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Supersymmetric contributions to $\mathrm{B_s} \rightarrow \mathrm{K}^-\pi^+$ decay*

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Abstract Recently, the CDF Collaboration has measured the branching fraction and time-integrated direct CP asymmetry of $\mathrm{B_s} \rightarrow \mathrm{K}^-\pi^+$ decay. The branching ratio is lower than the previous predictions based on QCD factorization. The experimental results favor a large CP asymmetry in $\mathrm{B_s} \rightarrow \mathrm{K}^-\pi^+$ decay while the standard model prediction is very small. We compute the supersymmetry contributions to $\mathrm{B_s} \rightarrow \mathrm{K}^-\pi^+$ decay using the mass insertion method, and find that the LR and RL mass insertions could suppress this branching ratio and increase this direct CP asymmetry well in line with the experimental data.

Key words $\mathrm{B_s}$ meson, branching ratio, CP asymmetry, supersymmetry, mass insertion

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1 Introduction

The decay modes of B mesons into pairs of charmless mesons are effective probes of CP violation in the standard model (SM), and are also sensitive to potential new physics (NP) scenarios beyond the SM. The two body charmless $\mathrm{B_s}$ decays will play a similar role in studying the CP asymmetries (CPAs), determining CKM matrix elements and constraining/searching for the indirect effects of various NP scenarios. Recently, the CDF Collaboration at Fermilab Tevatron has made the first measurements of charmless two-body $\mathrm{B_s} \rightarrow \mathrm{K}^-\pi^+$ decay [1, 2],

$$\mathcal{B}(\mathrm{B_s} \rightarrow \mathrm{K}^-\pi^+) = (5.0 \pm 0.7 \pm 0.8) \times 10^{-6},$$
$$\mathcal{A}_{CP}^{\mathrm{dir}}(\mathrm{B_s} \rightarrow \mathrm{K}^-\pi^+) = 0.39 \pm 0.15 \pm 0.08. \quad (1)$$

These measurements are important for understanding $\mathrm{B_s}$ physics, and also imply that many $\mathrm{B_s}$ decay modes could be precisely measured at the coming LHC-b. Compared with the theoretical predictions for these quantities based on the QCD factorization (QCDF) [3], the perturbative QCD (PQCD) [4], and the soft-collinear effective theory (SCET) [5], respectively, one would find the experimental measurements of this branching ratio agree with the SM predictions with SCET [6], but lower than the predictions with QCDF and PQCD [7, 8]. For the CDF measurement of $\mathcal{A}_{CP}^{\mathrm{dir}}(\mathrm{B_s} \rightarrow \mathrm{K}^-\pi^+)$, this value favors a large CPA in this $\mathrm{B_s}$ decay, although it is also compatible with zero at 2.3σ. In Refs. [9, 10], a robust test of the SM or a probe of NP is suggested by measuring the direct CP asymmetry in $\mathrm{B_s} \rightarrow \mathrm{K}^-\pi^+$ decay.

The decay $\mathrm{B_s} \rightarrow \mathrm{K}^-\pi^+$ has been extensively studied in the literature (for example, Refs. [7, 11]). The tree-dominated decay $\mathrm{B_s} \rightarrow \mathrm{K}^-\pi^+$ is induced by a $\bar{\mathrm{b}} \rightarrow \bar{\mathrm{u}}\mathrm{u}\bar{\mathrm{d}}$ transition at the quark level, where the direct CPAs are expected to be small in the SM. The measurements given in Eq. (1) will afford an opportunity to search NP scenarios beyond the SM.

