Direct CP Violation of $b \to s\gamma$ and CP Asymmetries of Non-Leptonic B Decays in Squark Flavor Mixing

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A. Hayakawa, Y. S., M. Tanimoto and K. Yamamoto, Phys. Lett. B **710** (2012) 446.

Y. S., M. Tanimoto and K. Yamamoto, arXiv:1205.1705 [hep-ph]. (PTP accepted)

概要

Introduction

B_d^0, B_s^0 中間子における CP の破れ

- DØ Collaboration の実験結果
  (like-sign dimuon charge asymmetry)

$$A_{sl}^b(\text{DØ}) = -(7.87 \pm 1.72 \pm 0.93) \times 10^{-3}.$$

$$\to A_{sl}^b(\text{SM}) = (-2.3^{+0.5}_{-0.6}) \times 10^{-4}\ (\text{SM から } 3.9\ \sigma \text{ のずれ})$$

A. Lenz, et al, A. Jantsch,C. Kaufhold,Phys. Rev. D **83** (2011) 036004 [arXiv:1008.1593 [hep-ph]].

- LHCb Collaboration の実験結果：Rencontres de Moriond EW 2012
  （非レプトン崩壊における CP-violating phase $B_s \to J/\psi\phi$）

$$\phi_s(\text{LHCb}) = -0.002 \pm 0.083 \pm 0.027$$

$$\to \phi_s^{J/\psi\phi}(\text{SM}) = -0.0363 \pm 0.0017 \text{ rad (SM と consistent)}$$

J. Charles *et al.* [CKMfitter Group Collaboration], Eur. Phys. J. C **41** (2005) 1 [hep-ph/0406184]

- LHC(ATLAS, CMS) では SUSY 粒子を探索している。
- しかし、直接探査ではまだ見つかっていない。

$$m_{\tilde{g}} \geq 1\text{TeV}, \quad m_{\tilde{q}} \geq 1\text{TeV}$$

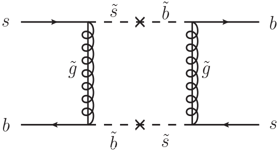
S.Chatrchyan *et all.* [CMS Collaboration], PRL 107 (2011)

- そこで、間接探査が重要になってくる。

B 中間子の CP violation ...

Mass Insertion Parameters

- Squark flavor mixing



$$M^2_{\tilde{d}_{LL}} = m^2_{\tilde{q}} \begin{pmatrix} 1+(\delta^{LL}_d)_{11} & (\delta^{LL}_d)_{12} & (\delta^{LL}_d)_{13} \\ (\delta^{LL}_d)^*_{12} & 1+(\delta^{LL}_d)_{22} & (\delta^{LL}_d)_{23} \\ (\delta^{LL}_d)^*_{13} & (\delta^{LL}_d)^*_{23} & 1+(\delta^{LL}_d)_{33} \end{pmatrix},$$

$$M^2_{\tilde{d}_{RR}} = m^2_{\tilde{q}} \begin{pmatrix} 1+(\delta^{RR}_d)_{11} & (\delta^{RR}_d)_{12} & (\delta^{RR}_d)_{13} \\ (\delta^{RR}_d)^*_{12} & 1+(\delta^{RR}_d)_{22} & (\delta^{RR}_d)_{23} \\ (\delta^{RR}_d)^*_{13} & (\delta^{RR}_d)^*_{23} & 1+(\delta^{RR}_d)_{33} \end{pmatrix},$$

$$M^2_{\tilde{d}_{LR}} = (M^2_{\tilde{d}_{RL}})^\dagger = m^2_{\tilde{q}} \begin{pmatrix} (\delta^{LR}_d)_{11} & (\delta^{LR}_d)_{12} & (\delta^{LR}_d)_{13} \\ (\delta^{LR}_d)_{21} & (\delta^{LR}_d)_{22} & (\delta^{LR}_d)_{23} \\ (\delta^{LR}_d)_{31} & (\delta^{LR}_d)_{32} & (\delta^{LR}_d)_{33} \end{pmatrix}.$$

