Search for New Phenomena in Final States with Two Leptons and One or No *b*-Tagged Jets at $\sqrt{s} = 13$ TeV Using the ATLAS Detector

G. Aad *et al.*^{*} (ATLAS Collaboration)

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A search for new phenomena is presented in final states with two leptons and one or no *b*-tagged jets. The event selection requires the two leptons to have opposite charge, the same flavor (electrons or muons), and a large invariant mass. The analysis is based on the full run-2 proton-proton collision dataset recorded at a center-of-mass energy of $\sqrt{s} = 13$ TeV by the ATLAS experiment at the LHC, corresponding to an integrated luminosity of 139 fb⁻¹. No significant deviation from the expected background is observed in the data. Inspired by the *B*-meson decay anomalies, a four-fermion contact interaction between two quarks (b, s) and two leptons (*ee* or $\mu\mu$) is used as a benchmark signal model, which is characterized by the energy scale and coupling, Λ and g_* , respectively. Contact interactions with Λ/g_* lower than 2.0 (2.4) TeV are excluded for electrons (muons) at the 95% confidence level, still far below the value that is favored by the *B*-meson decay anomalies. Model-independent limits are set as a function of the minimum dilepton invariant mass, which allow the results to be reinterpreted in various signal scenarios.

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Lepton flavor universality (LFU) is one of the fundamental predictions of the standard model (SM). LFU was tested extensively at LEP and SLD [1] and found to be compatible with the SM prediction. Recent measurements hint at a possible violation of LFU in rare B-meson decays [2–13] into a K meson and a pair of muons or electrons. Possible extensions to the SM suggest that the decay mechanism implies that physics beyond the SM (BSM) is present between the initial (b quark) and final states (s quark and two charged electrons or muons). The BSM interaction can be modeled using an effective field theory (EFT) with a four-point contact interaction between the fermions involved (*bsl* ℓ , $\ell = e, \mu$), where the scale and coupling of the underlying physics are denoted by Λ and g_* , respectively [14]. It can be searched for in final states with two opposite-charge and same-flavor leptons produced in association with exactly one b quark or without any b quarks. To explain the asymmetries measured in the B-meson decays, the $bs\ell\ell$ interaction would have to be different between electrons and muons. The phenomenological framework for this analysis was suggested in Ref. [16]. The B-meson decay anomalies could correspond to a *bsff* operator with $\Lambda/g_* \approx 30$ TeV [17,18], which is beyond the discovery reach of the present search. However, this unique signature may provide enhanced sensitivity to other signal scenarios as well [15,19]. Figure 1 shows Feynman diagrams for *B*-meson decays, via the SM and via a $bs\ell\ell$ contact interaction, and for the production process via a $bs\ell\ell$ contact interaction in proton-proton (pp) collisions [20].

In this Letter, a search for new phenomena is presented, using pp collisions at the Large Hadron Collider (LHC) with a center-of-mass energy of $\sqrt{s} = 13$ TeV. Data recorded by the ATLAS detector [21] during 2015–2018 are used, corresponding to an integrated luminosity of 139 fb⁻¹. Final states with two oppositely charged electrons or muons are considered separately and further categorized into events with either no *b*-tagged jets or exactly one *b*-tagged jet. The $bs\ell\ell$ EFT [16] is considered as a benchmark model, and model-independent results are also presented.

ATLAS is a multipurpose particle detector with a forward-backward symmetric cylindrical geometry and a near 4π coverage in a solid angle [22]. It consists of an inner tracking detector surrounded by a thin superconducting solenoid providing a 2 T axial magnetic field, electromagnetic and hadronic calorimeters, and a muon spectrometer. The inner tracking detector (ID) covers the pseudorapidity range $|\eta| < 2.5$. It consists of silicon pixel, silicon microstrip, and transition radiation tracking detector before run 2 [23,24]. Lead and liquid-argon (LAr) sampling calorimeters provide electromagnetic (EM) energy measurements with high granularity. A steel and scintillator-tile hadronic calorimeter covers the central pseudorapidity range

^{*}Full author list given at the end of the article.

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FIG. 1. Representative Feynman diagrams for the decay of a B^+ meson to a K^+ meson in association with two leptons (a) in the SM and (b) in the EFT approach and for production of two leptons via a $bs\ell\ell$ contact interaction in pp collisions (c) without and (d) with a b jet in the final state.

 $(|\eta| < 1.7)$. The end cap and forward regions are instrumented with LAr calorimeters for EM and hadronic energy measurements up to $|\eta| = 4.9$. The muon spectrometer (MS) surrounds the calorimeters and is based on three large aircore toroidal superconducting magnets with eight coils each. The field integral of the toroids ranges between 2.0 and 6.0 T m across most of the detector. The muon spectrometer includes a system of precision tracking chambers and fast detectors for triggering.

Monte Carlo (MC) simulations are used to model the expected SM background and the benchmark signals. All background and signal MC samples were generated using the five-flavor scheme. The POWHEG-BOX [v1] MC generator [25–28] was used to simulate at next-to-leading order (NLO) in QCD the inclusive hard-scattering $Z/\gamma^* \rightarrow \ell^+ \ell^$ sample, denoted as Z/γ^* + jets, using the CT10 parton distribution function (PDF) set [29]. It was interfaced to PYTHIA [8.186] to model the parton shower, hadronization. and underlying event, using the AZNLO tune [30] and the CTEQ6L1 PDF set [31]. The Z/γ^* + jets samples were normalized to next-to-next-to-leading order (NNLO) in QCD and corrected for remaining NLO electroweak effects following the procedure described in Ref. [32]. The effect of QED final-state radiation (FSR) was simulated with PHOTOS++ 3.52 [33,34]. The use of POWHEG-BOX was validated by a generator-level comparison with a sample produced by SHERPA [2.2.1] [35] using NLO matrix elements for up to two partons and leading-order (LO) matrix elements for up to four partons calculated with the Comix [36] and Open Loops 1 [37-39] libraries. Samples of diboson (W-boson) events, denoted by VV (W + jets), were simulated with SHERPA [2.2.2 (2.2.1)] [35] using the NNPDF3.0nnlo PDF set, with matrix elements at NLO in QCD with up to one (two) additional partons and up to three (four) additional parton emissions at LO [36-39]. For both VV and W + jets, the matrix elements were matched with the SHERPA parton shower [40] using the MEPS@NLO prescription [41-44] and the parameter tune developed by the SHERPA authors. The W + jets samples were normalized to a NNLO prediction [45]. The production of $t\bar{t}$ and single-top-quark Wt events was modeled using the POWHEG-BOX [v2] generator at NLO with the NNPDF3.0nlo PDF set and the h_{damp} parameter set to $1.5m_{top}$. Events were passed to PYTHIA [8.230] [46] to model the parton shower, hadronization, and underlying event, using the A14 parameter tune [47] and the NNPDF2.310 PDF set. For Wt events, the diagram removal scheme [48] was used to eliminate interference with $t\bar{t}$ production. The production of $t\bar{t}V$ events was modeled using the MadGraph5_aMC@NLO v2.3.3 [49] generator at NLO with the NNPDF3.0nlo PDF set. The events were interfaced to PYTHIA [8.210] using the A14 tune and the NNPDF2.310 PDF set. The EVTGEN 1.2.0 (1.6.0) program [50] was used to decay bottom and charm hadrons for the $t\bar{t}V$ and Z/γ^* + jets $(t\bar{t})$ processes. The bst ℓ EFT signal was generated at LO, using a model provided by the authors of Ref. [16] (see also [51]), with up to two partons in the final state MadGraph5_aMC@NLO by with the NNPDF2.310 PDF set and the A14 tune of PYTHIA [8] parameters. The CKKW-L merging algorithm [52] was used with a k_t -Durham parameter of 400 GeV. The cross section for the simulated signal with $\Lambda/g_* = 1$ TeV is 0.113 pb, for both electrons and muons. The ATLAS detector response was simulated with GEANT4 [53,54], except for signal samples, where a fast simulation [55] was used for the calorimeter response and GEANT4 for all other detector systems. The effect of multiple interactions in the same and neighboring bunch crossings (pileup) was modeled by overlaying simulated inelastic pp events generated by PYTHIA [8.186] [56] with the A3 tune [57] and the NNPDF2.310 PDF set [58]. The MC distributions were reweighted to the distribution of the average number of interactions per bunch crossing in data.

Only events taken during stable beam conditions, and for which all relevant components of the detector were operational, are considered. Single-lepton triggers were used [59,60], with p_T threshold of 60 GeV or 140 GeV for electrons, depending on the identification requirement, and 50 GeV for muons. Events must have a vertex with at least two tracks with a minimum p_T of 500 MeV, where the highest $\Sigma_{\text{tracks}} p_T^2$ vertex is chosen as the primary one [61].

Electrons are reconstructed from energy clusters in the EM calorimeter with ID tracks matched to them and are required to fulfill the "tight likelihood' identification criteria as well as calorimeter- and track-based isolation criteria [62]. Electrons must have a minimum transverse energy of 30 GeV and must be within the region $|\eta_{\text{cluster}}| < 2.47$, excluding the transition region between the barrel and the end cap, $1.37 < |\eta_{\text{cluster}}| < 1.52$. Muons are reconstructed from combined MS and ID tracks with a minimum p_T of 30 GeV, must fulfill the "high- p_T " identification criteria [63], which aim to optimize the momentum resolution for tracks with high transverse momentum, and must be within the region $|\eta| < 2.5$. For muons, track-based isolation criteria are required based on the scalar sum of the transverse momenta of the ID tracks associated with the primary vertex, excluding the muon track itself. Muon (electron) candidates are required to originate from the primary vertex by requiring the significance of the track's transverse impact parameter calculated relative to the beam line $d_0/\sigma(d_0)$ to be smaller than 3.0 (5.0). Furthermore, the longitudinal impact parameter z_0 , defined as the difference between the z coordinate of the point of closest approach to the beam line and the longitudinal position of the primary vertex, is required to satisfy $|z_0 \sin(\sigma)| < 0.5$ mm. Anti- k_t jets [64] are reconstructed from energy deposits in topological clusters of calorimeter cells [65], using the particle-flow algorithm [66] and a radius parameter of 0.4. The jet energy is calibrated at particle level [67]. Jets are required to be within $|\eta| < 2.5$ and to have a minimum p_T of 30 GeV. A jet vertex tagger [68] is used to suppress pileup contributions for jets with $|\eta| < 2.4$ and $p_T < 60$ GeV. Jets are identified as containing b hadrons using the DL1 algorithm [69,70], with a *b*-tagging efficiency of \sim 77% for *b* jets and a rejection factor of ~6 for c jets and ~110 for other light jets, based on simulated $t\bar{t}$ events. Finally, a sequential overlap-removal procedure is used as follows: in the first step, electrons that share a track with a muon are removed from the event; in the second step, any jet that has a ΔR to an electron that is smaller than 0.2 is removed from the event; and in the third step, electrons are removed from an event if they are geometrically closer than $\Delta R =$ 0.4 to any remaining jet. Jets within $\Delta R < 0.04 +$ 10 GeV/ $p_T(\mu)$ to a muon are removed from the event if they have, at most, two associated tracks with $p_T(\text{track}) > 0.5 \text{ GeV}$, otherwise the muon is removed.

Events are selected by requiring two same-flavor electrons or muons with opposite electric charge, where at least one of the leptons is required to geometrically match the object that fired the trigger. To ensure high trigger efficiency, the p_T threshold for the leading lepton is raised to 65 GeV. Two categories are defined depending on the presence of a *b*-tagged jet, targeting two different production mechanisms. The *b*-veto category, denoted by $e^+e^-/\mu^+\mu^- + 0b$, discards any event with a *b*-tagged jet, while the *b*-tag category, denoted by $e^+e^-/\mu^+\mu^- + 1b$, requires exactly one *b*-tagged jet in each event. No further requirement on the number of jets is made. Regions in each category are defined based on the dilepton invariant mass $m_{\ell\ell}$ and are selected to allow

high statistics to constrain the dominant backgrounds in dedicated control regions (CRs), validate the background estimation in dedicated validation regions (VRs), and keep a broad set of signal regions (SRs). SRs are defined with lower bounds on $m_{\ell\ell}, m_{\ell\ell}^{\min}$, ranging from 400 to 3200 (2000) GeV for the *b*-veto (*b*-tag) category with a step size of 100 GeV, where each SR is defined by requiring $m_{\ell\ell} > m_{\ell\ell}^{\min}$. CRs are defined in order to normalize the contribution of the two dominant background processes originating from $t\bar{t}$, Wt and $t\bar{t}V$, together denoted by "top," and Z/γ^* + jets processes. The Z/γ^* + jets CRs (Z-CRs) are defined by requiring events to be within $130 < m_{\ell\ell} < 250$ GeV, while the intermediate mass range, $250 < m_{\ell\ell} < 400$ GeV, serves as a VR to test the background modeling. For each Z-CR and VR, the same *b*-veto and *b*-tag categories as in the SRs are applied. Finally, a top-CR is constructed by requiring exactly two b-tagged jets and the dilepton invariant mass to satisfy $m_{\ell\ell} > 130$ GeV.

A fit-based extrapolation procedure is used to estimate the tails of the top $m_{\ell\ell}$ distributions, which suffer from low statistics in the MC simulation, using functions developed in other ATLAS searches [71],

$$f^{\mathrm{bkg1}}(m_{\ell\ell}) = \mathrm{e}^{-a} m^{b}_{\ell\ell} m^{c\log(m_{\ell\ell})}_{\ell\ell} \quad \text{and} \quad f^{\mathrm{bkg2}}(m_{\ell\ell}) = \frac{a}{(m_{\ell\ell} + b)^{c}},$$

where a, b, and c are free parameters. Several fits are performed by using both functions, while varying the start and end point of the fit range and using a χ^2 test to estimate the level of agreement between the fits and the MC prediction. The fit with the lowest χ^2 provides the nominal choice of the function parameter values, while all other fits with χ^2 probability smaller than a fixed χ^2 value are used for the uncertainty estimation. This fixed χ^2 value is chosen such that, near the transition point between the simulation and the extrapolation, the resulting uncertainty on the extrapolation is similar to the overall uncertainty, which is accounting for the experimental and modeling systematic uncertainty, and the statistical uncertainty of the simulated top background samples. Furthermore, checks are performed in order to make sure that the fitted function reproduces the MC event yields at lower values of $m_{\ell\ell}$ and that the cumulative distribution of the extrapolation is consistent with the integrated event yields in the MC samples. Finally, since the extrapolation is done for the combined top sample, which includes all top-related processes, it was checked that those processes have a similar $m_{\ell\ell}$ shape within uncertainties. For the top background extrapolation, the transition points between simulation and extrapolation in the $m_{\ell\ell}$ distributions are (1000, 1200, 1200 or 1300) GeV for the (0,1,2)-b-tagged jets selections, respectively, in the electron or muon channel. Above the transition point, only the extrapolation uncertainty is assigned to the top background sample. This

	$e^+e^- + 0b(1b)$ (%)		$\mu^+\mu^- + 0b(1b)$ (%)	
Source	Signal $0b(1b)$	Background $0b(1b)$	Signal $0b(1b)$	Background $0b(1b)$
Luminosity Pileup	1.7 (1.7) < 0.5 (< 0.5)	1.6 (1.5) < 0.5 (0.7)	1.7 (1.7) < 0.5 (< 0.5)	1.7 (1.7) < 0.5 (< 0.5)
Leptons Jets <i>b</i> tagging	8.7 (8.6) < 0.5 (1.8) < 0.5 (1.4)	8.6 (6.3) < 0.5 (3.4) < 0.5 (2.0)	8.5 (6.5) < 0.5 (1.6) < 0.5 (1.4)	9.1 (4.2) < 0.5 (1.9) < 0.5 (2.2)
Top bkg. extrapolation Multijet extrapolation		3.5 (32.0) 7.5 (15.0)		< 0.5 (36.0)
Top bkg. modeling Z/γ^* + jets bkg. modeling		< 0.5 (< 0.5) 9.4 (4.3)		< 0.5 (< 0.5) 10.0 (5.5)
MC statistics	0.6 (0.8)	1.9 (3.5)	0.7 (1.0)	1.7 (2.4)
Total	8.9 (9.1)	15.0 (37.0)	8.7 (7.1)	14.0 (37.0)

10 10 10 $\begin{array}{c} 10^{12} \\ 10^{1} \\ 10^{9} \\ 10^{9} \\ 10^{7} \\ 10^{6} \\ 10^{5} \\ 10^{4} \\ 10^{3} \\ 10^{2} \\ 10 \end{array}$ Events / 100 GeV Events / 100 GeV ATLAS - Data ATLAS - Data √s= 13 TeV, 139 fb⁻¹ Z/γ +jets √s= 13 TeV, 139 fb⁻¹ Z/γ +jets 10⁸ 10⁸ e⁺e +0b category, CR-only fit Multijet e⁺e +1b category, CR-only fit Top 10⁴ 10⁴ 10⁴ 10² 10² 10² Signal Regions Others Signal Regions Multijet Others Тор Bkg. Unc. Bkg. Unc. signal, $\Lambda/g_{\star} = 1$ signal, $\Lambda/g_* =$ 10⁻¹ 10⁻² 10 10 10 Data / bkg. Data / bkg. ·**** <u>†</u> † 10 10³ 3×10³ 10³ 5×10² 2×10³ 5×10² 2×10³ 3×10³ m_{ee} [GeV] m_{ee} [GeV] (a) (b) 10¹ 10¹ 10¹⁰ 10⁹ 10⁸ $\begin{array}{c} 10^{12} \\ 10^{11} \\ 10^{10} \\ 10^{9} \\ 10^{8} \\ 10^{7} \\ 10^{6} \\ 10^{5} \\ 10^{4} \\ 10^{3} \\ 10^{2} \\ 10 \end{array}$ Events / 100 GeV Events / 100 GeV ATLAS ATLAS - Data - Data √s= 13 TeV, 139 fb⁻¹ √s= 13 TeV, 139 fb⁻¹ Z/γ +jets Z/γ^{*}+jets $\mu^+\mu$ +0b category, CR-only fit μ⁺μ +1b category, CR only fit Others Top 10⁵ 10⁶ 10⁶ 10⁶ 10⁶ 10⁶ Signal Regions Signal Regions Others Тор Bkg. Unc. 👹 Bkg. Unc. signal, $\Lambda/g_{\star} = 1 \text{ TeV}$ signal, $\Lambda/g_{\star} = 1$ TeV 10⁻¹ 10⁻² 10⁻ 10⁻² 10 10 Data / bkg. Data / bkg 10 10 10³ 5×10² 10³ 2×10³ 5×10² 2×10³ 3×10³ 3×10³ $m_{\mu\mu}$ [GeV] $m_{\mu\mu}$ [GeV] (d) (c)

FIG. 2. Data overlaid on SM background postfit $m_{\ell\ell}$ distributions in the SRs of the (a) electron *b*-veto, (b) electron *b*-tag, (c) muon *b*-veto, and (d) muon *b*-tag categories. "Others" refers to diboson and W + jets events. MC statistical uncertainties and systematic uncertainties are considered (hatched band). The prefit signal distribution is presented as well for a hypothesis of $\Lambda/g_* = 1$ TeV. The bottom panels show the ratio of the data to the background prediction, while the arrows correspond to bins where the ratio is beyond the limits of the figure. The last bin is an overflow bin, which contains the yields in the bins beyond it. The dashed and dotted lines mark the transition point where the extrapolation is used in the analysis for the top and multijet backgrounds, respectively.

