Supersymmetric flavor-changing neutral currents at the LHC

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Interplay of collider and flavor physics - kick-off meeting

CERN (Geneve)

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Outline

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Based of the following references

- S. Béjar, J. Guasch and J. Solà, *Nucl.Phys.Proc.Suppl.* **157** (2006) 147 [hep-ph/0601191]
- S. Béjar, J. Guasch and J. Solà, *JHEP* **0510** (2005) 113 [hep-ph/0508043]
- J. Guasch, W. Hollik, S. Peñaranda and J. Solà, *Nucl.Phys.Proc.Suppl.* **157** (2006) 152 [hep-ph/0601218]
- DLV, J. Guasch, J. Solà, *JHEP* (in press), hep-ph/0710.0587
- S. Béjar, J. Guasch, DLV and J. Solà, in preparation

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- Therein we feel encouraged to seek for hints of distinctive phenomenology beyond the SM

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LL-block only: based on RG arguments Duncan ['83]

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Such couplings are free of GIM supressions

b $\longrightarrow$ sγ constraints

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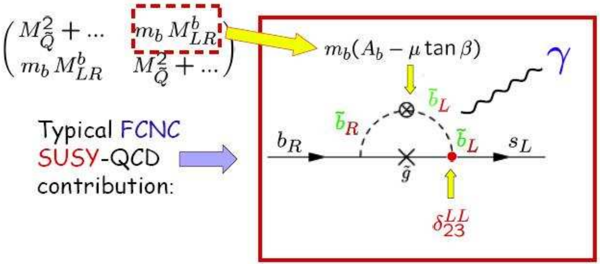

$$A(b \to s\gamma) \sim \delta^{(d)LL}_{23} \times \frac{m_b(A_b - \mu \tan\beta)}{M^2_{SUSY}} \times \frac{1}{m_{\tilde{g}}}$$

$b \to s\gamma$ constraints

But recall that we have quite accurate measurements for meson physics observables, e.g.

$$\mathcal{B}(b \to s\,\gamma) = (2.1 - 4.5) \times 10^{-4}$$

at the 3σ level CLEO, ALEPH, BELLE, BABAR

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Therefore ...

Non-standard flavor-changing effects in the $t\bar{c}$ sector also become constrained by $\mathcal{B}(b \longrightarrow s\gamma)$

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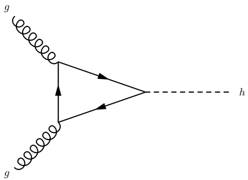

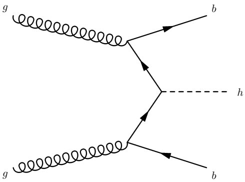

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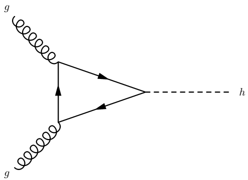

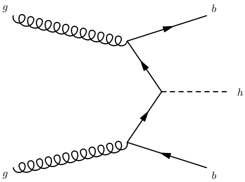

♠ Computational tools: *HIGLU* and *PPHTT* Spira et al. ['95]

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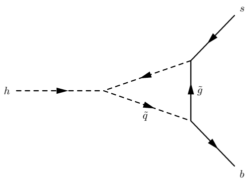

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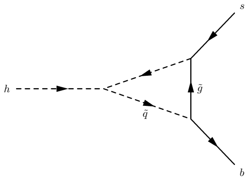

$$\mathcal{B}(h \to q\,\bar{q}') \quad = \quad \frac{\Gamma(h \to q\,\bar{q}')}{\sum_i \Gamma(h \to X_i)}$$

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$\Rightarrow$ We shall perform a MonteCarlo maximization along the MSSM parameter space Brein ['98]

