Testing ‘Natural SUSY’ at the LHC

Manuel Drees

Bonn University & Bethe Center for Theoretical Physics

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Introduction: Hierarchy Problem

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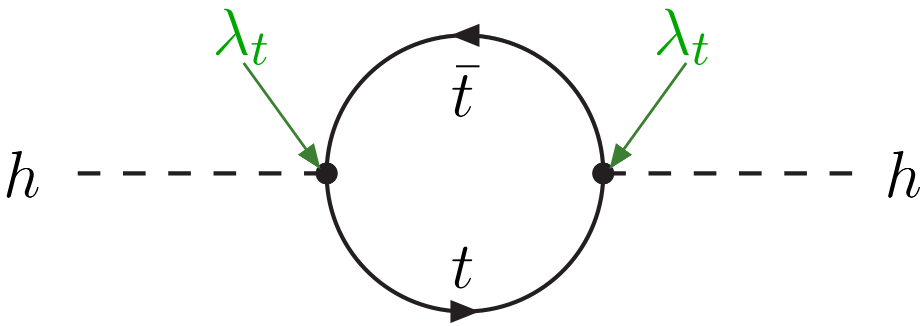

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Λ: cut–off for momentum in loop.

Introduction: Hierarchy Problem

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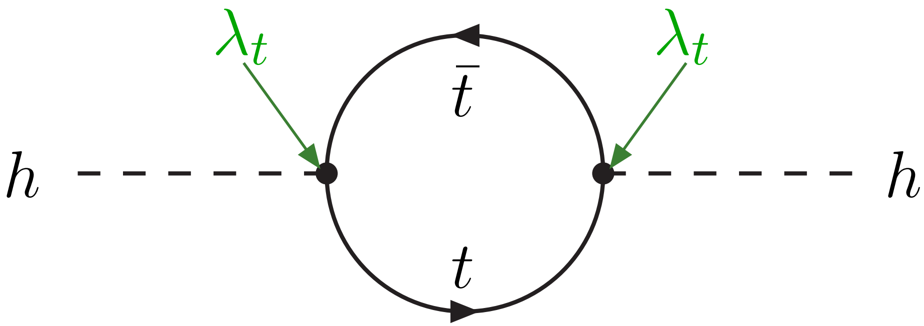

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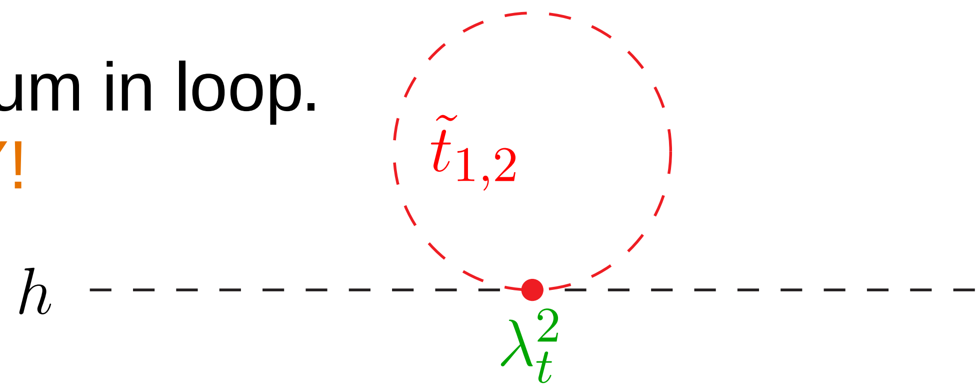
Are canceled in SUSY!



$\delta m^2_{h,\tilde{t}} = -\frac{3f_t^2}{8\pi^2}\Lambda^2 + \cdots$ Quadratic divergencies cancel exactly!

Adding up

$$\delta m_h^2 \sim \frac{3\lambda_t^2}{8\pi^2}\left(m_{\tilde{t}_1}^2 + m_{\tilde{t}_2}^2 - 2m_t^2 + |A_t|^2\right)\ln\frac{\Lambda^2}{m_h^2} + \cdots$$

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Should have seen stops and/or gluinos at the LHC??

