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A NEW HADRONIZATION SCHEME: THE CASE OF EXPLICIT CHARM DECAY

by

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Abstract: A model proposed recently for explaining the decay of pseudoscalar charmed mesons is applied to studying their explicit decay into two pseudoscalar mesons. The model realizes quark confinement and asymptotic freedom in a simple minded way which leads in a natural way to the enhancement of the hitherto neglected W-exchange and W-annihilation decay modes. The key ingredient giving rise to this enhancement is the appearance of a new term violating the vector (as well as the axial-vector) current conservation in addition to the usual one proportional to the differences (sums) of quark masses which are negligibly small. In the valence quark approximation these new contributions are estimated and found to be in quite good agreement with all available data. Many predictions are made which could and should be experimentally checked.

Key-words: Hadronization; Charm; Decay; Vector current conservation.

I. Introduction.

Our experimental knowledge of charmed meson decay has increased enormously in recent years, largely because of the results of the Mark III Collaboration[1].

This experimental information has gradually shown the limitations of the various theoretical models[2,3] mostly because the suppression of certain decay modes, expected from the effective color Hamiltonian, has not been confirmed by the data.

The discrepancy between the theoretical expectation and the experimental observation has been interpreted[4] as evidence of a non-spectator (N.S.) or W-exchange (W.E.) contribution much larger than expected from the traditional schemes favoring W-radiation (W.R.) charm decay mode. The difficulty with implementing this general observation lies in reconciling it with the assumption that the quarks produced in a weak decay behave essentially as free particles before hadronization occurs. In the traditional scheme[5] the W.E. contribution to the $D \to K\pi$ amplitude is suppressed due to the conservation of the vector meson current

$$\partial_\mu \bar{s}\gamma_\mu d = (m_s - m_d)\, \bar{s}\, d. \qquad (I.1)$$

This is the origin of the suppression of the W.E. decay of charmed mesons into two pseudoscalar mesons (and of the analogous suppression in the implicit D° decay) since it is proportional to the mass difference between the strange and the d-quark (which is negligible when compared with the charm quark mass c).

The recent observation[6] of a rather large branching ratio (B.R.) for $D^\circ \to \bar{K}^\circ\varphi$ which can only come from W.E. is the first explicit confirmation that this decay mode gives a contribution larger than anticipated; this may enhance drastically the role of the unknown form factor multiplying the W.E. amplitude but the net result is an increased difficulty in reconciling theory and experiment[7].

Perhaps the crucial role played by the $D^\circ \to \bar{K}^\circ \phi$ channel is best appreciated in that, omitting it, a suitably performed 1/N expansion seemed able to accomodate the other decay data which receive contribution from both W.R. and W.E. decay modes(8).

It is perhaps instructive to briefly review the various elements which make it so difficult to reconcile the data for non-leptonic decays of pseudoscalar charmed mesons with the conventional theoretical expectations from pure W.R. contribution:

i) the ratio $\tau(D^+)/\tau(D^\circ)$ is about 2 whereas it was expected to be close to one;

ii) the same holds for $B.R.(D^+ \to \ell^+ X)/B.R.(D^\circ \to \ell^+ X) \approx 2$ while it was expected to be of order one;

iii) two-body decays of the form $D^+ \to M^\circ \pi^+$ ($M^\circ = \bar{K}^\circ, \bar{K}^{\circ *}$) are systematically suppressed as compared with the predictions of the standard model whereas the opposite holds for the decays $D^\circ \to M^- \pi^+$ ($M^- = K^-, K^{-*}$) and $D^\circ \to = M^\circ \pi^\circ$ ($M^\circ = \bar{K}^\circ, \bar{K}^{\circ *}$);

iv) the latter decay-mode $D^\circ \to M^\circ \pi^\circ$ (which is allowed if W.E. is not negligible) is much underestimated when compared with the data;

v) the value $B.R.(D^\circ \to \bar{K}^\circ \phi) \approx 1\%$ implies(9), phenomenologically, the W.E. dominance in the decays $D^\circ \to \bar{K}^\circ \rho^\circ$ and $D^\circ \to \bar{K}^{\circ *} \rho^\circ$.

