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
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1. Model and motivation
2. Current bounds from 8 TeV CMS data
3. Improvements with jet substructure

SUSY with light 3rd generation

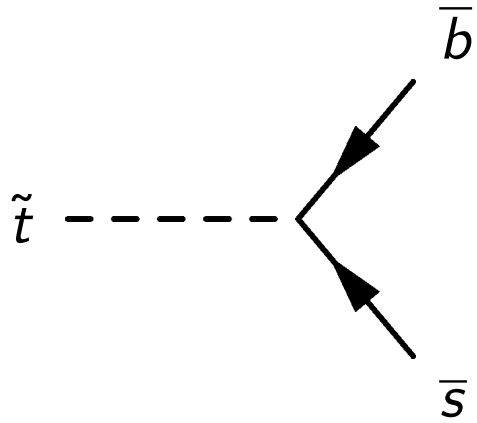
$$\delta m_{H_u}^2|_{\text{stop, LL}} = -\frac{3}{8\pi^2} y_t^2 \left(m_{Q_3}^2 + m_{u_3}^2 + |A_t|^2\right) \ln\left(\frac{\Lambda}{\text{TeV}}\right)$$

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

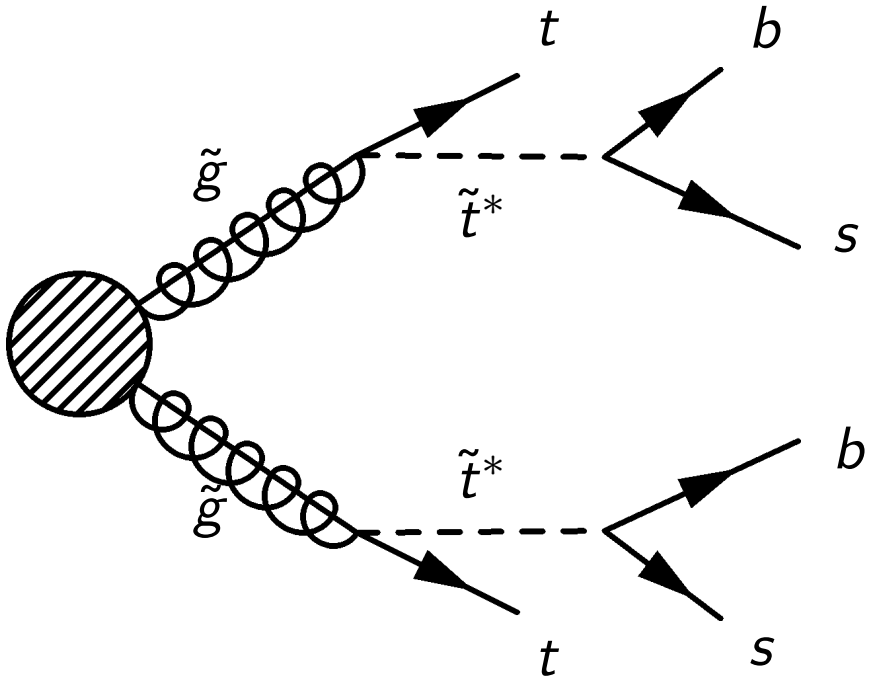
- Natural SUSY implies light stops and gluinos
- No signs of stops or gluinos at the LHC yet
  - $2 \times (\tilde{t} \to t + \tilde{\chi}^0)$ searches exclude $m_{\tilde{t}} \lesssim 600$ GeV
  - $2 \times (\tilde{g} \to t\bar{t} + \tilde{\chi}^0)$ searches exclude $m_{\tilde{g}} \lesssim 1$ TeV

R-Parity Violation / Minimal Flavor Violation

- But these searches rely on R-parity conservation $\Longrightarrow \not{E}_T$
- What if R-parity is not conserved?
  - e.g. Minimal Flavor Violation (MFV) (Csáki, Grossman, Heidenreich '11)
    - The only flavor-breaking spurions are holomorphic Yukawas
    - RPV couplings suppressed by Yukawas and CKM elements
    - $W \supset \lambda''_{ijk} U_i D_j D_k$
  - Forces us to look for $\not{E}_T$-less SUSY signals



