The Same-Sign Dilepton Signature of RPV/MFV SUSY

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Based on the paper by
Joshua Berger, Maxim Perelstein, M.S., Philip Tanedo
arXiv:1302.2146

1. Model and motivation
2. Recasting 8 TeV CMS data
3. Adding jet substructure cuts

SUSY with light 3rd generation

$$\delta m_{H_u}^2|_{\text{stop, LL}} = -\frac{3}{8\pi^2} y_t^2 \left(m_{Q_3}^2 + m_{u_3}^2 + |A_t|^2\right) \ln\left(\frac{\Lambda}{\text{TeV}}\right)$$

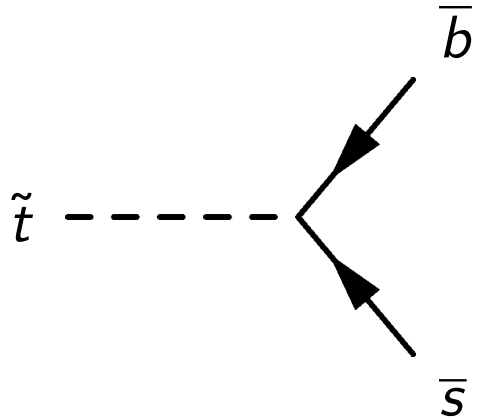
$$\delta m_{H_u}^2|_{\text{gluino, LL}} = -\frac{2}{\pi^2} y_t^2 \left(\frac{\alpha_s}{\pi}\right) |M_3|^2 \ln^2\left(\frac{\Lambda}{\text{TeV}}\right)$$

- Natural SUSY implies light stops and gluinos
- No signs of stops or gluinos at the LHC yet
  - $2 \times (\tilde{t} \to t + \tilde{\chi}^0)$ searches exclude $m_{\tilde{t}} \lesssim 600$ GeV
  - $2 \times (\tilde{g} \to t\bar{t} + \tilde{\chi}^0)$ searches exclude $m_{\tilde{g}} \lesssim 1$ TeV

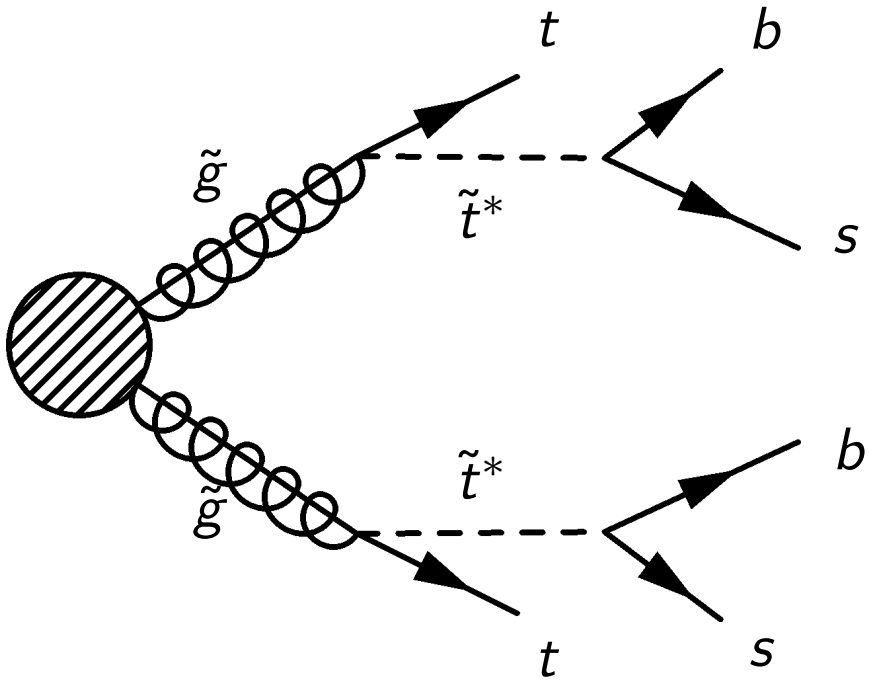
R-Parity Violation / Minimal Flavor Violation

