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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 $m_t \gtrsim m_{\tilde{t}_1} > m_{\tilde{\chi}_1^\pm}$ and the stop decays exclusively into a b-quark and a chargino $(\tilde{t}_1 \to \tilde{\chi}_1^\pm b)$. The chargino subsequently decays via a virtual or real W boson $(\tilde{\chi}_1^\pm \to W^{(*)}\tilde{\chi}_1^0)$. The masses of all other supersymmetric particles, including the mass of $\tilde{t}_2$, 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 $(m_{\tilde{\chi}_1^\pm} \simeq 2 \times m_{\tilde{\chi}_1^0})$; 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, ϕ) are used in the transverse plane, ϕ being the azimuthal angle around the beam pipe. The pseudorapidity is defined in terms of the polar angle θ as $\eta = -\ln\tan(\theta/2)$. The distance ΔR in the $\eta-\phi$ space is defined as $\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2}$.

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 `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 `CT10` [22]. Samples of W and Z/γ^* production, with accompanying light- and heavy-flavour jets, and $t\bar{t}$ with additional b-jets ($t\bar{t}b\bar{b}$) are generated using `ALPGEN` [23]. Samples of $Zt\bar{t}$, $Wt\bar{t}$ and $WWt\bar{t}$ are generated with `MadGraph` [24] interfaced to `PYTHIA` [25]. Diboson (WW, WZ, ZZ) production is generated with `HERWIG` [26]. Single top production is generated with `MC@NLO` for the s- and $t + W$-channels, and `AcerMC` [27] for the t-channel. Fragmentation and hadronisation modelling for the `ALPGEN` and `MC@NLO` samples are performed by `HERWIG`, using `JIMMY` [28] for the underlying event. `ALPGEN` and `POWHEG` [29] samples are used to assess the systematic uncertainties associated with the choice of generator for $t\bar{t}$ production, and `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 `MRST2007` LO [30] set is used with `HERWIG`, `CTEQ6L1` [31] with `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 `PYTHIA6` and `Herwig++` [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 `GEANT4` [38]. MC samples are reweighted 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}) $p_{\mathrm{T}} > 20$ 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 $p_{\mathrm{T}} > 10$ 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 η dependent correction factors based on MC simulation validated with extensive test-beam 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 $p_{\mathrm{T}} > 20$ 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, $\mathbf{p}_{\mathrm{T}}^{\mathrm{miss}}$, and its magnitude $E_{\mathrm{T}}^{\mathrm{miss}}$, 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/gluon) 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 tightest electron trigger has an efficiency of ∼97% for electrons with $p_{\mathrm{T}} > 25$ GeV. The muon trigger reaches an efficiency plateau of ∼90% in the end-caps for muons with $p_{\mathrm{T}} > 20$ GeV. The equivalent efficiency in the barrel region is ∼75% 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 $p_{\mathrm{T}} > 400$ 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 ± 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 $t\bar{t} \to WbW\bar{b} \to q\bar{q}'b\ell\bar{\nu}\bar{b}$ decay. Exactly one lepton is required, which must have $p_{\mathrm{T}} > 25$ GeV (20 GeV) for the electron (muon) channel and fulfil the trigger requirements. Events with an additional electron (muon) with $p_{\mathrm{T}} > 20$ 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 b-tagging requirements and at least two must fail them. Events are required to have a missing transverse momentum of $E_{\mathrm{T}}^{\mathrm{miss}} > 40$ GeV. Background from multi-jet processes, in which jets are misidentified as leptons, is rejected by requiring that the transverse mass of the lepton-$E_{\mathrm{T}}^{\mathrm{miss}}$ system, $m_{\mathrm{T}} = \sqrt{2p_{\mathrm{T}}^{\ell}E_{\mathrm{T}}^{\mathrm{miss}} - 2\mathbf{p}_{\mathrm{T}}^{\ell}\cdot\mathbf{p}_{\mathrm{T}}^{\mathrm{miss}}}$, is larger than 30 GeV.

The invariant mass of the hadronic top decay products (m_t^{had}) is used as an additional discriminating variable. In scenarios where the stop is lighter than the top, m_t^{had} will tend to be lower than for background $t\bar{t}$ processes, as illustrated in Fig. 1(a). Since there is an ambiguity as to which b-jet arises from the hadronic top decay (and additional ambiguities at higher jet multiplicities), the hadronic decay products are tagged using the following algorithm: for every possible combination of light and b-tagged jets in the event, the invariant masses m_W^{had} (of two light jets, m_{jj}), m_W^{lep} (assuming that the lepton and $E_{\mathrm{T}}^{\mathrm{miss}}$ arise from the $W \to \ell\nu$ decay), m_t^{had} and m_t^{lep} (the leptonic top mass) are calculated. A $t\bar{t}$ estimator of $P_{\mathrm{tot}} = P(m_W^{\mathrm{had}})P(m_W^{\mathrm{lep}})P(m_t^{\mathrm{lep}})P(m_t^{\mathrm{had}})$ is assigned to this combination, where $P(m)$ is related to the probability for reconstructing a particle of mass m, assuming a Gaussian probability density function with mean values taken from Ref. [46] and widths from MC simulation. The combination which maximises P_{tot} is used to assign one b-jet and two light flavour jets (one b-jet, the lepton and $E_{\mathrm{T}}^{\mathrm{miss}}$) as arising from the hadronic (leptonic) decay of the top quark.

