

Search for diphoton events with large missing transverse energy with 36 pb^{-1} of 7 TeV proton–proton collision data with the ATLAS detector

The ATLAS Collaboration*

CERN, 1211 Geneva 23, Switzerland

Received: 4 July 2011 / Revised: 12 August 2011

© CERN for the benefit of the ATLAS collaboration 2011. This article is published with open access at Springerlink.com

Abstract Making use of 36 pb^{-1} of proton–proton collision data at $\sqrt{s} = 7 \text{ TeV}$, the ATLAS Collaboration has performed a search for diphoton events with large missing transverse energy. Observing no excess of events above the Standard Model prediction, a 95% Confidence Level (CL) upper limit is set on the cross section for new physics of $\sigma < 0.38\text{--}0.65 \text{ pb}$ in the context of a generalised model of gauge-mediated supersymmetry breaking (GGM) with a bino-like lightest neutralino, and of $\sigma < 0.18\text{--}0.23 \text{ pb}$ in the context of a specific model with one universal extra dimension (UED). A 95% CL lower limit of 560 GeV, for bino masses above 50 GeV, is set on the GGM gluino mass, while a lower limit of $1/R > 961 \text{ GeV}$ is set on the UED compactification radius R . These limits provide the most stringent tests of these models to date.

1 Introduction

In high-energy proton–proton (pp) collisions, Standard Model (SM) production of diphoton ($\gamma\gamma$) events with two prompt photons and large missing transverse energy (E_T^{miss}) is due primarily to W/Z production with the associated electroweak production of two photons. Taking into account the branching ratios of W/Z decays that include at least one neutrino, the cross sections for events with large transverse energy (E_T) photons are well below 100 fb for 7 TeV pp collisions. In contrast, some new physics models predict much larger $\gamma\gamma + E_T^{\text{miss}}$ yields. This Letter reports on the search for $\gamma\gamma + E_T^{\text{miss}}$ events with 36 pb^{-1} of ATLAS data collected in 2010, extending a prior study [1] performed with 3.1 pb^{-1} . The results are interpreted in the context of a general model of gauge-mediated supersymmetry breaking (GGM) [2–4] as well as a model positing one universal extra dimension (UED) [5, 6].

* e-mail: atlas.publications@cern.ch

2 Supersymmetry

Supersymmetry (SUSY) [7–13] introduces a symmetry between fermions and bosons, resulting in a SUSY partner with identical quantum numbers (differing by half a unit of spin) for each SM particle. At the Large Hadron Collider (LHC), the dominant SUSY process would be the production of pairs of SUSY partners of quarks (squarks) or gluons (gluinos) via the strong interaction. These would then decay through cascades involving other sparticles until the lightest SUSY particle (LSP) is produced. Assuming R -parity conservation [14, 15], the LSP is stable and escapes detection.

No SUSY partners of SM particles have been observed yet, indicating that SUSY must be broken to decouple the masses of the SM particles and their SUSY partners. In gauge-mediated SUSY breaking (GMSB) models [16–22] the LSP is the gravitino \tilde{G} . GMSB experimental signatures are largely determined by the character of the next-to-lightest SUSY particle (NLSP), which for most of the GMSB parameter space is the lightest neutralino $\tilde{\chi}_1^0$. Should this neutralino be the SUSY partner of the U(1) gauge boson (the “bino”), the final decay in the cascade is dominated by $\tilde{\chi}_1^0 \rightarrow \gamma\tilde{G}$, with two cascades per event, leading to a final state $\gamma\gamma + E_T^{\text{miss}} + X$, where E_T^{miss} results from the escaping gravitinos and X represents SM particles emitted in the prompt cascade decays.

Previous searches for GMSB [23, 24] were performed using a minimal GMSB model [25]. To reduce the number of free parameters in this model, several assumptions are made, including gaugino mass unification. These assumptions lead to a mass hierarchy in which squarks and gluinos are much heavier than the lightest neutralino and chargino. For example, the current lower limit on the minimal GMSB neutralino mass of 175 GeV [24], based on the assumption of direct production of charginos and neutralinos and obtained

for the large integrated luminosity accumulated at the Tevatron, corresponds to gluino and squark mass limits in the TeV range. The data analysed in this Letter have a limited sensitivity to the minimal GMSB model and do not improve upon the current Tevatron limits.

In the following a GGM SUSY model [2–4] is considered for which the gluino and neutralino masses are treated as free parameters. The other sparticle masses were fixed to ~ 1.5 TeV, leading to a dominant production mode at $\sqrt{s} = 7$ TeV of a pair of gluinos that would decay via cascades into the neutralino NLSP. The NLSP was taken to be the bino-like neutralino, decaying promptly ($c\tau_{\text{NLSP}} < 0.1$ mm) into a photon and a gravitino. The branching fraction to $\gamma\tilde{G}$ is almost 100% for low neutralino masses and approaches $\cos^2\theta_W$ for neutralino masses well above the Z mass. The Higgsino mass term, μ , was set to 1.5 TeV and the ratio of the two Higgs vacuum expectation values, $\tan\beta$, to 2. Similar parameter values were used in the only previous study of this model, in which the CMS experiment excluded signal cross sections between 0.3 and 1.1 pb at 95% Confidence Level (CL) and determined limits on the squark, gluino and neutralino masses [26]. These limits derive from the copious production expected for accessible colour-charged sparticles (squarks, gluinos), and benefit from the increased collision energy even for relatively low integrated luminosity, extending the reach of the LHC beyond that of the current Tevatron data [4].

3 Extra dimensions

UED models [27] postulate the existence of additional spatial dimensions in which all SM particles can propagate, leading to the existence of a series of excitations for each SM particle known as a Kaluza–Klein (KK) tower. This analysis considers the case of a single UED, with compactification radius $R \approx 1$ TeV $^{-1}$. The masses of the states of successive levels in the tower are separated by $\approx 1/R$; for a given KK level, the approximate mass degeneracy of the KK excitations is broken by radiative corrections [28]. The lightest KK particle (LKP) is the KK photon of the first level, denoted γ^* . At the LHC, the main UED process would be the production via the strong interaction of a pair of first-level KK quarks and/or gluons [29], which would decay via cascades involving other KK particles until reaching the LKP at the end of the decay chain. If the UED model is embedded in a larger space with N additional eV $^{-1}$ -sized dimensions accessible only to gravity [30], the LKP could decay gravitationally via $\gamma^* \rightarrow \gamma + G$ [5, 6], where G represents one of a tower of eV-spaced graviton states, leading to a distribution of graviton mass between 0 and $1/R$. With two decay chains per event, the final state would again be $\gamma\gamma + E_{\text{T}}^{\text{miss}} + X$, where $E_{\text{T}}^{\text{miss}}$ results from the escaping gravitons and X represents SM particles emitted in the cascade decays.

The UED model considered here is defined by specifying R and Λ , the ultraviolet cut-off used in the calculation of radiative corrections to the KK masses. This analysis sets Λ such that $\Lambda R = 20$ [28]. For $1/R = 700$ GeV, the masses of the first-level KK photon, quark and gluon are 700, 815 and 865 GeV, respectively [31]. The γ^* mass is insensitive to Λ , while other KK masses typically change by a few percent when varying ΛR in the range 10–30. The gravitational decay widths of the KK particles are set by N and M_D , the Planck scale in the $(4 + N)$ -dimensional theory. For the chosen values of $N = 6$ and $M_D = 5$ TeV, and provided $1/R \lesssim 1$ TeV, the LKP is the only KK particle to have an appreciable rate of gravitational decay. The same parameter values were used in prior searches by D0 and ATLAS. D0 excluded values of $1/R < 477$ GeV at 95% CL [24]. ATLAS analysed 3.1 pb $^{-1}$ of pp collisions data at $\sqrt{s} = 7$ TeV, excluding values of $1/R < 729$ GeV at 95% CL [1].

4 Simulated samples

For the GGM model, the full mass spectrum and the gluino branching ratios and decay widths were calculated for a range of gluino and neutralino masses using SUSPECT 2.41 [32] and SDECAY 1.3 [33]. The SUSY Les Houches Accord files for the model used may be found online [34]. The Monte Carlo (MC) signal samples were produced using PYTHIA 6.423 [35] with MRST2007 LO* [36] parton distribution functions (PDF). Cross sections were calculated at next-to-leading order (NLO) using PROSPINO 2.1 [37]. In the case of the UED model, a range of $1/R$ values was generated using the leading-order (LO) implementation of the UED model in PYTHIA [31]; no NLO calculations of UED processes are currently available. For both sets of samples, the MC10 parameter tune [38] was used. All signal and SM background samples were passed through a GEANT4-based simulation [39] of the ATLAS detector [40] including the simulation of pileup (multiple pp collisions within the same bunch crossing) of approximately 2 events per bunch crossing, similar to that seen in the data. The MC samples were reconstructed with the same algorithms that were used for the data.

5 ATLAS detector

The ATLAS detector [41] is a multi-purpose apparatus with a forward-backward symmetric cylindrical geometry and nearly 4π solid angle coverage. Closest to the beamline are tracking detectors that use layers of silicon-based ($|\eta| < 2.5$) and straw-tube ($|\eta| < 2.0$) detectors,¹ located inside a

¹ATLAS uses a right-handed coordinate system with its origin at the nominal interaction point (IP) in the centre of the detector and the z -

thin superconducting solenoid that provides a 2 T magnetic field, to measure the trajectories of charged particles. The solenoid is surrounded by a hermetic calorimeter system. A lead liquid-argon (LAr) sampling calorimeter is divided into a central barrel calorimeter and two end-cap calorimeters, each housed in a separate cryostat. Fine-granularity LAr electromagnetic (EM) calorimeters provide coverage for $|\eta| < 3.2$ to precisely measure the energy and position of electrons and photons. In the region $|\eta| < 2.5$, the EM calorimeters are segmented into three longitudinal layers. The second layer, in which most of the EM shower energy is deposited, is divided into cells of granularity of $\Delta\eta \times \Delta\phi = 0.025 \times 0.025$, with the first layer segmented with finer granularity [41] to provide rejection of neutral mesons in jets when selecting isolated photons. A presampler, covering $|\eta| < 1.8$, is used to correct for energy lost upstream of the calorimeter. An iron-scintillator tile calorimeter provides hadronic coverage in the range $|\eta| < 1.7$. In the end-caps ($|\eta| > 1.5$), LAr hadronic calorimeters match the outer $|\eta|$ limits of the end-cap EM calorimeters. LAr forward calorimeters provide both EM and hadronic energy measurements, and extend the coverage to $|\eta| < 4.9$, which is required for reliable E_T^{miss} measurements. An extensive muon spectrometer system that incorporates large superconducting toroidal magnets lies outside the calorimeter system.

6 Photon and E_T^{miss} reconstruction

The reconstruction of photons is described in detail in [42]. To select photon candidates, EM calorimeter clusters were required to satisfy several quality criteria and lie outside problematic calorimeter regions. EM calorimeter clusters without any matching track were considered to be unconverted photons; clusters that have a track match were considered to be electrons; clusters matched to a conversion vertex were considered to be converted photons. A conversion vertex is either a vertex that has two electron-like tracks, as determined by transition radiation in the straw-tube tracker, and is consistent with a massless parent object, or one electron-like track that has no track hits in the pixel vertexing layer. Photon candidates were required to be within $|\eta| < 1.81$ and to be outside the transition region $1.37 < |\eta| < 1.52$ between the barrel and the end-cap calorimeters. The analysis used “loose” and “tight” photon selections [42], which include a limit on the fraction of the energy in the hadronic calorimeter as well as requirements

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 $\eta = -\ln \tan(\theta/2)$.

that the transverse width of the shower, measured in the middle layer of the EM calorimeter, be consistent with the narrow width expected for an EM shower. The tight photon selection uses, in addition, shape information from the first sampling layer to distinguish between isolated photons and photons from the decay of neutral mesons. The tight selection is approximately 85% efficient for both unconverted and converted photons while rejecting most of the background from hadronic jets [43].

The reconstruction of E_T^{miss} was based on topological calorimeter clusters [44] with $|\eta| < 4.5$. The cluster energy was calibrated to correct for the non-compensating calorimeter response, energy losses in dead material, and out-of-cluster energies. Rare events with large transverse energies that are unrelated to the collision, concentrated in a few cells, and due mainly to electronic discharges and noise, have been observed. Cuts were applied to eliminate such backgrounds, rejecting fewer than 0.3% of the selected events while having a negligible impact on the GGM and UED signal efficiencies.

7 Data analysis

The data sample was collected during stable beam periods of 7 TeV pp collisions at the LHC, and corresponds to an integrated luminosity of $(36 \pm 1) \text{ pb}^{-1}$. Selected events had to satisfy a trigger requiring either a single EM cluster with $E_T > 14 \text{ GeV}$ during the first 0.5 pb^{-1} of pp collisions or two loose photon candidates with $E_T > 15 \text{ GeV}$ thereafter. Furthermore, they had to contain at least one reconstructed primary vertex consistent with the average beam spot position and with at least five associated tracks. The trigger and vertex requirements are very close to 100% efficient for signal MC events.

Events were retained if they had at least two tight photon candidates, one with $E_T > 30 \text{ GeV}$ and the other with $E_T > 20 \text{ GeV}$. In addition, a photon isolation cut was applied, whereby the E_T in a cone of radius 0.2 in the η - ϕ space around the centre of the cluster, excluding all the cells belonging to the cluster (in a region with a size corresponding to 5×7 cells in $\eta \times \phi$ in the second layer of the EM calorimeter), had to be less than 10% of the transverse energy of the cluster. This requirement has a signal efficiency greater than 93% while rejecting a significant portion of the background from multijet events.

The signal region was defined as $E_T^{\text{miss}} > 125 \text{ GeV}$, chosen to maximise sensitivity to the GGM and UED signal final states.

A total of 762 $\gamma\gamma$ candidate events were observed passing all selection cuts except the E_T^{miss} cut. After the $E_T^{\text{miss}} > 125 \text{ GeV}$ cut, no candidate events survive in the data. The E_T of the leading photon for events in this sample is shown

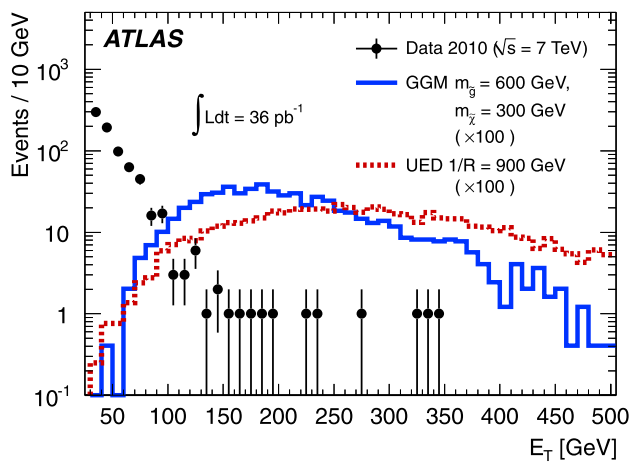


Fig. 1 The E_T spectrum of the leading photon in the $\gamma\gamma$ candidate events (points, statistical uncertainty only) together with the spectra from simulated GGM ($m_{\tilde{g}}/m_{\tilde{\chi}_1^0} = 600/300$ GeV) and UED ($1/R = 900$ GeV) samples, prior to the application of the $E_T^{\text{miss}} > 125$ GeV cut

in Fig. 1. Also shown is the E_T spectrum obtained from GGM MC samples for $m_{\tilde{g}} = 600$ GeV and $m_{\tilde{\chi}_1^0} = 300$ GeV and from UED MC samples for $1/R = 900$ GeV, representing model parameters near the expected exclusion limit.

8 Background estimation

Guided by the procedure developed in [24], the number of large E_T^{miss} diphoton events from SM sources can be grouped into two primary components and estimated with dedicated control samples. The first of these components, referred to as QCD background, arises from a mixture of SM processes that include $\gamma\gamma$ production as well as γ + jet and multijet events with at least one jet misidentified as a photon. The second background component is due to $W + X$ and $t\bar{t}$ events, for which final-state neutrinos produce significant E_T^{miss} . These can pass the selection if an electron from the W or t -quark decay is misidentified as a photon and the second photon is either a real photon ($W\gamma$ events), a jet faking a photon ($W + \text{jets}$ events), or a jet or second electron faking a photon ($t\bar{t}$ events).

In order to estimate the QCD background from γ + jet and multijet events, an independent “QCD $_{\gamma}$ ” control sample, designed to provide a model of the E_T^{miss} response for events with jets faking photons, was defined by selecting events for which at least one of the photon candidates did not pass the tight photon identification. The background from QCD events producing two prompt photons was modeled using the E_T^{miss} spectrum measured in a high-purity sample of $Z \rightarrow ee$ events, with no additional jets, selected by requiring two electrons [44] with $E_T > 30$ GeV and $E_T > 20$ GeV, respectively. Both electrons are required to have $|\eta| < 2.47$,

excluding the transition region $1.37 < |\eta| < 1.52$. In addition, the dielectron invariant mass was required to be consistent with the Z mass. As confirmed by MC simulation, the E_T^{miss} spectrum of the $Z \rightarrow ee$ sample with no additional jets, which is dominated by the calorimeter response to two genuine EM objects, accurately represents the E_T^{miss} response of SM $\gamma\gamma$ events.

The QCD background is the dominant source of observed $\gamma\gamma$ events at low E_T^{miss} and its spectrum, which contains a mixture of events with zero, one or two prompt photons, is expected to lie between the spectra from the QCD $_{\gamma}$ and $Z \rightarrow ee$ control samples. The E_T^{miss} spectrum of the QCD $_{\gamma}$ control sample, which provides the best description of the E_T^{miss} spectrum at low E_T^{miss} , was chosen to model the composite QCD background. The difference between this estimate and that derived from the $Z \rightarrow ee$ template was used to provide an estimate of the systematic uncertainty on the resulting background prediction. The QCD background was normalised to have the same number of events as the $\gamma\gamma$ candidate sample in the region $E_T^{\text{miss}} < 20$ GeV, where contributions from events with genuine E_T^{miss} , such as $W + X$ and $t\bar{t}$ events, can be neglected. It should be noted that a possible background contribution from $Z + X$ events, with the Z boson decaying to neutrinos, would be incorporated within this estimate of the QCD background, since it would enter the signal region through the misidentification of jets as photons.

The QCD $_{\gamma}$ template has one event with E_T^{miss} greater than 125 GeV, whereas the $Z \rightarrow ee$ template has none. Taking into account the expected ratio of events in the portion of the control region with $E_T^{\text{miss}} > 125$ GeV to those in the signal region, this leads to a QCD background prediction of $0.034 \pm 0.034(\text{stat}) \pm 0.034(\text{syst})$ events. The QCD $_{\gamma}$ E_T^{miss} spectrum is shown together with the $\gamma\gamma$ sample in Fig. 2.

