Boosting Searches for RPV Naural SUSY via Gluino Cascades

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work in progress

Natural (effective) SUSY

Light 3rd gen. superpartners & Heavy 1st, 2nd gen. superpartners

; maintaining EW naturalness while ameliorating SUSY flavor/CP problems

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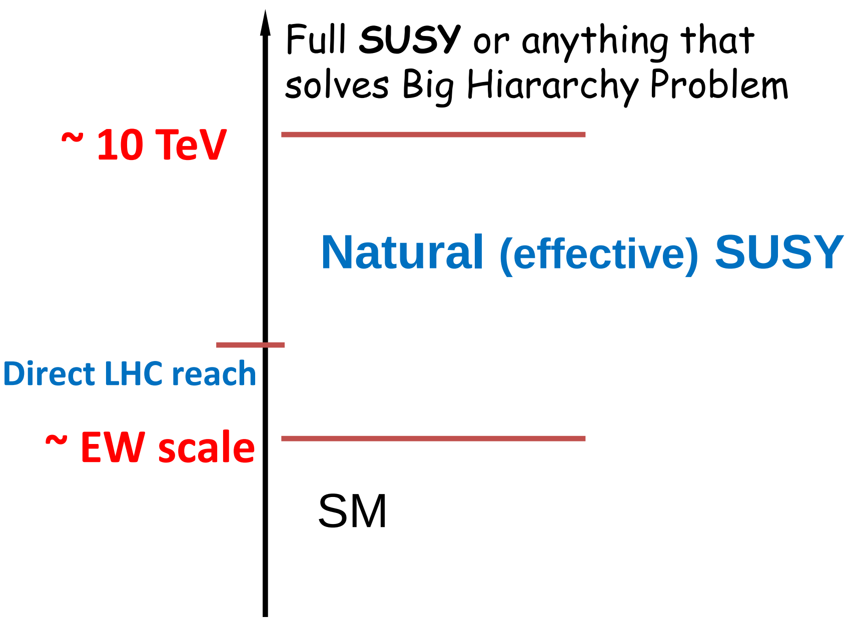
Bottom-Up Approach to Natural SUSY



Brust,Katz,Lawrence,Sundrum, '11

Ruderman, Papucci, Weiler '11 etc

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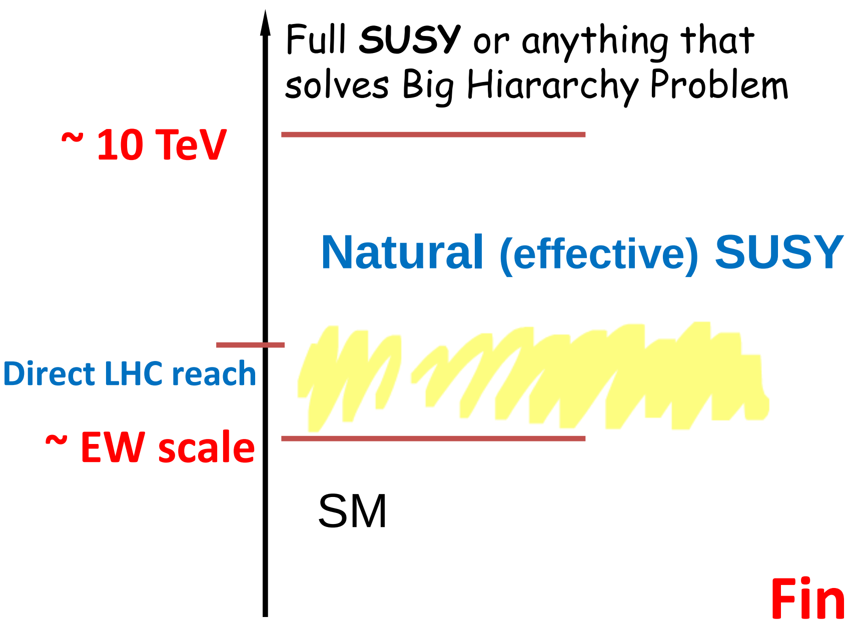

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1. Stop should not be heavy to cancel top-div. ~ 400 GeV is perfectly natural
2. LH sbottom $\tilde{b}_L$ should be light due to SU(2)L
3. Gluino $\tilde{g}$ at two-loop Higgs mass. $m_{\tilde{g}} < 2\, m_{\tilde{t}}$ (Majorana), 2x for Dirac gluino
4. Bino, Wino is not arbitarily heavy for naturalness, m < TeV
5. RH sbottom $\tilde{b}_R$ should be in spectrum to cancel $U(1)_Y$ D-term div. < TeV
6. Hisggino should not too heavy to avoid tree-level FT between μ and soft masses
7. All other particles ~ 10 TeV

Finding/excluding light 3rd gen. superpartners @ LHC is very important

R-Parity Violation (RPV)

Once we take low scale effective SUSY, R-parity starts losing some of its important motivations, e.g. QQQL will cause a rapid proton decay.

We need to either consider UV completions which are supersymmetric with R-parity or think of any other symmetry (e.g. L or B number) for proton decay.

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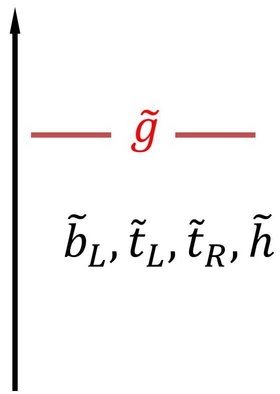
We will consider RPV in this talk, focusing on

$$W = \lambda\, UDD$$

λ is strong enough for squarks to decay promptly
λ is weak enough for squarks to avoid low-energy precision data/single-production
E.g. $\lambda > 10^{-7}$ (in absence of any suppression factor)

- Other RPV couplings LLE, LQD give leptons. They might be easy to spot.
- UDD is challenging, e.g. jetty final states.
- Use Lepton number conservation to forbid proton decay
- Stop/sbottom LSP always decay to either jets or a top and jets

Simplified Model with $\tilde{b}_L, \tilde{t}_L, \tilde{t}_R, \tilde{h}$ (assume: stop LSP)



1. Imagine very low cutoff scale ~ 1 TeV and postpone all theoretical issues to a more (non-minimal) theory beyond this low cutoff
2. It is a reasonable to assume that this could be a part of more complete UV-completion
3. We stick to stop LSP scenario (Higgsino or sbottom LSP leads to different story)

