

# Search for top-squark pair production in the single lepton final state in pp collisions at $\sqrt{s} = 8$ TeV

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Light top squarks are favored if Supersymmetry is the not-fine-tuned answer to the hierarchy problem. A search for top squark pair production is performed selecting events with a single isolated electron or muon, high  $p_T$  jets, and large missing transverse mass. The data sample consists of pp collisions corresponding to an integrated luminosity of  $19.5 \text{ fb}^{-1}$  at a center-of-mass energy  $\sqrt{s} = 8$  TeV, delivered by LHC during 2012 and recorded by the CMS experiment.

The observed data are consistent with the predicted standard model backgrounds. Constraints are set on two simplified supersymmetric models with pair produced top squarks. Assuming the top squark decay to be either to a top quark and a neutralino or to a bottom quark and a chargino, the analysis probes top squarks with masses up to about 650 GeV.

## Motivation

### The hierarchy problem:

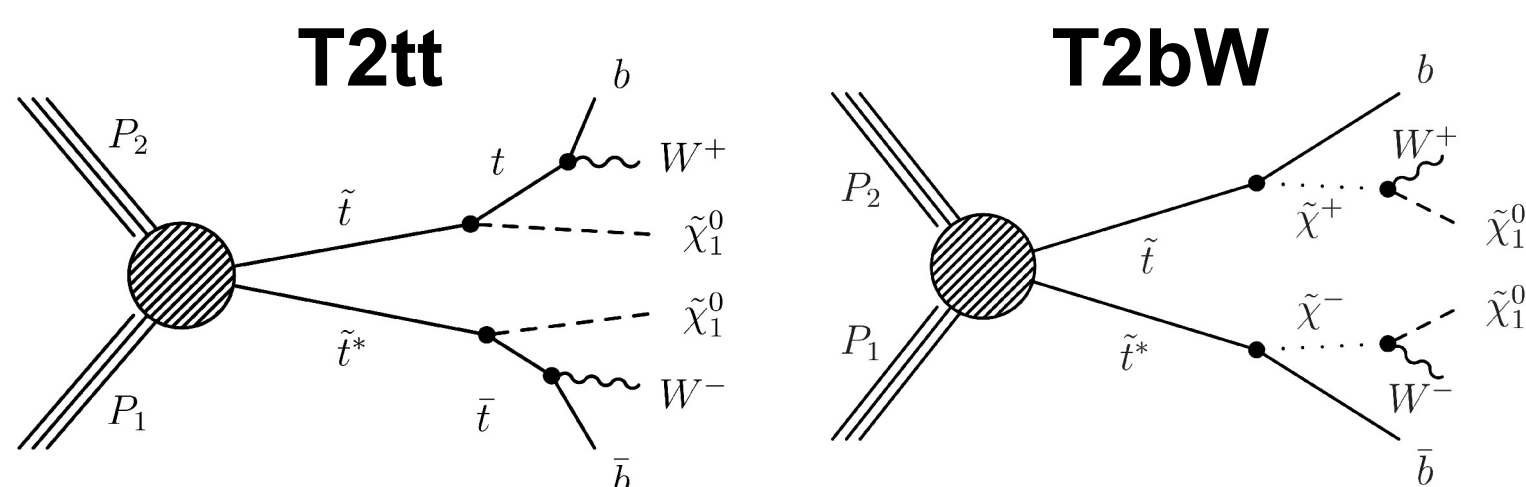
- Within the Standard Model, the corrections to the Higgs boson mass are quadratically divergent
- Fine tuning needed to reproduce the measured Higgs boson mass!**
- Within Supersymmetry (SUSY), additional loops with top squarks cancel top loop contribution to  $m_H$ 
  - "Not-Fine-Tuned" models require **light top squark**
  - R-parity conserving SUSY requires **pair-produced top squark** whose decay chains end with the neutral stable lightest supersymmetric particle  $\rightarrow$  Significant **missing transverse energy** (MET)

## Models Addressed

### Top-squark pair-production:

- Small mass** ( $\sim m_{top}$ ): large cross-section ( $\sigma \sim 40 \text{ pb}$ ), but signal looks like  $t\bar{t}$  ( $\sigma = 234 \text{ pb}$ )
- Large mass** ( $> m_{top}$ ): different kinematics, but small cross-section ( $\sigma \sim 10^{-2} \text{ pb}$  @  $m_{stop} = 650 \text{ GeV}$ )

