Search for top squark pair production in final states with two τ leptons, jets, and missing transverse momentum in $\sqrt{s} = 13$ TeV *pp*-collisions with the ATLAS detector

Taller de Altas Energías 2016

Michael Holzbock

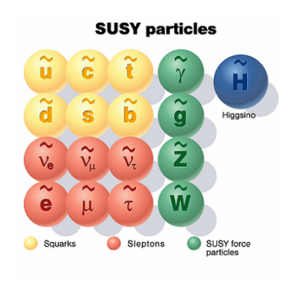
September 7, 2016

LMU Munich

(Short) Review of Supersymmetry

Motivation

- shortcomings of SM
  - no unification of coupl. const.
  - no (cold) dark matter candidate
  - loop corrections of Higgs mass
- can be solved by SUSY



Implementation

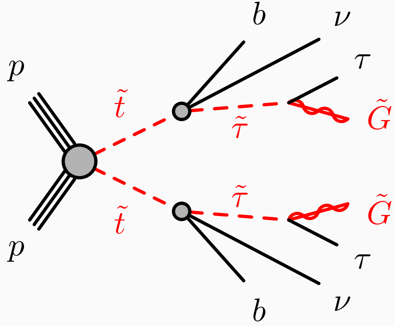
- extend symmetries of Poincaré group
- operator Q relating fermions and bosons:

  $Q\,|\mathrm{Boson}\rangle = |\mathrm{Fermion}\rangle$ and v.v.
- symmetry is broken by unknown mechanism

Signal Model

Production & Decay

- direct production of scalar-top pairs
- 3-body decay of stop to b-quark, neutrino and stau
- stau decays into tau and gravitino (LSP)
- simplified model (BRs = 1)
- lep-had final state



ICHEP: ATLAS-CONF-2016-048

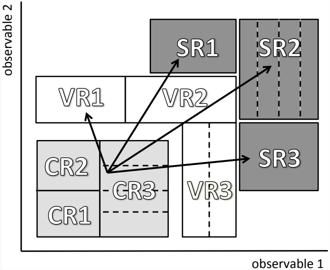
Final State

- 1 electron/muon
- 1 hadronic tau
- 2 b-jets
- large $E_{\mathrm{T}}^{\mathrm{miss}}$

Analysis Strategy

CR, VR & SR

- define signal-enriched region
- check and normalize background predictions in CR
- extrapolate from CR to SR
- verify extrapolation in VR

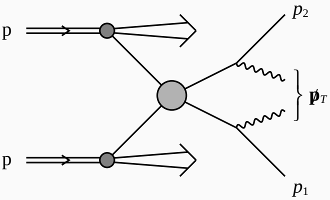


Implementation

- one SR, optimized for large stau masses
- background dominated by top–anti-top events
- tau reconstruction challenging
  $\rightarrow$ large fake (falsely reco. objects) rates
  $\rightarrow$ two dedicated for $t\bar{t}$ CRs for true and fake τ's

Event Selection

- triggered by e/μ signatures
- one reconstructed isolated e/μ
- one reco. hadronic τ of OS
- at least two jets

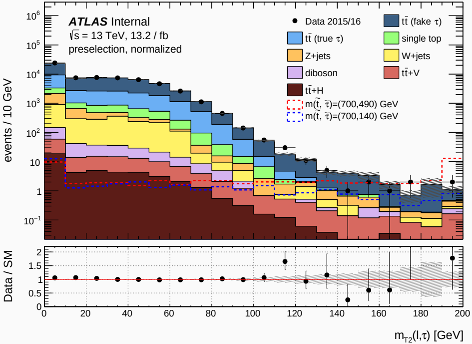


Discrimination against BG: m_{T2}

- generalization of m_{T} † for FS with multiple invisible particles
- $m_{\mathrm{T2}}^2 = \min_{\mathbf{q}_1+\mathbf{q}_2=\not{p}_{\mathrm{T}}} \left[\max\left\{m_T^2(\mathbf{p}_1,\mathbf{q}_1), m_T^2(\mathbf{p}_2,\mathbf{q}_2)\right\}\right]$
- $m_{\mathrm{T2}}(l,\tau)$ falls off steeply for BG, broad distribution for signal