+ RPV UDD coupling

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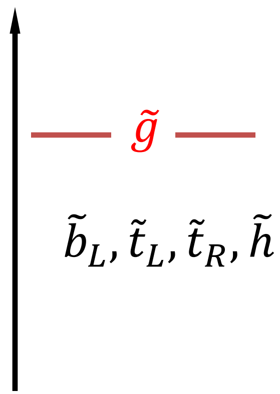

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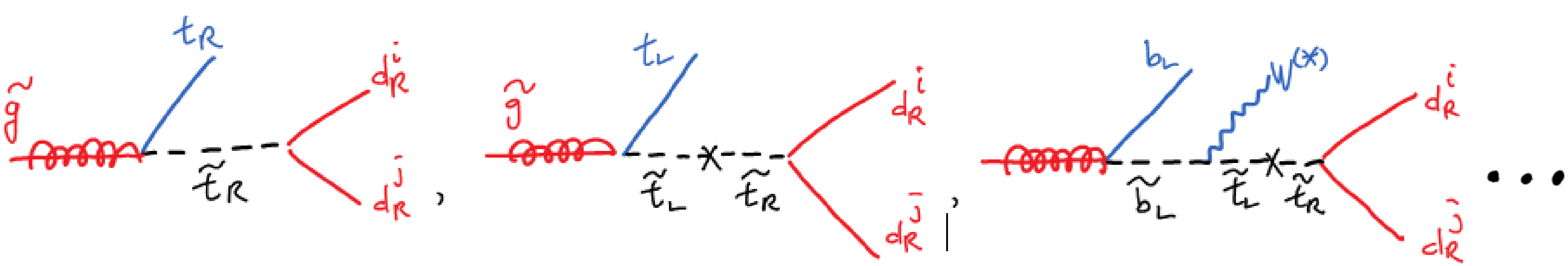
Gluino Decay via UDD



Current Status of RPV Natural SUSY

Stop Pair Production leads to 4 jets final state (dijet resonance pair)

1. Currently no meaningful bound from ATLAS/CMS on stop decaying dijet

   (not aware of any bound from Tevatron)

2. LEP bound on stop via UDD: mstop > 85 GeV, CERN-EP/2002-071

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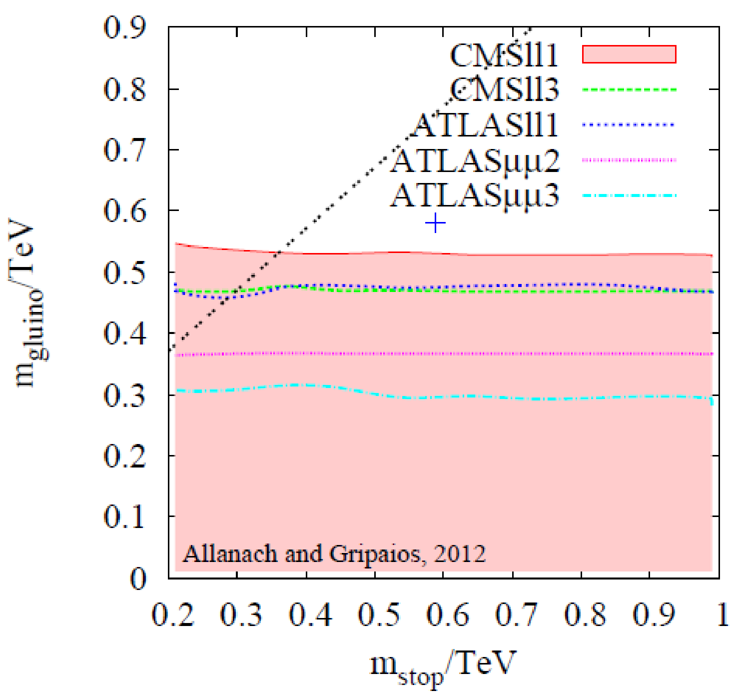
Gluino-Mediated Stop Search in RPV SUSY (UDD)

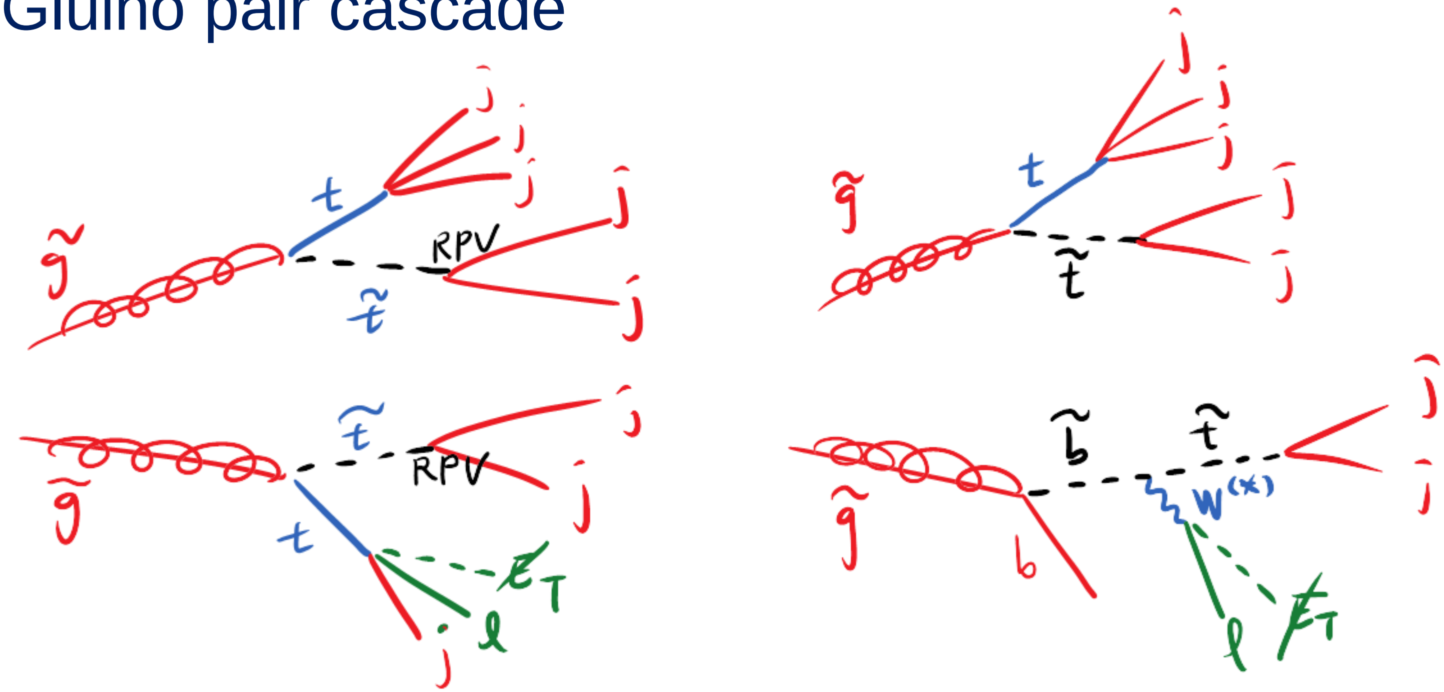
Allanach, Gripaios '12



1. Constraint on Majorana gluino in same sign dilepton search.
2. not directly translated to (partial) Dirac gluino
3. They assume that stop likely go to off-shell near/below the threshold
4. Note that on-shell stop/top decay region has very small exclusion region