### Two decay modes studied:



## Analysis Strategy

Full 2012  $\sqrt{s} = 8$  TeV data sample:  $\mathcal{L} = 19.5 \text{ fb}^{-1}$

### Baseline selection:

- 1 high  $p_T$  isolated  $e/\mu$ :**  $p_T > 25$  (30) GeV for  $e/\mu$
- anti- $k_T$  ( $R = 0.5$ ) jets:**  $p_T > 30$  GeV  
nJets  $\geq 4$   
at least one b-tagged jet
- MET > 100 GeV**
- Select events with  $M_T > 120$  GeV** in several signal regions defined with a cut-based or MVA approach
- Estimate backgrounds from MC**
  - Derive corrections/uncertainties in control regions

## Standard Model Backgrounds

### 1) $t\bar{t} \rightarrow l\bar{l} + jets$ (dominant)

- One lepton out of acceptance or not identified
- Large MET and  $M_T > M_W$  due to 2 neutrinos + missed lepton
- Additional jets from ISR/FSR

### 2) Single lepton top

- $t\bar{t} \rightarrow l + jets$ , single top  $\rightarrow$  Large  $M_T$  due to resolution effects and off-shell W

### 3) W + jets

### 4) Rare processes

- $t\bar{t}V, tW, VV, VVV, Z/\gamma^* + jets$

## Background and Uncertainties Estimation

### Control regions definitions:

SELECTION CRITERIA	exactly 1 $l$	> 1 $l$
0 b-tags	CR-0b: W+jets Validate W+jets $M_T$ tail	---
$\geq 1$ b-tags	SIGNAL REGION	CR-2 $l$ : $t\bar{t} \rightarrow 2l$ CR-2 $l$ : $t\bar{t} \rightarrow 2l + \text{isolated trk}/\tau_{had}$ Validate physics modeling and detector effects

