# Search for supersymmetry in $pp$ collisions at $\sqrt{s} = 7$ TeV in final states with missing transverse momentum and $b$-jets with the ATLAS detector

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The results of a search for supersymmetry in events with large missing transverse momentum and heavy-flavor jets using an integrated luminosity corresponding to 2.05 fb$^{-1}$ of $pp$ collisions at $\sqrt{s} = $ 7 TeV recorded with the ATLAS detector at the Large Hadron Collider are reported. No significant excess is observed with respect to the prediction for standard model processes. Results are interpreted in a variety of $R$-parity conserving models in which scalar bottoms and tops are the only scalar quarks to appear in the gluino decay cascade, and in an SO(10) model framework. Gluino masses up to 600–900 GeV are excluded, depending on the model considered.

## I. INTRODUCTION

Supersymmetry (SUSY) [1–9] is a framework that provides an extension of the standard model (SM) and naturally resolves the hierarchy problem [10–13] by introducing supersymmetric partners of the known bosons and fermions. In the MSSM [14–18], which is an $R$-parity conserving minimal supersymmetric extension of the SM, SUSY particles are produced in pairs and the lightest supersymmetric particle (LSP) is stable, providing a possible candidate for dark matter. In a large variety of models, the LSP is the lightest neutralino, $\tilde{\chi}^0_1$. The colored superpartners of quarks and gluons, the squarks ($\tilde{q}$) and gluinos ($\tilde{g}$), are expected to be produced in strong interaction processes at the center-of-mass energy of the Large Hadron Collider (LHC). Their decays via cascades ending with the LSP would produce striking experimental signatures. The undetected LSP results in missing transverse momentum (its magnitude is referred to as $E_T^{\text{miss}}$ in the following). The final states also contain multiple jets and possibly leptons. In the MSSM, the scalar partners of right-handed and left-handed quarks, $\tilde{q}_R$ and $\tilde{q}_L$, can mix to form two mass eigenstates. The mixing effect is proportional to the corresponding SM fermion masses and therefore becomes important for the third generation. Large mixing can yield scalar bottom (sbottom, $\tilde{b}_1$) and scalar top (stop, $\tilde{t}_1$) mass eigenstates which are significantly lighter than other squarks. Consequently, $\tilde{b}_1$ and $\tilde{t}_1$ could be produced with large cross sections at the LHC, either directly in pairs, or through $\tilde{g}\tilde{g}$ production with subsequent $\tilde{g} \to \tilde{b}_1 b$ or $\tilde{g} \to \tilde{t}_1 t$ decays (gluino-mediated production).

In this paper, a search for scalar top and bottom quarks using an integrated luminosity corresponding to 2.05 fb$^{-1}$ of $\sqrt{s} = 7$ TeV proton-proton collisions at the LHC is presented. Events are selected by requiring large $E_T^{\text{miss}}$, several jets, including $b$-quark jets ($b$-jets), and either vetoing (0-lepton channel) or requiring (1-lepton channel) charged leptons. The search is mostly sensitive to the gluino-mediated production of third generation squarks. Results are interpreted in the framework of various simplified models in which scalar bottoms and tops are the only squarks that appear in the gluino decay cascade, and in specific grand unification theories (GUTs) based on the gauge group SO(10) [19,20]. The GUT group SO(10) is especially compelling since it allows for gauge and matter unification. In the two SO(10) models considered in this paper, we also expect $t - b - \tau$ third generation Yukawa coupling unification at $Q = M_{\text{GUT}}$.

The paper is an update of a search presented by the ATLAS Collaboration using 35 pb$^{-1}$ of data collected in 2010 [21], with a number of improvements. The analysis has been extended by including more signal regions which profit from the increased available integrated luminosity and maximize the sensitivity to a large variety of SUSY scenarios. Data-driven methods are employed to estimate the contributions of SM background processes. Searches for scalar bottom quarks via $\tilde{g}\tilde{g}$ production have been also reported by the CMS [22] Collaboration. Searches sensitive to direct scalar bottom production irrespective of gluino mass have been published by the ATLAS Collaboration [23] using the same data set employed in this paper.

## II. THE ATLAS DETECTOR

The ATLAS detector [24] comprises an inner detector surrounded by a thin superconducting solenoid and a calorimeter system. Outside the calorimeters is an extensive muon spectrometer in a toroidal magnetic field.

The inner detector system is immersed in a 2 T axial magnetic field and provides tracking information for

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charged particles in a pseudorapidity range $|\eta| < 2.5$ [25]. The highest granularity is achieved around the vertex region using silicon pixel and microstrip (SCT) detectors. These detectors allow for an efficient tagging of jets originating from $b$-quark decays using impact parameter measurements and the reconstruction of secondary decay vertices. The transition radiation tracker (TRT), which surrounds the silicon detectors, contributes to track reconstruction up to $|\eta| = 2.0$ and improves electron identification by the detection of transition radiation.

The calorimeter system covers the pseudorapidity range $|\eta| < 4.9$. The highly segmented electromagnetic calorimeter consists of lead absorbers with liquid argon as the active material and covers the pseudorapidity range $|\eta| < 3.2$. In the region $|\eta| < 1.8$, a presampler detector using a thin layer of liquid argon is used to correct for the energy lost by electrons and photons upstream of the calorimeter. The hadronic tile calorimeter is a steel/scintillating-tile detector and is situated directly outside the envelope of the electromagnetic calorimeter. The two hadronic end-cap calorimeters have liquid argon as the active material, and copper absorbers. The calorimeter coverage is completed by forward calorimeters with liquid argon and copper and tungsten absorber material.

Muon detection is based on the deflection of muon tracks in the large superconducting air-core toroid magnets. Three eight-coil toroids, a barrel and two end-caps, generate the field for the muon spectrometer in the range $|\eta| < 2.7$. The toroids are instrumented with separate trigger and high-precision chambers.

## III. MONTE CARLO SIMULATION

Simulated event samples are used to aid in the description of the background and to model the SUSY signal. Top quark pair and single top quark production are simulated with MC@NLO [26], fixing the top quark mass at 172.5 GeV, and using the next-to-leading-order (NLO) parton density function (PDF) set CTEQ6.6 [27]. Additional Monte Carlo (MC) samples generated with POWHEG [28] and ACERMC [29] are used to estimate the event-generator systematic uncertainties. Samples of $W$ + jets, $Z$ + jets with light- and heavy-flavor jets, and $t\bar{t}$ with additional $b$-jets, $t\bar{t}b\bar{b}$, are generated with ALPGEN [30] and the PDF set CTEQ6L1 [31]. The fragmentation and hadronization for the ALPGEN and MC@NLO samples are performed with HERWIG [32], using JIMMY [33] for the underlying event. Samples of $Zt\bar{t}$ and $Wt\bar{t}$ are generated with MADGRAPH [34] interfaced to PYTHIA [35]. Diboson ($WW$, $WZ$, $ZZ$) samples are generated with HERWIG. The signal samples are generated using the HERWIG++ [36] v2.4.2 Monte Carlo program. The SUSY sample yields are normalized to the results of NLO calculations, as obtained using the PROSPINO [37] v2.1 program, and the parametrization of the PDFs is done with CTEQ6.6M [38]. The MC samples are produced using parameters tuned as described in Refs. [39,40] and are processed through a

TABLE I. The most important background processes and their production cross sections, multiplied by the relevant branching ratios (BR). The $\ell$ indicates all three types of leptons ($e$, $\mu$, $\tau$) summed together. Contributions from higher-order QCD corrections are included for $W$ and $Z$ boson production, for $t\bar{t}$ production, and for diboson production. The $Z/\gamma^* \to \ell^+\ell^-$ cross section is given for events with a dilepton invariant mass of at least 40 GeV. The cross sections for $t\bar{t}b\bar{b}$ and $t\bar{t} + W/Z$ production are given at leading order.

| Physics process | $\sigma$. BR [nb] (perturbative order) | |
|---|---|---|
| $W \to \ell\nu$ | 31.4 (NNLO) | [43–45] |
| $Z/\gamma^* \to \ell^+\ell^-$ | 3.20 (NNLO) | [43–45] |
| $Z \to \nu\bar{\nu}$ | 5.82 (NNLO) | [43–45] |
| $t\bar{t}$ | 0.165 (NLO + NNLL) | [46–48] |
| Single top | 0.085 (NLO + NNLL) | [46–48] |
| $t\bar{t}b\bar{b}$ | $0.9 \times 10^{-3}$ (LO) | [30] |
| $t\bar{t} + W/Z$ | $0.4 \times 10^{-3}$ (LO) | [34] |
| $WW$, $WZ$, $ZZ$ | 0.071 (NLO) | [49,50] |

detector simulation [41] based on GEANT4 [42]. The collision events considered in this search contain on average five proton-proton interactions per bunch crossing. This effect is included in the simulation, and MC events are reweighted to reproduce the mean expected number of collisions per bunch crossing estimated for data.

The background predictions, normalized to theoretical cross sections, including higher-order QCD corrections when available, are compared to data in control regions. The cross sections times branching ratio in the relevant final states used for each standard model background process are listed in Table I. The $W$ and $Z/\gamma^*$ production processes are normalized to the next-to-next-to-leading-order (NNLO) cross sections while the $t\bar{t}$ and single top production are normalized to the NLO + NNLL (next-to-next-to-leading logarithms) cross sections. The normalization of the diboson production is based on cross sections determined at NLO using MCFM [49,50]. The $t\bar{t}$ production in association with $W/Z$ or $b\bar{b}$ is normalized to LO.

For background from jet production from parton scattering processes (multijet in the following), no reliable prediction can be obtained from a leading-order Monte Carlo simulation and data-driven methods are used to determine the residual contributions of this background to the selected event samples, as discussed in Sec. VI.

## IV. OBJECT RECONSTRUCTION

A preselection of electron and muon candidates is used to estimate the contribution from nonisolated leptons and misidentified electrons, to veto on additional leptons in the event when required, and to calculate the value of $E_T^{\text{miss}}$. More stringent identification criteria are then applied for the final selections.

Electrons are reconstructed from energy clusters in the electromagnetic calorimeter matched to a track in the inner

detector. Candidates for the electron preselection must satisfy the "medium" [51] selection based on calorimeter shower shape, inner-detector track quality, and track-to-calorimeter cluster matching. Electrons used in the final selection are required to pass the "tight" [51] electron definition, which adds requirements on the ratio $E/p$ between the calorimeter cluster energy $E$ and the track momentum $p$, on the detection of transition radiation in the TRT, and on the isolation of the candidate. The scalar transverse momentum ($p_T$) sum of tracks within a cone in the $\eta$, $\phi$ plane of radius $\Delta R = 0.2$ around the electron candidate (excluding the electron track $p_T$ itself), $\Sigma_{p_T}$, must be less than 10% of the electron $p_T$. Medium electrons are required to pass kinematic requirements of $p_T > 20$ GeV and $|\eta| < 2.47$, while the $p_T$ threshold is raised to 25 GeV for tight electrons. In addition, electrons with a distance to the closest jet of $0.2 < \Delta R < 0.4$ are discarded.

Muons are identified as a match between an extrapolated inner detector track and one or more track segments in the muon spectrometer. A requirement on the minimum number of hits in each tracking device ensures the quality of the inner detector track reconstruction. Muons with a distance to the closest jet of $\Delta R < 0.4$ are discarded. In order to reject muons resulting from cosmic rays, tight criteria are applied on the proximity of the muon trajectories to the primary vertex (PV) [52]: $|z_\mu - z_{PV}| < 1$ mm and $|d_0| < 0.2$ mm, where $z_\mu$ is the $z$ coordinate of the extrapolated muon track at the point of closest approach to the PV, $z_{PV}$ is the coordinate of the PV, and $|d_0|$ is the magnitude of the impact parameter of the muon in the transverse plane. Preselected muons are required to satisfy all these requirements, and in addition to have $p_T > 10$ GeV and $\eta < 2.4$. For muons in the final selection, the $p_T$ requirement is raised to 20 GeV and the muon is required to be isolated with $\Sigma_{p_T} < 1.8$ GeV.

Jets are reconstructed from three-dimensional calorimeter energy clusters by using the anti-$k_t$ jet algorithm [53,54] with a radius parameter of 0.4. The measured jet energy is corrected for inhomogeneities and for the noncompensating nature of the calorimeter by using $p_T$- and $\eta$-dependent correction factors [55]. Jets are required to have $p_T > 20$ GeV and $|\eta| < 2.8$. Events with jets failing jet quality criteria against noise and noncollision backgrounds are rejected. The quality criteria used are the same as in Ref. [55]. Additionally, in the 0-lepton channel the three leading jets, if central ($|\eta| < 2$), are required to have a jet charged fraction (defined as the scalar sum of the transverse momenta of the tracks associated with the jet divided by the jet $p_T$) of at least 5%. Jets within a distance of $\Delta R = 0.2$ of a preselected electron are rejected, since these jets are likely to be electrons also reconstructed as jets. For jets in the signal regions, the $p_T$ requirement is tightened to 50 GeV to remove jets that are not associated with the hard scattering of interest.