† $m_{\mathrm{T}}^2 = m_p^2 + 2(E_{\mathrm{T}}^p \not{p}_{\mathrm{T}} - \mathbf{p}_{\mathrm{T}} \not{\mathbf{p}}_{\mathrm{T}})$

SR Definition



SR Definition

- $\mathrm{N}_{b\text{-jet}} \geq 1$
- $E_{\mathrm{T}}^{\mathrm{miss}} > 180$ GeV
- $p_{\mathrm{T}}(\tau) > 70$ GeV
- $m_{\mathrm{T2}}(l, \tau) > 100$ GeV

- verifying extrapolation of m_{T2} for true and fake τ's in two VRs
- correct normalization of $t\bar{t}$ with fake τ contribution is crucial
- crosschecks using adjusted selections
  - $\rightarrow$ normalization factor varies
  - $\rightarrow$ assign add. systematic uncertainty on this normalization

Systematic Uncertainties

Detector related

- trigger and object identification/reconstruction efficiencies
- energy calibration and resolution
- luminosity

Theory related

- factorization & renormalization scale, radiation and hard-scattering model
- cross sections and PDF sets

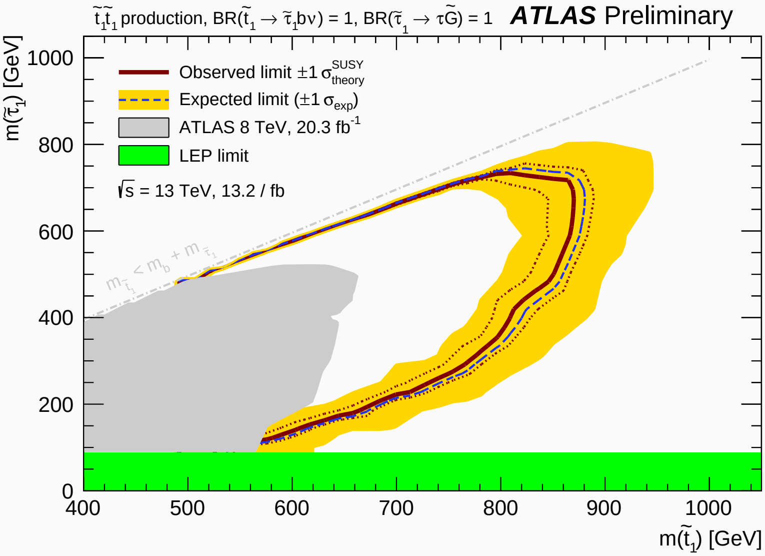
Dominated by uncertainties on $t\bar{t}$ modeling and normalization

Results

	SR
Observed events	4
Total background	3.4 ± 1.9
$t\bar{t}$ (fake τ)	2.5 ± 1.8
$t\bar{t} + V$	0.36 ± 0.19
$t\bar{t}$ (real τ)	$0.20^{+0.24}_{-0.20}$
diboson	$0.12^{+0.20}_{-0.12}$
$W+$jets	$0.07^{+0.09}_{-0.07}$
single-top	0.06 ± 0.06
$t\bar{t} + H$	0.05 ± 0.02
$Z+$jets	0.03 ± 0.01

- good agreement between observation and SM predictions
- update exclusion limits for this model

Exclusion Limits



Summary & Outlook

Summary

- search for direct stop-to-stau production with τ's in final state
- no excess above SM predictions observed
- increased exclusion limits for stop masses up to 870 GeV and for stau masses up to 730 GeV

Outlook

- publication for Moriond 2017 planned
- include had-had and lep-lep (reinterpretation) channels

