

PUBLISHED VERSION

The ATLAS collaboration

Search for direct third-generation squark pair production in final states with missing transverse momentum and two b-jets in $\sqrt{s} = 8$ TeV pp collisions with the ATLAS detector

The Journal of High Energy Physics, 2013; 2013(10):189-0-189-39

This article is distributed under the terms of the Creative Commons Attribution License which permits any use, distribution and reproduction in any medium, provided the original author(s) and source are credited.

Originally published at:

[http://doi.org/10.1007/JHEP10\(2013\)189](http://doi.org/10.1007/JHEP10(2013)189)

PERMISSIONS

<http://creativecommons.org/licenses/by/4.0/>



This is a human-readable summary of (and not a substitute for) the [license](#).

[Disclaimer](#)



You are free to:

Share — copy and redistribute the material in any medium or format

Adapt — remix, transform, and build upon the material

for any purpose, even commercially.

The licensor cannot revoke these freedoms as long as you follow the license terms.

Under the following terms:



Attribution — You must give [appropriate credit](#), provide a link to the license, and [indicate if changes were made](#). You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use.

No additional restrictions — You may not apply legal terms or [technological measures](#) that legally restrict others from doing anything the license permits.

<http://hdl.handle.net/2440/88547>

Search for direct third-generation squark pair production in final states with missing transverse momentum and two b -jets in $\sqrt{s} = 8$ TeV pp collisions with the ATLAS detector



The ATLAS collaboration

E-mail: atlas.publications@cern.ch

ABSTRACT: The results of a search for pair production of supersymmetric partners of the Standard Model third-generation quarks are reported. This search uses 20.1 fb^{-1} of pp collisions at $\sqrt{s} = 8$ TeV collected by the ATLAS experiment at the Large Hadron Collider. The lightest bottom and top squarks (\tilde{b}_1 and \tilde{t}_1 respectively) are searched for in a final state with large missing transverse momentum and two jets identified as originating from b -quarks. No excess of events above the expected level of Standard Model background is found. The results are used to set upper limits on the visible cross section for processes beyond the Standard Model. Exclusion limits at the 95% confidence level on the masses of the third-generation squarks are derived in phenomenological supersymmetric R -parity-conserving models in which either the bottom or the top squark is the lightest squark. The \tilde{b}_1 is assumed to decay via $\tilde{b}_1 \rightarrow b\tilde{\chi}_1^0$ and the \tilde{t}_1 via $\tilde{t}_1 \rightarrow b\tilde{\chi}_1^\pm$, with undetectable products of the subsequent decay of the $\tilde{\chi}_1^\pm$ due to the small mass splitting between the $\tilde{\chi}_1^\pm$ and the $\tilde{\chi}_1^0$.

KEYWORDS: Hadron-Hadron Scattering, Supersymmetry

Contents

1	Introduction	1
2	The ATLAS detector and data samples	2
3	Simulated event samples	3
4	Physics object reconstruction	4
5	Event selection	5
6	Background estimate	7
7	Systematic uncertainties	11
8	Results and interpretation	13
9	Conclusions	18
	The ATLAS collaboration	24

1 Introduction

Supersymmetry (SUSY) [1–9] provides an extension of the Standard Model (SM) that solves the hierarchy problem [10–13] by introducing supersymmetric partners of the known bosons and fermions. In the framework of the R -parity-conserving minimal supersymmetric extension of the SM (MSSM) [14–18], 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 ($\tilde{\chi}_1^0$). The coloured superpartners of quarks and gluons, the squarks (\tilde{q}) and the gluinos (\tilde{g}), if not too heavy, would be produced in strong interaction processes at the Large Hadron Collider (LHC) [19] and decay via cascades ending with the LSP. The undetected LSP would result in missing transverse momentum while the rest of the cascade would yield final states with multiple jets and possibly leptons.

A study of the expected SUSY particle spectrum derived from naturalness considerations [20, 21] suggests that the supersymmetric partners of the third-generation SM quarks are the lightest coloured supersymmetric particles. This may lead to the lightest bottom squark (sbottom, \tilde{b}_1) and top squark (stop, \tilde{t}_1) mass eigenstates being significantly lighter than the other squarks and the gluinos. As a consequence, \tilde{b}_1 and \tilde{t}_1 could be pair-produced with relatively large cross sections at the LHC.

Two possible sets of SUSY mass spectra are considered in this paper. In the first set of scenarios, the lightest sbottom is the only coloured sparticle contributing to the production processes and it only decays via $\tilde{b}_1 \rightarrow b\tilde{\chi}_1^0$. In the second set, the lightest stop is the only coloured sparticle allowed in the production processes and it decays exclusively via $\tilde{t}_1 \rightarrow b\tilde{\chi}_1^\pm$, where the lightest chargino ($\tilde{\chi}_1^\pm$) decays via a virtual W boson into the three-body final state $\tilde{\chi}_1^0 f \bar{f}'$. This article considers scenarios in the context of natural SUSY [20–22], which are characterised by a small value for $\Delta m \equiv m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0}$. As a consequence the fermions f and f' may have transverse momenta below the reconstruction thresholds applied in the analysis.

In both scenarios, events are characterised by the presence of two jets originating from the hadronisation of the b -quarks and large missing transverse momentum. Results of searches for direct sbottom and stop production have been previously reported by the ATLAS [23–28] and CMS [29–31] experiments at the LHC, and by the Tevatron [32, 33] and LEP [34–36] experiments.

2 The ATLAS detector and data samples

The ATLAS detector [37] consists of inner tracking devices surrounded by a superconducting solenoid, electromagnetic and hadronic calorimeters and a muon spectrometer with a magnetic field produced by a set of toroids. The inner detector (ID), in combination with a superconducting solenoid magnet with a central field of 2 T, provides precision tracking and momentum measurement of charged particles in a pseudorapidity¹ range $|\eta| < 2.5$ and allows efficient identification of jets originating from b -hadron decays using impact parameter measurements and reconstructed secondary decay vertices. The ID consists of a silicon pixel detector, a silicon microstrip detector and a straw tube tracker ($|\eta| < 2.0$) that also provides transition radiation measurements for electron identification. The calorimeter system covers the pseudorapidity range $|\eta| < 4.9$. It is composed of sampling calorimeters with either liquid argon or scintillating tiles as the active medium. The muon spectrometer has separate trigger and high-precision tracking chambers, the latter providing muon identification and momentum measurement for $|\eta| < 2.7$.

The data sample used in this analysis was taken during the period from March to December 2012 with the LHC operating at a pp centre-of-mass energy of $\sqrt{s} = 8$ TeV. Candidate signal events are selected using a trigger based on a missing transverse momentum selection (E_T^{miss}), which is found to be 99% efficient for events passing the offline selection of $E_T^{\text{miss}} > 150$ GeV. The trigger efficiency variations over data-taking periods are measured to be less than 1% after the offline requirements. After the application of beam, detector, and data-quality requirements, the total integrated luminosity considered is 20.1 fb^{-1} . The uncertainty on the integrated luminosity is $\pm 2.8\%$. It is derived, following the same methodology as that detailed in ref. [38], from a preliminary calibration of the

¹ATLAS uses a right-handed coordinate system with its origin at the nominal interaction point (IP) in the centre of the detector and the z -axis along the beam pipe. The x -axis points from the IP to the centre of the LHC ring, and the y -axis points upward. 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 η - ϕ space is defined as $\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2}$.

luminosity scale using beam-separation scans performed in November 2012. Events with final-state electrons or muons that satisfy single-lepton or dilepton triggers are used to define control regions in a total data sample of 20.3 fb^{-1} . A requirement on the transverse momentum $p_T > 25 \text{ GeV}$ is applied to the highest- p_T electron or muon to ensure the trigger selection is fully efficient.

3 Simulated event samples

Simulated Monte Carlo (MC) event samples are used to aid in the description of the background and to model the SUSY signal. All SM MC samples utilised in the analysis are produced using the ATLAS Underlying Event Tune 2B [39] and are processed through the ATLAS detector simulation [40] based on GEANT4 [41] or passed through a fast simulation using a parameterisation of the performance of the ATLAS electromagnetic and hadronic calorimeters [42]. The effect of multiple pp interactions per bunch crossing (pile-up) is also taken into account.

The top-quark pair ($t\bar{t}$) background is simulated with POWHEG-1.0 [43] interfaced to PYTHIA-6.426 [44] for the fragmentation and hadronisation processes. The top-quark mass is fixed at 172.5 GeV , and the next-to-leading-order (NLO) parton distribution function (PDF) set CT10 [45] is used. Samples from ALPGEN-2.14 [46] and POWHEG each interfaced to HERWIG-6.520 for the fragmentation and hadronisation processes, including JIMMY-4.31 [47] for the underlying event description, are used to estimate the generator and fragmentation systematic uncertainties, while ACERMC-3.8 [48] interfaced to PYTHIA samples are used to estimate the showering uncertainties. Single top-quark production for the s -channel and Wt processes is simulated with MC@NLO-4.06 interfaced to HERWIG+JIMMY, while the t -channel process is simulated with ACERMC interfaced to PYTHIA and using the CTEQ6L1 [45] PDF set. Samples of $t\bar{t}+W/Z$ events are generated using the leading-order generator MADGRAPH-5.1.4.8 [49] interfaced to PYTHIA for the fragmentation and hadronisation processes. Samples of Z/γ^* or W production, both in association with up to five jets, are produced with SHERPA-1.4.1 [50]. MC samples of dibosons (ZZ , WZ and WW) are generated using SHERPA.

The background predictions are normalised to theoretical cross sections, calculated including higher-order QCD corrections where available, and are compared to data in appropriate control regions. The inclusive cross sections for Z +jets and W +jets processes are calculated with DYNLO [51] with the MSTW 2008 next-to-next-to-leading-order PDF set [52]. Approximate NLO+NNLL (next-to-next-to-leading-logarithm) cross sections are used in the normalisation of the $t\bar{t}$ [53] and Wt [54] samples. Cross sections calculated at NLO are used for the $t\bar{t}+W$ and $t\bar{t}+Z$ samples [55] and for the diboson samples [56].

The SUSY signal samples are generated using MADGRAPH interfaced to PYTHIA (with PDF set CTEQ6L1) to ensure an accurate treatment of the initial-state radiation (ISR). Additional samples with different ISR parameter values are generated to evaluate the ISR systematic uncertainty. Polarisation effects due to the choice of left- and right-handed scalar sbottom or stop mixing were found to have a negligible impact on the analysis. Signal cross sections are calculated to next-to-leading-order in the strong coupling constant, adding the resummation of soft gluon emission at next-to-leading-logarithmic accuracy

(NLO+NLL) [57–59]. The nominal cross section and its uncertainty are taken from an envelope of cross-section predictions using different PDF sets and factorisation and renormalisation scales, as described in ref. [60].

4 Physics object reconstruction

Jets are reconstructed from three-dimensional cell-energy clusters in the calorimeter using the anti- k_t jet algorithm [61, 62] with a radius parameter of 0.4. The measured jet energy is corrected for inhomogeneities and for the non-compensating nature of the calorimeter by weighting energy deposits arising from electromagnetic and hadronic showers by correction factors derived from MC simulations and validated with data. An additional calibration is subsequently applied to the corrected jet energies, relating the response of the calorimeter to the true jet energy [63]. The impact of additional collisions in the same or neighbouring bunch crossings is accounted for using corrections derived as a function of the average number of interactions per event and of the number of reconstructed primary vertices. Jets are required to have $p_T > 20$ GeV, and are reconstructed in the range $|\eta| < 4.9$.

Events are rejected if they include jets failing the quality criteria described in ref. [63]. To further reject spurious jet signals originating from cosmic rays or detector malfunctions, additional criteria are applied to the charged p_T fraction (f_{ch}), defined as the sum of the p_T of all tracks associated with the jet divided by the jet p_T , and to the fraction of the jet energy contained in the electromagnetic layers of the calorimeter (f_{em}). Events are rejected if any of the two leading jets with $p_T > 100$ GeV and $|\eta| < 2.0$ satisfies either $f_{\text{ch}} < 0.02$ or both $f_{\text{ch}} < 0.05$ and $f_{\text{em}} > 0.9$. To remove jets from additional pp collisions, all jets with $p_T < 50$ GeV and $|\eta| < 2.5$ are required to have at least one track identified as coming from the primary vertex. The primary vertex itself is defined as the vertex with the highest summed track p_T^2 .

Jets within the nominal acceptance of the ID ($|\eta| < 2.5$) and with $p_T > 20$ GeV, are selected as originating from a b -quark (b -tagged) if they satisfy requirements on the impact parameter of the ID tracks, the secondary vertex reconstruction and the topology of b - and c -hadron decays inside the jet. The b -tagging algorithm [64] uses a multivariate technique and, for this analysis, is configured to achieve an efficiency of 60% for tagging b -jets in a MC sample of $t\bar{t}$ events with corresponding rejection factors of 580, 8 and 23 against jets originating from light quarks, c -quarks and τ -leptons, respectively.

Electrons are reconstructed from cell-energy clusters in the electromagnetic calorimeter matched to a track in the ID. Electron candidates are required to have $p_T > 7$ GeV and $|\eta| < 2.47$ and must satisfy the “medium” selection criteria described in ref. [65] and reoptimized for 2012 data. Electrons used to define the control regions are selected using the “tight” criteria, $p_T > 20$ GeV, and with an additional isolation requirement that the total transverse momentum of charged tracks within a cone of $\Delta R = 0.2$ around the candidate be less than 10% of the reconstructed p_T . Muon candidates are identified using a match between an extrapolated ID track and one or more track segments in the muon spectrometer [66], and are required to have $p_T > 6$ GeV and $|\eta| < 2.4$. Muons used to define the control regions are also required to have $p_T > 20$ GeV and less than 1.8 GeV deposited in the calorimeter within a cone of $\Delta R = 0.2$ around the candidate.

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 candidate. Then, any electron or muon candidate within $\Delta R = 0.4$ of any surviving jet is discarded.

The missing transverse momentum, $\mathbf{p}_T^{\text{miss}}$, with magnitude E_T^{miss} , is constructed as the negative of the vector sum of the transverse momentum of all muons and electrons with $p_T > 10$ GeV, jets with $p_T > 20$ GeV, and calibrated calorimeter energy clusters with $|\eta| < 4.9$ not assigned to these objects [67].

5 Event selection

Two sets of signal regions are defined to provide sensitivity to the kinematic topologies associated with different mass splittings between the sbottom or the stop and the neutralino. In all cases, the presence of at least one primary vertex (with at least five associated tracks with $p_T > 0.4$ GeV) is required. Events are selected with $E_T^{\text{miss}} > 150$ GeV and no electrons or muons identified in the final state. For the signal region selections, jets within $|\eta| < 2.8$ are ordered according to their p_T , with n being their total number, and two jets are required to be b -tagged. The following event-level variables are defined:

- $\Delta\phi_{\text{min}}$ is defined as the minimum azimuthal distance, $\Delta\phi$, between any of the three leading jets and the $\mathbf{p}_T^{\text{miss}}$ vector

$$\Delta\phi_{\text{min}} = \min(|\phi_1 - \phi_{\mathbf{p}_T^{\text{miss}}}|, |\phi_2 - \phi_{\mathbf{p}_T^{\text{miss}}}|, |\phi_3 - \phi_{\mathbf{p}_T^{\text{miss}}}|).$$

Background multi-jet events are typically characterised by small values of $\Delta\phi_{\text{min}}$;

- m_{eff} is defined as the scalar sum of the p_T of the k leading jets and the E_T^{miss}

$$m_{\text{eff}}(k) = \sum_{i=1}^k (p_T^{\text{jet}})_i + E_T^{\text{miss}},$$

where the index refers to the p_T -ordered list of jets;

- $H_{T,3}$ is defined as the scalar sum of the p_T of the n jets, without including the three leading jets

$$H_{T,3} = \sum_{i=4}^n (p_T^{\text{jet}})_i,$$

where the index refers to the p_T -ordered list of jets;

- m_{bb} is defined as the invariant mass of the two b -tagged jets in the event;
- m_{CT} is the contranverse mass [68] and is a kinematic variable that can be used to measure the masses of pair-produced semi-invisibly decaying heavy particles. For two identical decays of heavy particles into two visible particles (or particle aggregates) v_1 and v_2 , and two invisible particles, m_{CT} is defined as:

$$m_{CT}^2(v_1, v_2) = [E_T(v_1) + E_T(v_2)]^2 - [\mathbf{p}_T(v_1) - \mathbf{p}_T(v_2)]^2,$$

Description	Signal Regions	
	SRA	SRB
Event cleaning	Common to all SR	
Lepton veto	No e/μ after overlap removal with $p_T > 7(6)$ GeV for $e(\mu)$	
E_T^{miss}	> 150 GeV	> 250 GeV
Leading jet $p_T(j_1)$	> 130 GeV	> 150 GeV
Second jet $p_T(j_2)$	> 50 GeV,	> 30 GeV
Third jet $p_T(j_3)$	veto if > 50 GeV	> 30 GeV
$\Delta\phi(\mathbf{p}_T^{\text{miss}}, j_1)$	-	> 2.5
b -tagging	leading 2 jets ($p_T > 50$ GeV, $ \eta < 2.5$)	2nd- and 3rd-leading jets ($p_T > 30$ GeV, $ \eta < 2.5$)
	$n_{b\text{-jets}} = 2$	
$\Delta\phi_{\text{min}}$	> 0.4	> 0.4
$E_T^{\text{miss}}/m_{\text{eff}}(k)$	$E_T^{\text{miss}}/m_{\text{eff}}(2) > 0.25$	$E_T^{\text{miss}}/m_{\text{eff}}(3) > 0.25$
m_{CT}	$> 150, 200, 250, 300, 350$ GeV	-
$H_{T,3}$	—	< 50 GeV
m_{bb}	> 200 GeV	—

Table 1. Summary of the event selection in each signal region.

where $E_T = \sqrt{p_T^2 + m^2}$. In this analysis, v_1 and v_2 are the two b -jets from the squark decays and the invisible particles are the two $\tilde{\chi}_1^0$ particles or chargino decay products, depending on the assumption considered. The contranverse mass is an invariant under equal and opposite boosts of the parent particles in the transverse plane. For parent particles produced with small transverse boosts, m_{CT} is bounded from above by an analytical combination of particle masses. This bound is saturated when the two visible objects are co-linear. For $t\bar{t}$ events this kinematic bound is at 135 GeV. For production of sbottom pairs the bound is given by:

$$m_{CT}^{\text{max}} = \frac{m^2(\tilde{b}) - m^2(\tilde{\chi}_1^0)}{m(\tilde{b})}.$$

A similar equation can be written for production of stop pairs in terms of $m_{\tilde{t}_1}$ and $m_{\tilde{\chi}_1^\pm}$. A correction to m_{CT} for the transverse boost due to ISR is also applied [69].

The definition of the two signal regions is summarised in table 1. Signal region A (SRA) targets signal events with large mass splitting between the squark and the neutralino, identifying two b -tagged high- p_T leading jets as products of the two sbottom or stop decays. Events are rejected if any other central ($|\eta| < 2.8$) jets are found with $p_T > 50$ GeV. Multijet background is suppressed by selecting events with large $\Delta\phi_{\text{min}}$ and $E_T^{\text{miss}}/m_{\text{eff}}$. The requirement $m_{bb} > 200$ GeV is added to reduce backgrounds from production of top-quark (including top-quark pairs and single top-quark production processes), and Z -bosons in association with heavy-flavour jets. As a final selection criterion, five different thresholds

on m_{CT} ranging from 150 GeV to 350 GeV are applied. For a signal point corresponding to $m_{\tilde{b}_1} = 500$ GeV and $m_{\tilde{\chi}_1^0} = 1$ GeV, 3% of the simulated events are retained by the SRA selection with $m_{CT} > 250$ GeV.

Signal region B (SRB) is defined to enhance the sensitivity for a small squark-neutralino mass difference by explicitly selecting events with a high- p_T jet, which is likely to have been produced as initial state radiation, recoiling against the squark-pair system. High thresholds on the leading jet p_T and on the missing transverse momentum, which are required to be almost back-to-back in ϕ , are imposed. The leading jet is required to be not b -tagged, and two additional jets are required to be b -tagged. As for SRA, the multi-jet background is suppressed with appropriate selections on $\Delta\phi_{\min}$ and $E_T^{\text{miss}}/m_{\text{eff}}$. A final upper requirement on the additional hadronic activity in the event, $H_{T,3} < 50$ GeV completes the selection for SRB. For a signal point corresponding to $m_{\tilde{b}_1} = 300$ GeV and $m_{\tilde{\chi}_1^0} = 270$ GeV, 10% of the simulated events are retained by the SRB selection.

6 Background estimate

The dominant SM background processes in the signal regions are the production of W or Z bosons in association with heavy-flavour jets (referred to as $W+\text{hf}$ and $Z+\text{hf}$) and the production of top-quarks. Events with $Z+\text{hf}$ production followed by $Z \rightarrow \nu\bar{\nu}$ decay have the same signature as the signal and are the dominant background in SRA. Top-quark (dominant in SRB) and $W+\text{hf}$ production satisfy the signal region selections when a charged lepton is produced but the event is not rejected, either because the lepton is a hadronically decaying τ , or because the electron or muon is not reconstructed. The dominant backgrounds are normalised in dedicated control regions (CRs) and then extrapolated to the signal regions using MC simulation. The control regions, detailed below, are defined by explicitly requiring the presence of one or two leptons (electrons or muons) in the final state together with further selection criteria similar to those of the corresponding signal regions. In particular, events with additional lepton candidates are vetoed applying the same lepton requirements used to veto events in the signal regions. The single top-quark contribution accounts for 5% to 20% of the total top-quark background contribution, depending on the signal region considered, and is added to the $t\bar{t}$ background contribution with a relative normalisation corresponding to that predicted by the MC simulation, as described in section 3.

The contributions from diboson and $t\bar{t} + W/Z$ processes are sub-dominant and they are collectively called “Others” in the following. They are estimated from MC simulation for both the signal and the control regions.

Finally, the background from multi-jet production is estimated from data using a procedure described in detail in ref. [70] modified to account for the flavour of the jets. The procedure consists of smearing the jet response in low- E_T^{miss} seed events. The Gaussian core of the jet response function is obtained from dijet events, while the non-Gaussian tails are obtained from three-jet events, where the E_T^{miss} can be unambiguously attributed to the mis-measurement of one of the jets. The contribution from multi-jet production in the control regions is found to be negligible.

CRA_1L	CRA_SF	CRA_DF
One e or μ	$e^\pm e^\mp$ or $\mu^\pm \mu^\mp$	$e^\pm \mu^\mp$
Veto additional lepton candidates ($p_T(e) > 7 \text{ GeV}$ $p_T(\mu) > 6 \text{ GeV}$)		
Only two reconstructed jets with $p_T > 50 \text{ GeV}$		
$p_T(j_1) > 130 \text{ GeV}$	$p_T(j_1) > 50 \text{ GeV}$	$p_T(j_1) > 130 \text{ GeV}$
$p_T(j_2) > 50 \text{ GeV}$	$p_T(j_2) > 50 \text{ GeV}$	$p_T(j_2) > 50 \text{ GeV}$
$E_T^{\text{miss}} > 100 \text{ GeV}$	$E_T^{\text{miss}}(\text{lepton-corrected}) > 100 \text{ GeV}$	$E_T^{\text{miss}} > 100 \text{ GeV}$
Two reconstructed b -jets ($p_T > 50$)		
$40 \text{ GeV} < m_T < 100 \text{ GeV}$	$75 \text{ GeV} < m_{\ell\ell} < 105 \text{ GeV}$	$m_{\ell\ell} > 50 \text{ GeV}$
$m_{CT} > 150 \text{ GeV}$	lepton $p_T > 90 \text{ GeV}$	$m_{CT} > 75 \text{ GeV}$
—	$m_{bb} > 200 \text{ GeV}$	—

Table 2. Definitions of the three SRA control regions.