A $b$-tagging algorithm exploiting both impact parameter and secondary vertex information [56] is used to identify jets containing a $b$-hadron decay. This algorithm has a 60% efficiency for tagging $b$-jets in a MC sample of $t\bar{t}$ events, with a mistag rate for light quarks and gluons of less than 1% and for $c$ quarks of less than 10%. These $b$-jets are identified within the nominal acceptance of the inner detector ($|\eta| < 2.5$) and they are required to have $p_T > 50$ GeV.

The value of $E_T^{miss}$ [57] is the magnitude of the vector $\vec{E}_T^{miss}$, which is calculated as the vector sum of the transverse momenta of all reconstructed jets with $p_T > 20$ GeV and $|\eta| < 4.5$, all preselected electrons and muons, and calorimeter energy clusters which do not belong to other reconstructed objects.

During a fraction of the data-taking period (about 40% of the total integrated luminosity), a localized electronics failure in the liquid argon barrel calorimeter created a dead region in the second and third calorimeter layers ($\Delta\eta \times \Delta\phi \simeq 1.4 \times 0.2$) in which on average 30% of the incident jet energy is not measured. Negligible impact is found on the reconstruction efficiency for jets with $p_T > 20$ GeV. For events selected during this data period, if any jet with $p_T > 50$ GeV falls in the aforementioned region, the event is rejected. The loss in signal acceptance is smaller than 10% in the affected period for the models considered.

In the event selection, a number of variables derived from the reconstructed objects are used. The transverse mass $m_T$ formed by $E_T^{miss}$ and the $p_T$ of the lepton is defined as

$$m_T = \sqrt{2 p_T^{lep} E_T^{miss} - 2\vec{p}_T^{lep} \cdot \vec{E}_T^{miss}}. \tag{1}$$

The effective mass $m_{eff}$ is obtained as the scalar $p_T$ sum of all selected objects in the event:

$$m_{eff} = \sum_i (p_T^{jet})_i + E_T^{miss} + \sum_j (p_T^{lep})_j, \tag{2}$$

where the sums are over the number of jets, $i$, and the zero or one leptons, $j$, in a given signal region.

Finally, $\Delta\phi_{min}$ is defined as the minimum azimuthal separation between the selected jets in a given signal region and the $\vec{E}_T^{miss}$ direction.

## V. EVENT SELECTION

This search uses proton-proton collisions recorded from March to August 2011 at a center-of-mass energy of 7 TeV. After the application of beam, detector, and data quality requirements, the data set consists of a total integrated luminosity of $2.05 \pm 0.08$ fb$^{-1}$ [58,59]. Two groups of signal regions are defined based on the presence, or otherwise, of a charged lepton ($\ell = e, \mu$) in the final state and are further referred to as 0-lepton and 1-lepton channels. In the 0-lepton channel, a veto on preselected leptons is applied, while exactly one lepton is required in the 1-lepton channel. Events containing two or more leptons are the subject of a different study [60].

The data are selected with a three-level trigger system. A trigger requiring a high transverse momentum jet and

missing transverse momentum is used to select events for the 0-lepton channel. The plateau efficiency is reached for jets with $p_T > 130$ GeV and $E_T^{\mathrm{miss}} > 130$ GeV. A single electron trigger, reaching the plateau efficiency for offline electrons with $p_T \gtrsim 25$ GeV, and a combined muon-jet trigger, reaching the plateau efficiency for muons with $p_T \gtrsim 20$ GeV and jets with $p_T \gtrsim 60$ GeV, are used for the 1-lepton channel.

Events are required to have a reconstructed primary vertex associated with five or more tracks with $p_T > 0.4$ GeV, and must pass basic quality criteria against detector noise and noncollision backgrounds.

For the 0-lepton selection, at least one jet with $p_T > 130$ GeV, at least two additional jets with $p_T > 50$ GeV, and $E_T^{\mathrm{miss}} > 130$ GeV are required. At least one of the selected jets is required to be $b$-tagged. To reduce the amount of multijet background, where $E_T^{\mathrm{miss}}$ results from misreconstructed jets or from neutrinos emitted close to the direction of the jet axis, additional requirements of $\Delta\phi_{\mathrm{min}} > 0.4$ and $E_T^{\mathrm{miss}}/m_{\mathrm{eff}} > 0.25$ are applied.

Six signal regions are defined in order to obtain good signal sensitivity for the various models and parameter values studied. The regions are chosen by optimizing the expected significance in models in which pair-produced gluinos decay with 100% branching ratio to on- and/or off-shell scalar bottom quarks. The signal regions are characterized by the minimum number of $b$-jets in the final state and by different thresholds on $m_{\mathrm{eff}}$. The regions are labeled with the prefix SR0, and are listed in the upper section of Table II, together with a summary of the full selection applied.

For the 1-lepton channel, events are required to have exactly one lepton, a leading jet with $p_T > 60$ GeV, three further jets with $p_T > 50$ GeV, and $E_T^{\mathrm{miss}} > 80$ GeV. At least one jet is required to be $b$-tagged. SM background processes that lead to the production of a $W$ boson in the final state are rejected by requiring $m_T > 100$ GeV. Two signal regions, labeled with the prefix SR1 and summarized in Table II, are defined, based on different thresholds applied on the effective mass and the missing transverse momentum.

## VI. BACKGROUND ESTIMATION

Standard model processes contributing to the total background in the signal regions are top quark production (single and in pairs), the production of a $W$ or a $Z$ boson in association with heavy-flavor quarks (mostly $b$, but also $c$), and multijet production. The last enters in the signal regions if missing transverse momentum is produced in the final state, either because of the mismeasurement of one or more of the jets in the event, or because of the semileptonic decay of a heavy-flavor hadron.

*Top and $W/Z$ background estimation.* The dominant SM background contributions to the signal regions are evaluated using control regions with low expected yields from the targeted SUSY signals. They are defined by selecting events containing exactly one lepton, large $m_{\mathrm{eff}}$, and low $m_T$. The background estimation in each signal region is obtained by multiplying the number of events observed in the corresponding control region by a transfer factor, defined as the ratio of the MC predicted yield in the signal region to that in the control region:

$$N_{\mathrm{SR}} = \frac{N_{\mathrm{SR}}^{\mathrm{MC}}}{N_{\mathrm{CR}}^{\mathrm{MC}}}(N_{\mathrm{CR}}^{\mathrm{obs}} - N_{\mathrm{CR}}^{\mathrm{res}}) = T_f(N_{\mathrm{CR}}^{\mathrm{obs}} - N_{\mathrm{CR}}^{\mathrm{res}}), \quad (3)$$

where $N_{\mathrm{CR}}^{\mathrm{obs}}$ denotes the observed yield in the control region and $N_{\mathrm{CR}}^{\mathrm{res}}$ includes contributions from multijet production and, in the 0-lepton case, $W$ and $Z$ production. The advantage of this approach is that systematic uncertainties that are correlated between the numerator and the denominator of $T_f$ largely cancel out, provided that the event kinematics in the corresponding signal and control region are similar. Two control regions are defined for the 0-lepton channel, differing only in the number of $b$ tags required. These are used to determine the top background in the six signal regions. They are obtained by applying the same thresholds on the three jets and $E_T^{\mathrm{miss}}$ as for the SR0, but requiring exactly one signal electron or muon. The transverse mass must be in the range 40 GeV $< m_T < 100$ GeV and the effective mass $m_{\mathrm{eff}}$ should be larger than 600 GeV. The region CR0-1 is required to have at least one $b$ tag, and CR0-2 is required to have at least two $b$ tags. The definition

TABLE II. Signal regions' definition for the 0-lepton and 1-lepton channels. The first column summarizes the common preselection applied, while the last column specifies the selection defining the different signal regions.

| Preselection | Signal region name | Selection |
|---|---|---|
| No leptons, at least three jets, $p_T(j1) > 130$ GeV, $p_T(j2, j3) > 50$ GeV, $E_T^{\mathrm{miss}} > 130$ GeV, $E_T^{\mathrm{miss}}/m_{\mathrm{eff}} > 0.25$, $\Delta\phi_{\mathrm{min}} > 0.4$ | SR0-A1 | At least one $b$ tag, $m_{\mathrm{eff}} > 500$ GeV |
| | SR0-B1 | At least one $b$ tag, $m_{\mathrm{eff}} > 700$ GeV |
| | SR0-C1 | At least one $b$ tag, $m_{\mathrm{eff}} > 900$ GeV |
| | SR0-A2 | At least two $b$ tags, $m_{\mathrm{eff}} > 500$ GeV |
| | SR0-B2 | At least two $b$ tags, $m_{\mathrm{eff}} > 700$ GeV |
| | SR0-C2 | At least two $b$ tags, $m_{\mathrm{eff}} > 900$ GeV |
| One lepton, at least four jets, $p_T(j1) > 60$ GeV, $p_T(j2, j3, j4) > 50$ GeV, $E_T^{\mathrm{miss}} > 80$ GeV, $m_T > 100$ GeV, at least one $b$ tag | SR1-D | $m_{\mathrm{eff}} > 700$ GeV |
| | SR1-E | $m_{\mathrm{eff}} > 700$ GeV, $E_T^{\mathrm{miss}} > 200$ GeV |

TABLE III. Control regions' definition for the 0-lepton and 1-lepton channels. The first column summarizes the common preselection applied, while the last column specifies the selection defining the control regions.

| Preselection | Control region name | Selection |
|---|---|---|
| One lepton, at least three jets, $p_T(j1) > 130$ GeV, $p_T(j2, j3) > 50$ GeV, | CR0-1 | At least one $b$ tag |
| $E_T^{miss} > 130$ GeV, 40 GeV $< m_T < 100$ GeV, $m_{eff} > 600$ GeV | CR0-2 | At least two $b$ tags |
| One lepton, at least four jets, $p_T(j1) > 60$ GeV, $p_T(j2, j3, j4) > 50$ GeV, | CR1 | At least one $b$ tag |
| $E_T^{miss} > 80$ GeV, 40 GeV $< m_T < 100$ GeV, $m_{eff} > 500$ GeV | | |

of the control regions for the 0-lepton channel is summarized in the upper part of Table III. Figures 1 and 2 show the $E_T^{miss}$ and $m_{eff}$ distributions obtained in CR0-1 and CR0-2, respectively, for the 1-electron and 1-muon case.

The formula used to obtain the top background prediction in each of the six signal regions is