Boosting searches for RPV Natural SUSY via Gluino Cascades

Gluino pair cascade



1. Dijet bump associated with tops could be very suggestive hint that we are really seeing top partner
2. The mass gap between gluino and (s)tops could boost stop/tops (therefore, better handle)
3. We do not attempt to reconstruct all objects, e.g. just trying to catch some of them

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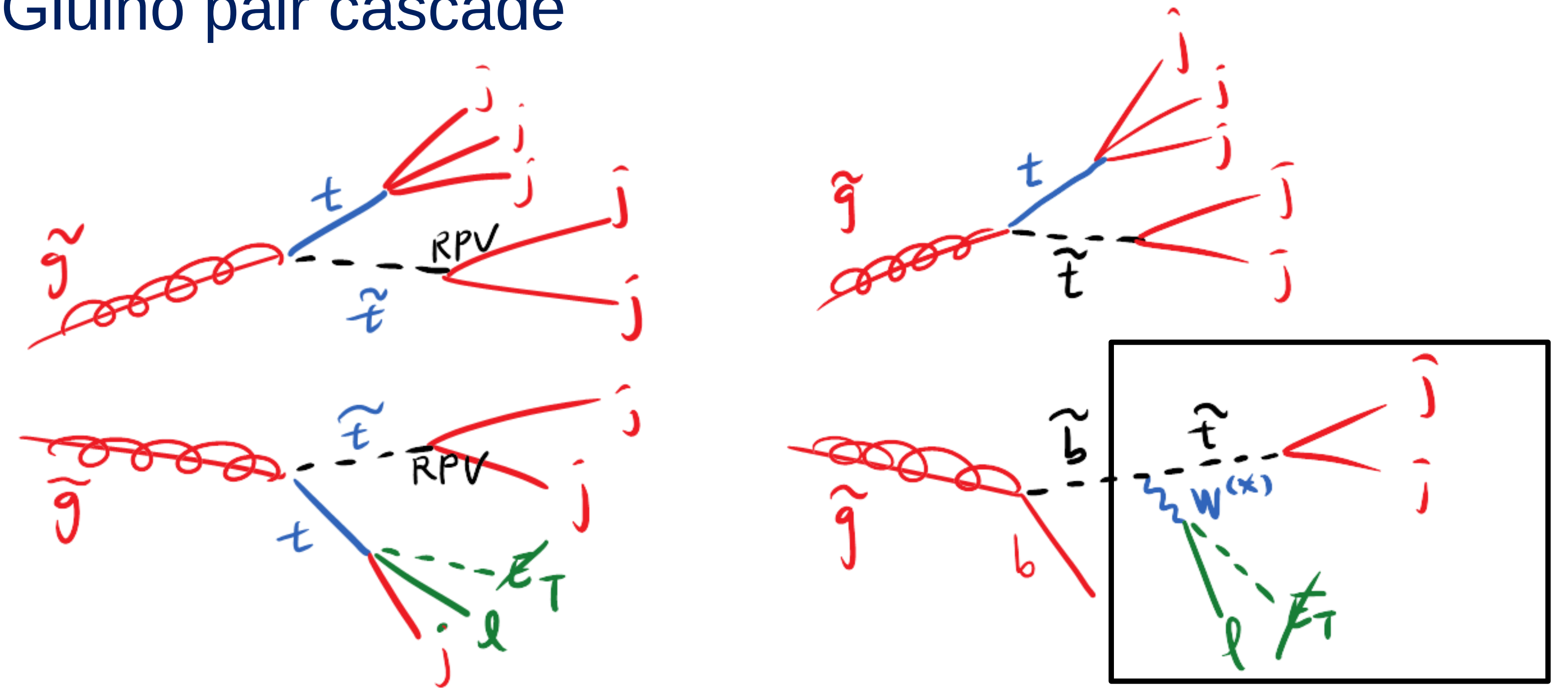

studied by Brust,Katz,Sundrum '12

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RPV SUSY hunting @8TeV

Natural SUSY

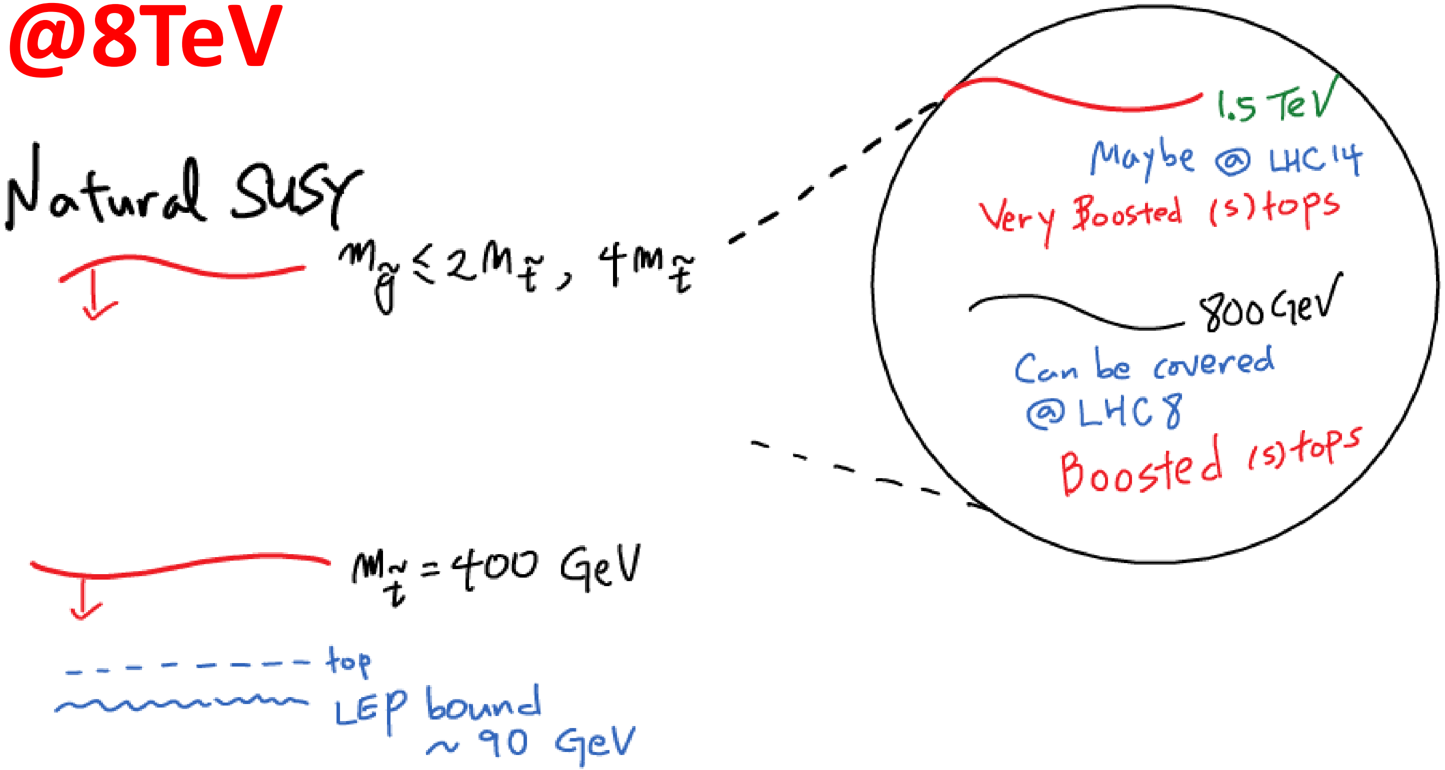
$m_{\tilde{g}} \lesssim 2m_{\tilde{t}},\ 4m_{\tilde{t}}$

