Spectroscopic assignments of $B_J^*(5732)$ and $B_1(5721)$ mesons

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Introduction

The aim of this paper is to discuss the possible spin-parity assignments of experimentally observed $B_J^*(5732)$ and $B_1(5721)$ mesons [1]. Based on the experimental and theoretical status of excited B mesons, the states $B_J^*(5732)$ and $B_1(5721)$, may belong to $L = 1$ ($P-$wave) states [2–9]. These theoretical predictions are not consistent with one another. As a result, a further test of calculations against experimental observations is required to identify these mesons. Here, we will use the leading order approximation of heavy quark effective theory to compute the masses of $1P-$wave B mesons. It is possible to use charm data to predict the B mesons. The heavy-quark flavour symmetry explores the flavour symmetry parameters $\Delta_F^{(c)} = \Delta_F^{(b)}$ and $\lambda_F^{(c)} = \lambda_F^{(b)}$ to determine the excited B meson masses [10, 11]. In the upcoming section, we discuss the Lagrangian presents the mass parameters of excited heavy-light flavor mesons in the framework of heavy quark effective theory.

Theory

The heavy quark effective theory (HQET) is constructed in the leading order approximation by expanding the QCD (Quantum Chromodynamics) Lagrangian in the power of $1/m_Q$ as

$$\mathcal{L}_{HQET} = \mathcal{L}_0 + \frac{1}{m_Q}\mathcal{L}_1 + \frac{1}{m_Q^2}\mathcal{L}_2 + ..., \qquad (1)$$

only the first term survives in the heavy quark mass limit because the leading Lagrangian in this case has an exact heavy quark spin-flavor symmetry (a detailed discussion is given in [12]). Using the fields in Eq. (10) in Ref. [13], the field $\Sigma = \xi^2$ of light pseudoscalar mesons and the kinetic terms of the heavy meson doublets are described in the effective Lagrangian as

$$\begin{aligned}\mathcal{L} =& iTr[\bar{H}_b\nu^\mu D_{\mu ba} H_a] + \frac{f_\pi^2}{8} Tr[\partial^\mu \Sigma \partial_\mu \Sigma^\dagger] \\ &+ Tr[\bar{S}_b(i\nu^\mu D_{\mu ba} - \delta_{ba}\Delta_S)S_a] \\ &+ Tr[\bar{T}_b^\alpha(i\nu^\mu D_{\mu ba} - \delta_{ba}\Delta_T)T_{a\alpha}],\end{aligned} \qquad (2)$$

where the mass parameter Δ_F (with $F = S$ and T) determines the mass splittings between excited and low-lying negative parity doublets [10]. The Lagrangian, given by [11],

$$\begin{aligned}\mathcal{L}_{1/m_Q} =& \frac{1}{2m_Q}\{\lambda_H Tr[\bar{H}_a\sigma^{\mu\nu}H_a\sigma_{\mu\nu}] \\ &- \lambda_S Tr[\bar{S}_a\sigma^{\mu\nu}S_a\sigma_{\mu\nu}] \\ &+ \lambda_T Tr[\bar{T}_a^\alpha\sigma^{\mu\nu}T_a^\alpha\sigma_{\mu\nu}]\},\end{aligned} \qquad (3)$$

breaks the mass degeneracy between meson doublet members.

Flavor symmetry implies that the mass splitting Δ_F between doublets and the mass splitting λ_F between spin-partners in doublets are both free of heavy quark flavour, whether charm (c) or bottom (b), *i.e.*,

$$\Delta_F^{(c)} = \Delta_F^{(b)} \qquad \lambda_F^{(c)} = \lambda_F^{(b)}; \qquad (4)$$

where F stands for $F = S$ and T represent P-wave first and second doublet, respectively [10, 11].

Note: The meson quantum state is represented by the symbol $\mathcal{N}\ ^{2S+1}L_J$; where $\mathcal{N}$, L, and S indicate radial, orbital, and intrinsic spin quantum numbers, respectively.

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TABLE I: Predicted masses of $1P$-wave B mesons (in MeV).

$\mathcal{N}\ ^{2S+1}L_J$	Present [10]	Exp. [1]	Ref. [2]	Ref. [3]	Ref. [4]
1^3P_0	5700	5698 $B_J^*(5732)$	5756	5756	5683
1^1P_1	5740	5726 $B_1(5721)$	5777	5779	5729
1^3P_1	5780		5784	5782	5754
1^3P_2	5800		5797	5796	5768

Results and Discussion

We previously investigated the strong decay of an experimentally observed excited D meson [14]. The ratio of strong decay rates identified the doublets: $(D_0^*(2400), D_1(2430))$ as $(1^3P_0, 1^1P_1)$ and $(D_1(2420), D_2^*(2460))$ as $(1^3P_1, 1^3P_2)$. This charm data are used to forecast the respective bottom mesons. It should be noted that the ground state masses of the B mesons are set by PDG (Particle Data Group) [1].

Table I lists the calculated masses of $1P$-wave B mesons together with the experimental data that are currently available and theoretical predictions. Our calculated mass 5700 MeV of $B(1^3P_0)$ is in good agreement with the experimentally measured mass 5698 MeV of $B_J^*(5732)$ [1]. $B_1(5721)$ is measured experimentally with spin-parity $J^P = 1^+$ [1]. This agrees with our prediction of $B(1^1P_1)$ by a mass difference of 14 MeV. Our finding 5800 MeV of $B(1^3P_2)$ is overestimated to the PDG fit value 5739.5 $\pm$ 0.7 MeV of $B_2^*(5747)^0$ [1] and is in good agreement with the predictions of [2, 3]. We expect future experimental investigations will provide more data in this regard.

The excited B mesons have been thoroughly studied using heavy quark effective theory. The masses of $1P$-wave B mesons are calculated. Our predictions, together with other results from several theoretical models and available experimental observations, provide the mass range of these mesons. The properties of other excited B mesons are also predicted [10], which will be helpful in upcoming experimental searches.

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