$$N_{SR0\text{-}\alpha j} = T_f^{\alpha j}(N_{CR0\text{-}j}^{obs} - N_{CR0\text{-}j}^{non\text{-}top}), \tag{4}$$
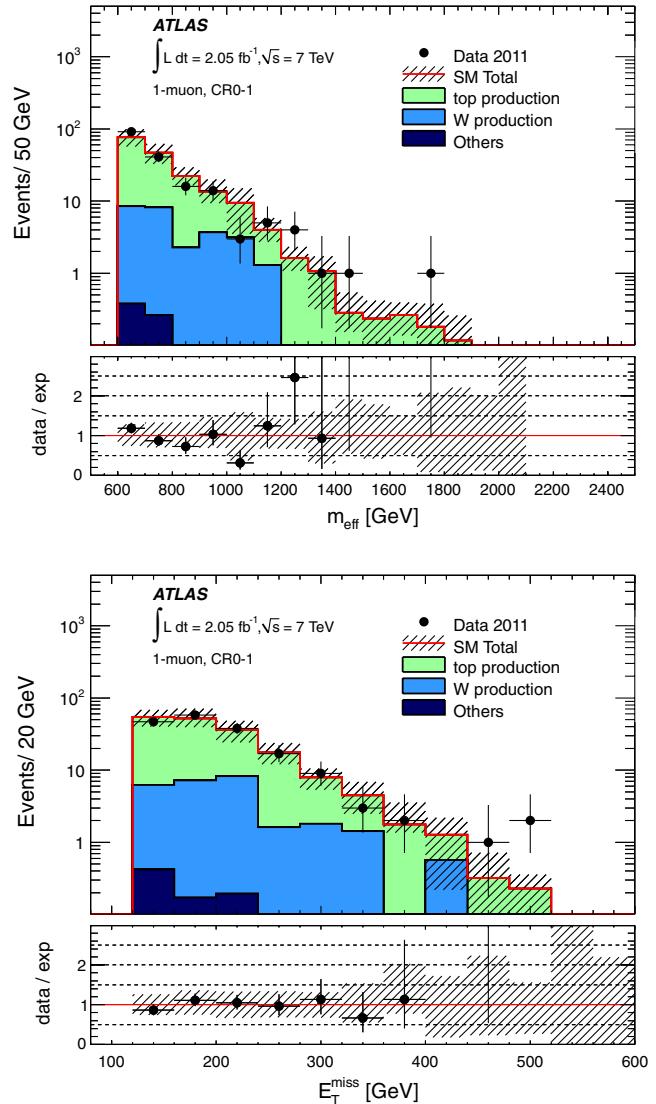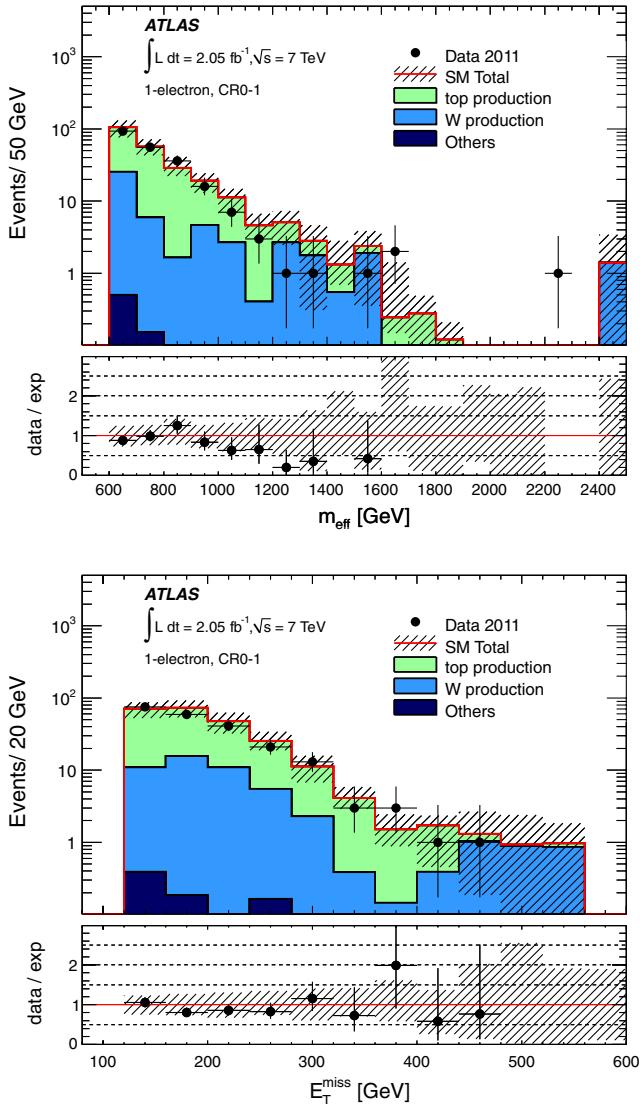


FIG. 1 (color online). Distribution of the effective mass (top) and $E_T^{miss}$ (bottom) in the CR0-1 control region for the 1-electron (left) and 1-muon (right) channels. The color labeled "others" includes contributions from $Z$, diboson, and multijet production processes. The hatched band shows the systematic uncertainty, which includes both experimental uncertainties (among which JES and $b$-tagging uncertainties are dominant) and theoretical uncertainties on the background normalization and shape. The small insets show the ratio between the observed distribution and that predicted for the standard model background. Although the distributions are presented separately for $e$ and $\mu$, the background estimation uses the sum of the $e$ and $\mu$ yields in the CR0.
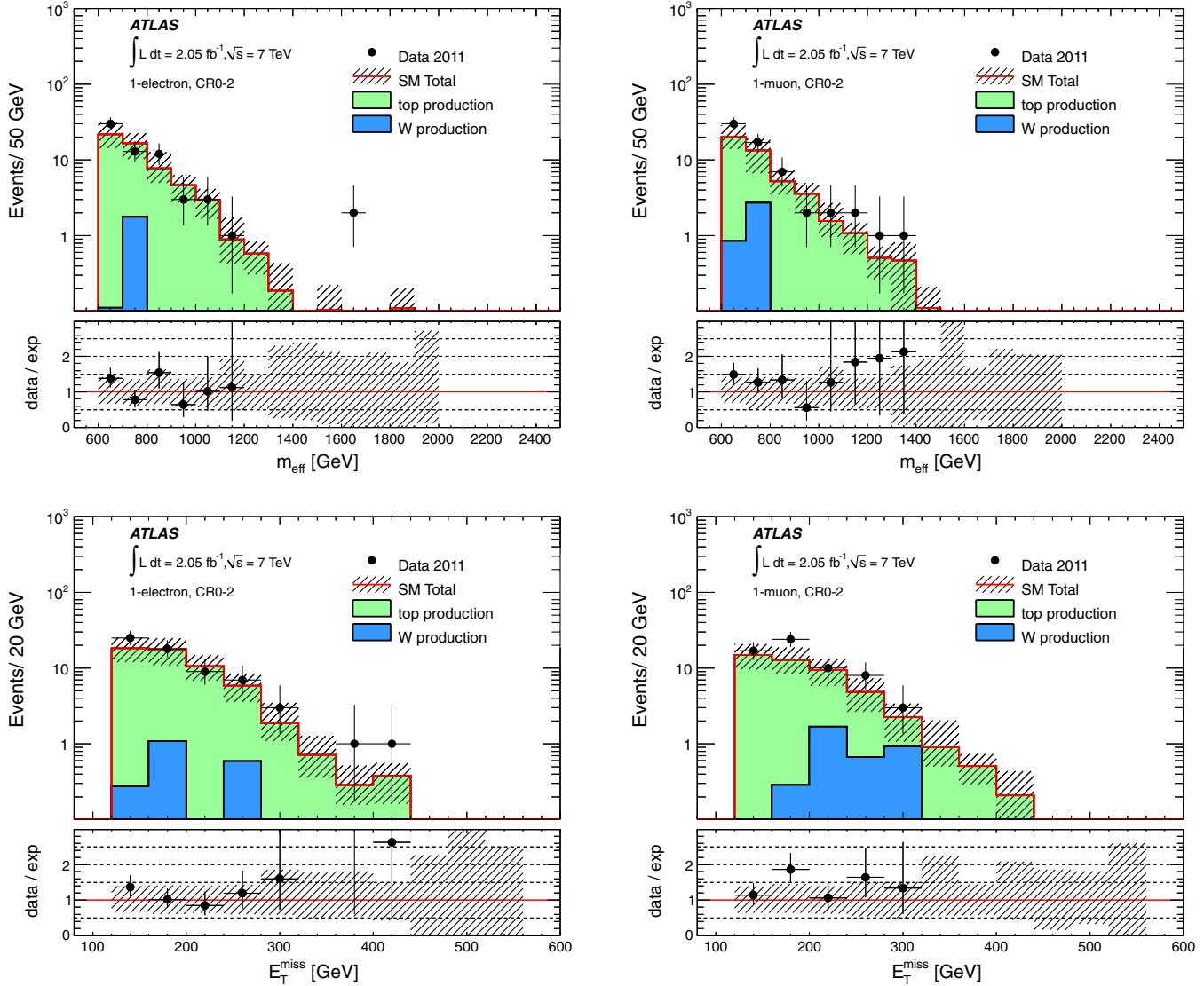
FIG. 2 (color online). Distribution of the effective mass (top) and $E_T^{miss}$ (bottom) in the CR0-2 control region for the 1-electron (left) and 1-muon (right) channels. The hatched band shows the systematic uncertainty, which includes both experimental uncertainties (among which JES and $b$-tagging uncertainties are dominant) and theoretical uncertainties on the background normalization and shape. The small insets show the ratio between the observed distribution and that predicted for the standard model background. Although the distributions are presented separately for $e$ and $\mu$, the background estimation uses the sum of the $e$ and $\mu$ yields in the CR0.

$$T_f^{\alpha j} = \frac{N_{\text{SR0-}\alpha j}^{\text{MC,top}}}{N_{\text{CR0-}j}^{\text{MC,top}}}, \tag{5}$$

where $\alpha = A, B, C, j = 1, 2$ denote the six signal regions, $N_{\text{CR0-}j}^{\text{non-top}}$ includes the estimate for $W$, $Z$ and multijet production in the control region $j$, and all numbers are the sum of the corresponding electron and muon channel yields.

The remaining SM contributions to the SR0 are mainly from $W$ and $Z$ production in association with heavy-flavor quarks. This corresponds to about 30% (10%) of the total background in the signal regions defined with one $b$ tag (two $b$ tags), and it is estimated from MC simulation.

For the 1-lepton channel signal regions, the total SM background (more than 90% of which consists of top quark production) is determined using a similar technique, but using one single transfer factor for top, $W/Z$, and diboson production processes. In this case, only one control region (CR1) is defined, requiring the same kinematic cuts applied in SR1-D, with the exception that the transverse mass should be in the range 40 GeV $< m_T < 100$ GeV and that $m_{\text{eff}} > 500$ GeV. The last row of Table III summarizes the event selection for the 1-lepton control region. Figure 3 shows the $E_T^{miss}$ and $m_{\text{eff}}$ distributions in CR1.

*Multijet background estimation.* The small contribution of multijet background in the SR0 signal region is estimated with the use of a jet response smearing technique [61].
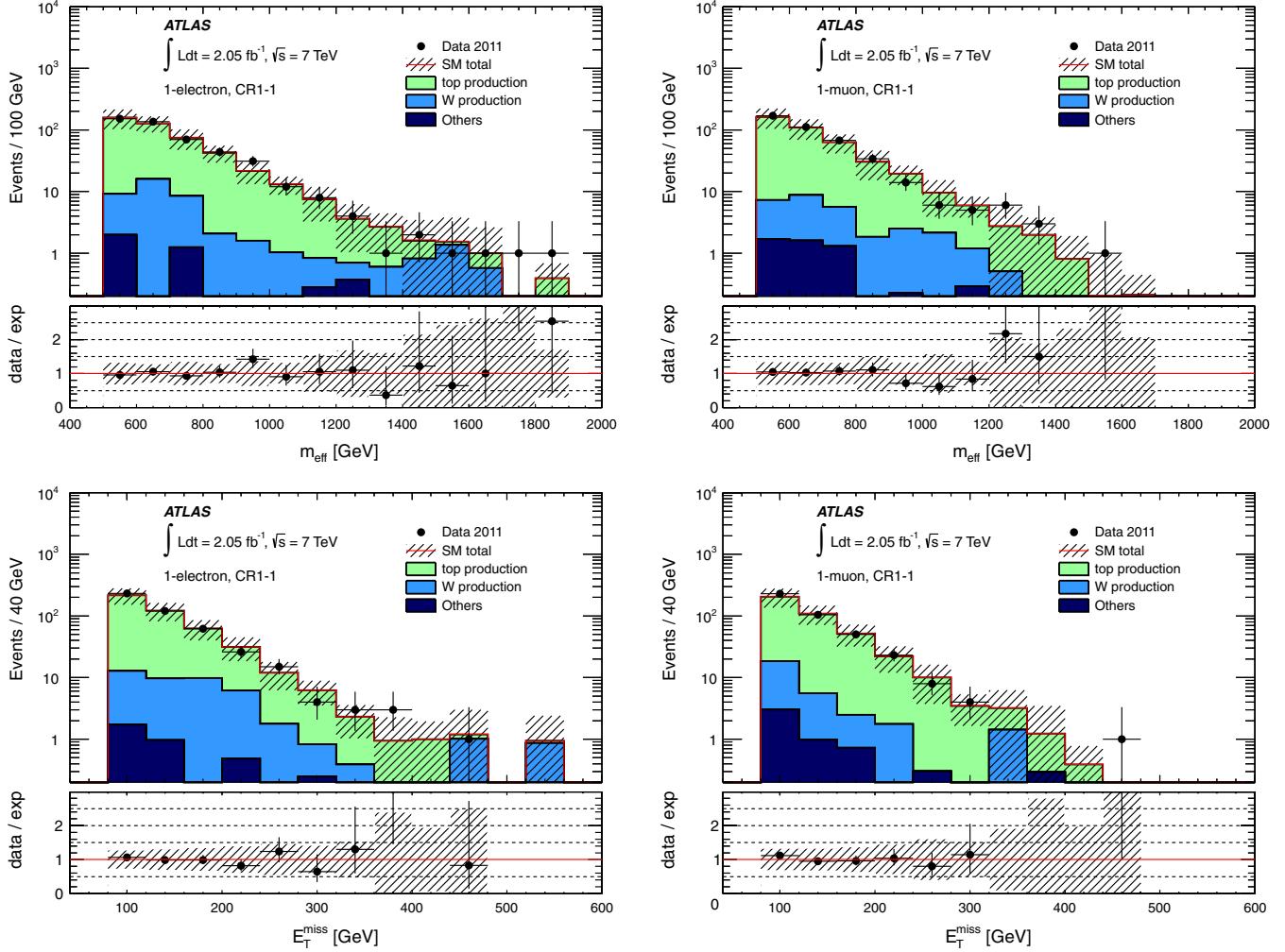
FIG. 3 (color online).   Distribution of the effective mass (top) and $E_T^{miss}$ (bottom) in the CR1 control region for the 1-electron (left) and 1-muon (right) channels. The color labeled others includes contributions from $Z$, diboson, and multijet production processes. The hatched band shows the systematic uncertainty, which includes both experimental uncertainties (among which JES and $b$-tagging uncertainties are dominant) and theoretical uncertainties on the background normalization and shape. The small insets show the ratio between the observed distribution and that predicted for the standard model background.

