

Flavor Changing Processes in SUSY Models with Hybrid Gauge- and Gravity-Mediation

based on 0812.0511 [hep-ph] with Yonit Hochberg and Yossi Nir, to
appear in JHEP.

Gudrun Hiller, Dortmund

* Data on FCNC suggest that – if $\Lambda_{NP} \sim \sqrt{s_{LHC}} \sim \Lambda_{EWKSB}$ – it is very natural that the suppression of flavor changing transitions is similar to the one in the SM

$$\mathcal{A}_{SM}(b \rightarrow q) \sim V_{tb}V_{tq}^* \cdot (m_t^2 - m_c^2)/m_W^2$$

$$\mathcal{A}_{NP}(b \rightarrow q) \sim f \cdot (m_t^2 - m_c^2)/\Lambda_{NP}^2 \quad f = \tilde{V}\tilde{V}^\dagger: \text{NP flavor mixing}$$

$$f \sim f_{SM} + \epsilon \text{ and } f_{SM} = \lambda^n, \lambda \simeq \sin \Theta_C \simeq 0.2.$$

* Flavor suppression as in the SM ($\epsilon = 0$):

Minimal Flavor Violation (MFV)

Chivukula, Georgi '87; d'Ambrosio et al '02 non-symmetry based definitions: Ali,London '99; Buras² '00

* Within MFV, the Yukawas are just parameters as in the SM.

- * The superpotential ($N = 1$, unbroken R-parity) is MFV !

$$W_{MSSM} = QY_u H_u U + QY_d H_d D + LY_e H_d E + \mu H_d H_u$$

- * Squark flavor-mixing within MFV expressed through quark-Yukawas

$$\tilde{m}_Q^2 = \tilde{m}^2 (a_1 \mathbf{1} + b_1 Y_u Y_u^\dagger + b_2 Y_d Y_d^\dagger) \quad \text{etc.}$$

Controlled departure from flavor-blind SUSY breaking.

- * Anomaly mediation, gauge mediation and CMSSM/mSUGRA (by construction) are MFV.

- * Highly degenerate squarks of 1st and 2nd generation:

$$\Delta m / \tilde{m} \sim \lambda_c^2 / 2; \quad \Delta m < 1 \text{ GeV}$$

- * 3rd generation squarks decoupled from first two (via V_{CKM}).

MFV b -physics predictions:

- * Small right-handed FCNC's.

- * Only CKM-induced CP-phases

→ $\arg(B_s - \bar{B}_s)$; many opportunities to test this with

$B \rightarrow (K^* \rightarrow K\pi)\mu^+\mu^-$; untagged $\bar{B}_s, B_s \rightarrow (\Phi \rightarrow KK)\mu^+\mu^-$ Bobeth et al

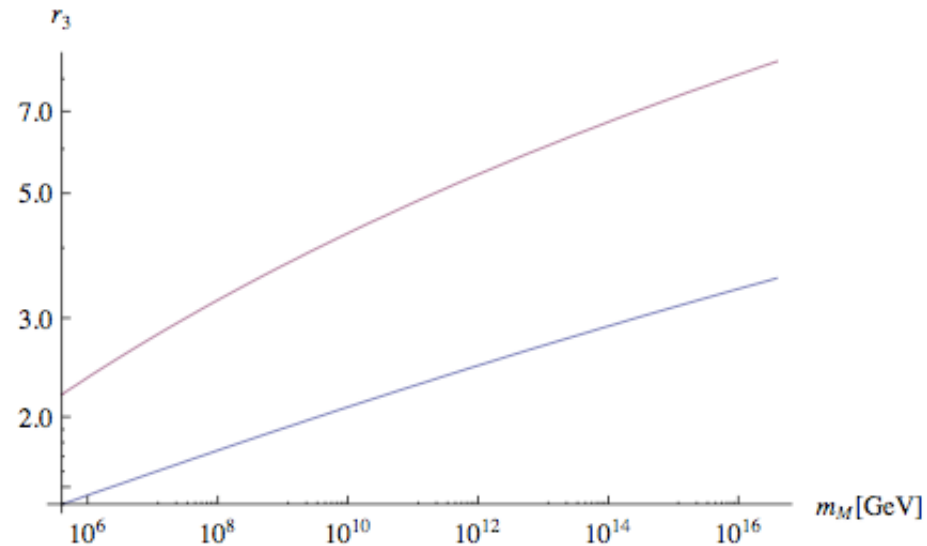
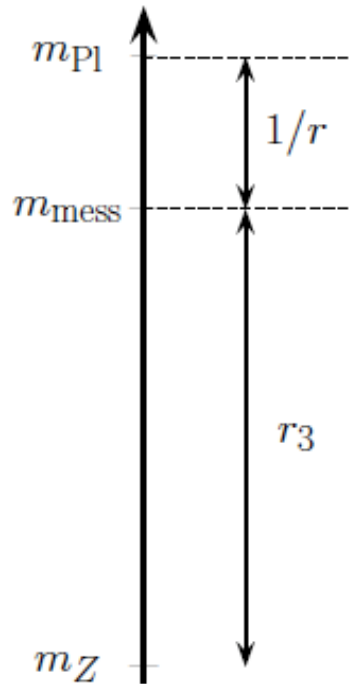
0805.2525

