Nonspectator contributions to inclusive charmless B decays

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The light quarks inside B mesons are usually treated as spectators and do not affect the decay rates which are assumed to be purely due to b quark decays. In this paper we calculate the nonspectator contributions to inclusive charmless B decays due to the spectator effects. We find that the nonspectator contributions to the branching ratio for $\bar{B}^0$ are small ($< 2 \times 10^{-4}$), but the contributions to $\Delta S = 0$ and $\Delta S = -1$, B^- decay branching ratios can be as large as -7.5×10^{-4} and 2×10^{-3} , and can modify the main three-body spectator b decay branching ratios by 10% and 20%, respectively. These contributions may play an important role in rare charmless B decays. [S0556-2821(99)03113-6]

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Studies of B physics greatly enrich our understanding of the interactions involving heavy quarks. In the heavy quark limit, the light quarks inside the B mesons are treated as spectators which do not affect the decay rates [1]. If the heavy quark is very heavy compared to the QCD scale Λ_{QCD} , this approximation is a good one because the effect from the light quark is suppressed by two powers in heavy quark mass compared with that of three-body decays of the b quark. However, in reality the b quark is not infinitely heavy; the suppression factor proportional to Λ_{QCD}^2/m_b^2 may be overcome by the enhancement factor of $16\pi^2$ in phase space because the spectator-effect-induced decays are two-body decays [2,3]. Therefore spectators may affect in some way the branching ratios, especially in rare B decays. We will refer the effects due to the light spectator quark inside the B meson as nonspectator effects.

It has been shown that the dominant nonspectator effects at the tree level can play an important role in missing charm and Λ_b lifetime problems [3,4]. Nonspectator effects also have important implications for exclusive decays [5]. The effects in exclusive decays are usually assumed to be small and are neglected. It has been shown that if the nonspectator contributions to $B^- \rightarrow \bar{K}^0 \pi^-$ are really small, it will be possible to determine one of the fundamental parameters γ in the unitarity triangle by measuring several B decay modes [6]. It is, however, very difficult to calculate the nonspectator contributions for exclusive decays. Without a reliable calculation, we have to find some ways to experimentally test if the nonspectator contributions are small [5]. On the other hand, the analogous contribution, the nonspectator contribution, in inclusive B decays may be easier to study. From this study one may also obtain some useful information about nonspectator contributions for exclusive decays [7]. In this paper we will carry out a calculation for the nonspectator contributions to the inclusive charmless B meson decays in the standard model including penguin contributions. We find that the nonspectator contributions to the inclusive charmless B decay branching ratios are small for $\bar{B}^0$, but can be as large as -7.4×10^{-4} and 2×10^{-3} compared with 0.5% and 1%

from the main three-body spectator b decays for B^- with $\Delta S = 0$ and $\Delta S = -1$, respectively.

In the standard model the quark level effective Hamiltonian responsible for charmless B decays is given by [8]

$$H_{eff} = \frac{4G_F}{\sqrt{2}} \left[V_{ub}V_{f_2q}^* [c_1 O_1(q) + c_2 O_2(q)] - V_{tb}V_{tq}^* \sum_{i=3-6} c_i O_i(q) \right], \quad (1)$$

where

$$\begin{aligned} O_1(q) &= \bar{u} \gamma_\mu L u \bar{q} \gamma^\mu L b, \quad O_2(q) = \bar{q} \gamma_\mu L u \bar{u} \gamma^\mu L b, \\ O_{3,5}(q) &= \bar{q} \gamma_\mu L b \bar{q}' \gamma^\mu L(R) q', \\ O_{4,6}(q) &= \bar{q}_\alpha \gamma_\mu L b \bar{q}'_\beta \gamma^\mu L(R) q'_\alpha, \end{aligned} \quad (2)$$

where $L(R) = (1 \mp \gamma_5)/2$, q' is summed over u, d, s , and q can be d or s depending on whether the processes are $\Delta S = 0$ or $\Delta S = -1$. In the above we have neglected electroweak penguin contributions. In our later discussions we will use the Wilson coefficients evaluated in Ref. [9].

There are several quark level processes corresponding to nonspectator contributions. They are shown in Figs. 1 and 2. Figures 1 and 2 are induced by tree and penguin operators, respectively. We will refer the contributions from Figs. 1(a),

FIG. 1. Diagrams for tree nonspectator contributions to charmless B meson decays.

