MSSM and B physics

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Fourth Mass Origin Workshop, Tsukuba, 8Mar2006

Based on

- P. Ko, G. Kramer, J.-h. Park, EPJC25(2002)
- G. L. Kane, P. Ko, C. Kolda, J.-h. Park, Haibin Wang, Lian-Tao Wang, PRL90(2003), PRD70(2004)
- P. Ko, A. Masiero, J.-h. Park, PRD72(2005).

CKM matrix

- Mixing matrix connecting weak interaction eigenstates and mass eigenstates of quarks.

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

- CKM matrix is hierarchical and has one CP phase.

$$V = \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix}$$

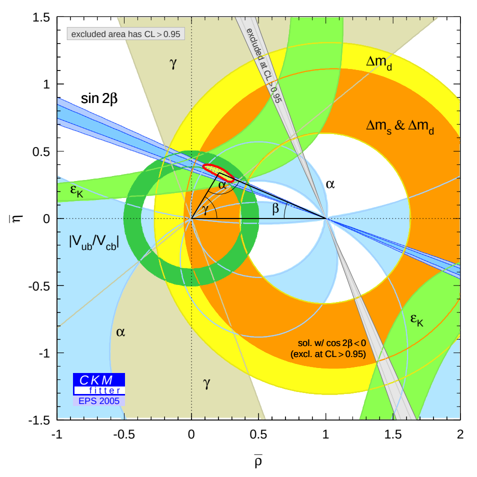
- Unitarity condition, $V^\dagger V = VV^\dagger = \mathbf{1}$, yields unitarity triangles.

Unitarity triangle on the (ρ, η) plane

- SM fit of (ρ, η)
- In the presence of new physics, constraints on (ρ, η) coming from loop level processes such as $\varepsilon_K, \Delta m_d$, and Δm_s, may be weaker.

  $\longrightarrow$

  γ-as-a-free-variable strategy.
- γ is not longer free even with loop level new physics due to constraints from $B \to DK$. $\gamma(DK) = (63^{+15}_{-13})^\circ$.



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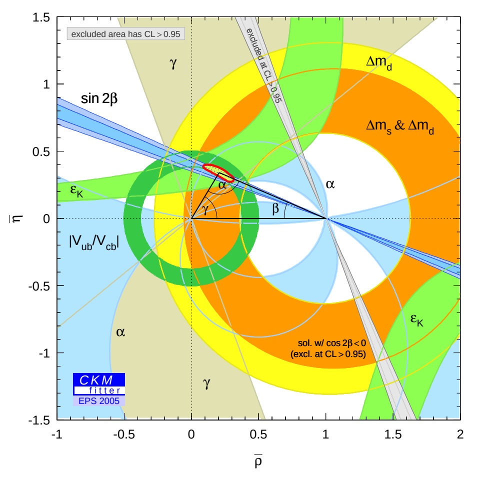

SUSY FCNC/CP problem

- Many of soft SUSY breaking parameters are complex and flavor violating, and a generic supersymmetric standard model results in huge flavor and CP violation.
- There should be a mechanism which controls FCNC and CP. This may be due to the SUSY breaking/mediation mechanism and/or flavor symmetry. We can get a clue to these mechanisms by studying FCNC and CP violation in supersymmetric models.
- Mass insertion approximation is a useful tool to present flavor violation through sfermions.

  $(\delta^d_{12})_{LL}$: dimensionless transition strength from $\widetilde{s}_L$ to $\widetilde{d}_L$.

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Weak effective Hamiltonian

$$H_{\text{eff}}^{\Delta B=1} = \sum_{p=u,c} \left[C_1^p O_1^p + C_2^p O_2^p\right] + \sum_{i=3}^{6} C_i O_i + C_{7\gamma} O_{7\gamma} + C_{8g} O_{8g} + \text{h.c.}$$

- Current-current operators

$$O_1^p = (\bar{p}b)_{V-A}(\bar{s}p)_{V-A}$$
$$O_2^p = (\bar{p}_\alpha b_\beta)_{V-A}(\bar{s}_\beta p_\alpha)_{V-A}$$

- QCD penguin operators

$$O_3 = (\bar{s}b)_{V-A} \sum_q (\bar{q}q)_{V-A}$$
$$O_4 = (\bar{s}_\alpha b_\beta)_{V-A} \sum_q (\bar{q}_\beta q_\alpha)_{V-A}$$
$$O_5 = (\bar{s}b)_{V-A} \sum_q (\bar{q}q)_{V+A}$$
$$O_6 = (\bar{s}_\alpha b_\beta)_{V-A} \sum_q (\bar{q}_\beta q_\alpha)_{V+A}$$

- (Chromo)magnetic penguin operators

$$O_{7\gamma} = -\frac{e}{8\pi^2} m_b \bar{s} \sigma_{\mu\nu}(1+\gamma_5) F^{\mu\nu} b$$
$$O_{8g} = -\frac{g_s}{8\pi^2} m_b \bar{s} \sigma_{\mu\nu}(1+\gamma_5) G^{\mu\nu} b$$

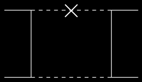
Gluino-squark loop contributions to Wilson coefficients

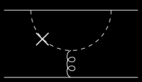
Gabbiani, Gabrielli, Masiero, Silvestrini, NPB(1996)
With S. Baek, J. H. Jang, P. Ko, NPB(2001)

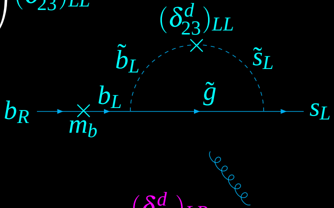
Beware typos.

