New Strategies for GMSB & RPV

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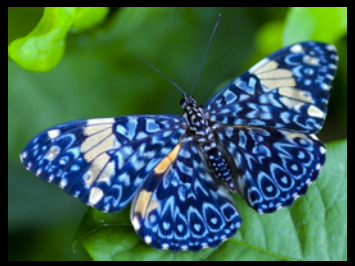
University of Pittsburgh
@ FNAL Workshop:
SUSY at the Near Energy Frontier
12 November 2013

Naturalist's World View

$\tilde{g}$

$\tilde{t}_L$

$\tilde{b}_L$



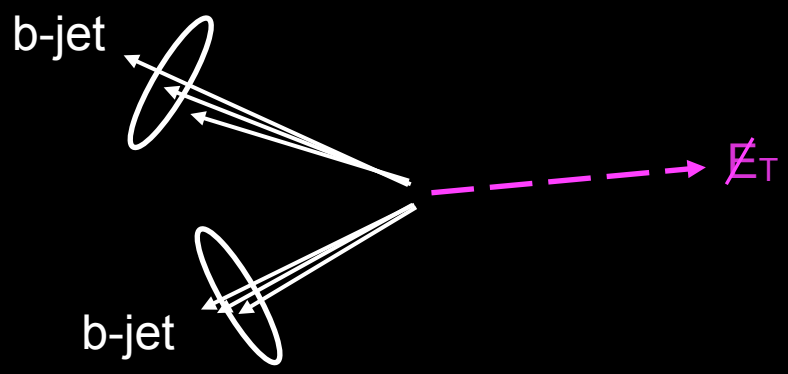
$\tilde{t}_R$

$\tilde{H}^{\pm}$

$\tilde{H}^0$s

* And extra Higgs bosons

Not All "Natural" GMSB Pheno is Immediately Distinctive



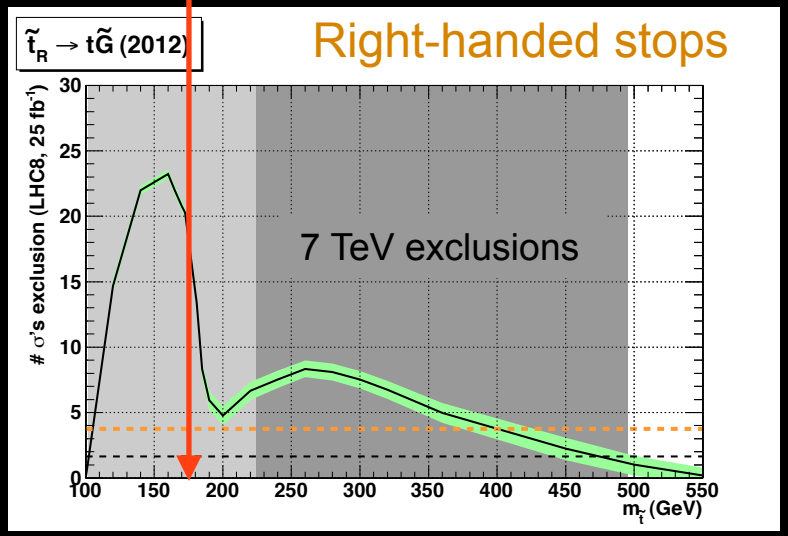
Sbottom pair decaying to binos or gravitinos?

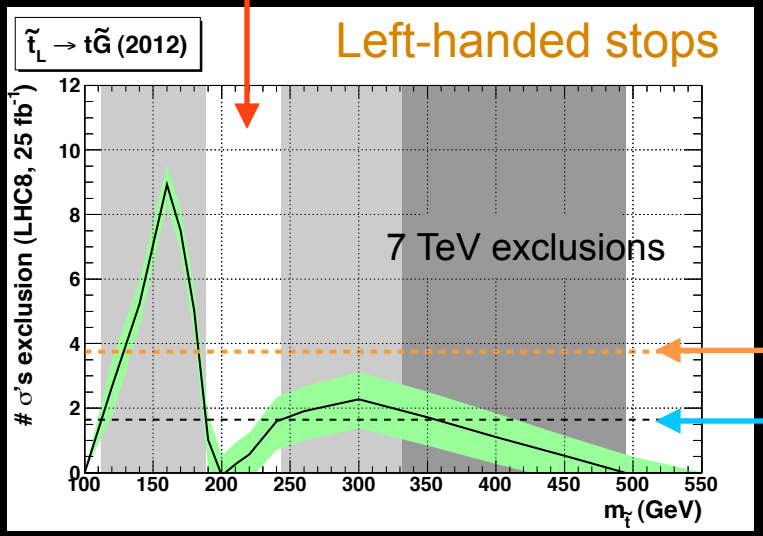
Regardless, already very well-covered!

Stop is the LOSP?

No stealth region!

Coverage gap due to spin





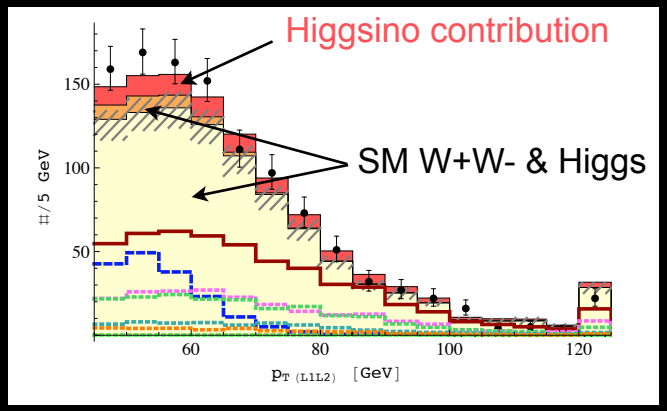
*Theorist analyses using dileptonic m_{T2} (25 fb^{-1} 8 TeV)

- Relaxed m_{T2} cut (95 GeV)
- Minimal jet requirements
  (1 b-tag for ee/μμ, inclusive for eμ)
- MET/M_{eff} cut

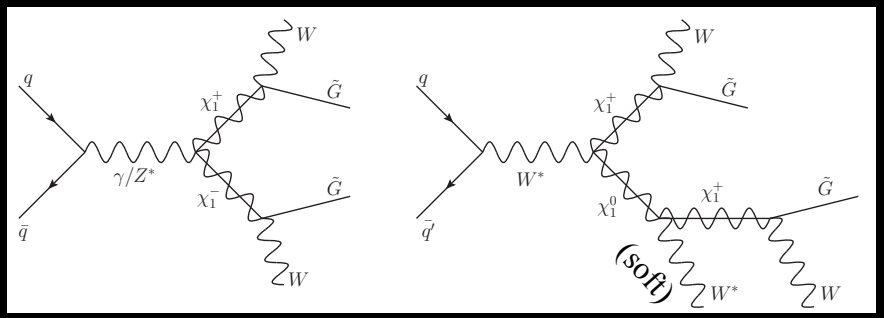
Kılıç & Tweedie (1211.6106)

also: Kats & Shih (1106.0030), Chou & Peskin (hep-ph/9909536)

Or is the Data Whispering $\tilde{H}^{\pm}$?