SSDL RPV signal



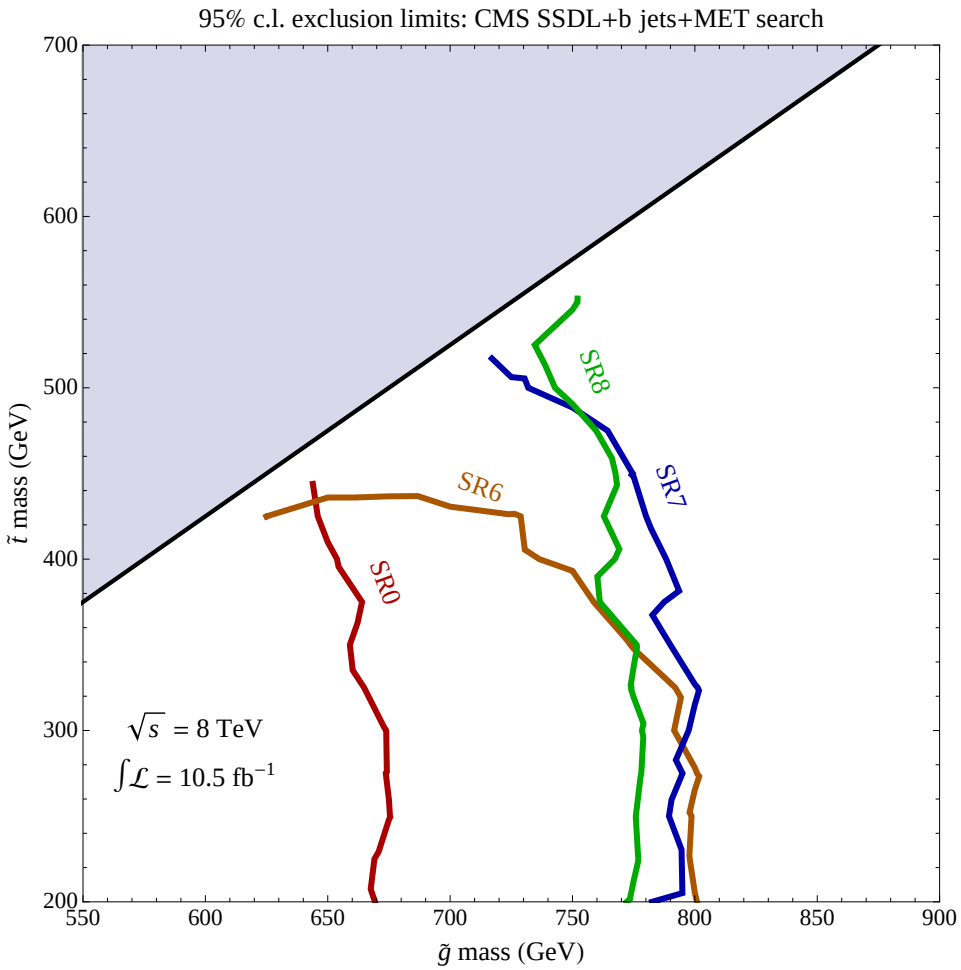
- Simplified model with light stop and gluino
  - Gluinos decay to top and stop
  - Stops decay via MFV coupling to b and s
  - Require all particles on-shell: $m_{\tilde{g}} > m_{\tilde{t}} + m_t$
- Same-sign dilepton (SSDL) signature with up to 4 b jets and low $\not{E}_T$
  - SSDL has very low SM background, so no $\not{E}_T$ cut needed

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
Total BG	1.7 ± 0.7	1.2 ± 0.6	8.1 ± 3.3
Event yield	1	1	9
N_{UL} (30% unc.)	3.9	4.0	10.5