- But these searches rely on R-parity conservation!
  - Theoretically, requires SUSY pair production, forbids proton decay, etc.
  - Experimentally, generates neutral LSP $\Longrightarrow \not{E}_T$
- What if R-parity is not conserved?
  - Theoretically, still leads to viable models
    - e.g. Minimal Flavor Violation (MFV) (Csáki, Grossman, Heidenreich)
  - Experimentally, forces us to look for $\not{E}_T$-less SUSY signals

$$W \supset \lambda''_{ijk} U_i D_j D_k$$



SSDL RPV signal



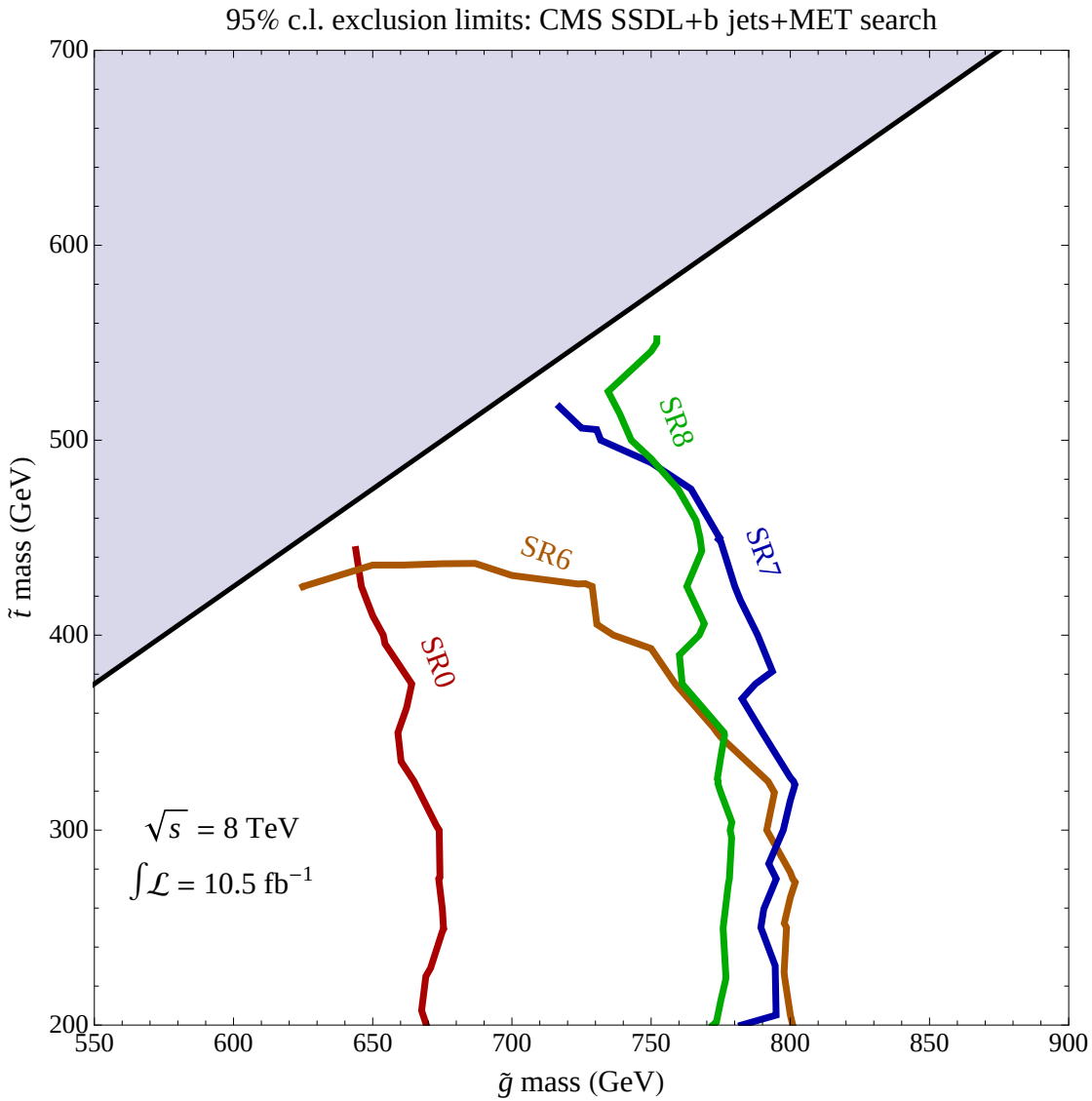
- Simplified model with light stop and gluino
  - Require all particles on-shell: $m_{\tilde{g}} > m_{\tilde{t}} + m_t$
- Same-sign dilepton (SSDL) signature with up to 4 b jets and little $\not{E}_T$

