



Search for supersymmetry in events with photons, bottom quarks, and missing transverse momentum in proton–proton collisions at a centre-of-mass energy of 7 TeV with the ATLAS detector

ATLAS Collaboration ^{*}

ARTICLE INFO

Article history:

Received 6 November 2012

Received in revised form 6 December 2012

Accepted 19 January 2013

Available online 26 January 2013

Editor: H. Weerts

Keywords:

Supersymmetry

Gauge mediation

Higgs boson

ABSTRACT

A search has been performed for the experimental signature of an isolated photon with high transverse momentum, at least one jet identified as originating from a bottom quark, and high missing transverse momentum. Such a final state may originate from supersymmetric models with gauge-mediated supersymmetry breaking in events in which one of a pair of higgsino-like neutralinos decays into a photon and a gravitino while the other decays into a Higgs boson and a gravitino. The search is performed using the full dataset of 7 TeV proton–proton collisions recorded with the ATLAS detector at the LHC in 2011, corresponding to an integrated luminosity of 4.7 fb^{-1} . A total of 7 candidate events are observed while 7.5 ± 2.2 events are expected from the Standard Model background. The results of the search are interpreted in the context of general gauge mediation to exclude certain regions of a benchmark plane for higgsino-like neutralino production.

© 2013 CERN. Published by Elsevier B.V. Open access under [CC BY-NC-ND license](#).

1. Introduction

Theories of gauge-mediated supersymmetry breaking (GMSB) presume a hidden sector in which supersymmetry is broken and the symmetry breaking is communicated to the visible sectors through Standard Model gauge boson interactions [1–6]. Such theories are attractive because the hypothesis of an intermediate hidden sector suppresses the magnitude of flavour-changing neutral currents. The lightest supersymmetric particle (LSP) in GMSB is the ultra-light gravitino (\tilde{G}), which under certain circumstances is a viable dark matter candidate [7]. The next-to-lightest supersymmetric particle (NLSP) may be the lightest neutralino $\tilde{\chi}_1^0$, often assumed to be a bino-like particle. The bino is the supersymmetric partner of the U(1) gauge field, coupling to the photon and Z boson with strengths that are determined by the weak mixing angle. This results in the $\tilde{\chi}_1^0$ decaying predominantly to a photon and the LSP. The classical signature of GMSB is, therefore, events with two isolated energetic photons and large missing transverse momentum ($E_{\text{T}}^{\text{miss}}$). Searches for such a signature at the LHC and the Tevatron established strong experimental constraints on GMSB models [8,9]. Recent extensions of the original GMSB idea, known as general gauge mediation (GGM) [10], evade these limits by allowing decoupled mass scales for strongly-interacting supersymmetric partners of the Standard Model particles.

In the GGM models considered in this Letter, the neutralino has higgsino or neutral wino (supersymmetric partners of the Higgs and neutral W bosons) components instead of being predominantly bino-like, and therefore, in addition to its conventional decay to a gravitino and a photon, it may decay to a gravitino and a Higgs boson or to a gravitino and a Z boson. This GGM signature could be identified as an excess of events with pairs of neutralinos decaying to these bosons, in all combinations, associated with high $E_{\text{T}}^{\text{miss}}$ [11]. In particular, for a light Higgs boson ($m_h < 130 \text{ GeV}$), which decays predominantly to $b\bar{b}$, one final-state signature is the combination of an isolated high transverse momentum (p_{T}) photon, jets originating from bottom quarks, and high $E_{\text{T}}^{\text{miss}}$. Such a signature arises when one neutralino decays to a gravitino and a photon and the other to a gravitino and a Higgs boson. This decay mode is therefore significant when both branching fractions are large, namely when the bino mass term M_1 approximately equals the higgsino mass parameter $-\mu$ [1].

This Letter describes the search for events with a “ $\gamma + b + E_{\text{T}}^{\text{miss}}$ topology”, consisting of an isolated high- p_{T} photon, large $E_{\text{T}}^{\text{miss}}$, and at least one jet that contains a b-hadron (“b-tagged jet”), in the full dataset of $\sqrt{s} = 7 \text{ TeV}$ pp collisions recorded in 2011 with the ATLAS detector at the LHC, corresponding to a total integrated luminosity of 4.7 fb^{-1} . This signature is complementary to searches for diphoton production accompanied by $E_{\text{T}}^{\text{miss}}$ [12,13], searches for b-jet production plus $E_{\text{T}}^{\text{miss}}$ [14,15], searches for lepton production plus $E_{\text{T}}^{\text{miss}}$ [16], and searches for Z bosons accompanied by photons and $E_{\text{T}}^{\text{miss}}$ [17]. The $\gamma + b + E_{\text{T}}^{\text{miss}}$ topology has not been

^{*} E-mail address: atlas.publications@cern.ch.

studied in any previous search and therefore the present analysis can also be considered as a model-independent search for new phenomena in this final state.

2. ATLAS detector

The ATLAS experiment [18] is a multi-purpose particle physics detector with a forward-backward symmetric cylindrical geometry and nearly 4π coverage in solid angle.¹ The collision point is surrounded by inner tracking devices followed by a superconducting solenoid providing a 2 T magnetic field, a calorimeter system, and a muon spectrometer. The inner tracker provides precision tracking of charged particles for pseudorapidities $|\eta| < 2.5$. It consists of pixel and silicon microstrip detectors inside the transition radiation tracker. The calorimeter system has liquid argon (LAr) or scintillator tiles as the active media. In the pseudorapidity region $|\eta| < 3.2$, high-granularity LAr electromagnetic (EM) sampling calorimeters are used. An iron/scintillator tile calorimeter provides hadronic coverage for $|\eta| < 1.7$. The end-cap and forward regions, spanning $1.5 < |\eta| < 4.9$, are instrumented with LAr calorimeters for both EM and hadronic measurements. The muon spectrometer consists of three large superconducting toroids with 24 coils, a system of trigger chambers, and precision tracking chambers, which provide triggering and tracking capabilities in the ranges $|\eta| < 2.4$ and $|\eta| < 2.7$, respectively.

3. Simulated samples

Standard Model processes that constitute the background to this search are simulated using several different generator programs. Events with single- or pair-production of top quarks are simulated using the MC@NLO [19] generator with the CT10 [20] parton distribution functions (PDFs), where the generator is interfaced to the HERWIG [21] and JIMMY [22] programs to include effects of fragmentation and hadronization and the underlying event. The POWHEG generator [23–25] is also used for studies of systematic uncertainties in these events. The $t\bar{t}\gamma$ background is simulated with the WHIZARD [26] generator, which incorporates a full calculation of the seven-particle final states $\ell\nu_\ell q\bar{q}'b\bar{b}\gamma$ and $\ell\bar{\nu}_\ell\bar{\ell}'\nu_\ell b\bar{b}\gamma$ (with $\ell/\ell' = e, \mu, \tau$) at leading order (LO). These events are generated with the CTEQ6L1 [27] PDFs and hadronized with HERWIG; additional photon(s) that may be radiated in the fragmentation process are generated by PHOTOS [28]. Multijet background (“QCD multijet”) events are simulated using the PYTHIA [29] generator. Diboson background events (W^+W^- , $W^\pm Z$, and ZZ) are simulated using HERWIG. Events with vector bosons accompanied by $b\bar{b}$ or light jets are simulated using ALPGEN [30] and HERWIG [21].

The production of signal events is simulated in two separate two-dimensional benchmark grids of points defined by specific GGM model parameters. The first grid has various gluino and neutralino masses ($m_{\tilde{g}}, m_{\tilde{\chi}_1^0}$), while the second grid has varying squark and neutralino masses ($m_{\tilde{q}}, m_{\tilde{\chi}_1^0}$). The fundamental parameters M_1 and μ together determine the lightest neutralino mass and are adjusted in such a way that the following branching ratios of the $\tilde{\chi}_1^0$ are approximately constant: $\text{BR}(\tilde{\chi}_1^0 \rightarrow h + \tilde{G}) \approx 56\%$, $\text{BR}(\tilde{\chi}_1^0 \rightarrow \gamma + \tilde{G}) \approx 33\%$, and $\text{BR}(\tilde{\chi}_1^0 \rightarrow Z + \tilde{G}) \approx 11\%$. These numbers vary by $\pm 2\%$ throughout the grids. The value of μ is chosen to be negative in order to make the branching ratio of the $\tilde{\chi}_1^0$ to

the lightest Higgs boson greater than that to the Z boson. Masses of the sleptons and coloured supersymmetric particles not used to make the grid are set to 2.5 TeV, and the lightest Higgs boson is in the decoupled regime with $m_A = 2$ TeV and $m_h = 115$ GeV, which results in a branching ratio $\text{BR}(h \rightarrow b\bar{b}) = 74\%$. Other parameters are the wino mass $M_2 = 2.5$ TeV, the ratio of Higgs doublet vacuum expectation values $\tan\beta = 1.5$, and the neutralino decay length $c\tau < 0.25$ mm. The small effect of a different choice of Higgs boson mass, $m_h = 125$ GeV, is discussed in Section 9. More generally, different choices of these parameters can modify slightly the relevant branching ratios but do not affect significantly the overall sensitivity reach for models of gauge mediation. The full mass spectrum and decay widths are calculated using SUSPECT, SDECAY, and HDECAY with the SUSY-HIT interface [31]. Events are generated with Herwig++ [32].

The signal production rate is dominated at high neutralino masses by strong production of gluinos and squarks, but at low neutralino masses the direct production of charginos and neutralinos is greatly enhanced. Signal cross sections are calculated to next-to-leading order in the strong coupling constant (NLO) using PROSPINO2 [33].² The nominal cross section and its uncertainty are taken from an envelope of cross-section predictions using different PDF sets and factorization and renormalization scales, as described in Ref. [38]. The PDF sets used for those calculations are CTEQ6.6M [39] and MSTW2008NLO [40].

Monte Carlo simulated event samples are generated with multiple pp interactions (pile-up) and are re-weighted by matching the distribution of the number of interactions per bunch crossing to that observed in the data. The samples are passed through the GEANT4 [41,42] simulation of the ATLAS detector and the same reconstruction software used for the data.

4. Event reconstruction

Jets are reconstructed from calibrated clustered energy deposits in the calorimeter using the anti- k_t jet clustering algorithm [43] with radius parameter $R = 0.4$. Clusters of calorimeter cells are seeded by cells with energy significantly above the measured noise. Jet energies are corrected for the effects of calorimeter non-compensation and inhomogeneities using p_T - and η -dependent calibration factors based on Monte Carlo simulations validated with extensive test-beam and collision-data studies [44]. Reconstructed jets with $p_T > 20$ GeV and $|\eta| < 2.8$ are used in this analysis.

A multivariate b -tagging algorithm that exploits both impact parameter and secondary vertex information is used to identify jets with $|\eta| < 2.5$ containing a b -hadron [45]. The working point used in this analysis has a 60% efficiency on a sample of b -jets from simulated $t\bar{t}$ events, with typical misidentification rates of 12% for c -jets and less than 0.2% for light-quark/gluon jets with $p_T > 20$ GeV and $|\eta| < 2.5$.

