SUSY effects in $B_{u,d} \to h_1 h_2$ decays with the mSUGRA model

Wenjuan Zou

Directed by Prof. Zhen-Jun Xiao

Nanjing Normal University

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I. Motivation

★ problems in SM

fine-tuning problem,

can not obtain unification,

failed to provide cold mark matter, etc.

★ puzzles in $B_{u,d} \to h_1 h_2$ decays

The data show some deviations from the SM expectations in $B \to K\eta', \pi\pi, \pi K, K\phi$ etc.

Therefore, people always think SM is incomplete and some new physics must be there.

II. The mSUGRA model

Four basic assumptions:

1.Minimal gauge group: $SU(3)_c \times SU(2)_L \times U(1)_Y$

2.Minimal particle content:

SM part		q	l	ν	g	$W^{\pm}, H_1^-, H_2^+$	γ, Z, h, H, A
super	Weak	$\tilde{q}_L, \tilde{q}_R$	$\tilde{l}_L, \tilde{l}_R$	$\tilde{\nu}$	$\tilde{g}$	$\tilde{W}^{\pm}, \tilde{h}_1^-, \tilde{h}_2^+$	$\tilde{B}, \tilde{W}^0, \tilde{h}_1^0, \tilde{h}_2^0$
partner	Mass	$\tilde{q}_1, \tilde{q}_2$	$\tilde{l}_1, \tilde{l}_2$	$\tilde{\nu}$	$\tilde{g}$	$\tilde{\chi}^{\pm}_{1,2}$	$\tilde{\chi}^0_{1,2,3,4}$

3.R-parity conservations: $R = (-1)^{2S+3B+L}$

4.Soft-SUSY breaking:

$$
\begin{aligned}
-\mathcal{L}_{soft} \quad = \quad & m^2_{H_2} H_2^\dagger H_2 + m^2_{H_1} H_1^\dagger H_1 + B\mu (H_1.H_2 + \text{h.c.}) \\
& + \frac{1}{2}\left[M_1 \tilde{B}\tilde{B} + M_2 \sum_{a=1}^{3} \tilde{W}^a \tilde{W}_a + M_3 \sum_{\alpha=1}^{8} \tilde{G}^\alpha \tilde{G}_\alpha \;+\; \text{h.c.} \right] \\
& + \Big[A^U Y^U \tilde{U}_R H_2.\tilde{Q} + A^D Y^D \tilde{D}_R H_1.\tilde{Q} + A^L Y^L \tilde{E}_R H_1.\tilde{L} + \; \text{h.c.} \\
& + (m^2_{\tilde{Q}}) \tilde{Q}_L^+ \tilde{Q}_L + (m^2_{\tilde{U}}) \tilde{U}_R^* \tilde{U}_R + (m^2_{\tilde{D}}) \tilde{D}_R^* \tilde{D}_R + (m^2_{\tilde{L}}) \tilde{L}_L^+ \tilde{l}_L + (m^2_{\tilde{E}}) \tilde{E}_R^* \tilde{E}_R \Big]
\end{aligned}
$$

The unification and universality hypotheses:

1. Unification of the gaugino masses:

$$M_1 = M_2 = M_3 = \mathbf{m}_{\frac{1}{2}}$$

2. Universal scalar masses:

$$m^2_{\tilde{Q}} = m^2_{\tilde{U}} = m^2_{\tilde{D}} = m^2_{\tilde{L}} = m^2_{\tilde{E}} = m^2_0 \mathbf{I}$$

$$m^2_{H_1} = m^2_{H_2} = \mathbf{m^2_0}$$

3. Universal trilinear coupling:

$$A_U = A_D = A_E = \mathbf{A_0}\mathbf{I}$$

Besides, according to the Condition for EWSB:

$$\langle \frac{\partial V_{Higgs}}{\partial H_1^0} \rangle = \langle \frac{\partial V_{Higgs}}{\partial H_2^0} \rangle \ = \ 0, \text{when} < H_1 >= \left(\begin{array}{c} \frac{v_1}{\sqrt{2}} \\ 0 \end{array} \right), < H_2 >= \left(\begin{array}{c} 0 \\ \frac{v_2}{\sqrt{2}} \end{array} \right)$$

two more parameters are left: sign(μ), $\tan\beta = \frac{v_2}{v_1}$

III. Parameter constraints

1. The $B \to X_s\gamma$ decay branching ratio:

$$2.77 \times 10^{-4} < Br(B \to X_s\gamma) < 4.33 \times 10^{-4}$$

2. The muon anomalous magnetic moment($g_\mu - 2$):
3. The electroweak precision observables m_Z, s_W^2:

$$\Delta\rho(SUSY) < 2 \times 10^{-3}$$

4. The experimental bounds for the mass of SUSY particle:

$$m_{\chi_1^+} \geq 104Gev, \; m_{\tilde{f}} \geq 100Gev \; \mathbf{(}\tilde{f} = \tilde{t}_1, \tilde{b}_1, \tilde{l}^{\pm}, \tilde{\nu}\mathbf{)}$$
$$m_{\tilde{g}} \geq 300Gev, \; m_{\tilde{q}_{1,2}} \geq 260Gev \; \mathbf{(}\tilde{q} = \tilde{u}, \tilde{d}, \tilde{s}, \tilde{c}\mathbf{)}$$
$$m_{H^0} \geq 114Gev \; \mathbf{(for\ large}\ m_A\mathbf{)}$$
$$m_{h,H^0} > 91Gev, \; m_A > 92Gev \; \mathbf{(for\ small}\ m_A\mathbf{)}$$

IV. B physics phenomenology

In the SM, the $\Delta B = 1$ effective Hamiltonian is:

$$\mathcal{H}_{eff} = \frac{G_F}{\sqrt{2}} \sum_{p=u,c} \lambda_p^q \Big\{ C_1(\mu) Q_1^q(\mu) + C_2(\mu) Q_2^q(\mu) + \sum_{k=3}^{10} C_k(\mu) Q_k(\mu)$$

$$+ \quad C_{7\gamma}(\mu) Q_{7\gamma}(\mu) + C_{8g}(\mu) Q_{8g}(\mu) \Big\} + \text{H.c.}$$

The NP effects will manifest themselves through two channels:

- $C_i(\mu) = C_i^{SM}(\mu) + C_i^{NP}(\mu)$
- $\tilde{C}_i(\mu) = \tilde{C}_i^{NP}(\mu)$

New particles propagated SUSY penguin diagrams are:

- the gauge boson $W^{\pm}$ and up-type quarks u, c, t;
- the charged Higgs boson $H^{\pm}$ and up-type quarks u, c, t;
- the charginos $\tilde{\chi}_{1,2}^{\pm}$ and the scalar up-type quarks $\tilde{u}, \tilde{c}, \tilde{t}$;
- the neutralinos $\tilde{\chi}_{1,2,3,4}^{0}$ and the down-type squarks $\tilde{d}, \tilde{s}, \tilde{b}$;
- the gauginos $\tilde{g}$ and the down-type squarks $\tilde{d}, \tilde{s}, \tilde{b}$.

