Probing SUSY with Higgs and B physics at the Tevatron and the LHC

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Based on works done in collaboration with:

D. Garcia, U. Nierste and C. Wagner, Nucl. Phys. B577, 2000; Phys. Lett. B499, 2001
S.Heinemeyer, C. Wagner and G. Weiglein, Eur.Phys. J.C45, 2006
A. Menon, R. Noriega, A Szynkman and C. Wagner, hep-ph/0603106
A. Menon and C. Wagner, in preparation

Outline

- Introduction ==> Higgs and Flavor in the Standard Model
- The Flavor Issue in Supersymmetry ==> Minimal Flavor Violation (MFV)

-- $\tan\beta$ **enhanced loop corrections to neutral Higgs-fermion couplings**

==> Flavor conserving processes :

Non-Standard MSSM Higgs production at the Tevatron and LHC

==> Flavor Changing Neutral Currents (FCNC)

B_S Mixing and the rare decay rate $B_S \rightarrow \mu^+\mu^-$

-- Loop FC effects in the Charged Higgs-fermion couplings

==> $\mathrm{BR}(b \rightarrow s\gamma)$ and $\mathrm{BR}(B_u \rightarrow \tau\nu)$

- Probing SUSY parameters through B and Higgs Physics at the Tevatron and LHC
- Conclusions

The Flavor Structure in the SM

- In the mass eigenstate basis, the interactions of the Higgs field are also flavor diagonal

$$\bar{d}_i(\hat{m}_i + h_i H)d_i, \qquad \text{with} \quad \hat{m}_i = h_i v$$

Flavor Changing effects arise from charged currents, which mix left-handed up and down quarks:

$$\bar{u}_{L,i} V_{CKM}^{ij} \gamma_\mu d_{L,j} W_\mu^+ + h.c. \quad \text{where} \quad V_{CKM} = U_L^\dagger D_L$$

- The CKM matrix is almost the identity ==> transitions between different flavors are suppressed in the SM

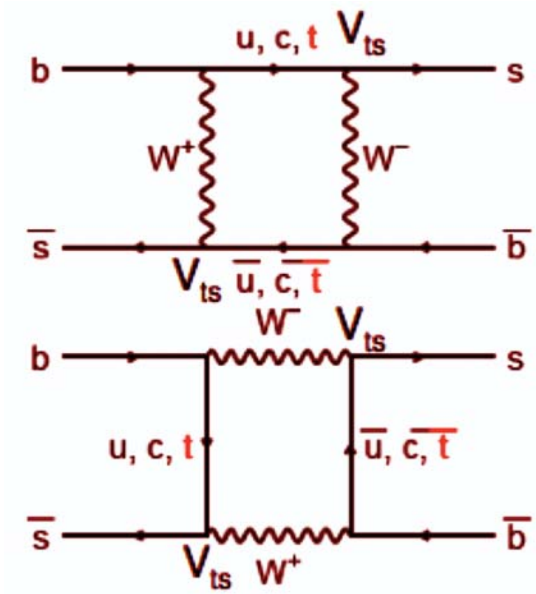
- The Higgs sector and the neutral gauge interactions do not lead to FCNC

FC effects in B observables in the SM

A) Bs mixing

$$B_s^0 = (\bar{b}\, s) \qquad \bar{B}_s^0 = (b\bar{s})$$

Flavor eigenstates mix via weak interactions



Mass eigenstates:

$$B_H = pB_s^0 + q\bar{B}_s^0 \qquad B_L = pB_s^0 - q\bar{B}_s^0$$

B_H and B_L differ from CP eigenstates:

$$q/p = e^{-i2\beta_S} \text{ with } \beta_S = O(10^{-2})$$

The B meson mass matrix $$M = \begin{bmatrix} M - i\Gamma/2 & M_{12} - i\Gamma_{12}/2 \\ M_{12}^* - i\Gamma_{12}^*/2 & M - i\Gamma/2 \end{bmatrix} \qquad \Gamma_{12} << M_{12}$$

$$\Delta M_s = M_{B_H} - M_{B_L} = 2\,|M_{12}| = \frac{G_F^2}{6\pi^2}\eta_B m_{B_S} \underbrace{\hat{B}_{B_S} f_{B_S}^2}_{\text{lattice}} M_W^2 S_0(m_t)\,|V_{ts}|^2$$

Short distance QCD corrections

Box-diagram

ΔM_S Direct Measurement and Global CKM Fit

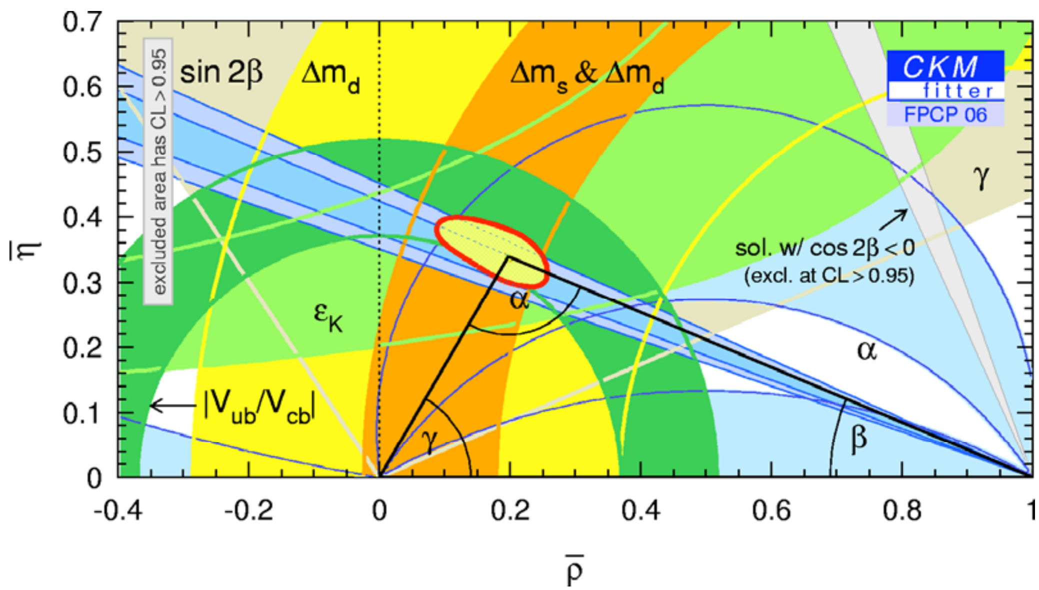
$$\Delta M_S^{\text{CDF.}} = 17.33^{+0.42}_{-0.21} \pm 0.07\, ps^{-1} \qquad 17\, ps^{-1} < \Delta M_S^{\text{D0@90\%C.L.}} < 21\, ps^{-1}$$

Using ratio

↓

$$\frac{\Delta m_s}{\Delta m_d} = \frac{m_{Bs}}{m_{Bd}} \frac{f_{Bs}^2 B_{Bs}}{f_{Bd}^2 B_{Bd}} \frac{|V_{ts}|^2}{|V_{td}|^2}$$

Minimize QCD lattice uncertainty providing a measurement of $|V_{ts}|/|V_{td}|$

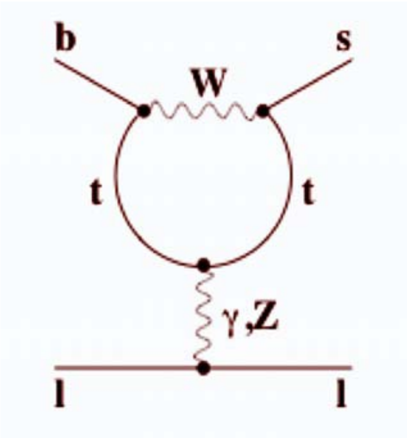


- SM fit:

CMK fit $\Rightarrow \Delta M_S = 21.7^{+5.9(+9.7)}_{-4.2(-6.8)}\, ps^{-1}$ at 1(2) σ C.L. $\quad \Rightarrow -14.1 < \Delta M_{B_s}^{NP}[ps^{-1}] < 2.4$

UT fit $\Rightarrow \Delta M_S = 21.5 \pm 2.6\, ps^{-1}$ at 1 σ C.L. $\quad \Rightarrow -9.4 < \Delta M_{B_s}^{NP}[ps^{-1}] < 1$ at 2σ