A photon candidate must have transverse momentum $p_T > 20$ GeV and must fulfil a set of “tight” identification requirements [46]. Moreover, the cluster associated with the photon should have $|\eta| < 2.37$ and should not be in the transition region between the barrel and end-cap calorimeters ($1.37 < |\eta| < 1.52$). An isolation criterion is applied in order to suppress the background from photons originating inside jets: the total calorimeter energy deposit, not including the photon candidate, inside a cone of $\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} = 0.2$ around the photon direction is required to be less than 5 GeV. Photon candidates identified from

¹ ATLAS uses a right-handed coordinate system with its origin at the nominal interaction point (IP) in the centre of the detector and the z -axis along the beam pipe. The x -axis points from the IP to the centre of the LHC ring, and the y -axis points upward. Cylindrical coordinates (r, ϕ) are used in the transverse plane, ϕ being the azimuthal angle around the beam pipe. The pseudorapidity is defined in terms of the polar angle θ as $\eta = -\ln \tan(\theta/2)$.

² The addition of the resummation of soft gluon emission at next-to-leading-logarithmic accuracy (NLL) [33–37] is performed in the case of strong SUSY pair-production.

conversions are included, but, in order to suppress the background from primary electrons misidentified as photons, the tracks of converted photon candidates are required to have no hits in the pixel detector.

Electron candidates are clustered energy deposits in the electromagnetic calorimeter matched to a track in the inner detector. They are required to have $p_T > 20$ GeV and $|\eta| < 2.47$, and must satisfy the “medium” electron shower shape and track selection criteria described in Ref. [47]. As for photons, electron candidates in the calorimeter transition region are vetoed.

Muon candidates with $|\eta| < 2.4$, reconstructed by combining tracks in the inner detector and tracks in the muon spectrometer, are required to have $p_T > 10$ GeV and also to pass muon quality requirements [48].

The measurement of the missing transverse momentum, including its magnitude E_T^{miss} , is based on the vector sum of the reconstructed transverse momenta in the event. Objects included in the sum are muons and electrons with $p_T > 10$ GeV, photons with $p_T > 20$ GeV, jets with $p_T > 20$ GeV, and calibrated calorimeter clusters that are not associated with any object with $|\eta| < 4.9$, as described in Ref. [49].

Any jet candidate lying within a distance $\Delta R < 0.2$ from an electron or photon is discarded. Also, in order to ensure that selected leptons and photons are not purely the result of hadronic activity, electrons and photons with distances $0.2 < \Delta R < 0.4$ from a jet are rejected, as are muons within $\Delta R < 0.4$ of a jet. The difference in requirements reflects the fact that only photons and electrons can potentially be reconstructed as jets. Since one of the main backgrounds in this analysis is due to electrons misidentified as photons, a preliminary suppression of the background is achieved by labelling an object an electron whenever an electron/photon ambiguity exists and by discarding the photon candidate if it lies within $\Delta R < 0.2$ of any electron.

5. Event selection

The data sample is collected with a trigger requiring at least one photon passing “loose” identification requirements [46] with $p_T > 80$ GeV; this trigger is fully efficient for the selection described below. The following selection criteria were optimized to maximize the sensitivity to the GGM scenarios considered, especially gluino/squark production: a candidate event should contain a photon with $p_T > 125$ GeV, at least two jets with $p_T > 20$ GeV, at least one of which is b -tagged, and $E_T^{\text{miss}} > 150$ GeV. The transverse mass of the photon and the missing transverse momentum $m_T(\gamma, E_T^{\text{miss}}) = \sqrt{2E_T^{\text{miss}} p_T^\gamma (1 - \cos\phi)}$, where ϕ is the azimuthal angle between the missing transverse momentum and the photon, is required to be greater than 100 GeV. This criterion removes events in which electrons or decay products of τ leptons, originating from W decay, are misidentified as photons. The minimum azimuthal angle between the E_T^{miss} direction and each of the two leading jets must be greater than 0.4. This condition suppresses multijet events in which the measured E_T^{miss} is due mostly to jet mismeasurement effects. Events with an identified electron or muon satisfying the criteria given in Section 4 are vetoed. This veto suppresses dileptonic and semileptonic $t\bar{t}$ events with a prompt photon or with a jet misidentified as a photon, and dileptonic events with an electron or a τ lepton misidentified as a photon. Finally, events with a second photon with $p_T > 50$ GeV are rejected. The main selection requirements are summarized in Table 1.

6. Background estimation

Events from $t\bar{t}$ production with a W boson decaying into leptons in the final state (leptonic $t\bar{t}$ background) contain a pair of

Table 1

Summary of event selection requirements.

1 photon ($p_T > 125$ GeV)	$m_T(\gamma, E_T^{\text{miss}}) > 100$ GeV
≥ 2 jets ($p_T > 20$ GeV)	$\Delta\phi(E_T^{\text{miss}}, \text{jet}) > 0.4$
≥ 1 b -tagged jet	veto e/μ
$E_T^{\text{miss}} > 150$ GeV	veto second photon

Table 2

Number of events in the signal region and in the lepton control region, as predicted by the $t\bar{t}$ MC@NLO and $t\bar{t}\gamma$ WHIZARD calculations, after subtracting the overlapping contribution from electrons misidentified as photons. Only statistical uncertainties are quoted.

Sample	Signal region	Lepton control region
$t\bar{t}$ MC@NLO	0.3 ± 0.2	0.5 ± 0.3
$t\bar{t}\gamma$ WHIZARD	2.5 ± 0.2	7.9 ± 0.4
Total	2.8 ± 0.3	8.4 ± 0.5
Data		10.1 ± 3.5

b -jets and genuine E_T^{miss} . These events may survive the signal selection procedure if an isolated high- p_T photon candidate is also present. Such a photon may be the result of the misidentification of an electron produced in the leptonic W decay, a genuine prompt photon, or a τ decay product or jet misidentified as a photon. All processes that give rise to final states $W(\rightarrow \ell\nu) + X$, including leptonic $t\bar{t}$, diboson, and single top backgrounds, are estimated using data-driven methods. Another large background estimated with data-driven methods is from multijet events. Finally, the small contribution from $Z(\rightarrow \nu\bar{\nu}) + \text{jets}$ background is estimated using Monte Carlo simulation.

A control sample (CS) is defined by selecting events according to the criteria described in Section 5 but replacing the photon selection by requiring the presence of an electron. Once the probability of an electron being misidentified as a photon (the “ $e \rightarrow \gamma$ misidentification rate”) is known, the number of events in the signal region with misidentified electrons can be deduced from this CS. The $e \rightarrow \gamma$ misidentification rate for different η regions is measured by selecting events with a photon and an electron in which the γe invariant mass is less than 20 GeV from the nominal Z boson mass of 91.2 GeV. The electron is required to pass the “tight” identification criteria [46], and the photon is required to pass the quality requirements of the signal region. The number of γe events is then divided by the number of e^+e^- pairs with one tight and one medium electron, and the ratio is taken to be the misidentification rate. The average misidentification rate for photons with $p_T > 100$ GeV is 1.8%. When this technique is applied to the data, 1.1 ± 0.1 (stat.) background events with electrons misidentified as photons are predicted in the signal region.

The prompt photon background cannot be separated from the backgrounds in which a jet or τ lepton is misidentified as a photon. Therefore, a single CS is used to estimate these backgrounds. The “lepton control region” is defined by requiring the presence of a lepton, in addition to the photon, and relaxing the E_T^{miss} cut to $80 < E_T^{\text{miss}} < 150$ GeV while keeping all the other selection criteria of Section 5. The lepton requirement strongly suppresses the multijet contamination, making it possible to use a lower E_T^{miss} threshold in order to increase the number of selected events and hence reduce the uncertainty on the background estimate. The lower E_T^{miss} threshold is chosen to be 80 GeV to ensure that the $t\bar{t}$ background remains the dominant contribution in the lepton control region. The results of the method for the signal region and the lepton control region are shown in Table 2. In order to prevent double counting, the background with electrons misidentified as photons is subtracted, leaving 10.1 events in the CS. Multiplying the 10.1 events observed in the CS by the simulation-based scale factor of

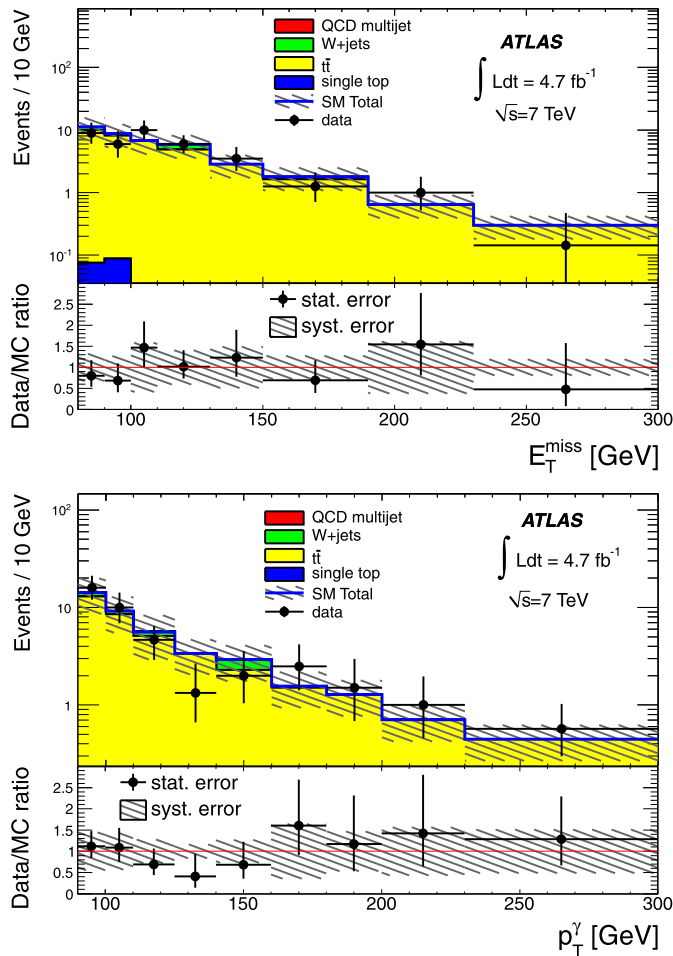


Fig. 1. The E_T^{miss} spectrum in the lepton control region with a relaxed p_T^γ requirement of 90 GeV and no $m_T(\gamma, E_T^{\text{miss}})$ cut (top) and the p_T^γ spectrum in the lepton control region with no upper bound on E_T^{miss} and no $m_T(\gamma, E_T^{\text{miss}})$ cut (bottom).

$2.8/8.4 = 0.33$ gives a prediction of 3.4 ± 1.7 (stat.) prompt photon and misidentified jet/ τ background events in the signal region. The uncertainty is dominated by the limited number of events in the CS data.