For SRA, the contributions from top-quark, Z +jets and W +jets production are estimated simultaneously with a profile likelihood fit to three control regions. For SRB it is difficult to identify a control region that probes the W +jets background normalisation. Therefore, this contribution is estimated purely from MC simulation as described in section 3, and only control regions for top-quark and Z +jets are defined.

A set of same-flavour opposite-sign two-lepton control regions with dilepton invariant mass near the Z mass ($75 < m_{\ell\ell} < 105 \text{ GeV}$) provides a data sample dominated by Z production. For these control regions, labelled in the following as CRA_SF and CRB_SF, the p_T of the leptons is added vectorially to the $\mathbf{p}_T^{\text{miss}}$ to mimic the expected missing transverse momentum spectrum of $Z \rightarrow \nu\bar{\nu}$ events, and is indicated in the following as E_T^{miss} (lepton corrected). In addition, the p_T of the leading lepton is required to be above 90 GeV in order to further enhance the Z production contribution. In the case of CRA_SF, a $m_{bb} > 200 \text{ GeV}$ selection is also imposed.

The set of control regions with exactly one lepton (e, μ) in the final state provides a data sample dominated by top-quark and W +jets production. A selection criterion is applied to the transverse mass, $40 \text{ GeV} < m_T < 100 \text{ GeV}$, where m_T is defined as:

$$m_T = \sqrt{2p_T^{\text{lep}} E_T^{\text{miss}} - 2\mathbf{p}_T^{\text{lep}} \cdot \mathbf{p}_T^{\text{miss}}}$$

In the following, these control regions are labelled as CRA_1L and CRB_1L. CRA_1L is used to estimate the contribution of the W +jets background, which is enhanced by the selection criterion $m_{CT} > 150 \text{ GeV}$ in SRA. CRB_1L is used to estimate the top-quark background in SRB.

To estimate top-quark production in SRA, a different-flavour opposite-sign two-lepton control region (CRA_DF) is defined requiring one electron and one muon in the final state with $m_{e\mu} > 50 \text{ GeV}$ and $m_{CT} > 75 \text{ GeV}$.

The definitions of the control regions are summarised in tables 2 and 3.

CRB_1L	CRB_SF
One e or μ	$e^\pm e^\mp$ or $\mu^\pm \mu^\mp$
Veto additional lepton candidates ($p_T(e) > 7 \text{ GeV}$ $p_T(\mu) > 6 \text{ GeV}$)	
Only three reconstructed jets with $p_T > 30 \text{ GeV}$	
$p_T(j_1) > 130 \text{ GeV}$	$p_T(j_1) > 50 \text{ GeV}$
$E_T^{\text{miss}} > 120 \text{ GeV}$	$E_T^{\text{miss}}(\text{lepton-corrected}) > 100 \text{ GeV}$
j_1 anti b -tagged; j_2 and j_3 b -tagged	
$40 \text{ GeV} < m_T < 100 \text{ GeV}$	$75 \text{ GeV} < m_{\ell\ell} < 105 \text{ GeV}$
—	Lepton $p_T > 90 \text{ GeV}$
$H_{T,3} < 50 \text{ GeV}$	

Table 3. Definitions of the two SRB control regions.

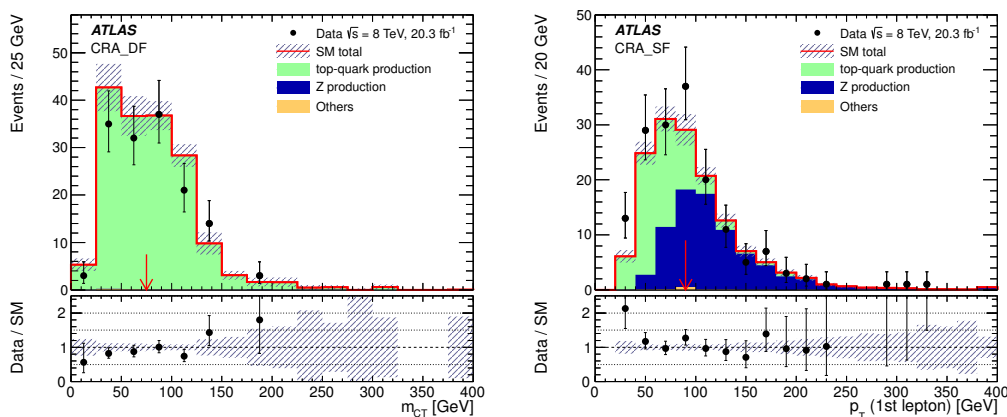


Figure 1. *Left:* m_{CT} distribution in CRA_DF omitting the requirement on the m_{CT} variable. *Right:* leading lepton p_T distribution in CRA_SF with all the selections applied except the requirement on this variable. The red arrows indicate where a selection on the corresponding variable is applied. The shaded band includes both the detector and theoretical systematic uncertainties. The SM prediction is normalised according to the MC expectations. The last bin in each histogram contains the integral of all events with values greater than the upper axis bound.

The distribution of the m_{CT} variable in CRA_DF (before the m_{CT} selection) and of the leading lepton p_T (before the p_T selection) in CRA_SF are shown before the fit in figure 1. Similarly, the transverse mass distribution of the leading-lepton- E_T^{miss} system in CRB_1L (before the m_T selection) and the invariant mass distribution of the two leptons in CRB_SF (before the $m_{\ell\ell}$ selection) are shown in figure 2. In these figures the data set used corresponds to an integrated luminosity of 20.3 fb^{-1} and the normalisations described in section 3 are assumed.

The observed numbers of events in the various CRs are used to generate internally consistent SM background estimates for each of the SRs via a profile likelihood fit. This procedure takes into account CR correlations due to common systematic uncertainties as well as contaminations from other SM processes and/or SUSY signal events, when a par-

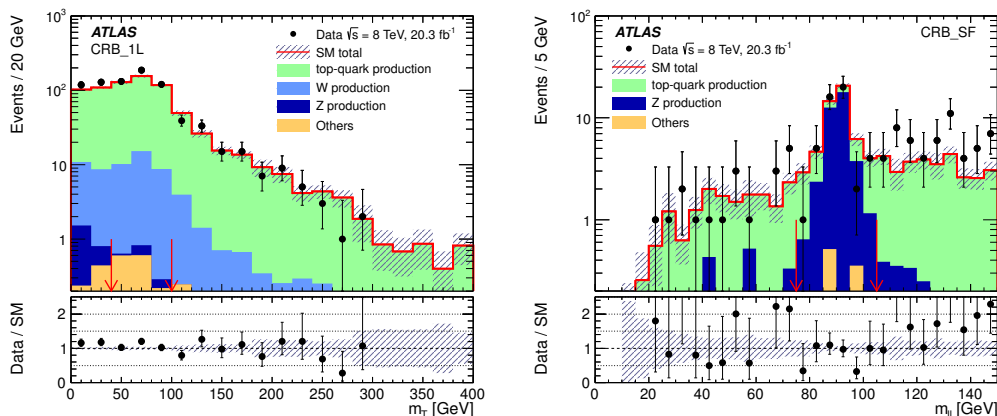


Figure 2. *Left:* transverse mass distribution of the leading-lepton- E_T^{miss} system in CRB_1L omitting the m_T requirement. *Right:* dilepton invariant mass distribution in CRB_SF omitting the $m_{\ell\ell}$ requirement. The red arrows indicate where a selection on the corresponding variable is applied. The shaded band includes both the detector and theoretical systematic uncertainties. The SM prediction is normalised according to the MC expectations.

ticular model is considered for exclusion. Systematic uncertainties, discussed in detail in section 7, are treated as nuisance parameters in the fit and are constrained with Gaussian functions taking into account correlations between sample estimates. The likelihood function is built as the product of Poisson probability functions, describing the observed and expected number of events in the control and (when excluding SUSY models) signal regions, and the constraints on the nuisance parameters. As a result, the impact of some of the systematic uncertainties that are correlated between the CRs and the corresponding SR is reduced.

The free parameters of the fit are the overall normalisation values of the top-quark, W +jets and Z +jets processes for SRA, and of the top-quark and Z +jets processes for SRB. The contributions from all other background processes are fixed at the values expected from MC. The fit results in the control regions are summarised in tables 4 and 5 for SRA and SRB, respectively. These results are found to be compatible with MC yields predicted before the fit, which are also given in the tables.

The predictions from the fit are in good agreement with the MC estimates with a maximum discrepancy of two standard deviations observed in one of the control regions.

The reliability of the MC extrapolation of the SM background estimate outside of the control regions is evaluated in several validation regions. The first set of validation regions is defined with the same kinematic selection as the control regions but requiring only one jet to be b -tagged. They are used to verify the performance of the b -tagging algorithm in a larger sample of events. A second set of validation regions is defined with the same selection criteria as the signal regions, but with one of the requirements inverted. In all cases these validation regions are background-dominated with a potential signal contamination of less than 20% for the signal models considered. For SRA, two validation regions are explored by imposing either $m_{CT} < 100$ GeV or $m_{bb} < 200$ GeV. To validate SRB, a validation region

Channel	CRA_1L	CRA_SF	CRA_DF
Observed events	135	68	75
Fitted background events			
Total SM	135 ± 11	68 ± 8	75 ± 9
Top-quark production	91 ± 17	10.0 ± 1.3	75 ± 9
Z production	0.46 ± 0.12	58 ± 8	$0.07^{+0.10}_{-0.07}$
W production	40 ± 20	< 0.1	0.06 ± 0.03
Others	3.8 ± 2.0	0.44 ± 0.18	0.37 ± 0.13
MC expected events			
Top-quark production	100	11.0	82
Z production	0.44	54	0.07
W production	42	< 0.1	0.07
Others	3.8	0.44	0.37

Table 4. Results of the fit for the control regions adopted for SRA. Expected yields derived from MC simulation using theoretical cross sections are also shown. Uncertainties quoted include statistical and detector-related systematic effects. The central values of the fitted sum of backgrounds in the control regions agree with the observations by construction. The uncertainty on the total background estimate can be smaller than some of the individual uncertainties due to anticorrelations.

with the selection $H_{T,3} > 50$ GeV is defined as well as a second validation region with two leptons of different flavour to verify the normalisation of the top-quark background.

Good agreement is found in each case, with a difference of less than one standard deviation between the expectations and the number of observed events.

7 Systematic uncertainties

The dominant detector-related systematic effects are due to the uncertainties on the jet energy scale (JES) and resolution (JER), and on the b -tagging efficiency. The impact of these uncertainties is reduced through the normalisation of the dominant backgrounds in the control regions with kinematic selections resembling those of the corresponding signal region.

The JES uncertainty is determined using the techniques described in refs. [63, 71], leading to a slight dependence on p_T , η , jet flavour, number of primary vertices and proximity to adjacent jets. The JER uncertainty is obtained from in-situ measurements of the jet response asymmetry in dijet events [63]. These uncertainties on jets are propagated to the E_T^{miss} measurement, and additional uncertainties on E_T^{miss} arising from energy deposits not associated with any reconstructed objects are also included. The relative impact on the event yields from the JES (JER) uncertainty is between 1–5% (1–8%) in the different SRA regions and is 3% (8%) in SRB.

Channel	CRB_1L	CRB_SF
Observed events	437	48
Fitted background events		
Total SM	437 ± 21	48 ± 7
Top-quark production	403 ± 27	16.2 ± 2.2
Z production	0.26 ± 0.15	31 ± 7
W production	32 ± 20	< 0.1
Others	1.4 ± 0.5	1.0 ± 0.5
MC expected events		
Top-quark production	370	15
Z production	0.32	38
W production	32	< 0.1
Others	1.4	1.0

Table 5. Results of the fit for the control regions adopted for SRB. Expected yields as derived from MC using theoretical cross sections are also shown. Uncertainties quoted include statistical and detector-related systematic effects. The central values of the fitted sum of backgrounds in the control regions agree with the observations by construction. The uncertainty on the total background estimate can be smaller than some of the individual uncertainties due to anticorrelations. The W production estimate is normalised using the nominal theoretical cross section and with the associated uncertainties discussed in section 7.

The b -tagging uncertainty is evaluated by varying the p_T - and flavour-dependent scale factors applied to each jet in the simulation within a range that reflects the systematic uncertainty on the measured tagging efficiency and rejection rates. The relative impact of this uncertainty on the final event yield is dominated by the uncertainty in the b -tagging efficiency. The uncertainty amounts to 2–10% in the different SRA regions and 2% in SRB.

In the case of SRB, an uncertainty is also associated with the requirement that jets with $p_T < 50$ GeV have at least one track originating from the primary vertex. It has a relative impact on the final event yields of 7%. Other detector systematic uncertainties like pile-up or trigger effects are found to have negligible impact on the analysis.

Theoretical uncertainties on the modeling of the $t\bar{t}$ +jets background are assessed. The uncertainty due to the choice of the MC generator is estimated by comparing the predictions of the POWHEG and ALPGEN generators, both interfaced to the HERWIG+JIMMY parton shower (PS) and hadronisation (HAD) calculations. The PS/HAD uncertainty is estimated by comparing samples generated with POWHEG interfaced to either PYTHIA or HERWIG+JIMMY. The uncertainty due to the ambiguity in the renormalisation and factorisation scales is estimated by individually doubling or halving them. The uncertainty in the ISR and final-state radiation (FSR) is estimated by comparing ACERMC samples generated with different amounts of ISR/FSR, as constrained by recent ATLAS measure-

Channel	SRA, m_{CT} selection					SRB
	150 GeV	200 GeV	250 GeV	300 GeV	350 GeV	
Observed	102	48	14	7	3	65
Total SM	94 ± 13	39 ± 6	15.8 ± 2.8	5.9 ± 1.1	2.5 ± 0.6	64 ± 10
Top-quark	11.1 ± 1.8	2.4 ± 1.4	0.44 ± 0.25	< 0.01	< 0.01	41 ± 7
Z production	66 ± 11	28 ± 5	11.4 ± 2.2	4.7 ± 0.9	1.9 ± 0.4	13 ± 4
W production	13 ± 6	4.9 ± 2.6	2.1 ± 1.1	1.0 ± 0.5	0.46 ± 0.26	8 ± 5
Others	4.3 ± 1.5	3.4 ± 1.3	1.8 ± 0.6	0.12 ± 0.11	$0.10^{+0.12}_{-0.10}$	2.0 ± 1.0
Multijet	0.21 ± 0.21	0.06 ± 0.06	0.02 ± 0.02	< 0.01	< 0.01	0.16 ± 0.16

Table 6. For each signal region, the observed event yield is compared with the background prediction obtained from the fit. Statistical, detector-related and theoretical systematic uncertainties are included, taking into account correlations.

ments [72]. The PDF uncertainties are derived by varying the 52 PDFs in the CT10 NLO error set following the Hessian method and rescaling to the 68% confidence level. Since $t\bar{t}$ and single top-quark productions are treated together, these theoretical uncertainties are also assigned to the single top contribution and it was checked that they account for the difference in event kinematics between the samples. The final relative uncertainties on the yields due to theoretical uncertainties in top-quark production modeling are less than 0.7% in SRA and 4% in SRB, dominated mostly by PS/HAD and scale uncertainties.

Uncertainties in the W/Z +jets simulation are evaluated by comparing the predictions of the SHERPA and ALPGEN generators and, by varying the SHERPA scales related to the matching scheme, the strong coupling constant, and the renormalisation and factorisation scales. The PDF uncertainties are evaluated following the same procedure as for the top-quark background. For SRB, W +jets production is estimated from MC simulation and an additional uncertainty of 26% due to the W +hf contribution is included [73]. The relative uncertainties on the yields are in the range 0.3–3.1% in SRA, mostly dominated by the difference between SHERPA and ALPGEN. For SRB, a 3% uncertainty is assigned to Z +hf and 9% to W +hf, the latter uncertainty being dominated by the MC normalisation.

An uncertainty of 100% is derived for the multi-jet prediction by studying variations of the resolution function. Finally, uncertainties of 30% and of 50% are assigned to the cross sections of $t\bar{t} + W$ and of $t\bar{t} + Z$ production, respectively [55, 74].

8 Results and interpretation

The number of data events observed in each signal region is reported in table 6, together with the SM background expectation after the fit. Figures 3 and 4 show the comparison between the SM prediction and the observed data for some relevant kinematic distributions in SRA and SRB, respectively. An example of a SUSY process with a large mass difference between the squark and the lightest neutralino is also shown for reference in each case.

No significant excess above the SM expectation is observed in any of the signal regions. The results are used to derive upper limits on the number of beyond the SM (BSM) events

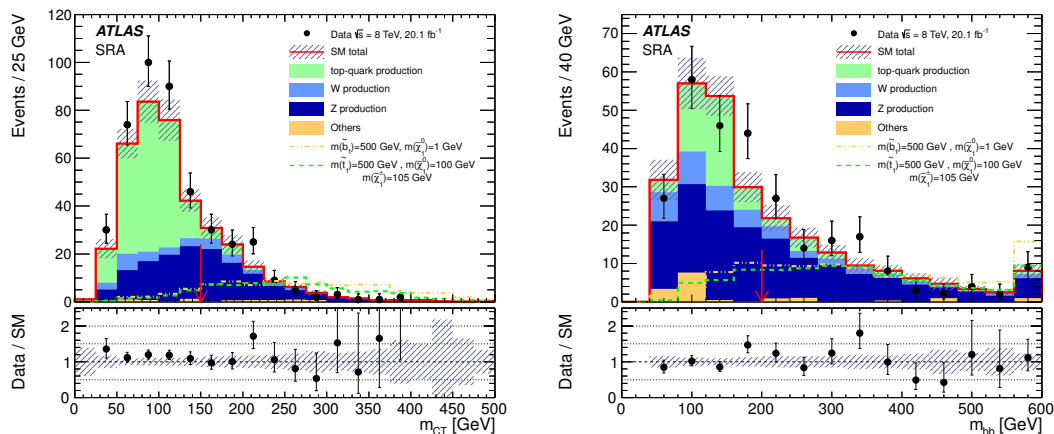


Figure 3. *Left:* m_{CT} distribution in SRA with all the selection criteria applied except the m_{CT} thresholds. *Right:* m_{bb} distribution in SRA with all selection criteria applied including $m_{CT} > 150$ GeV. The shaded band includes statistical, detector-related and theoretical systematic uncertainties. The backgrounds are normalised to the values determined in the fit. The red arrows indicate where a selection on the corresponding variable is applied. For illustration the distributions expected for two signal models are displayed. The models correspond to $m_{\tilde{b}_1} = 500$ GeV and $m_{\tilde{\chi}_1^0} = 1$ GeV (orange dash-dot line) and $m_{\tilde{t}_1} = 500$ GeV and $m_{\tilde{\chi}_1^0} = 100$ GeV (green dash line). The rightmost bin in the figures includes the overflows.

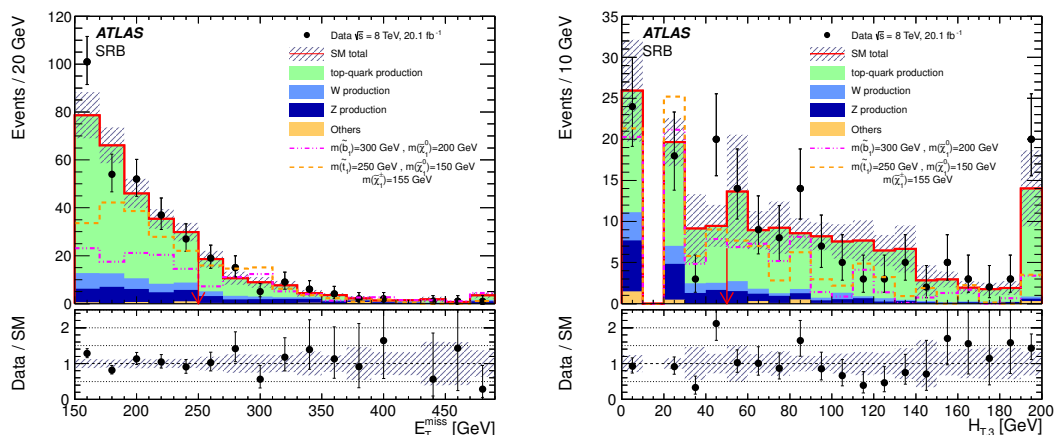


Figure 4. *Left:* E_T^{miss} distribution with all SRB selection criteria applied except the final E_T^{miss} requirement. *Right:* distribution of $H_{T,3}$ with all SRB selection criteria applied except the $H_{T,3}$ requirement. Since jets have $p_T > 20$ GeV by construction, the leftmost bin contains events where no additional jets are present ($H_{T,3} = 0$ GeV) while the second bin is empty. The shaded band includes statistical, detector-related and theoretical systematic uncertainties. The backgrounds are normalised to the values determined in the fit. The red arrows indicate where a selection on the corresponding variable is applied. For illustration the distributions expected for two signal models are displayed. The models correspond to $m_{\tilde{b}_1} = 300$ GeV and $m_{\tilde{\chi}_1^0} = 200$ GeV (purple dash-dot line) and $m_{\tilde{t}_1} = 250$ GeV and $m_{\tilde{\chi}_1^0} = 150$ GeV (orange dash line). The rightmost bin in the figures includes the overflows.

Signal Regions	Background estimate	Observed data	95% CL upper limit on			
			BSM event yield		σ_{vis} (fb)	
			exp.	obs.	exp.	obs.
SRA ($m_{CT} > 150$ GeV)	94 ± 13	102	32_{-9}^{+13}	38	$1.6_{-0.4}^{+0.6}$	1.9
SRA ($m_{CT} > 200$ GeV)	39 ± 6	48	19_{-5}^{+8}	26	$0.94_{-0.25}^{+0.40}$	1.3
SRA ($m_{CT} > 250$ GeV)	15.8 ± 2.8	14	$10.2_{-3.0}^{+4.6}$	9.0	$0.51_{-0.14}^{+0.22}$	0.45
SRA ($m_{CT} > 300$ GeV)	5.9 ± 1.1	7	$6.5_{-2.1}^{+3.3}$	7.5	$0.32_{-0.1}^{+0.16}$	0.37
SRA ($m_{CT} > 350$ GeV)	2.5 ± 0.6	3	$4.7_{-1.6}^{+2.6}$	5.2	$0.23_{-0.08}^{+0.13}$	0.26
SRB	64 ± 10	65	26_{-7}^{+10}	27	$1.21_{-0.35}^{+0.45}$	1.3

Table 7. Expected and observed event yields with the corresponding upper limits on BSM signal yields and $\sigma_{\text{vis}} = \sigma \cdot A \cdot \epsilon$ for all the signal regions defined.

for each signal region, assuming no systematic uncertainties for these events and neglecting any possible contamination in the control regions. Scaling by the integrated luminosity, these can be interpreted as a corresponding upper limit on the cross section, σ_{vis} , defined as

$$\sigma_{\text{vis}} = \sigma \cdot A \cdot \epsilon$$

where σ , A and ϵ are, respectively, the production cross section, the acceptance and the selection efficiency for a BSM signal. The 95% confidence level (CL) limits are computed using the *CLs* prescription [75]. Table 7 summarises, for each signal region, the estimated SM background yield, the observed numbers of events, and the expected and observed upper limits on event yields from a BSM signal and on σ_{vis} .

The results are interpreted in various SUSY scenarios assuming a SUSY particle mass hierarchy such that the lightest third-generation squark decays exclusively via $\tilde{b}_1 \rightarrow b\tilde{\chi}_1^0$ or $\tilde{t}_1 \rightarrow b\tilde{\chi}_1^\pm$ for production of sbottom or stop pairs, respectively. For the latter case, two different values of Δm between the lightest chargino and neutralino are probed to assess the impact of the lepton and jet vetoes applied in the analysis.

Systematic uncertainties on the signal acceptance include experimental uncertainties, mostly dominated by *b*-tagging (20–30% in SRA, \sim 15–30% in SRB) and JES (4–30% in SRA, 20–40% in SRB) uncertainties. These uncertainties are assumed to be fully correlated with those of the background.

