Heavy quark production by SUSY FCNC at the LHC

Jaume Guasch

Departament d'Estructura y Constituents de la Matèria
Universitat de Barcelona

S. Béjar, F. Dilmé, J.G., J. Solà, JHEP 0408 (2004) 018, hep-ph/0402188

S. Béjar, J.G., J. Solà, JHEP 0510 (2005) 113, hep-ph/0508043

J.G., W. Hollik, J. Solà, S. Peñaranda, in preparation

Outline

- Introduction
  - Model setup
- Contstraints & fine-tuning
- Higgs FCNC @ LHC
- Direct FCNC production @ LHC
- Conclusions

Introduction

Model setup

- Minimal Supersymmetric Standard Model $\oplus$ flavour mixing mass terms in the Left-Left sector

MSSM without mixing terms:

- Assuming Alignment at $\mu_0 \sim \Lambda$ $\Rightarrow$ RGE generates unalignment at $\mu_0 \sim 100\,\text{GeV}$ in the LL sector

  M.J. Duncan, **Nucl. Phys. B** 221, 285 (1993)

- Assuming Alignment: $\Gamma(\tilde{t} \to c\chi^0)$ is divergent (!)

  K.Hikasa, M.Kobayashi **Phys. Rev. D** 36, 724 (1987); G.Jahn, ITP-Karlsruhe Diplomarbeit (1998)

- One-loop FCNC: $H^\pm$, $\chi^\pm$

Introduction

Model setup

- Minimal Supersymmetric Standard Model $\bigoplus$ flavour mixing mass terms in the Left-Left sector

MSSM without mixing terms:

- Assuming Alignment at $\mu_0 \sim \Lambda$ $\Rightarrow$ RGE generates unalignment at $\mu_0 \sim 100$ GeV in the LL sector

  M.J. Duncan, **Nucl. Phys. B** 221, 285 (1993)

- Assuming Alignment: $\Gamma(\tilde{t} \to c\chi^0)$ is divergent (!)

  K.Hikasa, M.Kobayashi **Phys. Rev. D** 36, 724 (1987); G.Jahn, ITP-Karlsruhe Diplomarbeit (1998)

- One-loop FCNC: $H^{\pm}$, $\chi^{\pm}$

With flavour mixing terms:

- giving up Alignment
  * $\delta_{ij} = m^2_{ij}/(\tilde{m}_i \tilde{m}_j)$ $i \neq j$
  * δ_{ij} constrained (mass insertion approximation)

    $$\begin{aligned} \delta_{12} &\lesssim .1\,\sqrt{m_{\tilde{u}}\, m_{\tilde{c}}}/500\text{ GeV} \\ \delta_{13} &\lesssim .098\,\sqrt{m_{\tilde{u}}\, m_{\tilde{t}}}/500\text{ GeV} \\ \delta_{23} &\lesssim 8.2\, m_{\tilde{c}}\, m_{\tilde{t}}/(500\text{ GeV})^2 \end{aligned}$$

    F. Gabbiani *et. al.* **Nucl. Phys B** 477, 321 (1996)

  * $B(b \to s\gamma)$: additional contstraints

Contstraints & fine-tuning

- The Flavour-Changing terms are communicated from the up- to the down-sector by CKM

  e.g. M.Misiak, S.Pokorski, J. Rosiek, Adv.Ser.Direct.High Energy Phys.15:795-828,1998, hep-ph/9703442

$$(M^d_{LL})^2 = CKM^\dagger \times (M^u_{LL})^2 \times CKM$$

$$(M^d_{LL})^2 \not\parallel (M^d_{LL})^2_{\text{DIAG}} \qquad (M^u_{LL})^2 \not\parallel \mathbb{1}\,\tilde{M}^2$$

$\Rightarrow$ top-charm FCNC are constrained by $B(b \to s\gamma)$

- $BR^{exp}(b \to s\gamma) = (3.3 \pm 0.4) \times 10^{-4}$

  CLEO+ALEPH+BELLE+BABAR $\to$ Particle Data Group

- $BR^{SM}(b \to s\gamma) = (3.29 \pm 0.33) \times 10^{-4}$

  K. Chetyrkin, M. Misiak, M. Münz, Phys. Lett. B **400** (1997) 206 [Erratum-ibid. B **425** (1998) 414], hep-ph/9612313;

  A. J. Buras, A. Kwiatkowski and N. Pott, Phys. Lett. B **414** (1997) 157 [Erratum-ibid. B **434** (1998) 459], hep-ph/9707482;

  A. L. Kagan and M. Neubert, Eur. Phys. J. C **7** (1999) 5, hep-ph/9805303;

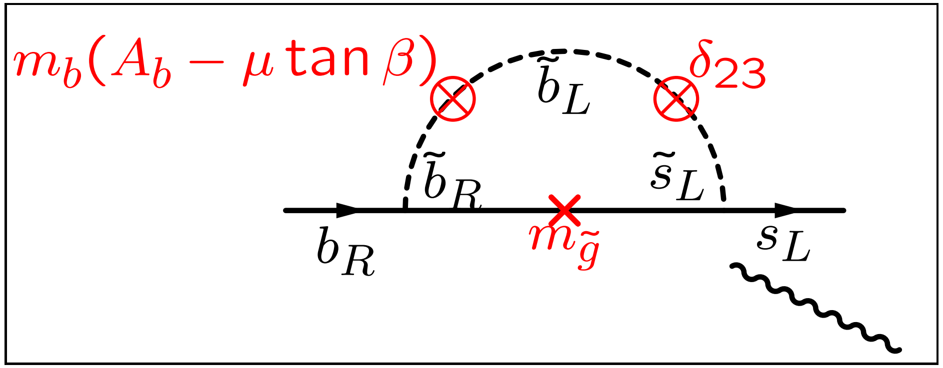
  $+ \cdots$

$B(b \to s\gamma)$

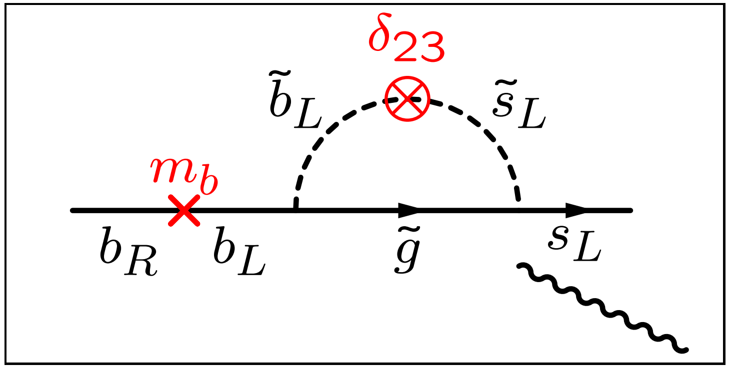
[True for Left-Left mixing only!]

- Relevant Wilson operator in the effective theory involves a chirality flip

$$O_7 = \frac{e}{16\pi^2} m_b \, (\bar{s}_L \, \sigma^{\mu\nu} \, b_R) \, F_{\mu\nu}$$



Leading, Double insertion



Sub-Leading, Single insertion

- The Feynman Amplitude:

$$A^{SUSY-QCD}(b \to s\gamma) \sim \delta_{23} \frac{m_b(A_b - \mu \tan\beta)}{M^2_{SUSY}} \times \frac{1}{m_{\tilde{g}}}$$

- Different coupling structure in Hqq' $(\sim \mu)$ and $bs\gamma$ $(\sim A_b - \mu \tan\beta)$

$\Rightarrow$ Possibility of small contribution to $A(b \to s\gamma)$ and large contribution to $BR(H \to qq')$

fine-tuning

- $A(b \to s\gamma) = A^{SM} + A^{SUSY-QCD} + \cdots$
- $BR^{exp}(b \to s\gamma) \simeq BR^{SM}(b \to s\gamma)$

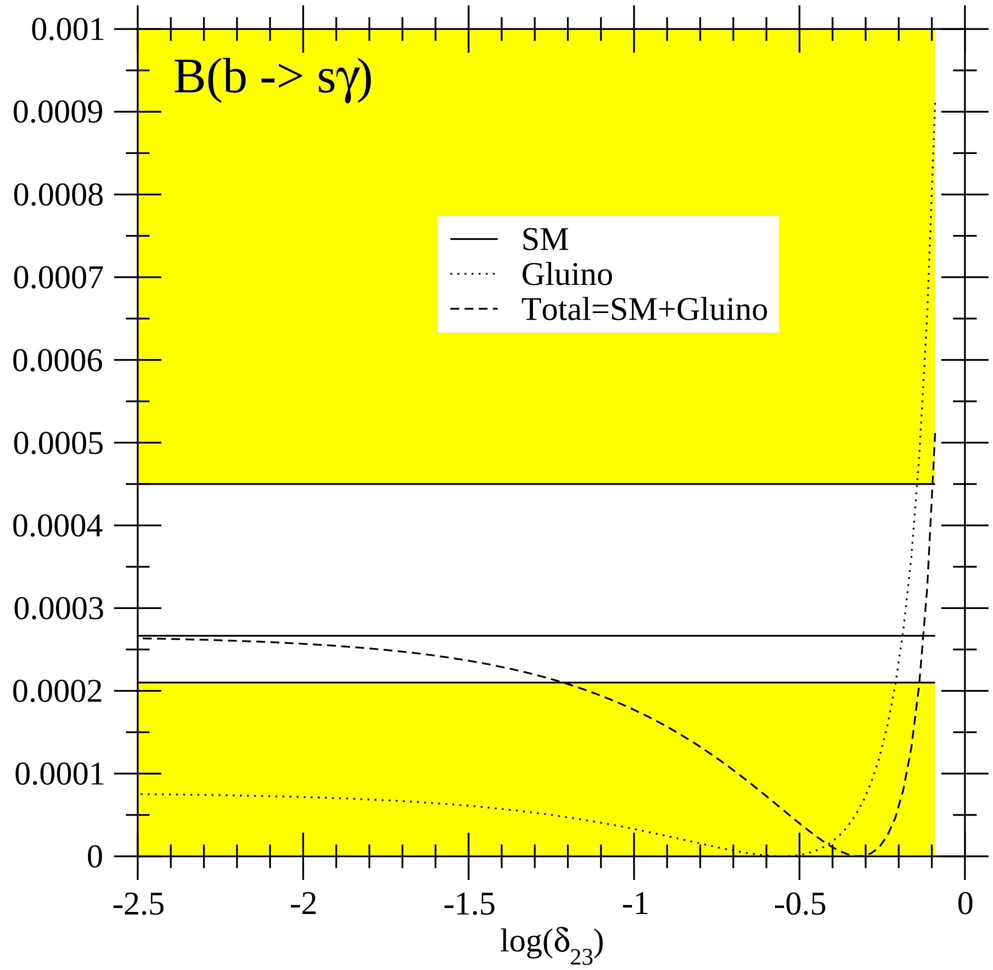
  $\Rightarrow$ $A^{SUSY-QCD} \ll A^{SM}$:

