

# Squark and Gaugino Hadroproduction and Decays in Non-Minimal Flavour Violating Supersymmetry

Björn Herrmann  
LPSC Grenoble

in collaboration with G. Bozzi, B. Fuks, and M. Klasen

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# Outline

- 1 Introduction
- 2 Experimental constraints
- 3 Benchmark points
- 4 Sparticle production
- 5 Conclusion

# Constrained Minimal Flavour Violation (cMFV)

- All **flavour-violating elements** of the squared sfermion mass matrices are zero

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- Sfermion mixing**  $(\tilde{f}_L, \tilde{f}_R) \rightarrow (\tilde{f}_1, \tilde{f}_2)$  with flavour conservation
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  - $\rightarrow$  three flavour-conserving mixing angles:  $\theta_{\tilde{b}}, \theta_{\tilde{t}}, \theta_{\tilde{\tau}}$
- In the squark sector, **flavour violation is governed by CKM-matrix** (e.g.  $\tilde{\chi} \tilde{q} q'$  vertex proportional to  $V_{qq'}$ )

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- Diagonalization through **6×6 rotation matrices** ( $m_{\tilde{q}_1} < \dots < m_{\tilde{q}_6}$ )

$$(\tilde{u}_1, \tilde{u}_2, \tilde{u}_3, \tilde{u}_4, \tilde{u}_5, \tilde{u}_6)^T = R^u (\tilde{u}_L, \tilde{c}_L, \tilde{t}_L, \tilde{u}_R, \tilde{c}_R, \tilde{t}_R)^T$$

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- In our analysis: only one new free parameter

$$\lambda_{LL}^{ct} = \lambda_{LL}^{bs} \equiv \lambda$$

→ no large difference allowed due to  $SU(2)$  gauge invariance

# Low-energy, EW precision and cosmological constraints

- Decay  $b \rightarrow s\gamma$ : NMFV contributes at the one-loop level (as also SM)

$$\text{BR}(b \rightarrow s\gamma) = (3.55 \pm 0.26) \times 10^{-4} \quad (\text{at } 2\sigma) \quad [\text{Barbiero et al. (2006)}]$$

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- **Neutralino relic density**:

$$0.094 < \Omega_{CDM} h^2 < 0.136 \quad (\text{at } 2\sigma) \quad [\text{Hamann et al. (2007)}]$$

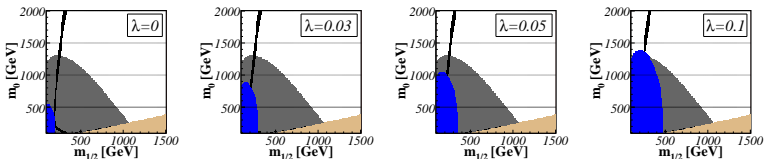
# Constraints on NMFV in mSUGRA

- **Inspect mSUGRA scenario**

→ Spectrum and constraints calculated using SPheno 2.2.3, FeynHiggs 2.5.1, and modified DarkSUSY 4.1 [Porod (2003), Heinemeyer *et al.* (2000), Gondolo *et al.* (2004)]

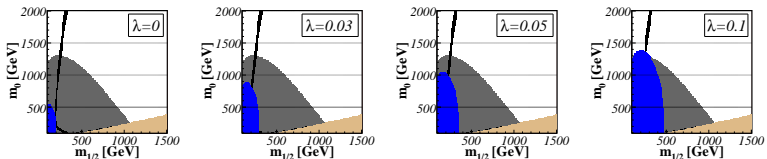
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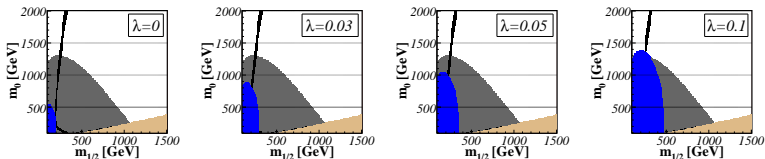
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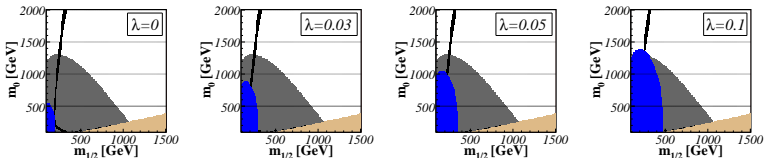
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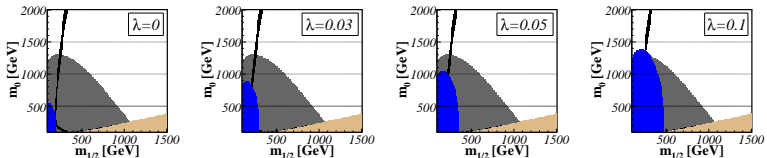
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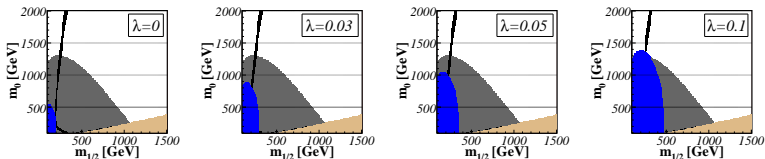


