Author(s): ATLAS Collaboration

Article Title: Search for contact interactions in dimuon events from pp collisions at sqrt[s]=7 TeV with the ATLAS detector

Year of publication: 2011

Link to published article:
http://dx.doi.org/10.1103/PhysRevD.84.011101

PHYSICAL REVIEW D **84,** 011101(R) (2011)

Search for contact interactions in dimuon events from pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector

G. Aad *et al.**

(ATLAS Collaboration)

(Received 22 April 2011; published 1 July 2011)

A search for contact interactions has been performed using dimuon events recorded with the ATLAS detector in proton-proton collisions at $\sqrt{s} = 7$ TeV. The data sample corresponds to an integrated luminosity of 42 pb^{-1}. No significant deviation from the standard model is observed in the dimuon mass spectrum, allowing the following 95% C.L. limits to be set on the energy scale of contact interactions: $\Lambda > 4.9$ TeV (4.5 TeV) for constructive (destructive) interference in the left-left isoscalar compositeness model. These limits are the most stringent to date for $\mu\mu qq$ contact interactions.

DOI: 10.1103/PhysRevD.84.011101 PACS numbers: 12.60.Rc, 13.85.Qk, 14.70.Pw

Phenomena beyond the standard model (SM), such as large extra spatial dimensions [1] or quark/lepton compositeness [2], may be described as a four-fermion contact interaction (CI) in the low energy limit. Such an approach is similar to that used by Fermi to describe nuclear β decay [3] long before the discovery of the W boson. One can describe a new interaction at a higher energy scale with an effective Lagrangian of the form [2]

$$\begin{aligned}\mathcal{L} = \frac{g^2}{2\Lambda^2}[&\eta_{LL}\overline{\psi}_L\gamma_\mu\psi_L\overline{\psi}_L\gamma^\mu\psi_L \\ &+ \eta_{RR}\overline{\psi}_R\gamma_\mu\psi_R\overline{\psi}_R\gamma^\mu\psi_R \\ &+ 2\eta_{LR}\overline{\psi}_L\gamma_\mu\psi_L\overline{\psi}_R\gamma^\mu\psi_R],\end{aligned} \quad (1)$$

where g is a coupling constant, Λ is the energy scale below which fermion constituents are bound (in the context of compositeness models), and $\psi_{L,R}$ are left-handed and right-handed fermion fields, respectively. The scale Λ is defined by the choices $g^2/4\pi = 1$ and η_{LL}, η_{LR}, $\eta_{RR} = \pm 1$. Different choices of the parameters η_{LL}, η_{LR}, and η_{RR} determine the helicity structure of the new interaction. For example, the analysis presented in this paper applies specifically to the left-left isoscalar model (LLIM) commonly used as a benchmark for contact interaction searches [4]. This model is defined by setting $\eta_{LL} = \pm 1$ and $\eta_{LR} = \eta_{RR} = 0$. With the introduction of a contact interaction, the differential cross section for the process $q\bar{q} \rightarrow \mu^+\mu^-$ becomes

$$\frac{d\sigma}{dm_{\mu\mu}} = \frac{d\sigma_{\text{DY}}}{dm_{\mu\mu}} - \eta_{LL}\frac{F_I(m_{\mu\mu})}{\Lambda^2} + \frac{F_C(m_{\mu\mu})}{\Lambda^4}, \quad (2)$$

where $m_{\mu\mu}$ is the final-state dimuon mass. The expression above includes a SM Drell-Yan (DY) term, as well as DY-CI interference (F_I) and pure contact interaction (F_C) terms (see Ref. [5] for a detailed expression). The DY term here incorporates both photon and Z^0 boson contributions. At the largest Λ values that this analysis is sensitive to, both interference and pure contact interaction terms play a significant role.

This paper presents the results of a search for contact interactions in the dimuon channel, taking advantage of the high pp collision energy of the LHC and the capabilities of ATLAS to detect and measure muons. The search strategy focuses on identifying a deviation from the SM in the dimuon mass spectrum, which is expected to be dominated by the DY process. Contributions from a new interaction would undergo either constructive ($\eta_{LL} = -1$) or destructive ($\eta_{LL} = +1$) interference with the DY contribution. If present, a signal would result in a broad deviation from the SM expectation rather than a peak in the mass spectrum. Given current experimental bounds on Λ (see below), such a deviation would appear at masses well above the Z^0 boson peak. Therefore, the measurement requires excellent muon identification and reconstruction at high momentum. A separate paper presents the results of a search for new heavy resonances in the dimuon mass spectrum [6]. Previous searches for contact interactions have been carried out in neutrino scattering [7], as well as at electron-positron [8–11], electron-proton [12,13], and hadron colliders [14–22]. For the channel under study, the best limits in the LLIM are $\Lambda^- > 4.2$ TeV for constructive interference and $\Lambda^+ > 2.9$ TeV for destructive interference, at 95% C.L. [14].

ATLAS is a multipurpose particle detector [23] designed for physics at the TeV scale. Charged particle tracking is provided by an inner detector consisting of a pixel detector, a silicon-strip tracker, and a transition radiation tracker, immersed in a 2 T solenoidal magnetic field. A high-granularity liquid-argon electromagnetic calorimeter surrounds the solenoid. Hadron calorimetry is provided by

*

an iron-scintillator tile calorimeter in the central rapidity range and a liquid-argon calorimeter in the end cap and forward rapidity range. A key detector component for this analysis is the muon spectrometer, which is designed to identify muons and measure both their trajectories and momenta with high accuracy: the design momentum resolution is 10% at momenta transverse to the beam line (p_T) of 1 TeV. The muon spectrometer comprises three toroidal magnet systems consisting of eight coils each with a bending power $\int B d\ell = 1$–7.5 Tm, a trigger system consisting of both resistive plate chambers and thin-gap chambers, and a set of precision monitored drift tubes and cathode strip chambers with a single-hit spatial resolution better than 100 μm to accurately measure muon curvature. Precision chambers are continuously monitored by an optical alignment system designed to determine relative chamber positions to an accuracy of 50 μm or better.

The data sample for this analysis was collected during LHC operations in 2010 and corresponds to a total integrated luminosity of 42 pb^{-1} collected with stable beam conditions and fully operational inner detector and muon spectrometer systems. Events with muons were selected by requiring the presence of at least one high-momentum muon passing all three rejection levels of the muon trigger system. The p_T threshold was initially set to 10 GeV but was raised to 13 GeV in the later parts of the data taking due to increasing luminosity.

This analysis follows the same event selection as the search for new heavy resonances. A summary is provided below; see Ref. [6] for a more complete description. Events with a good primary vertex are selected to suppress cosmic-ray events. Muon tracks reconstructed independently in the inner detector and muon spectrometer are combined with a fit to all associated hits, taking the energy loss in the calorimeter into account. The energy loss estimate uses either the parametrized expected energy loss or the energy measured in the calorimeter if this energy significantly exceeds the most probable energy loss. The combined tracks are required to have hits in all inner detector tracking systems, at least one hit in the nonbending plane, and at least three hits in each of the inner, middle, and outer precision chambers of the muon spectrometer. Tracks passing through poorly aligned chambers are rejected. The above hit requirements guarantee a reliable momentum measurement and good modeling by the detector simulation. Muon tracks are required to have $p_T > 25$ GeV, pseudorapidity $|\eta| < 2.4$ [24] to be within the acceptance of the inner detector tracking and muon spectrometer trigger systems, and a relative track isolation $\sum p_T^i / p_T < 0.05$, where the sum is over all inner detector tracks i within a $\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$ cone of 0.3 around the muon trajectory, to suppress backgrounds from heavy flavor decays. Additional requirements are placed on the impact parameter of the muon track to reduce cosmic-ray backgrounds to a negligible level. Finally, dimuon candidates are formed from all pairs of opposite-charge muons satisfying the above criteria, and the mass of those pairs is required to be greater than 70 GeV. There are 7743 dimuon events passing all selection requirements.

Drell-Yan, W + jets, and multijet events were generated with PYTHIA 6.421 [25] and MRST2007 LO* parton distribution functions (PDFs) [26]. Diboson (WW, WZ, and ZZ) events were produced with HERWIG 6.510 [27] and MRST2007 LO* PDFs. In the case of $t\bar{t}$, events were generated with MC@NLO 3.41 [28] to compute matrix elements, JIMMY 4.31 [29] to simulate the underlying event, HERWIG 6.510 to model parton showering and hadronization, and CTEQ 6.6 [30] for PDFs. For signal samples, PYTHIA 6.421 was used to produce the DY and CI processes simultaneously in order to properly account for the interference between the two processes. A mass-dependent QCD K factor corresponding to the ratio between next-to-next-to-leading order [31] and PYTHIA LO* DY differential cross sections was applied to these signal samples as well as pure DY samples. Similarly, a mass-dependent electroweak K factor was applied to account for higher order electroweak effects due to virtual gauge boson loops [32]. This correction was only applied to the DY cross section since the new physics included in the CI term has unknown couplings to SM gauge bosons. Implicitly, higher order electroweak corrections to the new interaction are included in the value of Λ. The QCD (electroweak) K factor varies between 1.16 (1.04) at low dimuon mass and 0.86 (0.85) at a mass of 2 TeV. The response of the ATLAS detector to these generated event samples was simulated with GEANT 4 [33,34].

Figure 1 shows the dimuon mass distribution for all selected events along with the predicted contributions

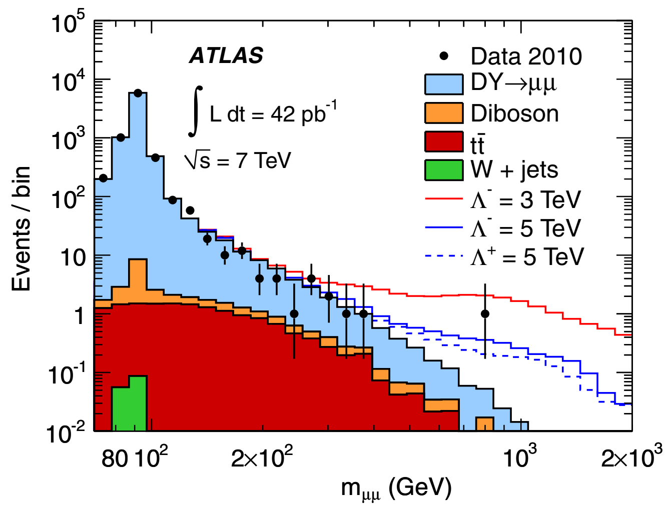

FIG. 1 (color online). Dimuon invariant mass distribution for data (points) and Monte Carlo simulations (histograms). The red (blue) line corresponds to the distribution expected in the presence of contact interactions with $\Lambda^- = 3$ TeV (5 TeV) for constructive interference. The dashed blue line corresponds to $\Lambda^+ = 5$ TeV for destructive interference.

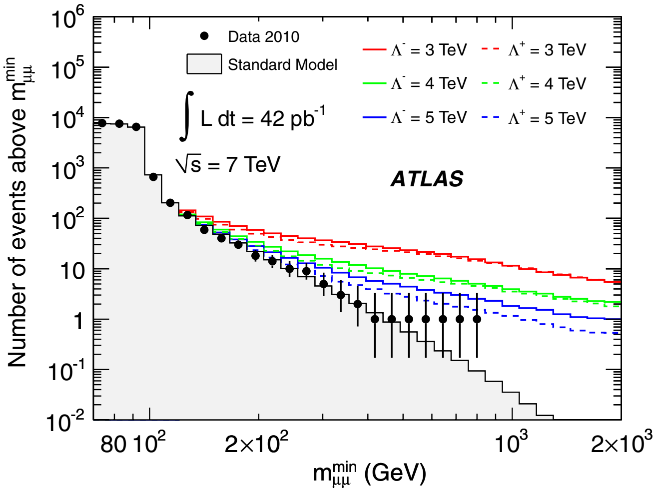

FIG. 2 (color online). Distribution of the number of events with dimuon mass above $m_{\mu\mu}^{\min}$ for data (points) and Monte Carlo simulations (histograms). The SM prediction is shown as the shaded grey histogram, whereas the solid (dashed) histograms correspond to the expected distributions in the presence of contact interactions with various scales Λ for constructive (destructive) interference.

from SM processes and CI for selected Λ values. Predictions for the various background processes are extracted from the Monte Carlo (MC) simulation. Besides the dominant DY contribution, we also account for a small dimuon yield from $t\bar{t}$ and diboson production. The small predicted yield from $t\bar{t}$ has been confirmed in the data by selecting events with high-mass electron-muon pairs (see Ref. [6]). Backgrounds from W production are effectively suppressed by requiring two selected muons in the event. Likewise, multijet backgrounds are reduced to a negligible amount (< 0.1 events in the selected sample) by the muon p_T and isolation requirements.

Table I presents the number of events in different bins of dimuon mass for data and MC simulation. The sum of MC predictions is normalized to the number of data events in the Z^0 peak mass region between 70 and 110 GeV. It should be noted that, prior to normalization, data and MC event yields agree within the uncertainty in the integrated luminosity. This normalization procedure removes sensitivity to mass-independent uncertainties such as the luminosity uncertainty. The overall acceptance of the selection is estimated to be 36% for simulated DY events in the signal region defined by $m_{\mu\mu} > 150$ GeV.

To estimate the level of agreement between the observed mass spectrum and the SM prediction, a large ensemble of SM-only pseudoexperiments was generated. For each such pseudoexperiment, a binned likelihood was computed to quantify the deviation from the SM expectation. In 56% of these pseudoexperiments, the deviation was found to be more significant than that observed in the data for the signal region, indicating good consistency between the data and the predicted spectrum. This level of agreement is illustrated in Fig. 2, which shows the number of events above a minimum mass $m_{\mu\mu}^{\min}$. Since no significant deviation is observed in the dimuon mass spectrum, we proceed with setting a limit on the energy scale Λ using a Bayesian method. Here, the prior probability distribution is chosen to be flat in $1/\Lambda^2$, motivated by the form of Eq. (2). Systematic uncertainties are incorporated in the limit setting by treating them as nuisance parameters ($\bar{\nu}$) that are marginalized in the calculation of the posterior probability $\mathcal{P}$. The 95% confidence level limit is then obtained by finding the value $\Lambda_{\rm lim}$ that satisfies $\int_0^{\theta_{\rm lim}} \mathcal{P}(\theta \mid \bar{n}, \bar{\nu}) d\theta = 0.95$, where $\theta = 1/\Lambda^2$ and $\bar{n}$ represents the observed number of events in the mass bins above 150 GeV, with bin boundaries as defined in Table I. Table II shows the expected number of events in each mass bin within the signal

TABLE I. Expected and observed number of events in the dimuon channel. The errors quoted originate from the limited MC statistics.

$m_{\mu\mu}$ (GeV)	70–110	110–130	130–150	150–170	170–200	200–240
DY	7547 ± 7	98.4 ± 0.8	33.4 ± 0.5	17.2 ± 0.3	12.8 ± 0.3	7.8 ± 0.2
$t\bar{t}$	6.0 ± 0.2	2.4 ± 0.1	1.7 ± 0.1	1.24 ± 0.04	1.22 ± 0.03	1.03 ± 0.03
Diboson	10.1 ± 0.1	0.8 ± 0.1	0.56 ± 0.04	0.48 ± 0.04	0.41 ± 0.03	0.28 ± 0.03
W + jets	0.14 ± 0.08	<0.05	<0.05	<0.05	<0.05	<0.05
Total	7563 ± 7	101.6 ± 0.8	35.7 ± 0.5	18.9 ± 0.3	14.4 ± 0.3	9.1 ± 0.2
Data	7563	101	41	11	11	7

$m_{\mu\mu}$ (GeV)	240–300	300–400	400–550	550–800	800–1200	1200–2000
DY	5.05 ± 0.11	2.49 ± 0.04	0.99 ± 0.01	0.29 ± 0.01	0.06 ± 0.01	<0.05
$t\bar{t}$	0.73 ± 0.02	0.37 ± 0.01	0.11 ± 0.01	<0.05	<0.05	<0.05
Diboson	0.24 ± 0.02	0.16 ± 0.02	0.06 ± 0.01	<0.05	<0.05	<0.05
W + jets	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Total	6.02 ± 0.11	3.03 ± 0.05	1.16 ± 0.02	0.33 ± 0.01	0.07 ± 0.01	<0.05
Data	6	2	0	1	0	0

TABLE II. Expected number of events in the signal region of the analysis for various contact interaction scales with constructive (Λ^-) and destructive (Λ^+) interference. The errors quoted originate from the limited MC statistics.

