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Large CPV in B_s meson mixing with EDM constraint in Supersymmetry

Norimi Yokozaki (Univ. of Tokyo)
collaboration with Motoi Endo(Univ. of Tokyo)

based on arxiv: 1012.5512

Outline

Anomalously large CP asymmetry in B_s meson mixing

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SUSY Standard Model

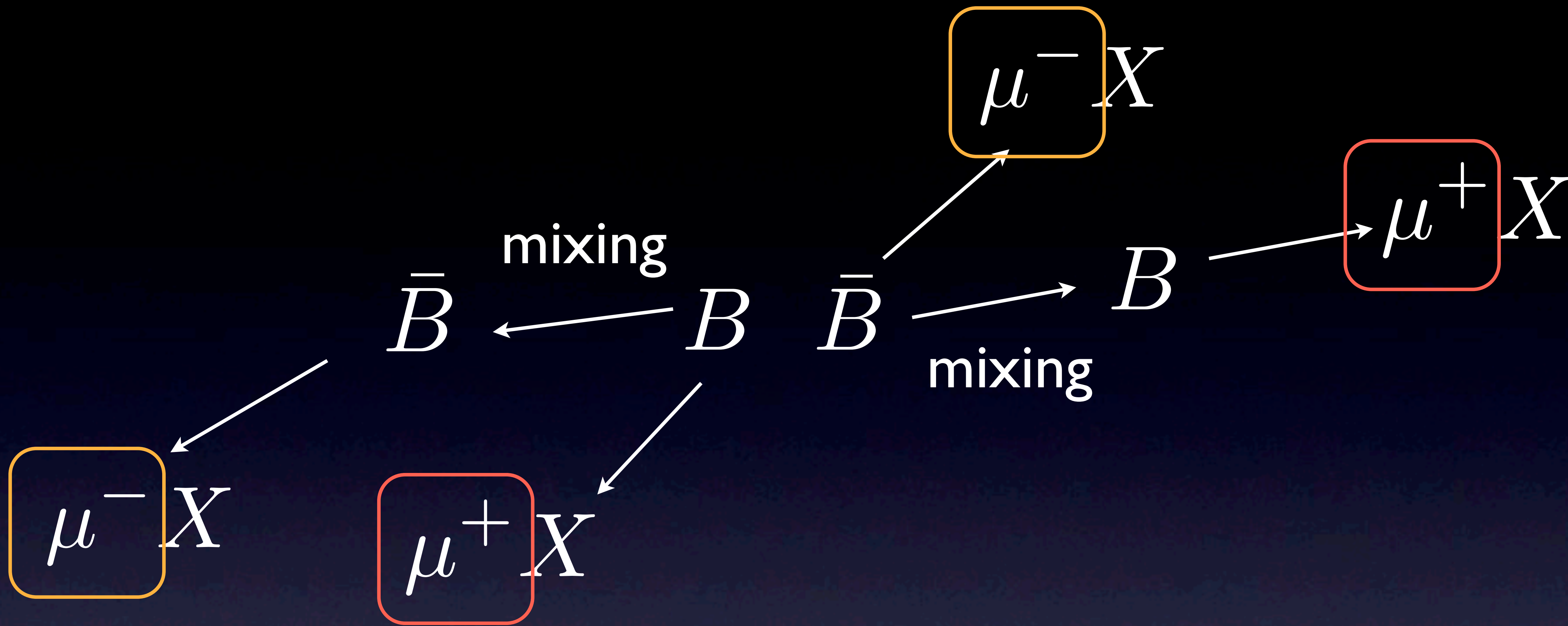
The like-sign dimuon charge asymmetry

- Like-sign dimuon charge asymmetry (D0, arXiv: 1005.2757)
- Interpreted by B meson mixing

$$(A^b_{sl})_{\text{exp}} \equiv \frac{N_b^{++} - N_b^{--}}{N_b^{++} + N_b^{--}} = -(9.57 \pm 2.51 \pm 1.46) \times 10^{-3}$$

$$(A^b_{sl})_{\text{SM}} = -(2.3^{+0.5}_{-0.6}) \times 10^{-4}$$ 3.2σ deviation

$N_b^{++(--)}$ number of events $b\bar{b} \to \mu^{+(-)}\mu^{+(-)}X$



Indicating anomalously large CP asymmetry in B meson mixing

The large mixing and constraints

Parametrizing NP effects as $h_q e^{2i\sigma_q} = \frac{(M_{12}^q)_{\rm NP}}{(M_{12}^q)_{\rm SM}}$

We need the large mixings
while they are constrained by

$$\Delta M_q \qquad \Delta\Gamma_q \qquad S_{\psi K} \qquad S_{\psi\phi}$$

(Ligeti et.al., 2010)

The large mixing and constraints

Parametrizing NP effects as $h_q e^{2i\sigma_q} = \frac{(M_{12}^q)_{\rm NP}}{(M_{12}^q)_{\rm SM}}$

χ^2 fit indicates $(h_s, \sigma_s) \simeq (1.8, 100^\circ)$

(h_d is small)

New CP phase and FV beyond CKM are required

(Ligeti et.al., 2010)

SUSY contributions

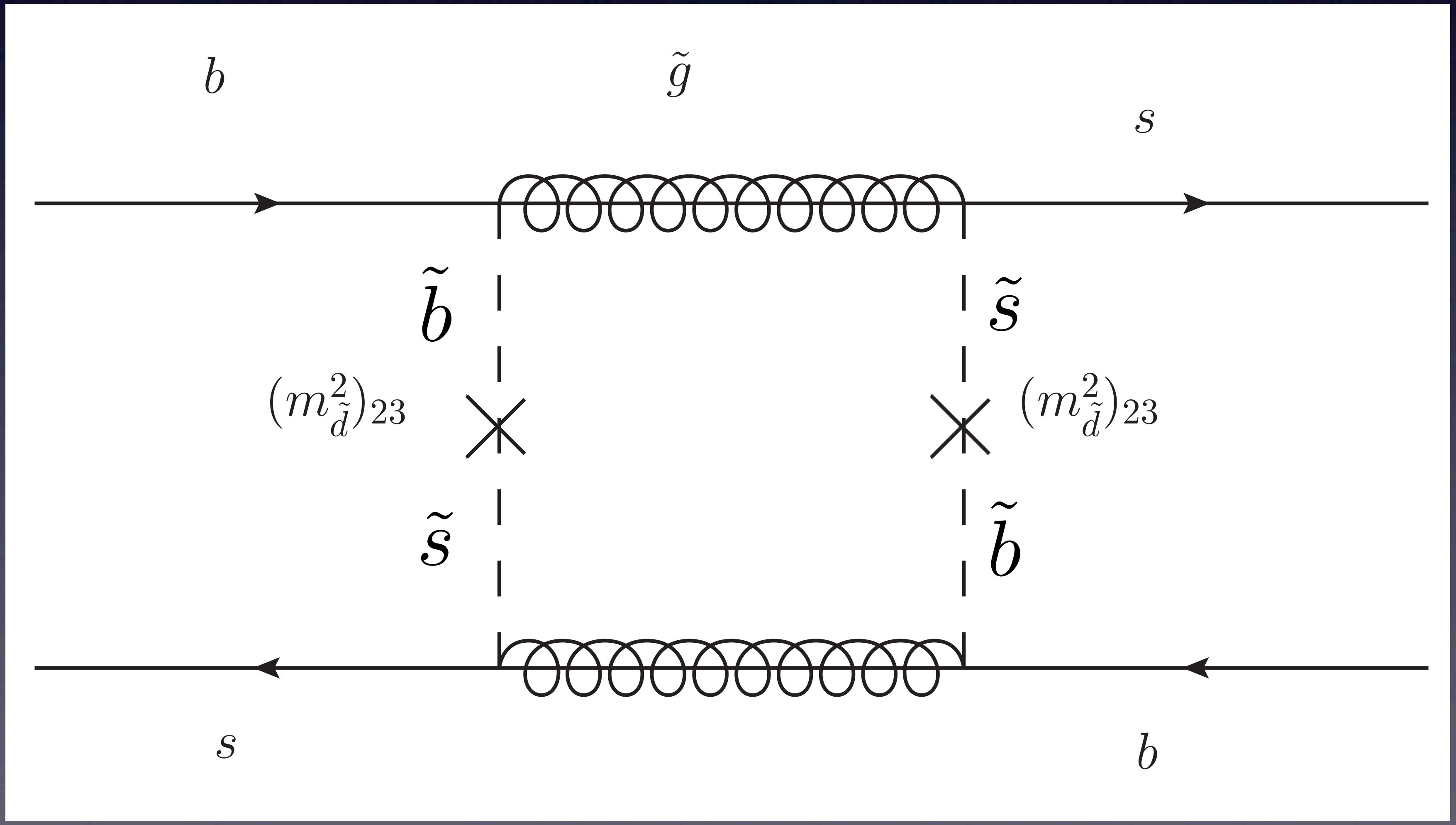
- One can include CPV and FV in soft breaking terms

