Determination of the Ratio of b-Quark Fragmentation Fractions fs/fd in pp Collisions at √s=7 TeV with the ATLAS Detector

Aad, G.; et al., [Unknown]; Aben, R.; Angelozzi, I.; Beemster, L.J.; Bentvelsen, S.C.M.; Berge, D.; Bobbink, G.J.; Bos, K.; Brenner, L.; Butti, P.; Castelli, A.; Colijn, A.P.; de Jong, P.J.; Deigaard, I.; Deluca, C.; Duda, D.; Ferrari, P.; Hartjes, F.G.; Hessey, N.P.; Hod, N.; Igonkina, O.; Karastathis, N.; Kluit, P.M.; Koffeman, E.N.; Linde, F.L.; Mahlstedt, J.; Meyer, J.; Oussoren, K.P.; Sabato, G.; Salek, D.; Slawinska, M.; Valencic, N.; van den Wollenberg, W.; van der Deijl, P.C.; van der Geer, R.; van der Graaf, H.; van Vulpen, I.B.; Verkerke, W.; Vermeulen, J.C.; Vreeswijk, M.; Weits, H.; Williams, S.

Published in:
Physical Review Letters

DOI:
10.1103/PhysRevLett.115.262001

Determination of the Ratio of b-Quark Fragmentation Fractions f_s/f_d in pp Collisions at $\sqrt{s} = 7$ TeV with the ATLAS Detector

G. Aad et al.*
(ATLAS Collaboration)

(Received 3 August 2015; published 30 December 2015)

With an integrated luminosity of 2.47 fb^{-1} recorded by the ATLAS experiment at the LHC, the exclusive decays $B_s^0 \to J/\psi\phi$ and $B_d^0 \to J/\psi K^{*0}$ of B mesons produced in pp collisions at $\sqrt{s} = 7$ TeV are used to determine the ratio of fragmentation fractions f_s/f_d. From the observed $B_s^0 \to J/\psi\phi$ and $B_d^0 \to J/\psi K^{*0}$ yields, the quantity $(f_s/f_d)[\mathcal{B}(B_s^0 \to J/\psi\phi)/\mathcal{B}(B_d^0 \to J/\psi K^{*0})]$ is measured to be $0.199 \pm 0.004(\mathrm{stat}) \pm 0.008(\mathrm{syst})$. Using a recent theory prediction for $[\mathcal{B}(B_s^0 \to J/\psi\phi)/\mathcal{B}(B_d^0 \to J/\psi K^{*0})]$ yields $(f_s/f_d) = 0.240 \pm 0.004(\mathrm{stat}) \pm 0.010(\mathrm{syst}) \pm 0.017(\mathrm{th})$. This result is based on a new approach that provides a significant improvement of the world average.

DOI: 10.1103/PhysRevLett.115.262001 PACS numbers: 14.40.Nd, 14.65.Fy

The production rate of B_s^0 (B_d^0) mesons is a product of the $b\bar{b}$ cross section, the instantaneous luminosity and the probability that the $\bar{b}$ quark is bound to an s (d) quark. The latter, denoted by the fragmentation fraction f_s (f_d), depends on the probability that in pQCD-inspired calculations [1,2], a soft gluon splits into $s\bar{s}$ ($d\bar{d}$) and that the overlap of the $\bar{b}$ and $s(d)$ wave functions is sufficiently large to produce a B_s^0 (B_d^0) bound state. In a similar fashion, B^+ mesons, B_c mesons, and b baryons are produced at the LHC with respective fragmentation fractions f_u, f_c, and f_{baryon}. The fragmentation fractions are about 40% each for u and d quarks, 10% for s quarks, at the percent level for c quarks, and ~8% for baryon production satisfying the constraint $f_u + f_d + f_s + f_c + f_{\mathrm{baryon}} = 1$. Precise knowledge of the fragmentation fractions is essential for measuring b-hadron cross sections and branching fractions at the LHC. In particular, for rare decays, such as the branching fraction measurement of $B_s^0 \to \mu^+\mu^-$ [3–5], a precise knowledge of f_s/f_d is important since it improves the sensitivity of searches for new physics processes beyond the standard model (SM). The fragmentation ratio f_s/f_d is a universal quantity that was measured by LEP experiments [6], CDF [7], and LHCb [8,9]. This Letter presents a measurement of f_s/f_d using $B_s^0 \to J/\psi\phi$ and $B_d^0 \to J/\psi K^{*0}$ decays.

The ratio of fragmentation fractions f_s/f_d is extracted from the measured $B_s^0 \to J/\psi\phi$ and $B_d^0 \to J/\psi K^{*0}$ signal yields, $N_{B_s^0}$, and $N_{B_d^0}$. These are converted into B_s^0 and B_d^0 meson yields after dividing by the branching fractions of the relevant decays and correcting for the relative efficiency $\mathcal{R}_{\mathrm{eff}}$ that is expressed as a product of acceptance and selection efficiency ratios for the two modes and is determined from Monte Carlo (MC) simulations:

$$\frac{f_s}{f_d} = \frac{N_{B_s^0}}{N_{B_d^0}} \frac{\mathcal{B}(B_d^0 \to J/\psi K^{*0})}{\mathcal{B}(B_s^0 \to J/\psi\phi)} \frac{\mathcal{B}(K^{*0} \to K^+\pi^-)}{\mathcal{B}(\phi \to K^+K^-)} \mathcal{R}_{\mathrm{eff}}, \quad (1)$$

where the J/ψ, ϕ, and K^{*0} are reconstructed in their $J/\psi \to \mu^+\mu^-$, $\phi \to K^+K^-$, and $K^{*0} \to K^+\pi^-$ final states [10], respectively. The data sample consists of pp collisions collected with the ATLAS detector at $\sqrt{s} = 7$ TeV corresponding to an integrated luminosity of $2.47 \pm 0.04\ \mathrm{fb}^{-1}$. The ATLAS multipurpose detector is described in detail in Ref. [11].

The PYTHIA 6 and 8 [12,13] MC generators with parameters tuned to reproduce ATLAS data [14] are used to simulate background and signal events, respectively. For the signal channels, the angular distributions are produced with the measured polarization parameters [15]. The detector response for the generated events is simulated with GEANT4 [16,17].

The $B_s^0 \to J/\psi\phi$ and $B_d^0 \to J/\psi K^{*0}$ signal candidates consist of two muons and two hadrons originating from a common secondary vertex. The J/ψ candidates are selected from the dimuon trigger sample requiring two oppositely charged muon candidates, each having a transverse momentum of $p_T > 4$ GeV. Reconstructed muon candidates are categorized either as combined or segment-tagged muons. A combined muon consists of an inner detector (ID) track combined with a muon spectrometer (MS) track using tight matching criteria, while a segment-tagged muon requires an ID track and track segments in the MS that are not reconstructed as an MS track [11]. The two muons, of which at least one must be a combined muon, are fitted to originate from the same two-track vertex. The

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

vertex fit chi-square per degree of freedom (dof) is required to be $\chi^2/\mathrm{dof} < 10$. To improve the sample purity, each muon track must have at least one hit in the pixel detector, more than five hits in the silicon strip detector and at least one hit in the transition radiation tracker that reduces the pseudorapidity coverage to $|\eta| < 2.0$ [18].

Since the dimuon mass resolution is different for muons reconstructed in the end caps ($1.05 < |\eta| < 2.5$) and for muons reconstructed in the barrel ($|\eta| < 1.05$), all accepted J/ψ candidates are divided into three classes: two barrel muons (BB), one end-cap and one barrel muon (EB), and two end-cap muons (EE). The parameters describing the dimuon mass distribution in the J/ψ signal region for the three pseudorapidity classes in data and in $B_s^0 \to J/\psi\phi$ and $B_d^0 \to J/\psi K^{*0}$ MC signal samples are extracted from maximum-likelihood fits. Signal events are selected requiring mass windows of $\pm 3\sigma$ around the J/ψ peak in data and simulations. For data, the selected signal regions are 2.991–3.197 GeV for BB, 2.955–3.235 GeV for EB, and 2.914–3.275 GeV for EE classes, while in simulations they are slightly smaller.

The B_s^0 candidates are reconstructed from a J/ψ candidate plus two oppositely charged hadrons with a kaon mass hypothesis assigned. The dimuon mass is constrained to the J/ψ mass [15], and the J/ψ and two kaons have to originate from the same vertex. All combinations are accepted if $p_T(B_s^0) > 8$ GeV, $\chi^2/\mathrm{dof} < 3$ for the vertex fit and the K^+K^- invariant mass lies in the range determined by ± 2 natural widths (Γ_ϕ) around the ϕ mass peak, $1011 < m_{K^+K^-} < 1028$ MeV. The $m_{K^+K^-}$ distribution is modeled with a Breit-Wigner line shape convolved with a Crystal Ball function [19]. The selected mass window retains 85% of signal events.

The B_d^0 candidates are reconstructed in a similar way. Here, one track of the K^{*0} decay is assigned a kaon mass hypothesis and the other track a pion mass hypothesis. Since ATLAS has limited kaon-pion separation capability in the momentum range relevant for this analysis, both $K\pi$ mass assignment combinations are tested. That with mass closest to the nominal K^{*0} mass is chosen, yielding the correct $K\pi$ selection for 86% of all K^{*0} candidates. The probability density function (PDF) for the invariant mass of correctly selected $K\pi$ candidates is modeled with a relativistic Breit-Wigner line shape convolved with a Crystal Ball function, while that where the K and π are swapped is modeled with a Gaussian function. The decay $B_s^0 \to J/\psi\phi$ produces a peaking background in $B_d^0 \to J/\psi K^{*0}$ that appears in the low K^{*0} mass region. To remove this contribution, the selected K^{*0} region is constrained to one K^{*0} decay width around the K^{*0} mass peak, corresponding to $847 < m_{K\pi} < 942$ MeV for data. Since the K^{*0} line shape is narrower in the MC simulations than in data, the $K\pi$ mass selection needs to be adjusted in simulations to produce identical efficiencies in data and simulations. For the K^+K^- mass selection, a similar procedure is used.

The signal-to-background ratios for $B_s^0 \to J/\psi\phi$ and $B_d^0 \to J/\psi K^{*0}$ decays are optimized using three variables with high background suppression power: the χ^2/dof of the B vertex fit, the transverse decay length L_{xy} defined as the length of the vector from the primary vertex (PV) [20] to the B decay vertex in the transverse plane, and the pointing angle α defined as the angle between the B meson transverse momentum and L_{xy}. If more than one PV candidate exists, the one is selected for which the sum of squared transverse momenta of all tracks originating from the vertex, $\sum p_T^2$, yields the highest value. The χ^2/dof, L_{xy} and α selection criteria are optimized using simulated $B_s^0 \to J/\psi\phi$ and $B_d^0 \to J/\psi K^{*0}$ events for signal and data sidebands for background.

To produce similar p_T and η distributions in data and MC, data-driven weights are obtained by the following procedure. Sideband-subtracted $B_s^0 \to J/\psi\phi$ ($B_d^0 \to J/\psi K^{*0}$) p_T and η distributions from data are compared with corresponding distributions in simulation in the signal region, $5.32 < m_{J/\psi\phi} < 5.42$ ($5.21 < m_{J/\psi K^{*0}} < 5.35$) GeV. The upper and lower sidebands $5.20 < m_{J/\psi\phi} < 5.25$ ($5.09 < m_{J/\psi K^{*0}} < 5.16$) GeV and $5.48 < m_{J/\psi\phi} < 5.53$ ($5.40 < m_{J/\psi K^{*0}} < 5.47$) GeV are selected such that their summed yields represent the expected backgrounds in the signal region for the data. The weights are obtained by dividing the yield in each p_T and η bin in data by the corresponding yield of the MC sample using only events with odd event numbers. Thus, for each bin (i) and (j) of the p_T and η distributions, a weight is determined as a product of a p_T-dependent and η-dependent weights:

$$W_{ij}(p_T,\eta) = \frac{n_i^{\mathrm{data}}(p_T)}{n_i^{\mathrm{MC}}(p_T)}\frac{n_j^{\mathrm{data}}(\eta)}{n_j^{\mathrm{MC}}(\eta)}, \tag{2}$$

where $n_i^{\mathrm{data/MC}}(p_T)$ is the normalized number of entries in the p_T bin i and $n_j^{\mathrm{data/MC}}(\eta)$ is that in the η bin j. To obtain good agreement between data and simulation, the procedure is repeated twice. The two sets of weights are multiplied and are used to correct the p_T and η distributions of the MC sample with even event numbers. From the corrected MC samples, distributions for χ^2/dof, L_{xy}, and α are determined, which are in good agreement with those measured in the data. The correlation between p_T and η is small and is accounted for in the systematic error.

For both modes, the dominant background originates from a J/ψ produced at the PV plus two oppositely charged hadrons (direct J/ψ) [21]. Since the hadrons are not associated with any $B_s^0(B_d^0)$ decay, the $J/\psi K^+K^-(J/\psi K^+\pi^-)$ invariant-mass spectrum does not peak but decreases with mass. Another large background consists of two random low-momentum, oppositely charged muons combined with two random charged hadrons. Here, the dimuon mass distribution does not peak at the J/ψ nor does the four-particle mass show any peaking structure. Inclusive decays $B \to J/\psi X$, where X is a single hadron or a collection of hadrons, provide a source of background that is very similar to the signal. If X consists of exactly two charged-particle tracks (without any π^0), the mode is topologically indistinguishable from the signal mode. Self-cross-feed, in which one or both hadrons from the $\phi(K^{*0})$ decay are replaced with random hadrons, is negligible. In addition, peaking backgrounds from $B_d^0 \to J/\psi K^{*0}$ and $B_d^0 \to J/\psi K^+\pi^-$ contribute to $B_s^0 \to J/\psi\phi$ while $B_d^0 \to J/\psi K^+\pi^-$ also contributes to $B_d^0 \to J/\psi K^{*0}$.

To reduce these backgrounds, the χ^2/dof, L_{xy} and α selections are optimized for each mode separately by determining the maximum value of $S/\sqrt{S+B}$ as a function of selected values for the observable to be optimized, where S represents the signal yield obtained from simulation and B is the background extracted from data sidebands. For the B_s^0 (B_d^0) mode, the optimization yields $\chi^2/\mathrm{dof} < 2.4\,(2.6)$, $L_{xy} > 0.26\,(0.30)$ mm, and $\alpha < 0.14\,(0.12)$ rad. In combination with the J/ψ mass requirement, the χ^2/dof selection reduces the combinatorial background significantly, while the L_{xy} and α selections remove most of the direct J/ψ background.

In the final sample, the signal yields $N_{B_s^0}$ and $N_{B_d^0}$ are extracted from unbinned extended maximum-likelihood fits to the $J/\psi K^+K^-$ and $J/\psi K^+\pi^-$ invariant-mass spectra, respectively. The B_s^0 signal PDF is modeled with three Gaussian functions with common mean that is determined from the fit, while widths and fractions are fixed to the values obtained from MC simulations. To account for possible width differences in the two narrowest Gaussian functions between data and simulation, an additional scale factor is introduced, which is left free in the fit. The peaking background PDF is modeled with a Crystal Ball function with parameters fixed to the values obtained in simulations. The peaking background yield of 652 ± 93 events is calculated from the B_d^0 signal yield. The selection efficiencies of both peaking background modes are determined from simulation and are fixed in the fit to data. The remaining residual backgrounds are modeled with an exponential function leaving fraction and exponent free in the fit to data.

The B_d^0 signal PDF is parametrized with three Gaussian functions that describe both the correctly reconstructed and swapped $K^+\pi^-$ events. The PDF of the peaking background is modeled with a sum of Crystal Ball and Gaussian functions for which the relative $B_d^0 \to J/\psi K^+\pi^-$ yield with respect to that of the $B_d^0 \to J/\psi K^{*0}$ signal is determined from the corresponding branching fractions and selection efficiencies, yielding $(4.7 \pm 2.4)\%$. Most of the residual background is modeled with an exponential function, while partially reconstructed $B \to J/\psi X$ decays require parametrization with a complementary error function. All parameters of the residual background PDFs are left free in the fit.

Figure 1 shows the measured $J/\psi\phi$ and $J/\psi K^{*0}$ invariant-mass spectra with fits overlaid. The fits yield $N_{B_s^0} = 6640 \pm 100$ $B_s^0 \to J/\psi\phi$ and $N_{B_d^0} = 36290 \pm 320$ $B_d^0 \to J/\psi K^{*0}$ signal events. The χ^2/dof values of the fits are 0.959 for B_s^0 and 0.945 for B_d^0, indicating that both fits describe the data well.