B_q-$\bar{B}_q$ 混合の dispersive part (gluino-squark box diagram)

$$M_{12}^{q,SUSY} = A_1^q \Big[A_2 \left\{ (\delta_d^{LL})_{ij}^2 + (\delta_d^{RR})_{ij}^2 \right\} + A_3^q (\delta_d^{LL})_{ij} (\delta_d^{RR})_{ij} + A_4^q \left\{ (\delta_d^{LR})_{ij}^2 + (\delta_d^{RL})_{ij}^2 \right\} + A_5^q (\delta_d^{LR})_{ij} (\delta_d^{RL})_{ij} \Big],$$

$$A_1^q = -\frac{\alpha_S^2}{216 m_{\tilde{q}}^2} \frac{2}{3} M_{B_q} f_{B_q}^2, \qquad A_2 = 24 x f_6(x) + 66 \tilde{f}_6(x),$$

$$A_3^q = \left\{ 384 \left(\frac{M_{B_q}}{m_j + m_i} \right)^2 + 72 \right\} x f_6(x) + \left\{ -24 \left(\frac{M_{B_q}}{m_j + m_i} \right)^2 + 36 \right\} \tilde{f}_6(x),$$

$$A_4^q = \left\{ -132 \left(\frac{M_{B_q}}{m_j + m_i} \right)^2 \right\} x f_6(x), \quad A_5^q = \left\{ -144 \left(\frac{M_{B_q}}{m_j + m_i} \right)^2 - 84 \right\} \tilde{f}_6(x).$$

($x = m_{\tilde{g}}^2 / m_{\tilde{q}}^2$, $m_{\tilde{g}}$: gluino mass)

$$A_2 : A_3^s : A_4^s : A_5^s \simeq -1 : 30 : 10 : 10 \quad @ m_{\tilde{g}} = 1\text{TeV}, \ m_{\tilde{q}} = 1\text{TeV}$$

LL, RR dominant の場合

- Mass Insertion (MI) パラメータの大きさが等しいと仮定：

$$(\delta_d^{LL})_{ij} = r_{ij} e^{2i\theta_{ij}^{LL}}, \qquad (\delta_d^{RR})_{ij} = r_{ij} e^{2i\theta_{ij}^{RR}}.$$

- LR, RL は $b \to s\gamma$ から制限を受ける

$$(\delta_d^{LR})_{ij} = (\delta_d^{RL})_{ij} = 0.$$

- B_q^0-$\bar{B}_q^0$ 混合の質量項：

$$
\begin{aligned}
M_{12}^q &= M_{12}^{q,\mathrm{SM}} + M_{12}^{q,\mathrm{SUSY}} \\
&= M_{12}^{q,\mathrm{SM}} \left(1 + \frac{M_{12}^{q,\mathrm{SUSY}}}{M_{12}^{q,\mathrm{SM}}} \right) \\
&= M_{12}^{q,\mathrm{SM}} (1 + h_q e^{2i\sigma_q})
\end{aligned}
$$

$$
M_{12}^{q,\mathrm{SM}} = \frac{G_F^2 M_{B_q}}{12\pi^2} M_W^2 (V_{tb} V_{tq}^*)^2 \hat{\eta}_B S_0(x_t) f_{B_q}^2 B_q
$$

- B_q^0-$\bar{B}_q^0$ 混合の崩壊項：

$$
\Gamma_{12}^q = \Gamma_{12}^{q,\mathrm{SM}}
$$

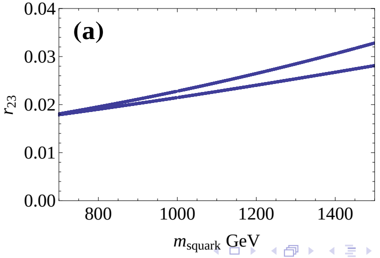
$$\frac{M_{12}^{q,\mathrm{SUSY}}}{M_{12}^{q,\mathrm{SM}}} = h_q e^{2i\sigma_q} \ ,$$

- r_{ij}, θ_{ij}^{LL}, θ_{ij}^{RR} について解く：

$$r_{ij} = \sqrt{\frac{h_q |M_{12}^{q,\mathrm{SM}}|}{\left| A_1^q \left(2A_2 \cos 2\left(\theta_{ij}^{LL} - \theta_{ij}^{RR}\right) + A_3^q \right) \right|}} \ ,$$

$$\theta_{ij}^{LL} + \theta_{ij}^{RR} = \sigma_q + \phi_q^{\mathrm{SM}} + \frac{n\pi}{2}, \quad (n = 0, \pm 1, \pm 2, \cdots).$$

