Testing Yukawa-Unified SUSY at the Tevatron and LHC

Andre Lessa

Homer L. Dodge Department of Physics and Astronomy
University of Oklahoma

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H. Baer, S. Kraml, A. Lessa, S. Sekmen and H. Summy
Beyond the Higgs boson at the Tevatron: Detecting gluinos from Yukawa-unified SUSY.
Phys. Lett. B685:72-78, 2010.

H. Baer, S. Kraml, A. Lessa and S. Sekmen
Testing Yukawa-unified SUSY during year 1 of LHC: the role of multiple b-jets, dileptons and $\not{E}_T$.
JHEP 1002:055, 2010.

Outline

- **Minimal SO(10)**
  - HS and DR3 Models
- **Implications at Low Energies**
  - Searches at the Tevatron
  - Searches at the LHC7
- **Conclusions**

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  - Viable leptogenesis scenarios...

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  - Only one **10** Higgs: $W = f\Psi_3\Gamma_a\Psi_3 H_a + ... \Rightarrow f_t = f_b = f_\tau$ ($\gtrsim M_{GUT}$)

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  - Just-so Higgs Splitting models (HS):
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  - DR3 models (DT+RHN+3GS):
    - All D-terms
    - Right handed neutrino effect on the RGEs (for $Q \gtrsim M_N = 10^{13}$ GeV)
    - Allows $m_{16}(3) \neq m_{16}(1,2)$ (achieved through $M_P \longrightarrow M_{GUT}$ running)

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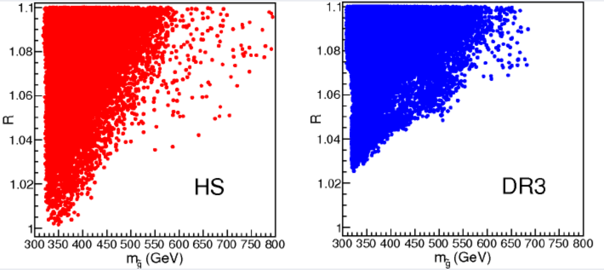

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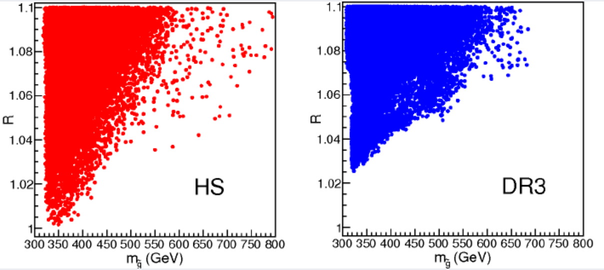

- General features:

- $m_{\tilde{q}}(1,2),\ m_{\tilde{\ell}} \sim 10$ TeV
- $\mu \sim$ 2-15 TeV
- $\widetilde{Z}_1 \sim$ bino
- $\widetilde{Z}_2 \sim$ wino
- $m_{\tilde{q}}(3) \sim 1 - 5$ TeV
- $m_{\tilde{g}} \sim 300 - 500$ GeV
- $m_{\widetilde{W}_1, \widetilde{Z}_2} \sim 100 - 180$ GeV
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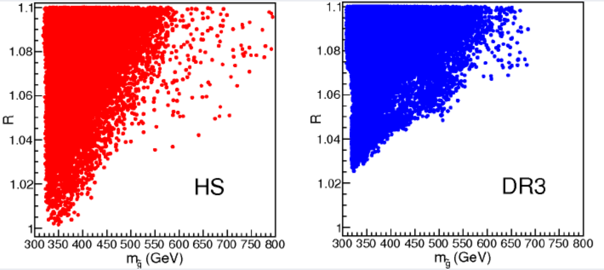

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$\Rightarrow$ Low energy effective theory

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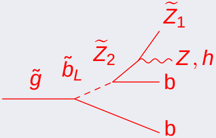

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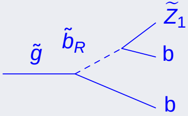

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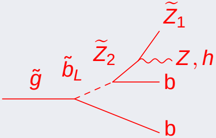