$m_{\mu\mu}$ (GeV)	150–170	170–200	200–240	240–300	300–400	400–550	550–800	800–1200	1200–2000
$\Lambda^- = 3$ TeV	19.1 ± 0.5	15.7 ± 0.4	11.2 ± 0.4	8.5 ± 0.3	7.9 ± 0.3	6.0 ± 0.3	6.5 ± 0.3	5.1 ± 0.2	3.0 ± 0.2
$\Lambda^- = 4$ TeV	18.8 ± 0.4	14.3 ± 0.4	10.0 ± 0.3	6.5 ± 0.2	5.0 ± 0.2	3.0 ± 0.2	2.3 ± 0.2	1.45 ± 0.12	1.08 ± 0.09
$\Lambda^- = 5$ TeV	17.4 ± 0.4	14.3 ± 0.4	9.4 ± 0.3	6.2 ± 0.2	4.3 ± 0.2	1.95 ± 0.13	1.29 ± 0.11	0.72 ± 0.08	0.36 ± 0.06
$\Lambda^- = 7$ TeV	17.3 ± 0.4	13.8 ± 0.4	9.3 ± 0.3	6.3 ± 0.2	3.3 ± 0.2	1.26 ± 0.10	0.58 ± 0.07	0.21 ± 0.04	0.11 ± 0.03
$\Lambda^+ = 2$ TeV	21.6 ± 0.6	19.3 ± 0.6	15.8 ± 0.5	15.2 ± 0.5	21.2 ± 0.6	21.6 ± 0.6	25.5 ± 0.6	21.4 ± 0.6	15.1 ± 0.5
$\Lambda^+ = 3$ TeV	18.6 ± 0.4	15.2 ± 0.4	10.1 ± 0.3	7.2 ± 0.3	5.5 ± 0.2	4.6 ± 0.2	5.3 ± 0.2	4.3 ± 0.2	3.1 ± 0.2
$\Lambda^+ = 4$ TeV	18.2 ± 0.4	14.3 ± 0.4	8.8 ± 0.3	6.1 ± 0.2	3.6 ± 0.2	2.10 ± 0.14	1.59 ± 0.12	1.52 ± 0.12	0.84 ± 0.08
$\Lambda^+ = 5$ TeV	18.5 ± 0.4	13.6 ± 0.3	8.8 ± 0.3	5.4 ± 0.2	2.9 ± 0.2	1.61 ± 0.12	0.88 ± 0.09	0.53 ± 0.07	0.28 ± 0.05

region for different scales Λ, as used in the calculation of the posterior probability.

Systematic errors are of both theoretical and experimental origins. Because the expected event yields are normalized to the Z^0 peak region, only momentum- or mass-dependent uncertainties are relevant. Theoretical uncertainties include PDF variations evaluated using the MSTW2008 PDF error set [35] in the absence of a full error set for the MRST2007 LO* PDF. This choice leads to conservative uncertainties in the event yields that grow from 3% at the Z^0 pole to 6% (9%) at a mass of 1 TeV (1.5 TeV). A cross-check was made by computing cross sections for both MSTW2008 and CTEQ 6.6 PDFs for a wide range of dimuon masses. Differences between the two choices of PDFs were always found to be smaller than the assigned uncertainty obtained from the MSTW2008 PDF set. The QCD K factor uncertainty in the DY and DY + CI cross sections is taken to be the difference between next-to-next-to-leading order and next-to-leading order DY cross sections as a function of dimuon mass. The electroweak K factor uncertainty in the DY cross section is taken to be the entire magnitude of the correction relative to the LO cross section. Uncertainties in the QCD (electroweak) K factor are mass dependent; for example, they amount to 3.0% (4.5%) at a mass of 1 TeV. Uncertainties in the $t\bar{t}$, diboson, and W + jets cross sections have a negligible impact on the limit. Finally, the statistical error of the DY + CI MC (shown in Table II) is included as a source of systematic error and has the largest effect on the limits.

The MC simulation is used to determine all acceptance and efficiency effects. Therefore, detailed comparisons between data and Monte Carlo simulation were performed to make sure that the simulation models the data well for our choice of muon track selection criteria, especially at higher p_T. Experimental uncertainties arise from the slight p_T dependence of muon efficiencies and from the impact of the intrinsic detector spatial resolution on the momentum resolution. At transverse momenta above 200 GeV, radiative losses due to bremsstrahlung in the detector material begin to affect the muon track pattern recognition. An uncertainty of 3% per TeV is assigned to the muon efficiency to conservatively account for the small p_T dependence predicted by the simulation. Muon momentum resolution at high p_T is most affected by the quality of the muon spectrometer alignment. The latter has been studied with high-momentum cosmic-ray muons traversing the center of the detector. It has also been studied in collision data with muons passing through detector regions with overlapping muon spectrometer chambers, thereby providing independent track fits from the redundant sets of hits in neighboring chambers and allowing the impact of the alignment of adjacent detector regions to be measured. Curvature smearing parameters derived from these studies are found to be $\delta(q/p_T) = 0.18 \pm 0.04$ TeV^{-1} for $|\eta| < 2.0$ and $\delta(q/p_T) = 0.7 \pm 0.2$ TeV^{-1} for $|\eta| > 2.0$, where q is the charge of the muon track. These parameters reflect the current level of understanding of the detector alignment and are expected to decrease with further data taking. We take the full magnitude of these smearing corrections as the systematic uncertainty in the momentum resolution. Comparison of the inclusive muon momentum spectrum between data and MC simulation does not show evidence for significant non-Gaussian tails in the data.

Using the Bayesian method described above, the expected 95% C.L. lower limits on the scale Λ are found to be 5.1 ± 0.3 TeV and 4.8 ± 0.3 TeV for constructive and destructive interference, respectively. The quoted uncertainty range is estimated with a large set of pseudoexperiments and corresponds to a 68% range around the median value of all the limits obtained from those pseudoexperiments. Systematic errors are already folded into the limit setting procedure and result in a decrease of the limit by about 0.1 TeV. The dominant source of uncertainty originates from the limited signal MC statistics. For the selected data sample, we set the following limits at 95% C.L.: $\Lambda^- > 4.9$ TeV for constructive interference and $\Lambda^+ > 4.5$ TeV for destructive interference in the LLIM with a prior flat in $1/\Lambda^2$. These values are compatible with the expected limits. If a prior flat in $1/\Lambda^4$ is chosen, both limits decrease by 0.3 TeV.

To conclude, a search for contact interactions has been carried out in a sample of dimuon events recorded by the ATLAS detector in pp collisions from the LHC at $\sqrt{s} = 7$ TeV. No significant deviation from the standard model is observed in the dimuon mass spectrum obtained from a data sample corresponding to an integrated luminosity of 42 pb^{-1}. Limits placed on the energy scale Λ are the most stringent to date for $\mu\mu qq$ contact interactions.

We thank CERN for the very successful operation of the LHC, as well as the support staff from our institutions without whom ATLAS could not be operated efficiently. We acknowledge the support of ANPCyT, Argentina; YerPhI, Armenia; ARC, Australia; BMWF, Austria; ANAS, Azerbaijan; SSTC, Belarus; CNPq and FAPESP, Brazil; NSERC, NRC, and CFI, Canada; CERN; CONICYT, Chile; CAS, MOST, and NSFC, China; COLCIENCIAS, Colombia; MSMT CR, MPO CR, and VSC CR, Czech Republic; DNRF, DNSRC, and Lundbeck Foundation, Denmark; ARTEMIS, European Union; IN2P3-CNRS, CEA-DSM/IRFU, France; GNAS, Georgia; BMBF, DFG, HGF, MPG, and AvH Foundation, Germany; GSRT, Greece; ISF, MINERVA, GIF, DIP, and Benoziyo Center, Israel; INFN, Italy; MEXT and JSPS, Japan; CNRST, Morocco; FOM and NWO, Netherlands; RCN, Norway; MNiSW, Poland; GRICES and FCT, Portugal; MERYS (MECTS), Romania; MES of Russia and ROSATOM, Russian Federation; JINR; MSTD, Serbia; MSSR, Slovakia; ARRS and MVZT, Slovenia; DST/NRF, South Africa; MICINN, Spain; SRC and Wallenberg Foundation, Sweden; SER, SNSF, and Cantons of Bern and Geneva, Switzerland; NSC, Taiwan; TAEK, Turkey; STFC, the Royal Society and Leverhulme Trust, United Kingdom; and 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.

[1] N. Arkani-Hamed, S. Dimopoulos, and G. Dvali, Phys. Lett. B **429**, 263 (1998).
[2] E. Eichten, K. Lane, and M. Peskin, Phys. Rev. Lett. **50**, 811 (1983).
[3] E. Fermi, Nuovo Cimento **11**, 1 (1934); Z. Phys. **88**, 161 (1934).
[4] K. Nakamura *et al.* (Particle Data Group), J. Phys. G **37**, 075021 (2010).
[5] E. Eichten, I. Hinchliffe, K. Lane, and C. Quigg, Rev. Mod. Phys. **56**, 579 (1984); **58**, 1065 (1986).
[6] ATLAS Collaboration, Phys. Lett. B **700**, 163 (2011).
[7] K. McFarland, Eur. Phys. J. A **24**, 161 (2005).
[8] S. Schael *et al.* (ALEPH Collaboration), Eur. Phys. J. C **49**, 411 (2007).
[9] J. Abdallah *et al.* (DELPHI Collaboration), Eur. Phys. J. C **45**, 589 (2006).
[10] M. Acciarri *et al.* (L3 Collaboration), Phys. Lett. B **489**, 81 (2000).
[11] G. Abbiendi *et al.* (OPAL Collaboration), Eur. Phys. J. C **33**, 173 (2004).
[12] C. Adloff *et al.* (H1 Collaboration), Phys. Lett. B **568**, 35 (2003).
[13] S. Chekanov *et al.* (ZEUS Collaboration), Phys. Lett. B **591**, 23 (2004).
[14] K. Abe *et al.* (CDF Collaboration), Phys. Rev. Lett. **79**, 2198 (1997).
[15] T. Affolder *et al.* (CDF Collaboration), Phys. Rev. Lett. **87**, 231803 (2001).
[16] A. Abulencia *et al.* (CDF Collaboration), Phys. Rev. Lett. **96**, 211801 (2006).
[17] B. Abbott *et al.* (D0 Collaboration), Phys. Rev. Lett. **82**, 4769 (1999).
[18] V. M. Abazov *et al.* (D0 Collaboration), Phys. Rev. Lett. **103**, 191803 (2009).
[19] V. Khachatryan *et al.* (CMS Collaboration), Phys. Rev. Lett. **105**, 262001 (2010).
[20] ATLAS Collaboration, Phys. Lett. B **694**, 327 (2011).
[21] V. Khachatryan *et al.* (CMS Collaboration), Phys. Rev. Lett. **106**, 201804 (2011)
[22] ATLAS Collaboration, New J. Phys. **13**, 053044 (2011).
[23] ATLAS Collaboration, J. Inst. **3**, S08003 (2008).
[24] ATLAS uses a right-handed coordinate system with its origin at the nominal interaction point in the center of the detector and the z axis along the beam pipe. The x axis points from the interaction point to the center of the LHC ring, and the y axis points upward. Cylindrical coordinates (r, ϕ) are used in the transverse plane, ϕ being the azimuthal angle around the beam pipe. The pseudorapidity is defined in terms of the polar angle θ as $\eta = -\ln\tan(\theta/2)$.
[25] T. Sjostrand, S. Mrenna, and P. Skands, J. High Energy Phys. 05 (2006) 026.
[26] A. Sherstnev and R. S. Thorne, Eur. Phys. J. C **55**, 553 (2008).
[27] G. Corcella *et al.*, J. High Energy Phys. 01 (2001) 010; arXiv:hep-ph/0210213.
[28] S. Frixione and B. Webber, J. High Energy Phys. 06 (2002) 029.
[29] J. M. Butterworth *et al.*, Z. Phys. C **72**, 637 (1996).
[30] P. M. Nadolsky *et al.*, Phys. Rev. D **78**, 013004 (2008).

[31] S. Catani et al., Phys. Rev. Lett. 103, 082001 (2009).
[32] C. M. Carloni Calame et al., J. High Energy Phys. 10 (2007) 109.
[33] ATLAS Collaboration, Eur. Phys. J. C 70, 823 (2010).
[34] S. Agnostinelli et al. (GEANT 4 Collaboration), Nucl. Instrum. Methods Phys. Res., Sect. A 506, 250 (2003); J. Allison et al., IEEE Trans. Nucl. Sci. 53, 270 (2006).
[35] A. D. Martin, W. J. Stirling, R. S. Thorne, and G. Watt, Eur. Phys. J. C 63, 189 (2009).

G. Aad,[48] B. Abbott,[111] J. Abdallah,[11] A. A. Abdelalim,[49] A. Abdesselam,[118] O. Abdinov,[10] B. Abi,[112] M. Abolins,[88] H. Abramowicz,[153] H. Abreu,[115] E. Acerbi,[89a,89b] B. S. Acharya,[164a,164b] D. L. Adams,[24] T. N. Addy,[56] J. Adelman,[175] M. Aderholz,[99] S. Adomeit,[98] P. Adragna,[75] T. Adye,[129] S. Aefsky,[22] J. A. Aguilar-Saavedra,[124b,b] M. Aharrouche,[81] S. P. Ahlen,[21] F. Ahles,[48] A. Ahmad,[148] M. Ahsan,[40] G. Aielli,[133a,133b] T. Akdogan,[18a] T. P. A. Åkesson,[79] G. Akimoto,[155] A. V. Akimov,[94] A. Akiyama,[67] M. S. Alam,[1] M. A. Alam,[76] S. Albrand,[55] M. Aleksa,[29] I. N. Aleksandrov,[65] F. Alessandria,[89a] C. Alexa,[25a] G. Alexander,[153] G. Alexandre,[49] T. Alexopoulos,[9] M. Alhroob,[20] M. Aliev,[15] G. Alimonti,[89a] J. Alison,[120] M. Aliyev,[10] P. P. Allport,[73] S. E. Allwood-Spiers,[53] J. Almond,[82] A. Aloisio,[102a,102b] R. Alon,[171] A. Alonso,[79] M. G. Alviggi,[102a,102b] K. Amako,[66] P. Amaral,[29] C. Amelung,[22] V. V. Ammosov,[128] A. Amorim,[124a,c] G. Amorós,[167] N. Amram,[153] C. Anastopoulos,[139] T. Andeen,[34] C. F. Anders,[20] K. J. Anderson,[30] A. Andreazza,[89a,89b] V. Andrei,[58a] M-L. Andrieux,[55] X. S. Anduaga,[70] A. Angerami,[34] F. Anghinolfi,[29] N. Anjos,[124a] A. Annovi,[47] A. Antonaki,[8] M. Antonelli,[47] S. Antonelli,[19a,19b] A. Antonov,[96] J. Antos,[144b] F. Anulli,[132a] S. Aoun,[83] L. Aperio Bella,[4] R. Apolle,[118] G. Arabidze,[88] I. Aracena,[143] Y. Arai,[66] A. T. H. Arce,[44] J. P. Archambault,[28] S. Arfaoui,[29,d] J-F. Arguin,[14] E. Arik,[18a,a] M. Arik,[18a] A. J. Armbruster,[87] O. Arnaez,[81] C. Arnault,[115] A. Artamonov,[95] G. Artoni,[132a,132b] D. Arutinov,[20] S. Asai,[155] R. Asfandiyarov,[172] S. Ask,[27] B. Åsman,[146a,146b] L. Asquith,[5] K. Assamagan,[24] A. Astbury,[169] A. Astvatsatourov,[52] G. Atoian,[175] B. Aubert,[4] B. Auerbach,[175] E. Auge,[115] K. Augsten,[127] M. Aurousseau,[145a] N. Austin,[73] R. Avramidou,[9] D. Axen,[168] C. Ay,[54] G. Azuelos,[93,e] Y. Azuma,[155] M. A. Baak,[29] G. Baccaglioni,[89a] C. Bacci,[134a,134b] A. M. Bach,[14] H. Bachacou,[136] K. Bachas,[29] G. Bachy,[29] M. Backes,[49] M. Backhaus,[20] E. Badescu,[25a] P. Bagnaia,[132a,132b] S. Bahinipati,[2] Y. Bai,[32a] D. C. Bailey,[158] T. Bain,[158] J. T. Baines,[129] O. K. Baker,[175] M. D. Baker,[24] S. Baker,[77] F. Baltasar Dos Santos Pedrosa,[29] E. Banas,[38] P. Banerjee,[93] Sw. Banerjee,[169] D. Banfi,[29] A. Bangert,[137] V. Bansal,[169] H. S. Bansil,[17] L. Barak,[171] S. P. Baranov,[94] A. Barashkou,[65] A. Barbaro Galtieri,[14] T. Barber,[27] E. L. Barberio,[86] D. Barberis,[50a,50b] M. Barbero,[20] D. Y. Bardin,[65] T. Barillari,[99] M. Barisonzi,[174] T. Barklow,[143] N. Barlow,[27] B. M. Barnett,[129] R. M. Barnett,[14] A. Baroncelli,[134a] A. J. Barr,[118] F. Barreiro,[80] J. Barreiro Guimarães da Costa,[57] P. Barrillon,[115] R. Bartoldus,[143] A. E. Barton,[71] D. Bartsch,[20] V. Bartsch,[149] R. L. Bates,[53] L. Batkova,[144a] J. R. Batley,[27] A. Battaglia,[16] M. Battistin,[29] G. Battistoni,[89a] F. Bauer,[136] H. S. Bawa,[143,f] B. Beare,[158] T. Beau,[78] P. H. Beauchemin,[118] R. Beccherle,[50a] P. Bechtle,[41] H. P. Beck,[16] M. Beckingham,[48] K. H. Becks,[174] A. J. Beddall,[18c] A. Beddall,[18c] S. Bedikian,[175] V. A. Bednyakov,[65] C. P. Bee,[83] M. Begel,[24] S. Behar Harpaz,[152] P. K. Behera,[63] M. Beimforde,[99] C. Belanger-Champagne,[166] P. J. Bell,[49] W. H. Bell,[49] G. Bella,[153] L. Bellagamba,[19a] F. Bellina,[29] M. Bellomo,[119a] A. Belloni,[57] O. Beloborodova,[107] K. Belotskiy,[96] O. Beltramello,[29] S. Ben Ami,[152] O. Benary,[153] D. Benchekroun,[135a] C. Benchouk,[83] M. Bendel,[81] B. H. Benedict,[163] N. Benekos,[165] Y. Benhammou,[153] D. P. Benjamin,[44] M. Benoit,[115] J. R. Bensinger,[22] K. Benslama,[130] S. Bentvelsen,[105] D. Berge,[29] E. Bergeaas Kuutmann,[41] N. Berger,[4] F. Berghaus,[169] E. Berglund,[49] J. Beringer,[14] K. Bernardet,[83] P. Bernat,[77] R. Bernhard,[48] C. Bernius,[24] T. Berry,[76] A. Bertin,[19a,19b] F. Bertinelli,[29] F. Bertolucci,[122a,122b] M. I. Besana,[89a,89b] N. Besson,[136] S. Bethke,[99] W. Bhimji,[45] R. M. Bianchi,[29] M. Bianco,[72a,72b] O. Biebel,[98] S. P. Bieniek,[77] J. Biesiada,[14] M. Biglietti,[134a,134b] H. Bilokon,[47] M. Bindi,[19a,19b] S. Binet,[115] A. Bingul,[18c] C. Bini,[132a,132b] C. Biscarat,[177] U. Bitenc,[48] K. M. Black,[21] R. E. Blair,[5] J.-B. Blanchard,[115] G. Blanchot,[29] T. Blazek,[144a] C. Blocker,[22] J. Blocki,[38] A. Blondel,[49] W. Blum,[81] U. Blumenschein,[54] G. J. Bobbink,[105] V. B. Bobrovnikov,[107] S. S. Bocchetta,[79] A. Bocci,[44] C. R. Boddy,[118] M. Boehler,[41] J. Boek,[174] N. Boelaert,[35] S. Böser,[77] J. A. Bogaerts,[29] A. Bogdanchikov,[107] A. Bogouch,[90,a] C. Bohm,[146a] V. Boisvert,[76] T. Bold,[163,g] V. Boldea,[25a] N. M. Bolnet,[136] M. Bona,[75] V. G. Bondarenko,[96] M. Boonekamp,[136] G. Boorman,[76] C. N. Booth,[139] S. Bordoni,[78] C. Borer,[16] A. Borisov,[128] G. Borissov,[71] I. Borjanovic,[12a] S. Borroni,[132a,132b] K. Bos,[105] D. Boscherini,[19a] M. Bosman,[11] H. Boterenbrood,[105] D. Botterill,[129] J. Bouchami,[93] J. Boudreau,[123] E. V. Bouhova-Thacker,[71] C. Boulahouache,[123] C. Bourdarios,[115] N. Bousson,[83] A. Boveia,[30] J. Boyd,[29] I. R. Boyko,[65] N. I. Bozhko,[128] I. Bozovic-Jelisavcic,[12b] J. Bracinik,[17] A. Braem,[29] P. Branchini,[134a] G. W. Brandenburg,[57] A. Brandt,[7] G. Brandt,[15] O. Brandt,[54] U. Bratzler,[156] B. Brau,[84] J. E. Brau,[114] H. M. Braun,[174]

