

CERN-PH-EP-2012-243

Submitted to: JHEP

Search for direct chargino production in anomaly-mediated supersymmetry breaking models based on a disappearing-track signature in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector

The ATLAS Collaboration

Abstract

A search for direct chargino production in anomaly-mediated supersymmetry breaking scenarios is performed in pp collisions at $\sqrt{s} = 7$ TeV using 4.7 fb^{-1} of data collected with the ATLAS experiment at the LHC. In these models, the lightest chargino is predicted to have a lifetime long enough to be detected in the tracking detectors of collider experiments. This analysis explores such models by searching for chargino decays that result in tracks with few associated hits in the outer region of the tracking system. The transverse-momentum spectrum of candidate tracks is found to be consistent with the expectation from the Standard Model background processes and constraints on chargino properties are obtained.

Search for direct chargino production in anomaly-mediated supersymmetry breaking models based on a disappearing-track signature in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector

The ATLAS collaboration

CERN, 1211 Geneva 23, Switzerland

E-mail: atlas.publication@cern.ch

ABSTRACT: A search for direct chargino production in anomaly-mediated supersymmetry breaking scenarios is performed in pp collisions at $\sqrt{s} = 7$ TeV using 4.7 fb^{-1} of data collected with the ATLAS experiment at the LHC. In these models, the lightest chargino is predicted to have a lifetime long enough to be detected in the tracking detectors of collider experiments. This analysis explores such models by searching for chargino decays that result in tracks with few associated hits in the outer region of the tracking system. The transverse-momentum spectrum of candidate tracks is found to be consistent with the expectation from the Standard Model background processes and constraints on chargino properties are obtained.

Contents

1	Introduction	1
2	The ATLAS detector	2
3	Data and simulated event samples	3
4	Event reconstruction and selection	3
4.1	Event reconstruction	4
4.2	Kinematic selection criteria	5
4.3	Disappearing-track selection criteria	5
5	Estimate of the p_T spectrum of the background contributions	7
5.1	Interacting charged hadrons	7
5.2	Electrons failing to satisfy identification criteria	8
6	Estimate of systematic uncertainties	9
7	Statistical analysis	11
8	Results	12
9	Conclusions	13

1 Introduction

Anomaly-mediated supersymmetry breaking (AMSB) models [1, 2], where soft supersymmetry (SUSY) breaking is caused by loop effects, provides a constrained mass spectrum of SUSY particles. In particular, the ratios of the three gaugino masses are given approximately by $M_1 : M_2 : M_3 \approx 3 : 1 : 7$, where M_i ($i = 1, 2, 3$) are the bino, wino and gluino masses, respectively. The lightest gaugino is the wino, and the lightest chargino ($\tilde{\chi}_1^\pm$) and neutralino ($\tilde{\chi}_1^0$ as the lightest supersymmetric particle) are the charged and neutral winos. The mass of $\tilde{\chi}_1^\pm$ ($m_{\tilde{\chi}_1^\pm}$) becomes slightly heavier than that of $\tilde{\chi}_1^0$ due to radiative corrections involving electroweak gauge bosons. The typical mass splitting between the charged and neutral winos ($\Delta m_{\tilde{\chi}_1}$) is 160–170 MeV¹. This phenomenological feature of the nearly degenerate $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_1^0$ has the important implication that the $\tilde{\chi}_1^\pm$ has a considerable lifetime and predominantly decays into $\tilde{\chi}_1^0$ plus a low-momentum (~ 100 MeV) π^\pm . The mean lifetime of the $\tilde{\chi}_1^\pm$ ($\tau_{\tilde{\chi}_1^\pm}$) is expected to be typically a fraction of a nanosecond. Therefore, some charginos will have decay lengths exceeding a few tens of centimeters at the energies

¹Throughout this paper, natural units are used, such that $\hbar = c = 1$.

of the Large Hadron Collider (LHC) and their tracks may have no or few associated hits in the outer region of the tracking system, causing them to be classified as “disappearing tracks”.

This paper describes a search for the production of long-lived AMSB charginos, via electroweak processes in pp collisions at $\sqrt{s} = 7$ TeV:

$$pp \rightarrow \tilde{\chi}_1^\pm \tilde{\chi}_1^0 j, \quad pp \rightarrow \tilde{\chi}_1^+ \tilde{\chi}_1^- j.$$

with their subsequent decays, where j denotes an energetic jet from initial-state radiation used to trigger the signal event. Since the $\tilde{\chi}_1^\pm$ could decay in the inner tracking volume and the $\tilde{\chi}_1^0$ escapes from the detector, the resulting signal topology is characterized by a high- p_T (transverse momentum) jet, large missing transverse momentum (its magnitude is denoted by E_T^{miss}), and a high- p_T disappearing track. A previous search for a disappearing-track signature [3] by the ATLAS collaboration was based on signal production via the strong interaction, resulting in final states with multiple high- p_T jets and large E_T^{miss} . Given the ratio $M_3/M_2 \approx 7$, the masses of coloured particles are comparatively large and thus the cross-sections are small compared to those from electroweak production.

2 The ATLAS detector

ATLAS is a multi-purpose detector [4], covering nearly the entire solid angle² around the collision point with layers of tracking devices surrounded by a superconducting solenoid providing a 2 tesla axial magnetic field, a calorimeter system, and a muon spectrometer. The inner detector (ID) provides track reconstruction in the region $|\eta| < 2.5$ and consists of pixel and silicon microstrip (SCT) detectors inside a straw tube transition radiation tracker (TRT). Of particular importance to this analysis is the TRT detector. The barrel TRT covers the region $|z| < 780$ mm and is divided into inner, middle, and outer concentric rings of 32 modules each, comprising a stack in azimuthal angle. They cover the radial ranges 563 mm to 694 mm (inner), 697 mm to 860 mm (middle), and 863 mm to 1066 mm (outer). A module consists of a carbon-fiber laminate shell and an array of straw tubes. The average numbers of pixel, SCT and TRT hits on a track going through the inner detector in the central region are about 3, 8 and 34, respectively. The calorimeter system covers the range $|\eta| < 4.9$. The electromagnetic calorimeter is a lead/liquid-argon (LAr) detector in the barrel ($|\eta| < 1.475$) and endcap ($1.375 < |\eta| < 3.2$) regions. The hadronic calorimeters are composed of a steel and scintillator barrel ($|\eta| < 1.7$), a LAr/copper endcap ($1.5 < |\eta| < 3.2$), and a LAr forward system ($3.1 < |\eta| < 4.9$) with copper and tungsten absorbers. The muon spectrometer consists of three large superconducting toroids, trigger chambers, and precision tracking chambers which provide muon momentum measurements up to $|\eta|$ of 2.7.

²ATLAS 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 coinciding with the axis of 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. Pseudorapidity is defined in terms of the polar angle θ as $\eta = -\ln \tan(\theta/2)$.

3 Data and simulated event samples

This search is based on pp collision data at $\sqrt{s} = 7$ TeV recorded by the ATLAS detector in 2011, corresponding to an integrated luminosity of 4.7 fb^{-1} after the application of beam, detector, and data quality requirements.

The large cross-section of QCD di-jet events especially at small p_T is suppressed at the trigger level by requiring at least one jet with $p_T > 55$ GeV, $E_T^{\text{miss}} > 55$ GeV, and $\Delta\phi_{\text{min}}^{\text{jet}-E_T^{\text{miss}}} > 1$ rad, where $\Delta\phi_{\text{min}}^{\text{jet}-E_T^{\text{miss}}}$ indicates the smallest azimuthal separation between the missing transverse momentum and either of the two highest- p_T jets with $p_T > 30$ GeV. The jet p_T and E_T^{miss} for the trigger are based on calorimeter information and measured at the electromagnetic scale. For background events E_T^{miss} is usually aligned with a high- p_T jet ($\Delta\phi_{\text{min}}^{\text{jet}-E_T^{\text{miss}}} \approx 0$ rad) since it is due to jet mis-measurements while for the signal $\Delta\phi_{\text{min}}^{\text{jet}-E_T^{\text{miss}}} \approx \pi$ rad as it arises from the outgoing neutralinos.

Simulated Monte Carlo (MC) events are used to assess the experimental sensitivity to given models. The minimal AMSB model is characterized by four parameters: the gravitino mass ($m_{3/2}$), the universal scalar mass (m_0), the ratio of Higgs vacuum expectation values at the electroweak scale ($\tan\beta$), and the sign of the higgsino mass term (μ). ISASUSY from ISAJET v7.80 [5] is used to calculate the SUSY mass spectrum and the decay tables. The MC signal samples are produced using Herwig++ [6] with MRST2007 LO* [7] parton distribution functions (PDFs). All simulated samples used in this paper are produced using a detector simulation based on GEANT4 [8, 9], and include multiple pp interactions per event (pile-up) to model that observed in data. Signal cross-sections are calculated at next-to-leading order (NLO) in the strong coupling constant using PROSPINO2 [10], as shown in figure 1. 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. [11]. Simulated points with chargino masses ranging from 70–300 GeV are studied, and in particular two reference points with $m_{\tilde{\chi}_1^\pm} \sim 100$ GeV and 200 GeV are illustrated in this paper. A large value of 1 TeV is used for m_0 in order to prevent the existence of a tachyonic slepton. However, the production cross-section is determined only by the wino mass ($\propto m_{3/2}$), and the results presented in this paper are largely independent of the other parameters. The mean lifetime $\tau_{\tilde{\chi}_1^\pm}$ is set to 1 ns, the value for which this analysis has the highest sensitivity. Samples with different mean lifetimes are obtained by applying event weights to the original sample, such that the distribution of the proper lifetime follows that for a given mean lifetime value. The branching fraction for the decay $\tilde{\chi}_1^\pm \rightarrow \tilde{\chi}_1^0 \pi^\pm$ is set to 100%.

4 Event reconstruction and selection

Kinematic selection criteria are applied which ensure high trigger efficiency while reducing the Standard Model (SM) background arising from unidentified charged leptons that survive a lepton veto. The vast majority of background events are removed by the TRT-based selection criteria that are used to identify the decay of the chargino.

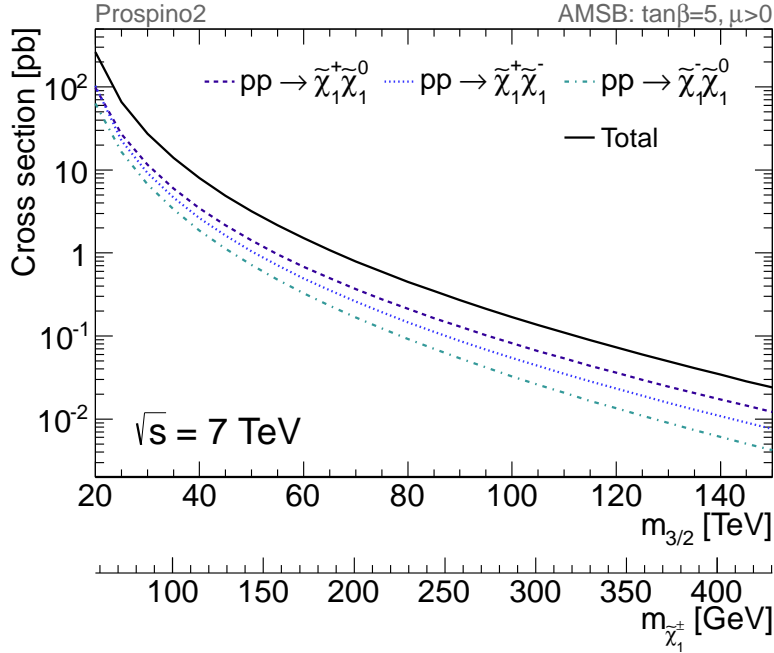


Figure 1. The cross-section for direct chargino production at $\sqrt{s} = 7$ TeV as a function of $m_{3/2}$. The corresponding $m_{\tilde{\chi}_1^\pm}$ values for each $m_{3/2}$ are also indicated.

4.1 Event reconstruction

The primary vertex [12] is required to have at least five associated tracks; when more than one such vertex is found, the vertex with the largest total $|p_T|^2$ of the associated tracks is chosen. Jets are reconstructed using the anti- k_t algorithm [13] with a distance parameter of 0.4. The inputs to the jet reconstruction algorithm are topological calorimeter energy clusters. The measurement of jet transverse momentum at the electromagnetic scale ($p_T^{\text{jet,EM}}$) underestimates hadronic jets due to the nature of the non-compensating calorimeters and dead material. Thus, an average correction depending on η and $p_T^{\text{jet,EM}}$ is applied to obtain the correct transverse momentum. The details of the jet calibration procedure are given in ref. [14]. In the analysis, requirements of $p_T > 20$ GeV and $|\eta| < 2.8$ are applied. Electron candidates are selected with “loose” identification requirements, as described in ref. [15] and required to fulfil the requirements of transverse energy, $E_T > 10$ GeV and $|\eta| < 2.47$. Muon candidates are identified by an algorithm which combines an ID track with either a track reconstructed in the muon spectrometer, or with a track segment in the innermost muon station [4, 16]. Furthermore, muons are required to have at least one hit in the innermost layer of the pixel detector ($N_{\text{b-layer}}$) if crossing an active module of that layer, more than one pixel hit (N_{pixel}), at least six SCT hits (N_{SCT}), $p_T > 10$ GeV and $|\eta| < 2.4$.

Following the object reconstruction described above, overlaps between jets and leptons are resolved. First, any jet candidate lying within a distance of $\Delta R \equiv \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} = 0.2$ of an electron is discarded. Then, any lepton candidate within a distance of $\Delta R = 0.4$

of any surviving jet is discarded.

The calculation of E_T^{miss} is based on the transverse momenta of jets and lepton candidates described above and all calorimeter energy clusters that are not associated to such objects [17].

4.2 Kinematic selection criteria

Following the trigger decision, selection requirements to suppress non-collision background events, given in ref. [14], are applied to jets. Candidate events are then required to have no electron or muon candidates (lepton veto) to suppress the background events from $W/Z +$ jets and top-quark pair-production processes. The candidates are required to have $E_T^{\text{miss}} > 90$ GeV and at least one jet with $p_T > 90$ GeV. In order to further suppress the QCD background, $\Delta\phi_{\text{min}}^{\text{jet}-E_T^{\text{miss}}} > 1.5$ rad for the two highest p_T jets with $p_T > 50$ GeV is imposed. The trigger selection is 98% efficient for signal events satisfying these selection requirements.

4.3 Disappearing-track selection criteria

The TRT detector provides substantial discrimination between penetrating and decaying charged particles: the average number of hits on a track going through the TRT in the barrel region is about 34 and consecutive hits can be observed along the track with small radial spacing between adjacent hits, while a smaller number is expected for charged particles that decay in the TRT volume. If a chargino decays in the TRT volume, the track is still found with a high efficiency based on hits in the pixel and SCT detectors. Such a chargino track candidate can therefore be fully reconstructed by the ATLAS standard track reconstruction algorithm.

The tracks originating from charginos are expected to have high- p_T and to be isolated. Therefore, chargino candidate tracks are required to fulfil the following criteria:

- (I) The track must have $N_{\text{pixel}} \geq 1$, $N_{\text{b-layer}} \geq 1$ if crossing an active module of the innermost pixel layer, $N_{\text{SCT}} \geq 6$, $|d_0| < 1.5$ mm and $|z_0 \sin \theta| < 1.5$ mm, where d_0 and z_0 are the transverse and longitudinal impact parameters with respect to the primary vertex.
- (II) The track must be isolated: there must be no tracks having p_T above 0.4 GeV within a cone of $\Delta R = 0.1$ around the candidate track. There must also be no jets having p_T above 50 GeV within a cone of $\Delta R = 0.4$.
- (III) The candidate track must have p_T above 10 GeV, and must be the highest- p_T isolated track in the event.
- (IV) The relative uncertainty on the momentum measurement must be below 20%.
- (V) The candidate track must point to the TRT barrel layers but not the region around $|\eta| = 0$ ($0.1 < |\eta| < 0.63$).
- (VI) The number of hits in the TRT outer module associated to the track ($N_{\text{TRT}}^{\text{outer}}$) must be less than five.

Criterion (I) is applied in order to ensure well-reconstructed primary tracks. Criteria (II) and (III) are employed to select chargino tracks that are isolated and have the highest p_T in most cases. Tracks seeded from an incorrect combination of SCT space-points could have anomalously high values of p_T and worse momentum resolution; criterion (IV) suppresses such tracks. Criterion (V) is based on the extrapolated track position and is used to avoid inactive regions of the TRT and reject muons failing identification due to a small gap in acceptance around $\eta = 0$. For criterion (VI), $N_{\text{TRT}}^{\text{outer}}$ is calculated by counting TRT hits lying on the extrapolated track. This criterion selects charginos decaying within the volume between the SCT outer layers and the TRT outer modules. Hereafter, unless explicitly stated otherwise, “high- p_T isolated track selection” and “disappearing-track selection” indicate criteria (I)–(V) and (I)–(VI), respectively. Figure 2 shows the $N_{\text{TRT}}^{\text{outer}}$ distributions with the high- p_T isolated track selection requirements for data, simulated signal MC events, and simulated MC SM background events. Details of the SM background MC samples are described in ref. [18]. When charginos decay before reaching the TRT outer module, $N_{\text{TRT}}^{\text{outer}}$ is expected to have a value near zero; conversely, charginos that reach the calorimeters and SM charged particles traversing the TRT typically have $N_{\text{TRT}}^{\text{outer}} \simeq 15$. The purity of chargino tracks in the signal MC events, defined as the fraction of candidate tracks matched to generated charginos, is almost 100% at this stage; criterion (VI) removes the vast majority of background events. Although it also reduces the signal efficiency, it strongly enhances the expected signal to background ratio. A summary of kinematic selection criteria, disappearing-track requirements, and the data reduction are given in table 1. Signal efficiencies are low at the first stage due to the trigger based on initial-state radiation. After the application of all selection criteria, 710 candidate events are selected.

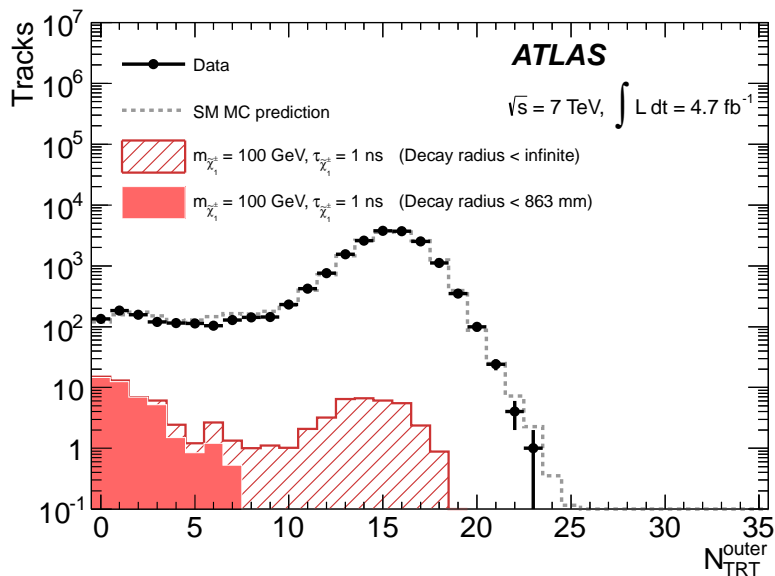


Figure 2. The $N_{\text{TRT}}^{\text{outer}}$ distribution for data and signal events ($m_{\chi_1^\pm} = 100$ GeV, $\tau_{\chi_1^\pm} = 1$ ns) with the high- p_T isolated track selection. The expectation from SM MC events, normalized to the number of observed events, is also shown.

Requirement	Observed	Signal events (efficiency [%])	
		$m_{\tilde{\chi}_1^\pm} = 100$ GeV	$m_{\tilde{\chi}_1^\pm} = 200$ GeV
Quality requirements and trigger	3765627	1983 (3.0)	283.3 (6.7)
Non-collision background rejection	2899498	1958 (3.0)	279.6 (6.6)
Lepton veto	2186581	1906 (2.9)	274.8 (6.5)
Leading jet $p_T > 90$ GeV	2054262	1497 (2.3)	237.7 (5.6)
$E_T^{\text{miss}} > 90$ GeV	1233864	1420 (2.2)	230.2 (5.5)
$\Delta\phi_{\text{min}}^{\text{jet}-E_T^{\text{miss}}} > 1.5$ rad	1191298	1402 (2.1)	227.4 (5.4)
High- p_T isolated track selection	18493	90.5 (0.14)	9.1 (0.26)
Disappearing-track selection	710	42.9 (0.066)	4.1 (0.12)

Table 1. Summary of selection requirements and data reduction for data and expected signal events ($\tau_{\tilde{\chi}_1^\pm} = 1$ ns). The signal selection efficiencies are also shown in parentheses.

5 Estimate of the p_T spectrum of the background contributions

According to MC simulation, the background contribution after the high- p_T isolated track selection comes predominantly from the $W(\rightarrow \tau\nu)$ +jets production in which τ decay products fulfil the selection criteria. Sub-leading contributions to the background come from prompt electrons failing to satisfy their identification criteria. A background estimation based on the MC simulation suffers from large uncertainties due to low numbers of tracks after all the selection requirements and has difficulty in simulating the properties of these background tracks. Therefore, an approach using data-driven control samples enriched in these background categories is employed to estimate the background track p_T spectrum. A simultaneous fit is then performed for signal and background yields using the p_T spectrum of observed tracks.