- * Large effects if $\tan\beta$ is large, e.g., in $B_{d,s} \rightarrow \mu\mu$.

- * Can we probe the (always present) effects from gravity mediation with gauge mediation being the dominant effect of SUSY-breaking ?
- * Is the model viable, or, what are the current constraints, arising from flavor physics, on hybrid gauge-gravity mediation ?

related works (sleptons): [Feng et al, 0712.0674](#); [Nomura et al, 0712.2074, 0802.2582](#)

Hybrid Gauge-Gravity Mediation



* MSSM-RGE-factor for soft squark masses $\tilde{m}^2(m_Z) = r_3 \tilde{m}^2(m_{mess})$

$$r_3 = r_3(m_M) = 1 + \frac{8}{3\pi} \left(\int_{\ln(m_Z)}^{\ln(m_M)} dt \frac{\alpha_3^3(t)}{\alpha_3^2(m_M)} \right) \frac{M_3^2(m_M)}{\tilde{m}^2(m_M)};$$

$$\frac{M_3^2(m_M)}{\tilde{m}_{12}^2(m_M)} = \frac{3}{8} N_M + \mathcal{O} \left[\left(\frac{\alpha_i}{\alpha_3} \right)^2 \right], \quad i = 1, 2, \quad \text{for } q = Q, U, D \quad r_3 \gtrsim 1 \text{ (mGMSB)}$$

* Ratio of soft masses $r = \tilde{m}_{gravity}^2 / \tilde{m}_{gauge}^2$

$$r \sim \left(\frac{m_M}{m_{Pl}} \right)^2 \left(\frac{4\pi}{\alpha_3(m_M)} \right)^2 \frac{3}{8} \frac{1}{N_M} \quad \text{(mGMSB; highest F-term couples to gauge mediation)}$$

* At the messenger scale m_M :

$$M_{\tilde{Q}_L}^2(m_M) = \tilde{m}_{\tilde{Q}_L}^2(\mathbf{1} + rX_{Q_L}),$$

$$M_{\tilde{D}_R}^2(m_M) = \tilde{m}_{\tilde{D}_R}^2(\mathbf{1} + rX_{D_R}),$$

$$M_{\tilde{U}_R}^2(m_M) = \tilde{m}_{\tilde{U}_R}^2(\mathbf{1} + rX_{U_R})$$

* Froggatt-Nielson-terms with V_{ij} : CKM, m_{q_i} : quark masses

$$(X_{q_{L,R}})_{ii} \sim 1, \quad (X_{q_L})_{ij} \sim |V_{ij}|, \quad (X_{q_R})_{ij} \sim \frac{m_{q_i}/m_{q_j}}{|V_{ij}|} \quad (i < j), \quad q = U, D.$$