The second significant background contribution, from $W + X$ and $t\bar{t}$ events, was estimated via an “electron–photon” control sample composed of events with both a photon and an electron with $E_T > 20$ GeV, with the additional requirement that either the electron or photon has $E_T > 30$ GeV, and scaled by the probability for an electron to be misidentified as a tight photon. This probability was estimated by comparing the rate at which photons and electrons pair with electrons to form an invariant mass consistent with that of the Z boson. The misidentification probability with the selection cuts used in this analysis varies between 5% and 12% as a function of η , since it depends on the amount of material in the inner detector. The E_T^{miss} spectrum for this control sample is shown in Fig. 3, compared to the expected contributions from various background sources. The electron–photon control sample has a significant contribution from $Z \rightarrow ee$ events, for which one electron fakes a photon, and from QCD. Both of these contributions must be subtracted in order to predict the contribution to the E_T^{miss}

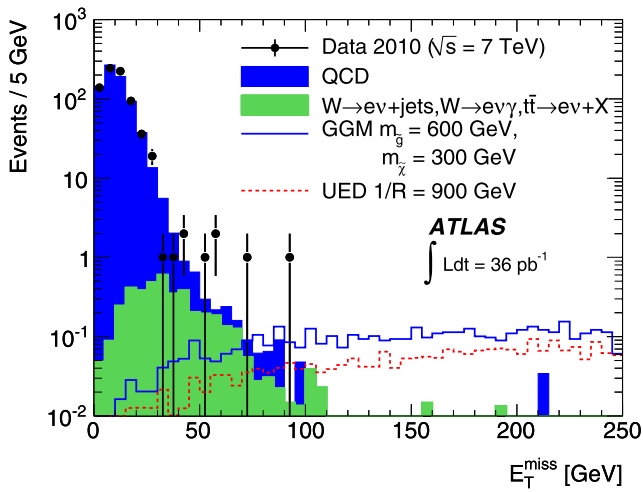


Fig. 2 E_T^{miss} spectra of the $\gamma\gamma$ candidates (points, statistical uncertainty only) and estimated background from the QCD (normalised to the number of $\gamma\gamma$ candidates with $E_T^{\text{miss}} < 20$ GeV) and $W(\rightarrow e\nu) + \text{jets}/\gamma$ and $t\bar{t}(\rightarrow e\nu) + \text{jets}$ sources, together with the spectra from simulated GGM ($m_{\tilde{g}}/m_{\tilde{\chi}_1^0} = 600/300$ GeV) and UED ($1/R = 900$ GeV) samples

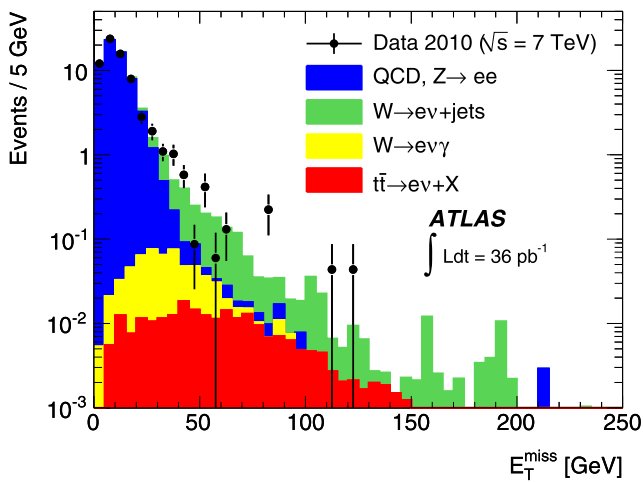


Fig. 3 E_T^{miss} spectrum of the electron–photon control sample (points, statistical uncertainty only), normalised according to the probability for an electron to be misidentified as a tight photon, compared to the sum of the expected background, broken down by component (stacked histograms). For the purpose of this comparison, the expected contribution from $W(\rightarrow e\nu) + \text{jets}/\gamma$ and $t\bar{t}(\rightarrow e\nu) + \text{jets}$ events is taken directly from MC. At low values of E_T^{miss} , the spectrum is dominated by QCD events and $Z \rightarrow ee$ events for which one of the electrons has been misidentified as a photon. These two classes of events are accounted for (blue histogram) by scaling the QCD_γ template to match the interval of the spectrum in the region $E_T^{\text{miss}} < 20$ GeV

distribution from events with genuine E_T^{miss} , such as $W + X$ and $t\bar{t}$ events. The contribution from QCD and $Z \rightarrow ee$ events was estimated by normalizing the QCD_γ E_T^{miss} distribution to the scaled electron–photon E_T^{miss} distribution in the region $E_T^{\text{miss}} < 20$ GeV, as shown in Fig. 3. This distribution was then subtracted from the scaled electron–photon

control sample, yielding a prediction for the contribution to the high- E_T^{miss} diphoton sample from $W + X$ and $t\bar{t}$ events. For $E_T^{\text{miss}} > 30$ GeV, the sample is dominated by events with genuine E_T^{miss} and electrons from $W \rightarrow e\nu$.

No events with $E_T^{\text{miss}} > 125$ GeV were observed in the electron–photon control sample; taking into account the measured electron-to-photon misidentification rate, this yields an upper limit on the background from $W + X$ and $t\bar{t}$ of 0.093 events at 90% CL. Two additional methods were employed to increase the statistical power of the electron–photon control sample. First, the photon selection requirement was loosened for the control sample, leading to an observation of one event in the signal region, and a corresponding background estimate of $0.027 \pm 0.027(\text{stat})$ events. Second, MC samples of the three main components ($W + \text{jets}$, $W + \gamma$ and $t\bar{t}$) were used to model the region where data is limited. The MC samples, which had the same electron and photon selection and scaling applied as for the electron–photon control sample, were normalised to the control sample, after the QCD and $Z \rightarrow ee$ subtraction, in the range $E_T^{\text{miss}} > 40$ GeV (to avoid the QCD and $Z \rightarrow ee$ dominated region at low E_T^{miss}). This MC extrapolation was used to determine the background with $E_T^{\text{miss}} > 125$ GeV, and led to an estimate of $0.057 \pm 0.015(\text{stat})$ background events. The estimate from the loosened-photon control sample provides a lower bound on the systematic uncertainty of this background component that lies 0.030 events below this central value. In addition, a Gaussian distribution with a mean of 0.057 and variance of 0.031 events has 90% of its probability density below 0.093 events, providing an upper bound of 0.031 events above the central value. Thus, a value of ± 0.031 events was chosen for the systematic uncertainty, yielding an estimate of $0.057 \pm 0.015(\text{stat}) \pm 0.031(\text{syst})$ for the background from $W + X$ and $t\bar{t}$ events. Also included in the quoted systematic uncertainty is the uncertainty ($\pm 10\%$) on the electron–photon fake rate and the uncertainty ($\pm 6\%$) on the subtraction of the QCD contribution to the scaled electron–photon control sample derived by replacing the QCD_γ distribution with that of the $Z \rightarrow ee$ sample when performing the subtraction.

In addition to the QCD, $W + X$ and $t\bar{t}$ contributions, a small irreducible background contribution of 0.004 events from $W(\rightarrow e\nu)\gamma\gamma$ and $Z(\rightarrow \nu\nu)\gamma\gamma$ events was estimated directly from MC simulation. Backgrounds due to cosmic-ray and non-collision activity were suppressed through the use of timing and jet-quality cuts and by the primary vertex requirement, and are not expected to contribute significantly in the signal region.

Figure 2 shows the E_T^{miss} spectrum of selected $\gamma\gamma$ candidates, superimposed on the total background prediction. Table 1 summarises the number of observed $\gamma\gamma$ candidates, as well as the expected backgrounds and two representative GGM and UED signal contributions, in several E_T^{miss}

Table 1 Numbers of observed $\gamma\gamma$ candidates, SM background candidates estimated from the QCD_γ and electron–photon control samples and $W(\rightarrow e\nu) + \text{jets}/\gamma$ and $t\bar{t}(\rightarrow e\nu) + \text{jets}$ MC, and expected signal events from GGM with $(m_{\tilde{g}}/m_{\tilde{\chi}_1^0}) = (600/300)$ GeV and UED with $1/R = 900$ GeV, given in various E_T^{miss} ranges. The uncertainties are

E_T^{miss} range [GeV]	Data events	Predicted background events			Expected signal events	
		Total	QCD	$W/t\bar{t}(\rightarrow e\nu) + \text{jets}/\gamma$	GGM	UED
0–20	698	–	–	–	0.05 ± 0.01	0.02 ± 0.01
20–75	63	61.4 ± 2.3	58.3 ± 2.2	2.99 ± 0.12	0.59 ± 0.05	0.25 ± 0.02
75–125	1	0.38 ± 0.08	0.17 ± 0.08	0.19 ± 0.03	0.96 ± 0.06	0.43 ± 0.02
>125	0	0.10 ± 0.04	0.034 ± 0.034	0.057 ± 0.015	4.66 ± 0.14	5.35 ± 0.11

ranges. No indication of an excess at high E_T^{miss} values, where UED and GGM are expected to dominate, is observed. No events are observed in the signal region $E_T^{\text{miss}} > 125$ GeV, compared to an expectation of $0.10 \pm 0.04(\text{stat}) \pm 0.05(\text{syst})$ background events.

9 Systematic uncertainties

The GGM signal efficiency was determined from MC over an area of GGM parameter space that ranges from 400 to 800 GeV for the gluino mass, and from 50 GeV to within 20 GeV of the gluino mass for the bino mass. The efficiency increases smoothly from 5% to 29% for $(m_{\tilde{g}}/m_{\tilde{\chi}_1^0}) = (400/50)$ GeV to $(800/780)$ GeV; for low $m_{\tilde{\chi}_1^0}$, the bulk of the E_T^{miss} distribution lies below the cut of 125 GeV, leading to a less efficient selection. The UED signal efficiency, also determined from MC, increases smoothly from 37% for $1/R = 700$ GeV to 44% for $1/R = 1200$ GeV.

The various relative systematic uncertainties on the extraction of the GGM and UED signal cross sections are summarised in Table 2 for the example GGM and UED samples, including the 3.4% uncertainty on the integrated luminosity [45, 46] and the 0.7% uncertainty on the trigger requirement. Some sources of systematic uncertainty depend on kinematic properties and are expected to differ between GGM and UED. The resulting ranges provided in the following are ordered from low to high in the associated scales, i.e. $m_{\tilde{g}}$, $m_{\tilde{\chi}_1^0}$ and $1/R$ in the case of GGM and UED, respectively.

Uncertainties on the efficiency for reconstructing and identifying the $\gamma\gamma$ pair arise from uncertainties on the impact of photon quality and isolation cuts, the scale of the photon E_T cut, the detailed material composition of the detector and from limitations in the MC description of the photon identification variables. The photon selection efficiency in the MC was tuned to match the efficiency observed in data by shifting the means of the discriminating variables used in

statistical only. The *first row*, for $E_T^{\text{miss}} < 20$ GeV, is the control region used to normalise the QCD background to the number of observed $\gamma\gamma$ candidates. The total predicted background events also include the small contribution from $W(\rightarrow e\nu)\gamma\gamma$ and $Z(\rightarrow \nu\nu)\gamma\gamma$ events

Table 2 Relative systematic uncertainties on the expected signal yield for GGM with $(m_{\tilde{g}}/m_{\tilde{\chi}_1^0}) = (600/300)$ GeV and UED with $1/R = 900$ GeV. No PDF and scale uncertainties are given for the UED case as the cross section is evaluated only to LO. More detail is provided in the text

Source of uncertainty	Uncertainty	
	GGM	UED
Integrated luminosity		3.4%
Trigger		0.7%
Photon identification		3.6%
Photon isolation	3.4%	1.5%
Effect of pileup		1.0%
E_T^{miss} reconstruction and scale	3.7%	1.1%
Signal MC statistics	2.6%	1.2%
Total signal uncertainty	7.6%	5.4%
PDF and scale	25%	–
Total	26%	5.4%

the photon selection, such as the shower widths. The resulting estimate of the photon identification efficiency, tuned in this way, was within 5% of that of the un-tuned MC for all values of E_T and η . A systematic uncertainty was assigned to the tuning according to the uncertainty on the background contamination in the data sample, as well as by replacing the data with a MC sample generated with the inactive material in the region between the interaction point and calorimeter surface increased in a manner that reflects the uncertainty on the actual material distribution. An additional systematic uncertainty on the overall photon selection arises from the uncertainty on the overall amount of material in front of the calorimeter, and has been estimated using the same MC sample. The systematic uncertainty associated with removing photons in problematic regions of the calorimeter was derived by comparing, in MC and data, the fraction of photons within a fiducial region surrounding areas of degraded detector response. Combined in quadrature, these sources

yielded a systematic uncertainty of 3.6% for both GGM and UED.

The systematic uncertainty on the efficiency of the isolation requirement was estimated by comparing distributions of the isolation variable for identified photons, after subtracting the estimated contributions from jets mistakenly identified as photons, with distributions of the isolation variable for MC photons. This yielded an uncertainty between 8.3% and 0.5% (GGM) and of 1.5% (UED). The systematic uncertainty arising from the photon energy scale (known to better than 1.5%) was found to be negligible. The influence of pileup, evaluated by comparing MC samples with different pileup configurations, led to a systematic uncertainty of 1.0%. Systematic effects due to the E_T^{miss} reconstruction, estimated by varying the cluster energies within established uncertainty ranges, and by varying the expected E_T^{miss} resolution between the measured performance and MC expectations, contributed an uncertainty of 10.9% to 0.8% (GGM) and 2.1% to 0.9% (UED) on the signal efficiency. Finally, an uncertainty between 3.8% and 1.1% was attributed to the limited statistics of the MC signal samples. Added in quadrature, the total systematic uncertainty on the signal yield varies between 15.1% and 5.6% (GGM) and 5.8% and 5.4% (UED).

In the case of GGM, the dominant theoretical uncertainties arise from the limited knowledge of the proton PDF and the appropriate factorisation and renormalisation scales. The PDF uncertainties in the GGM cross sections were evaluated by using the CTEQ6.6M PDF error sets [47] in the PROSPINO cross section calculation and are estimated to be between 12% and 25%. The factorisation and renormalisation scales in the NLO PROSPINO calculation were increased and decreased by a factor of two, leading to a systematic uncertainty between 16% and 19%. The total theoretical uncertainty for GGM ranges from 20% to 31%. In the case of UED, NLO calculations of the cross sections are not yet available, leading to arbitrarily large scale errors that artificially degrade the derived limit. Thus, the LO cross sections were used with no assignment of theoretical uncertainties, e.g. PDF or scale uncertainties. The UED results are presented in a way that allows limits to be derived for other assumptions about the size and uncertainty of the UED cross section (see Fig. 4).

10 Extraction of limits

Based on the observation of zero events with $E_T^{\text{miss}} > 125$ GeV and the expected background of $0.10 \pm 0.04(\text{stat}) \pm 0.05(\text{syst})$ events, a 95% CL upper limit was set on the number of events from new physics in the signal region.

Frequentist limits were derived using a profile likelihood ratio $\Lambda(s)$ [48], with the likelihood function of the fit given

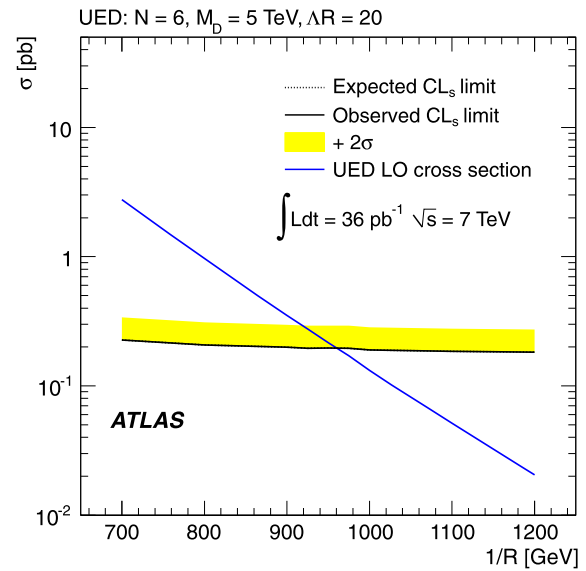


Fig. 4 Expected and observed 95% CL upper limits on the UED production cross section, and the LO theory cross section prediction, as a function of $1/R$. The observed limit, the $\pm 1\sigma$ expected error bands and the -2σ expected error band are degenerate with the expected limit. The UED model parameters are $N = 6$, $M_D = 5$ TeV and $\Delta R = 20$

by $L(n|s, b, \theta) = P_S \times C_{\text{Syst}}$; n represents the number of observed events in data, s the strength of the new physics signal under consideration, b the expected background contribution, and θ the systematic uncertainties. The P_S function is a Poisson probability distribution for the number of signal-region events and C_{Syst} represents the constraints on systematic uncertainties, which are treated as nuisance parameters with a Gaussian probability density. The one-sided exclusion p -values were obtained using the test statistic $\Lambda(s)$ distribution from pseudo-experiments, and the CL_s method was used to exclude possible contributions from the signal [49].

The number of events in the signal region from any scenario of physics beyond the SM (BSM) was found to be less than 3.0 at 95% CL. This number corresponds to 95% CL upper limits on production cross sections of $\sigma < 0.38\text{--}0.65$ pb in the GGM model ($m_{\tilde{\chi}_1^0} = 150$ GeV, $m_{\tilde{g}} = 400\text{--}800$ GeV) and $\sigma < 0.18\text{--}0.23$ pb in the UED model ($1/R = 700\text{--}1200$ GeV), shown as a function of $1/R$ for the case of the UED model in Fig. 4. These upper limits on cross section include systematic uncertainties on the background estimation, event selection and the luminosity.

These results can be interpreted in terms of 95% CL exclusion limits on specific parameters of the two new physics models considered. Figure 4 depicts the lower limit on the curvature parameter $1/R$ in the context of the UED model considered. The observed (expected) 95% CL exclusion region is $1/R < 961$ GeV ($1/R < 961$ GeV). Figure 5 shows the expected and observed lower limit on the GGM gluino mass as a function of the neutralino mass, with all other spar-

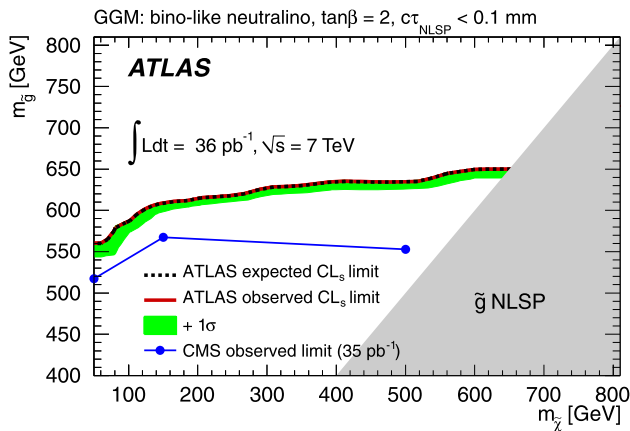


Fig. 5 Expected and observed 95% CL lower limits on the gluino mass as a function of the neutralino mass in the GGM model with a bino-like lightest neutralino as NLSP (the grey area indicates the region where the NLSP is the gluino, which was not considered here). The other sparticle masses are fixed to ~ 1.5 TeV. Further model parameters are $\tan\beta = 2$ and $c\tau_{\text{NLSP}} < 0.1$ mm. The observed limit and the -1σ expected error band are degenerate with the expected limit. CMS lower limits are from [26]

ticle masses, e.g. squarks, set to ~ 1.5 TeV. In addition to the experimental systematic uncertainties, the limit also takes into account theoretical uncertainty on the production cross section. The limit depends only weakly on the neutralino mass, and a lower observed (expected) gluino mass limit of 560 GeV (560 GeV) is obtained for neutralino masses above 50 GeV. For comparison the lower limits from CMS [26] on the gluino mass for neutralino masses of 50, 175 and 500 GeV are shown in the same figure.

The limits presented here, obtained with all squark masses set to ~ 1.5 TeV, are conservative, since values of other strongly charged sparticle (squark) masses that lie close to the excluded gluino mass increase the cross section for pair production of coloured SUSY particles, leading to a more stringent bounds on the gluino mass. The impact of variations in the systematic uncertainty is small: the observed limits change by less than 2 GeV if the magnitude of the systematic uncertainty is allowed to approach 0.

11 Conclusions

A search for $\gamma\gamma$ events with large E_T^{miss} , conducted using a 36 pb^{-1} sample of 7 TeV pp collision data recorded with the ATLAS detector at the LHC, found no evidence of an excess above the SM expectation: zero events were observed with an expected background of $0.10 \pm 0.04(\text{stat}) \pm 0.05(\text{syst})$. The results were used to set a model-independent 95% CL upper limit of 3.0 events on the observed number of diphoton events from new physics in the region $E_T^{\text{miss}} > 125$ GeV. 95% CL upper limits were also set on the production cross section for two particular models of new

physics: $\sigma < 0.38\text{--}0.65$ pb for the GGM model ($m_{\tilde{\chi}_1^0} = 150$ GeV) and $\sigma < 0.18\text{--}0.23$ pb for the UED model. These limits are interpreted in terms of constraints on parameters of specific new physics models. Under the GGM hypothesis, a lower limit on the gluino mass of 560 GeV is determined for bino masses above 50 GeV, while a lower limit of $1/R > 961$ GeV is set on the UED compactification radius R . These limits provide the most stringent tests of these models to date.

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, 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; ARTEMIS, European Union; IN2P3-CNRS, CEA-DSM/IRFU, France; GNAS, Georgia; BMBF, DFG, HGF, MPG and AvH Foundation, Germany; GSRT, Greece; ISF, MINERVA, GIF, DIP and Benoziyo Center, Israel; INFN, Italy; MEXT and JSPS, Japan; CNRST, Morocco; FOM and NWO, Netherlands; RCN, Norway; MNiSW, Poland; GRICES and FCT, Portugal; MERYS (MECTS), Romania; MES of Russia and ROSATOM, Russian Federation; JINR; MSTU, 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 distributed under the terms of the Creative Commons Attribution Noncommercial License which permits any noncommercial use, distribution, and reproduction in any medium, provided the original author(s) and source are credited.