$\sigma_{exp}/\sigma_{theory}$ = 1.1~1.2 ± 0.1
(both CMS & ATLAS)



best-fit: $m(\tilde{\chi}_2^0)$ = 130, $m(\tilde{\chi}_1^0)$ = 113, $m(\tilde{\chi}_1^{\pm})$ = 110

* Chargino can be lighter than neutralinos!
Kribs, Martin, Roy (0807.4963)

What do we do?:

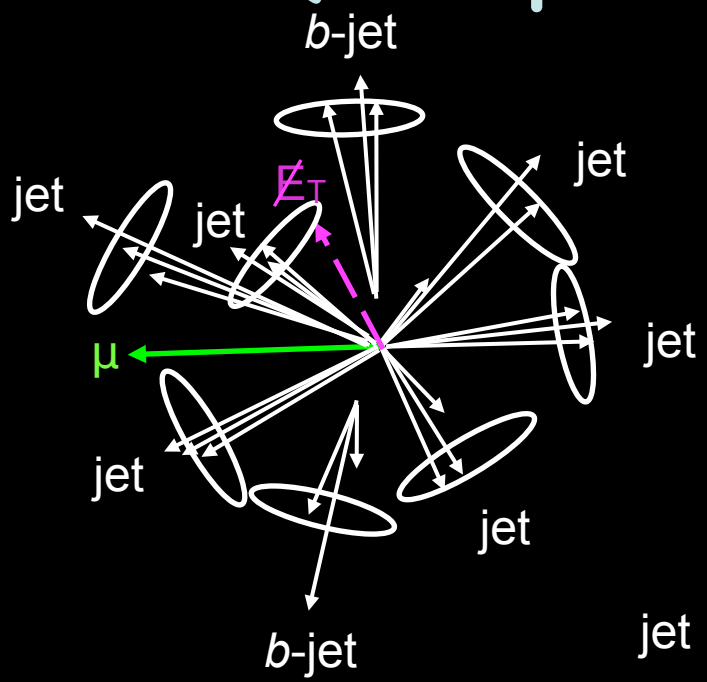
1) Wait until Run II makes squarks/gluino?
2) Refine W+W- calculations?
3) Look for cuts that improve S/B?

Curtin, Jaiswal, Meade (1206.6888)

Some Ways to Net RPV Stops

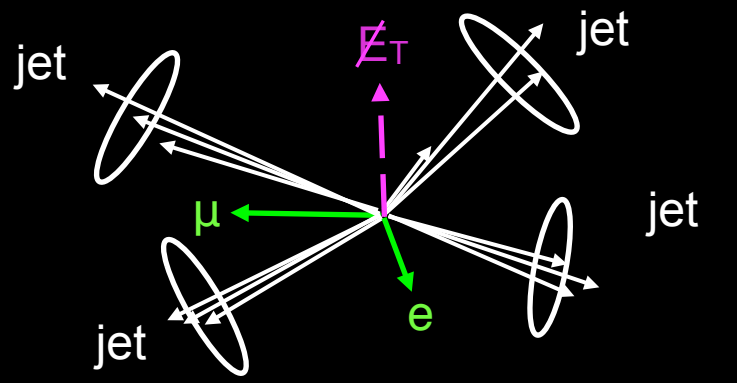
- Direct pair production, 2-body decay via RPV
  - can be straightforward (LQD) or really difficult (UDD)
- Direct pair production, decay to Higgsinos
  - Higgsino “soft cascade”, final 3-body LSP $\tilde{H}$ decay via RPV
  - encyclopedia of options
    - Dominant $\tilde{f}^*$ × (LH, LLE, LQD, UDD) × Flavors
  - several escape hatches require adjusting searches
- Produced in decays of heavier colored sparticles
  - gluino, heavy stop, sbottom
  - stop may decay directly via RPV, or through more complicated chains

Stop Production in Cascades (Stop → 2j, Unflavored)



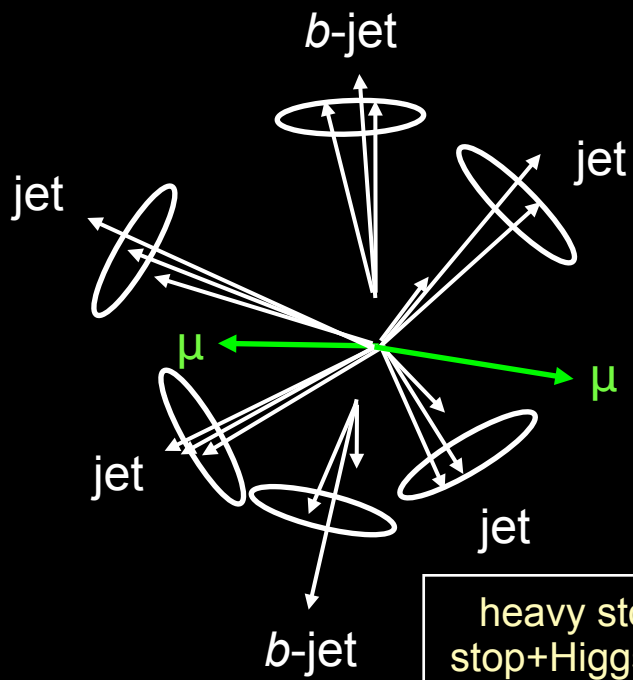
gluino pair to stops and tops

Lisanti, Schuster, Strassler, Toro (1107.5055)
Allanach & Gripaios (1202.6616)
Han, Katz, Son, Tweedie (1211.4025)
Berger, Perelstein, Saelim, Tanedo (1302.2146)
Evans, Kats, Shih, Strassler (1310.5758)
ATLAS-CONF-2013-007
ATLAS 1308.1841



sbottom pair to stops and leptonic W(*)s

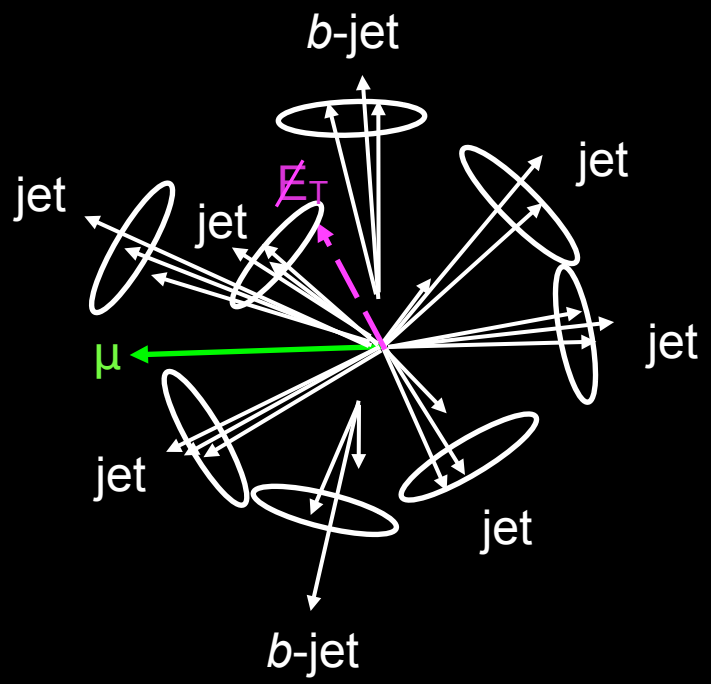
Brust, Katz, Sundrum (1206.2353)