(in flavor basis)

$$M_{\tilde{Q}_L}^2(m_Z) \sim \tilde{m}_{Q_L}^2 (r_3 \mathbf{1} + c_u Y_u Y_u^\dagger + c_d Y_d Y_d^\dagger + r X_{Q_L}),$$

$$M_{\tilde{U}_R}^2(m_Z) \sim \tilde{m}_{U_R}^2 (r_3 \mathbf{1} + c_{uR} Y_u^\dagger Y_u + r X_{U_R}),$$

$$M_{\tilde{D}_R}^2(m_Z) \sim \tilde{m}_{D_R}^2 (r_3 \mathbf{1} + c_{dR} Y_d^\dagger Y_d + r X_{D_R})$$

* c_u, c_d, c_{uR}, c_{dR} are RGE-induced and of order $[5/(16\pi^2)] \ln(m_M/m_Z)$ and can be $\mathcal{O}(1)$ for $m_M \sim m_{\text{GUT}}$.

* FN-terms are either RG-invariant to good approximation, or changed by $\mathcal{O}(1)$ factors, which is anyway the precision to which the X_{ij} are known.

(in basis with diagonal quark mass matrices and gluino couplings)

$$(\delta_{12}^u)_L \sim \frac{|V_{12}|}{r_3} \max(r, c_d y_b^2 |V_{ub} V_{cb}^*/V_{12}|) \sim r \frac{|V_{12}|}{r_3},$$

$$(\delta_{12}^d)_L \sim \frac{|V_{12}|}{r_3} \max(r, c_u y_t^2 |V_{ts} V_{td}^*/V_{12}|) \sim r \frac{|V_{12}|}{r_3},$$

$$(\delta_{i3}^u)_L \sim \frac{|V_{i3}|}{r_3} \max(r, c_d y_b^2) \sim \hat{r} \frac{|V_{i3}|}{r_3},$$

$$(\delta_{i3}^d)_L \sim \frac{|V_{i3}|}{r_3} \max(r, c_u y_t^2) \sim \frac{|V_{i3}|}{r_3}, \quad \hat{r} \equiv \max\{r, y_b^2\}.$$

$$(\delta_{ij}^q)_R \sim \frac{r}{r_3} \frac{m_{q_i}}{m_{q_j} |V_{ij}|}, \quad i \neq 3$$

* With $r > y_t^2 |V_{ts}|^2$ to have gravity contribution non-negligible.

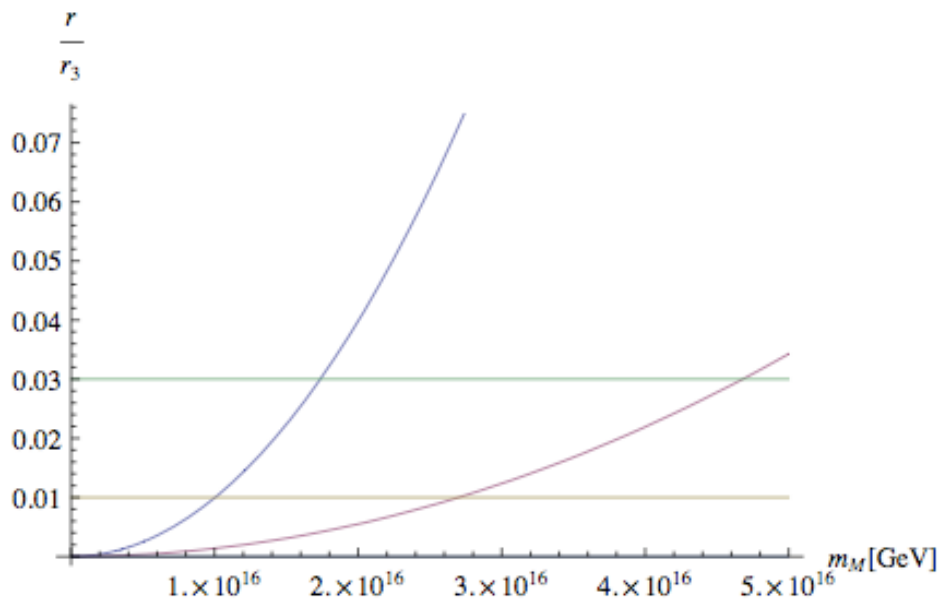
Hybrid Gauge-Gravity Mediation, δ_{ij}^q Predictions