References

1. ATLAS Collaboration, Phys. Rev. Lett. **106**, 121803 (2011). [arXiv:1012.4272](#) [hep-ex]
2. P. Meade, N. Seiberg, D. Shih, Prog. Theor. Phys. Suppl. **177**, 143 (2009). [arXiv:0801.3278](#) [hep-ph]
3. M. Buican, P. Meade, N. Seiberg, D. Shih, J. High Energy Phys. **03**, 016 (2009). [arXiv:0812.3668](#) [hep-ph]
4. J.T. Ruderman, D. Shih, General neutralino NLSPs at the early LHC. [arXiv:1103.6083](#) [hep-ph]
5. C. Macesanu, C. McMullen, S. Nandi, Phys. Lett. B **546**, 253 (2002). [arXiv:hep-ph/0207269](#)
6. C. Macesanu, Int. J. Mod. Phys. A **21**, 2259 (2006). [arXiv:hep-ph/0510418](#)
7. Y.A. Golfand, E.P. Likhman, JETP Lett. **13**, 323 (1971)
8. A. Neveu, J.H. Schwarz, Nucl. Phys. B **31**, 86 (1971)
9. A. Neveu, J.H. Schwarz, Phys. Rev. D **4**, 1109 (1971)
10. P. Ramond, Phys. Rev. D **3**, 2415 (1971)
11. D.V. Volkov, V.P. Akulov, Phys. Lett. B **46**, 109 (1973)

12. J. Wess, B. Zumino, Phys. Lett. B **49**, 52 (1974)
13. J. Wess, B. Zumino, Nucl. Phys. B **70**, 39 (1974)
14. P. Fayet, Phys. Lett. B **69**, 489 (1977)
15. G.R. Farrar, P. Fayet, Phys. Lett. B **76**, 575 (1978)
16. L. Alvarez-Gaume, M. Claudson, M. Wise, Nucl. Phys. B **207**, 96 (1982)
17. M. Dine, W. Fischler, M. Srednicki, Nucl. Phys. B **189**, 575 (1981)
18. S. Dimopoulos, S. Raby, Nucl. Phys. B **192**, 353 (1981)
19. C.R. Nappi, B.A. Ovrut, Phys. Lett. B **113**, 175 (1982)
20. M. Dine, A. Nelson, Phys. Rev. D **48**, 1277 (1993). [arXiv:hep-ph/9303230](#)
21. M. Dine, A. Nelson, Y. Shirman, Phys. Rev. D **51**, 1362 (1995). [hep-ph/9408384](#)
22. M. Dine, A. Nelson, Y. Nir, Y. Shirman, Phys. Rev. D **53**, 2658 (1996). [hep-ph/9507378](#)
23. CDF Collaboration, Phys. Rev. Lett. **104**, 011801 (2010). [arXiv:0910.3606](#) [hep-ex]
24. D0 Collaboration, Phys. Rev. Lett. **105**, 221802 (2010). [arXiv:1008.2133](#) [hep-ex]
25. B.C. Allanach et al., Eur. Phys. J. C **25**, 113 (2002). [arXiv:hep-ph/0202233](#)
26. CMS Collaboration, Search for supersymmetry in pp collisions at $\sqrt{s} = 7$ TeV in events with two photons and missing transverse energy. [arXiv:1103.0953](#) [hep-ex]
27. T. Appelquist, H.-C. Cheng, B.A. Dobrescu, Phys. Rev. D **64**, 035002 (2001). [arXiv:hep-ph/0012100](#)
28. H.-C. Cheng, K.T. Matchev, M. Schmaltz, Phys. Rev. D **66**, 056006 (2002). [arXiv:hep-ph/0205314](#)
29. C. Macesanu, C. McMullen, S. Nandi, Phys. Rev. D **66**, 015009 (2002). [arXiv:hep-ph/0201300](#)
30. A. De Rujula, A. Donini, M. Gavela, S. Rigolin, Phys. Lett. B **482**, 195 (2000). [arXiv:hep-ph/0001335](#)
31. M. ElKacimi, D. Goujdami, H. Przysiezniak, P.Z. Skands, Comput. Phys. Commun. **181**, 122 (2010). [arXiv:0901.4087](#) [hep-ph]
32. A. Djouadi, J.-L. Kneur, G. Moultaka, Comput. Phys. Commun. **176**, 426 (2007). [arXiv:hep-ph/0211331](#)
33. M. Muhlleitner, A. Djouadi, Y. Mambrini, Comput. Phys. Commun. **168**, 46 (2005). [arXiv:hep-ph/0311167](#)
34. <http://hepdata.cedar.ac.uk/resource/atlas/>
35. T. Sjostrand, S. Mrenna, P. Skands, J. High Energy Phys. **05**, 026 (2006). [arXiv:hep-ph/0603175](#)
36. A. Sherstnev, R.S. Thorne, Eur. Phys. J. C **55**, 553 (2008). [arXiv:0711.2473](#) [hep-ph]
37. W. Beenakker, R. Hopker, M. Spira, P. Zerwas, Nucl. Phys. B **492**, 51 (1997). [arXiv:hep-ph/9610490](#)
38. The ATLAS Collaboration, Charged particle multiplicities in pp interactions at $\sqrt{s} = 0.9$ and 7 TeV in a diffractive limited phase space measured with the ATLAS Detector at the LHC and a new PYTHIA6 tune. ATLAS-CONF-2010-031, July, 2010. <http://cdsweb.cern.ch/record/1277665>
39. S. Agostinelli et al. (GEANT4 Collaboration), Nucl. Instrum. Methods A **506**, 250 (2003)
40. ATLAS Collaboration, Eur. Phys. J. C **70**, 823 (2010). [arXiv:1005.4568](#) [physics.ins-det]
41. ATLAS Collaboration, J. Instrum. **3**, S08003 (2008)
42. ATLAS Collaboration, Phys. Rev. D **83**, 052005 (2011). [arXiv:1012.4389](#) [hep-ex]
43. The ATLAS Collaboration, Expected photon performance in the ATLAS experiment. ATL-PHYS-PUB-2011-007, Apr, 2011. <http://cdsweb.cern.ch/record/1345329>
44. ATLAS Collaboration, J. High Energy Phys. **1012**, 060 (2010). [arXiv:1010.2130](#) [hep-ex]
45. ATLAS Collaboration, Eur. Phys. J. C **71**, 1630 (2011). [arXiv:1101.2185](#) [hep-ex]
46. The ATLAS Collaboration, Updated luminosity determination in pp collisions at $\sqrt{s} = 7$ TeV using the ATLAS detector. ATLAS-CONF-2010-011, Mar, 2011. <http://cdsweb.cern.ch/record/1334563>
47. D. Stump, J. Huston, J. Pumplin, W.-K. Tung, H. Lai et al., J. High Energy Phys. **0310**, 046 (2003). [arXiv:hep-ph/0303013](#)
48. G. Cowan, K. Cranmer, E. Gross, O. Vitells, Eur. Phys. J. C **71**, 1554 (2011). [arXiv:1007.1727](#) [physics.data-an]
49. A.L. Read, J. Phys. G **28**, 2693 (2002)

The ATLAS Collaboration

G. Aad⁴⁸, B. Abbott¹¹¹, J. Abdallah¹¹, A.A. Abdelalim⁴⁹, A. Abdesselam¹¹⁸, O. Abdinov¹⁰, B. Abi¹¹², M. Abolins⁸⁸, H. Abramowicz¹⁵³, H. Abreu¹¹⁵, E. Acerbi^{89a,89b}, B.S. Acharya^{164a,164b}, D.L. Adams²⁴, T.N. Addy⁵⁶, J. Adelman¹⁷⁵, M. Aderholz⁹⁹, S. Adomeit⁹⁸, P. Adragna⁷⁵, T. Adye¹²⁹, S. Aefsky²², J.A. Aguilar-Saavedra^{124b,a}, M. Aharrouche⁸¹, S.P. Ahlen²¹, F. Ahles⁴⁸, A. Ahmad¹⁴⁸, M. Ahsan⁴⁰, G. Aielli^{133a,133b}, T. Akdogan^{18a}, T.P.A. Åkesson⁷⁹, G. Akimoto¹⁵⁵, A.V. Akimov⁹⁴, A. Akiyama⁶⁷, M.S. Alam¹, M.A. Alam⁷⁶, J. Albert¹⁶⁹, S. Albrand⁵⁵, M. Aleksa²⁹, I.N. Aleksandrov⁶⁵, F. Alessandria^{89a}, C. Alexa^{25a}, G. Alexander¹⁵³, G. Alexandre⁴⁹, T. Alexopoulos⁹, M. Alhroob²⁰, M. Aliev¹⁵, G. Alimonti^{89a}, J. Alison¹²⁰, M. Aliyev¹⁰, P.P. Allport⁷³, S.E. Allwood-Spiers⁵³, J. Almond⁸², A. Aloisio^{102a,102b}, R. Alon¹⁷¹, A. Alonso⁷⁹, M.G. Alvigi^{102a,102b}, K. Amako⁶⁶, P. Amaral²⁹, C. Amelung²², V.V. Ammosov¹²⁸, A. Amorim^{124a,b}, G. Amorós¹⁶⁷, N. Amram¹⁵³, C. Anastopoulos²⁹, N. Andari¹¹⁵, T. Andeen³⁴, C.F. Anders²⁰, K.J. Anderson³⁰, A. Andreazza^{89a,89b}, V. Andrei^{58a}, M.-L. Andrieux⁵⁵, X.S. Anduaga⁷⁰, A. Angerami³⁴, F. Anghinolfi²⁹, N. Anjos^{124a}, A. Anovi⁴⁷, A. Antonaki⁸, M. Antonelli⁴⁷, A. Antonov⁹⁶, J. Antos^{144b}, F. Anulli^{132a}, S. Aoun⁸³, L. Aperio Bella⁴, R. Apolle^{118,c},

G. Arabidze⁸⁸, I. Aracena¹⁴³, Y. Arai⁶⁶, A.T.H. Arce⁴⁴, J.P. Archambault²⁸, S. Arfaoui^{29,d}, J.-F. Arguin¹⁴, E. Arik^{18a,*}, M. Arik^{18a}, A.J. Armbruster⁸⁷, O. Arnaez⁸¹, C. Arnault¹¹⁵, A. Artamonov⁹⁵, G. Artoni^{132a,132b}, D. Arutinov²⁰, S. Asai¹⁵⁵, R. Asfandiyarov¹⁷², S. Ask²⁷, B. Åsman^{146a,146b}, L. Asquith⁵, K. Assamagan²⁴, A. Astbury¹⁶⁹, A. Astvatsatourov⁵², G. Atoian¹⁷⁵, B. Aubert⁴, B. Auerbach¹⁷⁵, E. Auge¹¹⁵, K. Augsten¹²⁷, M. Aourousseau^{145a}, N. Austin⁷³, R. Avramidou⁹, D. Axen¹⁶⁸, C. Ay⁵⁴, G. Azuelos^{93,e}, Y. Azuma¹⁵⁵, M.A. Baak²⁹, G. Baccaglioni^{89a}, C. Bacci^{134a,134b}, A.M. Bach¹⁴, H. Bachacou¹³⁶, K. Bachas²⁹, G. Bachy²⁹, M. Backes⁴⁹, M. Backhaus²⁰, E. Badescu^{25a}, P. Bagnaia^{132a,132b}, S. Bahinipati², Y. Bai^{32a}, D.C. Bailey¹⁵⁸, T. Bain¹⁵⁸, J.T. Baines¹²⁹, O.K. Baker¹⁷⁵, M.D. Baker²⁴, S. Baker⁷⁷, F. Baltasar Dos Santos Pedrosa²⁹, E. Banas³⁸, P. Banerjee⁹³, Sw. Banerjee¹⁷², D. Banfi²⁹, A. Bangert¹³⁷, V. Bansal¹⁶⁹, H.S. Bansil¹⁷, L. Barak¹⁷¹, S.P. Baranov⁹⁴, A. Barashkou⁶⁵, A. Barbaro Galtieri¹⁴, T. Barber²⁷, E.L. Barberio⁸⁶, D. Barberis^{50a,50b}, M. Barbero²⁰, D.Y. Bardin⁶⁵, T. Barillari⁹⁹, M. Barisonzi¹⁷⁴, T. Barklow¹⁴³, N. Barlow²⁷, B.M. Barnett¹²⁹, R.M. Barnett¹⁴, A. Baroncelli^{134a}, G. Barone⁴⁹, A.J. Barr¹¹⁸, F. Barreiro⁸⁰, J. Barreiro Guimarães da Costa⁵⁷, P. Barrillon¹¹⁵, R. Bartoldus¹⁴³, A.E. Barton⁷¹, D. Bartsch²⁰, V. Bartsch¹⁴⁹, R.L. Bates⁵³, L. Batkova^{144a}, J.R. Batley²⁷, A. Battaglia¹⁶, M. Battistin²⁹, G. Battistoni^{89a}, F. Bauer¹³⁶, H.S. Bawa^{143,f}, B. Beare¹⁵⁸, T. Beau⁷⁸, P.H. Beauchemin¹¹⁸, R. Beccherle^{50a}, P. Bechtel⁴¹, H.P. Beck¹⁶, M. Beckingham⁴⁸, K.H. Becks¹⁷⁴, A.J. Beddall^{18c}, A. Beddall^{18c}, S. Bedikian¹⁷⁵, V.A. Bednyakov⁶⁵, C.P. Bee⁸³, M. Begel²⁴, S. Behar Harpaz¹⁵², P.K. Behera⁶³, M. Beimforde⁹⁹, C. Belanger-Champagne⁸⁵, P.J. Bell⁴⁹, W.H. Bell⁴⁹, G. Bella¹⁵³, L. Bellagamba^{19a}, F. Bellina²⁹, M. Bellomo^{119a}, A. Belloni⁵⁷, O. Beloborodova¹⁰⁷, K. Belotskiy⁹⁶, O. Beltramello²⁹, S. Ben Ami¹⁵², O. Benary¹⁵³, D. Bencheekroun^{135a}, C. Benchouk⁸³, M. Bendel⁸¹, B.H. Benedict¹⁶³, N. Benekos¹⁶⁵, Y. Benhammou¹⁵³, D.P. Benjamin⁴⁴, M. Benoit¹¹⁵, J.R. Bensinger²², K. Benslama¹³⁰, S. Bentvelsen¹⁰⁵, D. Berge²⁹, E. Bergeaas Kuutmann⁴¹, N. Berger⁴, F. Berghaus¹⁶⁹, E. Berglund⁴⁹, J. Beringer¹⁴, K. Bernadet⁸³, P. Bernat⁷⁷, R. Bernhard⁴⁸, C. Bernius²⁴, T. Berry⁷⁶, A. Bertin^{19a,19b}, F. Bertinelli²⁹, F. Bertolucci^{122a,122b}, M.I. Besana^{89a,89b}, N. Besson¹³⁶, S. Bethke⁹⁹, W. Bhimji⁴⁵, R.M. Bianchi²⁹, M. Bianco^{72a,72b}, O. Biebel⁹⁸, S.P. Bieniek⁷⁷, J. Biesiada¹⁴, M. Biglietti^{134a,134b}, H. Bilokon⁴⁷, M. Bindi^{19a,19b}, S. Binet¹¹⁵, A. Bingul^{18c}, C. Bini^{132a,132b}, C. Biscarat¹⁷⁷, U. Bitenc⁴⁸, K.M. Black²¹, R.E. Blair⁵, J.-B. Blanchard¹¹⁵, G. Blanchot²⁹, T. Blazek^{144a}, C. Blocker²², J. Blocki³⁸, A. Blondel⁴⁹, W. Blum⁸¹, U. Blumenschein⁵⁴, G.J. Bobbink¹⁰⁵, V.B. Bobrovnikov¹⁰⁷, S.S. Bocchetta⁷⁹, A. Bocci⁴⁴, C.R. Boddy¹¹⁸, M. Boehler⁴¹, J. Boek¹⁷⁴, N. Boelaert³⁵, S. Böser⁷⁷, J.A. Bogaerts²⁹, A. Bogdanchikov¹⁰⁷, A. Bogouch^{90,*}, C. Bohm^{146a}, V. Boisvert⁷⁶, T. Bold^{163,g}, V. Boldea^{25a}, N.M. Bolnet¹³⁶, M. Bona⁷⁵, V.G. Bondarenko⁹⁶, M. Boonekamp¹³⁶, G. Boorman⁷⁶, C.N. Booth¹³⁹, S. Bordini⁷⁸, C. Borer¹⁶, A. Borisov¹²⁸, G. Borissov⁷¹, I. Borjanovic^{12a}, S. Borroni^{132a,132b}, K. Bos¹⁰⁵, D. Boscherini^{19a}, M. Bosman¹¹, H. Boterenbrood¹⁰⁵, D. Botterill¹²⁹, J. Bouchami⁹³, J. Boudreau¹²³, E.V. Bouhova-Thacker⁷¹, C. Boulahouache¹²³, C. Bourdarios¹¹⁵, N. Bousson⁸³, A. Boveia³⁰, J. Boyd²⁹, I.R. Boyko⁶⁵, N.I. Bozhko¹²⁸, I. Bozovic-Jelisavcic^{12b}, J. Bracinik¹⁷, A. Braem²⁹, P. Branchini^{134a}, G.W. Brandenburg⁵⁷, A. Brandt⁷, G. Brandt¹⁵, O. Brandt⁵⁴, U. Bratzler¹⁵⁶, B. Brau⁸⁴, J.E. Brau¹¹⁴, H.M. Braun¹⁷⁴, B. Brelief¹⁵⁸, J. Bremer²⁹, R. Brenner¹⁶⁶, S. Bressler¹⁵², D. Breton¹¹⁵, D. Britton⁵³, F.M. Brochu²⁷, I. Brock²⁰, R. Brock⁸⁸, T.J. Brodbeck⁷¹, E. Brodet¹⁵³, F. Broggi^{89a}, C. Bromberg⁸⁸, G. Brooijmans³⁴, W.K. Brooks^{31b}, G. Brown⁸², H. Brown⁷, P.A. Bruckman de Renstrom³⁸, D. Bruncko^{144b}, R. Bruneliere⁴⁸, S. Brunet⁶¹, A. Bruni^{19a}, G. Bruni^{19a}, M. Bruschi^{19a}, T. Buanes¹³, F. Bucci⁴⁹, J. Buchanan¹¹⁸, N.J. Buchanan², P. Buchholz¹⁴¹, R.M. Buckingham¹¹⁸, A.G. Buckley⁴⁵, S.I. Buda^{25a}, I.A. Budagov⁶⁵, B. Budick¹⁰⁸, V. Büscher⁸¹, L. Bugge¹¹⁷, D. Buiara-Clark¹¹⁸, O. Bulekov⁹⁶, M. Bunse⁴², T. Buran¹¹⁷, H. Burckhart²⁹, S. Burdin⁷³, T. Burgess¹³, S. Burke¹²⁹, E. Busato³³, P. Bussey⁵³, C.P. Buszello¹⁶⁶, F. Butin²⁹, B. Butler¹⁴³, J.M. Butler²¹, C.M. Buttar⁵³, J.M. Butterworth⁷⁷, W. Buttinger²⁷, T. Byatt⁷⁷, S. Cabrera Urbán¹⁶⁷, D. Caforio^{19a,19b}, O. Cakir^{3a}, P. Calafiura¹⁴, G. Calderini⁷⁸, P. Calfayan⁹⁸, R. Calkins¹⁰⁶, L.P. Caloba^{23a}, R. Caloi^{132a,132b}, D. Calvet³³, S. Calvet³³, R. Camacho Toro³³, P. Camarri^{133a,133b}, M. Cambiaghi^{119a,119b}, D. Cameron¹¹⁷, S. Campana²⁹, M. Campanelli⁷⁷, V. Canale^{102a,102b}, F. Canelli³⁰, A. Canepa^{159a}, J. Cantero⁸⁰, L. Capasso^{102a,102b}, M.D.M. Capeans Garrido²⁹, I. Caprini^{25a}, M. Caprini^{25a}, D. Capriotti⁹⁹, M. Capua^{36a,36b}, R. Caputo¹⁴⁸, C. Caramarcu^{25a}, R. Cardarelli^{133a}, T. Carli²⁹, G. Carlino^{102a}, L. Carminati^{89a,89b}, B. Caron^{159a}, S. Caron⁴⁸, G.D. Carrillo Montoya¹⁷², A.A. Carter⁷⁵, J.R. Carter²⁷, J. Carvalho^{124a,h}, D. Casadei¹⁰⁸, M.P. Casado¹¹, M. Cascella^{122a,122b}, C. Caso^{50a,50b,*}, A.M. Castaneda Hernandez¹⁷², E. Castaneda-Miranda¹⁷², V. Castillo Gimenez¹⁶⁷, N.F. Castro^{124a}, G. Cataldi^{72a}, F. Cataneo²⁹, A. Catinaccio²⁹, J.R. Catmore⁷¹, A. Cattai²⁹, G. Cattani^{133a,133b}, S. Caughron⁸⁸, D. Cauz^{164a,164c}, P. Cavalleri⁷⁸, D. Cavalli^{89a}, M. Cavallin-Sforza¹¹, V. Cavasinni^{122a,122b}, F. Ceradini^{134a,134b}, A.S. Cerqueira^{23a}, A. Cerri²⁹, L. Cerrito⁷⁵, F. Cerutti⁴⁷, S.A. Cetin^{18b}, F. Cevenini^{102a,102b}, A. Chafaq^{135a}, D. Chakraborty¹⁰⁶, K. Chan², B. Chapeau⁸⁵, J.D. Chapman²⁷, J.W. Chapman⁸⁷, E. Chareyre⁷⁸, D.G. Charlton¹⁷, V. Chavda⁸², C.A. Chavez Barajas²⁹, S. Cheatham⁸⁵, S. Chekanov⁵, S.V. Chekulaev^{159a}, G.A. Chelkov⁶⁵, M.A. Chelstowska¹⁰⁴, C. Chen⁶⁴, H. Chen²⁴, S. Chen^{32c}, T. Chen^{32c}, X. Chen¹⁷², S. Cheng^{32a}, A. Cheplakov⁶⁵, V.F. Chepurinov⁶⁵, R. Cherkaoui El Moursli^{135e}, V. Chernyatin²⁴, E. Cheu⁶, S.L. Cheung¹⁵⁸, L. Chevalier¹³⁶, G. Chiefari^{102a,102b}, L. Chikovani⁵¹, J.T. Childers^{58a}, A. Chilingarov⁷¹, G. Chiodini^{72a}, M.V. Chizhov⁶⁵, G. Choudalakis³⁰, S. Chouridou¹³⁷, I.A. Christidi⁷⁷, A. Christov⁴⁸, D. Chromek-Burckhart²⁹, M.L. Chu¹⁵¹, J. Chudoba¹²⁵, G. Ciapetti^{132a,132b}