BACKUP

CR and VR definitions

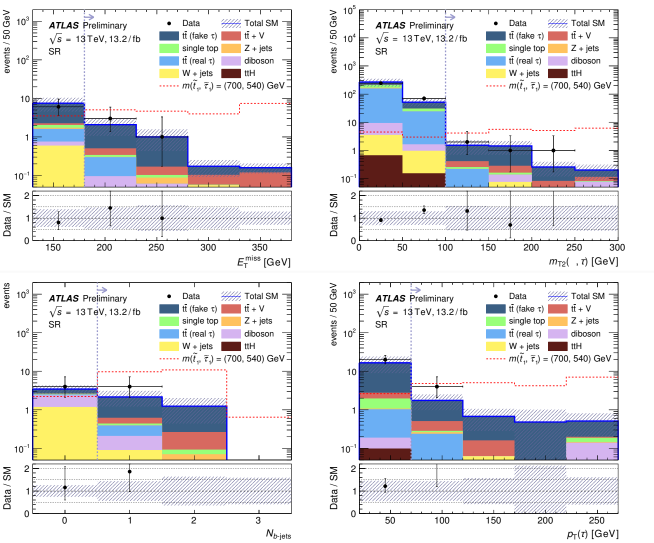
Variable	CR $t\bar{t}$ R5	CR $t\bar{t}$ F5	CR $t\bar{t}$ SS	CR W
$N_{b\text{-jet}}$	≥ 1	≥ 1	≥ 1	0
$E_{\mathrm{T}}^{\mathrm{miss}}$	> 180 GeV	> 120 GeV	> 150 GeV	> 100 GeV
$p_{\mathrm{T}}(\tau)$	> 70 GeV	> 70 GeV	> 20 GeV	< 90 GeV
$m_{\mathrm{T2}}(\ell,\tau)$	< 60 GeV	$20\,\mathrm{GeV} < m_{\mathrm{T2}}(\ell,\tau) < 60\,\mathrm{GeV}$	< 60 GeV	< 60 GeV
$m_{\mathrm{T}}(\ell)$	> 100 GeV	< 100 GeV	—	< 80 GeV
$m(\ell,\tau)$	—	—	—	> 80 GeV

Variable	VR $t\bar{t}$ R5	VR $t\bar{t}$ F5	VR $W+$jets $p_{\mathrm{T}}(\tau)$	VR $W+$jets $m_{\mathrm{T2}}(\ell,\tau)$
$N_{b\text{-jet}}$	≥ 1	≥ 1	0	0
$E_{\mathrm{T}}^{\mathrm{miss}}$	> 180 GeV	> 150 GeV	> 100 GeV	> 100 GeV
$p_{\mathrm{T}}(\tau)$	> 70 GeV	> 70 GeV	> 90 GeV	< 90 GeV
$m_{\mathrm{T2}}(\ell,\tau)$	$60\,\mathrm{GeV} < m_{\mathrm{T2}}(\ell,\tau) < 100\,\mathrm{GeV}$		< 100 GeV	> 60 GeV
$m_{\mathrm{T}}(\ell)$	> 100 GeV	< 100 GeV	< 80 GeV	< 80 GeV
$m(\ell,\tau)$	–	–	> 80 GeV	> 80 GeV

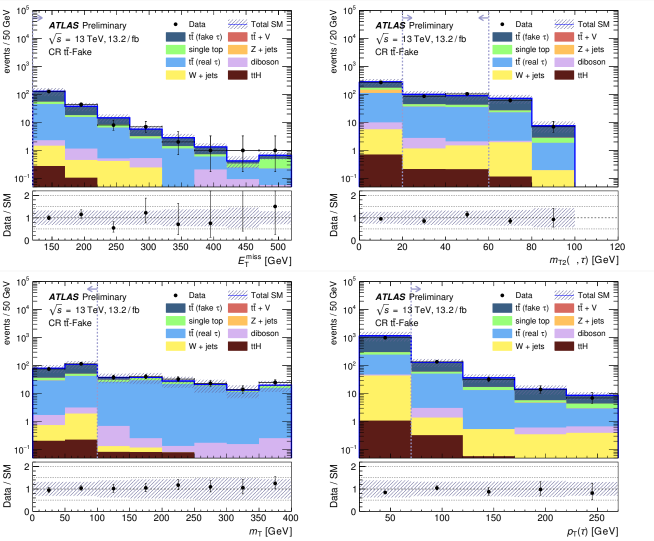
Model Independent Upper Limits

Signal channel	$\langle\epsilon\sigma\rangle_{\mathrm{obs}}^{95}$[fb]	S_{obs}^{95}	S_{exp}^{95}	CL_B	$p(s=0)$ (Z)
SR	0.55	7.3	$6.6^{+2.5}_{-1.6}$	0.65	0.41 (0.23)

N-1 Plots of SR



N-1 Plots of CR $t\bar{t}$ (fake τ)



N-1 Plots of CR $t\bar{t}$ (true τ)