UNIVERSITY OF AMSTERDAM

UvA-DARE (Digital Academic Repository)

Determination of the Relative Sign of the Higgs Boson Couplings to W and Z Bosons Using WH Production via Vector-Boson Fusion with the ATLAS Detector

Aad, G.; ATLAS Collaboration

DOI
10.1103/PhysRevLett.133.141801

Publication date
2024

Document Version
Final published version

Published in
Physical Review Letters

License
CC BY

Link to publication

Citation for published version (APA):
Aad, G., & ATLAS Collaboration (2024). Determination of the Relative Sign of the Higgs Boson Couplings to *W* and *Z* Bosons Using *WH* Production via Vector-Boson Fusion with the ATLAS Detector. *Physical Review Letters*, *133*(14), Article 141801. https://doi.org/10.1103/PhysRevLett.133.141801

General rights
It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Disclaimer/Complaints regulations
If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: https://uba.uva.nl/en/contact, or a letter to: Library of the University of Amsterdam, Secretariat, P.O. Box 19185, 1000 GD Amsterdam, The Netherlands. You will be contacted as soon as possible.

UvA-DARE is a service provided by the library of the University of Amsterdam (https://dare.uva.nl)

Download date:07 Sept 2026

Editors' Suggestion | Featured in Physics

Determination of the Relative Sign of the Higgs Boson Couplings to W and Z Bosons Using WH Production via Vector-Boson Fusion with the ATLAS Detector

G. Aad *et al.*[*]
(ATLAS Collaboration)

(Received 2 February 2024; revised 9 July 2024; accepted 22 August 2024; published 2 October 2024)

The associated production of Higgs and W bosons via vector-boson fusion is highly sensitive to the relative sign of the Higgs boson couplings to W and Z bosons. In this Letter, two searches for this process are presented, using 140 fb^{-1} of proton-proton collision data at $\sqrt{s} = 13$ TeV recorded by the ATLAS detector at the LHC. The first search targets scenarios with opposite-sign couplings of the W and Z bosons to the Higgs boson, while the second targets standard model-like scenarios with same-sign couplings. Both analyses consider Higgs boson decays into a pair of b quarks and W boson decays with an electron or muon. The data exclude the opposite-sign coupling hypothesis with a significance beyond 5σ, and the observed (expected) upper limit set on the cross section for vector-boson fusion WH production is 9.0 (8.7) times the standard model value at 95% confidence level.

DOI: 10.1103/PhysRevLett.133.141801

The study of the Higgs boson's couplings to W and Z bosons offers a crucial means of testing electroweak symmetry breaking in the standard model (SM). These couplings can be parametrized in terms of the coupling modifiers κ_W and κ_Z, where values of 1 correspond to the SM expectation, or in terms of their ratio $\lambda_{WZ} = \kappa_W/\kappa_Z$ [1]. Any deviation of λ_{WZ} from 1 would indicate a violation of the SM's custodial symmetry and be a clear sign of physics beyond the standard model (BSM).

By combining measurements of many Higgs boson production and decay modes, the ATLAS [2] and CMS [3] collaborations have measured $|\lambda_{WZ}|$ to be consistent with 1 with a precision of about 6%. However, this relies primarily on decays into WW^* or ZZ^*, vector-boson fusion (VBF) production, and WH and ZH associated production, all of which scale with the squares of κ_W and κ_Z. Therefore, the relative sign of these parameters is nearly unconstrained by current measurements, and they are both assumed to be positive in the coupling combinations. Negative values of λ_{WZ} are predicted by various models in which the observed Higgs boson is part of an isospin multiplet larger than a doublet [4], as in the Georgi-Machacek model [5], making an experimental determination of its sign a key priority. In contrast to those processes, the VBF WH production mechanism [6] includes diagrams where the Higgs boson couples to either a W or Z boson, as shown in Fig. 1. These diagrams interfere destructively in the SM, preserving unitarization of longitudinal gauge-boson scattering, but the interference becomes constructive for negative values of λ_{WZ}. This leads to an enhancement in the cross section, particularly for events with large Higgs or W boson momentum. Therefore, a measurement of this process can be used to constrain the available (κ_Z, κ_W) parameter space with either the same or opposite sign. Furthermore, the enhancement is due to tree-level interference, and therefore does not rely on assumptions regarding BSM loop contributions. Other proposals to measure the sign of λ_{WZ} include exploiting one-loop interference effects in $H \to 4\ell$ decays [7], or using W^+W^-H production [8].

This Letter presents two searches for VBF WH production at the LHC, each using 140.1 ± 1.2 fb^{-1} [9] of $\sqrt{s} = 13$ TeV pp collision data collected by the ATLAS detector during 2015–2018. The first search ("negative λ_{WZ}") targets BSM scenarios with a negative coupling ratio, while the second ("positive λ_{WZ}") targets SM-like production. Both analyses consider Higgs boson decays into $b\bar{b}$

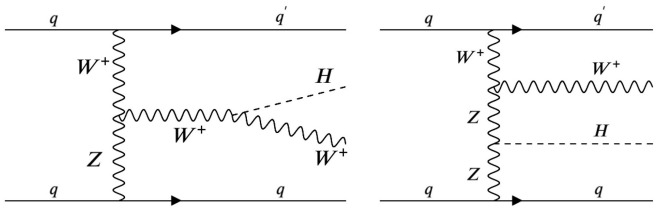

FIG. 1. Examples of leading-order Feynman diagrams for VBF WH production, where the Higgs boson interacts with either a W or Z boson. These diagrams interfere destructively if the Higgs boson couplings to W and Z have the same sign, and constructively if they have opposite sign.

[*]Full author list given at the end of the Letter.

Published by the American Physical Society under the terms of the Creative Commons Attribution 4.0 International license. Further distribution of this work must maintain attribution to the author(s) and the published article's title, journal citation, and DOI. Funded by SCOAP[3].

 © 2024 CERN, for the ATLAS Collaboration

and W boson decays with an electron or muon (directly or via a τ lepton). This leads to a final state with two b jets, two additional jets from the protons, a charged lepton, and missing transverse momentum ($E_{\mathrm{T}}^{\mathrm{miss}}$) from the neutrino(s).

The ATLAS experiment [10] is a multipurpose particle detector with a forward-backward symmetric cylindrical geometry and nearly 4π coverage in solid angle [11]. It consists of an inner detector (ID) for tracking surrounded by a thin superconducting solenoid providing a 2 T axial magnetic field, electromagnetic and hadron calorimeters, and a muon spectrometer. A two-level trigger system is used to select events. The first-level trigger is implemented in hardware and uses a subset of the detector information to accept events at a rate below 100 kHz. This is followed by a software-based trigger that reduces the accepted event rate to 100 kHz on average depending on the data-taking conditions. An extensive software suite [12] is used in data simulation, in the reconstruction and analysis of real and simulated data, in detector operations, and in the trigger and data acquisition systems of the experiment.

The VBF WH process was simulated at leading-order accuracy in α_{s} with MADGRAPH5_AMC@NLO [13] for the matrix element calculation, interfaced to PYTHIA8 [14] for parton showering, hadronization, and multiple parton interactions. The NNPDF3.0NLO parton distribution function set [15] was used. Predictions were obtained for various values of κ_W and κ_Z using the procedure outlined in Ref. [6]. Because the Lagrangian is insensitive to an overall sign change, only positive values of κ_W were simulated. The largest backgrounds come from $t\bar{t}$, $W+$ jets, and Wt single-top production, with smaller contributions from t- and s-channel single-top, $Z+$ jets, VV, VH, $t\bar{t}H$, and $t\bar{t}V$ production ($V = W$ or Z). Backgrounds from $t\bar{t}$ and single top quark production were simulated with POWHEG [16,17] interfaced to PYTHIA8. Overlap between Wt and $t\bar{t}$ production was handled using the diagram removal scheme [18]. The $W+$ jets and $Z+$ jets processes were simulated with SHERPA2.2.1 [19] for the matrix element and parton showering. Different parton multiplicities were merged using the CKKW-L [20] technique. Electroweak production of WZ plus two jets was simulated at leading order with MADGRAPH5_AMC@NLO interfaced to PYTHIA8. Other VV processes were simulated with SHERPA, version 2.2.1 for quark-initiated processes and 2.2.2 for gluon-initiated processes. Other Higgs boson processes were generated with POWHEG, with the MiNLO procedure [21] applied for quark-induced VH, and with PYTHIA8 used for parton showering. The $t\bar{t}V$ process was simulated at NLO with MADGRAPH5_AMC@NLO interfaced to PYTHIA8. The background arising from misidentified or nonprompt leptons is evaluated using events with inverted lepton isolation requirements. This background is seen to populate kinematic regions with low momentum objects and is found to be negligible after applying the final selection criteria that define the signal and control regions.

Events in the electron channel were selected online using a single-electron trigger [22]. In the muon channel, events where the vector sum of the offline $E_{\mathrm{T}}^{\mathrm{miss}}$ and the muon p_{T} is greater than 150 GeV were selected with an $E_{\mathrm{T}}^{\mathrm{miss}}$ trigger [23], while below this threshold a single-muon trigger [24] was used. (The trigger-level $E_{\mathrm{T}}^{\mathrm{miss}}$ calculation does not include muons, making this vector sum a close approximation of the trigger-level $E_{\mathrm{T}}^{\mathrm{miss}}$.) Because of the changing beam conditions, the kinematic and isolation requirements on the trigger objects varied during the data-taking period. Electrons are reconstructed offline by matching clusters of energy deposits in the electromagnetic calorimeter to tracks in the ID, which are fitted allowing for energy loss due to bremsstrahlung [25]. Events in the electron channel must have one electron candidate with $p_{\mathrm{T}} > 27$ GeV and $|\eta| < 2.47$ passing the "Tight" likelihood identification criteria and the "HighPtCaloOnly" isolation criteria of Ref. [25]. The electron must furthermore be matched to the primary vertex (the primary vertex is taken as the vertex with the highest sum of squared transverse momenta of associated tracks) by requiring $|d_0|/\sigma_{d_0} < 5$ and $|z_0 \sin(\theta)| < 0.5$ mm, where d_0 is the track's transverse impact parameter, σ_{d_0} is its uncertainty, and z_0 is the longitudinal impact parameter. Muons are reconstructed offline by matching tracks in the ID and muon spectrometer, accounting for energy loss in the calorimeters [26]. Events in the muon channel must have one muon satisfying $p_{\mathrm{T}} > 25$ GeV (27 GeV) if an $E_{\mathrm{T}}^{\mathrm{miss}}$ (a single-muon) trigger was used, $|\eta| < 2.5$, "Medium" quality, and "HighPtTrackOnly" isolation, as defined in Ref. [26]. Similarly to electrons, the track must satisfy $|d_0|/\sigma_{d_0} < 3$ and $|z_0 \sin(\theta)| < 0.5$ mm. In both channels, events are rejected if a second lepton is present. For this veto, the p_{T} requirement is lowered to 7 GeV, "Loose" identification and isolation requirements are applied [25,26], and the muon pseudorapidity range is widened to $|\eta| < 2.7$.

Jets are reconstructed from particle-flow objects [27], combined using the anti-k_t [28] algorithm with a radius parameter of 0.4. Jets in the central region ($|\eta| < 2.5$) must have $p_{\mathrm{T}} > 20$ GeV, while the p_{T} requirement is raised to 30 GeV for forward jets ($2.5 < |\eta| < 4.5$). To reduce the effect of multiple collisions per bunch crossing, jets in the central (forward) region with $p_{\mathrm{T}} < 60$ GeV (120 GeV) must have a jet vertex tagger [29] score > 0.5 (forward jet vertex tagger [30] score < 0.5). Jets in the central region may be "b tagged", i.e., identified as containing a b-hadron decay, by combining information from sources such as secondary-vertex reconstruction, track impact parameter measurements, and decay-chain fitting. The deep-learning algorithm DL1r [31,32] is used, with a working point that has 70% efficiency for b jets from top quark decays. The rates at which charm and light-flavor jets are incorrectly tagged as b jets are around 10% and 0.3%, respectively [33,34]. In addition to the standard jet calibration [27],

TABLE I. Definition of the signal regions used in the analyses. The SRs for the positive-λ_{WZ} analysis are orthogonal: events in $\mathrm{SR}^{+}_{\mathrm{tight}}$ are excluded from $\mathrm{SR}^{+}_{\mathrm{loose}}$. The definition of the W boson system is given in the text.

Variable	Description	SR^{-}	$\mathrm{SR}^{+}_{\mathrm{loose}}$	$\mathrm{SR}^{+}_{\mathrm{tight}}$
$m_{b\bar{b}}$	Invariant mass of the two b jets ($b\bar{b}$ system).	$\in(105, 145)$ GeV	$\in(105, 145)$ GeV	$\in(105, 145)$ GeV
$\Delta R_{b\bar{b}}$	ΔR between the two b jets.	< 1.2	< 1.6	< 1.2
$p_{\mathrm{T}}^{b\bar{b}}$	p_{T} of the $b\bar{b}$ system.	> 250 GeV	> 100 GeV	> 180 GeV
m_{jj}	Invariant mass of the VBF jets.	⋯	> 600 GeV	> 1000 GeV
Δy_{jj}	Rapidity separation of the VBF jets.	> 4.4	> 3.0	> 3.0
$m_{\mathrm{top}}^{\mathrm{lep}}$	Invariant mass of the W and either b jet that is closest to 172.7 GeV (m_{top}).	> 260 GeV	> 260 GeV	> 260 GeV
$\xi_{Wb\bar{b}}$	$(\lvert y_{Wb\bar{b}} - y_{jj}\rvert/\Delta y_{jj})$, where $y_{Wb\bar{b}}$ (y_{jj}) is the rapidity of the $Wb\bar{b}$ (VBF-jet) system.	< 0.3	< 0.3	< 0.3
$\Delta\phi(Wb\bar{b}, jj)$	Azimuthal separation between the $Wb\bar{b}$ system and the VBF-jet system.	⋯	⋯	> 2.7
$N_{\mathrm{jets}}^{\mathrm{veto}}$	Number of nontagged, non-VBF jets with $p_{\mathrm{T}} > 25$ GeV and $\lvert\eta\rvert < 2.5$.	⋯	≤ 1	$= 0$

two corrections are applied to b jets to improve their energy resolution [35]. First, if any "Medium" [26] muons with $p_{\mathrm{T}} > 5$ GeV and $|\eta| < 2.5$ are found within a cone of jet-p_{T}-dependent size around the jet axis, the four-momentum of the closest muon is added to that of the jet. After this, a residual correction is applied to equalize the response to jets with leptonic or hadronic decays of heavy-flavor hadrons. The $E_{\mathrm{T}}^{\mathrm{miss}}$ is calculated as the negative vector sum of the transverse momenta of all jets and leptons in the event, plus a track-based soft term accounting for other charged particles associated to the primary vertex [36].

Events must have exactly one charged lepton, exactly two b-tagged jets, and at least two nontagged jets. The two highest-p_{T} nontagged jets are chosen as the VBF jets, and these are required to have a rapidity separation of $\Delta y_{jj} > 3$. After these requirements, approximately 430 000 background events, primarily $t\bar{t}$, are expected from simulation, compared to 860 signal events if $\kappa_W = 1$ and $\kappa_Z = -1$, or 50 if both parameter values are 1. Selection criteria are applied to several kinematic variables to increase the signal-to-background ratio. These include the VBF jets' invariant mass m_{jj} and rapidity separation Δy_{jj}, as well as the b jets' invariant mass $m_{b\bar{b}}$, transverse momentum $p_{\mathrm{T}}^{b\bar{b}}$, and angular separation $\Delta R_{b\bar{b}}$. The W boson is reconstructed by summing the four-momenta of the lepton and neutrino, where the neutrino is assumed to have p_{T} equal to the observed $E_{\mathrm{T}}^{\mathrm{miss}}$ and η equal to that of the charged lepton. This is used to calculate the mass $m_{\mathrm{top}}^{\mathrm{lep}}$ of leptonically decaying top quarks, the centrality $\xi_{Wb\bar{b}}$, and $\Delta\phi(Wb\bar{b}, jj)$, according to the definitions in Table I. Finally, $N_{\mathrm{jets}}^{\mathrm{veto}}$ is defined as the number of jets with $p_{\mathrm{T}} > 25$ GeV and $|\eta| < 2.5$, which are not VBF or b-tagged jets. In the negative-λ_{WZ} analysis, a single signal region named SR^{-} is used, while the positive-λ_{WZ} analysis uses two orthogonal regions, $\mathrm{SR}^{+}_{\mathrm{loose}}$ and $\mathrm{SR}^{+}_{\mathrm{tight}}$, to enhance the sensitivity to the smaller SM signal. The selection criteria that define these regions are given in Table I; they were chosen to maximize the statistical significance, while keeping enough simulated events for robust estimation of the backgrounds and systematic uncertainties. Compared to the negative-λ_{WZ} signal, the SM signal has lower Higgs boson p_{T}, but similar VBF jet p_{T} and additional jet activity. This motivates the higher $p_{\mathrm{T}}^{b\bar{b}}$ threshold in SR^{-}, and the requirements on m_{jj} and $N_{\mathrm{jets}}^{\mathrm{veto}}$ in $\mathrm{SR}^{+}_{\mathrm{loose}}$ and $\mathrm{SR}^{+}_{\mathrm{tight}}$. Distributions of the key kinematic observables used to define the signal regions are presented as Supplemental Material [37].

In order to improve the background estimation, control regions (CRs) are defined for $t\bar{t}$, W + jets, and Wt, separately for the two analyses. The CRs are dominated by the targeted background and depleted of signal, while maintaining key kinematic features of the signal regions (SRs). The definitions of the CRs are given in the Appendix. For each analysis, the signal region(s) and the CRs are used together in a binned profile likelihood fit [38,39]. The number of events in each region is taken as the observable. The normalization of each of the main backgrounds is determined with an unconstrained parameter in the fit, $k_{t\bar{t}}$, k_W, or k_{Wt}, while systematic uncertainties are treated as nuisance parameters with Gaussian or Poisson constraints.

Systematic uncertainties considered for the electrons and muons include those in the trigger, reconstruction, identification, and isolation efficiencies, and the energy or momentum scale and resolution [25,26]. For jets, uncertainties are considered for the energy scale and resolution [40], the vertex tagging efficiency [29,30], and the b-tagging efficiency for b jets [32], c jets [33], and light jets [34]. Uncertainties in the momenta of all objects are propagated to the $E_{\mathrm{T}}^{\mathrm{miss}}$; additional uncertainties in the $E_{\mathrm{T}}^{\mathrm{miss}}$ are considered

for the soft term [36] and for the trigger efficiency. Systematic uncertainties in the modeling of the main backgrounds are assessed by replacing the nominal Monte Carlo (MC) predictions described previously with ones from MADGRAPH5_AMC@NLO interfaced to PYTHIA8, and, for $t\bar{t}$ and Wt, by using HERWIG7 as an alternative parton shower algorithm. The treatment of overlap between $t\bar{t}$ and Wt is varied by using the alternative diagram subtraction scheme [41]. These uncertainties are symmetrized. Additionally, the renormalization and factorization scales are varied by a factor of 2, and, for $t\bar{t}$ and Wt, other parameters sensitive to initial-state radiation are also varied [42]. Because the normalization of these backgrounds is unconstrained in the likelihood fit, the systematic uncertainties affect only the relative contribution in each region. Uncertainties in the cross section and acceptance of the smaller backgrounds are also considered, but their impact on the analysis is small. For the VBF WH signal, the renormalization and factorization scales, the parton distribution function, and α_s are varied [43]. In addition, an uncertainty in the modeling of additional jets in the positive-λ_{WZ} analysis is assessed by using an alternative MC sample with up to one additional parton in the matrix element, merged using the CKKW-L technique. The total uncertainties of the signal yields in the SRs range from 11% to 27%.

