DISCOVERY PROSPECTS FOR THE TOP SQUARK AT THE ATLAS EXPERIMENT AT THE HL-LHC

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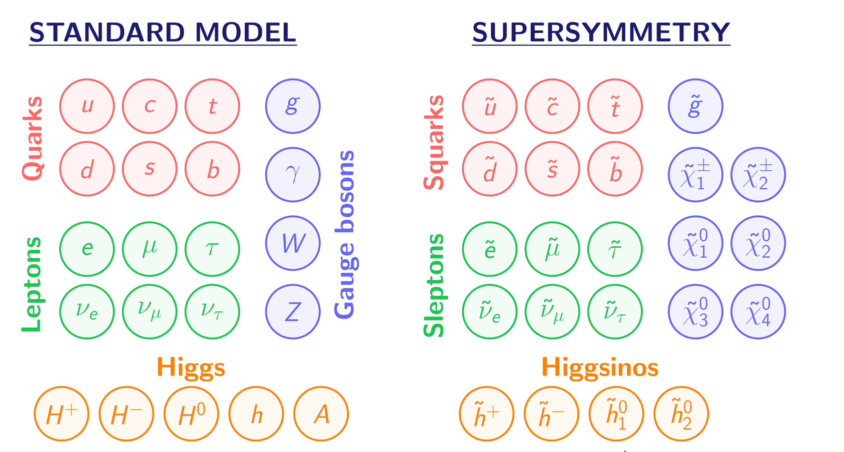
Abstract

Supersymmetry (SUSY) is one of the most interesting theories for Physics beyond the Standard Model and LHC experiments have searched for its evidence during Run1 and Run2. The search for direct production of top squark pairs in which each stop decays in two, three or four bodies depending on the hypotheses on its mass was performed, on data collected during Run2, in final states with two opposite-sign leptons (electrons or muons), jets and missing transverse momentum. The search placed lower limits at 95% confidence level on the top squark and neutralino masses up to 1 TeV and 500 GeV, respectively. This contribution describes the discovery prospects of a top squark in events with two leptons in the final state in the High-Luminosity (HL) LHC phase, when the accelerator is expected to reach a center-of-mass energy of 14 TeV and an integrated luminosity up to 3000 fb^{-1}, reporting recent results from a Public Note by the ATLAS experiment (ATL-PHYS-PUB-2024-001) [1].

Minimal Supersymmetric Standard Model (MSSM)



- Neutralinos ($\tilde{\chi}^0_{i=1...4}$) and charginos ($\tilde{\chi}^{\pm}_{j=1,2}$) are mass eigenstates obtained by linear combination of neutral or charged higgsinos and gauginos
- SUSY: Standard Model (SM) extension introducing a symmetry between bosons and fermions, predicting for every particle the existence of a superpartner whose spin differs by 1/2
- MSSM: from conservation of R-parity: $R = (-1)^{3(B-L)+2S}$ a stable LSP (*Lightest Supersymmetric Particle*) is predicted
- The lightest neutralino, $\tilde{\chi}^0_1$ is a possible neutral LSP and thus a Dark Matter candidate

Analysis strategy

- Supersymmetric signals were studied through Truth-level Monte Carlo samples which underwent a smearing procedure.
- For SM backgrounds fully reconstructed Monte Carlo samples have been used.
- The Signal Regions (SRs) definitions from the published analysis have been optimised to HL conditions, by renormalising samples to the predicted integrated luminosity and cross section, using the N-1 distributions in the relevant variables and computing the statistical significance across the signal grid while changing the thresholds of the selected cuts.