Minimal Supersymmetric Standard Model (MSSM) is an extension of the SM which emerges as one of the most promising candidates for NP beyond the SM. In the MSSM, a supersymmetric version of SM contributes to the Flavor Change Natural Current (FCNC) processes. The flavor-changing in these processes is intrinsically tied to usual CKM-induced flavor-changing of the SM. (If that was the only new source of flavor physics, we would say that the model is minimally flavor violating). But the general MSSM is not minimally flavor violation. For the generic MSSM, a new source of flavor violation is

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introduced by the squark mass matrices, which usually cannot be diagonalized on the same basis as the quark mass matrices. This means that gluinos (and other gaugios) will have flavor-changing couplings to quarks and squarks, which implies that FCNCs are mediated by gluinos and thus have strong interaction strength. In order to analyze the phenomenology of these couplings, it is helpful to rotate the effects so that they occur in squark propagators rather than in coupling, and to parametrize them in terms of dimensionless parameters. In this paper, we work in the usual mass insertion approximation (MIA) [12, 13], and study $B_s \to K^-\pi^+$ decay in the MSSM employing QCDF. We consider the LR, RL, LL and RR four kinds of mass insertions. We find that the LR and RL contributions can dominate and can explain the measurements of $B_s \to K^-\pi^+$ decay, while the LL and RR insertions are too small to affect $B_s \to K^-\pi^+$ significantly because of lacking the gluino mass enhancement. Therefore, with the ongoing B-physics at Tevatron, in particular with the onset of the LHC-b experiment, we expect a wealth of B_s decay data and measurements of these observables could restrict or reveal the parameter spaces of the LR and RL insertions in the near future.

This paper is arranged as follows. In Sec. 2, we give the expressions of the CP averaged branching ratios and the direct CPA within the QCDF approach in $B_s \to K^-\pi^+$ systems, where the MSSM mass insertion effects are included. We also tabulate the theoretical inputs in this section. Sec. 3 deals with the numerical results. Using bounds from ΔM_{B_d} and $\sin 2\beta$, we explore the mass insertion effects in the decay. Sec. 4 contains our summary and conclusion.

2 The theoretical frame for $B_s \to K^-\pi^+$ decays

2.1 The decay amplitudes in the SM

In the SM, the low energy effective Hamiltonian for the $b \to u\bar{u}d$ transition at the scale $\mu \sim m_b$ is given by [14]

$$\mathcal{H}_{\rm eff}^{\rm SM} = \frac{G_F}{\sqrt{2}} \sum_{\rm p=u,c} \lambda_{\rm p} \left(C_1^{\rm SM} Q_1^{\rm p} + C_2^{\rm SM} Q_2^{\rm p} + \sum_{i=3}^{10} C_i^{\rm SM} Q_i + C_{7\gamma}^{\rm SM} Q_{7\gamma} + C_{8\rm g}^{\rm SM} Q_{8\rm g} \right) + \text{h.c.}, \quad (2)$$

where $\lambda_{\rm p} = V_{\rm pb} V_{\rm pd}^*$ with $\rm p \in \{u, c\}$ are CKM factors, the Wilson coefficients within the SM $C_i^{\rm SM}$ can be found in Ref. [14], and the relevant operators Q_i are given as

