Properties of $b\bar{b}$ and B_c mesons in a nonrelativistic model

Bhaghyesh A.[1*] and K. B. Vijaya Kumar[2†]
[1] Department of Physics, M S Ramaiah University of Applied Sciences, Bangalore - 560058, INDIA and
[2] Department of Physics, Mangalore University, Mangalagangothri - 574199, INDIA

Introduction

The study of heavy quarkonium systems has played an important role in the development of quantum chromodynamics (QCD). Heavy quarkonium spectrum and decays provide useful information on understanding the nature of inter-quark forces and decay mechanisms [1]. Since the hadron spectrum cannot be obtained directly from QCD, one has to use other methods like potential model calculations, lattice gauge theory, effective field theory, etc., to investigate the hadron spectrum and its decays [1, 2]. Phenomenological potential models are still one of the important tools for studying the hadron spectrum and its decays. These models are either relativistic [3] or nonrelativistic [4].

The bottomonium system has come into the news recently with the ATLAS detector at the Large Hadron Collider (LHC) discovering the previously unobserved χ_b(3P) state [5]. Bottomonium consists of a bottom quark and its antiquark ($b\bar{b}$). B_c meson was first detected by the CDF collaboration at the Fermilab [6]. The present PDG estimate of B_c mass is 6.2756 ± 0.0011 GeV with mean life $\tau = (0.452 \pm 0.033) \times 10^{-12}$s [7]. B_c mesons provide a unique laboratory to investigate quark interactions and heavy quark dynamics. It is the only doubly heavy open flavor meson and are stable with widths below hundred keV.

In the present work, we have investigated the properties of bottomonium ($b\bar{b}$) and B_c mesons in a nonrelativistic potential model.

*Electronic address: bhaghyesh@gmail.com, bhaghyesh.pi.sh@msruas.ac.in
†Electronic address: kbvijayakumar57@gmail.com

Methodology

In the present analysis we have used the potential of the form

$$V(r) = -\frac{4A}{3r}\exp(-\mu r) + B(1-\exp(-\mu r)) + C$$

The above potential is a screened potential as suggested by unquenched lattice simulations [8]. In order to obtain the mass spectra of $b\bar{b}$ and B_c mesons we have solved the nonrelativistic Schrödinger equation with Hamiltonian

$$H = M + \frac{p^2}{2\mu} + V(r), \qquad (1)$$

numerically using Mathematica [9]. The spin dependent part of the one gluon exchange potential is added perturbatively for calculating the spin structure of these states. The model parameters and the wavefunction that produce the mass spectra are used to investigate the decay properties of these mesons.

Results and Discussions

In this work, we have obtained the spectra and decay properties of $b\bar{b}$ and B_c mesons in a screened potential model. The masses of S wave states for $b\bar{b}$ mesons are tabulated in Table I. The charge radii (in Fm) of these states

TABLE I: Bottomonium spectrum (in GeV)

State	Present	Exp.[7]	[10]	[11]	$< r^2 >^{1/2}$
$\Gamma(1S)$	9.469	9.460	9.459	9.46	0.22
$\Gamma(2S)$	10.046	10.023	10.026	10.016	0.52
$\Gamma(3S)$	10.384	10.355	10.367	10.351	0.78
$\Gamma(4S)$	10.644	10.579	10.624	10.611	1.02
$\Gamma(5S)$	10.861	10.865	10.836	10.831	1.24
$\eta_b(1S)$	9.366	9.389	9.392	9.389	
$\eta_b(2S)$	10.004		9.988	9.987	
$\eta_b(3S)$	10.353		10.338	10.33	

are also tabulated. The masses of B_c mesons are given in Table II. Table III gives the vector decay constants (f_v) of $b\bar{b}$ and B_c mesons. Our results are in good agreement with the experiment and with the predictions of other theoretical models. From our calculations we conclude that the screened potential model used in our analysis gives a reasonably good prediction for the spectra and decay properties of bottomonium and B_c mesons in agreement with the experiment.

TABLE II: B_c spectrum (in GeV)

State	Present	Exp.[7]	[10]	[3]	$< r^2 >^{1/2}$
1^3S_1	6.36		6.343	6.333	0.34
2^3S_1	6.925		6.997	6.904	0.73
3^3S_1	7.293		7.436	7.255	1.06
1^1S_0	6.277	6.276	6.256	6.272	
2^1S_0	6.879		6.939	6.85	
3^1S_0	7.258		7.388	7.225	

TABLE III: Vector decay constants, f_v (in MeV)

State	Present	[10]	Others
$\Gamma(1S)$	820	817	665 [4]
$\Gamma(2S)$	515	596	475 [4]
$\Gamma(3S)$	431	512	418 [4]
$B_c(1S)$	432	480	562 [3]
$B_c(2S)$	307	340	
$B_c(3S)$	263	287	

References

[1] N. Brambilla et al. (Quarkonium Working Group), CERN Yellow Report, CERN-2005-005 (2005), arXiv:hep-ph/0412158.

[2] E. Eichten, S. Godfrey, H. Mahlke, and J. L. Rosner, Rev. Mod. Phys. **80**, 1161 (2008), arXiv:hep-ph/0701208.

[3] D. Ebert, R. N. Faustov, V. O. Galkin, Eur. Phys. J. C **71**, 1825 (2011), arXiv: hep-ph/1111.0454.

[4] O. Lakhina, E. S. Swanson, Phys. Rev. D **74**, 014012 (2006), arXiv:hep-ph/0603164.

[5] G. Aad et al. (ATLAS Collaboration), Phys. Rev. Lett. **108**, 152001 (2012), arXiv: hep-ex/1112.5154.

[6] F. Abe et al. (CDF Collaboration), Phys. Rev. Lett. **81**, 2432 (1998).

[7] K. A. Olive et al. (Particle Data Group), Chin. Phys. C **38**, 090001 (2014).

[8] K. D. Born, E. Laermann, N. Pirch, T.F. Walsh, and P.M. Zerwas, Phys. Rev. D **40**, 1653 (1989).

[9] W. Lucha and F. Schoberl, Int. J. Mod. Phys. C **10**, 607 (1999), arXiv: hep-ph/9811453v2.

[10] B. Patel and P. C. Vinodkumar, J. Phys. G: Nucl. Part. Phys. **36**, 035003 (2009).

[11] Bai-Qing Li, K. T. Chao, Commun. Theor. Phys. **52**, 653 (2009), arXiv: hep-ph/0909.1369v1.