SUSY corrections to Wilson coefficients

By employing conservation of the vector current and Lorentz invariance, the effective vertex of the $b \to qg(\gamma)$ penguin processes can be written as

$$\Gamma_\mu^a(q^2) = \frac{ig_s}{4\pi^2}\bar{u}_q(p_q)T^a V_\mu(q^2)u_b(p_b)$$

with

$$V_\mu(q^2) = (q^2 g_{\mu\nu} - q_\mu q_\nu)\gamma^\nu \left[F_{1L}(q^2)P_L + F_{1R}(q^2)P_R\right] + i\sigma_{\mu\nu}q^\nu \left[F_{2L}(q^2)P_L + F_{2R}(q^2)P_R\right]$$

Then

$$C_k^{NP}(M_W) = -\frac{\alpha_s(M_W)}{24\pi}\left[\frac{G_F}{\sqrt{2}}\lambda_t\right]^{-1} A_k F_{1L}^g(0)$$

$$C_{7\gamma}^{NP}(M_W) = -\frac{F_{2R}^\gamma(0)}{2}\left[\frac{G_F}{\sqrt{2}}\lambda_t m_b\right]^{-1}$$

$$C_{8g}^{NP}(M_W) = -\frac{F_{2R}^g(0)}{2}\left[\frac{G_F}{\sqrt{2}}\lambda_t m_b\right]^{-1}$$

with $k = 3,4,5,6$ and $A_k = \{-1, 3, -1, 3\}$. The correction to $C_i (i = 7,8,9,10)$ has been ignored since they are suppressed by a factor of α_{em}/α_s.

Through scanning in the parameters spaces, we found

$$C_k^{NP}(M_W) \lesssim 10^{-5}$$

$C_{7\gamma}^{NP}(M_W)$ and $C_{8g}^{NP}(M_W)$ can be rather large and even flip the sign of the SM value of $C_{7\gamma}(M_W)$ and $C_{8g}(M_W)$.

Based on this, we chose three typical parameter points:

Case	m_0	$m_{\frac{1}{2}}$	A_0	$\tan\beta$	$Sign[\mu]$	$C_{7\gamma}(m_b)/C_{7\gamma}^{SM}(m_b)$
A	300	300	0	2	$-$	1.10
B	369	150	-400	40	$+$	-0.93
C	200	400	0	30	$+$	0.82

Calculation of decay amplitude

According to $\mathcal{H}_{eff}$, the decay amplitude is given as

$$\mathcal{A}(B \to M_1 M_2) = \frac{G_F}{\sqrt{2}} \sum_{p=u,c} \sum_i \lambda_p^q C_i(\mu) \langle M_1 M_2 | Q_i(\mu) | B \rangle$$

The remanent and also intractable problem is to calculate the hadronic matrix elements. The methods generally used are

- QCD factorization
- PQCD factorization

QCD factorization

In this scheme, based on the NF and in the heavy quark limit,

$$\langle M_1 M_2 | Q_i | B \rangle = \sum_j F_j^{B\to M_1} \int_0^1 du T_{ij}^I(u) \Phi_{M_2}(u) + (M_1 \leftrightarrow M_2) + \int_0^1 d\xi du dv T_i^{II}(\xi, u, v) \Phi_B(\xi) \Phi_{M_1}(v) \Phi_{M_2}(u)$$

With the factorized formula used, the decay amplitudes reads as

$$\mathcal{A}^f(B \to M_1 M_2) = \frac{G_F}{\sqrt{2}} \sum_{p=u,c} \sum_i \lambda_p^q a_i^p(\mu) \langle M_1 M_2 | Q_i(\mu) | B \rangle_{NF}$$

Factorized coefficient a_i^p:

$$a_i^p(M_1 M_2) = \left(C_i + \frac{C_{i\pm1}}{N_c}\right) N_i(M_2) + \frac{C_{i\pm1}}{N_c} \frac{C_F \alpha_s}{4\pi} \left[V_i(M_2) + \frac{4\pi^2}{N_c} H_i(M_1 M_2) \right] + P_i^p(M_2)$$

The annihilation contribution $\mathcal{A}^a(B \to M_1 M_2)$ which cannot be neglected for some $B \to PP, PV$ channels because of the chiral enhancement of order $\frac{m_B^2}{m_b m_q}$ take the form of

$$\mathcal{A}^a(B \to M_1 M_2) = \frac{G_F}{\sqrt{2}} \sum_{p=u,c} \sum_i \lambda_p^q f_B f_{M_1} f_{M_2} b_i(C_i, \chi_A)$$

where $C_i (i = 1 \sim 10)$ are Wilson coefficients and

$$\chi_A = \left(1 + \rho_A e^{i\phi_A}\right) \ln \frac{m_B}{\Lambda_h}$$

with $\rho_A \in [0, 1]$ and $\phi_A \in [-\pi, \pi]$. Obviously,

- In the mSUGRA model, the SUSY corrections to $\mathcal{A}^a(B \to M_1 M_2)$ are small.
- χ_A can cause large uncertainties to the theoretical predictions.

