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

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

• 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

\[ \bar{d}_i (\bar{m}_i + n_i H) d_i, \quad \text{with} \quad \bar{m}_i = n_i v \]

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) $B_s$ mixing

$B_s^0 = (bar{s}) \quad \bar{B}_s^0 = (b\bar{s})$

Flavor eigenstates mix via weak interactions

Mass eigenstates:

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

$B_H$ and $B_L$ differ from CP eigenstates:

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

The $B$ meson mass matrix

$M = \begin{bmatrix} M - i\Gamma/2 & M_{12} - i\Gamma_{12}/2 \\ M_{12}^* - i\Gamma_{12}^*/2 & M - i\Gamma/2 \end{bmatrix}$

$\Gamma_{12} << M_{12}$

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

Short distance QCD corrections

Box-diagram
Direct Measurement and Global CKM Fit

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

Using ratio

\[ \frac{\Delta m_s}{\Delta m_d} = \frac{m_{B_S}}{m_{B_d}} \frac{f_{B_S}^2 B_{B_S}}{f_{B_d}^2 B_{B_d}} \frac{|V_{ts}|^2}{|V_{td}|^2} \]

Minimize QCD lattice uncertainty providing a measurement of \(|V_{ts}|/|V_{td}|\)

- SM fit:
  
  CMK fit \(\Rightarrow \Delta M_S = 21.7^{+5.9 (+9.7)}_{-4.2 (-6.8)} \text{ps}^{-1}\) at 1(2) \(\sigma\) C.L.

  UT fit \(\Rightarrow \Delta M_S = 21.5 \pm 2.6 \text{ps}^{-1}\) at 1 \(\sigma\) C.L.

\[ \Rightarrow -14.1 < \Delta M_{B_s}^{\text{NP}} [\text{ps}^{-1}] < 2.4 \]

\[ \Rightarrow -9.4 < \Delta M_{B_s}^{\text{NP}} [\text{ps}^{-1}] < 1 \text{ at } 2\sigma \]
B) Rare decay rate $B_s \rightarrow \mu^+\mu^-$

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

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

- Present CDF limit: $\text{BR}(B_s \rightarrow \mu^+\mu^-) < 1.0 \times 10^{-7}$

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

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

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

$|\text{BR}(B \rightarrow X_S\gamma)^{\text{exp}} - \text{BR}(B \rightarrow X_S\gamma)^{SM}| < 1.3 \times 10^{-4}$
D) $B_u \rightarrow \tau \nu$ transition

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

In agreement with SM within errors

$$BR(B_u \rightarrow \tau \nu)^{exp} = (1.06^{+0.34}_{-0.28}^{+0.18}_{-0.16}) \times 10^{-4}$$
Flavor Beyond the Standard Model

• Two Higgs doublet Models:

Yukawa interactions \( \Rightarrow \)

\[
\bar{d}_{R,i} (\hat{h}^{ij}_{d,1} \phi_1 + \hat{h}^{ij}_{d,2} \phi_2) d_{L,j}
\]

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

\( \Rightarrow \)

\[
\hat{m}^{ij}_d = \hat{h}^{ij}_{d,1} v_1 + \hat{h}^{ij}_{d,2} v_2
\]

Diagonalization of the mass matrix will not give diagonal Yukawa couplings

\( \Rightarrow \)

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

\[
-L = \bar{\psi}_L^i \left( \hat{h}^{ij+}_{d} \phi_1 d^j_R + \hat{h}^{ij+}_{u} \phi_2 u^j_R \right) + h.c. \quad \bar{\psi}_L^i = \left( \begin{array}{c} \bar{u}_L \\ \bar{d}_L \end{array} \right)^i
\]

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

\[
\tilde{d}_{L,R}^i \tilde{\lambda} \tilde{\tilde{d}}_{L,R}^j \rightarrow \tilde{d}_{L,R} D_{L,R}^+ \tilde{D}_{L,R} \tilde{\lambda} \tilde{\tilde{d}}_{L,R}^i
\]

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

\[
\begin{bmatrix}
\tilde{d}_L^i \tilde{d}_R^j \\
\end{bmatrix} =
\begin{bmatrix}
M_Q^2 + v_1^2 \hat{h}_d^+ \hat{h}_d^+ + D_{d_L} & v_1 \left(A_d^* - \mu \tan \beta \right) \hat{h}_d^+ \\
v_1 \hat{h}_d \left(A_d - \mu^* \tan \beta \right) & M_D^2 + v_1^2 \hat{h}_d^+ \hat{h}_d^+ + D_{\tilde{d}_R}
\end{bmatrix}
\begin{bmatrix}
\tilde{d}_L^i \\
\tilde{d}_R^j
\end{bmatrix}
\]

recall \(V_{CKM} = U_L^* D_L\)

• 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 \( V_{\text{CKM}} \) as in SM.