5.1 Interacting charged hadrons

High- p_T charged hadrons (mostly charged pions) can interact with material in the TRT detector and some tracks can be labelled as disappearing tracks; according to MC simulation, they are responsible for more than 80% of the background in the signal search sample. The p_T spectrum of interacting hadron tracks is obtained from that of non-interacting hadron tracks, in a data-driven way using a data sample enriched in this background category as described in ref. [3]. In the p_T range above 10 GeV, where inelastic interactions dominate, the interaction rate has nearly no p_T -dependence [19]. By adopting the same kinematic selection criteria as those for the signal and ensuring a penetration through the TRT detector by requiring $N_{\text{TRT}}^{\text{outer}} > 10$, a sample of high- p_T non-interacting hadron tracks is obtained. The contamination from electron tracks and any chargino signal is removed by requiring the associated calorimeter activity, $E_T^{\text{cone20}}/p_T^{\text{track}}$, to be larger than 0.2, where E_T^{cone20} is the calorimeter transverse energy deposited in a cone of $\Delta R = 0.2$ around the track, excluding E_T of its corresponding calorimeter cluster, and p_T^{track} is the track p_T . According to MC simulation, the purity of non-interacting hadron tracks is $> 99\%$ after these requirements.

These hadron tracks have a steeply falling p_T spectrum, as shown in figure 3. An ansatz functional form $(1+x)^{a_0}/x^{a_1+a_2\ln(x)}$ is then fitted to the p_T spectrum of the control sample, where $x \equiv p_T^{\text{track}}$ and a_i ($i = 0, 1, 2$) are the fitted parameters. The data distribution is well described by this functional form; a χ^2 per degree of freedom (DOF) of 39/50 is calculated from the difference between the data and the best-fit form.

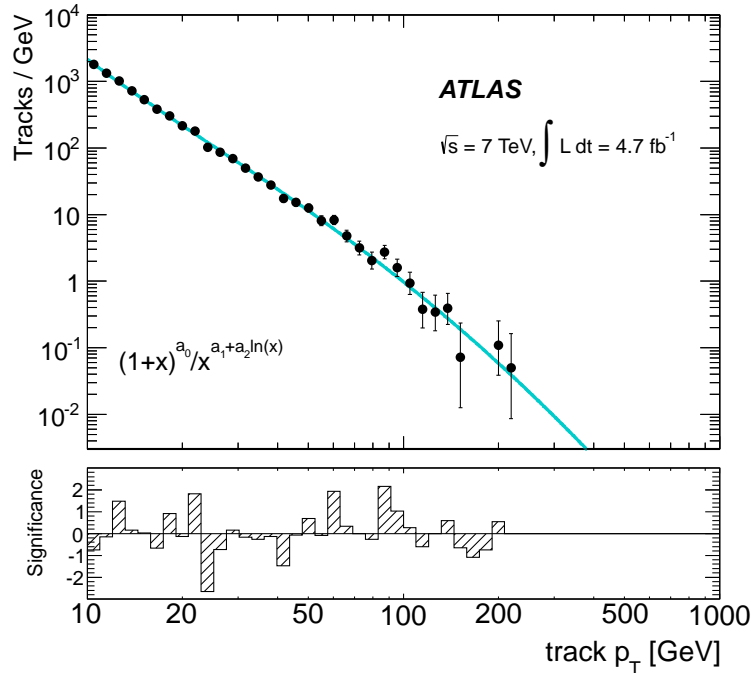


Figure 3. The p_T distribution of the hadron-track background control sample. The data and the fitted shape are shown by solid circles and a line, respectively. The significance of the residuals between the data and the fit model on a bin-by-bin basis is shown at the bottom of the figure.

5.2 Electrons failing to satisfy identification criteria

The charged lepton background is mostly due to large bremsstrahlung where, predominantly, low- p_T electrons contribute to this background. Muons failing to satisfy the identification criteria could be also classified as disappearing tracks; however, this contribution is negligibly small since the probability of bremsstrahlung photon emission is proportional to $1/m_\ell^2$, where m_ℓ is the lepton mass.

In order to estimate the electron background, a control sample is defined by requiring the same kinematic selection requirements as for the signal search sample, but requiring one electron that fulfils “medium” identification criteria [15] and the isolated track selection criteria; the purity of electrons is close to 100% according to MC simulation. The p_T spectrum of electrons without any identification requirements is obtained by applying the correction for the medium identification efficiency [15]. This efficiency depends on p_T and η ,

with an average value around 0.8. The p_T distribution of electron background tracks is then estimated by multiplying the corrected distribution (described above) by the probability of failing to satisfy the loose identification criteria (hence being retained in the signal search sample) and passing the disappearing-track selection criteria for electrons ($\mathcal{P}_e^{\text{dis}}$). For the measurement of $\mathcal{P}_e^{\text{dis}}$, a “tag-and-probe” method is applied to $Z \rightarrow ee$ events collected with unrescaled single-electron triggers. In order to ensure a very pure sample of $Z \rightarrow ee$ events, tag-electrons must be well isolated from jets and also required to fulfil “tight” identification criteria [15] and have $E_T > 25$ GeV. First, the $Z \rightarrow ee$ sample is selected by requiring no identified muons, at least one tag-electron and one high- p_T isolated track. Probe-electrons are selected without any identification requirements but with exactly the same high- p_T isolated track selection criteria used for chargino candidate tracks. Then, the reconstructed invariant mass is required to be within the range from 85–95 GeV; its value is calculated using the calorimeter energy for the tag and the track momentum for the probe. The track momentum is used for the probe electron, since in the absence of any electron identification the precise calorimeter energy is not well defined. The probability $\mathcal{P}_e^{\text{dis}}$ is finally given by the fraction of events in which the probe-electron passes the disappearing-track selection criteria; it ranges from 10^{-2} to 10^{-4} for $10 < p_T < 50$ GeV. Due to too few data events, the nominal values of $\mathcal{P}_e^{\text{dis}}$ are derived using MC events; no visible dependence on p_T is found, and the average $\mathcal{P}_e^{\text{dis}}$ values for data and MC events agree within 13%, which is taken as a systematic uncertainty.

Figure 4 shows the resulting p_T spectrum of electron background tracks; the systematic uncertainties on the identification efficiency are included. The p_T -dependent identification efficiency and $\mathcal{P}_e^{\text{dis}}$ produce a complicated spectrum; therefore, the electron background shape is determined by a fit to an extended functional form $(x + b_0)^{b_1} / (x + b_2)^{b_3 + b_4 \ln(x)}$ where $x \equiv p_T^{\text{track}}$ and b_i ($i = 0, 1, 2, 3, 4$) are the fitted parameters. The χ^2 per DOF is calculated to be 45/29. Using this function the number of electron background tracks in the signal search sample is estimated to be 115 ± 15 . Statistical errors and uncertainties on the identification efficiency and $\mathcal{P}_e^{\text{dis}}$ are considered in deriving the results.

6 Estimate of systematic uncertainties

The sources of systematic uncertainty on the signal expectation which have been considered are the: theoretical cross-section, parton radiation model, jet energy scale (JES) and resolution (JER), trigger efficiency, pile-up modelling, track reconstruction efficiency, and the integrated luminosity.

Theoretical uncertainties on the signal cross-section, already described in section 3, range from 6–8% depending on $m_{\tilde{\chi}_1^\pm}$. High- p_T jets originating from initial- and final-state radiation alter the signal acceptance. The uncertainties on these processes are estimated by varying generator tunes in the simulation as well as by generator-level studies with an additional jet in the matrix-element method using MADGRAPH5 [20]+PYTHIA6 [21], after applying the kinematic selection criteria. By adopting PDF tunes that provide less and more radiation and taking the maximum deviation from the nominal one, the uncertainty due to jet radiation is evaluated. The uncertainty arising from the matching of matrix

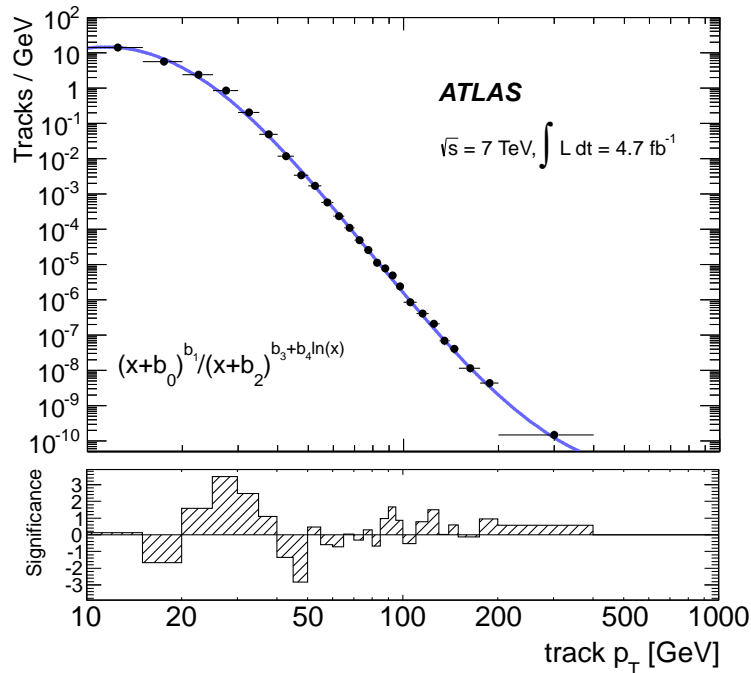


Figure 4. The estimated p_T distribution of electron background tracks. The data and the fitted shape are shown by solid circles and a line, respectively. The error bars representing statistical errors and uncertainties on the identification efficiency are invisibly small. The significance of the residuals between the data and the fit model on a bin-by-bin basis is shown at the bottom of the figure.

elements with parton showers is found by doubling and halving the default value of the matching parameter [22]. The resulting changes are combined in quadrature and yield an uncertainty of 10–15% depending on $m_{\tilde{\chi}_1^\pm}$. The uncertainties on the JES and JER result in a variation of the signal selection efficiency; the variation of the signal selection efficiency arising from these uncertainties is assessed according to ref. [14], and an uncertainty of 5–10% is assigned. An uncertainty of 3% on the trigger efficiency is assigned by taking the difference between data and MC $W \rightarrow \mu\nu$ samples. The uncertainty originating from the pile-up modelling in the simulation is evaluated by weighting simulated samples so that the average number of pile-up interactions is increased or decreased by 10%; an uncertainty of 0.5% is assigned. The ID material affects the track reconstruction efficiency and the uncertainty due to the material description in the MC simulation is assessed as described in ref. [23]. By comparing the track reconstruction efficiency to that obtained with the MC samples with an extra 10% of material in the tracking system, an uncertainty of 2%, in particular for tracks in the region of $|\eta| < 0.63$, is assigned. The absolute luminosity of pp collisions is determined with an uncertainty of 3.9% [24, 25]. The contributions of each systematic uncertainty in the signal expectation are summarized in table 2 for the two

reference signal samples.

Systematic uncertainties on the background are determined from the statistical uncertainties on the fit parameters and the full correlation matrix. In addition, the 13% uncertainty on the disappearing-track probability for electrons is considered (see section 5.2). Alternative fit functions for the p_T shapes of the electron and interacting hadron tracks are also checked, showing that these agree with each other and with the original form within the fit uncertainties. The effect on the sensitivity to the signals due to the choice of functional forms is thus found to be negligible.

Source	$m_{\tilde{\chi}_1^\pm} = 100 \text{ GeV} [\%]$	$m_{\tilde{\chi}_1^\pm} = 200 \text{ GeV} [\%]$
(Theoretical uncertainty)		
Cross section	7	7
(Uncertainty on the acceptance)		
Modeling of initial/final-state radiation	10	13
JES/JER	10	6
Trigger efficiency	3	3
Pile-up modelling	0.5	0.5
Track reconstruction efficiency	2	2
Luminosity	3.9	3.9
Sub-total	15	15

Table 2. Summary of systematic uncertainties [%] on the expectation of signal events.

7 Statistical analysis

In order to evaluate how well the observed data agree with a given signal model, a statistical test is performed based on maximizing a likelihood. The likelihood function for the track p_T in a sample of observed events (n_{obs}) is defined as

$$\prod^{n_{\text{obs}}} \frac{n_s \mathcal{F}_s(p_T) + n_h \mathcal{F}_h(p_T) + n_e \mathcal{F}_e(p_T)}{n_s + n_h + n_e} \times \mathcal{L}_{\text{sys}}, \quad (7.1)$$

where n_s , n_h and n_e are the number of signal events for a given value of the chargino mass and lifetime, the number of interacting hadron track events, and the number of electron track events, respectively. The probability density function of the signal (\mathcal{F}_s) is defined for a given value of the chargino mass and lifetime, and that of the interacting hadron (electron) tracks, \mathcal{F}_h (\mathcal{F}_e), is shown in figure 3 (4). In the fit, n_e is constrained to be its estimated value (see section 5.2). The effects of systematic uncertainties on the normalizations and the shape parameters describing the two p_T distributions of the background tracks are incorporated via the constraining terms, \mathcal{L}_{sys} , representing the product of normal and multivariate-normal distributions in which the variances are set to their uncertainties.

Figure 5 shows the p_T distribution for the selected data events compared to the background model obtained by the “background-only” fit in the p_T range above 10 GeV. The

best-fit values of n_h and n_e are 610 ± 30 and 105 ± 13 , respectively. The probability of the fit to describe the data is 0.54. The numbers of expected background and observed tracks in the region $p_T > 50$ (100) GeV are 14.8 ± 0.3 and 19 (2.20 ± 0.05 and 1), respectively, exhibiting no significant excess in the data. The selected examples for the signal are also shown in figure 5. The values of n_s for them, derived from the “signal + background” fit, are found to be consistent with zero.

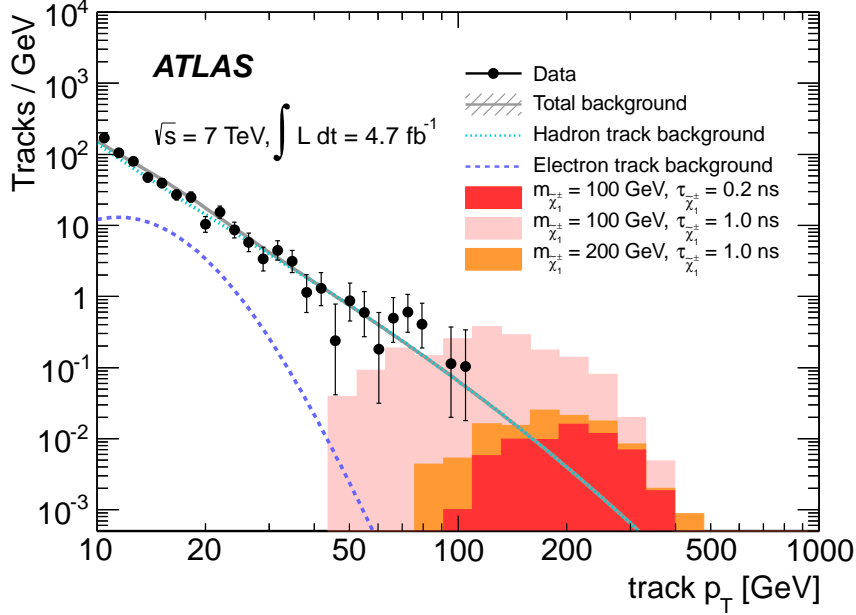


Figure 5. The p_T distribution of candidate tracks. The solid circles show data and lines show background shapes obtained using the “background-only” fit. The contributions of two background components and the signal expectations are also shown.

8 Results

In the absence of a signal, constraints on $m_{\tilde{\chi}_1^\pm}$ and $\tau_{\tilde{\chi}_1^\pm}$ are set. The upper limit on the production cross-section for a given $m_{\tilde{\chi}_1^\pm}$ and $\tau_{\tilde{\chi}_1^\pm}$ at 95% confidence level (CL) is set by a point where the CL of the “signal+background” hypothesis, based on the profile likelihood ratio [26] and the CL_s prescription [27], falls below 5% when scanning the CL along various values of signal strength. The constraint on the $\tau_{\tilde{\chi}_1^\pm}$ - $m_{\tilde{\chi}_1^\pm}$ parameter space is shown in figure 6. The expected limit is set by the median of the distribution of 95% CL limits calculated by pseudo-experiments with the expected background and no signal. The expected number of background events is derived from the background-only fit in the region $10 < p_T < 50$ GeV, where the systematic parameters are varied according to their systematic uncertainties when generating the ensemble of pseudo-experiments.

Figure 7 shows the constraint on the $\Delta m_{\tilde{\chi}_1} - m_{\tilde{\chi}_1^\pm}$ parameter space of the minimal AMSB model. The limits on $\tau_{\tilde{\chi}_1^\pm}$ are converted into limits on $\Delta m_{\tilde{\chi}_1}$ following ref. [28]. The

region excluded by the LEP2 searches [29–32] is also indicated. For $\Delta m_{\tilde{\chi}_1^\pm} = 160$ (170) MeV ($\tau_{\tilde{\chi}_1^\pm} \sim 0.3$ ns), the value most probable in the model, a new limit of $m_{\tilde{\chi}_1^\pm} > 103$ (85) GeV at 95% CL is obtained. For $\Delta m_{\tilde{\chi}_1} \sim 140$ MeV, a more stringent limit of $m_{\tilde{\chi}_1^\pm} > 260$ GeV is set.

The analysis is not performed for signals having $\tau_{\tilde{\chi}_1} > 10$ ns (corresponding $\Delta m_{\tilde{\chi}_1}$ being below the charged pion mass) because a significant fraction of charginos would traverse the ID before decaying, thereby reducing the event selection efficiency. These scenarios are considered as ‘stable’.

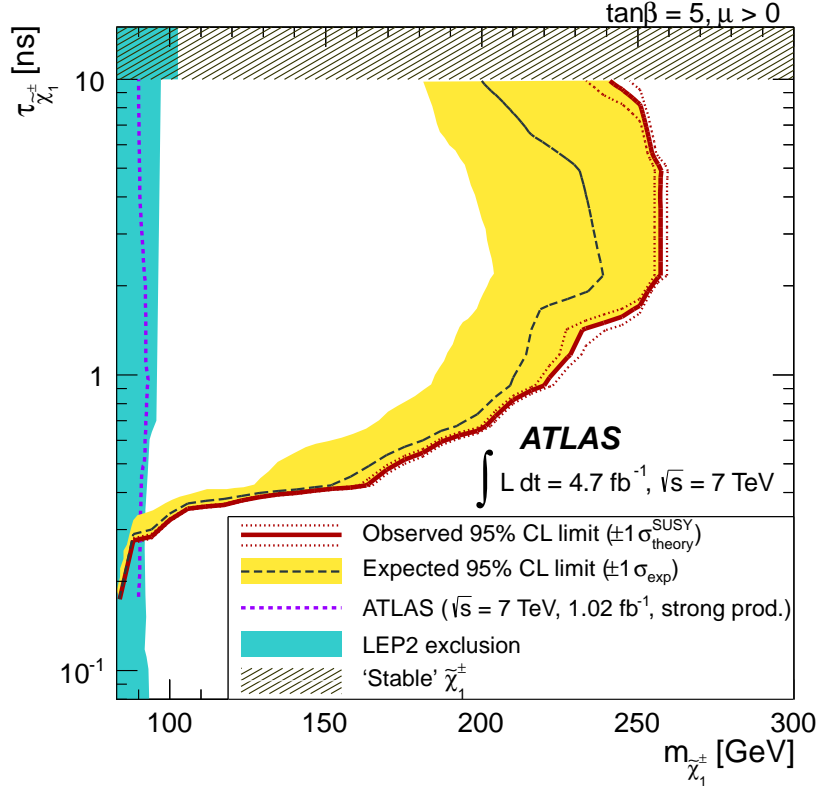


Figure 6. The constraint on the $\tau_{\tilde{\chi}_1^\pm}$ - $m_{\tilde{\chi}_1^\pm}$ space for $\tan\beta = 5$ and $\mu > 0$. The black dashed line shows the expected limits at 95% CL, with the surrounding shaded bands indicating the 1σ exclusions due to experimental uncertainties. Observed limits are indicated by the solid bold contour representing the nominal limit and the dotted lines on either side are obtained by varying the cross-section by the theoretical scale and PDF uncertainties. The previous result from ref. [3] and the combined LEP2 exclusion at 95% CL are also shown on the left by the dotted line and the shaded region, respectively.

