Observation of Spin Correlation in $t\bar{t}$ Events from pp Collisions at $\sqrt{s} = 7\,\text{TeV}$ Using the ATLAS Detector

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

A measurement of spin correlation in $t\bar{t}$ production is reported using data collected with the ATLAS detector at the LHC, corresponding to an integrated luminosity of 2.1 fb^{-1}. Candidate events are selected in the dilepton topology with large missing transverse energy and at least two jets. The difference in azimuthal angle between the two charged leptons in the laboratory frame is used to extract the correlation between the top and antitop quark spins. In the helicity basis the measured degree of correlation corresponds to $A_{\text{helicity}} = 0.40^{+0.09}_{-0.08}$, in agreement with the next-to-leading-order standard model prediction. The hypothesis of zero spin correlation is excluded at 5.1 standard deviations.

The top quark was discovered in 1995 [1,2] at the Tevatron proton-antiproton collider. The lifetime of the top quark is at least an order of magnitude shorter than the time scale for strong interactions, implying that the top quark decays before hadronization [3–7]. Therefore the spin of the top quark at production is transferred to its decay products and can be measured directly via their angular distributions [4]. While the polarization of t and $\bar{t}$ quarks in a hadronically produced $t\bar{t}$ sample is predicted to be very small, their spins are predicted to be correlated [8–10]. In this Letter the hypothesis that the correlation of the spin of top and antitop quarks in $t\bar{t}$ events is as expected in the standard model (SM), as opposed to the hypothesis that they are uncorrelated, is tested. This tests the precise predictions of $t\bar{t}$ pair production and of top quark decay, which is expected to occur before its spin is flipped by the strong interaction [9–13]. Many scenarios of new physics beyond the SM predict different spin correlations while keeping the $t\bar{t}$ production cross section within experimental and theoretical bounds [14–18]. For example, the spin correlation measured in this Letter may differ from the SM if the $t\bar{t}$ pairs were produced via the exchange of a virtual heavy scalar Higgs boson [19] or if the top quark decayed into a scalar charged Higgs boson and a b quark ($t \rightarrow H^+ b$) [20].

At the LHC $t\bar{t}$ production occurs mostly through the $gg \rightarrow t\bar{t}$ channel. At low $t\bar{t}$ invariant mass it is dominated by the fusion of like-helicity gluon pairs which produce top quarks in the left-left or right-right helicity configurations [13]. When these decay via $t\bar{t} \rightarrow W^+ W^- b\bar{b} \rightarrow l^+ \nu l^- \bar{\nu} b\bar{b}$ they produce charged leptons which possess correlations in

azimuthal angle, $\Delta\phi$ [21], in the laboratory frame [13]. In contrast, at the Tevatron production via $q\bar{q}$ annihilation dominates. The different production mechanisms and center-of-mass energies make a measurement of the spin correlation at both colliders complementary [22]. Both the CDF and D0 Collaborations have performed measurements of the spin correlation [23–25], with a recent analysis by the D0 Collaboration reporting evidence for the presence of spin correlation in $t\bar{t}$ events with a significance of 3.1 standard deviations [26].

The azimuthal angle between charged leptons is well measured by the ATLAS detector and does not require reconstruction of the top quarks. Figure 1 shows the distribution of charged lepton $\Delta\phi$ for generated events at parton level for $\sqrt{s} = 7$ TeV, using MC@NLO [27–29] with the CTEQ6.6 parton distribution function (PDF) [30] and a top quark mass of 172.5 GeV. It compares the
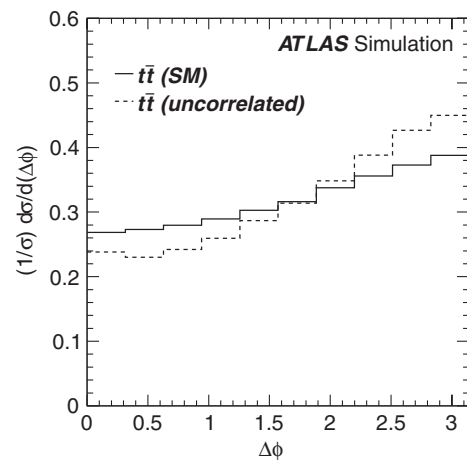

FIG. 1.   Normalized reconstructed charged lepton $\Delta\phi$ distribution for generated events at parton level for $\sqrt{s} = 7$ TeV using MC@NLO. The two histograms show the SM and uncorrelated spin scenarios.

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

SM prediction (solid line) to a scenario with no spin correlation between top and antitop quarks (dashed line).

The degree of correlation, A, is defined as the fractional difference between the number of events where the top and antitop quark spin orientations are aligned and those where the top quark spins have opposite alignment,

$$A = \frac{N(\uparrow\uparrow) + N(\downarrow\downarrow) - N(\uparrow\downarrow) - N(\downarrow\uparrow)}{N(\uparrow\uparrow) + N(\downarrow\downarrow) + N(\uparrow\downarrow) + N(\downarrow\uparrow)}. \quad (1)$$

The arrows denote the spins of the top and antitop quarks with respect to a chosen quantization axis. This analysis uses a fit to templates constructed from simulated event samples to determine the amount of spin correlation from the $\Delta\phi$ distribution. The fit result is converted into a value of A in two bases: the helicity basis, using the direction of flight of the top quark in the center-of-mass frame of the $t\bar{t}$ system [31,32], and the maximal basis which is optimized for $t\bar{t}$ production from gg fusion, as described in Ref. [12]. In the helicity basis the SM correlation coefficient is calculated to be $A_{\text{helicity}}^{\text{SM}} = 0.31$ [8], and in the maximal basis $A_{\text{maximal}}^{\text{SM}} = 0.44$, evaluated at matrix-element level using MC@NLO. Theoretical uncertainties due to the variation of factorization and renormalization scales and due to PDFs are of the order of 1% including next-to-leading-order (NLO) QCD corrections in $t\bar{t}$ production and top quark decay [22].

The ATLAS detector [33] at the LHC covers nearly the entire solid angle around the collision point. It consists of an inner tracking detector (ID) covering $|\eta| < 2.5$ and comprising a silicon pixel detector, a silicon microstrip detector and a transition radiation tracker. The ID is surrounded by a thin superconducting solenoid providing a 2 T magnetic field, followed by a liquid argon electromagnetic sampling calorimeter (LAr) with high granularity. An iron-scintillator tile calorimeter provides hadronic energy measurements in the central rapidity region ($|\eta| < 1.7$). The end-cap and forward regions are instrumented with LAr calorimeters for both electromagnetic (EM) and hadronic energy measurements up to $|\eta| < 4.9$. The calorimeter system is surrounded by a muon spectrometer (MS) with high-precision tracking chambers covering $|\eta| < 2.7$ and separate trigger chambers. The magnetic field is provided by a barrel and two end-cap superconducting toroid magnets. A three-level trigger system is used to select events with high-p_T leptons for this analysis. The first-level trigger is implemented in hardware and uses a subset of the detector information to reduce the trigger rate to 75 kHz. This is followed by two software-based trigger levels that together reduce the event rate to 200–400 Hz.

This analysis uses collision data with a center-of-mass energy of $\sqrt{s} = 7$ TeV recorded between 22 March and 22 August, 2011, corresponding to an integrated luminosity of 2.1 fb^{-1}. The luminosity is given with an uncertainty of 3.7% [34,35].

Monte Carlo (MC) simulation samples are used to evaluate the contributions, and shapes of distributions of kinematic variables, for signal $t\bar{t}$ events and background processes not evaluated from complementary data samples. All MC samples are processed with the GEANT4 [36] simulation of the ATLAS detector [37] and are passed through the same analysis chain as data. The simulation includes multiple pp interactions per bunch crossing (pileup). Events are weighted such that the distribution of the average number of interactions per bunch crossing matches that observed in data. The mean number of pileup interactions varies between 5.7 and 7.1 for the different data-taking periods.

Samples with SM spin correlation and without spin correlation are generated using MC@NLO with the CTEQ6.6 PDF set and a top quark mass of 172.5 GeV. In both cases the events are hadronized using the HERWIG shower model [38,39]. Within the statistical uncertainty of the MC generation the yields of the SM $t\bar{t}$ and uncorrelated $t\bar{t}$ samples are the same. The background MC samples are described in Ref. [40].

Candidate events are selected in the dilepton topology. Channels with τ leptons are not explicitly considered, but reconstructed leptons can arise from leptonic τ decays and are included in the signal MC samples. The full object and event selection is discussed in Ref. [40]; therefore only a brief overview is given here. The analysis requires events selected online by an inclusive single-lepton trigger (e or μ). The detailed trigger requirements vary throughout data taking, but the p_T threshold ensures that the triggered lepton candidate is in the efficiency plateau. Electron candidates are reconstructed using energy deposits in the EM calorimeter associated to reconstructed tracks of charged particles in the ID. Muon candidate reconstruction makes use of tracking in the MS and ID. Jets are reconstructed with the anti-k_t algorithm [41] with a radius parameter $R = 0.4$, starting from energy clusters of adjacent calorimeter cells. The symbol E_T^{miss} is used to denote the magnitude of the missing transverse momentum [42]. The following kinematic requirements are made:

(i) Electron candidates are required to have $p_T > 25$ GeV and $|\eta| < 2.47$, excluding electrons from the transition region between the barrel and end-cap calorimeters defined by $1.37 < |\eta| < 1.52$. Muon candidates are required to have $p_T > 20$ GeV and $|\eta| < 2.5$. Events must have exactly two oppositely-charged lepton candidates (e^+e^-, $\mu^+\mu^-$, $e^{\pm}\mu^{\mp}$).

(ii) Events must have at least two jets with $p_T > 25$ GeV and $|\eta| < 2.5$.

(iii) Events in the e^+e^- and $\mu^+\mu^-$ channels are required to have $m_{\ell\ell} > 15$ GeV to ensure compatibility with the MC samples and remove contributions from Υ and J/ψ production.

(iv) Events in the e^+e^- and $\mu^+\mu^-$ channels must satisfy $E_T^{\text{miss}} > 60$ GeV to suppress backgrounds from

Z/γ^* + jets and W + jets events. In addition, $m_{\ell\ell}$ must differ by at least 10 GeV from the Z-boson mass ($m_Z =$ 91 GeV) to further suppress the Z/γ^* + jets background.

(v) For the $e^\pm \mu^\mp$ channel, no E_T^{miss} or $m_{\ell\ell}$ cuts are applied. In this case, the remaining background from $Z/\gamma^*(\to \tau\tau)$ + jets production is further suppressed by requiring that the scalar sum of the p_T of all selected jets and leptons is greater than 130 GeV.

The event selection rejects Z/γ^* + jets events with low invariant mass and those with invariant mass near the Z-boson mass. However, Z/γ^* + jets events with an $e^+ e^-$ or $\mu^+ \mu^-$ invariant mass outside of these regions can enter the signal sample when there is large E_T^{miss}, typically from mismeasurement. These events are difficult to properly model in simulations due to uncertainties on the non-Gaussian tails of the E_T^{miss} distribution, on the cross section for Z-boson production with multiple jets, and on the lepton energy resolution. The Z/γ^* + jets background in dielectron and dimuon events is evaluated using a data-driven (DD) technique in which the MC simulation yield of Z/γ^* + jets events is normalized to the data using a control region defined by a dilepton invariant mass within 10 GeV of the Z-boson mass [40].

The backgrounds from events with misidentified (fake) leptons, primarily from W + jets events, are evaluated from data using a matrix method [43]. The matrix method makes use of the efficiency of real lepton identification and rate of lepton misidentification measured in several control regions, which are chosen to be enhanced in different sources of fake leptons [40]. Contributions from real leptons due to W + jets events in the fake lepton control region are subtracted using MC simulation. Comparisons of data and MC simulation in control regions are used to tune the rates to the expected signal region composition. The fake lepton yield is then estimated by weighting each event in a sample containing one or two loosely identified leptons.

The contributions from other electroweak background processes with two real leptons, such as single top, $Z \to \tau\tau$, WW, ZZ, and WZ production are determined from MC simulations normalized to the theoretical predictions. The expected numbers of signal and background events are compared to data in Table I. The number of observed events in each channel is: 477 for the $e^+ e^-$ channel, 906 for the $\mu^+ \mu^-$ channel, and 2930 for the $e^\pm \mu^\mp$ channel, which dominates the total yield due to the looser selection criteria.

A binned log-likelihood fit is used to extract the spin correlation from the $\Delta\phi$ distribution in data. The fit includes a linear superposition of the distribution from SM $t\bar{t}$ MC simulation with coefficient f^{SM}, and from the uncorrelated $t\bar{t}$ MC simulation with coefficient $(1 - f^{\mathrm{SM}})$. The $e^+ e^-$, $\mu^+ \mu^-$, and $e^\pm \mu^\mp$ channels are fitted simultaneously with a common value of f^{SM}, a $t\bar{t}$ normalization that is allowed to vary (per channel) and a fixed

TABLE I. Observed dilepton yield in data and the expected signal and background composition from MC and DD samples. Systematic uncertainties are included.

$Z/\gamma^*(\to e^+ e^- / \mu^+ \mu^-)$ + jets (MC + DD)	64^{+11}_{-16}
$Z/\gamma^*(\to \tau\tau)$ + jets (MC)	175 ± 29
Fake leptons (DD)	160^{+140}_{-70}
Single top (MC)	197 ± 21
Diboson (MC)	148 ± 20
Total (non-$t\bar{t}$)	740^{+150}_{-80}
$t\bar{t}$ (MC)	3530^{+280}_{-340}
Total expected	4270^{+320}_{-350}
Observed	4313

background normalization. The fitted $t\bar{t}$ normalizations are in agreement with the theoretical prediction of the production cross section [44]. Negative values of f^{SM} correspond to an anticorrelation of the top and antitop quark spins. A value of $f^{\mathrm{SM}} = 0$ implies that the spins are uncorrelated and values of $f^{\mathrm{SM}} > 1$ indicate a larger strength of the $t\bar{t}$ spin correlation than predicted by the SM. The extraction of f^{SM} using the fitting procedure has been verified over a wide range of possible values, $-1 \le f^{\mathrm{SM}} \le 2$, using MC simulation pseudoexperiments with full detector simulation.

Figure 2 shows the reconstructed $\Delta\phi$ distribution for the sum of the three dilepton channels in data. SM and uncorrelated $t\bar{t}$ MC samples are overlaid along with the expected backgrounds.

Systematic uncertainties are evaluated by applying the fit procedure to pseudoexperiments created from MC samples modified to reflect the systematic variations. The fit of f^{SM} is repeated to determine the effect of each

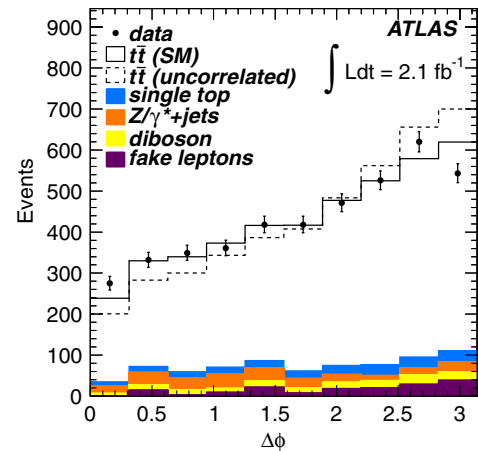FIG. 2 (color online). Reconstructed charged lepton $\Delta\phi$ distribution for the sum of the three dilepton channels. The integrated number of events for both the SM and the uncorrelated $t\bar{t}$ samples is fixed to the value from the fit. MC background samples are normalized using their predicted cross sections and the DD method in the case of Z/γ^* + jets. The fake lepton background is evaluated from data.

systematic uncertainty using the nominal templates. The difference between the means of Gaussian fits to the results from many pseudoexperiments using nominal and modified pseudodata is taken as the systematic uncertainty on f^{SM}.

The effect of the luminosity uncertainty is evaluated by scaling the number of signal and background events by the luminosity uncertainty, for backgrounds evaluated from MC simulation. Because of the finite size of the MC samples, the signal and background templates have statistical uncertainties. Each template bin is varied within its uncertainty, then f^{SM} is reevaluated. The resulting distribution for f^{SM} is fitted with a Gaussian. The width is taken as the MC simulation statistical uncertainty.

The mismodeling of the muon (electron) trigger, reconstruction, and selection efficiencies in the simulation is corrected using scale factors derived from measurements of the efficiency in data. $Z \rightarrow \mu^+ \mu^-$ ($Z \rightarrow e^+ e^-$) decays are used to obtain scale factors as a function of the kinematic variables of the leptons. Systematic uncertainties on these scale factors are evaluated by varying the selection of events used in the efficiency measurements and by checking the stability of the measurements over the course of the data-taking period. The modeling of the lepton momentum scale and resolution is studied using the reconstructed dilepton invariant mass distributions of Z/γ^* candidate events and the simulation is adjusted accordingly.