Events are then required to have $m_t^{\mathrm{had}} < \hat{\mu} - 0.5\hat{\sigma}$, where $\hat{\mu}$ and $\hat{\sigma}$ are the mean and width respectively of a Gaussian fit to the m_t^{had} distribution in a 40 GeV window around the top mass. This approach is taken to reduce some of the systematic uncertainties affecting the shape of this distribution, as detailed in Section 6.

In the 2-lepton channel, the following requirements are imposed to ensure that the event contains the required number of objects consistent with the $t\bar{t} \to WbW\bar{b} \to \ell\nu b\ell\bar{\nu}\bar{b}$ decay. Exactly two oppositely-charged leptons are required to pass the selection described in Section 4. For same-flavour pairs, the highest p_{T} lepton is required to have $p_{\mathrm{T}} > 25$ GeV (20 GeV) for electrons (muons). In the case of different-flavour pairs, either the electron must have $p_{\mathrm{T}} > 25$ GeV or the muon $p_{\mathrm{T}} > 20$ GeV. At least two jets are required in the event, of which the two with highest p_{T} are assumed to originate from the $t\bar{t}$ process. At least one of these two jets is required to be b-tagged. The event is required to fulfil $E_{\mathrm{T}}^{\mathrm{miss}} > 40$ 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 $\sqrt{s}_{\mathrm{min}}^{(\mathrm{sub})}$ [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:

$$\sqrt{s}_{\mathrm{min}}^{(\mathrm{sub})} = \left\{ \left(\sqrt{m_{(\mathrm{sub})}^2 + p_{\mathrm{T}}{}_{(\mathrm{sub})}^2} + \sqrt{\left(m^{\mathrm{miss}}\right)^2 + \left(E_{\mathrm{T}}^{\mathrm{miss}}\right)^2} \right)^2 - \left(\mathbf{p}_{\mathrm{T}(\mathrm{sub})} + \mathbf{p}_{\mathrm{T}}^{\mathrm{miss}} \right)^2 \right\}^{\frac{1}{2}}, \tag{1}$$

where $m_{(\mathrm{sub})}$ and $p_{\mathrm{T}(\mathrm{sub})}$ 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 $\sqrt{s}_{\mathrm{min}}^{(\mathrm{sub})}$ is calculated making the hypothesis that each event arises from $t\bar{t}$ production, with the invisible subsystem comprising one or two neutrinos, and therefore $m^{\mathrm{miss}} = 0$ in Eq. 1. With this assumption, the reconstructed $\sqrt{s}_{\mathrm{min}}^{(\mathrm{sub})}$ distribution for $t\bar{t}$ background events is expected to peak at around $m_{t\bar{t}} = 2m_t \simeq 345$ GeV. On the other hand, stop pair production will peak at lower values if the mass difference between the stop and the neutralino is less than the top mass, as illustrated in Figs. 1(b) and 1(d). Signal events are therefore selected by imposing an upper limit on $\sqrt{s}_{\rm min}^{(\rm sub)}$.

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 $\sqrt{s}_{\rm min}^{(\rm sub)}$ 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 $\sqrt{s}_{\rm min}^{(\rm sub)} < 250$ GeV, defining a signal region referred to hereafter as 1LSR. In the 2-lepton channel two signal regions are defined, the first requiring $\sqrt{s}_{\rm min}^{(\rm sub)} < 225$ GeV (2LSR1). The invariant mass of the two leptons and two jets ($m_{\ell\ell jj}$) was also found be a useful discriminating variable. Imposing $m_{\ell\ell jj} < 140$ GeV in combination with $\sqrt{s}_{\rm min}^{(\rm sub)} < 235$ 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/γ^*) 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 $N_{\rm CR}^{\rm obs}$ observed events (corrected for the contamination from other backgrounds), the number of events in the signal region is calculated as $N_{\rm SR} = N_{\rm CR}^{\rm obs} \times (N_{\rm SR}^{\rm MC}/N_{\rm CR}^{\rm MC})$, where $N_{\rm SR}^{\rm MC}$ and $N_{\rm CR}^{\rm MC}$ 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 $\hat{\mu} - 0.5\hat{\sigma} < m_t^{\rm had} < \hat{\mu} + 0.5\hat{\sigma}$ and $\sqrt{s}_{\rm min}^{(\rm sub)} < 320$ 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 $m_t^{\rm had} > 250$ 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 $m_{\ell\ell} > 101$ GeV and $\sqrt{s}_{\rm min}^{(\rm sub)} < 325$ 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, $81 < m_{\ell\ell} < 101$ GeV and $\sqrt{s}_{\rm min}^{(\rm sub)} < 225$ 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/γ^*+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 $p_{\rm T}$ of all jets up and down by $p_{\rm T}$ and η dependent factors, which are 5–3% for jets with $p_{\rm T}$ of 20–60 GeV. Repeating the analysis with these $p_{\rm T}$ 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 $p_{\rm T}$ of each jet by factors depending on the jet $p_{\rm T}$ and η. 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 $E_{\rm T}^{\rm miss}$ 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