$$\begin{aligned}
Q_1^{\rm p} &= (\bar{p}_\alpha \gamma^\mu L b_\alpha)(\bar{d}_\beta \gamma_\mu L p_\beta), \\
Q_2^{\rm p} &= (\bar{p}_\alpha \gamma^\mu L b_\beta)(\bar{d}_\beta \gamma_\mu L p_\alpha), \\
Q_3 &= (\bar{d}_\alpha \gamma^\mu L b_\alpha) \sum_{q'} (\bar{q}'_\beta \gamma_\mu L q'_\beta), \\
Q_4 &= (\bar{d}_\beta \gamma^\mu L b_\alpha) \sum_{q'} (\bar{q}'_\alpha \gamma_\mu L q'_\beta), \\
Q_5 &= (\bar{d}_\alpha \gamma^\mu L b_\alpha) \sum_{q'} (\bar{q}'_\beta \gamma_\mu R q'_\beta), \\
Q_6 &= (\bar{d}_\beta \gamma^\mu L b_\alpha) \sum_{q'} (\bar{q}'_\alpha \gamma_\mu R q'_\beta), \\
Q_7 &= \frac{3}{2} (\bar{d}_\alpha \gamma^\mu L b_\alpha) \sum_{q'} e_{q'} (\bar{q}'_\beta \gamma_\mu R q'_\beta), \\
Q_8 &= \frac{3}{2} (\bar{d}_\beta \gamma^\mu L b_\alpha) \sum_{q'} e_{q'} (\bar{q}'_\alpha \gamma_\mu R q'_\beta), \\
Q_9 &= \frac{3}{2} (\bar{d}_\alpha \gamma^\mu L b_\alpha) \sum_{q'} e_{q'} (\bar{q}'_\beta \gamma_\mu L q'_\beta), \\
Q_{10} &= \frac{3}{2} (\bar{d}_\beta \gamma^\mu L b_\alpha) \sum_{q'} e_{q'} (\bar{q}'_\alpha \gamma_\mu L q'_\beta), \\
Q_{7\gamma} &= \frac{e}{8\pi^2} m_b \bar{d}_\alpha \sigma^{\mu\nu} R b_\alpha F_{\mu\nu}, \\
Q_{8\rm g} &= \frac{g_s}{8\pi^2} m_b \bar{d}_\alpha \sigma^{\mu\nu} R T^a_{\alpha\beta} b_\beta G^{\rm a}_{\mu\nu},
\end{aligned} \quad (3)$$

where α and β are the color indices, and $L(R) = (1 \pm \gamma_5)$.

With the weak effective Hamiltonian given by Eq. (2), one can write the decay amplitudes for the relevant two-body hadronic $B \to M_1 M_2$ decays as

$$\mathcal{A}^{\rm SM}(\rm B \to M_1 M_2) = \langle M_1 M_2 | \mathcal{H}_{\rm eff}^{\rm SM} | B \rangle = \sum_{\rm p} \sum_i \lambda_{\rm p} C_i^{\rm SM}(\mu) \langle \rm M_1 M_2 | Q_i(\mu) | B \rangle . \quad (4)$$

The essential theoretical difficulty for obtaining the decay amplitude arises from the evaluation of hadronic matrix elements $\langle \rm M_1 M_2 | Q_i(\mu) | B \rangle$, for which we will employ the QCDF [3] throughout this paper. We will use the QCDF amplitudes of these decays derived in the comprehensive papers [7] as inputs for the SM amplitudes.

2.2 Supersymmetry effects in the decays

In supersymmetry (SUSY) extension of the SM with conserved R-parity, the potentially most important contributions to Wilson coefficients of penguins in the effective Hamiltonian arise from strong-interaction penguin and box diagrams with gluino-squark loops. They can contribute to FCNC processes because the gluinos have flavor-changing coupling to the quark and squark eigenstates. In SUSY, we only consider these potentially large gluino box and penguin contributions and neglect a multitude of other diagrams, which are parametrically suppressed by small electroweak gauge coupling. The relevant Wilson coefficients of the $b \to u\bar{u}d$ process due to the gluino box or penguin diagram involving the LL and LR insertion are given (at the scale $\mu \sim m_W \sim m_{\tilde{q}}$) by [13, 15, 16]