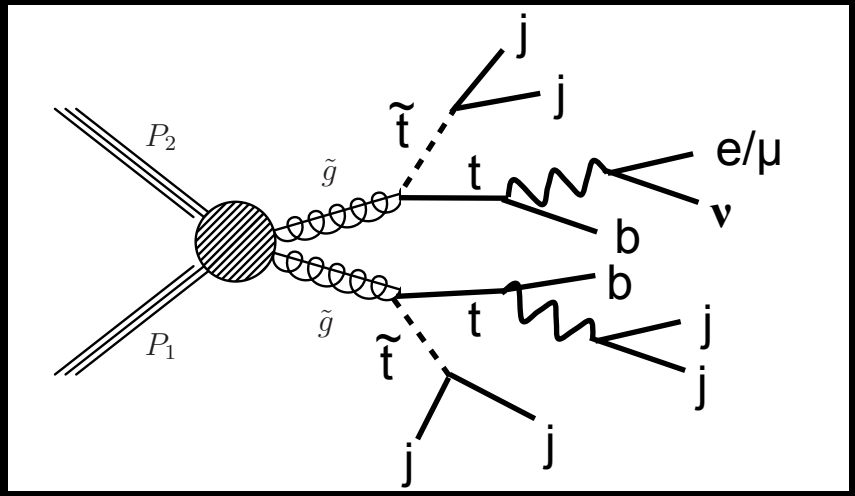


heavy stop pair to stop+Higgs & stop+Z

* Not studied in detail

Gluinos via 1-Lepton + Many Jets

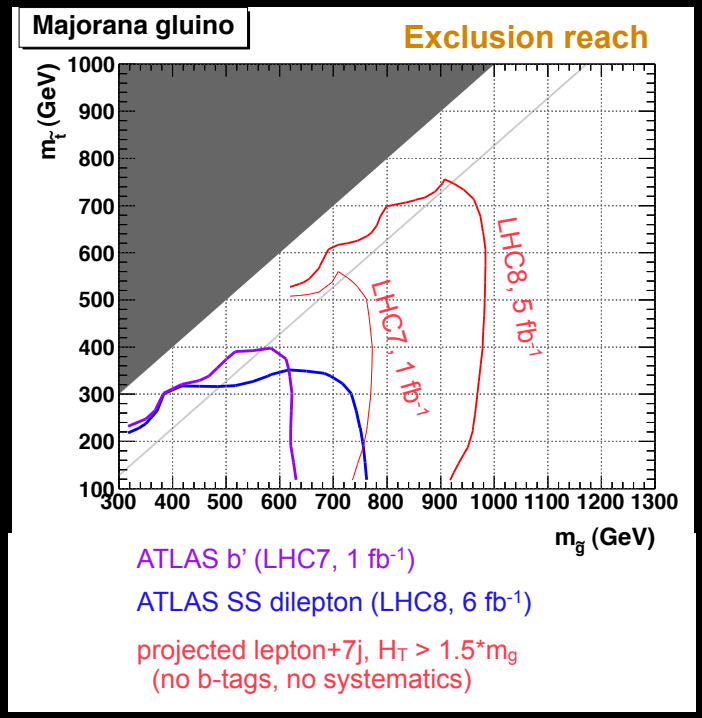




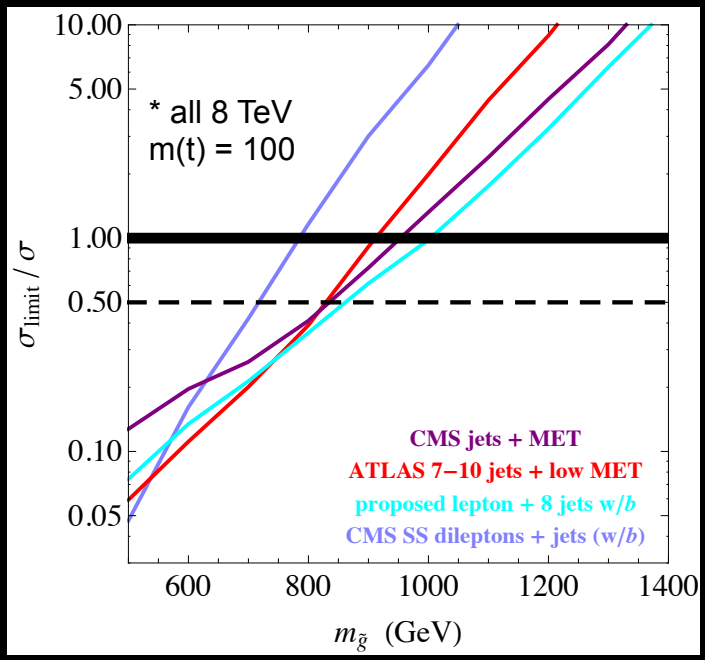
- Dilepton, incuding SS, is also an option (see ATLAS-CONF-2013-007, assuming $\tilde{t} \rightarrow bs$)
- However, higher l+jets BR potentially gives better reach (cf. RPC gluino searches)
- Also fewer options for SS dileptons (need SS tops)
- And note: If gluino is Dirac, no guarantee of SS top production

Gluinos via 1-Lepton + Many Jets

Han, Katz, Son, Tweedie (1211.4025)



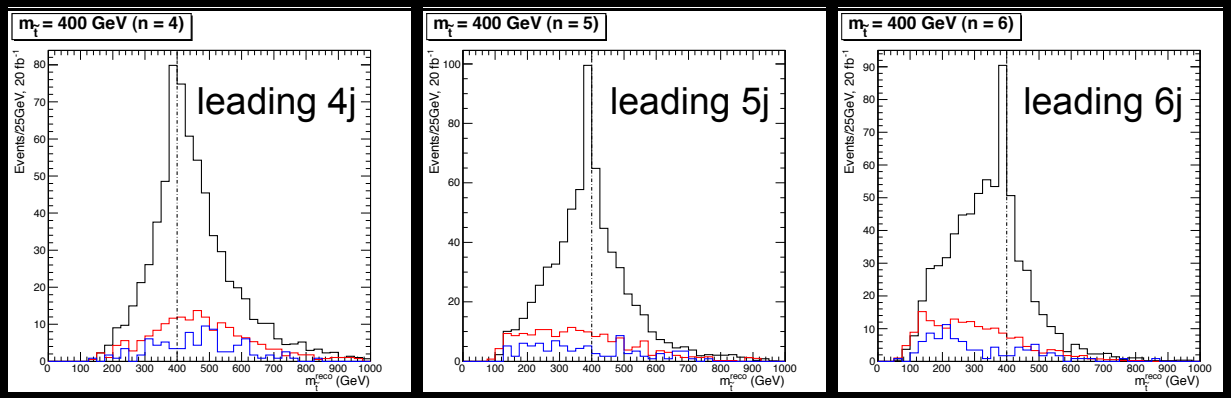
Evans, Kats, Shih, Strassler (1310.5758)



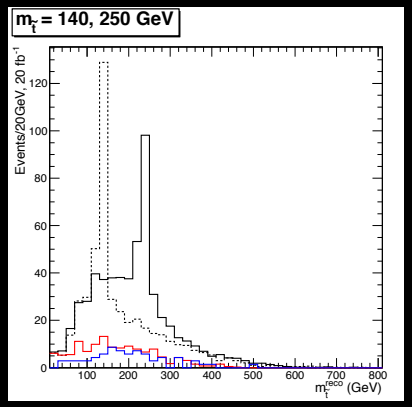
*See also Lisanti, Schuster, Strassler, Toro (1107.5055)

Going After the Stop Bump

$m(\tilde{g})$ = 800
$m(\tilde{t})$ = 400

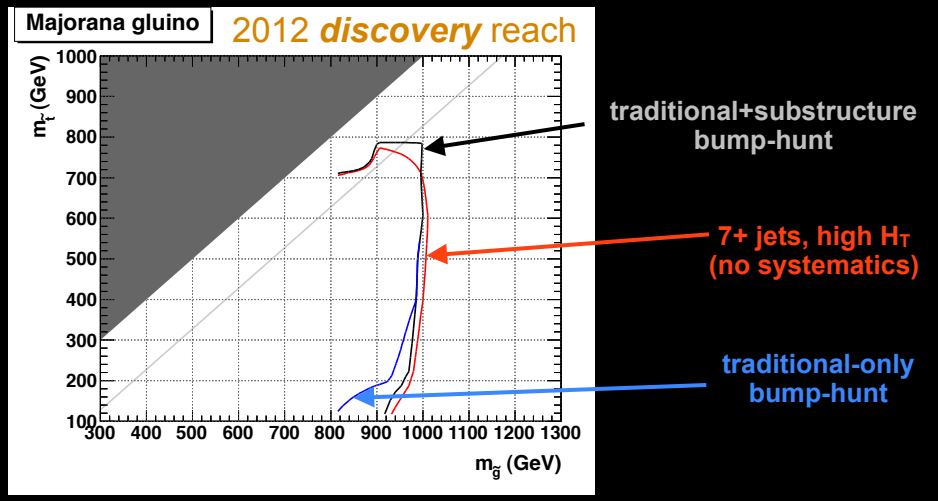


traditional jet reco: "best pair-of-pairs" amidst leading n jets (choose n carefully!)



