Squark Flavor Implications from $B \to K^{(*)} \ell^+ \ell^-$

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based on JHEP 1208 (2012) 152 [arXiv:1205.1500]
with A. Behring, G. Hiller, S. Schacht

Outline

a) constraints on effective $\mathscr{H}^{\Delta B=1}$ from $B \to K^{(*)} \ell^+ \ell^-$

b) implications for squark flavor mixing in MSSM

c) some predictions...
(for $B_s \to \mu^+ \mu^-$, rare top decays, flavor models)

ΔB=1 Effective Hamiltonian

$$\mathcal{H}_{eff} = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^{*} \sum_i C_i(\mu) O_i(\mu) + \text{h.c.}$$

short distance physics ($C_i(\mu)$)

long distance physics ($O_i(\mu)$)

most important operators for $B \to K^{(*)} \ell^+ \ell^-$:

$$O_7 \sim m_b [\bar{s}_L \sigma_{\mu\nu} b_R] F^{\mu\nu} \qquad O_{9(10)} \sim [\bar{s}_L \gamma_\mu b_L][\bar{l} \gamma^\mu (\gamma_5) l]$$

$C_i = C_i^{SM} + C_i^{NP}$

- $|C_7|$: quite constrained by $b \to s\,\gamma$ data
- C_9, C_{10}: plenty of room for New Physics

$B \to K^{(*)}\ell^+\ell^-$ at low $K^{(*)}$ recoil ➠

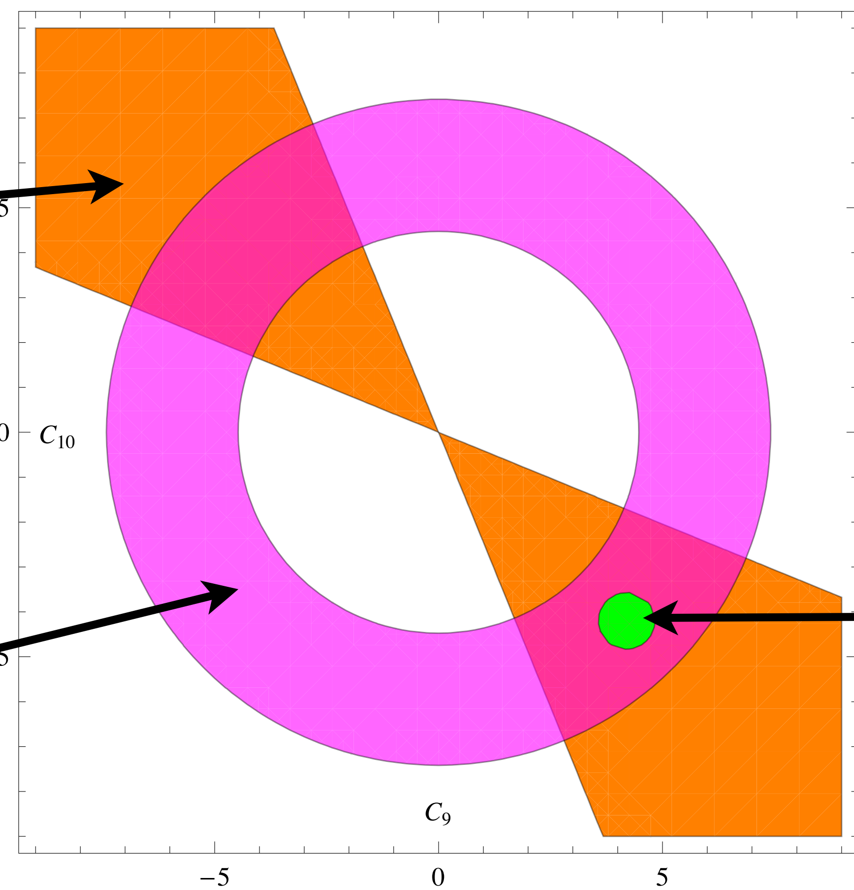
new C_9-C_{10} constraints

toy plot:

[taken from 1106.1547]

from
$A_{FB} \sim \mathrm{Re}\{C_9^* C_{10}\}$ at
low K* recoil

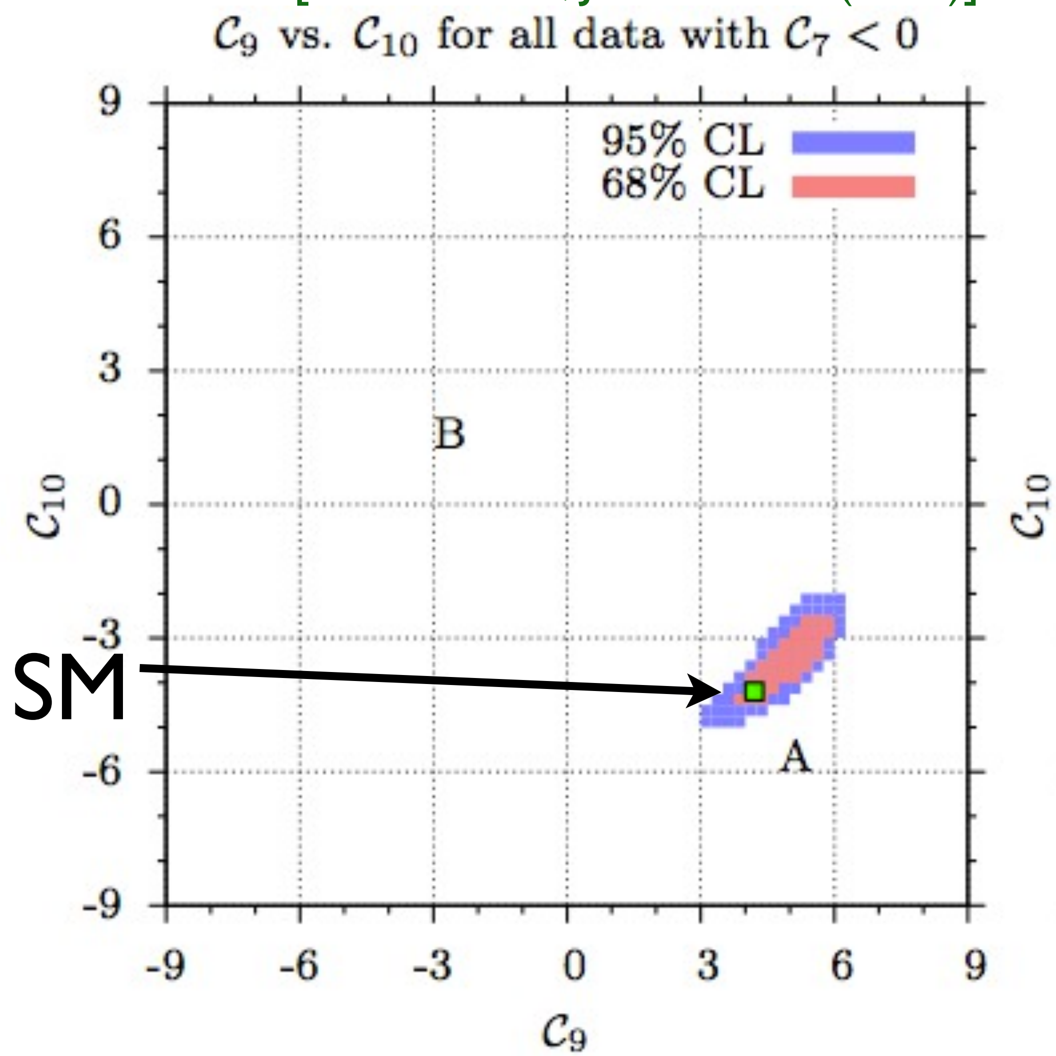
from
$BR(B \to K^* l^+ l^-) \sim$
$|C_9|^2 + |C_{10}|^2$



