MSSM Higgs and Flavor Physics at the Tevatron and the LHC

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Based on work done in collaboration with

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Flavor Structure of the SM

- Flavor Structure of the SM is derived from its simple fermion Lagrangian, which contains only gauge covariant kinetic terms and Yukawa interaction terms.

- The complete fermion Lagrangian reads

$$\mathcal{L} = \sum_i \bar{\Psi}^i_{L,R} \mathcal{D}^\mu \gamma_\mu \Psi^i_{L,R} + \sum_{i,j} \left(\bar{\Psi}^i_L h^d_{ij} H d^j_R + \bar{\Psi}^i_L h^u_{ij} (i\sigma_2 H^*) u^j_R + h.c. \right)$$

- The up and down quark mass matrices arise from the v.e.v. of the Higgs field, and once we diagonallize the mass matrix, the interactions of the Higgs field are also diagonal in flavor.

- For instance, in the mass eigenstate basis what we get is

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

where $\hat{m}_i$ and $\hat{h}_i$ are the diagonal masses and Yukawa couplings of the down quarks.

Flavor Changing Effects

- Flavor changing effects in the SM arise from the charged currents, which mix left-handed u and d quarks

$$\bar{u}_{L,i} V_{CKM}^{ij} \gamma_\mu d_{L,j} W_\mu^+ + h.c.$$

- where the CKM matrix appears from the missalignment of the up and down quark mass matrices, $V_{CKM} = U_L^\dagger D_L$

- The Higgs sector, as well as the neutral gauge interactions do not lead to FCNC. In former case, due to the allignment of the Yukawa interactions with the mass terms. In the latter case, due to the unitarity of the transformations connecting weak with mass eigenstates.

Two Higgs doublet Models

- Now, imagine there are two Higgs doublets.

$$\bar{d}_{R,i}\left(h^{ij}_{d,1}H_1 + h^{ij}_{d,2}H_2\right)d_{L,j}$$

- Both Higgs doublets will acquire different v.e.v.'s. The mass matrix will be equal to $m_d^{ij} = h^{ij}_{d,1}v_1 + h^{ij}_{d,2}v_2$
- It is clear that the diagonalization of the mass matrix will lead to the diagonalization of neither of the Yukawa couplings, which will remain off-diagonal in the mass eigenstate basis.
- This will induce large, usually unacceptable FCNC in the Higgs sector. Easiest solution: Up and down quarks should couple to only one of the Higgs bosons. This is what happens in the MSSM at tree-level.

Higgs Spectrum in the MSSM

- Supersymmetric extensions of the SM predict and extended Higgs sector. In particular, in the MSSM there are one charged and three neutral Higgs bosons.
- The masses of these Higgs bosons satisfy relationships that are mildly affected by radiative corrections. Therefore, the precise determination of these masses provides a consistency check of the MSSM scenario.
- The couplings of these Higgs bosons to fermions are also well determined by the parameters of the model, but they may be strongly affected by radiative corrections induced by the supersymmetry breaking parameters.

MSSM tree-level Higgs spectrum and properties

Minimal model: 2 Higgs SU(2) doublets

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

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

- Two Higgs doublets, H_1 and H_2 mix, with a mixing angle α, leading to the two CP-even Higgs bosons.

$$\mathbf{h} = -\sin\alpha\, \mathbf{H}_1^0 + \cos\alpha\, \mathbf{H}_2^0$$

$$\mathbf{H} = \cos\alpha\, \mathbf{H}_1^0 + \sin\alpha\, \mathbf{H}_2^0$$

- The charged and complex neutral parts of the two Higgs doublets lead to the Goldstone as well as the CP-odd and charged Higgs bosons

- Ratio of Higgs vacuum expectation values, $\tan\beta = \frac{v_2}{v_1}$, determines the mixing angle between Goldstones and Higgs states.

$$H^{\pm} = \sin\beta H_1^{\pm} - \cos\beta H_2^{\pm}$$

Higgs Couplings to (s)fermions

- At tree level, only one of the Higgs doublets couples to down-quarks and leptons, and the other couples to up quarks

$$\mathcal{L} = \bar{\Psi}_L^i \left(h_{d,ij} H_1 d_R + h_{u,ij} H_2 u_R \right) + h.c.$$

- Since the up and down quark sectors are diagonalized independently, the interactions remain flavor diagonal.

$$\bar{d}_L \frac{\hat{m}_d}{v_1} (- \sin\alpha \; h + \cos\alpha \; H) d_R + h.c.$$

- The charged Higgs interactions, as the charged gauge interactions, induce flavor violation by CKM factors. For instance, at tree-level

$$\bar{u}_L V_{CKM} \frac{\hat{m}_d \sin\beta}{v_1} d_R H^+ - \bar{d}_L V_{CKM}^\dagger \frac{\hat{m}_u \cos\beta}{v_2} u_R H^- + h.c.$$

- Trilinear interactions of Higgs with sfermions. In the simplest case,

$$\tilde{u}_L^* h_u (A_u H_2 - \mu^* H_1) \tilde{u}_R + \tilde{d}_L^* h_d (A_d H_1 - \mu^* H_2) \tilde{d}_R + h.c.$$

Loop Corrections to Higgs boson masses

- Most important corrections come from the stop sector,

$$M^2_{\tilde{t}} = \begin{pmatrix} m^2_Q + m^2_t + D_L & m_t X_t \\ m_t X_t & m^2_U + m^2_t + D_R \end{pmatrix}$$

where the off-diagonal term depends on the stop-Higgs trilinear couplings, $X_t = A_t - \mu^* / \tan\beta$

- For large CP-odd Higgs boson masses, and with $M_S = m_Q = m_U$ dominant one-loop corrections are given by,

$$m^2_h \approx M^2_Z \cos^2 2\beta + \frac{3m^4_t}{4\pi^2 v^2}\left(\log\left(\frac{M^2_S}{m^2_t}\right) + \frac{X^2_t}{M^2_S}\left(1 - \frac{X^2_t}{12\, M^2_S}\right) \right)$$

- After two-loop corrections:

• upper limit on Higgs mass:

$\underline{m_h \lesssim 135 \text{ GeV}}$

$M_S = 1 \to 2 \text{ TeV} \Longrightarrow \Delta m_h \simeq 2-5 \text{ GeV}$

$\Delta m_t = 1 \text{ GeV} \Longrightarrow \Delta m_h \sim 1 \text{ GeV}$

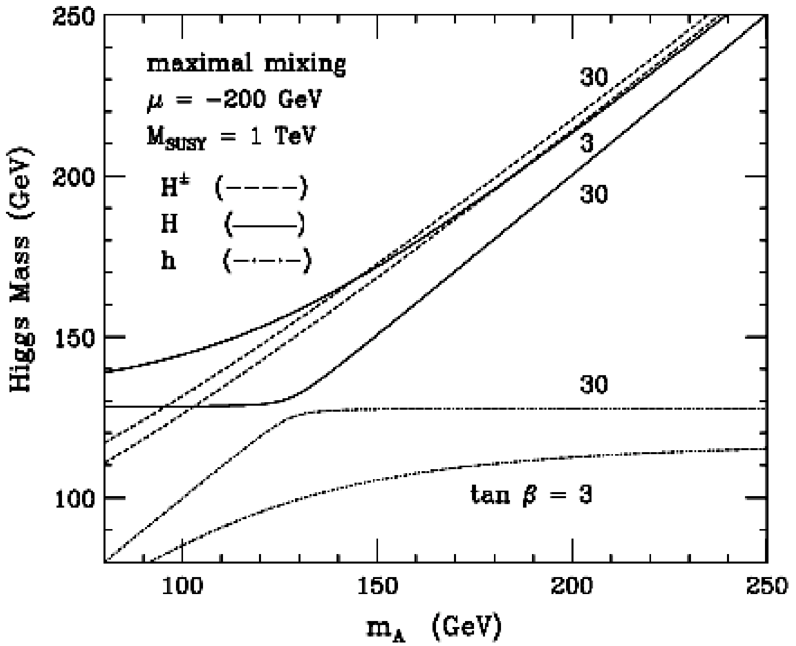
Minimal and Maximal Mixing

- The expressions minimal and maximal mixing, usually heard in MSSM Higgs boson searches are not really related to the mixing in the Higgs sector, but to the "mixing parameters" in the stop sector that "minimizes" or "maximizes" the lightest CP-even Higgs boson mass.

