mangalagangothri P.O., Mangalore - 574199, INDIA

Introduction

Heavy light mesons composed of one heavy quark and one light quark,They are the only mesons containing quarks of the third generation. In this respect, the physics of B mesons is complementary to that of the K mesons, which has contributed enormously to our understanding of elementary particles and their interactions. The rare decay of a neutral B meson to two oppositely charged kaons has been observed for the first time in LHCb experiment at CERN. B mesons are created when protons collide in the Large Hadron Collider and the observed decay happens to fewer than one in ten million B mesons. The properties of excited B and mesons as a good guide to help to identify the newly observed states.[1]. The B mesons, the ground state as well as first few orbitally excited stats, have been well established experimentally. Although other radially and orbitally excited states require further experimental investigation. The Hulthen potential is one of the important short-range potentials, which at short distances possesses asymptotic freedom, behaves like the Coulomb potential for small values of r, and decreases exponentially at large values. This behavior is in particular of interest in particle physics. In the present work we used variational approach. In the present work we used variational approach. The variational method is very efficient for solving radial schrodinger equation in the case of the ground states and excited states when the problems cannot be solved exactly [3]. In our calculation we get variational parameter for different heavy-light mesons. Having variational parameter eigenenergy will be obtained. For meson system, the Hulthen term acts like a Coulombic term. The spin dependent potential from One Gluon Exchange Potential (OGEP) is introduced.

Theoretical Background

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

$$H = K + V_{CONF} + V_{OGEP} \qquad (1)$$

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.,

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

Among different types of potential model , here we are going to introduce a new type of potential for the mesonic system that is the linear confining and the Hulthen potential V_H is defined as the

$$V_H(r) = -Ze^2\mu \frac{\exp(\frac{-r}{\mu})}{1-\exp(\frac{-r}{\mu})} \qquad (3)$$

Where μ_0 is a constant and μ is the screening parameter, determining the range for Hulthen potential. The Hulthen potential displays a typical property of the screening effect of a Coulomb-type interaction near the origin($r \to 0$), but it approaches to zero exponentially in the asymptotic region for $r \to \infty$. Hence in the limit $r \to 0$ the Hulthen potential behaves like coulomb -like potential with the strong coupling constant α_s is given by $V_H \simeq \frac{-4\alpha_s}{3r}$. Where α_s is the running coupling constant [2]. 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 [4].

$$V_{CONF}(r_{ij}) = -a_c r_{ij} \lambda_i \cdot \lambda_j \qquad (4)$$

*Electronic address: praviphysics@gmail.com

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

$$V_{OGEP} = V_H(r) + V_{SD}(r) \tag{5}$$

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.

$$V_{SD}(r) = \left(\frac{L\cdot S_c}{2m_c^2} + \frac{L\cdot S_b}{2m_b^2}\right)\left(-\frac{dV(r)}{rdr} + \frac{8}{3}\alpha_s\frac{1}{r^3}\right) + \frac{4}{3}\alpha_s\frac{1}{m_c m_b}\frac{L\cdot S}{r^3} + \frac{4}{3}\alpha_s\frac{2}{3m_c m_b}S_c\cdot S_b 4\pi\delta(r) + \frac{4}{3}\alpha_s\frac{1}{3m_c m_b}\left[3(S_c\cdot n)(S_b\cdot n) - S_c\cdot S_b\right]\frac{1}{r^3} \tag{6}$$

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

$$V_{OGEP}(\vec{r}_{ij}) = \frac{\alpha_s}{4}\vec{\lambda}_i\cdot\vec{\lambda}_j \left[\frac{1}{r_{ij}} - \frac{\pi}{M_i M_j}(1 + \frac{2}{3}\vec{\sigma}_i\cdot\vec{\sigma}_j)\delta(\vec{r}_{ij})\right] \tag{7}$$

Results and Conclusion

The variational technique represents a completely different way of getting approximate energies and wave functions for quantum mechanical systems. We construct a 5X5 Hamiltonian matrix for B 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 B mesons after diagonalization for successive values of n_{max} Table I shows our current estimates compared to the experimental values and the non relativistic approach (Godfrey-Isgur Quark Model(GI)).

TABLE I: Masses of $B(b\bar{q}, q \in u, d)$ Spectrum in MeV

$n\ ^{2S+1}L_J$	b	Present Work	Exp	GI
$1\ ^1P_1$	0.990	5749		5777
$2\ ^1P_1$	0.180	6246		6177
$3\ ^1P_1$	0.195	6641		6557
$1\ ^3P_0$	0.999	5734	5710 ± 20	5756
$2\ ^3P_0$	1.068	6242		6213
$3\ ^3P_0$	1.045	6556		6576
$1\ ^3P_1$	1.014	5755	5723.5 ± 2.0	5784
$2\ ^3P_1$	1.078	6258		6228
$3\ ^3P_1$	1.065	6655		6585
$1\ ^3P_2$	1.022	5763	5743 ± 5	5797
$2\ ^3P_2$	1.069	6244		6213
$3\ ^3P_2$	1.055	6574		6570
$1\ ^1D_2$	1.045	6076		6095
$2\ ^1D_2$	1.052	6426		6450
$3\ ^1D_2$	1.059	6753		6767
$1\ ^3D_1$	1.076	6098		6110
$2\ ^3D_1$	1.052	6422		6475
$3\ ^3D_1$	1.059	6751		6792
$1\ ^3D_2$	1.082	6080		6124
$2\ ^3D_2$	1.056	6430		6486
$3\ ^3D_2$	1.059	6758		6800
$1\ ^3D_3$	1.056	6068		6106
$2\ ^3D_3$	1.052	6422		6460
$3\ ^3D_3$	1.056	6745		6775

[a] The nonrelativistic approach (Godfrey-Isgur Quark model)

References

[1] Godfrey, Stephen and Moats, Kenneth and Swanson, Eric S.Phys. Rev. D.**94**, 054025, (2016)

[2] Bhaghyesh, K B Vijaya Kumar, Antony Prakash Monteiro, J. Phys.G **38**,085001, (2012)

[3] Hassanabadi, H. and Ghafourian,Few-Body Systems,**57**,254, (2016)

[4] Antony Prakash Monteiro and Manjunath Bhat and K. B. Vijaya Kumar International Journal of Modern Physics A,**32**, 1750021,(2017)