SM

actual analysis:

[Bobeth et. al., JHEP 01 107 (2012)]



➠ what are consequences for BSM models?
here: SUSY ➠ new constraints for squark FV?

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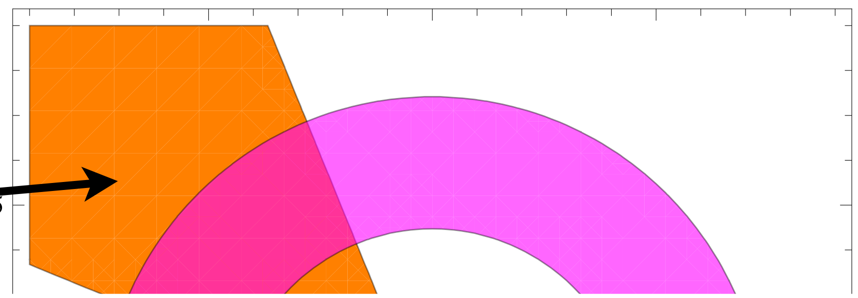

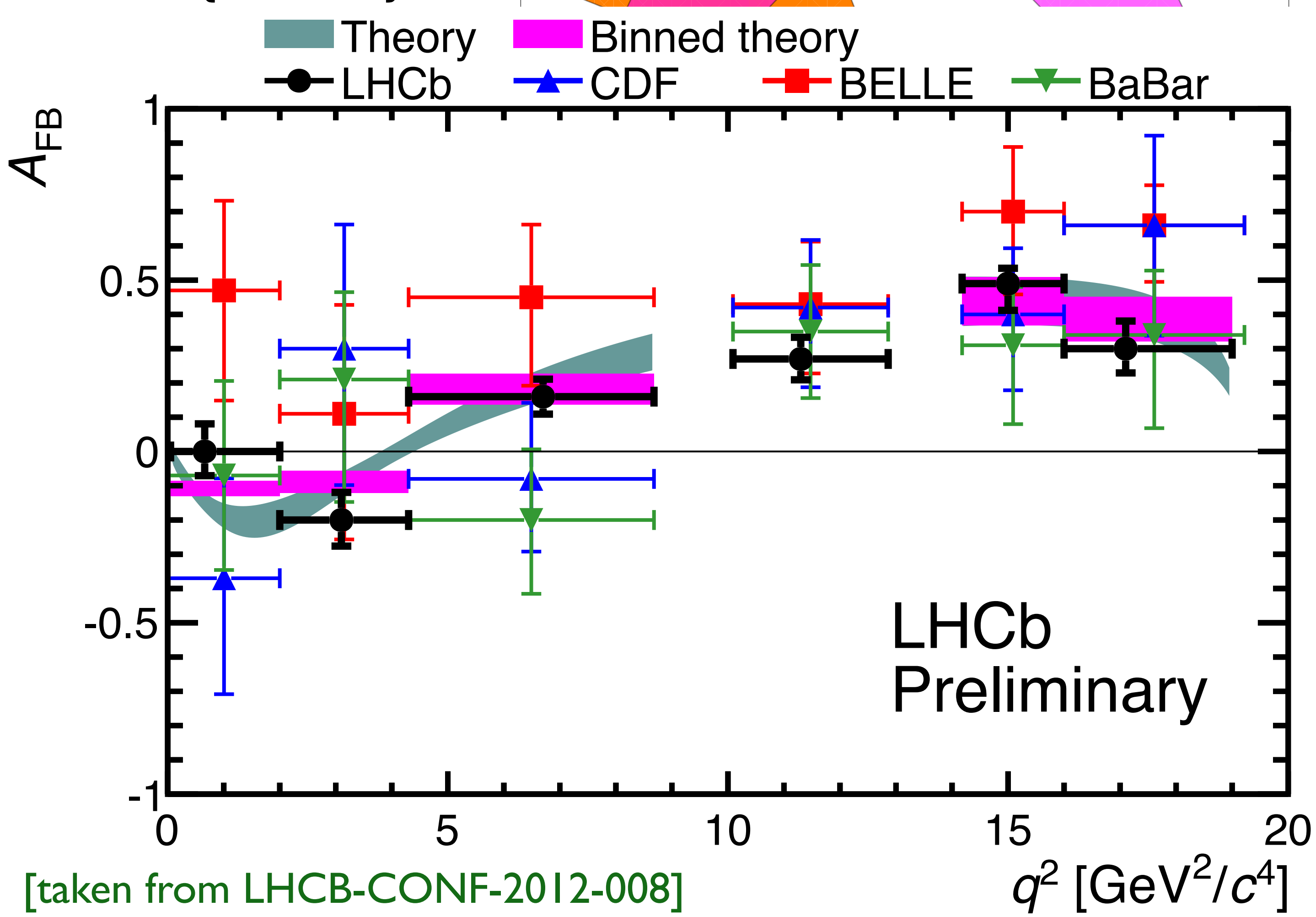

[taken from LHCB-CONF-2012-008]

