THE SEMILEPTONIC DECAYS OF D - MESONS

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The semileptonic $D \to P(V)l\bar{\nu}_l$ decays of D-mesons are studied using the method of phenomenological chiral Lagrangians(PCL). The expression of weak hadronic currents between pseudoscalar and vector states is obtained. Calculated partial widths for these decays are compared with the available theoretical and experimental data. It is shown that the theoretical and experimental ratios of the decay modes are in fair agreement.

At present the semileptonic decays of D-mesons are intensively studied in experiments [1,2]. Such decay channels are not described satisfactorily in the framework of varios approaches. For example, experimental measurements of the ratio $\frac{\Gamma(D\to K^* l^- \bar{\nu}_l)}{\Gamma(D\to K l^- \bar{\nu}_l)}$ give the unitial result that this ratio is only a little over one half, whereas theoretical models expect that it is about one [2].

In this paper semileptonic $D \to P(V)l\nu_l$ decays of D - mesons are studied using the method of phenomenological chiral Lagrangians (PCL) [3].

Note that chiral models have been used for describing charmed mesons [4-8] as well, though chiral symmetry at the level of charmed particles is rather strongly violated. In order to break the symmetry in case of the charmed particles the scheme of Oakes were extended to SU(4) by taking into account an additional rotation around the 10-th axis in the SU(4) space [8].

PCL, as a convenient method, was used with this symmetry violation scheme

for describing weak many-body nonleptonic decays of the Λ_c^+ - baryon [9]. In recent paper [10] two-body weak nonleptonic decays of D - mesons have been studied as well.

It is well known that $D \to V l \nu_l$ decay channels are unique "laboratory" for verification of weak hadron currents between pseudoscalar and vector meson

states. Main uncertainty in study of these decays is connected with this weak hadron current and so investigation of these decays are of interest.

Semileptonic decays of D-mesons are described by the Lagrangian

$$L_W = \frac{G_F}{\sqrt{2}}(J_\mu^{11-i12} \sin Q_c +$$

$J_\mu^{13-i14} \cos Q_c) l_\mu^+,$

where $G_F \simeq 10^{-5}/m_P^2$ is the Fermi constant,

Θ_c is the Cabibbo angle,

$l_\mu = \bar{u}_l \gamma_\mu (1 + \gamma_5) u_{\nu_l}$ is the

lepton current, and hadron currents have the form [3]

$$J_\mu^{11-i12} = -i\{\pi^- \partial_\mu$$

$\leftrightarrow$

$\bar{D}^0 - \frac{1}{\sqrt{2}}\pi^0 \partial_\mu$
$\leftrightarrow$ D$^- + K^0$
$\overleftrightarrow{\partial}_\mu$

D$_s^-\}$,

$$J_\mu^{13-i14} = -i\{K^- \; \partial_\mu$$

$\leftrightarrow$

$\bar{D}^0 + \bar{K}^0 \; \overleftrightarrow{\partial_\mu}$ D$^-$}.

Weak hadron currents between pseudoscalar and vector
meson states are obtained by including the gauge fields of these mesons in covariant derivatives [11] and have the form

$$J_\mu^i = F_\pi g v_\mu^a \varphi^b f_{abi},$$

where $F_\pi = 93$ MeV, g is the "universal" coupling constant,
that is fixed from experimental $\rho \to \pi\pi$ decay width:

$$\frac{g^2}{4\pi} \simeq 3.2,$$

v_μ^a and φ^b represent the fields of the 1^- and 0^-
- mesons, respectively.
The strong interaction Lagrangian of pseudoscalar and vector mesons has the form as well as [11]

$$L_S(1^-, 0^-) = g f_{klm} \varphi^l \partial_\mu \varphi^k v_\mu^m.$$

The decay amplitudes for these channels can be written as [9]