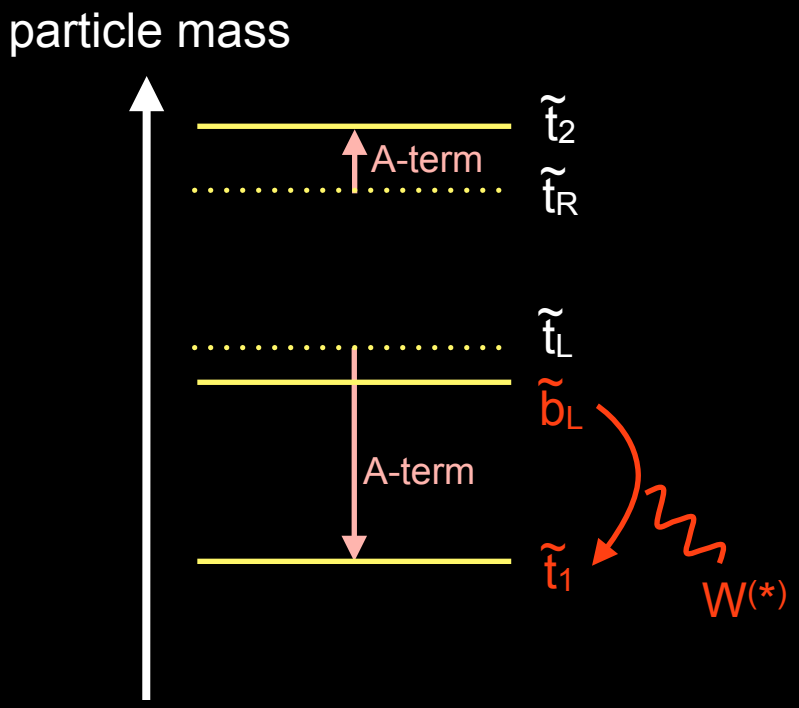
OR substructure reco: highest-p_T fat-jet (after top-jet veto)

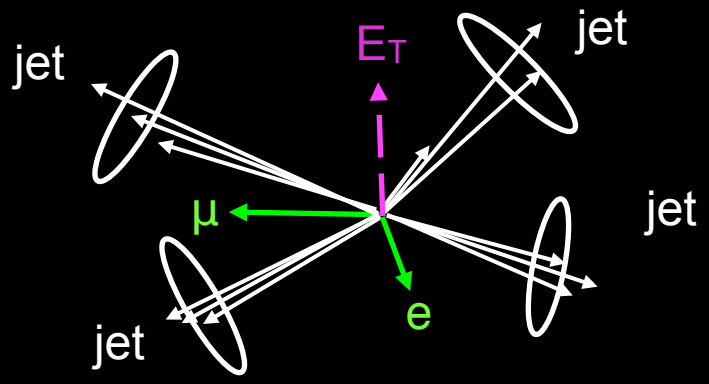
* Will be even more important in Run II

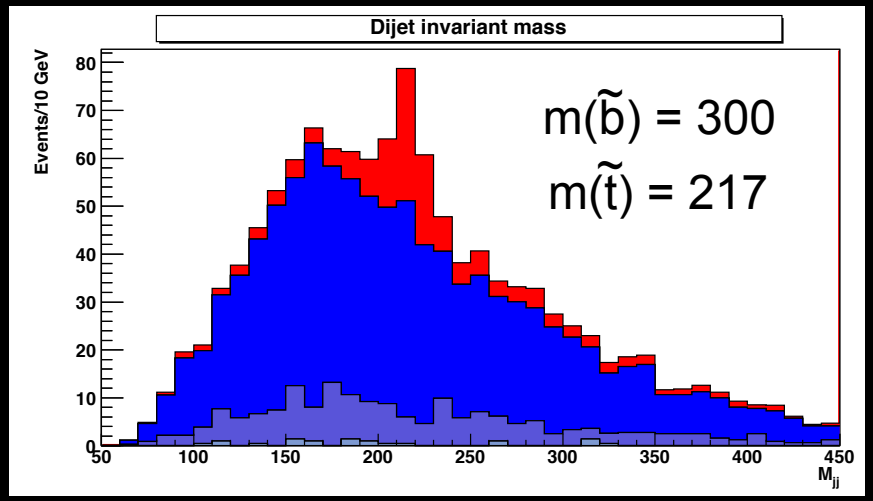


Han, Katz, Son, Tweedie (1211.4025)

Exploit Stop/Sbottom Sandwich



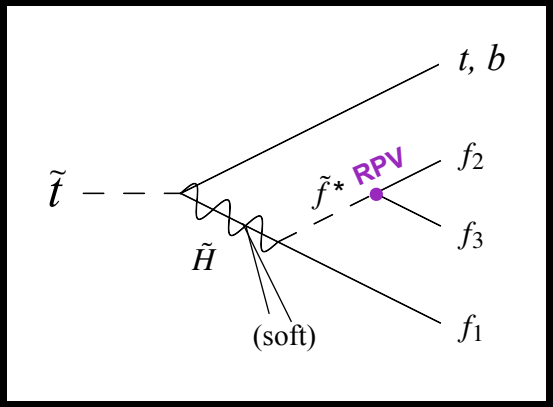




- trigger on dileptons from W(*)
- reconstruct stop with “best pair-of-pairs” of dijets

Brust, Katz, Sundrum (1206.2353)

Direct Stop Pair Production, Decay to Higgsinos

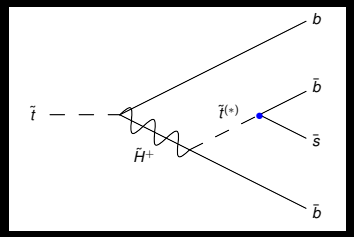


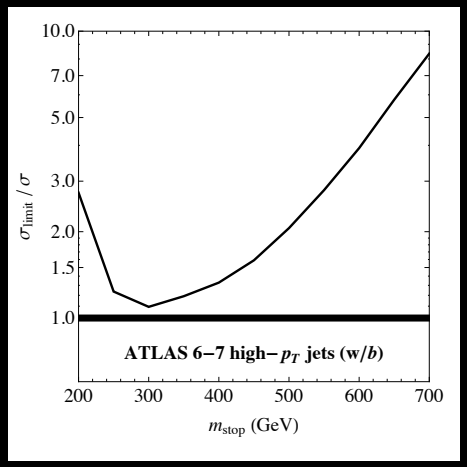
- b-jets ubiquitous (t/b # conserved in initial decay)
- potentially multiply-resonant (if no neutrinos)
- potentially very high jet multiplicity
- potentially lots of leptons and/or taus, flavor non-universality
- often small/nonexistant MET

