$SU(3)_{FLAVOR}$-ANALYSIS OF NONFACTORIZABLE CONTRIBUTIONS TO $D \to PP$ DECAYS

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ABSTRACT

We study charm D - meson decays to two pseudoscalar mesons in Cabibbo favored mode employing SU(3)-flavor for the nonfactorizable matrix elements. Using $D \to \bar{K}\pi$ and $D_s \to \bar{K}K$ to fix the reduced matrix elements, we obtain a consistent fit for η and η' emitting decays of D and D_s mesons.

It is now fairly established that the naive factorization model does not explain the data on weak hadronic decays of charm mesons. On one hand large $N_c \to \infty$ limit, which apparently was thought to be supported by D-meson phenomenology [1,2], has failed to explain B-meson decays, as B-meson data clearly demands [3] a positive value of the a_2-parameter. On the other hand even in D-meson decays, the two body Cabibbo favored decays of D^0 and D_s^+ involving η and η' in their final state have proven to be problematic for a universal choice of a_1 and a_2 [4]. Annihilation terms, if used to bridge the discrepancy between theory and experiment, require large form factors, particularly for $D \to \bar{K}^0 + \eta/\eta'$ and $D^0 \to \bar{K}^{*0} + \eta$ decays [4]. Further, factorization also fails to relate $D_s^+ \to \eta/\eta' + \pi^+/\rho^+$ decays with semileptonic decays $D_s^+ \to \eta/\eta' + e^+\nu$ [4,5] consistently.

Recently, there has been a growing interest in studying nonfactorizable terms for weak hadronic decays of charm and bottom mesons [6]. In an earlier work [7], we have searched for a systematics in the nonfactorizable contributions for various decays of D^0 and D^+ mesons involving isospin 1/2 and 3/2 final states. We observe that the nonfactorizable isospin 1/2 and 3/2 amplitudes have nearly the same ratio for $D \to \bar{K}\pi/\bar{K}\rho/\bar{K}^*\pi/\bar{K}a_1/\bar{K}^*\rho$ decay modes. In order to realize the full impact of isospin symmetry, and to relate D_s^+-decays with those of the nonstrange charm mesons, we generalize it to the SU(3)-flavor symmetry.

We analyze Cabibbo favored decays of D^0, D^+ and D_s^+ mesons to two pseudoscalar mesons. Determining the SU(3) reduced matrix elements from $D^+ \to \bar{K}^0\pi^+$ and $D_s^+ \to \bar{K}^0 K^+$, we obtain a consistent fit for $D^0 \to \bar{K} + \pi/\eta/\eta'$ and $D_s^+ \to \pi + \eta/\eta'$ decays.

We start with the effective weak Hamiltonian

$$H_w = \tilde{G}_F[c_1(\bar{u}d)(\bar{s}c) + c_2(\bar{s}d)(\bar{u}c)], \tag{1}$$

where $\tilde{G}_F = \frac{G_F}{\sqrt{2}} V_{ud} V_{cs}^*$ and $\bar{q}_1 q_2 \equiv \bar{q}_1 \gamma_\mu (1-\gamma_5) q_2$ represents color singlet $V-A$ current and the QCD coefficients at the charm mass scale are

$$c_1 = 1.26 \pm 0.04, \qquad c_2 = -0.51 \pm 0.05. \tag{2}$$

Separating the factorizable and nonfactorizable parts, the matrix element of the operator $(\bar{u}d)(\bar{s}c)$ in eq. (1) between initial and final states can be written as

$$\begin{aligned} < P_1 P_2|(\bar{u}d)(\bar{s}c)|D > \; &= \; < P_1|(\bar{u}d)|0 >< P_2|(\bar{s}c)|D > \\ &+ < P_1 P_2|(\bar{u}d)(\bar{s}c)|D >_{nonfac} . \end{aligned} \tag{3}$$