9 Conclusions

The results of a search for the direct production of long-lived charginos in pp collisions with the ATLAS detector using 4.7 fb^{-1} of data have been presented in the context of AMSB scenarios. The search is based on the signature of a high- p_T isolated track with few

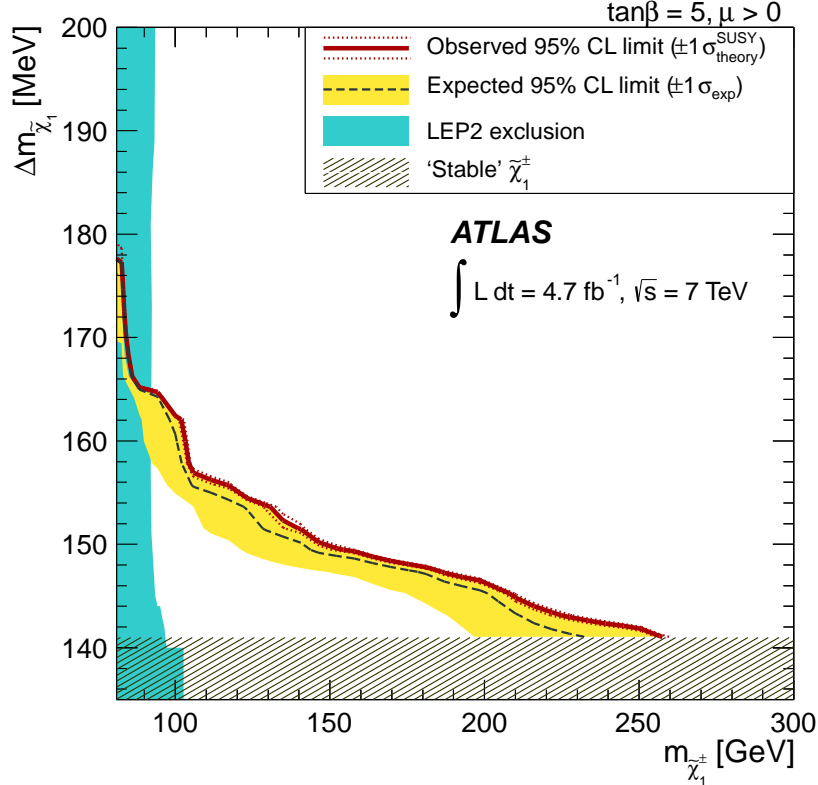


Figure 7. The constraint on the $\Delta m_{\tilde{\chi}_1} - m_{\tilde{\chi}_1^\pm}$ space of the AMSB model for $\tan\beta = 5$ and $\mu > 0$, where $\tau_{\tilde{\chi}_1^\pm}$ is varying as described in figure 6. The dashed line shows the expected limits at 95% CL, with the surrounding shaded bands indicating the 1σ exclusions due to experimental uncertainties. Observed limits are indicated by the solid bold contour representing the nominal limit and the dotted lines on either side are obtained by varying the cross-section by the theoretical scale and PDF uncertainties. The combined LEP2 exclusion at 95% CL is also shown on the left by the shaded region. Charginos in the lower shaded region could have significantly longer lifetime values for which this analysis has no sensitivity.

associated hits in the outer part of the ATLAS tracking system, arising from a chargino decay into a neutralino and a low- p_T pion. The p_T spectrum of observed candidate tracks is found to be consistent with the expectation from SM background processes. Constraints on the chargino mass and the mass splitting between the lightest chargino and neutralino are set. A chargino having a mass below 103 (85) GeV with a mass splitting of 160 (170) MeV, the most favoured scenario in the AMSB model, is excluded at 95% CL. This analysis provides a result complementary to the previous search based on signal production via the strong interaction [3] and improves the sensitivity. It also provides a largely AMSB-model-independent constraint on the chargino properties. From the viewpoint of self-annihilating dark matter, a wino-like lightest SUSY particle with a mass of $\mathcal{O}(100)$ GeV as obtained in certain AMSB scenarios, which simultaneously explains the observations by PAMELA [33] and Fermi LAT [34] as well as the WMAP relic density data [35], is of particular interest;

it could be addressed with an increased LHC energy, more integrated luminosity and an extension of the analysis using shorter tracks.

Acknowledgments

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 and ERC, European Union; IN2P3-CNRS, CEA-DSM/IRFU, France; GNSF, Georgia; BMBF, DFG, HGF, MPG and AvH Foundation, Germany; GSRT, 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 MVZT, 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.

References

- [1] G. F. Giudice, M. A. Luty, H. Murayama, and R. Rattazzi, *Gaugino Mass without Singlets*, *JHEP* **12** (1998) 027, [[hep-ph/9810442](#)].
- [2] L. Randall and R. Sundrum, *Out of this world supersymmetry breaking*, *Nucl. Phys.* **B557** (1999) 79–118, [[hep-th/9810155](#)].
- [3] **ATLAS** Collaboration, *Search for anomaly-mediated supersymmetry breaking with the ATLAS detector based on a disappearing-track signature in pp collisions at $\sqrt{s} = 7$ TeV*, *Eur. Phys. J.* **C72** (2012) 1993, [[arXiv:1202.4847](#)].
- [4] **ATLAS** Collaboration, *The ATLAS Experiment at the CERN Large Hadron Collider*, *JINST* **3** (2008) S08003.
- [5] F. E. Paige, S. D. Protopopescu, H. Baer, and X. Tata, *ISAJET 7.69: A Monte Carlo event generator for pp , $\bar{p}p$, and e^+e^- reactions*, [[hep-ph/0312045](#)].
- [6] M. Bahr, S. Gieseke, M. Gigg, D. Grellscheid, K. Hamilton, et al., *Herwig++ Physics and Manual*, *Eur. Phys. J.* **C58** (2008) 639–707, [[arXiv:0803.0883](#)].

- [7] A. Sherstnev and R. S. Thorne, *Parton Distributions for LO Generators*, *Eur. Phys. J.* **C55** (2008) 553–575, [[arXiv:0711.2473](#)].
- [8] **GEANT4** Collaboration, S. Agostinelli et al., *GEANT4: A simulation toolkit*, *Nucl. Instrum. Meth.* **A506** (2003) 250–303.
- [9] **ATLAS** Collaboration, *The ATLAS Simulation Infrastructure*, *Eur. Phys. J.* **C70** (2010) 823–874, [[arXiv:1005.4568](#)].
- [10] W. Beenakker, R. Hopker, M. Spira, and P. Zerwas, *Squark and gluino production at hadron colliders*, *Nucl. Phys.* **B492** (1997) 51–103, [[hep-ph/9610490](#)].
- [11] M. Kramer, A. Kulesza, R. van der Leeuw, M. Mangano, S. Padhi, et al., *Supersymmetry production cross sections in pp collisions at $\sqrt{s} = 7$ TeV*, [[arXiv:1206.2892](#)].
- [12] **ATLAS** Collaboration, *Performance of primary vertex reconstruction in proton-proton collisions at $\sqrt{s} = 7$ TeV in the ATLAS experiment*, ATLAS-CONF-2010-06, <http://cdsweb.cern.ch/record/128134>.
- [13] M. Cacciari, G. P. Salam, and G. Soyez, *The anti- k_t jet clustering algorithm*, *JHEP* **04** (2008) 063, [[arXiv:0802.1189](#)].
- [14] **ATLAS** Collaboration, *Jet energy measurement with the ATLAS detector in proton-proton collisions at $\sqrt{s} = 7$ TeV*, [[arXiv:1112.6426](#)], submitted to *Eur. Phys. J.*
- [15] **ATLAS** Collaboration, *Electron performance measurements with the ATLAS detector using the 2010 LHC proton-proton collision data*, *Eur. Phys. J.* **C72** (2012) 1909, [[arXiv:1110.3174](#)].
- [16] **ATLAS** Collaboration, *Measurement of the Transverse Momentum Distribution of W Bosons in pp Collisions at $\sqrt{s} = 7$ TeV with the ATLAS Detector*, *Phys. Rev.* **D85** (2012) 012005, [[arXiv:1108.6308](#)].
- [17] **ATLAS** Collaboration, *Performance of Missing Transverse Momentum Reconstruction in Proton-Proton Collisions at 7 TeV with ATLAS*, *Eur. Phys. J.* **C72** (2012) 1844, [[arXiv:1108.5602](#)].
- [18] **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*, [[arXiv:1208.0949](#)], submitted to *Phys. Rev.* **D**.
- [19] **Particle Data Group**, K. Nakamura et al., *Review of particle physics*, *J. Phys.* **G37** (2010) 075021. Corresponding data may be found at pages 398–399.
- [20] J. Alwall, M. Herquet, F. Maltoni, O. Mattelaer, and T. Stelzer, *MadGraph 5 : Going Beyond*, *JHEP* **1106** (2011) 128, [[arXiv:1106.0522](#)].
- [21] T. Sjöstrand, S. Mrenna, and P. Z. Skands, *PYTHIA 6.4 Physics and Manual*, *JHEP* **0605** (2006) 026, [[hep-ph/0603175](#)].
- [22] J. Alwall, S. Hoche, F. Krauss, N. Lavesson, L. Lönnblad, et al., *Comparative study of various algorithms for the merging of parton showers and matrix elements in hadronic collisions*, *Eur. Phys. J.* **C53** (2008) 473–500, [[arXiv:0706.2569](#)].
- [23] **ATLAS** Collaboration, *Measurements of underlying-event properties using neutral and charged particles in pp collisions at 900 GeV and 7 TeV with the ATLAS detector at the LHC*, *Eur. Phys. J.* **C71** (2011) 1636, [[arXiv:1103.1816](#)].

- [24] **ATLAS** Collaboration, *Luminosity Determination in pp Collisions at $\sqrt{s} = 7$ TeV Using the ATLAS Detector at the LHC*, *Eur. Phys. J.* **C71** (2011) 1630, [[arXiv:1101.2185](#)].
- [25] **ATLAS** Collaboration, *Luminosity Determination in pp Collisions at $\sqrt{s} = 7$ TeV using the ATLAS Detector in 2011*, ATLAS-CONF-2011-116, <http://cdsweb.cern.ch/record/1376384>.
- [26] G. Cowan, K. Cranmer, E. Gross, and O. Vitells, *Asymptotic formulae for likelihood-based tests of new physics*, *Eur. Phys. J.* **C71** (2011) 1554, [[arXiv:1007.1727](#)].
- [27] A. L. Read, *Presentation of search results: The $CL(s)$ technique*, *J. Phys.* **G28** (2002) 2693–2704.
- [28] C. Chen, M. Drees, and J. Gunion, *Addendum/erratum for ‘searching for invisible and almost invisible particles at e^+e^- colliders’ [[hep-ph/9512230](#)] and ‘a nonstandard string/SUSY scenario and its phenomenological implications’ [[hep-ph/9607421](#)]*, [[hep-ph/9902309](#)].
- [29] **ALEPH** Collaboration, A. Heister et al., *Search for charginos nearly mass degenerate with the lightest neutralino in e^+e^- collisions at center-of-mass energies up to 209 GeV*, *Phys. Lett.* **B533** (2002) 223–236, [[hep-ex/0203020](#)].
- [30] **OPAL** Collaboration, G. Abbiendi et al., *Search for nearly mass degenerate charginos and neutralinos at LEP*, *Eur. Phys. J.* **C29** (2003) 479–489, [[hep-ex/0210043](#)].
- [31] **DELPHI** Collaboration, J. Abdallah et al., *Search for SUSY in the AMSB scenario with the DELPHI detector*, *Eur. Phys. J.* **C34** (2004) 145–156, [[hep-ex/0403047](#)].
- [32] LEP2 SUSY Working Group, http://lepsusy.web.cern.ch/lepsusy/www/inoslowdmsummer02/charginolowdm_pub.html.
- [33] **PAMELA** Collaboration, O. Adriani et al., *An anomalous positron abundance in cosmic rays with energies 1.5–100 GeV*, *Nature* **458** (2009) 607–609, [[arXiv:0810.4995](#)].
- [34] **Fermi LAT** Collaboration, M. Ackermann et al., *Measurement of separate cosmic-ray electron and positron spectra with the Fermi Large Area Telescope*, *Phys. Rev. Lett.* **108** (2012) 011103, [[arXiv:1109.0521](#)].
- [35] N. Jarosik et al., *Seven-Year Wilkinson Microwave Anisotropy Probe (WMAP) Observations: Sky Maps, Systematic Errors, and Basic Results*, *Astrophys. J. Suppl.* **192** (2011) 14, [[arXiv:1001.4744](#)].

The ATLAS Collaboration

G. Aad⁴⁸, T. Abajyan²¹, B. Abbott¹¹¹, J. Abdallah¹², S. Abdel Khalek¹¹⁵,
A.A. Abdelalim⁴⁹, O. Abdinov¹¹, R. Aben¹⁰⁵, B. Abi¹¹², M. Abolins⁸⁸, O.S. AbouZeid¹⁵⁸,
H. Abramowicz¹⁵³, H. Abreu¹³⁶, B.S. Acharya^{164a,164b}, L. Adamczyk³⁸, D.L. Adams²⁵,
T.N. Addy⁵⁶, J. Adelman¹⁷⁶, S. Adomeit⁹⁸, P. Adragna⁷⁵, T. Adye¹²⁹, S. Aefsky²³,
J.A. Aguilar-Saavedra^{124b,a}, M. Agustoni¹⁷, M. Aharrouche⁸¹, S.P. Ahlen²², F. Ahles⁴⁸,
A. Ahmad¹⁴⁸, M. Ahsan⁴¹, G. Aielli^{133a,133b}, T. Akdogan^{19a}, T.P.A. Åkesson⁷⁹,
G. Akimoto¹⁵⁵, A.V. Akimov⁹⁴, M.S. Alam², M.A. Alam⁷⁶, J. Albert¹⁶⁹, S. Albrand⁵⁵,
M. Aleksa³⁰, I.N. Aleksandrov⁶⁴, F. Alessandria^{89a}, C. Alexa^{26a}, G. Alexander¹⁵³,
G. Alexandre⁴⁹, T. Alexopoulos¹⁰, M. Alhroob^{164a,164c}, M. Aliev¹⁶, G. Alimonti^{89a},
J. Alison¹²⁰, B.M.M. Allbrooke¹⁸, P.P. Allport⁷³, S.E. Allwood-Spiers⁵³, J. Almond⁸²,
A. Aloisio^{102a,102b}, R. Alon¹⁷², A. Alonso⁷⁹, F. Alonso⁷⁰, A. Altheimer³⁵,
B. Alvarez Gonzalez⁸⁸, M.G. Alviggi^{102a,102b}, K. Amako⁶⁵, C. Amelung²³,
V.V. Ammosov^{128,*}, S.P. Amor Dos Santos^{124a}, A. Amorim^{124a,b}, N. Amram¹⁵³,
C. Anastopoulos³⁰, L.S. Ancu¹⁷, N. Andari¹¹⁵, T. Andeen³⁵, C.F. Anders^{58b},
G. Anders^{58a}, K.J. Anderson³¹, A. Andreazza^{89a,89b}, V. Andrei^{58a}, M-L. Andrieux⁵⁵,
X.S. Anduaga⁷⁰, S. Angelidakis⁹, P. Anger⁴⁴, A. Angerami³⁵, F. Anghinolfi³⁰,
A. Anisenkov¹⁰⁷, N. Anjos^{124a}, A. Annovi⁴⁷, A. Antonaki⁹, M. Antonelli⁴⁷, A. Antonov⁹⁶,
J. Antos^{144b}, F. Anulli^{132a}, M. Aoki¹⁰¹, S. Aoun⁸³, L. Aperio Bella⁵, R. Apolle^{118,c},
G. Arabidze⁸⁸, I. Aracena¹⁴³, Y. Arai⁶⁵, A.T.H. Arce⁴⁵, S. Arfaoui¹⁴⁸, J-F. Arguin⁹³,
E. Arik^{19a,*}, M. Arik^{19a}, A.J. Armbruster⁸⁷, O. Arnaez⁸¹, V. Arnal⁸⁰, C. Arnault¹¹⁵,
A. Artamonov⁹⁵, G. Artoni^{132a,132b}, D. Arutinov²¹, S. Asai¹⁵⁵, S. Ask²⁸,
B. Åsman^{146a,146b}, L. Asquith⁶, K. Assamagan²⁵, A. Astbury¹⁶⁹, M. Atkinson¹⁶⁵,
B. Aubert⁵, E. Auge¹¹⁵, K. Augsten¹²⁷, M. Aurousseau^{145a}, G. Avolio³⁰, R. Avramidou¹⁰,
D. Axen¹⁶⁸, G. Azuelos^{93,d}, Y. Azuma¹⁵⁵, M.A. Baak³⁰, G. Baccaglioni^{89a},
C. Bacci^{134a,134b}, A.M. Bach¹⁵, H. Bachacou¹³⁶, K. Bachas³⁰, M. Backes⁴⁹,
M. Backhaus²¹, J. Backus Mayes¹⁴³, E. Badescu^{26a}, P. Bagnaia^{132a,132b}, S. Bahinipati³,
Y. Bai^{33a}, D.C. Bailey¹⁵⁸, T. Bain¹⁵⁸, J.T. Baines¹²⁹, O.K. Baker¹⁷⁶, M.D. Baker²⁵,
S. Baker⁷⁷, P. Balek¹²⁶, E. Banas³⁹, P. Banerjee⁹³, Sw. Banerjee¹⁷³, D. Banfi³⁰,
A. Bangert¹⁵⁰, V. Bansal¹⁶⁹, H.S. Bansil¹⁸, L. Barak¹⁷², S.P. Baranov⁹⁴,
A. Barbaro Galtieri¹⁵, T. Barber⁴⁸, E.L. Barberio⁸⁶, D. Barberis^{50a,50b}, M. Barbero²¹,
D.Y. Bardin⁶⁴, T. Barillari⁹⁹, M. Barisonzi¹⁷⁵, T. Barklow¹⁴³, N. Barlow²⁸,
B.M. Barnett¹²⁹, R.M. Barnett¹⁵, A. Baroncelli^{134a}, G. Barone⁴⁹, A.J. Barr¹¹⁸,
F. Barreiro⁸⁰, J. Barreiro Guimarães da Costa⁵⁷, P. Barrillon¹¹⁵, R. Bartoldus¹⁴³,
A.E. Barton⁷¹, V. Bartsch¹⁴⁹, A. Basye¹⁶⁵, R.L. Bates⁵³, L. Batkova^{144a}, J.R. Batley²⁸,
A. Battaglia¹⁷, M. Battistin³⁰, F. Bauer¹³⁶, H.S. Bawa^{143,e}, S. Beale⁹⁸, T. Beau⁷⁸,
P.H. Beauchemin¹⁶¹, R. Beccherle^{50a}, P. Bechtel²¹, H.P. Beck¹⁷, A.K. Becker¹⁷⁵,
S. Becker⁹⁸, M. Beckingham¹³⁸, K.H. Becks¹⁷⁵, A.J. Beddall^{19c}, A. Beddall^{19c},
S. Bedikian¹⁷⁶, V.A. Bednyakov⁶⁴, C.P. Bee⁸³, L.J. Beemster¹⁰⁵, M. Begel²⁵,
S. Behar Harpaz¹⁵², P.K. Behera⁶², M. Beimforde⁹⁹, C. Belanger-Champagne⁸⁵,
P.J. Bell⁴⁹, W.H. Bell⁴⁹, G. Bella¹⁵³, L. Bellagamba^{20a}, M. Bellomo³⁰, A. Belloni⁵⁷,
O. Beloborodova^{107,f}, K. Belotskiy⁹⁶, O. Beltramello³⁰, O. Benary¹⁵³,