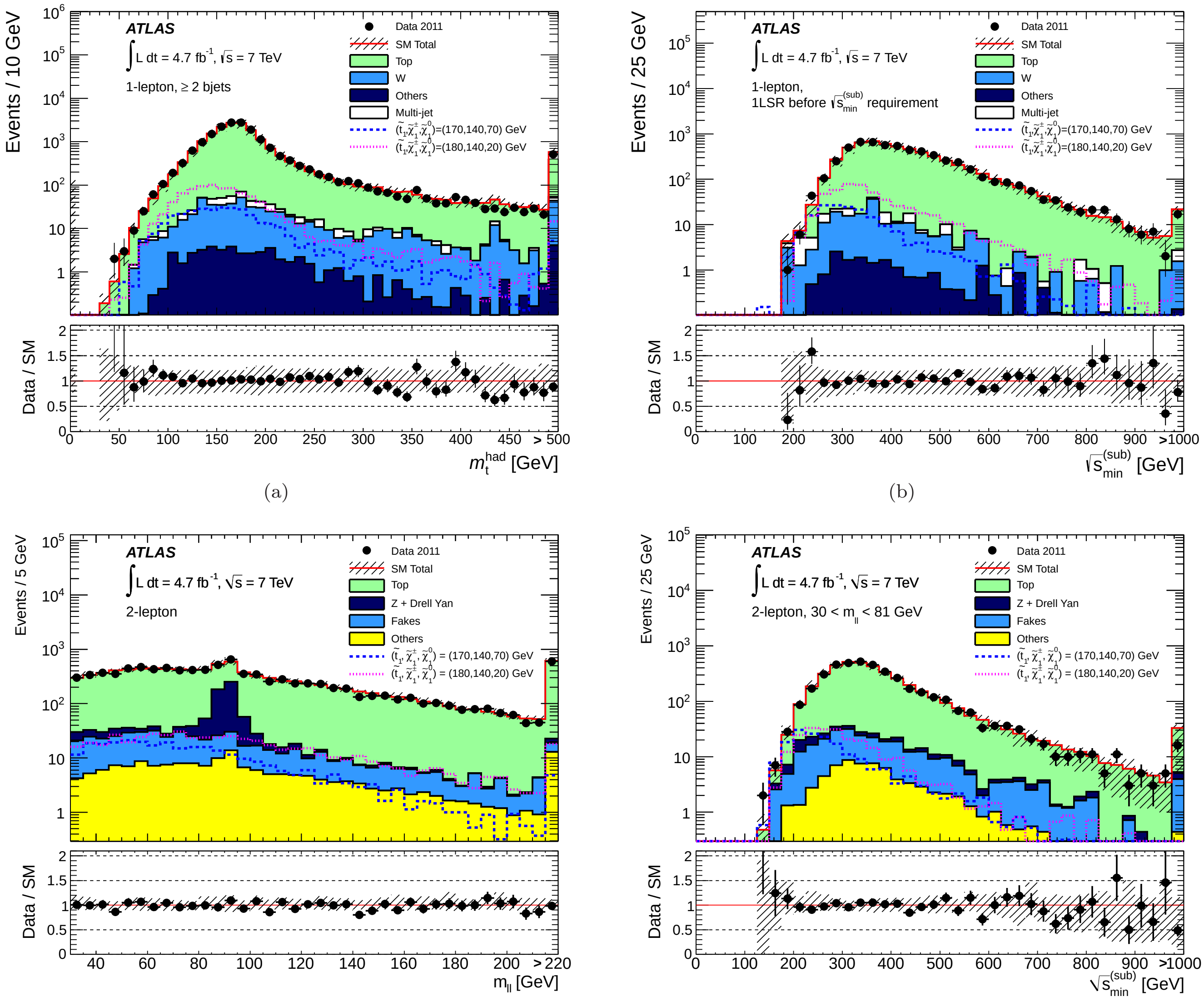

Figure 1: The 1-lepton channel m_t^{had} distribution after all requirements except those on m_t^{had} and $\sqrt{s}_{\mathrm{min}}^{(\mathrm{sub})}$ (a), and the $\sqrt{s}_{\mathrm{min}}^{(\mathrm{sub})}$ distribution after all requirements except that on $\sqrt{s}_{\mathrm{min}}^{(\mathrm{sub})}$ (b). For the 2-lepton channel, the $m_{\ell\ell}$ distribution is shown after all requirements except those on $m_{\ell\ell}$ and $\sqrt{s}_{\mathrm{min}}^{(\mathrm{sub})}$ (c), and the $\sqrt{s}_{\mathrm{min}}^{(\mathrm{sub})}$ distribution, before the requirements on $\sqrt{s}_{\mathrm{min}}^{(\mathrm{sub})}$ 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 reweighting 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 `MC@NLO` to those from `POWHEG` with the same parton shower model (`HERWIG`). The parton shower uncertainties are then calculated by comparing samples generated with the `HERWIG` and `PYTHIA` parton shower models, with the same generator (`POWHEG`). The uncertainty due to ISR/FSR is assessed using `AcerMC` samples with variations of `PYTHIA` parameters related to the ISR branching phase-space and the FSR low-p_{T} cut-off. 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