B. Brelier,[158] J. Bremer,[29] R. Brenner,[166] S. Bressler,[152] D. Breton,[115] D. Britton,[53] F. M. Brochu,[27] I. Brock,[20] R. Brock,[88] T. J. Brodbeck,[71] E. Brodet,[153] F. Broggi,[89a] C. Bromberg,[88] G. Brooijmans,[34] W. K. Brooks,[31b] G. Brown,[82] H. Brown,[7] E. Brubaker,[30] P. A. Bruckman de Renstrom,[38] D. Bruncko,[144b] R. Bruneliere,[48] S. Brunet,[61] A. Bruni,[19a] G. Bruni,[19a] M. Bruschi,[19a] T. Buanes,[13] F. Bucci,[49] J. Buchanan,[118] N. J. Buchanan,[2] P. Buchholz,[141] R. M. Buckingham,[118] A. G. Buckley,[45] S. I. Buda,[25a] I. A. Budagov,[65] B. Budick,[108] V. Büscher,[81] L. Bugge,[117] D. Buira-Clark,[118] O. Bulekov,[96] M. Bunse,[42] T. Buran,[117] H. Burckhart,[29] S. Burdin,[73] T. Burgess,[13] S. Burke,[129] E. Busato,[33] P. Bussey,[53] C. P. Buszello,[166] F. Butin,[29] B. Butler,[143] J. M. Butler,[21] C. M. Buttar,[53] J. M. Butterworth,[77] W. Buttinger,[27] T. Byatt,[77] S. Cabrera Urbán,[167] D. Caforio,[19a,19b] O. Cakir,[3a] P. Calafiura,[14] G. Calderini,[78] P. Calfayan,[98] R. Calkins,[106] L. P. Caloba,[23a] R. Caloi,[132a,132b] D. Calvet,[33] S. Calvet,[33] R. Camacho Toro,[33] A. Camard,[78] P. Camarri,[133a,133b] M. Cambiaghi,[119a,119b] D. Cameron,[117] J. Cammin,[20] S. Campana,[29] M. Campanelli,[77] V. Canale,[102a,102b] F. Canelli,[30] A. Canepa,[159a] J. Cantero,[80] L. Capasso,[102a,102b] M. D. M. Capeans Garrido,[29] I. Caprini,[25a] M. Caprini,[25a] D. Capriotti,[99] M. Capua,[36a,36b] R. Caputo,[148] C. Caramarcu,[25a] R. Cardarelli,[133a] T. Carli,[29] G. Carlino,[102a] L. Carminati,[89a,89b] B. Caron,[159a] S. Caron,[48] G. D. Carrillo Montoya,[172] A. A. Carter,[75] J. R. Carter,[27] J. Carvalho,[124a,h] D. Casadei,[108] M. P. Casado,[11] M. Cascella,[122a,122b] C. Caso,[50a,50b,a] A. M. Castaneda Hernandez,[172] E. Castaneda-Miranda,[172] V. Castillo Gimenez,[167] N. F. Castro,[124a] G. Cataldi,[72a] F. Cataneo,[29] A. Catinaccio,[29] J. R. Catmore,[71] A. Cattai,[29] G. Cattani,[133a,133b] S. Caughron,[88] D. Cauz,[164a,164c] P. Cavalleri,[78] D. Cavalli,[89a] M. Cavalli-Sforza,[11] V. Cavasinni,[122a,122b] A. Cazzato,[72a,72b] F. Ceradini,[134a,134b] A. S. Cerqueira,[23a] A. Cerri,[29] L. Cerrito,[75] F. Cerutti,[47] S. A. Cetin,[18b] F. Cevenini,[102a,102b] A. Chafaq,[135a] D. Chakraborty,[106] K. Chan,[2] B. Chapleau,[85] J. D. Chapman,[27] J. W. Chapman,[87] E. Chareyre,[78] D. G. Charlton,[17] V. Chavda,[82] S. Cheatham,[71] S. Chekanov,[5] S. V. Chekulaev,[159a] G. A. Chelkov,[65] M. A. Chelstowska,[104] C. Chen,[64] H. Chen,[24] L. Chen,[2] S. Chen,[32c] T. Chen,[32c] X. Chen,[172] S. Cheng,[32a] A. Cheplakov,[65] V. F. Chepurnov,[65] R. Cherkaoui El Moursli,[135e] V. Chernyatin,[24] E. Cheu,[6] S. L. Cheung,[158] L. Chevalier,[136] G. Chiefari,[102a,102b] L. Chikovani,[51] J. T. Childers,[58a] A. Chilingarov,[71] G. Chiodini,[72a] M. V. Chizhov,[65] G. Choudalakis,[30] S. Chouridou,[137] I. A. Christidi,[77] A. Christov,[48] D. Chromek-Burckhart,[29] M. L. Chu,[151] J. Chudoba,[125] G. Ciapetti,[132a,132b] K. Ciba,[37] A. K. Ciftci,[3a] R. Ciftci,[3a] D. Cinca,[33] V. Cindro,[74] M. D. Ciobotaru,[163] C. Ciocca,[19a,19b] A. Ciocio,[14] M. Cirilli,[87] M. Ciubancan,[25a] A. Clark,[49] P. J. Clark,[45] W. Cleland,[123] J. C. Clemens,[83] B. Clement,[55] C. Clement,[146a,146b] R. W. Clifft,[129] Y. Coadou,[83] M. Cobal,[164a,164c] A. Coccaro,[50a,50b] J. Cochran,[64] P. Coe,[118] J. G. Cogan,[143] J. Coggeshall,[165] E. Cogneras,[177] C. D. Cojocaru,[28] J. Colas,[4] A. P. Colijn,[105] C. Collard,[115] N. J. Collins,[17] C. Collins-Tooth,[53] J. Collot,[55] G. Colon,[84] P. Conde Muiño,[124a] E. Coniavitis,[118] M. C. Conidi,[11] M. Consonni,[104] S. Constantinescu,[25a] C. Conta,[119a,119b] F. Conventi,[102a,i] J. Cook,[29] M. Cooke,[14] B. D. Cooper,[77] A. M. Cooper-Sarkar,[118] N. J. Cooper-Smith,[76] K. Copic,[34] T. Cornelissen,[50a,50b] M. Corradi,[19a] F. Corriveau,[85,j] A. Cortes-Gonzalez,[165] G. Cortiana,[99] G. Costa,[89a] M. J. Costa,[167] D. Costanzo,[139] T. Costin,[30] D. Côté,[29] R. Coura Torres,[23a] L. Courneyea,[169] G. Cowan,[76] C. Cowden,[27] B. E. Cox,[82] K. Cranmer,[108] F. Crescioli,[122a,122b] M. Cristinziani,[20] G. Crosetti,[36a,36b] R. Crupi,[72a,72b] S. Crépé-Renaudin,[55] C.-M. Cuciuc,[25a] C. Cuenca Almenar,[175] T. Cuhadar Donszelmann,[139] S. Cuneo,[50a,50b] M. Curatolo,[47] C. J. Curtis,[17] P. Cwetanski,[61] H. Czirr,[141] Z. Czyczula,[117] S. D'Auria,[53] M. D'Onofrio,[73] A. D'Orazio,[132a,132b] A. Da Rocha Gesualdi Mello,[23a] P. V. M. Da Silva,[23a] C. Da Via,[82] W. Dabrowski,[37] A. Dahlhoff,[48] T. Dai,[87] C. Dallapiccola,[84] M. Dam,[35] M. Dameri,[50a,50b] D. S. Damiani,[137] H. O. Danielsson,[29] D. Dannheim,[99] V. Dao,[49] G. Darbo,[50a] G. L. Darlea,[25b] C. Daum,[105] J. P. Dauvergne,[29] W. Davey,[86] T. Davidek,[126] N. Davidson,[86] R. Davidson,[71] M. Davies,[93] A. R. Davison,[77] E. Dawe,[142] I. Dawson,[139] J. W. Dawson,[5,a] R. K. Daya,[39] K. De,[7] R. de Asmundis,[102a] S. De Castro,[19a,19b] P. E. De Castro Faria Salgado,[24] S. De Cecco,[78] J. de Graat,[98] N. De Groot,[104] P. de Jong,[105] C. De La Taille,[115] H. De la Torre,[80] B. De Lotto,[164a,164c] L. De Mora,[71] L. De Nooij,[105] M. De Oliveira Branco,[29] D. De Pedis,[132a] P. de Saintignon,[55] A. De Salvo,[132a] U. De Sanctis,[164a,164c] A. De Santo,[149] J. B. De Vivie De Regie,[115] S. Dean,[77] D. V. Dedovich,[65] J. Degenhardt,[120] M. Dehchar,[118] M. Deile,[98] C. Del Papa,[164a,164c] J. Del Peso,[80] T. Del Prete,[122a,122b] A. Dell'Acqua,[29] L. Dell'Asta,[89a,89b] M. Della Pietra,[102a,i] D. della Volpe,[102a,102b] M. Delmastro,[29] P. Delpierre,[83] N. Delruelle,[29] P. A. Delsart,[55] C. Deluca,[148] S. Demers,[175] M. Demichev,[65] B. Demirkoz,[11,k] J. Deng,[163] S. P. Denisov,[128] D. Derendarz,[38] J. E. Derkaoui,[135d] F. Derue,[78] P. Dervan,[73] K. Desch,[20] E. Devetak,[148] P. O. Deviveiros,[158] A. Dewhurst,[129] B. DeWilde,[148] S. Dhaliwal,[158] R. Dhullipudi,[24,l] A. Di Ciaccio,[133a,133b] L. Di Ciaccio,[4] A. Di Girolamo,[29] B. Di Girolamo,[29] S. Di Luise,[134a,134b] A. Di Mattia,[88] B. Di Micco,[29] R. Di Nardo,[133a,133b] A. Di Simone,[133a,133b] R. Di Sipio,[19a,19b] M. A. Diaz,[31a] F. Diblen,[18c] E. B. Diehl,[87] H. Dietl,[99] J. Dietrich,[48] T. A. Dietzsch,[58a] S. Diglio,[115]

