S-wave Masses of B Meson in a Non relativistic Quark Model with Hulthen Potential

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Introduction

B mesons are bound states of a b quark and a light anti-quark. They can be viewed as the hydrogen atoms of QCD with a light quark interacting with a heavy static quark.They are the only mesons containing quarks of the third generation. The current theory of particle physics, the Standard Model, has very specific predictions on the frequency and angle at which the B meson decays. Understanding the B mesons will give a more complete understanding of excited mesons and will also help put the newly discovered excited charmed mesons into the larger context. The Standard Model maintains that each particle will be powered by a certain level of energy, and emitted at a specific angle. The interest in studying B hadrons in the context of the Standard Model arises from the fact that B hadron decays provide valuable information on the weak mixing matrix.

The great importance of B physics lies further in the fact that its investigation allows valuable tests of the validity of the standard model. The Standard Model of Particle Physics is currently the most complete theory of fundamental processes in nature. Certain processes, such as flavour oscillations in the neutral B system or rare decays of B mesons which are induced by loop diagrams, are also sensitive to physics beyond the standard model with three generations. The observation of C P violation in the B system will certainly shed light on this important phenomenon, which is so far not fully understood. 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.

We have presented preliminary results for the S wave mass splittings of B mesons.

B mesons have been studied extensively over the years since their discovery in various colliders. e^+e beams can be tuned precisely to collide at specific resonances. The $\gamma(4S)$ state is just above the kinematic threshold for $B^+B, B^0\bar{B}^0$ production. Experiments of this type are Babar, Belle(II), CLEO, ARGUS. Second type of collider is hadronic collisions, either pp or p$\bar{p}$,have much larger production cross-sections, especially at the TeV scales of the LHC. Experiments of this type are at the TeVatron and the LHC.

Theoretical Background

In the non-relativistic limit, the energy term is expanded as the sum of the mass and kinetic energy. Hamiltonian is given by

$$H = K + V(r) \tag{1}$$

The Kinetic energy is given by

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

Where M_i and P_i are the mass and momentum of the i^{th} quark. K_{CM} is the kinetic energy of the Center of mass. [1].
V(r) is quark-antiquark interaction potential given by

$$V(r) = V_{conf}(r) + V_H(r) \tag{3}$$

In our model we have chosen linear confinement potential which represents the non perturbative effects of QCD that confines quarks within the color singlet system.

$$V_{conf}(r) = -\left[\frac{3}{4}V_0 + \frac{3}{4}cr\right]F_1{\cdot}F_2 \tag{4}$$

Where c and V_0 are constants.F is related to the Gell-Mann matrix.We have $F_1{\cdot}F_2 = \frac{-4}{3}$

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for the mesons.
The Hulthen potential V_H is defined as the

$$V_H(r) = -\mu_0 \frac{\exp(\frac{-r}{\mu})}{1-\exp(\frac{-r}{\mu})} \quad (5)$$

In the limit $r \rightarrow 0$ the Hulthen potential behaves like coulomb -like potential with the strong coupling constant α_s is given by $V_H \simeq \frac{-4\alpha_s}{3r}$ [2]

Spin Dependent Interactions

The spin dependent potential V_{SD} is introduced as an additional term to the potential to take into the account the spin-spin, spin orbit and tensor part interactions.[3]. Since we have considered ground state mass spectra in our calculation the spin orbit and tensor part of interaction vanishes. The spin dependence corrections to the non relativistic Hamiltonian gives the hyperfine splitting and the form generally used is.

$$V_{SD} = V_{SS}\Big[\frac{1}{2}\Big(S(S+1) - \frac{3}{4}\Big] \quad (6)$$

$$V_{SS}^{ij} = \frac{1}{3M_iM_j}\nabla^2 V_v(r) = \frac{32\pi\alpha_s}{9M_iM_j}\delta^3(r) \quad (7)$$

As the Lorentz structure of the terms in Eq.3 are not precisely known, it is presumed that the fraction in V(r) have partly scalar and vector nature. Therefore we use the ansatz

$$V_s(r) = \delta V_H(r) + \epsilon V_C(r) + V_0 \quad (8)$$

$$V_v(r) = (1-\delta)V_H(r) + (1-\epsilon)V_C(r) \quad (9)$$

where δ,$\epsilon < 1$. The constants δ and ϵ are fixed from the experimental spectrum.

Results and Conclusion

There are eight parameters in our model. These are the mass of bottom antiquark m_b and charm quark m_c, the other parameters are the confinement strength c, the harmonic oscillator size parameter b,the coupling constant α_s. The constant parameters are μ_0, μ and V_0.

$$m_b = 0.350 \text{ GeV} \quad \mathrm{m_c} = 4.591 \text{ GeV}$$
$$c = 30 \text{ GeV}^2 \;\; \mu_0 = -33.1 \text{ GeV b} = 0.5 \text{ fm}$$
$$\mu = 25.6 \text{ GeV}^{-1} \quad \mathrm{V_0} = -45 \text{ GeV}$$

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

$n\ ^{2S+1}L_J$	Meson	Exp Mass	Our model	[4][a]
$1\ ^1S_0$	B	5279.58 ± 0.17	5279	5277
$2\ ^1S_0$			5825	5822
$3\ ^1S_0$			6318	6117
$4\ ^1S_0$			6763	6335
$1\ ^3S_1$	B^*	5325.2 ± 0.4	5304	5325
$2\ ^3S_1$			5831	5848
$3\ ^3S_1$			6322	6136
$4\ ^3S_1$			6779	6351

[a]The nonrelativistic approach (Blankenbecler-Sugar equation)

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 after diagonalization for successive values of n_{max} Table I shows our current estimates compared to the experimental values and the non relativistic approach (Blankenbecler-Sugar equation).

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