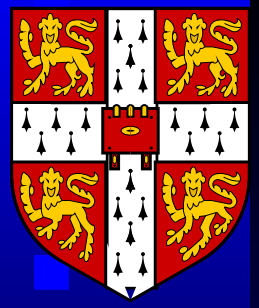


Hide and Seek With Natural SUSY

by

Ben Allanach[a] (University of Cambridge)

Talk outline

- Natural SUSY: bottom up philosophy
- 2011 LHC searches
- 2012 Searches

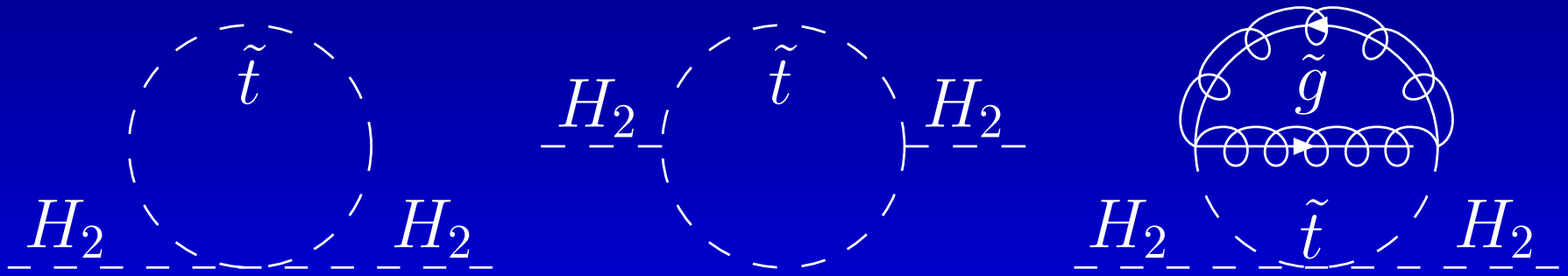
[a] Based on BCA, Gripaios, arXiv:1202.6616

Natural SUSY

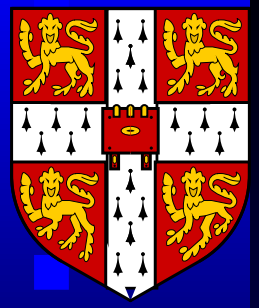
The particles coupling the most strongly to the higgs are the *stops*[a]. Minimising the MSSM Higgs potential,

$$-\frac{M_Z^2}{2} = |\mu|^2 + m_{H_2}^2,$$

$$\delta m_{H_2}^2 = \frac{-3h_t^2}{4\pi^2} m_{\tilde{t}}^2 \ln\left(\frac{\Lambda_{UV}}{m_{\tilde{t}}}\right)$$



[a] M. Papucci, J. T. Ruderman and A. Weiler, arXiv:1110.6926; C. Brust, A. Katz, S. Lawrence and R. Sundrum, arXiv:1110.6670



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$$\delta m_{H_2}^2 = \frac{-3h_t^2}{4\pi^2} m_{\tilde{t}}^2 \ln\left(\frac{\Lambda_{UV}}{m_{\tilde{t}}}\right)$$

No cancellation$\Rightarrow$

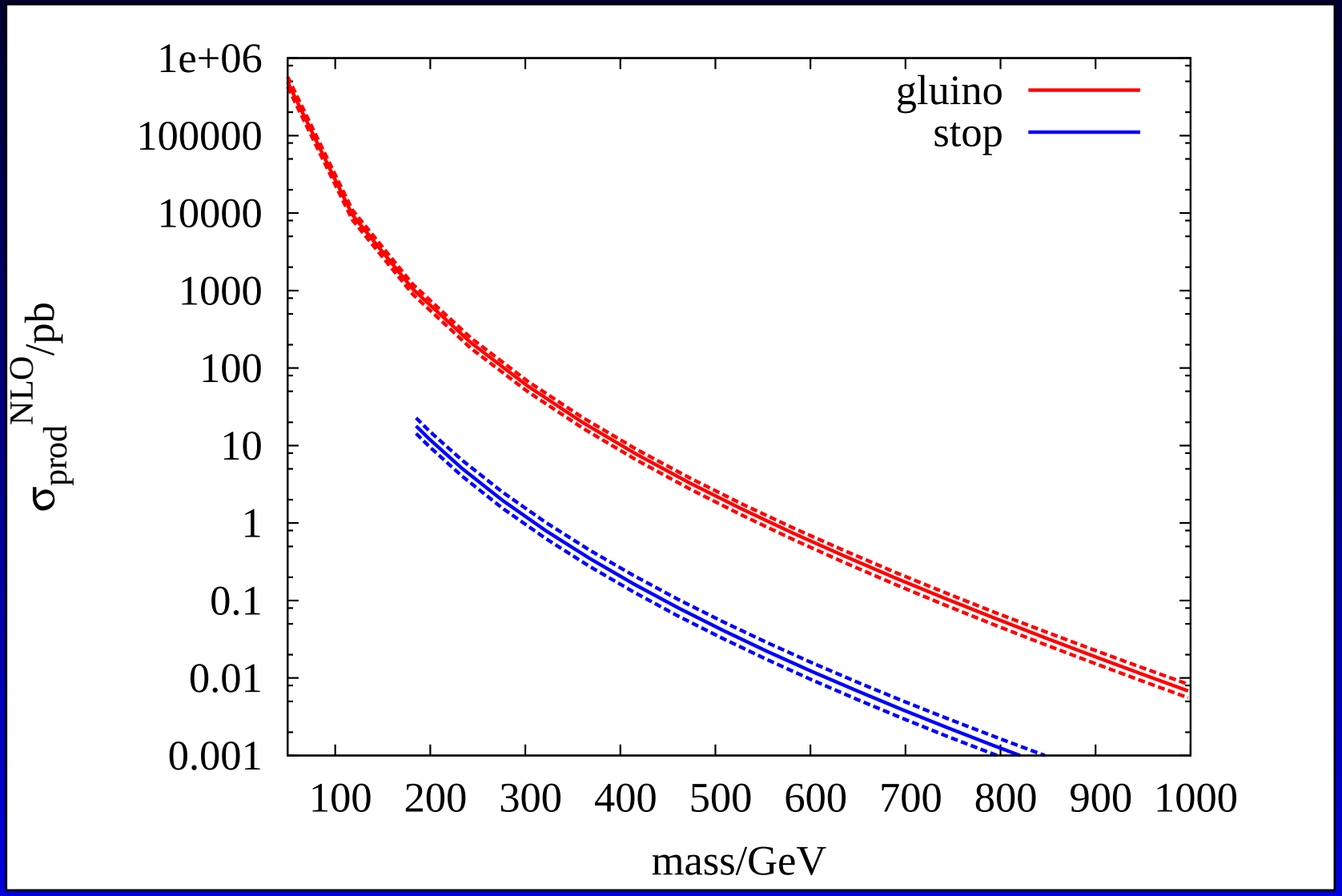
$$m_{\tilde{t}} \lesssim 700 \text{ GeV}, \qquad m_{\tilde{g}} \lesssim 1000 \text{ GeV}.$$

