

# UC Santa Cruz

## UC Santa Cruz Previously Published Works

### Title

Search for resonant diboson production in the  $\ell\ell q\bar{q}$  final state in pp collisions at  $\sqrt{s}=8$  TeV with the ATLAS detector

### Permalink

<https://escholarship.org/uc/item/6bn5h33h>

### Journal

European Physical Journal C, 75(2)

### ISSN

1434-6044

### Authors

ATLAS Collaboration

Aad, G

Abbott, B

et al.

### Publication Date

2015-02-01

### DOI

10.1140/epjc/s10052-015-3261-8

### Copyright Information

This work is made available under the terms of a Creative Commons Attribution License, available at <https://creativecommons.org/licenses/by/4.0/>

Peer reviewed

# Search for resonant diboson production in the $\ell\ell q\bar{q}$ final state in $pp$ collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector

ATLAS Collaboration\*

CERN, 1211 Geneva 23, Switzerland

Received: 23 September 2014 / Accepted: 7 January 2015 / Published online: 10 February 2015

© CERN for the benefit of the ATLAS collaboration 2015. This article is published with open access at Springerlink.com

**Abstract** This paper reports on a search for narrow resonances in diboson production in the  $\ell\ell q\bar{q}$  final state using  $pp$  collision data corresponding to an integrated luminosity of  $20 \text{ fb}^{-1}$  collected at  $\sqrt{s} = 8$  TeV with the ATLAS detector at the Large Hadron Collider. No significant excess of data events over the Standard Model expectation is observed. Upper limits at the 95 % confidence level are set on the production cross section times branching ratio for Kaluza–Klein gravitons predicted by the Randall–Sundrum model and for Extended Gauge Model  $W'$  bosons. These results lead to the exclusion of mass values below 740 and 1590 GeV for the graviton and  $W'$  boson respectively.

## 1 Introduction

This paper presents a search for narrow diboson resonances in the semileptonic decay channel  $ZW$  or  $ZZ \rightarrow \ell\ell q\bar{q}$  (where  $\ell$  stands for electron or muon) in  $pp$  collision data corresponding to an integrated luminosity of  $20 \text{ fb}^{-1}$  recorded with the ATLAS detector at a centre-of-mass energy  $\sqrt{s} = 8$  TeV at the Large Hadron Collider (LHC). This type of resonances appear in models such as Technicolor [1–3], Warped Extra Dimensions [4–6], and Grand Unified Theories [7–10]. The semileptonic decay channel has a relatively large branching ratio compared to the fully leptonic mode, while the requirement of the presence of two decay leptons can suppress the multijet background present in the fully hadronic mode. Additionally, the absence of neutrinos in the final state allows to reconstruct the invariant mass of the diboson system.

This analysis is optimized using two models with narrow resonances as benchmarks: spin-2 Kaluza–Klein (KK) gravitons ( $G^* \rightarrow ZZ$ ), and spin-1  $W'$  gauge bosons ( $W' \rightarrow ZW$ ) of the Sequential Standard Model (SSM) with modified coupling to  $ZW$ , also referred to as the Extended Gauge Model (EGM) [11]. For both models, the  $W$  and  $Z$  bosons from resonance decays are longitudinally polarized over a pole mass range relevant to this analysis.

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

The KK graviton interpretation is based on an extended Randall–Sundrum (RS) model with a warped extra dimension in which the Standard Model (SM) fields can propagate [12]. This extended “bulk” RS model avoids constraints on the original RS model [4], referred to as RS1 hereafter, from limits on flavour-changing neutral currents and from electroweak precision tests. The bulk RS model is characterized by a dimensionless coupling constant  $k/\bar{M}_{\text{Pl}} \sim 1$  where  $k$  is the curvature of the warped extra dimension and  $\bar{M}_{\text{Pl}} = M_{\text{Pl}}/\sqrt{8\pi}$  is the reduced Planck mass. The width relative to the mass of the bulk RS graviton with  $k/\bar{M}_{\text{Pl}} = 1$  varies between 3 and 6 % within the pole mass range of 300–2000 GeV.

The EGM introduces  $W'$  and  $Z'$  bosons with SM couplings to fermions and with the coupling strength of the heavy  $W'$  to  $WZ$  modified by a mixing factor  $\xi = c \times (m_W/m_{W'})^2$  relative to the SM couplings, where  $m_W$  and  $m_{W'}$  are the pole masses of the  $W$  and  $W'$  bosons respectively, and  $c$  is a coupling scaling factor. In this scenario the partial width of the  $W'$  boson to  $WZ$  scales linearly with  $m_{W'}$ , leading to a narrow resonance over the accessible mass range, in contrast to the SSM where the width grows rapidly as  $m_{W'}^5$ . For the simulated EGM  $W'$  samples used in the analysis, the natural  $W'$  width is about 3 % at a pole mass of 300 GeV and increases slightly to 4 % at a pole mass of 2000 GeV.

Previous searches for diboson resonances have been carried out using  $p\bar{p}$  collision data at  $\sqrt{s} = 1.96$  TeV at the Tevatron and  $pp$  collision data at  $\sqrt{s} = 7$ –8 TeV at the LHC. The D0 Collaboration searched for resonances in  $WW$  and  $ZW$  production [13, 14] and excluded  $W'$  bosons in the mass range of 180–690 GeV and RS1 gravitons in the mass interval 300–754 GeV at the 95 % confidence level (CL). The CDF experiment searched for resonances in the  $ZZ$  decay channel and set limits on the production cross section of RS1 gravitons in the mass range 300–1000 GeV at the 95 % CL [15]. The ATLAS Collaboration reported searches for resonant  $ZZ (\rightarrow \ell\ell\ell\ell', \ell\ell q\bar{q})$  [16],  $WW (\rightarrow \ell\nu q\bar{q})$  [17] and  $WZ (\rightarrow \ell\nu q\bar{q}, \ell\nu\ell\ell')$  [17, 18] production, and searches for new phenomena in high-mass  $WW (\rightarrow \ell\nu\ell'\nu')$  processes [19]

using  $pp$  collision data recorded at  $\sqrt{s} = 7$  TeV, except for the  $WZ \rightarrow \ell\nu\ell'\ell'$  search in Ref. [18], which used data recorded at  $\sqrt{s} = 8$  TeV. Here  $\ell'$  stands for an electron or muon. These studies excluded EGM  $W'$  bosons with masses up to 1.52 TeV for  $WZ$  final states, RS1 gravitons with masses up to 845 GeV for  $ZZ$  final states and up to 1.23 TeV for  $WW$  final states. The CMS Collaboration searched for  $ZZ$  and  $WW$  resonances in the semileptonic decay channel, setting exclusion limits on the production cross section of bulk RS gravitons [20]. In the fully hadronic channel, the CMS Collaboration excluded RS1 gravitons with  $k/\bar{M}_{\text{Pl}} = 0.1$  for masses up to 1.2 TeV, and  $W'$  bosons for masses up to 1.7 TeV [21]. Both of these searches implement jet substructure techniques to identify the event topology where the hadronic system from the decay of one or two gauge bosons is produced at high transverse momentum  $p_{\text{T}}$ , resulting in a single reconstructed jet. In the analysis presented here, a similar technique has been used to identify hadronically decaying  $W$  or  $Z$  boson produced at high  $p_{\text{T}}$ . This technique uses the characteristics of two cores (“sub-jets”) inside a single reconstructed jet and allows for a significant improvement in acceptance and selection efficiency for high mass states with boosted  $W$  and  $Z$  bosons over the previous analysis [16].

## 2 Analysis

In this study, three optimized sets of selection criteria classify  $ZW/ZZ \rightarrow \ell\ell q\bar{q}$  events into distinct kinematic regions, namely the “low- $p_{\text{T}}$  resolved region” (LR), “high- $p_{\text{T}}$  resolved region” (HR) and “merged region” (MR), based on the  $p_{\text{T}}$  of the dilepton and the hadronic system. In the LR and HR the hadronic boson decay is reconstructed as two distinct jets, whereas in the MR it is reconstructed as a single jet. In all three cases, the dilepton (hadronic system) mass is required to be consistent with the mass of the  $Z$  boson ( $W$  or  $Z$  boson). In the MR, additional jet substructure information, optimized for the identification of the hadronic decay of a longitudinally polarized high- $p_{\text{T}}$  boson, is used to improve the sensitivity. Finally, the  $\ell\ell q\bar{q}$  mass spectrum, reconstructed as the mass of the dilepton and the two-jet system in the LR and HR ( $m_{\ell\ell jj}$ ) or the dilepton and the single-jet system in the MR ( $m_{\ell\ell j}$ ), is examined for excesses with respect to the expectation from SM processes (background).

### 2.1 Detector and data sample

The ATLAS detector [22] consists of an inner detector (ID) providing charged particle tracking for the pseudorapidity<sup>1</sup>

<sup>1</sup> ATLAS uses a right-handed coordinate system with the  $z$ -axis along the beam pipe. The  $x$ -axis points to the centre of the LHC ring, and

**Table 1** Theoretical production cross section times branching ratio  $\sigma_{G^*}(pp \rightarrow G^*) \cdot \text{BR}(G^* \rightarrow ZZ)$  with  $k/\bar{M}_{\text{Pl}} = 1.0$  and  $\sigma_{W'}(pp \rightarrow W') \cdot \text{BR}(W' \rightarrow ZW)$  with  $c = 1$  for different pole masses of the resonances

Pole mass (GeV)	$\sigma_{G^*} \cdot \text{BR}$ (fb)	$\sigma_{W'} \cdot \text{BR}$ (fb)
500	540	4100
800	23	540
1400	0.44	33

range  $|\eta| < 2.5$ , surrounded by a superconducting solenoid, electromagnetic and hadronic calorimeters with a coverage of  $|\eta| < 4.9$ , and a muon spectrometer (MS) with toroidal magnets that provides muon identification in the range  $|\eta| < 2.7$ .

This study uses an integrated luminosity of  $20.3 \text{ fb}^{-1}$  of  $pp$  collision data collected in 2012. The luminosity is derived from beam-separation scans [23] and has an uncertainty of 2.8 %. Events are selected with lepton triggers that require the presence of at least one lepton (electron or muon) with  $p_{\text{T}}$  above 24 GeV. The trigger efficiency for signal events that pass the selection criteria described in Sect. 2.3 is approximately 92 % for the muon channel and greater than 99 % for the electron channel.

### 2.2 Simulated event samples

To model the acceptance and the reconstructed mass spectra for narrow resonances, benchmark signal samples are generated with pole masses between 300 and 2000 GeV, in 100 GeV steps. Additional samples are generated between 350 and 950 GeV for the bulk RS  $G^*$  signal so that the mass gap is reduced to 50 GeV, which is comparable to the detector resolution of the reconstructed  $\ell\ell q\bar{q}$  mass in this mass interval. The bulk RS  $G^*$  signal events are generated by CALCHEP [24] with  $k/\bar{M}_{\text{Pl}} = 1.0$ , and the  $W'$  signal sample is generated with PYTHIA 8 [25], setting the coupling scale factor  $c = 1$ . The factorization and renormalization scales are set to the resonance mass. The hadronisation and fragmentation are modelled with PYTHIA 8 in both cases, and the CTEQ6L1 [26] (MSTW2008LO [27]) parton distribution functions (PDFs) are used for the  $G^*$  ( $W'$ ) signal. The  $W'$  production cross section is scaled to a next-to-next-to-leading-order (NNLO) calculation in  $\alpha_s$  by ZWPROD [28]. Calculated production cross section times branching ratio values for different pole masses are given in Table 1.

Footnote 1 continued

the  $y$ -axis points upward. Cylindrical coordinates ( $R, \phi$ ) are used in the transverse plane,  $\phi$  being the azimuthal angle around the beam pipe. The pseudorapidity is defined in terms of the polar angle  $\theta$  as  $\eta = -\ln(\tan(\theta/2))$ .

The main background sources are  $Z$  bosons produced in association with jets ( $Z + \text{jets}$ ), followed by top-quark pair and non-resonant vector-boson pair production. The contribution from multijet events is negligible after the selection cuts described in Sect. 2.3. All background estimates are based on simulation. Additionally, the main background source,  $Z + \text{jets}$ , is estimated using constraints from data as described in Sect. 2.4. The  $Z + \text{jets}$  background is modelled by the SHERPA generator [29] with CT10 PDFs [30]. The top pair,  $s$ -channel single-top and  $Wt$  processes are modelled by the MC@NLO [31–34] generator with CT10 PDFs, interfaced to HERWIG [35,36] for hadronisation and JIMMY [37] for modelling of the underlying event. The top pair production cross section is calculated at NNLO in QCD including resummation of next-to-next-to-leading logarithmic soft gluon terms with Top++2.0 [38–43]. The  $t$ -channel single-top events are generated by AcerMC [44] with CTEQ6L1 PDFs and PYTHIA 6 [45] for hadronisation. The diboson events are produced with the HERWIG generator and CTEQ6L1 PDFs. The diboson production cross sections are normalized to predictions at next-to-leading-order accuracy as calculated with [46]. Generated events are processed with the ATLAS detector simulation program [47] based on the GEANT4 package [48]. Effects from additional inelastic  $pp$  interactions (pile-up) occurring in the same bunch crossing are taken into account by overlaying minimum-bias events simulated by PYTHIA 8.

### 2.3 Object and event selection

Electron candidates are selected from energy clusters in the electromagnetic calorimeter according to the medium criteria of Ref. [49], which impose requirements on the shower profile and demand an associated ID track. Offline reconstructed electrons are required to have  $p_T > 25$  GeV and  $|\eta| < 2.47$ . The transition region between the barrel and endcaps ( $1.37 < |\eta| < 1.52$ ) exhibits degraded energy resolution and is therefore excluded.

Muon candidates are reconstructed by combining ID and MS tracks which have consistent position, charge and momentum measurements [50]. The muon candidates are required to have  $p_T > 25$  GeV and  $|\eta| < 2.4$ .

A primary vertex reconstructed from at least three well-reconstructed charged particle tracks, each with  $p_T > 400$  MeV, is required in order to remove non-collision background. If an event contains more than one primary vertex candidate, the vertex with the highest  $\sum p_T^2$  of the associated tracks is selected. To ensure that both electrons or muons originate from the primary vertex, it is required that the product of the longitudinal impact parameter ( $z_0$ ) and the sine of the polar angle of the candidate ( $\theta$ ) satisfies  $|z_0 \sin(\theta)| < 0.5$  mm, and that the ratio of the transverse impact parameter ( $d_0$ ) to its uncertainty ( $\sigma_{d_0}$ ) for electrons (muons) fulfils

$|d_0|/\sigma_{d_0} < 6$  (3.5). In addition, the lepton candidates are required to be isolated from other tracks and calorimetric activity. The scalar sum of the transverse momenta of tracks within a cone of size  $\Delta R \equiv \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} = 0.2$  around the lepton track is required to be less than 15 % of the candidate  $p_T$ . Similarly, the sum of transverse energy deposits in the calorimeter within a cone of size  $\Delta R = 0.2$ , excluding the transverse energy due to the lepton, and corrected for the expected pile-up contribution, is required to be less than 30 % of the candidate  $p_T$  (calorimetric isolation).

To improve the acceptance for events with boosted  $Z$  bosons, with  $p_T > 800$  GeV, the isolation method is modified for dilepton objects: a dilepton track isolation variable is calculated for each lepton of a like-flavour pair by subtracting the  $p_T$  of the paired lepton from the  $p_T$  sum described above if it falls inside the isolation cone of the lepton under consideration. The modified scalar sum  $p_T$  variable for the dilepton isolation is required to be less than 15 % of the lepton  $p_T$ , as in the standard track isolation. The calorimetric isolation requirements are dropped if  $\Delta R(\ell\ell) < 0.25$ .

Jets are reconstructed from clusters of calorimeter cells using the anti- $k_t$  algorithm [51,52] with a distance parameter  $R = 0.4$ . Jets are required to be in the range  $|\eta| < 2.1$  and to have  $p_T > 30$  GeV after correcting for energy losses in passive material, the non-compensating response of the calorimeter and extra energy due to event pile-up [53]. Furthermore, for jets with  $p_T < 50$  GeV, the scalar sum  $p_T$  of associated tracks from the primary vertex is required to be at least 50 % of the scalar sum  $p_T$  of all associated tracks to suppress jets from pile-up interactions. The selected anti- $k_t$  jets are referred to as small- $R$  jets and denoted by “ $j$ ” hereafter.

For resonances with a mass above about 900 GeV, the  $q\bar{q}$  pair is often merged into a single jet and the fraction of merged  $q\bar{q}$  pairs increases with the resonance mass. Such jets are reconstructed with the Cambridge–Aachen jet clustering algorithm [54] with a distance parameter  $R = 1.2$ . To exploit the characteristics of the decay of the massive boson into a  $q\bar{q}$  pair, these jets are further required to pass a splitting and filtering algorithm similar to the algorithm described in Ref. [55] but optimized for the identification of very high- $p_T$  boson decays [56]. These jets are required to be within  $|\eta| < 1.2$  and to have  $p_T > 100$  GeV, and are referred to as large- $R$  jets or “ $J$ ” hereafter.

Events which contain exactly two electrons or muons satisfying the above criteria are selected if at least one is associated with a lepton trigger candidate. To select lepton pairs originating from a  $Z$  boson decay, the dilepton invariant mass ( $m_{\ell\ell}$ ) is required to be in the range  $66 \text{ GeV} < m_{\ell\ell} < 116 \text{ GeV}$ . The  $m_{\ell\ell}$  cut range is chosen to be wide to enhance the signal sensitivity, given that the dominant background is from the  $Z + \text{jets}$  processes and a narrower cut would not provide additional discrimination power. Muon-pair events are further required to have muons of opposite charge. The

**Table 2** Event yields in signal regions for data, expected backgrounds, and  $G^*$  and  $W'$  signals. The statistical and systematic uncertainties are given separately (in this order), except for the total background where the combined statistical and systematic uncertainty before (uncon-

strained) and after (constrained) the fit to the data in the signal regions is shown. The signal mass points correspond to 500 (LR), 800 (HR), 1400 (MR) GeV

Sample	LR	HR	MR
$Z + \text{jets}$	$9460 \pm 40 \pm 660$	$591 \pm 4 \pm 15$	$20.9 \pm 0.3 \pm 2.3$
$WW/WZ/ZZ$	$234 \pm 4 \pm 22$	$20.6 \pm 0.3 \pm 1.4$	$1.38 \pm 0.02 \pm 0.13$
$t\bar{t} + \text{Single } t$	$175.3 \pm 9.2 \pm 9.9$	–	–
Total (unconstrained)	$9870 \pm 690$	$612 \pm 17$	$22.3 \pm 2.5$
Total (constrained)	$9730 \pm 98$	$608.8 \pm 3.8$	$21.80 \pm 0.46$
Data	9728	619	25
$G^*$ signal	$1097 \pm 17 \pm 63$	$14.27 \pm 0.19 \pm 0.76$	$0.0995 \pm 0.0013 \pm 0.0059$
$W'$ signal	$1950 \pm 40 \pm 140$	$145.0 \pm 2.3 \pm 8.1$	$3.64 \pm 0.06 \pm 0.31$

opposite charge requirement is not required for electron-pair events because of a higher charge misidentification rate for high- $p_T$  electrons.

The three selection regions are differentiated by the  $p_T$  ranges for the leptonic  $Z$  decay candidate ( $p_T^{\ell\ell}$ ) and hadronic jet system, namely  $p_T^{\ell\ell} > 400$  GeV and  $p_T^j > 400$  GeV for the large- $R$  jet in the MR, and  $p_T^{\ell\ell} > 100$  (250) GeV and  $p_T^{jj} > 100$  (250) GeV for the two small- $R$  jets at low (high)  $p_T$  in the LR (HR). The mass of the hadronic jet system is required to be in the range  $70 \text{ GeV} < m_{jj/J} < 110 \text{ GeV}$  for both the hadronic  $W$  and  $Z$  decay candidates in all three regions. In the MR, the large- $R$  jet is split into subjets using an algorithm described in Ref. [55]. However, in contrast to the configuration used in Ref. [55], the mass relation between the large- $R$  jet and subjets, the mass drop, is not imposed. A subjet momentum balance variable is defined as  $\sqrt{y_F} = \min(p_T^{j1}, p_T^{j2})\Delta R_{12}/m_{12}$ , where  $p_T^{j1}$  and  $p_T^{j2}$  are the transverse momenta of the two leading subjets,  $\Delta R_{12}$  is their separation and  $m_{12}$  is their mass. To suppress jets from gluon radiation and splitting, the subjet momentum balance is required to be  $\sqrt{y_F} > 0.45$ . Events are classified by sequentially applying the criteria for the MR, HR, and LR, thus assigning each event exclusively to one region. Overall, the signal acceptance times efficiency after all selection requirements increases from 5 to 10 % at  $m_{G^*} = 300$  GeV to a plateau of 30–35 % above  $m_{G^*} = 500$  GeV for a signal sample of  $G^* \rightarrow ZZ \rightarrow \ell\ell q\bar{q}$ . The improvement in acceptance compared to the previous analysis [16] ranges up to a factor of five for masses above 1.5 TeV.

## 2.4 Background and event yield

The simulation of the main background source ( $Z + \text{jets}$ ) is corrected using data. The normalization and  $m_{\ell\ell jj/J}$  shape corrections of the simulated  $Z + \text{jets}$  background sample is determined from data in a control region defined by all selection cuts but with an inverted cut on  $m_{jj/J}$ , namely

$m_{jj/J} < 70$  GeV or  $m_{jj/J} > 110$  GeV, in the resolved and merged regions, respectively. The normalization corrections, obtained as the ratio of event yields in the data and  $Z + \text{jets}$  simulated samples for the electron and muon channel, after removing contributions from subdominant backgrounds from the data spectrum, range between 2 and 10 %. The  $m_{\ell\ell jj/J}$  shape correction is well reproduced with a linear fit to the ratio of data to  $Z + \text{jets}$  background, derived for each signal region after combining the electron and muon channels. This results in bin-by-bin corrections of up to 7 % in the LR, 3 % in the HR, and 22 % in the MR. The other backgrounds, from diboson and top production, are taken from simulation without applying corrections from data control regions.

The event yield in the three signal regions is summarized in Table 2. The total event yield with combined statistical and systematic uncertainties is given before and after the simultaneous fit to the three signal regions (cf. Sect. 3).