- * The RGE-factor r_3 suppresses flavor violation, i.e., the δ_{ij}^q .
- * The $(\delta_{i3}^d)_L$ is insensitive to gravity-mediation because of the dominant MFV-RGE contributions from gauge-mediation.
- * $\langle \delta_{ij}^q \rangle = \sqrt{(\delta_{ij}^q)_L (\delta_{ij}^q)_R}$ are independent of the CKM matrix elements.
- * The strongest bound on r is from $\langle \delta_{12}^d \rangle$

$$r/r_3 \lesssim 0.01 - 0.03$$

Hybrid Gauge-Gravity Mediation, δ_{ij}^q Predictions

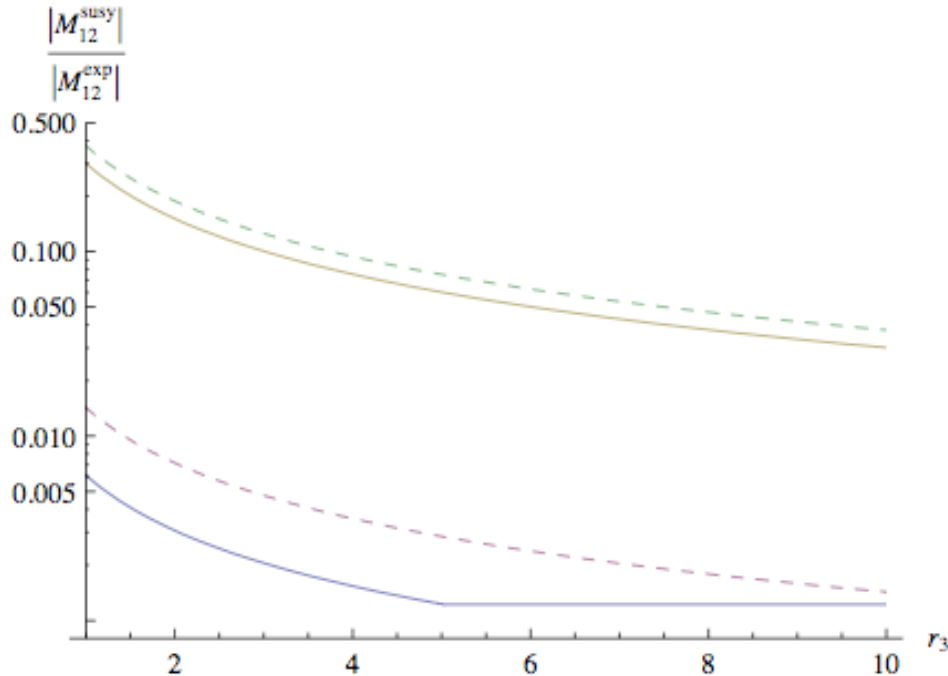
- * The strongest bound on r is from $\langle \delta_{12}^d \rangle$: $r/r_3 \lesssim 0.01 - 0.03$.



For number of messenger $N_M = 1$ (upper) and $N_M = 3$ (lower curve).

- * $m_M \lesssim m_{Pl}/10^3$ for $N_M = 1$ (mGMSB; highest F-term couples to gauge mediation).

Hybrid Gauge-Gravity Mediation, B, D -mixing



Upper two curves for $\tan \beta = 30$ and $m_{A^0} = 200$ GeV.

* B_d, B_s -mixing: Effects of order ten percent if $\tan \beta$ is large, otherwise one percent.

* D -mixing: $|M_{12}^{\text{susy}} / M_{12}^{\text{exp}}| \lesssim 5\%$ (order 1 in different flavor model possible).

$$R_{\mu\mu} = \frac{\mathcal{B}(B_s \rightarrow \mu^+ \mu^-)}{\mathcal{B}(B_d \rightarrow \mu^+ \mu^-)} \sim \frac{m_{B_s} f_{B_s}^2 \tau_{B_s}}{m_{B_d} f_{B_d}^2 \tau_{B_d}} \times r_{\text{ps}} \times \begin{cases} \frac{|V_{ts}|^2}{|V_{td}|^2} & \text{for (MFV, } (\delta_{i3}^d)_L), \\ \frac{|m_s V_{td}|^2}{|m_d V_{ts}|^2} & \text{for } ((\delta_{i3}^d)_R), \\ \frac{m_s}{m_d} & \text{for } (\langle \delta_{i3}^d \rangle), \end{cases}$$

* From top to bottom: 25 (MFV), 14, 19 (this FN-model);

$R_{\mu\mu}$ suppressed w.r.t. MFV/SM. Both Br's can be enhanced.

