Strategy to discover light stops/sbottoms with small mass-gap

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Work in progress with David Krohn and Lian-Tao Wang

Outline

- Introduction & Motivation
- Setup
- Kinematics
- Search strategy
- Application to light stops/sbottoms

Introduction & Motivation

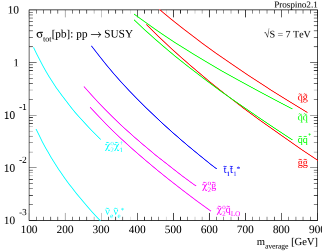
- Stops are important and special:
  - can give important loop contribution to Higgs mass (parameters).
- Light stops ($\sim$ 200GeV) are interesting, allowed and realizable:
  - Naturalness
  - Not ruled out yet.
  - Arise in many SUSY models.
- Light sbottoms are often accompanied.

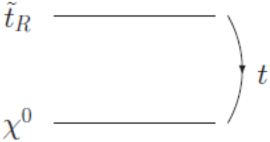
So interesting to look for light stops/sbottoms, and their discovery will tell us much about EWSB and SUSY!

Challenge

However, search is challenging.

- Small direct production (even smaller than $\tilde{g}, \tilde{u}$).
- Minimal scenario ($\tilde{t}_1 \tilde{t}_1^*$ with $\tilde{t}_1 \to t\chi^0$) will look very similar to $t\bar{t}$.
- Generally more sensitive to large mass-gap, and also many observables proposed (e.g. M_{T2} (Kats et al, Bai et al)).





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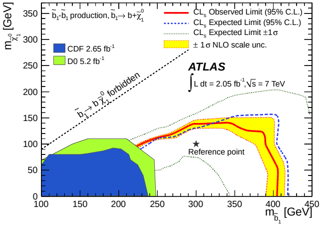

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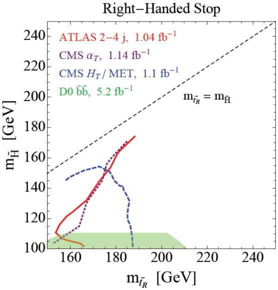

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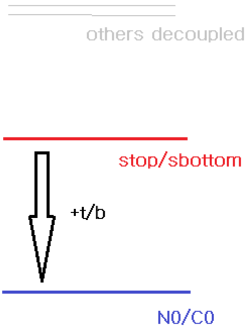
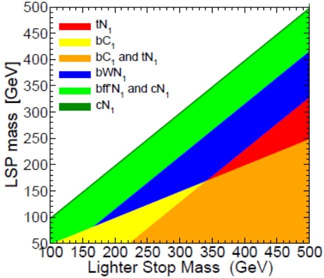
Setup

- Goal is to develop a better strategy for light $\tilde{t}_1/\tilde{b}_1$ with small-gap.

- Small modification of minimal scenario opens up various possibilities (χ^0 + light $\tilde{t}_1$ or $\tilde{b}_1$ + possible χ^+(almost degenerate)).





(stolen from Steve Martin's talk at Chicago LHC workshop.)

Setup

- We start with a simple case of

$$\tilde{b}_1\tilde{b}_1^* + ISR \to (b\chi^0)(\bar{b}\chi^0) + ISR$$

- As we'll see, the strategy developed for this can be applied to most other available channels in small-gap region
    - $\tilde{t}_1\tilde{t}_1^*$ with $\tilde{t}_1 \to b\chi^+$
    - $\tilde{t}_1\tilde{t}_1^*$ with $\tilde{t}_1 \to t^*\chi^0$
    - $\tilde{t}_1\tilde{t}_1^*$ with $\tilde{t}_1 \to c\chi^0$

(They all share common kinematic features that we'll utilize.)

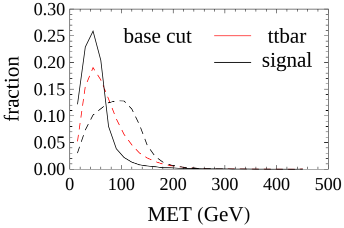
3. Kinematics of $\tilde{b}_1\tilde{b}_1^*$ with small mass-gap

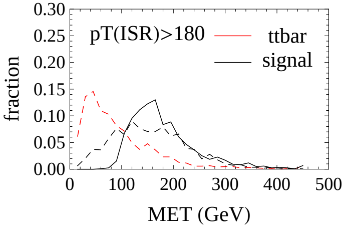
We focus on rejecting semi-leptonic $t\bar{t}$ bkgd.

Kinematics of $\tilde{b}_1 \tilde{b}_1^*$ vs. $t\bar{t}$

- $m_{\chi^0}/m_{\tilde{b}_1} \lesssim 1$ vs. $m_W/m_{top} \simeq 0.5$.
- Two χ^0 vs. single leptonic W.

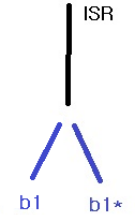
$\Rightarrow$ 1. Under the boost of ISR jet, high-MET is resulted in for signal, but not for $t\bar{t}$. The boost of $\tilde{b}_1$(due to high-p_T ISR) is efficiently transmitted to χ^0, and two χ^0s can be aligned.



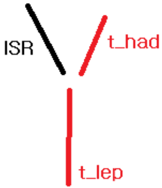


Kinematics of $\tilde{b}_1 \tilde{b}_1^*$ vs. $t\bar{t}$

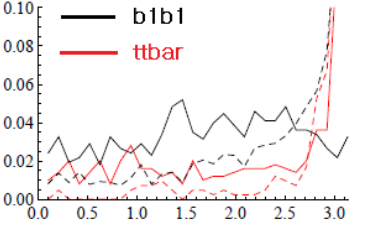
2. $t\bar{t}$ obtains high-MET from different configuration.



