V_{ub} extraction from exclusive decays

Dongsheng Du and Chun Liu
CCAST (World Laboratory), P.O. Box 8730, Beijing 100080, China
*and Institute of High Energy Physics, Academia Sinica, P.O. Box 918(4), Beijing 100039, P.R. China**
(Received 7 February 1994)

After using the heavy meson chiral perturbation theory and the monopole q^2 dependence of the form factors, and considering the SU(3) breaking corrections, we obtain $g = 0.30 \pm 0.06$ from the experimental data of the $D \to \overline{K}$ semileptonic decays, where g describes the interactions of heavy mesons with pseudo Goldstone bosons. This result still depends on the decay constant f_{D_s}. By applying this value to the $B \to \pi$ semileptonic decays, the Cabibbo-Kobayashi-Maskawa matrix element V_{ub} can be determined in a comparatively precise manner. Some theoretically clean two-body nonleptonic B meson decays are also discussed, which may be useful in determining V_{ub}.

PACS number(s): 12.15.Hh, 12.39.Fe, 13.20.He, 13.25.Hw

I. INTRODUCTION

The Cabibbo-Kobayashi-Maskawa (CKM) matrix element V_{ub} is an important parameter in the standard model. It plays a crucial role in our understanding of the mechanism of *CP* violation. The determination of its value from experiments depends on the knowledge about the nonperturbative aspects of QCD. Basically there are three ways of the extraction of V_{ub}: the first is from the exclusive B meson decays, the second is from the inclusive decays, and the last is from the purely leptonic decays of B mesons. In this paper, we focus on the first way. In the exclusive decays, the hadronic matrix elements of the weak currents need to be calculated by some nonperturbative QCD methods. In addition to the lattice simulation, the most powerful nonperturbative methods are the chiral symmetry and the QCD sum rules. We will use the results of these methods, which combine the heavy quark symmetry [1], as far as possible in calculating the hadronic matrix elements of the heavy-to-light meson transitions.

The heavy meson chiral perturbation theory [2] is essentially a model-independent method in calculating the low-momentum properties of mesons containing a single heavy quark. As a low energy effective field theory of QCD, by combining the chiral symmetry and the heavy quark symmetry, it can be used to study systematically the low energy strong interactions among the heavy mesons and the pseudo Goldstone bosons. Calculation in this theory is reliable when the energies of the Goldstone bosons are small compared to the typical scale of the chiral symmetry breaking. In the heavy-to-light meson semileptonic decays, from which V_{ub} is extracted, however, a large part of the phase space of the light pseudo scalar meson lies in the region where the chiral perturbation theory cannot be applied. So we can only apply the heavy meson chiral perturbation theory in the soft-pion limit. Beyond this limit, some other method has to be applied.

QCD sum rules [3] are analytic methods which are rooted in the QCD first principles. They can successfully describe the dependence of the hadronic matrix elements on intermediate values of the transferred momentum. In this paper, we are interested in the hadronic matrix element of heavy meson M with momentum P and light pseudo scalar meson m with momentum p, which is defined as follows:

$$\langle m(p)|V_\mu - A_\mu|M(P)\rangle = f_+(q^2)(P+p)_\mu + f_-(q^2)(P-p)_\mu \ , \qquad (1)$$

where V_μ and A_μ denote the vector and the axial-vector currents, respectively. $f_+(q^2)$ and $f_-(q^2)$ are the form factors with $q = P - p$. In the semileptonic decays which will be used to extract the parameter V_{ub}, the contribution of $f_-(q^2)$ is suppressed by the lepton mass. The result of QCD sum rule investigations for $f_+(q^2)$ is that it has a pole dependence:

$$f_+(q^2) = \frac{f_+(0)}{1 - q^2/m_{\rm pole}^2} \ , \qquad (2)$$

where the pole mass $m_{\rm pole}$ is the mass of the nearest resonance in the t channel. This result is in agreement with the assumption of the Bauer-Stech-Wirbel (BSW) model [4], and with the result of lattice QCD [5].