FIG. 2. Diagrams for penguin nonspectator contributions to charmless B meson decays.

1(b), 2(a), and 2(b) as usual nonspectator (UN) contributions, while refer those from Figs. 1(c), 2(c), and 2(d), which are due to Pauli interferences, as Pauli interference (PI) contributions. The PI contributions reduce the branching ratios. Using the optical theorem, the inclusive decay width of B can be written as the imaginary part of the forward matrix element of the transition operator T ,

$$\Gamma(B) = \frac{1}{m_B} \text{Im} \langle B | T | B \rangle = \frac{1}{2m_B} \langle B | \tilde{\Gamma} | B \rangle, \quad (3)$$

where T is given by

$$T = i \int d^4x T \{ H_{eff}(x), H_{eff}(0) \}. \quad (4)$$

Evaluating diagrams in Figs. 1 and 2 and neglecting terms proportional to light quark masses, we obtain

$$\begin{aligned} \tilde{\Gamma}^q(1a) = & -\frac{2}{3} \frac{G_F^2 |V_{ub} V_{uq}^*|^2 m_b^2}{\pi} \left[N \left(\frac{c_1}{N} + c_2 \right)^2 \right. \\ & \left. \times (O_{V-A}^u - O_{S-P}^u) + 2c_1^2 (T_{V-A}^u - T_{S-P}^u) \right], \end{aligned}$$

$$\begin{aligned} \tilde{\Gamma}(1b) = & -\frac{2}{3} \frac{G_F^2 |V_{ub} V_{ud}^*|^2 m_b^2}{\pi} \left[N \left(c_1 + \frac{c_2}{N} \right)^2 \right. \\ & \left. \times (O_{V-A}^d - O_{S-P}^d) + 2c_2^2 (T_{V-A}^d - T_{S-P}^d) \right], \end{aligned}$$

$$\begin{aligned} \tilde{\Gamma}^q(1c) = & 2 \frac{G_F^2 |V_{ub} V_{uq}^*|^2 m_b^2}{\pi} \left[\left(2c_1 c_2 + \frac{1}{N} (c_1^2 + c_2^2) \right) \right. \\ & \left. \times O_{V-A}^u + 2(c_1^2 + c_2^2) T_{V-A}^u \right], \end{aligned}$$

$$\begin{aligned} \tilde{\Gamma}(2a) = & -\frac{2}{3} \frac{G_F^2 |V_{tb} V_{td}^*|^2 m_b^2}{\pi} 3 \left\{ N \left[\left(c_3 + \frac{c_4}{N} \right)^2 \right. \right. \\ & \left. \left. + \left(c_5 + \frac{c_6}{N} \right)^2 \right] (O_{V-A}^d - O_{S-P}^d) \right. \\ & \left. + 2(c_4^2 + c_6^2) (T_{V-P}^d - T_{S-P}^d) \right\}, \end{aligned}$$

$$\begin{aligned} \tilde{\Gamma}^q(2b) = & -\frac{2}{3} \frac{G_F^2 |V_{tb} V_{tq}^*|^2 m_b^2}{\pi} \left[N \left(\frac{c_3}{N} + c_4 \right)^2 \right. \\ & \times (O_{V-A}^u - O_{S-P}^u) + 2c_3^2 (T_{V-P}^u - T_{S-P}^u) \\ & \left. - 6N \left(\frac{c_5}{N} + c_6 \right)^2 \tilde{O}_{S-P}^u - 12c_5^2 \tilde{T}_{S-P}^u \right], \end{aligned}$$

$$\begin{aligned} \tilde{\Gamma}^q(2c) = & 2 \frac{G_F^2 |V_{tb} V_{tq}^*|^2 m_b^2}{\pi} \left[\left(2c_3 c_4 + \frac{1}{N} (c_3^2 + c_4^2) \right) \right. \\ & \times O_{V-A}^u + 2(c_3^2 + c_4^2) T_{V-A}^u \\ & - \left(2c_5 c_6 + \frac{1}{N} (c_5^2 + c_6^2) \right) \left(\frac{2}{3} \tilde{O}_{S-P}^u - \frac{1}{6} \tilde{O}_{V-A}^u \right) \\ & \left. - 2(c_5^2 + c_6^2) \left(\frac{2}{3} \tilde{T}_{S-P}^u - \frac{1}{6} \tilde{T}_{V-A}^u \right) \right], \end{aligned}$$