TABLE I. Summary of the relative systematic uncertainties for signal regions with $m_{\ell\ell}^{\min} = 2000(1500)$ GeV before the fit is performed for the 0b (1b) categories. The background uncertainties are presented relative to the total SM prediction.

uncertainty is the dominant one in the *b*-tag categories. It is 46% (53%) and 223% (236%) relative to the nominal fitted extrapolation in the $e^+e^- + 1b \ (\mu^+\mu^- + 1b)$ category with $m_{\ell\ell}^{\min} = 1200$ and 2000 GeV, respectively.

The background contribution of events with reconstructed objects that have been misidentified as leptons, referred to as "multijet," is estimated using a data-driven approach in the electron channel. In the muon channel, this contribution is found to be negligible. The matrix method is used, similar to the procedure described in Ref. [32]. The probabilities that a jet and a real electron satisfy the electron identification criteria are evaluated, for both the nominal and the "loose likelihood" identification criteria, while for the former no isolation criteria are applied. Then these probabilities are used in order to estimate the multijet contribution in the selected region. The multijet background estimation suffers from low statistics at high m_{ff} , and an extrapolation procedure similar to that of the top processes is used, with transition points at (800, 600, 600) GeV for the (0,1,2)-btagged jets selections, respectively.

Experimental systematic uncertainties, related to the modeling of the detector response in the simulation, are considered. The uncertainty in the combined 2015–2018 integrated luminosity is 1.7% [72]. Uncertainties in electron and muon trigger, reconstruction, and identification efficiencies, and energy and momentum calibration and

resolution, are derived from data using $Z \rightarrow \ell \ell$ and $J/\psi \rightarrow \ell \ell$ decays [62,73]. Uncertainties in the jet energy scale and resolution are evaluated from MC simulations and from data using multijet, Z + jets, and $\gamma + \text{jets}$ events [67]. Uncertainties in the *b*-tagging efficiency are derived from data [74] for *b* jets, *c* jets, and other light jets. MC simulations are used to extrapolate the efficiencies to regions beyond the kinematic reach of each calibration. In order to assess the systematic uncertainty due to pileup, the reweighting to match simulation to data is varied within its uncertainty. Finally, uncertainties related to the top and multijet background extrapolation are evaluated as described earlier in the text.

Theoretical systematic uncertainties, related to the modeling of the background processes in the MC simulation, are considered as well. The Z/γ^* + jets PDF variation uncertainty is estimated using the 90% confidence level (C.L.) CT14nnlo PDF error set, following Refs. [32,75–77]. The uncertainty due to α_s is assessed by using the CT14nnlo PDF set where the value of $\alpha_s(m_Z) = 0.118$ is shifted by 0.003, while QCD scale uncertainties are obtained by varying the renormalization and factorization scales simultaneously by a factor of 2 up and down. The uncertainty due to the choice of PDF set is estimated by using the NNPDF3.0 PDF set instead of the nominal choice of CT14nnlo [77]. Corrections due to photon-induced processes are estimated using the



FIG. 3. Data overlaid on SM background postfit yields in the regions of the (a) electron *b*-veto, (b) electron *b*-tag, (c) muon *b*-veto, and (d) muon *b*-tag categories. "Others" refers to diboson and W + jets events. MC statistical uncertainties and systematic uncertainties are considered (hatched band). The left part of each figure presents the yields in the CRs and the VR of each category, while the right part presents the yields in the SRs of each category. The bottom panels show the ratio of the data to the background prediction, while the arrows correspond to bins where the ratio is beyond the limits of the figure. The range of the *y* axis is different between the left and right parts of the bottom panels, and the latter is presented at logarithmic scale. For the SRs, as the distribution is cumulative, each bin is contained in and therefore correlated with the lower mass bins.

MRST2004qed PDF set [78]. The uncertainty due to NLO electroweak corrections for the Z/γ^* + jets sample are evaluated as in Ref. [75]. For $t\bar{t}$ and single-top-quark production, an uncertainty in the cross section originating from scale, PDF + α_s , and top-quark-mass uncertainties is applied. The nominal sample is compared with a sample generated with MadGraph5_aMC@NLO to estimate the matrixelement uncertainty. To evaluate the parton-shower uncertainty, a sample simulated with POWHEG-BOX interfaced to HERWIG 7 [79] is used. To simulate higher parton radiation, the factorization and renormalization scales are varied by a factor of 0.5 in the matrix element using the "up" variation from the A14 parameter tune in the parton shower. For lower parton radiation, the renormalization and factorization scales are varied by a factor of 2.0 using the "down" variation in the parton shower. The impact of FSR is evaluated by changing the renormalization scale for QCD emission by factors of 0.5 or 2.0. For $t\bar{t}$ and single-top-quark events, the PDF uncertainty is derived using 30 eigenvector variations as specified in Ref. [77], to estimate distribution shape uncertainties. For $t\bar{t}$ production, the impact of factorization and renormalization scale uncertainties on the shapes of distributions is derived by varying those scales by a factor of 0.5 or 2.0. The nominal Wt sample is compared with a sample generated using the diagram subtraction scheme [48,80]. Finally, the statistical uncertainties of the simulated event samples are also taken into account.

Table I presents the systematic uncertainties for one signal region from each channel. Systematic uncertainties that are lower than 0.5% in a given region are not considered.

The signal and background yields are estimated using simultaneous maximum-likelihood fits of the signal-plusbackground and background-only hypothesis. Systematic and MC statistical uncertainties are included as nuisance parameters (NPs) and are constrained in the fit. Dedicated fit parameters are used as additional NPs to adjust the top and Z/γ^* + jets background normalizations. A likelihood



FIG. 4. Model-independent observed (solid line) and expected (dashed line) upper limit on the visible cross section ($\sigma_{vis} = \sigma \epsilon A$) for the (a) electron *b*-veto, (b) electron *b*-tag, (c) muon *b*-veto, and (d) muon *b*-tag categories. The uncertainty bands around the expected limit represent the 68% and 95% confidence intervals. The theory lines (dotted lines) correspond to particular Λ/g_* values of the signal model, and the red marker presents the strongest expected lower limit on Λ/g_* .

ratio test statistic is used to assess the compatibility of the data with the background-only hypothesis to derive limits on the BSM signals, following the procedure in Ref. [81]. Exclusion limits are set using the CL_s method [82], which is performed separately for each of the *b*-tag and *b*-veto categories in the electron and muon channels and by considering a single-bin SR and the relevant CRs per category.

The data agree well with the SM prediction in all of the VRs after the fit. The postfit $m_{\ell\ell}$ distributions in the SRs are presented in Fig. 2 for the background-only hypothesis, while the fit is done only at the CRs (CR-only fit) and then used to estimate the background yields. The cumulative $m_{\ell\ell}$ distribution for the signal regions after the CR-only fit to the data are shown in Fig. 3 together with the yields in the different CRs and VRs. The largest deviation from the SM prediction is observed in the $e^+e^- + 1b$ category, where a selection of $m_{ee}^{\min} = 1700 \text{ GeV}$ yields a local significance of 2.6σ . The global significance is estimated by generating pseudo-experiments using all of the electron *b*-tag SRs and found to be 1.5σ . Other notable local deviations are in the $e^+e^- + 1b$ category with $m_{ee}^{\min} =$ 1500, 1600, 2000(1900) GeV, which yields $2.1\sigma(2.0\sigma)$, and in the $e^+e^- + 0b$ category with $m_{ee}^{\min} = 2200$ GeV, which yields 2.1 σ . In the $\mu^+\mu^- + 0b$ category, a deficit of events is observed with up to 1.9σ , with a selection of $m_{uu}^{\min} = 1600$, 2800 GeV. In Fig. 4, model-independent upper limits on the signal cross section times selection efficiency times detector acceptance ($\sigma_{vis} = \sigma \epsilon A$) are presented for each signal region selection. For the $bs\ell\ell$ benchmark model, the strongest expected limits are found with a selection of $m_{\ell\ell}^{\min} = 1900(1500)$ GeV in the $e^+e^- +$ 0b(1b) category, which corresponds to expected and observed lower limits on Λ/g_* of up to 2.2 (2.2) and 2.0 (1.8) TeV, respectively, and with a selection of $m_{\ell\ell}^{\min} =$ 1800(1600) GeV in the $\mu^+\mu^- + 0b(1b)$ category, which corresponds to expected and observed lower limits on Λ/q_* of up to 2.1 (2.1) and 2.4 (2.0) TeV, respectively. The excluded values of Λ/g_* are far below the value favored by the anomalies, which is ≈ 30 TeV.

In summary, a search for new phenomena was conducted in final states with two electrons or muons in association with one or no *b*-tagged jets. The analysis was conducted using 139 fb⁻¹ of *pp* collision data at $\sqrt{s} = 13$ TeV recorded by the ATLAS detector at the Large Hadron Collider. No significant excess of events above the expected SM background is observed. Model-independent upper limits at 95% C.L. were set on the signal cross section in each of the signal regions. A first search for a *bsℓℓ* contact interaction is presented, and values of Λ/g_* smaller than 2.0 (2.4) TeV are excluded using the observed limits for electrons (muons) at 95% C.L., which is still far below the value that has been predicted in order to explain the *B*-meson decay anomalies.

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E. Ballabene,^{66a,66b} F. Balli,¹⁴⁰ W. K. Balunas,¹³⁰ J. Balz,⁹⁷ E. Banas,⁸² M. Bandieramonte,¹³⁴ A. Bandyopadhyay,¹⁷
L. Barak,¹⁵⁷ E. L. Barberio,¹⁰² D. Barberis,^{53b,53a} M. Barbero,⁹⁹ G. Barbour,⁹² K. N. Barends,^{31a} T. Barillari,¹¹²
M-S. Barisits,³⁴ J. Barkeloo,¹²⁷ T. Barklow,¹⁴⁹ B. M. Barnett,¹³⁹ R. M. Barnett,¹⁶ A. Baroncelli,^{58a} G. Barone,²⁷ A. J. Barr,¹³⁰ L. Barranco Navarro,^{43a,43b} F. Barreiro,⁹⁶ J. Barreiro Guimarães da Costa,^{13a} U. Barron,¹⁵⁷ S. Barsov,¹³³ F. Bartels,^{59a} R. Bartoldus,¹⁴⁹ G. Bartolini,⁹⁹ A. E. Barton,⁸⁷ P. Bartos,^{26a} A. Basalaev,⁴⁴ A. Basan,⁹⁷ I. Bashta,^{72a,72b} A. Bassalat,⁶² M. J. Basso,¹⁶² C. R. Basson,⁹⁸ R. L. Bates,⁵⁵ S. Batlamous,^{33e} J. R. Batley,³⁰ B. Batool,¹⁴⁷ M. Battaglia,¹⁴¹ M. Bauce,^{70a,70b} F. Bauer,¹²⁰ H. S. Bawa,²⁹ A. Bayirli,^{11c} J. B. Beacham,⁴⁷ T. Beau,¹³¹ P. H. Beauchemin,¹⁶⁵ F. Becherer,⁵⁰ P. Bechtle,²² H. P. Beck,^{18,f} K. Becker,¹⁷³ C. Becot,⁴⁴ A. J. Beddall,^{11a} V. A. Bednyakov,⁷⁷ C. P. Bee,¹⁵¹ T. A. Beermann,¹⁷⁷ M. Begalli,^{78b} M. Begel,²⁷ A. Behera,¹⁵¹ J. K. Behr,⁴⁴ C. Beirao Da Cruz E Silva,³⁴ J. F. Beirer,^{51,34} F. Beisiegel,²² M. Belfkir,⁴ G. Bella,¹⁵⁷ L. Bellagamba,^{21b} A. Bellerive,³² P. Bellos,¹⁹ K. Beloborodov,^{118b,118a} K. Belotskiy,¹⁰⁹ N. L. Belyaev,¹⁰⁹ D. Benchekroun,^{33a} Y. Benhammou,¹⁵⁸ D. P. Benjamin,²⁷ M. Benoit,²⁷ J. R. Bensinger,²⁴ S. Bentvelsen,¹¹⁶ L. Beresford, ³⁴ M. Beretta,⁴⁹ D. Berge,¹⁷ E. Bergeaas Kuutmann,¹⁶⁷ N. Berger,⁴ B. Bergmann,¹³⁷ L. J. Bergsten,²⁴ J. Beringer,¹⁶ S. Berlendis,⁶ G. Bernardi,¹³¹ C. Bernius,¹⁴⁹ F. U. Bernlochner,²² T. Berry,⁹¹ P. Berta,⁴⁴ A. Berthold,⁴⁶ I. A. Bertram,⁸⁷ O. Bessidskaia Bylund,¹⁷⁷ S. Bethke,¹¹² A. Betti,⁴⁰ A. J. Bevan,⁹⁰ S. Bhatta,¹⁵¹ D. S. Bhattacharya,¹⁷² P. Bhattarai,²⁴ V. S. Bhopatkar,⁵ R. Bi,¹³⁴ R. M. Bianchi,¹³⁴ O. Biebel,¹¹¹ R. Bielski,³⁴ N. V. Biesuz,^{69a,69b} M. Biglietti,^{72a} T. R. V. Billoud,¹³⁷ M. Bindi,⁵¹ A. Bingul,^{11d} C. Bini,^{70a,70b} S. Biondi,^{21b,21a} C. J. Birch-sykes,⁹⁸ G. A. Bird,^{19,139} M. Birman,¹⁷⁵ T. Bisanz,³⁴ J. P. Biswal,² D. Biswas,^{176,g} A. Bitadze,⁹⁸ C. Bittrich,⁴⁶ K. Bjørke,¹²⁹ I. Bloch,⁴⁴ C. Blocker,²⁴

A. Blue,⁵⁵ U. Blumenschein,⁹⁰ G. J. Bobbink,¹¹⁶ V. S. Bobrovnikov,^{118b,118a} D. Bogavac,¹² A. G. Bogdanchikov,^{118b,118a} C. Bohm,^{43a} V. Boisvert,⁹¹ P. Bokan,⁴⁴ T. Bold,^{81a} M. Bomben,¹³¹ M. Bona,⁹⁰ M. Boonekamp,¹⁴⁰ C. D. Booth,⁹¹
A. G. Borbély,⁵⁵ H. M. Borecka-Bielska,¹⁰⁷ L. S. Borgna,⁹² G. Borissov,⁸⁷ D. Bortoletto,¹³⁰ D. Boscherini,^{21b} M. Bosman,¹² A. G. Borbély, ⁵⁵ H. M. Borecka-Bielska, ¹⁰⁷ L. S. Borgna, ⁹² G. Borissov, ⁸⁷ D. Bortoletto, ¹³⁰ D. Boscherini, ^{21b} M. Bosman, ¹² J. D. Bossio Sola, ¹⁰¹ K. Bouaouda, ^{33a} J. Boudreau, ¹³⁴ E. V. Bouhova-Thacker, ⁸⁷ D. Bournediene, ³⁶ R. Bouquet, ¹³¹ A. Boveia, ¹²³ J. Boyd, ³⁴ D. Boye, ²⁷ I. R. Boyko, ⁷⁷ A. J. Bozson, ⁹¹ J. Bracinik, ¹⁹ N. Brahimi, ^{584,58c} G. Brandt, ¹⁷⁷ O. Brandt, ³⁰ F. Braren, ⁴⁴ B. Brau, ¹⁰⁰ J. E. Brau, ¹²⁷ W. D. Breaden Madden, ⁵⁵ K. Brendlinger, ⁴⁴ R. Brener, ¹⁷⁵ L. Brenner, ³⁴ R. Brenner, ¹⁶⁷ S. Bressler, ¹⁷⁵ B. Brickwedde, ⁹⁷ D. L. Briglin, ¹⁹ D. Britton, ⁵⁵ D. Britzger, ¹¹² I. Brock, ²² R. Brock, ¹⁰⁴ G. Brooijmans, ³⁷ W. K. Brooks, ^{142e} E. Brost, ²⁷ P. A. Bruckman de Renstrom, ⁸² B. Brüers, ⁴⁴ D. Bruncko, ^{26b} A. Bruni, ^{21b} G. Bruni, ^{21b} M. Bruschi, ^{21b} N. Bruscino, ^{70a,70b} L. Bryngemark, ¹⁴⁹ T. Buanes, ¹⁵ Q. Buat, ¹⁵¹ P. Buchholz, ¹⁴⁷ A. G. Buckley, ⁵⁵ I. A. Budagov, ⁷⁷ M. K. Bugge, ¹²⁹ O. Bulekov, ¹⁰⁹ B. A. Bullard, ⁵⁷ T. J. Burch, ¹¹⁷ S. Burdin, ⁸⁸ C. D. Burgard, ⁴⁴ A. M. Burger, ¹²⁵ B. Burghgrave, ⁷ J. T. P. Burr, ⁴⁴ C. D. Burton, ¹⁰ J. C. Burzynski, ¹⁰⁰ V. Büscher, ⁹⁷ P. J. Bussey, ⁵⁵ J. M. Butterworth, ⁹² W. Buttinger, ¹³⁹ C. J. Buxo Vazquez, ¹⁰⁴ A. R. Buzykaev, ^{118b,118a} G. Cabras, ^{21b,21a} S. Cabrera Urbán, ¹⁶⁹ D. Caforio, ⁵⁴ H. Cai, ¹³⁴ V. M. M. Cairo, ¹⁴⁰ O. Cakir, ^{3a} N. Calace, ³⁴ P. Calafiura, ¹⁶ G. Calderini, ¹³¹ P. Calfayan, ⁶³ G. Callea, ⁵⁵ L. P. Caloba, ^{78b} A. Catabaiano, ^{71a,71b} S. Calvente Lopez, ⁹⁶ D. Calvet, ⁵⁶ S. Calvet, ⁹⁰ M. Calvetti, ^{696,696} R. Caramotor, ¹³¹ S. Campaneli, ³² V. Canale, ^{67a,67b} A. Canesse, ¹⁰¹ M. Camo Bret, ⁷⁵ J. Canteron, ¹²⁹ C. Camincher, ¹⁷¹ M. Campaneli, ⁹² A. Carmplani, ³⁸ V. Canale, ^{67a,67b} A. Canesse, ¹⁰⁴ M. Cano, ^{71a,71b} S. Carter, ¹⁶³ T. Carlson, ¹¹⁵ E. Carquin, ¹⁴² S. Carrá, ⁴⁴ G. Carrino, ^{67a} B. T. Carlson, ¹³⁴ E. M. Carlson, B. Chargeishvili,^{155b} D. G. Charlton,¹⁹ T. P. Charman,⁹⁰ M. Chatterjee,¹⁸ C. C. Chau,³² S. Chekanov,⁵ S. V. Chekulaev,^{163a}
G. A. Chelkov,^{77,i} A. Chen,¹⁰³ B. Chen,¹⁵⁷ C. Chen,^{58a} C. H. Chen,⁷⁶ H. Chen,^{13c} H. Chen,²⁷ J. Chen,^{58a} J. Chen,³⁷ J. Chen,²⁴
S. Chen,¹³² S. J. Chen,^{13c} X. Chen,^{13b} Y. Chen,^{58a} Y-H. Chen,⁴⁴ C. L. Cheng,¹⁷⁶ H. C. Cheng,^{60a} H. J. Cheng,^{13a} G. A. Chen, ¹³ S. Chen, ¹⁵ X. Chen, ¹⁵ Y. Chen, ⁵⁸ Y. H. Chen, ⁴⁴ C. L. Cheng, ¹⁷⁶ H. C. Cheng, ^{6a} H. J. Cheng, ¹³
A. Cheplakov,⁷⁷ E. Cheremushkina, ⁴⁴ R. Cherkaoui El Moursli, ³³ E. Cheu, ⁶ K. Cheung, ⁶¹ L. Chevalier,¹⁴⁰ V. Chiarella,⁴⁹
G. Chiarelli, ^{69a} G. Chiodini, ^{65a} A. S. Chisholm, ¹⁹ A. Chitan, ^{25b} I. Chiu, ¹⁵⁹ Y. H. Chiu,¹⁷¹ M. V. Chizhov,⁷⁷³ K. Choi, ¹⁰ A. R. Chomont, ^{70a,70b} Y. Chou, ¹⁰⁰ Y. S. Chow, ¹¹⁶ L. D. Christopher,^{31f} M. C. Chu, ^{60a} X. Chu, ^{13a,13d} J. Chudoba, ¹³⁶
J. J. Chwastowski,⁸² D. Cieri,¹¹² K. M. Ciesla,⁸² V. Cindro,⁸⁹ I. A. Cioara,^{25b} A. Ciocio, ¹⁶ F. Cirotto, ^{67a,67b} Z. H. Citron, ^{175,48}
M. Citterio, ^{66a} D. A. Ciubotaru. ^{25b} B. M. Ciungu, ¹⁶² A. Clark,⁵² P. J. Clark,⁴⁸ J. M. Clavijo Columbie,⁴⁴ S. E. Clawson,⁹⁸
C. Clement, ^{43a,43b} L. Clissa, ^{11b,21a} Y. Coadou,⁹⁹ M. Cobal, ^{64a,64c} A. Coccaro, ^{53b} J. Cochran,⁷⁶ R. F. Coelho Barrue, ^{135a}
R. Coelho Lopes De Sa,¹⁰⁰ S. Coelli,^{66a} H. Cohen,¹⁵⁷ A. E. C. Coimbra,³⁴ B. Cole,³⁷ J. Collot,⁵⁶ P. Conde Muiño, ^{13a,13b}
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F. Crescioli, ¹³¹ M. Cristinziani,¹⁴⁷ M. Cristoforetti, ^{73a,73b,n} V. Croft, ¹⁶⁵ G. Crosetti, ^{39b,39a} A. Cueto,⁴
T. Dado,⁴⁵ S. Dabhi,^{31 T} T. Dai,¹⁰³ C. Dallapiccola, ¹⁰⁰ M. Dam,⁵³ S. Darmora,⁵ S. Czekierda,⁸² P. Czodrowski,^{81a}
T. Dado,⁴⁵ S. Dabhi,^{31 T} T. Dai,¹⁰³ C. Dallapiccola,¹⁰⁰ M. Dam,⁵³ S. Darmora,⁵ A. Dattagupta,¹²⁷ S. D'Auria,^{66a,66b} C. David,^{16a,4b}
<li L. D'Eramo,¹¹⁷ D. Derendarz,⁸² J. E. Derkaoui,^{33d} F. Derue,¹³¹ P. Dervan,⁸⁸ K. Desch,²² K. Dette,¹⁶² C. Deutsch,²²
P. O. Deviveiros,³⁴ F. A. Di Bello,^{70a,70b} A. Di Ciaccio,^{71a,71b} L. Di Ciaccio,⁴ C. Di Donato,^{67a,67b} A. Di Girolamo,³⁴ G. Di Gregorio,^{69a,69b} A. Di Luca,^{73a,73b} B. Di Micco,^{72a,72b} R. Di Nardo,^{72a,72b} C. Diaconu,⁹⁹ F. A. Dias,¹¹⁶