  Normal situation

  $\Rightarrow$ $A^{SUSY-QCD} \simeq -2A^{SM}$:

  Fine-Tuning!!!!
- At 3σ:

  $BR^{exp}(b \to s\gamma) = (2.1 - 4.5) \times 10^{-4}$



Higgs FCNC @ LHC

- SM values:

$$BR(H^{SM} \to b\bar{s}) \lesssim 10^{-7} \quad (m_H < 2M_W) \qquad\qquad BR(H^{SM} \to t\bar{c}) \lesssim 10^{-13}$$
$$\lesssim 10^{-10} \quad (m_H > m_t)$$

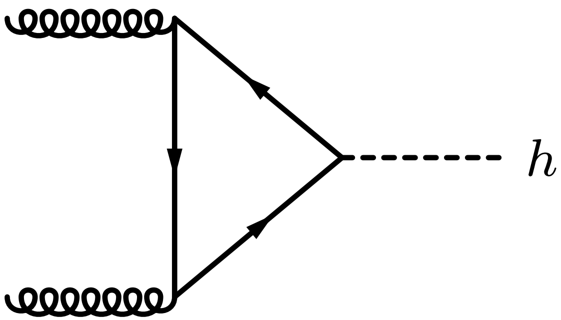
S. Béjar, J.G., J. Solà, **Nucl. Phys. B**675 (2003) 270, hep-ph/0307144

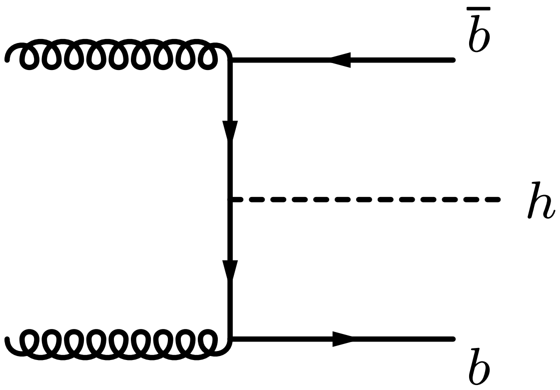
S. Béjar, F. Dilmé, J.G., J. Solà, JHEP 0408 (2004) 018, hep-ph/0402188

$$\sigma(pp \to h \to q\, q') \equiv \sigma(pp \to hX) B(h \to q\, q')$$
$$\equiv \sigma(pp \to hX) \frac{\Gamma(h \to q\,\bar{q}' + \bar{q}\, q')}{\sum_i \Gamma(h \to X_i)} \qquad (qq' \equiv bs \text{ or } tc)\,.$$

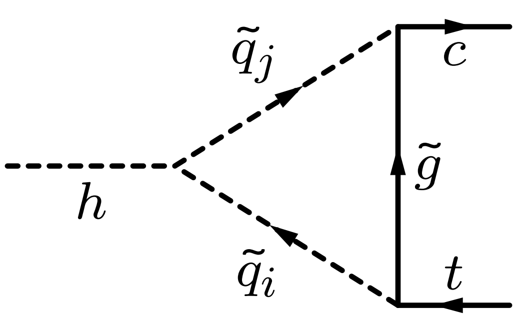
- $\sigma(pp \to hX)$: HIGLU and HQQ packages

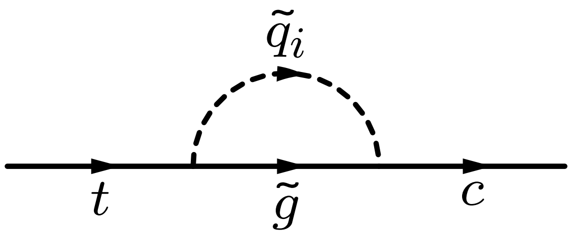
M. Spira, hep-ph/9510347; `http://people.web.psi.ch/~spira/higlu/`, and `http://people.web.psi.ch/~spira/hqq`





- $\Gamma(h \to X)$
  - Self-computed Leading Order 2- and 3-body decays
    - LO: Same QCD order in numerator and denominator
    - 3-body decays: necessary when $\Gamma(h \to b\bar{b}) \to 0$ (small α_{eff} scenario)
- $\Gamma(h- > q\bar{q}\prime)$: SUSY-QCD contributions
  - Don't assume alignment
  - Exact diagonalization of 6×6 squark mass matrix
  - Assume mixing only in the LL sector





- One-loop predicition for M_{h^0}, M_{H^0}, α

A. Dabelstein, *Z. Phys.* **C67** (1995) 495, hep-ph/9409375.

Some works

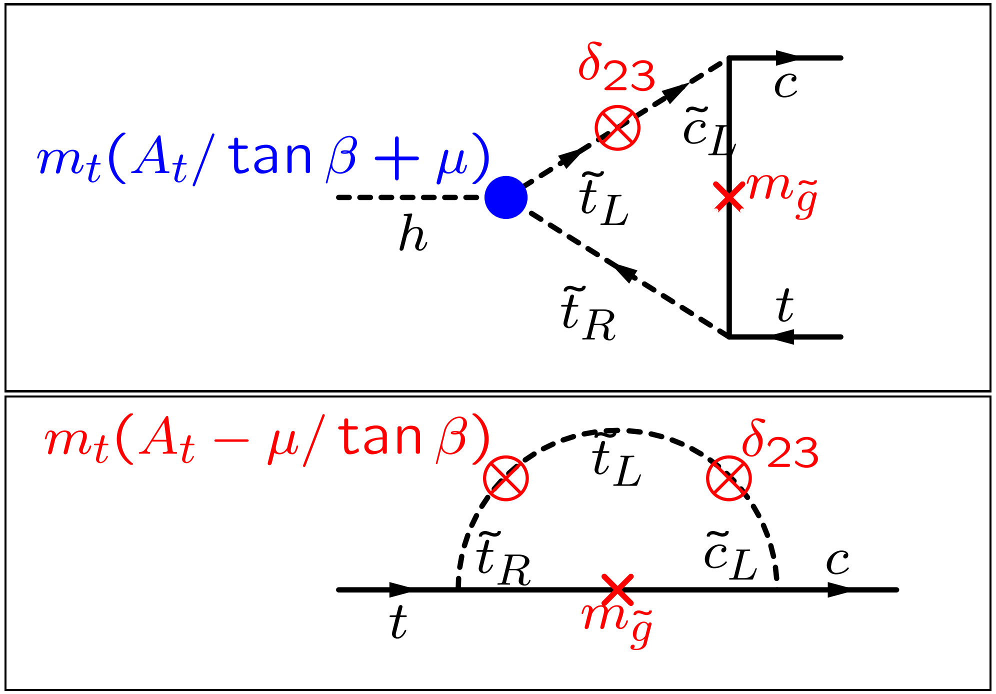
- $t \longrightarrow cX$ MSSM
  - J. G., QEMMSM Barcelona, Spain, hep-ph/9710267.
  - J. G., J. Solà, Nucl. Phys. B **562** (1999) 3 [hep-ph/9906268].
  - J. G., J. Solà, IWLC, Sitges, Spain, hep-ph/9909503.
  - S. Béjar, J. G., J. Solà, RADCOR00, Carmel, USA, hep-ph/0101294.
- $H \longrightarrow bs,\ H \longrightarrow tc$ MSSM
  - A.M. Curiel, M.J. Herrero, W. Hollik, F. Merz and S. Peñaranda, Phys. Rev. D **69** (2004) 075009 [hep-ph/0312135].
  - A.M. Curiel, M.J. Herrero, D. Temes, Phys. Rev. D**67** (2003) 075008 [hep-ph/0210335].
- $H \longrightarrow bs + b \longrightarrow s\gamma$
  - S. Béjar, F. Dilmé, J. G., J. Solà, JHEP **0408** (2004) 018 [hep-ph/0402188].
  - T. Hahn, W. Hollik, J.I. Illana, S. Peñaranda, talk at SUSY05, Durham, UK.
- $pp \longrightarrow H + H \longrightarrow bs + H \longrightarrow tc + b \longrightarrow s\gamma$
  - S. Béjar, J.G., J. Solà, JHEP **0510** (2005) 113, hep-ph/0508043

Some works

- $t \to cX$ MSSM
  - J. G., QEMMSM Barcelona, Spain, hep-ph/9710267.
  - J. G., J. Solà, Nucl. Phys. B **562** (1999) 3 [hep-ph/9906268].
  - J. G., J. Solà, IWLC, Sitges, Spain, hep-ph/9909503.
  - S. Béjar, J. G., J. Solà, RADCOR00, Carmel, USA, hep-ph/0101294.
- $H \to bs$, $H \to tc$ MSSM
  - A.M. Curiel, M.J. Herrero, W. Hollik, F. Merz and S. Peñaranda, Phys. Rev. D **69** (2004) 075009 [hep-ph/0312135].
  - A.M. Curiel, M.J. Herrero, D. Temes, Phys. Rev. D**67** (2003) 075008 [hep-ph/0210335].
- $H \to bs + b \to s\gamma$
  - S. Béjar, F. Dilmé, J. G., J. Solà, JHEP **0408** (2004) 018 [hep-ph/0402188].
  - T. Hahn, W. Hollik, J.I. Illana, S. Peñaranda, talk at SUSY05, Durham, UK.
- $pp \to H + H \to bs + H \to tc + b \to s\gamma$
  - S. Béjar, J.G., J. Solà, JHEP **0510** (2005) 113, hep-ph/0508043

Leading contributions

- Diagrams with a chirality flip are enhanced by $m_{\tilde{g}}$: mass-insertion approximation



- The terms proportional to A_t cancel in the sum.