$$\begin{aligned}
C_3^{\rm SUSY} &= -\frac{\alpha_s^2}{2\sqrt{2}G_F\lambda_t m_{\tilde{q}}^2}\left(-\frac{1}{9}B_1(x)-\frac{5}{9}B_2(x)\right.\\
&\quad \left.-\frac{1}{18}P_1(x)-\frac{1}{2}P_2(x)\right)(\delta_{LL}^d)_{13},\\
C_4^{\rm SUSY} &= -\frac{\alpha_s^2}{2\sqrt{2}G_F\lambda_t m_{\tilde{q}}^2}\left(-\frac{7}{3}B_1(x)+\frac{1}{3}B_2(x)\right.\\
&\quad \left.+\frac{1}{6}P_1(x)+\frac{3}{2}P_2(x)\right)(\delta_{LL}^d)_{13},\\
C_5^{\rm SUSY} &= -\frac{\alpha_s^2}{2\sqrt{2}G_F\lambda_t m_{\tilde{q}}^2}\left(\frac{10}{9}B_1(x)+\frac{1}{18}B_2(x)\right.\\
&\quad \left.-\frac{1}{18}P_1(x)-\frac{1}{2}P_2(x)\right)(\delta_{LL}^d)_{13},\\
C_6^{\rm SUSY} &= -\frac{\alpha_s^2}{2\sqrt{2}G_F\lambda_t m_{\tilde{q}}^2}\left(-\frac{2}{3}B_1(x)+\frac{7}{6}B_2(x)\right.\\
&\quad \left.+\frac{1}{6}P_1(x)+\frac{3}{2}P_2(x)\right)(\delta_{LL}^d)_{13},\\
C_{7\gamma}^{\rm SUSY} &= \frac{8\pi\alpha_s}{9\sqrt{2}G_F\lambda_t m_{\tilde{q}}^2}\left[(\delta_{LL}^d)_{13}M_4(x)\right.\\
&\quad \left.-(\delta_{LR}^d)_{13}\left(\frac{m_{\tilde{g}}}{m_b}\right)4B_1(x)\right],\\
C_{8g}^{\rm SUSY} &= -\frac{2\pi\alpha_s}{\sqrt{2}G_F\lambda_t m_{\tilde{q}}^2}\left[(\delta_{LL}^d)_{13}\left(\frac{3}{2}M_3(x)\right.\right.\\
&\quad \left.-\frac{1}{6}M_4(x)\right)+(\delta_{LR}^d)_{13}\left(\frac{m_{\tilde{g}}}{m_b}\right)\frac{1}{6}\left(4B_1(x)\right.\\
&\quad \left.\left.-9x^{-1}B_2(x)\right)\right],
\end{aligned} \tag{5}$$

where $x \equiv m_{\tilde{g}}^2/m_{\tilde{q}}^2$, and the loop functions $B_i(x)$, $P_i(x)$, $M_i(x)$ can be found in Ref. [15]. For the RR and RL insertions, we have additional operators $\tilde{Q}_{i=3\cdots6,7\gamma,8g}$ that are obtained by $L \leftrightarrow R$ in the SM operators given in Eq. (3). The associated Wilson coefficients $\widetilde{C}_{i=3\cdots6,7\gamma,8g}^{\rm SUSY}$ are dominated by their expressions as above with the replacement $L \leftrightarrow R$. The remaining coefficients are either dominated by their SM ($C_{1,2}$) or are electroweak penguins ($C_{7\cdots10}$) and are therefore small.

2.3 The total decay amplitudes

For LL and LR insertion, the NP effective operators have the same chirality as those of the SM, so the total decay amplitudes can be obtained from the SM in Ref. [7] by the replacing

$$C_i^{\rm SM} \to C_i^{\rm SM} + C_i^{\rm SUSY}. \tag{6}$$

For RL and RR insertion, the NP effective operators have the opposite chirality with those of the SM. We can get the corresponding decay amplitudes from the SM decay amplitudes by the following replacement [17],

$$C_i^{\rm SM} \to C_i^{\rm SM} - \widetilde{C}_i^{\rm SUSY}. \tag{7}$$

Then, the total branching ratio reads

$$\mathcal{B}(B_s \to M_1M_2) = \frac{\tau_{B_s}|p_c|}{8\pi m_{B_s}^2}\left|\mathcal{A}(B_s \to M_1M_2)\right|^2, \tag{8}$$

where τ_{B_s} is the B_s lifetime and $|p_c|$ is the center of mass momentum in the center of mass frame of B_s meson.

