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Search for squarks and gluinos with the ATLAS detector in final states with jets and missing transverse momentum and 20.3 fb^{-1} of $\sqrt{s}$=8 TeV proton-proton collision data

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Abstract

Weak scale supersymmetry is one of the best motivated and studied Standard Model extensions. It predicts the existence of new heavy coloured particles called squarks and gluinos which are the supersymmetric partners of the quarks and gluons respectively. The poster summarises results on inclusive searches for supersymmetric squarks and gluinos in events containing jets and missing transverse momentum without leptons. The searches use the full data sample of $20.3 fb^{-1}$ recorded in 2012 at $\sqrt{s}$ = 8 TeV centre-of-mass energy by the ATLAS experiment at the LHC.

Keywords: squark, gluino, boosted W, 0-lepton, SUSY

1. Introduction

The supersymmetric models, as one of the most natural extensions of the Standard Model, are extensively studied with the ATLAS detector at the LHC both directly and indirectly. This search is dedicated to one of many possible signatures, namely events with large missing transverse momentum and large transverse momenta of the jets are required and events containing leptons are vetoed. This signature is typical for potential production of squark/gluino pairs when R-parity is assumed to be conserved. Squarks and gluinos can decay directly or also via longer decay chains, producing many jets, into the lightest supersymmetric particle which is stable due to R-parity conservation and escapes the ATLAS detector undetected. So called simplified models are considered, which assume a branching ratio of 100% for a specific decay chain of the squark/gluino pair. Such models are widely studied by many SUSY analyses (this included) as they can be used to study specific event typologies and to place limits on a large variety of models for sparticle productions.

2. Event Selection

This analysis uses 15 signal regions (SRs), listed in the table 1, to search for deviations from the Standard Model. They are named according to the number of jets to which a requirement on the transverse momentum is placed. The last letter is dedicated to closer specification of the SR. Note that AntiKt jet algorithm [1] with cone size of 0.4 is used for all the jets and for all the SRs in this analysis. Each SR is optimized to yield the best exclusion limits for one or more simplified models. The following observables:

$$m_{\mathrm{eff}}(N\mathrm{j}) = \sum_{\mathrm{jet}}^{N} p_{\mathrm{T}}(\mathrm{jet}) + \mathbf{E}_{\mathrm{T}}^{\mathrm{miss}}$$
$$H_{\mathrm{T}} = \sum_{p_T > 40GeV} p_{\mathrm{T}}(\mathrm{jet})$$
$$m_{\mathrm{eff}}(\mathrm{incl.}) = H_{\mathrm{T}} + \mathbf{E}_{\mathrm{T}}^{\mathrm{miss}}$$

are used to define selection criteria for the SRs. The SRs are defined such that the contribution from multi-jet events from QCD processes is below 5%.

There are several additions in the recent publication [2] compared to the preliminary result [3]. One of them

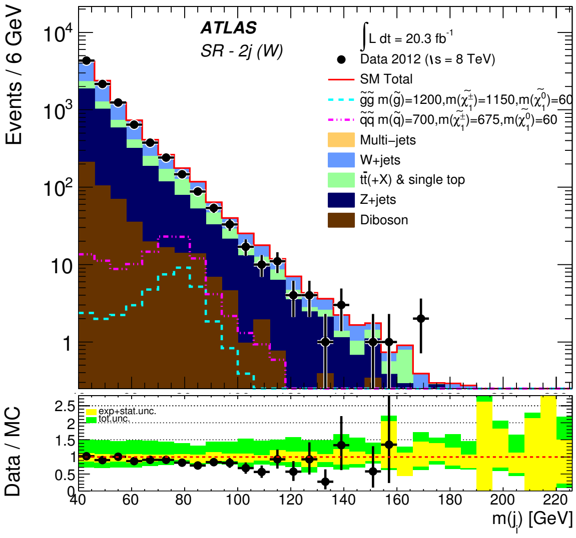

Figure 1: Invariant mass of the remaining jets when first jet in p_T was reconstructed as W. A mass window around the W mass peak is used for the reconstruction of the second W candidate.