  See also J.G., P.Häfliger, M.Spira Phys. Rev. **D68** 115001, 2003, hep-ph/0305101

- Equivalent structure for bs-channel

- We can write and effective Lagrangian:

$$G_{Hqq'} \sim \delta_{23}\,\frac{m_{\tilde{g}}\,\mu}{M^2_{SUSY}} \left\{ \begin{array}{cc} \cos(\beta-\alpha_{\text{eff}}) & (h^0) \\ \sin(\beta-\alpha_{\text{eff}}) & (H^0) \\ 1 & (A^0) \end{array} \right. \xrightarrow[\alpha_{\text{eff}} \to \beta-\pi/2]{M_{A^0} \gg M_Z} \left. \begin{array}{cc} 0 & (h^0) \\ 1 & (H^0) \\ 1 & (A^0) \end{array} \right\}$$

D. A. Demir, Phys. Lett. **B571**, 193–208 (2003), hep-ph/0303249.

small α_{eff}

- Large value of $BR(h \to qq') = \dfrac{\Gamma(h \to qq')}{\Gamma(h \to X)}$
  - $\Gamma(h \to qq')$ is large
  - $\Gamma(h \to X)$ is small:
    - ∗ Lightest Higgs boson: $\Gamma(h^0 \to b\bar{b}) \sim \left(\dfrac{\sin\alpha_{\text{eff}}}{\cos\beta}\right)^2$
    - ∗ in the small α_{eff} scenario:

      M. Carena, S. Heinemeyer, C. E. M. Wagner, G. Weiglein, Eur. Phys. J. **C26**, 601–607 (2003), `hep-ph/0202167`.

      $\Rightarrow$ $\Gamma(h^0 \to b\bar{b}) \to 0$

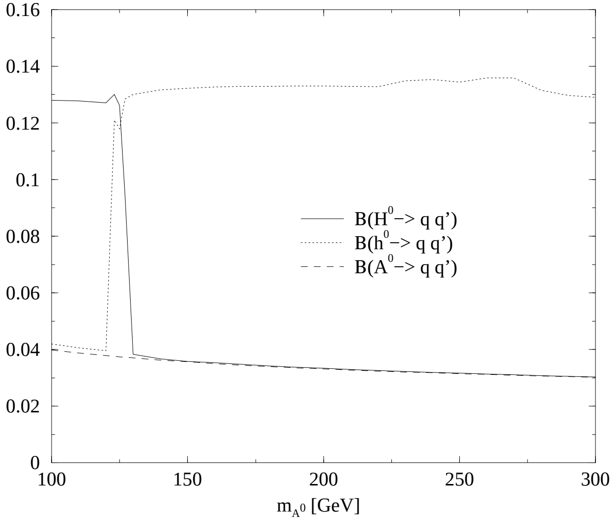
      $\Rightarrow$ $\Gamma(h^0 \to X) = \Gamma(h^0 \to c\bar{c} + gg + ZZ^* + W^{\pm}W^{\pm *})$: strongly suppressed

Numerical results $BR(h \to bs)$

- Find the maximum $BR(h \to bs)$: MSSM parameter space scan

fine-tuning

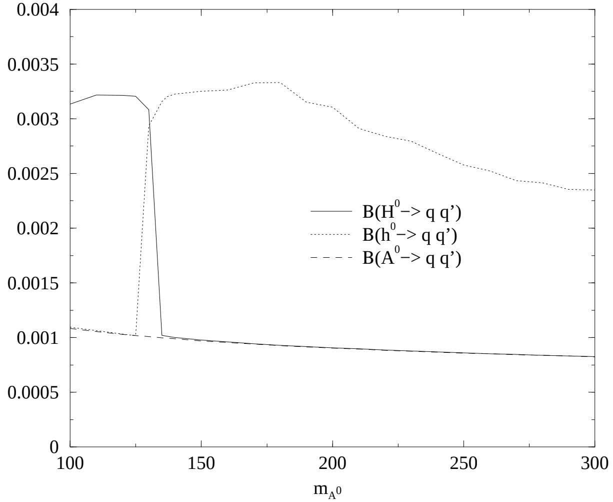
small α_{eff}



$BR^{max}(h^0) \sim 13\%$

no fine-tuning

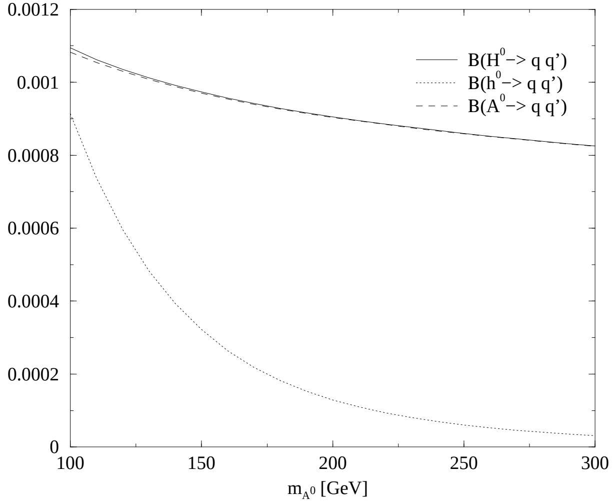
small α_{eff}



$BR^{max}(h^0) \sim 3.1 \times 10^{-3}$

no fine-tuning

no small α_{eff}



$BR(h^0) \sim 1.3 \times 10^{-4}$
$(M_{A^0} = 200\,\text{GeV})$

- We will avoid the fine-tuning region from now on

- The maximum $BR(h^0 \to bs)$ is obtained in the small α_{eff} scenario

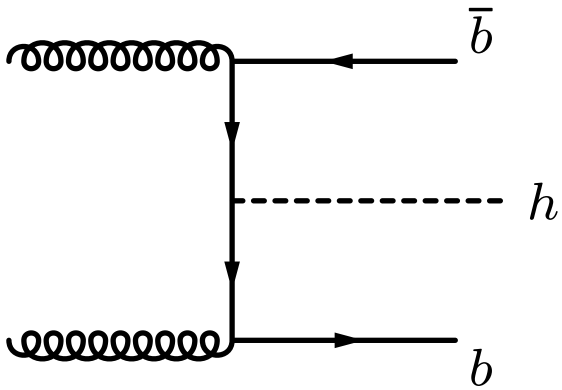
$BR^{max}(h \to bs)$

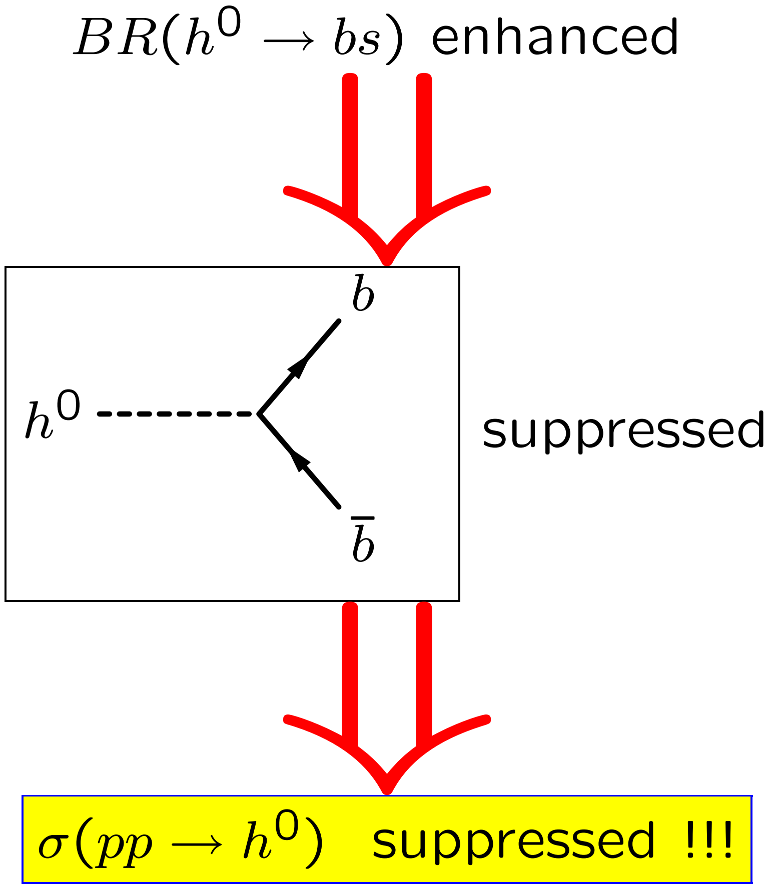
$M_{A^0} = 200$ GeV

Particle	H^0		h^0		A^0	
	Γ(GeV)	$B(h \to b\,s)$	Γ(GeV)	$B(h \to b\,s)$	Γ(GeV)	$B(h \to b\,s)$
small-α_{eff} fine-tuning	11.0	3.3×10^{-2}	1.6×10^{-3}	1.3×10^{-1}	11.3	3.3×10^{-2}
tree-Higgs fine-tuning	11.3	3.3×10^{-2}	5.4×10^{-3}	4.3×10^{-3}	11.3	3.3×10^{-2}
small-α_{eff} no-fine-tuning	11.2	9.1×10^{-4}	1.4×10^{-3}	3.1×10^{-3}	11.3	9.0×10^{-4}
tree-Higgs no-fine-tuning	11.3	9.1×10^{-4}	5.4×10^{-3}	1.3×10^{-4}	11.3	9.0×10^{-4}
$\tan\beta = 5$	0.11	2.0×10^{-3}	6.0×10^{-3}	1.7×10^{-4}	0.11	2.1×10^{-3}
$\tan\beta = 5$ tree Higgs	0.12	1.9×10^{-3}	4.4×10^{-3}	2.6×10^{-4}	0.11	2.1×10^{-3}
$\tan\beta = 5$ no-fine-tuning	0.15	3.8×10^{-4}	9.7×10^{-3}	1.1×10^{-4}	0.11	5.1×10^{-4}

Combination with production

- At large $\tan\beta$ the main production channel for h^0 is associated production: $\sigma(pp- > h^0 b\bar{b})$



