



Measurement of the ZZ Production Cross Section in pp Collisions at $\sqrt{s}=13$ TeV with the ATLAS Detector

Aad, G.; Abbott, B.; Abdallah, J.; Abdinov, O.; Abeloos, B; Aben, R.; Abolins, M.; AbouZeid, O.S.; Abramowicz, H.; Abreu, H.; Abreu, R.; Acharya, B.S.; Adamczyk, L.; Dam, Mogens; Hansen, Jørn Dines; Hansen, Jørgen Beck; Xella, Stefania; Hansen, Peter Henrik; Petersen, Troels Christian; Thomsen, Lotte Ansgaard; Pingel, Almut Maria; Løvschall-Jensen, Ask Emil; Alonso Diaz, Alejandro; Monk, James William; Pedersen, Lars Egholm; Wiglesworth, Graig; Galster, Gorm Aske Gram Krohn

Published in:
Physical Review Letters

DOI:
[10.1103/PhysRevLett.116.101801](https://doi.org/10.1103/PhysRevLett.116.101801)

Publication date:
2016

Document version
Publisher's PDF, also known as Version of record

Citation for published version (APA):
Aad, G., Abbott, B., Abdallah, J., Abdinov, O., Abeloos, B., Aben, R., ... Galster, G. A. G. K. (2016). Measurement of the ZZ Production Cross Section in pp Collisions at $\sqrt{s}=13$ TeV with the ATLAS Detector. *Physical Review Letters*, 116(10), [101801]. <https://doi.org/10.1103/PhysRevLett.116.101801>

Measurement of the ZZ Production Cross Section in pp Collisions at $\sqrt{s} = 13$ TeV with the ATLAS Detector

G. Aad *et al.**

(ATLAS Collaboration)

(Received 17 December 2015; published 10 March 2016)

The ZZ production cross section in proton-proton collisions at 13 TeV center-of-mass energy is measured using 3.2 fb^{-1} of data recorded with the ATLAS detector at the Large Hadron Collider. The considered Z boson candidates decay to an electron or muon pair of mass 66–116 GeV. The cross section is measured in a fiducial phase space reflecting the detector acceptance. It is also extrapolated to a total phase space for Z bosons in the same mass range and of all decay modes, giving $16.7^{+2.2}_{-2.0}(\text{stat})^{+0.9}_{-0.7}(\text{syst})^{+1.0}_{-0.7}(\text{lumi})$ pb. The results agree with standard model predictions.

DOI: 10.1103/PhysRevLett.116.101801

Studying the production of pairs of Z bosons in proton-proton (pp) interactions at the Large Hadron Collider (LHC) tests the electroweak sector of the standard model (SM) at the highest available energies. In pp collisions at a center-of-mass energy of $\sqrt{s} = 13$ TeV, ZZ production is dominated by quark-antiquark ($q\bar{q}$) interactions, with an $\mathcal{O}(10\%)$ contribution from loop-induced gluon-gluon (gg) interactions [1,2]. The SM ZZ production can proceed via a Higgs boson propagator, although this contribution is suppressed in the region where both Z bosons are produced on-shell. As such, non-Higgs ZZ production is an important background in studies of the Higgs boson [3–5]. It is also a background in searches for new physics producing pairs of Z bosons at high invariant mass [6,7] and sensitive to triple neutral-gauge-boson couplings, which are not allowed in the SM [8].

This Letter presents the first measurement of the ZZ production cross section in pp interactions at $\sqrt{s} = 13$ TeV. Throughout it, “Z boson” refers to the superposition of a Z boson and virtual photon with mass in the range 66–116 GeV. The analyzed data correspond to an integrated luminosity of $3.2 \pm 0.2 \text{ fb}^{-1}$, collected with the ATLAS detector [9]. The uncertainty of the integrated luminosity is derived, following a methodology similar to that detailed in Ref. [10], from a preliminary calibration of the luminosity scale using a pair of x - y beam-separation scans performed in June 2015. The ZZ production cross section was previously measured at $\sqrt{s} = 7$ and 8 TeV by the ATLAS and CMS Collaborations [11–13] and found to be consistent with SM predictions.

Candidate events are reconstructed in the fully leptonic $ZZ \rightarrow \ell^+ \ell^- \ell'^+ \ell'^-$ decay channel where ℓ and ℓ' can be an electron or a muon. The cross section $\sigma_{ZZ \rightarrow \ell^+ \ell^- \ell'^+ \ell'^-}^{\text{fid}}$ is found by counting candidate events, subtracting the expected contribution from background events, correcting for detector effects, and dividing by the integrated luminosity. It is measured in a fiducial phase space that corresponds closely to the experimental acceptance. In addition, an extrapolation of the cross section to a total phase space for Z bosons, σ_{ZZ}^{tot} , is performed. The presented cross-section measurements are inclusive with respect to additional jets. Small contributions from triboson production with two leptonically decaying Z bosons and a third hadronically decaying weak boson and contributions from double parton scattering are included in the measurement.

The fiducial phase space, which is designed to reflect the acceptance of the ATLAS detector (described below), is defined for simulated events by applying the following criteria to the final-state particle-level objects. Final-state electrons and muons are required to be prompt (i.e., to not originate from hadron or τ decay) and their kinematics are computed including the contributions from prompt photons with a distance in η - ϕ coordinates of $\Delta R_{\ell,\gamma} =$

$\sqrt{(\Delta\eta_{\ell,\gamma})^2 + (\Delta\phi_{\ell,\gamma})^2} < 0.1$ between the charged lepton and the photon, as motivated in Ref. [14]. (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 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 z axis. The pseudorapidity is defined in terms of the polar angle θ as $\eta = -\ln[\tan(\theta/2)]$.) The leptons are required to be well separated with $\Delta R_{\ell,\ell'} > 0.2$ between any two leptons. Each lepton must have a momentum component transverse to the beam direction $p_T > 20$ GeV and pseudorapidity $|\eta| < 2.7$. Events must have exactly four leptons satisfying the above

*Full author list given at the end of the article.

Published by the American Physical Society under the terms of the Creative Commons Attribution 3.0 License. Further distribution of this work must maintain attribution to the author(s) and the published article's title, journal citation, and DOI.

criteria forming two pairs of leptons of the same flavor and oppositely charged ($\mu^+\mu^-$ or e^+e^-). This gives rise to three signal channels: $4e$, 4μ , and $2e2\mu$. Each lepton pair must have an invariant mass in the range 66–116 GeV. In the $4e$ and 4μ channels, where there are two possible ways to form same-flavor oppositely charged lepton pairs, the combination that minimizes $|m_{\ell\ell,a} - m_Z| + |m_{\ell\ell,b} - m_Z|$ is chosen, where $m_{\ell\ell,a}$ and $m_{\ell\ell,b}$ are the invariant masses of the lepton pairs and m_Z is the mass of the Z boson.

The ATLAS detector is a multipurpose particle detector with a cylindrical geometry. It consists of layers of inner tracking detectors, calorimeters, and muon chambers. The inner detector (ID) covers the pseudorapidity range $|\eta| < 2.5$. The calorimeter covers the pseudorapidity range $|\eta| < 4.9$. Within $|\eta| < 2.47$ the finely segmented electromagnetic calorimeter identifies electromagnetic showers and measures their energy and position, providing electron identification together with the ID. The muon spectrometer (MS) surrounds the calorimeters and provides muon identification and measurement in the region $|\eta| < 2.7$ and triggering in the region $|\eta| < 2.4$.

A muon is reconstructed by matching a track (or track segment) reconstructed in the MS to a track reconstructed in the ID. Its momentum is calculated by combining the information from the two systems and correcting for energy deposited in the calorimeters. In regions of limited coverage of the MS ($|\eta| < 0.1$) or outside the ID acceptance ($2.5 < |\eta| < 2.7$), muons can also be reconstructed by matching calorimeter signals consistent with muons to ID tracks (calorimeter-tagged muons) or standalone in the MS [15], respectively.

An electron is reconstructed from an energy deposit (cluster) in the electromagnetic calorimeter matched to a track in the ID. Its momentum is computed from the cluster energy and the direction of the track. Electrons are distinguished from other particles using several identification criteria that rely on the shapes of electromagnetic showers as well as tracking and track-to-cluster matching quantities. The output of a likelihood function taking these quantities as input, similar to that described in Ref. [16], is used to identify electrons. Electrons sharing an ID track with a selected muon are ignored.

The leptons are required to be isolated from other particles using ID track information, and for muons using calorimeter information also (since standalone muons are outside the ID acceptance). The exact requirements depend on the lepton p_T and η and are designed to give a uniform 99% efficiency.

Leptons are required to originate from the primary vertex, defined as the reconstructed vertex with the largest sum of the p_T^2 of the associated tracks. To this end, the longitudinal impact parameter of each lepton track, calculated with respect to the vertex and multiplied by $\sin\theta$ of the track, is required to be less than 0.5 mm. Furthermore, the significance of the transverse impact parameter

calculated with respect to the beam line is required to be less than 3 (5) for muons (electrons). Standalone muons are exempt from both impact parameter requirements, as they do not have an ID track.

Candidate events are preselected by either a single-muon or dielectron trigger. As in the fiducial phase space described above, leptons must have $p_T > 20$ GeV. There are slight differences from the fiducial phase space: electrons must satisfy $|\eta| < 2.47$ due to the limited experimental acceptance, and at least one muon in the 4μ channel must satisfy $|\eta| < 2.4$, corresponding to the acceptance of the muon trigger. The other muons must satisfy $|\eta| < 2.7$. Events are ignored if more than one selected muon is calorimeter tagged or standalone. Apart from the above differences, reconstructed candidate events are selected using exactly the same criteria that define the fiducial phase space. A total of 63 events are observed, of which 15, 30, and 18 are in the $4e$, $2e2\mu$, and 4μ channels, respectively.

Monte Carlo (MC)-simulated event samples are used to obtain corrections for detector effects and to estimate background contributions. The principal signal sample is generated with the POWHEG method and framework [17–19], with a diboson event generator [20,21] used to simulate the ZZ production process at next-to-leading order (NLO). (Throughout this Letter, orders of calculations refer to perturbative expansions in the strong coupling constant α_S unless stated otherwise). The simulation of parton showering, of the underlying event, and of hadronization is performed with PYTHIA8 [22,23] using the AZNLO set of tuned parameters (tune) [24]. SHERPA [25–31] is used to generate a sample with the $q\bar{q}$ -initiated process simulated at NLO for ZZ plus zero or one additional jet and at leading order (LO) for two or three additional jets, as well as a sample with the loop-induced gg -initiated process simulated at LO with zero or one additional jet. These are used to include the loop-induced gg -initiated production, which is not included in the POWHEG+PYTHIA8 sample, as well as to estimate, by comparison of the various samples, a systematic uncertainty due to the choice of event generator. The CT10 NLO [32] parton distribution functions (PDFs) are used in the event generation for all samples above. Additional samples are generated to estimate the contribution from background events. Triboson events are simulated with SHERPA, using CT10 PDFs, and $t\bar{t}Z$ events are simulated with MADGRAPH [33] interfaced with PYTHIA8 using the NNPDF 2.3 LO PDFs [34] and the A14 tune [35].

In all MC samples, additional pp interactions occurring in the same bunch crossing as the ZZ production, or in nearby ones, are simulated with PYTHIA8 with MSTW 2008 LO PDFs [36] and the A2 tune [37]. The samples are then passed through a simulation of the ATLAS detector [38] based on GEANT4 [39]. Scale factors are applied to the simulated events to correct for the small differences from data in the trigger, reconstruction, identification, isolation,

and impact parameter efficiencies for electrons and muons [15,16]. Furthermore, the lepton momentum scales and resolutions are adjusted to match the data.

Background events from processes with at least four prompt leptons in the final state are estimated with the MC samples described above, including uncertainties from the cross-section values, luminosity, and reconstruction effects. Contributions of 0.07 ± 0.02 events from ZZ processes where at least one Z boson decays to τ leptons, 0.17 ± 0.05 events from nonhadronic triboson processes, and 0.30 ± 0.09 events from all-leptonic $t\bar{t}Z$ processes are predicted. Events from processes with two or three prompt leptons, e.g., Z , WW , WZ , $t\bar{t}$, and ZZ events where one Z boson decays hadronically, where associated jets or photons contain or fake a nonprompt lepton, can pass the event selection. This background contribution is estimated to be $0.09^{+1.08}_{-0.04}$ events, using control samples and a data-driven technique described in Ref. [11]. The uncertainty is dominated by the small number of events in the control samples. It can be asymmetric due to truncation, as background contributions cannot be negative. Background from two single Z bosons produced in different pp collisions in the same bunch crossing is estimated to be negligible. The total expected number of background events is 0.20 ± 0.05 ($0.25^{+0.40}_{-0.05}$, $0.17^{+1.00}_{-0.04}$) in the $4e$ ($2e2\mu$, 4μ) channel, giving a total of $0.62^{+1.08}_{-0.11}$ events.

A factor C_{ZZ} is applied to correct for detector inefficiencies and resolution effects. It relates the background-subtracted number of selected events to the number in the fiducial phase space, and is defined as the ratio of generated signal events passing the selection criteria using reconstructed objects to the number passing the fiducial criteria using generator-level objects. C_{ZZ} is determined with a combination of the POWHEG ZZ MC sample and the SHERPA loop-induced gg -initiated sample. The normalization of the latter is scaled to $\mathcal{O}(\alpha_s^3)$ accuracy [2] in order to improve the model used to correct the measurement. The C_{ZZ} value and its total uncertainty is determined to be 0.55 ± 0.02 (0.63 ± 0.02 , 0.81 ± 0.03) in the $4e$ ($2e2\mu$, 4μ) channel. The dominant systematic uncertainties come from the uncertainties of the scale factors used to correct lepton reconstruction and identification efficiencies in the simulation and the choice of MC generator. Other smaller uncertainties come from the scale and resolution of the lepton momenta, PDFs, and statistical fluctuations in the MC sample. Table I gives a breakdown of the systematic uncertainties.

Figure 1 shows the invariant mass of the leading- $p_{T,\ell\ell}$ and the subleading- $p_{T,\ell\ell}$ lepton pair ($\ell\ell$), as well as the invariant mass, transverse momentum, and rapidity of the four-lepton system. Distributions from data are compared to the signal and background expectations, with good agreement in general.

The fiducial cross section is determined using a maximum-likelihood fit to the event counts in the three signal

TABLE I. Relative uncertainties of the correction factor C_{ZZ} by signal channel, expressed in percent.

Source	$4e$	$2e2\mu$	4μ
Statistical (signal samples)	0.7	0.5	0.5
Theoretical (generator, PDFs)	2.5	2.5	2.5
Experimental efficiencies	2.3	2.2	2.0
Momentum scales and resolutions	0.4	0.2	0.1
Total	3.5	3.3	3.2

channels. A Poisson probability function is used to parametrize the number of expected events, multiplied by Gaussian distributions that model the nuisance parameters representing systematic uncertainties. This procedure can lead to asymmetric uncertainties as Poisson-distributed variables cannot be negative.

The cross section measured in the fiducial phase space is also extrapolated to the total phase space, which includes a correction for QED final-state radiation effects. The extrapolation factor is obtained from the same combination of MC samples as used in the C_{ZZ} determination. The ratio of the fiducial to full phase-space cross section is 0.39 ± 0.02 , in all three channels. It is corrected for the $\sim 3\%$ increase bias introduced by the pairing algorithm in the $4e$ and 4μ channels. The dominant systematic uncertainty comes from the difference between the nominal value and that obtained using the SHERPA samples. Smaller uncertainties are derived from PDF variations in the CT10 error set, differences between using PYTHIA8 and HERWIG++ [40] for simulating the rest of the event, and varying the QCD renormalization and factorization scales independently by a factor of 2. In order to extrapolate to the total cross section, the fiducial cross sections are divided by the ratio 0.39 ± 0.02 and corrected for the leptonic branching fraction $(3.3658\%)^2$ [41] (this value excludes γ^* contributions; including these, the branching fraction $ZZ \rightarrow \ell^+\ell^-\ell^+\ell^-$ is about 1.01–1.02 times larger).

The measured fiducial cross sections are shown in Table II and Fig. 2(a) along with a comparison to $\mathcal{O}(\alpha_s^2)$ calculations [1]. Table II also shows the total combined cross section. The CT10 next-to-next-to-leading order PDFs [45] and a dynamic scale equal to the mass of the four-lepton system are used in the calculation. The loop-induced gg -initiated process is included, and contributes 7.0% (5.8%) of the cross section in the fiducial (total) phase space. The predicted cross sections in the fiducial phase space are corrected for QED final-state radiation effects, which amount to a 4% reduction. The measurements agree with the SM predictions.

The theoretical predictions do not include the following effects. The loop-induced gg -initiated process calculated at $\mathcal{O}(\alpha_s^2)$ could receive large corrections at $\mathcal{O}(\alpha_s^3)$ of 70% [2], which would increase the prediction by 4%–5%. Electroweak corrections at next-to-leading order [46,47]

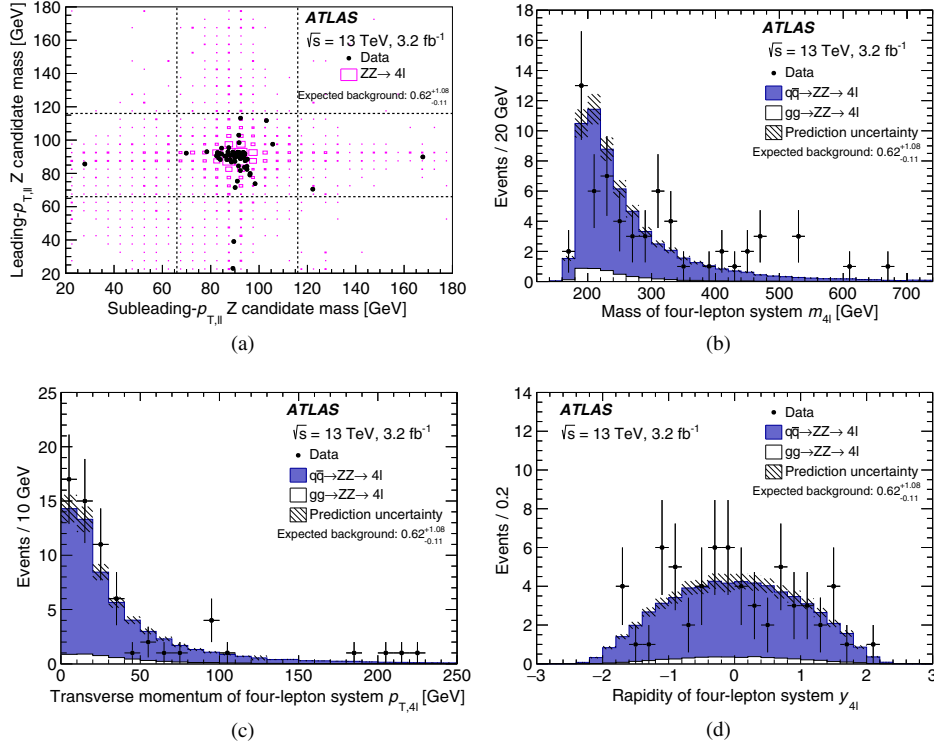


FIG. 1. (a) Invariant mass $m_{\ell\ell}$ of the leading- $p_{T,\ell\ell}$ vs the subleading- $p_{T,\ell\ell}$ lepton pair ($\ell\ell$), before the requirement $66 \text{ GeV} < m_{\ell\ell} < 116 \text{ GeV}$ is applied. The dashed lines indicate this requirement. (b) Invariant mass, (c) transverse momentum, and (d) rapidity of the four-lepton system in selected events. The points represent experimental data. The filled histograms show the signal prediction from simulation, including the $q\bar{q}$ and loop-induced gg -initiated process. The contributions are stacked. In the simulation, the prediction from POWHEG+PYTHIA8 combined with SHERPA is scaled to the $\mathcal{O}(\alpha_s^2)$ prediction. The uncertainties in the simulation are from the same sources as the C_{ZZ} uncertainty. In addition, 6% ZZ cross-section uncertainty and 5% integrated-luminosity uncertainty are included. The expected background of $0.62^{+1.08}_{-0.11}$ events is not shown as a histogram due to its small size.

are expected to reduce the cross section by 7%–8% [47]. Furthermore, the contribution from double parton scattering is not accounted for, but is expected to be an effect of less than 1% [48].