$$\boxed{\begin{array}{cc} m_{\tilde{q}}^2(\delta^d_{LL})_{23}\tilde{s}_L^*\tilde{b}_L & m_{\tilde{q}}^2(\delta^d_{RR})_{23}\tilde{s}_R^*\tilde{b}_R \\ (\delta^d_{LR})_{23} & (\delta^d_{RL})_{23} \end{array}}$$

squark mixings

Contributions to B_s meson mixing

Usually gluino box diagrams dominate SUSY contributions



$$\propto (\delta^d)^2_{23}/m^2_{soft}$$

A leading contribution to B_s meson mixing is

$$h_s e^{2i\sigma_s} \simeq -\mathcal{O}(100)\left[(\delta^d_{LL})_{23}(\delta^d_{RR})_{23}\right]$$

$$\boxed{h_q e^{2i\sigma_q} = \frac{(M^q_{12})_{\rm NP}}{(M^q_{12})_{\rm SM}}}$$

for m_{soft}=500 GeV

$(\delta^d_{LL})_{23} \sim (\delta^d_{RR})_{23} \sim 0.1$

$\arg\left[(\delta^d_{LL})_{23}(\delta^d_{RR})_{23}\right] \simeq 20^\circ$

are required for

$(h_s, \sigma_s) \simeq (1.8, 100^\circ)$

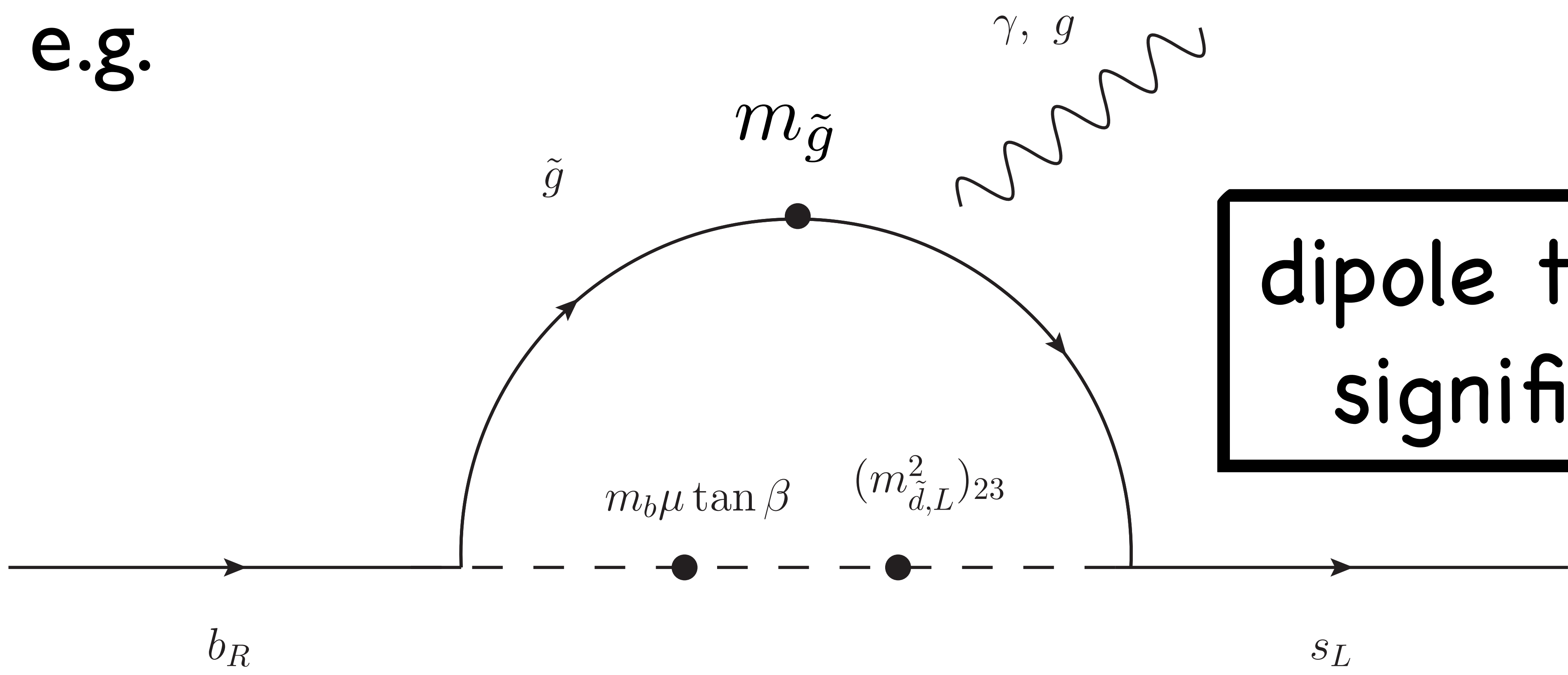
(LR and RL mixing are tightly constrained by $b \rightarrow s\gamma$)

Constraints

squark mixings induce b to s transition

$$m_{\tilde{q}}^2(\delta^d_{LL(RR)})_{23}\tilde{s}^*_{L(R)}\tilde{b}_{L(R)} + h.c.$$

e.g.