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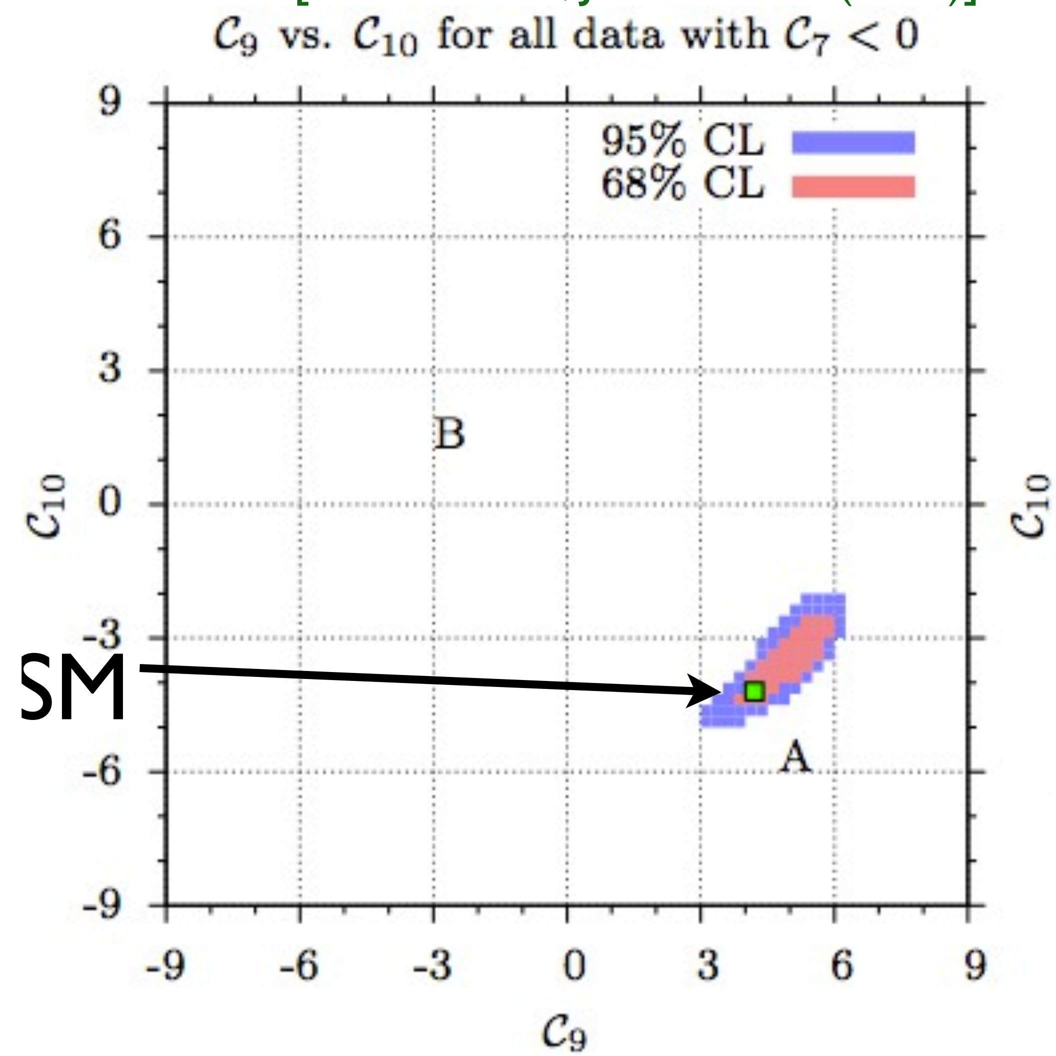

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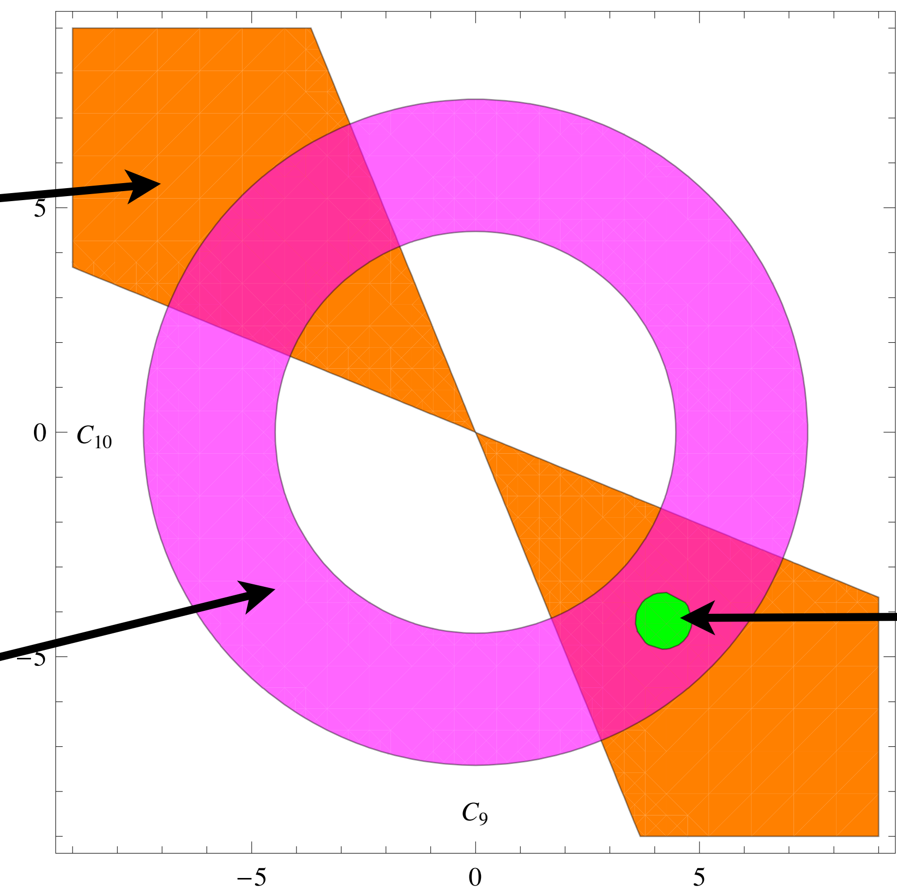