## 2.5 Systematic uncertainties

The main systematic uncertainty on the  $m_{\ell\ell jj/J}$  spectrum comes from the uncertainty in the  $Z + \text{jets}$  background modelling. The normalization uncertainty of the  $Z + \text{jets}$  background is estimated from the relative difference between the normalization corrections derived from the nominal control region ( $m_{jj/J} < 70$  GeV or  $> 110$  GeV) and either the lower or higher mass region, taking the larger of the two as an estimate of the systematic uncertainty. If the resulting uncertainty is smaller than the statistical uncertainty of the normalization correction from the nominal control region, the latter is used as the systematic uncertainty. The uncertainty of the shape correction is estimated from the uncertainty on the slope parameter of the linear fit and is treated as uncorrelated with respect to the normalization uncertainty. The combined normalization and shape uncertainties vary as a function of  $m_{\ell\ell jj/J}$  and range from 6 to 9 % in the LR, 2 to 8 % in the HR,

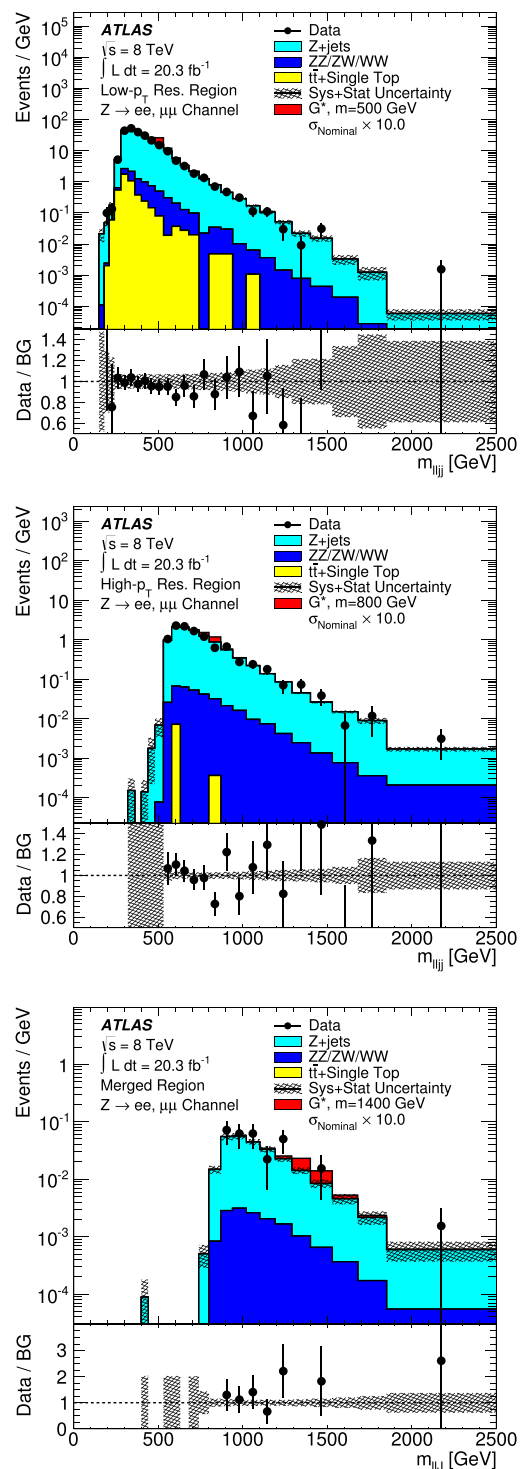
and 11 to 47 % in the MR. For all simulated samples, detector performance-related systematic uncertainties including the small- $R$  jet energy scale and resolution, large- $R$  jet energy, mass and momentum-balance scales and resolutions, the lepton reconstruction and identification efficiencies, and lepton momentum scales and resolutions are also considered. The large- $R$  jet energy and mass scale uncertainties are evaluated by comparing the ratio of calorimeter-based to track-based measurements in dijet data and simulated events, and are validated using a data sample of high- $p_T$   $W$  bosons produced in association with jets. A Kolmogorov–Smirnov (KS) test [57] is then performed between the nominal and systematically varied distributions for a given systematic uncertainty source to determine if it has a sizeable effect on the shape of background and signal estimations. Only significant systematic effects are retained in the analysis by requiring a KS probability of less than 10 %. For the normalization, if the event yield changes by more than half the statistical uncertainty of the nominal yield, the systematic uncertainty is included.

Uncertainties on signal acceptance due to PDF sets, renormalization and factorization scale choices, initial- and final-state gluon radiation (ISR/FSR) modelling, and LHC beam energy uncertainty are also considered. The PDF uncertainties are estimated by taking the acceptance difference between CTEQ11 and MSTW2008LO PDFs and adding it in quadrature to the difference between MSTW2008LO error sets. The uncertainties due to the scale and ISR/FSR modelling are estimated by varying relevant parameters in PYTHIA 8 by a factor of 2.0 and 0.5. The beam energy systematic uncertainty is assessed with simulation by varying the beam energy within the measured uncertainty of 0.66 % [58], leading to at most a 1 % effect on acceptance. The dominant uncertainty comes from ISR/FSR modelling and is approximately 5 %.

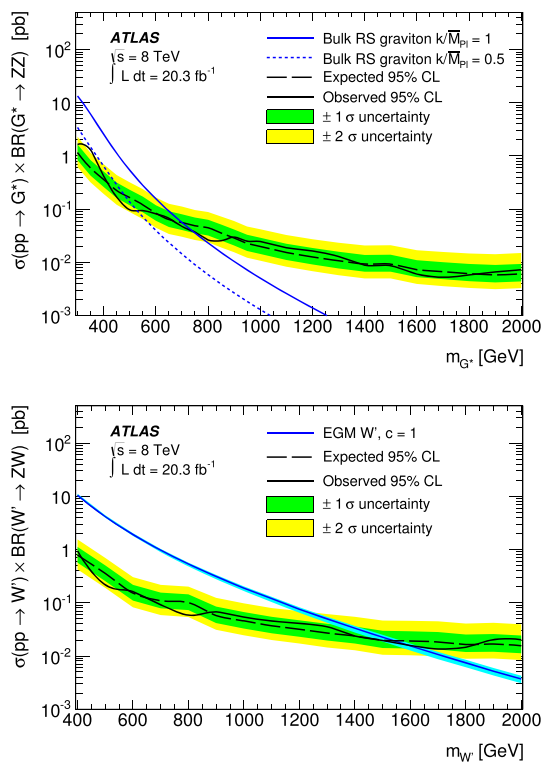
### 3 Results

The invariant mass of the diboson system is reconstructed from the  $\ell\ell jj$  or  $\ell\ell J$  system. The reconstructed  $m_{\ell\ell jj}$  distributions for data and simulated background events in the three signal regions are shown in Fig. 1 for the combined electron and muon channels. Good agreement is observed between the data and the background predictions, with  $p$  value<sup>2</sup> ranging from 0.98 to 0.10, and the results are presented as 95 % confidence level upper limits on the production cross section times branching ratio for the  $G^*$  and  $W'$  models. The upper limits are determined using the  $CL_s$  modified frequentist formalism [59] with a profile likelihood test statistic [60].

<sup>2</sup> The  $p$  value is the probability that the background can produce a fluctuation greater than or equal to the excess observed in data.



**Fig. 1** Reconstructed  $\ell\ell jj$  or  $\ell\ell J$  mass distributions in the data and for background after all the selection cuts are applied in the three kinematic regions referred to as the LR (top), HR (middle) and MR (bottom) in the text. The shaded regions show the full background uncertainty obtained by adding statistical and systematic uncertainties in quadrature, including the constraints on the background from the data control regions and before the fit to the data in the signal regions (cf. unconstrained case in Table 2). Also shown are the  $G^*$  signal yields expected for masses of 500, 800 and 1400 GeV with the production cross sections scaled by a factor 10



**Fig. 2** Observed and expected 95 % CL upper limits on the cross section times branching fraction as a function of the resonance pole mass for the  $G^*$  (top) and EGM  $W'$  (bottom). The LO (NNLO) theoretical cross sections for  $G^*$  (EGM  $W'$ ) production with  $k/\bar{M}_{Pl} = 0.5$  and 1.0 ( $c = 1$ ) are also shown. The band around the NNLO calculation represents the theoretical uncertainty on the NNLO calculation. The inner and outer bands on the expected limits represent  $\pm 1\sigma$  and  $\pm 2\sigma$  variations respectively

The test statistic is evaluated with a maximum likelihood fit of signal models and background predictions to the reconstructed  $m_{\ell\ell jj/J}$  spectra shown in Fig. 1. Systematic uncertainties and their correlations are taken into account as nuisance parameters with Gaussian constraints. The likelihood fit, which takes into account correlations between the systematic uncertainties, is performed for signal pole masses ranging between 300 and 850 GeV for the LR, 550 and 1800 GeV for the HR and 800 and 2000 GeV for the MR. Overlapping regions are fit simultaneously.

Figure 2 shows 95 % CL upper limits on the production cross section times branching fraction into  $ZZ$  or  $ZW$  as a function of the resonance pole mass. The theoretical predictions for the EGM  $W'$  and the bulk RS  $G^*$  with two different values of the coupling constant, shown in the figure, allow the extraction of observed (expected) lower mass limits of 1590 (1540) GeV for the  $W'$ , and 740 and 540 (700 and 490) GeV for the  $G^*$  with  $k/\bar{M}_{Pl} = 1.0$  and 0.5 respectively. The most powerful search regions are the LR for masses below 550 GeV, the HR from 500 to 850 GeV and the MR for higher masses.

## 4 Conclusion

In summary, a search for narrow, heavy resonances produced in  $pp$  collisions and decaying to diboson final states at the Large Hadron Collider has been performed. The data sample analysed, corresponding to an integrated luminosity of  $20 \text{ fb}^{-1}$  at  $\sqrt{s} = 8 \text{ TeV}$ , was recorded with the ATLAS detector. No significant excess over the Standard Model background expectation was found. Upper limits on the production cross section times branching ratio and mass exclusion limits are derived for  $W'$  bosons in the theoretical framework of an Extended Gauge Model and for gravitons in warped extra dimensions in the context of the bulk Randall–Sundrum model. The results represent a significant improvement over previously reported limits by ATLAS [16] due to increased  $pp$  collision energy and data set size as well as the development of new techniques to analyse heavily boosted decays of bosons.

**Acknowledgments** We thank CERN for the very successful operation of the LHC, as well as the support staff from our institutions without whom ATLAS could not be operated efficiently. We acknowledge the support of ANPCyT, Argentina; YerPhI, Armenia; ARC, Australia; BMWF and FWF, Austria; ANAS, Azerbaijan; SSTC, Belarus; CNPq and FAPESP, Brazil; NSERC, NRC and CFI, Canada; CERN; CONICYT, Chile; CAS, MOST and NSFC, China; COLCIENCIAS, Colombia; MSMT CR, MPO CR and VSC CR, Czech Republic; DNRF, DNSRC and Lundbeck Foundation, Denmark; EPLANET, ERC and NSRF, European Union; IN2P3-CNRS, CEA-DSM/IRFU, France; GNSF, Georgia; BMBF, DFG, HGF, MPG and AvH Foundation, Germany; GSRT and NSRF, Greece; ISF, MINERVA, GIF, I-CORE and Benoziyo Center, Israel; INFN, Italy; MEXT and JSPS, Japan; CNRST, Morocco; FOM and NWO, Netherlands; BRF and RCN, Norway; MNiSW and NCN, Poland; GRICES and FCT, Portugal; MNE/IFA, Romania; MES of Russia and ROSATOM, Russian Federation; JINR; MSTD, Serbia; MSSR, Slovakia; ARRS and MIZŠ, Slovenia; DST/NRF, South Africa; MINECO, 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, UK; DOE and NSF, USA. The crucial computing support from all WLCG partners is acknowledged gratefully, in particular from CERN and the ATLAS Tier-1 facilities at TRIUMF (Canada), NDGF (Denmark, Norway, Sweden), CC-IN2P3 (France), KIT/GridKA (Germany), INFN-CNAF (Italy), NL-T1 (Netherlands), PIC (Spain), ASGC (Taiwan), RAL (UK) and BNL (USA) and in the Tier-2 facilities worldwide.

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

Funded by SCOAP<sup>3</sup> / License Version CC BY 4.0.

## References

1. E. Eichten, K. Lane, Phys. Lett. B **669**, 235 (2008). [arXiv:0706.2339](https://arxiv.org/abs/0706.2339)
2. S. Catterall, L. Del Debbio, J. Giedt, L. Keegan, Phys. Rev. D **85**, 094501 (2012). [arXiv:1108.3794](https://arxiv.org/abs/1108.3794)

3. J. Andersen et al., Eur. Phys. J. Plus **126**, 81 (2011). [arXiv:1104.1255](#)
4. L. Randall, R. Sundrum, Phys. Rev. Lett. **83**, 3370 (1999). [arXiv:hep-ph/9905221](#)
5. L. Randall, R. Sundrum, Phys. Rev. Lett. **83**, 4690 (1999). [arXiv:hep-th/9906064](#)
6. H. Davoudiasl, J.L. Hewett, T.G. Rizzo, Phys. Rev. D **63**, 075004 (2001). [arXiv:hep-ph/0006041](#)
7. J.C. Pati, A. Salam, Phys. Rev. D **10**, 275 (1974)
8. H. Georgi, S. Glashow, Phys. Rev. Lett. **32**, 438 (1974)
9. H. Georgi, AIP Conf. Proc. **23**, 575 (1975)
10. H. Fritzsch, P. Minkowski, Ann. Phys. **93**, 193 (1975)
11. G. Altarelli, B. Mele, M. Ruiz-Altaba, Z. Phys. C **45**, 109 (1989). [Erratum-ibid C **47**, 676 (1990)]
12. K. Agashe et al., Phys. Rev. D **76**, 036006 (2007). [arXiv:hep-ph/0701186](#)
13. V.M. Abazov et al. (D0 Collaboration), Phys. Rev. Lett. **104**, 061801 (2010). [arXiv:0912.0715](#)
14. V.M. Abazov et al. (D0 Collaboration), Phys. Rev. Lett. **107**, 011801 (2011). [arXiv:1011.6278](#)
15. T. Aaltonen et al. (CDF Collaboration), Phys. Rev. D **85**, 12008 (2012). [arXiv:1111.3432](#)
16. ATLAS Collaboration, Phys. Lett. B **712**, 331 (2012). [arXiv:1203.0718](#)
17. ATLAS Collaboration, Phys. Rev. D **87**, 112006 (2013). [arXiv:1305.0125](#)
18. ATLAS Collaboration, Phys. Lett. B. [arXiv:1406.4456](#) [hep-ex]
19. ATLAS Collaboration, Phys. Lett. B **718**, 860 (2013). [arXiv:1208.2880](#)
20. CMS Collaboration, J. High Energy Phys. [arXiv:1405.3447](#) [hep-ex]
21. CMS Collaboration, J. High Energy Phys. [arXiv:1405.1994](#) [hep-ex]
22. ATLAS Collaboration, JINST **3**, S08003 (2008)
23. ATLAS Collaboration, Eur. Phys. J. C **73**, 2518 (2013). [arXiv:1302.4393](#)
24. A. Belyaev, N. Christensen, A. Pukhov, Comput. Phys. Commun. **184**, 1729 (2013). [arXiv:1207.6082](#). [CalcHEP 3.4.3; with the overestimate of the Randall–Sundrum graviton production cross section by a factor of four corrected as reported in <http://cp3-origins.dk/research/units/ed-tools> (2013)]
25. T. Sjostrand, S. Mrenna, P. Skands, J. High Energy Phys. **0605**, 026 (2006). [arXiv:hep-ph/0603175](#), PYTHIA 8.165
26. J. Pumplin et al., J. High Energy Phys. **0207**, 012 (2002). [arXiv:hep-ph/0201195](#)
27. A.D. Martin, W.J. Stirling, R.S. Thorne, G. Watt, Eur. Phys. J. C **63**, 189 (2009). [arXiv:0901.0002](#)
28. R. Hamberg, W.L. van Neerven, T. Matsuura, Nucl. Phys. B **359**, 343 (1991)
29. T. Gleisberg et al., J. High Energy Phys. **0902**, 007 (2009). [arXiv:0811.4622](#), SHERPA 1.4.1
30. H.-L. Lai et al., Phys. Rev. D **82**, 074024 (2010). [arXiv:1007.2241](#)
31. S. Frixione, B.R. Webber, J. High Energy Phys. **0206**, 029 (2002)
32. S. Frixione, P. Nason, B.R. Webber, J. High Energy Phys. **0308**, 007 (2003). [arXiv:hep-ph/0204244](#), v4.0.6
33. S. Frixione, E. Laenen, P. Motylinski, B.R. Webber, J. High Energy Phys. **0603**, 092 (2006). [arXiv:hep-ph/0512250](#)
34. S. Frixione, E. Laenen, P. Motylinski, B.R. Webber, C.D. White, J. High Energy Phys. **0807**, 029 (2008). [arXiv:0805.3067](#)
35. G. Marchesini, B.R. Webber, G. Abbiendi, I.G. Knowles, M.H. Seymour, L. Stanco, Comput. Phys. Commun. **67**, 465 (1992)
36. G. Corcella, I.G. Knowles, G. Marchesini, S. Moretti, K. Odagiri, P. Richardson, M.H. Seymour, B.R. Webber, J. High Energy Phys. **0101**, 010 (2001). [arXiv:hep-ph/0011363](#)
37. J. Butterworth, J. Forshaw, M. Seymour, Z. Phys. C **72**, 637 (1996). [hep-ph/9601371](#)
38. M. Cacciari, M. Czakon, M.L. Mangano, A. Mitov, P. Nason, Phys. Lett. B **710**, 612 (2012). [arXiv:1111.5869](#)
39. P. Bärrnreuther, M. Czakon, A. Mitov, Phys. Rev. Lett. **109**, 132001 (2012). [arXiv:1204.5201](#)
40. M. Czakon, A. Mitov, J. High Energy Phys. **1212**, 054 (2012). [arXiv:1207.0236](#)
41. M. Czakon, A. Mitov, J. High Energy Phys. **1301**, 080 (2013). [arXiv:1210.6832](#)
42. M. Czakon, P. Fiedler, A. Mitov, Phys. Rev. Lett. **110**, 252004 (2013). [arXiv:1303.6254](#)
43. M. Czakon, A. Mitov, Comput. Phys. Commun. **185**, 2930 (2014). [arXiv:1112.5675](#)
44. B.P. Kersevan, E. Richter-Was, Comput. Phys. Commun. **184**, 919 (2013). [arXiv:hep-ph/0405247](#)
45. T. Sjostrand, P. Eden, C. Friberg, L. Lonnblad, G. Miu, S. Mrenna, E. Norrbin, Comput. Phys. Commun. **135**, 238 (2001). [arXiv:hep-ph/0010017](#)
46. J.M. Campbell, R.K. Ellis, Phys. Rev. D **60**, 113006 (1999). [arXiv:hep-ph/9905386](#), v5.8
47. ATLAS Collaboration, Eur. Phys. J. C **70**, 823, (2010). [arXiv:1005.4568](#)
48. S. Agostinelli et al. (GEANT4 Collaboration), Nucl. Instrum. Methods A **506**, 250 (2003)
49. ATLAS Collaboration, Eur. Phys. J. C **74** 2941 (2014). [arXiv:1404.2240](#)
50. ATLAS Collaboration, Eur. Phys. J. C. [arXiv:1404.4562](#)
51. M. Cacciari, G.P. Salam, G. Soyez, J. High Energy Phys. **0804**, 063 (2008). [arXiv:0802.1189](#)
52. M. Cacciari, G.P. Salam, Phys. Lett. B **641**, 57 (2006). [arXiv:hep-ph/0512210](#)
53. ATLAS Collaboration, Eur. Phys. J. C **73** 2304 (2013). [arXiv:1112.6426](#)
54. Yu.L. Dokshitzer, G.D. Leder, S. Moretti, B.R. Webber, J. High Energy Phys. **9708**, 001 (1997). [arXiv:hep-ph/9707323](#). (M. Wobisch, T. Wengler. [arXiv:hep-ph/9907280](#))
55. J.M. Butterworth, A.R. Davison, M. Rubin, G.P. Salam, Phys. Rev. Lett. **100**, 242001 (2008). [arXiv:0802.2470](#)
56. ATLAS Collaboration, ATL-PHYS-PUB-2014-004 (2014). <http://cdsweb.cern.ch/record/1690048>. Accessed Sept 2014
57. F.E. James, in *Statistical Methods in Experimental Physics*, 2nd edn. (World Scientific Publishing Co., 2006), pp. 316–317
58. J. Wenninger, Report CERN-ATS-2013-040 (2013). <http://cdsweb.cern.ch/record/1546734>. Accessed Sept 2014
59. A. Read, J. Phys. G **28**, 2693 (2002)
60. G. Cowan, K. Cranmer, E. Gross, O. Vitells, Eur. Phys. J. C **71**, 1554 (2011). [arXiv:1007.1727](#)



