VU Research Portal

Spectrum and decay constants of heavy-light mesons

Bakker, B.L.G.

published in

Few-Body Systems

2008

DOI (link to publisher)

[10.1007/s00601-008-0264-0](https://doi.org/10.1007/s00601-008-0264-0)

document version

Publisher's PDF, also known as Version of record

[Link to publication in VU Research Portal](#)

citation for published version (APA)

Bakker, B. L. G. (2008). Spectrum and decay constants of heavy-light mesons. *Few-Body Systems*, 44(1-4), 91-93. <https://doi.org/10.1007/s00601-008-0264-0>

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal ?

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

E-mail address:

vuresearchportal.ub@vu.nl

Spectrum and decay constants of heavy-light mesons^{*}

B. L. G. Bakker^{**}

Department of Physics and Astronomy, Vrije Universiteit, Amsterdam, The Netherlands

Received 28 November 2007; Accepted 10 May 2008; Published online 4 December 2008
© Springer-Verlag 2008

Abstract Heavy-light mesons masses and decay constants are calculated within the framework of the field correlator model. Good agreement is obtained with the experimental data.

1 Introduction

Relativistic potential models [1] have been successful in QCD at the price of introducing quark masses as phenomenological parameters. In the field-correlator method (FCM) [2], one derives an effective Hamiltonian, which comprises both confinement and relativistic effects, and contains only universal quantities: the string tension σ , strong coupling constant α_s , and the current (pole) quark masses m_i .

2 Field-correlator method

The basic ingredients of the FCM are gauge links and Wilson loops

$$\Phi(y, x) = \text{P exp} \left(ig \int_x^y dz_\mu A_\mu \right), \quad W(C) = \text{P exp} \left(ig \oint dz_\mu A_\mu \right). \quad (1)$$

A local interaction $V(r)$ arises from the Wilson loop $W = \exp(-\int_0^T dt V)$

$$V(r) = V_0(r) + V_{\text{SS}} + V_{\text{LS}} + V_{\text{T}} + \Delta V_{\text{string}} + V_{\text{SE}}, \quad V_0(r)\sigma r - \frac{4}{3} \frac{\alpha_{\text{st}}(r)}{r}. \quad (2)$$

^{*} Presented at the 20th Few-Body Conference, Pisa, Italy, 10–14 September 2007

^{**} E-mail address: blg.bakker@few.vu.nl

Correspondence: B. L. G. Bakker, Department of Physics and Astronomy, Vrije Universiteit, De Boelelaan 1081, 1081 HV Amsterdam, The Netherlands

The contribution V_{SE} is due to the self-energy of the quarks [3] and ΔV_{string} is the contribution to the energy owing to the gluonic string between q and $\bar{q}$. The potential V_0 is included nonperturbatively, while the spin-dependent parts and the self-energy are treated as a perturbation. The mass of a 1S_0 -wave meson is given by $M_n(^1S_0) = M_{0n} - \frac{3}{4}\Delta_{\text{HF}} + \Delta_{\text{SE}}$, M_{0n} is given by

$$H_0 = \sqrt{m_1^2 + \mathbf{p}^2} + \sqrt{m_2^2 + \mathbf{p}^2} + V_0(r), \quad H_0\varphi_n = M_{0n}\varphi_n. \quad (3)$$

In the meson ($q\bar{q}$) case one considers the correlator $G_\Gamma(x)$ of the currents $j_\Gamma(x) = \bar{\psi}_1(x)\Gamma\psi_2(x)$, $\Gamma = t^a \otimes (1, \gamma_5, \gamma_\mu, \gamma_\mu\gamma_5)$, $t^a = \lambda^a/2$, $\text{Tr}(t^a t^b) = \frac{1}{2}\delta_{ab}$.

For pseudoscalar currents $G_P(x) = \langle j_P(x)j_P(0) \rangle_{\text{vac}}$ one finds

$$\begin{aligned} \int d^3\mathbf{x} G_P(x) &= N_c \left\langle 0 \left| \frac{Y_P}{\bar{\omega}_1\bar{\omega}_2} e^{-HT} \right| 0 \right\rangle \\ &= N_c \sum_n \frac{\langle Y_P \rangle_n |\varphi_n(0)|^2}{\langle \bar{\omega}_1 \rangle_n \langle \bar{\omega}_2 \rangle_n} e^{-M_n T} = \sum_n \frac{(M_n f_P^n)^2}{2M_n} e^{-M_n T}, \end{aligned} \quad (4)$$

with $Y_P = \frac{1}{4}\text{Tr}((m_1 - i\mathbf{p}_1)\gamma^5(m_2 + i\mathbf{p}_2)\gamma^5)$. The states $|n\rangle$ are the eigenstates of the Hamiltonian and M_n its eigenvalues. The factor $\langle Y_P \rangle$ can be computed in the c.m. system in terms of the relative momentum $\mathbf{p}$, which gives $\langle Y_P \rangle = m_1 m_2 + \langle \bar{\omega}_1 \rangle \langle \bar{\omega}_2 \rangle - \langle \mathbf{p}^2 \rangle$. It follows from the derivation of the SH that the quantities $\bar{\omega}_i$ are equal to the average of the operator $\sqrt{\mathbf{p}^2 + m_i^2}$: $\langle \bar{\omega}_i \rangle_n = \langle \varphi_n | \sqrt{\mathbf{p}^2 + m_i^2} | \varphi_n \rangle$.