The jet energy scale, jet energy resolution, and reconstruction efficiency affect the acceptance. The jet energy scale and its uncertainty are derived by combining information from test-beam data, LHC collision data and simulation [45]. For jets within the acceptance, the jet energy scale varies in the range 4%–10% as a function of jet p_T and η, including an additional uncertainty due to multiple pp interactions. The energy resolution for jets is measured in dijet events and agrees with predictions from simulation within 10% for jets with $p_T > 30$ GeV. The jet reconstruction efficiency is evaluated using minimum bias and dijet events and depends on the p_T of the jet. Its systematic uncertainty is in the range 1%–3% based on the comparison of data and MC simulation. The uncertainties from the energy scale and resolution corrections for leptons and jets are propagated into the calculation of E_T^{miss}.

The uncertainty on the kinematic properties of the $t\bar{t}$ signal events gives rise to systematic uncertainties on the shape of the $\Delta\phi$ distribution and signal acceptance. This is evaluated by considering the choice of generator, the parton shower and fragmentation model, the modeling of initial and final state radiation (ISR/FSR), the PDF and top quark mass. The generator uncertainty is evaluated by comparing the MC@NLO predictions with those of POWHEG [46–48] interfaced to HERWIG. To estimate the uncertainty due to the parton shower modeling and fragmentation, the difference between POWHEG interfaced to HERWIG (cluster

fragmentation) and PYTHIA [49] (string fragmentation) is taken. The uncertainty due to ISR/FSR is evaluated using the ACERMC generator [50] interfaced to the PYTHIA shower model, by varying the parameters controlling ISR and FSR in a range consistent with those used in the Perugia Hard/ Soft tune variations [51]. The average of the absolute values of the upward and downward variations is taken as the systematic uncertainty. The impact of the choice of PDF in simulation was studied by reweighting the MC samples to three PDF sets (CTEQ6.6, MSTW2008NLO [52], and NNPDF20 [53]) and taking the largest of either the variation interval (from the error sets) or difference between the central values of any two PDF sets [32]. The systematic uncertainty associated with the top quark mass is assessed using MC@NLO samples generated assuming different top quark masses in the range 167.5 to 177.5 GeV in increments of 2.5 GeV. The values of f^{SM} are fitted as a linear function of the top quark mass and a conservative systematic uncertainty is obtained by evaluating this function at 172.5 ± 2.5 GeV.

Overall normalization uncertainties on the backgrounds from single top quark and diboson production are taken to be 10% [54,55] and 5% [56], respectively. The resulting uncertainty on f^{SM} is found to be negligible. The systematic uncertainties from the background evaluations derived from the data include the statistical uncertainties in these methods as well as the systematic uncertainties arising from lepton and jet identification and reconstruction, and the MC simulation estimates used. An uncertainty on the DD Z/γ^* + jets estimation is evaluated by varying the E_T^{miss} cut in the control region by ± 5 GeV and is found to be negligible. A mismodeling of the Z-boson p_T is observed in the Z-boson dominated control region. The Z-boson p_T distribution is weighted to achieve agreement with data and the difference between the unweighted and weighted MC simulation is taken as an additional, but negligible, modeling uncertainty on f^{SM}. For the DD fake lepton background the systematic uncertainty affects the shape of the $\Delta\phi$ distribution. Systematic uncertainties are derived by adjusting the signal region composition based on uncertainties estimated from MC simulation, and by comparing data and MC samples. The different sources of fake leptons have different shapes and the change in relative flavor composition of the sample gives an estimate of the shape uncertainty.

Because of a hardware failure a small rectangular region of the LAr calorimeter could not be read out in a subset of the data (0.87 fb^{-1}). This affects the electron, jet, and E_T^{miss} reconstruction. Electrons within the affected region are rejected, as are events in which a jet with $p_T > 20$ GeV is in the affected region. The MC simulation is divided into subsamples based on the fraction of the total luminosity affected and treated in the same way as data. A systematic uncertainty is evaluated by comparing MC simulation with and without the jet and electron rejection.

TABLE II. Summary of the effect of statistical and systematic uncertainties on the measured value of f^{SM} for the combined fit.

Uncertainty source	Δf^{SM}
Data statistics	± 0.14
MC simulation template statistics	± 0.09
Luminosity	± 0.01
Lepton	± 0.01
Jet energy scale, resolution and efficiency	± 0.12
NLO generator	± 0.08
Parton shower and fragmentation	± 0.08
ISR/FSR	± 0.07
PDF uncertainty	± 0.07
Top quark mass	± 0.01
Fake leptons	$+0.16/-0.07$
Calorimeter readout	± 0.01
All systematics	$+0.27/-0.22$
Statistical + systematic	$+0.30/-0.26$

The effect of the systematic uncertainties in terms of Δf^{SM} are listed in Table II. The total systematic uncertainty is calculated by combining all systematic uncertainties in quadrature.

The measured value of f^{SM} for the combined fit is found to be $1.30 \pm 0.14(\mathrm{stat})\,{}^{+0.27}_{-0.22}(\mathrm{syst})$. This can be used to obtain a value for $A^{\mathrm{measured}}_{\mathrm{basis}}$ by applying it as a multiplicative factor to the NLO QCD prediction of A_{basis} using $A^{\mathrm{measured}}_{\mathrm{basis}} = A^{SM}_{\mathrm{basis}} \cdot f^{SM}$, where the subscript "basis" indicates a chosen spin basis [11]. For the helicity basis this results in $A_{\mathrm{helicity}} = 0.40 \pm 0.04(\mathrm{stat})\,{}^{+0.08}_{-0.07}(\mathrm{syst})$, and for the maximal basis $A_{\mathrm{maximal}} = 0.57 \pm 0.06(\mathrm{stat})\,{}^{+0.12}_{-0.10}(\mathrm{syst})$, where the SM predictions are 0.31 and 0.44, respectively. MC simulation pseudoexperiments including systematic uncertainties are used to calculate the probability that a value of f^{SM} or larger is measured using the assumption of $f^{SM} = 0$. For the observed limit the value of f^{SM} measured in data is used and for the expected limit a value of $f^{SM} = 1$ is used. The hypothesis of zero $t\bar{t}$ spin correlation is excluded with a significance of 5.1 standard deviations. The expected significance is 4.2 standard deviations.

In conclusion, the first measurement of $t\bar{t}$ spin correlation at the LHC has been presented using 2.1 fb^{-1} of ATLAS data in the dilepton decay topology. A template fit is performed to the $\Delta\phi$ distribution and the measured value of $f^{SM} = 1.30\,{}^{+0.27}_{-0.22}(\mathrm{syst})$ is consistent with the SM prediction. The data are inconsistent with the hypothesis of zero spin correlation with a significance of 5.1 standard deviations.

[1] S. Abachi *et al.* (D0 Collaboration), Phys. Rev. Lett. **74,** 2422 (1995).
[2] F. Abe *et al.* (CDF Collaboration), Phys. Rev. Lett. **74,** 2626 (1995).
[3] I. I. Y. Bigi, Y. L. Dokshitzer, V. A. Khoze, J. H. Kuhn, and P. M. Zerwas, Phys. Lett. B **181,** 157 (1986).
[4] M. Beneke *et al.*, arXiv:hep-ph/0003033.
[5] W. Bernreuther, J. Phys. G **35,** 083001 (2008).
[6] T. Aaltonen *et al.* (CDF Collaboration), Phys. Rev. Lett. **105,** 232003 (2010).
[7] V. M. Abazov *et al.* (D0 Collaboration), Phys. Rev. Lett. **106,** 022001 (2011).
[8] W. Bernreuther and Z. G. Si, Nucl. Phys. **B837,** 90 (2010); (private communication).
[9] G. Mahlon and S. Parke, Phys. Rev. D **53,** 4886 (1996).
[10] T. Stelzer and S. Willenbrock, Phys. Lett. B **374,** 169 (1996).
[11] W. Bernreuther, A. Brandenburg, Z. G. Si, and P. Uwer, Phys. Rev. Lett. **87,** 242002 (2001).
[12] P. Uwer, Phys. Lett. B **609,** 271 (2005).
[13] G. Mahlon and S. Parke, Phys. Rev. D **81,** 074024 (2010).
[14] R. Frederix and F. Maltoni, J. High Energy Phys. 01 (2009) 047.
[15] M. Arai, N. Okada, and K. Smolek, Phys. Rev. D **79,** 074019 (2009).
[16] G. L. Kane, G. A. Ladinsky, and C. P. Yuan, Phys. Rev. D **45,** 124 (1992).
[17] K. Cheung, Phys. Rev. D **55,** 4430 (1997).

[18] J.-Y. Liu, Z.-G. Si, and C.-X. Yue, Phys. Rev. D **81**, 015011 (2010).

[19] W. Bernreuther, M. Flesch, and P. Haberl, Phys. Rev. D **58**, 114031 (1998).

[20] V. M. Abazov *et al.* (D0 Collaboration), Phys. Rev. D **80**, 071102 (2009).

[21] The ATLAS coordinate system is right-handed with the pseudorapidity η defined as $\eta = -\ln[\tan(\theta/2)]$, where the polar angle θ is measured with respect to the LHC beam line. The azimuthal angle ϕ is measured with respect to the x axis, which points towards the center of the LHC ring. The z axis is parallel to the anticlockwise beam viewed from above. Transverse momentum and energy are defined as $p_T = p\sin\theta$ and $E_T = E\sin\theta$, respectively.

[22] W. Bernreuther, A. Brandenburg, Z.-G. Si, and P. Uwer, Nucl. Phys. **B690**, 81 (2004).

[23] T. Aaltonen *et al.* (CDF Collaboration), Phys. Rev. D **83**, 031104 (2011).

[24] V. M. Abazov *et al.* (D0 Collaboration), Phys. Rev. Lett. **107**, 032001 (2011).

[25] V. M. Abazov *et al.* (D0 Collaboration), Phys. Lett. B **702**, 16 (2011).

[26] V. M. Abazov *et al.* (D0 Collaboration), Phys. Rev. Lett. **108**, 032004 (2012).

[27] S. Frixione and B. R. Webber, J. High Energy Phys. 06 (2002) 029.

[28] S. Frixione, P. Nason, and B. Webber, J. High Energy Phys. 08 (2003) 007.

[29] S. Frixione, E. Laenen, P. Motylinski, and B. Webber, J. High Energy Phys. 03 (2006) 092.

[30] P. M. Nadolsky, H.-L. Lai, Q.-H. Cao, J. Huston, J. Pumplin, D. Stump, W.-K. Tung, and C.-P. Yuan, Phys. Rev. D **78**, 013004 (2008).

[31] F. Hubaut, E. Monnier, P. Pralavorio, K. Smolek, and V. Simak, Eur. Phys. J. C **44S2**, 13 (2005).

[32] ATLAS Collaboration, arXiv:0901.0512.

[33] ATLAS Collaboration, JINST **3**, S08003 (2008).

[34] ATLAS Collaboration, Eur. Phys. J. C **71**, 1630 (2011).

[35] ATLAS Collaboration, Report No. ATLAS-CONF-2011-116, https://cdsweb.cern.ch/record/1376384.

[36] GEANT4 Collaboration, Nucl. Instrum. Methods Phys. Res., Sect. A **506**, 250 (2003).

[37] ATLAS Collaboration, Eur. Phys. J. C **70**, 823 (2010).

[38] G. Corcella *et al.*, J. High Energy Phys. 01 (2001) 010.

[39] G. Corcella *et al.*, arXiv:hep-ph/0210213.

[40] ATLAS Collaboration, arXiv:1202.4892 [J. High Energy Phys. (to be published)].

[41] M. Cacciari, G. Salam, and G. Soyez, J. High Energy Phys. 04 (2008) 063.

[42] ATLAS Collaboration, Eur. Phys. J. C **72**, 1844 (2012).

[43] ATLAS Collaboration, Eur. Phys. J. C **71**, 1577 (2011).

[44] M. Aliev, H. Lacker, U. Langenfeld, S. Moch, P. Uwer, and M. Wiedermann, Comput. Phys. Commun. **182**, 1034 (2011).

[45] ATLAS Collaboration, arXiv:1112.6426 [Eur. Phys. J. C (to be published)].

[46] P. Nason, J. High Energy Phys. 11 (2004) 040.

[47] S. Frixione, P. Nason, and C. Oleari, J. High Energy Phys. 11 (2007) 070.

[48] S. Alioli, P. Nason, C. Oleari, and E. Re, J. High Energy Phys. 06 (2010) 043.

[49] T. Sjostrand, S. Mrenna, and P. Skands, J. High Energy Phys. 05 (2006) 026.

[50] B. Kersevan and E. Richter-Was, arXiv:hep-ph/0405247.

[51] P. Z. Skands, Phys. Rev. D **82**, 074018 (2010).

[52] A. D. Martin, W. J. Stirling, R. S. Thorne, and G. Watt, Eur. Phys. J. C **63**, 189 (2009).

[53] R. D. Ball, L. Del Debbio, S. Forte, A. Guffanti, J. I. Latorre, J. Rojo, and M. Ubiali, Nucl. Phys. **B838**, 136 (2010).

[54] J. Campbell, R. K. Ellis, and F. Tramontano, Phys. Rev. D **70**, 094012 (2004).

[55] N. Kidonakis, arXiv:1005.3330.

[56] J. Campbell and R. K. Ellis, Nucl. Phys. B, Proc. Suppl. **205–206**, 10 (2010).

G. Aad,[47] B. Abbott,[110] J. Abdallah,[11] S. Abdel Khalek,[114] A. A. Abdelalim,[48] A. Abdesselam,[117] O. Abdinov,[10] B. Abi,[111] M. Abolins,[87] O. S. AbouZeid,[157] H. Abramowicz,[152] H. Abreu,[114] E. Acerbi,[88a,88b] B. S. Acharya,[163a,163b] L. Adamczyk,[37] D. L. Adams,[24] T. N. Addy,[55] J. Adelman,[174] M. Aderholz,[98] S. Adomeit,[97] P. Adragna,[74] T. Adye,[128] S. Aefsky,[22] J. A. Aguilar-Saavedra,[123b,b] M. Aharrouche,[80] S. P. Ahlen,[21] F. Ahles,[47] A. Ahmad,[147] M. Ahsan,[40] G. Aielli,[132a,132b] T. Akdogan,[18a] T. P. A. Åkesson,[78] G. Akimoto,[154] A. V. Akimov,[93] A. Akiyama,[66] M. S. Alam,[1] M. A. Alam,[75] J. Albert,[168] S. Albrand,[54] M. Aleksa,[29] I. N. Aleksandrov,[64] F. Alessandria,[88a] C. Alexa,[25a] G. Alexander,[152] G. Alexandre,[48] T. Alexopoulos,[9] M. Alhroob,[20] M. Aliev,[15] G. Alimonti,[88a] J. Alison,[119] M. Aliyev,[10] B. M. M. Allbrooke,[17] P. P. Allport,[72] S. E. Allwood-Spiers,[52] J. Almond,[81] A. Aloisio,[101a,101b] R. Alon,[170] A. Alonso,[78] B. Alvarez Gonzalez,[87] M. G. Alviggi,[101a,101b] K. Amako,[65] P. Amaral,[29] C. Amelung,[22] V. V. Ammosov,[127] A. Amorim,[123a,c] G. Amorós,[166] N. Amram,[152] C. Anastopoulos,[29] L. S. Ancu,[16] N. Andari,[114] T. Andeen,[34] C. F. Anders,[20] G. Anders,[57a] K. J. Anderson,[30] A. Andreazza,[88a,88b] V. Andrei,[57a] M-L. Andrieux,[54] X. S. Anduaga,[69] A. Angerami,[34] F. Anghinolfi,[29] A. Anisenkov,[106] N. Anjos,[123a] A. Annovi,[46] A. Antonaki,[8] M. Antonelli,[46] A. Antonov,[95] J. Antos,[143b] F. Anulli,[131a] S. Aoun,[82] L. Aperio Bella,[4] R. Apolle,[117,d] G. Arabidze,[87] I. Aracena,[142] Y. Arai,[65] A. T. H. Arce,[44] S. Arfaoui,[147] J-F. Arguin,[14] E. Arik,[18a,a] M. Arik,[18a] A. J. Armbruster,[86] O. Arnaez,[80] V. Arnal,[79] C. Arnault,[114] A. Artamonov,[94] G. Artoni,[131a,131b] D. Arutinov,[20] S. Asai,[154] R. Asfandiyarov,[171] S. Ask,[27] B. Åsman,[145a,145b] L. Asquith,[5] K. Assamagan,[24] A. Astbury,[168] A. Astvatsatourov,[51] B. Aubert,[4] E. Auge,[114] K. Augsten,[126] M. Aurousseau,[144a] G. Avolio,[162]

