Search for a heavy top partner decaying in b+$\tilde{\chi}_1^{\pm}$ in final states with two leptons in proton proton collisions data collected at 8 TeV centre of mass energy

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In Supersymmetry, the scalar partners of right-handed and left-handed quarks, $\tilde{q}_R$ and $\tilde{q}_L$, mix to form two mass eigenstates, $\tilde{q}_1$ and $\tilde{q}_2$, with $\tilde{q}_1$ defined to be the lighter squark. In the case of the supersymmetric partner of the top quark (top squark, $\tilde{t}$), large mixing effects can lead to one top-squark mass eigenstate, $\tilde{t}_1$, that is significantly lighter than the other squarks. Renormalisation group effects are also stronger for the third-generation squarks, tending to drive their masses significantly lower than those of the other generations.

More specifically, naturalness considerations require that these squarks are lighter than approximately 500 GeV. The previous Tevatron and LHC searches set limits for such particles between 100 GeV and ∼700 GeV depending on the SUSY scenario.

The top squark can decay into a variety of final states, depending, amongst other factors, on the mass hierarchy of the (s)particles involved in the decay chain.

This analysis uses all the proton proton collisions data collected by the ATLAS experiment [?] in 2012 at 8 TeV centre of mass energy to search for the evidence of pair production of the lightest top squarks $\tilde{t}_1$, in the following referred as $\tilde{t}$ to simplify the notation, each one decaying through the pattern:

$$\tilde{t}\tilde{t} \rightarrow \tilde{\chi}_1^+ b \tilde{\chi}_1^- b \rightarrow W^{(*)+}\tilde{\chi}_1^0 b W^{(*)-}\tilde{\chi}_1^0 b \rightarrow \quad (1)$$

$$\rightarrow l^+\nu\tilde{\chi}_1^0 b l^- \nu \tilde{\chi}_1^0 b$$

where $\tilde{t}$ is the scalar top quark, $\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_1^0$ are, respectively, chargino and neutralino, and the second one is expected to be the lightest supersymmetric particle (LSP). The decay mode in [Eq. ??] can happen only if $m(\tilde{t})-m(b) \geq m(\tilde{\chi}_1^{\pm})$, i.e. it requires the chargino to be real.

The final state under study contains two b-jets, two W bosons, real (a) or virtual (b), and two invisible particles. Final events are requested to have two opposite sign (OS) leptons (electrons or muons), since only the leptonic decay mode of $W^{(*)}$ is considered. This signature occurs only in $\sim 4.6\%$ of the events, which is the probability that both $W^{(*)}$ decay leptonically. The main criterium to separate the signal from the background is based on a multivariate analysis (MVA) [?], with a learning algorithm derived from Monte Carlo generated signal and background events. Distinguishing variables exploit several geometrical and kinematical properties of the searched events. The purpose to apply the MVA technique to this physics process, already analyzed with a standard cut and count approach, is to improve sensitivity, thus covering the still unexcluded regions in the parameter space defined by $m_{\tilde{t}}$, $m_{\tilde{\chi}_1^{\pm}}$ and $m_{\tilde{\chi}_1^0}$. In this analysis, a bino-like $\tilde{\chi}_1^0$ is assumed, and previous experimental constraints from the LEP experiments ($m(\tilde{\chi}^{\pm}) > 103.5$ GeV) are taken into account. The lightest top squark is chosen to be the partner of the left-handed top quark ($\tilde{t}_L$ component), and it is the only coloured particle contributing to the production processes.

The kinematics of the $\tilde{t} \rightarrow b + \tilde{\chi}_1^{\pm}$ decay mode depend upon the mass hierarchy of the $\tilde{t}$, $\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_1^0$ particles. In order to be sensitive to all the possible mass splittings, two complementary analysis strategies are designed: one to target large $\tilde{\chi}_1^{\pm} - \tilde{\chi}_1^0$ mass splittings (larger than the W bosons mass), the other small $\tilde{\chi}_1^{\pm} - \tilde{\chi}_1^0$ mass splittings (smaller than the W bosons mass). The two strategies target two different scenarios:

1. compressed mass spectrum with soft leptons (addressed by a "MET trigger" selection);

2. mass spectrum with hard leptons (addressed by a "Lepton trigger" selection).

The analysis is designed separately for both scenarios. Events are required to contain exactly two opposite charge leptons (OS), with the same flavour (SF, $\mu\mu$ or ee) or with a different flavour (DF, $e\mu$).