D. Benchekroun^{135a}, K. Bendtz^{146a,146b}, N. Benekos¹⁶⁵, Y. Benhammou¹⁵³,
 E. Benhar Nocchioli⁴⁹, J.A. Benitez Garcia^{159b}, D.P. Benjamin⁴⁵, M. Benoit¹¹⁵,
 J.R. Bensingher²³, K. Benslama¹³⁰, S. Bentvelsen¹⁰⁵, D. Berge³⁰, E. Bergeaas Kuutmann⁴²,
 N. Berger⁵, F. Berghaus¹⁶⁹, E. Berglund¹⁰⁵, J. Beringer¹⁵, P. Bernat⁷⁷, R. Bernhard⁴⁸,
 C. Bernius²⁵, T. Berry⁷⁶, C. Bertella⁸³, A. Bertin^{20a,20b}, F. Bertolucci^{122a,122b},
 M.I. Besana^{89a,89b}, G.J. Besjes¹⁰⁴, N. Besson¹³⁶, S. Bethke⁹⁹, W. Bhimji⁴⁶,
 R.M. Bianchi³⁰, L. Bianchini²³, M. Bianco^{72a,72b}, O. Biebel⁹⁸, S.P. Bieniek⁷⁷,
 K. Bierwagen⁵⁴, J. Biesiada¹⁵, M. Biglietti^{134a}, H. Bilokon⁴⁷, M. Bindi^{20a,20b}, S. Binet¹¹⁵,
 A. Bingul^{19c}, C. Bini^{132a,132b}, C. Biscarat¹⁷⁸, B. Bittner⁹⁹, K.M. Black²², R.E. Blair⁶,
 J.-B. Blanchard¹³⁶, G. Blanchot³⁰, T. Blazek^{144a}, I. Bloch⁴², C. Blocker²³, J. Blocki³⁹,
 A. Blondel⁴⁹, W. Blum⁸¹, U. Blumenschein⁵⁴, G.J. Bobbink¹⁰⁵, V.B. Bobrovnikov¹⁰⁷,
 S.S. Bocchetta⁷⁹, A. Bocci⁴⁵, C.R. Boddy¹¹⁸, M. Boehler⁴⁸, J. Boek¹⁷⁵, N. Boelaert³⁶,
 J.A. Bogaerts³⁰, A. Bogdanchikov¹⁰⁷, A. Bogouch^{90,*}, C. Boehm^{146a}, J. Boehm¹²⁵,
 V. Boisvert⁷⁶, T. Bold³⁸, V. Boldea^{26a}, N.M. Bolnet¹³⁶, M. Bomben⁷⁸, M. Bona⁷⁵,
 M. Boonekamp¹³⁶, S. Bordoni⁷⁸, C. Borer¹⁷, A. Borisov¹²⁸, G. Borissov⁷¹,
 I. Borjanovic^{13a}, M. Borri⁸², S. Borroni⁸⁷, J. Bortfeldt⁹⁸, V. Bortolotto^{134a,134b}, K. Bos¹⁰⁵,
 D. Boscherini^{20a}, M. Bosman¹², H. Boterenbrood¹⁰⁵, J. Bouchami⁹³, J. Boudreau¹²³,
 E.V. Bouhova-Thacker⁷¹, D. Boumediene³⁴, C. Bourdarios¹¹⁵, N. Bousson⁸³, A. Boveia³¹,
 J. Boyd³⁰, I.R. Boyko⁶⁴, I. Bozovic-Jelisavcic^{13b}, J. Bracinik¹⁸, P. Branchini^{134a},
 A. Brandt⁸, G. Brandt¹¹⁸, O. Brandt⁵⁴, U. Bratzler¹⁵⁶, B. Brau⁸⁴, J.E. Brau¹¹⁴,
 H.M. Braun^{175,*}, S.F. Brazzale^{164a,164c}, B. Brelier¹⁵⁸, J. Bremer³⁰, K. Brendlinger¹²⁰,
 R. Brenner¹⁶⁶, S. Bressler¹⁷², D. Britton⁵³, F.M. Brochu²⁸, I. Brock²¹, R. Brock⁸⁸,
 F. Broggi^{89a}, C. Bromberg⁸⁸, J. Bronner⁹⁹, G. Brooijmans³⁵, T. Brooks⁷⁶,
 W.K. Brooks^{32b}, G. Brown⁸², H. Brown⁸, P.A. Bruckman de Renstrom³⁹, D. Bruncko^{144b},
 R. Bruneliere⁴⁸, S. Brunet⁶⁰, A. Bruni^{20a}, G. Bruni^{20a}, M. Bruschi^{20a}, T. Buanes¹⁴,
 Q. Buat⁵⁵, F. Bucci⁴⁹, J. Buchanan¹¹⁸, P. Buchholz¹⁴¹, R.M. Buckingham¹¹⁸,
 A.G. Buckley⁴⁶, S.I. Buda^{26a}, I.A. Budagov⁶⁴, B. Budick¹⁰⁸, V. Büscher⁸¹, L. Bugge¹¹⁷,
 O. Bulekov⁹⁶, A.C. Bundock⁷³, M. Bunse⁴³, T. Buran¹¹⁷, H. Burckhart³⁰, S. Burdin⁷³,
 T. Burgess¹⁴, S. Burke¹²⁹, E. Busato³⁴, P. Bussey⁵³, C.P. Buszello¹⁶⁶, B. Butler¹⁴³,
 J.M. Butler²², C.M. Buttar⁵³, J.M. Butterworth⁷⁷, W. Buttinger²⁸, M. Byszewski³⁰,
 S. Cabrera Urbán¹⁶⁷, D. Caforio^{20a,20b}, O. Cakir^{4a}, P. Calafiura¹⁵, G. Calderini⁷⁸,
 P. Calfayan⁹⁸, R. Calkins¹⁰⁶, L.P. Caloba^{24a}, R. Caloi^{132a,132b}, D. Calvet³⁴, S. Calvet³⁴,
 R. Camacho Toro³⁴, P. Camarri^{133a,133b}, D. Cameron¹¹⁷, L.M. Caminada¹⁵,
 R. Caminal Armadans¹², S. Campana³⁰, M. Campanelli⁷⁷, V. Canale^{102a,102b},
 F. Canelli^{31,g}, A. Canepa^{159a}, J. Cantero⁸⁰, R. Cantrill⁷⁶, L. Capasso^{102a,102b},
 M.D.M. Capeans Garrido³⁰, I. Caprini^{26a}, M. Caprini^{26a}, D. Capriotti⁹⁹, M. Capua^{37a,37b},
 R. Caputo⁸¹, R. Cardarelli^{133a}, T. Carli³⁰, G. Carlino^{102a}, L. Carminati^{89a,89b}, B. Caron⁸⁵,
 S. Caron¹⁰⁴, E. Carquin^{32b}, G.D. Carrillo-Montoya¹⁷³, A.A. Carter⁷⁵, J.R. Carter²⁸,
 J. Carvalho^{124a,h}, D. Casadei¹⁰⁸, M.P. Casado¹², M. Cascella^{122a,122b}, C. Caso^{50a,50b,*},
 A.M. Castaneda Hernandez^{173,i}, E. Castaneda-Miranda¹⁷³, V. Castillo Gimenez¹⁶⁷,
 N.F. Castro^{124a}, G. Cataldi^{72a}, P. Catastini⁵⁷, A. Catinaccio³⁰, J.R. Catmore³⁰,
 A. Cattai³⁰, G. Cattani^{133a,133b}, S. Caughron⁸⁸, V. Cavaliere¹⁶⁵, P. Cavalleri⁷⁸,
 D. Cavalli^{89a}, M. Cavalli-Sforza¹², V. Cavasinni^{122a,122b}, F. Ceradini^{134a,134b},

A.S. Cerqueira^{24b}, A. Cerri³⁰, L. Cerrito⁷⁵, F. Cerutti⁴⁷, S.A. Cetin^{19b}, A. Chafaq^{135a},
 D. Chakraborty¹⁰⁶, I. Chalupkova¹²⁶, K. Chan³, P. Chang¹⁶⁵, B. Chapleau⁸⁵,
 J.D. Chapman²⁸, J.W. Chapman⁸⁷, E. Chareyre⁷⁸, D.G. Charlton¹⁸, V. Chavda⁸²,
 C.A. Chavez Barajas³⁰, S. Cheatham⁸⁵, S. Chekanov⁶, S.V. Chekulaev^{159a},
 G.A. Chelkov⁶⁴, M.A. Chelstowska¹⁰⁴, C. Chen⁶³, H. Chen²⁵, S. Chen^{33c}, X. Chen¹⁷³,
 Y. Chen³⁵, Y. Cheng³¹, A. Cheplakov⁶⁴, R. Cherkaoui El Moursli^{135e}, V. Chernyatin²⁵,
 E. Cheu⁷, S.L. Cheung¹⁵⁸, L. Chevalier¹³⁶, G. Chiefari^{102a,102b}, L. Chikovani^{51a,*},
 J.T. Childers³⁰, A. Chilingarov⁷¹, G. Chiodini^{72a}, A.S. Chisholm¹⁸, R.T. Chislett⁷⁷,
 A. Chitan^{26a}, M.V. Chizhov⁶⁴, G. Choudalakis³¹, S. Chouridou¹³⁷, I.A. Christidi⁷⁷,
 A. Christov⁴⁸, D. Chromek-Burckhart³⁰, M.L. Chu¹⁵¹, J. Chudoba¹²⁵,
 G. Ciapetti^{132a,132b}, A.K. Ciftci^{4a}, R. Ciftci^{4a}, D. Cinca³⁴, V. Cindro⁷⁴, C. Ciocca^{20a,20b},
 A. Ciocio¹⁵, M. Cirilli⁸⁷, P. Cirkovic^{13b}, Z.H. Citron¹⁷², M. Citterio^{89a}, M. Ciubancan^{26a},
 A. Clark⁴⁹, P.J. Clark⁴⁶, R.N. Clarke¹⁵, W. Cleland¹²³, J.C. Clemens⁸³, B. Clement⁵⁵,
 C. Clement^{146a,146b}, Y. Coadou⁸³, M. Cobal^{164a,164c}, A. Coccaro¹³⁸, J. Cochran⁶³,
 L. Coffey²³, J.G. Cogan¹⁴³, J. Coggeshall¹⁶⁵, E. Cogneras¹⁷⁸, J. Colas⁵, S. Cole¹⁰⁶,
 A.P. Colijn¹⁰⁵, N.J. Collins¹⁸, C. Collins-Tooth⁵³, J. Collot⁵⁵, T. Colombo^{119a,119b},
 G. Colon⁸⁴, G. Compostella⁹⁹, P. Conde Muiño^{124a}, E. Coniavitis¹⁶⁶, M.C. Conidi¹²,
 S.M. Consonni^{89a,89b}, V. Consorti⁴⁸, S. Constantinescu^{26a}, C. Conta^{119a,119b}, G. Conti⁵⁷,
 F. Conventi^{102a,j}, M. Cooke¹⁵, B.D. Cooper⁷⁷, A.M. Cooper-Sarkar¹¹⁸, K. Copic¹⁵,
 T. Cornelissen¹⁷⁵, M. Corradi^{20a}, F. Corriveau^{85,k}, A. Cortes-Gonzalez¹⁶⁵, G. Cortiana⁹⁹,
 G. Costa^{89a}, M.J. Costa¹⁶⁷, D. Costanzo¹³⁹, D. Côté³⁰, L. Courneyea¹⁶⁹, G. Cowan⁷⁶,
 C. Cowden²⁸, B.E. Cox⁸², K. Cranmer¹⁰⁸, F. Crescioli^{122a,122b}, M. Cristinziani²¹,
 G. Crosetti^{37a,37b}, S. Crépé-Renaudin⁵⁵, C.-M. Cuciuc^{26a}, C. Cuenca Almenar¹⁷⁶,
 T. Cuhadar Donszelmann¹³⁹, M. Curatolo⁴⁷, C.J. Curtis¹⁸, C. Cuthbert¹⁵⁰,
 P. Cwetanski⁶⁰, H. Cziri¹⁴¹, P. Czodrowski⁴⁴, Z. Czyczula¹⁷⁶, S. D'Auria⁵³,
 M. D'Onofrio⁷³, A. D'Orazio^{132a,132b}, M.J. Da Cunha Sargedas De Sousa^{124a},
 C. Da Via⁸², W. Dabrowski³⁸, A. Dafinca¹¹⁸, T. Dai⁸⁷, C. Dallapiccola⁸⁴, M. Dam³⁶,
 M. Dameri^{50a,50b}, D.S. Damiani¹³⁷, H.O. Danielsson³⁰, V. Dao⁴⁹, G. Darbo^{50a},
 G.L. Darlea^{26b}, J.A. Dassoulas⁴², W. Davey²¹, T. Davidek¹²⁶, N. Davidson⁸⁶,
 R. Davidson⁷¹, E. Davies^{118,c}, M. Davies⁹³, O. Davignon⁷⁸, A.R. Davison⁷⁷,
 Y. Davygora^{58a}, E. Dawe¹⁴², I. Dawson¹³⁹, R.K. Daya-Ishmukhametova²³, K. De⁸,
 R. de Asmundis^{102a}, S. De Castro^{20a,20b}, S. De Cecco⁷⁸, J. de Graat⁹⁸, N. De Groot¹⁰⁴,
 P. de Jong¹⁰⁵, C. De La Taille¹¹⁵, H. De la Torre⁸⁰, F. De Lorenzi⁶³, L. de Mora⁷¹,
 L. De Nooij¹⁰⁵, D. De Pedis^{132a}, A. De Salvo^{132a}, U. De Sanctis^{164a,164c}, A. De Santo¹⁴⁹,
 J.B. De Vivie De Regie¹¹⁵, G. De Zorzi^{132a,132b}, W.J. Dearnaley⁷¹, R. Debbé²⁵,
 C. Debenedetti⁴⁶, B. Dechenaux⁵⁵, D.V. Dedovich⁶⁴, J. Degenhardt¹²⁰, J. Del Peso⁸⁰,
 T. Del Prete^{122a,122b}, T. Delemontex⁵⁵, M. Deliyergiyev⁷⁴, A. Dell'Acqua³⁰,
 L. Dell'Asta²², M. Della Pietra^{102a,j}, D. della Volpe^{102a,102b}, M. Delmastro⁵,
 P.A. Delsart⁵⁵, C. Deluca¹⁰⁵, S. Demers¹⁷⁶, M. Demichev⁶⁴, B. Demirkoz^{12,l}, J. Deng¹⁶³,
 S.P. Denisov¹²⁸, D. Derendarz³⁹, J.E. Derkaoui^{135d}, F. Derue⁷⁸, P. Dervan⁷³, K. Desch²¹,
 E. Devetak¹⁴⁸, P.O. Deviveiros¹⁰⁵, A. Dewhurst¹²⁹, B. DeWilde¹⁴⁸, S. Dhaliwal¹⁵⁸,
 R. Dhullipudi^{25,m}, A. Di Ciaccio^{133a,133b}, L. Di Ciaccio⁵, C. Di Donato^{102a,102b},
 A. Di Girolamo³⁰, B. Di Girolamo³⁰, S. Di Luise^{134a,134b}, A. Di Mattia¹⁷³, B. Di Micco³⁰,

R. Di Nardo⁴⁷, A. Di Simone^{133a,133b}, R. Di Sipio^{20a,20b}, M.A. Diaz^{32a}, E.B. Diehl⁸⁷,
 J. Dietrich⁴², T.A. Dietzsch^{58a}, S. Diglio⁸⁶, K. Dindar Yagci⁴⁰, J. Dingfelder²¹,
 F. Dimut^{26a}, C. Dionisi^{132a,132b}, P. Dita^{26a}, S. Dita^{26a}, F. Dittus³⁰, F. Djama⁸³,
 T. Djobava^{51b}, M.A.B. do Vale^{24c}, A. Do Valle Wemans^{124a,n}, T.K.O. Doan⁵, M. Dobbs⁸⁵,
 D. Dobos³⁰, E. Dobson^{30,o}, J. Dodd³⁵, C. Doglioni⁴⁹, T. Doherty⁵³, Y. Doi^{65,*},
 J. Dolejsi¹²⁶, I. Dolenc⁷⁴, Z. Dolezal¹²⁶, B.A. Dolgoshein^{96,*}, T. Dohmae¹⁵⁵,
 M. Donadelli^{24d}, J. Donini³⁴, J. Dopke³⁰, A. Doria^{102a}, A. Dos Anjos¹⁷³, A. Dotti^{122a,122b},
 M.T. Dova⁷⁰, A.D. Doxiadis¹⁰⁵, A.T. Doyle⁵³, N. Dressnandt¹²⁰, M. Dris¹⁰, J. Dubbert⁹⁹,
 S. Dube¹⁵, E. Duchovni¹⁷², G. Duckeck⁹⁸, D. Duda¹⁷⁵, A. Dudarev³⁰, F. Dudziak⁶³,
 M. Dührssen³⁰, I.P. Duerdoth⁸², L. Duflot¹¹⁵, M-A. Dufour⁸⁵, L. Duguid⁷⁶,
 M. Dunford^{58a}, H. Duran Yildiz^{4a}, R. Duxfield¹³⁹, M. Dwuznik³⁸, F. Dydak³⁰,
 M. Düren⁵², W.L. Ebenstein⁴⁵, J. Ebke⁹⁸, S. Eckweiler⁸¹, K. Edmonds⁸¹, W. Edson²,
 C.A. Edwards⁷⁶, N.C. Edwards⁵³, W. Ehrenfeld⁴², T. Eifert¹⁴³, G. Eigen¹⁴,
 K. Einsweiler¹⁵, E. Eisenhandler⁷⁵, T. Ekelof¹⁶⁶, M. El Kacimi^{135c}, M. Ellert¹⁶⁶, S. Elles⁵,
 F. Ellinghaus⁸¹, K. Ellis⁷⁵, N. Ellis³⁰, J. Elmsheuser⁹⁸, M. Elsing³⁰, D. Emelianov¹²⁹,
 R. Engelmann¹⁴⁸, A. Engl⁹⁸, B. Epp⁶¹, J. Erdmann⁵⁴, A. Ereditato¹⁷, D. Eriksson^{146a},
 J. Ernst², M. Ernst²⁵, J. Ernwein¹³⁶, D. Errede¹⁶⁵, S. Errede¹⁶⁵, E. Ertel⁸¹,
 M. Escalier¹¹⁵, H. Esch⁴³, C. Escobar¹²³, X. Espinal Curull¹², B. Esposito⁴⁷, F. Etienne⁸³,
 A.I. Etienne¹³⁶, E. Etzion¹⁵³, D. Evangelakou⁵⁴, H. Evans⁶⁰, L. Fabbri^{20a,20b}, C. Fabre³⁰,
 R.M. Fakhruddinov¹²⁸, S. Falciano^{132a}, Y. Fang¹⁷³, M. Fanti^{89a,89b}, A. Farbin⁸,
 A. Farilla^{134a}, J. Farley¹⁴⁸, T. Farooque¹⁵⁸, S. Farrell¹⁶³, S.M. Farrington¹⁷⁰,
 P. Farthouat³⁰, F. Fassi¹⁶⁷, P. Fassnacht³⁰, D. Fassouliotis⁹, B. Fatholahzadeh¹⁵⁸,
 A. Favareto^{89a,89b}, L. Fayard¹¹⁵, S. Fazio^{37a,37b}, R. Febbraro³⁴, P. Federic^{144a},
 O.L. Fedin¹²¹, W. Fedorko⁸⁸, M. Fehling-Kaschek⁴⁸, L. Feligioni⁸³, D. Fellmann⁶,
 C. Feng^{33d}, E.J. Feng⁶, A.B. Fenyuk¹²⁸, J. Ferencei^{144b}, W. Fernando⁶, S. Ferrag⁵³,
 J. Ferrando⁵³, V. Ferrara⁴², A. Ferrari¹⁶⁶, P. Ferrari¹⁰⁵, R. Ferrari^{119a},
 D.E. Ferreira de Lima⁵³, A. Ferrer¹⁶⁷, D. Ferrere⁴⁹, C. Ferretti⁸⁷,
 A. Ferretto Parodi^{50a,50b}, M. Fiascaris³¹, F. Fiedler⁸¹, A. Filipčič⁷⁴, F. Filthaut¹⁰⁴,
 M. Fincke-Keeler¹⁶⁹, M.C.N. Fiolhais^{124a,h}, L. Fiorini¹⁶⁷, A. Firan⁴⁰, G. Fischer⁴²,
 M.J. Fisher¹⁰⁹, M. Flechl⁴⁸, I. Fleck¹⁴¹, J. Fleckner⁸¹, P. Fleischmann¹⁷⁴,
 S. Fleischmann¹⁷⁵, T. Flick¹⁷⁵, A. Floderus⁷⁹, L.R. Flores Castillo¹⁷³, M.J. Flowerdew⁹⁹,
 T. Fonseca Martin¹⁷, A. Formica¹³⁶, A. Forti⁸², D. Fortin^{159a}, D. Fournier¹¹⁵,
 A.J. Fowler⁴⁵, H. Fox⁷¹, P. Francavilla¹², M. Franchini^{20a,20b}, S. Franchino^{119a,119b},
 D. Francis³⁰, T. Frank¹⁷², M. Franklin⁵⁷, S. Franz³⁰, M. Fraternali^{119a,119b}, S. Fratina¹²⁰,
 S.T. French²⁸, C. Friedrich⁴², F. Friedrich⁴⁴, R. Froeschl³⁰, D. Froidevaux³⁰, J.A. Frost²⁸,
 C. Fukunaga¹⁵⁶, E. Fullana Torregrosa³⁰, B.G. Fulsom¹⁴³, J. Fuster¹⁶⁷, C. Gabaldon³⁰,
 O. Gabizon¹⁷², T. Gadfort²⁵, S. Gadomski⁴⁹, G. Gagliardi^{50a,50b}, P. Gagnon⁶⁰,
 C. Galea⁹⁸, B. Galhardo^{124a}, E.J. Gallas¹¹⁸, V. Gallo¹⁷, B.J. Gallop¹²⁹, P. Gallus¹²⁵,
 K.K. Gan¹⁰⁹, Y.S. Gao^{143,e}, A. Gaponenko¹⁵, F. Garbersen¹⁷⁶, M. Garcia-Sciveres¹⁵,
 C. García¹⁶⁷, J.E. García Navarro¹⁶⁷, R.W. Gardner³¹, N. Garelli³⁰, H. Garitaonandia¹⁰⁵,
 V. Garonne³⁰, C. Gatti⁴⁷, G. Gaudio^{119a}, B. Gaur¹⁴¹, L. Gauthier¹³⁶, P. Gauzzi^{132a,132b},
 I.L. Gavrilenko⁹⁴, C. Gay¹⁶⁸, G. Gaycken²¹, E.N. Gazis¹⁰, P. Ge^{33d}, Z. Gecse¹⁶⁸,
 C.N.P. Gee¹²⁹, D.A.A. Geerts¹⁰⁵, Ch. Geich-Gimbel²¹, K. Gellerstedt^{146a,146b},