The additive systematic uncertainties result from the $B_s^0 \to J/\psi\phi$ and $B_d^0 \to J/\psi K^{*0}$ signal and background parametrizations. The contribution from the signal shape parametrization is calculated by varying the five fixed parameters within $\pm 1\sigma$ in a multivariate Gaussian function that takes into account all correlations. For nonpeaking backgrounds, the exponential function is replaced with a second-order polynomial for the B_s^0 and with a second-order polynomial plus an error function for the B_d^0. The difference in signal yield with respect to the nominal fit is taken as a systematic error. For peaking backgrounds, the

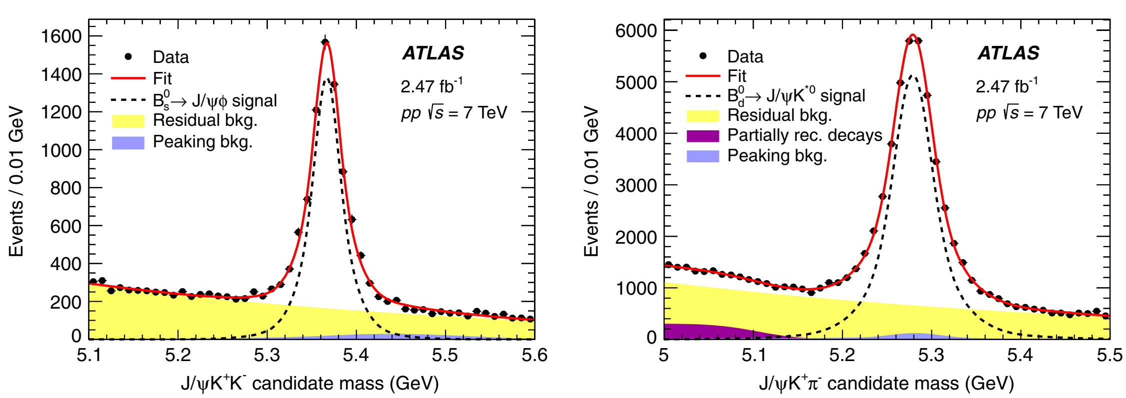

FIG. 1 (color online). The invariant-mass spectra of $B_s^0 \to J/\psi\phi$ (left panel) and $B_d^0 \to J/\psi K^{*0}$ decays (right panel) for data (points with error bars), total fit (solid line), signal (dashed line), residual background (yellow shaded), partially reconstructed events (magenta shaded) and peaking background (blue shaded).

TABLE I. Measured B_s^0 and B_d^0 signal yields, the efficiency ratio $\mathcal{R}_{\rm eff}$ extracted from simulations, world averages for ϕ and K^{*0} decay branching fractions, as well as corresponding systematic uncertainties σ on $(f_s/f_d)[\mathcal{B}(B_s^0 \to J/\psi\phi)/\mathcal{B}(B_d^0 \to J/\psi K^{*0})]$.

Observable	Value	σ	Reference
$N_{B_s^0}$	$6640 \pm 100 \pm 220$	3.3%	
$N_{B_d^0}$	$36290 \pm 320 \pm 650$	1.8%	
$\mathcal{R}_{\rm eff}$	$0.799 \pm 0.001 \pm 0.010$	1.3%	
$\mathcal{B}(\phi \to K^+K^-)$	0.489 ± 0.005	1.0%	[15]
$\mathcal{B}(K^{*0} \to K^+\pi^-)$	0.66503 ± 0.00014	0.02%	[15]
Total		4.1%	

fixed parameters are varied by $\pm 1\sigma$, and the difference with respect to the nominal yield is taken as a systematic error. In addition, since S-wave contributions from $B_s^0 \to J/\psi K^+K^-$ and $B_s^0 \to J/\psi f_0(980)$ decays to $B_s^0 \to J/\psi\phi$ and $B_d^0 \to J/\psi K^{*0}$ are neglected in the fits, an uncertainty is derived using the ATLAS measured contribution of 2.4% [22] for $B_s^0 \to J/\psi\phi$, and the contribution of 1% for $B_d^0 \to J/\psi K^{*0}$ derived from the MC simulation. All additive systematic errors are added in quadrature, yielding total additive uncertainties of 220 $N_{B_s^0}$ and 650 $N_{B_d^0}$ events.

The multiplicative systematic uncertainty includes contributions from the relative efficiency and the branching fractions of the ϕ and K^{*0} decays. The uncertainty on the relative efficiency is dominated by the uncertainty on the ϕ/K^{*0} selection (1.2%), which is obtained by varying the fixed fit parameters in the ϕ and K^{*0} fits by $\pm 1\sigma$ and adding all contributions in quadrature. Other uncertainties from the J/ψ selection (0.2%), reweighting (0.4%), B_s^0 and B_d^0 lifetimes (0.002%), and the contribution due to uncertainties in the polarization parameters (0.01%) are negligible. Varying the selection criteria of χ^2/dof, L_{xy} and α gives negligible contributions. Table I summarizes the contributions of the additive and multiplicative systematic errors.

From the ratio $N_{B_s^0}/N_{B_d^0}$ after efficiency correction and division by ϕ and K^{*0} decay branching fractions, ATLAS measures

$$\frac{f_s}{f_d}\frac{\mathcal{B}(B_s^0 \to J/\psi\phi)}{\mathcal{B}(B_d^0 \to J/\psi K^{*0})} = 0.199 \pm 0.004(\text{stat}) \pm 0.008(\text{syst}). \quad (3)$$

A perturbative QCD prediction [23] yields

$$\frac{\mathcal{B}(B_s^0 \to J/\psi\phi)}{\mathcal{B}(B_d^0 \to J/\psi K^{*0})} = 0.83^{+0.03}_{-0.02}(\omega_B)^{+0.01}_{-0.00}(f_M)^{+0.01}_{-0.02}(a_i)^{+0.01}_{-0.02}(m_c),$$

where the uncertainties result from the shape parameter ω_B of the B meson wave function, meson decay constants f_M, Gegenbauer moments a_i in the wave functions of the light vector mesons and the c-quark mass. Adding all contributions linearly yields a 7.1% theory error. Using this prediction, the ratio of fragmentation fractions is measured to be

$$\frac{f_s}{f_d} = 0.240 \pm 0.004(\text{stat}) \pm 0.010(\text{syst}) \pm 0.017(\text{th}). \quad (4)$$

Figure 2 (right panel) shows the ATLAS f_s/f_d measurement in comparison with results from LEP [6], CDF [6,7], and LHCb [8,9]. The ratio f_s/f_d may depend on p_T and η of the B meson; e.g., LHCb observes a p_T but no η dependence of f_s/f_d [8]. Figure 2 (left panel) shows the p_T dependence of f_s/f_d for ATLAS and that of other

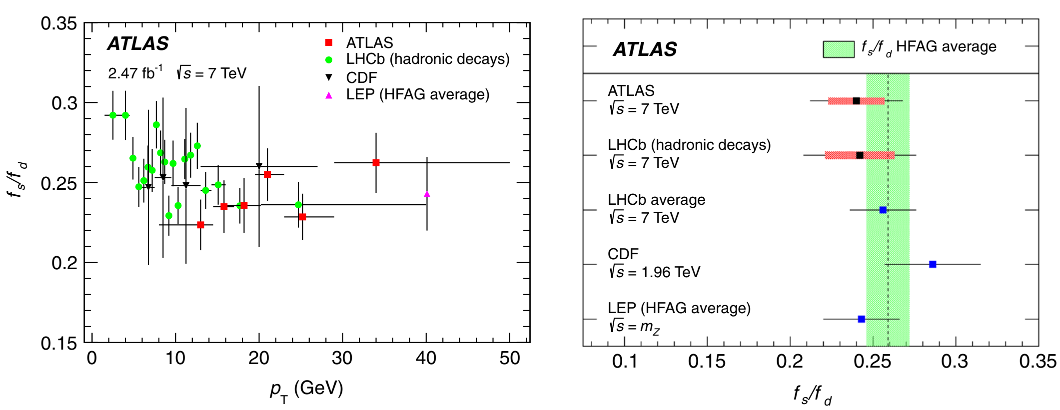

FIG. 2 (color online). (Left panel) Measurements of f_s/f_d versus B meson p_T for CDF [7], LHCb [8], and ATLAS, where the ATLAS data points are plotted at the average p_T of the events in each bin. The error bars show statistical and systematic errors added in quadrature. The LEP ratio, taken from Ref. [6], is plotted at an average p_T value in Z decays. (Right panel) Measurements of f_s/f_d (black and blue points with error bars) from LEP [6], CDF [6], LHCb [8,9], and ATLAS. The total experimental error (thin black line) is added linearly to the theory error (thick red line). The green-shaded region shows the HFAG average obtained using the blue points.

experiments. To investigate the p_T and η dependence of f_s/f_d, the data sample is divided into six p_T bins in the range 8 GeV $< p_T <$ 50 GeV and into four η bins for $|\eta| < 2.5$ such that the number of events in each bin is approximately equal. The f_s/f_d distributions as a function of p_T and η have been fitted with a uniform (first-order polynomial) distribution yielding fit p values 0.54 (0.66) and 0.66 (0.49), respectively. No significant f_s/f_d dependence on p_T and $|\eta|$ is seen at the present level of accuracy.

In summary, this Letter reports on the first ATLAS measurement of the ratio of $B_s^0 \to J/\psi\phi$ and $B_d^0 \to J/\psi K^{*0}$ branching fractions multiplied by the ratio of fragmentation fractions f_s/f_d from which f_s/f_d is determined. The data were produced at the LHC in pp collisions at $\sqrt{s} = 7$ TeV and correspond to an integrated luminosity of 2.47 fb^{-1} . This f_s/f_d measurement, obtained with a new approach, agrees with the LHCb [8,9] results, improving the world average considerably. A comparison with the CDF [6,7] measurement and the LEP [6] average confirms the universality of f_s/f_d. The ATLAS data show no dependence on p_T nor on $|\eta|$ within the kinematic range tested.

We thank CERN for the very successful operation of the LHC, as well as the support staff from our institutions without whom ATLAS could not be operated efficiently. We acknowledge the support of ANPCyT, Argentina; YerPhI, Armenia; ARC, Australia; BMWFW and FWF, Austria; ANAS, Azerbaijan; SSTC, Belarus; CNPq and FAPESP, Brazil; NSERC, NRC, and CFI, Canada; CERN; CONICYT, Chile; CAS, MOST, and NSFC, China; COLCIENCIAS, Colombia; MSMT CR, MPO CR, and VSC CR, Czech Republic; DNRF, DNSRC, and Lundbeck Foundation, Denmark; EPLANET, ERC, and NSRF, European Union; IN2P3-CNRS, CEA-DSM/IRFU, France; GNSF, Georgia; BMBF, DFG, HGF, MPG, and AvH Foundation, Germany; GSRT and NSRF, Greece; ISF, MINERVA, GIF, I-CORE, and Benoziyo Center, Israel; INFN, Italy; MEXT and JSPS, Japan; CNRST, Morocco; FOM and NWO, Netherlands; BRF and RCN, Norway; MNiSW and NCN, Poland; GRICES and FCT, Portugal; MNE/IFA, Romania; MES of Russia and ROSATOM, Russian Federation; JINR; MSTD, Serbia; MSSR, Slovakia; ARRS and MIZŠ, Slovenia; DST/NRF, South Africa; MINECO, Spain; SRC and Wallenberg Foundation, Sweden; SER, SNSF, and Cantons of Bern and Geneva, Switzerland; NSC, Taiwan; TAEK, Turkey; STFC, the Royal Society and Leverhulme Trust, United Kingdom; DOE and NSF, USA. The crucial computing support from all WLCG partners is acknowledged gratefully, in particular, from CERN and the ATLAS Tier-1 facilities at TRIUMF (Canada), NDGF (Denmark, Norway, Sweden), CC-IN2P3 (France), KIT/GridKA (Germany), INFN-CNAF (Italy), NL-T1 (Netherlands), PIC (Spain), ASGC (Taiwan), RAL (UK) and BNL (USA), and in the Tier-2 facilities worldwide.

[1] E. Braaten, K. Cheung, S. Fleming, and T. C. Yuan, Perturbative QCD fragmentation functions as a model for heavy-quark fragmentation, Phys. Rev. D **51**, 4819 (1995).

[2] K. Cheung, Recent progress on perturbative QCD fragmentation functions, arXiv:hep-ph/9505365.

[3] ATLAS Collaboration, Search for the decay $B_s^0 \to \mu^+\mu^-$ with the ATLAS detector, Phys. Lett. B **713**, 387 (2012).

[4] R. Aaij *et al.* (LHCb Collaboration), Measurement of the $B_s^0 \to \mu^+\mu^-$ Branching Fraction and Search for $B^0 \to \mu^+\mu^-$ Decays at the LHCb Experiment, Phys. Rev. Lett. **111**, 101805 (2013).

[5] CMS Collaboration, Measurement of the $B_s^0 \to \mu^+\mu^-$ Branching Fraction and Search for $B^0 \to \mu^+\mu^-$ with the CMS Experiment, Phys. Rev. Lett. **111**, 101804 (2013).

[6] Y. Amhis *et al.* (Heavy Flavor Averaging Group), Averages of b-hadron, c-hadron, and τ-lepton properties as of summer 2014, arXiv:1412.7515.

[7] T. Aaltonen *et al.* (CDF Collaboration), $BR(B_s^0 \to J/\psi\phi)$ measurement and extraction of the fragmentation fractions, Public CDF Note No. 10795, 2012.

[8] R. Aaij *et al.* (LHCb Collaboration), Measurement of the fragmentation fraction ratio f_s/f_d and its dependence on B meson kinematics, J. High Energy Phys. 04 (2013) 001.

[9] R. Aaij *et al.* (LHCb Collaboration), Updated average f_s/f_d b-hadron production fraction ratio for 7 TeV pp collisions, Report No. LHCb-CONF-2013-011, 2013.

[10] Charge conjugation is implied unless stated otherwise.

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

[12] T. Sjöstrand, S. Mrenna, and P. Z. Skands, PYTHIA 6.4 physics and manual, J. High Energy Phys. 05 (2006) 026.

[13] T. Sjöstrand, S. Mrenna, and P. Z. Skands, A brief introduction to PYTHIA 8.1, Comput. Phys. Commun. **178**, 852 (2008).

[14] ATLAS Collaboration, ATLAS tunes of PYTHIA 6 and Pythia 8 for MC11, Report No. ATL-PHYS-PUB-2011-009, http://cdsweb.cern.ch/record/1363300.

[15] K. A. Olive *et al.* (Particle Data Group), Review of particle physics, Chin. Phys. C **38**, 090001 (2014).

[16] S. Agostinelli *et al.* (GEANT4 Collaboration), GEANT4—a simulation toolkit, Nucl. Instrum. Methods Phys. Res., Sect. A **506**, 250 (2003).

[17] ATLAS Collaboration, The ATLAS simulation infrastructure, Eur. Phys. J. C **70**, 823 (2010).

[18] ATLAS uses a right-handed coordinate system with its origin at the nominal interaction point (IP) in the center of the detector and the z axis along the beam pipe. The x axis points from the IP to the center of the LHC ring, and the y axis points upward. Cylindrical coordinates (r, ϕ) are used in the transverse plane, ϕ being the azimuthal angle around the beam pipe. The pseudorapidity is defined in terms of the polar angle θ as $\eta = -\ln\tan(\theta/2)$.

[19] T. Skwarnicki, A study of the radiative cascade transitions between the Upsilon-prime and Upsilon resonances, Ph.D. thesis, Report No. DESY-F31-86-02, 1986.

[20] The PV is the parton interaction vertex. The one of interest is that where the B meson is produced.

[21] ATLAS Collaboration, Measurement of the differential cross-sections of inclusive, prompt and non-prompt J/ψ production in proton-proton collisions at $\sqrt{s} = 7$ TeV, Nucl. Phys. **B850**, 387 (2011).

[22] ATLAS Collaboration, Flavour tagged time-dependent angular analysis of the $B_s^0 \to J/\psi\phi$ decay and extraction of $\Delta\Gamma_s$ and the weak phase ϕ_s in ATLAS, Phys. Rev. D **90**, 052007 (2014).

[23] X. Liu, W. Wang, and Y. Xie, Penguin pollution in $B_s^0 \to J/\psi V$ decays and impact on the extraction of the $B_s^0 - \bar{B}_s^0$ mixing phase, Phys. Rev. D **89**, 094010 (2014).

