PROCEEDINGS OF SCIENCE

Search for scalar top quark pair production in final states with one isolated lepton, jets, and missing transverse momentum in $\sqrt{s} = 13$ TeV pp collisions with the ATLAS detector

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One of the most important parameters to compose supersymmetry is the mass of supersymmetric partner of the third generation quarks. Top squark mass lighter than 1 TeV is favored in theory, however the evidence of the top squark have not been indicated from the various searches in Run-1. Therefore, a wide range of scenarios with different mass splittings between the top squark, the lightest chargino and the lightest neutralino should be considered. The poster presents recent ATLAS results from searches for direct stop pair production, decaying to a bottom quark and the lightest chargino, using the proton-proton collisions at a centre-of-mass energy of 13 TeV recorded by the ATLAS detector and corresponding to an integrated luminosity of 13.2 fb^{-1}. In particular, new dedicated search was developed to cover compressed phase spaces between the top squark and the lightest chargino and the result greatly extended the LHC Run-1 exclusion limit.

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[†]A footnote may follow.

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1. Introduction

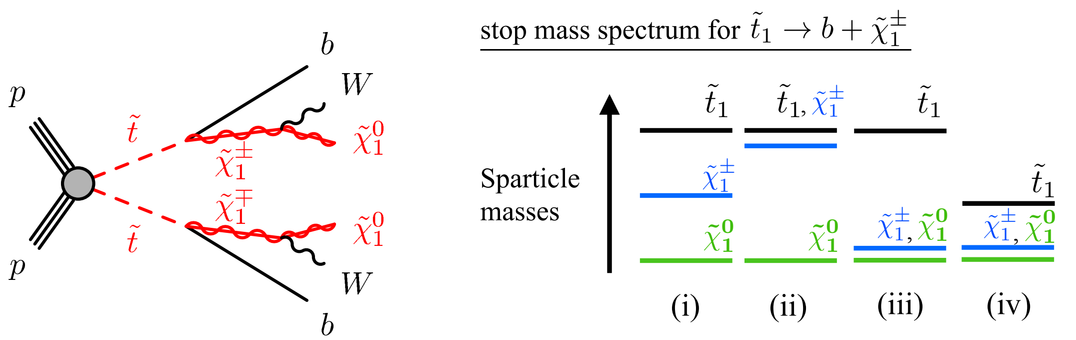
Supersymmetry (SUSY) is one of the most important theory for beyond the Standard Model (SM). It suppresses some known problems like the hierarchy problem, the divergence of the Higgs boson mass and etc. Especially, the mass of supersymmetric partner of the third generation quarks is the important parameter to understand these things. From the point of view of the theory, the mass of scalar top quark (stop) lighter than 1 TeV is favored, however the evidence of stop was not discovered from various searches of direct stop pair production in Run-1 with 20.1 fb^{-1} data at a center-of-mass energy of 8 TeV. Therefore, a wide range of scenarios with different mass splittings between the top squark, the lightest chargino and the lightest neutralino should be considered.

In this proceeding, a search for stop pair production decaying to a bottom quark and the chargino using the proton-proton collisions at a centre-of-mass energy of 13 TeV. The data collected with the ATLAS detector [1] in 2015 and 2016 corresponding to an integrated luminosity of 13.2 fb^{-1} are used. In particular, new dedicated search was developed to cover compressed phase spaces between the top squark and the lightest chargino.

2. Signals

Figure 1(a) shows the $\tilde{t}_1 \to b + \tilde{\chi}_1^{\pm}$ diagram and there are 4 models with each different mass spectrum (Figure 1(b)).

The 1st left spectrum (Figure 1(b)(i)) has the mass of chargino to be double of neutralino. The 2nd left spectrum (Figure 1(b)(ii)) is compress masses between stop and chargino assuming $\Delta m(\tilde{t}_1, \tilde{\chi}_1^{\pm}) = 10$ GeV. These models were searched at Run-2 with 13.2 fb^{-1}, especially the 2nd left spectrum was focused on in this proceeding. Other spectrums (Figure 1(b)(ii), (iv)) are compressed between chargino and neutralino and these should be soft ($\Delta m(\tilde{\chi}_1^{\pm}, \tilde{\chi}_1^0) \sim O(1)$ GeV) assuming Higgsino lightest suppersymmetric particle (LSP) [2].



