New physics with $t\bar{t}$-like final states

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Relevant questions from the Top subgroup charge

From section 3 – Kinematics of top-like final states

- To what extent can precision studies of cross-sections and kinematic distributions for top-like final states at hadron colliders be used to constrain models of physics beyond the Standard Model?
- Which cross-sections and distributions are particularly important for this purpose? Are existing theoretical predictions for those final states adequate? What are the prospects for improving them?

From section 5 – New particles decaying/coupled to top-like final states

- Are there new particles that decay to top-like final states and other SM or BSM particles? What are the current constraints on their masses and couplings?
- What are the best ways to search for such particles at a hadron collider? What is the dependence on kinematics and final state? What sensitivity can be reached in such searches?

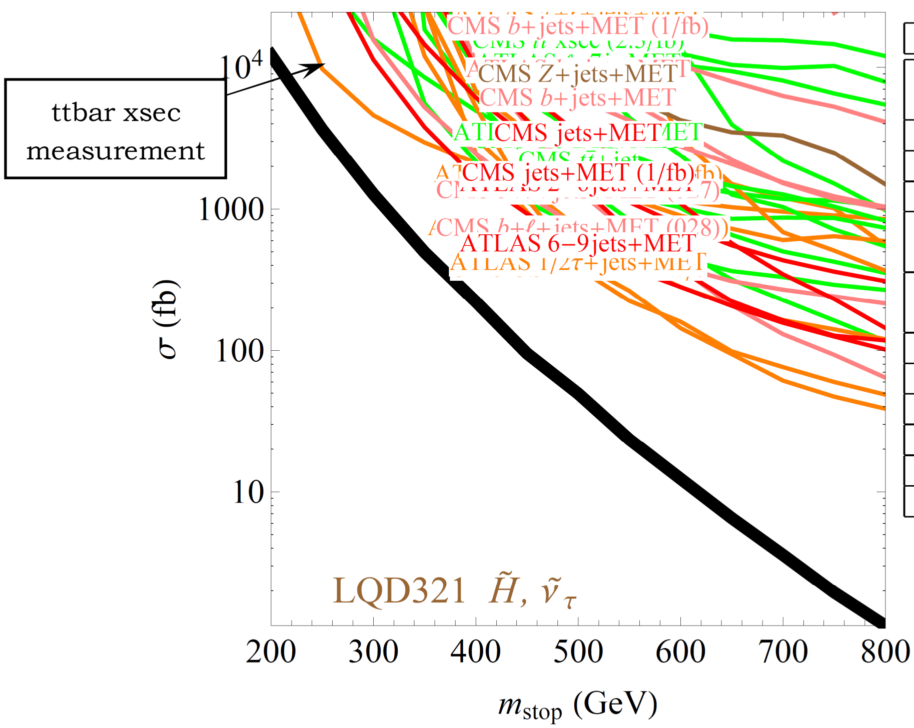
Motivation

Most searches (SUSY etc) require large MET, H_T to eliminate ttbar → Low sensitivity to ttbar-like new physics

Example *arXiv:1209.0764*

Stop pair production (decays via charginos, neutralinos, etc.) in RPV MSSM

In some cases, limits from **ttbar cross section measurements** better than **new physics searches!**



final state	collab.	$\mathcal{L}$ (fb^{-1})
$t\bar{t}$	ATLAS CMS	0.70 2.0-2.3
$t\bar{t}$ + jet	CMS	5.0
$t\bar{t}$ + m_T	ATLAS	1.04
leptonic m_{T2}	ATLAS	4.7
ℓ + jets + MET	CMS ATLAS	4.7 4.7
OS $\ell\ell$ + MET	CMS ATLAS	4.98 1.04, 4.7
SS $\ell\ell$ + MET	ATLAS	1.04, 2.05
SS $\ell\ell$	ATLAS	1.6, 4.7
SS $\ell\ell$ (+ MET)	CMS	4.98
SS $\ell\ell$ + b (+ MET)	CMS	4.98
b' (SS $\ell\ell$)	ATLAS	4.7
b' (SS $\ell\ell$ or 3ℓ+b)	CMS	4.9

final state	collab.	$\mathcal{L}$ (fb^{-1})
3 or 4 ℓ	ATLAS	1.02
3 ℓ + MET	ATLAS	2.06, 4.7
4 ℓ + MET	ATLAS	2.06
3 or 4 ℓ (+ MET)	CMS	4.98
1 or 2 τ + jets + MET	ATLAS	2.05, 4.7
τ + ℓ + jets + MET	ATLAS CMS	4.7 5.0
b + ℓ + jets + MET	ATLAS CMS	2.05 4.96-4.98
b + jets + MET	ATLAS CMS	2.05, 4.7 1.1, 4.98
(b)-jets with α_T	CMS	1.14, 4.98
jets + MET	ATLAS CMS	4.7 1.1, 4.98
Z + jets + MET	CMS ATLAS	4.98 2.05

Motivation

Most searches (SUSY etc) require large MET, H_T to eliminate ttbar → Low sensitivity to ttbar-like new physics

Motivation to re-interpret ttbar analyses as new physics searches

In which ways can ttbar-like new physics differ from ttbar?

↓

What distributions would it be useful to measure?

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How precisely can they be measured?

How well can they be modeled theoretically?

Opportunities for data-driven methods?