Using the Fierz identity

$$(\bar{u}d)(\bar{s}c) = \frac{1}{N_c}(\bar{s}d)(\bar{u}c) + \frac{1}{2}\sum_{a=1}^{8}(\bar{s}\lambda^a d)(\bar{u}\lambda^a c), \tag{4}$$

where $\bar{q}_1 \lambda^a q_2 \equiv \bar{q}_1 \gamma_\mu (1-\gamma_5)\lambda^a q_2$ represents color octet current, the nonfactorizable part of the matrix element in eq.(3) can be expanded as

$$\begin{aligned} < P_1 P_2|(\bar{u}d)(\bar{s}c)|D >_{nonfac} \; &= \; \frac{1}{N_c} < P_2|(\bar{s}d)|0 >< P_1|(\bar{u}c)|D > \\ +\frac{1}{2} < P_1 P_2|\sum_{a=1}^{8}(\bar{s}\lambda^a d)(\bar{u}\lambda^a c)|D >_{nonfac} &+ \frac{1}{N_c} < P_1 P_2|(\bar{s}d)(\bar{u}c)|D >_{nonfac} . \end{aligned} \tag{5}$$

Performing a similar treatment to the other operator $(\bar{s}d)(\bar{u}c)$ in eq.(1), the decay amplitude becomes

$$\begin{aligned} < P_1 P_2|H_w|D > \; = \; &\tilde{G}_F[a_1 < P_1|(\bar{u}d)|0 >< P_2|(\bar{s}c)|D > \\ &+a_2 < P_2|(\bar{s}d)|0 >< P_1|(\bar{u}c)|D > \\ &+c_2(< P_1 P_2|H_w^8|D > + < P_1 P_2|H_w^1|D >)_{nonfac} \end{aligned}$$

$$+c_1(< P_1P_2|\tilde{H}_w^8|D> + < P_1P_2|\tilde{H}_w^1|D>)_{nonfac}\ ], \tag{6}$$

where

$$a_{1,2} = c_{1,2} + \frac{c_{2,1}}{N_c}, \tag{7}$$

$$\begin{aligned} H_w^8 &= \frac{1}{2}\sum_{a=1}^{8}(\bar{s}\lambda^a d)(\bar{u}\lambda^a c), \quad \tilde{H}_w^8 = \frac{1}{2}\sum_{a=1}^{8}(\bar{u}\lambda^a d)(\bar{s}\lambda^a c); \\ H_w^1 &= \frac{1}{N_c}(\bar{s}d)(\bar{u}c), \quad \tilde{H}_w^1 = \frac{1}{N_c}(\bar{u}d)(\bar{s}c). \end{aligned} \tag{8}$$

Thus nonfactorizable effects arise through the Hamiltonian made up of color-octet currents (H_w^8 and $\tilde{H}_w^8$) and also of color singlet currents (H_w^1 and $\tilde{H}_w^1$).

Matrix elements of the first and the second terms in eq. (6) can be calculated using the factorization scheme [1]. These are given in Table I. So long as one restricts to the color singlet intermediate states, remaining terms in eq.(6) are ignored and one usually treats a_1 and a_2 as input parameters in place of using $N_c = 3$ in reality. It is generally believed [1, 8] that the $D \to \bar{K}\pi$ decays favour $N_c \to \infty$ limit, i.e.,

$$a_1 \approx 1.26, \quad a_2 \approx -0.51. \tag{9}$$

However, it has been shown that this does not explain all the decay modes of charm mesons [4,5]. For instance, the observed $D^0 \to \bar{K^0}\eta$ and $D^0 \to \bar{K^0}\eta'$ decay widths are considerably larger than those predicted in the spectator quark model. Also in $D \to PV$ mode, measured branching ratios for $D^0 \to \bar{K^{*0}}\eta$, $D_s^+ \to \eta/\eta' + \rho^+$, are higher than those predicted by the spectator quark diagrams. For $D_s^+ \to \eta/\eta' + \pi^+$, though factorization can account for substantial part of the measured branching ratios, it fails to relate them to corresponding semileptonic decays $D_s^+ \to \eta/\eta' + e^+\nu$ consistently [4,5]. In addition to the spectator quark diagram, factorizable W-exchange or W-annihilation diagrams may contribute to the weak nonleptonic decays of D mesons. However, for $D \to PP$ decays, such contributions are helicity suppressed [1]. For D meson decays, these are futher color-suppressed as these involve QCD coefficient c_2, whereas for $D_s^+ \to PP$ decays these vanish [4] due to the conserved vector (CVC) nature of isovector current $(\bar{u}d)$. Therefore, it is desirable to investigate nonfactorizable contributions more seriously.

