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1. Introduction
Supersymmetry (SUSY) [1–9] is an extension of the Standard Model (SM) which naturally resolves the hierarchy problem by introducing supersymmetric partners to the known fermions and bosons. In the framework of a generic $R$-parity conserving minimal supersymmetric extension of the SM (MSSM) [10–14], SUSY particles are produced in pairs and the lightest supersymmetric particle (LSP) is stable. In a large variety of models the LSP is the lightest neutralino, $\tilde{\chi}_1^0$, which only interacts weakly. The scalar partners of right-handed and left-handed quarks (squarks) can mix to form two mass eigenstates ($\tilde{q}_1$, $\tilde{q}_2$). In particular, the lightest top squark (stop, $\tilde{t}_1$), could have a mass similar to, or lower than, the top quark ($t$) mass.

In this Letter, a search for direct stop pair production is presented targeting these scenarios. A SUSY particle mass hierarchy is assumed such that $m_t \gtrsim m_{\tilde{t}_1} > m_{\tilde{\chi}_1^0}$ and the stop decays exclusively into a $b$-quark and a chargino ($\tilde{t}_1 \rightarrow \tilde{\chi}_1^\pm b$). The chargino subsequently decays via a virtual or real $W$ boson ($\tilde{\chi}_1^\pm \rightarrow W^{(*)}\tilde{\chi}_0^n$). The masses of all other supersymmetric particles, including the mass of $t_2$, are assumed to be above the TeV scale. In the case where $m_{\tilde{t}_1} \sim m_t$, direct stop pair production will lead to final states very similar to SM $t\bar{t}$ events, which form the dominant background. In the first stage of the analysis the $t\bar{t}$ system (including stop pairs) is reconstructed from final states which contain exclusively one or two leptons ($\ell = e, \mu$), $b$-jets, light flavour jets, and large missing transverse momentum. The use of event-based mass scale variables allows discrimination between stop pairs and the $t\bar{t}$ background. The results are interpreted in three MSSM scenarios where stop and neutralino masses are varied and different assumptions are made about the chargino–neutralino mass difference: gaugino universality ($m_{\tilde{\chi}_1^\pm} \simeq 2m_{\tilde{\chi}_1^0}$); fixed chargino mass of 106 GeV (above the present exclusion limit from LEP [15]); and fixed stop mass of 180 GeV with variations of the chargino–neutralino mass difference. Previous results for direct production of top squark pairs in the same MSSM scenarios have been presented by the CDF [16] and ATLAS Collaborations [17].

2. The ATLAS Detector
The ATLAS detector is described in detail elsewhere [18]. It comprises an inner detector (ID) surrounded by a thin superconducting solenoid, a calorimeter system and an extensive muon spectrometer embedded in a toroidal magnetic field. The ID tracking system consists of a silicon pixel detector, a silicon microstrip detector (SCT), and a transition radiation tracker (TRT). It provides tracking information for charged particles in a pseudorapidity\(^1\) range $|\eta| < 2.5$ and allows efficient identification of jets originating from $b$-hadron decays using impact parameter measurements to reconstruct secondary decay vertices. The ID is immersed in a 2 T axial magnetic field and is surrounded by high-granularity liquid-argon (LAr) sampling electromagnetic calorimeters. An iron/scintillator tile calorimeter provides hadronic energy

\(^1\)ATLAS uses a right-handed coordinate system with its origin at the nominal interaction point (IP) in the centre of the detector, with the $z$-axis coinciding with the beam pipe axis. The $x$-axis points from the IP to the centre of the LHC ring, and the $y$-axis points upwards. Cylindrical coordinates $(r, \phi)$ are used in the transverse plane, $\phi$ being the azimuthal angle around the beam pipe. The pseudorapidity is defined in terms of the polar angle $\theta$ as $\eta = -\ln \tan(\theta/2)$. The distance $\Delta R$ in the $\eta - \phi$ space is defined as $\Delta R = \sqrt{(\Delta \eta)^2 + (\Delta \phi)^2}$. March 26, 2013
measurements in the central pseudorapidity range ($|\eta| < 1.7$). In the forward regions ($1.5 < |\eta| < 4.9$), it is complemented by two end-cap calorimeters using LAr as the active material and copper or tungsten as an absorber. The muon spectrometer (MS) surrounds the calorimeters and consists of three large superconducting eight-coil toroids, a system of tracking chambers, and detectors for triggering. The MS is segmented into barrel ($|\eta| < 1.05$) and end-cap regions ($1.05 < |\eta| < 2.7$).