IV. Results and discussion

★ Results of branching ratios (in unit of 10^{-6})

$B \to PP$ $(b \to d)$	$\mu = m_b/2$					$\mu = m_b$					$\mu = 2m_b$				
	SM		mSUGRA			SM		mSUGRA			SM		mSUGRA		
	Br^f	Br^{f+a}	A	B	C	Br^f	Br^{f+a}	A	B	C	Br^f	Br^{f+a}	A	B	C
$\bar{B}^0 \to \pi^+\pi^-$	9.23	9.90	9.20	9.46	9.23	9.19	9.74	9.16	9.42	9.19	9.08	9.56	9.05	9.31	9.09
$B^- \to \pi^-\pi^0$	6.12	6.12	6.12	6.13	6.12	6.25	6.25	6.25	6.27	6.25	6.42	6.42	6.41	6.43	6.42
$B^- \to \pi^-\eta$	3.81	3.77	3.78	4.04	3.81	3.85	3.83	3.82	4.07	3.85	3.92	3.91	3.89	4.15	3.92
$B^- \to \pi^-\eta'$	2.71	2.74	2.69	2.88	2.71	2.74	2.76	2.72	2.90	2.74	2.82	2.84	2.80	2.98	2.82
$\bar{B}^0 \to \pi^0\pi^0$	0.16	0.16	0.16	0.19	0.16	0.16	0.15	0.15	0.19	0.16	0.17	0.16	0.17	0.20	0.17
$\bar{B}^0 \to \pi^0\eta$	0.17	0.19	0.16	0.24	0.17	0.16	0.17	0.15	0.22	0.16	0.15	0.16	0.14	0.21	0.15
$\bar{B}^0 \to \pi^0\eta'$	0.10	0.14	0.10	0.15	0.11	0.09	0.12	0.09	0.13	0.09	0.09	0.12	0.09	0.13	0.09
$\bar{B}^0 \to \eta\eta$	0.15	0.20	0.15	0.18	0.15	0.14	0.18	0.14	0.16	0.14	0.14	0.17	0.14	0.17	0.14
$\bar{B}^0 \to \eta\eta'$	0.15	0.17	0.14	0.17	0.15	0.14	0.16	0.13	0.16	0.14	0.14	0.16	0.14	0.16	0.14
$\bar{B}^0 \to \eta'\eta'$	0.14	0.22	0.14	0.16	0.14	0.13	0.19	0.12	0.14	0.13	0.13	0.18	0.12	0.14	0.13
$\bar{B}^0 \to \bar{K}^0K^0$	0.65	0.89	0.61	0.96	0.65	0.63	0.80	0.59	0.92	0.63	0.60	0.74	0.56	0.89	0.60
$B^- \to K^-K^0$	0.71	0.84	0.66	1.05	0.71	0.68	0.79	0.64	1.0	0.68	0.65	0.74	0.61	0.96	0.65

$B \to PV$ ($b \to d$)	$\mu = m_b/2$					$\mu = m_b$					$\mu = 2m_b$				
	SM		mSUGRA			SM		mSUGRA			SM		mSUGRA		
	Br^f	Br^{f+a}	A	B	C	Br^f	Br^{f+a}	A	B	C	Br^f	Br^{f+a}	A	B	C
$B^- \to \pi^- \rho^0$	11.2	11.2	11.2	11.2	11.2	11.5	11.4	11.5	11.5	11.5	11.8	11.8	11.8	11.8	11.8
$B^- \to \pi^0 \rho^-$	14.8	14.9	14.8	14.9	14.8	14.9	15.0	14.9	15.0	14.9	15.1	15.2	15.1	15.2	15.1
$\bar{B}^0 \to \pi^+ \rho^-$	21.2	22.3	21.2	21.5	21.2	21.2	22.1	21.1	21.4	21.2	20.9	21.7	20.9	21.2	20.9
$\bar{B}^0 \to \pi^- \rho^+$	14.3	15.1	14.3	14.4	14.3	14.3	14.9	14.3	14.3	14.3	14.1	14.7	14.1	14.2	14.1
$B^- \to \pi^- \omega$	9.09	8.70	9.01	9.24	9.09	9.25	8.98	9.24	9.38	9.25	9.48	9.29	9.47	9.59	9.48
$B^- \to \eta \rho^-$	6.50	6.19	6.49	6.61	6.50	6.55	6.35	6.54	6.64	6.55	6.67	6.52	6.66	6.75	6.67
$B^- \to \eta' \rho^-$	4.60	4.39	4.59	4.67	4.60	4.66	4.51	4.65	4.71	4.66	4.78	4.67	4.77	4.82	4.78
$\bar{B}^0 \to \pi^0 \rho^0$	0.538	0.417	0.541	0.532	0.538	0.524	0.419	0.527	0.512	0.523	0.602	0.502	0.605	0.585	0.601
$\bar{B}^0 \to \pi^0 \omega$	0.019	0.013	0.017	0.043	0.019	0.014	0.007	0.013	0.032	0.014	0.012	0.004	0.011	0.025	0.012
$\bar{B}^0 \to \eta \rho^0$	0.004	0.021	0.003	0.010	0.004	0.003	0.016	0.003	0.006	0.003	0.003	0.014	0.004	0.004	0.003
$\bar{B}^0 \to \eta' \rho^0$	0.035	0.066	0.036	0.033	0.035	0.033	0.058	0.034	0.029	0.033	0.034	0.055	0.035	0.029	0.034
$\bar{B}^0 \to \eta \omega$	0.278	0.351	0.276	0.295	0.278	0.249	0.308	0.247	0.262	0.249	0.269	0.323	0.268	0.279	0.269
$\bar{B}^0 \to \eta' \omega$	0.274	0.337	0.274	0.283	0.274	0.253	0.305	0.252	0.259	0.253	0.276	0.323	0.275	0.281	0.276
$B^- \to \pi^- \phi$	0.008	—	0.008	0.008	0.008	0.006	—	0.006	0.006	0.006	0.005	—	0.005	0.005	0.005
$\bar{B}^0 \to \pi^0 \phi$	0.003	—	0.003	0.003	0.003	0.002	—	0.002	0.002	0.002	0.002	—	0.002	0.002	0.002
$\bar{B}^0 \to \eta \phi$	0.002	0.001	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
$\bar{B}^0 \to \eta' \phi$	0.002	0.003	0.002	0.002	0.002	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
$B^- \to K^- K^{*0}$	0.12	0.17	0.10	0.31	0.12	0.11	0.15	0.10	0.28	0.11	0.10	0.12	0.08	0.24	0.10
$\bar{B}^0 \to \bar{K}^0 K^{*0}$	0.11	0.14	0.10	0.29	0.11	0.10	0.13	0.09	0.26	0.11	0.09	0.11	0.08	0.22	0.10
$B^- \to K^0 K^{*-}$	0.10	0.16	0.11	0.03	0.10	0.11	0.16	0.12	0.04	0.11	0.13	0.17	0.14	0.07	0.13
$\bar{B}^0 \to K^0 \bar{K}^{*0}$	0.09	0.15	0.10	0.02	0.09	0.10	0.15	0.11	0.04	0.10	0.12	0.16	0.13	0.06	0.12