It is well known that nonfactorizable terms cannot be determined unambiguiously without making some assumptions [6] as these involve nonperturbative effects arising due to soft-gluon exchange. We thus employ SU(3)-flavor-symmetry [9] to handle these matrix elements. In the SU(3) framework, the weak Hamiltonians H_w^8, $\tilde{H}_w^8$, H_w^1 and $\tilde{H}_w^1$ for Cabibbo-enhanced mode behave like H_{13}^2 component of 6^* and 15 representations of the SU(3). Since H_w^8 and $\tilde{H}_w^8$ transform into each other under interchange of u and s quarks, which forms V-spin subgroup of the SU(3), we assume the reduced amplitudes to follow

$$< P_1 P_2 || \tilde{H}_w^8 || D > = < P_1 P_2 || H_w^8 || D > . \tag{10}$$

Then, the matrix elements $< \ P_1 P_2 | H_w^8 | D \ >$ can be considered as $weak\ spurion + D \to P + P$ scattering process, whose general structure can be written as

$$\begin{aligned} < P_1 P_2 | H_w^8 | D > \quad = \quad & b_1 (P_a^m P_m^c P^b) H_{[b,c]}^a + d_1 (P_a^m P_m^c P^b) H_{(b,c)}^a \\ & + e_1 (P_m^b P_a^c P^m) H_{(b,c)}^a + f_1 (P_m^m P_a^b P^c) H_{(b,c)}^a \end{aligned} \tag{11}$$

where P^a denotes triplet of D-mesons $P^a \equiv (D^0,\ D^+,\ D_s^+)$ and P_b^a denotes $3 \otimes 3$ matrix of uncharmed pseudoscalar mesons,

$$P_b^a \quad = \quad \begin{pmatrix} P_1^1 & \pi^+ & K^+ \\ \pi^- & P_2^2 & K^0 \\ K^- & \bar{K}^0 & P_3^3 \end{pmatrix} \tag{12}$$

with

$$P_1^1 \quad = \quad \frac{\pi^0}{\sqrt{2}} + \frac{\eta_8}{\sqrt{6}} + \frac{\eta_0}{\sqrt{3}},$$

$$P^2_2 = -\frac{\pi^0}{\sqrt{2}} + \frac{\eta_8}{\sqrt{6}} + \frac{\eta_0}{\sqrt{3}},$$

$$P^3_3 = -\frac{2\eta_8}{\sqrt{6}} + \frac{\eta_0}{\sqrt{3}}.$$

Particle data group [10] defines the physical $\eta - \eta'$ mixing as

$$\eta = \eta_8 \cos\phi - \eta_0 \sin\phi,$$

$$\eta' = \eta_8 \sin\phi + \eta_0 \cos\phi, \tag{13}$$

where $\phi = -10^0$ and $\phi = -19^0$ follow from the quadratic mass formula and the two photon decays widths respectively [10]. We employ the following basis [4]

$$\eta = \frac{1}{\sqrt{2}}(u\bar{u} + d\bar{d})\sin\theta - (s\bar{s})\cos\theta,$$

$$\eta' = \frac{1}{\sqrt{2}}(u\bar{u} + d\bar{d})\cos\theta + (s\bar{s})\sin\theta, \tag{14}$$

where θ is given by

$$\theta = \theta_{ideal} - \phi. \tag{15}$$

Performing a similar treatment for H^1_w and $\tilde{H}^1_w$, i.e.

$$< P_1 P_2||\tilde{H}^1_w||D > = < P_1 P_2||H^1_w||D >, \tag{16}$$

the matrix elements $< P_1 P_2|H^1_w|D >$ are obtained from

$$< P_1 P_2|H^1_w|D > = b_2(P^m_a P^c_m P^b)H^a_{[b,c]} + d_2(P^m_a P^c_m P^b)H^a_{(b,c)}$$

$$+ e_2(P^b_m P^c_a P^m)H^a_{(b,c)} + f_2(P^m_m P^b_a P^c)H^a_{(b,c)} \tag{17}$$

Since the C.G. coefficients appearing in the eqs. (11) and (17) are the same, the unknown reduced amplitudes get combined as

$$b = b_1 + b_2, \;\; d = d_1 + d_2, \;\; e = e_1 + e_2, \;\; f = f_1 + f_2, \tag{18}$$

when the matrix elements are substituted in eq.(6).