C. Gemme^{50a}, A. Gemmell⁵³, M.H. Genest⁵⁵, S. Gentile^{132a,132b}, M. George⁵⁴,
 S. George⁷⁶, P. Gerlach¹⁷⁵, A. Gershon¹⁵³, C. Geweniger^{58a}, H. Ghazlane^{135b},
 N. Ghodbane³⁴, B. Giacobbe^{20a}, S. Giagu^{132a,132b}, V. Giakoumopoulou⁹, V. Giangiobbe¹²,
 F. Gianotti³⁰, B. Gibbard²⁵, A. Gibson¹⁵⁸, S.M. Gibson³⁰, M. Gilchriese¹⁵, D. Gillberg²⁹,
 A.R. Gillman¹²⁹, D.M. Gingrich^{3,d}, J. Ginzburg¹⁵³, N. Giokaris⁹, M.P. Giordani^{164c},
 R. Giordano^{102a,102b}, F.M. Giorgi¹⁶, P. Giovannini⁹⁹, P.F. Giraud¹³⁶, D. Giugni^{89a},
 M. Giunta⁹³, P. Giusti^{20a}, B.K. Gjelsten¹¹⁷, L.K. Gladilin⁹⁷, C. Glasman⁸⁰, J. Glatzer²¹,
 A. Glazov⁴², K.W. Glitza¹⁷⁵, G.L. Glonti⁶⁴, J.R. Goddard⁷⁵, J. Godfrey¹⁴²,
 J. Godlewski³⁰, M. Goebel⁴², T. Göpfert⁴⁴, C. Goeringer⁸¹, C. Gössling⁴³, S. Goldfarb⁸⁷,
 T. Golling¹⁷⁶, A. Gomes^{124a,b}, L.S. Gomez Fajardo⁴², R. Gonçalo⁷⁶,
 J. Goncalves Pinto Firmino Da Costa⁴², L. Gonella²¹, S. González de la Hoz¹⁶⁷,
 G. Gonzalez Parra¹², M.L. Gonzalez Silva²⁷, S. Gonzalez-Sevilla⁴⁹, J.J. Goodson¹⁴⁸,
 L. Goossens³⁰, P.A. Gorbounov⁹⁵, H.A. Gordon²⁵, I. Gorelov¹⁰³, G. Gorfine¹⁷⁵,
 B. Gorini³⁰, E. Gorini^{72a,72b}, A. Gorišek⁷⁴, E. Gornicki³⁹, B. Gosdzik⁴², A.T. Goshaw⁶,
 M. Gosselink¹⁰⁵, M.I. Gostkin⁶⁴, I. Gough Eschrich¹⁶³, M. Gouighri^{135a}, D. Goujdami^{135c},
 M.P. Goulette⁴⁹, A.G. Goussiou¹³⁸, C. Goy⁵, S. Gozpinar²³, I. Grabowska-Bold³⁸,
 P. Grafström^{20a,20b}, K.-J. Grahn⁴², E. Gramstad¹¹⁷, F. Grancagnolo^{72a}, S. Grancagnolo¹⁶,
 V. Grassi¹⁴⁸, V. Gratchev¹²¹, N. Grau³⁵, H.M. Gray³⁰, J.A. Gray¹⁴⁸, E. Graziani^{134a},
 O.G. Grebenyuk¹²¹, T. Greenshaw⁷³, Z.D. Greenwood^{25,m}, K. Gregersen³⁶, I.M. Gregor⁴²,
 P. Grenier¹⁴³, J. Griffiths⁸, N. Grigalashvili⁶⁴, A.A. Grillo¹³⁷, S. Grinstein¹², Ph. Gris³⁴,
 Y.V. Grishkevich⁹⁷, J.-F. Grivaz¹¹⁵, E. Gross¹⁷², J. Grosse-Knetter⁵⁴, J. Groth-Jensen¹⁷²,
 K. Grybel¹⁴¹, D. Guest¹⁷⁶, C. Guicheney³⁴, S. Guindon⁵⁴, U. Gul⁵³, J. Gunther¹²⁵,
 B. Guo¹⁵⁸, J. Guo³⁵, P. Gutierrez¹¹¹, N. Guttman¹⁵³, O. Gutzwiller¹⁷³, C. Guyot¹³⁶,
 C. Gwenlan¹¹⁸, C.B. Gwilliam⁷³, A. Haas¹⁰⁸, S. Haas³⁰, C. Haber¹⁵, H.K. Hadavand⁸,
 D.R. Hadley¹⁸, P. Haefner²¹, F. Hahn³⁰, S. Haider³⁰, Z. Hajduk³⁹, H. Hakobyan¹⁷⁷,
 D. Hall¹¹⁸, K. Hamacher¹⁷⁵, P. Hamal¹¹³, K. Hamano⁸⁶, M. Hamer⁵⁴, A. Hamilton^{145b,p},
 S. Hamilton¹⁶¹, L. Han^{33b}, K. Hanagaki¹¹⁶, K. Hanawa¹⁶⁰, M. Hance¹⁵, C. Handel⁸¹,
 P. Hanke^{58a}, J.R. Hansen³⁶, J.B. Hansen³⁶, J.D. Hansen³⁶, P.H. Hansen³⁶, P. Hansson¹⁴³,
 K. Hara¹⁶⁰, G.A. Hare¹³⁷, T. Harenberg¹⁷⁵, S. Harkusha⁹⁰, D. Harper⁸⁷,
 R.D. Harrington⁴⁶, O.M. Harris¹³⁸, J. Hartert⁴⁸, F. Hartjes¹⁰⁵, T. Haruyama⁶⁵,
 A. Harvey⁵⁶, S. Hasegawa¹⁰¹, Y. Hasegawa¹⁴⁰, S. Hassani¹³⁶, S. Haug¹⁷, M. Hauschild³⁰,
 R. Hauser⁸⁸, M. Havranek²¹, C.M. Hawkes¹⁸, R.J. Hawkings³⁰, A.D. Hawkins⁷⁹,
 T. Hayakawa⁶⁶, T. Hayashi¹⁶⁰, D. Hayden⁷⁶, C.P. Hays¹¹⁸, H.S. Hayward⁷³,
 S.J. Haywood¹²⁹, S.J. Head¹⁸, V. Hedberg⁷⁹, L. Heelan⁸, S. Heim⁸⁸, B. Heinemann¹⁵,
 S. Heisterkamp³⁶, L. Helary²², C. Heller⁹⁸, M. Heller³⁰, S. Hellman^{146a,146b}, D. Hellmich²¹,
 C. Hensens¹², R.C.W. Henderson⁷¹, M. Henke^{58a}, A. Henrichs¹⁷⁶,
 A.M. Henriques Correia³⁰, S. Henrot-Versille¹¹⁵, C. Hensel⁵⁴, T. Henß¹⁷⁵,
 C.M. Hernandez⁸, Y. Hernández Jiménez¹⁶⁷, R. Herrberg¹⁶, G. Herten⁴⁸,
 R. Hertenberger⁹⁸, L. Hervas³⁰, G.G. Hesketh⁷⁷, N.P. Hesse¹⁰⁵, E. Higón-Rodríguez¹⁶⁷,
 J.C. Hill²⁸, K.H. Hiller⁴², S. Hillert²¹, S.J. Hillier¹⁸, I. Hinchliffe¹⁵, E. Hines¹²⁰,
 M. Hirose¹¹⁶, F. Hirsch⁴³, D. Hirschbuehl¹⁷⁵, J. Hobbs¹⁴⁸, N. Hod¹⁵³,
 M.C. Hodgkinson¹³⁹, P. Hodgson¹³⁹, A. Hoecker³⁰, M.R. Hoferkamp¹⁰³, J. Hoffman⁴⁰,
 D. Hoffmann⁸³, M. Hohlfeld⁸¹, M. Holder¹⁴¹, S.O. Holmgren^{146a}, T. Holy¹²⁷,

J.L. Holzbauer⁸⁸, T.M. Hong¹²⁰, L. Hooft van Huysduynen¹⁰⁸, S. Horner⁴⁸,
 J-Y. Hostachy⁵⁵, S. Hou¹⁵¹, A. Hoummada^{135a}, J. Howard¹¹⁸, J. Howarth⁸², I. Hristova¹⁶,
 J. Hrivnac¹¹⁵, T. Hryn'ova⁵, P.J. Hsu⁸¹, S.-C. Hsu¹⁵, D. Hu³⁵, Z. Hubacek¹²⁷,
 F. Hubaut⁸³, F. Huegging²¹, A. Huettmann⁴², T.B. Huffman¹¹⁸, E.W. Hughes³⁵,
 G. Hughes⁷¹, M. Huhtinen³⁰, M. Hurwitz¹⁵, N. Huseynov^{64,q}, J. Huston⁸⁸, J. Huth⁵⁷,
 G. Iacobucci⁴⁹, G. Iakovidis¹⁰, M. Ibbotson⁸², I. Ibragimov¹⁴¹, L. Iconomidou-Fayard¹¹⁵,
 J. Idarraga¹¹⁵, P. Iengo^{102a}, O. Igonkina¹⁰⁵, Y. Ikegami⁶⁵, M. Ikeno⁶⁵, D. Iliadis¹⁵⁴,
 N. Ilic¹⁵⁸, T. Ince⁹⁹, J. Inigo-Golfin³⁰, P. Ioannou⁹, M. Iodice^{134a}, K. Iordanidou⁹,
 V. Ippolito^{132a,132b}, A. Irles Quiles¹⁶⁷, C. Isaksson¹⁶⁶, M. Ishino⁶⁷, M. Ishitsuka¹⁵⁷,
 R. Ishmukhametov¹⁰⁹, C. Issever¹¹⁸, S. Istin^{19a}, A.V. Ivashin¹²⁸, W. Iwanski³⁹,
 H. Iwasaki⁶⁵, J.M. Izen⁴¹, V. Izzo^{102a}, B. Jackson¹²⁰, J.N. Jackson⁷³, P. Jackson¹,
 M.R. Jaekel³⁰, V. Jain⁶⁰, K. Jakobs⁴⁸, S. Jakobsen³⁶, T. Jakoubek¹²⁵, J. Jakubek¹²⁷,
 D.O. Jamin¹⁵¹, D.K. Jana¹¹¹, E. Jansen⁷⁷, H. Jansen³⁰, A. Jantsch⁹⁹, M. Janus⁴⁸,
 G. Jarlskog⁷⁹, L. Jeanty⁵⁷, I. Jen-La Plante³¹, D. Jennens⁸⁶, P. Jenni³⁰,
 A.E. Loevschall-Jensen³⁶, P. Jež³⁶, S. Jézéquel⁵, M.K. Jha^{20a}, H. Ji¹⁷³, W. Ji⁸¹, J. Jia¹⁴⁸,
 Y. Jiang^{33b}, M. Jimenez Belenguer⁴², S. Jin^{33a}, O. Jinnouchi¹⁵⁷, M.D. Joergensen³⁶,
 D. Joffe⁴⁰, M. Johansen^{146a,146b}, K.E. Johansson^{146a}, P. Johansson¹³⁹, S. Johnert⁴²,
 K.A. Johns⁷, K. Jon-And^{146a,146b}, G. Jones¹⁷⁰, R.W.L. Jones⁷¹, T.J. Jones⁷³, C. Joram³⁰,
 P.M. Jorge^{124a}, K.D. Joshi⁸², J. Jovicevic¹⁴⁷, T. Jovin^{13b}, X. Ju¹⁷³, C.A. Jung⁴³,
 R.M. Jungst³⁰, V. Juranek¹²⁵, P. Jussel⁶¹, A. Juste Rozas¹², S. Kabana¹⁷, M. Kaci¹⁶⁷,
 A. Kaczmarska³⁹, P. Kadlecik³⁶, M. Kado¹¹⁵, H. Kagan¹⁰⁹, M. Kagan⁵⁷,
 E. Kajomovitz¹⁵², S. Kalinin¹⁷⁵, L.V. Kalinovskaya⁶⁴, S. Kama⁴⁰, N. Kanaya¹⁵⁵,
 M. Kaneda³⁰, S. Kaneti²⁸, T. Kanno¹⁵⁷, V.A. Kantserov⁹⁶, J. Kanzaki⁶⁵, B. Kaplan¹⁰⁸,
 A. Kapliy³¹, J. Kaplon³⁰, D. Kar⁵³, M. Karagounis²¹, K. Karakostas¹⁰, M. Karnevskiy⁴²,
 V. Kartvelishvili⁷¹, A.N. Karyukhin¹²⁸, L. Kashif¹⁷³, G. Kasieczka^{58b}, R.D. Kass¹⁰⁹,
 A. Kastanas¹⁴, M. Kataoka⁵, Y. Kataoka¹⁵⁵, E. Katsoufis¹⁰, J. Katzy⁴², V. Kaushik⁷,
 K. Kawagoe⁶⁹, T. Kawamoto¹⁵⁵, G. Kawamura⁸¹, M.S. Kayl¹⁰⁵, S. Kazama¹⁵⁵,
 V.A. Kazanin¹⁰⁷, M.Y. Kazarinov⁶⁴, R. Keeler¹⁶⁹, P.T. Keener¹²⁰, R. Kehoe⁴⁰, M. Keil⁵⁴,
 G.D. Kekelidze⁶⁴, J.S. Keller¹³⁸, M. Kenyon⁵³, O. Kepka¹²⁵, N. Kerschen³⁰,
 B.P. Kerševan⁷⁴, S. Kersten¹⁷⁵, K. Kessoku¹⁵⁵, J. Keung¹⁵⁸, F. Khalil-zada¹¹,
 H. Khandanyan^{146a,146b}, A. Khanov¹¹², D. Kharchenko⁶⁴, A. Khodinov⁹⁶, A. Khomich^{58a},
 T.J. Khoo²⁸, G. Khoriauli²¹, A. Khoroshilov¹⁷⁵, V. Khovanskiy⁹⁵, E. Khramov⁶⁴,
 J. Khubua^{51b}, H. Kim^{146a,146b}, S.H. Kim¹⁶⁰, N. Kimura¹⁷¹, O. Kind¹⁶, B.T. King⁷³,
 M. King⁶⁶, R.S.B. King¹¹⁸, J. Kirk¹²⁹, A.E. Kiryunin⁹⁹, T. Kishimoto⁶⁶, D. Kisielewska³⁸,
 T. Kitamura⁶⁶, T. Kittelmann¹²³, K. Kiuchi¹⁶⁰, E. Kladiva^{144b}, M. Klein⁷³, U. Klein⁷³,
 K. Kleinknecht⁸¹, M. Klemetti⁸⁵, A. Klier¹⁷², P. Klimek^{146a,146b}, A. Klimentov²⁵,
 R. Klingenberg⁴³, J.A. Klinger⁸², E.B. Klinkby³⁶, T. Klioutchnikova³⁰, P.F. Klok¹⁰⁴,
 S. Klous¹⁰⁵, E.-E. Kluge^{58a}, T. Kluge⁷³, P. Kluit¹⁰⁵, S. Kluth⁹⁹, E. Kneringer⁶¹,
 E.B.F.G. Knoop⁸³, A. Knue⁵⁴, B.R. Ko⁴⁵, T. Kobayashi¹⁵⁵, M. Kobel⁴⁴, M. Kocian¹⁴³,
 P. Kodys¹²⁶, K. Köneke³⁰, A.C. König¹⁰⁴, S. Koenig⁸¹, L. Köpke⁸¹, F. Koetsveld¹⁰⁴,
 P. Koesesarki²¹, T. Koffas²⁹, E. Koffeman¹⁰⁵, L.A. Kogan¹¹⁸, S. Kohlmann¹⁷⁵, F. Kohn⁵⁴,
 Z. Kohout¹²⁷, T. Kohriki⁶⁵, T. Koi¹⁴³, G.M. Kolachev^{107,*}, H. Kolanoski¹⁶,
 V. Kolesnikov⁶⁴, I. Koletsou^{89a}, J. Koll⁸⁸, A.A. Komar⁹⁴, Y. Komori¹⁵⁵, T. Kondo⁶⁵,

T. Kono^{42,r}, A.I. Kononov⁴⁸, R. Konoplich^{108,s}, N. Konstantinidis⁷⁷, R. Kopeliansky¹⁵²,
 S. Koperny³⁸, K. Korcyl³⁹, K. Kordas¹⁵⁴, A. Korn¹¹⁸, A. Korol¹⁰⁷, I. Korolkov¹²,
 E.V. Korolkova¹³⁹, V.A. Korotkov¹²⁸, O. Kortner⁹⁹, S. Kortner⁹⁹, V.V. Kostyukhin²¹,
 S. Kotov⁹⁹, V.M. Kotov⁶⁴, A. Kotwal⁴⁵, C. Kourkoumelis⁹, V. Kouskoura¹⁵⁴,
 A. Koutsman^{159a}, R. Kowalewski¹⁶⁹, T.Z. Kowalski³⁸, W. Kozanecki¹³⁶, A.S. Kozhin¹²⁸,
 V. Kral¹²⁷, V.A. Kramarenko⁹⁷, G. Kramberger⁷⁴, M.W. Krasny⁷⁸, A. Krasznahorkay¹⁰⁸,
 J.K. Kraus²¹, S. Kreiss¹⁰⁸, F. Krejci¹²⁷, J. Kretzschmar⁷³, N. Krieger⁵⁴, P. Krieger¹⁵⁸,
 K. Kroeninger⁵⁴, H. Kroha⁹⁹, J. Kroll¹²⁰, J. Kroseberg²¹, J. Krstic^{13a}, U. Kruchonak⁶⁴,
 H. Krüger²¹, T. Kruker¹⁷, N. Krumnack⁶³, Z.V. Krumshteyn⁶⁴, M.K. Kruse⁴⁵,
 T. Kubota⁸⁶, S. Kuday^{4a}, S. Kuehn⁴⁸, A. Kugel^{58c}, T. Kuhl⁴², D. Kuhn⁶¹, V. Kukhtin⁶⁴,
 Y. Kulchitsky⁹⁰, S. Kuleshov^{32b}, C. Kummer⁹⁸, M. Kuna⁷⁸, J. Kunkle¹²⁰, A. Kupco¹²⁵,
 H. Kurashige⁶⁶, M. Kurata¹⁶⁰, Y.A. Kurochkin⁹⁰, V. Kus¹²⁵, E.S. Kuwertz¹⁴⁷,
 M. Kuze¹⁵⁷, J. Kvita¹⁴², R. Kwee¹⁶, A. La Rosa⁴⁹, L. La Rotonda^{37a,37b}, L. Labarga⁸⁰,
 J. Labbe⁵, S. Lablak^{135a}, C. Lacasta¹⁶⁷, F. Lacava^{132a,132b}, J. Lacey²⁹, H. Lacker¹⁶,
 D. Lacour⁷⁸, V.R. Lacuesta¹⁶⁷, E. Ladygin⁶⁴, R. Lafaye⁵, B. Laforge⁷⁸, T. Lagouri¹⁷⁶,
 S. Lai⁴⁸, E. Laisne⁵⁵, M. Lamanna³⁰, L. Lambourne⁷⁷, C.L. Lampen⁷, W. Lampl⁷,
 E. Lancon¹³⁶, U. Landgraf⁴⁸, M.P.J. Landon⁷⁵, V.S. Lang^{58a}, C. Lange⁴²,
 A.J. Lankford¹⁶³, F. Lanni²⁵, K. Lantzschi¹⁷⁵, S. Laplace⁷⁸, C. Lapoire²¹, J.F. Laporte¹³⁶,
 T. Lari^{89a}, A. Larner¹¹⁸, M. Lassnig³⁰, P. Laurelli⁴⁷, V. Lavorini^{37a,37b}, W. Lavrijsen¹⁵,
 P. Laycock⁷³, O. Le Dortz⁷⁸, E. Le Guirriec⁸³, E. Le Menedeu¹², T. LeCompte⁶,
 F. Ledroit-Guillon⁵⁵, H. Lee¹⁰⁵, J.S.H. Lee¹¹⁶, S.C. Lee¹⁵¹, L. Lee¹⁷⁶, M. Lefebvre¹⁶⁹,
 M. Legendre¹³⁶, F. Legger⁹⁸, C. Leggett¹⁵, M. Lehmacher²¹, G. Lehmann Miotto³⁰,
 X. Lei⁷, M.A.L. Leite^{24d}, R. Leitner¹²⁶, D. Lellouch¹⁷², B. Lemmer⁵⁴, V. Lendermann^{58a},
 K.J.C. Leney^{145b}, T. Lenz¹⁰⁵, G. Lenzen¹⁷⁵, B. Lenzi³⁰, K. Leonhardt⁴⁴, S. Leontsinis¹⁰,
 F. Lepold^{58a}, C. Leroy⁹³, J-R. Lessard¹⁶⁹, C.G. Lester²⁸, C.M. Lester¹²⁰, J. Levêque⁵,
 D. Levin⁸⁷, L.J. Levinson¹⁷², A. Lewis¹¹⁸, G.H. Lewis¹⁰⁸, A.M. Leyko²¹, M. Leyton¹⁶,
 B. Li⁸³, H. Li¹⁴⁸, H.L. Li³¹, S. Li^{33b,t}, X. Li⁸⁷, Z. Liang^{118,u}, H. Liao³⁴, B. Liberti^{133a},
 P. Lichard³⁰, M. Lichtnecker⁹⁸, K. Lie¹⁶⁵, W. Liebig¹⁴, C. Limbach²¹, A. Limosani⁸⁶,
 M. Limper⁶², S.C. Lin^{151,v}, F. Linde¹⁰⁵, J.T. Linnemann⁸⁸, E. Lipeles¹²⁰, A. Lipniacka¹⁴,
 T.M. Liss¹⁶⁵, D. Lissauer²⁵, A. Lister⁴⁹, A.M. Litke¹³⁷, C. Liu²⁹, D. Liu¹⁵¹, H. Liu⁸⁷,
 J.B. Liu⁸⁷, L. Liu⁸⁷, M. Liu^{33b}, Y. Liu^{33b}, M. Livan^{119a,119b}, S.S.A. Livermore¹¹⁸,
 A. Lleres⁵⁵, J. Llorente Merino⁸⁰, S.L. Lloyd⁷⁵, E. Lobodzinska⁴², P. Loch⁷,
 W.S. Lockman¹³⁷, T. Loddenkoetter²¹, F.K. Loebinger⁸², A. Loginov¹⁷⁶, C.W. Loh¹⁶⁸,
 T. Lohse¹⁶, K. Lohwasser⁴⁸, M. Lokajicek¹²⁵, V.P. Lombardo⁵, R.E. Long⁷¹, L. Lopes^{124a},
 D. Lopez Mateos⁵⁷, J. Lorenz⁹⁸, N. Lorenzo Martinez¹¹⁵, M. Losada¹⁶², P. Loscutoff¹⁵,
 F. Lo Sterzo^{132a,132b}, M.J. Losty^{159a,*}, X. Lou⁴¹, A. Lounis¹¹⁵, K.F. Loureiro¹⁶², J. Love⁶,
 P.A. Love⁷¹, A.J. Lowe^{143,e}, F. Lu^{33a}, H.J. Lubatti¹³⁸, C. Luci^{132a,132b}, A. Lucotte⁵⁵,
 A. Ludwig⁴⁴, D. Ludwig⁴², I. Ludwig⁴⁸, J. Ludwig⁴⁸, F. Luehring⁶⁰, G. Luijckx¹⁰⁵,
 W. Lukas⁶¹, L. Luminari^{132a}, E. Lund¹¹⁷, B. Lund-Jensen¹⁴⁷, B. Lundberg⁷⁹,
 J. Lundberg^{146a,146b}, O. Lundberg^{146a,146b}, J. Lundquist³⁶, M. Lungwitz⁸¹, D. Lynn²⁵,
 E. Lytken⁷⁹, H. Ma²⁵, L.L. Ma¹⁷³, G. Maccarrone⁴⁷, A. Macchiolo⁹⁹, B. Maček⁷⁴,
 J. Machado Miguens^{124a}, R. Mackeprang³⁶, R.J. Madaras¹⁵, H.J. Maddocks⁷¹,
 W.F. Mader⁴⁴, R. Maenner^{58c}, T. Maeno²⁵, P. Mättig¹⁷⁵, S. Mättig⁸¹, L. Magnoni¹⁶³,