$$\text{Minimal Mixing :} \qquad X_t = 0, \qquad \mu = \pm 200\text{GeV}$$

$$\text{Maximal Mixing :} \qquad X_t = \sqrt{6}\, M_{\text{SUSY}}, \qquad \mu = \pm 200\text{GeV}$$

MSSM Higgs Masses as a function of M_A



$$m_H^2 \cos^2(\beta-\alpha) + m_h^2 \sin^2(\beta-\alpha) = [m_h^{max}(\tan\beta)]^2$$

- $\cos^2(\beta-\alpha) \to 1$ for large $\tan\beta$, low m_A
  $\Longrightarrow$ H has SM-like couplings to W,Z
- $\sin^2(\beta-\alpha) \to 1$ for large m_A
  $\Longrightarrow$ h has SM-like couplings to W,Z

for large $\tan\beta$:

always one CP-even Higgs with SM-like couplings to W,Z and mass below $m_h^{max} \leq 135$ GeV

- **Mild variation of the charged Higgs mass with SUSY spectrum**

$$m^2_{H^{+-}} = m_A^2 - (\lambda_4 - \lambda_5)v^2 \approx m_A^2 + M_W^2$$

If sizeable μ and sizeable $A_t \times A_b < 0 \Rightarrow \lambda_4 - \lambda_5 > 0$ (smaller m_{H^m})

LEP MSSM HIGGS limits: $\longrightarrow$ $m_{H^\pm} > 78.6\text{GeV}$

$m_h > 91.0\text{GeV}$; $m_A > 91.9\text{GeV}$; $m_h^{\text{SM-like}} > 114.6\text{GeV}$

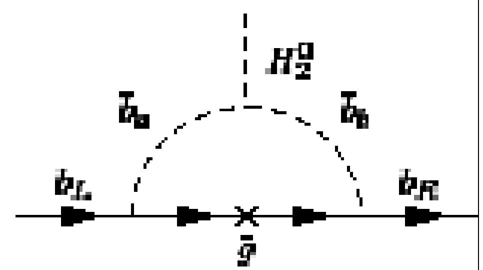
Radiative Corrections to Higgs Couplings

- Couplings of down and up quark fermions to both Higgs fields arise after radiative corrections.

- This is a reflection of the breakdown of supersymmetry at low energies. Passing to a representation in which both Higgs have the same hypercharge, we can write

$$\mathcal{L} = \bar{d}_L (h_d H_1^0 + \Delta h_d H_2^0) d_R$$

- The radiatively induced coupling depens on ratios of supersymmetry breaking parameters



$$m_b = h_b v_1 \left(1 + \frac{\Delta h_b}{h_b} \tan\beta \right)$$

$$\frac{\Delta_b}{\tan\beta} = \frac{\Delta h_b}{h_b} \simeq \frac{2\alpha_s}{3\pi} \frac{\mu M_{\tilde{g}}}{\max(m^2_{\tilde{b}_i}, M^2_{\tilde{g}})} + \frac{h_t^2}{16\pi^2} \frac{\mu A_t}{\max(m^2_{\tilde{t}_i}, \mu^2)}$$

Interactions after radiative corrections

- The appearence of couplings to the "wrong" Higgs induced FCNC, to be discussed below and also modifications of the diagonal couplings to third generation fermions

$$g_{hbb} = -\frac{\sin\alpha\, m_b}{v\cos\beta(1+\Delta_b)}\left(1 - \frac{\Delta_b}{\tan\alpha\tan\beta}\right), \qquad g_{Hbb} = \frac{\cos\alpha\, m_b}{v\cos\beta(1+\Delta_b)}\left(1 - \Delta_b\frac{\tan\alpha}{\tan\beta}\right)$$

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

- At large values of m_A and/or $\tan\beta$, one reaches a "decoupling" limit, in which one of the CP-even Higgs bosons couples in a SM way, and the other couples in a way similar to the CP-odd boson.

Couplings to down quarks and leptons

- In the large $\tan\beta$ regime, for m_A larger than 135 GeV

$$\sin\alpha \simeq -\cos\beta \ll 1, \qquad \sin\beta \simeq \cos\alpha \simeq 1$$

- Radiative corrections may produce a small difference between these quantities, what leads to large variations of their ratios.

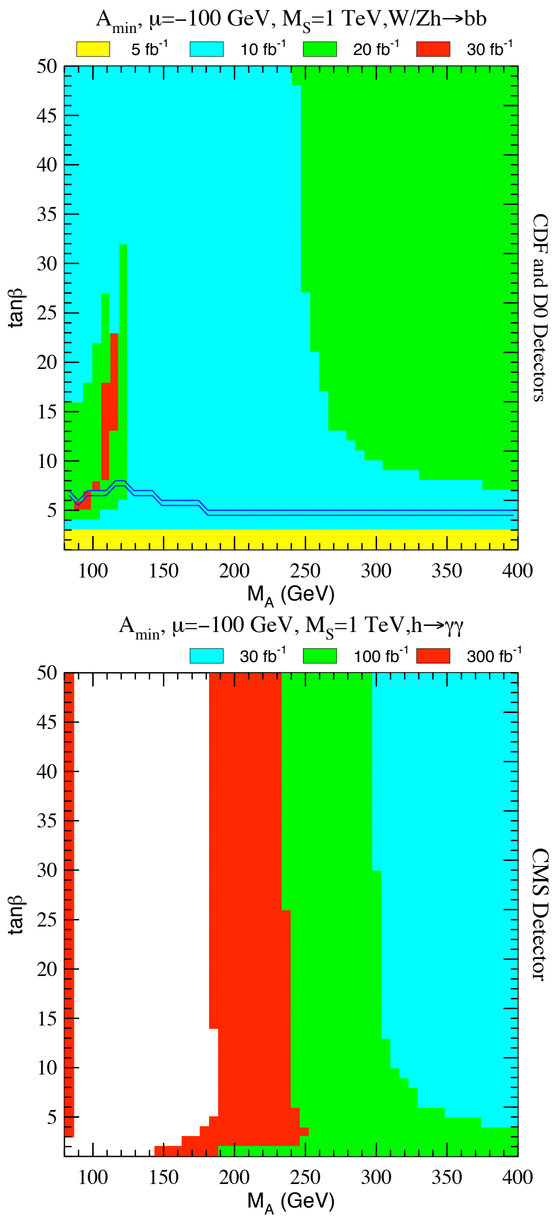
- For values of $(\mu\ A_t) < 0$, the mismatch is such that can induce a perfect decoupling of down quark fermions to the lightest CP-even Higgs (or, in general, the one with SM-like couplings to the gauge bosons).

- For this to happen

$$\Delta_b \simeq \tan\beta \tan\alpha, \quad \rightarrow \quad \Delta h_b \simeq \sin\alpha$$

- The tau coupling is not suppressed in exactly the same parameter as the bottom coupling !

Case with small values of $\mu\ A_t$

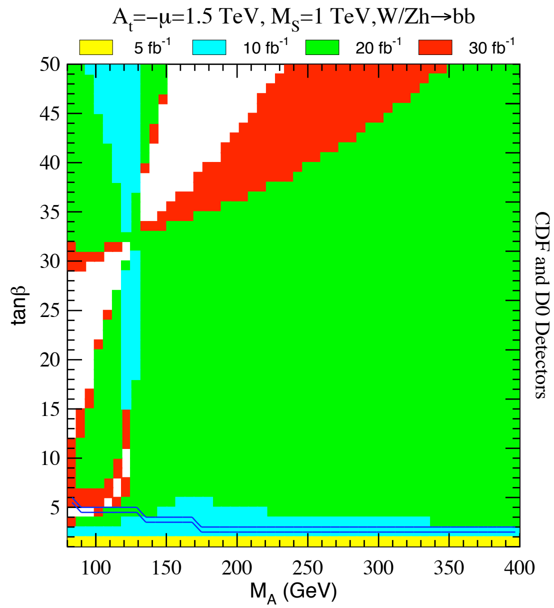


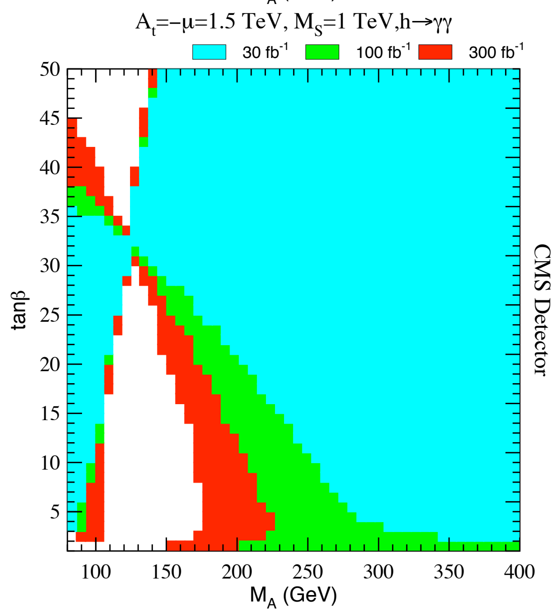
Carena, Mrenna, C.W. '00

Three sigma evidence region at the Tevatron, in the bb final state channel, covers a region complementary to the one covered by the LHC in the photon-photon final state channel.