Table II presents the normalization factors and background yields in each SR obtained from the fit, as well as the predicted signal and observed data yields. No significant pulls or constraints on any nuisance parameters are observed. Because the CRs are not fully pure in the targeted background, the normalization factors for these backgrounds are anticorrelated by up to 71% (for instance, a higher value of $k_{t\bar{t}}$ would imply more $t\bar{t}$ in the $W+$ jets CR, and therefore a lower k_W; see the Supplemental Material [37] for more information). This results in the total predicted yield having an uncertainty smaller than the uncertainty in some individual components. The postfit values of $k_{t\bar{t}}$ and k_W are close to unity, indicating good modeling by the simulation. The values of k_{Wt} are significantly below 1 because the MC prediction exceeds the data in the Wt CRs. The phase space selected in this analysis is highly sensitive to the treatment of $t\bar{t}$–Wt overlap; when using the alternative diagram substraction scheme, a deficit of MC events is seen in the Wt CRs, and values of k_{Wt} close to 3 are obtained. The difference between the baseline MC prediction and data is therefore smaller than the difference between the two MC predictions used to estimate the systematic uncertainty. Moreover, because the Wt normalization is determined from the fit to data, the uncertainty in the measured signal strength from this source is less than 10% of the total uncertainty.

In the negative-λ_{WZ} analysis, 70 data events are observed in SR^-, compared to an expectation of 80.6 ± 8.6 assuming the SM (including 2.93 ± 0.35 signal events), or 361 ± 46 in the $\kappa_W = 1, \kappa_Z = -1$ scenario. (This is less than the sum of signal and background in Table II, due to the effect that signal contamination in the CRs would have on the background normalization factors.) Figure 2 shows confidence regions in the (κ_Z, κ_W) plane derived from the fit. These are compared with the confidence regions obtained from a combination of the ATLAS Higgs boson measurements collected in Ref. [2]. This combination assumes that all coupling modifiers other than κ_W and κ_Z are positive. The resulting fit excludes negative values of κ_W, primarily because of interference with the top quark in the loop decay $H \to \gamma\gamma$. However, a region of parameter space with negative values of κ_Z lies within one of the 2σ boundaries from the previous measurements. This region is excluded by the present analysis with significance much greater than 5σ. Thus the sign of λ_{WZ} is determined to be positive.

TABLE II. Normalization factors, expected background and signal yields, and observed data yields in each signal region. The background yields are given after the fit to data, while the signal yields show both the prefit expectation and the fitted values. The VBF WH signal corresponds to the prediction with $\kappa_W = 1$, $\kappa_Z = -1$ for SR^-, and $\kappa_W = 1$, $\kappa_Z = 1$ for $\mathrm{SR}^+_{\mathrm{loose}}$ and $\mathrm{SR}^+_{\mathrm{tight}}$. The uncertainty in the total background is smaller than the quadrature sum of individual uncertainty components because of correlations.

	Negative λ_{WZ}	Positive λ_{WZ}
$k_{t\bar{t}}$	$0.88^{+0.30}_{-0.35}$	$0.96^{+0.21}_{-0.23}$
k_W	$1.12^{+0.34}_{-0.25}$	$1.25^{+0.33}_{-0.24}$
k_{Wt}	$0.32^{+0.39}_{-0.13}$	$0.31^{+0.37}_{-0.14}$
$\mu = \sigma/\sigma_{\mathrm{pred}}$	$-0.027^{+0.054}_{-0.057}$	$0.9^{+4.0}_{-4.3}$

	SR^-	$\mathrm{SR}^+_{\mathrm{loose}}$	$\mathrm{SR}^+_{\mathrm{tight}}$
$t\bar{t}$	42 ± 19	172 ± 35	15.0 ± 5.8
$W+$ jets	26 ± 13	84 ± 32	14.1 ± 7.6
Wt	4.6 ± 7.0	8 ± 13	0.8 ± 1.5
Other background	5.4 ± 1.6	16.2 ± 4.2	3.0 ± 1.5
Total background	77.7 ± 8.6	279 ± 15	32.9 ± 5.8
VBF WH, prefit	285 ± 45	4.15 ± 0.56	2.30 ± 0.62
VBF WH, postfit	-8 ± 17	4 ± 17	2.2 ± 9.8
Data	70	274	37

In the positive-λ_{WZ} analysis, 274 (37) events are observed in $\mathrm{SR}^+_{\mathrm{loose}}$ ($\mathrm{SR}^+_{\mathrm{tight}}$), compared to an expected background of 279 ± 15 (32.9 ± 5.8), and a SM signal of 4.15 ± 0.56 (2.30 ± 0.62). The fitted value of the signal strength $\mu = \sigma/\sigma_{\mathrm{pred}}$ is $0.9^{+2.3}_{-2.6}(\mathrm{stat})^{+3.3}_{-3.4}(\mathrm{syst}) = 0.9^{+4.0}_{-4.3}$, indicating compatibility of the data with both the SM and background-only hypotheses. The largest systematic uncertainties come from the $W+$ jets and $t\bar{t}$ modeling, and the jet energy resolution. An upper limit of 9.0 is set on the signal strength at 95% confidence level (CL), compared to an expected limit of 8.7. The 95% CL limit on the cross section for SM-like

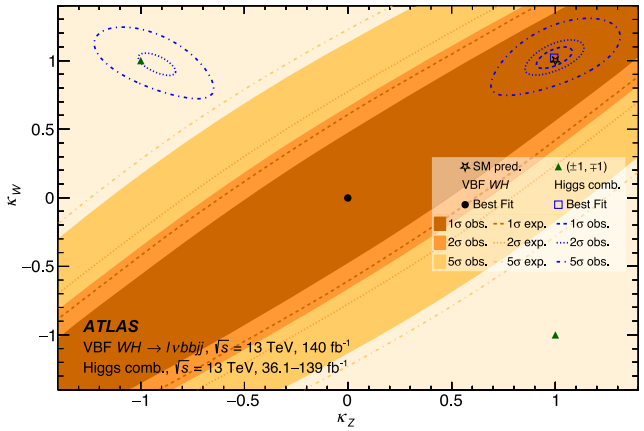

FIG. 2. Fit results in the (κ_Z, κ_W) plane, using the negative-λ_{WZ} analysis. The results are overlaid with the confidence regions (shown in blue) from a separate fit using a combination of the Higgs boson measurements collected in Ref. [2]. This fit assumes that all Higgs boson couplings besides the ones represented are positive, and that only SM particles contribute to loop processes. Confidence regions are constructed from the log-likelihood ratio $\Lambda_{\mathrm{LR}} = -2\ln(L/L_{\mathrm{max}})$, where L_{max} is the likelihood for the best-fit point, which is shown as a black dot for the VBF WH analysis or a blue dot for the Higgs combination. The 1σ, 2σ, and 5σ regions are defined by Λ_{LR} values smaller than 2.30, 6.18, and 28.7, respectively. The SM value is marked with a star, while green triangles mark the points with $\kappa_Z = \pm 1$, $\kappa_W = \mp 1$.

VBF WH production times the branching ratio $H \to b\bar{b}$ is 308 fb.

In conclusion, the VBF WH process has been studied by the ATLAS experiment, using 140 fb^{-1} of pp collision data at $\sqrt{s} = 13$ TeV. Events with two b jets, a charged lepton, and two additional jets with a large rapidity gap are considered. No excess of events is observed above the SM expectation. The 95% CL upper limit set on the cross section for SM-like VBF WH production is 9.0 times the SM prediction, compared to an expected limit of 8.7. The W and Z boson couplings to the Higgs boson are determined to have the same sign, with previously unexcluded opposite-sign hypotheses now excluded with significance beyond 5σ.

Acknowledgments—We thank CERN for the very successful operation of the LHC and its injectors, as well as the support staff at CERN and at our institutions worldwide without whom ATLAS could not be operated efficiently. The crucial computing support from all WLCG partners is acknowledged gratefully, in particular from CERN, the ATLAS Tier-1 facilities at TRIUMF/SFU (Canada), NDGF (Denmark, Norway, Sweden), CC-IN2P3 (France), KIT/GridKA (Germany), INFN-CNAF (Italy), NL-T1 (Netherlands), PIC (Spain), RAL (UK) and BNL (USA), the Tier-2 facilities worldwide, and large non-WLCG resource providers. Major contributors of computing resources are listed in Ref. [44]. We gratefully acknowledge the support of ANPCyT, Argentina; YerPhI, Armenia; ARC, Australia; BMWFW and FWF, Austria; ANAS, Azerbaijan; CNPq and FAPESP, Brazil; NSERC, NRC, and CFI, Canada; CERN; ANID, Chile; CAS, MOST, and NSFC, China; Minciencias, Colombia; MEYS CR, Czech Republic; DNRF and DNSRC, Denmark; IN2P3-CNRS and CEA-DRF/IRFU, France; SRNSFG, Georgia; BMBF, HGF, and MPG, Germany; GSRI, Greece; RGC and Hong Kong SAR, China; ISF and Benoziyo Center, Israel; INFN, Italy; MEXT and JSPS, Japan; CNRST, Morocco; NWO, Netherlands; RCN, Norway; MEiN, Poland; FCT, Portugal; MNE/IFA, Romania; MESTD, Serbia; MSSR, Slovakia; ARRS and MIZŠ, Slovenia; DSI/NRF, South Africa; MICINN, Spain; SRC and Wallenberg Foundation, Sweden; SERI, SNSF, and Cantons of Bern and Geneva, Switzerland; MOST, Taipei; TENMAK, Türkiye; STFC, United Kingdom; DOE and NSF, USA. Individual groups and members have received support from BCKDF, CANARIE, CRC, and DRAC, Canada; CERN-CZ, PRIMUS 21/SCI/017, and UNCE SCI/013, Czech Republic; COST, ERC, ERDF, Horizon 2020, ICSC-NextGenerationEU, and Marie Skłodowska-Curie Actions, European Union; Investissements d'Avenir Labex, Investissements d'Avenir Idex, and ANR, France; DFG and AvH Foundation, Germany; Herakleitos, Thales, and Aristeia programmes cofinanced by EU-ESF and the Greek NSRF, Greece; BSF-NSF and MINERVA, Israel; Norwegian Financial Mechanism 2014-2021, Norway; NCN and NAWA, Poland; La Caixa Banking Foundation, CERCA Programme Generalitat de Catalunya and PROMETEO and GenT Programmes Generalitat Valenciana, Spain; Göran Gustafssons Stiftelse, Sweden; The Royal Society and Leverhulme Trust, United Kingdom. In addition, individual members wish to acknowledge support from Chile: Agencia Nacional de Investigación y Desarrollo (FONDECYT 1190886, FONDECYT 1210400, FONDECYT 1230812, FONDECYT 1230987); China: National Natural Science Foundation of China (NSFC—12175119, NSFC 12275265, NSFC-12075060); Czech Republic: PRIMUS Research Programme (PRIMUS/21/SCI/017); EU: H2020 European Research Council (ERC—101002463); European Union: European Research Council (ERC—948254), Horizon 2020 Framework Programme (MUCCA—CHIST-ERA-19-XAI-00), European Union, Future Artificial Intelligence Research (FAIR-NextGenerationEU PE00000013), Italian Center for High Performance Computing, Big Data and Quantum Computing (ICSC, NextGenerationEU), Marie Sklodowska-Curie Actions (EU H2020 MSC IF Grant No. 101033496); France: Agence Nationale de la Recherche (ANR-20-CE31-0013, ANR-21-CE31-0013, ANR-21-CE31-0022), Investissements d'Avenir Idex (ANR-11-LABX-0012), Investissements d'Avenir Labex (ANR-11-LABX-0012); Germany: Baden-Württemberg Stiftung (BW Stiftung-Postdoc Eliteprogramme), Deutsche Forschungsgemeinschaft (DFG—469666862, DFG—CR

312/5-1); Italy: Istituto Nazionale di Fisica Nucleare (FELLINI G.A. n. 754496, ICSC, NextGenerationEU); Japan: Japan Society for the Promotion of Science (JSPS KAKENHI JP21H05085, JSPS KAKENHI JP22H01227, JSPS KAKENHI JP22H04944, JSPS KAKENHI JP22KK0227); Netherlands: Netherlands Organisation for Scientific Research (NWO Veni 2020—VI.Veni.202.179); Norway: Research Council of Norway (RCN-314472); Poland: Polish National Agency for Academic Exchange (PPN/PPO/2020/1/00002/U/00001), Polish National Science Centre (NCN 2021/42/E/ST2/00350, NCN OPUS nr 2022/47/B/ST2/03059, NCN UMO-2019/34/E/ST2/00393, UMO-2020/37/B/ST2/01043, UMO-2021/40/C/ST2/00187); Slovenia: Slovenian Research Agency (ARIS grant J1-3010); Spain: BBVA Foundation (LEO22-1-603), Generalitat Valenciana (Artemisa, FEDER, IDIFEDER/2018/048), La Caixa Banking Foundation (LCF/BQ/PI20/11760025), Ministry of Science and Innovation (MCIN & NextGenEU PCI2022-135018-2, MICIN & FEDER PID2021-125273NB, RYC2019-028510-I, RYC2020-030254-I, RYC2021-031273-I, RYC2022-038164-I), PROMETEO and GenT Programmes Generalitat Valenciana (CIDEGENT/2019/023, CIDEGENT/2019/027); Sweden: Swedish Research Council (VR 2018-00482, VR 2022-03845, VR 2022-04683, VR grant 2021-03651), Knut and Alice Wallenberg Foundation (KAW 2017.0100, KAW 2018.0157, KAW 2018.0458, KAW 2019.0447); Switzerland: Swiss National Science Foundation (SNSF—PCEFP2_194658); United Kingdom: Leverhulme Trust (Leverhulme Trust RPG-2020-004); USA: U.S. Department of Energy (ECA DE-AC02-76SF00515), Neubauer Family Foundation.

[1] LHC Higgs Cross Section Working Group, *Handbook of LHC Higgs Cross Sections: 3. Higgs Properties*, edited by S. Heinemeyer, C. Mariotti, G. Passarino, and R. Tanaka (2013), arXiv:1307.1347.

[2] ATLAS Collaboration, A detailed map of Higgs boson interactions by the ATLAS experiment ten years after the discovery, Nature (London) **607**, 52 (2022); **612**, E24 (2022).

[3] CMS Collaboration, A portrait of the Higgs boson by the CMS experiment ten years after the discovery, Nature (London) **607**, 60 (2022); **623**, E4 (2023).

[4] I. Low and J. Lykken, Revealing the electroweak properties of a new scalar resonance, J. High Energy Phys. 10 (2010) 053.

[5] H. Georgi and M. Machacek, Doubly charged Higgs bosons, Nucl. Phys. **B262**, 463 (1985).

[6] D. Stolarski and Y. Wu, Tree-level interference in vector boson fusion production of Vh, Phys. Rev. D **102**, 033006 (2020).

[7] Y. Chen, J. Lykken, M. Spiropulu, D. Stolarski, and R. Vega-Morales, Golden probe of electroweak symmetry breaking, Phys. Rev. Lett. **117**, 241801 (2016).

[8] C.-W. Chiang, X.-G. He, and G. Li, Measuring the ratio of HWW and HZZ couplings through W^+W^-H production, J. High Energy Phys. 08 (2018) 126.

[9] ATLAS Collaboration, Luminosity determination in pp collisions at $\sqrt{s} = 13$ TeV using the ATLAS detector at the LHC, Eur. Phys. J. C **83**, 982 (2023).

[10] ATLAS Collaboration, The ATLAS experiment at the CERN Large Hadron Collider, J. Instrum. **3**, S08003 (2008).

[11] ATLAS uses a right-handed coordinate system with its origin at the nominal interaction point (IP) in the center of the detector and the z axis along the beam pipe. The x axis points from the IP to the center of the LHC ring, and the y axis points upward. Polar 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 $\eta = -\ln\tan(\theta/2)$ and is equal to rapidity $y = 0.5\ln[(E + p_z)/(E - p_z)]$ in the relativistic limit. Angular distance is measured in units of $\Delta R \equiv \sqrt{(\Delta y)^2 + (\Delta\phi)^2}$. The transverse momentum is defined as $p_{\mathrm{T}} = \sqrt{p_x^2 + p_y^2}$.

[12] ATLAS Collaboration, The ATLAS collaboration software and firmware, Report No. ATL-SOFT-PUB-2021-001, 2021, https://cds.cern.ch/record/2767187.

[13] J. Alwall *et al.*, The automated computation of tree-level and next-to-leading order differential cross sections, and their matching to parton shower simulations, J. High Energy Phys. 07 (2014) 079.

[14] T. Sjöstrand *et al.*, An introduction to PYTHIA8.2, Comput. Phys. Commun. **191**, 159 (2015).

[15] R. D. Ball *et al.* (NNPDF Collaboration), Parton distributions for the LHC run II, J. High Energy Phys. 04 (2015) 040.

[16] S. Frixione, G. Ridolfi, and P. Nason, A positive-weight next-to-leading-order Monte Carlo for heavy flavour hadroproduction, J. High Energy Phys. 09 (2007) 126.

[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, E. Laenen, P. Motylinski, C. White, and B. R. Webber, Single-top hadroproduction in association with a W boson, J. High Energy Phys. 07 (2008) 029.

[19] E. Bothmann *et al.*, Event generation with SHERPA2.2, SciPost Phys. **7**, 034 (2019).

[20] L. Lönnblad, Correcting the colour-dipole cascade model with fixed order matrix elements, J. High Energy Phys. 05 (2002) 046.

[21] G. Luisoni, P. Nason, C. Oleari, and F. Tramontano, $HW^{\pm}/HZ + 0$ and 1 jet at NLO with the POWHEG BOX interfaced to GoSam and their merging within MiNLO, J. High Energy Phys. 10 (2013) 083.

[22] ATLAS Collaboration, Performance of electron and photon triggers in ATLAS during LHC Run 2, Eur. Phys. J. C **80**, 47 (2020).

[23] ATLAS Collaboration, Performance of the missing transverse momentum triggers for the ATLAS detector during Run-2 data taking, J. High Energy Phys. 08 (2020) 080.

[24] ATLAS Collaboration, Performance of the ATLAS muon triggers in Run 2, J. Instrum. **15**, P09015 (2020).