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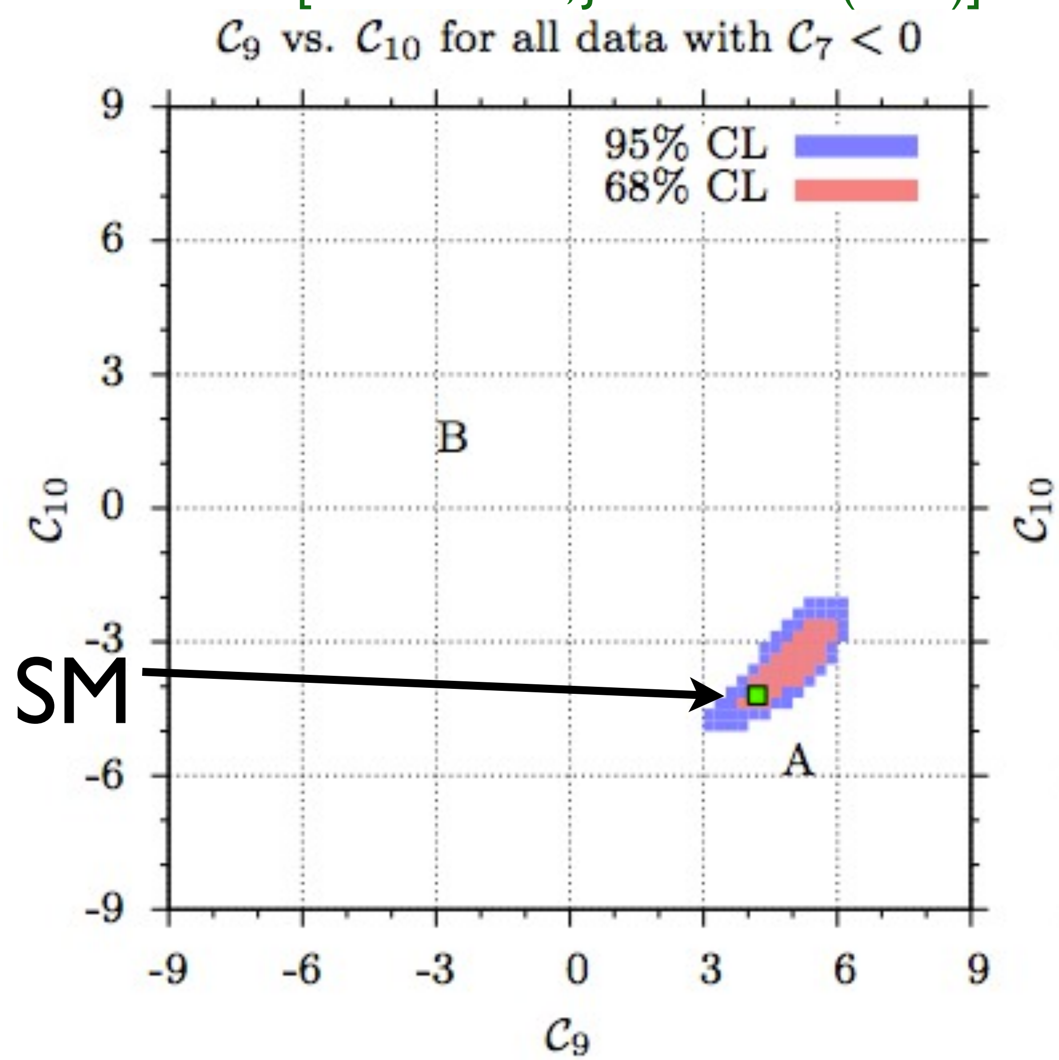

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Squark mass matrices in SCKM basis

symbolically

$$M^2_{\tilde{u}} \equiv \left(\begin{array}{cc|ccc|ccc}
 & & & L & & & R & \\
 & & \tilde{u} & \tilde{c} & \tilde{t} & \tilde{u} & \tilde{c} & \tilde{t} \\
 & \tilde{u} & m^2_{\tilde{u}_L} & (\Delta^u_{12})_{LL} & (\Delta^u_{13})_{LL} & (\Delta^u_{11})_{LR} & (\Delta^u_{12})_{LR} & (\Delta^u_{13})_{LR} \\
L & \tilde{c} & (\Delta^u_{12})^*_{LL} & m^2_{\tilde{c}_L} & (\Delta^u_{23})_{LL} & (\Delta^u_{21})_{LR} & (\Delta^u_{22})_{LR} & (\Delta^u_{23})_{LR} \\
 & \tilde{t} & (\Delta^u_{13})^*_{LL} & (\Delta^u_{23})^*_{LL} & m^2_{\tilde{t}_L} & (\Delta^u_{31})_{LR} & (\Delta^u_{32})_{LR} & (\Delta^u_{33})_{LR} \\
\hline
 & \tilde{u} & & & & m^2_{\tilde{u}_R} & (\Delta^u_{12})_{RR} & (\Delta^u_{13})_{RR} \\
R & \tilde{c} & & h.c. & & (\Delta^u_{12})^*_{RR} & m^2_{\tilde{c}_R} & (\Delta^u_{23})_{RR} \\
 & \tilde{t} & & & & (\Delta^u_{13})^*_{RR} & (\Delta^u_{23})^*_{RR} & m^2_{\tilde{t}_R}
\end{array}\right) \sim \begin{pmatrix} \tilde{m}^2_Q & A_U \\ A_U & \tilde{m}^2_U \end{pmatrix}$$

