Search for a Structure in the $B_s^0\pi^\pm$ Invariant Mass Spectrum with the ATLAS Experiment

M. Aaboud *et al.**
(ATLAS Collaboration)

(Received 8 February 2018; revised manuscript received 29 March 2018; published 18 May 2018)

A search for the narrow structure, $X(5568)$, reported by the D0 Collaboration in the decay sequence $X \to B_s^0\pi^\pm$, $B_s^0 \to J/\psi\phi$, is presented. The analysis is based on a data sample recorded with the ATLAS detector at the LHC corresponding to 4.9 fb^{-1} of pp collisions at 7 TeV and 19.5 fb^{-1} at 8 TeV. No significant signal was found. Upper limits on the number of signal events, with properties corresponding to those reported by D0, and on the X production rate relative to B_s^0 mesons, ρ_X, were determined at 95% confidence level. The results are $N(X) < 382$ and $\rho_X < 0.015$ for B_s^0 mesons with transverse momenta above 10 GeV, and $N(X) < 356$ and $\rho_X < 0.016$ for transverse momenta above 15 GeV. Limits are also set for potential $B_s^0\pi^\pm$ resonances in the mass range 5550 to 5700 MeV.

DOI: 10.1103/PhysRevLett.120.202007

The D0 Collaboration reported evidence of a narrow structure, $X(5568)$, in the decay $X \to B_s^0\pi^\pm$ with $B_s^0 \to J/\psi\phi$ in proton-antiproton collisions at a center-of-mass energy of $\sqrt{s} = 1.96$ TeV at the Tevatron collider [1]. The structure was interpreted as a tetraquark with four different quark flavors: b, s, u, and d. The mass and natural width of this state were fitted to be $m = 5567.8 \pm 2.9(\text{stat})^{+0.9}_{-1.9}(\text{syst})$ and $\Gamma = 21.9 \pm 6.4(\text{stat})^{+5.0}_{-2.5}(\text{syst})$ MeV, respectively, and the signal significance is 5.1σ. The ratio ρ_X of the yield of $X(5568)$ to the yield of the B_s^0 meson for a transverse momentum range $10 < p_T(B_s^0) < 30$ GeV was measured to be $0.086 \pm 0.019(\text{stat}) \pm 0.014(\text{syst})$. The result initiated a discussion of the nature of the new state and prospects for observation of other tetraquark hadrons [2–6]. Recently, the D0 Collaboration reported further evidence for the resonance $X(5568)$ [7] in the decay sequence $X \to B_s^0\pi^\pm$, $B_s^0 \to \mu^\mp\nu D_s{}^\pm$, $D_s{}^\pm \to \phi\pi^\pm$, which is consistent with their previous measurement [1]. However, searches for $X(5568)$ in decays to $B_s^0\pi^\pm$, $B_s^0 \to J/\psi\phi$ performed by the LHCb [8] and CMS [9] Collaborations in proton-proton (pp) collisions at the LHC and by the CDF Collaboration [10] at the Tevatron, revealed no signal. The upper limits $\rho_X < 0.024$ [LHCb, $p_T(B_s^0) > 10$ GeV], $\rho_X < 0.011$ [CMS, $p_T(B_s^0) > 10$ GeV] and $\rho_X < 0.010$ [CMS, $p_T(B_s^0) > 15$ GeV] at 95% confidence level (C.L.) were determined within the acceptances of the LHCb and CMS experiments. CDF set an upper limit $\rho_X < 0.067$ at 95% C.L. within a kinematic range similar to that of D0 [1].