R. Avramidou,[9] D. Axen,[167] C. Ay,[53] G. Azuelos,[92,e] Y. Azuma,[154] M. A. Baak,[29] G. Baccaglioni,[88a]
C. Bacci,[133a,133b] A. M. Bach,[14] H. Bachacou,[135] K. Bachas,[29] M. Backes,[48] M. Backhaus,[20] E. Badescu,[25a]
P. Bagnaia,[131a,131b] S. Bahinipati,[2] Y. Bai,[32a] D. C. Bailey,[157] T. Bain,[157] J. T. Baines,[128] O. K. Baker,[174]
M. D. Baker,[24] S. Baker,[76] E. Banas,[38] P. Banerjee,[92] Sw. Banerjee,[171] D. Banfi,[29] A. Bangert,[149] V. Bansal,[168]
H. S. Bansil,[17] L. Barak,[170] S. P. Baranov,[93] A. Barashkou,[64] A. Barbaro Galtieri,[14] T. Barber,[47] E. L. Barberio,[85]
D. Barberis,[49a,49b] M. Barbero,[20] D. Y. Bardin,[64] T. Barillari,[98] M. Barisonzi,[173] T. Barklow,[142] N. Barlow,[27]
B. M. Barnett,[128] R. M. Barnett,[14] A. Baroncelli,[133a] G. Barone,[48] A. J. Barr,[117] F. Barreiro,[79]
J. Barreiro Guimarães da Costa,[56] P. Barrillon,[114] R. Bartoldus,[142] A. E. Barton,[70] V. Bartsch,[148] R. L. Bates,[52]
L. Batkova,[143a] J. R. Batley,[27] A. Battaglia,[16] M. Battistin,[29] F. Bauer,[135] H. S. Bawa,[142,f] S. Beale,[97] T. Beau,[77]
P. H. Beauchemin,[160] R. Beccherle,[49a] P. Bechtle,[20] H. P. Beck,[16] S. Becker,[97] M. Beckingham,[137] K. H. Becks,[173]
A. J. Beddall,[18c] A. Beddall,[18c] S. Bedikian,[174] V. A. Bednyakov,[64] C. P. Bee,[82] M. Begel,[24] S. Behar Harpaz,[151]
P. K. Behera,[62] M. Beimforde,[98] C. Belanger-Champagne,[84] P. J. Bell,[48] W. H. Bell,[48] G. Bella,[152] L. Bellagamba,[19a]
F. Bellina,[29] M. Bellomo,[29] A. Belloni,[56] O. Beloborodova,[106,g] K. Belotskiy,[95] O. Beltramello,[29] O. Benary,[152]
D. Benchekroun,[134a] C. Benchouk,[82] M. Bendel,[80] N. Benekos,[164] Y. Benhammou,[152] E. Benhar Noccioli,[48]
J. A. Benitez Garcia,[158b] D. P. Benjamin,[44] M. Benoit,[114] J. R. Bensinger,[22] K. Benslama,[129] S. Bentvelsen,[104]
D. Berge,[29] E. Bergeaas Kuutmann,[41] N. Berger,[4] F. Berghaus,[168] E. Berglund,[104] J. Beringer,[14] P. Bernat,[76]
R. Bernhard,[47] C. Bernius,[24] T. Berry,[75] C. Bertella,[82] A. Bertin,[19a,19b] F. Bertinelli,[29] F. Bertolucci,[121a,121b]
M. I. Besana,[88a,88b] N. Besson,[135] S. Bethke,[98] W. Bhimji,[45] R. M. Bianchi,[29] M. Bianco,[71a,71b] O. Biebel,[97]
S. P. Bieniek,[76] K. Bierwagen,[53] J. Biesiada,[14] M. Biglietti,[133a] H. Bilokon,[46] M. Bindi,[19a,19b] S. Binet,[114]
A. Bingul,[18c] C. Bini,[131a,131b] C. Biscarat,[176] U. Bitenc,[47] K. M. Black,[21] R. E. Blair,[5] J.-B. Blanchard,[135]
G. Blanchot,[29] T. Blazek,[143a] C. Blocker,[22] J. Blocki,[38] A. Blondel,[48] W. Blum,[80] U. Blumenschein,[53]
G. J. Bobbink,[104] V. B. Bobrovnikov,[106] S. S. Bocchetta,[78] A. Bocci,[44] C. R. Boddy,[117] M. Boehler,[41] J. Boek,[173]
N. Boelaert,[35] J. A. Bogaerts,[29] A. Bogdanchikov,[106] A. Bogouch,[89,a] C. Bohm,[145a] J. Bohm,[124] V. Boisvert,[75]
T. Bold,[37] V. Boldea,[25a] N. M. Bolnet,[135] M. Bomben,[77] M. Bona,[74] V. G. Bondarenko,[95] M. Bondioli,[162]
M. Boonekamp,[135] C. N. Booth,[138] S. Bordoni,[77] C. Borer,[16] A. Borisov,[127] G. Borissov,[70] I. Borjanovic,[12a]
M. Borri,[81] S. Borroni,[86] V. Bortolotto,[133a,133b] K. Bos,[104] D. Boscherini,[19a] M. Bosman,[11] H. Boterenbrood,[104]
D. Botterill,[128] J. Bouchami,[92] J. Boudreau,[122] E. V. Bouhova-Thacker,[70] D. Boumediene,[33] C. Bourdarios,[114]
N. Bousson,[82] A. Boveia,[30] J. Boyd,[29] I. R. Boyko,[64] N. I. Bozhko,[127] I. Bozovic-Jelisavcic,[12b] J. Bracinik,[17]
A. Braem,[29] P. Branchini,[133a] G. W. Brandenburg,[56] A. Brandt,[7] G. Brandt,[117] O. Brandt,[53] U. Bratzler,[155] B. Brau,[83]
J. E. Brau,[113] H. M. Braun,[173] B. Brelier,[157] J. Bremer,[29] K. Brendlinger,[119] R. Brenner,[165] S. Bressler,[170]
D. Britton,[52] F. M. Brochu,[27] I. Brock,[20] R. Brock,[87] T. J. Brodbeck,[70] E. Brodet,[152] F. Broggi,[88a] C. Bromberg,[87]
J. Bronner,[98] G. Brooijmans,[34] W. K. Brooks,[31b] G. Brown,[81] H. Brown,[7] P. A. Bruckman de Renstrom,[38]
D. Bruncko,[143b] R. Bruneliere,[47] S. Brunet,[60] A. Bruni,[19a] G. Bruni,[19a] M. Bruschi,[19a] T. Buanes,[13] Q. Buat,[54]
F. Bucci,[48] J. Buchanan,[117] N. J. Buchanan,[2] P. Buchholz,[140] R. M. Buckingham,[117] A. G. Buckley,[45] S. I. Buda,[25a]
I. A. Budagov,[64] B. Budick,[107] V. Büscher,[80] L. Bugge,[116] O. Bulekov,[95] M. Bunse,[42] T. Buran,[116] H. Burckhart,[29]
S. Burdin,[72] T. Burgess,[13] S. Burke,[128] E. Busato,[33] P. Bussey,[52] C. P. Buszello,[165] F. Butin,[29] B. Butler,[142]
J. M. Butler,[21] C. M. Buttar,[52] J. M. Butterworth,[76] W. Buttinger,[27] S. Cabrera Urbán,[166] D. Caforio,[19a,19b] O. Cakir,[3a]
P. Calafiura,[14] G. Calderini,[77] P. Calfayan,[97] R. Calkins,[105] L. P. Caloba,[23a] R. Caloi,[131a,131b] D. Calvet,[33] S. Calvet,[33]
R. Camacho Toro,[33] P. Camarri,[132a,132b] M. Cambiaghi,[118a,118b] D. Cameron,[116] L. M. Caminada,[14] S. Campana,[29]
M. Campanelli,[76] V. Canale,[101a,101b] F. Canelli,[30,h] A. Canepa,[158a] J. Cantero,[79] L. Capasso,[101a,101b]
M. D. M. Capeans Garrido,[29] I. Caprini,[25a] M. Caprini,[25a] D. Capriotti,[98] M. Capua,[36a,36b] R. Caputo,[80]
R. Cardarelli,[132a] T. Carli,[29] G. Carlino,[101a] L. Carminati,[88a,88b] B. Caron,[84] S. Caron,[103] E. Carquin,[31b]
G. D. Carrillo Montoya,[171] A. A. Carter,[74] J. R. Carter,[27] J. Carvalho,[123a,i] D. Casadei,[107] M. P. Casado,[11]
M. Cascella,[121a,121b] C. Caso,[49a,49b,a] A. M. Castaneda Hernandez,[171] E. Castaneda-Miranda,[171]
V. Castillo Gimenez,[166] N. F. Castro,[123a] G. Cataldi,[71a] F. Cataneo,[29] A. Catinaccio,[29] J. R. Catmore,[29] A. Cattai,[29]
G. Cattani,[132a,132b] S. Caughron,[87] D. Cauz,[163a,163c] P. Cavalleri,[77] D. Cavalli,[88a] M. Cavalli-Sforza,[11]
V. Cavasinni,[121a,121b] F. Ceradini,[133a,133b] A. S. Cerqueira,[23b] A. Cerri,[29] L. Cerrito,[74] F. Cerutti,[46] S. A. Cetin,[18b]
F. Cevenini,[101a,101b] A. Chafaq,[134a] D. Chakraborty,[105] K. Chan,[2] B. Chapleau,[84] J. D. Chapman,[27] J. W. Chapman,[86]
E. Chareyre,[77] D. G. Charlton,[17] V. Chavda,[81] C. A. Chavez Barajas,[29] S. Cheatham,[84] S. Chekanov,[5]
S. V. Chekulaev,[158a] G. A. Chelkov,[64] M. A. Chelstowska,[103] C. Chen,[63] H. Chen,[24] S. Chen,[32c] T. Chen,[32c]
X. Chen,[171] S. Cheng,[32a] A. Cheplakov,[64] V. F. Chepurnov,[64] R. Cherkaoui El Moursli,[134e] V. Chernyatin,[24] E. Cheu,[6]

S. L. Cheung,[157] L. Chevalier,[135] G. Chiefari,[101a,101b] L. Chikovani,[50a] J. T. Childers,[29] A. Chilingarov,[70]
G. Chiodini,[71a] A. S. Chisholm,[17] R. T. Chislett,[76] M. V. Chizhov,[64] G. Choudalakis,[30] S. Chouridou,[136]
I. A. Christidi,[76] A. Christov,[47] D. Chromek-Burckhart,[29] M. L. Chu,[150] J. Chudoba,[124] G. Ciapetti,[131a,131b]
A. K. Ciftci,[3a] R. Ciftci,[3a] D. Cinca,[33] V. Cindro,[73] M. D. Ciobotaru,[162] C. Ciocca,[19a] A. Ciocio,[14] M. Cirilli,[86]
M. Citterio,[88a] M. Ciubancan,[25a] A. Clark,[48] P. J. Clark,[45] W. Cleland,[122] J. C. Clemens,[82] B. Clement,[54]
C. Clement,[145a,145b] R. W. Clifft,[128] Y. Coadou,[82] M. Cobal,[163a,163c] A. Coccaro,[171] J. Cochran,[63] P. Coe,[117]
J. G. Cogan,[142] J. Coggeshall,[164] E. Cogneras,[176] J. Colas,[4] A. P. Colijn,[104] N. J. Collins,[17] C. Collins-Tooth,[52]
J. Collot,[54] G. Colon,[83] P. Conde Muiño,[123a] E. Coniavitis,[117] M. C. Conidi,[11] M. Consonni,[103] S. M. Consonni,[88a,88b]
V. Consorti,[47] S. Constantinescu,[25a] C. Conta,[118a,118b] G. Conti,[56] F. Conventi,[101a,j] J. Cook,[29] M. Cooke,[14]
B. D. Cooper,[76] A. M. Cooper-Sarkar,[117] K. Copic,[14] T. Cornelissen,[173] M. Corradi,[19a] F. Corriveau,[84,k]
A. Cortes-Gonzalez,[164] G. Cortiana,[98] G. Costa,[88a] M. J. Costa,[166] D. Costanzo,[138] T. Costin,[30] D. Côté,[29]
R. Coura Torres,[23a] L. Courneyea,[168] G. Cowan,[75] C. Cowden,[27] B. E. Cox,[81] K. Cranmer,[107] F. Crescioli,[121a,121b]
M. Cristinziani,[20] G. Crosetti,[36a,36b] R. Crupi,[71a,71b] S. Crépé-Renaudin,[54] C.-M. Cuciuc,[25a] C. Cuenca Almenar,[174]
T. Cuhadar Donszelmann,[138] M. Curatolo,[46] C. J. Curtis,[17] C. Cuthbert,[149] P. Cwetanski,[60] H. Czirr,[140]
P. Czodrowski,[43] Z. Czyczula,[174] S. D'Auria,[52] M. D'Onofrio,[72] A. D'Orazio,[131a,131b] P. V. M. Da Silva,[23a]
C. Da Via,[81] W. Dabrowski,[37] A. Dafinca,[117] T. Dai,[86] C. Dallapiccola,[83] M. Dam,[35] M. Dameri,[49a,49b]
D. S. Damiani,[136] H. O. Danielsson,[29] D. Dannheim,[98] V. Dao,[48] G. Darbo,[49a] G. L. Darlea,[25b] W. Davey,[20]
T. Davidek,[125] N. Davidson,[85] R. Davidson,[70] E. Davies,[117,d] M. Davies,[92] A. R. Davison,[76] Y. Davygora,[57a]
E. Dawe,[141] I. Dawson,[138] J. W. Dawson,[5,a] R. K. Daya-Ishmukhametova,[22] K. De,[7] R. de Asmundis,[101a]
S. De Castro,[19a,19b] P. E. De Castro Faria Salgado,[24] S. De Cecco,[77] J. de Graat,[97] N. De Groot,[103] P. de Jong,[104]
C. De La Taille,[114] H. De la Torre,[79] B. De Lotto,[163a,163c] L. de Mora,[70] L. De Nooij,[104] D. De Pedis,[131a]
A. De Salvo,[131a] U. De Sanctis,[163a,163c] A. De Santo,[148] J. B. De Vivie De Regie,[114] G. De Zorzi,[131a,131b] S. Dean,[76]
W. J. Dearnaley,[70] R. Debbe,[24] C. Debenedetti,[45] B. Dechenaux,[54] D. V. Dedovich,[64] J. Degenhardt,[119]
M. Dehchar,[117] C. Del Papa,[163a,163c] J. Del Peso,[79] T. Del Prete,[121a,121b] T. Delemontex,[54] M. Deliyergiyev,[73]
A. Dell'Acqua,[29] L. Dell'Asta,[21] M. Della Pietra,[101a,j] D. della Volpe,[101a,101b] M. Delmastro,[4] N. Delruelle,[29]
P. A. Delsart,[54] C. Deluca,[147] S. Demers,[174] M. Demichev,[64] B. Demirkoz,[11,l] J. Deng,[162] S. P. Denisov,[127]
D. Derendarz,[38] J. E. Derkaoui,[134d] F. Derue,[77] P. Dervan,[72] K. Desch,[20] E. Devetak,[147] P. O. Deviveiros,[104]
A. Dewhurst,[128] B. DeWilde,[147] S. Dhaliwal,[157] R. Dhullipudi,[24,m] A. Di Ciaccio,[132a,132b] L. Di Ciaccio,[4]
A. Di Girolamo,[29] B. Di Girolamo,[29] S. Di Luise,[133a,133b] A. Di Mattia,[171] B. Di Micco,[29] R. Di Nardo,[46]
A. Di Simone,[132a,132b] R. Di Sipio,[19a,19b] M. A. Diaz,[31a] F. Diblen,[18c] E. B. Diehl,[86] J. Dietrich,[41] T. A. Dietzsch,[57a]
S. Diglio,[85] K. Dindar Yagci,[39] J. Dingfelder,[20] C. Dionisi,[131a,131b] P. Dita,[25a] S. Dita,[25a] F. Dittus,[29] F. Djama,[82]
T. Djobava,[50b] M. A. B. do Vale,[23c] A. Do Valle Wemans,[123a] T. K. O. Doan,[4] M. Dobbs,[84] R. Dobinson,[29,a]
D. Dobos,[29] E. Dobson,[29,n] J. Dodd,[34] C. Doglioni,[48] T. Doherty,[52] Y. Doi,[65,a] J. Dolejsi,[125] I. Dolenc,[73]
Z. Dolezal,[125] B. A. Dolgoshein,[95,a] T. Dohmae,[154] M. Donadelli,[23d] M. Donega,[119] J. Donini,[33] J. Dopke,[29]
A. Doria,[101a] A. Dos Anjos,[171] M. Dosil,[11] A. Dotti,[121a,121b] M. T. Dova,[69] J. D. Dowell,[17] A. D. Doxiadis,[104]
A. T. Doyle,[52] Z. Drasal,[125] J. Drees,[173] N. Dressnandt,[119] H. Drevermann,[29] C. Driouichi,[35] M. Dris,[9] J. Dubbert,[98]
S. Dube,[14] E. Duchovni,[170] G. Duckeck,[97] A. Dudarev,[29] F. Dudziak,[63] M. Dührssen,[29] I. P. Duerdoth,[81] L. Duflot,[114]
M-A. Dufour,[84] M. Dunford,[29] H. Duran Yildiz,[3a] R. Duxfield,[138] M. Dwuznik,[37] F. Dydak,[29] M. Düren,[51]
W. L. Ebenstein,[44] J. Ebke,[97] S. Eckweiler,[80] K. Edmonds,[80] C. A. Edwards,[75] N. C. Edwards,[52] W. Ehrenfeld,[41]
T. Ehrich,[98] T. Eifert,[142] G. Eigen,[13] K. Einsweiler,[14] E. Eisenhandler,[74] T. Ekelof,[165] M. El Kacimi,[134c] M. Ellert,[165]
S. Elles,[4] F. Ellinghaus,[80] K. Ellis,[74] N. Ellis,[29] J. Elmsheuser,[97] M. Elsing,[29] D. Emeliyanov,[128] R. Engelmann,[147]
A. Engl,[97] B. Epp,[61] A. Eppig,[86] J. Erdmann,[53] A. Ereditato,[16] D. Eriksson,[145a] J. Ernst,[1] M. Ernst,[24] J. Ernwein,[135]
D. Errede,[164] S. Errede,[164] E. Ertel,[80] M. Escalier,[114] C. Escobar,[122] X. Espinal Curull,[11] B. Esposito,[46] F. Etienne,[82]
A. I. Etienvre,[135] E. Etzion,[152] D. Evangelakou,[53] H. Evans,[60] L. Fabbri,[19a,19b] C. Fabre,[29] R. M. Fakhrutdinov,[127]
S. Falciano,[131a] Y. Fang,[171] M. Fanti,[88a,88b] A. Farbin,[7] A. Farilla,[133a] J. Farley,[147] T. Farooque,[157] S. Farrell,[162]
S. M. Farrington,[117] P. Farthouat,[29] P. Fassnacht,[29] D. Fassouliotis,[8] B. Fatholahzadeh,[157] A. Favareto,[88a,88b]
L. Fayard,[114] S. Fazio,[36a,36b] R. Febbraro,[33] P. Federic,[143a] O. L. Fedin,[120] W. Fedorko,[87] M. Fehling-Kaschek,[47]
L. Feligioni,[82] D. Fellmann,[5] C. Feng,[32d] E. J. Feng,[30] A. B. Fenyuk,[127] J. Ferencei,[143b] J. Ferland,[92] W. Fernando,[108]
S. Ferrag,[52] J. Ferrando,[52] V. Ferrara,[41] A. Ferrari,[165] P. Ferrari,[104] R. Ferrari,[118a] D. E. Ferreira de Lima,[52]
A. Ferrer,[166] M. L. Ferrer,[46] D. Ferrere,[48] C. Ferretti,[86] A. Ferretto Parodi,[49a,49b] M. Fiascaris,[30] F. Fiedler,[80]
A. Filipčič,[73] A. Filippas,[9] F. Filthaut,[103] M. Fincke-Keeler,[168] M. C. N. Fiolhais,[123a,i] L. Fiorini,[166] A. Firan,[39]