  - 2-step cascade decay
  - OS/SF dileptons
  - **Multi-b's**
  - "Soft" $\not{E}_T$

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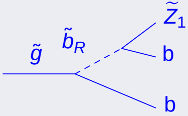

  - 1-step cascade decay
  - No leptons
  - **Multi-b's**
  - "Hard" $\not{E}_T$

Benchmark Points

- HSb:
  $m_{16} = 10$ TeV, $m_{10} = 12$ TeV,
  $M_D = 3.3$ TeV, $m_{1/2} = 44$ GeV,
  $A_0 = -2$ TeV, $\tan\beta = 50$

- DR3b:
  $m_{16} = 12$ TeV, $m_{16}(3) = 11$ TeV, $m_{10} = 14$ TeV
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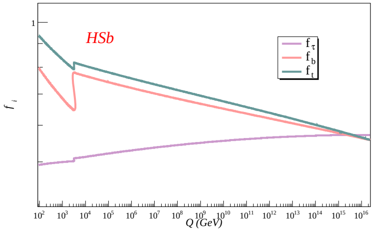

  - R = 1.025

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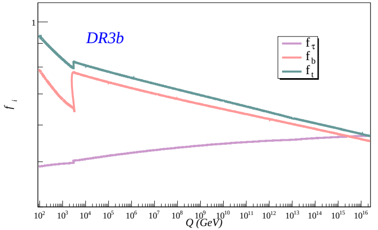

  - R = 1.027

Tevatron Searches

Tevatron Searches - HS

- Cuts:
  - 1 jet with $|\eta| < 0.8$ and
  - $n(l) = 0$, $n(j) \geq 4$, $\Delta\phi(j1, j2) < 160°$

	$\not{E}_T$	H_T	$E_T(j1)$	$E_T(j2)$	$E_T(j3)$	$E_T(j4)$
BMPT	$\geq$ 75 GeV	–	15	15	15	15
CDF	$\geq$ 90 GeV	280	95	55	55	25
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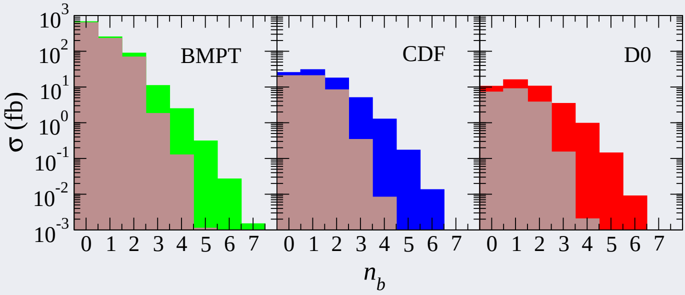

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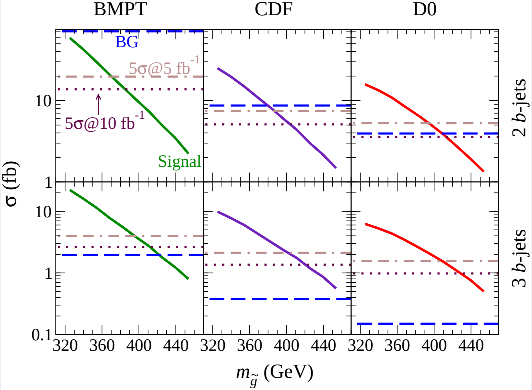

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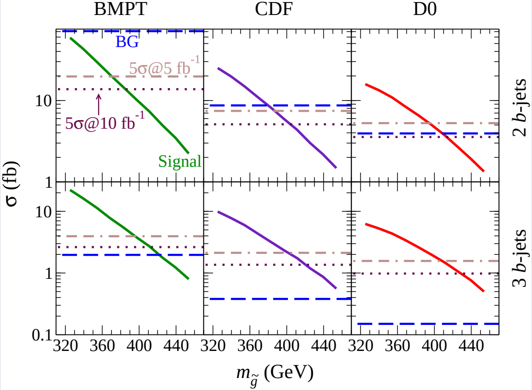