T. Dias Do Vale,^{135a} M. A. Diaz,^{142a} F. G. Diaz Capriles,²² J. Dickinson,¹⁶ M. Didenko,¹⁶⁹ E. B. Diehl,¹⁰³ J. Dietrich,¹⁷ S. Díez Cornell,⁴⁴ C. Diez Pardos,¹⁴⁷ A. Dimitrievska,¹⁶ W. Ding,^{13b} J. Dingfelder,²² I-M. Dinu,^{25b} S. J. Dittmeier,^{59b} S. Díez Cornell,⁴⁴ C. Diez Pardos,¹⁴⁷ A. Dimitrievska,¹⁰ W. Ding,¹³⁰ J. Dingfelder,²² I-M. Dinu,²³⁰ S. J. Dittmeier,⁵⁷⁰ F. Dittus,³⁴ F. Djama,⁹⁹ T. Djobava,^{155b} J. I. Djuvsland,¹⁵ M. A. B. Do Vale,¹⁴³ D. Dodsworth,²⁴ C. Doglioni,⁹⁴ J. Dolejsi,¹³⁸ Z. Dolezal,¹³⁸ M. Donadelli,^{78c} B. Dong,^{58c} J. Donini,³⁶ A. D'onofrio,^{13c} M. D'Onofrio,⁸⁸ J. Dopke,¹³⁹ A. Doria,^{67a} M. T. Dova,⁸⁶ A. T. Doyle,⁵⁵ E. Drechsler,¹⁴⁸ E. Dreyer,¹⁴⁸ T. Dreyer,⁵¹ A. S. Drobac,¹⁶⁵ D. Du,^{58b} T. A. du Pree,¹¹⁶ F. Dubinin,¹⁰⁸ M. Dubovsky,^{26a} A. Dubreuil,⁵² E. Duchovni,¹⁷⁵ G. Duckeck,¹¹¹ O. A. Ducu,^{34,25b} D. Duda,¹¹² A. Dudarev,³⁴ M. D'uffizi,⁹⁸ L. Duflot,⁶² M. Dührssen,³⁴ C. Dülsen,¹⁷⁷ A. E. Dumitriu,^{25b} M. Dunford,^{59a} S. Dungs,⁴⁵ A. Duperrin,⁹⁹ H. Duran Yildiz,^{3a} M. Düren,⁵⁴ A. Durglishvili,^{155b} B. Dutta,⁴⁴ D. Duvnjak,¹ G. I. Dyckes,¹³² M. Dyndal,^{81a} S. Dysch,⁹⁸ B. S. Dziedzic,⁸² B. Eckerova,^{26a} M. G. Eggleston,⁴⁷ E. Egidio Purcino De Souza,^{78b} L. F. Ehrke,⁵² T. Eifert,⁷ G. Eigen,¹⁵ K. Einsweiler,¹⁶ T. Ekelof,¹⁶⁷ Y. El Ghazali,^{33b} H. El Jarrari,^{33e} A. El Moussaouy,^{33a} V. Ellajosyula,¹⁶⁷ M. Ellert,¹⁶⁷ F. Ellinghaus,¹⁷⁷ A. A. Elliot,⁹⁰ N. Ellis,³⁴ J. Elmsheuser,²⁷ M. Elsing,³⁴ D. Emeliyanov,¹³⁹ A. Emerman,³⁷ Y. Enari,¹⁵⁹ J. Frdmann,⁴⁵ A. Freditato,¹⁸ P. A. Frland,⁸² M. Frrenst,¹⁷⁷ M. Escalier,⁶² C. Escohar,¹⁶⁹ O. Estrada Pastor,¹⁶⁹ E. Etzion,¹⁵⁷ J. Erdmann,⁴⁵ A. Ereditato,¹⁸ P. A. Erland,⁸² M. Errenst,¹⁷⁷ M. Escalier,⁶² C. Escobar,¹⁶⁹ O. Estrada Pastor,¹⁶⁹ E. Etzion,¹⁵⁷ G. Evans,^{135a} H. Evans,⁶³ M. O. Evans,¹⁵² A. Ezhilov,¹³³ F. Fabbri,⁵⁵ L. Fabbri,^{21b,21a} V. Fabiani,¹¹⁵ G. Facini,¹⁷³
V. Fadeyev,¹⁴¹ R. M. Fakhrutdinov,¹¹⁹ S. Falciano,^{70a} P. J. Falke,²² S. Falke,³⁴ J. Faltova,¹³⁸ Y. Fan,^{13a} Y. Fang,^{13a} Y. Fang,^{13a}
G. Fanourakis,⁴² M. Fanti,^{66a,66b} M. Faraj,^{58c} A. Farbin,⁷ A. Farilla,^{72a} E. M. Farina,^{68a,68b} T. Farooque,¹⁰⁴ S. M. Farrington,⁴⁸
P. Farthouat,³⁴ F. Fassi,^{33e} D. Fassouliotis,⁸ M. Faucci Giannelli,^{71a,71b} W. J. Fawcett,³⁰ L. Fayard,⁶² O. L. Fedin,^{133,0} P. Farthouat,³⁴ F. Fassi,^{35e} D. Fassouliotis,⁸ M. Faucci Giannelli,^{71a,71b} W. J. Fawcett,³⁰ L. Fayard,⁶² O. L. Fedin,^{133,o} A. Fehr,¹⁸ M. Feickert,¹⁶⁸ L. Feligioni,⁹⁹ A. Fell,¹⁴⁵ C. Feng,^{58b} M. Feng,^{13b} M. J. Fenton,¹⁶⁶ A. B. Fenyuk,¹¹⁹ S. W. Ferguson,⁴¹ J. Ferrando,⁴⁴ A. Ferrari,¹⁶⁷ P. Ferrari,¹¹⁶ R. Ferrari,^{68a} D. Ferrere,⁵² C. Ferretti,¹⁰³ F. Fiedler,⁹⁷ A. Filipčič,⁸⁹ F. Filthaut,¹¹⁵ M. C. N. Fiolhais,^{136a,136c,p} L. Fiorini,¹⁶⁹ F. Fischer,¹⁴⁷ J. Fischer,⁹⁷ W. C. Fisher,¹⁰⁴ T. Fitschen,¹⁹ I. Fleck,¹⁴⁷ P. Fleischmann,¹⁰³ T. Flick,¹⁷⁷ B. M. Flierl,¹¹¹ L. Flores,¹³² L. R. Flores Castillo,^{60a} F. M. Follega,^{73a,73b} N. Fomin,¹⁵ J. H. Foo,¹⁶² G. T. Forcolin,^{73a,73b} B. C. Forland,⁶³ A. Formica,¹⁴⁰ F. A. Förster,¹² A. C. Forti,⁹⁸ E. Fortin,⁹⁹ M. G. Foti,¹³⁰ D. Fournier,⁶² H. Fox,⁸⁷ P. Francavilla,^{69a,69b} S. Francescato,^{70a,70b} M. Franchini,^{21b,21a} S. Franchino,^{59a} D. Francis,³⁴ L. Franco,⁴ L. Franconi,¹⁸ M. Franklin,⁵⁷ G. Frattari,^{70a,70b} A. C. Freegard,⁹⁰ P. M. Freeman,¹⁹ B. Freund,¹⁰⁷ W. S. Freund,^{78b} E. M. Freundlich,⁴⁵ D. Froidevaux,³⁴ J. A. Frost,¹³⁰ Y. Fu,^{58a} M. Fujimoto,¹²² E. Fullana Torregrosa,¹⁶⁹ J. Fuster,¹⁶⁹ A. Gabrielli,^{21b,21a} A. Gabrielli,³⁴ P. Gadow,⁴⁴ G. Gagliardi,^{53b,53a} L. G. Gagnon,¹⁶ G. E. Gallardo,¹³⁰ E. J. Gallas,¹³⁰ B. J. Gallop,¹³⁹ R. Gamboa Goni,⁹⁰ K. K. Gan,¹²³ S. Ganguly,¹⁷⁵ J. Gao,^{58a} Y. Gao,⁴⁸ Y. S. Gao,^{29,q} F. M. Garay Walls,^{142a} C. García,¹⁶⁹ J. E. García Navarro,¹⁶⁹ J. A. García Pascual,^{13a} M. Garcia-Sciveres,¹⁶ R. W. Gardner,³⁵ D. Garg,⁷⁵ S. Gargiulo,⁵⁰ C. A. Garner,¹⁶² V. Garonne,¹²⁹ S. J. Gasiorowski,¹⁴⁴ P. Gaspar,^{78b} G. Gaudio,^{68a} P. Gauzzi,^{70a,70b} I. L. Gavrilenko,¹⁰⁸ A. Gavrilyuk,¹²⁰ C. Gay,¹⁷⁰ G. Gaycken,⁴⁴ E. N. Gazis,⁹ A. A. Geanta,^{25b} C. M. Gee,¹⁴¹ C. N. P. Gee,¹³⁹ I. L. Gavrilenko, ¹⁰⁵ A. Gavrilyuk, ¹⁰⁵ C. Gay, ¹¹⁶ G. Gaycken, ¹¹ E. N. Gazis, ⁵ A. A. Geanta, ²⁰⁵ C. M. Gee, ¹¹⁷ C. N. P. Gee, ¹⁰⁵ J. Geisen, ⁹⁴ M. Geisen, ⁹⁷ C. Gemme, ^{53b} M. H. Genest, ⁵⁶ S. Gentile, ^{70a,70b} S. George, ⁹¹ T. Geralis, ⁴² L. O. Gerlach, ⁵¹ P. Gessinger-Befurt, ⁹⁷ M. Ghasemi Bostanabad, ¹⁷¹ M. Ghneimat, ¹⁴⁷ A. Ghosh, ¹⁶⁶ A. Ghosh, ⁷⁵ B. Giacobbe, ^{21b} S. Giagu, ^{70a,70b} N. Giangiacomi, ¹⁶² P. Giannetti, ^{69a} A. Giannini, ^{67a,67b} S. M. Gibson, ⁹¹ M. Gignac, ¹⁴¹ D. T. Gil, ^{81b} B. J. Gilbert, ³⁷ D. Gillberg, ³² G. Gilles, ¹⁷⁷ N. E. K. Gillwald, ⁴⁴ D. M. Gingrich, ^{2,e} M. P. Giordani, ^{64a,64c} P. F. Giraud, ¹⁴⁰ G. Giugliarelli, ^{64a,64c} D. Giugni, ^{66a} F. Giuli, ^{71a,71b} I. Gkialas, ^{8,r} E. L. Gkougkousis, ¹² P. Gkountoumis, ⁹ L. K. Gladilin, ¹¹⁰ C. Glasman, ⁹⁶ G. R. Gledhill, ¹²⁷ M. Glisic, ¹²⁷ I. Gnesi, ^{39b,s} M. Goblirsch-Kolb, ²⁴ D. Godin, ¹⁰⁷ S. Goldfarb, ¹⁰² T. Golling, ⁵² D. Golubkov, ¹¹⁹ J. P. Gombas, ¹⁰⁴ A. Gomes, ^{135a,135b} R. Goncalves Gama, ⁵¹ R. Gonçalo, ^{135a,135c} G. Gonella, ¹²⁷ L. Gonella, ¹⁸ A. Gones, ⁸⁸ B. Goncalves Gama, ⁵¹ R. Gonçalo, ¹²⁵ B. Generales Leone ⁸⁸ A. Gongadze,⁷⁷ F. Gonnella,¹⁹ J. L. Gonski,³⁷ S. González de la Hoz,¹⁶⁹ S. Gonzalez Fernandez,¹² R. Gonzalez Lopez,⁸⁸ C. Gonzalez Renteria,¹⁶ R. Gonzalez Suarez,¹⁶⁷ S. Gonzalez-Sevilla,⁵² G. R. Gonzalvo Rodriguez,¹⁶⁹ R. Y. González Andana,^{142a} L. Goossens,³⁴ N. A. Gorasia,¹⁹ P. A. Gorbounov,¹²⁰ H. A. Gordon,²⁷ B. Gorini,³⁴ E. Gorini,^{65a,65b} A. Gorišek,⁸⁹ A. T. Goshaw,⁴⁷ M. I. Gostkin,⁷⁷ C. A. Gottardo,¹¹⁵ M. Gouighri,^{33b} V. Goumarre,⁴⁴ E. Gorini, ¹⁴⁴ N. Gorisek, ¹⁴ A. I. Goshaw, ¹⁶ H. I. Gostkin, ¹⁷ C. A. Gottardo, ¹⁷ M. Goulgni, ¹⁷ V. Goumarre, A. G. Goussiou, ¹⁴⁴ N. Govender, ^{31c} C. Goy, ⁴ I. Grabowska-Bold, ^{81a} K. Graham, ³² E. Gramstad, ¹²⁹ S. Grancagnolo, ¹⁷ M. Grandi, ¹⁵² V. Gratchev, ¹³³ P. M. Gravila, ^{25f} F. G. Gravili, ^{65a,65b} H. M. Gray, ¹⁶ C. Grefe, ²² I. M. Gregor, ⁴⁴ P. Grenier, ¹⁴⁹ K. Grevtsov, ⁴⁴ C. Grieco, ¹² N. A. Grieser, ¹²⁴ A. A. Grillo, ¹⁴¹ K. Grimm, ^{29,t} S. Grinstein, ^{12,u} J.-F. Grivaz, ⁶² S. Groh, ⁹⁷ E. Gross, ¹⁷⁵ J. Grosse-Knetter, ⁵¹ Z. J. Grout, ⁹² C. Grud, ¹⁰³ A. Grummer, ¹¹⁴ J. C. Grundy, ¹³⁰ L. Guan, ¹⁰³ W. Guan, ¹⁷⁶ C. Gubbels, ¹⁷⁰ J. Guenther, ³⁴ J. G. R. Guerrero Rojas, ¹⁶⁹ F. Guescini, ¹¹² D. Guest, ¹⁷ R. Gugel, ⁹⁷ A. Guida, ⁴⁴ T. Guillemin, ⁴ S. Guindon, ³⁴ J. Guo, ^{58c} L. Guo, ⁶² Y. Guo, ¹⁰³ R. Gupta, ⁴⁴ S. Gurbuz, ²² G. Gustavino, ¹²⁴ M. Guth, ⁵⁰ P. Gutierrez, ¹²⁴ K. E. Gross, ¹²³ C. G. Gustavino, ¹²⁴ M. Guth, ⁵⁰ P. Gutierrez, ¹²⁴ K. E. Grivaz, ¹²⁰ C. G. Gustavino, ¹²⁴ M. Guth, ⁵⁰ P. Gutierrez, ¹²⁴ K. E. Grivaz, ¹²⁰ C. G. Gustavino, ¹²⁴ M. Guth, ⁵⁰ P. Gutierrez, ¹²⁴ K. E. Grivaz, ¹²⁰ C. G. Gustavino, ¹²⁴ M. Guth, ⁵⁰ P. Gutierrez, ¹²⁴ K. E. Grivaz, ¹²⁰ C. Grivaz, ¹²¹ C. Grivaz, ¹²² C. Grivaz, ¹²⁴ K. Grivaz, ¹²⁵ G. Grivaz, ¹²⁴ K. Griva L. F. Gutierrez Zagazeta,¹³² C. Gutschow,⁹² C. Guyot,¹⁴⁰ C. Gwenlan,¹³⁰ C. B. Gwilliam,⁸⁸ E. S. Haaland,¹²⁹ A. Haas,¹²¹ M. Habedank,¹⁷ C. Haber,¹⁶ H. K. Hadavand,⁷ A. Hadef,⁹⁷ M. Haleem,¹⁷² J. Haley,¹²⁵ J. J. Hall,¹⁴⁵ G. Halladjian,¹⁰⁴ G. D. Hallewell,⁹⁹ L. Halser,¹⁸ K. Hamano,¹⁷¹ H. Hamdaoui,^{33e} M. Hamer,²² G. N. Hamity,⁴⁸ K. Han,^{58a} L. Han,^{13c}

