Radiative Transitions of B and B_s 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. Which has contributed enormously to our understanding of elementary particles and their interactions. 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.The goal of the present work is to obtain the decay widths and understand the uncertainties in the calculation in the frame work of non-relativistic quark models. In the non-relativistic models this is satisfied for the c, b and t quarks. For B and B_s system quark velocities are sizeable and hence needs significant corrections, but are still very small to make any significant changes in the spectra and radiative decays[1] $\gamma(4S)$(ARGUS,CLEO,Belle.BaBAr) and $\gamma(5s)$ (CLEO,Belle) resonance as well as at higher energies at the Z resonance (SLC,LEP) in $p\bar{p}$(Tevatron) and pp collisions (LHC).

Radiative Transitions

1. E_1 *Transition*

Radiative transitions could play an important role in the discovery and identification of B and B s states. They are sensitive to the internal structure of states, in particular to $^3L_L -^1 L_L$ mixing for states with J = L.

*Electronic address: praviphysics@gmail.com

The electric dipole (E_1) and magnetic dipole (M_1) radiative widths. The E1 matrix elements are determined by using the variational radial wave functions of the initial and the final state and explicitly performing the angular integration given by[3]

$$\Gamma_{fi} = \frac{4\alpha}{9}\Big(\frac{e_Q m_{\bar{q}} - e_{\bar{q}} m_Q}{m_{\bar{Q}} + m_Q}\Big)^2 k^3 | < f|r|i > |^2 \frac{E_f}{M_i} \quad (1)$$
$$X \begin{cases} 1 & for^3P_J \rightarrow^3 S_1 \\ 1 & for^1P_1 \rightarrow^1 S_0 \\ (2J+1)/3 & for^3S_1 \rightarrow^3 P_J \\ 1 & for^1S_0 \rightarrow^1 P_1 \end{cases}$$

Here,α is the fine structure constant, k is the photon energy, $e_{\bar{q}}$ e_Q are the quark charges in units of the proton charge, E_f is the energy of the final meson state, M_i is the mass of the initial meson state, and $m_{\bar{q}}$ and m_Q are the quark masses employed within the present work.[2]

M_1 *Transition*

Radiative transitions which flip spin are described by magnetic dipole (M1) transitions. The rates for magnetic dipole transitions between S-wave heavy-light bound states are given in the nonrelativistic approximation by

$$\Gamma_{M1}(i \rightarrow f + \gamma) = \frac{16\alpha}{3}\mu^2 k^3 (2J - f + 1)| < f|j_0(kr/2)|i > |^2 \quad (2)$$

where the magnetic dipole moment is

$$\mu = \frac{e_Q m_{\bar{q}} - e_{\bar{q}} m_Q}{4 m_{\bar{Q}} m_Q} \quad (3)$$

and k is the photon energy.

TABLE I: E1 Transition widths of neutral charge B meson in keV

E1 Transition Initial Meson	Final Meson	This (Γ) Work	[4] (Γ)
$B(2S) \to B(1P)$			
$B(2^3S_1)$	$B(1^3P_0)$	26	21.4
$B(2^3S_1)$	$B(1^3P_2)$	54	51.6
$B(2^3S_1)$	$B_1(1P)$	41	11.67
$B(2^3S_1)$	$B'_1(1P)$	39	25.9
$B(2^1S_0)$	$B_1(1P)$	38	49.6
$B(2^1S_0)$	$B'_1(1P)$	31	25.2
$B(1P) \to B(1S)$			
$B(1^3P_0)$	$B(1^3s_1)$	250	116.9
$B(1^3P_2)$	$B(1^3S_1)$	330	177.7
$B_1(1P)$	$B(1^3S_1)$	150	53.1
$B'_{s1}(1P)$	$B_s(1^3S_1)$	442	108.5
$B_1(1P)$	$B(1^1S_0)$	218	130.2
$B'_1(1P)$	$B(1^1S_0)$	221	60.4

TABLE II: E1 Transition widths of neutral charge B_s meson in keV

E1 Transition Initial Meson	Final Meson	This (Γ) Work	[4] (Γ)
$B_s(2S) \to B_s(1P)$			
$B_s(2^3S_1)$	$B_s(1^3P_0)$	21	17.2
$B_s(2^3S_1)$	$B_s(1^3P_2)$	29	25.6
$B_s(2^3S_1)$	$B_{s1}(1P)$	36	9.4
$B_s(2^3S_1)$	$B'_{s1}(1P)$	21	12.6
$B_s(2^1S_0)$	$B_{s1}(1P)$	64	41.7
$B_s(2^1S_0)$	$B'_{s1}(1P)$	23	12.3
$B_s(1P) \to B_s(1S)$			
$B_s(1^3P_0)$	$B_s(1^3s_1)$	145	84.7
$B_s(1^3P_2)$	$B_s(1^3S_1)$	201	159
$B_{s1}(1P)$	$B_s(1^3S_1)$	102	39.5
$B'_{s1}(1P)$	$B_s(1^3S_1)$	142	98.8
$B_{s1}(1P)$	$B_s(1^1S_0)$	156	97.7
$B'_{s1}(1P)$	$B_s(1^1S_0)$	165	56.6

Results and Conclusion

The model wave function, model parameters and the masses of the B and B_s Meson states obtained have been used to study the decay properties. Measuring radiative widths can help identify newly observed states and in addition, given the sensitivity of radiative transitions to details of the models, precise measurements of electromagnetic transition rates would provide stringent tests of the various calculations. Most of the predictions for $E1$ and M1 transitions are in qualitative agreement with other theoretical models.

TABLE III: M1 Transition widths of neutral B meson in keV

Initial Meson	Final Meson	This (Γ) Work	[4] (Γ)
$B(1^3S_1)$	$B(1^1S_0)$	0.3	0.1
$B(2^3S_1)$	$B(1^1S_0)$	14	8.0
$B(2^3S_1)$	$B(2^1S_0)$	0.124	0.05
$B(2^1S_0)$	$B(1^3S_1)$	1.6	0.9
$B_1(1P)$	$B(1^3P_0)$	0.09	0.03
$B'_1(1P)$	$B(1^3P_0)$	0.08	0.01

TABLE IV: M1 Transition widths of neutral B_s meson in keV

Initial Meson	Final Meson	This (Γ) Work	[4] (Γ)
$B_s(1^3S_1)$	$B_s(1^1S_0)$	0.2	0.1
$B_s(2^3S_1)$	$B_s(1^1S_0)$	8	4.0
$B_s(2^3S_1)$	$B_s(2^1S_0)$	0.212	0.02
$B_s(2^1S_0)$	$B_s(1^3S_1)$	1.1	0.1
$B_{s1}(1P)$	$B_s(1^3P_0)$	0.06	0.02
$B'_{s1}(1P)$	$B_s(1^3P_0)$	0.02	0.05

References

[1] K. Olive, et al., Review of particle physics, Chinese Physics C 38 **(9)** (2014) 090001.

[2] N Devlani and A.K Rai, Eur. Phys. J. A (2012)**48**:104

[3] Stephan Godfrey, Kenneth Moats and Eric S. Swanson,arXiv:1607.02169v2[hep-ph] 17 Jul 2017

[4] Qi- Fang Lu, Ting-Ting Pan, Yan-Yan Wang, En wang, and De-Min Li, arXiv:1607.02169v2[hep-ph] 11 Jul 2016.