- QCD penguin operators

$$C_{3,\ldots,6} = -\frac{\alpha_s^2}{4\widetilde{m}^2}\left(\quad \cdots \quad + \quad \cdots \quad \right)(\delta_{23}^d)_{LL}$$



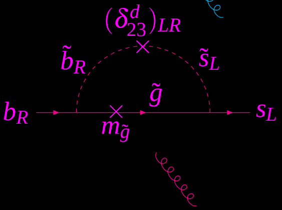




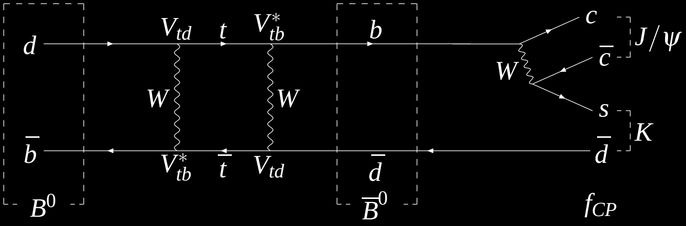
- Magnetic operators

$$C_{7\gamma} = -\frac{4\pi Q_b \alpha_s}{3\widetilde{m}^2}\left[(\delta_{23}^d)_{LL} M_4(x) - (\delta_{23}^d)_{LR}\left(\frac{m_{\tilde{g}}}{m_b}\right) 4B_1(x)\right],$$

$$C_{8g} = -\frac{\pi\alpha_s}{\widetilde{m}^2}\left[(\delta_{23}^d)_{LL}\left(\frac{3}{2}M_3(x) - \frac{1}{6}M_4(x)\right) + (\delta_{23}^d)_{LR}\left(\frac{m_{\tilde{g}}}{m_b}\right)\frac{1}{6}\left(4B_1(x) - 9x^{-1}B_2(x)\right)\right]$$



Overview of CP violation in B system



- Time dependent CP asymmetry

$$\mathscr{A}_{CP}(t) \equiv \frac{\Gamma(\overline{B^0}(t) \to f_{CP}) - \Gamma(B^0(t) \to f_{CP})}{\Gamma(\overline{B^0}(t) \to f_{CP}) + \Gamma(B^0(t) \to f_{CP})} = -C_{f_{CP}} \cos(\Delta m_d t) + S_{f_{CP}} \sin(\Delta m_d t),$$

$$C_{f_{CP}} = \frac{1 - |\lambda_{f_{CP}}|^2}{1 + |\lambda_{f_{CP}}|^2}, \quad S_{f_{CP}} = \frac{2\,\mathrm{Im}\lambda_{f_{CP}}}{1 + |\lambda_{f_{CP}}|^2}, \quad \lambda_{f_{CP}} \equiv \mp e^{-2i(\beta+\theta_d)} \frac{\overline{A}(\overline{B^0} \to f_{CP})}{A(B^0 \to f_{CP})}$$

- B^0–$\overline{B^0}$ mixing $\quad 2m_B M_{12} \equiv \langle \overline{B^0} | H_{\rm eff}^{\Delta B=2} | B^0 \rangle = \frac{1}{2} \Delta m_d \, e^{-i2(\beta+\theta_d)}$

Outline

1. B^0–$\overline{B^0}$ mixing, $B \to J/\psi K_S$, $B \to X_d \gamma$ in general MSSM
2. $B_d \to \phi K_S$ CP asymmetries as a probe of SUSY
3. $B_d \to \phi K_S$ CP asymmetry and $\varepsilon'/\varepsilon_K$
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Possible SUSY effects on $b \to d$ transitions

With P. Ko, G. Kramer, EPJC(2002)

- Mass insertion approximation with $m_{\tilde{g}} = \widetilde{m} = 500$ GeV
- Scan over one of δ_{13}^d's as well as γ.
- Constraints

$$\Delta m_d = (0.472 \pm 0.017)\ \mathrm{ps}^{-1}, \quad \sin 2\beta_{J/\psi} = 0.79 \pm 0.10,$$
$$\underline{B(B \to X_d \gamma) < 1 \times 10^{-5}}$$

- Predictions

$$A_{ll} \equiv \frac{N(BB) - N(\overline{B}\overline{B})}{N(BB) + N(\overline{B}\overline{B})} \approx \mathrm{Im}\left(\frac{\Gamma_{12} \approx \Gamma_{12}^{\mathrm{SM}}}{M_{12}^{\mathrm{SM}} + M_{12}^{\mathrm{SUSY}}} \right)$$
$$A_{\mathrm{CP}}^{b \to d\gamma} \equiv \frac{\Gamma(B \to X_d \gamma) - \Gamma(\overline{B} \to \overline{X_d} \gamma)}{\Gamma(B \to X_d \gamma) + \Gamma(\overline{B} \to \overline{X_d} \gamma)}$$

- Consider two cases: Single $(\delta_{13}^d)_{LL}$ insertion, Single $(\delta_{13}^d)_{LR}$ insertion.

LL insertion

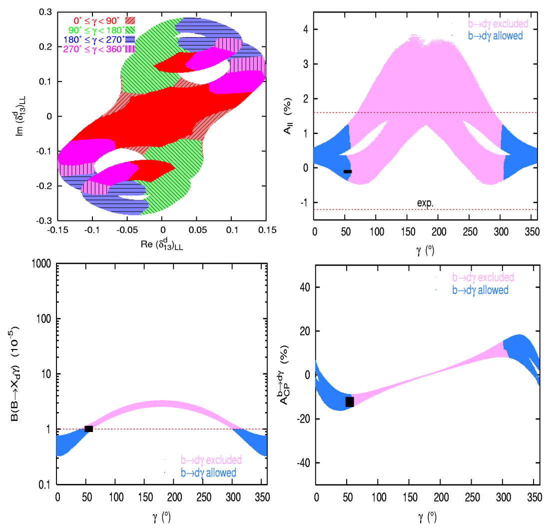
- Hatched region for

$$B(B \to X_d\,\gamma) > 1 \times 10^{-5}.$$

- A_{ll} can have sign opposite to that of SM value.
- $B \to X_d\,\gamma$ strongly constrains $|(\delta^d_{13})_{LL}| \lesssim 0.2$

$$\rightsquigarrow \quad -60^\circ \lesssim \gamma \lesssim 60^\circ.$$

- Imposing $B(B \to X_d\,\gamma) > 1 \times 10^{-6}$ does not make any difference.



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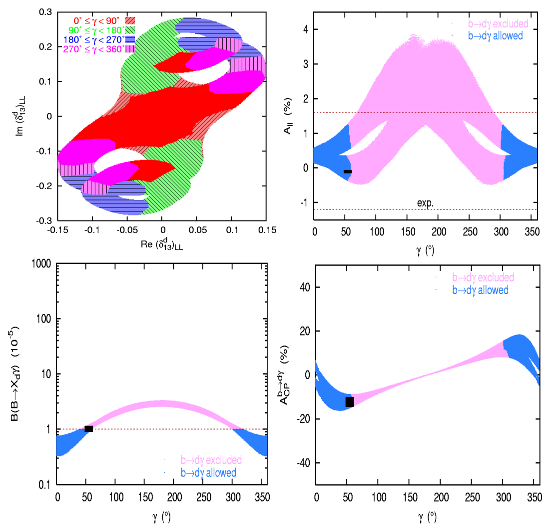