Both measurements are quite challenging in this case, but weak boson fusion becomes a complentary channel that allows the coverage of the full range of masses.

Case with large, negative values of $\mu\ A_t$





Carena, Mrenna,C.W. '00

The cancellations of the bottom coupling become apparent in this case.

Tevatron reach highly affected, while LHC reach in the gamma-gamma mode highly enhanced, due to an increase in the $\mathrm{BR}(h \to \gamma\gamma)$

In general, at the LHC, complementarity between photon and fermion modes is quite relevant to ensure the discovery of the SM-like Higgs boson.

Searches for Non-Standard Higgs bosons

- Non-standard Higgs bosons are characterized by enhanced couplings to the b-quarks and tau-leptons.

$$g_{Abb} \simeq g_{Hbb} \simeq \frac{m_b \tan\beta}{(1+\Delta_b)v}, \qquad g_{A\tau\tau} \simeq g_{H\tau\tau} \simeq \frac{m_\tau \tan\beta}{v}$$

- Couplings to gauge bosons and other fermions are suppressed.

- Considering the values of the running bottom and tau masses and the fact that there are three colors of quarks, one gets

$$\mathrm{BR}(A \to bb) \simeq \frac{9}{9+(1+\Delta_b)^2}, \qquad \mathrm{BR}(A \to \tau\tau) \simeq \frac{(1+\Delta_b)^2}{9+(1+\Delta_b)^2}$$

Searches for non-standard Higgs bosons

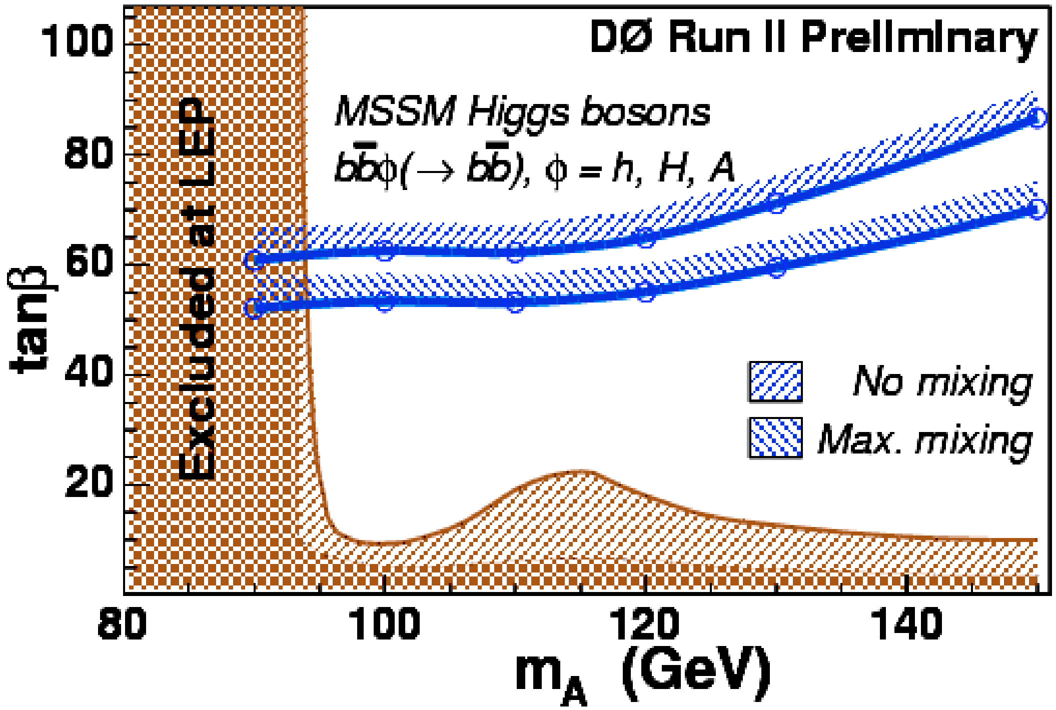
- Searches at the Tevatron and the LHC are induced by production channels associated with the large bottom Yukawa coupling.

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

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

- Since, depending on the parameters, $\Delta_b \simeq \pm\mathcal{O}(1)$ there may be a strong deependence on the parameters in the bb search channel, which is strongly reduced in the tau tau mode.
- The tau mode provides a more stable definition of the bound on $\tan\beta$ as well as of the future reach of the LHC.

Present Tevatron reach in the CP conserving MSSM Higgs sector



$200\mathrm{pb}^{-1}$

$p\bar{p} \to \phi b\bar{b} \to b\bar{b}b\bar{b}$ with

ϕ = A/h or A/H

With about 5 fb-1 one can expect to test the regime with:

$$\tan\beta \approx 10 \text{ and } \mathrm{m}_A \approx 100\,\mathrm{GeV} \;---\; \tan\beta \approx 50 \text{ and } \mathrm{m}_A \approx 250\,\mathrm{GeV}$$

• Interesting to study the direct reach in tanb-CP-odd Higgs mass/ Hi masses and compare with indirect reach via sensitivity to $\mathrm{BR}(B_s \to \mu^+\mu-)$

Searches at the Tevatron in the bb mode. Current limits from D0

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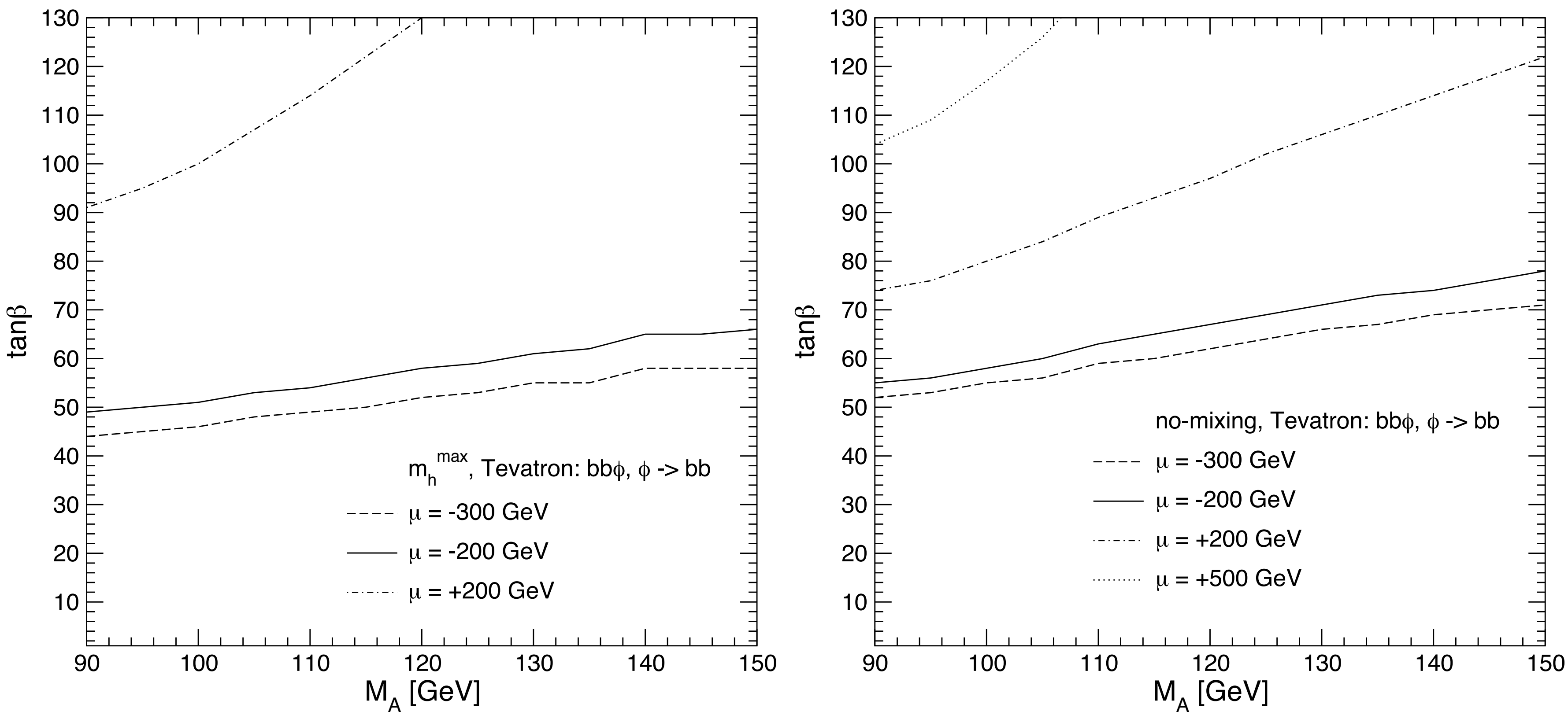

