A REMARK CONCERNING 20 FLET DOMINANCE IN CHARM DECAYS

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ABSTRACT

Based on V spin consideration, it is argued that 20 dominance in the effective weak Lagrangian does not strongly reduce the inclusive decay rate of D⁺ mesons. Decays of the type D → Kφ, K⁺π⁻, φπ are discussed in pointing out that 20 dominance should lead to a large enhancement of D⁺ → K⁰ρ⁺, (K⁰)⁺π⁺ over D⁺ → K⁺π⁻; W exchange, on the other hand, leads to a sizeable suppression of D⁰ → K⁻ρ⁺, (K⁻)⁺π⁺ relative to D⁰ → K⁻π⁺.

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One attempt to accommodate recent experimental findings on $D$ decays — mainly $\tau(D^+) \geq 4 \times \tau(D^0)$ — is based on two assumptions\textsuperscript{1)}: first one assumes strong $20$ dominance in the effective Lagrangian describing weak non-leptonic decays

\begin{equation}
\mathcal{L} = \tilde{G} \left\{ \frac{f_+}{2} \left[ \frac{c}{u} \cdot \frac{c}{d} - \frac{c}{u} \cdot \frac{c}{s} \right] + \frac{f_0}{2} \left[ \frac{c}{u} \cdot \frac{c}{d} + \frac{c}{u} \cdot \frac{c}{s} \right] \right\}
\end{equation}

\begin{equation}
\tilde{G} \equiv \frac{1}{G^2} \cos^2 \theta_c
\end{equation}

with $f_-/f_+ \approx 10$, whereas the conventional leading log result gives $f_-/f_+ \approx 3$\textsuperscript{2)}. Given this assumption it is then apparent that the coupling in the first square bracket of Eq. (1) dominates the transitions. One notes the negative sign between the two terms and concludes that their contributions to $D^+ \to \bar{K}^0\pi^+$ cancel. From there a second assumption is made that this cancellation is effective also for multibody final states since they are thought to come from two clusters. We find that this latter argument is implausible.

As has been stressed in the literature, it is convenient to use $V$ spin in discussing the effective weak Lagrangian\textsuperscript{3)}. $V$ spin groups $u$ and $s$ quarks into a doublet and $c$ and $d$ into singlets, making the $D^+$ meson a $V$ spin singlet, as is the charm changing part of the $20$plet. Therefore, it can generate $D^+$ decays only into $V = 0$ states. The final configuration of $\bar{K}^0$ and $\pi^+$, however, has to be symmetric under exchange due to Bose statistics and $SU(3)$ symmetry. Since this decay proceeds in an $s$ wave and $\bar{K}^0$ and $\pi^+$ are both $V$ spin doublets, they have to be in a $V = 1$ state. Thus the enhanced $20$ part of the effective weak Lagrangian does not contribute to such a mode (in the limit of $V$ spin symmetry):

\begin{equation}
D^+ \xrightarrow{20} \bar{K}^0\pi^+
\end{equation}

Yet one notes\textsuperscript{3)} that if a two-body or quasi-two-body decay proceeds in a $p$ wave, for example $D^+ \to \bar{K}^0\pi^+$, the final state can form a $V$ spin singlet. In the limit of $SU(6)$ symmetry it will even be a pure $V = 0$ state:

\begin{equation}
D^+ \xrightarrow{20} \bar{K}^0\eta^+
\end{equation}

or, in general,
\[ D^+ \xrightarrow{20} (0^{-+})(1^{-+}) \]  

(4)

where \( (J^P) \) denotes spin and parity, respectively.

Thus the decay of \( D^+ \) into two cluster states can proceed via the 20 in a p wave and should be enhanced. Therefore, we do not find it convincing that 20 dominance should lead to a strong suppression of inclusive \( D^+ \) decays. We are aware that the validity of our criticism might be disputed along the following line

Using an SU(3) decomposition, where the enhanced part of the effective Lagrangian transforms like a 5, one finds that the final state hadrons have to be in an 8 or 10 state, since

\[ \langle D | L \rangle ^{20} \cong 3 \otimes 6 = 10 + 8 \]  

(5)

Since \( K^0 \rho^+ \) (and \( \bar{K}^0 \pi^+ \)) carry isospin \( I = 3/2 \), they can be contained only in an antisymmetric 10 representation. One could argue that since 10 is an exotic representation for mesons in the quark model, its amplitudes should be suppressed. We find such an argument unconvincing, since -- just numerically -- a suppression of the order of \( \tau(D^+)/\tau(D^0) \sim 6 \) is required.