LR insertion

- Hatched region for

$$B(B \to X_d\gamma) > 1 \times 10^{-5}.$$

- Not much effect on A_{ll}.
- $B \to X_d\gamma$ even more strongly constrains $|(\delta^d_{13})_{LR}| \lesssim 10^{-2}$

$$\rightsquigarrow \; 30^\circ \lesssim \gamma \lesssim 80^\circ.$$

- Nevertheless,

$$-25\% \lesssim A_{\rm CP}^{b\to d\gamma} \lesssim +30\%.$$

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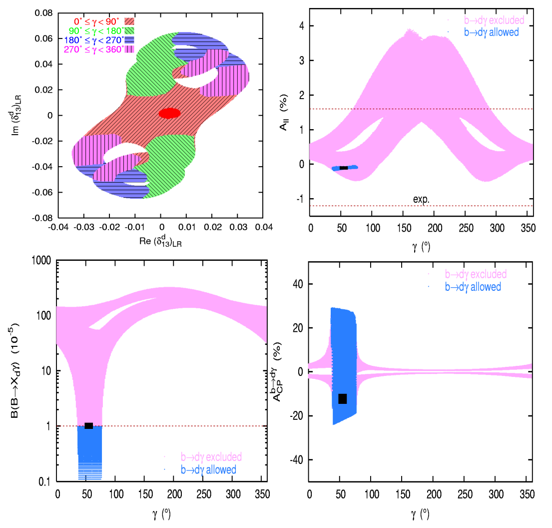

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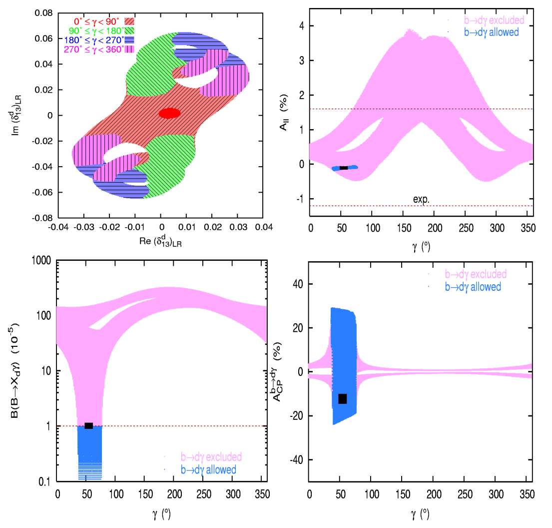

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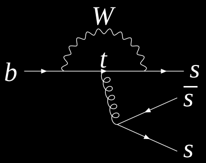
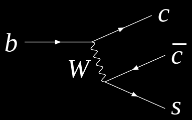
Why $B_d \to \phi K_S$?

- Absence of tree level diagram in the Standard Model
  $\longrightarrow$ Sensitive to New Physics.



+ New Physics at one loop

- Compare $B_d \to J/\psi K_S$:



CPV measurements did not agree with SM very well

- SM prediction

$$\lambda_{\phi K}^{\text{SM}} = -e^{-2i\beta},$$
$$C_{\phi K}^{\text{SM}} = \frac{1-|\lambda_{\phi K}^{\text{SM}}|^2}{1+|\lambda_{\phi K}^{\text{SM}}|^2} = 0,$$
$$S_{\phi K}^{\text{SM}} = \frac{2\,\text{Im}\lambda_{\phi K}^{\text{SM}}}{1+|\lambda_{\phi K}^{\text{SM}}|^2} = \sin 2\beta = 0.734 \pm 0.054$$

- Measurements

	$S_{\phi K}$	$C_{\phi K}$
BaBar[1]	$+0.45 \pm 0.43 \pm 0.07$	$-0.38 \pm 0.37 \pm 0.12$
Belle[2]	$-0.96 \pm 0.50^{+0.09}_{-0.11}$	$+0.15 \pm 0.29 \pm 0.07$
Average	-0.15 ± 0.33	-0.05 ± 0.24
Avg. – SM	-2.7σ	-0.2σ

[1] T. Browder, Talk at LP03.

[2] Belle Collaboration, PRL91(2003)

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- Measurements

	$S_{\phi K}$	$C_{\phi K}$
BaBar[1]	$+0.50 \pm 0.25^{+0.07}_{-0.04}$	$0.00 \pm 0.23 \pm 0.05$
Belle[2]	$+0.44 \pm 0.27 \pm 0.05$	$-0.14 \pm 0.17 \pm 0.07$
Average	$+0.47 \pm 0.19$	-0.09 ± 0.14
Avg. – SM	$-1.1\ \sigma$	$-0.6\ \sigma$

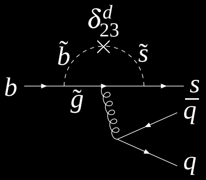
[1] BABAR Collaboration, PRD(2005)
[2] Belle Collaboration, hep-ex/0507037

Strange-beauty squark scenario

- New Physics in the decay amplitude

$$\lambda_{\phi K} \equiv -e^{-2i\beta} \boxed{\frac{\overline{A}(\overline{B^0} \to \phi K_S)}{A(B^0 \to \phi K_S)}}$$

- Gluino-squark loops



, $q = u, d, s, c, b$ $\quad + \quad$ boxes

- Four types of mass insertions:

$$\delta^d_{23} = (\delta^d_{23})_{LL}, (\delta^d_{23})_{RR}, (\delta^d_{23})_{LR}, (\delta^d_{23})_{RL}.$$

Numerical analysis of gluino-squark loops

With G. L. Kane, P. Ko, C. Kolda, Haibin Wang, Lian-Tao Wang, PRL(2003), PRD(2004)

- Mass insertion approximation with $m_{\tilde{g}} = \widetilde{m} = 400$ GeV
- QCD factorization for hadronic matrix elements

Beneke, Buchalla, Neubert, Sachrajda

- Scan over one of δ^d_{23}'s such that

$$2.0 \times 10^{-4} < B(B \to X_s \gamma) < 4.5 \times 10^{-4}, \quad \Delta M_s > 14.9 \text{ ps}^{-1}$$

A. Stocchi, hep-ph/0010222

LL or RR for large B_s–$\overline{B}_s$ mixing

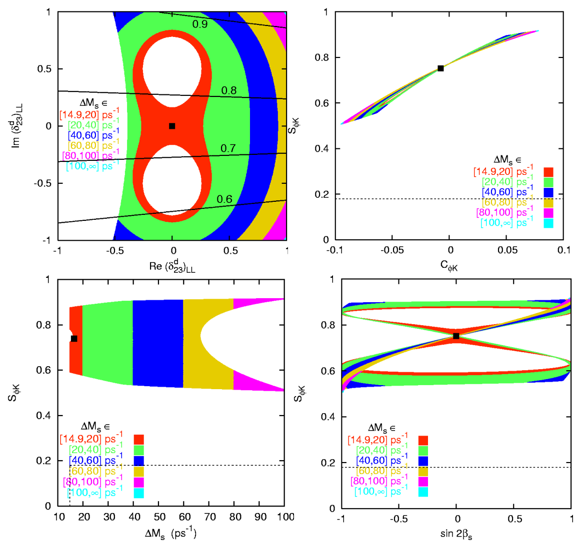
- LL plots for

$$m_{\tilde{g}} = \tilde{m} = 400 \text{ GeV}.$$

- $(\delta^d_{23})_{LL}$ can not significantly lower $S_{\phi K}$.

$$S_{\phi K} \gtrsim 0.05 \quad \text{for}$$
$$m_{\tilde{g}} = \tilde{m} = 250 \text{ GeV}.$$

- But large effects possible in B_s–$\overline{B}_s$ mixing
- RR is similar to LL except for $B \to X_s\gamma$.