K. Ciba³⁷, A.K. Ciftci^{3a}, R. Ciftci^{3a}, D. Cinca³³, V. Cindro⁷⁴, M.D. Ciobotaru¹⁶³, C. Ciocca^{19a,19b}, A. Ciocio¹⁴, M. Cirilli⁸⁷, M. Ciubancan^{25a}, A. Clark⁴⁹, P.J. Clark⁴⁵, W. Cleland¹²³, J.C. Clemens⁸³, B. Clement⁵⁵, C. Clement^{146a,146b}, R.W. Clift¹²⁹, Y. Coadou⁸³, M. Cobal^{164a,164c}, A. Coccaro^{50a,50b}, J. Cochran⁶⁴, P. Coe¹¹⁸, J.G. Cogan¹⁴³, J. Coggeshall¹⁶⁵, E. Cogneras¹⁷⁷, C.D. Cojocar²⁸, J. Colas⁴, A.P. Colijn¹⁰⁵, C. Collard¹¹⁵, N.J. Collins¹⁷, C. Collins-Tooth⁵³, J. Collot⁵⁵, G. Colon⁸⁴, P. Conde Muiño^{124a}, E. Coniavitis¹¹⁸, M.C. Conidi¹¹, M. Consonni¹⁰⁴, V. Consorti⁴⁸, S. Constantinescu^{25a}, C. Conta^{119a,119b}, F. Conventi^{102a,i}, J. Cook²⁹, M. Cooke¹⁴, B.D. Cooper⁷⁷, A.M. Cooper-Sarkar¹¹⁸, N.J. Cooper-Smith⁷⁶, K. Copic³⁴, T. Cornelissen^{50a,50b}, M. Corradi^{19a}, F. Corriveau^{85j}, A. Cortes-Gonzalez¹⁶⁵, G. Cortiana⁹⁹, G. Costa^{89a}, M.J. Costa¹⁶⁷, D. Costanzo¹³⁹, T. Costin³⁰, D. Côté²⁹, R. Coura Torres^{23a}, L. Courneyea¹⁶⁹, G. Cowan⁷⁶, C. Cowden²⁷, B.E. Cox⁸², K. Cranmer¹⁰⁸, F. Crescioli^{122a,122b}, M. Cristinziani²⁰, G. Crosetti^{36a,36b}, R. Crupi^{72a,72b}, S. Crépe-Renaudin⁵⁵, C.-M. Cuciuc^{25a}, C. Cuenca Almenar¹⁷⁵, T. Cuhadar Donszelmann¹³⁹, S. Cuneo^{50a,50b}, M. Curatolo⁴⁷, C.J. Curtis¹⁷, P. Cwetanski⁶¹, H. Czirr¹⁴¹, Z. Czynzula¹¹⁷, S. D'Auria⁵³, M. D'Onofrio⁷³, A. D'Orazio^{132a,132b}, P.V.M. Da Silva^{23a}, C. Da Via⁸², W. Dabrowski³⁷, T. Dai⁸⁷, C. Dallapiccola⁸⁴, M. Dam³⁵, M. Dameri^{50a,50b}, D.S. Damiani¹³⁷, H.O. Daniels²⁹, D. Dannheim⁹⁹, V. Dao⁴⁹, G. Darbo^{50a}, G.L. Darlea^{25b}, C. Daum¹⁰⁵, J.P. Dauvergne²⁹, W. Davey⁸⁶, T. Davidek¹²⁶, N. Davidson⁸⁶, R. Davidson⁷¹, E. Davies^{118,c}, M. Davies⁹³, A.R. Davison⁷⁷, Y. Davygora^{58a}, E. Dawe¹⁴², I. Dawson¹³⁹, J.W. Dawson^{5,*}, R.K. Daya³⁹, K. De⁷, R. de Asmundis^{102a}, S. De Castro^{19a,19b}, P.E. De Castro Faria Salgado²⁴, S. De Cecco⁷⁸, J. de Graat⁹⁸, N. De Groot¹⁰⁴, P. de Jong¹⁰⁵, C. De La Taille¹¹⁵, H. De la Torre⁸⁰, B. De Lotto^{164a,164c}, L. De Mora⁷¹, L. De Nooij¹⁰⁵, M. De Oliveira Branco²⁹, D. De Pedis^{132a}, P. de Saintignon⁵⁵, A. De Salvo^{132a}, U. De Sanctis^{164a,164c}, A. De Santo¹⁴⁹, J.B. De Vivie De Regie¹¹⁵, S. Dean⁷⁷, D.V. Dedovich⁶⁵, J. Degenhardt¹²⁰, M. Dehchar¹¹⁸, M. Deile⁹⁸, C. Del Papa^{164a,164c}, J. Del Peso⁸⁰, T. Del Prete^{122a,122b}, M. Deliyergiyev⁷⁴, A. Dell'Acqua²⁹, L. Dell'Asta^{89a,89b}, M. Della Pietra^{102a,i}, D. della Volpe^{102a,102b}, M. Delmastro²⁹, P. Delpierre⁸³, N. Delruelle²⁹, P.A. Delsart⁵⁵, C. Deluca¹⁴⁸, S. Demers¹⁷⁵, M. Demichev⁶⁵, B. Demirkoz^{11,k}, J. Deng¹⁶³, S.P. Denisov¹²⁸, D. Derendarz³⁸, J.E. Derkaoui^{135d}, F. Derue⁷⁸, P. Dervan⁷³, K. Desch²⁰, E. Devetak¹⁴⁸, P.O. Deviveiros¹⁵⁸, A. Dewhurst¹²⁹, B. DeWilde¹⁴⁸, S. Dhaliwal¹⁵⁸, R. Dhullipudi^{24,1}, A. Di Ciaccio^{133a,133b}, L. Di Ciaccio⁴, A. Di Girolamo²⁹, B. Di Girolamo²⁹, S. Di Luise^{134a,134b}, A. Di Mattia⁸⁸, B. Di Micco²⁹, R. Di Nardo^{133a,133b}, A. Di Simone^{133a,133b}, R. Di Sipio^{19a,19b}, M.A. Diaz^{31a}, F. Diblen^{18c}, E.B. Diehl⁸⁷, J. Dietrich⁴¹, T.A. Dietzsch^{58a}, S. Diglio¹¹⁵, K. Dindar Yagci³⁹, J. Dingfelder²⁰, C. Dionisi^{132a,132b}, P. Dita^{25a}, S. Dita^{25a}, F. Dittus²⁹, F. Djama⁸³, T. Djobava⁵¹, M.A.B. do Vale^{23a}, A. Do Valle Wemans^{124a}, T.K.O. Doan⁴, M. Dobbs⁸⁵, R. Dobinson^{29,*}, D. Dobos⁴², E. Dobson²⁹, M. Dobson¹⁶³, J. Dodd³⁴, C. Doglioni¹¹⁸, T. Doherty⁵³, Y. Doi^{66,*}, J. Dolejsi¹²⁶, I. Dolenc⁷⁴, Z. Dolezal¹²⁶, B.A. Dolgoshein^{96,*}, T. Dohmae¹⁵⁵, M. Donadelli^{23b}, M. Donega¹²⁰, J. Donini⁵⁵, J. Dopke²⁹, A. Doria^{102a}, A. Dos Anjos¹⁷², M. Dosiil¹¹, A. Dotti^{122a,122b}, M.T. Dova⁷⁰, J.D. Dowell¹⁷, A.D. Doxiadis¹⁰⁵, A.T. Doyle⁵³, Z. Drasal¹²⁶, J. Drees¹⁷⁴, N. Dressnandt¹²⁰, H. Drevermann²⁹, C. Driouichi³⁵, M. Dris⁹, J. Dubbert⁹⁹, T. Dubbs¹³⁷, S. Dube¹⁴, E. Duchovni¹⁷¹, G. Duckeck⁹⁸, A. Dudarev²⁹, F. Dudziak⁶⁴, M. Dührssen²⁹, I.P. Duerdoth⁸², L. Dufлот¹¹⁵, M.-A. Dufour⁸⁵, M. Dunford²⁹, H. Duran Yildiz^{3b}, R. Duxfield¹³⁹, M. Dwuznik³⁷, F. Dydak²⁹, D. Dzahini⁵⁵, M. Düren⁵², W.L. Ebenstein⁴⁴, J. Ebke⁹⁸, S. Eckert⁴⁸, S. Eckweiler⁸¹, K. Edmonds⁸¹, C.A. Edwards⁷⁶, N.C. Edwards⁵³, W. Ehrenfeld⁴¹, T. Ehrich⁹⁹, T. Eifert²⁹, G. Eigen¹³, K. Einsweiler¹⁴, E. Eisenhandler⁷⁵, T. Ekelof¹⁶⁶, M. El Kacimi^{135c}, M. Ellert¹⁶⁶, S. Elles⁴, F. Ellinghaus⁸¹, K. Ellis⁷⁵, N. Ellis²⁹, J. Elmsheuser⁹⁸, M. Elsing²⁹, R. Ely¹⁴, D. Emeliyanov¹²⁹, R. Engelmann¹⁴⁸, A. Engl⁹⁸, B. Epp⁶², A. Eppig⁸⁷, J. Erdmann⁵⁴, A. Ereditato¹⁶, D. Eriksson^{146a}, J. Ernst¹, M. Ernst²⁴, J. Ernwein¹³⁶, D. Errede¹⁶⁵, S. Errede¹⁶⁵, E. Ertel⁸¹, M. Escalier¹¹⁵, C. Escobar¹⁶⁷, X. Espinal Curull¹¹, B. Esposito⁴⁷, F. Etienne⁸³, A.I. Etiennevire¹³⁶, E. Etzion¹⁵³, D. Evangelakou⁵⁴, H. Evans⁶¹, L. Fabbri^{19a,19b}, C. Fabre²⁹, R.M. Fakhruddinov¹²⁸, S. Falciano^{132a}, Y. Fang¹⁷², M. Fanti^{89a,89b}, A. Farbin⁷, A. Farilla^{134a}, J. Farley¹⁴⁸, T. Farooque¹⁵⁸, S.M. Farrington¹¹⁸, P. Farthouat²⁹, P. Fassnacht²⁹, D. Fassouliotis⁸, B. Fatholahzadeh¹⁵⁸, A. Favareto^{89a,89b}, L. Fayard¹¹⁵, S. Fazio^{36a,36b}, R. Febbraro³³, P. Federic^{144a}, O.L. Fedin¹²¹, W. Fedorko⁸⁸, M. Fehling-Kaschek⁴⁸, L. Felgioni⁸³, D. Fellmann⁵, C.U. Felzmann⁸⁶, C. Feng^{32d}, E.J. Feng³⁰, A.B. Fenyuk¹²⁸, J. Ferencei^{144b}, J. Ferland⁹³, W. Fernando¹⁰⁹, S. Ferrag⁵³, J. Ferrando⁵³, V. Ferrara⁴¹, A. Ferrari¹⁶⁶, P. Ferrari¹⁰⁵, R. Ferrari^{119a}, A. Ferrer¹⁶⁷, M.L. Ferrer⁴⁷, D. Ferrere⁴⁹, C. Ferretti⁸⁷, A. Ferretto Parodi^{50a,50b}, M. Fiascaris³⁰, F. Fiedler⁸¹, A. Filipčič⁷⁴, A. Filippas⁹, F. Filthaut¹⁰⁴, M. Fincke-Keeler¹⁶⁹, M.C.N. Fiolhais^{124a,h}, L. Fiorini¹⁶⁷, A. Firan³⁹, G. Fischer⁴¹, P. Fischer²⁰, M.J. Fisher¹⁰⁹, S.M. Fisher¹²⁹, M. Flechl⁴⁸, I. Fleck¹⁴¹, J. Fleckner⁸¹, P. Fleischmann¹⁷³, S. Fleischmann¹⁷⁴, T. Flick¹⁷⁴, L.R. Flores Castillo¹⁷², M.J. Flowerdew⁹⁹, F. Föhlich^{58a}, M. Fokitis⁹, T. Fonseca Martin¹⁶, D.A. Forbush¹³⁸, A. Formica¹³⁶, A. Forti⁸², D. Fortin^{159a}, J.M. Foster⁸², D. Fournier¹¹⁵, A. Foussat²⁹, A.J. Fowler⁴⁴, K. Fowler¹³⁷, H. Fox⁷¹, P. Francavilla^{122a,122b}, S. Franchino^{119a,119b}, D. Francis²⁹, T. Frank¹⁷¹, M. Franklin⁵⁷, S. Franz²⁹, M. Fraternali^{119a,119b}, S. Fratina¹²⁰, S.T. French²⁷, R. Froeschl²⁹, D. Froidevaux²⁹, J.A. Frost²⁷, C. Fukunaga¹⁵⁶, E. Fullana Torregrosa²⁹, J. Fuster¹⁶⁷, C. Gabaldon²⁹, O. Gabizon¹⁷¹, T. Gadfort²⁴, S. Gadomski⁴⁹, G. Gagliardi^{50a,50b}, P. Gagnon⁶¹, C. Galea⁹⁸, E.J. Gallas¹¹⁸, M.V. Gallas²⁹, V. Gallo¹⁶, B.J. Gallop¹²⁹, P. Gallus¹²⁵, E. Galyaev⁴⁰, K.K. Gan¹⁰⁹, Y.S. Gao^{143,f}, V.A. Gapienko¹²⁸, A. Gaponenko¹⁴, F. Garbersen¹⁷⁵, M. Garcia-Sciveres¹⁴, C. Garcia¹⁶⁷, J.E. Garcia Navarro⁴⁹, R.W. Gardner³⁰, N. Garelli²⁹, H. Garitaonandia¹⁰⁵, V. Garonne²⁹,