- $h_s \simeq 0.1$
- $r_{23} \simeq 0.02$ $(m_{\tilde{q}} = 1\mathrm{TeV})$



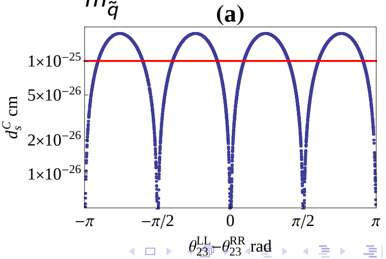
Constraint

- cEDM の制限: (J. Hisano and Y. Shimizu, PRD **70** (2004))

$$d_s^C = c\frac{\alpha_s}{4\pi}\frac{m_{\tilde{g}}}{m_{\tilde{q}}^2}\left(-\frac{1}{3}N_1(x) - 3N_2(x)\right) \mathrm{Im}\left[(\delta_d^{LL})_{23}(\delta_d^{LR})_{33}(\delta_d^{RR})_{23}^*\right]$$
$$= c\frac{\alpha_s}{4\pi}\frac{m_{\tilde{g}} m_b \mu \tan\beta}{m_{\tilde{q}}^4}\left(\frac{1}{3}N_1(x) + 3N_2(x)\right) r_{23}^2 \sin 2(\theta_{23}^{LL} - \theta_{23}^{RR}).$$

$$(\delta_d^{LR})_{33} = m_b\frac{A_b - \mu\tan\beta}{m_{\tilde{q}}^2}$$

- $\theta_{23}^{LL} - \theta_{23}^{RR}$ に制限 ($\mu\tan\beta = 5000\mathrm{GeV}$)
- $e|d_s^C| < 1.0 \times 10^{-25}$ecm



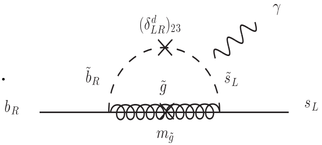
- $b \to s\gamma$ 崩壊からの制限：A. J. Buras, hep-ph/9806471.

$$\frac{BR(b \to X_s\gamma)}{BR(b \to X_c e\bar{\nu}_e)} = \frac{|V_{ts}^* V_{tb}|^2}{|V_{cb}|^2} \frac{6\alpha}{\pi f(z)} C_{7\gamma}^{\mathrm{eff}\,2},$$

$$\alpha = \frac{e^2}{4\pi}, \quad f(z) = 1 - 8z + 8z^3 - z^4 - 12z^2 \ln z, \quad z = \frac{m_c^2}{m_b^2}.$$

- $C_{7\gamma}^{\mathrm{eff}}$: Wilson coefficient

$$C_{7\gamma}^{\mathrm{eff}\,2} = |C_{7\gamma}(\mathrm{SM}) + C_{7\gamma}^{\tilde{g}}(\mathrm{SUSY})|^2 + |\tilde{C}_{7\gamma}^{\tilde{g}}(\mathrm{SUSY})|^2.$$



$$C_{7\gamma}(\mathrm{SM}) = \frac{3x_t^3 - 2x_t^2}{4(x_t^2 - 1)^4} \ln x_t + \frac{-8x_t^3 - 5x_t^2 + 7x_t}{24(x_t - 1)^3}, \quad x_t = \frac{m_t^2}{M_W^2},$$

$$C_{7\gamma}^{\tilde{g}}(\mathrm{SUSY}) = -\frac{\sqrt{2}\alpha_s\pi}{6G_F V_{tb} V_{ts}^* m_{\tilde{q}}^2} \frac{8}{3} \left[(\delta_d^{LL})_{23} \left(M_3(x) - \mu \tan\beta \frac{m_{\tilde{g}}}{m_{\tilde{q}}^2} M_a(x) \right) + (\delta_d^{LR})_{23} \frac{m_{\tilde{g}}}{m_b} M_1(x) \right]$$

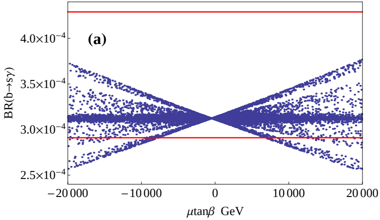
$$\tilde{C}_{7\gamma}^{\tilde{g}}(\mathrm{SUSY}) : C_{7\gamma}^{\tilde{g}}(\mathrm{SUSY})(L \leftrightarrow R), \quad x = \frac{m_{\tilde{g}}^2}{m_{\tilde{q}}^2}.$$

- 実験結果：PDG(2011)

$$BR(b \to s\gamma) = (3.60 \pm 0.23) \times 10^{-4}$$

- SM：Misiak *et al.*, PRL98(2007)

$$BR(b \to s\gamma) = (3.15 \pm 0.23) \times 10^{-4}$$



- 実験結果：ICHEP 2012 (BaBar)

$$BR(b \to s\gamma) = (3.31 \pm 0.35) \times 10^{-4}$$

- Time dependent CP asymmetry

$$\mathcal{S}_f = \frac{2\mathrm{Im}\lambda_f}{|\lambda_f|^2+1}, \quad \lambda_f = \frac{q}{p}\bar{\rho}, \quad \bar{\rho} \equiv \frac{\bar{A}(\bar{B}_q^0 \to f)}{A(B_q^0 \to f)}.$$