SUSY-QCD maximum contributions b — s channel

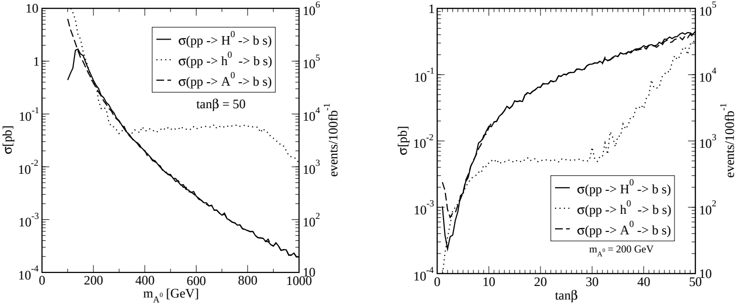

Figure 1: SUSY-QCD maximum contribution to $\sigma(pp \to h \to b\bar{s} + \bar{b}s)$ (in pb) and the corresponding number of events per 100 fb^{-1} of integrated luminosity at the LHC, as a function of M_{A^0}(left) and $\tan\beta$ (right). Béjar, Guasch, Solà ['05]

SUSY-QCD maximum contributions b — s channel

	H^0	h^0	A^0
$\sigma(pp \to h \to b\bar{s} + \bar{b}s)$	0.90 pb	0.68 pb	0.74 pb
events/100fb^{-1}	9×10^4	6.8×10^4	7.4×10^4
δ_{23}	0.24	0.05	0.36
M_{SUSY}	990 GeV	670 GeV	990 GeV
A_b	-2750 GeV	-1960 GeV	-2860 GeV
μ	-720 GeV	-990 GeV	-460 GeV

Table 1: Maximum value of $\sigma : SUSY - QCD(pp \to h \to b\bar{s} + \bar{b}s)$ (and of the number of bs events per 100 fb^{-1}) in the LHC, for $M_{A^0} = 200$ GeV and $\tan\beta = 50$.

Worthnoting features

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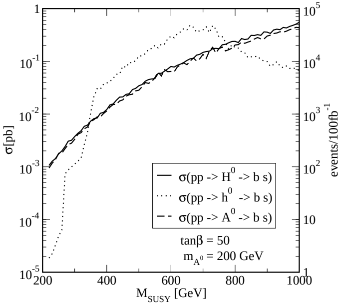

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$\Rightarrow$ Maximum σ's are obtained at large M_{SUSY} (~ 1TeV)

SUSY-EW maximum contributions b — s channel

	H^0	h^0	A^0
$\sigma(\mathrm{pp} \to h \to \mathrm{b}\bar{\mathrm{s}} + \bar{\mathrm{b}}\mathrm{s})$	2.4 pb	2.0 pb	0.4 pb
events/100fb^{-1}	2.4×10^5	2.0×10^5	8×10^4
δ_{23}	0	0	0
M_{SUSY}	510 GeV	530 GeV	510 GeV
A_b	1500 GeV	-1550 GeV	1100 GeV
μ	720 GeV	650 GeV	720 GeV

Table 2: Maximum value of $\sigma_{SUSY-EW}(\mathrm{pp} \to h \to \mathrm{b}\bar{\mathrm{s}} + \bar{\mathrm{b}}\mathrm{s})$ (and of the number of bs events per 100 fb^{-1}) in the LHC, for $M_{A^0} = 200$ GeV and $\tan\beta = 50$.

SUSY-QCD maximum contributions t — c channel

	H^0	A^0
$\sigma(\mathrm{pp} \to h \to \mathrm{t}\bar{\mathrm{c}} + \bar{\mathrm{t}}\mathrm{c})$	4.4×10^{-3} pb	1.2×10^{-3} pb
events/100 fb^{-1}	440	120
δ_{23}	0.79	0.74
M_{SUSY}	880 GeV	850 GeV
A_t	-2590 GeV	2410 GeV
μ	-700 GeV	-930 GeV

Table 3: Maximum value of $\sigma_{SUSY-QCD}(\mathrm{pp} \to h \to \mathrm{t}\bar{\mathrm{c}} + \bar{\mathrm{t}}\mathrm{c})$ (and of the number of bs events per 100 fb^{-1}) in the LHC, for $M_{A^0} = 300$GeV and $\tan\beta = 5$

SUSY-EW maximum contributions t — c channel

	H^0	A^0
$\sigma(\mathrm{pp} \to h \to \mathrm{t}\bar{\mathrm{c}} + \bar{\mathrm{t}}\mathrm{c})$	2.94×10^{-5} pb	1.93×10^{-5} pb
events/100 fb^{-1}	~ 1	~ 1
δ_{23}	0	0
M_{SUSY}	502.46 GeV	504.46 GeV
A_t	-139.84 GeV	-195.71 GeV
μ	662.33 GeV	648.56 GeV

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Summing up ...