To employ the above-mentioned theoretical approaches, we will choose the experimentally viable process $B \to \pi l \nu (l = e, \mu)$ in extracting V_{ub}. In calculating the hadronic matrix elements of the heavy-to-light meson transitions, at first we will use the heavy meson chiral perturbation theory to obtain the value of the form factor $f_+(q^2_{\rm max})$ which corresponds to the soft-pion limit. Then beyond this limit, the monopole q^2 dependence of the function f_+ [Eq. (2)] will be used for all the other values of q^2. The matrix element $\langle \pi|V - A|B\rangle$ can be related to the matrix elements $\langle \pi|V - A|D\rangle$ and $\langle \overline{K}|V - A|D\rangle$

*Mailing address.

through the heavy quark symmetry and the chiral symmetry in the soft-pion limit. This paper mainly analyzes the matrix elements $\langle \overline{K}|V-A|D\rangle$ and, as an outcome, $\langle \pi|V-A|B\rangle$. This analysis is subject to some theoretical uncertainties due to large SU(3) breaking effects. Within the framework of the heavy meson chiral perturbation theory, these breaking effects have been calculated at the one-loop level [6–9]. We will include them in the analysis. On the other hand, this analysis has less uncertainty due to experimental error, because the experimental data of $D\to\overline{K}$ semileptonic decays are much more precise than those of the $D\to\pi$ semileptonic decays.

For extracting V_{ub}, several authors have discussed the relations among the matrix elements $\langle \pi|V-A|D\rangle$, $\langle \overline{K}|V-A|D\rangle$ and $\langle \pi|V-A|B\rangle$, $\langle K|V-A|B\rangle$ by heavy quark symmetry [1,10]; however, the SU(3) symmetry breaking effects could not be included systematically. In this paper, by including the chiral symmetry breaking corrections, the $D\to\overline{K}$ semileptonic decays are analyzed in Sec. II, and the obtained result is combined with that from $D\to\pi$ [8]. For the coupling constant g, which describes the interactions of heavy mesons with pseudo Goldstone bosons, we obtain $g=0.30\pm0.05$. This value is much more precise than the previous direct estimation from the D^* meson strong and radiative decays [7]. But this result relies on the value of the decay constant f_{D_s}, and of course, the monopole q^2 dependence of the form factor, in addition to the approximation in considering the SU(3) corrections. By applying this value of g, the $B\to\pi$ semileptonic decay, and hence the CKM matrix element V_{ub}, is discussed in Sec. III. Although the final result for the branching ratio relies on the decay constant f_B, its uncertainty induced by g is rather small. Section IV discusses the extraction of V_{ub} via some nonleptonic decays. We summarize our results in the final section.

II. $D\to\overline{K}$ SEMILEPTONIC DECAYS

The hadronic matrix element appearing in the $D\to\overline{K}$ semileptonic decays can be parametrized as Eq. (1). To the leading order, the heavy meson chiral perturbation theory gives that

$$f_+ + f_- = -\frac{f_M}{f}\left(1-\frac{g v\cdot p}{v\cdot p+\Delta}\right) , \tag{3}$$

and

$$f_+ - f_- = -\frac{g f_M m_D}{f(v\cdot p+\Delta)} , \tag{4}$$

where f_M and f are the decay constants of the heavy and light mesons, respectively, $v=P/m_D$ denotes the four-velocity of the heavy meson, $\Delta=m^*_{D_s}-m_D$, and g is the coupling constant describing the interactions of heavy mesons with pseudo Goldstone bosons. The chiral symmetry breaking can be further calculated in the same way as that in the $B\to K$ transitions [9]. These corrections in general involve two kinds of contributions. One is from the additional terms in the chiral Lagrangian, the other is from the nonanalytic corrections which are determined by the loops of the leading term Lagrangian due to the different Goldstone masses. Although the total corrections are independent of the renormalization scale μ, each of the two kinds is μ dependent. When μ is chosen to be the chiral symmetry breaking scale, that is 1 GeV, the dominant corrections are in fact the chiral logarithms because of the small light quark masses [6,7]. We will only take these chiral logarithms as the chiral symmetry breaking corrections in the following analysis.