To reach the efficiency plateau for the trigger items used in the analysis, for MET triggered events $E_T^{miss} > 120\ GeV$ is requested, while for Lepton triggered events, at least one lepton must satisfy the leading p_T requirement ($p_T > 25$ GeV for electrons and for muons).

Then, in both cases, events are retained only if they contain at least two jets with $p_T > 20$ GeV, but no b tagging is applied to these jets. In addition, two different sets of preselection cuts are applied to MET triggered events and to Lepton triggered events, before analyzing them with the multivariate technique, in order to: remove low-mass resonances and to take into account, in case of SF, the lack of Monte Carlo simulated Drell-Yan samples for very low-mass; optimize the signal sensitivity over the $m(\chi_1^0) - m(\chi_1^{\pm})$ plane:

- **(MET Trigger: MC1)** $m_{ll} > 8\ GeV$;
- **(Lepton trigger: LC1)** $E_T^{miss} > 50$ GeV, $m_{ll} > 20\ GeV$ and $m_{eff} > 200$ GeV. In case of SF a Z veto is applied: m_{ll} outside the window [71 GeV,111 GeV] is requested;
- **(Lepton trigger: LC2)** $E_T^{miss} > 50$ GeV, $m_{ll} > 20\ GeV$ and $m_{eff} > 300$ GeV. In case of SF a Z veto is applied: m_{ll} outside the window [71 GeV,111 GeV] is requested;

Several discrimination methods implemented in TMVA were tested, but the best discriminating power was achieved with a Boosted Decision Trees technique (BDT) using a Gradient boosting algorithm (BDTG). Several variables were considered as input for the training procedure in MVA, but finally 11 were used, according to their effectiveness in discriminating signal from background and to their agreement in data-MC comparison. Different reference points (RP) were chosen for DF and SF trainings. These points enters in the final definition of signal regions in the analysis. The dominant SM background processes are top-quark pair production and diboson production. Events with fake leptons are estimated with a data-driven technique.

The final exclusion limits at 95% CL in the $m(\tilde{\chi}_1^{\pm}) - m(\chi_1^0)$ plane for a 300 GeV mass stop, obtained from the combination of the MET trigger based and the Lepton trigger based analyses after using the best signal regions, are shown in Fig. **??** [**?**].

Fig. **??** shows the following contours:

- (a) thick solid red line: observed limit in which all uncertainties are included in the fit as nuisance parameters, with the exception of the theoretical signal uncertainties (PDF, scales);

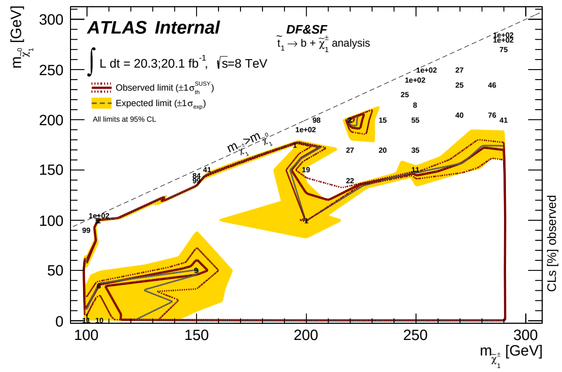

Figure 1. Exclusion limits at 95% CL in the $m(\tilde{\chi}_1^{\pm}) - m(\chi_1^0)$ plane for a 300 GeV mass stop obtained from the combination of the MET trigger based and the Lepton trigger based analyses. The numbers shown in the plots are the observed CLs values.

- (b) long-dashed dark line: expected limit in which all uncertainties are included in the fit as nuisance parameters, with the exception of the theoretical signal uncertainties (PDF, scales);

and the following uncertainty bands:

- thin dark-red dotted lines: $\pm1\sigma$ lines around observed limit. To produce them the limit calculation (a) is re-run increasing or decreasing the signal cross section by the theoretical signal uncertainties (PDF, scales).
- yellow band: $\pm1\sigma$ band around expected limit. The band contours are the $\pm1\sigma$ results of the fit (b).

The numbers shown in the plots are the observed CLs values: the signal points over the grid for which these values are > 0.05 cannot be excluded and stay outside the thick solid red line.

The combination of DF and SF channels results in an improvement over most part of the plane with respect to the limits obtained with DF and SF channels separately.

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