K. Dindar Yagci,[39] J. Dingfelder,[20] C. Dionisi,[132a,132b] P. Dita,[25a] S. Dita,[25a] F. Dittus,[29] F. Djama,[83] R. Djilkibaev,[108] T. Djobava,[51] M. A. B. do Vale,[23a] A. Do Valle Wemans,[124a] T. K. O. Doan,[4] M. Dobbs,[85] R. Dobinson,[29,a] D. Dobos,[42] E. Dobson,[29] M. Dobson,[163] J. Dodd,[34] O. B. Dogan,[18a,a] C. Doglioni,[118] T. Doherty,[53] Y. Doi,[66,a] J. Dolejsi,[126] I. Dolenc,[74] Z. Dolezal,[126] B. A. Dolgoshein,[96,a] T. Dohmae,[155] M. Donadelli,[23b] M. Donega,[120] J. Donini,[55] J. Dopke,[29] A. Doria,[102a] A. Dos Anjos,[172] M. Dosil,[11] A. Dotti,[122a,122b] M. T. Dova,[70] J. D. Dowell,[17] A. D. Doxiadis,[105] A. T. Doyle,[53] Z. Drasal,[126] J. Drees,[174] N. Dressnandt,[120] H. Drevermann,[29] C. Driouichi,[35] M. Dris,[9] J. Dubbert,[99] T. Dubbs,[137] S. Dube,[14] E. Duchovni,[171] G. Duckeck,[98] A. Dudarev,[29] F. Dudziak,[64] M. Dührssen,[29] I. P. Duerdoth,[82] L. Duflot,[115] M-A. Dufour,[85] M. Dunford,[29] H. Duran Yildiz,[3b] R. Duxfield,[139] M. Dwuznik,[37] F. Dydak,[29] D. Dzahini,[55] M. Düren,[52] W. L. Ebenstein,[44] J. Ebke,[98] S. Eckert,[48] S. Eckweiler,[81] K. Edmonds,[81] C. A. Edwards,[76] W. Ehrenfeld,[41] T. Ehrich,[99] T. Eifert,[29] G. Eigen,[13] K. Einsweiler,[14] E. Eisenhandler,[75] T. Ekelof,[166] M. El Kacimi,[135c] M. Ellert,[166] S. Elles,[4] F. Ellinghaus,[81] K. Ellis,[75] N. Ellis,[29] J. Elmsheuser,[98] M. Elsing,[29] R. Ely,[14] D. Emeliyanov,[129] R. Engelmann,[148] A. Engl,[98] B. Epp,[62] A. Eppig,[87] J. Erdmann,[54] A. Ereditato,[16] D. Eriksson,[146a] J. Ernst,[1] M. Ernst,[24] J. Ernwein,[136] D. Errede,[165] S. Errede,[165] E. Ertel,[81] M. Escalier,[115] C. Escobar,[167] X. Espinal Curull,[11] B. Esposito,[47] F. Etienne,[83] A. I. Etienvre,[136] E. Etzion,[153] D. Evangelakou,[54] H. Evans,[61] L. Fabbri,[19a,19b] C. Fabre,[29] R. M. Fakhrutdinov,[128] S. Falciano,[132a] A. C. Falou,[115] Y. Fang,[172] M. Fanti,[89a,89b] A. Farbin,[7] A. Farilla,[134a] J. Farley,[148] T. Farooque,[158] S. M. Farrington,[118] P. Farthouat,[29] P. Fassnacht,[29] D. Fassouliotis,[8] B. Fatholahzadeh,[158] A. Favareto,[89a,89b] L. Fayard,[115] S. Fazio,[36a,36b] R. Febbraro,[33] P. Federic,[144a] O. L. Fedin,[121] I. Fedorko,[29] W. Fedorko,[88] M. Fehling-Kaschek,[48] L. Feligioni,[83] D. Fellmann,[5] C. U. Felzmann,[86] C. Feng,[32d] E. J. Feng,[30] A. B. Fenyuk,[128] J. Ferencei,[144b] J. Ferland,[93] W. Fernando,[109] S. Ferrag,[53] J. Ferrando,[53] V. Ferrara,[41] A. Ferrari,[166] P. Ferrari,[105] R. Ferrari,[119a] A. Ferrer,[167] M. L. Ferrer,[47] D. Ferrere,[49] C. Ferretti,[87] A. Ferretto Parodi,[50a,50b] M. Fiascaris,[30] F. Fiedler,[81] A. Filipčič,[74] A. Filippas,[9] F. Filthaut,[104] M. Fincke-Keeler,[169] M. C. N. Fiolhais,[124a,h] L. Fiorini,[11] A. Firan,[39] G. Fischer,[41] P. Fischer,[20] M. J. Fisher,[109] S. M. Fisher,[129] M. Flechl,[48] I. Fleck,[141] J. Fleckner,[81] P. Fleischmann,[173] S. Fleischmann,[174] T. Flick,[174] L. R. Flores Castillo,[172] M. J. Flowerdew,[99] F. Föhlisch,[58a] M. Fokitis,[9] T. Fonseca Martin,[16] D. A. Forbush,[138] A. Formica,[136] A. Forti,[82] D. Fortin,[159a] J. M. Foster,[82] D. Fournier,[115] A. Foussat,[29] A. J. Fowler,[44] K. Fowler,[137] H. Fox,[71] P. Francavilla,[122a,122b] S. Franchino,[119a,119b] D. Francis,[29] T. Frank,[171] M. Franklin,[57] S. Franz,[29] M. Fraternali,[119a,119b] S. Fratina,[120] S. T. French,[27] R. Froeschl,[29] D. Froidevaux,[29] J. A. Frost,[27] C. Fukunaga,[156] E. Fullana Torregrosa,[29] J. Fuster,[167] C. Gabaldon,[29] O. Gabizon,[171] T. Gadfort,[24] S. Gadomski,[49] G. Gagliardi,[50a,50b] P. Gagnon,[61] C. Galea,[98] E. J. Gallas,[118] M. V. Gallas,[29] V. Gallo,[16] B. J. Gallop,[129] P. Gallus,[125] E. Galyaev,[40] K. K. Gan,[109] Y. S. Gao,[143,f] V. A. Gapienko,[128] A. Gaponenko,[14] F. Garberson,[175] M. Garcia-Sciveres,[14] C. García,[167] J. E. García Navarro,[49] R. W. Gardner,[30] N. Garelli,[29] H. Garitaonandia,[105] V. Garonne,[29] J. Garvey,[17] C. Gatti,[47] G. Gaudio,[119a] O. Gaumer,[49] B. Gaur,[141] L. Gauthier,[136] I. L. Gavrilenko,[94] C. Gay,[168] G. Gaycken,[20] J-C. Gayde,[29] E. N. Gazis,[9] P. Ge,[32d] C. N. P. Gee,[129] D. A. A. Geerts,[105] Ch. Geich-Gimbel,[20] K. Gellerstedt,[146a,146b] C. Gemme,[50a] A. Gemmell,[53] M. H. Genest,[98] S. Gentile,[132a,132b] M. George,[54] S. George,[76] P. Gerlach,[174] A. Gershon,[153] C. Geweniger,[58a] H. Ghazlane,[135b] P. Ghez,[4] N. Ghodbane,[33] B. Giacobbe,[19a] S. Giagu,[132a,132b] V. Giakoumopoulou,[8] V. Giangiobbe,[122a,122b] F. Gianotti,[29] B. Gibbard,[24] A. Gibson,[158] S. M. Gibson,[29] L. M. Gilbert,[118] M. Gilchriese,[14] V. Gilewsky,[91] D. Gillberg,[28] A. R. Gillman,[129] D. M. Gingrich,[2,e] J. Ginzburg,[153] N. Giokaris,[8] R. Giordano,[102a,102b] F. M. Giorgi,[15] P. Giovannini,[99] P. F. Giraud,[136] D. Giugni,[89a] M. Giunta,[132a,132b] P. Giusti,[19a] B. K. Gjelsten,[117] L. K. Gladilin,[97] C. Glasman,[80] J. Glatzer,[48] A. Glazov,[41] K. W. Glitza,[174] G. L. Glonti,[65] J. Godfrey,[142] J. Godlewski,[29] M. Goebel,[41] T. Göpfert,[43] C. Goeringer,[81] C. Gössling,[42] T. Göttfert,[99] S. Goldfarb,[87] D. Goldin,[39] T. Golling,[175] S. N. Golovnia,[128] A. Gomes,[124a,c] L. S. Gomez Fajardo,[41] R. Gonçalo,[76] J. Goncalves Pinto Firmino Da Costa,[41] L. Gonella,[20] A. Gonidec,[29] S. Gonzalez,[172] S. González de la Hoz,[167] M. L. Gonzalez Silva,[26] S. Gonzalez-Sevilla,[49] J. J. Goodson,[148] L. Goossens,[29] P. A. Gorbounov,[95] H. A. Gordon,[24] I. Gorelov,[103] G. Gorfine,[174] B. Gorini,[29] E. Gorini,[72a,72b] A. Gorišek,[74] E. Gornicki,[38] S. A. Gorokhov,[128] V. N. Goryachev,[128] B. Gosdzik,[41] M. Gosselink,[105] M. I. Gostkin,[65] M. Gouanère,[4] I. Gough Eschrich,[163] M. Gouighri,[135a] D. Goujdami,[135c] M. P. Goulette,[49] A. G. Goussiou,[138] C. Goy,[4] I. Grabowska-Bold,[163,g] V. Grabski,[176] P. Grafström,[29] C. Grah,[174] K-J. Grahn,[147] F. Grancagnolo,[72a] S. Grancagnolo,[15] V. Grassi,[148] V. Gratchev,[121] N. Grau,[34] H. M. Gray,[29] J. A. Gray,[148] E. Graziani,[134a] O. G. Grebenyuk,[121] D. Greenfield,[129] T. Greenshaw,[73] Z. D. Greenwood,[24,l] I. M. Gregor,[41] P. Grenier,[143] E. Griesmayer,[46] J. Griffiths,[138] N. Grigalashvili,[65] A. A. Grillo,[137] S. Grinstein,[11] Ph. Gris,[33] Y. V. Grishkevich,[97] J.-F. Grivaz,[115] J. Grognuz,[29] M. Groh,[99] E. Gross,[171] J. Grosse-Knetter,[54] J. Groth-Jensen,[79]

K. Grybel,[141] V. J. Guarino,[5] D. Guest,[175] C. Guicheney,[33] A. Guida,[72a,72b] T. Guillemin,[4] S. Guindon,[54] H. Guler,[85,m] J. Gunther,[125] B. Guo,[158] J. Guo,[34] A. Gupta,[30] Y. Gusakov,[65] V. N. Gushchin,[128] A. Gutierrez,[93] P. Gutierrez,[111] N. Guttman,[153] O. Gutzwiller,[172] C. Guyot,[136] C. Gwenlan,[118] C. B. Gwilliam,[73] A. Haas,[143] S. Haas,[29] C. Haber,[14] R. Hackenburg,[24] H. K. Hadavand,[39] D. R. Hadley,[17] P. Haefner,[99] F. Hahn,[29] S. Haider,[29] Z. Hajduk,[38] H. Hakobyan,[176] J. Haller,[54] K. Hamacher,[174] P. Hamal,[113] A. Hamilton,[49] S. Hamilton,[161] H. Han,[32a] L. Han,[32b] K. Hanagaki,[116] M. Hance,[120] C. Handel,[81] P. Hanke,[58a] J. R. Hansen,[35] J. B. Hansen,[35] J. D. Hansen,[35] P. H. Hansen,[35] P. Hansson,[143] K. Hara,[160] G. A. Hare,[137] T. Harenberg,[174] S. Harkusha,[90] D. Harper,[87] R. D. Harrington,[21] O. M. Harris,[138] K. Harrison,[17] J. Hartert,[48] F. Hartjes,[105] T. Haruyama,[66] A. Harvey,[56] S. Hasegawa,[101] Y. Hasegawa,[140] S. Hassani,[136] M. Hatch,[29] D. Hauff,[99] S. Haug,[16] M. Hauschild,[29] R. Hauser,[88] M. Havranek,[20] B. M. Hawes,[118] C. M. Hawkes,[17] R. J. Hawkings,[29] D. Hawkins,[163] T. Hayakawa,[67] D Hayden,[76] H. S. Hayward,[73] S. J. Haywood,[129] E. Hazen,[21] M. He,[32d] S. J. Head,[17] V. Hedberg,[79] L. Heelan,[7] S. Heim,[88] B. Heinemann,[14] S. Heisterkamp,[35] L. Helary,[4] M. Heldmann,[48] M. Heller,[115] S. Hellman,[146a,146b] C. Helsens,[11] R. C. W. Henderson,[71] M. Henke,[58a] A. Henrichs,[54] A. M. Henriques Correia,[29] S. Henrot-Versille,[115] F. Henry-Couannier,[83] C. Hensel,[54] T. Henß,[174] C. M. Hernandez,[7] Y. Hernández Jiménez,[167] R. Herrberg,[15] A. D. Hershenhorn,[152] G. Herten,[48] R. Hertenberger,[98] L. Hervas,[29] N. P. Hessey,[105] A. Hidvegi,[146a] E. Higón-Rodriguez,[167] D. Hill,[5,a] J. C. Hill,[27] N. Hill,[5] K. H. Hiller,[41] S. Hillert,[20] S. J. Hillier,[17] I. Hinchliffe,[14] E. Hines,[120] M. Hirose,[116] F. Hirsch,[42] D. Hirschbuehl,[174] J. Hobbs,[148] N. Hod,[153] M. C. Hodgkinson,[139] P. Hodgson,[139] A. Hoecker,[29] M. R. Hoeferkamp,[103] J. Hoffman,[39] D. Hoffmann,[83] M. Hohlfeld,[81] M. Holder,[141] A. Holmes,[118] S. O. Holmgren,[146a] T. Holy,[127] J. L. Holzbauer,[88] Y. Homma,[67] L. Hooft van Huysduynen,[108] T. Horazdovsky,[127] C. Horn,[143] S. Horner,[48] K. Horton,[118] J-Y. Hostachy,[55] S. Hou,[151] M. A. Houlden,[73] A. Hoummada,[135a] J. Howarth,[82] D. F. Howell,[118] I. Hristova,[41] J. Hrivnac,[115] I. Hruska,[125] T. Hryn'ova,[4] P. J. Hsu,[175] S.-C. Hsu,[14] G. S. Huang,[111] Z. Hubacek,[127] F. Hubaut,[83] F. Huegging,[20] T. B. Huffman,[118] E. W. Hughes,[34] G. Hughes,[71] R. E. Hughes-Jones,[82] M. Huhtinen,[29] P. Hurst,[57] M. Hurwitz,[14] U. Husemann,[41] N. Huseynov,[65,n] J. Huston,[88] J. Huth,[57] G. Iacobucci,[102a] G. Iakovidis,[9] M. Ibbotson,[82] I. Ibragimov,[141] R. Ichimiya,[67] L. Iconomidou-Fayard,[115] J. Idarraga,[115] M. Idzik,[37] P. Iengo,[102a,102b] O. Igonkina,[105] Y. Ikegami,[66] M. Ikeno,[66] Y. Ilchenko,[39] D. Iliadis,[154] D. Imbault,[78] M. Imhaeuser,[174] M. Imori,[155] T. Ince,[20] J. Inigo-Golfin,[29] P. Ioannou,[8] M. Iodice,[134a] G. Ionescu,[4] A. Irles Quiles,[167] K. Ishii,[66] A. Ishikawa,[67] M. Ishino,[66] R. Ishmukhametov,[39] C. Issever,[118] S. Istin,[18a] Y. Itoh,[101] A. V. Ivashin,[128] W. Iwanski,[38] H. Iwasaki,[66] J. M. Izen,[40] V. Izzo,[102a] B. Jackson,[120] J. N. Jackson,[73] P. Jackson,[143] M. R. Jaekel,[29] V. Jain,[61] K. Jakobs,[48] S. Jakobsen,[35] J. Jakubek,[127] D. K. Jana,[111] E. Jankowski,[158] E. Jansen,[77] A. Jantsch,[99] M. Janus,[20] G. Jarlskog,[79] L. Jeanty,[57] K. Jelen,[37] I. Jen-La Plante,[30] P. Jenni,[29] A. Jeremie,[4] P. Jež,[35] S. Jézéquel,[4] M. K. Jha,[19a] H. Ji,[172] W. Ji,[81] J. Jia,[148] Y. Jiang,[32b] M. Jimenez Belenguer,[41] G. Jin,[32b] S. Jin,[32a] O. Jinnouchi,[157] M. D. Joergensen,[35] D. Joffe,[39] L. G. Johansen,[13] M. Johansen,[146a,146b] K. E. Johansson,[146a] P. Johansson,[139] S. Johnert,[41] K. A. Johns,[6] K. Jon-And,[146a,146b] G. Jones,[82] R. W. L. Jones,[71] T. W. Jones,[77] T. J. Jones,[73] O. Jonsson,[29] C. Joram,[29] P. M. Jorge,[124a,c] J. Joseph,[14] X. Ju,[130] V. Juranek,[125] P. Jussel,[62] V. V. Kabachenko,[128] S. Kabana,[16] M. Kaci,[167] A. Kaczmarska,[38] P. Kadlecik,[35] M. Kado,[115] H. Kagan,[109] M. Kagan,[57] S. Kaiser,[99] E. Kajomovitz,[152] S. Kalinin,[174] L. V. Kalinovskaya,[65] S. Kama,[39] N. Kanaya,[155] M. Kaneda,[155] T. Kanno,[157] V. A. Kantserov,[96] J. Kanzaki,[66] B. Kaplan,[175] A. Kapliy,[30] J. Kaplon,[29] D. Kar,[43] M. Karagoz,[118] M. Karnevskiy,[41] K. Karr,[5] V. Kartvelishvili,[71] A. N. Karyukhin,[128] L. Kashif,[172] A. Kasmi,[39] R. D. Kass,[109] A. Kastanas,[13] M. Kataoka,[4] Y. Kataoka,[155] E. Katsoufis,[9] J. Katzy,[41] V. Kaushik,[6] K. Kawagoe,[67] T. Kawamoto,[155] G. Kawamura,[81] M. S. Kayl,[105] V. A. Kazanin,[107] M. Y. Kazarinov,[65] J. R. Keates,[82] R. Keeler,[169] R. Kehoe,[39] M. Keil,[54] G. D. Kekelidze,[65] M. Kelly,[82] J. Kennedy,[98] C. J. Kenney,[143] M. Kenyon,[53] O. Kepka,[125] N. Kerschen,[29] B. P. Kerševan,[74] S. Kersten,[174] K. Kessoku,[155] C. Ketterer,[48] J. Keung,[158] M. Khakzad,[28] F. Khalil-zada,[10] H. Khandanyan,[165] A. Khanov,[112] D. Kharchenko,[65] A. Khodinov,[148] A. G. Kholodenko,[128] A. Khomich,[58a] T. J. Khoo,[27] G. Khoriauli,[20] A. Khoroshilov,[174] N. Khovanskiy,[65] V. Khovanskiy,[95] E. Khramov,[65] J. Khubua,[51] H. Kim,[7] M. S. Kim,[2] P. C. Kim,[143] S. H. Kim,[160] N. Kimura,[170] O. Kind,[15] B. T. King,[73] M. King,[67] R. S. B. King,[118] J. Kirk,[129] G. P. Kirsch,[118] L. E. Kirsch,[22] A. E. Kiryunin,[99] D. Kisielewska,[37] T. Kittelmann,[123] A. M. Kiver,[128] H. Kiyamura,[67] E. Kladiva,[144b] J. Klaiber-Lodewigs,[42] M. Klein,[73] U. Klein,[73] K. Kleinknecht,[81] M. Klemetti,[85] A. Klier,[171] A. Klimentov,[24] R. Klingenberg,[42] E. B. Klinkby,[35] T. Klioutchnikova,[29] P. F. Klok,[104] S. Klous,[105] E.-E. Kluge,[58a] T. Kluge,[73] P. Kluit,[105] S. Kluth,[99] E. Kneringer,[62] J. Knobloch,[29] E. B. F. G. Knoops,[83] A. Knue,[54] B. R. Ko,[44] T. Kobayashi,[155] M. Kobel,[43] B. Koblitz,[29] M. Kocian,[143] A. Kocnar,[113] P. Kodys,[126] K. Köneke,[29] A. C. König,[104] S. Koenig,[81] L. Köpke,[81]