	Number of events		
Process	1LSR	2LSR1	2LSR2
Top	$24 \pm 3 \pm 5$	$89 \pm 6 \pm 10$	$36 \pm 2 \pm 5$
W+jets	$6 \pm 1 \pm 2$	—	—
Z+jets	$0.5 \pm 0.3 \pm 0.3$	$11 \pm 4 \pm 3$	$3 \pm 1 \pm 1$
Fake leptons	$7 \pm 1 \pm 2$	$12 \pm 5 \pm 11$	$6 \pm 4 \pm 4$
Others	$0.3 \pm 0.1 \pm 0.1$	$2.7 \pm 0.9 \pm 0.7$	$0.9 \pm 0.2 \pm 0.5$
Total SM	$38 \pm 3 \pm 7$	$115 \pm 8 \pm 15$	$46 \pm 4 \pm 7$
Data	50	123	47
$m_{\tilde{t}_1} = 170$ GeV, $m_{\tilde{\chi}_1^0} = 70$ GeV	$26 \pm 2 \pm 6$	$57 \pm 3 \pm 6$	$36 \pm 2 \pm 4$
$m_{\tilde{t}_1} = 180$ GeV, $m_{\tilde{\chi}_1^0} = 20$ GeV	$20 \pm 2 \pm 4$	$41 \pm 3 \pm 5$	$27 \pm 2 \pm 3$
	95% CL upper limits		
σ_{vis} (expected) [fb]	4.2	9.3	4.6
σ_{vis} (observed) [fb]	6.1	11	5.2

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/γ^* 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 σ 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 ϵ 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 μ 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 $m_{\tilde{\chi}_1^0} = 55$ 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 $m_{\tilde{\chi}_1^0} = 70$ GeV, $m_{\tilde{\chi}_1^\pm} = 140$ GeV is still excluded. The scenario with $m_{\tilde{\chi}_1^\pm} = 106$ GeV is shown in Fig. 2(c), where stop masses are excluded between 123–167 GeV for $m_{\tilde{\chi}_1^0} = 55$ GeV. Neutralino masses of 70 GeV are excluded for $125 < m_{\tilde{t}_1} < 155$ 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 $\tilde{t}_1 \to \tilde{\chi}_1^\pm b$ is the only allowed decay mode, followed by $\tilde{\chi}_1^\pm \to W^{(*)}\tilde{\chi}_1^0$. For scenarios in which $m_{\tilde{\chi}_1^\pm} \simeq 2 \times m_{\tilde{\chi}_1^0}$, stop masses between 120–167 GeV are excluded for $m_{\tilde{\chi}_1^0} = 55$ GeV. For a fixed