An important issue in evaluating the scale factor with simulated events is that the MC@NLO generator does not produce $t\bar{t}\gamma$ final states with a matrix element calculation; rather, it produces the $t\bar{t}$ hard process, and supplemental photon radiation is generated by HERWIG and PHOTOS. The WHIZARD generator is better suited for $t\bar{t}\gamma$ studies with high- p_T photons, since the photon is generated from a matrix element calculation. To avoid double counting in the two samples, events in the MC@NLO simulation sample with a prompt photon are removed. Even though the CS is dominated by $t\bar{t}\gamma$ events, and the $t\bar{t}\gamma$ simulations alone are used for the scale factor calculation, this technique gives a total estimate for all of the $W(\rightarrow \ell\nu) + X$ background processes, which are present by construction in the CS.

To verify that the event characteristics used in this method are well modelled in the lepton control region, the E_T^{miss} and p_T^γ distributions in the data and simulation are shown in Fig. 1. The distributions agree within uncertainties.

Multijet events, another source of background, may contain genuine photons or misidentified jets that hadronize to an isolated π^0 . High E_T^{miss} is rare in multijet events but can be realized by mismeasured jets or by heavy-flavour quark jets decaying semileptonically. To estimate the multijet contribution in the sig-

Table 3

Definition of the control regions CR1, CR2, CR3, and signal region SR for the multijet background estimation.

	$E_T^{\text{miss}} < 100$ GeV	$E_T^{\text{miss}} > 150$ GeV
≥ 1 b -tag	CR1	SR
0 b -tag	CR2	CR3

nal region (SR), control regions (CRs) are defined with events that fail the b -tag requirement or the E_T^{miss} requirement (see Table 3).

The CR3 data sample is contaminated by $t\bar{t}$, single top, and W/Z + jets events that have genuine E_T^{miss} , and this contamination must be removed. This contamination $N_{\text{CR3}}^{\text{MC,multijet}}$ is estimated from the Monte Carlo simulation and accounts for approximately 45% of the events in the CR3. A scale factor between the tagged and untagged samples is calculated in the low $E_T^{\text{miss}} < 100$ GeV control regions ($N_{\text{CR1}}^{\text{Data}}/N_{\text{CR2}}^{\text{Data}}$), and this scale factor is subsequently applied to the high- E_T^{miss} region of the untagged CS to obtain the prediction for the signal region:

$$N_{\text{SR}}^{\text{Pred}} = (N_{\text{CR3}}^{\text{Data}} - N_{\text{CR3}}^{\text{MC,multijet}}) \times \left[\frac{N_{\text{CR1}}^{\text{Data}}}{N_{\text{CR2}}^{\text{Data}}} \right].$$

In order to check the accuracy of this method, the background estimate is calculated after all selection requirements and then repeated without the $m_T(\gamma, E_T^{\text{miss}}) > 100$ GeV requirement, which is expected to have little effect on the multijet background. The two calculations yield predictions of 3.3 ± 0.7 (stat.) ± 0.6 (syst.) events before the $m_T(\gamma, E_T^{\text{miss}})$ requirement and 2.7 ± 0.7 (stat.) ± 0.7 (syst.) events after all requirements, with uncertainty due only to limited statistics in the CRs. The difference of 0.6 events is used as a systematic uncertainty associated with this method. The number of expected QCD multijet events in the signal region is therefore 2.7 ± 1.1 events.

Finally, the $Z(\rightarrow \nu\bar{\nu}) + \text{jets}$ process is estimated, from studies of simulated events, to contribute 0.3 ± 0.3 events in the signal region. The background from other sources is estimated to be negligible.

7. Systematic uncertainties on the background

The main source of systematic uncertainties on the background is the scale factor derived from simulation for prompt photon and misidentified jet or τ processes. The uncertainty on this factor is dominated by the theoretical uncertainties on the $t\bar{t}$ processes. Uncertainties such as Monte Carlo modelling and different initial- and final-state radiation models are evaluated by comparing Ac-erMC (LO) [50], MC@NLO (NLO), and POWHEG (NLO) $t\bar{t}$ simulations. The impact of using different fragmentation and hadronization models is estimated by comparing two POWHEG samples, one showered with HERWIG and the other with PYTHIA. The uncertainty is defined as the greatest difference among the resulting scale factors with respect to the MC@NLO factor and is evaluated to be 17%. Other systematic uncertainties are smaller since the scale factor is a ratio of the event population in the signal and control regions and most of the uncertainties cancel out. The effects of the jet energy scale [51] and jet energy resolution uncertainties [44] are determined to be 4% and 2%, respectively, and the relative uncertainty due to the b -tagging efficiency is evaluated to be 1%. The systematic uncertainty in the photon identification is based on the results of data-driven measurements with $Z \rightarrow e^+e^-$ decays and contributes 1% uncertainty in the scale factor. The systematic uncertainty due to pile-up is estimated to cause background variations of up to 4%, while the systematic uncertainty due to lepton identification, specifically in the lepton veto

Table 4

Summary of relative systematic uncertainties on the numbers of background and signal events (for the representative signal point $m_{\tilde{g}} = 900$ GeV, $m_{\tilde{\chi}_1^0} = 450$ GeV). Theoretical uncertainties on the background originate from the Monte Carlo modelling and different initial- and final-state radiation models. Theoretical uncertainties on the signal cross section originate from the PDFs, renormalization and factorization scales, and α_s .

Source of uncertainty	Background	Signal
Lepton identification	6%	3%
Jet energy scale	4%	1%
Jet energy resolution	2%	<1%
Photon identification	1%	6%
b -Tagging	1%	4%
Pile-up	4%	1%
Theoretical uncertainties	17%	9%
Monte Carlo statistics	–	3%
Luminosity	<1%	4%

in the event selection, is estimated to be 6%. The impact of the luminosity uncertainty is less than 1% because only the small contribution from $Z(\rightarrow \nu\bar{\nu}) + \text{jets}$ background is normalized using the integrated luminosity.

8. Signal efficiencies and systematic uncertainties

The combined product of acceptance and efficiency of the event selection is calculated with simulated events for each point in the GGM benchmark grids. Low $m_{\tilde{\chi}_1^0}$ values typically result in gravitinos with relatively low p_T , which translates to lower efficiency for the E_T^{miss} requirement relative to high- $m_{\tilde{\chi}_1^0}$ points. A typical efficiency for high-mass gluino points ($m_{\tilde{g}} = 900$ GeV, $m_{\tilde{\chi}_1^0} = 450$ GeV) is 10%, including the branching ratio for all Higgs boson decays and the contribution from neutralino decays to Z bosons that subsequently decay to $b\bar{b}$. Uncertainties on the signal cross section due to PDFs, renormalization and factorization scales, and the strong coupling constant α_s are calculated separately for each production process as described in Ref. [38] and combined into an overall uncertainty that varies significantly for different signal points. Most of the signal points have a combined cross-section uncertainty of 2–5% but the total uncertainty can reach 50% for the points with very large gluino masses. The uncertainties on the signal acceptance include an uncertainty ranging from 3% to 16% due to the limited number of simulated events at each benchmark grid point. The uncertainty on the jet energy scale and jet energy resolution, b -tagging efficiency, photon and lepton identification, luminosity, and pile-up are evaluated as in Section 7. The uncertainties on the jet energy scale and jet energy resolution vary from 1% to 10% across the different signal points. The relative uncertainty on the signal selection efficiency due to the uncertainty in the b -tagging efficiency varies between 1% and 16% throughout the signal grid. The systematic uncertainty on the photon identification is less than 6%. The systematic uncertainty on lepton identification is 3%. Scaling the number of pile-up events in simulation gives rise to variations of up to 6% throughout the grid. The systematic uncertainty on luminosity is evaluated to be 4% [52,53]. All the sources of described background and signal systematic uncertainties are summarized in Table 4.

9. Results

Table 5 summarizes the expected number of Standard Model events and observed data events in the signal region. A total of 7.5 ± 2.2 events are expected for the no-signal hypothesis while 7 events are observed. The distribution of E_T^{miss} after all requirements except on E_T^{miss} itself is shown in Fig. 2,

Table 5

Summary of the expected number of Standard Model events in the signal region and the number of events observed in the data. The systematic and statistical uncertainties, both included, are of the same order.

Background source	Expected events
Electron misidentified as photon	1.1 ± 0.1
Prompt photon and misidentified jet/ τ	3.4 ± 1.8
QCD multijet	2.7 ± 1.1
$Z(\rightarrow \nu\nu) + \text{jets}$	0.3 ± 0.3
Total number of expected events	7.5 ± 2.2
Observed events in the data	7

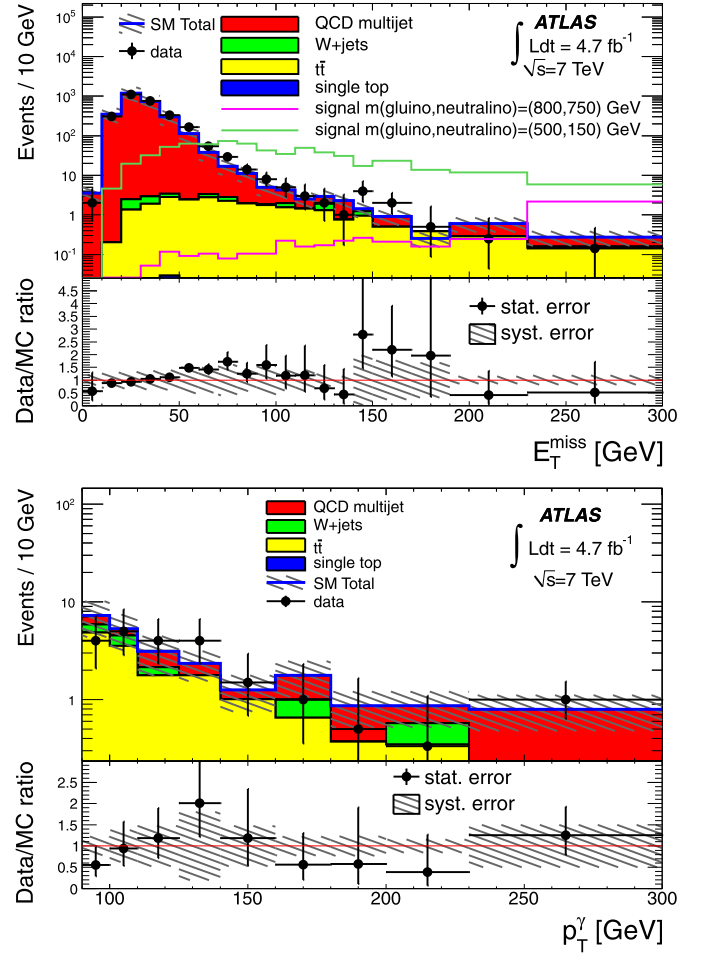


Fig. 2. The E_T^{miss} distribution after all selection criteria except the E_T^{miss} cut (top) and the p_T^γ distribution after all selection criteria except those on $m_T(\gamma, E_T^{\text{miss}})$ and $\Delta\phi(E_T^{\text{miss}}, \text{jet})$ (bottom).

along with the distribution of p_T^γ after all requirements except those on $m_T(\gamma, E_T^{\text{miss}})$ and $\Delta\phi(E_T^{\text{miss}}, \text{jet})$. The distribution of $m_T(\gamma, E_T^{\text{miss}})$ after all requirements except that on $\Delta\phi(E_T^{\text{miss}}, \text{jet})$ and the distribution of $\Delta\phi(E_T^{\text{miss}}, \text{jet})$ after all requirements except that on $m_T(\gamma, E_T^{\text{miss}})$ are shown in Fig. 3. The observed data agree with the background-only predictions.