G. Fischer,[41] P. Fischer,[20] M. J. Fisher,[108] M. Flechl,[47] I. Fleck,[140] J. Fleckner,[80] P. Fleischmann,[172]
S. Fleischmann,[173] T. Flick,[173] A. Floderus,[78] L. R. Flores Castillo,[171] M. J. Flowerdew,[98] M. Fokitis,[9]
T. Fonseca Martin,[16] D. A. Forbush,[137] A. Formica,[135] A. Forti,[81] D. Fortin,[158a] J. M. Foster,[81] D. Fournier,[114]
A. Foussat,[29] A. J. Fowler,[44] K. Fowler,[136] H. Fox,[70] P. Francavilla,[11] S. Franchino,[118a,118b] D. Francis,[29] T. Frank,[170]
M. Franklin,[56] S. Franz,[29] M. Fraternali,[118a,118b] S. Fratina,[119] S. T. French,[27] F. Friedrich,[43] R. Froeschl,[29]
D. Froidevaux,[29] J. A. Frost,[27] C. Fukunaga,[155] E. Fullana Torregrosa,[29] J. Fuster,[166] C. Gabaldon,[29] O. Gabizon,[170]
T. Gadfort,[24] S. Gadomski,[48] G. Gagliardi,[49a,49b] P. Gagnon,[60] C. Galea,[97] E. J. Gallas,[117] V. Gallo,[16] B. J. Gallop,[128]
P. Gallus,[124] K. K. Gan,[108] Y. S. Gao,[142,f] V. A. Gapienko,[127] A. Gaponenko,[14] F. Garberson,[174] M. Garcia-Sciveres,[14]
C. García,[166] J. E. García Navarro,[166] R. W. Gardner,[30] N. Garelli,[29] H. Garitaonandia,[104] V. Garonne,[29] J. Garvey,[17]
C. Gatti,[46] G. Gaudio,[118a] B. Gaur,[140] L. Gauthier,[135] P. Gauzzi,[131a,131b] I. L. Gavrilenko,[93] C. Gay,[167] G. Gaycken,[20]
J-C. Gayde,[29] E. N. Gazis,[9] P. Ge,[32d] C. N. P. Gee,[128] D. A. A. Geerts,[104] Ch. Geich-Gimbel,[20] K. Gellerstedt,[145a,145b]
C. Gemme,[49a] A. Gemmell,[52] M. H. Genest,[54] S. Gentile,[131a,131b] M. George,[53] S. George,[75] P. Gerlach,[173]
A. Gershon,[152] C. Geweniger,[57a] H. Ghazlane,[134b] N. Ghodbane,[33] B. Giacobbe,[19a] S. Giagu,[131a,131b]
V. Giakoumopoulou,[8] V. Giangiobbe,[11] F. Gianotti,[29] B. Gibbard,[24] A. Gibson,[157] S. M. Gibson,[29] L. M. Gilbert,[117]
V. Gilewsky,[90] D. Gillberg,[28] A. R. Gillman,[128] D. M. Gingrich,[2,e] J. Ginzburg,[152] N. Giokaris,[8] M. P. Giordani,[163c]
R. Giordano,[101a,101b] F. M. Giorgi,[15] P. Giovannini,[98] P. F. Giraud,[135] D. Giugni,[88a] M. Giunta,[92] P. Giusti,[19a]
B. K. Gjelsten,[116] L. K. Gladilin,[96] C. Glasman,[79] J. Glatzer,[47] A. Glazov,[41] K. W. Glitza,[173] G. L. Glonti,[64]
J. R. Goddard,[74] J. Godfrey,[141] J. Godlewski,[29] M. Goebel,[41] T. Göpfert,[43] C. Goeringer,[80] C. Gössling,[42]
T. Göttfert,[98] S. Goldfarb,[86] T. Golling,[174] A. Gomes,[123a,c] L. S. Gomez Fajardo,[41] R. Gonçalo,[75]
J. Goncalves Pinto Firmino Da Costa,[41] L. Gonella,[20] A. Gonidec,[29] S. Gonzalez,[171] S. González de la Hoz,[166]
G. Gonzalez Parra,[11] M. L. Gonzalez Silva,[26] S. Gonzalez-Sevilla,[48] J. J. Goodson,[147] L. Goossens,[29]
P. A. Gorbounov,[94] H. A. Gordon,[24] I. Gorelov,[102] G. Gorfine,[173] B. Gorini,[29] E. Gorini,[71a,71b] A. Gorišek,[73]
E. Gornicki,[38] S. A. Gorokhov,[127] V. N. Goryachev,[127] B. Gosdzik,[41] M. Gosselink,[104] M. I. Gostkin,[64]
I. Gough Eschrich,[162] M. Gouighri,[134a] D. Goujdami,[134c] M. P. Goulette,[48] A. G. Goussiou,[137] C. Goy,[4]
S. Gozpinar,[22] I. Grabowska-Bold,[37] P. Grafström,[29] K-J. Grahn,[41] F. Grancagnolo,[71a] S. Grancagnolo,[15]
V. Grassi,[147] V. Gratchev,[120] N. Grau,[34] H. M. Gray,[29] J. A. Gray,[147] E. Graziani,[133a] O. G. Grebenyuk,[120]
T. Greenshaw,[72] Z. D. Greenwood,[24,m] K. Gregersen,[35] I. M. Gregor,[41] P. Grenier,[142] J. Griffiths,[137]
N. Grigalashvili,[64] A. A. Grillo,[136] S. Grinstein,[11] Y. V. Grishkevich,[96] J.-F. Grivaz,[114] M. Groh,[98] E. Gross,[170]
J. Grosse-Knetter,[53] J. Groth-Jensen,[170] K. Grybel,[140] V. J. Guarino,[5] D. Guest,[174] C. Guicheney,[33] A. Guida,[71a,71b]
S. Guindon,[53] H. Guler,[84,o] J. Gunther,[124] B. Guo,[157] J. Guo,[34] A. Gupta,[30] Y. Gusakov,[64] V. N. Gushchin,[127]
P. Gutierrez,[110] N. Guttman,[152] O. Gutzwiller,[171] C. Guyot,[135] C. Gwenlan,[117] C. B. Gwilliam,[72] A. Haas,[142]
S. Haas,[29] C. Haber,[14] H. K. Hadavand,[39] D. R. Hadley,[17] P. Haefner,[98] F. Hahn,[29] S. Haider,[29] Z. Hajduk,[38]
H. Hakobyan,[175] D. Hall,[117] J. Haller,[53] K. Hamacher,[173] P. Hamal,[112] M. Hamer,[53] A. Hamilton,[144b,p]
S. Hamilton,[160] H. Han,[32a] L. Han,[32b] K. Hanagaki,[115] K. Hanawa,[159] M. Hance,[14] C. Handel,[80] P. Hanke,[57a]
J. R. Hansen,[35] J. B. Hansen,[35] J. D. Hansen,[35] P. H. Hansen,[35] P. Hansson,[142] K. Hara,[159] G. A. Hare,[136]
T. Harenberg,[173] S. Harkusha,[89] D. Harper,[86] R. D. Harrington,[45] O. M. Harris,[137] K. Harrison,[17] J. Hartert,[47]
F. Hartjes,[104] T. Haruyama,[65] A. Harvey,[55] S. Hasegawa,[100] Y. Hasegawa,[139] S. Hassani,[135] M. Hatch,[29] D. Hauff,[98]
S. Haug,[16] M. Hauschild,[29] R. Hauser,[87] M. Havranek,[20] B. M. Hawes,[117] C. M. Hawkes,[17] R. J. Hawkings,[29]
A. D. Hawkins,[78] D. Hawkins,[162] T. Hayakawa,[66] T. Hayashi,[159] D. Hayden,[75] H. S. Hayward,[72] S. J. Haywood,[128]
E. Hazen,[21] M. He,[32d] S. J. Head,[17] V. Hedberg,[78] L. Heelan,[7] S. Heim,[87] B. Heinemann,[14] S. Heisterkamp,[35]
L. Helary,[4] C. Heller,[97] M. Heller,[29] S. Hellman,[145a,145b] D. Hellmich,[20] C. Helsens,[11] R. C. W. Henderson,[70]
M. Henke,[57a] A. Henrichs,[53] A. M. Henriques Correia,[29] S. Henrot-Versille,[114] F. Henry-Couannier,[82] C. Hensel,[53]
T. Henß,[173] C. M. Hernandez,[7] Y. Hernández Jiménez,[166] R. Herrberg,[15] A. D. Hershenhorn,[151] G. Herten,[47]
R. Hertenberger,[97] L. Hervas,[29] G. G. Hesketh,[76] N. P. Hessey,[104] E. Higón-Rodriguez,[166] D. Hill,[5,a] J. C. Hill,[27]
N. Hill,[5] K. H. Hiller,[41] S. Hillert,[20] S. J. Hillier,[17] I. Hinchliffe,[14] E. Hines,[119] M. Hirose,[115] F. Hirsch,[42]
D. Hirschbuehl,[173] J. Hobbs,[147] N. Hod,[152] M. C. Hodgkinson,[138] P. Hodgson,[138] A. Hoecker,[29]
M. R. Hoeferkamp,[102] J. Hoffman,[39] D. Hoffmann,[82] M. Hohlfeld,[80] M. Holder,[140] S. O. Holmgren,[145a] T. Holy,[126]
J. L. Holzbauer,[87] Y. Homma,[66] T. M. Hong,[119] L. Hooft van Huysduynen,[107] T. Horazdovsky,[126] C. Horn,[142]
S. Horner,[47] J-Y. Hostachy,[54] S. Hou,[150] M. A. Houlden,[72] A. Hoummada,[134a] J. Howarth,[81] D. F. Howell,[117]
I. Hristova,[15] J. Hrivnac,[114] I. Hruska,[124] T. Hryn'ova,[4] P. J. Hsu,[80] S.-C. Hsu,[14] G. S. Huang,[110] Z. Hubacek,[126]
F. Hubaut,[82] F. Huegging,[20] A. Huettmann,[41] T. B. Huffman,[117] E. W. Hughes,[34] G. Hughes,[70] R. E. Hughes-Jones,[81]