L. Han, ^{58a} S. Han, ¹⁶ Y. F. Han, ¹⁶² K. Hanagaki, ^{79,v} M. Hance, ¹⁴¹ M. D. Hank, ³⁵ R. Hankache, ⁹⁸ E. Hansen, ⁹⁴ J. B. Hansen, ³⁸ J. D. Hansen, ³⁸ M. C. Hansen, ²² P. H. Hansen, ³⁸ K. Hara, ¹⁶⁴ T. Harenberg, ¹⁷⁷ S. Harkusha, ¹⁰⁵ Y. T. Harris, ¹³⁰ P. F. Harrison, ¹⁷³ N. M. Hartman, ¹⁴⁹ N. M. Hartmann, ¹¹¹ Y. Hasegawa, ¹⁴⁶ A. Hasib, ⁴⁸ S. Hassani, ¹⁴⁰ S. Haug, ¹⁸ R. Hauser, ¹⁰⁴ M. Havranek, ¹³⁷ C. M. Hawkes, ¹⁹ R. J. Hawkings, ³⁴ S. Hayashida, ¹¹³ D. Hayden, ¹⁰⁴ C. Hayes, ¹⁰³ R. L. Hayes, ¹⁷⁰ C. P. Hays, ¹³⁰ J. M. Hays, ⁹⁰ H. S. Hayward, ⁸⁸ S. J. Haywood, ¹³⁹ F. He, ^{58a} Y. He, ¹⁶⁰ Y. He, ¹³¹ M. P. Heath, ⁴⁸ V. Hedberg, ⁹⁴ A. L. Heggelund,¹²⁹ N. D. Hehir,⁹⁰ C. Heidegger,⁵⁰ K. K. Heidegger,⁵⁰ W. D. Heidorn,⁷⁶ J. Heilman,³² S. Heim,⁴⁴ T. Heim,¹⁶ B. Heinemann,^{44,w} J. G. Heinlein,¹³² J. J. Heinrich,¹²⁷ L. Heinrich,³⁴ J. Hejbal,¹³⁶ L. Helary,⁴⁴ A. Held,¹²¹ S. Hellesund,¹²⁹ C. M. Helling,¹⁴¹ S. Hellman,^{43a,43b} C. Helsens,³⁴ R. C. W. Henderson,⁸⁷ L. Henkelmann,³⁰ A. M. Henriques Correia,³⁴ H. Herde,¹⁴⁹ Y. Hernández Jiménez,¹⁵¹ H. Herr,⁹⁷ M. G. Herrmann,¹¹¹ T. Herrmann,⁴⁶ G. Herten,⁵⁰ R. Hertenberger,¹¹¹ L. Hervas,³⁴ N. P. Hessey,^{163a} H. Hibi,⁸⁰ S. Higashino,⁷⁹ E. Higón-Rodriguez,¹⁶⁹ K. K. Hill,²⁷ K. H. Hiller,⁴⁴ S. J. Hillier,¹⁹ M. Hils,⁴⁶ I. Hinchliffe,¹⁶ F. Hinterkeuser,²² M. Hirose,¹²⁸ S. Hirose,¹⁶⁴ D. Hirschbuehl,¹⁷⁷ B. Hiti,⁸⁹ O. Hladik,¹³⁶
J. Hobbs,¹⁵¹ R. Hobincu,^{25e} N. Hod,¹⁷⁵ M. C. Hodgkinson,¹⁴⁵ B. H. Hodkinson,³⁰ A. Hoecker,³⁴ J. Hofer,⁴⁴ D. Hohn,⁵⁰ J. Hobbs, ¹⁰ R. Hobincu, ¹⁰ N. Hod, ¹⁰ M. C. Hodgkinson, ¹⁰ B. H. Hodkinson, ¹⁰ A. Hoecker, ¹¹ J. Hofer, ¹⁰ D. Hohn, ¹¹ T. Holm, ²² T. R. Holmes, ³⁵ M. Holzbock, ¹¹² L. B. A. H. Hommels, ³⁰ B. P. Honan, ⁹⁸ T. M. Hong, ¹³⁴ J. C. Honig, ⁵⁰ A. Hönle, ¹¹² B. H. Hooberman, ¹⁶⁸ W. H. Hopkins, ⁵ Y. Horii, ¹¹³ P. Horn, ⁴⁶ L. A. Horyn, ³⁵ S. Hou, ¹⁵⁴ J. Howarth, ⁵⁵ J. Hoya, ⁸⁶ M. Hrabovsky, ¹²⁶ A. Hrynevich, ¹⁰⁶ T. Hryn'ova, ⁴ P. J. Hsu, ⁶¹ S.-C. Hsu, ¹⁴⁴ Q. Hu, ³⁷ S. Hu, ^{58c} Y. F. Hu, ^{13a,13d,x} D. P. Huang, ⁹² X. Huang, ^{13c} Y. Huang, ^{13a} Z. Hubacek, ¹³⁷ F. Hubaut, ⁹⁹ M. Huebner, ²² F. Huegging, ²² T. B. Huffman, ¹³⁰ M. Huhtinen, ³⁴ R. Hulsken, ⁵⁶ N. Huseynov, ^{77,y} J. Huston, ¹⁰⁴ J. Huth, ⁵⁷ R. Hyneman, ¹⁴⁹ S. Hyrych, ^{26a} G. Iacobucci, ⁵² R. Hubacker, ¹⁴⁷ R. Hubacker, ¹⁴⁷ P. Hubacker, ¹⁴⁸ P. Hyneman, ¹⁴⁹ S. Hyrych, ^{26a} G. Iacobucci, ⁵² P. F. Hubacker, ¹⁴⁷ P. Hubacker, ¹⁴⁸ P. Hyneman, ¹⁴⁹ P. Hyneman, ¹⁴⁹ P. Hubacker, ¹⁴⁷ P. Hubacker, ¹⁴⁸ P. Hubacker, ¹⁴⁸ P. Hubacker, ¹⁴⁸ P. Hubacker, ¹⁴⁸ P. Hyneman, ¹⁴⁹ P. Hubacker, ¹⁴⁸ P. Hubacker, ¹⁴⁸ P. Hubacker, ¹⁴⁹ P. Huba G. Iakovidis,²⁷ I. Ibragimov,¹⁴⁷ L. Iconomidou-Fayard,⁶² P. Iengo,³⁴ R. Ignazzi,³⁸ R. Iguchi,¹⁵⁹ T. Iizawa,⁵² Y. Ikegami,⁷⁹ N. Ilic,¹⁶² H. Imam,^{33a} T. Ingebretsen Carlson,^{43a,43b} G. Introzzi,^{68a,68b} M. Iodice,^{72a} V. Ippolito,^{70a,70b} M. Ishino,¹⁵⁹ W. Islam,¹²⁵ C. Issever,^{17,44} S. Istin,^{11c,z} J. M. Iturbe Ponce,^{60a} R. Iuppa,^{73a,73b} A. Ivina,¹⁷⁵ J. M. Izen,⁴¹ V. Izzo,^{67a} P. Jacka,¹³⁶ P. Jackson,¹ R. M. Jacobs,⁴⁴ B. P. Jaeger,¹⁴⁸ C. S. Jagfeld,¹¹¹ G. Jäkel,¹⁷⁷ K. B. Jakobi,⁹⁷ K. Jakobs,⁵⁰ T. Jakoubek,¹⁷⁵ J. Jamieson, ⁵⁵ K. W. Janas, ^{81a} G. Jarlskog, ⁹⁴ A. E. Jaspan, ⁸⁸ N. Javadov, ^{77.y} T. Javůrek, ³⁴ M. Javurkova, ¹⁰⁰ F. Jeanneau, ¹⁴⁰ L. Jeanty, ¹²⁷ J. Jejelava, ^{155a} P. Jenni, ^{50,aa} S. Jézéquel, ⁴ J. Jia, ¹⁵¹ Z. Jia, ^{13c} Y. Jiang, ^{58a} S. Jiggins, ⁵⁰ J. Jimenez Pena, ¹¹² S. Jin, ^{13c} A. Jinaru, ^{25b} O. Jinnouchi, ¹⁶⁰ H. Jivan, ^{31f} P. Johansson, ¹⁴⁵ K. A. Johns, ⁶ C. A. Johnson, ⁶³ E. Jones, ¹⁷³ R. W. L. Jones, ⁸⁷ T. J. Jones, ⁸⁸ J. Jovicevic, ⁵¹ X. Ju, ¹⁶ J. J. Junggeburth, ³⁴ A. Juste Rozas, ^{12,u} A. Kaczmarska, ⁸² M. Kado, ^{70a,70b} H. Kagan, ¹²³ M. Kagan, ¹⁴⁹ A. Kahn, ³⁷ C. Kahra, ⁹⁷ T. Kaji, ¹⁷⁴ E. Kajomovitz, ¹⁵⁶ C. W. Kalderon, ²⁷ A. Kaluza, ⁹⁷ A. Kamenshchikov, ¹¹⁹ M. Kagan, ¹⁴¹ S. Kang, ⁷⁶ Y. Kaji, ¹⁷⁴ E. Kajomovitz, ¹⁵⁶ C. W. Kalderon, ²⁷ A. Kaluza, ⁹⁷ A. Kamenshchikov, ¹¹⁹ M. Kagan, ¹⁴¹ S. Kang, ⁷⁶ Y. Kaji, ¹¹³ J. Kang, ¹¹³ J. Kaji, ¹⁷⁴ B. Kaji, ¹⁷⁴ D. Kaji, ¹⁷⁵ D. Kaji, ¹⁷⁵ D. Kaji, ¹⁷⁴ D. Kaji, ¹⁷⁴ D. Kaji, ¹⁷⁴ D. Kaji, ¹⁷⁴ D. Kaji, ¹⁷⁵ D. Kaji, ¹⁷⁶ D. Kaji, ¹⁷⁴ D. Kaji, ¹⁷⁴ D. Kaji, ¹⁷⁴ D. Kaji, ¹⁷⁴ D. Kaji, ¹⁷⁵ D. Kaji, ¹⁷⁵ D. Kaji, ¹⁷⁶ D. Kaji, ¹⁷⁶ D. Kaji, ¹⁷⁵ D. Kaji, ¹⁷⁶ D. Kaji, ¹⁷⁸ D. Kaji, ¹⁷⁸ D. Kaji, ¹⁷⁸ D. Kaji, ¹⁷⁸ D. Kaji, ¹⁷⁹ D. Ka M. Kaneda,¹⁵⁹ N. J. Kang,¹⁴¹ S. Kang,⁷⁶ Y. Kano,¹¹³ J. Kanzaki,⁷⁹ D. Kar,^{31f} K. Karava,¹³⁰ M. J. Kareem,^{163b} I. Karkanias,¹⁵⁸ Kancua, N. J. Kang, S. Kang, T. Kano, J. Kano, J. Kanzaki, D. Kai, K. Karava, M. J. Karceni, T. Karkanas, S. N. Karpov,⁷⁷ Z. M. Karpova,⁷⁷ V. Kartvelishvili,⁸⁷ A. N. Karyukhin,¹¹⁹ E. Kasimi,¹⁵⁸ C. Kato,^{58d} J. Katzy,⁴⁴
K. Kawade,¹⁴⁶ K. Kawagoe,⁸⁵ T. Kawaguchi,¹¹³ T. Kawamoto,¹⁴⁰ G. Kawamura,⁵¹ E. F. Kay,¹⁷¹ F. I. Kaya,¹⁶⁵ S. Kazakos,¹²
V. F. Kazanin,^{118b,118a} Y. Ke,¹⁵¹ J. M. Keaveney,^{31a} R. Keeler,¹⁷¹ J. S. Keller,³² D. Kelsey,¹⁵² J. J. Kempster,¹⁹ J. Kendrick,¹⁹
K. E. Kennedy,³⁷ O. Kepka,¹³⁶ S. Kersten,¹⁷⁷ B. P. Kerševan,⁸⁹ S. Ketabchi Haghighat,¹⁶² M. Khandoga,¹³¹ A. Khanov,¹²⁵ K. E. Kennedy,³⁷ O. Kepka,¹³⁶ S. Kersten,¹⁷⁷ B. P. Kerševan,⁸⁹ S. Ketabchi Haghighat,¹⁶² M. Khandoga,¹³¹ A. Khanov,¹²⁵ A. G. Kharlamov,^{118b,118a} T. Kharlamova,^{118b,118a} E. E. Khoda,¹⁷⁰ T. J. Khoo,¹⁷ G. Khoriauli,¹⁷² E. Khramov,⁷⁷ J. Khubua,^{155b} S. Kido,⁸⁰ M. Kiehn,³⁴ A. Kilgallon,¹²⁷ E. Kim,¹⁶⁰ Y. K. Kim,³⁵ N. Kimura,⁹² A. Kirchhoff,⁵¹ D. Kirchmeier,⁴⁶ J. Kirk,¹³⁹ A. E. Kiryunin,¹¹² T. Kishimoto,¹⁵⁹ D. P. Kisliuk,¹⁶² V. Kitali,⁴⁴ C. Kitsaki,⁹ O. Kivernyk,²² T. Klapdor-Kleingrothaus,⁵⁰ M. Klassen,^{59a} C. Klein,³² L. Klein,¹⁷² M. H. Klein,¹⁰³ M. Klein,⁸⁸ U. Klein,⁸⁸ P. Klimek,³⁴ A. Klimentov,²⁷ F. Klimpel,³⁴ T. Klingl,²² T. Klioutchnikova,³⁴ F. F. Klitzner,¹¹¹ P. Kluit,¹¹⁶ S. Kluth,¹¹² E. Kneringer,⁷⁴ T. M. Knight,¹⁶² A. Knue,⁵⁰ D. Kobayashi,⁸⁵ M. Kobel,⁴⁶ M. Kocian,¹⁴⁹ T. Kodama,¹⁵⁹ P. Kodys,¹³⁹ D. M. Koeck,¹⁵² P. T. Koenig,²² T. Koffas,³² N. M. Köhler,³⁴ M. Kolb,¹⁴⁰ I. Koletsou,⁴ T. Komarek,¹²⁶ K. Köneke,⁵⁰ A. X. Y. Kong,¹ T. Kono,¹²² V. Konstantinides,⁹² N. Korstantinidis,⁹² B. Konya,⁹⁴ R. Kopeliansky,⁶³ S. Koperny,^{81a} K. Korcyl,⁸² K. Kordas,¹⁵⁸ G. Kortner,¹¹² V. Kostyukhin,^{145,161} A. Kotsokechagia,⁶² A. Kotwal,⁴⁷ A. Koulouris,³⁴ A. Kourkoumeli-Charalampidi,^{68a,68b} C. Kourkoumelis,⁸ F. Kourlitis,⁵ R. Kowalewski,¹⁷¹ W. Kozanecki,¹⁴⁰ A. S. Kozhin,¹¹⁹ V. A. Kramarenko,¹¹⁰ C. Kourkoumelis,⁸ E. Kourlitis,⁵ R. Kowalewski,¹⁷¹ W. Kozanecki,¹⁴⁰ A. S. Kozhin,¹¹⁹ V. A. Kramarenko,¹¹⁰ G. Kramberger,⁸⁹ D. Krasnopevtsev,^{58a} M. W. Krasny,¹³¹ A. Krasznahorkay,³⁴ J. A. Kremer,⁹⁷ J. Kretzschmar,⁸⁸ K. Kreul,¹⁷ P. Krieger,¹⁶² F. Krieter,¹¹¹ S. Krishnamurthy,¹⁰⁰ A. Krishnan,^{59b} M. Krivos,¹³⁸ K. Krizka,¹⁶ K. Kroeninger,⁴⁵ H. Kroha,¹¹² J. Kroll,¹³⁶ J. Kroll,¹³² K. S. Krowpman,¹⁰⁴ U. Kruchonak,⁷⁷ H. Krüger,²² N. Krumnack,⁷⁶ M. C. Kruse,⁴⁷ J. A. Krzysiak,⁸² A. Kubota,¹⁶⁰ O. Kuchinskaia,¹⁶¹ S. Kuday,^{3b} D. Kuechler,⁴⁴ J. T. Kuechler,⁴⁴ S. Kuehn,³⁴ T. Kuhl,⁴⁴ V. Kukhtin,⁷⁷ Y. Kulchitsky,^{105,bb} S. Kuleshov,^{142c} M. Kumar,^{31f} N. Kumari,⁹⁹ M. Kuna,⁵⁶ A. Kupco,¹³⁶ T. Kupfer,⁴⁵ O. Kuprash,⁵⁰ H. Kurashige,⁸⁰ L. L. Kurchaninov,^{163a} Y. A. Kurochkin,¹⁰⁵ A. Kurova,¹⁰⁹ M. G. Kurth,^{13a,13d} E. S. Kuwertz,³⁴ M. Kuze,¹⁶⁰ A. K. Kvam,¹⁴⁴ J. Kvita,¹²⁶ T. Kwan,¹⁰¹ C. Lacasta,¹⁷⁰ F. Lacava,^{70a,70b} H. Lacker,¹⁷ D. Lacour,¹³¹ N. N. Lad,⁹² E. Ladygin,⁷⁷