Multijet events with possibly large $E_T^{miss}$ are obtained by smearing jet energies in low $E_T^{miss}$ "seed" events according to jet response functions obtained with the MC simulation. The Gaussian core of the response function is tuned to data by considering the jet balance in dijet events, while its non-Gaussian tail is adapted to reproduce the response in three-jet events where the $E_T^{miss}$ can be unambiguously associated to a single jet.

TABLE IV.   Expected background composition and comparison of the predicted total SM event yield to the measured event yield for 2.05 fb$^{-1}$ for each of the control regions defined in the text. The column "top" includes contributions from the single top, $t\bar{t}$, $t\bar{t}b\bar{b}$, and $t\bar{t} + W/Z$ production processes. The quoted uncertainty on the SM prediction includes only experimental systematic uncertainties (among which jet energy scale and $b$-tagging uncertainties are dominant).

| Control region | Top | $W/Z$ | Multijet/diboson | SM | Data (2.05 fb$^{-1}$) |
|---|---|---|---|---|---|
| CR0-1 (1 $e$) | 187 | 48 | 1 | $235 \pm 45$ | 217 |
| CR0-1 (1 $\mu$) | 146 | 22 | 1 | $169 \pm 45$ | 177 |
| CR0-2 (1 $e$) | 53 | 2 | 0.1 | $55 \pm 20$ | 64 |
| CR0-2 (1 $\mu$) | 42 | 3 | 0.1 | $45 \pm 17$ | 62 |
| CR1 (1 $e$) | 414 | 40 | 3.6 | $460 \pm 100$ | 465 |
| CR1 (1 $\mu$) | 377 | 25 | 5.2 | $410 \pm 110$ | 420 |

The number of multijet events in the CR0, CR1 control regions and SR1 signal regions is estimated using a matrix method similar to the one described in Ref. [62]. The probability of misidentifying a tight lepton is estimated by computing the probability that preselected leptons are identified as signal leptons in low-$E_T^{miss}$ control regions dominated by multijet events.

*Total background.* The number of expected events for 2.05 fb$^{-1}$ of integrated luminosity as predicted by the MC and by the data-driven multijet estimate for all control regions is compared to that obtained in data in Table IV. The uncertainty quoted on the standard model prediction includes experimental systematic uncertainties (jet energy scale and resolution, *b*-tagging efficiency, lepton identification and energy scale, and luminosity determination).

Further selection regions are used to validate the MC prediction in different kinematic regimes (in particular, for small and large values of $m_T$ at low value of $m_{eff}$, for both the 0-lepton and 1-lepton channels). In all cases, a good agreement between the data and MC predictions is found.

## VII. SYSTEMATIC UNCERTAINTIES ON BACKGROUND ESTIMATION

Various systematic uncertainties affecting the background rates in the signal regions have been considered. Their treatment is discussed in the following paragraphs, and their impact on the absolute predicted event yield in the control and signal regions is evaluated. Such uncertainties are used either directly ($W$, $Z$ for the 0-lepton channel) in the evaluation of the predicted background in the signal regions or to compute the $T_f$. In the latter case, the uncertainties on the absolute predicted event yield in the control regions and signal regions are propagated using Eq. (3) to obtain the signal region uncertainties.

Experimental systematic uncertainties arise from several sources:

*Jet energy scale and resolution uncertainty.* The uncertainty on the jet energy scale (JES), derived using single particle response and test beam data, varies as a function of the jet $p_T$ and pseudorapidity and it is about 2% at $p_T = 50$ GeV in the central detector region. Additional systematic uncertainties arise from the dependence of the jet response on the number of expected interactions per bunch crossing and on the jet flavor. The total jet energy scale uncertainty at $p_T = 50$ GeV in the central detector region is about 5% [55]. The jet energy scale uncertainty is propagated to obtain an uncertainty on the event yield by varying it by $\pm 1\sigma$ in the MC simulation. Uncertainties related to the jet energy resolution (JER) are obtained with an *in situ* measurement of the jet response asymmetry in dijet events [63]. Their impact on the event yield is estimated by applying an additional smearing to the jet transverse momenta. The JES and JER relative uncertainties on the event yield amount to a total of 20%–40% (depending

on the signal region) and are completely dominated by the JES uncertainty.

*b-tagging efficiency and mistagging uncertainties.* The uncertainty associated with the tagging procedure used to identify *b*-jets is evaluated by varying the *b*-tagging efficiency and mistagging rates within the uncertainties evaluated on the central values measured *in situ* [56]. The resulting relative uncertainty on the event yield is about 20% (35%) in the one *b* tag (two *b* tags) signal region.

*Further experimental uncertainties.* Other systematic uncertainties arise from the imperfect knowledge of the lepton identification efficiency and energy scale, from the rate of lepton misidentification, and from the luminosity determination. Their contribution to the final uncertainty is found to be negligibly small.

All the experimental systematic uncertainties are included, together with process-specific uncertainties, in the evaluation of the background uncertainty:

*Multijet background.* The systematic uncertainty on the estimation of the multijet background in the SR0 is determined by taking into account statistical uncertainties and possible biases in the selection of the seed events, as well as uncertainties in the tuning of the tail of the jet response function in the three-jet events. The relative uncertainty varies between 50% and 70% depending on the SR0 considered.

The estimated multijet background in the SR1 is affected by systematic uncertainties related to the determination of the lepton misidentification rate and to the subtraction of nonmultijet contributions to the event yield in the multijet enhanced region. The estimated relative uncertainty is 90% in SR1-D and 100% and SR1-E.

*W and Z production processes.* Systematic uncertainties on $W$ and $Z$ production are evaluated by varying the relative cross sections of the samples generated with the ALPGEN MC with different numbers of outgoing partons [64], resulting in an uncertainty of about 30%. Additional uncertainties of about 70% on the production cross section of $W$ and $Z$ bosons in association with *b* quarks are considered. They are derived from direct measurements [23,65], and extrapolated using the MC simulation to include differences in the phase space regions probed by this analysis. Uncertainties related to the parton density function choice have been evaluated and found to be small compared to the large uncertainty already considered.

*Top production processes.* Theoretical uncertainties on the shape of $t\bar{t}$ and single top kinematic distributions are evaluated by comparing different LO and NLO generators (ALPGEN or POWHEG, the latter using both PYTHIA and HERWIG as parton shower), and using different parton shower tunes, still consistent with data from previous experiments [64]. An additional uncertainty of 100% is considered for $t\bar{t}$ production in association with $b\bar{b}$ or $W/Z$.

The $T_f$, used for the top and total SM background determination in the SR0 and SR1, respectively, are

TABLE V. Relative systematic uncertainties (in percent) associated with the background estimated by using transfer factors for all the signal regions considered. The column "others" includes statistical uncertainties on the event yield in the control regions, and, in the case of the 0-lepton channel, systematic uncertainties on the nontop production contributions subtracted from the control regions. The column "theory" contains theoretical uncertainties on the top production process addressed as discussed in the text.

| SR | JES/JER | $b$ tag | Lepton ID | Theory | Others | Total |
|---|---|---|---|---|---|---|
| SR0-A1 | 4 | 3 | 2 | 11 | 10 | 15 |
| SR0-B1 | 3 | 3 | 2 | 20 | 10 | 22 |
| SR0-C1 | 3 | 4 | 2 | 35 | 11 | 37 |
| SR0-A2 | 3 | 3 | 2 | 15 | 11 | 19 |
| SR0-B2 | 3 | 4 | 2 | 20 | 10 | 22 |
| SR0-C2 | 3 | 2 | 2 | 30 | 12 | 32 |
| SR1-D | 6 | 1 | 1 | 34 | 7 | 35 |
| SR1-E | 7 | 1 | 1 | 53 | 10 | 55 |

computed using MC predictions. Their values span from 1.8 to 0.05 depending on the signal region considered. Their associated uncertainty arises from both experimental (JES and JER, $b$-tagging efficiency and fake rate, lepton identification and energy scale) and event-generator level uncertainties. The use of control regions with similar kinematical properties to those of the signal regions strongly suppresses experimental uncertainties. Theoretical uncertainties typically dominate the total uncertainty on the $T_f$, which varies between 15% and 35%.

A summary of the systematic uncertainties for the background estimates with the use of transfer factors is shown in Table V.

## VIII. RESULTS

The $m_{\mathrm{eff}}$ and $E_T^{\mathrm{miss}}$ distributions are shown in Fig. 4 for SR0-A1 and SR0-A2, and in Fig. 5 for SR1-D. Tables VI and VII show the standard model background predictions
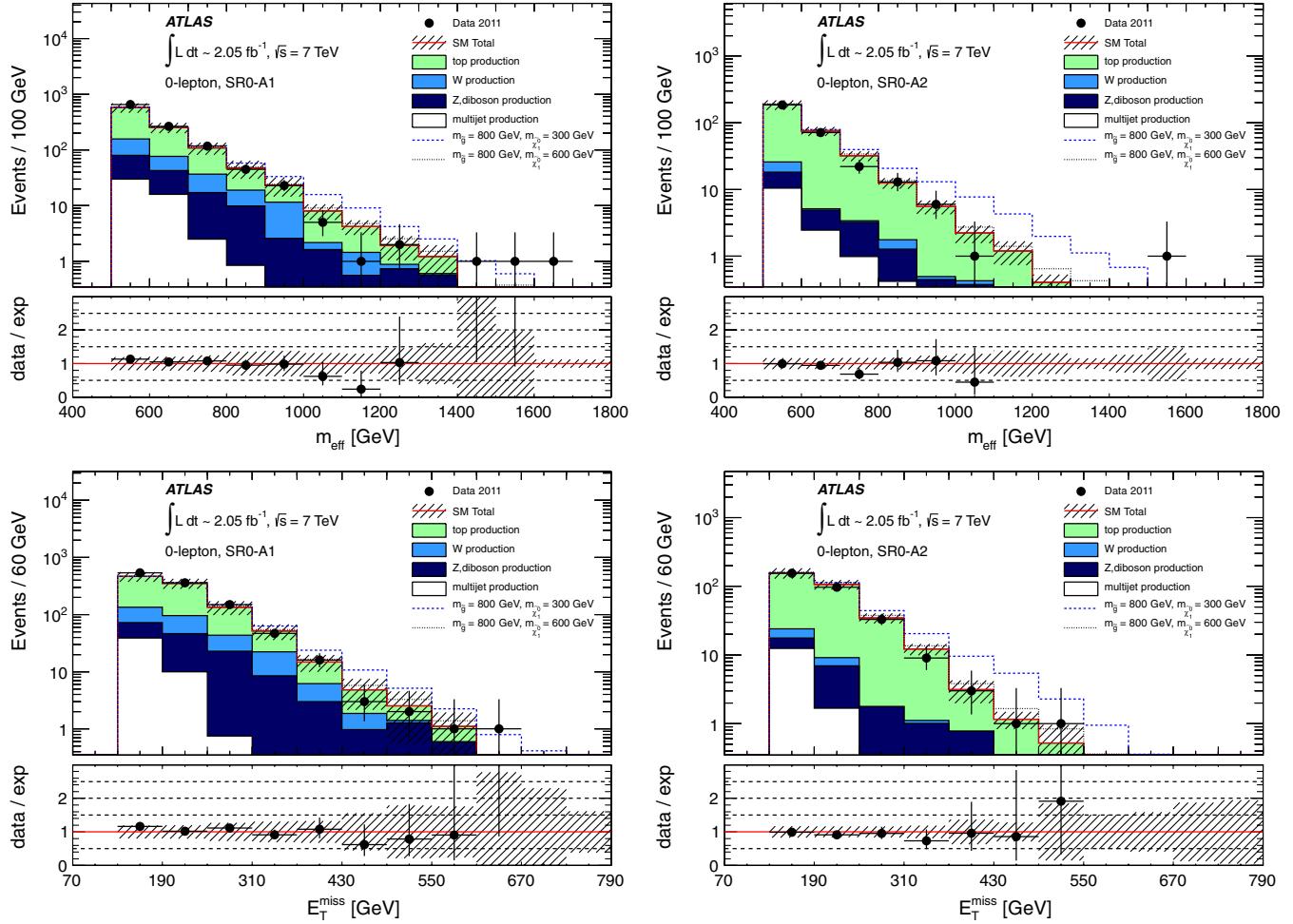