G. Aad,[85] B. Abbott,[113] J. Abdallah,[151] O. Abdinov,[11] R. Aben,[107] M. Abolins,[90] O. S. AbouZeid,[158] H. Abramowicz,[153] H. Abreu,[152] R. Abreu,[116] Y. Abulaiti,[146a,146b] B. S. Acharya,[164a,164b,b] L. Adamczyk,[38a] D. L. Adams,[25] J. Adelman,[108] S. Adomeit,[100] T. Adye,[131] A. A. Affolder,[74] T. Agatonovic-Jovin,[13] J. Agricola,[54] J. A. Aguilar-Saavedra,[126a,126f] S. P. Ahlen,[22] F. Ahmadov,[65,c] G. Aielli,[133a,133b] H. Akerstedt,[146a,146b] T. P. A. Åkesson,[81] A. V. Akimov,[96] G. L. Alberghi,[20a,20b] J. Albert,[169] S. Albrand,[55] M. J. Alconada Verzini,[71] M. Aleksa,[30] I. N. Aleksandrov,[65] C. Alexa,[26a] G. Alexander,[153] T. Alexopoulos,[10] M. Alhroob,[113] G. Alimonti,[91a] L. Alio,[85] J. Alison,[31] S. P. Alkire,[35] B. M. M. Allbrooke,[149] P. P. Allport,[74] A. Aloisio,[104a,104b] A. Alonso,[36] F. Alonso,[71] C. Alpigiani,[76] A. Altheimer,[35] B. Alvarez Gonzalez,[30] D. Álvarez Piqueras,[167] M. G. Alviggi,[104a,104b] B. T. Amadio,[15] K. Amako,[66] Y. Amaral Coutinho,[24a] C. Amelung,[23] D. Amidei,[89] S. P. Amor Dos Santos,[126a,126c] A. Amorim,[126a,126b] S. Amoroso,[48] N. Amram,[153] G. Amundsen,[23] C. Anastopoulos,[139] L. S. Ancu,[49] N. Andari,[108] T. Andeen,[35] C. F. Anders,[58b] G. Anders,[30] J. K. Anders,[74] K. J. Anderson,[31] A. Andreazza,[91a,91b] V. Andrei,[58a] S. Angelidakis,[9] I. Angelozzi,[107] P. Anger,[44] A. Angerami,[35] F. Anghinolfi,[30] A. V. Anisenkov,[109,d] N. Anjos,[12] A. Annovi,[124a,124b] M. Antonelli,[47] A. Antonov,[98] J. Antos,[144b] F. Anulli,[132a] M. Aoki,[66] L. Aperio Bella,[18] G. Arabidze,[90] Y. Arai,[66] J. P. Araque,[126a] A. T. H. Arce,[45] F. A. Arduh,[71] J-F. Arguin,[95] S. Argyropoulos,[42] M. Arik,[19a] A. J. Armbruster,[30] O. Arnaez,[30] V. Arnal,[82] H. Arnold,[48] M. Arratia,[28] O. Arslan,[21] A. Artamonov,[97] G. Artoni,[23] S. Asai,[155] N. Asbah,[42] A. Ashkenazi,[153] B. Åsman,[146a,146b] L. Asquith,[149] K. Assamagan,[25] R. Astalos,[144a] M. Atkinson,[165] N. B. Atlay,[141] K. Augsten,[128] M. Aurousseau,[145b] G. Avolio,[30] B. Axen,[15] M. K. Ayoub,[117] G. Azuelos,[95,e] M. A. Baak,[30] A. E. Baas,[58a] M. J. Baca,[18] C. Bacci,[134a,134b] H. Bachacou,[136] K. Bachas,[154] M. Backes,[30] M. Backhaus,[30] P. Bagiacchi,[132a,132b] P. Bagnaia,[132a,132b] Y. Bai,[33a] T. Bain,[35] J. T. Baines,[131] O. K. Baker,[176] E. M. Baldin,[109,d] P. Balek,[129] T. Balestri,[148] F. Balli,[84] E. Banas,[39] Sw. Banerjee,[173] A. A. E. Bannoura,[175] H. S. Bansil,[18] L. Barak,[30] E. L. Barberio,[88] D. Barberis,[50a,50b] M. Barbero,[85] T. Barillari,[101] M. Barisonzi,[164a,164b] T. Barklow,[143] N. Barlow,[28] S. L. Barnes,[84] B. M. Barnett,[131] R. M. Barnett,[15] Z. Barnovska,[5] A. Baroncelli,[134a] G. Barone,[23] A. J. Barr,[120] F. Barreiro,[82] J. Barreiro Guimarães da Costa,[57] R. Bartoldus,[143] A. E. Barton,[72] P. Bartos,[144a] A. Basalaev,[123] A. Bassalat,[117] A. Basye,[165] R. L. Bates,[53] S. J. Batista,[158] J. R. Batley,[28] M. Battaglia,[137] M. Bauce,[132a,132b] F. Bauer,[136] H. S. Bawa,[143,f] J. B. Beacham,[111] M. D. Beattie,[72] T. Beau,[80] P. H. Beauchemin,[161] R. Beccherle,[124a,124b] P. Bechtle,[21] H. P. Beck,[17,g] K. Becker,[120] M. Becker,[83] S. Becker,[100] M. Beckingham,[170] C. Becot,[117] A. J. Beddall,[19b] A. Beddall,[19b] V. A. Bednyakov,[65] C. P. Bee,[148] L. J. Beemster,[107] T. A. Beermann,[175] M. Begel,[25] J. K. Behr,[120] C. Belanger-Champagne,[87] W. H. Bell,[49] G. Bella,[153] L. Bellagamba,[20a] A. Bellerive,[29] M. Bellomo,[86] K. Belotskiy,[98] O. Beltramello,[30] O. Benary,[153] D. Benchekroun,[135a] M. Bender,[100] K. Bendtz,[146a,146b] N. Benekos,[10] Y. Benhammou,[153] E. Benhar Noccioli,[49] J. A. Benitez Garcia,[159b] D. P. Benjamin,[45] J. R. Bensinger,[23] S. Bentvelsen,[107] L. Beresford,[120] M. Beretta,[47] D. Berge,[107] E. Bergeaas Kuutmann,[166] N. Berger,[5] F. Berghaus,[169] J. Beringer,[15] C. Bernard,[22] N. R. Bernard,[86] C. Bernius,[110] F. U. Bernlochner,[21] T. Berry,[77] P. Berta,[129] C. Bertella,[83] G. Bertoli,[146a,146b] F. Bertolucci,[124a,124b] C. Bertsche,[113] D. Bertsche,[113] M. I. Besana,[91a] G. J. Besjes,[36] O. Bessidskaia Bylund,[146a,146b] M. Bessner,[42] N. Besson,[136] C. Betancourt,[48] S. Bethke,[101] A. J. Bevan,[76] W. Bhimji,[15] R. M. Bianchi,[125] L. Bianchini,[23] M. Bianco,[30] O. Biebel,[100] D. Biedermann,[16] S. P. Bieniek,[78] M. Biglietti,[134a] J. Bilbao De Mendizabal,[49] H. Bilokon,[47] M. Bindi,[54] S. Binet,[117] A. Bingul,[19b] C. Bini,[132a,132b] S. Biondi,[20a,20b] C. W. Black,[150] J. E. Black,[143] K. M. Black,[22] D. Blackburn,[138] R. E. Blair,[6] J.-B. Blanchard,[136] J. E. Blanco,[77] T. Blazek,[144a] I. Bloch,[42] C. Blocker,[23] W. Blum,[83,a] U. Blumenschein,[54] G. J. Bobbink,[107] V. S. Bobrovnikov,[109,d] S. S. Bocchetta,[81] A. Bocci,[45] C. Bock,[100] M. Boehler,[48] J. A. Bogaerts,[30] D. Bogavac,[13] A. G. Bogdanchikov,[109] C. Bohm,[146a] V. Boisvert,[77] T. Bold,[38a] V. Boldea,[26a] A. S. Boldyrev,[99] M. Bomben,[80] M. Bona,[76] M. Boonekamp,[136] A. Borisov,[130] G. Borissov,[72] S. Borroni,[42] J. Bortfeldt,[100] V. Bortolotto,[60a,60b,60c] K. Bos,[107] D. Boscherini,[20a] M. Bosman,[12] J. Boudreau,[125] J. Bouffard,[2] E. V. Bouhova-Thacker,[72] D. Boumediene,[34] C. Bourdarios,[117] N. Bousson,[114] A. Boveia,[30] J. Boyd,[30] I. R. Boyko,[65] I. Bozic,[13] J. Bracinik,[18] A. Brandt,[8] G. Brandt,[54] O. Brandt,[58a]

U. Bratzler,[156] B. Brau,[86] J. E. Brau,[116] H. M. Braun,[175,a] S. F. Brazzale,[164a,164c] W. D. Breaden Madden,[53] K. Brendlinger,[122] A. J. Brennan,[88] L. Brenner,[107] R. Brenner,[166] S. Bressler,[172] K. Bristow,[145c] T. M. Bristow,[46] D. Britton,[53] D. Britzger,[42] F. M. Brochu,[28] I. Brock,[21] R. Brock,[90] J. Bronner,[101] G. Brooijmans,[35] T. Brooks,[77] W. K. Brooks,[32b] J. Brosamer,[15] E. Brost,[116] J. Brown,[55] P. A. Bruckman de Renstrom,[39] D. Bruncko,[144b] R. Bruneliere,[48] A. Bruni,[20a] G. Bruni,[20a] M. Bruschi,[20a] N. Bruscino,[21] L. Bryngemark,[81] T. Buanes,[14] Q. Buat,[142] P. Buchholz,[141] A. G. Buckley,[53] S. I. Buda,[26a] I. A. Budagov,[65] F. Buehrer,[48] L. Bugge,[119] M. K. Bugge,[119] O. Bulekov,[98] D. Bullock,[8] H. Burckhart,[30] S. Burdin,[74] C. D. Burgard,[48] B. Burghgrave,[108] S. Burke,[131] I. Burmeister,[43] E. Busato,[34] D. Büscher,[48] V. Büscher,[83] P. Bussey,[53] J. M. Butler,[22] A. I. Butt,[3] C. M. Buttar,[53] J. M. Butterworth,[78] P. Butti,[107] W. Buttinger,[25] A. Buzatu,[53] A. R. Buzykaev,[109,d] S. Cabrera Urbán,[167] D. Caforio,[128] V. M. Cairo,[37a,37b] O. Cakir,[4a] N. Calace,[49] P. Calafiura,[15] A. Calandri,[136] G. Calderini,[80] P. Calfayan,[100] L. P. Caloba,[24a] D. Calvet,[34] S. Calvet,[34] R. Camacho Toro,[31] S. Camarda,[42] P. Camarri,[133a,133b] D. Cameron,[119] R. Caminal Armadans,[165] S. Campana,[30] M. Campanelli,[78] A. Campoverde,[148] V. Canale,[104a,104b] A. Canepa,[159a] M. Cano Bret,[33e] J. Cantero,[82] R. Cantrill,[126a] T. Cao,[40] M. D. M. Capeans Garrido,[30] I. Caprini,[26a] M. Caprini,[26a] M. Capua,[37a,37b] R. Caputo,[83] R. Cardarelli,[133a] F. Cardillo,[48] T. Carli,[30] G. Carlino,[104a] L. Carminati,[91a,91b] S. Caron,[106] E. Carquin,[32a] G. D. Carrillo-Montoya,[30] J. R. Carter,[28] J. Carvalho,[126a,126c] D. Casadei,[78] M. P. Casado,[12] M. Casolino,[12] E. Castaneda-Miranda,[145b] A. Castelli,[107] V. Castillo Gimenez,[167] N. F. Castro,[126a,h] P. Catastini,[57] A. Catinaccio,[30] J. R. Catmore,[119] A. Cattai,[30] J. Caudron,[83] V. Cavaliere,[165] D. Cavalli,[91a] M. Cavalli-Sforza,[12] V. Cavasinni,[124a,124b] F. Ceradini,[134a,134b] B. C. Cerio,[45] K. Cerny,[129] A. S. Cerqueira,[24b] A. Cerri,[149] L. Cerrito,[76] F. Cerutti,[15] M. Cerv,[30] A. Cervelli,[17] S. A. Cetin,[19c] A. Chafaq,[135a] D. Chakraborty,[108] I. Chalupkova,[129] P. Chang,[165] J. D. Chapman,[28] D. G. Charlton,[18] C. C. Chau,[158] C. A. Chavez Barajas,[149] S. Cheatham,[152] A. Chegwidden,[90] S. Chekanov,[6] S. V. Chekulaev,[159a] G. A. Chelkov,[65,i] M. A. Chelstowska,[89] C. Chen,[64] H. Chen,[25] K. Chen,[148] L. Chen,[33d,j] S. Chen,[33c] X. Chen,[33f] Y. Chen,[67] H. C. Cheng,[89] Y. Cheng,[31] A. Cheplakov,[65] E. Cheremushkina,[130] R. Cherkaoui El Moursli,[135e] V. Chernyatin,[25,a] E. Cheu,[7] L. Chevalier,[136] V. Chiarella,[47] G. Chiarelli,[124a,124b] G. Chiodini,[73a] A. S. Chisholm,[18] R. T. Chislett,[78] A. Chitan,[26a] M. V. Chizhov,[65] K. Choi,[61] S. Chouridou,[9] B. K. B. Chow,[100] V. Christodoulou,[78] D. Chromek-Burckhart,[30] J. Chudoba,[127] A. J. Chuinard,[87] J. J. Chwastowski,[39] L. Chytka,[115] G. Ciapetti,[132a,132b] A. K. Ciftci,[4a] D. Cinca,[53] V. Cindro,[75] I. A. Cioara,[21] A. Ciocio,[15] F. Cirotto,[104a,104b] Z. H. Citron,[172] M. Ciubancan,[26a] A. Clark,[49] B. L. Clark,[57] P. J. Clark,[46] R. N. Clarke,[15] W. Cleland,[125] C. Clement,[146a,146b] Y. Coadou,[85] M. Cobal,[164a,164c] A. Coccaro,[49] J. Cochran,[64] L. Coffey,[23] J. G. Cogan,[143] L. Colasurdo,[106] B. Cole,[35] S. Cole,[108] A. P. Colijn,[107] J. Collot,[55] T. Colombo,[58c] G. Compostella,[101] P. Conde Muiño,[126a,126b] E. Coniavitis,[48] S. H. Connell,[145b] I. A. Connelly,[77] V. Consorti,[48] S. Constantinescu,[26a] C. Conta,[121a,121b] G. Conti,[30] F. Conventi,[104a,k] M. Cooke,[15] B. D. Cooper,[78] A. M. Cooper-Sarkar,[120] T. Cornelissen,[175] M. Corradi,[20a] F. Corriveau,[87,l] A. Corso-Radu,[163] A. Cortes-Gonzalez,[12] G. Cortiana,[101] G. Costa,[91a] M. J. Costa,[167] D. Costanzo,[139] D. Côté,[8] G. Cottin,[28] G. Cowan,[77] B. E. Cox,[84] K. Cranmer,[110] G. Cree,[29] S. Crépé-Renaudin,[55] F. Crescioli,[80] W. A. Cribbs,[146a,146b] M. Crispin Ortuzar,[120] M. Cristinziani,[21] V. Croft,[106] G. Crosetti,[37a,37b] T. Cuhadar Donszelmann,[139] J. Cummings,[176] M. Curatolo,[47] C. Cuthbert,[150] H. Czirr,[141] P. Czodrowski,[3] S. D'Auria,[53] M. D'Onofrio,[74] M. J. Da Cunha Sargedas De Sousa,[126a,126b] C. Da Via,[84] W. Dabrowski,[38a] A. Dafinca,[120] T. Dai,[89] O. Dale,[14] F. Dallaire,[95] C. Dallapiccola,[86] M. Dam,[36] J. R. Dandoy,[31] N. P. Dang,[48] A. C. Daniells,[18] M. Danninger,[168] M. Dano Hoffmann,[136] V. Dao,[48] G. Darbo,[50a] S. Darmora,[8] J. Dassoulas,[3] A. Dattagupta,[61] W. Davey,[21] C. David,[169] T. Davidek,[129] E. Davies,[120,m] M. Davies,[153] P. Davison,[78] Y. Davygora,[58a] E. Dawe,[88] I. Dawson,[139] R. K. Daya-Ishmukhametova,[86] K. De,[8] R. de Asmundis,[104a] A. De Benedetti,[113] S. De Castro,[20a,20b] S. De Cecco,[80] N. De Groot,[106] P. de Jong,[107] H. De la Torre,[82] F. De Lorenzi,[64] D. De Pedis,[132a] A. De Salvo,[132a] U. De Sanctis,[149] A. De Santo,[149] J. B. De Vivie De Regie,[117] W. J. Dearnaley,[72] R. Debbe,[25] C. Debenedetti,[137] D. V. Dedovich,[65] I. Deigaard,[107] J. Del Peso,[82] T. Del Prete,[124a,124b] D. Delgove,[117] F. Deliot,[136] C. M. Delitzsch,[49] M. Deliyergiyev,[75] A. Dell'Acqua,[30] L. Dell'Asta,[22] M. Dell'Orso,[124a,124b] M. Della Pietra,[104a,k] D. della Volpe,[49] M. Delmastro,[5] P. A. Delsart,[55] C. Deluca,[107] D. A. DeMarco,[158] S. Demers,[176] M. Demichev,[65] A. Demilly,[80] S. P. Denisov,[130] D. Derendarz,[39] J. E. Derkaoui,[135d] F. Derue,[80] P. Dervan,[74] K. Desch,[21] C. Deterre,[42] P. O. Deviveiros,[30] A. Dewhurst,[131] S. Dhaliwal,[23] A. Di Ciaccio,[133a,133b] L. Di Ciaccio,[5] A. Di Domenico,[132a,132b] C. Di Donato,[104a,104b] A. Di Girolamo,[30] B. Di Girolamo,[30] A. Di Mattia,[152] B. Di Micco,[134a,134b] R. Di Nardo,[47] A. Di Simone,[48] R. Di Sipio,[158] D. Di Valentino,[29] C. Diaconu,[85] M. Diamond,[158] F. A. Dias,[46] M. A. Diaz,[32a] E. B. Diehl,[89] J. Dietrich,[16] S. Diglio,[85] A. Dimitrievska,[13] J. Dingfelder,[21] P. Dita,[26a] S. Dita,[26a] F. Dittus,[30] F. Djama,[85] T. Djobava,[51b] J. I. Djuvsland,[58a] M. A. B. do Vale,[24c] D. Dobos,[30] M. Dobre,[26a] C. Doglioni,[81] T. Dohmae,[155] J. Dolejsi,[129] Z. Dolezal,[129] B. A. Dolgoshein,[98,a] M. Donadelli,[24d]