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MD, J.S. Kim

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In our first scan:
$|\mu| \leq 500$ GeV
$m_{\tilde{t}_i},\ m_{\tilde{g}}$ as small as possible
(implies $m_{\tilde{b}_1}$ is also “light”)
All other sparticles, heavy Higgses out of LHC range.

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We don’t claim that this is necessarily the only version of natural SUSY – hence the quotation marks!

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- Compare with LHC results using CheckMATE

  ATLAS: $0\,\ell + 2b$; $2\,\ell$ (direct stop); $\ell^\pm \ell^\pm$; $3\,\ell$; $1\,\ell + (b-)$jets (stop); Monojet or $c-$jet (stop); $1\,\ell + \geq 4$ jets; $0\,\ell + 2b + 4$ or more jets; $0\,\ell + 2$ to 6 jets; 0 or $1\,\ell +$ $3\,b$; 1 or $2\,\ell + 3$ to 6 jets; $2\,\ell$ (razor)

  CMS: $\alpha_T + b$; $\ell^\pm \ell^\mp + 3\,b$.

  All searches require some missing E_T.

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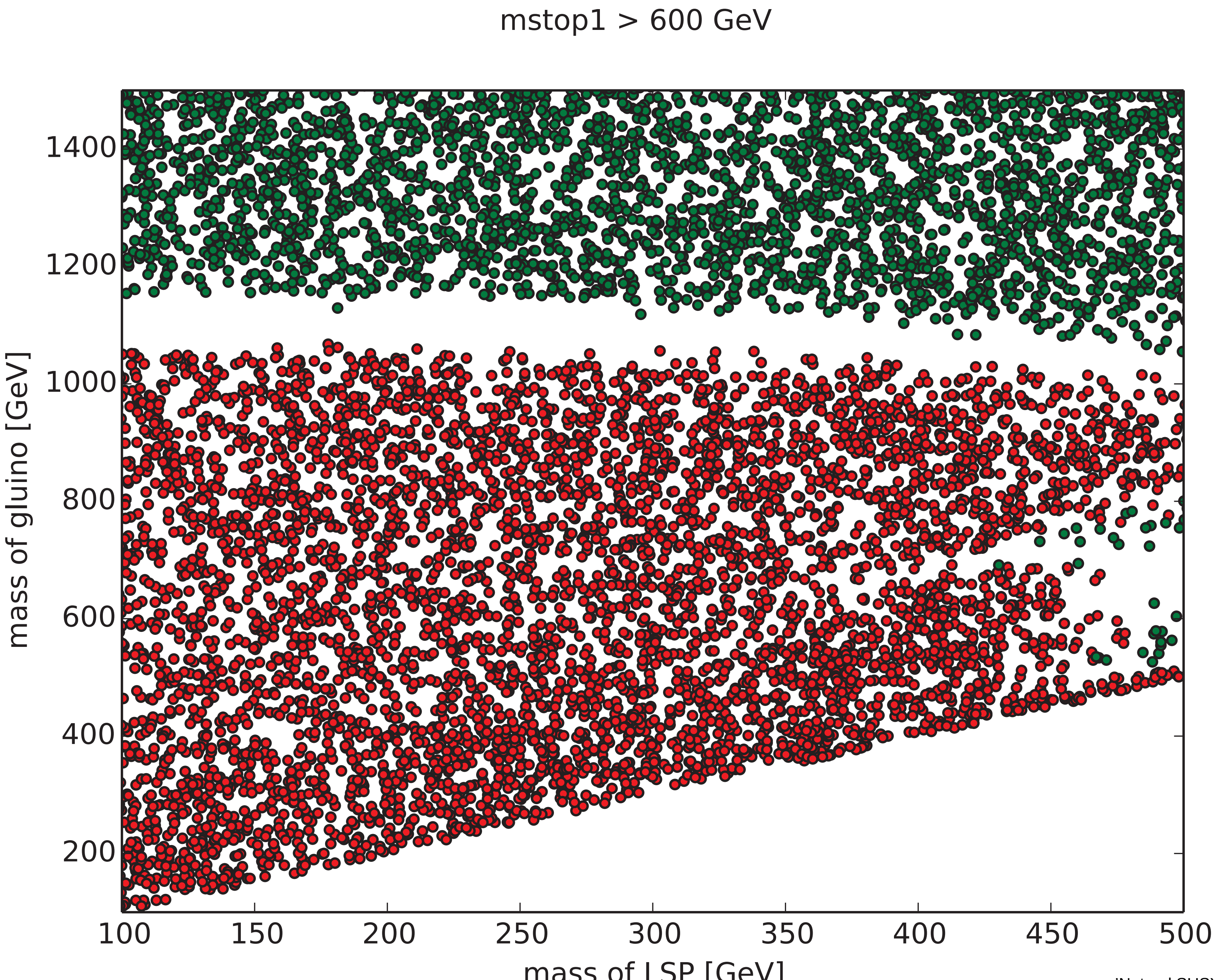
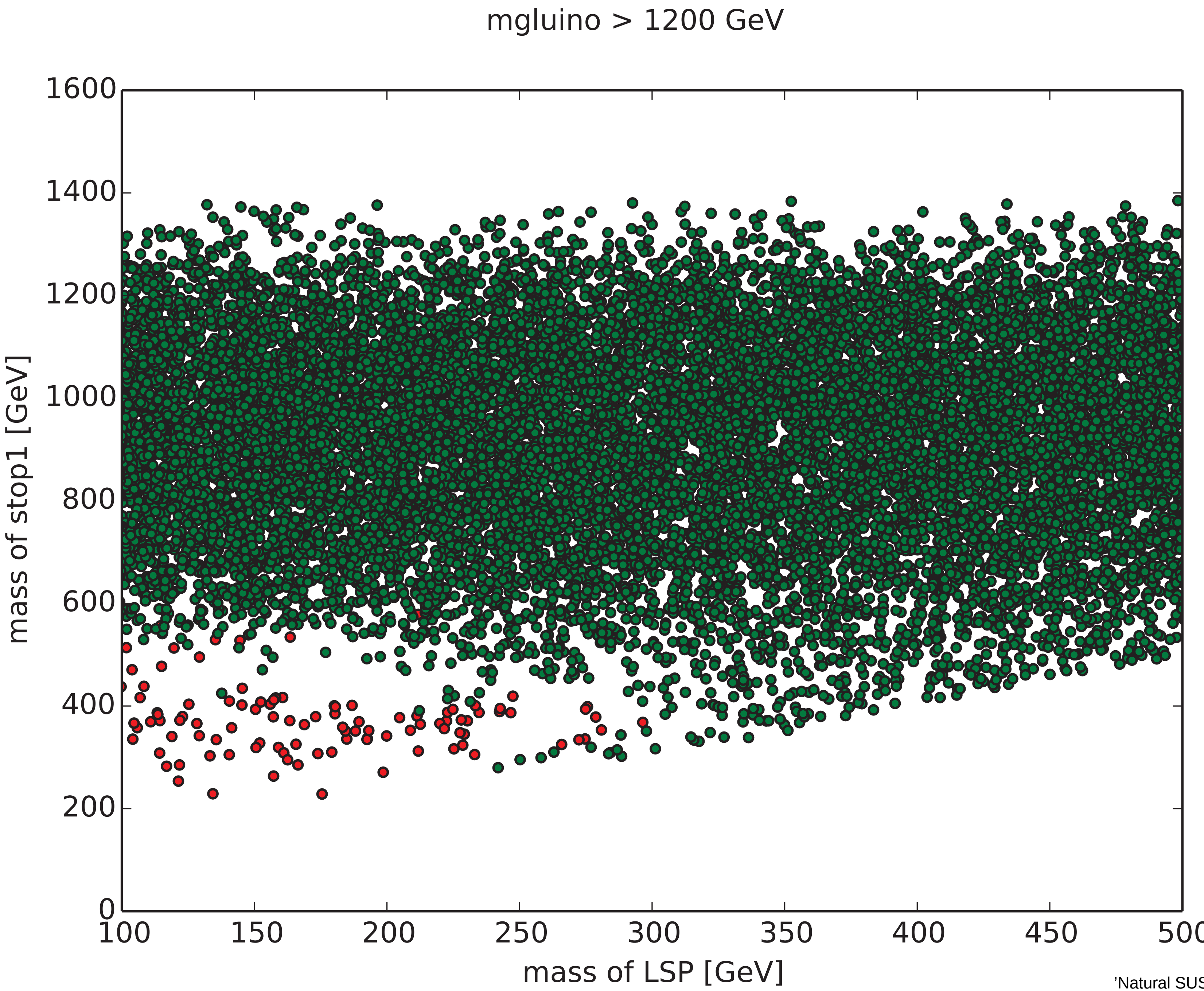
- Doesn’t work for “smart” multivariate analyses