FIG. 4 (color online).   Distribution of the effective mass (top) and $E_T^{\mathrm{miss}}$ (bottom) in SR0-A1 (left) and SR0-A2 (right). The hatched band shows the systematic uncertainty, which includes both experimental uncertainties (among which JES and $b$-tagging uncertainties are dominant) and theoretical uncertainties on the background normalization and shape. The small insets show the ratio between the observed distribution and that predicted for the standard model background.
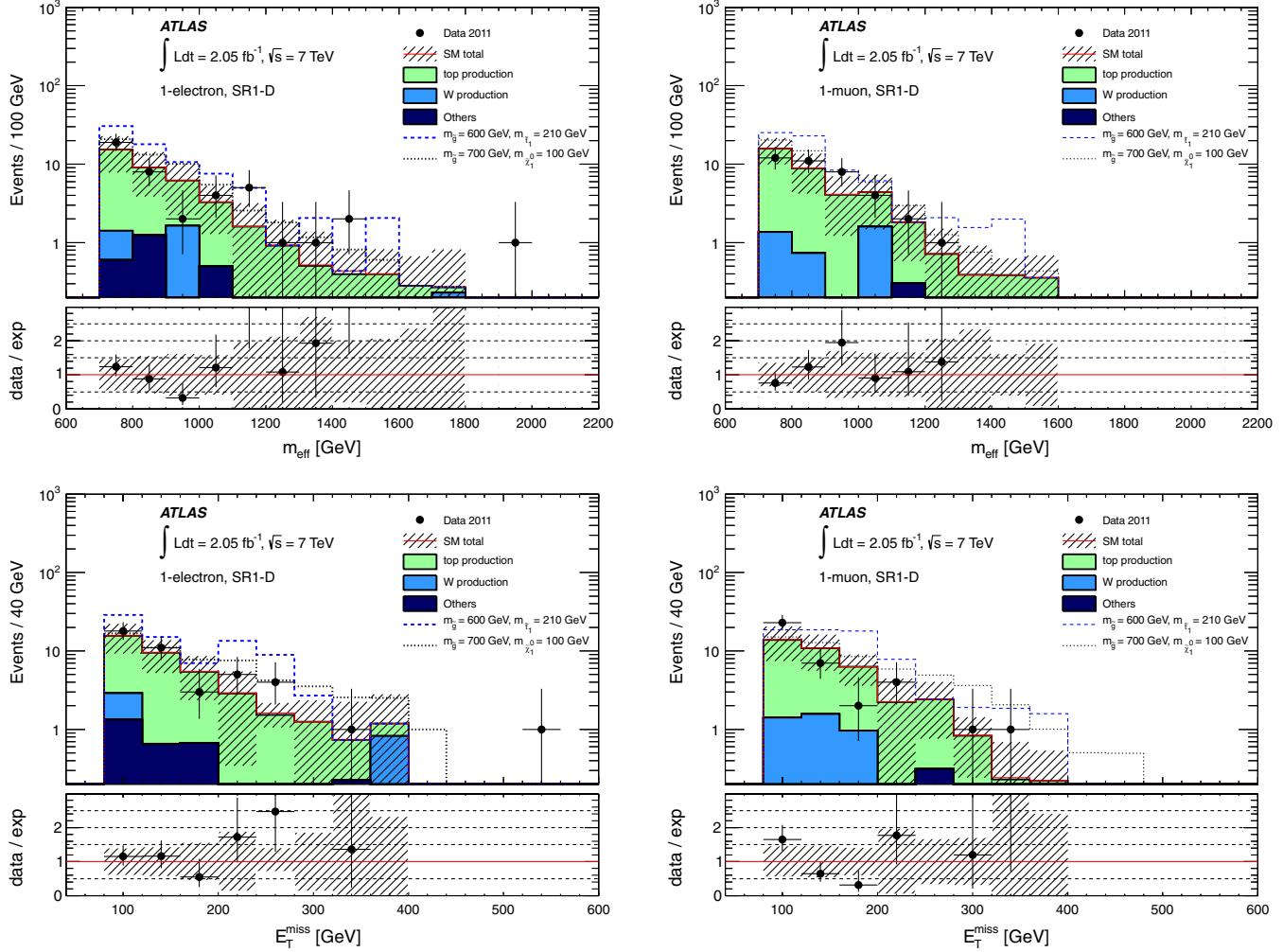
FIG. 5 (color online). Distribution of the effective mass (top) and $E_T^{miss}$ (bottom) for the 1-electron (left) and 1-muon (right) channel in SR1-D. The color labeled "others" includes contributions from $Z$, diboson, and multijet production processes. The hatched band shows the systematic uncertainty, which includes both experimental uncertainties (among which JES and $b$-tagging uncertainties are dominant) and theoretical uncertainties on the background normalization and shape. The small insets show the ratio between the observed distribution and that predicted for the standard model background.

and the observed number of events corresponding to 2.05 fb$^{-1}$ in all signal regions. The top background in the 0-lepton signal regions is estimated making use of the transfer factors, and its uncertainty corresponds to the total

systematic uncertainty of Table V. In parentheses, the MC prediction is reported for comparison. The $W/Z$ background and uncertainty in the SR0 are estimated directly with the MC simulation. The multijet background

TABLE VI. Summary of the expected and observed event yields corresponding to 2.05 fb$^{-1}$ in the six 0-lepton channel signal regions. The errors on the top contribution correspond to the total errors of Table V. The errors quoted for all background processes include all the systematic uncertainties discussed in the text. The numbers in parentheses in the "top" column are the yields predicted by the MC simulation.

| SR | Top | W/Z | Multijet/diboson | Total | Data |
|---|---|---|---|---|---|
| SR0-A1 | $705 \pm 110$ (725) | $248 \pm 150$ | $53 \pm 21$ | $1000 \pm 180$ | 1112 |
| SR0-B1 | $119 \pm 26$ (122) | $67 \pm 42$ | $7.3 \pm 4.7$ | $190 \pm 50$ | 197 |
| SR0-C1 | $22 \pm 8$ (22) | $16 \pm 11$ | $1.5 \pm 1$ | $39 \pm 14$ | 34 |
| SR0-A2 | $272 \pm 52$ (212) | $23 \pm 15$ | $21 \pm 12$ | $316 \pm 54$ | 299 |
| SR0-B2 | $47 \pm 10$ (37) | $4.5 \pm 3$ | $2.8 \pm 1.7$ | $54 \pm 11$ | 43 |
| SR0-C2 | $8.5 \pm 3$ (6.6) | $0.8 \pm 1$ | $0.5 \pm 0.4$ | $9.8 \pm 3.2$ | 8 |

TABLE VII. Summary of the expected and observed event yields corresponding to 2.05 fb$^{-1}$ in the two 1-lepton channel signal regions. The standard model estimation is derived with the data-driven method discussed in the text. The numbers in parentheses in the "SM background" column are the sum of the yield predicted by the MC and the data-driven estimate for the multijet background.

| SR | SM background | Data |
|----|---------------|------|
| SR1-D ($e$) | $39 \pm 12$ (39) | 43 |
| SR1-D ($\mu$) | $38 \pm 14$ (37) | 38 |
| SR1-E ($e$) | $8.1 \pm 3.4$ (7.9) | 11 |
| SR1-E ($\mu$) | $6.3 \pm 4.2$ (6.1) | 6 |

contribution in the SR0, obtained with a data-driven estimate, is summed together with that of the diboson background. The SM background uncertainty in the SR1 corresponds to the total systematic uncertainty of Table V, plus a small contribution arising from the data-driven estimate of the multijet background.

The results are consistent with the standard model predictions, and they are therefore translated into 95% confidence-level (CL) upper limits on contributions from new physics using the $CL_s$ prescription [66]. The likelihood function used is written as $L(n|s, b, \theta) = P_s \times C_{\text{Syst}}$, where $n$ represents the number of observed events in data, $s$ is the SUSY signal under consideration, $b$ is the background, and $\theta$ represents the systematic uncertainties. The $P_s$ function is a Poisson-probability distribution for event counts in the defined signal region and $C_{\text{Syst}}$ represents the constraints on systematic uncertainties, which are treated as nuisance parameters with a Gaussian probability density function and correlated when appropriate.

Upper limits at 95% CL on the number of signal events in the signal regions are obtained independently of new physics models and assuming no signal contamination in

TABLE VIII. Observed and expected 95% CL upper limits on the non-SM contributions to all signal regions. Limits are given on the number of signal events and in terms of visible cross sections. No assumptions are made on the possible presence of non-SM signal in the control regions. The systematic uncertainties on the SM background estimation are included.

| SR | 95% CL upper limit | |
|----|----|----|
| | N events observed (expected) | $\sigma_{\text{vis}}$ (fb) observed (expected) |
| SR0-A1 | 580 (520) | 283 (254) |
| SR0-B1 | 133 (133) | 65 (65) |
| SR0-C1 | 31.6 (34.6) | 15.4 (16.9) |
| SR0-A2 | 124 (134) | 61 (66) |
| SR0-B2 | 29.6 (31.0) | 14.4 (15.0) |
| SR0-C2 | 8.9 (10.3) | 4.3 (5.0) |
| SR1-D | 45.5 (42.1) | 22.2 (20.5) |
| SR1-E | 17.5 (15.3) | 8.5 (7.5) |

the control regions for the 0-lepton and 1-lepton final states. Results for observed and expected upper limits on the number of non-SM events in the signal regions are shown in Table VIII, as well as upper limits on the visible cross section, $\sigma_{\text{vis}}$, defined as cross section times experimental acceptance and efficiency.

## IX. INTERPRETATION IN SIMPLIFIED SUSY MODELS

The interpretation of the results in terms of 95% CL exclusion limits is given for several SUSY scenarios. The exclusion limit contours are derived by subtracting possible signal contributions from the data yield in the control regions employed to estimate the SM background. The signal contamination is not negligible only for SUSY models leading to leptonic final states and accounts for less than 5% of the SM predictions around the expected exclusion limit contours.

Simplified models are characterized by well-defined SUSY particle production and decay modes yielding the final states under study. In the scenarios considered here scalar bottoms and tops are the only squarks to appear in the gluino decay cascade, leading to final states with large $b$-jet multiplicity. The models listed below are addressed (in parentheses the channel which is used for the interpretation of the result is given):

*Gluino-sbottom models (0-lepton).* MSSM scenarios where the $\tilde{b}_1$ is the lightest squark, all other squarks are heavier than the gluino, and $m_{\tilde{g}} > m_{\tilde{b}_1} > m_{\tilde{\chi}_1^0}$, such that the branching ratio for $\tilde{g} \rightarrow \tilde{b}_1 b$ decays is 100%. Sbottoms are produced via $\tilde{g}\tilde{g}$ or by direct pair production $\tilde{b}_1\tilde{b}_1$ and are assumed to decay exclusively via $\tilde{b}_1 \rightarrow b\tilde{\chi}_1^0$, where $m_{\tilde{\chi}_1^0}$ is set to 60 GeV. Exclusion limits are presented in the $(m_{\tilde{g}}, m_{\tilde{b}_1})$ plane.

*Gbb models (0-lepton).* Simplified scenarios, where $\tilde{b}_1$ is the lightest squark but $m_{\tilde{g}} < m_{\tilde{b}_1}$. Pair production of gluinos is the only process taken into account since the mass of all other sparticles apart from the $\tilde{\chi}_1^0$ is set above the TeV scale. A three-body decay via off-shell sbottom is assumed for the gluino, such that $\tilde{b}_1^{(*)} \rightarrow b\tilde{\chi}_1^0$ (BR = 100% for $\tilde{g} \rightarrow b\bar{b}\tilde{\chi}_1^0$). Exclusion limits are presented in the $(m_{\tilde{g}}, m_{\tilde{\chi}_1^0})$ plane.

*Gluino-stop models (1-lepton).* MSSM scenarios where the $\tilde{t}_1$ is the lightest squark, all other squarks are heavier than the gluino, and $m_{\tilde{g}} > m_{\tilde{t}_1} + m_t$, such that the branching ratio for $\tilde{g} \rightarrow \tilde{t}_1 t$ decays is 100%. Stops are produced via $\tilde{g}\tilde{g}$ and $\tilde{t}_1\tilde{t}_1$ and are assumed to decay exclusively via $\tilde{t}_1 \rightarrow b\tilde{\chi}_1^{\pm}$. The neutralino mass is set to 60 GeV, the chargino mass to 120 GeV, and the latter is assumed to decay through a virtual $W$ boson [BR($\tilde{\chi}_1^{\pm} \rightarrow \tilde{\chi}_1^0 l^{\pm}\nu$) = 11%]. If $m_{\tilde{t}_1} > m_{\tilde{\chi}_1^0} + m_t$, the decay $\tilde{t}_1 \rightarrow t\tilde{\chi}_1^0$ is also kinematically allowed, with BR depending on the MSSM parameters settings. However, this mode is not considered for this interpretation, leading to

conservative results, and is adopted in the *Gtt* scenario, described below. Exclusion limits are presented in the $(m_{\tilde{g}}, m_{\tilde{t}_1})$ plane.