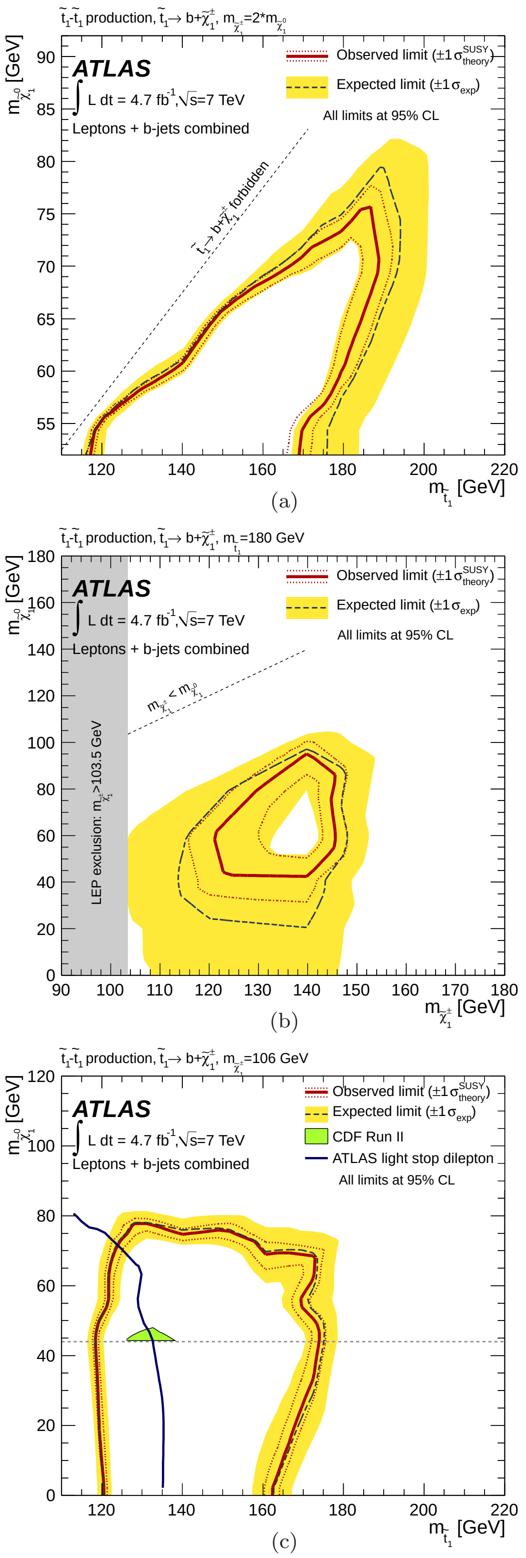

Figure 2: Exclusion limits at 95% CL for the scenarios described in the text. The dashed (solid) lines show the expected (observed) limits, including all uncertainties except for the theoretical signal cross section uncertainty (PDF and scale). The bands around the expected limits show the $\pm 1\sigma$ results. The lines around the observed limits represent the results obtained when moving the nominal signal cross section up or down by the $\pm 1\sigma$ theoretical uncertainty. In (c), results are compared to previous limits from the Tevatron [16], where the lowest neutralino mass considered was 44 GeV (dotted line), and from ATLAS [17].

stop mass of 180 GeV, a region around $m_{\tilde{\chi}_1^0} = 70$ GeV, $m_{\tilde{\chi}_1^\pm} = 140$ GeV is excluded. In the scenario where $m_{\tilde{\chi}_1^\pm} = 106$ GeV, neutralino masses of 70 GeV are excluded for $125 < m_{\tilde{t}_1} < 155$ GeV, significantly extending previous limits in such scenarios.

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P. Starovoitov[42], R. Staszewski[39], A. Staude[98], P. Stavina[144a,*], G. Steele[53], P. Steinbach[44], P. Steinberg[25], I. Stekl[127],
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J. Strandberg[147], S. Strandberg[146a,146b], A. Strandlie[117], M. Strang[109], E. Strauss[143], M. Strauss[111], P. Strizenec[144b],
R. Ströhmer[174], D.M. Strom[114], J.A. Strong[76,*], R. Stroynowski[40], J. Strube[129], B. Stugu[14], I. Stumer[25,*],
J. Stupak[148], P. Sturm[175], N.A. Styles[42], D.A. Soh[151,w], D. Su[143], HS. Subramania[3], A. Succurro[12], Y. Sugaya[116],
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B. Yabsley[150], S. Yacoob[145a,am], M. Yamada[65], H. Yamaguchi[155], A. Yamamoto[65], K. Yamamoto[63], S. Yamamoto[155], T. Yamamura[155], T. Yamanaka[155], J. Yamaoka[45], T. Yamazaki[155], Y. Yamazaki[66], Z. Yan[22], H. Yang[87], U.K. Yang[82], Y. Yang[60], Z. Yang[146a,146b], S. Yanush[91], L. Yao[33a], Y. Yao[15], Y. Yasu[65], G.V. Ybeles Smit[130], J. Ye[40], S. Ye[25], M. Yilmaz[4c], R. Yoosoofmiya[123], K. Yorita[171], R. Yoshida[6], C. Young[143], C.J. Young[118], S. Youssef[22], D. Yu[25], J. Yu[8], J. Yu[112], L. Yuan[66], A. Yurkewicz[106], B. Zabinski[39], R. Zaidan[62], A.M. Zaitsev[128], Z. Zajacova[30], L. Zanello[132a,132b], D. Zanzi[99], A. Zaytsev[25], C. Zeitnitz[175], M. Zeman[125], A. Zemla[39], C. Zendler[21], O. Zenin[128], T. Ženiš[144a], Z. Zinonos[122a,122b], S. Zenz[15], D. Zerwas[115], G. Zevi della Porta[57], Z. Zhan[33d], D. Zhang[33b,ak], H. Zhang[88], J. Zhang[6], X. Zhang[33d], Z. Zhang[115], L. Zhao[108], T. Zhao[138], Z. Zhao[33b], A. Zhemchugov[64], J. Zhong[118], B. Zhou[87], N. Zhou[163], Y. Zhou[151], C.G. Zhu[33d], H. Zhu[42], J. Zhu[87], Y. Zhu[33b], X. Zhuang[98], V. Zhuravlov[99], D. Zieminska[60], N.I. Zimin[64], R. Zimmermann[21], S. Zimmermann[21], S. Zimmermann[48], M. Ziolkowski[141], R. Zitoun[5], L. Živković[35], V.V. Zmouchko[128,*], G. Zobernig[173], A. Zoccoli[20a,20b], M. zur Nedden[16], V. Zutshi[106], L. Zwalinski[30].