For SRB, the uncertainties due to the modelling of ISR processes are assessed by changing the strength of the parton shower controlled by PYTHIA and by doubling and halving the values of the following three parameters: (i) the factorisation and renormalisation scales; (ii) the matching distance between a parton and a jet; (iii) the scale at which α_S is evaluated at every parton radiation step. The relative changes due to each of these individual variations are assumed to be uncorrelated and are added in quadrature. The overall uncertainty due to ISR depends on the mass difference between the squark and the LSP, with a maximum value of 30% on the signal acceptance when the mass difference is on the order of 10 GeV and quickly dropping down to a plateau of 7–10% for mass differences above 25 GeV. This uncertainty has a negligible dependence on the squark mass for the mass range considered in this analysis.

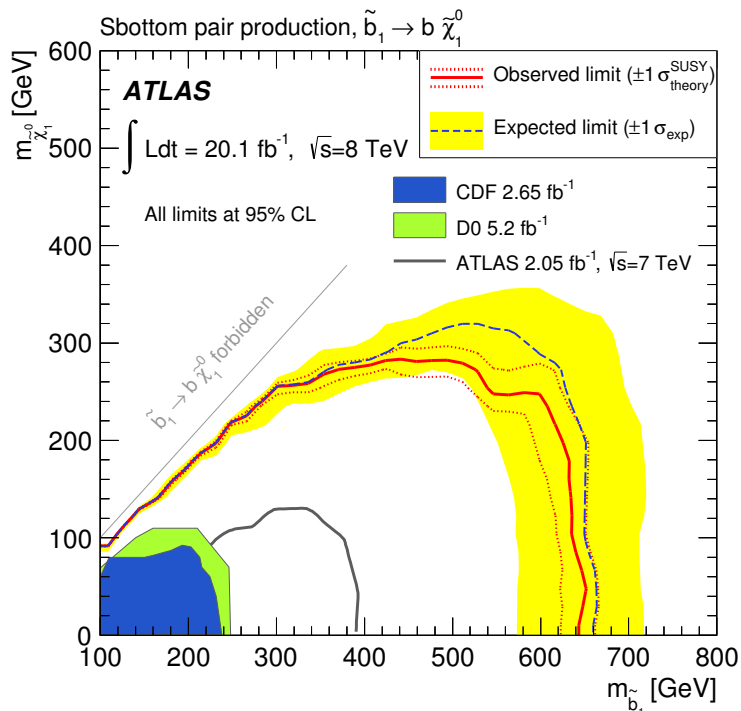


Figure 5. Expected and observed exclusion limits at 95% CL in the $(m_{\tilde{b}_1}, m_{\tilde{\chi}_1^0})$ mass plane for the sbottom pair production scenario considered. The signal region providing the best expected CLs exclusion limit is chosen at each point. The dashed (solid) lines show the expected (observed) limits, including all uncertainties except for the theoretical signal cross-section uncertainty (PDF and scale). The bands around the expected limits show the $\pm 1\sigma$ uncertainties. The dotted 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. Previous limits published by ATLAS [23], CDF [32] and D0 [33] are also shown.

Figure 5 shows the observed (solid lines) and expected (dashed lines) exclusion limits for the sbottom pair production scenario obtained by taking, for each signal mass configuration, the signal region with the best expected limit. These limits are obtained using a likelihood test which compares the observed numbers of events in the signal regions with the fitted background expectation and the ensuing signal contamination in the corresponding CRs for a given model. Sensitivity to scenarios with large mass difference ($> 100 \text{ GeV}$) between the \tilde{b}_1 and the $\tilde{\chi}_1^0$ is achieved with the successive m_{CT} thresholds used in SRA. Sensitivity to scenarios with smaller mass differences is achieved predominantly with the dedicated SRB selection. Sbottom masses up to 620 GeV are excluded at 95% CL for $m_{\tilde{\chi}_1^0} < 120 \text{ GeV}$. Differences in mass above 50 GeV between the \tilde{b}_1 and the $\tilde{\chi}_1^0$ are excluded up to sbottom masses of 300 GeV. If the branching ratio of $\tilde{b}_1 \rightarrow b \tilde{\chi}_1^0$ is reduced to 60% and assuming that the analysis is not sensitive to other possible decays, the excluded upper limit on the sbottom mass for $m_{\tilde{\chi}_1^0} < 150 \text{ GeV}$ is reduced to 520 GeV. Similarly for $m_{\tilde{b}_1} = 250 \text{ GeV}$, the upper limit on $m_{\tilde{\chi}_1^0}$ is reduced by 30 GeV.

In the case of stop pair production with the stop decaying only into $b \tilde{\chi}_1^\pm$, the model depends on the masses of the three SUSY particles involved in the decay, $m_{\tilde{t}_1}$, $m_{\tilde{\chi}_1^\pm}$ and $m_{\tilde{\chi}_1^0}$. Limits are derived using the same procedure adopted for the sbottom pair production

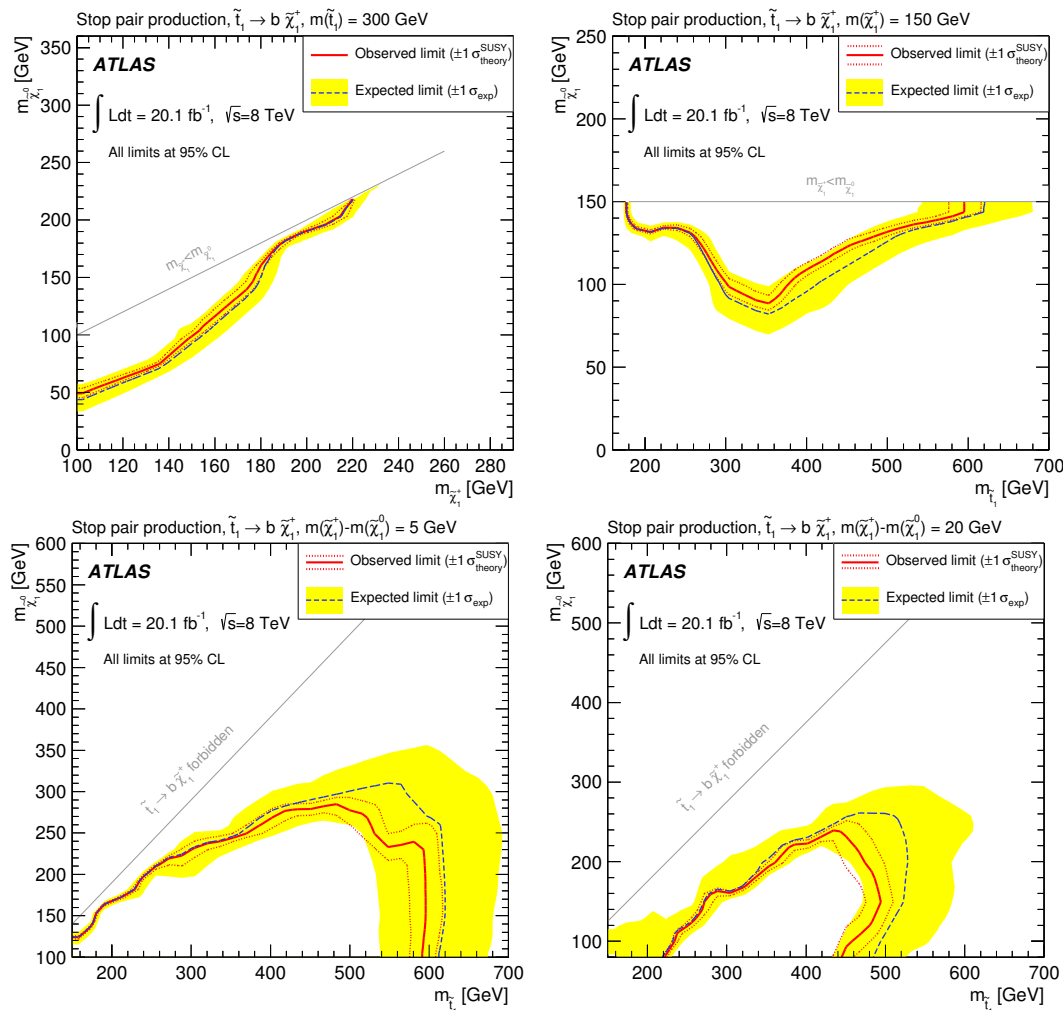


Figure 6. Expected and observed exclusion limits at 95% CL for the different stop pair production scenarios considered. Upper left: $(m_{\tilde{\chi}_1^\pm}, m_{\tilde{\chi}_1^0})$ mass plane with $m_{\tilde{t}_1} = 300$ GeV. Upper right: $(m_{\tilde{t}_1}, m_{\tilde{\chi}_1^0})$ mass plane with $m_{\tilde{\chi}_1^\pm} = 150$ GeV. Lower left: $(m_{\tilde{t}_1}, m_{\tilde{\chi}_1^0})$ mass plane with $m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} = 5$ GeV. Lower right: $(m_{\tilde{t}_1}, m_{\tilde{\chi}_1^0})$ mass plane with $m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} = 20$ GeV. The signal region providing the best expected CL_s exclusion limit is chosen at each point. 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 $\pm 1\sigma$ uncertainties. The dotted 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. The excluded regions are above (below) the curves for the upper (lower) figures. For the bottom two figures, the lower bound of the vertical axis corresponds to the LEP limit of the lightest chargino mass, 103.5 GeV [34–36].

scenario and are presented in figure 6 under the additional assumptions that $m_{\tilde{t}_1} = 300$ GeV (upper left), $m_{\tilde{\chi}_1^\pm} = 150$ GeV (upper right), or for a fixed value of the mass difference $\Delta m = m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0}$ of 5 GeV (lower left) and 20 GeV (lower right). The limits presented assume that the chargino decays promptly at the interaction point, as it is the case for $\Delta m \gtrsim 100$ MeV [76]. Stop masses up to 580 GeV (440 GeV) are excluded for $\Delta m = 5$ GeV (20 GeV) and for

$m_{\tilde{\chi}_1^0} = 100$ GeV. For $\Delta m = 5$ GeV (20 GeV), neutralino masses up to 270 GeV (220 GeV) are excluded for $m_{\tilde{t}_1} = 420$ GeV. In the $\Delta m = 20$ GeV, a smaller fraction of the $(m_{\tilde{t}_1}, m_{\tilde{\chi}_1^0})$ plane is excluded since this scenario has a lower efficiency given that electrons and muons often have a p_T above the reconstruction threshold.

9 Conclusions

The results of a search for third-generation squark pair production in pp collisions at $\sqrt{s} = 8$ TeV based on 20.1 fb⁻¹ of ATLAS data are reported. Events with large E_T^{miss} and two b -tagged jets are analysed. The results are in agreement with SM predictions for backgrounds and translate into 95% CL upper limits on the sbottom (stop) and neutralino masses in a given MSSM scenario for which the exclusive decay $\tilde{b}_1 \rightarrow b\tilde{\chi}_1^0$ ($\tilde{t}_1 \rightarrow b\tilde{\chi}_1^\pm$) is assumed. For sbottom pairs decaying exclusively to $b\tilde{\chi}_1^0$, sbottom masses up to 620 GeV are excluded at 95% CL for $m_{\tilde{\chi}_1^0} < 150$ GeV. Differences in mass above 50 GeV between the \tilde{b}_1 and the $\tilde{\chi}_1^0$ are excluded up to sbottom masses of 300 GeV. These limits significantly extend previous results.

For stop pairs decaying exclusively into $b\tilde{\chi}_1^\pm$, stop masses up to 580 GeV (440 GeV) are excluded for $\Delta m = m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} = 5$ GeV (20 GeV) and for $m_{\tilde{\chi}_1^0} = 100$ GeV. For $\Delta m = 5$ GeV (20 GeV), neutralino masses up to 270 GeV (220 GeV) are excluded for $m_{\tilde{t}_1} = 420$ GeV.

Acknowledgements

We thank CERN for the very successful operation of the LHC, as well as the support staff from our institutions without whom ATLAS could not be operated efficiently.

We acknowledge the support of ANPCyT, Argentina; YerPhI, Armenia; ARC, Australia; BMWF and FWF, Austria; ANAS, Azerbaijan; SSTC, Belarus; CNPq and FAPESP, Brazil; NSERC, NRC and CFI, Canada; CERN; CONICYT, Chile; CAS, MOST and NSFC, China; COLCIENCIAS, Colombia; MSMT CR, MPO CR and VSC CR, Czech Republic; DNRf, DNSRC and Lundbeck Foundation, Denmark; EPLANET, ERC and NSRF, European Union; IN2P3-CNRS, CEA-DSM/IRFU, France; GNSF, Georgia; BMBF, DFG, HGF, MPG and AvH Foundation, Germany; GSRT and NSRF, Greece; ISF, MINERVA, GIF, DIP and Benoziyo Center, Israel; INFN, Italy; MEXT and JSPS, Japan; CNRST, Morocco; FOM and NWO, Netherlands; BRF and RCN, Norway; MNiSW, Poland; GRICES and FCT, Portugal; MERYS (MECTS), Romania; MES of Russia and ROSATOM, Russian Federation; JINR; MSTD, Serbia; MSSR, Slovakia; ARRS and MIZŠ, Slovenia; DST/NRF, South Africa; MICINN, Spain; SRC and Wallenberg Foundation, Sweden; SER, SNSF and Cantons of Bern and Geneva, Switzerland; NSC, Taiwan; TAEK, Turkey; STFC, the Royal Society and Leverhulme Trust, United Kingdom; DOE and NSF, United States of America.

The crucial computing support from all WLCG partners is acknowledged gratefully, in particular from CERN and the ATLAS Tier-1 facilities at TRIUMF (Canada), NDGF (Denmark, Norway, Sweden), CC-IN2P3 (France), KIT/GridKA (Germany), INFN-CNAF (Italy), NL-T1 (Netherlands), PIC (Spain), ASGC (Taiwan), RAL (UK) and BNL (USA) and in the Tier-2 facilities worldwide.

Open Access. This article is distributed under the terms of the Creative Commons Attribution License which permits any use, distribution and reproduction in any medium, provided the original author(s) and source are credited.

References

- [1] H. Miyazawa, *Baryon number changing currents*, *Prog. Theor. Phys.* **36** (1966) 1266.
- [2] P. Ramond, *Dual theory for free fermions*, *Phys. Rev. D* **3** (1971) 2415 [INSPIRE].
- [3] Y. Golfand and E. Likhtman, *Extension of the algebra of Poincaré group generators and violation of p invariance*, *JETP Lett.* **13** (1971) 323 [INSPIRE].
- [4] A. Neveu and J. Schwarz, *Factorizable dual model of pions*, *Nucl. Phys. B* **31** (1971) 86 [INSPIRE].
- [5] A. Neveu and J. Schwarz, *Quark model of dual pions*, *Phys. Rev. D* **4** (1971) 1109 [INSPIRE].
- [6] J.-L. Gervais and B. Sakita, *Field theory interpretation of supergauge in dual models*, *Nucl. Phys. B* **34** (1971) 632 [INSPIRE].
- [7] D.V. Volkov and V.P. Akulov, *Is the neutrino a goldstone particle?*, *Phys. Lett. B* **46** (1973) 109 [INSPIRE].
- [8] J. Wess and B. Zumino, *A lagrangian model invariant under supergauge transformations*, *Phys. Lett. B* **49** (1974) 52 [INSPIRE].
- [9] J. Wess and B. Zumino, *Supergauge transformations in four-dimensions*, *Nucl. Phys. B* **70** (1974) 39 [INSPIRE].
- [10] S. Weinberg, *Implications of dynamical symmetry breaking*, *Phys. Rev. D* **13** (1976) 974 [INSPIRE].
- [11] E. Gildener, *Gauge symmetry hierarchies*, *Phys. Rev. D* **14** (1976) 1667 [INSPIRE].
- [12] S. Weinberg, *Implications of dynamical symmetry breaking: an addendum*, *Phys. Rev. D* **19** (1979) 1277 [INSPIRE].
- [13] L. Susskind, *Dynamics of spontaneous symmetry breaking in the Weinberg-Salam theory*, *Phys. Rev. D* **20** (1979) 2619 [INSPIRE].
- [14] P. Fayet, *Supersymmetry and weak, electromagnetic and strong interactions*, *Phys. Lett. B* **64** (1976) 159 [INSPIRE].
- [15] P. Fayet, *Spontaneously broken supersymmetric theories of weak, electromagnetic and strong interactions*, *Phys. Lett. B* **69** (1977) 489 [INSPIRE].
- [16] G.R. Farrar and P. Fayet, *Phenomenology of the production, decay and detection of new hadronic states associated with supersymmetry*, *Phys. Lett. B* **76** (1978) 575 [INSPIRE].
- [17] P. Fayet, *Relations between the masses of the superpartners of leptons and quarks, the goldstino couplings and the neutral currents*, *Phys. Lett. B* **84** (1979) 416 [INSPIRE].
- [18] S. Dimopoulos and H. Georgi, *Softly broken supersymmetry and SU(5)*, *Nucl. Phys. B* **193** (1981) 150 [INSPIRE].
- [19] L. Evans and P. Bryant, *LHC machine*, *2008 JINST* **3** S08001 [INSPIRE].
- [20] R. Barbieri and G. Giudice, *Upper bounds on supersymmetric particle masses*, *Nucl. Phys. B* **306** (1988) 63 [INSPIRE].

- [21] B. de Carlos and J. Casas, *One loop analysis of the electroweak breaking in supersymmetric models and the fine tuning problem*, *Phys. Lett. B* **309** (1993) 320 [[hep-ph/9303291](#)] [[INSPIRE](#)].
- [22] M. Papucci, J.T. Ruderman and A. Weiler, *Natural SUSY endures*, *JHEP* **09** (2012) 035 [[arXiv:1110.6926](#)] [[INSPIRE](#)].
- [23] ATLAS collaboration, *Search for scalar bottom pair production with the ATLAS detector in pp collisions at $\sqrt{s} = 7$ TeV*, *Phys. Rev. Lett.* **108** (2012) 181802 [[arXiv:1112.3832](#)] [[INSPIRE](#)].
- [24] ATLAS collaboration, *Search for a heavy top-quark partner in final states with two leptons with the ATLAS detector at the LHC*, *JHEP* **11** (2012) 094 [[arXiv:1209.4186](#)] [[INSPIRE](#)].
- [25] ATLAS collaboration, *Search for light top squark pair production in final states with leptons and b^- jets with the ATLAS detector in $\sqrt{s} = 7$ TeV proton-proton collisions*, *Phys. Lett. B* **720** (2013) 13 [[arXiv:1209.2102](#)] [[INSPIRE](#)].
- [26] ATLAS collaboration, *Search for light scalar top quark pair production in final states with two leptons with the ATLAS detector in $\sqrt{s} = 7$ TeV proton-proton collisions*, *Eur. Phys. J. C* **72** (2012) 2237 [[arXiv:1208.4305](#)] [[INSPIRE](#)].
- [27] ATLAS collaboration, *Search for direct top squark pair production in final states with one isolated lepton, jets and missing transverse momentum in $\sqrt{s} = 7$ TeV pp collisions using 4.7 fb^{-1} of ATLAS data*, *Phys. Rev. Lett.* **109** (2012) 211803 [[arXiv:1208.2590](#)] [[INSPIRE](#)].
- [28] ATLAS collaboration, *Search for a supersymmetric partner to the top quark in final states with jets and missing transverse momentum at $\sqrt{s} = 7$ TeV with the ATLAS detector*, *Phys. Rev. Lett.* **109** (2012) 211802 [[arXiv:1208.1447](#)] [[INSPIRE](#)].
- [29] CMS collaboration, *Search for new physics in events with same-sign dileptons and b jets in pp collisions at $\sqrt{s} = 8$ TeV*, *JHEP* **03** (2013) 037 [Erratum *ibid.* **1307** (2013) 041] [[arXiv:1212.6194](#)] [[INSPIRE](#)].
- [30] CMS collaboration, *Search for supersymmetry in final states with missing transverse energy and 0, 1, 2, or at least 3 b-quark jets in 7 TeV pp collisions using the variable α_T* , *JHEP* **01** (2013) 077 [[arXiv:1210.8115](#)] [[INSPIRE](#)].
- [31] CMS collaboration, *Search for supersymmetry in hadronic final states with missing transverse energy using the variables α_T and b-quark multiplicity in pp collisions at 8 TeV*, *Eur. Phys. J. C* **73** (2013) 2568 [[arXiv:1303.2985](#)] [[INSPIRE](#)].
- [32] CDF collaboration, T. Aaltonen et al., *Search for the production of scalar bottom quarks in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV*, *Phys. Rev. Lett.* **105** (2010) 081802 [[arXiv:1005.3600](#)] [[INSPIRE](#)].
- [33] D0 collaboration, V.M. Abazov et al., *Search for scalar bottom quarks and third-generation leptoquarks in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV*, *Phys. Lett. B* **693** (2010) 95 [[arXiv:1005.2222](#)] [[INSPIRE](#)].
- [34] LEP SUSY Working Group, *Combined LEP chargino results, up to 208 GeV for large m_0* , [LEPSUSYWG/01-03.1](#) (2001).
- [35] LEP SUSY Working Group, *Combined LEP selectron/smuon/stau results, 183–208 GeV*, [LEPSUSYWG/04-01.1](#) (2004).
- [36] <http://lepsusy.web.cern.ch/lepsusy/Welcome.html>.
- [37] ATLAS collaboration, *The ATLAS experiment at the CERN Large Hadron Collider*, *2008 JINST* **3** S08003 [[INSPIRE](#)].