$$\begin{aligned} \tilde{\Gamma}^q(2d) = & 2 \frac{G_F^2 |V_{tb} V_{tq}^*|^2 m_b^2}{\pi} \left[\left(2c_3 c_4 + \frac{1}{N} (c_3^2 + c_4^2) \right) \right. \\ & \times O_{V-A}^d + 2(c_3^2 + c_4^2) T_{V-A}^d \\ & - \left(2c_5 c_6 + \frac{1}{N} (c_5^2 + c_6^2) \right) \left(\frac{2}{3} \tilde{O}_{S-P}^d - \frac{1}{6} \tilde{O}_{V-A}^d \right) \\ & \left. - 2(c_5^2 + c_6^2) \left(\frac{2}{3} \tilde{T}_{S-P}^d - \frac{1}{6} \tilde{T}_{V-A}^d \right) \right], \quad (5) \end{aligned}$$

$$O_{V-A}^q = \bar{b} \gamma_\mu L q \bar{q} \gamma^\mu L b, \quad O_{S-P}^q = \bar{b} L q \bar{q} R b,$$

$$T_{V-A}^q = \bar{b} \gamma_\mu L T^a q \bar{q} \gamma^\mu L T^a b,$$

$$T_{S-P}^q = \bar{b} L T^a q \bar{q} R T^a b,$$

$$\tilde{O}_{V-A}^q = \bar{b} \gamma_\mu R q \bar{q} \gamma^\mu R b, \quad \tilde{O}_{S-P}^q = \bar{b} R q \bar{q} L b,$$

$$\tilde{T}_{V-A}^q = \bar{b} \gamma_\mu R T^a q \bar{q} \gamma^\mu R T^a b,$$

$$\tilde{T}_{S-P}^q = \bar{b} R T^a q \bar{q} L T^a b. \quad (6)$$

From the above we can obtain the nonspectator contributions to B^- and $\bar{B}^0$ decays using Eq. (3). For $\Delta S=0$ decays, we have

$$\begin{aligned}
 \Gamma(B^- \rightarrow X) = & \Gamma_0 |V_{ub} V_{ud}^*|^2 \left\{ \left[N \left(\frac{c_1}{N} + c_2 \right)^2 (B_2 - B_1) + 2c_1^2 (\varepsilon_2 - \varepsilon_1) \right] + 3 \left[\left(2c_1 c_2 + \frac{1}{N} (c_1^2 + c_2^2) \right) B_1 + 2(c_1^2 + c_2^2) \varepsilon_1 \right] \right\} \\
 & + \Gamma_0 |V_{tb} V_{td}^*|^2 \left\{ \left[N \left(\frac{c_3}{N} + c_4 \right)^2 (B_2 - B_1) + 2c_3^2 (\varepsilon_2 - \varepsilon_1) + 6N \left(\frac{c_5}{N} + c_6 \right)^2 \tilde{B}_2 + 12c_5^2 \tilde{\varepsilon}_2 \right] \right. \\
 & + 3 \left[\left(2c_3 c_4 + \frac{1}{N} (c_3^2 + c_4^2) \right) B_1 + 2(c_3^2 + c_4^2) \varepsilon_1 - \left(2c_5 c_6 + \frac{1}{N} (c_5^2 + c_6^2) \right) \left(\frac{2}{3} \tilde{B}_2 - \frac{1}{6} \tilde{B}_1 \right) \right. \\
 & \left. \left. - 2(c_5^2 + c_6^2) \left(\frac{2}{3} \tilde{\varepsilon}_2 - \frac{1}{6} \tilde{\varepsilon}_1 \right) \right] \right\}, \\
 \Gamma(\bar{B}^0 \rightarrow X) = & \Gamma_0 |V_{ub} V_{ud}^*|^2 \left[N \left(c_1 + \frac{c_2}{N} \right)^2 (B_2 - B_1) + 2c_2^2 (\varepsilon_2 - \varepsilon_1) \right] + 3 \Gamma_0 |V_{tb} V_{td}^*|^2 \left\{ N \left[\left(c_3 + \frac{c_4}{N} \right)^2 + \left(c_5 + \frac{c_6}{N} \right)^2 \right] \right. \\
 & \times (B_2 - B_1) + 2(c_4^2 + c_6^2) (\varepsilon_2 - \varepsilon_1) + 3 \left[\left(2c_3 c_4 + \frac{1}{N} (c_3^2 + c_4^2) \right) B_1 + 2(c_3^2 + c_4^2) \varepsilon_1 - \left(2c_5 c_6 + \frac{1}{N} (c_5^2 + c_6^2) \right) \right. \\
 & \left. \left. \times \left(\frac{2}{3} \tilde{B}_2 - \frac{1}{6} \tilde{B}_1 \right) - 2(c_5^2 + c_6^2) \left(\frac{2}{3} \tilde{\varepsilon}_2 - \frac{1}{6} \tilde{\varepsilon}_1 \right) \right] \right\}. \tag{7}
 \end{aligned}$$