[1] School of Chemistry and Physics, University of Adelaide, Adelaide, Australia
[2] Physics Department, SUNY Albany, Albany NY, United States of America
[3] Department of Physics, University of Alberta, Edmonton AB, Canada
[4] [(a)] Department of Physics, Ankara University, Ankara; [(b)] Department of Physics, Dumlupinar University, Kutahya; [(c)] Department of Physics, Gazi University, Ankara; [(d)] Division of Physics, TOBB University of Economics and Technology, Ankara; [(e)] Turkish Atomic Energy Authority, Ankara, Turkey
[5] LAPP, CNRS/IN2P3 and Université de Savoie, Annecy-le-Vieux, France
[6] High Energy Physics Division, Argonne National Laboratory, Argonne IL, United States of America
[7] Department of Physics, University of Arizona, Tucson AZ, United States of America
[8] Department of Physics, The University of Texas at Arlington, Arlington TX, United States of America
[9] Physics Department, University of Athens, Athens, Greece
[10] Physics Department, National Technical University of Athens, Zografou, Greece
[11] Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan
[12] Institut de Física d'Altes Energies and Departament de Física de la Universitat Autònoma de Barcelona and ICREA, Barcelona, Spain
[13] [(a)] Institute of Physics, University of Belgrade, Belgrade; [(b)] Vinca Institute of Nuclear Sciences, University of Belgrade, Belgrade, Serbia
[14] Department for Physics and Technology, University of Bergen, Bergen, Norway
[15] Physics Division, Lawrence Berkeley National Laboratory and University of California, Berkeley CA, United States of America
[16] Department of Physics, Humboldt University, Berlin, Germany
[17] Albert Einstein Center for Fundamental Physics and Laboratory for High Energy Physics, University of Bern, Bern, Switzerland
[18] School of Physics and Astronomy, University of Birmingham, Birmingham, United Kingdom
[19] [(a)] Department of Physics, Bogazici University, Istanbul; [(b)] Division of Physics, Dogus University, Istanbul; [(c)] Department of Physics Engineering, Gaziantep University, Gaziantep; [(d)] Department of Physics, Istanbul Technical University, Istanbul, Turkey
[20] [(a)] INFN Sezione di Bologna; [(b)] Dipartimento di Fisica, Università di Bologna, Bologna, Italy
[21] Physikalisches Institut, University of Bonn, Bonn, Germany
[22] Department of Physics, Boston University, Boston MA, United States of America
[23] Department of Physics, Brandeis University, Waltham MA, United States of America
[24] [(a)] Universidade Federal do Rio De Janeiro COPPE/EE/IF, Rio de Janeiro; [(b)] Federal University of Juiz de Fora (UFJF), Juiz de Fora; [(c)] Federal University of Sao Joao del Rei (UFSJ), Sao Joao del Rei; [(d)] Instituto de Fisica, Universidade de Sao Paulo, Sao Paulo, Brazil
[25] Physics Department, Brookhaven National Laboratory, Upton NY, United States of America
[26] [(a)] National Institute of Physics and Nuclear Engineering, Bucharest; [(b)] University Politehnica Bucharest, Bucharest; [(c)] West University in Timisoara, Timisoara, Romania
[27] Departamento de Física, Universidad de Buenos Aires, Buenos Aires, Argentina
[28] Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom
[29] Department of Physics, Carleton University, Ottawa ON, Canada
[30] CERN, Geneva, Switzerland
[31] Enrico Fermi Institute, University of Chicago, Chicago IL, United States of America
[32] [(a)] Departamento de Física, Pontificia Universidad Católica de Chile, Santiago; [(b)] Departamento de Física, Universidad Técnica Federico Santa María, Valparaíso, Chile
[33] [(a)] Institute of High Energy Physics, Chinese Academy of Sciences, Beijing; [(b)] Department of Modern Physics,