R. Lafaye,⁴ B. Laforge,¹³¹ T. Lagouri,^{142d} S. Lai,⁵¹ I. K. Lakomiec,^{81a} N. Lalloue,⁵⁶ J. E. Lambert,¹²⁴ S. Lammers,⁶³ W. Lampl,⁶ C. Lampoudis,¹⁵⁸ E. Lançon,²⁷ U. Landgraf,⁵⁰ M. P. J. Landon,⁹⁰ V. S. Lang,⁵⁰ J. C. Lange,⁵¹ R. J. Langenberg,¹⁰⁰ A. J. Lankford,¹⁶⁶ F. Lanni,²⁷ K. Lantzsch,²² A. Lanza,^{68a} A. Lapertosa,^{53b,53a} J. F. Laporte,¹⁴⁰ T. Lari,^{66a} K. J. Langenoerg, A. J. Lankfold, F. Lanni, K. Lantzsch, A. Lanza, A. Lapertosa, M. J. F. Laporte, T. Lari, ⁴⁴ P. Lebert, ¹⁶ K. Lehmann, ¹⁸ N. Lebedev, ⁷⁶ M. LeBlanc, ³⁴ W. A. Leight, ⁴⁴ A. Leisos, ¹⁵⁸ C. Lebert, ¹⁸ G. Lehmann, ¹⁸ G. Lehmann Miotto, ³⁴ W. A. Leight, ⁴⁴ A. Leisos, ¹⁸ M. Letebvre, ¹⁷ C. Leggett, ¹⁷ K. Lehmann, ¹⁷ N. Lehmann, ¹⁶ O. Lemann, ¹⁶ O. Lemann, ¹⁶ N. Leinson, ¹⁷ C. E. Leight, ¹⁷ A. Leisos, ¹⁸
M. A. L. Leit, ⁷⁸ C. E. Leitgeb, ⁴⁴ R. Leitner, ¹³⁸ K. J. C. Leney, ⁴⁰ T. Lenz, ²² S. Leone, ⁶⁹ a. C. Leonidopoulos, ⁴⁸ A. Leopold, ¹³¹
C. Leroy, ¹⁰⁷ R. Les, ¹⁰⁴ C. G. Lester, ³⁰ M. Levchenko, ¹³³ J. Levôque, ⁴ D. Levin, ¹⁰³ L. J. Levinson, ¹⁷⁵ D. J. Lewis, ¹⁹ B. Li, ¹³⁶
B. Li, ⁵⁸⁶ C. Q. Li, ⁵⁸⁶ C. Q. Li, ⁵⁸⁶ S. H. Li, ⁵⁸⁴ H. Li, ⁵⁸⁴ J. Li, ⁵⁸⁶ K. Li, ¹¹⁴ L. Li, ⁵⁸⁴ A. Li, ⁵⁸⁴ S. Li, ¹¹³⁰ Z. Li, ¹¹⁰ Z. Li, ¹¹⁰ Z. Li, ⁸⁸ Z. Liang, ^{13a} M. Liberatore, ⁴⁴ B. Liberti, ⁷¹⁴ K. Lie, ^{60c} K. Lin, ¹⁰⁴ R. A. Linck, ⁶³
R. E. Lindley, ⁶ J. H. Lindon, ² A. Linss, ⁴⁴ A. L. Lionti, ⁵² E. Lipeles, ¹³² A. Lipniacka, ¹⁵ T. M. Liss, ^{168,ce} A. Lister, ¹⁷⁰
J. D. Little, ⁷ B. Liu, ^{13a} B. X. Liu, ¹⁴⁸ J. B. Liu, ^{58a} M. Livan, ^{68a,68b} A. Lleres, ⁵⁶ J. Llorente Merino, ¹⁴⁸ S. L. Lloyd, ⁹⁰
E. M. Lobodzinska, ⁴⁴ P. Loch, ⁶ S. Loffredo, ^{71a,71b} T. Lohse, ¹⁷ K. Lohwasser, ¹⁴⁵ M. Lokajicek, ¹³⁶ J. D. Long, ¹⁶⁸ R. E. Long, ⁸⁷
I. Longarini, ^{70a,70b} L. Longo, ³⁴ R. Longo, ¹⁶⁸ I. Lopez Paz, ¹² A. Lopez Solis, ⁴⁴ J. Lorenz, ¹¹¹ N. Lorenzo Martinez, ⁴
A. M. Lory, ¹¹¹ A. Lösle, ⁵⁰ X. Lou, ^{43a,43b} X. Lou, ^{13a} A. Lounis, ⁶² J. Love, ⁵ P. A. Love, ⁸⁷ J. J. Lozano Bahilo, ¹⁶⁹ G. Lu, ^{13a}
M. Lu, ^{58a} S. Lu, ¹³² Y. J. Lu, ⁶¹ H. J. Lubatti, ¹⁴⁴ C. Luci, ^{70a,70b} F.L. Lucio Alves, ¹³² A. Licote, ⁵⁶ F. Luchring, ⁶³ I. Luise, ¹⁵¹
L. Luminari, ^{70a} B. Lund-Jensen, ¹⁵⁰ N. A. Luongo, ¹²⁷ M. S. Lutz, ¹⁵⁷ D. Lynn, ²⁷ H. Lyons, ⁸⁸ R. Lysak, ¹³⁶ E. Lytken, ⁹⁴
F. Lyu, ^{13a} V. Lyubushkina, ⁷⁷ H. Ma, ²⁷ L. L. Ma, ^{58b} Y. Ma, ⁹² D. M. Mac Donell, ¹⁷¹ G. Maccarrone, ⁴⁹
C. M. Macdonald, ¹⁴⁵ J. C. MacDonald, ¹⁴⁵ R. M. A. L. Leite,^{78c} C. E. Leitgeb,⁴⁴ R. Leitner,¹³⁸ K. J. C. Leney,⁴⁰ T. Lenz,²² S. Leone,^{69a} C. Leonidopoulos,⁴⁸ A. Leopold,¹³¹ T. A. Martin,¹⁷³ V. J. Martin,⁴⁸ B. Martin dit Latour,¹⁵ L. Martinelli,^{70a,70b} M. Martinez,^{12,u} P. Martinez Agullo,¹⁶⁹ V. I. Martine, ¹⁰⁰ S. Martin-Haugh, ¹³⁹ V. S. Martoiu, ^{25b} A. C. Martyniuk, ⁹² A. Marzin, ³⁴ S. R. Maschek, ¹¹² L. Masetti, ⁹⁷ T. Mashimo, ¹⁵⁹ J. Masik, ⁹⁸ A. L. Maslennikov, ^{118b,118a} L. Massa, ^{21b,21a} P. Massarotti, ^{67a,67b} P. Mastrandrea, ^{69a,69b} A. Mastroberardino, ^{39b,39a} T. Masubuchi, ¹⁵⁹ D. Matakias, ²⁷ T. Mathisen, ¹⁶⁷ A. Matic, ¹¹¹ N. Matsuzawa,¹⁵⁹ J. Maurer,^{25b} B. Maček,⁸⁹ D. A. Maximov,^{118b,118a} R. Mazini,¹⁵⁴ I. Maznas,¹⁵⁸ S. M. Mazza,¹⁴¹ C. Mc Ginn,²⁷ J. P. Mc Gowan,¹⁰¹ S. P. Mc Kee,¹⁰³ T. G. McCarthy,¹¹² W. P. McCormack,¹⁶ E. F. McDonald,¹⁰² A. E. McDougall,¹¹⁶ J. A. Mcfayden,¹⁵² G. Mchedlidze,^{155b} M. A. McKay,⁴⁰ K. D. McLean,¹⁷¹ S. J. McMahon,¹³⁹ P. C. McNamara,¹⁰² R. A. McPherson,^{171,m} J. E. Mdhluli,^{31f} Z. A. Meadows,¹⁰⁰ S. Meehan,³⁴ T. Megy,³⁶ S. Mehlhase,¹¹¹ A. Mehta,⁸⁸ B. Meirose,⁴¹ D. Melini,¹⁵⁶ B. R. Mellado Garcia,^{31f} F. Meloni,⁴⁴ A. Melzer,²² E. D. Mendes Gouveia,^{135a} A. M. Mendes Jacques Da Costa,¹⁹ H. Y. Meng,¹⁶² L. Meng,³⁴ S. Menke,¹¹² M. Mentink,³⁴ E. Meoni,^{39b,39a} S. A. M. Merkt,¹³⁴ C. Merlassino,¹³⁰ P. Mermod,^{52,a} L. Merola,^{67a,67b} C. Meroni,^{66a} G. Merz,¹⁰³ O. Meshkov,^{110,108} J. K. R. Meshreki,¹⁴⁸ J. Metcalfe,⁵ A. S. Mete,⁵ C. Meyer,⁶³ J-P. Meyer,¹⁴⁰ M. Michetti,¹⁷ R. P. Middleton,¹³⁹ L. Mijović,⁴⁸ G. Mikenberg,¹⁷⁵ M. Mikestikova,¹³⁶ M. Mikuž,⁸⁹ H. Mildner,¹⁴⁵ A. Milic,¹⁶² C. D. Milke,⁴⁰ D. W. Miller,³⁵ L. S. Miller,³² A. Milov,¹⁷⁵ D. A. Milstead,^{43a,43b} A. A. Minaenko,¹¹⁹ I. A. Minashvili,^{155b} L. Mince,⁵⁵ A. I. Mincer,¹²¹ B. Mindur,^{81a} M. Mineev,⁷⁷ Y. Minegishi,¹⁵⁹ Y. Mino,⁸³ L. M. Mir,¹² M. Miralles Lopez,¹⁶⁹ M. Mironova,¹³⁰ T. Mitani,¹⁷⁴ V. A. Mitsou,¹⁶⁹ M. Mittal,^{58c} O. Miu,¹⁶² P. S. Miyagawa,⁹⁰ Y. Miyazaki,⁸⁵ A. Mizukami,⁷⁹ J. U. Mjörnmark,⁹⁴ T. Mkrtchyan,^{59a} M. Miynarikova, ¹¹⁷ T. Moa, ^{43a,43b} S. Mobius, ⁵¹ K. Mochizuki, ¹⁰⁷ P. Moder, ⁴⁴ P. Mogg, ¹¹¹ A. F. Mohammed, ^{13a}
S. Mohapatra, ³⁷ G. Mokgatitswane, ^{31f} B. Mondal, ¹⁴⁷ S. Mondal, ¹³⁷ K. Mönig, ⁴⁴ E. Monnier, ⁹⁹ A. Montalbano, ¹⁴⁸ J. Montejo Berlingen, ³⁴ M. Montella, ¹²³ F. Monticelli, ⁸⁶ N. Morange, ⁶² A. L. Moreira De Carvalho, ^{135a} M. Moreno Llácer, ¹⁶⁹ C. Moreno Martinez, ¹² P. Morettini, ^{53b} M. Morgenstern, ¹⁵⁶ S. Morgenstern, ¹⁷³ D. Mori, ¹⁴⁸ M. Morii, ⁵⁷ M. Morinaga, ¹⁵⁹ V. Morisbak, ¹²⁹ A. K. Morley, ³⁴ A. P. Morris, ⁹² L. Morvaj, ³⁴ P. Moschovakos, ³⁴ B. Moser, ¹¹⁶ M. Mosidze, ^{155b} T. Moskalets, ⁵⁰ P. Moskvitina, ¹¹⁵ J. Moss, ^{29,ff} E. J. W. Moyse, ¹⁰⁰ S. Muanza, ⁹⁹ J. Mueller, ¹³⁴

D. Muenstermann,⁸⁷ G. A. Mullier,⁹⁴ J. J. Mullin,¹³² D. P. Mungo,^{66a,66b} J. L. Munoz Martinez,¹² F. J. Munoz Sanchez,⁹⁸ M. Murin,⁹⁸ P. Murin,^{26b} W. J. Murray,^{173,139} A. Murrone,^{66a,66b} J. M. Muse,¹²⁴ M. Muškinja,¹⁶ C. Mwewa,²⁷ A. G. Myagkov,^{119,i} A. A. Myers,¹³⁴ G. Myers,⁶³ M. Myska,¹³⁷ B. P. Nachman,¹⁶ O. Nackenhorst,⁴⁵ A. Nag Nag,⁴⁶ K. Nagai,¹³⁰ K. Nagano,⁷⁹ J. L. Nagle,²⁷ E. Nagy,⁹⁹ A. M. Nairz,³⁴ Y. Nakahama,¹¹³ K. Nakamura,⁷⁹ H. Nanjo,¹²⁸ F. Napolitano,^{59a} R. Narayan,⁴⁰ I. Naryshkin,¹³³ M. Naseri,³² C. Nass,²² T. Naumann,⁴⁴ G. Navarro,^{20a} F. Napolitano, ^{59a} R. Narayan, ⁴⁰ I. Naryshkin, ¹³³ M. Naseri, ³² C. Nass, ²² T. Naumann, ⁴⁴ G. Navarro, ^{20a}
J. Navarro-Gonzalez, ¹⁶⁹ P. Y. Nechaeva, ¹⁰⁸ F. Nechansky, ⁴⁴ T. J. Neep, ¹⁹ A. Negri, ^{68a,68b} M. Negrini, ^{21b} C. Nellist, ¹¹⁵ C. Nelson, ¹⁰¹ K. Nelson, ¹⁰³ M. E. Nelson, ^{43a,43b} S. Nemecek, ¹³⁶ M. Nessi, ^{34,gg} M. S. Neubauer, ¹⁶⁸ F. Neuhaus, ⁹⁷
J. Neundorf, ⁴⁴ R. Newhouse, ¹⁷⁰ P. R. Newman, ¹⁹ C. W. Ng, ¹³⁴ Y. S. Ng, ¹⁷ Y. W. Y. Ng, ¹⁶⁶ B. Ngair, ^{33e} H. D. N. Nguyen, ⁹⁹
T. Nguyen Manh, ¹⁰⁷ R. B. Nickerson, ¹³⁰ R. Nicolaidou, ¹⁴⁰ D. S. Nielsen, ³⁸ J. Nielsen, ¹⁴¹ M. Niemeyer, ⁵¹ N. Nikiforou, ¹⁰
V. Nikolaenko, ^{119,i} I. Nikolic-Audit, ¹³¹ K. Nikolopoulos, ¹⁹ P. Nilsson, ²⁷ H. R. Nindhito, ⁵² A. Nisati, ^{70a} N. Nishu, ²
R. B. Norisam, ⁹² J. Novak, ⁸⁹ T. Novak, ⁴⁴ O. Novgorodova, ⁴⁶ L. Novotny, ¹³⁷ R. Novotny, ¹¹⁴ L. Nozka, ¹²⁶ K. Ntekas, ¹⁶⁶
E. Nurse, ⁹² F. G. Oakham, ^{32,e} J. Ocariz, ¹³¹ A. Ochi, ⁸⁰ I. Ochoa, ^{13a} J. P. Ochoa-Ricoux, ^{142a} K. O'Connor, ²⁴ S. Oda, ⁸⁵
S. Odaka, ⁷⁹ S. Oerdek, ¹⁶⁷ A. Ogrodnik, ^{81a} A. Oh, ⁹⁸ C. C. Ohm, ¹⁵⁰ H. Oide, ¹⁶⁰ R. Oishi, ¹⁵⁹ M. L. Ojeda, ¹⁶² Y. Okazaki, ⁸³
M. W. O'Keefe, ⁸⁸ Y. Okumura, ¹⁵⁹ A. Olariu, ^{25b} L. F. Oleiro Seabra, ^{135a} S. A. Olivares Pino, ^{142d} D. Oliveira Damazio, ²⁷
D. Oliveira Goncalves, ^{78a} J. L. Oliver, ¹ M. J. R. Olsson, ¹⁶⁶ A. Olszewski, ⁸² J. Olszowska, ⁸² Ö. O. Öncel, ²² D. C. O'Neil, ¹⁴⁸
A. P. O'neill, ¹³⁰ A. Onofre, ^{135a,135e} P. U. E. Onyisi, ¹⁰ H. Oppen, ¹²⁹ R. G. Oreamuno Madriz, ¹¹⁷ M. J. Oreglia, ³⁵ A. P. O'neill,¹³⁰ A. Onofre,^{135a,135e} P. U. E. Onyisi,¹⁰ H. Oppen,¹²⁹ R. G. Oreamuno Madriz,¹¹⁷ M. J. Oreglia,³⁵ G. E. Orellana,⁸⁶ D. Orestano,^{72a,72b} N. Orlando,¹² R. S. Orr,¹⁶² V. O'Shea,⁵⁵ R. Ospanov,^{58a} G. Otero y Garzon,²⁸ H. Otono,⁸⁵ P. S. Ott,^{59a} G. J. Ottino,¹⁶ M. Ouchrif,^{33d} J. Ouellette,²⁷ F. Ould-Saada,¹²⁹ A. Ouraou,^{140,a} Q. Ouyang,^{13a} M. Owen,⁵⁵ R. E. Owen,¹³⁹ V. E. Ozcan,^{11c} N. Ozturk,⁷ S. Ozturk,^{11c} J. Pacalt,¹²⁶ H. A. Pacey,³⁰ K. Pachal,⁴⁷ A. Pacheco Pages,¹² C. Padilla Aranda,¹² S. Pagan Griso,¹⁶ G. Palacino,⁶³ S. Palazzo,⁴⁸ S. Palestini,³⁴ M. Palka,^{81b} P. Palni,^{81a} D. K. Panchal,¹⁰ C. E. Pandini,⁵² J. G. Panduro Vazquez,⁹¹ P. Pani,⁴⁴ G. Panizzo,^{64a,64c} L. Paolozzi,⁵² C. Papadatos,¹⁰⁷ S. Parajuli,⁴⁰ A. Paramonov,⁵ C. Paraskevopoulos,⁹ D. Paredes Hernandez,^{60b} S. R. Paredes Saenz,¹³⁰ B. Parida,¹⁷⁵ T. H. Park,¹⁶² A. J. Parker,²⁹ M. A. Parker,³⁰ F. Parodi,^{53b,53a} E. W. Parrish,¹¹⁷ J. A. Parsons,³⁷ U. Parzefall,⁵⁰ L. Pascual Dominguez,¹⁵⁷ V. R. Pascuzzi,¹⁶ F. Pasquali,¹¹⁶ E. Pasqualucci,^{70a} S. Passaggio,^{53b} F. Pastore,⁹¹ P. Pasuwan,^{43a,43b} J. R. Pater,⁹⁸ A. Pathak,¹⁷⁶ J. Patton,⁸⁸ T. Pauly,³⁴ J. Pearkes,¹⁴⁹ M. Pedersen,¹²⁹ L. Pedraza Diaz,¹¹⁵ R. Pedro,^{135a} T. Peiffer,⁵¹ J. R. Pater, ⁹⁸ A. Pathak, ¹⁷⁶ J. Patton, ⁸⁸ T. Pauly, ³⁴ J. Pearkes, ¹⁴⁹ M. Pedersen, ¹²⁹ L. Pedraza Diaz, ¹¹⁵ R. Pedro, ^{135a} T. Peiffer, ⁵¹ S. V. Peleganchuk, ^{118b,118a} O. Penc, ¹³⁶ C. Peng, ^{60b} H. Peng, ^{58a} M. Penzin, ¹⁶¹ B. S. Peralva, ^{78a} M. M. Perego, ⁶² A. P. Pereira Peixoto, ^{135a} L. Pereira Sanchez, ^{43a,43b} D. V. Perepelitsa, ²⁷ E. Perez Codina, ^{163a} M. Perganti, ⁹ L. Perini, ^{66a,66b} H. Pernegger, ³⁴ S. Perrella, ³⁴ A. Perrevoort, ¹¹⁵ K. Peters, ⁴⁴ R. F. Y. Peters, ⁹⁸ B. A. Petersen, ³⁴ T. C. Petersen, ³⁸ E. Petit, ⁹⁹ V. Petousis, ¹³⁷ C. Petridou, ¹⁵⁸ P. Petroff, ⁶² F. Petrucci, ^{72a,72b} M. Pettee, ¹⁷⁸ N. E. Pettersson, ³⁴ K. Petukhova, ¹³⁸ A. Peyaud, ¹⁴⁰ R. Pezoa, ^{142e} L. Pezzotti, ^{68a,68b} G. Pezzullo, ¹⁷⁸ T. Pham, ¹⁰² P. W. Phillips, ¹³⁹ M. W. Phipps, ¹⁶⁸ G. Piacquadio, ¹⁵¹ E. Pianori, ¹⁶ F. Piazza, ^{66a,66b} A. Picazio, ¹⁰⁰ R. Piegaia, ²⁸ D. Pietreanu, ^{25b} J. E. Pilcher, ³⁵ A. D. Pilkington, ⁹⁸ M. Pinamonti, ^{64a,64c} J. L. Pinfold, ² C. Pitman Donaldson, ⁹² D. A. Pizzi, ³² L. Pizzimento, ^{71a,71b} A. Pizzini, ¹¹⁶ M.-A. Pleier, ²⁷ V. Plesanovs, ⁵⁰ V. Pleskot, ¹³⁸ E. Plotnikova, ⁷⁷ P. Podberezko, ^{118b,118a} R. Poettgen, ⁹⁴ R. Poggi, ⁵² L. Poggioli, ¹³¹ I. Pogrebnyak, ¹⁰⁴ D. Pohl, ²² I. Pokharel, ⁵¹ G. Polesello, ^{68a} A. Poley, ^{148,163a} A. Policicchio, ^{70a,70b} R. Polifka, ¹³⁸ A. Polini, ^{21b} C. S. Pollard, ⁴⁴ Z. B. Pollock, ¹²³ V. Polychronakos, ²⁷ D. Ponomarenko, ¹⁰⁹ L. Pontecorvo, ³⁴ S. Popa, ^{25a} G. A. Popeneciu, ^{25d} L. Portales, ⁴ J. Poveda, ¹⁶⁹ T. D. Powell, ¹⁴⁵ G. Pownall, ⁴⁴ M. E. Pozo Astigarraga, ³⁴ A. Prades Ibanez, ¹⁶⁹ P. Pralavorio, ⁹⁹ T. Poulsen,⁴⁴ J. Poveda,¹⁶⁹ T. D. Powell,¹⁴⁵ G. Pownall,⁴⁴ M. E. Pozo Astigarraga,³⁴ A. Prades Ibanez,¹⁶⁹ P. Pralavorio,⁹⁹ M. M. Prapa,⁴² S. Prell,⁷⁶ D. Price,⁹⁸ M. Primavera,^{65a} M. A. Principe Martin,⁹⁶ M. L. Proffitt,¹⁴⁵ N. Proklova,¹⁰⁹ K. Prokofiev, ^{60c} F. Prokoshin,⁷⁷ S. Protopopescu,²⁷ J. Proudfoot,⁵ M. Przybycien,^{81a} D. Pudzha,¹³⁴ P. Puzo,⁶²
D. Pyatiizbyantseva,¹⁰⁹ J. Qian,¹⁰³ Y. Qin,⁹⁸ A. Quadt,⁵¹ M. Queitsch-Maitland,³⁴ G. Rabanal Bolanos,⁵⁷ F. Ragusa,^{66a,66b}
G. Rahal,⁹⁵ J. A. Raine,⁵² S. Rajagopalan,²⁷ K. Ran,^{13a,13d} D. F. Rassloff,^{59a} D. M. Rauch,⁴⁴ S. Rave,⁹⁷ B. Ravina,⁵⁵
I. Ravinovich,¹⁷⁵ M. Raymond,³⁴ A. L. Read,¹²⁹ N. P. Readioff,¹⁴⁵ D. M. Rebuzzi,^{68a,68b} G. Redlinger,²⁷ K. Reeves,⁴¹ D. Reikher, ¹⁵⁷ A. Reis, ⁹⁷ A. Rej, ¹⁴⁷ C. Rembser, ³⁴ A. Renardi, ⁴⁴ M. Renda, ^{25b} M. B. Rendel, ¹¹² A. G. Rennie, ⁵⁵ S. Resconi, ^{66a} E. D. Resseguie, ¹⁶ S. Rettie, ⁹² B. Reynolds, ¹²³ E. Reynolds, ¹⁹ M. Rezaei Estabragh, ¹⁷⁷
 O. L. Rezanova, ^{118b,118a} P. Reznicek, ¹³⁸ E. Ricci, ^{73a,73b} R. Richter, ¹¹² S. Richter, ⁴⁴ E. Richter-Was, ^{81b} M. Ridel, ¹³¹ P. Rieck,¹¹² P. Riedler,³⁴ O. Rifki,⁴⁴ M. Rijssenbeek,¹⁵¹ A. Rimoldi,^{68a,68b} M. Rimoldi,⁴⁴ L. Rinaldi,^{21b} T. T. Rinn,¹⁶⁸ M. P. Rinnagel,¹¹¹ G. Ripellino,¹⁵⁰ I. Riu,¹² P. Rivadeneira,⁴⁴ J. C. Rivera Vergara,¹⁷¹ F. Rizatdinova,¹²⁵ E. Rizvi,⁹⁰ C. Rizzi,⁵² B. A. Roberts,¹⁷³ S. H. Robertson,^{101,m} M. Robin,⁴⁴ D. Robinson,³⁰ C. M. Robles Gajardo,^{142e}