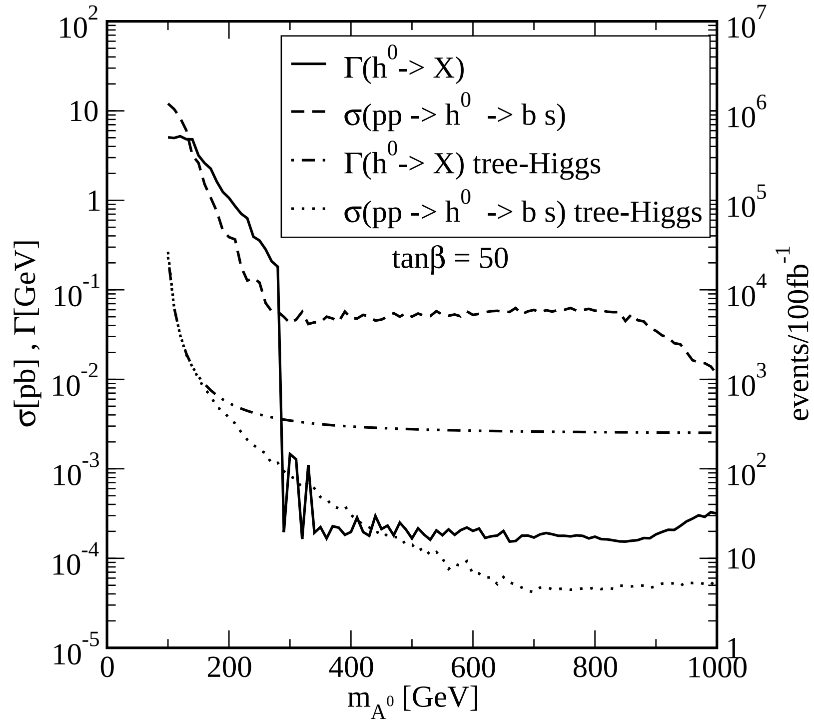


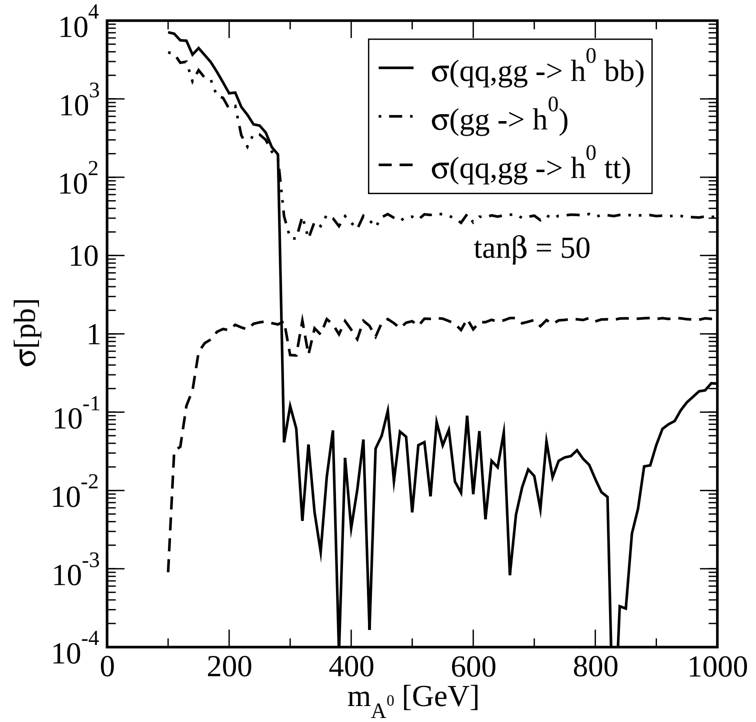
Combined analysis

$\sigma(pp \to h \to qq')$

$\sigma(pp \to h \to bs)$

- Maximized production rates for h^0
- $M_{A^0} < 300\,\text{GeV}$: enhancement of $\sigma(pp \to h^0)$ dominates
- $M_{A^0} > 300\,\text{GeV}$: supression of $\Gamma(h^0 \to X)$ dominates



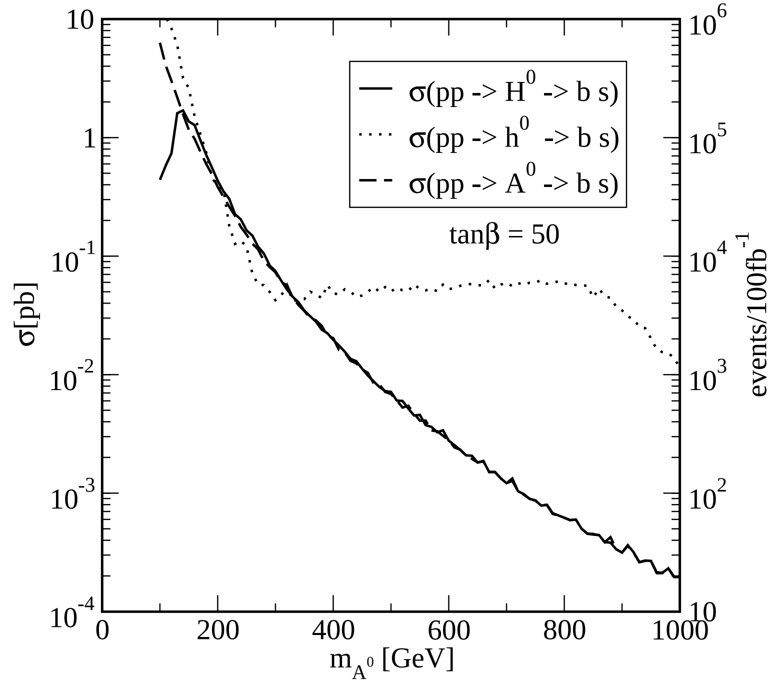


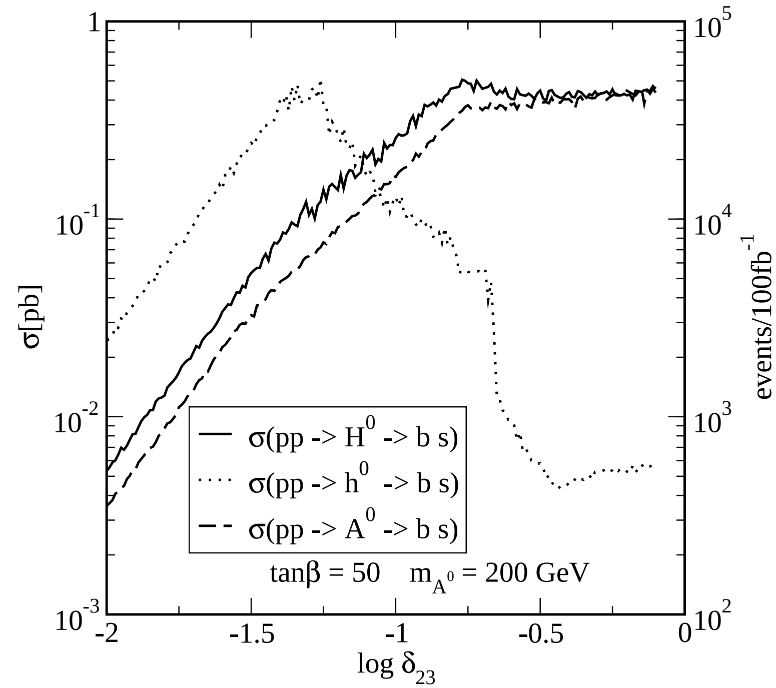
- h^0:
  - $M_{A^0} > 300\,\text{GeV}$: small α_{eff}
  - Dominant contributions are not the leading ones ($\cos(\beta - \alpha_{\text{eff}}) \to 0$)
  - Maximum attained for small δ_{23}, $M_{SUSY} \sim 700\,\text{GeV}$

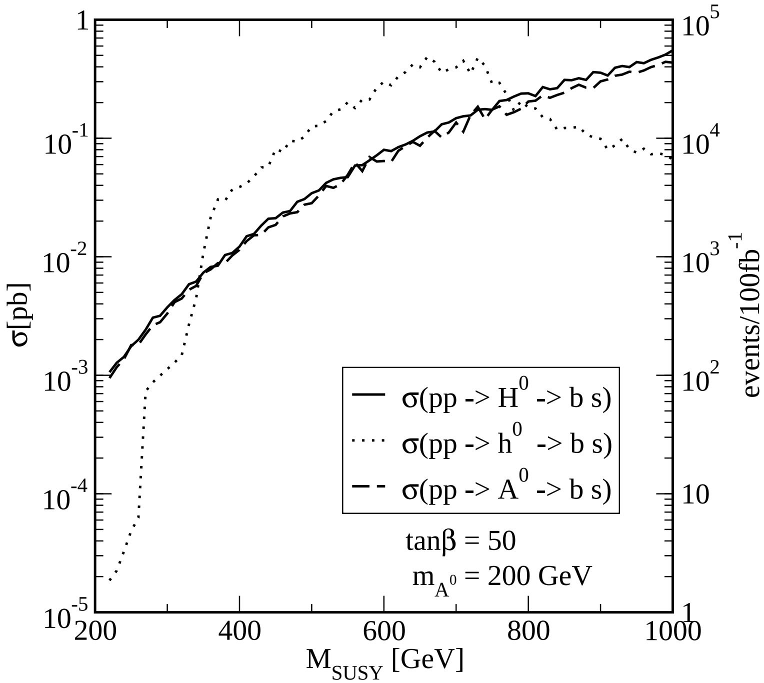
$\Rightarrow$ parameters for which small α_{eff} is possible

$\Rightarrow$ Larger $\delta_{23} \Rightarrow$ smaller μ ($b \to s\gamma$)

$\Rightarrow$ Small $M_{SUSY} \Rightarrow$ small δ_{23} ($b \to s\gamma$)