(a) Diagrams illustrating the considered signal model, which is referred to as $\tilde{t}_1 \to b + \tilde{\chi}_1^{\pm}$. In this diagrams, the charge-conjugate symbols are omitted for simplicity: this model begin with a top squark-antisquark pair.

(b) Illustration of stop mass spectrum for $\tilde{t}_1 \to b + \tilde{\chi}_1^{\pm}$. This spectrum shows 4 models.

Figure 1: Illustration of the signal diagram and stop mass spectrum for $\tilde{t}_1 \to b + \tilde{\chi}_1^{\pm}$.

The most characteristic of small $\Delta\mathrm{m}(\tilde{\mathrm{t}}_1, \tilde{\chi}_1^{\pm})$ model is including b-jets with extremely small momentum decayed from stop. It is not possible to detect b-jets, therefore new b-veto signal region (SR) showed at Section 3 is defined and $\mathrm{t\bar{t}}$ background was effectively rejected. This model stop masses are excluded up to 450 GeV, for a neutralino mass about 1 GeV in Run-1 [3].

3. Signal Region and Background estimation

The analysis presented uses selections on various observables to enhance signal relative to the SM background. SR is defined using Monte Carlo (MC) simulation of the signal processes and the SM background, control regions (CRs) are used to estimate those backgrounds. Table 1 shows the SR (bCbv) and CR for this dedicated search [4]. Number of b-jets is exactly zero (veto) to detect the signal and to reject $t\bar{t}$ background. In addition, the SR focus on specified topology with large-R jet to reject the $W+$jets background. By requiring the high momentum jets with $p_{\mathrm{T}_{1,2}} > 120,\ 80$ GeV, high $E_{\mathrm{T}}^{\mathrm{miss}}$ with $E_{\mathrm{T}}^{\mathrm{miss}} > 360$ GeV and high $H_{\mathrm{T,sig}}^{\mathrm{miss}}$ described in Ref. [5] with $H_{\mathrm{T,sig}}^{\mathrm{miss}} > 16$, two jets decayed from the W boson are released close region and the mass of large-R jet constructed with these jets peaked around the mass of W boson for signal. On the other hand, the $W+$jets background is W boson with leptonic decay plus Initial State Radiations (ISR). In this case, the mass of large-R jet constructed with ISRs distribute like flat.

Table 1: Overview of the event selections for bC SR and the associated $t\bar{t}$ (TCR) and $W+$jets (WCR) control regions.

Common event selection			
Trigger	$E_{\mathrm{T}}^{\mathrm{miss}}$ trigger		
Lepton	exactly one lepton (e, μ), no additional leptons		
Jets	at least two jets, and $\lvert\Delta\phi(\mathrm{jet_i}, \vec{p}_{\mathrm{T}}^{\mathrm{miss}})\rvert > 0.4$ for i $\in \{1,2\}$		
Valiables	bCbv	TCR	WCR
Number of (jets, b-jets)	$(\geq 2, = 0)$	$(\geq 2, \geq 1)$	$(\geq 2, = 0)$
jet $p_{\mathrm{T_i}}$	$\geq (120, 80)$	$\geq (120, 80)$	$\geq (120, 80)$
$E_{\mathrm{T}}^{\mathrm{miss}}$	> 360	> 360	> 360
$H_{\mathrm{T,sig}}^{\mathrm{miss}}$	> 16	> 16	> 16
m_{T}	> 200	[30, 90]	[30,90]
$\lvert\Delta\phi(\mathrm{jet_i}, \vec{p}_{\mathrm{T}}^{\mathrm{miss}})\rvert$ (i = 1, 2)	$> (2.0, 0.8)$	$> (2.0, 0.8)$	$> (2.0, 0.8)$
Leading large-R jet mass [GeV]	[70, 100]	[70, 100]	[70, 100]
$\lvert\Delta\phi(\mathrm{lepton}, \vec{p}_{\mathrm{T}}^{\mathrm{miss}})\rvert$	> 1.2	-	-

An important part of this analysis is to achieve reliable predictions of remaining backgrounds. $t\bar{t}$ and $W+$jets are estimated from TCR and WCR in Table 1. These are constructed by modifying the transverse mass $m_{\mathrm{T}} = \sqrt{2 \cdot p_{\mathrm{T}}^{l} \cdot E_{\mathrm{T}}^{\mathrm{miss}}(1 - \cos\Delta\phi(\vec{l}, \vec{p}_{\mathrm{T}}^{\mathrm{miss}}))}$ selection in the SR to be a window whose upper edge is near the W boson mass. Other backgrounds are estimated with MC predictions normalized with the best known theoretical cross-sections.