## ATLAS Collaboration

G. Aad<sup>84</sup>, B. Abbott<sup>112</sup>, J. Abdallah<sup>152</sup>, S. Abdel Khalek<sup>116</sup>, O. Abdinov<sup>11</sup>, R. Aben<sup>106</sup>, B. Abi<sup>113</sup>, M. Abolins<sup>89</sup>, O. S. AbouZeid<sup>159</sup>, H. Abramowicz<sup>154</sup>, H. Abreu<sup>153</sup>, R. Abreu<sup>30</sup>, Y. Abulaiti<sup>147a,147b</sup>, B. S. Acharya<sup>165a,165b,a</sup>, L. Adamczyk<sup>38a</sup>, D. L. Adams<sup>25</sup>, J. Adelman<sup>177</sup>, S. Adomeit<sup>99</sup>, T. Adye<sup>130</sup>, T. Agatonovic-Jovin<sup>13a</sup>, J. A. Aguilar-Saavedra<sup>125a,125f</sup>, M. Agustoni<sup>17</sup>, S. P. Ahlen<sup>22</sup>, F. Ahmadov<sup>64,b</sup>, G. Aielli<sup>134a,134b</sup>, H. Akerstedt<sup>147a,147b</sup>, T. P. A. Åkesson<sup>80</sup>, G. Akimoto<sup>156</sup>, A. V. Akimov<sup>95</sup>, G. L. Alberghi<sup>20a,20b</sup>, J. Albert<sup>170</sup>, S. Albrand<sup>55</sup>, M. J. Alconada Verzini<sup>70</sup>, M. Aleksa<sup>30</sup>, I. N. Aleksandrov<sup>64</sup>, C. Alexa<sup>26a</sup>, G. Alexander<sup>154</sup>, G. Alexandre<sup>49</sup>, T. Alexopoulos<sup>10</sup>, M. Alhroob<sup>165a,165b</sup>, G. Alimonti<sup>90a</sup>, L. Alio<sup>84</sup>, J. Alison<sup>31</sup>, B. M. M. Allbrooke<sup>18</sup>, L. J. Allison<sup>71</sup>, P. P. Allport<sup>73</sup>, J. Almond<sup>83</sup>, A. Aloisio<sup>103a,103b</sup>, A. Alonso<sup>36</sup>, F. Alonso<sup>70</sup>, C. Alpigiani<sup>75</sup>, A. Altheimer<sup>35</sup>, B. Alvarez Gonzalez<sup>89</sup>, M. G. Alviggi<sup>103a,103b</sup>, K. Amako<sup>65</sup>, Y. Amaral Coutinho<sup>24a</sup>, C. Amelung<sup>23</sup>, D. Amidei<sup>88</sup>, S. P. Amor Dos Santos<sup>125a,125c</sup>, A. Amorim<sup>125a,125b</sup>, S. Amoroso<sup>48</sup>, N. Amram<sup>154</sup>, G. Amundsen<sup>23</sup>, C. Anastopoulos<sup>140</sup>, L. S. Ancu<sup>49</sup>, N. Andari<sup>30</sup>, T. Andeen<sup>35</sup>, C. F. Anders<sup>58b</sup>, G. Anders<sup>30</sup>, K. J. Anderson<sup>31</sup>, A. Andreazza<sup>90a,90b</sup>, V. Andrei<sup>58a</sup>, X. S. Anduaga<sup>70</sup>, S. Angelidakis<sup>9</sup>, I. Angelozzi<sup>106</sup>, P. Anger<sup>44</sup>, A. Angerami<sup>35</sup>, F. Anghinolfi<sup>30</sup>, A. V. Anisenkov<sup>108.c</sup>, N. Anjos<sup>125a</sup>, A. Annovi<sup>47</sup>, A. Antonaki<sup>9</sup>, M. Antonelli<sup>47</sup>, A. Antonov<sup>97</sup>, J. Antos<sup>145b</sup>, F. Anulli<sup>133a</sup>, M. Aoki<sup>65</sup>, L. Aperio Bella<sup>18</sup>, R. Apolle<sup>119.d</sup>, G. Arabidze<sup>89</sup>, I. Aracena<sup>144</sup>, Y. Arai<sup>65</sup>, J. P. Araque<sup>125a</sup>, A. T. H. Arce<sup>45</sup>, J-F. Arguin<sup>94</sup>, S. Argyropoulos<sup>42</sup>, M. Arik<sup>19a</sup>, A. J. Armbruster<sup>30</sup>, O. Arnaez<sup>30</sup>, V. Arnal<sup>81</sup>, H. Arnold<sup>48</sup>, M. Arratia<sup>28</sup>, O. Arslan<sup>21</sup>, A. Artamonov<sup>96</sup>, G. Artoni<sup>23</sup>, S. Asai<sup>156</sup>, N. Asbah<sup>42</sup>, A. Ashkenazi<sup>154</sup>, B. Åsman<sup>147a,147b</sup>, L. Asquith<sup>6</sup>, K. Assamagan<sup>25</sup>, R. Astalos<sup>145a</sup>, M. Atkinson<sup>166</sup>, N. B. Atlay<sup>142</sup>, B. Auerbach<sup>6</sup>, K. Augsten<sup>127</sup>, M. Aurousseau<sup>146b</sup>, G. Avolio<sup>30</sup>, G. Azuelos<sup>94.e</sup>, Y. Azuma<sup>156</sup>, M. A. Baak<sup>30</sup>, A. E. Baas<sup>58a</sup>, C. Bacci<sup>135a,135b</sup>, H. Bachacou<sup>137</sup>, K. Bachas<sup>155</sup>, M. Backes<sup>30</sup>, M. Backhaus<sup>30</sup>, J. Backus Mayes<sup>144</sup>, E. Badescu<sup>26a</sup>, P. Bagicchi<sup>133a,133b</sup>, P. Bagnaia<sup>133a,133b</sup>, Y. Bai<sup>33a</sup>, T. Bain<sup>35</sup>, J. T. Baines<sup>130</sup>, O. K. Baker<sup>177</sup>, P. Balek<sup>128</sup>, F. Balli<sup>137</sup>, E. Banas<sup>39</sup>, Sw. Banerjee<sup>174</sup>, A. A. E. Bannoura<sup>176</sup>, V. Bansal<sup>170</sup>, H. S. Bansil<sup>18</sup>, L. Barak<sup>173</sup>, S. P. Baranov<sup>95</sup>, E. L. Barberio<sup>87</sup>, D. Barberis<sup>50a,50b</sup>, M. Barbero<sup>84</sup>, T. Barillari<sup>100</sup>, M. Barisonzi<sup>176</sup>, T. Barklow<sup>144</sup>, N. Barlow<sup>28</sup>, B. M. Barnett<sup>130</sup>, R. M. Barnett<sup>15</sup>, Z. Barnovska<sup>5</sup>, A. Baroncelli<sup>135a</sup>, G. Barone<sup>49</sup>, A. J. Barr<sup>119</sup>, F. Barreiro<sup>81</sup>, J. Barreiro Guimarães da Costa<sup>57</sup>, R. Bartoldus<sup>144</sup>, A. E. Barton<sup>71</sup>, P. Bartos<sup>145a</sup>, V. Bartsch<sup>150</sup>, A. Bassalat<sup>116</sup>, A. Basye<sup>166</sup>, R. L. Bates<sup>53</sup>, J. R. Batley<sup>28</sup>, M. Battaglia<sup>138</sup>, M. Battistin<sup>30</sup>, F. Bauer<sup>137</sup>, H. S. Bawa<sup>144.f</sup>, M. D. Beattie<sup>71</sup>, T. Beau<sup>79</sup>, P. H. Beauchemin<sup>162</sup>, R. Beccherle<sup>123a,123b</sup>, P. Bechtel<sup>21</sup>, H. P. Beck<sup>17</sup>, K. Becker<sup>176</sup>, S. Becker<sup>99</sup>, M. Beckingham<sup>171</sup>, C. Becot<sup>116</sup>, A. J. Beddall<sup>19c</sup>, A. Beddall<sup>19c</sup>, S. Bedikian<sup>177</sup>, V. A. Bednyakov<sup>64</sup>, C. P. Bee<sup>149</sup>, L. J. Beamster<sup>106</sup>, T. A. Beermann<sup>176</sup>, M. Begel<sup>25</sup>, K. Behr<sup>119</sup>, C. Belanger-Champagne<sup>86</sup>, P. J. Bell<sup>49</sup>, W. H. Bell<sup>49</sup>, G. Bella<sup>154</sup>, L. Bellagamba<sup>20a</sup>, A. Bellerive<sup>29</sup>, M. Bellomo<sup>85</sup>, K. Belotskiy<sup>97</sup>, O. Beltramello<sup>30</sup>, O. Benary<sup>154</sup>, D. Bencheikroun<sup>136a</sup>, K. Bendtz<sup>147a,147b</sup>, N. Benekos<sup>166</sup>, Y. Benhammou<sup>154</sup>, E. Benhar Nocchioli<sup>49</sup>, J. A. Benitez Garcia<sup>160b</sup>, D. P. Benjamin<sup>45</sup>, J. R. Bensinger<sup>23</sup>, K. Benslama<sup>131</sup>, S. Bentvelsen<sup>106</sup>, D. Berge<sup>106</sup>, E. Bergeaas Kuutmann<sup>167</sup>, N. Berger<sup>5</sup>, F. Berghaus<sup>170</sup>, J. Beringer<sup>15</sup>, C. Bernard<sup>22</sup>, P. Bernat<sup>77</sup>, C. Bernius<sup>78</sup>, F. U. Bernlochner<sup>170</sup>, T. Berry<sup>76</sup>, P. Berta<sup>128</sup>, C. Bertella<sup>84</sup>, G. Bertoli<sup>147a,147b</sup>, F. Bertolucci<sup>123a,123b</sup>, C. Bertsche<sup>112</sup>, D. Bertsche<sup>112</sup>, M. I. Besana<sup>90a</sup>, G. J. Besjes<sup>105</sup>, O. Bessidskaia Bylund<sup>147a,147b</sup>, M. Bessner<sup>42</sup>, N. Besson<sup>137</sup>, C. Betancourt<sup>48</sup>, S. Bethke<sup>100</sup>, W. Bhimji<sup>46</sup>, R. M. Bianchi<sup>124</sup>, L. Bianchini<sup>23</sup>, M. Bianco<sup>30</sup>, O. Biebel<sup>99</sup>, S. P. Bieniek<sup>77</sup>, K. Bierwagen<sup>54</sup>, J. Biesiada<sup>15</sup>, M. Biglietti<sup>135a</sup>, J. Bilbao De Mendizabal<sup>49</sup>, H. Bilokon<sup>47</sup>, M. Bindl<sup>54</sup>, S. Binet<sup>116</sup>, A. Bingul<sup>19c</sup>, C. Bini<sup>133a,133b</sup>, C. W. Black<sup>151</sup>, J. E. Black<sup>144</sup>, K. M. Black<sup>22</sup>, D. Blackburn<sup>139</sup>, R. E. Blair<sup>6</sup>, J.-B. Blanchard<sup>137</sup>, T. Blazek<sup>145a</sup>, I. Bloch<sup>42</sup>, C. Blocker<sup>23</sup>, W. Blum<sup>82.\*</sup>, U. Blumenschein<sup>54</sup>, G. J. Bobbink<sup>106</sup>, V. S. Bobrovnikov<sup>108.c</sup>, S. S. Bocchetta<sup>80</sup>, A. Bocci<sup>45</sup>, C. Bock<sup>99</sup>, C. R. Boddy<sup>119</sup>, M. Boehler<sup>48</sup>, T. T. Boek<sup>176</sup>, J. A. Bogaerts<sup>30</sup>, A. G. Bogdanchikov<sup>108</sup>, A. Bogouch<sup>91.\*</sup>, C. Bohm<sup>147a</sup>, J. Bohm<sup>126</sup>, V. Boisvert<sup>76</sup>, T. Bold<sup>38a</sup>, V. Boldea<sup>26a</sup>, A. S. Boldyrev<sup>98</sup>, M. Bomben<sup>79</sup>, M. Bona<sup>75</sup>, M. Boonekamp<sup>137</sup>, A. Borisov<sup>129</sup>, G. Borissov<sup>71</sup>, M. Borri<sup>83</sup>, S. Borroni<sup>42</sup>, J. Bortfeldt<sup>99</sup>, V. Bortolotto<sup>135a,135b</sup>, K. Bos<sup>106</sup>, D. Boscherini<sup>20a</sup>, M. Bosman<sup>12</sup>, H. Boterenbrood<sup>106</sup>, J. Boudreau<sup>124</sup>, J. Bouffard<sup>2</sup>, E. V. Bouhova-Thacker<sup>71</sup>, D. Boumediene<sup>34</sup>, C. Bourdarios<sup>116</sup>, N. Bousson<sup>113</sup>, S. Boutouil<sup>136d</sup>, A. Boveia<sup>31</sup>, J. Boyd<sup>30</sup>, I. R. Boyko<sup>64</sup>, I. Bozic<sup>13a</sup>, J. Bracinik<sup>18</sup>, A. Brandt<sup>8</sup>, G. Brandt<sup>15</sup>, O. Brandt<sup>58a</sup>, U. Bratzler<sup>157</sup>, B. Brau<sup>85</sup>, J. E. Brau<sup>115</sup>, H. M. Braun<sup>176.\*</sup>, S. F. Brazzale<sup>165a,165c</sup>, B. Brelier<sup>159</sup>, K. Brendlinger<sup>121</sup>, A. J. Brennan<sup>87</sup>, R. Brenner<sup>167</sup>, S. Bressler<sup>173</sup>, K. Bristow<sup>146c</sup>, T. M. Bristow<sup>46</sup>, D. Britton<sup>53</sup>, F. M. Brochu<sup>28</sup>, I. Brock<sup>21</sup>, R. Brock<sup>89</sup>, C. Bromberg<sup>89</sup>, J. Bronner<sup>100</sup>, G. Brooijmans<sup>35</sup>, T. Brooks<sup>76</sup>, W. K. Brooks<sup>32b</sup>, J. Brosamer<sup>15</sup>, E. Brost<sup>115</sup>, J. Brown<sup>55</sup>, P. A. Bruckman de Renstrom<sup>39</sup>, D. Bruncko<sup>145b</sup>, R. Bruneliere<sup>48</sup>, S. Brunet<sup>60</sup>, A. Bruni<sup>20a</sup>, G. Bruni<sup>20a</sup>, M. Bruschi<sup>20a</sup>, L. Bryngemark<sup>80</sup>, T. Buanes<sup>14</sup>, Q. Buat<sup>143</sup>, F. Bucchi<sup>49</sup>, P. Buchholz<sup>142</sup>, R. M. Buckingham<sup>119</sup>, A. G. Buckley<sup>53</sup>, S. I. Buda<sup>26a</sup>, I. A. Budagov<sup>64</sup>, F. Buehrer<sup>48</sup>, L. Bugge<sup>118</sup>, M. K. Bugge<sup>118</sup>, O. Bulekov<sup>97</sup>, A. C. Bundock<sup>73</sup>, H. Burckhart<sup>30</sup>, S. Burdin<sup>73</sup>, B. Burghgrave<sup>107</sup>, S. Burke<sup>130</sup>, I. Burmeister<sup>43</sup>, E. Busato<sup>34</sup>, D. Büscher<sup>48</sup>, V. Büscher<sup>82</sup>, P. Bussey<sup>53</sup>, C. P. Buszello<sup>167</sup>, B. Butler<sup>57</sup>, J. M. Butler<sup>22</sup>, A. I. Butt<sup>3</sup>, C. M. Buttar<sup>53</sup>, J. M. Butterworth<sup>77</sup>, P. Butti<sup>106</sup>, W. Buttinger<sup>28</sup>

A. Buzatu<sup>53</sup>, M. Byszewski<sup>10</sup>, S. Cabrera Urbán<sup>168</sup>, D. Caforio<sup>20a,20b</sup>, O. Cakir<sup>4a</sup>, P. Calafiura<sup>15</sup>, A. Calandri<sup>137</sup>, G. Calderini<sup>79</sup>, P. Calfayan<sup>99</sup>, R. Calkins<sup>107</sup>, L. P. Caloba<sup>24a</sup>, D. Calvet<sup>34</sup>, S. Calvet<sup>34</sup>, R. Camacho Toro<sup>49</sup>, S. Camarda<sup>42</sup>, D. Cameron<sup>118</sup>, L. M. Caminada<sup>15</sup>, R. Caminal Armadans<sup>12</sup>, S. Campana<sup>30</sup>, M. Campanelli<sup>77</sup>, A. Campoverde<sup>149</sup>, V. Canale<sup>103a,103b</sup>, A. Canepa<sup>160a</sup>, M. Cano Bret<sup>75</sup>, J. Cantero<sup>81</sup>, R. Cantrill<sup>125a</sup>, T. Cao<sup>40</sup>, M. D. M. Capeans Garrido<sup>30</sup>, I. Caprini<sup>26a</sup>, M. Caprini<sup>26a</sup>, M. Capua<sup>37a,37b</sup>, R. Caputo<sup>82</sup>, R. Cardarelli<sup>134a</sup>, T. Carli<sup>30</sup>, G. Carlino<sup>103a</sup>, L. Carminati<sup>90a,90b</sup>, S. Caron<sup>105</sup>, E. Carquin<sup>32a</sup>, G. D. Carrillo-Montoya<sup>146c</sup>, J. R. Carter<sup>28</sup>, J. Carvalho<sup>125a,125c</sup>, D. Casadei<sup>77</sup>, M. P. Casado<sup>12</sup>, M. Casolino<sup>12</sup>, E. Castaneda-Miranda<sup>146b</sup>, A. Castelli<sup>106</sup>, V. Castillo Gimenez<sup>168</sup>, N. F. Castro<sup>125a</sup>, P. Catastini<sup>57</sup>, A. Catinaccio<sup>30</sup>, J. R. Catmore<sup>118</sup>, A. Cattai<sup>30</sup>, G. Cattani<sup>134a,134b</sup>, J. Caudron<sup>82</sup>, V. Cavaliere<sup>166</sup>, D. Cavalli<sup>90a</sup>, M. Cavalli-Sforza<sup>12</sup>, V. Cavasinni<sup>123a,123b</sup>, F. Ceradini<sup>135a,135b</sup>, B. C. Cerio<sup>45</sup>, K. Cerny<sup>128</sup>, A. S. Cerqueira<sup>24b</sup>, A. Cerri<sup>150</sup>, L. Cerrito<sup>75</sup>, F. Cerutti<sup>15</sup>, M. Cerv<sup>30</sup>, A. Cervelli<sup>17</sup>, S. A. Cetin<sup>19b</sup>, A. Chafaq<sup>136a</sup>, D. Chakraborty<sup>107</sup>, I. Chalupkova<sup>128</sup>, P. Chang<sup>166</sup>, B. Chapleau<sup>86</sup>, J. D. Chapman<sup>28</sup>, D. Charfeddine<sup>116</sup>, D. G. Charlton<sup>18</sup>, C. C. Chau<sup>159</sup>, C. A. Chavez Barajas<sup>150</sup>, S. Cheatham<sup>86</sup>, A. Chegwiddden<sup>89</sup>, S. Chekanov<sup>6</sup>, S. V. Chekulaev<sup>160a</sup>, G. A. Chelkov<sup>64,g</sup>, M. A. Chelstowska<sup>88</sup>, C. Chen<sup>63</sup>, H. Chen<sup>25</sup>, K. Chen<sup>149</sup>, L. Chen<sup>33d,h</sup>, S. Chen<sup>33c</sup>, X. Chen<sup>146c</sup>, Y. Chen<sup>66</sup>, Y. Chen<sup>35</sup>, H. C. Cheng<sup>88</sup>, Y. Cheng<sup>31</sup>, A. Cheplakov<sup>64</sup>, R. Cherkaoui El Moursli<sup>136e</sup>, V. Chernyatin<sup>25,\*</sup>, E. Cheu<sup>7</sup>, L. Chevalier<sup>137</sup>, V. Chiarella<sup>47</sup>, G. Chiefari<sup>103a,103b</sup>, J. T. Childers<sup>6</sup>, A. Chilingarov<sup>71</sup>, G. Chiodini<sup>72a</sup>, A. S. Chisholm<sup>18</sup>, R. T. Chislett<sup>77</sup>, A. Chitan<sup>26a</sup>, M. V. Chizhov<sup>64</sup>, S. Chouridou<sup>9</sup>, B. K. B. Chow<sup>99</sup>, D. Chromek-Burckhart<sup>30</sup>, M. L. Chu<sup>152</sup>, J. Chudoba<sup>126</sup>, J. J. Chwastowski<sup>39</sup>, L. Chytka<sup>114</sup>, G. Ciapetti<sup>133a,133b</sup>, A. K. Ciftci<sup>4a</sup>, R. Ciftci<sup>4a</sup>, D. Cinca<sup>53</sup>, V. Cindro<sup>74</sup>, A. Ciocio<sup>15</sup>, P. Cirkovic<sup>13b</sup>, Z. H. Citron<sup>173</sup>, M. Citterio<sup>90a</sup>, M. Ciubancan<sup>26a</sup>, A. Clark<sup>49</sup>, P. J. Clark<sup>46</sup>, R. N. Clarke<sup>15</sup>, W. Cleland<sup>124</sup>, J. C. Clemens<sup>84</sup>, C. Clement<sup>147a,147b</sup>, Y. Coadou<sup>84</sup>, M. Cobal<sup>165a,165c</sup>, A. Coccaro<sup>139</sup>, J. Cochran<sup>63</sup>, L. Coffey<sup>23</sup>, J. G. Cogan<sup>144</sup>, J. Coggeshall<sup>166</sup>, B. Cole<sup>35</sup>, S. Cole<sup>107</sup>, A. P. Colijn<sup>106</sup>, J. Collot<sup>55</sup>, T. Colombo<sup>58c</sup>, G. Colon<sup>85</sup>, G. Compostella<sup>100</sup>, P. Conde Muiño<sup>125a,125b</sup>, E. Coniavitis<sup>48</sup>, M. C. Conidi<sup>12</sup>, S. H. Connell<sup>146b</sup>, I. A. Connelly<sup>76</sup>, S. M. Consonni<sup>90a,90b</sup>, V. Consorti<sup>48</sup>, S. Constantinescu<sup>26a</sup>, C. Conta<sup>120a,120b</sup>, G. Conti<sup>57</sup>, F. Conventi<sup>103a,i</sup>, M. Cooke<sup>15</sup>, B. D. Cooper<sup>77</sup>, A. M. Cooper-Sarkar<sup>119</sup>, N. J. Cooper-Smith<sup>76</sup>, K. Copic<sup>15</sup>, T. Cornelissen<sup>176</sup>, M. Corradi<sup>20a</sup>, F. Corriveau<sup>86,j</sup>, A. Corso-Radu<sup>164</sup>, A. Cortes-Gonzalez<sup>12</sup>, G. Cortiana<sup>100</sup>, G. Costa<sup>90a</sup>, M. J. Costa<sup>168</sup>, D. Costanzo<sup>140</sup>, D. Côte<sup>8</sup>, G. Cottin<sup>28</sup>, G. Cowan<sup>76</sup>, B. E. Cox<sup>83</sup>, K. Cranmer<sup>109</sup>, G. Cree<sup>29</sup>, S. Crépe-Renaudin<sup>55</sup>, F. Crescioli<sup>79</sup>, W. A. Cribbs<sup>147a,147b</sup>, M. Crispin Ortuzar<sup>119</sup>, M. Cristinziani<sup>21</sup>, V. Croft<sup>105</sup>, G. Crosetti<sup>37a,37b</sup>, C.-M. Cucuc<sup>26a</sup>, T. Cuhadar Donszelmann<sup>140</sup>, J. Cummings<sup>177</sup>, M. Curatolo<sup>47</sup>, C. Cuthbert<sup>151</sup>, H. Czir<sup>142</sup>, P. Czodrowski<sup>3</sup>, Z. Czyczula<sup>177</sup>, S. D'Auria<sup>53</sup>, M. D'Onofrio<sup>73</sup>, M. J. Da Cunha Sargedas De Sousa<sup>125a,125b</sup>, C. Da Via<sup>83</sup>, W. Dabrowski<sup>38a</sup>, A. Dafinca<sup>119</sup>, T. Dai<sup>88</sup>, O. Dale<sup>14</sup>, F. Dallaire<sup>94</sup>, C. Dallapiccola<sup>85</sup>, M. Dam<sup>36</sup>, A. C. Daniells<sup>18</sup>, M. Dano Hoffmann<sup>137</sup>, V. Dao<sup>48</sup>, G. Darbo<sup>50a</sup>, S. Darmora<sup>8</sup>, J. A. Dassoulas<sup>42</sup>, A. Dattagupta<sup>60</sup>, W. Davey<sup>21</sup>, C. David<sup>170</sup>, T. Davidek<sup>128</sup>, E. Davies<sup>119,d</sup>, M. Davies<sup>154</sup>, O. Davignon<sup>79</sup>, A. R. Davison<sup>77</sup>, P. Davison<sup>77</sup>, Y. Davygora<sup>58a</sup>, E. Dawe<sup>143</sup>, I. Dawson<sup>140</sup>, R. K. Daya-Ishmukhametova<sup>85</sup>, K. De<sup>8</sup>, R. de Asmundis<sup>103a</sup>, S. De Castro<sup>20a,20b</sup>, S. De Cecco<sup>79</sup>, N. De Groot<sup>105</sup>, P. de Jong<sup>106</sup>, H. De la Torre<sup>81</sup>, F. De Lorenzi<sup>63</sup>, L. De Nooij<sup>106</sup>, D. De Pedis<sup>133a</sup>, A. De Salvo<sup>133a</sup>, U. De Sanctis<sup>150</sup>, A. De Santo<sup>150</sup>, J. B. De Vivie De Regie<sup>116</sup>, W. J. Dearnaley<sup>71</sup>, R. Debe<sup>25</sup>, C. Debenedetti<sup>138</sup>, B. Dechenaux<sup>55</sup>, D. V. Dedovich<sup>64</sup>, I. Deigaard<sup>106</sup>, J. Del Peso<sup>81</sup>, T. Del Prete<sup>123a,123b</sup>, F. Deliot<sup>137</sup>, C. M. Delitzsch<sup>49</sup>, M. Deliyergiyev<sup>74</sup>, A. Dell'Acqua<sup>30</sup>, L. Dell'Asta<sup>22</sup>, M. Dell'Orso<sup>123a,123b</sup>, M. Della Pietra<sup>103a,i</sup>, D. della Volpe<sup>49</sup>, M. Delmastro<sup>5</sup>, P. A. Delsart<sup>55</sup>, C. Deluca<sup>106</sup>, S. Demers<sup>177</sup>, M. Demichev<sup>64</sup>, A. Demilly<sup>79</sup>, S. P. Denisov<sup>129</sup>, D. Derendarz<sup>39</sup>, J. E. Derkaoui<sup>136d</sup>, F. Derue<sup>79</sup>, P. Dervan<sup>73</sup>, K. Desch<sup>21</sup>, C. Deterre<sup>42</sup>, P. O. Deviveiros<sup>106</sup>, A. Dewhurst<sup>130</sup>, S. Dhaliwal<sup>106</sup>, A. Di Ciaccio<sup>134a,134b</sup>, L. Di Ciaccio<sup>5</sup>, A. Di Domenico<sup>133a,133b</sup>, C. Di Donato<sup>103a,103b</sup>, A. Di Girolamo<sup>30</sup>, B. Di Girolamo<sup>30</sup>, A. Di Mattia<sup>153</sup>, B. Di Micco<sup>135a,135b</sup>, R. Di Nardo<sup>47</sup>, A. Di Simone<sup>48</sup>, R. Di Sipio<sup>20a,20b</sup>, D. Di Valentino<sup>29</sup>, F. A. Dias<sup>46</sup>, M. A. Diaz<sup>32a</sup>, E. B. Diehl<sup>88</sup>, J. Dietrich<sup>42</sup>, T. A. Dietzsch<sup>58a</sup>, S. Diglio<sup>84</sup>, A. Dimitrievska<sup>13a</sup>, J. Dingfelder<sup>21</sup>, C. Dionisi<sup>133a,133b</sup>, P. Dita<sup>26a</sup>, S. Dita<sup>26a</sup>, F. Dittus<sup>30</sup>, F. Djama<sup>84</sup>, T. Djobava<sup>51b</sup>, M. A. B. do Vale<sup>24c</sup>, A. Do Valle Wemans<sup>125a,125g</sup>, D. Dobos<sup>30</sup>, C. Doglioni<sup>49</sup>, T. Doherty<sup>53</sup>, T. Dohmae<sup>156</sup>, J. Dolejsi<sup>128</sup>, Z. Dolezal<sup>128</sup>, B. A. Dolgoshein<sup>97,\*</sup>, M. Donadelli<sup>24d</sup>, S. Donati<sup>123a,123b</sup>, P. Dondero<sup>120a,120b</sup>, J. Donini<sup>34</sup>, J. Dopke<sup>130</sup>, A. Doria<sup>103a</sup>, M. T. Dova<sup>70</sup>, A. T. Doyle<sup>53</sup>, M. Dris<sup>10</sup>, J. Dubbert<sup>88</sup>, S. Dube<sup>15</sup>, E. Dubreuil<sup>34</sup>, E. Duchovni<sup>173</sup>, G. Duckeck<sup>99</sup>, O. A. Ducu<sup>26a</sup>, D. Duda<sup>176</sup>, A. Dudarev<sup>30</sup>, F. Dudziak<sup>63</sup>, L. Dufflot<sup>116</sup>, L. Duguid<sup>76</sup>, M. Dührssen<sup>30</sup>, M. Dunford<sup>58a</sup>, H. Duran Yildiz<sup>4a</sup>, M. Düren<sup>52</sup>, A. Durglishvili<sup>51b</sup>, M. Dwuznik<sup>38a</sup>, M. Dyndal<sup>38a</sup>, J. Ebke<sup>99</sup>, W. Edson<sup>2</sup>, N. C. Edwards<sup>46</sup>, W. Ehrenfeld<sup>21</sup>, T. Eifert<sup>144</sup>, G. Eigen<sup>14</sup>, K. Einsweiler<sup>15</sup>, T. Ekelof<sup>167</sup>, M. El Kacimi<sup>136c</sup>, M. Ellert<sup>167</sup>, S. Elles<sup>5</sup>, F. Ellinghaus<sup>82</sup>, N. Ellis<sup>30</sup>, J. Elmsheuser<sup>99</sup>, M. Elsing<sup>30</sup>, D. Emelianov<sup>130</sup>, Y. Enari<sup>156</sup>, O. C. Endner<sup>82</sup>, M. Endo<sup>117</sup>, R. Engelmann<sup>149</sup>, J. Erdmann<sup>177</sup>, A. Ereditato<sup>17</sup>, D. Eriksson<sup>147a</sup>, G. Ernis<sup>176</sup>, J. Ernst<sup>2</sup>, M. Ernst<sup>25</sup>, J. Ernwein<sup>137</sup>, D. Errede<sup>166</sup>, S. Errede<sup>166</sup>, E. Ertel<sup>82</sup>, M. Escalier<sup>116</sup>, H. Esch<sup>43</sup>, C. Escobar<sup>124</sup>, B. Esposito<sup>47</sup>, A. I. Etienne<sup>137</sup>, E. Etzion<sup>154</sup>, H. Evans<sup>60</sup>, A. Ezhilov<sup>122</sup>, L. Fabbri<sup>20a,20b</sup>, G. Facini<sup>31</sup>, R. M. Fakhruddinov<sup>129</sup>, S. Falciano<sup>133a</sup>, R. J. Falla<sup>77</sup>, J. Faltova<sup>128</sup>, Y. Fang<sup>33a</sup>, M. Fanti<sup>90a,90b</sup>, A. Farbin<sup>8</sup>, A. Farilla<sup>135a</sup>, T. Farooque<sup>12</sup>