The measured total cross section is compared to measurements at lower center-of-mass energies and to a prediction from MCFM [49] with the CT14 NLO PDFs [50], which is calculated at $\mathcal{O}(\alpha_s^1)$ accuracy for the $q\bar{q}$ -initiated process and at $\mathcal{O}(\alpha_s^2)$ accuracy for the loop-induced gg -initiated process and is shown vs center-of-mass

energy in Fig. 2(b). The cross section increases by a factor of more than 2 with a center-of-mass energy increase from 8 TeV to 13 TeV.

In summary, ATLAS has measured the ZZ production cross section in 3.2 fb^{-1} of 13 TeV pp collisions at the LHC using the fully leptonic decay channel $ZZ \rightarrow \ell^+ \ell^- \ell'^+ \ell'^-$. Fiducial cross sections as well as a total cross section for Z bosons with mass 66–116 GeV have been measured and agree well with $\mathcal{O}(\alpha_s^2)$ SM predictions.

TABLE II. Cross-section measurement results compared to the $\mathcal{O}(\alpha_s^2)$ standard model predictions. The per-channel and combined fiducial cross sections are shown along with the combined total cross section. For experimental results, the statistical, systematic, and luminosity uncertainties are shown. For theoretical predictions, the PDF and renormalization and factorization scale uncertainties added in quadrature are shown.

	Measurement			$\mathcal{O}(\alpha_s^2)$ prediction
$\sigma_{ZZ \rightarrow e^+ e^- e^+ e^-}^{\text{fid}}$	$8.4^{+2.4}_{-2.0}$ (stat)	$+0.4_{-0.2}$ (syst)	$+0.5_{-0.3}$ (lumi)	$6.9^{+0.2}_{-0.2}$ fb
$\sigma_{ZZ \rightarrow e^+ e^- \mu^+ \mu^-}^{\text{fid}}$	$14.7^{+2.9}_{-2.5}$ (stat)	$+0.6_{-0.4}$ (syst)	$+0.9_{-0.6}$ (lumi)	$13.6^{+0.4}_{-0.4}$ fb
$\sigma_{ZZ \rightarrow \mu^+ \mu^- \mu^+ \mu^-}^{\text{fid}}$	$6.8^{+1.8}_{-1.5}$ (stat)	$+0.3_{-0.3}$ (syst)	$+0.4_{-0.3}$ (lumi)	$6.9^{+0.2}_{-0.2}$ fb
$\sigma_{ZZ \rightarrow \ell^+ \ell^- \ell'^+ \ell'^-}^{\text{fid}}$	$29.7^{+3.9}_{-3.6}$ (stat)	$+1.0_{-0.8}$ (syst)	$+1.7_{-1.3}$ (lumi)	$27.4^{+0.9}_{-0.8}$ fb
σ_{ZZ}^{tot}	$16.7^{+2.2}_{-2.0}$ (stat)	$+0.9_{-0.7}$ (syst)	$+1.0_{-0.7}$ (lumi)	$15.6^{+0.4}_{-0.4}$ pb

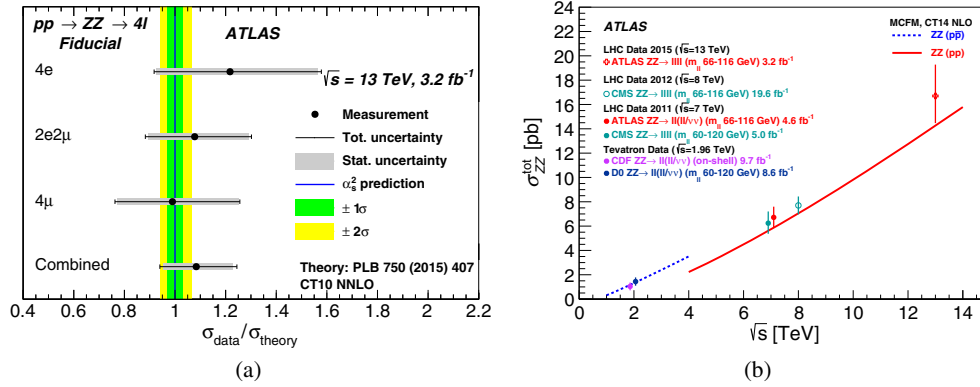


FIG. 2. (a) Comparison between measured fiducial cross sections and $\mathcal{O}(\alpha_s^2)$ predictions. (b) Total cross section compared to measurements at lower center-of-mass energies by ATLAS, CMS, CDF, and D0 [11–13,42,43], and to a prediction from MCFM at $\mathcal{O}(\alpha_s^1)$ accuracy for the $q\bar{q}$ -initiated process and at $\mathcal{O}(\alpha_s^2)$ accuracy for the loop-induced gg -initiated process. A full $\mathcal{O}(\alpha_s^2)$ prediction (known to improve agreement at $\sqrt{s} = 13$ TeV) was not yet available for all the different center-of-mass energies. Some data points are shifted horizontally to improve readability. The ZZ cross section as function of \sqrt{s} in the range 130–209 GeV was also measured at the LEP 2 e^+e^- collider [44].

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; BMWFW and FWF, Austria; ANAS, Azerbaijan; SSTC, Belarus; CNPq and FAPESP, Brazil; NSERC, NRC and CFI, Canada; CERN; CONICYT, Chile; CAS, MOST and NSFC, China; COLCIENCIAS, Colombia; MSMT CR, MPO CR and VSC CR, Czech Republic; DNRF, DNSRC and Lundbeck Foundation, Denmark; IN2P3-CNRS, CEA-DSM/IRFU, France; GNSF, Georgia; BMBF, HGF, and MPG, Germany; GSRT, Greece; RGC, Hong Kong SAR, China; ISF, I-CORE and Benoziyo Center, Israel; INFN, Italy; MEXT and JSPS, Japan; CNRST, Morocco; FOM and NWO, Netherlands; RCN, Norway; MNiSW and NCN, Poland; FCT, Portugal; MNE/IFA, Romania; MES of Russia and NRC KI, Russian Federation; JINR; MSTB, Serbia; MSSR, Slovakia; ARRS and MIZŠ, Slovenia; DST/NRF, South Africa; MINECO, Spain; SRC and Wallenberg Foundation, Sweden; SERI, SNSF and Cantons of Bern and Geneva, Switzerland; MOST, Taiwan; TAEK, Turkey; STFC, United Kingdom; DOE and NSF, United States of America. In addition, individual groups and members have received support from BCKDF, the Canada Council, CANARIE, CRC, Compute Canada, FQRNT, and the Ontario Innovation Trust, Canada; EPLANET, ERC, FP7, Horizon 2020 and Marie Skłodowska-Curie Actions, European Union; Investissements d’Avenir Labex and Idex, ANR, Region Auvergne and Fondation Partager le Savoir, France; DFG and AvH Foundation, Germany; Herakleitos, Thales and Aristeia programmes co-financed by EU-ESF and the Greek NSRF; BSF, GIF and Minerva, Israel; BRF, Norway; the Royal Society, and Leverhulme Trust, United Kingdom. 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] M. Grazzini, S. Kallweit, and D. Rathlev, ZZ production at the LHC: Fiducial cross sections and distributions in NNLO QCD, *Phys. Lett. B* **750**, 407 (2015).
- [2] F. Caola, K. Melnikov, R. Rönsch, and L. Tancredi, QCD corrections to ZZ production in gluon fusion at the LHC, *Phys. Rev. D* **92**, 094028 (2015).
- [3] ATLAS Collaboration, Measurements of the Total and Differential Higgs Boson Production Cross Sections Combining the $H \rightarrow \gamma\gamma$ and $H \rightarrow ZZ^* \rightarrow 4\ell$ Decay Channels at $\sqrt{s} = 8$ TeV with the ATLAS Detector, *Phys. Rev. Lett.* **115**, 091801 (2015).
- [4] ATLAS Collaboration, Constraints on the off-shell Higgs boson signal strength in the high-mass ZZ and WW final states with the ATLAS detector, *Eur. Phys. J. C* **75**, 335 (2015).
- [5] CMS Collaboration, Limits on the Higgs boson lifetime and width from its decay to four charged leptons, *Phys. Rev. D* **92**, 072010 (2015).
- [6] ATLAS Collaboration, Search for an additional, heavy Higgs boson in the $H \rightarrow ZZ$ decay channel at $\sqrt{s} = 8$ TeV in pp collision data with the ATLAS detector, *Eur. Phys. J. C* **76**, 45 (2016).
- [7] CMS Collaboration, Search for massive resonances decaying into pairs of boosted bosons in semi-leptonic final states at $\sqrt{s} = 8$ TeV, *J. High Energy Phys.* **08** (2014) 174.

- [8] U. Baur and D. L. Rainwater, Probing neutral gauge boson self-interactions in ZZ production at hadron colliders, *Phys. Rev. D* **62**, 113011 (2000).
- [9] ATLAS Collaboration, The ATLAS Experiment at the CERN Large Hadron Collider, *J. Inst.* **3**, S08003 (2008).
- [10] ATLAS Collaboration, Improved luminosity determination in pp collisions at $\sqrt{s} = 7$ TeV using the ATLAS detector at the LHC, *Eur. Phys. J. C* **73**, 2518 (2013).
- [11] ATLAS Collaboration, Measurement of ZZ production in pp collisions at $\sqrt{s} = 7$ TeV and limits on anomalous ZZZ and ZZ γ couplings with the ATLAS detector, *J. High Energy Phys.* **03** (2013) 128.
- [12] CMS Collaboration, Measurement of the $pp \rightarrow ZZ$ production cross section and constraints on anomalous triple gauge couplings in four-lepton final states at $\sqrt{s} = 8$ TeV, *Phys. Lett. B* **740**, 250 (2015).
- [13] CMS Collaboration, Measurement of the ZZ production cross section and search for anomalous couplings in $2\ell 2\ell'$ final states in pp collisions at $\sqrt{s} = 7$ TeV, *J. High Energy Phys.* **01** (2013) 063.
- [14] ATLAS Collaboration, Report No. ATL-PHYS-PUB-2015-013, <http://cdsweb.cern.ch/record/2022743>.
- [15] ATLAS Collaboration, Report No. ATL-PHYS-PUB-2015-037, <http://cdsweb.cern.ch/record/2047831>.
- [16] ATLAS Collaboration, Report No. ATLAS-CONF-2014-032, <http://cdsweb.cern.ch/record/1706245>.
- [17] P. Nason, A new method for combining NLO QCD with shower Monte Carlo algorithms, *J. High Energy Phys.* **11** (2004) 040.
- [18] S. Frixione, P. Nason, and C. Oleari, Matching NLO QCD computations with Parton Shower simulations: The POWHEG method, *J. High Energy Phys.* **11** (2007) 070.
- [19] S. Alioli, P. Nason, C. Oleari, and E. Re, A general framework for implementing NLO calculations in shower Monte Carlo programs: The POWHEG BOX, *J. High Energy Phys.* **06** (2010) 043.
- [20] T. Melia, P. Nason, R. Rötsch, and G. Zanderighi, W^+W^- , WZ and ZZ production in the POWHEG-BOX, *J. High Energy Phys.* **11** (2011) 078.
- [21] P. Nason and G. Zanderighi, W^+W^- , WZ and ZZ production in the POWHEG-BOX-V2, *Eur. Phys. J. C* **74**, 2702 (2014).
- [22] T. Sjöstrand, S. Mrenna, and P. Skands, PYTHIA 6.4 physics and manual, *J. High Energy Phys.* **05** (2006) 026.
- [23] T. Sjöstrand, S. Mrenna, and P. Skands, A brief introduction to PYTHIA 8.1, *Comput. Phys. Commun.* **178**, 852 (2008).
- [24] ATLAS Collaboration, Measurement of the Z/γ^* boson transverse momentum distribution in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector, *J. High Energy Phys.* **09** (2014) 145.
- [25] T. Gleisberg, S. Höche, F. Krauss, M. Schönherr, S. Schumann, F. Siegert, and J. Winter, Event generation with SHERPA 1.1, *J. High Energy Phys.* **02** (2009) 007.
- [26] S. Höche, F. Krauss, S. Schumann, and F. Siegert, QCD matrix elements and truncated showers, *J. High Energy Phys.* **05** (2009) 053.
- [27] T. Gleisberg and S. Höche, Comix, a new matrix element generator, *J. High Energy Phys.* **12** (2008) 039.
- [28] S. Schumann and F. Krauss, A parton shower algorithm based on Catani-Seymour dipole factorisation, *J. High Energy Phys.* **03** (2008) 038.
- [29] M. Schönherr and F. Krauss, Soft photon radiation in particle decays in SHERPA, *J. High Energy Phys.* **12** (2008) 018.
- [30] F. Cascioli, P. Maierhöfer, and S. Pozzorini, Scattering Amplitudes with Open Loops, *Phys. Rev. Lett.* **108**, 111601 (2012).
- [31] S. Höche, F. Krauss, M. Schönherr, and F. Siegert, QCD matrix elements + parton showers: The NLO case, *J. High Energy Phys.* **04** (2013) 027.
- [32] H.-L. Lai, M. Guzzi, J. Huston, Z. Li, P. M. Nadolsky, J. Pumplin, and C.-P. Yuan, New parton distributions for collider physics, *Phys. Rev. D* **82**, 074024 (2010).
- [33] J. Alwall, M. Herquet, F. Maltoni, O. Mattelaer, and T. Stelzer, MADGRAPH5: Going beyond, *J. High Energy Phys.* **06** (2011) 128.
- [34] R. D. Ball *et al.*, Parton distributions with LHC data, *Nucl. Phys.* **B867**, 244 (2013).
- [35] ATLAS Collaboration, Report No. ATL-PHYS-PUB-2014-021, 2014, <http://cdsweb.cern.ch/record/1966419>.
- [36] A. D. Martin, W. J. Stirling, R. S. Thorne, and G. Watt, Parton distributions for the LHC, *Eur. Phys. J. C* **63**, 189 (2009).
- [37] ATLAS Collaboration, Report No. ATL-PHYS-PUB-2012-003, 2012, <http://cds.cern.ch/record/1474107>.
- [38] ATLAS Collaboration, The ATLAS Simulation Infrastructure, *Eur. Phys. J. C* **70**, 823 (2010).
- [39] S. Agostinelli *et al.*, GEANT4—A simulation toolkit, *Nucl. Instrum. Methods Phys. Res., Sect. A* **506**, 250 (2003).
- [40] S. Gieseke *et al.*, HERWIG++ 2.5 release note, [arXiv:1102.1672](https://arxiv.org/abs/1102.1672).
- [41] K. A. Olive *et al.*, Review of particle physics, *Chin. Phys. C* **38**, 090001 (2014).
- [42] T. Aaltonen *et al.* (CDF Collaboration), Measurement of the ZZ production cross section using the full CDF II data set, *Phys. Rev. D* **89**, 112001 (2014).
- [43] V. M. Abazov *et al.* (D0 Collaboration), A measurement of the WZ and ZZ production cross sections using leptonic final states in 8.6 fb^{-1} of $p\bar{p}$ collisions, *Phys. Rev. D* **85**, 112005 (2012).
- [44] S. Schael *et al.* (ALEPH, DELPHI, L3, and OPAL Collaborations, LEP Electroweak Working Group), Electroweak measurements in electron-positron collisions at W -boson-pair energies at LEP, *Phys. Rep.* **532**, 119 (2013).
- [45] J. Gao, M. Guzzi, J. Huston, H.-L. Lai, Z. Li, P. Nadolsky, J. Pumplin, D. Stump, and C.-P. Yuan, CT10 next-to-next-to-leading order global analysis of QCD, *Phys. Rev. D* **89**, 033009 (2014).
- [46] A. Bierweiler, T. Kasprzik, and J. H. Kühn, Vector-boson pair production at the LHC to $\mathcal{O}(\alpha^3)$ accuracy, *J. High Energy Phys.* **12** (2013) 071.
- [47] B. Biedermann *et al.*, Electroweak corrections to $pp \rightarrow \mu^+\mu^-e^+e^- + X$ at the LHC—a Higgs background study, [arXiv:1601.07787](https://arxiv.org/abs/1601.07787).
- [48] ATLAS Collaboration, Measurement of hard double-parton interactions in $W(\rightarrow \ell\nu) + 2$ jet events at