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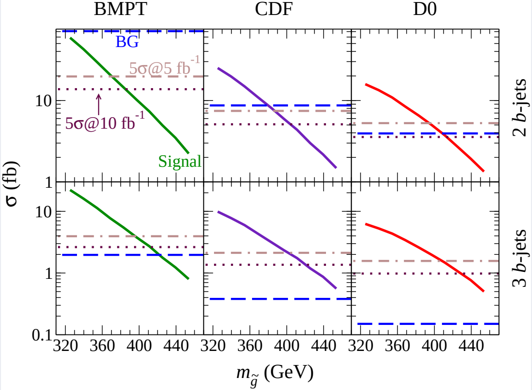

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⇒ $R \lesssim$ 1.04 (1.05)

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- Cuts:
  - Jet cuts: $n(j) \geq 4$ with $E_T(j) \geq 50$ GeV, $\eta(j) \leq 3$, $E_T(j1) \geq 100$ GeV
  - Lepton cuts: $E_T(\ell) \geq 10$ GeV and $\eta(\ell) \leq 2$
  - $S_T \geq 0.2$, $\not{E}_T > 100$ GeV

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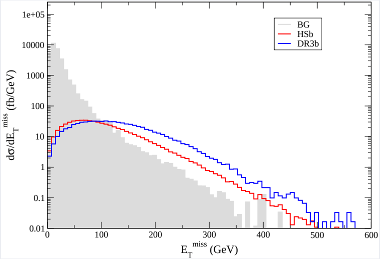

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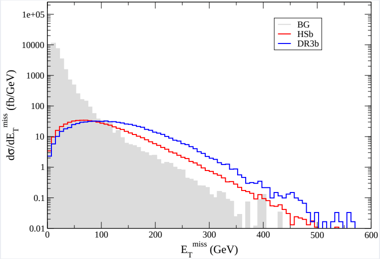
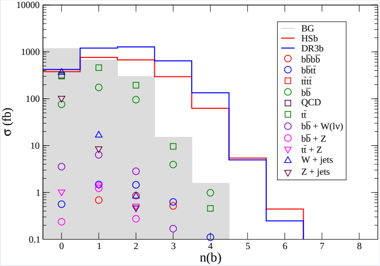
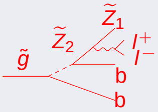




LHC7 Searches

Dilepton Signal

- HSb: $\tilde{g} \rightarrow \widetilde{Z}_2 + b\bar{b}$ (63 %)
- DR3b: $\tilde{g} \rightarrow \widetilde{Z}_2 + b\bar{b}$ (11%)



LHC7 Searches

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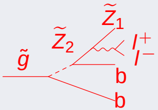

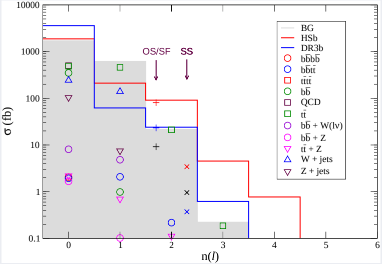

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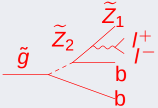

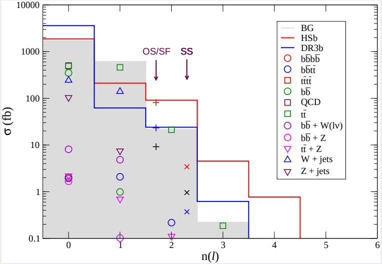

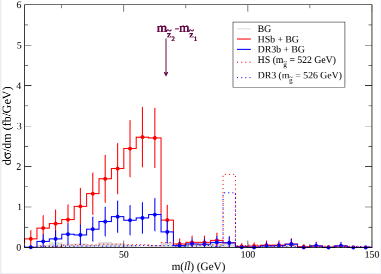

LHC7 Reach

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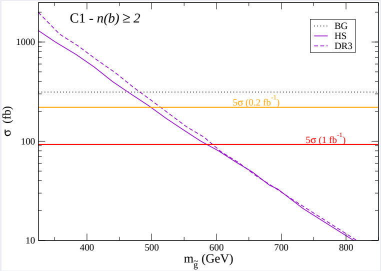