Since no excess is observed above the background-only prediction, the main result of the search is to constrain contributions from physics beyond the Standard Model. The profile likelihood is used with an asymptotic approximation and the CL_s method to calculate confidence limits [54,55]. From the number of observed and expected events, a 95% confidence level upper limit on the visible

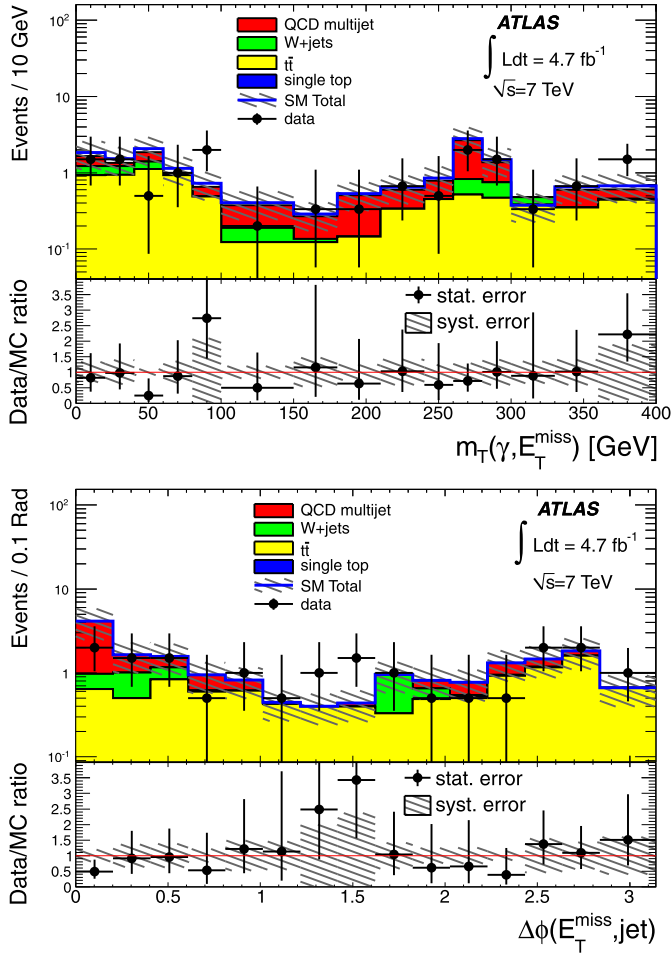


Fig. 3. The $m_T(\gamma, E_T^{\text{miss}})$ distribution after all selection criteria except the one for $\Delta\phi(E_T^{\text{miss}}, \text{jet})$ (top) and the $\Delta\phi(E_T^{\text{miss}}, \text{jet})$ distribution after all selection criteria except the one on $m_T(\gamma, E_T^{\text{miss}})$ (bottom).

cross section, defined by the product of production cross section times efficiency times acceptance, is derived. The expected 95% confidence limit is 8.1 events, corresponding to an upper limit on the visible cross section of 1.7 fb. The observed limit is 7.4 events, corresponding to a visible cross section of 1.6 fb.

The calculated acceptances for the simulated signal events and their cross sections are used in the framework of the specific GGM models described in Section 1 to map the excluded signal region. For each point in the benchmark plane observed upper limits on the signal strength are calculated, including both strong production of squarks and gluinos and weak production of neutralinos and charginos. Observed and expected limits for the combined production processes are shown in Fig. 4. The grey zone at the lower right represents the theoretically forbidden region where the lightest neutralino is no longer the NLSP. Gluino masses less than 900 GeV and squark masses less than 1020 GeV for neutralino masses above 220 GeV are excluded in the respective planes. The production cross sections at points with high neutralino mass and high gluino or squark mass are low, and an insufficient number of events is expected there. For points at very low neutralino mass the cross section is high but the expected E_T^{miss} is relatively low and only a small fraction of events pass the event selection. For this region the direct gaugino production through weak interactions is sizeable. The points at intermediate neutralino mass ($220 < m_{\tilde{\chi}_1^0} < 380$ GeV) are excluded by this search, regardless of gluino or squark masses, purely on the basis of the ex-

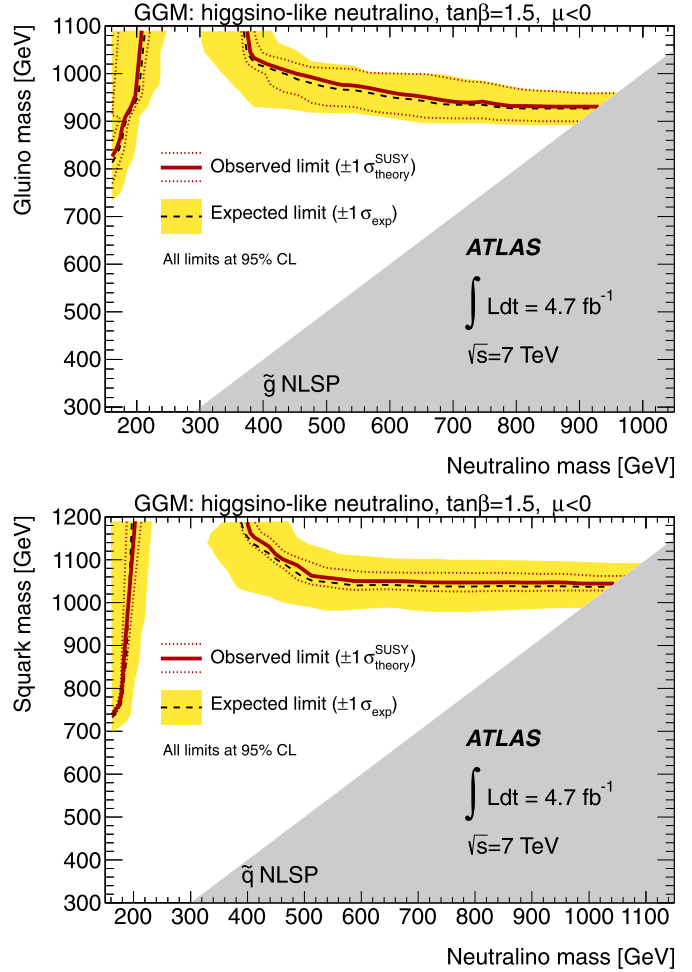


Fig. 4. Excluded region in the gluino–neutralino benchmark plane (top) and the squark–neutralino plane (bottom). The solid contour marks the observed exclusion, the dotted contours mark the expected exclusions if the signal cross section is shifted by $\pm 1\sigma$, and the dashed black line marks the expected exclusion. The shaded band gives the $\pm 1\sigma$ ranges of the expected limit distribution. The grey lower-right regions, corresponding to models with gluino or squark NLSP, are not considered.

pected weak production. This gives rise to the “chimney”-shaped exclusion region extending beyond the top edge of the benchmark plane.

If a Higgs boson mass $m_h = 125$ GeV is used instead of 115 GeV, the branching ratio to $b\bar{b}$ is reduced, and the exclusion is weakened. The important differences in excluded cross section for supersymmetric particle production, at high gluino mass and moderately high neutralino mass, are about 10%. In this relevant region, a 10% change in cross section corresponds to a 10 GeV reduction in the 900 GeV gluino mass exclusion.

10. Conclusions

A search for supersymmetry with a signature consisting of an isolated high transverse momentum photon, a b -tagged jet, and high missing transverse momentum is performed using 4.7 fb $^{-1}$ of $\sqrt{s} = 7$ TeV pp collision data recorded with the ATLAS detector at the LHC. Seven events are observed, consistent with the expected Standard Model background of 7.5 ± 2.2 events. A model-independent 95% confidence level upper limit of 1.6 fb is set on the visible cross section of events passing the selection. The cross-section limits are used to constrain higgsino-like neutralino production for a typical GGM model in two benchmark planes. These

are the first direct experimental constraints on this signature. For neutralino masses greater than 220 GeV, this search excludes gluino masses less than 900 GeV and squark masses less than 1020 GeV in the gluino–neutralino and squark–neutralino benchmark planes, respectively.

Acknowledgements

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

We acknowledge the support of ANPCyT, Argentina; YerPhI, Armenia; ARC, Australia; BMWF and FWF, Austria; ANAS, Azerbaijan; SSTC, Belarus; CNPq and FAPESP, Brazil; NSERC, NRC and CFI, Canada; CERN; CONICYT, Chile; CAS, MOST and NSFC, China; COLCIENCIAS, Colombia; MSMT CR, MPO CR and VSC CR, Czech Republic; DNRF, DNSRC and Lundbeck Foundation, Denmark; EPLANET, ERC and NSRF, European Union; IN2P3–CNRS, CEA–DSM/IRFU, France; GNSF, Georgia; BMBF, DFG, HGF, MPG and AvH Foundation, Germany; GSRT and NSRF, Greece; ISF, MINERVA, GIF, DIP and Benoziyo Center, Israel; INFN, Italy; MEXT and JSPS, Japan; CNRST, Morocco; FOM and NWO, Netherlands; BRF and RCN, Norway; MNiSW, Poland; GRICES and FCT, Portugal; MERYS (MECTS), Romania; MES of Russia and ROSATOM, Russian Federation; JINR; MSTB, 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.

Open access

This article is published Open Access at [sciencedirect.com](http://www.sciencedirect.com). It is distributed under the terms of the Creative Commons Attribution License 3.0, which permits unrestricted use, distribution, and reproduction in any medium, provided the original authors and source are credited.