♠ b – s channel

- Maximum cross sections of $\mathcal{O} \sim 1\,\mathrm{pb}$ for $h = (\mathrm{h}^0, \mathrm{H}^0, \mathrm{A}^0)$ (regardless of considering SUSY-QCD or SUSY-EW contributions)
- On the whole we can pick up production rates of $\simeq 2 \times 10^5$ events per 100 fb^{-1} $\int \mathcal{L}$
- Optimal MSSM configurations: large M_{SUSY}, large $\tan\beta$, low δ_{23}
- The h^0 case depend critically on quantum corrections (small α_{eff} scenarios)

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b – s channel

- Huge b-background embedding
- Cumbersome handling of $b\bar{s}$ signatures (e.g. due to possible jet misidentification)

- Clear-cut single top-quark signature (even more in association with c-jets ?)
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$\Rightarrow$ Large rates, but hard to tackle

♠ **t – c channel**

- Clear-cut single top-quark signature (even more in association with c-jets ?)
- Non-negligible SM $t\bar{c}$ background

$\Rightarrow$ Lower rates and difficult to tackle, but still leaving us a chance...!

Outline

General features

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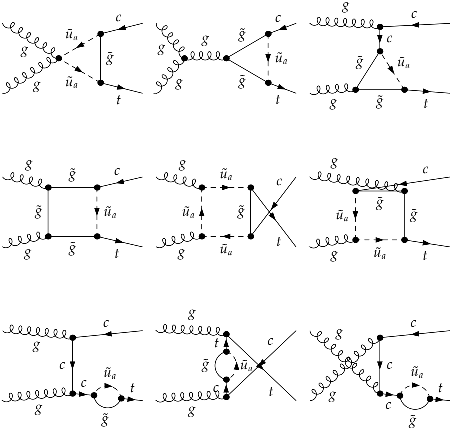
- Computational skills: FeynArts, FormCalc and LoopTools [T. Hahn www.feynarts.de] together with HadCalc M.Rauch ['06]

SUSY-QCD contribution



SUSY-QCD contribution

$\tan\beta$	5
A_t(GeV)	2238.25
A_b(GeV)	2000
$m_{\tilde{g}}$(GeV)	200
M_{SUSY}(GeV)	746
μ(GeV)	400
$\delta_{23}^{LL}(u)$	0.7

Table 5: Set (I) of MSSM parameters (favoring SUSY-QCD) Guasch, Hollik, Peñaranda, Solà ['06]

SUSY-QCD contribution

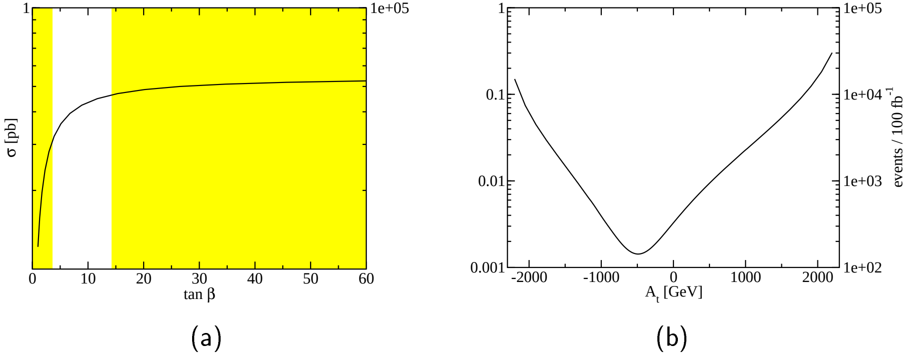


Figure 2: SUSY-QCD contribution to the total cross section $\sigma_{t\bar{c}}$ (in pb) and the corresponding number of events per 100 fb^{-1} of integrated luminosity at the LHC, as a function of **a)** $\tan\beta$ and **b)** A_t for the set I of MSSM parameters. The shaded region in **a)** is excluded by B_{exp}(b $\rightarrow$ sγ). DLV, Guasch, Solà ['07].