Experimental $\not{E}_T$ searches$\Rightarrow$

$$m_{\tilde{t}} > 500 \text{ GeV}, \qquad m_{\tilde{g}} > 900 \text{ GeV}.$$

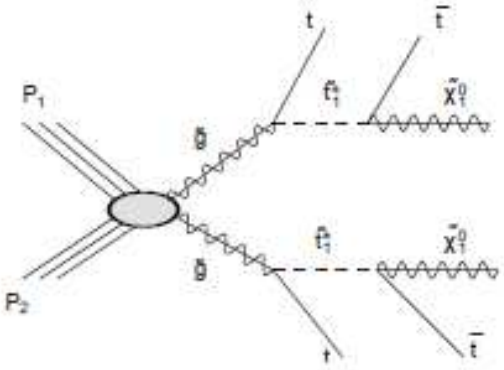
[a] M. Papucci, J. T. Ruderman and A. Weiler, arXiv:1110.6926; C. Brust, A. Katz, S. Lawrence and R. Sundrum, arXiv:1110.6670

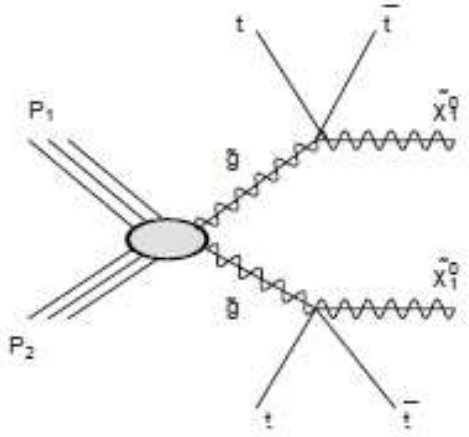
Gluino/stop production at LHC7

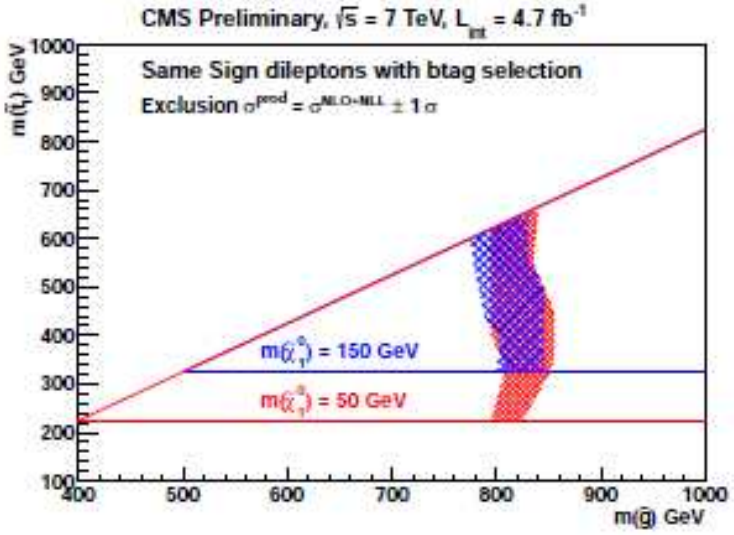


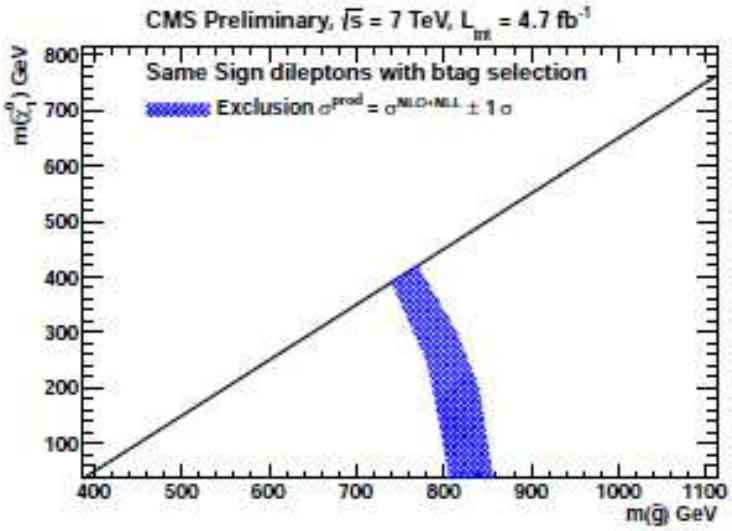
gt: $\not{E}_T > 50/120$ **GeV,** $N_b \geq 2$, $\#j \geq 2$, $H_T > 320$ **GeV**

Interpret in a gluino-mediated stop scenario with on-shell (left) or off-shell stops (right)