In this paper, we discuss the implication on the explicit two-body decays of pseudoscalar charmed mesons of a hadronization model in which the W.E. contribution is naturally enhanced. This model has been proposed in a recent paper(10) where it has been shown to provide a straightforward explanation for points i) and ii) above. Furthermore, as discussed in ref. 11, the model is rather atypical and makes specific testable predictions such as a noticeable decay $F^+ \to \pi^+ \pi^\circ$ in violation of the $\Delta I=1$ rule. This is a striking prediction which we urge the experimentalists to check.

In Sec. II we briefly review the model (for more details the reader is referred to ref. 10) especially emphasizing its connection with the violation of the vector and the axial-vector current conservation. Sec. III is devoted to evaluating the decay widths of a pseudoscalar charmed meson into two pseudoscalar light mesons in the valence quark approximation[3] whereas results and predictions[11] are discussed in Sec. IV. Some conclusions are drawn in Sec. V. The $\overline{K}^*\phi$ decay is discussed elsewhere[12].

It should be stressed from the start that the major ambiguities in our analysis are connected with the poor knowledge of the form factors entering in the game. We have no new insight on this point for which we rely entirely on previous analyses.

II. Outline of the model.

The quark confinement postulate of the QCD-like schemes constitues the basis of a recent model[10] according to which, in the rest frame of the decaying charmed meson, the quarks produced in a weak decay are described by a free wave damped by a gaussian whose width x_0 is taken to represent the distance beyond which hadronization takes place

$$\psi(\vec{x},t) = \omega(p)\ \exp(-ip_\mu x^\mu)\ \exp(-\vec{x}^2/2x_0^2) \qquad \text{(II.1)}$$

Formally, this amounts to assuming that

$$\vec{p} \to -i\vec{\partial}\ -i\vec{x}/x_0^2 \qquad \text{(II.2)}$$

which, in turns, yields a Dirac equation of the form

$$(i\gamma^\mu\partial_\mu + i\ \vec{\gamma}\cdot\vec{x}/x_0^2\ -m)\ \psi(\vec{x},t) = 0. \qquad \text{(II.3)}$$

where, the non-hermitian "potential" $i\vec{\gamma}\cdot\vec{x}/x_0^2$ has a natural interpretation as it induces a probability non-conservation implying that the quarks produced eventually disappear, and leave place to hadrons in the asymptotic states.

In ref. 10 we go quite at length to show how the model under discussion amounts to having free-quarks only within a distance x_0 and how this implies replacing exact three-momentum conservation (at the level of the produced quarks, not of the mesons in the final state) enforced by a Dirac delta function by a "gaussian" smearing of a width $\approx 1/x_0$. This reduces to the "free" case (when leptons i.e. truly elementary particles rather than quarks are produced) in the limit $x_0 \to \infty$ which is the frame in which the usual theoretical models are formulated.

Taking eq. (II.3) and the analogous one for $\bar{\psi}$, with a standard procedure we get

$$\partial_\mu \bar{\psi}' \gamma^\mu \psi = i(m'-m)\, \bar{\psi}' \psi - 2\bar{\psi}' \, (\vec{\gamma}\cdot\vec{x})/(x_0^2)\, \psi \qquad \text{(II.4)}$$

and

$$\partial_\mu \bar{\psi}' \gamma^\mu \gamma_5 \psi = i(m'+m)\, \bar{\psi}' \gamma_5 \psi - 2\bar{\psi}' (\vec{\gamma}\cdot\vec{x})/(x_0^2)\, \gamma_5 \psi. \qquad \text{(II.5)}$$

The last terms on the r.h.s. of eqs. (II.4,5) represent new contributions to the violations of vector and axial currents respectively, in addition to those, vanishihgly small in the N.S. case (see eq. (I.1)) proportional to the sums and differences of the masses of the quarks produced. In particular, the new term in eq. (II.4) will be responsible for increasing the rate at which charmed mesons decay in two pseudoscalar mesons due to the W.E. mode. Similarly, the new term in eq. (II.5) will be responsible for increasing the rate at which charmed mesons decay in a vector and a pseudoscalar meson through W.E.. Also, this latter term is responsible for increasing significantly the total decay widths of D° and F^+ (as compared with D^+) which receive contributions not only from W.R. (responsible for the D^+ width) but, respectively, from W.E. and W.A. (W-annihilation) as shown in ref. 10.