[25] ATLAS Collaboration, Electron and photon performance measurements with the ATLAS detector using

the 2015–2017 LHC proton–proton collision data, J. Instrum. **14**, P12006 (2019).
[26] ATLAS Collaboration, Muon reconstruction and identification efficiency in ATLAS using the full Run 2 pp collision data set at $\sqrt{s} = 13$ TeV, Eur. Phys. J. C **81**, 578 (2021).
[27] ATLAS Collaboration, Jet reconstruction and performance using particle flow with the ATLAS detector, Eur. Phys. J. C **77**, 466 (2017).
[28] M. Cacciari, G. P. Salam, and G. Soyez, The anti-k_t jet clustering algorithm, J. High Energy Phys. 04 (2008) 063.
[29] ATLAS Collaboration, Tagging and suppression of pileup jets with the ATLAS detector, Report No. ATLAS-CONF-2014-018, 2014, https://cds.cern.ch/record/1700870.
[30] ATLAS Collaboration, Forward jet vertex tagging using the particle flow algorithm, Report No. ATL-PHYS-PUB-2019-026, 2019, https://cds.cern.ch/record/2683100.
[31] ATLAS Collaboration, Optimisation and performance studies of the ATLAS b-tagging algorithms for the 2017-18 LHC run, Report No. ATL-PHYS-PUB-2017-013, 2017, https://cds.cern.ch/record/2273281.
[32] ATLAS Collaboration, ATLAS b-jet identification performance and efficiency measurement with $t\bar{t}$ events in pp collisions at $\sqrt{s} = 13$ TeV, Eur. Phys. J. C **79**, 970 (2019).
[33] ATLAS Collaboration, Measurement of the c-jet mistagging efficiency in $t\bar{t}$ events using pp collision data at $\sqrt{s} = 13$ TeV collected with the ATLAS detector, Eur. Phys. J. C **82**, 95 (2022).
[34] ATLAS Collaboration, Calibration of the light-flavour jet mistagging efficiency of the b-tagging algorithms with $Z +$ jets events using 139 fb^{-1} of ATLAS proton–proton collision data at $\sqrt{s} = 13$ TeV, Eur. Phys. J. C **83**, 728 (2023).
[35] ATLAS Collaboration, Evidence for the $H \to b\bar{b}$ decay with the ATLAS detector, J. High Energy Phys. 12 (2017) 024.
[36] ATLAS Collaboration, Performance of missing transverse momentum reconstruction with the ATLAS detector using proton–proton collisions at $\sqrt{s} = 13$ TeV, Eur. Phys. J. C **78**, 903 (2018).
[37] See Supplemental Material at http://link.aps.org/supplemental/10.1103/PhysRevLett.133.141801 for additional information on the analysis and results.
[38] M. G. Kendall and A. Stuart, *The Advanced Theory of Statistics, Volume 2: Inference and Relationship* (Charles Griffin, London, 1961).
[39] G. Cowan, K. Cranmer, E. Gross, and O. Vitells, Asymptotic formulae for likelihood-based tests of new physics, Eur. Phys. J. C **71**, 1554 (2011).
[40] ATLAS Collaboration, Jet energy scale and resolution measured in proton–proton collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector, Eur. Phys. J. C **81**, 689 (2021).
[41] C. D. White, S. Frixione, E. Laenen, and F. Maltoni, Isolating Wt production at the LHC, J. High Energy Phys. 11 (2009) 074.
[42] ATLAS Collaboration, Study of top-quark pair modelling and uncertainties using ATLAS measurements at $\sqrt{s} = 13$ TeV, Report No. ATL-PHYS-PUB-2020-023, 2020, https://cds.cern.ch/record/2730443.
[43] J. Butterworth *et al.*, PDF4LHC recommendations for LHC Run II, J. Phys. G **43**, 023001 (2016).
[44] ATLAS Collaboration, ATLAS computing acknowledgements, Report No. ATL-SOFT-PUB-2023-001, 2023, https://cds.cern.ch/record/2869272.

End Matter

Appendix—In order to improve the background estimation, control regions (CRs) are defined for $t\bar{t}$, $W +$ jets, and Wt, separately for the two analyses. The CRs are designed to be dominated by the targeted background and depleted of signal, while maintaining important kinematic features of the signal regions. Table III presents the definitions of the CRs for each of the two analyses. The $t\bar{t}$ CRs use the high $m_{b\bar{b}}$ sideband, and consider values of Δy_{jj} or m_{jj} that are lower than in the SRs. The $t\bar{t}$ events with high $m_{\text{top}}^{\text{lep}}$ often have a

TABLE III. Definitions of the control regions for $t\bar{t}$, $W +$ jets, and Wt. The W boson's transverse momentum p_{T}^{W} is the vector sum of the lepton p_{T} and $E_{\text{T}}^{\text{miss}}$; the W boson's transverse mass is calculated as $m_{\text{T}}^{W} = \sqrt{2E_{\text{T}}^{\text{miss}} p_{\text{T}}^{\ell}(1 - \cos\phi)}$, where ϕ is the azimuthal angle between the lepton and $E_{\text{T}}^{\text{miss}}$; p_{T}^{j1} is the p_{T} of the leading VBF jet. Other variables are defined in Table I.

Variable	$t\bar{t}$ CR$^-$	$t\bar{t}$ CR$^+$	$W +$ jets CR$^-$	$W +$ jets CR$^+$	Wt CR$^-$	Wt CR$^+$
$m_{b\bar{b}}$	> 145 GeV	> 145 GeV	< 70 GeV	< 70 GeV	> 145 GeV	> 145 GeV
$\Delta R_{b\bar{b}}$	< 1.2	< 1.2	$< 2.23 - 0.007\, p_{\text{T}}^{b\bar{b}}/\text{GeV}$	$< 2.23 - 0.007\, p_{\text{T}}^{b\bar{b}}/\text{GeV}$	> 1.5	> 1.6
$p_{\text{T}}^{b\bar{b}}$	> 200 GeV	⋯	$\in (150, 250)$ GeV	> 80 GeV	> 250 GeV	> 180 GeV
$m_{\text{top}}^{\text{lep}}$	> 260 GeV	> 220 GeV	> 275 GeV	> 260 GeV	> 320 GeV	> 320 GeV
Δy_{jj}	$\in (3, 4.4)$	> 3	> 3	> 3	> 3	> 3
m_{jj}	⋯	$\in (400, 1000)$ GeV	⋯	> 500 GeV	⋯	> 500 GeV
$N_{\text{jets}}^{\text{veto}}$	⋯	< 2	⋯	< 1	⋯	< 2
p_{T}^{W}	⋯	< 350 GeV	⋯	⋯	> 250 GeV	> 250 GeV
m_{T}^{W}	⋯	⋯	⋯	< 200 GeV	⋯	⋯
p_{T}^{j1}	⋯	⋯	> 70 GeV	> 70 GeV	< 350 GeV	< 350 GeV

misidentified charm jet in place of the b jet from leptonic top quark decay; to preserve this feature, the $t\bar{t}$ CRs maintain a minimum threshold for this variable. The $W+$jets CRs use a two-dimensional cut on $\Delta R_{b\bar{b}}$ and $p_{\mathrm{T}}^{b\bar{b}}$ to find events where the b jets are too close together to be consistent with the Higgs boson mass. The Wt CRs use high values of $\Delta R_{b\bar{b}}$ to remove signal, and high values of $m_{\mathrm{top}}^{\mathrm{lep}}$ and W boson p_{T} to reduce the contamination from $t\bar{t}$ events.

G. Aad,[102] B. Abbott,[120] K. Abeling,[55] N. J. Abicht,[49] S. H. Abidi,[29] A. Aboulhorma,[35e] H. Abramowicz,[151] H. Abreu,[150] Y. Abulaiti,[117] B. S. Acharya,[69a,69b,b] C. Adam Bourdarios,[4] L. Adamczyk,[86a] S. V. Addepalli,[26] M. J. Addison,[101] J. Adelman,[115] A. Adiguzel,[21c] T. Adye,[134] A. A. Affolder,[136] Y. Afik,[39] M. N. Agaras,[13] J. Agarwala,[73a,73b] A. Aggarwal,[100] C. Agheorghiesei,[27c] A. Ahmad,[36] F. Ahmadov,[38,c] W. S. Ahmed,[104] S. Ahuja,[95] X. Ai,[62e] G. Aielli,[76a,76b] A. Aikot,[163] M. Ait Tamlihat,[35e] B. Aitbenchikh,[35a] I. Aizenberg,[169] M. Akbiyik,[100] T. P. A. Åkesson,[98] A. V. Akimov,[37] D. Akiyama,[168] N. N. Akolkar,[24] S. Aktas,[21a] K. Al Khoury,[41] G. L. Alberghi,[23b] J. Albert,[165] P. Albicocco,[53] G. L. Albouy,[60] S. Alderweireldt,[52] Z. L. Alegria,[121] M. Aleksa,[36] I. N. Aleksandrov,[38] C. Alexa,[27b] T. Alexopoulos,[10] F. Alfonsi,[23b] M. Algren,[56] M. Alhroob,[120] B. Ali,[132] H. M. J. Ali,[91] S. Ali,[148] S. W. Alibocus,[92] M. Aliev,[145] G. Alimonti,[71a] W. Alkakhi,[55] C. Allaire,[66] B. M. M. Allbrooke,[146] J. F. Allen,[52] C. A. Allendes Flores,[137f] P. P. Allport,[20] A. Aloisio,[72a,72b] F. Alonso,[90] C. Alpigiani,[138] M. Alvarez Estevez,[99] A. Alvarez Fernandez,[100] M. Alves Cardoso,[56] M. G. Alviggi,[72a,72b] M. Aly,[101] Y. Amaral Coutinho,[83b] A. Ambler,[104] C. Amelung,[36] M. Amerl,[101] C. G. Ames,[109] D. Amidei,[106] S. P. Amor Dos Santos,[130a] K. R. Amos,[163] V. Ananiev,[125] C. Anastopoulos,[139] T. Andeen,[11] J. K. Anders,[36] S. Y. Andrean,[47a,47b] A. Andreazza,[71a,71b] S. Angelidakis,[9] A. Angerami,[41,d] A. V. Anisenkov,[37] A. Annovi,[74a] C. Antel,[56] M. T. Anthony,[139] E. Antipov,[145] M. Antonelli,[53] F. Anulli,[75a] M. Aoki,[84] T. Aoki,[153] J. A. Aparisi Pozo,[163] M. A. Aparo,[146] L. Aperio Bella,[48] C. Appelt,[18] A. Apyan,[26] N. Aranzabal,[36] S. J. Arbiol Val,[87] C. Arcangeletti,[53] A. T. H. Arce,[51] E. Arena,[92] J-F. Arguin,[108] S. Argyropoulos,[54] J.-H. Arling,[48] O. Arnaez,[4] H. Arnold,[114] G. Artoni,[75a,75b] H. Asada,[111] K. Asai,[118] S. Asai,[153] N. A. Asbah,[61] K. Assamagan,[29] R. Astalos,[28a] S. Atashi,[160] R. J. Atkin,[33a] M. Atkinson,[162] H. Atmani,[35f] P. A. Atmasiddha,[128] K. Augsten,[132] S. Auricchio,[72a,72b] A. D. Auriol,[20] V. A. Austrup,[101] G. Avolio,[36] K. Axiotis,[56] G. Azuelos,[108,e] D. Babal,[28b] H. Bachacou,[135] K. Bachas,[152,f] A. Bachiu,[34] F. Backman,[47a,47b] A. Badea,[61] T. M. Baer,[106] P. Bagnaia,[75a,75b] M. Bahmani,[18] D. Bahner,[54] A. J. Bailey,[163] V. R. Bailey,[162] J. T. Baines,[134] L. Baines,[94] O. K. Baker,[172] E. Bakos,[15] D. Bakshi Gupta,[8] V. Balakrishnan,[120] R. Balasubramanian,[114] E. M. Baldin,[37] P. Balek,[86a] E. Ballabene,[23b,23a] F. Balli,[135] L. M. Baltes,[63a] W. K. Balunas,[32] J. Balz,[100] E. Banas,[87] M. Bandieramonte,[129] A. Bandyopadhyay,[24] S. Bansal,[24] L. Barak,[151] M. Barakat,[48] E. L. Barberio,[105] D. Barberis,[57b,57a] M. Barbero,[102] M. Z. Barel,[114] K. N. Barends,[33a] T. Barillari,[110] M-S. Barisits,[36] T. Barklow,[143] P. Baron,[122] D. A. Baron Moreno,[101] A. Baroncelli,[62a] G. Barone,[29] A. J. Barr,[126] J. D. Barr,[96] L. Barranco Navarro,[47a,47b] F. Barreiro,[99] J. Barreiro Guimarães da Costa,[14a] U. Barron,[151] M. G. Barros Teixeira,[130a] S. Barsov,[37] F. Bartels,[63a] R. Bartoldus,[143] A. E. Barton,[91] P. Bartos,[28a] A. Basan,[100] M. Baselga,[49] A. Bassalat,[66,g] M. J. Basso,[156a] C. R. Basson,[101] R. L. Bates,[59] S. Batlamous,[35e] J. R. Batley,[32] B. Batool,[141] M. Battaglia,[136] D. Battulga,[18] M. Bauce,[75a,75b] M. Bauer,[36] P. Bauer,[24] L. T. Bazzano Hurrell,[30] J. B. Beacham,[51] T. Beau,[127] J. Y. Beaucamp,[90] P. H. Beauchemin,[158] P. Bechtle,[24] H. P. Beck,[19,h] K. Becker,[167] A. J. Beddall,[82] V. A. Bednyakov,[38] C. P. Bee,[145] L. J. Beemster,[15] T. A. Beermann,[36] M. Begalli,[83d] M. Begel,[29] A. Behera,[145] J. K. Behr,[48] J. F. Beirer,[36] F. Beisiegel,[24] M. Belfkir,[159] G. Bella,[151] L. Bellagamba,[23b] A. Bellerive,[34] P. Bellos,[20] K. Beloborodov,[37] D. Benchekroun,[35a] F. Bendebba,[35a] Y. Benhammou,[151] M. Benoit,[29] J. R. Bensinger,[26] S. Bentvelsen,[114] L. Beresford,[48] M. Beretta,[53] E. Bergeaas Kuutmann,[161] N. Berger,[4] B. Bergmann,[132] J. Beringer,[17a] G. Bernardi,[5] C. Bernius,[143] F. U. Bernlochner,[24] F. Bernon,[36,102] A. Berrocal Guardia,[13] T. Berry,[95] P. Berta,[133] A. Berthold,[50] I. A. Bertram,[91] S. Bethke,[110] A. Betti,[75a,75b] A. J. Bevan,[94] N. K. Bhalla,[54] M. Bhamjee,[33c] S. Bhatta,[145] D. S. Bhattacharya,[166] P. Bhattarai,[143]

V. S. Bhopatkar,[121] R. Bi,[29,i] R. M. Bianchi,[129] G. Bianco,[23b,23a] O. Biebel,[109] R. Bielski,[123] M. Biglietti,[77a] M. Bindi,[55] A. Bingul,[21b] C. Bini,[75a,75b] A. Biondini,[92] C. J. Birch-sykes,[101] G. A. Bird,[20,134] M. Birman,[169] M. Biros,[133] S. Biryukov,[146] T. Bisanz,[49] E. Bisceglie,[43b,43a] J. P. Biswal,[134] D. Biswas,[141] A. Bitadze,[101] K. Bjørke,[125] I. Bloch,[48] A. Blue,[59] U. Blumenschein,[94] J. Blumenthal,[100] G. J. Bobbink,[114] V. S. Bobrovnikov,[37] M. Boehler,[54] B. Boehm,[166] D. Bogavac,[36] A. G. Bogdanchikov,[37] C. Bohm,[47a] V. Boisvert,[95] P. Bokan,[48] T. Bold,[86a] M. Bomben,[5] M. Bona,[94] M. Boonekamp,[135] C. D. Booth,[95] A. G. Borbély,[59] I. S. Bordulev,[37] H. M. Borecka-Bielska,[108] G. Borissov,[91] D. Bortoletto,[126] D. Boscherini,[23b] M. Bosman,[13] J. D. Bossio Sola,[36] K. Bouaouda,[35a] N. Bouchhar,[163] J. Boudreau,[129] E. V. Bouhova-Thacker,[91] D. Boumediene,[40] R. Bouquet,[165] A. Boveia,[119] J. Boyd,[36] D. Boye,[29] I. R. Boyko,[38] J. Bracinik,[20] N. Brahimi,[62d] G. Brandt,[171] O. Brandt,[32] F. Braren,[48] B. Brau,[103] J. E. Brau,[123] R. Brener,[169] L. Brenner,[114] R. Brenner,[161] S. Bressler,[169] D. Britton,[59] D. Britzger,[110] I. Brock,[24] G. Brooijmans,[41] W. K. Brooks,[137f] E. Brost,[29] L. M. Brown,[165] L. E. Bruce,[61] T. L. Bruckler,[126] P. A. Bruckman de Renstrom,[87] B. Brüers,[48] A. Bruni,[23b] G. Bruni,[23b] M. Bruschi,[23b] N. Bruscino,[75a,75b] T. Buanes,[16] Q. Buat,[138] D. Buchin,[110] A. G. Buckley,[59] O. Bulekov,[37] B. A. Bullard,[143] S. Burdin,[92] C. D. Burgard,[49] A. M. Burger,[40] B. Burghgrave,[8] O. Burlayenko,[54] J. T. P. Burr,[32] C. D. Burton,[11] J. C. Burzynski,[142] E. L. Busch,[41] V. Büscher,[100] P. J. Bussey,[59] J. M. Butler,[25] C. M. Buttar,[59] J. M. Butterworth,[96] W. Buttinger,[134] C. J. Buxo Vazquez,[107] A. R. Buzykaev,[37] S. Cabrera Urbán,[163] L. Cadamuro,[66] D. Caforio,[58] H. Cai,[129] Y. Cai,[14a,14e] Y. Cai,[14c] V. M. M. Cairo,[36] O. Cakir,[3a] N. Calace,[36] P. Calafiura,[17a] G. Calderini,[127] P. Calfayan,[68] G. Callea,[59] L. P. Caloba,[83b] D. Calvet,[40] S. Calvet,[40] M. Calvetti,[74a,74b] R. Camacho Toro,[127] S. Camarda,[36] D. Camarero Munoz,[26] P. Camarri,[76a,76b] M. T. Camerlingo,[72a,72b] D. Cameron,[36] C. Camincher,[165] M. Campanelli,[96] A. Camplani,[42] V. Canale,[72a,72b] A. Canesse,[104] J. Cantero,[163] Y. Cao,[162] F. Capocasa,[26] M. Capua,[43b,43a] A. Carbone,[71a,71b] R. Cardarelli,[76a] J. C. J. Cardenas,[8] F. Cardillo,[163] G. Carducci,[43b,43a] T. Carli,[36] G. Carlino,[72a] J. I. Carlotto,[13] B. T. Carlson,[129,j] E. M. Carlson,[165,156a] L. Carminati,[71a,71b] A. Carnelli,[135] M. Carnesale,[75a,75b] S. Caron,[113] E. Carquin,[137f] S. Carrá,[71a] G. Carratta,[23b,23a] F. Carrio Argos,[33g] J. W. S. Carter,[155] T. M. Carter,[52] M. P. Casado,[13,k] M. Caspar,[48] F. L. Castillo,[4] L. Castillo Garcia,[13] V. Castillo Gimenez,[163] N. F. Castro,[130a,130e] A. Catinaccio,[36] J. R. Catmore,[125] V. Cavaliere,[29] N. Cavalli,[23b,23a] V. Cavasinni,[74a,74b] Y. C. Cekmecelioglu,[48] E. Celebi,[21a] F. Celli,[126] M. S. Centonze,[70a,70b] V. Cepaitis,[56] K. Cerny,[122] A. S. Cerqueira,[83a] A. Cerri,[146] L. Cerrito,[76a,76b] F. Cerutti,[17a] B. Cervato,[141] A. Cervelli,[23b] G. Cesarini,[53] S. A. Cetin,[82] D. Chakraborty,[115] J. Chan,[170] W. Y. Chan,[153] J. D. Chapman,[32] E. Chapon,[135] B. Chargeishvili,[149b] D. G. Charlton,[20] M. Chatterjee,[19] C. Chauhan,[133] S. Chekanov,[6] S. V. Chekulaev,[156a] G. A. Chelkov,[38,l] A. Chen,[106] B. Chen,[151] B. Chen,[165] H. Chen,[14c] H. Chen,[29] J. Chen,[62c] J. Chen,[142] M. Chen,[126] S. Chen,[153] S. J. Chen,[14c] X. Chen,[62c,135] X. Chen,[14b,m] Y. Chen,[62a] C. L. Cheng,[170] H. C. Cheng,[64a] S. Cheong,[143] A. Cheplakov,[38] E. Cheremushkina,[48] E. Cherepanova,[114] R. Cherkaoui El Moursli,[35e] E. Cheu,[7] K. Cheung,[65] L. Chevalier,[135] V. Chiarella,[53] G. Chiarelli,[74a] N. Chiedde,[102] G. Chiodini,[70a] A. S. Chisholm,[20] A. Chitan,[27b] M. Chitishvili,[163] M. V. Chizhov,[38] K. Choi,[11] A. R. Chomont,[75a,75b] Y. Chou,[103] E. Y. S. Chow,[113] T. Chowdhury,[33g] K. L. Chu,[169] M. C. Chu,[64a] X. Chu,[14a,14e] J. Chudoba,[131] J. J. Chwastowski,[87] D. Cieri,[110] K. M. Ciesla,[86a] V. Cindro,[93] A. Ciocio,[17a] F. Cirotto,[72a,72b] Z. H. Citron,[169,n] M. Citterio,[71a] D. A. Ciubotaru,[27b] A. Clark,[56] P. J. Clark,[52] C. Clarry,[155] J. M. Clavijo Columbie,[48] S. E. Clawson,[48] C. Clement,[47a,47b] J. Clercx,[48] Y. Coadou,[102] M. Cobal,[69a,69c] A. Coccaro,[57b] R. F. Coelho Barrue,[130a] R. Coelho Lopes De Sa,[103] S. Coelli,[71a] A. E. C. Coimbra,[71a,71b] B. Cole,[41] J. Collot,[60] P. Conde Muiño,[130a,130g] M. P. Connell,[33c] S. H. Connell,[33c] I. A. Connelly,[59] E. I. Conroy,[126] F. Conventi,[72a,o] H. G. Cooke,[20] A. M. Cooper-Sarkar,[126] A. Cordeiro Oudot Choi,[127] L. D. Corpe,[40] M. Corradi,[75a,75b] F. Corriveau,[104,p] A. Cortes-Gonzalez,[18] M. J. Costa,[163] F. Costanza,[4] D. Costanzo,[139] B. M. Cote,[119] G. Cowan,[95] K. Cranmer,[170] D. Cremonini,[23b,23a] S. Crépé-Renaudin,[60] F. Crescioli,[127] M. Cristinziani,[141] M. Cristoforetti,[78a,78b] V. Croft,[114] J. E. Crosby,[121] G. Crosetti,[43b,43a] A. Cueto,[99] T. Cuhadar Donszelmann,[160] H. Cui,[14a,14e] Z. Cui,[7] W. R. Cunningham,[59] F. Curcio,[43b,43a] P. Czodrowski,[36] M. M. Czurylo,[63b] M. J. Da Cunha Sargedas De Sousa,[57b,57a] J. V. Da Fonseca Pinto,[83b] C. Da Via,[101] W. Dabrowski,[86a] T. Dado,[49] S. Dahbi,[33g] T. Dai,[106] D. Dal Santo,[19] C. Dallapiccola,[103] M. Dam,[42] G. D'amen,[29] V. D'Amico,[109] J. Damp,[100] J. R. Dandoy,[34] M. Danninger,[142] V. Dao,[36] G. Darbo,[57b] S. Darmora,[6] S. J. Das,[29,i] S. D'Auria,[71a,71b] C. David,[156b] T. Davidek,[133]