$$M\,(D(p) \to P(p_1) l(k_l) \nu(k_\nu)) = G_F \bar{U}(k_\nu)[f_1 +$$

g$_1\gamma_5 + \hat{p}\,(f_2 + g_2\gamma_5) +$
$+\hat{p}_1\,(f_3 + g_3\gamma_5)]U(k_l),$

$$M\,(D(p) \to V(p_1) l(k_l) \nu(k_\nu)) = G_F \epsilon^\lambda$$

$\mu \bar{U}(k_\nu)\gamma_\mu[f_1 + g_1\gamma_5 + \hat{p}\,(f_2 +$
g$_2\gamma_5 +$
$+\hat{p}_1\,(f_3 + g_3\gamma_5)]U(k_l),$

where ϵ_μ^λ is the polarization vector of 1^--mesons,

f_i and g_i are the form
factors that depend on the final state momenta;
$q = p - p_1$; k_l, k_ν are the lepton 4-momenta
$(\hat{p}_i \equiv p_{i\mu}\gamma^\mu)$.
Using these Lagrangians we calculated the partial widths of semileptonic
$D \to P(V)l\nu_l$ decays by means of the TWIST code [12]
(see Table 1,2).

Table 1 shows that the calculated branching ratios of
$D \to Pl^-\bar{\nu}_l$ decays are in a good agreement with
available experimental data [2], within the experimental errors, except for
the $D \to K^0 e^- \nu_e$ channel. Though the result obtained for this decay
channel is in agreement with relativistic quark model prediction [13] and
with the experiments [14].
The calculated partial widths for the $D \to Vl\bar{\nu}_l$ decays
(see Table 2) are in a good agreement with
experimental data [2,15] as well, within the experimental errors, except for
the $D \to K^* l^- \nu_l$ channels. Though the result obtained for the
$D \to K^* e^- \nu_e$ decay channel is in a good agreement with
Nambu-Iona-Lasinio model [7] prediction:

$$\Gamma(D \to K^* e^- \nu_e) = (1.92 \pm 0.54) \times 10^{10} c^{-1}.$$

The calculated results for the $D \to \rho l^- \bar{\nu}_l$ channels are
in a good agreement with heavy quark effective theory [16] and lattice QCD
predictions [17-20].
Comparison of the calculated results and available experimental data [2,14,15]
gives:

$$R_1 \equiv$$

$\Gamma(D^0 \to K^-\pi^+)[10] = 0.79, R_1^{exp} = 0.95 \pm 0.04;$

$$R_2 \equiv$$

$\Gamma(D^0 \to K^-\pi^+)[10] = 0.72, R_2^{exp} = 0.80 \pm 0.10;$

$$R_3 \equiv$$

$\Gamma(D^- \to K^0 e^- \bar{\nu}_e) = 0.94, R_3^{exp} =$

$1.06^{+0.48}_{-0.34}$;

$$R_4 \equiv$$

$\Gamma(\bar{D}^0 \to K^+ e^- \bar{\nu}_e) = 0.93, R_4^{exp} =$
$0.84 \pm 0.12.$

$$R_5 \equiv$$

$\Gamma(D^- \to K^{*0} e^- \bar{\nu}_e) = 0.037, R_5^{exp} =$
$0.045 \pm 0.014 \pm 0.009$;

$$R_6 \equiv$$

$\Gamma(D^- \to K^{*0} \mu^- \bar{\nu}_\mu) = 0.038, R_6^{exp} =$
$0.051 \pm 0.015 \pm 0.009$;

$$R_7 \equiv$$

$\Gamma(D^- \to K^{*0} l^- \bar{\nu}_l) = 0.037, R_7^{exp} =$
0.047 ± 0.013;

$$R_8 \equiv$$

$\Gamma(\bar{D}^0 \to K^+ e^- \bar{\nu}_e) = 0.26, R_8^{exp} =$
$0.51 \pm 0.18 \pm 0.06$;

$$R_9 \equiv$$

$\Gamma(D^- \to K^0 e^- \bar{\nu}_e) = 0.27, R_9^{exp} =$
$0.65 \pm 0.09 \pm 0.10$;

$$R_{10} \equiv$$

$\Gamma(\bar{D}^0 \to K^+ \mu^- \bar{\nu}_\mu) = 0.26,$
$\mathrm{R}_{10}^{exp} = 0.43 \pm 0.09 \pm 0.09.$