References

- [1] M. Dine, W. Fischler, Phys. Lett. B 110 (1982) 227, [http://dx.doi.org/10.1016/0370-2693\(82\)91241-2](http://dx.doi.org/10.1016/0370-2693(82)91241-2).
- [2] L. Alvarez-Gaume, M. Claudson, M.B. Wise, Nucl. Phys. B 207 (1982) 96, [http://dx.doi.org/10.1016/0550-3213\(82\)90138-9](http://dx.doi.org/10.1016/0550-3213(82)90138-9).
- [3] C.R. Nappi, B.A. Ovrut, Phys. Lett. B 113 (1982) 175, [http://dx.doi.org/10.1016/0370-2693\(82\)90418-X](http://dx.doi.org/10.1016/0370-2693(82)90418-X).
- [4] M. Dine, A.E. Nelson, Phys. Rev. D 48 (1993) 1277, <http://dx.doi.org/10.1103/PhysRevD.48.1277>, arXiv:hep-ph/9303230.
- [5] M. Dine, A.E. Nelson, Y. Shirman, Phys. Rev. D 51 (1995) 1362, <http://dx.doi.org/10.1103/PhysRevD.51.1362>, arXiv:hep-ph/9408384.
- [6] M. Dine, A.E. Nelson, Y. Nir, Y. Shirman, Phys. Rev. D 53 (1996) 2658, <http://dx.doi.org/10.1103/PhysRevD.53.2658>, arXiv:hep-ph/9507378.
- [7] J.L. Feng, Ann. Rev. Astron. Astrophys. 48 (2010) 495, <http://dx.doi.org/10.1146/annurev-astro-082708-101659>, arXiv:1003.0904.
- [8] V.M. Abazov, et al., DO Collaboration, Phys. Rev. Lett. 105 (2010) 221802, <http://dx.doi.org/10.1103/PhysRevLett.105.221802>, arXiv:1008.2133.
- [9] ATLAS Collaboration, Phys. Lett. B 718 (2) (2012) 411, arXiv:1209.0753.
- [10] P. Meade, N. Seiberg, D. Shih, Prog. Theor. Phys. Suppl. 177 (2009) 143, <http://dx.doi.org/10.1143/PTPS.177.143>, arXiv:0801.3278.
- [11] J.T. Ruderman, D. Shih, JHEP 1208 (2012) 159, [http://dx.doi.org/10.1007/JHEP08\(2012\)159](http://dx.doi.org/10.1007/JHEP08(2012)159), arXiv:1103.6083.
- [12] ATLAS Collaboration, Phys. Lett. B 710 (2012) 519, <http://dx.doi.org/10.1016/j.physletb.2012.02.054>, arXiv:1111.4116.
- [13] CMS Collaboration, Phys. Rev. Lett. 106 (2011) 211802, <http://dx.doi.org/10.1103/PhysRevLett.106.211802>, arXiv:1103.0953.
- [14] ATLAS Collaboration, Phys. Rev. D 85 (2012) 112006, <http://dx.doi.org/10.1103/PhysRevD.85.112006>, arXiv:1203.6193.
- [15] ATLAS Collaboration, Eur. Phys. J. C 72 (2012) 2174, <http://dx.doi.org/10.1140/epjc/s10052-012-2174-z>.
- [16] ATLAS Collaboration, Phys. Rev. D 86 (2012) 092002, <http://dx.doi.org/10.1103/PhysRevD.86.092002>.
- [17] V.M. Abazov, et al., DO Collaboration, Phys. Rev. D 86 (2012) 071701, <http://dx.doi.org/10.1103/PhysRevD.86.071701>, arXiv:1203.5311.
- [18] ATLAS Collaboration, JINST 3 (2008) S08003, <http://dx.doi.org/10.1088/1748-0221/3/08/S08003>.
- [19] S. Frixione, B.R. Webber, JHEP 0206 (2002) 029, arXiv:hep-ph/0204244.
- [20] H.-L. Lai, et al., Phys. Rev. D 82 (2010) 074024, <http://dx.doi.org/10.1103/PhysRevD.82.074024>, arXiv:1007.2241.
- [21] G. Corcella, et al., JHEP 0101 (2001) 010, arXiv:hep-ph/0011363.
- [22] J. Butterworth, J.R. Forshaw, M. Seymour, Z. Phys. C 72 (1996) 637, <http://dx.doi.org/10.1007/s002880050286>, arXiv:hep-ph/9601371.
- [23] P. Nason, JHEP 0411 (2004) 040, <http://dx.doi.org/10.1088/1126-6708/2004/11/040>, arXiv:hep-ph/0409146.
- [24] S. Frixione, P. Nason, C. Oleari, JHEP 0711 (2007) 070, <http://dx.doi.org/10.1088/1126-6708/2007/11/070>, arXiv:0709.2092.
- [25] S. Alioli, P. Nason, C. Oleari, E. Re, JHEP 1006 (2010) 043, [http://dx.doi.org/10.1007/JHEP06\(2010\)043](http://dx.doi.org/10.1007/JHEP06(2010)043), arXiv:1002.2581.
- [26] W. Kilian, T. Ohl, J. Reuter, Eur. Phys. J. C 71 (2011) 1742, <http://dx.doi.org/10.1140/epjc/s10052-011-1742-y>, arXiv:0708.4233.
- [27] J. Pumplin, et al., JHEP 0207 (2002) 012, arXiv:hep-ph/0201195.
- [28] E. Barberio, B. van Eijk, Z. Was, Comput. Phys. Commun. 66 (1991) 115, [http://dx.doi.org/10.1016/0010-4655\(91\)90012-A](http://dx.doi.org/10.1016/0010-4655(91)90012-A).
- [29] T. Sjostrand, S. Mrenna, P.Z. Skands, JHEP 0605 (2006) 026, <http://dx.doi.org/10.1088/1126-6708/2006/05/026>, arXiv:hep-ph/0603175.
- [30] M.L. Mangano, et al., JHEP 0307 (2003) 001, arXiv:hep-ph/0206293.
- [31] A. Djouadi, M. Muhlleitner, M. Spira, Acta Phys. Polon. B 38 (2007) 635, arXiv:hep-ph/0609292.
- [32] M. Bahr, et al., Eur. Phys. J. C 58 (2008) 639, <http://dx.doi.org/10.1140/epjc/s10052-008-0798-9>, arXiv:0803.0883.
- [33] W. Beenakker, R. Hopker, M. Spira, P. Zerwas, Nucl. Phys. B 492 (1997) 51, [http://dx.doi.org/10.1016/S0550-3213\(97\)00084-9](http://dx.doi.org/10.1016/S0550-3213(97)00084-9), arXiv:hep-ph/9610490.
- [34] A. Kulesza, L. Motyka, Phys. Rev. Lett. 102 (2009) 111802, <http://dx.doi.org/10.1103/PhysRevLett.102.111802>, arXiv:0807.2405.
- [35] A. Kulesza, L. Motyka, Phys. Rev. D 80 (2009) 095004, <http://dx.doi.org/10.1103/PhysRevD.80.095004>, arXiv:0905.4749.
- [36] W. Beenakker, et al., JHEP 0912 (2009) 041, <http://dx.doi.org/10.1088/1126-6708/2009/12/041>, arXiv:0909.4418.
- [37] W. Beenakker, et al., Int. J. Mod. Phys. A 26 (2011) 2637, <http://dx.doi.org/10.1142/S0217751X11053560>, arXiv:1105.1110.
- [38] M. Kramer, et al., Supersymmetry production cross sections in pp collisions at $\sqrt{s} = 7$ TeV, Technical Report CERN-PH-TH-2012-163, 2012, <https://cds.cern.ch/record/1456029>, arXiv:1206.2892.
- [39] P.M. Nadolsky, et al., Phys. Rev. D 78 (2008) 013004, arXiv:0802.0007.
- [40] A. Martin, W.J. Stirling, R.S. Thorne, G. Watt, Eur. Phys. J. C 63 (2009) 189, arXiv:0901.0002.
- [41] S. Agostinelli, et al., GEANT4 Collaboration, Nucl. Instrum. Meth. A 506 (2003) 250, [http://dx.doi.org/10.1016/S0168-9002\(03\)01368-8](http://dx.doi.org/10.1016/S0168-9002(03)01368-8).
- [42] ATLAS Collaboration, Eur. Phys. J. C 70 (2010) 823, <http://dx.doi.org/10.1140/epjc/s10052-010-1429-9>, arXiv:1005.4568.
- [43] M. Cacciari, G.P. Salam, G. Soyez, JHEP 0804 (2008) 063, <http://dx.doi.org/10.1088/1126-6708/2008/04/063>, arXiv:0802.1189.
- [44] ATLAS Collaboration, Eur. Phys. J. C, in press, arXiv:1112.6426.
- [45] ATLAS Collaboration, Measurement of the b -tag efficiency in a sample of jets containing muons with 5 fb^{-1} of data from the ATLAS detector, Technical Report ATLAS-CONF-2012-043, 2012, <http://cdsweb.cern.ch/record/1435197>.
- [46] ATLAS Collaboration, Phys. Rev. D 83 (2011) 052005, <http://dx.doi.org/10.1103/PhysRevD.83.052005>, arXiv:1012.4389.
- [47] ATLAS Collaboration, Eur. Phys. J. C 72 (2012) 1909, <http://dx.doi.org/10.1140/epjc/s10052-012-1909-1>, arXiv:1110.3174.
- [48] ATLAS Collaboration, Phys. Lett. B 709 (2012) 137, <http://dx.doi.org/10.1016/j.physletb.2012.01.076>, arXiv:1110.6189.
- [49] ATLAS Collaboration, Eur. Phys. J. C 72 (2012) 1844, <http://dx.doi.org/10.1140/epjc/s10052-011-1844-6>, arXiv:1108.5602.
- [50] B.P. Kersevan, E. Richter-Was, The Monte Carlo event generator AcerMC version 2.0 with interfaces to PYTHIA 6.2 and HERWIG 6.5, Technical Report TPJU-6-2004, TPJU, Cracow, 2004.
- [51] ATLAS Collaboration, Eur. Phys. J. C, in press, arXiv:1112.6426.
- [52] ATLAS Collaboration, Eur. Phys. J. C 71 (2011) 1630, <http://dx.doi.org/10.1140/epjc/s10052-011-1630-5>, arXiv:1101.2185.
- [53] ATLAS Collaboration, Luminosity determination in pp collisions at $\sqrt{s} = 7$ TeV using the ATLAS detector in 2011, Technical Report ATLAS-CONF-2011-116, 2011, <http://cdsweb.cern.ch/record/1376384>.

[54] G. Cowan, K. Cranmer, E. Gross, O. Vitells, Eur. Phys. J. C 71 (2011) 1554, <http://dx.doi.org/10.1140/epjc/s10052-011-1554-0>, arXiv:1007.1727.

[55] A.L. Read, J. Phys. G 28 (2002) 2693, <http://dx.doi.org/10.1088/0954-3899/28/10/313>.