In order to better understand the physical origin of the new pieces of currents generated in our model, it is best to carry on the usual Gordon decomposition[13].

$$J_\mu = \bar{\psi}'\gamma_\mu\psi = (1/2m)\ (\partial\bar{\psi}'/\partial x^\mu\ \psi - \bar{\psi}'\ \partial\psi/\partial x^\mu) -$$

$$- (1/m+m')\ \partial/\partial x^\nu\ (\bar{\psi}'\sigma_\mu{}^\nu\psi) \qquad \text{(II.6)}$$

Let us denote by $j_\mu^{(1)}$ and $j_\mu^{(2)}$ the first and second term at the r.h.s. of eq. (II.6).

$j_\mu^{(1)}$ is, formally, identical to the current one defines non-relativistically (if we replace the Schrödinger wave function with the Dirac's one). $j_\mu^{(2)}$, on the other hand, which is sometimes called the spin current, has no counterpart in the Schrödinger case.

Taking the positive energy part of a Dirac wave packet with a gaussian (II.1)

$$\psi^+(\vec{x},t) = \int d^3\vec{p}/(2\pi)^{3/2}\ \sqrt{m/E}\ \sum_{\pm s}\ b(p,s)\ e^{-ip\cdot x-\vec{x}^2/2x_0^2} \qquad \text{(II.7)}$$

and writing the vector part of the current we have

$$\vec{J} = \int d^3\vec{p}\int d^3\vec{p}'\ (mm'/EE')^{1/2}\ (x_0^3/8\pi^{3/2})\ 1/(m+m')$$

$$\exp\left[-i(E'-E)t - (\vec{p}-\vec{p}')^2\ x_0^2/4\right] \sum_{\pm s,\pm s'} b^*(p',s')\ b(p,s)$$

$$\bar{u}(p',s')\ [(\vec{p}+\vec{p}')+i\ \vec{\sigma}\ \ \gamma_0(E'-E)\ -i\ \vec{\sigma}\wedge(\vec{p}'-\vec{p})]\ u(p,s) \qquad \text{(II.8)}$$

Eq. (II.8) makes quite clear the origin of $j_\mu^{(2)}$. This term disappears in the "free" particles case (leptons) when exact three-momentum conservation is restored. This is quite obvious from eq. (II.8): in the "free" case ($x_0 \to \infty$), $(x_0{}^3\pi^{3/2}\ \exp(\vec{p}'-\vec{p})^2\ x_0{}^2/4 \to (2\pi)^3\ \delta(\vec{p}'-\vec{p})$ which kills $j_\mu{}^{(2)}$. In our case, the deviation from exact three-momenta conservation of the produced quarks which is induced by the gaussian factor makes the new term $j_\mu(2)$ non negligible when the width of the distribution of b(p,s) is much broader then $1/x_0{}^2$ (the same kind of analysis can be repeated for the axial vector term).

III. Application of the model to explicit charm decay.

We wish now to discuss how our model accomodates the data and what new predictions it makes concerning the explicit decay of charmed mesons as the consequence of the enhancement of the W.E. and W.A. contributions. These are essentially zero in conventional models but the new terms in eq. (II.4,5) are going to modify the situation. As an example, consider the decay $D^\circ \to K^-\pi^+$. Using eq. (II.4) we find

$$M = G/\sqrt{2}\ [f_\pi+(m_c-m_s)\ \langle K^-|\bar{s}c|D^\circ\rangle +$$

$$+f_{D^\circ}(m_s-m_d)\ \langle K^-\pi^+|\bar{s}d|0\rangle - (2i/x_0{}^2)f_\pi\langle K^-|\bar{s}\vec{\gamma}\cdot\vec{x}c|D^\circ\rangle$$

$$-(2i/x_0{}^2)f_{D^\circ}\ \langle K^-\pi^+|\bar{s}\vec{\gamma}\cdot\vec{x}c|0\rangle \qquad \text{(III.1)}$$

which illustrates how new W.E. contributions come about.

In order to perform explicit calculations, however, it is more convenient to resort to the customary Valence Quark Approximation[3] in the frame of the so called vacuum saturation. The key point which distinguishes our model is the replacement of the four-momentum transfer by the sum of the fourmomenta of the quarks produced in the weak interaction

$$-if_P\ P^\mu \to -if_P(p_1{}^\mu+p_2{}^\mu) = \langle P|A^\mu|0\rangle \qquad \text{(III.2)}$$

In (III.2) P is the pseudoscalar meson which produces or is produced by the quarks p_1 and p_2 according to whether we are looking at the W.E. or the W.R. contribution in the decay

$$P \to p_1 + p_2 \to P_1 + P_2 \qquad \text{(III.3)}$$

Eq. (III.2) is to be contracted with the hadronic vector current contribution

$$\langle P_1 | V_\mu | P_2 \rangle = f_+(q^2)\ (P_{1\mu}+P_{2\mu}) + f_-(q^2)(P_{1\mu}-P_{2\mu}) \qquad \text{(III.4)}$$

in which f_+ and f_- are form factors (among which f_- is credited to be very small); P_1 and P_2 are the four vectors of the final mesons; q is the four-momentum transfer $q_\mu = P_{1\mu} - P_{2\mu}$.