And for $\Delta S = -1$ decays, we have

$$\begin{aligned}
 \Gamma(B^- \rightarrow X_s) = & \Gamma_0 |V_{ub} V_{us}|^2 \left\{ \left[N \left(\frac{c_1}{N} + c_2 \right)^2 (B_2 - B_1) + 2c_1^2 (\varepsilon_2 - \varepsilon_1) \right] + 3 \left[\left(2c_1 c_2 + \frac{1}{N} (c_1^2 + c_2^2) \right) B_1 + 2(c_1^2 + c_2^2) \varepsilon_1 \right] \right\} \\
 & + \Gamma_0 |V_{tb} V_{ts}^*|^2 \left\{ \left[N \left(\frac{c_3}{N} + c_4 \right)^2 (B_2 - B_1) + 2c_3^2 (\varepsilon_2 - \varepsilon_1) + 6N \left(\frac{c_5}{N} + c_6 \right)^2 \tilde{B}_2 + 12c_5^2 \tilde{\varepsilon}_2 \right] \right. \\
 & + 3 \left[\left(2c_3 c_4 + \frac{1}{N} (c_3^2 + c_4^2) \right) B_1 + 2(c_3^2 + c_4^2) \varepsilon_1 - 2c_5 c_6 + \frac{1}{N} (c_5^2 + c_6^2) \left(\frac{2}{3} \tilde{B}_2 - \frac{1}{6} \tilde{B}_1 \right) - 2(c_5^2 + c_6^2) \left(\frac{2}{3} \tilde{\varepsilon}_2 - \frac{1}{6} \tilde{\varepsilon}_1 \right) \right] \right\}, \\
 \Gamma(\bar{B}^0 \rightarrow X_s) = & 3 \Gamma_0 |V_{tb} V_{ts}^*|^2 \left[\left(2c_3 c_4 + \frac{1}{N} (c_3^2 + c_4^2) \right) B_1 + 2(c_3^2 + c_4^2) \varepsilon_1 - 2c_5 c_6 + \frac{1}{N} (c_5^2 + c_6^2) \right. \\
 & \left. \times \left(\frac{2}{3} \tilde{B}_2 - \frac{1}{6} \tilde{B}_1 \right) - 2(c_5^2 + c_6^2) \left(\frac{2}{3} \tilde{\varepsilon}_2 - \frac{1}{6} \tilde{\varepsilon}_1 \right) \right], \tag{8}
 \end{aligned}$$

where $\Gamma_0 = G_F^2 m_b^2 m_B^2 f_B^2 / 12\pi$, and the parameters B_i ($\tilde{B}_i$) and ε_i ($\tilde{\varepsilon}_i$) are defined as follows:

$$\begin{aligned}
 \langle B | \bar{b} \gamma_\mu L q \bar{q} \gamma^\mu L b | B \rangle &= \frac{f_B^2 m_B^2}{4} B_1, & \langle B | \bar{b} R q \bar{q} L b | B \rangle &= \frac{f_B^2 m_B^2}{4} \tilde{B}_2, \\
 \langle B | \bar{b} L q \bar{q} R b | B \rangle &= \frac{f_B^2 m_B^2}{4} B_2, & \langle B | \bar{b} \gamma_\mu R T^a q \bar{q} \gamma^\mu R T^a b | B \rangle &= \frac{f_B^2 m_B^2}{4} \tilde{\varepsilon}_1, \\
 \langle B | \bar{b} \gamma_\mu L T^a q \bar{q} \gamma^\mu L T^a b | B \rangle &= \frac{f_B^2 m_B^2}{4} \varepsilon_1, & \langle B | \bar{b} R T^a q \bar{q} L T^a b | B \rangle &= \frac{f_B^2 m_B^2}{4} \tilde{\varepsilon}_2. \\
 \langle B | \bar{b} L T^a q \bar{q} R T^a b | B \rangle &= \frac{f_B^2 m_B^2}{4} \varepsilon_2, \\
 \langle B | \bar{b} \gamma_\mu R q \bar{q} \gamma^\mu R b | B \rangle &= \frac{f_B^2 m_B^2}{4} \tilde{B}_1,
 \end{aligned}$$