S. Farrell<sup>15</sup>, S. M. Farrington<sup>171</sup>, P. Farthouat<sup>30</sup>, F. Fassi<sup>136e</sup>, P. Fassnacht<sup>30</sup>, D. Fassouliotis<sup>9</sup>, A. Favareto<sup>50a,50b</sup>, L. Fayard<sup>116</sup>, P. Federic<sup>145a</sup>, O. L. Fedin<sup>122,k</sup>, W. Fedorko<sup>169</sup>, M. Fehling-Kaschek<sup>48</sup>, S. Feigl<sup>30</sup>, L. Feligioni<sup>84</sup>, C. Feng<sup>33d</sup>, E. J. Feng<sup>6</sup>, H. Feng<sup>88</sup>, A. B. Fenyuk<sup>129</sup>, S. Fernandez Perez<sup>30</sup>, S. Ferrag<sup>53</sup>, J. Ferrando<sup>53</sup>, A. Ferrari<sup>167</sup>, P. Ferrari<sup>106</sup>, R. Ferrari<sup>120a</sup>, D. E. Ferreira de Lima<sup>53</sup>, A. Ferrer<sup>168</sup>, D. Ferrere<sup>49</sup>, C. Ferretti<sup>88</sup>, A. Ferretto Parodi<sup>50a,50b</sup>, M. Fiascaris<sup>31</sup>, F. Fiedler<sup>82</sup>, A. Filipčič<sup>74</sup>, M. Filipuzzi<sup>42</sup>, F. Filthaut<sup>105</sup>, M. Fincke-Keeler<sup>170</sup>, K. D. Finelli<sup>151</sup>, M. C. N. Fiolhais<sup>125a,125c</sup>, L. Fiorini<sup>168</sup>, A. Firan<sup>40</sup>, A. Fischer<sup>2</sup>, J. Fischer<sup>176</sup>, W. C. Fisher<sup>89</sup>, E. A. Fitzgerald<sup>23</sup>, M. Flechl<sup>48</sup>, I. Fleck<sup>142</sup>, P. Fleischmann<sup>88</sup>, S. Fleischmann<sup>176</sup>, G. T. Fletcher<sup>140</sup>, G. Fletcher<sup>75</sup>, T. Flick<sup>176</sup>, A. Floderus<sup>80</sup>, L. R. Flores Castillo<sup>174,1</sup>, A. C. Florez Bustos<sup>160b</sup>, M. J. Flowerdew<sup>100</sup>, A. Formica<sup>137</sup>, A. Forti<sup>83</sup>, D. Fortin<sup>160a</sup>, D. Fournier<sup>116</sup>, H. Fox<sup>71</sup>, S. Fracchia<sup>12</sup>, P. Francavilla<sup>79</sup>, M. Franchini<sup>20a,20b</sup>, S. Franchino<sup>30</sup>, D. Francis<sup>30</sup>, L. Franconi<sup>118</sup>, M. Franklin<sup>57</sup>, S. Franz<sup>61</sup>, M. Fraternali<sup>120a,120b</sup>, S. T. French<sup>28</sup>, C. Friedrich<sup>42</sup>, F. Friedrich<sup>44</sup>, D. Froidevaux<sup>30</sup>, J. A. Frost<sup>28</sup>, C. Fukunaga<sup>157</sup>, E. Fullana Torregrosa<sup>82</sup>, B. G. Fulsom<sup>144</sup>, J. Fuster<sup>168</sup>, C. Gabaldon<sup>55</sup>, O. Gabizon<sup>176</sup>, A. Gabrielli<sup>20a,20b</sup>, A. Gabrielli<sup>133a,133b</sup>, S. Gadatsch<sup>106</sup>, S. Gadomski<sup>49</sup>, G. Gagliardi<sup>50a,50b</sup>, P. Gagnon<sup>60</sup>, C. Galea<sup>105</sup>, B. Galhardo<sup>125a,125c</sup>, E. J. Gallas<sup>119</sup>, V. Gallo<sup>17</sup>, B. J. Gallop<sup>130</sup>, P. Gallus<sup>127</sup>, G. Galster<sup>36</sup>, K. K. Gan<sup>110</sup>, J. Gao<sup>33b,h</sup>, Y. S. Gao<sup>144,f</sup>, F. M. Garay Walls<sup>46</sup>, F. Garberson<sup>177</sup>, C. García<sup>168</sup>, J. E. García Navarro<sup>168</sup>, M. Garcia-Sciveres<sup>15</sup>, R. W. Gardner<sup>31</sup>, N. Garelli<sup>144</sup>, V. Garonne<sup>30</sup>, C. Gatti<sup>47</sup>, G. Gaudio<sup>120a</sup>, B. Gaur<sup>142</sup>, L. Gauthier<sup>94</sup>, P. Gauzzi<sup>133a,133b</sup>, I. L. Gavrilenko<sup>95</sup>, C. Gay<sup>169</sup>, G. Gaycken<sup>21</sup>, E. N. Gazis<sup>10</sup>, P. Ge<sup>33d</sup>, Z. Gecse<sup>169</sup>, C. N. P. Gee<sup>130</sup>, D. A. A. Geerts<sup>106</sup>, Ch. Geich-Gimbel<sup>21</sup>, K. Gellerstedt<sup>147a,147b</sup>, C. Gemme<sup>50a</sup>, A. Gemmell<sup>53</sup>, M. H. Genest<sup>55</sup>, S. Gentile<sup>133a,133b</sup>, M. George<sup>54</sup>, S. George<sup>76</sup>, D. Gerbaudo<sup>164</sup>, A. Gershon<sup>154</sup>, H. Ghazlane<sup>136b</sup>, N. Ghodbane<sup>34</sup>, B. Giacobbe<sup>20a</sup>, S. Giagu<sup>133a,133b</sup>, V. Giangiobbe<sup>12</sup>, P. Giannetti<sup>123a,123b</sup>, F. Gianotti<sup>30</sup>, B. Gibbard<sup>25</sup>, S. M. Gibson<sup>76</sup>, M. Gilchriese<sup>15</sup>, T. P. S. Gillam<sup>28</sup>, D. Gillberg<sup>30</sup>, G. Gilles<sup>34</sup>, D. M. Gingrich<sup>3,e</sup>, N. Giokaris<sup>9</sup>, M. P. Giordani<sup>165a,165c</sup>, R. Giordano<sup>103a,103b</sup>, F. M. Giorgi<sup>20a</sup>, F. M. Giorgi<sup>16</sup>, P. F. Giraud<sup>137</sup>, D. Giugni<sup>90a</sup>, C. Giuliani<sup>48</sup>, M. Giulini<sup>58b</sup>, B. K. Gjelsten<sup>118</sup>, S. Gkaitatzis<sup>155</sup>, I. Gkialas<sup>155,m</sup>, L. K. Gladilin<sup>98</sup>, C. Glasman<sup>81</sup>, J. Glatzer<sup>30</sup>, P. C. F. Glaysher<sup>46</sup>, A. Glazov<sup>42</sup>, G. L. Glonti<sup>64</sup>, M. Goblirsch-Kolb<sup>100</sup>, J. R. Goddard<sup>75</sup>, J. Godlewski<sup>30</sup>, C. Goeringer<sup>82</sup>, S. Goldfarb<sup>88</sup>, T. Golling<sup>177</sup>, D. Golubkov<sup>129</sup>, A. Gomes<sup>125a,125b,125d</sup>, L. S. Gomez Fajardo<sup>42</sup>, R. Gonçalo<sup>125a</sup>, J. Goncalves Pinto Firmino Da Costa<sup>137</sup>, L. Gonella<sup>21</sup>, S. González de la Hoz<sup>168</sup>, G. Gonzalez Parra<sup>12</sup>, S. Gonzalez-Sevilla<sup>49</sup>, L. Goossens<sup>30</sup>, P. A. Gorbounov<sup>96</sup>, H. A. Gordon<sup>25</sup>, I. Gorelov<sup>104</sup>, B. Gorini<sup>30</sup>, E. Gorini<sup>72a,72b</sup>, A. Gorišek<sup>74</sup>, E. Gornicki<sup>39</sup>, A. T. Goshaw<sup>6</sup>, C. Gössling<sup>43</sup>, M. I. Gostkin<sup>64</sup>, M. Gouighri<sup>136a</sup>, D. Goujdami<sup>136c</sup>, M. P. Goulette<sup>49</sup>, A. G. Goussiou<sup>139</sup>, C. Goy<sup>5</sup>, S. Gozpinar<sup>23</sup>, H. M. X. Grabas<sup>137</sup>, L. Graber<sup>54</sup>, I. Grabowska-Bold<sup>38a</sup>, P. Grafström<sup>20a,20b</sup>, K.-J. Grahn<sup>42</sup>, J. Gramling<sup>49</sup>, E. Gramstad<sup>118</sup>, S. Grancagnolo<sup>16</sup>, V. Grassi<sup>149</sup>, V. Gratchev<sup>122</sup>, H. M. Gray<sup>30</sup>, E. Graziani<sup>135a</sup>, O. G. Grebenyuk<sup>122</sup>, Z. D. Greenwood<sup>78,n</sup>, K. Gregersen<sup>77</sup>, I. M. Gregor<sup>42</sup>, P. Grenier<sup>144</sup>, J. Griffiths<sup>8</sup>, A. A. Grillo<sup>138</sup>, K. Grimm<sup>71</sup>, S. Grinstein<sup>12,o</sup>, Ph. Gris<sup>34</sup>, Y. V. Grishkevich<sup>98</sup>, J.-F. Grivaz<sup>116</sup>, J. P. Grohs<sup>44</sup>, A. Grohsjean<sup>42</sup>, E. Gross<sup>173</sup>, J. Grosse-Knetter<sup>54</sup>, G. C. Grossi<sup>134a,134b</sup>, J. Groth-Jensen<sup>173</sup>, Z. J. Grout<sup>150</sup>, L. Guan<sup>33b</sup>, J. Guenther<sup>127</sup>, F. Guescini<sup>49</sup>, D. Guest<sup>177</sup>, O. Gueta<sup>154</sup>, C. Guicheney<sup>34</sup>, E. Guido<sup>50a,50b</sup>, T. Guillemin<sup>116</sup>, S. Guindon<sup>2</sup>, U. Gul<sup>53</sup>, C. Gumpert<sup>44</sup>, J. Guo<sup>35</sup>, S. Gupta<sup>119</sup>, P. Gutierrez<sup>112</sup>, N. G. Gutierrez Ortiz<sup>53</sup>, C. Gutsche<sup>77</sup>, N. Guttman<sup>154</sup>, C. Guyot<sup>137</sup>, C. Gwenlan<sup>119</sup>, C. B. Gwilliam<sup>73</sup>, A. Haas<sup>109</sup>, C. Haber<sup>15</sup>, H. K. Hadavand<sup>8</sup>, N. Haddad<sup>136e</sup>, P. Haefner<sup>21</sup>, S. Hageböeck<sup>21</sup>, Z. Hajduk<sup>39</sup>, H. Hakobyan<sup>178</sup>, M. Haleem<sup>42</sup>, D. Hall<sup>119</sup>, G. Halladjian<sup>89</sup>, K. Hamacher<sup>176</sup>, P. Hamal<sup>114</sup>, K. Hamano<sup>170</sup>, M. Hamer<sup>54</sup>, A. Hamilton<sup>146a</sup>, S. Hamilton<sup>162</sup>, G. N. Hamity<sup>146c</sup>, P. G. Hamnett<sup>42</sup>, L. Han<sup>33b</sup>, K. Hanagaki<sup>117</sup>, K. Hanawa<sup>156</sup>, M. Hance<sup>15</sup>, P. Hanke<sup>58a</sup>, R. Hanna<sup>137</sup>, J. B. Hansen<sup>36</sup>, J. D. Hansen<sup>36</sup>, P. H. Hansen<sup>36</sup>, K. Hara<sup>161</sup>, A. S. Hard<sup>174</sup>, T. Harenberg<sup>176</sup>, F. Hariri<sup>116</sup>, S. Harkusha<sup>91</sup>, D. Harper<sup>88</sup>, R. D. Harrington<sup>46</sup>, O. M. Harris<sup>139</sup>, P. F. Harrison<sup>171</sup>, F. Hartjes<sup>106</sup>, M. Hasegawa<sup>66</sup>, S. Hasegawa<sup>102</sup>, Y. Hasegawa<sup>141</sup>, A. Hasib<sup>112</sup>, S. Hassani<sup>137</sup>, S. Haug<sup>17</sup>, M. Hauschild<sup>30</sup>, R. Hauser<sup>89</sup>, M. Havranek<sup>126</sup>, C. M. Hawkes<sup>18</sup>, R. J. Hawkins<sup>30</sup>, A. D. Hawkins<sup>80</sup>, T. Hayashi<sup>161</sup>, D. Hayden<sup>89</sup>, C. P. Hays<sup>119</sup>, H. S. Hayward<sup>73</sup>, S. J. Haywood<sup>130</sup>, S. J. Head<sup>18</sup>, T. Heck<sup>82</sup>, V. Hedberg<sup>80</sup>, L. Heelan<sup>8</sup>, S. Heim<sup>121</sup>, T. Heim<sup>176</sup>, B. Heinemann<sup>15</sup>, L. Heinrich<sup>109</sup>, J. Hejbal<sup>126</sup>, L. Helary<sup>22</sup>, C. Heller<sup>99</sup>, M. Heller<sup>30</sup>, S. Hellman<sup>147a,147b</sup>, D. Hellmich<sup>21</sup>, C. Helsens<sup>30</sup>, J. Henderson<sup>119</sup>, R. C. W. Henderson<sup>71</sup>, Y. Heng<sup>174</sup>, C. Hengler<sup>42</sup>, A. Henrichs<sup>177</sup>, A. M. Henriques Correia<sup>30</sup>, S. Henrot-Versille<sup>116</sup>, C. Hensel<sup>54</sup>, G. H. Herbert<sup>16</sup>, Y. Hernández Jiménez<sup>168</sup>, R. Herrberg-Schubert<sup>16</sup>, G. Herten<sup>48</sup>, R. Hertenberger<sup>99</sup>, L. Hervas<sup>30</sup>, G. G. Hesketh<sup>77</sup>, N. P. Hessey<sup>106</sup>, R. Hickling<sup>75</sup>, E. Higón-Rodríguez<sup>168</sup>, E. Hill<sup>170</sup>, J. C. Hill<sup>28</sup>, K. H. Hiller<sup>42</sup>, S. Hillert<sup>21</sup>, S. J. Hillier<sup>18</sup>, I. Hinchliffe<sup>15</sup>, E. Hines<sup>121</sup>, M. Hirose<sup>158</sup>, D. Hirschbuehl<sup>176</sup>, J. Hobbs<sup>149</sup>, N. Hod<sup>106</sup>, M. C. Hodgkinson<sup>140</sup>, P. Hodgson<sup>140</sup>, A. Hoecker<sup>30</sup>, M. R. Hoferkamp<sup>104</sup>, F. Hoenig<sup>99</sup>, J. Hoffman<sup>40</sup>, D. Hoffmann<sup>84</sup>, J. I. Hofmann<sup>58a</sup>, M. Hohlfeld<sup>82</sup>, T. R. Holmes<sup>15</sup>, T. M. Hong<sup>121</sup>, L. Hooft van Huysduynen<sup>109</sup>, W. H. Hopkins<sup>115</sup>, Y. Horii<sup>102</sup>, J.-Y. Hostachy<sup>55</sup>, S. Hou<sup>152</sup>, A. Hoummada<sup>136a</sup>, J. Howard<sup>119</sup>, J. Howarth<sup>42</sup>, M. Hrabovsky<sup>114</sup>, I. Hristova<sup>16</sup>, J. Hrivnac<sup>116</sup>, T. Hryn'ova<sup>5</sup>, C. Hsu<sup>146c</sup>, P. J. Hsu<sup>82</sup>, S.-C. Hsu<sup>139</sup>, D. Hu<sup>35</sup>, X. Hu<sup>88</sup>, Y. Huang<sup>42</sup>, Z. Hubacek<sup>30</sup>, F. Hubaut<sup>84</sup>, F. Huegging<sup>21</sup>, T. B. Huffman<sup>119</sup>, E. W. Hughes<sup>35</sup>, G. Hughes<sup>71</sup>, M. Huhtinen<sup>30</sup>, T. A. Hülsing<sup>82</sup>, M. Hurwitz<sup>15</sup>, N. Huseynov<sup>64,b</sup>, J. Huston<sup>89</sup>, J. Huth<sup>57</sup>, G. Iacobucci<sup>49</sup>, G. Iakovidis<sup>10</sup>, I. Ibragimov<sup>142</sup>,