The direct CP asymmetry is defined as

$$\mathcal{A}_{CP}^{\rm dir} = \frac{\mathcal{B}(\bar{B}_s \to \bar{f}) - \mathcal{B}(B_s \to f)}{\mathcal{B}(\bar{B}_s \to \bar{f}) + \mathcal{B}(B_s \to f)}. \tag{9}$$

2.4 Input parameters

The input parameters are collected in Table 1. In our numerical results, we will use the input parameters which are varied randomly within the 1σ range.

Table 1. Default values of the input parameters and the $\pm1\sigma$ error ranges for the sensitive parameters used in our numerical calculations.

$m_{B_s}=5.366$ GeV, $m_{K^\pm}=0.494$ GeV, $m_{\pi^\pm}=0.140$ GeV, $\overline{m}_b(\overline{m}_b)=(4.20\pm0.07)$ GeV, $\overline{m}_u(2\ \text{GeV})=(0.0015\text{–}0.003)$ GeV, $\overline{m}_d(2\ \text{GeV})=(0.003\text{–}0.007)$ GeV, $\tau_{B_s}=(1.437^{+0.030}_{-0.031})$ ps.	[18]
for the SM predictions: $A=0.810\pm0.013$, $\lambda=0.2259\pm0.0016$, $\bar{\rho}=0.154\pm0.022$, $\bar{\eta}=0.342\pm0.014$. for the SUSY predictions: $A=0.810\pm0.013$, $\lambda=0.2259\pm0.0016$, $\bar{\rho}=0.177\pm0.044$, $\bar{\eta}=0.360\pm0.031$.	[19]
$f_K=0.160$ GeV, $f_\pi=0.131$ GeV, $f_{B_s}=(0.245\pm0.025)$ GeV, $F_0^{B_s\to K}(0)=0.30^{+0.04}_{-0.03}$.	[20–22]
$\lambda_B=(0.46\pm0.11)$ GeV.	[23]
$\alpha_1^\pi=0$, $\alpha_2^\pi=0.20\pm0.15$, $\alpha_1^K=0.2\pm0.2$, $\alpha_2^K=0.1\pm0.3$	[7]

We have two remarks on the input parameters:

1) Wilson coefficients: The SM Wilson coefficients $C_i^{\rm SM}$ are obtained from the expressions in Ref. [14]. The SUSY Wilson coefficients at low energy $C_i^{\rm SUSY}(\mu\sim m_{\rm b})$ can be obtained from $C_i^{\rm SUSY}(m_{\tilde{\rm q}})$ in Eq. (5) by using the Renormalization Group equation as discussed in Ref. [14],

$$C(\mu)=U_5(\mu,m_{\tilde{\rm q}})C(m_{\tilde{\rm q}}), \tag{10}$$

where C is the 6×1 column vector of the Wilson coefficients and $U_5(\mu,m_{\tilde{\rm q}})$ is the five-flavor 6×6 evolution matrix. The detailed explicitness of $U_5(\mu,m_{\tilde{\rm q}})$ is given in Ref. [14]. The coefficients $C_{7\gamma}^{\rm SUSY}$ and $C_{8\rm g}^{\rm SUSY}$ at the $\mu\sim m_{\rm b}$ scale are given by [24, 25]

$$\begin{aligned} C_{7\gamma}^{\rm SUSY}(\mu) &= \eta^2 C_{7\gamma}^{\rm SUSY}(m_{\tilde{\rm q}})+\frac{8}{3}(\eta-\eta^2)C_{8\rm g}^{\rm SUSY}(m_{\tilde{\rm q}}),\\ C_{8\rm g}^{\rm SUSY}(\mu) &= \eta C_{8\rm g}^{\rm SUSY}(m_{\tilde{\rm q}}), \end{aligned} \tag{11}$$

where

$$\eta=\left(\frac{\alpha_{\rm s}(m_{\tilde{\rm q}})}{\alpha_{\rm s}(m_{\rm t})}\right)^{\frac{2}{21}}\left(\frac{\alpha_{\rm s}(m_{\rm t})}{\alpha_{\rm s}(m_{\rm b})}\right)^{\frac{2}{23}}.$$

2) CKM matrix element: For the SM predictions, we use the CKM matrix elements from the Wolfenstein parameters of the latest analysis within the SM in Ref. [19], and for the SUSY predictions, we take CKM matrix elements in terms of the Wolfenstein parameters of the NP generalized analysis results in Ref. [19].