$m_{\tilde{t}_1} > 700$ **GeV**



$m_{\tilde{g}} > 1200$ GeV



Results

- Scenario is *safe* (from 8 TeV data), if $m_{\tilde{g}} > 1.15$ TeV and $(m_{\tilde{t}_1} > 650$ GeV or $m_{\rm LSP} > 320$ GeV$)$

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- Some scenarios with $m_{\tilde{g}} \leq 800$ GeV are allowed: $m_{\rm LSP} \gtrsim 430$ GeV
- Smallest allowed masses in scan: $m_{\tilde{g},{\rm min}} = 480$ GeV, $m_{\tilde{t}_1,{\rm min}} = 260$ GeV

Including $g_\mu - 2$

- Measured nomalous magnetic moment of the muon somewhat above SM prediction:

$$(g_\mu - 2)_{\rm exp} - (g_\mu - 2)_{\rm SM} = (576 \pm 160) \times 10^{-11} \quad (3.6\sigma!)$$

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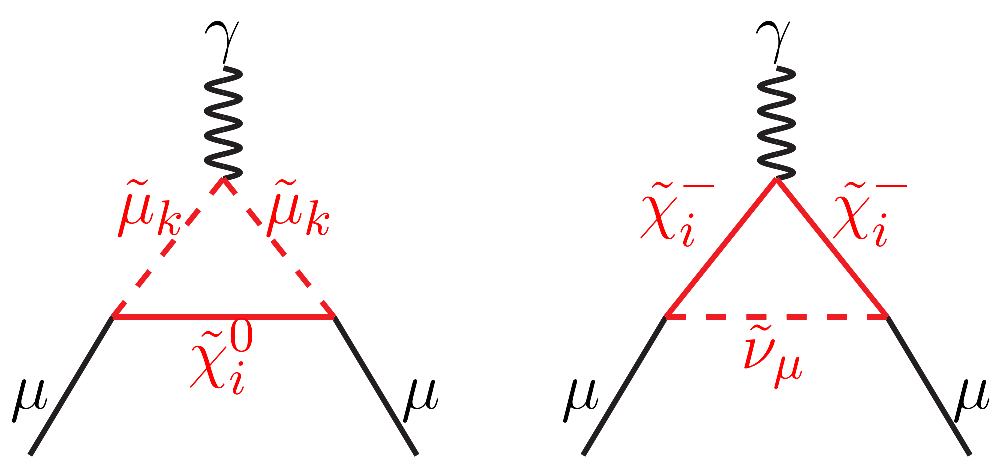
- SUSY contributions can be sizable; can have either sign.



SUSY Contributions to $g_\mu - 2$

Let

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- $a_\mu^{\text{SUSY}} \sim \frac{\alpha}{\pi} \frac{m_\mu^2}{M^2} \tan\beta\,, \quad M = \max(m_{\tilde{\chi}}, m_{\tilde{\mu}})$

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- To avoid FCNC: take $m_{\tilde e_{L,R}} = m_{\tilde\mu_{L,R}}$, but allow $m_{\tilde\mu_L} \neq m_{\tilde\mu_R}$