The one-loop diagrams contributing to the form factors of Eq. (1) have been given in Refs. [8] and [9]. In evaluating these diagrams, we make the following approximations.

(i) The up and down quark masses are neglected, and the η meson mass is expressed in terms of the kaon mass,

$$m_\eta^2=\frac{4}{3}m_K^2 . \tag{5}$$

(ii) The mass splitting Δ in the loops are set to zero except when they appear in a pole. Then using the results of Ref. [9], we obtain in the soft kaon limit that

$$\begin{aligned}&\langle \overline{K}(p_K)|\bar{s}\gamma^\mu(1-\gamma_5)c|D(v)\rangle\\ &=-\frac{f_M m_D v^\mu}{f}\left[1-\left(\frac{52}{9}+\frac{11}{6}g^2\right)\chi\right]\\ &\quad -g\frac{f_M m_D}{f}\frac{p_K^\mu-v^\mu v\cdot p_K}{v\cdot p_K+\Delta}\left[1-\left(\frac{28}{9}+\frac{89}{18}g^2\right)\chi\right] ,\end{aligned} \tag{6}$$

where χ is defined as

$$\chi=\frac{m_K^2}{16\pi^2 f_\pi^2}\ln\frac{m_K^2}{\mu^2} . \tag{7}$$

After considering the renormalization of the decay constants and the wave functions of the meson fields, we find that Eq. (6) becomes

$$\begin{aligned}&\langle \overline{K}(p_K)|\bar{s}\gamma^\mu(1-\gamma_5)c|D(v)\rangle\\ &=-\frac{f_{D_s} m_D v^\mu}{f_K}-g\frac{f_{D_s} m_D}{f_K}\frac{p_K^\mu-v^\mu v\cdot p_K}{v\cdot p_K+\Delta}\\ &\quad\times\left[1+\left(\frac{8}{3}-\frac{28}{9}g^2\right)\chi\right] .\end{aligned} \tag{8}$$

The above equation will have the same structure as Eqs. (3) and (4), if the renormalized coupling constant g_K is introduced:

$$g_K=g\left[1+\left(\frac{8}{3}-\frac{28}{9}g^2\right)\chi\right] . \tag{9}$$

From the experiments, we can fix the value of the parameter g_K, and hence the parameter g which is universal and will be needed in estimating the hadronic matrix element of $B \to \pi$. In the $D \to \overline{K}$ semileptonic decays, the value of the form factor $f_+(q^2)$ at $q^2 = 0$ GeV^2 has been precisely measured [11],

$$|f_+(0)| = 0.70 \pm 0.04 \ . \tag{10}$$

The soft kaon limit is at $q^2_{\rm max} = (m_D - m_K)^2$. The value of $f_+(q^2_{\rm max})$ is related to $f_+(0)$ through Eq. (2) with $m_{\rm pole} = m_{D_s^*}$. As we have mentioned previously, this relation is both a QCD sum rule result [3] and a quark model assumption [4]. Combining Eqs. (1),(2),(8), and (9), we get

$$g_K = -\frac{m_K + \Delta}{m_D - m_K}\left[\frac{2 f_K}{f_{D_s}}\frac{m^2_{D_s^*}}{m^2_{D_s^*} - (m_D - m_K)^2} f_+(0) + 1\right]. \tag{11}$$

By taking $f_{D_s} = 283$ MeV, which is the weight-averaged value of the experiments [12], the numerical results for g_K and g given in Eq. (9) are

$$\begin{aligned} g_K &= 0.21 \pm 0.04 \ [f_+(0) < 0] \\ &= -1.28 \pm 0.04 \ [f_+(0) > 0] \ , \end{aligned} \tag{12}$$

$$\begin{aligned} g &= 0.30 \pm 0.06 \ [f_+(0) < 0] \\ &= -0.98 \pm 0.03 \ [f_+(0) > 0] \ . \end{aligned} \tag{13}$$

The SU(3) correction to the coupling constant is about 30%.