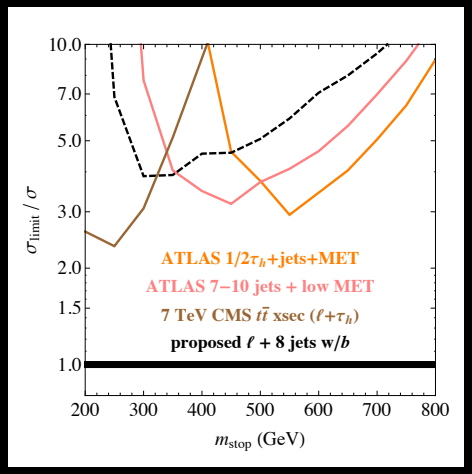
Evans & Kats (1209.0764, 1311.0890)

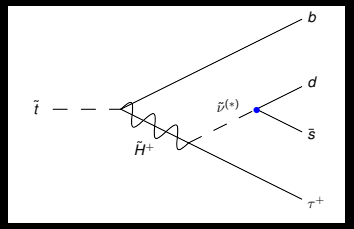
* Also working on direct Higgsino production

Some Lessons



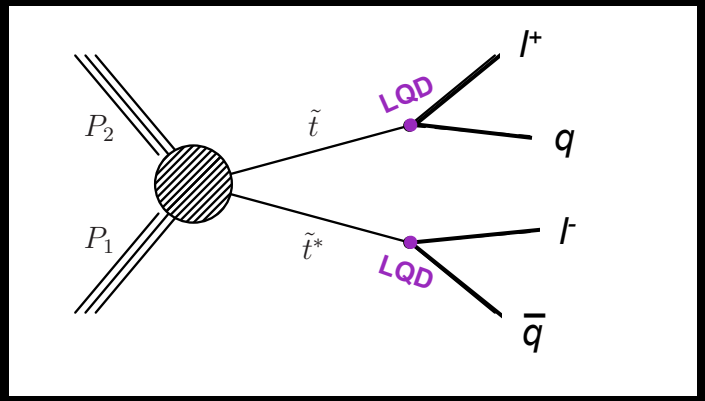


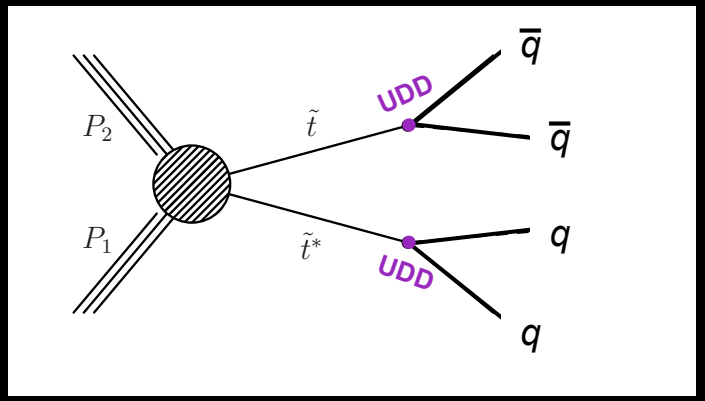




- Many options well-covered “for free” by non-dedicated searches
  - LHC7 exclusions: LLE 600~800, LQD 300~700, UDD sometimes ~350
  - see Evans & Kats papers for full discussions and limitations
- All-jets is difficult, but up to 6 b-jets per event
  - most high-multiplicity b-jet searches involve large MET
- Ditau+jets can benefit from more b-tags, more jets to beat top
- More targeted strategies in development (Evans & Gu)

Direct Stop Pair Production, Direct RPV Decay

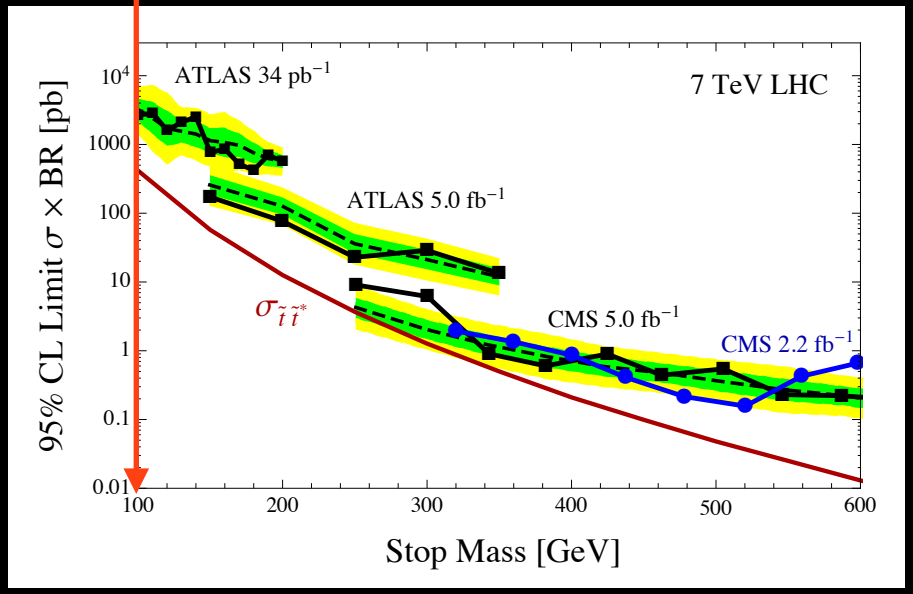


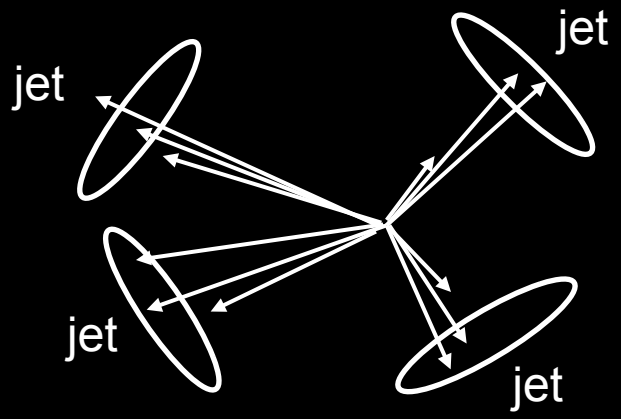


- LQD well-covered by leptoquark searches
  - LHC7 exclusions: 550~800 Evans & Kats (1209.0764)
  - non-dedicated coverage for tau+d/s is also strong
- UDD difficult to trigger, large QCD background
  - use ATLAS b-jet trigger Franceschini & Torre (1212.3622)
  - LHC Run II, HL-LHC (Snowmass) Duggan, et al (1308.3903)
  - jet substructure Bai, Katz, Tweedie (1309.6631)