- At loop level: FCNC generated by two main effects:
  1) Both Higgs doublets couple to up and down sectors
     \( \Rightarrow \) 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
     \( \Rightarrow \) 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

\[
(X_{\text{FC}})_{ij} = (h_u^+ h_u^-)_{ij} \propto m_t^2 \ V_{3i}^{\text{CKM*}} V_{3j}^{\text{CKM}} \quad \text{for } i \neq j
\]
\( \tan \beta \) enhanced loop corrections to neutral Higgs-fermion couplings

\[-L_{\text{eff.}} = \bar{d}_R^0 \hat{h}_d \left[ \phi_1^{0*} + \phi_2^{0*} \left( \hat{e}_0 + \hat{e}_y \hat{h}_u^+ \hat{h}_u^- \right) \right] d_L^0 + \phi_2^0 \bar{u}_R^0 \hat{h}_u^0 u_L^0 + h.c. \]

\( \mathcal{E} \) loop factors intimately connected to the structure of the squark mass matrices.

- In terms of the quark mass eigenstates

\[-L_{\text{eff}} = \frac{1}{v^2} \left( \tan \beta \phi_1^{0*} - \phi_2^{0*} \right) \bar{d}_R M_d \left[ V_{\text{CKM}}^+ R^{-1} V_{\text{CKM}} \right] d_L + \frac{1}{v^2} \Phi_2^{0*} \bar{d}_R M_d d_L + \Phi_2^0 \bar{u}_R M_u u_L + h.c. \]

and \( R = 1 + \varepsilon_0 \tan \beta + \varepsilon_y \tan \beta |h_u|^2 \Rightarrow R \) diagonal

Dependence on SUSY parameters

\[ \varepsilon_0^i \approx \frac{2 \alpha_s}{3\pi} \frac{\mu^* M_{\tilde{g}}^*}{\max \left[ m^2_{\tilde{d}_1}, m^2_{\tilde{d}_2}, M_{\tilde{g}}^2 \right]} \]

\[ \varepsilon_y \approx \frac{\mu^* A_t^*}{16\pi^2} \max \left[ m^2_{\tilde{t}_1}, m^2_{\tilde{t}_2}, \mu^2 \right] \]
Looking at $V_{CKM} \equiv I \Rightarrow$ Flavor Conserving Higgs-fermion couplings

$$
-L_{\text{eff}} = \frac{1}{v^2} \left( \tan \beta \, \Phi_1^0 \Phi_2^0 \right) b_R^* M_d b_L + \frac{1}{v^2} \Phi_2^* b_R^* M_d b_L + h.c.
$$

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

2 Higgs SU(2) doublets $\phi_1$ and $\phi_2$ : after Higgs Mechanism

$\Rightarrow$ 5 physical states: 2 CP-even $h, H$ with mixing angle $\alpha$

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

such that:

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

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

Hence:

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

$$
-L_{\text{eff}} = \frac{m_b}{(1+\Delta_b) v} \phi_1^0 b_R^* b_L + h.c.
$$

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

$$g_{Abb} \approx g_{Hbb} \approx \frac{m_b \tan \beta}{(1+\Delta_b) v}
$$

deestroy basic relation

$$g_A / g_{Hbb} / g_{A / H \tau \tau} \neq m_b / m_\tau$$
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

\[ BR(A \rightarrow b\bar{b}) \equiv \frac{9}{9 + (1 + \Delta_b)^2} \quad BR(A \rightarrow \tau^+\tau^-) \equiv \frac{(1 + \Delta_b)^2}{9 + (1 + \Delta_b)^2} \]

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.: \( X_t = A_t - \mu / \tan \beta \)

\[
p\bar{p} \rightarrow b\bar{b} \phi, \quad \phi \rightarrow b\bar{b} \quad \Rightarrow \text{based on D0 } \rightarrow 260 \text{pb}^{-1}
\]

- Enhanced reach for negative values of \( \mu \)
- Strong dependence on SUSY parameters

\[
\sigma(b\bar{b} \phi)BR(\phi \rightarrow b\bar{b}) \propto 1/(1 + \Delta_b)^2 \Rightarrow \text{enhanced for } \Delta_b < 0 \iff \mu < 0 \text{ (if } A_t \text{ and } M_{\tilde{g}} > 0)\]

M. C. et al. hep-ph/0511023
B) In the tau tau inclusive mode

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

- Important reach for large tanb, small \( m_A \)
- Weaker dependence on SUSY parameters via radiative corrections