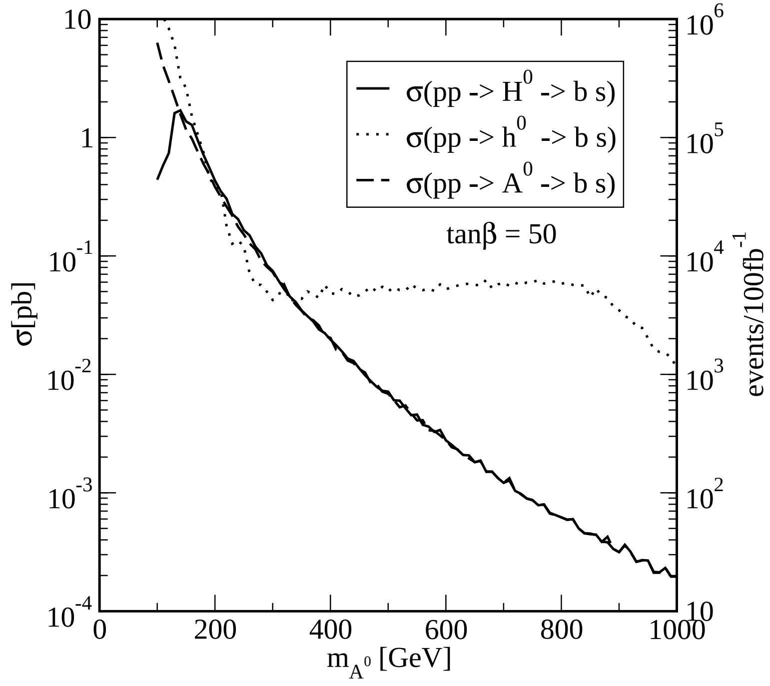


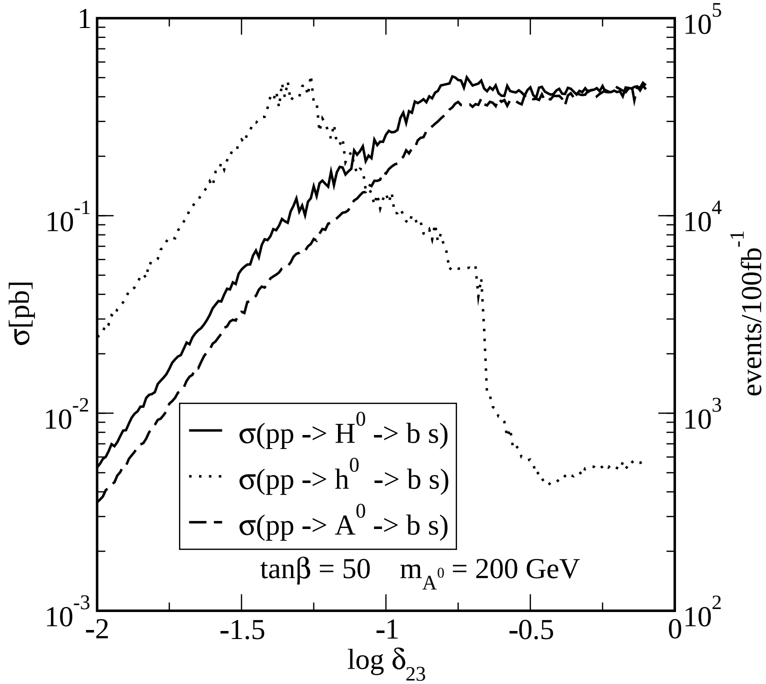


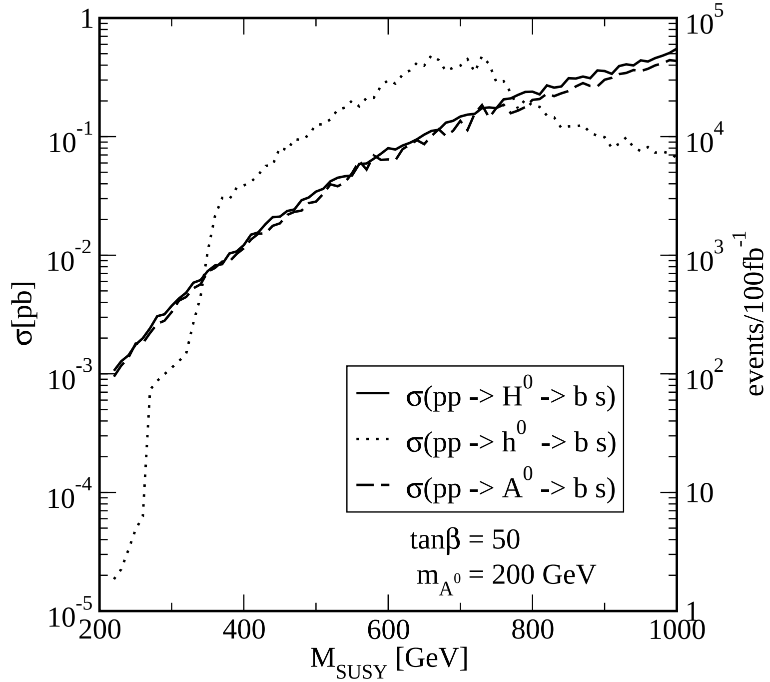


- H^0/A^0
  - Decrease with M_{A^0} due to x-section
  - Dominant contributions are the leading ones
  - Maximum at large M_{SUSY}

    $\Rightarrow$ Large $M_{SUSY} \Longrightarrow$ small $B(b \to s\gamma) \Longrightarrow$ larger δ_{23} allowed
  - Large $\delta_{23} \Rightarrow \mu$ has to decrease to obtain acceptable $B(b \to s\gamma) \Rightarrow BR(H^0/A^0 \to bs)$ can not grow.







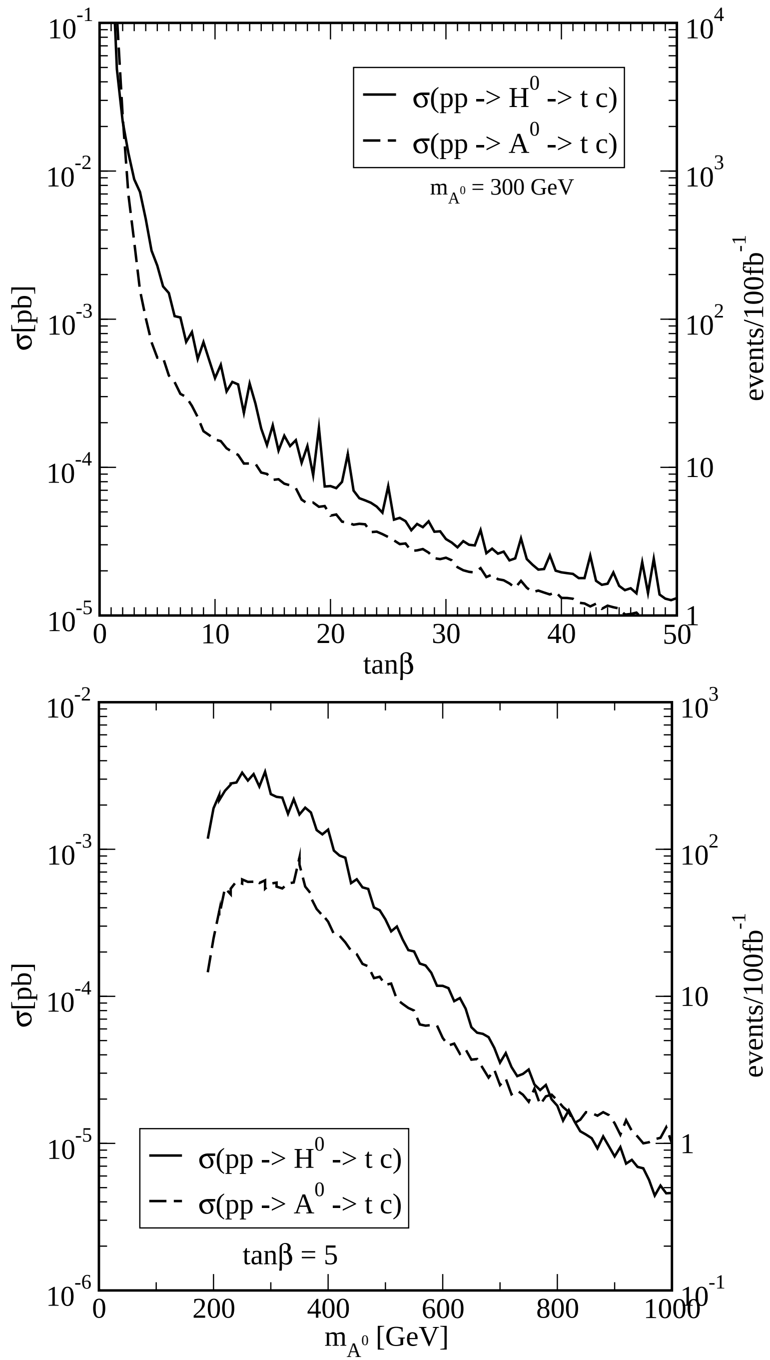
Maximum rates $M_{A^0} = 200\,\text{GeV}, \tan\beta = 50$

h	H^0	h^0	A^0
$\sigma(pp \to h \to b\,s)$	0.45 pb	0.34 pb	0.37 pb
events/100 fb^{-1}	4.5×10^4	3.4×10^4	3.7×10^4
$B(h \to bs)$	9.3×10^{-4}	2.1×10^{-4}	8.9×10^{-4}
$\Gamma(h \to X)$	10.9 GeV	1.00 GeV	11.3 GeV
δ_{23}	$10^{-0.62}$	$10^{-1.32}$	$10^{-0.44}$
$m_{\tilde{q}}$	990 GeV	670 GeV	990 GeV
A_b	-2750 GeV	-1960 GeV	-2860 GeV
μ	-720 GeV	-990 GeV	-460 GeV
$B(b \to s\gamma)$	4.50×10^{-4}	4.47×10^{-4}	4.39×10^{-4}

$\sigma(pp \to h \to tc)$

- Only H^0/A^0 possible
- Large at small $\tan\beta$:

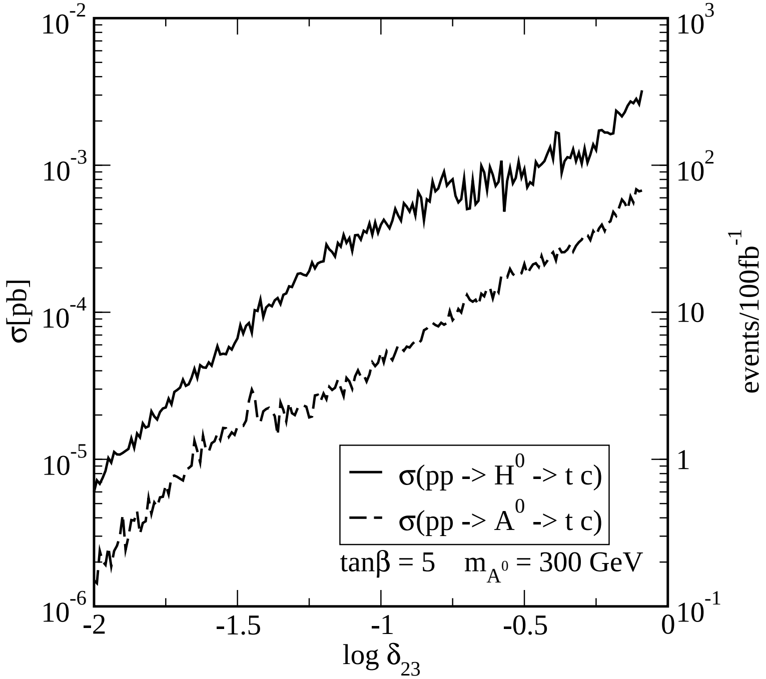
  $\Rightarrow$ no equivalent of small $\alpha_{\rm eff}$
- differences at small M_{A^0}:
  - Near threshold for $H^0 \to \tilde{q}_1\tilde{q}_1$
  - not possible for A^0

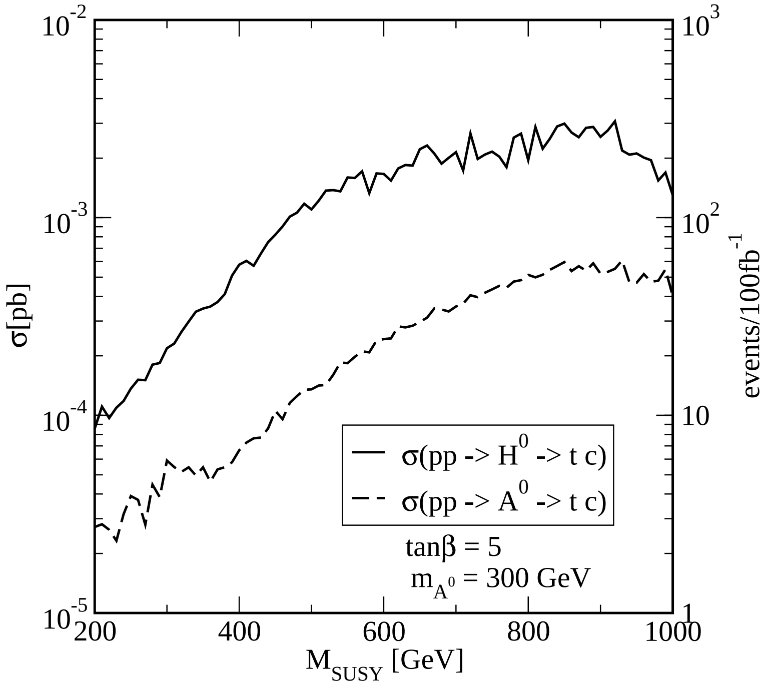


- Maximum at maximal δ_{23}
- Maximum at maximal M_{SUSY}
- One physical squark is always light