dipole type is significant

NP contributions $\propto (\delta^d_{LL(RR)})_{23}\tan\beta/m^2_{soft}$

Constraints

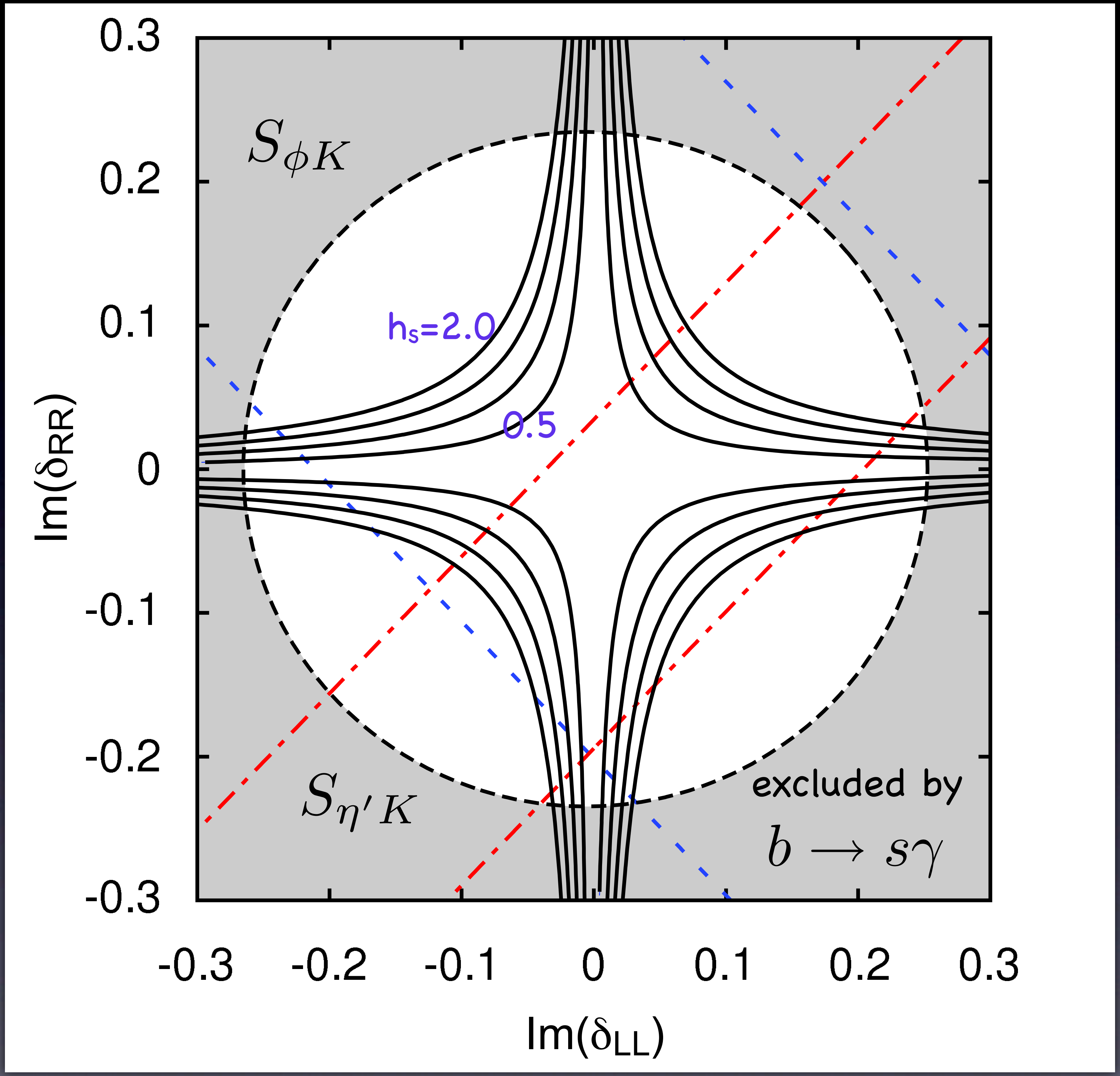
Values sensitive to $b \rightarrow s$ transition

- $Br(b \rightarrow s\gamma)$
- Mixing induced asymmetries for $S_{\varphi KS}$, $S_{\eta' KS}$

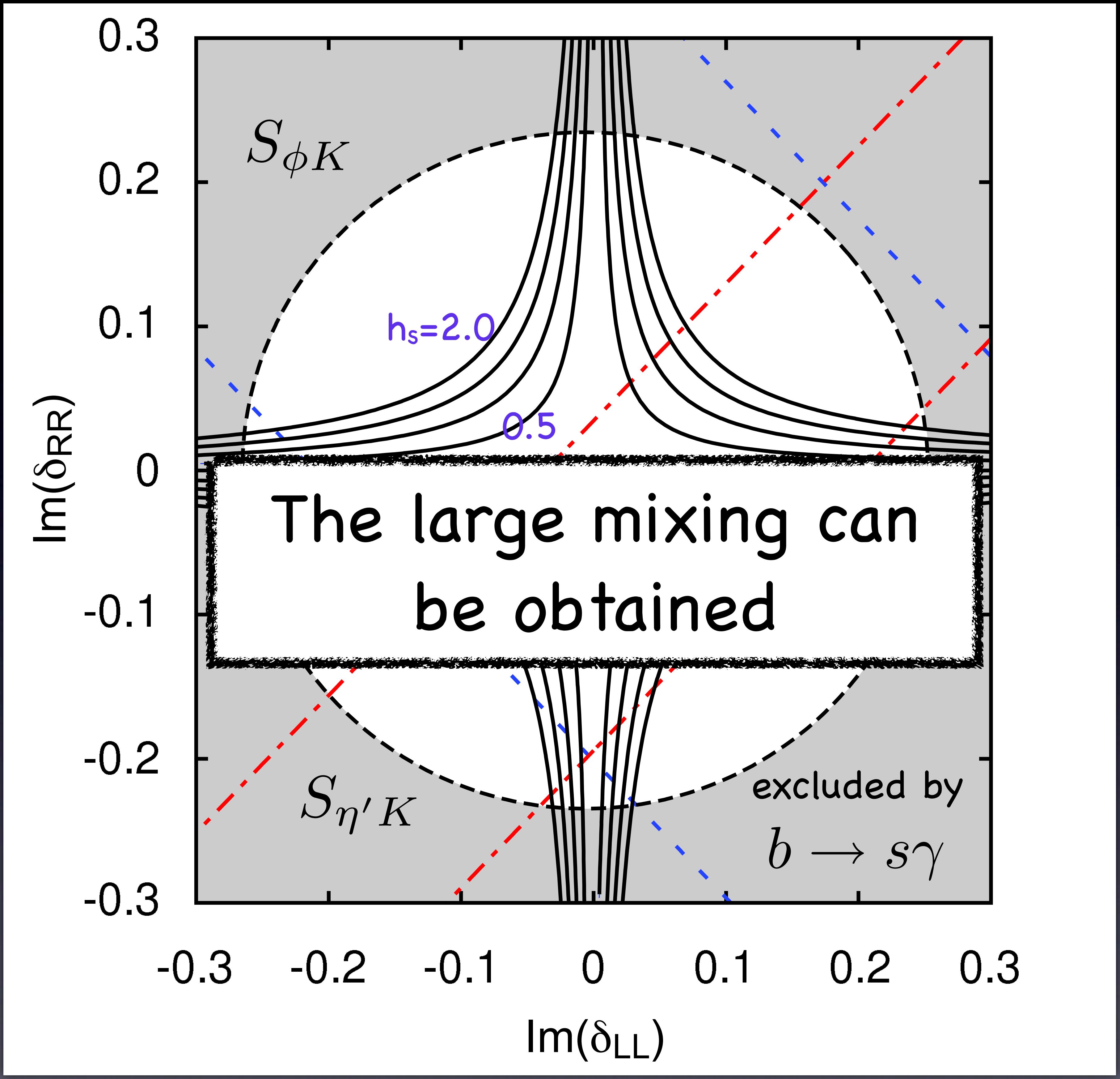
consistent with SM prediction(2σ)