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,a}, L. Adamczyk³⁸, D.L. Adams²⁵, T.N. Addy⁵⁶, J. Adelman¹⁷⁶, S. Adomeit⁹⁸, P. Adragna⁷⁵, T. Adye¹²⁹, S. Aefsky²³, J.A. Aguilar-Saavedra^{124b,b}, M. Agustoni¹⁷, M. Aharrouche⁸¹, S.P. Ahlen²², F. Ahles⁴⁸, A. Ahmad¹⁴⁸, M. Ahsan⁴¹, G. Aielli^{133a,133b}, T.P.A. Åkesson⁷⁹, G. Akimoto¹⁵⁵, A.V. Akimov⁹⁴, 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,c}, 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,d}, G. Arabidze⁸⁸, I. Aracena¹⁴³, Y. Arai⁶⁵, A.T.H. Arce⁴⁵, S. Arfaoui¹⁴⁸, J.-F. Arguin⁹³, S. Argyropoulos⁴², E. Arik^{19a,*}, M. Arik^{19a}, A.J. Armbruster⁸⁷, O. Arnaez⁸¹, V. Arnal⁸⁰, A. Artamonov⁹⁵, G. Artoni^{132a,132b}, D. Arutinov²¹, S. Asai¹⁵⁵, S. Ask²⁸, B. Åsman^{146a,146b}, L. Asquith⁶, K. Assamagan^{25,e}, A. Astbury¹⁶⁹, M. Atkinson¹⁶⁵, B. Aubert⁵, E. Auge¹¹⁵, K. Augsten¹²⁶, M. Auresseau^{145a}, G. Avolio³⁰, D. Axen¹⁶⁸, G. Azuelos^{93,f}, Y. Azuma¹⁵⁵, M.A. Baak³⁰, G. Baccaglioni^{89a}, C. Bacci^{134a,134b}, A.M. Bach¹⁵, H. Bachacou¹³⁶, K. Bachas¹⁵⁴, 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. Balek¹²⁷, 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, 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,g}, S. Beale⁹⁸, T. Beau⁷⁸, P.H. Beauchemin¹⁶¹, R. Beccherle^{50a}, P. Bechtel²¹, H.P. Beck¹⁷, 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,h}, K. Belotskiy⁹⁶, O. Beltramello³⁰, O. Benary¹⁵³, D. Benchekroun^{135a}, K. Bendtz^{146a,146b}, N. Benekos¹⁶⁵, Y. Benhammou¹⁵³, E. Benhar Noccioli⁴⁹, J.A. Benitez Garcia^{159b}, D.P. Benjamin⁴⁵, M. Benoit¹¹⁵, J.R. Bensinger²³, 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, C.W. Black¹⁵⁰, K.M. Black²², R.E. Blair⁶, J.-B. Blanchard¹³⁶, T. Blazek^{144a}, I. Bloch⁴², C. Blocker²³, J. Blocki³⁹, A. Blondel⁴⁹, W. Blum⁸¹, U. Blumenschein⁵⁴, G.J. Bobbink¹⁰⁵, V.S. Bobrovnikov¹⁰⁷, S.S. Bocchetta⁷⁹, A. Bocci⁴⁵, C.R. Boddy¹¹⁸, M. Boehler⁴⁸, J. Boek¹⁷⁵, T.T. Boek¹⁷⁵, N. Boelaert³⁶, J.A. Bogaerts³⁰, A. Bogdanchikov¹⁰⁷, A. Bogouch^{90,*}, C. Bohm^{146a}, J. Bohm¹²⁵, V. Boisvert⁷⁶, T. Bold³⁸, V. Boldea^{26a}, N.M. Bolnet¹³⁶, M. Bomben⁷⁸, M. Bona⁷⁵, M. Boonekamp¹³⁶, S. Bordini⁷⁸, 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. Brelrier¹⁵⁸,
 J. Bremer³⁰, K. Brendlinger¹²⁰, R. Brenner¹⁶⁶, S. Bressler¹⁷², T.M. Bristow^{145b}, 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, P.A. Bruckman de Renstrom³⁹, D. Bruncko^{144b},
 R. Bruneliere⁴⁸, S. Brunet⁶⁰, A. Bruni^{20a}, G. Bruni^{20a}, M. Bruschi^{20a}, L. Bryngemark⁷⁹, 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. Canelli³¹, 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-Montoya^{145b}, A.A. Carter⁷⁵, J.R. Carter²⁸, J. Carvalho^{124a,i},
 D. Casadei¹⁰⁸, M.P. Casado¹², M. Cascella^{122a,122b}, C. Caso^{50a,50b,*}, A.M. Castaneda Hernandez^{173,j},
 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. Cerri¹⁵, L. Cerrito⁷⁵, F. Cerutti¹⁵, S.A. Cetin^{19b}, A. Chafaq^{135a}, D. Chakraborty¹⁰⁶,
 I. Chalupkova¹²⁷, K. Chan³, P. Chang¹⁶⁵, B. Chapleau⁸⁵, J.D. Chapman²⁸, J.W. Chapman⁸⁷,
 D.G. Charlton¹⁸, V. Chavda⁸², C.A. Chavez Barajas³⁰, S. Cheatham⁸⁵, S. Chekanov⁶, S.V. Chekulav^{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, A. Ciochio¹⁵, 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, 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,k}, M. Cooke¹⁵, B.D. Cooper⁷⁷, A.M. Cooper-Sarkar¹¹⁸,
 K. Copic¹⁵, T. Cornelissen¹⁷⁵, M. Corradi^{20a}, F. Corriveau^{85,l}, A. Cortes-Gonzalez¹⁶⁵, G. Cortiana⁹⁹,
 G. Costa^{89a}, M.J. Costa¹⁶⁷, D. Costanzo¹³⁹, D. Côté³⁰, L. Courneyea¹⁶⁹, G. Cowan⁷⁶, B.E. Cox⁸²,
 K. Cranmer¹⁰⁸, F. Crescioli⁷⁸, M. Cristinziani²¹, G. Crosetti^{37a,37b}, S. Crépé-Renaudin⁵⁵, C.-M. Cuciuc^{26a},
 C. Cuenca Almenar¹⁷⁶, T. Cuhadar Donszelmann¹³⁹, J. Cummings¹⁷⁶, M. Curatolo⁴⁷, C.J. Curtis¹⁸,
 C. Cuthbert¹⁵⁰, P. Cwetanski⁶⁰, H. Czirr¹⁴¹, 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, F. Dallaire⁹³, 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. Davidek¹²⁷, N. Davidson⁸⁶, R. Davidson⁷¹, E. Davies^{118,d}, 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,k}, D. della Volpe^{102a,102b}, M. Delmastro⁵, P.A. Delsart⁵⁵, C. Deluca¹⁰⁵, S. Demers¹⁷⁶,

M. Demichev⁶⁴, B. Demirköz^{12,m}, 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,n}, 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 Mattia¹⁵², 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. Dinut^{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,o}, T.K.O. Doan⁵,
 M. Dobbs⁸⁵, D. Dobos³⁰, E. Dobson^{30,p}, J. Dodd³⁵, C. Doglioni⁴⁹, T. Doherty⁵³, Y. Doi^{65,*}, J. Dolejsi¹²⁷,
 Z. Dolezal¹²⁷, 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. Dufлот¹¹⁵, M.-A. Dufour⁸⁵, L. Duguid⁷⁶, M. Dunford^{58a},
 H. Duran Yildiz^{4a}, R. Duxfield¹³⁹, M. Dwuznik³⁸, M. Düren⁵², W.L. Ebenstein⁴⁵, J. Ebke⁹⁸,
 S. Eckweiler⁸¹, 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. Emeliyanov¹²⁹, R. Engelmann¹⁴⁸, A. Engl⁹⁸,
 B. Epp⁶¹, J. Erdmann¹⁷⁶, 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. Etievre¹³⁶, E. Etzion¹⁵³, D. Evangelakou⁵⁴, H. Evans⁶⁰, L. Fabbri^{20a,20b},
 C. Fabre³⁰, R.M. Fakhruddinov¹²⁸, S. Falciano^{132a}, Y. Fang^{33a}, 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, P. Federic^{144a}, O.L. Fedin¹²¹,
 W. Fedorko⁸⁸, M. Fehling-Kaschek⁴⁸, L. Felgioni⁸³, 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,i},
 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,
 A.C. Florez Bustos^{159b}, 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, D. Froidevaux³⁰, J.A. Frost²⁸, C. Fukunaga¹⁵⁶, E. Fullana Torregrosa¹²⁷,
 B.G. Fulson¹⁴³, 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,g}, A. Gaponenko¹⁵, F. Garbersson¹⁷⁶, 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. Gece¹⁶⁸, 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, D. Gerbaudo¹², P. Gerlach¹⁷⁵, A. Gershon¹⁵³, C. Geweniger^{58a}, H. Ghazlane^{135b},
 N. Ghodbane³⁴, B. Giacobbe^{20a}, S. Giagu^{132a,132b}, V. Giangiobbe¹², F. Gianotti³⁰, B. Gibbard²⁵,
 A. Gibson¹⁵⁸, S.M. Gibson³⁰, M. Gilchriese¹⁵, D. Gillberg²⁹, A.R. Gillman¹²⁹, D.M. Gingrich^{3,f},
 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, 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, D. Golubkov¹²⁸, A. Gomes^{124a,c},
 L.S. Gomez Fajardo⁴², R. Gonçalves⁷⁶, 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, 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,n}, K. Gregersen³⁶, I.M. Gregor⁴², P. Grenier¹⁴³, J. Griffiths⁸, N. Grigalashvili⁶⁴, A.A. Grillo¹³⁷, K. Grimm⁷¹, S. Grinstein¹², Ph. Gris³⁴, Y.V. Grishkevich⁹⁷, J.-F. Grivaz¹¹⁵, A. Grohsjean⁴², E. Gross¹⁷², J. Grosse-Knetter⁵⁴, J. Groth-Jensen¹⁷², K. Grybel¹⁴¹, D. Guest¹⁷⁶, C. Guicheney³⁴, E. Guido^{50a,50b}, 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, Z. Hajduk³⁹, H. Hakobyan¹⁷⁷, D. Hall¹¹⁸, K. Hamacher¹⁷⁵, P. Hamal¹¹³, K. Hamano⁸⁶, M. Hamer⁵⁴, A. Hamilton^{145b,q}, 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, 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. Hawking³⁰, 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. Heim¹²⁰, B. Heinemann¹⁵, S. Heisterkamp³⁶, L. Helary²², C. Heller⁹⁸, M. Heller³⁰, S. Hellman^{146a,146b}, D. Hellmich²¹, C. Helsens¹², R.C.W. Henderson⁷¹, M. Henke^{58a}, A. Henrichs¹⁷⁶, A.M. Henriques Correia³⁰, S. Henrot-Versille¹¹⁵, C. Hensel⁵⁴, C.M. Hernandez⁸, Y. Hernández Jiménez¹⁶⁷, R. Herrberg¹⁶, G. Herten⁴⁸, R. Hertenberger⁹⁸, L. Hervas³⁰, G.G. Hesketh⁷⁷, N.P. Hessey¹⁰⁵, 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. Holy¹²⁶, 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. Hsu¹³⁸, D. Hu³⁵, Z. Hubacek¹²⁶, F. Hubaut⁸³, F. Huegging²¹, A. Huettmann⁴², T.B. Huffman¹¹⁸, E.W. Hughes³⁵, G. Hughes⁷¹, M. Huhtinen³⁰, M. Hurwitz¹⁵, N. Huseynov^{64,r}, 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, P. Ioannou⁹, M. Iodice^{134a}, K. Iordanidou⁹, V. Ippolito^{132a,132b}, A. Irlas 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. Jain², K. Jakobs⁴⁸, S. Jakobsen³⁶, T. Jakoubek¹²⁵, J. Jakubek¹²⁶, D.O. Jamin¹⁵¹, D.K. Jana¹¹¹, E. Jansen⁷⁷, H. Jansen³⁰, J. Janssen²¹, A. Jantsch⁹⁹, M. Janus⁴⁸, R.C. Jared¹⁷³, 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, D. Kar⁵³, M. Karagounis²¹, K. Karakostas¹⁰, M. Karnevskiy^{58b}, V. Kartvelishvili⁷¹, A.N. Karyukhin¹²⁸, L. Kashif¹⁷³, G. Kasieczka^{58b}, R.D. Kass¹⁰⁹, A. Kastanas¹⁴, M. Kataoka⁵, Y. Kataoka¹⁵⁵, J. Katzy⁴², V. Kaushik⁷, K. Kawagoe⁶⁹, T. Kawamoto¹⁵⁵, G. Kawamura⁸¹, M.S. Kayl¹⁰⁵, S. Kazama¹⁵⁵, V.F. 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. Khoraiuli²¹, 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. Knoops⁸³, A. Knue⁵⁴, B.R. Ko⁴⁵, T. Kobayashi¹⁵⁵, M. Kobel⁴⁴, M. Kocian¹⁴³, P. Kodys¹²⁷, K. Köneke³⁰, A.C. König¹⁰⁴, S. Koenig⁸¹, L. Köpke⁸¹, F. Koetsveld¹⁰⁴, P. Koevesarki²¹, T. Koffas²⁹, E. Koffeman¹⁰⁵, L.A. Kogan¹¹⁸, S. Kohlmann¹⁷⁵, F. Kohn⁵⁴, Z. Kohout¹²⁶, 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,s}, A.I. Kononov⁴⁸, R. Konoplich^{108,t}, 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. Kral¹²⁶, V.A. Kramarenko⁹⁷, G. Kramberger⁷⁴, M.W. Krasny⁷⁸, A. Krasznahorkay¹⁰⁸, J.K. Kraus²¹, A. Kravchenko²⁵, S. Kreiss¹⁰⁸, F. Krejci¹²⁶, J. Kretzschmar⁷³, K. Kreutzfeldt⁵², 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. Kudah^{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, 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, 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. Lantsch¹⁷⁵, A. Lanza^{119a}, 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. Lehmann²¹, G. Lehmann Miotto³⁰, A.G. Leister¹⁷⁶, M.A.L. Leite^{24d}, R. Leitner¹²⁷, 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. Li^{33b}, B. Li⁸³, H. Li¹⁴⁸, H.L. Li³¹, S. Li^{33b,u}, X. Li⁸⁷, Z. Liang^{118,v}, H. Liao³⁴, B. Liberti^{133a}, P. Lichard³⁰, M. Lichtnecker⁹⁸, K. Lie¹⁶⁵, W. Liebig¹⁴, C. Limbach²¹, A. Limosani⁸⁶, M. Limper⁶², S.C. Lin^{151,w}, F. Linde¹⁰⁵, J.T. Linnemann⁸⁸, E. Lipeles¹²⁰, A. Lipniacka¹⁴, T.M. Liss¹⁶⁵, D. Lissauer²⁵, A. Lister⁴⁹, A.M. Litke¹³⁷, C. Liu²⁹, D. Liu¹⁵¹, 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,g}, F. Lu^{33a}, H.J. Lubatti¹³⁸, C. Luci^{132a,132b}, A. Lucotte⁵⁵, 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}, D. Macina³⁰, R. Mackeprang³⁶, R.J. Madaras¹⁵, H.J. Maddocks⁷¹, W.F. Mader⁴⁴, R. Maenner^{58c}, T. Maeno²⁵, P. Mättig¹⁷⁵, S. Mättig⁴², L. Magnoni¹⁶³, E. Magradze⁵⁴, K. Mahboubi⁴⁸, J. Mahlstedt¹⁰⁵, S. Mahmoud⁷³, G. Mahout¹⁸, C. Maiani¹³⁶, C. Maidantchik^{24a}, A. Maio^{124a,c}, 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, J. Mamuzic^{13b}, A. Manabe⁶⁵, L. Mandelli^{89a}, I. Mandić⁷⁴, R. Mandrysch⁶², J. Maneira^{124a}, A. Manfredini⁹⁹, L. Manhaes de Andrade Filho^{24b}, J.A. Manjarres Ramos¹³⁶, A. Mann⁹⁸, P.M. Manning¹³⁷, A. Manousakis-Katsikakis⁹, B. Mansoulie¹³⁶, R. Mantifel⁸⁵, 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, 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, H. Martinez¹³⁶, 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, H. Matsunaga¹⁵⁵, T. Matsushita⁶⁶, C. Mattravers^{118,d}, J. Maurer⁸³, S.J. Maxfield⁷³, D.A. Maximov^{107,h}, 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. Mchedlidze^{51b}, T. Mclaughlan¹⁸, S.J. McMahon¹²⁹, R.A. McPherson^{169,l}, A. Meade⁸⁴, J. Mechnich¹⁰⁵, M. Mechtel¹⁷⁵, M. Medinnis⁴², S. Meehan³¹, 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,x}, 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,y}, J. Metcalfe²⁵, A.S. Mete¹⁶³, C. Meyer⁸¹, C. Meyer³¹, J.-P. Meyer¹³⁶, J. Meyer¹⁷⁴, J. Meyer⁵⁴, S. Michal³⁰, L. Micu^{26a}, R.P. Middleton¹²⁹, S. Migas⁷³, L. Mijović¹³⁶, G. Mikenberg¹⁷², M. Mikestikova¹²⁵, M. Mikuž⁷⁴, 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,z}, 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. Musto¹⁵², 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,d}, 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,aa}, 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, J. Novakova¹²⁷, 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,f}, 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,i}, D. Oliveira Damazio²⁵, E. Oliver Garcia¹⁶⁷, D. Olivito¹²⁰, A. Olszewski³⁹, J. Olszowska³⁹, A. Onofre^{124a,ab}, P.U.E. Onyisi^{31,ac}, 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. Paelari⁷, 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,ad}, 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,ae}, 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,af},

