Search for direct top squark production and decay in bff' and lightest neutralino in final states with two leptons in pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector

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The Standard Model (SM) of particle physics is believed to be the low energy limit of a more general theory. Many arguments point to the need to extend the SM, among them the need to stabilize the Higgs mass against radiative corrections from Planck scale physics and the need to explain the nature of dark matter (DM). Both these shortcomings might be addressed by new physics at the TeV scale and motivate many of the new particle searches at the LHC.

In the framework of a generic R-parity-conserving Minimal Supersymmetric Standard Model (MSSM) the top squark $\tilde{t}_1$ is supposed to be the lightest one and it decays directly to the lightest neutralino $\tilde{\chi}_1^0$. For mass differences below the W-boson mass between the stop quark and the neutralino, the former one could decay via a four body decay $\tilde{t}_1 \to bff'\tilde{\chi}_1^0$ through off shell t quark and W boson. For this decay the only analysis published by ATLAS capable of reaching a better sensitivity with respect to the the analyses carried out on Run I data is the mono-jet analysis[1]. For this motivation, a new analysis on the data collected in the LHC RunII at 13 TeV centre of mass energy has been performed, searching for $\tilde{t}_1\bar{\tilde{t}}_1$ production with subsequent four-body decays in events with a high p_T jet, E_T^{miss} and two soft leptons, corresponding to signal events with leptonic decays of two off-shell W bosons.

The distinguishing variables involved in the analyses exploit several geometrical and kinematical properties of the searched events. A set of preselection requirements has been applied: events are required to have exactly two oppositely charged signal leptons (electrons, muons, or one of each) with the invariant mass of these two objects (regardless of the flavours of the leptons in the pair), m_{ll}, being greater than 10 GeV in order to remove leptons from low mass resonances. Signal events can be distinguished from SM processes if a high-p_T jet from initial state radiation (ISR[2]) leads to a boost of the sparticle pair system and enhances the amount of E_T^{miss}, that is requested to be greater than 200 GeV, while the other decay products would typically remain soft. Then, at least 2 jets are requested in the event, and the leading jet is regarded as ISR jet candidate and required to have $p_T > 150$ GeV. Since the jets resulting from $\tilde{t}_1$ decays tend to be soft, at most one more energetic jet is accepted in the event and the transverse momentum of the third jet (if existing) is requested to have $p_T^{j_3}/E_T^{\mathrm{miss}} < 0.14$. Since the two leptons are expected to be soft, upper limits on their p_T of 80 GeV and 35 GeV are applied for the leading and the sub-leading lepton, respectively.

After this preselection cuts, the signal candidates are required to be in the signal region (SR) defined using the two variables R_{lj}[1] and R_{ll}[2] that are requested to be > 0.35 and > 12, respectively, to reject potential multijet and $t\bar{t}$ backgrounds, respectively. Finally, the request that the two most energetic jets in the event must not be tagged as b-jets is applied, by exploiting the fact that the b-jets in the $\tilde{t}_1$ four-body decay chain have soft p_T spectra and are reconstructed with low efficiency.

The analysis has been tested using MC generated samples in order to valuate its sensitivity[3] to the discovery of the SUSY particles. A grid of 58 MC generated signal points has been used, corresponding to $m_{\tilde{t}_1} \in [260, 650]$ GeV and $m_{\tilde{\chi}_1^0} \in [180, 640]$ GeV as shown in Figure 1. The largest SM background contributions are originated by the $t\bar{t}$ and diboson production and the Z boson decaying into $\tau\tau$ with both τ leptons decaying leptonically.

[1] $E_T^{\mathrm{miss}}/(E_T^{\mathrm{miss}} + \sum p_T^{\mathrm{jets}} + \sum p_T^{\mathrm{leps}})$, here leps are the two leptons in the event and jets are the 4 leading jets (if they exist).

[2] $E_T^{\mathrm{miss}}/(p_T^{l_1} + p_T^{l_2})$, here l_1 and l_2 are the two leptons in the event.