B. Davis-Purcell,[34] I. Dawson,[94] H. A. Day-hall,[132] K. De,[8] R. De Asmundis,[72a] N. De Biase,[48] S. De Castro,[23b,23a] N. De Groot,[113] P. de Jong,[114] H. De la Torre,[115] A. De Maria,[14c] A. De Salvo,[75a] U. De Sanctis,[76a,76b] F. De Santis,[70a,70b] A. De Santo,[146] J. B. De Vivie De Regie,[60] D. V. Dedovich,[38] J. Degens,[114] A. M. Deiana,[44] F. Del Corso,[23b,23a] J. Del Peso,[99] F. Del Rio,[63a] L. Delagrange,[127] F. Deliot,[135] C. M. Delitzsch,[49] M. Della Pietra,[72a,72b] D. Della Volpe,[56] A. Dell'Acqua,[36] L. Dell'Asta,[71a,71b] M. Delmastro,[4] P. A. Delsart,[60] S. Demers,[172] M. Demichev,[38] S. P. Denisov,[37] L. D'Eramo,[40] D. Derendarz,[87] F. Derue,[127] P. Dervan,[92] K. Desch,[24] C. Deutsch,[24] F. A. Di Bello,[57b,57a] A. Di Ciaccio,[76a,76b] L. Di Ciaccio,[4] A. Di Domenico,[75a,75b] C. Di Donato,[72a,72b] A. Di Girolamo,[36] G. Di Gregorio,[36] A. Di Luca,[78a,78b] B. Di Micco,[77a,77b] R. Di Nardo,[77a,77b] C. Diaconu,[102] M. Diamantopoulou,[34] F. A. Dias,[114] T. Dias Do Vale,[142] M. A. Diaz,[137a,137b] F. G. Diaz Capriles,[24] M. Didenko,[163] E. B. Diehl,[106] L. Diehl,[54] S. Díez Cornell,[48] C. Diez Pardos,[141] C. Dimitriadi,[161,24] A. Dimitrievska,[17a] J. Dingfelder,[24] I-M. Dinu,[27b] S. J. Dittmeier,[63b] F. Dittus,[36] F. Djama,[102] T. Djobava,[149b] J. I. Djuvsland,[16] C. Doglioni,[101,98] A. Dohnalova,[28a] J. Dolejsi,[133] Z. Dolezal,[133] K. M. Dona,[39] M. Donadelli,[83c] B. Dong,[107] J. Donini,[40] A. D'Onofrio,[72a,72b] M. D'Onofrio,[92] J. Dopke,[134] A. Doria,[72a] N. Dos Santos Fernandes,[130a] P. Dougan,[101] M. T. Dova,[90] A. T. Doyle,[59] M. A. Draguet,[126] E. Dreyer,[169] I. Drivas-koulouris,[10] M. Drnevich,[117] A. S. Drobac,[158] M. Drozdova,[56] D. Du,[62a] T. A. du Pree,[114] F. Dubinin,[37] M. Dubovsky,[28a] E. Duchovni,[169] G. Duckeck,[109] O. A. Ducu,[27b] D. Duda,[52] A. Dudarev,[36] E. R. Duden,[26] M. D'uffizi,[101] L. Duflot,[66] M. Dührssen,[36] A. E. Dumitriu,[27b] M. Dunford,[63a] S. Dungs,[49] K. Dunne,[47a,47b] A. Duperrin,[102] H. Duran Yildiz,[3a] M. Düren,[58] A. Durglishvili,[149b] B. L. Dwyer,[115] G. I. Dyckes,[17a] M. Dyndal,[86a] B. S. Dziedzic,[87] Z. O. Earnshaw,[146] G. H. Eberwein,[126] B. Eckerova,[28a] S. Eggebrecht,[55] E. Egidio Purcino De Souza,[127] L. F. Ehrke,[56] G. Eigen,[16] K. Einsweiler,[17a] T. Ekelof,[161] P. A. Ekman,[98] S. El Farkh,[35b] Y. El Ghazali,[35b] H. El Jarrari,[36] A. El Moussaouy,[108] V. Ellajosyula,[161] M. Ellert,[161] F. Ellinghaus,[171] N. Ellis,[36] J. Elmsheuser,[29] M. Elsing,[36] D. Emeliyanov,[134] Y. Enari,[153] I. Ene,[17a] S. Epari,[13] P. A. Erland,[87] M. Errenst,[171] M. Escalier,[66] C. Escobar,[163] E. Etzion,[151] G. Evans,[130a] H. Evans,[68] L. S. Evans,[95] M. O. Evans,[146] A. Ezhilov,[37] S. Ezzarqtouni,[35a] F. Fabbri,[59] L. Fabbri,[23b,23a] G. Facini,[96] V. Fadeyev,[136] R. M. Fakhrutdinov,[37] D. Fakoudis,[100] S. Falciano,[75a] L. F. Falda Ulhoa Coelho,[36] P. J. Falke,[24] J. Faltova,[133] C. Fan,[162] Y. Fan,[14a] Y. Fang,[14a,14e] M. Fanti,[71a,71b] M. Faraj,[69a,69b] Z. Farazpay,[97] A. Farbin,[8] A. Farilla,[77a] T. Farooque,[107] S. M. Farrington,[52] F. Fassi,[35e] D. Fassouliotis,[9] M. Faucci Giannelli,[76a,76b] W. J. Fawcett,[32] L. Fayard,[66] P. Federic,[133] P. Federicova,[131] O. L. Fedin,[37,l] G. Fedotov,[37] M. Feickert,[170] L. Feligioni,[102] D. E. Fellers,[123] C. Feng,[62b] M. Feng,[14b] Z. Feng,[114] M. J. Fenton,[160] A. B. Fenyuk,[37] L. Ferencz,[48] R. A. M. Ferguson,[91] S. I. Fernandez Luengo,[137f] P. Fernandez Martinez,[13] M. J. V. Fernoux,[102] J. Ferrando,[91] A. Ferrari,[161] P. Ferrari,[114,113] R. Ferrari,[73a] D. Ferrere,[56] C. Ferretti,[106] F. Fiedler,[100] P. Fiedler,[132] A. Filipčič,[93] E. K. Filmer,[1] F. Filthaut,[113] M. C. N. Fiolhais,[130a,130c,q] L. Fiorini,[163] W. C. Fisher,[107] T. Fitschen,[101] P. M. Fitzhugh,[135] I. Fleck,[141] P. Fleischmann,[106] T. Flick,[171] M. Flores,[33d,r] L. R. Flores Castillo,[64a] L. Flores Sanz De Acedo,[36] F. M. Follega,[78a,78b] N. Fomin,[16] J. H. Foo,[155] B. C. Forland,[68] A. Formica,[135] A. C. Forti,[101] E. Fortin,[36] A. W. Fortman,[61] M. G. Foti,[17a] L. Fountas,[9,s] D. Fournier,[66] H. Fox,[91] P. Francavilla,[74a,74b] S. Francescato,[61] S. Franchellucci,[56] M. Franchini,[23b,23a] S. Franchino,[63a] D. Francis,[36] L. Franco,[113] V. Franco Lima,[36] L. Franconi,[48] M. Franklin,[61] G. Frattari,[26] A. C. Freegard,[94] W. S. Freund,[83b] Y. Y. Frid,[151] J. Friend,[59] N. Fritzsche,[50] A. Froch,[54] D. Froidevaux,[36] J. A. Frost,[126] Y. Fu,[62a] S. Fuenzalida Garrido,[137f] M. Fujimoto,[102] K. Y. Fung,[64a] E. Furtado De Simas Filho,[83b] M. Furukawa,[153] J. Fuster,[163] A. Gabrielli,[23b,23a] A. Gabrielli,[155] P. Gadow,[36] G. Gagliardi,[57b,57a] L. G. Gagnon,[17a] E. J. Gallas,[126] B. J. Gallop,[134] K. K. Gan,[119] S. Ganguly,[153] Y. Gao,[52] F. M. Garay Walls,[137a,137b] B. Garcia,[29] C. García,[163] A. Garcia Alonso,[114] A. G. Garcia Caffaro,[172] J. E. García Navarro,[163] M. Garcia-Sciveres,[17a] G. L. Gardner,[128] R. W. Gardner,[39] N. Garelli,[158] D. Garg,[80] R. B. Garg,[143,t] J. M. Gargan,[52] C. A. Garner,[155] C. M. Garvey,[33a] P. Gaspar,[83b] V. K. Gassmann,[158] G. Gaudio,[73a] V. Gautam,[13] P. Gauzzi,[75a,75b] I. L. Gavrilenko,[37] A. Gavrilyuk,[37] C. Gay,[164] G. Gaycken,[48] E. N. Gazis,[10] A. A. Geanta,[27b] C. M. Gee,[136] A. Gekow,[119] C. Gemme,[57b] M. H. Genest,[60] S. Gentile,[75a,75b] A. D. Gentry,[112] S. George,[95] W. F. George,[20] T. Geralis,[46] P. Gessinger-Befurt,[36] M. E. Geyik,[171] M. Ghani,[167] M. Ghneimat,[141] K. Ghorbanian,[94] A. Ghosal,[141] A. Ghosh,[160] A. Ghosh,[7] B. Giacobbe,[23b] S. Giagu,[75a,75b] T. Giani,[114] P. Giannetti,[74a] A. Giannini,[62a] S. M. Gibson,[95] M. Gignac,[136] D. T. Gil,[86b] A. K. Gilbert,[86a] B. J. Gilbert,[41]

D. Gillberg,[34] G. Gilles,[114] N. E. K. Gillwald,[48] L. Ginabat,[127] D. M. Gingrich,[2,e] M. P. Giordani,[69a,69c] P. F. Giraud,[135] G. Giugliarelli,[69a,69c] D. Giugni,[71a] F. Giuli,[36] I. Gkialas,[9,s] L. K. Gladilin,[37] C. Glasman,[99] G. R. Gledhill,[123] G. Glemža,[48] M. Glisic,[123] I. Gnesi,[43b,u] Y. Go,[29,i] M. Goblirsch-Kolb,[36] B. Gocke,[49] D. Godin,[108] B. Gokturk,[21a] S. Goldfarb,[105] T. Golling,[56] M. G. D. Gololo,[33g] D. Golubkov,[37] J. P. Gombas,[107] A. Gomes,[130a,130b] G. Gomes Da Silva,[141] A. J. Gomez Delegido,[163] R. Gonçalo,[130a,130c] G. Gonella,[123] L. Gonella,[20] A. Gongadze,[149c] F. Gonnella,[20] J. L. Gonski,[41] R. Y. González Andana,[52] S. González de la Hoz,[163] R. Gonzalez Lopez,[92] C. Gonzalez Renteria,[17a] M. V. Gonzalez Rodrigues,[48] R. Gonzalez Suarez,[161] S. Gonzalez-Sevilla,[56] G. R. Gonzalvo Rodriguez,[163] L. Goossens,[36] B. Gorini,[36] E. Gorini,[70a,70b] A. Gorišek,[93] T. C. Gosart,[128] A. T. Goshaw,[51] M. I. Gostkin,[38] S. Goswami,[121] C. A. Gottardo,[36] S. A. Gotz,[109] M. Gouighri,[35b] V. Goumarre,[48] A. G. Goussiou,[138] N. Govender,[33c] I. Grabowska-Bold,[86a] K. Graham,[34] E. Gramstad,[125] S. Grancagnolo,[70a,70b] M. Grandi,[146] C. M. Grant,[1,135] P. M. Gravila,[27f] F. G. Gravili,[70a,70b] H. M. Gray,[17a] M. Greco,[70a,70b] C. Grefe,[24] I. M. Gregor,[48] P. Grenier,[143] S. G. Grewe,[110] C. Grieco,[13] A. A. Grillo,[136] K. Grimm,[31] S. Grinstein,[13,v] J.-F. Grivaz,[66] E. Gross,[169] J. Grosse-Knetter,[55] C. Grud,[106] J. C. Grundy,[126] L. Guan,[106] W. Guan,[29] C. Gubbels,[164] J. G. R. Guerrero Rojas,[163] G. Guerrieri,[69a,69c] F. Guescini,[110] R. Gugel,[100] J. A. M. Guhit,[106] A. Guida,[18] E. Guilloton,[167,134] S. Guindon,[36] F. Guo,[14a,14e] J. Guo,[62c] L. Guo,[48] Y. Guo,[106] R. Gupta,[48] R. Gupta,[129] S. Gurbuz,[24] S. S. Gurdasani,[54] G. Gustavino,[36] M. Guth,[56] P. Gutierrez,[120] L. F. Gutierrez Zagazeta,[128] M. Gutsche,[50] C. Gutschow,[96] C. Gwenlan,[126] C. B. Gwilliam,[92] E. S. Haaland,[125] A. Haas,[117] M. Habedank,[48] C. Haber,[17a] H. K. Hadavand,[8] A. Hadef,[50] S. Hadzic,[110] A. I. Hagan,[91] J. J. Hahn,[141] E. H. Haines,[96] M. Haleem,[166] J. Haley,[121] J. J. Hall,[139] G. D. Hallewell,[102] L. Halser,[19] K. Hamano,[165] M. Hamer,[24] G. N. Hamity,[52] E. J. Hampshire,[95] J. Han,[62b] K. Han,[62a] L. Han,[14c] L. Han,[62a] S. Han,[17a] Y. F. Han,[155] K. Hanagaki,[84] M. Hance,[136] D. A. Hangal,[41,d] H. Hanif,[142] M. D. Hank,[128] R. Hankache,[101] J. B. Hansen,[42] J. D. Hansen,[42] P. H. Hansen,[42] K. Hara,[157] D. Harada,[56] T. Harenberg,[171] S. Harkusha,[37] M. L. Harris,[103] Y. T. Harris,[126] J. Harrison,[13] N. M. Harrison,[119] P. F. Harrison,[167] N. M. Hartman,[110] N. M. Hartmann,[109] Y. Hasegawa,[140] R. Hauser,[107] C. M. Hawkes,[20] R. J. Hawkings,[36] Y. Hayashi,[153] S. Hayashida,[111] D. Hayden,[107] C. Hayes,[106] R. L. Hayes,[114] C. P. Hays,[126] J. M. Hays,[94] H. S. Hayward,[92] F. He,[62a] M. He,[14a,14e] Y. He,[154] Y. He,[48] N. B. Heatley,[94] V. Hedberg,[98] A. L. Heggelund,[125] N. D. Hehir,[94,a] C. Heidegger,[54] K. K. Heidegger,[54] W. D. Heidorn,[81] J. Heilman,[34] S. Heim,[48] T. Heim,[17a] J. G. Heinlein,[128] J. J. Heinrich,[123] L. Heinrich,[110,w] J. Hejbal,[131] L. Helary,[48] A. Held,[170] S. Hellesund,[16] C. M. Helling,[164] S. Hellman,[47a,47b] R. C. W. Henderson,[91] L. Henkelmann,[32] A. M. Henriques Correia,[36] H. Herde,[98] Y. Hernández Jiménez,[145] L. M. Herrmann,[24] T. Herrmann,[50] G. Herten,[54] R. Hertenberger,[109] L. Hervas,[36] M. E. Hesping,[100] N. P. Hessey,[156a] H. Hibi,[85] E. Hill,[155] S. J. Hillier,[20] J. R. Hinds,[107] F. Hinterkeuser,[24] M. Hirose,[124] S. Hirose,[157] D. Hirschbuehl,[171] T. G. Hitchings,[101] B. Hiti,[93] J. Hobbs,[145] R. Hobincu,[27e] N. Hod,[169] M. C. Hodgkinson,[139] B. H. Hodkinson,[32] A. Hoecker,[36] D. D. Hofer,[106] J. Hofer,[48] T. Holm,[24] M. Holzbock,[110] L. B. A. H. Hommels,[32] B. P. Honan,[101] J. Hong,[62c] T. M. Hong,[129] B. H. Hooberman,[162] W. H. Hopkins,[6] Y. Horii,[111] S. Hou,[148] A. S. Howard,[93] J. Howarth,[59] J. Hoya,[6] M. Hrabovsky,[122] A. Hrynevich,[48] T. Hryn'ova,[4] P. J. Hsu,[65] S.-C. Hsu,[138] Q. Hu,[62a] Y. F. Hu,[14a,14e] S. Huang,[64b] X. Huang,[14c] X. Huang,[14a,14e] Y. Huang,[139] Y. Huang,[14a] Z. Huang,[101] Z. Hubacek,[132] M. Huebner,[24] F. Huegging,[24] T. B. Huffman,[126] C. A. Hugli,[48] M. Huhtinen,[36] S. K. Huiberts,[16] R. Hulsken,[104] N. Huseynov,[12] J. Huston,[107] J. Huth,[61] R. Hyneman,[143] G. Iacobucci,[56] G. Iakovidis,[29] I. Ibragimov,[141] L. Iconomidou-Fayard,[66] P. Iengo,[72a,72b] R. Iguchi,[153] T. Iizawa,[126] Y. Ikegami,[84] N. Ilic,[155] H. Imam,[35a] M. Ince Lezki,[56] T. Ingebretsen Carlson,[47a,47b] G. Introzzi,[73a,73b] M. Iodice,[77a] V. Ippolito,[75a,75b] R. K. Irwin,[92] M. Ishino,[153] W. Islam,[170] C. Issever,[18,48] S. Istin,[21a,x] H. Ito,[168] J. M. Iturbe Ponce,[64a] R. Iuppa,[78a,78b] A. Ivina,[169] J. M. Izen,[45] V. Izzo,[72a] P. Jacka,[131,132] P. Jackson,[1] R. M. Jacobs,[48] B. P. Jaeger,[142] C. S. Jagfeld,[109] G. Jain,[156a] P. Jain,[54] K. Jakobs,[54] T. Jakoubek,[169] J. Jamieson,[59] K. W. Janas,[86a] M. Javurkova,[103] F. Jeanneau,[135] L. Jeanty,[123] J. Jejelava,[149a,y] P. Jenni,[54,z] C. E. Jessiman,[34] S. Jézéquel,[4] C. Jia,[62b] J. Jia,[145] X. Jia,[61] X. Jia,[14a,14e] Z. Jia,[14c] S. Jiggins,[48] J. Jimenez Pena,[13] S. Jin,[14c] A. Jinaru,[27b] O. Jinnouchi,[154] P. Johansson,[139] K. A. Johns,[7] J. W. Johnson,[136] D. M. Jones,[32] E. Jones,[48] P. Jones,[32] R. W. L. Jones,[91] T. J. Jones,[92] H. L. Joos,[55,36] R. Joshi,[119] J. Jovicevic,[15] X. Ju,[17a] J. J. Junggeburth,[103] T. Junkermann,[63a] A. Juste Rozas,[13,v] M. K. Juzek,[87] S. Kabana,[137e] A. Kaczmarska,[87] M. Kado,[110]