3. Simulated Event Samples

Monte Carlo (MC) simulated event samples are used to develop and validate the analysis procedure and to help evaluate the SM backgrounds in the signal regions. Production of top quark pairs is simulated with $\text{MC@NLO}$ [19–21], using a top quark mass of 172.5 GeV and the next-to-leading-order (NLO) parton distribution function (PDF) set $\text{CT10}$ [22]. Samples of $W$ and $Z\gamma^*$ production, with accompanying light- and heavy-flavour jets, and $t\bar{t}$ with additional $b$-jets ($t\bar{t}bb$) are generated using $\text{ALPGEN}$ [23]. Samples of $Zt\bar{t}$, $Wt\bar{t}$ and $WWt\bar{t}$ are generated with $\text{MadGraph}$ [24] interfaced to $\text{PYTHIA6}$ [25]. Diboson ($WW$, $WZ$, $ZZ$) production is generated with $\text{HERWIG}$ [26]. Single top production is generated with $\text{MC@NLO}$ for the $s$- and $t + W$-channels, and $\text{AcerMC}$ [27] for the $t$-channel. Fragmentation and hadronisation modelling for the $\text{ALPGEN}$ and $\text{MC@NLO}$ samples are performed by $\text{HERWIG}$, using $\text{JIMMY}$ [28] for the underlying event. $\text{ALPGEN}$ and $\text{POWHEG}$ [29] samples are used to assess the systematic uncertainties associated with the choice of generator for $t\bar{t}$ production, and $\text{AcerMC}$ samples are used to assess the uncertainties associated with initial and final state radiation (ISR/FSR). The choice of PDF depends on the generator: the $\text{MRST2007 LO}$ [30] set is used with $\text{HERWIG}$, $\text{CTEQ6L1}$ [31] with $\text{ALPGEN}$. The background predictions are normalised to the theoretical cross sections, including higher-order QCD corrections when available, as detailed in Ref. [32].

Direct stop pair production samples are generated using $\text{PYTHIA6}$ and $\text{Hervig++}$ [33]. Polarisation effects due to the choice of left- and right-handed scalar top mixing were found to have a negligible impact on the analysis. Signal cross sections are calculated to NLO in the strong coupling constant, adding the resummation of soft gluon emission at next-to-leading-logarithmic accuracy (NLO + NLL) [34–36].

All MC samples are produced using a detector simulation [37] based on $\text{GEANT4}$ [38]. MC samples are re-weighted such that the number of additional proton-proton interactions per bunch crossing (pile-up) agrees with that observed in data.

4. Event Reconstruction and Preselection

Electron candidates are reconstructed from energy clusters in the electromagnetic calorimeters matched to a track in the ID. They are required to have momentum in the transverse plane ($p_T > 20$ GeV, $|\eta| < 2.47$ and to pass the “medium” shower shape and track selection criteria of Ref. [39].

Muons are reconstructed using an algorithm [40] that combines information from the ID and MS. Candidate muons are required to have $p_T > 10$ GeV, $|\eta| < 2.4$, and be reconstructed with sufficient numbers of hits in the pixel, SCT and TRT detectors. In order to reject muons originating from cosmic rays, events containing muon candidates with a closest approach distance greater than 1 mm to the primary vertex in the $z$ direction, or a transverse impact parameter greater than 0.2 mm, are rejected. The primary vertex itself is defined as the vertex with the highest summed track $p_T^2$.

Jet candidates are reconstructed using the anti-$k_T$ jet clustering algorithm [41] with a radius parameter of $R = 0.4$. The measured jet energy is corrected for inhomogeneities and for the non-compensating nature of the calorimeter using $p_T$ and $\eta$ dependent correction factors based on MC simulation validated with extensive testbeam and collision-data studies. Furthermore, the reconstructed jet is modified such that its direction points to the primary vertex, and events containing jets likely to have arisen from detector noise or cosmic rays are rejected [42]. Only jet candidates with corrected transverse momenta $p_T > 20$ GeV and $|\eta| < 4.5$ are retained.

Following their reconstruction, candidate jets and leptons may point to the same energy deposits in the calorimeter. These overlaps are resolved by first discarding any jet candidate within $\Delta R = 0.2$ of an electron. Then, any electron or muon candidate remaining within $\Delta R = 0.4$ of any surviving jet is also discarded.