$m_{\tilde{t}} = 400$ GeV

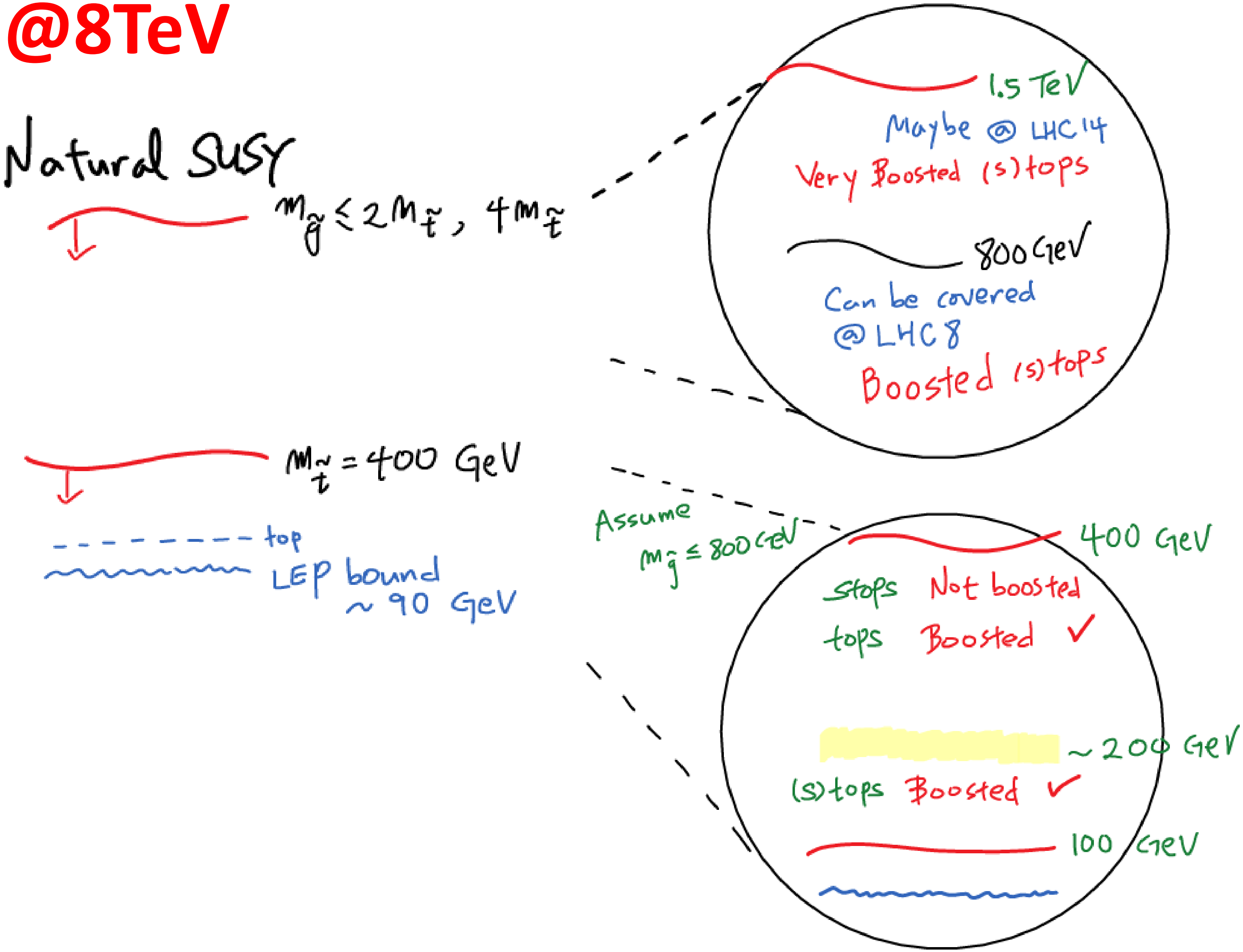
top

LEP bound
~ 90 GeV

RPV SUSY hunting @8TeV



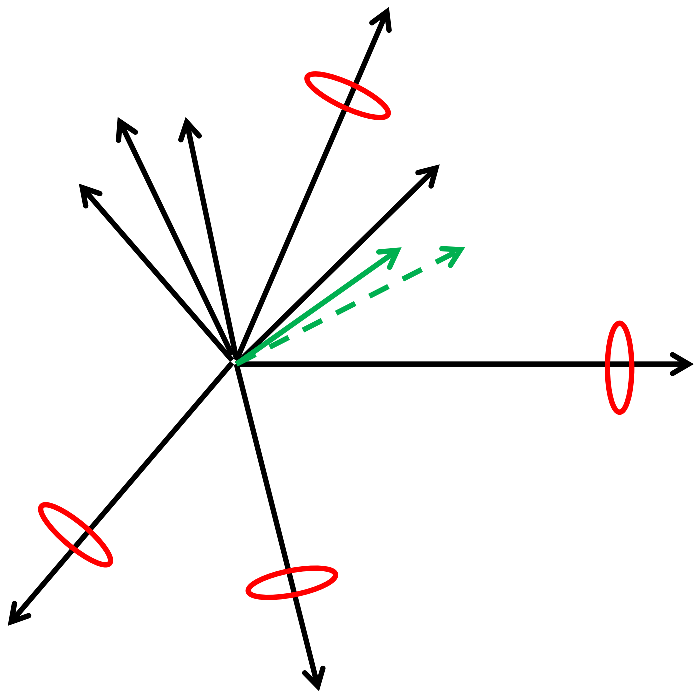
RPV SUSY hunting @8TeV



High stop mass search

Low stop mass search

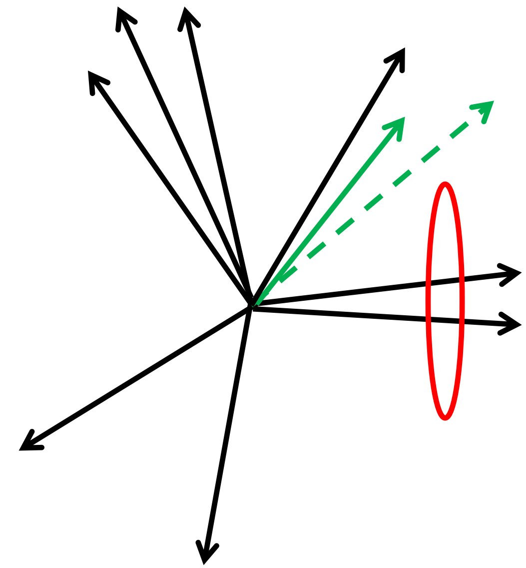
High stop mass search



Keyword: **Mass Hierarchy**

Traditional jets + TopTagger

Low stop mass search



Keyword: **BOOSTed**

TopTagger + Fat-stop-jet

Overall procedure

Decide gluino scale of interest

↓

hT, pT cuts

↙ ↘

High stop mass search (not boosted)

Low stop mass search (boosted)

do not ask too much for top (unless you need)

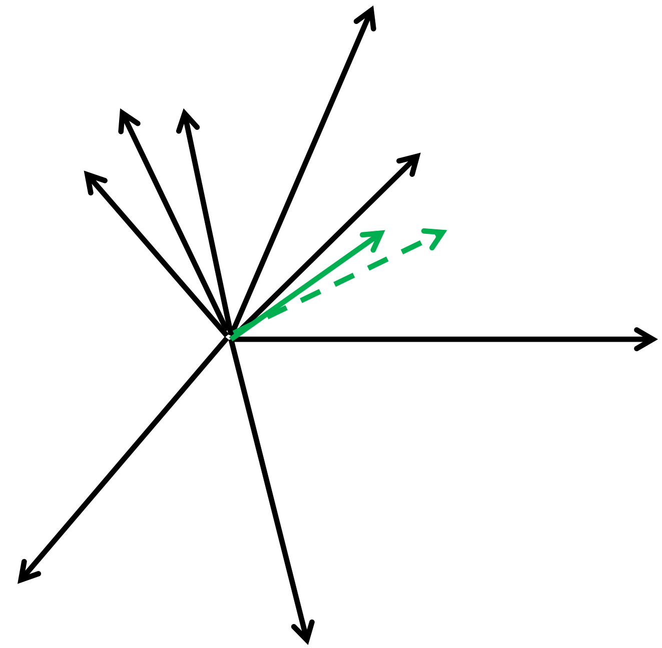
↓

Purify top → **reco gluino if possible**