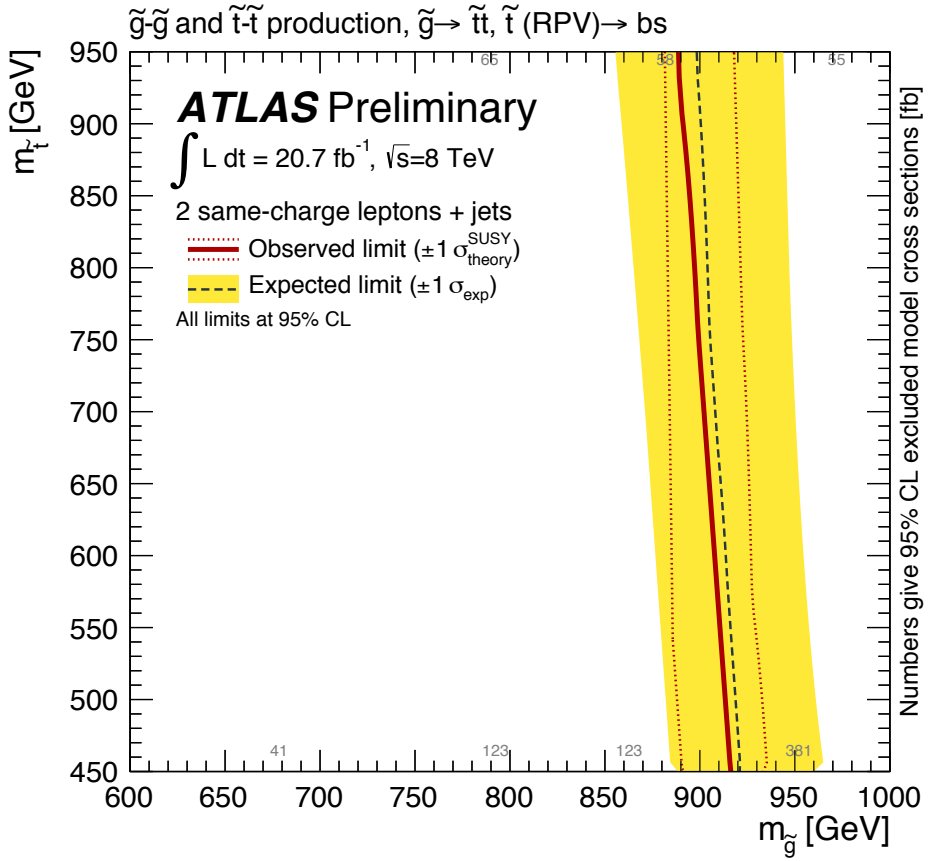
- Recasted the most recent CMS search for SSDL and b jets:
  8 TeV run, 10.5 fb^{-1} (ICHEP)
  - $R = 0.5$ anti-kt jets with $p_T > 40$ GeV
- 10k MC signal events in Pythia; NLO cross section from Prospino
- Followed the analysis procedure suggested by CMS, except for calculating our own lepton isolation efficiencies
  - Our signal tends to have more hadronic activity near leptons than their benchmark model

Recast with 10.5 fb^{-1} of data



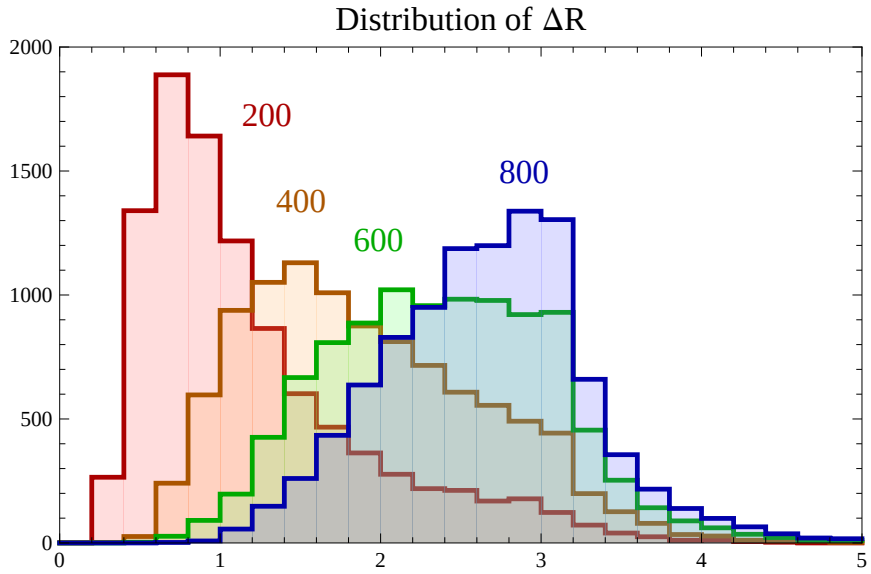
- $m_{\tilde{g}} \lesssim 800$ GeV excluded at 95% CL