M. Huhtinen,[29] P. Hurst,[56] M. Hurwitz,[14] U. Husemann,[41] N. Huseynov,[64,q] J. Huston,[87] J. Huth,[56] G. Iacobucci,[48]
G. Iakovidis,[9] M. Ibbotson,[81] I. Ibragimov,[140] R. Ichimiya,[66] L. Iconomidou-Fayard,[114] J. Idarraga,[114] P. Iengo,[101a]
O. Igonkina,[104] Y. Ikegami,[65] M. Ikeno,[65] Y. Ilchenko,[39] D. Iliadis,[153] N. Ilic,[157] M. Imori,[154] T. Ince,[20]
J. Inigo-Golfin,[29] P. Ioannou,[8] M. Iodice,[133a] V. Ippolito,[131a,131b] A. Irles Quiles,[166] C. Isaksson,[165] A. Ishikawa,[66]
M. Ishino,[67] R. Ishmukhametov,[39] C. Issever,[117] S. Istin,[18a] A. V. Ivashin,[127] W. Iwanski,[38] H. Iwasaki,[65] J. M. Izen,[40]
V. Izzo,[101a] B. Jackson,[119] J. N. Jackson,[72] P. Jackson,[142] M. R. Jaekel,[29] V. Jain,[60] K. Jakobs,[47] S. Jakobsen,[35]
J. Jakubek,[126] D. K. Jana,[110] E. Jankowski,[157] E. Jansen,[76] H. Jansen,[29] A. Jantsch,[98] M. Janus,[47] G. Jarlskog,[78]
L. Jeanty,[56] K. Jelen,[37] I. Jen-La Plante,[30] P. Jenni,[29] A. Jeremie,[4] P. Jež,[35] S. Jézéquel,[4] M. K. Jha,[19a] H. Ji,[171] W. Ji,[80]
J. Jia,[147] Y. Jiang,[32b] M. Jimenez Belenguer,[41] G. Jin,[32b] S. Jin,[32a] O. Jinnouchi,[156] M. D. Joergensen,[35] D. Joffe,[39]
L. G. Johansen,[13] M. Johansen,[145a,145b] K. E. Johansson,[145a] P. Johansson,[138] S. Johnert,[41] K. A. Johns,[6]
K. Jon-And,[145a,145b] G. Jones,[117] R. W. L. Jones,[70] T. W. Jones,[76] T. J. Jones,[72] O. Jonsson,[29] C. Joram,[29]
P. M. Jorge,[123a] J. Joseph,[14] J. Jovicevic,[146] T. Jovin,[12b] X. Ju,[171] C. A. Jung,[42] R. M. Jungst,[29] V. Juranek,[124]
P. Jussel,[61] A. Juste Rozas,[11] V. V. Kabachenko,[127] S. Kabana,[16] M. Kaci,[166] A. Kaczmarska,[38] P. Kadlecik,[35]
M. Kado,[114] H. Kagan,[108] M. Kagan,[56] S. Kaiser,[98] E. Kajomovitz,[151] S. Kalinin,[173] L. V. Kalinovskaya,[64]
S. Kama,[39] N. Kanaya,[154] M. Kaneda,[29] S. Kaneti,[27] T. Kanno,[156] V. A. Kantserov,[95] J. Kanzaki,[65] B. Kaplan,[174]
A. Kapliy,[30] J. Kaplon,[29] D. Kar,[43] M. Karagounis,[20] M. Karagoz,[117] M. Karnevskiy,[41] K. Karr,[5] V. Kartvelishvili,[70]
A. N. Karyukhin,[127] L. Kashif,[171] G. Kasieczka,[57b] R. D. Kass,[108] A. Kastanas,[13] M. Kataoka,[4] Y. Kataoka,[154]
E. Katsoufis,[9] J. Katzy,[41] V. Kaushik,[6] K. Kawagoe,[66] T. Kawamoto,[154] G. Kawamura,[80] M. S. Kayl,[104]
V. A. Kazanin,[106] M. Y. Kazarinov,[64] R. Keeler,[168] R. Kehoe,[39] M. Keil,[53] G. D. Kekelidze,[64] J. S. Keller,[137]
J. Kennedy,[97] M. Kenyon,[52] O. Kepka,[124] N. Kerschen,[29] B. P. Kerševan,[73] S. Kersten,[173] K. Kessoku,[154] J. Keung,[157]
F. Khalil-zada,[10] H. Khandanyan,[164] A. Khanov,[111] D. Kharchenko,[64] A. Khodinov,[95] A. G. Kholodenko,[127]
A. Khomich,[57a] T. J. Khoo,[27] G. Khoriauli,[20] A. Khoroshilov,[173] N. Khovanskiy,[64] V. Khovanskiy,[94] E. Khramov,[64]
J. Khubua,[50b] H. Kim,[145a,145b] M. S. Kim,[2] S. H. Kim,[159] N. Kimura,[169] O. Kind,[15] B. T. King,[72] M. King,[66]
R. S. B. King,[117] J. Kirk,[128] L. E. Kirsch,[22] A. E. Kiryunin,[98] T. Kishimoto,[66] D. Kisielewska,[37] T. Kittelmann,[122]
A. M. Kiver,[127] E. Kladiva,[143b] J. Klaiber-Lodewigs,[42] M. Klein,[72] U. Klein,[72] K. Kleinknecht,[80] M. Klemetti,[84]
A. Klier,[170] P. Klimek,[145a,145b] A. Klimentov,[24] R. Klingenberg,[42] J. A. Klinger,[81] E. B. Klinkby,[35]
T. Klioutchnikova,[29] P. F. Klok,[103] S. Klous,[104] E.-E. Kluge,[57a] T. Kluge,[72] P. Kluit,[104] S. Kluth,[98] N. S. Knecht,[157]
E. Kneringer,[61] J. Knobloch,[29] E.B.F.G. Knoops,[82] A. Knue,[53] B. R. Ko,[44] T. Kobayashi,[154] M. Kobel,[43]
M. Kocian,[142] P. Kodys,[125] K. Köneke,[29] A. C. König,[103] S. Koenig,[80] L. Köpke,[80] F. Koetsveld,[103] P. Koevesarki,[20]
T. Koffas,[28] E. Koffeman,[104] L. A. Kogan,[117] F. Kohn,[53] Z. Kohout,[126] T. Kohriki,[65] T. Koi,[142] T. Kokott,[20]
G. M. Kolachev,[106] H. Kolanoski,[15] V. Kolesnikov,[64] I. Koletsou,[88a] J. Koll,[87] M. Kollefrath,[47] S. D. Kolya,[81]
A. A. Komar,[93] Y. Komori,[154] T. Kondo,[65] T. Kono,[41,r] A. I. Kononov,[47] R. Konoplich,[107,s] N. Konstantinidis,[76]
A. Kootz,[173] S. Koperny,[37] K. Korcyl,[38] K. Kordas,[153] V. Koreshev,[127] A. Korn,[117] A. Korol,[106] I. Korolkov,[11]
E. V. Korolkova,[138] V. A. Korotkov,[127] O. Kortner,[98] S. Kortner,[98] V. V. Kostyukhin,[20] M. J. Kotamäki,[29] S. Kotov,[98]
V. M. Kotov,[64] A. Kotwal,[44] C. Kourkoumelis,[8] V. Kouskoura,[153] A. Koutsman,[158a] R. Kowalewski,[168]
T. Z. Kowalski,[37] W. Kozanecki,[135] A. S. Kozhin,[127] V. Kral,[126] V. A. Kramarenko,[96] G. Kramberger,[73]
M. W. Krasny,[77] A. Krasznahorkay,[107] J. Kraus,[87] J. K. Kraus,[20] A. Kreisel,[152] F. Krejci,[126] J. Kretzschmar,[72]
N. Krieger,[53] P. Krieger,[157] K. Kroeninger,[53] H. Kroha,[98] J. Kroll,[119] J. Kroseberg,[20] J. Krstic,[12a] U. Kruchonak,[64]
H. Krüger,[20] T. Kruker,[16] N. Krumnack,[63] Z. V. Krumshteyn,[64] A. Kruth,[20] T. Kubota,[85] S. Kuday,[3a] S. Kuehn,[47]
A. Kugel,[57c] T. Kuhl,[41] D. Kuhn,[61] V. Kukhtin,[64] Y. Kulchitsky,[89] S. Kuleshov,[31b] C. Kummer,[97] M. Kuna,[77]
N. Kundu,[117] J. Kunkle,[119] A. Kupco,[124] H. Kurashige,[66] M. Kurata,[159] Y. A. Kurochkin,[89] V. Kus,[124]
E. S. Kuwertz,[146] M. Kuze,[156] J. Kvita,[141] R. Kwee,[15] A. La Rosa,[48] L. La Rotonda,[36a,36b] L. Labarga,[79] J. Labbe,[4]
S. Lablak,[134a] C. Lacasta,[166] F. Lacava,[131a,131b] H. Lacker,[15] D. Lacour,[77] V. R. Lacuesta,[166] E. Ladygin,[64]
R. Lafaye,[4] B. Laforge,[77] T. Lagouri,[79] S. Lai,[47] E. Laisne,[54] M. Lamanna,[29] L. Lambourne,[76] C. L. Lampen,[6]
W. Lampl,[6] E. Lancon,[135] U. Landgraf,[47] M. P. J. Landon,[74] J. L. Lane,[81] C. Lange,[41] A. J. Lankford,[162] F. Lanni,[24]
K. Lantzsch,[173] S. Laplace,[77] C. Lapoire,[20] J. F. Laporte,[135] T. Lari,[88a] A. V. Larionov,[127] A. Larner,[117] C. Lasseur,[29]
M. Lassnig,[29] P. Laurelli,[46] V. Lavorini,[36a,36b] W. Lavrijsen,[14] P. Laycock,[72] A. B. Lazarev,[64] O. Le Dortz,[77]
E. Le Guirriec,[82] C. Le Maner,[157] E. Le Menedeu,[9] C. Lebel,[92] T. LeCompte,[5] F. Ledroit-Guillon,[54] H. Lee,[104]
J. S. H. Lee,[115] S. C. Lee,[150] L. Lee,[174] M. Lefebvre,[168] M. Legendre,[135] A. Leger,[48] B. C. LeGeyt,[119] F. Legger,[97]
C. Leggett,[14] M. Lehmacher,[20] G. Lehmann Miotto,[29] X. Lei,[6] M. A. L. Leite,[23d] R. Leitner,[125] D. Lellouch,[170]
M. Leltchouk,[34] B. Lemmer,[53] V. Lendermann,[57a] K. J. C. Leney,[144b] T. Lenz,[104] G. Lenzen,[173] B. Lenzi,[29]

K. Leonhardt,[43] S. Leontsinis,[9] C. Leroy,[92] J-R. Lessard,[168] J. Lesser,[145a] C. G. Lester,[27] A. Leung Fook Cheong,[171]
J. Levêque,[4] D. Levin,[86] L. J. Levinson,[170] M. S. Levitski,[127] A. Lewis,[117] G. H. Lewis,[107] A. M. Leyko,[20]
M. Leyton,[15] B. Li,[82] H. Li,[171,t] S. Li,[32b,u] X. Li,[86] Z. Liang,[117,v] H. Liao,[33] B. Liberti,[132a] P. Lichard,[29]
M. Lichtnecker,[97] K. Lie,[164] W. Liebig,[13] R. Lifshitz,[151] C. Limbach,[20] A. Limosani,[85] M. Limper,[62] S. C. Lin,[150,w]
F. Linde,[104] J. T. Linnemann,[87] E. Lipeles,[119] L. Lipinsky,[124] A. Lipniacka,[13] T. M. Liss,[164] D. Lissauer,[24] A. Lister,[48]
A. M. Litke,[136] C. Liu,[28] D. Liu,[150] H. Liu,[86] J. B. Liu,[86] M. Liu,[32b] Y. Liu,[32b] M. Livan,[118a,118b]
S. S. A. Livermore,[117] A. Lleres,[54] J. Llorente Merino,[79] S. L. Lloyd,[74] E. Lobodzinska,[41] P. Loch,[6]
W. S. Lockman,[136] T. Loddenkoetter,[20] F. K. Loebinger,[81] A. Loginov,[174] C. W. Loh,[167] T. Lohse,[15] K. Lohwasser,[47]
M. Lokajicek,[124] J. Loken,[117] V. P. Lombardo,[4] R. E. Long,[70] L. Lopes,[123a] D. Lopez Mateos,[56] J. Lorenz,[97]
N. Lorenzo Martinez,[114] M. Losada,[161] P. Loscutoff,[14] F. Lo Sterzo,[131a,131b] M. J. Losty,[158a] X. Lou,[40] A. Lounis,[114]
K. F. Loureiro,[161] J. Love,[21] P. A. Love,[70] A. J. Lowe,[142,f] F. Lu,[32a] H. J. Lubatti,[137] C. Luci,[131a,131b] A. Lucotte,[54]
A. Ludwig,[43] D. Ludwig,[41] I. Ludwig,[47] J. Ludwig,[47] F. Luehring,[60] G. Luijckx,[104] W. Lukas,[61] D. Lumb,[47]
L. Luminari,[131a] E. Lund,[116] B. Lund-Jensen,[146] B. Lundberg,[78] J. Lundberg,[145a,145b] J. Lundquist,[35] M. Lungwitz,[80]
G. Lutz,[98] D. Lynn,[24] J. Lys,[14] E. Lytken,[78] H. Ma,[24] L. L. Ma,[171] J. A. Macana Goia,[92] G. Maccarrone,[46]
A. Macchiolo,[98] B. Maček,[73] J. Machado Miguens,[123a] R. Mackeprang,[35] R. J. Madaras,[14] W. F. Mader,[43]
R. Maenner,[57c] T. Maeno,[24] P. Mättig,[173] S. Mättig,[41] L. Magnoni,[29] E. Magradze,[53] Y. Mahalalel,[152] K. Mahboubi,[47]
S. Mahmoud,[72] G. Mahout,[17] C. Maiani,[131a,131b] C. Maidantchik,[23a] A. Maio,[123a,c] S. Majewski,[24] Y. Makida,[65]
N. Makovec,[114] P. Mal,[135] B. Malaescu,[29] Pa. Malecki,[38] P. Malecki,[38] V. P. Maleev,[120] F. Malek,[54] U. Mallik,[62]
D. Malon,[5] C. Malone,[142] S. Maltezos,[9] V. Malyshev,[106] S. Malyukov,[29] R. Mameghani,[97] J. Mamuzic,[12b]
A. Manabe,[65] L. Mandelli,[88a] I. Mandić,[73] R. Mandrysch,[15] J. Maneira,[123a] P. S. Mangeard,[87]
L. Manhaes de Andrade Filho,[23a] I. D. Manjavidze,[64] A. Mann,[53] P. M. Manning,[136] A. Manousakis-Katsikakis,[8]
B. Mansoulie,[135] A. Manz,[98] A. Mapelli,[29] L. Mapelli,[29] L. March,[79] J. F. Marchand,[28] F. Marchese,[132a,132b]
G. Marchiori,[77] M. Marcisovsky,[124] C. P. Marino,[168] F. Marroquim,[23a] R. Marshall,[81] Z. Marshall,[29] F. K. Martens,[157]
S. Marti-Garcia,[166] A. J. Martin,[174] B. Martin,[29] B. Martin,[87] F. F. Martin,[119] J. P. Martin,[92] Ph. Martin,[54]
T. A. Martin,[17] V. J. Martin,[45] B. Martin dit Latour,[48] S. Martin-Haugh,[148] M. Martinez,[11] V. Martinez Outschoorn,[56]
A. C. Martyniuk,[168] M. Marx,[81] F. Marzano,[131a] A. Marzin,[110] L. Masetti,[80] T. Mashimo,[154] R. Mashinistov,[93]
J. Masik,[81] A. L. Maslennikov,[106] I. Massa,[19a,19b] G. Massaro,[104] N. Massol,[4] P. Mastrandrea,[131a,131b]
A. Mastroberardino,[36a,36b] T. Masubuchi,[154] P. Matricon,[114] H. Matsumoto,[154] H. Matsunaga,[154] T. Matsushita,[66]
C. Mattravers,[117,d] J. M. Maugain,[29] J. Maurer,[82] S. J. Maxfield,[72] D. A. Maximov,[106,g] E. N. May,[5] A. Mayne,[138]
R. Mazini,[150] M. Mazur,[20] M. Mazzanti,[88a] S. P. Mc Kee,[86] A. McCarn,[164] R. L. McCarthy,[147] T. G. McCarthy,[28]
N. A. McCubbin,[128] K. W. McFarlane,[55] J. A. Mcfayden,[138] H. McGlone,[52] G. Mchedlidze,[50b] R. A. McLaren,[29]
T. Mclaughlan,[17] S. J. McMahon,[128] R. A. McPherson,[168,k] A. Meade,[83] J. Mechnich,[104] M. Mechtel,[173]
M. Medinnis,[41] R. Meera-Lebbai,[110] T. Meguro,[115] R. Mehdiyev,[92] S. Mehlhase,[35] A. Mehta,[72] K. Meier,[57a]
B. Meirose,[78] C. Melachrinos,[30] B. R. Mellado Garcia,[171] L. Mendoza Navas,[161] Z. Meng,[150,t] A. Mengarelli,[19a,19b]
S. Menke,[98] C. Menot,[29] E. Meoni,[11] K. M. Mercurio,[56] P. Mermod,[48] L. Merola,[101a,101b] C. Meroni,[88a]
F. S. Merritt,[30] H. Merritt,[108] A. Messina,[29] J. Metcalfe,[102] A. S. Mete,[63] C. Meyer,[80] C. Meyer,[30] J-P. Meyer,[135]
J. Meyer,[172] J. Meyer,[53] T. C. Meyer,[29] W. T. Meyer,[63] J. Miao,[32d] S. Michal,[29] L. Micu,[25a] R. P. Middleton,[128]
S. Migas,[72] L. Mijović,[41] G. Mikenberg,[170] M. Mikestikova,[124] M. Mikuž,[73] D. W. Miller,[30] R. J. Miller,[87]
W. J. Mills,[167] C. Mills,[56] A. Milov,[170] D. A. Milstead,[145a,145b] D. Milstein,[170] A. A. Minaenko,[127]
M. Miñano Moya,[166] I. A. Minashvili,[64] A. I. Mincer,[107] B. Mindur,[37] M. Mineev,[64] Y. Ming,[171] L. M. Mir,[11]
G. Mirabelli,[131a] L. Miralles Verge,[11] A. Misiejuk,[75] J. Mitrevski,[136] G. Y. Mitrofanov,[127] V. A. Mitsou,[166]
S. Mitsui,[65] P. S. Miyagawa,[138] K. Miyazaki,[66] J. U. Mjörnmark,[78] T. Moa,[145a,145b] P. Mockett,[137] S. Moed,[56]
V. Moeller,[27] K. Mönig,[41] N. Möser,[20] S. Mohapatra,[147] W. Mohr,[47] S. Mohrdieck-Möck,[98] A. M. Moisseev,[127,a]
R. Moles-Valls,[166] J. Molina-Perez,[29] J. Monk,[76] E. Monnier,[82] S. Montesano,[88a,88b] F. Monticelli,[69]
S. Monzani,[19a,19b] R. W. Moore,[2] G. F. Moorhead,[85] C. Mora Herrera,[48] A. Moraes,[52] N. Morange,[135] J. Morel,[53]
G. Morello,[36a,36b] D. Moreno,[80] M. Moreno Llácer,[166] P. Morettini,[49a] M. Morgenstern,[43] M. Morii,[56] J. Morin,[74]
A. K. Morley,[29] G. Mornacchi,[29] S. V. Morozov,[95] J. D. Morris,[74] L. Morvaj,[100] H. G. Moser,[98] M. Mosidze,[50b]
J. Moss,[108] R. Mount,[142] E. Mountricha,[9,x] S. V. Mouraviev,[93] E. J. W. Moyse,[83] M. Mudrinic,[12b] F. Mueller,[57a]
J. Mueller,[122] K. Mueller,[20] T. A. Müller,[97] T. Mueller,[80] D. Muenstermann,[29] A. Muir,[167] Y. Munwes,[152]
W. J. Murray,[128] I. Mussche,[104] E. Musto,[101a,101b] A. G. Myagkov,[127] M. Myska,[124] J. Nadal,[11] K. Nagai,[159]
K. Nagano,[65] A. Nagarkar,[108] Y. Nagasaka,[59] M. Nagel,[98] A. M. Nairz,[29] Y. Nakahama,[29] K. Nakamura,[154]