For a comparison, the results of the coupling g extracted from the $D^0 \to \pi^- e^+ \nu_e$ decay are listed in the following [8]:

$$\begin{aligned} g &= 0.30 \pm 0.13 \ [f_+^\pi(0) < 0] \\ &= -0.50 \pm 0.11 \ [f_+^\pi(0) > 0] \ , \end{aligned} \tag{14}$$

where we have used the D meson decay constant $f_D = 220$ MeV. From Eqs. (13) and (14), it is clear that $g > 0$ is a reasonable choice. Although the determination of g from $D \to \overline{K}$ semileptonic decays has a larger SU(3) correction ($\sim 30\%$) than that from $D \to \pi$ semileptonic decay ($\sim 20\%$), its experimental error in the former case is rather small. To be more precise, the results given in Eqs. (13) and (14) can be combined,

$$g = 0.30 \pm 0.05 \ . \tag{15}$$

This value will be used to calculate $B \to \pi$ semileptonic decays. It should be noted that this result depends on the value of f_{D_S} in which the experimental errors are still large [12] and they are expected to be reduced in the near future. However, the result is not sensitive to the value of f_D which has been used in getting Eq. (14), because Eq. (13) plays the main role in fixing this value.

III. V_{ub} EXTRACTION FROM $B \to \pi$ SEMILEPTONIC DECAYS

In the $B \to \pi l \nu (l = e, \mu)$ semileptonic decays, the CKM matrix element V_{ub} can be determined if we have reliable knowledge about the form factor $f_+(q^2)$. In the limit of vanishing lepton masses, the differential decay rate is given by

$$\frac{d\Gamma}{dx} = \frac{G_F^2 m_B^5}{192\pi^3}|V_{ub}|^2\{(1 - x + r^2)^2 - 4r^2\}^{3/2}|f_+|^2 \ , \tag{16}$$

where $r = m_\pi/m_B$, $x = q^2/m_B^2$. f_+ is a function of q^2. The heavy meson chiral perturbation theory results in the form factors given in Eqs. (3) and (4) in the soft-pion limit. In this case, $\Delta = m_{B^*} - m_B$. There is a large region in the phase space where the pion energy is beyond the accepted range of the soft-pion limit. Beyond this limit, the QCD sum rules (and also the BSW model) give out the q^2 dependence of the function f_+ in Eq. (2). By combining Eqs. (2)–(4) and (16), neglecting the quantity r and taking $m_{B^*} = m_B$, the total decay rate can be obtained easily,

$$\Gamma = \frac{G_F^2 m_B^5}{384\pi^3}|V_{ub}|^2 f_+^2(0) \ , \tag{17}$$

where

$$f_+(0) = -\frac{1}{2}\frac{m_{B^*}^2 - (m_B - m_\pi)^2}{m_{B^*}^2}\left(1 + \frac{m_B - m_\pi}{m_\pi + \Delta} g\right)\frac{f_B}{f_\pi} \ . \tag{18}$$

The experimental measurements of the $D^* \to D\pi$ decays and the D^* radiative decays provide an upper limit and a lower limit to the coupling g, respectively [7],

$$0.1 < g^2 < 0.5 \ . \tag{19}$$

We obtain the following range for the total decay rate of the process $B^0 \to \pi^- e^+ \nu$:

$$\Gamma = |V_{ub}|^2\left(\frac{f_B}{190 \text{ MeV}}\right)^2 (1.1 - 4.9) \times 10^{-11} \text{ GeV} \ . \tag{20}$$

The corresponding branch ratio is

$$B = \left|\frac{V_{ub}}{0.005}\right|^2\left(\frac{f_B}{190 \text{ MeV}}\right)^2 (0.54 - 2.4) \times 10^{-3} \ . \tag{21}$$

Due to Eq. (19), the uncertainty of the branching ratio is still large and has to be narrowed for a more accurate estimation.