- [38] ATLAS collaboration, *Improved luminosity determination in pp collisions at $\sqrt{s} = 7$ TeV using the ATLAS detector at the LHC*, *Eur. Phys. J. C* **73** (2013) 2518 [[arXiv:1302.4393](#)] [[INSPIRE](#)].
- [39] ATLAS collaboration, *ATLAS tunes of PYTHIA 6 and PYTHIA 8 for MC11*, *ATL-PHYS-PUB-2011-009* (2011).
- [40] ATLAS collaboration, *The ATLAS simulation infrastructure*, *Eur. Phys. J. C* **70** (2010) 823 [[arXiv:1005.4568](#)] [[INSPIRE](#)].
- [41] GEANT4 collaboration, S. Agostinelli et al., *GEANT4: a simulation toolkit*, *Nucl. Instrum. Meth. A* **506** (2003) 250 [[INSPIRE](#)].
- [42] ATLAS collaboration, *The simulation principle and performance of the ATLAS fast calorimeter simulation FastCaloSim*, *ATL-PHYS-PUB-2010-013* (2010).
- [43] S. Frixione, P. Nason and C. Oleari, *Matching NLO QCD computations with Parton Shower simulations: the POWHEG method*, *JHEP* **11** (2007) 070 [[arXiv:0709.2092](#)] [[INSPIRE](#)].
- [44] T. Sjöstrand, S. Mrenna and P.Z. Skands, *PYTHIA 6.4 physics and manual*, *JHEP* **05** (2006) 026 [[hep-ph/0603175](#)] [[INSPIRE](#)].
- [45] P.M. Nadolsky, H.-L. Lai, Q.-H. Cao, J. Huston, J. Pumplin, et al., *Implications of CTEQ global analysis for collider observables*, *Phys. Rev. D* **78** (2008) 013004 [[arXiv:0802.0007](#)] [[INSPIRE](#)].
- [46] M.L. Mangano, M. Moretti, F. Piccinini, R. Pittau and A.D. Polosa, *ALPGEN, a generator for hard multiparton processes in hadronic collisions*, *JHEP* **07** (2003) 001 [[hep-ph/0206293](#)] [[INSPIRE](#)].
- [47] J. Butterworth, J.R. Forshaw and M. Seymour, *Multiparton interactions in photoproduction at HERA*, *Z. Phys. C* **72** (1996) 637 [[hep-ph/9601371](#)] [[INSPIRE](#)].
- [48] B.P. Kersevan and E. Richter-Was, *The Monte Carlo event generator AcerMC versions 2.0 to 3.8 with interfaces to PYTHIA 6.4, HERWIG 6.5 and ARIADNE 4.1*, *Comput. Phys. Commun.* **184** (2013) 919 [[INSPIRE](#)].
- [49] J. Alwall, M. Herquet, F. Maltoni, O. Mattelaer and T. Stelzer, *MadGraph 5: going beyond*, *JHEP* **06** (2011) 128 [[arXiv:1106.0522](#)] [[INSPIRE](#)].
- [50] T. Gleisberg et al., *Event generation with SHERPA 1.1*, *JHEP* **02** (2009) 007 [[arXiv:0811.4622](#)] [[INSPIRE](#)].
- [51] S. Catani, L. Cieri, G. Ferrera, D. de Florian and M. Grazzini, *Vector boson production at hadron colliders: a fully exclusive QCD calculation at NNLO*, *Phys. Rev. Lett.* **103** (2009) 082001 [[arXiv:0903.2120](#)] [[INSPIRE](#)].
- [52] A. Martin, W. Stirling, R. Thorne and G. Watt, *Parton distributions for the LHC*, *Eur. Phys. J. C* **63** (2009) 189 [[arXiv:0901.0002](#)] [[INSPIRE](#)].
- [53] M. Aliev et al., *HATHOR: HAdronic Top and Heavy quarks crOss section calculatoR*, *Comput. Phys. Commun.* **182** (2011) 1034 [[arXiv:1007.1327](#)] [[INSPIRE](#)].
- [54] N. Kidonakis, *Two-loop soft anomalous dimensions for single top quark associated production with a W^- or H^-* , *Phys. Rev. D* **82** (2010) 054018 [[arXiv:1005.4451](#)] [[INSPIRE](#)].
- [55] M. Garzelli, A. Kardos, C. Papadopoulos and Z. Trócsányi, *$t\bar{t} W^{+-}$ and $t\bar{t} Z$ Hadroproduction at NLO accuracy in QCD with Parton Shower and Hadronization effects*, *JHEP* **11** (2012) 056 [[arXiv:1208.2665](#)] [[INSPIRE](#)].
- [56] T. Binoth, M. Ciccolini, N. Kauer and M. Krämer, *Gluon-induced W-boson pair production at the LHC*, *JHEP* **12** (2006) 046 [[hep-ph/0611170](#)] [[INSPIRE](#)].

- [57] W. Beenakker, M. Krämer, T. Plehn, M. Spira and P. Zerwas, *Stop production at hadron colliders*, *Nucl. Phys. B* **515** (1998) 3 [[hep-ph/9710451](#)] [[INSPIRE](#)].
- [58] W. Beenakker et al., *Supersymmetric top and bottom squark production at hadron colliders*, *JHEP* **08** (2010) 098 [[arXiv:1006.4771](#)] [[INSPIRE](#)].
- [59] W. Beenakker et al., *Squark and gluino hadroproduction*, *Int. J. Mod. Phys. A* **26** (2011) 2637 [[arXiv:1105.1110](#)] [[INSPIRE](#)].
- [60] M. Krämer et al., *Supersymmetry production cross sections in pp collisions at $\sqrt{s} = 7$ TeV*, [arXiv:1206.2892](#) [[INSPIRE](#)].
- [61] M. Cacciari, G.P. Salam and G. Soyez, *The anti- k_t jet clustering algorithm*, *JHEP* **04** (2008) 063 [[arXiv:0802.1189](#)] [[INSPIRE](#)].
- [62] M. Cacciari and G.P. Salam, *Dispelling the N^3 myth for the k_t jet-finder*, *Phys. Lett. B* **641** (2006) 57 [[hep-ph/0512210](#)] [[INSPIRE](#)].
- [63] ATLAS collaboration, *Jet energy measurement with the ATLAS detector in proton-proton collisions at $\sqrt{s} = 7$ TeV*, *Eur. Phys. J. C* **73** (2013) 2304 [[arXiv:1112.6426](#)] [[INSPIRE](#)].
- [64] ATLAS collaboration, *Commissioning of the ATLAS high-performance b-tagging algorithms in the 7 TeV collision data*, [ATLAS-CONF-2011-102](#) (2011).
- [65] ATLAS collaboration, *Electron performance measurements with the ATLAS detector using the 2010 LHC proton-proton collision data*, *Eur. Phys. J. C* **72** (2012) 1909 [[arXiv:1110.3174](#)] [[INSPIRE](#)].
- [66] ATLAS collaboration, *Measurement of the $W \rightarrow \ell\nu$ and $Z/\gamma^* \rightarrow \ell\ell$ production cross sections in proton-proton collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector*, *JHEP* **12** (2010) 060 [[arXiv:1010.2130](#)] [[INSPIRE](#)].
- [67] ATLAS collaboration, *Performance of missing transverse momentum reconstruction in proton-proton collisions at 7 TeV with ATLAS*, *Eur. Phys. J. C* **72** (2012) 1844 [[arXiv:1108.5602](#)] [[INSPIRE](#)].
- [68] D.R. Tovey, *On measuring the masses of pair-produced semi-invisibly decaying particles at hadron colliders*, *JHEP* **04** (2008) 034 [[arXiv:0802.2879](#)] [[INSPIRE](#)].
- [69] G. Polesello and D.R. Tovey, *Supersymmetric particle mass measurement with the boost-corrected contranverse mass*, *JHEP* **03** (2010) 030 [[arXiv:0910.0174](#)] [[INSPIRE](#)].
- [70] ATLAS collaboration, *Search for squarks and gluinos with the ATLAS detector in final states with jets and missing transverse momentum using 4.7 fb^{-1} of $\sqrt{s} = 7$ TeV proton-proton collision data*, *Phys. Rev. D* **87** (2013) 012008 [[arXiv:1208.0949](#)] [[INSPIRE](#)].
- [71] ATLAS collaboration, *Single hadron response measurement and calorimeter jet energy scale uncertainty with the ATLAS detector at the LHC*, *Eur. Phys. J. C* **73** (2013) 2305 [[arXiv:1203.1302](#)] [[INSPIRE](#)].
- [72] ATLAS collaboration, *Measurement of $t\bar{t}$ production with a veto on additional central jet activity in pp collisions at $\sqrt{s} = 7$ TeV using the ATLAS detector*, *Eur. Phys. J. C* **72** (2012) 2043 [[arXiv:1203.5015](#)] [[INSPIRE](#)].
- [73] ATLAS collaboration, *Measurement of the cross-section for W boson production in association with b-jets in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector*, *JHEP* **06** (2013) 084 [[arXiv:1302.2929](#)] [[INSPIRE](#)].
- [74] J.M. Campbell and R.K. Ellis, *$t\bar{t}W^{+-}$ production and decay at NLO*, *JHEP* **07** (2012) 052 [[arXiv:1204.5678](#)] [[INSPIRE](#)].

- [75] A.L. Read, *Presentation of search results: the CL(s) technique*, *J. Phys. G* **28** (2002) 2693 [[INSPIRE](#)].
- [76] C. Chen, M. Drees and J. Gunion, *A nonstandard string/SUSY scenario and its phenomenological implications*, *Phys. Rev. D* **55** (1997) 330 [*Erratum ibid.* **D 60** (1999) 039901] [[hep-ph/9607421](#)] [[INSPIRE](#)].

The ATLAS collaboration

G. Aad⁴⁸, T. Abajyan²¹, B. Abbott¹¹², J. Abdallah¹², S. Abdel Khalek¹¹⁶, O. Abdinov¹¹, R. Aben¹⁰⁶, B. Abi¹¹³, M. Abolins⁸⁹, O.S. AbouZeid¹⁵⁹, H. Abramowicz¹⁵⁴, H. Abreu¹³⁷, Y. Abulaiti^{147a,147b}, B.S. Acharya^{165a,165b,a}, L. Adamczyk^{38a}, D.L. Adams²⁵, T.N. Addy⁵⁶, J. Adelman¹⁷⁷, S. Adomeit⁹⁹, T. Adye¹³⁰, S. Aefsky²³, T. Agatonovic-Jovin^{13b}, J.A. Aguilar-Saavedra^{125b,b}, M. Agustoni¹⁷, S.P. Ahlen²², A. Ahmad¹⁴⁹, M. Ahsan⁴¹, G. Aielli^{134a,134b}, T.P.A. Åkesson⁸⁰, G. Akimoto¹⁵⁶, A.V. Akimov⁹⁵, M.A. Alam⁷⁶, J. Albert¹⁷⁰, S. Albrand⁵⁵, M.J. Alconada Verzini⁷⁰, M. Aleksa³⁰, I.N. Aleksandrov⁶⁴, F. Alessandria^{90a}, C. Alexa^{26a}, G. Alexander¹⁵⁴, G. Alexandre⁴⁹, T. Alexopoulos¹⁰, M. Alhroob^{165a,165c}, M. Aliev¹⁶, G. Alimonti^{90a}, L. Alio⁸⁴, J. Alison³¹, B.M.M. Allbrooke¹⁸, L.J. Allison⁷¹, P.P. Allport⁷³, S.E. Allwood-Spiers⁵³, J. Almond⁸³, A. Aloisio^{103a,103b}, R. Alon¹⁷³, A. Alonso³⁶, F. Alonso⁷⁰, A. Altheimer³⁵, B. Alvarez Gonzalez⁸⁹, M.G. Alvigi^{103a,103b}, K. Amako⁶⁵, Y. Amaral Coutinho^{24a}, C. Amelung²³, V.V. Ammosov^{129,*}, S.P. Amor Dos Santos^{125a}, A. Amorim^{125a,c}, S. Amoroso⁴⁸, N. Amram¹⁵⁴, C. Anastopoulos³⁰, L.S. Ancu¹⁷, N. Andari³⁰, T. Andeen³⁵, C.F. Anders^{58b}, G. Anders^{58a}, K.J. Anderson³¹, A. Andreazza^{90a,90b}, V. Andrei^{58a}, X.S. Anduaga⁷⁰, S. Angelidakis⁹, P. Anger⁴⁴, A. Angerami³⁵, F. Anghinolfi³⁰, A.V. Anisenkov¹⁰⁸, N. Anjos^{125a}, A. Annovi⁴⁷, A. Antonaki⁹, M. Antonelli⁴⁷, A. Antonov⁹⁷, J. Antos^{145b}, F. Anulli^{133a}, M. Aoki¹⁰², L. Aperio Bella¹⁸, R. Apolle^{119,d}, G. Arabidze⁸⁹, I. Aracena¹⁴⁴, Y. Arai⁶⁵, A.T.H. Arce⁴⁵, S. Arfaoui¹⁴⁹, J-F. Arguin⁹⁴, S. Argyropoulos⁴², E. Arik^{19a,*}, M. Arik^{19a}, A.J. Armbruster⁸⁸, O. Arnaez⁸², V. Arnal⁸¹, O. Arslan²¹, A. Artamonov⁹⁶, G. Artoni^{133a,133b}, D. Arutinov²¹, S. Asai¹⁵⁶, N. Asbah⁹⁴, S. Ask²⁸, B. Åsman^{147a,147b}, L. Asquith⁶, K. Assamagan²⁵, R. Astalos^{145a}, A. Astbury¹⁷⁰, M. Atkinson¹⁶⁶, N.B. Atlay¹⁴², B. Auerbach⁶, E. Auge¹¹⁶, K. Augsten¹²⁷, M. Aurousseau^{146b}, G. Avolio³⁰, D. Axen¹⁶⁹, G. Azuelos^{94,e}, Y. Azuma¹⁵⁶, M.A. Baak³⁰, C. Bacci^{135a,135b}, A.M. Bach¹⁵, H. Bachacou¹³⁷, K. Bachas¹⁵⁵, M. Backes³⁰, M. Backhaus²¹, J. Backus Mayes¹⁴⁴, E. Badescu^{26a}, P. Bagiacchi^{133a,133b}, P. Bagnaia^{133a,133b}, Y. Bai^{33a}, D.C. Bailey¹⁵⁹, T. Bain³⁵, J.T. Baines¹³⁰, O.K. Baker¹⁷⁷, S. Baker⁷⁷, P. Balek¹²⁸, F. Balli¹³⁷, E. Banas³⁹, Sw. Banerjee¹⁷⁴, D. Banfi³⁰, A. Bangert¹⁵¹, V. Bansal¹⁷⁰, H.S. Bansil¹⁸, L. Barak¹⁷³, S.P. Baranov⁹⁵, T. Barber⁴⁸, E.L. Barberio⁸⁷, D. Barberis^{50a,50b}, M. Barbero⁸⁴, D.Y. Bardin⁶⁴, T. Barillari¹⁰⁰, M. Barisonzi¹⁷⁶, T. Barklow¹⁴⁴, N. Barlow²⁸, B.M. Barnett¹³⁰, R.M. Barnett¹⁵, A. Baroncelli^{135a}, G. Barone⁴⁹, A.J. Barr¹¹⁹, F. Barreiro⁸¹, J. Barreiro Guimarães da Costa⁵⁷, R. Bartoldus¹⁴⁴, A.E. Barton⁷¹, V. Bartsch¹⁵⁰, A. Basye¹⁶⁶, R.L. Bates⁵³, L. Batkova^{145a}, J.R. Batley²⁸, M. Battistin³⁰, F. Bauer¹³⁷, H.S. Bawa^{144,f}, S. Beale⁹⁹, T. Beau⁷⁹, P.H. Beauchemin¹⁶², R. Beccherle^{50a}, P. Bechtel²¹, H.P. Beck¹⁷, K. Becker¹⁷⁶, S. Becker⁹⁹, M. Beckingham¹³⁹, K.H. Becks¹⁷⁶, A.J. Beddall^{19c}, A. Beddall^{19c}, S. Bedikian¹⁷⁷, V.A. Bednyakov⁶⁴, C.P. Bee⁸⁴, L.J. Beemster¹⁰⁶, T.A. Beermann¹⁷⁶, M. Begel²⁵, C. Belanger-Champagne⁸⁶, P.J. Bell⁴⁹, W.H. Bell⁴⁹, G. Bella¹⁵⁴, L. Bellagamba^{20a}, A. Bellerive²⁹, M. Bellomo³⁰, A. Belloni⁵⁷, O.L. Beloborodova^{108,g}, K. Belotskiy⁹⁷, O. Beltramello³⁰, O. Benary¹⁵⁴, D. Benchekroun^{136a}, K. Bendtz^{147a,147b}, N. Benekos¹⁶⁶, Y. Benhammou¹⁵⁴, E. Benhar Nocchioli⁴⁹, J.A. Benitez Garcia^{160b}, D.P. Benjamin⁴⁵, J.R. Bensinger²³, K. Benslama¹³¹, S. Bentvelsen¹⁰⁶, D. Berge³⁰, E. Bergeas Kuutmann¹⁶, N. Berger⁵, F. Berghaus¹⁷⁰, E. Berglund¹⁰⁶, J. Beringer¹⁵, C. Bernard²², P. Bernat⁷⁷, R. Bernhard⁴⁸, C. Bernius⁷⁸, F.U. Bernlochner¹⁷⁰, T. Berry⁷⁶, C. Bertella⁸⁴, F. Bertolucci^{123a,123b}, M.I. Besana^{90a}, G.J. Besjes¹⁰⁵, O. Bessidskaia^{147a,147b}, N. Besson¹³⁷, S. Bethke¹⁰⁰, W. Bhimji⁴⁶, R.M. Bianchi¹²⁴, L. Bianchini²³, M. Bianco^{72a,72b}, O. Biebel⁹⁹, S.P. Bieniek⁷⁷, K. Bierwagen⁵⁴, J. Biesiada¹⁵, M. Biglietti^{135a}, J. Bilbao De Mendizabal⁴⁹, H. Bilokon⁴⁷, M. Bindi^{20a,20b}, S. Binet¹¹⁶, A. Bingul^{19c}, C. Bini^{133a,133b}, B. Bittner¹⁰⁰, C.W. Black¹⁵¹, J.E. Black¹⁴⁴, K.M. Black²², D. Blackburn¹³⁹, R.E. Blair⁶, J.-B. Blanchard¹³⁷, T. Blazek^{145a}, I. Bloch⁴², C. Blocker²³, J. Blocki³⁹, W. Blum^{82,*}, U. Blumenschein⁵⁴, G.J. Bobbink¹⁰⁶, V.S. Bobrovnikov¹⁰⁸, S.S. Bocchetta⁸⁰, A. Bocchi⁴⁵, C.R. Boddy¹¹⁹, M. Boehler⁴⁸, J. Boek¹⁷⁶, T.T. Boek¹⁷⁶, N. Boelaert³⁶, J.A. Bogaerts³⁰, A.G. Bogdanchikov¹⁰⁸, A. Bogouch^{91,*}, C. Bohm^{147a}, J. Bohm¹²⁶, V. Boisvert⁷⁶, T. Bold^{38a}, V. Boldea^{26a}, N.M. Bolnet¹³⁷, M. Bomben⁷⁹, M. Bona⁷⁵, M. Boonekamp¹³⁷, S. Bordon⁷⁹,

C. Borer¹⁷, A. Borisov¹²⁹, G. Borissov⁷¹, M. Borri⁸³, S. Borroni⁴², J. Bortfeldt⁹⁹,
 V. Bortolotto^{135a,135b}, K. Bos¹⁰⁶, D. Boscherini^{20a}, M. Bosman¹², H. Boterenbrood¹⁰⁶,
 J. Bouchami⁹⁴, J. Boudreau¹²⁴, E.V. Bouhova-Thacker⁷¹, D. Boumediene³⁴, C. Bourdarios¹¹⁶,
 N. Bousson⁸⁴, S. Boutouil^{136d}, A. Boveia³¹, J. Boyd³⁰, I.R. Boyko⁶⁴, I. Bozovic-Jelisavcic^{13b},
 J. Bracinik¹⁸, P. Branchini^{135a}, A. Brandt⁸, G. Brandt¹⁵, O. Brandt⁵⁴, U. Bratzler¹⁵⁷, B. Brau⁸⁵,
 J.E. Brau¹¹⁵, H.M. Braun^{176,*}, S.F. Brazzale^{165a,165c}, B. Brelier¹⁵⁹, J. Bremer³⁰,
 K. Brendlinger¹²¹, R. Brenner¹⁶⁷, S. Bressler¹⁷³, T.M. Bristow⁴⁶, D. Britton⁵³, F.M. Brochu²⁸,
 I. Brock²¹, R. Brock⁸⁹, F. Broggi^{90a}, C. Bromberg⁸⁹, J. Bronner¹⁰⁰, G. Brooijmans³⁵, T. Brooks⁷⁶,
 W.K. Brooks^{32b}, E. Brost¹¹⁵, G. Brown⁸³, J. Brown⁵⁵, P.A. Bruckman de Renstrom³⁹,
 D. Bruncko^{145b}, R. Bruneliere⁴⁸, S. Brunet⁶⁰, A. Bruni^{20a}, G. Bruni^{20a}, M. Bruschi^{20a},
 L. Bryngemark⁸⁰, T. Buanes¹⁴, Q. Buat⁵⁵, F. Bucci⁴⁹, J. Buchanan¹¹⁹, P. Buchholz¹⁴²,
 R.M. Buckingham¹¹⁹, A.G. Buckley⁴⁶, S.I. Buda^{26a}, I.A. Budagov⁶⁴, B. Budick¹⁰⁹, F. Buehrer⁴⁸,
 L. Bugge¹¹⁸, O. Bulekov⁹⁷, A.C. Bundock⁷³, M. Bunse⁴³, T. Buran^{118,*}, H. Burckhart³⁰,
 S. Burdin⁷³, T. Burgess¹⁴, S. Burke¹³⁰, E. Busato³⁴, V. Büscher⁸², P. Bussey⁵³, C.P. Buszello¹⁶⁷,
 B. Butler⁵⁷, J.M. Butler²², C.M. Buttar⁵³, J.M. Butterworth⁷⁷, W. Buttinger²⁸, M. Byszewski¹⁰,
 S. Cabrera Urbán¹⁶⁸, D. Caforio^{20a,20b}, O. Cakir^{4a}, P. Calafiura¹⁵, G. Calderini⁷⁹, P. Calfayan⁹⁹,
 R. Calkins¹⁰⁷, L.P. Caloba^{24a}, R. Caloi^{133a,133b}, D. Calvet³⁴, S. Calvet³⁴, R. Camacho Toro⁴⁹,
 P. Camarri^{134a,134b}, D. Cameron¹¹⁸, L.M. Caminada¹⁵, R. Caminal Armadans¹², S. Campana³⁰,
 M. Campanelli⁷⁷, V. Canale^{103a,103b}, F. Canelli³¹, A. Canepa^{160a}, J. Cantero⁸¹, R. Cantrill⁷⁶,
 T. Cao⁴⁰, M.D.M. Capeans Garrido³⁰, I. Caprini^{26a}, M. Caprini^{26a}, D. Capriotti¹⁰⁰,
 M. Capua^{37a,37b}, R. Caputo⁸², R. Cardarelli^{134a}, T. Carli³⁰, G. Carlino^{103a}, L. Carminati^{90a,90b},
 S. Caron¹⁰⁵, E. Carquin^{32b}, G.D. Carrillo-Montoya^{146c}, A.A. Carter⁷⁵, J.R. Carter²⁸,
 J. Carvalho^{125a,h}, D. Casadei⁷⁷, M.P. Casado¹², C. Caso^{50a,50b,*}, E. Castaneda-Miranda¹⁷⁴,
 A. Castelli¹⁰⁶, V. Castillo Gimenez¹⁶⁸, N.F. Castro^{125a}, G. Cataldi^{72a}, P. Catastini⁵⁷,
 A. Catinaccio³⁰, J.R. Catmore³⁰, A. Cattai³⁰, G. Cattani^{134a,134b}, S. Caughron⁸⁹, V. Cavaliere¹⁶⁶,
 D. Cavalli^{90a}, M. Cavalli-Sforza¹², V. Cavasinni^{123a,123b}, F. Ceradini^{135a,135b}, B. Cerio⁴⁵,
 A.S. Cerqueira^{24b}, A. Cerri¹⁵, L. Cerrito⁷⁵, F. Cerutti¹⁵, A. Cervelli¹⁷, S.A. Cetin^{19b},
 A. Chafaq^{136a}, D. Chakraborty¹⁰⁷, I. Chalupkova¹²⁸, K. Chan³, P. Chang¹⁶⁶, B. Chapleau⁸⁶,
 J.D. Chapman²⁸, J.W. Chapman⁸⁸, D.G. Charlton¹⁸, V. Chavda⁸³, C.A. Chavez Barajas³⁰,
 S. Cheatham⁸⁶, S. Chekanov⁶, S.V. Chekulaev^{160a}, G.A. Chelkov⁶⁴, M.A. Chelstowska⁸⁸,
 C. Chen⁶³, H. Chen²⁵, S. Chen^{33c}, X. Chen¹⁷⁴, Y. Chen³⁵, Y. Cheng³¹, A. Cheplakov⁶⁴,
 R. Cherkaoui El Moursli^{136e}, V. Chernyatin^{25,*}, E. Cheu⁷, L. Chevalier¹³⁷, V. Chiarella⁴⁷,
 G. Chiefari^{103a,103b}, J.T. Childers³⁰, A. Chilingarov⁷¹, G. Chiodini^{72a}, A.S. Chisholm¹⁸,
 R.T. Chislett⁷⁷, A. Chitan^{26a}, M.V. Chizhov⁶⁴, G. Choudalakis³¹, S. Chouridou⁹, B.K.B. Chow⁹⁹,
 I.A. Christidi⁷⁷, A. Christov⁴⁸, D. Chromek-Burckhart³⁰, M.L. Chu¹⁵², J. Chudoba¹²⁶,
 G. Ciapetti^{133a,133b}, A.K. Ciftci^{4a}, R. Ciftci^{4a}, D. Cinca⁶², V. Cindro⁷⁴, A. Ciocio¹⁵, M. Cirilli⁸⁸,
 P. Cirkovic^{13b}, Z.H. Citron¹⁷³, M. Citterio^{90a}, M. Ciubancan^{26a}, A. Clark⁴⁹, P.J. Clark⁴⁶,
 R.N. Clarke¹⁵, J.C. Clemens⁸⁴, B. Clement⁵⁵, C. Clement^{147a,147b}, Y. Coadou⁸⁴,
 M. Cokal^{165a,165c}, A. Coccaro¹³⁹, J. Cochran⁶³, S. Coelli^{90a}, L. Coffey²³, J.G. Cogan¹⁴⁴,
 J. Coggeshall¹⁶⁶, J. Colas⁵, B. Cole³⁵, S. Cole¹⁰⁷, A.P. Colijn¹⁰⁶, C. Collins-Tooth⁵³, J. Collot⁵⁵,
 T. Colombo^{120a,120b}, G. Colon⁸⁵, G. Compostella¹⁰⁰, P. Conde Muiño^{125a}, E. Coniavitis¹⁶⁷,
 M.C. Conidi¹², S.M. Consonni^{90a,90b}, V. Consorti⁴⁸, S. Constantinescu^{26a}, C. Conta^{120a,120b},
 G. Conti⁵⁷, F. Conventi^{103a,i}, M. Cooke¹⁵, B.D. Cooper⁷⁷, A.M. Cooper-Sarkar¹¹⁹,
 N.J. Cooper-Smith⁷⁶, K. Copic¹⁵, T. Cornelissen¹⁷⁶, M. Corradi^{20a}, F. Corriveau^{86,j},
 A. Corso-Radu¹⁶⁴, A. Cortes-Gonzalez¹², G. Cortiana¹⁰⁰, G. Costa^{90a}, M.J. Costa¹⁶⁸,
 D. Costanzo¹⁴⁰, D. Côté⁸, G. Cottin^{32a}, L. Courneyea¹⁷⁰, G. Cowan⁷⁶, B.E. Cox⁸³,
 K. Cranmer¹⁰⁹, S. Crépe-Renaudin⁵⁵, F. Crescioli⁷⁹, M. Cristinziani²¹, G. Crosetti^{37a,37b},
 C.-M. Cuciuc^{26a}, C. Cuenca Almenar¹⁷⁷, T. Cuhadar Donszelmann¹⁴⁰, J. Cummings¹⁷⁷,
 M. Curatolo⁴⁷, C. Cuthbert¹⁵¹, H. Cziri¹⁴², P. Czodrowski⁴⁴, Z. Czyczula¹⁷⁷, S. D'Auria⁵³,
 M. D'Onofrio⁷³, A. D'Orazio^{133a,133b}, M.J. Da Cunha Sargedas De Sousa^{125a}, C. Da Via⁸³,
 W. Dabrowski^{38a}, A. Dafinca¹¹⁹, T. Dai⁸⁸, F. Dallaire⁹⁴, C. Dallapiccola⁸⁵, M. Dam³⁶,
 D.S. Damiani¹³⁸, A.C. Daniells¹⁸, V. Dao¹⁰⁵, G. Darbo^{50a}, G.L. Darlea^{26c}, S. Darmora⁸,