There exists a straight correspondence between the terms appearing in (11) and (17) and various quark level processes. The first two terms, involving the coefficients $b's$ and $d's$, represent W-annihilation or W-exchange diagrams. Notice that unlike factorizable W-exchange or W-annihilation diagrams, these diagrams are not suppressed on the basis of the helicity arguments due to the involvement of gluons. The third term, having coefficient $e's$, represents spectator quark like diagram where the uncharmed quark in the parent D-meson flows into one of the final state mesons. The last term is like a hair-pin diagram, where $q\bar{q}$ generated in the process hadronizes to one of the final state mesons. Thus obtained nonfactorizable contributions to various $D \to PP$ decays are given in Table II.

Now we proceed to determine the SU(3) reduced amplitudes b, d, e, f. First, we calculate the factorizable contributions to various decays using $N_c = 3$, which yields

$$a_1 = 1.09, \quad a_2 = -0.09 \tag{19}$$

For the form factors, we use

$$F_0^{DK}(0) = 0.76, \quad F_0^{D\pi}(0) = 0.83, \tag{20}$$

as guided by the semileptonic decays [8, 12], and

$$\begin{aligned} F_0^{D\eta}(0) = 0.68, &\quad F_0^{D\eta'}(0) = 0.65, \\ F_0^{D_s\eta}(0) = 0.72, &\quad F_0^{D_s\eta'}(0) = 0.70, \end{aligned} \tag{21}$$

from the BSW model [1]. Numerical values of the factorizbale amplitudes are given in col (iii) of Table I.

$D \to \bar{K}\pi$ decays involve elastic final state interactions (FSI) whereas the remaining decays are not affected by them. As a result, the isospin amplitudes

1/2 and 3/2 appearing in $D \to \bar{K}\pi$ decays develop different phases;

$$\begin{aligned}
A(D^0 \to K^-\pi^+) &= \frac{1}{\sqrt{3}}[A_{3/2}e^{i\delta_{3/2}} + \sqrt{2}A_{1/2}e^{i\delta_{1/2}}], \\
A(D^0 \to \bar{K}^0\pi^0) &= \frac{1}{\sqrt{3}}[\sqrt{2}A_{3/2}e^{i\delta_{3/2}} - A_{1/2}e^{i\delta_{1/2}}], \\
A(D^+ \to \bar{K}^0\pi^+) &= \sqrt{3}A_{3/2}e^{i\delta_{3/2}}. \qquad (22)
\end{aligned}$$

which yield the following phase independent [7,11] expressions:

$$\begin{aligned}
|A(D^0 \to K^-\pi^+)|^2 + |A(D^0 \to \bar{K}^0\pi^0)|^2 &= |A_{1/2}|^2 + |A_{3/2}|^2, \\
|A(D^+ \to \bar{K}^0\pi^+)|^2 &= 3|A_{3/2}|^2. \qquad (23)
\end{aligned}$$

These relations allow one to work without the phases. Writing the total decay amplitude as sum of factorizable and nonfactorizable parts

$$A(D \to \bar{K}\pi) = A^f(D \to \bar{K}\pi) + A^{nf}(D \to \bar{K}\pi), \qquad (24)$$

we obtain

$$\begin{aligned}
A^{nf}_{1/2} &= \frac{1}{\sqrt{3}}\{\sqrt{2}A^{nf}(D^0 \to K^-\pi^+) - A^{nf}(D^0 \to \bar{K}^0\pi^0)\}, \qquad (25) \\
A^{nf}_{3/2} &= \frac{1}{\sqrt{3}}\{A^{nf}(D^0 \to K^-\pi^+) + \sqrt{2}A^{nf}(D^0 \to \bar{K}^0\pi^0)\}, \\
&= \frac{1}{\sqrt{3}}\{A^{nf}(D^+ \to \bar{K}^0\pi^+)\}. \qquad (26)
\end{aligned}$$

The last relation (26) leads to the following constraint:

$$\frac{b+d}{e} = \frac{c_1 + c_2}{c_2 - c_1} = -0.424 \pm 0.042. \qquad (27)$$

Experimental value $B(D^+ \to \bar{K}^0\pi^+) = 2.74 \pm 0.29\%$ yields, up to a scale factor $\tilde{G}_F$,

$$e = -0.094 \pm 0.027\, GeV^3. \qquad (28)$$

This in turn predicts sum of the branching ratios of $D^0 \to \bar{K}\pi$ decay modes,

$$B(D^0 \to K^-\pi^+) + B(D^0 \to \bar{K}^0\pi^0) = 6.30 \pm 0.67\% \quad (6.06 \pm 0.30\%\ Expt.) \qquad (29)$$