E. Magradze⁵⁴, K. Mahboubi⁴⁸, J. Mahlstedt¹⁰⁵, S. Mahmoud⁷³, G. Mahout¹⁸,
 C. Maiani¹³⁶, C. Maidantchik^{24a}, A. Maio^{124a,b}, S. Majewski²⁵, Y. Makida⁶⁵,
 N. Makovec¹¹⁵, P. Mal¹³⁶, B. Malaescu³⁰, Pa. Malecki³⁹, P. Malecki³⁹, V.P. Maleev¹²¹,
 F. Malek⁵⁵, U. Mallik⁶², D. Malon⁶, C. Malone¹⁴³, S. Maltezos¹⁰, V. Malyshev¹⁰⁷,
 S. Malyukov³⁰, R. Mameghani⁹⁸, J. Mamuzic^{13b}, A. Manabe⁶⁵, L. Mandelli^{89a},
 I. Mandić⁷⁴, R. Mandrysch¹⁶, J. Maneira^{124a}, A. Manfredini⁹⁹, P.S. Mangeard⁸⁸,
 L. Manhaes de Andrade Filho^{24b}, J.A. Manjarres Ramos¹³⁶, A. Mann⁵⁴,
 P.M. Manning¹³⁷, A. Manousakis-Katsikakis⁹, B. Mansoulie¹³⁶, A. Mapelli³⁰,
 L. Mapelli³⁰, L. March¹⁶⁷, J.F. Marchand²⁹, F. Marchese^{133a,133b}, G. Marchiori⁷⁸,
 M. Marcisovsky¹²⁵, C.P. Marino¹⁶⁹, F. Marroquim^{24a}, Z. Marshall³⁰, F.K. Martens¹⁵⁸,
 L.F. Marti¹⁷, S. Marti-Garcia¹⁶⁷, B. Martin³⁰, B. Martin⁸⁸, J.P. Martin⁹³, T.A. Martin¹⁸,
 V.J. Martin⁴⁶, B. Martin dit Latour⁴⁹, S. Martin-Haugh¹⁴⁹, M. Martinez¹²,
 V. Martinez Outschoorn⁵⁷, A.C. Martyniuk¹⁶⁹, M. Marx⁸², F. Marzano^{132a}, A. Marzin¹¹¹,
 L. Masetti⁸¹, T. Mashimo¹⁵⁵, R. Mashinistov⁹⁴, J. Masik⁸², A.L. Maslennikov¹⁰⁷,
 I. Massa^{20a,20b}, G. Massaro¹⁰⁵, N. Massol⁵, P. Mastrandrea¹⁴⁸, A. Mastroberardino^{37a,37b},
 T. Masubuchi¹⁵⁵, P. Matricon¹¹⁵, H. Matsunaga¹⁵⁵, T. Matsushita⁶⁶, C. Mattravers^{118,c},
 J. Maurer⁸³, S.J. Maxfield⁷³, A. Mayne¹³⁹, R. Mazini¹⁵¹, M. Mazur²¹,
 L. Mazzaferro^{133a,133b}, M. Mazzanti^{89a}, J. Mc Donald⁸⁵, S.P. Mc Kee⁸⁷, A. McCarn¹⁶⁵,
 R.L. McCarthy¹⁴⁸, T.G. McCarthy²⁹, N.A. McCubbin¹²⁹, K.W. McFarlane^{56,*},
 J.A. Mcfayden¹³⁹, G. Mchedlize^{51b}, T. McLaughlan¹⁸, S.J. McMahon¹²⁹,
 R.A. McPherson^{169,k}, A. Meade⁸⁴, J. Mechnich¹⁰⁵, M. Mechtel¹⁷⁵, M. Medinnis⁴²,
 R. Meera-Lebbai¹¹¹, T. Meguro¹¹⁶, S. Mehlhase³⁶, A. Mehta⁷³, K. Meier^{58a}, B. Meirose⁷⁹,
 C. Melachrinou³¹, B.R. Mellado Garcia¹⁷³, F. Meloni^{89a,89b}, L. Mendoza Navas¹⁶²,
 Z. Meng^{151,w}, A. Mengarelli^{20a,20b}, S. Menke⁹⁹, E. Meoni¹⁶¹, K.M. Mercurio⁵⁷,
 P. Mermod⁴⁹, L. Merola^{102a,102b}, C. Meroni^{89a}, F.S. Merritt³¹, H. Merritt¹⁰⁹,
 A. Messina^{30,x}, J. Metcalfe²⁵, A.S. Mete¹⁶³, C. Meyer⁸¹, C. Meyer³¹, J-P. Meyer¹³⁶,
 J. Meyer¹⁷⁴, J. Meyer⁵⁴, T.C. Meyer³⁰, S. Michal³⁰, L. Micu^{26a}, R.P. Middleton¹²⁹,
 S. Migas⁷³, L. Mijović¹³⁶, G. Mikenberg¹⁷², M. Mikestikova¹²⁵, M. Mikuz⁷⁴,
 D.W. Miller³¹, R.J. Miller⁸⁸, W.J. Mills¹⁶⁸, C. Mills⁵⁷, A. Milov¹⁷²,
 D.A. Milstead^{146a,146b}, D. Milstein¹⁷², A.A. Minaenko¹²⁸, M. Miñano Moya¹⁶⁷,
 I.A. Minashvili⁶⁴, A.I. Mincer¹⁰⁸, B. Mindur³⁸, M. Mineev⁶⁴, Y. Ming¹⁷³, L.M. Mir¹²,
 G. Mirabelli^{132a}, J. Mitrevski¹³⁷, V.A. Mitsou¹⁶⁷, S. Mitsui⁶⁵, P.S. Miyagawa¹³⁹,
 J.U. Mjörnmark⁷⁹, T. Moa^{146a,146b}, V. Moeller²⁸, K. Mönig⁴², N. Möser²¹,
 S. Mohapatra¹⁴⁸, W. Mohr⁴⁸, R. Moles-Valls¹⁶⁷, A. Molfetas³⁰, J. Monk⁷⁷, E. Monnier⁸³,
 J. Montejo Berlingen¹², F. Monticelli⁷⁰, S. Monzani^{20a,20b}, R.W. Moore³,
 G.F. Moorhead⁸⁶, C. Mora Herrera⁴⁹, A. Moraes⁵³, N. Morange¹³⁶, J. Morel⁵⁴,
 G. Morello^{37a,37b}, D. Moreno⁸¹, M. Moreno Llácer¹⁶⁷, P. Morettini^{50a}, M. Morgenstern⁴⁴,
 M. Morii⁵⁷, A.K. Morley³⁰, G. Mornacchi³⁰, J.D. Morris⁷⁵, L. Morvaj¹⁰¹, H.G. Moser⁹⁹,
 M. Mosidze^{51b}, J. Moss¹⁰⁹, R. Mount¹⁴³, E. Mountricha^{10,y}, S.V. Mouraviev^{94,*},
 E.J.W. Moyse⁸⁴, F. Mueller^{58a}, J. Mueller¹²³, K. Mueller²¹, T.A. Müller⁹⁸, T. Mueller⁸¹,
 D. Muenstermann³⁰, Y. Munwes¹⁵³, W.J. Murray¹²⁹, I. Mussche¹⁰⁵, E. Musto^{102a,102b},
 A.G. Myagkov¹²⁸, M. Myska¹²⁵, O. Nackenhorst⁵⁴, J. Nadal¹², K. Nagai¹⁶⁰, R. Nagai¹⁵⁷,
 K. Nagano⁶⁵, A. Nagarkar¹⁰⁹, Y. Nagasaka⁵⁹, M. Nagel⁹⁹, A.M. Nairz³⁰, Y. Nakahama³⁰,

K. Nakamura¹⁵⁵, T. Nakamura¹⁵⁵, I. Nakano¹¹⁰, G. Nanava²¹, A. Napier¹⁶¹,
 R. Narayan^{58b}, M. Nash^{77,c}, T. Nattermann²¹, T. Naumann⁴², G. Navarro¹⁶²,
 H.A. Neal⁸⁷, P.Yu. Nechaeva⁹⁴, T.J. Neep⁸², A. Negri^{119a,119b}, G. Negri³⁰, M. Negrini^{20a},
 S. Nektarijevic⁴⁹, A. Nelson¹⁶³, T.K. Nelson¹⁴³, S. Nemecek¹²⁵, P. Nemethy¹⁰⁸,
 A.A. Nepomuceno^{24a}, M. Nessi^{30,z}, M.S. Neubauer¹⁶⁵, M. Neumann¹⁷⁵, A. Neusiedl⁸¹,
 R.M. Neves¹⁰⁸, P. Nevski²⁵, F.M. Newcomer¹²⁰, P.R. Newman¹⁸, V. Nguyen Thi Hong¹³⁶,
 R.B. Nickerson¹¹⁸, R. Nicolaidou¹³⁶, B. Nicquevert³⁰, F. Niedercorn¹¹⁵, J. Nielsen¹³⁷,
 N. Nikiforou³⁵, A. Nikiforov¹⁶, V. Nikolaenko¹²⁸, I. Nikolic-Audit⁷⁸, K. Nikolics⁴⁹,
 K. Nikolopoulos¹⁸, H. Nilsen⁴⁸, P. Nilsson⁸, Y. Ninomiya¹⁵⁵, A. Nisati^{132a}, R. Nisius⁹⁹,
 T. Nobe¹⁵⁷, L. Nodulman⁶, M. Nomachi¹¹⁶, I. Nomidis¹⁵⁴, S. Norberg¹¹¹, M. Nordberg³⁰,
 P.R. Norton¹²⁹, J. Novakova¹²⁶, M. Nozaki⁶⁵, L. Nozka¹¹³, I.M. Nugent^{159a},
 A.-E. Nuncio-Quiroz²¹, G. Nunes Hanninger⁸⁶, T. Nunnemann⁹⁸, E. Nurse⁷⁷,
 B.J. O'Brien⁴⁶, D.C. O'Neil¹⁴², V. O'Shea⁵³, L.B. Oakes⁹⁸, F.G. Oakham^{29,d},
 H. Oberlack⁹⁹, J. Ocariz⁷⁸, A. Ochi⁶⁶, S. Oda⁶⁹, S. Odaka⁶⁵, J. Odier⁸³, H. Ogren⁶⁰,
 A. Oh⁸², S.H. Oh⁴⁵, C.C. Ohm³⁰, T. Ohshima¹⁰¹, W. Okamura¹¹⁶, H. Okawa²⁵,
 Y. Okumura³¹, T. Okuyama¹⁵⁵, A. Olariu^{26a}, A.G. Olchevski⁶⁴, S.A. Olivares Pino^{32a},
 M. Oliveira^{124a,h}, D. Oliveira Damazio²⁵, E. Oliver Garcia¹⁶⁷, D. Olivito¹²⁰,
 A. Olszewski³⁹, J. Olszowska³⁹, A. Onofre^{124a,aa}, P.U.E. Onyisi³¹, C.J. Oram^{159a},
 M.J. Oreglia³¹, Y. Oren¹⁵³, D. Orestano^{134a,134b}, N. Orlando^{72a,72b}, I. Orlov¹⁰⁷,
 C. Oropeza Barrera⁵³, R.S. Orr¹⁵⁸, B. Osculati^{50a,50b}, R. Ospanov¹²⁰, C. Osuna¹²,
 G. Otero y Garzon²⁷, J.P. Ottersbach¹⁰⁵, M. Ouchrif^{135d}, E.A. Ouellette¹⁶⁹,
 F. Ould-Saada¹¹⁷, A. Ouraou¹³⁶, Q. Ouyang^{33a}, A. Ovcharova¹⁵, M. Owen⁸², S. Owen¹³⁹,
 V.E. Ozcan^{19a}, N. Ozturk⁸, A. Pacheco Pages¹², C. Padilla Aranda¹², S. Pagan Griso¹⁵,
 E. Paganis¹³⁹, C. Pahl⁹⁹, F. Paige²⁵, P. Pais⁸⁴, K. Pajchel¹¹⁷, G. Palacino^{159b},
 C.P. Paleari⁷, S. Palestini³⁰, D. Pallin³⁴, A. Palma^{124a}, J.D. Palmer¹⁸, Y.B. Pan¹⁷³,
 E. Panagiotopoulou¹⁰, J.G. Panduro Vazquez⁷⁶, P. Pani¹⁰⁵, N. Panikashvili⁸⁷,
 S. Panitkin²⁵, D. Pantea^{26a}, A. Papadelis^{146a}, Th.D. Papadopoulou¹⁰, A. Paramonov⁶,
 D. Paredes Hernandez³⁴, W. Park^{25,ab}, M.A. Parker²⁸, F. Parodi^{50a,50b}, J.A. Parsons³⁵,
 U. Parzefall⁴⁸, S. Pashapour⁵⁴, E. Pasqualucci^{132a}, S. Passaggio^{50a}, A. Passeri^{134a},
 F. Pastore^{134a,134b,*}, Fr. Pastore⁷⁶, G. Pásztor^{49,ac}, S. Patariaia¹⁷⁵, N. Patel¹⁵⁰,
 J.R. Pater⁸², S. Patricelli^{102a,102b}, T. Pauly³⁰, M. Pecsny^{144a}, S. Pedraza Lopez¹⁶⁷,
 M.I. Pedraza Morales¹⁷³, S.V. Peleganchuk¹⁰⁷, D. Pelikan¹⁶⁶, H. Peng^{33b}, B. Penning³¹,
 A. Penson³⁵, J. Penwell⁶⁰, M. Perantoni^{24a}, K. Perez^{35,ad}, T. Perez Cavalcanti⁴²,
 E. Perez Codina^{159a}, M.T. Pérez García-Estañ¹⁶⁷, V. Perez Reale³⁵, L. Perini^{89a,89b},
 H. Pernegger³⁰, R. Perrino^{72a}, P. Perrodo⁵, V.D. Peshekhonov⁶⁴, K. Peters³⁰,
 B.A. Petersen³⁰, J. Petersen³⁰, T.C. Petersen³⁶, E. Petit⁵, A. Petridis¹⁵⁴, C. Petridou¹⁵⁴,
 E. Petrolo^{132a}, F. Petrucci^{134a,134b}, D. Petschull⁴², M. Pettei¹⁴², R. Pezoa^{32b}, A. Phan⁸⁶,
 P.W. Phillips¹²⁹, G. Piacquadio³⁰, A. Picazio⁴⁹, E. Piccaro⁷⁵, M. Piccini^{20a,20b},
 S.M. Piec⁴², R. Piegai²⁷, D.T. Pignotti¹⁰⁹, J.E. Pilcher³¹, A.D. Pilkington⁸²,
 J. Pina^{124a,b}, M. Pinamonti^{164a,164c}, A. Pinder¹¹⁸, J.L. Pinfold³, B. Pinto^{124a},
 C. Pizio^{89a,89b}, M. Plamondon¹⁶⁹, M.-A. Pleier²⁵, E. Plotnikova⁶⁴, A. Poblaguev²⁵,
 S. Poddar^{58a}, F. Podlyski³⁴, L. Poggioli¹¹⁵, D. Pohl²¹, M. Pohl⁴⁹, G. Polesello^{119a},
 A. Policicchio^{37a,37b}, A. Polini^{20a}, J. Poll⁷⁵, V. Polychronakos²⁵, D. Pomeroy²³,

K. Pommès³⁰, L. Pontecorvo^{132a}, B.G. Pope⁸⁸, G.A. Popeneciu^{26a}, D.S. Popovic^{13a},
 A. Poppleton³⁰, X. Portell Bueso³⁰, G.E. Pospelov⁹⁹, S. Pospisil¹²⁷, I.N. Potrap⁹⁹,
 C.J. Potter¹⁴⁹, C.T. Potter¹¹⁴, G. Poulard³⁰, J. Poveda⁶⁰, V. Pozdnyakov⁶⁴, R. Prabhu⁷⁷,
 P. Pralavorio⁸³, A. Pranko¹⁵, S. Prasad³⁰, R. Pravahan²⁵, S. Prell⁶³, K. Pretzl¹⁷,
 D. Price⁶⁰, J. Price⁷³, L.E. Price⁶, D. Prieur¹²³, M. Primavera^{72a}, K. Prokofiev¹⁰⁸,
 F. Prokoshin^{32b}, S. Protopopescu²⁵, J. Proudfoot⁶, X. Prudent⁴⁴, M. Przybycien³⁸,
 H. Przysieczniak⁵, S. Psoroulas²¹, E. Ptacek¹¹⁴, E. Pueschel⁸⁴, J. Purdham⁸⁷,
 M. Purohit^{25,ab}, P. Puzo¹¹⁵, Y. Pylypchenko⁶², J. Qian⁸⁷, A. Quadt⁵⁴, D.R. Quarrie¹⁵,
 W.B. Quayle¹⁷³, F. Quinonez^{32a}, M. Raas¹⁰⁴, V. Radeka²⁵, V. Radescu⁴², P. Radloff¹¹⁴,
 T. Rador^{19a}, F. Ragusa^{89a,89b}, G. Rahal¹⁷⁸, A.M. Rahimi¹⁰⁹, D. Rahm²⁵,
 S. Rajagopalan²⁵, M. Rammensee⁴⁸, M. Rammes¹⁴¹, A.S. Randle-Conde⁴⁰,
 K. Randrianarivony²⁹, F. Rauscher⁹⁸, T.C. Rave⁴⁸, M. Raymond³⁰, A.L. Read¹¹⁷,
 D.M. Rebuffi^{119a,119b}, A. Redelbach¹⁷⁴, G. Redlinger²⁵, R. Reece¹²⁰, K. Reeves⁴¹,
 E. Reinherz-Aronis¹⁵³, A. Reinsch¹¹⁴, I. Reisinger⁴³, C. Rembser³⁰, Z.L. Ren¹⁵¹,
 A. Renaud¹¹⁵, M. Rescigno^{132a}, S. Resconi^{89a}, B. Resende¹³⁶, P. Reznicek⁹⁸,
 R. Rezvani¹⁵⁸, R. Richter⁹⁹, E. Richter-Was^{5,ae}, M. Ridel⁷⁸, M. Rijpstra¹⁰⁵,
 M. Rijssenbeek¹⁴⁸, A. Rimoldi^{119a,119b}, L. Rinaldi^{20a}, R.R. Rios⁴⁰, I. Riu¹²,
 G. Rivoltella^{89a,89b}, F. Rizatdinova¹¹², E. Rizvi⁷⁵, S.H. Robertson^{85,k},
 A. Robichaud-Veronneau¹¹⁸, D. Robinson²⁸, J.E.M. Robinson⁸², A. Robson⁵³,
 J.G. Rocha de Lima¹⁰⁶, C. Roda^{122a,122b}, D. Roda Dos Santos³⁰, A. Roe⁵⁴, S. Roe³⁰,
 O. Røhne¹¹⁷, S. Rolli¹⁶¹, A. Romaniouk⁹⁶, M. Romano^{20a,20b}, G. Romeo²⁷,
 E. Romero Adam¹⁶⁷, N. Rompotis¹³⁸, L. Roos⁷⁸, E. Ros¹⁶⁷, S. Rosati^{132a}, K. Rosbach⁴⁹,
 A. Rose¹⁴⁹, M. Rose⁷⁶, G.A. Rosenbaum¹⁵⁸, E.I. Rosenberg⁶³, P.L. Rosendahl¹⁴,
 O. Rosenthal¹⁴¹, L. Rosselet⁴⁹, V. Rossetti¹², E. Rossi^{132a,132b}, L.P. Rossi^{50a},
 M. Rotaru^{26a}, I. Roth¹⁷², J. Rothberg¹³⁸, D. Rousseau¹¹⁵, C.R. Royon¹³⁶, A. Rozanov⁸³,
 Y. Rozen¹⁵², X. Ruan^{33a,af}, F. Rubbo¹², I. Rubinskiy⁴², N. Ruckstuhl¹⁰⁵, V.I. Rud⁹⁷,
 C. Rudolph⁴⁴, G. Rudolph⁶¹, F. Rühr⁷, A. Ruiz-Martinez⁶³, L. Rumyantsev⁶⁴,
 Z. Rurikova⁴⁸, N.A. Rusakovich⁶⁴, A. Ruschke⁹⁸, J.P. Rutherford⁷, P. Ruzicka¹²⁵,
 Y.F. Ryabov¹²¹, M. Rybar¹²⁶, G. Rybkin¹¹⁵, N.C. Ryder¹¹⁸, A.F. Saavedra¹⁵⁰,
 I. Sadeh¹⁵³, H.F.W. Sadrozinski¹³⁷, R. Sadykov⁶⁴, F. Safai Tehrani^{132a}, H. Sakamoto¹⁵⁵,
 G. Salamanna⁷⁵, A. Salamon^{133a}, M. Saleem¹¹¹, D. Salek³⁰, D. Salihagic⁹⁹, A. Salnikov¹⁴³,
 J. Salt¹⁶⁷, B.M. Salvachua Ferrando⁶, D. Salvatore^{37a,37b}, F. Salvatore¹⁴⁹, A. Salvucci¹⁰⁴,
 A. Salzburger³⁰, D. Sampsonidis¹⁵⁴, B.H. Samset¹¹⁷, A. Sanchez^{102a,102b},
 V. Sanchez Martinez¹⁶⁷, H. Sandaker¹⁴, H.G. Sander⁸¹, M.P. Sanders⁹⁸, M. Sandhoff¹⁷⁵,
 T. Sandoval²⁸, C. Sandoval¹⁶², R. Sandstroem⁹⁹, D.P.C. Sankey¹²⁹, A. Sansoni⁴⁷,
 C. Santamarina Rios⁸⁵, C. Santoni³⁴, R. Santonico^{133a,133b}, H. Santos^{124a},
 J.G. Saraiva^{124a}, T. Sarangi¹⁷³, E. Sarkisyan-Grinbaum⁸, F. Sarri^{122a,122b},
 G. Sartisohn¹⁷⁵, O. Sasaki⁶⁵, Y. Sasaki¹⁵⁵, N. Sasao⁶⁷, I. Satsounkevitch⁹⁰, G. Sauvage^{5,*},
 E. Sauvan⁵, J.B. Sauvan¹¹⁵, P. Savard^{158,d}, V. Savinov¹²³, D.O. Savu³⁰, L. Sawyer^{25,m},
 D.H. Saxon⁵³, J. Saxon¹²⁰, C. Sbarra^{20a}, A. Sbrizzi^{20a,20b}, D.A. Scannicchio¹⁶³,
 M. Scarcella¹⁵⁰, J. Schaarschmidt¹¹⁵, P. Schacht⁹⁹, D. Schaefer¹²⁰, U. Schäfer⁸¹,
 A. Schaelicke⁴⁶, S. Schaep²¹, S. Schaetzl^{58b}, A.C. Schaffer¹¹⁵, D. Schaile⁹⁸,
 R.D. Schamberger¹⁴⁸, A.G. Schamov¹⁰⁷, V. Scharf^{58a}, V.A. Schegelsky¹²¹, D. Scheirich⁸⁷,