### For each control region:

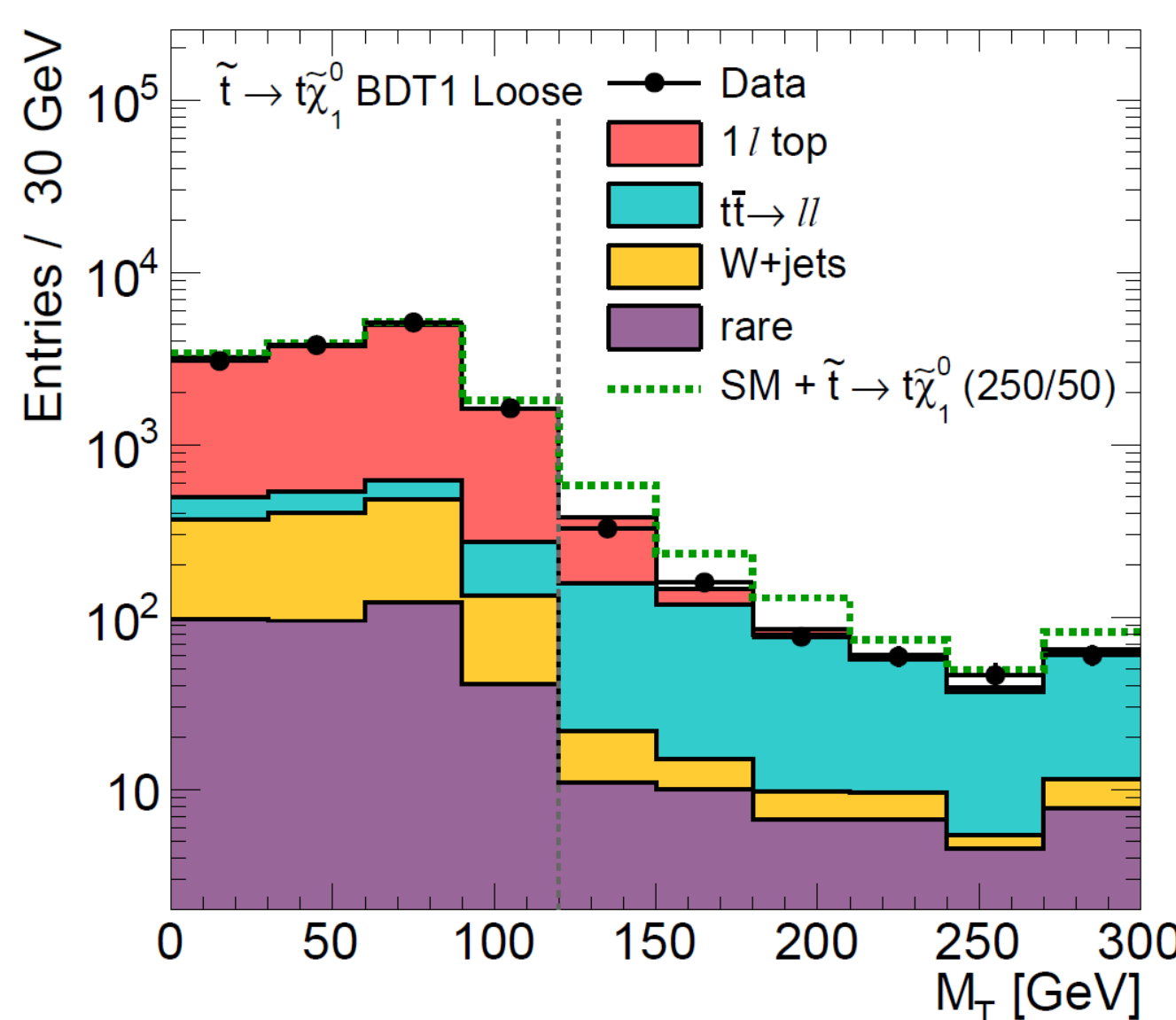
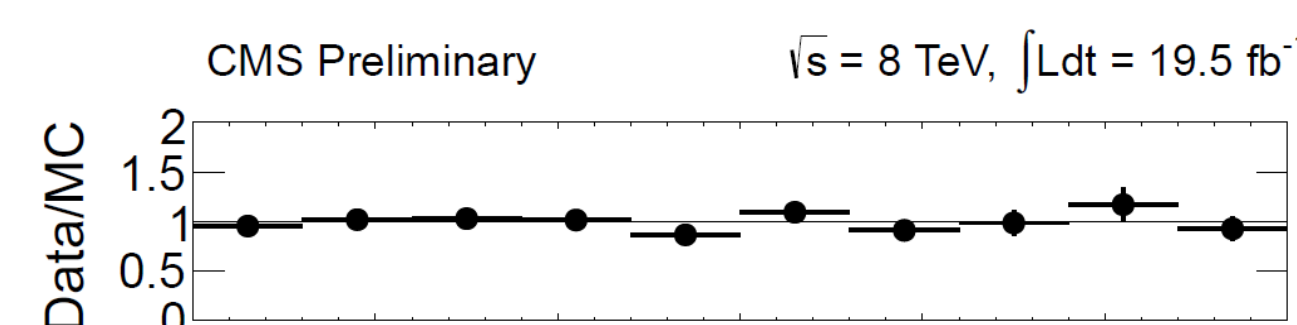
- 1) Normalize MC to data in  $M_T$  peak region  $\rightarrow$  reduce uncertainties from  $\sigma(t\bar{t})$ , luminosity, ...
- 2) Extrapolate to large  $M_T$
- 3) Derive corrections and uncertainties on the "peak-to-tail" ratios

$$N_{pred} = N_{MC} \left( \frac{\text{data}}{MC} \right)_{\text{peak}} \left( \frac{\text{data}}{MC} \right)_R$$

$\uparrow$  Predicted bkg in signal region       $\uparrow$   $M_T$  peak normalization       $\uparrow$  Data/MC correction  
"raw" MC prediction in signal region