- Mixing: $q/p = \sqrt{M_{12}^{q*}/M_{12}^q}$
- Ampritude:

$$H_{eff} = \frac{4G_F}{\sqrt{2}}\left[\sum_{q'=u,c} V_{q'b}V_{q's}^* \sum_{i=1,2} C_i O_i^{(q')} - V_{tb}V_{ts}^* \sum_{i=3-6,7\gamma,8G}\left(C_i O_i + \widetilde{C}_i \widetilde{O}_i\right)\right]$$

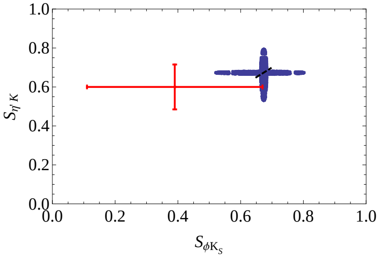
$$A^{\mathrm{SUSY}}(B_d^0 \to \phi K_S) \propto C_{8G}^{\tilde{g}}(m_b) + \tilde{C}_{8G}^{\tilde{g}}(m_b),$$

$$A^{\mathrm{SUSY}}(B_d^0 \to \eta' K) \propto C_{8G}^{\tilde{g}}(m_b) - \tilde{C}_{8G}^{\tilde{g}}(m_b),$$

$$C_{8G}^{\tilde{g}} \simeq -\frac{\sqrt{2}\alpha_s\pi}{2G_F V_{tb}V_{ts}^* m_{\tilde{q}}^2}\left[(\delta_d^{LL})_{23}\left\{\left(\frac{1}{3}M_3(x)+3M_4(x)\right) - \mu\tan\beta\frac{m_{\tilde{g}}}{m_{\tilde{q}}^2}\left(\frac{1}{3}M_a(x)+3M_b(x)\right)\right\}\right.$$

$$\left. +(\delta_d^{LR})_{23}\frac{m_{\tilde{g}}}{m_b}\left(\frac{1}{3}M_1(x)+3M_2(x)\right)\right], \quad \tilde{C}_{8G}^{\tilde{g}} : \; C_{8G}^{\tilde{g}}(L \leftrightarrow R)$$

- $B_d \to \phi K_S,\ \eta' K$



- 実験結果：$S_{\phi K_S} = 0.39 \pm 0.17,\ S_{\eta' K} = 0.60 \pm 0.07$
- SM：$S_{J/\psi K_S} = 0.671 \pm 0.0023$

SUSY のパラメータ

- Mass Insertion (MI) パラメータの $(\delta_d^{LR})_{ij}$, $(\delta_d^{RL})_{ij}$ からの寄与が大きい場合を考える。

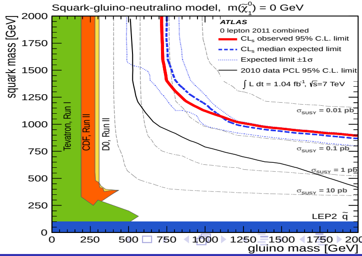
  $\rightarrow M_{12}^{q,SUSY}$ が小さいため like-sign dimuon charge asymmetry は小さくなる。$(q = d, s)$

$$M_{12}^{q,SUSY} = A_1^q \Big[A_2 \left\{ (\delta_d^{LL})_{ij}^2 + (\delta_d^{RR})_{ij}^2 \right\} + A_3^q (\delta_d^{LL})_{ij} (\delta_d^{RR})_{ij} + A_4^q \left\{ (\delta_d^{LR})_{ij}^2 + (\delta_d^{RL})_{ij}^2 \right\} + A_5^q (\delta_d^{LR})_{ij} (\delta_d^{RL})_{ij} \Big]$$

- A_i^q: squark mass と gluino mass の関数
- $m_{\tilde{g}} = 1.5$ TeV, $m_{\tilde{q}} = 1$ TeV

G. Aad *et al.* [ATLAS Collaboration], Phys. Lett. B **710** (2012) 67;

Rencontres de Moriond EW 2012



$b \to s\gamma$

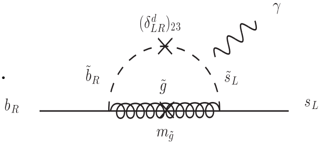
- $b \to s\gamma$ 崩壊からの制限：A. J. Buras, hep-ph/9806471.