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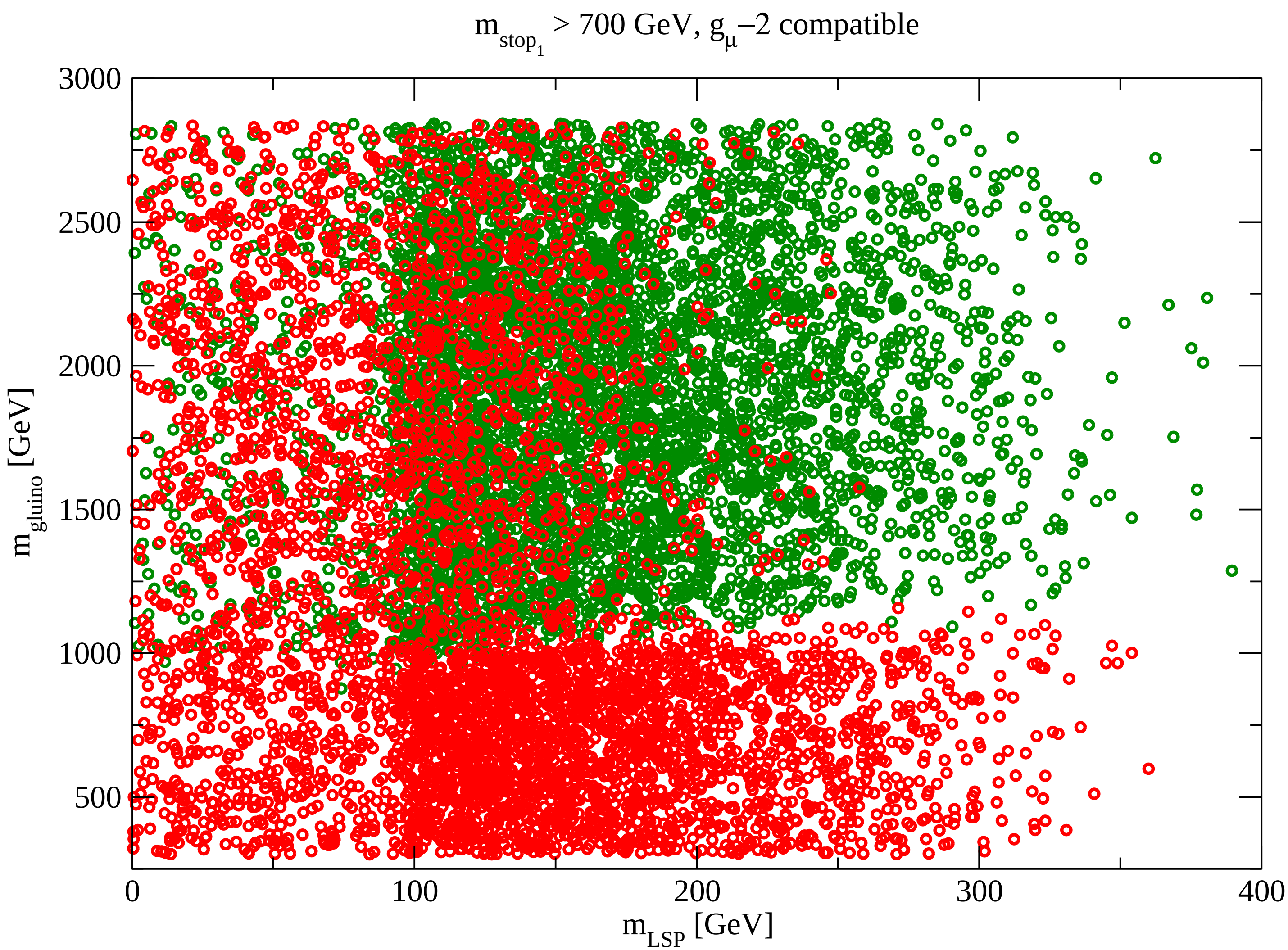
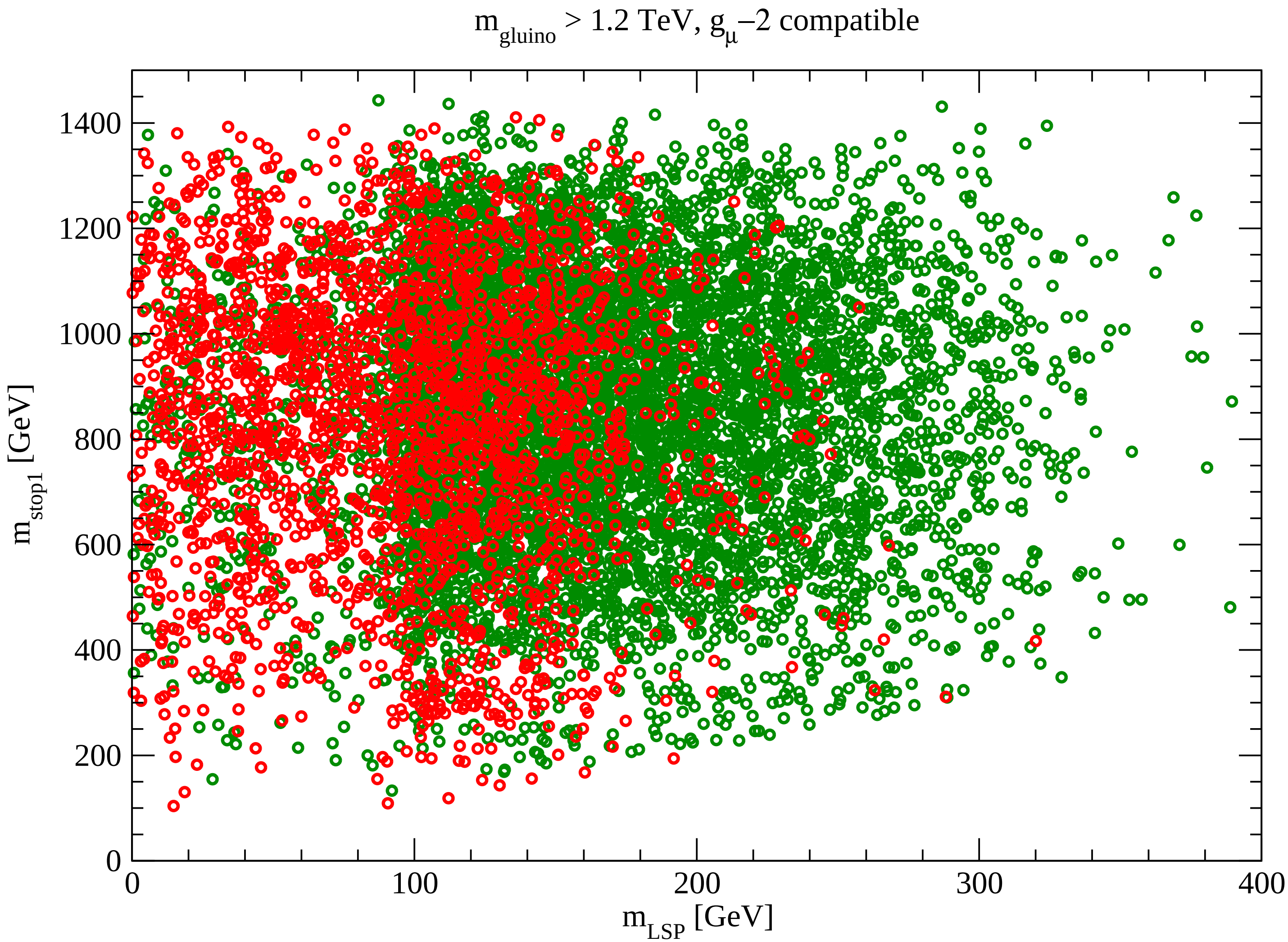
  - Cascade decays $\tilde{g} \rightarrow \tilde{\chi} \rightarrow \tilde{l} \rightarrow l$
- Longer cascades: can reduce reach! $\tilde{g} \rightarrow \tilde{\chi}_4 \rightarrow \tilde{\chi}_3 \rightarrow \tilde{\chi}_1$ produces more, but softer jets then $\tilde{g} \rightarrow \tilde{\chi}_1^0$ directly