J. Garvey¹⁷, C. Gatti⁴⁷, G. Gaudio^{119a}, O. Gaumer⁴⁹, B. Gaur¹⁴¹, L. Gauthier¹³⁶, I.L. Gavrilenko⁹⁴, C. Gay¹⁶⁸, G. Gaycken²⁰, J.-C. Gayde²⁹, E.N. Gazis⁹, P. Ge^{32d}, C.N.P. Gee¹²⁹, D.A.A. Geerts¹⁰⁵, Ch. Geich-Gimbel²⁰, K. Gellerstedt^{146a,146b}, C. Gemme^{50a}, A. Gemmell⁵³, M.H. Genest⁹⁸, S. Gentile^{132a,132b}, M. George⁵⁴, S. George⁷⁶, P. Gerlach¹⁷⁴, A. Gershon¹⁵³, C. Geweniger^{58a}, H. Ghazlane^{135b}, P. Ghez⁴, N. Ghodbane³³, B. Giacobbe^{19a}, S. Giagu^{132a,132b}, V. Giakoumopoulou⁸, V. Giangiobbe^{122a,122b}, F. Gianotti²⁹, B. Gibbard²⁴, A. Gibson¹⁵⁸, S.M. Gibson²⁹, L.M. Gilbert¹¹⁸, M. Gilchriese¹⁴, V. Gilevsky⁹¹, D. Gillberg²⁸, A.R. Gillman¹²⁹, D.M. Gingrich^{2,e}, J. Ginzburg¹⁵³, N. Giokaris⁸, R. Giordano^{102a,102b}, F.M. Giorgi¹⁵, P. Giovannini⁹⁹, P.F. Giraud¹³⁶, D. Giugni^{89a}, M. Giunta^{132a,132b}, P. Giusti^{19a}, B.K. Gjelsten¹¹⁷, L.K. Gladilin⁹⁷, C. Glasman⁸⁰, J. Glatzer⁴⁸, A. Glazov⁴¹, K.W. Glitza¹⁷⁴, G.L. Glonti⁶⁵, J. Godfrey¹⁴², J. Godlewski²⁹, M. Goebel⁴¹, T. Göpfert⁴³, C. Goeringer⁸¹, C. Gössling⁴², T. Göttfert⁹⁹, S. Goldfarb⁸⁷, D. Goldin³⁹, T. Golling¹⁷⁵, S.N. Golovnia¹²⁸, A. Gomes^{124a,b}, L.S. Gomez Fajardo⁴¹, R. Gonçalves⁷⁶, J. Goncalves Pinto Firmino Da Costa⁴¹, L. Gonella²⁰, A. Gonidec²⁹, S. Gonzalez¹⁷², S. González de la Hoz¹⁶⁷, M.L. Gonzalez Silva²⁶, S. Gonzalez-Sevilla⁴⁹, J.J. Goodson¹⁴⁸, L. Goossens²⁹, P.A. Gorbounov⁹⁵, H.A. Gordon²⁴, I. Gorelov¹⁰³, G. Gorfine¹⁷⁴, B. Gorini²⁹, E. Gorini^{72a,72b}, A. Gorišek⁷⁴, E. Gornicki³⁸, S.A. Gorokhov¹²⁸, V.N. Goryachev¹²⁸, B. Gosdzik⁴¹, M. Gosselink¹⁰⁵, M.I. Gostkin⁶⁵, M. Gouanère⁴, I. Gough Eschrich¹⁶³, M. Goughri^{135a}, D. Goujdami^{135c}, M.P. Goulette⁴⁹, A.G. Goussiou¹³⁸, C. Goy⁴, I. Grabowska-Bold^{163,g}, V. Grabski¹⁷⁶, P. Grafström²⁹, C. Grah¹⁷⁴, K.-J. Grah⁴¹, F. Grancagnolo^{72a}, S. Grancagnolo¹⁵, V. Grassi¹⁴⁸, V. Gratchev¹²¹, N. Grau³⁴, H.M. Gray²⁹, J.A. Gray¹⁴⁸, E. Graziani^{134a}, O.G. Grebenyuk¹²¹, D. Greenfield¹²⁹, T. Greenshaw⁷³, Z.D. Greenwood^{24,1}, I.M. Gregor⁴¹, P. Grenier¹⁴³, J. Griffiths¹³⁸, N. Grigalashvili⁶⁵, A.A. Grillo¹³⁷, S. Grinstein¹¹, Y.V. Grishkevich⁹⁷, J.-F. Grivaz¹¹⁵, J. Grognuz²⁹, M. Groh⁹⁹, E. Gross¹⁷¹, J. Grosse-Knetter⁵⁴, J. Groth-Jensen¹⁷¹, K. Grybel¹⁴¹, V.J. Guarino⁵, D. Guest¹⁷⁵, C. Guicheney³³, A. Guida^{72a,72b}, T. Guillemin⁴, S. Guindon⁵⁴, H. Guler^{85,m}, J. Gunther¹²⁵, B. Guo¹⁵⁸, J. Guo³⁴, A. Gupta³⁰, Y. Gusakov⁶⁵, V.N. Gushchin¹²⁸, A. Gutierrez⁹³, P. Gutierrez¹¹¹, N. Guttman¹⁵³, O. Gutzwiller¹⁷², C. Guyot¹³⁶, C. Gwenlan¹¹⁸, C.B. Gwilliam⁷³, A. Haas¹⁴³, S. Haas²⁹, C. Haber¹⁴, R. Hackenberg²⁴, H.K. Hadavand³⁹, D.R. Hadley¹⁷, P. Haefner⁹⁹, F. Hahn²⁹, S. Haider²⁹, Z. Hajduk³⁸, H. Hakobyan¹⁷⁶, J. Haller⁵⁴, K. Hamacher¹⁷⁴, P. Hamal¹¹³, A. Hamilton⁴⁹, S. Hamilton¹⁶¹, H. Han^{32a}, L. Han^{32b}, K. Hanagaki¹¹⁶, M. Hance¹²⁰, C. Handel⁸¹, P. Hanke^{58a}, J.R. Hansen³⁵, J.B. Hansen³⁵, J.D. Hansen³⁵, P.H. Hansen³⁵, P. Hansson¹⁴³, K. Hara¹⁶⁰, G.A. Hare¹³⁷, T. Harenberg¹⁷⁴, S. Harkusha⁹⁰, D. Harper⁸⁷, R.D. Harrington²¹, O.M. Harris¹³⁸, K. Harrison¹⁷, J. Hartert⁴⁸, F. Hartjes¹⁰⁵, T. Haruyama⁶⁶, A. Harvey⁵⁶, S. Hasegawa¹⁰¹, Y. Hasegawa¹⁴⁰, S. Hassani¹³⁶, M. Hatch²⁹, D. Hauff⁹⁹, S. Haug¹⁶, M. Hauschild²⁹, R. Hauser⁸⁸, M. Havranek²⁰, B.M. Hawes¹¹⁸, C.M. Hawkes¹⁷, R.J. Hawkings²⁹, D. Hawkins¹⁶³, T. Hayakawa⁶⁷, D. Hayden⁷⁶, H.S. Hayward⁷³, S.J. Haywood¹²⁹, E. Hazen²¹, M. He^{32d}, S.J. Head¹⁷, V. Hedberg⁷⁹, L. Heelan⁷, S. Heim⁸⁸, B. Heinenmann¹⁴, S. Heisterkamp³⁵, L. Helary⁴, M. Heller¹¹⁵, S. Hellman^{146a,146b}, D. Hellmich²⁰, C. Helsens¹¹, R.C.W. Henderson⁷¹, M. Henke^{58a}, A. Henrichs⁵⁴, A.M. Henriques Correia²⁹, S. Henrot-Versille¹¹⁵, F. Henry-Couannier⁸³, C. Hensel⁵⁴, T. Henß¹⁷⁴, C.M. Hernandez⁷, Y. Hernández Jiménez¹⁶⁷, R. Herrberg¹⁵, A.D. Hershenhorn¹⁵², G. Herten⁴⁸, R. Hertenberger⁹⁸, L. Hervas²⁹, N.P. Hessey¹⁰⁵, A. Hidvegi^{146a}, E. Higón-Rodríguez¹⁶⁷, D. Hill^{5,*}, J.C. Hill²⁷, N. Hill⁵, K.H. Hille⁴¹, S. Hillert²⁰, S.J. Hillier¹⁷, I. Hinchliffe¹⁴, E. Hines¹²⁰, M. Hirose¹¹⁶, F. Hirsch⁴², D. Hirschbuehl¹⁷⁴, J. Hobbs¹⁴⁸, N. Hod¹⁵³, M.C. Hodgkinson¹³⁹, P. Hodgson¹³⁹, A. Hoecker²⁹, M.R. Hoferkamp¹⁰³, J. Hoffman³⁹, D. Hoffmann⁸³, M. Hohlfeld⁸¹, M. Holder¹⁴¹, A. Holmes¹¹⁸, S.O. Holmgren^{146a}, T. Holy¹²⁷, J.L. Holzbauer⁸⁸, Y. Homma⁶⁷, T.M. Hong¹²⁰, L. Hooft van Huysduynen¹⁰⁸, T. Horazdovsky¹²⁷, C. Horn¹⁴³, S. Horner⁴⁸, K. Horton¹¹⁸, J.-Y. Hostachy⁵⁵, S. Hou¹⁵¹, M.A. Houlden⁷³, A. Hoummada^{135a}, J. Howarth⁸², D.F. Howell¹¹⁸, I. Hristova⁴¹, J. Hrivnac¹¹⁵, I. Hruska¹²⁵, T. Hryn'ova⁴, P.J. Hsu¹⁷⁵, S.-C. Hsu¹⁴, G.S. Huang¹¹¹, Z. Hubacek¹²⁷, F. Hubaut⁸³, F. Huegging²⁰, T.B. Huffman¹¹⁸, E.W. Hughes³⁴, G. Hughes⁷¹, R.E. Hughes-Jones⁸², M. Huhtinen²⁹, P. Hurst⁵⁷, M. Hurwitz¹⁴, U. Husemann⁴¹, N. Huseynov^{65,n}, J. Huston⁸⁸, J. Huth⁵⁷, G. Iacobucci⁴⁹, G. Iakovidis⁹, M. Ibbotson⁸², I. Ibragimov¹⁴¹, R. Ichimiya⁶⁷, L. Iconomidou-Fayard¹¹⁵, J. Idarraga¹¹⁵, M. Idzik³⁷, P. Iengo^{102a,102b}, O. Igonkina¹⁰⁵, Y. Ikegami⁶⁶, M. Ikeno⁶⁶, Y. Ilchenko³⁹, D. Iliadis¹⁵⁴, D. Imbault⁷⁸, M. Imhaeuser¹⁷⁴, M. Imori¹⁵⁵, T. Ince²⁰, J. Inigo-Golfin²⁹, P. Ioannou⁸, M. Iodice^{134a}, G. Ionescu⁴, A. Irls Quiles¹⁶⁷, K. Ishii⁶⁶, A. Ishikawa⁶⁷, M. Ishino⁶⁶, R. Ishmukhametov³⁹, C. Issever¹¹⁸, S. Istin^{18a}, Y. Itoh¹⁰¹, A.V. Ivashin¹²⁸, W. Iwanski³⁸, H. Iwasaki⁶⁶, J.M. Izen⁴⁰, V. Izzo^{102a}, B. Jackson¹²⁰, J.N. Jackson⁷³, P. Jackson¹⁴³, M.R. Jaekel²⁹, V. Jain⁶¹, K. Jakobs⁴⁸, S. Jakobsen³⁵, J. Jakubek¹²⁷, D.K. Jana¹¹¹, E. Jankowski¹⁵⁸, E. Jansen⁷⁷, A. Jantsch⁹⁹, M. Janus²⁰, G. Jarlskog⁷⁹, L. Jeanty⁵⁷, K. Jelen³⁷, I. Jen-La Plante³⁰, P. Jenni²⁹, A. Jeremie⁴, P. Jež³⁵, S. Jézéquel⁴, M.K. Jha^{19a}, H. Ji¹⁷², W. Ji⁸¹, J. Jia¹⁴⁸, Y. Jiang^{32b}, M. Jimenez Belenguer⁴¹, G. Jin^{32b}, S. Jin^{32a}, O. Jinnouchi¹⁵⁷, M.D. Joergensen³⁵, D. Joffe³⁹, L.G. Johansen¹³, M. Johansen^{146a,146b}, K.E. Johansson^{146a}, P. Johansson¹³⁹, S. Johnert⁴¹, K.A. Johns⁶, K. Jon-And^{146a,146b}, G. Jones⁸², R.W.L. Jones⁷¹, T.W. Jones⁷⁷, T.J. Jones⁷³, O. Jonsson²⁹, C. Joram²⁹, P.M. Jorge^{124a,b}, J. Joseph¹⁴, T. Jovin^{12b}, X. Ju¹³⁰, V. Juranek¹²⁵, P. Jussel⁶², V.V. Kabachenko¹²⁸, S. Kabana¹⁶, M. Kaci¹⁶⁷, A. Kaczmarzka³⁸, P. Kadlecik³⁵, M. Kado¹¹⁵, H. Kagan¹⁰⁹, M. Kagan⁵⁷, S. Kaiser⁹⁹, E. Kajomovitz¹⁵², S. Kalinin¹⁷⁴, L.V. Kalinovskaya⁶⁵, S. Kama³⁹, N. Kanaya¹⁵⁵, M. Kaneda²⁹, T. Kanno¹⁵⁷, V.A. Kantserov⁹⁶, J. Kanzaki⁶⁶, B. Kaplan¹⁷⁵, A. Kapliy³⁰, J. Kaplon²⁹, D. Kar⁴³, M. Karagoz¹¹⁸, M. Karnevskiy⁴¹, K. Kari⁵, V. Kartvelishvili⁷¹, A.N. Karyukhin¹²⁸, L. Kashif¹⁷², A. Kasmi³⁹, R.D. Kass¹⁰⁹,

A. Kastanas¹³, M. Kataoka⁴, Y. Kataoka¹⁵⁵, E. Katsoufis⁹, J. Katzy⁴¹, V. Kaushik⁶, K. Kawagoe⁶⁷, T. Kawamoto¹⁵⁵, G. Kawamura⁸¹, M.S. Kayl¹⁰⁵, V.A. Kazanin¹⁰⁷, M.Y. Kazarinov⁶⁵, J.R. Keates⁸², R. Keeler¹⁶⁹, R. Kehoe³⁹, M. Keil⁵⁴, G.D. Kekelidze⁶⁵, M. Kelly⁸², J. Kennedy⁹⁸, C.J. Kenney¹⁴³, M. Kenyon⁵³, O. Kepka¹²⁵, N. Kerschen²⁹, B.P. Kerševan⁷⁴, S. Kersten¹⁷⁴, K. Kessoku¹⁵⁵, C. Ketterer⁴⁸, J. Keung¹⁵⁸, M. Khakzad²⁸, F. Khalil-zada¹⁰, H. Khandanyan¹⁶⁵, A. Khanov¹¹², D. Kharchenko⁶⁵, A. Khodinov⁹⁶, A.G. Kholodenko¹²⁸, A. Khomich^{58a}, T.J. Khoo²⁷, G. Khorauli²⁰, A. Khoroshilov¹⁷⁴, N. Khovanskiy⁶⁵, V. Khovanskiy⁹⁵, E. Khramov⁶⁵, J. Khubua⁵¹, H. Kim⁷, M.S. Kim², P.C. Kim¹⁴³, S.H. Kim¹⁶⁰, N. Kimura¹⁷⁰, O. Kind¹⁵, B.T. King⁷³, M. King⁶⁷, R.S.B. King¹¹⁸, J. Kirk¹²⁹, G.P. Kirsch¹¹⁸, L.E. Kirsch²², A.E. Kiryunin⁹⁹, D. Kisielewska³⁷, T. Kittelmann¹²³, A.M. Kiver¹²⁸, H. Kiyamura⁶⁷, E. Kladiva^{144b}, J. Klaiber-Lodewigs⁴², M. Klein⁷³, U. Klein⁷³, K. Kleinknecht⁸¹, M. Klemetti⁸⁵, A. Klier¹⁷¹, A. Klimentov²⁴, R. Klingenberg⁴², E.B. Klinkby³⁵, T. Klioutchnikova²⁹, P.F. Klok¹⁰⁴, S. Klous¹⁰⁵, E.-E. Kluge^{58a}, T. Kluge⁷³, P. Kluit¹⁰⁵, S. Kluth⁹⁹, E. Kneringer⁶², J. Knobloch²⁹, E.B.F.G. Knoops⁸³, A. Knue⁵⁴, B.R. Ko⁴⁴, T. Kobayashi¹⁵⁵, M. Kobel⁴³, M. Kocian¹⁴³, A. Kocnar¹¹³, P. Kodys¹²⁶, K. Köneke²⁹, A.C. König¹⁰⁴, S. Koenig⁸¹, L. Köpke⁸¹, F. Koetsveld¹⁰⁴, P. Koevesarki²⁰, T. Koffas²⁹, E. Koffeman¹⁰⁵, F. Kohn⁵⁴, Z. Kohout¹²⁷, T. Kohriki⁶⁶, T. Koi¹⁴³, T. Kokott²⁰, G.M. Kolachev¹⁰⁷, H. Kolanoski¹⁵, V. Kolesnikov⁶⁵, I. Koletsou^{89a}, J. Koll⁸⁸, D. Kollar²⁹, M. Kollefrath⁴⁸, S.D. Kolya⁸², A.A. Komar⁹⁴, J.R. Komaragiri¹⁴², Y. Komori¹⁵⁵, T. Kondo⁶⁶, T. Kono^{41.o}, A.I. Kononov⁴⁸, R. Konoplich^{108.p}, N. Konstantinidis⁷⁷, A. Kootz¹⁷⁴, S. Koperny³⁷, S.V. Kopikov¹²⁸, K. Korcyl³⁸, K. Kordas¹⁵⁴, V. Koreshev¹²⁸, A. Korn¹⁴, A. Korol¹⁰⁷, I. Korolkov¹¹, E.V. Korolkova¹³⁹, V.A. Korotkov¹²⁸, O. Kortner⁹⁹, S. Kortner⁹⁹, V.V. Kostyukhin²⁰, M.J. Kotamäki²⁹, S. Kotov⁹⁹, V.M. Kotov⁶⁵, A. Kotwal⁴⁴, C. Kourkoumelis⁸, V. Kouskoura¹⁵⁴, A. Koutsman¹⁰⁵, R. Kowalewski¹⁶⁹, T.Z. Kowalski³⁷, W. Kozanecki¹³⁶, A.S. Kozhin¹²⁸, V. Kral¹²⁷, V.A. Kramarenko⁹⁷, G. Kramberger⁷⁴, O. Krasel⁴², M.W. Krasny⁷⁸, A. Krasznahorkay¹⁰⁸, J. Kraus⁸⁸, A. Kreisel¹⁵³, F. Krciji¹²⁷, J. Kretzschmar⁷³, N. Krieger⁵⁴, P. Krieger¹⁵⁸, K. Kroeninger⁵⁴, H. Kroha⁹⁹, J. Kroll¹²⁰, J. Kroseberg²⁰, J. Krstic^{12a}, U. Kruchonak⁶⁵, H. Krüger²⁰, T. Kruker¹⁶, Z.V. Krumshteyn⁶⁵, A. Kruth²⁰, T. Kubota⁸⁶, S. Kuehn⁴⁸, A. Kugel^{58c}, T. Kuhl¹⁷⁴, D. Kuhn⁶², V. Kukhtin⁶⁵, Y. Kulchitsky⁹⁰, S. Kuleshov^{31b}, C. Kummer⁹⁸, M. Kuna⁷⁸, N. Kundu¹¹⁸, J. Kunkle¹²⁰, A. Kupco¹²⁵, H. Kurashige⁶⁷, M. Kurata¹⁶⁰, Y.A. Kurochkin⁹⁰, V. Kus¹²⁵, W. Kuykendall¹³⁸, M. Kuze¹⁵⁷, P. Kuzhir⁹¹, O. Kvasnicka¹²⁵, J. Kvita²⁹, R. Kwee¹⁵, A. La Rosa¹⁷², L. La Rotonda^{36a,36b}, L. Labarga⁸⁰, J. Labbe⁴, S. Lablak^{135a}, C. Lacasta¹⁶⁷, F. Lacava^{132a,132b}, H. Lacker¹⁵, D. Lacour⁷⁸, V.R. Lacuesta¹⁶⁷, E. Ladygin⁶⁵, R. Lafaye⁴, B. Laforge⁷⁸, T. Lagouri⁸⁰, S. Lai⁴⁸, E. Laisne⁵⁵, M. Lamanna²⁹, C.L. Lampen⁶, W. Lampl⁶, E. Lancon¹³⁶, U. Landgraf⁴⁸, M.P.J. Landon⁷⁵, H. Landsman¹⁵², J.L. Lane⁸², C. Lange⁴¹, A.J. Lankford¹⁶³, F. Lanni²⁴, K. Lantzsch²⁹, S. Laplace⁷⁸, C. Lapoire²⁰, J.F. Laporte¹³⁶, T. Lari^{89a}, A.V. Larionov¹²⁸, A. Lerner¹¹⁸, C. Lasseur²⁹, M. Lassnig²⁹, W. Lau¹¹⁸, P. Laurelli⁴⁷, A. Lavarato¹¹⁸, W. Lavrijsen¹⁴, P. Laycock⁷³, A.B. Lazarev⁶⁵, A. Lazzaro^{89a,89b}, O. Le Dortz⁷⁸, E. Le Guirriec⁸³, C. Le Maner¹⁵⁸, E. Le Menedeu¹³⁶, C. Lebel⁹³, T. LeCompte⁵, F. Ledroit-Guillon⁵⁵, H. Lee¹⁰⁵, J.S.H. Lee¹⁵⁰, S.C. Lee¹⁵¹, L. Lee¹⁷⁵, M. Lefebvre¹⁶⁹, M. Legendre¹³⁶, A. Leger⁴⁹, B.C. LeGeyt¹²⁰, F. Legger⁹⁸, C. Leggett¹⁴, M. Lehmacher²⁰, G. Lehmann Miotto²⁹, X. Lei⁶, M.A.L. Leite^{23b}, R. Leitner¹²⁶, D. Lellouch¹⁷¹, J. Lellouch⁷⁸, M. Leltchouk³⁴, V. Lendermann^{58a}, K.J.C. Leney^{145b}, T. Lenz¹⁷⁴, G. Lenzen¹⁷⁴, B. Lenzi²⁹, K. Leonhardt⁴³, S. Leontsinis⁹, C. Leroy⁹³, J.-R. Lessard¹⁶⁹, J. Lesser^{146a}, C.G. Lester²⁷, A. Leung Fook Cheong¹⁷², J. Levêque⁴, D. Levin⁸⁷, L.J. Levinson¹⁷¹, M.S. Levitski¹²⁸, M. Lewandowska²¹, A. Lewis¹¹⁸, G.H. Lewis¹⁰⁸, A.M. Leyko²⁰, M. Leyton¹⁵, B. Li⁸³, H. Li¹⁷², S. Li^{32b,d}, X. Li⁸⁷, Z. Liang³⁹, Z. Liang^{118,q}, B. Liberti^{133a}, P. Lichard²⁹, M. Lichtnecker⁹⁸, K. Lie¹⁶⁵, W. Liebig¹³, R. Lifshitz¹⁵², J.N. Lilley¹⁷, C. Limbach²⁰, A. Limosani⁸⁶, M. Limper⁶³, S.C. Lin^{151,r}, F. Linde¹⁰⁵, J.T. Linnemann⁸⁸, E. Lipeles¹²⁰, L. Lipinsky¹²⁵, A. Lipniacka¹³, T.M. Liss¹⁶⁵, D. Lissauer²⁴, A. Lister⁴⁹, A.M. Litke¹³⁷, C. Liu²⁸, D. Liu^{151,s}, H. Liu⁸⁷, J.B. Liu⁸⁷, M. Liu^{32b}, S. Liu², Y. Liu^{32b}, M. Livan^{119a,119b}, S.S.A. Livermore¹¹⁸, A. Lleres⁵⁵, J. Llorente Merino⁸⁰, S.L. Lloyd⁷⁵, E. Lobodzinska⁴¹, P. Loch⁶, W.S. Lockman¹³⁷, S. Lockwitz¹⁷⁵, T. Loddenkoetter²⁰, F.K. Loebinger⁸², A. Loginov¹⁷⁵, C.W. Loh¹⁶⁸, T. Lohse¹⁵, K. Lohwasser⁴⁸, M. Lokajicek¹²⁵, J. Loken¹¹⁸, V.P. Lombardo⁴, R.E. Long⁷¹, L. Lopes^{124a,b}, D. Lopez Mateos^{34,t}, M. Losada¹⁶², P. Loscutoff¹⁴, F. Lo Sterzo^{132a,132b}, M.J. Losty^{159a}, X. Lou⁴⁰, A. Lounis¹¹⁵, K.F. Loureiro¹⁶², J. Love²¹, P.A. Love⁷¹, A.J. Lowe^{143,f}, F. Lu^{32a}, H.J. Lubatti¹³⁸, C. Luci^{132a,132b}, A. Lucotte⁵⁵, A. Ludwig⁴³, D. Ludwig⁴¹, I. Ludwig⁴⁸, J. Ludwig⁴⁸, F. Luehring⁶¹, G. Luijckx¹⁰⁵, D. Lumb⁴⁸, L. Luminari^{132a}, E. Lund¹¹⁷, B. Lund-Jensen¹⁴⁷, B. Lundberg⁷⁹, J. Lundberg^{146a,146b}, J. Lundquist³⁵, M. Lungwitz⁸¹, A. Lupi^{122a,122b}, G. Lutz⁹⁹, D. Lynn²⁴, J. Lys¹⁴, E. Lytken⁷⁹, H. Ma²⁴, L.L. Ma¹⁷², J.A. Macana Goia⁹³, G. Maccarrone⁴⁷, A. Macchiolo⁹⁹, B. Maček⁷⁴, J. Machado Miguens^{124a}, D. Macina⁴⁹, R. Mackeprang³⁵, R.J. Madaras¹⁴, W.F. Mader⁴³, R. Maenner^{58c}, T. Maeno²⁴, P. Mättig¹⁷⁴, S. Mättig⁴¹, P.J. Magalhaes Martins^{124a,h}, L. Magnoni²⁹, E. Magradze⁵⁴, Y. Mahalalel¹⁵³, K. Mahboubi⁴⁸, G. Mahout¹⁷, C. Maiani^{132a,132b}, C. Maidantchik^{23a}, A. Maio^{124a,b}, S. Majewski²⁴, Y. Makida⁶⁶, N. Makovec¹¹⁵, P. Mal⁶, Pa. Malecki³⁸, P. Malecki³⁸, V.P. Maleev¹²¹, F. Malek⁵⁵, U. Mallik⁶³, D. Malon⁵, S. Maltezos⁹, V. Malyshev¹⁰⁷, S. Malyukov²⁹, R. Mameghani⁹⁸, J. Mamuzic^{12b}, A. Manabe⁶⁶, L. Mandelli^{89a}, I. Mandić⁷⁴, R. Mandrysch¹⁵, J. Maneira^{124a}, P.S. Mangeard⁸⁸, I.D. Manjavidze⁶⁵, A. Mann⁵⁴, P.M. Manning¹³⁷, A. Manousakis-Katsikakis⁸, B. Mansoulie¹³⁶, A. Manz⁹⁹, A. Mapelli²⁹, L. Mapelli²⁹, L. March⁸⁰, J.F. Marchand²⁹, F. Marchese^{133a,133b}, G. Marchiori⁷⁸, M. Marcisovsky¹²⁵, A. Marin^{21,*}, C.P. Marino⁶¹, F. Marroquim^{23a},