$B \to VV$ $(b \to d)$	$\mu = m_b/2$				$\mu = m_b$				$\mu = 2m_b$			
	SM	mSUGRA			SM	mSUGRA			SM	mSUGRA		
	Br^f	A	B	C	Br^f	A	B	C	Br^f	A	B	C
$\bar{B}^0 \to \rho^+\rho^-$	27.8	27.7	28.1	27.8	27.5	27.5	27.8	27.5	27.1	27.0	27.3	27.1
$B^- \to \rho^-\rho^0$	18.4	18.4	18.4	18.4	18.7	18.7	18.7	18.7	19.1	19.1	19.1	19.1
$B^- \to \rho^-\omega$	16.6	16.5	17.0	16.6	16.6	16.6	16.9	16.6	16.8	16.7	17.1	16.8
$\bar{B}^0 \to \rho^0\rho^0$	0.38	0.38	0.40	0.38	0.33	0.32	0.34	0.33	0.35	0.35	0.36	0.35
$\bar{B}^0 \to \rho^0\omega$	0.09	0.08	0.17	0.09	0.07	0.06	0.13	0.07	0.05	0.05	0.11	0.05
$\bar{B}^0 \to \omega\omega$	0.40	0.39	0.44	0.40	0.33	0.33	0.37	0.33	0.33	0.33	0.37	0.34
$\bar{B}^0 \to \rho^0\phi$	0.004	0.004	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
$B^- \to \rho^-\phi$	0.009	0.009	0.009	0.009	0.007	0.007	0.007	0.007	0.006	0.006	0.006	0.006
$\bar{B}^0 \to \omega\phi$	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.002	0.002	0.002	0.002
$\bar{B}^0 \to \bar{K}^{*0}K^{*0}$	0.28	0.25	0.46	0.28	0.22	0.20	0.37	0.22	0.17	0.16	0.30	0.18
$B^- \to K^{*-}K^{*0}$	0.30	0.28	0.50	0.30	0.24	0.22	0.40	0.24	0.19	0.17	0.33	0.19

$B \to PP$ $(b \to s)$	$\mu = m_b/2$					$\mu = m_b$					$\mu = 2m_b$				
	SM		mSUGRA			SM		mSUGRA			SM		mSUGRA		
	Br^f	Br^{f+a}	A	B	C	Br^f	Br^{f+a}	A	B	C	Br^f	Br^{f+a}	A	B	C
$\bar{B}^0 \to \pi^+ K^-$	9.91	12.2	9.09	15.5	9.96	9.60	11.4	8.94	15.0	9.65	9.29	10.8	8.65	14.6	9.35
$\bar{B}^0 \to \pi^0 \bar{K}^0$	4.41	5.31	4.47	6.97	4.42	4.23	4.94	3.92	6.64	4.24	4.05	4.62	3.75	6.36	4.06
$B^- \to \pi^- \bar{K}^0$	12.7	15.6	11.9	19.1	12.8	12.3	14.6	11.5	18.3	12.3	11.8	13.6	11.0	17.5	11.8
$B^- \to \pi^0 K^-$	7.23	8.46	6.48	10.7	7.26	7.02	8.00	6.60	10.4	7.05	6.79	7.58	6.38	10.1	6.82
$\bar{B}^0 \to \bar{K}^0 \eta$	1.79	1.98	1.71	2.30	1.79	1.63	1.78	1.56	2.13	1.63	1.50	1.61	1.42	1.99	1.50
$\bar{B}^0 \to \bar{K}^0 \eta'$	35.0	45.9	35.5	47.9	35.1	32.2	40.6	30.6	44.3	32.3	31.0	37.6	29.4	42.8	31.0
$B^- \to K^- \eta$	2.57	2.82	2.63	3.12	2.57	2.37	2.56	2.29	2.89	2.37	2.18	2.33	2.10	2.68	2.17
$B^- \to K^- \eta'$	36.7	48.6	37.1	50.6	36.8	33.7	42.9	32.0	46.9	33.8	32.5	39.8	30.8	45.4	32.5

$B \to PV$ $(b \to s)$	$\mu = m_b/2$					$\mu = m_b$					$\mu = 2m_b$				
	SM		mSUGRA			SM		mSUGRA			SM		mSUGRA		
	Br^f	Br^{f+a}	A	B	C	Br^f	Br^{f+a}	A	B	C	Br^f	Br^{f+a}	A	B	C
$B^- \to \pi^- \bar{K}^{*0}$	2.19	3.17	1.82	5.85	2.21	2.08	2.83	1.75	5.26	2.10	1.82	2.39	1.53	4.57	1.83
$B^- \to \pi^0 K^{*-}$	2.00	2.37	1.89	4.15	2.02	1.94	2.23	1.75	3.85	1.96	1.81	2.03	1.64	3.50	1.82
$\bar{B}^0 \to \pi^0 \bar{K}^{*0}$	0.33	0.49	0.42	1.45	0.33	0.30	0.42	0.22	1.24	0.30	0.24	0.33	0.17	1.03	0.24
$\bar{B}^0 \to \pi^+ K^{*-}$	1.68	2.27	1.52	4.38	1.70	1.62	2.07	1.42	3.99	1.64	1.49	1.82	1.31	3.55	1.50
$B^- \to K^- \phi$	2.73	4.08	2.37	6.06	2.75	2.46	3.47	2.14	5.31	2.47	2.04	2.79	1.77	4.49	2.05
$\bar{B}^0 \to \bar{K}^0 \phi$	2.53	3.66	2.19	5.60	2.55	2.27	3.12	2.00	4.90	2.28	1.89	2.52	1.64	4.15	1.90
$B^- \to K^- \rho^0$	1.24	1.70	2.18	0.72	1.23	1.39	1.77	1.47	0.87	1.38	1.66	2.01	1.73	1.12	1.65
$B^- \to \bar{K}^0 \rho^-$	1.92	3.08	2.16	0.55	1.91	2.14	3.07	2.34	0.89	2.13	2.58	3.29	2.76	1.39	2.57
$\bar{B}^0 \to K^- \rho^+$	4.05	5.61	4.70	2.11	4.02	4.38	5.64	4.63	2.64	4.35	4.91	5.98	5.13	3.32	4.88
$\bar{B}^0 \to \bar{K}^0 \rho^0$	2.22	3.10	2.10	1.11	2.20	2.32	3.02	2.46	1.37	2.31	2.52	3.10	2.64	1.69	2.51
$B^- \to K^- \omega$	2.43	3.14	3.46	1.43	2.41	2.33	2.87	2.45	1.51	2.32	2.51	2.95	2.61	1.76	2.50
$\bar{B}^0 \to \bar{K}^0 \omega$	1.09	1.66	1.55	0.45	1.09	0.99	1.41	1.07	0.46	0.98	1.11	1.46	1.18	0.62	1.10
$B^- \to \eta K^{*-}$	4.31	5.64	4.44	4.68	4.32	4.64	5.72	4.55	5.26	4.65	5.18	6.08	5.06	6.06	5.20
$\bar{B}^0 \to \eta \bar{K}^{*0}$	4.58	5.98	4.63	4.86	4.58	4.94	6.07	4.85	5.45	4.94	5.46	6.40	5.34	6.20	5.46
$B^- \to \eta' K^{*-}$	1.86	2.71	1.80	0.93	1.84	2.13	2.95	2.36	0.83	2.11	2.51	3.25	2.73	1.12	2.49
$\bar{B}^0 \to \eta' \bar{K}^{*0}$	1.21	1.99	1.04	0.61	1.20	1.40	2.17	1.58	0.43	1.38	1.72	2.42	1.89	0.65	1.71