B) Rare decay rate $B_S \to \mu^+\mu^-$

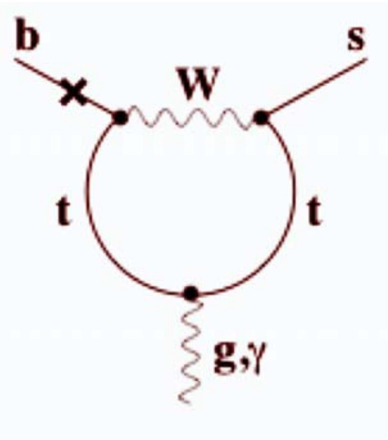


$$\text{SM amplitude} \propto V_{ts} \frac{m_\mu}{M_W}$$

$$BR(B_s \to \mu^+\mu^-)_{SM} \approx (3.8 \pm 1.0) \times 10^{-9}$$

- Present CDF limit: $BR(B_s \to \mu^+\mu^-) < 1.\,10^{-7}$

C) Rare decay rate $B \to X_S\gamma$

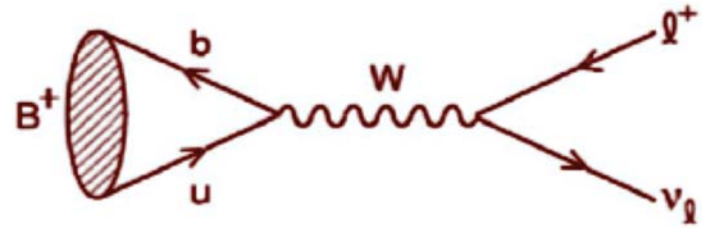


$$BR(B \to X_S\gamma)^{SM}_{E_\gamma > 1.8\,GeV} = (3.38\ {}^{+0.31}_{-0.42}\ {}^{+0.32}_{-0.30}) \times 10^{-4}$$

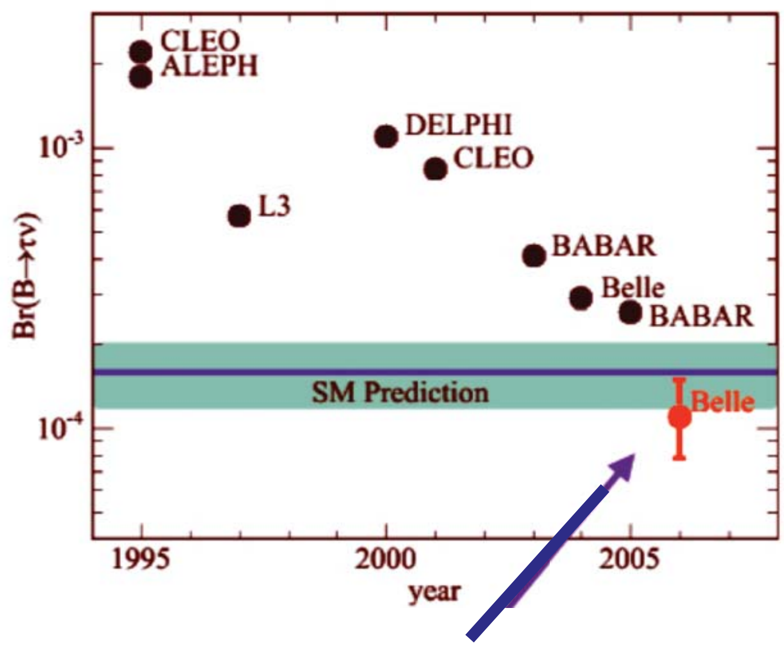
Estimated bound on New Physics
using Belle results ==> Neubert 05

$$|BR(B \to X_S\gamma)^{exp} - BR(B \to X_S\gamma)^{SM}| < 1.3 \times 10^{-4}$$

D) $B_u \to \tau\nu$ transition



$$BR(B_u \to \tau\nu)^{SM} = \frac{G_F^2 m_B m_\tau^2}{8\pi}\left(1-\frac{m_\tau^2}{m_B^2}\right) f_B^2 |V_{ub}|^2 \tau_B = (1.59 \pm 0.40)\ \times 10^{-4}$$



In agreement with SM within errors

$$BR(B_u \to \tau\nu)^{\exp} = (1.06\ {}^{+0.34}_{-0.28}\ {}^{+0.18}_{-0.16})\ 10^{-4}$$

Flavor Beyond the Standard Model

- **Two Higgs doublet Models:**

  Yukawa interactions ==> $\bar{d}_{R,i}(\hat{h}^{ij}_{d,1}\ \phi_1 + \hat{h}^{ij}_{d,2}\ \phi_2)\ d_{L,j}$

The Higgs doublets acquire different v.e.v.'s and the mass matrix reads

==> $\hat{m}^{ij}_d = \hat{h}^{ij}_{d,1}\mathrm{v}_1 + \hat{h}^{ij}_{d,2}\mathrm{v}_2$

Diagonalization of the mass matrix will not give diagonal Yukawa couplings
==> will induce large, usually unacceptable FCNC in the Higgs sector

Easiest solution: One Higgs doublet couples only to down quarks and the other couples to up quarks only

Supersymmetry, at tree level

$$-L = \overline{\psi}^i_L\left(\hat{h}^{ij^+}_d\ \phi_1 d^j_R + \hat{h}^{ij^+}_u\ \phi_2 u^j_R\right) + h.c. \qquad \overline{\psi}^i_L = \begin{pmatrix} \overline{u}_L \\ \overline{d}_L \end{pmatrix}^i$$

Since the up and down sectors are diagonalized independently, the Higgs interactions remain flavor diagonal at tree level.

The flavor problem in SUSY Theories

SUSY breaking mechanisms ==> can give rise to large FCNC effects

- Novel sfermion-gaugino-fermion interactions, e.g. for the down sector

$$\bar{d}^i_{L,R}\ \tilde{\lambda}\ \tilde{d}^j_{L,R} \rightarrow \bar{d}_{L,R} D^+_{L,R} \tilde{D}_{L,R} \tilde{\lambda}\ \tilde{d}_{L,R}$$

recall $V_{CKM} = U^+_L D_L$

where $\tilde{D}_{L,R}$ come from the block diagonalization of the squark mass matrix

$$\begin{pmatrix} \tilde{d}^{i\,*}_L & \tilde{d}^{i\,*}_R \end{pmatrix} \begin{pmatrix} M_Q^2 + \mathrm{v}_1^2 \hat{h}_d^+ \hat{h}_d + D_{\tilde{d}_L} & \mathrm{v}_1 \left(A_d^* - \mu \tan\beta\right) \hat{h}_d^+ \\ \mathrm{v}_1 \hat{h}_d \left(A_d - \mu^* \tan\beta\right) & M_D^2 + \mathrm{v}_1^2 \hat{h}_d \hat{h}_d^+ + D_{\tilde{d}_R} \end{pmatrix} \begin{pmatrix} \tilde{d}^i_L \\ \tilde{d}^i_R \end{pmatrix}$$

- The diagonal entries are 3x3 matrices with M_Q^2, M_D^2 the soft SUSY breaking mass matrices and the rest proportional to the Yukawa or I
- The off-diagonal matrices are proportional to the Yukawa and to the soft SUSY breaking matrices A_d coming from the trilinear interactions of the Higgs doublets with the sfermions

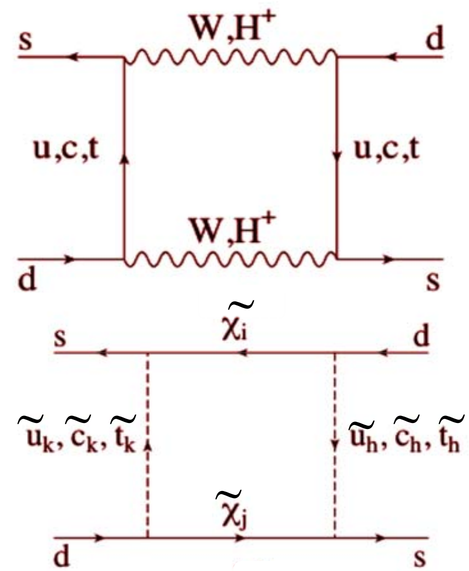
$$\tilde{u}_L^* \left(A_u^* \phi_2 - \mu \phi_1\right) \hat{h}_u^+ \tilde{u}_R + \tilde{d}_L^* \left(A_d^* \phi_1 - \mu \phi_2\right) \hat{h}_d^+ \tilde{d}_R + h.c.$$

Minimal Flavor Violation

- At tree level: the quarks and squarks diagonalized by the same matrices

$$\tilde{D}_{L,R} = D_{L,R}; \quad \tilde{U}_{L,R} = U_{L,R}$$

Hence, in the quark mass eigenbasis the only FC effects arise from charged currents via V_{CKM} as in SM.



Isidori, Retico
Buras et al.

- At loop level: FCNC generated by two main effects:
  1) Both Higgs doublets couple to up and down sectors
  ==> important effects in the B system at large tan beta

  2) Soft SUSY breaking parameters obey Renormalization Group equations: given their values at the SUSY scale, they change significantly at low energies
  ==> RG evolution adds terms prop. to $h_d h_d^+$ and $h_u h_u^+$, and h.c.