3 Numerical results and analysis

In this section, we summarize our numerical results and analysis in the $\rm B_s\to K^-\pi^+$ decay. First, we will show our estimations in the SM with full theoretical uncertainties of sensitive parameters. Then, we will investigate the SUSY effects in this decay.

Using the input parameters given in Section 2.4, the numerical results in the SM are presented in the second line of Table 2, which are consistent with the those in Ref. [7]. For the color-allowed tree-dominated decay $\rm B_s\to K^-\pi^+$, power corrections have limited impact, and the main sources of theoretical uncertainties in the branching ratio are CKM matrix elements and form factors. Its direct CPA can be predicted quite precisely, and found to be very small due to small penguin amplitudes.

Now we will consider each possible mass insertion $(\delta^{\rm d}_{\rm AB})_{13}$ for AB = LL, LR, RL, RR only one at a time, neglecting the interferences between different insertions products, but keeping their interferences with the SM amplitude. In the SM, the very small direct CPA of this decay comes from the weak phase of small penguin amplitudes. In order to have nonzero CPA, we need at least two independent amplitudes with different weak phases. In the SUSY models we are considering, the weak phases reside in the complex mass insertion parameters δs and appear in the SUSY Wilson coefficients in Eq. (5). These weak phases are odd under a CP transformation. Considering the existent bounds from $\Delta M_{\rm d}$, $\cos2\beta$ and $S_{\psi\rm K_s}$ in Ref. [26], we will scan over the modulus of the flavor-changing mass insertions $\big(|(\sigma^{\rm d}_{\rm LL})_{13}|\leqslant0.12,\ |(\sigma^{\rm d}_{\rm RR})_{13}|\leqslant0.25,\ |(\sigma^{\rm d}_{\rm LR,RL})_{13}|\leqslant0.03\big)$, and vary all phases randomly between $-\pi$ and π. We will calculate all observables for a fixed gluino and squark mass of 500 GeV.

Table 2. The theoretical predictions for $\mathcal{B}$ (in units of 10^{-6}), $\mathcal{A}_{CP}^{\rm dir}$ (in units of 10^{-2}) in $\rm B_s\to K^-\pi^+$ decay within QCDF.

	$\mathcal{B}(\rm B_s\to K^-\pi^+)$	$\mathcal{A}_{CP}^{\rm dir}(\rm B_s\to K^-\pi^+)$
in the SM	$[6.89,15.67]$	$[-8.11,-1.44]$
with $(\delta^{\rm d}_{\rm LL})_{13}$	$[6.88,19.21]$	$[-7.89,-1.24]$
with $(\delta^{\rm d}_{\rm RR})_{13}$	$[6.71,19.80]$	$[-8.14,-1.23]$
with $(\delta^{\rm d}_{\rm LR})_{13}$	$[0.02,61.38]$	$[-54.84,57.00]$
with $(\delta^{\rm d}_{\rm RL})_{13}$	$[0.01,69.22]$	$[-54.72,76.14]$