L. Iconomidou-Fayard<sup>116</sup>, E. Ideal<sup>177</sup>, P. Ingo<sup>103a</sup>, O. Igonkina<sup>106</sup>, T. Iizawa<sup>172</sup>, Y. Ikegami<sup>65</sup>, K. Ikematsu<sup>142</sup>, M. Ikeno<sup>65</sup>, Y. Ilchenko<sup>31,p</sup>, D. Iliadis<sup>155</sup>, N. Ilic<sup>159</sup>, Y. Inamaru<sup>66</sup>, T. Ince<sup>100</sup>, P. Ioannou<sup>9</sup>, M. Iodice<sup>135a</sup>, K. Iordanidou<sup>9</sup>, V. Ippolito<sup>57</sup>, A. Irlles Quiles<sup>168</sup>, C. Isaksson<sup>167</sup>, M. Ishino<sup>67</sup>, M. Ishitsuka<sup>158</sup>, R. Ishmukhametov<sup>110</sup>, C. Issever<sup>119</sup>, S. Istin<sup>19a</sup>, J. M. Iturbe Ponce<sup>83</sup>, R. Iuppa<sup>134a,134b</sup>, J. Ivarsson<sup>80</sup>, W. Iwanski<sup>39</sup>, H. Iwasaki<sup>65</sup>, J. M. Izen<sup>41</sup>, V. Izzo<sup>103a</sup>, B. Jackson<sup>121</sup>, M. Jackson<sup>73</sup>, P. Jackson<sup>1</sup>, M. R. Jaekel<sup>30</sup>, V. Jain<sup>2</sup>, K. Jakobs<sup>48</sup>, S. Jakobsen<sup>30</sup>, T. Jakoubek<sup>126</sup>, J. Jakubek<sup>127</sup>, D. O. Jamin<sup>152</sup>, D. K. Jana<sup>78</sup>, E. Jansen<sup>77</sup>, H. Jansen<sup>30</sup>, J. Janssen<sup>21</sup>, M. Janus<sup>171</sup>, G. Jarlskog<sup>80</sup>, N. Javadov<sup>64,b</sup>, T. Javůrek<sup>48</sup>, L. Jeanty<sup>15</sup>, J. Jejelava<sup>51a,q</sup>, G.-Y. Jeng<sup>151</sup>, D. Jennens<sup>87</sup>, P. Jenni<sup>48,r</sup>, J. Jentsch<sup>43</sup>, C. Jeske<sup>171</sup>, S. Jézéquel<sup>5</sup>, H. Ji<sup>174</sup>, J. Jia<sup>149</sup>, Y. Jiang<sup>33b</sup>, M. Jimenez Belenguer<sup>42</sup>, S. Jin<sup>33a</sup>, A. Jinaru<sup>26a</sup>, O. Jinnouchi<sup>158</sup>, M. D. Joergensen<sup>36</sup>, K. E. Johansson<sup>147a,147b</sup>, P. Johansson<sup>140</sup>, K. A. Johns<sup>7</sup>, K. Jon-And<sup>147a,147b</sup>, G. Jones<sup>171</sup>, R. W. L. Jones<sup>71</sup>, T. J. Jones<sup>73</sup>, J. Jongmanns<sup>58a</sup>, P. M. Jorge<sup>125a,125b</sup>, K. D. Joshi<sup>83</sup>, J. Jovicevic<sup>148</sup>, X. Ju<sup>174</sup>, C. A. Jung<sup>43</sup>, R. M. Jungst<sup>30</sup>, P. Jussel<sup>61</sup>, A. Juste Rozas<sup>12,o</sup>, M. Kaci<sup>168</sup>, A. Kaczmarzka<sup>39</sup>, M. Kado<sup>116</sup>, H. Kagan<sup>110</sup>, M. Kagan<sup>144</sup>, E. Kajomovitz<sup>45</sup>, C. W. Kalderon<sup>119</sup>, S. Kama<sup>40</sup>, A. Kamenshchikov<sup>129</sup>, N. Kanaya<sup>156</sup>, M. Kaneda<sup>30</sup>, S. Kaneti<sup>28</sup>, V. A. Kantserov<sup>97</sup>, J. Kanzaki<sup>65</sup>, B. Kaplan<sup>109</sup>, A. Kapliy<sup>31</sup>, D. Kar<sup>53</sup>, K. Karakostas<sup>10</sup>, N. Karastathis<sup>10</sup>, M. J. Kareem<sup>54</sup>, M. Karnevskiy<sup>82</sup>, S. N. Karpov<sup>64</sup>, Z. M. Karpova<sup>64</sup>, K. Karthik<sup>109</sup>, V. Kartvelishvili<sup>71</sup>, A. N. Karyukhin<sup>129</sup>, L. Kashif<sup>174</sup>, G. Kasieczka<sup>58b</sup>, R. D. Kass<sup>110</sup>, A. Kastanas<sup>14</sup>, Y. Kataoka<sup>156</sup>, A. Katre<sup>49</sup>, J. Katzy<sup>42</sup>, V. Kaushik<sup>7</sup>, K. Kawagoe<sup>69</sup>, T. Kawamoto<sup>156</sup>, G. Kawamura<sup>54</sup>, S. Kazama<sup>156</sup>, V. F. Kazanin<sup>108</sup>, M. Y. Kazarinov<sup>64</sup>, R. Keeler<sup>170</sup>, R. Kehoe<sup>40</sup>, M. Keil<sup>54</sup>, J. S. Keller<sup>42</sup>, J. J. Kempster<sup>76</sup>, H. Keoshkerian<sup>5</sup>, O. Kepka<sup>126</sup>, B. P. Kerševan<sup>74</sup>, S. Kersten<sup>176</sup>, K. Kessoku<sup>156</sup>, J. Keung<sup>159</sup>, F. Khalil-zada<sup>11</sup>, H. Khandanyan<sup>147a,147b</sup>, A. Khanov<sup>113</sup>, A. Khodinov<sup>97</sup>, A. Khomich<sup>58a</sup>, T. J. Khoo<sup>28</sup>, G. Khoraiuli<sup>21</sup>, A. Khoroshilov<sup>176</sup>, V. Khovanskiy<sup>96</sup>, E. Khramov<sup>64</sup>, J. Khubua<sup>51b</sup>, H. Y. Kim<sup>8</sup>, H. Kim<sup>147a,147b</sup>, S. H. Kim<sup>161</sup>, N. Kimura<sup>172</sup>, O. Kind<sup>16</sup>, B. T. King<sup>73</sup>, M. King<sup>168</sup>, R. S. B. King<sup>119</sup>, S. B. King<sup>169</sup>, J. Kirk<sup>130</sup>, A. E. Kiryunin<sup>100</sup>, T. Kishimoto<sup>66</sup>, D. Kisielewska<sup>38a</sup>, F. Kiss<sup>48</sup>, T. Kittelmann<sup>124</sup>, K. Kiuchi<sup>161</sup>, E. Kladiva<sup>145b</sup>, M. Klein<sup>73</sup>, U. Klein<sup>73</sup>, K. Kleinknecht<sup>82</sup>, P. Klimek<sup>147a,147b</sup>, A. Klimentov<sup>25</sup>, R. Klingenberg<sup>43</sup>, J. A. Klinger<sup>83</sup>, T. Klioutchnikova<sup>30</sup>, P. F. Klok<sup>105</sup>, E.-E. Kluge<sup>58a</sup>, P. Kluit<sup>106</sup>, S. Kluth<sup>100</sup>, E. Kneringer<sup>61</sup>, E. B. F. G. Knoop<sup>84</sup>, A. Knue<sup>53</sup>, D. Kobayashi<sup>158</sup>, T. Kobayashi<sup>156</sup>, M. Kobel<sup>44</sup>, M. Kocian<sup>144</sup>, P. Kodys<sup>128</sup>, P. Koevesarki<sup>21</sup>, T. Koffas<sup>29</sup>, E. Koffeman<sup>106</sup>, L. A. Kogan<sup>119</sup>, S. Kohlmann<sup>176</sup>, Z. Kohout<sup>127</sup>, T. Kohriki<sup>65</sup>, T. Koi<sup>144</sup>, H. Kolanoski<sup>16</sup>, I. Koletsou<sup>5</sup>, J. Koll<sup>89</sup>, A. A. Komar<sup>95,\*</sup>, Y. Komori<sup>156</sup>, T. Kondo<sup>65</sup>, N. Kondrashova<sup>42</sup>, K. Köneke<sup>48</sup>, A. C. König<sup>105</sup>, S. König<sup>82</sup>, T. Kono<sup>65,s</sup>, R. Konoplich<sup>109,t</sup>, N. Konstantinidis<sup>77</sup>, R. Kopeliansky<sup>153</sup>, S. Koperny<sup>38a</sup>, L. Köpke<sup>82</sup>, A. K. Kopp<sup>48</sup>, K. Korcyl<sup>39</sup>, K. Kordas<sup>155</sup>, A. Korn<sup>77</sup>, A. A. Korol<sup>108,c</sup>, I. Korolkov<sup>12</sup>, E. V. Korolkova<sup>140</sup>, V. A. Korotkov<sup>129</sup>, O. Kortner<sup>100</sup>, S. Kortner<sup>100</sup>, V. V. Kostyukhin<sup>21</sup>, V. M. Kotov<sup>64</sup>, A. Kotwal<sup>45</sup>, C. Kourkoumelis<sup>9</sup>, V. Kouskoura<sup>155</sup>, A. Koutsman<sup>160a</sup>, R. Kowalewski<sup>170</sup>, T. Z. Kowalski<sup>38a</sup>, W. Kozanecki<sup>137</sup>, A. S. Kozhin<sup>129</sup>, V. Kral<sup>127</sup>, V. A. Kramarenko<sup>98</sup>, G. Kramberger<sup>74</sup>, D. Krasnopevtsev<sup>97</sup>, M. W. Krasny<sup>79</sup>, A. Krasznahorkay<sup>30</sup>, J. K. Kraus<sup>21</sup>, A. Kravchenko<sup>25</sup>, S. Kreiss<sup>109</sup>, M. Kretz<sup>58c</sup>, J. Kretschmar<sup>73</sup>, K. Kreutzfeldt<sup>52</sup>, P. Krieger<sup>159</sup>, K. Kroeninger<sup>54</sup>, H. Kroha<sup>100</sup>, J. Kroll<sup>121</sup>, J. Kroseberg<sup>21</sup>, J. Krstic<sup>13a</sup>, U. Kruchonak<sup>64</sup>, H. Krüger<sup>21</sup>, T. Kruker<sup>17</sup>, N. Krumnack<sup>63</sup>, Z. V. Krumshteyn<sup>64</sup>, A. Kruse<sup>174</sup>, M. C. Kruse<sup>45</sup>, M. Kruskal<sup>22</sup>, T. Kubota<sup>87</sup>, S. Kudah<sup>4a</sup>, S. Kuehn<sup>48</sup>, A. Kugel<sup>58c</sup>, A. Kuhl<sup>138</sup>, T. Kuhl<sup>42</sup>, V. Kukhtin<sup>64</sup>, Y. Kulchitsky<sup>91</sup>, S. Kuleshov<sup>32b</sup>, M. Kuna<sup>133a,133b</sup>, J. Kunkle<sup>121</sup>, A. Kupco<sup>126</sup>, H. Kurashige<sup>66</sup>, Y. A. Kurochkin<sup>91</sup>, R. Kurumida<sup>66</sup>, V. Kus<sup>126</sup>, E. S. Kuwertz<sup>148</sup>, M. Kuze<sup>158</sup>, J. Kvita<sup>114</sup>, A. La Rosa<sup>49</sup>, L. La Rotonda<sup>37a,37b</sup>, C. Lacasta<sup>168</sup>, F. Lacava<sup>133a,133b</sup>, J. Lacey<sup>29</sup>, H. Lacker<sup>16</sup>, D. Lacour<sup>79</sup>, V. R. Lacuesta<sup>168</sup>, E. Ladygin<sup>64</sup>, R. Lafaye<sup>5</sup>, B. Laforge<sup>79</sup>, T. Lagouri<sup>177</sup>, S. Lai<sup>48</sup>, H. Laier<sup>58a</sup>, L. Lambourne<sup>77</sup>, S. Lammers<sup>60</sup>, C. L. Lampen<sup>7</sup>, W. Lamp<sup>7</sup>, E. Lançon<sup>137</sup>, U. Landgraf<sup>48</sup>, M. P. J. Landon<sup>75</sup>, V. S. Lang<sup>58a</sup>, A. J. Lankford<sup>164</sup>, F. Lanni<sup>25</sup>, K. Lantzsck<sup>30</sup>, S. Laplace<sup>79</sup>, C. Lapoire<sup>21</sup>, J. F. Laporte<sup>137</sup>, T. Lari<sup>90a</sup>, F. Lasagni Manghi<sup>20a,20b</sup>, M. Lassnig<sup>30</sup>, P. Laurelli<sup>47</sup>, W. Lavrijsen<sup>15</sup>, A. T. Law<sup>138</sup>, P. Laycock<sup>73</sup>, O. Le Dortz<sup>79</sup>, E. Le Guirriec<sup>84</sup>, E. Le Menedeu<sup>12</sup>, T. LeCompte<sup>6</sup>, F. Ledroit-Guillon<sup>55</sup>, C. A. Lee<sup>152</sup>, H. Lee<sup>106</sup>, J. S. H. Lee<sup>117</sup>, S. C. Lee<sup>152</sup>, L. Lee<sup>1</sup>, G. Lefebvre<sup>79</sup>, M. Lefebvre<sup>170</sup>, F. Legger<sup>99</sup>, C. Leggett<sup>15</sup>, A. Lehan<sup>73</sup>, M. Lehmacher<sup>21</sup>, G. Lehmann Miotto<sup>30</sup>, X. Lei<sup>7</sup>, W. A. Leight<sup>29</sup>, A. Leisos<sup>155</sup>, A. G. Leister<sup>177</sup>, M. A. L. Leite<sup>24d</sup>, R. Leitner<sup>128</sup>, D. Lellouch<sup>173</sup>, B. Lemmer<sup>54</sup>, K. J. C. Leney<sup>77</sup>, T. Lenz<sup>21</sup>, G. Lenzen<sup>176</sup>, B. Lenzi<sup>30</sup>, R. Leone<sup>7</sup>, S. Leone<sup>123a,123b</sup>, C. Leonidopoulos<sup>46</sup>, S. Leontsinis<sup>10</sup>, C. Leroy<sup>94</sup>, C. G. Lester<sup>28</sup>, C. M. Lester<sup>121</sup>, M. Levchenko<sup>122</sup>, J. Levêque<sup>5</sup>, D. Levin<sup>88</sup>, L. J. Levinson<sup>173</sup>, M. Levy<sup>18</sup>, A. Lewis<sup>119</sup>, G. H. Lewis<sup>109</sup>, A. M. Leyko<sup>21</sup>, M. Leyton<sup>41</sup>, B. Li<sup>33b,u</sup>, B. Li<sup>84</sup>, H. Li<sup>149</sup>, H. L. Li<sup>31</sup>, L. Li<sup>45</sup>, L. Li<sup>33e</sup>, S. Li<sup>45</sup>, Y. Li<sup>33c,v</sup>, Z. Liang<sup>138</sup>, H. Liao<sup>34</sup>, B. Liberti<sup>134a</sup>, P. Lichard<sup>30</sup>, K. Lie<sup>166</sup>, J. Liebal<sup>21</sup>, W. Liebig<sup>14</sup>, C. Limbach<sup>21</sup>, A. Limosani<sup>87</sup>, S. C. Lin<sup>152,w</sup>, T. H. Lin<sup>82</sup>, F. Linde<sup>106</sup>, B. E. Lindquist<sup>149</sup>, J. T. Linnemann<sup>89</sup>, E. Lipeles<sup>121</sup>, A. Lipniacka<sup>14</sup>, M. Lisovsky<sup>42</sup>, T. M. Liss<sup>166</sup>, D. Lissauer<sup>25</sup>, A. Lister<sup>169</sup>, A. M. Litke<sup>138</sup>, B. Liu<sup>152</sup>, D. Liu<sup>152</sup>, J. B. Liu<sup>33b</sup>, K. Liu<sup>33b,x</sup>, L. Liu<sup>88</sup>, M. Liu<sup>45</sup>, M. Liu<sup>33b</sup>, Y. Liu<sup>33b</sup>, M. Livan<sup>120a,120b</sup>, S. S. A. Livermore<sup>119</sup>, A. Lleres<sup>55</sup>, J. Llorente Merino<sup>81</sup>, S. L. Lloyd<sup>75</sup>, F. Lo Sterzo<sup>152</sup>, E. Lobodzinska<sup>42</sup>, P. Loch<sup>7</sup>, W. S. Lockman<sup>138</sup>, T. Loddenkoetter<sup>21</sup>, F. K. Loebinger<sup>83</sup>, A. E. Loevschall-Jensen<sup>36</sup>, A. Loginov<sup>177</sup>, T. Lohse<sup>16</sup>, K. Lohwasser<sup>42</sup>, M. Lokajicek<sup>126</sup>, V. P. Lombardo<sup>5</sup>, B. A. Long<sup>22</sup>, J. D. Long<sup>88</sup>, R. E. Long<sup>71</sup>, L. Lopes<sup>125a</sup>, D. Lopez Mateos<sup>57</sup>, B. Lopez Paredes<sup>140</sup>,

I. Lopez Paz<sup>12</sup>, J. Lorenz<sup>99</sup>, N. Lorenzo Martinez<sup>60</sup>, M. Losada<sup>163</sup>, P. Loscutoff<sup>15</sup>, X. Lou<sup>41</sup>, A. Lounis<sup>116</sup>, J. Love<sup>6</sup>, P. A. Love<sup>71</sup>, A. J. Lowe<sup>144,f</sup>, F. Lu<sup>33a</sup>, N. Lu<sup>88</sup>, H. J. Lubatti<sup>139</sup>, C. Luci<sup>133a,133b</sup>, A. Lucotte<sup>55</sup>, F. Luehring<sup>60</sup>, W. Lukas<sup>61</sup>, L. Luminari<sup>133a</sup>, O. Lundberg<sup>147a,147b</sup>, B. Lund-Jensen<sup>148</sup>, M. Lungwitz<sup>82</sup>, D. Lynn<sup>25</sup>, R. Lysak<sup>126</sup>, E. Lytken<sup>80</sup>, H. Ma<sup>25</sup>, L. L. Ma<sup>33d</sup>, G. Maccarrone<sup>47</sup>, A. Macchiolo<sup>100</sup>, J. Machado Miguens<sup>125a,125b</sup>, D. Macina<sup>30</sup>, D. Madaffari<sup>84</sup>, R. Madar<sup>48</sup>, H. J. Maddocks<sup>71</sup>, W. F. Mader<sup>44</sup>, A. Madsen<sup>167</sup>, M. Maeno<sup>8</sup>, T. Maeno<sup>25</sup>, A. Maevskiy<sup>98</sup>, E. Magradze<sup>54</sup>, K. Mahboubi<sup>48</sup>, J. Mahlstedt<sup>106</sup>, S. Mahmoud<sup>73</sup>, C. Maiani<sup>137</sup>, C. Maidantchik<sup>24a</sup>, A. A. Maier<sup>100</sup>, A. Maio<sup>125a,125b,125d</sup>, S. Majewski<sup>115</sup>, Y. Makida<sup>65</sup>, N. Makovec<sup>116</sup>, P. Mal<sup>137,y</sup>, B. Malaescu<sup>79</sup>, Pa. Malecki<sup>39</sup>, V. P. Maleev<sup>122</sup>, F. Malek<sup>55</sup>, U. Mallik<sup>62</sup>, D. Malon<sup>6</sup>, C. Malone<sup>144</sup>, S. Maltezos<sup>10</sup>, V. M. Malyshev<sup>108</sup>, S. Malyukov<sup>30</sup>, J. Mamuzic<sup>13b</sup>, B. Mandelli<sup>30</sup>, L. Mandelli<sup>90a</sup>, I. Mandić<sup>74</sup>, R. Mandrysch<sup>62</sup>, J. Maneira<sup>125a,125b</sup>, A. Manfredini<sup>100</sup>, L. Manhaes de Andrade Filho<sup>24b</sup>, J. A. Manjarres Ramos<sup>160b</sup>, A. Mann<sup>99</sup>, P. M. Manning<sup>138</sup>, A. Manousakis-Katsikakis<sup>9</sup>, B. Mansoulie<sup>137</sup>, R. Mantifel<sup>86</sup>, L. Mapelli<sup>30</sup>, L. March<sup>146c</sup>, J. F. Marchand<sup>29</sup>, G. Marchiori<sup>79</sup>, M. Marcisovsky<sup>126</sup>, C. P. Marino<sup>170</sup>, M. Marjanovic<sup>13a</sup>, C. N. Marques<sup>125a</sup>, F. Marroquim<sup>24a</sup>, S. P. Marsden<sup>83</sup>, Z. Marshall<sup>15</sup>, L. F. Marti<sup>17</sup>, S. Marti-Garcia<sup>168</sup>, B. Martin<sup>30</sup>, B. Martin<sup>89</sup>, T. A. Martin<sup>171</sup>, V. J. Martin<sup>46</sup>, B. Martin dit Latour<sup>14</sup>, H. Martinez<sup>137</sup>, M. Martinez<sup>12.o</sup>, S. Martin-Haugh<sup>130</sup>, A. C. Martyniuk<sup>77</sup>, M. Marx<sup>139</sup>, F. Marzano<sup>133a</sup>, A. Marzin<sup>30</sup>, L. Masetti<sup>82</sup>, T. Mashimo<sup>156</sup>, R. Mashinistov<sup>95</sup>, J. Masik<sup>83</sup>, A. L. Maslennikov<sup>108c</sup>, I. Massa<sup>20a,20b</sup>, L. Massa<sup>20a,20b</sup>, N. Massol<sup>5</sup>, P. Mastrandrea<sup>149</sup>, A. Mastroberardino<sup>37a,37b</sup>, T. Masubuchi<sup>156</sup>, P. Mättig<sup>176</sup>, J. Mattmann<sup>82</sup>, J. Maurer<sup>26a</sup>, S. J. Maxfield<sup>73</sup>, D. A. Maximov<sup>108.c</sup>, R. Mazini<sup>152</sup>, L. Mazzaferro<sup>134a,134b</sup>, G. Mc Goldrick<sup>159</sup>, S. P. Mc Kee<sup>88</sup>, A. McCarn<sup>88</sup>, R. L. McCarthy<sup>149</sup>, T. G. McCarthy<sup>29</sup>, N. A. McCubbin<sup>130</sup>, K. W. McFarlane<sup>56,\*</sup>, J. A. McFayden<sup>77</sup>, G. Mchedlidze<sup>54</sup>, S. J. McMahon<sup>130</sup>, R. A. McPherson<sup>170j</sup>, J. Mechnich<sup>106</sup>, M. Medinnis<sup>42</sup>, S. Meehan<sup>31</sup>, S. Mehlhase<sup>99</sup>, A. Mehta<sup>73</sup>, K. Meier<sup>58a</sup>, C. Meineck<sup>99</sup>, B. Meirose<sup>80</sup>, C. Melachrinos<sup>31</sup>, B. R. Mellado Garcia<sup>146c</sup>, F. Meloni<sup>17</sup>, A. Mengarelli<sup>20a,20b</sup>, S. Menke<sup>100</sup>, E. Meoni<sup>162</sup>, K. M. Mercurio<sup>57</sup>, S. Mergelmeyer<sup>21</sup>, N. Meric<sup>137</sup>, P. Mermod<sup>49</sup>, L. Merola<sup>103a,103b</sup>, C. Meroni<sup>90a</sup>, F. S. Merritt<sup>31</sup>, H. Merritt<sup>110</sup>, A. Messina<sup>30.z</sup>, J. Metcalfe<sup>25</sup>, A. S. Mete<sup>164</sup>, C. Meyer<sup>82</sup>, C. Meyer<sup>121</sup>, J-P. Meyer<sup>137</sup>, J. Meyer<sup>30</sup>, R. P. Middleton<sup>130</sup>, S. Migas<sup>73</sup>, L. Mijovic<sup>21</sup>, G. Mikenberg<sup>173</sup>, M. Mikesikova<sup>126</sup>, M. Mikuž<sup>74</sup>, A. Milic<sup>30</sup>, D. W. Miller<sup>31</sup>, C. Mills<sup>46</sup>, A. Milov<sup>173</sup>, D. A. Milstead<sup>147a,147b</sup>, D. Milstein<sup>173</sup>, A. A. Minaenko<sup>129</sup>, Y. Minami<sup>156</sup>, I. A. Minashvili<sup>64</sup>, A. I. Mincer<sup>109</sup>, B. Mindur<sup>38a</sup>, M. Mineev<sup>64</sup>, Y. Ming<sup>174</sup>, L. M. Mir<sup>12</sup>, G. Mirabelli<sup>133a</sup>, T. Mitani<sup>172</sup>, J. Mitrevski<sup>99</sup>, V. A. Mitsou<sup>168</sup>, S. Mitsui<sup>65</sup>, A. Miucci<sup>49</sup>, P. S. Miyagawa<sup>140</sup>, J. U. Mjörnmark<sup>80</sup>, T. Moa<sup>147a,147b</sup>, K. Mochizuki<sup>84</sup>, S. Mohapatra<sup>35</sup>, W. Mohr<sup>48</sup>, S. Molander<sup>147a,147b</sup>, R. Moles-Valls<sup>168</sup>, K. Mönig<sup>42</sup>, C. Monini<sup>55</sup>, J. Monk<sup>36</sup>, E. Monnier<sup>84</sup>, J. Montejo Berlingen<sup>12</sup>, F. Monticelli<sup>70</sup>, S. Monzani<sup>133a,133b</sup>, R. W. Moore<sup>3</sup>, N. Morange<sup>62</sup>, D. Moreno<sup>82</sup>, M. Moreno Llácer<sup>54</sup>, P. Morettini<sup>50a</sup>, M. Morgenstern<sup>44</sup>, M. Morii<sup>57</sup>, S. Moritz<sup>82</sup>, A. K. Morley<sup>148</sup>, G. Mornacchi<sup>30</sup>, J. D. Morris<sup>75</sup>, L. Morvaj<sup>102</sup>, H. G. Moser<sup>100</sup>, M. Mosidze<sup>51b</sup>, J. Moss<sup>110</sup>, K. Motohashi<sup>158</sup>, R. Mount<sup>144</sup>, E. Mountricha<sup>25</sup>, S. V. Mouraviev<sup>95.\*</sup>, E. J. W. Moyse<sup>85</sup>, S. Muanza<sup>84</sup>, R. D. Mudd<sup>18</sup>, F. Mueller<sup>58a</sup>, J. Mueller<sup>124</sup>, K. Mueller<sup>21</sup>, T. Mueller<sup>28</sup>, T. Mueller<sup>82</sup>, D. Muenstermann<sup>49</sup>, Y. Munwes<sup>154</sup>, J. A. Murillo Quijada<sup>18</sup>, W. J. Murray<sup>130,171</sup>, H. Musheghyan<sup>54</sup>, E. Musto<sup>153</sup>, A. G. Myagkov<sup>129,aa</sup>, M. Myska<sup>127</sup>, O. Nackenhorst<sup>54</sup>, J. Nadal<sup>54</sup>, K. Nagai<sup>61</sup>, R. Nagai<sup>158</sup>, Y. Nagai<sup>84</sup>, K. Nagano<sup>65</sup>, A. Nagarkar<sup>110</sup>, Y. Nagasaka<sup>59</sup>, M. Nagel<sup>100</sup>, A. M. Nairz<sup>30</sup>, Y. Nakahama<sup>30</sup>, K. Nakamura<sup>65</sup>, T. Nakamura<sup>156</sup>, I. Nakano<sup>111</sup>, H. Namasivayam<sup>41</sup>, G. Nanava<sup>21</sup>, R. Narayan<sup>58b</sup>, T. Nattermann<sup>21</sup>, T. Naumann<sup>42</sup>, G. Navarro<sup>163</sup>, R. Nayyar<sup>7</sup>, H. A. Neal<sup>88</sup>, P. Yu. Nechaeva<sup>95</sup>, T. J. Neep<sup>83</sup>, P. D. Nef<sup>144</sup>, A. Negri<sup>120a,120b</sup>, G. Negri<sup>30</sup>, M. Negrini<sup>20a</sup>, S. Nektarijevic<sup>49</sup>, C. Nellist<sup>116</sup>, A. Nelson<sup>164</sup>, T. K. Nelson<sup>144</sup>, S. Nemecek<sup>126</sup>, P. Nemethy<sup>109</sup>, A. A. Nepomuceno<sup>24a</sup>, M. Nessi<sup>30.ab</sup>, M. S. Neubauer<sup>166</sup>, M. Neumann<sup>176</sup>, R. M. Neves<sup>109</sup>, P. Nevski<sup>25</sup>, P. R. Newman<sup>18</sup>, D. H. Nguyen<sup>6</sup>, R. B. Nickerson<sup>119</sup>, R. Nicolaidou<sup>137</sup>, B. Niquevert<sup>30</sup>, J. Nielsen<sup>138</sup>, N. Nikiforou<sup>35</sup>, A. Nikiforov<sup>16</sup>, V. Nikolaenko<sup>129,aa</sup>, I. Nikolic-Audit<sup>79</sup>, K. Nikolics<sup>49</sup>, K. Nikolopoulos<sup>18</sup>, P. Nilsson<sup>8</sup>, Y. Ninomiya<sup>156</sup>, A. Nisati<sup>133a</sup>, R. Nisius<sup>100</sup>, T. Nobe<sup>158</sup>, L. Nodulman<sup>6</sup>, M. Nomachi<sup>117</sup>, I. Nomidis<sup>29</sup>, S. Norberg<sup>112</sup>, M. Nordberg<sup>30</sup>, O. Novgorodova<sup>44</sup>, S. Nowak<sup>100</sup>, M. Nozaki<sup>65</sup>, L. Nozka<sup>114</sup>, K. Ntekas<sup>10</sup>, G. Nunes Hanninger<sup>87</sup>, T. Nunnemann<sup>99</sup>, E. Nurse<sup>77</sup>, F. Nuti<sup>87</sup>, B. J. O'Brien<sup>46</sup>, F. O'grady<sup>7</sup>, D. C. O'Neil<sup>143</sup>, V. O'Shea<sup>53</sup>, F. G. Oakham<sup>29,e</sup>, H. Oberlack<sup>100</sup>, T. Obermann<sup>21</sup>, J. Ocariz<sup>79</sup>, A. Ochi<sup>66</sup>, M. I. Ochoa<sup>77</sup>, S. Oda<sup>69</sup>, S. Odaka<sup>65</sup>, H. Ogren<sup>60</sup>, A. Oh<sup>83</sup>, S. H. Oh<sup>45</sup>, C. C. Ohm<sup>15</sup>, H. Ohman<sup>167</sup>, W. Okamura<sup>117</sup>, H. Okawa<sup>25</sup>, Y. Okumura<sup>31</sup>, T. Okuyama<sup>156</sup>, A. Olariu<sup>26a</sup>, A. G. Olchevski<sup>64</sup>, S. A. Olivares Pino<sup>46</sup>, D. Oliveira Damazio<sup>25</sup>, E. Oliver Garcia<sup>168</sup>, A. Olszewski<sup>39</sup>, J. Olszowska<sup>39</sup>, A. Onofre<sup>125a,125c</sup>, P. U. E. Onyisi<sup>31.p</sup>, C. J. Oram<sup>160a</sup>, M. J. Oreglia<sup>31</sup>, Y. Oren<sup>154</sup>, D. Orestano<sup>135a,135b</sup>, N. Orlando<sup>72a,72b</sup>, C. Oropeza Barrera<sup>53</sup>, R. S. Orr<sup>159</sup>, B. Osculati<sup>50a,50b</sup>, R. Ospanov<sup>121</sup>, G. Otero y Garzon<sup>27</sup>, H. Otono<sup>69</sup>, M. Ouchrif<sup>136d</sup>, E. A. Ouellette<sup>170</sup>, F. Ould-Saada<sup>118</sup>, A. Ouraou<sup>137</sup>, K. P. Oussoren<sup>106</sup>, Q. Ouyang<sup>33a</sup>, A. Ovcharova<sup>15</sup>, M. Owen<sup>83</sup>, V. E. Ozcan<sup>19a</sup>, N. Ozturk<sup>8</sup>, K. Pachal<sup>119</sup>, A. Pacheco Pages<sup>12</sup>, C. Padilla Aranda<sup>12</sup>, M. Pagáčová<sup>48</sup>, S. Pagan Griso<sup>15</sup>, E. Paganis<sup>140</sup>, C. Pahl<sup>100</sup>, F. Paige<sup>25</sup>, P. Pais<sup>85</sup>, K. Pajchel<sup>118</sup>, G. Palacino<sup>160b</sup>, S. Palestini<sup>30</sup>, M. Palka<sup>38b</sup>, D. Pallin<sup>34</sup>, A. Palma<sup>125a,125b</sup>, J. D. Palmer<sup>18</sup>, Y. B. Pan<sup>174</sup>, E. Panagiotopoulou<sup>10</sup>, J. G. Panduro Vazquez<sup>76</sup>, P. Pani<sup>106</sup>, N. Panikashvili<sup>88</sup>, S. Panitkin<sup>25</sup>, D. Pantea<sup>26a</sup>, L. Paolozzi<sup>134a,134b</sup>, Th. D. Papadopolou<sup>10</sup>, K. Papageorgiou<sup>155.m</sup>, A. Paramonov<sup>6</sup>, D. Paredes Hernandez<sup>34</sup>, M. A. Parker<sup>28</sup>, F. Parodi<sup>50a,50b</sup>, J. A. Parsons<sup>35</sup>, U. Parzefall<sup>48</sup>,

