論文の内容の要旨

Search for Supersymmetric Partners of the Top Quark with Leptonic Signatures

(レプトニック終状態を用いたトップクォークの超対称性パートナーの探索)

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Supersymmetry (SUSY) is one of the most elegant theories that can provide solutions to the problems in the Standard Model. Natural SUSY models favor a light scalar top quark (stop, $\tilde{t}_1$) and light higgsinos. This dissertation presents two searches for direct productions of scalar top quarks using collision data at a center of mass energy of $\sqrt{s} = 13$ TeV collected with the ATLAS detector at the Large Hadron Collider. Both searches use leptonic signatures, which contain exactly one charged lepton (electron or muon) and high missing transverse momentum.

The first search is performed using data collected in 2015–2016, corresponding to an integrated luminosity of 36 fb^{-1}. The lightest supersymmetric particle (LSP, $\tilde{\chi}_1^0$) is assumed to be a higgsino, and a large mass-splitting between the stop and the LSP is considered. A realistic higgsino LSP model was designed, considering three decay modes: $\tilde{t}_1 \to t\tilde{\chi}_1^0$, $t\tilde{\chi}_2^0$, and $b\tilde{\chi}_1^\pm$, where $\tilde{\chi}_2^0$ and $\tilde{\chi}_1^\pm$ are the second lightest neutralino and the lightest chargino, respectively. A signal region targeting the $\tilde{t}_1 \to b\tilde{\chi}_1^\pm$ decay is optimized exploiting low p_{T} leptons. No significant excess over the Standard Model prediction is observed. Figure 1 shows exclusion limits in three scenarios: mostly left-handed stop, mostly right-handed stop, and large $\tan\beta$. In these scenarios, stop masses up to 800 GeV are excluded for the LSP with a mass of 150 GeV at 95% confidence level.

When a mass difference between the stop and LSP is small, the final state contains

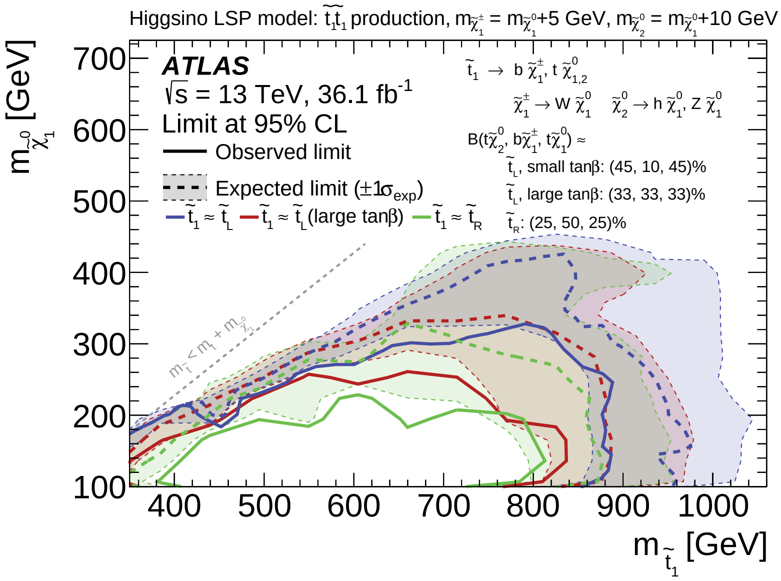

Figure 1: Observed (solid lines) and expected (dashed lines) exclusion limits at 95% confidence level in the plane of $m_{\tilde{t}_1}$ versus the mass of neutralino LSP ($m_{\tilde{\chi}_1^0}$). The higgsino-like LSP simplified model with $m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_1^0} + 5$ GeV and $m_{\tilde{\chi}_2^0} = m_{\tilde{\chi}_1^0} + 10$ GeV is considered. The three scenarios: $\tilde{t}_1 \sim \tilde{t}_R$ (green), $\tilde{t}_1 \sim \tilde{t}_L$ (blue), and large $\tan\beta$ (red) are shown. In the region below the gray dashed line, the $\tilde{t}_1$ is kinematically allowed to decay into an on-shell top quark and the LSP.

b-hadrons with low transverse momentum (p_{T}). Since the standard ATLAS b-tagging algorithm is sub-optimal for such low p_{T} hadrons, a new soft b-tagging algorithm has been developed. The algorithm is based on the reconstruction of secondary vertices. Dedicated requirements for low p_{T} b-hadrons are used, such as loose requirements on the impact parameter or overlap removal between tracks and high p_{T} jets. It shows a significant improvement in identification efficiency for low momentum b-hadrons compared to the standard b-hadron identification algorithm in ATLAS as shown in Figure 2.