To consistently use the results of the last section, we have to include the one-loop results into the form factor calculation. By a similar procedure to the last section, we see that the hadronic matrix element is

$$\langle \pi(p_\pi)|\overline{u}\gamma^\mu(1-\gamma_5)b|\overline{B}(v)\rangle = -\frac{f_B m_B v^\mu}{f_\pi} - g_\pi \frac{f_B m_B}{f_\pi}\frac{p_\pi^\mu - v^\mu v\cdot p_\pi}{v\cdot p_\pi + \Delta} \ . \tag{22}$$

Both Refs. [8] and [9] have given the renormalized coupling constant g_π,

$$g_\pi = g\left[1 - \left(1 + \frac{35}{9}g^2\right)\chi\right] , \qquad (23)$$

where the value of g has been given in Eq. (15) numerically. In calculating the decay rate with chiral logarithmic corrections, all we need is to substitute the "bare" coupling g in the expression of Eq. (18) with g_π. Therefore, for the semileptonic decay $B^0 \to \pi^- e^+ \nu$, we obtain

$$\Gamma = |V_{ub}|^2 \left(\frac{f_B}{190\ \text{MeV}}\right)^2 (1.3 \pm 0.4) \times 10^{-11}\ \text{GeV} ,$$

$$B = \left|\frac{V_{ub}}{0.005}\right|^2 \left(\frac{f_B}{190\ \text{MeV}}\right)^2 (6.4 \pm 2.0) \times 10^{-4} . \qquad (24)$$

Compared with Eqs. (20) and (21), the error of the above estimation is rather small. We see that, as a result of Eq. (18), the determination of V_{ub} still depends on the value of f_B. When f_B, Γ, or the branching ratio are measured, we can determine the value of $|V_{ub}|$ from Eq. (24).

IV. V_{ub} EXTRACTION FROM NONLEPTONIC DECAYS

For the sake of increasing the precision of V_{ub} determination, one can also try to find some theoretically clean B meson nonleptonic exclusive decay channels [13]. In this case, the factorization hypothesis has to be used in practical analysis. Therefore, the heavy meson chiral perturbation theory and the QCD sum rules can be applied just as in the case of the semileptonic decays. In addition, the numerical results can be obtained by using the value of the coupling constant g we have given in Eq. (15).

The decay processes which we consider can be described by the external W-emission diagram. A $\overline{B}$ meson decays to a pion and a charmed pseudo scalar $D_{(s)}$ or vector $D^*_{(s)}$ meson which comes from a color singlet charged current. After factorization, the amplitude of the process is expressed by the product of two matrix elements. With the definition of the $\overline{B} \to \pi$ matrix element Eq. (1), the widths of the decay can be easily calculated:

$$\Gamma = \frac{G_F^2 |V_{ub}V_{ci}|^2 m_B^3 f_{D_{(s)}}^2}{32\pi} [(1 + r^2 - t)^2 - 4r^2]^{1/2} [(1 - r^2) f_+(m_{D_{(s)}}^2) + t f_-(m_{D_{(s)}}^2)]^2 \qquad (25)$$

for the decay $\overline{B} \to \pi D^-_{(s)}$

$$\Gamma = \frac{G_F^2 |V_{ub}V_{ci}|^2 m_B^3 f_{D^*_{(s)}}^2}{32\pi} [(1 + r^2 - t)^2 - 4r^2]^{3/2} f_+^2(m_{D^*_{(s)}}^2) \qquad (26)$$

for the decay $\overline{B} \to \pi D^{*-}_{(s)}$, where i denotes d or s, and $t = m^2_{D^{(*)}_{(s)}}/m^2_B$.