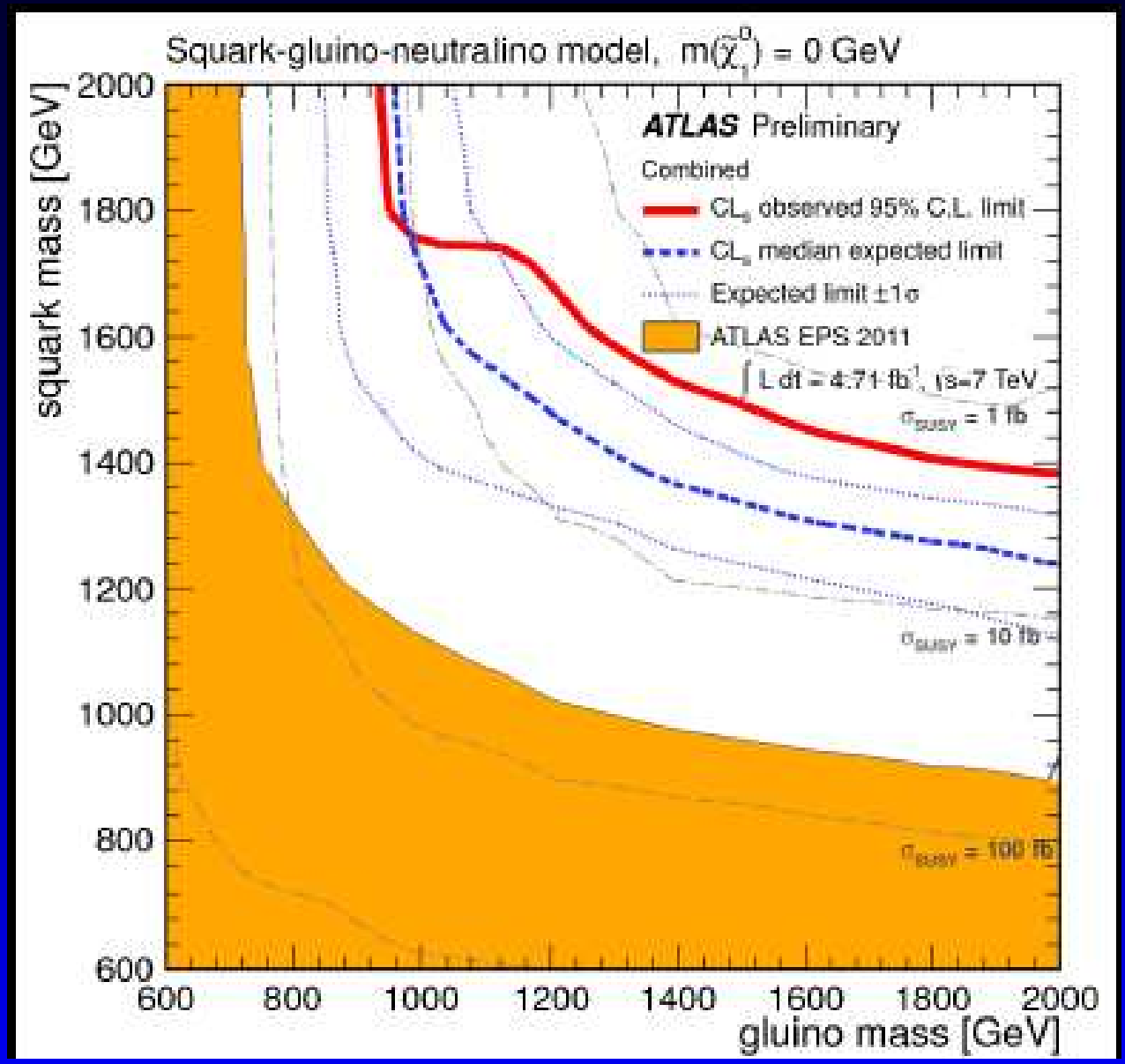


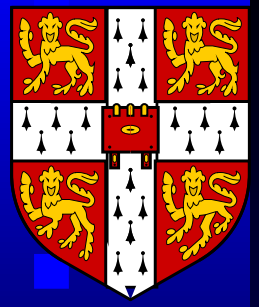






Jets Plus $\not{E}_T$ Search



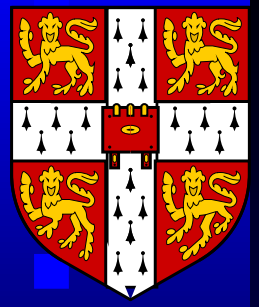


Implications of 2011 Data

Naturalness is under pressure. Ways to get around it:

- Compressed spectra[a]
- RPV decreases/removes the $\not{E}_T$.
  - Explains why natural SUSY hasn't been found yet
  - Like-sign dileptons is a generic signature, as we'll see
- If first two generation squarks are quite heavy, bounds from current jets plus $\not{E}_T$ searches become less stringent
- Suggests a simplified model with only light stops and light gluinos: remains natural

[a] LeCompte, Martin arXiv:1111.6897



Review of R-Parity

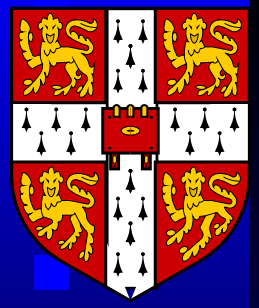
The superpotential of the MSSM can be seperated into two parts:

$$\begin{aligned} W_{R_p} &= h^e_{ij} L_i H_1 \bar{E}_j + h^d_{ij} Q_i H_1 \bar{D}_j \\ &\quad + h^u_{ij} Q_i H_2 \bar{U}_j + \mu H_1 H_2, \\ W_{\not{R}_P} &= \frac{1}{2}\lambda_{ijk} L_i L_j \bar{E}_k + \lambda'_{ijk} L_i Q_j \bar{D}_k \\ &\quad + \frac{1}{2}\lambda''_{ijk} \bar{U}_i \bar{D}_j \bar{D}_k + \kappa_i L_i H_2. \end{aligned}$$

W_{R_p} is what is usually meant by the MSSM.

$\mathcal{Q}$: Why ban $W_{\not{R}_P}$?