The second search targets a small mass difference between the stop and the LSP, using data collected in 2015–2018, corresponding to an integrated luminosity of 139 fb^{-1}. The final state in the compressed scenarios is the stop four body decay $\tilde{t}_1 \to bff'\tilde{\chi}_1^0$, where $f^{(\prime)}$ denotes a fermion. In order to increase the acceptance of the compressed signal, secondary vertices reconstructed by the soft b-tagging algorithm is used in this search. No excess is found in this search, and stop masses up to 640 GeV for the LSP with a mass of 580 GeV are excluded as shown in Figure 3.

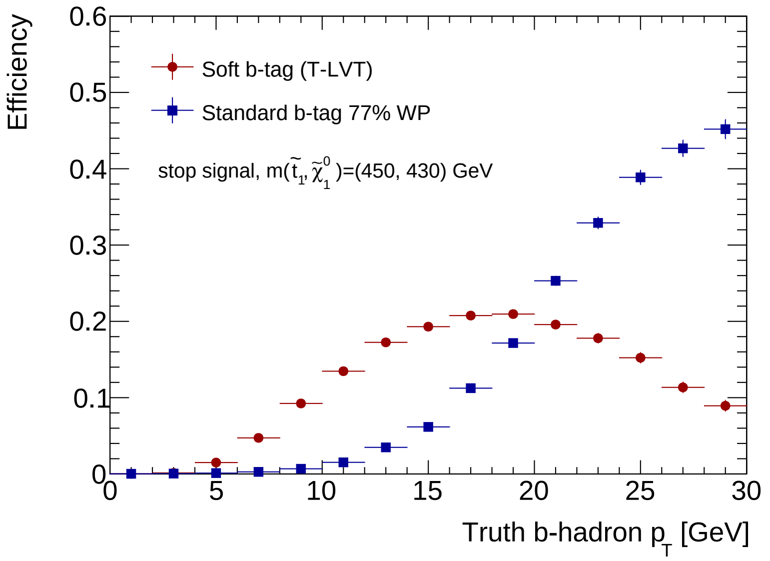

Figure 2: Efficiency of the soft b-tagging algorithm and the standard b-tagging as a function of truth b-hadron p_{T}. Weakly decaying b-hadrons in the stop signal are considered. The efficiency is defined as the fraction of b-hadrons which are tagged by the b-tagger.

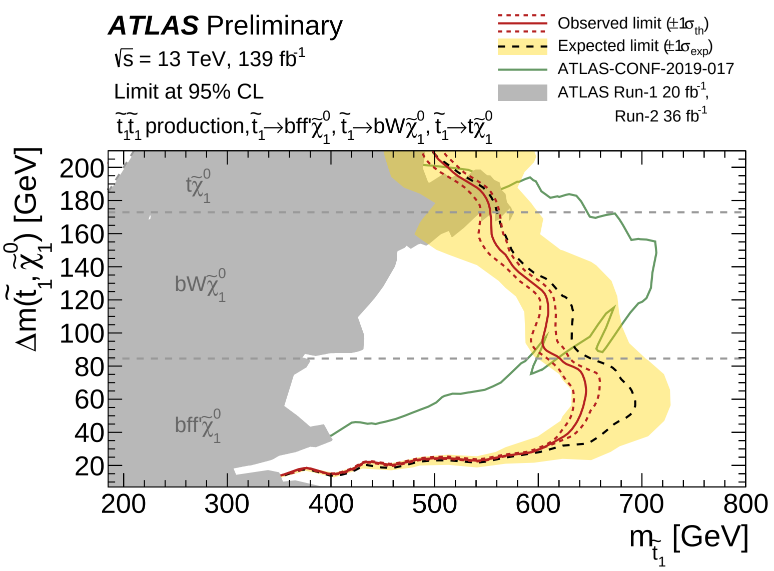

Figure 3: Expected (black dashed) and observed (red solid) limits at 95% confidence level in the plane of $m_{\tilde{t}_1}$ versus $\Delta m(\tilde{t}_1, \tilde{\chi}_1^0)$. The yellow band displays $\pm 1\ \sigma$ variation of the expected limit, and the red dotted lines along the observed line show the uncertainty in the stop cross section. The gray region shows the previously excluded area from the ATLAS Run 1 and Run 2 in 2015–2016.