M. C. et al. hep-ph/0511023
Loop-induced Higgs mediated FCNC in the down-quark sector

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

\[ -L_{FCNC} = \bar{d}^j_R \left( X^S_{RL} \right)^{ji} d^i_L \phi_s + h.c. \quad \text{with } i \neq j \quad \phi_s = h, H, A \]

and

\[ \left( X^S_{RL} \right)^{ji} = \frac{m_{d_{ij}} h_t^2 (x^S_2 - x^S_1 \tan \beta) \tan \beta}{\sqrt{1 + \epsilon^i_0 \tan \beta}} V^*_3 \tan \beta V^3 \]

Example: case of universal soft SUSY squark mass parameters

\( x^S_1, x^S_2 \) are the components of the h, H and A in \( \phi^0_1, \phi^0_2 \)

\[ \Rightarrow \tan \beta^2 \text{ enhanced coupling for H/A or h/A, depending on value of } m_A \]

- Effects of RG evolution proportional to \( h_u h_u^+ \) in \( M_Q \) \[ \Rightarrow \left( X^S_{RL} \right)^{ji} \propto \Delta_b / \tan \beta - \epsilon^{1,2}_0 \]

L-H. squarks are not diagonalized by the same rotation as L-H. quarks

\[ \Rightarrow \text{induces FC in the left-handed quark-squark-gluino vertex prop } V_{CKM} \]
Correlation between Bs mixing and $\text{BR}(B_s \rightarrow \mu^+ \mu^-)$ due to $\tan \beta$ enhanced Higgs mediated flavor violating effects

\begin{align*}
\left( \Delta M_{B_s} \right)^{\text{SUSY}} & \propto - \frac{X_{RL}^{32} X_{LR}^{32}}{m_A^2} \\
\text{BR}(B_s \rightarrow \mu^+ \mu^-)^{\text{SUSY}} & \propto \frac{|X_{RL}^{32}|^2 \tan \beta^2}{m_A^4}
\end{align*}

Negative sign with respect to SM

• SUSY contributions strongly correlated, and for Minimal Flavor Violation

$$\frac{\Delta M_{B_s}}{\text{BR}(B_s \rightarrow \mu^+ \mu^-)} \propto \frac{m_A^2}{\tan \beta^2}$$

to maximize $\Delta M_{B_s}^{DP}$ for a given value of $\text{BR}(B_s \rightarrow \mu^+ \mu^-) \iff$ minimize $\tan \beta$ (for fixed $m_A$)

$\Rightarrow$ choose large, negative values of $\varepsilon_0$ and $\varepsilon_Y$ (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 $\text{BR}(B_s \rightarrow \mu^+\mu^-)$?

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

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

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

For natural values of $m_A < 1000 \, \text{GeV} \Rightarrow$ largest contributions at most a few ps$^{-1}$

$\Delta M_{B_s}^{\text{SUSY}} \approx 3 \, \text{ps}^{-1} \Rightarrow$ improve the agreement with experiment

$\Rightarrow$ imply that $\text{BR}(B_s \rightarrow \mu^+\mu^-)$ 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.

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

\[
P_{RL}^{3i} \approx \frac{\sqrt{2}}{v} \, \bar{m}_i \cot \beta \, V_{CKM}^{3i} \left( 1 - \tan \beta (\varepsilon_0^i - \varepsilon_y^i h_b^2) \right) \]

\[
P_{LR}^{j3} = \frac{\sqrt{2}}{v} \, \frac{m_b \tan \beta}{(1 + \varepsilon_0^3 \tan \beta)} \, V_{CKM}^{j3} \]

This type of corrections are most important in constraining new physics from $B \rightarrow X_S \gamma$ and $B_u \rightarrow \tau \nu$.
Important SUSY contributions to $BR(B \rightarrow X_s \gamma)$

- **Chargino-Stop amplitude**

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

- **Charged Higgs amplitude in the large $\tan\beta$ limit**

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

with $\delta h_t = h_t (\varepsilon_0' - \varepsilon_y h_b^2) \propto h_t \frac{2\alpha_s}{3\pi} \mu M_{\tilde{g}}$

If: At $\sim 0$ (==> small stop mixing ==> light SM-like Higgs at Tevatron reach!)