- $\sqrt{s} = 7$ TeV with the ATLAS detector, *New J. Phys.* **15**, 033038 (2013).
- [49] J. M. Campbell and R. K. Ellis, An update on vector boson pair production at hadron colliders, *Phys. Rev. D* **60**, 113006 (1999).
- [50] S. Dulat, T.-J. Hou, J. Gao, M. Guzzi, J. Huston, P. Nadolsky, J. Pumplin, C. Schmidt, D. Stump, and C.-P. Yuan, New parton distribution functions from a global analysis of quantum chromodynamics, *Phys. Rev. D* **93**, 033006 (2016).
-
- G. Aad,⁸⁵ B. Abbott,¹¹² J. Abdallah,¹⁵⁰ O. Abdinov,¹¹ B. Abeloos,¹¹⁶ R. Aben,¹⁰⁶ M. Abolins,⁹⁰ O. S. AbouZeid,¹³⁶ H. Abramowicz,¹⁵² H. Abreu,¹⁵¹ R. Abreu,¹¹⁵ Y. Abulaiti,^{145a,145b} B. S. Acharya,^{163a,163b,a} L. Adamczyk,^{38a} D. L. Adams,²⁵ J. Adelman,¹⁰⁷ S. Adomeit,⁹⁹ T. Adye,¹³⁰ A. A. Affolder,⁷⁴ T. Agatonovic-Jovin,¹³ J. Agricola,⁵⁴ J. A. Aguilar-Saavedra,^{125a,125f} S. P. Ahlen,²² F. Ahmadov,^{65,b} G. Aielli,^{132a,132b} H. Akerstedt,^{145a,145b} T. P. A. Åkesson,⁸¹ A. V. Akimov,⁹⁵ G. L. Alberghi,^{20a,20b} J. Albert,¹⁶⁸ S. Albrand,⁵⁵ M. J. Alconada Verzini,⁷¹ M. Aleksa,³⁰ I. N. Aleksandrov,⁶⁵ C. Alexa,^{26b} G. Alexander,¹⁵² T. Alexopoulos,¹⁰ M. Alhroob,¹¹² G. Alimonti,^{91a} L. Alio,⁸⁵ J. Alison,³¹ S. P. Alkire,³⁵ B. M. M. Allbrooke,¹⁴⁸ B. W. Allen,¹¹⁵ P. P. Allport,¹⁸ A. Aloisio,^{103a,103b} A. Alonso,³⁶ F. Alonso,⁷¹ C. Alpigiani,¹³⁷ B. Alvarez Gonzalez,³⁰ D. Álvarez Piqueras,¹⁶⁶ M. G. Alviggi,^{103a,103b} B. T. Amadio,¹⁵ K. Amako,⁶⁶ Y. Amaral Coutinho,^{24a} C. Amelung,²³ D. Amidei,⁸⁹ S. P. Amor Dos Santos,^{125a,125c} A. Amorim,^{125a,125b} S. Amoroso,³⁰ N. Amram,¹⁵² G. Amundsen,²³ C. Anastopoulos,¹³⁸ L. S. Ancu,⁴⁹ N. Andari,¹⁰⁷ T. Andeen,³¹ C. F. Anders,^{58b} G. Anders,³⁰ J. K. Anders,⁷⁴ K. J. Anderson,³¹ A. Andreazza,^{91a,91b} V. Andrei,^{58a} S. Angelidakis,⁹ I. Angelozzi,¹⁰⁶ P. Anger,⁴⁴ A. Angerami,³⁵ F. Anghinolfi,³⁰ A. V. Anisenkov,^{108,c} N. Anjos,¹² A. Annovi,^{123a,123b} M. Antonelli,⁴⁷ A. Antonov,⁹⁷ J. Antos,^{143b} F. Anulli,^{131a} M. Aoki,⁶⁶ L. Aperio Bella,¹⁸ G. Arabidze,⁹⁰ Y. Arai,⁶⁶ J. P. Araque,^{125a} A. T. H. Arce,⁴⁵ F. A. Arduh,⁷¹ J.-F. Arguin,⁹⁴ S. Argyropoulos,⁶³ M. Arik,^{19a} A. J. Armbruster,³⁰ L. J. Armitage,⁷⁶ O. Arnaez,³⁰ H. Arnold,⁴⁸ M. Arratia,²⁸ O. Arslan,²¹ A. Artamonov,⁹⁶ G. Artoni,¹¹⁹ S. Artz,⁸³ S. Asai,¹⁵⁴ N. Asbah,⁴² A. Ashkenazi,¹⁵² B. Åsman,^{145a,145b} L. Asquith,¹⁴⁸ K. Assamagan,²⁵ R. Astalos,^{143a} M. Atkinson,¹⁶⁴ N. B. Atlay,¹⁴⁰ K. Augsten,¹²⁷ G. Avolio,³⁰ B. Axen,¹⁵ M. K. Ayoub,¹¹⁶ G. Azuelos,^{94,d} M. A. Baak,³⁰ A. E. Baas,^{58a} M. J. Baca,¹⁸ H. Bachacou,¹³⁵ K. Bachas,^{73a,73b} M. Backes,³⁰ M. Backhaus,³⁰ P. Bagiacchi,^{131a,131b} P. Bagnaia,^{131a,131b} Y. Bai,^{33a} J. T. Baines,¹³⁰ O. K. Baker,¹⁷⁵ E. M. Baldin,^{108,c} P. Balek,¹²⁸ T. Balestri,¹⁴⁷ F. Balli,¹³⁵ W. K. Balunas,¹²¹ E. Banas,³⁹ Sw. Banerjee,^{172,e} A. A. E. Bannoura,¹⁷⁴ L. Barak,³⁰ E. L. Barberio,⁸⁸ D. Barberis,^{50a,50b} M. Barbero,⁸⁵ T. Barillari,¹⁰⁰ M. Barisonzi,^{163a,163b} T. Barklow,¹⁴² N. Barlow,²⁸ S. L. Barnes,⁸⁴ B. M. Barnett,¹³⁰ R. M. Barnett,¹⁵ Z. Barnovska,⁵ A. Baroncelli,^{133a} G. Barone,²³ A. J. Barr,¹¹⁹ L. Barranco Navarro,¹⁶⁶ F. Barreiro,⁸² J. Barreiro Guimarães da Costa,^{33a} R. Bartoldus,¹⁴² A. E. Barton,⁷² P. Bartos,^{143a} A. Basalaev,¹²² A. Bassalat,¹¹⁶ A. Basye,¹⁶⁴ R. L. Bates,⁵³ S. J. Batista,¹⁵⁷ J. R. Batley,²⁸ M. Battaglia,¹³⁶ M. Bauce,^{131a,131b} F. Bauer,¹³⁵ H. S. Bawa,^{142,f} J. B. Beacham,¹¹⁰ M. D. Beattie,⁷² T. Beau,⁸⁰ P. H. Beauchemin,¹⁶⁰ R. Beccherle,^{123a,123b} P. Bechtel,²¹ H. P. Beck,^{17,g} K. Becker,¹¹⁹ M. Becker,⁸³ M. Beckingham,¹⁶⁹ C. Becot,¹⁰⁹ A. J. Beddall,^{19e} A. Beddall,^{19b} V. A. Bednyakov,⁶⁵ M. Bedognetti,¹⁰⁶ C. P. Bee,¹⁴⁷ L. J. Beemster,¹⁰⁶ T. A. Beermann,³⁰ M. Begel,²⁵ J. K. Behr,¹¹⁹ C. Belanger-Champagne,⁸⁷ A. S. Bell,⁷⁸ W. H. Bell,⁴⁹ G. Bella,¹⁵² L. Bellagamba,^{20a} A. Bellerive,²⁹ M. Bellomo,⁸⁶ K. Belotskiy,⁹⁷ O. Beltramello,³⁰ N. L. Belyaev,⁹⁷ O. Benary,¹⁵² D. Bencheikroun,^{134a} M. Bender,⁹⁹ K. Bendtz,^{145a,145b} N. Benekos,¹⁰ Y. Benhammou,¹⁵² E. Benhar Nocchioli,¹⁷⁵ J. Benitez,⁶³ J. A. Benitez Garcia,^{158b} D. P. Benjamin,⁴⁵ J. R. Bensinger,²³ S. Bentvelsen,¹⁰⁶ L. Beresford,¹¹⁹ M. Beretta,⁴⁷ D. Berge,¹⁰⁶ E. Bergeas Kuutmann,¹⁶⁵ N. Berger,⁵ F. Berghaus,¹⁶⁸ J. Beringer,¹⁵ S. Berlendis,⁵⁵ C. Bernard,²² N. R. Bernard,⁸⁶ C. Bernius,¹⁰⁹ F. U. Bernlochner,²¹ T. Berry,⁷⁷ P. Berta,¹²⁸ C. Bertella,⁸³ G. Bertoli,^{145a,145b} F. Bertolucci,^{123a,123b} I. A. Bertram,⁷² C. Bertsche,¹¹² D. Bertsche,¹¹² G. J. Besjes,³⁶ O. Bessidskaia Bylund,^{145a,145b} M. Bessner,⁴² N. Besson,¹³⁵ C. Betancourt,⁴⁸ S. Bethke,¹⁰⁰ A. J. Bevan,⁷⁶ W. Bhimji,¹⁵ R. M. Bianchi,¹²⁴ L. Bianchini,²³ M. Bianco,³⁰ O. Biebel,⁹⁹ D. Biedermann,¹⁶ R. Bielski,⁸⁴ N. V. Biesuz,^{123a,123b} M. Biglietti,^{133a} J. Bilbao De Mendizabal,⁴⁹ H. Bilokon,⁴⁷ M. Bindi,⁵⁴ S. Binet,¹¹⁶ A. Bingul,^{19b} C. Bini,^{131a,131b} S. Biondi,^{20a,20b} D. M. Bjergaard,⁴⁵ C. W. Black,¹⁴⁹ J. E. Black,¹⁴² K. M. Black,²² D. Blackburn,¹³⁷ R. E. Blair,⁶ J.-B. Blanchard,¹³⁵ J. E. Blanco,⁷⁷ T. Blazek,^{143a} I. Bloch,⁴² C. Blocker,²³ W. Blum,^{83,†} U. Blumenschein,⁵⁴ S. Blunier,^{32a} G. J. Bobbink,¹⁰⁶ V. S. Bobrovnikov,^{108,c} S. S. Bocchetta,⁸¹ A. Bocchi,⁴⁵ C. Bock,⁹⁹ M. Boehler,⁴⁸ D. Boerner,¹⁷⁴ J. A. Bogaerts,³⁰ D. Bogavac,¹³ A. G. Bogdanchikov,¹⁰⁸ C. Bohm,^{145a} V. Boisvert,⁷⁷ T. Bold,^{38a} V. Boldea,^{26b} A. S. Boldyrev,⁹⁸ M. Bomben,⁸⁰ M. Bona,⁷⁶ M. Boonekamp,¹³⁵ A. Borisov,¹²⁹ G. Borissov,⁷² J. Bortfeldt,⁹⁹ D. Bortoletto,¹¹⁹ V. Bortolotto,^{60a,60b,60c} K. Bos,¹⁰⁶ D. Boscherini,^{20a} M. Bosman,¹² J. D. Bossio Sola,²⁷ J. Boudreau,¹²⁴ J. Bouffard,² E. V. Bouhova-Thacker,⁷² D. Boumediene,³⁴ C. Bourdarios,¹¹⁶ N. Bousson,¹¹³ S. K. Boutle,⁵³ A. Boveia,³⁰ J. Boyd,³⁰

I. R. Boyko,⁶⁵ J. Bracinik,¹⁸ A. Brandt,⁸ G. Brandt,⁵⁴ O. Brandt,^{58a} U. Bratzler,¹⁵⁵ B. Brau,⁸⁶ J. E. Brau,¹¹⁵ H. M. Braun,^{174,†} W. D. Breaden Madden,⁵³ K. Brendlinger,¹²¹ A. J. Brennan,⁸⁸ L. Brenner,¹⁰⁶ R. Brenner,¹⁶⁵ S. Bressler,¹⁷¹ T. M. Bristow,⁴⁶ D. Britton,⁵³ D. Britzger,⁴² F. M. Brochu,²⁸ I. Brock,²¹ R. Brock,⁹⁰ G. Brooijmans,³⁵ T. Brooks,⁷⁷ W. K. Brooks,^{32b} J. Brosamer,¹⁵ E. Brost,¹¹⁵ J. H. Broughton,¹⁸ P. A. Bruckman de Renstrom,³⁹ D. Bruncko,^{143b} R. Bruneliere,⁴⁸ A. Bruni,^{20a} G. Bruni,^{20a} BH Brunt,²⁸ M. Bruschi,^{20a} N. Bruscolo,²¹ P. Bryant,³¹ L. Bryngemark,⁸¹ T. Buanes,¹⁴ Q. Buat,¹⁴¹ P. Buchholz,¹⁴⁰ A. G. Buckley,⁵³ I. A. Budagov,⁶⁵ F. Buehrer,⁴⁸ M. K. Bugge,¹¹⁸ O. Bulekov,⁹⁷ D. Bullock,⁸ H. Burckhart,³⁰ S. Burdin,⁷⁴ C. D. Burgard,⁴⁸ B. Burghgrave,¹⁰⁷ K. Burka,³⁹ S. Burke,¹³⁰ I. Burmeister,⁴³ E. Busato,³⁴ D. Büscher,⁴⁸ V. Büscher,⁸³ P. Bussey,⁵³ J. M. Butler,²² A. I. Butt,³ C. M. Buttar,⁵³ J. M. Butterworth,⁷⁸ P. Butti,¹⁰⁶ W. Buttinger,²⁵ A. Buzatu,⁵³ A. R. Buzykaev,^{108,c} S. Cabrera Urbán,¹⁶⁶ D. Caforio,¹²⁷ V. M. Cairo,^{37a,37b} O. Cakir,^{4a} N. Calace,⁴⁹ P. Calafiura,¹⁵ A. Calandri,⁸⁵ G. Calderini,⁸⁰ P. Calfayan,⁹⁹ L. P. Caloba,^{24a} D. Calvet,³⁴ S. Calvet,³⁴ T. P. Calvet,⁸⁵ R. Camacho Toro,³¹ S. Camarda,⁴² P. Camarri,^{132a,132b} D. Cameron,¹¹⁸ R. Caminal Armadans,¹⁶⁴ C. Camincher,⁵⁵ S. Campana,³⁰ M. Campanelli,⁷⁸ A. Campoverde,¹⁴⁷ V. Canale,^{103a,103b} A. Canepa,^{158a} M. Cano Bret,^{33e} J. Cantero,⁸² R. Cantrill,^{125a} T. Cao,⁴⁰ M. D. M. Capeans Garrido,³⁰ I. Caprini,^{26b} M. Caprini,^{26b} M. Capua,^{37a,37b} R. Caputo,⁸³ R. M. Carbone,³⁵ R. Cardarelli,^{132a} F. Cardillo,⁴⁸ T. Carli,³⁰ G. Carlino,^{103a} L. Carminati,^{91a,91b} S. Caron,¹⁰⁵ E. Carquin,^{32a} G. D. Carrillo-Montoya,³⁰ J. R. Carter,²⁸ J. Carvalho,^{125a,125c} D. Casadei,⁷⁸ M. P. Casado,^{12,h} M. Casolino,¹² D. W. Casper,¹⁶² E. Castaneda-Miranda,^{144a} A. Castelli,¹⁰⁶ V. Castillo Gimenez,¹⁶⁶ N. F. Castro,^{125a,i} A. Catinaccio,³⁰ J. R. Catmore,¹¹⁸ A. Cattai,³⁰ J. Caudron,⁸³ V. Cavaliere,¹⁶⁴ D. Cavalli,^{91a} M. Cavalli-Sforza,¹² V. Cavasinni,^{123a,123b} F. Ceradini,^{133a,133b} L. Cerda Alberich,¹⁶⁶ B. C. Cerio,⁴⁵ A. S. Cerqueira,^{24b} A. Cerri,¹⁴⁸ L. Cerrito,⁷⁶ F. Cerutti,¹⁵ M. Cerv,³⁰ A. Cervelli,¹⁷ S. A. Cetin,^{19d} A. Chafaq,^{134a} D. Chakraborty,¹⁰⁷ I. Chalupkova,¹²⁸ S. K. Chan,⁵⁷ Y. L. Chan,^{60a} P. Chang,¹⁶⁴ J. D. Chapman,²⁸ D. G. Charlton,¹⁸ A. Chatterjee,⁴⁹ C. C. Chau,¹⁵⁷ C. A. Chavez Barajas,¹⁴⁸ S. Che,¹¹⁰ S. Cheatham,⁷² A. Chegwidan,⁹⁰ S. Chekanov,⁶ S. V. Chekulaev,^{158a} G. A. Chelkov,^{65,j} M. A. Chelstowska,⁸⁹ C. Chen,⁶⁴ H. Chen,²⁵ K. Chen,¹⁴⁷ S. Chen,^{33c} S. Chen,¹⁵⁴ X. Chen,^{33f} Y. Chen,⁶⁷ H. C. Cheng,⁸⁹ Y. Cheng,³¹ A. Cheplakov,⁶⁵ E. Cheremushkina,¹²⁹ R. Cherkaoui El Moursli,^{134e} V. Chernyatin,^{25,†} E. Cheu,⁷ L. Chevalier,¹³⁵ V. Chiarella,⁴⁷ G. Chiarelli,^{123a,123b} G. Chiodini,^{73a} A. S. Chisholm,¹⁸ A. Chitan,^{26b} M. V. Chizhov,⁶⁵ K. Choi,⁶¹ S. Chouridou,⁹ B. K. B. Chow,⁹⁹ V. Christodoulou,⁷⁸ D. Chromek-Burckhart,³⁰ J. Chudoba,¹²⁶ A. J. Chuinard,⁸⁷ J. J. Chwastowski,³⁹ L. Chytka,¹¹⁴ G. Ciapetti,^{131a,131b} A. K. Ciftci,^{4a} D. Cinca,⁵³ V. Cindro,⁷⁵ I. A. Cioara,²¹ A. Ciocio,¹⁵ F. Cirotto,^{103a,103b} Z. H. Citron,¹⁷¹ M. Ciubancan,^{26b} A. Clark,⁴⁹ B. L. Clark,⁵⁷ P. J. Clark,⁴⁶ R. N. Clarke,¹⁵ C. Clement,^{145a,145b} Y. Coadou,⁸⁵ M. Cobal,^{163a,163c} A. Coccaro,⁴⁹ J. Cochran,⁶⁴ L. Coffey,²³ L. Colasurdo,¹⁰⁵ B. Cole,³⁵ S. Cole,¹⁰⁷ A. P. Colijn,¹⁰⁶ J. Collot,⁵⁵ T. Colombo,³⁰ G. Compostella,¹⁰⁰ P. Conde Muño,^{125a,125b} E. Coniavitis,⁴⁸ S. H. Connell,^{144b} I. A. Connelly,⁷⁷ V. Consorti,⁴⁸ S. Constantinescu,^{26b} C. Conta,^{120a,120b} G. Conti,³⁰ F. Conventi,^{103a,k} M. Cooke,¹⁵ B. D. Cooper,⁷⁸ A. M. Cooper-Sarkar,¹¹⁹ T. Cornelissen,¹⁷⁴ M. Corradi,^{131a,131b} F. Corriveau,^{87,l} A. Corso-Radu,¹⁶² A. Cortes-Gonzalez,¹² G. Cortiana,¹⁰⁰ G. Costa,^{91a} M. J. Costa,¹⁶⁶ D. Costanzo,¹³⁸ G. Cottin,²⁸ G. Cowan,⁷⁷ B. E. Cox,⁸⁴ K. Cranmer,¹⁰⁹ S. J. Crawley,⁵³ G. Cree,²⁹ S. Crépe-Renaudin,⁵⁵ F. Crescioli,⁸⁰ W. A. Cribbs,^{145a,145b} M. Crispin Ortuzar,¹¹⁹ M. Cristinziani,²¹ V. Croft,¹⁰⁵ G. Crosetti,^{37a,37b} T. Cuhadar Donszelmann,¹³⁸ J. Cummings,¹⁷⁵ M. Curatolo,⁴⁷ J. Cúth,⁸³ C. Cuthbert,¹⁴⁹ H. Czirr,¹⁴⁰ P. Czodrowski,³ S. D'Auria,⁵³ M. D'Onofrio,⁷⁴ M. J. Da Cunha Sargedas De Sousa,^{125a,125b} C. Da Via,⁸⁴ W. Dabrowski,^{38a} T. Dai,⁸⁹ O. Dale,¹⁴ F. Dallaire,⁹⁴ C. Dallapiccola,⁸⁶ M. Dam,³⁶ J. R. Dandoy,³¹ N. P. Dang,⁴⁸ A. C. Daniells,¹⁸ N. S. Dann,⁸⁴ M. Danninger,¹⁶⁷ M. Dano Hoffmann,¹³⁵ V. Dao,⁴⁸ G. Darbo,^{50a} S. Darmora,⁸ J. Dassoulas,³ A. Dattagupta,⁶¹ W. Davey,²¹ C. David,¹⁶⁸ T. Davidek,¹²⁸ M. Davies,¹⁵² P. Davison,⁷⁸ Y. Davygora,^{58a} E. Dawe,⁸⁸ I. Dawson,¹³⁸ R. K. Daya-Ishmukhametova,⁸⁶ K. De,⁸ R. de Asmundis,^{103a} A. De Benedetti,¹¹² S. De Castro,^{20a,20b} S. De Cecco,⁸⁰ N. De Groot,¹⁰⁵ P. de Jong,¹⁰⁶ H. De la Torre,⁸² F. De Lorenzi,⁶⁴ D. De Pedis,^{131a} A. De Salvo,^{131a} U. De Sanctis,¹⁴⁸ A. De Santo,¹⁴⁸ J. B. De Vivie De Regie,¹¹⁶ W. J. Dearnaley,⁷² R. Debbe,²⁵ C. Debenedetti,¹³⁶ D. V. Dedovich,⁶⁵ I. Deigaard,¹⁰⁶ J. Del Peso,⁸² T. Del Prete,^{123a,123b} D. Delgove,¹¹⁶ F. Deliot,¹³⁵ C. M. Delitzsch,⁴⁹ M. Deliyergiyev,⁷⁵ A. Dell'Acqua,³⁰ L. Dell'Asta,²² M. Dell'Orso,^{123a,123b} M. Della Pietra,^{103a,k} D. della Volpe,⁴⁹ M. Delmastro,⁵ P. A. Delsart,⁵⁵ C. Deluca,¹⁰⁶ D. A. DeMarco,¹⁵⁷ S. Demers,¹⁷⁵ M. Demichev,⁶⁵ A. Demilly,⁸⁰ S. P. Denisov,¹²⁹ D. Denysiuk,¹³⁵ D. Derendarz,³⁹ J. E. Derkaoui,^{134d} F. Derue,⁸⁰ P. Dervan,⁷⁴ K. Desch,²¹ C. Deterre,⁴² K. Dette,⁴³ P. O. Deviveiros,³⁰ A. Dewhurst,¹³⁰ S. Dhaliwal,²³ A. Di Ciaccio,^{132a,132b} L. Di Ciaccio,⁵ W. K. Di Clemente,¹²¹ A. Di Domenico,^{131a,131b} C. Di Donato,^{131a,131b} A. Di Girolamo,³⁰ B. Di Girolamo,³⁰ A. Di Mattia,¹⁵¹ B. Di Micco,^{133a,133b} R. Di Nardo,⁴⁷ A. Di Simone,⁴⁸ R. Di Sipio,¹⁵⁷ D. Di Valentino,²⁹ C. Diaconu,⁸⁵ M. Diamond,¹⁵⁷ F. A. Dias,⁴⁶ M. A. Diaz,^{32a} E. B. Diehl,⁸⁹ J. Dietrich,¹⁶ S. Diglio,⁸⁵ A. Dimitrievska,¹³ J. Dingfelder,²¹ P. Dita,^{26b} S. Dita,^{26b} F. Dittus,³⁰ F. Djama,⁸⁵