S. Donati,[124a,124b] P. Dondero,[121a,121b] J. Donini,[34] J. Dopke,[131] A. Doria,[104a] M. T. Dova,[71] A. T. Doyle,[53] E. Drechsler,[54] M. Dris,[10] E. Dubreuil,[34] E. Duchovni,[172] G. Duckeck,[100] O. A. Ducu,[26a,85] D. Duda,[107] A. Dudarev,[30] L. Duflot,[117] L. Duguid,[77] M. Dührssen,[30] M. Dunford,[58a] H. Duran Yildiz,[4a] M. Düren,[52] A. Durglishvili,[51b] D. Duschinger,[44] M. Dyndal,[38a] C. Eckardt,[42] K. M. Ecker,[101] R. C. Edgar,[89] W. Edson,[2] N. C. Edwards,[46] W. Ehrenfeld,[21] T. Eifert,[30] G. Eigen,[14] K. Einsweiler,[15] T. Ekelof,[166] M. El Kacimi,[135c] M. Ellert,[166] S. Elles,[5] F. Ellinghaus,[175] A. A. Elliot,[169] N. Ellis,[30] J. Elmsheuser,[100] M. Elsing,[30] D. Emeliyanov,[131] Y. Enari,[155] O. C. Endner,[83] M. Endo,[118] J. Erdmann,[43] A. Ereditato,[17] G. Ernis,[175] J. Ernst,[2] M. Ernst,[25] S. Errede,[165] E. Ertel,[83] M. Escalier,[117] H. Esch,[43] C. Escobar,[125] B. Esposito,[47] A. I. Etienvre,[136] E. Etzion,[153] H. Evans,[61] A. Ezhilov,[123] L. Fabbri,[20a,20b] G. Facini,[31] R. M. Fakhrutdinov,[130] S. Falciano,[132a] R. J. Falla,[78] J. Faltova,[129] Y. Fang,[33a] M. Fanti,[91a,91b] A. Farbin,[8] A. Farilla,[134a] T. Farooque,[12] S. Farrell,[15] S. M. Farrington,[170] P. Farthouat,[30] F. Fassi,[135e] P. Fassnacht,[30] D. Fassouliotis,[9] M. Faucci Giannelli,[77] A. Favareto,[50a,50b] L. Fayard,[117] P. Federic,[144a] O. L. Fedin,[123,n] W. Fedorko,[168] S. Feigl,[30] L. Feligioni,[85] C. Feng,[33d] E. J. Feng,[6] H. Feng,[89] A. B. Fenyuk,[130] L. Feremenga,[8] P. Fernandez Martinez,[167] S. Fernandez Perez,[30] J. Ferrando,[53] A. Ferrari,[166] P. Ferrari,[107] R. Ferrari,[121a] D. E. Ferreira de Lima,[53] A. Ferrer,[167] D. Ferrere,[49] C. Ferretti,[89] A. Ferretto Parodi,[50a,50b] M. Fiascaris,[31] F. Fiedler,[83] A. Filipčič,[75] M. Filipuzzi,[42] F. Filthaut,[106] M. Fincke-Keeler,[169] K. D. Finelli,[150] M. C. N. Fiolhais,[126a,126c] L. Fiorini,[167] A. Firan,[40] A. Fischer,[2] C. Fischer,[12] J. Fischer,[175] W. C. Fisher,[90] E. A. Fitzgerald,[23] N. Flaschel,[42] I. Fleck,[141] P. Fleischmann,[89] S. Fleischmann,[175] G. T. Fletcher,[139] G. Fletcher,[76] R. R. M. Fletcher,[122] T. Flick,[175] A. Floderus,[81] L. R. Flores Castillo,[60a] M. J. Flowerdew,[101] A. Formica,[136] A. Forti,[84] D. Fournier,[117] H. Fox,[72] S. Fracchia,[12] P. Francavilla,[80] M. Franchini,[20a,20b] D. Francis,[30] L. Franconi,[119] M. Franklin,[57] M. Frate,[163] M. Fraternali,[121a,121b] D. Freeborn,[78] S. T. French,[28] F. Friedrich,[44] D. Froidevaux,[30] J. A. Frost,[120] C. Fukunaga,[156] E. Fullana Torregrosa,[83] B. G. Fulsom,[143] T. Fusayasu,[102] J. Fuster,[167] C. Gabaldon,[55] O. Gabizon,[175] A. Gabrielli,[20a,20b] A. Gabrielli,[132a,132b] G. P. Gach,[38a] S. Gadatsch,[30] S. Gadomski,[49] G. Gagliardi,[50a,50b] P. Gagnon,[61] C. Galea,[106] B. Galhardo,[126a,126c] E. J. Gallas,[120] B. J. Gallop,[131] P. Gallus,[128] G. Galster,[36] K. K. Gan,[111] J. Gao,[33b,85] Y. Gao,[46] Y. S. Gao,[143,f] F. M. Garay Walls,[46] F. Garberson,[176] C. García,[167] J. E. García Navarro,[167] M. Garcia-Sciveres,[15] R. W. Gardner,[31] N. Garelli,[143] V. Garonne,[119] C. Gatti,[47] A. Gaudiello,[50a,50b] G. Gaudio,[121a] B. Gaur,[141] L. Gauthier,[95] P. Gauzzi,[132a,132b] I. L. Gavrilenko,[96] C. Gay,[168] G. Gaycken,[21] E. N. Gazis,[10] P. Ge,[33d] Z. Gecse,[168] C. N. P. Gee,[131] Ch. Geich-Gimbel,[21] M. P. Geisler,[58a] C. Gemme,[50a] M. H. Genest,[55] S. Gentile,[132a,132b] M. George,[54] S. George,[77] D. Gerbaudo,[163] A. Gershon,[153] S. Ghasemi,[141] H. Ghazlane,[135b] B. Giacobbe,[20a] S. Giagu,[132a,132b] V. Giangiobbe,[12] P. Giannetti,[124a,124b] B. Gibbard,[25] S. M. Gibson,[77] M. Gilchriese,[15] T. P. S. Gillam,[28] D. Gillberg,[30] G. Gilles,[34] D. M. Gingrich,[3,e] N. Giokaris,[9] M. P. Giordani,[164a,164c] F. M. Giorgi,[20a] F. M. Giorgi,[16] P. F. Giraud,[136] P. Giromini,[47] D. Giugni,[91a] C. Giuliani,[48] M. Giulini,[58b] B. K. Gjelsten,[119] S. Gkaitatzis,[154] I. Gkialas,[154] E. L. Gkougkousis,[117] L. K. Gladilin,[99] C. Glasman,[82] J. Glatzer,[30] P. C. F. Glaysher,[46] A. Glazov,[42] M. Goblirsch-Kolb,[101] J. R. Goddard,[76] J. Godlewski,[39] S. Goldfarb,[89] T. Golling,[49] D. Golubkov,[130] A. Gomes,[126a,126b,126d] R. Gonçalo,[126a] J. Goncalves Pinto Firmino Da Costa,[136] L. Gonella,[21] S. González de la Hoz,[167] G. Gonzalez Parra,[12] S. Gonzalez-Sevilla,[49] L. Goossens,[30] P. A. Gorbounov,[97] H. A. Gordon,[25] I. Gorelov,[105] B. Gorini,[30] E. Gorini,[73a,73b] A. Gorišek,[75] E. Gornicki,[39] A. T. Goshaw,[45] C. Gössling,[43] M. I. Gostkin,[65] D. Goujdami,[135c] A. G. Goussiou,[138] N. Govender,[145b] E. Gozani,[152] H. M. X. Grabas,[137] L. Graber,[54] I. Grabowska-Bold,[38a] P. O. J. Gradin,[166] P. Grafström,[20a,20b] K-J. Grahn,[42] J. Gramling,[49] E. Gramstad,[119] S. Grancagnolo,[16] V. Gratchev,[123] H. M. Gray,[30] E. Graziani,[134a] Z. D. Greenwood,[79,o] K. Gregersen,[78] I. M. Gregor,[42] P. Grenier,[143] J. Griffiths,[8] A. A. Grillo,[137] K. Grimm,[72] S. Grinstein,[12,p] Ph. Gris,[34] J.-F. Grivaz,[117] J. P. Grohs,[44] A. Grohsjean,[42] E. Gross,[172] J. Grosse-Knetter,[54] G. C. Grossi,[79] Z. J. Grout,[149] L. Guan,[89] J. Guenther,[128] F. Guescini,[49] D. Guest,[176] O. Gueta,[153] E. Guido,[50a,50b] T. Guillemin,[117] S. Guindon,[2] U. Gul,[53] C. Gumpert,[44] J. Guo,[33e] Y. Guo,[33b] S. Gupta,[120] G. Gustavino,[132a,132b] P. Gutierrez,[113] N. G. Gutierrez Ortiz,[78] C. Gutschow,[44] C. Guyot,[136] C. Gwenlan,[120] C. B. Gwilliam,[74] A. Haas,[110] C. Haber,[15] H. K. Hadavand,[8] N. Haddad,[135e] P. Haefner,[21] S. Hageböck,[21] Z. Hajduk,[39] H. Hakobyan,[177] M. Haleem,[42] J. Haley,[114] D. Hall,[120] G. Halladjian,[90] G. D. Hallewell,[85] K. Hamacher,[175] P. Hamal,[115] K. Hamano,[169] A. Hamilton,[145a] G. N. Hamity,[139] P. G. Hamnett,[42] L. Han,[33b] K. Hanagaki,[66,q] K. Hanawa,[155] M. Hance,[15] P. Hanke,[58a] R. Hanna,[136] J. B. Hansen,[36] J. D. Hansen,[36] M. C. Hansen,[21] P. H. Hansen,[36] K. Hara,[160] A. S. Hard,[173] T. Harenberg,[175] F. Hariri,[117] S. Harkusha,[92] R. D. Harrington,[46] P. F. Harrison,[170] F. Hartjes,[107] M. Hasegawa,[67] Y. Hasegawa,[140] A. Hasib,[113] S. Hassani,[136] S. Haug,[17] R. Hauser,[90] L. Hauswald,[44] M. Havranek,[127] C. M. Hawkes,[18] R. J. Hawkings,[30] A. D. Hawkins,[81] T. Hayashi,[160] D. Hayden,[90] C. P. Hays,[120] J. M. Hays,[76] H. S. Hayward,[74] S. J. Haywood,[131] S. J. Head,[18] T. Heck,[83] V. Hedberg,[81] L. Heelan,[8] S. Heim,[122] T. Heim,[175] B. Heinemann,[15] L. Heinrich,[110] J. Hejbal,[127] L. Helary,[22]