M. Robles Manzano,⁹⁷ A. Robson,⁵⁵ A. Rocchi,^{71a,71b} C. Roda,^{69a,69b} S. Rodriguez Bosca,^{59a} A. Rodriguez Rodriguez,⁵⁰ A. M. Rodríguez Vera,^{163b} S. Roe,³⁴ J. Roggel,¹⁷⁷ O. Røhne,¹²⁹ R. A. Rojas,^{142e} B. Roland,⁵⁰ C. P. A. Roland,⁶³ J. Roloff,²⁷
A. Romaniouk,¹⁰⁹ M. Romano,^{21b,21a} N. Rompotis,⁸⁸ M. Ronzani,¹²¹ L. Roos,¹³¹ S. Rosati,^{70a} G. Rosin,¹⁰⁰ B. J. Rosser,¹³²
E. Rossi,¹⁶² E. Rossi,⁴ E. Rossi,^{67a,67b} L. P. Rossi,^{53b} L. Rossin,⁴⁴ R. Rosten,¹²³ M. Rotaru,^{25b} B. Rottler,⁵⁰ D. Rousseau,⁶²
D. Rousso,³⁰ G. Rovelli,^{68a,68b} A. Roy,¹⁰ A. Rozanov,⁹⁹ Y. Rozen,¹⁵⁶ X. Ruan,^{31f} A. J. Ruby,⁸⁸ T. A. Ruggeri,¹ F. Rühr,⁵⁰ A. Ruiz-Martinez,¹⁶⁹ A. Rummler,³⁴ Z. Rurikova,⁵⁰ N. A. Rusakovich,⁷⁷ H. L. Russell,³⁴ L. Rustige,³⁶ J. P. Rutherfoord,⁶ E. M. Rüttinger,¹⁴⁵ M. Rybar,¹³⁸ E. B. Rye,¹²⁹ A. Ryzhov,¹¹⁹ J. A. Sabater Iglesias,⁴⁴ P. Sabatini,¹⁶⁹ L. Sabetta,^{70a,70b} H. F-W. Sadrozinski,¹⁴¹ R. Sadykov,⁷⁷ F. Safai Tehrani,^{70a} B. Safarzadeh Samani,¹⁵² M. Safdari,¹⁴⁹ P. Saha,¹¹⁷ S. Saha,¹⁰¹ M. Sahinsoy,¹¹² A. Sahu,¹⁷⁷ M. Saimpert,¹⁴⁰ M. Saito,¹⁵⁹ T. Saito,¹⁵⁹ D. Salamani,⁵² G. Salamanna,^{72a,72b} A. Salnikov,¹⁴⁹ M. Saninsoy, A. Sanu, M. Saninpert, M. Sano, T. Sano, D. Sananama, G. Sananama, A. Sannkov, J. Salt,¹⁶⁹ A. Salvador Salas,¹² D. Salvatore,^{39b,39a} F. Salvatore,¹⁵² A. Salzburger,³⁴ D. Sammel,⁵⁰ D. Sampsonidis,¹⁵⁸ D. Sampsonidou,^{58d,58c} J. Sánchez,¹⁶⁹ A. Sanchez Pineda,⁴ V. Sanchez Sebastian,¹⁶⁹ H. Sandaker,¹²⁹ C. O. Sander,⁴⁴ I. G. Sanderswood,⁸⁷ J. A. Sandesara,¹⁰⁰ M. Sandhoff,¹⁷⁷ C. Sandoval,^{20b} D. P. C. Sankey,¹³⁹ M. Sannino,^{53b,53a} Y. Sano,¹¹³ A. Sansoni,⁴⁹ C. Santoni,³⁶ H. Santos,^{136a,136b} S. N. Santpur,¹⁶ A. Santra,¹⁷⁵ K. A. Saoucha,¹⁴⁵ A. Sapronov,⁷⁷ A. Sansoni, ¹C. Santoni, ¹H. Santos, ¹S. N. Santpur, ^A. Santra, ^K. A. Saoucha, ^A. Sapronov, J. G. Saraiva, ^{135a,135d} O. Sasaki, ⁷⁹ K. Sato, ¹⁶⁴ C. Sauer, ^{59b} F. Sauerburger, ⁵⁰ E. Sauvan, ⁴ P. Savard, ^{162,e} R. Sawada, ¹⁵⁹ C. Sawyer, ¹³⁹ L. Sawyer, ⁹³ I. Sayago Galvan, ¹⁶⁹ C. Sbarra, ^{21b} A. Sbrizzi, ^{64a,64c} T. Scanlon, ⁹² J. Schaarschmidt, ¹⁴⁴ P. Schacht, ¹¹² D. Schaefer, ³⁵ L. Schaefer, ¹³² U. Schäfer, ⁹⁷ A. C. Schaffer, ⁶² D. Schaile, ¹¹¹ R. D. Schamberger, ¹⁵¹ E. Schanet, ¹¹¹ C. Scharf, ¹⁷ N. Scharmberg, ⁹⁸ V. A. Schegelsky, ¹³³ D. Scheirich, ¹³⁸ F. Schenck, ¹⁷ M. Schernau, ¹⁶⁶ C. Schiavi, ^{53b,53a} L. K. Schildgen,²² Z. M. Schillaci,²⁴ E. J. Schioppa,^{65a,65b} M. Schioppa,^{39b,39a} B. Schlag,⁹⁷ K. E. Schleicher,⁵⁰ S. Schlenker,³⁴ K. Schmieden,⁹⁷ C. Schmitt,⁹⁷ S. Schmitt,⁴⁴ L. Schoeffel,¹⁴⁰ A. Schoening,^{59b} P. G. Scholer,⁵⁰ E. Schopf,¹³⁰ M. Schott,⁹⁷ J. Schovancova,³⁴ S. Schramm,⁵² F. Schroeder,¹⁷⁷ H-C. Schultz-Coulon,^{59a} P. G. Scholer, "E. Schopf, "M. Schott, "J. Schovancova," S. Schramm, F. Schroeder, "H-C. Schultz-Coulon, "M. Schumacher,⁵⁰ B. A. Schumm,¹⁴¹ Ph. Schune,¹⁴⁰ A. Schwartzman,¹⁴⁹ T. A. Schwarz,¹⁰³ Ph. Schwemling,¹⁴⁰
R. Schwienhorst,¹⁰⁴ A. Sciandra,¹⁴¹ G. Sciolla,²⁴ F. Scuri,^{69a} F. Scutti,¹⁰² C. D. Sebastiani,⁸⁸ K. Sedlaczek,⁴⁵ P. Seema,¹⁷ S. C. Seidel,¹¹⁴ A. Seiden,¹⁴¹ B. D. Seidlitz,²⁷ T. Seiss,³⁵ C. Seitz,⁴⁴ J. M. Seixas,^{78b} G. Sekhniaidze,^{67a} S. J. Sekula,⁴⁰
L. P. Selem,⁴ N. Semprini-Cesari,^{21b,21a} S. Sen,⁴⁷ C. Serfon,²⁷ L. Serin,⁶² L. Serkin,^{64a,64b} M. Sessa,^{58a} H. Severini,¹²⁴ S. Sevova,¹⁴⁹ F. Sforza,^{53b,53a} A. Sfyrla,⁵² E. Shabalina,⁵¹ R. Shaheen,¹⁵⁰ J. D. Shahinian,¹³² N. W. Shaikh,^{43a,43b}
D. Shaked Renous,¹⁷⁵ L. Y. Shan,^{13a} M. Shapiro,¹⁶ A. Sharma,³⁴ A. S. Sharma,⁴ P. B. Shatalov,¹²⁰ K. Shaw,¹⁵² D. Shaked Kenous, L. I. Shan, W. Shapiro, A. Sharma, A. S. Sharma, S. Sharma, P. B. Shatalov, ¹² K. Shaw, ³²
S. M. Shaw, ⁹⁸ P. Sherwood, ⁹² L. Shi, ⁹² C. O. Shimmin, ¹⁷⁸ Y. Shimogama, ¹⁷⁴ J. D. Shinner, ⁹¹ I. P. J. Shipsey, ¹³⁰ S. Shirabe, ⁵²
M. Shiyakova, ⁷⁷ J. Shlomi, ¹⁷⁵ M. J. Shochet, ³⁵ J. Shojaii, ¹⁰² D. R. Shope, ¹⁵⁰ S. Shrestha, ¹²³ E. M. Shrif, ^{31f} M. J. Shroff, ¹⁷¹
E. Shulga, ¹⁷⁵ P. Sicho, ¹³⁶ A. M. Sickles, ¹⁶⁸ E. Sideras Haddad, ^{31f} O. Sidiropoulou, ³⁴ A. Sidoti, ^{21b,21a} F. Siegert, ⁴⁶
Dj. Sijacki, ¹⁴ M. V. Silva Oliveira, ³⁴ S. B. Silverstein, ^{43a} S. Simion, ⁶² R. Simoniello, ³⁴ S. Simsek, ^{11b} P. Sinervo, ¹⁶²
V. Sinetckii, ¹¹⁰ S. Singh, ¹⁴⁸ S. Sinha, ⁴⁴ S. Sinha, ^{31f} M. Sioli, ^{21b,21a} I. Siral, ¹²⁷ S. Yu. Sivoklokov, ¹¹⁰ J. Sjölin, ^{43a,43b} A. Skaf, ⁵¹
E. Shorda, ⁹⁴ P. Shubia, ¹²⁴ M. Shupingko, ⁸² K. Shupa, ¹⁶⁵ V. Smelhtin, ¹⁷⁵ P. U. Suvet, ¹³⁹ J. Suvet, ¹³⁹ J. Suvet, ¹³⁸ S. Y. S. ¹⁰⁹ V. Sinetckii, ¹¹⁰ S. Singh, ¹⁴⁸ S. Sinha, ⁴⁴ S. Sinha, ³¹⁷ M. Siol, ^{21b,21a} I. Siral, ¹²⁷ S. Yu. Sivoklokov, ¹¹⁰ J. Sjólin, ^{43a,43b} A. Skaf, ⁵¹
 E. Skorda, ⁹⁴ P. Skubic, ¹²⁴ M. Slawinska, ⁸² K. Sliwa, ¹⁶⁵ V. Smakhtin, ¹⁷⁵ B. H. Smart, ¹³⁰ J. Smiesko, ¹³⁸ S. Yu. Smirnov, ¹⁰⁹
 Y. Smirnov, ¹⁰⁹ L. N. Smirnova, ^{110,hh} O. Smirnova, ⁹⁴ E. A. Smith, ³⁵ H. A. Smith, ¹³⁰ M. Smizanska, ⁸⁷ K. Smolek, ¹³⁷
 A. Smykiewicz, ⁸² A. A. Snesarev, ¹⁰⁸ H. L. Snoek, ¹¹⁶ S. Snyder, ²⁷ R. Sobie, ^{171,m} A. Soffer, ¹⁵⁷ F. Sohns, ⁵¹
 C. A. Solans Sanchez, ³⁴ E. Yu. Soldatov, ¹⁰⁹ U. Soldevila, ¹⁶⁹ A. A. Solodkov, ¹¹⁹ S. Solomon, ⁵⁰ A. Soloshenko, ⁷⁷
 O. V. Solovyanov, ¹¹⁹ V. Solovyev, ¹³³ P. Sommer, ¹⁴⁵ H. Son, ¹⁶⁵ A. Sonay, ¹² W. Y. Song, ^{163b} A. Sopczak, ¹³⁷ A. L. Sopio, ⁹²
 F. Sopkova, ^{26b} S. Sottocornola, ^{68a,68b} R. Soualah, ^{64a,64c} A. M. Soukharev, ^{118b,118a} Z. Soumaini, ^{33e} D. South, ⁴⁴
 Spagnolo, ^{65a,65b} M. Spalla, ¹¹² M. Spangenberg, ¹⁷³ F. Spanò, ⁹¹ D. Sperlich, ⁵⁰ T. M. Spieker, ^{59a} G. Spigo, ³⁴ M. Spina, ¹⁵²
 D. P. Spiteri, ⁵⁵ M. Spousta, ¹³⁸ A. Stabile, ^{66a,66b} B. L. Stamas, ¹¹⁷ R. Stamen, ^{59a} M. Stamenkovic, ¹¹⁶ A. Stampekis, ¹⁹
 M. Stanke, ²² E. Stanecka, ⁸² B. Stanislaus, ³⁴ M. M. Stanitzki, ⁴⁴ M. Stankaityte, ¹³⁰ B. Stapf, ⁴⁴ E. A. Starchenko, ¹¹⁹
 G. H. Stark, ¹⁴¹ J. Stark, ⁹⁹ D. M. Starko, ^{163b} P. Staroba, ¹³⁶ P. Starovoitov, ^{59a} S. Stärz, ¹⁰¹ R. Stazewski, ⁸² G. Stavropoulos, ⁴²
 P. Steinberg, ²⁷ A. L. Steinhebel, ¹²⁷ B. Stelzer, ^{148,163a} H. J. Stelzer, ¹³⁴ O. Stelzer-Chilton, ^{163a} H. Stenzel, ⁵⁴ T. J. Stevenson, ¹⁵²
 G. A. Stewart, ³⁴ M. C. Stockton, ³⁴ G. Stoicea, ^{25b} M. Stolarski, ^{135a} S. Stonjek, ¹¹² A. Straessner, ⁴⁶ J. Strandberg, ¹⁵⁰
 S. Strandberg, ^{43a,43b} M. S. Sun,¹⁰³ S. Sun,¹⁷⁶ X. Sun,⁹⁸ O. Sunneborn Gudnadottir,¹⁶⁷ C. J. E. Suster,¹⁵³ M. R. Sutton,¹⁵⁴ M. Svatos,¹³⁶ M. Swiatlowski,^{163a} T. Swirski,¹⁷² I. Sykora,^{26a} M. Sykora,¹³⁸ T. Sykora,¹³⁸ D. Ta,⁹⁷ K. Tackmann,^{44,ii} A. Taffard,¹⁶⁶ R. Tafirout,^{163a} E. Tagiev,¹¹⁹ R. H. M. Taibah,¹³¹ R. Takashima,⁸⁴ K. Takeda,⁸⁰ T. Takeshita,¹⁴⁶ E. P. Takeva,⁴⁸ Y. Takubo,⁷⁹