$\mathcal{A}$: "Proton decay"



Gluinos With R_p Violation

- We assume lightish $\tilde{g}$, $\tilde{t}_R$. If one has lepton number violating LLE or LH_1 operators, the gluinos decay producing various leptons. These cases ought to be easy to find, and are good candidates for searches. Get same-sign leptons.
- With LQD operators, the stops will again decay into leptons, easy to see. Flavour constraints imply that L_3QD operators are likely to be the largest. Get same-sign leptons in $\sim \frac{7}{9}$ of $\tilde{g}\tilde{g}$ events.
- With UDD operators, the (right-handed) top decays direcly into jets.

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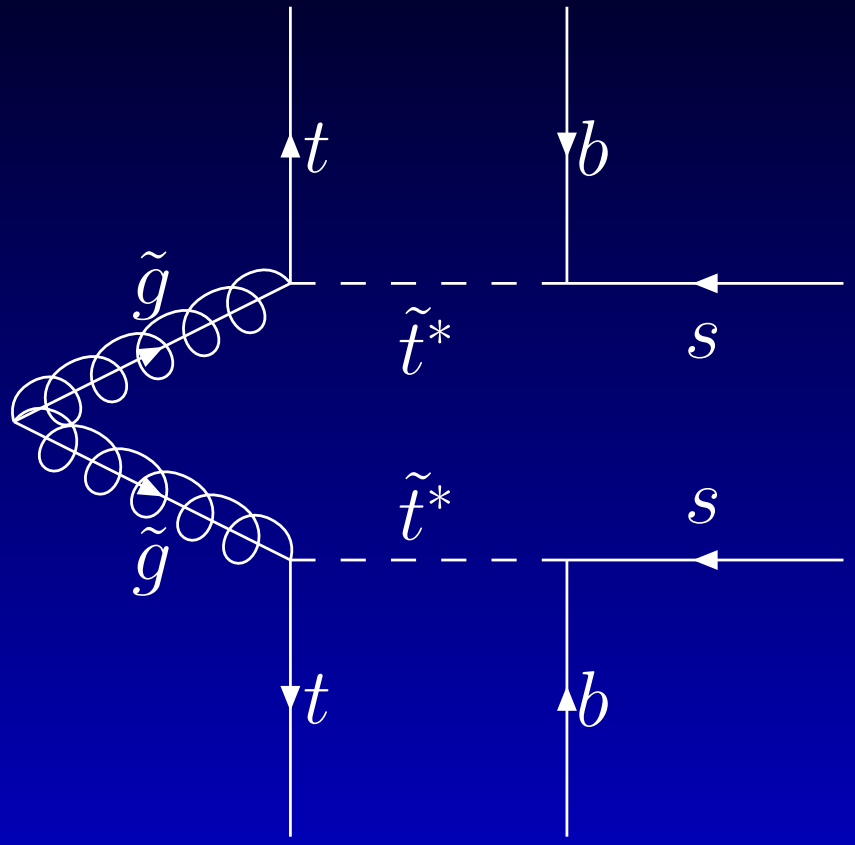
Baryon Number Violating Example



Can lead to natural SUSY with light stops and gluinos that hasn't been excluded yet. *A difficult case*[a]: $W \supset \lambda''_{ijk} U_i D_j D_k$.

[a] BCA and Ben Gripaios, arXiv:1202.6616

$\tilde{g}\tilde{g}$ production dominates. Here, you can look for like-sign di-leptons since gluinos decay into t and $\bar{t}$ with equal branching ratios.

Other Light States

How robust is the same-sign dilepton signature in the case that other states are also light?

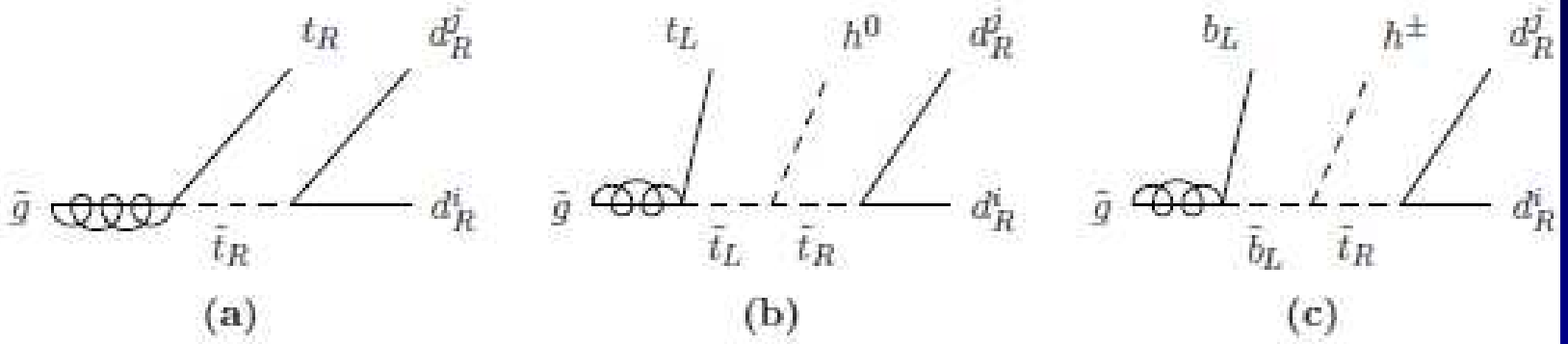


Figure 1. Gluino decays without right-handed bottom squarks in the presence of $W \supset U_3 D_i D_j$, via (a) right-handed top, (b) left-handed top, and (c) left-handed bottom. Same sign leptons are obtained in (c) only if the charged Higgs subsequently decays to $t\bar{b}$ or to leptons.