$M_{A^0} = 300\,\text{GeV}, \tan\beta = 5$

h	H^0	A^0
$\sigma(pp \to h \to t\,c)$	2.4×10^{-3} pb	5.8×10^{-4} pb
events/100 fb^{-1}	240	58
$B(h \to tc)$	1.9×10^{-3}	5.7×10^{-4}
$\Gamma(h \to X)$	0.41 GeV	0.39 GeV
δ_{23}	$10^{-0.10}$	$10^{-0.13}$
$m_{\tilde{q}}$	880 GeV	850 GeV
A_t	-2590 GeV	2410 GeV
μ	-700 GeV	-930 GeV
$B(b \to s\gamma)$	4.13×10^{-4}	4.47×10^{-4}



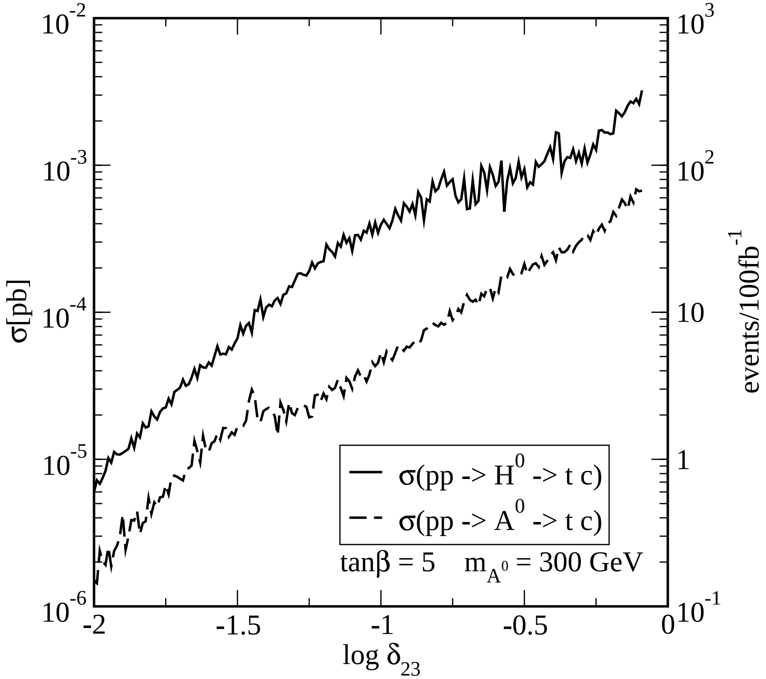


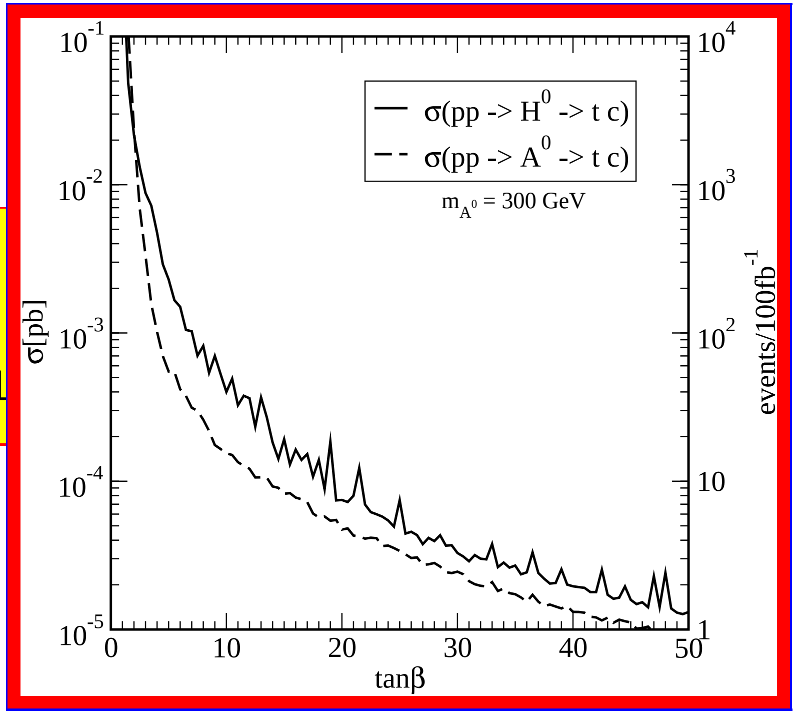
- Maximum at maximal δ_{23}
- Maximum at maximal M_{SUSY}
- One physical squark is always light

$M_{A^0} = 300\,\text{GeV}, \tan\beta = 5$

h	H^0	A^0
$\sigma(pp \to h \to t\,c)$	2.4×10^{-3} pb	5.8×10^{-4} pb
events/100 fb^{-1}	240	58
$B(h \to tc)$	1.9×10^{-3}	5.7×10^{-4}
$\Gamma(h \to X)$	0.41 GeV	0.39 GeV
δ_{23}	$10^{-0.10}$	$10^{-0.13}$
$m_{\tilde{q}}$	880 GeV	850 GeV
A_t	−2590 GeV	2410 GeV
μ	−700 GeV	−930 GeV
$B(b \to s\gamma)$	4.13×10^{-4}	4.47×10^{-4}

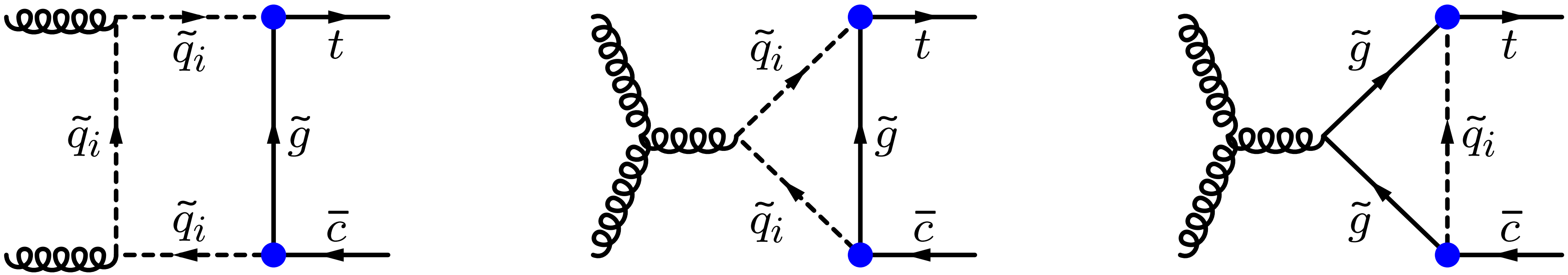
- $\tan\beta = 4 \Longrightarrow \sim 500$ events/100 fb^{-1}
- $\tan\beta = 3 \Longrightarrow \sim 900$ events/100 fb^{-1}
- $\tan\beta = 2 \Longrightarrow \sim 2000$ events/100 fb^{-1}





Direct FCNC production @ LHC

$pp[gg] \to tc$



- Previous computation

  J.J. Lui *et al.*, **Nucl. Phys. B** 705 (2005) 3, hep-ph/0404099

  - No complete parameter analysis
  - Main effects from Left-Right mixing

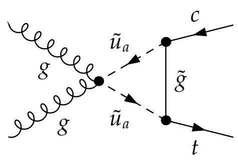
- Computation: FeynArts, FormCalc, LoopTools

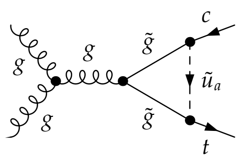
  T. Hahn, *et al.*, http://www.feynarts.de

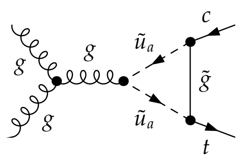
- Leading terms from Left-Left sector: similar structure to $b \to s\gamma$

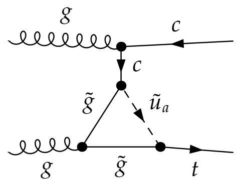
$$A(gg \to t\bar{c}) \sim \delta_{23} \frac{m_t(A_t - \mu/\tan\beta)}{M^2_{SUSY}} \times \frac{1}{m_{\tilde{g}}}$$