J.A. Dassoulas⁴², W. Davey²¹, C. David¹⁷⁰, T. Davidek¹²⁸, E. Davies^{119,d}, M. Davies⁹⁴,
 O. Davignon⁷⁹, A.R. Davison⁷⁷, Y. Davygora^{58a}, E. Dawe¹⁴³, I. Dawson¹⁴⁰,
 R.K. Daya-Ishmukhametova²³, K. De⁸, R. de Asmundis^{103a}, S. De Castro^{20a,20b}, S. De Cecco⁷⁹,
 J. de Graat⁹⁹, N. De Groot¹⁰⁵, P. de Jong¹⁰⁶, C. De La Taille¹¹⁶, H. De la Torre⁸¹,
 F. De Lorenzi⁶³, L. De Nooij¹⁰⁶, D. De Pedis^{133a}, A. De Salvo^{133a}, U. De Sanctis^{165a,165c},
 A. De Santo¹⁵⁰, J.B. De Vivie De Regie¹¹⁶, G. De Zorzi^{133a,133b}, W.J. Dearnaley⁷¹, R. Debbe²⁵,
 C. Debenedetti⁴⁶, B. Dechenaux⁵⁵, D.V. Dedovich⁶⁴, J. Degenhardt¹²¹, J. Del Peso⁸¹,
 T. Del Prete^{123a,123b}, T. Delemontex⁵⁵, M. Deliyergiyev⁷⁴, A. Dell'Acqua³⁰, L. Dell'Asta²²,
 M. Della Pietra^{103a,i}, D. della Volpe^{103a,103b}, M. Delmastro⁵, P.A. Delsart⁵⁵, C. Deluca¹⁰⁶,
 S. Demers¹⁷⁷, M. Demichev⁶⁴, A. Demilly⁷⁹, B. Demirkoz^{12,k}, S.P. Denisov¹²⁹, D. Derendarz³⁹,
 J.E. Derkaoui^{136d}, F. Derue⁷⁹, P. Dervan⁷³, K. Desch²¹, P.O. Deviveiros¹⁰⁶, A. Dewhurst¹³⁰,
 B. DeWilde¹⁴⁹, S. Dhaliwal¹⁰⁶, R. Dhullipudi^{78,l}, A. Di Ciaccio^{134a,134b}, L. Di Ciaccio⁵,
 C. Di Donato^{103a,103b}, A. Di Girolamo³⁰, B. Di Girolamo³⁰, S. Di Luise^{135a,135b}, A. Di Mattia¹⁵³,
 B. Di Micco^{135a,135b}, R. Di Nardo⁴⁷, A. Di Simone⁴⁸, R. Di Sipio^{20a,20b}, M.A. Diaz^{32a},
 E.B. Diehl⁸⁸, J. Dietrich⁴², T.A. Dietzsch^{58a}, S. Diglio⁸⁷, K. Dindar Yagci⁴⁰, J. Dingfelder²¹,
 F. Dinut^{26a}, C. Dionisi^{133a,133b}, P. Dita^{26a}, S. Dita^{26a}, F. Dittus³⁰, F. Djama⁸⁴, T. Djobava^{51b},
 M.A.B. do Vale^{24c}, A. Do Valle Wemans^{125a,m}, T.K.O. Doan⁵, D. Dobos³⁰, E. Dobson⁷⁷,
 J. Dodd³⁵, C. Doglioni⁴⁹, T. Doherty⁵³, T. Dohmae¹⁵⁶, Y. Doi^{65,*}, J. Dolejsi¹²⁸, Z. Dolezal¹²⁸,
 B.A. Dolgoshein^{97,*}, M. Donadelli^{24d}, J. Donini³⁴, J. Dopke³⁰, A. Doria^{103a}, A. Dos Anjos¹⁷⁴,
 A. Dotti^{123a,123b}, M.T. Dova⁷⁰, A.T. Doyle⁵³, M. Dris¹⁰, J. Dubbert⁸⁸, S. Dube¹⁵, E. Dubreuil³⁴,
 E. Duchovni¹⁷³, G. Duckeck⁹⁹, D. Duda¹⁷⁶, A. Dudarev³⁰, F. Dudziak⁶³, L. Dufflot¹¹⁶,
 M-A. Dufour⁸⁶, L. Duguid⁷⁶, M. Dührssen³⁰, M. Dunford^{58a}, H. Duran Yildiz^{4a}, M. Düren⁵²,
 M. Dwuznik^{38a}, J. Ebke⁹⁹, W. Edson², C.A. Edwards⁷⁶, N.C. Edwards⁴⁶, W. Ehrenfeld²¹,
 T. Eifert¹⁴⁴, G. Eigen¹⁴, K. Einsweiler¹⁵, E. Eisenhandler⁷⁵, T. Ekelof¹⁶⁷, M. El Kacimi^{136c},
 M. Ellert¹⁶⁷, S. Elles⁵, F. Ellinghaus⁸², K. Ellis⁷⁵, N. Ellis³⁰, J. Elmsheuser⁹⁹, M. Elsing³⁰,
 D. Emeliyanov¹³⁰, Y. Enari¹⁵⁶, O.C. Endner⁸², R. Engelmann¹⁴⁹, A. Engl⁹⁹, J. Erdmann¹⁷⁷,
 A. Ereditato¹⁷, D. Eriksson^{147a}, J. Ernst², M. Ernst²⁵, J. Ernwein¹³⁷, D. Errede¹⁶⁶, S. Errede¹⁶⁶,
 E. Ertel⁸², M. Escalier¹¹⁶, H. Esch⁴³, C. Escobar¹²⁴, X. Espinal Curull¹², B. Esposito⁴⁷,
 F. Etienne⁸⁴, A.I. Etievre¹³⁷, E. Etzion¹⁵⁴, D. Evangelakou⁵⁴, H. Evans⁶⁰, L. Fabbri^{20a,20b},
 C. Fabre³⁰, G. Facini³⁰, R.M. Fakhruddinov¹²⁹, S. Falciano^{133a}, Y. Fang^{33a}, M. Fanti^{90a,90b},
 A. Farbin⁸, A. Farilla^{135a}, T. Farooque¹⁵⁹, S. Farrell¹⁶⁴, S.M. Farrington¹⁷¹, P. Farthouat³⁰,
 F. Fassi¹⁶⁸, P. Fassnacht³⁰, D. Fassouliotis⁹, B. Fatholahzadeh¹⁵⁹, A. Favareto^{90a,90b}, L. Fayard¹¹⁶,
 P. Federic^{145a}, O.L. Fedin¹²², W. Fedorko¹⁶⁹, M. Fehling-Kaschek⁴⁸, L. Feligioni⁸⁴, C. Feng^{33d},
 E.J. Feng⁶, H. Feng⁸⁸, A.B. Fenyuk¹²⁹, J. Ferencei^{145b}, W. Fernando⁶, S. Ferrag⁵³, J. Ferrando⁵³,
 V. Ferrara⁴², A. Ferrari¹⁶⁷, P. Ferrari¹⁰⁶, R. Ferrari^{120a}, D.E. Ferreira de Lima⁵³, A. Ferrer¹⁶⁸,
 D. Ferrere⁴⁹, C. Ferretti⁸⁸, A. Ferretto Parodi^{50a,50b}, M. Fiascaris³¹, F. Fiedler⁸², A. Filipčič⁷⁴,
 M. Filipuzzi⁴², F. Filthaut¹⁰⁵, M. Fincke-Keeler¹⁷⁰, K.D. Finelli⁴⁵, M.C.N. Fiolhais^{125a,h},
 L. Fiorini¹⁶⁸, A. Firan⁴⁰, J. Fischer¹⁷⁶, M.J. Fisher¹¹⁰, E.A. Fitzgerald²³, M. Flechl⁴⁸, I. Fleck¹⁴²,
 P. Fleischmann¹⁷⁵, S. Fleischmann¹⁷⁶, G.T. Fletcher¹⁴⁰, G. Fletcher⁷⁵, T. Flick¹⁷⁶, A. Floderus⁸⁰,
 L.R. Flores Castillo¹⁷⁴, A.C. Florez Bustos^{160b}, M.J. Flowerdew¹⁰⁰, T. Fonseca Martin¹⁷,
 A. Formica¹³⁷, A. Forti⁸³, D. Fortin^{160a}, D. Fournier¹¹⁶, H. Fox⁷¹, P. Francavilla¹²,
 M. Franchini^{20a,20b}, S. Franchino³⁰, D. Francis³⁰, M. Franklin⁵⁷, S. Franz⁶¹, M. Fraternali^{120a,120b},
 S. Fratina¹²¹, S.T. French²⁸, C. Friedrich⁴², F. Friedrich⁴⁴, D. Froidevaux³⁰, J.A. Frost²⁸,
 C. Fukunaga¹⁵⁷, E. Fullana Torregrosa¹²⁸, B.G. Fulsom¹⁴⁴, J. Fuster¹⁶⁸, C. Gabaldon³⁰,
 O. Gabizon¹⁷³, A. Gabrielli^{20a,20b}, A. Gabrielli^{133a,133b}, S. Gadatsch¹⁰⁶, T. Gadfort²⁵,
 S. Gadomski⁴⁹, G. Gagliardi^{50a,50b}, P. Gagnon⁶⁰, C. Galea⁹⁹, B. Galhardo^{125a}, E.J. Gallas¹¹⁹,
 V. Gallo¹⁷, B.J. Gallop¹³⁰, P. Gallus¹²⁷, G. Galster³⁶, K.K. Gan¹¹⁰, R.P. Gandrajula⁶²,
 Y.S. Gao^{144,f}, A. Gaponenko¹⁵, F.M. Garay Walls⁴⁶, F. Garberon¹⁷⁷, C. García¹⁶⁸,
 J.E. García Navarro¹⁶⁸, M. Garcia-Sciveres¹⁵, R.W. Gardner³¹, N. Garelli¹⁴⁴, V. Garonne³⁰,
 C. Gatti⁴⁷, G. Gaudio^{120a}, B. Gaur¹⁴², L. Gauthier⁹⁴, P. Gauzzi^{133a,133b}, I.L. Gavrilenko⁹⁵,
 C. Gay¹⁶⁹, G. Gaycken²¹, E.N. Gazis¹⁰, P. Ge^{33d,n}, Z. Gecse¹⁶⁹, C.N.P. Gee¹³⁰, D.A.A. Geerts¹⁰⁶,
 Ch. Geich-Gimbel²¹, K. Gellerstedt^{147a,147b}, C. Gemme^{50a}, A. Gemmell⁵³, M.H. Genest⁵⁵,

S. Gentile^{133a,133b}, M. George⁵⁴, S. George⁷⁶, D. Gerbaudo¹⁶⁴, A. Gershon¹⁵⁴, H. Ghazlane^{136b}, N. Ghodbane³⁴, B. Giacobbe^{20a}, S. Giagu^{133a,133b}, V. Giangiobbe¹², P. Giannetti^{123a,123b}, F. Gianotti³⁰, B. Gibbard²⁵, S.M. Gibson⁷⁶, M. Gilchriese¹⁵, T.P.S. Gillam²⁸, D. Gillberg³⁰, A.R. Gillman¹³⁰, D.M. Gingrich^{3,e}, N. Giokaris⁹, M.P. Giordani^{165c}, R. Giordano^{103a,103b}, F.M. Giorgi¹⁶, P. Giovannini¹⁰⁰, P.F. Giraud¹³⁷, D. Giugni^{90a}, C. Giuliani⁴⁸, M. Giunta⁹⁴, B.K. Gjelsten¹¹⁸, I. Gkialas^{155,o}, L.K. Gladilin⁹⁸, C. Glasman⁸¹, J. Glatzer²¹, A. Glazov⁴², G.L. Glonti⁶⁴, M. Goblirsch-Kolb¹⁰⁰, J.R. Goddard⁷⁵, J. Godfrey¹⁴³, J. Godlewski³⁰, M. Goebel⁴², C. Goeringer⁸², S. Goldfarb⁸⁸, T. Golling¹⁷⁷, D. Golubkov¹²⁹, A. Gomes^{125a,c}, L.S. Gomez Fajardo⁴², R. Gonalo⁷⁶, J. Goncalves Pinto Firmino Da Costa⁴², L. Gonella²¹, S. Gonzalez de la Hoz¹⁶⁸, G. Gonzalez Parra¹², M.L. Gonzalez Silva²⁷, S. Gonzalez-Sevilla⁴⁹, J.J. Goodson¹⁴⁹, L. Goossens³⁰, P.A. Gorbounov⁹⁶, H.A. Gordon²⁵, I. Gorelov¹⁰⁴, G. Gorfine¹⁷⁶, B. Gorini³⁰, E. Gorini^{72a,72b}, A. Gorišek⁷⁴, E. Gornicki³⁹, A.T. Goshaw⁶, C. Gossling⁴³, M.I. Gostkin⁶⁴, I. Gough Eschrich¹⁶⁴, M. Goughri^{136a}, D. Goujdami^{136c}, M.P. Goulette⁴⁹, A.G. Goussiou¹³⁹, C. Goy⁵, S. Gozpinar²³, H.M.X. Grabas¹³⁷, L. Graber⁵⁴, I. Grabowska-Bold^{38a}, P. Grafstrom^{20a,20b}, K-J. Grah⁴², E. Gramstad¹¹⁸, F. Grancagnolo^{72a}, S. Grancagnolo¹⁶, V. Grassi¹⁴⁹, V. Gratchev¹²², H.M. Gray³⁰, J.A. Gray¹⁴⁹, E. Graziani^{135a}, O.G. Grebenyuk¹²², T. Greenshaw⁷³, Z.D. Greenwood^{78,l}, K. Gregersen³⁶, I.M. Gregor⁴², P. Grenier¹⁴⁴, J. Griffiths⁸, N. Grigalashvili⁶⁴, A.A. Grillo¹³⁸, K. Grimm⁷¹, S. Grinstein^{12,p}, Ph. Gris³⁴, Y.V. Grishkevich⁹⁸, J.-F. Grivaz¹¹⁶, J.P. Grohs⁴⁴, A. Grohsjean⁴², E. Gross¹⁷³, J. Grosse-Knetter⁵⁴, J. Groth-Jensen¹⁷³, K. Grybel¹⁴², F. Guescini⁴⁹, D. Guest¹⁷⁷, O. Gueta¹⁵⁴, C. Guicheney³⁴, E. Guido^{50a,50b}, T. Guillemin¹¹⁶, S. Guindon², U. Gul⁵³, J. Gunther¹²⁷, J. Guo³⁵, S. Gupta¹¹⁹, P. Gutierrez¹¹², N.G. Gutierrez Ortiz⁵³, N. Guttman¹⁵⁴, O. Gutzwiller¹⁷⁴, C. Guyot¹³⁷, C. Gwenlan¹¹⁹, C.B. Gwilliam⁷³, A. Haas¹⁰⁹, C. Haber¹⁵, H.K. Hadavand⁸, P. Haefner²¹, Z. Hajduk³⁹, H. Hakobyan¹⁷⁸, D. Hall¹¹⁹, G. Halladjian⁶², K. Hamacher¹⁷⁶, P. Hamal¹¹⁴, K. Hamano⁸⁷, M. Hamer⁵⁴, A. Hamilton^{146a,q}, S. Hamilton¹⁶², L. Han^{33b}, K. Hanagaki¹¹⁷, K. Hanawa¹⁵⁶, M. Hance¹⁵, C. Handel⁸², P. Hanke^{58a}, J.R. Hansen³⁶, J.B. Hansen³⁶, J.D. Hansen³⁶, P.H. Hansen³⁶, P. Hansson¹⁴⁴, K. Hara¹⁶¹, A.S. Hard¹⁷⁴, T. Harenberg¹⁷⁶, S. Harkusha⁹¹, D. Harper⁸⁸, R.D. Harrington⁴⁶, O.M. Harris¹³⁹, J. Hartert⁴⁸, F. Hartjes¹⁰⁶, A. Harvey⁵⁶, S. Hasegawa¹⁰², Y. Hasegawa¹⁴¹, S. Hassani¹³⁷, S. Haug¹⁷, M. Hauschild³⁰, R. Hauser⁸⁹, M. Havranek²¹, C.M. Hawkes¹⁸, R.J. Hawkings³⁰, A.D. Hawkins⁸⁰, T. Hayashi¹⁶¹, D. Hayden⁸⁹, C.P. Hays¹¹⁹, H.S. Hayward⁷³, S.J. Haywood¹³⁰, S.J. Head¹⁸, T. Heck⁸², V. Hedberg⁸⁰, L. Heelan⁸, S. Heim¹²¹, B. Heinemann¹⁵, S. Heisterkamp³⁶, J. Hejbal¹²⁶, L. Helary²², C. Heller⁹⁹, M. Heller³⁰, S. Hellman^{147a,147b}, D. Hellmich²¹, C. Helsens³⁰, J. Henderson¹¹⁹, R.C.W. Henderson⁷¹, A. Henrichs¹⁷⁷, A.M. Henriques Correia³⁰, S. Henrot-Versille¹¹⁶, C. Hensel⁵⁴, G.H. Herbert¹⁶, C.M. Hernandez⁸, Y. Hernandez Jimenez¹⁶⁸, R. Herrberg-Schubert¹⁶, G. Herten⁴⁸, R. Hertenberger⁹⁹, L. Hervas³⁰, G.G. Hesketh⁷⁷, N.P. Hessey¹⁰⁶, R. Hickling⁷⁵, E. Higon-Rodriguez¹⁶⁸, J.C. Hill²⁸, K.H. Hiller⁴², S. Hillert²¹, S.J. Hillier¹⁸, I. Hinchliffe¹⁵, E. Hines¹²¹, M. Hirose¹¹⁷, D. Hirschbuehl¹⁷⁶, J. Hobbs¹⁴⁹, N. Hod¹⁰⁶, M.C. Hodgkinson¹⁴⁰, P. Hodgson¹⁴⁰, A. Hoecker³⁰, M.R. Hoferkamp¹⁰⁴, J. Hoffman⁴⁰, D. Hoffmann⁸⁴, J.I. Hofmann^{58a}, M. Hohlfeld⁸², S.O. Holmgren^{147a}, J.L. Holzbauer⁸⁹, T.M. Hong¹²¹, L. Hooft van Huysduyten¹⁰⁹, J-Y. Hostachy⁵⁵, S. Hou¹⁵², A. Hoummada^{136a}, J. Howard¹¹⁹, J. Howarth⁸³, M. Hrabovsky¹¹⁴, I. Hristova¹⁶, J. Hrivnac¹¹⁶, T. Hryn'ova⁵, P.J. Hsu⁸², S.-C. Hsu¹³⁹, D. Hu³⁵, X. Hu²⁵, Y. Huang^{33a}, Z. Hubacek³⁰, F. Hubaut⁸⁴, F. Huegging²¹, A. Huettmann⁴², T.B. Huffman¹¹⁹, E.W. Hughes³⁵, G. Hughes⁷¹, M. Huhtinen³⁰, T.A. Hulsing⁸², M. Hurwitz¹⁵, N. Huseynov^{64,r}, J. Huston⁸⁹, J. Huth⁵⁷, G. Iacobucci⁴⁹, G. Iakovidis¹⁰, I. Ibragimov¹⁴², L. Iconomidou-Fayard¹¹⁶, J. Idarraga¹¹⁶, P. Iengo^{103a}, O. Igonkina¹⁰⁶, Y. Ikegami⁶⁵, K. Ikematsu¹⁴², M. Ikeno⁶⁵, D. Iliadis¹⁵⁵, N. Ilic¹⁵⁹, T. Ince¹⁰⁰, P. Ioannou⁹, M. Iodice^{135a}, K. Iordanidou⁹, V. Ippolito^{133a,133b}, A. Irls Quiles¹⁶⁸, C. Isaksson¹⁶⁷, M. Ishino⁶⁷, M. Ishitsuka¹⁵⁸, R. Ishmukhametov¹¹⁰, C. Issever¹¹⁹, S. Istin^{19a}, A.V. Ivashin¹²⁹, W. Iwanski³⁹, H. Iwasaki⁶⁵, J.M. Izen⁴¹, V. Izzo^{103a}, B. Jackson¹²¹, J.N. Jackson⁷³, P. Jackson¹, M.R. Jaekel³⁰, V. Jain², K. Jakobs⁴⁸, S. Jakobsen³⁶, T. Jakoubek¹²⁶, J. Jakubek¹²⁷, D.O. Jamin¹⁵², D.K. Jana¹¹², E. Jansen⁷⁷, H. Jansen³⁰, J. Janssen²¹, M. Janus¹⁷¹, R.C. Jared¹⁷⁴,