For the above width formulas, a few remarks should be made. (i) The Wilson coefficient a_1 has not been included (or $|a_1|$ has been simply set to unity). In the BSW model [4], its central value is $|a_1| = 1.11$. However, in a recent analysis of heavy quark effective theory, $|a_1| = 0.88$ [14]. (ii) To our knowledge, there is still no concrete model-independent conclusion for the form factor $f_-(q^2)$. In the later evaluation, $f_-(q^2)$ will be of the BSW model assumed q^2 dependence [4]. Therefore, there are some additional theoretical uncertainties in calculating the $\overline{B} \to \pi D^-_{(s)}$ decays. (iii) The decays $\overline{B} \to \pi D^-$ and $\overline{B} \to \pi D^{*-}$ are double CKM suppressed. So the $\overline{B} \to \pi D_s^-$ and $\overline{B} \to \pi D_s^{*-}$ are the favorite modes for our purpose.

The numerical results of various decay modes which we are interested in are listed in Table I. The decay constants have been assumed as $f_B = 190$ MeV, $f_D = f_{D^*} = 220$ MeV, $f_{D_s} = f_{D_s^*} = 283$ MeV. We have taken the coupling $g = 0.30$. The measurement of $B^0 \to \pi^- D_s^+$ gives $|V_{ub}| < 0.01$.

Note that the method we have used to calculate the nonleptonic decays still relies on the factorization hypothesis. As a test of this hypothesis, we further evaluate the following quantity assuming factorization:

$$R = \frac{\Gamma(\overline{B}^0 \to \pi^+ D_s^{*-})}{d\Gamma(\overline{B}^0 \to \pi^+ e^- \overline{\nu}_e)/dq^2|_{q^2 = m^2_{D_s^*}}} = 6\pi^2 f^2_{D_s^*} |V_{cs}|^2 . \qquad (27)$$

The measurement of R, which can be performed in a B factor, will provide this test.

To eliminate the uncertainties associated with the Wilson coefficient a_1, we may consider the ratios of the branching fractions in which both a_1 and $f_{D_s^*}$ cancel,

TABLE I. Branching ratios of some nonleptonic decay channels of the $\overline{B}$ meson.

Modes	B
πD^-	$0.30\lvert V_{ub}\rvert^2$
πD^{*-}	$0.23\lvert V_{ub}\rvert^2$
πD_s^-	$9.6\lvert V_{ub}\rvert^2$
πD_s^{*-}	$7.4\lvert V_{ub}\rvert^2$

such as

$$R' = B(\overline{B}^0 \to \pi^+ D_s^{*-})/B(\overline{B}^0 \to D^+ D_s^{*-}) \approx 1.2 \left| \frac{V_{ub}}{V_{cd}} \right|^2 , \quad (28)$$

where the process $\overline{B}^0 \to D^+ D_s^{*-}$ has been considered in Ref. [14]. This ratio is expected to be measured in the near future, and that will provide us the value of V_{ub} with less theoretical uncertainties. Such kind of ratios are also free of systematic experimental errors.

V. SUMMARY

By using the results of the heavy meson chiral perturbation theory and the QCD sum rules, the CKM matrix element V_{ub} can be extracted with less experimental errors in a model-independent way. The hadronic matrix elements of the heavy meson to light pseudo scalar meson semileptonic decays can be calculated reliably with these two methods. For the decays of $B \to \pi$, the precision of the calculation is subject to the uncertainty of the coupling constatnt g. The uncertainty is large from direct estimation [see Eq. (19)]. The data of the $D \to \overline{K}$ semileptonic decays may provide more precise information of the value g in principle, despite the large SU(3) corrections. If only the one-loop chiral logarithms are taken as the leading SU(3) corrections (with the renormalization scale at 1 GeV), the value of g can be fixed by the $D \to \overline{K}$ semileptonic decays with comparative preciseness. Combining with the value obtained from the $D \to \pi$ semileptonic decay, we have got $g = 0.30 \pm 0.05$. The confidence level of this result still relies on the value of the decay constant f_{D_s}. This value g has then been applied to the evaluation of the $B \to \pi$ semileptonic decays. We have obtained the resulting branching ratio for $\overline{B}^0 \to \pi^+ e^- \overline{\nu}_e$,

$$B = \left| \frac{V_{ub}}{0.005} \right|^2 \left(\frac{f_B}{190 \text{ MeV}} \right)^2 (6.4 \pm 2.0) \times 10^{-4} .$$