The above definitions are inspired by the factorization approximation calculation. In this approximation, $B_i = \tilde{B}_i = 1$ and $\varepsilon_i = \tilde{\varepsilon}_i = 0$. Conservation of strong interaction implies $B_i = \tilde{B}_i$ and $\varepsilon_i = \tilde{\varepsilon}_i$. There have been some attempts to calculate ε_i [10]. Using the QCD sum rules [11][12], it has been shown that $\varepsilon_1 \approx -0.15$ (-0.14) and $\varepsilon_2 \approx 0$ (-0.08). Lattice calculations obtain [13] $B_1 = 1.06(8)$, $B_2 = 1.01(6)$, $\varepsilon_1 = -0.01(3)$, and $\varepsilon_2 = -0.01(2)$ which suppressingly

TABLE I. The nonspectator contributions to the branching ratios of B mesons for (a) $B_1=B_2=1$, $\varepsilon_1=\varepsilon_2=0$ and (b) $B_1=B_2=1$, $\varepsilon_1=-0.15$, $\varepsilon_2=0$, with $m_b=4.8$ GeV, $f_B=0.2$ GeV, $|V_{ub}|/|V_{cb}|=0.08$, $|V_{cb}|=|V_{ts}|=0.038$, and $|V_{td}|=|V_{ub}|$.

$\Delta S=0$					
B^-	(a)	(b)	$\bar{B}^0$	(a)	(b)
Tree					
UN	0	1.1×10^{-5}		0	1.4×10^{-4}
PI	-2.8×10^{-4}	-7.6×10^{-4}		0	0
Penguin					
UN	1.2×10^{-5}	1.2×10^{-5}		0	1.14×10^{-6}
PI	-0.7×10^{-6}	-1.4×10^{-6}		-0.68×10^{-6}	-1.36×10^{-6}
$\Delta S=-1$					
B^-	(a)	(b)	$\bar{B}^0$	(a)	(b)
Tree					
UN	0	5.7×10^{-7}		0	0
PI	-1.4×10^{-5}	-3.9×10^{-5}		0	0
Penguin					
UN	1.9×10^{-3}	1.9×10^{-3}		0	0
PI	-1.1×10^{-4}	-2.2×10^{-4}		-1.1×10^{-4}	-2.1×10^{-4}

agree well with vacuum saturation estimates. To see how the results change with hadronic parameters, we will take two sets of representative values in our latter analyses: (a) $B_i(\tilde{B}_i)=1$, $\varepsilon_i(\tilde{\varepsilon}_i)=0$ and (b) $B_i(\tilde{B}_i)=1$, $\varepsilon_1(\tilde{\varepsilon}_1)=-0.15$, $\varepsilon_2(\tilde{\varepsilon}_2)=0$. The numerical values also depend on the values of several KM matrix elements and the B decay constant f_B . We will use the values for these parameters given in the caption to Table I for illustration. One can easily find out the changes using Eqs. (7) and (8) for other values of the parameters involved. Our numerical results for the branching ratios are given in Table I.

In the factorization approximation, $\bar{B}^0$ decays do not receive tree nonspectator contributions and B^- decays only receive PI contributions. Note also that even nonfactorizable contributions are included; the tree PI terms do not contribute to $\bar{B}^0$ decays.