8 TeV CMS search (CMS-SUS-12-017)

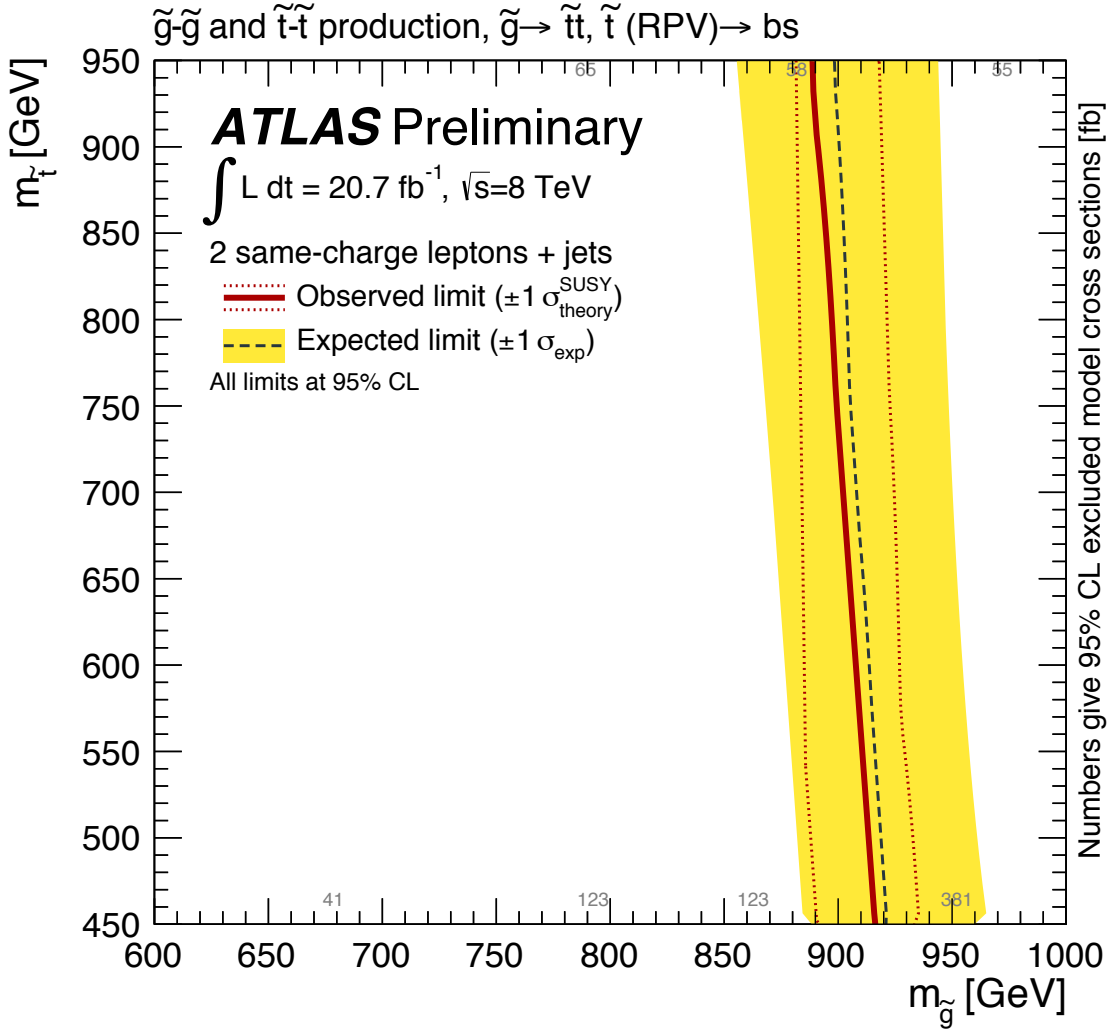
	SR6	SR7	SR8
# of jets	≥ 4	≥ 3	≥ 4
# of b-tags	≥ 2	≥ 3	≥ 2
$\not{E}_T$	> 120 GeV	> 50 GeV	> 0 GeV
H_T	> 320 GeV	> 200 GeV	> 320 GeV

