Hadron Loop effects on B Meson Masses in a Non Relativistic Quark Model.

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Introduction

Among the variety of hadrons available in nature and produced in B-factory experiments Belle BaBar and LHC proton-proton collisions, B-mesons play a fundamental role. They are bound-states of two quarks one a bottom quark, the other one of the lighter quarks (up, down, strange or charm). They decay through the weak interaction to lighter hadrons and/or leptons.Mesons with masses below their lowest OZI-allowed strong-decay thresholds have very small widths [4]. Most of the hadronic B decays involve $b \to c$ transition at the quark level, resulting in a charmed hadron or charmonium in the final state. The study of B mesons continues to be one of the most productive fields in particle physics. Most quark models treat hadrons as manifestly stable bound states of quarks, ignoring the fact that the strong binding force of quarks is of comparable order of magnitude as the strong forces that cause hadronic decay. The problem is that such an approach ignores the possible real mass shifts due to two-meson channels effects. Being heavy,bottom hadrons have revealed several channels for few decays, categorized as leptonic, semi-leptonic and hadronic decays. The two-body weak hadronic decays of heavy flavor hadrons emitting vector mesons and pseudo scalar mesons $B \to VV$ decays, $B \to PP$ decays and $B \to VP$ decays. However $B \to VV$,decays are more complicated than $B \to VP$, $B \to PP$ because of the three possible partial waves in the final state.

Theoretical Background

In a potential model approach the entire dynamics of quarks in a meson is governed by a Hamiltonian has kinetic energy term (K) and a potential energy (V), that is

$$H = K + V.$$

The potential energy V is the sum of the heavy-quark potential $V_H(\vec{r})$ and linear confining potential $V_{conf}(\vec{r})$. The Hulthen potential is one of the important short-range potentials which behaves like Coulomb potential for small values of r and decreases exponentially for large values of r.The Hulthen potential V_H is defined as the [1]

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

The non−central part of OGEP has two terms, namely the spin−orbit interaction $V^{SO}_{OGEP}(\vec{r})$ and tensor term $V^{ten}_{OGEP}(\vec{r})$. In this model it is assumed that the strong decay of meson A (with a quark q_1 and an anti-quark q_2) takes place through the creation of a pair of quark(q_3) and anti-quark(q_4) from vacuum with quantum number $J^{PC} = 0^{++}$. The created quark anti-qurak pair recombines with the quark and anti-qurak in the initial meson state forming final meson states i.e, mesons B and C. In the coupled channel model, the full hadronic state is given by

$$|\psi\rangle = |A\rangle + \sum_{BC} |BC\rangle \quad (2)$$

for open flavour strong decay $A \to BC$. Here A, B, C denote mesons.
The wave function $|\psi\rangle$ obeys the equation

$$H|\psi\rangle = M|\psi\rangle \quad (3)$$

The Hamiltonian H for this combined system consists of a valence Hamiltonian H_0 and an interaction Hamiltonian H_I which couples the valence and continuum sectors. The matrix element of the valence-continuum coupling Hamiltonian is given by [2].

$$\langle BC|H_I|A\rangle = h_{fi}\delta(\vec{P}_A - \vec{P}_B - \vec{P}_C) \quad (4)$$

where h_{fi} is the decay amplitude.

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The mass shift of meson A due to its continuum coupling to BC can be expressed in terms of partial wave amplitude $\mathscr{M}_{LS}$ [3].

$$\Delta M_A^{(BC)} = \int_0^\infty dp \frac{p^2}{E_B + E_C - M_A - i\varepsilon} \int d\Omega_p |h_{fi}(p)|^2$$
$$= \int_0^\infty dp \frac{p^2}{E_B + E_C - M_A - i\varepsilon} \sum_{LS} |\mathscr{M}_{LS}|^2$$

$$\Delta M_A^{(BC)} = \mathscr{P} \int_0^\infty dp \frac{p^2}{E_B + E_C - M_A} \sum_{LS} |\mathscr{M}_{LS}|^2$$
$$+ i\pi \left(\frac{p * E_B * E_C}{M_A} \sum_{LS} |\mathscr{M}_{LS}|^2 \right) |_{E_B + E_C = M_A}$$

Results and Discussions

The analysis is performed within the $^3P_0$ model for light -quark pair creation. To calculate mass shift we need to know the physical mass M of the B-meson using a non relativistic quark model using an Hulthen potential. Following the non relativistic model we constructed the model pair-creation interaction from the potential in the quark model. It includes linear confinement and Coulomb like one gluon exchange potential. We evaluate the bare state masses and shifts due to Bπ, B^* π,Bρ,B^* ρ,B η,B^* η,$B\omega$,B^* ω,B_s K,B_s^* K,B_s K^*,B_s^* K^* loops (with $M_B = 5279.26 MeV$,$M_\pi = 139.5 MeV$, $M_{B^*} = 5324.6 MeV$, $M_{B-s} = 5366.77 MeV$, $M_\eta = 547.86 MeV$, $M_K = 493.67 MeV$, $M_{K^*} = 892.0 MeV$, $M_\rho = 775.4 MeV$, $M_\omega = 782.65 MeV$ and $M_{B_s^*} = 5415.4 MeV$. The mass shifts calculated in our model due to the hadron loop effects are listed in Table 1.

The modern meson spectroscopy must take both real and vitual strong decay into account in order to arrive at minimally reliable predictions. In particular, when a meson is narrow, one cannot automatically conclude that coupled channel effects will also be small.

Table 1 The mass and mass shifts of B-meson states in MeV

$n^{2S+1}L_J$	The Mass	Bπ	B η	B_s K	Bρ	$B\omega$	B^* π	B^* η	B_s^* K	B^* ρ	B^* ω	B_s K^*	B_s^* K^*	Total
1^1S_0	5280	0	18.28	0	0	0	0	0	13.91	11.77	11.71	10.49	20.19	86.35
1^3S_1	5324	7.10	5.14	6.54	4.27	4.24	13.09	9.29	9.17	8.17	8.13	7.25	14.00	96.39
1^1P_1	5776	0	0	0	0	0	24.53	19.29	18.94	13.52	13.36	10.63	1983	120.1
1^3P_0	5717	12.65	18.65	15.74	10.31	10.18	0	0	0	0	0	0	36.29	103.74
1^3P_1	5784	0	0	0	0	0	38.26	31.63	31.39	20.81	20.59	16.84	36.79	196.31
1^3P_2	5796	17.16	12.79	11.22	9.10	9.01	33.38	15.61	15.17	12.69	12.59	10.59	37.33	196.64
1^1D_2	6081	0	0	0	0	0	30.59	34.31	83.35	26.69	25.80	16.32	32.67	249.73
1^3D_1	6151	25.23	23.34	7.3	12.99	10.37	0.93	54.40	44.30	14.06	9.65	4.04	55.79	262.24
1^3D_2	6141	0	0	0	0	0	63.15	5.13	60.62	80.56	45.65	28.30	38.85	322.24
1^3D_3	6015	17.22	18.17	23.50	16.68	16.30	11.43	25.95	26.54	20.32	20.13	16.57	14.67	227.48

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