T. Nakamura,[154] I. Nakano,[109] G. Nanava,[20] A. Napier,[160] R. Narayan,[57b] M. Nash,[76,d] N. R. Nation,[21]
T. Nattermann,[20] T. Naumann,[41] G. Navarro,[161] H. A. Neal,[86] E. Nebot,[79] P.Yu. Nechaeva,[93] T. J. Neep,[81]
A. Negri,[118a,118b] G. Negri,[29] S. Nektarijevic,[48] A. Nelson,[162] T. K. Nelson,[142] S. Nemecek,[124] P. Nemethy,[107]
A. A. Nepomuceno,[23a] M. Nessi,[29,y] M. S. Neubauer,[164] A. Neusiedl,[80] R. M. Neves,[107] P. Nevski,[24] P. R. Newman,[17]
V. Nguyen Thi Hong,[135] R. B. Nickerson,[117] R. Nicolaidou,[135] L. Nicolas,[138] B. Nicquevert,[29] F. Niedercorn,[114]
J. Nielsen,[136] T. Niinikoski,[29] N. Nikiforou,[34] A. Nikiforov,[15] V. Nikolaenko,[127] K. Nikolaev,[64] I. Nikolic-Audit,[77]
K. Nikolics,[48] K. Nikolopoulos,[24] H. Nilsen,[47] P. Nilsson,[7] Y. Ninomiya,[154] A. Nisati,[131a] T. Nishiyama,[66]
R. Nisius,[98] L. Nodulman,[5] M. Nomachi,[115] I. Nomidis,[153] M. Nordberg,[29] B. Nordkvist,[145a,145b] P. R. Norton,[128]
J. Novakova,[125] M. Nozaki,[65] L. Nozka,[112] I. M. Nugent,[158a] A.-E. Nuncio-Quiroz,[20] G. Nunes Hanninger,[85]
T. Nunnemann,[97] E. Nurse,[76] B. J. O'Brien,[45] S. W. O'Neale,[17,a] D. C. O'Neil,[141] V. O'Shea,[52] L. B. Oakes,[97]
F. G. Oakham,[28,e] H. Oberlack,[98] J. Ocariz,[77] A. Ochi,[66] S. Oda,[154] S. Odaka,[65] J. Odier,[82] H. Ogren,[60] A. Oh,[81]
S. H. Oh,[44] C. C. Ohm,[145a,145b] T. Ohshima,[100] H. Ohshita,[139] T. Ohsugi,[58] S. Okada,[66] H. Okawa,[162] Y. Okumura,[100]
T. Okuyama,[154] A. Olariu,[25a] M. Olcese,[49a] A. G. Olchevski,[64] S. A. Olivares Pino,[31a] M. Oliveira,[123a,i]
D. Oliveira Damazio,[24] E. Oliver Garcia,[166] D. Olivito,[119] A. Olszewski,[38] J. Olszowska,[38] C. Omachi,[66]
A. Onofre,[123a,z] P. U. E. Onyisi,[30] C. J. Oram,[158a] M. J. Oreglia,[30] Y. Oren,[152] D. Orestano,[133a,133b] N. Orlando,[71a,71b]
I. Orlov,[106] C. Oropeza Barrera,[52] R. S. Orr,[157] B. Osculati,[49a,49b] C. Osuna,[11] G. Otero y Garzon,[26]
J. P. Ottersbach,[104] M. Ouchrif,[134d] E. A. Ouellette,[168] F. Ould-Saada,[116] A. Ouraou,[135] Q. Ouyang,[32a]
A. Ovcharova,[14] M. Owen,[81] S. Owen,[138] V. E. Ozcan,[18a] N. Ozturk,[7] A. Pacheco Pages,[11] C. Padilla Aranda,[11]
S. Pagan Griso,[14] E. Paganis,[138] F. Paige,[24] P. Pais,[83] K. Pajchel,[116] G. Palacino,[158b] C. P. Paleari,[6] S. Palestini,[29]
D. Pallin,[33] A. Palma,[123a] J. D. Palmer,[17] Y. B. Pan,[171] E. Panagiotopoulou,[9] B. Panes,[31a] N. Panikashvili,[86]
S. Panitkin,[24] D. Pantea,[25a] M. Panuskova,[124] V. Paolone,[122] A. Papadelis,[145a] Th.D. Papadopoulou,[9] A. Paramonov,[5]
D. Paredes Hernandez,[33] W. Park,[24,aa] M. A. Parker,[27] F. Parodi,[49a,49b] J. A. Parsons,[34] U. Parzefall,[47] S. Pashapour,[53]
E. Pasqualucci,[131a] S. Passaggio,[49a] A. Passeri,[133a] F. Pastore,[133a,133b] Fr. Pastore,[75] G. Pásztor,[48,bb] S. Pataraia,[173]
N. Patel,[149] J. R. Pater,[81] S. Patricelli,[101a,101b] T. Pauly,[29] M. Pecsy,[143a] M. I. Pedraza Morales,[171]
S. V. Peleganchuk,[106] H. Peng,[32b] R. Pengo,[29] B. Penning,[30] A. Penson,[34] J. Penwell,[60] M. Perantoni,[23a] K. Perez,[34,cc]
T. Perez Cavalcanti,[41] E. Perez Codina,[11] M. T. Pérez García-Estañ,[166] V. Perez Reale,[34] L. Perini,[88a,88b]
H. Pernegger,[29] R. Perrino,[71a] P. Perrodo,[4] S. Persembe,[3a] V. D. Peshekhonov,[64] K. Peters,[29] B. A. Petersen,[29]
J. Petersen,[29] T. C. Petersen,[35] E. Petit,[4] A. Petridis,[153] C. Petridou,[153] E. Petrolo,[131a] F. Petrucci,[133a,133b]
D. Petschull,[41] M. Petteni,[141] R. Pezoa,[31b] A. Phan,[85] P. W. Phillips,[128] G. Piacquadio,[29] A. Picazio,[48] E. Piccaro,[74]
M. Piccinini,[19a,19b] S. M. Piec,[41] R. Piegaia,[26] D. T. Pignotti,[108] J. E. Pilcher,[30] A. D. Pilkington,[81] J. Pina,[123a,c]
M. Pinamonti,[163a,163c] A. Pinder,[117] J. L. Pinfold,[2] J. Ping,[32c] B. Pinto,[123a] O. Pirotte,[29] C. Pizio,[88a,88b]
M. Plamondon,[168] M.-A. Pleier,[24] A. V. Pleskach,[127] E. Plotnikova,[64] A. Poblaguev,[24] S. Poddar,[57a] F. Podlyski,[33]
L. Poggioli,[114] T. Poghosyan,[20] M. Pohl,[48] F. Polci,[54] G. Polesello,[118a] A. Policicchio,[36a,36b] A. Polini,[19a] J. Poll,[74]
V. Polychronakos,[24] D. M. Pomarede,[135] D. Pomeroy,[22] K. Pommès,[29] L. Pontecorvo,[131a] B. G. Pope,[87]
G. A. Popeneciu,[25a] D. S. Popovic,[12a] A. Poppleton,[29] X. Portell Bueso,[29] C. Posch,[21] G. E. Pospelov,[98] S. Pospisil,[126]
I. N. Potrap,[98] C. J. Potter,[148] C. T. Potter,[113] G. Poulard,[29] J. Poveda,[171] V. Pozdnyakov,[64] R. Prabhu,[76]
P. Pralavorio,[82] A. Pranko,[14] S. Prasad,[29] R. Pravahan,[7] S. Prell,[63] K. Pretzl,[16] L. Pribyl,[29] D. Price,[60] J. Price,[72]
L. E. Price,[5] M. J. Price,[29] D. Prieur,[122] M. Primavera,[71a] K. Prokofiev,[107] F. Prokoshin,[31b] S. Protopopescu,[24]
J. Proudfoot,[5] X. Prudent,[43] M. Przybycien,[37] H. Przysiezniak,[4] S. Psoroulas,[20] E. Ptacek,[113] E. Pueschel,[83]
J. Purdham,[86] M. Purohit,[24,aa] P. Puzo,[114] Y. Pylypchenko,[62] J. Qian,[86] Z. Qian,[82] Z. Qin,[41] A. Quadt,[53]
D. R. Quarrie,[14] W. B. Quayle,[171] F. Quinonez,[31a] M. Raas,[103] V. Radescu,[41] B. Radics,[20] P. Radloff,[113] T. Rador,[18a]
F. Ragusa,[88a,88b] G. Rahal,[176] A. M. Rahimi,[108] D. Rahm,[24] S. Rajagopalan,[24] M. Rammensee,[47] M. Rammes,[140]
A. S. Randle-Conde,[39] K. Randrianarivony,[28] P. N. Ratoff,[70] F. Rauscher,[97] T. C. Rave,[47] M. Raymond,[29]
A. L. Read,[116] D. M. Rebuzzi,[118a,118b] A. Redelbach,[172] G. Redlinger,[24] R. Reece,[119] K. Reeves,[40] A. Reichold,[104]
E. Reinherz-Aronis,[152] A. Reinsch,[113] I. Reisinger,[42] C. Rembser,[29] Z. L. Ren,[150] A. Renaud,[114] M. Rescigno,[131a]
S. Resconi,[88a] B. Resende,[135] P. Reznicek,[97] R. Rezvani,[157] A. Richards,[76] R. Richter,[98] E. Richter-Was,[4,dd]
M. Ridel,[77] M. Rijpstra,[104] M. Rijssenbeek,[147] A. Rimoldi,[118a,118b] L. Rinaldi,[19a] R. R. Rios,[39] I. Riu,[11]
G. Rivoltella,[88a,88b] F. Rizatdinova,[111] E. Rizvi,[74] S. H. Robertson,[84,k] A. Robichaud-Veronneau,[117] D. Robinson,[27]
J. E. M. Robinson,[76] A. Robson,[52] J. G. Rocha de Lima,[105] C. Roda,[121a,121b] D. Roda Dos Santos,[29] D. Rodriguez,[161]
A. Roe,[53] S. Roe,[29] O. Røhne,[116] V. Rojo,[1] S. Rolli,[160] A. Romaniouk,[95] M. Romano,[19a,19b] V. M. Romanov,[64]
G. Romeo,[26] E. Romero Adam,[166] L. Roos,[77] E. Ros,[166] S. Rosati,[131a] K. Rosbach,[48] A. Rose,[148] M. Rose,[75]

G. A. Rosenbaum,[157] E. I. Rosenberg,[63] P. L. Rosendahl,[13] O. Rosenthal,[140] L. Rosselet,[48] V. Rossetti,[11] E. Rossi,[131a,131b] L. P. Rossi,[49a] M. Rotaru,[25a] I. Roth,[170] J. Rothberg,[137] D. Rousseau,[114] C. R. Royon,[135] A. Rozanov,[82] Y. Rozen,[151] X. Ruan,[32a,ee] I. Rubinskiy,[41] B. Ruckert,[97] N. Ruckstuhl,[104] V. I. Rud,[96] C. Rudolph,[43] G. Rudolph,[61] F. Rühr,[6] F. Ruggieri,[133a,133b] A. Ruiz-Martinez,[63] V. Rumiantsev,[90,a] L. Rumyantsev,[64] K. Runge,[47] Z. Rurikova,[47] N. A. Rusakovich,[64] J. P. Rutherfoord,[6] C. Ruwiedel,[14] P. Ruzicka,[124] Y. F. Ryabov,[120] V. Ryadovikov,[127] P. Ryan,[87] M. Rybar,[125] G. Rybkin,[114] N. C. Ryder,[117] S. Rzaeva,[10] A. F. Saavedra,[149] I. Sadeh,[152] H.F-W. Sadrozinski,[136] R. Sadykov,[64] F. Safai Tehrani,[131a] H. Sakamoto,[154] G. Salamanna,[74] A. Salamon,[132a] M. Saleem,[110] D. Salihagic,[98] A. Salnikov,[142] J. Salt,[166] B. M. Salvachua Ferrando,[5] D. Salvatore,[36a,36b] F. Salvatore,[148] A. Salvucci,[103] A. Salzburger,[29] D. Sampsonidis,[153] B. H. Samset,[116] A. Sanchez,[101a,101b] V. Sanchez Martinez,[166] H. Sandaker,[13] H. G. Sander,[80] M. P. Sanders,[97] M. Sandhoff,[173] T. Sandoval,[27] C. Sandoval,[161] R. Sandstroem,[98] S. Sandvoss,[173] D. P. C. Sankey,[128] A. Sansoni,[46] C. Santamarina Rios,[84] C. Santoni,[33] R. Santonico,[132a,132b] H. Santos,[123a] J. G. Saraiva,[123a] T. Sarangi,[171] E. Sarkisyan-Grinbaum,[7] F. Sarri,[121a,121b] G. Sartisohn,[173] O. Sasaki,[65] N. Sasao,[67] I. Satsounkevitch,[89] G. Sauvage,[4] E. Sauvan,[4] J. B. Sauvan,[114] P. Savard,[157,e] V. Savinov,[122] D. O. Savu,[29] L. Sawyer,[24,m] D. H. Saxon,[52] J. Saxon,[119] L. P. Says,[33] C. Sbarra,[19a] A. Sbrizzi,[19a,19b] O. Scallon,[92] D. A. Scannicchio,[162] M. Scarcella,[149] J. Schaarschmidt,[114] P. Schacht,[98] D. Schaefer,[119] U. Schäfer,[80] S. Schaepe,[20] S. Schaetzel,[57b] A. C. Schaffer,[114] D. Schaile,[97] R. D. Schamberger,[147] A. G. Schamov,[106] V. Scharf,[57a] V. A. Schegelsky,[120] D. Scheirich,[86] M. Schernau,[162] M. I. Scherzer,[34] C. Schiavi,[49a,49b] J. Schieck,[97] M. Schioppa,[36a,36b] S. Schlenker,[29] J. L. Schlereth,[5] E. Schmidt,[47] K. Schmieden,[20] C. Schmitt,[80] S. Schmitt,[57b] M. Schmitz,[20] A. Schöning,[57b] M. Schott,[29] D. Schouten,[158a] J. Schovancova,[124] M. Schram,[84] C. Schroeder,[80] N. Schroer,[57c] G. Schuler,[29] M. J. Schultens,[20] J. Schultes,[173] H.-C. Schultz-Coulon,[57a] H. Schulz,[15] J. W. Schumacher,[20] M. Schumacher,[47] B. A. Schumm,[136] Ph. Schune,[135] C. Schwanenberger,[81] A. Schwartzman,[142] Ph. Schwemling,[77] R. Schwienhorst,[87] R. Schwierz,[43] J. Schwindling,[135] T. Schwindt,[20] M. Schwoerer,[4] G. Sciolla,[22] W. G. Scott,[128] J. Searcy,[113] G. Sedov,[41] E. Sedykh,[120] E. Segura,[11] S. C. Seidel,[102] A. Seiden,[136] F. Seifert,[43] J. M. Seixas,[23a] G. Sekhniaidze,[101a] S. J. Sekula,[39] K. E. Selbach,[45] D. M. Seliverstov,[120] B. Sellden,[145a] G. Sellers,[72] M. Seman,[143b] N. Semprini-Cesari,[19a,19b] C. Serfon,[97] L. Serin,[114] L. Serkin,[53] R. Seuster,[98] H. Severini,[110] M. E. Sevior,[85] A. Sfyrla,[29] E. Shabalina,[53] M. Shamim,[113] L. Y. Shan,[32a] J. T. Shank,[21] Q. T. Shao,[85] M. Shapiro,[14] P. B. Shatalov,[94] L. Shaver,[6] K. Shaw,[163a,163c] D. Sherman,[174] P. Sherwood,[76] A. Shibata,[107] H. Shichi,[100] S. Shimizu,[29] M. Shimojima,[99] T. Shin,[55] M. Shiyakova,[64] A. Shmeleva,[93] M. J. Shochet,[30] D. Short,[117] S. Shrestha,[63] E. Shulga,[95] M. A. Shupe,[6] P. Sicho,[124] A. Sidoti,[131a] F. Siegert,[47] Dj. Sijacki,[12a] O. Silbert,[170] J. Silva,[123a] Y. Silver,[152] D. Silverstein,[142] S. B. Silverstein,[145a] V. Simak,[126] O. Simard,[135] Lj. Simic,[12a] S. Simion,[114] B. Simmons,[76] R. Simoniello,[88a,88b] M. Simonyan,[35] P. Sinervo,[157] N. B. Sinev,[113] V. Sipica,[140] G. Siragusa,[172] A. Sircar,[24] A. N. Sisakyan,[64] S.Yu. Sivoklokov,[96] J. Sjölin,[145a,145b] T. B. Sjursen,[13] L. A. Skinnari,[14] H. P. Skottowe,[56] K. Skovpen,[106] P. Skubic,[110] N. Skvorodnev,[22] M. Slater,[17] T. Slavicek,[126] K. Sliwa,[160] J. Sloper,[29] V. Smakhtin,[170] B. H. Smart,[45] S.Yu. Smirnov,[95] Y. Smirnov,[95] L. N. Smirnova,[96] O. Smirnova,[78] B. C. Smith,[56] D. Smith,[142] K. M. Smith,[52] M. Smizanska,[70] K. Smolek,[126] A. A. Snesarev,[93] S. W. Snow,[81] J. Snow,[110] J. Snuverink,[104] S. Snyder,[24] M. Soares,[123a] R. Sobie,[168,k] J. Sodomka,[126] A. Soffer,[152] C. A. Solans,[166] M. Solar,[126] J. Solc,[126] E. Soldatov,[95] U. Soldevila,[166] E. Solfaroli Camillocci,[131a,131b] A. A. Solodkov,[127] O. V. Solovyanov,[127] N. Soni,[2] V. Sopko,[126] B. Sopko,[126] M. Sosebee,[7] R. Soualah,[163a,163c] A. Soukharev,[106] S. Spagnolo,[71a,71b] F. Spanò,[75] R. Spighi,[19a] G. Spigo,[29] F. Spila,[131a,131b] R. Spiwoks,[29] M. Spousta,[125] T. Spreitzer,[157] B. Spurlock,[7] R. D. St. Denis,[52] J. Stahlman,[119] R. Stamen,[57a] E. Stanecka,[38] R. W. Stanek,[5] C. Stanescu,[133a] M. Stanescu-Bellu,[41] S. Stapnes,[116] E. A. Starchenko,[127] J. Stark,[54] P. Staroba,[124] P. Starovoitov,[90] A. Staude,[97] P. Stavina,[143a] G. Steele,[52] P. Steinbach,[43] P. Steinberg,[24] I. Stekl,[126] B. Stelzer,[141] H. J. Stelzer,[87] O. Stelzer-Chilton,[158a] H. Stenzel,[51] S. Stern,[98] K. Stevenson,[74] G. A. Stewart,[29] J. A. Stillings,[20] M. C. Stockton,[84] K. Stoerig,[47] G. Stoicea,[25a] S. Stonjek,[98] P. Strachota,[125] A. R. Stradling,[7] A. Straessner,[43] J. Strandberg,[146] S. Strandberg,[145a,145b] A. Strandlie,[116] M. Strang,[108] E. Strauss,[142] M. Strauss,[110] P. Strizenec,[143b] R. Ströhmer,[172] D. M. Strom,[113] J. A. Strong,[75,a] R. Stroynowski,[39] J. Strube,[128] B. Stugu,[13] I. Stumer,[24,a] J. Stupak,[147] P. Sturm,[173] N. A. Styles,[41] D. A. Soh,[150,v] D. Su,[142] HS. Subramania,[2] A. Succurro,[11] Y. Sugaya,[115] T. Sugimoto,[100] C. Suhr,[105] K. Suita,[66] M. Suk,[125] V. V. Sulin,[93] S. Sultansoy,[3d] T. Sumida,[67] X. Sun,[54] J. E. Sundermann,[47] K. Suruliz,[138] S. Sushkov,[11] G. Susinno,[36a,36b] M. R. Sutton,[148] Y. Suzuki,[65] Y. Suzuki,[66] M. Svatos,[124] Yu.M. Sviridov,[127] S. Swedish,[167] I. Sykora,[143a] T. Sykora,[125] B. Szeless,[29] J. Sánchez,[166] D. Ta,[104] K. Tackmann,[41] A. Taffard,[162] R. Tafirout,[158a] N. Taiblum,[152] Y. Takahashi,[100] H. Takai,[24] R. Takashima,[68]