*Gtt models (1-lepton)*. Simplified scenarios, where $\tilde{t}_1$ is the lightest squark but $m_{\tilde{g}} < m_{\tilde{t}_1}$. Pair production of gluinos is the only process taken into account since the mass of all other sparticles apart from the $\tilde{\chi}_1^0$ is set above the TeV scale. A three-body decay via off-shell stop is assumed for the gluino, such that $\tilde{t}_1^{(*)} \to t\tilde{\chi}_1^0$ (BR = 100% for $\tilde{g} \to t\bar{t}\tilde{\chi}_1^0$). Exclusion limits are presented in the $(m_{\tilde{g}}, m_{\tilde{\chi}_1^0})$ plane.

*Gtb models (1-lepton)*. Simplified scenarios, where $\tilde{b}_1$ and $\tilde{t}_1$ are the lightest squarks but $m_{\tilde{g}} < m_{\tilde{b}_1, \tilde{t}_1}$. As for the models above, pair production of gluinos is the only process taken into account, with gluinos decaying via virtual stops or sbottoms with a BR of 100% assumed for $\tilde{t}_1 \to b + \tilde{\chi}_1^\pm$ and $\tilde{b}_1 \to t + \tilde{\chi}_1^\pm$, respectively. The mass difference between charginos and neutralinos is set to 2 GeV, such that the products of $\tilde{\chi}_1^\pm \to \tilde{\chi}_1^0 + ff'$ are invisible to the event selection, and gluino decays result in three-body final states ($b\bar{t}\tilde{\chi}_1^0$ or $t\bar{b}\tilde{\chi}_1^0$). Exclusion limits are presented in the $(m_{\tilde{g}}, m_{\tilde{\chi}_1^0})$ plane.

The 0-lepton analysis is mostly sensitive to the SUSY scenarios where sbottom production dominates, while the 1-lepton analysis results are employed to set exclusion limits in models characterized by on-shell or off-shell stop production, where top-enriched final states are expected. Since several signal regions are defined for each analysis, the SR with the best expected sensitivity at each point in parameter space is adopted as the nominal result across the different planes.

The efficiency times acceptance of the selection strongly depends on the parameters of the model and the signal region considered. It varies between 5% and 50% in the proximity of the expected limit for the gluino-sbottom model. For the *Gbb* models, the efficiency times acceptance is highly dependent on the difference in mass between the gluino and the neutralino. It is about 1% for a mass difference of about 200 GeV, and it increases up to 45% for larger mass splitting. In the *Gtb*, gluino-stop, and *Gtt* models, the efficiency times acceptance varies typically between 1% and 20% in the proximity of the expected limit.

Systematic uncertainties on the signal include experimental (JES, JER, *b*-tagging) and theoretical uncertainties. Experimental uncertainties are considered fully correlated with those obtained for the background, and they typically amount to 10%–30% depending on the signal region and model considered. Theoretical uncertainties on the expected SUSY signal are estimated by varying the factorization and renormalization scales in PROSPINO between half and twice their default values and by considering the PDF uncertainties provided by CTEQ6. Uncertainties are calculated for individual production processes and are typically 20%–35% in the vicinity of the expected limit.

Figure 6 shows the observed and expected exclusion regions in the $(m_{\tilde{g}}, m_{\tilde{b}_1})$ plane for the gluino-sbottom
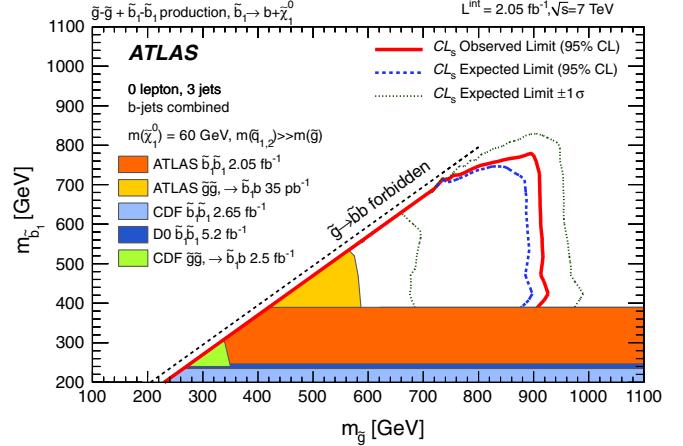


FIG. 6 (color online). Observed and expected 95% CL exclusion limits in the $(m_{\tilde{g}}, m_{\tilde{b}_1})$ plane (gluino-sbottom models). For each scenario, the signal region providing the best expected limit is chosen. The neutralino mass is assumed to be 60 GeV and the NLO cross sections are calculated using PROSPINO. The result is compared to previous results from ATLAS [21] and CDF [69] searches which assume the same gluino-sbottom decays hypotheses. Exclusion limits from the CDF [70], D0 [71], and ATLAS [23] experiments on direct sbottom pair production are also shown.

model. The selection SR0-C2 provides the best sensitivity in most cases. If $m_{\tilde{g}} - m_{\tilde{b}_1} < 100$ GeV, signal regions with one *b* tag are preferred, due to the lower number of expected *b*-jets above $p_T$ thresholds. Gluino masses below 920 GeV are excluded for sbottom masses up to about 800 GeV. The exclusion is less stringent in the region with low $m_{\tilde{g}} - m_{\tilde{b}_1}$, where low $E_T^{\text{miss}}$ is expected. This search extends the previous ATLAS exclusion limit in the same scenario by about 200 GeV, and it is complementary to direct searches for sbottom pair production published by the ATLAS Collaboration [23] using the same data set. The limits do not strongly depend on the neutralino mass assumption as long as $m_{\tilde{g}} - m_{\tilde{\chi}_0}$ is larger than 300 GeV, due to the harsh kinematic cuts.

The interpretation of the results in the *Gbb* models, defined in the $(m_{\tilde{g}}, m_{\tilde{\chi}_1^0})$ plane at sbottom mass larger than 1 TeV, can be considered complementary to the previous one, defined in $m_{\tilde{g}}, m_{\tilde{b}_1}$ at fixed $\tilde{\chi}_1^0$ mass. Figure 7 shows the expected and observed exclusion limit contours and the maximum 95% upper cross section limit for each model. Gluino masses below 900 GeV are excluded for neutralino masses up to about 300 GeV.

Figures 8–10 report the interpretations of the 1-lepton analysis results in different scenarios. As for the 0-lepton results, the selection yielding the best expected limit for a given parameter point is used.

Figure 8 shows upper limits in the $(m_{\tilde{g}}, m_{\tilde{t}_1})$ plane for the gluino-stop model. Gluino masses below 620 GeV are excluded at 95% CL for stop masses up to 440 GeV. The observed and expected upper limits at 95% CL extracted in
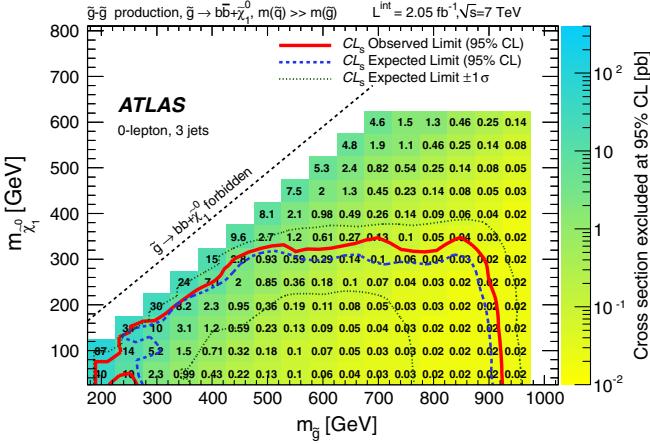
FIG. 7 (color online). Observed and expected 95% CL exclusion limits in the ($m_{\tilde{g}}$, $m_{\tilde{\chi}_1^0}$) plane (*Gbb* models). For each scenario, the signal region selection providing the best expected limit is chosen.
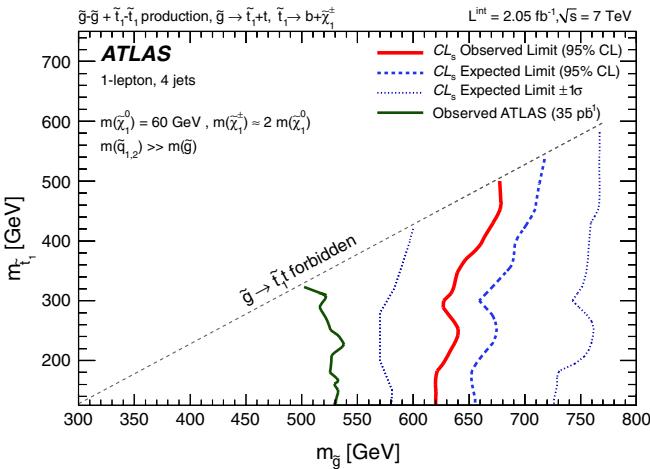


FIG. 8 (color online). The observed and expected 95% CL exclusion limits in the ($m_{\tilde{g}}$, $m_{\tilde{t}_1}$) plane (gluino-stop models) using the best expected limit between SR1-D and SR1-E for each signal point. The result is compared to previous results from ATLAS [21] searches which assume the same gluino-stop decays hypotheses.



FIG. 9 (color online). The observed and expected 95% CL exclusion limits in the ($m_{\tilde{g}}$, $m_{\tilde{\chi}_1^0}$) plane (*Gtt*) using the best expected limit between SR1-D and SR1-E for each signal point. The observed and expected 95% CL exclusion limits in the ($m_{\tilde{g}}$, $m_{\tilde{\chi}_1^0}$) plane (*Gtb* models) using the best expected limit between SR1-D and SR1-E for each signal point.



FIG. 10 (color online). The observed and expected 95% CL exclusion limits in the ($m_{\tilde{g}}$, $m_{\tilde{\chi}_1^0}$) plane (*Gtb* models) using the best expected limit between SR1-D and SR1-E for each signal point.

the ($m_{\tilde{g}}$, $m_{\tilde{\chi}_1^0}$) plane for the *Gtt* models are shown in Fig. 9. The upper cross section limits at 95% CL are also reported for each MSSM scenario. In this case, gluino masses below 750 GeV are excluded at 95% CL for $m_{\tilde{\chi}_1^0} = 50$ GeV while neutralino masses below 160 GeV are excluded at 95% CL for $m_{\tilde{g}} = 700$ GeV.

Figure 10 shows upper limits at 95% CL for the *Gtb* models. Only scenarios with chargino masses above the experimental limits from LEP experiments are considered, and gluino masses below 720 GeV are excluded at 95% CL for $m_{\tilde{\chi}_1^0} = 100$ GeV while neutralino masses below 200 GeV are excluded at 95% CL for $m_{\tilde{g}} = 600$ GeV.
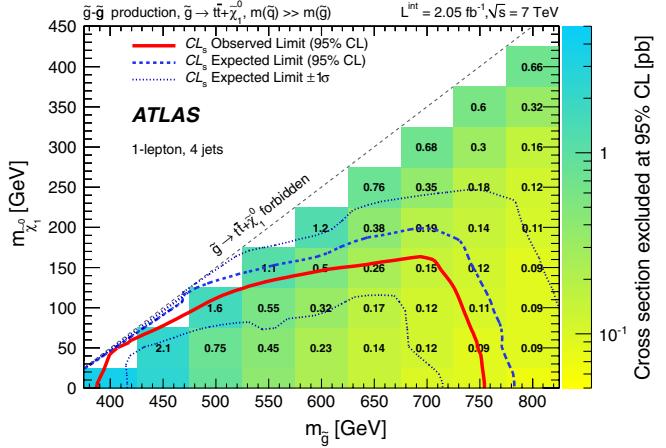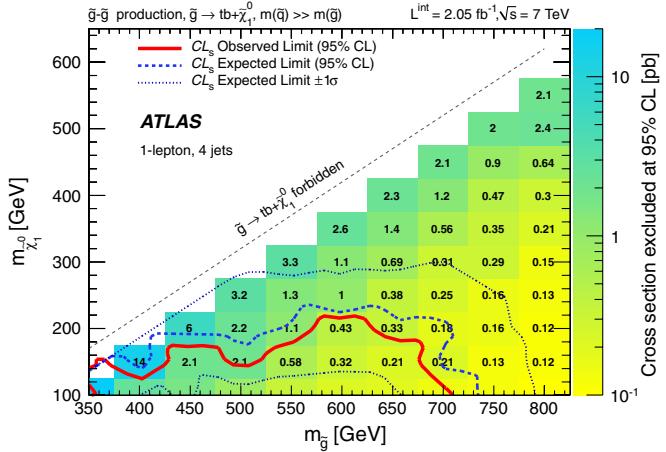
The contribution of the 0-lepton channel signal regions to the significance has been also evaluated for this scenario and found to be lower than that of the 1-lepton channel.