F. Koetsveld,[104] P. Koevesarki,[20] T. Koffas,[29] E. Koffeman,[105] F. Kohn,[54] Z. Kohout,[127] T. Kohriki,[66] T. Koi,[143] T. Kokott,[20] G. M. Kolachev,[107] H. Kolanoski,[15] V. Kolesnikov,[65] I. Koletsou,[89a] J. Koll,[88] D. Kollar,[29] M. Kollefrath,[48] S. D. Kolya,[82] A. A. Komar,[94] J. R. Komaragiri,[142] T. Kondo,[66] T. Kono,[41,o] A. I. Kononov,[48] R. Konoplich,[108,p] N. Konstantinidis,[77] A. Kootz,[174] S. Koperny,[37] S. V. Kopikov,[128] K. Korcyl,[38] K. Kordas,[154] V. Koreshev,[128] A. Korn,[14] A. Korol,[107] I. Korolkov,[11] E. V. Korolkova,[139] V. A. Korotkov,[128] O. Kortner,[99] S. Kortner,[99] V. V. Kostyukhin,[20] M. J. Kotamäki,[29] S. Kotov,[99] V. M. Kotov,[65] A. Kotwal,[44] C. Kourkoumelis,[8] V. Kouskoura,[154] A. Koutsman,[105] R. Kowalewski,[169] T. Z. Kowalski,[37] W. Kozanecki,[136] A. S. Kozhin,[128] V. Kral,[127] V. A. Kramarenko,[97] G. Kramberger,[74] O. Krasel,[42] M. W. Krasny,[78] A. Krasznahorkay,[108] J. Kraus,[88] A. Kreisel,[153] F. Krejci,[127] J. Kretzschmar,[73] N. Krieger,[54] P. Krieger,[158] K. Kroeninger,[54] H. Kroha,[99] J. Kroll,[120] J. Kroseberg,[20] J. Krstic,[12a] U. Kruchonak,[65] H. Krüger,[20] Z. V. Krumshteyn,[65] A. Kruth,[20] T. Kubota,[155] S. Kuehn,[48] A. Kugel,[58c] T. Kuhl,[174] D. Kuhn,[62] V. Kukhtin,[65] Y. Kulchitsky,[90] S. Kuleshov,[31b] C. Kummer,[98] M. Kuna,[78] N. Kundu,[118] J. Kunkle,[120] A. Kupco,[125] H. Kurashige,[67] M. Kurata,[160] Y. A. Kurochkin,[90] V. Kus,[125] W. Kuykendall,[138] M. Kuze,[157] P. Kuzhir,[91] O. Kvasnicka,[125] J. Kvita,[29] R. Kwee,[15] A. La Rosa,[29] L. La Rotonda,[36a,36b] L. Labarga,[80] J. Labbe,[4] S. Lablak,[135a] C. Lacasta,[167] F. Lacava,[132a,132b] H. Lacker,[15] D. Lacour,[78] V. R. Lacuesta,[167] E. Ladygin,[65] R. Lafaye,[4] B. Laforge,[78] T. Lagouri,[80] S. Lai,[48] E. Laisne,[55] M. Lamanna,[29] C. L. Lampen,[6] W. Lampl,[6] E. Lancon,[136] U. Landgraf,[48] M. P. J. Landon,[75] H. Landsman,[152] J. L. Lane,[82] C. Lange,[41] A. J. Lankford,[163] F. Lanni,[24] K. Lantzsch,[29] V. V. Lapin,[128,a] S. Laplace,[78] C. Lapoire,[20] J. F. Laporte,[136] T. Lari,[89a] A. V. Larionov,[128] A. Larner,[118] C. Lasseur,[29] M. Lassnig,[29] W. Lau,[118] P. Laurelli,[47] A. Lavorato,[118] W. Lavrijsen,[14] P. Laycock,[73] A. B. Lazarev,[65] A. Lazzaro,[89a,89b] O. Le Dortz,[78] E. Le Guirriec,[83] C. Le Maner,[158] E. Le Menedeu,[136] A. Lebedev,[64] C. Lebel,[93] T. LeCompte,[5] F. Ledroit-Guillon,[55] H. Lee,[105] J. S. H. Lee,[150] S. C. Lee,[151] L. Lee,[175] M. Lefebvre,[169] M. Legendre,[136] A. Leger,[49] B. C. LeGeyt,[120] F. Legger,[98] C. Leggett,[14] M. Lehmacher,[20] G. Lehmann Miotto,[29] X. Lei,[6] M. A. L. Leite,[23b] R. Leitner,[126] D. Lellouch,[171] J. Lellouch,[78] M. Leltchouk,[34] V. Lendermann,[58a] K. J. C. Leney,[145b] T. Lenz,[174] G. Lenzen,[174] B. Lenzi,[136] K. Leonhardt,[43] S. Leontsinis,[9] C. Leroy,[93] J-R. Lessard,[169] J. Lesser,[146a] C. G. Lester,[27] A. Leung Fook Cheong,[172] J. Levêque,[4] D. Levin,[87] L. J. Levinson,[171] M. S. Levitski,[128] M. Lewandowska,[21] A. Lewis,[118] G. H. Lewis,[108] A. M. Leyko,[20] M. Leyton,[15] B. Li,[83] H. Li,[172] S. Li,[32b] X. Li,[87] Z. Liang,[39] Z. Liang,[118,q] B. Liberti,[133a] P. Lichard,[29] M. Lichtnecker,[98] K. Lie,[165] W. Liebig,[13] R. Lifshitz,[152] J. N. Lilley,[17] C. Limbach,[20] A. Limosani,[86] M. Limper,[63] S. C. Lin,[151,r] F. Linde,[105] J. T. Linnemann,[88] E. Lipeles,[120] L. Lipinsky,[125] A. Lipniacka,[13] T. M. Liss,[165] D. Lissauer,[24] A. Lister,[49] A. M. Litke,[137] C. Liu,[28] D. Liu,[151,s] H. Liu,[87] J. B. Liu,[87] M. Liu,[32b] S. Liu,[2] Y. Liu,[32b] M. Livan,[119a,119b] S. S. A. Livermore,[118] A. Lleres,[55] J. Llorente Merino,[80] S. L. Lloyd,[75] E. Lobodzinska,[41] P. Loch,[6] W. S. Lockman,[137] S. Lockwitz,[175] T. Loddenkoetter,[20] F. K. Loebinger,[82] A. Loginov,[175] C. W. Loh,[168] T. Lohse,[15] K. Lohwasser,[48] M. Lokajicek,[125] J. Loken,[118] V. P. Lombardo,[4] R. E. Long,[71] L. Lopes,[124a,c] D. Lopez Mateos,[34,t] M. Losada,[162] P. Loscutoff,[14] F. Lo Sterzo,[132a,132b] M. J. Losty,[159a] X. Lou,[40] A. Lounis,[115] K. F. Loureiro,[162] J. Love,[21] P. A. Love,[71] A. J. Lowe,[143,f] F. Lu,[32a] L. Lu,[39] H. J. Lubatti,[138] C. Luci,[132a,132b] A. Lucotte,[55] A. Ludwig,[43] D. Ludwig,[41] I. Ludwig,[48] J. Ludwig,[48] F. Luehring,[61] G. Luijckx,[105] D. Lumb,[48] L. Luminari,[132a] E. Lund,[117] B. Lund-Jensen,[147] B. Lundberg,[79] J. Lundberg,[146a,146b] J. Lundquist,[35] M. Lungwitz,[81] A. Lupi,[122a,122b] G. Lutz,[99] D. Lynn,[24] J. Lys,[14] E. Lytken,[79] H. Ma,[24] L. L. Ma,[172] J. A. Macana Goia,[93] G. Maccarrone,[47] A. Macchiolo,[99] B. Maček,[74] J. Machado Miguens,[124a] D. Macina,[49] R. Mackeprang,[35] R. J. Madaras,[14] W. F. Mader,[43] R. Maenner,[58c] T. Maeno,[24] P. Mättig,[174] S. Mättig,[41] P. J. Magalhaes Martins,[124a,h] L. Magnoni,[29] E. Magradze,[54] Y. Mahalalel,[153] K. Mahboubi,[48] G. Mahout,[17] C. Maiani,[132a,132b] C. Maidantchik,[23a] A. Maio,[124a,c] S. Majewski,[24] Y. Makida,[66] N. Makovec,[115] P. Mal,[6] Pa. Malecki,[38] P. Malecki,[38] V. P. Maleev,[121] F. Malek,[55] U. Mallik,[63] D. Malon,[5] S. Maltezos,[9] V. Malyshev,[107] S. Malyukov,[29] R. Mameghani,[98] J. Mamuzic,[12b] A. Manabe,[66] L. Mandelli,[89a] I. Mandić,[74] R. Mandrysch,[15] J. Maneira,[124a] P. S. Mangeard,[88] I. D. Manjavidze,[65] A. Mann,[54] P. M. Manning,[137] A. Manousakis-Katsikakis,[8] B. Mansoulie,[136] A. Manz,[99] A. Mapelli,[29] L. Mapelli,[29] L. March,[80] J. F. Marchand,[29] F. Marchese,[133a,133b] G. Marchiori,[78] M. Marcisovsky,[125] A. Marin,[21,a] C. P. Marino,[61] F. Marroquim,[23a] R. Marshall,[82] Z. Marshall,[29] F. K. Martens,[158] S. Marti-Garcia,[167] A. J. Martin,[175] B. Martin,[29] B. Martin,[88] F. F. Martin,[120] J. P. Martin,[93] Ph. Martin,[55] T. A. Martin,[17] B. Martin dit Latour,[49] M. Martinez,[11] V. Martinez Outschoorn,[57] A. C. Martyniuk,[82] M. Marx,[82] F. Marzano,[132a] A. Marzin,[111] L. Masetti,[81] T. Mashimo,[155] R. Mashinistov,[94] J. Masik,[82] A. L. Maslennikov,[107] M. Maß,[42] I. Massa,[19a,19b] G. Massaro,[105] N. Massol,[4] A. Mastroberardino,[36a,36b] T. Masubuchi,[155] M. Mathes,[20] P. Matricon,[115] H. Matsumoto,[155] H. Matsunaga,[155] T. Matsushita,[67] C. Mattravers,[118,u] J. M. Maugain,[29] S. J. Maxfield,[73] D. A. Maximov,[107]

E. N. May,[5] A. Mayne,[139] R. Mazini,[151] M. Mazur,[20] M. Mazzanti,[89a] E. Mazzoni,[122a,122b] S. P. Mc Kee,[87] A. McCarn,[165] R. L. McCarthy,[148] T. G. McCarthy,[28] N. A. McCubbin,[129] K. W. McFarlane,[56] J. A. Mcfayden,[139] H. McGlone,[53] G. Mchedlidze,[51] R. A. McLaren,[29] T. Mclaughlan,[17] S. J. McMahon,[129] R. A. McPherson,[169,j] A. Meade,[84] J. Mechnich,[105] M. Mechtel,[174] M. Medinnis,[41] R. Meera-Lebbai,[111] T. Meguro,[116] R. Mehdiyev,[93] S. Mehlhase,[35] A. Mehta,[73] K. Meier,[58a] J. Meinhardt,[48] B. Meirose,[79] C. Melachrinos,[30] B. R. Mellado Garcia,[172] L. Mendoza Navas,[162] Z. Meng,[151,s] A. Mengarelli,[19a,19b] S. Menke,[99] C. Menot,[29] E. Meoni,[11] K. M. Mercurio,[57] P. Mermod,[118] L. Merola,[102a,102b] C. Meroni,[89a] F. S. Merritt,[30] A. Messina,[29] J. Metcalfe,[103] A. S. Mete,[64] S. Meuser,[20] C. Meyer,[81] J-P. Meyer,[136] J. Meyer,[173] J. Meyer,[54] T. C. Meyer,[29] W. T. Meyer,[64] J. Miao,[32d] S. Michal,[29] L. Micu,[25a] R. P. Middleton,[129] P. Miele,[29] S. Migas,[73] L. Mijović,[41] G. Mikenberg,[171] M. Mikestikova,[125] M. Mikuž,[74] D. W. Miller,[143] R. J. Miller,[88] W. J. Mills,[168] C. Mills,[57] A. Milov,[171] D. A. Milstead,[146a,146b] D. Milstein,[171] A. A. Minaenko,[128] M. Miñano,[167] I. A. Minashvili,[65] A. I. Mincer,[108] B. Mindur,[37] M. Mineev,[65] Y. Ming,[130] L. M. Mir,[11] G. Mirabelli,[132a] L. Miralles Verge,[11] A. Misiejuk,[76] J. Mitrevski,[137] G. Y. Mitrofanov,[128] V. A. Mitsou,[167] S. Mitsui,[66] P. S. Miyagawa,[82] K. Miyazaki,[67] J. U. Mjörnmark,[79] T. Moa,[146a,146b] P. Mockett,[138] S. Moed,[57] V. Moeller,[27] K. Mönig,[41] N. Möser,[20] S. Mohapatra,[148] B. Mohn,[13] W. Mohr,[48] S. Mohrdieck-Möck,[99] A. M. Moisseev,[128,a] R. Moles-Valls,[167] J. Molina-Perez,[29] J. Monk,[77] E. Monnier,[83] S. Montesano,[89a,89b] F. Monticelli,[70] S. Monzani,[19a,19b] R. W. Moore,[2] G. F. Moorhead,[86] C. Mora Herrera,[49] A. Moraes,[53] A. Morais,[124a,c] N. Morange,[136] G. Morello,[36a,36b] D. Moreno,[81] M. Moreno Llácer,[167] P. Morettini,[50a] M. Morii,[57] J. Morin,[75] Y. Morita,[66] A. K. Morley,[29] G. Mornacchi,[29] M-C. Morone,[49] S. V. Morozov,[96] J. D. Morris,[75] H. G. Moser,[99] M. Mosidze,[51] J. Moss,[109] R. Mount,[143] E. Mountricha,[9] S. V. Mouraviev,[94] E. J. W. Moyse,[84] M. Mudrinic,[12b] F. Mueller,[58a] J. Mueller,[123] K. Mueller,[20] T. A. Müller,[98] D. Muenstermann,[29] A. Muijs,[105] A. Muir,[168] Y. Munwes,[153] K. Murakami,[66] W. J. Murray,[129] I. Mussche,[105] E. Musto,[102a,102b] A. G. Myagkov,[128] M. Myska,[125] J. Nadal,[11] K. Nagai,[160] K. Nagano,[66] Y. Nagasaka,[60] A. M. Nairz,[29] Y. Nakahama,[115] K. Nakamura,[155] I. Nakano,[110] G. Nanava,[20] A. Napier,[161] M. Nash,[77,u] N. R. Nation,[21] T. Nattermann,[20] T. Naumann,[41] G. Navarro,[162] H. A. Neal,[87] E. Nebot,[80] P. Yu. Nechaeva,[94] A. Negri,[119a,119b] G. Negri,[29] S. Nektarijevic,[49] A. Nelson,[64] S. Nelson,[143] T. K. Nelson,[143] S. Nemecek,[125] P. Nemethy,[108] A. A. Nepomuceno,[23a] M. Nessi,[29,v] S. Y. Nesterov,[121] M. S. Neubauer,[165] A. Neusiedl,[81] R. M. Neves,[108] P. Nevski,[24] P. R. Newman,[17] R. B. Nickerson,[118] R. Nicolaidou,[136] L. Nicolas,[139] B. Nicquevert,[29] F. Niedercorn,[115] J. Nielsen,[137] T. Niinikoski,[29] A. Nikiforov,[15] V. Nikolaenko,[128] K. Nikolaev,[65] I. Nikolic-Audit,[78] K. Nikolopoulos,[24] H. Nilsen,[48] P. Nilsson,[7] Y. Ninomiya,[155] A. Nisati,[132a] T. Nishiyama,[67] R. Nisius,[99] L. Nodulman,[5] M. Nomachi,[116] I. Nomidis,[154] H. Nomoto,[155] M. Nordberg,[29] B. Nordkvist,[146a,146b] P. R. Norton,[129] J. Novakova,[126] M. Nozaki,[66] M. Nožička,[41] L. Nozka,[113] I. M. Nugent,[159a] A.-E. Nuncio-Quiroz,[20] G. Nunes Hanninger,[20] T. Nunnemann,[98] E. Nurse,[77] T. Nyman,[29] B. J. O'Brien,[45] S. W. O'Neale,[17,a] D. C. O'Neil,[142] V. O'Shea,[53] F. G. Oakham,[28,e] H. Oberlack,[99] J. Ocariz,[78] A. Ochi,[67] S. Oda,[155] S. Odaka,[66] J. Odier,[83] H. Ogren,[61] A. Oh,[82] S. H. Oh,[44] C. C. Ohm,[146a,146b] T. Ohshima,[101] H. Ohshita,[140] T. K. Ohska,[66] T. Ohsugi,[59] S. Okada,[67] H. Okawa,[163] Y. Okumura,[101] T. Okuyama,[155] M. Olcese,[50a] A. G. Olchevski,[65] M. Oliveira,[124a,h] D. Oliveira Damazio,[24] E. Oliver Garcia,[167] D. Olivito,[120] A. Olszewski,[38] J. Olszowska,[38] C. Omachi,[67] A. Onofre,[124a,w] P. U. E. Onyisi,[30] C. J. Oram,[159a] M. J. Oreglia,[30] Y. Oren,[153] D. Orestano,[134a,134b] I. Orlov,[107] C. Oropeza Barrera,[53] R. S. Orr,[158] E. O. Ortega,[130] B. Osculati,[50a,50b] R. Ospanov,[120] C. Osuna,[11] G. Otero y Garzon,[26] J. P. Ottersbach,[105] M. Ouchrif,[135d] F. Ould-Saada,[117] A. Ouraou,[136] Q. Ouyang,[32a] M. Owen,[82] S. Owen,[139] O. K. Øye,[13] V. E. Ozcan,[18a] N. Ozturk,[7] A. Pacheco Pages,[11] C. Padilla Aranda,[11] E. Paganis,[139] F. Paige,[24] K. Pajchel,[117] S. Palestini,[29] D. Pallin,[33] A. Palma,[124a,c] J. D. Palmer,[17] Y. B. Pan,[172] E. Panagiotopoulou,[9] B. Panes,[31a] N. Panikashvili,[87] S. Panitkin,[24] D. Pantea,[25a] M. Panuskova,[125] V. Paolone,[123] A. Papadelis,[146a] Th. D. Papadopoulou,[9] A. Paramonov,[5] W. Park,[24,x] M. A. Parker,[27] F. Parodi,[50a,50b] J. A. Parsons,[34] U. Parzefall,[48] E. Pasqualucci,[132a] A. Passeri,[134a] F. Pastore,[134a,134b] Fr. Pastore,[29] G. Pásztor,[49,y] S. Pataraia,[172] N. Patel,[150] J. R. Pater,[82] S. Patricelli,[102a,102b] T. Pauly,[29] M. Pecsy,[144a] M. I. Pedraza Morales,[172] S. V. Peleganchuk,[107] H. Peng,[172] R. Pengo,[29] A. Penson,[34] J. Penwell,[61] M. Perantoni,[23a] K. Perez,[34,t] T. Perez Cavalcanti,[41] E. Perez Codina,[11] M. T. Pérez García-Estañ,[167] V. Perez Reale,[34] I. Peric,[20] L. Perini,[89a,89b] H. Pernegger,[29] R. Perrino,[72a] P. Perrodo,[4] S. Persembe,[3a] V. D. Peshekhonov,[65] O. Peters,[105] B. A. Petersen,[29] J. Petersen,[29] T. C. Petersen,[35] E. Petit,[83] A. Petridis,[154] C. Petridou,[154] E. Petrolo,[132a] F. Petrucci,[134a,134b] D. Petschull,[41] M. Petteni,[142] R. Pezoa,[31b] A. Phan,[86] A. W. Phillips,[27] P. W. Phillips,[129] G. Piacquadio,[29] E. Piccaro,[75] M. Piccinini,[19a,19b] A. Pickford,[53] S. M. Piec,[41] R. Piegaia,[26] J. E. Pilcher,[30] A. D. Pilkington,[82] J. Pina,[124a,c]