in good agreement with experiment. Using the experimental value of $B(D_s^+ \rightarrow \bar{K}^o K^+) = 3.5 \pm 0.7\%$, we find (in GeV^3)

$$b = +0.080 \pm 0.026, \tag{30}$$

$$d = -0.040 \pm 0.026. \tag{31}$$

Note that the unknown reduced amplitude f appears only in decays involving η and η' in the final state. We find that experimental values of these decay rates require (in GeV^3):

$$\begin{aligned} f &= -0.145 \pm 0.077 \quad \text{for} \quad D^0 \rightarrow \bar{K}^0\eta, \\ f &= -0.115 \pm 0.012 \quad \text{for} \quad D^0 \rightarrow \bar{K}^0\eta', \\ f &= -0.104 \pm 0.163 \quad \text{for} \quad D_s^+ \rightarrow \eta\pi^+, \\ f &= -0.081 \pm 0.073 \quad \text{for} \quad D_s^+ \rightarrow \eta'\pi^+. \end{aligned} \tag{32}$$

In Tables III, we calculate branching ratios for all the four η, η' emitting decay modes for different choice of f, for $\phi = -10^o$ and -19^o. It is clear that for $f = -0.12$ and $\phi = -10^o$, all the branching ratios match well with experiment. For the sake of comparison with factorizable terms, nonfactorizable contributions to various modes for $f = -0.12$ are given in column (iii) of the Table II. Color-suppressed decays obviously require large nonfactorizable contributions.

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Table I

Spectator-quark decay amplitudes ($\times\ \tilde{G}_F\ GeV^3$)

Process	Amplitude	$\phi\ =\ -10^0$	$\phi\ =\ -19^0$
$D^+ \to \bar{K}^0\pi^+$	$a_1 f_\pi(m_D^2 - m_K^2)F_0^{DK}(m_\pi^2)$ $+\ a_2 f_K(m_D^2 - m_\pi^2)F_0^{D\pi}(m_K^2)$	+0.311	+0.311
$D^0 \to K^-\pi^+$	$a_1 f_\pi(m_D^2 - m_K^2)F_0^{DK}(m_\pi^2)$	+0.354	+0.354
$D^0 \to \bar{K}^0\pi^0$	$\frac{1}{\sqrt{2}}a_2 f_K(m_D^2 - m_\pi^2)F_0^{D\pi}(m_K^2)$	-0.030	-0.030
$D^0 \to \bar{K}^0\eta$	$\frac{1}{\sqrt{2}}a_2 sin\theta f_K(m_D^2 - m_\eta^2)F_0^{D\eta}(m_K^2)$	-0.016	-0.019
$D^0 \to \bar{K}^0\eta'$	$\frac{1}{\sqrt{2}}a_2 cos\theta f_K(m_D^2 - m_{\eta'}^2)F_0^{D\eta'}(m_K^2)$	-0.013	-0.010
$D_s^+ \to \bar{K}^0K^+$	$a_2 f_K(m_{D_s}^2 - m_K^2)F_0^{D_sK}(m_K^2)$	-0.035	-0.035
$D_s^+ \to \pi^0\pi^+$	0	0	0
$D_s^+ \to \eta\pi^+$	$-a_1 cos\theta f_\pi(m_{D_s}^2 - m_\eta^2)F_0^{D_s\eta}(m_\pi^2)$	-0.261	-0.216
$D_s^+ \to \eta'\pi^+$	$a_1 sin\theta f_\pi(m_{D_s}^2 - m_{\eta'}^2)F_0^{D_s\eta'}(m_\pi^2)$	+0.213	+0.243

Table II

Nonfactorizable contributions to $D \to PP$ decays ($\times\ \tilde{G}_F\ GeV^3$)