In the usual "free" quarks scheme (with exact three momentum conservation at the quark level $\vec{p}_1+\vec{p}_2=\vec{P}$), the standard form of the squared matrix element is, aside from color and Cabibbo factors,

$$|M|^2 = G^2/2\ f_P^2\ [f_+(q^2)(m_{P_1}{}^2 - m_{P_2}{}^2\ ) + f_-(q^2) M_P{}^2]^2 \qquad \text{(III.5)}$$

where $q^2 = M_P{}^2$. M_P, m_{P_1} and m_{P_2} are the masses of the pseudoscalar mesons P, P_1 and P_2 respectively.

When the quarks produced are free only within a distance x_0 and a gaussian damping (II.1) is assumed, the "exact" three-momentum conservation given by a Dirac delta function is replaced by a gaussian[10] momentum spread of width x_0 and eq. (III.5) is considerably modified

$$|M|^2 = G^2/2\ f_P^2\ \{aM_P{}^2[f_+(q^2)\ (P_1+P_2) + f_-(q^2)(P_1-P_2)]^2$$

$$+ b\ [f_+(q^2)\ (m_{P_1}{}^2 - m_{P_2}{}^2) + f_-(q^2) q^2]^2\} \qquad \text{(III.6)}$$

In (III.6) we have introduced

$$a = -(1/\omega^2 x_0^2)\ \mathrm{erf}(x_0\omega/\sqrt{2}) + (2/\pi)^{\frac{1}{2}}\ (1/\omega x_0 + \omega x_0)\ \exp-(x_0^2\omega^2/2) \qquad \text{(III.7)}$$

$$b = (1 + 1/\omega^2 x_0^2)\ \mathrm{erf}(x_0\omega/\sqrt{2}) - (2/\pi)^{\frac{1}{2}}\ (2\omega x_0/3 + 1/\omega x_0)\ \exp-(x_0^2\omega^2/2) \qquad \text{(III.8)}$$

where erf(z) is the usual error function whose asymptotic behavior is

$$\mathrm{erf}(z) \underset{z \to \infty}{\to} 1.$$

ω is equal to M_p or to $E_1 - E_2$ according to whether we are analyzing a W.E. or W.R. contribution.

Eq. (III.8) implies

$$\lim_{x_0 \to \infty} a = 0$$

$$\lim_{x_0 \to \infty} b = 1 \qquad \text{(III.9)}$$

Eqs. (III.6-8) tell us that the modifications introduced by our model are represented by: i) the new term proportional to a and ii) the variations in b. When use is made of (III.9) we see that the conventional contribution (III.5) is recovered (as expected) in the "free" quark case $x_0 \to \infty$.

If we now use

$$(P_1+P_2)^2 = 2m_{P_1}^{\ 2} + 2m_{P_2}^{\ 2} - M_P^2$$

$$(P_1-P_2)^2 = M_P^2$$

$$(P_1^2-P_2^2) = m_{P_1}^{\ 2} - m_{P_2}^{\ 2}$$

in (III.6), we find (up, again, to colour and Cabibbo factors)

$$|M|^2 = G^2/2\, f_P{}^2 \{a[f_+{}^2(q^2)\,(2m_{P_1}{}^2+2m_{P_2}{}^2-M_P{}^2)\,M_P{}^2+f_-{}^2(q^2)M_P{}^4] +$$

$$+\, b[f_+{}^2(q^2)\,(m_{P_1}{}^2-m_{P_2}{}^2)^2 + f_-(q^2)M_P{}^4] + 2(a+b)\,\{f_+(q^2)\,\cdot$$

$$f(q^2)M_P{}^2(m_{P_1}{}^2-m_{P_2}{}^2)\}\} \qquad \text{(III.10)}$$

It is quite clear that in (III.10) the most relevant new contribution is the term $f_+{}^2(q^2)M_P{}^4$ which multiplies <u>a</u> and which vanishes, as already mentioned, when $x_0 \to \infty$.

