PROCEEDINGS OF SCIENCE

Supersymmetry - ATLAS

Xuanhong Lou[a,*] **on behalf of the ATLAS collaboration**

[a] *Stockholm University,*
Frescativägen, 11419 Stockholm, Sweden

E-mail: xuanhong.lou@cern.ch

Several searches for the supersymmetric partners of the Standard Model particles in a variety of final states are presented. These searches are performed using data collected at a centre-of-mass energy of 13 TeV with the ATLAS detector during the LHC Run 2, corresponding to an integrated luminosity of 139 fb^{-1}. No significant deviations from the Standard Model expectation are observed, while stringent limits on the supersymmetric particle masses have been placed in the context of various supersymmetric models.

The Eleventh Annual Conference on Large Hadron Collider Physics (LHCP2023)
22-26 May 2023
Belgrade, Serbia

*Speaker

PoS(LHCP2023)158

1. Introduction

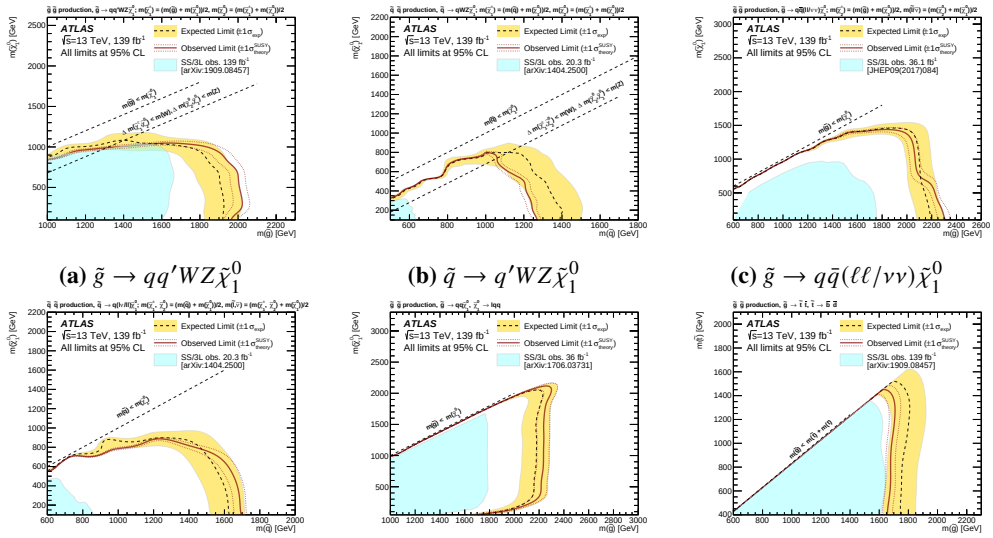
Supersymmetry (SUSY) predicts the existence of supersymmetric partners of the Standard Model (SM) particles and has been considered as one of the most attractive beyond standard model (BSM) theories. The recent highlights of SUSY searches performed using data collected by the ATLAS detector [1] at the Large Hadron Collider (LHC) [2] are presented, including a search for squarks or gluinos [3], a search for electroweakinos and staus [4], and a search for Higgsinos which decay into a light gravitino [5].

2. Search for pair production of squarks or gluinos decaying via sleptons or weak bosons in final states with two same-sign or three leptons

A recent SUSY search in ATLAS targets pair production of gluinos or squarks in final states with either two same-sign leptons or three leptons [3]. Different types of decay modes are considered, covering scenarios from R-parity-conserving (RPC) to R-parity-violating (RPV) models.

In the RPC scenario where squarks or gluinos decay into SM gauge bosons and the lightest SUSY particles (LSP) $\tilde{\chi}_1^0$ via cascade decays, i.e. $\tilde{\chi}_1^\pm \to \tilde{\chi}_2^0 W^\pm \to \tilde{\chi}_1^0 Z W^\pm$ (Figures 1a and 1b), the squark/gluino and $\tilde{\chi}_1^0$ masses are varied independently. The masses of intermediate superpartners are then set to the mass average of their parent in the decay chain and $\tilde{\chi}_1^0$. Similarly, for squarks or gluinos decaying into sleptons and subsequently into SM leptons and $\tilde{\chi}_1^0$ LSPs, i.e. $\tilde{\chi}_1^\pm (\to \ell\tilde{\nu}/\tilde{\ell}\nu) \to \ell\nu\tilde{\chi}_1^0$ (Figure 1c) and $\tilde{\chi}_2^0 (\to \tilde{\ell}\ell) \to \ell^+\ell^-\tilde{\chi}_1^0$ (Figure 1d), only the squark/gluino and $\tilde{\chi}_1^0$ masses are varied.

Direct $\tilde{\chi}_1^0$ decay into SM leptons and quarks, $\tilde{g} \to q\bar{q}\tilde{\chi}_1^0$, $\tilde{\chi}_1^0 \to \ell qq$, via a non-zero RPV coupling λ' of LQD type (Figure 1e), and $\tilde{g} \to t\bar{t}, \tilde{t} \to \bar{b}\bar{d}$ decays via a non-zero RPV coupling λ'' of UDD type (Figure 1f) are also considered.