S. Hellman,[146a,146b] D. Hellmich,[21] C. Helsens,[12] J. Henderson,[120] R. C. W. Henderson,[72] Y. Heng,[173] C. Hengler,[42] A. Henrichs,[176] A. M. Henriques Correia,[30] S. Henrot-Versille,[117] G. H. Herbert,[16] Y. Hernández Jiménez,[167] R. Herrberg-Schubert,[16] G. Herten,[48] R. Hertenberger,[100] L. Hervas,[30] G. G. Hesketh,[78] N. P. Hessey,[107] J. W. Hetherly,[40] R. Hickling,[76] E. Higón-Rodriguez,[167] E. Hill,[169] J. C. Hill,[28] K. H. Hiller,[42] S. J. Hillier,[18] I. Hinchliffe,[15] E. Hines,[122] R. R. Hinman,[15] M. Hirose,[157] D. Hirschbuehl,[175] J. Hobbs,[148] N. Hod,[107] M. C. Hodgkinson,[139] P. Hodgson,[139] A. Hoecker,[30] M. R. Hoeferkamp,[105] F. Hoenig,[100] M. Hohlfeld,[83] D. Hohn,[21] T. R. Holmes,[15] M. Homann,[43] T. M. Hong,[125] L. Hooft van Huysduynen,[110] W. H. Hopkins,[116] Y. Horii,[103] A. J. Horton,[142] J-Y. Hostachy,[55] S. Hou,[151] A. Hoummada,[135a] J. Howard,[120] J. Howarth,[42] M. Hrabovsky,[115] I. Hristova,[16] J. Hrivnac,[117] T. Hryn'ova,[5] A. Hrynevich,[93] C. Hsu,[145c] P. J. Hsu,[151,r] S.-C. Hsu,[138] D. Hu,[35] Q. Hu,[33b] X. Hu,[89] Y. Huang,[42] Z. Hubacek,[128] F. Hubaut,[85] F. Huegging,[21] T. B. Huffman,[120] E. W. Hughes,[35] G. Hughes,[72] M. Huhtinen,[30] T. A. Hülsing,[83] N. Huseynov,[65,c] J. Huston,[90] J. Huth,[57] G. Iacobucci,[49] G. Iakovidis,[25] I. Ibragimov,[141] L. Iconomidou-Fayard,[117] E. Ideal,[176] Z. Idrissi,[135e] P. Iengo,[30] O. Igonkina,[107] T. Iizawa,[171] Y. Ikegami,[66] K. Ikematsu,[141] M. Ikeno,[66] Y. Ilchenko,[31,s] D. Iliadis,[154] N. Ilic,[143] T. Ince,[101] G. Introzzi,[121a,121b] P. Ioannou,[9] M. Iodice,[134a] K. Iordanidou,[35] V. Ippolito,[57] A. Irles Quiles,[167] C. Isaksson,[166] M. Ishino,[68] M. Ishitsuka,[157] R. Ishmukhametov,[111] C. Issever,[120] S. Istin,[19a] J. M. Iturbe Ponce,[84] R. Iuppa,[133a,133b] J. Ivarsson,[81] W. Iwanski,[39] H. Iwasaki,[66] J. M. Izen,[41] V. Izzo,[104a] S. Jabbar,[3] B. Jackson,[122] M. Jackson,[74] P. Jackson,[1] M. R. Jaekel,[30] V. Jain,[2] K. Jakobs,[48] S. Jakobsen,[30] T. Jakoubek,[127] J. Jakubek,[128] D. O. Jamin,[114] D. K. Jana,[79] E. Jansen,[78] R. Jansky,[62] J. Janssen,[21] M. Janus,[54] G. Jarlskog,[81] N. Javadov,[65,c] T. Javůrek,[48] L. Jeanty,[15] J. Jejelava,[51a,t] G.-Y. Jeng,[150] D. Jennens,[88] P. Jenni,[48,u] J. Jentzsch,[43] C. Jeske,[170] S. Jézéquel,[5] H. Ji,[173] J. Jia,[148] Y. Jiang,[33b] S. Jiggins,[78] J. Jimenez Pena,[167] S. Jin,[33a] A. Jinaru,[26a] O. Jinnouchi,[157] M. D. Joergensen,[36] P. Johansson,[139] K. A. Johns,[7] K. Jon-And,[146a,146b] G. Jones,[170] R. W. L. Jones,[72] T. J. Jones,[74] J. Jongmanns,[58a] P. M. Jorge,[126a,126b] K. D. Joshi,[84] J. Jovicevic,[159a] X. Ju,[173] C. A. Jung,[43] P. Jussel,[62] A. Juste Rozas,[12,p] M. Kaci,[167] A. Kaczmarska,[39] M. Kado,[117] H. Kagan,[111] M. Kagan,[143] S. J. Kahn,[85] E. Kajomovitz,[45] C. W. Kalderon,[120] S. Kama,[40] A. Kamenshchikov,[130] N. Kanaya,[155] S. Kaneti,[28] V. A. Kantserov,[98] J. Kanzaki,[66] B. Kaplan,[110] L. S. Kaplan,[173] A. Kapliy,[31] D. Kar,[145c] K. Karakostas,[10] A. Karamaoun,[3] N. Karastathis,[10,107] M. J. Kareem,[54] E. Karentzos,[10] M. Karnevskiy,[83] S. N. Karpov,[65] Z. M. Karpova,[65] K. Karthik,[110] V. Kartvelishvili,[72] A. N. Karyukhin,[130] L. Kashif,[173] R. D. Kass,[111] A. Kastanas,[14] Y. Kataoka,[155] C. Kato,[155] A. Katre,[49] J. Katzy,[42] K. Kawagoe,[70] T. Kawamoto,[155] G. Kawamura,[54] S. Kazama,[155] V. F. Kazanin,[109,d] R. Keeler,[169] R. Kehoe,[40] J. S. Keller,[42] J. J. Kempster,[77] H. Keoshkerian,[84] O. Kepka,[127] B. P. Kerševan,[75] S. Kersten,[175] R. A. Keyes,[87] F. Khalil-zada,[11] H. Khandanyan,[146a,146b] A. Khanov,[114] A. G. Kharlamov,[109,d] T. J. Khoo,[28] V. Khovanskiy,[97] E. Khramov,[65] J. Khubua,[51b,v] S. Kido,[67] H. Y. Kim,[8] S. H. Kim,[160] Y. K. Kim,[31] N. Kimura,[154] O. M. Kind,[16] B. T. King,[74] M. King,[167] S. B. King,[168] J. Kirk,[131] A. E. Kiryunin,[101] T. Kishimoto,[67] D. Kisielewska,[38a] F. Kiss,[48] K. Kiuchi,[160] O. Kivernyk,[136] E. Kladiva,[144b] M. H. Klein,[35] M. Klein,[74] U. Klein,[74] K. Kleinknecht,[83] P. Klimek,[146a,146b] A. Klimentov,[25] R. Klingenberg,[43] J. A. Klinger,[139] T. Klioutchnikova,[30] E.-E. Kluge,[58a] P. Kluit,[107] S. Kluth,[101] J. Knapik,[39] E. Kneringer,[62] E. B. F. G. Knoops,[85] A. Knue,[53] A. Kobayashi,[155] D. Kobayashi,[157] T. Kobayashi,[155] M. Kobel,[44] M. Kocian,[143] P. Kodys,[129] T. Koffas,[29] E. Koffeman,[107] L. A. Kogan,[120] S. Kohlmann,[175] Z. Kohout,[128] T. Kohriki,[66] T. Koi,[143] H. Kolanoski,[16] I. Koletsou,[5] A. A. Komar,[96,a] Y. Komori,[155] T. Kondo,[66] N. Kondrashova,[42] K. Köneke,[48] A. C. König,[106] T. Kono,[66] R. Konoplich,[110,w] N. Konstantinidis,[78] R. Kopeliansky,[152] S. Koperny,[38a] L. Köpke,[83] A. K. Kopp,[48] K. Korcyl,[39] K. Kordas,[154] A. Korn,[78] A. A. Korol,[109,d] I. Korolkov,[12] E. V. Korolkova,[139] O. Kortner,[101] S. Kortner,[101] T. Kosek,[129] V. V. Kostyukhin,[21] V. M. Kotov,[65] A. Kotwal,[45] A. Kourkoumeli-Charalampidi,[154] C. Kourkoumelis,[9] V. Kouskoura,[25] A. Koutsman,[159a] R. Kowalewski,[169] T. Z. Kowalski,[38a] W. Kozanecki,[136] A. S. Kozhin,[130] V. A. Kramarenko,[99] G. Kramberger,[75] D. Krasnopevtsev,[98] M. W. Krasny,[80] A. Krasznahorkay,[30] J. K. Kraus,[21] A. Kravchenko,[25] S. Kreiss,[110] M. Kretz,[58c] J. Kretzschmar,[74] K. Kreutzfeldt,[52] P. Krieger,[158] K. Krizka,[31] K. Kroeninger,[43] H. Kroha,[101] J. Kroll,[122] J. Kroseberg,[21] J. Krstic,[13] U. Kruchonak,[65] H. Krüger,[21] N. Krumnack,[64] A. Kruse,[173] M. C. Kruse,[45] M. Kruskal,[22] T. Kubota,[88] H. Kucuk,[78] S. Kuday,[4b] S. Kuehn,[48] A. Kugel,[58c] F. Kuger,[174] A. Kuhl,[137] T. Kuhl,[42] V. Kukhtin,[65] Y. Kulchitsky,[92] S. Kuleshov,[32b] M. Kuna,[132a,132b] T. Kunigo,[68] A. Kupco,[127] H. Kurashige,[67] Y. A. Kurochkin,[92] V. Kus,[127] E. S. Kuwertz,[169] M. Kuze,[157] J. Kvita,[115] T. Kwan,[169] D. Kyriazopoulos,[139] A. La Rosa,[137] J. L. La Rosa Navarro,[24d] L. La Rotonda,[37a,37b] C. Lacasta,[167] F. Lacava,[132a,132b] J. Lacey,[29] H. Lacker,[16] D. Lacour,[80] V. R. Lacuesta,[167] E. Ladygin,[65] R. Lafaye,[5] B. Laforge,[80] T. Lagouri,[176] S. Lai,[54] L. Lambourne,[78] S. Lammers,[61] C. L. Lampen,[7] W. Lampl,[7] E. Lançon,[136] U. Landgraf,[48] M. P. J. Landon,[76] V. S. Lang,[58a] J. C. Lange,[12] A. J. Lankford,[163] F. Lanni,[25] K. Lantzsch,[21] A. Lanza,[121a] S. Laplace,[80] C. Lapoire,[30] J. F. Laporte,[136] T. Lari,[91a] F. Lasagni Manghi,[20a,20b] M. Lassnig,[30] P. Laurelli,[47] W. Lavrijsen,[15]

A. T. Law,[137] P. Laycock,[74] T. Lazovich,[57] O. Le Dortz,[80] E. Le Guirriec,[85] E. Le Menedeu,[12] M. LeBlanc,[169] T. LeCompte,[6] F. Ledroit-Guillon,[55] C. A. Lee,[145b] S. C. Lee,[151] L. Lee,[1] G. Lefebvre,[80] M. Lefebvre,[169] F. Legger,[100] C. Leggett,[15] A. Lehan,[74] G. Lehmann Miotto,[30] X. Lei,[7] W. A. Leight,[29] A. Leisos,[154,x] A. G. Leister,[176] M. A. L. Leite,[24d] R. Leitner,[129] D. Lellouch,[172] B. Lemmer,[54] K. J. C. Leney,[78] T. Lenz,[21] B. Lenzi,[30] R. Leone,[7] S. Leone,[124a,124b] C. Leonidopoulos,[46] S. Leontsinis,[10] C. Leroy,[95] C. G. Lester,[28] M. Levchenko,[123] J. Levêque,[5] D. Levin,[89] L. J. Levinson,[172] M. Levy,[18] A. Lewis,[120] A. M. Leyko,[21] M. Leyton,[41] B. Li,[33b,y] H. Li,[148] H. L. Li,[31] L. Li,[45] L. Li,[33e] S. Li,[45] X. Li,[84] Y. Li,[33c,z] Z. Liang,[137] H. Liao,[34] B. Liberti,[133a] A. Liblong,[158] P. Lichard,[30] K. Lie,[165] J. Liebal,[21] W. Liebig,[14] C. Limbach,[21] A. Limosani,[150] S. C. Lin,[151,aa] T. H. Lin,[83] F. Linde,[107] B. E. Lindquist,[148] J. T. Linnemann,[90] E. Lipeles,[122] A. Lipniacka,[14] M. Lisovyi,[58b] T. M. Liss,[165] D. Lissauer,[25] A. Lister,[168] A. M. Litke,[137] B. Liu,[151,bb] D. Liu,[151] H. Liu,[89] J. Liu,[85] J. B. Liu,[33b] K. Liu,[85] L. Liu,[165] M. Liu,[45] M. Liu,[33b] Y. Liu,[33b] M. Livan,[121a,121b] A. Lleres,[55] J. Llorente Merino,[82] S. L. Lloyd,[76] F. Lo Sterzo,[151] E. Lobodzinska,[42] P. Loch,[7] W. S. Lockman,[137] F. K. Loebinger,[84] A. E. Loevschall-Jensen,[36] A. Loginov,[176] T. Lohse,[16] K. Lohwasser,[42] M. Lokajicek,[127] B. A. Long,[22] J. D. Long,[89] R. E. Long,[72] K. A. Looper,[111] L. Lopes,[126a] D. Lopez Mateos,[57] B. Lopez Paredes,[139] I. Lopez Paz,[12] J. Lorenz,[100] N. Lorenzo Martinez,[61] M. Losada,[162] P. Loscutoff,[15] P. J. Lösel,[100] X. Lou,[33a] A. Lounis,[117] J. Love,[6] P. A. Love,[72] N. Lu,[89] H. J. Lubatti,[138] C. Luci,[132a,132b] A. Lucotte,[55] F. Luehring,[61] W. Lukas,[62] L. Luminari,[132a] O. Lundberg,[146a,146b] B. Lund-Jensen,[147] D. Lynn,[25] R. Lysak,[127] E. Lytken,[81] H. Ma,[25] L. L. Ma,[33d] G. Maccarrone,[47] A. Macchiolo,[101] C. M. Macdonald,[139] B. Maček,[75] J. Machado Miguens,[122,126b] D. Macina,[30] D. Madaffari,[85] R. Madar,[34] H. J. Maddocks,[72] W. F. Mader,[44] A. Madsen,[166] J. Maeda,[67] S. Maeland,[14] T. Maeno,[25] A. Maevskiy,[99] E. Magradze,[54] K. Mahboubi,[48] J. Mahlstedt,[107] C. Maiani,[136] C. Maidantchik,[24a] A. A. Maier,[101] T. Maier,[100] A. Maio,[126a,126b,126d] S. Majewski,[116] Y. Makida,[66] N. Makovec,[117] B. Malaescu,[80] Pa. Malecki,[39] V. P. Maleev,[123] F. Malek,[55] U. Mallik,[63] D. Malon,[6] C. Malone,[143] S. Maltezos,[10] V. M. Malyshev,[109] S. Malyukov,[30] J. Mamuzic,[42] G. Mancini,[47] B. Mandelli,[30] L. Mandelli,[91a] I. Mandić,[75] R. Mandrysch,[63] J. Maneira,[126a,126b] A. Manfredini,[101] L. Manhaes de Andrade Filho,[24b] J. Manjarres Ramos,[159b] A. Mann,[100] A. Manousakis-Katsikakis,[9] B. Mansoulie,[136] R. Mantifel,[87] M. Mantoani,[54] L. Mapelli,[30] L. March,[145c] G. Marchiori,[80] M. Marcisovsky,[127] C. P. Marino,[169] M. Marjanovic,[13] D. E. Marley,[89] F. Marroquim,[24a] S. P. Marsden,[84] Z. Marshall,[15] L. F. Marti,[17] S. Marti-Garcia,[167] B. Martin,[90] T. A. Martin,[170] V. J. Martin,[46] B. Martin dit Latour,[14] M. Martinez,[12,p] S. Martin-Haugh,[131] V. S. Martoiu,[26a] A. C. Martyniuk,[78] M. Marx,[138] F. Marzano,[132a] A. Marzin,[30] L. Masetti,[83] T. Mashimo,[155] R. Mashinistov,[96] J. Masik,[84] A. L. Maslennikov,[109,d] I. Massa,[20a,20b] L. Massa,[20a,20b] N. Massol,[5] P. Mastrandrea,[148] A. Mastroberardino,[37a,37b] T. Masubuchi,[155] P. Mättig,[175] J. Mattmann,[83] J. Maurer,[26a] S. J. Maxfield,[74] D. A. Maximov,[109,d] R. Mazini,[151] S. M. Mazza,[91a,91b] L. Mazzaferro,[133a,133b] G. Mc Goldrick,[158] S. P. Mc Kee,[89] A. McCarn,[89] R. L. McCarthy,[148] T. G. McCarthy,[29] N. A. McCubbin,[131] K. W. McFarlane,[56,a] J. A. Mcfayden,[78] G. Mchedlidze,[54] S. J. McMahon,[131] R. A. McPherson,[169,l] M. Medinnis,[42] S. Meehan,[145a] S. Mehlhase,[100] A. Mehta,[74] K. Meier,[58a] C. Meineck,[100] B. Meirose,[41] B. R. Mellado Garcia,[145c] F. Meloni,[17] A. Mengarelli,[20a,20b] S. Menke,[101] E. Meoni,[161] K. M. Mercurio,[57] S. Mergelmeyer,[21] P. Mermod,[49] L. Merola,[104a,104b] C. Meroni,[91a] F. S. Merritt,[31] A. Messina,[132a,132b] J. Metcalfe,[25] A. S. Mete,[163] C. Meyer,[83] C. Meyer,[122] J-P. Meyer,[136] J. Meyer,[107] H. Meyer Zu Theenhausen,[58a] R. P. Middleton,[131] S. Miglioranzi,[164a,164c] L. Mijović,[21] G. Mikenberg,[172] M. Mikestikova,[127] M. Mikuž,[75] M. Milesi,[88] A. Milic,[30] D. W. Miller,[31] C. Mills,[46] A. Milov,[172] D. A. Milstead,[146a,146b] A. A. Minaenko,[130] Y. Minami,[155] I. A. Minashvili,[65] A. I. Mincer,[110] B. Mindur,[38a] M. Mineev,[65] Y. Ming,[173] L. M. Mir,[12] T. Mitani,[171] J. Mitrevski,[100] V. A. Mitsou,[167] A. Miucci,[49] P. S. Miyagawa,[139] J. U. Mjörnmark,[81] T. Moa,[146a,146b] K. Mochizuki,[85] S. Mohapatra,[35] W. Mohr,[48] S. Molander,[146a,146b] R. Moles-Valls,[21] K. Mönig,[42] C. Monini,[55] J. Monk,[36] E. Monnier,[85] J. Montejo Berlingen,[12] F. Monticelli,[71] S. Monzani,[132a,132b] R. W. Moore,[3] N. Morange,[117] D. Moreno,[162] M. Moreno Llácer,[54] P. Morettini,[50a] D. Mori,[142] M. Morii,[57] M. Morinaga,[155] V. Morisbak,[119] S. Moritz,[83] A. K. Morley,[150] G. Mornacchi,[30] J. D. Morris,[76] S. S. Mortensen,[36] A. Morton,[53] L. Morvaj,[103] M. Mosidze,[51b] J. Moss,[111] K. Motohashi,[157] R. Mount,[143] E. Mountricha,[25] S. V. Mouraviev,[96,a] E. J. W. Moyse,[86] S. Muanza,[85] R. D. Mudd,[18] F. Mueller,[101] J. Mueller,[125] R. S. P. Mueller,[100] T. Mueller,[28] D. Muenstermann,[49] P. Mullen,[53] G. A. Mullier,[17] J. A. Murillo Quijada,[18] W. J. Murray,[170,131] H. Musheghyan,[54] E. Musto,[152] A. G. Myagkov,[130,cc] M. Myska,[128] B. P. Nachman,[143] O. Nackenhorst,[54] J. Nadal,[54] K. Nagai,[120] R. Nagai,[157] Y. Nagai,[85] K. Nagano,[66] A. Nagarkar,[111] Y. Nagasaka,[59] K. Nagata,[160] M. Nagel,[101] E. Nagy,[85] A. M. Nairz,[30] Y. Nakahama,[30] K. Nakamura,[66] T. Nakamura,[155] I. Nakano,[112] H. Namasivayam,[41] R. F. Naranjo Garcia,[42] R. Narayan,[31] D. I. Narrias Villar,[58a] T. Naumann,[42] G. Navarro,[162] R. Nayyar,[7] H. A. Neal,[89] P. Yu. Nechaeva,[96] T. J. Neep,[84] P. D. Nef,[143] A. Negri,[121a,121b] M. Negrini,[20a] S. Nektarijevic,[106] C. Nellist,[117] A. Nelson,[163]