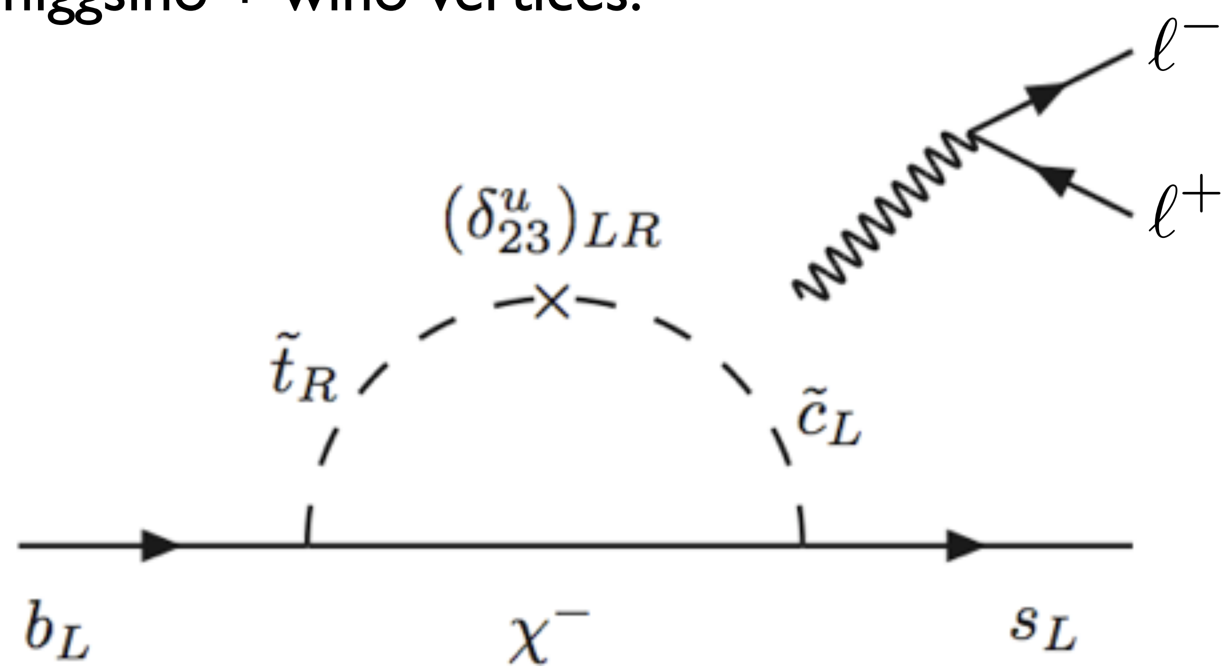
($M^2_{\tilde{d}}$: analogous...)

we try to constrain $(\Delta^u_{23})_{LR}$
more precisely: the
dimensionless parameter $(\delta^u_{23})_{LR} = \dfrac{(\Delta^u_{23})_{LR}}{\frac{1}{6}\left(5m^2_{\tilde{q}} + m^2_{\tilde{t}_R}\right)}$

other squark flavor parameters:
quite constraint by b→sγ and/or subleading in C_9,C_{10} !

$C_{9,10}^{NP}$ from squark-chargino loops

example: Z,γ-penguin with
higgsino + wino vertices:



$$C_9^{\mathrm{MI},\tilde{\chi}} = \frac{K^*_{cs}}{K^*_{ts}} \frac{1}{4\, s_W^2} \frac{\lambda_t}{g_2} \left((4 s_W^2 - 1) F^{\text{Z-p.}} + 4 s_W^2 \frac{m_W^2}{m_{\tilde{q}}^2} F^{\gamma\text{-p.}} - \frac{m_W^2}{m_{\tilde{q}}^2} F^{\text{box}} \right) (\delta^u_{23})_{LR}$$

$$C_{10}^{\mathrm{MI},\tilde{\chi}} = \frac{K^*_{cs}}{K^*_{ts}} \frac{1}{4\, s_W^2} \frac{\lambda_t}{g_2} \left(F^{\text{Z-p.}} + \frac{m_W^2}{m_{\tilde{q}}^2} F^{\text{box}} \right) (\delta^u_{23})_{LR}$$

[Cho et al.;’96 and Lunghi et al.;’99]

SUSY parameter scan

test each parameter point for

- $b \to s\gamma$ constraints
- EW precision constraints
- Higgs-, chargino-, stop mass limits

	$\tan\beta$	$m_{H^\pm}$	M_2	$\lvert\mu\rvert$	$m_{\tilde{t}_R}$	A_t	$(\delta_{23}^u)_{LR}$
min.	3	300	100	80	170	−3000	−0.85
max.	15	1000	1000	1000	800	3000	0.85