The two-dimensional missing transverse momentum vector, $p_T^{\text{miss}}$, and its magnitude $E_T^{\text{miss}}$, are computed from the negative of the vector sum of the $p_T$ of the reconstructed electrons, muons and jets, and all energy clusters with $|\eta| < 4.9$ not associated with such objects.

Electrons must additionally pass the “tight” electron criteria of Ref. [39], and be isolated such that the scalar $p_T$ sum of tracks within a cone of $\Delta R = 0.2$ around the electron candidate (not including the electron track) must be less than 10% of the electron $p_T$. Muons must also be isolated such that the $p_T$ sum of tracks (not including the muon track) within $\Delta R = 0.2$ is less than 1.8 GeV. Jets are further required to lie within $|\eta| < 2.5$ and must have more than 75% of $p_T$-weighted ID tracks associated to the primary vertex. This reduces the presence of jets arising from uncorrelated soft collisions (pile-up) and discards jets without reconstructed tracks.

A $b$-tagging algorithm [43] is used to identify jets containing a $b$-hadron decay. The algorithm uses a multivariate technique based on the properties of the secondary vertex, of tracks within the jet, and of the jet itself. The nominal $b$-tagging efficiency, determined from $t\bar{t}$ MC events, is on average 60%, with a misidentification, or mis-tag, rate for $c$-quark (light-quark/ghon) jets of 10% (1%).
5. Signal Region Definitions

The data are selected with a three-level trigger system.

The events used in this search satisfied single-lepton trigger requirements that varied with the data-taking period. The widest electron trigger has an efficiency of \( \sim0.97\%\) for electrons with \( p_T > 25\) GeV. The muon trigger reaches an efficiency plateau of \( \sim0.95\%\) in the end-caps for muons with \( p_T > 20\) GeV. The equivalent efficiency in the barrel region is \( \sim75\%\) due to a lower geometrical acceptance for the muon trigger chambers in this region.

Collision events are selected by requiring at least one reconstructed vertex with at least five associated tracks with \( p_T > 400\) MeV, consistent with the beam spot position. Two signal regions are defined containing either exclusively one or two charged leptons (\( \ell = e, \mu \)) in the final state, referred to hereafter as the 1- and 2-lepton channels respectively. A total integrated luminosity of \( 4.7 \pm 0.2\) fb\(^{-1}\) is used, following the beam, detector and data-quality requirements as described in Refs. [44, 45].

In the 1-lepton channel, events are required to contain the minimum number of objects expected from the \( tl \to WbWb \to q\bar{q}'b\bar{b}b\) decay. Exactly one lepton is required, which must have \( p_T > 25\) GeV (20 GeV) for the electron (muon) channel and fulfill the trigger requirements. Events with an additional electron (muon) with \( p_T > 20\) GeV (10 GeV) are rejected to ensure no events are classified as belonging to both 1- and 2-lepton channels. A minimum of four jets are required in the event, at least two of which must pass the selection described in Section 6:

- Events are required to have \( p_T > 30\) GeV (25 GeV) for the muon (electrons) channel and fulfill the trigger requirements.
- At least one jet is required to have \( p_T > 40\) GeV (25 GeV).
- At least one jet is required to have \( p_T > 40\) GeV (25 GeV). In the case of different-flavour pairs, either the electron must have \( p_T > 25\) GeV or the muon \( p_T > 20\) GeV.

In the 2-lepton channel, the following requirements are imposed to ensure that the event contains the required number of objects consistent with the \( tl \to WbWb \to \ell\nu b\bar{b}b\) decay. Exactly two oppositely-charged leptons are required to pass the selection described in Section 4. Events are required to fulfill \( E_T^{miss} > 40\) GeV and the invariant mass of the two leptons \( (m_\ell\ell)\) must satisfy \( 30 < m_\ell\ell < 81\) GeV to increase the discrimination against the background, as illustrated in Fig. 1(c).

In order to distinguish between stop and top pair production the mass scale subsystem variable \( \sqrt{s}_{min}^{(sub)}\) [47] is employed. Conceptually, the variable is constructed by dividing an event’s topology into a subsystem comprising both the visible and invisible particles originating from the hard-scattering process of interest and a set of other visible particles labelled as coming from other, “upstream”, processes such as the underlying event or ISR. With these definitions, the minimum invariant mass compatible with the subsystem is:

\[
\sqrt{s}_{min}^{(sub)} = \left\{ \left( \frac{m_{(sub)}^2 + p_T^{(sub)}^2}{2} \right)^{1/2} + \sqrt{\left( m_{miss}^2 + E_T^{miss} \right)^2} \right\}^{1/2}, \tag{1}
\]

where \( m_{(sub)} \) and \( p_T^{(sub)} \) are the invariant mass and the transverse momentum of the visible subsystem particles. The variable \( m_{miss} \) is the scalar sum of the invisible particle masses in the event. The final term in Eq. 1 is a two-dimensional vector sum representing the boost correction in the transverse plane caused by upstream processes. In this analysis \( \sqrt{s}_{min}^{(sub)} \) is calculated making the hypothesis that each event arises from \( tl \) production, with the invisible subsystem comprising one or two neutrinos, and therefore \( m_{miss} = 0 \) in Eq. 1.