$m_{\tilde{t}_1} > 700$ **GeV,** $g_\mu - 2$ **compatible**



$m_{\tilde{g}} > 1200$ **GeV,** $g_\mu - 2$ **compatible**



Warning: No matching yet!

Filtering

- Demand higgsino–like LSP. (Most natural for given $\tilde{\chi}^0$ spectrum.)
  $\Rightarrow \tilde{g}, \tilde{t}_1 \rightarrow \tilde{\chi}_1^0$ directly is preferred! (Since $m_{\tilde{u},\tilde{d},\ldots} < m_{\tilde{t}}$.)
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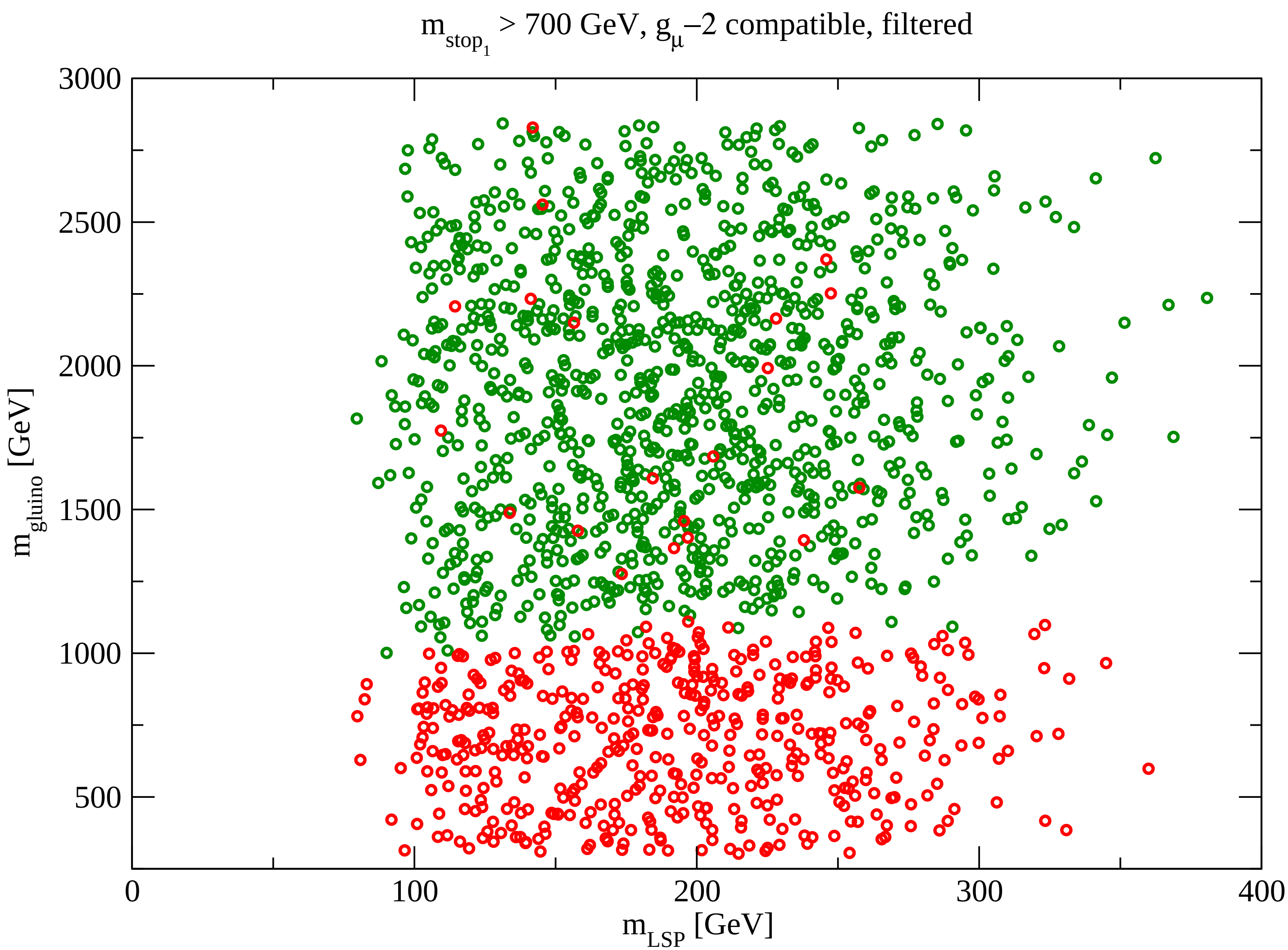
- Remove spectra that can be probed via direct slepton or electroweakino pair production. (Uses masses only: removes some points that are actually allowed.)