G. Jarlskog⁸⁰, L. Jeanty⁵⁷, G.-Y. Jeng¹⁵¹, I. Jen-La Plante³¹, D. Jennens⁸⁷, P. Jenni³⁰, J. Jentsch⁴³, C. Jeske¹⁷¹, S. Jézéquel⁵, M.K. Jha^{20a}, H. Ji¹⁷⁴, W. Ji⁸², J. Jia¹⁴⁹, Y. Jiang^{33b}, M. Jimenez Belenguer⁴², S. Jin^{33a}, O. Jinnouchi¹⁵⁸, M.D. Joergensen³⁶, D. Joffe⁴⁰, K.E. Johansson^{147a}, P. Johansson¹⁴⁰, S. Johnert⁴², K.A. Johns⁷, K. Jon-And^{147a,147b}, G. Jones¹⁷¹, R.W.L. Jones⁷¹, T.J. Jones⁷³, P.M. Jorge^{125a}, K.D. Joshi⁸³, J. Jovicevic¹⁴⁸, X. Ju¹⁷⁴, C.A. Jung⁴³, R.M. Jungst³⁰, P. Jussel⁶¹, A. Juste Rozas^{12,p}, M. Kaci¹⁶⁸, A. Kaczmarek³⁹, P. Kadlecik³⁶, M. Kado¹¹⁶, H. Kagan¹¹⁰, M. Kagan¹⁴⁴, E. Kajomovitz¹⁵³, S. Kalinin¹⁷⁶, S. Kama⁴⁰, N. Kanaya¹⁵⁶, M. Kaneda³⁰, S. Kaneti²⁸, T. Kanno¹⁵⁸, V.A. Kantserov⁹⁷, J. Kanzaki⁶⁵, B. Kaplan¹⁰⁹, A. Kapliy³¹, D. Kar⁵³, K. Karakostas¹⁰, N. Karastathis¹⁰, M. Karnevskiy⁸², S.N. Karpov⁶⁴, V. Kartvelishvili⁷¹, A.N. Karyukhin¹²⁹, L. Kashif¹⁷⁴, G. Kasieczka^{58b}, R.D. Kass¹¹⁰, A. Kastanas¹⁴, Y. Kataoka¹⁵⁶, A. Katre⁴⁹, J. Katzy⁴², V. Kaushik⁷, K. Kawagoe⁶⁹, T. Kawamoto¹⁵⁶, G. Kawamura⁵⁴, S. Kazama¹⁵⁶, V.F. Kazanin¹⁰⁸, M.Y. Kazarinov⁶⁴, R. Keeler¹⁷⁰, P.T. Keener¹²¹, R. Kehoe⁴⁰, M. Keil⁵⁴, J.S. Keller¹³⁹, H. Keoshkerian⁵, O. Kepka¹²⁶, B.P. Kerševan⁷⁴, S. Kersten¹⁷⁶, K. Kessoku¹⁵⁶, J. Keung¹⁵⁹, F. Khalil-zada¹¹, H. Khandanyan^{147a,147b}, A. Khanov¹¹³, D. Kharchenko⁶⁴, A. Khodinov⁹⁷, A. Khomich^{58a}, T.J. Khoo²⁸, G. Khoraiuli²¹, A. Khoroshilov¹⁷⁶, V. Khovanskiy⁹⁶, E. Khramov⁶⁴, J. Khubua^{51b}, H. Kim^{147a,147b}, S.H. Kim¹⁶¹, N. Kimura¹⁷², O. Kind¹⁶, B.T. King⁷³, M. King⁶⁶, R.S.B. King¹¹⁹, S.B. King¹⁶⁹, J. Kirk¹³⁰, A.E. Kiryunin¹⁰⁰, T. Kishimoto⁶⁶, D. Kisielewska^{38a}, T. Kitamura⁶⁶, T. Kittelmann¹²⁴, K. Kiuchi¹⁶¹, E. Kladiva^{145b}, M. Klein⁷³, U. Klein⁷³, K. Kleinknecht⁸², M. Klemetti⁸⁶, P. Klimek^{147a,147b}, A. Klimentov²⁵, R. Klingleberg⁴³, J.A. Klinger⁸³, E.B. Klinkby³⁶, T. Klioutchnikova³⁰, P.F. Klok¹⁰⁵, E.-E. Kluge^{58a}, P. Kluit¹⁰⁶, S. Kluth¹⁰⁰, E. Kneringer⁶¹, E.B.F.G. Knoops⁸⁴, A. Knue⁵⁴, B.R. Ko⁴⁵, T. Kobayashi¹⁵⁶, M. Kobel⁴⁴, M. Kocian¹⁴⁴, P. Kodys¹²⁸, S. Koenig⁸², P. Kovesarki²¹, T. Koffas²⁹, E. Koffeman¹⁰⁶, L.A. Kogan¹¹⁹, S. Kohlmann¹⁷⁶, F. Kohn⁵⁴, Z. Kohout¹²⁷, T. Kohriki⁶⁵, T. Koi¹⁴⁴, H. Kolanoski¹⁶, I. Koletsou^{90a}, J. Koll⁸⁹, A.A. Komar⁹⁵, Y. Komori¹⁵⁶, T. Kondo⁶⁵, K. Köneke⁴⁸, A.C. König¹⁰⁵, T. Kono^{42,s}, R. Konoplich^{109,t}, N. Konstantinidis⁷⁷, R. Kopeliansky¹⁵³, S. Koperny^{38a}, L. Köpcke⁸², A.K. Kopp⁴⁸, K. Korcyl³⁹, K. Kordas¹⁵⁵, A. Korn⁴⁶, A.A. Korol¹⁰⁸, I. Korolkov¹², E.V. Korolkova¹⁴⁰, V.A. Korotkov¹²⁹, O. Kortner¹⁰⁰, S. Kortner¹⁰⁰, V.V. Kostyukhin²¹, S. Kotov¹⁰⁰, V.M. Kotov⁶⁴, A. Kotwal⁴⁵, C. Kourkoumelis⁹, V. Kouskoura¹⁵⁵, A. Koutsman^{160a}, R. Kowalewski¹⁷⁰, T.Z. Kowalski^{38a}, W. Kozanecki¹³⁷, A.S. Kozhin¹²⁹, V. Kral¹²⁷, V.A. Kramarenko⁹⁸, G. Kramberger⁷⁴, M.W. Krasny⁷⁹, A. Krasznahorkay¹⁰⁹, J.K. Kraus²¹, A. Kravchenko²⁵, S. Kreiss¹⁰⁹, J. Kretzschmar⁷³, K. Kreutzfeldt⁵², N. Krieger⁵⁴, P. Krieger¹⁵⁹, K. Kroeninger⁵⁴, H. Kroha¹⁰⁰, J. Kroll¹²¹, J. Kroseberg²¹, J. Krstic^{13a}, U. Kruchonak⁶⁴, H. Krüger²¹, T. Kruker¹⁷, N. Krumnack⁶³, Z.V. Krumshteyn⁶⁴, A. Kruse¹⁷⁴, M.K. Kruse⁴⁵, M. Kruskal²², T. Kubota⁸⁷, S. Kудay^{4a}, S. Kuehn⁴⁸, A. Kugel^{58c}, T. Kuhl⁴², V. Kukhtin⁶⁴, Y. Kulchitsky⁹¹, S. Kuleshov^{32b}, M. Kuna⁷⁹, J. Kunkle¹²¹, A. Kupco¹²⁶, H. Kurashige⁶⁶, M. Kurata¹⁶¹, Y.A. Kurochkin⁹¹, V. Kus¹²⁶, E.S. Kuwertz¹⁴⁸, M. Kuze¹⁵⁸, J. Kvita¹⁴³, R. Kwee¹⁶, A. La Rosa⁴⁹, L. La Rotonda^{37a,37b}, L. Labarga⁸¹, S. Lablak^{136a}, C. Lacasta¹⁶⁸, F. Lacava^{133a,133b}, J. Lacey²⁹, H. Lacker¹⁶, D. Lacour⁷⁹, V.R. Lacuesta¹⁶⁸, E. Ladygin⁶⁴, R. Lafaye⁵, B. Laforge⁷⁹, T. Lagouri¹⁷⁷, S. Lai⁴⁸, H. Lai^{58a}, E. Laisne⁵⁵, L. Lambourne⁷⁷, C.L. Lampen⁷, W. Lampl⁷, E. Lançon¹³⁷, U. Landgraf⁴⁸, M.P.J. Landon⁷⁵, V.S. Lang^{58a}, C. Lange⁴², A.J. Lankford¹⁶⁴, F. Lanni²⁵, K. Lantzsch³⁰, A. Lanza^{120a}, S. Laplace⁷⁹, C. Lapoire²¹, J.F. Laporte¹³⁷, T. Lari^{90a}, A. Larner¹¹⁹, M. Lassnig³⁰, P. Laurelli⁴⁷, V. Lavorini^{37a,37b}, W. Lavrijsen¹⁵, P. Laycock⁷³, B.T. Le⁵⁵, O. Le Dortz⁷⁹, E. Le Guirriec⁸⁴, E. Le Menedeu¹², T. LeCompte⁶, F. Ledroit-Guillon⁵⁵, C.A. Lee¹⁵², H. Lee¹⁰⁶, J.S.H. Lee¹¹⁷, S.C. Lee¹⁵², L. Lee¹⁷⁷, G. Lefebvre⁷⁹, M. Lefebvre¹⁷⁰, M. Legendre¹³⁷, F. Legger⁹⁹, C. Leggett¹⁵, A. Lehan⁷³, M. Lehmann²¹, G. Lehmann Miotto³⁰, A.G. Leister¹⁷⁷, M.A.L. Leite^{24d}, R. Leitner¹²⁸, D. Lellouch¹⁷³, B. Lemmer⁵⁴, V. Lendermann^{58a}, K.J.C. Leney^{146c}, T. Lenz¹⁰⁶, G. Lenzen¹⁷⁶, B. Lenzi³⁰, R. Leone⁷, K. Leonhardt⁴⁴, S. Leontsinis¹⁰, C. Leroy⁹⁴, J.-R. Lessard¹⁷⁰, C.G. Lester²⁸, C.M. Lester¹²¹, J. Levêque⁵, D. Levin⁸⁸, L.J. Levinson¹⁷³, A. Lewis¹¹⁹, G.H. Lewis¹⁰⁹, A.M. Leyko²¹, M. Leyton¹⁶, B. Li^{33b,u}, B. Li⁸⁴, H. Li¹⁴⁹, H.L. Li³¹, S. Li⁴⁵, X. Li⁸⁸, Z. Liang^{119,v}, H. Liao³⁴, B. Liberti^{134a}, P. Lichard³⁰,

K. Lie¹⁶⁶, J. Liebal²¹, W. Liebig¹⁴, C. Limbach²¹, A. Limosani⁸⁷, M. Limper⁶², S.C. Lin^{152,w},
 F. Linde¹⁰⁶, B.E. Lindquist¹⁴⁹, J.T. Linnemann⁸⁹, E. Lipeles¹²¹, A. Lipniacka¹⁴, M. Lisovyi⁴²,
 T.M. Liss¹⁶⁶, D. Lissauer²⁵, A. Lister¹⁶⁹, A.M. Litke¹³⁸, B. Liu¹⁵², D. Liu¹⁵², J.B. Liu^{33b},
 K. Liu^{33b,x}, L. Liu⁸⁸, M. Liu⁴⁵, M. Liu^{33b}, Y. Liu^{33b}, M. Livan^{120a,120b}, S.S.A. Livermore¹¹⁹,
 A. Lleres⁵⁵, J. Llorente Merino⁸¹, S.L. Lloyd⁷⁵, F. Lo Sterzo^{133a,133b}, E. Lobodzinska⁴², P. Loch⁷,
 W.S. Lockman¹³⁸, T. Loddenkoetter²¹, F.K. Loebinger⁸³, A.E. Loevschall-Jensen³⁶,
 A. Loginov¹⁷⁷, C.W. Loh¹⁶⁹, T. Lohse¹⁶, K. Lohwasser⁴⁸, M. Lokajicek¹²⁶, V.P. Lombardo⁵,
 R.E. Long⁷¹, L. Lopes^{125a}, D. Lopez Mateos⁵⁷, B. Lopez Paredes¹⁴⁰, J. Lorenz⁹⁹,
 N. Lorenzo Martinez¹¹⁶, M. Losada¹⁶³, P. Loscutoff¹⁵, M.J. Losty^{160a,*}, X. Lou⁴¹, A. Lounis¹¹⁶,
 K.F. Loureiro¹⁶³, J. Love⁶, P.A. Love⁷¹, A.J. Lowe^{144,f}, F. Lu^{33a}, H.J. Lubatti¹³⁹,
 C. Luci^{133a,133b}, A. Lucotte⁵⁵, D. Ludwig⁴², I. Ludwig⁴⁸, J. Ludwig⁴⁸, F. Luehring⁶⁰, W. Lukas⁶¹,
 L. Luminari^{133a}, E. Lund¹¹⁸, J. Lundberg^{147a,147b}, O. Lundberg^{147a,147b}, B. Lund-Jensen¹⁴⁸,
 M. Lungwitz⁸², D. Lynn²⁵, R. Lysak¹²⁶, E. Lytken⁸⁰, H. Ma²⁵, L.L. Ma^{33d}, G. Maccarrone⁴⁷,
 A. Macchiolo¹⁰⁰, B. Maček⁷⁴, J. Machado Miguens^{125a}, D. Macina³⁰, R. Mackeprang³⁶,
 R. Madar⁴⁸, R.J. Madaras¹⁵, H.J. Maddocks⁷¹, W.F. Mader⁴⁴, A. Madsen¹⁶⁷, M. Maeno⁵,
 T. Maeno²⁵, L. Magnoni¹⁶⁴, E. Magradze⁵⁴, K. Mahboubi⁴⁸, J. Mahlstedt¹⁰⁶, S. Mahmoud⁷³,
 G. Mahout¹⁸, C. Maiani¹³⁷, C. Maidantchik^{24a}, A. Maio^{125a,c}, S. Majewski¹¹⁵, Y. Makida⁶⁵,
 N. Makovec¹¹⁶, P. Mal^{137,y}, B. Malaescu⁷⁹, Pa. Malecki³⁹, V.P. Maleev¹²², F. Malek⁵⁵,
 U. Mallik⁶², D. Malon⁶, C. Malone¹⁴⁴, S. Maltezos¹⁰, V.M. Malyshev¹⁰⁸, S. Malyukov³⁰,
 J. Mamuzic^{13b}, L. Mandelli^{90a}, I. Mandić⁷⁴, R. Mandrysch⁶², J. Maneira^{125a}, A. Manfredini¹⁰⁰,
 L. Manhaes de Andrade Filho^{24b}, J.A. Manjarres Ramos¹³⁷, A. Mann⁹⁹, P.M. Manning¹³⁸,
 A. Manousakis-Katsikakis⁹, B. Mansoulie¹³⁷, R. Mantifel⁸⁶, L. Mapelli³⁰, L. March¹⁶⁸,
 J.F. Marchand²⁹, F. Marchese^{134a,134b}, G. Marchiori⁷⁹, M. Marcisovsky¹²⁶, C.P. Marino¹⁷⁰,
 C.N. Marques^{125a}, F. Marroquin^{24a}, Z. Marshall¹²¹, L.F. Marti¹⁷, S. Marti-Garcia¹⁶⁸,
 B. Martin³⁰, B. Martin⁸⁹, J.P. Martin⁹⁴, T.A. Martin¹⁷¹, V.J. Martin⁴⁶, B. Martin dit Latour⁴⁹,
 H. Martinez¹³⁷, M. Martinez^{12,p}, S. Martin-Haugh¹⁵⁰, A.C. Martyniuk¹⁷⁰, M. Marx⁸³,
 F. Marzano^{133a}, A. Marzin¹¹², L. Masetti⁸², T. Mashimo¹⁵⁶, R. Mashinistov⁹⁵, J. Masik⁸³,
 A.L. Maslennikov¹⁰⁸, I. Massa^{20a,20b}, N. Massol⁵, P. Mastrandrea¹⁴⁹, A. Mastroberardino^{37a,37b},
 T. Masubuchi¹⁵⁶, H. Matsunaga¹⁵⁶, T. Matsushita⁶⁶, P. Mättig¹⁷⁶, S. Mättig⁴², J. Mattmann⁸²,
 C. Mattraversi^{119,d}, J. Maurer⁸⁴, S.J. Maxfield⁷³, D.A. Maximov^{108,g}, R. Mazini¹⁵²,
 L. Mazzaferro^{134a,134b}, M. Mazzanti^{90a}, S.P. Mc Kee⁸⁸, A. McCarn¹⁶⁶, R.L. McCarthy¹⁴⁹,
 T.G. McCarthy²⁹, N.A. McCubbin¹³⁰, K.W. McFarlane^{56,*}, J.A. McFayden¹⁴⁰, G. Mchedlidze^{51b},
 T. McLaughlan¹⁸, S.J. McMahon¹³⁰, R.A. McPherson^{170,j}, A. Meade⁸⁵, J. Mechnich¹⁰⁶,
 M. Mechtel¹⁷⁶, M. Medinnis⁴², S. Meehan³¹, R. Meera-Lebbai¹¹², S. Mehlhase³⁶, A. Mehta⁷³,
 K. Meier^{58a}, C. Meineck⁹⁹, B. Meirose⁸⁰, C. Melachrinou³¹, B.R. Mellado Garcia^{146c},
 F. Meloni^{90a,90b}, L. Mendoza Navas¹⁶³, A. Mengarelli^{20a,20b}, S. Menke¹⁰⁰, E. Meoni¹⁶²,
 K.M. Mercurio⁵⁷, S. Mergelmeyer²¹, N. Meric¹³⁷, P. Mermod⁴⁹, L. Merola^{103a,103b}, C. Meroni^{90a},
 F.S. Merritt³¹, H. Merritt¹¹⁰, A. Messina^{30,z}, J. Metcalfe²⁵, A.S. Mete¹⁶⁴, C. Meyer⁸²,
 C. Meyer³¹, J-P. Meyer¹³⁷, J. Meyer³⁰, J. Meyer⁵⁴, S. Michal³⁰, R.P. Middleton¹³⁰, S. Migas⁷³,
 L. Mijović¹³⁷, G. Mikenberg¹⁷³, M. Mikesstikova¹²⁶, M. Mikuž⁷⁴, D.W. Miller³¹, W.J. Mills¹⁶⁹,
 C. Mills⁵⁷, A. Milov¹⁷³, D.A. Milstead^{147a,147b}, D. Milstein¹⁷³, A.A. Minaenko¹²⁹,
 M. Miñano Moya¹⁶⁸, I.A. Minashvili⁶⁴, A.I. Mincer¹⁰⁹, B. Mindur^{38a}, M. Mineev⁶⁴, Y. Ming¹⁷⁴,
 L.M. Mir¹², G. Mirabelli^{133a}, T. Mitani¹⁷², J. Mitrevski¹³⁸, V.A. Mitsou¹⁶⁸, S. Mitsui⁶⁵,
 P.S. Miyagawa¹⁴⁰, J.U. Mjörnmark⁸⁰, T. Moe^{147a,147b}, V. Moeller²⁸, S. Mohapatra¹⁴⁹,
 W. Mohr⁴⁸, R. Moles-Valls¹⁶⁸, A. Molfetas³⁰, K. Mönig⁴², C. Monini⁵⁵, J. Monk³⁶, E. Monnier⁸⁴,
 J. Montejo Berlingen¹², F. Monticelli⁷⁰, S. Monzani^{20a,20b}, R.W. Moore³, C. Mora Herrera⁴⁹,
 A. Moraes⁵³, N. Morange⁶², J. Morel⁵⁴, D. Moreno⁸², M. Moreno Llácer¹⁶⁸, P. Morettini^{50a},
 M. Morgenstern⁴⁴, M. Morii⁵⁷, S. Moritz⁸², A.K. Morley¹⁴⁸, G. Mornacchi³⁰, J.D. Morris⁷⁵,
 L. Morvaj¹⁰², H.G. Moser¹⁰⁰, M. Mosidze^{51b}, J. Moss¹¹⁰, R. Mount¹⁴⁴, E. Mountricha^{10,aa},
 S.V. Mouraviev^{95,*}, E.J.W. Moyses⁸⁵, R.D. Mudd¹⁸, F. Mueller^{58a}, J. Mueller¹²⁴, K. Mueller²¹,
 T. Mueller²⁸, T. Mueller⁸², D. Muenstermann⁴⁹, Y. Munwes¹⁵⁴, J.A. Murillo Quijada¹⁸,
 W.J. Murray¹³⁰, I. Mussche¹⁰⁶, E. Musto¹⁵³, A.G. Myagkov^{129,ab}, M. Myska¹²⁶,