H. Kagan,[119] M. Kagan,[143] A. Kahn,[41] A. Kahn,[128] C. Kahra,[100] T. Kaji,[153] E. Kajomovitz,[150] N. Kakati,[169] I. Kalaitzidou,[54] C. W. Kalderon,[29] A. Kamenshchikov,[155] N. J. Kang,[136] D. Kar,[33g] K. Karava,[126] M. J. Kareem,[156b] E. Karentzos,[54] I. Karkanias,[152] O. Karkout,[114] S. N. Karpov,[38] Z. M. Karpova,[38] V. Kartvelishvili,[91] A. N. Karyukhin,[37] E. Kasimi,[152] J. Katzy,[48] S. Kaur,[34] K. Kawade,[140] M. P. Kawale,[120] C. Kawamoto,[88] T. Kawamoto,[62a] E. F. Kay,[36] F. I. Kaya,[158] S. Kazakos,[107] V. F. Kazanin,[37] Y. Ke,[145] J. M. Keaveney,[33a] R. Keeler,[165] G. V. Kehris,[61] J. S. Keller,[34] A. S. Kelly,[96] J. J. Kempster,[146] K. E. Kennedy,[41] P. D. Kennedy,[100] O. Kepka,[131] B. P. Kerridge,[167] S. Kersten,[171] B. P. Kerševan,[93] S. Keshri,[66] L. Keszeghova,[28a] S. Ketabchi Haghighat,[155] R. A. Khan,[129] A. Khanov,[121] A. G. Kharlamov,[37] T. Kharlamova,[37] E. E. Khoda,[138] M. Kholodenko,[37] T. J. Khoo,[18] G. Khoriauli,[166] J. Khubua,[149b,a] Y. A. R. Khwaira,[66] A. Kilgallon,[123] D. W. Kim,[47a,47b] Y. K. Kim,[39] N. Kimura,[96] M. K. Kingston,[55] A. Kirchhoff,[55] C. Kirfel,[24] F. Kirfel,[24] J. Kirk,[134] A. E. Kiryunin,[110] C. Kitsaki,[10] O. Kivernyk,[24] M. Klassen,[63a] C. Klein,[34] L. Klein,[166] M. H. Klein,[44] M. Klein,[92] S. B. Klein,[56] U. Klein,[92] P. Klimek,[36] A. Klimentov,[29] T. Klioutchnikova,[36] P. Kluit,[114] S. Kluth,[110] E. Kneringer,[79] T. M. Knight,[155] A. Knue,[49] R. Kobayashi,[88] D. Kobylianskii,[169] S. F. Koch,[126] M. Kocian,[143] P. Kodyš,[133] D. M. Koeck,[123] P. T. Koenig,[24] T. Koffas,[34] O. Kolay,[50] I. Koletsou,[4] T. Komarek,[122] K. Köneke,[54] A. X. Y. Kong,[1] T. Kono,[118] N. Konstantinidis,[96] P. Kontaxakis,[56] B. Konya,[98] R. Kopeliansky,[68] S. Koperny,[86a] K. Korcyl,[87] K. Kordas,[152,aa] A. Korn,[96] S. Korn,[55] I. Korolkov,[13] N. Korotkova,[37] B. Kortman,[114] O. Kortner,[110] S. Kortner,[110] W. H. Kostecka,[115] V. V. Kostyukhin,[141] A. Kotsokechagia,[135] A. Kotwal,[51] A. Koulouris,[36] A. Kourkoumeli-Charalampidi,[73a,73b] C. Kourkoumelis,[9] E. Kourlitis,[110,w] O. Kovanda,[146] R. Kowalewski,[165] W. Kozanecki,[135] A. S. Kozhin,[37] V. A. Kramarenko,[37] G. Kramberger,[93] P. Kramer,[100] M. W. Krasny,[127] A. Krasznahorkay,[36] J. W. Kraus,[171] J. A. Kremer,[48] T. Kresse,[50] J. Kretzschmar,[92] K. Kreul,[18] P. Krieger,[155] S. Krishnamurthy,[103] M. Krivos,[133] K. Krizka,[20] K. Kroeninger,[49] H. Kroha,[110] J. Kroll,[131] J. Kroll,[128] K. S. Krowpman,[107] U. Kruchonak,[38] H. Krüger,[24] N. Krumnack,[81] M. C. Kruse,[51] O. Kuchinskaia,[37] S. Kuday,[3a] S. Kuehn,[36] R. Kuesters,[54] T. Kuhl,[48] V. Kukhtin,[38] Y. Kulchitsky,[37,l] S. Kuleshov,[137d,137b] M. Kumar,[33g] N. Kumari,[48] P. Kumari,[156b] A. Kupco,[131] T. Kupfer,[49] A. Kupich,[37] O. Kuprash,[54] H. Kurashige,[85] L. L. Kurchaninov,[156a] O. Kurdysh,[66] Y. A. Kurochkin,[37] A. Kurova,[37] M. Kuze,[154] A. K. Kvam,[103] J. Kvita,[122] T. Kwan,[104] N. G. Kyriacou,[106] L. A. O. Laatu,[102] C. Lacasta,[163] F. Lacava,[75a,75b] H. Lacker,[18] D. Lacour,[127] N. N. Lad,[96] E. Ladygin,[38] B. Laforge,[127] T. Lagouri,[137e] F. Z. Lahbabi,[35a] S. Lai,[55] I. K. Lakomiec,[86a] N. Lalloue,[60] J. E. Lambert,[165] S. Lammers,[68] W. Lampl,[7] C. Lampoudis,[152,aa] A. N. Lancaster,[115] E. Lançon,[29] U. Landgraf,[54] M. P. J. Landon,[94] V. S. Lang,[54] R. J. Langenberg,[103] O. K. B. Langrekken,[125] A. J. Lankford,[160] F. Lanni,[36] K. Lantzsch,[24] A. Lanza,[73a] A. Lapertosa,[57b,57a] J. F. Laporte,[135] T. Lari,[71a] F. Lasagni Manghi,[23b] M. Lassnig,[36] V. Latonova,[131] A. Laudrain,[100] A. Laurier,[150] S. D. Lawlor,[139] Z. Lawrence,[101] R. Lazaridou,[167] M. Lazzaroni,[71a,71b] B. Le,[101] E. M. Le Boulicaut,[51] B. Leban,[93] A. Lebedev,[81] M. LeBlanc,[101] F. Ledroit-Guillon,[60] A. C. A. Lee,[96] S. C. Lee,[148] S. Lee,[47a,47b] T. F. Lee,[92] L. L. Leeuw,[33c] H. P. Lefebvre,[95] M. Lefebvre,[165] C. Leggett,[17a] G. Lehmann Miotto,[36] M. Leigh,[56] W. A. Leight,[103] W. Leinonen,[113] A. Leisos,[152,bb] M. A. L. Leite,[83c] C. E. Leitgeb,[48] R. Leitner,[133] K. J. C. Leney,[44] T. Lenz,[24] S. Leone,[74a] C. Leonidopoulos,[52] A. Leopold,[144] C. Leroy,[108] R. Les,[107] C. G. Lester,[32] M. Levchenko,[37] J. Levêque,[4] D. Levin,[106] L. J. Levinson,[169] M. P. Lewicki,[87] D. J. Lewis,[4] A. Li,[5] B. Li,[62b] C. Li,[62a] C-Q. Li,[110] H. Li,[62a] H. Li,[62b] H. Li,[14c] H. Li,[14b] H. Li,[62b] J. Li,[62c] K. Li,[138] L. Li,[62c] M. Li,[14a,14e] Q. Y. Li,[62a] S. Li,[14a,14e] S. Li,[62d,62c,cc] T. Li,[5] X. Li,[104] Z. Li,[126] Z. Li,[104] Z. Li,[14a,14e] S. Liang,[14a,14e] Z. Liang,[14a] M. Liberatore,[135] B. Liberti,[76a] K. Lie,[64c] J. Lieber Marin,[83b] H. Lien,[68] K. Lin,[107] R. E. Lindley,[7] J. H. Lindon,[2] E. Lipeles,[128] A. Lipniacka,[16] A. Lister,[164] J. D. Little,[4] B. Liu,[14a] B. X. Liu,[142] D. Liu,[62d,62c] J. B. Liu,[62a] J. K. K. Liu,[32] K. Liu,[62d,62c] M. Liu,[62a] M. Y. Liu,[62a] P. Liu,[14a] Q. Liu,[62d,138,62c] X. Liu,[62a] X. Liu,[62b] Y. Liu,[14d,14e] Y. L. Liu,[62b] Y. W. Liu,[62a] J. Llorente Merino,[142] S. L. Lloyd,[94] E. M. Lobodzinska,[48] P. Loch,[7] T. Lohse,[18] K. Lohwasser,[139] E. Loiacono,[48] M. Lokajicek,[131,a] J. D. Lomas,[20] J. D. Long,[162] I. Longarini,[160] L. Longo,[70a,70b] R. Longo,[162] I. Lopez Paz,[67] A. Lopez Solis,[48] N. Lorenzo Martinez,[4] A. M. Lory,[109] G. Löschcke Centeno,[146] O. Loseva,[37] X. Lou,[47a,47b] X. Lou,[14a,14e] A. Lounis,[66] J. Love,[6] P. A. Love,[91] G. Lu,[14a,14e] M. Lu,[80] S. Lu,[128] Y. J. Lu,[65] H. J. Lubatti,[138] C. Luci,[75a,75b] F. L. Lucio Alves,[14c] A. Lucotte,[60] F. Luehring,[68] I. Luise,[145] O. Lukianchuk,[66] O. Lundberg,[144] B. Lund-Jensen,[144,a] N. A. Luongo,[6] M. S. Lutz,[151]

A. B. Lux,[25] D. Lynn,[29] H. Lyons,[92] R. Lysak,[131] E. Lytken,[98] V. Lyubushkin,[38] T. Lyubushkina,[38] M. M. Lyukova,[145] H. Ma,[29] K. Ma,[62a] L. L. Ma,[62b] W. Ma,[62a] Y. Ma,[121] D. M. Mac Donell,[165] G. Maccarrone,[53] J. C. MacDonald,[100] P. C. Machado De Abreu Farias,[83b] R. Madar,[40] W. F. Mader,[50] T. Madula,[96] J. Maeda,[85] T. Maeno,[29] H. Maguire,[139] V. Maiboroda,[135] A. Maio,[130a,130b,130d] K. Maj,[86a] O. Majersky,[48] S. Majewski,[123] N. Makovec,[66] V. Maksimovic,[15] B. Malaescu,[127] Pa. Malecki,[87] V. P. Maleev,[37] F. Malek,[60,dd] M. Mali,[93] D. Malito,[95] U. Mallik,[80] S. Maltezos,[10] S. Malyukov,[38] J. Mamuzic,[13] G. Mancini,[53] G. Manco,[73a,73b] J. P. Mandalia,[94] I. Mandić,[93] L. Manhaes de Andrade Filho,[83a] I. M. Maniatis,[169] J. Manjarres Ramos,[102,ee] D. C. Mankad,[169] A. Mann,[109] B. Mansoulie,[135] S. Manzoni,[36] L. Mao,[62c] X. Mapekula,[33c] A. Marantis,[152,bb] G. Marchiori,[5] M. Marcisovsky,[131] C. Marcon,[71a] M. Marinescu,[20] S. Marium,[48] M. Marjanovic,[120] E. J. Marshall,[91] Z. Marshall,[17a] S. Marti-Garcia,[163] T. A. Martin,[167] V. J. Martin,[52] B. Martin dit Latour,[16] L. Martinelli,[75a,75b] M. Martinez,[13,v] P. Martinez Agullo,[163] V. I. Martinez Outschoorn,[103] P. Martinez Suarez,[13] S. Martin-Haugh,[134] V. S. Martoiu,[27b] A. C. Martyniuk,[96] A. Marzin,[36] D. Mascione,[78a,78b] L. Masetti,[100] T. Mashimo,[153] J. Masik,[101] A. L. Maslennikov,[37] P. Massarotti,[72a,72b] P. Mastrandrea,[74a,74b] A. Mastroberardino,[43b,43a] T. Masubuchi,[153] T. Mathisen,[161] J. Matousek,[133] N. Matsuzawa,[153] J. Maurer,[27b] B. Maček,[93] D. A. Maximov,[37] R. Mazini,[148] I. Maznas,[152] M. Mazza,[107] S. M. Mazza,[136] E. Mazzeo,[71a,71b] C. Mc Ginn,[29] J. P. Mc Gowan,[104] S. P. Mc Kee,[106] C. C. McCracken,[164] E. F. McDonald,[105] A. E. McDougall,[114] J. A. Mcfayden,[146] R. P. McGovern,[128] G. Mchedlidze,[149b] R. P. Mckenzie,[33g] T. C. Mclachlan,[48] D. J. Mclaughlin,[96] S. J. McMahon,[134] C. M. Mcpartland,[92] R. A. McPherson,[165,p] S. Mehlhase,[109] A. Mehta,[92] D. Melini,[150] B. R. Mellado Garcia,[33g] A. H. Melo,[55] F. Meloni,[48] A. M. Mendes Jacques Da Costa,[101] H. Y. Meng,[155] L. Meng,[91] S. Menke,[110] M. Mentink,[36] E. Meoni,[43b,43a] G. Mercado,[115] C. Merlassino,[69a,69c] L. Merola,[72a,72b] C. Meroni,[71a,71b] G. Merz,[106] J. Metcalfe,[6] A. S. Mete,[6] C. Meyer,[68] J-P. Meyer,[135] R. P. Middleton,[134] L. Mijović,[52] G. Mikenberg,[169] M. Mikestikova,[131] M. Mikuž,[93] H. Mildner,[100] A. Milic,[36] C. D. Milke,[44] D. W. Miller,[39] E. H. Miller,[143] L. S. Miller,[34] A. Milov,[169] D. A. Milstead,[47a,47b] T. Min,[14c] A. A. Minaenko,[37] I. A. Minashvili,[149b] L. Mince,[59] A. I. Mincer,[117] B. Mindur,[86a] M. Mineev,[38] Y. Mino,[88] L. M. Mir,[13] M. Miralles Lopez,[163] M. Mironova,[17a] A. Mishima,[153] M. C. Missio,[113] A. Mitra,[167] V. A. Mitsou,[163] Y. Mitsumori,[111] O. Miu,[155] P. S. Miyagawa,[94] T. Mkrtchyan,[63a] M. Mlinarevic,[96] T. Mlinarevic,[96] M. Mlynarikova,[36] S. Mobius,[19] P. Moder,[48] P. Mogg,[109] M. H. Mohamed Farook,[112] A. F. Mohammed,[14a,14e] S. Mohapatra,[41] G. Mokgatitswane,[33g] L. Moleri,[169] B. Mondal,[141] S. Mondal,[132] K. Mönig,[48] E. Monnier,[102] L. Monsonis Romero,[163] J. Montejo Berlingen,[13] M. Montella,[119] F. Montereali,[77a,77b] F. Monticelli,[90] S. Monzani,[69a,69c] N. Morange,[66] A. L. Moreira De Carvalho,[130a] M. Moreno Llácer,[163] C. Moreno Martinez,[56] P. Morettini,[57b] S. Morgenstern,[36] M. Morii,[61] M. Morinaga,[153] A. K. Morley,[36] F. Morodei,[75a,75b] L. Morvaj,[36] P. Moschovakos,[36] B. Moser,[36] M. Mosidze,[149b] T. Moskalets,[54] P. Moskvitina,[113] J. Moss,[31,ff] E. J. W. Moyse,[103] O. Mtintsilana,[33g] S. Muanza,[102] J. Mueller,[129] D. Muenstermann,[91] R. Müller,[19] G. A. Mullier,[161] A. J. Mullin,[32] J. J. Mullin,[128] D. P. Mungo,[155] D. Munoz Perez,[163] F. J. Munoz Sanchez,[101] M. Murin,[101] W. J. Murray,[167,134] A. Murrone,[71a,71b] M. Muškinja,[17a] C. Mwewa,[29] A. G. Myagkov,[37,l] A. J. Myers,[8] G. Myers,[68] M. Myska,[132] B. P. Nachman,[17a] O. Nackenhorst,[49] A. Nag,[50] K. Nagai,[126] K. Nagano,[84] J. L. Nagle,[29,i] E. Nagy,[102] A. M. Nairz,[36] Y. Nakahama,[84] K. Nakamura,[84] K. Nakkalil,[5] H. Nanjo,[124] R. Narayan,[44] E. A. Narayanan,[112] I. Naryshkin,[37] M. Naseri,[34] S. Nasri,[159] C. Nass,[24] G. Navarro,[22a] J. Navarro-Gonzalez,[163] R. Nayak,[151] A. Nayaz,[18] P. Y. Nechaeva,[37] F. Nechansky,[48] L. Nedic,[126] T. J. Neep,[20] A. Negri,[73a,73b] M. Negrini,[23b] C. Nellist,[114] C. Nelson,[104] K. Nelson,[106] S. Nemecek,[131] M. Nessi,[36,gg] M. S. Neubauer,[162] F. Neuhaus,[100] J. Neundorf,[48] R. Newhouse,[164] P. R. Newman,[20] C. W. Ng,[129] Y. W. Y. Ng,[48] B. Ngair,[35e] H. D. N. Nguyen,[108] R. B. Nickerson,[126] R. Nicolaidou,[135] J. Nielsen,[136] M. Niemeyer,[55] J. Niermann,[55,36] N. Nikiforou,[36] V. Nikolaenko,[37,l] I. Nikolic-Audit,[127] K. Nikolopoulos,[20] P. Nilsson,[29] I. Ninca,[48] H. R. Nindhito,[56] G. Ninio,[151] A. Nisati,[75a] N. Nishu,[2] R. Nisius,[110] J-E. Nitschke,[50] E. K. Nkadimeng,[33g] T. Nobe,[153] D. L. Noel,[32] T. Nommensen,[147] M. B. Norfolk,[139] R. R. B. Norisam,[96] B. J. Norman,[34] M. Noury,[35a] J. Novak,[93] T. Novak,[48] L. Novotny,[132] R. Novotny,[112] L. Nozka,[122] K. Ntekas,[160] N. M. J. Nunes De Moura Junior,[83b] E. Nurse,[96] J. Ocariz,[127] A. Ochi,[85] I. Ochoa,[130a] S. Oerdek,[48,hh] J. T. Offermann,[39] A. Ogrodnik,[133] A. Oh,[101] C. C. Ohm,[144] H. Oide,[84] R. Oishi,[153] M. L. Ojeda,[48]