$$-0.3 \times 10^{-4} < \Delta \mathrm{Br}(b \to s\gamma) < 1.4 \times 10^{-4}$$

$$0.20 < S_{\phi K} < 0.88, \qquad 0.45 < S_{\eta' K} < 0.73$$



$$\mu = m_{\tilde{q}} = 500\text{GeV}, \quad \tan\beta = 10$$



$$\mu = m_{\tilde{q}} = 500\mathrm{GeV}, \quad \tan\beta = 10$$

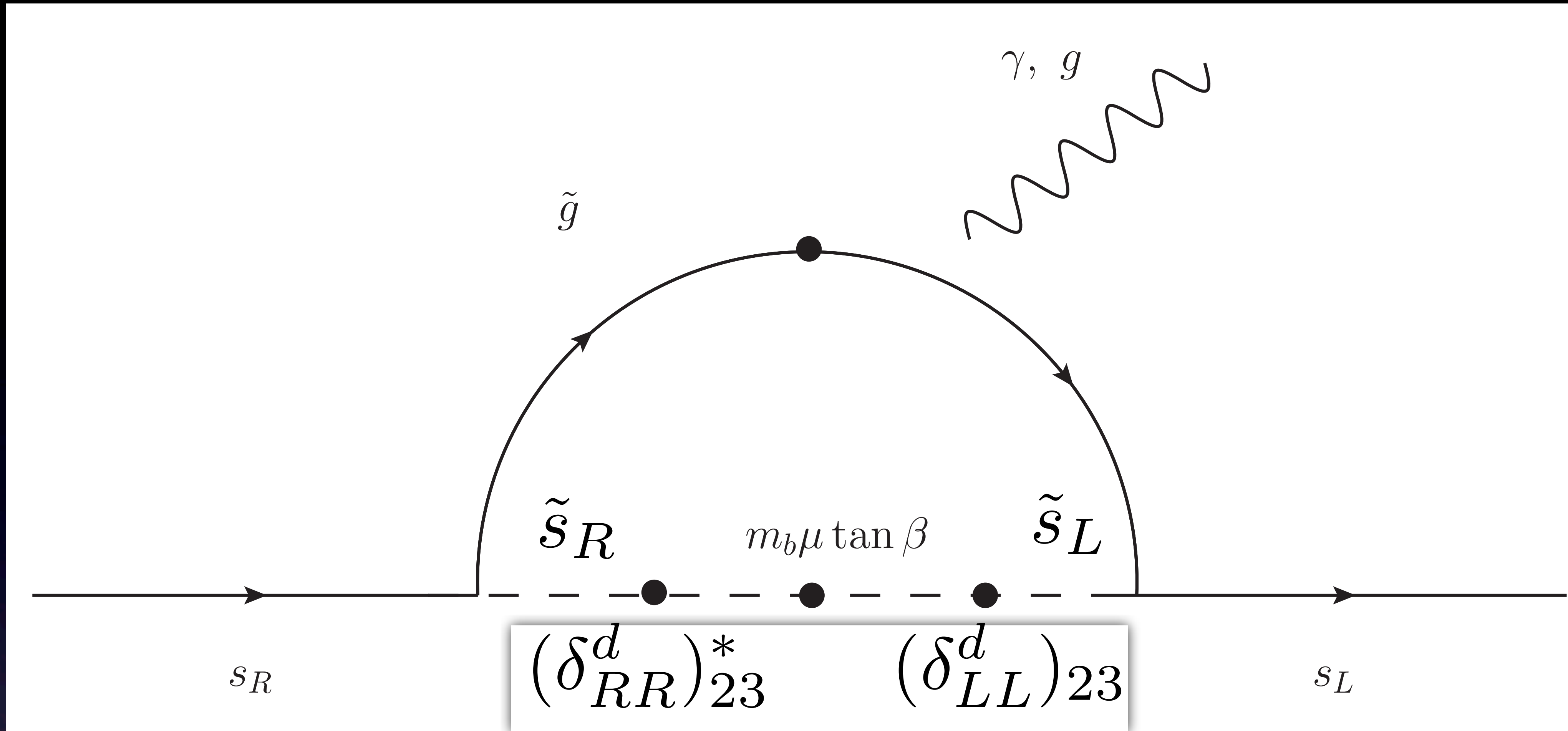
The EDM constraint

Large CP phase in the mixing
$(h_s, \sigma_s) \simeq (1.8, 100^\circ)$

$\Rightarrow$ $\arg\left[(\delta^d_{LL(RR)})_{23}\right] \sim 1$

However, the CP phase is severely constrained by the neutron EDM

$d_n < 0.29 \times 10^{-25}$ cm (90% C.L.)



$$d_s^c \propto \tan\beta\, \mathrm{Im}\left[(\delta^d_{LL})_{23}(\delta^d_{RR})^*_{23}\right]/m^2_{soft}$$

(h_s also scale as δ^2/m_{soft}^2)