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. Petteni¹⁴², R. Pezoa^{32b}, A. Phan⁸⁶, P.W. Phillips¹²⁹, G. Piacquadio³⁰, A. Picazio⁴⁹, E. Piccaro⁷⁵, M. Piccinini^{20a,20b}, S.M. Piec⁴², R. Piegaia²⁷, D.T. Pignotti¹⁰⁹, J.E. Pilcher³¹, A.D. Pilkington⁸², J. Pina^{124a,c}, M. Pinamonti^{164a,164c}, A. Pinder¹¹⁸, J.L. Pinfold³, A. Pingel³⁶, B. Pinto^{124a}, C. Pizio^{89a,89b}, 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. Pospisil¹²⁶, 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. Przysiezniak⁵, S. Psoroulas²¹, E. Ptacek¹¹⁴, E. Pueschel⁸⁴, D. Poldon¹⁴⁸, J. Purdham⁸⁷, M. Purohit^{25,ad}, P. Puzo¹¹⁵, Y. Pylypchenko⁶², J. Qian⁸⁷, A. Quadt⁵⁴, D.R. Quarrie¹⁵, W.B. Quayle¹⁷³, M. Raas¹⁰⁴, V. Radeka²⁵, V. Radescu⁴², P. Radloff¹¹⁴, F. Ragusa^{89a,89b}, G. Rahal¹⁷⁸, A.M. Rahimi¹⁰⁹, D. Rahm²⁵, S. Rajagopalan²⁵, M. Rammensee⁴⁸, M. Rammes¹⁴¹, A.S. Randle-Conde⁴⁰, K. Randrianarivony²⁹, K. Rao¹⁶³, F. Rauscher⁹⁸, T.C. Rave⁴⁸, M. Raymond³⁰, A.L. Read¹¹⁷, D.M. Rebuffi^{119a,119b}, A. Redelbach¹⁷⁴, G. Redlinger²⁵, R. Reece¹²⁰, K. Reeves⁴¹, 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,ag}, 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,l}, 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, P.L. Rosendahl¹⁴, O. Rosenthal¹⁴¹, L. Rossetet⁴⁹, 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,ah}, F. Rubbo¹², I. Rubinskiy⁴², N. Ruckstuhl¹⁰⁵, V.I. Rud⁹⁷, C. Rudolph⁴⁴, G. Rudolph⁶¹, F. Rühr⁷, A. Ruiz-Martinez⁶³, L. Rummyantsev⁶⁴, Z. Rurikova⁴⁸, N.A. Rusakovich⁶⁴, A. Ruschke⁹⁸, J.P. Rutherford⁷, N. Ruthmann⁴⁸, P. Ruzicka¹²⁵, Y.F. Ryabov¹²¹, M. Rybar¹²⁷, 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}, I. Santoyo Castillo¹⁴⁹, J.G. Saraiva^{124a}, T. Sarangi¹⁷³, E. Sarkisyan-Grinbaum⁸, B. Sarrazin²¹, 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,f}, V. Savinov¹²³, D.O. Savu³⁰, L. Sawyer^{25,n}, 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. Schaepe²¹, S. Schaetzel^{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}, 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, A. Schwartzman¹⁴³, Ph. Schwegler⁹⁹, Ph. Schwemling⁷⁸, R. Schwienhorst⁸⁸, R. Schwierz⁴⁴, J. Schwindling¹³⁶, T. Schwindt²¹, M. Schwoerer⁵, F.G. Sciacca¹⁷, 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. Sfyra³⁰, 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. Simak¹²⁶, 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. Sivoklov⁹⁷, J. Sjölin^{146a,146b}, T.B. Sjurson¹⁴, L.A. Skinnari¹⁵, H.P. Skottowe⁵⁷, K. Skovpen¹⁰⁷,
 P. Skubic¹¹¹, M. Slater¹⁸, T. Slavicek¹²⁶, 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. Smolek¹²⁶, A.A. Snesarev⁹⁴, S.W. Snow⁸², J. Snow¹¹¹, S. Snyder²⁵,
 R. Sobie^{169,l}, J. Sodomka¹²⁶, A. Soffer¹⁵³, C.A. Solans¹⁶⁷, M. Solar¹²⁶, J. Solc¹²⁶, E.Yu. Soldatov⁹⁶,
 U. Soldevila¹⁶⁷, E. Solfaroli Camillocci^{132a,132b}, A.A. Solodkov¹²⁸, O.V. Solovyanov¹²⁸, V. Solovyev¹²¹,
 N. Soni¹, A. Sood¹⁵, V. Sopko¹²⁶, B. Sopko¹²⁶, M. Sosebee⁸, R. Soualah^{164a,164c}, P. Soueid⁹³,
 A. Soukharev¹⁰⁷, S. Spagnolo^{72a,72b}, F. Spanò⁷⁶, R. Spighi^{20a}, G. Spigo³⁰, R. Spiwoks³⁰, M. Spousta^{127,ai},
 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. Stekl¹²⁶, 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. Stoicea^{26a}, S. Stonjek⁹⁹, P. Strachota¹²⁷,
 A.R. Stradling⁸, A. Straessner⁴⁴, J. Strandberg¹⁴⁷, S. Strandberg^{146a,146b}, A. Strandlie¹¹⁷, M. Strang¹⁰⁹,
 E. Strauss¹⁴³, M. Strauss¹¹¹, P. Strizenec^{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,v},
 D. Su¹⁴³, H.S. Subramania³, R. Subramaniam²⁵, A. Succurro¹², Y. Sugaya¹¹⁶, C. Suhr¹⁰⁶, M. Suk¹²⁷,
 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. Sykora¹²⁷,
 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,h},
 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. Tas¹²⁷, M. Tasevsky¹²⁵, E. Tassi^{37a,37b}, 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,l}, 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,h},
 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, E. Torrence¹¹⁴, H. Torres⁷⁸, E. Torrón Pastor¹⁶⁷,
 J. Toth^{83,ae}, F. Touchard⁸³, D.R. Tovey¹³⁹, T. Trefzger¹⁷⁴, L. Tremblet³⁰, A. Tricoli³⁰, I.M. Trigger^{159a},
 S. Trincz-Duvoid⁷⁸, M.F. Tripiana⁷⁰, N. Triplett²⁵, W. Trischuk¹⁵⁸, B. Trocmé⁵⁵, C. Troncon^{89a},
 M. Trottier-McDonald¹⁴², P. True⁸⁸, M. Trzebinski³⁹, A. Trzupek³⁹, C. Tsarouchas³⁰, J.C.-L. Tseng¹¹⁸,
 M. Tsiakiris¹⁰⁵, P.V. Tsiarehka⁹⁰, D. Tsionou^{5,aj}, 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. Turecek¹²⁶, 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. Ughetto⁸³, 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. Vacek¹²⁶, B. Vachon⁸⁵, S. Vahsen¹⁵,
 S. Valentini^{20a,20b}, A. Valero¹⁶⁷, S. Valkar¹²⁷, 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, J. Van Nieuwkoop¹⁴², I. van Vulpen¹⁰⁵, M. Vanadia⁹⁹, W. Vandelli³⁰, A. Vaniachine⁶, P. Vankov⁴², F. Vannucci⁷⁸, R. Vari^{132a}, E.W. Varnes⁷, 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.f}, I. Vichou¹⁶⁵, T. Vickey^{145b.ak}, 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. Vlasak¹²⁶, A. Vogel²¹, P. Vokac¹²⁶, G. Volpi⁴⁷, M. Volpi⁸⁶, G. Volpini^{89a}, H. von der Schmitt⁹⁹, H. von Radziewski⁴⁸, E. von Toerne²¹, V. Vorobel¹²⁷, V. Vorwerk¹², M. Vos¹⁶⁷, R. Voss³⁰, J.H. Vossebeld⁷³, N. Vranjes¹³⁶, M. Vranjes Milosavljevic¹⁰⁵, V. Vrba¹²⁵, M. Vreeswijk¹⁰⁵, T. Vu Anh⁴⁸, R. Vuillermet³⁰, I. Vukotic³¹, W. Wagner¹⁷⁵, P. Wagner²¹, 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. Wang⁴⁰, J. Wang¹⁵¹, J. Wang^{33a}, 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, J.S. Webster³¹, A.R. Weidberg¹¹⁸, P. Weigell⁹⁹, J. Weingarten⁵⁴, C. Weiser⁴⁸, P.S. Wells³⁰, T. Wenaus²⁵, D. Wendland¹⁶, Z. Weng^{151.v}, 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, 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.s}, I. Wilhelm¹²⁷, H.G. Wilkens³⁰, J.Z. Will⁹⁸, E. Williams³⁵, H.H. Williams¹²⁰, S. Williams²⁸, 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.i}, 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.al}, E. Wulf³⁵, B.M. Wynne⁴⁶, S. Xella³⁶, M. Xiao¹³⁶, S. Xie⁴⁸, C. Xu^{33b.z}, D. Xu^{33a}, L. Xu^{33b}, B. Yabsley¹⁵⁰, S. Yacoub^{145a.am}, 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. Yasu⁶⁵, E. Yatsenko⁴², J. Ye⁴⁰, S. Ye²⁵, A.L. Yen⁵⁷, M. Yilmaz^{4c}, R. Yoosofmiya¹²³, K. Yorita¹⁷¹, R. Yoshida⁶, K. Yoshihara¹⁵⁵, C. Young¹⁴³, C.J. Young¹¹⁸, S. Youssef²², D. Yu²⁵, D.R. Yu¹⁵, J. Yu⁸, J. Yu¹¹², L. Yuan⁶⁶, A. Yurkewicz¹⁰⁶, B. Zabinski³⁹, R. Zaidan⁶², A.M. Zaitsev¹²⁸, L. Zanello^{132a,132b}, D. Zanzi⁹⁹, A. Zaytsev²⁵, C. Zeitnitz¹⁷⁵, M. Zeman¹²⁵, A. Zemla³⁹, O. Zenin¹²⁸, T. Ženiš^{144a}, Z. Zinonos^{122a,122b}, D. Zerwas¹¹⁵, G. Zevi della Porta⁵⁷, D. Zhang⁸⁷, 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