- Recasted the most recent CMS search for SSDL and b jets: 8 TeV run, 10.5 fb^{-1} (ICHEP)
  - $R = 0.5$ anti-kt jets with $p_T > 40$ GeV
  - Leptons with $p_T > 20$ GeV
  - Z veto
- Generated MC signal events in Pythia; calculated NLO cross section in Prospino
- Followed the analysis procedure suggested by CMS, except for calculating our own lepton isolation efficiencies
- Compared our predicted numbers of signal events to the published 95%CL bounds

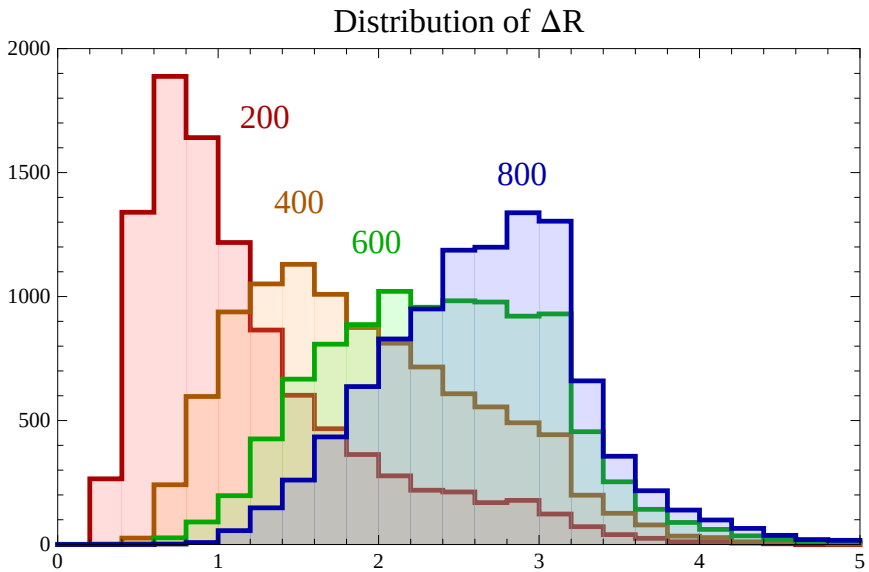
Recast with 10.5 fb^{-1} of data



ATLAS 8 TeV with 20.7 fb^{-1} of data (ATLAS-CONF-2013-007)