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



- $m_{\tilde{g}} \lesssim 900$ GeV excluded at 95% CL

Stop jets

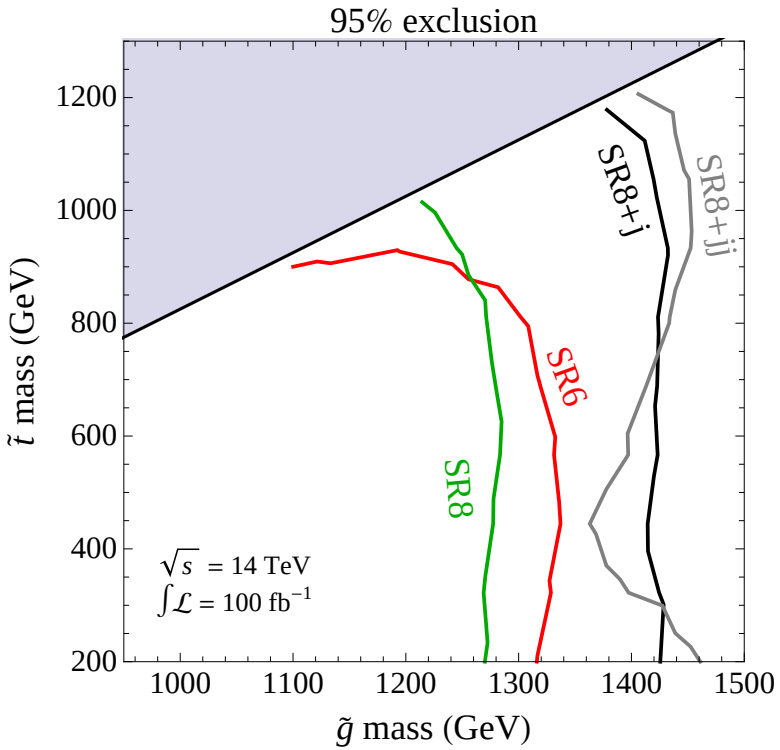


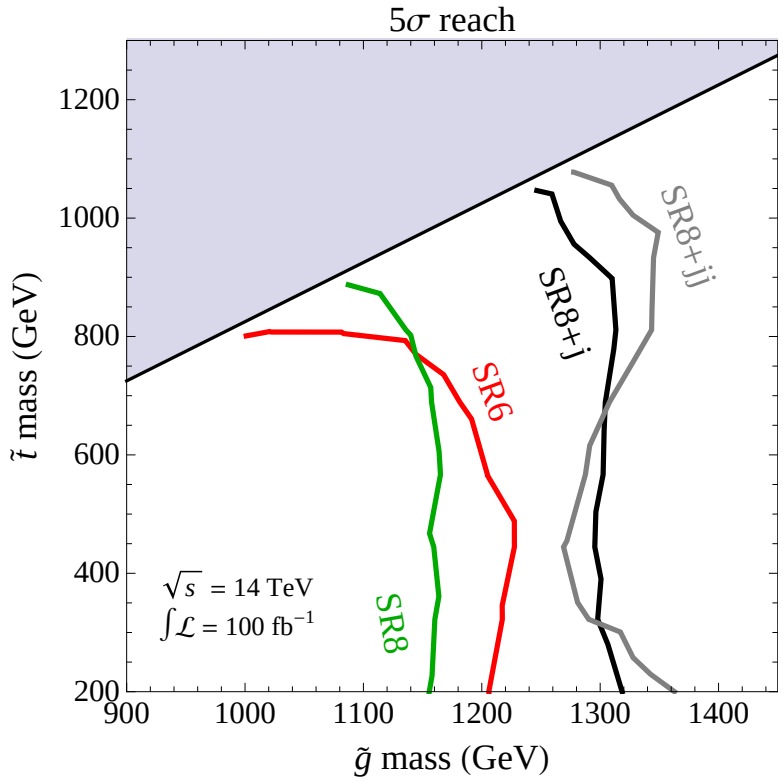
- If $m_{\tilde{t}} \ll m_{\tilde{g}}$, stops will lead to boosted stop jets
  - Invariant mass
  - Jet substructure techniques: BDRS, N-subjettiness, etc.
- If we can tag these stop jets, we can improve the reach for $m_{\tilde{t}} \ll m_{\tilde{g}}$