The fact that the new term in $|M|^2$ (i.e. the one proportional to <u>a</u> in eq. (III.6)) sums up incoherently to the traditional one (proportional to <u>b</u> in eq. (III.6)) is due to the property of the interaction in our model. This is exhibited in eq. (II.2) and is analyzed in detail in ref. 10.

Although implicit in all we have said so far, the new term proportional to <u>a</u> in eq. (III.6) is mainly responsible for the W.E. contribution (just like W.R. contributes mostly to the traditional term proportional to <u>b</u>). In ref. 4 one can already find the observation that agreement with the data on $D \to K\pi$ using N.S. contributions can only be obtained if the W.E. contribution is imaginary.

IV. <u>Predictions and Comparison with the data.</u>

Before proceeding to evaluating the various contributions to the decay of a pseudoscalar charmed meson into two light (uncharmed) pseudoscalar mesons, it is perhaps instructive to examine the variations of <u>a</u> and <u>b</u> (eq. (III.6)) for various values of $z = \omega x_0$. This is shown in Table I

TABLE I

Variation of a and b (eqs. 7,8)) with $z = \omega x_0$

z	a	b
0.14	-0.034	0.036
0.28	-0.024	0.026
0.5	-0.003	0.033
1	-0.026	0.234
1.5	-0.083	0.561
2	-0.115	0.851
2.5	-0.114	1.014
3	-0.099	1.07

Some comments are in order: i) the function a(z) has a mininum around z=2, i.e. exactly for that value of the gaussian width x_0(= 0.2F) which we have obtained as an estimate from the analysis of the implicit D^0 and F^+ decays via W.E. and W.A. (ref. 10); ii) the W.R. contribution is strongly suppressed for small values of z, i.e., for small values of the energy transfer from the charmed to the non strange meson (in the case of charged current) or strange meson (in the case of neutral current). This was already discussed in ref. 10.

Both previous considerations go in the right direction. The first enhances the W.E. contribution i.e. increases the $\bar{K}^0\pi^0$ width (which is suppressed in conventional models); the second decreases the $D^+ \to \bar{K}^0\pi^+$ decay as compared with $D^0 \to \bar{K}^0 e^+\nu$[14].

Just like in the case of implicit decays[10], the determination of x_0 is quite uncontroversial in what concerns the W.E.

contribution (which is evaluated in the rest frame of the decaying charmed meson). The inherent limitations of our model discussed at length in ref. 10 make the analysis of the W.R. contribution more difficult to handle. For this reason, in analogy to what done in ref. 10, we prefer to take b in eq. (III.6) as a free parameter to be determined from one decay mode (such as $D^+ \to \bar{K}^\circ\pi^+$) in which W.R. is the only contribution. Furthermore, we will take this constant to be the same whether the final state is $\bar{K}^\circ\pi$ or $\pi^\circ\pi$. In the following, we take $b = 0.5$.

We also recall that color and Cabibbo factors are missing from (III.6). The latter is a $\cos^4\theta$ for Cabibbo allowed decay whereas the color factors a_1 and a_2 mutiplying (III.6) are $a_1 = (2c_+ + c_-)/3$ and $a_2 = (2c_+ - c_-)/3$ according to whether it is a charged or neutral current contribution (such as, for instance, the W.R. contribution to $D^\circ \to K^+\pi^-$ or to $D^\circ \to \bar{K}^\circ\pi^\circ$ respectively.

For the remaining parameters to be adjusted, we take $f_{D^\circ} = f_F = 0.2$ GeV as determined from implicit charm decay(10). We also take $f_-(q^2) = 0$ as it is customary and $c_+ = 0.66$, $c_- = 2.3$(10,11,12) leading to $a_1 = 1.21$ and $a_2 = 0.33$.

Finally, for $f_+(q^2)$ we take one of the parametrizations to be found in the literature(3,7,8) confining ourselves to the "scalar" contribution

$$f_+(q^2,0^+) = z(1-q^2/m^2(D^+)) \qquad \text{(IV.1)}$$

where z is of order unity for pure W.R. contribution.