SRs definitions

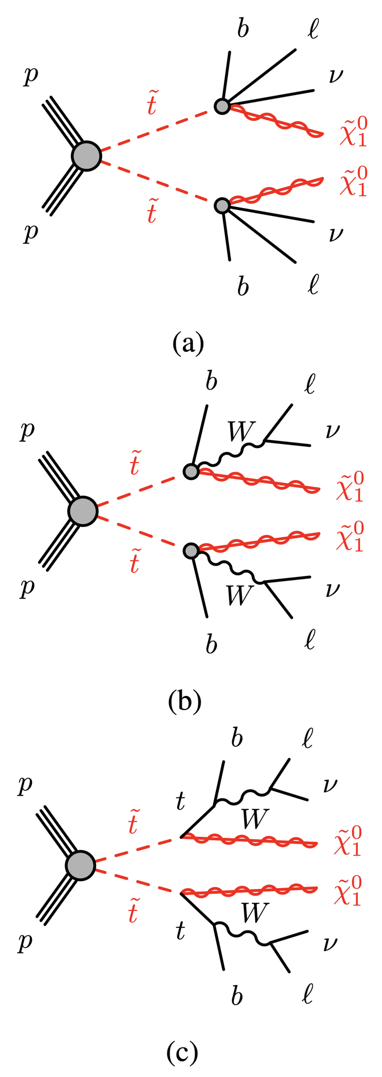
The 3-body decay analysis defines two SRs, targeting signals with $\Delta m(\tilde{t}_1, \tilde{\chi}^0_1) \sim m(W)$ and $\Delta m(\tilde{t}_1, \tilde{\chi}^0_1) \sim m(t)$ respectively. These selections have also been extended to the 2-body kinematic region.

<table>
<tr><th></th><th colspan="2">SR^{3-body}_W</th><th colspan="2">SR^{3-body}_t</th></tr>
<tr><td>Lepton flavour</td><td>DF</td><td>SF</td><td>DF</td><td>SF</td></tr>
<tr><td>$p_T(\ell_1)$ [GeV]</td><td colspan="2">> 25</td><td colspan="2">> 25</td></tr>
<tr><td>$p_T(\ell_2)$ [GeV]</td><td colspan="2">> 20</td><td colspan="2">> 20</td></tr>
<tr><td>$m_{\ell\ell}$ [GeV]</td><td colspan="2">> 20</td><td colspan="2">> 20</td></tr>
<tr><td>$|m_{\ell\ell} - m_Z|$ [GeV]</td><td>–</td><td>> 20</td><td>–</td><td>> 20</td></tr>
<tr><td>n_{b-jets}</td><td colspan="2">$= 0$</td><td colspan="2">≥ 1</td></tr>
<tr><td>$\Delta\phi^R_\beta$ [rad]</td><td colspan="2">> 2.3</td><td colspan="2">> 2.3</td></tr>
<tr><td>E_T^{miss} significance</td><td colspan="2">> 15</td><td colspan="2">> 14</td></tr>
<tr><td>$1/\gamma_{R+1}$</td><td colspan="2">> 0.76</td><td colspan="2">> 0.76</td></tr>
<tr><td>R_{p_T}</td><td colspan="2">> 0.78</td><td colspan="2">> 0.75</td></tr>
<tr><td>M^R_Δ [GeV]</td><td colspan="2">> 110</td><td colspan="2">> 132</td></tr>
</table>

The 4-body decay analysis defines two SRs, targeting signals with large or small $\Delta m(\tilde{t}_1, \tilde{\chi}^0_1)$

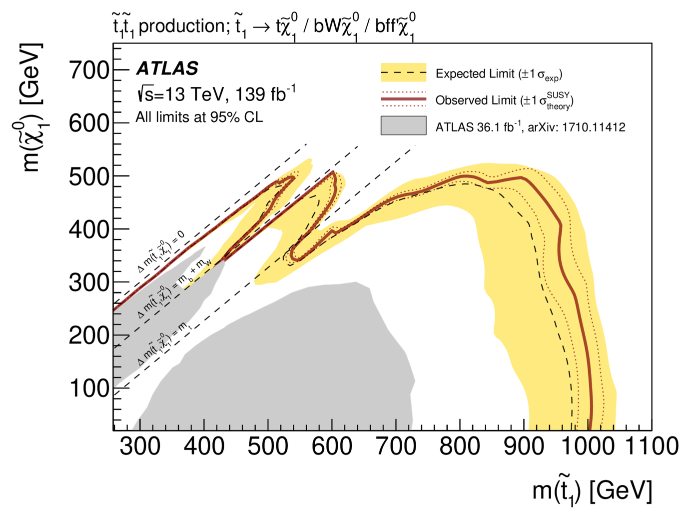
	$SR^{4-body}_{Small\Delta m}$	$SR^{4-body}_{Large\Delta m}$
$p_T(\ell_1)$ [GeV]	[5, 25]	< 100
$p_T(\ell_2)$ [GeV]	[5, 10]	[10, 20]
$m_{\ell\ell}$ [GeV]	> 10	> 10
$p_T(j_1)$ [GeV]	> 150	> 150
min $\Delta R_{\ell_2,j_i}$	> 1	> 1
E_T^{miss} significance	> 10	> 18
$p^{\ell\ell}_{T,boost}$ [GeV]	> 450	> 450
E_T^{miss} [GeV]	> 500	> 500
$R_{2\ell}$	> 25	> 13
$R_{2\ell 4j}$	> 0.45	> 0.44

Target of the analysis



The aim of the study is investigating the sensitivity to the discovery of top squark decaying in 2, 3 and 4 bodies with 2 charged leptons in the final states.