UDD Exclusions Snapshot

100 GeV limit set by Tevatron



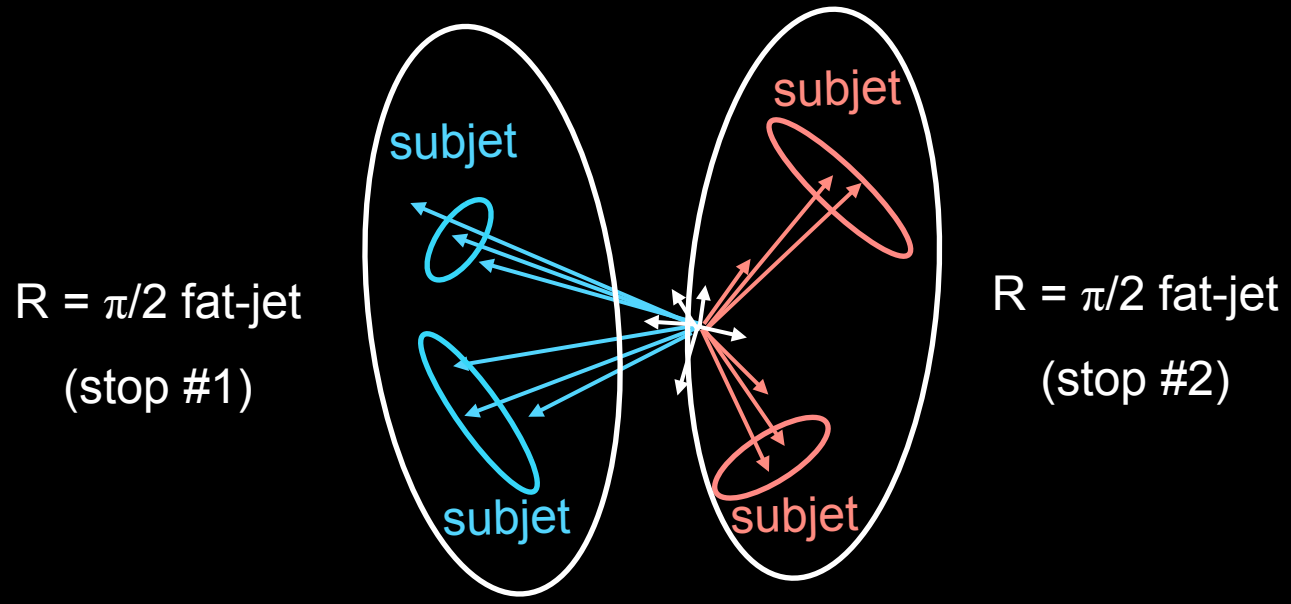


form best pair-of-pairs

Coverage creeps upward due to progressively harder 4j triggers/cuts

* All searches to date are untagged
None use 8 TeV data

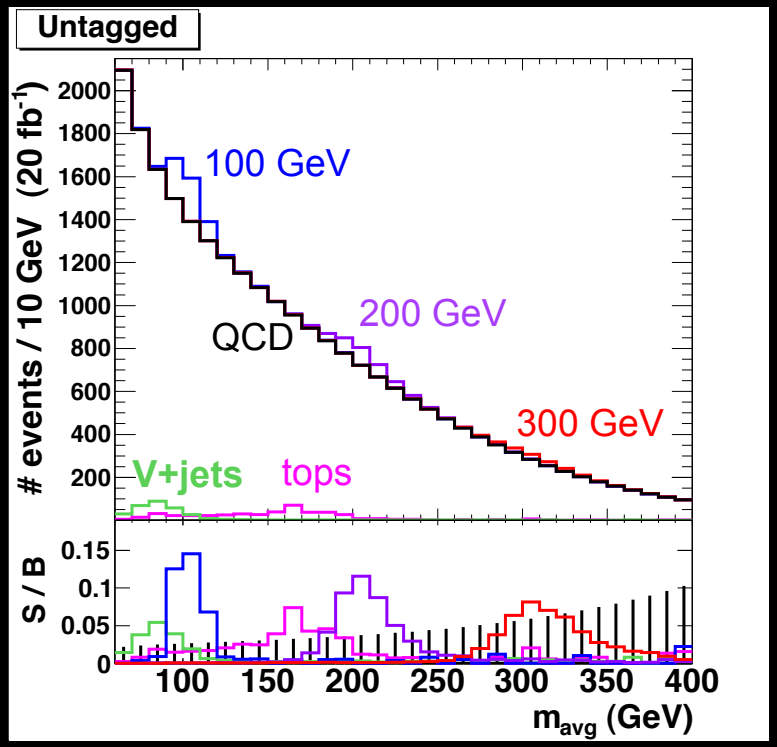
Jet Substructure Approach

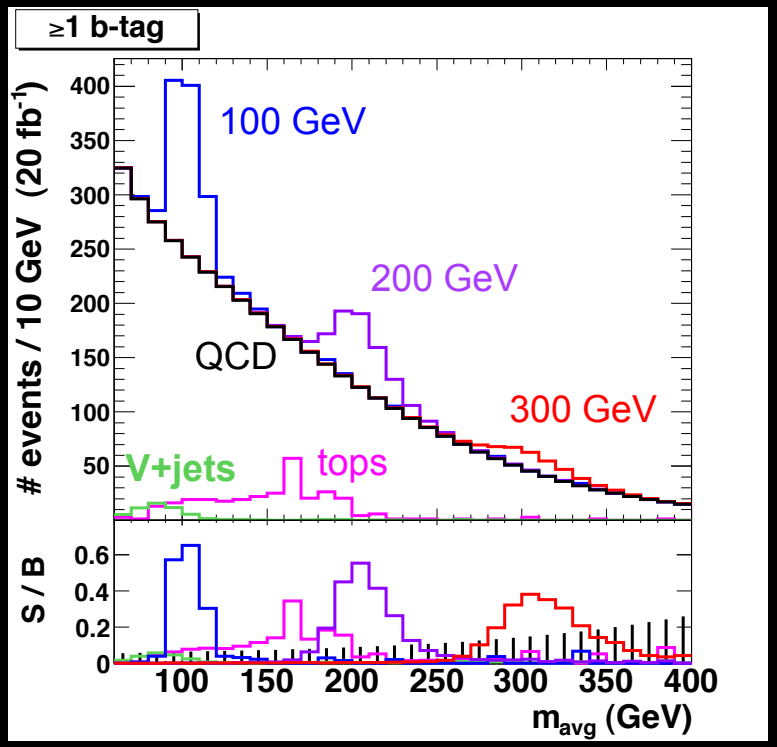


- Focus on (semi-)boosted stop production
- "Jet" sizes not fixed
- Triggered with H_T, not individual jet p_T's
  - we assumed 900 GeV (can go lower)
  - this is our only dimensionful cut
- QCD continuum becomes ~featureless

Bai, Katz, Tweedie (1309.6631)