$$\frac{BR(b\to X_s\gamma)}{BR(b\to X_c e\bar{\nu}_e)} = \frac{|V_{ts}^* V_{tb}|^2}{|V_{cb}|^2}\frac{6\alpha}{\pi f(z)} C_{7\gamma}^{\mathrm{eff}\,2},$$

$$\alpha = \frac{e^2}{4\pi}, \quad f(z) = 1 - 8z + 8z^3 - z^4 - 12z^2 \ln z, \quad z = \frac{m_c^2}{m_b^2}.$$

- $C_{7\gamma}^{\mathrm{eff}}$: Wilson coefficient

$$C_{7\gamma}^{\mathrm{eff}\,2} = |C_{7\gamma}(\mathrm{SM}) + C_{7\gamma}^{\tilde{g}}(\mathrm{SUSY})|^2 + |\tilde{C}_{7\gamma}^{\tilde{g}}(\mathrm{SUSY})|^2.$$



$$C_{7\gamma}(\mathrm{SM}) = \frac{3x_t^3 - 2x_t^2}{4(x_t^2-1)^4}\ln x_t + \frac{-8x_t^3 - 5x_t^2 + 7x_t}{24(x_t-1)^3}, \quad x_t = \frac{m_t^2}{M_W^2},$$

$$C_{7\gamma}^{\tilde{g}}(\mathrm{SUSY}) = -\frac{\sqrt{2}\alpha_s\pi}{6G_F V_{tb} V_{ts}^* m_{\tilde{q}}^2}\frac{8}{3}\left[(\delta_d^{LL})_{23}\left(M_3(x) - \mu\tan\beta\frac{m_{\tilde{g}}}{m_{\tilde{q}}^2}M_a(x)\right) + (\delta_d^{LR})_{23}\frac{m_{\tilde{g}}}{m_b}M_1(x)\right]$$

$$\tilde{C}_{7\gamma}^{\tilde{g}}(\mathrm{SUSY}) : C_{7\gamma}^{\tilde{g}}(\mathrm{SUSY})(L \leftrightarrow R), \quad x = \frac{m_{\tilde{g}}^2}{m_{\tilde{q}}^2}.$$

- Direct CP violation $A_{CP}^{b\to s\gamma}$:

$$A_{\rm CP}^{b\to s\gamma} = \left.\frac{\Gamma(\bar{B}\to X_s\gamma)-\Gamma(B\to X_{\bar{s}}\gamma)}{\Gamma(\bar{B}\to X_s\gamma)+\Gamma(B\to X_{\bar{s}}\gamma)}\right|_{E_\gamma>(1-\delta)E_\gamma^{\rm max}}$$

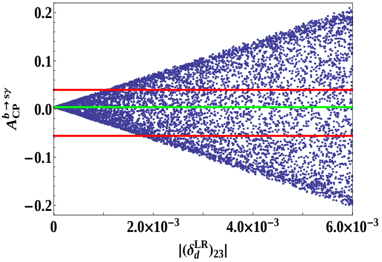
$$= \frac{\alpha_s(m_b)}{|C_{7\gamma}|^2}\left[\frac{40}{81}{\rm Im}[C_2C_{7\gamma}^*] - \frac{8z}{9}[v(z)+b(z,\delta)]{\rm Im}\left[\left(1+\frac{V_{us}^*V_{ub}}{V_{ts}^*V_{tb}}\right)C_2C_{7\gamma}^*\right]\right.$$

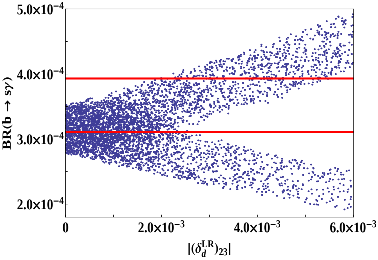
$$\left. -\frac{4}{9}{\rm Im}[C_{8G}C_{7\gamma}^*] + \frac{8z}{27}b(z,\delta){\rm Im}\left[\left(1+\frac{V_{us}^*V_{ub}}{V_{ts}^*V_{tb}}\right)C_2C_{8G}^*\right]\right],$$

$$C_{8G}^{\tilde{g}}({\rm SUSY}) \simeq -\frac{\sqrt{2}\alpha_s\pi}{2G_FV_{tb}V_{ts}^*m_{\tilde{q}}^2}\left[(\delta_d^{LL})_{23}\left\{\left(\frac{1}{3}M_3(x)+3M_4(x)\right)\right.\right.$$

$$\left.\left. -\mu\tan\beta\frac{m_{\tilde{g}}}{m_{\tilde{q}}^2}\left(\frac{1}{3}M_a(x)+3M_b(x)\right)\right\} + (\delta_d^{LR})_{23}\frac{m_{\tilde{g}}}{m_b}\left(\frac{1}{3}M_1(x)+3M_2(x)\right)\right]$$