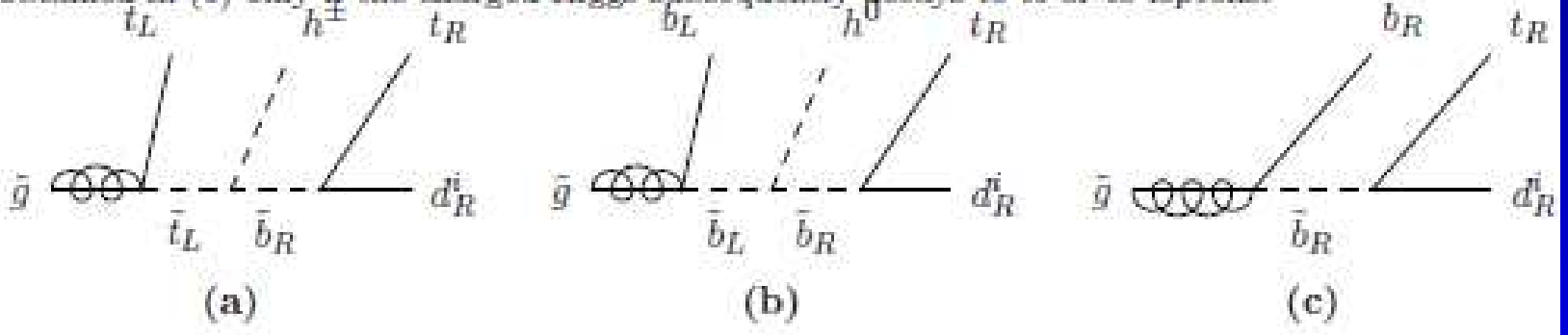
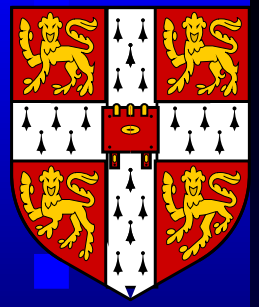


Figure 2. Gluino decays with right-handed bottom squarks in the presence of $W \supset U_3 D_i D_3$, via (a) left-handed top squark, (b) left-handed bottom squark, and (c) right-handed bottom squark.



Can we avoid SS dileptons?

- For $m_{H^\pm} > m_t + m_b$, $H^+ \to t\bar{b}$ dominates, which again will yield same-sign dileptons.
- $H^+ \to \tau^+ \nu_\tau$ is also OK, since we'll get like-sign di-taus.
- Only fly in the ointment comes from Fig. 1c: when $H^+ \to c\bar{b}$ (but only happens when $\tan\beta \ll m_t V_{cb}/m_\tau \sim 3$, which seems unlikely).

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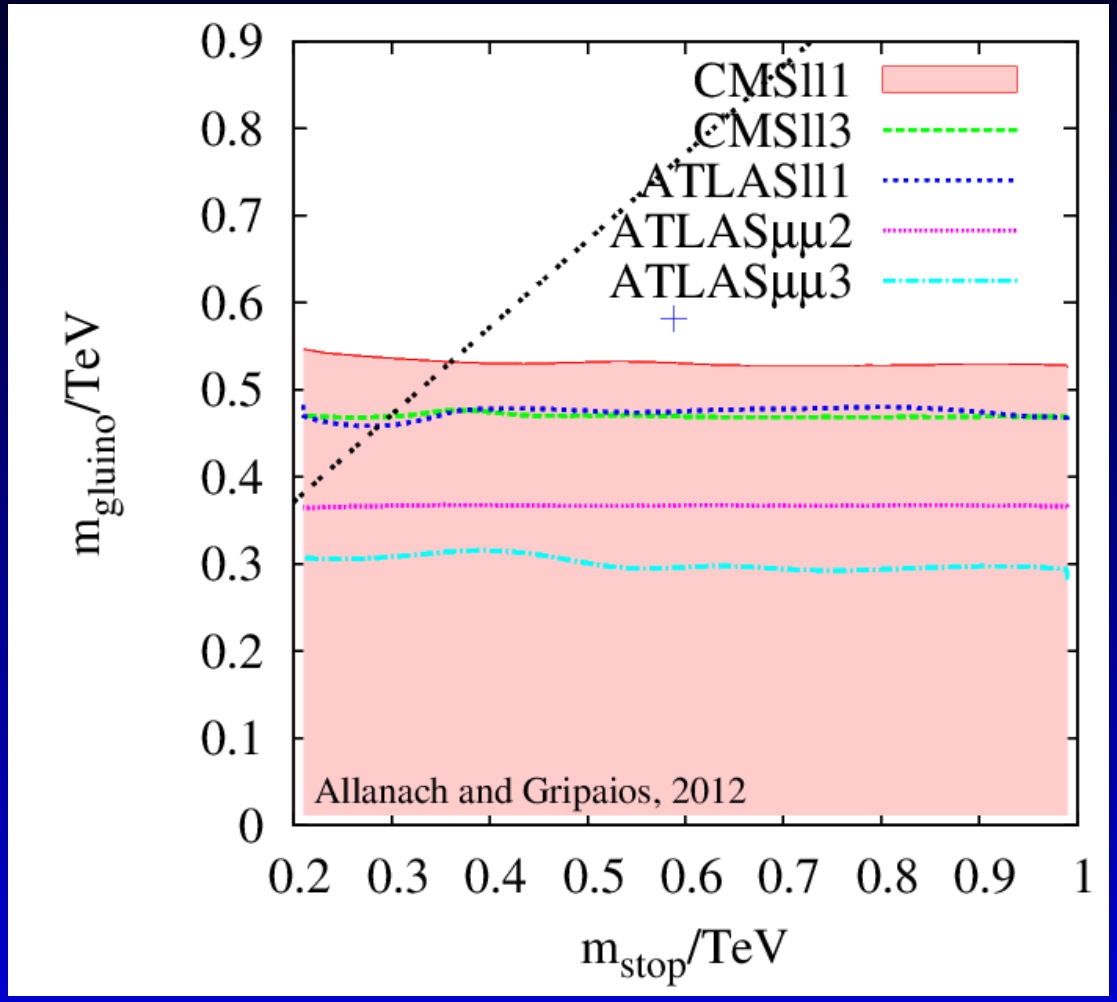
Same-sign $\not{E}_T$ Limits

