Comparison study of Decay Constants of Heavy Quark Mesons *

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Introduction

The spectroscopy of states containig heavy quarks Q has undergone a great importance in recent years, providing an exceptional window into tests of QCD. CLEO and BES-III will make new contribution to heavy quark spectroscopy. Goals include the best possible determination of f_D and f_{Ds} and measurement of the CKM factors. The success of the non-relativistic model is that the effects like screening of short-range Coulombic potential and sting-breaking of long range confining potentials have been taken into account. We find that all the heavy quark mesons like charmonium, B, B_s, D and D_s mesons may be considered as non-relativistic quarkonia as far as their wave functions and decay amplitudes are concerned. Though the phenomenological interaction potential adopted for the study is not directly derived or related to the basic QCD interactions, it might contain certain contributions from physical processes involving QCD. In quark models one assumes a potential interaction among quarks which makes model as a non-relativistic approach. Therefore, the systems that are best suited for study in quark models are the heavy quark system which contain c or b quarks. The bare masses of u, d and s quarks are 2 MeV, 4 MeV and 96 MeV, respectively.

Theoretical Background

Recently several well-established S and P wave states of charmonium, B, B_s, D and D_s mesons have been observed by various experimental groups. The exact nature of these states is still to be confirmed. In the present work, a comprehensive investigation of heavy quark meson properties within the framework of phenomenological potential models have been investigated. Conventional S, P D and F wave of charmonium and S, P and D wave of B, B_s D and D_s meson spectra and their decay properties have been obtained and compared with experimental results and with other theoretical models. In general, the present analysis shows that the phenomenological NRQM formalism gives a reasonably good description of heavy quark mesons mass spectrum and decay properties. The decay constants provide information about the short-distance structure of hadrons. The obtained results for decay constants are in agreement with available experimental data.

We have made a comparative study of the decay constants of pseudoscalar and vector heavy mesons calculated in three models. In all the three models, we have only calculated mass spectrum and the decay constants. The Van Royen-Weisskopf relation has been used for the calculation of the decay constants for both pseudoscalar and vector mesons.[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

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QCD correction factor is,

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

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

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

where $\Delta_p = 2$ and $\Delta_v = 8/3$.

Results and Discussions

In all the three heavy quark mesons, the decay rates are related to the value of the radial wave function at the zero separation of the quark–antiquark and are sensitive to α_s. So, one of the tests for the success of our three theoretical models is the correct prediction of the decay constants. This analysis will help to study the uncertainties in the extracted values of the decay constants.

The calculated decay constants are tabulated. f_p and f_v corresponds to the pseudoscalar and vector decay constants calculated without the QCD correction factor, while $\bar{f}_p$ and $\bar{f}_v$ corresponds to the pseudoscalar and vector decay constants calculated including QCD correction factor. The decay constants for both pseudoscalar and vector charmonium calculated using the Van Royen-Weisskopf relation. It can be seen that the ratio f_p/f_v is > 1. Like most of non relativistic models, in this work we have assumed $\Psi_p(0) \approx \Psi_v(0)$. Since $m_v > m_p$, using the Van Royen-Weisskopf formula, one always obtain $f_p/f_v > 1$. For heavy mesons, the ratios of pseudoscalar and vector decay constants $f_p/f-v$ are also predicted by heavy quark effective theory to be < 1. From our calculations, it can be seen that the ratios $f_p/f-v < 1$. Thus the ratios calculated using the expressions for f_p and f_v calculated, provide results consistent with experiment and with the predictions.

The calculated decay constants for the D and D_S mesons are f_D = 342 MeV and f_{D_S} = 387 MeV. Obtained results for masses of B and D mesons are in good agreement with the available experimental data. The ratio of the decay constants of charmed and charmed strange mesons $f_{D_S}/f_D = 1.13$. The PDG value is $f_{D_S}/f_D = 1.26 \pm 0.026$. For the bottom and bottom strange meson $f_{B_S}/f_B = 1.16$. Our ratio for $\frac{f_{B_S^*}}{f_{B^*}}$ = 1.19 which is analogous to lattice calculations $\frac{f_{B_S^*}}{f_{B^*}} = 1.14 \pm 0.08$. We also calculated ratio $\frac{f_{B_S}/f_B}{f_{D_S}/f_D}$ = 1.02. This is consistent with the lattice determination 0.018±0.006.

Table 2$c\bar{c}$ Decay Constants(MeV)

State	$f_{p/v}$	$\bar{f}_{p/v}$	Exp.	[4]	[2]	[3]
$\eta_c(1S)$	456	325	335±75	402	292	458
$\eta_c(2S)$	345	255		240		347
J/ψ	445	301	411±7	393	459	467
$\psi(2S)$	355	221	279±8	293	364	351

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

	B		[5]	B_s		[5]
	Present $f_{p/v}$	Present $\bar{f}_{p/v}$		Present $f_{p/v}$	Present $\bar{f}_{p/v}$	
$B^{\pm}$	236	211	188	274	258	240
B^*	241	224	328	288	271	393

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

	D		[6]	D_s		[6]
	Present $f_{p/v}$	Present $\bar{f}_{p/v}$		Present $f_{p/v}$	Present $\bar{f}_{p/v}$	
$D^{\pm}$	342	311	188	387	334	240
D^*	351	301	328	398	311	393

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