With this assumption, the reconstructed \( \sqrt{s}_{min}^{(sub)} \) distribution for \( tl \) background events is expected to peak at around \( m_\ell \approx 2m_t \simeq 345\) GeV. On the other hand, stop pair production will peak at lower values if the mass difference between the stop and the neu-
In the 1-lepton channel, the visible subsystem comprises the single lepton, two light flavour jets and two b-jets. In events where combinatorial ambiguities arise, the subsystem objects are chosen which give the highest estimator in the algorithm described above. In the 2-lepton channel, the two leptons and the two leading jets are used. In both channels, the upper limit on $\sqrt{s}_{\text{min}}$ has been chosen to maximise the expected signal efficiency with respect to background rejection, across a range of scenarios described in Section 1. In the 1-lepton channel, the optimal requirement is $\sqrt{s}_{\text{min}} < 250$ GeV, defining a signal region referred to hereafter as ILSR. In the 2-lepton channel two signal regions are defined, the first requiring $\sqrt{s}_{\text{min}} < 225$ GeV (2LSR1). The invariant mass of the two leptons and two jets ($m_{\ell\ell jj}$) was also found to be a useful discriminating variable. Imposing $m_{\ell\ell jj} < 140$ GeV in combination with $\sqrt{s}_{\text{min}} < 235$ GeV was found to give the optimal performance and defines a second signal region (2LSR2).

6. Background Estimation

The dominant SM background process in the 1-lepton (2-lepton) channel arises from single-lepton (dilepton) $t\bar{t}$ decays, comprising 60% (80%) of the total background. The second most significant background in the 1-lepton (2-lepton) channel arises from $W$ ($Z/\gamma$) production in association with jets from heavy flavour quarks. For both channels, similar methods are used to estimate these backgrounds. For each channel and background process a control region is defined that is rich in the background of interest. The region is kinematically similar to the signal region but distinct from it, such that the signal and control regions have no events in common. For a control region containing $N_{\text{CR}}^{\text{obs}}$ observed events (corrected for the contamination from other backgrounds), the number of events in the signal region is calculated as $N_{\text{SR}} = N_{\text{CR}}^{\text{obs}} \times (N_{\text{MC}}/N_{\text{CR}})$, where $N_{\text{SR}}^{\text{MC}}$ and $N_{\text{CR}}^{\text{MC}}$ are the MC-based estimates in the signal and control regions respectively. The advantage of this method is that many systematic uncertainties partially cancel.

In the 1-lepton channel, the $t\bar{t}$ background is determined with a control region defined identically to the signal region, except that $\mu - 0.5\bar{\sigma} < m_{\text{ad}} < \mu + 0.5\bar{\sigma}$ and $\sqrt{s}_{\text{min}} < 320$ GeV, corresponding to a $t\bar{t}$ purity of 93%. The definition of a control region using these fitted parameters reduces the systematic uncertainties related to the jet energy scale and resolution. A high-purity $W+b$-jets control region is more difficult to define due to the kinematic similarity with $t\bar{t}$ events, which have a higher fiducial cross section. A control region can, however, be defined with $38\%$ purity for $W+b$-jets events by requiring $m_{\text{ad}}^2 > 250$ GeV and that the invariant mass of the two $b$-jets is less than 50 GeV. As the $t\bar{t}$ contamination in this region is still relatively high (60%), the $W+b$-jets and $t\bar{t}$ contributions are determined by scaling their contributions simultaneously such that the total number of events matches the data in both control regions.

In the 2-lepton channel, the $t\bar{t}$ background (including dileptonic $Wt$ decays) is determined using a control region identical to the signal region except that $m_{t\bar{t}} > 101$ GeV and $\sqrt{s}_{\text{min}} < 235$ GeV, with 94% purity of $t\bar{t}$ events. The $Z+jets$ background, with $Z$ decaying to any of the three lepton flavours, is determined in a region requiring two same-flavour leptons, $81 < m_{t\bar{t}} < 101$ GeV and $\sqrt{s}_{\text{min}} < 225$ GeV, with a $Z$ purity of 90%.