1. Main targets are dijet bumps in gluino cascades.
2. Major background is ttbar + nj. Top tagging itself does not improve S/B much.
3. Strict top identification only after finding dijet bump, e.g. once we observe dijet resonance bump we need to figure out who this guy is. Associated top could carry an important information about its identity.

High stop mass search

$m_{\tilde{t}}/m_{\tilde{g}} > 1/4$



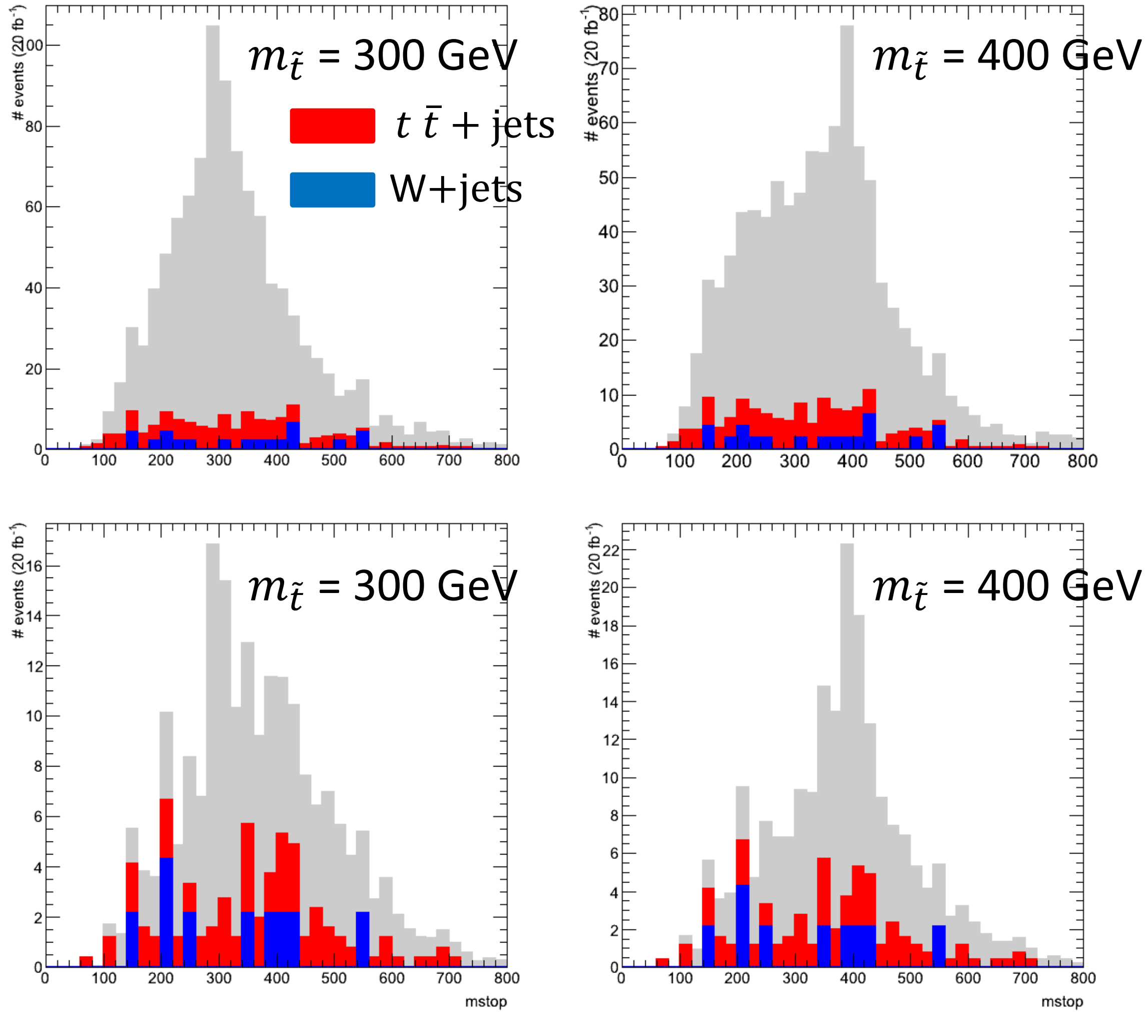
1. Lepton Isolation
2. Jet clustering: 0.4 anti-Kt
3. Take 5 leading jets and look for dijet pairs with the smallest mass difference
4. Remove four jets from step 3
5. Jet clustering on the remaining: 1.5 C/A
6. Run TopTagger (e.g. HEPTopTagger)
7. Demand is_maybe_top() without imposing top mass window