Possible handles on ttbar-like new physics

Examples – all from real (theory) life

- Many extra jets
- Extra (or fewer) *b*-jets
- Off-shell tops
- Excess in just one of the channels
- Different p_T distributions for leptons and/or jets
- Effect on reconstructed ttbar invariant mass
- MET not coming from the W (i.e., m_T or m_{T2} tail)
- Events with leptons but without real MET
- Jets and/or leptons forming resonances (on-shell intermediate particles)

Motivated measurements

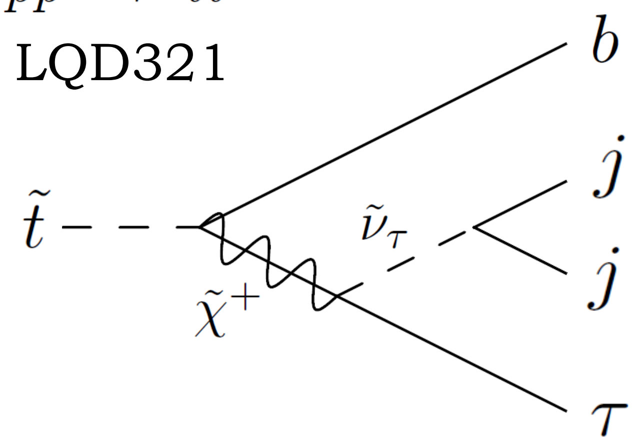
- Distributions of the number of jets and *b*-jets
- Distributions of MET, m_T (1-lepton), m_{T2} (2-lepton)
- Comparative ttbar xsec (or distributions) in different channels
- Measurements of the top reconstruction efficiency
- Searches for resonances within the ttbar sample

and many more!

Example 1

$pp \rightarrow \tilde{t}\tilde{t}^*$

LQD321



- Similar to ttbar in the di-tau channel
- Re-interpretation of searches sets no limits
- ttbar xsec measurements closest to setting limit

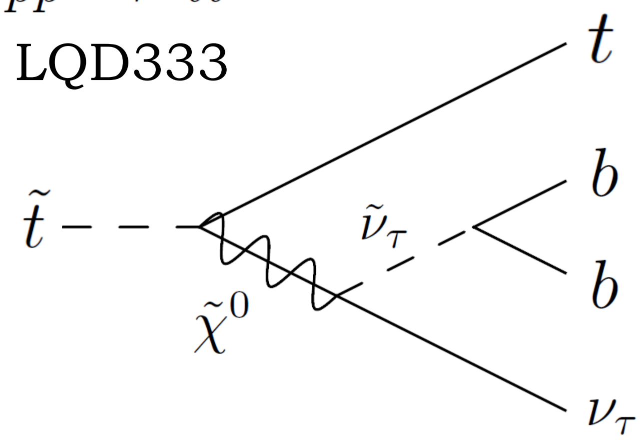
Distinguishing characteristics

- 4 extra jets per event
- Possibly no excess in other ttbar channels
  $\rightarrow$ Data-driven backgrounds can be used
- Different kinematic distributions (MET, b-jet p_T, etc.)
- Pairs of dijet resonances (if sneutrino is on-shell)

Example 2

$pp \to \tilde{t}\tilde{t}^*$

LQD333



- Similar to ttbar + jets
- Re-interpretation of searches sets no limit

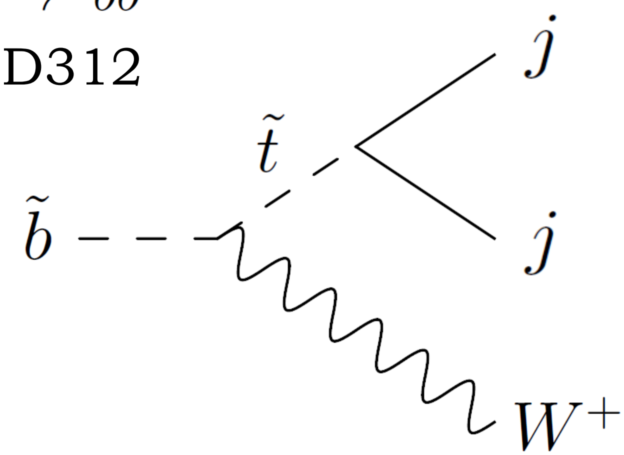
Distinguishing characteristics

- 4 extra b-jets per event
- Tops may be off-shell
- Differences in kinematics
- Pairs of b-tagged dijet resonances (if sneutrino is on-shell)

Example 3

$pp \rightarrow \tilde{b}\tilde{b}^*$

UDD312



- ttbar + jets is a major background
- Best limits ~ 150-200 GeV – from ttbar xsec

Distinguishing characteristics

- 2 extra jets per event
- Deficiency of *b*-tags
- Differences in kinematics
- Pairs of dijet resonances (if stop is on-shell)

See our write-up for many additional examples...

How to proceed?

Straightforward goals

- Decide on a set of benchmark new physics scenarios.
- Examine existing measurements of various ttbar distributions. Estimate their sensitivity to the benchmark scenarios (at present, and projections for the future).
- Identify useful types of measurements that are not currently being done. Estimate their sensitivity.

Important questions along the way

- Which distributions can be simulated reliably?
- Which distributions can be extrapolated from data?
- How should systematic uncertainties be estimated in each case?