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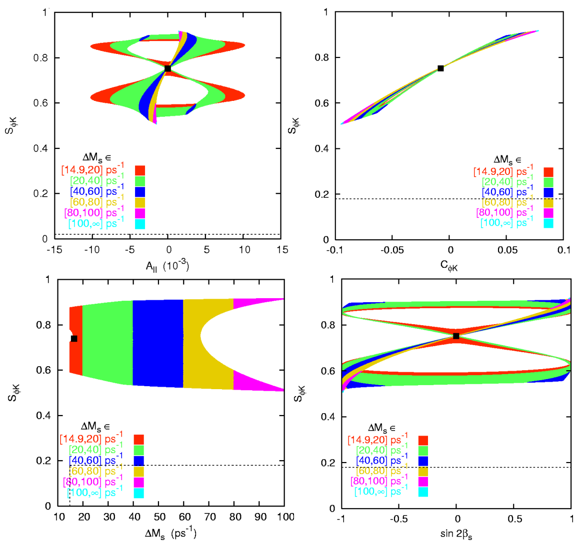
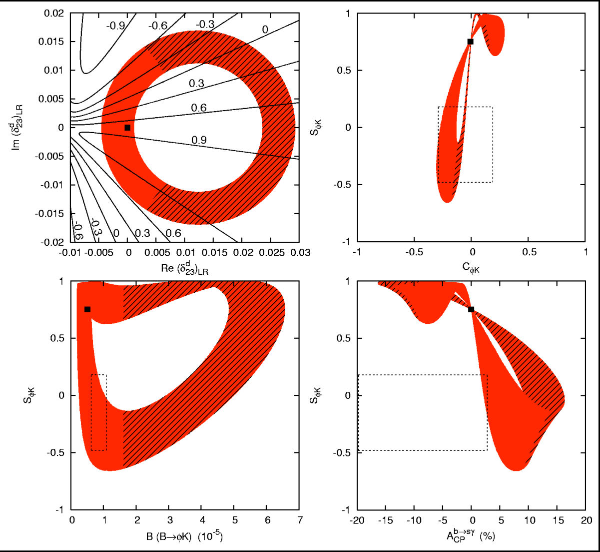


LR or RL for big change of $S_{\phi K}$

- LR plots for

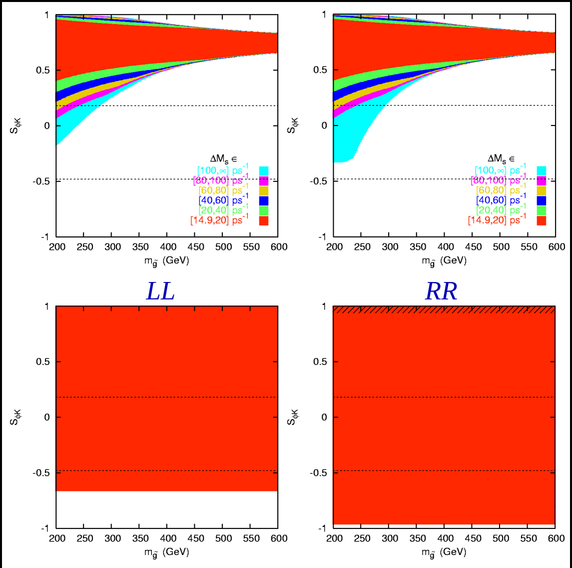
$$m_{\tilde{g}} = \tilde{m} = 400 \text{ GeV}.$$

- $-0.6 < S_{\phi K} < 1$ for $|(\delta^d_{23})_{LR}| \sim 10^{-2}$.
- Correlations between $S_{\phi K}$ and $C_{\phi K}$, $S_{\phi K}$ and $A_{\rm CP}^{b\to s\gamma}$.
- Hatched region for $B(B \to \phi K) > 1.6 \times 10^{-5}$.
- Not much effect on B_s–$\overline{B}_s$ mixing.



Sparticle mass dependence

- Allow $|\delta^d_{23}| < 1$ consistent with $B(B \to X_s \gamma)$. Fix $\frac{m^2_{\tilde{g}}}{\tilde{m}^2} = 1$.
- For LL or RR, SUSY effect rapidly decouples as $\tilde{m}$ increases.
- For LR or RL, SUSY effect remains constant.



LL RR

LR RL dominance

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RR insertion is well motivated

- Sizeable $\tilde{s}_R$–$\tilde{b}_R$ mixing is expected in SUSY SU(5) with right-handed neutrinos.

Moroi, PLB(2000)

- Also in SUSY SO(10).

Chang, Masiero, Murayama, PRD(2003)

- U(1) flavor symmetry + SUSY may lead to large $\tilde{s}_R$–$\tilde{b}_R$ mixing.

Chua, Hou, PRL(2001)

Chua, Hou, Nagashima, PRL(2004)

$RR + RL$ double insertion greatly affects $S_{\phi K}$

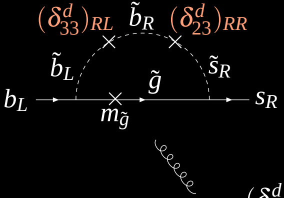
Harnik, Larson, Murayama, PRD(2004)

- For large $\tan\beta$, an induced RL insertion can give significant (chromo)magnetic contributions.

Gabbiani, Masiero, NPB(1989)

With Baek, Jang, Ko, PRD(2000)

- This mechanism was used to explain $S_{\phi K}^{\rm exp} < S_{\phi K}^{\rm SM}$.



