Hadronic and Leptonic decay widths of D and D_s Mesons using Dirac formalism

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Introduction

The decay of charged meson is important annihilation channel through the exchange of the virtual W boson. Though this annihilation process is rare, they have clear experimental signatures due to the presence of highly energetic leptons, hadrons in the final state. There exist experimental observations [1] of the hadronic and leptonic decays of D and D_s mesons. The decays of mesons entail an appropriate representation of the initial state of the decaying mesons in terms of the constituent quark and antiquark with their respective momenta and spin. Thus, it is appropriate to compute the branching ratio here.

Theoretical Framework

For the present study, we assume that the constituent quarks inside a meson are independently confined by an average potential of the form [2, 3]

$$V(r) = \frac{1}{2}(1+\gamma_0)(\lambda r^{0.1} + V_0) \qquad (1)$$

By numerically solving the two component (positive and negative energy) solution of Dirac eqn., we obtained binding energy and the radial solution [3]. The parameters are fixed from the spectroscopic study of D and D_s mesons. The optimized quark mass parameters m_c, $m_{u,d}$ and m_s are 1.27 GeV, 0.003 GeV and 0.1 GeV respectively. The radial solutions are employed to compute the decay constants, $f_{(D,D_s)}$ [3–5] and also the form factors, $f_+(q^2)$ corresponding to the decay properties of these mesons studied in this paper.

The leptonic width of the mesons (D, D_s) is computed using the relation given by [6]

$$\Gamma_{(D,D_s^+\to l^+\nu_l)} = \frac{G_F^2}{8\pi} f_{D,D_s}^2 |V_{cq}|^2 m_l^2 \left(1-\frac{m_l^2}{M_{D,D_s}^2}\right)^2 M_{D,D_s} \qquad (2)$$

The hadronic decay widths are calculated by [7, 8]

$$\Gamma_{(D,D_s\to H+\pi)} = C_f \frac{G_F^2\ |V_{cq}|^2 |V_{q_1q_2}|^2 f_\pi^2}{32\ \pi\ M_{D,D_s}^3} \times [\lambda(M_{D,D_s}^2, M_H^2, M_\pi^2)]^{\frac{3}{2}} |f_+^2(q^2)| \qquad (3)$$

C_f is the color factor and $(|V_{cs}|, |V_{cd}|, |V_{us}|)$ are the CKM matrices. f_π is the decay constant of π meson.

Results and Discussion

The present branching ratios for $D_s \to \tau\bar{\nu}_\tau$ (5.706×10^{-2}) and $D_s \to \mu\bar{\nu}_\mu$ (5.812×10^{-2}) are in excellent agreement with the experimental results $(5.43\pm0.31)\times10^{-2}$ and $(5.90\pm0.33)\times10^{-3}$ respectively and the branching ratios for $D\to\tau\bar{\nu}_\tau$ (9.73×10^{-4}) and $D\to\mu\bar{\nu}_\mu$ (3.846×10^{-4}) are also in very good agreement with the experimental results $(<1.2\times10^{-2})$ and (3.82×10^{-3}) respectively over other theoretical predictions vide Table I. The hadronic branching ratio, BR $(D_s\to\phi\ \pi^+)$ of 4.62% obtained here in very good agreement with the PDG value of 4.5 ± 0.4%. The BR $(D_s\to K^0\ \pi^+)$, 2.16×10^{-3} is also in good accord with the value of $2.40\pm0.18\times10^{-3}$ reported by Belle

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TABLE I: The leptonic decay widths and Branching Ratio (BR) of D and D_S mesons.

Process	Γ (keV) Present	Γ (keV) [5]	BR Present	BR [9]	BR [5]	BR Experiment [1]
$D^+ \to \tau\bar{\nu_\tau}$	6.157×10^{-10}	4.72×10^{-13}	9.73×10^{-4}	1.05×10^{-3}	7.54×10^{-4}	$< 1.2 \times 10^{-3}$
$D^+ \to \mu\bar{\nu_\mu}$	2.433×10^{-10}	1.79×10^{-13}	3.84×10^{-4}	4.3×10^{-3}	2.87×10^{-4}	3.82×10^{-4}
$D^+ \to e\bar{\nu_e}$	5.706×10^{-15}	$\cdots$	9.02×10^{-9}	1.00×10^{-8}	. . .	$< 8.8 \times 10^{-6}$
$D_s \to \tau\bar{\nu_\tau}$	7.508×10^{-8}	6.090×10^{-8}	5.706×10^{-2}	4.22×10^{-2}	4.3×10^{-2}	$(5.43 \pm 0.31) \times 10^{-2}$
$D_s \to \mu\bar{\nu_\mu}$	7.648×10^{-9}	6.240×10^{-9}	5.812×10^{-3}	4.25×10^{-3}	4.41×10^{-3}	$(5.90 \pm 0.33) \times 10^{-3}$
$D_s \to e\bar{\nu_e}$	1.792×10^{-13}	. . .	1.362×10^{-7}	1.00×10^{-7}	. . .	$< 1.2 \times 10^{-4}$

TABLE II: The Hadronic decay widths and Branching Ratio (BR) of D and D_S mesons.

Process	Γ (keV) Present	BR Present	BR [10]	BR Experiment [1]
$D^0 \to K^- \pi^+$	6.153×10^{-14}	3.835×10^{-2}	$(3.91 \pm 0.17)\%$	$(3.91 \pm 0.08)\%$ [11]
$D^0 \to K^+ \pi^-$	1.716×10^{-16}	1.069×10^{-4}	$(1.12 \pm 0.05) \times 10^{-4}$	$(1.48 \pm 0.07) \times 10^{-4}$ [11]
$D_s \to \phi \pi^+$	4.724×10^{-8}	4.62 %	4.38 ±0.35	$(4.5 \pm 0.4)\%$
$D_s \to K^0 \pi^+$	2.216×10^{-9}	2.16×10^{-3}	$(2.73 \pm 0.26) \times 10^{-3}$	$(2.40 \pm 0.18) \times 10^{-3}$ [12]

Collaboration [12]. The BR($D^0 \to K^-\pi^+$) and BR ($D^0 \to K^+\pi^-$) obtained here are in very good agreement with the respective Experimental values [11].

Acknowledgments

The work is part of Major research project NO. F. 40-457/2011(SR) funded by UGC. One of the author (BP) acknowledges the support through Fast Track project funded by DST (SR/FTP/PS-52/2011).

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