S. Nemecek,[127] P. Nemethy,[110] A. A. Nepomuceno,[24a] M. Nessi,[30,dd] M. S. Neubauer,[165] M. Neumann,[175] R. M. Neves,[110] P. Nevski,[25] P. R. Newman,[18] D. H. Nguyen,[6] R. B. Nickerson,[120] R. Nicolaidou,[136] B. Nicquevert,[30] J. Nielsen,[137] N. Nikiforou,[35] A. Nikiforov,[16] V. Nikolaenko,[130,cc] I. Nikolic-Audit,[80] K. Nikolopoulos,[18] J. K. Nilsen,[119] P. Nilsson,[25] Y. Ninomiya,[155] A. Nisati,[132a] R. Nisius,[101] T. Nobe,[155] M. Nomachi,[118] I. Nomidis,[29] T. Nooney,[76] S. Norberg,[113] M. Nordberg,[30] O. Novgorodova,[44] S. Nowak,[101] M. Nozaki,[66] L. Nozka,[115] K. Ntekas,[10] G. Nunes Hanninger,[88] T. Nunnemann,[100] E. Nurse,[78] F. Nuti,[88] B. J. O'Brien,[46] F. O'grady,[7] D. C. O'Neil,[142] V. O'Shea,[53] F. G. Oakham,[29,e] H. Oberlack,[101] T. Obermann,[21] J. Ocariz,[80] A. Ochi,[67] I. Ochoa,[78] J. P. Ochoa-Ricoux,[32a] S. Oda,[70] S. Odaka,[66] H. Ogren,[61] A. Oh,[84] S. H. Oh,[45] C. C. Ohm,[15] H. Ohman,[166] H. Oide,[30] W. Okamura,[118] H. Okawa,[160] Y. Okumura,[31] T. Okuyama,[66] A. Olariu,[26a] S. A. Olivares Pino,[46] D. Oliveira Damazio,[25] E. Oliver Garcia,[167] A. Olszewski,[39] J. Olszowska,[39] A. Onofre,[126a,126e] P. U. E. Onyisi,[31,s] C. J. Oram,[159a] M. J. Oreglia,[31] Y. Oren,[153] D. Orestano,[134a,134b] N. Orlando,[154] C. Oropeza Barrera,[53] R. S. Orr,[158] B. Osculati,[50a,50b] R. Ospanov,[84] G. Otero y Garzon,[27] H. Otono,[70] M. Ouchrif,[135d] F. Ould-Saada,[119] A. Ouraou,[136] K. P. Oussoren,[107] Q. Ouyang,[33a] A. Ovcharova,[15] M. Owen,[53] R. E. Owen,[18] V. E. Ozcan,[19a] N. Ozturk,[8] K. Pachal,[142] A. Pacheco Pages,[12] C. Padilla Aranda,[12] M. Pagáčová,[48] S. Pagan Griso,[15] E. Paganis,[139] F. Paige,[25] P. Pais,[86] K. Pajchel,[119] G. Palacino,[159b] S. Palestini,[30] M. Palka,[38b] D. Pallin,[34] A. Palma,[126a,126b] Y. B. Pan,[173] E. Panagiotopoulou,[10] C. E. Pandini,[80] J. G. Panduro Vazquez,[77] P. Pani,[146a,146b] S. Panitkin,[25] D. Pantea,[26a] L. Paolozzi,[49] Th. D. Papadopoulou,[10] K. Papageorgiou,[154] A. Paramonov,[6] D. Paredes Hernandez,[154] M. A. Parker,[28] K. A. Parker,[139] F. Parodi,[50a,50b] J. A. Parsons,[35] U. Parzefall,[48] E. Pasqualucci,[132a] S. Passaggio,[50a] F. Pastore,[134a,134b,a] Fr. Pastore,[77] G. Pásztor,[29] S. Pataraia,[175] N. D. Patel,[150] J. R. Pater,[84] T. Pauly,[30] J. Pearce,[169] B. Pearson,[113] L. E. Pedersen,[36] M. Pedersen,[119] S. Pedraza Lopez,[167] R. Pedro,[126a,126b] S. V. Peleganchuk,[109,d] D. Pelikan,[166] O. Penc,[127] C. Peng,[33a] H. Peng,[33b] B. Penning,[31] J. Penwell,[61] D. V. Perepelitsa,[25] E. Perez Codina,[159a] M. T. Pérez García-Estañ,[167] L. Perini,[91a,91b] H. Pernegger,[30] S. Perrella,[104a,104b] R. Peschke,[42] V. D. Peshekhonov,[65] K. Peters,[30] R. F. Y. Peters,[84] B. A. Petersen,[30] T. C. Petersen,[36] E. Petit,[42] A. Petridis,[1] C. Petridou,[154] P. Petroff,[117] E. Petrolo,[132a] F. Petrucci,[134a,134b] N. E. Pettersson,[157] R. Pezoa,[32b] P. W. Phillips,[131] G. Piacquadio,[143] E. Pianori,[170] A. Picazio,[49] E. Piccaro,[76] M. Piccinini,[20a,20b] M. A. Pickering,[120] R. Piegaia,[27] D. T. Pignotti,[111] J. E. Pilcher,[31] A. D. Pilkington,[84] J. Pina,[126a,126b,126d] M. Pinamonti,[164a,164c,ee] J. L. Pinfold,[3] A. Pingel,[36] S. Pires,[80] H. Pirumov,[42] M. Pitt,[172] C. Pizio,[91a,91b] L. Plazak,[144a] M.-A. Pleier,[25] V. Pleskot,[129] E. Plotnikova,[65] P. Plucinski,[146a,146b] D. Pluth,[64] R. Poettgen,[146a,146b] L. Poggioli,[117] D. Pohl,[21] G. Polesello,[121a] A. Poley,[42] A. Policicchio,[37a,37b] R. Polifka,[158] A. Polini,[20a] C. S. Pollard,[53] V. Polychronakos,[25] K. Pommès,[30] L. Pontecorvo,[132a] B. G. Pope,[90] G. A. Popeneciu,[26b] D. S. Popovic,[13] A. Poppleton,[30] S. Pospisil,[128] K. Potamianos,[15] I. N. Potrap,[65] C. J. Potter,[149] C. T. Potter,[116] G. Poulard,[30] J. Poveda,[30] V. Pozdnyakov,[65] P. Pralavorio,[85] A. Pranko,[15] S. Prasad,[30] S. Prell,[64] D. Price,[84] L. E. Price,[6] M. Primavera,[73a] S. Prince,[87] M. Proissl,[46] K. Prokofiev,[60c] F. Prokoshin,[32b] E. Protopapadaki,[136] S. Protopopescu,[25] J. Proudfoot,[6] M. Przybycien,[38a] E. Ptacek,[116] D. Puddu,[134a,134b] E. Pueschel,[86] D. Puldon,[148] M. Purohit,[25,ff] P. Puzo,[117] J. Qian,[89] G. Qin,[53] Y. Qin,[84] A. Quadt,[54] D. R. Quarrie,[15] W. B. Quayle,[164a,164b] M. Queitsch-Maitland,[84] D. Quilty,[53] S. Raddum,[119] V. Radeka,[25] V. Radescu,[42] S. K. Radhakrishnan,[148] P. Radloff,[116] P. Rados,[88] F. Ragusa,[91a,91b] G. Rahal,[178] S. Rajagopalan,[25] M. Rammensee,[30] C. Rangel-Smith,[166] F. Rauscher,[100] S. Rave,[83] T. Ravenscroft,[53] M. Raymond,[30] A. L. Read,[119] N. P. Readioff,[74] D. M. Rebuzzi,[121a,121b] A. Redelbach,[174] G. Redlinger,[25] R. Reece,[137] K. Reeves,[41] L. Rehnisch,[16] J. Reichert,[122] H. Reisin,[27] M. Relich,[163] C. Rembser,[30] H. Ren,[33a] A. Renaud,[117] M. Rescigno,[132a] S. Resconi,[91a] O. L. Rezanova,[109,d] P. Reznicek,[129] R. Rezvani,[95] R. Richter,[101] S. Richter,[78] E. Richter-Was,[38b] O. Ricken,[21] M. Ridel,[80] P. Rieck,[16] C. J. Riegel,[175] J. Rieger,[54] M. Rijssenbeek,[148] A. Rimoldi,[121a,121b] L. Rinaldi,[20a] B. Ristić,[49] E. Ritsch,[30] I. Riu,[12] F. Rizatdinova,[114] E. Rizvi,[76] S. H. Robertson,[87,l] A. Robichaud-Veronneau,[87] D. Robinson,[28] J. E. M. Robinson,[42] A. Robson,[53] C. Roda,[124a,124b] S. Roe,[30] O. Røhne,[119] S. Rolli,[161] A. Romaniouk,[98] M. Romano,[20a,20b] S. M. Romano Saez,[34] E. Romero Adam,[167] N. Rompotis,[138] M. Ronzani,[48] L. Roos,[80] E. Ros,[167] S. Rosati,[132a] K. Rosbach,[48] P. Rose,[137] P. L. Rosendahl,[14] O. Rosenthal,[141] V. Rossetti,[146a,146b] E. Rossi,[104a,104b] L. P. Rossi,[50a] J. H. N. Rosten,[28] R. Rosten,[138] M. Rotaru,[26a] I. Roth,[172] J. Rothberg,[138] D. Rousseau,[117] C. R. Royon,[136] A. Rozanov,[85] Y. Rozen,[152] X. Ruan,[145c] F. Rubbo,[143] I. Rubinskiy,[42] V. I. Rud,[99] C. Rudolph,[44] M. S. Rudolph,[158] F. Rühr,[48] A. Ruiz-Martinez,[30] Z. Rurikova,[48] N. A. Rusakovich,[65] A. Ruschke,[100] H. L. Russell,[138] J. P. Rutherfoord,[7] N. Ruthmann,[48] Y. F. Ryabov,[123] M. Rybar,[165] G. Rybkin,[117] N. C. Ryder,[120] A. F. Saavedra,[150] G. Sabato,[107] S. Sacerdoti,[27] A. Saddique,[3] H. F-W. Sadrozinski,[137] R. Sadykov,[65] F. Safai Tehrani,[132a] M. Sahinsoy,[58a] M. Saimpert,[136] T. Saito,[155] H. Sakamoto,[155] Y. Sakurai,[171] G. Salamanna,[134a,134b] A. Salamon,[133a] J. E. Salazar Loyola,[32b] M. Saleem,[113] D. Salek,[107] P. H. Sales De Bruin,[138] D. Salihagic,[101] A. Salnikov,[143]