M. Talby,⁹⁹ A. A. Talyshev,^{118b,118a} K. C. Tam,^{60b} N. M. Tamir,¹⁵⁷ A. Tanaka,¹⁵⁹ J. Tanaka,¹⁵⁹ R. Tanaka,⁶² Z. Tao,¹⁷⁰ S. Tapia Araya,⁷⁶ S. Tapprogge,⁹⁷ A. Tarek Abouelfadl Mohamed,¹⁰⁴ S. Tarem,¹⁵⁶ K. Tariq,^{58b} G. Tarna,^{25b,jj}
G. F. Tartarelli,^{66a} P. Tas,¹³⁸ M. Tasevsky,¹³⁶ E. Tassi,^{39b,39a} G. Tateno,¹⁵⁹ Y. Tayalati,^{33e} G. N. Taylor,¹⁰² W. Taylor,^{163b}
H. Teagle,⁸⁸ A. S. Tee,¹⁷⁶ R. Teixeira De Lima,¹⁴⁹ P. Teixeira-Dias,⁹¹ H. Ten Kate,³⁴ J. J. Teoh,¹¹⁶ K. Terashi,¹⁵⁹ J. Terron,⁹⁶
S. Terzo,¹² M. Testa,⁴⁹ R. J. Teuscher,^{162,m} N. Themistokleous,⁴⁸ T. Theveneaux-Pelzer,¹⁷ O. Thielmann,¹⁷⁷ D. W. Thomas,⁹¹
J. P. Thomas,¹⁹ E. A. Thompson,⁴⁴ P. D. Thompson,¹⁹ E. Thomson,¹³² E. J. Thorpe,⁹⁰ Y. Tian,⁵¹ V. O. Tikhomirov,^{108,kk}
Yu. A. Tikhonov,^{118b,118a} S. Timoshenko,¹⁰⁹ P. Tipton,¹⁷⁸ S. Tisserant,⁹⁹ S. H. Tlou,^{31f} A. Tnourji,³⁶ K. Todome,^{21b,21a}
S. Todorova-Nova,¹³⁸ S. Todt,⁴⁶ M. Togawa,⁷⁹ J. Tojo,⁸⁵ S. Tokár,^{26a} K. Tokushuku,⁷⁹ E. Tolley,¹²³ R. Tombs,³⁰
M. Tomoto,^{79,113} L. Tompkins,¹⁴⁹ P. Tornambe,¹⁰⁰ E. Torrence,¹²⁷ H. Torres,⁴⁶ E. Torró Pastor,¹⁶⁹ M. Toscani,³² C. Tosciri,³⁵
J. Toth,^{99,II} D. R. Tovey,¹⁴⁵ A. Traeet,¹⁵ C. J. Treado,¹²¹ T. Trefzger,¹⁷² A. Tricoli,²⁷ I. M. Trigger,^{163a} S. Trincaz-Duvoid,¹³¹
D. A. Trischuk,¹⁷⁰ W. Trischuk,¹⁶² B. Trocmé,⁵⁶ A. Trofymov,⁶² C. Troncon,^{66a} F. Trovato,¹⁵² L. Truong,^{31c} M. Trzebinski,⁸²
A. Trzupek,⁸² F. Tsai,¹⁵¹ A. Tsiamis,¹⁵⁸ P. V. Tsiareshka,^{105,bb} A. Tsirigotis,^{158,cc} V. Tsiskaridze,¹⁵¹ E. G. Tskhadadze,^{155a}
M. Tsopoulou,¹⁵⁸ I. I. Tsukerman,¹²⁰ V. Tsulaia,¹⁶ S. Tsuno,⁷⁹ O. Tsur,¹⁵⁶ D. Tsybychev,¹⁵¹ Y. Tu,^{60b} A. Tudorache,^{25b}
V. Tudorache,^{25b} A. N. Tuna,³⁴ S. Turchikhin,⁷⁷ D. Turgeman,¹⁷⁵ I. Turk Cakir,^{35,mm} R. J. Turner,¹⁹ R. Turra,^{66a} P. M. Tuts,³⁷
<l B. Vachon,¹⁰¹ K. O. H. Vadla,¹²⁹ T. Vafeiadis,³⁴ C. Valderanis,¹¹¹ E. Valdes Santurio,^{43a,430} M. Valente,^{103a}
S. Valentinetti,^{21b,21a} A. Valero,¹⁶⁹ L. Valéry,⁴⁴ R. A. Vallance,¹⁹ A. Vallier,⁹⁹ J. A. Valls Ferrer,¹⁶⁹ T. R. Van Daalen,¹² P. Van Gemmeren,⁵ S. Van Stroud,⁹² I. Van Vulpen,¹¹⁶ M. Vanadia,^{71a,71b} W. Vandelli,³⁴ M. Vandenbroucke,¹⁴⁰ E. R. Vandewall,¹²⁵ D. Vannicola,^{70a,70b} L. Vannoli,^{53b,53a} R. Vari,^{70a} E. W. Varnes,⁶ C. Varni,^{53b,53a} T. Varol,¹⁵⁴ D. Varouchas,⁶² K. E. Varvell,¹⁵³ M. E. Vasile,^{25b} L. Vaslin,³⁶ G. A. Vasquez,¹⁷¹ F. Vazeille,³⁶ D. Vazquez Furelos,¹² T. Vazquez Schroeder,³⁴ J. Veatch,⁵¹ V. Vecchio,⁹⁸ M. J. Veen,¹¹⁶ I. Veliscek,¹³⁰ L. M. Veloce,¹⁶² F. Veloso,^{135a,135c} S. Veneziano,^{70a} A. Ventura,^{65a,65b} A. Verbytskyi,¹¹² M. Verducci,^{69a,69b} C. Vergis,²² M. Verissimo De Araujo,^{78b} W. Verkerke,¹¹⁶ A. T. Vermeulen,¹¹⁶ J. C. Vermeulen,¹¹⁶ C. Vernieri,¹⁴⁹ P. J. Verschuuren,⁹¹ M. L. Vesterbacka,¹²¹ M. C. Vetterli,^{148,e} N. Viaux Maira,^{142e} T. Vickey,¹⁴⁵ O. E. Vickey Boeriu,¹⁴⁵ G. H. A. Viehhauser,¹³⁰ L. Vigani,^{59b} M. Villa,^{21b,21a} M. Villaplana Perez,¹⁶⁹ E. M. Villhauer,⁴⁸ E. Vilucchi,⁴⁹ M. G. Vincter,³² G. S. Virdee,¹⁹ A. Vishwakarma,⁴⁸ C. Vittori ^{21b,21a} I. Vivarelli ¹⁵² V. Vladimirov,¹⁷³ F. Voevodina,¹¹² M. Vogel,¹⁷⁷ P. Vokac,¹³⁷ J. Von Ahnen,⁴⁴ M. Vina, M. Vinapiana Perez, E. M. Vinnader, E. Vilucchi, M. G. Vincer, G. S. Virdee, A. Vishwakarnia, C. Vittori, ^{21b,21a} I. Vivarelli, ¹⁵² V. Vladimirov, ¹⁷³ E. Voevodina, ¹¹² M. Vogel, ¹⁷⁷ P. Vokac, ¹³⁷ J. Von Ahnen, ⁴⁴
S. E. von Buddenbrock, ^{31f} E. Von Toerne, ²² V. Vorobel, ¹³⁸ K. Vorobev, ¹⁰⁹ M. Vos, ¹⁶⁹ J. H. Vossebeld, ⁸⁸ M. Vozak, ⁹⁸ N. Vranjes, ¹⁴ M. Vranjes Milosavljevic, ¹⁴ V. Vrba, ^{137,a} M. Vreeswijk, ¹¹⁶ N. K. Vu, ⁹⁹ R. Vuillermet, ³⁴ I. Vukotic, ³⁵ S. Wada, ¹⁶⁴ C. Wagner, ¹⁰⁰ P. Wagner, ²² W. Wagner, ¹⁷⁷ S. Wahdan, ¹⁷⁷ H. Wahlberg, ⁸⁶ R. Wakasa, ¹⁶⁴ M. Wakida, ¹¹³
V. M. Walbrecht, ¹¹² J. Walder, ¹³⁹ R. Walker, ¹¹¹ S. D. Walker, ⁹¹ W. Walkowiak, ¹⁴⁷ A. M. Wang, ⁵⁷ A. Z. Wang, ¹⁵⁴ c. Wang, ⁵⁸ S. Wada, C. Wagner, F. Wagner, W. Wagner, S. Wandah, H. Wanberg, K. Wakasa, M. Waktda,
V. M. Walbrecht, ¹¹² J. Walder, ¹³⁹ R. Walker, ¹¹¹ S. D. Walker, ⁹¹ W. Walkowiak, ¹⁴⁷ A. M. Wang, ⁵⁷ A. Z. Wang, ¹⁷⁶ C. Wang, ⁵⁸⁶ C. Wang, ⁵⁸⁶ H. Wang, ⁶¹⁶ P. Wang, ⁴⁰ R.-J. Wang, ⁹⁷ R. Wang, ⁵⁷ R. Wang, ¹¹⁷ S. M. Wang, ¹⁵⁴ S. Wang, ⁵⁸⁵ T. Wang, ⁵⁸⁶ W. T. Wang, ^{58a} W. X. Wang, ^{58a} X. Wang, ⁶⁸ Y. Wang, ^{58a} Z. Wang, ¹⁰³ C. Wanotayaroj, ³⁴ A. Warburton, ¹⁰¹ C. P. Ward, ³⁰ R. J. Ward, ¹⁹ N. Warrack, ⁵⁵ A. T. Watson, ¹⁹ M. F. Watson, ¹⁰ G. Watts, ¹⁴⁴ B. M. Waugh, ⁹² A. F. Webb, ¹⁰ C. Weber, ²⁷ M. S. Weber, ¹⁸ S. A. Weber, ³² S. M. Weber, ^{59a} C. Wei, ^{55a} Y. Wei, ¹³⁰ A. R. Weidberg, ¹³⁰ J. Weingarten, ⁴⁵ M. Weirich, ⁹⁷ C. Weiser, ⁵⁰ P. S. Wells, ³⁴ T. Wenaus, ²⁷ B. Wendland, ⁴⁵ T. Wengler, ³⁴ S. Wenig, ³⁴ N. Wermes, ²² M. Wessels, ^{59a} K. Whalen, ¹²⁷ A. M. Wharton, ⁸⁷ A. S. White, ⁵⁷ A. White, ⁷ M. J. Whites, ¹⁰ D. Whiteson, ¹⁶⁶ W. Wiedenmann, ¹⁷⁶ C. Wiel, ⁴⁶ M. Wielers, ¹³⁹ N. Wieseotte, ⁹⁷ C. Wiglesworth, ³⁸ L. A. M. Wiłk-Fuchs, ⁵⁰ D. J. Wilbern, ¹²⁴ H. G. Wilkens, ³⁴ L. J. Wilkins, ⁹¹ D. M. Williams, ³⁷ H. H. Williams, ¹³² S. Williams, ³⁰ S. Willocq, ¹⁰⁰ P. J. Windischhofer, ¹³⁰ I. Wolnert, ¹²⁵ B. T. Winter, ⁵⁰ M. Wittgen, ¹⁴⁹ M. Wobisch, ⁹³ A. Wolf, ⁹⁷ R. Wölker, ¹³⁰ J. Wollrath, ¹⁶⁶ M. W. Wolter, ⁸² H. Wolters, ^{135a,135c} V. W. S. Wong, ¹⁷⁰ A. F. Wongel, ⁴⁴ S. D. Worm, ⁴⁴ B. K. Wosiek, ⁸² K. W. Woźniak, ⁸² K. Wraight, ⁵⁵ J. Wu, ^{13a,13d} S. L. Wu, ¹⁷⁶ X. Wu, ⁵² Y. Wu, ^{58a} Z. Wu, ^{140,58a} J. Wuerzinger, ¹³⁰ T. R. Wyatt, ⁹⁸ B. M. Wynne, ⁴⁸ S. Xella, ³⁸ J. Xiang, ^{60c} X. Xiao, ¹⁰³ X. Xie, ^{58a} I. Xiotidis, ¹⁵² D. Xu, ^{13a} H. Xu, ^{58a} H. Xu, ^{58a} R. Xu, ¹³² W. Xu, ¹⁰³ Y. Xu, ^{13b} Z. Xu, ^{58b} Z. Xu, ¹⁴⁹ B. Yabsley, ¹⁵³ S. Yacoob, ^{31a} N. Yamaguchi, ⁸⁵ Y. Yamaguchi, ¹⁶⁰ M. Yamatani, ¹⁵⁹ H. Yamauchi, ¹⁶⁴ T. Yama T. Ženiš,^{26a} S. Zenz,⁹⁰ S. Zerradi,^{33a} D. Zerwas,⁶² M. Zgubič,¹³⁰ B. Zhang,^{13c} D. F. Zhang,^{13b} G. Zhang,^{13b} J. Zhang,⁵ K. Zhang,^{13a} L. Zhang,^{13c} M. Zhang,¹⁶⁸ R. Zhang,¹⁷⁶ S. Zhang,¹⁰³ X. Zhang,^{58c} X. Zhang,^{58b} Z. Zhang,⁶² P. Zhao,⁴⁷ Y. Zhao,¹⁴¹ Z. Zhao,^{58a} A. Zhemchugov,⁷⁷ Z. Zheng,¹⁰³ D. Zhong,¹⁶⁸ B. Zhou,¹⁰³ C. Zhou,¹⁷⁶ H. Zhou,⁶ N. Zhou,^{58c} Y. Zhou,⁶ C. G. Zhu,^{58b} C. Zhu,^{13a,13d} H. L. Zhu,^{58a} H. Zhu,^{13a} J. Zhu,^{13a} Y. Zhu,^{58a} X. Zhuang,^{13a} K. Zhukov,¹⁰⁸ V. Zhulanov,^{118b,118a} D. Zieminska,⁶³ N. I. Zimine,⁷⁷ S. Zimmermann,^{50,a} M. Ziolkowski,¹⁴⁷ L. Živković,¹⁴ A. Zoccoli,^{21b,21a} K. Zoch,⁵² T. G. Zorbas,¹⁴⁵ O. Zormpa,⁴² W. Zou,³⁷ and L. Zwalinski³⁴

(ATLAS Collaboration)

¹Department of Physics, University of Adelaide, Adelaide, Australia

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

^{3a}Department of Physics, Ankara University, Ankara, Turkey

^{3b}Istanbul Avdin University, Application and Research Center for Advanced Studies, Istanbul, Turkey

^{3c}Division of Physics, TOBB University of Economics and Technology, Ankara, Turkey

LAPP, Univ. Savoie Mont Blanc, CNRS/IN2P3, Annecy, France

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

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

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

⁸Physics Department, National and Kapodistrian University of Athens, Athens, Greece

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

¹⁰Department of Physics, University of Texas at Austin, Austin, Texas, USA

^{11a}Bahcesehir University, Faculty of Engineering and Natural Sciences, Istanbul, Turkey

^{11b}Istanbul Bilgi University, Faculty of Engineering and Natural Sciences, Istanbul, Turkey ^{11c}Department of Physics, Bogazici University, Istanbul, Turkey

^{11d}Department of Physics Engineering, Gaziantep University, Gaziantep, Turkey

¹²Institut de Física d'Altes Energies (IFAE), Barcelona Institute of Science and Technology, Barcelona, Spain

^{13a}Institute of High Energy Physics, Chinese Academy of Sciences, Beijing, China ^{13b}Physics Department, Tsinghua University, Beijing, China

^{13c}Department of Physics, Nanjing University, Nanjing, China

^{13d}University of Chinese Academy of Science (UCAS), Beijing, China

¹⁴Institute of Physics, University of Belgrade, Belgrade, Serbia

¹⁵Department for Physics and Technology, University of Bergen, Bergen, Norway

¹⁶Physics Division, Lawrence Berkeley National Laboratory and University of California, Berkeley, California, USA

¹⁷Institut für Physik, Humboldt Universität zu Berlin, Berlin, Germany

¹⁸Albert Einstein Center for Fundamental Physics and Laboratory for High Energy Physics,

University of Bern, Bern, Switzerland

¹⁹School of Physics and Astronomy, University of Birmingham, Birmingham, United Kingdom

^{20a}Facultad de Ciencias y Centro de Investigaciónes, Universidad Antonio Nariño, Bogotá, Colombia

^{20b}Departamento de Física, Universidad Nacional de Colombia, Bogotá, Colombia, Colombia

^aINFN Bologna and Università di Bologna, Dipartimento di Fisica, Bologna, Italy

^{21b}INFN Sezione di Bologna, Bologna, Italy

²²Physikalisches Institut, Universität Bonn, Bonn, Germany

²³Department of Physics, Boston University, Boston, Massachusetts, USA

²⁴Department of Physics, Brandeis University, Waltham, Massachusetts, USA

^{25a}Transilvania University of Brasov, Brasov, Romania

^{25b}Horia Hulubei National Institute of Physics and Nuclear Engineering, Bucharest, Romania

^{25c}Department of Physics, Alexandru Ioan Cuza University of Iasi, Iasi, Romania

^{25d}National Institute for Research and Development of Isotopic and Molecular Technologies,

Physics Department, Clui-Napoca, Romania

^{25e}University Politehnica Bucharest, Bucharest, Romania

^{25f}West University in Timisoara, Timisoara, Romania

^{26a}Faculty of Mathematics, Physics and Informatics, Comenius University, Bratislava, Slovak Republic

^{26b}Department of Subnuclear Physics, Institute of Experimental Physics of the Slovak Academy of Sciences, Kosice, Slovak Republic

²⁷Physics Department, Brookhaven National Laboratory, Upton, New York, USA

²⁸Departamento de Física, Universidad de Buenos Aires, Buenos Aires, Argentina

²⁹California State University, California, USA

³⁰Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom

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^{31a}Department of Physics, University of Cape Town, Cape Town, South Africa

^{31b}iThemba Labs, Western Cape, South Africa

³¹^cDepartment of Mechanical Engineering Science, University of Johannesburg, Johannesburg, South Africa

^{31d}National Institute of Physics, University of the Philippines Diliman, Philippines

^{31e}University of South Africa, Department of Physics, Pretoria, South Africa

^{31f}School of Physics, University of the Witwatersrand, Johannesburg, South Africa

³²Department of Physics, Carleton University, Ottawa ON, Canada

^{33a}Faculté des Sciences Ain Chock, Réseau Universitaire de Physique des Hautes Energies—Université Hassan II,

Casablanca, Morocco

^{33b}Faculté des Sciences, Université Ibn-Tofail, Kénitra, Morocco

^{33c}Faculté des Sciences Semlalia, Université Cadi Ayyad, LPHEA-Marrakech, Morocco