M. Schernau¹⁶³, M.I. Scherzer³⁵, C. Schiavi^{50a,50b}, J. Schieck⁹⁸, M. Schioppa^{37a,37b},
S. Schlenker³⁰, E. Schmidt⁴⁸, K. Schmieden²¹, C. Schmitt⁸¹, S. Schmitt^{58b}, M. Schmitz²¹,
B. Schneider¹⁷, U. Schnoor⁴⁴, L. Schoeffel¹³⁶, A. Schoening^{58b}, A.L.S. Schorlemmer⁵⁴,
M. Schott³⁰, D. Schouten^{159a}, J. Schovancova¹²⁵, M. Schram⁸⁵, C. Schroeder⁸¹,
N. Schroer^{58c}, M.J. Schultens²¹, J. Schultes¹⁷⁵, H.-C. Schultz-Coulon^{58a}, H. Schulz¹⁶,
M. Schumacher⁴⁸, B.A. Schumm¹³⁷, Ph. Schune¹³⁶, C. Schwanenberger⁸²,
A. Schwartzman¹⁴³, Ph. Schwegler⁹⁹, Ph. Schwemling⁷⁸, R. Schwienhorst⁸⁸, R. Schwierz⁴⁴,
J. Schwindling¹³⁶, T. Schwindt²¹, M. Schwoerer⁵, G. Sciolla²³, W.G. Scott¹²⁹,
J. Searcy¹¹⁴, G. Sedov⁴², E. Sedykh¹²¹, S.C. Seidel¹⁰³, A. Seiden¹³⁷, F. Seifert⁴⁴,
J.M. Seixas^{24a}, G. Sekhniaidze^{102a}, S.J. Sekula⁴⁰, K.E. Selbach⁴⁶, D.M. Seliverstov¹²¹,
B. Sellden^{146a}, G. Sellers⁷³, M. Seman^{144b}, N. Semprini-Cesari^{20a,20b}, C. Serfon⁹⁸,
L. Serin¹¹⁵, L. Serkin⁵⁴, R. Seuster^{159a}, H. Severini¹¹¹, A. Sfyrta³⁰, E. Shabalina⁵⁴,
M. Shamim¹¹⁴, L.Y. Shan^{33a}, J.T. Shank²², Q.T. Shao⁸⁶, M. Shapiro¹⁵, P.B. Shatalov⁹⁵,
K. Shaw^{164a,164c}, D. Sherman¹⁷⁶, P. Sherwood⁷⁷, S. Shimizu¹⁰¹, M. Shimojima¹⁰⁰,
T. Shin⁵⁶, M. Shiyakova⁶⁴, A. Shmeleva⁹⁴, M.J. Shochet³¹, D. Short¹¹⁸, S. Shrestha⁶³,
E. Shulga⁹⁶, M.A. Shupe⁷, P. Sicho¹²⁵, A. Sidoti^{132a}, F. Siegert⁴⁸, Dj. Sijacki^{13a},
O. Silbert¹⁷², J. Silva^{124a}, Y. Silver¹⁵³, D. Silverstein¹⁴³, S.B. Silverstein^{146a}, V. Simak¹²⁷,
O. Simard¹³⁶, Lj. Simic^{13a}, S. Simion¹¹⁵, E. Simioni⁸¹, B. Simmons⁷⁷, R. Simoniello^{89a,89b},
M. Simonyan³⁶, P. Sinervo¹⁵⁸, N.B. Sinev¹¹⁴, V. Sipica¹⁴¹, G. Siragusa¹⁷⁴, A. Sircar²⁵,
A.N. Sisakyan^{64,*}, S.Yu. Sivoklokov⁹⁷, J. Sjölin^{146a,146b}, T.B. Sjursen¹⁴, L.A. Skinnari¹⁵,
H.P. Skottowe⁵⁷, K. Skovpen¹⁰⁷, P. Skubic¹¹¹, M. Slater¹⁸, T. Slavicek¹²⁷, K. Sliwa¹⁶¹,
V. Smakhtin¹⁷², B.H. Smart⁴⁶, L. Smestad¹¹⁷, S.Yu. Smirnov⁹⁶, Y. Smirnov⁹⁶,
L.N. Smirnova⁹⁷, O. Smirnova⁷⁹, B.C. Smith⁵⁷, D. Smith¹⁴³, K.M. Smith⁵³,
M. Smizanska⁷¹, K. Smolek¹²⁷, A.A. Snesarev⁹⁴, S.W. Snow⁸², J. Snow¹¹¹, S. Snyder²⁵,
R. Sobie^{169,k}, J. Sodomka¹²⁷, A. Soffer¹⁵³, C.A. Solans¹⁶⁷, M. Solar¹²⁷, J. Solc¹²⁷,
E.Yu. Soldatov⁹⁶, U. Soldevila¹⁶⁷, E. Solfaroli Camillocci^{132a,132b}, A.A. Solodkov¹²⁸,
O.V. Solovyanov¹²⁸, V. Solovyev¹²¹, N. Soni¹, V. Sopko¹²⁷, B. Sopko¹²⁷, M. Sosebee⁸,
R. Soualah^{164a,164c}, A. Soukharev¹⁰⁷, S. Spagnolo^{72a,72b}, F. Spanò⁷⁶, R. Spighi^{20a},
G. Spigo³⁰, R. Spiwoks³⁰, M. Spousta^{126,ag}, T. Spreitzer¹⁵⁸, B. Spurlock⁸,
R.D. St. Denis⁵³, J. Stahlman¹²⁰, R. Stamen^{58a}, E. Stanecka³⁹, R.W. Stanek⁶,
C. Stanescu^{134a}, M. Stanescu-Bellu⁴², M.M. Stanitzki⁴², S. Stapnes¹¹⁷,
E.A. Starchenko¹²⁸, J. Stark⁵⁵, P. Staroba¹²⁵, P. Starovoitov⁴², R. Staszewski³⁹,
A. Staude⁹⁸, P. Stavina^{144a,*}, G. Steele⁵³, P. Steinbach⁴⁴, P. Steinberg²⁵, I. Stekl¹²⁷,
B. Stelzer¹⁴², H.J. Stelzer⁸⁸, O. Stelzer-Chilton^{159a}, H. Stenzel⁵², S. Stern⁹⁹,
G.A. Stewart³⁰, J.A. Stillings²¹, M.C. Stockton⁸⁵, K. Stoerig⁴⁸, G. Stoica^{26a},
S. Stonjek⁹⁹, P. Strachota¹²⁶, A.R. Stradling⁸, A. Straessner⁴⁴, J. Strandberg¹⁴⁷,
S. Strandberg^{146a,146b}, A. Strandlie¹¹⁷, M. Strang¹⁰⁹, E. Strauss¹⁴³, M. Strauss¹¹¹,
P. Striznec^{144b}, R. Ströhmer¹⁷⁴, D.M. Strom¹¹⁴, J.A. Strong^{76,*}, R. Stroynowski⁴⁰,
B. Stugu¹⁴, I. Stumer^{25,*}, J. Stupak¹⁴⁸, P. Sturm¹⁷⁵, N.A. Styles⁴², D.A. Soh^{151,u},
D. Su¹⁴³, H.S. Subramania³, R. Subramaniam²⁵, A. Succurro¹², Y. Sugaya¹¹⁶, C. Suhr¹⁰⁶,
M. Suk¹²⁶, V.V. Sulin⁹⁴, S. Sultansoy^{4d}, T. Sumida⁶⁷, X. Sun⁵⁵, J.E. Sundermann⁴⁸,
K. Suruliz¹³⁹, G. Susinno^{37a,37b}, M.R. Sutton¹⁴⁹, Y. Suzuki⁶⁵, Y. Suzuki⁶⁶, M. Svatos¹²⁵,
S. Swedish¹⁶⁸, I. Sykora^{144a}, T. Sykora¹²⁶, J. Sánchez¹⁶⁷, D. Ta¹⁰⁵, K. Tackmann⁴²,

A. Taffard¹⁶³, R. Tafirout^{159a}, N. Taiblum¹⁵³, Y. Takahashi¹⁰¹, H. Takai²⁵,
 R. Takashima⁶⁸, H. Takeda⁶⁶, T. Takeshita¹⁴⁰, Y. Takubo⁶⁵, M. Talby⁸³,
 A. Talyshev^{107,f}, M.C. Tamsett²⁵, K.G. Tan⁸⁶, J. Tanaka¹⁵⁵, R. Tanaka¹¹⁵, S. Tanaka¹³¹,
 S. Tanaka⁶⁵, A.J. Tanasijczuk¹⁴², K. Tani⁶⁶, N. Tannoury⁸³, S. Tapprogge⁸¹, D. Tardif¹⁵⁸,
 S. Tarem¹⁵², F. Tarrade²⁹, G.F. Tartarelli^{89a}, P. Tas¹²⁶, M. Tasevsky¹²⁵, E. Tassi^{37a,37b},
 M. Tatarkhanov¹⁵, Y. Tayalati^{135d}, C. Taylor⁷⁷, F.E. Taylor⁹², G.N. Taylor⁸⁶,
 W. Taylor^{159b}, M. Teinturier¹¹⁵, F.A. Teischinger³⁰, M. Teixeira Dias Castanheira⁷⁵,
 P. Teixeira-Dias⁷⁶, K.K. Temming⁴⁸, H. Ten Kate³⁰, P.K. Teng¹⁵¹, S. Terada⁶⁵,
 K. Terashi¹⁵⁵, J. Terron⁸⁰, M. Testa⁴⁷, R.J. Teuscher^{158,k}, J. Therhaag²¹,
 T. Theveneaux-Pelzer⁷⁸, S. Thoma⁴⁸, J.P. Thomas¹⁸, E.N. Thompson³⁵,
 P.D. Thompson¹⁸, P.D. Thompson¹⁵⁸, A.S. Thompson⁵³, L.A. Thomsen³⁶,
 E. Thomson¹²⁰, M. Thomson²⁸, W.M. Thong⁸⁶, R.P. Thun⁸⁷, F. Tian³⁵, M.J. Tibbetts¹⁵,
 T. Tic¹²⁵, V.O. Tikhomirov⁹⁴, Y.A. Tikhonov^{107,f}, S. Timoshenko⁹⁶, E. Tiouchichine⁸³,
 P. Tipton¹⁷⁶, S. Tisserant⁸³, T. Todorov⁵, S. Todorova-Nova¹⁶¹, B. Toggerson¹⁶³,
 J. Tojo⁶⁹, S. Tokár^{144a}, K. Tokushuku⁶⁵, K. Tollefson⁸⁸, M. Tomoto¹⁰¹, L. Tompkins³¹,
 K. Toms¹⁰³, A. Tonoyan¹⁴, C. Topfel¹⁷, N.D. Topilin⁶⁴, I. Torchiani³⁰, E. Torrence¹¹⁴,
 H. Torres⁷⁸, E. Torr o Pastor¹⁶⁷, J. Toth^{83,ac}, F. Touchard⁸³, D.R. Tovey¹³⁹,
 T. Trefzger¹⁷⁴, L. Tremblet³⁰, A. Tricoli³⁰, I.M. Trigger^{159a}, S. Trincaz-Duvoid⁷⁸,
 M.F. Tripiana⁷⁰, N. Triplett²⁵, W. Trischuk¹⁵⁸, B. Trocm e⁵⁵, C. Troncon^{89a},
 M. Trottier-McDonald¹⁴², P. True⁸⁸, M. Trzebinski³⁹, A. Trzupek³⁹, C. Tsarouchas³⁰,
 J.C-L. Tseng¹¹⁸, M. Tsiakiris¹⁰⁵, P.V. Tsiareshka⁹⁰, D. Tsionou^{5,ah}, G. Tsipolitis¹⁰,
 S. Tsiskaridze¹², V. Tsiskaridze⁴⁸, E.G. Tskhadadze^{51a}, I.I. Tsukerman⁹⁵, V. Tsulaia¹⁵,
 J.-W. Tsung²¹, S. Tsuno⁶⁵, D. Tsybychev¹⁴⁸, A. Tua¹³⁹, A. Tudorache^{26a},
 V. Tudorache^{26a}, J.M. Tuggle³¹, M. Turala³⁹, D. Turecek¹²⁷, I. Turk Cakir^{4e},
 E. Turlay¹⁰⁵, R. Turra^{89a,89b}, P.M. Tuts³⁵, A. Tykhonov⁷⁴, M. Tylmad^{146a,146b},
 M. Tyndel¹²⁹, G. Tzanakos⁹, K. Uchida²¹, I. Ueda¹⁵⁵, R. Ueno²⁹, M. Ugland¹⁴,
 M. Uhlenbrock²¹, M. Uhrmacher⁵⁴, F. Ukegawa¹⁶⁰, G. Unal³⁰, A. Undrus²⁵, G. Unel¹⁶³,
 Y. Unno⁶⁵, D. Urbaniec³⁵, P. Urquijo²¹, G. Usai⁸, M. Uslenghi^{119a,119b}, L. Vacavant⁸³,
 V. Vacek¹²⁷, B. Vachon⁸⁵, S. Vahsen¹⁵, J. Valenta¹²⁵, S. Valentineti^{20a,20b}, A. Valero¹⁶⁷,
 S. Valkar¹²⁶, E. Valladolid Gallego¹⁶⁷, S. Vallecorsa¹⁵², J.A. Valls Ferrer¹⁶⁷,
 R. Van Berg¹²⁰, P.C. Van Der Deijl¹⁰⁵, R. van der Geer¹⁰⁵, H. van der Graaf¹⁰⁵,
 R. Van Der Leeuw¹⁰⁵, E. van der Poel¹⁰⁵, D. van der Ster³⁰, N. van Eldik³⁰,
 P. van Gemmeren⁶, I. van Vulpen¹⁰⁵, M. Vanadia⁹⁹, W. Vandelli³⁰, A. Vaniachine⁶,
 P. Vankov⁴², F. Vannucci⁷⁸, R. Vari^{132a}, T. Varol⁸⁴, D. Varouchas¹⁵, A. Vartapetian⁸,
 K.E. Varvell¹⁵⁰, V.I. Vassilakopoulos⁵⁶, F. Vazeille³⁴, T. Vazquez Schroeder⁵⁴,
 G. Vegni^{89a,89b}, J.J. Veillet¹¹⁵, F. Veloso^{124a}, R. Veness³⁰, S. Veneziano^{132a},
 A. Ventura^{72a,72b}, D. Ventura⁸⁴, M. Venturi⁴⁸, N. Venturi¹⁵⁸, V. Vercesi^{119a},
 M. Verducci¹³⁸, W. Verkerke¹⁰⁵, J.C. Vermeulen¹⁰⁵, A. Vest⁴⁴, M.C. Vetterli^{142,d},
 I. Vichou¹⁶⁵, T. Vickey^{145b,ai}, O.E. Vickey Boeriu^{145b}, G.H.A. Viehhauser¹¹⁸, S. Viel¹⁶⁸,
 M. Villa^{20a,20b}, M. Villaplana Perez¹⁶⁷, E. Vilucchi⁴⁷, M.G. Vincter²⁹, E. Vinek³⁰,
 V.B. Vinogradov⁶⁴, M. Virchaux^{136,*}, J. Virzi¹⁵, O. Vitells¹⁷², M. Viti⁴², I. Vivarelli⁴⁸,
 F. Vives Vaque³, S. Vlachos¹⁰, D. Vladoiu⁹⁸, M. Vlasak¹²⁷, A. Vogel²¹, P. Vokac¹²⁷,
 G. Volpi⁴⁷, M. Volpi⁸⁶, G. Volpini^{89a}, H. von der Schmitt⁹⁹, H. von Radziewski⁴⁸,