* Since $(\delta_{i3}^d)_R \gtrsim (\delta_{i3}^d)_L \rightarrow$ look for RH-currents, possibly even with CP-violation.

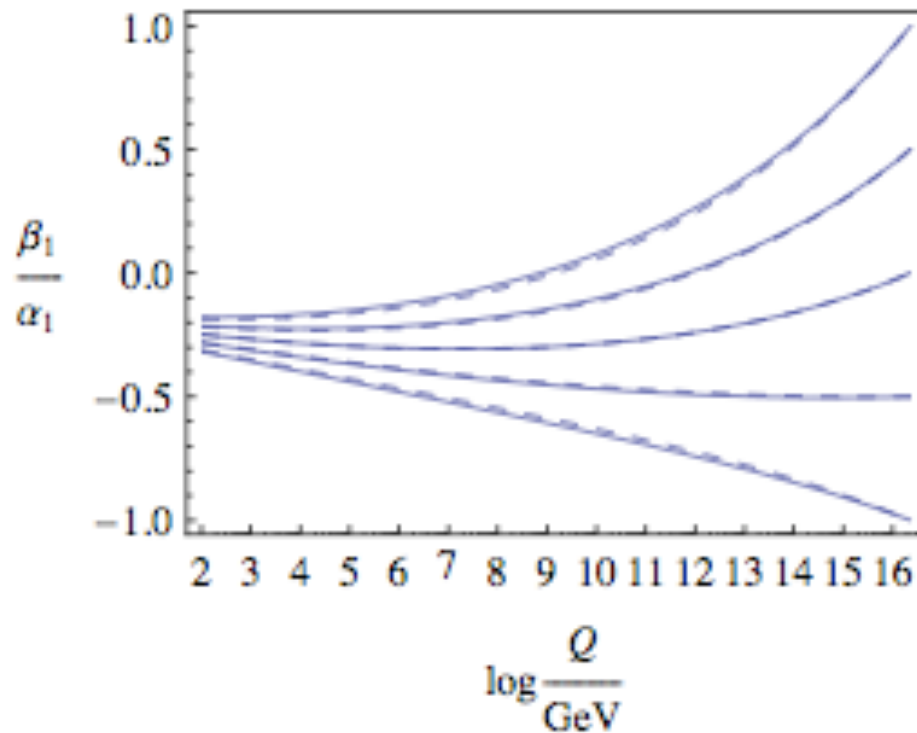
- We considered the effects of gravity-induced SUSY-breaking within gauge mediation. The model is a viable non-MFV scenario if the separation between the Planck and the messenger scale is sufficiently large.
- Given a model of flavor at the Planck scale, the hybrid gauge-gravity model is predictive, and can be tested with precision flavor experiments.
- The analysis can be extended to general gauge mediation by using distinct $r_3(Q)$, $r_3(U)$, $r_3(D)$ and relaxing the mGMSB squark-gluino mass relation; Then, also $r_3(X) < 1$ becomes possible.