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

⁷ Department of Physics, University of Arizona, Tucson, AZ, United States

⁸ Department of Physics, The University of Texas at Arlington, Arlington, TX, United States

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

- 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
- ²³ Department of Physics, Brandeis University, Waltham, MA, United States
- 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
- 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 Fisica, 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
- ³² (a) Departamento de Fisica, Pontificia Universidad Católica de Chile, Santiago; (b) Departamento de Fisica, Universidad Técnica Federico Santa María, Valparaíso, Chile
- ³³ (a) Institute of High Energy Physics, Chinese Academy of Sciences, Beijing; (b) Department of Modern Physics, University of Science and Technology of China, Anhui; (c) Department of Physics, Nanjing University, Jiangsu; (d) School of Physics, Shandong University, Shandong; (e) Physics Department, Shanghai Jiao Tong University, Shanghai, China
- ³⁴ Laboratoire de Physique Corpusculaire, Clermont Université Blaise Pascal and CNRS/IN2P3, Clermont-Ferrand, France
- ³⁵ Nevis Laboratory, Columbia University, Irvington, NY, United States
- ³⁶ Niels Bohr Institute, University of Copenhagen, Copenhagen, 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
- ⁴¹ Physics Department, University of Texas at Dallas, Richardson, TX, United States
- 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
- ⁴⁶ SUPA – School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom
- ⁴⁷ INFN Laboratori Nazionali di Frascati, Frascati, Italy
- ⁴⁸ Fakultät für Mathematik und Physik, Albert-Ludwigs-Universität, Freiburg, Germany
- ⁴⁹ Section de Physique, Université de Genève, Geneva, Switzerland
- ⁵⁰ (a) INFN Sezione di Genova; (b) Dipartimento di Fisica, Università di Genova, Genova, Italy
- ⁵¹ (a) E. Andronikashvili Institute of Physics, Iv. Javakishvili Tbilisi State University, Tbilisi; (b) High Energy Physics Institute, Tbilisi State University, Tbilisi, Georgia
- ⁵² II Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen, Germany
- ⁵³ SUPA – School of Physics and Astronomy, University of Glasgow, Glasgow, United Kingdom
- ⁵⁴ II Physikalisches Institut, Georg-August-Universität, Göttingen, Germany
- ⁵⁵ Laboratoire de Physique Subatomique et de Cosmologie, Université Joseph Fourier and CNRS/IN2P3 and Institut National Polytechnique de Grenoble, Grenoble, France
- ⁵⁶ Department of Physics, Hampton University, Hampton, VA, United States
- ⁵⁷ Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge, MA, United States
- ⁵⁸ (a) Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Heidelberg; (b) Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Mannheim, Germany
- ⁵⁹ technische Informatik, Ruprecht-Karls-Universität Heidelberg, Mannheim, Germany
- ⁶⁰ Faculty of Applied Information Science, Hiroshima Institute of Technology, Hiroshima, Japan
- ⁶¹ Department of Physics, Indiana University, Bloomington, IN, United States
- ⁶² Institut für Astro- und Teilchenphysik, Leopold-Franzens-Universität, Innsbruck, Austria
- ⁶³ University of Iowa, Iowa City, IA, United States
- ⁶⁴ Department of Physics and Astronomy, Iowa State University, Ames, IA, United States
- ⁶⁵ Joint Institute for Nuclear Research, JINR Dubna, Dubna, Russia
- ⁶⁶ KEK, High Energy Accelerator Research Organization, Tsukuba, Japan
- ⁶⁷ Graduate School of Science, Kobe University, Kobe, Japan
- ⁶⁸ Faculty of Science, Kyoto University, Kyoto, Japan
- ⁶⁹ Kyoto University of Education, Kyoto, Japan
- ⁷⁰ Department of Physics, Kyushu University, Fukuoka, Japan
- ⁷¹ Instituto de Fisica La Plata, Universidad Nacional de La Plata and CONICET, La Plata, Argentina
- ⁷² Physics Department, Lancaster University, Lancaster, United Kingdom
- ⁷³ (a) INFN Sezione di Lecce; (b) Dipartimento di Matematica e Fisica, Università del Salento, Lecce, Italy
- ⁷⁴ Oliver Lodge Laboratory, University of Liverpool, Liverpool, United Kingdom
- ⁷⁵ Department of Physics, Jožef Stefan Institute and University of Ljubljana, Ljubljana, Slovenia
- ⁷⁶ School of Physics and Astronomy, Queen Mary University of London, London, United Kingdom
- ⁷⁷ Department of Physics, Royal Holloway University of London, Surrey, United Kingdom
- ⁷⁸ Department of Physics and Astronomy, University College London, London, United Kingdom
- ⁷⁹ Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France
- ⁸⁰ Fysiska institutionen, Lunds universitet, Lund, Sweden
- ⁸¹ Departamento de Fisica Teorica C-15, Universidad Autonoma de Madrid, Madrid, Spain
- ⁸² Institut für Physik, Universität Mainz, Mainz, Germany
- ⁸³ School of Physics and Astronomy, University of Manchester, Manchester, United Kingdom
- ⁸⁴ CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France
- ⁸⁵ Department of Physics, University of Massachusetts, Amherst, MA, United States
- ⁸⁶ Department of Physics, McGill University, Montreal, QC, Canada
- ⁸⁷ School of Physics, University of Melbourne, Victoria, Australia
- ⁸⁸ Department of Physics, The University of Michigan, Ann Arbor, MI, United States
- ⁸⁹ Department of Physics and Astronomy, Michigan State University, East Lansing, MI, United States
- ⁹⁰ (a) INFN Sezione di Milano; (b) Dipartimento di Fisica, Università di Milano, Milano, Italy
- ⁹¹ B.I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk, Belarus

- ⁹¹ National Scientific and Educational Centre for Particle and High Energy Physics, Minsk, Belarus
- ⁹² Department of Physics, Massachusetts Institute of Technology, Cambridge, MA, United States
- 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
- 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
- ¹⁰⁷ Budker Institute of Nuclear Physics, SB RAS, Novosibirsk, Russia
- ¹⁰⁸ Department of Physics, New York University, New York, NY, United States
- ¹⁰⁹ Ohio State University, Columbus, OH, United States
- ¹¹⁰ Faculty of Science, Okayama University, Okayama, Japan
- ¹¹¹ Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman, OK, United States
- ¹¹² Department of Physics, Oklahoma State University, Stillwater, OK, United States
- ¹¹³ Palacký University, RCPTM, Olomouc, Czech Republic
- ¹¹⁴ Center for High Energy Physics, University of Oregon, Eugene, OR, United States
- 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
- 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
- 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 Czech Technical University in Prague, Praha, Czech Republic
- ¹²⁷ Faculty of Mathematics and Physics, Charles 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 et aux Energies Alternatives), Gif-sur-Yvette, France
- ¹³⁷ Santa Cruz Institute for Particle Physics, University of California Santa Cruz, Santa Cruz, CA, United States
- ¹³⁸ Department of Physics, University of Washington, Seattle, WA, United States
- 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
- 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
- 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
- ¹⁶² Centro de Investigaciones, Universidad Antonio Narino, Bogota, Colombia
- ¹⁶³ Department of Physics and Astronomy, University of California Irvine, Irvine, CA, United States
- 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

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