The input parameters are m_i , α_s and σ . We take $\sigma = 0.18 \text{ GeV}^2$ for all HL mesons as well as in light mesons and in heavy quarkonia [4]. The m_i are the conventional pole masses which are defined through the Lagrangian (current) masses in the $\overline{MS}$ -scheme, see [4, 5] and references therein. We use $m_b = 4.78$, $m_c = 1.40$, $m_s = 0.180$, $m_u = 0.005$, $m_d = 0.008 \text{ GeV}$. The coupling $\alpha_{\text{st}}(r)$ in the gluon-exchange term is taken here as the vector coupling $\alpha_B(r)$ in background perturbation theory (in two-loop approximation) from ref. [6].

3 Results and discussion

The masses we calculated for the S -wave pseudoscalar heavy-light mesons are shown in Table 1. The experimental numbers are taken from [5] and $M(B_s^*)$ from [7]. The decay constants are calculated using Eq. (4) and shown in Table 2. The experimental data are from [8] (D, D_s) and [9] (B).

We used our analytical expressions for f_P to determine the decay constants $f_{D(D_s)}$ and $f_{B(B_s)}$ for the ground states. By a comparison to recent experimental data we could determine the running mass of the strange quark, $m_s(\mu)$ at the low scale: $m_s(\mu = 0.5 \text{ GeV}) = 180 \text{ MeV}$. We make the following observations:

The calculated masses $M(^1S_0)$ and $M(^3S_1)$ of all HL mesons agree with the experimental numbers within $\pm 5 \text{ MeV}$. Our prediction for B_c^* is $M(B_c^*) = 6325(10) \text{ MeV}$.

For the decay constants the values $f_D = 210(10) \text{ MeV}$ and $f_{D_s} = 260(10) \text{ MeV}$ are obtained. Their ratio $f_{D_s}/f_D = 1.25(2)$ is close to the experimental number $1.23(15)$ [8].

Our decay constants $f_B = 182(8) \text{ MeV}$ and $f_{B_s} = 216(8) \text{ MeV}$ give the ratio $f_{B_s}/f_B = 1.19(1)$ which agrees with the recent unquenched lattice number [10].

Table 1 The masses (in MeV) of the ground states

	$D^\pm$	$D^{*\pm}$	D_s	D_s^*	B	B^*	B_s	B_s^*
Calculation	1869.1	2010.3	1966.8	2107.1	5279.3	5324.2	5362.0	5407.4
Experiment	1869.3 ± 0.4	2010.0 ± 0.4	1968.2 ± 0.4	2112.0 ± 0.6	5279.0 ± 0.5	5325.0 ± 0.6	5367.7 ± 1.8	5411.7 ± 3.2

Table 2 The decay constants f_P (in MeV)

	D	D_s	B	B_s	B_c
Calculation	210(10)	260(10)	182(8)	216(8)	438(10)
Experiment	222.6(20)	274(23)	160 $^{+50}_{-80}$ 229(70)		

References

1. Barnes T, Godfrey S, Swanson ES (2005) Phys Rev D 72:054026; Swanson ES (2006) Phys Rep 429:243 and references therein
2. Simonov YuA (1996) Lecture notes in physics 479:144. Springer, Heidelberg; Simonov YuA (1995) Phys At Nucl 58:107 [Yad. Fiz. 58:113]; [hep-ph/9311247]; Simonov YuA (2000) In: Ferreira L, Nogueira P, Silva-Marco J (eds.) Proc XVIIth autumn school, Lisboa, Portugal, 29 Sept.–4 Oct. 1999, p. 60. World Scientific, Singapore; [hep-ph/9911237]; Badalian AM, Bakker BLG, Simonov YuA (2007) Phys Rev D 75:116001
3. Simonov YuA (2001) Phys Lett B 515:137; [hep-ph/0105141]; see Erratum in: Di Giacomo A, Simonov YuA (2004) Phys Lett B 595:368
4. Badalian AM, Veselov AI, Bakker BLG (2004) Phys Atom Nucl 67:1367; [hep-ph/0311010]; Badalian AM, Veselov AI, Bakker BLG (2005) J Phys G 31:417
5. Eidelman S, et al. [Particle Data Group] (2004) Phys Lett B 592:1
6. Badalian AM, Kuzmenko DS (2002) Phys Rev D 65:016004
7. Mommsen R (2006) [hep-ex/0612003]; Bonvicini G, et al. (2006) Phys Rev Lett 96:022002; Abulencia A, et al. (2006) Phys Rev Lett 96:082002
8. Artuso M, et al. (2006) [hep-ex/0607074]; (2005) Phys Rev Lett 95:251801; Bonvicini G, et al. (2004) Phys Rev D 70:112004; Artuso M, et al.: [arXiv:0704.0629]; Pedlar TK, et al.: [arXiv:0704.0437]
9. Aubert B, et al. (2006) [hep-ex/0607094]; [hep-ex/0608019]; Corwin LA, et al. (2006) [hep-ex/0611019]; Ikado K, et al. (2006) Phys Rev Lett 97:251802; [hep-ex/0604018]
10. Aubin C, et al. (2005) Phys Rev Lett 95:122002; (2004) Phys Rev D 70:114501; Davies CTH, et al. (2004) Phys Rev Lett 92:022001; Gray A, et al. (2005) Phys Rev Lett 95:212001