The extraction of V_{ub} from the two-body nonleptonic decays has also been discussed. The mode $\overline{B} \to \pi D_s^{*-}$ has been considered as the best nonleptonic decay channel.

ACKNOWLEDGMENTS

We would like to thank D. X. Zhang and X. J. Zhou for helpful discussions. This work was supported in part by the Foundation of the State Science and Technology Commission and the National Natural Science Foundation.

[1] N. Isgur and M. B. Wise, Phys. Lett. B **232**, 113 (1989); **237**, 527 (1990).
[2] M. B. Wise, Phys. Rev. D **45**, R2188 (1992); G. Burdman and J. F. Donoghue, Phys. Lett. B **280**, 287 (1992); T. M. Yan, H. Y. Cheng, C. Y. Cheung, G. L. Lin, Y. C. Lin, and H. L. Yu, Phys. Rev. D **46**, 1148 (1992).
[3] M. A. Shifman, A. I. Vainshtein, and V. I. Zakharov, Nucl. Phys. **B147**, 383 (1979). For a review see P. Colangelo, talk delivered at the Third Workshop on Tau-Charm Factory, Marbella, Spain, 1993 (unpublished).
[4] M. Wirbel, B. Stech, and M. Bauer, Z. Phys. C **29**, 637 (1985); M. Bauer, B. Stech, and M. Wirbel, *ibid.* **34**, 103 (1987).
[5] V. Lubics, G. Martinelli, M. S. McCarthy, and C. T. Sachrajda, Phys. Lett. B **274**, 415 (1992); A. Abada *et al.*, Nucl. Phys. **B416**, 675 (1994).
[6] B. Grinstein, E. Jenkins, A. V. Manohar, M. J. Savage, and M. B. Wise, Nucl. Phys. **B380**, 369 (1992); E. Jenkins and M. J. Savage, Phys. Lett. B **281**, 331 (1992); J. L. Goity, Phys. Rev. D **46**, 3929 (1992); D. S. Du and D. X. Zhang, *ibid.* **48**, 4163 (1993); H. Y. Cheng *et al.*, *ibid.* **49**, 5857 (1994).
[7] J. F. Amundson, C. G. Boyd, E. Jenkins, M. Luke, A. V. Manohar, J. L. Rosner, M. J. Savage, and M. B. Wise, Phys. Lett. B **296**, 415 (1992); P. Cho and H. Georgi, *ibid.* **296**, 408 (1992).
[8] R. Fleischer, Phys. Lett. B **303**, 147 (1993).
[9] A. F. Falk and B. Grinstein, Nucl. Phys. **B416**, 771 (1994).
[10] G. Kramer, T. Mannel, and G. A. Schuler, Z. Phys. C **51**, 649 (1991); Q. P. Xu, Phys. Lett. B **306**, 363 (1993).
[11] D. Bortoletto, talk given at the 1992 Physics in Collision Conference, 1992 (unpublished).
[12] WA 75 Collaboration, S. Aoki *et al.*, Prog. Theor. Phys. **89**, 131 (1993); CLEO Collaboration, D. Acosta *et al.*, Phys. Rev. D **49**, 5690 (1994).
[13] D. Choudhury, D. Indumati, A. Soni, and S. U. Sankar, Phys. Rev. D **45**, 217 (1992); N. G. Deshpande and C. O. Dib, Phys. Lett. B **319**, 313 (1993).
[14] D. S. Du and C. Liu, Phys. Rev. D **48**, 3397 (1993).