## Results

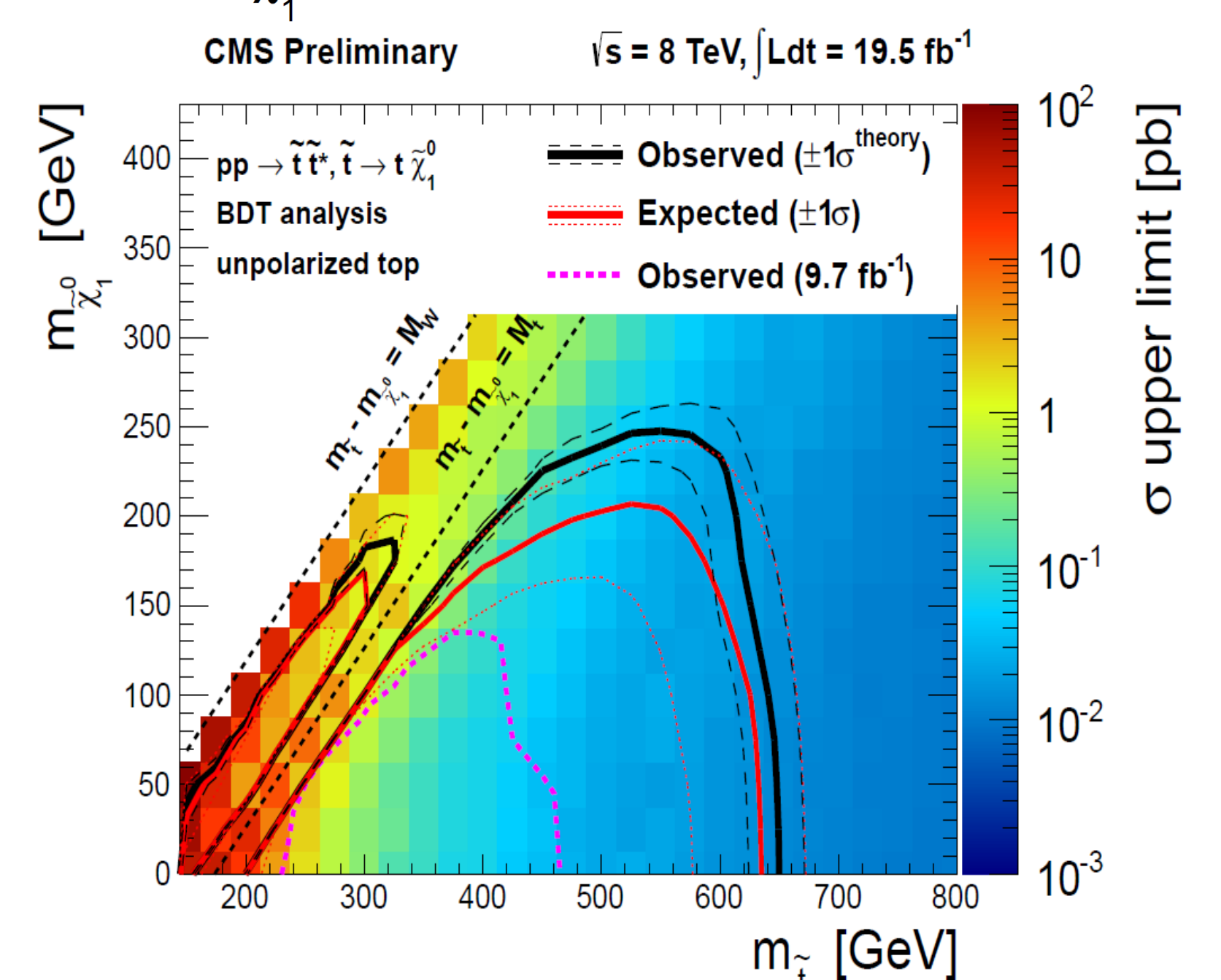
Data consistent with background prediction  $\rightarrow$  **no evidence for top-squark**



