Decay constants of Pseudoscalar and Vector D, D_s, B and B_s Mesons *

K. B. Vijaya Kumar[1], Praveen P. D'souza[1 2], Vipin Naik N. S.[1 2], A. P. Monteiro[2], and E. Deepak DSilva [2]

[1]*Department of Studies in Physics, Mangalore University, Mangaluru - 574199, INDIA and*
[2]*Post Graduate Department of Physics, St. Philomena College, Puttur - 574202, INDIA*

Introduction

One of the important characteristics of the mesons is the decay constant which can be directly measured in experiment in many cases. Therefore, they can provide a precise manner to compare different theoretical approaches and check their accuracy. The QCD motivated Coulomb like potential plus linear confining potential with color magnetic spin-dependent interactions have described the charmonium and bottomonium states successfully. These studies have been extended to other heavy mesons such as charmed strange mesons, bottom strange mesons and bottom charmed mesons. The spectroscopy of states containing heavy quarks provides an exceptional window to test the QCD. Many experimental groups such as BESIII at the Beijing Electron Positron Collider (BEPC), E835 at Fermilab and CLEO at the Cornell Electron Storage Ring (CESR), the B-meson factories, BaBar at PEP-II, Belle at KEKB, the CDF and D0 experiments at Fermilab, the Selex experiment at Fermilab, ZEUS and H1 at DESY, PHENIX and STAR at RHIC, NA60 and LHCb at CERN are producing and expected to provide more precise data in upcoming experiments. The new future facility PANDA at FAIR, GSI facilities offer more significant challenges and opportunities in theoretical high energy physics.

Theoretical Background

One of the important quantities that can be obtained through potential models is the vector and pseudoscalar decay constants of heavy mesons. Decay constants are important because they can be used to estimate the hadronic matrix elements and provide information about the short distance structure of hadrons and non-perturbative QCD dynamics. Precise knowledge of their values play very important roles, for example in determination of CKM matrix elements, study of weak decays, meson mixing, etc. They are input parameters which constrains various decays and processes and their precise knowledge is important in various experimental measurements. The pseudoscalar (f_p) and the vector (f_v) decay constants are defined through the matrix elements [1]

$$f_p = \sqrt{\frac{3}{m_p}} \int \frac{d^3k}{(2\pi)^3} \sqrt{1+\frac{m_Q}{E_k}} \sqrt{1+\frac{m_{\bar{Q}}}{E_{\bar{k}}}} \left(1-\frac{k^2}{(E_k+m_Q)(E_{\bar{k}}+m_{\bar{Q}})}\right) \phi(\vec{k}) \quad (1)$$

$$f_v = \sqrt{\frac{3}{m_v}} \int \frac{d^3k}{(2\pi)^3} \phi(\vec{k}) \sqrt{1+\frac{m_Q}{E_k}} \sqrt{1+\frac{m_{\bar{Q}}}{E_{\bar{k}}}} \left(1+\frac{k^2}{3(E_k+m_Q)(E_{\bar{k}}+m_{\bar{Q}})}\right) \quad (2)$$

In the nonrelativistic limit ($p^2/m^2 \to 0$), the above two equations reduces to the well-known Van Royen Weisskopf relation for the meson decay constants[1].

$$f^2_{p/v} = \frac{12\,|\Psi_{p/v}(0)|^2}{m_{p/v}}. \quad (3)$$

The meson decay constants including first order QCD correction factor is,

$$\bar{f}^2_{p/v} = \frac{12\,|\Psi_{p/v}(0)|^2}{m_{p/v}} C^2(\alpha_s), \quad (4)$$

*Electronic address: praviphysics@gmail.com

where $C(\alpha_s)$ is [1],

$$C(\alpha_s) = 1 - \frac{\alpha_s}{\pi}\left(\Delta_{p/v} - \frac{m_Q - m_{\bar{Q}}}{m_Q + m_{\bar{Q}}}\ln\frac{m_Q}{m_{\bar{Q}}}\right), \quad (5)$$

where $\Delta_p = 2$ and $\Delta_v = 8/3$. In our work, we have used the three-dimensional harmonic oscillator wave function which has been extensively used in atomic and nuclear physics is used as the trial wave function for obtaining the $Q\bar{Q}$ mass spectrum.

$$\psi_{nlm}(r,\theta,\phi) =$$
$$N\left(\frac{r}{b}\right)^l L_n^{l+1/2}(\frac{r}{b})exp\left(-\frac{r^2}{2b^2}\right)Y_{lm}(\theta,\phi)$$

where $|N|$ is the normalizing constant given by

$$|N|^2 = \frac{2\alpha^3 n!}{\sqrt{\pi}}\frac{2^{(2(n+l)+1)}}{(2n+2l+1)!}(n+l)! \quad (6)$$

and $L_n^{l+1/2}(x)$ are the associated Laguerre polynomials,

Results and Discussions

The decay properties of heavy-light mesons (B, B_s, D and D_s mesons) were calculated in the non-relativistic quark model. A NRQM is proposed for the study of mesonic systems. The proposed NRQM includes OGEP for D and D_s mesons and Hulthen Potential for B and B_s mesons. The pseudoscalar and vector decay constants of B and D meson were calculated using the non-relativistic wave functions obtained during the mass spectrum calculations.

Table 2 Decay constants of pseudoscalar and vector B mesons (B and B_s mesons in MeV)

	B $f_{p/v}$	$\bar{f}_{p/v}$	[2]	B_s $f_{p/v}$	$\bar{f}_{p/v}$	[2]
$B^{\pm}$	236	211	188	274	258	240
B^*	241	224	328	288	271	393

The higher order radial and orbital excitations of the B and B_S mesons have been recently reported in experiments. We notice that decay constants of the B and B_S mesons are very sensitive to the precise values of masses of bottom meson. The calculated decay constants are $f_B = 236$,$f_{B_S} = 274$,$f_B^* = 241$ and $f_{B_S^*} = 288$. Radiative transition widths were calculated using a non-relativistic formalism using respective wave functions. The decay constant $f_{p/v} = 202.57$ MeV of D meson has been obtained using non-relativistic wave function. Recently, several well established S and P wave states like D_s, D_s^*, $D_{s0}^*(2317)$, $D_{s1}(2460)$ have been observed by various experimental groups. The study of the decay constants is of importance as it provides information on the CKM matrix elements. In table $f_{p/v}$ corresponds to the pseudoscalar decay constants calculated without QCD correction factor, while $\bar{f}_{p/v}$ corresponds to the pseudoscalar and vector constants including QCD correction factor. The calculated decay constants are f_D is 342, f_{D_S} is 387, f_D^* is 351 and $f_{D_S^*}$ is 398. The ratio of the D and D_S meson decay constants f_{D_S}/f_D is 1.132. The corresponding PDG values f_{D_S}/f_D is 1.64 ±0.011. The decay constants of pseudoscalar and vector D meson are listed in table. We calculated the decay constant of pseudoscalar and vector B B_s,D and D_s mesons without and with the QCD corrections,

Table 2 Decay constants of pseudoscalar and vector D mesons (D and D_s mesons in MeV)

	D $f_{p/v}$	$\bar{f}_{p/v}$	[3]	D_s $f_{p/v}$	$\bar{f}_{p/v}$	[3]
$D^{\pm}$	342	311	188	387	334	240
D^*	351	301	328	398	311	393

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