The contribution to the background from events where a jet is misidentified as a lepton, or where a lepton from a $b$- or $c$-hadron decay is selected (referred to as “fake” lepton background), is estimated using a data-driven technique in both channels [39, 48]. The probability of such a misidentification is estimated by relaxing the electron and muon identification criteria to obtain control samples dominated by multi-jet production. In the 1-lepton channel, the main contribution is from multi-jet events. In the 2-lepton channel, the dominant contribution is from processes containing one real and one fake lepton, such as $W$-jet or single-lepton $t\bar{t}$ decays. The contribution from events containing two fake leptons was found to be negligible.

Other less significant processes in the 1-lepton channel include $Z/\gamma^* +jets$ and single top quark production. Diboson and $t\bar{t} + X$ ($X = W, Z, WW, b\bar{b}$) production give a minor contribution to both channels. The contribution to the total background from these processes (referred to as “Others” in the following and in Fig. 1) is 2.5% (2%) in the 1-lepton (2-lepton) channel, and is taken directly from the MC predictions.

7. Systematic Uncertainties

The effect of the jet energy scale (JES) uncertainty on the final event yield is calculated by shifting the $p_T$ of all jets up and down by $p_T$ and $\eta$ dependent factors, which are 5–3% for jets with $p_T$ of 20–60 GeV. Repeating the analysis with these $p_T$ shifts applied to the MC simulation leads to variations on the final background estimate of 6–10% depending on the signal region. The uncertainty due to the jet energy resolution (JER) is calculated by smearing the $p_T$ of each jet by factors depending on the jet $p_T$ and $\eta$. The smearing on a single jet is typically around 10%, and results in an overall uncertainty of 1–10%. Systematic uncertainties in the lepton identification efficiency amount to 1%. The uncertainty on the $E_T^{\text{miss}}$ due to the energy scale of the clusters in the calorimeter not associated with jets and electrons is evaluated using the method described in Ref. [49], extended to include pile-up uncertainties. The effect is up to 9% on the total background estimate depending on the signal region. The uncertainty
Figure 1: The 1-lepton channel $m_{\ell\ell}^{\text{had}}$ distribution after all requirements except those on $m_{\ell\ell}^{\text{had}}$ and $\sqrt{s}_{\text{min}}^{(\text{sub})}$ (a), and the $\sqrt{s}_{\text{min}}^{(\text{sub})}$ distribution after all requirements except those on $\sqrt{s}_{\text{min}}^{(\text{sub})}$ (b). For the 2-lepton channel, the $m_{\ell\ell}$ distribution is shown after all requirements except those on $m_{\ell\ell}$ and $\sqrt{s}_{\text{min}}^{(\text{sub})}$ (c), and the $\sqrt{s}_{\text{min}}^{(\text{sub})}$ distribution, before the requirements on $\sqrt{s}_{\text{min}}^{(\text{sub})}$ itself (d). The last bin in each histogram contains the integral of all events with values greater than the upper axis bound. The hatched bands display the total uncertainties on the background expectation and the dashed lines show the expected distributions for two signal models. The bottom panels show the ratio of data to the expected background (points) and the total uncertainty on the background (hatched area).

due to $b$-tagging is evaluated by varying the $b$-tagging efficiency and mis-tag rates within the uncertainties of the measured values [50-52], giving an effect of 1% in all signal regions. The uncertainty associated with pile-up re-weighting is evaluated by varying the number of interactions per bunch-crossing by 10%. The overall effect on the predicted background yield is at most 3%.

Uncertainties related to the overall normalisation of the top background are reduced compared to estimates based purely on MC simulation by employing the method described in Sec. 6. Residual uncertainties related to the shape of the predicted kinematic distributions are described in the following. Theoretical uncertainties on the $t\bar{t}$ background due to the choice of generator are evaluated by comparing event yields from $\text{MC@NLO}$ to those from $\text{POWHEG}$ with the same parton shower model ($\text{HERWIG}$). The parton shower uncertainties are then calculated by comparing samples generated with the $\text{HERWIG}$ and $\text{PYTHIA}$ parton shower models, with the same generator ($\text{POWHEG}$). The uncertainty due to ISR/FSR is assessed using $\text{AcerMC}$ samples with variations of $\text{PYTHIA}$ parameters related to the ISR branching phase-space and the FSR low-$p_T$ cutoff. These variations are chosen to produce jet activity in $t\bar{t}$ events that is consistent with the data [53, 54]. The total uncertainty on the $t\bar{t}$ estimate due to these effects amounts to 10–15%. Uncertainties due to the PDF choice
shows the observed number of events in data —