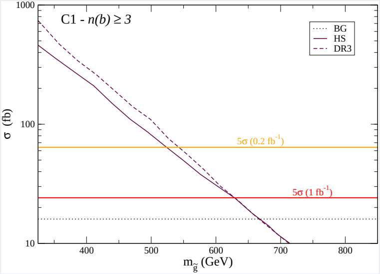

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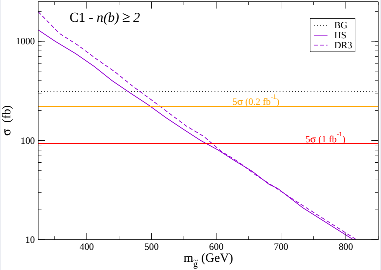

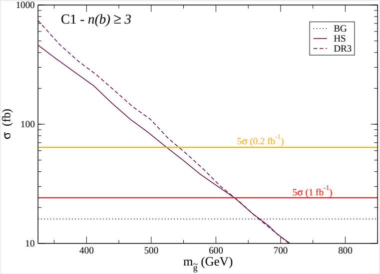

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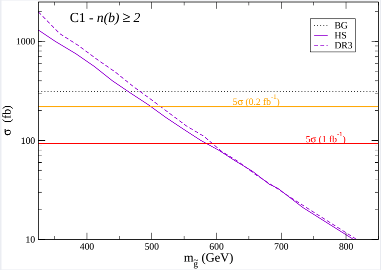
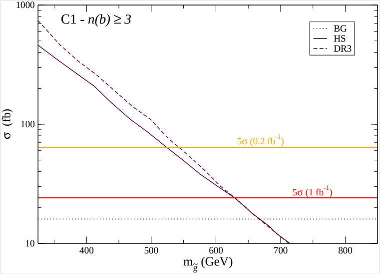


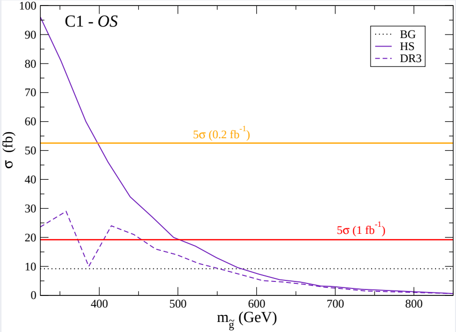


- *Large Signal*
- *BG $\gtrsim$ Signal*

- *Small signal*
- *Signal $\gg$ BG*

LHC7 Reach

- Complementary Dilepton Signal:



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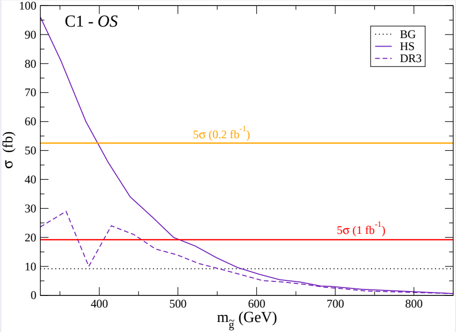

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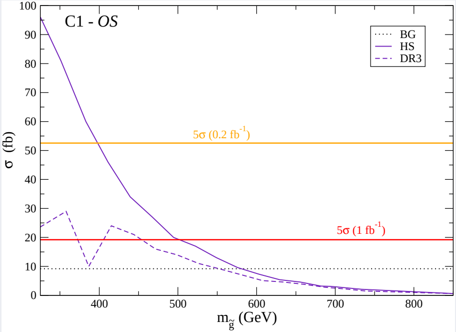

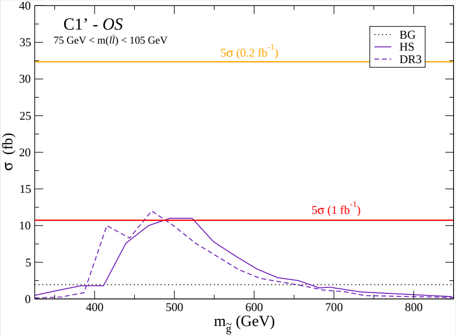

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  - M_{eff}, $m(b, b)$ and $m(l^+l^-)$ could provide the first clues for the low energy sparticle masses

Thanks!

