PROCEEDINGS OF SCIENCE

Searches for supersymmetry in final states with at least two hadronically decaying tau leptons using the ATLAS detector

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Final states with tau leptons are experimentally challenging but open up exciting opportunities for supersymmetry (SUSY) searches. SUSY models with light sleptons could offer a dark matter candidate consistent with the observed relic dark matter density due to accessible co-annihilation processes. Additionally, final states with hadronically decaying taus in LHC Run-2 benefit from the increased available dataset and improved tau identification using machine learning algorithms. We present analyses that use the full Run 2 dataset of $\sqrt{s}$ = 13 TeV proton-proton collision events recorded by ATLAS, which significantly extend existing limits on the electroweak production of supersymmetric particles in hadronic tau final states and extend the simplified models studied in these signatures.

41st International Conference on High Energy physics - ICHEP2022
6-13 July, 2022
Bologna, Italy

[*] Speaker

https://pos.sissa.it/

PoS(ICHEP2022)1073

ATL-PHYS¿-PROC-2022-001
17 November 2022

1. Introduction

Supersymmetry (SUSY) [1] is an extension to the Standard Model (SM) postulating a mirrored SM particle with spin difference of one half. A subset of these SUSY models can provide a Dark Matter candidate when R-parity [2] is conserved. The simplified SUSY models considered in this analysis scrutinize a subset of the SUSY parameter space, all particles not included in the interaction are assumed to be decoupled. Gauginos, the SUSY partners to SM gauge fields (Bino, Wino) form charged and neutral mass eigenstates referred to as charginos and neutralinos. In this paper, the search for the pair production of the lightest chargino ($\tilde{\chi}_1^{\pm}$) or $\tilde{\chi}_1^{\pm}$ with the next-to-lightest neutralino ($\tilde{\chi}_2^0$) is presented. The $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ pair decays via intermediate staus (Figure 1a, 1b) or a W and Higgs boson, consistent with the 125 GeV SM Higgs boson (Figure 1c). In the simplified models discussed, the final state expected in the ATLAS detector [3] includes at least two hadronically decaying tau leptons, benefiting from the latest ATLAS neural network τ-identification [4]. Even though these final states are experimentally challenging in the hadronic environment of proton-proton collisions provided by the LHC [5], final states with tau leptons are of particular interest to SUSY searches. Light sleptons, in particular light scalar tau leptons, can provide the right Dark Matter relic density. In the following, a brief summary of the results from these searches is presented; a comprehensive discussion can be found in [6].

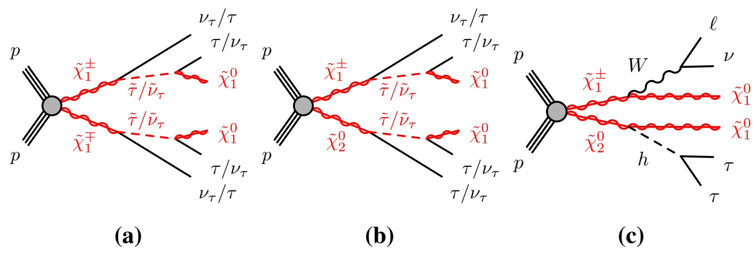


Figure 1: Simplified supersymmetry models covered in this discussion. A representative feynman diagram of a $\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}$ (a), $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ (b) production decaying via an intermediate stau and a $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production in a decay via a SM W and Higgs boson (c) [6].

2. Intermediate stau channel

The simplified models described in Figure 1a and 1b are investigated in two statistically independent analyses, in two kinematically orthogonal final states: at least two oppositely charged hadronically decaying tau leptons (OS) as well as a pair of same-sign (SS) hadronically decaying taus. A final state of OS taus can be generated through both $\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\pm}$ as well as $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production, whereas a SS final state is only possible in the $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production. In both final states considered here, two orthogonal scenarios, targeting low and high $\tilde{\chi}_1^{\pm}$ masses were developed. Unbinned signal regions have been designed and interpreted using a profile likelihood. A data-driven background estimation (*ABCD-method*) was used to estimate the contribution from Multi-jet SM processes. The production of SM W bosons in association with jets is estimated based on Monte Carlo simulation, normalised to data in control regions independently for both the OS and SS analysis.

The SS analysis uses control regions for the estimation of top related SM processes, whereas the OS analysis is employing a Monte Carlo based estimation. An overview of all validation and signal region used in the two analyses is shown in Figure 2.

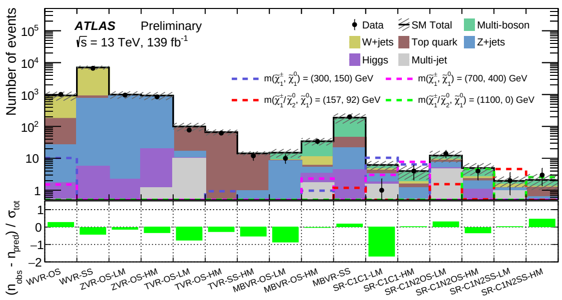


Figure 2: Overview of all validation and signal regions in the OS and SS analysis in the intermediate stau scenario [6].