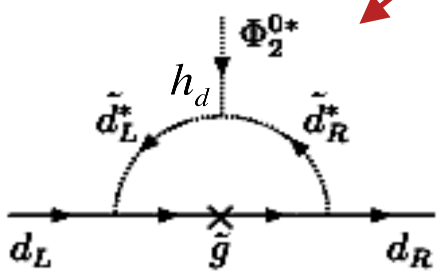
In both cases the effective coupling governing FCNC processes

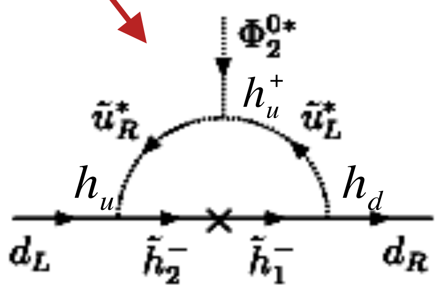
D'Ambrosio, Giudice, Isidori, Strumia

$$(X_{FC})_{ij} = (h_u^+ h_u)_{ij} \propto m_t^2 \, \mathrm{V}_{3i}^{\mathrm{CKM}*} \mathrm{V}_{3j}^{\mathrm{CKM}} \qquad \text{for } i \neq j$$

$\tan\beta$ enhanced loop corrections to neutral Higgs-fermion couplings

$$-L_{eff.} = \overline{d}_R^0 \hat{h}_d \left[\phi_1^{0^*} + \phi_2^{0^*}\left(\hat{\varepsilon}_0 + \hat{\varepsilon}_Y \hat{h}_u^+ \hat{h}_u\right)\right] d_L^o + \phi_2^0 \overline{u}_R^0 \hat{h}_u u_L^0 + h.c.$$





ε loop factors intimately connected to the structure of the squark mass matrices.

- **In terms of the quark mass eigenstates** Dedes , Pilaftsis

$$h_u = M_u / v_2$$

$$-L_{eff} = \frac{1}{v_2}\left(\tan\beta\,\Phi_1^{0^*} - \Phi_2^{0^*}\right)\overline{d}_R M_d\left[V_{CKM}^+ R^{-1} V_{CKM}\right] d_L + \frac{1}{v_2}\Phi_2^{0^*}\overline{d}_R M_d d_L + \Phi_2^0 \overline{u}_R M_u u_L + h.c.$$

and $R = 1 + \varepsilon_0 \tan\beta + \varepsilon_Y \tan\beta |h_u|^2$ ➔ R diagonal

Dependence on SUSY parameters ➔

$$\varepsilon_0^i \approx \frac{2\alpha_s}{3\pi}\frac{\mu^* M_{\tilde{g}}^*}{\max\left[m_{\tilde{d}_1^i}^2, m_{\tilde{d}_2^i}^2, M_{\tilde{g}}^2\right]} \qquad \varepsilon_Y \approx \frac{\mu^* A_t^*}{16\pi^2 \max\left[m_{\tilde{t}_1}^2, m_{\tilde{t}_2}^2, \mu^2\right]}$$

Looking at $V_{CKM} \cong I \Rightarrow$ Flavor Conserving Higgs-fermion couplings

$$-L_{eff} = \frac{1}{v_2}\left(\tan\beta\,\Phi_1^{0^*} - \Phi_2^{0^*}\right)\overline{b}_R M_d \frac{1}{R^{33}} b_L + \frac{1}{v_2}\Phi_2^{0^*}\overline{b}_R M_d b_L + h.c.$$

$$R^{33} = 1 + \left(\varepsilon_0^3 + \varepsilon_Y h_t^2\right)\tan\beta \equiv 1 + \Delta_b$$

2 Higgs SU(2) doublets ϕ_1 and ϕ_2 : after Higgs Mechanism

==> 5 physical states: 2 CP-even h, H with mixing angle α

1 CP-odd A and a charged pair $H^{\pm}$

such that :

$$\phi_1^0 = -\sin\alpha\, h + \cos\alpha\, H + i\sin\beta\, A$$
$$\phi_2^0 = \cos\alpha\, h + \sin\alpha\, H - i\cos\beta\, A$$

and at large $\tan\beta$, $m_A > m_h^{max}$:

$\cos\alpha \approx \sin\beta$; $\sin\alpha \approx -\cos\beta$

Hence:

$$H + iA \cong \sin\beta\ \phi_1^0 - \cos\beta\ \phi_2^0$$

$$-L_{eff} = \frac{m_b\tan\beta}{(1+\Delta_b)v}\phi_1^{0*}\overline{b}_R b_L + h.c. \longrightarrow g_{Abb} \cong g_{Hbb} \cong \frac{m_b\tan\beta}{(1+\Delta_b)v}$$

destroy basic relation

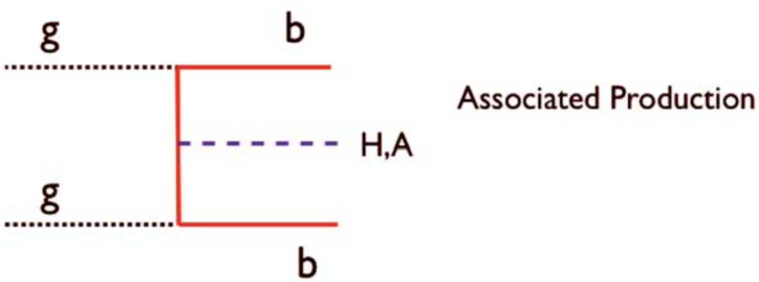
$$g_{A/H\,bb}/g_{A/H\,\tau\tau} \neq m_b/m_\tau$$

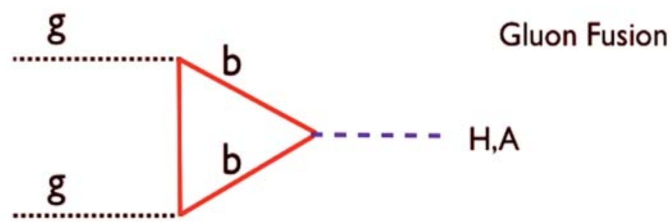
$$|\Delta_\tau| << |\Delta_b| \Rightarrow g_{A\tau\tau} \cong g_{H\tau\tau} \cong m_\tau\tan\beta/v$$

Non-Standard Higgs Production at the Tevatron and LHC

- Enhanced couplings to b quarks and tau-leptons
- Considering value of running bottom mass and 3 quark colors

$$BR(A \to b\bar{b}) \cong \frac{9}{9 + (1+\Delta_b)^2} \qquad BR(A \to \tau^+\tau^-) \cong \frac{(1+\Delta_b)^2}{9 + (1+\Delta_b)^2}$$





$$\sigma(b\bar{b}A) \times BR(A \to b\bar{b}) \cong \sigma(b\bar{b}A)_{SM} \times \frac{\tan\beta^2}{(1+\Delta_b)^2} \times \frac{9}{(1+\Delta_b)^2 + 9}$$

$$\sigma(b\bar{b}, gg \to A) \times BR(A \to \tau\tau) \cong \sigma(b\bar{b}, gg \to A)_{SM} \times \frac{\tan\beta^2}{(1+\Delta_b)^2 + 9}$$

There may be a strong dependence on the SUSY parameters in the bb search channel. This dependence is much weaker in the tau-tau channel

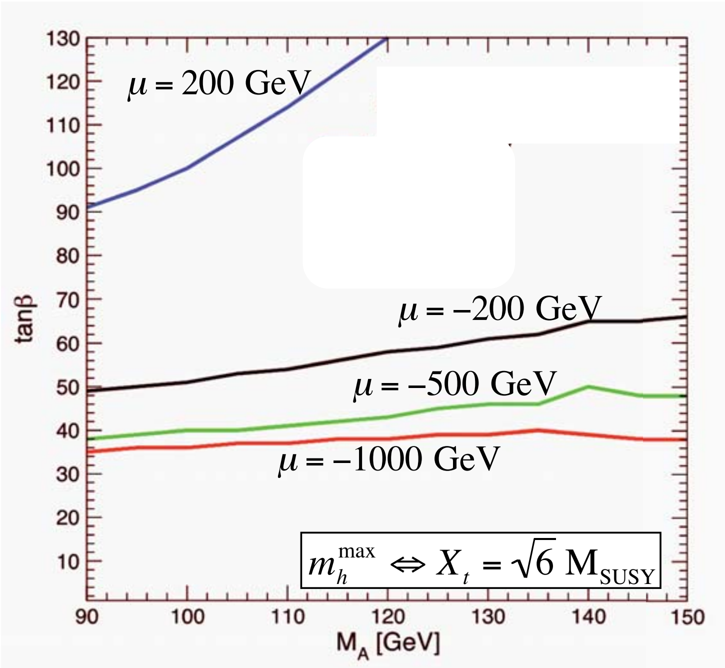
Searches for Non-Standard Higgs bosons at the Tevatron