R. Marshall⁸², Z. Marshall²⁹, F.K. Martens¹⁵⁸, S. Marti-Garcia¹⁶⁷, A.J. Martin¹⁷⁵, B. Martin²⁹, B. Martin⁸⁸, F.F. Martin¹²⁰, J.P. Martin⁹³, Ph. Martin⁵⁵, T.A. Martin¹⁷, B. Martin dit Latour⁴⁹, M. Martinez¹¹, V. Martinez Outschoorn⁵⁷, A.C. Martyniuk⁸², M. Marx⁸², F. Marzano^{132a}, A. Marzin¹¹¹, L. Masetti⁸¹, T. Mashimo¹⁵⁵, R. Mashinistov⁹⁴, J. Masik⁸², A.L. Maslennikov¹⁰⁷, M. Maß⁴², I. Massa^{19a,19b}, G. Massaro¹⁰⁵, N. Massol⁴, P. Mastrandrea^{132a,132b}, A. Mastroberardino^{36a,36b}, T. Masubuchi¹⁵⁵, M. Mathes²⁰, P. Matricon¹¹⁵, H. Matsumoto¹⁵⁵, H. Matsunaga¹⁵⁵, T. Matsushita⁶⁷, C. Mat-travers^{118,c}, J.M. Maugain²⁹, S.J. Maxfield⁷³, D.A. Maximov¹⁰⁷, E.N. May⁵, A. Mayne¹³⁹, R. Mazini¹⁵¹, M. Mazur²⁰, M. Mazzanti^{89a}, E. Mazzoni^{122a,122b}, S.P. Mc Kee⁸⁷, A. McCarn¹⁶⁵, R.L. McCarthy¹⁴⁸, T.G. McCarthy²⁸, N.A. McCubbin¹²⁹, K.W. McFarlane⁵⁶, J.A. Mcfayden¹³⁹, H. McGlone⁵³, G. Mchedlidze⁵¹, R.A. McLaren²⁹, T. McLaughlan¹⁷, S.J. McMahon¹²⁹, R.A. McPherson^{169,j}, A. Meade⁸⁴, J. Mechnich¹⁰⁵, M. Mechtel¹⁷⁴, M. Medinnis⁴¹, R. Meera-Lebbai¹¹¹, T. Meguro¹¹⁶, R. Mehdiyev⁹³, S. Mehlhase³⁵, A. Mehta⁷³, K. Meier^{58a}, J. Meinhardt⁴⁸, B. Meirose⁷⁹, C. Melachrinou³⁰, B.R. Mellado Garcia¹⁷², L. Mendoza Navas¹⁶², Z. Meng^{151,s}, A. Mengarelli^{19a,19b}, S. Menke⁹⁹, C. Menot²⁹, E. Meoni¹¹, K.M. Mercurio⁵⁷, P. Mermod¹¹⁸, L. Merola^{102a,102b}, C. Meroni^{89a}, F.S. Merritt³⁰, A. Messina²⁹, J. Metcalfe¹⁰³, A.S. Mete⁶⁴, S. Meuser²⁰, C. Meyer⁸¹, J.-P. Meyer¹³⁶, J. Meyer¹⁷³, J. Meyer⁵⁴, T.C. Meyer²⁹, W.T. Meyer⁶⁴, J. Miao^{32d}, S. Michal²⁹, L. Micu^{25a}, R.P. Middleton¹²⁹, P. Miele²⁹, S. Migas⁷³, L. Mijović⁴¹, G. Mikenberg¹⁷¹, M. Mikesstikova¹²⁵, M. Mikuž⁷⁴, D.W. Miller¹⁴³, R.J. Miller⁸⁸, W.J. Mills¹⁶⁸, C. Mills⁵⁷, A. Milov¹⁷¹, D.A. Milstead^{146a,146b}, D. Milstein¹⁷¹, A.A. Minaenko¹²⁸, M. Miñano¹⁶⁷, I.A. Minashvili⁶⁵, A.I. Mincer¹⁰⁸, B. Mindur³⁷, M. Mineev⁶⁵, Y. Ming¹³⁰, L.M. Mir¹¹, G. Mirabelli^{132a}, L. Miralles Verge¹¹, A. Misiejuk⁷⁶, J. Mitrevski¹³⁷, G.Y. Mitrofanov¹²⁸, V.A. Mitsou¹⁶⁷, S. Mitsui⁶⁶, P.S. Miyagawa⁸², K. Miyazaki⁶⁷, J.U. Mjörnmark⁷⁹, T. Moa^{146a,146b}, P. Mockett¹³⁸, S. Moed⁵⁷, V. Moeller²⁷, K. Mönig⁴¹, N. Möser²⁰, S. Mohapatra¹⁴⁸, B. Mohn¹³, W. Mohr⁴⁸, S. Mohrdieck-Möck⁹⁹, A.M. Moiseev^{128,*}, R. Moles-Valls¹⁶⁷, J. Molina-Perez²⁹, J. Monk⁷⁷, E. Monnier⁸³, S. Montesano^{89a,89b}, F. Monticelli⁷⁰, S. Monzani^{19a,19b}, R.W. Moore², G.F. Moorhead⁸⁶, C. Mora Herrera⁴⁹, A. Moraes⁵³, A. Morais^{124a,b}, N. Morange¹³⁶, J. Morel⁵⁴, G. Morello^{36a,36b}, D. Moreno⁸¹, M. Moreno Llácer¹⁶⁷, P. Morettini^{50a}, M. Morii⁵⁷, J. Morin⁷⁵, Y. Morita⁶⁶, A.K. Morley²⁹, G. Mornacchi²⁹, M.-C. Morone⁴⁹, S.V. Morozov⁹⁶, J.D. Morris⁷⁵, L. Morvaj¹⁰¹, H.G. Moser⁹⁹, M. Mosidze⁵¹, J. Moss¹⁰⁹, R. Mount¹⁴³, E. Mountricha¹³⁶, S.V. Mouraviev⁹⁴, E.J.W. Moyses⁸⁴, M. Mudrinic^{12b}, F. Mueller^{58a}, J. Mueller¹²³, K. Mueller²⁰, T.A. Müller⁹⁸, D. Muenstermann²⁹, A. Muijs¹⁰⁵, A. Muir¹⁶⁸, Y. Munwes¹⁵³, K. Murakami⁶⁶, W.J. Murray¹²⁹, I. Mussche¹⁰⁵, E. Musto^{102a,102b}, A.G. Myagkov¹²⁸, M. Myska¹²⁵, J. Nadal¹¹, K. Nagai¹⁶⁰, K. Nagano⁶⁶, Y. Nagasaka⁶⁰, A.M. Nairz²⁹, Y. Nakahama²⁹, K. Nakamura¹⁵⁵, I. Nakano¹¹⁰, G. Nanava²⁰, A. Napier¹⁶¹, M. Nash^{77,c}, N.R. Nation²¹, T. Nattermann²⁰, T. Naumann⁴¹, G. Navarro¹⁶², H.A. Neal⁸⁷, E. Nebot⁸⁰, P.Yu. Nechaeva⁹⁴, A. Negri^{119a,119b}, G. Negri²⁹, S. Nektarijevic⁴⁹, A. Nelson⁶⁴, S. Nelson¹⁴³, T.K. Nelson¹⁴³, S. Nemecek¹²⁵, P. Nemethy¹⁰⁸, A.A. Nepomuceno^{23a}, M. Nessi^{29,u}, S.Y. Nesterov¹²¹, M.S. Neubauer¹⁶⁵, A. Neusiedl⁸¹, R.M. Neves¹⁰⁸, P. Nevski²⁴, P.R. Newman¹⁷, R.B. Nickerson¹¹⁸, R. Nicolaidou¹³⁶, L. Nicolas¹³⁹, B. Niquevert²⁹, F. Niedercorn¹¹⁵, J. Nielsen¹³⁷, T. Niinikoski²⁹, A. Nikiforov¹⁵, V. Nikolaenko¹²⁸, K. Nikolaev⁶⁵, I. Nikolic-Audit⁷⁸, K. Nikolics⁴⁹, K. Nikolopoulos²⁴, H. Nilsen⁴⁸, P. Nilsson⁷, Y. Ninomiya¹⁵⁵, A. Nisati^{132a}, T. Nishiyama⁶⁷, R. Nisius⁹⁹, L. Nodulman⁵, M. Nomachi¹¹⁶, I. Nomidis¹⁵⁴, M. Nordberg²⁹, B. Nordkvist^{146a,146b}, P.R. Norton¹²⁹, J. Novakova¹²⁶, M. Nozaki⁶⁶, M. Nožička⁴¹, L. Nozka¹¹³, I.M. Nugent^{159a}, A.-E. Nuncio-Quiroz²⁰, G. Nunes Hanninger⁸⁶, T. Nunnemann⁹⁸, E. Nurse⁷⁷, T. Nyman²⁹, B.J. O'Brien⁴⁵, S.W. O'Neale^{17,*}, D.C. O'Neil¹⁴², V. O'Shea⁵³, F.G. Oakham^{28,e}, H. Oberlack⁹⁹, J. Ocariz⁷⁸, A. Ochi⁶⁷, S. Oda¹⁵⁵, S. Odaka⁶⁶, J. Odier⁸³, H. Ogren⁶¹, A. Oh⁸², S.H. Oh⁴⁴, C.C. Ohm^{146a,146b}, T. Ohshima¹⁰¹, H. Ohshita¹⁴⁰, T.K. Ohska⁶⁶, T. Ohsugi⁵⁹, S. Okada⁶⁷, H. Okawa¹⁶³, Y. Okumura¹⁰¹, T. Okuyama¹⁵⁵, M. Olcese^{50a}, A.G. Olchevski⁶⁵, M. Oliveira^{124a,h}, D. Oliveira Damazio²⁴, E. Oliver Garcia¹⁶⁷, D. Olivito¹²⁰, A. Olszewski³⁸, J. Olszowska³⁸, C. Omachi⁶⁷, A. Onofre^{124a,v}, P.U.E. Onyisi³⁰, C.J. Oram^{159a}, M.J. Oreglia³⁰, Y. Oren¹⁵³, D. Orestano^{134a,134b}, I. Orlov¹⁰⁷, C. Oropeza Barrera⁵³, R.S. Orr¹⁵⁸, B. Osculati^{50a,50b}, R. Ospanov¹²⁰, C. Osuna¹¹, G. Otero y Garzon²⁶, J.P. Ottersbach¹⁰⁵, M. Ouchrif^{135d}, F. Ould-Saada¹¹⁷, A. Ouraou¹³⁶, Q. Ouyang^{32a}, M. Owen⁸², S. Owen¹³⁹, O.K. Øye¹³, V.E. Ozcan^{18a}, N. Ozturk⁷, A. Pacheco Pages¹¹, C. Padilla Aranda¹¹, S. Pagan Griso¹⁴, E. Paganis¹³⁹, F. Paige²⁴, K. Pajchel¹¹⁷, S. Palestini²⁹, D. Pallin³³, A. Palma^{124a,b}, J.D. Palmer¹⁷, Y.B. Pan¹⁷², E. Panagiotopoulou⁹, B. Panes^{31a}, N. Panikashvili⁸⁷, S. Panitkin²⁴, D. Pantea^{25a}, M. Panuskova¹²⁵, V. Paolone¹²³, A. Papadellis^{146a}, Th.D. Papadopoulou⁹, A. Paramonov⁵, W. Park^{24,w}, M.A. Parker²⁷, F. Parodi^{50a,50b}, J.A. Parsons³⁴, U. Parzefall⁴⁸, E. Pasqualucci^{132a}, A. Passeri^{134a}, F. Pastore^{134a,134b}, Fr. Pastore²⁹, G. Pásztor^{49,x}, S. Patariaia¹⁷², N. Patel¹⁵⁰, J.R. Pater⁸², S. Patricelli^{102a,102b}, T. Pauly²⁹, M. Pecsny^{144a}, M.I. Pedraza Morales¹⁷², S.V. Peleganchuk¹⁰⁷, H. Peng¹⁷², R. Pengo²⁹, A. Penson³⁴, J. Penwell⁶¹, M. Perantoni^{23a}, K. Perez^{34,t}, T. Perez Cavalcanti⁴¹, E. Perez Codina¹¹, M.T. Pérez García-Estáñ¹⁶⁷, V. Perez Reale³⁴, L. Perini^{89a,89b}, H. Pernegger²⁹, R. Perrino^{72a}, P. Perrodo⁴, S. Persema^{3a}, V.D. Peshekhonov⁶⁵, O. Peters¹⁰⁵, B.A. Petersen²⁹, J. Petersen²⁹, T.C. Petersen³⁵, E. Petit⁸³, A. Petridis¹⁵⁴, C. Petridou¹⁵⁴, E. Petrolo^{132a}, F. Petrucci^{134a,134b}, D. Petschull⁴¹, M. Petteni¹⁴², R. Pezoa^{31b}, A. Phan⁸⁶, A.W. Phillips²⁷, P.W. Phillips¹²⁹, G. Piacquadio²⁹, E. Piccaro⁷⁵, M. Piccinini^{19a,19b}, A. Pickford⁵³, S.M. Piec⁴¹, R. Piegai²⁶, J.E. Pilcher³⁰, A.D. Pilkington⁸², J. Pina^{124a,b}, M. Pinamonti^{164a,164c}, A. Pinder¹¹⁸, J.L. Pinfold², J. Ping^{32c}, B. Pinto^{124a,b}, O. Pirotte²⁹, C. Pizio^{89a,89b}, R. Placakyte⁴¹, M. Plamondon¹⁶⁹, W.G. Plano⁸², M.-A. Pleier²⁴, A.V. Pleskach¹²⁸, A. Poblaguev²⁴, S. Poddar^{58a}, F. Podlyski³³

L. Poggioli¹¹⁵, T. Poghosyan²⁰, M. Pohl⁴⁹, F. Polci⁵⁵, G. Polesello^{119a}, A. Policicchio¹³⁸, A. Polini^{19a}, J. Poll⁷⁵, V. Polychronakos²⁴, D.M. Pomarede¹³⁶, D. Pomeroy²², K. Pommès²⁹, L. Pontecorvo^{132a}, B.G. Pope⁸⁸, G.A. Popeneciu^{25a}, D.S. Popovic^{12a}, A. Poppleton²⁹, X. Portell Bueso⁴⁸, R. Porter¹⁶³, C. Posch²¹, G.E. Pospelov⁹⁹, S. Pospisil¹²⁷, I.N. Potrap⁹⁹, C.J. Potter¹⁴⁹, C.T. Potter¹¹⁴, G. Poulard²⁹, J. Poveda¹⁷², R. Prabhu⁷⁷, P. Pralavorio⁸³, S. Prasad⁵⁷, R. Prava-han⁷, S. Prell⁶⁴, K. Pretzl¹⁶, L. Pribyl²⁹, D. Price⁶¹, L.E. Price⁵, M.J. Price²⁹, P.M. Prichard⁷³, D. Prieur¹²³, M. Primavera^{72a}, K. Prokofiev¹⁰⁸, F. Prokoshin^{31b}, S. Protopopescu²⁴, J. Proudfoot⁵, X. Prudent⁴³, H. Przysiezniak⁴, S. Psoroulas²⁰, E. Ptacek¹¹⁴, J. Purdham⁸⁷, M. Purohit^{24,w}, P. Puza¹¹⁵, Y. Pylypchenko¹¹⁷, J. Qian⁸⁷, Z. Qian⁸³, Z. Qin⁴¹, A. Quadt⁵⁴, D.R. Quarrie¹⁴, W.B. Quayle¹⁷², F. Quinonez^{31a}, M. Raas¹⁰⁴, V. Radescu^{58b}, B. Radics²⁰, T. Rador^{18a}, F. Ragusa^{89a,89b}, G. Rahal¹⁷⁷, A.M. Rahimi¹⁰⁹, D. Rahm²⁴, S. Rajagopalan²⁴, M. Rammensee⁴⁸, M. Rammes¹⁴¹, M. Ramstedt^{146a,146b}, K. Randrianarivony²⁸, P.N. Ratoff⁷¹, F. Rauscher⁹⁸, E. Rauter⁹⁹, M. Raymond²⁹, A.L. Read¹¹⁷, D.M. Rebuffi^{119a,119b}, A. Redelbach¹⁷³, G. Redlinger²⁴, R. Reece¹²⁰, K. Reeves⁴⁰, A. Reichold¹⁰⁵, E. Reinherz-Aronis¹⁵³, A. Reinsch¹¹⁴, I. Reisinger⁴², D. Reljic^{12a}, C. Rembser²⁹, Z.L. Ren¹⁵¹, A. Renaud¹¹⁵, P. Renkel³⁹, M. Rescigno^{132a}, S. Resconi^{89a}, B. Resende¹³⁶, P. Reznicek⁹⁸, R. Rezvani¹⁵⁸, A. Richards⁷⁷, R. Richter⁹⁹, E. Richter-Was^{38,y}, M. Ridet⁷⁸, S. Rieke⁸¹, M. Rijpstra¹⁰⁵, M. Rijssenbeek¹⁴⁸, A. Rimoldi^{119a,119b}, L. Rinaldi^{19a}, R.R. Rios³⁹, I. Riu¹¹, G. Rivoltella^{89a,89b}, F. Rizat-dinova¹¹², E. Rizvi⁷⁵, S.H. Robertson^{85j}, A. Robichaud-Veronneau⁴⁹, D. Robinson²⁷, J.E.M. Robinson⁷⁷, M. Robin-son¹¹⁴, A. Robson⁵³, J.G. Rocha de Lima¹⁰⁶, C. Roda^{122a,122b}, D. Roda Dos Santos²⁹, S. Rodier⁸⁰, D. Rodriguez¹⁶², Y. Rodriguez Garcia¹⁵, A. Roe⁵⁴, S. Roe²⁹, O. Røhne¹¹⁷, V. Rojo¹, S. Rolli¹⁶¹, A. Romaniouk⁹⁶, V.M. Romanov⁶⁵, G. Romeo²⁶, D. Romero Maltrana^{31a}, L. Roos⁷⁸, E. Ros¹⁶⁷, S. Rosati^{132a,132b}, K. Rosbach⁴⁹, M. Rose⁷⁶, G.A. Rosen-baum¹⁵⁸, E.I. Rosenberg⁶⁴, P.L. Rosendahl¹³, L. Rossetti⁴⁹, V. Rossetti¹¹, E. Rossi^{102a,102b}, L.P. Rossi^{50a}, L. Rossi^{89a,89b}, M. Rotaru^{25a}, I. Roth¹⁷¹, J. Rothberg¹³⁸, D. Rousseau¹¹⁵, C.R. Royon¹³⁶, A. Rozanov⁸³, Y. Rozen¹⁵², X. Ruan¹¹⁵, I. Ru-binskiy⁴¹, B. Ruckert⁹⁸, N. Ruckstuhl¹⁰⁵, V.I. Rud⁹⁷, C. Rudolph⁴³, G. Rudolph⁶², F. Rühr⁶, F. Ruggieri^{134a,134b}, A. Ruiz-Martinez⁶⁴, E. Rulikowska-Zarebska³⁷, V. Rumiantsev^{91,*}, L. Rummyantsev⁶⁵, K. Runge⁴⁸, O. Runolfsson²⁰, Z. Rurikova⁴⁸, N.A. Rusakovich⁶⁵, D.R. Rust⁶¹, J.P. Rutherford⁶, C. Ruwiedel¹⁴, P. Ruzicka¹²⁵, Y.F. Ryabov¹²¹, V. Ryadovikov¹²⁸, P. Ryan⁸⁸, M. Rybar¹²⁶, G. Rybkin¹¹⁵, N.C. Ryder¹¹⁸, S. Rzaeva¹⁰, A.F. Saavedra¹⁵⁰, I. Sadeh¹⁵³, H.F.-W. Sadrozinski¹³⁷, R. Sadykov⁶⁵, F. Safai Tehrani^{132a,132b}, H. Sakamoto¹⁵⁵, G. Salamanna⁷⁵, A. Salamon^{133a}, M. Saleem¹¹¹, D. Salihagic⁹⁹, A. Salnikov¹⁴³, J. Salt¹⁶⁷, B.M. Salvachua Ferrando⁵, D. Salvatore^{36a,36b}, F. Salvatore¹⁴⁹, A. Salvucci¹⁰⁴, A. Salzburger²⁹, D. Sampsonidis¹⁵⁴, B.H. Samset¹¹⁷, A. Sanchez^{102a,102b}, H. Sandaker¹³, H.G. Sander⁸¹, M.P. Sanders⁹⁸, M. Sandhoff¹⁷⁴, T. Sandoval²⁷, R. Sandstroem⁹⁹, S. Sandvoss¹⁷⁴, D.P.C. Sankey¹²⁹, A. Sansoni⁴⁷, C. Santamarina Rios⁸⁵, C. Santoni³³, R. Santonico^{133a,133b}, H. Santos^{124a}, J.G. Saraiva^{124a,b}, T. Sarangi¹⁷², E. Sarkisyan-Grinbaum⁷, F. Sarri^{122a,122b}, G. Sarti-sohn¹⁷⁴, O. Sasaki⁶⁶, T. Sasaki⁶⁶, N. Sasao⁶⁸, I. Satsounkevitch⁹⁰, G. Sauvage⁴, E. Sauvan⁴, J.B. Sauvan¹¹⁵, P. Savard^{158,e}, V. Savinov¹²³, D.O. Savu²⁹, P. Savva⁹, L. Sawyer^{24,l}, D.H. Saxon⁵³, L.P. Says³³, C. Sbarra^{19a,19b}, A. Sbrizzi^{19a,19b}, O. Scallion⁹³, D.A. Scannicchio¹⁶³, J. Schaarschmidt¹¹⁵, P. Schacht⁹⁹, U. Schäfer⁸¹, S. Schaepe²⁰, S. Schaezel^{58b}, A.C. Schaffer¹¹⁵, D. Schaile⁹⁸, R.D. Schamberger¹⁴⁸, A.G. Schamov¹⁰⁷, V. Scharf^{58a}, V.A. Schegelsky¹²¹, D. Scheirich⁸⁷, M.I. Scherzer¹⁴, C. Schiavi^{50a,50b}, J. Schieck⁹⁸, M. Schioppa^{36a,36b}, S. Schlenker²⁹, J.L. Schlereth⁵, E. Schmidt⁴⁸, K. Schmieden²⁰, C. Schmitt⁸¹, S. Schmitt^{58b}, M. Schmitz²⁰, A. Schöning^{58b}, M. Schott²⁹, D. Schouten¹⁴², J. Schovan-cova¹²⁵, M. Schram⁸⁵, C. Schroeder⁸¹, N. Schroer^{58c}, S. Schuh²⁹, G. Schuler²⁹, J. Schultes¹⁷⁴, H.-C. Schultz-Coulon^{58a}, H. Schulz¹⁵, J.W. Schumacher²⁰, M. Schumacher⁴⁸, B.A. Schumm¹³⁷, Ph. Schune¹³⁶, C. Schwanenberger⁸², A. Schwartz-man¹⁴³, Ph. Schwemling⁷⁸, R. Schwienhorst⁸⁸, R. Schwierz⁴³, J. Schwindling¹³⁶, T. Schwindt²⁰, W.G. Scott¹²⁹, J. Searcy¹¹⁴, E. Sedykh¹²¹, E. Segura¹¹, S.C. Seidel¹⁰³, A. Seiden¹³⁷, F. Seifert⁴³, J.M. Seixas^{23a}, G. Sekhniaidze^{102a}, D.M. Seliver-stov¹²¹, B. Sellden^{146a}, G. Sellers⁷³, M. Seman^{144b}, N. Semprini-Cesari^{19a,19b}, C. Serfon⁹⁸, L. Serin¹¹⁵, R. Seuster⁹⁹, H. Severini¹¹¹, M.E. Sevier⁸⁶, A. Sfyrila²⁹, E. Shabalina⁵⁴, M. Shamim¹¹⁴, L.Y. Shan^{32a}, J.T. Shank²¹, Q.T. Shao⁸⁶, M. Shapiro¹⁴, P.B. Shatalov⁹⁵, L. Shaver⁶, C. Shaw⁵³, K. Shaw^{164a,164c}, D. Sherman¹⁷⁵, P. Sherwood⁷⁷, A. Shibata¹⁰⁸, H. Shichi¹⁰¹, S. Shimizu²⁹, M. Shimojima¹⁰⁰, T. Shin⁵⁶, A. Shmeleva⁹⁴, M.J. Shochet³⁰, D. Short¹¹⁸, M.A. Shupe⁶, P. Sicho¹²⁵, A. Sidoti^{132a,132b}, A. Siebel¹⁷⁴, F. Siegert⁴⁸, J. Siegrist¹⁴, Dj. Sijacki^{12a}, O. Silbert¹⁷¹, J. Silva^{124a,b}, Y. Sil-ver¹⁵³, D. Silverstein¹⁴³, S.B. Silverstein^{146a}, V. Simak¹²⁷, O. Simard¹³⁶, Lj. Simic^{12a}, S. Simion¹¹⁵, B. Simmons⁷⁷, M. Simonyan³⁵, P. Sinervo¹⁵⁸, N.B. Sinev¹¹⁴, V. Sipica¹⁴¹, G. Siragusa¹⁷³, A.N. Sisakyan⁶⁵, S.Yu. Sivoklokov⁹⁷, J. Sjölin^{146a,146b}, T.B. Sjrnsen¹³, L.A. Skinnari¹⁴, K. Skovpen¹⁰⁷, P. Skubic¹¹¹, N. Skvorodnev²², M. Slater¹⁷, T. Slavicek¹²⁷, K. Sliwa¹⁶¹, T.J. Sloan⁷¹, J. Sloper²⁹, V. Smakhtin¹⁷¹, S.Yu. Smirnov⁹⁶, L.N. Smirnova⁹⁷, O. Smirnova⁷⁹, B.C. Smith⁵⁷, D. Smith¹⁴³, K.M. Smith⁵³, M. Smizanska⁷¹, K. Smolek¹²⁷, A.A. Snesarev⁹⁴, S.W. Snow⁸², J. Snow¹¹¹, J. Snuverink¹⁰⁵, S. Snyder²⁴, M. Soares^{124a}, R. Sobie^{169,j}, J. Sodomka¹²⁷, A. Soffer¹⁵³, C.A. Solans¹⁶⁷, M. Solar¹²⁷, J. Solc¹²⁷, E. Soldatov⁹⁶, U. Sol-devila¹⁶⁷, E. Solfaroli Camillocci^{132a,132b}, A.A. Solodkov¹²⁸, O.V. Solovyanov¹²⁸, J. Sondericker²⁴, N. Soni², V. Sopko¹²⁷, B. Sopko¹²⁷, M. Sorbi^{89a,89b}, M. Sosebee⁷, A. Soukharev¹⁰⁷, S. Spagnolo^{72a,72b}, F. Spanò³⁴, R. Spighi^{19a}, G. Spigo²⁹, F. Spila^{132a,132b}, E. Spiriti^{134a}, R. Spiwoks²⁹, M. Spousta¹²⁶, T. Spreitzer¹⁵⁸, B. Spurlock⁷, R.D.St. Denis⁵³, T. Stahl¹⁴¹,