back up slides

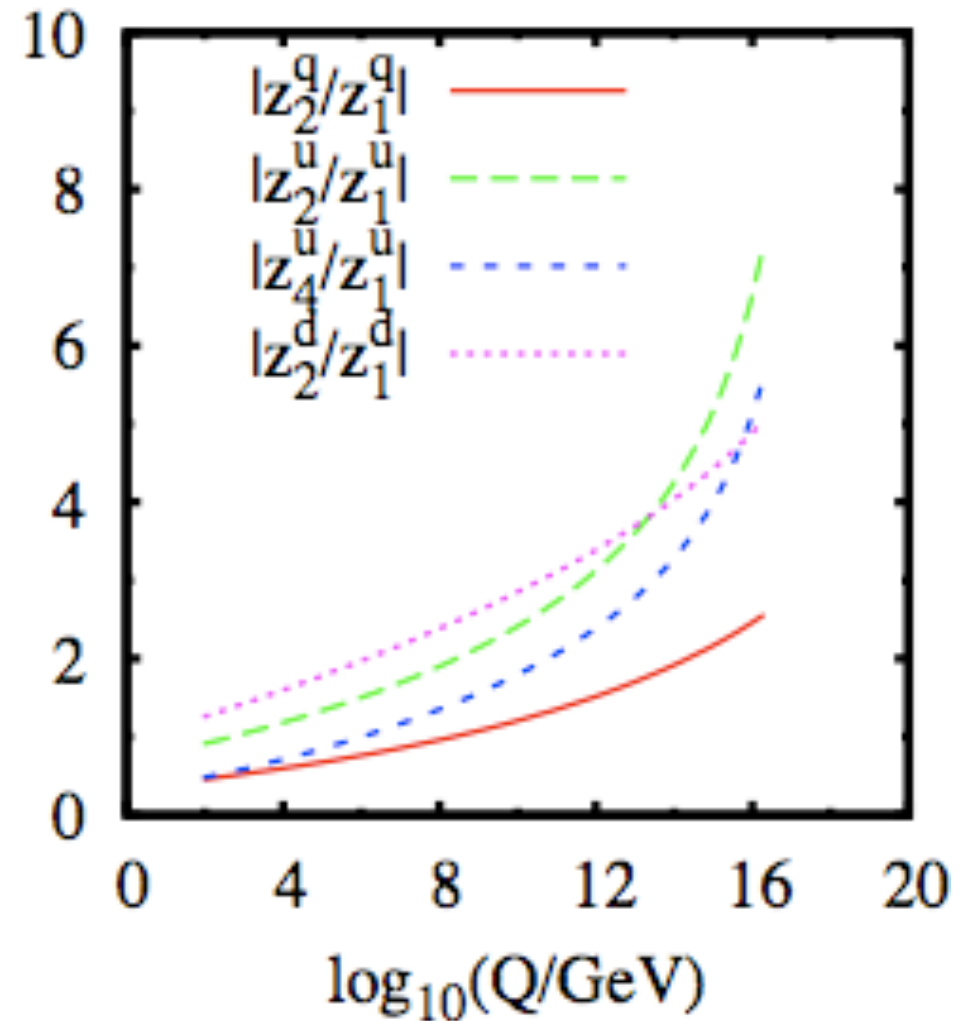
Running MFV Coefficients b_i/a_j

left: SPS2 (middle curve: $b_i(M_{GUT} = 0)$) [Paradisi et al 0805.3989](#)

right: AMSB [Allanach et al 0902.4880](#)