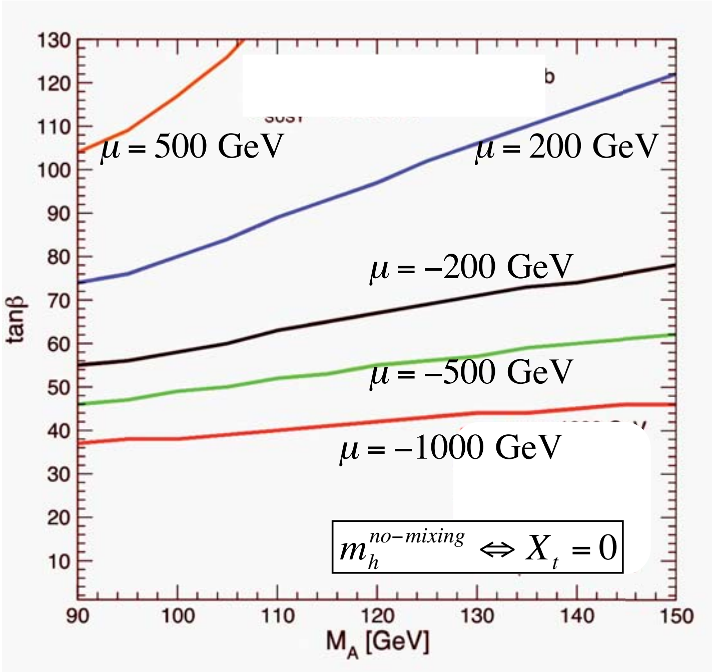
A) In the bb mode ==> probe large region of $\tan\beta - m_A$ plane

Stop mixing param.: $X_t = A_t - \mu/\tan\beta$

$$p\bar{p} \to b\bar{b}\,\phi, \quad \phi \to b\bar{b}$$

$\Rightarrow$ based on D0 $\to 260\text{pb}^{-1}$





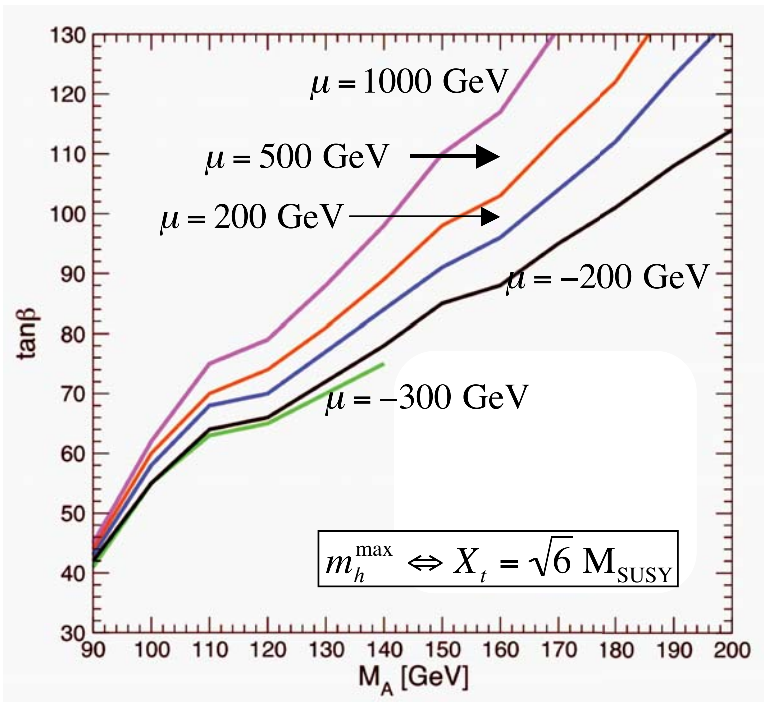
- Enhanced reach for negative values of μ
- Strong dependence on SUSY parameters

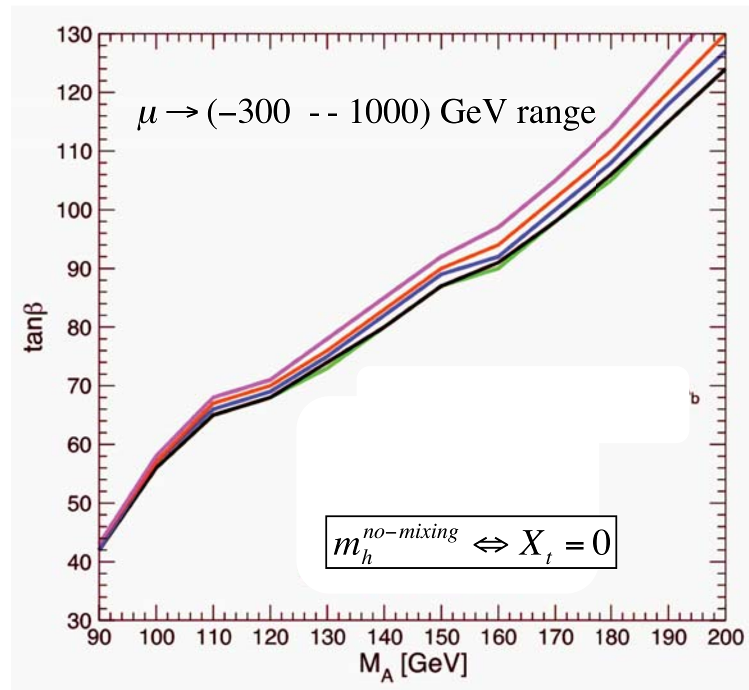
M. C. et al. hep-ph/0511023

$$\sigma(b\bar{b}\phi)BR(\phi \to b\bar{b}) \propto 1/(1+\Delta_b)^2 \Rightarrow \text{enhanced for } \Delta_b < 0 \;\Leftrightarrow \mu < 0 \;\; (\text{if } A_t \text{ and } M_{\tilde{g}} > 0)$$

B) In the tau tau inclusive mode

$$p\bar{p} \to X\phi, \quad \phi \to \tau^+\tau^- \quad \Rightarrow \text{ based on CDF: } 310\text{pb}^{-1}$$





M. C. et al. hep-ph/0511023

- Important reach for large tanb, small m_A

- Weaker dependence on SUSY parameters via radiative corrections

Loop-induced Higgs mediated FCNC in the down-quark sector

- **In the MFV scenario, the neutral Higgs flavor changing Lagrangian**

$$-L_{FCNC} = \bar{d}_R^{\,j}\left(X_{RL}^S\right)^{ji} d_L^i\ \phi_S + h.c. \qquad \text{with } \mathrm{i} \neq \mathrm{j} \quad \phi_{\mathrm{S}} = h, H, A$$

$$\text{and} \quad \left(\mathrm{X}_{\mathrm{RL}}^{\mathrm{S}}\right)^{ji} = \frac{\overline{m}_{d\,j}\, h_t^2\, \varepsilon_Y \left(x_2^S - x_1^S \tan\beta\right)\tan\beta}{\mathrm{v}\left(1+\varepsilon_0^{\mathrm{j}}\tan\beta\right)\left(1+\Delta_b\right)} \mathrm{V}_{\mathrm{CKM}}^{3\mathrm{j}\,*}\mathrm{V}_{\mathrm{CKM}}^{3\mathrm{i}}$$

Example: case of universal soft SUSY squark mass parameters

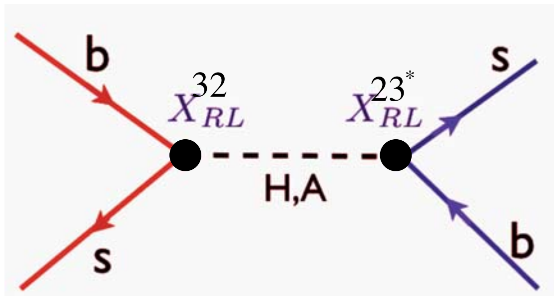
x_1^S, x_2^S are the components of the h, H and A in ϕ_1^0, ϕ_2^0
==> $\tan\beta^2$ enhanced coupling for H/A or h/A, depending on value of m_A

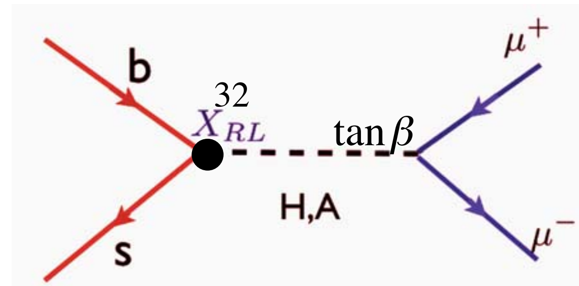
- Effects of RG evolution proportional to $h_u h_u^+ \text{ in } M_Q \quad \Rightarrow \left(X_{RL}^S\right)^{ji} \propto \Delta_b / \tan\beta - \varepsilon_0^{1,2}$

L-H. squarks are not diagonalized by the same rotation as L-H. quarks
==> induces FC in the left-handed quark-squark-gluino vertex prop V_{CKM}

Correlation between Bs mixing and $\mathrm{BR}(B_S \to \mu^+\mu^-)$

due to $\tan\beta$ enhanced Higgs mediated flavor violating effects





$$\left(\Delta M_{B_S}\right)^{SUSY} \propto \ominus \frac{X_{RL}^{32} X_{LR}^{32}}{m_A^2}$$

Negative sign with respect to SM

$$BR(B_S \to \mu^+\mu^-)^{SUSY} \propto \frac{\left|X_{RL}^{32}\right|^2 \tan\beta^2}{m_A^4}$$

- SUSY contributions strongly correlated, and for Minimal Flavor Violation

$$\frac{\Delta M_{B_S}}{BR(B_S \to \mu^+\mu^-)} \propto \frac{m_A^2}{\tan\beta^2}$$

to maximize $\Delta M_{B_S}^{DP}$ for a given value of $\mathrm{BR}(B_S \to \mu^+\mu^-)$ $\Leftrightarrow$ minimize $\tan\beta$ (for fixed m_A)

$\Rightarrow$ choose large, negative values of ε_0 and ε_Y (large implies $\mu \approx M_{\tilde{g}} \approx 2M_{\tilde{q}} \approx \frac{2}{3}A_t$)

What can we learn from Bs-mixing?