T. Djobava,^{51b} J. I. Djuvslund,^{58a} M. A. B. do Vale,^{24c} D. Dobos,³⁰ M. Dobre,^{26b} C. Doglioni,⁸¹ T. Dohmae,¹⁵⁴ J. Dolejsi,¹²⁸ Z. Dolezal,¹²⁸ B. A. Dolgoshein,^{97,†} M. Donadelli,^{24d} S. Donati,^{123a,123b} P. Dondero,^{120a,120b} J. Donini,³⁴ J. Dopke,¹³⁰ A. Doria,^{103a} M. T. Dova,⁷¹ A. T. Doyle,⁵³ E. Drechsler,⁵⁴ M. Dris,¹⁰ Y. Du,^{33d} J. Duarte-Campderros,¹⁵² E. Duchovni,¹⁷¹ G. Duckeck,⁹⁹ O. A. Ducu,^{26b} D. Duda,¹⁰⁶ A. Dudarev,³⁰ L. Dufлот,¹¹⁶ L. Duguid,⁷⁷ M. Dürrssen,³⁰ M. Dunford,^{58a} H. Duran Yildiz,^{4a} M. Düren,⁵² A. Durglishvili,^{51b} D. Duschinger,⁴⁴ B. Dutta,⁴² M. Dyndal,^{38a} C. Eckardt,⁴² K. M. Ecker,¹⁰⁰ R. C. Edgar,⁸⁹ W. Edson,² N. C. Edwards,⁴⁶ T. Eifert,³⁰ G. Eigen,¹⁴ K. Einsweiler,¹⁵ T. Ekelof,¹⁶⁵ M. El Kacimi,^{134c} V. Ellajosyula,⁸⁵ M. Ellert,¹⁶⁵ S. Elles,⁵ F. Ellinghaus,¹⁷⁴ A. A. Elliot,¹⁶⁸ N. Ellis,³⁰ J. Elmsheuser,⁹⁹ M. Elsing,³⁰ D. Emelianov,¹³⁰ Y. Enari,¹⁵⁴ O. C. Endner,⁸³ M. Endo,¹¹⁷ J. S. Ennis,¹⁶⁹ J. Erdmann,⁴³ A. Ereditato,¹⁷ G. Ernis,¹⁷⁴ J. Ernst,² M. Ernst,²⁵ S. Errede,¹⁶⁴ E. Ertel,⁸³ M. Escalier,¹¹⁶ H. Esch,⁴³ C. Escobar,¹²⁴ B. Esposito,⁴⁷ A. I. Etienne,¹³⁵ E. Etzion,¹⁵² H. Evans,⁶¹ A. Ezhilov,¹²² L. Fabbri,^{20a,20b} G. Facini,³¹ R. M. Fakhruddinov,¹²⁹ S. Falciano,^{131a} R. J. Falla,⁷⁸ J. Faltova,¹²⁸ Y. Fang,^{33a} M. Fanti,^{91a,91b} A. Farbin,⁸ A. Farilla,^{133a} C. Farina,¹²⁴ T. Farooque,¹² S. Farrell,¹⁵ S. M. Farrington,¹⁶⁹ P. Farthouat,³⁰ F. Fassi,^{134e} P. Fassnacht,³⁰ D. Fassouliotis,⁹ M. Fauci Giannelli,⁷⁷ A. Favareto,^{50a,50b} L. Fayard,¹¹⁶ O. L. Fedin,^{122,m} W. Fedorko,¹⁶⁷ S. Feigl,¹¹⁸ L. Feligioni,⁸⁵ C. Feng,^{33d} E. J. Feng,³⁰ H. Feng,⁸⁹ A. B. Fenyuk,¹²⁹ L. Feremenga,⁸ P. Fernandez Martinez,¹⁶⁶ S. Fernandez Perez,¹² J. Ferrando,⁵³ A. Ferrari,¹⁶⁵ P. Ferrari,¹⁰⁶ R. Ferrari,^{120a} D. E. Ferreira de Lima,⁵³ A. Ferrer,¹⁶⁶ D. Ferrere,⁴⁹ C. Ferretti,⁸⁹ A. Ferretto Parodi,^{50a,50b} F. Fiedler,⁸³ A. Filipčič,⁷⁵ M. Filipuzzi,⁴² F. Filthaut,¹⁰⁵ M. Fincke-Keeler,¹⁶⁸ K. D. Finelli,¹⁴⁹ M. C. N. Fiolhais,^{125a,125c} L. Fiorini,¹⁶⁶ A. Firan,⁴⁰ A. Fischer,² C. Fischer,¹² J. Fischer,¹⁷⁴ W. C. Fisher,⁹⁰ N. Flaschel,⁴² I. Fleck,¹⁴⁰ P. Fleischmann,⁸⁹ G. T. Fletcher,¹³⁸ G. Fletcher,⁷⁶ R. R. M. Fletcher,¹²¹ T. Flick,¹⁷⁴ A. Floderus,⁸¹ L. R. Flores Castillo,^{60a} M. J. Flowerdew,¹⁰⁰ G. T. Forcolin,⁸⁴ A. Formica,¹³⁵ A. Forti,⁸⁴ D. Fournier,¹¹⁶ H. Fox,⁷² S. Fracchia,¹² P. Francavilla,⁸⁰ M. Franchini,^{20a,20b} D. Francis,³⁰ L. Franconi,¹¹⁸ M. Franklin,⁵⁷ M. Frate,¹⁶² M. Fraternali,^{120a,120b} D. Freeborn,⁷⁸ S. M. Fressard-Batraneanu,³⁰ F. Friedrich,⁴⁴ D. Froidevaux,³⁰ J. A. Frost,¹¹⁹ C. Fukunaga,¹⁵⁵ E. Fullana Torregrosa,⁸³ T. Fusayasu,¹⁰¹ J. Fuster,¹⁶⁶ C. Gabaldon,⁵⁵ O. Gabizon,¹⁷⁴ A. Gabrielli,^{20a,20b} A. Gabrielli,¹⁵ G. P. Gach,^{38a} S. Gadatsch,³⁰ S. Gadomski,⁴⁹ G. Gagliardi,^{50a,50b} P. Gagnon,⁶¹ C. Galea,¹⁰⁵ B. Galhardo,^{125a,125c} E. J. Gallas,¹¹⁹ B. J. Gallop,¹³⁰ P. Gallus,¹²⁷ G. Galster,³⁶ K. K. Gan,¹¹⁰ J. Gao,^{33b,85} Y. Gao,⁴⁶ Y. S. Gao,^{142,f} F. M. Garay Walls,⁴⁶ C. García,¹⁶⁶ J. E. García Navarro,¹⁶⁶ M. Garcia-Sciveres,¹⁵ R. W. Gardner,³¹ N. Garelli,¹⁴² V. Garonne,¹¹⁸ A. Gascon Bravo,⁴² C. Gatti,⁴⁷ A. Gaudiello,^{50a,50b} G. Gaudio,^{120a} B. Gaur,¹⁴⁰ L. Gauthier,⁹⁴ I. L. Gavrilenko,⁹⁵ C. Gay,¹⁶⁷ G. Gaycken,²¹ E. N. Gazis,¹⁰ Z. Gecse,¹⁶⁷ C. N. P. Gee,¹³⁰ Ch. Geich-Gimbel,²¹ M. P. Geisler,^{58a} C. Gemme,^{50a} M. H. Genest,⁵⁵ C. Geng,^{33b,n} S. Gentile,^{131a,131b} S. George,⁷⁷ D. Gerbaudo,¹⁶² A. Gershon,¹⁵² S. Ghasemi,¹⁴⁰ H. Ghazlane,^{134b} B. Giacobbe,^{20a} S. Giagu,^{131a,131b} P. Giannetti,^{123a,123b} B. Gibbard,²⁵ S. M. Gibson,⁷⁷ M. Gignac,¹⁶⁷ M. Gilchriese,¹⁵ T. P. S. Gillam,²⁸ D. Gillberg,²⁹ G. Gilles,¹⁷⁴ D. M. Gingrich,^{3,d} N. Giokaris,⁹ M. P. Giordani,^{163a,163c} F. M. Giorgi,^{20a} F. M. Giorgi,¹⁶ P. F. Giraud,¹³⁵ P. Giromini,⁵⁷ D. Giugni,^{91a} C. Giuliani,¹⁰⁰ M. Giulini,^{58b} B. K. Gjelsten,¹¹⁸ S. Gkaitatzis,¹⁵³ I. Gkialas,¹⁵³ E. L. Gkougkousis,¹¹⁶ L. K. Gladilin,⁹⁸ C. Glasman,⁸² J. Glatzer,³⁰ P. C. F. Glaysher,⁴⁶ A. Glazov,⁴² M. Goblirsch-Kolb,¹⁰⁰ J. Godlewski,³⁹ S. Goldfarb,⁸⁹ T. Golling,⁴⁹ D. Golubkov,¹²⁹ A. Gomes,^{125a,125b,125d} R. Gonçalo,^{125a} J. Goncalves Pinto Firmino Da Costa,¹³⁵ L. Gonella,¹⁸ A. Gongadze,⁶⁵ S. González de la Hoz,¹⁶⁶ G. Gonzalez Parra,¹² S. Gonzalez-Sevilla,⁴⁹ L. Goossens,³⁰ P. A. Gorbounov,⁹⁶ H. A. Gordon,²⁵ I. Gorelov,¹⁰⁴ B. Gorini,³⁰ E. Gorini,^{73a,73b} A. Gorišek,⁷⁵ E. Gornicki,³⁹ A. T. Goshaw,⁴⁵ C. Gössling,⁴³ M. I. Gostkin,⁶⁵ C. R. Goudet,¹¹⁶ D. Goujdami,^{134c} A. G. Goussiou,¹³⁷ N. Govender,^{144b} E. Gozani,¹⁵¹ L. Graber,⁵⁴ I. Grabowska-Bold,^{38a} P. O. J. Gradin,¹⁶⁵ P. Grafström,^{20a,20b} J. Gramling,⁴⁹ E. Gramstad,¹¹⁸ S. Grancagnolo,¹⁶ V. Gratchev,¹²² H. M. Gray,³⁰ E. Graziani,^{133a} Z. D. Greenwood,^{79,o} C. Grefe,²¹ K. Gregersen,⁷⁸ I. M. Gregor,⁴² P. Grenier,¹⁴² K. Grevtsov,⁵ J. Griffiths,⁸ A. A. Grillo,¹³⁶ K. Grimm,⁷² S. Grinstein,^{12,p} Ph. Gris,³⁴ J.-F. Grivaz,¹¹⁶ S. Groh,⁸³ J. P. Grohs,⁴⁴ E. Gross,¹⁷¹ J. Grosse-Knetter,⁵⁴ G. C. Grossi,⁷⁹ Z. J. Grout,¹⁴⁸ L. Guan,⁸⁹ W. Guan,¹⁷² J. Guenther,¹²⁷ F. Guescini,⁴⁹ D. Guest,¹⁶² O. Gueta,¹⁵² E. Guido,^{50a,50b} T. Guillemin,⁵ S. Guindon,² U. Gul,⁵³ C. Gumpert,³⁰ J. Guo,^{33e} Y. Guo,^{33b,n} S. Gupta,¹¹⁹ G. Gustavino,^{131a,131b} P. Gutierrez,¹¹² N. G. Gutierrez Ortiz,⁷⁸ C. Gutsche,⁴⁴ C. Guyot,¹³⁵ C. Gwenlan,¹¹⁹ C. B. Gwilliam,⁷⁴ A. Haas,¹⁰⁹ C. Haber,¹⁵ H. K. Hadavand,⁸ N. Haddad,^{134e} A. Hadeef,⁸⁵ P. Haefner,²¹ S. Hageböck,²¹ Z. Hajduk,³⁹ H. Hakobyan,^{176,†} M. Haleem,⁴² J. Haley,¹¹³ D. Hall,¹¹⁹ G. Halladjian,⁹⁰ G. D. Hallewell,⁸⁵ K. Hamacher,¹⁷⁴ P. Hamal,¹¹⁴ K. Hamano,¹⁶⁸ A. Hamilton,^{144a} G. N. Hamity,¹³⁸ P. G. Hamnett,⁴² L. Han,^{33b} K. Hanagaki,^{66,q} K. Hanawa,¹⁵⁴ M. Hance,¹³⁶ B. Haney,¹²¹ P. Hanke,^{58a} R. Hanna,¹³⁵ J. B. Hansen,³⁶ J. D. Hansen,³⁶ M. C. Hansen,²¹ P. H. Hansen,³⁶ K. Hara,¹⁵⁹ A. S. Hard,¹⁷² T. Harenberg,¹⁷⁴ F. Hariri,¹¹⁶ S. Harkusha,⁹² R. D. Harrington,⁴⁶ P. F. Harrison,¹⁶⁹ F. Hartjes,¹⁰⁶ M. Hasegawa,⁶⁷ Y. Hasegawa,¹³⁹ A. Hasib,¹¹² S. Hassani,¹³⁵ S. Haug,¹⁷ R. Hauser,⁹⁰ L. Hauswald,⁴⁴ M. Havranek,¹²⁶ C. M. Hawkes,¹⁸ R. J. Hawkins,³⁰ A. D. Hawkins,⁸¹ D. Hayden,⁹⁰ C. P. Hays,¹¹⁹ J. M. Hays,⁷⁶ H. S. Hayward,⁷⁴

S. J. Haywood,¹³⁰ S. J. Head,¹⁸ T. Heck,⁸³ V. Hedberg,⁸¹ L. Heelan,⁸ S. Heim,¹²¹ T. Heim,¹⁵ B. Heinemann,¹⁵ J. J. Heinrich,⁹⁹ L. Heinrich,¹⁰⁹ C. Heinz,⁵² J. Hejbal,¹²⁶ L. Helary,²² S. Hellman,^{145a,145b} C. Helsens,³⁰ J. Henderson,¹¹⁹ R. C. W. Henderson,⁷² Y. Heng,¹⁷² S. Henkelmann,¹⁶⁷ A. M. Henriques Correia,³⁰ S. Henrot-Versille,¹¹⁶ G. H. Herbert,¹⁶ Y. Hernández Jiménez,¹⁶⁶ G. Herten,⁴⁸ R. Hertenberger,⁹⁹ L. Hervas,³⁰ G. G. Hesketh,⁷⁸ N. P. Hesse,¹⁰⁶ J. W. Hetherly,⁴⁰ R. Hickling,⁷⁶ E. Higón-Rodríguez,¹⁶⁶ E. Hill,¹⁶⁸ J. C. Hill,²⁸ K. H. Hiller,⁴² S. J. Hillier,¹⁸ I. Hinchliffe,¹⁵ E. Hines,¹²¹ R. R. Hinman,¹⁵ M. Hirose,¹⁵⁶ D. Hirschbuehl,¹⁷⁴ J. Hobbs,¹⁴⁷ N. Hod,¹⁰⁶ M. C. Hodgkinson,¹³⁸ P. Hodgson,¹³⁸ A. Hoecker,³⁰ M. R. Hoferkamp,¹⁰⁴ F. Hoenig,⁹⁹ M. Hohlfeld,⁸³ D. Hohn,²¹ T. R. Holmes,¹⁵ M. Homann,⁴³ T. M. Hong,¹²⁴ B. H. Hooberman,¹⁶⁴ W. H. Hopkins,¹¹⁵ Y. Horii,¹⁰² A. J. Horton,¹⁴¹ J.-Y. Hostachy,⁵⁵ S. Hou,¹⁵⁰ A. Hoummada,^{134a} J. Howard,¹¹⁹ J. Howarth,⁴² M. Hrabovsky,¹¹⁴ I. Hristova,¹⁶ J. Hrivnac,¹¹⁶ T. Hryn'ova,⁵ A. Hrynevich,⁹³ C. Hsu,^{144c} P. J. Hsu,^{150,r} S.-C. Hsu,¹³⁷ D. Hu,³⁵ Q. Hu,^{33b} Y. Huang,⁴² Z. Hubacek,¹²⁷ F. Hubaut,⁸⁵ F. Huegging,²¹ T. B. Huffman,¹¹⁹ E. W. Hughes,³⁵ G. Hughes,⁷² M. Huhtinen,³⁰ T. A. Hülsing,⁸³ N. Huseynov,^{65,b} J. Huston,⁹⁰ J. Huth,⁵⁷ G. Iacobucci,⁴⁹ G. Iakovidis,²⁵ I. Ibragimov,¹⁴⁰ L. Iconomidou-Fayard,¹¹⁶ E. Ideal,¹⁷⁵ Z. Idrissi,^{134e} P. Iengo,³⁰ O. Igonkina,¹⁰⁶ T. Iizawa,¹⁷⁰ Y. Ikegami,⁶⁶ M. Ikeno,⁶⁶ Y. Ilchenko,^{31,s} D. Iliadis,¹⁵³ N. Ilic,¹⁴² T. Ince,¹⁰⁰ G. Introzzi,^{120a,120b} P. Ioannou,^{9,†} M. Iodice,^{133a} K. Iordanidou,³⁵ V. Ippolito,⁵⁷ A. Irlles Quiles,¹⁶⁶ C. Isaksson,¹⁶⁵ M. Ishino,⁶⁸ M. Ishitsuka,¹⁵⁶ R. Ishmukhametov,¹¹⁰ C. Issever,¹¹⁹ S. Istin,^{19a} F. Ito,¹⁵⁹ J. M. Iturbe Ponce,⁸⁴ R. Iuppa,^{132a,132b} J. Ivarsson,⁸¹ W. Iwanski,³⁹ H. Iwasaki,⁶⁶ J. M. Izen,⁴¹ V. Izzo,^{103a} S. Jabbar,³ B. Jackson,¹²¹ M. Jackson,⁷⁴ P. Jackson,¹ V. Jain,² K. B. Jakobi,⁸³ K. Jakobs,⁴⁸ S. Jakobsen,³⁰ T. Jakoubek,¹²⁶ D. O. Jamin,¹¹³ D. K. Jana,⁷⁹ E. Jansen,⁷⁸ R. Jansky,⁶² J. Janssen,²¹ M. Janus,⁵⁴ G. Jarlskog,⁸¹ N. Javadov,^{65,b} T. Javůrek,⁴⁸ F. Jeanneau,¹³⁵ L. Jeanty,¹⁵ J. Jejelava,^{51a,t} G.-Y. Jeng,¹⁴⁹ D. Jennens,⁸⁸ P. Jenni,^{48,u} J. Jentsch,⁴³ C. Jeske,¹⁶⁹ S. Jézéquel,⁵ H. Ji,¹⁷² J. Jia,¹⁴⁷ H. Jiang,⁶⁴ Y. Jiang,^{33b} S. Jiggins,⁷⁸ J. Jimenez Pena,¹⁶⁶ S. Jin,^{33a} A. Jinaru,^{26b} O. Jinnouchi,¹⁵⁶ P. Johansson,¹³⁸ K. A. Johns,⁷ W. J. Johnson,¹³⁷ K. Jon-And,^{145a,145b} G. Jones,¹⁶⁹ R. W. L. Jones,⁷² S. Jones,⁷ T. J. Jones,⁷⁴ J. Jongmanns,^{58a} P. M. Jorge,^{125a,125b} J. Jovicevic,^{158a} X. Ju,¹⁷² A. Juste Rozas,^{12,p} M. K. Köhler,¹⁷¹ A. Kaczmarek,³⁹ M. Kado,¹¹⁶ H. Kagan,¹¹⁰ M. Kagan,¹⁴² S. J. Kahn,⁸⁵ E. Kajomovitz,⁴⁵ C. W. Kalderon,¹¹⁹ A. Kaluza,⁸³ S. Kama,⁴⁰ A. Kamenshchikov,¹²⁹ N. Kanaya,¹⁵⁴ S. Kaneti,²⁸ V. A. Kantserov,⁹⁷ J. Kanzaki,⁶⁶ B. Kaplan,¹⁰⁹ L. S. Kaplan,¹⁷² A. Kapliy,³¹ D. Kar,^{144c} K. Karakostas,¹⁰ A. Karamaoun,³ N. Karastathis,^{10,106} M. J. Kareem,⁵⁴ E. Karentzos,¹⁰ M. Karneevskiy,⁸³ S. N. Karpov,⁶⁵ Z. M. Karpova,⁶⁵ K. Karthik,¹⁰⁹ V. Kartvelishvili,⁷² A. N. Karyukhin,¹²⁹ K. Kasahara,¹⁵⁹ L. Kashif,¹⁷² R. D. Kass,¹¹⁰ A. Kastanas,¹⁴ Y. Kataoka,¹⁵⁴ C. Kato,¹⁵⁴ A. Katre,⁴⁹ J. Katzy,⁴² K. Kawade,¹⁰² K. Kawagoe,⁷⁰ T. Kawamoto,¹⁵⁴ G. Kawamura,⁵⁴ S. Kazama,¹⁵⁴ V. F. Kazanin,^{108,c} R. Keeler,¹⁶⁸ R. Kehoe,⁴⁰ J. S. Keller,⁴² J. J. Kempster,⁷⁷ H. Keoshkerian,⁸⁴ O. Kepka,¹²⁶ B. P. Kerševan,⁷⁵ S. Kersten,¹⁷⁴ R. A. Keyes,⁸⁷ F. Khalil-zada,¹¹ H. Khandanyan,^{145a,145b} A. Khanov,¹¹³ A. G. Kharlamov,^{108,c} T. J. Khoo,²⁸ V. Khovanskiy,⁹⁶ E. Khramov,⁶⁵ J. Khubua,^{51b,v} S. Kido,⁶⁷ H. Y. Kim,⁸ S. H. Kim,¹⁵⁹ Y. K. Kim,³¹ N. Kimura,¹⁵³ O. M. Kind,¹⁶ B. T. King,⁷⁴ M. King,¹⁶⁶ S. B. King,¹⁶⁷ J. Kirk,¹³⁰ A. E. Kiryunin,¹⁰⁰ T. Kishimoto,⁶⁷ D. Kisielewska,^{38a} F. Kiss,⁴⁸ K. Kiuchi,¹⁵⁹ O. Kivernyk,¹³⁵ E. Kladiva,^{143b} M. H. Klein,³⁵ M. Klein,⁷⁴ U. Klein,⁷⁴ K. Kleinknecht,⁸³ P. Klimek,^{145a,145b} A. Klimentov,²⁵ R. Klingenberg,⁴³ J. A. Klinger,¹³⁸ T. Klioutchnikova,³⁰ E.-E. Kluge,^{58a} P. Kluit,¹⁰⁶ S. Kluth,¹⁰⁰ J. Knapik,³⁹ E. Kneringer,⁶² E. B. F. G. Knoops,⁸⁵ A. Knue,⁵³ A. Kobayashi,¹⁵⁴ D. Kobayashi,¹⁵⁶ T. Kobayashi,¹⁵⁴ M. Kobel,⁴⁴ M. Kocian,¹⁴² P. Kodys,¹²⁸ T. Koffas,²⁹ E. Koffeman,¹⁰⁶ L. A. Kogan,¹¹⁹ T. Kohriki,⁶⁶ T. Koi,¹⁴² H. Kolanoski,¹⁶ M. Kolb,^{58b} I. Koletsou,⁵ A. A. Komar,^{95,†} Y. Komori,¹⁵⁴ T. Kondo,⁶⁶ N. Kondrashova,⁴² K. Köneke,⁴⁸ A. C. König,¹⁰⁵ T. Kono,^{66,w} R. Konoplich,^{109,x} N. Konstantinidis,⁷⁸ R. Kopeliansky,⁶¹ S. Koperny,^{38a} L. Köpke,⁸³ A. K. Kopp,⁴⁸ K. Korcyl,³⁹ K. Kordas,¹⁵³ A. Korn,⁷⁸ A. A. Korol,^{108,c} I. Korolkov,¹² E. V. Korolkova,¹³⁸ O. Kortner,¹⁰⁰ S. Kortner,¹⁰⁰ T. Kosek,¹²⁸ V. V. Kostyukhin,²¹ V. M. Kotov,⁶⁵ A. Kotwal,⁴⁵ A. Kourkoumelis-Charalampidi,¹⁵³ C. Kourkoumelis,⁹ V. Kouskoura,²⁵ A. Koutsman,^{158a} A. B. Kowalewska,³⁹ R. Kowalewski,¹⁶⁸ T. Z. Kowalski,^{38a} W. Kozanecki,¹³⁵ A. S. Kozhin,¹²⁹ V. A. Kramarenko,⁹⁸ G. Kramberger,⁷⁵ D. Krasnopevtsev,⁹⁷ M. W. Krasny,⁸⁰ A. Krasznahorkay,³⁰ J. K. Kraus,²¹ A. Kravchenko,²⁵ M. Kretz,^{58c} J. Kretzschmar,⁷⁴ K. Kreutzfeldt,⁵² P. Krieger,¹⁵⁷ K. Krizka,³¹ K. Kroeninger,⁴³ H. Kroha,¹⁰⁰ J. Kroll,¹²¹ J. Kroseberg,²¹ J. Krstic,¹³ U. Kruchonak,⁶⁵ H. Krüger,²¹ N. Krumnack,⁶⁴ A. Kruse,¹⁷² M. C. Kruse,⁴⁵ M. Kruskal,²² T. Kubota,⁸⁸ H. Kucuk,⁷⁸ S. Kudahy,^{4b} J. T. Kuechler,¹⁷⁴ S. Kuehn,⁴⁸ A. Kugel,^{58c} F. Kuger,¹⁷³ A. Kuhl,¹³⁶ T. Kuhl,⁴² V. Kukhtin,⁶⁵ R. Kukla,¹³⁵ Y. Kulchitsky,⁹² S. Kuleshov,^{32b} M. Kuna,^{131a,131b} T. Kunigo,⁶⁸ A. Kupco,¹²⁶ H. Kurashige,⁶⁷ Y. A. Kurochkin,⁹² V. Kus,¹²⁶ E. S. Kuwertz,¹⁶⁸ M. Kuze,¹⁵⁶ J. Kvita,¹¹⁴ T. Kwan,¹⁶⁸ D. Kyriazopoulos,¹³⁸ A. La Rosa,¹⁰⁰ J. L. La Rosa Navarro,^{24d} L. La Rotonda,^{37a,37b} C. Lacasta,¹⁶⁶ F. Lacava,^{131a,131b} J. Lacey,²⁹ H. Lacker,¹⁶ D. Lacour,⁸⁰ V. R. Lacuesta,¹⁶⁶ E. Ladygin,⁶⁵ R. Lafaye,⁵ B. Laforge,⁸⁰ T. Lagouri,¹⁷⁵ S. Lai,⁵⁴ S. Lammers,⁶¹ W. Lampl,⁷ E. Lançon,¹³⁵ U. Landgraf,⁴⁸ M. P. J. Landon,⁷⁶ V. S. Lang,^{58a} J. C. Lange,¹² A. J. Lankford,¹⁶² F. Lanni,²⁵ K. Lantzsch,²¹ A. Lanza,^{120a}