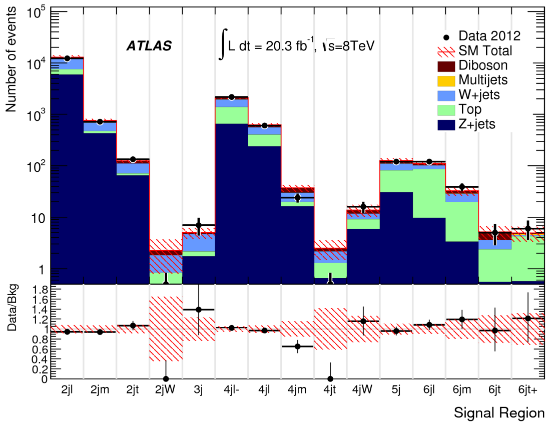

Figure 2: Comparison of the observed and expected event yields in each SR.

is the use of the new SRs 2jW and 4jW, dedicated to final states with two hadronically decaying boosted W bosons. We distinguish ”resolved Ws”, where two quarks from the W-boson decay lead to two isolated jets, and ”unresolved Ws”, where both quarks jets are reconstructed within one jet. The W bosons are consequently reconstructed using the invariant mass of one (two) jets for unresolved (resolved) W, respectively. In the fig. 1 dedicated to SR 2jW, there is invariant mass distribution of the remaining jets, where the largest jet ordered in p_T is already identified as unresolved W. A clear enhancement is visible near the W mass in the distribution of the SUSY signals, indicating that the method is efficient to reconstruct boosted W pairs. Both signal regions are most powerful for the so-called 1-step simplified models ($\tilde{g} \to \tilde{\chi}^{\pm} q\bar{q} \to \tilde{\chi}^0 q\bar{q} W^{\pm}$) where the difference between the masses of the $\tilde{\chi}^{\pm}$ and $\tilde{\chi}^0$ is large.

3. Background estimation

Control regions (CRs) are used to determine the background. They are kinematically close to SRs, but contain a large number of background events and a small expected contribution of the SUSY signal. Four CRs are defined, each dedicated to one of the most dominant background processes (see table 2). The event yield for a given background process in the SRs is estimated according to eq. 1.

$$N(\text{SR,est}) = N(\text{CR,obs}) \frac{N(\text{SR,raw})}{N(\text{CR,raw})} \qquad (1)$$

where N(SR,raw)/N(CR,raw) is the transfer factor, determined either from Monte Carlo simulation or from data-driven methods where possible. N(CR,obs) is the observed event count in a given control region. A likelihood fit is used to normalize the background processes in all CRs.

Using this procedure, a significant reduction of systematic uncertainties can be achieved in comparison with MC simulation only (i.e. roughly by factor 2-10 in case of the jet energy scale uncertainty). Event counting in the SRs is used to calculate the confidence level (CL) for the exclusion and discovery fits. Since no excess is observed, a maximal likelihood method is used to set 95% CL exclusion limits for SUSY models.

4. Results and Interpretations

The observed number of events in each SR compared to the expectation from SM processes is shown in the fig. 2. In general good agreement is found between data and SM expectation. The result was therefore used to provide exclusion limits for many SUSY models [2]. An example is shown in fig. 3 where the 2jW and 4jW signal regions mentioned previously have a significant impact ($\tilde{g}$ mass limits are extended above 1200 GeV), especially in regions of $x \sim 1$ where x is defined as $x = (m_{\tilde{\chi}^{\pm}} - m_{\tilde{\chi}^0})/(m_{\tilde{g}} - m_{\tilde{\chi}^0})$.

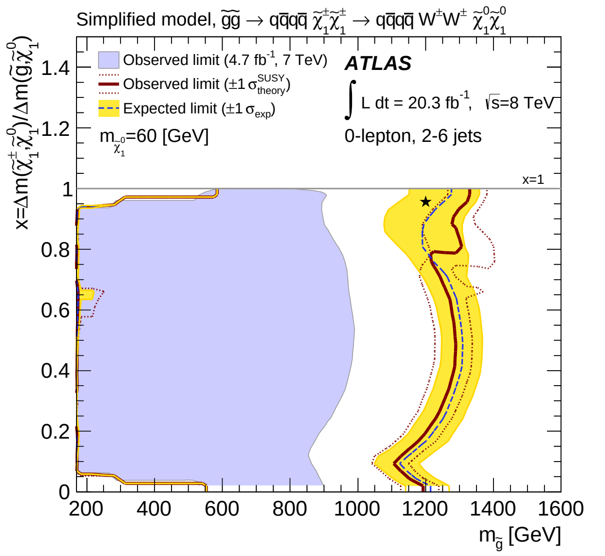

Figure 3: Exclusion limit plot for simplified model of gluino pair production followed by 1-step decay: $\tilde{g} \to \tilde{\chi}^{\pm} q\bar{q} \to \tilde{\chi}^0 q\bar{q} W^{\pm}$. Impact of W SRs is visible as prolonged excluded area for $x \sim 1$.