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

- What if we add a cut on the number of "high-mass jets" (jets with invariant mass $> m_t$)?
  - Already rate-limited at 8 TeV, so let's go up to 14 TeV and 100 fb^{-1}
- 10k signal events in Pythia with full hadronization
  - Scaled up to NLO cross sections from Prospino
- Irreducible bkgds: 500k $t\bar{t}W$ events and 500k $t\bar{t}Z$ events
  - MadGraph + Pythia; scaled up to NLO cross sections
- Reducible bkgd cross section:
  - $\zeta = (\text{Total bkgd rate})/(\text{Irreducible bkgd rate})$
  - Compute ζ at 8 TeV from CMS search
  - Estimate ζ at 14 TeV by scaling by dominant cross sections
- Cluster jets with $R = 1.0$ anti-kt

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

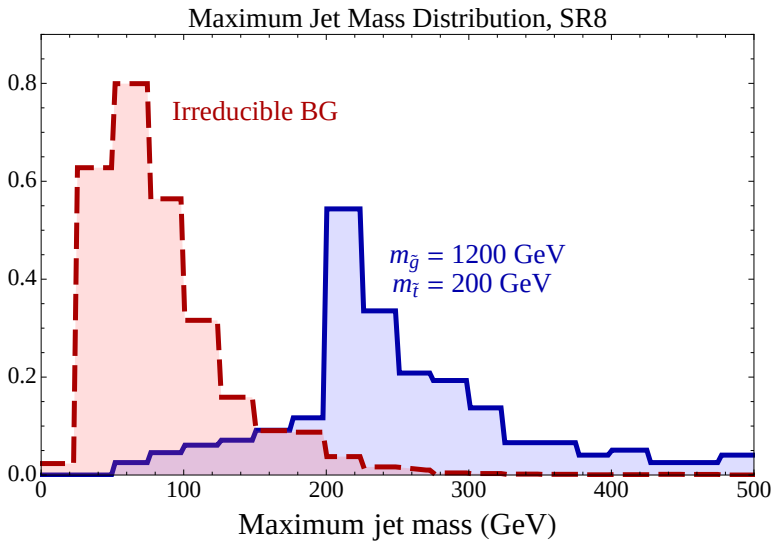




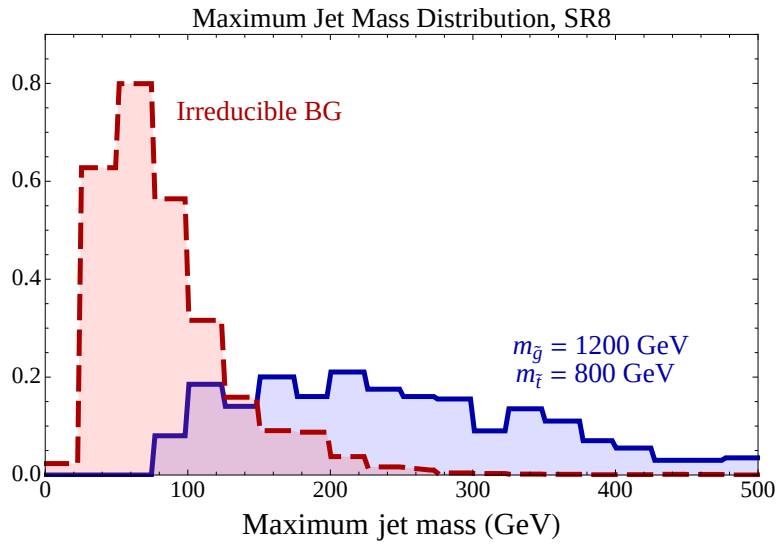
- Without jet mass cut, exclude $m_{\tilde{g}} \lesssim 1.3$ TeV
- With jet mass cuts, exclude $m_{\tilde{g}} \lesssim 1.45$ TeV

Accidental substructure

- Unrelated partons may be clustered together (Cohen, Izaguirre, Lisanti, Lou '12)
  - Especially true if heavy objects are produced near rest in the lab frame
  - Especially affects high multiplicity final states

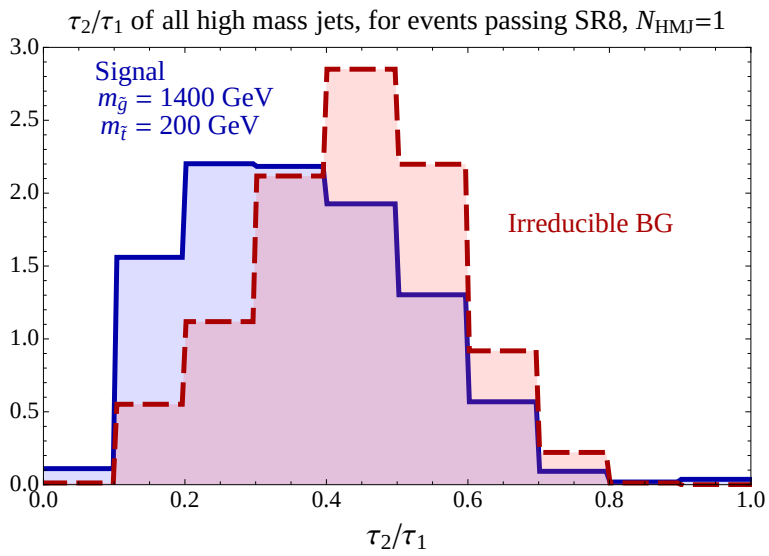


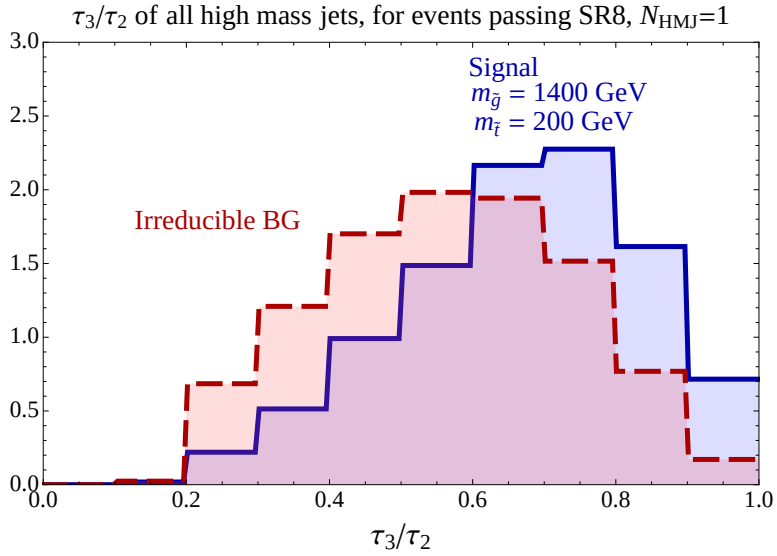
$m_{\tilde{t}} \ll m_{\tilde{g}}$



$m_{\tilde{t}} \sim m_{\tilde{g}}$

N-subjettiness (Thaler, Van Tilburg)