S. Laplace,⁸⁰ C. Lapoire,³⁰ J. F. Laporte,¹³⁵ T. Lari,^{91a} F. Lasagni Manghi,^{20a,20b} M. Lassnig,³⁰ P. Laurelli,⁴⁷ W. Lavrijsen,¹⁵ A. T. Law,¹³⁶ P. Laycock,⁷⁴ T. Lazovich,⁵⁷ O. Le Dortz,⁸⁰ E. Le Guirriec,⁸⁵ E. Le Menedeu,¹² E. P. Le Quilleuc,¹³⁵ M. LeBlanc,¹⁶⁸ T. LeCompte,⁶ F. Ledroit-Guillon,⁵⁵ C. A. Lee,²⁵ S. C. Lee,¹⁵⁰ L. Lee,¹ G. Lefebvre,⁸⁰ M. Lefebvre,¹⁶⁸ F. Legger,⁹⁹ C. Leggett,¹⁵ A. Lehan,⁷⁴ G. Lehmann Miotto,³⁰ X. Lei,⁷ W. A. Leight,²⁹ A. Leisos,^{153,y} A. G. Leister,¹⁷⁵ M. A. L. Leite,^{24d} R. Leitner,¹²⁸ D. Lellouch,¹⁷¹ B. Lemmer,⁵⁴ K. J. C. Leney,⁷⁸ T. Lenz,²¹ B. Lenzi,³⁰ R. Leone,⁷ S. Leone,^{123a,123b} C. Leonidopoulos,⁴⁶ S. Leontsinis,¹⁰ C. Leroy,⁹⁴ A. A. J. Lesage,¹³⁵ C. G. Lester,²⁸ M. Levchenko,¹²² J. Levêque,⁵ D. Levin,⁸⁹ L. J. Levinson,¹⁷¹ M. Levy,¹⁸ A. M. Leyko,²¹ M. Leyton,⁴¹ B. Li,^{33b,z} H. Li,¹⁴⁷ H. L. Li,³¹ L. Li,⁴⁵ L. Li,^{33e} Q. Li,^{33a} S. Li,⁴⁵ X. Li,⁸⁴ Y. Li,¹⁴⁰ Z. Liang,¹³⁶ H. Liao,³⁴ B. Liberti,^{132a} A. Liblong,¹⁵⁷ P. Lichard,³⁰ K. Lie,¹⁶⁴ J. Liebal,²¹ W. Liebig,¹⁴ C. Limbach,²¹ A. Limosani,¹⁴⁹ S. C. Lin,^{150,aa} T. H. Lin,⁸³ B. E. Lindquist,¹⁴⁷ E. Lipeles,¹²¹ A. Lipniacka,¹⁴ M. Lisovyi,^{58b} T. M. Liss,¹⁶⁴ D. Lissauer,¹⁶⁷ A. M. Lister,¹³⁶ B. Liu,^{150,bb} D. Liu,¹⁵⁰ H. Liu,⁸⁹ H. Liu,²⁵ J. Liu,⁸⁵ J. B. Liu,^{33b} K. Liu,⁸⁵ L. Liu,¹⁶⁴ M. Liu,⁴⁵ M. Liu,^{33b} Y. L. Liu,^{33b} Y. Liu,^{33b} M. Livan,^{120a,120b} A. Lleres,⁵⁵ J. Llorente Merino,⁸² S. L. Lloyd,⁷⁶ F. Lo Sterzo,¹⁵⁰ E. Lobodzinska,⁴² P. Loch,⁷ W. S. Lockman,¹³⁶ F. K. Loebinger,⁸⁴ A. E. Loevschall-Jensen,³⁶ K. M. Loew,²³ A. Loginov,¹⁷⁵ T. Lohse,¹⁶ K. Lohwasser,⁴² M. Lokajicek,¹²⁶ B. A. Long,²² J. D. Long,¹⁶⁴ R. E. Long,⁷² L. Longo,^{73a,73b} K. A. Looper,¹¹⁰ L. Lopes,^{125a} D. Lopez Mateos,⁵⁷ B. Lopez Paredes,¹³⁸ I. Lopez Paz,¹² A. Lopez Solis,⁸⁰ J. Lorenz,⁹⁹ N. Lorenzo Martinez,⁶¹ M. Losada,¹⁶¹ P. J. Lösel,⁹⁹ X. Lou,^{33a} A. Lounis,¹¹⁶ J. Love,⁶ P. A. Love,⁷² H. Lu,^{60a} N. Lu,⁸⁹ H. J. Lubatti,¹³⁷ C. Luci,^{131a,131b} A. Lucotte,⁵⁵ C. Luedtke,⁴⁸ F. Luehring,⁶¹ W. Lukas,⁶² L. Luminari,^{131a} O. Lundberg,^{145a,145b} B. Lund-Jensen,¹⁴⁶ D. Lynn,²⁵ R. Lysak,¹²⁶ E. Lytken,⁸¹ H. Ma,²⁵ L. L. Ma,^{33d} G. Maccarrone,⁴⁷ A. Macchiolo,¹⁰⁰ C. M. Macdonald,¹³⁸ B. Maček,⁷⁵ J. Machado Miguens,^{121,125b} D. Madaffari,⁸⁵ R. Madar,³⁴ H. J. Maddocks,¹⁶⁵ W. F. Mader,⁴⁴ A. Madsen,⁴² J. Maeda,⁶⁷ S. Maeland,¹⁴ T. Maeno,²⁵ A. Maevskiy,⁹⁸ E. Magradze,⁵⁴ J. Mahlstedt,¹⁰⁶ C. Maiani,¹¹⁶ C. Maidantchik,^{24a} A. A. Maier,¹⁰⁰ T. Maier,⁹⁹ A. Maio,^{125a,125b,125d} S. Majewski,¹¹⁵ Y. Makida,⁶⁶ N. Makovec,¹¹⁶ B. Malaescu,⁸⁰ Pa. Malecki,³⁹ V. P. Maleev,¹²² F. Malek,⁵⁵ U. Mallik,⁶³ D. Malon,⁶ C. Malone,¹⁴² S. Maltezos,¹⁰ V. M. Malyshev,¹⁰⁸ S. Malyukov,³⁰ J. Mamuzic,⁴² G. Mancini,⁴⁷ B. Mandelli,³⁰ L. Mandelli,^{91a} I. Mandić,⁷⁵ J. Maneira,^{125a,125b} L. Manhaes de Andrade Filho,^{24b} J. Manjarres Ramos,^{158b} A. Mann,⁹⁹ B. Mansoulié,¹³⁵ R. Mantifel,⁸⁷ M. Mantoani,⁵⁴ S. Manzoni,^{91a,91b} L. Mapelli,³⁰ G. Marceca,²⁷ L. March,⁴⁹ G. Marchiori,⁸⁰ M. Marcisovsky,¹²⁶ M. Marjanovic,¹³ D. E. Marley,⁸⁹ F. Marroquim,^{24a} S. P. Marsden,⁸⁴ Z. Marshall,¹⁵ L. F. Marti,¹⁷ S. Marti-Garcia,¹⁶⁶ B. Martin,⁹⁰ T. A. Martin,¹⁶⁹ V. J. Martin,⁴⁶ B. Martin dit Latour,¹⁴ M. Martinez,^{12,p} S. Martin-Haugh,¹³⁰ V. S. Martoiu,^{26b} A. C. Martyniuk,⁷⁸ M. Marx,¹³⁷ F. Marzano,^{131a} A. Marzin,³⁰ L. Masetti,⁸³ T. Mashimo,¹⁵⁴ R. Mashinistov,⁹⁵ J. Masik,⁸⁴ A. L. Maslennikov,^{108,c} I. Massa,^{20a,20b} L. Massa,^{20a,20b} P. Mastrandrea,⁵ A. Mastroberardino,^{37a,37b} T. Masubuchi,¹⁵⁴ P. Mättig,¹⁷⁴ J. Mattmann,⁸³ J. Maurer,^{26b} S. J. Maxfield,⁷⁴ D. A. Maximov,^{108,c} R. Mazini,¹⁵⁰ S. M. Mazza,^{91a,91b} N. C. Mc Fadden,¹⁰⁴ G. Mc Goldrick,¹⁵⁷ S. P. Mc Kee,⁸⁹ A. McCarn,⁸⁹ R. L. McCarthy,¹⁴⁷ T. G. McCarthy,²⁹ L. I. McClymont,⁷⁸ K. W. McFarlane,^{56,†} J. A. Mcfayden,⁷⁸ G. Mchedlidze,⁵⁴ S. J. McMahon,¹³⁰ R. A. McPherson,^{168,l} M. Medinnis,⁴² S. Meehan,¹³⁷ S. Mehlhase,⁹⁹ A. Mehta,⁷⁴ K. Meier,^{58a} C. Meineck,⁹⁹ B. Meirose,⁴¹ B. R. Mellado Garcia,^{144c} F. Meloni,¹⁷ A. Mengarelli,^{20a,20b} S. Menke,¹⁰⁰ E. Meoni,¹⁶⁰ K. M. Mercurio,⁵⁷ S. Mergelmeyer,¹⁶ P. Mermod,⁴⁹ L. Merola,^{103a,103b} C. Meroni,^{91a} F. S. Merritt,³¹ A. Messina,^{131a,131b} J. Metcalfe,⁶ A. S. Mete,¹⁶² C. Meyer,⁸³ C. Meyer,¹²¹ J-P. Meyer,¹³⁵ J. Meyer,¹⁰⁶ H. Meyer Zu Theenhausen,^{58a} R. P. Middleton,¹³⁰ S. Miglioranzi,^{163a,163c} L. Mijović,²¹ G. Mikenberg,¹⁷¹ M. Mikestikova,¹²⁶ M. Mikuž,⁷⁵ M. Milesi,⁸⁸ A. Milic,³⁰ D. W. Miller,³¹ C. Mills,⁴⁶ A. Milov,¹⁷¹ D. A. Milstead,^{145a,145b} A. A. Minaenko,¹²⁹ Y. Minami,¹⁵⁴ I. A. Minashvili,⁶⁵ A. I. Mincer,¹⁰⁹ B. Mindur,^{38a} M. Mineev,⁶⁵ Y. Ming,¹⁷² L. M. Mir,¹² K. P. Mistry,¹²¹ T. Mitani,¹⁷⁰ J. Mitrevski,⁹⁹ V. A. Mitsou,¹⁶⁶ A. Miucci,⁴⁹ P. S. Miyagawa,¹³⁸ J. U. Mjörnmark,⁸¹ T. Moa,^{145a,145b} K. Mochizuki,⁸⁵ S. Mohapatra,³⁵ W. Mohr,⁴⁸ S. Molander,^{145a,145b} R. Moles-Valls,²¹ R. Monden,⁶⁸ M. C. Mondragon,⁹⁰ K. Mönig,⁴² J. Monk,³⁶ E. Monnier,⁸⁵ A. Montalbano,¹⁴⁷ J. Montejo Berlingen,³⁰ F. Monticelli,⁷¹ S. Monzani,^{91a,91b} R. W. Moore,³ N. Morange,¹¹⁶ D. Moreno,¹⁶¹ M. Moreno Llácer,⁵⁴ P. Morettini,^{50a} D. Mori,¹⁴¹ T. Mori,¹⁵⁴ M. Morii,⁵⁷ M. Morinaga,¹⁵⁴ V. Morisbak,¹¹⁸ S. Moritz,⁸³ A. K. Morley,¹⁴⁹ G. Mornacchi,³⁰ J. D. Morris,⁷⁶ S. S. Mortensen,³⁶ L. Morvaj,¹⁴⁷ M. Mosidze,^{51b} J. Moss,¹⁴² K. Motohashi,¹⁵⁶ R. Mount,¹⁴² E. Mountricha,²⁵ S. V. Mouraviev,^{95,†} E. J. W. Moyse,⁸⁶ S. Muanza,⁸⁵ R. D. Mudd,¹⁸ F. Mueller,¹⁰⁰ J. Mueller,¹²⁴ R. S. P. Mueller,⁹⁹ T. Mueller,²⁸ D. Muenstermann,⁷² P. Mullen,⁵³ G. A. Mullier,¹⁷ F. J. Munoz Sanchez,⁸⁴ J. A. Murillo Quijada,¹⁸ W. J. Murray,^{169,130} H. Musheghyan,⁵⁴ A. G. Myagkov,^{129,cc} M. Myska,¹²⁷ B. P. Nachman,¹⁴² O. Nackenhorst,⁴⁹ J. Nadal,⁵⁴ K. Nagai,¹¹⁹ R. Nagai,^{66,w} Y. Nagai,⁸⁵ K. Naganano,⁶⁶ Y. Nagasaka,⁵⁹ K. Nagata,¹⁵⁹ M. Nagel,¹⁰⁰ E. Nagy,⁸⁵ A. M. Nairz,³⁰ Y. Nakahama,³⁰ K. Nakamura,⁶⁶ T. Nakamura,¹⁵⁴ I. Nakano,¹¹¹ H. Namasivayam,⁴¹ R. F. Naranjo Garcia,⁴² R. Narayan,³¹ D. I. Narrias Villar,^{58a} I. Naryshkin,¹²² T. Naumann,⁴²