Stop jets

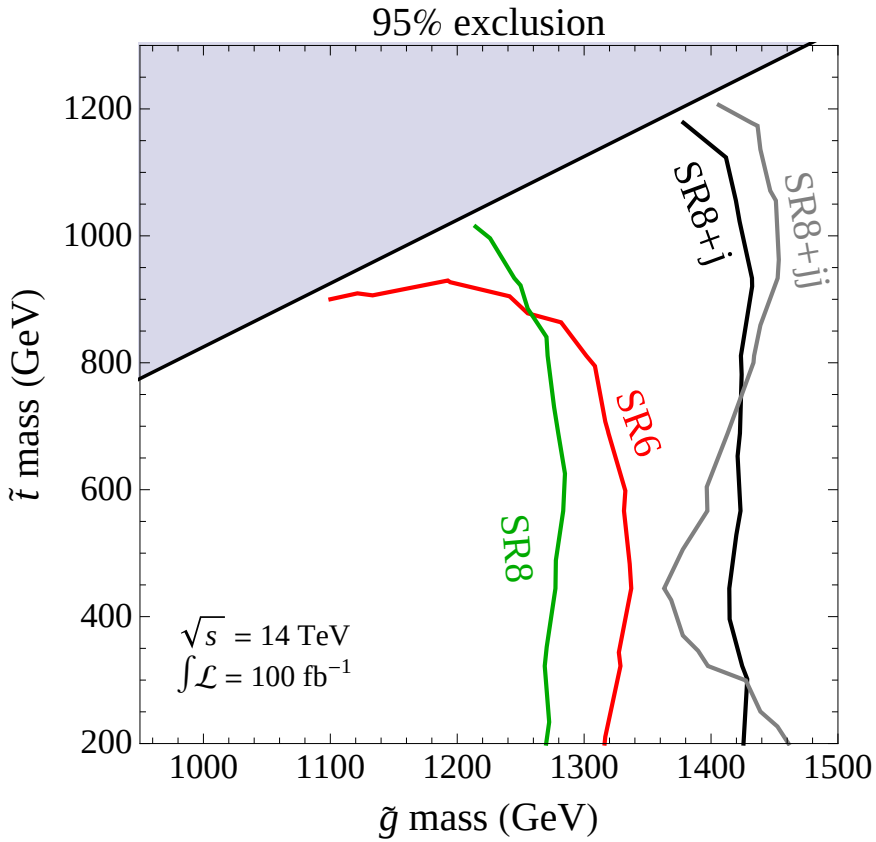


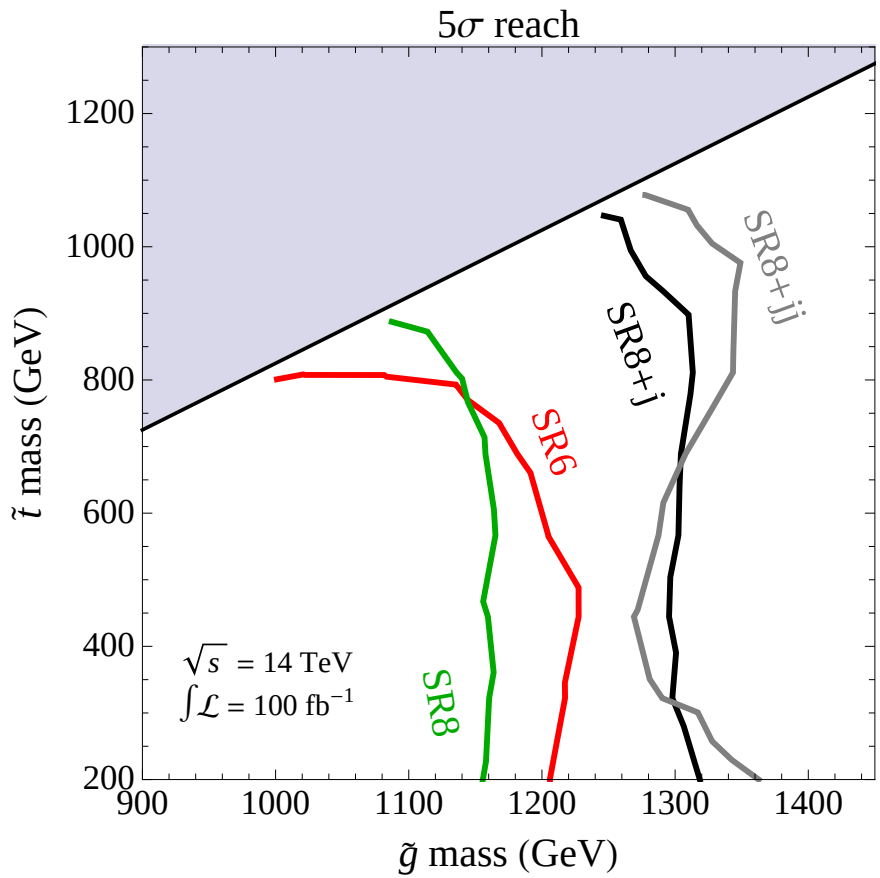
- If $m_{\tilde{t}} \ll m_{\tilde{g}}$, stops will lead to boosted stop jets
  - Jet substructure techniques: BDRS, N-subjettiness, etc.
  - Invariant mass