The calculated and experimental ratios of the partial widths of the $D \to P(V) l \bar{\nu}_l$ decays are in a good agreement. Note that PCL as compared to other approaches differs also by correct description of the ratio $\frac{\Gamma(D \to K^* l^- \bar{\nu}_l)}{\Gamma(D \to K l^- \bar{\nu}_l)}$

(see R_8, R_9 and R_{10}). Perhaps, taking into account contributions from intermediate vector
resonance states (see [9,10]) into these decay probabilities allows also to describe more satisfactorily R_9.

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Table 1. The partial widths $\Gamma(10^{10} sec^{-1})$
for semileptonic $D \to P l^- \bar{\nu}_l$ decays.

Decays	PCL	Experiment [2]
$D^- \to K^0 \mu^- \bar{\nu_\mu}$	10.3	$6.62^{+2.84}_{-1.89}$
$D^- \to \pi^0 \mu^- \bar{\nu_\mu}$	0.47	$---$
$\bar{D}^0 \to K^+ \mu^- \bar{\nu_\mu}$	10.2	8 ± 1
$\bar{D}^0 \to \pi^+ \mu^- \bar{\nu_\mu}$	0.94	$---$
$D_s^- \to \bar{K}^0 \mu^- \bar{\nu_\mu}$	0.81	$---$
$D^- \to K^0 e^- \bar{\nu_e}$	11.0	6.24 ± 0.85
$D^- \to \pi^0 e^- \bar{\nu_e}$	1.0	$---$
$\bar{D}^0 \to K^+ e^- \bar{\nu_e}$	11.0	9.16 ± 0.53
$\bar{D}^0 \to \pi^+ e^- \bar{\nu_e}$	1.0	$0.94^{+0.29}_{-0.24}$
$D_s^- \to \bar{K}^0 e^- \bar{\nu_e}$	0.84	$---$

Table 2. The partial widths $\Gamma(10^{10} sec^{-1})$
for semileptonic $D \to V l \nu_l$ decays.

Decays	PCL	Experiment [2]
$D^- \to K^{*0} \mu^- \bar{\nu_\mu}$	2.47	$4.26 \pm 0.57; 2.84 \pm 0.38$
$D^- \to \rho^0 \mu^- \bar{\nu_\mu}$	0.93×10^{-1}	$(1.89^{+1.42}_{-1.23}) \times 10^{-1}; 0.22 \pm 0.07 \pm 0.05$[15]
$\bar{D}^0 \to K^{*+} \mu^- \bar{\nu_\mu}$	2.48	$---$
$\bar{D}^0 \to \rho^+ \mu^- \bar{\nu_\mu}$	1.85×10^{-1}	$---$
$D_s^- \to \bar{K}^{*0} \mu^- \bar{\nu_\mu}$	1.89×10^{-1}	$---$
$D^- \to K^{*0} e^- \bar{\nu_e}$	2.73	$4.54 \pm 0.47; 3.03 \pm 0.31$
$D^- \to \rho^0 e^- \bar{\nu_e}$	1.01×10^{-1}	$\prec (3.5 \pm 0.1) \times 10^{-1}; 0.20 \pm 0.07 \pm 0.05$[15]
$\bar{D}^0 \to K^{*+} e^- \bar{\nu_e}$	2.76	$4.84 \pm 0.79; 3.32 \pm 0.55$
$\bar{D}^0 \to \rho^+ e^- \bar{\nu_e}$	2.02×10^{-1}	$---$
$D_s^- \to \bar{K}^{*0} e^- \bar{\nu_e}$	2.05×10^{-1}	$---$