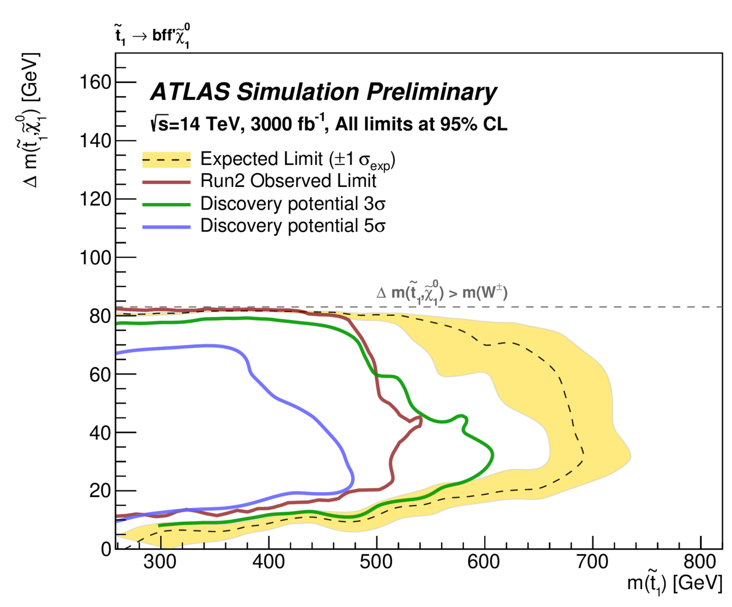
$$\Delta m(\tilde{t}_1, \tilde{\chi}^0_1) < m(b) + m(W) \Rightarrow \tilde{t}_1 \to bff'\tilde{\chi}^0_1 \quad \text{(4 bodies) (a)}$$
$$m(b) + m(W) < \Delta m(\tilde{t}_1, \tilde{\chi}^0_1) < m(t) \Rightarrow \tilde{t}_1 \to bW\tilde{\chi}^0_1 \quad \text{(3 bodies) (b)}$$
$$\Delta m(\tilde{t}_1, \tilde{\chi}^0_1) > m(t) \Rightarrow \tilde{t}_1 \to t\tilde{\chi}^0_1 \quad \text{(2 bodies) (c)}$$

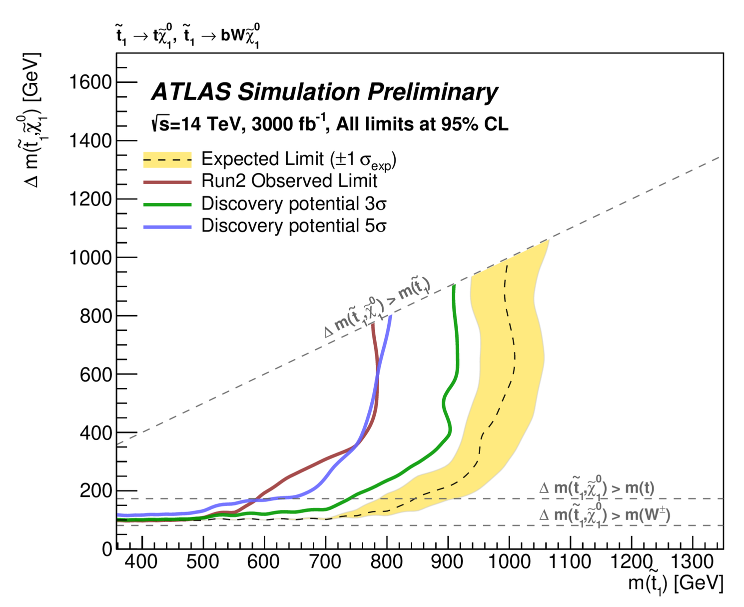


The selection strategy is based on a previous published analysis on Run2 data [2], which produced an exclusion contour at 95% CL