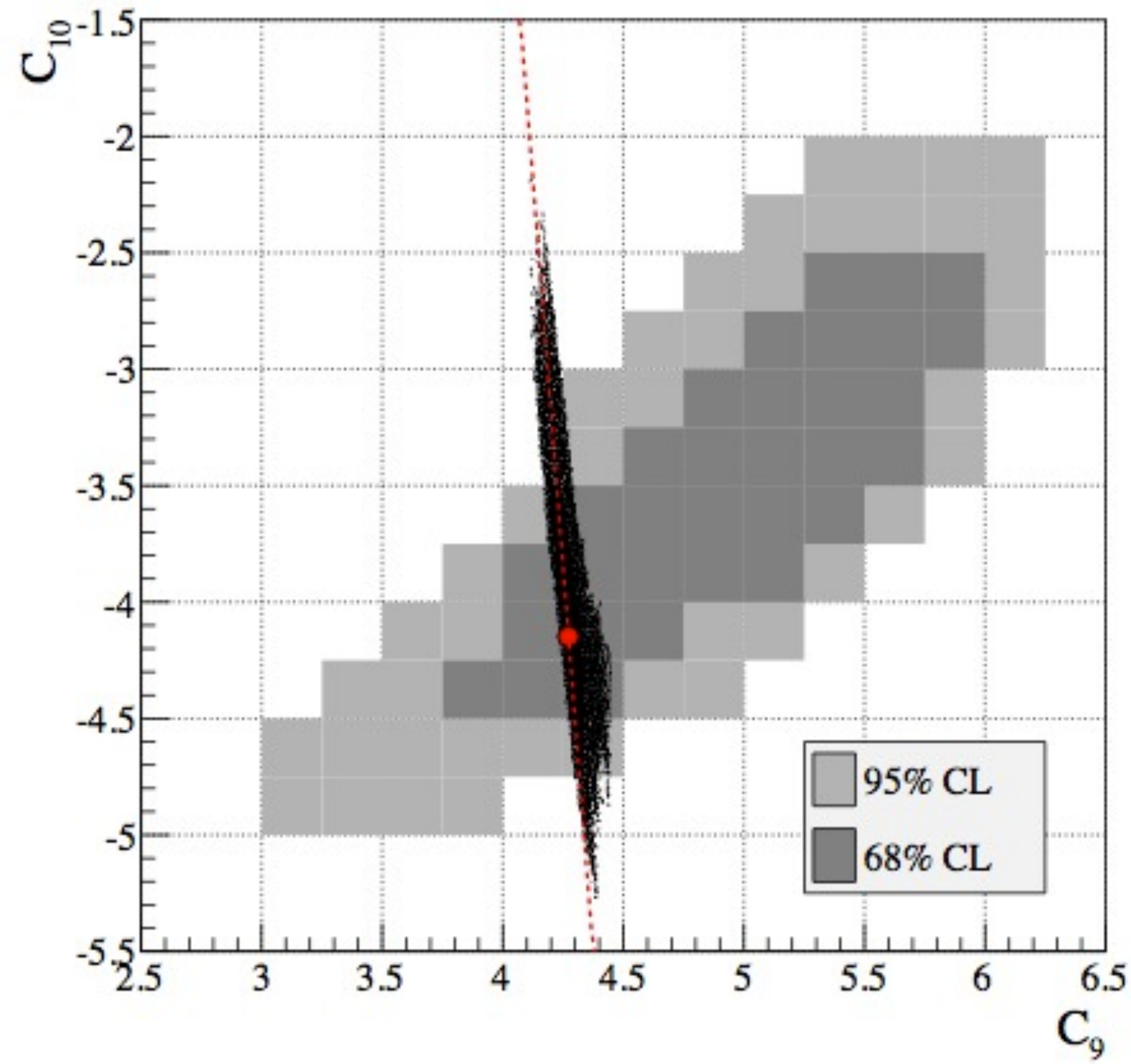
➠ maximal reach:

(1) for MFV-SUSY

- $|C_9^{NP}/C_9^{SM}| < 3\%$
- $|C_{10}^{NP}/C_{10}^{SM}| < 11\%$

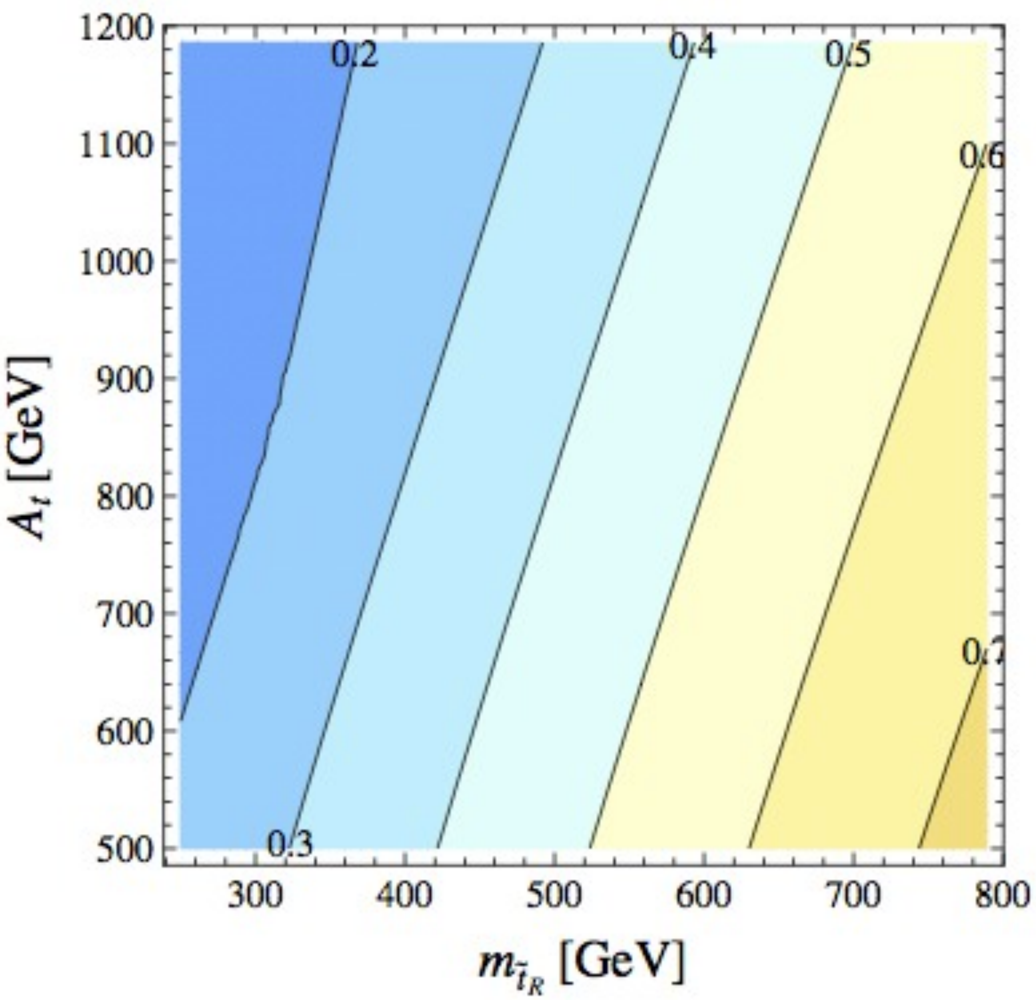
(2) for $(\delta_{23}^u)_{LR} \neq 0$

- $|C_9^{NP}/C_9^{SM}| < 4\%$
- $|C_{10}^{NP}/C_{10}^{SM}| < 47\%$

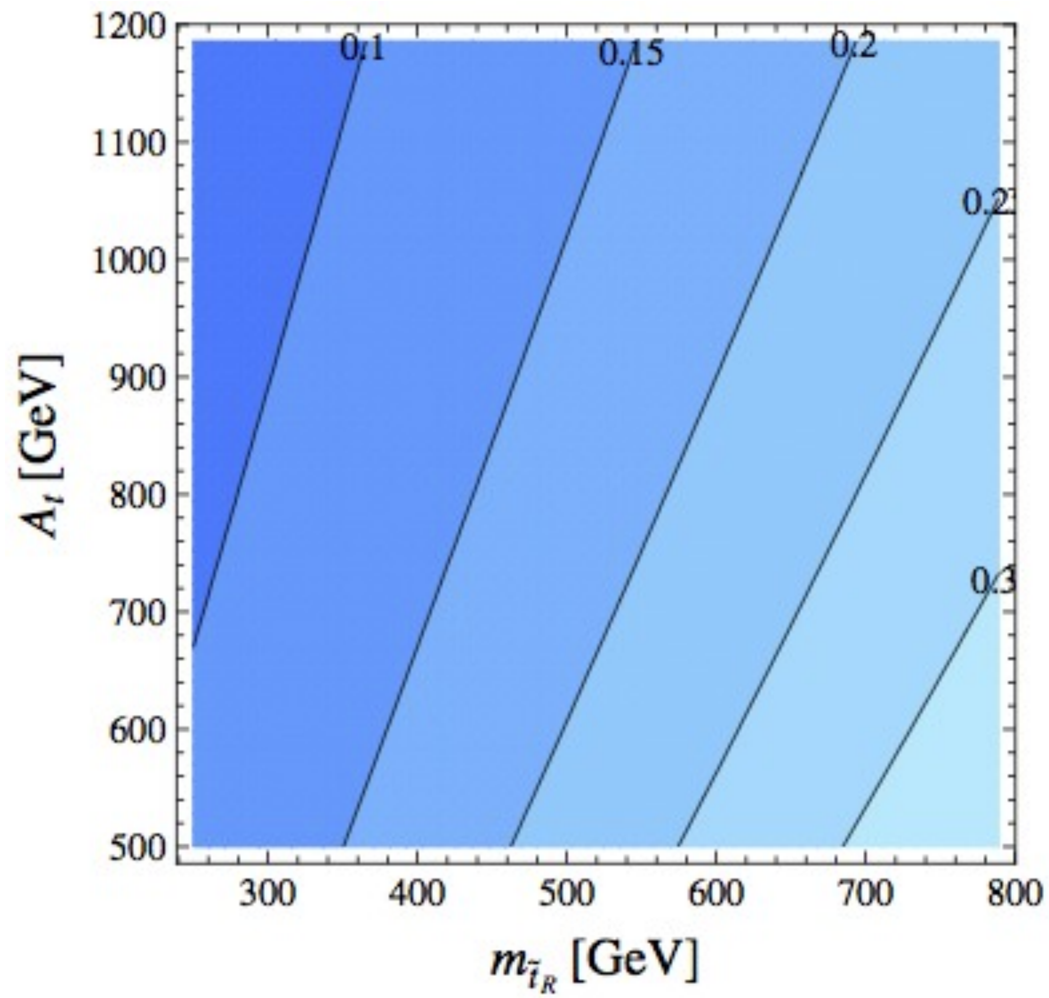


Improvement of $(\delta^u_{23})_{LR}$ -constraints

only b→sγ:



including $B \to K^{(*)} l^+ l^-$:



other SUSY parameters:

$$m_{\tilde{\nu}} = 100\,\text{GeV},\ m_{H^\pm} = 300\,\text{GeV},\ \tan\beta = 4,$$

$$M_2 = 150\,\text{GeV},\ \mu = -300\,\text{GeV},\ m_{\tilde{q}} = 1000\,\text{GeV}$$

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

if effects from (pseudo-)scalar operators can be neglected:

$$\mathcal{B}(\bar{B}_s \to \mu^+\mu^-) \propto \; f_{B_s}^2 |C_{10}|^2$$

⟹ can (indirectly) infer:

$$1 \times 10^{-9} \lesssim \mathcal{B}(\bar{B}_s \to \mu^+\mu^-) < 5(6) \times 10^{-9}$$

- SUSY can't completely cancel SM contribution
- upper bound: comparable to exp. limit

$$\mathcal{B}(\bar{B}_s \to \mu^+\mu^-) < 4.5\,(3.8) \times 10^{-9}$$

[LHCb, PRL 108 (2012)]

Implications for rare top decays

- negligible in SM
- largest effect on t→c γ, t→c g, t→c Z rates in MSSM

from gluino loops with $(\delta^u_{23})_{LR}$

- we update previous upper limits [Cao et al, PRD 75, 2007]

required Br. ratios for 5σ discovery at ATLAS: [Veloso, 2008]

	ATLAS 100 fb^{-1}
$t \to c\gamma$	3.0×10^{-5}
$t \to cg$	1.4×10^{-3}
$t \to cZ$	1.4×10^{-4}

we find: $\mathcal{B}(t \to c\gamma) \lesssim 2.1 \times 10^{-8}, \quad \mathcal{B}(t \to cg) \lesssim 7.2 \times 10^{-7}, \quad \mathcal{B}(t \to cZ) \lesssim 1.0 \times 10^{-7}$

⇒ orders of magnitude too low...