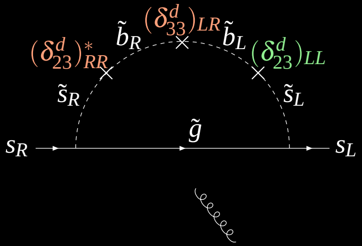
$$\propto (\delta^d_{23})_{RR}(\delta^d_{33})_{RL} \times \frac{m_{\tilde{g}}}{m_b}$$

$$(\delta^d_{33})_{RL} \equiv \frac{m_b(A_b - \mu^* \tan\beta)}{\widetilde{m}^2}$$

Strange quark chromoEDM

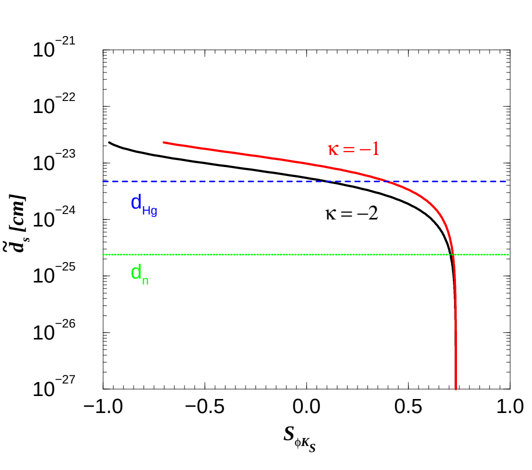
Hisano, Shimizu, PLB(2004)

- LL insertions are generically expected, e.g., from RG running.
- $(\delta^d_{23})_{LL}$ can complete a diagram for strange quark chromoEDM.



Hadronic EDM constraints

- Correlation between strange quark CEDM $\tilde{d}_s$ and $S_{\phi K}$ for $(\delta^d_{23})_{LL} = -0.04$.
- Lines are the upper bound on $\tilde{d}_s$ from ^{199}Hg and neutron EDM.
- κ parameterizes uncertainty in $\widetilde{O}_{8g}$ matrix element.
- $S_{\phi K}$ strongly restricted around the SM value.



Hisano, Shimizu, PRD70(2004)

$B_d \to \eta' K_S$ CP asymmetry

- Parity transformation results in

$$\left.\frac{A^{\rm SUSY}}{A^{\rm SM}}\right|_{\phi K_S} \simeq (0.23+0.04i)[(\delta^d_{23})_{LL}+(\delta^d_{23})_{RR}]+(95+14i)[(\delta^d_{23})_{LR}+(\delta^d_{23})_{RL}]$$

$$\left.\frac{A^{\rm SUSY}}{A^{\rm SM}}\right|_{\eta' K_S} \simeq (0.23+0.04i)[(\delta^d_{23})_{LL}-(\delta^d_{23})_{RR}]+(99+15i)[(\delta^d_{23})_{LR}-(\delta^d_{23})_{RL}]$$

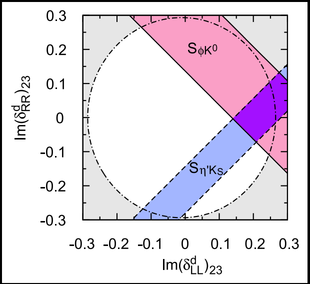
Kagan, Talk at BCP2

Khalil, Kou, PRL(2003)

- Contours of $S_{\phi K}$ and $S_{\eta' K}$ on $({\rm Im}(\delta^d_{23})_{LL},\ {\rm Im}(\delta^d_{23})_{RR})$ plane for $\widetilde{m} = m_{\tilde{g}} = 500$ GeV, $\mu \tan\beta = 5$ TeV.

  Data favors LL insertion.

  Endo, Mishima, Yamaguchi, PLB(2005) $\longrightarrow$



- But, right-handed new physics remains strangely beautiful.

Larson, Murayama, Perez, JHEP(2005)

$S_{\phi K}$ and $\varepsilon'/\varepsilon_K$

With P. Ko, A. Masiero, PRD(2005)

- Generically we expect $(\delta^d_{13})_{LL} \sim \lambda^3 \sim 8 \times 10^{-3}$.
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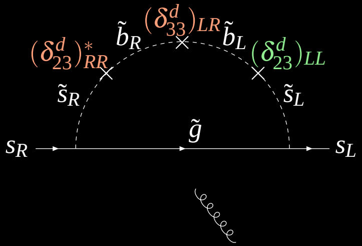

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  Gabbiani, Gabrielli, Masiero, Silvestrini, NPB(1996)
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  With Kane, Ko, Kolda, Wang×2, PRD(2004)
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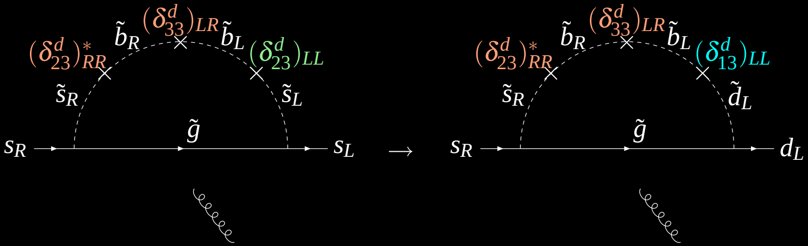

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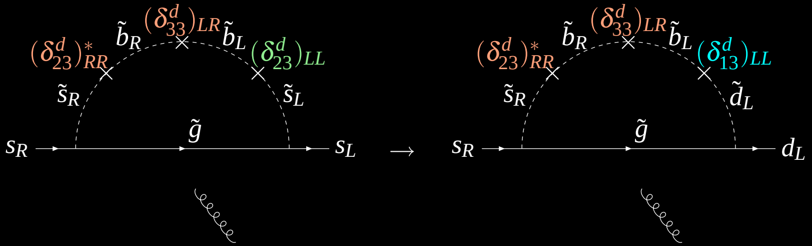

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Numerical analysis

- $\Delta S = 1$ effective Hamiltonian

$$O_{8g} = -\frac{g_s}{8\pi^2} m_s \bar{d}\,\sigma_{\mu\nu}(1+\gamma_5) G^{\mu\nu} s$$

$$C_{8g} = \frac{\pi\alpha_s}{\widetilde{m}^2}\frac{m_{\tilde{g}}}{m_s}\left[\frac{1}{6}N_1(x) + \frac{3}{2}N_2(x)\right](\delta^d_{13})_{LL}(\delta^d_{33})_{LR}(\delta^d_{32})_{RR}$$