Process	Amplitude	$\phi = -10^0$	$\phi = -19^0$
$D^+ \to \bar{K}^0\pi^+$	$2(c_1 + c_2)\ e$	-0.141	-0.141
$D^0 \to K^-\pi^+$	$c_2\ (b + d + e)$	+0.028	+0.028
$D^0 \to \bar{K}^0\pi^0$	$\frac{1}{\sqrt{2}}c_1\ (-b - d + e)$	-0.119	-0.119
$D^0 \to \bar{K}^0\eta$	$c_1[\frac{sin\theta}{\sqrt{2}}\ (b + d + e + 2f)\ -\ cos\theta(b + d + f)]$	-0.115	-0.154
$D^0 \to \bar{K}^0\eta'$	$c_1[\frac{cos\theta}{\sqrt{2}}\ (b + d + e + 2f)\ +\ sin\theta(b + d + f)]$	-0.256	-0.235
$D_s^+ \to \bar{K}^0K^+$	$c_1\ (-b + d + e)$	-0.268	-0.268
$D_s^+ \to \pi^0\pi^+$	0	0	0
$D_s^+ \to \eta\pi^+$	$c_2[\sqrt{2}sin\theta\ (-b + d + f)\ -\ cos\theta(e + f)]$	+0.046	+0.076
$D_s^+ \to \eta'\pi^+$	$c_2[\sqrt{2}cos\theta\ (-b + d + f)\ +\ sin\theta(e + f)]$	+0.199	+0.189

Table III

Branching (%) of η/η' emitting decays including nonfactorization terms

Decay	$\phi = -10^o$			$\phi = -19^o$			Expt.
	$f = -0.10$,	-0.12,	-0.14	$f = -0.10$,	-0.12,	-0.14	
$D^0 \to \eta \bar{K}^0$	0.53	0.59	0.66	0.86	1.02	1.19	0.68±0.11
$D^0 \to \eta' \bar{K}^0$	1.28	1.81	2.43	1.04	1.51	2.06	1.66±0.29
$D_s^+ \to \eta \pi^+$	1.93	1.87	1.82	0.86	0.80	0.73	1.9±0.4
$D_s^+ \to \eta' \pi^+$	5.17	5.64	6.13	5.73	6.22	6.72	4.7±1.4

References

[1] M. Bauer, B.Stech and M. Wirbel, Z. Phys. C **34**, 103 (1987); M. Wirbel, B. Stech and M. Bauer, Z. Phys. C **29**, 637 (1985).

[2] N. Isgur, D. Scora, B. Grinstein and M. Wise, Phys. Rev. D **39**, 799 (1989).

[3] M. Gourdin, A. N. Kamal, Y. Y. Keum and X. Y. Pham, Phys. Letts. B **333**, 507 (1994); CLEP collaboration: M.S. Alam *et al.*, Phys. Rev. D **50**, 43 (1994); D. G. Cassel, 'Physics from CLEO', talk delivered at Lake-Louise Winter Institute on 'Quarks and Colliders', Feb. (1995).

[4] R. C. Verma, A. N. Kamal and M. P. Khanna, Z. Phys. C. **65**, 255 (1995).

[5] R. C. Verma, 'A Puzzle in $D, D_s \rightarrow \eta/\eta' + P/V'$, talk delivered at Lake Louise Winter Institute on 'Quarks and Colliders' Feb. (1995).

[6] H. Y. Cheng, Z. Phys. C. **32**, 237 (1986), 'Nonfactorizable contributions to nonleptonic Weak Decays of Heavy Mesons', IP-ASTP- 11 -94, June (1994); J. M. Soares, Phys. Rev. D **51**, 3518 (1995); A. N. Kamal and A. B. Santra, 'Nonfactorization and color Suppressed $B \rightarrow \psi(\psi(2S)) + K(K^*)$ Decays, University of Alberta preprint (1995); Nonfactorization and the Decays $D_s^+ \rightarrow \phi\pi^+, \phi\rho^+$, and $\phi e^+\nu_e$ Alberta-Thy-1-95, Jan (1995); A. N. Kamal, A. B. Santra, T. Uppal and R. C. Verma, 'Nonfactorization in Hadronic two-body Cabibbo favored decays of D^0 and D^+, Alberta-Thy-08-95, Feb. (1995).

[7] R. C. Verma, Zeits. Phys. C (1995) *in press*

[8] L.L Chau and H. Y. Cheng, Phys. Lett. **B 333**, 514 (1994).

[9] R. C. Verma and A. N. Kamal, Phys. Rev. D, **35**, 3515 (1987); Phys. Rev. D, **43**, 829 (1990).

[10] L. Montanet et al., Particle data group, Phys. Rev. D **50**, 3-I (1994).

[11] A. N. Kamal and T. N. Pham, Phys. Rev. D, **50**, 6849 (1994).

[12] M. S. Witherall, International Symposium on Lepton and Photon Interactions at High Energies, Ithaca, N.Y. (1993), edited by P. Drell and D. Rubin, AIP Conf. Proc. No. 302 (AIP, New York) p. 198.