Y. Okumura,[153] L. F. Oleiro Seabra,[130a] S. A. Olivares Pino,[137d] D. Oliveira Damazio,[29] D. Oliveira Goncalves,[83a] J. L. Oliver,[160] Ö. O. Öncel,[54] A. P. O'Neill,[19] A. Onofre,[130a,130e] P. U. E. Onyisi,[11] M. J. Oreglia,[39] G. E. Orellana,[90] D. Orestano,[77a,77b] N. Orlando,[13] R. S. Orr,[155] V. O'Shea,[59] L. M. Osojnak,[128] R. Ospanov,[62a] G. Otero y Garzon,[30] H. Otono,[89] P. S. Ott,[63a] G. J. Ottino,[17a] M. Ouchrif,[35d] J. Ouellette,[29] F. Ould-Saada,[125] M. Owen,[59] R. E. Owen,[134] K. Y. Oyulmaz,[21a] V. E. Ozcan,[21a] F. Ozturk,[87] N. Ozturk,[8] S. Ozturk,[82] H. A. Pacey,[126] A. Pacheco Pages,[13] C. Padilla Aranda,[13] G. Padovano,[75a,75b] S. Pagan Griso,[17a] G. Palacino,[68] A. Palazzo,[70a,70b] J. Pan,[172] T. Pan,[64a] D. K. Panchal,[11] C. E. Pandini,[114] J. G. Panduro Vazquez,[95] H. D. Pandya,[1] H. Pang,[14b] P. Pani,[48] G. Panizzo,[69a,69c] L. Paolozzi,[56] C. Papadatos,[108] S. Parajuli,[162] A. Paramonov,[6] C. Paraskevopoulos,[10] D. Paredes Hernandez,[64b] K. R. Park,[41] T. H. Park,[155] M. A. Parker,[32] F. Parodi,[57b,57a] E. W. Parrish,[115] V. A. Parrish,[52] J. A. Parsons,[41] U. Parzefall,[54] B. Pascual Dias,[108] L. Pascual Dominguez,[151] E. Pasqualucci,[75a] S. Passaggio,[57b] F. Pastore,[95] P. Pasuwan,[47a,47b] P. Patel,[87] U. M. Patel,[51] J. R. Pater,[101] T. Pauly,[36] J. Pearkes,[143] M. Pedersen,[125] R. Pedro,[130a] S. V. Peleganchuk,[37] O. Penc,[36] E. A. Pender,[52] K. E. Penski,[109] M. Penzin,[37] B. S. Peralva,[83d] A. P. Pereira Peixoto,[60] L. Pereira Sanchez,[47a,47b] D. V. Perepelitsa,[29,i] E. Perez Codina,[156a] M. Perganti,[10] L. Perini,[71a,71b,a] H. Pernegger,[36] O. Perrin,[40] K. Peters,[48] R. F. Y. Peters,[101] B. A. Petersen,[36] T. C. Petersen,[42] E. Petit,[102] V. Petousis,[132] C. Petridou,[152,aa] A. Petrukhin,[141] M. Pettee,[17a] N. E. Pettersson,[36] A. Petukhov,[37] K. Petukhova,[133] R. Pezoa,[137f] L. Pezzotti,[36] G. Pezzullo,[172] T. M. Pham,[170] T. Pham,[105] P. W. Phillips,[134] G. Piacquadio,[145] E. Pianori,[17a] F. Piazza,[123] R. Piegaia,[30] D. Pietreanu,[27b] A. D. Pilkington,[101] M. Pinamonti,[69a,69c] J. L. Pinfold,[2] B. C. Pinheiro Pereira,[130a] A. E. Pinto Pinoargote,[100,135] L. Pintucci,[69a,69c] K. M. Piper,[146] A. Pirttikoski,[56] D. A. Pizzi,[34] L. Pizzimento,[64b] A. Pizzini,[114] M.-A. Pleier,[29] V. Plesanovs,[54] V. Pleskot,[133] E. Plotnikova,[38] G. Poddar,[4] R. Poettgen,[98] L. Poggioli,[127] I. Pokharel,[55] S. Polacek,[133] G. Polesello,[73a] A. Poley,[142,156a] R. Polifka,[132] A. Polini,[23b] C. S. Pollard,[167] Z. B. Pollock,[119] V. Polychronakos,[29] E. Pompa Pacchi,[75a,75b] D. Ponomarenko,[113] L. Pontecorvo,[36] S. Popa,[27a] G. A. Popeneciu,[27d] A. Poreba,[36] D. M. Portillo Quintero,[156a] S. Pospisil,[132] M. A. Postill,[139] P. Postolache,[27c] K. Potamianos,[167] P. A. Potepa,[86a] I. N. Potrap,[38] C. J. Potter,[32] H. Potti,[1] T. Poulsen,[48] J. Poveda,[163] M. E. Pozo Astigarraga,[36] A. Prades Ibanez,[163] J. Pretel,[54] D. Price,[101] M. Primavera,[70a] M. A. Principe Martin,[99] R. Privara,[122] T. Procter,[59] M. L. Proffitt,[138] N. Proklova,[128] K. Prokofiev,[64c] G. Proto,[110] S. Protopopescu,[29] J. Proudfoot,[6] M. Przybycien,[86a] W. W. Przygoda,[86b] A. Psallidas,[46] J. E. Puddefoot,[139] D. Pudzha,[37] D. Pyatiizbyantseva,[37] J. Qian,[106] D. Qichen,[101] Y. Qin,[101] T. Qiu,[52] A. Quadt,[55] M. Queitsch-Maitland,[101] G. Quetant,[56] R. P. Quinn,[164] G. Rabanal Bolanos,[61] D. Rafanoharana,[54] F. Ragusa,[71a,71b] J. L. Rainbolt,[39] J. A. Raine,[56] S. Rajagopalan,[29] E. Ramakoti,[37] I. A. Ramirez-Berend,[34] K. Ran,[48,14e] N. P. Rapheeha,[33g] H. Rasheed,[27b] V. Raskina,[127] D. F. Rassloff,[63a] A. Rastogi,[17a] S. Rave,[100] B. Ravina,[55] I. Ravinovich,[169] M. Raymond,[36] A. L. Read,[125] N. P. Readioff,[139] D. M. Rebuzzi,[73a,73b] G. Redlinger,[29] A. S. Reed,[110] K. Reeves,[26] J. A. Reidelsturz,[171] D. Reikher,[151] A. Rej,[49] C. Rembser,[36] A. Renardi,[48] M. Renda,[27b] M. B. Rendel,[110] F. Renner,[48] A. G. Rennie,[160] A. L. Rescia,[48] S. Resconi,[71a] M. Ressegotti,[57b,57a] S. Rettie,[36] J. G. Reyes Rivera,[107] E. Reynolds,[17a] O. L. Rezanova,[37] P. Reznicek,[133] N. Ribaric,[91] E. Ricci,[78a,78b] R. Richter,[110] S. Richter,[47a,47b] E. Richter-Was,[86b] M. Ridel,[127] S. Ridouani,[35d] P. Rieck,[117] P. Riedler,[36] E. M. Riefel,[47a,47b] J. O. Rieger,[114] M. Rijssenbeek,[145] A. Rimoldi,[73a,73b] M. Rimoldi,[36] L. Rinaldi,[23b,23a] T. T. Rinn,[29] M. P. Rinnagel,[109] G. Ripellino,[161] I. Riu,[13] P. Rivadeneira,[48] J. C. Rivera Vergara,[165] F. Rizatdinova,[121] E. Rizvi,[94] B. A. Roberts,[167] B. R. Roberts,[17a] S. H. Robertson,[104,p] D. Robinson,[32] C. M. Robles Gajardo,[137f] M. Robles Manzano,[100] A. Robson,[59] A. Rocchi,[76a,76b] C. Roda,[74a,74b] S. Rodriguez Bosca,[63a] Y. Rodriguez Garcia,[22a] A. Rodriguez Rodriguez,[54] A. M. Rodríguez Vera,[156b] S. Roe,[36] J. T. Roemer,[160] A. R. Roepe-Gier,[136] J. Roggel,[171] O. Røhne,[125] R. A. Rojas,[103] C. P. A. Roland,[127] J. Roloff,[29] A. Romaniouk,[37] E. Romano,[73a,73b] M. Romano,[23b] A. C. Romero Hernandez,[162] N. Rompotis,[92] L. Roos,[127] S. Rosati,[75a] B. J. Rosser,[39] E. Rossi,[126] E. Rossi,[72a,72b] L. P. Rossi,[57b] L. Rossini,[54] R. Rosten,[119] M. Rotaru,[27b] B. Rottler,[54] C. Rougier,[102,ee] D. Rousseau,[66] D. Rousso,[32] A. Roy,[162] S. Roy-Garand,[155] A. Rozanov,[102] Z. M. A. Rozario,[59] Y. Rozen,[150] X. Ruan,[33g] A. Rubio Jimenez,[163] A. J. Ruby,[92] V. H. Ruelas Rivera,[18] T. A. Ruggeri,[1] A. Ruggiero,[126] A. Ruiz-Martinez,[163] A. Rummler,[36] Z. Rurikova,[54] N. A. Rusakovich,[38] H. L. Russell,[165] G. Russo,[75a,75b] J. P. Rutherfoord,[7] S. Rutherford Colmenares,[32]

K. Rybacki,[91] M. Rybar,[133] E. B. Rye,[125] A. Ryzhov,[44] J. A. Sabater Iglesias,[56] P. Sabatini,[163] H. F-W. Sadrozinski,[136] F. Safai Tehrani,[75a] B. Safarzadeh Samani,[134] M. Safdari,[143] S. Saha,[165] M. Sahinsoy,[110] A. Saibel,[163] M. Saimpert,[135] M. Saito,[153] T. Saito,[153] D. Salamani,[36] A. Salnikov,[143] J. Salt,[163] A. Salvador Salas,[151] D. Salvatore,[43b,43a] F. Salvatore,[146] A. Salzburger,[36] D. Sammel,[54] D. Sampsonidis,[152,aa] D. Sampsonidou,[123] J. Sánchez,[163] A. Sanchez Pineda,[4] V. Sanchez Sebastian,[163] H. Sandaker,[125] C. O. Sander,[48] J. A. Sandesara,[103] M. Sandhoff,[171] C. Sandoval,[22b] D. P. C. Sankey,[134] T. Sano,[88] A. Sansoni,[53] L. Santi,[75a,75b] C. Santoni,[40] H. Santos,[130a,130b] A. Santra,[169] K. A. Saoucha,[116b] J. G. Saraiva,[130a,130d] J. Sardain,[7] O. Sasaki,[84] K. Sato,[157] C. Sauer,[63b] F. Sauerburger,[54] E. Sauvan,[4] P. Savard,[155,e] R. Sawada,[153] C. Sawyer,[134] L. Sawyer,[97] I. Sayago Galvan,[163] C. Sbarra,[23b] A. Sbrizzi,[23b,23a] T. Scanlon,[96] J. Schaarschmidt,[138] P. Schacht,[110] U. Schäfer,[100] A. C. Schaffer,[66,44] D. Schaile,[109] R. D. Schamberger,[145] C. Scharf,[18] M. M. Schefer,[19] V. A. Schegelsky,[37] D. Scheirich,[133] F. Schenck,[18] M. Schernau,[160] C. Scheulen,[55] C. Schiavi,[57b,57a] E. J. Schioppa,[70a,70b] M. Schioppa,[43b,43a] B. Schlag,[143,t] K. E. Schleicher,[54] S. Schlenker,[36] J. Schmeing,[171] M. A. Schmidt,[171] K. Schmieden,[100] C. Schmitt,[100] N. Schmitt,[100] S. Schmitt,[48] L. Schoeffel,[135] A. Schoening,[63b] P. G. Scholer,[54] E. Schopf,[126] M. Schott,[100] J. Schovancova,[36] S. Schramm,[56] F. Schroeder,[171] T. Schroer,[56] H-C. Schultz-Coulon,[63a] M. Schumacher,[54] B. A. Schumm,[136] Ph. Schune,[135] A. J. Schuy,[138] H. R. Schwartz,[136] A. Schwartzman,[143] T. A. Schwarz,[106] Ph. Schwemling,[135] R. Schwienhorst,[107] A. Sciandra,[136] G. Sciolla,[26] F. Scuri,[74a] C. D. Sebastiani,[92] K. Sedlaczek,[115] P. Seema,[18] S. C. Seidel,[112] A. Seiden,[136] B. D. Seidlitz,[41] C. Seitz,[48] J. M. Seixas,[83b] G. Sekhniaidze,[72a] L. Selem,[60] N. Semprini-Cesari,[23b,23a] D. Sengupta,[56] V. Senthilkumar,[163] L. Serin,[66] L. Serkin,[69a,69b] M. Sessa,[76a,76b] H. Severini,[120] F. Sforza,[57b,57a] A. Sfyrla,[56] E. Shabalina,[55] R. Shaheen,[144] J. D. Shahinian,[128] D. Shaked Renous,[169] L. Y. Shan,[14a] M. Shapiro,[17a] A. Sharma,[36] A. S. Sharma,[164] P. Sharma,[80] S. Sharma,[48] P. B. Shatalov,[37] K. Shaw,[146] S. M. Shaw,[101] A. Shcherbakova,[37] Q. Shen,[62c,5] D. J. Sheppard,[142] P. Sherwood,[96] L. Shi,[96] X. Shi,[14a] C. O. Shimmin,[172] J. D. Shinner,[95] I. P. J. Shipsey,[126] S. Shirabe,[56,gg] M. Shiyakova,[38,ii] J. Shlomi,[169] M. J. Shochet,[39] J. Shojaii,[105] D. R. Shope,[125] B. Shrestha,[120] S. Shrestha,[119,jj] E. M. Shrif,[33g] M. J. Shroff,[165] P. Sicho,[131] A. M. Sickles,[162] E. Sideras Haddad,[33g] A. Sidoti,[23b] F. Siegert,[50] Dj. Sijacki,[15] F. Sili,[90] J. M. Silva,[20] M. V. Silva Oliveira,[29] S. B. Silverstein,[47a] S. Simion,[66] R. Simoniello,[36] E. L. Simpson,[59] H. Simpson,[146] L. R. Simpson,[106] N. D. Simpson,[98] S. Simsek,[82] S. Sindhu,[55] P. Sinervo,[155] S. Singh,[155] S. Sinha,[48] S. Sinha,[101] M. Sioli,[23b,23a] I. Siral,[36] E. Sitnikova,[48] S. Yu. Sivoklokov,[37,a] J. Sjölin,[47a,47b] A. Skaf,[55] E. Skorda,[20] P. Skubic,[120] M. Slawinska,[87] V. Smakhtin,[169] B. H. Smart,[134] S. Yu. Smirnov,[37] Y. Smirnov,[37] L. N. Smirnova,[37,l] O. Smirnova,[98] A. C. Smith,[41] E. A. Smith,[39] H. A. Smith,[126] J. L. Smith,[92] R. Smith,[143] M. Smizanska,[91] K. Smolek,[132] A. A. Snesarev,[37] S. R. Snider,[155] H. L. Snoek,[114] S. Snyder,[29] R. Sobie,[165,p] A. Soffer,[151] C. A. Solans Sanchez,[36] E. Yu. Soldatov,[37] U. Soldevila,[163] A. A. Solodkov,[37] S. Solomon,[26] A. Soloshenko,[38] K. Solovieva,[54] O. V. Solovyanov,[40] V. Solovyev,[37] P. Sommer,[36] A. Sonay,[13] W. Y. Song,[156b] J. M. Sonneveld,[114] A. Sopczak,[132] A. L. Sopio,[96] F. Sopkova,[28b] J. D. Sorenson,[112] I. R. Sotarriva Alvarez,[154] V. Sothilingam,[63a] O. J. Soto Sandoval,[137c,137b] S. Sottocornola,[68] R. Soualah,[116b] Z. Soumaimi,[35e] D. South,[48] N. Soybelman,[169] S. Spagnolo,[70a,70b] M. Spalla,[110] D. Sperlich,[54] G. Spigo,[36] S. Spinali,[91] D. P. Spiteri,[59] M. Spousta,[133] E. J. Staats,[34] A. Stabile,[71a,71b] R. Stamen,[63a] A. Stampekis,[20] M. Standke,[24] E. Stanecka,[87] M. V. Stange,[50] B. Stanislaus,[17a] M. M. Stanitzki,[48] B. Stapf,[48] E. A. Starchenko,[37] G. H. Stark,[136] J. Stark,[102,ee] D. M. Starko,[156b] P. Staroba,[131] P. Starovoitov,[63a] S. Stärz,[104] R. Staszewski,[87] G. Stavropoulos,[46] J. Steentoft,[161] P. Steinberg,[29] B. Stelzer,[142,156a] H. J. Stelzer,[129] O. Stelzer-Chilton,[156a] H. Stenzel,[58] T. J. Stevenson,[146] G. A. Stewart,[36] J. R. Stewart,[121] M. C. Stockton,[36] G. Stoicea,[27b] M. Stolarski,[130a] S. Stonjek,[110] A. Straessner,[50] J. Strandberg,[144] S. Strandberg,[47a,47b] M. Stratmann,[171] M. Strauss,[120] T. Strebler,[102] P. Strizenec,[28b] R. Ströhmer,[166] D. M. Strom,[123] R. Stroynowski,[44] A. Strubig,[47a,47b] S. A. Stucci,[29] B. Stugu,[16] J. Stupak,[120] N. A. Styles,[48] D. Su,[143] S. Su,[62a] W. Su,[62d] X. Su,[62a,66] K. Sugizaki,[153] V. V. Sulin,[37] M. J. Sullivan,[92] D. M. S. Sultan,[78a,78b] L. Sultanaliyeva,[37] S. Sultansoy,[3b] T. Sumida,[88] S. Sun,[106] S. Sun,[170] O. Sunneborn Gudnadottir,[161] N. Sur,[102] M. R. Sutton,[146] H. Suzuki,[157] M. Svatos,[131] M. Swiatlowski,[156a] T. Swirski,[166] I. Sykora,[28a] M. Sykora,[133] T. Sykora,[133] D. Ta,[100] K. Tackmann,[48,hh] A. Taffard,[160] R. Tafirout,[156a] J. S. Tafoya Vargas,[66] E. P. Takeva,[52] Y. Takubo,[84] M. Talby,[102] A. A. Talyshev,[37] K. C. Tam,[64b]