M. Pinamonti,[164a,164c] A. Pinder,[118] J. L. Pinfold,[2] J. Ping,[32c] B. Pinto,[124a,c] O. Pirotte,[29] C. Pizio,[89a,89b] R. Placakyte,[41] M. Plamondon,[169] W. G. Plano,[82] M.-A. Pleier,[24] A. V. Pleskach,[128] A. Poblaguev,[24] S. Poddar,[58a] F. Podlyski,[33] L. Poggioli,[115] T. Poghosyan,[20] M. Pohl,[49] F. Polci,[55] G. Polesello,[119a] A. Policicchio,[138] A. Polini,[19a] J. Poll,[75] V. Polychronakos,[24] D. M. Pomarede,[136] D. Pomeroy,[22] K. Pommès,[29] L. Pontecorvo,[132a] B. G. Pope,[88] G. A. Popeneciu,[25a] D. S. Popovic,[12a] A. Poppleton,[29] X. Portell Bueso,[48] R. Porter,[163] C. Posch,[21] G. E. Pospelov,[99] S. Pospisil,[127] I. N. Potrap,[99] C. J. Potter,[149] C. T. Potter,[114] G. Poulard,[29] J. Poveda,[172] R. Prabhu,[77] P. Pralavorio,[83] S. Prasad,[57] R. Pravahan,[7] S. Prell,[64] K. Pretzl,[16] L. Pribyl,[29] D. Price,[61] L. E. Price,[5] M. J. Price,[29] P. M. Prichard,[73] D. Prieur,[123] M. Primavera,[72a] K. Prokofiev,[108] F. Prokoshin,[31b] S. Protopopescu,[24] J. Proudfoot,[5] X. Prudent,[43] H. Przysiezniak,[4] S. Psoroulas,[20] E. Ptacek,[114] J. Purdham,[87] M. Purohit,[24,x] P. Puzo,[115] Y. Pylypchenko,[117] J. Qian,[87] Z. Qian,[83] Z. Qin,[41] A. Quadt,[54] D. R. Quarrie,[14] W. B. Quayle,[172] F. Quinonez,[31a] M. Raas,[104] V. Radescu,[58b] B. Radics,[20] T. Rador,[18a] F. Ragusa,[89a,89b] G. Rahal,[177] A. M. Rahimi,[109] D. Rahm,[24] S. Rajagopalan,[24] M. Rammensee,[48] M. Rammes,[141] M. Ramstedt,[146a,146b] K. Randrianarivony,[28] P. N. Ratoff,[71] F. Rauscher,[98] E. Rauter,[99] M. Raymond,[29] A. L. Read,[117] D. M. Rebuzzi,[119a,119b] A. Redelbach,[173] G. Redlinger,[24] R. Reece,[120] K. Reeves,[40] A. Reichold,[105] E. Reinherz-Aronis,[153] A. Reinsch,[114] I. Reisinger,[42] D. Reljic,[12a] C. Rembser,[29] Z. L. Ren,[151] A. Renaud,[115] P. Renkel,[39] B. Rensch,[35] M. Rescigno,[132a] S. Resconi,[89a] B. Resende,[136] P. Reznicek,[98] R. Rezvani,[158] A. Richards,[77] R. Richter,[99] E. Richter-Was,[38,z] M. Ridel,[78] S. Rieke,[81] M. Rijpstra,[105] M. Rijssenbeek,[148] A. Rimoldi,[119a,119b] L. Rinaldi,[19a] R. R. Rios,[39] I. Riu,[11] G. Rivoltella,[89a,89b] F. Rizatdinova,[112] E. Rizvi,[75] S. H. Robertson,[85,j] A. Robichaud-Veronneau,[49] D. Robinson,[27] J. E. M. Robinson,[77] M. Robinson,[114] A. Robson,[53] J. G. Rocha de Lima,[106] C. Roda,[122a,122b] D. Roda Dos Santos,[29] S. Rodier,[80] D. Rodriguez,[162] Y. Rodriguez Garcia,[15] A. Roe,[54] S. Roe,[29] O. Røhne,[117] V. Rojo,[1] S. Rolli,[161] A. Romaniouk,[96] V. M. Romanov,[65] G. Romeo,[26] D. Romero Maltrana,[31a] L. Roos,[78] E. Ros,[167] S. Rosati,[132a,132b] K. Rosbach,[49] M. Rose,[76] G. A. Rosenbaum,[158] E. I. Rosenberg,[64] P. L. Rosendahl,[13] L. Rosselet,[49] V. Rossetti,[11] E. Rossi,[102a,102b] L. P. Rossi,[50a] L. Rossi,[89a,89b] M. Rotaru,[25a] I. Roth,[171] J. Rothberg,[138] D. Rousseau,[115] C. R. Royon,[136] A. Rozanov,[83] Y. Rozen,[152] X. Ruan,[115] I. Rubinskiy,[41] B. Ruckert,[98] N. Ruckstuhl,[105] V. I. Rud,[97] G. Rudolph,[62] F. Rühr,[6] F. Ruggieri,[134a,134b] A. Ruiz-Martinez,[64] E. Rulikowska-Zarebska,[37] V. Rumiantsev,[91,a] L. Rumyantsev,[65] K. Runge,[48] O. Runolfsson,[20] Z. Rurikova,[48] N. A. Rusakovich,[65] D. R. Rust,[61] J. P. Rutherfoord,[6] C. Ruwiedel,[14] P. Ruzicka,[125] Y. F. Ryabov,[121] V. Ryadovikov,[128] P. Ryan,[88] M. Rybar,[126] G. Rybkin,[115] N. C. Ryder,[118] S. Rzaeva,[10] A. F. Saavedra,[150] I. Sadeh,[153] H. F.-W. Sadrozinski,[137] R. Sadykov,[65] F. Safai Tehrani,[132a,132b] H. Sakamoto,[155] G. Salamanna,[105] A. Salamon,[133a] M. Saleem,[111] D. Salihagic,[99] A. Salnikov,[143] J. Salt,[167] B. M. Salvachua Ferrando,[5] D. Salvatore,[36a,36b] F. Salvatore,[149] A. Salvucci,[104] A. Salzburger,[29] D. Sampsonidis,[154] B. H. Samset,[117] H. Sandaker,[13] H. G. Sander,[81] M. P. Sanders,[98] M. Sandhoff,[174] P. Sandhu,[158] T. Sandoval,[27] R. Sandstroem,[105] S. Sandvoss,[174] D. P. C. Sankey,[129] A. Sansoni,[47] C. Santamarina Rios,[85] C. Santoni,[33] R. Santonico,[133a,133b] H. Santos,[124a] J. G. Saraiva,[124a,c] T. Sarangi,[172] E. Sarkisyan-Grinbaum,[7] F. Sarri,[122a,122b] G. Sartisohn,[174] O. Sasaki,[66] T. Sasaki,[66] N. Sasao,[68] I. Satsounkevitch,[90] G. Sauvage,[4] J. B. Sauvan,[115] P. Savard,[158,e] V. Savinov,[123] D. O. Savu,[29] P. Savva,[9] L. Sawyer,[24,l] D. H. Saxon,[53] L. P. Says,[33] C. Sbarra,[19a,19b] A. Sbrizzi,[19a,19b] O. Scallon,[93] D. A. Scannicchio,[163] J. Schaarschmidt,[115] P. Schacht,[99] U. Schäfer,[81] S. Schaepe,[20] S. Schaetzel,[58b] A. C. Schaffer,[115] D. Schaile,[98] R. D. Schamberger,[148] A. G. Schamov,[107] V. Scharf,[58a] V. A. Schegelsky,[121] D. Scheirich,[87] M. I. Scherzer,[14] C. Schiavi,[50a,50b] J. Schieck,[98] M. Schioppa,[36a,36b] S. Schlenker,[29] J. L. Schlereth,[5] E. Schmidt,[48] M. P. Schmidt,[175,a] K. Schmieden,[20] C. Schmitt,[81] S. Schmitt,[58b] M. Schmitz,[20] A. Schöning,[58b] M. Schott,[29] D. Schouten,[142] J. Schovancova,[125] M. Schram,[85] C. Schroeder,[81] N. Schroer,[58c] S. Schuh,[29] G. Schuler,[29] J. Schultes,[174] H.-C. Schultz-Coulon,[58a] H. Schulz,[15] J. W. Schumacher,[20] M. Schumacher,[48] B. A. Schumm,[137] Ph. Schune,[136] C. Schwanenberger,[82] A. Schwartzman,[143] Ph. Schwemling,[78] R. Schwienhorst,[88] R. Schwierz,[43] J. Schwindling,[136] W. G. Scott,[129] J. Searcy,[114] E. Sedykh,[121] E. Segura,[11] S. C. Seidel,[103] A. Seiden,[137] F. Seifert,[43] J. M. Seixas,[23a] G. Sekhniaidze,[102a] D. M. Seliverstov,[121] B. Sellden,[146a] G. Sellers,[73] M. Seman,[144b] N. Semprini-Cesari,[19a,19b] C. Serfon,[98] L. Serin,[115] R. Seuster,[99] H. Severini,[111] M. E. Sevior,[86] A. Sfyrla,[29] E. Shabalina,[54] M. Shamim,[114] L. Y. Shan,[32a] J. T. Shank,[21] Q. T. Shao,[86] M. Shapiro,[14] P. B. Shatalov,[95] L. Shaver,[6] C. Shaw,[53] K. Shaw,[164a,164c] D. Sherman,[175] P. Sherwood,[77] A. Shibata,[108] S. Shimizu,[29] M. Shimojima,[100] T. Shin,[56] A. Shmeleva,[94] M. J. Shochet,[30] D. Short,[118] M. A. Shupe,[6] P. Sicho,[125] A. Sidoti,[132a,132b] A. Siebel,[174] F. Siegert,[48] J. Siegrist,[14] Dj. Sijacki,[12a] O. Silbert,[171] J. Silva,[124a,c] Y. Silver,[153] D. Silverstein,[143] S. B. Silverstein,[146a] V. Simak,[127] O. Simard,[136] Lj. Simic,[12a] S. Simion,[115] B. Simmons,[77] M. Simonyan,[35] P. Sinervo,[158] N. B. Sinev,[114] V. Sipica,[141] G. Siragusa,[81] A. N. Sisakyan,[65] S. Yu. Sivoklokov,[97]