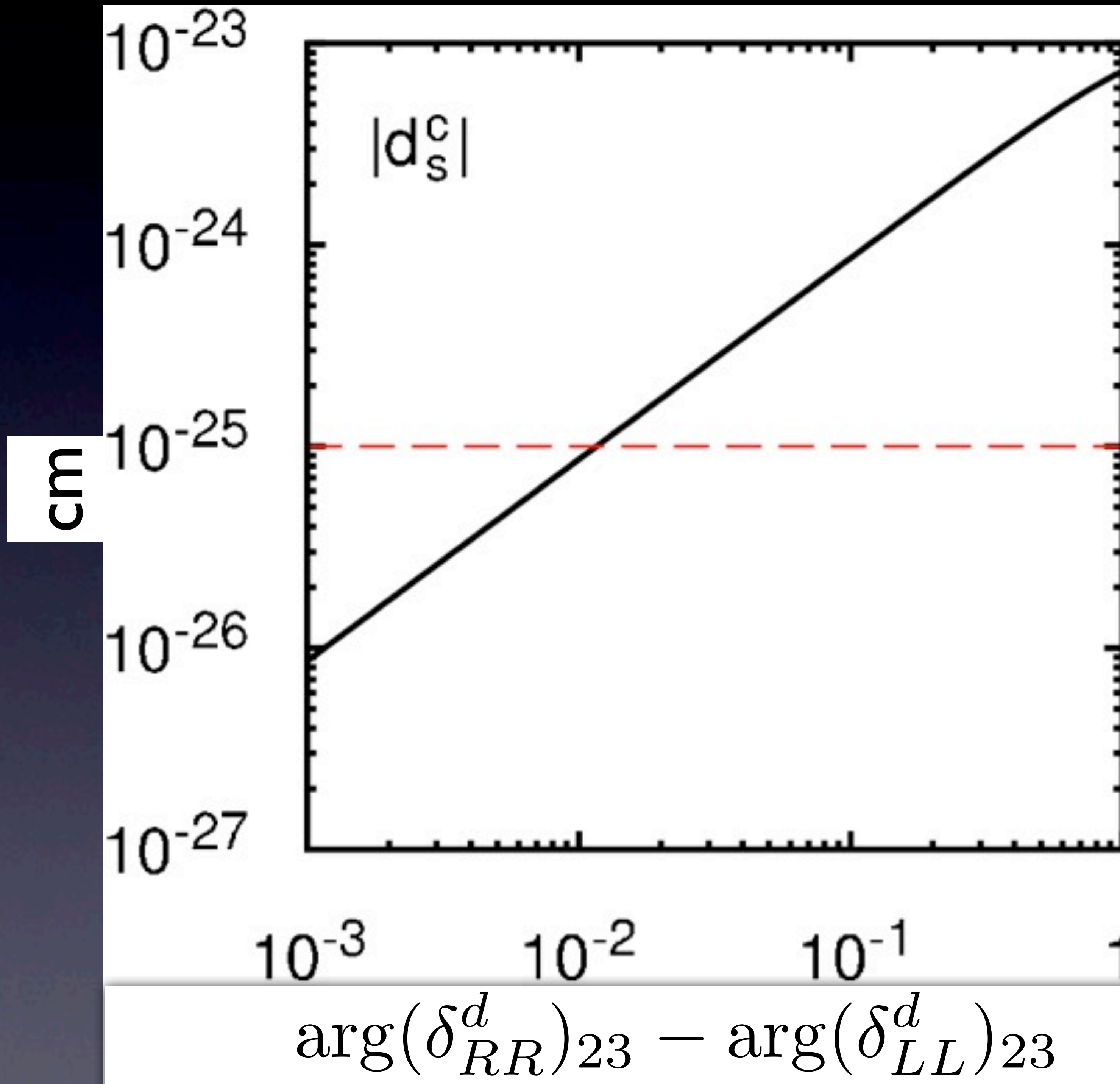
The CEDM of the strange quark

(as a sea quark)

Neutron EDM

(Hisano and Shimizu, 2004)

The EDM constraint



$|(\delta^d_{LL,RR})_{23}| = 0.08$

$(h_s \simeq 1.8)$

tanβ=10

m_{soft}=500GeV

The phase difference should be small as O(10^{-2})

Summary of the gluino dominant case

$$\arg\left[(\delta^d_{LL(RR)})_{23}\right] \sim 1$$ required for the dimuon charge asymmetry

The EDM constraint is severe

Summary of the gluino dominant case

$\arg\left[(\delta^d_{LL(RR)})_{23}\right] \sim 1$ required for the dimuon charge asymmetry

↓

The EDM constraint is severe

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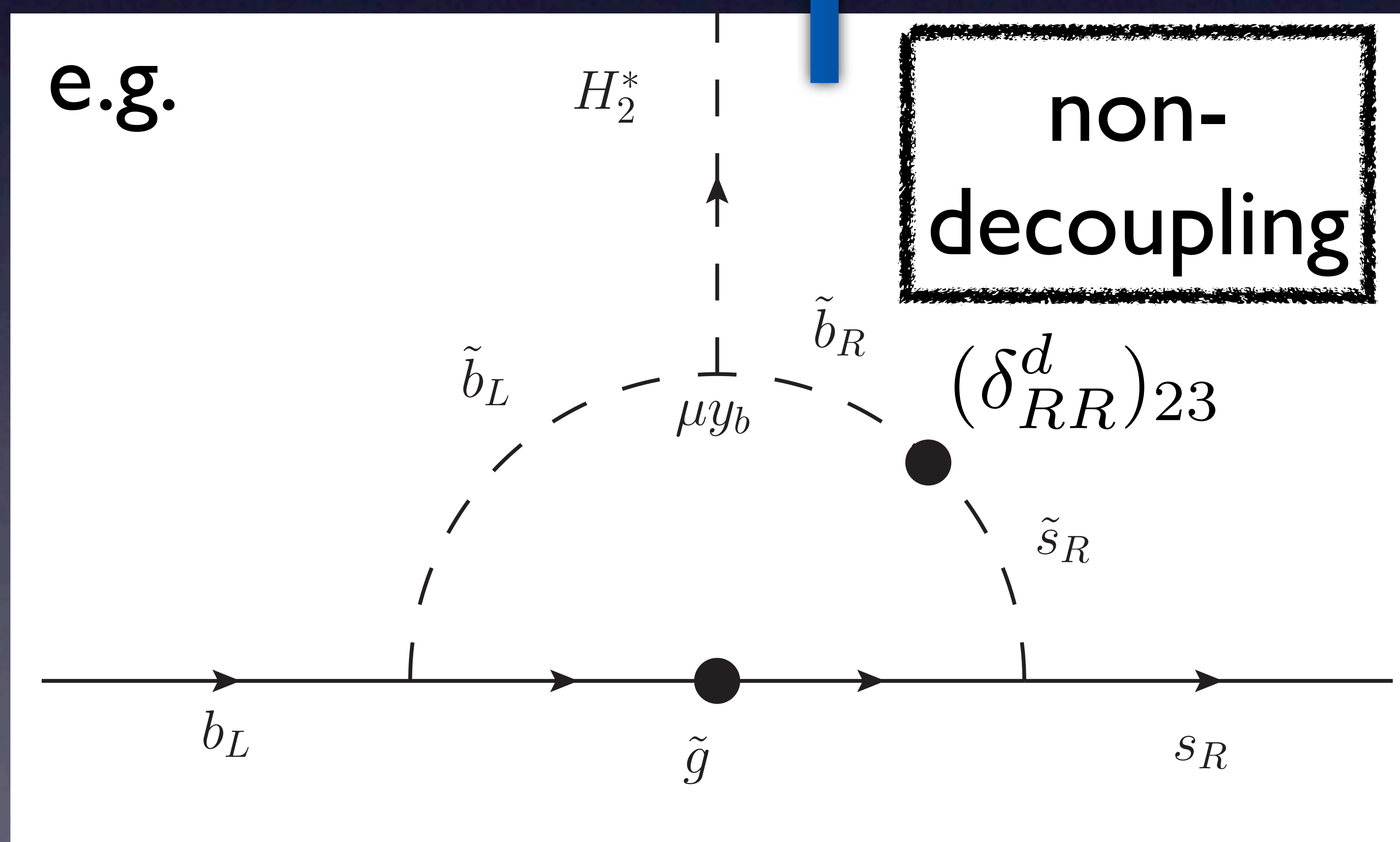
Higgs dominant case

CPV and FV in Higgs sector

$$-\mathcal{L} = Y_{d,i} Q_i H_d D_i^c + \boxed{Y'_{d,ij}} Q_i H_u^* D_j^c + h.c.$$