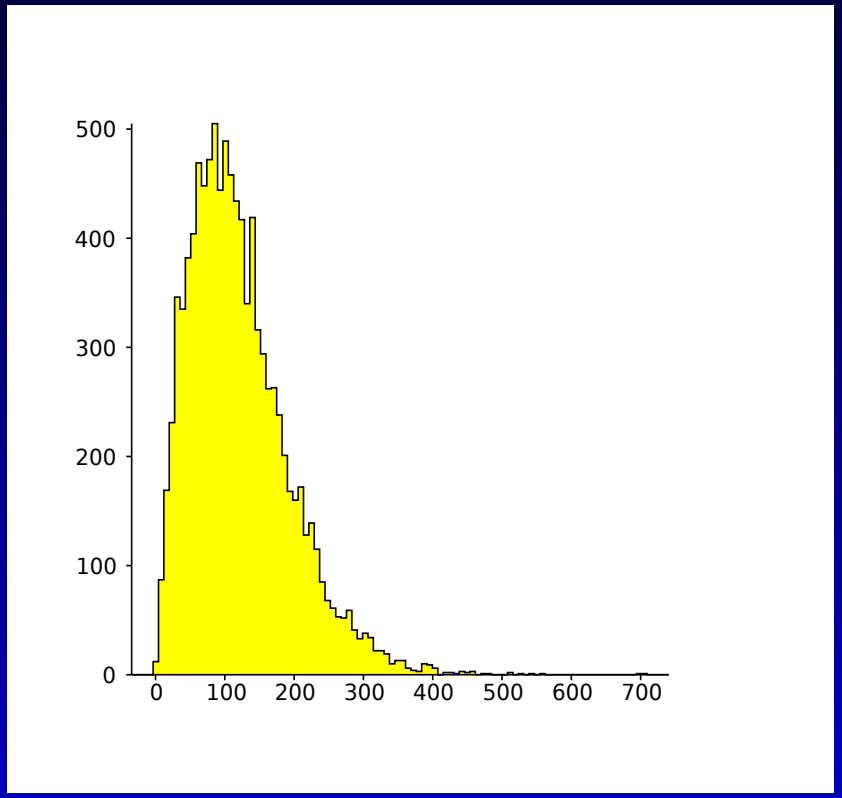


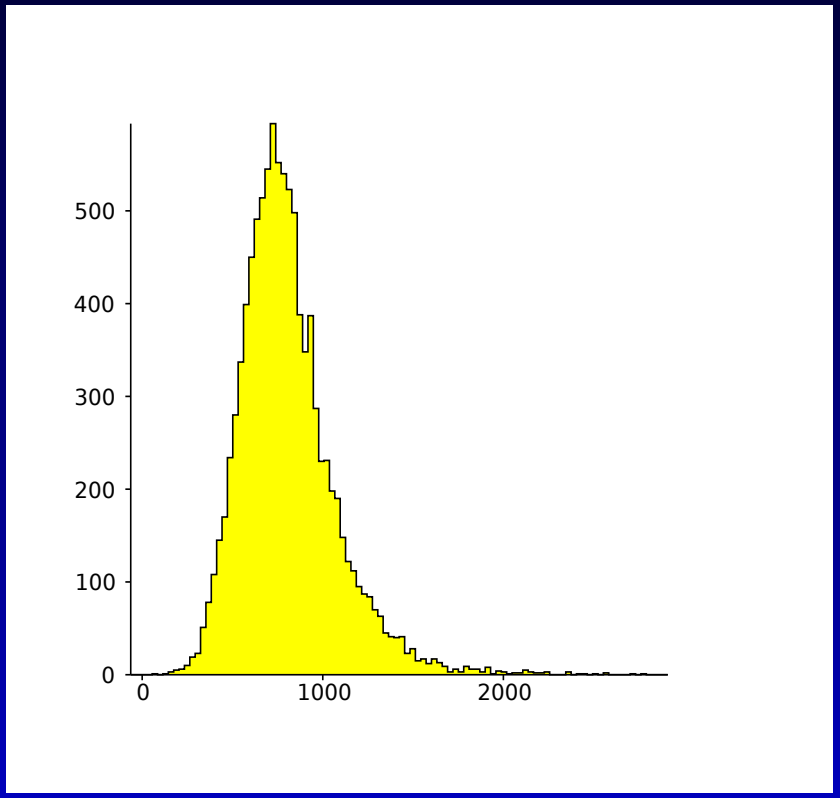
CMSS$ll1^a$: $H_T > 400$ GeV, $|\not{E}_T| > 120$ GeV

[a] CMS-PAS-SUS-010; ATLAS-CONF-2012-004

Test Point

$m_{\tilde{g}} = 588$ GeV, $m_{\tilde{t}} = 581$ GeV.





LH panel: $\not{E}_T/GeV$, RH panel: H_T/GeV

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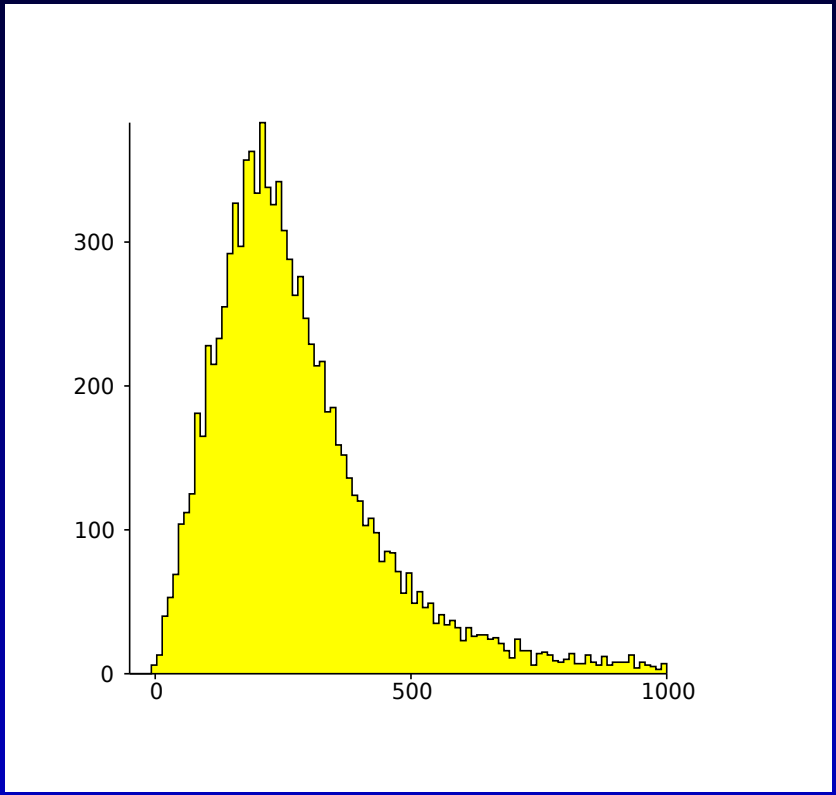