E. von Toerne²¹, V. Vorobel¹²⁶, V. Vorwerk¹², M. Vos¹⁶⁷, R. Voss³⁰, T.T. Voss¹⁷⁵,
 J.H. Vossebeld⁷³, N. Vranjes¹³⁶, M. Vranjes Milosavljevic¹⁰⁵, V. Vrba¹²⁵, M. Vreeswijk¹⁰⁵,
 T. Vu Anh⁴⁸, R. Vuillermet³⁰, I. Vukotic³¹, W. Wagner¹⁷⁵, P. Wagner¹²⁰, H. Wahlen¹⁷⁵,
 S. Wahrmund⁴⁴, J. Wakabayashi¹⁰¹, S. Walch⁸⁷, J. Walder⁷¹, R. Walker⁹⁸,
 W. Walkowiak¹⁴¹, R. Wall¹⁷⁶, P. Waller⁷³, B. Walsh¹⁷⁶, C. Wang⁴⁵, H. Wang¹⁷³,
 H. Wang^{33b,aj}, J. Wang¹⁵¹, J. Wang⁵⁵, R. Wang¹⁰³, S.M. Wang¹⁵¹, T. Wang²¹,
 A. Warburton⁸⁵, C.P. Ward²⁸, D.R. Wardrope⁷⁷, M. Warsinsky⁴⁸, A. Washbrook⁴⁶,
 C. Wasicki⁴², I. Watanabe⁶⁶, P.M. Watkins¹⁸, A.T. Watson¹⁸, I.J. Watson¹⁵⁰,
 M.F. Watson¹⁸, G. Watts¹³⁸, S. Watts⁸², A.T. Waugh¹⁵⁰, B.M. Waugh⁷⁷, M.S. Weber¹⁷,
 P. Weber⁵⁴, J.S. Webster³¹, A.R. Weidberg¹¹⁸, P. Weigell⁹⁹, J. Weingarten⁵⁴, C. Weiser⁴⁸,
 P.S. Wells³⁰, T. Wenaus²⁵, D. Wendland¹⁶, Z. Weng^{151,u}, T. Wengler³⁰, S. Wenig³⁰,
 N. Wermes²¹, M. Werner⁴⁸, P. Werner³⁰, M. Werth¹⁶³, M. Wessels^{58a}, J. Wetter¹⁶¹,
 C. Weydert⁵⁵, K. Whalen²⁹, A. White⁸, M.J. White⁸⁶, S. White^{122a,122b},
 S.R. Whitehead¹¹⁸, D. Whiteson¹⁶³, D. Whittington⁶⁰, F. Wicek¹¹⁵, D. Wicke¹⁷⁵,
 F.J. Wickens¹²⁹, W. Wiedenmann¹⁷³, M. Wielers¹²⁹, P. Wienemann²¹, C. Wiglesworth⁷⁵,
 L.A.M. Wiik-Fuchs²¹, P.A. Wijeratne⁷⁷, A. Wildauer⁹⁹, M.A. Wildt^{42,r}, I. Wilhelm¹²⁶,
 H.G. Wilkens³⁰, J.Z. Will⁹⁸, E. Williams³⁵, H.H. Williams¹²⁰, W. Willis³⁵, S. Willocq⁸⁴,
 J.A. Wilson¹⁸, M.G. Wilson¹⁴³, A. Wilson⁸⁷, I. Wingerter-Seez⁵, S. Winkelmann⁴⁸,
 F. Winklmeier³⁰, M. Wittgen¹⁴³, S.J. Wollstadt⁸¹, M.W. Wolter³⁹, H. Wolters^{124a,h},
 W.C. Wong⁴¹, G. Wooden⁸⁷, B.K. Wosiek³⁹, J. Wotschack³⁰, M.J. Woudstra⁸²,
 K.W. Wozniak³⁹, K. Wraight⁵³, M. Wright⁵³, B. Wrona⁷³, S.L. Wu¹⁷³, X. Wu⁴⁹,
 Y. Wu^{33b,ak}, E. Wulf³⁵, B.M. Wynne⁴⁶, S. Xella³⁶, M. Xiao¹³⁶, S. Xie⁴⁸, C. Xu^{33b,y},
 D. Xu¹³⁹, B. Yabsley¹⁵⁰, S. Yacoob^{145a,al}, M. Yamada⁶⁵, H. Yamaguchi¹⁵⁵,
 A. Yamamoto⁶⁵, K. Yamamoto⁶³, S. Yamamoto¹⁵⁵, T. Yamamura¹⁵⁵, T. Yamanaka¹⁵⁵,
 T. Yamazaki¹⁵⁵, Y. Yamazaki⁶⁶, Z. Yan²², H. Yang⁸⁷, U.K. Yang⁸², Y. Yang¹⁰⁹,
 Z. Yang^{146a,146b}, S. Yanush⁹¹, L. Yao^{33a}, Y. Yao¹⁵, Y. Yasu⁶⁵, G.V. Ybeles Smit¹³⁰,
 J. Ye⁴⁰, S. Ye²⁵, M. Yilmaz^{4c}, R. Yoosofmiya¹²³, K. Yorita¹⁷¹, R. Yoshida⁶,
 K. Yoshihara¹⁵⁵, C. Young¹⁴³, C.J. Young¹¹⁸, S. Youssef²², D. Yu²⁵, J. Yu⁸, J. Yu¹¹²,
 L. Yuan⁶⁶, A. Yurkewicz¹⁰⁶, B. Zabinski³⁹, R. Zaidan⁶², A.M. Zaitsev¹²⁸, Z. Zajacova³⁰,
 L. Zanello^{132a,132b}, D. Zanzi⁹⁹, A. Zaytsev²⁵, C. Zeitnitz¹⁷⁵, M. Zeman¹²⁵, A. Zemla³⁹,
 C. Zender²¹, O. Zenin¹²⁸, T. Ženiš^{144a}, Z. Zinonos^{122a,122b}, S. Zenz¹⁵, D. Zerwas¹¹⁵,
 G. Zevi della Porta⁵⁷, D. Zhang^{33b,aj}, H. Zhang⁸⁸, J. Zhang⁶, X. Zhang^{33d}, Z. Zhang¹¹⁵,
 L. Zhao¹⁰⁸, Z. Zhao^{33b}, A. Zhemchugov⁶⁴, J. Zhong¹¹⁸, B. Zhou⁸⁷, N. Zhou¹⁶³,
 Y. Zhou¹⁵¹, C.G. Zhu^{33d}, H. Zhu⁴², J. Zhu⁸⁷, Y. Zhu^{33b}, X. Zhuang⁹⁸, V. Zhuravlov⁹⁹,
 A. Zibell⁹⁸, D. Zieminska⁶⁰, N.I. Zimin⁶⁴, R. Zimmermann²¹, S. Zimmermann²¹,
 S. Zimmermann⁴⁸, M. Ziolkowski¹⁴¹, R. Zitoun⁵, L. Živković³⁵, V.V. Zmouchko^{128,*},
 G. Zobernig¹⁷³, A. Zoccoli^{20a,20b}, M. zur Nedden¹⁶, V. Zutshi¹⁰⁶, 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, Dumlupinar University, Kutahya; (c) Department of Physics, Gazi University, Ankara; (d)

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

- ³¹ Enrico Fermi Institute, University of Chicago, Chicago IL, United States of America
- ³² ^(a) Departamento de Física, Pontificia Universidad Católica de Chile, Santiago; ^(b) Departamento de Física, Universidad Técnica Federico Santa María, Valparaíso, Chile
- ³³ ^(a) Institute of High Energy Physics, Chinese Academy of Sciences, Beijing; ^(b) Department of Modern Physics, University of Science and Technology of China, Anhui; ^(c) Department of Physics, Nanjing University, Jiangsu; ^(d) School of Physics, Shandong University, Shandong, China
- ³⁴ Laboratoire de Physique Corpusculaire, Clermont Université and Université Blaise Pascal and CNRS/IN2P3, Clermont-Ferrand, France
- ³⁵ Nevis Laboratory, Columbia University, Irvington NY, United States of America
- ³⁶ Niels Bohr Institute, University of Copenhagen, Kobenhavn, Denmark
- ³⁷ ^(a) INFN Gruppo Collegato di Cosenza; ^(b) Dipartimento di Fisica, Università della Calabria, Arcavata di Rende, Italy
- ³⁸ AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Krakow, Poland
- ³⁹ The Henryk Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences, Krakow, Poland
- ⁴⁰ Physics Department, Southern Methodist University, Dallas TX, United States of America
- ⁴¹ Physics Department, University of Texas at Dallas, Richardson TX, United States of America
- ⁴² DESY, Hamburg and Zeuthen, Germany
- ⁴³ Institut für Experimentelle Physik IV, Technische Universität Dortmund, Dortmund, Germany
- ⁴⁴ Institut für Kern- und Teilchenphysik, Technical University Dresden, Dresden, Germany
- ⁴⁵ Department of Physics, Duke University, Durham NC, United States of America
- ⁴⁶ SUPA - School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom
- ⁴⁷ INFN Laboratori Nazionali di Frascati, Frascati, Italy
- ⁴⁸ Fakultät für Mathematik und Physik, Albert-Ludwigs-Universität, Freiburg, Germany
- ⁴⁹ Section de Physique, Université de Genève, Geneva, Switzerland
- ⁵⁰ ^(a) INFN Sezione di Genova; ^(b) Dipartimento di Fisica, Università di Genova, Genova, Italy
- ⁵¹ ^(a) E. Andronikashvili Institute of Physics, Iv. Javakhishvili Tbilisi State University, Tbilisi; ^(b) High Energy Physics Institute, Tbilisi State University, Tbilisi, Georgia
- ⁵² II Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen, Germany
- ⁵³ SUPA - School of Physics and Astronomy, University of Glasgow, Glasgow, United Kingdom
- ⁵⁴ II Physikalisches Institut, Georg-August-Universität, Göttingen, Germany
- ⁵⁵ Laboratoire de Physique Subatomique et de Cosmologie, Université Joseph Fourier and CNRS/IN2P3 and Institut National Polytechnique de Grenoble, Grenoble, France
- ⁵⁶ Department of Physics, Hampton University, Hampton VA, United States of America
- ⁵⁷ Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge MA,

United States of America

⁵⁸ ^(a) Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Heidelberg; ^(b) Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg; ^(c) ZITI Institut für technische Informatik, Ruprecht-Karls-Universität Heidelberg, Mannheim, Germany

⁵⁹ Faculty of Applied Information Science, Hiroshima Institute of Technology, Hiroshima, Japan

⁶⁰ Department of Physics, Indiana University, Bloomington IN, United States of America

⁶¹ Institut für Astro- und Teilchenphysik, Leopold-Franzens-Universität, Innsbruck, Austria

⁶² University of Iowa, Iowa City IA, United States of America

⁶³ Department of Physics and Astronomy, Iowa State University, Ames IA, United States of America

⁶⁴ Joint Institute for Nuclear Research, JINR Dubna, Dubna, Russia

⁶⁵ KEK, High Energy Accelerator Research Organization, Tsukuba, Japan

⁶⁶ Graduate School of Science, Kobe University, Kobe, Japan

⁶⁷ Faculty of Science, Kyoto University, Kyoto, Japan

⁶⁸ Kyoto University of Education, Kyoto, Japan

⁶⁹ Department of Physics, Kyushu University, Fukuoka, Japan

⁷⁰ Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata, Argentina

⁷¹ Physics Department, Lancaster University, Lancaster, United Kingdom

⁷² ^(a) INFN Sezione di Lecce; ^(b) Dipartimento di Matematica e Fisica, Università del Salento, Lecce, Italy

⁷³ Oliver Lodge Laboratory, University of Liverpool, Liverpool, United Kingdom

⁷⁴ Department of Physics, Jožef Stefan Institute and University of Ljubljana, Ljubljana, Slovenia

⁷⁵ School of Physics and Astronomy, Queen Mary University of London, London, United Kingdom

⁷⁶ Department of Physics, Royal Holloway University of London, Surrey, United Kingdom

⁷⁷ Department of Physics and Astronomy, University College London, London, United Kingdom

⁷⁸ Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France

⁷⁹ Fysiska institutionen, Lunds universitet, Lund, Sweden

⁸⁰ Departamento de Física Teórica C-15, Universidad Autónoma de Madrid, Madrid, Spain

⁸¹ Institut für Physik, Universität Mainz, Mainz, Germany

⁸² School of Physics and Astronomy, University of Manchester, Manchester, United Kingdom

⁸³ CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France

⁸⁴ Department of Physics, University of Massachusetts, Amherst MA, United States of America

- ⁸⁵ Department of Physics, McGill University, Montreal QC, Canada
- ⁸⁶ School of Physics, University of Melbourne, Victoria, Australia
- ⁸⁷ Department of Physics, The University of Michigan, Ann Arbor MI, United States of America
- ⁸⁸ Department of Physics and Astronomy, Michigan State University, East Lansing MI, United States of America
- ⁸⁹ ^(a) INFN Sezione di Milano; ^(b) Dipartimento di Fisica, Università di Milano, Milano, Italy
- ⁹⁰ B.I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk, Republic of Belarus
- ⁹¹ National Scientific and Educational Centre for Particle and High Energy Physics, Minsk, Republic of Belarus
- ⁹² Department of Physics, Massachusetts Institute of Technology, Cambridge MA, United States of America
- ⁹³ Group of Particle Physics, University of Montreal, Montreal QC, Canada
- ⁹⁴ P.N. Lebedev Institute of Physics, Academy of Sciences, Moscow, Russia
- ⁹⁵ Institute for Theoretical and Experimental Physics (ITEP), Moscow, Russia
- ⁹⁶ Moscow Engineering and Physics Institute (MEPhI), Moscow, Russia
- ⁹⁷ Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia
- ⁹⁸ Fakultät für Physik, Ludwig-Maximilians-Universität München, München, Germany
- ⁹⁹ Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), München, Germany
- ¹⁰⁰ Nagasaki Institute of Applied Science, Nagasaki, Japan
- ¹⁰¹ Graduate School of Science and Kobayashi-Maskawa Institute, Nagoya University, Nagoya, Japan
- ¹⁰² ^(a) INFN Sezione di Napoli; ^(b) Dipartimento di Scienze Fisiche, Università di Napoli, Napoli, Italy
- ¹⁰³ Department of Physics and Astronomy, University of New Mexico, Albuquerque NM, United States of America
- ¹⁰⁴ Institute for Mathematics, Astrophysics and Particle Physics, Radboud University Nijmegen/Nikhef, Nijmegen, Netherlands
- ¹⁰⁵ Nikhef National Institute for Subatomic Physics and University of Amsterdam, Amsterdam, Netherlands
- ¹⁰⁶ Department of Physics, Northern Illinois University, DeKalb IL, United States of America
- ¹⁰⁷ Budker Institute of Nuclear Physics, SB RAS, Novosibirsk, Russia
- ¹⁰⁸ Department of Physics, New York University, New York NY, United States of America
- ¹⁰⁹ Ohio State University, Columbus OH, United States of America
- ¹¹⁰ Faculty of Science, Okayama University, Okayama, Japan
- ¹¹¹ Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman OK, United States of America
- ¹¹² Department of Physics, Oklahoma State University, Stillwater OK, United States of America

- 113 Palacký University, RCPTM, Olomouc, Czech Republic
- 114 Center for High Energy Physics, University of Oregon, Eugene OR, United States of America
- 115 LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France
- 116 Graduate School of Science, Osaka University, Osaka, Japan
- 117 Department of Physics, University of Oslo, Oslo, Norway
- 118 Department of Physics, Oxford University, Oxford, United Kingdom
- 119 ^(a) INFN Sezione di Pavia; ^(b) Dipartimento di Fisica, Università di Pavia, Pavia, Italy
- 120 Department of Physics, University of Pennsylvania, Philadelphia PA, United States of America
- 121 Petersburg Nuclear Physics Institute, Gatchina, Russia
- 122 ^(a) INFN Sezione di Pisa; ^(b) Dipartimento di Fisica E. Fermi, Università di Pisa, Pisa, Italy
- 123 Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh PA, United States of America
- 124 ^(a) 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
- 125 Institute of Physics, Academy of Sciences of the Czech Republic, Praha, Czech Republic
- 126 Faculty of Mathematics and Physics, Charles University in Prague, Praha, Czech Republic
- 127 Czech Technical University in Prague, Praha, Czech Republic
- 128 State Research Center Institute for High Energy Physics, Protvino, Russia
- 129 Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom
- 130 Physics Department, University of Regina, Regina SK, Canada
- 131 Ritsumeikan University, Kusatsu, Shiga, Japan
- 132 ^(a) INFN Sezione di Roma I; ^(b) Dipartimento di Fisica, Università La Sapienza, Roma, Italy
- 133 ^(a) INFN Sezione di Roma Tor Vergata; ^(b) Dipartimento di Fisica, Università di Roma Tor Vergata, Roma, Italy
- 134 ^(a) INFN Sezione di Roma Tre; ^(b) Dipartimento di Fisica, Università Roma Tre, Roma, Italy
- 135 ^(a) Faculté des Sciences Ain Chock, Réseau Universitaire de Physique des Hautes Energies - Université Hassan II, Casablanca; ^(b) Centre National de l'Energie des Sciences Techniques Nucleaires, Rabat; ^(c) Faculté des Sciences Semlalia, Université Cadi Ayyad, LPHEA-Marrakech; ^(d) Faculté des Sciences, Université Mohamed Premier and LPTPM, Oujda; ^(e) Faculté des sciences, Université Mohammed V-Agdal, Rabat, Morocco
- 136 DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat à l'Energie Atomique), Gif-sur-Yvette, France
- 137 Santa Cruz Institute for Particle Physics, University of California Santa Cruz, Santa Cruz CA, United States of America

- 138 Department of Physics, University of Washington, Seattle WA, United States of America
- 139 Department of Physics and Astronomy, University of Sheffield, Sheffield, United Kingdom
- 140 Department of Physics, Shinshu University, Nagano, Japan
- 141 Fachbereich Physik, Universität Siegen, Siegen, Germany
- 142 Department of Physics, Simon Fraser University, Burnaby BC, Canada
- 143 SLAC National Accelerator Laboratory, Stanford CA, United States of America
- 144 (a) Faculty of Mathematics, Physics & Informatics, Comenius University, Bratislava; (b) Department of Subnuclear Physics, Institute of Experimental Physics of the Slovak Academy of Sciences, Kosice, Slovak Republic
- 145 (a) Department of Physics, University of Johannesburg, Johannesburg; (b) School of Physics, University of the Witwatersrand, Johannesburg, South Africa
- 146 (a) Department of Physics, Stockholm University; (b) The Oskar Klein Centre, Stockholm, Sweden
- 147 Physics Department, Royal Institute of Technology, Stockholm, Sweden
- 148 Departments of Physics & Astronomy and Chemistry, Stony Brook University, Stony Brook NY, United States of America
- 149 Department of Physics and Astronomy, University of Sussex, Brighton, United Kingdom
- 150 School of Physics, University of Sydney, Sydney, Australia
- 151 Institute of Physics, Academia Sinica, Taipei, Taiwan
- 152 Department of Physics, Technion: Israel Institute of Technology, Haifa, Israel
- 153 Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel
- 154 Department of Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece
- 155 International Center for Elementary Particle Physics and Department of Physics, The University of Tokyo, Tokyo, Japan
- 156 Graduate School of Science and Technology, Tokyo Metropolitan University, Tokyo, Japan
- 157 Department of Physics, Tokyo Institute of Technology, Tokyo, Japan
- 158 Department of Physics, University of Toronto, Toronto ON, Canada
- 159 (a) TRIUMF, Vancouver BC; (b) Department of Physics and Astronomy, York University, Toronto ON, Canada
- 160 Faculty of Pure and Applied Sciences, University of Tsukuba, Tsukuba, Japan
- 161 Department of Physics and Astronomy, Tufts University, Medford MA, United States of America
- 162 Centro de Investigaciones, Universidad Antonio Narino, Bogota, Colombia
- 163 Department of Physics and Astronomy, University of California Irvine, Irvine CA, United States of America
- 164 (a) INFN Gruppo Collegato di Udine; (b) ICTP, Trieste; (c) Dipartimento di Chimica, Fisica e Ambiente, Università di Udine, Udine, Italy
- 165 Department of Physics, University of Illinois, Urbana IL, United States of America

- ¹⁶⁶ Department of Physics and Astronomy, University of Uppsala, Uppsala, Sweden
- ¹⁶⁷ Instituto de Física Corpuscular (IFIC) and Departamento de Física Atómica, Molecular y Nuclear and Departamento de Ingeniería Electrónica and Instituto de Microelectrónica de Barcelona (IMB-CNM), University of Valencia and CSIC, Valencia, Spain
- ¹⁶⁸ Department of Physics, University of British Columbia, Vancouver BC, Canada
- ¹⁶⁹ Department of Physics and Astronomy, University of Victoria, Victoria BC, Canada
- ¹⁷⁰ Department of Physics, University of Warwick, Coventry, United Kingdom
- ¹⁷¹ Waseda University, Tokyo, Japan
- ¹⁷² Department of Particle Physics, The Weizmann Institute of Science, Rehovot, Israel
- ¹⁷³ Department of Physics, University of Wisconsin, Madison WI, United States of America
- ¹⁷⁴ Fakultät für Physik und Astronomie, Julius-Maximilians-Universität, Würzburg, Germany
- ¹⁷⁵ Fachbereich C Physik, Bergische Universität Wuppertal, Wuppertal, Germany
- ¹⁷⁶ Department of Physics, Yale University, New Haven CT, United States of America
- ¹⁷⁷ Yerevan Physics Institute, Yerevan, Armenia
- ¹⁷⁸ Centre de Calcul de l'Institut National de Physique Nucléaire et de Physique des Particules (IN2P3), Villeurbanne, France
- ^a Also at Laboratório de Instrumentação e Física Experimental de Partículas - LIP, Lisboa, Portugal
- ^b Also at Faculdade de Ciências and CFNUL, Universidade de Lisboa, Lisboa, Portugal
- ^c Also at Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom
- ^d Also at TRIUMF, Vancouver BC, Canada
- ^e Also at Department of Physics, California State University, Fresno CA, United States of America
- ^f Also at Novosibirsk State University, Novosibirsk, Russia
- ^g Also at Fermilab, Batavia IL, United States of America
- ^h Also at Department of Physics, University of Coimbra, Coimbra, Portugal
- ⁱ Also at Department of Physics, UASLP, San Luis Potosi, Mexico
- ^j Also at Università di Napoli Parthenope, Napoli, Italy
- ^k Also at Institute of Particle Physics (IPP), Canada
- ^l Also at Department of Physics, Middle East Technical University, Ankara, Turkey
- ^m Also at Louisiana Tech University, Ruston LA, United States of America
- ⁿ Also at Dep Física and CEFITEC of Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Caparica, Portugal
- ^o Also at Department of Physics and Astronomy, University College London, London, United Kingdom
- ^p Also at Department of Physics, University of Cape Town, Cape Town, South Africa
- ^q Also at Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan
- ^r Also at Institut für Experimentalphysik, Universität Hamburg, Hamburg, Germany
- ^s Also at Manhattan College, New York NY, United States of America

- ^t Also at CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France
- ^u Also at School of Physics and Engineering, Sun Yat-sen University, Guanzhou, China
- ^v Also at Academia Sinica Grid Computing, Institute of Physics, Academia Sinica, Taipei, Taiwan
- ^w Also at School of Physics, Shandong University, Shandong, China
- ^x Also at Dipartimento di Fisica, Università La Sapienza, Roma, Italy
- ^y Also at DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat à l'Energie Atomique), Gif-sur-Yvette, France
- ^z Also at Section de Physique, Université de Genève, Geneva, Switzerland
- ^{aa} Also at Departamento de Física, Universidade de Minho, Braga, Portugal
- ^{ab} Also at Department of Physics and Astronomy, University of South Carolina, Columbia SC, United States of America
- ^{ac} Also at Institute for Particle and Nuclear Physics, Wigner Research Centre for Physics, Budapest, Hungary
- ^{ad} Also at California Institute of Technology, Pasadena CA, United States of America
- ^{ae} Also at Institute of Physics, Jagiellonian University, Krakow, Poland
- ^{af} Also at LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France
- ^{ag} Also at Nevis Laboratory, Columbia University, Irvington NY, United States of America
- ^{ah} Also at Department of Physics and Astronomy, University of Sheffield, Sheffield, United Kingdom
- ^{ai} Also at Department of Physics, Oxford University, Oxford, United Kingdom
- ^{aj} Also at Institute of Physics, Academia Sinica, Taipei, Taiwan
- ^{ak} Also at Department of Physics, The University of Michigan, Ann Arbor MI, United States of America
- ^{al} Also at Discipline of Physics, University of KwaZulu-Natal, Durban, South Africa
- * Deceased