CPV and FV in Higgs sector

$$-\mathcal{L} = Y_{d,i} Q_i H_d D_i^c + \boxed{Y'_{d,ij}} Q_i H_u^* D_j^c + h.c.$$

Large m_{soft} limit

Gluino contributions decouple

CPV and FV in Higgs sector

$$-\mathcal{L} = Y_{d,i} Q_i H_d D_i^c + Y'_{d,ij} Q_i H_u^* D_j^c + h.c.$$

After diagonalizing mass matrix

$$\mathcal{L} = Y'_{ij} Q_i H_u^* D_j^c - \boxed{Y'_{ij} \tan\beta\, Q_i D_j^c H_d} + \text{h.c.}.$$

$Y'_{d,ij} \propto Y_b$ → $\tan^2\beta$ enhancement

Dependence on tanβ

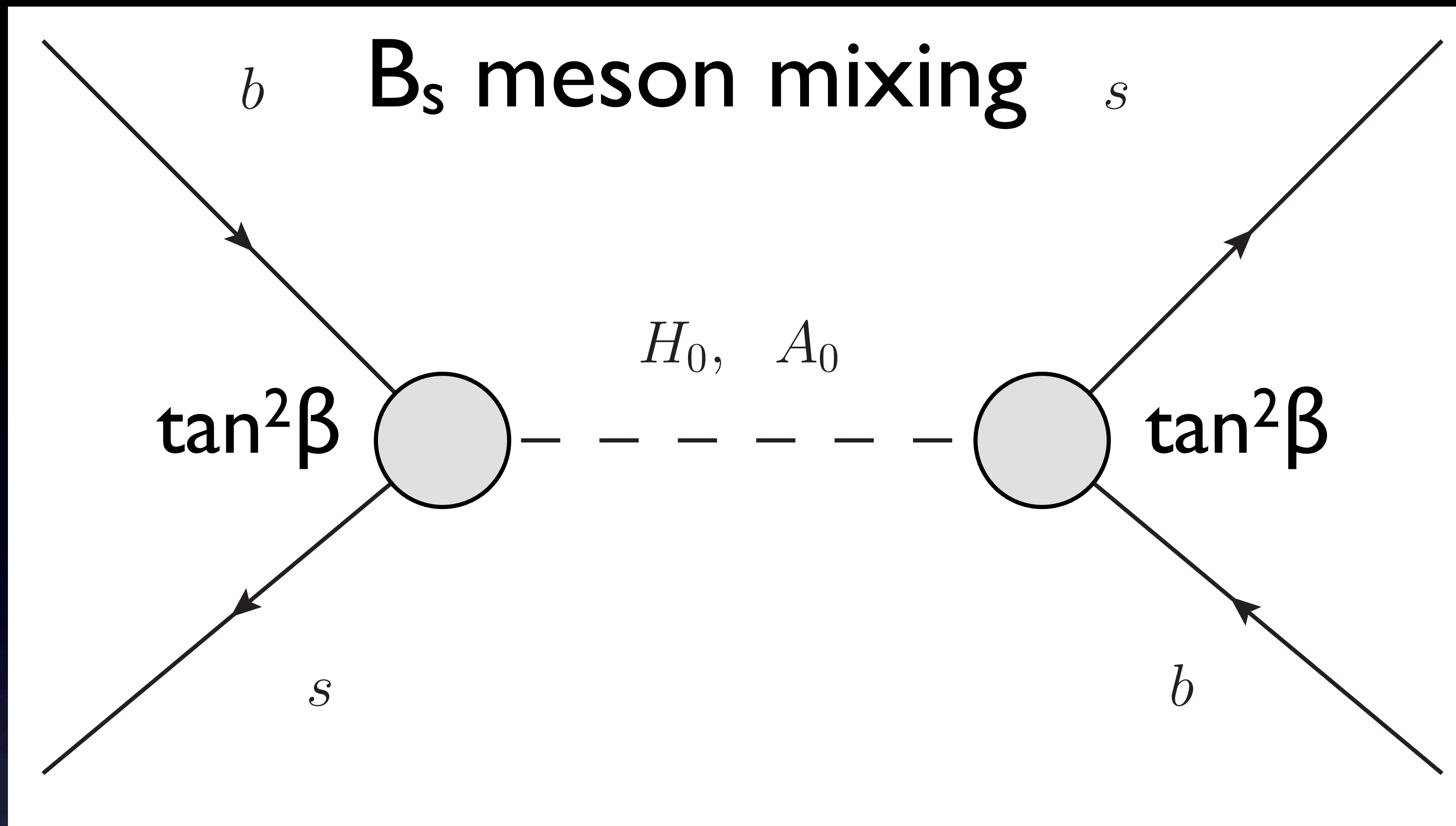
Observables depends on tanβ as

- B_s meson mixing (h_s) $\tan^4\beta$
- BR($B_s \to \mu^+\mu^-$) $\tan^6\beta$

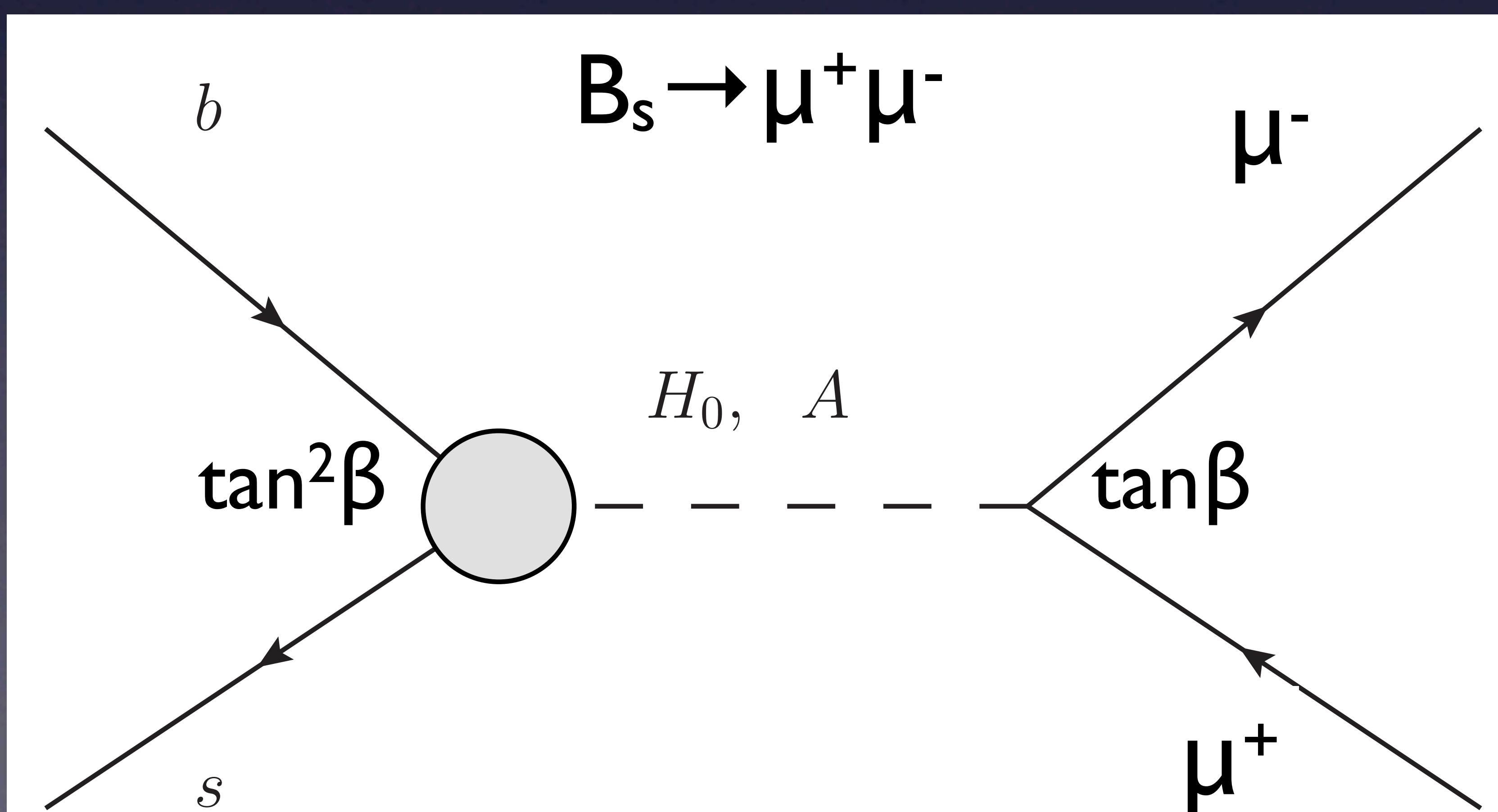
- EDM, BR($b \to s\gamma$), $S_{\phi KS}$, $S_{\eta' KS}$