$B \to VV$ $(b \to s)$	$\mu = m_b/2$				$\mu = m_b$				$\mu = 2m_b$			
	SM	mSUGRA			SM	mSUGRA			SM	mSUGRA		
	Br^f	A	B	C	Br^f	A	B	C	Br^f	A	B	C
$\bar{B}^0 \to K^{*-}\rho^+$	3.74	3.49	6.44	3.76	3.11	2.87	5.32	3.13	2.60	2.40	4.44	2.61
$\bar{B}^0 \to \bar{K}^{*0}\rho^0$	0.81	1.00	1.90	0.82	0.57	0.48	1.42	0.57	0.38	0.31	1.04	0.38
$B^- \to K^{*-}\rho^0$	4.43	4.23	6.63	4.44	3.87	3.65	5.74	3.88	3.40	3.21	5.02	3.41
$B^- \to \bar{K}^{*0}\rho^-$	5.38	4.94	9.15	5.41	4.36	4.00	7.51	4.38	3.48	3.17	6.14	3.50
$\bar{B}^0 \to \bar{K}^{*0}\omega$	2.35	1.95	3.76	2.36	1.90	1.75	3.12	1.90	1.50	1.38	2.58	1.51
$B^- \to K^{*-}\omega$	2.02	2.11	3.19	2.03	1.70	1.59	2.71	1.71	1.45	1.35	2.32	1.45
$\bar{B}^0 \to \bar{K}^{*0}\phi$	5.61	5.06	9.91	5.64	4.24	3.83	7.82	4.26	3.13	2.80	6.15	3.15
$B^- \to K^{*-}\phi$	6.09	5.49	10.76	6.12	4.60	4.16	8.50	4.63	3.40	3.04	6.68	3.42

According to the above results, one can see easily

1) the SUSY corrections to the $b \to s$ transition processes are generally larger than those to the $b \to d$ processes.

2)For most channels, μ-dependence of the results is weak in QCDF approach.

3)In Case A and C, the SUSY corrections are always small, but in case B, the results are interesting.

For $\mathrm{b} \to \mathrm{d}$ processes and in Case B, we can classify them as follows

- $\bar{B}^0 \to \pi^+\pi^-, \pi^\pm\rho^\mp, \rho^+\rho^- \quad B^- \to \pi^-\pi^0, \pi^-\eta^{(\prime)}, \pi^0\rho^-, \pi^-\rho^0, \pi^-\omega, \rho^-\eta^{(\prime)}, \rho^-\rho^0, \rho^-\omega$

  $\propto a_1 \sim 1.$ The SUSY corrections are always small in all the parameter space. In Case B, the corrections are less than 6%.

- $\bar{B}^0 \to \pi^0\pi^0, \pi^0\eta^{(\prime)}, \eta^{(\prime)}\eta^{(\prime)}, \pi^0\rho^0, \pi^0\omega, \rho^0\eta^{(\prime)}, \omega\eta^{(\prime)}, \rho^0\rho^0, \rho^0\omega, \omega\omega$。

  $\propto a_2 \sim 0.2.$ Though the size of SUSY corrections are small, the corrections may provide a large improvement to these channels, especially for $B \to \pi^0\omega$, a 130% increase.

- $\bar{B}^0 \to \pi^0\phi, \eta^{(\prime)}\phi, \rho^0\phi, \omega\phi \quad B^- \to \pi^-\phi, \rho^-\phi$

  $\propto a_{3,5,7,9}.$ The SUSY corrections in all parameter space can hardly affect them.

- $\bar{B}^0 \to \bar{K}^0K^0, \bar{K}^0K^{*0}, \bar{K}^{*0}K^{*0} \quad B^- \to K^-K^0, K^-K^{*0}, K^{*-}K^{*0}$

  $\propto (a_{4(10)} + \gamma_\chi a_{6(8)}).$ The SUSY corrections can increase their BR significantly in case B and are far larger than the annihilation contributions.

- $\bar{B}^0 \to K^0\bar{K}^{*0} \quad B^- \to K^0K^{*-}$

  $\propto (a_{4(10)} - \gamma_\chi a_{6(8)}).$ The SUSY corrections will decrease their BR greatly.

For $\mathrm{b} \to \mathrm{s}$ processes and in Case B, we can classify them as follows

- $B \to K(\pi, \eta^{(')}, \phi), K^*(\pi, \omega, \phi, \rho)$
  $\propto (a_{4(10)} + \gamma_\chi a_{6(8)})$. The SUSY corrections are large and improve their BR by about $30\% \sim 260\%$.

- $B \to K\rho, K\omega$
  $\propto (a_{4(10)} - \gamma_\chi a_{6(8)})$. Their BR will be decreased by $30\% \sim 60\%$ after the inclusion of SUSY corrections.