Jet mass cuts at 14 TeV and 100 fb^{-1}

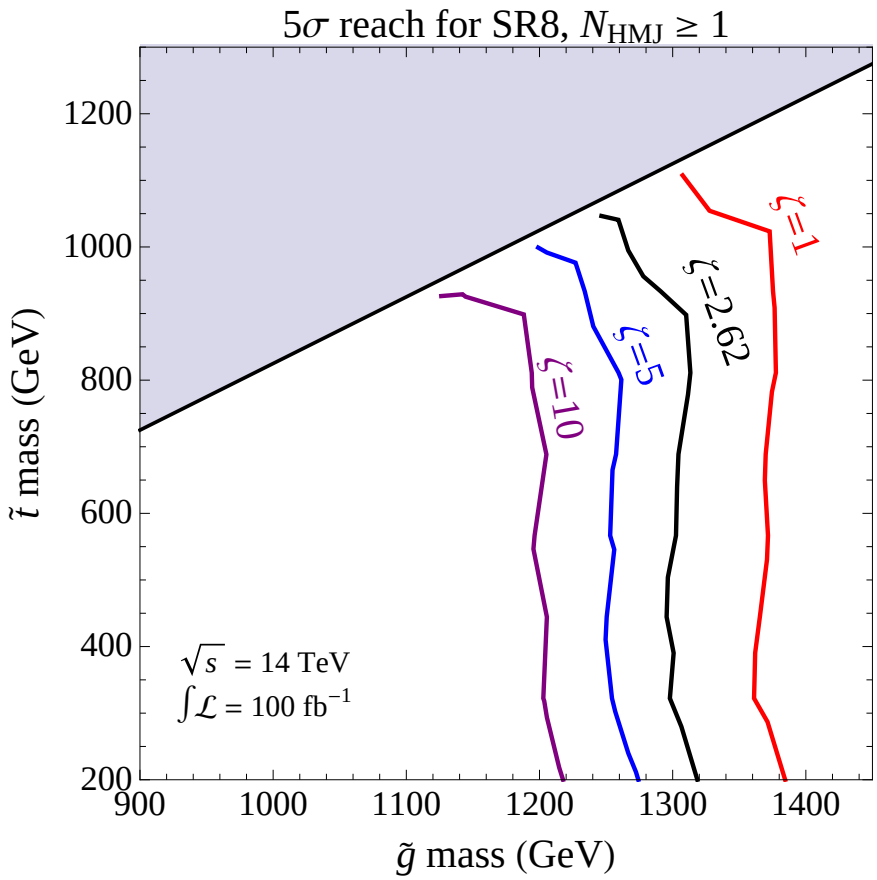
- What if we cut on the number of jets with invariant mass $> m_t$?
  - Already rate-limited at 8 TeV, so let's go up to 14 TeV and 100 fb^{-1}
- Simulate signal in Pythia with full hadronization; calculate NLO cross sections in Prospino
- Simulate irreducible bkgds ($t\bar{t}W$ and $t\bar{t}Z$) in MadGraph, hadronize in Pythia; scale to NLO cross sections
- Reducible bkgd cross section:
  - $\zeta = (\text{Total bkgd rate})/(\text{Irreducible bkgd rate})$
  - Compute ζ from CMS study at 8 TeV
  - Scale irreducible rate up to 14 TeV with $\sigma_{t\bar{t}W}$ and $\sigma_{t\bar{t}Z}$
  - Scale reducible rate up to 14 TeV with $\sigma_{t\bar{t}}$
  - Apply new estimate for ζ at 14 TeV
- Cluster jets with $R = 1.0$ anti-kt