J. Salt,[167] D. Salvatore,[37a,37b] F. Salvatore,[149] A. Salvucci,[60a] A. Salzburger,[30] D. Sammel,[48] D. Sampsonidis,[154] A. Sanchez,[104a,104b] J. Sánchez,[167] V. Sanchez Martinez,[167] H. Sandaker,[119] R. L. Sandbach,[76] H. G. Sander,[83] M. P. Sanders,[100] M. Sandhoff,[175] C. Sandoval,[162] R. Sandstroem,[101] D. P. C. Sankey,[131] M. Sannino,[50a,50b] A. Sansoni,[47] C. Santoni,[34] R. Santonico,[133a,133b] H. Santos,[126a] I. Santoyo Castillo,[149] K. Sapp,[125] A. Sapronov,[65] J. G. Saraiva,[126a,126d] B. Sarrazin,[21] O. Sasaki,[66] Y. Sasaki,[155] K. Sato,[160] G. Sauvage,[5,a] E. Sauvan,[5] G. Savage,[77] P. Savard,[158,e] C. Sawyer,[131] L. Sawyer,[79,o] J. Saxon,[31] C. Sbarra,[20a] A. Sbrizzi,[20a,20b] T. Scanlon,[78] D. A. Scannicchio,[163] M. Scarcella,[150] V. Scarfone,[37a,37b] J. Schaarschmidt,[172] P. Schacht,[101] D. Schaefer,[30] R. Schaefer,[42] J. Schaeffer,[83] S. Schaepe,[21] S. Schaetzel,[58b] U. Schäfer,[83] A. C. Schaffer,[117] D. Schaile,[100] R. D. Schamberger,[148] V. Scharf,[58a] V. A. Schegelsky,[123] D. Scheirich,[129] M. Schernau,[163] C. Schiavi,[50a,50b] C. Schillo,[48] M. Schioppa,[37a,37b] S. Schlenker,[30] K. Schmieden,[30] C. Schmitt,[83] S. Schmitt,[58b] S. Schmitt,[42] B. Schneider,[159a] Y. J. Schnellbach,[74] U. Schnoor,[44] L. Schoeffel,[136] A. Schoening,[58b] B. D. Schoenrock,[90] E. Schopf,[21] A. L. S. Schorlemmer,[54] M. Schott,[83] D. Schouten,[159a] J. Schovancova,[8] S. Schramm,[49] M. Schreyer,[174] C. Schroeder,[83] N. Schuh,[83] M. J. Schultens,[21] H.-C. Schultz-Coulon,[58a] H. Schulz,[16] M. Schumacher,[48] B. A. Schumm,[137] Ph. Schune,[136] C. Schwanenberger,[84] A. Schwartzman,[143] T. A. Schwarz,[89] Ph. Schwegler,[101] H. Schweiger,[84] Ph. Schwemling,[136] R. Schwienhorst,[90] J. Schwindling,[136] T. Schwindt,[21] F. G. Sciacca,[17] E. Scifo,[117] G. Sciolla,[23] F. Scuri,[124a,124b] F. Scutti,[21] J. Searcy,[89] G. Sedov,[42] E. Sedykh,[123] P. Seema,[21] S. C. Seidel,[105] A. Seiden,[137] F. Seifert,[128] J. M. Seixas,[24a] G. Sekhniaidze,[104a] K. Sekhon,[89] S. J. Sekula,[40] D. M. Seliverstov,[123,a] N. Semprini-Cesari,[20a,20b] C. Serfon,[30] L. Serin,[117] L. Serkin,[164a,164b] T. Serre,[85] M. Sessa,[134a,134b] R. Seuster,[159a] H. Severini,[113] T. Sfiligoj,[75] F. Sforza,[30] A. Sfyrla,[30] E. Shabalina,[54] M. Shamim,[116] L. Y. Shan,[33a] R. Shang,[165] J. T. Shank,[22] M. Shapiro,[15] P. B. Shatalov,[97] K. Shaw,[164a,164b] S. M. Shaw,[84] A. Shcherbakova,[146a,146b] C. Y. Shehu,[149] P. Sherwood,[78] L. Shi,[151,gg] S. Shimizu,[67] C. O. Shimmin,[163] M. Shimojima,[102] M. Shiyakova,[65] A. Shmeleva,[96] D. Shoaleh Saadi,[95] M. J. Shochet,[31] S. Shojaii,[91a,91b] S. Shrestha,[111] E. Shulga,[98] M. A. Shupe,[7] S. Shushkevich,[42] P. Sicho,[127] P. E. Sidebo,[147] O. Sidiropoulou,[174] D. Sidorov,[114] A. Sidoti,[20a,20b] F. Siegert,[44] Dj. Sijacki,[13] J. Silva,[126a,126d] Y. Silver,[153] S. B. Silverstein,[146a] V. Simak,[128] O. Simard,[5] Lj. Simic,[13] S. Simion,[117] E. Simioni,[83] B. Simmons,[78] D. Simon,[34] P. Sinervo,[158] N. B. Sinev,[116] M. Sioli,[20a,20b] G. Siragusa,[174] A. N. Sisakyan,[65,a] S. Yu. Sivoklokov,[99] J. Sjölin,[146a,146b] T. B. Sjursen,[14] M. B. Skinner,[72] H. P. Skottowe,[57] P. Skubic,[113] M. Slater,[18] T. Slavicek,[128] M. Slawinska,[107] K. Sliwa,[161] V. Smakhtin,[172] B. H. Smart,[46] L. Smestad,[14] S. Yu. Smirnov,[98] Y. Smirnov,[98] L. N. Smirnova,[99,hh] O. Smirnova,[81] M. N. K. Smith,[35] R. W. Smith,[35] M. Smizanska,[72] K. Smolek,[128] A. A. Snesarev,[96] G. Snidero,[76] S. Snyder,[25] R. Sobie,[169,l] F. Socher,[44] A. Soffer,[153] D. A. Soh,[151,gg] G. Sokhrannyi,[75] C. A. Solans,[30] M. Solar,[128] J. Solc,[128] E. Yu. Soldatov,[98] U. Soldevila,[167] A. A. Solodkov,[130] A. Soloshenko,[65] O. V. Solovyanov,[130] V. Solovyev,[123] P. Sommer,[48] H. Y. Song,[33b] N. Soni,[1] A. Sood,[15] A. Sopczak,[128] B. Sopko,[128] V. Sopko,[128] V. Sorin,[12] D. Sosa,[58b] M. Sosebee,[8] C. L. Sotiropoulou,[124a,124b] R. Soualah,[164a,164c] A. M. Soukharev,[109,d] D. South,[42] B. C. Sowden,[77] S. Spagnolo,[73a,73b] M. Spalla,[124a,124b] M. Spangenberg,[170] F. Spanò,[77] W. R. Spearman,[57] D. Sperlich,[16] F. Spettel,[101] R. Spighi,[20a] G. Spigo,[30] L. A. Spiller,[88] M. Spousta,[129] T. Spreitzer,[158] R. D. St. Denis,[53,a] S. Staerz,[44] J. Stahlman,[122] R. Stamen,[58a] S. Stamm,[16] E. Stanecka,[39] C. Stanescu,[134a] M. Stanescu-Bellu,[42] M. M. Stanitzki,[42] S. Stapnes,[119] E. A. Starchenko,[130] J. Stark,[55] P. Staroba,[127] P. Starovoitov,[58a] R. Staszewski,[39] P. Stavina,[144a,a] P. Steinberg,[25] B. Stelzer,[142] H. J. Stelzer,[30] O. Stelzer-Chilton,[159a] H. Stenzel,[52] G. A. Stewart,[53] J. A. Stillings,[21] M. C. Stockton,[87] M. Stoebe,[87] G. Stoicea,[26a] P. Stolte,[54] S. Stonjek,[101] A. R. Stradling,[8] A. Straessner,[44] M. E. Stramaglia,[17] J. Strandberg,[147] S. Strandberg,[146a,146b] A. Strandlie,[119] E. Strauss,[143] M. Strauss,[113] P. Strizenec,[144b] R. Ströhmer,[174] D. M. Strom,[116] R. Stroynowski,[40] A. Strubig,[106] S. A. Stucci,[17] B. Stugu,[14] N. A. Styles,[42] D. Su,[143] J. Su,[125] R. Subramaniam,[79] A. Succurro,[12] Y. Sugaya,[118] C. Suhr,[108] M. Suk,[128] V. V. Sulin,[96] S. Sultansoy,[4c] T. Sumida,[68] S. Sun,[57] X. Sun,[33a] J. E. Sundermann,[48] K. Suruliz,[149] G. Susinno,[37a,37b] M. R. Sutton,[149] S. Suzuki,[66] M. Svatos,[127] M. Swiatlowski,[143] I. Sykora,[144a] T. Sykora,[129] D. Ta,[90] C. Taccini,[134a,134b] K. Tackmann,[42] J. Taenzer,[158] A. Taffard,[163] R. Tafirout,[159a] N. Taiblum,[153] H. Takai,[25] R. Takashima,[69] H. Takeda,[67] T. Takeshita,[140] Y. Takubo,[66] M. Talby,[85] A. A. Talyshev,[109,d] J. Y. C. Tam,[174] K. G. Tan,[88] J. Tanaka,[155] R. Tanaka,[117] S. Tanaka,[66] B. B. Tannenwald,[111] N. Tannoury,[21] S. Tapprogge,[83] S. Tarem,[152] F. Tarrade,[29] G. F. Tartarelli,[91a] P. Tas,[129] M. Tasevsky,[127] T. Tashiro,[68] E. Tassi,[37a,37b] A. Tavares Delgado,[126a,126b] Y. Tayalati,[135d] F. E. Taylor,[94] G. N. Taylor,[88] W. Taylor,[159b] F. A. Teischinger,[30] M. Teixeira Dias Castanheira,[76] P. Teixeira-Dias,[77] K. K. Temming,[48] D. Temple,[142] H. Ten Kate,[30] P. K. Teng,[151] J. J. Teoh,[118] F. Tepel,[175] S. Terada,[66] K. Terashi,[155] J. Terron,[82] S. Terzo,[101] M. Testa,[47] R. J. Teuscher,[158,l] T. Theveneaux-Pelzer,[34] J. P. Thomas,[18] J. Thomas-Wilsker,[77] E. N. Thompson,[35] P. D. Thompson,[18] R. J. Thompson,[84] A. S. Thompson,[53] L. A. Thomsen,[176] E. Thomson,[122] M. Thomson,[28] R. P. Thun,[89,a]

M. J. Tibbetts,[15] R. E. Ticse Torres,[85] V. O. Tikhomirov,[96,ii] Yu. A. Tikhonov,[109,d] S. Timoshenko,[98] E. Tiouchichine,[85] P. Tipton,[176] S. Tisserant,[85] K. Todome,[157] T. Todorov,[5] S. Todorova-Nova,[129] J. Tojo,[70] S. Tokár,[144a] K. Tokushuku,[66] K. Tollefson,[90] E. Tolley,[57] L. Tomlinson,[84] M. Tomoto,[103] L. Tompkins,[143,jj] K. Toms,[105] E. Torrence,[116] H. Torres,[142] E. Torró Pastor,[138] J. Toth,[85,kk] F. Touchard,[85] D. R. Tovey,[139] T. Trefzger,[174] L. Tremblet,[30] A. Tricoli,[30] I. M. Trigger,[159a] S. Trincaz-Duvoid,[80] M. F. Tripiana,[12] W. Trischuk,[158] B. Trocmé,[55] C. Troncon,[91a] M. Trottier-McDonald,[15] M. Trovatelli,[169] P. True,[90] L. Truong,[164a,164c] M. Trzebinski,[39] A. Trzupek,[39] C. Tsarouchas,[30] J. C-L. Tseng,[120] P. V. Tsiareshka,[92] D. Tsionou,[154] G. Tsipolitis,[10] N. Tsirintanis,[9] S. Tsiskaridze,[12] V. Tsiskaridze,[48] E. G. Tskhadadze,[51a] I. I. Tsukerman,[97] V. Tsulaia,[15] S. Tsuno,[66] D. Tsybychev,[148] A. Tudorache,[26a] V. Tudorache,[26a] A. N. Tuna,[122] S. A. Tupputi,[20a,20b] S. Turchikhin,[99,hh] D. Turecek,[128] R. Turra,[91a,91b] A. J. Turvey,[40] P. M. Tuts,[35] A. Tykhonov,[49] M. Tylmad,[146a,146b] M. Tyndel,[131] I. Ueda,[155] R. Ueno,[29] M. Ughetto,[146a,146b] M. Ugland,[14] F. Ukegawa,[160] G. Unal,[30] A. Undrus,[25] G. Unel,[163] F. C. Ungaro,[48] Y. Unno,[66] C. Unverdorben,[100] J. Urban,[144b] P. Urquijo,[88] P. Urrejola,[83] G. Usai,[8] A. Usanova,[62] L. Vacavant,[85] V. Vacek,[128] B. Vachon,[87] C. Valderanis,[83] N. Valencic,[107] S. Valentinetti,[20a,20b] A. Valero,[167] L. Valery,[12] S. Valkar,[129] E. Valladolid Gallego,[167] S. Vallecorsa,[49] J. A. Valls Ferrer,[167] W. Van Den Wollenberg,[107] P. C. Van Der Deijl,[107] R. van der Geer,[107] H. van der Graaf,[107] N. van Eldik,[152] P. van Gemmeren,[6] J. Van Nieuwkoop,[142] I. van Vulpen,[107] M. C. van Woerden,[30] M. Vanadia,[132a,132b] W. Vandelli,[30] R. Vanguri,[122] A. Vaniachine,[6] F. Vannucci,[80] G. Vardanyan,[177] R. Vari,[132a] E. W. Varnes,[7] T. Varol,[40] D. Varouchas,[80] A. Vartapetian,[8] K. E. Varvell,[150] F. Vazeille,[34] T. Vazquez Schroeder,[87] J. Veatch,[7] L. M. Veloce,[158] F. Veloso,[126a,126c] T. Velz,[21] S. Veneziano,[132a] A. Ventura,[73a,73b] D. Ventura,[86] M. Venturi,[169] N. Venturi,[158] A. Venturini,[23] V. Vercesi,[121a] M. Verducci,[132a,132b] W. Verkerke,[107] J. C. Vermeulen,[107] A. Vest,[44] M. C. Vetterli,[142,e] O. Viazlo,[81] I. Vichou,[165] T. Vickey,[139] O. E. Vickey Boeriu,[139] G. H. A. Viehhauser,[120] S. Viel,[15] R. Vigne,[62] M. Villa,[20a,20b] M. Villaplana Perez,[91a,91b] E. Vilucchi,[47] M. G. Vincter,[29] V. B. Vinogradov,[65] I. Vivarelli,[149] F. Vives Vaque,[3] S. Vlachos,[10] D. Vladoiu,[100] M. Vlasak,[128] M. Vogel,[32a] P. Vokac,[128] G. Volpi,[124a,124b] M. Volpi,[88] H. von der Schmitt,[101] H. von Radziewski,[48] E. von Toerne,[21] V. Vorobel,[129] K. Vorobev,[98] M. Vos,[167] R. Voss,[30] J. H. Vossebeld,[74] N. Vranjes,[13] M. Vranjes Milosavljevic,[13] V. Vrba,[127] M. Vreeswijk,[107] R. Vuillermet,[30] I. Vukotic,[31] Z. Vykydal,[128] P. Wagner,[21] W. Wagner,[175] H. Wahlberg,[71] S. Wahrmund,[44] J. Wakabayashi,[103] J. Walder,[72] R. Walker,[100] W. Walkowiak,[141] C. Wang,[151] F. Wang,[173] H. Wang,[15] H. Wang,[40] J. Wang,[42] J. Wang,[33a] K. Wang,[87] R. Wang,[6] S. M. Wang,[151] T. Wang,[21] T. Wang,[35] X. Wang,[176] C. Wanotayaroj,[116] A. Warburton,[87] C. P. Ward,[28] D. R. Wardrope,[78] A. Washbrook,[46] C. Wasicki,[42] P. M. Watkins,[18] A. T. Watson,[18] I. J. Watson,[150] M. F. Watson,[18] G. Watts,[138] S. Watts,[84] B. M. Waugh,[78] S. Webb,[84] M. S. Weber,[17] S. W. Weber,[174] J. S. Webster,[31] A. R. Weidberg,[120] B. Weinert,[61] J. Weingarten,[54] C. Weiser,[48] H. Weits,[107] P. S. Wells,[30] T. Wenaus,[25] T. Wengler,[30] S. Wenig,[30] N. Wermes,[21] M. Werner,[48] P. Werner,[30] M. Wessels,[58a] J. Wetter,[161] K. Whalen,[116] A. M. Wharton,[72] A. White,[8] M. J. White,[1] R. White,[32b] S. White,[124a,124b] D. Whiteson,[163] F. J. Wickens,[131] W. Wiedenmann,[173] M. Wielers,[131] P. Wienemann,[21] C. Wiglesworth,[36] L. A. M. Wiik-Fuchs,[21] A. Wildauer,[101] H. G. Wilkens,[30] H. H. Williams,[122] S. Williams,[107] C. Willis,[90] S. Willocq,[86] A. Wilson,[89] J. A. Wilson,[18] I. Wingerter-Seez,[5] F. Winklmeier,[116] B. T. Winter,[21] M. Wittgen,[143] J. Wittkowski,[100] S. J. Wollstadt,[83] M. W. Wolter,[39] H. Wolters,[126a,126c] B. K. Wosiek,[39] J. Wotschack,[30] M. J. Woudstra,[84] K. W. Wozniak,[39] M. Wu,[55] M. Wu,[31] S. L. Wu,[173] X. Wu,[49] Y. Wu,[89] T. R. Wyatt,[84] B. M. Wynne,[46] S. Xella,[36] D. Xu,[33a] L. Xu,[25] B. Yabsley,[150] S. Yacoob,[145a] R. Yakabe,[67] M. Yamada,[66] D. Yamaguchi,[157] Y. Yamaguchi,[118] A. Yamamoto,[66] S. Yamamoto,[155] T. Yamanaka,[155] K. Yamauchi,[103] Y. Yamazaki,[67] Z. Yan,[22] H. Yang,[33e] H. Yang,[173] Y. Yang,[151] W-M. Yao,[15] Y. Yasu,[66] E. Yatsenko,[5] K. H. Yau Wong,[21] J. Ye,[40] S. Ye,[25] I. Yeletskikh,[65] A. L. Yen,[57] E. Yildirim,[42] K. Yorita,[171] R. Yoshida,[6] K. Yoshihara,[122] C. Young,[143] C. J. S. Young,[30] S. Youssef,[22] D. R. Yu,[15] J. Yu,[8] J. M. Yu,[89] J. Yu,[114] L. Yuan,[67] S. P. Y. Yuen,[21] A. Yurkewicz,[108] I. Yusuff,[28,ll] B. Zabinski,[39] R. Zaidan,[63] A. M. Zaitsev,[130,cc] J. Zalieckas,[14] A. Zaman,[148] S. Zambito,[57] L. Zanello,[132a,132b] D. Zanzi,[88] C. Zeitnitz,[175] M. Zeman,[128] A. Zemla,[38a] Q. Zeng,[143] K. Zengel,[23] O. Zenin,[130] T. Ženiš,[144a] D. Zerwas,[117] D. Zhang,[89] F. Zhang,[173] H. Zhang,[33c] J. Zhang,[6] L. Zhang,[48] R. Zhang,[33b] X. Zhang,[33d] Z. Zhang,[117] X. Zhao,[40] Y. Zhao,[33d,117] Z. Zhao,[33b] A. Zhemchugov,[65] J. Zhong,[120] B. Zhou,[89] C. Zhou,[45] L. Zhou,[35] L. Zhou,[40] N. Zhou,[33f] C. G. Zhu,[33d] H. Zhu,[33a] J. Zhu,[89] Y. Zhu,[33b] X. Zhuang,[33a] K. Zhukov,[96] A. Zibell,[174] D. Zieminska,[61] N. I. Zimine,[65] C. Zimmermann,[83] S. Zimmermann,[48] Z. Zinonos,[54] M. Zinser,[83] M. Ziolkowski,[141] L. Živković,[13] G. Zobernig,[173] A. Zoccoli,[20a,20b] M. zur Nedden,[16] G. Zurzolo, [104a,104b] and L. Zwalinski[30]

(ATLAS Collaboration)