Searches at the Tevatron in the tau tau mode

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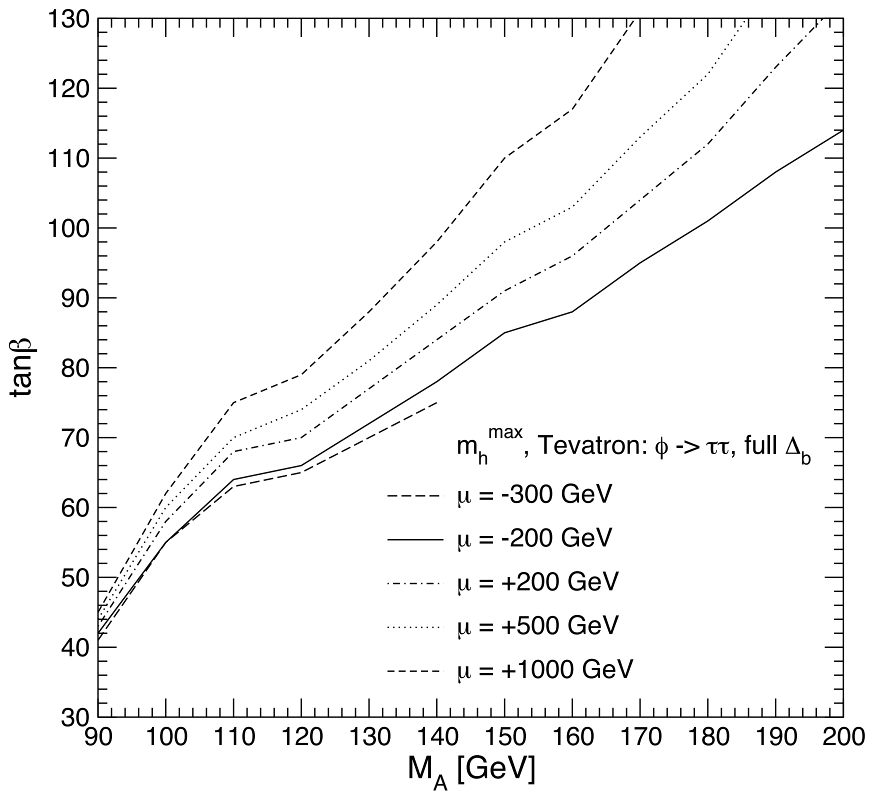

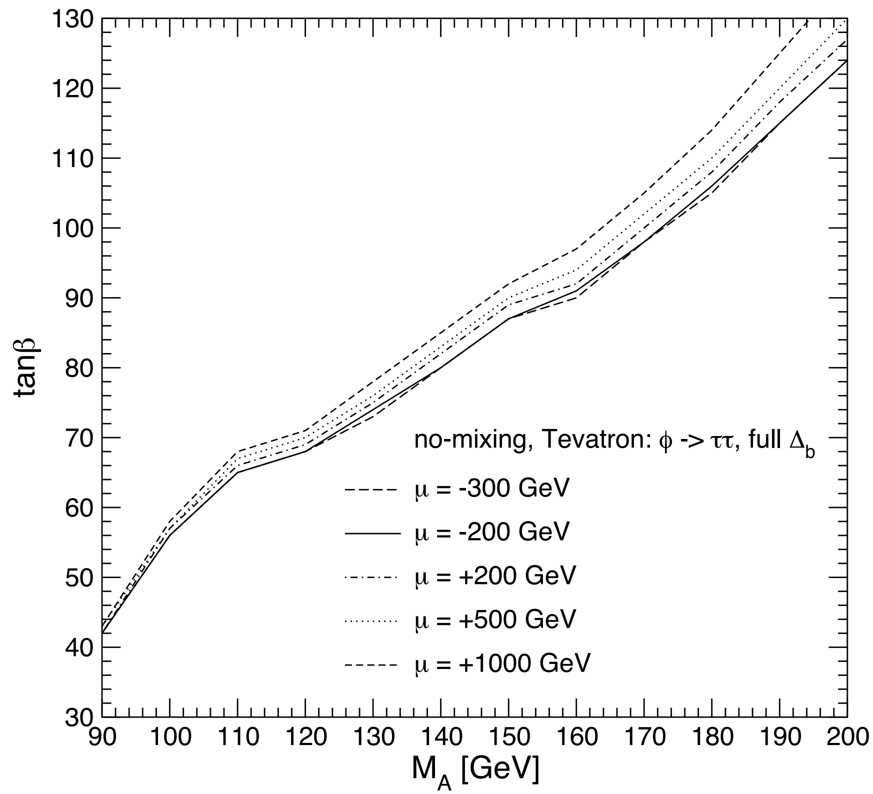

Searches at the LHC in the tau mode

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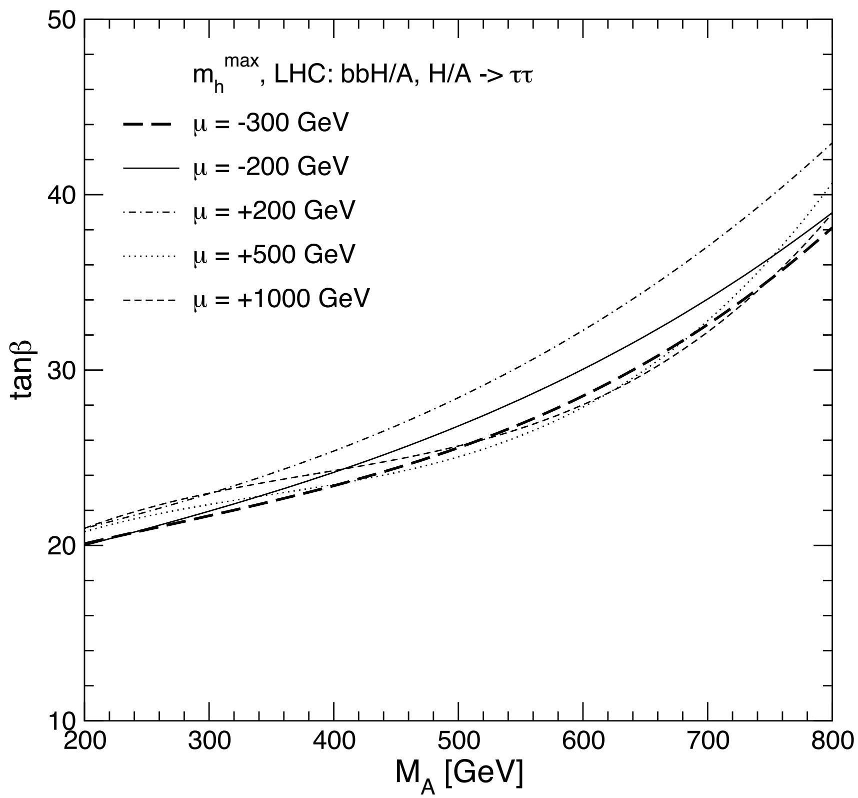
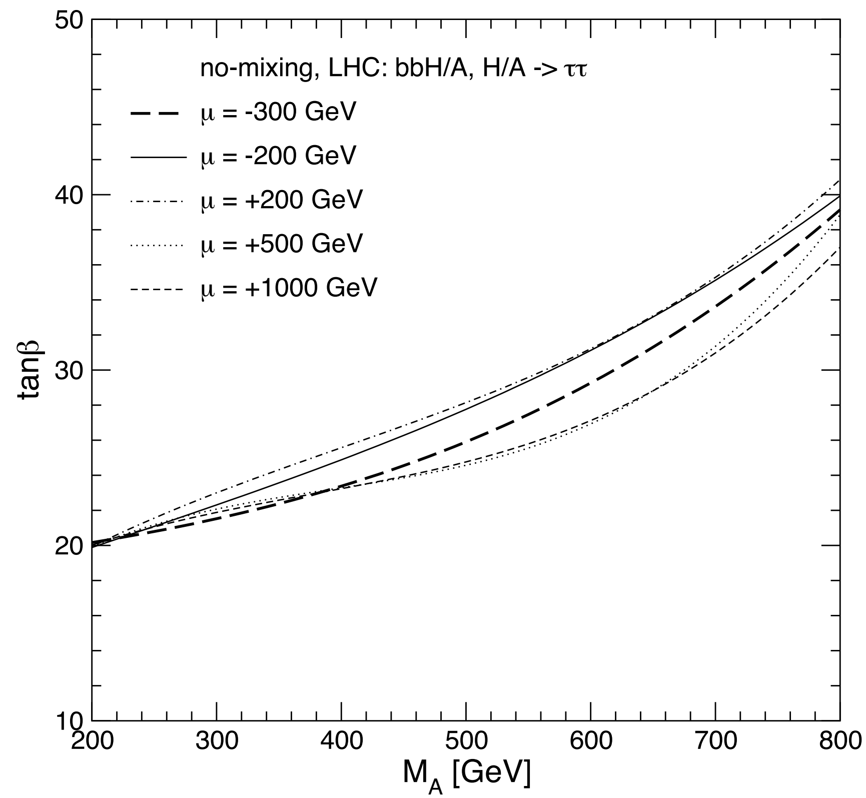




