

## Decay Constant and Leptonic Branching Fraction of D Meson

Vikas Patel<sup>1,2,\*</sup>, Keval Gandhi<sup>1,†</sup>, Virendrasinh Kher<sup>3,‡</sup> and Ajay Kumar Rai<sup>1,§</sup>

<sup>1</sup> Department of Applied Physics, Sardar Vallabhbhai National Institute of Technology, Surat 395007, Gujarat, India.

<sup>2</sup> Department of physics, Uka Tarsadia University, Bardoli 394250, Gujarat, India. and

<sup>3</sup> Applied Physics Department, Polytechnic, The M S University of Baroda, Vadodara 390002, Gujarat, India.

### 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,

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

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,

$$BR = \Gamma \times \tau, \quad (2)$$

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

$$\Gamma(D^+ \rightarrow l^+ \nu_l) = \frac{G_F^2}{8\pi} f_D^2 |V_{cu}|^2 m_l^2 \left(1 - \frac{m_l^2}{m_D^2}\right)^2 M_D \quad (3)$$

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		

\*Electronic address: patelvikas2710@gmail.com

†Electronic address: keval.physics@yahoo.com

‡Electronic address: vkhher@yahoo.com

§Electronic address: raiajayk@gmail.com

### 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
$f_{V_{cor}}$	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 PANDA [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	$D^+ \rightarrow \tau^+ \nu_\tau$ $BR_\tau \times 10^{-3}$	$D^+ \rightarrow \mu^+ \nu_\mu$ $BR_\mu \times 10^{-4}$	$D^+ \rightarrow e^+ \nu_e$ $BR_e$
Present	0.99	2.68	$0.631 \times 10^{-8}$
[19]	0.86	2.47	$0.58 \times 10^{-8}$
[18]	1.05	4.3	1.0
[3]	< 1.2	$3.74 \pm 0.17$	$< 8.8 \times 10^{-6}$

### References

- [1] G.Goldhaber *et al.*,Phys. Lett. B **69**, 503 (1977).
- [2] S. Abachi *et al.*, Phys. Lett. B **212**, 533 (1988).
- [3] M.Tanabashi *et al.*, (Particle Data Group), Phys. Rev. D **98**, 030001 (2018).
- [4] A.K. Rai, B. Patel and P.C. Vinodkumar, Phys. Rev. C **78**, 055202 (2008).
- [5] A.K. Rai, J. N. Pandya and P.C. Vinodkumar, J. Phys. G **31**, 1453 (2005).
- [6] A.K. Rai, R. H. Parmar and P.C. Vinodkumar, J. Phys. G **28**, 2275 (2002).
- [7] V. Kher and A.K. Rai, Chin. Phys. C **7**, 083101 (2018).
- [8] N. Devlani and A.K. Rai, Eur. Phys. J. A **48**, 104 (2014).
- [9] N. Devlani and A.K. Rai, Phys. Rev. D **84**, 074030 (2011).
- [10] A.K. Rai and D. P. Rathaud, Eur. Phys. J. C **75**, 462 (2015).
- [11] K. Gandhi *et al.*, DAE Symp. on Nucl. Phys. **63** (2018).
- [12] R. Van Royen, V. Weisskopf, Nuovo Cimento A **50**, 617 (1967).
- [13] E. Braaten, S. Fleming, Phys. Rev. D **52**, 181 (1995).
- [14] D. Asner *et al.*, *arXiv:1010.1589* (2010).
- [15] C.T.H. Davies *et al.*, Phys. Rev. D **82**, 114504(2010).
- [16] K. Bowler, *et al.*, Nucl. Phys. B **619**, 507 (2001).
- [17] D. Silverman, H. Yao, Phys. Rev. D **38**, 214 (1988).
- [18] N. Devlani, A.K. Rai, Int. J. Theor. Phys. **52**, 2196 (2013).
- [19] V. Kher, N. Devlani and A.K. Rai, Chin. Phys. C **41**, 073101 (2017).
- [20] D. Ebert, R.N. Faustov, V.O. Galkin, Phys. Lett. B **635**, 93 (2006).
- [21] B. Singh *et al.* (PANDA Collaboration); Phys. Rev. D **95**, 032003 (2017); Eur. Phys. J. A **52**, 325 (2016); Nucl. Phys. A **954**, 323 (2016); Eur. Phys. J. A **51**, 107 (2015); *arxiv:1704.02713* (2017); G. Barucca *et al.*, Eur. Phys. J. A, **55**, 42 (2019).