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
[34] Laboratoire de Physique Corpusculaire, Clermont Université and Université Blaise Pascal and CNRS/IN2P3, Clermont-Ferrand, France
[35] Nevis Laboratory, Columbia University, Irvington NY, United States of America
[36] Niels Bohr Institute, University of Copenhagen, Kobenhavn, Denmark
[37] [(a)] INFN Gruppo Collegato di Cosenza; [(b)] Dipartimento di Fisica, Università della Calabria, Arcavata di Rende, Italy
[38] AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Krakow, Poland
[39] The Henryk Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences, Krakow, Poland
[40] Physics Department, Southern Methodist University, Dallas TX, United States of America
[41] Physics Department, University of Texas at Dallas, Richardson TX, United States of America
[42] DESY, Hamburg and Zeuthen, Germany
[43] Institut für Experimentelle Physik IV, Technische Universität Dortmund, Dortmund, Germany
[44] Institut für Kern- und Teilchenphysik, Technical University Dresden, Dresden, Germany
[45] Department of Physics, Duke University, Durham NC, United States of America
[46] SUPA - School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom
[47] INFN Laboratori Nazionali di Frascati, Frascati, Italy
[48] Fakultät für Mathematik und Physik, Albert-Ludwigs-Universität, Freiburg, Germany
[49] Section de Physique, Université de Genève, Geneva, Switzerland
[50] [(a)] INFN Sezione di Genova; [(b)] Dipartimento di Fisica, Università di Genova, Genova, Italy
[51] [(a)] E. Andronikashvili Institute of Physics, Iv. Javakhishvili Tbilisi State University, Tbilisi; [(b)] High Energy Physics Institute, Tbilisi State University, Tbilisi, Georgia
[52] II Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen, Germany
[53] SUPA - School of Physics and Astronomy, University of Glasgow, Glasgow, United Kingdom
[54] II Physikalisches Institut, Georg-August-Universität, Göttingen, Germany
[55] Laboratoire de Physique Subatomique et de Cosmologie, Université Joseph Fourier and CNRS/IN2P3 and Institut National Polytechnique de Grenoble, Grenoble, France
[56] Department of Physics, Hampton University, Hampton VA, United States of America
[57] Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge MA, United States of America
[58] [(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
[59] Faculty of Applied Information Science, Hiroshima Institute of Technology, Hiroshima, Japan
[60] Department of Physics, Indiana University, Bloomington IN, United States of America
[61] Institut für Astro- und Teilchenphysik, Leopold-Franzens-Universität, Innsbruck, Austria
[62] University of Iowa, Iowa City IA, United States of America
[63] Department of Physics and Astronomy, Iowa State University, Ames IA, United States of America
[64] Joint Institute for Nuclear Research, JINR Dubna, Dubna, Russia
[65] KEK, High Energy Accelerator Research Organization, Tsukuba, Japan
[66] Graduate School of Science, Kobe University, Kobe, Japan
[67] Faculty of Science, Kyoto University, Kyoto, Japan
[68] Kyoto University of Education, Kyoto, Japan
[69] Department of Physics, Kyushu University, Fukuoka, Japan
[70] Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata, Argentina
[71] Physics Department, Lancaster University, Lancaster, United Kingdom
[72] [(a)] INFN Sezione di Lecce; [(b)] Dipartimento di Matematica e Fisica, Università del Salento, Lecce, Italy
[73] Oliver Lodge Laboratory, University of Liverpool, Liverpool, United Kingdom
[74] Department of Physics, Jožef Stefan Institute and University of Ljubljana, Ljubljana, Slovenia
[75] School of Physics and Astronomy, Queen Mary University of London, London, United Kingdom
[76] Department of Physics, Royal Holloway University of London, Surrey, United Kingdom
[77] Department of Physics and Astronomy, University College London, London, United Kingdom
[78] Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France
[79] Fysiska institutionen, Lunds universitet, Lund, Sweden
[80] Departamento de Fisica Teorica C-15, Universidad Autonoma de Madrid, Madrid, Spain

[81] Institut für Physik, Universität Mainz, Mainz, Germany
[82] School of Physics and Astronomy, University of Manchester, Manchester, United Kingdom
[83] CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France
[84] Department of Physics, University of Massachusetts, Amherst MA, United States of America
[85] Department of Physics, McGill University, Montreal QC, Canada
[86] School of Physics, University of Melbourne, Victoria, Australia
[87] Department of Physics, The University of Michigan, Ann Arbor MI, United States of America
[88] Department of Physics and Astronomy, Michigan State University, East Lansing MI, United States of America
[89] [a] INFN Sezione di Milano; [b] Dipartimento di Fisica, Università di Milano, Milano, Italy
[90] B.I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk, Republic of Belarus
[91] National Scientific and Educational Centre for Particle and High Energy Physics, Minsk, Republic of Belarus
[92] Department of Physics, Massachusetts Institute of Technology, Cambridge MA, United States of America
[93] Group of Particle Physics, University of Montreal, Montreal QC, Canada
[94] P.N. Lebedev Institute of Physics, Academy of Sciences, Moscow, Russia
[95] Institute for Theoretical and Experimental Physics (ITEP), Moscow, Russia
[96] Moscow Engineering and Physics Institute (MEPhI), Moscow, Russia
[97] Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia
[98] Fakultät für Physik, Ludwig-Maximilians-Universität München, München, Germany
[99] Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), München, Germany
[100] Nagasaki Institute of Applied Science, Nagasaki, Japan
[101] Graduate School of Science and Kobayashi-Maskawa Institute, Nagoya University, Nagoya, Japan
[102] [a] INFN Sezione di Napoli; [b] Dipartimento di Scienze Fisiche, Università di Napoli, Napoli, Italy
[103] Department of Physics and Astronomy, University of New Mexico, Albuquerque NM, United States of America
[104] Institute for Mathematics, Astrophysics and Particle Physics, Radboud University Nijmegen/Nikhef, Nijmegen, Netherlands
[105] Nikhef National Institute for Subatomic Physics and University of Amsterdam, Amsterdam, Netherlands
[106] Department of Physics, Northern Illinois University, DeKalb IL, United States of America
[107] Budker Institute of Nuclear Physics, SB RAS, Novosibirsk, Russia
[108] Department of Physics, New York University, New York NY, United States of America
[109] Ohio State University, Columbus OH, United States of America
[110] Faculty of Science, Okayama University, Okayama, Japan
[111] Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman OK, United States of America
[112] Department of Physics, Oklahoma State University, Stillwater OK, United States of America
[113] Palacký University, RCPTM, Olomouc, Czech Republic
[114] Center for High Energy Physics, University of Oregon, Eugene OR, United States of America
[115] LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France
[116] Graduate School of Science, Osaka University, Osaka, Japan
[117] Department of Physics, University of Oslo, Oslo, Norway
[118] Department of Physics, Oxford University, Oxford, United Kingdom
[119] [a] INFN Sezione di Pavia; [b] Dipartimento di Fisica, Università di Pavia, Pavia, Italy
[120] Department of Physics, University of Pennsylvania, Philadelphia PA, United States of America
[121] Petersburg Nuclear Physics Institute, Gatchina, Russia
[122] [a] INFN Sezione di Pisa; [b] Dipartimento di Fisica E. Fermi, Università di Pisa, Pisa, Italy
[123] Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh PA, United States of America
[124] [a] Laboratorio de Instrumentacao e Fisica Experimental de Particulas - LIP, Lisboa, Portugal; [b] Departamento de Fisica Teorica y del Cosmos and CAFPE, Universidad de Granada, Granada, Spain
[125] Institute of Physics, Academy of Sciences of the Czech Republic, Praha, Czech Republic
[126] Faculty of Mathematics and Physics, Charles University in Prague, Praha, Czech Republic
[127] Czech Technical University in Prague, Praha, Czech Republic
[128] State Research Center Institute for High Energy Physics, Protvino, Russia
[129] Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom
[130] Physics Department, University of Regina, Regina SK, Canada
[131] Ritsumeikan University, Kusatsu, Shiga, Japan
[132] [a] INFN Sezione di Roma I; [b] Dipartimento di Fisica, Università La Sapienza, Roma, Italy
[133] [a] INFN Sezione di Roma Tor Vergata; [b] Dipartimento di Fisica, Università di Roma Tor Vergata, Roma, Italy
[134] [a] INFN Sezione di Roma Tre; [b] Dipartimento di Fisica, Università Roma Tre, Roma, Italy

