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Bakker, B.L.G.

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Spectrum and decay constants of heavy-light mesons*

B. L. G. Bakker**

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

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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

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

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

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

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** *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 $V_{\rm SE}$ is due to the self-energy of the quarks [3] and $\varDelta V_{\rm string}$ 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 $M_n({}^1S_0) = M_{0n} - \frac{3}{4}\varDelta_{\rm HF} + \varDelta_{\rm SE}$, M_{0n} is given by

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

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

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

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

with $Y_P = \frac{1}{4}\mathrm{Tr}((m_1 - i\not{p}_1)\gamma^5(m_2 + i\not{p}_2)\gamma^5)$. 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 $\boldsymbol{p}$, which gives $\langle Y_P\rangle = m_1 m_2 + \langle\bar{\omega}_1\rangle\langle\bar{\omega}_2\rangle - \langle\boldsymbol{p}^2\rangle$. It follows from the derivation of the SH that the quantities $\bar{\omega}_i$ are equal to the average of the operator $\sqrt{\boldsymbol{p}^2 + m_i^2}$: $\langle\bar{\omega}_i\rangle_n = \langle\varphi_n|\sqrt{\boldsymbol{p}^2 + m_i^2}|\varphi_n\rangle$.

The input parameters are m_i, α_s and σ. We take $\sigma = 0.18\,\mathrm{GeV}^2$ 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 $m_b = 4.78$, $m_c = 1.40$, $m_s = 0.180$, $m_u = 0.005$, $m_d = 0.008\,\mathrm{GeV}$. The coupling $\alpha_{\rm st}(r)$ 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: $m_s(\mu = 0.5\,\mathrm{GeV}) = 180\,\mathrm{MeV}$. We make the following observations:

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

For the decay constants the values $f_D = 210(10)$ MeV and $f_{D_s} = 260(10)$ 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 $f_B = 182(8)\,\mathrm{MeV}$ and $f_{B_s} = 216(8)\,\mathrm{MeV}$ 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 $\pm$ 0.4	2010.0 $\pm$ 0.4	1968.2 $\pm$ 0.4	2112.0 $\pm$ 0.6	5279.0 $\pm$ 0.5	5325.0 $\pm$ 0.6	5367.7 $\pm$ 1.8	5411.7 $\pm$ 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)		

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