Table 1: Predicted and observed number of events in all signal regions together with their statistical and systematic uncertainties. No values are shown for the W+jets contributions in the 2-lepton signal regions as these are included in the fake contributions. The expected number of events for two signal scenarios, both with a chargino mass of 140 GeV, are also shown. The observed and expected upper limits at 95% confidence level on $\sigma_{\text{vis}} = \sigma \times A \times \epsilon$ are also given.

and errors are found to be negligible.

In the 1-lepton channel, the theoretical uncertainty in the $W$ estimate due to variations of the factorisation, renormalisation and matching scales is found to be 15%. Similar uncertainties on the $Z/\gamma^*$ contribution in the 2-lepton channel are 9% (2%) in 2LSR1 (2LSR2).

Uncertainties on the data-driven background from fake leptons arise from the lepton fake rate determination and from the definition of the fake-enriched control regions. The effect is between 45–84% of the fake contribution.

Theoretical uncertainties on the stop pair production cross section are taken from an envelope of predictions which use different PDF sets and factorisation and renormalisation scales, as described in Ref. [55]. Signal uncertainties on JES (10–30%), JER (1–30%) and $b$-tagging (5–10%) vary depending on the sparticle masses and the signal channel considered. They are treated as fully correlated with their respective background uncertainties. Finally, the luminosity uncertainty is 3.9%.

8. Results and Interpretation

Table 1 shows the observed number of events in data and the SM predictions for the signal regions of the 1- and 2-lepton channels. In all SRs, the data are in good agreement with the SM expectations.

The results are translated into 95% confidence-level (CL) upper limits on contributions from new physics using the $CL_s$ prescription [56] with a profile log-likelihood ratio as a test statistic [57], where the parameter to describe the non-SM signal strength is constrained to be non-negative in the fit. As shown in Table 1, the three signal regions are used to set limits on the visible cross section of the new physics models, $\sigma_{\text{vis}} = \sigma \times A \times \epsilon$, where $\sigma$ is the total production cross section for any non-SM signal, $A$ is the acceptance defined by the fraction of events passing the geometric and kinematic selections at particle level, and $\epsilon$ is the detector reconstruction, identification and trigger efficiency. Results are interpreted in the MSSM scenarios described in Section 1. In order to maximise the sensitivity of the analysis, results from the 1- and 2-lepton channels are combined using the following method: for each signal point, the 2-lepton signal region (2LSR1 or 2LSR2) which yields the lowest expected $CL_s$ value is chosen. This region is then statistically combined with the 1LSR by multiplying the respective likelihood functions. Correlated systematic uncertainties are treated as common between the two channels, and a common signal strength parameter $\mu$ is applied. The effect of signal contamination in the control regions (typically 5–10% depending on the signal point) is also considered. In the gaugino universality scenario, shown in Fig. 2(a), stop masses between 120–167 GeV are excluded for $m_{\tilde{\chi}^0_1} = 55$ GeV. The sensitivity of the search is also evaluated for a stop mass of 180 GeV in the chargino–neutralino mass plane, as shown in Fig. 2(b). In such a scenario, where the stop-top mass difference is small, a region around $m_{\tilde{\chi}^0_1} = 70$ GeV, $m_{\tilde{\chi}^\pm_1} = 140$ GeV is still excluded. The scenario with $m_{\tilde{\chi}^\pm_1} = 106$ GeV is shown in Fig. 2(c), where stop masses are excluded between 125–167 GeV for $m_{\tilde{\chi}^0_1} = 55$ GeV. Neutralino masses of 70 GeV are excluded for 125 $< m_{\tilde{\chi}^0_1} < 155$ GeV.

9. Conclusions

A search has been performed for top squarks with masses near to, or less than, the top quark mass. Good agreement is observed between data and the SM predictions in all channels. The results allow limits to be set on the stop mass, assuming that $\tilde{t}_1 \rightarrow \tilde{\chi}^\pm_1 b$ is the only allowed decay mode, followed by $\tilde{\chi}^\pm_1 \rightarrow W^{(*)} \tilde{\chi}^0_1$. For scenarios in which $m_{\tilde{\chi}^\pm_1} \approx 2 \times m_{\tilde{\chi}^0_1}$, stop masses between 120–167 GeV are excluded for $m_{\tilde{\chi}^0_1} = 55$ GeV. For a fixed
stop mass of 180 GeV, a region around $m_{\tilde{t}_R} = 70$ GeV, $m_{\tilde{t}_L} = 140$ GeV is excluded. In the scenario where $m_{\tilde{t}_L} = 106$ GeV, neutralino masses of 70 GeV are excluded for $25 < m_{\tilde{t}_L} < 155$ GeV, significantly extending previous limits in such scenarios.