J. Sjölin,[146a,146b] T. B. Sjursen,[13] L. A. Skinnari,[14] K. Skovpen,[107] P. Skubic,[111] N. Skvorodnev,[22] M. Slater,[17] T. Slavicek,[127] K. Sliwa,[161] T. J. Sloan,[71] J. Sloper,[29] V. Smakhtin,[171] S. Yu. Smirnov,[96] L. N. Smirnova,[97] O. Smirnova,[79] B. C. Smith,[57] D. Smith,[143] K. M. Smith,[53] M. Smizanska,[71] K. Smolek,[127] A. A. Snesarev,[94] S. W. Snow,[82] J. Snow,[111] J. Snuverink,[105] S. Snyder,[24] M. Soares,[124a] R. Sobie,[169,j] J. Sodomka,[127] A. Soffer,[153] C. A. Solans,[167] M. Solar,[127] J. Solc,[127] E. Soldatov,[96] U. Soldevila,[167] E. Solfaroli Camillocci,[132a,132b] A. A. Solodkov,[128] O. V. Solovyanov,[128] J. Sondericker,[24] N. Soni,[2] V. Sopko,[127] B. Sopko,[127] M. Sorbi,[89a,89b] M. Sosebee,[7] A. Soukharev,[107] S. Spagnolo,[72a,72b] F. Spanò,[34] R. Spighi,[19a] G. Spigo,[29] F. Spila,[132a,132b] E. Spiriti,[134a] R. Spiwoks,[29] M. Spousta,[126] T. Spreitzer,[158] B. Spurlock,[7] R. D. St. Denis,[53] T. Stahl,[141] J. Stahlman,[120] R. Stamen,[58a] E. Stanecka,[29] R. W. Stanek,[5] C. Stanescu,[134a] S. Stapnes,[117] E. A. Starchenko,[128] J. Stark,[55] P. Staroba,[125] P. Starovoitov,[91] A. Staude,[98] P. Stavina,[144a] G. Stavropoulos,[14] G. Steele,[53] P. Steinbach,[43] P. Steinberg,[24] I. Stekl,[127] B. Stelzer,[142] H. J. Stelzer,[41] O. Stelzer-Chilton,[159a] H. Stenzel,[52] K. Stevenson,[75] G. A. Stewart,[53] J. A. Stillings,[20] T. Stockmanns,[20] M. C. Stockton,[29] K. Stoerig,[48] G. Stoicea,[25a] S. Stonjek,[99] P. Strachota,[126] A. R. Stradling,[7] A. Straessner,[43] J. Strandberg,[147] S. Strandberg,[146a,146b] A. Strandlie,[117] M. Strang,[109] E. Strauss,[143] M. Strauss,[111] P. Strizenec,[144b] R. Ströhmer,[173] D. M. Strom,[114] J. A. Strong,[76,a] R. Stroynowski,[39] J. Strube,[129] B. Stugu,[13] I. Stumer,[24,a] J. Stupak,[148] P. Sturm,[174] D. A. Soh,[151,q] D. Su,[143] HS. Subramania,[2] A. Succurro,[11] Y. Sugaya,[116] T. Sugimoto,[101] C. Suhr,[106] K. Suita,[67] M. Suk,[126] V. V. Sulin,[94] S. Sultansoy,[3d] T. Sumida,[29] X. Sun,[55] J. E. Sundermann,[48] K. Suruliz,[164a,164b] S. Sushkov,[11] G. Susinno,[36a,36b] M. R. Sutton,[139] Y. Suzuki,[66] M. Svatos,[125] Yu. M. Sviridov,[128] S. Swedish,[168] I. Sykora,[144a] T. Sykora,[126] B. Szeless,[29] J. Sánchez,[167] D. Ta,[105] K. Tackmann,[41] A. Taffard,[163] R. Tafirout,[159a] A. Taga,[117] N. Taiblum,[153] Y. Takahashi,[101] H. Takai,[24] R. Takashima,[69] H. Takeda,[67] T. Takeshita,[140] M. Talby,[83] A. Talyshev,[107] M. C. Tamsett,[24] J. Tanaka,[155] R. Tanaka,[115] S. Tanaka,[131] S. Tanaka,[66] Y. Tanaka,[100] K. Tani,[67] N. Tannoury,[83] G. P. Tappern,[29] S. Tapprogge,[81] D. Tardif,[158] S. Tarem,[152] F. Tarrade,[24] G. F. Tartarelli,[89a] P. Tas,[126] M. Tasevsky,[125] E. Tassi,[36a,36b] M. Tatarkhanov,[14] C. Taylor,[77] F. E. Taylor,[92] G. N. Taylor,[86] W. Taylor,[159b] M. Teixeira Dias Castanheira,[75] P. Teixeira-Dias,[76] K. K. Temming,[48] H. Ten Kate,[29] P. K. Teng,[151] S. Terada,[66] K. Terashi,[155] J. Terron,[80] M. Terwort,[41,o] M. Testa,[47] R. J. Teuscher,[158,j] J. Thadome,[174] J. Therhaag,[20] T. Theveneaux-Pelzer,[78] M. Thioye,[175] S. Thoma,[48] J. P. Thomas,[17] E. N. Thompson,[84] P. D. Thompson,[17] P. D. Thompson,[158] A. S. Thompson,[53] E. Thomson,[120] M. Thomson,[27] R. P. Thun,[87] T. Tic,[125] V. O. Tikhomirov,[94] Y. A. Tikhonov,[107] C. J. W. P. Timmermans,[104] P. Tipton,[175] F. J. Tique Aires Viegas,[29] S. Tisserant,[83] J. Tobias,[48] B. Toczek,[37] T. Todorov,[4] S. Todorova-Nova,[161] B. Toggerson,[163] J. Tojo,[66] S. Tokár,[144a] K. Tokunaga,[67] K. Tokushuku,[66] K. Tollefson,[88] M. Tomoto,[101] L. Tompkins,[14] K. Toms,[103] G. Tong,[32a] A. Tonoyan,[13] C. Topfel,[16] N. D. Topilin,[65] I. Torchiani,[29] E. Torrence,[114] E. Torró Pastor,[167] J. Toth,[83,y] F. Touchard,[83] D. R. Tovey,[139] D. Traynor,[75] T. Trefzger,[173] J. Treis,[20] L. Tremblet,[29] A. Tricoli,[29] I. M. Trigger,[159a] S. Trincaz-Duvoid,[78] T. N. Trinh,[78] M. F. Tripiana,[70] N. Triplett,[64] W. Trischuk,[158] A. Trivedi,[24,x] B. Trocmé,[55] C. Troncon,[89a] M. Trottier-McDonald,[142] A. Trzupek,[38] C. Tsarouchas,[29] J. C-L. Tseng,[118] M. Tsiakiris,[105] P. V. Tsiareshka,[90] D. Tsionou,[4] G. Tsipolitis,[9] V. Tsiskaridze,[48] E. G. Tskhadadze,[51] I. I. Tsukerman,[95] V. Tsulaia,[123] J.-W. Tsung,[20] S. Tsuno,[66] D. Tsybychev,[148] A. Tua,[139] J. M. Tuggle,[30] M. Turala,[38] D. Turecek,[127] I. Turk Cakir,[3e] E. Turlay,[105] R. Turra,[89a,89b] P. M. Tuts,[34] A. Tykhonov,[74] M. Tylmad,[146a,146b] M. Tyndel,[129] H. Tyrvainen,[29] G. Tzanakos,[8] K. Uchida,[20] I. Ueda,[155] R. Ueno,[28] M. Ugland,[13] M. Uhlenbrock,[20] M. Uhrmacher,[54] F. Ukegawa,[160] G. Unal,[29] D. G. Underwood,[5] A. Undrus,[24] G. Unel,[163] Y. Unno,[66] D. Urbaniec,[34] E. Urkovsky,[153] P. Urrejola,[31a] G. Usai,[7] M. Uslenghi,[119a,119b] L. Vacavant,[83] V. Vacek,[127] B. Vachon,[85] S. Vahsen,[14] J. Valenta,[125] P. Valente,[132a] S. Valentinetti,[19a,19b] S. Valkar,[126] E. Valladolid Gallego,[167] S. Vallecorsa,[152] J. A. Valls Ferrer,[167] H. van der Graaf,[105] E. van der Kraaij,[105] R. Van Der Leeuw,[105] E. van der Poel,[105] D. van der Ster,[29] B. Van Eijk,[105] N. van Eldik,[84] P. van Gemmeren,[5] Z. van Kesteren,[105] I. van Vulpen,[105] W. Vandelli,[29] G. Vandoni,[29] A. Vaniachine,[5] P. Vankov,[41] F. Vannucci,[78] F. Varela Rodriguez,[29] R. Vari,[132a] E. W. Varnes,[6] D. Varouchas,[14] A. Vartapetian,[7] K. E. Varvell,[150] V. I. Vassilakopoulos,[56] F. Vazeille,[33] G. Vegni,[89a,89b] J. J. Veillet,[115] C. Vellidis,[8] F. Veloso,[124a] R. Veness,[29] S. Veneziano,[132a] A. Ventura,[72a,72b] D. Ventura,[138] M. Venturi,[48] N. Venturi,[16] V. Vercesi,[119a] M. Verducci,[138] W. Verkerke,[105] J. C. Vermeulen,[105] A. Vest,[43] M. C. Vetterli,[142,e] I. Vichou,[165] T. Vickey,[145b,aa] G. H. A. Viehhauser,[118] S. Viel,[168] M. Villa,[19a,19b] M. Villaplana Perez,[167] E. Vilucchi,[47] M. G. Vincter,[28] E. Vinek,[29] V. B. Vinogradov,[65] M. Virchaux,[136,a] S. Viret,[33] J. Virzi,[14] A. Vitale,[19a,19b] O. Vitells,[171] M. Viti,[41] I. Vivarelli,[48] F. Vives Vaque,[11] S. Vlachos,[9] M. Vlasak,[127] N. Vlasov,[20] A. Vogel,[20] P. Vokac,[127] G. Volpi,[47] M. Volpi,[11] G. Volpini,[89a] H. von der Schmitt,[99] J. von Loeben,[99] H. von Radziewski,[48] E. von Toerne,[20]

V. Vorobel,[126] A. P. Vorobiev,[128] V. Vorwerk,[11] M. Vos,[167] R. Voss,[29] T. T. Voss,[174] J. H. Vossebeld,[73] N. Vranjes,[12a] M. Vranjes Milosavljevic,[12a] V. Vrba,[125] M. Vreeswijk,[105] T. Vu Anh,[81] R. Vuillermet,[29] I. Vukotic,[115] W. Wagner,[174] P. Wagner,[120] H. Wahlen,[174] J. Wakabayashi,[101] J. Walbersloh,[42] S. Walch,[87] J. Walder,[71] R. Walker,[98] W. Walkowiak,[141] R. Wall,[175] P. Waller,[73] C. Wang,[44] H. Wang,[172] H. Wang,[32b] J. Wang,[151] J. Wang,[32d] J. C. Wang,[138] R. Wang,[103] S. M. Wang,[151] A. Warburton,[85] C. P. Ward,[27] M. Warsinsky,[48] P. M. Watkins,[17] A. T. Watson,[17] M. F. Watson,[17] G. Watts,[138] S. Watts,[82] A. T. Waugh,[150] B. M. Waugh,[77] J. Weber,[42] M. Weber,[129] M. S. Weber,[16] P. Weber,[54] A. R. Weidberg,[118] P. Weigell,[99] J. Weingarten,[54] C. Weiser,[48] H. Wellenstein,[22] P. S. Wells,[29] M. Wen,[47] T. Wenaus,[24] S. Wendler,[123] Z. Weng,[151,q] T. Wengler,[29] S. Wenig,[29] N. Wermes,[20] M. Werner,[48] P. Werner,[29] M. Werth,[163] M. Wessels,[58a] C. Weydert,[55] K. Whalen,[28] S. J. Wheeler-Ellis,[163] S. P. Whitaker,[21] A. White,[7] M. J. White,[86] S. White,[24] S. R. Whitehead,[118] D. Whiteson,[163] D. Whittington,[61] F. Wicek,[115] D. Wicke,[174] F. J. Wickens,[129] W. Wiedenmann,[172] M. Wielers,[129] P. Wienemann,[20] C. Wiglesworth,[73] L. A. M. Wiik,[48] P. A. Wijeratne,[77] A. Wildauer,[167] M. A. Wildt,[41,o] I. Wilhelm,[126] H. G. Wilkens,[29] J. Z. Will,[98] E. Williams,[34] H. H. Williams,[120] W. Willis,[34] S. Willocq,[84] J. A. Wilson,[17] M. G. Wilson,[143] A. Wilson,[87] I. Wingerter-Seez,[4] S. Winkelmann,[48] F. Winklmeier,[29] M. Wittgen,[143] M. W. Wolter,[38] H. Wolters,[124a,h] G. Wooden,[118] B. K. Wosiek,[38] J. Wotschack,[29] M. J. Woudstra,[84] K. Wraight,[53] C. Wright,[53] B. Wrona,[73] S. L. Wu,[172] X. Wu,[49] Y. Wu,[32b] E. Wulf,[34] R. Wunstorf,[42] B. M. Wynne,[45] L. Xaplanteris,[9] S. Xella,[35] S. Xie,[48] Y. Xie,[32a] C. Xu,[32b] D. Xu,[139] G. Xu,[32a] B. Yabsley,[150] M. Yamada,[66] A. Yamamoto,[66] K. Yamamoto,[64] S. Yamamoto,[155] T. Yamamura,[155] J. Yamaoka,[44] T. Yamazaki,[155] Y. Yamazaki,[67] Z. Yan,[21] H. Yang,[87] U. K. Yang,[82] Y. Yang,[61] Y. Yang,[32a] Z. Yang,[146a,146b] S. Yanush,[91] W-M. Yao,[14] Y. Yao,[14] Y. Yasu,[66] G. V. Ybeles Smit,[130] J. Ye,[39] S. Ye,[24] M. Yilmaz,[3c] R. Yoosoofmiya,[123] K. Yorita,[170] R. Yoshida,[5] C. Young,[143] S. Youssef,[21] D. Yu,[24] J. Yu,[7] J. Yu,[32c,bb] L. Yuan,[32a,cc] A. Yurkewicz,[148] V. G. Zaets,[128] R. Zaidan,[63] A. M. Zaitsev,[128] Z. Zajacova,[29] Yo. K. Zalite,[121] L. Zanello,[132a,132b] P. Zarzhitsky,[39] A. Zaytsev,[107] C. Zeitnitz,[174] M. Zeller,[175] A. Zemla,[38] C. Zendler,[20] A. V. Zenin,[128] O. Zenin,[128] T. Ženiš,[144a] Z. Zenonos,[122a,122b] S. Zenz,[14] D. Zerwas,[115] G. Zevi della Porta,[57] Z. Zhan,[32d] D. Zhang,[32b] H. Zhang,[88] J. Zhang,[5] X. Zhang,[32d] Z. Zhang,[115] L. Zhao,[108] T. Zhao,[138] Z. Zhao,[32b] A. Zhemchugov,[65] S. Zheng,[32a] J. Zhong,[151,dd] B. Zhou,[87] N. Zhou,[163] Y. Zhou,[151] C. G. Zhu,[32d] H. Zhu,[41] Y. Zhu,[172] X. Zhuang,[98] V. Zhuravlov,[99] D. Zieminska,[61] R. Zimmermann,[20] S. Zimmermann,[20] S. Zimmermann,[48] M. Ziolkowski,[141] R. Zitoun,[4] L. Živković,[34] V. V. Zmouchko,[128,a] G. Zobernig,[172] A. Zoccoli,[19a,19b] Y. Zolnierowski,[4] A. Zsenei,[29] M. zur Nedden,[15] V. Zutshi,[106] and L. Zwalinski[29]

(ATLAS Collaboration)

[1]*University at Albany, Albany, New York, USA*
[2]*Department of Physics, University of Alberta, Edmonton, Alberta, Canada*
[3a]*Department of Physics, Ankara University, Ankara, Turkey*
[3b]*Department of Physics, Dumlupinar University, Kutahya, Turkey*
[3c]*Department of Physics, Gazi University, Ankara, Turkey*
[3d]*Division of Physics, TOBB University of Economics and Technology, Ankara, Turkey*
[3e]*Turkish Atomic Energy Authority, Ankara, Turkey*
[4]*LAPP, CNRS/IN2P3 and Université de Savoie, Annecy-le-Vieux, France*
[5]*High Energy Physics Division, Argonne National Laboratory, Argonne, Illinois, USA*
[6]*Department of Physics, University of Arizona, Tucson, Arizona, USA*
[7]*Department of Physics, The University of Texas at Arlington, Arlington, Texas, USA*
[8]*Physics Department, University of Athens, Athens, Greece*
[9]*Physics Department, National Technical University of Athens, Zografou, Greece*
[10]*Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan*
[11]*Institut de Física d'Altes Energies and Universitat Autònoma de Barcelona and ICREA, Barcelona, Spain*
[12a]*Institute of Physics, University of Belgrade, Belgrade, Serbia*
[12b]*Vinca Institute of Nuclear Sciences, Belgrade, Serbia*
[13]*Department for Physics and Technology, University of Bergen, Bergen, Norway*
[14]*Physics Division, Lawrence Berkeley National Laboratory and University of California, Berkeley, California, USA*
[15]*Department of Physics, Humboldt University, Berlin, Germany*
[16]*Albert Einstein Center for Fundamental Physics and Laboratory for High Energy Physics, University of Bern, Bern, Switzerland*
[17]*School of Physics and Astronomy, University of Birmingham, Birmingham, United Kingdom*
[18a]*Department of Physics, Bogazici University, Istanbul, Turkey*
[18b]*Division of Physics, Dogus University, Istanbul, Turkey*