The SUSY numerical predictions in $\rm B_s\to K^-\pi^+$ decay in the framework of the MIA are listed in the last four lines of Table 2. From Table 2, we found the effects of $(\delta^{\rm d}_{\rm LL})_{13}$ and $(\delta^{\rm d}_{\rm RR})_{13}$ mass insertions are almost negligible in $\rm B_s\to K^-\pi^+$ decay, and they will not provide any significant effect on the branching ratio and the direct CPA of this decay, in other words, the current data of $\rm B_s\to K^-\pi^+$ cannot be explained by the LL and RR mass insertions. But, the case of the LR or RL insertion is very different from that of either LL or RR. The LR and RL mass insertions only generate (chromo)magnetic operators $Q_{7\gamma,8\rm g}$ and $\tilde{Q}_{7\gamma,8\rm g}$, respectively. In particular, the LR and the RL insertion contributions are enhanced by $m_{\tilde g}/m_{\rm b}$ due to the chirality flip from the gluino in the loop compared with the contribution including the SM one. In these cases, even a small $(\delta^{\rm d}_{\rm LR})_{13}$ or $(\delta^{\rm d}_{\rm RL})_{13}$ can have large effects in $\rm B_s\to K^-\pi^+$ decay.

In addition, we will also study the sensitivities of this branching ratio and the direct CPA of $\rm B_s\to K^-\pi^+$ decay to each LR and RL insertion parameter, and we will present the distributions and correlations of $\mathcal{B}$ and $\mathcal{A}_{CP}^{\rm dir}$ within the modulus and weak phases of each LR and RL insertion parameter in Fig. 1 by three-dimensional scatter plots.

First, we discuss the LR mass insertion effects shown in Fig. 1(a), (b). Fig. 1(a) shows the sensitivity of $\mathcal{B}(\rm B_s\to K^-\pi^+)$ to $|(\delta^{\rm d}_{\rm LR})_{13}|$ and $\phi_{\rm LR}$, and we find $\mathcal{B}(\rm B_s\to K^-\pi^+)$ is very sensitive to both $|(\delta^{\rm d}_{\rm LR})_{13}|$ and $\phi_{\rm LR}$. $\mathcal{B}(\rm B_s\to K^-\pi^+)$ tends to have larger allowed ranges with $|(\delta^d_{LR})_{13}|$ and $|\phi_{LR}|$. Fig. 1 (b) exhibits the possible ranges of $\mathcal{A}^{dir}_{CP}(B_s \to K^-\pi^+)$, which could be greatly enlarged when $|(\delta^d_{LR})_{13}| \in [0.02, 0.03]$ and $\phi_{LR} \in [-90°, -30°]$. It is interesting to note that $\mathcal{A}^{dir}_{CP}(B_s \to K^-\pi^+)$ could be enlarged to 0.57 and $\mathcal{B}(B_s \to K^-\pi^+)$ could be strongly suppressed when ϕ_{LR} is near $-60°$ and $|(\sigma^d_{LR})_{13}| \in [0.015, 0.030]$.

Then we discuss the RL mass insertion effects shown in Fig. 1(c), (d). In Fig. 1(c), we find $\mathcal{B}(B_s \to K^-\pi^+)$ tend to have larger allowed ranges with $|(\delta^d_{RL})_{13}|$, which has a similar trend as this branching ratio with $|(\delta^d_{LR})_{13}|$, but $\mathcal{B}(B_s \to K^-\pi^+)$ tends to have a smaller range with $|\phi_{RL}|$, which is different from this branching ratio with $|\phi_{LR}|$. In Fig. 1(d), we can see the possible ranges of $\mathcal{A}^{dir}_{CP}(B_s \to K^-\pi^+)$ could be greatly enlarged when $|(\delta^d_{RL})_{13}| \in [0.015, 0.030]$ and $\phi_{RL} \in [90°, 150°]$. $\mathcal{A}^{dir}_{CP}(B_s \to K^-\pi^+)$ could be enlarged to 0.76 and $\mathcal{B}(B_s \to K^-\pi^+)$ could be strongly suppressed when ϕ_{LR} is near 120° and $|(\sigma^d_{LR})_{13}| \in [0.015, 0.030]$.

Thus, we have found that the LR and RL insertions can explain the recent experimental data of $B_s \to K^-\pi^+$ decay (large direct CPA and small branching ratio) at the same time.