^{33d}LPMR, Faculté des Sciences, Université Mohamed Premier, Oujda, Morocco

^{33e}Faculté des sciences, Université Mohammed V, Rabat, Morocco

^{33f}Mohammed VI Polytechnic University, Ben Guerir, Morocco

³⁴CERN, Geneva, Switzerland

³⁵Enrico Fermi Institute, University of Chicago, Chicago, Illinois, USA

³⁶LPC, Université Clermont Auvergne, CNRS/IN2P3, Clermont-Ferrand, France
 ³⁷Nevis Laboratory, Columbia University, Irvington, New York, USA

³⁸Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark

^aDipartimento di Fisica, Università della Calabria, Rende, Italy

^{39b}INFN Gruppo Collegato di Cosenza, Laboratori Nazionali di Frascati, Italy

⁴⁰Physics Department, Southern Methodist University, Dallas, Texas, USA

⁴¹Physics Department, University of Texas at Dallas, Richardson, Texas, USA

⁴²National Centre for Scientific Research "Demokritos", Agia Paraskevi, Greece

^{43a}Department of Physics, Stockholm University, Stockholm, Sweden

^{43b}Oskar Klein Centre, Stockholm, Sweden

⁴⁴Deutsches Elektronen-Synchrotron DESY, Hamburg and Zeuthen, Germany

⁴⁵Lehrstuhl für Experimentelle Physik IV, Technische Universität Dortmund, Dortmund, Germany

⁴⁶Institut für Kern- und Teilchenphysik, Technische Universität Dresden, Dresden, Germany ⁴⁷Department of Physics, Duke University, Durham, North Carolina, USA

⁴⁸SUPA—School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom

⁴⁹INFN e Laboratori Nazionali di Frascati, Frascati, Italy

⁵⁰Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Freiburg, Germany

⁵¹II. Physikalisches Institut, Georg-August-Universität Göttingen, Göttingen, Germany

⁵²Département de Physique Nucléaire et Corpusculaire, Université de Genève, Genève, Switzerland

^{53a}Dipartimento di Fisica, Università di Genova, Genova, Italy

^{53b}INFN Sezione di Genova, Genova, Italy

⁵⁴II. Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen, Germany

⁵⁵SUPA—School of Physics and Astronomy, University of Glasgow, Glasgow, United Kingdom

⁵⁶LPSC, Université Grenoble Alpes, CNRS/IN2P3, Grenoble INP, Grenoble, France

⁵⁷Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge, Massachusetts, USA

^{38a}Department of Modern Physics and State Key Laboratory of Particle Detection and Electronics,

University of Science and Technology of China, Hefei, China

^{58b}Institute of Frontier and Interdisciplinary Science and Key Laboratory of Particle Physics and Particle Irradiation (MOE), Shandong University, Qingdao, China

58c School of Physics and Astronomy, Shanghai Jiao Tong University, Key Laboratory for Particle Astrophysics and Cosmology (MOE), SKLPPC, Shanghai, China

^{58d}Tsung-Dao Lee Institute, Shanghai, China

^{59a}Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany

⁹⁹Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany

^{60a}Department of Physics, Chinese University of Hong Kong, Shatin, N.T., Hong Kong, China

^{60b}Department of Physics, University of Hong Kong, Hong Kong, China

^{60c}Department of Physics and Institute for Advanced Study, Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, China

⁶¹Department of Physics, National Tsing Hua University, Hsinchu, Taiwan

⁶²IJCLab, Université Paris-Saclay, CNRS/IN2P3, 91405, Orsay, France

⁶³Department of Physics, Indiana University, Bloomington, Indiana, USA

^{64a}INFN Gruppo Collegato di Udine, Sezione di Trieste, Udine, Italy ^{64b}ICTP, Trieste, Italy

^{64c}Dipartimento Politecnico di Ingegneria e Architettura, Università di Udine, Udine, Italy

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^{65a}INFN Sezione di Lecce, Lecce, Italy

^{65b}Dipartimento di Matematica e Fisica, Università del Salento, Lecce, Italy

66a INFN Sezione di Milano, Milano, Italy

^{66b}Dipartimento di Fisica, Università di Milano, Milano, Italy

^{67a}INFN Sezione di Napoli, Napoli, Italy

^{67b}Dipartimento di Fisica, Università di Napoli, Napoli, Italy

^{68a}INFN Sezione di Pavia, Pavia, Italy

^{68b}Dipartimento di Fisica, Università di Pavia, Pavia, Italy

^{69a}INFN Sezione di Pisa, Pisa, Italy

^{69b}Dipartimento di Fisica E.Fermi, Università di Pisa, Pisa, Italy ^{70a}INFN Sezione di Roma, Roma, Italy

^{70b}Dipartimento di Fisica, Sapienza Università di Roma, Roma, Italy

^{71a}INFN Sezione di Roma Tor Vergata, Roma, Italy

^{71b}Dipartimento di Fisica, Università di Roma Tor Vergata, Roma, Italy

^{72a}INFN Sezione di Roma Tre, Roma, Italy

^{72b}Dipartimento di Matematica e Fisica, Università Roma Tre, Roma, Italy

^{73a}INFN-TIFPA, Trento, Italy

^{73b}Università degli Studi di Trento, Trento, Italy

⁷⁴Institut für Astro- und Teilchenphysik, Leopold-Franzens-Universität, Innsbruck, Austria ⁷⁵University of Iowa, Iowa City, Iowa, USA

⁷⁶Department of Physics and Astronomy, Iowa State University, Ames, Iowa, USA

Joint Institute for Nuclear Research, Dubna, Russia

^{78a}Departamento de Engenharia Elétrica, Universidade Federal de Juiz de Fora (UFJF), Juiz de Fora, Brazil

⁷⁸⁶Universidade Federal do Rio De Janeiro COPPE/EE/IF, Rio de Janeiro, Brazil

^{78c}Instituto de Física, Universidade de São Paulo, São Paulo, Brazil

⁷⁹KEK, High Energy Accelerator Research Organization, Tsukuba, Japan

⁸⁰Graduate School of Science, Kobe University, Kobe, Japan

^{81a}AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Krakow, Poland

^{81b}Marian Smoluchowski Institute of Physics, Jagiellonian University, Krakow, Poland

⁸²Institute of Nuclear Physics Polish Academy of Sciences, Krakow, Poland

⁸³Faculty of Science, Kyoto University, Kyoto, Japan

⁸⁴Kyoto University of Education, Kyoto, Japan

⁸⁵Research Center for Advanced Particle Physics and Department of Physics, Kyushu University, Fukuoka, Japan

⁶Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata, Argentina

⁸⁷Physics Department, Lancaster University, Lancaster, United Kingdom

⁸⁸Oliver Lodge Laboratory, University of Liverpool, Liverpool, United Kingdom

⁸⁹Department of Experimental Particle Physics, Jožef Stefan Institute and Department of Physics,

University of Ljubljana, Ljubljana, Slovenia

⁹⁰School of Physics and Astronomy, Queen Mary University of London, London, United Kingdom

⁹¹Department of Physics, Royal Holloway University of London, Egham, United Kingdom

⁹²Department of Physics and Astronomy, University College London, London, United Kingdom

93 Louisiana Tech University, Ruston, Louisiana, USA

⁹⁴Fysiska institutionen, Lunds universitet, Lund, Sweden

⁹⁵Centre de Calcul de l'Institut National de Physique Nucléaire et de Physique des Particules (IN2P3), Villeurbanne, France

⁶Departamento de Física Teorica C-15 and CIAFF, Universidad Autónoma de Madrid, Madrid, Spain

⁷Institut für Physik, Universität Mainz, Mainz, Germany

⁹⁸School of Physics and Astronomy, University of Manchester, Manchester, United Kingdom

⁹⁹CPPM, Aix-Marseille Université, CNRS/IN2P3, Marseille, France

¹⁰⁰Department of Physics, University of Massachusetts, Amherst, Massachusetts, USA

Department of Physics, McGill University, Montreal, Quebec, Canada

¹⁰²School of Physics, University of Melbourne, Victoria, Australia

¹⁰³Department of Physics, University of Michigan, Ann Arbor, Michigan, USA

¹⁰⁴Department of Physics and Astronomy, Michigan State University, East Lansing, Michigan, USA

¹⁰⁵B.I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk, Belarus

¹⁰⁶Research Institute for Nuclear Problems of Byelorussian State University, Minsk, Belarus

¹⁰⁷Group of Particle Physics, University of Montreal, Montreal, Quebec, Canada

¹⁰⁸P.N. Lebedev Physical Institute of the Russian Academy of Sciences, Moscow, Russia

¹⁰⁹National Research Nuclear University MEPhI, Moscow, Russia

¹¹⁰D.V. Skobeltsyn Institute of Nuclear Physics, M.V. Lomonosov Moscow State University, Moscow, Russia

¹¹¹Fakultät für Physik, Ludwig-Maximilians-Universität München, München, Germany

¹¹²Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), München, Germany

¹¹³Graduate School of Science and Kobayashi-Maskawa Institute, Nagoya University, Nagoya, Japan

¹¹⁴Department of Physics and Astronomy, University of New Mexico, Albuquerque, New Mexico, USA

¹¹⁵Institute for Mathematics, Astrophysics and Particle Physics, Radboud University/Nikhef, Nijmegen, Netherlands

¹⁶Nikhef National Institute for Subatomic Physics and University of Amsterdam, Amsterdam, Netherlands

¹¹⁷Department of Physics, Northern Illinois University, DeKalb, Illinois, USA

^{118a}Budker Institute of Nuclear Physics and NSU, SB RAS, Novosibirsk, Russia

^{118b}Novosibirsk State University, Novosibirsk, Russia

¹¹⁹Institute for High Energy Physics of the National Research Centre Kurchatov Institute, Protvino, Russia

¹²⁰Institute for Theoretical and Experimental Physics named by A.I. Alikhanov of National Research Centre "Kurchatov Institute",

Moscow, Russia

¹²¹Department of Physics, New York University, New York, New York, USA

²²Ochanomizu University, Otsuka, Bunkyo-ku, Tokyo, Japan

¹²³Ohio State University, Columbus, Ohio, USA

¹²⁴Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman, Oklahoma, USA

Department of Physics, Oklahoma State University, Stillwater, Oklahoma, USA

¹²⁶Palacký University, Joint Laboratory of Optics, Olomouc, Czech Republic

¹²⁷Institute for Fundamental Science, University of Oregon, Eugene, Oregon, USA

¹²⁸Graduate School of Science, Osaka University, Osaka, Japan

¹²⁹Department of Physics, University of Oslo, Oslo, Norway

¹³⁰Department of Physics, Oxford University, Oxford, United Kingdom

¹³¹LPNHE, Sorbonne Université, Université de Paris, CNRS/IN2P3, Paris, France

¹³²Department of Physics, University of Pennsylvania, Philadelphia, Pennsylvania, USA

¹³³Konstantinov Nuclear Physics Institute of National Research Centre "Kurchatov Institute", PNPI, St. Petersburg, Russia

¹³⁴Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh, Pennsylvania, USA

^aLaboratório de Instrumentação e Física Experimental de Partículas—LIP, Lisboa, Portugal

^{135b}Departamento de Física, Faculdade de Ciências, Universidade de Lisboa, Lisboa, Portugal

¹³⁵ Departamento de Física, Universidade de Coimbra, Coimbra, Portugal

^{135d}Centro de Física Nuclear da Universidade de Lisboa, Lisboa, Portugal

¹³⁵eDepartamento de Física, Universidade do Minho, Braga, Portugal

^{135f}Departamento de Física Teórica y del Cosmos, Universidad de Granada, Granada (Spain), Spain

^{135g}Dep Física and CEFITEC of Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Caparica, Portugal

^{135h}Instituto Superior Técnico, Universidade de Lisboa, Lisboa, Portugal

¹³⁶Institute of Physics of the Czech Academy of Sciences, Prague, Czech Republic

¹³⁷Czech Technical University in Prague, Prague, Czech Republic

¹³⁸Charles University, Faculty of Mathematics and Physics, Prague, Czech Republic

¹³⁹Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom

¹⁴⁰IRFU, CEA, Université Paris-Saclay, Gif-sur-Yvette, France

¹⁴¹Santa Cruz Institute for Particle Physics, University of California Santa Cruz, Santa Cruz, California, USA

^{142a}Departamento de Física, Pontificia Universidad Católica de Chile, Santiago, Chile ^{142b}Universidad de la Serena, La Serena, Chile

^{142c}Universidad Andres Bello, Department of Physics, Santiago, Chile

^{142d}Instituto de Alta Investigación, Universidad de Tarapacá, Arica, Chile

^{142e}Departamento de Física, Universidad Técnica Federico Santa María, Valparaíso, Chile

³Universidade Federal de São João del Rei (UFSJ), São João del Rei, Brazil

¹⁴⁴Department of Physics, University of Washington, Seattle, Washington State, USA

¹⁴⁵Department of Physics and Astronomy, University of Sheffield, Sheffield, United Kingdom ¹⁴⁶Department of Physics, Shinshu University, Nagano, Japan

¹⁴⁷Department Physik, Universität Siegen, Siegen, Germany

¹⁴⁸Department of Physics, Simon Fraser University, Burnaby, Burnaby, Canada

⁴⁹SLAC National Accelerator Laboratory, Stanford, California, USA

¹⁵⁰Department of Physics, Royal Institute of Technology, Stockholm, Sweden

¹⁵¹Departments of Physics and Astronomy, Stony Brook University, Stony Brook, New York, USA

²Department of Physics and Astronomy, University of Sussex, Brighton, United Kingdom

¹⁵³School of Physics, University of Sydney, Sydney, Australia

¹⁵⁴Institute of Physics, Academia Sinica, Taipei, Taiwan

^{155a}E. Andronikashvili Institute of Physics, Iv. Javakhishvili Tbilisi State University, Tbilisi, Georgia

^{155b}High Energy Physics Institute, Tbilisi State University, Tbilisi, Georgia

¹⁵⁶Department of Physics, Technion, Israel Institute of Technology, Haifa, Israel

¹⁵⁷Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel

⁵⁸Department of Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece

¹⁵⁹International Center for Elementary Particle Physics and Department of Physics, University of Tokyo, Tokyo, Japan

¹⁶⁰Department of Physics, Tokyo Institute of Technology, Tokyo, Japan

¹⁶¹Tomsk State University, Tomsk, Russia

¹⁶²Department of Physics, University of Toronto, Toronto, Ontario, Canada

^{163a}TRIUMF, Vancouver, British Columbia, Canada

^{163b}Department of Physics and Astronomy, York University, Toronto, Ontario, Canada

¹⁶⁴Division of Physics and Tomonaga Center for the History of the Universe, Faculty of Pure and Applied Sciences, University of

Tsukuba, Tsukuba, Japan

¹⁶⁵Department of Physics and Astronomy, Tufts University, Medford, Massachusetts, USA

¹⁶⁶Department of Physics and Astronomy, University of California Irvine, Irvine, California, USA

¹⁶⁷Department of Physics and Astronomy, University of Uppsala, Uppsala, Sweden

¹⁶⁸Department of Physics, University of Illinois, Urbana, Illinois, USA

¹⁶⁹Instituto de Física Corpuscular (IFIC), Centro Mixto Universidad de Valencia—CSIC, Valencia, Spain

¹⁷⁰Department of Physics, University of British Columbia, Vancouver, British Columbia, Canada

¹⁷¹Department of Physics and Astronomy, University of Victoria, Victoria, British Columbia, Canada

¹⁷²Fakultät für Physik und Astronomie, Julius-Maximilians-Universität Würzburg, Würzburg, Germany

¹⁷³Department of Physics, University of Warwick, Coventry, United Kingdom

¹⁷⁴Waseda University, Tokyo, Japan

¹⁷⁵Department of Particle Physics and Astrophysics, Weizmann Institute of Science, Rehovot, Israel

¹⁷⁶Department of Physics, University of Wisconsin, Madison, Wisconsin, USA

¹⁷⁷Fakultät für Mathematik und Naturwissenschaften, Fachgruppe Physik, Bergische Universität Wuppertal, Wuppertal, Germany

¹⁷⁸Department of Physics, Yale University, New Haven, Connecticut, USA

^aDeceased.

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

^cAlso at Istanbul University, Department of Physics, Istanbul, Turkey.

- ^dAlso at Instituto de Fisica Teorica, IFT-UAM/CSIC, Madrid, Spain.
- ^eAlso at TRIUMF, Vancouver, British Columbia, Canada.
- ^fAlso at Department of Physics, University of Fribourg, Fribourg, Switzerland.
- ^gAlso at Department of Physics and Astronomy, University of Louisville, Louisville, Kentucky, USA.
- ^hAlso at Departament de Fisica de la Universitat Autonoma de Barcelona, Barcelona, Spain.
- ¹Also at Moscow Institute of Physics and Technology State University, Dolgoprudny, Russia.

^JAlso at Faculty of Physics, Sofia University, 'St. Kliment Ohridski', Sofia, Bulgaria.

- ^kAlso at Department of Physics, Ben Gurion University of the Negev, Beer Sheva, Israel.
- ¹Also at Universita di Napoli Parthenope, Napoli, Italy.

^mAlso at Institute of Particle Physics (IPP), Victoria, BC, Canada.

- ⁿAlso at Bruno Kessler Foundation, Trento, Italy.
- ^oAlso at Department of Physics, St. Petersburg State Polytechnical University, St. Petersburg, Russia.
- ^pAlso at Borough of Manhattan Community College, City University of New York, New York, New York, USA.
- ^qAlso at Department of Physics, California State University, Fresno, USA.
- ^rAlso at Department of Financial and Management Engineering, University of the Aegean, Chios, Greece.
- ^sAlso at Centro Studi e Ricerche Enrico Fermi, Italy.
- ^tAlso at Department of Physics, California State University, East Bay, USA.
- ^uAlso at Institucio Catalana de Recerca i Estudis Avancats, ICREA, Barcelona, Spain.
- ^vAlso at Graduate School of Science, Osaka University, Osaka, Japan.
- ^wAlso at Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Freiburg, Germany.
- ^xAlso at University of Chinese Academy of Sciences (UCAS), Beijing, China.
- ^yAlso at Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan.
- ^zAlso at Yeditepe University, Physics Department, Istanbul, Turkey.
- ^{aa}Also at CERN, Geneva, Switzerland.
- ^{bb}Also at Joint Institute for Nuclear Research, Dubna, Russia.
- ^{cc}Also at Hellenic Open University, Patras, Greece.
- ^{dd}Also at Center for High Energy Physics, Peking University, China.
- ee Also at The City College of New York, New York, New York, USA.
- ^{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 Faculty of Physics, M.V. Lomonosov Moscow State University, Moscow, Russia.

- ⁱⁱAlso at Institut für Experimentalphysik, Universität Hamburg, Hamburg, Germany. ^{ji}Also at CPPM, Aix-Marseille Université, CNRS/IN2P3, Marseille, France. ^{kk}Also at National Research Nuclear University MEPhI, Moscow, Russia. ^{II}Also at Institute for Particle and Nuclear Physics, Wigner Research Centre for Physics, Budapest, Hungary.
- ^{mm}Also at Giresun University, Faculty of Engineering, Giresun, Turkey.
- ⁿⁿAlso at Department of Physics and Astronomy, Michigan State University, East Lansing, Michigan, USA.