G. Navarro,¹⁶¹ R. Nayyar,⁷ H. A. Neal,⁸⁹ P. Yu. Nechaeva,⁹⁵ T. J. Neep,⁸⁴ P. D. Nef,¹⁴² A. Negri,^{120a,120b} M. Negrini,^{20a} S. Nektarijevic,¹⁰⁵ C. Nellist,¹¹⁶ A. Nelson,¹⁶² S. Nemecek,¹²⁶ P. Nemethy,¹⁰⁹ A. A. Nepomuceno,^{24a} M. Nessi,^{30,dd} M. S. Neubauer,¹⁶⁴ M. Neumann,¹⁷⁴ R. M. Neves,¹⁰⁹ P. Nevski,²⁵ P. R. Newman,¹⁸ D. H. Nguyen,⁶ R. B. Nickerson,¹¹⁹ R. Nicolaidou,¹³⁵ B. Nicquevert,³⁰ J. Nielsen,¹³⁶ A. Nikiforov,¹⁶ V. Nikolaenko,^{129,cc} I. Nikolic-Audit,⁸⁰ K. Nikolopoulos,¹⁸ J. K. Nilsen,¹¹⁸ P. Nilsson,²⁵ Y. Ninomiya,¹⁵⁴ A. Nisati,^{131a} R. Nisius,¹⁰⁰ T. Nobe,¹⁵⁴ L. Nodulman,⁶ M. Nomachi,¹¹⁷ I. Nomidis,²⁹ T. Nooney,⁷⁶ S. Norberg,¹¹² M. Nordberg,³⁰ O. Novgorodova,⁴⁴ S. Nowak,¹⁰⁰ M. Nozaki,⁶⁶ L. Nozka,¹¹⁴ K. Ntekas,¹⁰ E. Nurse,⁷⁸ F. Nuti,⁸⁸ F. O'grady,⁷ D. C. O'Neil,¹⁴¹ A. A. O'Rourke,⁴² V. O'Shea,⁵³ F. G. Oakham,^{29,d} H. Oberlack,¹⁰⁰ T. Obermann,²¹ J. Ocariz,⁸⁰ A. Ochi,⁶⁷ I. Ochoa,³⁵ J. P. Ochoa-Ricoux,^{32a} S. Oda,⁷⁰ S. Odaka,⁶⁶ H. Ogren,⁶¹ A. Oh,⁸⁴ S. H. Oh,⁴⁵ C. C. Ohm,¹⁵ H. Ohman,¹⁶⁵ H. Oide,³⁰ H. Okawa,¹⁵⁹ Y. Okumura,³¹ T. Okuyama,⁶⁶ A. Olariu,^{26b} L. F. Oleiro Seabra,^{125a} S. A. Olivares Pino,⁴⁶ D. Oliveira Damazio,²⁵ A. Olszewski,³⁹ J. Olszowska,³⁹ A. Onofre,^{125a,125e} K. Onogi,¹⁰² P. U. E. Onyisi,^{31,s} C. J. Oram,^{158a} M. J. Oreglia,³¹ Y. Oren,¹⁵² D. Orestano,^{133a,133b} N. Orlando,^{60b} R. S. Orr,¹⁵⁷ B. Osculati,^{50a,50b} R. Ospanov,⁸⁴ G. Otero y Garzon,²⁷ H. Otono,⁷⁰ M. Ouchrif,^{134d} F. Ould-Saada,¹¹⁸ A. Ouraou,¹³⁵ K. P. Oussoren,¹⁰⁶ Q. Ouyang,^{33a} A. Ovcharova,¹⁵ M. Owen,⁵³ R. E. Owen,¹⁸ V. E. Ozcan,^{19a} N. Ozturk,⁸ K. Pachal,¹⁴¹ A. Pacheco Pages,¹² C. Padilla Aranda,¹² M. Pagáčová,⁴⁸ S. Pagan Griso,¹⁵ F. Paige,²⁵ P. Pais,⁸⁶ K. Pajchel,¹¹⁸ G. Palacino,^{158b} S. Palestini,³⁰ M. Palka,^{38b} D. Pallin,³⁴ A. Palma,^{125a,125b} E. St. Panagiotopoulou,¹⁰ C. E. Pandini,⁸⁰ J. G. Panduro Vazquez,⁷⁷ P. Pani,^{145a,145b} S. Panitkin,²⁵ D. Pantea,^{26b} L. Paolozzi,⁴⁹ Th. D. Papadopoulos,¹⁰ K. Papageorgiou,¹⁵³ A. Paramonov,⁶ D. Paredes Hernandez,¹⁷⁵ M. A. Parker,²⁸ K. A. Parker,¹³⁸ F. Parodi,^{50a,50b} J. A. Parsons,³⁵ U. Parzefall,⁴⁸ V. Pascuzzi,¹⁵⁷ E. Pasqualucci,^{131a} S. Passaggio,^{50a} F. Pastore,^{133a,133b,†} Fr. Pastore,⁷⁷ G. Pásztor,²⁹ S. Pataria,¹⁷⁴ N. D. Patel,¹⁴⁹ J. R. Pater,⁸⁴ T. Pauly,³⁰ J. Pearce,¹⁶⁸ B. Pearson,¹¹² L. E. Pedersen,³⁶ M. Pedersen,¹¹⁸ S. Pedraza Lopez,¹⁶⁶ R. Pedro,^{125a,125b} S. V. Peleganchuk,^{108,c} D. Pelikan,¹⁶⁵ O. Penc,¹²⁶ C. Peng,^{33a} H. Peng,^{33b} J. Penwell,⁶¹ B. S. Peralva,^{24b} D. V. Perepelitsa,²⁵ E. Perez Codina,^{158a} L. Perini,^{91a,91b} H. Pernegger,³⁰ S. Perrella,^{103a,103b} R. Peschke,⁴² V. D. Peshekhonov,⁶⁵ K. Peters,³⁰ R. F. Y. Peters,⁸⁴ B. A. Petersen,³⁰ T. C. Petersen,³⁶ E. Petit,⁵⁵ A. Petridis,¹ C. Petridou,¹⁵³ P. Petroff,¹¹⁶ E. Petrolo,^{131a} M. Petrov,¹¹⁹ F. Petrucci,^{133a,133b} N. E. Pettersson,¹⁵⁶ A. Peyaud,¹³⁵ R. Pezoa,^{32b} P. W. Phillips,¹³⁰ G. Piacquadio,¹⁴² E. Pianori,¹⁶⁹ A. Picazio,⁸⁶ E. Piccaro,⁷⁶ M. Piccinini,^{20a,20b} M. A. Pickering,¹¹⁹ R. Piegai,²⁷ J. E. Pilcher,³¹ A. D. Pilkington,⁸⁴ A. W. J. Pin,⁸⁴ J. Pina,^{125a,125b,125d} M. Pinamonti,^{163a,163c,ee} J. L. Pinfold,³ A. Pingel,³⁶ S. Pires,⁸⁰ H. Pirumov,⁴² M. Pitt,¹⁷¹ L. Plazak,^{143a} M.-A. Pleier,²⁵ V. Pleskot,⁸³ E. Plotnikova,⁶⁵ P. Plucinski,^{145a,145b} D. Pluth,⁶⁴ R. Poettgen,^{145a,145b} L. Poggioli,¹¹⁶ D. Pohl,²¹ G. Polesello,^{120a} A. Poley,⁴² A. Policicchio,^{37a,37b} R. Polifka,¹⁵⁷ A. Polini,^{20a} C. S. Pollard,⁵³ V. Polychronakos,²⁵ K. Pommès,³⁰ L. Pontecorvo,^{131a} B. G. Pope,⁹⁰ G. A. Popeneciu,^{26c} D. S. Popovic,¹³ A. Poppleton,³⁰ S. Pospisil,¹²⁷ K. Potamianos,¹⁵ I. N. Potrap,⁶⁵ C. J. Potter,²⁸ C. T. Potter,¹¹⁵ G. Poulard,³⁰ J. Poveda,³⁰ V. Pozdnyakov,⁶⁵ M. E. Pozo Astigarraga,³⁰ P. Pralavorio,⁸⁵ A. Pranko,¹⁵ S. Prell,⁶⁴ D. Price,⁸⁴ L. E. Price,⁶ M. Primavera,^{73a} S. Prince,⁸⁷ M. Proissl,⁴⁶ K. Prokofiev,^{60c} F. Prokoshin,^{32b} S. Protopopescu,²⁵ J. Proudfoot,⁶ M. Przybycien,^{38a} D. Puddu,^{133a,133b} D. Poldon,¹⁴⁷ M. Purohit,^{25,ff} P. Puzo,¹¹⁶ J. Qian,⁸⁹ G. Qin,⁵³ Y. Qin,⁸⁴ A. Quadt,⁵⁴ D. R. Quarrie,¹⁵ W. B. Quayle,^{163a,163b} M. Queitsch-Maitland,⁸⁴ D. Quilty,⁵³ S. Raddum,¹¹⁸ V. Radeka,²⁵ V. Radescu,⁴² S. K. Radhakrishnan,¹⁴⁷ P. Radloff,¹¹⁵ P. Rados,⁸⁸ F. Ragusa,^{91a,91b} G. Rahal,¹⁷⁷ S. Rajagopalan,²⁵ M. Rammensee,³⁰ C. Rangel-Smith,¹⁶⁵ M. G. Ratti,^{91a,91b} F. Rauscher,⁹⁹ S. Rave,⁸³ T. Ravenscroft,⁵³ M. Raymond,³⁰ A. L. Read,¹¹⁸ N. P. Readioff,⁷⁴ D. M. Rebuffi,^{120a,120b} A. Redelbach,¹⁷³ G. Redlinger,²⁵ R. Reece,¹³⁶ K. Reeves,⁴¹ L. Rehnisch,¹⁶ J. Reichert,¹²¹ H. Reisin,²⁷ C. Rembser,³⁰ H. Ren,^{33a} M. Rescigno,^{131a} S. Resconi,^{91a} O. L. Rezanova,^{108,c} P. Reznicek,¹²⁸ R. Rezvani,⁹⁴ R. Richter,¹⁰⁰ S. Richter,⁷⁸ E. Richter-Was,^{38b} O. Ricken,²¹ M. Ridel,⁸⁰ P. Rieck,¹⁶ C. J. Riegel,¹⁷⁴ J. Rieger,⁵⁴ O. Rifki,¹¹² M. Rijssenbeek,¹⁴⁷ A. Rimoldi,^{120a,120b} L. Rinaldi,^{20a} B. Ristić,⁴⁹ E. Ritsch,³⁰ I. Riu,¹² F. Rizatdinova,¹¹³ E. Rizvi,⁷⁶ S. H. Robertson,^{87,1} A. Robichaud-Veronneau,⁸⁷ D. Robinson,²⁸ J. E. M. Robinson,⁴² A. Robson,⁵³ C. Roda,^{123a,123b} Y. Rodina,⁸⁵ A. Rodriguez Perez,¹² D. Rodriguez Rodriguez,¹⁶⁶ S. Roe,³⁰ C. S. Rogan,⁵⁷ O. Røhne,¹¹⁸ A. Romaniouk,⁹⁷ M. Romano,^{20a,20b} S. M. Romano Saez,³⁴ E. Romero Adam,¹⁶⁶ N. Rompotis,¹³⁷ M. Ronzani,⁴⁸ L. Roos,⁸⁰ E. Ros,¹⁶⁶ S. Rosati,^{131a} K. Rosbach,⁴⁸ P. Rose,¹³⁶ O. Rosenthal,¹⁴⁰ V. Rossetti,^{145a,145b} E. Rossi,^{103a,103b} L. P. Rossi,^{50a} J. H. N. Rosten,²⁸ R. Rosten,¹³⁷ M. Rotaru,^{26b} I. Roth,¹⁷¹ J. Rothberg,¹³⁷ D. Rousseau,¹¹⁶ C. R. Royon,¹³⁵ A. Rozanov,⁸⁵ Y. Rozen,¹⁵¹ X. Ruan,^{144c} F. Rubbo,¹⁴² I. Rubinskiy,⁴² V. I. Rud,⁹⁸ M. S. Rudolph,¹⁵⁷ F. Rühr,⁴⁸ A. Ruiz-Martinez,³⁰ Z. Rurikova,⁴⁸ N. A. Rusakovich,⁶⁵ A. Ruschke,⁹⁹ H. L. Russell,¹³⁷ J. P. Rutherford,⁷ N. Ruthmann,³⁰ Y. F. Ryabov,¹²² M. Rybar,¹⁶⁴ G. Rybkin,¹¹⁶ S. Ryu,⁶ A. Ryzhov,¹²⁹ A. F. Saavedra,¹⁴⁹ G. Sabato,¹⁰⁶ S. Sacerdoti,²⁷ H. F.-W. Sadrozinski,¹³⁶ R. Sadykov,⁶⁵ F. Safai Tehrani,^{131a} P. Saha,¹⁰⁷ M. Sahinsoy,^{58a} M. Saimpert,¹³⁵ T. Saito,¹⁵⁴ H. Sakamoto,¹⁵⁴ Y. Sakurai,¹⁷⁰

G. Salamanna,^{133a,133b} A. Salamon,^{132a,132b} J. E. Salazar Loyola,^{32b} D. Salek,¹⁰⁶ P. H. Sales De Bruin,¹³⁷ D. Salihagic,¹⁰⁰
A. Salmikov,¹⁴² J. Salt,¹⁶⁶ D. Salvatore,^{37a,37b} F. Salvatore,¹⁴⁸ A. Salvucci,^{60a} A. Salzburger,³⁰ D. Sammel,⁴⁸
D. Sampsonidis,¹⁵³ A. Sanchez,^{103a,103b} J. Sánchez,¹⁶⁶ V. Sanchez Martinez,¹⁶⁶ H. Sandaker,¹¹⁸ R. L. Sandbach,⁷⁶
H. G. Sander,⁸³ M. P. Sanders,⁹⁹ M. Sandhoff,¹⁷⁴ C. Sandoval,¹⁶¹ R. Sandstroem,¹⁰⁰ D. P. C. Sankey,¹³⁰ M. Sannino,^{50a,50b}
A. Sansoni,⁴⁷ C. Santoni,³⁴ R. Santonico,^{132a,132b} H. Santos,^{125a} I. Santoyo Castillo,¹⁴⁸ K. Sapp,¹²⁴ A. Saprnov,⁶⁵
J. G. Saraiva,^{125a,125d} B. Sarrazin,²¹ O. Sasaki,⁶⁶ Y. Sasaki,¹⁵⁴ K. Sato,¹⁵⁹ G. Sauvage,^{5,†} E. Sauvan,⁵ G. Savage,⁷⁷
P. Savard,^{157,d} C. Sawyer,¹³⁰ L. Sawyer,^{79,o} J. Saxon,³¹ C. Sbarra,^{20a} A. Sbrizzi,^{20a,20b} T. Scanlon,⁷⁸ D. A. Scannicchio,¹⁶²
M. Scarcella,¹⁴⁹ V. Scarfone,^{37a,37b} J. Schaarschmidt,¹⁷¹ P. Schacht,¹⁰⁰ D. Schaefer,³⁰ R. Schaefer,⁴² J. Schaeffer,⁸³
S. Schaepe,²¹ S. Schaezel,^{58b} U. Schäfer,⁸³ A. C. Schaffer,¹¹⁶ D. Schaile,⁹⁹ R. D. Schamberger,¹⁴⁷ V. Scharf,^{58a}
V. A. Schegelsky,¹²² D. Scheirich,¹²⁸ M. Schernau,¹⁶² C. Schiavi,^{50a,50b} C. Schillo,⁴⁸ M. Schioppa,^{37a,37b} S. Schlenker,³⁰
K. Schmieden,³⁰ C. Schmitt,⁸³ S. Schmitt,⁴² S. Schmitz,⁸³ B. Schneider,^{158a} Y. J. Schnellbach,⁷⁴ U. Schnoor,⁴⁸
L. Schoeffel,¹³⁵ A. Schoening,^{58b} B. D. Schoenrock,⁹⁰ E. Schopf,²¹ A. L. S. Schorlemmer,⁴³ M. Schott,⁸³ D. Schouten,^{158a}
J. Schovancova,⁸ S. Schramm,⁴⁹ M. Schreyer,¹⁷³ N. Schuh,⁸³ M. J. Schultens,²¹ H.-C. Schultz-Coulon,^{58a} H. Schulz,¹⁶
M. Schumacher,⁴⁸ B. A. Schumm,¹³⁶ Ph. Schune,¹³⁵ C. Schwanenberger,⁸⁴ A. Schwartzman,¹⁴² T. A. Schwarz,⁸⁹
Ph. Schwegler,¹⁰⁰ H. Schweiger,⁸⁴ Ph. Schwemling,¹³⁵ R. Schwienhorst,⁹⁰ J. Schwindling,¹³⁵ T. Schwindt,²¹ G. Sciolla,²³
F. Scuri,^{123a,123b} F. Scutti,⁸⁸ J. Searcy,⁸⁹ P. Seema,²¹ S. C. Seidel,¹⁰⁴ A. Seiden,¹³⁶ F. Seifert,¹²⁷ J. M. Seixas,^{24a}
G. Sekhniaidze,^{103a} K. Sekhon,⁸⁹ S. J. Sekula,⁴⁰ D. M. Seliverstov,^{122,†} N. Semprini-Cesari,^{20a,20b} C. Serfon,³⁰ L. Serin,¹¹⁶
L. Serkin,^{163a,163b} M. Sessa,^{133a,133b} R. Seuster,^{158a} H. Severini,¹¹² T. Sfiligoj,⁷⁵ F. Sforza,³⁰ A. Sfyrla,⁴⁹ E. Shabalina,⁵⁴
N. W. Shaikh,^{145a,145b} L. Y. Shan,^{33a} R. Shang,¹⁶⁴ J. T. Shank,²² M. Shapiro,¹⁵ P. B. Shatalov,⁹⁶ K. Shaw,^{163a,163b}
S. M. Shaw,⁸⁴ A. Shcherbakova,^{145a,145b} C. Y. Shehu,¹⁴⁸ P. Sherwood,⁷⁸ L. Shi,^{150,gg} S. Shimizu,⁶⁷ C. O. Shimmin,¹⁶²
M. Shimojima,¹⁰¹ M. Shiyakova,^{65,hh} A. Shmeleva,⁹⁵ D. Shoaleh Saadi,⁹⁴ M. J. Shochet,³¹ S. Shojaii,^{91a,91b} S. Shrestha,¹¹⁰
E. Shulga,⁹⁷ M. A. Shupe,⁷ P. Sicho,¹²⁶ P. E. Sidebo,¹⁴⁶ O. Sidiropoulou,¹⁷³ D. Sidorov,¹¹³ A. Sidoti,^{20a,20b} F. Siegert,⁴⁴
Dj. Sijacki,¹³ J. Silva,^{125a,125d} S. B. Silverstein,^{145a} V. Simak,¹²⁷ O. Simard,⁵ Lj. Simic,¹³ S. Simion,¹¹⁶ E. Simioni,⁸³
B. Simmons,⁷⁸ D. Simon,³⁴ M. Simon,⁸³ P. Sinervo,¹⁵⁷ N. B. Sinev,¹¹⁵ M. Sioli,^{20a,20b} G. Siragusa,¹⁷³ S. Yu. Sivoklov,⁹⁸
J. Sjölin,^{145a,145b} T. B. Sjørnsen,¹⁴ M. B. Skinner,⁷² H. P. Skottowe,⁵⁷ P. Skubic,¹¹² M. Slater,¹⁸ T. Slavicek,¹²⁷
M. Slawinska,¹⁰⁶ K. Sliwa,¹⁶⁰ V. Smakhtin,¹⁷¹ B. H. Smart,⁵ L. Smestad,¹⁴ S. Yu. Smirnov,⁹⁷ Y. Smirnov,⁹⁷
L. N. Smirnova,^{98,ii} O. Smirnova,⁸¹ M. N. K. Smith,³⁵ R. W. Smith,³⁵ M. Smizanska,⁷² K. Smolek,¹²⁷ A. A. Snesarev,⁹⁵
G. Snidero,⁷⁶ S. Snyder,²⁵ R. Sobie,^{168,l} F. Socher,⁴⁴ A. Soffer,¹⁵² D. A. Soh,^{150,gg} G. Sokhrannyi,⁷⁵ C. A. Solans Sanchez,³⁰
M. Solar,¹²⁷ E. Yu. Soldatov,⁹⁷ U. Soldevila,¹⁶⁶ A. A. Solodkov,¹²⁹ A. Soloshenko,⁶⁵ O. V. Solovyanov,¹²⁹ V. Solovyev,¹²²
P. Sommer,⁴⁸ H. Y. Song,^{33b,z} N. Soni,¹ A. Sood,¹⁵ A. Sopczak,¹²⁷ V. Sopko,¹²⁷ V. Sorin,¹² D. Sosa,^{58b}
C. L. Sotiropoulou,^{123a,123b} R. Soualah,^{163a,163c} A. M. Soukharev,^{108,c} D. South,⁴² B. C. Sowden,⁷⁷ S. Spagnolo,^{73a,73b}
M. Spalla,^{123a,123b} M. Spangenberg,¹⁶⁹ F. Spanò,⁷⁷ D. Sperlich,¹⁶ F. Spettel,¹⁰⁰ R. Spighi,^{20a} G. Spigo,³⁰ L. A. Spiller,⁸⁸
M. Spousta,¹²⁸ R. D. St. Denis,^{53,†} A. Stabile,^{91a} S. Staerz,³⁰ J. Stahlman,¹²¹ R. Stamen,^{58a} S. Stamm,¹⁶ E. Stanecka,³⁹
R. W. Stanek,⁶ C. Stanescu,^{133a} M. Stanescu-Bellu,⁴² M. M. Stanitzki,⁴² S. Stapnes,¹¹⁸ E. A. Starchenko,¹²⁹ G. H. Stark,³¹
J. Stark,⁵⁵ P. Staroba,¹²⁶ P. Starovoitov,^{58a} R. Staszewski,³⁹ P. Steinberg,²⁵ B. Stelzer,¹⁴¹ H. J. Stelzer,³⁰
O. Stelzer-Chilton,^{158a} H. Stenzel,⁵² G. A. Stewart,⁵³ J. A. Stillings,²¹ M. C. Stockton,⁸⁷ M. Stoebe,⁸⁷ G. Stoicea,^{26b}
P. Stolte,⁵⁴ S. Stonjek,¹⁰⁰ A. R. Stradling,⁸ A. Straessner,⁴⁴ M. E. Stramaglia,¹⁷ J. Strandberg,¹⁴⁶ S. Strandberg,^{145a,145b}
A. Strandlie,¹¹⁸ M. Strauss,¹¹² P. Strizenec,^{143b} R. Ströhmer,¹⁷³ D. M. Strom,¹¹⁵ R. Stroynowski,⁴⁰ A. Strubig,¹⁰⁵
S. A. Stucci,¹⁷ B. Stugu,¹⁴ N. A. Styles,⁴² D. Su,¹⁴² J. Su,¹²⁴ R. Subramaniam,⁷⁹ S. Suchek,^{58a} Y. Sugaya,¹¹⁷ M. Suk,¹²⁷
V. V. Sulin,⁹⁵ S. Sultansoy,^{4c} T. Sumida,⁶⁸ S. Sun,⁵⁷ X. Sun,^{33a} J. E. Sundermann,⁴⁸ K. Suruliz,¹⁴⁸ G. Susinno,^{37a,37b}
M. R. Sutton,¹⁴⁸ S. Suzuki,⁶⁶ M. Svatos,¹²⁶ M. Swiatlowski,³¹ I. Sykora,^{143a} T. Sykora,¹²⁸ D. Ta,⁴⁸ C. Taccini,^{133a,133b}
K. Tackmann,⁴² J. Taenzer,¹⁵⁷ A. Taffard,¹⁶² R. Tafirout,^{158a} N. Taiblum,¹⁵² H. Takai,²⁵ R. Takashima,⁶⁹ H. Takeda,⁶⁷
T. Takeshita,¹³⁹ Y. Takubo,⁶⁶ M. Talby,⁸⁵ A. A. Talyshev,^{108,c} J. Y. C. Tam,¹⁷³ K. G. Tan,⁸⁸ J. Tanaka,¹⁵⁴ R. Tanaka,¹¹⁶
S. Tanaka,⁶⁶ B. B. Tannenwald,¹¹⁰ S. Tapia Araya,^{32b} S. Tapprogge,⁸³ S. Tarem,¹⁵¹ G. F. Tartarelli,^{91a} P. Tas,¹²⁸
M. Tasevsky,¹²⁶ T. Tashiro,⁶⁸ E. Tassi,^{37a,37b} A. Tavares Delgado,^{125a,125b} Y. Tayalati,^{134d} A. C. Taylor,¹⁰⁴ G. N. Taylor,⁸⁸
P. T. E. Taylor,⁸⁸ W. Taylor,^{158b} F. A. Teischinger,³⁰ P. Teixeira-Dias,⁷⁷ K. K. Temming,⁴⁸ D. Temple,¹⁴¹ H. Ten Kate,³⁰
P. K. Teng,¹⁵⁰ J. J. Teoh,¹¹⁷ F. Tepel,¹⁷⁴ S. Terada,⁶⁶ K. Terashi,¹⁵⁴ J. Terron,⁸² S. Terzo,¹⁰⁰ M. Testa,⁴⁷ R. J. Teuscher,^{157,1}
T. Thevenaux-Pelzer,⁸⁵ J. P. Thomas,¹⁸ J. Thomas-Wilsker,⁷⁷ E. N. Thompson,³⁵ P. D. Thompson,¹⁸ R. J. Thompson,⁸⁴
A. S. Thompson,⁵³ L. A. Thomsen,¹⁷⁵ E. Thomson,¹²¹ M. Thomson,²⁸ M. J. Tibbetts,¹⁵ R. E. Ticse Torres,⁸⁵