  tanβ enhancement (approximately)

  Constrains are less severe

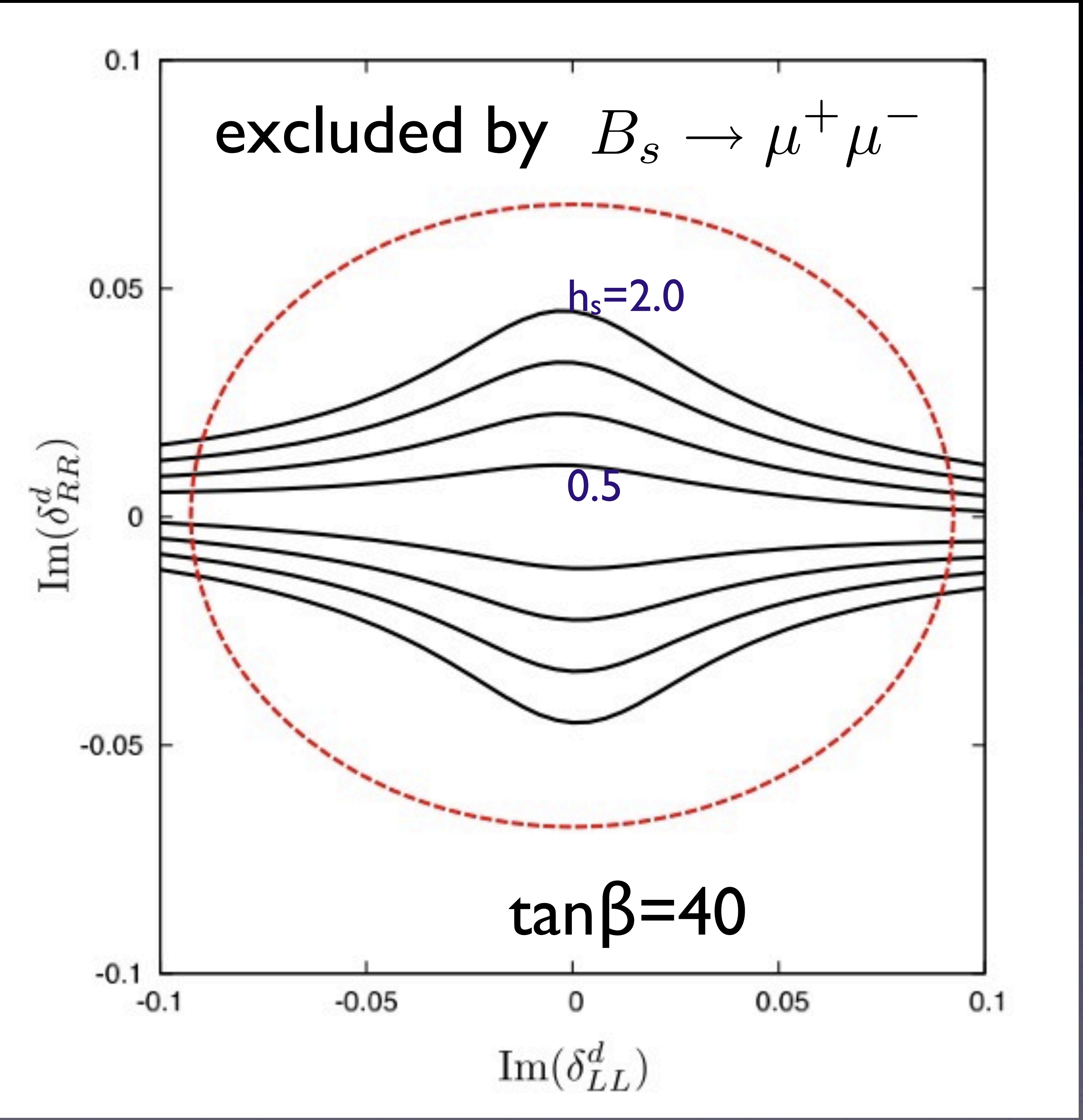


$$h_s e^{2i\sigma_s}$$
$$\propto \tan^4 \beta / m_H^2$$



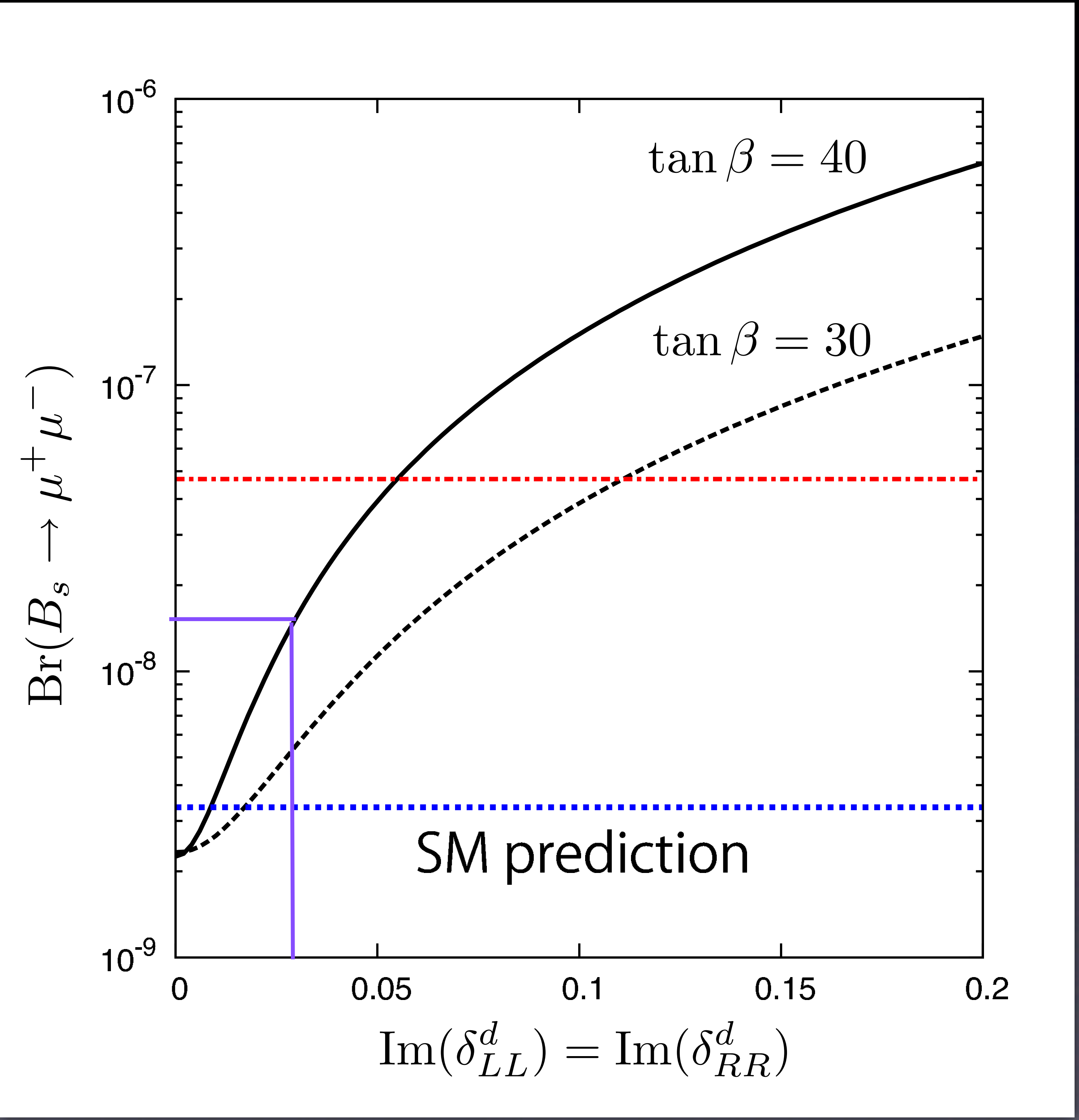
$$\mathrm{Br}(B_s \to \mu^+ \mu^-)$$
$$\propto \tan^6 \beta / m_H^4$$

h_s vs $B_s \to \mu^+\mu^-$



δ~0.03 is required for h_s=1.8 m_H=500 GEV

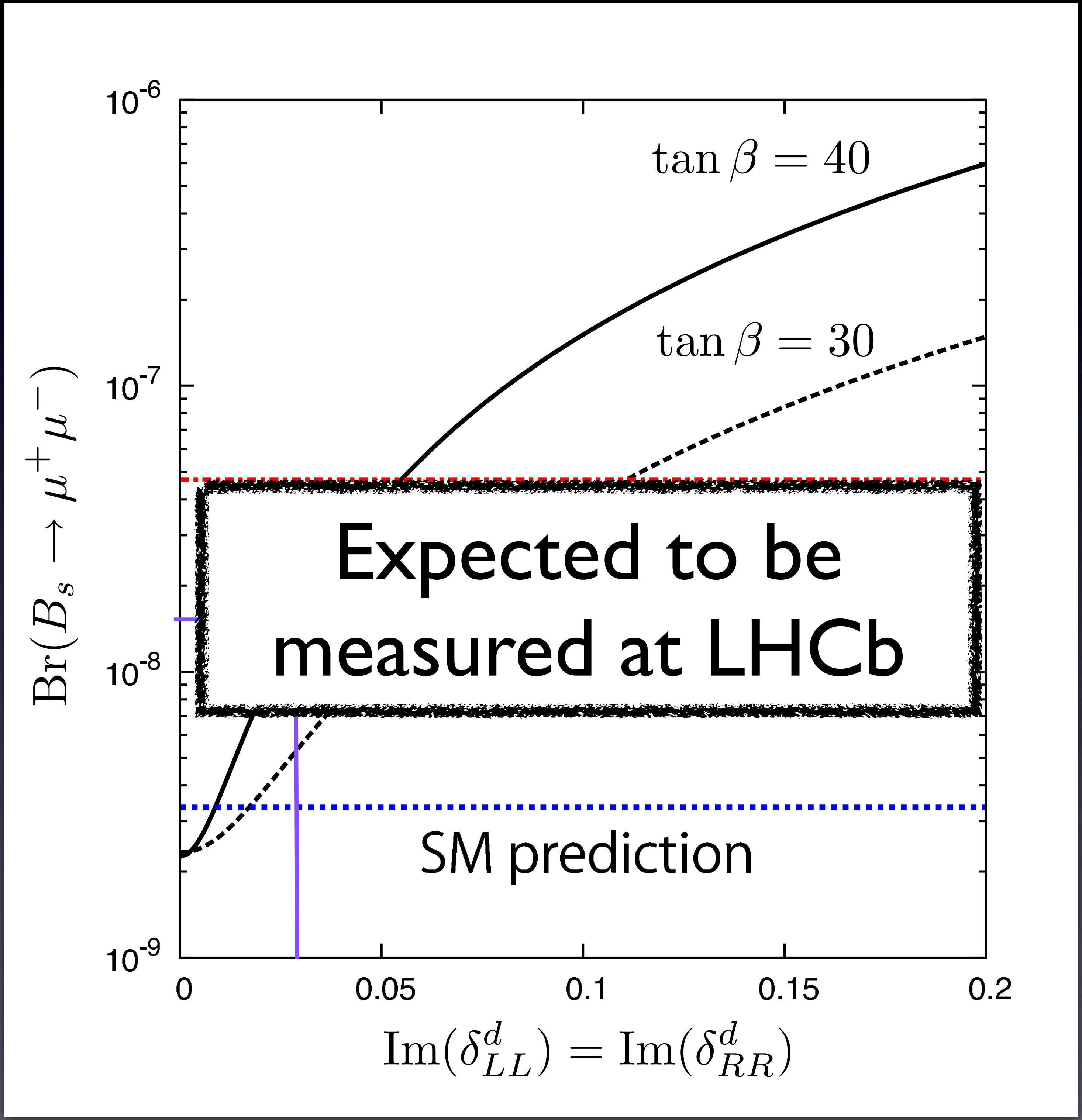
$B_s \to \mu^+\mu^-$



$\delta \sim 0.03$ for $h_s = 1.8$

$m_H = 500$ GeV

$B_s \to \mu^+\mu^-$



$\delta \sim 0.03$ for h_s=1.8

m_H=500 GeV

Conclusion

- In the gluino dominant case, EDM constraint is severe
- In the Higgs dominant case, the large mixing and its phase are explained
- $B_s \to \mu^+ \mu^-$ is expected to be measured at the LHCb

Thank you