5. Conclusion

The full ATLAS dataset at 8 TeV with an integrated luminosity of 20.3 fb^{-1} was analysed to search for SUSY signals in the 0-lepton 2-6 jet channel. All results are in very good agreement with the Standard Model prediction and therefore exclusion limits for many SUSY models are provided. New signal regions for boosted W bosons have been developed and optimized to be sensitive to a larger part of SUSY parameter space.

References

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[3] The ATLAS Collaboration, *Search for squarks and gluinos with the ATLAS detector in final states with jets and missing transverse momentum and 20.3 fb^{-1} of $\sqrt{s}$=8 TeV proton-proton collision data*, Tech. Rep. ATLAS-CONF-2013-047, CERN, Geneva, May, 2013.

Requirement	Signal Region					
	2jl	**2jm**	**2jt**	**2jW**	**3j**	**4jW**
$\mathbf{E}_T^{miss}$[GeV] >	160					
$p_T(j_1)$ [GeV] >	130					
$p_T(j_2)$ [GeV] >	60					
$p_T(j_3)$ [GeV] >	–				60	40
$p_T(j_4)$ [GeV] >	–					40
$\Delta\phi(\text{jet}_{1,2,(3)}, \mathbf{E}_T^{miss})_{min}$ >	0.4					
$\Delta\phi(\text{jet}_{i>3}, \mathbf{E}_T^{miss})_{min}$ >	–					0.2
W candidates	–			$2(W \to j)$	–	$(W \to j) + (W \to jj)$
$\mathbf{E}_T^{miss}/\sqrt{H_T}$ [GeV$^{1/2}$] >	8	15		–		
$\mathbf{E}_T^{miss}/m_{eff}(N_j)$ >	–			0.25	0.3	0.35
m_{eff}(incl.) [GeV] >	800	1200	1600	1800	2200	1100

Requirement	Signal Region								
	4jl-	**4jl**	**4jm**	**4jt**	**5j**	**6jl**	**6jm**	**6jt**	**6jt+**
$\mathbf{E}_T^{miss}$[GeV] >	160								
$p_T(j_1)$ [GeV] >	130								
$p_T(j_2)$ [GeV] >	60								
$p_T(j_3)$ [GeV] >	60								
$p_T(j_4)$ [GeV] >	60								
$p_T(j_5)$ [GeV] >	–				60				
$p_T(j_6)$ [GeV] >	–					60			
$\Delta\phi(\text{jet}_{1,2,(3)}, \mathbf{E}_T^{miss})_{min}$ >	0.4								
$\Delta\phi(\text{jet}_{i>3}, \mathbf{E}_T^{miss})_{min}$ >	0.2								
$\mathbf{E}_T^{miss}/\sqrt{H_T}$ [GeV$^{1/2}$] >	10		–						
$\mathbf{E}_T^{miss}/m_{eff}(N_j)$ >	–		0.4	0.25	0.2			0.25	0.15
m_{eff}(incl.) [GeV] >	700	1000	1300	2200	1200	900	1200	1500	1700

Table 1: Selection criteria for all 15 SRs. The W SRs are introduced to search for final states with boosted Ws.

CR	SR background	CR process	CR selection
CRγ	$Z(\to \nu\nu)$+jets	γ+jets	Isolated photon
CRQ	Multi-jets	Multi-jets	SR with reversed requirements on (i) $\Delta\phi(\text{jet}, \mathbf{E}_T^{miss})_{min}$ and (ii) $\mathbf{E}_T^{miss}/m_{eff}(N_j)$ or $\mathbf{E}_T^{miss}/\sqrt{H_T}$
CRW	$W(\to \ell\nu)$+jets	$W(\to \ell\nu)$+jets	30 GeV < $m_T(\ell, \mathbf{E}_T^{miss})$ < 100 GeV, b-veto
CRT	$t\bar{t}$ and single-t	$t\bar{t} \to b\bar{b}qq'\ell\nu$	30 GeV < $m_T(\ell, \mathbf{E}_T^{miss})$ < 100 GeV, b tag

Table 2: All the CRs used in the fit are summarized in this table. Each of them is dedicated to specific process.