E. Pasqualucci<sup>133a</sup>, S. Passaggio<sup>50a</sup>, A. Passeri<sup>135a</sup>, F. Pastore<sup>135a,135b,\*</sup>, Fr. Pastore<sup>76</sup>, G. Pásztor<sup>29</sup>, S. Patarraia<sup>176</sup>, N. D. Patel<sup>151</sup>, J. R. Pater<sup>83</sup>, S. Patricelli<sup>103a,103b</sup>, T. Pauly<sup>30</sup>, J. Pearce<sup>170</sup>, L. E. Pedersen<sup>36</sup>, M. Pedersen<sup>118</sup>, S. Pedraza Lopez<sup>168</sup>, R. Pedro<sup>125a,125b</sup>, S. V. Peleganchuk<sup>108</sup>, D. Pelikan<sup>167</sup>, H. Peng<sup>33b</sup>, B. Penning<sup>31</sup>, J. Penwell<sup>60</sup>, D. V. Perepelitsa<sup>25</sup>, E. Perez Codina<sup>160a</sup>, M. T. Pérez García-Estañ<sup>168</sup>, V. Perez Reale<sup>35</sup>, L. Perini<sup>90a,90b</sup>, H. Pernegger<sup>30</sup>, S. Perrella<sup>103a,103b</sup>, R. Perrino<sup>72a</sup>, R. Peschke<sup>42</sup>, V. D. Peshekhonov<sup>64</sup>, K. Peters<sup>30</sup>, R. F. Y. Peters<sup>83</sup>, B. A. Petersen<sup>30</sup>, T. C. Petersen<sup>36</sup>, E. Petit<sup>42</sup>, A. Petridis<sup>147a,147b</sup>, C. Petridou<sup>155</sup>, E. Petrolo<sup>133a</sup>, F. Petrucci<sup>135a,135b</sup>, N. E. Pettersson<sup>158</sup>, R. Pezoa<sup>32b</sup>, P. W. Phillips<sup>130</sup>, G. Piacquadio<sup>144</sup>, E. Pianori<sup>171</sup>, A. Picazio<sup>49</sup>, E. Piccaro<sup>75</sup>, M. Piccinini<sup>20a,20b</sup>, R. Piegai<sup>27</sup>, D. T. Pignotti<sup>110</sup>, J. E. Pilcher<sup>31</sup>, A. D. Pilkington<sup>77</sup>, J. Pina<sup>125a,125b,125d</sup>, M. Pinamonti<sup>165a,165c,ac</sup>, A. Pinder<sup>119</sup>, J. L. Pinfold<sup>3</sup>, A. Pingel<sup>36</sup>, B. Pinto<sup>125a</sup>, S. Pires<sup>79</sup>, M. Pitt<sup>173</sup>, C. Pizio<sup>90a,90b</sup>, L. Plazak<sup>145a</sup>, M.-A. Pleier<sup>25</sup>, V. Pleskot<sup>128</sup>, E. Plotnikova<sup>64</sup>, P. Plucinski<sup>147a,147b</sup>, S. Poddar<sup>58a</sup>, F. Podlyski<sup>34</sup>, R. Poettgen<sup>82</sup>, L. Poggioli<sup>116</sup>, D. Pohl<sup>21</sup>, M. Pohl<sup>49</sup>, G. Polesello<sup>120a</sup>, A. Policicchio<sup>37a,37b</sup>, R. Polifka<sup>159</sup>, A. Polini<sup>20a</sup>, C. S. Pollard<sup>45</sup>, V. Polychronakos<sup>25</sup>, K. Pommès<sup>30</sup>, L. Pontecorvo<sup>133a</sup>, B. G. Pope<sup>89</sup>, G. A. Popeneciu<sup>26b</sup>, D. S. Popovic<sup>13a</sup>, A. Poppleton<sup>30</sup>, X. Portell Bueso<sup>12</sup>, S. Pospisil<sup>127</sup>, K. Potamianos<sup>15</sup>, I. N. Potrap<sup>64</sup>, C. J. Potter<sup>150</sup>, C. T. Potter<sup>115</sup>, G. Poulard<sup>30</sup>, J. Poveda<sup>60</sup>, V. Pozdnyakov<sup>64</sup>, P. Pralavorio<sup>84</sup>, A. Pranko<sup>15</sup>, S. Prasad<sup>30</sup>, R. Pravahan<sup>8</sup>, S. Prell<sup>63</sup>, D. Price<sup>83</sup>, J. Price<sup>73</sup>, L. E. Price<sup>6</sup>, D. Prieur<sup>124</sup>, M. Primavera<sup>72a</sup>, M. Proissl<sup>46</sup>, K. Prokofiev<sup>47</sup>, F. Prokoshin<sup>32b</sup>, E. Protopapadaki<sup>137</sup>, S. Protopopescu<sup>25</sup>, J. Proudfoot<sup>6</sup>, M. Przybycien<sup>38a</sup>, H. Przysieszniak<sup>5</sup>, E. Ptacek<sup>115</sup>, D. Puddu<sup>135a,135b</sup>, E. Pueschel<sup>85</sup>, D. Pudlon<sup>149</sup>, M. Purohit<sup>25,ad</sup>, P. Puzo<sup>116</sup>, J. Qian<sup>88</sup>, G. Qin<sup>53</sup>, Y. Qin<sup>83</sup>, A. Quadri<sup>54</sup>, D. R. Quarrie<sup>15</sup>, W. B. Quayle<sup>165a,165b</sup>, M. Queitsch-Maitland<sup>83</sup>, D. Quilty<sup>53</sup>, A. Qureshi<sup>160b</sup>, V. Radeka<sup>25</sup>, V. Radescu<sup>42</sup>, S. K. Radhakrishnan<sup>149</sup>, P. Radloff<sup>115</sup>, P. Rados<sup>87</sup>, F. Ragusa<sup>90a,90b</sup>, G. Rahal<sup>179</sup>, S. Rajagopalan<sup>25</sup>, M. Rammensee<sup>30</sup>, A. S. Randle-Conde<sup>40</sup>, C. Rangel-Smith<sup>167</sup>, K. Rao<sup>164</sup>, F. Rauscher<sup>99</sup>, T. C. Rave<sup>48</sup>, T. Ravenscroft<sup>53</sup>, M. Raymond<sup>30</sup>, A. L. Read<sup>118</sup>, N. P. Readioff<sup>73</sup>, D. M. Rebuffi<sup>120a,120b</sup>, A. Redelbach<sup>175</sup>, G. Redlinger<sup>25</sup>, R. Reece<sup>138</sup>, K. Reeves<sup>41</sup>, L. Rehnisch<sup>16</sup>, H. Reisin<sup>27</sup>, M. Relich<sup>164</sup>, C. Rembser<sup>30</sup>, H. Ren<sup>33a</sup>, Z. L. Ren<sup>152</sup>, A. Renaud<sup>116</sup>, M. Rescigno<sup>133a</sup>, S. Resconi<sup>90a</sup>, O. L. Rezanova<sup>108,c</sup>, P. Reznicek<sup>128</sup>, R. Rezvani<sup>94</sup>, R. Richter<sup>100</sup>, M. Ridel<sup>79</sup>, P. Rieck<sup>16</sup>, J. Rieger<sup>54</sup>, M. Rijssenbeek<sup>149</sup>, A. Rimoldi<sup>120a,120b</sup>, L. Rinaldi<sup>20a</sup>, E. Ritsch<sup>61</sup>, I. Riu<sup>12</sup>, F. Rizatdinova<sup>113</sup>, E. Rizvi<sup>75</sup>, S. H. Robertson<sup>86,j</sup>, A. Robichaud-Veronneau<sup>86</sup>, D. Robinson<sup>28</sup>, J. E. M. Robinson<sup>83</sup>, A. Robson<sup>53</sup>, C. Roda<sup>123a,123b</sup>, L. Rodrigues<sup>30</sup>, S. Roe<sup>30</sup>, O. Røhne<sup>118</sup>, S. Rolli<sup>162</sup>, A. Romaniouk<sup>97</sup>, M. Romano<sup>20a,20b</sup>, E. Romero Adam<sup>168</sup>, N. Rompotis<sup>139</sup>, M. Ronzani<sup>48</sup>, L. Roos<sup>79</sup>, E. Ros<sup>168</sup>, S. Rosati<sup>133a</sup>, K. Rosbach<sup>49</sup>, M. Rose<sup>76</sup>, P. Rose<sup>138</sup>, P. L. Rosendahl<sup>14</sup>, O. Rosenthal<sup>142</sup>, V. Rossetti<sup>147a,147b</sup>, E. Rossi<sup>103a,103b</sup>, L. P. Rossi<sup>50a</sup>, R. Rosten<sup>139</sup>, M. Rotaru<sup>26a</sup>, I. Roth<sup>173</sup>, J. Rothberg<sup>139</sup>, D. Rousseau<sup>116</sup>, C. R. Royon<sup>137</sup>, A. Rozanov<sup>84</sup>, Y. Rozen<sup>153</sup>, X. Ruan<sup>146c</sup>, F. Rubbo<sup>12</sup>, I. Rubinskiy<sup>42</sup>, V. I. Rud<sup>98</sup>, C. Rudolph<sup>44</sup>, M. S. Rudolph<sup>159</sup>, F. Rühr<sup>48</sup>, A. Ruiz-Martinez<sup>30</sup>, Z. Rurikova<sup>48</sup>, N. A. Rusakovich<sup>64</sup>, A. Ruschke<sup>99</sup>, J. P. Rutherford<sup>7</sup>, N. Ruthmann<sup>48</sup>, Y. F. Ryabov<sup>122</sup>, M. Rybar<sup>128</sup>, G. Rybkin<sup>116</sup>, N. C. Ryder<sup>119</sup>, A. F. Saavedra<sup>151</sup>, S. Sacerdoti<sup>27</sup>, A. Saddique<sup>3</sup>, I. Sadeh<sup>154</sup>, H. F.-W. Sadrozinski<sup>138</sup>, R. Sadykov<sup>64</sup>, F. Safai Tehrani<sup>133a</sup>, H. Sakamoto<sup>156</sup>, Y. Sakurai<sup>172</sup>, G. Salamanna<sup>135a,135b</sup>, A. Salamon<sup>134a</sup>, M. Saleem<sup>112</sup>, D. Salek<sup>106</sup>, P. H. Sales De Bruin<sup>139</sup>, D. Salihagic<sup>100</sup>, A. Salnikov<sup>144</sup>, J. Salt<sup>168</sup>, D. Salvatore<sup>37a,37b</sup>, F. Salvatore<sup>150</sup>, A. Salvucci<sup>105</sup>, A. Salzburger<sup>30</sup>, D. Sampsonidis<sup>155</sup>, A. Sanchez<sup>103a,103b</sup>, J. Sánchez<sup>168</sup>, V. Sanchez Martinez<sup>168</sup>, H. Sandaker<sup>14</sup>, R. L. Sandbach<sup>75</sup>, H. G. Sander<sup>82</sup>, M. P. Sanders<sup>99</sup>, M. Sandhoff<sup>176</sup>, T. Sandoval<sup>28</sup>, C. Sandoval<sup>163</sup>, R. Sandstroem<sup>100</sup>, D. P. C. Sankey<sup>130</sup>, A. Sansoni<sup>47</sup>, C. Santoni<sup>34</sup>, R. Santonico<sup>134a,134b</sup>, H. Santos<sup>125a</sup>, I. Santoyo Castillo<sup>150</sup>, K. Sapp<sup>124</sup>, A. Sapronov<sup>64</sup>, J. G. Saraiva<sup>125a,125d</sup>, B. Sarrazin<sup>21</sup>, G. Sartisohn<sup>176</sup>, O. Sasaki<sup>65</sup>, Y. Sasaki<sup>156</sup>, G. Sauvage<sup>5,\*</sup>, E. Sauvan<sup>5</sup>, P. Savard<sup>159,e</sup>, D. O. Savu<sup>30</sup>, C. Sawyer<sup>119</sup>, L. Sawyer<sup>78,n</sup>, D. H. Saxon<sup>53</sup>, J. Saxon<sup>121</sup>, C. Sbarra<sup>20a</sup>, A. Sbrizzi<sup>20a,20b</sup>, T. Scanlon<sup>77</sup>, D. A. Scannicchio<sup>164</sup>, M. Scarcella<sup>151</sup>, V. Scarfone<sup>37a,37b</sup>, J. Schaarschmidt<sup>173</sup>, P. Schacht<sup>100</sup>, D. Schaefer<sup>30</sup>, R. Schaefer<sup>42</sup>, S. Schaepe<sup>21</sup>, S. Schaezel<sup>58b</sup>, U. Schäfer<sup>82</sup>, A. C. Schaffer<sup>116</sup>, D. Schaile<sup>99</sup>, R. D. Schamberger<sup>149</sup>, V. Scharf<sup>58a</sup>, V. A. Schegelsky<sup>122</sup>, D. Scheirich<sup>128</sup>, M. Schernau<sup>164</sup>, M. I. Scherzer<sup>35</sup>, C. Schiavi<sup>50a,50b</sup>, J. Schieck<sup>99</sup>, C. Schillo<sup>48</sup>, M. Schioppa<sup>37a,37b</sup>, S. Schlenker<sup>30</sup>, E. Schmidt<sup>48</sup>, K. Schmieden<sup>30</sup>, C. Schmitt<sup>82</sup>, S. Schmitt<sup>58b</sup>, B. Schneider<sup>17</sup>, Y. J. Schnellbach<sup>73</sup>, U. Schnoor<sup>44</sup>, L. Schoeffel<sup>137</sup>, A. Schoening<sup>58b</sup>, B. D. Schoenrock<sup>89</sup>, A. L. S. Schorlemmer<sup>54</sup>, M. Schott<sup>82</sup>, D. Schouten<sup>160a</sup>, J. Schovancova<sup>25</sup>, S. Schramm<sup>159</sup>, M. Schreyer<sup>175</sup>, C. Schroeder<sup>82</sup>, N. Schuh<sup>82</sup>, M. J. Schultens<sup>21</sup>, H.-C. Schultz-Coulon<sup>58a</sup>, H. Schulz<sup>16</sup>, M. Schumacher<sup>48</sup>, B. A. Schumm<sup>138</sup>, Ph. Schune<sup>137</sup>, C. Schwanenberger<sup>83</sup>, A. Schwartzman<sup>144</sup>, T. A. Schwarz<sup>88</sup>, Ph. Schwegler<sup>100</sup>, Ph. Schwemling<sup>137</sup>, R. Schwienhorst<sup>89</sup>, J. Schwindling<sup>137</sup>, T. Schwindt<sup>21</sup>, M. Schwoerer<sup>5</sup>, F. G. Sciacca<sup>17</sup>, E. Scifo<sup>116</sup>, G. Sciolla<sup>23</sup>, W. G. Scott<sup>130</sup>, F. Scuri<sup>123a,123b</sup>, F. Scutti<sup>21</sup>, J. Searcy<sup>88</sup>, G. Sedov<sup>42</sup>, E. Sedykh<sup>122</sup>, S. C. Seidel<sup>104</sup>, A. Seiden<sup>138</sup>, F. Seifert<sup>127</sup>, J. M. Seixas<sup>24a</sup>, G. Sekhniaidze<sup>103a</sup>, S. J. Sekula<sup>40</sup>, K. E. Selbach<sup>46</sup>, D. M. Seliverstov<sup>122,\*</sup>, G. Sellers<sup>73</sup>, N. Semprini-Cesari<sup>20a,20b</sup>, C. Serfon<sup>30</sup>, L. Serin<sup>116</sup>, L. Serkin<sup>54</sup>, T. Serre<sup>84</sup>, R. Seuster<sup>160a</sup>, H. Severini<sup>112</sup>, T. Sfiligoi<sup>74</sup>, F. Sforza<sup>100</sup>, A. Sfyrta<sup>30</sup>, E. Shabalina<sup>54</sup>, M. Shamim<sup>115</sup>, L. Y. Shan<sup>33a</sup>, R. Shang<sup>166</sup>, J. T. Shank<sup>22</sup>, M. Shapiro<sup>15</sup>, P. B. Shatalov<sup>96</sup>, K. Shaw<sup>165a,165b</sup>, C. Y. Shehu<sup>150</sup>, P. Sherwood<sup>77</sup>, L. Shi<sup>152,ae</sup>, S. Shimizu<sup>66</sup>, C. O. Shimmin<sup>164</sup>, M. Shimojima<sup>101</sup>, M. Shiyakova<sup>64</sup>, A. Shmeleva<sup>95</sup>, M. J. Shochet<sup>31</sup>, D. Short<sup>119</sup>, S. Shrestha<sup>63</sup>,