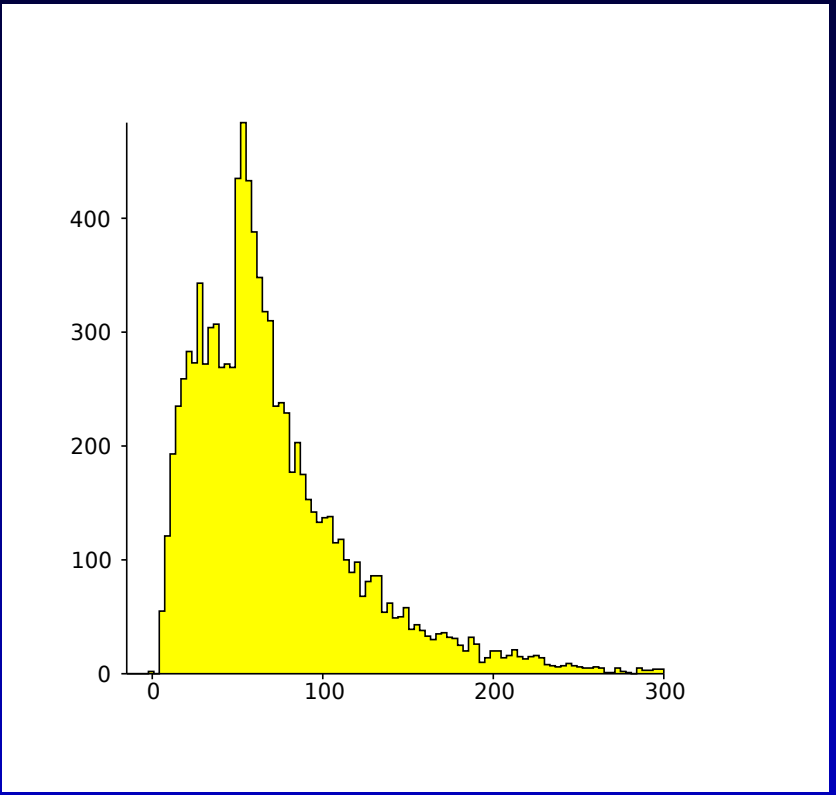

LH panel: $p_T(j_1)/GeV$, RH panel: $p_T(l_1)/GeV$

Test Point

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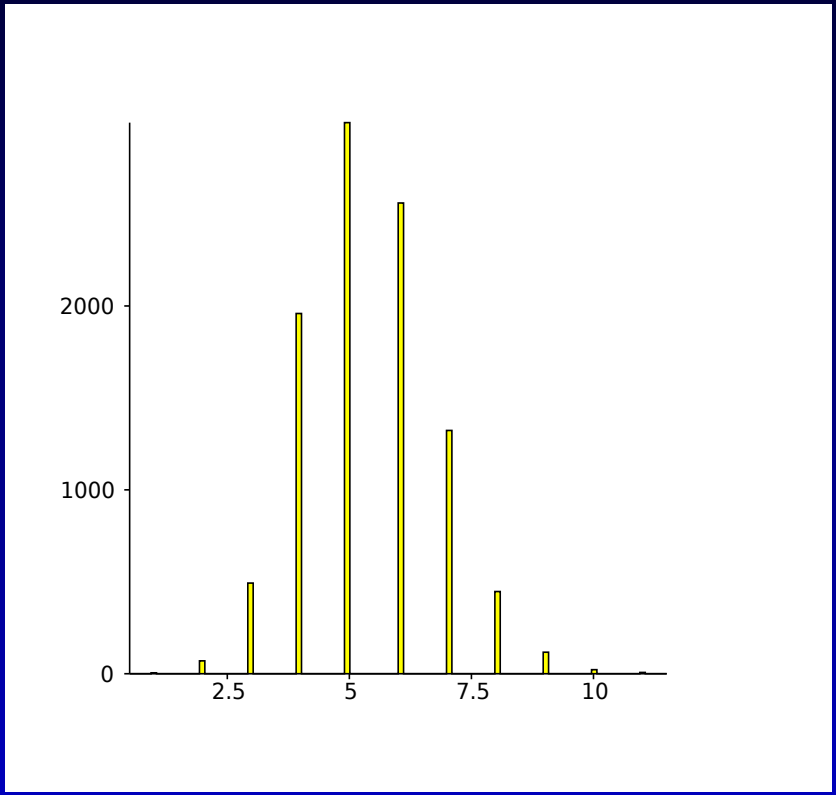
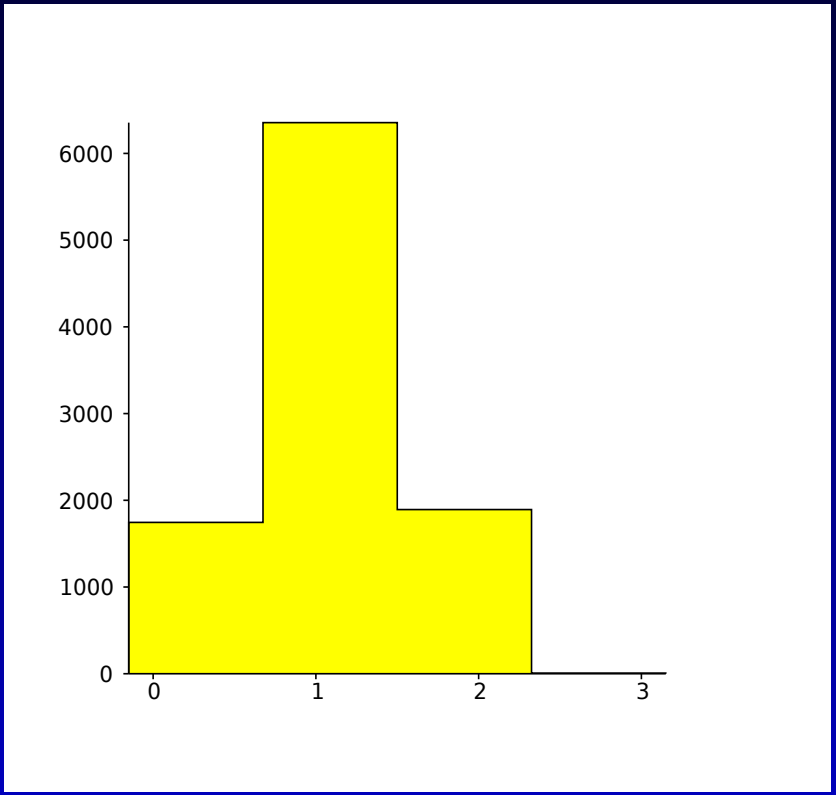