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- $\Delta\rho$  excludes only very high SUSY masses (not shown)

# Benchmark points for mSUGRA

- We propose the following **allowed benchmark points** [Bozzi, Fuks, BjHe, Klasen (2007)]

	$m_0$ [GeV]	$m_{1/2}$ [GeV]	$A_0$ [GeV]	$\tan \beta$	$\text{sgn}(\mu)$	$\lambda$ bounds
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- **In this talk:** focus on benchmark point B

→ "collider-friendly"

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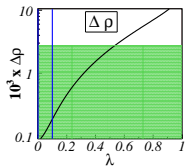
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→ numerical study of constraints, squark mass splitting and flavour content,  
squark and gaugino production and decay

# Point B: Constraints

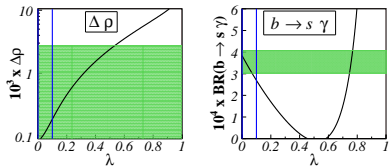
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 → large allowed range ( $\lambda \leq 0.52$ ), due to important experimental errors

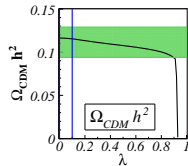
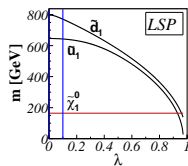
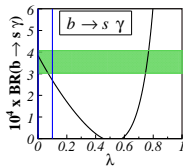
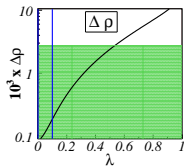
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- Very stringent constraint from  $b \rightarrow s \gamma$   
→ small error band and very sensitive to  $\lambda$   
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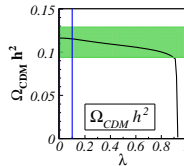
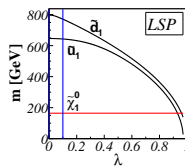
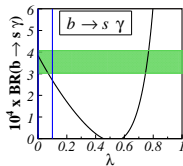
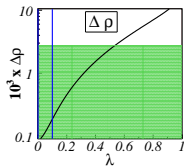


# Point B: Constraints



- $a_{\mu}^{SUSY} \simeq 14 \times 10^{-4}$  independent of  $\lambda$  (not shown)
- $\Delta\rho$  depends strongly on squark flavours, helicity and masses  
→ large allowed range ( $\lambda \leq 0.52$ ), due to important experimental errors
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- Small mass difference between LSP and NLSPs at large  $\lambda$   
→  $\Omega_{CDM} h^2$  falls due to important coannihilations and light squark propagated annihilation processes

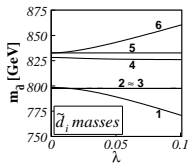
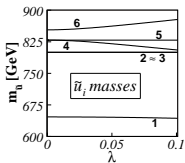
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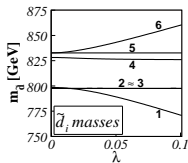
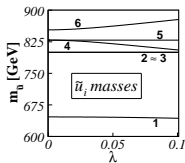
⇒ Allowed region close to (c)MFV:  $0 \lesssim \lambda \lesssim 0.1$

# Point B: Mass splitting and flavour content



[Bozzi, Fuks, BjHe, Klasen (2007)]

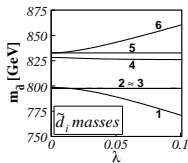
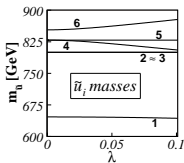
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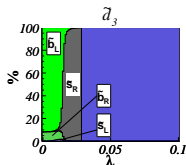
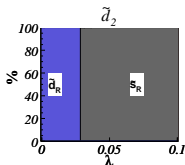
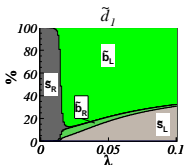
- Hermitian squark mass matrices depend continuously on the single parameter  $\lambda$ 
  - their eigenvalues do not cross (avoided crossings)
  - exchange of the flavour content between the involved eigenstates

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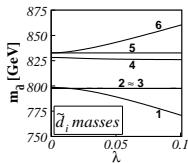
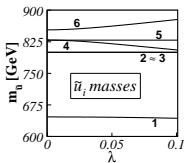