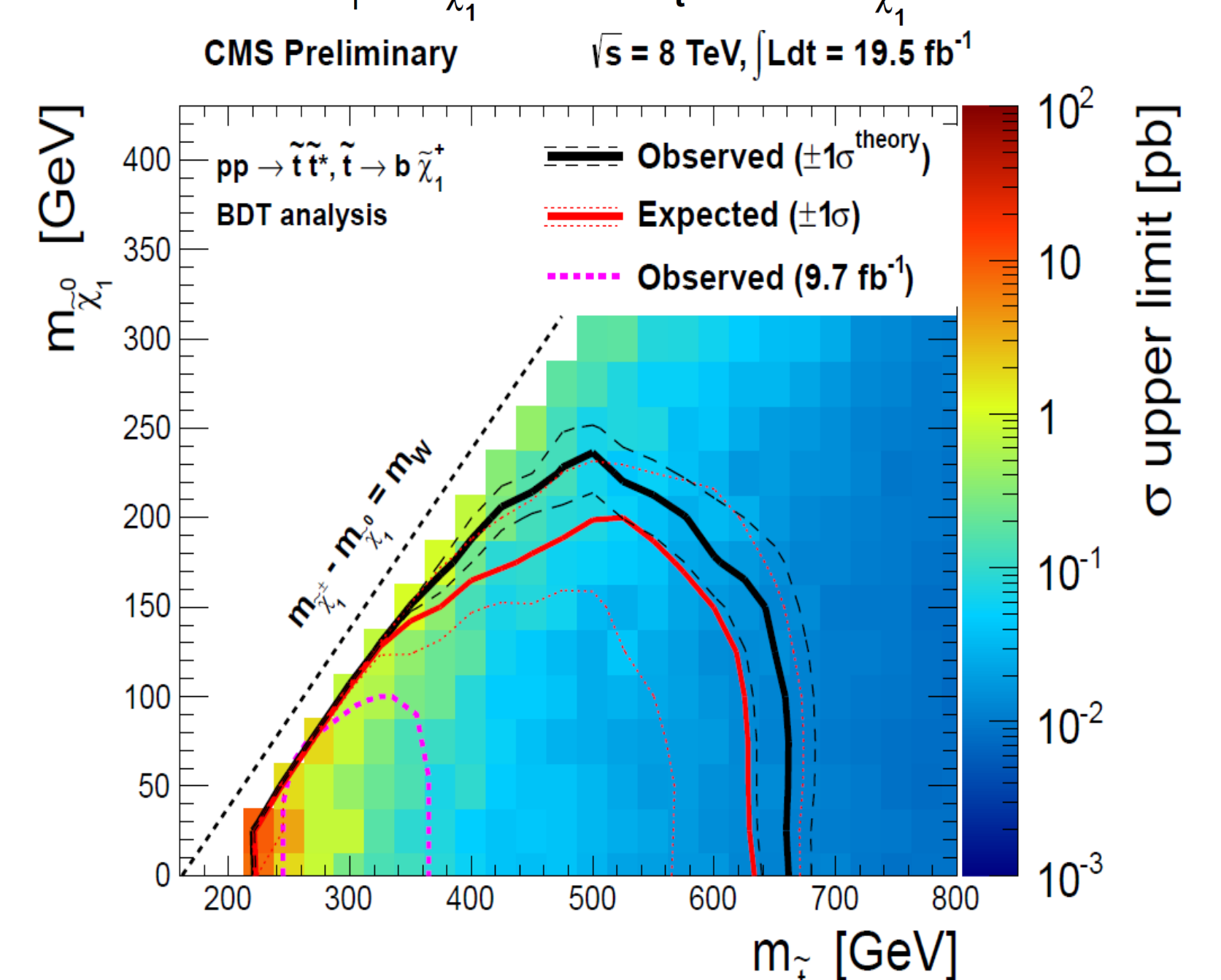
Sample	$\bar{t} \rightarrow b\tilde{\chi}_1^+$ $x=0.5$			
	BDT1	BDT2 Loose	BDT2 Tight	BDT3
$t\bar{t} \rightarrow l\bar{l}$	40 $\pm$ 5	21 $\pm$ 4	4 $\pm$ 2	6 $\pm$ 2
1 $l$ Top	24 $\pm$ 10	15 $\pm$ 7	4 $\pm$ 3	4 $\pm$ 2
W+jets	5 $\pm$ 1	5 $\pm$ 1	2 $\pm$ 1	3 $\pm$ 1
Rare	8 $\pm$ 4	8 $\pm$ 4	3 $\pm$ 1	4 $\pm$ 2
<b>Total</b>	<b>77 <math>\pm</math> 12</b>	<b>50 <math>\pm</math> 9</b>	<b>13 <math>\pm</math> 4</b>	<b>17 <math>\pm</math> 4</b>
Data	67	35	12	13
$\bar{t} \rightarrow b\tilde{\chi}_1^+$ (250/50/0.5)	66 $\pm$ 27	30 $\pm$ 20	< 6.0	< 6.0
$\bar{t} \rightarrow b\tilde{\chi}_1^+$ (650/50/0.5)	3.5 $\pm$ 0.4	9.5 $\pm$ 0.7	5.6 $\pm$ 0.5	8.3 $\pm$ 0.6

## Interpretation

### T2tt, $\bar{t} \rightarrow t\tilde{\chi}_1^0$ :



### T2bW, $\bar{t} \rightarrow b\tilde{\chi}_1^\pm, m_{\tilde{\chi}_1^\pm} = 0.5 m_{\tilde{t}} + 0.5 m_{\tilde{\chi}_1^0}$ :



## Conclusions

- A search for top squark pair production in a single lepton final state has been performed on the full 2012 data recorded by the CMS experiment
- Observed yields are consistent with predicted background  $\rightarrow$  **no evidence for top-squark**
- Limits have been set on SMS, testing **top squarks masses up to 650 GeV and neutralinos masses up to 250 GeV**, depending on the model

## Reference



CMS Physics Analysis Summary:  
CMS-PAS-SUS-13-011  
<http://cds.cern.ch/record/1547550>

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