H. Takeda,[66] T. Takeshita,[139] Y. Takubo,[65] M. Talby,[82] A. Talyshev,[106,g] M. C. Tamsett,[24] J. Tanaka,[154] R. Tanaka,[114]
S. Tanaka,[130] S. Tanaka,[65] Y. Tanaka,[99] A. J. Tanasijczuk,[141] K. Tani,[66] N. Tannoury,[82] G. P. Tappern,[29]
S. Tapprogge,[80] D. Tardif,[157] S. Tarem,[151] F. Tarrade,[28] G. F. Tartarelli,[88a] P. Tas,[125] M. Tasevsky,[124] E. Tassi,[36a,36b]
M. Tatarkhanov,[14] Y. Tayalati,[134d] C. Taylor,[76] F. E. Taylor,[91] G. N. Taylor,[85] W. Taylor,[158b] M. Teinturier,[114]
M. Teixeira Dias Castanheira,[74] P. Teixeira-Dias,[75] K. K. Temming,[47] H. Ten Kate,[29] P. K. Teng,[150] S. Terada,[65]
K. Terashi,[154] J. Terron,[79] M. Testa,[46] R. J. Teuscher,[157,k] J. Thadome,[173] J. Therhaag,[20] T. Theveneaux-Pelzer,[77]
M. Thioye,[174] S. Thoma,[47] J. P. Thomas,[17] E. N. Thompson,[34] P. D. Thompson,[17] P. D. Thompson,[157]
A. S. Thompson,[52] L. A. Thomsen,[35] E. Thomson,[119] M. Thomson,[27] R. P. Thun,[86] F. Tian,[34] M. J. Tibbetts,[14]
T. Tic,[124] V. O. Tikhomirov,[93] Y. A. Tikhonov,[106,g] S. Timoshenko,[95] P. Tipton,[174] F. J. Tique Aires Viegas,[29]
S. Tisserant,[82] B. Toczek,[37] T. Todorov,[4] S. Todorova-Nova,[160] B. Toggerson,[162] J. Tojo,[65] S. Tokár,[143a]
K. Tokunaga,[66] K. Tokushuku,[65] K. Tollefson,[87] M. Tomoto,[100] L. Tompkins,[30] K. Toms,[102] G. Tong,[32a]
A. Tonoyan,[13] C. Topfel,[16] N. D. Topilin,[64] I. Torchiani,[29] E. Torrence,[113] H. Torres,[77] E. Torró Pastor,[166] J. Toth,[82,bb]
F. Touchard,[82] D. R. Tovey,[138] T. Trefzger,[172] L. Tremblet,[29] A. Tricoli,[29] I. M. Trigger,[158a] S. Trincaz-Duvoid,[77]
T. N. Trinh,[77] M. F. Tripiana,[69] W. Trischuk,[157] A. Trivedi,[24,aa] B. Trocmé,[54] C. Troncon,[88a]
M. Trottier-McDonald,[141] M. Trzebinski,[38] A. Trzupek,[38] C. Tsarouchas,[29] J.C-L. Tseng,[117] M. Tsiakiris,[104]
P. V. Tsiareshka,[89] D. Tsionou,[4,ff] G. Tsipolitis,[9] V. Tsiskaridze,[47] E. G. Tskhadadze,[50a] I. I. Tsukerman,[94]
V. Tsulaia,[14] J.-W. Tsung,[20] S. Tsuno,[65] D. Tsybychev,[147] A. Tua,[138] A. Tudorache,[25a] V. Tudorache,[25a]
J. M. Tuggle,[30] M. Turala,[38] D. Turecek,[126] I. Turk Cakir,[3e] E. Turlay,[104] R. Turra,[88a,88b] P. M. Tuts,[34] A. Tykhonov,[73]
M. Tylmad,[145a,145b] M. Tyndel,[128] G. Tzanakos,[8] K. Uchida,[20] I. Ueda,[154] R. Ueno,[28] M. Ugland,[13] M. Uhlenbrock,[20]
M. Uhrmacher,[53] F. Ukegawa,[159] G. Unal,[29] D. G. Underwood,[5] A. Undrus,[24] G. Unel,[162] Y. Unno,[65] D. Urbaniec,[34]
G. Usai,[7] M. Uslenghi,[118a,118b] L. Vacavant,[82] V. Vacek,[126] B. Vachon,[84] S. Vahsen,[14] J. Valenta,[124] P. Valente,[131a]
S. Valentinetti,[19a,19b] S. Valkar,[125] E. Valladolid Gallego,[166] S. Vallecorsa,[151] J. A. Valls Ferrer,[166]
H. van der Graaf,[104] E. van der Kraaij,[104] R. Van Der Leeuw,[104] E. van der Poel,[104] D. van der Ster,[29] N. van Eldik,[83]
P. van Gemmeren,[5] Z. van Kesteren,[104] I. van Vulpen,[104] M. Vanadia,[98] W. Vandelli,[29] G. Vandoni,[29] A. Vaniachine,[5]
P. Vankov,[41] F. Vannucci,[77] F. Varela Rodriguez,[29] R. Vari,[131a] E. W. Varnes,[6] T. Varol,[83] D. Varouchas,[14]
A. Vartapetian,[7] K. E. Varvell,[149] V. I. Vassilakopoulos,[55] F. Vazeille,[33] T. Vazquez Schroeder,[53] G. Vegni,[88a,88b]
J. J. Veillet,[114] C. Vellidis,[8] F. Veloso,[123a] R. Veness,[29] S. Veneziano,[131a] A. Ventura,[71a,71b] D. Ventura,[137]
M. Venturi,[47] N. Venturi,[157] V. Vercesi,[118a] M. Verducci,[137] W. Verkerke,[104] J. C. Vermeulen,[104] A. Vest,[43]
M. C. Vetterli,[141,e] I. Vichou,[164] T. Vickey,[144b,gg] O. E. Vickey Boeriu,[144b] G. H. A. Viehhauser,[117] S. Viel,[167]
M. Villa,[19a,19b] M. Villaplana Perez,[166] E. Vilucchi,[46] M. G. Vincter,[28] E. Vinek,[29] V. B. Vinogradov,[64]
M. Virchaux,[135,a] J. Virzi,[14] O. Vitells,[170] M. Viti,[41] I. Vivarelli,[47] F. Vives Vaque,[2] S. Vlachos,[9] D. Vladoiu,[97]
M. Vlasak,[126] N. Vlasov,[20] A. Vogel,[20] P. Vokac,[126] G. Volpi,[46] M. Volpi,[85] M. Volpini,[88a] H. von der Schmitt,[98]
J. von Loeben,[98] H. von Radziewski,[47] E. von Toerne,[20] V. Vorobel,[125] A. P. Vorobiev,[127] V. Vorwerk,[11] M. Vos,[166]
R. Voss,[29] T. T. Voss,[173] J. H. Vossebeld,[72] N. Vranjes,[135] M. Vranjes Milosavljevic,[104] V. Vrba,[124] M. Vreeswijk,[104]
T. Vu Anh,[47] R. Vuillermet,[29] I. Vukotic,[114] W. Wagner,[173] P. Wagner,[119] H. Wahlen,[173] J. Wakabayashi,[100]
S. Walch,[86] J. Walder,[70] R. Walker,[97] W. Walkowiak,[140] R. Wall,[174] P. Waller,[72] C. Wang,[44] H. Wang,[171]
H. Wang,[32b,hh] J. Wang,[150] J. Wang,[54] J. C. Wang,[137] R. Wang,[102] S. M. Wang,[150] T. Wang,[20] A. Warburton,[84]
C. P. Ward,[27] M. Warsinsky,[47] C. Wasicki,[41] P. M. Watkins,[17] A. T. Watson,[17] I. J. Watson,[149] M. F. Watson,[17]
G. Watts,[137] S. Watts,[81] A. T. Waugh,[149] B. M. Waugh,[76] M. Weber,[128] M. S. Weber,[16] P. Weber,[53] A. R. Weidberg,[117]
P. Weigell,[98] J. Weingarten,[53] C. Weiser,[47] H. Wellenstein,[22] P. S. Wells,[29] T. Wenaus,[24] D. Wendland,[15]
S. Wendler,[122] Z. Weng,[150,v] T. Wengler,[29] S. Wenig,[29] N. Wermes,[20] M. Werner,[47] P. Werner,[29] M. Werth,[162]
M. Wessels,[57a] J. Wetter,[160] C. Weydert,[54] K. Whalen,[28] S. J. Wheeler-Ellis,[162] S. P. Whitaker,[21] A. White,[7]
M. J. White,[85] S. R. Whitehead,[117] D. Whiteson,[162] D. Whittington,[60] F. Wicek,[114] D. Wicke,[173] F. J. Wickens,[128]
W. Wiedenmann,[171] M. Wielers,[128] P. Wienemann,[20] C. Wiglesworth,[74] L. A. M. Wiik-Fuchs,[47] P. A. Wijeratne,[76]
A. Wildauer,[166] M. A. Wildt,[41,r] I. Wilhelm,[125] H. G. Wilkens,[29] J. Z. Will,[97] E. Williams,[34] H. H. Williams,[119]
W. Willis,[34] S. Willocq,[83] J. A. Wilson,[17] M. G. Wilson,[142] A. Wilson,[86] I. Wingerter-Seez,[4] S. Winkelmann,[47]
F. Winklmeier,[29] M. Wittgen,[142] M. W. Wolter,[38] H. Wolters,[123a,i] W. C. Wong,[40] G. Wooden,[86] B. K. Wosiek,[38]
J. Wotschack,[29] M. J. Woudstra,[83] K. W. Wozniak,[38] K. Wraight,[52] C. Wright,[52] M. Wright,[52] B. Wrona,[72]
S. L. Wu,[171] X. Wu,[48] Y. Wu,[32b,ii] E. Wulf,[34] R. Wunstorf,[42] B. M. Wynne,[45] S. Xella,[35] M. Xiao,[135] S. Xie,[47]
Y. Xie,[32a] C. Xu,[32b,x] D. Xu,[138] G. Xu,[32a] B. Yabsley,[149] S. Yacoob,[144b] M. Yamada,[65] H. Yamaguchi,[154]
A. Yamamoto,[65] K. Yamamoto,[63] S. Yamamoto,[154] T. Yamamura,[154] T. Yamanaka,[154] J. Yamaoka,[44] T. Yamazaki,[154]

Y. Yamazaki,[66] Z. Yan,[21] H. Yang,[86] U. K. Yang,[81] Y. Yang,[60] Y. Yang,[32a] Z. Yang,[145a,145b] S. Yanush,[90] Y. Yao,[14] Y. Yasu,[65] G. V. Ybeles Smit,[129] J. Ye,[39] S. Ye,[24] M. Yilmaz,[3c] R. Yoosoofmiya,[122] K. Yorita,[169] R. Yoshida,[5] C. Young,[142] S. Youssef,[21] D. Yu,[24] J. Yu,[7] J. Yu,[111] L. Yuan,[32a,jj] A. Yurkewicz,[105] B. Zabinski,[38] V. G. Zaets,[127] R. Zaidan,[62] A. M. Zaitsev,[127] Z. Zajacova,[29] L. Zanello,[131a,131b] A. Zaytsev,[106] C. Zeitnitz,[173] M. Zeller,[174] M. Zeman,[124] A. Zemla,[38] C. Zendler,[20] O. Zenin,[127] T. Ženiš,[143a] Z. Zinonos,[121a,121b] S. Zenz,[14] D. Zerwas,[114] G. Zevi della Porta,[56] Z. Zhan,[32d] D. Zhang,[32b,hh] H. Zhang,[87] J. Zhang,[5] X. Zhang,[32d] Z. Zhang,[114] L. Zhao,[107] T. Zhao,[137] Z. Zhao,[32b] A. Zhemchugov,[64] S. Zheng,[32a] J. Zhong,[117] B. Zhou,[86] N. Zhou,[162] Y. Zhou,[150] C. G. Zhu,[32d] H. Zhu,[41] J. Zhu,[86] Y. Zhu,[32b] X. Zhuang,[97] V. Zhuravlov,[98] D. Zieminska,[60] R. Zimmermann,[20] S. Zimmermann,[20] S. Zimmermann,[47] M. Ziolkowski,[140] R. Zitoun,[4] L. Živković,[34] V. V. Zmouchko,[127,a] G. Zobernig,[171] A. Zoccoli,[19a,19b] Y. Zolnierowski,[4] A. Zsenei,[29] M. zur Nedden,[15] V. Zutshi,[105] and L. Zwalinski[29]

(ATLAS Collaboration)

[1]*University at Albany, Albany, New York, USA*
[2]*Department of Physics, University of Alberta, Edmonton, Alberta, Canada*
[3a]*Department of Physics, Ankara University, Ankara, Turkey*
[3b]*Department of Physics, Dumlupinar University, Kutahya, Turkey*
[3c]*Department of Physics, Gazi University, Ankara, Turkey*
[3d]*Division of Physics, TOBB University of Economics and Technology, Ankara, Turkey*
[3e]*Turkish Atomic Energy Authority, Ankara, Turkey*
[4]*LAPP, CNRS/IN2P3 and Université de Savoie, Annecy-le-Vieux, France*
[5]*High Energy Physics Division, Argonne National Laboratory, Argonne, Illinois, USA*
[6]*Department of Physics, University of Arizona, Tucson, Arizona, USA*
[7]*Department of Physics, The University of Texas at Arlington, Arlington, Texas, USA*
[8]*Physics Department, University of Athens, Athens, Greece*
[9]*Physics Department, National Technical University of Athens, Zografou, Greece*
[10]*Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan*
[11]*Institut de Física d'Altes Energies and Departament de Física de la Universitat Autònoma de Barcelona and ICREA, Barcelona, Spain*
[12a]*Institute of Physics, University of Belgrade, Belgrade, Serbia*
[12b]*Vinca Institute of Nuclear Sciences, University of Belgrade, Belgrade, Serbia*
[13]*Department for Physics and Technology, University of Bergen, Bergen, Norway*
[14]*Physics Division, Lawrence Berkeley National Laboratory and University of California, Berkeley, California, USA*
[15]*Department of Physics, Humboldt University, Berlin, Germany*
[16]*Albert Einstein Center for Fundamental Physics and Laboratory for High Energy Physics, University of Bern, Bern, Switzerland*
[17]*School of Physics and Astronomy, University of Birmingham, Birmingham, United Kingdom*
[18a]*Department of Physics, Bogazici University, Istanbul, Turkey*
[18b]*Division of Physics, Dogus University, Istanbul, Turkey*
[18c]*Department of Physics Engineering, Gaziantep University, Gaziantep, Turkey*
[18d]*Department of Physics, Istanbul Technical University, Istanbul, Turkey*
[19a]*INFN Sezione di Bologna, Bologna, Italy*
[19b]*Dipartimento di Fisica, Università di Bologna, Bologna, Italy*
[20]*Physikalisches Institut, University of Bonn, Bonn, Germany*
[21]*Department of Physics, Boston University, Boston, Massachusetts, USA*
[22]*Department of Physics, Brandeis University, Waltham, Massachusetts, USA*
[23a]*Universidade Federal do Rio De Janeiro COPPE/EE/IF, Rio de Janeiro, Brazil*
[23b]*Federal University of Juiz de Fora (UFJF), Juiz de Fora, Brazil*
[23c]*Federal University of Sao Joao del Rei (UFSJ), Sao Joao del Rei, Brazil*
[23d]*Instituto de Fisica, Universidade de Sao Paulo, Sao Paulo, Brazil*
[24]*Physics Department, Brookhaven National Laboratory, Upton, New York, USA*
[25a]*National Institute of Physics and Nuclear Engineering, Bucharest, Romania*
[25b]*University Politehnica Bucharest, Bucharest, Romania*
[25c]*West University in Timisoara, Timisoara, Romania*
[26]*Departamento de Física, Universidad de Buenos Aires, Buenos Aires, Argentina*
[27]*Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom*
[28]*Department of Physics, Carleton University, Ottawa, Ontario, Canada*
[29]*CERN, Geneva, Switzerland*
[30]*Enrico Fermi Institute, University of Chicago, Chicago, Illinois, USA*