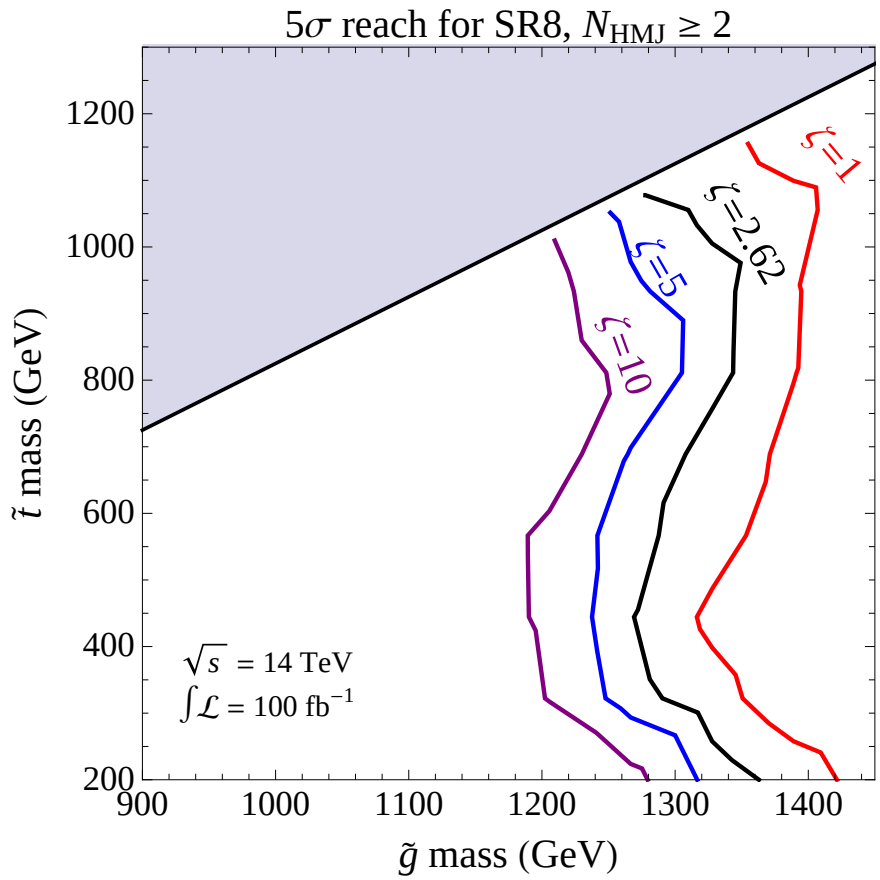
Jet mass cuts at 14 TeV and 100 fb^{-1}





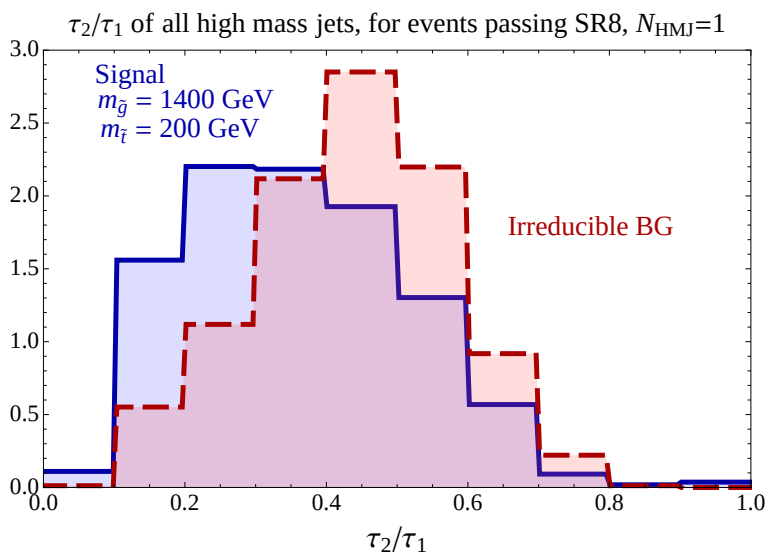
Jet mass cuts at 14 TeV and 100 fb^{-1}

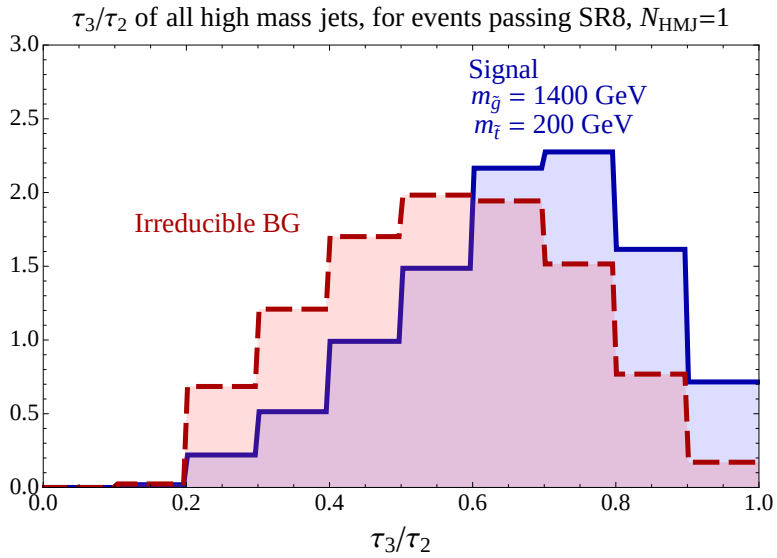




- Results do not vary much with ζ!
- Evidence of accidental substructure (Cohen, Izaguirre, Lisanti, Lou)

N-subjettiness (Thaler, Van Tilburg)





Final discussion

- RPV/MFV SUSY predicts an SSDL w/ b-jets signature at the LHC.
- ATLAS and CMS currently exclude this model for $m_{\tilde{g}} < 800 - 900$ GeV.
- The CMS search at 14 TeV and 100 fb^{-1} should be able to exclude this model for $m_{\tilde{g}} < 1.3$ TeV.
- Adding a cut on the number of jets with $m > m_t$ improves the exclusion to $m_{\tilde{g}} < 1.45$ TeV.
- Similar techniques can be used for non-MFV models of RPV SUSY, as well as for Dirac gluinos.