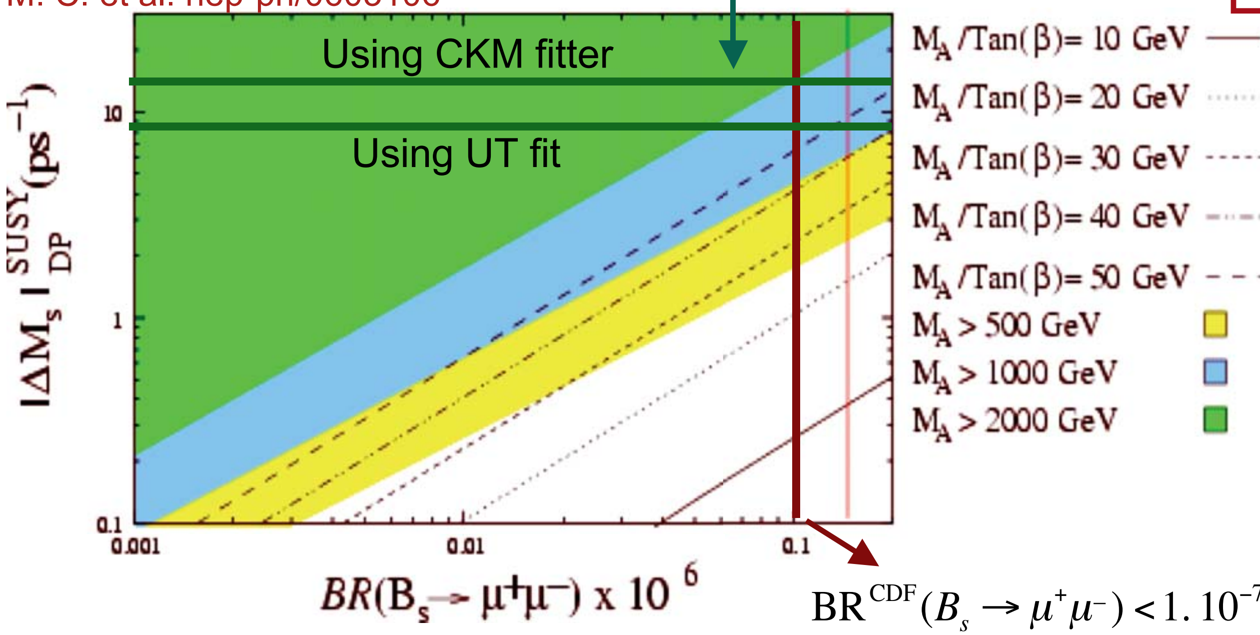
How strong is the bound on $BR(B_s \to \mu^+\mu-)$?

Upper bound on NP from CDF ==> $\Delta M_S = 17.33^{+0.42}_{-0.21} \pm 0.07\, ps^{-1}$

$\Delta M_S^{CKM} = 21.7^{+5.9(+9.7)}_{-4.2(-6.8)}\, ps^{-1}$

$\Delta M_S^{UT} = 21.5 \pm 2.6\, ps^{-1}$

M. C. et al. hep-ph/0603106



$BR^{CDF}(B_s \to \mu^+\mu^-) < 1.\,10^{-7}$

A/H at the reach of the Tevatron or the LHC

strong constraints on $|\Delta M_S|^{SUSY}_{DP}$

large ε factors implies heavy squark mass and trilinear terms

For natural values of m_A< 1000 GeV ==> largest contributions at most a few ps-1

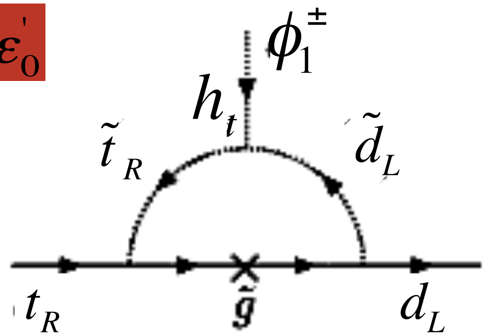
$|\Delta M_{B_S}|^{SUSY}_{DP} \approx 3\, ps^{-1}$ $\Rightarrow$ improve the agreement with experiment

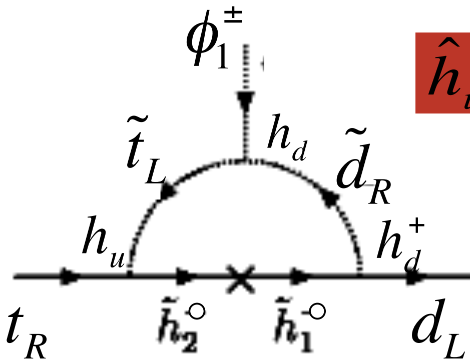
$\Rightarrow$ imply that $BR(B_S \to \mu^+\mu^-)$ should be at the Tevatron reach

Flavor Changing in the charged Higgs coupling

- Similar to the neutral Higgs case, we have $\tan\beta$ enhanced loop corrections which depend on SUSY parameters

$\hat{h}_u \ \varepsilon_0^{'}$





$\hat{h}_u \ \varepsilon_Y^{'} \hat{h}_d^{+} \hat{h}_d$

$$-L_{eff}^{H^{\pm}} = \bar{u}_R^{j} \ P_{RL}^{ji} \ d_L^{i} \ H^{+} + \bar{u}_L^{j} \ P_{LR}^{ji} \ d_R^{i} \ H^{+} + h.c.$$

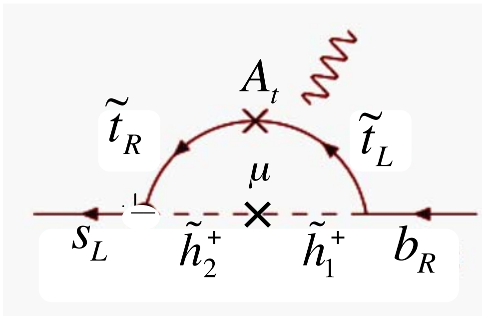
$$P_{RL}^{3i} \approx \frac{\sqrt{2}}{\mathrm{v}} \overline{m}_t \cot\beta \ V_{CKM}^{3i} \left(1 - \tan\beta\left(\varepsilon_0^{'} - \varepsilon_Y^{'} h_b^2\right)\right)$$

$$P_{LR}^{j3} = \frac{\sqrt{2}}{\mathrm{v}} \frac{\overline{m}_b \tan\beta}{\left(1 + \varepsilon_0^{3^*} \ \tan\beta\right)} V_{CKM}^{j3}$$

$$P_{LR}^{33} = P_{LR}^{j3}(J \to 3, \ \varepsilon_0^{3^*} \to \Delta_b^{*})$$

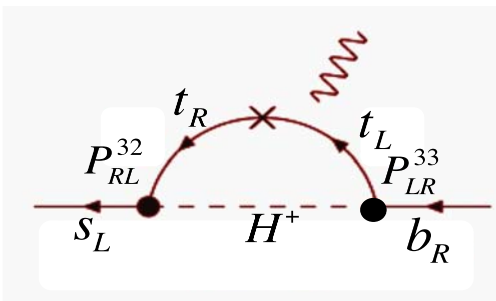
This type of corrections are most important in constraining new physics from $B \to X_S\gamma$ and $B_u \to \tau\nu$

Important SUSY contributions to $BR(B \to X_s\gamma)$



- Chargino-Stop amplitude

$$A(b \to s\gamma)_{\chi^+} \propto \frac{\mu A_t \tan\beta\, m_b}{(1+\Delta_b)}\, h_t^2 f[m_{\tilde{t}_1}, m_{\tilde{t}_2}, \mu]\, V_{ts}$$