Note: reconstructing leptonic top might also be possible (reconstruct gluino too ?)

SUSY at bumps: High stop mass

$m_{\tilde{t}}/m_{\tilde{g}} > 1/4$

L = 20/fb @8TeV



600 GeV (Dirac)

hT > 900 GeV
ptj (1st ~4th) > 90 GeV
Br ($\tilde{g}\tilde{g}$->2top+2stop) = 1/2
(rescale to your Br)

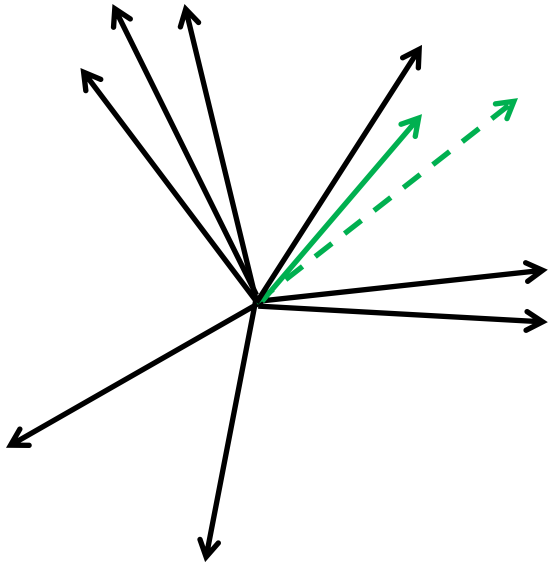
800 GeV (Dirac)

hT > 1100 GeV
ptj (1st ~4th) > 100 GeV
Br ($\tilde{g}\tilde{g}$->2top+2stop) = 1/2
(rescale to your Br)

Signal: MG5 w/ RPV MSSM_UFO + Pythia8, Bkg: MG5| fastjet2.4.1
no PU, no k-factor, no detector effect, no smearing are included

Low stop mass search

$m_{\tilde{t}}/m_{\tilde{g}} < 1/4$



1. Lepton Isolation
2. Jet clustering: 1.5 C/A
3. Run TopTagger (e.g. HEPTopTagger)
4. Demand W-boson in loosely tagged top-candidates
5. Choose the one whose mass is cloesest to top mass if multiple candidates exist
6. Remove top-candidate from step 5
7. Run BDRS on the hardest fat-jet among the remaining
8. Form Dijet mass out of two subjets from step 7

Note: reconstructing leptonic top might also be possible (reconstruct gluino too ?)

SUSY at bumps: Low stop mass

L = 20/fb @8TeV

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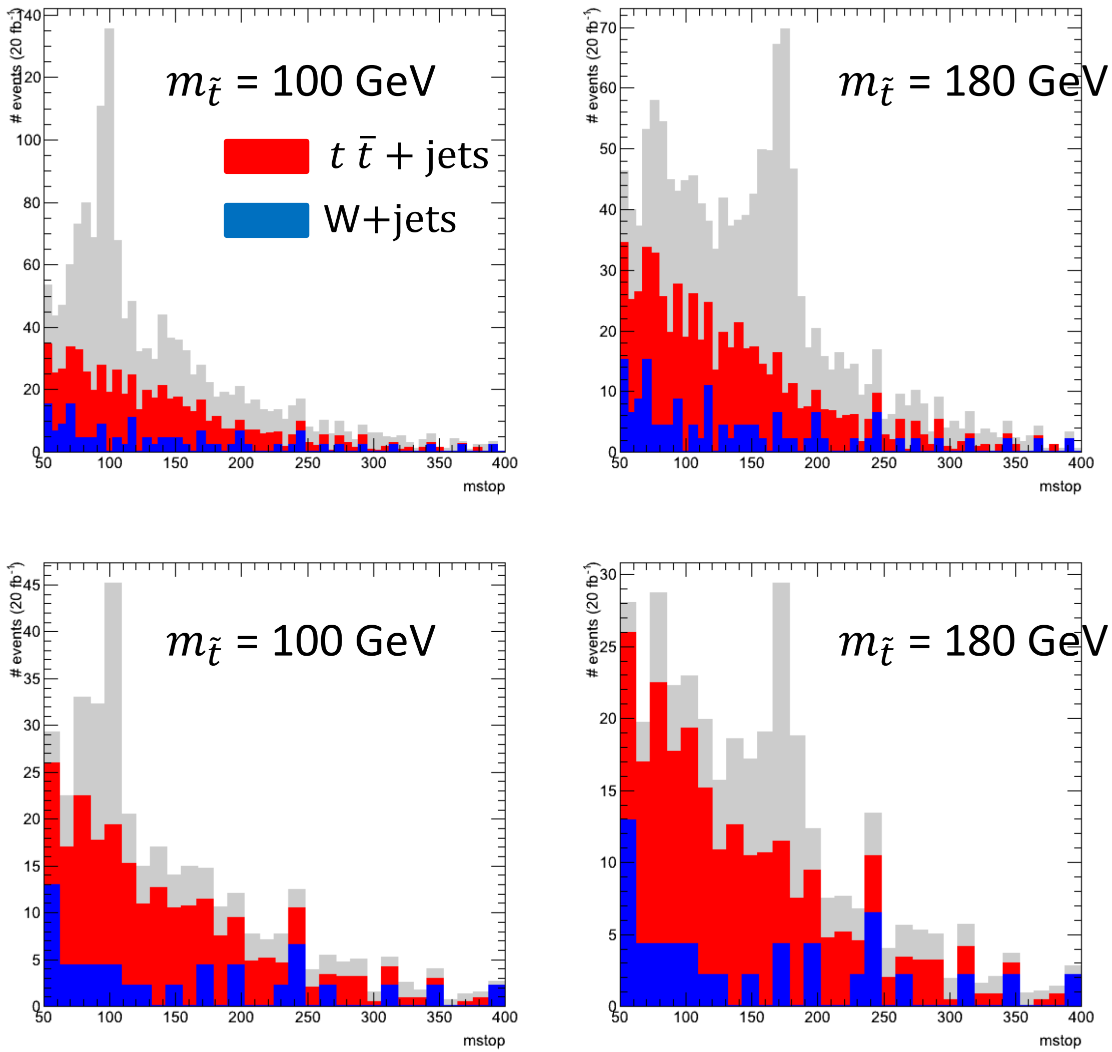