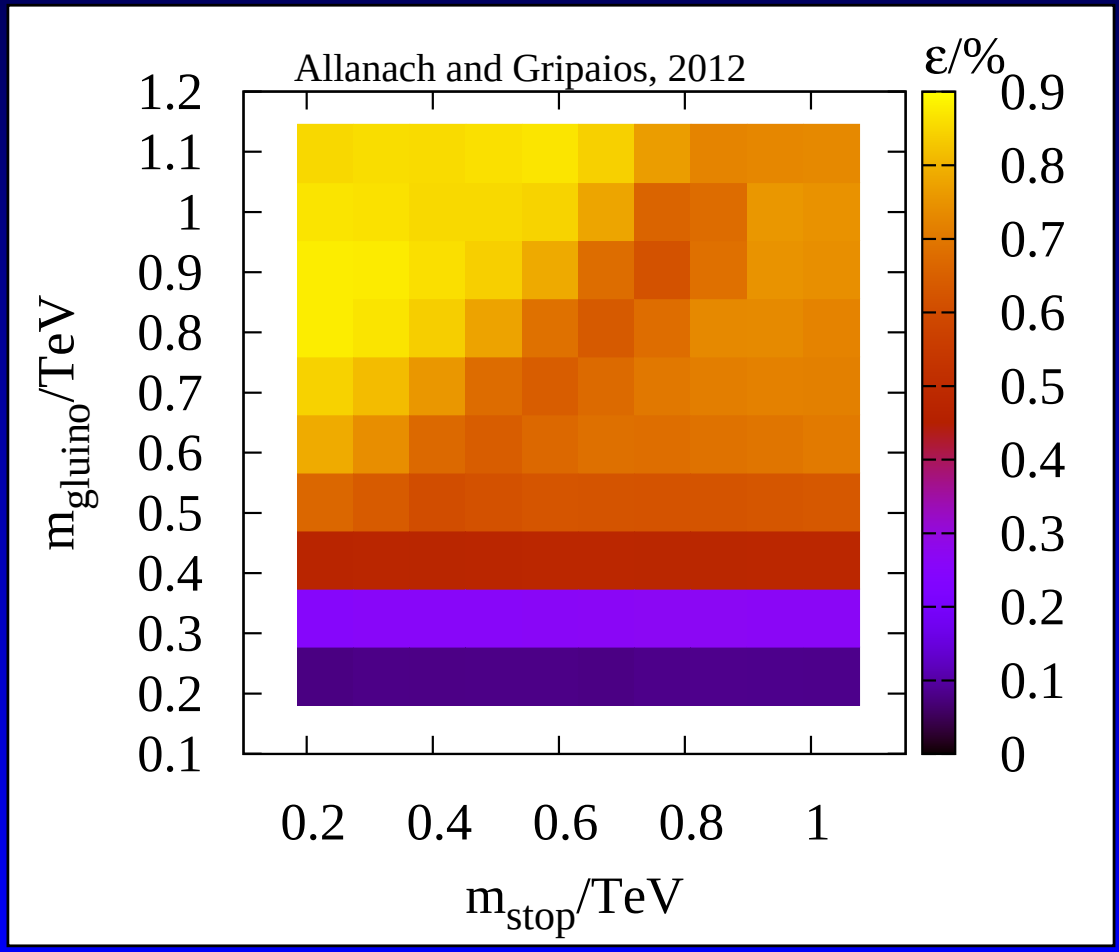


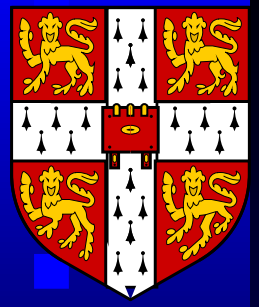
LH panel: N_J, RH panel: $N_{isol\ e,\mu}$

Efficiencies of CMS$ll\not{E}_T$

$$\epsilon = \frac{\text{SUSY events past cuts}}{\text{SUSY events}}$$

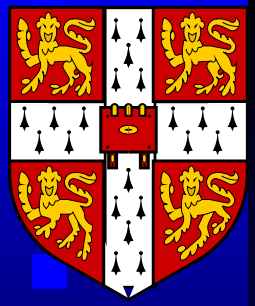
You pay for the di-leptonic tt branching ratio.





Summary

- R_p violation allows natural SUSY with lightish gluinos and squarks that have not yet been ruled out by searches.
- Same-sign dilepton searches *without* huge $\not{E}_T$ cut will be interesting. It covers almost all possible cases of RPV operator.
- In case of $U_i D_j D_k$ operators, current searches $\Rightarrow m_{\tilde{g}} > 550$ GeV.
- Opportunity to tailor searches including $b-$tags, leptons and jets.
- Many other channels to look at which may have higher sensitivity than di-leptons.



Backup

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