O. Nackenhorst⁵⁴, J. Nadal¹², K. Nagai⁶¹, R. Nagai¹⁵⁸, Y. Nagai⁸⁴, K. Nagano⁶⁵, A. Nagarkar¹¹⁰, Y. Nagasaka⁵⁹, M. Nagel¹⁰⁰, A.M. Nairz³⁰, Y. Nakahama³⁰, K. Nakamura⁶⁵, T. Nakamura¹⁵⁶, I. Nakano¹¹¹, H. Namasivayam⁴¹, G. Nanava²¹, A. Napier¹⁶², R. Narayan^{58b}, M. Nash^{77,d}, T. Nattermann²¹, T. Naumann⁴², G. Navarro¹⁶³, H.A. Neal⁸⁸, P.Yu. Nechaeva⁹⁵, T.J. Neep⁸³, A. Negri^{120a,120b}, G. Negri³⁰, M. Negrini^{20a}, S. Nektarijevic⁴⁹, A. Nelson¹⁶⁴, T.K. Nelson¹⁴⁴, S. Nemecek¹²⁶, P. Nemethy¹⁰⁹, A.A. Nepomuceno^{24a}, M. Nessi^{30,ac}, M.S. Neubauer¹⁶⁶, M. Neumann¹⁷⁶, A. Neusiedl⁸², R.M. Neves¹⁰⁹, P. Nevski²⁵, F.M. Newcomer¹²¹, P.R. Newman¹⁸, D.H. Nguyen⁶, V. Nguyen Thi Hong¹³⁷, R.B. Nickerson¹¹⁹, R. Nicolaidou¹³⁷, B. Nicquevert³⁰, J. Nielsen¹³⁸, N. Nikiforou³⁵, A. Nikiforov¹⁶, V. Nikolaenko^{129,ab}, I. Nikolic-Audit⁷⁹, K. Nikolics⁴⁹, K. Nikolopoulos¹⁸, P. Nilsson⁸, Y. Ninomiya¹⁵⁶, A. Nisati^{133a}, R. Nisius¹⁰⁰, T. Nobe¹⁵⁸, L. Nodulman⁶, M. Nomachi¹¹⁷, I. Nomidis¹⁵⁵, S. Norberg¹¹², M. Nordberg³⁰, J. Novakova¹²⁸, M. Nozaki⁶⁵, L. Nozka¹¹⁴, K. Ntekas¹⁰, A.-E. Nuncio-Quiroz²¹, G. Nunes Hanninger⁸⁷, T. Nunnemann⁹⁹, E. Nurse⁷⁷, B.J. O'Brien⁴⁶, F. O'grady⁷, D.C. O'Neil¹⁴³, V. O'Shea⁵³, L.B. Oakes⁹⁹, F.G. Oakham^{29,e}, H. Oberlack¹⁰⁰, J. Ocariz⁷⁹, A. Ochi⁶⁶, M.I. Ochoa⁷⁷, S. Oda⁶⁹, S. Odaka⁶⁵, J. Odier⁸⁴, H. Ogren⁶⁰, A. Oh⁸³, S.H. Oh⁴⁵, C.C. Ohm³⁰, T. Ohshima¹⁰², W. Okamura¹¹⁷, H. Okawa²⁵, Y. Okumura³¹, T. Okuyama¹⁵⁶, A. Olariu^{26a}, A.G. Olchevski⁶⁴, S.A. Olivares Pino⁴⁶, M. Oliveira^{125a,h}, D. Oliveira Damazio²⁵, E. Oliver Garcia¹⁶⁸, D. Olivito¹²¹, A. Olszewski³⁹, J. Olszowska³⁹, A. Onofre^{125a,ad}, P.U.E. Onyisi^{31,ae}, C.J. Oram^{160a}, M.J. Oreglia³¹, Y. Oren¹⁵⁴, D. Orestano^{135a,135b}, N. Orlando^{72a,72b}, C. Oropeza Barrera⁵³, R.S. Orr¹⁵⁹, B. Osculati^{50a,50b}, R. Ospanov¹²¹, G. Otero y Garzon²⁷, H. Otono⁶⁹, J.P. Ottersbach¹⁰⁶, M. Ouchrif^{136d}, E.A. Ouellette¹⁷⁰, F. Ould-Saada¹¹⁸, A. Ouraou¹³⁷, K.P. Oussoren¹⁰⁶, Q. Ouyang^{33a}, A. Ovcharova¹⁵, M. Owen⁸³, S. Owen¹⁴⁰, V.E. Ozcan^{19a}, N. Ozturk⁸, K. Pachal¹¹⁹, A. Pacheco Pages¹², C. Padilla Aranda¹², S. Pagan Griso¹⁵, E. Paganis¹⁴⁰, C. Pahl¹⁰⁰, F. Paige²⁵, P. Pais⁸⁵, K. Pajchel¹¹⁸, G. Palacino^{160b}, C.P. Paleari⁷, S. Palestini³⁰, D. Pallin³⁴, A. Palma^{125a}, J.D. Palmer¹⁸, Y.B. Pan¹⁷⁴, E. Panagiotopoulou¹⁰, J.G. Panduro Vazquez⁷⁶, P. Pani¹⁰⁶, N. Panikashvili⁸⁸, S. Panitkin²⁵, D. Pantea^{26a}, A. Papadelis^{147a}, Th.D. Papadopoulou¹⁰, K. Papageorgiou^{155,o}, A. Paramonov⁶, D. Paredes Hernandez³⁴, M.A. Parker²⁸, F. Parodi^{50a,50b}, J.A. Parsons³⁵, U. Parzefall⁴⁸, S. Pashapour⁵⁴, E. Pasqualucci^{133a}, S. Passaggio^{50a}, A. Passeri^{135a}, F. Pastore^{135a,135b,*}, Fr. Pastore⁷⁶, G. Pásztor^{49,af}, S. Pataraja¹⁷⁶, N.D. Patel¹⁵¹, J.R. Pater⁸³, S. Patricelli^{103a,103b}, T. Pauly³⁰, J. Pearce¹⁷⁰, M. Pedersen¹¹⁸, S. Pedraza Lopez¹⁶⁸, M.I. Pedraza Morales¹⁷⁴, S.V. Peleganchuk¹⁰⁸, D. Pelikan¹⁶⁷, H. Peng^{33b}, B. Penning³¹, A. Penson³⁵, J. Penwell⁶⁰, D.V. Perepelitsa³⁵, T. Perez Cavalcanti⁴², E. Perez Codina^{160a}, M.T. Pérez García-Están¹⁶⁸, V. Perez Reale³⁵, L. Perini^{90a,90b}, H. Pernegger³⁰, R. Perrino^{72a}, V.D. Peshekhonov⁶⁴, K. Peters³⁰, R.F.Y. Peters^{54,ag}, B.A. Petersen³⁰, J. Petersen³⁰, T.C. Petersen³⁶, E. Petit⁵, A. Petridis^{147a,147b}, C. Petridou¹⁵⁵, E. Petrolo^{133a}, F. Petrucci^{135a,135b}, M. Petteni¹⁴³, R. Pezoa^{32b}, A. Phan⁸⁷, P.W. Phillips¹³⁰, G. Piacquadio¹⁴⁴, E. Pianori¹⁷¹, A. Picazio⁴⁹, E. Piccaro⁷⁵, M. Piccinini^{20a,20b}, S.M. Piec⁴², R. Piegai²⁷, D.T. Pignotti¹¹⁰, J.E. Pilcher³¹, A.D. Pilkington⁷⁷, J. Pina^{125a,c}, M. Pinamonti^{165a,165c,ah}, A. Pinder¹¹⁹, J.L. Pinfold³, A. Pingel³⁶, B. Pinto^{125a}, C. Pizio^{90a,90b}, M.-A. Pleier²⁵, V. Pleskot¹²⁸, E. Plotnikova⁶⁴, P. Plucinski^{147a,147b}, S. Poddar^{58a}, F. Podlyski³⁴, R. Poettgen⁸², L. Poggioli¹¹⁶, D. Pohl²¹, M. Pohl⁴⁹, G. Polesello^{120a}, A. Policicchio^{37a,37b}, R. Polifka¹⁵⁹, A. Polini^{20a}, C.S. Pollard⁴⁵, V. Polychronakos²⁵, D. Pomeroy²³, K. Pommès³⁰, L. Pontecorvo^{133a}, B.G. Pope⁸⁹, G.A. Popeneciu^{26b}, D.S. Popovic^{13a}, A. Poppleton³⁰, X. Portell Bueso¹², G.E. Pospelov¹⁰⁰, S. Pospisil¹²⁷, I.N. Potrap⁶⁴, C.J. Potter¹⁵⁰, C.T. Potter¹¹⁵, G. Poulard³⁰, J. Poveda⁶⁰, V. Pozdnyakov⁶⁴, R. Prabhu⁷⁷, P. Pralavorio⁸⁴, A. Pranko¹⁵, S. Prasad³⁰, R. Pravahan²⁵, S. Prell⁶³, D. Price⁶⁰, J. Price⁷³, L.E. Price⁶, D. Prieur¹²⁴, M. Primavera^{72a}, M. Proissl⁴⁶, K. Prokofiev¹⁰⁹, F. Prokoshin^{32b}, E. Protopapadaki¹³⁷, S. Protopopescu²⁵, J. Proudfoot⁶, X. Prudent⁴⁴, M. Przybycien^{38a}, H. Przysiezniak⁵, S. Psoroulas²¹, E. Ptacek¹¹⁵, E. Pueschel⁸⁵, D. Puldon¹⁴⁹, M. Purohit^{25,ai}, P. Puza¹¹⁶, Y. Pylypchenko⁶², J. Qian⁸⁸, A. Quadt⁵⁴, D.R. Quarrie¹⁵, W.B. Quayle^{146c}, D. Quilty⁵³, M. Raas¹⁰⁵, V. Radeka²⁵, V. Radescu⁴², P. Radloff¹¹⁵, F. Ragusa^{90a,90b}, G. Rahal¹⁷⁹, S. Rajagopalan²⁵, M. Rammensee⁴⁸, M. Rammes¹⁴², A.S. Randle-Conde⁴⁰, C. Rangel-Smith⁷⁹,

K. Rao¹⁶⁴, F. Rauscher⁹⁹, T.C. Rave⁴⁸, T. Ravenscroft⁵³, M. Raymond³⁰, A.L. Read¹¹⁸,
 D.M. Rebuzzi^{120a,120b}, A. Redelbach¹⁷⁵, G. Redlinger²⁵, R. Reece¹²¹, K. Reeves⁴¹, A. Reinsch¹¹⁵,
 I. Reisinger⁴³, M. Relich¹⁶⁴, C. Rembser³⁰, Z.L. Ren¹⁵², A. Renaud¹¹⁶, M. Rescigno^{133a},
 S. Resconi^{90a}, B. Resende¹³⁷, P. Reznicek⁹⁹, R. Rezvani⁹⁴, R. Richter¹⁰⁰, E. Richter-Was^{38b},
 M. Ridel⁷⁹, P. Rieck¹⁶, M. Rijssenbeek¹⁴⁹, A. Rimoldi^{120a,120b}, L. Rinaldi^{20a}, R.R. Rios⁴⁰,
 E. Ritsch⁶¹, I. Riu¹², G. Rivoltella^{90a,90b}, F. Rizatdinova¹¹³, E. Rizvi⁷⁵, S.H. Robertson^{86,j},
 A. Robichaud-Veronneau¹¹⁹, D. Robinson²⁸, J.E.M. Robinson⁸³, A. Robson⁵³,
 J.G. Rocha de Lima¹⁰⁷, C. Roda^{123a,123b}, D. Roda Dos Santos³⁰, A. Roe⁵⁴, S. Roe³⁰,
 O. Røhne¹¹⁸, S. Rolli¹⁶², A. Romaniouk⁹⁷, M. Romano^{20a,20b}, G. Romeo²⁷, E. Romero Adam¹⁶⁸,
 N. Rompotis¹³⁹, L. Roos⁷⁹, E. Ros¹⁶⁸, S. Rosati^{133a}, K. Rosbach⁴⁹, A. Rose¹⁵⁰, M. Rose⁷⁶,
 P.L. Rosendahl¹⁴, O. Rosenthal¹⁴², V. Rossetti¹², E. Rossi^{133a,133b}, L.P. Rossi^{50a}, M. Rotaru^{26a},
 I. Roth¹⁷³, J. Rothberg¹³⁹, D. Rousseau¹¹⁶, C.R. Royon¹³⁷, A. Rozanov⁸⁴, Y. Rozen¹⁵³,
 X. Ruan^{146c}, F. Rubbo¹², I. Rubinskiy⁴², N. Ruckstuhl¹⁰⁶, V.I. Rud⁹⁸, C. Rudolph⁴⁴,
 M.S. Rudolph¹⁵⁹, F. Rühr⁷, A. Ruiz-Martinez⁶³, L. Rumyantsev⁶⁴, Z. Rurikova⁴⁸,
 N.A. Rusakovich⁶⁴, A. Ruschke⁹⁹, J.P. Rutherford⁷, N. Ruthmann⁴⁸, P. Ruzicka¹²⁶,
 Y.F. Ryabov¹²², M. Rybar¹²⁸, G. Rybkin¹¹⁶, N.C. Ryder¹¹⁹, A.F. Saavedra¹⁵¹, A. Saddique³,
 I. Sadeh¹⁵⁴, H.F.-W. Sadrozinski¹³⁸, R. Sadykov⁶⁴, F. Safai Tehrani^{133a}, H. Sakamoto¹⁵⁶,
 G. Salamanna⁷⁵, A. Salamon^{134a}, M. Saleem¹¹², D. Salek³⁰, D. Salihagic¹⁰⁰, A. Salnikov¹⁴⁴,
 J. Salt¹⁶⁸, B.M. Salvachua Ferrando⁶, D. Salvatore^{37a,37b}, F. Salvatore¹⁵⁰, A. Salvucci¹⁰⁵,
 A. Salzburger³⁰, D. Sampsonidis¹⁵⁵, A. Sanchez^{103a,103b}, J. Sánchez¹⁶⁸, V. Sanchez Martinez¹⁶⁸,
 H. Sandaker¹⁴, H.G. Sander⁸², M.P. Sanders⁹⁹, M. Sandhoff¹⁷⁶, T. Sandoval²⁸, C. Sandoval¹⁶³,
 R. Sandstroem¹⁰⁰, D.P.C. Sankey¹³⁰, A. Sansoni⁴⁷, C. Santoni³⁴, R. Santonico^{134a,134b},
 H. Santos^{125a}, I. Santoyo Castillo¹⁵⁰, K. Sapp¹²⁴, A. Saponov⁶⁴, J.G. Saraiva^{125a}, T. Sarangi¹⁷⁴,
 E. Sarkisyan-Grinbaum⁸, B. Sarrazin²¹, F. Sarri^{123a,123b}, G. Sartisohn¹⁷⁶, O. Sasaki⁶⁵,
 Y. Sasaki¹⁵⁶, N. Sasao⁶⁷, I. Satsounkevitch⁹¹, G. Sauvage^{5,*}, E. Sauvan⁵, J.B. Sauvan¹¹⁶,
 P. Savard^{159,e}, V. Savinov¹²⁴, D.O. Savu³⁰, C. Sawyer¹¹⁹, L. Sawyer^{78,l}, D.H. Saxon⁵³,
 J. Saxon¹²¹, C. Sbarra^{20a}, A. Sbrizzi³, D.A. Scannicchio¹⁶⁴, M. Scarcella¹⁵¹, J. Schaarschmidt¹¹⁶,
 P. Schacht¹⁰⁰, D. Schaefer¹²¹, A. Schaelicke⁴⁶, S. Schaepe²¹, S. Schaezel^{58b}, U. Schäfer⁸²,
 A.C. Schaffer¹¹⁶, D. Schaile⁹⁹, R.D. Schamberger¹⁴⁹, V. Scharf^{58a}, V.A. Schegelsky¹²²,
 D. Scheirich⁸⁸, M. Schernau¹⁶⁴, M.I. Scherzer³⁵, C. Schiavi^{50a,50b}, J. Schieck⁹⁹, C. Schillo⁴⁸,
 M. Schioppa^{37a,37b}, S. Schlenker³⁰, E. Schmidt⁴⁸, K. Schmieden³⁰, C. Schmitt⁸², C. Schmitt⁹⁹,
 S. Schmitt^{58b}, B. Schneider¹⁷, Y.J. Schnellbach⁷³, U. Schnoor⁴⁴, L. Schoeffel¹³⁷, A. Schoening^{58b},
 A.L.S. Schorlemmer⁵⁴, M. Schott⁸², D. Schouten^{160a}, J. Schovancova¹²⁶, M. Schram⁸⁶,
 C. Schroeder⁸², N. Schroer^{58c}, M.J. Schultens²¹, H.-C. Schultz-Coulon^{58a}, H. Schulz¹⁶,
 M. Schumacher⁴⁸, B.A. Schumm¹³⁸, Ph. Schune¹³⁷, A. Schwartzman¹⁴⁴, Ph. Schwegler¹⁰⁰,
 Ph. Schwemling¹³⁷, R. Schwienhorst⁸⁹, J. Schwindling¹³⁷, T. Schwindt²¹, M. Schwoerer⁵,
 F.G. Sciaccia¹⁷, E. Scifo¹¹⁶, G. Sciolla²³, W.G. Scott¹³⁰, F. Scutti²¹, J. Searcy⁸⁸, G. Sedov⁴²,
 E. Sedykh¹²², S.C. Seidel¹⁰⁴, A. Seiden¹³⁸, F. Seifert⁴⁴, J.M. Seixas^{24a}, G. Sekhniaidze^{103a},
 S.J. Sekula⁴⁰, K.E. Selbach⁴⁶, D.M. Seliverstov¹²², G. Sellers⁷³, M. Seman^{145b},
 N. Semprini-Cesari^{20a,20b}, C. Serfon³⁰, L. Serin¹¹⁶, L. Serkin⁵⁴, T. Serre⁸⁴, R. Seuster^{160a},
 H. Severini¹¹², A. Sfyrla³⁰, E. Shabalina⁵⁴, M. Shamim¹¹⁵, L.Y. Shan^{33a}, J.T. Shank²²,
 Q.T. Shao⁸⁷, M. Shapiro¹⁵, P.B. Shatalov⁹⁶, K. Shaw^{165a,165c}, P. Sherwood⁷⁷, S. Shimizu⁶⁶,
 M. Shimojima¹⁰¹, T. Shin⁵⁶, M. Shiyakova⁶⁴, A. Shmeleva⁹⁵, M.J. Shochet³¹, D. Short¹¹⁹,
 S. Shrestha⁶³, E. Shulga⁹⁷, M.A. Shupe⁷, S. Shushkevich⁴², P. Sicho¹²⁶, A. Sidoti^{133a}, F. Siegert⁴⁸,
 Dj. Sijacki^{13a}, O. Silbert¹⁷³, J. Silva^{125a}, Y. Silver¹⁵⁴, D. Silverstein¹⁴⁴, S.B. Silverstein^{147a},
 V. Simak¹²⁷, O. Simard⁵, Lj. Simic^{13a}, S. Simion¹¹⁶, E. Simioni⁸², B. Simmons⁷⁷,
 R. Simoniello^{90a,90b}, M. Simonyan³⁶, P. Sinervo¹⁵⁹, N.B. Sinev¹¹⁵, V. Sipica¹⁴², G. Siragusa¹⁷⁵,
 A. Sircar⁷⁸, A.N. Sisakyan^{64,*}, S.Yu. Sivoklov⁹⁸, J. Sjölin^{147a,147b}, T.B. Sjursen¹⁴,
 L.A. Skinnari¹⁵, H.P. Skottowe⁵⁷, K.Yu. Skovpen¹⁰⁸, P. Skubic¹¹², M. Slater¹⁸, T. Slavicek¹²⁷,
 K. Sliwa¹⁶², V. Smakhtin¹⁷³, B.H. Smart⁴⁶, L. Smestad¹¹⁸, S.Yu. Smirnov⁹⁷, Y. Smirnov⁹⁷,
 L.N. Smirnova^{98,aj}, O. Smirnova⁸⁰, K.M. Smith⁵³, M. Smizanska⁷¹, K. Smolek¹²⁷,
 A.A. Snesev⁹⁵, G. Snidero⁷⁵, J. Snow¹¹², S. Snyder²⁵, R. Sobie^{170,j}, J. Sodomka¹²⁷, A. Soffer¹⁵⁴,

D.A. Soh^{152,v}, C.A. Solans³⁰, M. Solar¹²⁷, J. Solc¹²⁷, E.Yu. Soldatov⁹⁷, U. Soldevila¹⁶⁸,
 E. Solfaroli Camillocci^{133a,133b}, A.A. Solodkov¹²⁹, O.V. Solovyanov¹²⁹, V. Solovyev¹²², N. Soni¹,
 A. Sood¹⁵, V. Sopko¹²⁷, B. Sopko¹²⁷, M. Sosebee⁸, R. Soualah^{165a,165c}, P. Soueid⁹⁴,
 A.M. Soukharev¹⁰⁸, D. South⁴², S. Spagnolo^{72a,72b}, F. Spanò⁷⁶, W.R. Spearman⁵⁷, R. Spighi^{20a},
 G. Spigo³⁰, M. Spousta^{128,ak}, T. Spreitzer¹⁵⁹, B. Spurlock⁸, R.D. St. Denis⁵³, J. Stahlman¹²¹,
 R. Stamen^{58a}, E. Stanecka³⁹, R.W. Stanek⁶, C. Stanescu^{135a}, M. Stanescu-Bellu⁴²,
 M.M. Stanitzki⁴², S. Stapnes¹¹⁸, E.A. Starchenko¹²⁹, J. Stark⁵⁵, P. Staroba¹²⁶, P. Starovoitov⁴²,
 R. Staszewski³⁹, A. Staude⁹⁹, P. Stavina^{145a,*}, G. Steele⁵³, P. Steinbach⁴⁴, P. Steinberg²⁵,
 I. Stekl¹²⁷, B. Stelzer¹⁴³, H.J. Stelzer⁸⁹, O. Stelzer-Chilton^{160a}, H. Stenzel⁵², S. Stern¹⁰⁰,
 G.A. Stewart³⁰, J.A. Stillings²¹, M.C. Stockton⁸⁶, M. Stoebe⁸⁶, K. Stoerig⁴⁸, G. Stoicea^{26a},
 S. Stonjek¹⁰⁰, A.R. Stradling⁸, A. Straessner⁴⁴, J. Strandberg¹⁴⁸, S. Strandberg^{147a,147b},
 A. Strandlie¹¹⁸, M. Strang¹¹⁰, E. Strauss¹⁴⁴, M. Strauss¹¹², P. Strizenc^{145b}, R. Ströhmer¹⁷⁵,
 D.M. Strom¹¹⁵, J.A. Strong^{76,*}, R. Stroynowski⁴⁰, B. Stugu¹⁴, I. Stumer^{25,*}, J. Stupak¹⁴⁹,
 P. Sturm¹⁷⁶, N.A. Styles⁴², D. Su¹⁴⁴, HS. Subramania³, R. Subramaniam⁷⁸, A. Succurro¹²,
 Y. Sugaya¹¹⁷, C. Suhr¹⁰⁷, M. Suk¹²⁷, V.V. Sulim⁹⁵, S. Sultansoy^{4c}, T. Sumida⁶⁷, X. Sun⁵⁵,
 J.E. Sundermann⁴⁸, K. Suruliz¹⁴⁰, G. Susinno^{37a,37b}, M.R. Sutton¹⁵⁰, Y. Suzuki⁶⁵, M. Svatos¹²⁶,
 S. Swedish¹⁶⁹, M. Swiatlowski¹⁴⁴, I. Sykora^{145a}, T. Sykora¹²⁸, D. Ta¹⁰⁶, K. Tackmann⁴²,
 A. Taffard¹⁶⁴, R. Tafirout^{160a}, N. Taiblum¹⁵⁴, Y. Takahashi¹⁰², H. Takai²⁵, R. Takashima⁶⁸,
 H. Takeda⁶⁶, T. Takeshita¹⁴¹, Y. Takubo⁶⁵, M. Talby⁸⁴, A.A. Talyshev^{108,g}, J.Y.C. Tam¹⁷⁵,
 M.C. Tamsett^{78,al}, K.G. Tan⁸⁷, J. Tanaka¹⁵⁶, R. Tanaka¹¹⁶, S. Tanaka¹³², S. Tanaka⁶⁵,
 A.J. Tanasijczuk¹⁴³, K. Tani⁶⁶, N. Tannoury⁸⁴, S. Tapprogge⁸², S. Tarem¹⁵³, F. Tarrade²⁹,
 G.F. Tartarelli^{90a}, P. Tas¹²⁸, M. Tasevsky¹²⁶, T. Tashiro⁶⁷, E. Tassi^{37a,37b},
 A. Tavares Delgado^{125a}, Y. Tayalati^{136d}, C. Taylor⁷⁷, F.E. Taylor⁹³, G.N. Taylor⁸⁷, W. Taylor^{160b},
 M. Teinturier¹¹⁶, F.A. Teischinger³⁰, M. Teixeira Dias Castanheira⁷⁵, P. Teixeira-Dias⁷⁶,
 K.K. Temming⁴⁸, H. Ten Kate³⁰, P.K. Teng¹⁵², S. Terada⁶⁵, K. Terashi¹⁵⁶, J. Terron⁸¹,
 M. Testa⁴⁷, R.J. Teuscher^{159,j}, J. Therhaag²¹, T. Theveneaux-Pelzer³⁴, S. Thoma⁴⁸,
 J.P. Thomas¹⁸, E.N. Thompson³⁵, P.D. Thompson¹⁸, P.D. Thompson¹⁵⁹, A.S. Thompson⁵³,
 L.A. Thomsen³⁶, E. Thomson¹²¹, M. Thomson²⁸, W.M. Thong⁸⁷, R.P. Thun^{88,*}, F. Tian³⁵,
 M.J. Tibbetts¹⁵, T. Tic¹²⁶, V.O. Tikhomirov⁹⁵, Yu.A. Tikhonov^{108,g}, S. Timoshenko⁹⁷,
 E. Tiouchichine⁸⁴, P. Tipton¹⁷⁷, S. Tisserant⁸⁴, T. Todorov⁵, S. Todorova-Nova¹²⁸,
 B. Toggerson¹⁶⁴, J. Tojo⁶⁹, S. Tokár^{145a}, K. Tokushuku⁶⁵, K. Tollefson⁸⁹, L. Tomlinson⁸³,
 M. Tomoto¹⁰², L. Tompkins³¹, K. Toms¹⁰⁴, A. Tonoyan¹⁴, C. Topfel¹⁷, N.D. Topilin⁶⁴,
 E. Torrence¹¹⁵, H. Torres⁷⁹, E. Torró Pastor¹⁶⁸, J. Toth^{84,af}, F. Touchard⁸⁴, D.R. Tovey¹⁴⁰,
 H.L. Tran¹¹⁶, T. Trefzger¹⁷⁵, L. Tremblet³⁰, A. Tricoli³⁰, I.M. Trigger^{160a}, S. Trincaz-Duvoid⁷⁹,
 M.F. Tripiana⁷⁰, N. Triplett²⁵, W. Trischuk¹⁵⁹, B. Trocmé⁵⁵, C. Troncon^{90a},
 M. Trotter-McDonald¹⁴³, M. Trovatelli^{135a,135b}, P. True⁸⁹, M. Trzebinski³⁹, A. Trzupek³⁹,
 C. Tsarouchas³⁰, J.C-L. Tseng¹¹⁹, M. Tsiakiris¹⁰⁶, P.V. Tsiarashka⁹¹, D. Tsionou¹³⁷,
 G. Tsipolitis¹⁰, S. Tsiskaridze¹², V. Tsiskaridze⁴⁸, E.G. Tskhadadze^{51a}, I.I. Tsukerman⁹⁶,
 V. Tsulaia¹⁵, J.-W. Tsung²¹, S. Tsuno⁶⁵, D. Tsybychev¹⁴⁹, A. Tua¹⁴⁰, A. Tudorache^{26a},
 V. Tudorache^{26a}, J.M. Tuggle³¹, A.N. Tuna¹²¹, S. Turchikhin^{98,aj}, D. Turecek¹²⁷, I. Turk Cakir^{4d},
 R. Turra^{90a,90b}, P.M. Tuts³⁵, A. Tykhonov⁷⁴, M. Tylmad^{147a,147b}, M. Tyndel¹³⁰, K. Uchida²¹,
 I. Ueda¹⁵⁶, R. Ueno²⁹, M. Ughetto⁸⁴, M. Ugland¹⁴, M. Uhlenbrock²¹, F. Ukegawa¹⁶¹, G. Unal³⁰,
 A. Undrus²⁵, G. Unel¹⁶⁴, F.C. Ungaro⁴⁸, Y. Unno⁶⁵, D. Urbaniec³⁵, P. Urquijo²¹, G. Usai⁸,
 A. Usanova⁶¹, L. Vacavant⁸⁴, V. Vacek¹²⁷, B. Vachon⁸⁶, S. Vahsen¹⁵, N. Valencic¹⁰⁶,
 S. Valentini^{20a,20b}, A. Valero¹⁶⁸, L. Valery³⁴, S. Valkar¹²⁸, E. Valladolid Gallego¹⁶⁸,
 S. Vallecorsa¹⁵³, J.A. Valls Ferrer¹⁶⁸, R. Van Berg¹²¹, P.C. Van Der Deijl¹⁰⁶, R. van der Geer¹⁰⁶,
 H. van der Graaf¹⁰⁶, R. Van Der Leeuw¹⁰⁶, D. van der Ster³⁰, N. van Eldik³⁰, P. van Gemmeren⁶,
 J. Van Nieuwkoop¹⁴³, I. van Vulpen¹⁰⁶, M. Vanadia¹⁰⁰, W. Vandelli³⁰, A. Vaniachine⁶,
 P. Vankov⁴², F. Vannucci⁷⁹, R. Vari^{133a}, E.W. Varnes⁷, T. Varol⁸⁵, D. Varouchas¹⁵,
 A. Vartapetian⁸, K.E. Varvell¹⁵¹, V.I. Vassilakopoulos⁵⁶, F. Vazeille³⁴, T. Vazquez Schroeder⁵⁴,
 J. Veatch⁷, F. Veloso^{125a}, S. Veneziano^{133a}, A. Ventura^{72a,72b}, D. Ventura⁸⁵, M. Venturi⁴⁸,
 N. Venturi¹⁵⁹, V. Vercesi^{120a}, M. Verducci¹³⁹, W. Verkerke¹⁰⁶, J.C. Vermeulen¹⁰⁶, A. Vest⁴⁴,