[18c]*Department of Physics Engineering, Gaziantep University, Gaziantep, Turkey*
[18d]*Department of Physics, Istanbul Technical University, Istanbul, Turkey*
[19a]*INFN Sezione di Bologna, Bologna, Italy*
[19b]*Dipartimento di Fisica, Università di Bologna, Bologna, Italy*
[20]*Physikalisches Institut, University of Bonn, Bonn, Germany*
[21]*Department of Physics, Boston University, Boston, Massachusetts, USA*
[22]*Department of Physics, Brandeis University, Waltham, Massachusetts, USA*
[23a]*Universidade Federal do Rio de Janeiro COPPE/EE/IF, Rio de Janeiro, Brazil*
[23b]*Instituto de Fisica, Universidade de Sao Paulo, Sao Paulo, Brazil*
[24]*Physics Department, Brookhaven National Laboratory, Upton, New York, USA*
[25a]*National Institute of Physics and Nuclear Engineering, Bucharest, Romania*
[25b]*University Politehnica Bucharest, Bucharest, Romania*
[25c]*West University in Timisoara, Timisoara, Romania*
[26]*Departamento de Física, Universidad de Buenos Aires, Buenos Aires, Argentina*
[27]*Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom*
[28]*Department of Physics, Carleton University, Ottawa, Ontario, Canada*
[29]*CERN, Geneva, Switzerland*
[30]*Enrico Fermi Institute, University of Chicago, Chicago, Illinois, USA*
[31a]*Departamento de Fisica, Pontificia Universidad Católica de Chile, Santiago, Chile*
[31b]*Departamento de Física, Universidad Técnica Federico Santa María, Valparaíso, Chile*
[32a]*Institute of High Energy Physics, Chinese Academy of Sciences, Beijing, China*
[32b]*Department of Modern Physics, University of Science and Technology of China, Anhui, China*
[32c]*Department of Physics, Nanjing University, Jiangsu, China*
[32d]*High Energy Physics Group, Shandong University, Shandong, China*
[33]*Laboratoire de Physique Corpusculaire, Clermont Université and Université Blaise Pascal and CNRS/IN2P3, Aubiere cedex, France*
[34]*Nevis Laboratory, Columbia University, Irvington, New York, USA*
[35]*Niels Bohr Institute, University of Copenhagen, Kobenhavn, Denmark*
[36a]*INFN Gruppo Collegato di Cosenza, Cosenza, Italy*
[36b]*Dipartimento di Fisica, Università della Calabria, Arcavata di Rende, Italy*
[37]*Faculty of Physics and Applied Computer Science, AGH-University of Science and Technology, Krakow, Poland*
[38]*The Henryk Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences, Krakow, Poland*
[39]*Physics Department, Southern Methodist University, Dallas, Texas, USA*
[40]*Physics Department, University of Texas at Dallas, Richardson, Texas, USA*
[41]*DESY, Hamburg and Zeuthen, Germany*
[42]*Institut für Experimentelle Physik IV, Technische Universität Dortmund, Dortmund, Germany*
[43]*Institut für Kern- und Teilchenphysik, Technical University Dresden, Dresden, Germany*
[44]*Department of Physics, Duke University, Durham, North Carolina, USA*
[45]*SUPA—School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom*
[46]*Fachhochschule Wiener Neustadt, Wiener Neustadt, Austria*
[47]*INFN Laboratori Nazionali di Frascati, Frascati, Italy*
[48]*Fakultät für Mathematik und Physik, Albert-Ludwigs-Universität, Freiburg i.Br., Germany*
[49]*Section de Physique, Université de Genève, Geneva, Switzerland*
[50a]*INFN Sezione di Genova, Genova, Italy*
[50b]*Dipartimento di Fisica, Università di Genova, Genova, Italy*
[51]*Institute of Physics and HEP Institute, Georgian Academy of Sciences and Tbilisi State University, Tbilisi, Georgia*
[52]*II Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen, Germany*
[53]*SUPA—School of Physics and Astronomy, University of Glasgow, Glasgow, United Kingdom*
[54]*II Physikalisches Institut, Georg-August-Universität, Göttingen, Germany*
[55]*Laboratoire de Physique Subatomique et de Cosmologie, Université Joseph Fourier and CNRS/IN2P3 and Institut National Polytechnique de Grenoble, Grenoble, France*
[56]*Department of Physics, Hampton University, Hampton, Virginia, ,USA*
[57]*Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge, Massachusetts, USA*
[58a]*Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany*
[58b]*Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany*
[58c]*ZITI Institut für technische Informatik, Ruprecht-Karls-Universität Heidelberg, Mannheim, Germany*
[59]*Faculty of Science, Hiroshima University, Hiroshima, Japan*
[60]*Faculty of Applied Information Science, Hiroshima Institute of Technology, Hiroshima, Japan*
[61]*Department of Physics, Indiana University, Bloomington, Indiana, USA*
[62]*Institut für Astro- und Teilchenphysik, Leopold-Franzens-Universität, Innsbruck, Austria*
[63]*University of Iowa, Iowa City, Iowa, USA*

[64]Department of Physics and Astronomy, Iowa State University, Ames, Iowa, USA
[65]Joint Institute for Nuclear Research, JINR Dubna, Dubna, Russia
[66]KEK, High Energy Accelerator Research Organization, Tsukuba, Japan
[67]Graduate School of Science, Kobe University, Kobe, Japan
[68]Faculty of Science, Kyoto University, Kyoto, Japan
[69]Kyoto University of Education, Kyoto, Japan
[70]Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata, Argentina
[71]Physics Department, Lancaster University, Lancaster, United Kingdom
[72a]INFN Sezione di Lecce, Lecce, Italy
[72b]Dipartimento di Fisica, Università del Salento, Lecce, Italy
[73]Oliver Lodge Laboratory, University of Liverpool, Liverpool, United Kingdom
[74]Department of Physics, Jožef Stefan Institute and University of Ljubljana, Ljubljana, Slovenia
[75]Department of Physics, Queen Mary University of London, London, United Kingdom
[76]Department of Physics, Royal Holloway University of London, Surrey, United Kingdom
[77]Department of Physics and Astronomy, University College London, London, United Kingdom
[78]Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France
[79]Fysiska institutionen, Lunds Universitet, Lund, Sweden
[80]Departamento de Fisica Teorica C-15, Universidad Autonoma de Madrid, Madrid, Spain
[81]Institut für Physik, Universität Mainz, Mainz, Germany
[82]School of Physics and Astronomy, University of Manchester, Manchester, United Kingdom
[83]CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France
[84]Department of Physics, University of Massachusetts, Amherst, Massachusetts, USA
[85]Department of Physics, McGill University, Montreal, Quebec, Canada
[86]School of Physics, University of Melbourne, Victoria, Australia
[87]Department of Physics, The University of Michigan, Ann Arbor, Michigan, USA
[88]Department of Physics and Astronomy, Michigan State University, East Lansing Michigan, USA
[89a]INFN Sezione di Milano, Milano, Italy
[89b]Dipartimento di Fisica, Università di Milano, Milano, Italy
[90]B. I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk, Republic of Belarus
[91]National Scientific and Educational Centre for Particle and High Energy Physics, Minsk, Republic of Belarus
[92]Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA
[93]Group of Particle Physics, University of Montreal, Montreal, Quebec, Canada
[94]P. N. Lebedev Institute of Physics, Academy of Sciences, Moscow, Russia
[95]Institute for Theoretical and Experimental Physics, Moscow, Russia
[96]Moscow Engineering and Physics Institute, Moscow, Russia
[97]Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia
[98]Fakultät für Physik, Ludwig-Maximilians-Universität München, München, Germany
[99]Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), München, Germany
[100]Nagasaki Institute of Applied Science, Nagasaki, Japan
[101]Graduate School of Science, Nagoya University, Nagoya, Japan
[102a]INFN Sezione di Napoli, Napoli, Italy
[102b]Dipartimento di Scienze Fisiche, Università di Napoli, Napoli, Italy
[103]Department of Physics and Astronomy, University of New Mexico, Albuquerque, New Mexico, USA
[104]Institute for Mathematics, Astrophysics and Particle Physics, Radboud University Nijmegen/Nikhef, Nijmegen, The Netherlands
[105]Nikhef National Institute for Subatomic Physics and University of Amsterdam, Amsterdam, The Netherlands
[106]Department of Physics, Northern Illinois University, DeKalb, Illinois, USA
[107]Budker Institute of Nuclear Physics, Novosibirsk, Russia
[108]Department of Physics, New York University, New York, New York, USA
[109]Ohio State University, Columbus, Ohio, USA
[110]Faculty of Science, Okayama University, Okayama, Japan
[111]Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman, Oklahoma, USA
[112]Department of Physics, Oklahoma State University, Stillwater, Oklahoma, USA
[113]Palacký University, RCPTM, Olomouc, Czech Republic
[114]Center for High Energy Physics, University of Oregon, Eugene, Oregon, USA
[115]LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France
[116]Graduate School of Science, Osaka University, Osaka, Japan
[117]Department of Physics, University of Oslo, Oslo, Norway
[118]Department of Physics, Oxford University, Oxford, United Kingdom
[119a]INFN Sezione di Pavia, Pavia, Italy
[119b]Dipartimento di Fisica Nucleare e Teorica, Università di Pavia, Pavia, Italy
[120]Department of Physics, University of Pennsylvania, Philadelphia, Pennsylvania, USA

[121]*Petersburg Nuclear Physics Institute, Gatchina, Russia*
[122a]*INFN Sezione di Pisa, Pisa, Italy*
[122b]*Dipartimento di Fisica E. Fermi, Università di Pisa, Pisa, Italy*
[123]*Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh, Pennsylvania, USA*
[124a]*Laboratorio de Instrumentacao e Fisica Experimental de Particulas, Lisboa, Portugal*
[124b]*Departamento de Fisica Teorica y del Cosmos and CAFPE, Universidad de Granada, Granada, Portugal*
[125]*Institute of Physics, Academy of Sciences of the Czech Republic, Praha, Czech Republic*
[126]*Faculty of Mathematics and Physics, Charles University in Prague, Praha, Czech Republic*
[127]*Czech Technical University in Prague, Praha, Czech Republic*
[128]*State Research Center Institute for High Energy Physics, Protvino, Russia*
[129]*Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom*
[130]*Physics Department, University of Regina, Regina, Saskatchewan, Canada*
[131]*Ritsumeikan University, Kusatsu, Shiga, Japan*
[132a]*INFN Sezione di Roma I, Roma, Italy*
[132b]*Dipartimento di Fisica, Università La Sapienza, Roma, Italy*
[133a]*INFN Sezione di Roma Tor Vergata, Roma, Italy*
[133b]*Dipartimento di Fisica, Università di Roma Tor Vergata, Roma, Italy*
[134a]*INFN Sezione di Roma Tre, Roma, Italy*
[134b]*Dipartimento di Fisica, Università Roma Tre, Roma, Italy*
[135a]*Faculté des Sciences Ain Chock, Réseau Universitaire de Physique des Hautes Energies—Université Hassan II, Casablanca, Morocco*
[135b]*Centre National de l'Energie des Sciences Techniques Nucleaires, Rabat, Morocco*
[135c]*Université Cadi Ayyad, Faculté des Sciences Semlalia Département de Physique, B.P. 2390 Marrakech 40000, Morocco*
[135d]*Faculté des Sciences, Université Mohamed Premier and LPTPM, Oujda, Morocco*
[135e]*Faculté des Sciences, Université Mohammed V, Rabat, Morocco*
[136]*DSM/IRFU, CEA Saclay, Gif-sur-Yvette, France*
[137]*Santa Cruz Institute for Particle Physics, University of California Santa Cruz, Santa Cruz, California, USA*
[138]*Department of Physics, University of Washington, Seattle, Washington, USA*
[139]*Department of Physics and Astronomy, University of Sheffield, Sheffield, United Kingdom*
[140]*Department of Physics, Shinshu University, Nagano, Japan*
[141]*Fachbereich Physik, Universität Siegen, Siegen, Germany*
[142]*Department of Physics, Simon Fraser University, Burnaby, British Columbia, Canada*
[143]*SLAC National Accelerator Laboratory, Stanford, California, USA*
[144a]*Faculty of Mathematics, Physics and Informatics, Comenius University, Bratislava, Slovak Republic*
[144b]*Department of Subnuclear Physics, Institute of Experimental Physics of the Slovak Academy of Sciences, Kosice, Slovak Republic*
[145a]*Department of Physics, University of Johannesburg, Johannesburg, South Africa*
[145b]*School of Physics, University of the Witwatersrand, Johannesburg, South Africa*
[146a]*Department of Physics, Stockholm UniversityStockholm, Sweden*
[146b]*The Oskar Klein Centre, Stockholm, Sweden*
[147]*Physics Department, Royal Institute of Technology, Stockholm, Sweden*
[148]*Department of Physics and Astronomy, Stony Brook University, Stony Brook, New York, USA*
[149]*Department of Physics and Astronomy, University of Sussex, Brighton, United Kingdom*
[150]*School of Physics, University of Sydney, Sydney, Australia*
[151]*Institute of Physics, Academia Sinica, Taipe, Taiwan*
[152]*Department of Physics, Technion: Israel Institute of Technology, Haifa, Israel*
[153]*Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel*
[154]*Department of Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece*
[155]*International Center for Elementary Particle Physics and Department of Physics, The University of Tokyo, Tokyo, Japan*
[156]*Graduate School of Science and Technology, Tokyo Metropolitan University, Tokyo, Japan*
[157]*Department of Physics, Tokyo Institute of Technology, Tokyo, Japan*
[158]*Department of Physics, University of Toronto, Toronto, Ontario, Canada*
[159a]*TRIUMF, Vancouver, British Columbia, Canada*
[159b]*Department of Physics and Astronomy, York University, Toronto, Ontario, Canada*
[160]*Institute of Pure and Applied Sciences, University of Tsukuba, Ibaraki, Japan*
[161]*Science and Technology Center, Tufts University, Medford, Massachusetts, USA*
[162]*Centro de Investigaciones, Universidad Antonio Narino, Bogota, Colombia*
[163]*Department of Physics and Astronomy, University of California Irvine, Irvine, California, USA*
[164a]*INFN Gruppo Collegato di Udine, Udine, Italy*
[164b]*ICTP, Trieste, Italy*
[164c]*Dipartimento di Fisica, Università di Udine, Udine, Italy*

[165]*Department of Physics, University of Illinois, Urbana, Illinois, USA*
[166]*Department of Physics and Astronomy, University of Uppsala, Uppsala, Sweden*
[167]*Instituto de Física Corpuscular and Departamento de Física Atómica, Molecular y Nuclear and Departamento de Ingenierá Electrónica and Instituto de Microelectrónica de Barcelona, University of Valencia and CSIC, Valencia, Spain*
[168]*Department of Physics, University of British Columbia, Vancouver, British Columbia, Canada*
[169]*Department of Physics and Astronomy, University of Victoria, Victoria, British Columbia, Canada*
[170]*Waseda University, Tokyo, Japan*
[171]*Department of Particle Physics, The Weizmann Institute of Science, Rehovot, Israel*
[172]*Department of Physics, University of Wisconsin, Madison, Wisconsin, USA*
[173]*Fakultät für Physik und Astronomie, Julius-Maximilians-Universität, Würzburg, Germany*
[174]*Fachbereich C Physik, Bergische Universität Wuppertal, Wuppertal, Germany*
[175]*Department of Physics, Yale University, New Haven, Connecticut, USA*
[176]*Yerevan Physics Institute, Yerevan, Armenia*
[177]*Domaine scientifique de la Doua, Centre de Calcul CNRS/IN2P3, Villeurbanne cedex, France*

[z]Deceased.
[a]Also at Laboratorio de Instrumentacao e Fisica Experimental de Particulas, Lisboa, Portugal.
[b]Also at Faculdade de Ciencias and CFNUL, Universidade de Lisboa, Lisboa, Portugal.
[c]Also at CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France.
[d]Also at TRIUMF, Vancouver, British Columbia, Canada.
[e]Also at Department of Physics, California State University, Fresno, CA, USA.
[f]Also at Faculty of Physics and Applied Computer Science, AGH-University of Science and Technology, Krakow, Poland.
[g]Also at Department of Physics, University of Coimbra, Coimbra, Portugal.
[h]Also at Università di Napoli Parthenope, Napoli, Italy
[i]Also at Institute of Particle Physics, Canada.
[j]Also at Department of Physics, Middle East Technical University, Ankara, Turkey.
[k]Also at Louisiana Tech University, Ruston, LA, USA.
[l]Also at Group of Particle Physics, University of Montreal, Montreal, Quebec, Canada.
[m]Also at Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan.
[n]Also at Institut für Experimentalphysik, Universität Hamburg, Hamburg, Germany.
[o]Also at Manhattan College, New York, NY, USA.
[p]Also at School of Physics and Engineering, Sun Yat-sen University, Guanzhou, China.
[q]Also at Academia Sinica Grid Computing, Institute of Physics, Academia Sinica, Taipei, Taiwan.
[r]Also at High Energy Physics Group, Shandong University, Shandong, China.
[s]Also at California Institute of Technology, Pasadena, CA, USA.
[t]Also at Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom.
[u]Also at Section de Physique, Université de Genève, Geneva, Switzerland.
[v]Also at Departamento de Fisica, Universidade de Minho, Braga, Portugal.
[w]Also at Department of Physics and Astronomy, University of South Carolina, Columbia, SC, USA.
[x]Also at KFKI Research Institute for Particle and Nuclear Physics, Budapest, Hungary.
[y]Also at Institute of Physics, Jagiellonian University, Krakow, Poland.
[z]Also at Department of Physics, Oxford University, Oxford, United Kingdom.
[aa]Also at DSM/IRFU, CEA Saclay, Gif-sur-Yvette, France.
[bb]Also at Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France.
[cc]Also at Department of Physics, Nanjing University, Jiangsu, China.