- - 1-loop RGEs:

$$\frac{d(M_i/\alpha_i)}{dt} = 0 \Rightarrow \frac{\alpha_1}{M_1} = \frac{\alpha_2}{M_2} = \frac{\alpha_3}{M_3}$$

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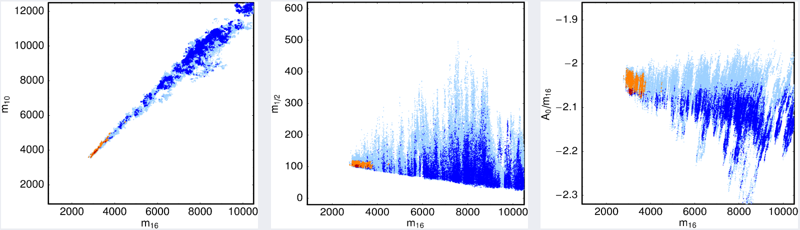
  $\longrightarrow$ lower gluino masses are allowed!
- LEP2 limit: $m_{\tilde{g}} \gtrsim 320$ GeV
  ($m_{\tilde{g}} \gtrsim 425$ GeV in mSUGRA)

HS Model



(Baer *et al.*, JHEP0803 (2008), 056)

$$\Rightarrow R = \frac{\max[f_t, f_b, f_\tau]}{\min[f_t, f_b, f_\tau]} < 1.1, 1.05$$

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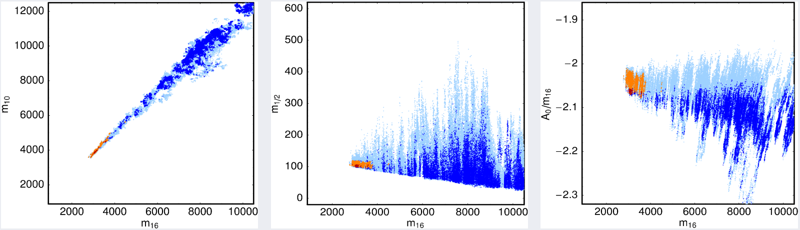

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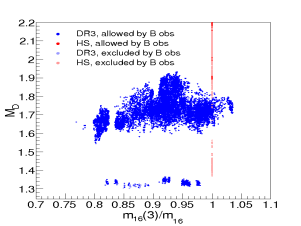
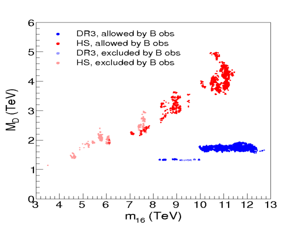
- Unification is obtained at the $\lesssim$ 5% level, if:
  - $m_{16} \sim$ 3-15 TeV
  - $A_0 \sim -2m_{16}$
  - $m_{10} \sim 1.2m_{16}$
  - $m_{1/2} \ll m_{16}$
  - $\tan\beta \sim 50$

DR3 vs HS

- Parameter space: $m_{16}, \mathbf{m_{16}(3)}, m_{10}, m_{1/2}, A_0, \tan\beta, sign(\mu), M_D$





- $m_{16} \sim$ 8-15 TeV
- $m_{16}(1,2) \gtrsim m_{16}(3)$
  (consistent with $M_P \longrightarrow M_{GUT}$ running)
- M_D is more constrained
  (tachyonic scalars)

(Baer *et al.*, JHEP0909 (2009), 005)

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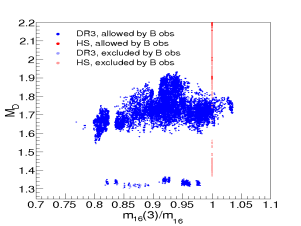