- $B \to K^*\eta^{(')}$
  $\propto (a_{4(10)} \pm \gamma_\chi a_{6(8)})$. For $B \to K^*\eta$ decay, the inclusion of SUSY corrections will increase their BR by about 10%. However, for $B \to K^*\eta^{'}$, their BR are decreased by about 70%

★ Results of CP violating parameters (in unit of %)

$B_u \to PP$	Type	EXP	SM		mSUGRA		
					Case A	Case B	Case C
		$\mathcal{A}_{CP}$	$\mathcal{A}_{CP}^{f}$	$\mathcal{A}_{CP}^{f+a}$	$\mathcal{A}_{CP}^{f}$	$\mathcal{A}_{CP}^{f}$	$\mathcal{A}_{CP}^{f}$
$B^{\pm} \to \pi^{\pm}\pi^{0}$	I	1 ± 6	-1.24	-1.24	-1.23	-1.29	-1.24
$B^{\pm} \to \pi^{\pm}\eta$	I	-11 ± 8	-13.0	-13.5	-13.0	-13.4	-13.0
$B^{\pm} \to \pi^{\pm}\eta'$	I	14 ± 15	-6.94	-7.71	-6.83	-7.64	-6.95
$B^{\pm} \to K^{\pm}K^{0}$	I	15 ± 33	-26.8	-24.0	-27.6	-22.0	-26.7
$B^{\pm} \to K^{\pm}\pi^{0}$	I	4 ± 4	8.28	7.45	8.70	6.09	8.26
$B^{\pm} \to K^{\pm}\eta$	I	-33 ± 12	-13.7	-12.8	-14.1	-11.5	-13.7
$B^{\pm} \to K^{\pm}\eta'$	I	3.1 ± 2.1	2.38	2.04	2.46	1.94	2.38
$B^{\pm} \to \pi^{\pm}K^{0}$	I	-2 ± 4	1.00	0.91	1.03	0.81	0.99

$B_d \to PP$	EXP		SM				mSUGRA					
							Case A		Case B		Case C	
	C_f^f	S_f^f	C_f^f	S_f^f	C_f^{f+a}	S_f^{f+a}	C_f^f	S_f^f	C_f^f	S_f^f	C_f^f	S_f^f
$B_d \to \pi^{\pm}\pi^{\mp}$	-37 ± 10	-50 ± 12	4.5	-59.8	4.4	-62.6	4.5	-59.0	4.5	-65.1	4.5	-59.9
$B_d \to \pi^0\pi^0$	$-0.28^{+0.39}_{-0.40}$	-	-55.9	68.6	-61.9	76.0	-55.6	66.2	-55.9	79.7	-55.9	68.6
$B_d \to \pi^0\eta$	-	-	34.4	-11.7	31.1	12.0	35.3	-11.9	29.2	-10.7	34.4	-11.7
$B_d \to \pi^0\eta^{'}$	-	-	35.2	30.4	30.6	51.8	36.2	31.3	29.6	25.5	35.2	30.4
$B_d \to \eta\eta$	-	-	50.2	-84.5	45.1	-86.7	50.4	-84.8	48.5	-82.2	50.2	-84.5
$B_d \to \eta\eta^{'}$	-	-	37.6	-92.6	33.8	-94.1	37.5	-92.7	37.6	-91.4	37.6	-92.6
$B_d \to \eta^{'}\eta^{'}$	-	-	27.4	-95.1	24.4	-93.1	27.3	-95.3	27.7	-93.1	27.4	-95.1
$B_d \to \bar{K}^0K^0$	-	-	26.8	-7.6	23.6	-7.0	27.6	-7.6	22.0	-7.1	26.7	-7.6
$B_d \to K_S^0\pi^0$	-2 ± 13	31 ± 26	3.8	82.3	3.4	81.8	4.0	82.5	2.8	81.4	3.77	82.3
$B_d \to K_S^0\eta$	-	-	7.09	83.0	6.65	82.7	7.31	83.1	5.94	82.4	7.08	83.0
$B_d \to K_S^0\eta^{'}$	-7 ± 7	50 ± 9	-2.03	75.3	-1.82	75.2	-2.09	75.2	-1.72	75.5	-2.03	75.3

$B_d \to PP$	Type	EXP	SM		mSUGRA		
					Case A	Case B	Case C
		$\mathcal{A}_{CP}$	$\mathcal{A}_{CP}^{f}$	$\mathcal{A}_{CP}^{f+a}$	$\mathcal{A}_{CP}^{f}$	$\mathcal{A}_{CP}^{f}$	$\mathcal{A}_{CP}^{f}$
$B_d \to \pi^{\pm}\pi^{\mp}$	II	-	-31.4	-32.7	-31.1	-33.9	-31.5
$B_d \to \pi^0\pi^0$	II	-	69.1	76.6	67.8	74.4	61.1
$B_d \to \pi^0\eta$	II	-	-28.0	-14.6	-28.7	-24.2	-28.0
$B_d \to \pi^0\eta^{'}$	II	-	-8.48	4.72	-8.70	-7.18	-8.46
$B_d \to \eta\eta$	II	-	-73.0	-70.7	-73.3	-70.8	-73.0
$B_d \to \eta\eta^{'}$	II	-	-68.6	-66.9	-68.6	-68.1	-68.6
$B_d \to \eta^{'}\eta^{'}$	II	-	-63.1	-60.2	-63.2	-62.4	-63.1
$B_d \to \bar{K}^0 K^0$	II	-	-21.0	-18.7	-21.6	-17.7	-21.0
$B_d \to K^{\pm}\pi^{\mp}$	I	-11.5 ± 1.8	5.36	4.54	5.75	3.47	5.35
$B_d \to K_s^0\pi^0$	II	-	36.7	36.7	36.7	36.9	36.7
$B_d \to K_s^0\eta$	II	-	34.9	35.0	34.8	35.4	34.9
$B_d \to K_s^0\eta^{'}$	II	-	37.2	37.0	37.2	37.1	37.2