- Fix $\quad (\delta^d_{13})_{LL} = 8\times 10^{-3}\times e^{-2.7i}, \quad \widetilde{m} = m_{\tilde{g}} = 500$ GeV.
- Scan over

$$-1 \le \mathrm{Re}(\delta^d_{23})_{RR},\ \mathrm{Im}(\delta^d_{23})_{RR} \le 1$$

imposing

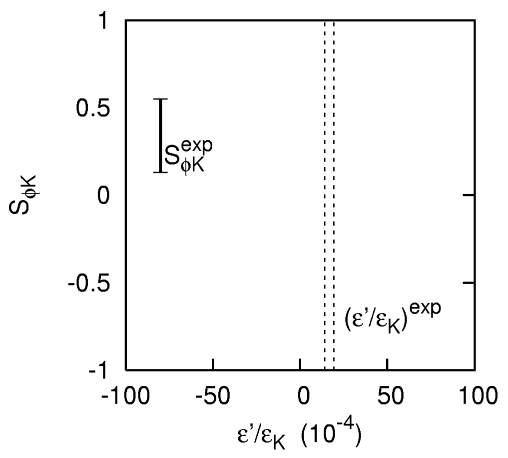
$$2.0\times 10^{-4} \le B(B\to X_s\gamma) \le 4.5\times 10^{-4},$$

$$\Delta M_s \ge 14.9\ \mathrm{ps}^{-1}.$$

Result for $\mu \tan\beta = 5$ TeV

- Correlation between $S_{\phi K}$ and $\varepsilon'/\varepsilon_K$.
- $0.25 < S_{\phi K} < 1$ for $\varepsilon'/\varepsilon_K = (16.7 \pm 2.6) \times 10^{-4}$.

  PDG 2004



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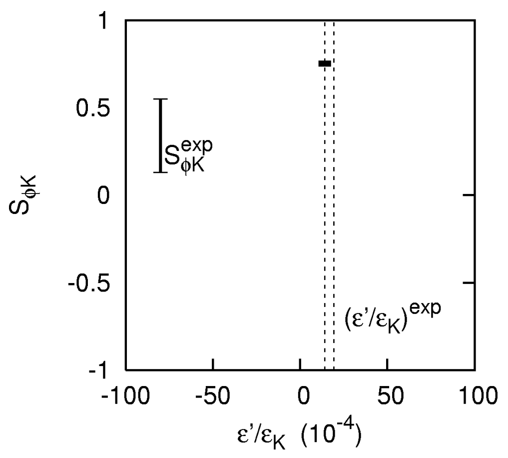

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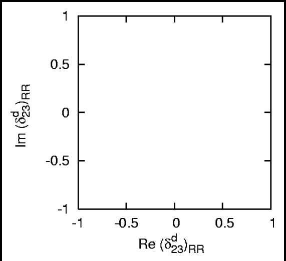
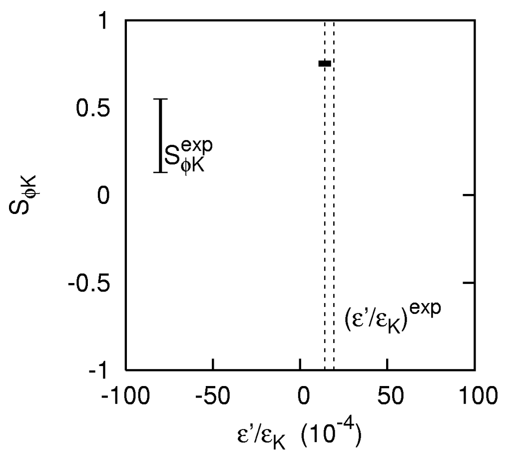
SUSY contribution





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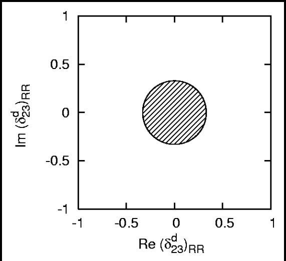
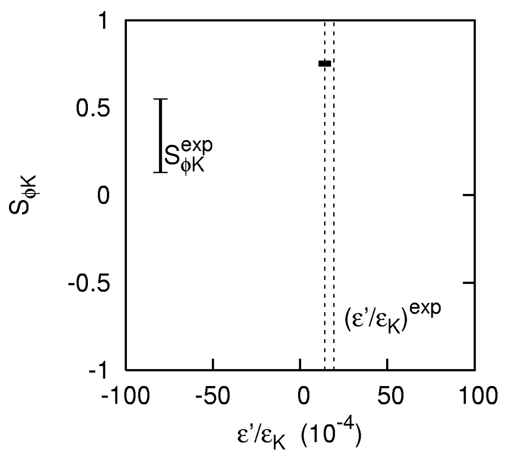
$B(B \to X_s \gamma)$ constraint





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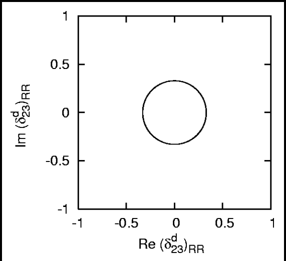

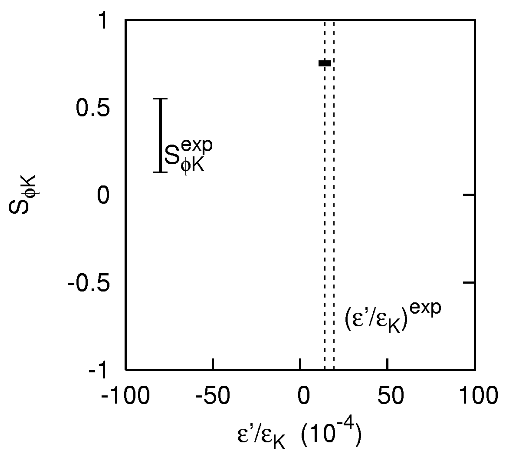

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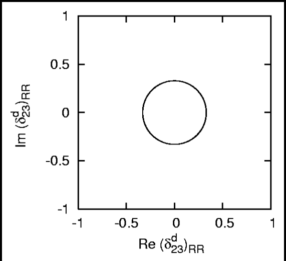

