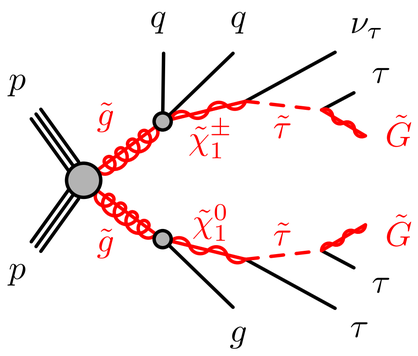
Search for Supersymmetry in Events with Large Missing Transverse Momentum, Jets, and at Least One Tau Lepton in 21 fb^{-1} of $\sqrt{s}$ = 8 TeV Proton-Proton Collisions with the ATLAS Detector

Ø. Dale on behalf of the ATLAS collaboration

Department of Physics and Technology, University of Bergen

Introduction

Supersymmetry (SUSY) is theoretically attractive as it can potentially solve the Standard Model (SM) Hierarchy problem and produce a candidate for Dark Matter.



In many SUSY models final states are tau rich. If such SUSY events are produced at the LHC they will leave signatures in the ATLAS detector containing missing transverse energy (E_T^{miss}) from the LSP escaping detection, along with jets and taus produced in the decay of the initial squark/gluino pair. The results are interpreted in three such tau rich models.

The tau lepton in ATLAS

- ~60% of taus decay hadronically into mesons and a neutrino
- Reconstructed from these well collimated mesons
- Detector signature similar to QCD jets, distinguishable by:
  - Width of the jet
  - Number of constituent particles
- Necessitates identification of taus by BDT discriminator using shower information from both the tracker and calorimeter

GMSB:

- LSP predominantly a light gravitino
- Lightest stau NLSP at large tanβ → taus

mSUGRA/CMSSM:

- Plane where the lightest Higgs boson mass is compatible with the recent discovery of a Higgs boson at the LHC

nGM:

- Constructed from general gauge mediation
- Weak scale SUSY parameters chosen to reduce fine tuning in the Higgs sector

Event Selection

Construct orthogonal search channels containing at least one hadronically decaying tau aimed at strong production of sparticles:

- Channels with exactly one and two or more taus
- Veto events with electrons and muons
- Trigger on events containing jets with high transverse momentum and large missing transverse momentum

Kinematic variables

$$m_{\mathrm{T}}^{\tau} = \sqrt{2 p_{\mathrm{T}}^{\tau} E_{\mathrm{T}}^{\mathrm{miss}} (1 - \cos(\Delta\phi(\tau, E_{\mathrm{T}}^{\mathrm{miss}})))}$$

$$H_{\mathrm{T}} = \sum p_{\mathrm{T}}^{\tau} + \sum_{i=1,2} p_{\mathrm{T}}^{\mathrm{jet_i}}$$

$$m_{\mathrm{eff}} = H_{\mathrm{T}} + E_{\mathrm{T}}^{\mathrm{miss}}$$

Main background characteristics:

- Multijet: E_T^{miss} from mis-measured jets and tau(s) from mis-identified QCD jets (fakes)
  - → Discriminating variables: ΔΦ (jet, E_T^{miss}) and E_T^{miss}/m_{eff}
- W+jets, Z+jets and top: Contains E_T^{miss} from neutrinos, jets and both true and fake taus
  - → Discriminating variables: m_T^{τ} and H_T