Average-Mass Spectra

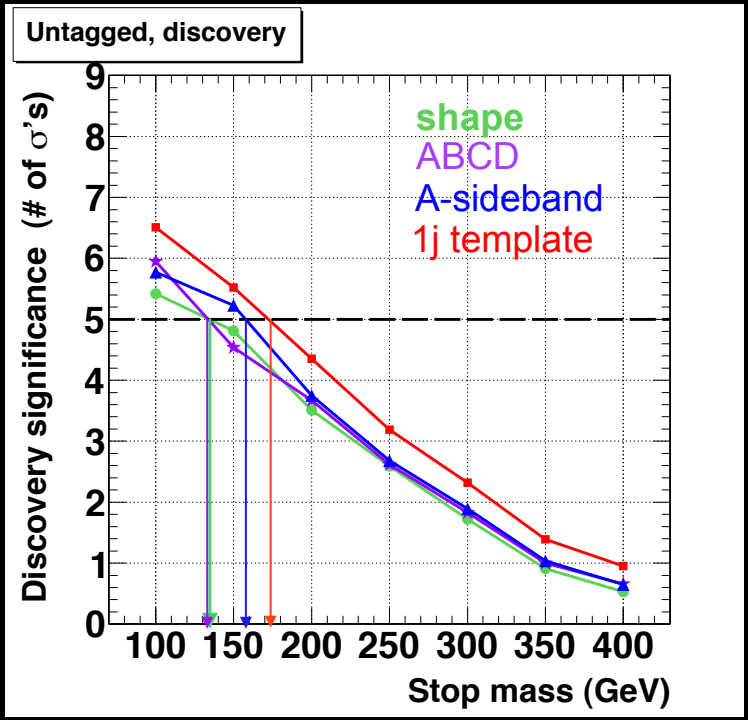




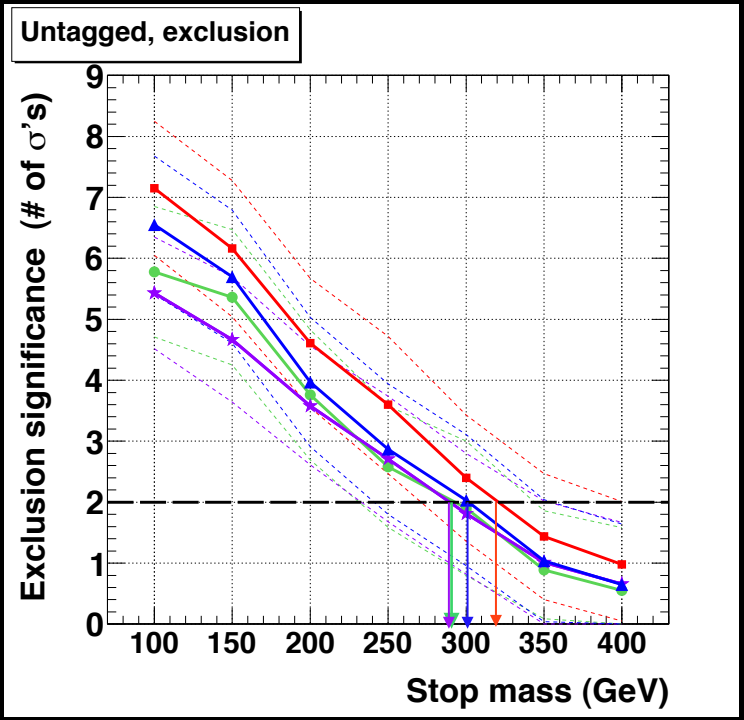
(assuming ~100% BR to bd/bs)