- Charged Higgs amplitude in the large tanb limit

$$A(b \to s\gamma)_{H^+} \propto \frac{(h_t - \delta h_t \tan\beta)\, m_b}{(1+\Delta_b)}\, g[m_t, m_{H^+}]\, V_{ts}$$

$$\text{with } \delta h_t = h_t\left(\varepsilon_0^{'} - \varepsilon_Y^{'} h_b^2\right) \propto h_t \frac{2\alpha_S}{3\pi} \mu M_{\tilde{g}}$$

If: At ~0 (==> small stop mixing ==> light SM-like Higgs at Tevatron reach!)
==>small contributions to $b \to s\gamma$ from chargino-stops
+ large $\mu M_{\tilde{g}} > 0$ ==> cancellation of charged Higgs contribution
NO constraint on tanb-ma plane from $b \to s\gamma$

Recall: bound on New Physics
using Belle result : Neubert'05 ==> $|\mathrm{BR}(B \to X_s\gamma)^{\exp} - \mathrm{BR}(B \to X_s\gamma)^{SM}| < 1.3 \times 10^{-4}$

B and Higgs Physics at the Tevatron and the LHC

explore complementary regions of SUSY parameter space

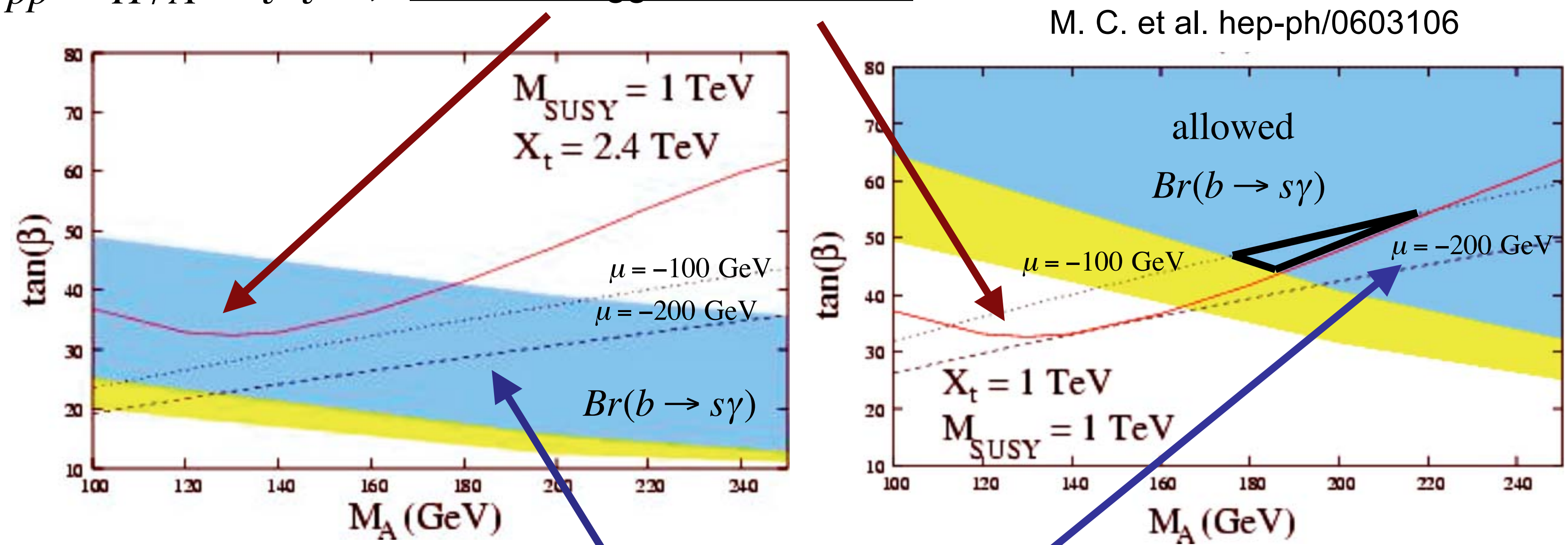
Large to moderate values of X_t ==> SM like Higgs heavier than 120 GeV

$BR(B_S \to \mu^+\mu^-) \propto |\mu A_t|^2 \Rightarrow$ Experimental bound ==> small μ

Small $\mu < 0$ ==> $\cong$ constant H^+ and enhanced negative $\chi^+ - \tilde{t}$ contributions to $BR(b \to s\gamma)$

$p\bar{p} \to H/A \to \tau^+\tau^- \Rightarrow$ Tevatron Higgs reach with 1fb^{-1}

M. C. et al. hep-ph/0603106



CDF limit : $BR(B_S \to \mu^+\mu^-) < 1 \times 10^{-7}$

Tevatron/LHC Non-Standard Higgs searches at small X_t, sizeable μ

- Interesting region since light SM-like Higgs lighter than 125 GeV
- No constraints from $BR(B_s \to \mu^+\mu^-)$
- Mild constraints from $BR(b \to s\gamma)$ if large $\mu M_{\tilde{g}} > 0$

BUT, important constraint from recent measurement of $BR(B_u \to \tau\nu)$

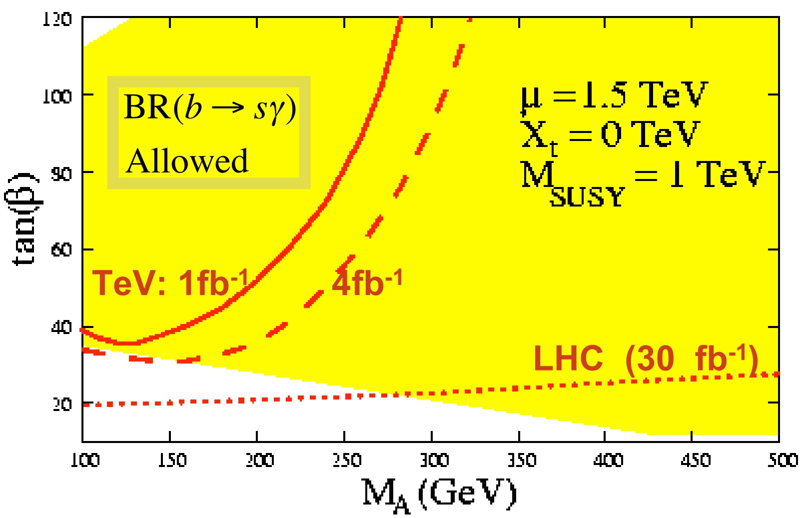
$$\frac{BR(B_u \to \tau\nu)^{SUSY}}{BR(B_u \to \tau\nu)^{SM}} = \left[1 - \left(\frac{m_B^2}{m_{H^\pm}^2}\right)\frac{\tan\beta^2}{(1+\Delta_b)}\right] \Leftrightarrow \frac{BR(B_u \to \tau\nu)^{\exp}}{BR(B_u \to \tau\nu)^{SM}} = 0.67^{+0.30}_{-0.27}$$

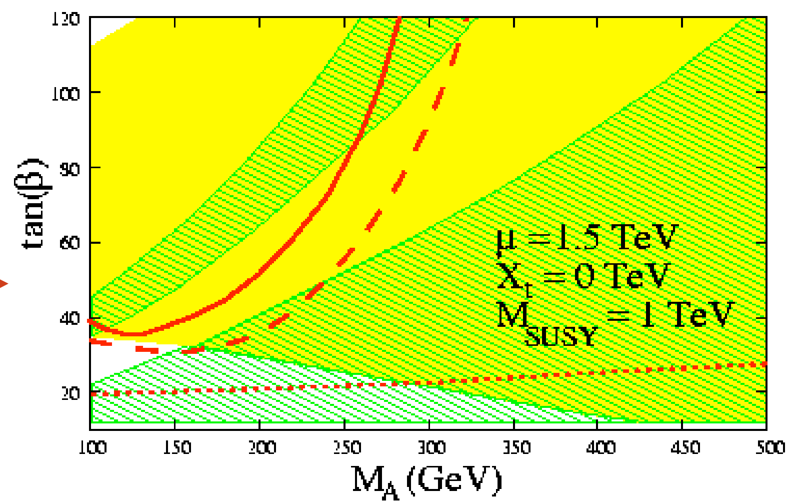
M.C., Menon, Wagner

Red lines: Tevatron and LHC Higgs reach:

$$p\bar{p} \to H/A \to \tau^+\tau^- \Rightarrow$$

Green : Allowed by $BR(B_u \to \tau\nu)$

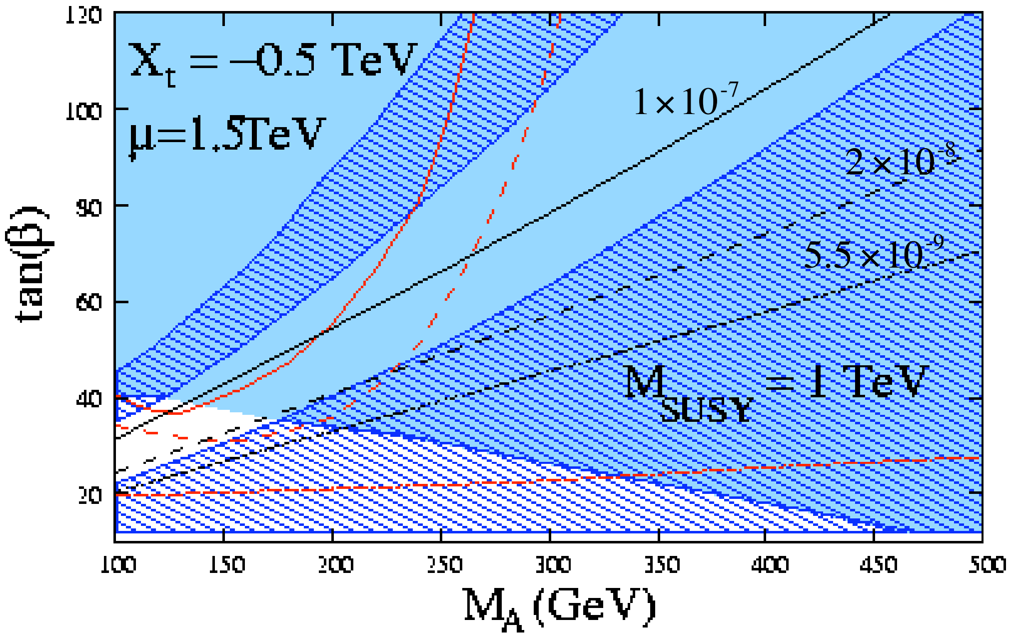




Tevatron and LHC searches at small/moderate X_t and large mu

- H/A Higgs reach is marginal at the Tevatron, unless $\mathrm{BR}(B_S \to \mu^+\mu^-)$ observed as well

- A relatively large region of SUSY parameter space can be probed at the LHC even for relatively "low" luminosities



Red Lines: $pp \to H/A \to \tau^+\tau^-$
with 1,4 fb^{-1} at the Tevatron
with 30 fb^{-1} at the LHC

Light Blue: $BR(b \to s\gamma)$ Allowed

Hatched Area: $\mathrm{BR}(B_u \to \tau\nu)$ Allowed

$$BR(B_s \to \mu^-\mu^+) \text{ reach:}$$

Tevatron: 1×10^{-7} (present);

2×10^{-8} ($8\mathrm{fb}^{-1}$)

LHC: 5.5×10^{-9} (10 fb^{-1})

Conclusions

• Bs-mixing measurement ==> consistent with the SM, within errors.

==> in MFV SUSY models, with large tanb, consistent with $BR(B_s \to \mu^+\mu^-)$ bound.

However, it imposes strict constraints on General Flavor Violation SUSY Models.

- For ΔM_{B_S} and $\mathrm{BR}(\mathrm{B_u} \to \tau\nu)$ a better agreement between theory and experiment can be accomodated in MFV via large tanb effects,
  and can be probed by improving the reach on $BR(B_s \to \mu^+\mu^-)$

Conclusions (continued)

- **The Non-Standard MSSM Higgs searches at the Tevatron and the LHC can be strongly constrained by B physics measurements depending on the SUSY parameter space.**

-- sizeable LR stop mixing <==> small/moderate mu ==> B searches more powerful

-- small stop mixing (Xt≈0) and large Higgsino mass parameter μ
==> good for the Tevatron ==> has sensitivity to discover all 3 MSSM neutral Higgs bosons

-- increasing the stop mixing for sizeable mu
==> Tevatron A/H searches become marginal, but excellent window of opportunity for LHC

- **Tevatron results will yield important information for the LHC**

-- Non-observation of $B_s \to \mu^+\mu^-$ at the Tevatron ==> reduced parameter space for non-Standard MSSM Higgs searches at the LHC, specially for large X_t and $\mu < 0$

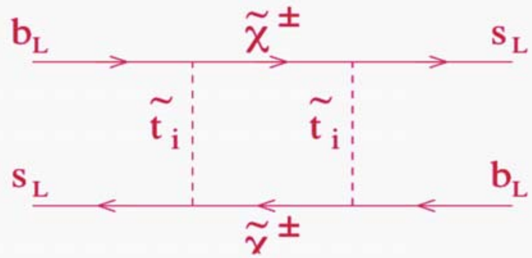
-- Discovery of H/A at the Tevatron, without positive results from leptonic rare Bs decay ==> small X_t an large μ or Deviations from MFV

EXTRAS

- Other Examples ==> MFV from GUT's and General Flavor SUSY Models
- Direct SUSY Dark Matter detection <==> Higgs searches at the Tevatron

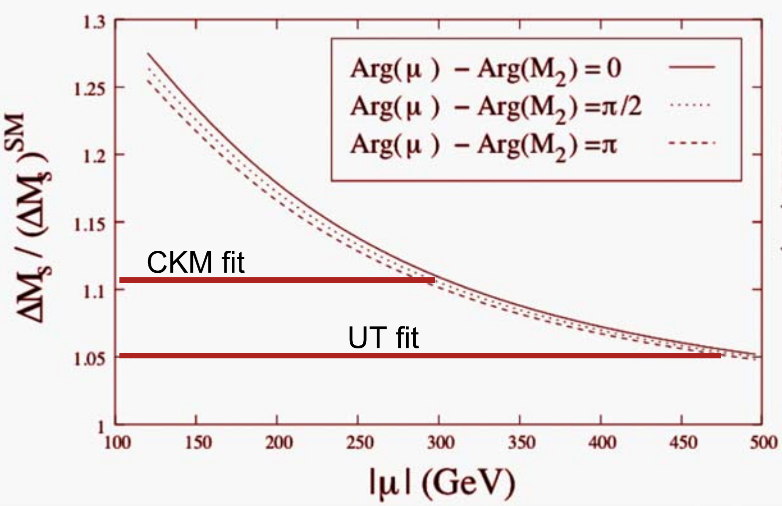
Stop-Chargino Contributions to ΔM_s in MFV

- Light stops and charginos can give substantial contributions to ΔM_s even for low values of $\tan\beta$.

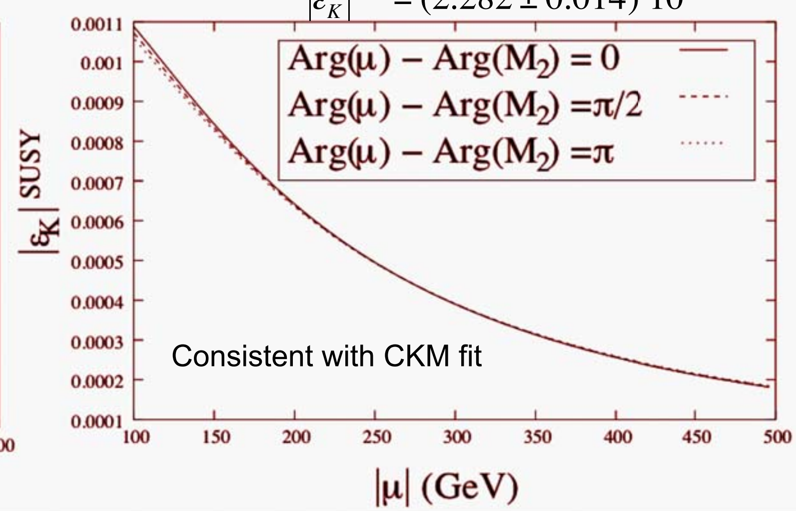


Light stop scenario ==> compatible with Electroweak Baryogenesis

- However these kinds of SUSY particle spectra can also induce large contributions to ϵ_K if SM CP phase is order $\pi/3$.



$$|\varepsilon_K|^{\exp} = (2.282 \pm 0.014)\ 10^{-3}$$



Within this scenario, small values of mu (< 250 GeV) are strongly disfavor by bounds from Bs-mixing

MFV Models with Grand Unification

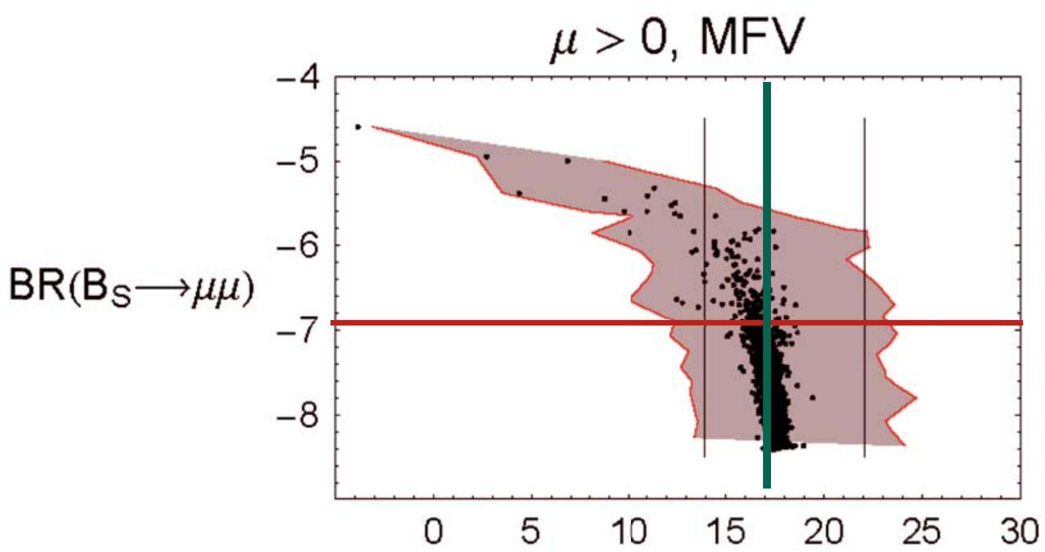
- Consider effects of renormalization group evolution of SUSY parameters defined at the GUT scale