(e) SPS4

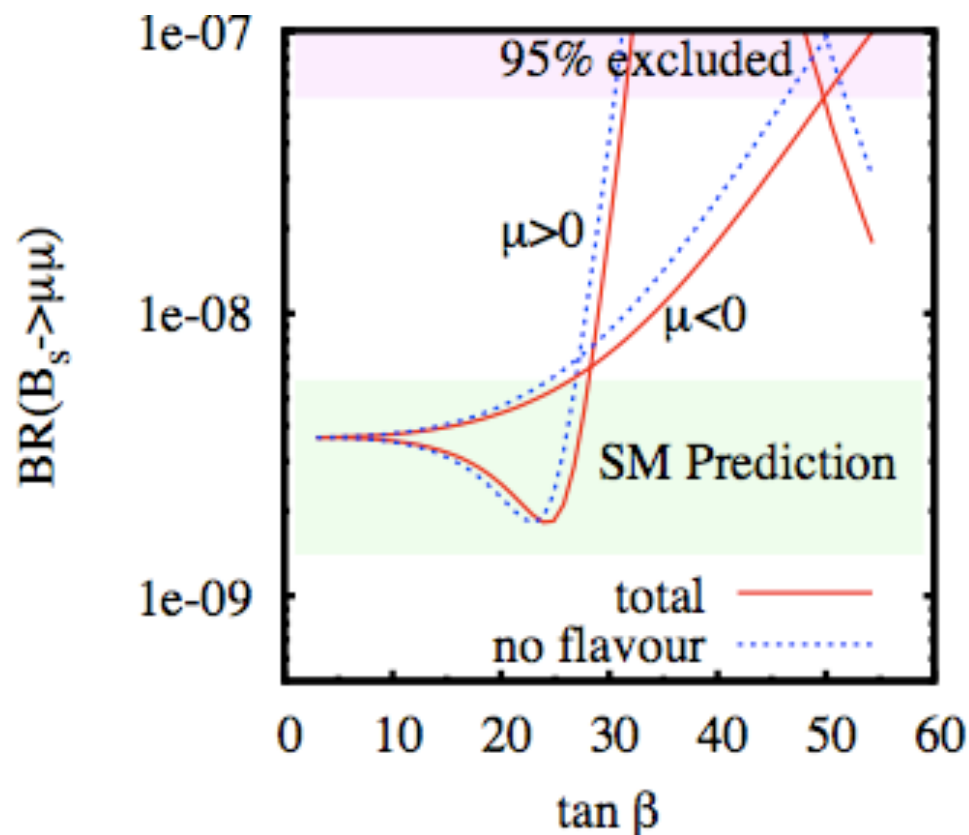
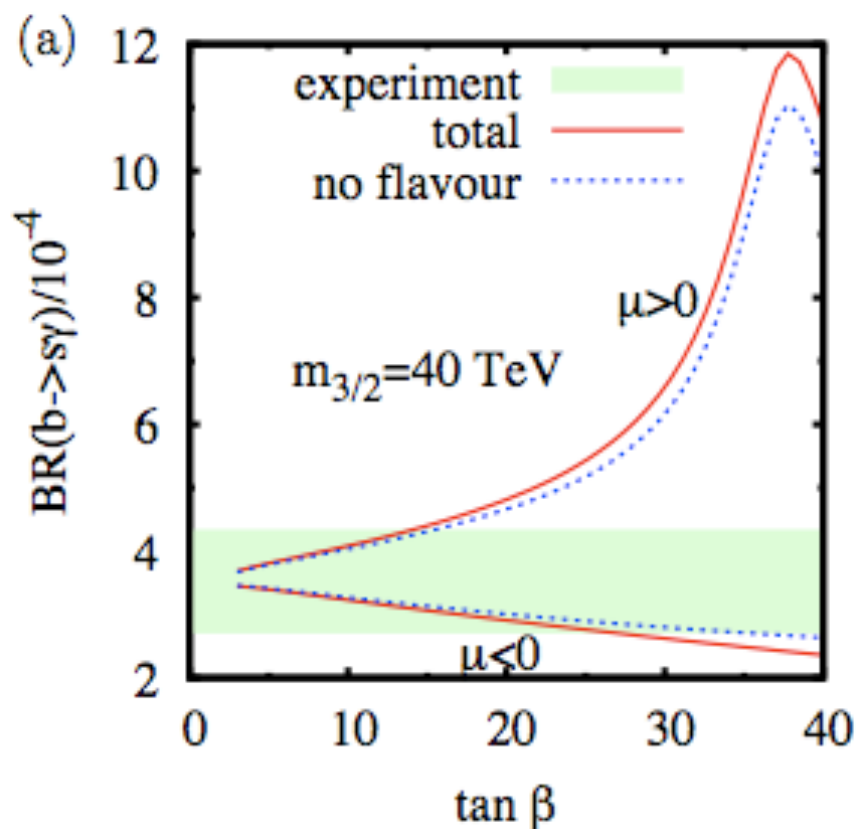


For low $\tan\beta$, mAMSB becomes exactly flavor blind in the QIR-fixed point limit of Y_t [0902.4880](#).

Testing MFV-SUSY with FCNC-Loops

* Predictive $\mathcal{O}(1)$ effects within MFV models if $\tan\beta$ largish. many works

Here, AMSB ($m_{3/2} = 40$ TeV) Figs from Allanach et al 0902.4880



Analytical expressions for the full flavor structure, that is, a_i, b_j or $(\delta^q)_{ij}$, within mAMSB 0902.4880.