- MI パラメータの大きさは等しくとる：
  $(\delta_d^{LR})_{23} = |(\delta_d^{LR})_{23}|e^{2i\theta_{23}^{LR}}$, $(\delta_d^{RL})_{23} = |(\delta_d^{LR})_{23}|e^{2i\theta_{23}^{RL}}$
- $m_{\tilde{g}} = 1.5$ TeV, $m_{\tilde{q}} = 1$ TeV





$$|(\delta_d^{LR})_{23}| \leq 5.5 \times 10^{-3}$$

B 中間子の非レプトン崩壊における CP の破れ

- Time dependent CP asymmetry

$$\mathcal{S}_f = \frac{2\mathrm{Im}\lambda_f}{|\lambda_f|^2+1}, \quad \lambda_f = \frac{q}{p}\bar{\rho}, \quad \bar{\rho} \equiv \frac{\bar{A}(\bar{B}_q^0 \to f)}{A(B_q^0 \to f)}.$$

- Mixing: $q/p = \sqrt{M_{12}^{q*}/M_{12}^{q}}$
- Ampritude:

$$H_{\mathrm{eff}} = \frac{4G_F}{\sqrt{2}}\left[\sum_{q'=u,c} V_{q'b}V_{q's}^* \sum_{i=1,2} C_i O_i^{(q')} - V_{tb}V_{ts}^* \sum_{i=3-6,7\gamma,8G}\left(C_i O_i + \tilde{C}_i\tilde{O}_i\right)\right]$$

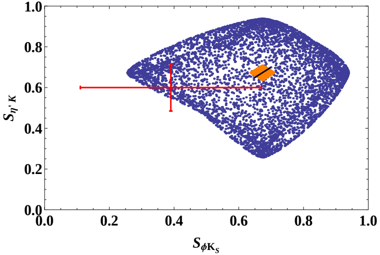
$$A^{\mathrm{SUSY}}(B_d^0 \to \phi K_S) \propto C_{8G}^{\tilde{g}}(m_b) + \tilde{C}_{8G}^{\tilde{g}}(m_b),$$

$$A^{\mathrm{SUSY}}(B_d^0 \to \eta' K) \propto C_{8G}^{\tilde{g}}(m_b) - \tilde{C}_{8G}^{\tilde{g}}(m_b),$$

$$C_{8G}^{\tilde{g}} \simeq -\frac{\sqrt{2}\alpha_s\pi}{2G_F V_{tb}V_{ts}^* m_{\tilde{q}}^2}\left[(\delta_d^{LL})_{23}\left\{\left(\frac{1}{3}M_3(x)+3M_4(x)\right) - \mu\tan\beta\frac{m_{\tilde{g}}}{m_{\tilde{q}}^2}\left(\frac{1}{3}M_a(x)+3M_b(x)\right)\right\}\right.$$

$$\left. +(\delta_d^{LR})_{23}\frac{m_{\tilde{g}}}{m_b}\left(\frac{1}{3}M_1(x)+3M_2(x)\right)\right], \quad \tilde{C}_{8G}^{\tilde{g}} : C_{8G}^{\tilde{g}}(L \leftrightarrow R)$$

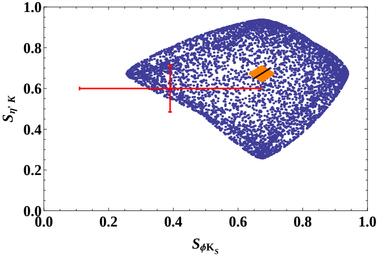
$B_d^0 \to J/\psi K_S, \eta' K$

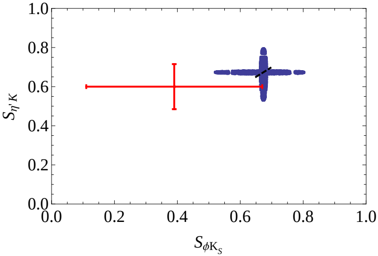


Summary

- $\mu\tan\beta$ が小さく、like-sign dimuon asymmetry が小さい場合でも、$(\delta_d^{LR})_{ij}$, $(\delta_d^{RL})_{ij}$ からの寄与が大きい場合、B_d^0 中間子、または B_s^0 中間子の非レプトン崩壊における CP の破れの大きさ S_f は SM からずれる可能性があることが分かった。

- $(\delta_d^{LR})_{23}$, $(\delta_d^{RL})_{23}$ dominance
- $(\delta_d^{LL})_{23}$, $(\delta_d^{RR})_{23}$ dominance