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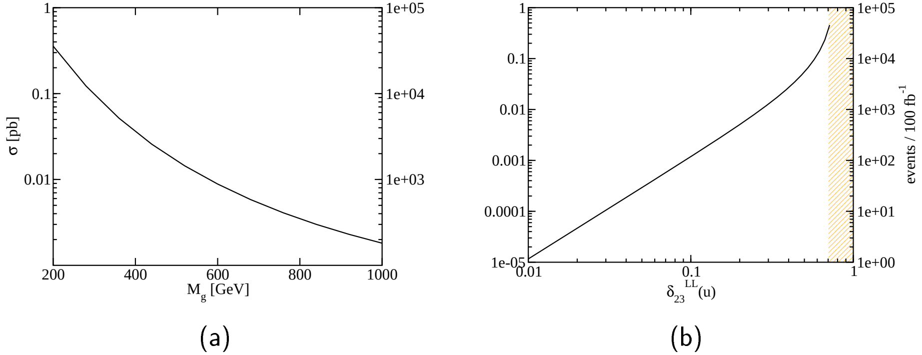

Figure 3: SUSY-QCD contribution to the total cross section $\sigma_{t\bar{c}}$ (in pb) and the corresponding number of events per 100 fb^{-1} of integrated luminosity at the LHC, as a function of **a)** $m_{\tilde{g}}$ and **b)** $\delta_{23}^{LL}(u)$ for the set (I) of MSSM parameters. DLV, Guasch, Solà ['07].

SUSY-QCD contribution

- In the most favorable scenarios, those triggered by light gluino masses and large intergenerational mixing, we get production rates of $2\sigma_{t\bar{c}} \sim 10^5$ events per 100 fb^{-1} of integrated luminosity at the LHC
- Notice thus that

$$\frac{\sigma(gg \to t\bar{c})_{\rm SUSY-QCD}}{\sigma(gg \to t\bar{c})_{\rm SM}} \sim 10^7$$

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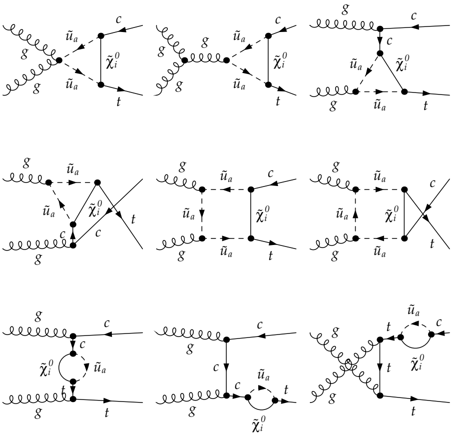
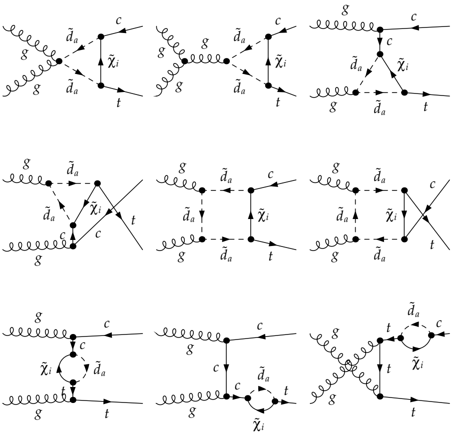
SUSY-EW contribution



SUSY-EW contribution



SUSY-EW contribution

$\tan\beta$	10
A_t(GeV)	-300
A_b(GeV)	-300
A_τ(GeV)	-300
$m_{\tilde{g}}$(GeV)	2000
M_{SUSY}(GeV)	250
μ(GeV)	400
M_1(GeV)	48
M_2(GeV)	102
M_{A^0}(GeV)	150
$\delta_{23}^{LL}(u)$	0.7

Table 6: Set (II) of MSSM parameters (favoring SUSY-EW)