4. Result and Exclusion limit

Table 2 shows the number of observed and expected events. The number of observed event is 7 and the total number of expected event is 7.4 $\pm$ 1.8. Therefore, there is no evidence for new physics and the observed event is in agreement with predictions from the SM.

Table 2: The numbers of observed events in the SR together with the expected numbers of background events and their uncertainties as predicted by the background-only fits, the scaling factors for the background predictions in the fit (NF), and the probabilities (represented by the p0 values) that the observed numbers of events are compatible with the background-only hypothesis.

Signal Region	bCbv
Observed	7
Total background	7.4 $\pm$ 1.8
$t\bar{t}$	0.26$\pm$0.18
$W+$jets	5.4$\pm$1.8
Single top	0.24$\pm$0.23
$t\bar{t}+$V	0.12$\pm$0.03
Diboson	1.1$\pm$0.4
$Z+$jets	0.22$\pm$0.20
$t\bar{t}$ NF	0.73$\pm$0.22
$W+$jets NF	0.97$\pm$0.12
$p_0(\sigma)$	0.50 (0)
$N^{\rm limit}_{\rm non-SM}$ exp. (95% CL)	$7.3^{+3.5}_{-2.2}$
$N^{\rm limit}_{\rm non-SM}$ obs. (95% CL)	7.2

Exclusion limits are also derived this model. The result is obtained using the CL prescription as used for the model-independent limits, but with the model-dependent selection. The expected and observed exclusion contours for the $\tilde{t}_1 \to b + \tilde{\chi}^{\pm}_1$ decay model is shown in Figure 2. This model stop masses are excluded between 450 and 800 GeV, for a neutralino mass about 1 GeV.

5. Conclusion and Prospect

This proceeding presents a search for scalar top quark pair production in final states with one isolated lepton, jets, and missing transverse momentum. New dedicated search was developed to cover compressed phase spaces between the top squark and the lightest chargino. The search uses 13.2 fb^{-1} of LHC pp collision data collected by the ATLAS experiment at a center-of-mass-energy of $\sqrt{s} = 13$ TeV. No significant excess over the Standard Model prediction is observed. Stops are excluded at 95% confidence level up to a mass of 800 GeV for an neutralino mass in the range of 1 to 300 GeV.

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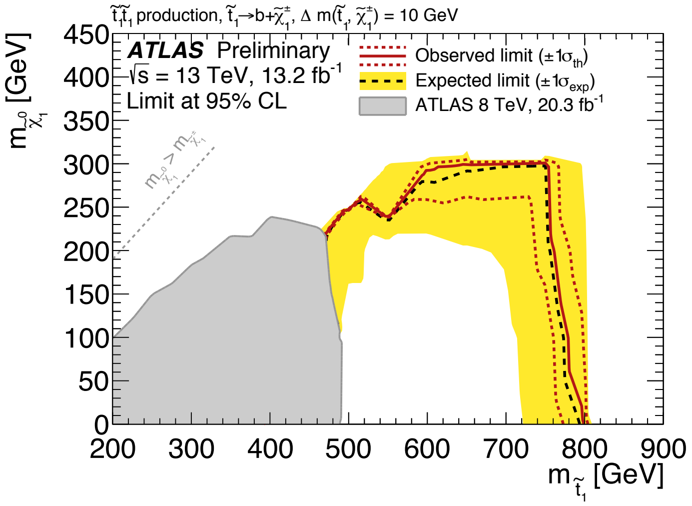

Figure 2: Expected (black dashed) and observed (red solid) 95% CL excluded region in the plane of $m_{\tilde{t}_1}$ vs.$m_{\tilde{\chi}_1^0}$, assumming $\mathbf{BR}(\tilde{t}_1 \rightarrow b + \tilde{\chi}_1^{\pm}) = 100\%$.

References

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