Couplings of the charged Higgs

- The couplings of the charged Higgs are determined, at tree level, by the lepton and quark masses and by $\tan\beta$

- The dominant couplings are those of the third generation

$$g_{H^- t\bar{b}} = \frac{\sqrt{2}}{\mathrm{v}}\left[m_t \cot\beta \, \mathrm{P_R} + m_b \tan\beta \, \mathrm{P_L}\right]; \quad g_{H^- \tau^+ \nu} = \frac{\sqrt{2}}{\mathrm{v}}\left[m_\tau \tan\beta \, \mathrm{P_L}\right]$$

- Observe that due to the structure of the couplings, the rate of the charged Higgs decay into second generation quarks will be much smaller than the one of the decay into tau-leptons and neutrinos.

- Therefore, if the charged Higgs boson is lighter than the top quark and $\tan\beta$ is large, the charged Higgs decays predominantly into tau leptons and neutrinos.

Charged Higgs Boson Decay Properties

- Searches for charged Higgs bosons are mostly done in the tau-neutrino decay channel.
- The branching ratio of this decay depends strongly on the mass of the charged Higgs boson.

$$BR(H^\pm \to \tau\nu_\tau) \simeq 1, \qquad m_{H^\pm} < m_t$$

$$\mathrm{BR}(H^\pm \to \tau\nu_\tau) \simeq \frac{(1+\Delta_b)^2}{(1+\Delta_b)^2 + 9(1 - m_t^2/m_{H^\pm}^2)}, \qquad m_{H^\pm} > m_t + m_b$$

- At the Tevatron, only the first option is available, and the charged Higgs boson is produced in the decay of a top quark, with a width that depends on the bottom Yukawa coupling. Hence, there is a strong parameter dependence on this channel, which is reduced at the LHC.

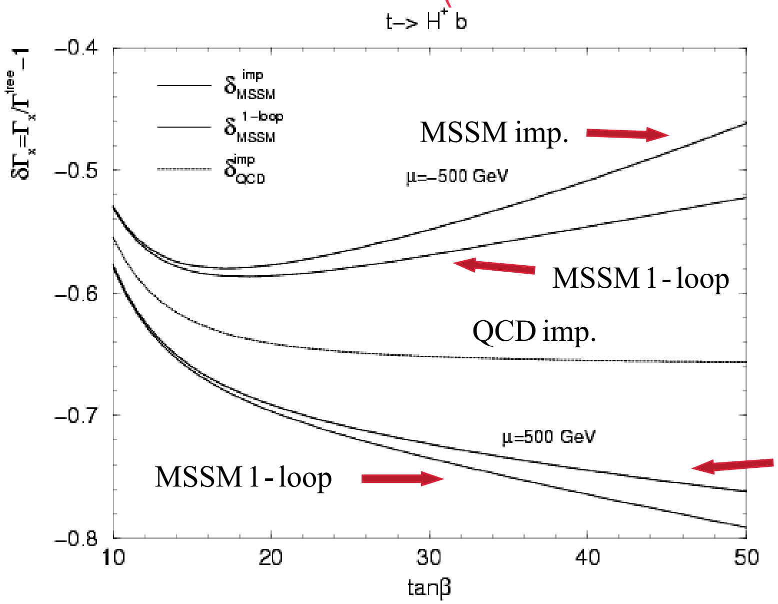
Quantum Corrections to $\Gamma\left(t \to bH^+\right)$

- leading and subleading log(Q/mb) resummed using m_b running in Γ^0 &
- One-loop finite QCD terms also included

$$\Gamma_{QCD}^{imp.}(t \to bH^+, \tan\beta \geq 10) = \frac{g^2}{64\pi M_W^2} m_t (1-q_{H^+})^2 \overline{m}_b^2(m_t^2) \tan^2\beta \times \left\{1 + \frac{\alpha_s(m_t^2)}{\pi} \left[7 - \frac{8\pi^2}{9} - 2\log(1-q_{H^+}) + 2(1-q_{H^+}) + \left(\frac{4}{9} + \frac{2}{3}\log(1-q_{H^+})\right)(1-q_{H^+})^2\right]\right\}$$