V. O. Tikhomirov,^{95,jj} Yu. A. Tikhonov,^{108,c} S. Timoshenko,⁹⁷ E. Tiouchichine,⁸⁵ P. Tipton,¹⁷⁵ S. Tisserant,⁸⁵ K. Todome,¹⁵⁶ T. Todorov,^{5,†} S. Todorova-Nova,¹²⁸ J. Tojo,⁷⁰ S. Tokár,^{143a} K. Tokushuku,⁶⁶ E. Tolley,⁵⁷ L. Tomlinson,⁸⁴ M. Tomoto,¹⁰² L. Tompkins,^{142,kk} K. Toms,¹⁰⁴ B. Tong,⁵⁷ E. Torrence,¹¹⁵ H. Torres,¹⁴¹ E. Torró Pastor,¹³⁷ J. Toth,^{85,ll} F. Touchard,⁸⁵ D. R. Tovey,¹³⁸ T. Trefzger,¹⁷³ L. Tremblet,³⁰ A. Tricoli,³⁰ I. M. Trigger,^{158a} S. Trincaz-Duvoid,⁸⁰ M. F. Tripania,¹² W. Trischuk,¹⁵⁷ B. Trocmé,⁵⁵ A. Trofymov,⁴² C. Troncon,^{91a} M. Trottier-McDonald,¹⁵ M. Trovatelli,¹⁶⁸ L. Truong,^{163a,163b} M. Trzebinski,³⁹ A. Trzupek,³⁹ J. C.-L. Tseng,¹¹⁹ P. V. Tsiareshka,⁹² G. Tsipolitis,¹⁰ N. Tsirintanis,⁹ S. Tsiskaridze,¹² V. Tsiskaridze,⁴⁸ E. G. Tskhadadze,^{51a} K. M. Tsui,^{60a} I. I. Tsukerman,⁹⁶ V. Tsulaia,¹⁵ S. Tsuno,⁶⁶ D. Tsybychev,¹⁴⁷ A. Tudorache,^{26b} V. Tudorache,^{26b} A. N. Tuna,⁵⁷ S. A. Tupputi,^{20a,20b} S. Turchikhin,^{98,ii} D. Turecek,¹²⁷ D. Turgeman,¹⁷¹ R. Turra,^{91a,91b} A. J. Turvey,⁴⁰ P. M. Tuts,³⁵ M. Tylmad,^{145a,145b} M. Tyndel,¹³⁰ I. Ueda,¹⁵⁴ R. Ueno,²⁹ M. Ughetto,^{145a,145b} F. Ukegawa,¹⁵⁹ G. Unal,³⁰ A. Undrus,²⁵ G. Unel,¹⁶² F. C. Ungaro,⁸⁸ Y. Unno,⁶⁶ C. Unverdorben,⁹⁹ J. Urban,^{143b} P. Urquijo,⁸⁸ P. Urrejola,⁸³ G. Usai,⁸ A. Usanova,⁶² L. Vacavant,⁸⁵ V. Vacek,¹²⁷ B. Vachon,⁸⁷ C. Valderanis,⁸³ E. Valdes Santurio,^{145a,145b} N. Valencic,¹⁰⁶ S. Valentinetti,^{20a,20b} A. Valero,¹⁶⁶ L. Valery,¹² S. Valkar,¹²⁸ S. Vallecorsa,⁴⁹ J. A. Valls Ferrer,¹⁶⁶ W. Van Den Wollenberg,¹⁰⁶ P. C. Van Der Deijl,¹⁰⁶ R. van der Geer,¹⁰⁶ H. van der Graaf,¹⁰⁶ N. van Eldik,¹⁵¹ P. van Gemmeren,⁶ J. Van Nieuwkoop,¹⁴¹ I. van Vulpen,¹⁰⁶ M. C. van Woerden,³⁰ M. Vanadia,^{131a,131b} W. Vandelli,³⁰ R. Vanguri,¹²¹ A. Vaniachine,⁶ P. Vankov,¹⁰⁶ G. Vardanyan,¹⁷⁶ R. Vari,^{131a} E. W. Varnes,⁷ T. Varol,⁴⁰ D. Varouchas,⁸⁰ A. Vartapetian,⁸ K. E. Varvell,¹⁴⁹ F. Vazeille,³⁴ T. Vazquez Schroeder,⁸⁷ J. Veatch,⁷ L. M. Veloce,¹⁵⁷ F. Veloso,^{125a,125c} S. Veneziano,^{131a} A. Ventura,^{73a,73b} M. Venturi,¹⁶⁸ N. Venturi,¹⁵⁷ A. Venturini,²³ V. Vercesi,^{120a} M. Verducci,^{131a,131b} W. Verkerke,¹⁰⁶ J. C. Vermeulen,¹⁰⁶ A. Vest,^{44,mmm} M. C. Vetterli,^{141,d} O. Viazlo,⁸¹ I. Vichou,¹⁶⁴ T. Vickey,¹³⁸ O. E. Vickey Boeriu,¹³⁸ G. H. A. Viehhauser,¹¹⁹ S. Viel,¹⁵ R. Vigne,⁶² M. Villa,^{20a,20b} M. Villaplana Perez,^{91a,91b} E. Vilucchi,⁴⁷ M. G. Vincter,²⁹ V. B. Vinogradov,⁶⁵ I. Vivarelli,¹⁴⁸ S. Vlachos,¹⁰ M. Vlasak,¹²⁷ M. Vogel,¹⁷⁴ P. Vokac,¹²⁷ G. Volpi,^{123a,123b} M. Volpi,⁸⁸ H. von der Schmitt,¹⁰⁰ E. von Toerne,²¹ V. Vorobel,¹²⁸ K. Vorobev,⁹⁷ M. Vos,¹⁶⁶ R. Voss,³⁰ J. H. Vossebeld,⁷⁴ N. Vranjes,¹³ M. Vranjes Milosavljevic,¹³ V. Vrba,¹²⁶ M. Vreeswijk,¹⁰⁶ R. Vuillermet,³⁰ I. Vukotic,³¹ Z. Vykydal,¹²⁷ P. Wagner,²¹ W. Wagner,¹⁷⁴ H. Wahlberg,⁷¹ S. Wahrenmund,⁴⁴ J. Wakabayashi,¹⁰² J. Walder,⁷² R. Walker,⁹⁹ W. Walkowiak,¹⁴⁰ V. Wallangen,^{145a,145b} C. Wang,¹⁵⁰ C. Wang,^{33d,85} F. Wang,¹⁷² H. Wang,¹⁵ H. Wang,⁴⁰ J. Wang,⁴² J. Wang,¹⁴⁹ K. Wang,⁸⁷ R. Wang,⁶ S. M. Wang,¹⁵⁰ T. Wang,²¹ T. Wang,³⁵ X. Wang,¹⁷⁵ C. Wanotayaroj,¹¹⁵ A. Warburton,⁸⁷ C. P. Ward,²⁸ D. R. Wardrope,⁷⁸ A. Washbrook,⁴⁶ P. M. Watkins,¹⁸ A. T. Watson,¹⁸ I. J. Watson,¹⁴⁹ M. F. Watson,¹⁸ G. Watts,¹³⁷ S. Watts,⁸⁴ B. M. Waugh,⁷⁸ S. Webb,⁸³ M. S. Weber,¹⁷ S. W. Weber,¹⁷³ J. S. Webster,⁶ A. R. Weidberg,¹¹⁹ B. Weinert,⁶¹ J. Weingarten,⁵⁴ C. Weiser,⁴⁸ H. Weits,¹⁰⁶ P. S. Wells,³⁰ T. Wenaus,²⁵ T. Wengler,³⁰ S. Wenig,³⁰ N. Wermes,²¹ M. Werner,⁴⁸ P. Werner,³⁰ M. Wessels,^{58a} J. Wetter,¹⁶⁰ K. Whalen,¹¹⁵ A. M. Wharton,⁷² A. White,⁸ M. J. White,¹ R. White,^{32b} S. White,^{123a,123b} D. Whiteson,¹⁶² F. J. Wickens,¹³⁰ W. Wiedenmann,¹⁷² M. Wielers,¹³⁰ P. Wienemann,²¹ C. Wiglesworth,³⁶ L. A. M. Wiik-Fuchs,²¹ A. Wildauer,¹⁰⁰ H. G. Wilkens,³⁰ H. H. Williams,¹²¹ S. Williams,¹⁰⁶ C. Willis,⁹⁰ S. Willocq,⁸⁶ J. A. Wilson,¹⁸ I. Wingerter-Seez,⁵ F. Winklmeier,¹¹⁵ O. J. Winston,¹⁴⁸ B. T. Winter,²¹ M. Wittgen,¹⁴² J. Wittkowski,⁹⁹ A. Wolf,⁸³ S. J. Wollstadt,⁸³ M. W. Wolter,³⁹ H. Wolters,^{125a,125c} B. K. Wosiek,³⁹ J. Wotschack,³⁰ M. J. Woudstra,⁸⁴ K. W. Wozniak,³⁹ M. Wu,⁵⁵ M. Wu,³¹ S. L. Wu,¹⁷² X. Wu,⁴⁹ Y. Wu,⁸⁹ T. R. Wyatt,⁸⁴ B. M. Wynne,⁴⁶ S. Xella,³⁶ D. Xu,^{33a} L. Xu,²⁵ B. Yabsley,¹⁴⁹ S. Yacoob,^{144a} R. Yakabe,⁶⁷ D. Yamaguchi,¹⁵⁶ Y. Yamaguchi,¹¹⁷ A. Yamamoto,⁶⁶ S. Yamamoto,¹⁵⁴ T. Yamanaka,¹⁵⁴ K. Yamauchi,¹⁰² Y. Yamazaki,⁶⁷ Z. Yan,²² H. Yang,^{33e} H. Yang,¹⁷² Y. Yang,¹⁵⁰ Z. Yang,¹⁴ W.-M. Yao,¹⁵ Y. C. Yap,⁸⁰ Y. Yasu,⁶⁶ E. Yatsenko,⁵ K. H. Yau Wong,²¹ J. Ye,⁴⁰ S. Ye,²⁵ I. Yeletsikh,⁶⁵ A. L. Yen,⁵⁷ E. Yildirim,⁴² K. Yorita,¹⁷⁰ R. Yoshida,⁶ K. Yoshihara,¹²¹ C. Young,¹⁴² C. J. S. Young,³⁰ S. Youssef,²² D. R. Yu,¹⁵ J. Yu,⁸ J. M. Yu,⁸⁹ J. Yu,⁶⁴ L. Yuan,⁶⁷ S. P. Y. Yuen,²¹ I. Yusuff,^{28,nn} B. Zabinski,³⁹ R. Zaidan,^{33d} A. M. Zaitsev,^{129,cc} N. Zakharchuk,⁴² J. Zalieckas,¹⁴ A. Zaman,¹⁴⁷ S. Zambito,⁵⁷ L. Zanello,^{131a,131b} D. Zanzi,⁸⁸ C. Zeitnitz,¹⁷⁴ M. Zeman,¹²⁷ A. Zemla,^{38a} J. C. Zeng,¹⁶⁴ Q. Zeng,¹⁴² K. Zengel,²³ O. Zenin,¹²⁹ T. Ženiš,^{143a} D. Zerwas,¹¹⁶ D. Zhang,⁸⁹ F. Zhang,¹⁷² G. Zhang,^{33b,z} H. Zhang,^{33c} J. Zhang,⁶ L. Zhang,⁴⁸ R. Zhang,²¹ R. Zhang,^{33b,oo} X. Zhang,^{33d} Z. Zhang,¹¹⁶ X. Zhao,⁴⁰ Y. Zhao,^{33d,116} Z. Zhao,^{33b} A. Zhemchugov,⁶⁵ J. Zhong,¹¹⁹ B. Zhou,⁸⁹ C. Zhou,⁴⁵ L. Zhou,³⁵ L. Zhou,⁴⁰ M. Zhou,¹⁴⁷ N. Zhou,^{33f} C. G. Zhu,^{33d} H. Zhu,^{33a} J. Zhu,⁸⁹ Y. Zhu,^{33b} X. Zhuang,^{33a} K. Zhukov,⁹⁵ A. Zibell,¹⁷³ D. Zieminska,⁶¹ N. I. Zimine,⁶⁵ C. Zimmermann,⁸³ S. Zimmermann,⁴⁸ Z. Zinonos,⁵⁴ M. Zinser,⁸³ M. Ziolkowski,¹⁴⁰ L. Živković,¹³ G. Zobernig,¹⁷² A. Zoccoli,^{20a,20b} M. zur Nedden,¹⁶ G. Zurzolo,^{103a,103b} and L. Zwalinski³⁰

(ATLAS Collaboration)

- ¹*Department of Physics, University of Adelaide, Adelaide, Australia*
- ²*Physics Department, SUNY Albany, Albany, New York, USA*
- ³*Department of Physics, University of Alberta, Edmonton, Alberta, Canada*
- ^{4a}*Department of Physics, Ankara University, Ankara, Turkey*
- ^{4b}*Istanbul Aydin University, Istanbul, Turkey*
- ^{4c}*Division of Physics, TOBB University of Economics and Technology, Ankara, Turkey*
- ⁵*LAPP, CNRS/IN2P3 and Université Savoie Mont Blanc, Annecy-le-Vieux, France*
- ⁶*High Energy Physics Division, Argonne National Laboratory, Argonne, Illinois, USA*
- ⁷*Department of Physics, University of Arizona, Tucson, Arizona, USA*
- ⁸*Department of Physics, The University of Texas at Arlington, Arlington, Texas, USA*
- ⁹*Physics Department, University of Athens, Athens, Greece*
- ¹⁰*Physics Department, National Technical University of Athens, Zografou, Greece*
- ¹¹*Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan*
- ¹²*Institut de Física d'Altes Energies (IFAE), The Barcelona Institute of Science and Technology, Barcelona, Spain*
- ¹³*Institute of Physics, University of Belgrade, Belgrade, Serbia*
- ¹⁴*Department for Physics and Technology, University of Bergen, Bergen, Norway*
- ¹⁵*Physics Division, Lawrence Berkeley National Laboratory and University of California, Berkeley, California, USA*
- ¹⁶*Department of Physics, Humboldt University, Berlin, Germany*
- ¹⁷*Albert Einstein Center for Fundamental Physics and Laboratory for High Energy Physics, University of Bern, Bern, Switzerland*
- ¹⁸*School of Physics and Astronomy, University of Birmingham, Birmingham, United Kingdom*
- ^{19a}*Department of Physics, Bogazici University, Istanbul, Turkey*
- ^{19b}*Department of Physics Engineering, Gaziantep University, Gaziantep, Turkey*
- ^{19d}*Istanbul Bilgi University, Faculty of Engineering and Natural Sciences, Istanbul, Turkey*
- ^{19c}*Bahcesehir University, Faculty of Engineering and Natural Sciences, Istanbul, Turkey*
- ^{20a}*INFN Sezione di Bologna, Italy*
- ^{20b}*Dipartimento di Fisica e Astronomia, Università di Bologna, Bologna, Italy*
- ²¹*Physikalisches Institut, University of Bonn, Bonn, Germany*
- ²²*Department of Physics, Boston University, Boston, Massachusetts, USA*
- ²³*Department of Physics, Brandeis University, Waltham, Massachusetts, USA*
- ^{24a}*Universidade Federal do Rio De Janeiro COPPE/EE/IF, Rio de Janeiro, Brazil*
- ^{24b}*Electrical Circuits Department, Federal University of Juiz de Fora (UFJF), Juiz de Fora, Brazil*
- ^{24c}*Federal University of Sao Joao del Rei (UFSJ), Sao Joao del Rei, Brazil*
- ^{24d}*Instituto de Física, Universidade de Sao Paulo, Sao Paulo, Brazil*
- ²⁵*Physics Department, Brookhaven National Laboratory, Upton, New York, USA*
- ^{26a}*Transilvania University of Brasov, Brasov, Romania*
- ^{26b}*National Institute of Physics and Nuclear Engineering, Bucharest, Romania*
- ^{26c}*National Institute for Research and Development of Isotopic and Molecular Technologies, Physics Department, Cluj Napoca, Romania*
- ^{26d}*University Politehnica Bucharest, Bucharest, Romania*
- ^{26c}*West University in Timisoara, Timisoara, Romania*
- ²⁷*Departamento de Física, Universidad de Buenos Aires, Buenos Aires, Argentina*
- ²⁸*Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom*
- ²⁹*Department of Physics, Carleton University, Ottawa, Ontario, Canada*
- ³⁰*CERN, Geneva, Switzerland*
- ³¹*Enrico Fermi Institute, University of Chicago, Chicago, Illinois, USA*
- ^{32a}*Departamento de Física, Pontificia Universidad Católica de Chile, Santiago, Chile*
- ^{32b}*Departamento de Física, Universidad Técnica Federico Santa María, Valparaíso, Chile*
- ^{33a}*Institute of High Energy Physics, Chinese Academy of Sciences, Beijing, China*
- ^{33b}*Department of Modern Physics, University of Science and Technology of China, Anhui, China*
- ^{33c}*Department of Physics, Nanjing University, Jiangsu, China*
- ^{33d}*School of Physics, Shandong University, Shandong, China*
- ^{33c}*Department of Physics and Astronomy, Shanghai Key Laboratory for Particle Physics and Cosmology, Shanghai Jiao Tong University, Shanghai; (also affiliated with PKU-CHEP), China*
- ^{33f}*Physics Department, Tsinghua University, Beijing 100084, China*
- ³⁴*Laboratoire de Physique Corpusculaire, Clermont Université and Université Blaise Pascal and CNRS/IN2P3, Clermont-Ferrand, France*
- ³⁵*Nevis Laboratory, Columbia University, Irvington, New York, USA*
- ³⁶*Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark*
- ^{37a}*INFN Gruppo Collegato di Cosenza, Laboratori Nazionali di Frascati, Italy*
- ^{37b}*Dipartimento di Fisica, Università della Calabria, Rende, Italy*