[1]*Department of Physics, University of Adelaide, Adelaide, Australia*
[2]*Physics Department, SUNY Albany, Albany New York, USA*
[3]*Department of Physics, University of Alberta, Edmonton Alberta, Canada*
[4a]*Department of Physics, Ankara University, Ankara, Turkey*
[4b]*Istanbul Aydin University, Istanbul, Turkey*
[4c]*Division of Physics, TOBB University of Economics and Technology, Ankara, Turkey*
[5]*LAPP, CNRS/IN2P3 and Université Savoie Mont Blanc, Annecy-le-Vieux, France*
[6]*High Energy Physics Division, Argonne National Laboratory, Argonne, Illinois, USA*
[7]*Department of Physics, University of Arizona, Tucson, Arizona, USA*
[8]*Department of Physics, The University of Texas at Arlington, Arlington, Texas, USA*
[9]*Physics Department, University of Athens, Athens, Greece*
[10]*Physics Department, National Technical University of Athens, Zografou, Greece*
[11]*Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan*
[12]*Institut de Física d'Altes Energies and Departament de Física de la Universitat Autònoma de Barcelona, Barcelona, Spain*
[13]*Institute of Physics, University of Belgrade, Belgrade, Serbia*
[14]*Department for Physics and Technology, University of Bergen, Bergen, Norway*
[15]*Physics Division, Lawrence Berkeley National Laboratory and University of California, Berkeley, California, USA*
[16]*Department of Physics, Humboldt University, Berlin, Germany*
[17]*Albert Einstein Center for Fundamental Physics and Laboratory for High Energy Physics, University of Bern, Bern, Switzerland*
[18]*School of Physics and Astronomy, University of Birmingham, Birmingham, United Kingdom*
[19a]*Department of Physics, Bogazici University, Istanbul, Turkey*
[19b]*Department of Physics Engineering, Gaziantep University, Gaziantep, Turkey*
[19c]*Department of Physics, Dogus University, Istanbul, Turkey*
[20a]*INFN Sezione di Bologna, Bologna, Italy*
[20b]*Dipartimento di Fisica e Astronomia, Università di Bologna, Bologna, Italy*
[21]*Physikalisches Institut, University of Bonn, Bonn, Germany*
[22]*Department of Physics, Boston University, Boston, Massachusetts, USA*
[23]*Department of Physics, Brandeis University, Waltham, Massachusetts, USA*
[24a]*Universidade Federal do Rio De Janeiro COPPE/EE/IF, Rio de Janeiro, Brazil*
[24b]*Electrical Circuits Department, Federal University of Juiz de Fora (UFJF), Juiz de Fora, Brazil*
[24c]*Federal University of Sao Joao del Rei (UFSJ), Sao Joao del Rei, Brazil*
[24d]*Instituto de Fisica, Universidade de Sao Paulo, Sao Paulo, Brazil*
[25]*Physics Department, Brookhaven National Laboratory, Upton, New York, USA*
[26a]*National Institute of Physics and Nuclear Engineering, Bucharest, Romania*
[26b]*National Institute for Research and Development of Isotopic and Molecular Technologies, Physics Department, Cluj Napoca, Romania*
[26c]*University Politehnica Bucharest, Bucharest, Romania*
[26d]*West University in Timisoara, Timisoara, Romania*
[27]*Departamento de Física, Universidad de Buenos Aires, Buenos Aires, Argentina*
[28]*Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom*
[29]*Department of Physics, Carleton University, Ottawa, Ontario, Canada*
[30]*CERN, Geneva, Switzerland*
[31]*Enrico Fermi Institute, University of Chicago, Chicago, Illionois, USA*
[32a]*Departamento de Física, Pontificia Universidad Católica de Chile, Santiago, Chile*
[32b]*Departamento de Física, Universidad Técnica Federico Santa María, Valparaíso, Chile*
[33a]*Institute of High Energy Physics, Chinese Academy of Sciences, Beijing, China*
[33b]*Department of Modern Physics, University of Science and Technology of China, Anhui, China*
[33c]*Department of Physics, Nanjing University, Jiangsu, China*
[33d]*School of Physics, Shandong University, Shandong, China*
[33e]*Department of Physics and Astronomy, Shanghai Key Laboratory for Particle Physics and Cosmology, Shanghai Jiao Tong University, Shanghai, China*
[33f]*Physics Department, Tsinghua University, Beijing 100084, China*
[34]*Laboratoire de Physique Corpusculaire, Clermont Université and Université Blaise Pascal and CNRS/IN2P3, Clermont-Ferrand, France*
[35]*Nevis Laboratory, Columbia University, Irvington, New York, USA*
[36]*Niels Bohr Institute, University of Copenhagen, Kobenhavn, Denmark*
[37a]*INFN Gruppo Collegato di Cosenza, Laboratori Nazionali di Frascati, Frascati, Italy*
[37b]*Dipartimento di Fisica, Università della Calabria, Rende, Italy*
[38a]*AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Krakow, Poland*
[38b]*Marian Smoluchowski Institute of Physics, Jagiellonian University, Krakow, Poland*

[39]*Institute of Nuclear Physics Polish Academy of Sciences, Krakow, Poland*
[40]*Physics Department, Southern Methodist University, Dallas, Texas, USA*
[41]*Physics Department, University of Texas at Dallas, Richardson, Texas, USA*
[42]*DESY, Hamburg and Zeuthen, Germany*
[43]*Institut für Experimentelle Physik IV, Technische Universität Dortmund, Dortmund, Germany*
[44]*Institut für Kern- und Teilchenphysik, Technische Universität Dresden, Dresden, Germany*
[45]*Department of Physics, Duke University, Durham, North Carolina, USA*
[46]*SUPA - School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom*
[47]*INFN Laboratori Nazionali di Frascati, Frascati, Italy*
[48]*Fakultät für Mathematik und Physik, Albert-Ludwigs-Universität, Freiburg, Germany*
[49]*Section de Physique, Université de Genève, Geneva, Switzerland*
[50a]*INFN Sezione di Genova, Genova, Italy*
[50b]*Dipartimento di Fisica, Università di Genova, Genova, Italy*
[51a]*E. Andronikashvili Institute of Physics, Iv. Javakhishvili Tbilisi State University, Tbilisi, Georgia*
[51b]*High Energy Physics Institute, Tbilisi State University, Tbilisi, Georgia*
[52]*II Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen, Germany*
[53]*SUPA - School of Physics and Astronomy, University of Glasgow, Glasgow, United Kingdom*
[54]*II Physikalisches Institut, Georg-August-Universität, Göttingen, Germany*
[55]*Laboratoire de Physique Subatomique et de Cosmologie, Université Grenoble-Alpes, CNRS/IN2P3, Grenoble, France*
[56]*Department of Physics, Hampton University, Hampton, Virginia, USA*
[57]*Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge, Massachsetts, USA*
[58a]*Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany*
[58b]*Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany*
[58c]*ZITI Institut für technische Informatik, Ruprecht-Karls-Universität Heidelberg, Mannheim, Germany*
[59]*Faculty of Applied Information Science, Hiroshima Institute of Technology, Hiroshima, Japan*
[60a]*Department of Physics, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong, China*
[60b]*Department of Physics, The University of Hong Kong, Hong Kong, China*
[60c]*Department of Physics, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, China*
[61]*Department of Physics, Indiana University, Bloomington, Indiana, USA*
[62]*Institut für Astro- und Teilchenphysik, Leopold-Franzens-Universität, Innsbruck, Austria*
[63]*University of Iowa, Iowa City, Iowa, USA*
[64]*Department of Physics and Astronomy, Iowa State University, Ames, Iowa, USA*
[65]*Joint Institute for Nuclear Research, JINR Dubna, Dubna, Russia*
[66]*KEK, High Energy Accelerator Research Organization, Tsukuba, Japan*
[67]*Graduate School of Science, Kobe University, Kobe, Japan*
[68]*Faculty of Science, Kyoto University, Kyoto, Japan*
[69]*Kyoto University of Education, Kyoto, Japan*
[70]*Department of Physics, Kyushu University, Fukuoka, Japan*
[71]*Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata, Argentina*
[72]*Physics Department, Lancaster University, Lancaster, United Kingdom*
[73a]*INFN Sezione di Lecce, Lecce, Italy*
[73b]*Dipartimento di Matematica e Fisica, Università del Salento, Lecce, Italy*
[74]*Oliver Lodge Laboratory, University of Liverpool, Liverpool, United Kingdom*
[75]*Department of Physics, Jožef Stefan Institute and University of Ljubljana, Ljubljana, Slovenia*
[76]*School of Physics and Astronomy, Queen Mary University of London, London, United Kingdom*
[77]*Department of Physics, Royal Holloway University of London, Surrey, United Kingdom*
[78]*Department of Physics and Astronomy, University College London, London, United Kingdom*
[79]*Louisiana Tech University, Ruston LA, United States of America*
[80]*Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France*
[81]*Fysiska institutionen, Lunds universitet, Lund, Sweden*
[82]*Departamento de Fisica Teorica C-15, Universidad Autonoma de Madrid, Madrid, Spain*
[83]*Institut für Physik, Universität Mainz, Mainz, Germany*
[84]*School of Physics and Astronomy, University of Manchester, Manchester, United Kingdom*
[85]*CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France*
[86]*Department of Physics, University of Massachusetts, Amherst, Massachusetts, USA*
[87]*Department of Physics, McGill University, Montreal, Québec, Canada*
[88]*School of Physics, University of Melbourne, Victoria, Australia*
[89]*Department of Physics, The University of Michigan, Ann Arbor, Michigan, USA*
[90]*Department of Physics and Astronomy, Michigan State University, East Lansing, Michigan, USA*
[91a]*INFN Sezione di Milano, Milano, Italy*

[91b]*Dipartimento di Fisica, Università di Milano, Milano, Italy*
[92]*B.I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk, Republic of Belarus*
[93]*National Scientific and Educational Centre for Particle and High Energy Physics, Minsk, Republic of Belarus*
[94]*Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA*
[95]*Group of Particle Physics, University of Montreal, Montreal, Québec, Canada*
[96]*P.N. Lebedev Institute of Physics, Academy of Sciences, Moscow, Russia*
[97]*Institute for Theoretical and Experimental Physics (ITEP), Moscow, Russia*
[98]*National Research Nuclear University MEPhI, Moscow, Russia*
[99]*D.V. Skobeltsyn Institute of Nuclear Physics, M.V. Lomonosov Moscow State University, Moscow, Russia*
[100]*Fakultät für Physik, Ludwig-Maximilians-Universität München, München, Germany*
[101]*Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), München, Germany*
[102]*Nagasaki Institute of Applied Science, Nagasaki, Japan*
[103]*Graduate School of Science and Kobayashi-Maskawa Institute, Nagoya University, Nagoya, Japan*
[104a]*INFN Sezione di Napoli, Napoli, Italy*
[104b]*Dipartimento di Fisica, Università di Napoli, Napoli, Italy*
[105]*Department of Physics and Astronomy, University of New Mexico, Albuquerque, New Mexico, USA*
[106]*Institute for Mathematics, Astrophysics and Particle Physics, Radboud University Nijmegen/Nikhef, Nijmegen, Netherlands*
[107]*Nikhef National Institute for Subatomic Physics and University of Amsterdam, Amsterdam, Netherlands*
[108]*Department of Physics, Northern Illinois University, DeKalb, Illionois, USA*
[109]*Budker Institute of Nuclear Physics, SB RAS, Novosibirsk, Russia*
[110]*Department of Physics, New York University, New York, New York, USA*
[111]*Ohio State University, Columbus, Ohio, USA*
[112]*Faculty of Science, Okayama University, Okayama, Japan*
[113]*Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman, Oklahoma, USA*
[114]*Department of Physics, Oklahoma State University, Stillwater, Oklahoma, USA*
[115]*Palacký University, RCPTM, Olomouc, Czech Republic*
[116]*Center for High Energy Physics, University of Oregon, Eugene, Oregon, USA*
[117]*LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France*
[118]*Graduate School of Science, Osaka University, Osaka, Japan*
[119]*Department of Physics, University of Oslo, Oslo, Norway*
[120]*Department of Physics, Oxford University, Oxford, United Kingdom*
[121a]*INFN Sezione di Pavia, Pavia, Italy*
[121b]*Dipartimento di Fisica, Università di Pavia, Pavia, Italy*
[122]*Department of Physics, University of Pennsylvania, Philadelphia, Pennsylvania, USA*
[123]*National Research Centre "Kurchatov Institute" B.P.Konstantinov Petersburg Nuclear Physics Institute, St. Petersburg, Russia*
[124a]*INFN Sezione di Pisa, Pisa, Italy*
[124b]*Dipartimento di Fisica E. Fermi, Università di Pisa, Pisa, Italy*
[125]*Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh, Pennsylvania, USA*
[126a]*Laboratório de Instrumentação e Física Experimental de Partículas - LIP, Lisboa, Portugal*
[126b]*Faculdade de Ciências, Universidade de Lisboa, Lisboa, Portugal*
[126c]*Department of Physics, University of Coimbra, Coimbra, Portugal*
[126d]*Centro de Física Nuclear da Universidade de Lisboa, Lisboa, Portugal*
[126e]*Departamento de Fisica, Universidade do Minho, Braga, Portugal*
[126f]*Departamento de Fisica Teorica y del Cosmos and CAFPE, Universidad de Granada, Granada (Spain), Portugal*
[126g]*Dep Fisica and CEFITEC of Faculdade de Ciencias e Tecnologia, Universidade Nova de Lisboa, Caparica, Portugal*
[127]*Institute of Physics, Academy of Sciences of the Czech Republic, Praha, Czech Republic*
[128]*Czech Technical University in Prague, Praha, Czech Republic*
[129]*Faculty of Mathematics and Physics, Charles University in Prague, Praha, Czech Republic*
[130]*State Research Center Institute for High Energy Physics, Protvino, Russia*
[131]*Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom*
[132a]*INFN Sezione di Roma, Roma, Italy*
[132b]*Dipartimento di Fisica, Sapienza Università di Roma, Roma, Italy*
[133a]*INFN Sezione di Roma Tor Vergata, Roma, Italy*
[133b]*Dipartimento di Fisica, Università di Roma Tor Vergata, Roma, Italy*
[134a]*INFN Sezione di Roma Tre, Roma, Italy*
[134b]*Dipartimento di Matematica e Fisica, Università Roma Tre, Roma, Italy*
[135a]*Faculté des Sciences Ain Chock, Réseau Universitaire de Physique des Hautes Energies - Université Hassan II, Casablanca, Morocco*
[135b]*Centre National de l'Energie des Sciences Techniques Nucleaires, Rabat, Morocco*
[135c]*Faculté des Sciences Semlalia, Université Cadi Ayyad, LPHEA-Marrakech, Morocco*

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

[a]Deceased.
[b]Also at Department of Physics, King's College London, London, United Kingdom.
[c]Also at Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan.
[d]Also at Novosibirsk State University, Novosibirsk, Russia.
[e]Also at TRIUMF, Vancouver BC, Canada.

[f]Also at Department of Physics, California State University, Fresno CA, USA.
[g]Also at Department of Physics, University of Fribourg, Fribourg, Switzerland.
[h]Also at Departamento de Fisica e Astronomia, Faculdade de Ciencias, Universidade do Porto, Portugal.
[i]Also at Tomsk State University, Tomsk, Russia.
[j]Also at CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France.
[k]Also at Universita di Napoli Parthenope, Napoli, Italy.
[l]Also at Institute of Particle Physics (IPP), Canada.
[m]Also at Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom.
[n]Also at Department of Physics, St. Petersburg State Polytechnical University, St. Petersburg, Russia.
[o]Also at Louisiana Tech University, Ruston LA, USA.
[p]Also at Institucio Catalana de Recerca i Estudis Avancats, ICREA, Barcelona, Spain.
[q]Also at Graduate School of Science, Osaka University, Osaka, Japan.
[r]Also at Department of Physics, National Tsing Hua University, Taiwan.
[s]Also at Department of Physics, The University of Texas at Austin, Austin TX, USA.
[t]Also at Institute of Theoretical Physics, Ilia State University, Tbilisi, Georgia.
[u]Also at CERN, Geneva, Switzerland.
[v]Also at Georgian Technical University (GTU),Tbilisi, Georgia.
[w]Also at Manhattan College, New York NY, USA.
[x]Also at Hellenic Open University, Patras, Greece.
[y]Also at Institute of Physics, Academia Sinica, Taipei, Taiwan.
[z]Also at LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France.
[aa]Also at Academia Sinica Grid Computing, Institute of Physics, Academia Sinica, Taipei, Taiwan.
[bb]Also at School of Physics, Shandong University, Shandong, China.
[cc]Also at Moscow Institute of Physics and Technology State University, Dolgoprudny, Russia.
[dd]Also at Section de Physique, Université de Genève, Geneva, Switzerland.
[ee]Also at International School for Advanced Studies (SISSA), Trieste, Italy.
[ff]Also at Department of Physics and Astronomy, University of South Carolina, Columbia SC, USA.
[gg]Also at School of Physics and Engineering, Sun Yat-sen University, Guangzhou, China.
[hh]Also at Faculty of Physics, M.V.Lomonosov Moscow State University, Moscow, Russia.
[ii]Also at National Research Nuclear University MEPhI, Moscow, Russia.
[jj]Also at Department of Physics, Stanford University, Stanford CA, USA.
[kk]Also at Institute for Particle and Nuclear Physics, Wigner Research Centre for Physics, Budapest, Hungary.
[ll]Also at University of Malaya, Department of Physics, Kuala Lumpur, Malaysia.