N. M. Tamir,[151] A. Tanaka,[153] J. Tanaka,[153] R. Tanaka,[66] M. Tanasini,[57b,57a] Z. Tao,[164] S. Tapia Araya,[137f] S. Tapprogge,[100] A. Tarek Abouelfadl Mohamed,[107] S. Tarem,[150] K. Tariq,[14a] G. Tarna,[102,27b] G. F. Tartarelli,[71a] P. Tas,[133] M. Tasevsky,[131] E. Tassi,[43b,43a] A. C. Tate,[162] G. Tateno,[153] Y. Tayalati,[35e,kk] G. N. Taylor,[105] W. Taylor,[156b] A. S. Tee,[170] R. Teixeira De Lima,[143] P. Teixeira-Dias,[95] J. J. Teoh,[155] K. Terashi,[153] J. Terron,[99] S. Terzo,[13] M. Testa,[53] R. J. Teuscher,[155,p] A. Thaler,[79] O. Theiner,[56] N. Themistokleous,[52] T. Theveneaux-Pelzer,[102] O. Thielmann,[171] D. W. Thomas,[95] J. P. Thomas,[20] E. A. Thompson,[17a] P. D. Thompson,[20] E. Thomson,[128] Y. Tian,[55] V. Tikhomirov,[37,l] Yu. A. Tikhonov,[37] S. Timoshenko,[37] D. Timoshyn,[133] E. X. L. Ting,[1] P. Tipton,[172] S. H. Tlou,[33g] A. Tnourji,[40] K. Todome,[154] S. Todorova-Nova,[133] S. Todt,[50] M. Togawa,[84] J. Tojo,[89] S. Tokár,[28a] K. Tokushuku,[84] O. Toldaiev,[68] R. Tombs,[32] M. Tomoto,[84,111] L. Tompkins,[143,t] K. W. Topolnicki,[86b] E. Torrence,[123] H. Torres,[102,ee] E. Torró Pastor,[163] M. Toscani,[30] C. Tosciri,[39] M. Tost,[11] D. R. Tovey,[139] A. Traeet,[16] I. S. Trandafir,[27b] T. Trefzger,[166] A. Tricoli,[29] I. M. Trigger,[156a] S. Trincaz-Duvoid,[127] D. A. Trischuk,[26] B. Trocmé,[60] C. Troncon,[71a] L. Truong,[33c] M. Trzebinski,[87] A. Trzupek,[87] F. Tsai,[145] M. Tsai,[106] A. Tsiamis,[152,aa] P. V. Tsiareshka,[37] S. Tsigaridas,[156a] A. Tsirigotis,[152,bb] V. Tsiskaridze,[155] E. G. Tskhadadze,[149a] M. Tsopoulou,[152,aa] Y. Tsujikawa,[88] I. I. Tsukerman,[37] V. Tsulaia,[17a] S. Tsuno,[84] K. Tsuri,[118] D. Tsybychev,[145] Y. Tu,[64b] A. Tudorache,[27b] V. Tudorache,[27b] A. N. Tuna,[61] S. Turchikhin,[57b,57a] I. Turk Cakir,[3a] R. Turra,[71a] T. Turtuvshin,[38,ll] P. M. Tuts,[41] S. Tzamarias,[152,aa] P. Tzanis,[10] E. Tzovara,[100] F. Ukegawa,[157] P. A. Ulloa Poblete,[137c,137b] E. N. Umaka,[29] G. Unal,[36] M. Unal,[11] A. Undrus,[29] G. Unel,[160] J. Urban,[28b] P. Urquijo,[105] P. Urrejola,[137a] G. Usai,[8] R. Ushioda,[154] M. Usman,[108] Z. Uysal,[21b] V. Vacek,[132] B. Vachon,[104] K. O. H. Vadla,[125] T. Vafeiadis,[36] A. Vaitkus,[96] C. Valderanis,[109] E. Valdes Santurio,[47a,47b] M. Valente,[156a] S. Valentinetti,[23b,23a] A. Valero,[163] E. Valiente Moreno,[163] A. Vallier,[102,ee] J. A. Valls Ferrer,[163] D. R. Van Arneman,[114] T. R. Van Daalen,[138] A. Van Der Graaf,[49] P. Van Gemmeren,[6] M. Van Rijnbach,[125,36] S. Van Stroud,[96] I. Van Vulpen,[114] M. Vanadia,[76a,76b] W. Vandelli,[36] M. Vandenbroucke,[135] E. R. Vandewall,[121] D. Vannicola,[151] L. Vannoli,[57b,57a] R. Vari,[75a] E. W. Varnes,[7] C. Varni,[17b] T. Varol,[148] D. Varouchas,[66] L. Varriale,[163] K. E. Varvell,[147] M. E. Vasile,[27b] L. Vaslin,[84] G. A. Vasquez,[165] A. Vasyukov,[38] F. Vazeille,[40] T. Vazquez Schroeder,[36] J. Veatch,[31] V. Vecchio,[101] M. J. Veen,[103] I. Veliscek,[126] L. M. Veloce,[155] F. Veloso,[130a,130c] S. Veneziano,[75a] A. Ventura,[70a,70b] S. Ventura Gonzalez,[135] A. Verbytskyi,[110] M. Verducci,[74a,74b] C. Vergis,[24] M. Verissimo De Araujo,[83b] W. Verkerke,[114] J. C. Vermeulen,[114] C. Vernieri,[143] M. Vessella,[103] M. C. Vetterli,[142,e] A. Vgenopoulos,[152,aa] N. Viaux Maira,[137f] T. Vickey,[139] O. E. Vickey Boeriu,[139] G. H. A. Viehhauser,[126] L. Vigani,[63b] M. Villa,[23b,23a] M. Villaplana Perez,[163] E. M. Villhauer,[52] E. Vilucchi,[53] M. G. Vincter,[34] G. S. Virdee,[20] A. Vishwakarma,[52] A. Visibile,[114] C. Vittori,[36] I. Vivarelli,[146] E. Voevodina,[110] F. Vogel,[109] J. C. Voigt,[50] P. Vokac,[132] Yu. Volkotrub,[86a] J. Von Ahnen,[48] E. Von Toerne,[24] B. Vormwald,[36] V. Vorobel,[133] K. Vorobev,[37] M. Vos,[163] K. Voss,[141] J. H. Vossebeld,[92] M. Vozak,[114] L. Vozdecky,[94] N. Vranjes,[15] M. Vranjes Milosavljevic,[15] M. Vreeswijk,[114] N. K. Vu,[62d,62c] R. Vuillermet,[36] O. Vujinovic,[100] I. Vukotic,[39] S. Wada,[157] C. Wagner,[103] J. M. Wagner,[17a] W. Wagner,[171] S. Wahdan,[171] H. Wahlberg,[90] M. Wakida,[111] J. Walder,[134] R. Walker,[109] W. Walkowiak,[141] A. Wall,[128] T. Wamorkar,[6] A. Z. Wang,[136] C. Wang,[100] C. Wang,[62c] H. Wang,[17a] J. Wang,[64a] R.-J. Wang,[100] R. Wang,[61] R. Wang,[6] S. M. Wang,[148] S. Wang,[62b] T. Wang,[62a] W. T. Wang,[80] W. Wang,[14a] X. Wang,[14c] X. Wang,[162] X. Wang,[62c] Y. Wang,[62d] Y. Wang,[14c] Z. Wang,[106] Z. Wang,[62d,51,62c] Z. Wang,[106] A. Warburton,[104] R. J. Ward,[20] N. Warrack,[59] A. T. Watson,[20] H. Watson,[59] M. F. Watson,[20] E. Watton,[59,134] G. Watts,[138] B. M. Waugh,[96] C. Weber,[29] H. A. Weber,[18] M. S. Weber,[19] S. M. Weber,[63a] C. Wei,[62a] Y. Wei,[126] A. R. Weidberg,[126] E. J. Weik,[117] J. Weingarten,[49] M. Weirich,[100] C. Weiser,[54] C. J. Wells,[48] T. Wenaus,[29] B. Wendland,[49] T. Wengler,[36] N. S. Wenke,[110] N. Wermes,[24] M. Wessels,[63a] A. M. Wharton,[91] A. S. White,[61] A. White,[8] M. J. White,[1] D. Whiteson,[160] L. Wickremasinghe,[124] W. Wiedenmann,[170] M. Wielers,[134] C. Wiglesworth,[42] D. J. Wilbern,[120] H. G. Wilkens,[36] D. M. Williams,[41] H. H. Williams,[128] S. Williams,[32] S. Willocq,[103] B. J. Wilson,[101] P. J. Windischhofer,[39] F. I. Winkel,[30] F. Winklmeier,[123] B. T. Winter,[54] J. K. Winter,[101] M. Wittgen,[143] M. Wobisch,[97] Z. Wolffs,[114] J. Wollrath,[160] M. W. Wolter,[87] H. Wolters,[130a,130c] A. F. Wongel,[48] E. L. Woodward,[41] S. D. Worm,[48] B. K. Wosiek,[87] K. W. Woźniak,[87] S. Wozniewski,[55] K. Wraight,[59] C. Wu,[20] J. Wu,[14a,14e] M. Wu,[64a] M. Wu,[113] S. L. Wu,[170] X. Wu,[56] Y. Wu,[62a] Z. Wu,[135] J. Wuerzinger,[110,w] T. R. Wyatt,[101] B. M. Wynne,[52] S. Xella,[42]

L. Xia,[14c] M. Xia,[14b] J. Xiang,[64c] M. Xie,[62a] X. Xie,[62a] S. Xin,[14a,14e] A. Xiong,[123] J. Xiong,[17a] D. Xu,[14a] H. Xu,[62a] L. Xu,[62a] R. Xu,[128] T. Xu,[106] Y. Xu,[14b] Z. Xu,[52] Z. Xu,[14c] B. Yabsley,[147] S. Yacoob,[33a] Y. Yamaguchi,[154] E. Yamashita,[153] H. Yamauchi,[157] T. Yamazaki,[17a] Y. Yamazaki,[85] J. Yan,[62c] S. Yan,[126] Z. Yan,[25] H. J. Yang,[62c,62d] H. T. Yang,[62a] S. Yang,[62a] T. Yang,[64c] X. Yang,[36] X. Yang,[14a] Y. Yang,[44] Y. Yang,[62a] Z. Yang,[62a] W-M. Yao,[17a] Y. C. Yap,[48] H. Ye,[14c] H. Ye,[55] J. Ye,[14a] S. Ye,[29] X. Ye,[62a] Y. Yeh,[96] I. Yeletskikh,[38] B. K. Yeo,[17b] M. R. Yexley,[96] P. Yin,[41] K. Yorita,[168] S. Younas,[27b] C. J. S. Young,[36] C. Young,[143] C. Yu,[14a,14e,mm] Y. Yu,[62a] M. Yuan,[106] R. Yuan,[62b] L. Yue,[96] M. Zaazoua,[62a] B. Zabinski,[87] E. Zaid,[52] Z. K. Zak,[87] T. Zakareishvili,[149b] N. Zakharchuk,[34] S. Zambito,[56] J. A. Zamora Saa,[137d,137b] J. Zang,[153] D. Zanzi,[54] O. Zaplatilek,[132] C. Zeitnitz,[171] H. Zeng,[14a] J. C. Zeng,[162] D. T. Zenger Jr.,[26] O. Zenin,[37] T. Ženiš,[28a] S. Zenz,[94] S. Zerradi,[35a] D. Zerwas,[66] M. Zhai,[14a,14e] D. F. Zhang,[139] J. Zhang,[62b] J. Zhang,[6] K. Zhang,[14a,14e] L. Zhang,[14c] P. Zhang,[14a,14e] R. Zhang,[170] S. Zhang,[106] S. Zhang,[44] T. Zhang,[153] X. Zhang,[62c] X. Zhang,[62b] Y. Zhang,[62c,5] Y. Zhang,[96] Y. Zhang,[14c] Z. Zhang,[17a] Z. Zhang,[66] H. Zhao,[138] T. Zhao,[62b] Y. Zhao,[136] Z. Zhao,[62a] A. Zhemchugov,[38] J. Zheng,[14c] K. Zheng,[162] X. Zheng,[62a] Z. Zheng,[143] D. Zhong,[162] B. Zhou,[106] H. Zhou,[7] N. Zhou,[62c] Y. Zhou,[7] C. G. Zhu,[62b] J. Zhu,[106] Y. Zhu,[62c] Y. Zhu,[62a] X. Zhuang,[14a] K. Zhukov,[37] V. Zhulanov,[37] N. I. Zimine,[38] J. Zinsser,[63b] M. Ziolkowski,[141] L. Živković,[15] A. Zoccoli,[23b,23a] K. Zoch,[61] T. G. Zorbas,[139] O. Zormpa,[46] W. Zou,[41] and L. Zwalinski[36]

(ATLAS Collaboration)

[1]*Department of Physics, University of Adelaide, Adelaide, Australia*
[2]*Department of Physics, University of Alberta, Edmonton, Alberta, Canada*
[3a]*Department of Physics, Ankara University, Ankara, Türkiye*
[3b]*Division of Physics, TOBB University of Economics and Technology, Ankara, Türkiye*
[4]*LAPP, Université Savoie Mont Blanc, CNRS/IN2P3, Annecy, France*
[5]*APC, Université Paris Cité, CNRS/IN2P3, Paris, France*
[6]*High Energy Physics Division, Argonne National Laboratory, Argonne, Illinois, USA*
[7]*Department of Physics, University of Arizona, Tucson, Arizona, United States of America*
[8]*Department of Physics, University of Texas at Arlington, Arlington, Texas, USA*
[9]*Physics Department, National and Kapodistrian University of Athens, Athens, Greece*
[10]*Physics Department, National Technical University of Athens, Zografou, Greece*
[11]*Department of Physics, University of Texas at Austin, Austin, Texas, USA*
[12]*Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan*
[13]*Institut de Física d'Altes Energies (IFAE), Barcelona Institute of Science and Technology, Barcelona, Spain*
[14a]*Institute of High Energy Physics, Chinese Academy of Sciences, Beijing, China*
[14b]*Physics Department, Tsinghua University, Beijing, China*
[14c]*Department of Physics, Nanjing University, Nanjing, China*
[14d]*School of Science, Shenzhen Campus of Sun Yat-sen University, China*
[14e]*University of Chinese Academy of Science (UCAS), Beijing, China*
[15]*Institute of Physics, University of Belgrade, Belgrade, Serbia*
[16]*Department for Physics and Technology, University of Bergen, Bergen, Norway*
[17a]*Physics Division, Lawrence Berkeley National Laboratory, Berkeley, California, USA*
[17b]*University of California, Berkeley, California, USA*
[18]*Institut für Physik, Humboldt Universität zu Berlin, Berlin, Germany*
[19]*Albert Einstein Center for Fundamental Physics and Laboratory for High Energy Physics, University of Bern, Bern, Switzerland*
[20]*School of Physics and Astronomy, University of Birmingham, Birmingham, United Kingdom*
[21a]*Department of Physics, Bogazici University, Istanbul, Türkiye*
[21b]*Department of Physics Engineering, Gaziantep University, Gaziantep, Türkiye*
[21c]*Department of Physics, Istanbul University, Istanbul, Türkiye*
[22a]*Facultad de Ciencias y Centro de Investigaciónes, Universidad Antonio Nariño, Bogotá, Colombia*
[22b]*Departamento de Física, Universidad Nacional de Colombia, Bogotá, Colombia*
[23a]*Dipartimento di Fisica e Astronomia A. Righi, Università di Bologna, Bologna, Italy*
[23b]*INFN Sezione di Bologna, Italy*
[24]*Physikalisches Institut, Universität Bonn, Bonn, Germany*
[25]*Department of Physics, Boston University, Boston, Massachusetts, USA*
[26]*Department of Physics, Brandeis University, Waltham, Massachusetts, USA*