- ^{38a}AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Krakow, Poland
- ^{38b}Marian Smoluchowski Institute of Physics, Jagiellonian University, Krakow, Poland
- ³⁹Institute of Nuclear Physics Polish Academy of Sciences, Krakow, Poland
- ⁴⁰Physics Department, Southern Methodist University, Dallas, Texas, USA
- ⁴¹Physics Department, University of Texas at Dallas, Richardson, Texas, USA
- ⁴²DESY, Hamburg and Zeuthen, Germany
- ⁴³Institut für Experimentelle Physik IV, Technische Universität Dortmund, Dortmund, Germany
- ⁴⁴Institut für Kern- und Teilchenphysik, Technische Universität Dresden, Dresden, Germany
- ⁴⁵Department of Physics, Duke University, Durham, North Carolina, USA
- ⁴⁶SUPA—School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom
- ⁴⁷INFN Laboratori Nazionali di Frascati, Frascati, Italy
- ⁴⁸Fakultät für Mathematik und Physik, Albert-Ludwigs-Universität, Freiburg, Germany
- ⁴⁹Section de Physique, Université de Genève, Geneva, Switzerland
- ^{50a}INFN Sezione di Genova, Italy
- ^{50b}Dipartimento di Fisica, Università di Genova, Genova, Italy
- ^{51a}E. Andronikashvili Institute of Physics, Iv. Javakishvili Tbilisi State University, Tbilisi, Georgia
- ^{51b}High Energy Physics Institute, Tbilisi State University, Tbilisi, Georgia
- ⁵²II Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen, Germany
- ⁵³SUPA—School of Physics and Astronomy, University of Glasgow, Glasgow, United Kingdom
- ⁵⁴II Physikalisches Institut, Georg-August-Universität, Göttingen, Germany
- ⁵⁵Laboratoire de Physique Subatomique et de Cosmologie, Université Grenoble-Alpes, CNRS/IN2P3, Grenoble, France
- ⁵⁶Department of Physics, Hampton University, Hampton, Virginia, USA
- ⁵⁷Laboratory 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
- ⁵⁹Faculty of Applied Information Science, Hiroshima Institute of Technology, Hiroshima, Japan
- ^{60a}Department of Physics, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong, China
- ^{60b}Department of Physics, The University of Hong Kong, Hong Kong, China
- ^{60c}Department of Physics, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, China
- ⁶¹Department of Physics, Indiana University, Bloomington, Indiana, USA
- ⁶²Institut für Astro- und Teilchenphysik, Leopold-Franzens-Universität, Innsbruck, Austria
- ⁶³University of Iowa, Iowa City Iowa, USA
- ⁶⁴Department of Physics and Astronomy, Iowa State University, Ames, Iowa, USA
- ⁶⁵Joint Institute for Nuclear Research, JINR Dubna, Dubna, Russia
- ⁶⁶KEK, High Energy Accelerator Research Organization, Tsukuba, Japan
- ⁶⁷Graduate School of Science, Kobe University, Kobe, Japan
- ⁶⁸Faculty of Science, Kyoto University, Kyoto, Japan
- ⁶⁹Kyoto University of Education, Kyoto, Japan
- ⁷⁰Department of Physics, Kyushu University, Fukuoka, Japan
- ⁷¹Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata, Argentina
- ⁷²Physics Department, Lancaster University, Lancaster, United Kingdom
- ^{73a}INFN Sezione di Lecce, Italy
- ^{73b}Dipartimento di Matematica e Fisica, Università del Salento, Lecce, Italy
- ⁷⁴Oliver Lodge Laboratory, University of Liverpool, Liverpool, United Kingdom
- ⁷⁵Department of Physics, Jožef Stefan Institute and University of Ljubljana, Ljubljana, Slovenia
- ⁷⁶School of Physics and Astronomy, Queen Mary University of London, London, United Kingdom
- ⁷⁷Department of Physics, Royal Holloway University of London, Surrey, United Kingdom
- ⁷⁸Department of Physics and Astronomy, University College London, London, United Kingdom
- ⁷⁹Louisiana Tech University, Ruston, Louisiana, USA
- ⁸⁰Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France
- ⁸¹Fysiska institutionen, Lunds universitet, Lund, Sweden
- ⁸²Departamento de Física Teórica C-15, Universidad Autónoma de Madrid, Madrid, Spain
- ⁸³Institut für Physik, Universität Mainz, Mainz, Germany
- ⁸⁴School of Physics and Astronomy, University of Manchester, Manchester, United Kingdom
- ⁸⁵CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France
- ⁸⁶Department of Physics, University of Massachusetts, Amherst, Massachusetts, USA
- ⁸⁷Department of Physics, McGill University, Montreal, Québec, Canada
- ⁸⁸School of Physics, University of Melbourne, Victoria, Australia
- ⁸⁹Department of Physics, The University of Michigan, Ann Arbor, Michigan, USA

- ⁹⁰*Department of Physics and Astronomy, Michigan State University, East Lansing, Michigan, USA*
- ^{91a}*INFN Sezione di Milano, Italy*
- ^{91b}*Dipartimento di Fisica, Università di Milano, Milano, Italy*
- ⁹²*B.I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk, Republic of Belarus*
- ⁹³*National Scientific and Educational Centre for Particle and High Energy Physics, Minsk, Republic of Belarus*
- ⁹⁴*Group of Particle Physics, University of Montreal, Montreal, Québec, Canada*
- ⁹⁵*P.N. Lebedev Physical Institute of the Russian Academy of Sciences, Moscow, Russia*
- ⁹⁶*Institute for Theoretical and Experimental Physics (ITEP), Moscow, Russia*
- ⁹⁷*National Research Nuclear University MEPhI, Moscow, Russia*
- ⁹⁸*D.V. Skobeltsyn Institute of Nuclear Physics, M.V. Lomonosov Moscow State University, Moscow, Russia*
- ⁹⁹*Fakultät für Physik, Ludwig-Maximilians-Universität München, München, Germany*
- ¹⁰⁰*Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), München, Germany*
- ¹⁰¹*Nagasaki Institute of Applied Science, Nagasaki, Japan*
- ¹⁰²*Graduate School of Science and Kobayashi-Maskawa Institute, Nagoya University, Nagoya, Japan*
- ^{103a}*INFN Sezione di Napoli, Italy*
- ^{103b}*Dipartimento di Fisica, Università di Napoli, Napoli, Italy*
- ¹⁰⁴*Department of Physics and Astronomy, University of New Mexico, Albuquerque, New Mexico, USA*
- ¹⁰⁵*Institute for Mathematics, Astrophysics and Particle Physics, Radboud University Nijmegen/Nikhef, Nijmegen, The Netherlands*
- ¹⁰⁶*Nikhef National Institute for Subatomic Physics and University of Amsterdam, Amsterdam, The Netherlands*
- ¹⁰⁷*Department of Physics, Northern Illinois University, DeKalb, Illinois, USA*
- ¹⁰⁸*Budker Institute of Nuclear Physics, SB RAS, Novosibirsk, Russia*
- ¹⁰⁹*Department of Physics, New York University, New York, New York, USA*
- ¹¹⁰*Ohio State University, Columbus, Ohio, USA*
- ¹¹¹*Faculty of Science, Okayama University, Okayama, Japan*
- ¹¹²*Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman, Oklahoma, USA*
- ¹¹³*Department of Physics, Oklahoma State University, Stillwater, Oklahoma, USA*
- ¹¹⁴*Palacký University, RCPTM, Olomouc, Czech Republic*
- ¹¹⁵*Center for High Energy Physics, University of Oregon, Eugene, Oregon, USA*
- ¹¹⁶*LAL, Univ. Paris-Sud, CNRS/IN2P3, Université Paris-Saclay, Orsay, France*
- ¹¹⁷*Graduate School of Science, Osaka University, Osaka, Japan*
- ¹¹⁸*Department of Physics, University of Oslo, Oslo, Norway*
- ¹¹⁹*Department of Physics, Oxford University, Oxford, United Kingdom*
- ^{120a}*INFN Sezione di Pavia, Italy*
- ^{120b}*Dipartimento di Fisica, Università di Pavia, Pavia, Italy*
- ¹²¹*Department of Physics, University of Pennsylvania, Philadelphia, Pennsylvania, USA*
- ¹²²*National Research Centre 'Kurchatov Institute' B.P.Konstantinov Petersburg Nuclear Physics Institute, St. Petersburg, Russia*
- ^{123a}*INFN Sezione di Pisa, Italy*
- ^{123b}*Dipartimento di Fisica E. Fermi, Università di Pisa, Pisa, Italy*
- ¹²⁴*Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh, Pennsylvania, USA*
- ^{125a}*Laboratório de Instrumentação e Física Experimental de Partículas—LIP, Lisboa, Portugal*
- ^{125b}*Faculdade de Ciências, Universidade de Lisboa, Lisboa, Portugal*
- ^{125c}*Department of Physics, University of Coimbra, Coimbra, Portugal*
- ^{125d}*Centro de Física Nuclear da Universidade de Lisboa, Lisboa, Portugal*
- ^{125e}*Departamento de Física, Universidade do Minho, Braga, Portugal*
- ^{125f}*Departamento de Física Teórica y del Cosmos and CAFPE, Universidad de Granada, Granada, Spain*
- ^{125g}*Dep Física and CEFITEC of Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Caparica, Portugal*
- ¹²⁶*Institute of Physics, Academy of Sciences of the Czech Republic, Praha, Czech Republic*
- ¹²⁷*Czech Technical University in Prague, Praha, Czech Republic*
- ¹²⁸*Faculty of Mathematics and Physics, Charles University in Prague, Praha, Czech Republic*
- ¹²⁹*State Research Center Institute for High Energy Physics (Protvino), NRC KI, Russia*
- ¹³⁰*Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom*
- ^{131a}*INFN Sezione di Roma, Italy*
- ^{131b}*Dipartimento di Fisica, Sapienza Università di Roma, Roma, Italy*
- ^{132a}*INFN Sezione di Roma Tor Vergata, Italy*
- ^{132b}*Dipartimento di Fisica, Università di Roma Tor Vergata, Roma, Italy*
- ^{133a}*INFN Sezione di Roma Tre, Italy*
- ^{133b}*Dipartimento di Matematica e Fisica, Università Roma Tre, Roma, Italy*
- ^{134a}*Faculté des Sciences Ain Chock, Réseau Universitaire de Physique des Hautes Energies—Université Hassan II, Casablanca, Morocco*
- ^{134b}*Centre National de l'Énergie des Sciences Techniques Nucleaires, Rabat, Morocco*

- ^{134c}*Faculté des Sciences Semlalia, Université Cadi Ayyad, LPHEA-Marrakech, Morocco*
- ^{134d}*Faculté des Sciences, Université Mohamed Premier and LTPM, Oujda, Morocco*
- ^{134e}*Faculté des sciences, Université Mohammed V, Rabat, Morocco*
- ¹³⁵*DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat à l'Energie Atomique et aux Energies Alternatives), Gif-sur-Yvette, France*
- ¹³⁶*Santa Cruz Institute for Particle Physics, University of California Santa Cruz, Santa Cruz, California, USA*
- ¹³⁷*Department of Physics, University of Washington, Seattle, Washington, USA*
- ¹³⁸*Department of Physics and Astronomy, University of Sheffield, Sheffield, United Kingdom*
- ¹³⁹*Department of Physics, Shinshu University, Nagano, Japan*
- ¹⁴⁰*Fachbereich Physik, Universität Siegen, Siegen, Germany*
- ¹⁴¹*Department of Physics, Simon Fraser University, Burnaby, British Columbia, Canada*
- ¹⁴²*SLAC National Accelerator Laboratory, Stanford, California, USA*
- ^{143a}*Faculty of Mathematics, Physics & Informatics, Comenius University, Bratislava, Slovak Republic*
- ^{143b}*Department of Subnuclear Physics, Institute of Experimental Physics of the Slovak Academy of Sciences, Kosice, Slovak Republic*
- ^{144a}*Department of Physics, University of Cape Town, Cape Town, South Africa*
- ^{144b}*Department of Physics, University of Johannesburg, Johannesburg, South Africa*
- ^{144c}*School of Physics, University of the Witwatersrand, Johannesburg, South Africa*
- ^{145a}*Department of Physics, Stockholm University, Sweden*
- ^{145b}*The Oskar Klein Centre, Stockholm, Sweden*
- ¹⁴⁶*Physics Department, Royal Institute of Technology, Stockholm, Sweden*
- ¹⁴⁷*Departments of Physics & Astronomy and Chemistry, Stony Brook University, Stony Brook, New York, USA*
- ¹⁴⁸*Department of Physics and Astronomy, University of Sussex, Brighton, United Kingdom*
- ¹⁴⁹*School of Physics, University of Sydney, Sydney, Australia*
- ¹⁵⁰*Institute of Physics, Academia Sinica, Taipei, Taiwan*
- ¹⁵¹*Department of Physics, Technion: Israel Institute of Technology, Haifa, Israel*
- ¹⁵²*Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel*
- ¹⁵³*Department of Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece*
- ¹⁵⁴*International Center for Elementary Particle Physics and Department of Physics, The University of Tokyo, Tokyo, Japan*
- ¹⁵⁵*Graduate School of Science and Technology, Tokyo Metropolitan University, Tokyo, Japan*
- ¹⁵⁶*Department of Physics, Tokyo Institute of Technology, Tokyo, Japan*
- ¹⁵⁷*Department of Physics, University of Toronto, Toronto, Ontario, Canada*
- ^{158a}*TRIUMF, Vancouver, British Columbia, Canada*
- ^{158b}*Department of Physics and Astronomy, York University, Toronto, Ontario, Canada*
- ¹⁵⁹*Faculty of Pure and Applied Sciences, and Center for Integrated Research in Fundamental Science and Engineering, University of Tsukuba, Tsukuba, Japan*
- ¹⁶⁰*Department of Physics and Astronomy, Tufts University, Medford, Massachusetts, USA*
- ¹⁶¹*Centro de Investigaciones, Universidad Antonio Narino, Bogota, Colombia*
- ¹⁶²*Department of Physics and Astronomy, University of California Irvine, Irvine, California, USA*
- ^{163a}*INFN Gruppo Collegato di Udine, Sezione di Trieste, Udine, Italy*
- ^{163b}*ICTP, Trieste, Italy*
- ^{163c}*Dipartimento di Chimica, Fisica e Ambiente, Università di Udine, Udine, Italy*
- ¹⁶⁴*Department of Physics, University of Illinois, Urbana, Illinois, USA*
- ¹⁶⁵*Department of Physics and Astronomy, University of Uppsala, Uppsala, Sweden*
- ¹⁶⁶*Instituto de Física Corpuscular (IFIC) and Departamento de Física Atómica, Molecular y Nuclear and Departamento de Ingeniería Electrónica and Instituto de Microelectrónica de Barcelona (IMB-CNM), University of Valencia and CSIC, Valencia, Spain*
- ¹⁶⁷*Department of Physics, University of British Columbia, Vancouver, British Columbia, Canada*
- ¹⁶⁸*Department of Physics and Astronomy, University of Victoria, Victoria, British Columbia, Canada*
- ¹⁶⁹*Department of Physics, University of Warwick, Coventry, United Kingdom*
- 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*Fakultät für Mathematik und Naturwissenschaften, Fachgruppe Physik, Bergische Universität Wuppertal, Wuppertal, Germany*
- ¹⁷⁵*Department of Physics, Yale University, New Haven, Connecticut, USA*
- ¹⁷⁶*Yerevan Physics Institute, Yerevan, Armenia*
- ¹⁷⁷*Centre de Calcul de l'Institut National de Physique Nucléaire et de Physique des Particules (IN2P3), Villeurbanne, France*

[†]Deceased.

^aAlso at Department of Physics, King's College London, London, United Kingdom.

^bAlso at Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan.

- ^c Also at Novosibirsk State University, Novosibirsk, Russia.
- ^d Also at TRIUMF, Vancouver British Columbia, Canada.
- ^e Also at Department of Physics & Astronomy, University of Louisville, Louisville, Kentucky, USA.
- ^f Also at Department of Physics, California State University, Fresno, California, USA.
- ^g Also at Department of Physics, University of Fribourg, Fribourg, Switzerland.
- ^h Also at Departament de Física de la Universitat Autònoma de Barcelona, Barcelona, Spain.
- ⁱ Also at Departamento de Física e Astronomia, Faculdade de Ciências, Universidade do Porto, Portugal.
- ^j Also at Tomsk State University, Tomsk, Russia.
- ^k Also at Università di Napoli Parthenope, Napoli, Italy.
- ^l Also at Institute of Particle Physics (IPP), Canada.
- ^m Also at Department of Physics, St. Petersburg State Polytechnical University, St. Petersburg, Russia.
- ⁿ Also at Department of Physics, The University of Michigan, Ann Arbor, Michigan, USA.
- ^o Also at Louisiana Tech University, Ruston, Louisiana, USA.
- ^p Also at Institutio Catalana de Recerca i Estudis Avancats, ICREA, Barcelona, Spain.
- ^q Also at Graduate School of Science, Osaka University, Osaka, Japan.
- ^r Also at Department of Physics, National Tsing Hua University, Taiwan.
- ^s Also at Department of Physics, The University of Texas at Austin, Austin, Texas, USA.
- ^t Also at Institute of Theoretical Physics, Ilia State University, Tbilisi, Georgia.
- ^u Also at CERN, Geneva, Switzerland.
- ^v Also at Georgian Technical University (GTU), Tbilisi, Georgia.
- ^w Also at O Chadai Academic Production, Ochanomizu University, Tokyo, Japan.
- ^x Also at Manhattan College, New York, New York, USA.
- ^y Also at Hellenic Open University, Patras, Greece.
- ^z Also at Institute of Physics, Academia Sinica, Taipei, Taiwan.
- ^{aa} Also at Academia Sinica Grid Computing, Institute of Physics, Academia Sinica, Taipei, Taiwan.
- ^{bb} Also at School of Physics, Shandong University, Shandong, China.
- ^{cc} Also at Moscow Institute of Physics and Technology State University, Dolgoprudny, Russia.
- ^{dd} Also at Section de Physique, Université de Genève, Geneva, Switzerland.
- ^{ee} Also at International School for Advanced Studies (SISSA), Trieste, Italy.
- ^{ff} Also at Department of Physics and Astronomy, University of South Carolina, Columbia, South Carolina, USA.
- ^{gg} Also at School of Physics and Engineering, Sun Yat-sen University, Guangzhou, China.
- ^{hh} Also at Institute for Nuclear Research and Nuclear Energy (INRNE) of the Bulgarian Academy of Sciences, Sofia, Bulgaria.
- ⁱⁱ Also at Faculty of Physics, M.V.Lomonosov Moscow State University, Moscow, Russia.
- ^{jj} Also at National Research Nuclear University MEPhI, Moscow, Russia.
- ^{kk} Also at Department of Physics, Stanford University, Stanford, California, USA.
- ^{ll} Also at Institute for Particle and Nuclear Physics, Wigner Research Centre for Physics, Budapest, Hungary.
- ^{mm} Also at Flensburg University of Applied Sciences, Flensburg, Germany.
- ⁿⁿ Also at University of Malaya, Department of Physics, Kuala Lumpur, Malaysia.
- ^{oo} Also at CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France.