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University of Science and Technology of China, Anhui; (c) Department of Physics, Nanjing University, Jiangsu; (d) School of Physics, Shandong University, Shandong; (e) Physics Department, Shanghai Jiao Tong University, Shanghai, China

Laboratoire de Physique Corpusculaire, Clermont Université et Université Blaise Pascal and CNRS/IN2P3, Clermont-Ferrand, France

Nevis Laboratory, Columbia University, Irvington NY, United States of America

Niels Bohr Institute, University of Copenhagen, Kobenhavn, Denmark

(a) INFN Gruppo Collegato di Cosenza; (b) Dipartimento di Fisica, Università della Calabria, Arcavata di Rende, Italy

AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Krakow, Poland

The Henryk Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences, Krakow, Poland

Physics Department, Southern Methodist University, Dallas TX, United States of America

Physics Department, University of Texas at Dallas, Richardson TX, United States of America

DESY, Hamburg and Zeuthen, Germany

Institut für Experimentelle Physik IV, Technische Universität Dortmund, Dortmund, Germany

Department of Physics, Duke University, Durham NC, United States of America

SUPA - School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom

INFN Laboratori Nazionali di Frascati, Frascati, Italy

Fakultät für Mathematik und Physik, Albert-Ludwigs-Universität, Freiburg, Germany

Section de Physique, Université de Genève, Geneva, Switzerland

(a) INFN Sezione di Genova; (b) Dipartimento di Fisica, Università di Genova, Genova, Italy

(a) E. Andronikashvili Institute of Physics, iv. Javakhishvili Tbilisi State University, Tbilisi; (b) High Energy Physics Institute, Tbilisi State University, Tbilisi, Georgia

II Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen, Germany

SUPA - School of Physics and Astronomy, University of Glasgow, Glasgow, United Kingdom

II Physikalisches Institut, Georg-August-Universität, Göttingen, Germany

Laboratoire de Physique Subatomique et de Cosmologie, Université Joseph Fourier and CNRS/IN2P3 and Institut National Polytechnique de Grenoble, Grenoble, France

Department of Physics, Hampton University, Hampton VA, United States of America

Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge MA, United States of America

(a) Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Heidelberg; (b) Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg; (c) ZITI Institut für technische Informatik, Ruprecht-Karls-Universität Heidelberg, Mannheim, Germany

Faculty of Applied Information Science, Hiroshima Institute of Technology, Hiroshima, Japan

Department of Physics, Indiana University, Bloomington IN, United States of America

Institut für Astro- und Teilchenphysik, Leopold-Franzens-Universität, Innsbruck, Austria

University of Iowa, Iowa City IA, United States of America

Department of Physics and Astronomy, Iowa State University, Ames IA, United States of America

Joint Institute for Nuclear Research, JINR Dubna, Dubna, Russia

KEK, High Energy Accelerator Research Organization, Tsukuba, Japan

Graduate School of Science, Kobe University, Kobe, Japan

Faculty of Science, Kyoto University, Kyoto, Japan

Kyoto University of Education, Kyoto, Japan

Department of Physics, Kyushu University, Fukuoka, Japan

Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata, Argentina

Physics Department, Lancaster University, Lancaster, United Kingdom

(a) INFN Sezione di Lecce; (b) Dipartimento di Matematica e Fisica, Università del Salento, Lecce, Italy

Oliver Lodge Laboratory, University of Liverpool, Liverpool, United Kingdom

Department of Physics, Józef Stefan Institute and University of Ljubljana, Ljubljana, Slovenia

School of Physics and Astronomy, Queen Mary University of London, London, United Kingdom

Department of Physics, Royal Holloway University of London, Surrey, United Kingdom

Department of Physics and Astronomy, University College London, London, United Kingdom

Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France

Fysiska institutionen, Lunds universitet, Lund, Sweden

Departamento de Fisica Teorica C-15, Universidad Autonoma de Madrid, Madrid, Spain
135 (a) Faculté des Sciences Ain Chock, Réseau Universitaire de Physique des Hautes Energies - Université Hassan II, Casablanca; (b) Centre National de l’Énergie des Sciences Techniques Nucléaires, Rabat; (c) Faculté des Sciences Semlalia, Université Cadi Ayyad, LPEHA-Marrakech; (d) Faculté des Sciences, Université Mohamed Premier and LPTPM, Oujda; (e) Faculté des sciences, Université Mohammed V-Agdal, Rabat, Morocco

136 DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l’Univers), CEA Saclay (Commissariat à l’Énergie Atomique), Gif-sur-Yvette, France

137 Santa Cruz Institute for Particle Physics, University of California Santa Cruz, Santa Cruz CA, United States of America

138 Department of Physics, University of Washington, Seattle WA, United States of America

139 Department of Physics and Astronomy, University of Sheffield, Sheffield, United Kingdom

140 Department of Physics, Shinshu University, Nagano, Japan

141 Fachbereich Physik, Universität Siegen, Siegen, Germany

142 Department of Physics, Simon Fraser University, Burnaby BC, Canada

143 SLAC National Accelerator Laboratory, Stanford CA, United States of America

144 (a) Faculty of Mathematics, Physics & Informatics, Comenius University, Bratislava; (b) Department of Subnuclear Physics, Institute of Experimental Physics of the Slovak Academy of Sciences, Kosice, Slovak Republic

145 (a) Department of Physics, University of Johannesburg, Johannesburg; (b) School of Physics, University of the Witwatersrand, Johannesburg, South Africa

146 (a) Department of Physics, Stockholm University; (b) The Oskar Klein Centre, Stockholm, Sweden

147 Physics Department, Royal Institute of Technology, Stockholm, Sweden

148 Departments of Physics & Astronomy and Chemistry, Stony Brook University, Stony Brook NY, United States of America

149 Department of Physics and Astronomy, University of Sussex, Brighton, United Kingdom

150 School of Physics, University of Sydney, Sydney, Australia

151 Institute of Physics, Academia Sinica, Taipei, Taiwan

152 Department of Physics, Technion: Israel Institute of Technology, Haifa, Israel

153 Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel

154 Department of Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece

155 International Center for Elementary Particle Physics and Department of Physics, The University of Tokyo, Tokyo, Japan

156 Graduate School of Science and Technology, Tokyo Metropolitan University, Tokyo, Japan

157 Department of Physics, Tokyo Institute of Technology, Tokyo, Japan

158 Department of Physics, University of Toronto, Toronto ON, Canada

159 (a) TRIUMF, Vancouver BC; (b) Department of Physics and Astronomy, York University, Toronto ON, Canada

160 Faculty of Pure and Applied Sciences, University of Tsukuba, Tsukuba, Japan

161 Department of Physics and Astronomy, Tufts University, Medford MA, United States of America

162 Centro de Investigaciones, Universidad Antonio Narino, Bogota, Colombia

163 Department of Physics and Astronomy, University of California Irvine, Irvine CA, United States of America

164 (a) INFN Gruppo Collegato di Udine; (b) ICTP, Trieste; (c) Dipartimento di Chimica, Fisica e Ambiente, Università di Udine, Udine, Italy

165 Department of Physics, University of Illinois, Urbana IL, United States of America

166 Department of Physics and Astronomy, University of Uppsala, Uppsala, Sweden

167 Instituto de Física Corpuscular (IFIC) and Departamento de Física Atómica, Molecular y Nuclear and Departamento de Ingeniería Electrónica and Instituto de Microelectrónica de Barcelona (IMB-CNM), University of Valencia and CSIC, Valencia, Spain

168 Department of Physics, University of British Columbia, Vancouver BC, Canada

169 Department of Physics and Astronomy, University of Victoria, Victoria BC, Canada

170 Department of Physics, University of Warwick, Coventry, United Kingdom

171 Waseda University, Tokyo, Japan

172 Department of Particle Physics, The Weizmann Institute of Science, Rehovot, Israel

173 Department of Physics, University of Wisconsin, Madison WI, United States of America

174 Fakultät für Physik und Astronomie, Julius-Maximilians-Universität, Würzburg, Germany

175 Fachbereich C Physik, Bergische Universität Wuppertal, Wuppertal, Germany

176 Department of Physics, Yale University, New Haven CT, United States of America

177 Yerevan Physics Institute, Yerevan, Armenia

178 Centre de Calcul de l’Institut National de Physique Nucléaire et de Physique des Particules (IN2P3), Villeurbanne, France