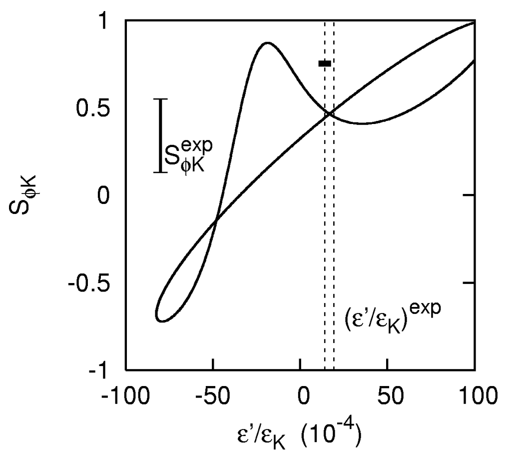

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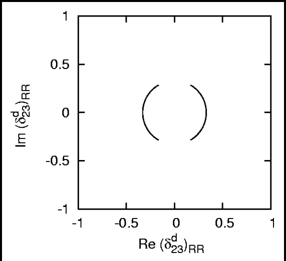
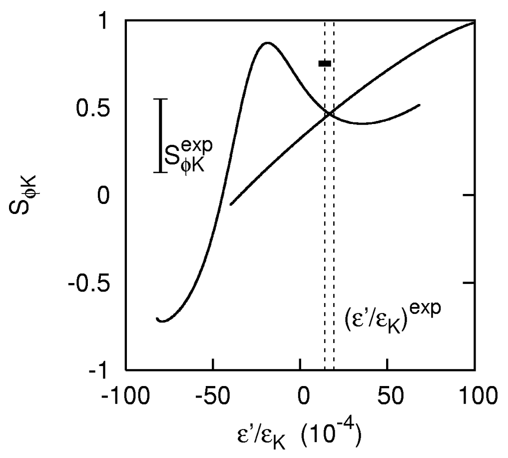
ΔM_s constraint





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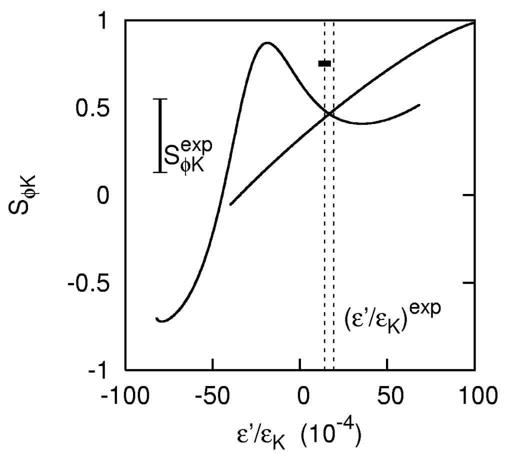

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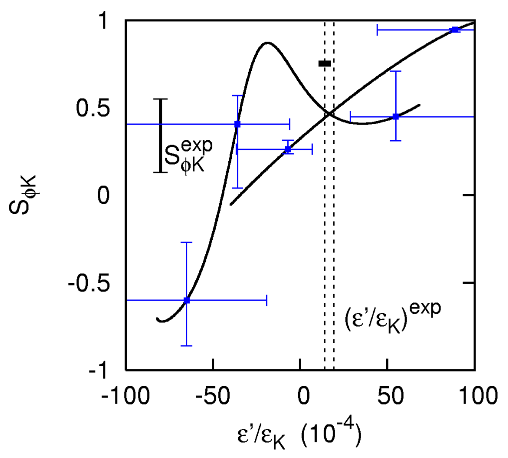
  PDG 2004

Hadronic uncertainties



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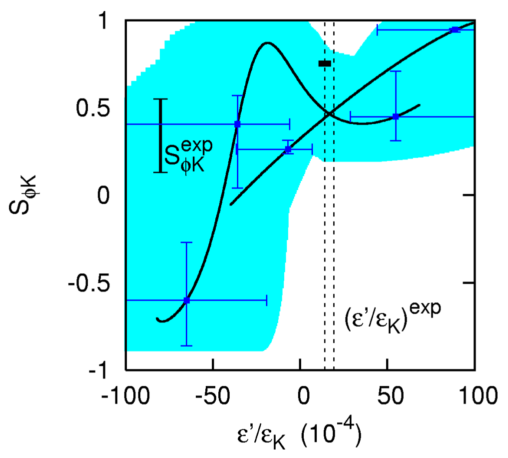

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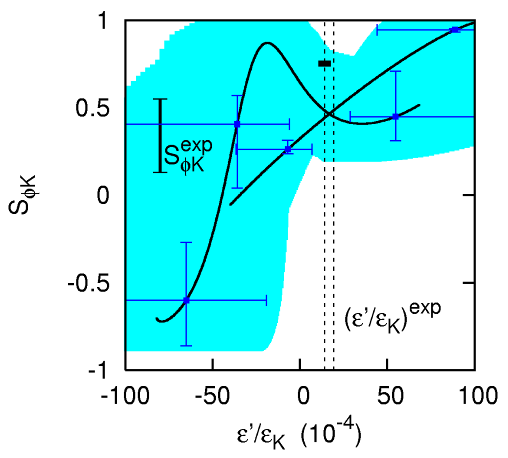

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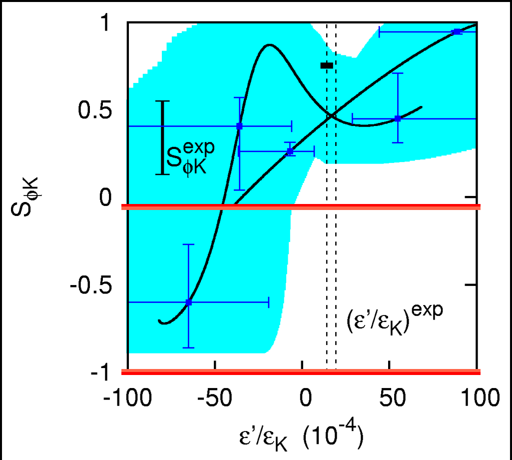
Old Belle data excludes this scenario

hep-ex/0207098



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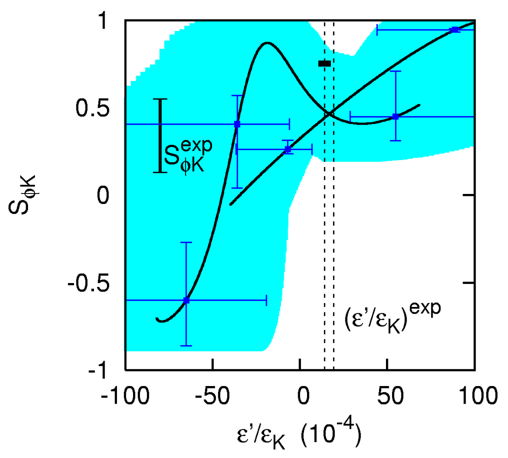
For $S_{\eta' K}$, do
$(\varepsilon'/\varepsilon_K)_{\mathrm{SUSY}} \to -(\varepsilon'/\varepsilon_K)_{\mathrm{SUSY}}$