- $\mu\tan\beta$ が小さい場合を考える。
  → ストレンジクォークの chromo electric dipole moment (cEDM) d_s^C の制限が小さくなる。

$$d_s^C = c\frac{\alpha_s}{4\pi}\frac{m_{\tilde{g}}}{m_{\tilde{q}}^2}\left(-\frac{1}{3}N_1(x) - 3N_2(x)\right)\mathrm{Im}\left[(\delta_d^{LL})_{23}(\delta_d^{LR})_{33}(\delta_d^{RR})_{23}^*\right]$$

$b \to d\gamma$

- $b \to d\gamma$ 崩壊からの制限：A. J. Buras, hep-ph/9806471.

$$\frac{BR(b \to X_d\gamma)}{BR(b \to X_c e\bar{\nu}_e)} = \frac{|V_{td}^* V_{tb}|^2}{|V_{cb}|^2} \frac{6\alpha}{\pi f(z)} C_{7\gamma}^{\mathrm{eff}\,2},$$

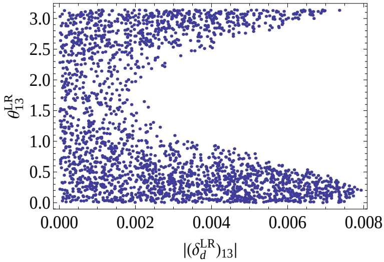
$$C_{7\gamma}^{\mathrm{eff}\,2} = |C_{7\gamma}(\mathrm{SM}) + C_{7\gamma}^{\tilde{g}}(\mathrm{SUSY})|^2 + |\tilde{C}_{7\gamma}^{\tilde{g}}(\mathrm{SUSY})|^2.$$

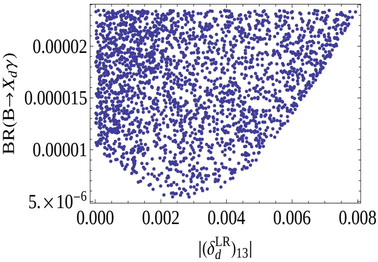
$$C_{7\gamma}(\mathrm{SM}) = \frac{3x_t^3 - 2x_t^2}{4(x_t^2 - 1)^4} \ln x_t + \frac{-8x_t^3 - 5x_t^2 + 7x_t}{24(x_t - 1)^3}, \quad x_t = \frac{m_t^2}{M_W^2},$$

$$C_{7\gamma}^{\tilde{g}}(\mathrm{SUSY}) = -\frac{\sqrt{2}\alpha_s \pi}{6 G_F V_{tb} V_{td}^* m_{\tilde{q}}^2} \frac{8}{3} \left[(\delta_d^{LL})_{13} \left(M_3(x) - \mu \tan\beta \frac{m_{\tilde{g}}}{m_{\tilde{q}}^2} M_a(x) \right) + (\delta_d^{LR})_{13} \frac{m_{\tilde{g}}}{m_b} M_1(x) \right]$$

$$\tilde{C}_{7\gamma}^{\tilde{g}}(\mathrm{SUSY}) : C_{7\gamma}^{\tilde{g}}(\mathrm{SUSY})(L \leftrightarrow R), \quad x = \frac{m_{\tilde{g}}^2}{m_{\tilde{q}}^2}.$$

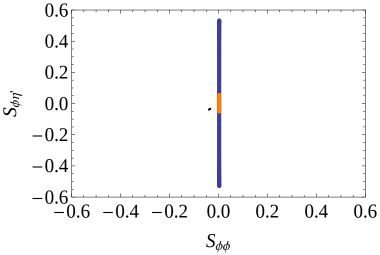
- MI パラメータの大きさは等しくとる：
  $(\delta_d^{LR})_{13} = r_{13} e^{2i\theta_{13}^{LR}}$, $(\delta_d^{RL})_{13} = r_{13} e^{2i\theta_{13}^{RL}}$
- $m_{\tilde{g}} = 1.5$ TeV, $m_{\tilde{q}} = 1$ TeV