$B_u \to PV$	Type	EXP	SM		mSUGRA		
					Case A	Case B	Case C
		$\mathcal{A}_{CP}$	$\mathcal{A}^f_{CP}$	$\mathcal{A}^{f+a}_{CP}$	$\mathcal{A}^f_{CP}$	$\mathcal{A}^f_{CP}$	$\mathcal{A}^f_{CP}$
$B^\pm \to \pi^\pm \rho^0$	I	-7^{+12}_{-13}	2.63	2.81	2.60	2.75	2.63
$B^\pm \to \pi^\pm \omega$	I	-4 ± 8	-1.51	-1.52	-1.44	-2.05	-1.52
$B^\pm \to \pi^0 \rho^\pm$	I	1 ± 11	-1.36	-1.47	-1.34	-1.46	-1.36
$B^\pm \to \rho^\pm \eta$	I	-3 ± 16	0.13	0.14	0.19	-0.35	0.12
$B^\pm \to \rho^\pm \eta^{'}$	I	-	7.35	7.49	7.41	6.79	7.64
$B^\pm \to K^\pm K^{*0}$	I	-	-52.7	-46.0	-56.7	-34.4	-52.5
$B^\pm \to K^{*\pm} K^0$	I	-	-2.55	-2.92	-2.43	-4.03	-2.56
$B^\pm \to \pi^0 K^{*\pm}$	I	4 ± 29	9.26	8.56	9.81	6.32	9.26
$B^\pm \to \pi^\pm K^{*0}$	I	-9.3 ± 6	2.01	1.71	2.19	1.27	2.00
$B^\pm \to K^\pm \phi$	I	3.7 ± 5.0	2.12	1.75	2.27	1.44	2.12
$B^\pm \to K^0 \rho^\pm$	I	-	0.12	0.16	0.12	0.19	0.12
$B^\pm \to K^\pm \rho^0$	I	31^{+12}_{-11}	-13.5	-11.6	-13.1	-17.2	-13.6
$B^\pm \to K^\pm \omega$	I	2 ± 7	-6.61	-5.90	-6.43	-8.21	-6.61
$B^\pm \to K^{*\pm} \eta$	I	3^{+11}_{-10}	3.19	2.98	3.21	3.08	3.19
$B^\pm \to K^{*\pm} \eta^{'}$	I	-	-27.5	-19.9	-25.1	-64.5	-27.7

$B_d \to PV$	EXP		SM				mSUGRA Case A		mSUGRA Case B		mSUGRA Case C	
	C_f^f	S_f^f	C_f^f	S_f^f	C_f^{f+a}	S_f^{f+a}	C_f^f	S_f^f	C_f^f	S_f^f	C_f^f	S_f^f
$B_d \to \pi^0\rho^0$	53^{+85}_{-68}		-4.47	-32.1	-3.03	-35.8	-2.94	-35.2	-15.8	-8.92	-4.55	-32.0
$B_d \to \pi^0\omega$	-	-	74.4	-62.5	94.6	32.3	73.0	-56.8	61.6	-64.9	74.4	-62.6
$B_d \to \eta\rho^0$	-	-	6.28	-29.3	1.94	-32.7	-4.51	-52.4	47.6	87.9	6.73	-28.0
$B_d \to \eta^{\prime}\rho^0$	-	-	46.5	-69.5	37.3	-63.3	44.8	-73.6	58.1	-24.6	46.6	-69.3
$B_d \to \eta\omega$	-	-	8.36	-41.5	5.48	-38.0	7.14	-39.4	16.9	-55.6	8.43	-41.5
$B_d \to \eta^{\prime}\omega$	-	-	-18.4	-28.9	-17.9	-25.5	-19.3	-27.0	-11.5	-42.9	-18.4	-29.0
$B_d \to K_s^0\phi$	-9 ± 14	47 ± 19	-2.12	76.9	-1.85	76.6	-2.27	76.9	-1.44	76.9	-2.11	76.9
$B_d \to K_s^0\rho^0$	64 ± 48	17 ± 48	-9.15	62.1	-7.91	63.8	-8.85	62.6	-12.3	57.1	-9.16	62.1
$B_d \to K_s^0\omega$	-44 ± 23	64 ± 30	9.71	89.9	8.26	87.9	9.36	89.5	13.5	93.9	9.73	90.0

Channel	Model			C_f	S_f	$C_{\bar f}$	$S_{\bar f}$
$B_d \to \pi^{\pm}\rho^{\mp}$	SM		f	19.7	-29.6	-19.1	-26.8
			$f+a$	19.6	-28.8	-19.0	-26.1
	mSUGRA	Case A	f	19.6	-29.1	-19.1	-26.3
		Case B	f	20.1	-33.5	-19.6	-30.8
		Case C	f	19.7	-29.6	-19.1	-26.9
$B_d \to K^{*0}K_s^0$	SM		f	34.4	-3.81	24.7	1.82
			$f+a$	36.7	-3.08	15.0	1.39
	mSUGRA	Case A	f	48.5	-3.09	13.6	1.62
		Case B	f	-60.9	-5.98	80.3	2.79
		Case C	f	33.7	-3.77	25.2	1.78

$B_d \to PV$	Type	EXP	SM		mSUGRA		
					Case A	Case B	Case C
		$\mathcal{A}_{CP}$	$\mathcal{A}^{f}_{CP}$	$\mathcal{A}^{f+a}_{CP}$	$\mathcal{A}^{f}_{CP}$	$\mathcal{A}^{f}_{CP}$	$\mathcal{A}^{f}_{CP}$
$\bar{B}^0_d \to \pi^+\rho^-$	III	-	-12.7	-12.4	-12.5	-14.3	-12.7
$\bar{B}^0_d \to \pi^-\rho^+$	III	-	-15.0	-14.7	-14.7	-17.2	-15.0
$B_d \to \pi^0\rho^0$	II	-	-12.4	-15.1	-14.8	6.06	-12.3
$B_d \to \pi^0\omega$	II	-	-78.3	-46.4	-74.7	-71.1	-78.4
$B_d \to \eta\rho^0$	II	-	-18.0	-16.8	-22.0	10.8	-17.7
$B_d \to \eta'\rho^0$	II	-	-63.5	-54.5	-64.3	-49.6	-63.4
$B_d \to \eta\omega$	II	-	-25.2	-21.7	-23.4	-37.5	-25.3
$B_d \to \eta'\omega$	II	-	-1.72	-0.46	-0.26	-12.9	-1.82
$\bar{B}^0_d \to K^{*0}K^0_s$	III	-	-44.1	-38.6	-45.2	-33.7	-44.1
$\bar{B}^0_d \to \bar{K}^{*0}K^0_s$	III	-	7.27	5.56	6.11	17.3	7.33
$B_d \to \pi^0\bar{K}^{*0}$	I	-1^{+27}_{-26}	-15.4	-12.9	-18.1	-7.34	-15.3
$B_d \to \pi^\mp K^{*\pm}$	I	-5 ± 14	-0.32	-0.37	-0.28	-0.26	-0.22
$B_d \to K^0_s\phi$	II	-	38.0	37.7	38.1	37.6	38.0
$B_d \to K^\pm\rho^\mp$	I	17^{+15}_{-16}	-4.51	-3.25	-4.20	-8.18	-4.52
$B_d \to K^0_s\rho^0$	II	-	35.5	35.5	35.6	19.2	35.5
$B_d \to K^0_s\omega$	II	-	36.5	36.5	36.5	35.9	36.5
$B_d \to \eta\bar{K}^{*0}$	I	-1 ± 8	4.93	4.45	4.97	4.69	4.93
$B_d \to \eta'\bar{K}^{*0}$	I	-	-11.2	-8.15	-10.4	-23.8	-11.3