(a)



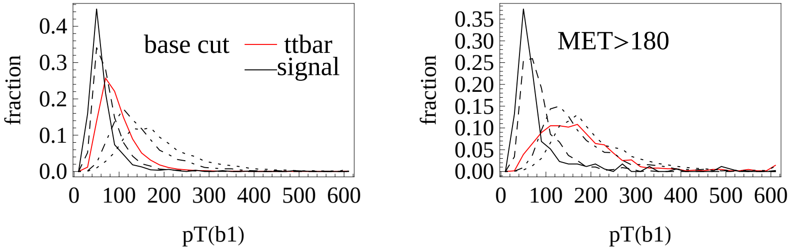
(b)



$\Delta\phi(t,\bar{t})$ or $\Delta\phi(\tilde{b}_1,\tilde{b}_1^*)$ spectrum

Kinematics of $\tilde{b}_1 \tilde{b}_1^*$ vs. $t\bar{t}$

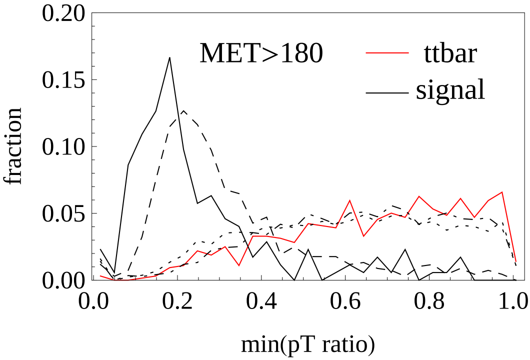
3. With high-MET, signal *b*-jets stay relatively softer.



4. Search strategy

Discriminating Observable

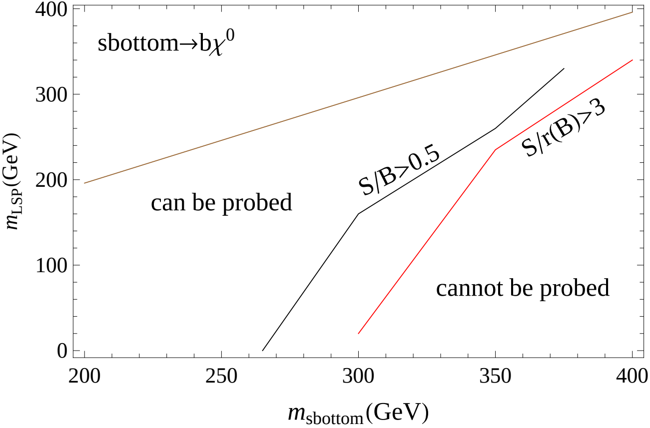
- We can look for a jet (attributable to ISR) having p_T much greater than that of b-jets in high-MET events. (our specific choice is 2.8 times greater)



Ex: 300GeV $\tilde{b}_1$ with $\Delta m = 50$GeV, we can retain 10% of signal, and reject 99.8% of $t\bar{t}$.

Discovery reach

@ 8TeV $30fb^{-1}$



Sys dominated. Need to think more on very squeezed case ($\Delta m \lesssim 30$GeV).

5. Application to other processes with small-gap

The same observables can be used to look for other important channels too.

Application to others with small-gap

Processes sharing the same kinematic feature:

1. $\tilde{t}_1 \to b\chi^+$: just smaller x-section and BR.
2. $\tilde{t}_1 \to c\chi^0$: can be important when only four-body decay $\tilde{t}_1 \to bW^*\chi^0$. c-tag is less efficient.

   Ex) 300GeV $\tilde{t}_1$ w/ $\Delta m \sim 40$GeV: $S/B \sim 0.3, S/\sqrt{B} > 6$ at 8TeV $100 fb^{-1}$.

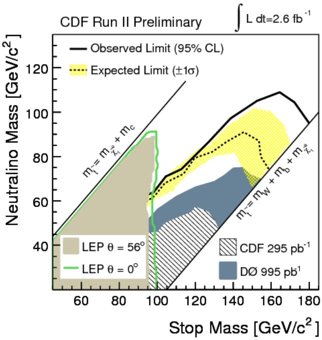


Figure: from CDF note 9834

Application to others with small-gap

Process with similar kinematic feature:

3. $\tilde{t}_1 \to t^* \chi^0$: Off-shell top produces soft decay products and deviations from on-shell top. b and ℓ. Could be easier in various directions, e.g. $m(b\ell)$ (Kats, Shih).

   Ex) $m(b\ell)$ and our cuts work similarly well for $\sim$ 300GeV $\tilde{t}_1$.

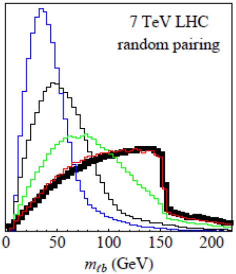


Figure: 1106.0030 Kats, Shih

Summary and prospect

- If we can discover (light) stops/sbottoms, we can learn really a lot about EWSB and SUSY.
- Squeezed case is especially hard to probe.
- However, useful kinematic differences exist.
- Measuring p_T ratio (rather than p_T itself) turns out to help greatly.
- Can also be applied to various other new physics, e.g. squeezed top-partner, charged Higgs.