E. Shulga<sup>97</sup>, M. A. Shupe<sup>7</sup>, S. Shushkevich<sup>42</sup>, P. Sicho<sup>126</sup>, O. Sidiropoulou<sup>155</sup>, D. Sidorov<sup>113</sup>, A. Sidoti<sup>133a</sup>, F. Siegert<sup>44</sup>, Dj. Sijacki<sup>13a</sup>, J. Silva<sup>125a,125d</sup>, Y. Silver<sup>154</sup>, D. Silverstein<sup>144</sup>, S. B. Silverstein<sup>147a</sup>, V. Simak<sup>127</sup>, O. Simard<sup>5</sup>, Lj. Simic<sup>13a</sup>, S. Simion<sup>116</sup>, E. Simioni<sup>82</sup>, B. Simmons<sup>77</sup>, R. Simoniello<sup>90a,90b</sup>, M. Simonyan<sup>36</sup>, P. Sinervo<sup>159</sup>, N. B. Sinev<sup>115</sup>, V. Sipica<sup>142</sup>, G. Siragusa<sup>175</sup>, A. Sircar<sup>78</sup>, A. N. Sisakyan<sup>64,\*</sup>, S. Yu. Sivoklov<sup>98</sup>, J. Sjölin<sup>147a,147b</sup>, T. B. Sjurson<sup>14</sup>, H. P. Skottowe<sup>57</sup>, K. Yu. Skovpen<sup>108</sup>, P. Skubic<sup>112</sup>, M. Slater<sup>18</sup>, T. Slavicek<sup>127</sup>, K. Sliwa<sup>162</sup>, V. Smakhtin<sup>173</sup>, B. H. Smart<sup>46</sup>, L. Smestad<sup>14</sup>, S. Yu. Smirnov<sup>97</sup>, Y. Smirnov<sup>97</sup>, L. N. Smirnova<sup>98,af</sup>, O. Smirnova<sup>80</sup>, K. M. Smith<sup>53</sup>, M. Smizanska<sup>71</sup>, K. Smolek<sup>127</sup>, A. A. Snesarev<sup>95</sup>, G. Snidero<sup>75</sup>, S. Snyder<sup>25</sup>, R. Sobie<sup>170,j</sup>, F. Socher<sup>44</sup>, A. Soffer<sup>154</sup>, D. A. Soh<sup>152,ae</sup>, C. A. Solans<sup>30</sup>, M. Solar<sup>127</sup>, J. Solc<sup>127</sup>, E. Yu. Soldatov<sup>97</sup>, U. Soldevila<sup>168</sup>, A. A. Solodkov<sup>129</sup>, A. Soloshenko<sup>64</sup>, O. V. Solovyanov<sup>129</sup>, V. Solovyev<sup>122</sup>, P. Sommer<sup>48</sup>, H. Y. Song<sup>33b</sup>, N. Soni<sup>1</sup>, A. Sood<sup>15</sup>, A. Sopczak<sup>127</sup>, B. Sopko<sup>127</sup>, V. Sopko<sup>127</sup>, V. Sorin<sup>12</sup>, M. Sosebee<sup>8</sup>, R. Soualah<sup>165a,165c</sup>, P. Soueid<sup>94</sup>, A. M. Soukharev<sup>108c</sup>, D. South<sup>42</sup>, S. Spagnolo<sup>72a,72b</sup>, F. Spano<sup>76</sup>, W. R. Spearman<sup>57</sup>, F. Spettel<sup>100</sup>, R. Spighi<sup>20a</sup>, G. Spigo<sup>30</sup>, L. A. Spiller<sup>87</sup>, M. Spousta<sup>128</sup>, T. Spreitzer<sup>159</sup>, B. Spurlock<sup>8</sup>, R. D. St. Denis<sup>53,\*</sup>, S. Staerz<sup>44</sup>, J. Stahlman<sup>121</sup>, R. Stamen<sup>58a</sup>, S. Stamm<sup>16</sup>, E. Stanecka<sup>39</sup>, R. W. Stanek<sup>6</sup>, C. Stanescu<sup>135a</sup>, M. Stanescu-Bellu<sup>42</sup>, M. M. Stanitzki<sup>42</sup>, S. Stapnes<sup>118</sup>, E. A. Starchenko<sup>129</sup>, J. Stark<sup>55</sup>, P. Staroba<sup>126</sup>, P. Starovoitov<sup>42</sup>, R. Staszewski<sup>39</sup>, P. Stavina<sup>145a,\*</sup>, P. Steinberg<sup>25</sup>, B. Stelzer<sup>143</sup>, H. J. Stelzer<sup>30</sup>, O. Stelzer-Chilton<sup>160a</sup>, H. Stenzel<sup>52</sup>, S. Stern<sup>100</sup>, G. A. Stewart<sup>53</sup>, J. A. Stillings<sup>21</sup>, M. C. Stockton<sup>86</sup>, M. Stoebe<sup>86</sup>, G. Stoicea<sup>26a</sup>, P. Stolte<sup>54</sup>, S. Stonjek<sup>100</sup>, A. R. Stradling<sup>8</sup>, A. Straessner<sup>44</sup>, M. E. Stramaglia<sup>17</sup>, J. Strandberg<sup>148</sup>, S. Strandberg<sup>147a,147b</sup>, A. Strandlie<sup>118</sup>, E. Strauss<sup>144</sup>, M. Strauss<sup>112</sup>, P. Strizenc<sup>145b</sup>, R. Ströhmer<sup>175</sup>, D. M. Strom<sup>115</sup>, R. Stroynowski<sup>40</sup>, A. Strubig<sup>105</sup>, S. A. Stucci<sup>17</sup>, B. Stugu<sup>14</sup>, N. A. Styles<sup>42</sup>, D. Su<sup>144</sup>, J. Su<sup>124</sup>, R. Subramaniam<sup>78</sup>, A. Succurro<sup>12</sup>, Y. Sugaya<sup>117</sup>, C. Suhr<sup>107</sup>, M. Suk<sup>127</sup>, V. V. Sulin<sup>95</sup>, S. Sultansoy<sup>4c</sup>, T. Sumida<sup>67</sup>, S. Sun<sup>57</sup>, X. Sun<sup>33a</sup>, J. E. Sundermann<sup>48</sup>, K. Suruliz<sup>140</sup>, G. Susinno<sup>37a,37b</sup>, M. R. Sutton<sup>150</sup>, Y. Suzuki<sup>65</sup>, M. Svatos<sup>126</sup>, S. Swedish<sup>169</sup>, M. Swiatlowski<sup>144</sup>, I. Sykora<sup>145a</sup>, T. Sykora<sup>128</sup>, D. Ta<sup>89</sup>, C. Taccini<sup>135a,135b</sup>, K. Tackmann<sup>42</sup>, J. Taenzer<sup>159</sup>, A. Taffard<sup>164</sup>, R. Tafirout<sup>160a</sup>, N. Taiblum<sup>154</sup>, H. Takai<sup>25</sup>, R. Takashima<sup>68</sup>, H. Takeda<sup>66</sup>, T. Takeshita<sup>141</sup>, Y. Takubo<sup>65</sup>, M. Talby<sup>84</sup>, A. A. Talyshev<sup>108,c</sup>, J. Y. C. Tam<sup>175</sup>, K. G. Tan<sup>87</sup>, J. Tanaka<sup>156</sup>, R. Tanaka<sup>116</sup>, S. Tanaka<sup>132</sup>, S. Tanaka<sup>65</sup>, A. J. Tanasijczuk<sup>143</sup>, B. B. Tannenwald<sup>110</sup>, N. Tannoury<sup>21</sup>, S. Tapprogge<sup>82</sup>, S. Tarem<sup>153</sup>, F. Tarrade<sup>29</sup>, G. F. Tartarelli<sup>90a</sup>, P. Tas<sup>128</sup>, M. Tasevsky<sup>126</sup>, T. Tashiro<sup>67</sup>, E. Tassi<sup>37a,37b</sup>, A. Tavares Delgado<sup>125a,125b</sup>, Y. Tayalati<sup>136d</sup>, F. E. Taylor<sup>93</sup>, G. N. Taylor<sup>87</sup>, W. Taylor<sup>160b</sup>, F. A. Teischinger<sup>30</sup>, M. Teixeira Dias Castanheira<sup>75</sup>, P. Teixeira-Dias<sup>76</sup>, K. K. Temming<sup>48</sup>, H. Ten Kate<sup>30</sup>, P. K. Teng<sup>152</sup>, J. J. Teoh<sup>117</sup>, S. Terada<sup>65</sup>, K. Terashi<sup>156</sup>, J. Terron<sup>81</sup>, S. Terzo<sup>100</sup>, M. Testa<sup>47</sup>, R. J. Teuscher<sup>159,j</sup>, J. Therhaag<sup>21</sup>, T. Theveneaux-Pelzer<sup>34</sup>, J. P. Thomas<sup>18</sup>, J. Thomas-Wilsker<sup>76</sup>, E. N. Thompson<sup>35</sup>, P. D. Thompson<sup>18</sup>, P. D. Thompson<sup>159</sup>, R. J. Thompson<sup>83</sup>, A. S. Thompson<sup>53</sup>, L. A. Thomsen<sup>36</sup>, E. Thomson<sup>121</sup>, M. Thomson<sup>28</sup>, W. M. Thong<sup>87</sup>, R. P. Thun<sup>88,\*</sup>, F. Tian<sup>35</sup>, M. J. Tibbetts<sup>15</sup>, V. O. Tikhomirov<sup>95,ag</sup>, Yu. A. Tikhonov<sup>108,c</sup>, S. Timoshenko<sup>97</sup>, E. Tiouchichine<sup>84</sup>, P. Tipton<sup>177</sup>, S. Tisserant<sup>84</sup>, T. Todorov<sup>5</sup>, S. Todorova-Nova<sup>128</sup>, B. Toggerson<sup>7</sup>, J. Tojo<sup>69</sup>, S. Tokár<sup>145a</sup>, K. Tokushuku<sup>65</sup>, K. Tollefson<sup>89</sup>, E. Tolley<sup>57</sup>, L. Tomlinson<sup>83</sup>, M. Tomoto<sup>102</sup>, L. Tompkins<sup>31</sup>, K. Toms<sup>104</sup>, N. D. Topilin<sup>64</sup>, E. Torrence<sup>115</sup>, H. Torres<sup>143</sup>, E. Torró Pastor<sup>168</sup>, J. Toth<sup>84,ah</sup>, F. Touchard<sup>84</sup>, D. R. Tovey<sup>140</sup>, H. L. Tran<sup>116</sup>, T. Trefzger<sup>175</sup>, L. Tremblet<sup>30</sup>, A. Tricoli<sup>30</sup>, I. M. Trigger<sup>160a</sup>, S. Trincaz-Duvoid<sup>79</sup>, M. F. Tripiana<sup>12</sup>, W. Trischuk<sup>159</sup>, B. Trocmé<sup>55</sup>, C. Troncon<sup>90a</sup>, M. Trotter-McDonald<sup>15</sup>, M. Trovatelli<sup>135a,135b</sup>, P. True<sup>89</sup>, M. Trzebinski<sup>39</sup>, A. Trzupek<sup>39</sup>, C. Tsarouchas<sup>30</sup>, J. C-L. Tseng<sup>119</sup>, P. V. Tsiarshka<sup>91</sup>, D. Tsionou<sup>137</sup>, G. Tsipolitis<sup>10</sup>, N. Tsirintanis<sup>9</sup>, S. Tsiskaridze<sup>12</sup>, V. Tsiskaridze<sup>48</sup>, E. G. Tskhadadze<sup>51a</sup>, I. I. Tsukerman<sup>96</sup>, V. Tsulaia<sup>15</sup>, S. Tsuno<sup>65</sup>, D. Tsybychev<sup>149</sup>, A. Tudorache<sup>26a</sup>, V. Tudorache<sup>26a</sup>, A. N. Tuna<sup>121</sup>, S. A. Tupputi<sup>20a,20b</sup>, S. Turchikhin<sup>98,af</sup>, D. Turecek<sup>127</sup>, I. Turk Cakir<sup>4d</sup>, R. Turra<sup>90a,90b</sup>, P. M. Tuts<sup>35</sup>, A. Tykhonov<sup>49</sup>, M. Tylmad<sup>147a,147b</sup>, M. Tyndel<sup>130</sup>, K. Uchida<sup>21</sup>, I. Ueda<sup>156</sup>, R. Ueno<sup>29</sup>, M. Ughetto<sup>84</sup>, M. Ugland<sup>14</sup>, M. Uhlenbrock<sup>21</sup>, F. Ukegawa<sup>161</sup>, G. Unal<sup>30</sup>, A. Undrus<sup>25</sup>, G. Unel<sup>164</sup>, F. C. Ungaro<sup>48</sup>, Y. Unno<sup>65</sup>, C. Unverdorben<sup>99</sup>, D. Urbaniec<sup>35</sup>, P. Urquijo<sup>87</sup>, G. Usai<sup>8</sup>, A. Usanova<sup>61</sup>, L. Vacavant<sup>84</sup>, V. Vacek<sup>127</sup>, B. Vachon<sup>86</sup>, N. Valencic<sup>106</sup>, S. Valentinetti<sup>20a,20b</sup>, A. Valero<sup>168</sup>, L. Valery<sup>34</sup>, S. Valkar<sup>128</sup>, E. Valladolid Gallego<sup>168</sup>, S. Vallecorsa<sup>49</sup>, J. A. Valls Ferrer<sup>168</sup>, W. Van Den Wollenberg<sup>106</sup>, P. C. Van Der Deijl<sup>106</sup>, R. van der Geer<sup>106</sup>, H. van der Graaf<sup>106</sup>, R. Van Der Leeuw<sup>106</sup>, D. van der Ster<sup>30</sup>, N. van Eldik<sup>30</sup>, P. van Gemmeren<sup>6</sup>, J. Van Nieuwkoop<sup>143</sup>, I. van Vulpen<sup>106</sup>, M. C. van Woerden<sup>30</sup>, M. Vanadia<sup>133a,133b</sup>, W. Vandelli<sup>30</sup>, R. Vanguri<sup>121</sup>, A. Vaniachine<sup>6</sup>, P. Vankov<sup>42</sup>, F. Vannucci<sup>79</sup>, G. Vardanyan<sup>178</sup>, R. Vari<sup>133a</sup>, E. W. Varnes<sup>7</sup>, T. Varol<sup>85</sup>, D. Varouchas<sup>79</sup>, A. Vartapetian<sup>8</sup>, K. E. Varvell<sup>151</sup>, F. Vazeille<sup>34</sup>, T. Vazquez Schroeder<sup>54</sup>, J. Veatch<sup>7</sup>, F. Veloso<sup>125a,125c</sup>, S. Veneziano<sup>133a</sup>, A. Ventura<sup>72a,72b</sup>, D. Ventura<sup>85</sup>, M. Venturi<sup>170</sup>, N. Venturi<sup>159</sup>, A. Venturini<sup>23</sup>, V. Vercesi<sup>120a</sup>, M. Verducci<sup>133a,133b</sup>, W. Verkerke<sup>106</sup>, J. C. Vermeulen<sup>106</sup>, A. Vest<sup>44</sup>, M. C. Vetterli<sup>143,e</sup>, O. Viazlo<sup>80</sup>, I. Vichou<sup>166</sup>, T. Vickey<sup>146c,ai</sup>, O. E. Vickey Boeriu<sup>146c</sup>, G. H. A. Viehhauser<sup>119</sup>, S. Viel<sup>169</sup>, R. Vigne<sup>30</sup>, M. Villa<sup>20a,20b</sup>, M. Villaplana Perez<sup>90a,90b</sup>, E. Vilucchi<sup>47</sup>, M. G. Vincker<sup>29</sup>, V. B. Vinogradov<sup>64</sup>, J. Virzi<sup>15</sup>, I. Vivarelli<sup>150</sup>, F. Vives Vaque<sup>3</sup>, S. Vlachos<sup>10</sup>, D. Vladoiu<sup>99</sup>, M. Vlasak<sup>127</sup>, A. Vogel<sup>21</sup>, M. Vogel<sup>32a</sup>, P. Vokac<sup>127</sup>, G. Volpi<sup>123a,123b</sup>, M. Volpi<sup>87</sup>, H. von der Schmitt<sup>100</sup>, H. von Radziewski<sup>48</sup>, E. von Toerne<sup>21</sup>, V. Vorobel<sup>128</sup>, K. Vorobev<sup>97</sup>, M. Vos<sup>168</sup>, R. Voss<sup>30</sup>, J. H. Vossebeld<sup>73</sup>, N. Vranjes<sup>137</sup>, M. Vranjes Milosavljevic<sup>13a</sup>, V. Vrba<sup>126</sup>, M. Vreeswijk<sup>106</sup>, T. Vu Anh<sup>48</sup>, R. Vuillemet<sup>30</sup>, I. Vukotic<sup>31</sup>, Z. Vykydal<sup>127</sup>

P. Wagner<sup>21</sup>, W. Wagner<sup>176</sup>, H. Wahlberg<sup>70</sup>, S. Wahrmund<sup>44</sup>, J. Wakabayashi<sup>102</sup>, J. Walder<sup>71</sup>, R. Walker<sup>99</sup>, W. Walkowiak<sup>142</sup>, R. Wall<sup>177</sup>, P. Waller<sup>73</sup>, B. Walsh<sup>177</sup>, C. Wang<sup>152,aj</sup>, C. Wang<sup>45</sup>, F. Wang<sup>174</sup>, H. Wang<sup>15</sup>, H. Wang<sup>40</sup>, J. Wang<sup>42</sup>, J. Wang<sup>33a</sup>, K. Wang<sup>86</sup>, R. Wang<sup>104</sup>, S. M. Wang<sup>152</sup>, T. Wang<sup>21</sup>, X. Wang<sup>177</sup>, C. Wanotayaroj<sup>115</sup>, A. Warburton<sup>86</sup>, C. P. Ward<sup>28</sup>, D. R. Wardrope<sup>77</sup>, M. Warsinsky<sup>48</sup>, A. Washbrook<sup>46</sup>, C. Wasicki<sup>42</sup>, P. M. Watkins<sup>18</sup>, A. T. Watson<sup>18</sup>, I. J. Watson<sup>151</sup>, M. F. Watson<sup>18</sup>, G. Watts<sup>139</sup>, S. Watts<sup>83</sup>, B. M. Waugh<sup>77</sup>, S. Webb<sup>83</sup>, M. S. Weber<sup>17</sup>, S. W. Weber<sup>175</sup>, J. S. Webster<sup>31</sup>, A. R. Weidberg<sup>119</sup>, P. Weigell<sup>100</sup>, B. Weinert<sup>60</sup>, J. Weingarten<sup>54</sup>, C. Weiser<sup>48</sup>, H. Weits<sup>106</sup>, P. S. Wells<sup>30</sup>, T. Wenaus<sup>25</sup>, D. Wendland<sup>16</sup>, Z. Weng<sup>152,ac</sup>, T. Wengler<sup>30</sup>, S. Wenig<sup>30</sup>, N. Wermes<sup>21</sup>, M. Werner<sup>48</sup>, P. Werner<sup>30</sup>, M. Wessels<sup>58a</sup>, J. Wetter<sup>162</sup>, K. Whalen<sup>29</sup>, A. White<sup>8</sup>, M. J. White<sup>1</sup>, R. White<sup>32b</sup>, S. White<sup>123a,123b</sup>, D. Whiteson<sup>164</sup>, D. Wicke<sup>176</sup>, F. J. Wickens<sup>130</sup>, W. Wiedenmann<sup>174</sup>, M. Wielers<sup>130</sup>, P. Wienemann<sup>21</sup>, C. Wiglesworth<sup>36</sup>, L. A. M. Wiik-Fuchs<sup>21</sup>, P. A. Wijeratne<sup>77</sup>, A. Wildauer<sup>100</sup>, M. A. Wildt<sup>42,ak</sup>, H. G. Wilkens<sup>30</sup>, J. Z. Will<sup>99</sup>, H. H. Williams<sup>121</sup>, S. Williams<sup>28</sup>, C. Willis<sup>89</sup>, S. Willocq<sup>85</sup>, A. Wilson<sup>88</sup>, J. A. Wilson<sup>18</sup>, I. Wingerter-Seez<sup>5</sup>, F. Winklmeier<sup>115</sup>, B. T. Winter<sup>21</sup>, M. Wittgen<sup>144</sup>, T. Wittig<sup>43</sup>, J. Wittkowski<sup>99</sup>, S. J. Wollstadt<sup>82</sup>, M. W. Wolter<sup>39</sup>, H. Wolters<sup>125a,125c</sup>, B. K. Wosiek<sup>39</sup>, J. Wotschack<sup>30</sup>, M. J. Woudstra<sup>83</sup>, K. W. Wozniak<sup>39</sup>, M. Wright<sup>53</sup>, M. Wu<sup>55</sup>, M. Wu<sup>31</sup>, S. L. Wu<sup>174</sup>, X. Wu<sup>49</sup>, Y. Wu<sup>88</sup>, E. Wulf<sup>35</sup>, T. R. Wyatt<sup>83</sup>, B. M. Wynne<sup>46</sup>, S. Xella<sup>36</sup>, M. Xiao<sup>137</sup>, D. Xu<sup>33a</sup>, L. Xu<sup>33b,al</sup>, B. Yabsley<sup>151</sup>, S. Yacoub<sup>146b,am</sup>, R. Yakabe<sup>66</sup>, M. Yamada<sup>65</sup>, H. Yamaguchi<sup>156</sup>, Y. Yamaguchi<sup>117</sup>, A. Yamamoto<sup>65</sup>, K. Yamamoto<sup>63</sup>, S. Yamamoto<sup>156</sup>, T. Yamamura<sup>156</sup>, T. Yamanaka<sup>156</sup>, K. Yamauchi<sup>102</sup>, Y. Yamazaki<sup>66</sup>, Z. Yan<sup>22</sup>, H. Yang<sup>33e</sup>, H. Yang<sup>174</sup>, U. K. Yang<sup>83</sup>, Y. Yang<sup>110</sup>, S. Yanush<sup>92</sup>, L. Yao<sup>33a</sup>, W-M. Yao<sup>15</sup>, Y. Yasu<sup>65</sup>, E. Yatsenko<sup>42</sup>, K. H. Yau Wong<sup>21</sup>, J. Ye<sup>40</sup>, S. Ye<sup>25</sup>, I. Yeletsikh<sup>64</sup>, A. L. Yen<sup>57</sup>, E. Yildirim<sup>42</sup>, M. Yilmaz<sup>4b</sup>, R. Yoosofmiya<sup>124</sup>, K. Yorita<sup>172</sup>, R. Yoshida<sup>6</sup>, K. Yoshihara<sup>156</sup>, C. Young<sup>144</sup>, C. J. S. Young<sup>30</sup>, S. Youssef<sup>22</sup>, D. R. Yu<sup>15</sup>, J. Yu<sup>8</sup>, J. M. Yu<sup>88</sup>, J. Yu<sup>113</sup>, L. Yuan<sup>66</sup>, A. Yurkewicz<sup>107</sup>, I. Yusuff<sup>28,an</sup>, B. Zabinski<sup>39</sup>, R. Zaidan<sup>62</sup>, A. M. Zaitsev<sup>129,aa</sup>, A. Zaman<sup>149</sup>, S. Zambito<sup>23</sup>, L. Zanello<sup>133a,133b</sup>, D. Zanzi<sup>100</sup>, C. Zeitnitz<sup>176</sup>, M. Zeman<sup>127</sup>, A. Zemla<sup>38a</sup>, K. Zengel<sup>23</sup>, O. Zenin<sup>129</sup>, T. Ženiš<sup>145a</sup>, D. Zerwas<sup>116</sup>, G. Zevi della Porta<sup>57</sup>, D. Zhang<sup>88</sup>, F. Zhang<sup>174</sup>, H. Zhang<sup>89</sup>, J. Zhang<sup>6</sup>, L. Zhang<sup>152</sup>, X. Zhang<sup>33d</sup>, Z. Zhang<sup>116</sup>, Z. Zhao<sup>33b</sup>, A. Zhemchugov<sup>64</sup>, J. Zhong<sup>119</sup>, B. Zhou<sup>88</sup>, L. Zhou<sup>35</sup>, N. Zhou<sup>164</sup>, C. G. Zhu<sup>33d</sup>, H. Zhu<sup>33a</sup>, J. Zhu<sup>88</sup>, Y. Zhu<sup>33b</sup>, X. Zhuang<sup>33a</sup>, K. Zhukov<sup>95</sup>, A. Zibell<sup>175</sup>, D. Zieminska<sup>60</sup>, N. I. Zimine<sup>64</sup>, C. Zimmermann<sup>82</sup>, R. Zimmermann<sup>21</sup>, S. Zimmermann<sup>21</sup>, S. Zimmermann<sup>48</sup>, Z. Zinonos<sup>54</sup>, M. Ziolkowski<sup>142</sup>, G. Zobernig<sup>174</sup>, A. Zoccoli<sup>20a,20b</sup>, M. zur Nedden<sup>16</sup>, G. Zurzolo<sup>103a,103b</sup>, V. Zutshi<sup>107</sup>, L. Zwalinski<sup>30</sup>

<sup>1</sup> Department of Physics, University of Adelaide, Adelaide, Australia

<sup>2</sup> Physics Department, SUNY Albany, Albany, NY, USA

<sup>3</sup> Department of Physics, University of Alberta, Edmonton, AB, Canada

<sup>4</sup> (a) Department of Physics, Ankara University, Ankara, Turkey; (b) Department of Physics, Gazi University, Ankara, Turkey; (c) Division of Physics, TOBB University of Economics and Technology, Ankara, Turkey; (d) Turkish Atomic Energy Authority, Ankara, Turkey