All validation regions in the OS and SS analysis show very good agreement between SM prediction and data. Here all experimental as well as theoretical uncertainties have been estimated and taken into account. No significant deviations from the SM expectations have been observed in the signal regions in both the OS and SS analysis. In the OS signal region targeting the low mass $\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\pm}$ production (SR-C1C1-LM), an underfluctuation in data has been observed, but not in any association with the signal expectation.

Model dependent limits on the free model parameters, the $\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_1^0$ masses have been set, excluding $\tilde{\chi}_1^{\pm}$ masses of up to 1160 GeV in the statistical combination of both analyses at 95% Confidence Level (CL). The SS analysis is contributing exclusion sensitivity towards the kinematic diagonal, leading to an exclusion of $\tilde{\chi}_1^{\pm}\tilde{\chi}_1^0$ mass differences as low as 30 GeV for a $\tilde{\chi}_1^{\pm}$ mass of 80 GeV. The OS provides leading sensitivity towards high $\tilde{\chi}_1^{\pm}$ masses.

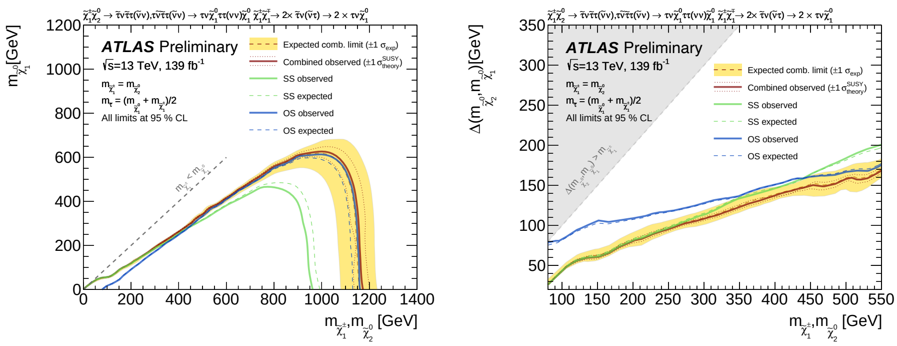
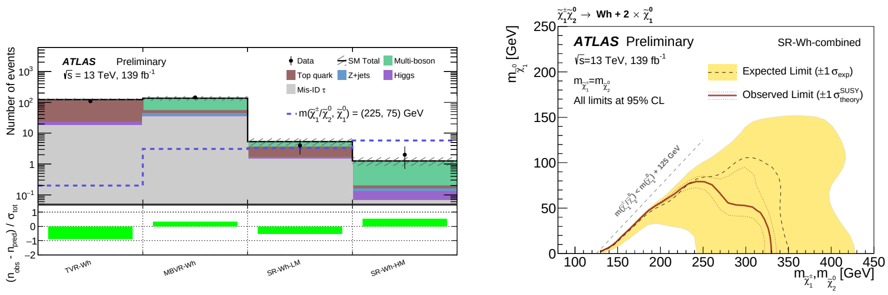


Figure 3: Exclusion limits at 95% CL in the $\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0$, $\tilde{\chi}_1^0$mass plane (a), and $\Delta(m_{\tilde{\chi}_2^0}, m_{\tilde{\chi}_1^0})$, $\tilde{\chi}_1^0$ plane (b) [6].

3. Intermediate Wh channel

The third analysis in this paper is the $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production decaying via a SM W and Higgs boson. This analysis is selecting events based on light lepton triggers, requiring exactly one light lepton as well as at least two hadronically decaying tau leptons. Here, a fake-factor approach was followed to estimate the SM background contribution of fake taus, dominantly stemming from from Multi-jet as well as W+jets SM processes. SM backgrounds including top related processes are estimated in a top control region and validated in TVR-Wh shown in Figure 4a. A low and high mass signal region was designed, targeting low and high $\tilde{\chi}_1^{\pm}$ masses. These signal regions are not mutually exclusive and are combined using the best expected sensitivity of both regions. No significant deviations from the SM expectation have been observed in either the validation or signal regions, taking into account all experimental and theoretical uncertainties. Exclusion limits at 95% CL have been set in the $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ mass plane (see Figure 4b). $\tilde{\chi}_1^{\pm}$ masses up to 330 GeV have been excluded for a massless $\tilde{\chi}_1^0$.



(a) Region overview **(b)** Exclusion limit

Figure 4: Wh validation and signal regions (a) and model dependent exclusion limits at 95% CL (b) [6].

4. Conclusion

In this paper a set of newly published searches for SUSY with the ATLAS detector in final states with at least two hadronically decaying tau leptons was discussed. These searches are based on proton-proton collision events provided by the LHC Run-2. The direct production of gauginos decaying via intermediate staus or a W and Higgs boson was investigated. Exclusion limits of $\tilde{\chi}_1^{\pm}$ masses in the intermediate stau decay have been significantly extended with respect to partial Run-2 analyses and have been investigated in a new, same-sign final state. The Wh decay channel has been investigated in a new di-tau final state and extended its final state coverage.

References

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