[31a]Departamento de Fisica, Pontificia Universidad Católica de Chile, Santiago, Chile

[31b]Departamento de Física, Universidad Técnica Federico Santa María, Valparaíso, Chile

[32a]Institute of High Energy Physics, Chinese Academy of Sciences, Beijing, China

[32b]Department of Modern Physics, University of Science and Technology of China, Anhui, China

[32c]Department of Physics, Nanjing University, Jiangsu, China

[32d]School of Physics, Shandong University, Shandong, China

[33]Laboratoire de Physique Corpusculaire, Clermont Université and Université Blaise Pascal and CNRS/IN2P3,
Aubiere Cedex, France

[34]Nevis Laboratory, Columbia University, Irvington, New York, USA

[35]Niels Bohr Institute, University of Copenhagen, Kobenhavn, Denmark

[36a]INFN Gruppo Collegato di Cosenza, Cosenza, Italy

[36b]Dipartimento di Fisica, Università della Calabria, Arcavata di Rende, Italy

[37]AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Krakow, Poland

[38]The Henryk Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences, Krakow, Poland

[39]Physics Department, Southern Methodist University, Dallas, Texas, USA

[40]Physics Department, University of Texas at Dallas, Richardson, Texas, USA

[41]DESY, Hamburg and Zeuthen, Germany

[42]Institut für Experimentelle Physik IV, Technische Universität Dortmund, Dortmund, Germany

[43]Institut für Kern- und Teilchenphysik, Technical University Dresden, Dresden, Germany

[44]Department of Physics, Duke University, Durham, North Carolina, USA

[45]SUPA - School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom

[46]INFN Laboratori Nazionali di Frascati, Frascati, Italy

[47]Fakultät für Mathematik und Physik, Albert-Ludwigs-Universität, Freiburg i.Br., Germany

[48]Section de Physique, Université de Genève, Geneva, Switzerland

[49a]INFN Sezione di Genova, Italy

[49b]Dipartimento di Fisica, Università di Genova, Genova, Italy

[50a]E.Andronikashvili Institute of Physics, Tbilisi State University, Tbilisi, Georgia

[50b]High Energy Physics Institute, Tbilisi State University, Tbilisi, Georgia

[51]II Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen, Germany

[52]SUPA - School of Physics and Astronomy, University of Glasgow, Glasgow, United Kingdom

[53]II Physikalisches Institut, Georg-August-Universität, Göttingen, Germany

[54]Laboratoire de Physique Subatomique et de Cosmologie, Université Joseph Fourier and CNRS/IN2P3 and Institut National
Polytechnique de Grenoble, Grenoble, France

[55]Department of Physics, Hampton University, Hampton, Virginia, USA

[56]Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge, Massachusetts, USA

[57a]Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany

[57b]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany

[57c]ZITI Institut für technische Informatik, Ruprecht-Karls-Universität Heidelberg, Mannheim, Germany

[58]Faculty of Science, Hiroshima University, Hiroshima, Japan

[59]Faculty of Applied Information Science, Hiroshima Institute of Technology, Hiroshima, Japan

[60]Department of Physics, Indiana University, Bloomington, Indiana, USA

[61]Institut für Astro- und Teilchenphysik, Leopold-Franzens-Universität, Innsbruck, Austria

[62]University of Iowa, Iowa City, Iowa, USA

[63]Department of Physics and Astronomy, Iowa State University, Ames, Iowa, USA

[64]Joint Institute for Nuclear Research, JINR Dubna, Dubna, Russia

[65]KEK, High Energy Accelerator Research Organization, Tsukuba, Japan

[66]Graduate School of Science, Kobe University, Kobe, Japan

[67]Faculty of Science, Kyoto University, Kyoto, Japan

[68]Kyoto University of Education, Kyoto, Japan

[69]Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata, Argentina

[70]Physics Department, Lancaster University, Lancaster, United Kingdom

[71a]INFN Sezione di Lecce, Italy

[71b]Dipartimento di Fisica, Università del Salento, Lecce, Italy

[72]Oliver Lodge Laboratory, University of Liverpool, Liverpool, United Kingdom

[73]Department of Physics, Jožef Stefan Institute and University of Ljubljana, Ljubljana, Slovenia

[74]School of Physics and Astronomy, Queen Mary University of London, London, United Kingdom

[75]Department of Physics, Royal Holloway University of London, Surrey, United Kingdom

[76]Department of Physics and Astronomy, University College London, London, United Kingdom

[77]Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France

[78]Fysiska institutionen, Lunds universitet, Lund, Sweden

[79]Departamento de Fisica Teorica C-15, Universidad Autonoma de Madrid, Madrid, Spain

[80]Institut für Physik, Universität Mainz, Mainz, Germany

[81]School of Physics and Astronomy, University of Manchester, Manchester, United Kingdom

[82]CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France

[83]Department of Physics, University of Massachusetts, Amherst, Massachusetts, USA

[84]Department of Physics, McGill University, Montreal, Quebec, Canada

[85]School of Physics, University of Melbourne, Victoria, Australia

[86]Department of Physics, The University of Michigan, Ann Arbor, Michigan, USA

[87]Department of Physics and Astronomy, Michigan State University, East Lansing, Michigan, USA

[88a]INFN Sezione di Milano, Milano, Italy

[88b]Dipartimento di Fisica, Università di Milano, Milano, Italy

[89]B.I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk, Republic of Belarus

[90]National Scientific and Educational Centre for Particle and High Energy Physics, Minsk, Republic of Belarus

[91]Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA

[92]Group of Particle Physics, University of Montreal, Montreal, Quebec, Canada

[93]P.N. Lebedev Institute of Physics, Academy of Sciences, Moscow, Russia

[94]Institute for Theoretical and Experimental Physics (ITEP), Moscow, Russia

[95]Moscow Engineering and Physics Institute (MEPhI), Moscow, Russia

[96]Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia

[97]Fakultät für Physik, Ludwig-Maximilians-Universität München, München, Germany

[98]Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), München, Germany

[99]Nagasaki Institute of Applied Science, Nagasaki, Japan

[100]Graduate School of Science, Nagoya University, Nagoya, Japan

[101a]INFN Sezione di Napoli, Napoli, Italy

[101b]Dipartimento di Scienze Fisiche, Università di Napoli, Napoli, Italy

[102]Department of Physics and Astronomy, University of New Mexico, Albuquerque, New Mexico, USA

[103]Institute for Mathematics, Astrophysics and Particle Physics, Radboud University Nijmegen/Nikhef, Nijmegen, The Netherlands

[104]Nikhef National Institute for Subatomic Physics and University of Amsterdam, Amsterdam, The Netherlands

[105]Department of Physics, Northern Illinois University, DeKalb, Illinois, USA

[106]Budker Institute of Nuclear Physics, SB RAS, Novosibirsk, Russia

[107]Department of Physics, New York University, New York, New York, USA

[108]The Ohio State University, Columbus, Ohio, USA

[109]Faculty of Science, Okayama University, Okayama, Japan

[110]Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman, Oklahoma, USA

[111]Department of Physics, Oklahoma State University, Stillwater, Oklahoma, USA

[112]Palacký University, RCPTM, Olomouc, Czech Republic

[113]Center for High Energy Physics, University of Oregon, Eugene, Oregon, USA

[114]LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France

[115]Graduate School of Science, Osaka University, Osaka, Japan

[116]Department of Physics, University of Oslo, Oslo, Norway

[117]Department of Physics, Oxford University, Oxford, United Kingdom

[118a]INFN Sezione di Pavia, Pavia, Italy

[118b]Dipartimento di Fisica, Università di Pavia, Pavia, Italy

[119]Department of Physics, University of Pennsylvania, Philadelphia, Pennsylvania, USA

[120]Petersburg Nuclear Physics Institute, Gatchina, Russia

[121a]INFN Sezione di Pisa, Pisa, Italy

[121b]Dipartimento di Fisica E. Fermi, Università di Pisa, Pisa, Italy

[122]Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh, Pennsylvania, USA

[123a]Laboratorio de Instrumentacao e Fisica Experimental de Particulas - LIP, Lisboa, Portugal

[123b]Departamento de Fisica Teorica y del Cosmos and CAFPE, Universidad de Granada, Granada, Spain

[124]Institute of Physics, Academy of Sciences of the Czech Republic, Praha, Czech Republic

[125]Faculty of Mathematics and Physics, Charles University in Prague, Praha, Czech Republic

[126]Czech Technical University in Prague, Praha, Czech Republic

[127]State Research Center Institute for High Energy Physics, Protvino, Russia

[128]Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom

[129]Physics Department, University of Regina, Regina, Saskatchewan, Canada

[130]Ritsumeikan University, Kusatsu, Shiga, Japan

[131a]INFN Sezione di Roma I, Roma, Italy

[131b]Dipartimento di Fisica, Università La Sapienza, Roma, Italy

[132a]INFN Sezione di Roma Tor Vergata, Roma, Italy

[132b]Dipartimento di Fisica, Università di Roma Tor Vergata, Roma, Italy

[133a]INFN Sezione di Roma Tre, Roma, Italy

[133b]*Dipartimento di Fisica, Università Roma Tre, Roma, Italy*

[134a]*Faculté des Sciences Ain Chock, Réseau Universitaire de Physique des Hautes Energies - Université Hassan II, Casablanca, Morocco*

[134b]*Centre National de l'Energie des Sciences Techniques Nucleaires, Rabat, Morocco*

[134c]*Faculté des Sciences Semlalia, Université Cadi Ayyad, LPHEA-Marrakech, Morocco*

[134d]*Faculté des Sciences, Université Mohamed Premier and LPTPM, Oujda, Morocco*

[134e]*Faculté des Sciences, Université Mohammed V- Agdal, Rabat, Morocco*

[135]*DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat a l'Energie Atomique), Gif-sur-Yvette, France*

[136]*Santa Cruz Institute for Particle Physics, University of California Santa Cruz, Santa Cruz, California, USA*

[137]*Department of Physics, University of Washington, Seattle, Washington, USA*

[138]*Department of Physics and Astronomy, University of Sheffield, Sheffield, United Kingdom*

[139]*Department of Physics, Shinshu University, Nagano, Japan*

[140]*Fachbereich Physik, Universität Siegen, Siegen, Germany*

[141]*Department of Physics, Simon Fraser University, Burnaby, British Columbia, Canada*

[142]*SLAC National Accelerator Laboratory, Stanford, California, USA*

[143a]*Faculty of Mathematics, Physics & Informatics, Comenius University, Bratislava, Slovak Republic*

[143b]*Department of Subnuclear Physics, Institute of Experimental Physics of the Slovak Academy of Sciences, Kosice, Slovak Republic*

[144a]*Department of Physics, University of Johannesburg, Johannesburg, South Africa*

[144b]*School of Physics, University of the Witwatersrand, Johannesburg, South Africa*

[145a]*Department of Physics, Stockholm University, Sweden*

[145b]*The Oskar Klein Centre, Stockholm, Sweden*

[146]*Physics Department, Royal Institute of Technology, Stockholm, Sweden*

[147]*Departments of Physics & Astronomy and Chemistry, Stony Brook University, Stony Brook, New York, USA*

[148]*Department of Physics and Astronomy, University of Sussex, Brighton, United Kingdom*

[149]*School of Physics, University of Sydney, Sydney, Australia*

[150]*Institute of Physics, Academia Sinica, Taipei, Taiwan*

[151]*Department of Physics, Technion: Israel Institute of Technology, Haifa, Israel*

[152]*Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel*

[153]*Department of Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece*

[154]*International Center for Elementary Particle Physics and Department of Physics, The University of Tokyo, Tokyo, Japan*

[155]*Graduate School of Science and Technology, Tokyo Metropolitan University, Tokyo, Japan*

[156]*Department of Physics, Tokyo Institute of Technology, Tokyo, Japan*

[157]*Department of Physics, University of Toronto, Toronto, Ontario, Canada*

[158a]*TRIUMF, Vancouver, British Columbia, Canada*

[158b]*Department of Physics and Astronomy, York University, Toronto, Ontario, Canada*

[159]*Institute of Pure and Applied Sciences, University of Tsukuba,1-1-1 Tennodai, Tsukuba, Ibaraki 305-8571, Japan*

[160]*Science and Technology Center, Tufts University, Medford, Massachusetts, USA*

[161]*Centro de Investigaciones, Universidad Antonio Narino, Bogota, Colombia*

[162]*Department of Physics and Astronomy, University of California Irvine, Irvine, California, USA*

[163a]*INFN Gruppo Collegato di Udine, Udine, Italy*

[163b]*ICTP, Trieste, Italy*

[163c]*Dipartimento di Chimica, Fisica e Ambiente, Università di Udine, Udine, Italy*

[164]*Department of Physics, University of Illinois, Urbana, Illinois, USA*

[165]*Department of Physics and Astronomy, University of Uppsala, Uppsala, Sweden*

[166]*Instituto de Física Corpuscular (IFIC) and Departamento de Física Atómica, Molecular y Nuclear and Departamento de Ingeniería Electrónica and Instituto de Microelectrónica de Barcelona (IMB-CNM), University of Valencia and CSIC, Valencia, Spain*

[167]*Department of Physics, University of British Columbia, Vancouver, British Columbia, Canada*

[168]*Department of Physics and Astronomy, University of Victoria, Victoria, British Columbia, Canada*

[169]*Waseda University, Tokyo, Japan*

[170]*Department of Particle Physics, The Weizmann Institute of Science, Rehovot, Israel*

[171]*Department of Physics, University of Wisconsin, Madison, Wisconsin, USA*

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

[173]*Fachbereich C Physik, Bergische Universität Wuppertal, Wuppertal, Germany*

[174]*Department of Physics, Yale University, New Haven, Connecticut, USA*

[175]*Yerevan Physics Institute, Yerevan, Armenia*

[176]*Domaine scientifique de la Doua, Centre de Calcul CNRS/IN2P3, Villeurbanne Cedex, France*

[a]Deceased.

[b]Also at Laboratorio de Instrumentacao e Fisica Experimental de Particulas—LIP, Lisboa, Portugal.

[c]Also at Faculdade de Ciencias and CFNUL, Universidade de Lisboa, Lisboa, Portugal.

[d]Also at Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom.

[e]Also at TRIUMF, Vancouver, BC, Canada.

[f]Also at Department of Physics, California State University, Fresno, CA, USA.

[g]Also at Novosibirsk State University, Novosibirsk, Russia.

[h]Also at Fermilab, Batavia, IL, USA.

[i]Also at Department of Physics, University of Coimbra, Coimbra, Portugal.

[j]Also at Università di Napoli Parthenope, Napoli, Italy.

[k]Also at Institute of Particle Physics (IPP), Canada.

[l]Also at Department of Physics, Middle East Technical University, Ankara, Turkey.

[m]Also at Louisiana Tech University, Ruston, LA, USA.

[n]Also at Department of Physics and Astronomy, University College London, London, United Kingdom.

[o]Also at Group of Particle Physics, University of Montreal, Montreal, QC, Canada.

[p]Also at Department of Physics, University of Cape Town, Cape Town, South Africa.

[q]Also at Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan.

[r]Also at Institut für Experimentalphysik, Universität Hamburg, Hamburg, Germany.

[s]Also at Manhattan College, New York, NY, USA.

[t]Also at School of Physics, Shandong University, Shandong, China.

[u]Also at CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France.

[v]Also at School of Physics and Engineering, Sun Yat-sen University, Guanzhou, China.

[w]Also at Academia Sinica Grid Computing, Institute of Physics, Academia Sinica, Taipei, Taiwan.

[x]Also at DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat a l'Energie Atomique), Gif-sur-Yvette, France.

[y]Also at Section de Physique, Université de Genève, Geneva, Switzerland.

[z]Also at Departamento de Fisica, Universidade de Minho, Braga, Portugal.

[aa]Also at Department of Physics and Astronomy, University of South Carolina, Columbia, SC, USA.

[bb]Also at Institute for Particle and Nuclear Physics, Wigner Research Centre for Physics, Budapest, Hungary.

[cc]Also at California Institute of Technology, Pasadena, CA, USA.

[dd]Also at Institute of Physics, Jagiellonian University, Krakow, Poland.

[ee]Also at LAL, Univ. Paris-Sud and CNRS/IN2P3, Orsay, France.

[ff]Also at Department of Physics and Astronomy, University of Sheffield, Sheffield, United Kingdom.

[gg]Also at Department of Physics, Oxford University, Oxford, United Kingdom.

[hh]Also at Institute of Physics, Academia Sinica, Taipei, Taiwan.

[ii]Also at Department of Physics, The University of Michigan, Ann Arbor, MI, USA.

[jj]Also at Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France.