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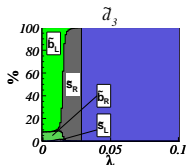
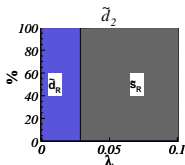
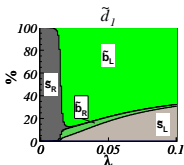


# Point B: Mass splitting and flavour content



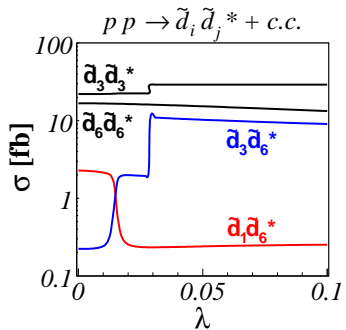
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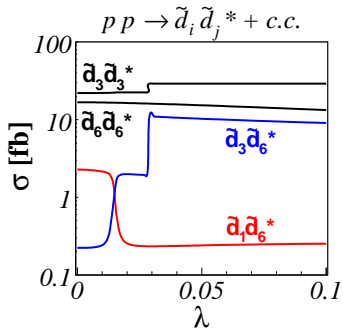
- Large mixing between 2<sup>nd</sup> and 3<sup>rd</sup> generations, even for small  $\lambda$

# Point B: Squark-antisquark pair production at the LHC

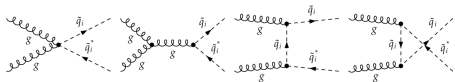


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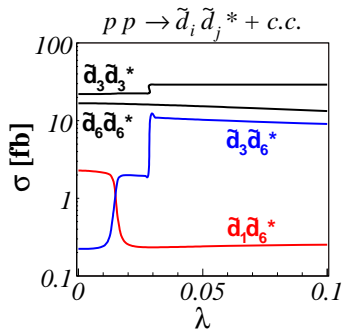
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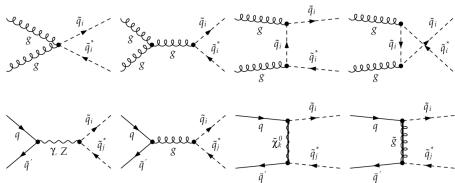
- Diagonal pairs dominated by gluon fusion diagrams
  - strong production, i.e. large cross section
  - low sensitivity to  $\lambda$  due to flavour independent  $g\tilde{q}\tilde{q}$  vertex



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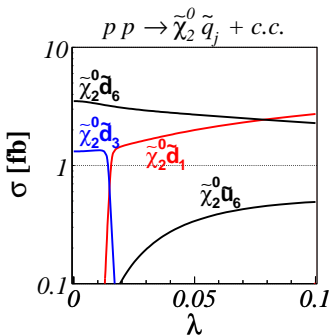
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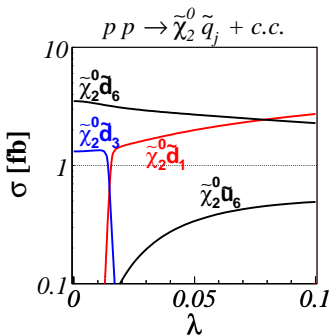
- **Diagonal pairs dominated by gluon fusion diagrams**
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- **Non-diagonal pairs: only  $q\bar{q}$  annihilation diagrams**
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# Point B: Squark-neutralino production at the LHC

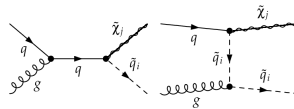
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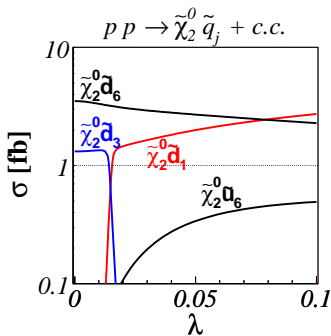
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[Bozzi, Fuks, BjHe, Klasen (2007)]

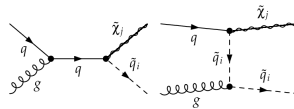


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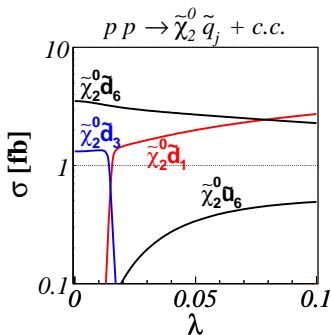


- Semi-strong production (0.1 - 10 fb)