SUSY-EW contribution

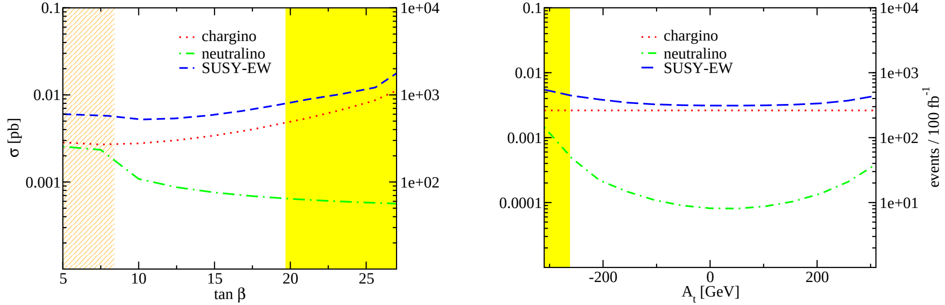


Figure 4: SUSY-EW contribution to the total cross section $\sigma_{t\bar{c}}$ (in pb) and the corresponding number of events per 100 fb^{-1} of integrated luminosity at the LHC, as a function of $\tan\beta$ (left) and A_t (right) for the parameters of Set (II).The dashed regions are ruled out by the mass bounds on the lightest chargino and neutralino states. DLV, Guasch, Solà ['07].

SUSY-EW contribution

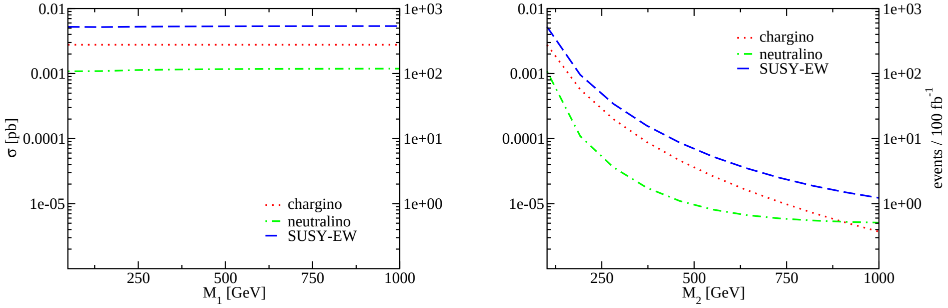


Figure 5: SUSY-EW contribution to the total cross section $\sigma_{t\bar{c}}$ (in pb) and the corresponding number of events per 100 fb^{-1}of integrated luminosity at the LHC, as a function of M_1 (left) and M_2 (right) for the set II of MSSM parameters. DLV, Guasch, Solà ['07].

On the whole ...

basic features

- The SUSY-EW contribution to $\sigma(\mathrm{pp} \to \mathrm{t}\bar{\mathrm{c}} + \bar{\mathrm{t}}\mathrm{c})$ becomes optimal for large δ_{23} and low mass scales (in contradistinction to the Higgs-mediated mechanism)
- There are regions in the MSSM parameter space where the SUSY-EW contribution becomes of sizeable on its own, irrespectively of the SUSY-QCD effects being supressed by large gluino masses
- Such scenarios bring us lower (but still sizeable) production rates of 10^3 events per 100 fb^{-1} of integrated luminosity, irrespectively of the SUSY

Outline

Conclusions

- We have discussed the heavy quark pair production of the guise $t\bar{c}$, $b\bar{s}$ through flavor-changing (direct and Higgs-mediated) interactions within the MSSM, in correspondence with the stringent $b \to s\gamma$ constraints.

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channel	t − c	b − s
Optimal Higgs-mediated FC interaction		
SUSY-QCD (Higgs-med.)	$\sim 10^2$	$\sim 10^5$
SUSY-QCD (direct)	~ 1	~ 10
SUSY-EW (Higgs-med.)	~ 1	$\sim 10^5$
SUSY-EW (direct)	~ 5	$\sim 10^2$
Optimal direct FC interaction		
SUSY-QCD (direct)	$\sim 10^5$	$\sim 10^2$
SUSY-EW (direct)	$\sim 10^3$	$\sim 10^2$

Conclusions

- Both mechanisms can lead to sizeable rates of FCNC quark pair production within different MSSM configurations.
- Direct FCNC production reveals to be the most efficient FCNC mechanism in the tc channel, while the Higgs-mediated one dominates in the $b\bar{s}$ case
- SUSY-FCNC interactions turn out to be the most competitive $t\bar{c}$ ($b\bar{s}$) sources, dominating over other alternative mechanisms such as 2HDM or technicolor models.
- In spite of the many difficulties involved, the detection of such kind of events, if efficiently tagged and confidently isolated from the background, could lead to evidence of New Physics - of likely SUSY nature.

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Based of the following references

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