[135] [(a)] Faculté des Sciences Ain Chock, Réseau Universitaire de Physique des Hautes Energies - Université Hassan II, Casablanca; [(b)] Centre National de l'Energie des Sciences Techniques Nucleaires, Rabat; [(c)] Faculté des Sciences Semlalia, Université Cadi Ayyad, LPHEA-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 a l'Energie 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

[a] Also at Laboratorio de Instrumentacao e Fisica Experimental de Particulas - LIP, Lisboa, Portugal
[b] Also at Faculdade de Ciencias and CFNUL, Universidade de Lisboa, Lisboa, Portugal
[c] Also at Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom
[d] Also at Department of Physics, University of Johannesburg, Johannesburg, South Africa
[e] Also at TRIUMF, Vancouver BC, Canada
[f] Also at Department of Physics, California State University, Fresno CA, United States of America
[g] Also at Novosibirsk State University, Novosibirsk, Russia
[h] Also at Department of Physics, University of Coimbra, Coimbra, Portugal
[i] Also at Department of Physics, UASLP, San Luis Potosi, Mexico
[j] Also at Università di Napoli Parthenope, Napoli, Italy
[k] Also at Institute of Particle Physics (IPP), Canada
[l] Also at Department of Physics, Middle East Technical University, Ankara, Turkey
[m] Also at Louisiana Tech University, Ruston LA, United States of America
[n] Also at Dep Fisica and CEFITEC of Faculdade de Ciencias e Tecnologia, Universidade Nova de Lisboa, Caparica, Portugal
[o] Also at Department of Physics and Astronomy, University College London, London, United Kingdom
[p] Also at Group of Particle Physics, University of Montreal, Montreal QC, Canada
[q] Also at Department of Physics, University of Cape Town, Cape Town, South Africa
[r] Also at Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan
[s] Also at Institut für Experimentalphysik, Universität Hamburg, Hamburg, Germany
[t] Also at Manhattan College, New York NY, United States of America
[u] Also at School of Physics, Shandong University, Shandong, China
[v] Also at CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France
[w] Also at School of Physics and Engineering, Sun Yat-sen University, Guanzhou, China
[x] Also at Academia Sinica Grid Computing, Institute of Physics, Academia Sinica, Taipei, Taiwan
[y] Also at Dipartimento di Fisica, Università La Sapienza, Roma, Italy
[z] Also at DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat a l'Energie Atomique), Gif-sur-Yvette, France
[aa] Also at Section de Physique, Université de Genève, Geneva, Switzerland
[ab] Also at Departamento de Fisica, Universidade de Minho, Braga, Portugal
[ac] Also at Department of Physics and Astronomy, University of South Carolina, Columbia SC, United States of America
[ad] Also at Institute for Particle and Nuclear Physics, Wigner Research Centre for Physics, Budapest, Hungary
[ae] Also at California Institute of Technology, Pasadena CA, United States of America
[af] Also at Institute of Physics, Jagiellonian University, Krakow, Poland
[ag] Also at LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France
[ah] Also at Nevis Laboratory, Columbia University, Irvington NY, United States of America
[ai] Also at Department of Physics and Astronomy, University of Sheffield, Sheffield, United Kingdom
[aj] Also at Department of Physics, Oxford University, Oxford, United Kingdom
[ak] Also at Institute of Physics, Academia Sinica, Taipei, Taiwan
[al] Also at Department of Physics, The University of Michigan, Ann Arbor MI, United States of America
[am] Also at Discipline of Physics, University of KwaZulu-Natal, Durban, South Africa
* Deceased