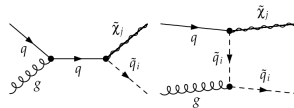
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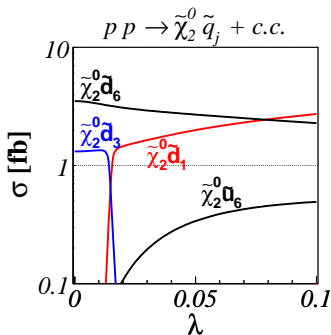


[Bozzi, Fuks, BjHe, Klasen (2007)]

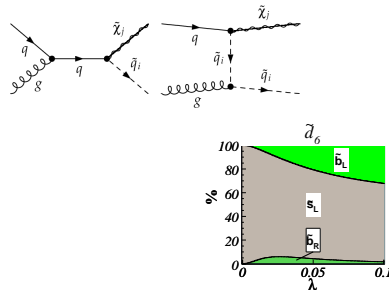


- Semi-strong production (0.1 - 10 fb)
- Quite sensitive to flavour violation due to  $q\tilde{q}\tilde{\chi}$  vertex  
→ avoided crossing / mass-flip between  $\tilde{d}_1$  and  $\tilde{d}_3$

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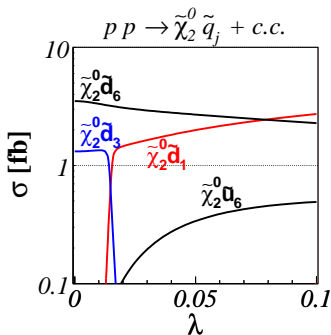


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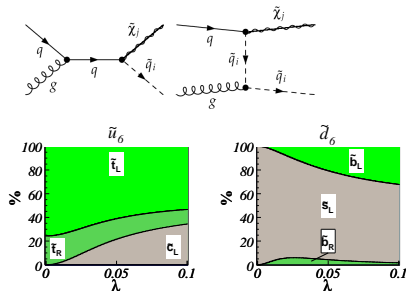


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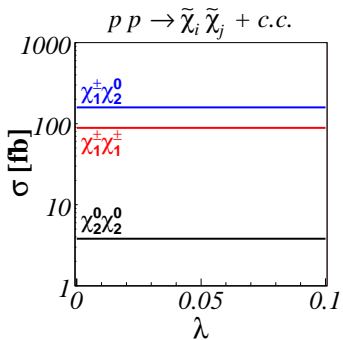


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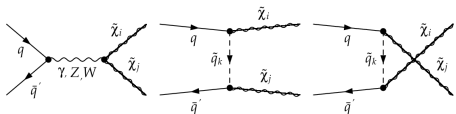


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- $\tilde{u}_6\tilde{\chi}_2^0$  cross section increases with  $\lambda$  due to **charm/top content in  $\tilde{u}_6$**

# Point B: Gaugino pair production at the LHC

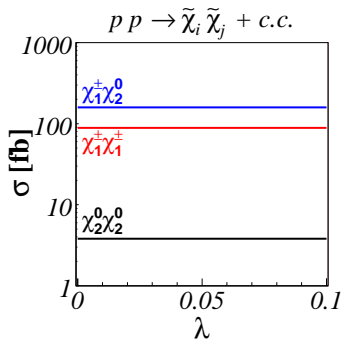


[Bozzi, Fuks, BjHe, Klasen (2007)]

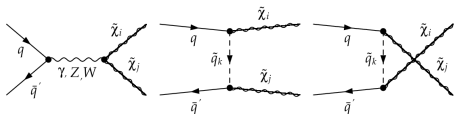




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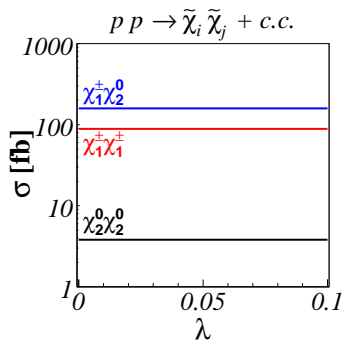


[Bozzi, Fuks, BjHe, Klasen (2007)]

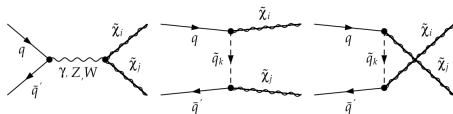


- Large cross sections due to light gauginos

# Point B: Gaugino pair production at the LHC



[Bozzi, Fuks, BjHe, Klasen (2007)]



- Large cross sections due to light gauginos
- Insensitive to flavour violation  
→ sum over all physical squark states

# Conclusion and perspectives

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- **Work in progress / Perspectives**
  - numerical decay study (include 3-body decays)
  - similar analysis for GMSB scenario (include gravitino)
  - implement higher order corrections
  - analysis for  $\lambda_{LL}^{sb} \neq \lambda_{LL}^{ct}$