ATLAS NOTE

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First look at proton–proton collision data at $\sqrt{s}$ = 13 TeV in preparation for a search for squarks and gluinos in events with missing transverse energy, jets, and one isolated electron or muon.

The ATLAS Collaboration

Abstract

This note presents a distribution of the transverse mass in events with one isolated electron or muon, at least four jets, and significant missing transverse energy. The dataset corresponds to an integrated luminosity of 78 pb^{-1} of proton–proton collisions taken at a centre-of-mass energy of $\sqrt{s}$ = 13 TeV by the ATLAS experiment at the Large Hadron Collider. The analysis is carried out in preparation for a search for squarks and gluinos in the same final state.

1 Introduction

Supersymmetry (SUSY) [1–9] is a theoretically favoured extension of the Standard Model (SM), which for each particle degree of freedom of the SM predicts another degree of freedom with a different spin. These degrees of freedom combine into physical superpartners of the SM particles: scalar partners of quarks and leptons (squarks ($\tilde{q}$) and sleptons), fermionic partners of gauge and Higgs bosons (gluinos ($\tilde{g}$), charginos ($\tilde{\chi}_i^{\pm}$, with i = 1,2) and neutralinos ($\tilde{\chi}_i^0$ with i = 1,2,3,4)), all with identical quantum numbers to their SM partners, except spin. Since no superpartner of any of the SM particles has been observed, SUSY must be a broken symmetry.

The discovery (or exclusion) of weak-scale SUSY is one of the highest physics priorities for the LHC. The primary target for early Supersymmetry searches in proton–proton (pp) collisions at a centre-of-mass energy of 13 TeV at the LHC, given their large expected cross-section, is the strong production of gluinos and squarks.

Under the hypothesis of R-parity conservation [10–13], SUSY partners are produced in pairs and decay either directly or via intermediate supersymmetric particles to the Lightest Supersymmetric Particle (LSP) which is stable and, in a large variety of models, is assumed to be the lightest neutralino ($\tilde{\chi}_1^0$) which escapes detection. The undetected $\tilde{\chi}_1^0$ would result in substantial missing transverse momentum ($\boldsymbol{p}_{\mathrm{T}}^{\mathrm{miss}}$, with magnitude $E_{\mathrm{T}}^{\mathrm{miss}}$), while the rest of the cascade, originating from the decays of squarks and gluinos, would yield final states with multiple jets and possibly leptons.

This note contains a glimpse at the very first proton–proton collision data taken with the ATLAS experiment at 13 TeV in preparation for searches for squarks and gluinos in final states with missing transverse momentum, jets, and one isolated electron or muon.

2 Dataset, Triggers, Simulated Samples

2.1 Dataset and trigger

This analysis uses data collected by the ATLAS detector in proton–proton collisions at the LHC at a centre-of-mass energy of $\sqrt{s}$ = 13 TeV in 2015. After applying beam-, data- and detector-quality criteria, the total integrated luminosity available amounts to 78 pb^{-1}. The uncertainty on the integrated luminosity is 9%. It is derived, following a methodology similar to that detailed in Ref. [14], from a preliminary calibration of the luminosity scale using a pair of x-y beam-separation scans performed in June 2015. A combination of single electron and muon triggers was used to collect this dataset, requiring that the recorded events contain at least one isolated electron or muon with $p_{\mathrm{T}} > 24$ GeV.

2.2 Simulated samples

Several Monte Carlo simulated samples are used to model the Standard Model background processes and an example signal in this analysis.

For the generation of $t\bar{t}$ and single top-quarks in the Wt and s-channel the Powheg-Box v2 [15] generator with the CT10 PDF sets in the matrix element calculations is used. Electroweak t-channel single top-quark events are generated using the Powheg-Box v1 generator. This generator uses the 4-flavour scheme for the

NLO matrix elements calculations together with the fixed four-flavour PDF set CT10f4. For this process, the top quarks are decayed using MadSpin [16] preserving all spin correlations, while for all processes the parton shower, fragmentation, and the underlying event are simulated using Pythia6.428 [17] with the CTEQ6L1 PDF sets and the corresponding Perugia 2012 tune (P2012) [18]. The top mass is set to 172.5 GeV. The EvtGen v1.2.0 program [19] is used for properties of the bottom and charm hadron decays.