-- gauge coupling and gaugino mass unification

-- Non-universal squark and trilinear mass parameters

Includes contraints from $b \to s\gamma, (g-2)_\mu, \Omega_{DM}$
and direct searches from colliders

Lunghi, Vives, Porod, hep-ph/0605177



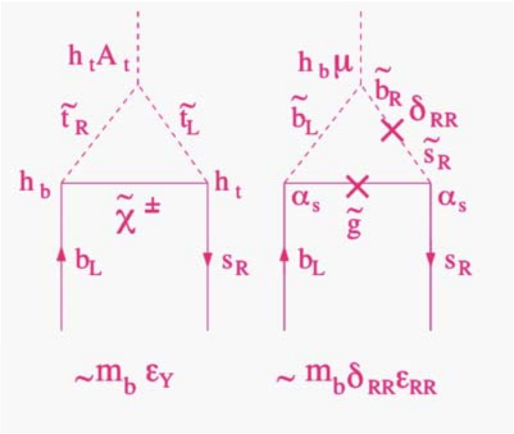
ΔM_{B_S}

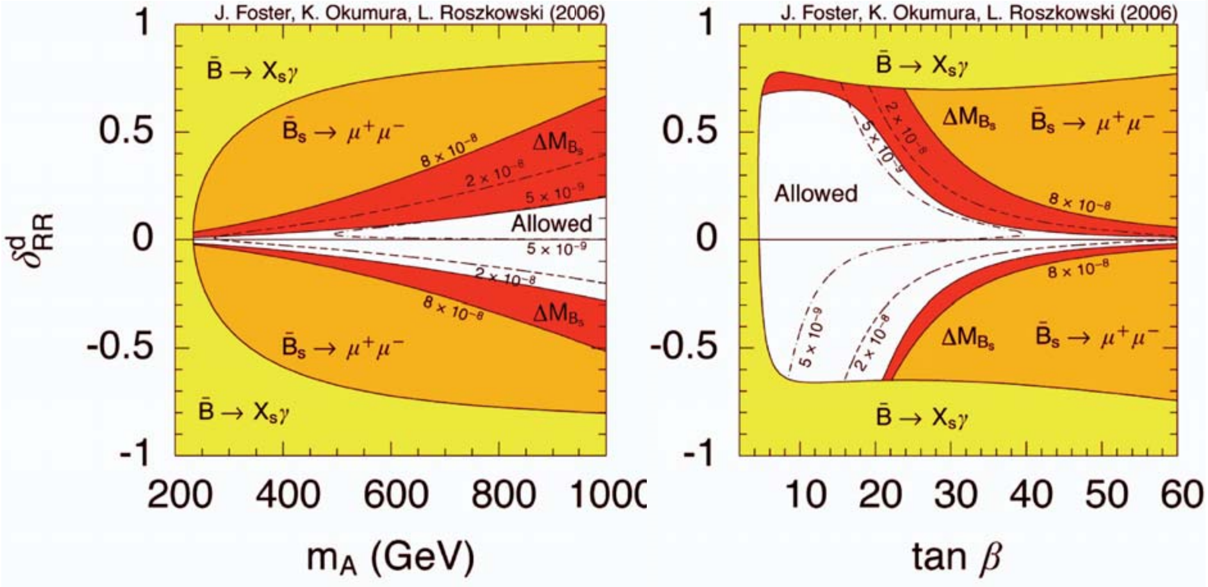
$BR(B_s \to \mu^+\mu^-)$

General Flavor Violation Models in SUSY (GFVM)

In GFVM ==> flavor violating entries of the squarks and trilinear mass parameters treated as being arbitrary

$$\left(\delta^d_{RR}\right)^{ij} = (m^2_{d,RR})^{ij} \Big/ \sqrt{(m^2_{d,RR})^{ii}(m^2_{d,RR})^{jj}} \Rightarrow$$





Tevatron measurement of ΔM_{B_S}
==> RR insertions are forbidden or, A_t and/or tanb must be very small

- Strict new constraints on general models of SUSY flavor violation arise form recent data on ΔM_{B_S} and $\mathrm{BR}(B_s \to \mu^+\mu^-)$

CDMS DM searches Vs the Tevatron H/A searches

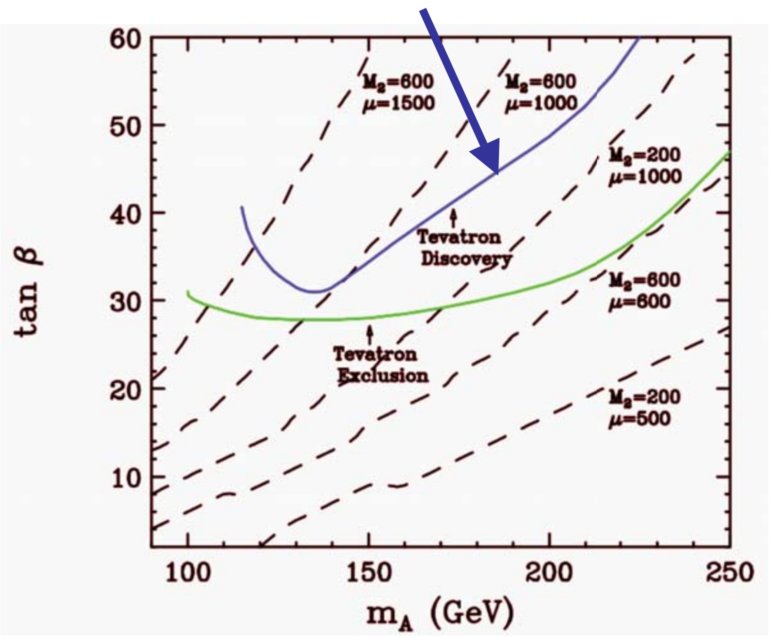
- If the lightest neutralino makes up the DM of the universe

==> CDMS current limits disfavor discovery of H/A at the Tevatron, unless the neutralino has a large higgsino component $\Rightarrow \mu >> M_2$

==> a positive signal at CDMS will be very encouraging for Higgs searches

==> Evidence for H/A at the Tevatron without a CDMS signal would suggest large μ

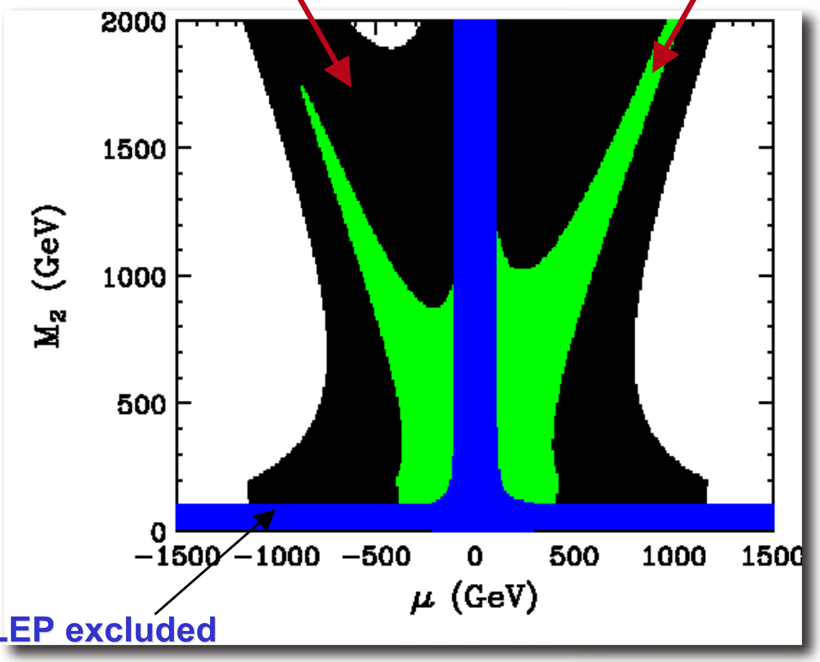
Tevatron reach in $p\bar{p} \rightarrow A/H \rightarrow \tau^+\tau^-$ with 4 fb^{-1}



CDMS 2007 Projection

CDMS 2007

Current CDMS



LEP excluded

M.C, Hooper, Skands, hep-ph/0603180