[3] The significance is defined as the Z-value Z_n assuming Gaussian distribution for the error of the background[3]

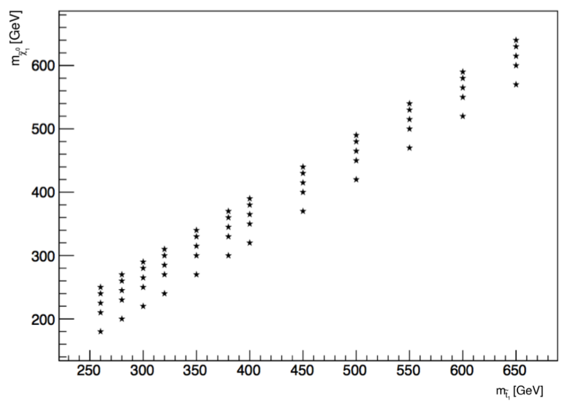

Figure 1: Signal grid of MC generated samples used for the analysis shown in the $m_{\tilde{t}_1}, m_{\tilde{\chi}_1^0}$ mass plane.

These contributions have been evaluated by constraining the normalization of their yields with observed data in dedicated control regions, and then extrapolating these yields to the SR. A relevant background arises also from fake and non-prompt leptons (FNP) and has been estimated from data using the matrix method. The background predictions are tested in validation regions that are defined to be kinematically similar, but disjoint, to both the control and signal regions. The main uncertainties of the analysis are systematic uncertainties (dominated by normalization factor for $t\bar{t}$ and diboson samples) and statistical uncertainties due to low MC statistics. The expected sensitivity of the analysis is reported in Figure 3 and it shows that the analysis is able to reach high enough sensitivity for discovery in regions yet to be excluded by previous analysis if a comparable significant excess will be found in the data.

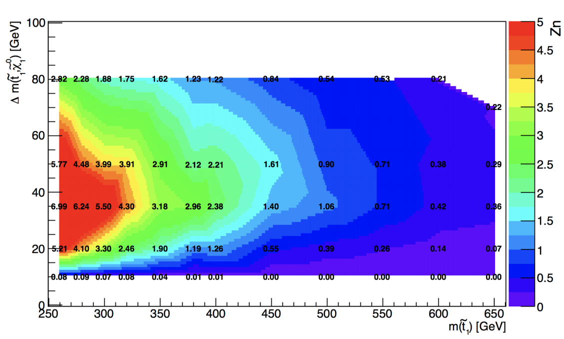

Figure 2: Expected sensitivity of the analysis. The color scale shows the significance obtained along the $m_{\tilde{t}_1}, m_{\tilde{\chi}_1^0}$ mass plane.

In case no excess in the data will be found by the analysis, the sensitivity for discovery can be reinterpreted as exclusion limits by using the CLs variable [4]. The expected limits are reported in Figure 2 which shows that the analysis is able to expand the current limits covering a larger area towards higher $\tilde{t}_1$ masses.

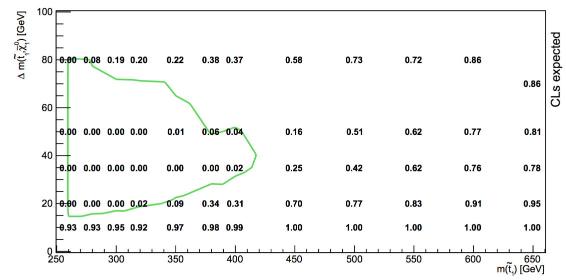

Figure 3: Expected exclusion contour (green solid line) obtained in case of no excess in the data using CLs.

REFERENCES

1. Search for the Supersymmetric Partner of the Top Quark in the Jets+E$_T$miss Final State at $\sqrt{s}$ = 13 TeV, ATLAS Collaboration, ATLAS-CONF-2016-077.
2. Revealing Compressed Stops Using High-Momentum Recoils, arXiv:1506.07885v1.
3. J. T. Linnemann. Measures of Significance in HEP and Astrophysics, 2003, ECONF C030908:MOBT001,2003; arXiv:physics/0312059.
4. Glen Cowan, Kyle Cranmer, Eilam Gross and Ofer Vitells. Asymptotic formulae for likelihood-based tests of new physics, 2010, Eur.Phys.J.C71:1554,2011; arXiv:1007.1727.