Events containing W or Z bosons associated with jets are simulated using the SHERPA 2.1.1 [20] generator. Matrix elements are calculated for up to two partons at NLO and four partons at LO using the Comix [21] and OpenLoops [22] matrix element generators and merged with the SHERPA parton shower [23] using the ME+PSNLO prescription [24]. The CT10 parton distribution functions (PDF) [25] is used in association to authors tuning.

Diboson processes (WW, WZ, ZZ, $W\gamma$ and $Z\gamma$) are simulated using the SHERPA 2.1.1 generator. Matrix elements are calculated for no or one parton at NLO and up to three partons at LO using the Comix and OpenLoops matrix element generators and merged with the Sherpa parton shower using the ME+PSNLO prescription. The CT10 PDF set is used in association to authors tuning.

As an example signal sample, a simplified model point with gluino pair production is chosen, where the gluinos exclusively decay via $\tilde{\chi}_1^{\pm}$ to the $\tilde{\chi}_1^0$. The masses are set to values close to the run-1 exclusion limits [26] ($m(\tilde{g})$ = 1225 GeV, $m(\tilde{\chi}_1^{\pm})$ = 625 GeV and $m(\tilde{\chi}_1^0)$ = 25 GeV). The signal is generated with Madgraph 5 [27] interfaced with PYTHIA v.8.1 [28] for the parton shower model.

3 Event Selection & Results

In previous searches [26] and optimisation studies [29], the transverse mass,

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

has been seen to be an excellent discriminating variable between Standard Model backgrounds and a SUSY signal arising from gluino or squark pair production in final states containing one isolated lepton. Monitoring the performance in this variable is thus an important preparation for searches for squarks and gluinos in final states with missing transverse momentum, jets, and one isolated electron or muon. It is computed using the transverse momentum of the lepton, p_T^{ℓ}, the missing transverse energy, $E_{\mathrm{T}}^{\mathrm{miss}}$, and the angle between lepton and $E_{\mathrm{T}}^{\mathrm{miss}}$. This analysis uses the TST $E_{\mathrm{T}}^{\mathrm{miss}}$ as described in [30].

Events are selected with one isolated electron or muon with $p_T^{\ell} > 35$ GeV, at least four jets with $p_{\mathrm{T}} > 30$ GeV, and missing transverse energy of $E_{\mathrm{T}}^{\mathrm{miss}} > 100$ GeV. The dominant Standard Model backgrounds are in descending order $t\bar{t}$, W+jets, single t, diboson and Z+jets production. Any multi-jet background is assumed to be negligible after these preselection criteria due to the tight criteria on $E_{\mathrm{T}}^{\mathrm{miss}}$ and the lepton isolation [26].

The normalisation of the two major backgrounds $t\bar{t}$ and W+jets production is determined in a simultaneous likelihood fit to data in control regions using HistFitter [31]. The $t\bar{t}$ control region is defined using the same preselection criteria as above, but also requiring that at least one jet among the four selected jets was tagged as b-jet using a multivariate tagging algorithm [32]. Furthermore, the transverse mass is restricted to $40 < m_{\mathrm{T}} < 100$ GeV. The W+jets control region is defined in a similar way with the only difference being the requirement that no jet among the four selected jets is tagged as b-jet. The other minor