J. Stahlman¹²⁰, R. Stamen^{58a}, E. Stanecka²⁹, R.W. Stanek⁵, C. Stanescu^{134a}, S. Stapnes¹¹⁷, E.A. Starchenko¹²⁸, J. Stark⁵⁵, P. Staroba¹²⁵, P. Starovoitov⁹¹, A. Stauder⁹⁸, P. Stavina^{144a}, G. Stavropoulos¹⁴, G. Steele⁵³, P. Steinbach⁴³, P. Steinberg²⁴, I. Stekl¹²⁷, B. Stelzer¹⁴², H.J. Stelzer⁴¹, O. Stelzer-Chilton^{159a}, H. Stenzel⁵², K. Stevenson⁷⁵, G.A. Stewart²⁹, J.A. Stillings²⁰, T. Stockmanns²⁰, M.C. Stockton²⁹, K. Stoerig⁴⁸, G. Stoica^{25a}, S. Stonjek⁹⁹, P. Strachota¹²⁶, A.R. Stradling⁷, A. Straessner⁴³, J. Strandberg¹⁴⁷, S. Strandberg^{146a,146b}, A. Strandlie¹¹⁷, M. Strang¹⁰⁹, E. Strauss¹⁴³, M. Strauss¹¹¹, P. Strizenecek^{144b}, R. Ströhmer¹⁷³, D.M. Strom¹¹⁴, J.A. Strong^{76,*}, R. Stroynowski³⁹, J. Strube¹²⁹, B. Stugu¹³, I. Stumer^{24,*}, J. Stupak¹⁴⁸, P. Sturm¹⁷⁴, D.A. Soh^{151,q}, D. Su¹⁴³, H.S. Subramania², A. Succurro¹¹, Y. Sugaya¹¹⁶, T. Sugimoto¹⁰¹, C. Suhr¹⁰⁶, K. Suita⁶⁷, M. Suk¹²⁶, V.V. Sulim⁹⁴, S. Sultansoy^{3d}, T. Sumida²⁹, X. Sun⁵⁵, J.E. Sundermann⁴⁸, K. Suruliz¹³⁹, S. Sushkov¹¹, G. Susinno^{36a,36b}, M.R. Sutton¹⁴⁹, Y. Suzuki⁶⁶, M. Svatos¹²⁵, Yu.M. Sviridov¹²⁸, S. Swedish¹⁶⁸, I. Sykora^{144a}, T. Sykora¹²⁶, B. Szeless²⁹, J. Sánchez¹⁶⁷, D. Ta¹⁰⁵, K. Tackmann⁴¹, A. Taffard¹⁶³, R. Tafirout^{159a}, A. Taga¹¹⁷, N. Taiblum¹⁵³, Y. Takahashi¹⁰¹, H. Takai²⁴, R. Takashima⁶⁹, H. Takeda⁶⁷, T. Takeshita¹⁴⁰, M. Talby⁸³, A. Talyshev¹⁰⁷, M.C. Tamsett²⁴, J. Tanaka¹⁵⁵, R. Tanaka¹¹⁵, S. Tanaka¹³¹, S. Tanaka⁶⁶, Y. Tanaka¹⁰⁰, K. Tani⁶⁷, N. Tannoury⁸³, G.P. Tapern²⁹, S. Tapprogge⁸¹, D. Tardif¹⁵⁸, S. Tarem¹⁵², F. Tarrade²⁴, G.F. Tartarelli^{89a}, P. Tas¹²⁶, M. Tasevsky¹²⁵, E. Tassi^{36a,36b}, M. Tatarkhanov¹⁴, C. Taylor⁷⁷, F.E. Taylor⁹², G.N. Taylor⁸⁶, W. Taylor^{159b}, M. Teixeira Dias Castanheira⁷⁵, P. Teixeira-Dias⁷⁶, K.K. Temming⁴⁸, H. Ten Kate²⁹, P.K. Teng¹⁵¹, S. Terada⁶⁶, K. Terashi¹⁵⁵, J. Terron⁸⁰, M. Terwort^{41,o}, M. Testa⁴⁷, R.J. Teuscher^{158j}, J. Thadome¹⁷⁴, J. Therhaag²⁰, T. Theveneaux-Pelzer⁷⁸, M. Thioye¹⁷⁵, S. Thoma⁴⁸, J.P. Thomas¹⁷, E.N. Thompson⁸⁴, P.D. Thompson¹⁷, P.D. Thompson¹⁵⁸, A.S. Thompson⁵³, E. Thomson¹²⁰, M. Thomson²⁷, R.P. Thun⁸⁷, T. Tic¹²⁵, V.O. Tikhomirov⁹⁴, Y.A. Tikhonov¹⁰⁷, C.J.W.P. Timmermans¹⁰⁴, P. Tipton¹⁷⁵, F.J. Tique Aires Viegas²⁹, S. Tisserant⁸³, J. Tobias⁴⁸, B. Toczek³⁷, T. Todorov⁴, S. Todorova-Nova¹⁶¹, B. Toggerson¹⁶³, J. Tojo⁶⁶, S. Tokár^{144a}, K. Tokunaga⁶⁷, K. Tokushuku⁶⁶, K. Tollefson⁸⁸, M. Tomoto¹⁰¹, L. Tompkins¹⁴, K. Toms¹⁰³, G. Tong^{32a}, A. Tonoyan¹³, C. Topfel¹⁶, N.D. Topilin⁶⁵, I. Torchiani²⁹, E. Torrence¹¹⁴, H. Torres⁷⁸, E. Torró Pastor¹⁶⁷, J. Toth^{83,x}, F. Touchard⁸³, D.R. Tovey¹³⁹, D. Traynor⁷⁵, T. Trefzger¹⁷³, L. Tremblet²⁹, A. Tricoli²⁹, I.M. Trigger^{159a}, S. Trincas-Duvoid⁷⁸, T.N. Trinh⁷⁸, M.F. Tripijana⁷⁰, W. Trischuk¹⁵⁸, A. Trivedi^{24,w}, B. Trocme⁵⁵, C. Troncon^{89a}, M. Trotter-McDonald¹⁴², A. Trzupek³⁸, C. Tsarouchas²⁹, J.C.-L. Tseng¹¹⁸, M. Tsiakiris¹⁰⁵, P.V. Tsiareshka⁹⁰, D. Tsionou⁴, G. Tsipolitis⁹, V. Tsiskaridze⁴⁸, E.G. Tskhadadze⁵¹, I.I. Tsukerman⁹⁵, V. Tsulaia¹⁴, J.-W. Tsung²⁰, S. Tsuno⁶⁶, D. Tsybychev¹⁴⁸, A. Tua¹³⁹, J.M. Tugge³⁰, M. Turala³⁸, D. Turecek¹²⁷, I. Turk Cakir^{3e}, E. Turlay¹⁰⁵, R. Turra^{89a,89b}, P.M. Tuts³⁴, A. Tykhonov⁷⁴, M. Tyllmad^{146a,146b}, M. Tyndel¹²⁹, H. Tyrvaainen²⁹, G. Tzanakos⁸, K. Uchida²⁰, I. Ueda¹⁵⁵, R. Ueno²⁸, M. Ugland¹³, M. Uhlenbrock²⁰, M. Uhrmacher⁵⁴, F. Ukegawa¹⁶⁰, G. Unal²⁹, D.G. Underwood⁵, A. Undrus²⁴, G. Unel¹⁶³, Y. Unno⁶⁶, D. Urbaniec³⁴, E. Urkovsky¹⁵³, P. Urrejola^{31a}, G. Usai⁷, M. Uslenghi^{119a,119b}, L. Vacavant⁸³, V. Vacek¹²⁷, B. Vachon⁸⁵, S. Vahsen¹⁴, J. Valenta¹²⁵, P. Valente^{132a}, S. Valentinetti^{19a,19b}, S. Valkar¹²⁶, E. Valladolid Gallego¹⁶⁷, S. Vallecorsa¹⁵², J.A. Valls Ferrer¹⁶⁷, H. van der Graaf¹⁰⁵, E. van der Kraaij¹⁰⁵, R. Van Der Leeuw¹⁰⁵, E. van der Poel¹⁰⁵, D. van der Ster²⁹, B. Van Eijk¹⁰⁵, N. van Eldik⁸⁴, P. van Gemmeren⁵, Z. van Kesteren¹⁰⁵, I. van Vulpen¹⁰⁵, W. Vandelli²⁹, G. Vandoni²⁹, A. Vaniachine⁵, P. Vankov⁴¹, F. Vannucci⁷⁸, F. Varela Rodriguez²⁹, R. Vari^{132a}, E.W. Varnes⁶, D. Varouchas¹⁴, A. Vartapetian⁷, K.E. Varvell¹⁵⁰, V.I. Vassilakopoulos⁵⁶, F. Vazeille³³, G. Vegni^{89a,89b}, J.J. Veillet¹¹⁵, C. Vellidis⁸, F. Veloso^{124a}, R. Veness²⁹, S. Veneziano^{132a}, A. Ventura^{72a,72b}, D. Ventura¹³⁸, M. Venturi⁴⁸, N. Venturi¹⁶, V. Vercesi^{119a}, M. Verducci¹³⁸, W. Verkerke¹⁰⁵, J.C. Vermeulen¹⁰⁵, A. Vest⁴³, M.C. Vetterli^{142,e}, I. Vichou¹⁶⁵, T. Vickey^{145b,z}, G.H.A. Viehhauser¹¹⁸, S. Viel¹⁶⁸, M. Villa^{19a,19b}, M. Villaplana Perez¹⁶⁷, E. Vilucchi⁴⁷, M.G. Vincker²⁸, E. Vinek²⁹, V.B. Vinogradov⁶⁵, M. Virchaux^{136,*}, J. Virzi¹⁴, O. Vitells¹⁷¹, M. Viti⁴¹, I. Vivarelli⁴⁸, F. Vives Vaque¹¹, S. Vlachos⁹, M. Vlasak¹²⁷, N. Vlasov²⁰, A. Vogel²⁰, P. Vokac¹²⁷, G. Volpi⁴⁷, M. Volpi¹¹, G. Volpini^{89a}, H. von der Schmitt⁹⁹, J. von Loeben⁹⁹, H. von Radziewski⁴⁸, E. von Toerne²⁰, V. Vorobel¹²⁶, A.P. Vorobiev¹²⁸, V. Vorwerk¹¹, M. Vos¹⁶⁷, R. Voss²⁹, T.T. Voss¹⁷⁴, J.H. Vossebeld⁷³, N. Vranjes^{12a}, M. Vranjes Milosavljevic^{12a}, V. Vrba¹²⁵, M. Vreeswijk¹⁰⁵, T. Vu Anh⁸¹, R. Vuillemet²⁹, I. Vukotic¹¹⁵, W. Wagner¹⁷⁴, P. Wagner¹²⁰, H. Wahlen¹⁷⁴, J. Wakabayashi¹⁰¹, J. Walbersloh⁴², S. Walch⁸⁷, J. Walder⁷¹, R. Walker⁹⁸, W. Walkowiak¹⁴¹, R. Wall¹⁷⁵, P. Waller⁷³, C. Wang⁴⁴, H. Wang¹⁷², H. Wang^{32b,aa}, J. Wang¹⁵¹, J. Wang^{32d}, J.C. Wang¹³⁸, R. Wang¹⁰³, S.M. Wang¹⁵¹, A. Warburton⁸⁵, C.P. Ward²⁷, M. Warsinsky⁴⁸, P.M. Watkins¹⁷, A.T. Watson¹⁷, M.F. Watson¹⁷, G. Watts¹³⁸, S. Watts⁸², A.T. Waugh¹⁵⁰, B.M. Waugh⁷⁷, J. Weber⁴², M. Weber¹²⁹, M.S. Weber¹⁶, P. Weber⁵⁴, A.R. Weidberg¹¹⁸, P. Weigell⁹⁹, J. Weingarten⁵⁴, C. Weiser⁴⁸, H. Wellenstein²², P.S. Wells²⁹, M. Wen⁴⁷, T. Wenaus²⁴, S. Wendler¹²³, Z. Weng^{151,q}, T. Wengler²⁹, S. Wenig²⁹, N. Wermes²⁰, M. Werner⁴⁸, P. Werner²⁹, M. Werth¹⁶³, M. Wessels^{58a}, C. Weydert⁵⁵, K. Whalen²⁸, S.J. Wheeler-Ellis¹⁶³, S.P. Whitaker²¹, A. White⁷, M.J. White⁸⁶, S. White²⁴, S.R. Whitehead¹¹⁸, D. Whiteson¹⁶³, D. Whittington⁶¹, F. Wicek¹¹⁵, D. Wicke¹⁷⁴, F.J. Wickens¹²⁹, W. Wiedenmann¹⁷², M. Wielders¹²⁹, P. Wienemann²⁰, C. Wiglesworth⁷⁵, L.A.M. Wiik⁴⁸, P.A. Wijeratne⁷⁷, A. Wildauer¹⁶⁷, M.A. Wildt^{41,o}, I. Wilhelm¹²⁶, H.G. Wilkens²⁹, J.Z. Will⁹⁸, E. Williams³⁴, H.H. Williams¹²⁰, W. Willis³⁴, S. Willocq⁸⁴, J.A. Wilson¹⁷, M.G. Wilson¹⁴³, A. Wilson⁸⁷, I. Wingerter-Seez⁴, S. Winkelmann⁴⁸, F. Winklmeier²⁹, M. Wittgen¹⁴³, M.W. Wolter³⁸, H. Wolters^{124a,h}, G. Wooden¹¹⁸, B.K. Wosiek³⁸, J. Wotschack²⁹, M.J. Woudstra⁸⁴, K. Wraight⁵³, C. Wright⁵³, B. Wrona⁷³, S.L. Wu¹⁷²,