For $\Delta S=0$ decays, the nonspectator contributions are dominated by the PI contribution at the tree level which reduces the total branching ratio by -2.8×10^{-4} in the factorization approximation. Nonfactorizable effects can change the situation significantly. Using $\varepsilon_1=-0.15$ and keeping the other parameters unchanged, the total branching ratio can be reduced by -7.6×10^{-4} for B^- decays, and the branching ratio for $\bar{B}^0$ decay can be increased by 1.4×10^{-4} from UN contributions. These effects, although small for total branching ratios, when studying rare charmless $\Delta S=0$ decays, may play an important role. For example for even just a few percent of the nonspectator contributions finding their way to $B^- \rightarrow \pi^- \pi^0$, the branching ratio for this exclusive decay can change by more than 10%. The penguin nonspectator contributions are much smaller ($< 2 \times 10^{-5}$) and do not play an important role.

The branching ratios for charmless and $\Delta S=0$, B^- , and

$\bar{B}^0$ decays are of order 5×10^{-3} from the three-body b quark decays [14]. The nonspectator contributions discussed here can reach 6%–12% of the main three-body spectator b decay contributions. Also the nonspectator contributions decrease the branching ratio for B^- and increase the branching ratio for $\bar{B}^0$. Experiments in the future may be able to observe these effects.

For $\Delta S=-1$ B meson decays, the roles played by tree and penguin nonspectator contributions are reversed. The nonspectator contributions can increase the branching ratio for B^- decays by as much as 1.9×10^{-3} . $\bar{B}^0$ decays only receive PI contributions and the branching ratio can be reduced at few times the 10^{-4} level. The tree nonspectator contributions to B^- can reduce the total branching ratio by a few times 10^{-5} . This is small, but may still play an important role in the study of rare $B^- \rightarrow \bar{K}^0 \pi^-$ decay. Usually the tree amplitude for this decay is assumed to be extremely small. If this is true, this decay mode can be used in combination with several other decays, for example, $B^- \rightarrow K^- \pi^0$ and $B^- \rightarrow \pi^- \pi^0$ decays, to determine the parameter γ in the KM unitarity triangle [6]. If the nonspectator contribution to the branching ratio of $B^- \rightarrow \bar{K}^0 \pi^-$ decay is large $O(10^{-6})$ (10% of the inclusive nonspectator contributions), it will cause a large uncertainty in the determination of the angle γ . However, at present we do have reliable ways to make a vigorous calculation. More detailed study is required.

The nonspectator contributions to the total branching ratios for $\Delta S=-1$ B mesons are small, but can be 20% of the main three-body b quark decay contribution ($\text{Br} \sim 1\%$) [14] to charmless B meson decays. This contribution cannot be neglected. Also the nonspectator contributions affect B^- and $\bar{B}^0$ differently. Experiments in the future may observe such

effects. Another important feature of the nonspectator contributions is that the decay modes induced by nonspectator effects are two-body type. Their effect may be more eminent if a kinematic cut requiring the decays to be two hard jets with small invariant mass is applied.

We would like to comment on the penguin nonspectator effects on the missing charm and the Λ_b lifetime problems before conclude the paper. For this discussion, we will also need to consider final states with charm quarks because this is the main nonspectator contribution. It has been shown that tree nonspectator contributions can be important [3]. From factorization calculations without PI contributions, one might think the penguin contributions to be important. In this case, the dominant tree nonspectator contribution is from $b\bar{d} \rightarrow c\bar{u}$ which is proportional to $(c_1 + c_2/N)^2$, whereas the penguin nonspectator contribution is dominated by $b\bar{d} \rightarrow s\bar{d}$ as can be seen from our previous discussions. Because of the accidental cancellation between c_1 and c_2/N for $N=3$, the penguin contribution is about 20 times the tree contribution in the factorization approximation. However, this result is very sensitive to the values of ε_i . With $\varepsilon_1 = -0.15$, for example, the tree nonspectator contribution is 10 times larger

than the penguin contribution. Also, when PI contributions are included, the main tree contribution is proportional to $c_1 c_2$ which is not small. The tree nonspectator contributions turn out to be 15–30 times larger than the penguin nonspectator contributions.

We also carried out a detailed calculation for the penguin nonspectator contributions to the Λ_b lifetime. We again find that the penguin nonspectator contributions are only a few percent of the tree nonspectator contributions. We conclude that the penguin nonspectator contributions do not play an important role in solving the missing charm and Λ_b lifetime problems.

Note added. After we finished our calculations we became aware of Ref. [15] in which the penguin contributions to nonspectator effects were calculated. However, the calculation in Ref. [15] was not complete where Pauli-interference contributions were not included which in fact are the dominant contributions from penguin diagrams.

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