Event selection criteria for the three final states

	1τ SR	2τ GMSB SR	2τ nGM SR
Pre-selection	$p_{\mathrm{T}}^{\mathrm{jet1}} > 130$ GeV, $p_{\mathrm{T}}^{\mathrm{jet2}} > 30$ GeV, $E_{\mathrm{T}}^{\mathrm{miss}} > 150$ GeV		
Taus	$N_\tau^{\mathrm{medium}} = 1$, $p_T^\tau > 30$ GeV	$N_\tau^{\mathrm{loose}} \geq 2$, $p_T^\tau > 20$ GeV	
Light leptons	$N_\ell = 0$		
QCD rejection	$\Delta(\phi_{jet_{1,2}-\mathbf{p}_{\mathrm{T}}^{\mathrm{miss}}}) > 0.3$ rad, $E_{\mathrm{T}}^{\mathrm{miss}}/m_{\mathrm{eff}} > 0.3$	$\Delta(\phi_{jet_{1,2}-\mathbf{p}_{\mathrm{T}}^{\mathrm{miss}}}) > 0.3$ rad	
Signal cuts	$m_T^\tau > 140$ GeV, $H_T > 800$ GeV	$m_{\mathrm{T}}^{\tau_1} + m_{\mathrm{T}}^{\tau_2} \geq 150$ GeV, $H_T > 900$ GeV	$m_{\mathrm{T}}^{\tau_1} + m_{\mathrm{T}}^{\tau_2} \geq 250$ GeV, $H_T > 600$ GeV, $N_{\mathrm{jet}} \geq 4$

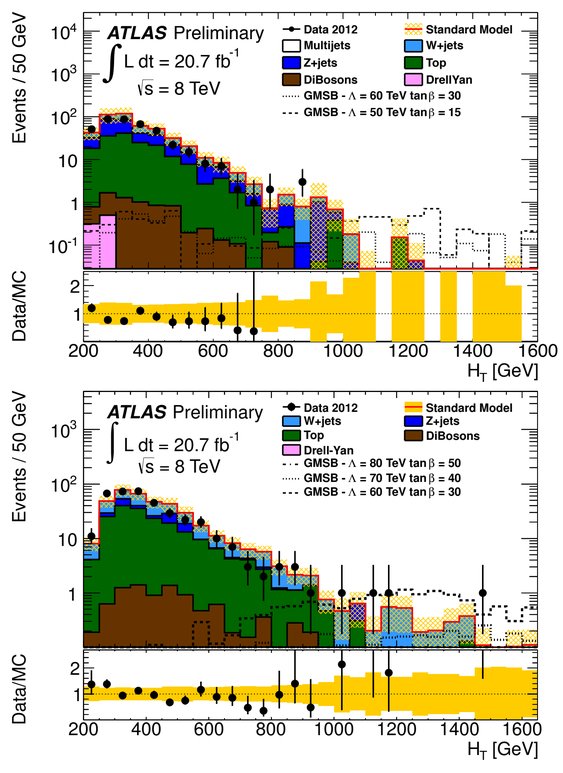
Background Estimation

Correct MC background expectations in the signal regions (SRs) by process dependent scaling factors derived from the data to MC event yields in control regions (CRs). Reduces effects of possible mis-modelling of tau mis-identification probabilitites and kinematics in the MC simulation.

Correlations between backgrounds taken into account by solving the matrix equation:

$$\mathbf{N}^{\mathrm{data}} = A\boldsymbol{\omega},$$

where $\mathbf{N}^{\mathrm{data}}$ is the observed data events in each CR. The matrix A contains MC expectation for each CR (row) and each background (column). The vector of scaling factors, $\boldsymbol{\omega}$, for each background is obtained by inverting A.



Distributions after all analysis requirements but the H_T requirement for the one tau (top) and two tau (bottom) GMSB SRs.

One tau:

- Matrix method for Top, W+jets and Z+jets
- Separated into events with true/fake taus
- ABCD method in space of ΔΦ (jet, E_T^{miss}) and tau ID used to estimate multijets

Two tau:

- Matrix method for Top, W+jets and Z+jets (GMSB) and single scale factor for Top (nGM)
- True/fake tau composition of CRs as in SRs
- Sideband with low ΔΦ (jet, E_T^{miss}) and E_T^{miss}/m_{eff} used to estimate multijets

Main systematic uncertainties

- Extrapolation from CRs to SRs
- Jet energy scale and resolution
- Tau energy scale
- Pileup re-weighting