**Be careful of top background!

2012 Sensitivities, Untagged



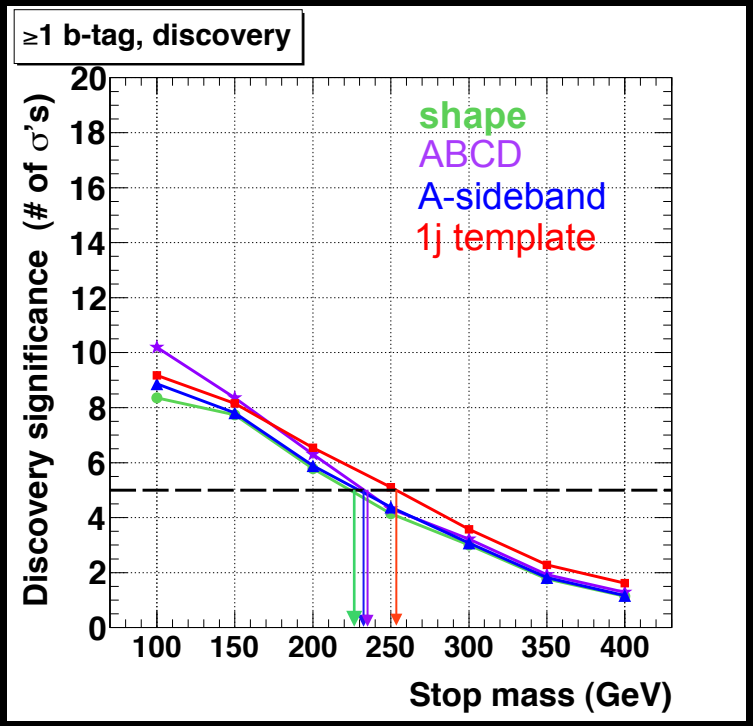
discover ~150 GeV



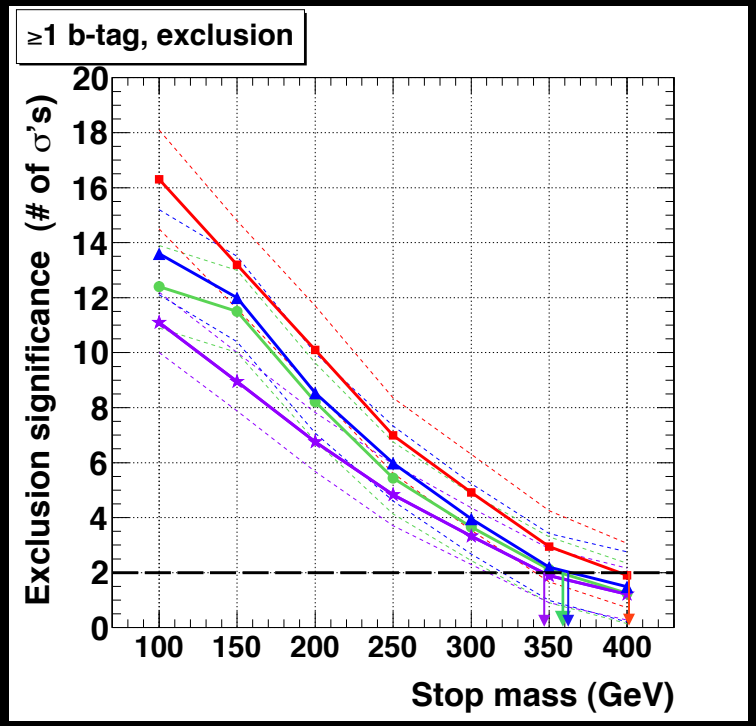
exclude ~300 GeV

*$\Delta\chi^2$ discriminator, Statistical errors ONLY

2012 Sensitivities, b-tagged



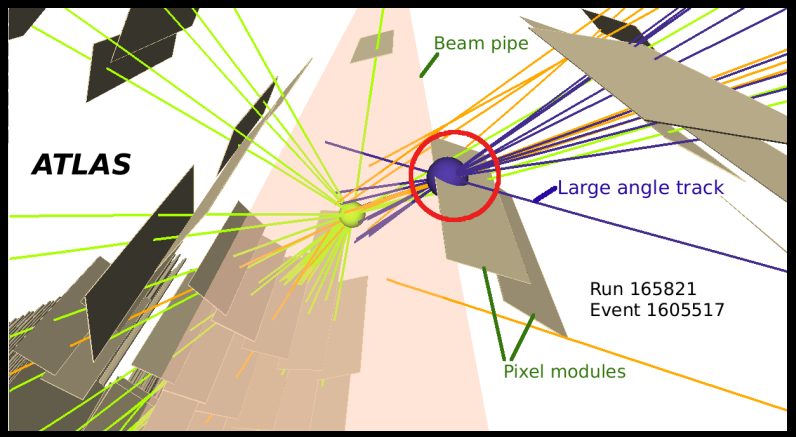
discover ~250 GeV

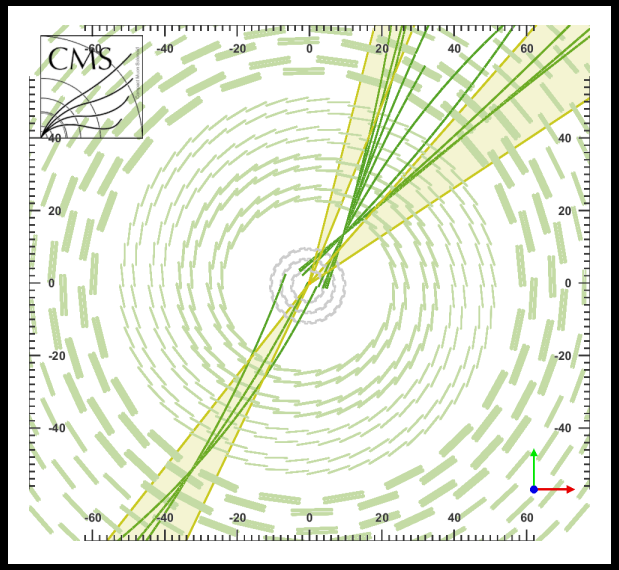


exclude 350~400 GeV

* $\Delta\chi^2$ discriminator, Statistical errors ONLY, Not re-optimized

Thinking Outside the Beampipe





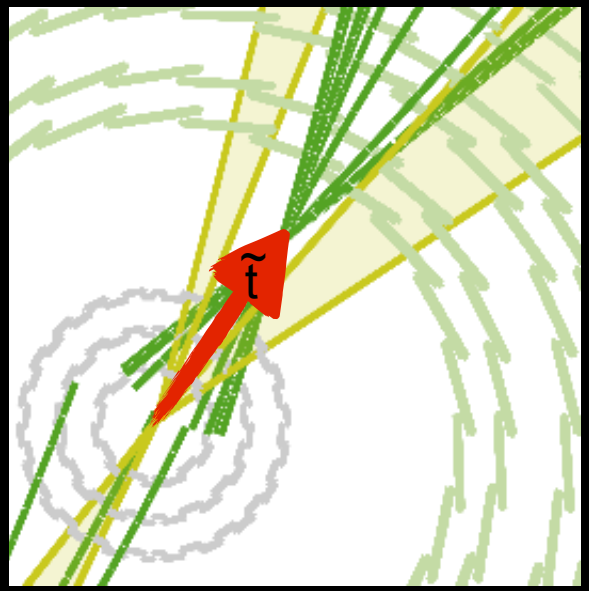
$$c\tau_{\mathrm{GMSB}} \sim 0.1\mathrm{mm} \left(\frac{100\ \mathrm{GeV}}{\tilde{m}}\right)^{5} \left(\frac{\sqrt{F}}{100\ \mathrm{TeV}}\right)^{4}$$

$$c\tau_{\mathrm{RPV}} \sim 0.1\mathrm{mm} \left(\frac{100\ \mathrm{GeV}}{\tilde{m}}\right) \left(\frac{10^{-6}}{\lambda}\right)^{2}$$

* formulas for 2-body decays

A Displaced RPV Stop Recast

- $m(\tilde{t}) = 150$ & $\sqrt{\hat{s}} > 400 \Rightarrow \sigma \sim 30$ pb
  via direct QCD pair production
- ~50% chance to get neutral stop-hadron
- ~50% pass basic acceptance, ~5% reco efficiency for $c\tau \sim 40$ cm
- luminosity ~ 20,000 pb^{-1}
- TOTAL: 30 * 0.5 * 0.5 * 0.05 * 20,000 = 7,500 events
- O(1) background $\Rightarrow$ limit is ~5 events



CMS PAS EXO-12-038

Generalizes in many directions: displaced W/Z/h in GMSB, displaced 3-jet? (RPV gluino/neutralino, GMSB stop), displaced 1-jet + FSR? (GMSB squark/gluino)

Summary / Incomplete Laundry List

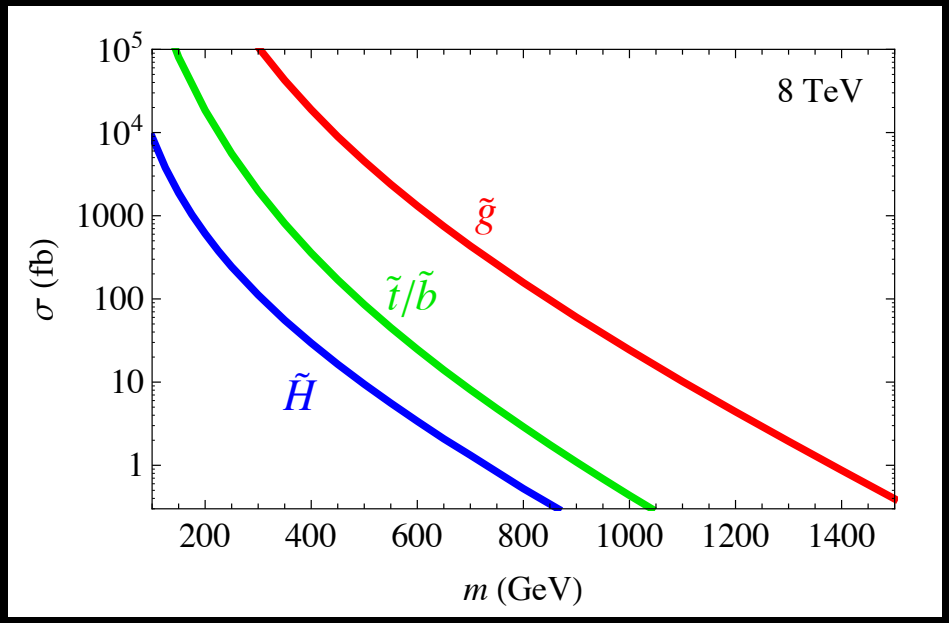
- LOSP stop in GMSB is never stealthy (but LH is annoying)
- WW excess may hint at GMSB Higgsinos
- RPV stop LSP bump might be found in decays of (Dirac) gluino, sbottom (heavier stop?)
- Direct stop pair → RPV Higgsinos strongly constrained “for free”, but gaps suggest new strategies (more b-tags!)
- Direct stop pair → 4j discoverable *now* using substructure, even without b-tags
- Huge potential for both GMSB & RPV coverage in displaced decay searches

Conclusion

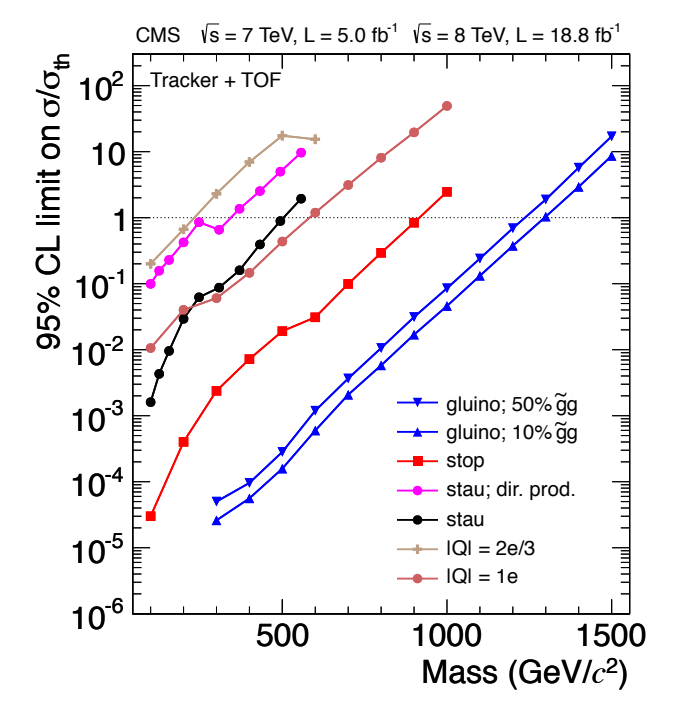
- The number of places for SUSY to hide is rapidly shrinking, but....
- Exotic creatures may still be hiding in the data!

More…

Natural SUSY Cross Sections



"Stable" Charged L(O)SP



CMS 1305.0491

Cut Flow (Untagged)

* 8 TeV
20/fb