- Very small but nonzero separation between signal and background
- Potential for use in the future

Wider applicability

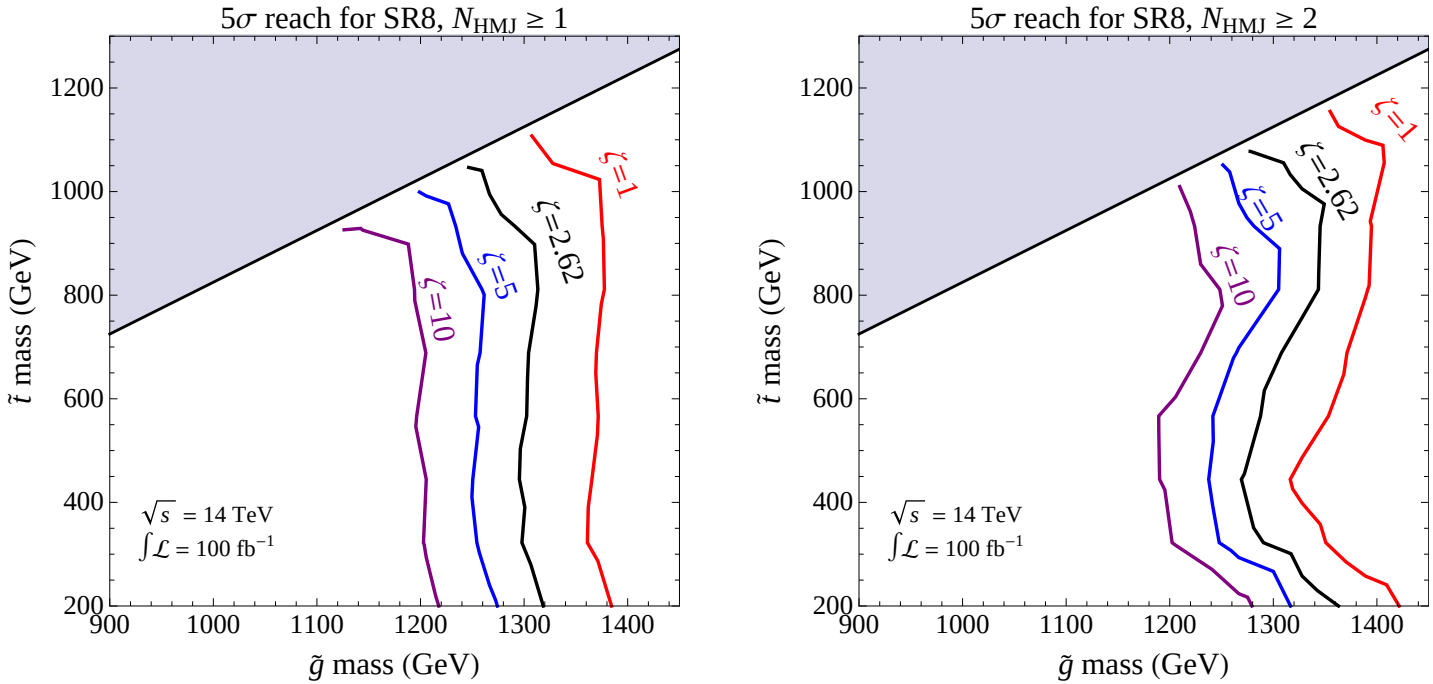
- Non-MFV models of RPV SUSY
  - Fewer b-jets, but still ≥ 2 b-jets from tops
- Dirac gluinos
  - OSDL, but jet substructure still helps

Summary

- 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.
- Wider applicability to non-MFV RPV, Dirac gluinos, etc.

Backup slides

ζ-dependence, or lack thereof



- Results do not vary much with $\zeta \sim (\text{Reducible bkgd rate})$!
- No reason to believe that cut efficiencies for reducible and irreducible backgrounds are remarkably different
- Even though we did not model the reducible backgrounds directly, we expect our results to be robust