X. Wu⁴⁹, Y. Wu^{32b,ab}, E. Wulf³⁴, R. Wunstorf⁴², B.M. Wynne⁴⁵, L. Xaplanteris⁹, S. Xella³⁵, S. Xie⁴⁸, Y. Xie^{32a}, C. Xu^{32b,ac}, D. Xu¹³⁹, G. Xu^{32a}, B. Yabsley¹⁵⁰, M. Yamada⁶⁶, A. Yamamoto⁶⁶, K. Yamamoto⁶⁴, S. Yamamoto¹⁵⁵, T. Yamamura¹⁵⁵, J. Yamaoka⁴⁴, T. Yamazaki¹⁵⁵, Y. Yamazaki⁶⁷, Z. Yan²¹, H. Yang⁸⁷, U.K. Yang⁸², Y. Yang⁶¹, Y. Yang^{32a}, Z. Yang^{146a,146b}, S. Yanush⁹¹, W.-M. Yao¹⁴, Y. Yao¹⁴, Y. Yasu⁶⁶, G.V. Ybeles Smit¹³⁰, J. Ye³⁹, S. Ye²⁴, M. Yilmaz^{3c}, R. Yoosooftmiya¹²³, K. Yorita¹⁷⁰, R. Yoshida⁵, C. Young¹⁴³, S. Youssef²¹, D. Yu²⁴, J. Yu⁷, J. Yu^{32c,ac}, L. Yuan^{32a,ad}, A. Yurkewicz¹⁴⁸, V.G. Zaets¹²⁸, R. Zaidan⁶³, A.M. Zaitsev¹²⁸, Z. Zajacova²⁹, Yo.K. Zalite¹²¹, L. Zanello^{132a,132b}, P. Zarzhitsky³⁹, A. Zaytsev¹⁰⁷, C. Zeitnitz¹⁷⁴, M. Zeller¹⁷⁵, A. Zemla³⁸, C. Zender²⁰, A.V. Zenin¹²⁸, O. Zenin¹²⁸, T. Ženiš^{144a}, Z. Zenonos^{122a,122b}, S. Zenz¹⁴, D. Zerwas¹¹⁵, G. Zevi della Porta⁵⁷, Z. Zhan^{32d}, D. Zhang^{32b,aa}, H. Zhang⁸⁸, J. Zhang⁵, X. Zhang^{32d}, Z. Zhang¹¹⁵, L. Zhao¹⁰⁸, T. Zhao¹³⁸, Z. Zhao^{32b}, A. Zhemchugov⁶⁵, S. Zheng^{32a}, J. Zhong^{151,ae}, B. Zhou⁸⁷, N. Zhou¹⁶³, Y. Zhou¹⁵¹, C.G. Zhu^{32d}, H. Zhu⁴¹, J. Zhu⁸⁷, Y. Zhu¹⁷², X. Zhuang⁹⁸, V. Zhuravlov⁹⁹, D. Zieminska⁶¹, R. Zimmermann²⁰, S. Zimmermann²⁰, S. Zimmermann⁴⁸, M. Ziolkowski¹⁴¹, R. Zitoun⁴, L. Živković³⁴, V.V. Zmouchko^{128,*}, G. Zobernig¹⁷², A. Zoccoli^{19a,19b}, Y. Zolnierowski⁴, A. Zsenei²⁹, M. zur Nedden¹⁵, V. Zutshi¹⁰⁶, L. Zwalinski²⁹

¹University at Albany, Albany, NY, USA

²Department of Physics, University of Alberta, Edmonton AB, Canada

^{3(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

⁴LAPP, CNRS/IN2P3 and Université de Savoie, Annecy-le-Vieux, France

⁵High Energy Physics Division, Argonne National Laboratory, Argonne IL, USA

⁶Department of Physics, University of Arizona, Tucson AZ, USA

⁷Department of Physics, The University of Texas at Arlington, Arlington TX, USA

⁸Physics Department, University of Athens, Athens, Greece

⁹Physics Department, National Technical University of Athens, Zografou, Greece

¹⁰Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan

¹¹Institut de Física d'Altes Energies and Universitat Autònoma de Barcelona and ICREA, Barcelona, Spain

^{12(a)}Institute of Physics, University of Belgrade, Belgrade; ^(b)Vinca Institute of Nuclear Sciences, Belgrade, Serbia

¹³Department for Physics and Technology, University of Bergen, Bergen, Norway

¹⁴Physics Division, Lawrence Berkeley National Laboratory and University of California, Berkeley CA, USA

¹⁵Department of Physics, Humboldt University, Berlin, Germany

¹⁶Albert Einstein Center for Fundamental Physics and Laboratory for High Energy Physics, University of Bern, Bern, Switzerland

¹⁷School of Physics and Astronomy, University of Birmingham, Birmingham, UK

^{18(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

^{19(a)}INFN Sezione di Bologna; ^(b)Dipartimento di Fisica, Università di Bologna, Bologna, Italy

²⁰Physikalisches Institut, University of Bonn, Bonn, Germany

²¹Department of Physics, Boston University, Boston MA, USA

²²Department of Physics, Brandeis University, Waltham MA, USA

^{23(a)}Universidade Federal do Rio De Janeiro COPPE/EE/IF, Rio de Janeiro; ^(b)Instituto de Física, Universidade de Sao Paulo, Sao Paulo, Brazil

²⁴Physics Department, Brookhaven National Laboratory, Upton NY, USA

^{25(a)}National Institute of Physics and Nuclear Engineering, Bucharest; ^(b)University Politehnica Bucharest, Bucharest;

^(c)West University in Timisoara, Timisoara, Romania

²⁶Departamento de Física, Universidad de Buenos Aires, Buenos Aires, Argentina

²⁷Cavendish Laboratory, University of Cambridge, Cambridge, UK

²⁸Department of Physics, Carleton University, Ottawa ON, Canada

²⁹CERN, Geneva, Switzerland

³⁰Enrico Fermi Institute, University of Chicago, Chicago IL, USA

^{31(a)}Departamento de Física, Pontificia Universidad Católica de Chile, Santiago; ^(b)Departamento de Física, Universidad Técnica Federico Santa María, Valparaíso, Chile

^{32(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)High Energy Physics Group, Shandong University, Shandong, China

- ³³Laboratoire de Physique Corpusculaire, Clermont Université and Université Blaise Pascal and CNRS/IN2P3, Aubiere Cedex, France
- ³⁴Nevis Laboratory, Columbia University, Irvington NY, USA
- ³⁵Niels Bohr Institute, University of Copenhagen, Kobenhavn, Denmark
- ^{36(a)}INFN Gruppo Collegato di Cosenza; ^(b)Dipartimento di Fisica, Università della Calabria, Arcavata di Rende, Italy
- ³⁷Faculty of Physics and Applied Computer Science, AGH-University of Science and Technology, Krakow, Poland
- ³⁸The Henryk Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences, Krakow, Poland
- ³⁹Physics Department, Southern Methodist University, Dallas TX, USA
- ⁴⁰Physics Department, University of Texas at Dallas, Richardson TX, USA
- ⁴¹DESY, Hamburg and Zeuthen, Germany
- ⁴²Institut für Experimentelle Physik IV, Technische Universität Dortmund, Dortmund, Germany
- ⁴³Institut für Kern- und Teilchenphysik, Technical University Dresden, Dresden, Germany
- ⁴⁴Department of Physics, Duke University, Durham NC, USA
- ⁴⁵SUPA - School of Physics and Astronomy, University of Edinburgh, Edinburgh, UK
- ⁴⁶Fachhochschule Wiener Neustadt, Johannes Gutenbergstrasse 3, 2700 Wiener Neustadt, Austria
- ⁴⁷INFN Laboratori Nazionali di Frascati, Frascati, Italy
- ⁴⁸Fakultät für Mathematik und Physik, Albert-Ludwigs-Universität, Freiburg i.Br., Germany
- ⁴⁹Section de Physique, Université de Genève, Geneva, Switzerland
- ^{50(a)}INFN Sezione di Genova; ^(b)Dipartimento di Fisica, Università di Genova, Genova, Italy
- ⁵¹Institute of Physics and HEP Institute, Georgian Academy of Sciences and Tbilisi State University, Tbilisi, Georgia
- ⁵²II Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen, Germany
- ⁵³SUPA - School of Physics and Astronomy, University of Glasgow, Glasgow, UK
- ⁵⁴II Physikalisches Institut, Georg-August-Universität, Göttingen, Germany
- ⁵⁵Laboratoire de Physique Subatomique et de Cosmologie, Université Joseph Fourier and CNRS/IN2P3 and Institut National Polytechnique de Grenoble, Grenoble, France
- ⁵⁶Department of Physics, Hampton University, Hampton VA, USA
- ⁵⁷Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge MA, USA
- ^{58(a)}Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Heidelberg; ^(b)Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg; ^(c)ZITI Institut für technische Informatik, Ruprecht-Karls-Universität Heidelberg, Mannheim, Germany
- ⁵⁹Faculty of Science, Hiroshima University, Hiroshima, Japan
- ⁶⁰Faculty of Applied Information Science, Hiroshima Institute of Technology, Hiroshima, Japan
- ⁶¹Department of Physics, Indiana University, Bloomington IN, USA
- ⁶²Institut für Astro- und Teilchenphysik, Leopold-Franzens-Universität, Innsbruck, Austria
- ⁶³University of Iowa, Iowa City IA, USA
- ⁶⁴Department of Physics and Astronomy, Iowa State University, Ames IA, USA
- ⁶⁵Joint Institute for Nuclear Research, JINR Dubna, Dubna, Russia
- ⁶⁶KEK, High Energy Accelerator Research Organization, Tsukuba, Japan
- ⁶⁷Graduate School of Science, Kobe University, Kobe, Japan
- ⁶⁸Faculty of Science, Kyoto University, Kyoto, Japan
- ⁶⁹Kyoto University of Education, Kyoto, Japan
- ⁷⁰Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata, Argentina
- ⁷¹Physics Department, Lancaster University, Lancaster, UK
- ^{72(a)}INFN Sezione di Lecce; ^(b)Dipartimento di Fisica, Università del Salento, Lecce, Italy
- ⁷³Oliver Lodge Laboratory, University of Liverpool, Liverpool, UK
- ⁷⁴Department of Physics, Jožef Stefan Institute and University of Ljubljana, Ljubljana, Slovenia
- ⁷⁵Department of Physics, Queen Mary University of London, London, UK
- ⁷⁶Department of Physics, Royal Holloway University of London, Surrey, UK
- ⁷⁷Department of Physics and Astronomy, University College London, London, UK
- ⁷⁸Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France
- ⁷⁹Fysiska Institutionen, Lunds Universitet, Lund, Sweden
- ⁸⁰Departamento de Física Teórica C-15, Universidad Autónoma de Madrid, Madrid, Spain

- ⁸¹Institut für Physik, Universität Mainz, Mainz, Germany
- ⁸²School of Physics and Astronomy, University of Manchester, Manchester, UK
- ⁸³CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France
- ⁸⁴Department of Physics, University of Massachusetts, Amherst MA, USA
- ⁸⁵Department of Physics, McGill University, Montreal QC, Canada
- ⁸⁶School of Physics, University of Melbourne, Victoria, Australia
- ⁸⁷Department of Physics, The University of Michigan, Ann Arbor MI, USA
- ⁸⁸Department of Physics and Astronomy, Michigan State University, East Lansing MI, USA
- ⁸⁹(a)INFN Sezione di Milano; (b)Dipartimento di Fisica, Università di Milano, Milano, Italy
- ⁹⁰B.I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk, Republic of Belarus
- ⁹¹National Scientific and Educational Centre for Particle and High Energy Physics, Minsk, Republic of Belarus
- ⁹²Department of Physics, Massachusetts Institute of Technology, Cambridge MA, USA
- ⁹³Group of Particle Physics, University of Montreal, Montreal QC, Canada
- ⁹⁴P.N. Lebedev Institute of Physics, Academy of Sciences, Moscow, Russia
- ⁹⁵Institute for Theoretical and Experimental Physics (ITEP), Moscow, Russia
- ⁹⁶Moscow Engineering and Physics Institute (MEPhI), Moscow, Russia
- ⁹⁷Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia
- ⁹⁸Fakultät für Physik, Ludwig-Maximilians-Universität München, München, Germany
- ⁹⁹Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), München, Germany
- ¹⁰⁰Nagasaki Institute of Applied Science, Nagasaki, Japan
- ¹⁰¹Graduate School of Science, Nagoya University, Nagoya, Japan
- ¹⁰²(a)INFN Sezione di Napoli; (b)Dipartimento di Scienze Fisiche, Università di Napoli, Napoli, Italy
- ¹⁰³Department of Physics and Astronomy, University of New Mexico, Albuquerque NM, USA
- ¹⁰⁴Institute for Mathematics, Astrophysics and Particle Physics, Radboud University Nijmegen/Nikhef, Nijmegen, Netherlands
- ¹⁰⁵Nikhef National Institute for Subatomic Physics and University of Amsterdam, Amsterdam, Netherlands
- ¹⁰⁶Department of Physics, Northern Illinois University, DeKalb IL, USA
- ¹⁰⁷Budker Institute of Nuclear Physics (BINP), Novosibirsk, Russia
- ¹⁰⁸Department of Physics, New York University, New York NY, USA
- ¹⁰⁹Ohio State University, Columbus OH, USA
- ¹¹⁰Faculty of Science, Okayama University, Okayama, Japan
- ¹¹¹Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman OK, USA
- ¹¹²Department of Physics, Oklahoma State University, Stillwater OK, USA
- ¹¹³Palacký University, RCPTM, Olomouc, Czech Republic
- ¹¹⁴Center for High Energy Physics, University of Oregon, Eugene OR, USA
- ¹¹⁵LAL, Univ. Paris-Sud and CNRS/IN2P3, Orsay, France
- ¹¹⁶Graduate School of Science, Osaka University, Osaka, Japan
- ¹¹⁷Department of Physics, University of Oslo, Oslo, Norway
- ¹¹⁸Department of Physics, Oxford University, Oxford, UK
- ¹¹⁹(a)INFN Sezione di Pavia; (b)Dipartimento di Fisica Nucleare e Teorica, Università di Pavia, Pavia, Italy
- ¹²⁰Department of Physics, University of Pennsylvania, Philadelphia PA, USA
- ¹²¹Petersburg Nuclear Physics Institute, Gatchina, Russia
- ¹²²(a)INFN Sezione di Pisa; (b)Dipartimento di Fisica E. Fermi, Università di Pisa, Pisa, Italy
- ¹²³Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh PA, USA
- ¹²⁴(a)Laboratorio de Instrumentacao e Fisica Experimental de Particulas - LIP, Lisboa, Portugal; (b)Departamento de Fisica Teorica y del Cosmos and CAFPE, Universidad de Granada, Granada, Spain
- ¹²⁵Institute of Physics, Academy of Sciences of the Czech Republic, Praha, Czech Republic
- ¹²⁶Faculty of Mathematics and Physics, Charles University in Prague, Praha, Czech Republic
- ¹²⁷Czech Technical University in Prague, Praha, Czech Republic
- ¹²⁸State Research Center Institute for High Energy Physics, Protvino, Russia
- ¹²⁹Particle Physics Department, Rutherford Appleton Laboratory, Didcot, UK
- ¹³⁰Physics Department, University of Regina, Regina SK, Canada
- ¹³¹Ritsumeikan 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'Énergie des Sciences Techniques Nucleaires, Rabat; ^(c)Université Cadi Ayyad, Faculté des sciences Semlalia Département de Physique, B.P. 2390 Marrakech 40000; ^(d)Faculté des Sciences, Université Mohamed Premier and LTPM, Oujda; ^(e)Faculté des Sciences, Université Mohammed V, Rabat, Morocco
- ¹³⁶DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat à l'Énergie Atomique), Gif-sur-Yvette, France
- ¹³⁷Santa Cruz Institute for Particle Physics, University of California Santa Cruz, Santa Cruz CA, USA
- ¹³⁸Department of Physics, University of Washington, Seattle WA, USA
- ¹³⁹Department of Physics and Astronomy, University of Sheffield, Sheffield, UK
- ¹⁴⁰Department of Physics, Shinshu University, Nagano, Japan
- ¹⁴¹Fachbereich Physik, Universität Siegen, Siegen, Germany
- ¹⁴²Department of Physics, Simon Fraser University, Burnaby BC, Canada
- ¹⁴³SLAC National Accelerator Laboratory, Stanford CA, USA
- ^{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
- ¹⁴⁷Physics Department, Royal Institute of Technology, Stockholm, Sweden
- ¹⁴⁸Department of Physics and Astronomy, Stony Brook University, Stony Brook NY, USA
- ¹⁴⁹Department of Physics and Astronomy, University of Sussex, Brighton, UK
- ¹⁵⁰School of Physics, University of Sydney, Sydney, Australia
- ¹⁵¹Institute of Physics, Academia Sinica, Taipei, Taiwan
- ¹⁵²Department of Physics, Technion: Israel Inst. of Technology, Haifa, Israel
- ¹⁵³Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel
- ¹⁵⁴Department of Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece
- ¹⁵⁵International Center for Elementary Particle Physics and Department of Physics, The University of Tokyo, Tokyo, Japan
- ¹⁵⁶Graduate School of Science and Technology, Tokyo Metropolitan University, Tokyo, Japan
- ¹⁵⁷Department of Physics, Tokyo Institute of Technology, Tokyo, Japan
- ¹⁵⁸Department of Physics, University of Toronto, Toronto ON, Canada
- ^{159(a)}TRIUMF, Vancouver BC; ^(b)Department of Physics and Astronomy, York University, Toronto ON, Canada
- ¹⁶⁰Institute of Pure and Applied Sciences, University of Tsukuba, Ibaraki, Japan
- ¹⁶¹Science and Technology Center, Tufts University, Medford MA, USA
- ¹⁶²Centro de Investigaciones, Universidad Antonio Narino, Bogota, Colombia
- ¹⁶³Department of Physics and Astronomy, University of California Irvine, Irvine CA, USA
- ^{164(a)}INFN Gruppo Collegato di Udine; ^(b)ICTP, Trieste; ^(c)Dipartimento di Fisica, Università di Udine, Udine, Italy
- ¹⁶⁵Department of Physics, University of Illinois, Urbana IL, USA
- ¹⁶⁶Department of Physics and Astronomy, University of Uppsala, Uppsala, Sweden
- ¹⁶⁷Instituto 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
- ¹⁶⁸Department of Physics, University of British Columbia, Vancouver BC, Canada
- ¹⁶⁹Department of Physics and Astronomy, University of Victoria, Victoria BC, Canada
- ¹⁷⁰Waseda University, Tokyo, Japan
- ¹⁷¹Department of Particle Physics, The Weizmann Institute of Science, Rehovot, Israel
- ¹⁷²Department of Physics, University of Wisconsin, Madison WI, USA
- ¹⁷³Fakultät für Physik und Astronomie, Julius-Maximilians-Universität, Würzburg, Germany
- ¹⁷⁴Fachbereich C Physik, Bergische Universität Wuppertal, Wuppertal, Germany
- ¹⁷⁵Department of Physics, Yale University, New Haven CT, USA

- ¹⁷⁶Yerevan Physics Institute, Yerevan, Armenia
- ¹⁷⁷Domaine scientifique de la Doua, Centre de Calcul CNRS/IN2P3, Villeurbanne Cedex, France
- ^aAlso at Laboratorio de Instrumentacao e Fisica Experimental de Particulas - LIP, Lisboa, Portugal
- ^bAlso at Faculdade de Ciencias and CFNUL, Universidade de Lisboa, Lisboa, Portugal
- ^cAlso at Particle Physics Department, Rutherford Appleton Laboratory, Didcot, UK
- ^dAlso at CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France
- ^eAlso at TRIUMF, Vancouver BC, Canada
- ^fAlso at Department of Physics, California State University, Fresno CA, USA
- ^gAlso at Faculty of Physics and Applied Computer Science, AGH-University of Science and Technology, Krakow, Poland
- ^hAlso at Department of Physics, University of Coimbra, Coimbra, Portugal
- ⁱAlso at Università di Napoli Parthenope, Napoli, Italy
- ^jAlso at Institute of Particle Physics (IPP), Canada
- ^kAlso at Department of Physics, Middle East Technical University, Ankara, Turkey
- ^lAlso at Louisiana Tech University, Ruston LA, USA
- ^mAlso at Group of Particle Physics, University of Montreal, Montreal QC, Canada
- ⁿAlso at Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan
- ^oAlso at Institut für Experimentalphysik, Universität Hamburg, Hamburg, Germany
- ^pAlso at Manhattan College, New York NY, USA
- ^qAlso at School of Physics and Engineering, Sun Yat-sen University, Guanzhou, China
- ^rAlso at Academia Sinica Grid Computing, Institute of Physics, Academia Sinica, Taipei, Taiwan
- ^sAlso at High Energy Physics Group, Shandong University, Shandong, China
- ^tAlso at California Institute of Technology, Pasadena CA, USA
- ^uAlso at Section de Physique, Université de Genève, Geneva, Switzerland
- ^vAlso at Departamento de Fisica, Universidade de Minho, Braga, Portugal
- ^wAlso at Department of Physics and Astronomy, University of South Carolina, Columbia SC, USA
- ^xAlso at KFKI Research Institute for Particle and Nuclear Physics, Budapest, Hungary
- ^yAlso at Institute of Physics, Jagiellonian University, Krakow, Poland
- ^zAlso at Department of Physics, Oxford University, Oxford, UK
- ^{aa}Also at Institute of Physics, Academia Sinica, Taipei, Taiwan
- ^{ab}Also at Department of Physics, The University of Michigan, Ann Arbor MI, USA
- ^{ac}Also at DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat a l'Energie Atomique), Gif-sur-Yvette, France
- ^{ad}Also at Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France
- ^{ae}Also at Department of Physics, Nanjing University, Jiangsu, China
- *Deceased