<sup>5</sup> LAPP and CNRS/IN2P3 and Université de Savoie, Annecy-le-Vieux, France

<sup>6</sup> High Energy Physics Division, Argonne National Laboratory, Argonne, IL, USA

<sup>7</sup> Department of Physics, University of Arizona, Tucson, AZ, USA

<sup>8</sup> Department of Physics, The University of Texas at Arlington, Arlington, TX, USA

<sup>9</sup> Physics Department, University of Athens, Athens, Greece

<sup>10</sup> Physics Department, National Technical University of Athens, Zografou, Greece

<sup>11</sup> Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan

<sup>12</sup> Departament de Física de la, Institut de Física d'Altes Energies, Universitat Autònoma de Barcelona, Barcelona, Spain

<sup>13</sup> (a) Institute of Physics, University of Belgrade, Belgrade, Serbia; (b) Vinca Institute of Nuclear Sciences, University of Belgrade, Belgrade, Serbia

<sup>14</sup> Department for Physics and Technology, University of Bergen, Bergen, Norway

<sup>15</sup> Physics Division, Lawrence Berkeley National Laboratory, University of California, Berkeley, CA, USA

<sup>16</sup> Department of Physics, Humboldt University, Berlin, Germany

<sup>17</sup> Laboratory for High Energy Physics, Albert Einstein Center for Fundamental Physics, University of Bern, Bern, Switzerland

<sup>18</sup> School of Physics and Astronomy, University of Birmingham, Birmingham, UK

<sup>19</sup> (a) Department of Physics, Bogazici University, Istanbul, Turkey; (b) Department of Physics, Dogus University, Istanbul, Turkey; (c) Department of Physics Engineering, Gaziantep University, Gaziantep, Turkey

<sup>20</sup> (a) INFN Sezione di Bologna, Bologna, Italy; (b) Dipartimento di Fisica e Astronomia, Università di Bologna, Bologna, Italy

<sup>21</sup> Physikalisches Institut, University of Bonn, Bonn, Germany



- <sup>22</sup> Department of Physics, Boston University, Boston, MA, USA
- <sup>23</sup> Department of Physics, Brandeis University, Waltham, MA, USA
- <sup>24</sup> (a) Universidade Federal do Rio De Janeiro COPPE/EE/IF, Rio de Janeiro, Brazil; (b) Federal University of Juiz de Fora (UFJF), Juiz de Fora, Brazil; (c) Federal University of Sao Joao del Rei (UFSJ), Sao Joao del Rei, Brazil; (d) Instituto de Fisica, Universidade de Sao Paulo, São Paulo, Brazil
- <sup>25</sup> Physics Department, Brookhaven National Laboratory, Upton, NY, USA
- <sup>26</sup> (a) National Institute of Physics and Nuclear Engineering, Bucharest, Romania; (b) Physics Department, National Institute for Research and Development of Isotopic and Molecular Technologies, Cluj Napoca, Romania; (c) University Politehnica Bucharest, Bucharest, Romania; (d) West University in Timisoara, Timisoara, Romania
- <sup>27</sup> Departamento de Física, Universidad de Buenos Aires, Buenos Aires, Argentina
- <sup>28</sup> Cavendish Laboratory, University of Cambridge, Cambridge, UK
- <sup>29</sup> Department of Physics, Carleton University, Ottawa, ON, Canada
- <sup>30</sup> CERN, Geneva, Switzerland
- <sup>31</sup> Enrico Fermi Institute, University of Chicago, Chicago, IL, USA
- <sup>32</sup> (a) Departamento de Física, Pontificia Universidad Católica de Chile, Santiago, Chile; (b) Departamento de Física, Universidad Técnica Federico Santa María, Valparaíso, Chile
- <sup>33</sup> (a) Institute of High Energy Physics, Chinese Academy of Sciences, Beijing, China; (b) Department of Modern Physics, University of Science and Technology of China, Hefei, Anhui, China; (c) Department of Physics, Nanjing University, Nanjing, Jiangsu, China; (d) School of Physics, Shandong University, Jinan, Shandong, China; (e) Physics Department, Shanghai Jiao Tong University, Shanghai, China
- <sup>34</sup> Laboratoire de Physique Corpusculaire, Clermont Université and Université Blaise Pascal and CNRS/IN2P3, Clermont-Ferrand, France
- <sup>35</sup> Nevis Laboratory, Columbia University, Irvington, NY, USA
- <sup>36</sup> Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark
- <sup>37</sup> (a) INFN Gruppo Collegato di Cosenza, Laboratori Nazionali di Frascati, Frascati, Italy; (b) Dipartimento di Fisica, Università della Calabria, Rende, Italy
- <sup>38</sup> (a) Faculty of Physics and Applied Computer Science, AGH University of Science and Technology, Kraków, Poland; (b) Marian Smoluchowski Institute of Physics, Jagiellonian University, Kraków, Poland
- <sup>39</sup> The Henryk Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences, Kraków, Poland
- <sup>40</sup> Physics Department, Southern Methodist University, Dallas, TX, USA
- <sup>41</sup> Physics Department, University of Texas at Dallas, Richardson, TX, USA
- <sup>42</sup> DESY, Hamburg and Zeuthen, Germany
- <sup>43</sup> Institut für Experimentelle Physik IV, Technische Universität Dortmund, Dortmund, Germany
- <sup>44</sup> Institut für Kern- und Teilchenphysik, Technische Universität Dresden, Dresden, Germany
- <sup>45</sup> Department of Physics, Duke University, Durham, NC, USA
- <sup>46</sup> SUPA-School of Physics and Astronomy, University of Edinburgh, Edinburgh, UK
- <sup>47</sup> INFN Laboratori Nazionali di Frascati, Frascati, Italy
- <sup>48</sup> Fakultät für Mathematik und Physik, Albert-Ludwigs-Universität, Freiburg, Germany
- <sup>49</sup> Section de Physique, Université de Genève, Geneva, Switzerland
- <sup>50</sup> (a) INFN Sezione di Genova, Genoa, Italy; (b) Dipartimento di Fisica, Università di Genova, Genoa, Italy
- <sup>51</sup> (a) E. Andronikashvili Institute of Physics, Iv. Javakishvili Tbilisi State University, Tbilisi, Georgia; (b) High Energy Physics Institute, Tbilisi State University, Tbilisi, Georgia
- <sup>52</sup> II Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen, Germany
- <sup>53</sup> SUPA-School of Physics and Astronomy, University of Glasgow, Glasgow, UK
- <sup>54</sup> II Physikalisches Institut, Georg-August-Universität, Göttingen, Germany
- <sup>55</sup> Laboratoire de Physique Subatomique et de Cosmologie, Université Grenoble-Alpes, CNRS/IN2P3, Grenoble, France
- <sup>56</sup> Department of Physics, Hampton University, Hampton, VA, USA
- <sup>57</sup> Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge, MA, USA
- <sup>58</sup> (a) Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany; (b) Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany; (c) ZITI Institut für technische Informatik, Ruprecht-Karls-Universität Heidelberg, Mannheim, Germany
- <sup>59</sup> Faculty of Applied Information Science, Hiroshima Institute of Technology, Hiroshima, Japan
- <sup>60</sup> Department of Physics, Indiana University, Bloomington, IN, USA

- <sup>61</sup> Institut für Astro- und Teilchenphysik, Leopold-Franzens-Universität, Innsbruck, Austria
- <sup>62</sup> University of Iowa, Iowa City, IA, USA
- <sup>63</sup> Department of Physics and Astronomy, Iowa State University, Ames, IA, USA
- <sup>64</sup> Joint Institute for Nuclear Research, JINR Dubna, Dubna, Russia
- <sup>65</sup> KEK, High Energy Accelerator Research Organization, Tsukuba, Japan
- <sup>66</sup> Graduate School of Science, Kobe University, Kobe, Japan
- <sup>67</sup> Faculty of Science, Kyoto University, Kyoto, Japan
- <sup>68</sup> Kyoto University of Education, Kyoto, Japan
- <sup>69</sup> Department of Physics, Kyushu University, Fukuoka, Japan
- <sup>70</sup> Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata, Argentina
- <sup>71</sup> Physics Department, Lancaster University, Lancaster, UK
- <sup>72</sup> <sup>(a)</sup> INFN Sezione di Lecce, Lecce, Italy; <sup>(b)</sup> Dipartimento di Matematica e Fisica, Università del Salento, Lecce, Italy
- <sup>73</sup> Oliver Lodge Laboratory, University of Liverpool, Liverpool, UK
- <sup>74</sup> Department of Physics, Jožef Stefan Institute and University of Ljubljana, Ljubljana, Slovenia
- <sup>75</sup> School of Physics and Astronomy, Queen Mary University of London, London, UK
- <sup>76</sup> Department of Physics, Royal Holloway University of London, Surrey, UK
- <sup>77</sup> Department of Physics and Astronomy, University College London, London, UK
- <sup>78</sup> Louisiana Tech University, Ruston, LA, USA
- <sup>79</sup> Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France
- <sup>80</sup> Fysiska institutionen, Lunds universitet, Lund, Sweden
- <sup>81</sup> Departamento de Física Teórica C-15, Universidad Autónoma de Madrid, Madrid, Spain
- <sup>82</sup> Institut für Physik, Universität Mainz, Mainz, Germany
- <sup>83</sup> School of Physics and Astronomy, University of Manchester, Manchester, UK
- <sup>84</sup> CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France
- <sup>85</sup> Department of Physics, University of Massachusetts, Amherst, MA, USA
- <sup>86</sup> Department of Physics, McGill University, Montreal, QC, Canada
- <sup>87</sup> School of Physics, University of Melbourne, Parkville, VIC, Australia
- <sup>88</sup> Department of Physics, The University of Michigan, Ann Arbor, MI, USA
- <sup>89</sup> Department of Physics and Astronomy, Michigan State University, East Lansing, MI, USA
- <sup>90</sup> <sup>(a)</sup> INFN Sezione di Milano, Milan, Italy; <sup>(b)</sup> Dipartimento di Fisica, Università di Milano, Milan, Italy
- <sup>91</sup> B.I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk, Republic of Belarus
- <sup>92</sup> National Scientific and Educational Centre for Particle and High Energy Physics, Minsk, Republic of Belarus
- <sup>93</sup> Department of Physics, Massachusetts Institute of Technology, Cambridge, MA, USA
- <sup>94</sup> Group of Particle Physics, University of Montreal, Montreal, QC, Canada
- <sup>95</sup> P.N. Lebedev Institute of Physics, Academy of Sciences, Moscow, Russia
- <sup>96</sup> Institute for Theoretical and Experimental Physics (ITEP), Moscow, Russia
- <sup>97</sup> Moscow Engineering and Physics Institute (MEPhI), Moscow, Russia
- <sup>98</sup> D.V. Skobel'syn Institute of Nuclear Physics, M.V. Lomonosov Moscow State University, Moscow, Russia
- <sup>99</sup> Fakultät für Physik, Ludwig-Maximilians-Universität München, Munich, Germany
- <sup>100</sup> Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), Munich, Germany
- <sup>101</sup> Nagasaki Institute of Applied Science, Nagasaki, Japan
- <sup>102</sup> Graduate School of Science and Kobayashi-Maskawa Institute, Nagoya University, Nagoya, Japan
- <sup>103</sup> <sup>(a)</sup> INFN Sezione di Napoli, Naples, Italy; <sup>(b)</sup> Dipartimento di Fisica, Università di Napoli, Naples, Italy
- <sup>104</sup> Department of Physics and Astronomy, University of New Mexico, Albuquerque, NM, USA
- <sup>105</sup> Institute for Mathematics, Astrophysics and Particle Physics, Radboud University Nijmegen/Nikhef, Nijmegen, The Netherlands
- <sup>106</sup> Nikhef National Institute for Subatomic Physics and University of Amsterdam, Amsterdam, The Netherlands
- <sup>107</sup> Department of Physics, Northern Illinois University, DeKalb, IL, USA
- <sup>108</sup> Budker Institute of Nuclear Physics, SB RAS, Novosibirsk, Russia
- <sup>109</sup> Department of Physics, New York University, New York, NY, USA
- <sup>110</sup> Ohio State University, Columbus, OH, USA
- <sup>111</sup> Faculty of Science, Okayama University, Okayama, Japan

- 112 Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman, OK, USA
- 113 Department of Physics, Oklahoma State University, Stillwater, OK, USA
- 114 Palacký University, RCPTM, Olomouc, Czech Republic
- 115 Center for High Energy Physics, University of Oregon, Eugene, OR, USA
- 116 LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France
- 117 Graduate School of Science, Osaka University, Osaka, Japan
- 118 Department of Physics, University of Oslo, Oslo, Norway
- 119 Department of Physics, Oxford University, Oxford, UK
- 120 (a) INFN Sezione di Pavia, Pavia, Italy; (b) Dipartimento di Fisica, Università di Pavia, Pavia, Italy
- 121 Department of Physics, University of Pennsylvania, Philadelphia, PA, USA
- 122 Petersburg Nuclear Physics Institute, Gatchina, Russia
- 123 (a) INFN Sezione di Pisa, Pisa, Italy; (b) Dipartimento di Fisica E. Fermi, Università di Pisa, Pisa, Italy
- 124 Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh, PA, USA
- 125 (a) Laboratório de Instrumentação e Física Experimental de Partículas-LIP, Lisbon, Portugal; (b) Faculdade de Ciências, Universidade de Lisboa, Lisbon, Portugal; (c) Department of Physics, University of Coimbra, Coimbra, Portugal; (d) Centro de Física Nuclear da Universidade de Lisboa, Lisbon, Portugal; (e) Departamento de Física, Universidade do Minho, Braga, Portugal; (f) Departamento de Física Teórica y del Cosmos and CAFPE, Universidad de Granada, Granada, Spain; (g) Dep Física and CEFITEC of Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Caparica, Portugal
- 126 Institute of Physics, Academy of Sciences of the Czech Republic, Prague, Czech Republic
- 127 Czech Technical University in Prague, Prague, Czech Republic
- 128 Faculty of Mathematics and Physics, Charles University in Prague, Prague, Czech Republic
- 129 State Research Center Institute for High Energy Physics, Protvino, Russia
- 130 Particle Physics Department, Rutherford Appleton Laboratory, Didcot, UK
- 131 Physics Department, University of Regina, Regina, SK, Canada
- 132 Ritsumeikan University, Kusatsu, Shiga, Japan
- 133 (a) INFN Sezione di Roma, Rome, Italy; (b) Dipartimento di Fisica, Sapienza Università di Roma, Rome, Italy
- 134 (a) INFN Sezione di Roma Tor Vergata, Rome, Italy; (b) Dipartimento di Fisica, Università di Roma Tor Vergata, Rome, Italy
- 135 (a) INFN Sezione di Roma Tre, Rome, Italy; (b) Dipartimento di Matematica e Fisica, Università Roma Tre, Rome, Italy
- 136 (a) Faculté des Sciences Ain Chock, Réseau Universitaire de Physique des Hautes Energies-Université Hassan II, Casablanca, Morocco; (b) Centre National de l'Énergie des Sciences Techniques Nucleaires, Rabat, Morocco; (c) Faculté des Sciences Semlalia, Université Cadi Ayyad, LPHEA-Marrakech, Marrakech, Morocco; (d) Faculté des Sciences, Université Mohamed Premier and LPTPM, Oujda, Morocco; (e) Faculté des Sciences, Université Mohammed V-Agdal, Rabat, Morocco
- 137 DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat à l'Énergie Atomique et aux Énergies Alternatives), Gif-sur-Yvette, France
- 138 Santa Cruz Institute for Particle Physics, University of California Santa Cruz, Santa Cruz, CA, USA
- 139 Department of Physics, University of Washington, Seattle, WA, USA
- 140 Department of Physics and Astronomy, University of Sheffield, Sheffield, UK
- 141 Department of Physics, Shinshu University, Nagano, Japan
- 142 Fachbereich Physik, Universität Siegen, Siegen, Germany
- 143 Department of Physics, Simon Fraser University, Burnaby, BC, Canada
- 144 SLAC National Accelerator Laboratory, Stanford, CA, USA
- 145 (a) Faculty of Mathematics, Physics and Informatics, Comenius University, Bratislava, Slovak Republic; (b) Department of Subnuclear Physics, Institute of Experimental Physics of the Slovak Academy of Sciences, Kosice, Slovak Republic
- 146 (a) Department of Physics, University of Cape Town, Cape Town, South Africa; (b) Department of Physics, University of Johannesburg, Johannesburg, South Africa; (c) School of Physics, University of the Witwatersrand, Johannesburg, South Africa
- 147 (a) Department of Physics, Stockholm University, Stockholm, Sweden; (b) The Oskar Klein Centre, Stockholm, Sweden
- 148 Physics Department, Royal Institute of Technology, Stockholm, Sweden
- 149 Departments of Physics and Astronomy and Chemistry, Stony Brook University, Stony Brook, NY, USA
- 150 Department of Physics and Astronomy, University of Sussex, Brighton, UK

- <sup>151</sup> School of Physics, University of Sydney, Sydney, Australia
- <sup>152</sup> Institute of Physics, Academia Sinica, Taipei, Taiwan
- <sup>153</sup> Department of Physics, Technion: Israel Institute of Technology, Haifa, Israel
- <sup>154</sup> Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel
- <sup>155</sup> Department of Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece
- <sup>156</sup> Department of Physics, International Center for Elementary Particle Physics, The University of Tokyo, Tokyo, Japan
- <sup>157</sup> Graduate School of Science and Technology, Tokyo Metropolitan University, Tokyo, Japan
- <sup>158</sup> Department of Physics, Tokyo Institute of Technology, Tokyo, Japan
- <sup>159</sup> Department of Physics, University of Toronto, Toronto, ON, Canada
- <sup>160</sup> <sup>(a)</sup> TRIUMF, Vancouver, BC, Canada; <sup>(b)</sup> Department of Physics and Astronomy, York University, Toronto, ON, Canada
- <sup>161</sup> Faculty of Pure and Applied Sciences, University of Tsukuba, Tsukuba, Japan
- <sup>162</sup> Department of Physics and Astronomy, Tufts University, Medford, MA, USA
- <sup>163</sup> Centro de Investigaciones, Universidad Antonio Narino, Bogotá, Colombia
- <sup>164</sup> Department of Physics and Astronomy, University of California Irvine, Irvine, CA, USA
- <sup>165</sup> <sup>(a)</sup> INFN Gruppo Collegato di Udine, Sezione di Trieste, Udine, Italy; <sup>(b)</sup> ICTP, Trieste, Italy; <sup>(c)</sup> Dipartimento di Chimica, Fisica e Ambiente, Università di Udine, Udine, Italy
- <sup>166</sup> Department of Physics, University of Illinois, Urbana, IL, USA
- <sup>167</sup> Department of Physics and Astronomy, University of Uppsala, Uppsala, Sweden
- <sup>168</sup> Instituto de Física Corpuscular (IFIC) and Departamento de Física Atómica, Molecular y Nuclear and Departamento de Ingeniería Electrónica and Instituto de Microelectrónica de Barcelona (IMB-CNM), University of Valencia and CSIC, Valencia, Spain
- <sup>169</sup> Department of Physics, University of British Columbia, Vancouver, BC, Canada
- <sup>170</sup> Department of Physics and Astronomy, University of Victoria, Victoria, BC, Canada
- <sup>171</sup> Department of Physics, University of Warwick, Coventry, UK
- <sup>172</sup> Waseda University, Tokyo, Japan
- <sup>173</sup> Department of Particle Physics, The Weizmann Institute of Science, Rehovot, Israel
- <sup>174</sup> Department of Physics, University of Wisconsin, Madison, WI, USA
- <sup>175</sup> Fakultät für Physik und Astronomie, Julius-Maximilians-Universität, Würzburg, Germany
- <sup>176</sup> Fachbereich C Physik, Bergische Universität Wuppertal, Wuppertal, Germany
- <sup>177</sup> Department of Physics, Yale University, New Haven, CT, USA
- <sup>178</sup> Yerevan Physics Institute, Yerevan, Armenia
- <sup>179</sup> Centre de Calcul de l'Institut National de Physique Nucléaire et de Physique des Particules (IN2P3), Villeurbanne, France
- <sup>a</sup> Also at Department of Physics, King's College London, London, UK
- <sup>b</sup> Also at Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan
- <sup>c</sup> Also at Novosibirsk State University, Novosibirsk, Russia
- <sup>d</sup> Also at Particle Physics Department, Rutherford Appleton Laboratory, Didcot, UK
- <sup>e</sup> Also at TRIUMF, Vancouver, BC, Canada
- <sup>f</sup> Also at Department of Physics, California State University, Fresno, CA, USA
- <sup>g</sup> Also at Tomsk State University, Tomsk, Russia
- <sup>h</sup> Also at CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France
- <sup>i</sup> Also at Università di Napoli Parthenope, Naples, Italy
- <sup>j</sup> Also at Institute of Particle Physics (IPP), Victoria, Canada
- <sup>k</sup> Also at Department of Physics, St. Petersburg State Polytechnical University, St. Petersburg, Russia
- <sup>l</sup> Also at Chinese University of Hong Kong, Hong Kong, China
- <sup>m</sup> Also at Department of Financial and Management Engineering, University of the Aegean, Chios, Greece
- <sup>n</sup> Also at Louisiana Tech University, Ruston, LA, USA
- <sup>o</sup> Also at Institutio Catalana de Recerca i Estudis Avancats, ICREA, Barcelona, Spain
- <sup>p</sup> Also at Department of Physics, The University of Texas at Austin, Austin, TX, USA
- <sup>q</sup> Also at Institute of Theoretical Physics, Ilia State University, Tbilisi, Georgia
- <sup>r</sup> Also at CERN, Geneva, Switzerland
- <sup>s</sup> Also at O Chadai Academic Production, Ochanomizu University, Tokyo, Japan

- <sup>t</sup> Also at Manhattan College, New York, NY, USA
- <sup>u</sup> Also at Institute of Physics, Academia Sinica, Taipei, Taiwan
- <sup>v</sup> Also at LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France
- <sup>w</sup> Also at Academia Sinica Grid Computing, Institute of Physics, Academia Sinica, Taipei, Taiwan
- <sup>x</sup> Also at Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France
- <sup>y</sup> Also at School of Physical Sciences, National Institute of Science Education and Research, Bhubaneswar, India
- <sup>z</sup> Also at Dipartimento di Fisica, Sapienza Università di Roma, Rome, Italy
- <sup>aa</sup> Also at Moscow Institute of Physics and Technology State University, Dolgoprudny, Russia
- <sup>ab</sup> Also at Section de Physique, Université de Genève, Geneva, Switzerland
- <sup>ac</sup> Also at International School for Advanced Studies (SISSA), Trieste, Italy
- <sup>ad</sup> Also at Department of Physics and Astronomy, University of South Carolina, Columbia, SC, USA
- <sup>ae</sup> Also at School of Physics and Engineering, Sun Yat-sen University, Guangzhou, China
- <sup>af</sup> Also at Faculty of Physics, M.V. Lomonosov Moscow State University, Moscow, Russia
- <sup>ag</sup> Also at Moscow Engineering and Physics Institute (MEPhI), Moscow, Russia
- <sup>ah</sup> Also at Institute for Particle and Nuclear Physics, Wigner Research Centre for Physics, Budapest, Hungary
- <sup>ai</sup> Also at Department of Physics, Oxford University, Oxford, UK
- <sup>aj</sup> Also at Department of Physics, Nanjing University, Jiangsu, China
- <sup>ak</sup> Also at Institut für Experimentalphysik, Universität Hamburg, Hamburg, Germany
- <sup>al</sup> Also at Department of Physics, The University of Michigan, Ann Arbor, MI, USA
- <sup>am</sup> Also at Discipline of Physics, University of KwaZulu-Natal, Durban, South Africa
- <sup>an</sup> Also at Department of Physics, University of Malaya, Kuala Lumpur, Malaysia
- \* Deceased