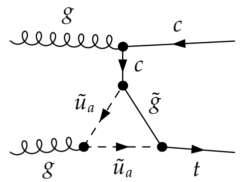
Feynman Diagrams

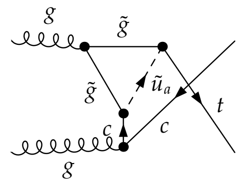

T1 C1 N1

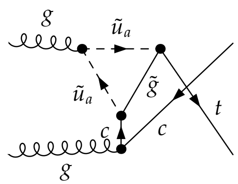

T2 C1 N2

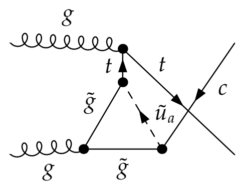

T2 C1 N3

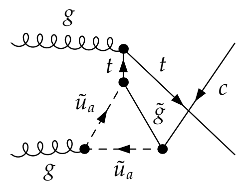

T3 C1 N4

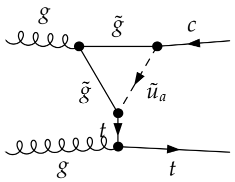

T3 C1 N5

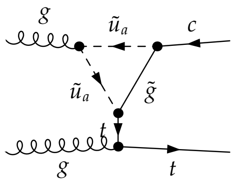

T4 C1 N6

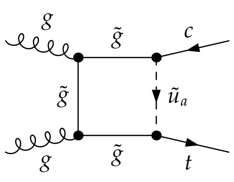

T4 C1 N7

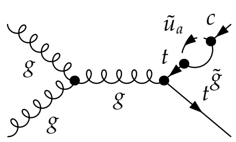

T5 C1 N8

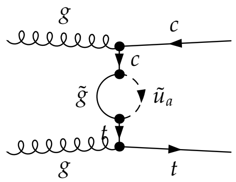

T5 C1 N9

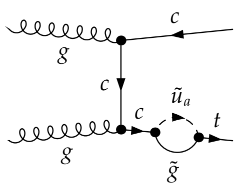

T6 C1 N10

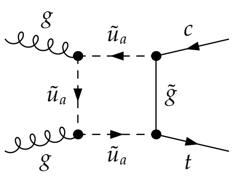

T6 C1 N11

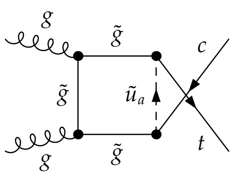

T7 C1 N12

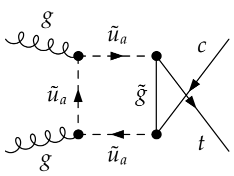

T11 C1 N19

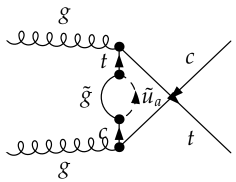

T12 C1 N20

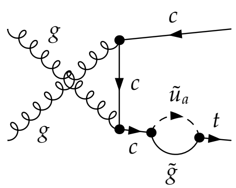

T13 C1 N21

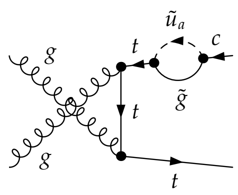

T7 C1 N13

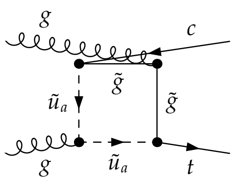

T8 C1 N14

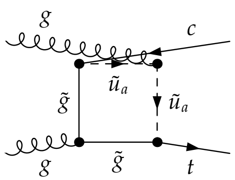

T8 C1 N15

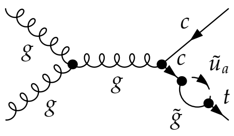

T14 C1 N22

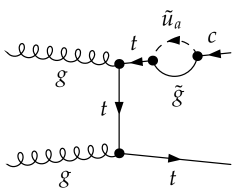

T15 C1 N23


T16 C1 N24


T9 C1 N16


T9 C1 N17


T10 C1 N18


T17 C1 N25

Comparison with Higgs FCNC

- Take parameters of maximum $\sigma(pp \to h \to t\, c)$: Large M_{SUSY} and $m_{\tilde{g}}$
  - $M_{SUSY} \simeq m_{\tilde{g}} \simeq 880\,\text{GeV}$, $\mu \simeq -700\,\text{GeV}$, $\delta_{23} \simeq 10^{-0.1} \simeq 0.79$

    $$\sigma(pp[gg] \to t\bar{c}) \simeq 1.8 \times 10^{-3}\ \text{pb}$$

    $\Rightarrow$ Same order of magnitude as Higgs-mediated FCNC

Maximum rates

$$A(gg \to t\bar{c}) \sim \delta_{23} \frac{m_t(A_t - \mu/\tan\beta)}{M^2_{SUSY}} \times \frac{1}{m_{\tilde{g}}}$$

- Large rates $\Longrightarrow$ Large δ_{23} and Large $(A_t - \mu/\tan\beta)$

  $\Rightarrow$ high sensitivity to A_t

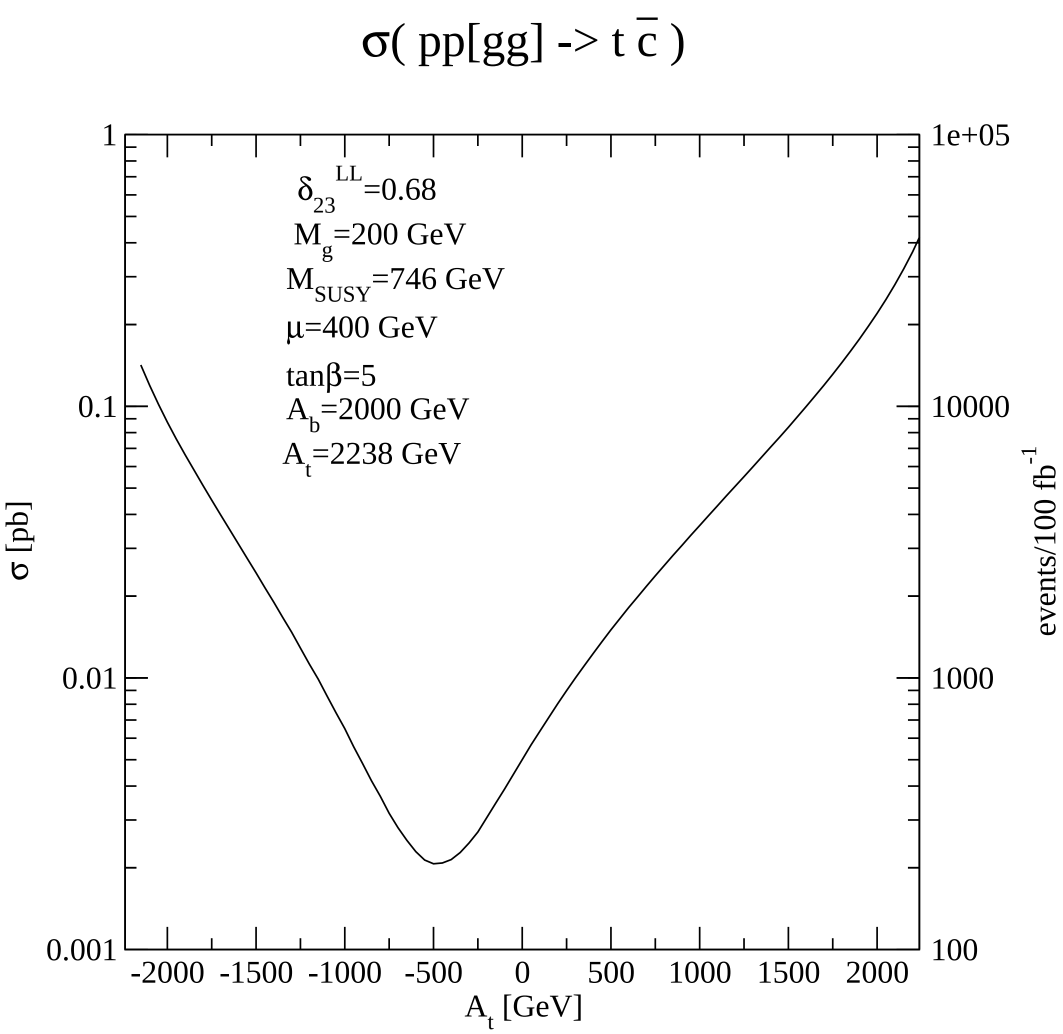
  $\Rightarrow$ Left-Left flavour mixing $\oplus$ Left-Right stop mixing $\Longrightarrow$ similar to Left-Right flavour mixing

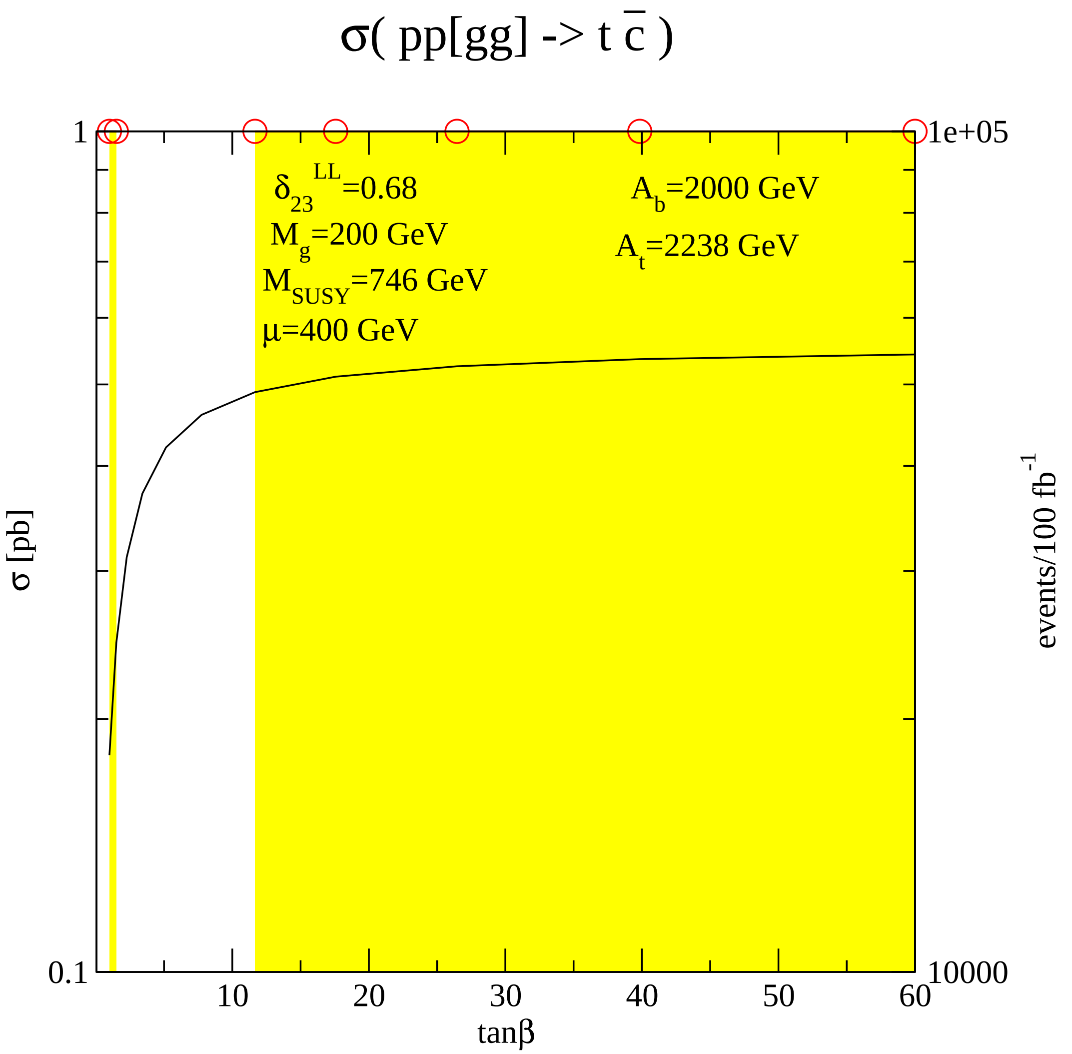
  $\Rightarrow$ Similar analysis of $B(b \to s\gamma)$