M.C. Vetterli^{143,e}, I. Vichou¹⁶⁶, T. Vickey^{146c,am}, O.E. Vickey Boeriu^{146c}, G.H.A. Viehhauser¹¹⁹, S. Viel¹⁶⁹, R. Vigne³⁰, M. Villa^{20a,20b}, M. Villaplana Perez¹⁶⁸, E. Vilucchi⁴⁷, M.G. Vincter²⁹, V.B. Vinogradov⁶⁴, J. Virzi¹⁵, O. Vitells¹⁷³, M. Viti⁴², I. Vivarelli⁴⁸, F. Vives Vaque³, S. Vlachos¹⁰, D. Vladoiu⁹⁹, M. Vlasak¹²⁷, A. Vogel²¹, P. Vokac¹²⁷, G. Volpi⁴⁷, M. Volpi⁸⁷, G. Volpini^{90a}, H. von der Schmitt¹⁰⁰, H. von Radziewski⁴⁸, E. von Toerne²¹, V. Vorobel¹²⁸, M. Vos¹⁶⁸, R. Voss³⁰, J.H. Vossebeld⁷³, N. Vranjes¹³⁷, M. Vranjes Milosavljevic¹⁰⁶, V. Vrba¹²⁶, M. Vreeswijk¹⁰⁶, T. Vu Anh⁴⁸, R. Vuillermet³⁰, I. Vukotic³¹, Z. Vykydal¹²⁷, W. Wagner¹⁷⁶, P. Wagner²¹, S. Wahrmund⁴⁴, J. Wakabayashi¹⁰², S. Walch⁸⁸, J. Walder⁷¹, R. Walker⁹⁹, W. Walkowiak¹⁴², R. Wall¹⁷⁷, P. Waller⁷³, B. Walsh¹⁷⁷, C. Wang⁴⁵, H. Wang¹⁷⁴, H. Wang⁴⁰, J. Wang¹⁵², J. Wang^{33a}, K. Wang⁸⁶, R. Wang¹⁰⁴, S.M. Wang¹⁵², T. Wang²¹, X. Wang¹⁷⁷, A. Warburton⁸⁶, C.P. Ward²⁸, D.R. Wardrope⁷⁷, M. Warsinsky⁴⁸, A. Washbrook⁴⁶, C. Wasicki⁴², I. Watanabe⁶⁶, P.M. Watkins¹⁸, A.T. Watson¹⁸, I.J. Watson¹⁵¹, M.F. Watson¹⁸, G. Watts¹³⁹, S. Watts⁸³, A.T. Waugh¹⁵¹, B.M. Waugh⁷⁷, M.S. Weber¹⁷, J.S. Webster³¹, A.R. Weidberg¹¹⁹, P. Weigell¹⁰⁰, J. Weingarten⁵⁴, C. Weiser⁴⁸, H. Weits¹⁰⁶, P.S. Wells³⁰, T. Wenaus²⁵, D. Wendland¹⁶, Z. Weng^{152,v}, T. Wengler³⁰, S. Wenig³⁰, N. Vermes²¹, M. Werner⁴⁸, P. Werner³⁰, M. Werth¹⁶⁴, M. Wessels^{58a}, J. Wetter¹⁶², K. Whalen²⁹, A. White⁸, M.J. White⁸⁷, R. White^{32b}, S. White^{123a,123b}, D. Whiteson¹⁶⁴, D. Whittington⁶⁰, D. Wicke¹⁷⁶, F.J. Wickens¹³⁰, W. Wiedenmann¹⁷⁴, M. Wielers^{80,d}, P. Wienemann²¹, C. Wiglesworth³⁶, L.A.M. Wiik-Fuchs²¹, P.A. Wijeratne⁷⁷, A. Wildauer¹⁰⁰, M.A. Wildt^{42,s}, I. Wilhelm¹²⁸, H.G. Wilkens³⁰, J.Z. Will⁹⁹, E. Williams³⁵, H.H. Williams¹²¹, S. Williams²⁸, W. Willis^{35,*}, S. Willocq⁸⁵, J.A. Wilson¹⁸, A. Wilson⁸⁸, I. Wingerter-Seetz⁵, S. Winkelmann⁴⁸, F. Winklmeier³⁰, M. Wittgen¹⁴⁴, T. Wittig⁴³, J. Wittkowski⁹⁹, S.J. Wollstadt⁸², M.W. Wolter³⁹, H. Wolters^{125a,h}, W.C. Wong⁴¹, G. Wooden⁸⁸, B.K. Wosiek³⁹, J. Wotschack³⁰, M.J. Woudstra⁸³, K.W. Wozniak³⁹, K. Wraight⁵³, M. Wright⁵³, B. Wrona⁷³, S.L. Wu¹⁷⁴, X. Wu⁴⁹, Y. Wu⁸⁸, E. Wulf³⁵, B.M. Wynne⁴⁶, S. Xella³⁶, M. Xiao¹³⁷, C. Xu^{33b,aa}, D. Xu^{33a}, L. Xu^{33b,an}, B. Yabsley¹⁵¹, S. Yacoob^{146b,ao}, M. Yamada⁶⁵, H. Yamaguchi¹⁵⁶, Y. Yamaguchi¹⁵⁶, A. Yamamoto⁶⁵, K. Yamamoto⁶³, S. Yamamoto¹⁵⁶, T. Yamamura¹⁵⁶, T. Yamanaka¹⁵⁶, K. Yamauchi¹⁰², Y. Yamazaki⁶⁶, Z. Yan²², H. Yang^{33e}, H. Yang¹⁷⁴, U.K. Yang⁸³, Y. Yang¹¹⁰, Z. Yang^{147a,147b}, S. Yanush⁹², L. Yao^{33a}, Y. Yasu⁶⁵, E. Yatsenko⁴², K.H. Yau Wong²¹, J. Ye⁴⁰, S. Ye²⁵, A.L. Yen⁵⁷, E. Yildirim⁴², M. Yilmaz^{4b}, R. Yoosoofmiya¹²⁴, K. Yorita¹⁷², R. Yoshida⁶, K. Yoshihara¹⁵⁶, C. Young¹⁴⁴, C.J.S. Young¹¹⁹, S. Youssef²², D.R. Yu¹⁵, J. Yu⁸, J. Yu¹¹³, L. Yuan⁶⁶, A. Yurkewicz¹⁰⁷, B. Zabinski³⁹, R. Zaidan⁶², A.M. Zaitsev^{129,ab}, S. Zambito²³, L. Zanello^{133a,133b}, D. Zanzi¹⁰⁰, A. Zaytsev²⁵, C. Zeitnitz¹⁷⁶, M. Zeman¹²⁷, A. Zemla³⁹, O. Zenin¹²⁹, T. Ženis^{145a}, D. Zerwas¹¹⁶, G. Zevi della Porta⁵⁷, D. Zhang⁸⁸, H. Zhang⁸⁹, J. Zhang⁶, L. Zhang¹⁵², X. Zhang^{33d}, Z. Zhang¹¹⁶, Z. Zhao^{33b}, A. Zhemchugov⁶⁴, J. Zhong¹¹⁹, B. Zhou⁸⁸, N. Zhou¹⁶⁴, C.G. Zhu^{33d}, H. Zhu⁴², J. Zhu⁸⁸, Y. Zhu^{33b}, X. Zhuang^{33a}, A. Zibell⁹⁹, D. Zieminska⁶⁰, N.I. Zimin⁶⁴, C. Zimmermann⁸², R. Zimmermann²¹, S. Zimmermann²¹, S. Zimmermann⁴⁸, Z. Zinonos^{123a,123b}, M. Ziolkowski¹⁴², R. Zitoun⁵, L. Živković³⁵, G. Zobernig¹⁷⁴, A. Zoccoli^{20a,20b}, M. zur Nedden¹⁶, G. Zurzolo^{103a,103b}, V. Zutshi¹⁰⁷, L. Zwalinski³⁰

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, Gazi University, Ankara; ^(c) Division of Physics, TOBB University of Economics and Technology, Ankara; ^(d) 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, 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) Department of Physics, Dogus University, Istanbul; ^(c) Department of Physics Engineering, Gaziantep University, Gaziantep, Turkey
- ²⁰ ^(a) INFN Sezione di Bologna; ^(b) Dipartimento di Fisica e Astronomia, 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) National Institute for Research and Development of Isotopic and Molecular Technologies, Physics Department, Cluj Napoca; ^(c) University Politehnica Bucharest, Bucharest; ^(d) 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, Rende, Italy
- ³⁸ ^(a) AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Krakow; ^(b) Marian Smoluchowski Institute of Physics, Jagiellonian University, 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, Technische Universität 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. Javakishvili 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 Louisiana Tech University, Ruston LA, United States of America
- 79 Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France
- 80 Fysiska institutionen, Lunds universitet, Lund, Sweden
- 81 Departamento de Física Teórica C-15, Universidad Autónoma de Madrid, Madrid, Spain
- 82 Institut für Physik, Universität Mainz, Mainz, Germany
- 83 School of Physics and Astronomy, University of Manchester, Manchester, United Kingdom
- 84 CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France
- 85 Department of Physics, University of Massachusetts, Amherst MA, United States of America
- 86 Department of Physics, McGill University, Montreal QC, Canada
- 87 School of Physics, University of Melbourne, Victoria, Australia

- 88 Department of Physics, The University of Michigan, Ann Arbor MI, United States of America
- 89 Department of Physics and Astronomy, Michigan State University, East Lansing MI, United States of America
- 90 ^(a) INFN Sezione di Milano; ^(b) Dipartimento di Fisica, Università di Milano, Milano, Italy
- 91 B.I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk, Republic of Belarus
- 92 National Scientific and Educational Centre for Particle and High Energy Physics, Minsk, Republic of Belarus
- 93 Department of Physics, Massachusetts Institute of Technology, Cambridge MA, United States of America
- 94 Group of Particle Physics, University of Montreal, Montreal QC, Canada
- 95 P.N. Lebedev Institute of Physics, Academy of Sciences, Moscow, Russia
- 96 Institute for Theoretical and Experimental Physics (ITEP), Moscow, Russia
- 97 Moscow Engineering and Physics Institute (MEPhI), Moscow, Russia
- 98 D.V.Skobeltzyn Institute of Nuclear Physics, M.V.Lomonosov Moscow State University, Moscow, Russia
- 99 Fakultät für Physik, Ludwig-Maximilians-Universität München, München, Germany
- 100 Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), München, Germany
- 101 Nagasaki Institute of Applied Science, Nagasaki, Japan
- 102 Graduate School of Science and Kobayashi-Maskawa Institute, Nagoya University, Nagoya, Japan
- 103 ^(a) INFN Sezione di Napoli; ^(b) Dipartimento di Scienze Fisiche, Università di Napoli, Napoli, Italy
- 104 Department of Physics and Astronomy, University of New Mexico, Albuquerque NM, United States of America
- 105 Institute for Mathematics, Astrophysics and Particle Physics, Radboud University Nijmegen/Nikhef, Nijmegen, Netherlands
- 106 Nikhef National Institute for Subatomic Physics and University of Amsterdam, Amsterdam, Netherlands
- 107 Department of Physics, Northern Illinois University, DeKalb IL, United States of America
- 108 Budker Institute of Nuclear Physics, SB RAS, Novosibirsk, Russia
- 109 Department of Physics, New York University, New York NY, United States of America
- 110 Ohio State University, Columbus OH, United States of America
- 111 Faculty of Science, Okayama University, Okayama, Japan
- 112 Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman OK, United States of America
- 113 Department of Physics, Oklahoma State University, Stillwater OK, United States of America
- 114 Palacký University, RCPTM, Olomouc, Czech Republic
- 115 Center for High Energy Physics, University of Oregon, Eugene OR, United States of America
- 116 LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France
- 117 Graduate School of Science, Osaka University, Osaka, Japan
- 118 Department of Physics, University of Oslo, Oslo, Norway
- 119 Department of Physics, Oxford University, Oxford, United Kingdom
- 120 ^(a) INFN Sezione di Pavia; ^(b) Dipartimento di Fisica, Università di Pavia, Pavia, Italy
- 121 Department of Physics, University of Pennsylvania, Philadelphia PA, United States of America
- 122 Petersburg Nuclear Physics Institute, Gatchina, Russia
- 123 ^(a) INFN Sezione di Pisa; ^(b) Dipartimento di Fisica E. Fermi, Università di Pisa, Pisa, Italy
- 124 Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh PA, United States of America
- 125 ^(a) Laboratório de Instrumentação e Física Experimental de Partículas - LIP, Lisboa, Portugal; ^(b) Departamento de Física Teórica y del Cosmos and CAFPE, Universidad de Granada, Granada, Spain
- 126 Institute of Physics, Academy of Sciences of the Czech Republic, Praha, Czech Republic
- 127 Czech Technical University in Prague, Praha, Czech Republic

- 128 Faculty of Mathematics and Physics, Charles University in Prague, Praha, Czech Republic
129 State Research Center Institute for High Energy Physics, Protvino, Russia
130 Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom
131 Physics Department, University of Regina, Regina SK, Canada
132 Ritsumeikan University, Kusatsu, Shiga, Japan
133 ^(a) INFN Sezione di Roma I; ^(b) Dipartimento di Fisica, Università La Sapienza, Roma, Italy
134 ^(a) INFN Sezione di Roma Tor Vergata; ^(b) Dipartimento di Fisica, Università di Roma Tor Vergata, Roma, Italy
135 ^(a) INFN Sezione di Roma Tre; ^(b) Dipartimento di Matematica e Fisica, Università Roma Tre, Roma, Italy
136 ^(a) Faculté des Sciences Ain Chock, Réseau Universitaire de Physique des Hautes Energies - Université Hassan II, Casablanca; ^(b) Centre National de l'Énergie des Sciences Techniques 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
137 DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat à l'Énergie Atomique et aux Énergies Alternatives), Gif-sur-Yvette, France
138 Santa Cruz Institute for Particle Physics, University of California Santa Cruz, Santa Cruz CA, United States of America
139 Department of Physics, University of Washington, Seattle WA, United States of America
140 Department of Physics and Astronomy, University of Sheffield, Sheffield, United Kingdom
141 Department of Physics, Shinshu University, Nagano, Japan
142 Fachbereich Physik, Universität Siegen, Siegen, Germany
143 Department of Physics, Simon Fraser University, Burnaby BC, Canada
144 SLAC National Accelerator Laboratory, Stanford CA, United States of America
145 ^(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
146 ^(a) Department of Physics, University of Cape Town, Cape Town; ^(b) Department of Physics, University of Johannesburg, Johannesburg; ^(c) School of Physics, University of the Witwatersrand, Johannesburg, South Africa
147 ^(a) Department of Physics, Stockholm University; ^(b) The Oskar Klein Centre, Stockholm, Sweden
148 Physics Department, Royal Institute of Technology, Stockholm, Sweden
149 Departments of Physics & Astronomy and Chemistry, Stony Brook University, Stony Brook NY, United States of America
150 Department of Physics and Astronomy, University of Sussex, Brighton, United Kingdom
151 School of Physics, University of Sydney, Sydney, Australia
152 Institute of Physics, Academia Sinica, Taipei, Taiwan
153 Department of Physics, Technion: Israel Institute of Technology, Haifa, Israel
154 Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel
155 Department of Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece
156 International Center for Elementary Particle Physics and Department of Physics, The University of Tokyo, Tokyo, Japan
157 Graduate School of Science and Technology, Tokyo Metropolitan University, Tokyo, Japan
158 Department of Physics, Tokyo Institute of Technology, Tokyo, Japan
159 Department of Physics, University of Toronto, Toronto ON, Canada
160 ^(a) TRIUMF, Vancouver BC; ^(b) Department of Physics and Astronomy, York University, Toronto ON, Canada
161 Faculty of Pure and Applied Sciences, University of Tsukuba, Tsukuba, Japan
162 Department of Physics and Astronomy, Tufts University, Medford MA, United States of America
163 Centro de Investigaciones, Universidad Antonio Narino, Bogota, Colombia

- ¹⁶⁴ Department of Physics and Astronomy, University of California Irvine, Irvine CA, United States of America
- ¹⁶⁵ ^(a) INFN Gruppo Collegato di Udine; ^(b) ICTP, Trieste; ^(c) Dipartimento di Chimica, Fisica e Ambiente, Università di Udine, Udine, Italy
- ¹⁶⁶ Department of Physics, University of Illinois, Urbana IL, United States of America
- ¹⁶⁷ Department of Physics and Astronomy, University of Uppsala, Uppsala, Sweden
- ¹⁶⁸ 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
- ¹⁶⁹ Department of Physics, University of British Columbia, Vancouver BC, Canada
- ¹⁷⁰ Department of Physics and Astronomy, University of Victoria, Victoria BC, Canada
- ¹⁷¹ Department of Physics, University of Warwick, Coventry, United Kingdom
- ¹⁷² Waseda University, Tokyo, Japan
- ¹⁷³ Department of Particle Physics, The Weizmann Institute of Science, Rehovot, Israel
- ¹⁷⁴ Department of Physics, University of Wisconsin, Madison WI, United States of America
- ¹⁷⁵ Fakultät für Physik und Astronomie, Julius-Maximilians-Universität, Würzburg, Germany
- ¹⁷⁶ Fachbereich C Physik, Bergische Universität Wuppertal, Wuppertal, Germany
- ¹⁷⁷ Department of Physics, Yale University, New Haven CT, United States of America
- ¹⁷⁸ Yerevan Physics Institute, Yerevan, Armenia
- ¹⁷⁹ Centre de Calcul de l'Institut National de Physique Nucléaire et de Physique des Particules (IN2P3), Villeurbanne, France
- ^a Also at Department of Physics, King's College London, London, United Kingdom
- ^b Also at Laboratório de Instrumentação e Física Experimental de Partículas - LIP, Lisboa, Portugal
- ^c Also at Faculdade de Ciências and CFNUL, Universidade de Lisboa, Lisboa, Portugal
- ^d Also at Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom
- ^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 Università di Napoli Parthenope, Napoli, Italy
- ^j Also at Institute of Particle Physics (IPP), Canada
- ^k Also at Department of Physics, Middle East Technical University, Ankara, Turkey
- ^l Also at Louisiana Tech University, Ruston LA, United States of America
- ^m Also at Dep Física and CEFITEC of Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Caparica, Portugal
- ⁿ Also at Department of Physics and Astronomy, Michigan State University, East Lansing MI, United States of America
- ^o Also at Department of Financial and Management Engineering, University of the Aegean, Chios, Greece
- ^p Also at Institutio Catalana de Recerca i Estudis Avancats, ICREA, Barcelona, Spain
- ^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 Institute of Physics, Academia Sinica, Taipei, Taiwan
- ^v Also at School of Physics and Engineering, Sun Yat-sen University, Guanzhou, China
- ^w Also at Academia Sinica Grid Computing, Institute of Physics, Academia Sinica, Taipei, Taiwan
- ^x Also at Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France
- ^y Also at School of Physical Sciences, National Institute of Science Education and Research, Bhubaneswar, India

- ^z Also at Dipartimento di Fisica, Università La Sapienza, Roma, Italy
- ^{aa} Also at DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat à l'Energie Atomique et aux Energies Alternatives), Gif-sur-Yvette, France
- ^{ab} Also at Moscow Institute of Physics and Technology State University, Dolgoprudny, Russia
- ^{ac} Also at Section de Physique, Université de Genève, Geneva, Switzerland
- ^{ad} Also at Departamento de Fisica, Universidade de Minho, Braga, Portugal
- ^{ae} Also at Department of Physics, The University of Texas at Austin, Austin TX, United States of America
- ^{af} Also at Institute for Particle and Nuclear Physics, Wigner Research Centre for Physics, Budapest, Hungary
- ^{ag} Also at DESY, Hamburg and Zeuthen, Germany
- ^{ah} Also at International School for Advanced Studies (SISSA), Trieste, Italy
- ^{ai} Also at Department of Physics and Astronomy, University of South Carolina, Columbia SC, United States of America
- ^{aj} Also at Faculty of Physics, M.V.Lomonosov Moscow State University, Moscow, Russia
- ^{ak} Also at Nevis Laboratory, Columbia University, Irvington NY, United States of America
- ^{al} Also at Physics Department, Brookhaven National Laboratory, Upton NY, United States of America
- ^{am} Also at Department of Physics, Oxford University, Oxford, United Kingdom
- ^{an} Also at Department of Physics, The University of Michigan, Ann Arbor MI, United States of America
- ^{ao} Also at Discipline of Physics, University of KwaZulu-Natal, Durban, South Africa
- * Deceased