## X. INTERPRETATION IN SO(10) MODELS

In addition to the simplified model interpretation, results are interpreted in the context of two SO(10) models [67] with $t - b - \tau$ Yukawa coupling unification : the D-term splitting model, DR3, and the Higgs splitting model, HS. For both models the SUSY particle mass spectrum is characterized by the low masses of the gluinos (300–600 GeV), charginos (100–180 GeV), and

FIG. 11 (color online).   Cross sections as a function of the gluino mass for DR3 (a) and HS (b) models. The observed and expected 95% CL exclusion limits are shown, respectively, by red solid and blue dotted lines. For each gluino mass, the signal region yielding the best expected limit is used. The NLO theoretical cross section from PROSPINO is shown in black. Previous limits obtained by ATLAS [21] with $\mathcal{L} = 35$ pb$^{-1}$ are superimposed for reference.

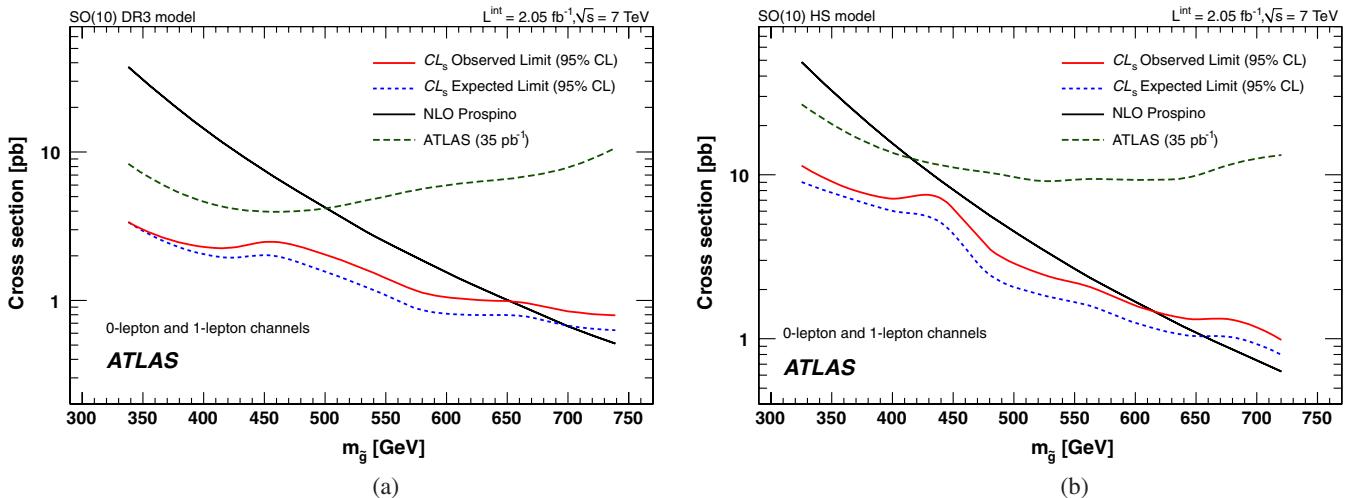neutralinos (50–90 GeV), whereas all scalar particles have masses beyond the TeV scale. Depending on the sparticle masses, chargino-neutralino or gluino-pair production dominates. At low gluino masses, the three-body gluino decays $\tilde{g} \to b\bar{b}\tilde{\chi}_1^0$ and $\tilde{g} \to b\bar{b}\tilde{\chi}_2^0$ dominate in the DR3 and the HS model, respectively. Final states with high $b$-jet multiplicities are then expected in both models with a harder $E_T^{\mathrm{miss}}$ spectrum in the DR3 scenario due to the direct gluino decay into $\chi_1^0$ and with a higher lepton content in the HS scenario due to the subsequent decay $\tilde{\chi}_2^0 \to \ell\bar{\ell}\tilde{\chi}_1^0$. For heavy gluinos, the gluino decay modes $\tilde{g} \to bt\tilde{\chi}_1^{\pm}$ and $\tilde{g} \to t\bar{t}\tilde{\chi}_1^0$ become more relevant, enhancing final states with leptons in both scenarios.

Results of both 0-lepton and 1-lepton analyses have been employed to extract exclusion limits at 95% CL on the gluino mass in the two SO(10) scenarios, DR3 and HS. The 0-lepton analysis has the best sensitivity at low gluino masses while the lepton-based selection is more sensitive to heavy gluinos. For each gluino mass, the signal region leading to the best expected significance is used to extract the 95% CL exclusion limits. Figure 11 shows the PROSPINO NLO cross section and the observed and expected upper limit at 95% CL for the DR3 [Fig. 11(a)] and HS [Fig. 11(b)] models as a function of the gluino mass. At the nominal NLO cross section, gluino masses below 650 GeV and 620 GeV are excluded at 95% CL for the DR3 and HS models, respectively.

These limits on the gluino masses can be interpreted in terms of Yukawa coupling unification in the third generation. The degree of Yukawa unification is quantified by

$$R = \max(f_t, f_b, f_\tau) / \min(f_t, f_b, f_\tau), \qquad (6)$$

where $f_t, f_b, f_\tau$ are the $t$, $b$, and $\tau$ Yukawa couplings evaluated at the scale $Q = M_{\mathrm{GUT}}$. In both DR3 and HS

model lines, the degree of Yukawa unification increases together with the gluino mass, and Yukawa coupling unification occurs at a few percent level only for $m_{\tilde{g}} \leq 500$ GeV. Consequently, the most favored range of gluino masses is excluded for the two SO(10) model lines considered as the degree of Yukawa unification should be further loosened up to pull the gluino mass to higher values. However, Yukawa coupling unification can still be realized at a few percent level for heavier gluino masses in different model lines [68].

## XI. CONCLUSIONS

An updated search for supersymmetry in final states with missing transverse momentum and at least one or two $b$-jets in proton-proton collisions at 7 TeV is presented. The results are based on data corresponding to an integrated luminosity of 2.05 fb$^{-1}$ collected by ATLAS at the Large Hadron Collider during 2011. The search is sensitive mainly to gluino-mediated production of sbottoms and stops, the supersymmetric partners of the third generation quarks, which, due to mixing effects, might be the lightest squarks. No excess above the expectations from standard model processes was found and the results are used to exclude parameter regions in various $R$-parity conserving SUSY models.

Gluino masses up to 800–900 GeV are excluded at 95% CL in simplified models where the squark $\tilde{b}_1$ is produced either on- or off-shell and decays in 100% of the cases into $b\tilde{\chi}_1^0$. In scenarios where the squark $\tilde{t}_1$ is produced (on- or off-shell) via gluino decay, gluino masses up to 620–750 GeV (depending on the specific model considered) are excluded at 95% CL. In models where gluinos decay via an off-shell stop or sbottom ($bt\tilde{\chi}_1^0$ final

states), gluino masses are excluded up to about 720 GeV for a neutralino mass of 100 GeV.

In specific models based on the gauge group SO(10), gluinos with masses below 650 GeV and 620 GeV are excluded for the DR3 and HS models, respectively. This analysis significantly extends the previous published limits on the same subject by the ATLAS and CMS collaborations.

## ACKNOWLEDGMENTS

[1] H. Miyazawa, Prog. Theor. Phys. **36**, 1266 (1966).

[2] P. Ramond, Phys. Rev. D **3**, 2415 (1971).

[3] Y. Golfand and E. Likhtman, JETP Lett. **13**, 323 (1971).

[4] A. Neveu and J. H. Schwarz, Nucl. Phys. **B31**, 86 (1971).

[5] A. Neveu and J. H. Schwarz, Phys. Rev. D **4**, 1109 (1971).

[6] J. Gervais and B. Sakita, Nucl. Phys. **B34**, 632 (1971).

[7] D. Volkov and V. Akulov, Phys. Lett. **46B**, 109 (1973).

[8] J. Wess and B. Zumino, Phys. Lett. **49B**, 52 (1974).

[9] J. Wess and B. Zumino, Nucl. Phys. **B70**, 39 (1974).

[10] S. Weinberg, Phys. Rev. D **13**, 974 (1976).

[11] E. Gildener, Phys. Rev. D **14**, 1667 (1976).

[12] S. Weinberg, Phys. Rev. D **19**, 1277 (1979).

[13] L. Susskind, Phys. Rev. D **20**, 2619 (1979).

[14] P. Fayet, Phys. Lett. **64B**, 159 (1976).

[15] P. Fayet, Phys. Lett. **69B**, 489 (1977).

[16] G. R. Farrar and P. Fayet, Phys. Lett. **76B**, 575 (1978).

[17] P. Fayet, Phys. Lett. **84B**, 416 (1979).

[18] S. Dimopoulos and H. Georgi, Nucl. Phys. **B193**, 150 (1981).

[19] H. Fritzsch and P. Minkowski, Ann. Phys. (N.Y.) **93**, 193 (1975).

[20] M. Gell-Mann, P. Ramond, and R. Slansky, Rev. Mod. Phys. **50**, 721 (1978).

[21] ATLAS Collaboration, Phys. Lett. B **701**, 398 (2011).

[22] CMS Collaboration, J. High Energy Phys. 07 (2011) 113.

[23] ATLAS Collaboration, Phys. Rev. Lett. **108**, 181802 (2012).

[24] ATLAS Collaboration, JINST **3**, S08003 (2008).

[25] ATLAS uses a right-handed coordinate system, with the $z$ axis along the beam line. The azimuthal angle $\phi$ is measured around the beam axis and the polar angle $\theta$ is the angle from the beam axis. The pseudorapidity is defined as $\eta = -\ln\tan(\theta/2)$. The distance $\Delta R$ in the $\eta - \phi$ space is defined as $\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2}$.

[26] S. Frixione and B. Webber, arXiv:hep-ph/0601192.

[27] P. M. Nadolsky, H.-L. Lai, Q.-H. Cao, J. Huston, J. Pumplin, D. Stump, W.-K. Tung, and C.-P. Yuan, Phys. Rev. D **78**, 013004 (2008).

[28] S. Frixione, P. Nason, and C. Oleari, J. High Energy Phys. 11 (2007) 070.

[29] B. Kersevan and E. Richter-Was, arXiv:hep-ph/0405247.

[30] M. Mangano, F. Piccinini, A. D. Polosa, M. Moretti, and R. Pittau, J. High Energy Phys. 07 (2003) 001.

[31] J. Pumplin, D. R. Stump, J. Huston, H.-L. Lai, P. Nadolsky, and W.-K. Tung, J. High Energy Phys. 07 (2002) 012.

[32] G. Corcella, I. G. Knowles, G. Marchesini, S. Moretti, K. Odagiri, P. Richardson, M. H. Seymour, and B. R. Webber, J. High Energy Phys. 01 (2001) 010.

[33] J. Butterworth, J. R. Forshaw, and M. Seymour, Z. Phys. C **72**, 637 (1996).

[34] J. Alwall, M. Herquet, F. Maltoni, O. Mattelaer, and T. Stelzer, J. High Energy Phys. 06 (2011) 128.

[35] T. Sjöstrand, S. Mrenna, and P. Skands, J. High Energy Phys. 05 (2006) 026.

[36] M. Bahr et al., Eur. Phys. J. C **58**, 639 (2008).

[37] W. Beenakker, M. Kramer, T. Plehn, M. Spira, and P. Zerwas, Nucl. Phys. **B515**, 3 (1998).

[38] D. Stump, J. Huston, J. Pumplin, W.-K. Tung, H.-L. Lai, S. Kuhlmann, and J. F. Owens, J. High Energy Phys. 10 (2003) 046.

[39] ATLAS Collaboration, Report No. ATL-PHYS-PUB-2010-014, 2010 [http://cdsweb.cern.ch/record/1303025].

[40] ATLAS Collaboration, Report No. ATLAS-CONF-2010-031, 2010 [http://cdsweb.cern.ch/record/1277665].

[41] ATLAS Collaboration, Eur. Phys. J. C **70**, 823 (2010).

[42] S. Agostinelli *et al.* (GEANT4), Nucl. Instrum. Methods Phys. Res., Sect. A **506**, 250 (2003).

[43] R. Hamberg, W. L. van Neerven, and T. Matsuura, Nucl. Phys. **B359**, 343 (1991); **B644**, 403(E) (2002).