600 GeV (Dirac)

hT > 900 GeV
mtop > 140 GeV
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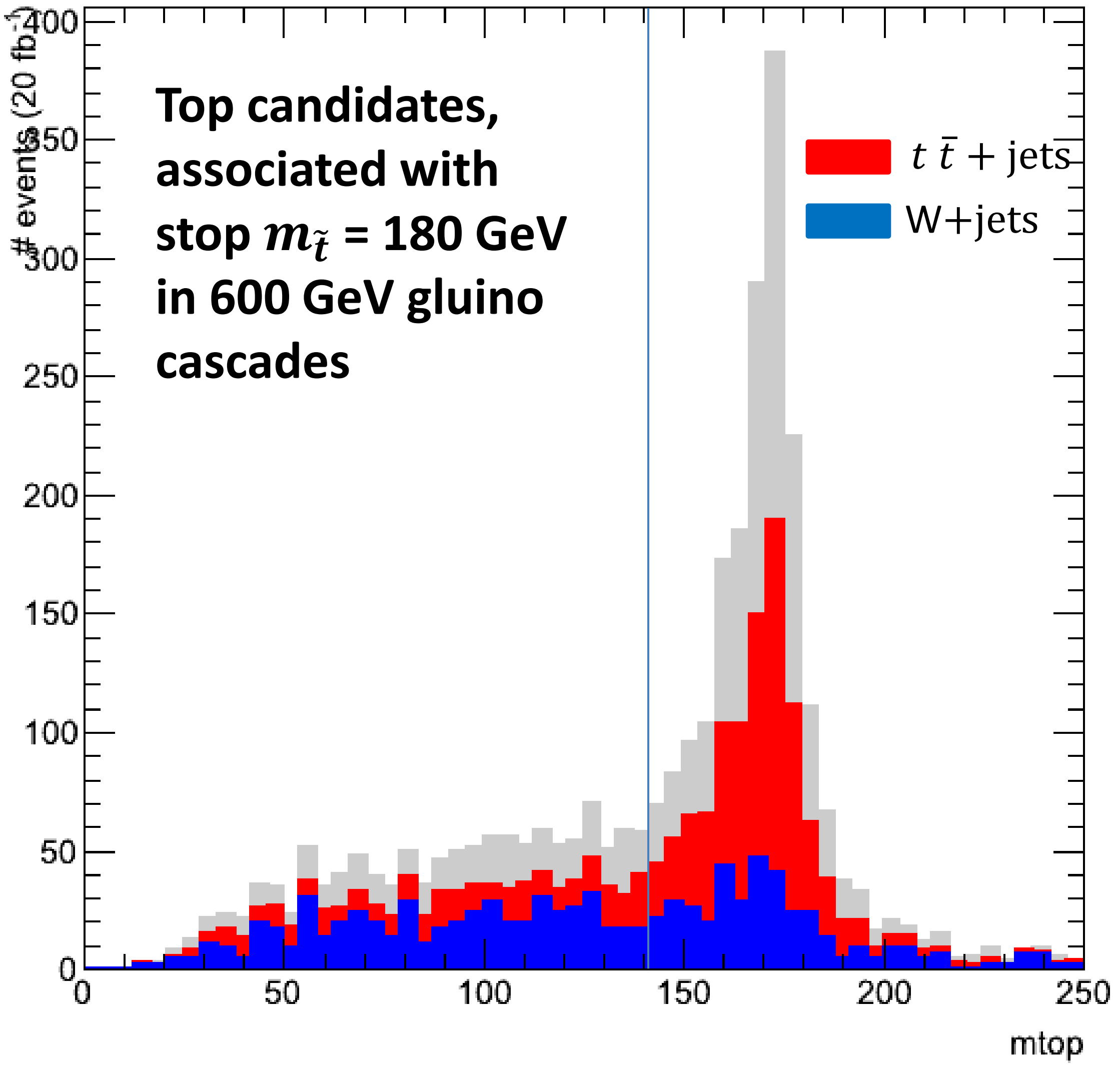
Top-side