$$q_{H^+} = \frac{m_{H^+}^2}{m_t^2}$$

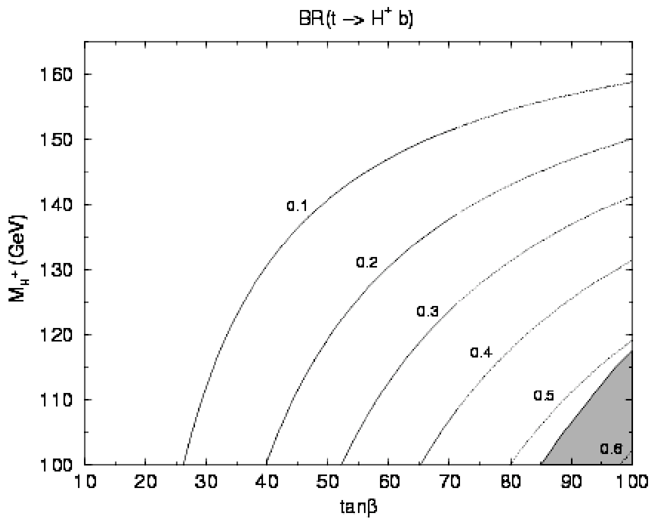
$A_t = M_{\tilde{g}} = 1$ TeV



$m_{H^m} = 125$ GeV

$$\Gamma^{\rm imp} = \Gamma_{QCD}^{\rm imp.} \frac{1}{(1+\Delta_b)^2}$$

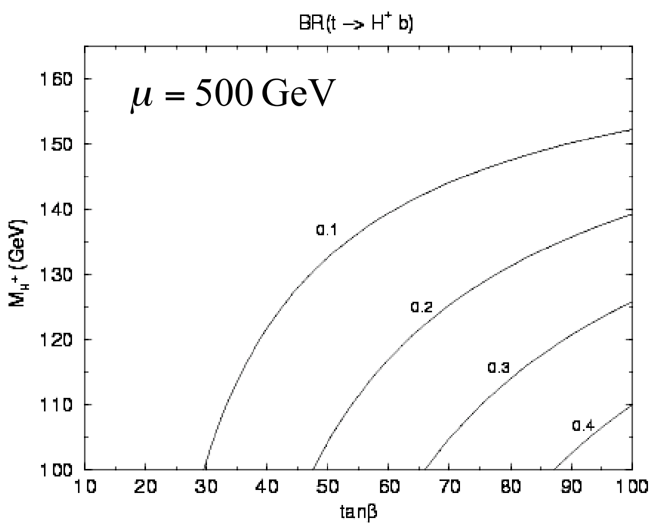
Charged Higgs Searches at theTevatron

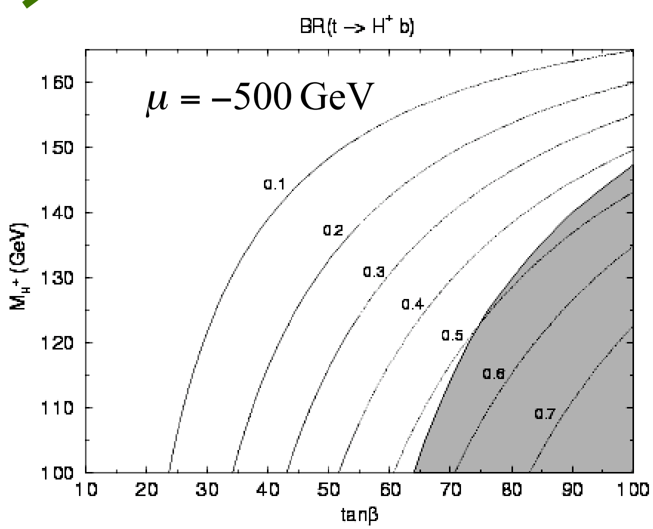


Curves of constant $\mathrm{BR}\left(t \to bH^{+}\right)$ after resummation of LOand NLO logs fo QCD

Shaded area excluded by DO RunI analysis
Similar for CDF.

Including SUSY corrections for large tanb and a heavy SUSY spectrum





Drastic variations on bounds in the $\tan\beta - m_{H^m}$ **plane depending on MSSM parameter space**

M.C., Garcia, Nierste, Wagner

Search for charged Higgs Bosons at the LHC

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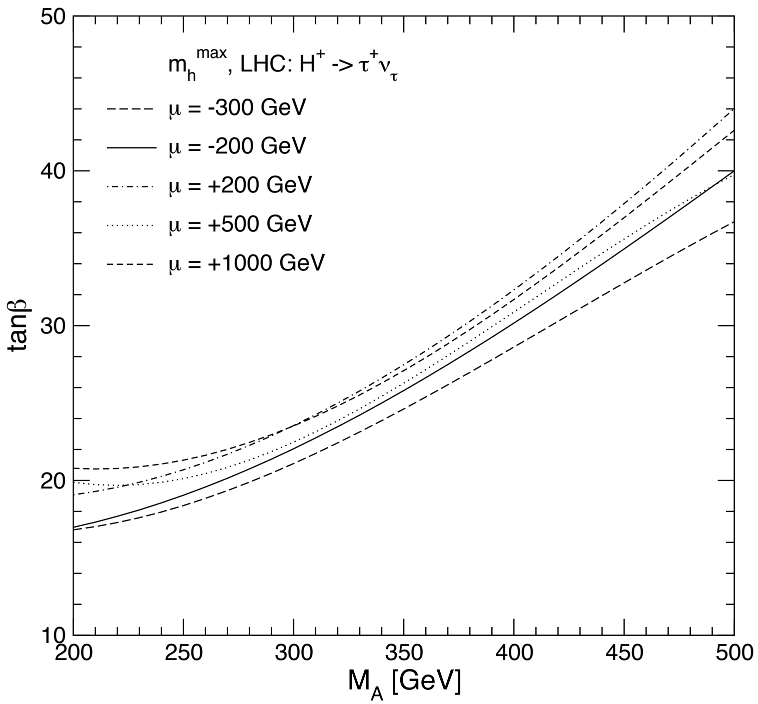
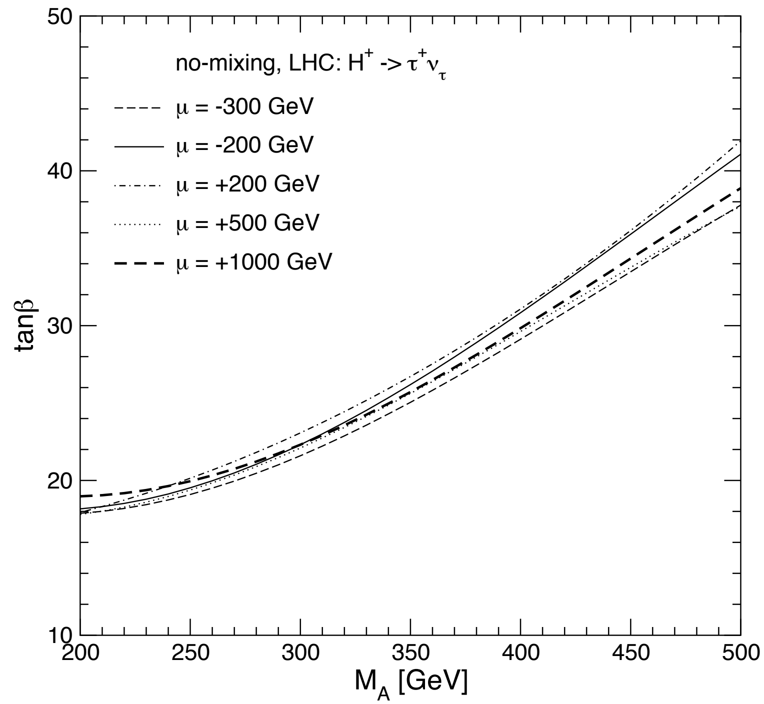




Flavor Changing Neutral Currents

- As described above, since at the loop level the down quarks couple to both Higgs fields, there will be FCNC in the Higgs sector

$$\bar{d}_R \left(D_R^\dagger h_d D_L \right) D_L^\dagger \left[H_1^0 + (E_g + E_u h_u^\dagger h_u) H_2^0 \right] D_L d_L + h.c.$$

- We need that, when the Higgs field are replaced by v.e.v.'s, the whole expression becomes diagonal, and equal to the masses. We also know that $D_L^\dagger h_u^\dagger h_u D_L = V_{CKM}^\dagger |\hat{h_u}|^2 V_{CKM}$
- Hence, $D_R^\dagger h_d D_L \simeq \frac{\hat{m}_d}{v_1} V_{CKM}^\dagger \left(1 + \tan\beta (E_g + E_t h_t^2)\right)^{-1} V_{CKM}$
- Keeping only the non-diagonal, flavor changing interactions, we get

$$\mathcal{L}_{FCNC} \simeq \bar{d}_R \frac{\hat{m}_d}{v_1} \left(1 + \tan\beta V_{CKM}^\dagger (E_g + E_t \hat{h_t}^2) V_{CKM}\right)^{-1} d_L \left(H_1^0 - \frac{H_2^0}{\tan\beta} \right)$$

- The above formulae are valid in two interesting cases: The first one is when all squark masses are approximately the same, and therefore Eg and Eu are Universal and diagonal.

- The second case is when the up and down quark masses are universal, apart from a correction which depends on powers of $h_u^\dagger h_u$, as happens with flavor universal masses which evolve according the the RG equations for moderate or small values of $\tan\beta$

- In this second case, the two terms are diagonalized simultaneously. But this can only arise for flavor violating couplings, governed by the CKM elements in the down quark-squark-gluino sector.

- A slightly different scheme is the one denoted as minimal flavor violation, in which squark and quark mass matrices may be diagonalized simultaneously (in block) at tree level. These three possibilities collapse into a single one when the squark masses are universal.

Comments on FCNC. Universal Case

- If one ignores the second and third generation, the FCNC Lagrangian agrees with the previously presented one, once we identify

$$\Delta_b = (E_g + E_t h_t^2) \tan\beta$$

- Since, in the universal case considered, only Eu h_u^2 does not commute with the Cabibbo rotation, all the FCNC effects are proportional to Et, and to the Cabibbo angle.

$$\mathcal{L}_{\rm FCNC} = \bar{d}_R^i \frac{\hat{m}_{d,i}}{v_1} R^{-1} E_t V_{3i}^* V_{3j} \hat{h_t}^2 R^{-1} d_L^j (H + iA) + h.c.$$

$$R = 1 + E_g I + E_t \hat{h}_u^2$$

- This provides a predictive scheme for the calculation of FCNC in the MSSM.