$m_{\tilde{t}_1} > 700$ **GeV,** $g_\mu - 2$ **compatible, filtered**



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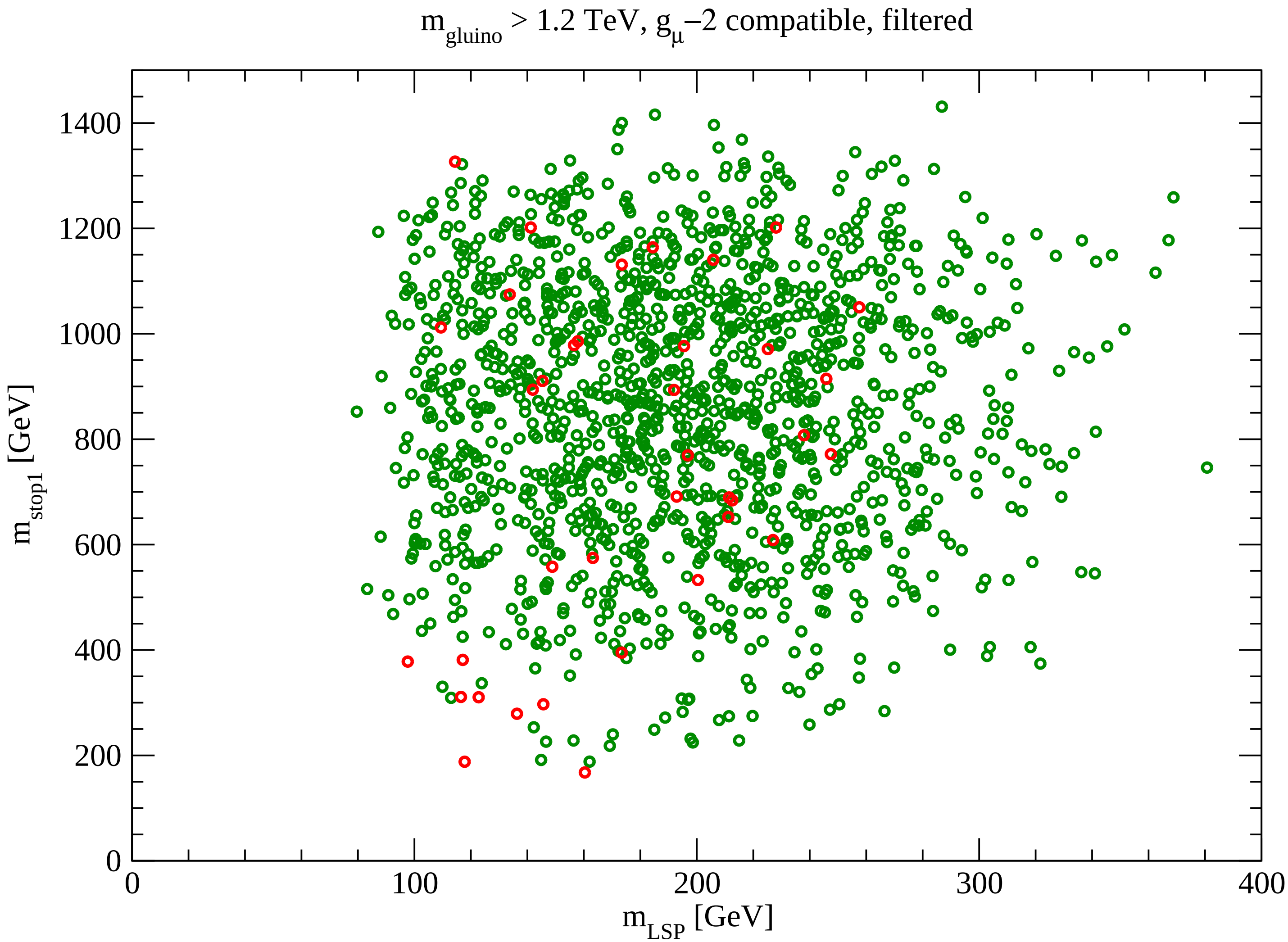

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- Little change in LHC reach for gluinos and stops!

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- LHC experiments collected ~ 40 fb^{-1} of data at $\sqrt{s} = 13$ TeV. No signal yet, bounds are beginning to appear $\Rightarrow$ increases pressure on 'Natural SUSY'!

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  - Electroweakino, slepton sector constrained significantly by direct searches; bounds differ from “simplified models”!