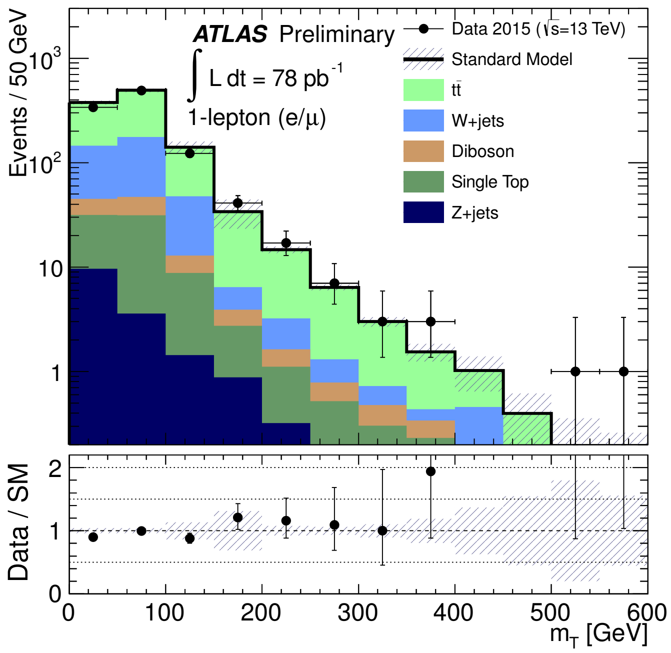

Figure 1: Distribution of the transverse mass for selected events in data and simulation after the fit. The uncertainty band on the Standard Model expectations includes statistical and experimental uncertainties as described in the text.

backgrounds are directly taken from Monte Carlo simulation and normalised to the integrated luminosity of the data and using the cross-section predictions described in Section 2.2.

In addition to the statistical uncertainties from the simulated samples, various systematic uncertainties are included in the fitting procedure: jet energy scale uncertainties, lepton momentum/energy resolution and scale uncertainties, lepton identification uncertainties, missing transverse energy resolution and scale uncertainties, and uncertainties related to the tagging of *b*-jets.

The distribution of the transverse mass after the preselection criteria and after normalising the $t\bar{t}$ and W+jets backgrounds is shown in Fig. 1, and also in Fig. 2 with a scaled gluino signal overlaid for illustration.

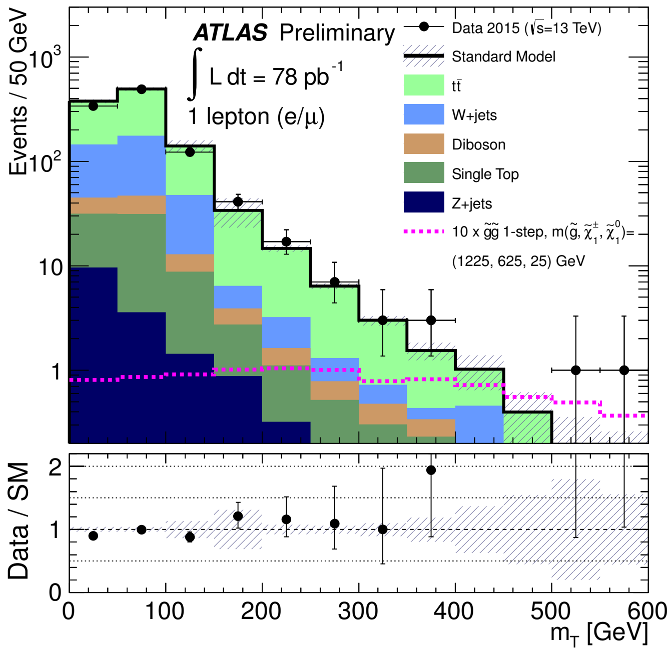

Figure 2: Distribution of the transverse mass for selected events in data and simulation after the fit. The uncertainty band on the Standard Model expectations includes statistical and experimental uncertainties as described in the text. A SUSY signal, scaled by a factor 10, with gluino pair-production and the gluinos exclusively decaying via $\tilde{g} \rightarrow \tilde{\chi}_1^{\pm} \rightarrow \tilde{\chi}_1^0$ and $m(\tilde{g})$ = 1225 GeV, $m(\tilde{\chi}_1^{\pm})$ = 625 GeV, $m(\tilde{\chi}_1^0)$ = 25 GeV is overlaid.

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