If the usual analysis of form factors(3) can be generalized from the case of pure W.R. contribution to the much more delicate case of W.E. contribution(14,15), we have at least to reconsider the possible value of z. It has in fact been stressed recently(4) that the large number of resonances in the region between 1 and 2 GeV makes it plausible that this parameter may be significantly larger (especially since many of these resonances are fairly broad). A recent analysis of the pseudoscalar form factor[7] estimates that an effective z may be as much as ~3.7 without conflicting with PCAC. In our analysis we take z = 3 for W.E.

For a complete discussion on this point, see ref. 16.

The detailed predictions of our model are compared with the data (when they exist[1]) in Table II where the results of the 1/N calculation of ref. 7,15 is also shown for comparison.

TABLE II

The prediction our our model compared with the data (ref. 1) and with the results of ref. 7,15. All values in units of $10^{10}\ s^{-1}$.

Reaction	Experiment	This model	1/N calculation
$\Gamma(D^+ \to \bar{K}^0\pi^+)$	4.5 ± 1.0	input	2.6
$\Gamma(D^0 \to K^-\pi^+)$	14.0 ± 2.0	13.9	20.1
$\Gamma(D^0 \to \bar{K}^0\pi^0)$	5.5 ± 1.2	4.1	4.1
$\Gamma(D^0 \to \bar{K}^0\eta)$	4.6 ± 2.2	5.8	2.1
$\Gamma(D^0 \to \pi^+\pi^-)$	0.5 ± 0.2	0.86	1.4
$\Gamma(D^+ \to \pi^+\pi^0)$	$<0.8 \pm 0.2$	0.81	--
$\Gamma(D^0 \to K^-K^+)$	1.7 ± 0.4	1.1	1.9
$\Gamma(D^+ \to \bar{K}^0K^+)$	1.4 ± 0.5	1.4	1.9
$\Gamma(D^0 \to \bar{K}^0K^0)$		~0.03	
$\Gamma(F^+ \to \pi^+\pi^0)$		9.0	
$\Gamma(F^+ \to K^+\bar{K}^0)$		7.2	
$\Gamma(F^+ \to \eta\pi^+)$		13.6	

When there are no entries in the column "esperiment" in Table II, our values are to be taken as predictions which we hope will soon be tested.

V. Conclusions.

The results of Table II speak for themselves. The model gives a host of results which compare quite well with the available data. Combining the results reported here with those of previous analyses(10,11,12), we conclude that our model, in spite of its limitations and of its naiveté, is quite successful. Ultimately, of course, the success (or failure) of a theoretical scheme can only be established from its agreement with all existing data and from its predictive power. As repeatedly emphasized our scheme not only is in many points in agreement with the data on both implicit and explicit charm decay as we have seen in this and in previous papers(10,12) but is flexible and simple enough to make specific predictions (see refs. 11,12 and Table II). A thorough investigation of these predictions is called for.

On the theoretical sides, some aspects of the model which we have not been able to analyze deserve being further clarified, especially its formal non-covariance with the limitations that this implies. Possible remedies, briefly outlined in ref. 10 will be investigated as well as the application of the model to other decay channels.

Note added in proof.

After completion of this paper, we have become aware of a new result by the MARK III Collaboration (R. H. Schindler SLAC - PUB - 4135 October 1986 to be published in High Energy Electron - Positron Physics and W. Toki SLAC - PUB - 4153 December 1986).

This result is $\Gamma(F^+ \to \bar{K}^*_s K^+)/\Gamma(F^+ \to \phi\pi^+) = 0.44 \pm 0.12 \pm 0.21$ which using $BR(F^+ \to \phi\pi^+) = 4\%$ and their $\tau(F^+)$ lifetime $= 3.85^{+0.65}_{-0.48}$

10^{-13} s. gives $\Gamma(F^+ \to K_S^* K^+) = 4.6\ 10^{10}\ s^{-1}$.

Assuming a rough equality of $\Gamma(F^+ \to \bar{K}_S^* K^+)$ and $\Gamma(F^+ \to \bar{K}_L^* K^+)$, this would suggest an $F^+ \to \bar{K}^* K^+$ width of about $9 \cdot 10^{10}\ s^{-1}$ which compares very well with the prediction of our model quoted in Table II ($\sim 7.2 \cdot 10^{10}\ s^{-1}$). This is especially remarkable if attention is paid to the fact that the $F^+ \to \bar{K}^* K^+$ width predicted by the usual model (refs. 2,3) is of order unit (in $10^{10}\ s^{-1}$).

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