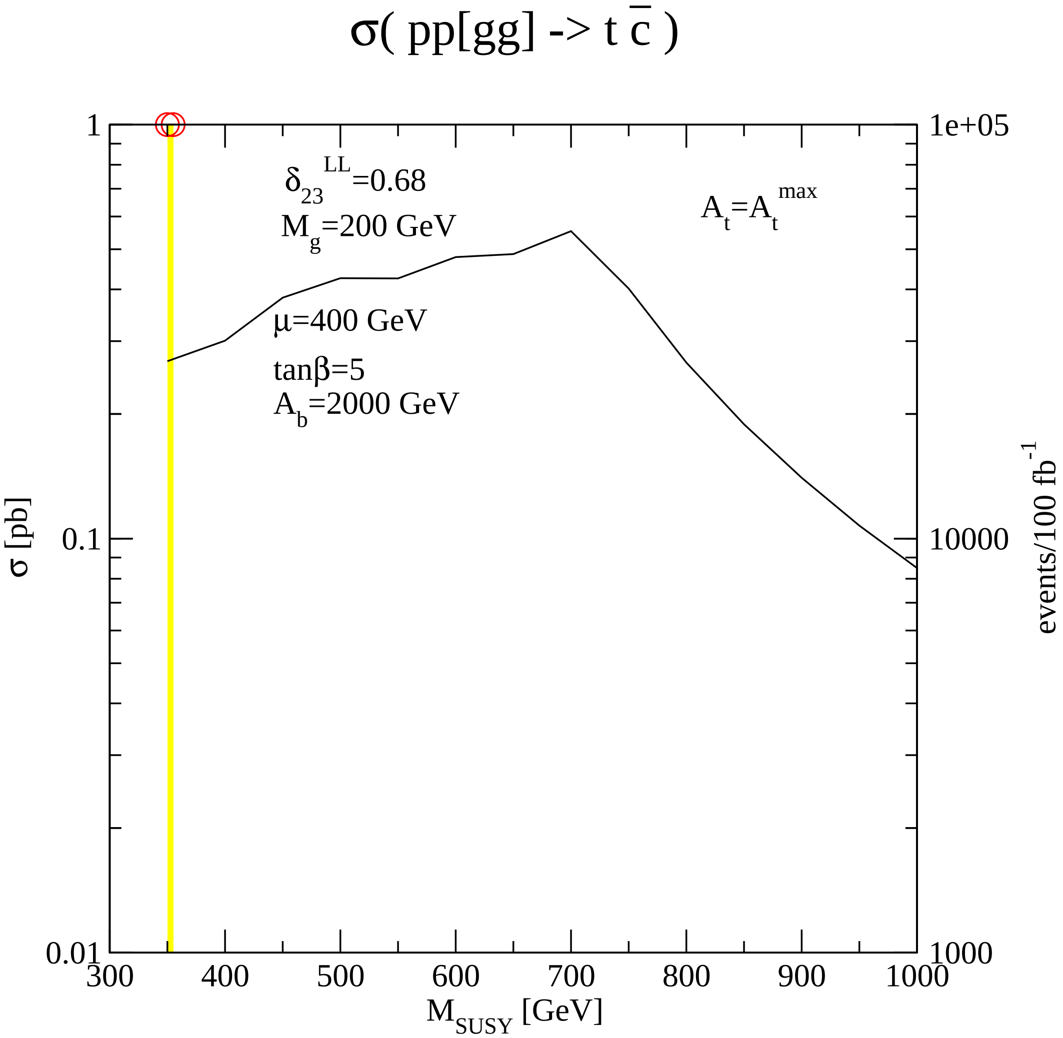
- Analytical approximation to maximization:
  - Find the maximum value of: $\delta_{23} \times (A_t - \mu/\tan\beta)$
  - Physical mass constraints: upper limit on: $\delta_{23}^2 + (A_t - \mu/\tan\beta)^2$
  - Non-colour breaking vauca: additional contstraints on A_t
  - Low value of M_{SUSY}
  - Similar analytical expressions to find the contstraints from $B(b \to s\gamma)$

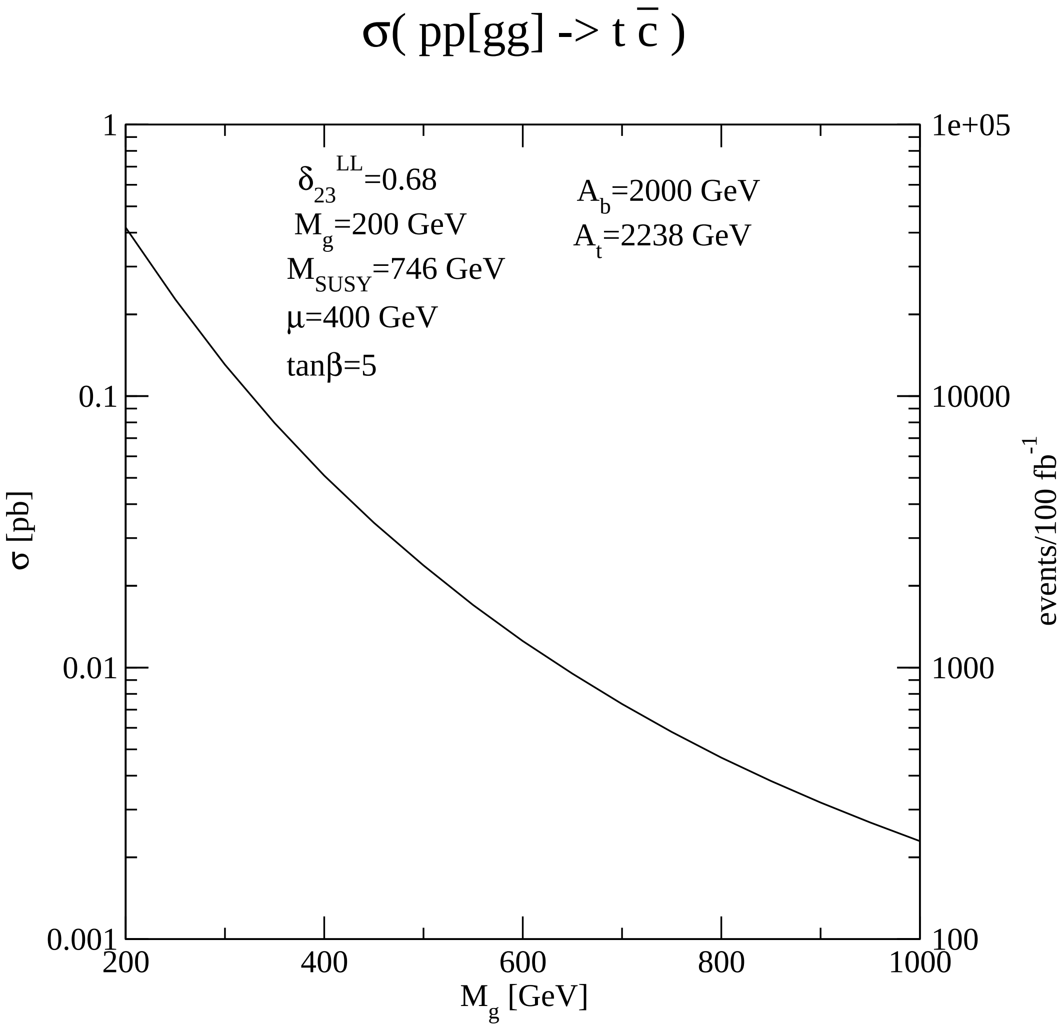
$\Rightarrow$ $\tan\beta = 5,\ \mu = 400\,\text{GeV},\ A_t = 2238\,\text{GeV},\ A_b = 2000\,\text{GeV},$

$\Rightarrow$ $\delta_{23} = 0.68,\ M_{SUSY} = 750\,\text{GeV},$ low $m_{\tilde{g}}$


σ(pp[gg] -> t c̄)
δ23 LL=0.68
Mg=200 GeV
MSUSY=746 GeV
μ=400 GeV
tanβ=5
Ab=2000 GeV
At=2238 GeV
σ [pb]
events/100 fb-1
At [GeV]


σ(pp[gg] -> t c̄)
δ23 LL=0.68
Mg=200 GeV
MSUSY=746 GeV
μ=400 GeV
Ab=2000 GeV
At=2238 GeV
σ [pb]
events/100 fb-1
tanβ





⇒ Cross-sections ∼ 0.5 pb possible

⇒ ∼ 100,000 events/100 fb^{-1} for $t\bar{c}$ processes

⇒ Only with Left-Left intergenerational mixing

Conclusions

Higgs Mediated

- $h - b - s$ and $h - t - c$ FCNC couplings are enhanced in the general MSSM
- restrictions from $b \to s\gamma$:
  - Allow extremelly large couplings in fine-tuned regions
  - in non-fine-tuned regions: still 4–10 orders of magnitude larger than SM
- $h - q - q'$ are large at large M_{SUSY}:
  - Leading contributions to $h - q - q'$ do not depend on the average SUSY mass scale
  - at low M_{SUSY} the FCNC couplings are restricted by $b \to s\gamma$

- $h \to bs$:
  - Maximum of $BR(h^0 \to bs)$ obtained in small $\alpha_{\rm eff}$

	SM	small $\alpha_{\rm eff}$	tree-Higgs
$BR(h^0 \to bs)$	$\lesssim 10^{-7}$	3×10^{-3}	10^{-4}

  - Production at LHC: negative correlations between production and decay
    - $\sigma(pp \to h \to bs) \lesssim 0.5$ pb $\Longrightarrow 5 \times 10^4$ events/100 fb^{-1}
    - light quarks: difficult to see at LHC

- $H^0/A^0 \to tc$:

	SM	MSSM
$BR(H^0/A^0 \to tc)$	$\lesssim 10^{-13}$	$\lesssim 3 \times 10^{-3}$

  - production at LHC: decreases fast with mass
  - increases fast at low $\tan\beta$:

$\tan\beta$	5	4	3	2
$\sigma(pp \to H^0 \to tc)$	3 fb	5 fb	9 fb	20 fb
events/100 fb^{-1}	300	500	900	2000

  - Several thousand events could be produced
  - Possibility of tagging on single top

Direct process

- Parameters for maximum Higgs-mediated rates

  ⇒ Similar rates for direct process

  ⇒ **But direct process can give much larger rates**

- Reproduce previous results

- Left-Left flavour mixing gives large rates

- Analytical approximation to maximization

  – Maximal possible value of $\delta_{23} \times (A_t - \mu/\tan\beta)$

- Low sensitivity to $\tan\beta$

- $\sigma(pp[gg] \to t\bar{c}) \sim 0.5$ pb $\Longrightarrow$ 10^5 events/100 fb^{-1} $[m_{\tilde{g}} \sim 200\,\text{GeV}]$

  – 2–3 orders of magnitude larger than Higgs-mediated

Index

- Outline
- Introduction
  - Model setup
- Contstraints & fine-tuning
  - $B(b \to s\gamma)$
  - fine-tuning
- Higgs FCNC @ LHC
  - Some works
  - Leading contributions
  - small α_{eff}
- Numerical results $BR(h \to bs)$
  - $BR^{max}(h \to bs)$
  - Combination with production
- Combined analysis $\sigma(pp \to h \to qq')$
  - $\sigma(pp \to h \to bs)$
  - $\sigma(pp \to h \to tc)$
- Direct FCNC production @ LHC
  - Comparison with Higgs FCNC
  - Maximum rates
- Conclusions
  - Higgs Mediated
  - Direct process