Results

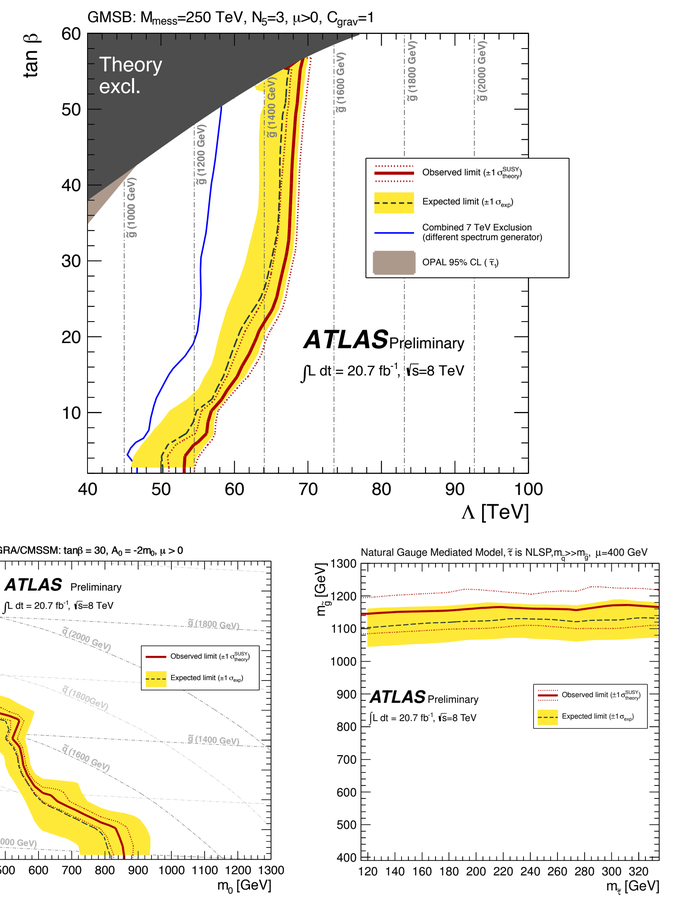
–	1τ	2τ GMSB region	2τ nGM region
Multi-jet	0.03±0.01	0.14 ± 0.04	0.04 ± 0.02
W + jets	1.9 ± 0.5 ± 0.7	3.8 ± 1.1 ± 0.9	0.3 ± 0.2 ± 0.4
Z + jets	2.1 ± 1.2 ± 1.7	0.3 ± 0.3 ± 0.5	0.02 ± 0.02 ± 0.01
top	0.7 ± 0.6 ± 0.3	2.4 ± 0.7 ± 1.4	3.1 ± 1.0 ± 1.7
di-boson	0.1±0.1 ± 0.1	0.6 ± 0.2 ± 0.2	0.02 ± 0.02 ± 0.02
Total background	4.9±1.5 ±1.3	7.2 ± 1.3 ± 1.6	3.5 ± 1.1 ± 1.9
Data	3	5	1

All SR results are consistent with SM expectations. Set limits at 95% Confidence Level (CL) using the profile likelihood ratio method and the CL_S criterion. Uncertainties on the background and signal expectations are treated as Gaussian-distributed nuisance parameters in the likelihood fit.

Model independent upper limits:

–	1τ	2τ GMSB region	2τ nGM region
Obs (exp) limit on signal events	8.3 ($9.0^{+2.7}_{-2.2}$)	8.7 ($9.6^{+5.2}_{-2.4}$)	5.0 ($6.3^{+3.7}_{-0.6}$)
Obs limit on Cross Section (fb)	0.40	0.42	0.24

Model dependent limits:



Expected and observed 95% CL lower limits on the SUSY model grid parameters. GMSB: combined limit one and two tau, mSUGRA/CMSSM: one tau limit only, nGM: two tau limit only

Conclusion

A search for SUSY in final states with jets, E_T^{miss}, and one or more hadronically decaying tau leptons is performed using 20.7 fb^{-1} of $\sqrt{s}$ = 8 TeV pp collision data recorded with the ATLAS detector at the LHC. No excess above the expected SM backgrounds is observed and limits are set on new physics phenomena and in the context of GMSB, mSUGRA/CMSSM and nGM.

References

The ATLAS collaboration, *Search for Supersymmetry in Events with Large Missing Transverse Momentum, Jets, and at Least One Tau Lepton in 21 fb−1 of √s = 8 TeV Proton-Proton Collision Data with the ATLAS Detector*, ATLAS-CONF-2013-026.