(a) $\tilde{g} \to qq'WZ\tilde{\chi}_1^0$ **(b)** $\tilde{q} \to q'WZ\tilde{\chi}_1^0$ **(c)** $\tilde{g} \to q\bar{q}(\ell\ell/\nu\nu)\tilde{\chi}_1^0$

(d) $\tilde{q} \to q(\ell\nu/\ell\ell/\nu\nu)\tilde{\chi}_1^0$ **(e)** $\tilde{g} \to q\bar{q}\tilde{\chi}_1^0, \tilde{\chi}_1^0 \to \ell qq$ **(f)** $\tilde{g} \to t\bar{t}, \tilde{t} \to \bar{b}\bar{d}$

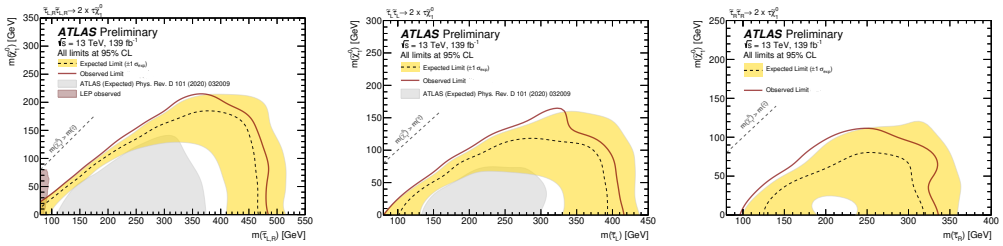
Figure 1: Observed (red line) and expected (black dashed line) 95% CL exclusion regions for $\tilde{g}$, $\tilde{q}$, $\tilde{\chi}_1^0$ and $\tilde{t}$ masses [3]. The light blue area indicates the observed limits obtained by previous ATLAS searches [6–12].

No significant excess over the Standard Model expectation is observed. The results are interpreted in the context of simplified models featuring gluino or squark pair production in RPC and RPV scenarios. Lower limits on particle masses are derived at 95% confidence level (CL) for these models, reaching as high as 2.2 TeV for gluinos and 1.7 TeV for squarks.

3. Search for electroweak SUSY production in final states with two τ-leptons

Another recent SUSY search in ATLAS focuses on events with two high-momentum τ-leptons, low jet activity and significant missing transverse momentum [4], which covers three different scenarios.

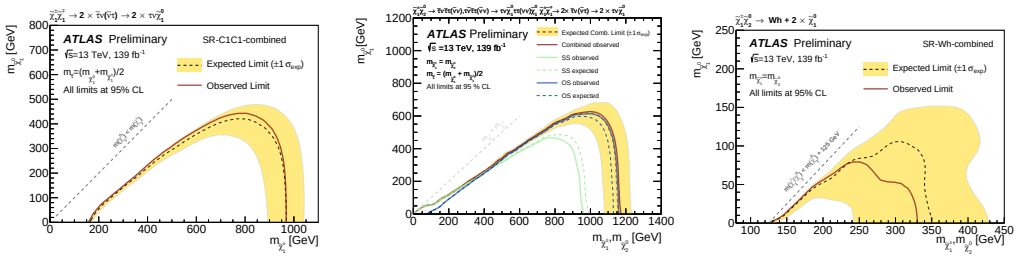
The first scenario considers the direct production of $\tilde{\tau}_L\tilde{\tau}_L$ and/or $\tilde{\tau}_R\tilde{\tau}_R$, with each $\tilde{\tau}$ decaying to a τ-lepton and a $\tilde{\chi}_1^0$ (Figure 2). Four Boosted Decision Trees are trained to optimise the sensitivity in specific regions of the $\tilde{\tau} - \tilde{\chi}_1^0$ mass parameter space.



(a) $\tilde{\tau}_{L,R} \to \tau\tilde{\chi}_1^0$ **(b)** $\tilde{\tau}_L \to \tau\tilde{\chi}_1^0$ **(c)** $\tilde{\tau}_R \to \tau\tilde{\chi}_1^0$

Figure 2: Observed (red line) and expected (black dashed line) 95% CL exclusion regions for simplified models of (a) $\tilde{\tau}_{L,R}\tilde{\tau}_{L,R}$ production, (b) $\tilde{\tau}_L\tilde{\tau}_L$ production, and (c) $\tilde{\tau}_R\tilde{\tau}_R$ production [4]. The grey area indicates the expected limits obtained by a previous ATLAS search [11].

The second scenario includes the production of neutralinos and charginos, $\tilde{\chi}_1^+\tilde{\chi}_1^-$ (Figure 3a) and $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ (Figure 3b), which decay to $\tilde{\chi}_1^0$ only through intermediate staus or tau sneutrinos with equal branching fraction.