Nevertheless, if one argues that for whatever reason clusters are produced dominantly in an s wave at an energy of \( \sim M_D \), further analysis along the following lines will still show that \( D^+ \to K^0 \rho^+ \), \( (\bar{K}^0) \pi^+ \) will occur at an enhanced rate while \( D^0 \) decays are unaffected:

\[ \frac{BR(D^+ \to K^0 \rho^+)}{BR(D^+ \to K^0 \pi^+)} \sim \left( \frac{Z}{3} (1+Z)f_+ + \frac{2}{3} (1-Z)f_- \right)^2 \frac{BR(D^0 \to K^- \rho^+)}{BR(D^0 \to K^- \pi^+)} \]  

(6)

\( Z \), in the notation of Ref. 4), gives the ratio between the amplitudes where the spectator quark goes into the pseudoscalar or into the vector meson. In Ref. 4), \( Z \sim 1 \) was chosen. As discussed above, in the limit of SU(6) symmetry \( Z \sim -1 \) is the appropriate choice leading to

\[ \frac{BR(D^+ \to \bar{K}^0 \rho^+)}{BR(D^+ \to \bar{K}^0 \pi^+)} \sim 25 \times \frac{BR(D^0 \to K^- \rho^+)}{BR(D^0 \to K^- \pi^+)} \]  

(7)
for $f_+/f_- \sim 10$. SU(6) symmetry breaking will, of course, decrease this ratio substantially: for example, $Z \sim -\frac{1}{2}$ reduces the enhancement factor in Eq. (7) to 16. The numbers for $D \to K^*\pi$ are quite similar.

At present it is not clear how to calculate rigorously $BR(D \to K\pi)$ and $BR(D \to K\pi, K^*\pi)$. Yet it seems plausible that these two rates are roughly equal\(^4\) (up to a factor of two maybe). Then, Eq. (7) tells us:

$$BR(D^+ \to \overline{K}^0_{s}, (K^0)^*_{s}\pi^+ \sim O(15) \times BR(D^+ \to \overline{K}^0_{s}\pi^+) \sim O(20-30\%)$$ (8)

In other words, these decays should be major modes for the $D^+$ meson which does not seem to be the case, at least as far as $D^+ \to (K^0)^*_{s}\pi^+$ is concerned. If they were not seen it would pose an even bigger puzzle in a scheme invoking 20 dominance than in other models, as we shall see below.

An analogous situation exists for Cabibbo disfavoured $D^+$ decays, where $p$ wave decays like $D^+ \to \rho^0\pi^+$, $\rho^+\pi^0$ are enhanced relative to the $s$ wave decay $D^+ \to \pi^+\pi^0$, in the same way as discussed above.

Again, assuming that the "normal", i.e., unenhanced $p$ and $s$ wave decays are roughly the same, one finds:

$$BR(D^+ \to \gamma_{s}\pi^+) \sim O(15) \times BR(D^+ \to \pi^+\pi^0)$$

With $BR(D^+ \to \pi^+\pi^0) \leq \frac{1}{2} \tau g^2 \theta_C \times BR(D^+ \to \overline{K}^0_{s}\pi^+)$ one obtains

$$\frac{BR(D^+ \to \gamma_{s}\pi^+)}{BR(D^+ \to \overline{K}^0_{s}\pi^+)} \leq 0.4$$

which is still compatible with the presently stated upper limit on $BR(D^+ \to \pi^+\pi^-\pi^+)$.

We finish with a short remark on what one expects if weak exchange or annihilation diagrams\(^4\) are responsible for the $D^0/D^0$ lifetime difference. There the final state in $D^0$ decays has to carry $U$ spin 1 with $U_3 = -1$, where $U$ spin groups $d$ and $s$ quarks into a doublet and $u$ and $c$ quarks into singlets. $K^-\pi^+$, $K^-\rho^+$ and $(K^-)^*\pi^+$ can form such a symmetric $U$ spin 1 state. In the limit of SU(6) symmetry, $K^-\rho^+$ and $(K^-)^*\pi^+$ have to be in a totally symmetric state; yet they are in a $p$ wave and therefore:

$$D^0 \to \overline{K}^0_{s}, (K^0)^*_{s}\pi^+$$

in the SU(6) limit. Thus, in this model we also obtain a relative enhancement of the analogous $D^+$ decays:
where we have allowed for large SU(6) symmetry breaking, which reduces the relative enhancement. One should note that although qualitatively the situation is the same as for 20 dominance, as far as the relative size is concerned, the actual numbers are much smaller.

Furthermore, arguing as above that "normal", i.e., unenhanced rates for $D \to K\pi$ and $D \to K\rho$, $K^*\pi$ should be roughly the same, one finds that transition rates for the decays $D^0 \to K^-\rho^+$, $(K^-)^*\pi^+$ should be smaller by a factor of roughly three than the rates for $D^0 \to K^-\pi^+$. This is in clear contrast to the case of 20 dominance.

REFERENCES