- Main effects at the Tevatron: $\mathrm{BR}(B_s \to \mu^+\mu^-), \quad \text{and} \;\; \Delta M_{B_s}$

Flavor Violating b s couplings

$$\bar{b}_R X_{RL} s_L H + h.c. = \bar{b}_R \frac{m_b \tan\beta}{v} \frac{E_t h_t^2 \tan\beta\, V_{ts}}{(1+\Delta_b)(1+E_g \tan\beta)} s_L \; H + h.c.$$

Also, $$\bar{s}_R \frac{m_s \tan\beta}{v} \frac{E_t h_t^2 \tan\beta\, V_{ts}^*}{(1+\Delta_b)(1+E_g \tan\beta)} b_L \; H + h.c.$$

An interesting correlation appears between the SUSY contribution to different processes

$$BR(B_s \to \mu^+\mu^-) \simeq \frac{X_{RL}^2 \tan^2\beta}{m_A^4}$$

$$(\Delta M_{B_s})^{\rm SUSY} \simeq -\frac{X_{RL}^2}{m_A^2}$$

Probing the large tanb region at the Tevatron

$$\boxed{B_s \to \mu^+ \mu -}$$

$$\text{SM amplitude} \propto \mathrm{V}_{ts} \frac{\mathrm{m}_\mu}{\mathrm{M}_W}$$

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

- Present CDF limit: $\mathrm{BR}(B_s \to \mu^+ \mu -) < 2.\ \ 10^{-7}$

- In the MSSM with two Higgs doublets: Babu, Kolda, 99; Dedes, Pilaftsis, 02

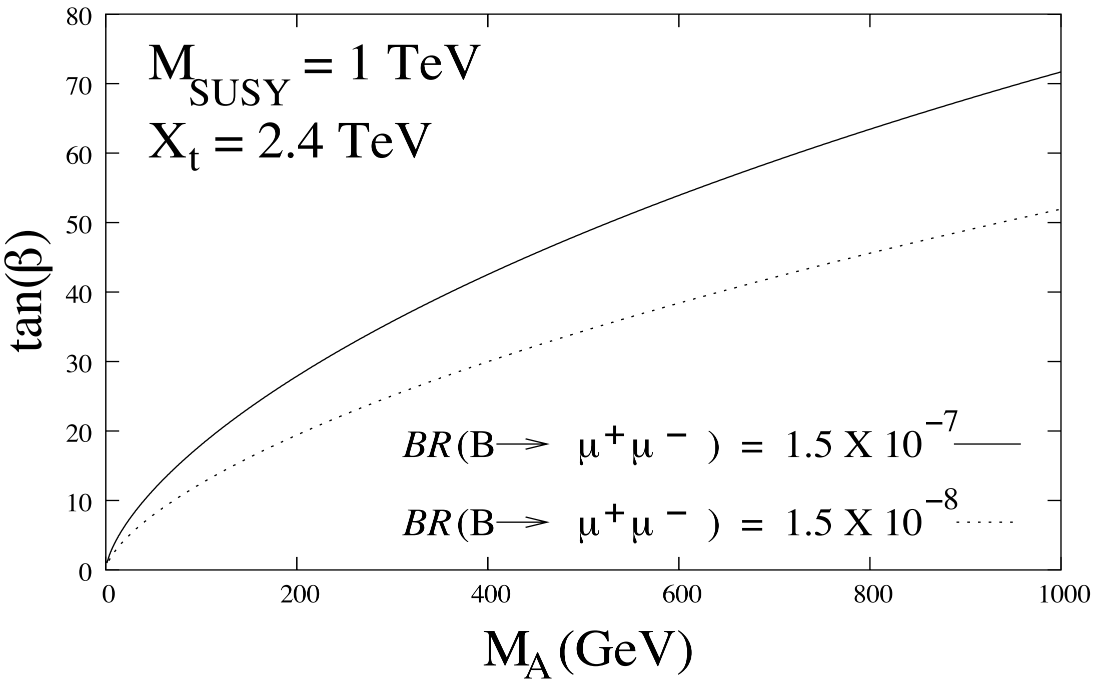
$$\mathrm{BR}(B_s \to \mu^+ \mu -)_{MSSM} \propto \left| V_{tb} V_{ts}^* \right|^2 \frac{\tan^6 \beta}{m_{H_i}^4}$$

- Higgs mediated FCNC contributions can enhance the Branching ratio by 3 orders of magnitude

- Searches at the Tevatron explore regions of the tanb-Higgs masses parameter space in a very efficient way!

- Important effects of CP violation

Searches for Higgs mediated FCNC at the Tevatron



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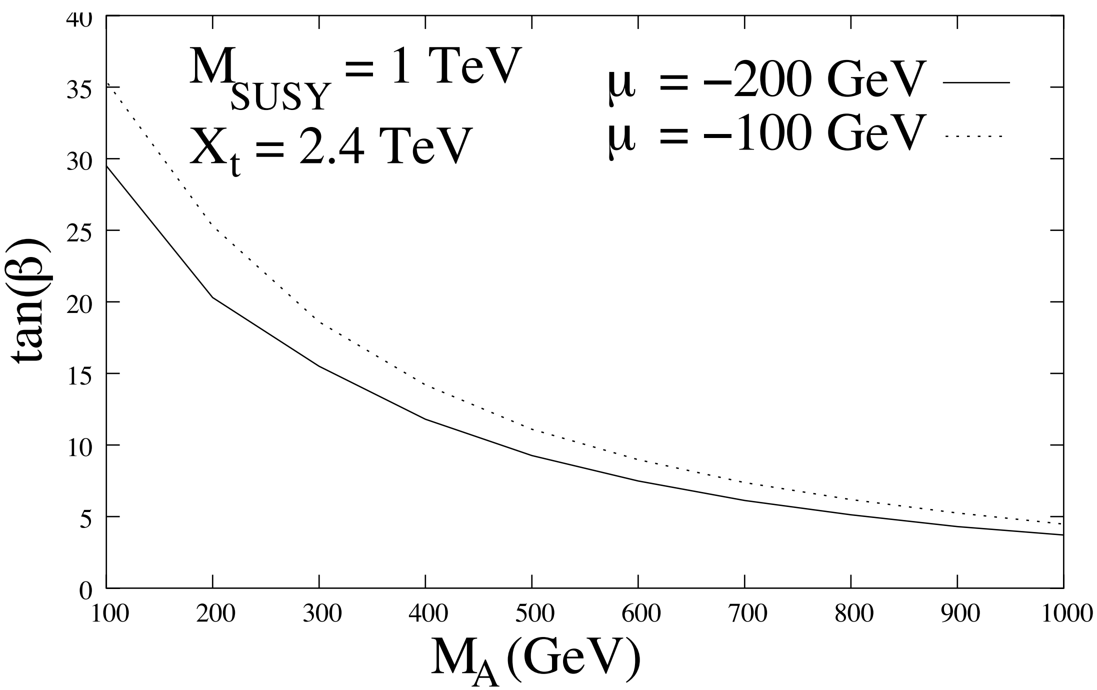
Bounds from $\mathrm{BR}(b \to s\gamma)$

$$\mathcal{A}_{\mathrm{SUSY}} \simeq C_1 X_{RL} + C_2 \frac{m_t^2}{m_{H^+}^2} \ll \mathcal{A}_{SM}$$



In general, it is difficult to accomodate a light CP-odd Higgs, with mass and couplings in the Tevatron range, in SUSY minimal flavor violating models.