(a) $\tilde{\chi}_1^+\tilde{\chi}_1^-$, intermediate $\tilde{\tau}/\tilde{\nu}_\tau$ **(b)** $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$, intermediate $\tilde{\tau}/\tilde{\nu}_\tau$ **(c)** $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$, intermediate Wh

Figure 3: Observed (red line) and expected (black dashed line) 95% CL exclusion regions for simplified models of (a) $\tilde{\chi}_1^+\tilde{\chi}_1^-$ production, (b) $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ production decaying via intermediate $\tilde{\tau}/\tilde{\nu}_\tau$ and (c) $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ production decaying via intermediate Wh [4]. The green (blue) curves in (b) are from the contribution of the same-sign (opposite-sign) tau pair scenarios.

The last scenario is the direct production of $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ decaying via the lightest neutral Higgs boson (h), consistent with the SM Higgs boson with a mass of 125 GeV, a W boson and two neutralinos (Figure 3c). In this channel, the final state τ-leptons are required to have opposite electric charge and an invariant mass compatible with m_h.

No significant excess over the Standard Model expectation is observed. Exclusion limits at 95% CL are also placed on simplified models of direct stau production, excluding mass-degenerate $\tilde{\tau}_{L,R}$ up to 500 GeV, $\tilde{\tau}_L$ up to 425 GeV, and $\tilde{\tau}_R$ up to 350 GeV. The sensitivity to $\tilde{\tau}_R\tilde{\tau}_R$ production obtained in this search is the first for this process reported by ATLAS. In the scenario of $\tilde{\chi}_1^+\tilde{\chi}_1^-$ ($\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$) decaying into $\tilde{\chi}_1^0$ via intermediate staus, exclusion limits are placed for masses up to 970 GeV (1160 GeV). For $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ decaying via intermediate Wh, gaugino masses up to 330 GeV are excluded for a massless $\tilde{\chi}_1^0$ LSP.

4. Search for pair-produced Higgsinos decaying via Higgs or Z bosons to final states containing a pair of photons and a pair of b-jets

This ATLAS search targets the pair production of higgsinos ($\tilde{\chi}_1^0$) which decay into a light gravitino ($\tilde{G}$) either via a Higgs or Z boson [5]. Three non-overlapping signal-enriched regions are defined and optimised based on studies of simplified gauge-mediated supersymmetry models with varying $\tilde{\chi}_1^0$ mass, and of differing values of the branching fraction $\mathcal{B}(\tilde{\chi}_1^0 \to h\tilde{G})$, allowing for a statistical combination which further enhances the sensitivity.

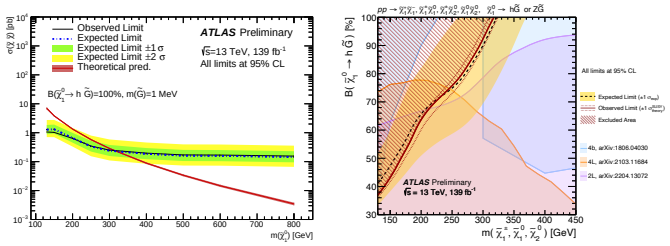


Figure 4: Observed and expected 95% CL exclusion limits on (left) the pure-higgsino cross-section assuming $\mathcal{B}(\tilde{\chi}_1^0 \to h\tilde{G}) = 100\%$ for different $\tilde{\chi}_1^0$ masses and (right) the pure-higgsino branching fraction to $\mathcal{B}(\tilde{\chi}_1^0 \to h\tilde{G})$ as a function of the higgsino mass $m_{\tilde{\chi}_1^0}$ assuming it decays via either $\tilde{\chi}_1^0 \to h\tilde{G}$ or $\tilde{\chi}_1^0 \to Z\tilde{G}$ [5].

No significant excess over the Standard Model expectation is observed. A 95% CL lower limit on the higgsino mass $m_{\tilde{\chi}_1^0}$ is set at 320 GeV assuming $\mathcal{B}(\tilde{\chi}_1^0 \to h\tilde{G}) = 100\%$, excluding the region between 250 to 300 GeV where the previous ATLAS search [13] did not managed to exclude, while the upper limit on $\mathcal{B}(\tilde{\chi}_1^0 \to h\tilde{G})$ is placed at 36% for $m_{\tilde{\chi}_1^0}$ at 130 GeV, as shown in Figure 4.

References

[1] ATLAS Collaboration, 2008 JINST 3 S08003.

[2] Lyndon Evans and Philip Bryant, 2008 JINST 3 S08001.

[3] ATLAS Collaboration, arXiv:2307.01094 [hep-ex].

[4] ATLAS Collaboration, ATLAS-CONF-2023-029.

[5] ATLAS Collaboration, ATLAS-CONF-2023-009.

[6] ATLAS Collaboration, JHEP 10 (2015) 054.

[7] ATLAS Collaboration, Phys. Rev. D 96 (2017) 112010.

[8] ATLAS Collaboration, JHEP 06 (2020) 046.

[9] ATLAS Collaboration, JHEP 10 (2020) 062.

[10] ATLAS Collaboration, Eur. Phys. J. C 80 (2020) 123.

[11] ATLAS Collaboration, Phys. Rev. D 101 (2020) 032009.

[12] ATLAS Collaboration, Eur. Phys. J. C 81 (2021) 1023.

[13] ATLAS Collaboration, Phys. Rev. D 98 (2018) 092002.