Decay Constant and Leptonic Branching Fraction of D Meson

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Introduction

In 1977 the SLAC (Stanford Linear Accelerator Center) had been studied the momentum spectra of D^0 and $D^{\pm}$ mesons in e^+e^- annihilation at the center of mass energy $\sqrt{s} = 4$ GeV [1]. They observed charged and neutral states of D^* first time which has mass approximately 2.01 GeV/c^2. In 1988, the same experimental group studied e^+e^- annihilation $\sqrt{s} = 29$ GeV [2]. Experimentally, the ground state masses of the D mesons are well established with their respective spin-parity Ref. [3]. The mass spectra of radial as well as orbitally excited states have been studied by several theoretical approaches [4–11]. In this paper, we are using the radial excited states mass of D mesons $1^1S_0(1.889)$ GeV and $1^3S_1(2.007)$ GeV and determine the decay constant and leptonic branching fraction using Gaussian wave function with help of coulomb plus screening potential.

Decay Constants ($f_{p/v}$)

The decay constant of meson is important parameter in the study of leptonic or non leptonic weak decay process. Incorporating a first order QCD correction factor in the Van-Royan-Weisskopf formula [12]. We compute decay constants using this relation,

$$f_{p/v}^2 = \frac{12|\Psi_{p/v}(0)|^2}{M_{p/v}}\bar{C}^2(\alpha_s), \tag{1}$$

where $\bar{C}^2(\alpha_s)$ is the QCD correction factor given by [13]. The computed pseudoscalar (f_p) and vector (f_v) decay constants are tabulated in Table 1 and 2. Results of the pseudoscalar decay constant without and with QCD correction are compare with Heavy Flavor Averaging group [14] and Lattice results [15] where the vector decay constant is very close to the lattice results Ref. [16].

Leptonic Branching Fraction

The leptonic branching fraction for the (1^1S_0) D mesons are obtained using the formula,

$$BR = \Gamma \times \tau, \tag{2}$$

where Γ is the leptonic decay width for D^+ meson as given by [15]

$$\Gamma(D^+ \to l^+ v_l) = \frac{G_F^2}{8\pi} f_D^2 |V_{cu}|^2 m_l^2 (1 - \frac{m_l^2}{m_D^2})^2 M_D \tag{3}$$

and $\tau_D = 0.5$ ps [17]. The branching fractions are computed using using Eq.(4) are tabulated in Table 3 which show that the prediction from Gaussian wave function are close to the experimental measurements.

TABLE I: Pseudoscalar decay constant (in GeV).

state	1S	2S	3S
f_{Pcor}	0.168	0.073	0.045
f_p	0.245	0.108	0.066
[14]	0.230		
[18]	0.220		
[19]	0.217		
[20]	0.234		

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Results and Discussion

The pseudoscalar decay constant with QCD correction for D meson is 0.168 GeV. Which is underestimated and without QCD correction is 0.245 GeV, which is overestimated by 15, 25, 28 and 11 MeV respectively with Refs. [14, 18–20]. The vector decay constant with QCD correction for D meson is 0.173 GeV, which is underestimated and without QCD correction is 0.254 GeV, which is overestimated by 17, 23, 31 and 23 MeV respectively with Refs. [14, 18–20]. Using the parameters:

TABLE II: Vector decay constant (in GeV).

state	1S	2S	3S
f_{Vcor}	0.173	0.074	0.045
f_V	0.254	0.108	0.066
[14]	0.237		
[18]	0.231		
[19]	0.223		
[20]	0.231		

$e = 0.510998910 \times 10^{-3}$, $\mu = 0.105658367$, $\tau = 1.77684$, $G_F = 1.16637 \times 10^{-5}$; we have computed the leptonic branching fractions of D mesons are tabulated in Table 3. The leptonic branching fractions show that the predicted values are close to Ref. [16, 17] and also near to experimental observations [3]. The future experimental facility $\overline{\text{P}}$ANDA [21] is expected to provides more precise data in charm sector. The details of this study will be presented in the conference.

TABLE III: Branching fraction(Leptonic)of the D meson.

state	$D^+ \to \tau^+\nu_\tau$ $BR_\tau \times 10^{-3}$	$D^+ \to \mu^+\nu_\mu$ $BR_\mu \times 10^{-4}$	$D^+ \to e^+\nu_e$ BR_e
Present	0.99	2.68	0.631×10^{-8}
[19]	0.86	2.47	0.58×10^{-8}
[18]	1.05	4.3	1.0
[3]	< 1.2	3.74 ± 0.17	$< 8.8 \times 10^{-6}$

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