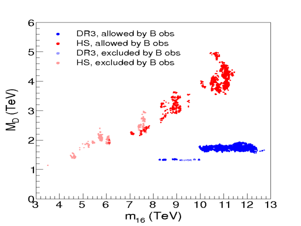

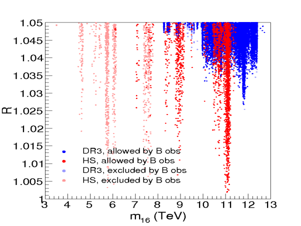

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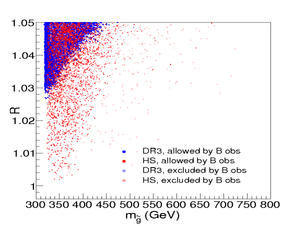
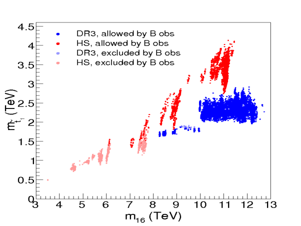
- $R \geq 1.025$

Phenomenology of Yukawa Unified models

- Masses:





- TeV scale 3rd generation
- $m_{\tilde{g}} \lesssim 500$ GeV

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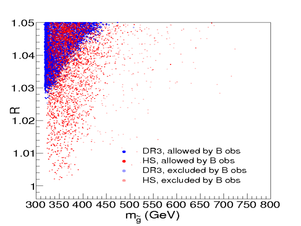

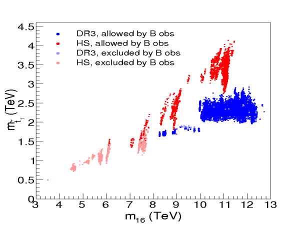

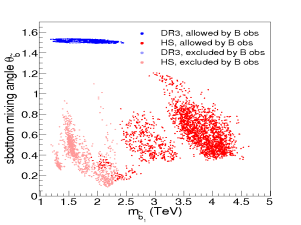

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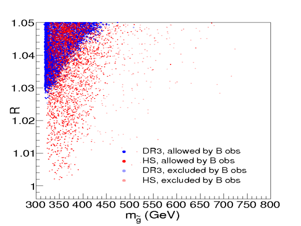

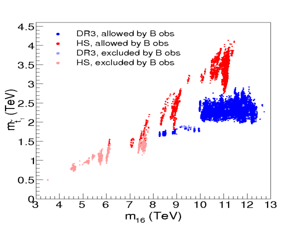

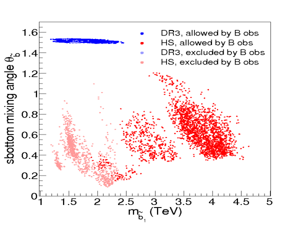

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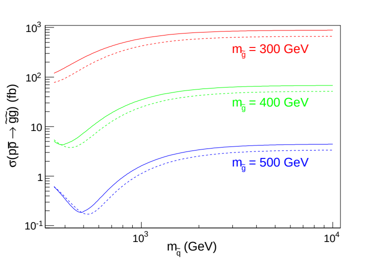
- TeV scale 3rd generation
- $m_{\tilde{g}} \lesssim 500$ GeV
- D-Term in DR3:
  $m^2_{\tilde{b}_R} = m^2_{16} - 3M^2_D$
  $m^2_{\tilde{t},\tilde{b}_L} = m^2_{16} + M^2_D$
  $\Rightarrow m_{\tilde{b}_R}$ **is the lightest squark state**

Tevatron Searches - HS

- Heavy squarks $\longrightarrow$ large cross-sections!



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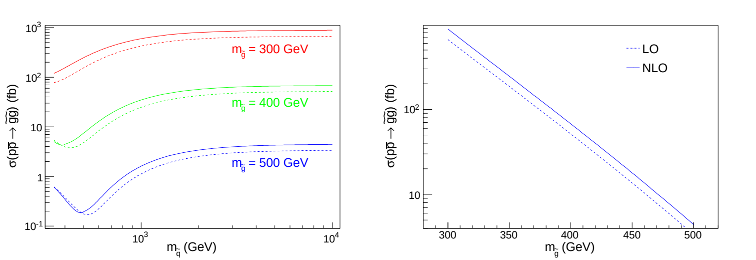

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