Example

L = 20/fb @8TeV

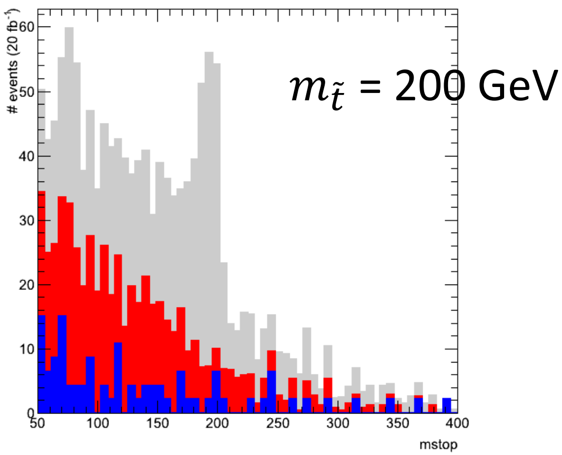


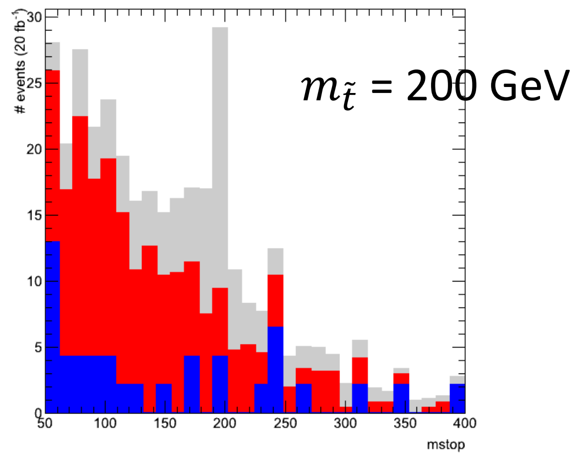
SUSY at bumps: Crossover

L = 20/fb @8TeV

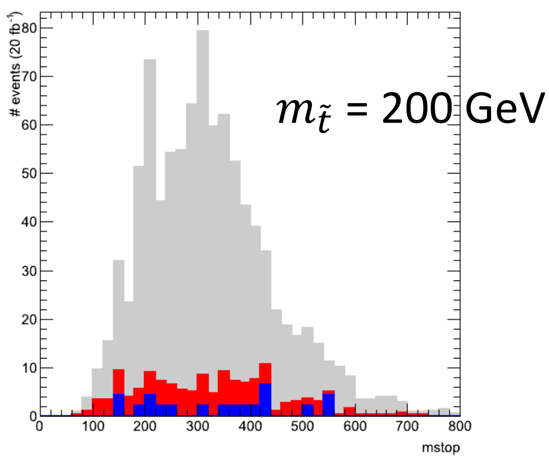
m_{gluino} = 600 GeV

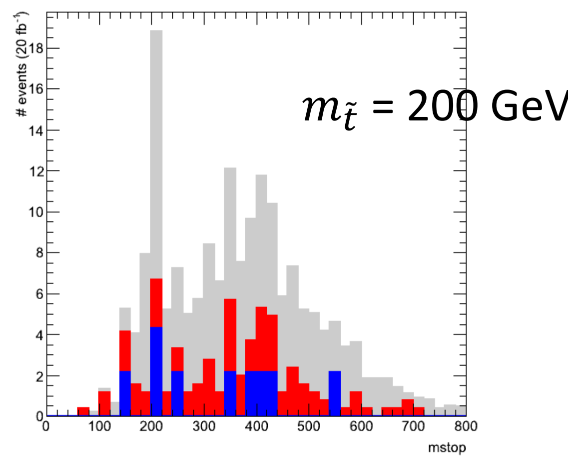
m_{gluino} = 800 GeV





← BDRS





← Trad-

Signal: MG5 w/ RPV MSSM_UFO + Pythia8, Bkg: MG5| fastjet2.4.1
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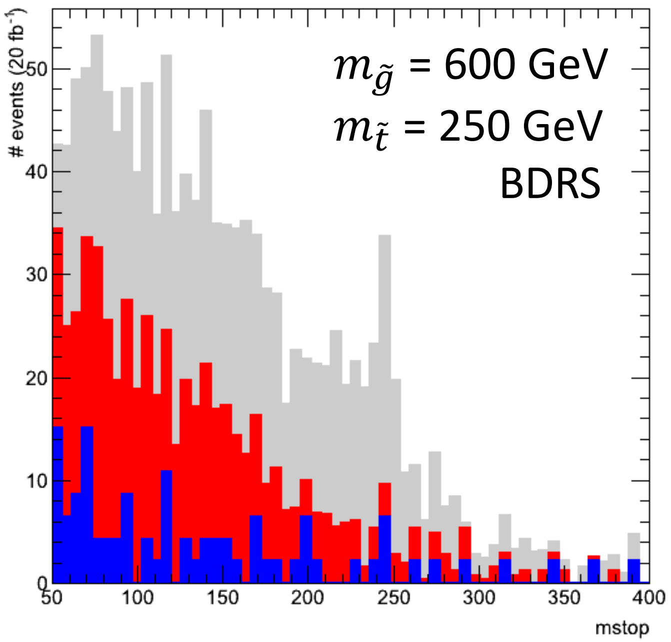
Summary

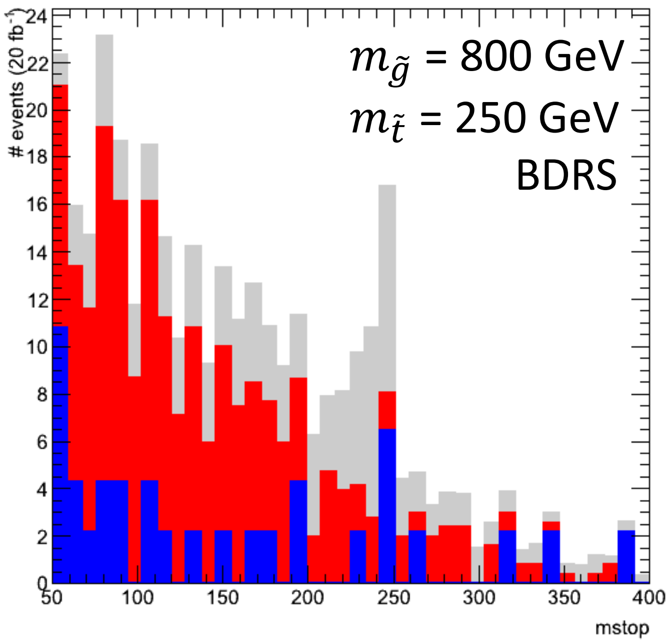
1. We propose new search which should be sensitive to certain RPV spectra, e.g. stop LSP in RPV natural SUSY
   a. Gluino lighter than 800 GeV can be discovered/excluded @8TeV
   b. Stop can be discovered as a bump in a dijet mass distribution. Bump behavior is much more pronounced when boosted (jetsubstructure)
   c. Associated top could tell us about the identity of dijet bump (e.g. Top partner)
   d. Stop-sbottom could play a role of a complimentary channel
2. All our results (procedures, plots) in this talk are still preliminary (will be updated in a coming paper)

Some comment & future work

1. We did not look at @7TeV data yet (will be available soon).
2. Measuring SO/SS in dileptonic channel could tell us the Dirac nature of gluino (work in progress)
3. Boosting sbottom, $\tilde{\mathrm{b}} \rightarrow \mathrm{W} + \tilde{\mathrm{t}} \rightarrow 4$ jets (future work ?)
4. Unexplored TeV scale gluino can be reached @14TeV. More spectacular signature ? (future work)



$m_{\tilde{g}}$ = 600 GeV
$m_{\tilde{t}}$ = 250 GeV
BDRS
events (20 fb^{-1})
mstop



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