$B \to VV$	Type	EXP	SM	mSUGRA Case A	mSUGRA Case B	mSUGRA Case C
		$\mathcal{A}_{CP}$	$\mathcal{A}^f_{CP}$	$\mathcal{A}^f_{CP}$	$\mathcal{A}^f_{CP}$	$\mathcal{A}^f_{CP}$
$B^- \to \rho^- \rho^0$	I	-9 ± 16	-0.16	-0.16	-0.16	-0.16
$B^- \to \rho^- \omega$	I	5 ± 26	-5.60	-5.54	-5.99	-5.61
$B^- \to \rho^- \phi$	I	-	-2.29	-2.29	-2.29	-2.29
$B^- \to K^{*-} K^{*0}$	I	-	-28.2	-29.4	-21.6	-28.2
$B_d \to K^{*-} \rho^+$	I	-	17.8	19.3	10.5	17.8
$B_d \to \bar{K}^{*0} \rho^0$	I	-	-21.1	-23.4	-11.9	-21.0
$B^- \to K^{*-} \rho^0$	I	20^{+32}_{-29}	18.7	19.6	13.8	18.7
$B^- \to \bar{K}^{*0} \rho^-$	I	-14 ± 43	1.57	1.63	1.25	1.57
$B_d \to \bar{K}^{*0} \omega$	I	-	12.8	13.4	9.68	12.8
$B^- \to K^{*-} \omega$	I	-	32.5	34.3	22.4	32.5
$B_d \to \bar{K}^{*0} \phi$	I	0 ± 7	1.75	1.81	1.38	1.75
$B^- \to K^{*-} \phi$	I	5 ± 11	1.75	1.81	1.38	1.75
		C_f	C_f	C_f	C_f	C_f
$B_d \to \rho^+ \rho^-$	II	-3 ± 17	1.79	1.79	1.74	1.79
$B_d \to \rho^0 \rho^0$	II	-	-33.3	-31.6	-43.6	-33.4
$B_d \to \rho^0 \omega$	II	-	32.1	33.9	23.2	32.0
$B_d \to \omega\omega$	II	-	45.4	44.6	49.9	45.5
$B_d \to \rho^0 \phi$	II	-	2.29	2.29	2.29	2.29
$B_d \to \omega\phi$	II	-	2.30	2.30	2.30	2.30
$B_d \to \bar{K}^{*0} K^{*0}$	II	-	28.2	29.4	21.6	28.2

From the results of CPV parameters given above, one can see also in Case B the corrections can be interesting for most channels:

- For $B_{u,d} \to PP$ decays, the SUSY corrections are generally small or moderate and trend to make the SM predictions decreased. The largest correction is about -33% for $B_d \to \pi^{\pm} K^{\mp}$ decays;
- For $B_{u,d} \to PV$ decays, the SUSY corrections on the direct or indirect CP violations of most channels can be rather large. The largest corrections even reach a factor of 7 for the DCPV of $B^0 \to \eta\rho^0$, about 253% increase for $B^0 \to \pi^0\rho^0$ and 100% enhancement for $B^0 \to \eta\omega$;
- For $B \to VV$ decays, the SUSY corrections make most channels, such as $B \to K^*\rho$, K^*K^*, $K^*\omega$, $K^*\phi$ and $\rho^0\omega$, have a smaller CPV than those in SM. For $\bar{B}^0 \to \bar{K}^{*0}\rho^0$, the corrections can even reach -44%. But for $B \to \rho^{\pm}\omega$, $\rho^0\rho^0$ and $\omega\omega$, their CP violations are increased, especially for $B^0 \to \rho^0\rho^0$ which is increased by about 30%.

Discussion

- Only in the parameter space where $C_{7\gamma}(m_b)$ has a flipped sign with the SM one, can the SUSY contributions be significant.
- For BR, the SUSY contributions to some channels can improve the consistency of the theoretical predictions, especially the center values, with the data.
- For $B \to K(\pi, \eta^{(\prime)}, \phi), K^*(\pi, \omega, \phi, \rho)$ decays, though their BR are sensitive to the large SUSY contributions, the theoretical errors coming from χ_A, the form factor and the light mass prevent us from testing the SUSY signals. Taking $B \to \pi^\pm K^\pm$ as an example,

$$Br(B^- \to \pi^- \overline{K}^0) = \begin{cases} 14.6\ ^{+5.4}_{-4.6}(F_0)\ ^{+4.4}_{-2.8}(\bar{m}_s)\ ^{+9.7}_{-4.1}(\chi_A), & \text{SM}, \\ 21.0\ ^{+7.9}_{-6.6}(F_0)\ ^{+5.7}_{-3.6}(\bar{m}_s)^{+11.5}_{-5.0}(\chi_A), & \text{Case}-\text{B}, \end{cases}$$

- For CPV, though no new weak phase is introduced in the mSUGRA model, the SUSY contributions to most channels still can be significant.

- With large SUSY contributions added, for $B^0 \to \eta\rho^0$, C_f can be increased from 0.06 to 0.48. Except this channel has small BR ($\sim 10^{-8}$) and is hard for experiments to measure, it may be significative for testing the SUSY signals.
- For the very interesting channel, $B \to \pi^\pm K^\mp$ which has been proved to have large DCPV, with a -33% decrease from the SUSY corrections, A_{CP} still has a different sign with the data.

Currently, the experimental data are not precise enough, and the theory is still immature. Therefore, Great progress in both the theory and experiment is still expected for us to draw a conclusion.

Thank you!