Implications for flavor-models ?

constraints still not very strong

➠ only models with large $(\delta^u_{23})_{LR} \sim A^u_{23}$ are affected

example: radiative flavor violation model of [Crivellin et al.;'11]

setup:

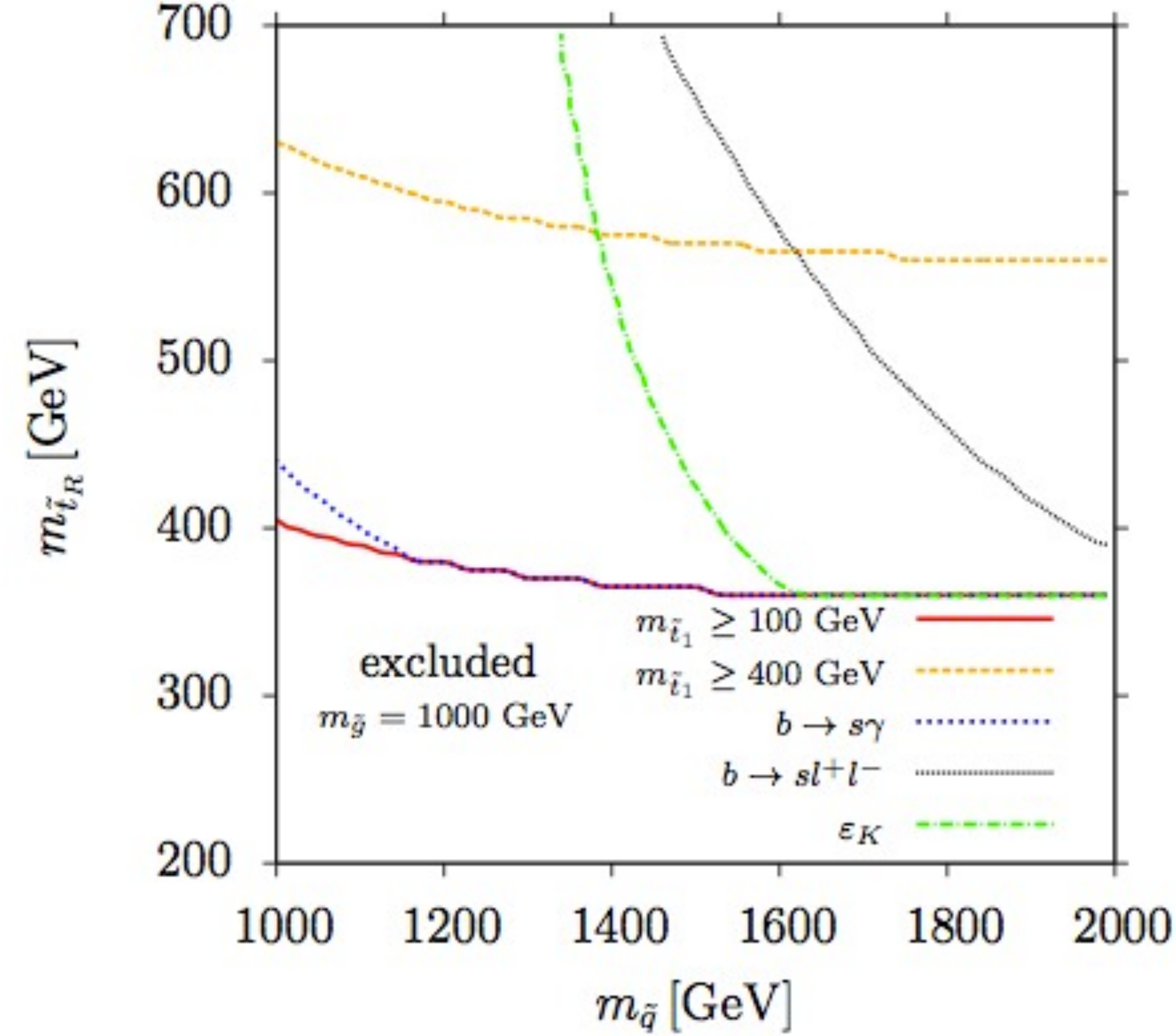
$$(Y_q^{tree})_{ij} = \delta_{i,3}\delta_{j,3}\lambda_q \qquad V_{CKM}^{tree} = \mathbf{1}_3$$

$\tilde{m}^2_Q, \tilde{m}^2_U, \tilde{m}^2_D$: diag, 1.+2. el. degenerate

flavor-breaking from A-terms only!

- quark mixing + masses generated from SUSY-loops with flavor-breaking A-terms
- to generate V_{cb} in up-sector need large A^u_{23}

we can (further) constrain this model...


700
600
500
400
300
200
1000
1200
1400
1600
1800
2000
$m_{\tilde{t}_R}$ [GeV]
$m_{\tilde{q}}$ [GeV]
excluded
$m_{\tilde{g}} = 1000$ GeV
$m_{\tilde{t}_1} \geq 100$ GeV
$m_{\tilde{t}_1} \geq 400$ GeV
$b \to s\gamma$
$b \to sl^+l^-$
ε_K

Conclusions

- we exploit improved constraints on C_9/C_{10} (stemming from theoretical and experimental progress in $B \to K^{(*)} \ell^+ \ell^-$ decays)
- most sensitive SUSY flavor parameter: $(\delta^u_{23})_{LR}$
  we find $(\delta^u_{23})_{LR} \lesssim 0.1$ (depending on flavor-diag. parameters)
- some implications:
  - ⋆ lower bound on $BR(B_s \to \mu^+ \mu^-)$ (in absence of scalar operators)
  - ⋆ invisibility of rare top decays at LHC strenghtened
  - ⋆ can restrict models with large A^u_{23} (e.g. RFV models)