[27a]Transilvania University of Brasov, Brasov, Romania
[27b]Horia Hulubei National Institute of Physics and Nuclear Engineering, Bucharest, Romania
[27c]Department of Physics, Alexandru Ioan Cuza University of Iasi, Iasi, Romania
[27d]National Institute for Research and Development of Isotopic and Molecular Technologies, Physics Department, Cluj-Napoca, Romania
[27e]National University of Science and Technology Politechnica, Bucharest, Romania
[27f]West University in Timisoara, Timisoara, Romania
[27g]Faculty of Physics, University of Bucharest, Bucharest, Romania
[28a]Faculty of Mathematics, Physics and Informatics, Comenius University, Bratislava, Slovak Republic
[28b]Department of Subnuclear Physics, Institute of Experimental Physics of the Slovak Academy of Sciences, Kosice, Slovak Republic
[29]Physics Department, Brookhaven National Laboratory, Upton, New York, USA
[30]Universidad de Buenos Aires, Facultad de Ciencias Exactas y Naturales, Departamento de Física, y CONICET, Instituto de Física de Buenos Aires (IFIBA), Buenos Aires, Argentina
[31]California State University, California, USA
[32]Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom
[33a]Department of Physics, University of Cape Town, Cape Town, South Africa
[33b]iThemba Labs, Western Cape, South Africa
[33c]Department of Mechanical Engineering Science, University of Johannesburg, Johannesburg, South Africa
[33d]National Institute of Physics, University of the Philippines Diliman (Philippines), Philippines
[33e]University of South Africa, Department of Physics, Pretoria, South Africa
[33f]University of Zululand, KwaDlangezwa, South Africa
[33g]School of Physics, University of the Witwatersrand, Johannesburg, South Africa
[34]Department of Physics, Carleton University, Ottawa, Ontario, Canada
[35a]Faculté des Sciences Ain Chock, Réseau Universitaire de Physique des Hautes Energies—Université Hassan II, Casablanca, Morocco
[35b]Faculté des Sciences, Université Ibn-Tofail, Kénitra, Morocco
[35c]Faculté des Sciences Semlalia, Université Cadi Ayyad, LPHEA-Marrakech, Morocco
[35d]LPMR, Faculté des Sciences, Université Mohamed Premier, Oujda, Morocco
[35e]Faculté des sciences, Université Mohammed V, Rabat, Morocco
[35f]Institute of Applied Physics, Mohammed VI Polytechnic University, Ben Guerir, Morocco
[36]CERN, Geneva, Switzerland
[37]Affiliated with an institute covered by a cooperation agreement with CERN
[38]Affiliated with an international laboratory covered by a cooperation agreement with CERN
[39]Enrico Fermi Institute, University of Chicago, Chicago, Illinois, USA
[40]LPC, Université Clermont Auvergne, CNRS/IN2P3, Clermont-Ferrand, France
[41]Nevis Laboratory, Columbia University, Irvington, New York, USA
[42]Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark
[43a]Dipartimento di Fisica, Università della Calabria, Rende, Italy
[43b]INFN Gruppo Collegato di Cosenza, Laboratori Nazionali di Frascati, Italy
[44]Physics Department, Southern Methodist University, Dallas, Texas, USA
[45]Physics Department, University of Texas at Dallas, Richardson, Texas, USA
[46]National Centre for Scientific Research "Demokritos", Agia Paraskevi, Greece
[47a]Department of Physics, Stockholm University, Sweden
[47b]Oskar Klein Centre, Stockholm, Sweden
[48]Deutsches Elektronen-Synchrotron DESY, Hamburg and Zeuthen, Germany
[49]Fakultät Physik, Technische Universität Dortmund, Dortmund, Germany
[50]Institut für Kern- und Teilchenphysik, Technische Universität Dresden, Dresden, Germany
[51]Department of Physics, Duke University, Durham, North Carolina, USA
[52]SUPA—School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom
[53]INFN e Laboratori Nazionali di Frascati, Frascati, Italy
[54]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Freiburg, Germany
[55]II. Physikalisches Institut, Georg-August-Universität Göttingen, Göttingen, Germany
[56]Département de Physique Nucléaire et Corpusculaire, Université de Genève, Genève, Switzerland
[57a]Dipartimento di Fisica, Università di Genova, Genova, Italy
[57b]INFN Sezione di Genova, Italy
[58]II. Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen, Germany
[59]SUPA—School of Physics and Astronomy, University of Glasgow, Glasgow, United Kingdom
[60]LPSC, Université Grenoble Alpes, CNRS/IN2P3, Grenoble INP, Grenoble, France
[61]Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge, Massachusetts, USA

[62a]Department of Modern Physics and State Key Laboratory of Particle Detection and Electronics, University of Science and Technology of China, Hefei, China
[62b]Institute of Frontier and Interdisciplinary Science and Key Laboratory of Particle Physics and Particle Irradiation (MOE), Shandong University, Qingdao, China
[62c]School of Physics and Astronomy, Shanghai Jiao Tong University, Key Laboratory for Particle Astrophysics and Cosmology (MOE), SKLPPC, Shanghai, China
[62d]Tsung-Dao Lee Institute, Shanghai, China
[62e]School of Physics and Microelectronics, Zhengzhou University, China
[63a]Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany
[63b]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany
[64a]Department of Physics, Chinese University of Hong Kong, Shatin, N.T., Hong Kong, China
[64b]Department of Physics, University of Hong Kong, Hong Kong, China
[64c]Department of Physics and Institute for Advanced Study, Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, China
[65]Department of Physics, National Tsing Hua University, Hsinchu, Taiwan
[66]IJCLab, Université Paris-Saclay, CNRS/IN2P3, 91405, Orsay, France
[67]Centro Nacional de Microelectrónica (IMB-CNM-CSIC), Barcelona, Spain
[68]Department of Physics, Indiana University, Bloomington, Indiana, USA
[69a]INFN Gruppo Collegato di Udine, Sezione di Trieste, Udine, Italy
[69b]ICTP, Trieste, Italy
[69c]Dipartimento Politecnico di Ingegneria e Architettura, Università di Udine, Udine, Italy
[70a]INFN Sezione di Lecce, Italy
[70b]Dipartimento di Matematica e Fisica, Università del Salento, Lecce, Italy
[71a]INFN Sezione di Milano, Italy
[71b]Dipartimento di Fisica, Università di Milano, Milano, Italy
[72a]INFN Sezione di Napoli, Italy
[72b]Dipartimento di Fisica, Università di Napoli, Napoli, Italy
[73a]INFN Sezione di Pavia, Italy
[73b]Dipartimento di Fisica, Università di Pavia, Pavia, Italy
[74a]INFN Sezione di Pisa, Italy
[74b]Dipartimento di Fisica E. Fermi, Università di Pisa, Pisa, Italy
[75a]INFN Sezione di Roma, Italy
[75b]Dipartimento di Fisica, Sapienza Università di Roma, Roma, Italy
[76a]INFN Sezione di Roma Tor Vergata, Italy
[76b]Dipartimento di Fisica, Università di Roma Tor Vergata, Roma, Italy
[77a]INFN Sezione di Roma Tre, Italy
[77b]Dipartimento di Matematica e Fisica, Università Roma Tre, Roma, Italy
[78a]INFN-TIFPA, Italy
[78b]Università degli Studi di Trento, Trento, Italy
[79]Universität Innsbruck, Department of Astro and Particle Physics, Innsbruck, Austria
[80]University of Iowa, Iowa City, Iowa, USA
[81]Department of Physics and Astronomy, Iowa State University, Ames, Iowa, USA
[82]Istinye University, Sariyer, Istanbul, Türkiye
[83a]Departamento de Engenharia Elétrica, Universidade Federal de Juiz de Fora (UFJF), Juiz de Fora, Brazil
[83b]Universidade Federal do Rio De Janeiro COPPE/EE/IF, Rio de Janeiro, Brazil
[83c]Instituto de Física, Universidade de São Paulo, São Paulo, Brazil
[83d]Rio de Janeiro State University, Rio de Janeiro, Brazil
[84]KEK, High Energy Accelerator Research Organization, Tsukuba, Japan
[85]Graduate School of Science, Kobe University, Kobe, Japan
[86a]AGH University of Krakow, Faculty of Physics and Applied Computer Science, Krakow, Poland
[86b]Marian Smoluchowski Institute of Physics, Jagiellonian University, Krakow, Poland
[87]Institute of Nuclear Physics Polish Academy of Sciences, Krakow, Poland
[88]Faculty of Science, Kyoto University, Kyoto, Japan
[89]Research Center for Advanced Particle Physics and Department of Physics, Kyushu University, Fukuoka, Japan
[90]Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata, Argentina
[91]Physics Department, Lancaster University, Lancaster, United Kingdom
[92]Oliver Lodge Laboratory, University of Liverpool, Liverpool, United Kingdom
[93]Department of Experimental Particle Physics, Jožef Stefan Institute and Department of Physics, University of Ljubljana, Ljubljana, Slovenia
[94]School of Physics and Astronomy, Queen Mary University of London, London, United Kingdom

[95]Department of Physics, Royal Holloway University of London, Egham, United Kingdom
[96]Department of Physics and Astronomy, University College London, London, United Kingdom
[97]Louisiana Tech University, Ruston, Los Angeles, USA
[98]Fysiska institutionen, Lunds universitet, Lund, Sweden
[99]Departamento de Física Teorica C-15 and CIAFF, Universidad Autónoma de Madrid, Madrid, Spain
[100]Institut für Physik, Universität Mainz, Mainz, Germany
[101]School of Physics and Astronomy, University of Manchester, Manchester, United Kingdom
[102]CPPM, Aix-Marseille Université, CNRS/IN2P3, Marseille, France
[103]Department of Physics, University of Massachusetts, Amherst, Massachusetts, USA
[104]Department of Physics, McGill University, Montreal, Quebec, Canada
[105]School of Physics, University of Melbourne, Victoria, Australia
[106]Department of Physics, University of Michigan, Ann Arbor, Michigan, USA
[107]Department of Physics and Astronomy, Michigan State University, East Lansing, Michigan, USA
[108]Group of Particle Physics, University of Montreal, Montreal, Quebec, Canada
[109]Fakultät für Physik, Ludwig-Maximilians-Universität München, München, Germany
[110]Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), München, Germany
[111]Graduate School of Science and Kobayashi-Maskawa Institute, Nagoya University, Nagoya, Japan
[112]Department of Physics and Astronomy, University of New Mexico, Albuquerque, New Mexico, USA
[113]Institute for Mathematics, Astrophysics and Particle Physics, Radboud University/Nikhef, Nijmegen, Netherlands
[114]Nikhef National Institute for Subatomic Physics and University of Amsterdam, Amsterdam, Netherlands
[115]Department of Physics, Northern Illinois University, DeKalb, Illinois, USA
[116a]New York University Abu Dhabi, Abu Dhabi, United Arab Emirates
[116b]University of Sharjah, Sharjah, United Arab Emirates
[117]Department of Physics, New York University, New York, New York, USA
[118]Ochanomizu University, Otsuka, Bunkyo-ku, Tokyo, Japan
[119]Ohio State University, Columbus, Ohio, USA
[120]Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman, Oklahoma, USA
[121]Department of Physics, Oklahoma State University, Stillwater, Oklahoma, USA
[122]Palacký University, Joint Laboratory of Optics, Olomouc, Czech Republic
[123]Institute for Fundamental Science, University of Oregon, Eugene, Oregon, USA
[124]Graduate School of Science, Osaka University, Osaka, Japan
[125]Department of Physics, University of Oslo, Oslo, Norway
[126]Department of Physics, Oxford University, Oxford, United Kingdom
[127]LPNHE, Sorbonne Université, Université Paris Cité, CNRS/IN2P3, Paris, France
[128]Department of Physics, University of Pennsylvania, Philadelphia, Pennsylvania, USA
[129]Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh, Pennsylvania, USA
[130a]Laboratório de Instrumentação e Física Experimental de Partículas—LIP, Lisboa, Portugal
[130b]Departamento de Física, Faculdade de Ciências, Universidade de Lisboa, Lisboa, Portugal
[130c]Departamento de Física, Universidade de Coimbra, Coimbra, Portugal
[130d]Centro de Física Nuclear da Universidade de Lisboa, Lisboa, Portugal
[130e]Departamento de Física, Universidade do Minho, Braga, Portugal
[130f]Departamento de Física Teórica y del Cosmos, Universidad de Granada, Granada (Spain), Spain
[130g]Departamento de Física, Instituto Superior Técnico, Universidade de Lisboa, Lisboa, Portugal
[131]Institute of Physics of the Czech Academy of Sciences, Prague, Czech Republic
[132]Czech Technical University in Prague, Prague, Czech Republic
[133]Charles University, Faculty of Mathematics and Physics, Prague, Czech Republic
[134]Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom
[135]IRFU, CEA, Université Paris-Saclay, Gif-sur-Yvette, France
[136]Santa Cruz Institute for Particle Physics, University of California Santa Cruz, Santa Cruz, California, USA
[137a]Departamento de Física, Pontificia Universidad Católica de Chile, Santiago, Chile
[137b]Millennium Institute for Subatomic physics at high energy frontier (SAPHIR), Santiago, Chile
[137c]Instituto de Investigación Multidisciplinario en Ciencia y Tecnología, y Departamento de Física, Universidad de La Serena, Chile
[137d]Universidad Andres Bello, Department of Physics, Santiago, Chile
[137e]Instituto de Alta Investigación, Universidad de Tarapacá, Arica, Chile
[137f]Departamento de Física, Universidad Técnica Federico Santa María, Valparaíso, Chile
[138]Department of Physics, University of Washington, Seattle, Washington, USA
[139]Department of Physics and Astronomy, University of Sheffield, Sheffield, United Kingdom
[140]Department of Physics, Shinshu University, Nagano, Japan
[141]Department Physik, Universität Siegen, Siegen, Germany
[142]Department of Physics, Simon Fraser University, Burnaby, British Columbia, Canada

[143]SLAC National Accelerator Laboratory, Stanford, California, USA
[144]Department of Physics, Royal Institute of Technology, Stockholm, Sweden
[145]Departments of Physics and Astronomy, Stony Brook University, Stony Brook, New York, USA
[146]Department of Physics and Astronomy, University of Sussex, Brighton, United Kingdom
[147]School of Physics, University of Sydney, Sydney, Australia
[148]Institute of Physics, Academia Sinica, Taipei, Taiwan
[149a]E. Andronikashvili Institute of Physics, Iv. Javakhishvili Tbilisi State University, Tbilisi, Georgia
[149b]High Energy Physics Institute, Tbilisi State University, Tbilisi, Georgia
[149c]University of Georgia, Tbilisi, Georgia
[150]Department of Physics, Technion, Israel Institute of Technology, Haifa, Israel
[151]Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel
[152]Department of Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece
[153]International Center for Elementary Particle Physics and Department of Physics, University of Tokyo, Tokyo, Japan
[154]Department of Physics, Tokyo Institute of Technology, Tokyo, Japan
[155]Department of Physics, University of Toronto, Toronto, Ontario, Canada
[156a]TRIUMF, Vancouver, British Columbia, Canada
[156b]Department of Physics and Astronomy, York University, Toronto, Ontario, Canada
[157]Division of Physics and Tomonaga Center for the History of the Universe, Faculty of Pure and Applied Sciences, University of Tsukuba, Tsukuba, Japan
[158]Department of Physics and Astronomy, Tufts University, Medford, Massachusetts, USA
[159]United Arab Emirates University, Al Ain, United Arab Emirates
[160]Department of Physics and Astronomy, University of California Irvine, Irvine, California, USA
[161]Department of Physics and Astronomy, University of Uppsala, Uppsala, Sweden
[162]Department of Physics, University of Illinois, Urbana, Illinois, USA
[163]Instituto de Física Corpuscular (IFIC), Centro Mixto Universidad de Valencia—CSIC, Valencia, Spain
[164]Department of Physics, University of British Columbia, Vancouver, British Columbia, Canada
[165]Department of Physics and Astronomy, University of Victoria, Victoria, British Columbia, Canada
[166]Fakultät für Physik und Astronomie, Julius-Maximilians-Universität Würzburg, Würzburg, Germany
[167]Department of Physics, University of Warwick, Coventry, United Kingdom
[168]Waseda University, Tokyo, Japan
[169]Department of Particle Physics and Astrophysics, Weizmann Institute of Science, Rehovot, Israel
[170]Department of Physics, University of Wisconsin, Madison, Wisconsin, USA
[171]Fakultät für Mathematik und Naturwissenschaften, Fachgruppe Physik, Bergische Universität Wuppertal, Wuppertal, Germany
[172]Department of Physics, Yale University, New Haven, Connecticut, USA

[a]Deceased.
[b]Also at Department of Physics, King's College London, London, United Kingdom.
[c]Also at Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan.
[d]Also at Lawrence Livermore National Laboratory, Livermore, USA.
[e]Also at TRIUMF, Vancouver, British Columbia, Canada.
[f]Also at Department of Physics, University of Thessaly, Greece.
[g]Also at An-Najah National University, Nablus, Palestine.
[h]Also at Department of Physics, University of Fribourg, Fribourg, Switzerland.
[i]Also at University of Colorado Boulder, Department of Physics, Colorado, USA.
[j]Also at Department of Physics, Westmont College, Santa Barbara, USA.
[k]Also at Departament de Fisica de la Universitat Autonoma de Barcelona, Barcelona, Spain.
[l]Also at Affiliated with an institute covered by a cooperation agreement with CERN.
[m]Also at The Collaborative Innovation Center of Quantum Matter (CICQM), Beijing, China.
[n]Also at Department of Physics, Ben Gurion University of the Negev, Beer Sheva, Israel.
[o]Also at Università di Napoli Parthenope, Napoli, Italy.
[p]Also at Institute of Particle Physics (IPP), Canada.
[q]Also at Borough of Manhattan Community College, City University of New York, New York, New York, USA.
[r]Also at National Institute of Physics, University of the Philippines Diliman (Philippines), Philippines.
[s]Also at Department of Financial and Management Engineering, University of the Aegean, Chios, Greece.
[t]Also at Department of Physics, Stanford University, Stanford, California, USA.
[u]Also at Centro Studi e Ricerche Enrico Fermi, Italy.
[v]Also at Institucio Catalana de Recerca i Estudis Avancats, ICREA, Barcelona, Spain.
[w]Also at Technical University of Munich, Munich, Germany.
[x]Also at Yeditepe University, Physics Department, Istanbul, Türkiye.
[y]Also at Institute of Theoretical Physics, Ilia State University, Tbilisi, Georgia.

[z]Also at CERN, Geneva, Switzerland.
[aa]Also at Center for Interdisciplinary Research and Innovation (CIRI-AUTH), Thessaloniki, Greece.
[bb]Also at Hellenic Open University, Patras, Greece.
[cc]Also at Center for High Energy Physics, Peking University, China.
[dd]Also at Department of Physics, Stellenbosch University, South Africa.
[ee]Also at L2IT, Université de Toulouse, CNRS/IN2P3, UPS, Toulouse, France.
[ff]Also at Department of Physics, California State University, Sacramento, USA.
[gg]Also at Département de Physique Nucléaire et Corpusculaire, Université de Genève, Genève, Switzerland.
[hh]Also at Institut für Experimentalphysik, Universität Hamburg, Hamburg, Germany.
[ii]Also at Institute for Nuclear Research and Nuclear Energy (INRNE) of the Bulgarian Academy of Sciences, Sofia, Bulgaria.
[jj]Also at Washington College, Chestertown, Maryland, USA.
[kk]Also at Institute of Applied Physics, Mohammed VI Polytechnic University, Ben Guerir, Morocco.
[ll]Also at Institute of Physics and Technology, Mongolian Academy of Sciences, Ulaanbaatar, Mongolia.
[mm]Also at University of Chinese Academy of Sciences (UCAS), Beijing, China.