[44] K. Melnikov and F. Petriello, Phys. Rev. D **74**, 114017 (2006).

[45] K. Melnikov and F. Petriello, Phys. Rev. Lett. **96**, 231803 (2006).

[46] R. Bonciani, S. Catani, M. L. Mangano, and P. Nason, Nucl. Phys. **B529**, 424 (1998).

[47] S. Moch and P. Uwer, Phys. Rev. D **78**, 034003 (2008).

[48] M. Beneke, M. Czakon, P. Falgari, A. Mitov, and C. Schwinn, Phys. Lett. B **690**, 483 (2010).

[49] J. Campbell and R. Ellis, Phys. Rev. D **60**, 113006 (1999).

[50] J. M. Campbell, R. K. Ellis, and C. Williams, J. High Energy Phys. 07 (2011) 018.

[51] ATLAS Collaboration, Eur. Phys. J. C **72**, 1909 (2012).

[52] In case of multiple vertices, the primary vertex is taken to be the one for which the sum of the square of momenta of the associated tracks $p_T^2$ is the largest.

[53] M. Cacciari, G. Salam, and G. Soyez, J. High Energy Phys. 04 (2008) 063.

[54] M. Cacciari and G. Salam, Phys. Lett. B **641**, 57 (2006).

[55] ATLAS Collaboration, arXiv:1112.6426 [Eur. Phys. J. C (to be published)].

[56] ATLAS Collaboration, Report No. ATLAS-CONF-2011-102, 2011 [http://cdsweb.cern.ch/record/1369219].

[57] ATLAS Collaboration, Eur. Phys. J. C **72**, 1844 (2012).

[58] ATLAS Collaboration, Eur. Phys. J. C **71**, 1630 (2011).

[59] ATLAS Collaboration, Report No. ATLAS-CONF-2011-116, 2011 [http://cdsweb.cern.ch/record/1376384].

[60] ATLAS Collaboration, Report No. CERN-PH-EP-2012-061, 2012 [http://cdsweb.cern.ch/record/1423602/].

[61] ATLAS Collaboration, Phys. Lett. B **710**, 67 (2012).

[62] ATLAS Collaboration, J. High Energy Phys. 12 (2010) 060.

[63] ATLAS Collaboration, Report No. ATLAS-CONF-2010-054, 2010 [http://cdsweb.cern.ch/record/1281311/].

[64] ATLAS Collaboration, Eur. Phys. J. C **71**, 1577 (2011).

[65] ATLAS Collaboration, Phys. Lett. B **707**, 418 (2012).

[66] G. Cowan, K. Cranmer, E. Gross, and O. Vitells, Eur. Phys. J. C **71**, 1554 (2011).

[67] H. Baer, S. Kraml, A. Lessa, and S. Sekmen, J. High Energy Phys. 02 (2010) 055.

[68] H. Baer, H. Raza, and Q. Shafi, arXiv:1201.5668.

[69] T. Aaltonen *et al.* (CDF Collaboration), Phys. Rev. Lett. **102**, 221801 (2009).

[70] T. Aaltonen *et al.* (CDF Collaboration), Phys. Rev. Lett. **105**, 081802 (2010).

[71] V. M. Abazov *et al.* (D0 Collaboration), Phys. Lett. B **693**, 95 (2010).

G. Aad,[47] B. Abbott,[109] J. Abdallah,[11] S. Abdel Khalek,[113] A. A. Abdelalim,[48] A. Abdesselam,[116] O. Abdinov,[10] B. Abi,[110] M. Abolins,[86] O. S. AbouZeid,[156] H. Abramowicz,[151] H. Abreu,[113] E. Acerbi,[87a,87b] B. S. Acharya,[162a,162b] L. Adamczyk,[37] D. L. Adams,[24] T. N. Addy,[55] J. Adelman,[173] M. Aderholz,[97] S. Adomeit,[96] P. Adragna,[73] T. Adye,[127] S. Aefsky,[22] J. A. Aguilar-Saavedra,[122b,b] M. Aharrouche,[79] S. P. Ahlen,[21] F. Ahles,[47] A. Ahmad,[146] M. Ahsan,[40] G. Aielli,[131a,131b] T. Akdogan,[18a] T. P. A. Åkesson,[77] G. Akimoto,[153] A. V. Akimov,[92] A. Akiyama,[65] M. S. Alam,[1] M. A. Alam,[74] J. Albert,[167] S. Albrand,[54] M. Aleksa,[29] I. N. Aleksandrov,[63] F. Alessandria,[87a] C. Alexa,[25a] G. Alexander,[151] G. Alexandre,[48] T. Alexopoulos,[9] M. Alhroob,[20] M. Aliev,[15] G. Alimonti,[87a] J. Alison,[118] M. Aliyev,[10] B. M. M. Allbrooke,[17] P. P. Allport,[71] S. E. Allwood-Spiers,[52] J. Almond,[80] A. Aloisio,[100a,100b] R. Alon,[169] A. Alonso,[77] B. Alvarez Gonzalez,[86] M. G. Alviggi,[100a,100b] K. Amako,[64] P. Amaral,[29] C. Amelung,[22] V. V. Ammosov,[126] A. Amorim,[122a,c] G. Amorós,[165] N. Amram,[151] C. Anastopoulos,[29] L. S. Ancu,[16] N. Andari,[113] T. Andeen,[34] C. F. Anders,[20] G. Anders,[57a] K. J. Anderson,[30] A. Andreazza,[87a,87b] V. Andrei,[57a] M-L. Andrieux,[54] X. S. Anduaga,[68] A. Angerami,[34] F. Anghinolfi,[29] A. Anisenkov,[105] N. Anjos,[122a] A. Annovi,[46] A. Antonaki,[8] M. Antonelli,[46] A. Antonov,[94] J. Antos,[142b] F. Anulli,[130a] S. Aoun,[81] L. Aperio Bella,[4] R. Apolle,[116,d] G. Arabidze,[86] I. Aracena,[141] Y. Arai,[64] A. T. H. Arce,[44] S. Arfaoui,[146] J-F. Arguin,[14] E. Arik,[18a,a] M. Arik,[18a] A. J. Armbruster,[85] O. Arnaez,[79] V. Arnal,[78] C. Arnault,[113] A. Artamonov,[93] G. Artoni,[130a,130b] D. Arutinov,[20] S. Asai,[153] R. Asfandiyarov,[170] S. Ask,[27] B. Åsman,[144a,144b] L. Asquith,[5] K. Assamagan,[24] A. Astbury,[167] A. Astvatsatourov,[51] B. Aubert,[4] E. Auge,[113] K. Augsten,[125] M. Aurousseau,[143a] G. Avolio,[161] R. Avramidou,[9] D. Axen,[166] C. Ay,[53] G. Azuelos,[91,e] Y. Azuma,[153] M. A. Baak,[29] G. Baccaglioni,[87a] C. Bacci,[132a,132b] A. M. Bach,[14] H. Bachacou,[134] K. Bachas,[29] M. Backes,[48] M. Backhaus,[20] E. Badescu,[25a] P. Bagnaia,[130a,130b] S. Bahinipati,[2] Y. Bai,[32a] D. C. Bailey,[156] T. Bain,[156] J. T. Baines,[127] O. K. Baker,[173] M. D. Baker,[24] S. Baker,[75] E. Banas,[38] P. Banerjee,[91] Sw. Banerjee,[170] D. Banfi,[29] A. Bangert,[148] V. Bansal,[167] H. S. Bansil,[17] L. Barak,[169] S. P. Baranov,[92] A. Barashkou,[63] A. Barbaro Galtieri,[14] T. Barber,[47] E. L. Barberio,[84] D. Barberis,[49a,49b] M. Barbero,[20] D. Y. Bardin,[63] T. Barillari,[97] M. Barisonzi,[172] T. Barklow,[141] N. Barlow,[27]

B. M. Barnett,[127] R. M. Barnett,[14] A. Baroncelli,[132a] G. Barone,[48] A. J. Barr,[116] F. Barreiro,[78]
J. Barreiro Guimarães da Costa,[56] P. Barrillon,[113] R. Bartoldus,[141] A. E. Barton,[69] V. Bartsch,[147] R. L. Bates,[52]
L. Batkova,[142a] J. R. Batley,[27] A. Battaglia,[16] M. Battistin,[29] F. Bauer,[134] H. S. Bawa,[141,f] S. Beale,[96] T. Beau,[76]
P. H. Beauchemin,[159] R. Beccerle,[49a] P. Bechtle,[20] H. P. Beck,[16] S. Becker,[96] M. Beckingham,[136] K. H. Becks,[172]
A. J. Beddall,[18c] A. Beddall,[18c] S. Bedikian,[173] V. A. Bednyakov,[63] C. P. Bee,[81] M. Begel,[24] S. Behar Harpaz,[150]
P. K. Behera,[61] M. Beimforde,[97] C. Belanger-Champagne,[83] P. J. Bell,[48] W. H. Bell,[48] G. Bella,[151] L. Bellagamba,[19a]
F. Bellina,[29] M. Bellomo,[29] A. Belloni,[56] O. Beloborodova,[105,g] K. Belotskiy,[94] O. Beltramello,[29] O. Benary,[151]
D. Benchekroun,[133a] M. Bendel,[79] N. Benekos,[163] Y. Benhammou,[151] E. Benhar Noccioli,[48] J. A. Benitez Garcia,[157b]
D. P. Benjamin,[44] M. Benoit,[113] J. R. Bensinger,[22] K. Benslama,[128] S. Bentvelsen,[103] D. Berge,[29]
E. Bergeaas Kuutmann,[41] N. Berger,[4] F. Berghaus,[167] E. Berglund,[103] J. Beringer,[14] P. Bernat,[75] R. Bernhard,[47]
C. Bernius,[24] T. Berry,[74] C. Bertella,[81] A. Bertin,[19a,19b] F. Bertinelli,[29] F. Bertolucci,[120a,120b] M. I. Besana,[87a,87b]
N. Besson,[134] S. Bethke,[97] W. Bhimji,[45] R. M. Bianchi,[29] M. Bianco,[70a,70b] O. Biebel,[96] S. P. Bieniek,[75]
K. Bierwagen,[53] J. Biesiada,[14] M. Biglietti,[132a] H. Bilokon,[46] M. Bindi,[19a,19b] S. Binet,[113] A. Bingul,[18c]
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J. A. Bogaerts,[29] A. Bogdanchikov,[105] A. Bogouch,[88,a] C. Bohm,[144a] J. Bohm,[123] V. Boisvert,[74] T. Bold,[37]
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V. Bortolotto,[132a,132b] K. Bos,[103] D. Boscherini,[19a] M. Bosman,[11] H. Boterenbrood,[103] D. Botterill,[127] J. Bouchami,[91]
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I. R. Boyko,[63] N. I. Bozhko,[126] I. Bozovic-Jelisavcic,[12b] J. Bracinik,[17] A. Braem,[29] P. Branchini,[132a]
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R. Brock,[86] T. J. Brodbeck,[69] E. Brodet,[151] F. Broggi,[87a] C. Bromberg,[86] J. Bronner,[97] G. Brooijmans,[34]
W. K. Brooks,[31b] G. Brown,[80] H. Brown,[7] P. A. Bruckman de Renstrom,[38] D. Bruncko,[142b] R. Bruneliere,[47]
S. Brunet,[59] A. Bruni,[19a] G. Bruni,[19a] M. Bruschi,[19a] T. Buanes,[13] Q. Buat,[54] F. Bucci,[48] J. Buchanan,[116]
N. J. Buchanan,[2] P. Buchholz,[139] R. M. Buckingham,[116] A. G. Buckley,[45] S. I. Buda,[25a] I. A. Budagov,[63]
B. Budick,[106] V. Büscher,[79] L. Bugge,[115] O. Bulekov,[94] M. Bunse,[42] T. Buran,[115] H. Burckhart,[29] S. Burdin,[71]
T. Burgess,[13] S. Burke,[127] E. Busato,[33] P. Bussey,[52] C. P. Buszello,[164] F. Butin,[29] B. Butler,[141] J. M. Butler,[21]
C. M. Buttar,[52] J. M. Butterworth,[75] W. Buttinger,[27] S. Cabrera Urbán,[165] D. Caforio,[19a,19b] O. Cakir,[3a] P. Calafiura,[14]
G. Calderini,[76] P. Calfayan,[96] R. Calkins,[104] L. P. Caloba,[23a] R. Caloi,[130a,130b] D. Calvet,[33] S. Calvet,[33]
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E. Chareyre,[76] D. G. Charlton,[17] V. Chavda,[80] C. A. Chavez Barajas,[29] S. Cheatham,[83] S. Chekanov,[5]
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M. Citterio,[87a] M. Ciubancan,[25a] A. Clark,[48] P. J. Clark,[45] W. Cleland,[121] J. C. Clemens,[81] B. Clement,[54]
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