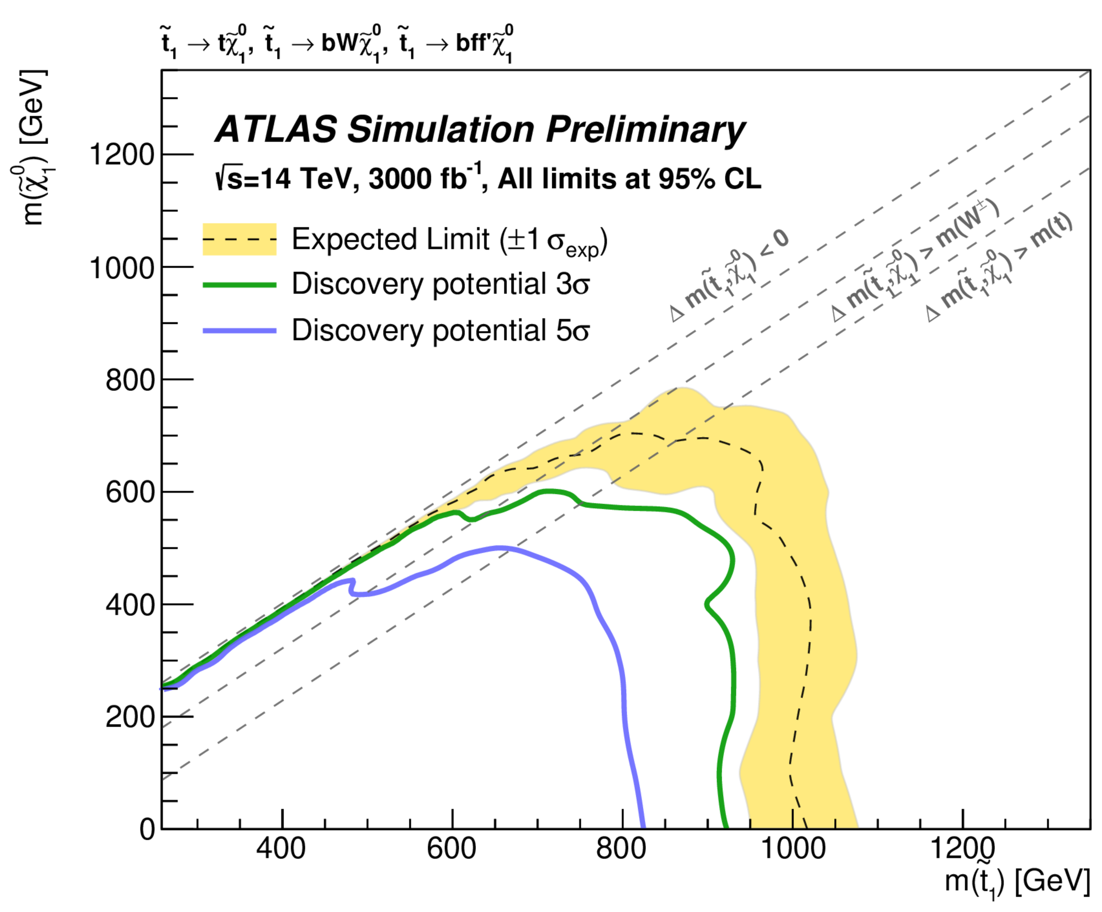
Results

Expected exclusion and discovery contours have been produced separately for 3-body and 4-body, and then statistically combined for the final results, which are expected to be conservative as this analysis does not use the HL-LHC upgraded detector simulation and no assumptions have been made on potential improvements in particle reconstruction algorithms.





The final results, after statistically combining the 3-body and 4-body selections, show an improvement over the Run2 paper, mainly in exclusion sensitivity.



References

[1] ATLAS Collaboration, *Prospects for a search for direct pair production of top squarks at the high-luminosity LHC with the ATLAS detector*, ATL-PHYS-PUB-2024-001

[2] ATLAS Collaboration, *Search for new phenomena in events with two opposite-charge leptons, jets and missing transverse momentum in pp collisions at $\sqrt{s}$=13 TeV with the ATLAS detector*, Journal of High Energy Physics 04, 165 (2021), DOI:10.1007/JHEP04(2021)165, arXiv:2102.01444

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