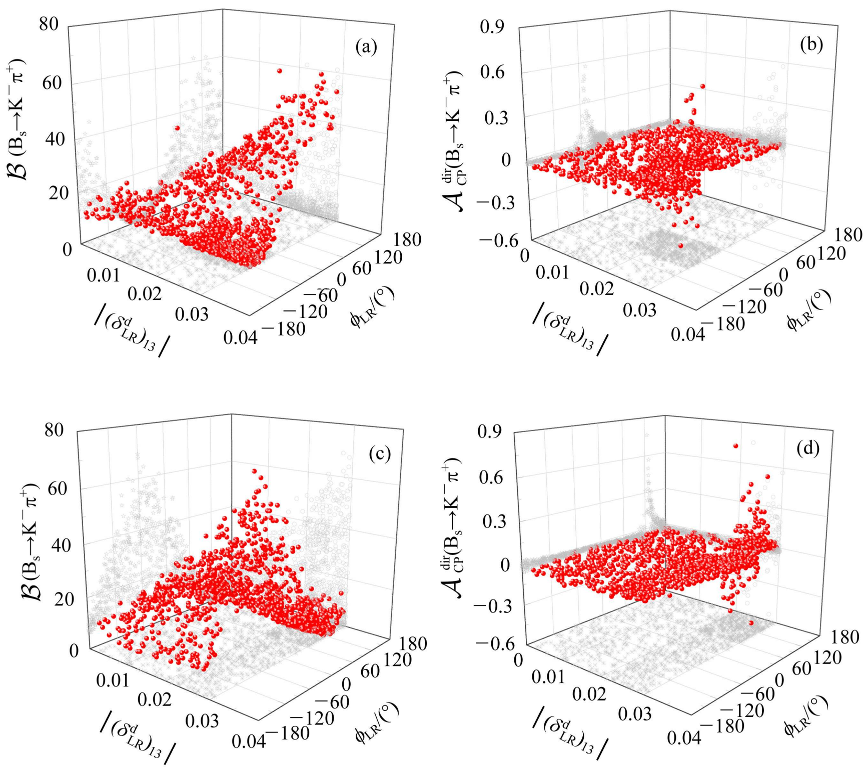

Fig. 1. The effects of $(\delta^d_{LR})_{13}$ and $(\delta^d_{RL})_{13}$ in $B_s \to K^-\pi^+$ decays. $\mathcal{A}^{dir}_{CP}$ and $\mathcal{B}$ are in units of 10^{-2} and 10^{-6}, respectively.

4 Conclusions

Motivated by recent results from the CDF, which favor a small branching ratio and a possible large CP asymmetry in $B_s \to K^-\pi^+$ decay, we have studied the SUSY contributions with the mass insertions based on the QCDF approach. We have found that the LL and RR mass insertions have negligible effects in $B_s \to K^-\pi^+$ decay. But, the LR and RL mass insertions can explain the small branching ratio and the possible large CP asymmetry from the CDF collaboration.

The LR and RL insertions can generate sizable effects in $B_s \to K^-\pi^+$ decay since their contributions are enhanced by $m_{\tilde{g}}/m_b$. When $|(\sigma^d_{LR,RL})_{13}| \in [0.015, 0.030]$, ϕ_{LR} is near $-60°$ and ϕ_{RL} is near 120°, supersymmetric effects could suppress $\mathcal{B}(B_s \to K^-\pi^+)$. At the same time, supersymmetric effects could enhance $\mathcal{A}^{dir}_{CP}(B_s \to K^-\pi^+)$. The future measurements or precise meansurements of the branching ratio, the direct CP asymmetry of $B_s \to K^-\pi^+$ decay could be used to shrink or reveal the relevant LR and RL mass insertion parameter spaces. The results in this paper could be useful for probing SUSY effects and searching direct SUSY signals at Tevatron and LHC in the near future.

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