Outline

1. B^0–$\overline{B^0}$ mixing, $B \to J/\psi K_S$, $B \to X_d \gamma$ in general MSSM
2. $B_d \to \phi K_S$ CP asymmetries as a probe of SUSY
3. $B_d \to \phi K_S$ CP asymmetry and $\varepsilon'/\varepsilon_K$
4. Summary

Summary

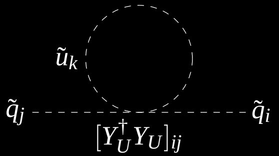
- $B \to X_d \gamma$ strongly constrains $(\delta^d_{13})_{LL}$ and $(\delta^d_{13})_{LR}$. Still, its direct CP asymmetry can be very different from the SM value.
- $S_{\phi K}$ is more sensitive to $(\delta^d_{23})_{LR}$ or $(\delta^d_{23})_{RL}$ than $(\delta^d_{23})_{LL}$ or $(\delta^d_{23})_{RR}$. $(\delta^d_{23})_{LL}$ or $(\delta^d_{23})_{RR}$ can lead to large B_s–$\overline{B}_s$ mixing.
- CPV in $b \to s$ transitions such as $S_{\phi K}$ can be related to $\varepsilon'/\varepsilon_K$ in an RR mixing scenario.

An example setup

- SU(5) GUT + right-handed neutrinos.
- Seesaw mechanism.
- Universal boundary conditions at M_*.
- Neutrino mass spectrum with normal hierarchy.
- Hierarchical neutrino Yukawa coupling eigenvalues.
  $\rightarrow$ Small $(\delta^d_{12})_{RR}$, $(\delta^d_{13})_{RR}$.
  $\rightarrow$ Clear correlation between $\varepsilon'/\varepsilon_K$ and $S_{\phi K}$.
- M_N and Y_ν diagonalized simultaneously.
- (Moderately) high $\tan\beta$.

Radiative generation of sflavor mixing

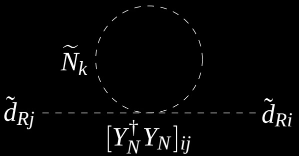
- Left-handed squark mixings



$$\rightsquigarrow \boxed{(\delta_{ij}^d)_{LL} \sim V_{ti}^* V_{tj}}$$

$$(m_{\tilde{q}}^2)_{ij} \simeq -\frac{1}{8\pi^2}[V^\dagger \lambda_u^2 V]_{ij}(3m_0^2 + A^2)\left(3\log\frac{M_*}{M_{\rm GUT}} + \log\frac{M_{\rm GUT}}{M_W}\right)$$

- Right-handed down squark mixings



$$\rightsquigarrow \boxed{|(\delta_{ij}^d)_{RR}| \sim y_{\nu_3}^2 [V_L^*]_{3i}[V_L]_{3j}}$$

$$(m_{\tilde{d}}^2)_{ij} \simeq -\frac{1}{8\pi^2} e^{-i(\phi_i^{(L)} - \phi_j^{(L)})} y_{\nu_k}^2 [V_L^*]_{ki}[V_L]_{kj}(3m_0^2 + A^2)\log\frac{M_*}{M_{\rm GUT}}$$

Result for $\mu \tan\beta = 1$ TeV

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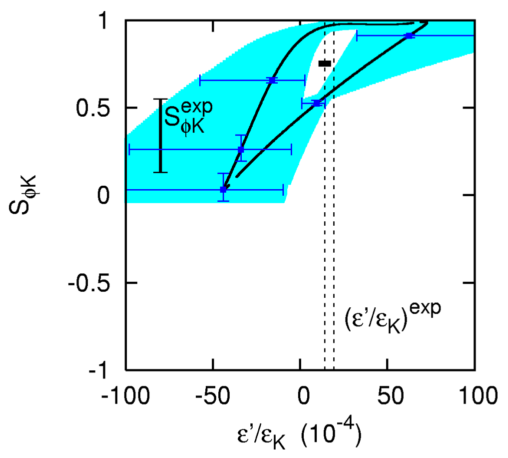


ε_K

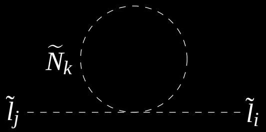
- Box diagrams with triple insertions of $(\delta^d_{13})_{LL}(\delta^d_{33})_{LR}(\delta^d_{32})_{RR} \equiv (\delta^d_{12})^{\rm eff}_{LR}$ may contribute to ε_K.
- $B(B \to X_s\gamma)$ constrains
$$|(\delta^d_{12})^{\rm eff}_{LR}| \lesssim 2 \times 10^{-4}.$$
- $|(\varepsilon'/\varepsilon_K)_{\rm SUSY}| < |(\varepsilon'/\varepsilon_K)_{\rm exp}|$ implies
$$|{\rm Im}(\delta^d_{12})^{\rm eff}_{LR}| \lesssim 2 \times 10^{-5}.$$

Gabbiani, Gabrielli, Masiero, Silvestrini, NPB(1996)

- Then,
$$\sqrt{|{\rm Im}[(\delta^d_{12})^{\rm eff}_{LR}]^2|} \lesssim 6 \times 10^{-5},$$
- As a consequence,
$$|(\varepsilon_K)_{\rm SUSY}| \lesssim \frac{1}{30}|(\varepsilon_K)_{\rm exp}|.$$
- ε_K is always safe if $\varepsilon'/\varepsilon_K$ constraint is satisfied.

$\tau \to \mu\gamma$

- $\overline{5} = \{\overline{D}, \widehat{\Theta}_L^\dagger L\} \quad \to$
  Left-handed slepton mixing is related to right-handed sdown mixing



$$\rightsquigarrow (m^2_{\tilde{l}})_{ij} \simeq -\frac{1}{8\pi^2} y^2_{\nu_k} [V_L]_{ki} [V_L^*]_{kj} (3m_0^2 + A^2) \log \frac{M_*}{M_{N_k}}$$

$$\sim (m^2_{\tilde{d}})_{ij}$$

- If we impose

$$B(\tau^\pm \to \mu^\pm \gamma) < 6.8 \times 10^{-8},$$

BABAR Collaboration, hep-ex/0502032

$|(\delta^d_{23})_{RR}| \lesssim 0.03$ for $\tan\beta = 10$ and $Y_D = Y_E^T$.

Ciuchini, Masiero, Silvestrini, Vempati, Vives, PRL(2004)

$\to$ SUSY effect becomes small.

- Not much difference even if we relax $Y_D = Y_E^T$ to account for $m_e/m_d \neq m_\mu/m_s$.
- Note $(\varepsilon'/\varepsilon_K)$–$S_{\phi K}$ correlation is not specific to GUT.