Correlation between Higgs mediated flavor violating effects

- Higgs mediated contribution to Delta Ms has the opposite sign as the SM one, unless it is very large.
- Bounds on the Branching ratio of Bs to muons, together with bounds on the loop corrections Eu and Eg already puts a strong constraint on the possible Higgs mediated contribution to Delta Ms

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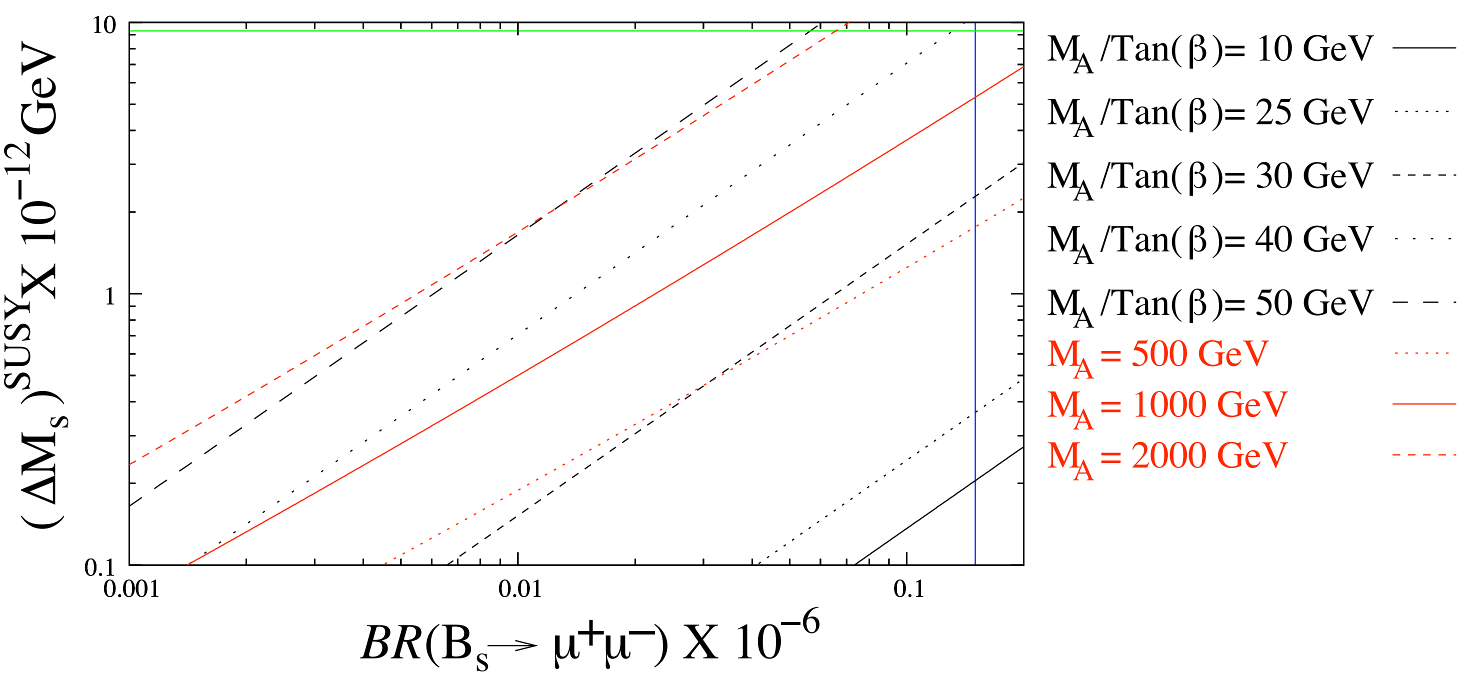

Size of Effects in Minimal Flavor Violation Scheme

- Minimal flavor violation refers here to the fact that all the effects are induced by Cabibbo mixing.
- Positive contributions to Delta Ms can appear from stop--chargino box diagrams. The plot below was performed by trying to maximize these effects.

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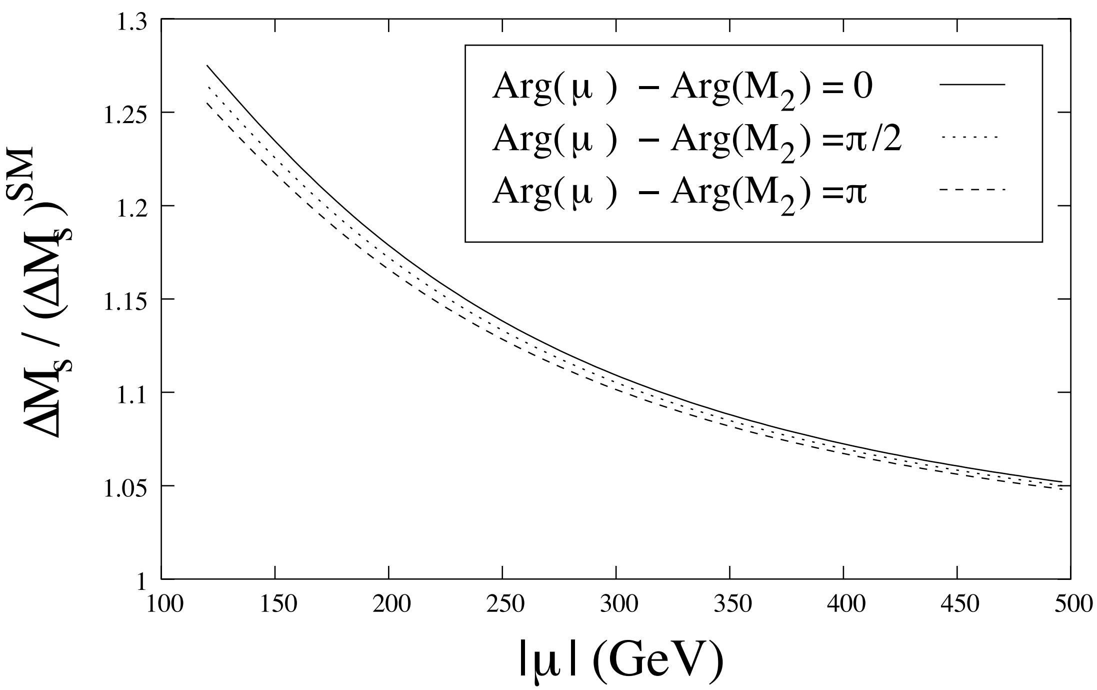

Conclusions

- Higgs Physics in the MSSM presents interesting variations from the SM ones.
- Not only there are additional Higgs bosons, with enhanced couplings to leptons and down quarks, but the Higgs sector properties are strongly affected by radiative corrections
- Searches at the Tevatron become more efficient in the bb mode, but the bounds are strongly dependent on the choice of third generation mass parameters. Reach in the tau mode becomes more stable under parameter changes.
- Flavor changing neutral currents in the Higgs sector are induced at the loop level, with interesting effects testable at the Tevatron in the near future.

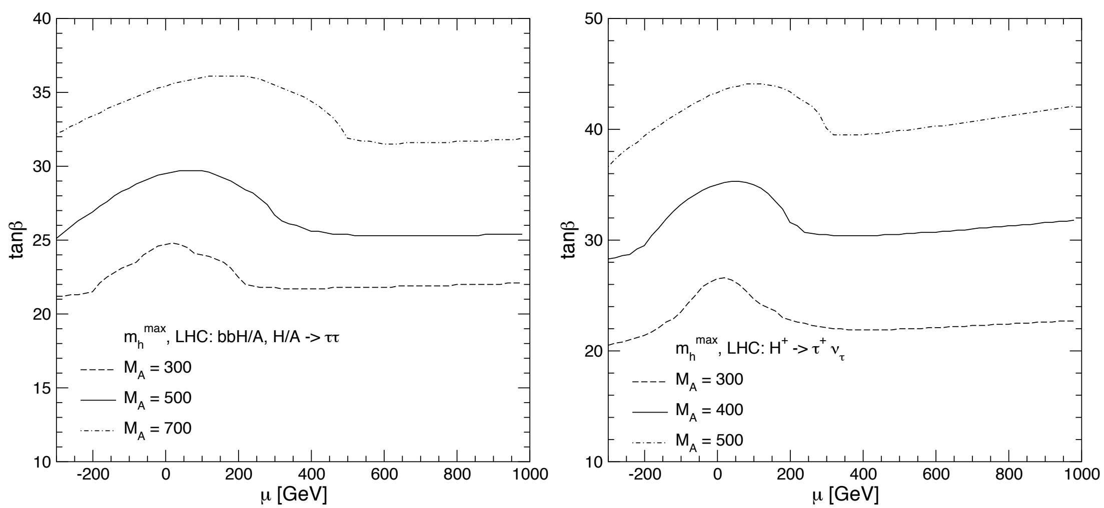

Figure 7: Variation of the 5σ discovery contour as a function of the parameter μ in the $m_h^{\max}$ scenario for the $pp \to H, A \to \tau^+\tau^-$ process (left) and the $H^\pm \to \tau^\pm \nu_\tau$ process (right).