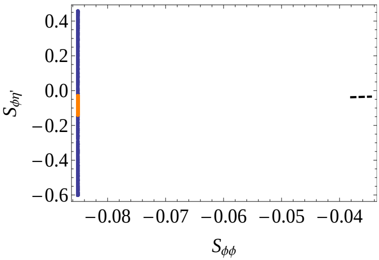


- $\theta_{23}^{LR} = \theta_{23}^{RL}$ の場合

- $\phi_s = -0.002$
  （実験の中央値）



- $\phi_s = -0.002 \pm 0.083 \pm 0.027$
  （実験の 90% C.L. の端）



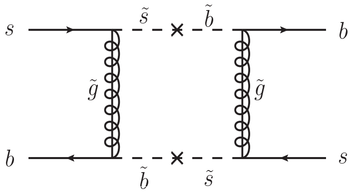
Like-sign dimuon charge asymmetry

- B_q^0-$\bar{B}_q^0$ 混合の質量項：

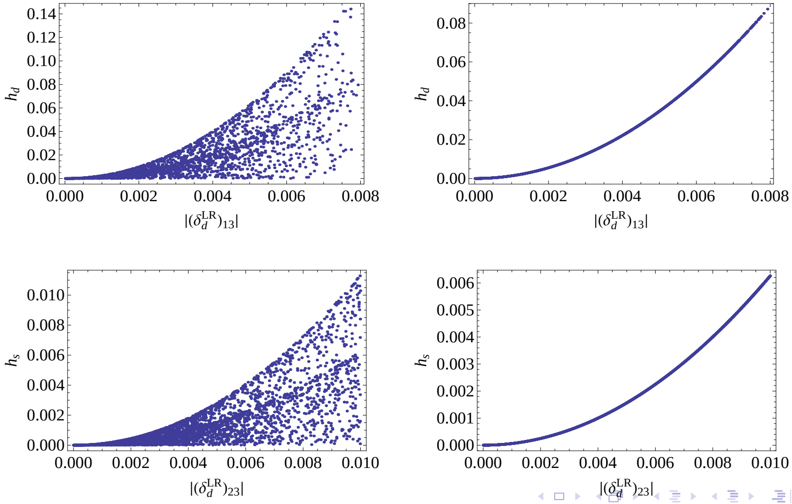
$$
\begin{aligned}
M_{12}^q &= M_{12}^{q,\mathrm{SM}} + M_{12}^{q,\mathrm{SUSY}} \\
&= M_{12}^{q,\mathrm{SM}} \left(1 + \frac{M_{12}^{q,\mathrm{SUSY}}}{M_{12}^{q,\mathrm{SM}}}\right) \\
&= M_{12}^{q,\mathrm{SM}} (1 + h_q e^{2i\sigma_q})
\end{aligned}
$$

- B_q^0-$\bar{B}_q^0$ 混合の崩壊項：

$$
\Gamma_{12}^q = \Gamma_{12}^{q,\mathrm{SM}}
$$



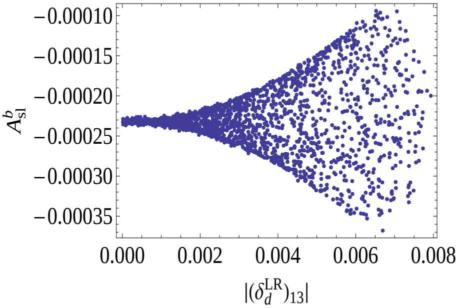
- MI パラメータの大きさと h_q の図 (左：$\theta_{ij}^{LR} \neq \theta_{ij}^{RL}$, 右：$\theta_{ij}^{LR} = \theta_{ij}^{RL}$)



- Like-sign dimuon charge asymmetry:

$$A_{sl}^{b} \equiv \frac{N_b^{++} - N_b^{--}}{N_b^{++} + N_b^{--}} = (0.506 \pm 0.043) a_{sl}^{d} + (0.494 \pm 0.043) a_{sl}^{s} \ ,$$

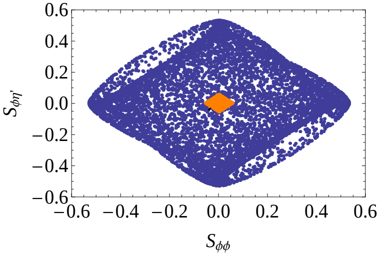
$$a_{sl}^{q} \equiv \frac{\Gamma(\bar{B}_q^0 \to \mu^+ X) - \Gamma(B_q^0 \to \mu^- X)}{\Gamma(\bar{B}_q^0 \to \mu^+ X) + \Gamma(B_q^0 \to \mu^- X)} \simeq \mathrm{Im}\left(\frac{\Gamma_{12}^{q}}{M_{12}^{q}}\right) .$$



$$A_{sl}^{b}(\text{DØ}) = -(7.87 \pm 1.72 \pm 0.93) \times 10^{-3} .$$

$B_s^0 \longrightarrow \phi\phi, \phi\eta'$

- $\theta_{23}^{LR} \neq \theta_{23}^{RL}$ の場合



- $\theta_{23}^{LR} = \theta_{23}^{RL}$ の場合