== small contributions to $b \rightarrow s\gamma$ from chargino-stops

+ large $\mu M_{\tilde{g}} > 0$ ==> cancellation of charged Higgs contribution

NO constraint on $\tan\beta$-$m_a$ plane from $b \rightarrow s\gamma$

Recall: bound on New Physics

using Belle result: Neubert'05

$$|BR(B \rightarrow X_s \gamma)^{\text{exp}} - BR(B \rightarrow X_s \gamma)^{\text{SM}}| < 1.3 \times 10^{-4}$$
B and Higgs Physics at the Tevatron and the LHC
explore complementary regions of SUSY parameter space

Large to moderate values of $X_t \implies$ SM like Higgs heavier than 120 GeV

$BR(B_S \rightarrow \mu^+\mu^-) \propto |\mu A_t|^2 \implies$ Experimental bound $\implies$ small $\mu$

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

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

CDF limit : $BR(B_S \rightarrow \mu^+\mu^-) < 1 \times 10^{-7}$
Tevatron/LHC Non-Standard Higgs searches at small $X_t$, sizeable $\mu$

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

**BUT**, important constraint from recent measurement of $\text{BR}(B_u \rightarrow \tau\nu)$

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

Red lines: Tevatron and LHC Higgs reach:

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

Green: Allowed by $\text{BR}(B_u \rightarrow \tau\nu)$

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

- H/A Higgs reach is marginal at the Tevatron, unless $\text{BR}(B_s \rightarrow \mu^+\mu^-)$ observed as well
- A relatively large region of SUSY parameter space can be probed at the LHC even for relatively “low” luminosities

\[ X_t = -0.5 \text{ TeV} \]
\[ \mu = 1.5 \text{ TeV} \]

Red Lines: \( pp \rightarrow H/A \rightarrow \tau^+\tau^- \)
with 1.4 fb\(^{-1}\) at the Tevatron
with 30 fb\(^{-1}\) at the LHC

Light Blue: $\text{BR}(b \rightarrow s\gamma)$ Allowed

Hatched Area: $\text{BR}(B_u \rightarrow \tau\nu)$ Allowed

$\text{BR}(B_s \rightarrow \mu^-\mu^+)$ reach:
- Tevatron: $1 \times 10^{-7}$ (present);
  \[ 2 \times 10^{-8} \ (8 \text{ fb}^{-1}) \]
- LHC: $5.5 \times 10^{-9}$ (10 fb\(^{-1}\))
Conclusions

• Bs-mixing measurement $\Rightarrow$ consistent with the SM, within errors.

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

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

• For $\Delta M_{B_s}$ and $BR(B_u \rightarrow \tau\nu)$ a better agreement between theory and experiment can be accommodated in MFV via large tanb effects, and can be probed by improving the reach on $BR(B_s \rightarrow \mu^+\mu^-)$.
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 $\iff$ small/moderate $\mu$ $\implies$ B searches more powerful

  -- small stop mixing ($X_t \approx 0$) and large Higgsino mass parameter $\mu$
  $\implies$ good for the Tevatron $\implies$ has sensitivity to discover all 3 MSSM neutral Higgs bosons

  -- increasing the stop mixing for sizeable $\mu$
  $\implies$ 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 $\implies$ 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 $B_s$ decay $\implies$ small $X_t$ an large $\mu$ or Deviations from MFV
• 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 $\Delta M_s$ in MFV

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

  \[ \exp K = (2.282 \pm 0.014) \times 10^{-3} \]

  Light stop scenario ==> compatible with Electroweak Baryogenesis

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

  \[ |\epsilon_K|^{\text{exp}} = (2.282 \pm 0.014) \times 10^{-3} \]

Within this scenario, small values of $\mu$ (< 250 GeV) are strongly disfavor by bounds from $B_s$-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 constraints from $b \rightarrow s \gamma, (g - 2)_\mu, \Omega_{DM}$ and direct searches from colliders


\[ BR(B_s \rightarrow \mu^+ \mu^-) \]
General Flavor Violation Models in SUSY (GFVM)

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

\[
\left( \delta_{d,RR}^d \right)^{ij} = \left( m^2_{d,RR} \right)^{ij} \sqrt{\left( m^2_{d,RR} \right)^{ii} \left( m^2_{d,RR} \right)^{jj}} \equiv \]

• Strict new constraints on general models of SUSY flavor violation arise from recent data on $\Delta M_{B_s}$ and $\text{BR}(B_s \rightarrow \mu^+\mu^-)$

Tevatron measurement of $\Delta M_{B_s}$

==> RR insertions are forbidden or, $A_t$ and/or $\tan \beta$ must be very small
Evidence for H/A at the Tevatron without a CDMS signal would suggest large CDMS DM searches Vs the Tevatron H/A searches

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

⇒ 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 \( \mu \)

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**CDMS DM searches Vs the Tevatron H/A searches**

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

CDMS 2007 Projection

\[ \mu >> M_2 \]

- CDMS current limits disfavor discovery of H/A at the Tevatron, unless the neutralino has a large higgsino component

⇒ 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 \( \mu \)

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

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\[ \mu >> M_2 \]