In this Letter, a search for the $X(5568)$ state by the ATLAS experiment at the LHC is presented (B_s^0 refers to both the B_s^0 and $\bar{B}_s^0$ mesons). The B_s^0 mesons are reconstructed in their decays to $J/\psi(\mu^+\mu^-)\phi(K^+K^-)$. The analysis is based on a combined sample of pp collision data at $\sqrt{s} = 7$ and 8 TeV corresponding to integrated luminosities of 4.9 and 19.5 fb^{-1}, respectively. The ATLAS detector [11] covers nearly the entire solid angle around the collision point with layers of tracking detectors, calorimeters, and muon chambers. The muon and tracking systems are of particular importance in the reconstruction of B mesons. The inner tracking detector (ID) consists of a silicon pixel detector, a silicon microstrip detector and a transition radiation tracker. The muon spectrometer (MS) surrounds the calorimeters and consists of three large superconducting toroids with eight coils each, a system of tracking chambers, and detectors for triggering. To study the detector response, to estimate backgrounds, and to model systematic effects, 12×10^6 Monte Carlo (MC) simulated $B_s^0 \to J/\psi\phi$ and 1×10^6 $B_s^0\pi^\pm$ events were generated using Pythia 8.183 [12,13] tuned with ATLAS data [14]. Multiple overlaid proton-proton collisions (pileup) were simulated with Pythia soft QCD processes. The detector response was simulated using the ATLAS simulation framework [15] based on GEANT4 [16]. The MC events were weighted to reproduce the same pileup and trigger conditions as in the data. As in the D0 analysis [1], the $B_s^0\pi^\pm$ resonance was generated using the Breit-Wigner (BW) parametrization appropriate for an S-wave two-body decay near threshold:

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

$$F_{\mathrm{BW}}(m(B_s^0\pi^\pm), m_X, \Gamma_X) = \frac{m(B_s^0\pi^\pm) m_X \Gamma(m(B_s^0\pi^\pm), \Gamma_X)}{(m_X^2 - m^2(B_s^0\pi^\pm))^2 + m_X^2 \Gamma^2(m(B_s^0\pi^\pm), \Gamma_X)}, \quad (1)$$

where $m(B_s^0\pi^\pm)$ is the invariant mass of the $B_s^0\pi^\pm$ candidate and m_X and Γ_X are the mass and the natural width of the resonance. The mass-dependent width is $\Gamma(m(B_s^0\pi^\pm), \Gamma_X) = \Gamma_X \times (q_1/q_0)$, where q_1 and q_0 are the magnitudes of the three-vector momenta of the B_s^0 meson in the rest frame of the $B_s^0\pi^\pm$ system at the invariant masses equal to $m(B_s^0\pi^\pm)$ and m_X, respectively. The mass and the width were set to $m_X = 5567.8$ MeV and $\Gamma_X = 21.9$ MeV, as reported in Ref. [1]. The events were selected by the dimuon triggers [17] based on identification of a $J/\psi \to \mu^+\mu^-$ decay, with p_T thresholds of either 4 or 6 GeV, with both symmetric, (4, 4) or (6, 6) GeV, and asymmetric, (4,6) GeV, combinations. In addition, each event must contain at least one reconstructed primary vertex (PV), formed from at least six ID tracks. The selection of J/ψ and $\phi \to K^+K^-$ candidates is identical to the one described in detail in Ref. [18]. Candidates for $B_s^0 \to J/\psi\phi$ decays are selected by fitting the tracks for each combination of $J/\psi \to \mu^+\mu^-$ and $\phi \to K^+K^-$ to a common vertex. The fit is further constrained by fixing the invariant mass of the two muon tracks to the J/ψ mass [19]. A quadruplet of tracks is accepted for further analysis if the vertex fit has a $\chi^2/\mathrm{d.o.f.} < 3$. For each B_s^0 meson candidate the proper decay time t is extracted using the method described in Ref. [18]. Events with $t > 0.2$ ps are selected to reduce the background from the events with a J/ψ produced directly in the pp collision. If there is more than one accepted B_s^0 candidate in the event, the candidate with the lowest $\chi^2/\mathrm{d.o.f.}$ of the vertex fit is selected. For the selected events the average number of proton-proton interactions per bunch crossing is 21, necessitating a choice of the best candidate for the PV at which the B_s^0 meson is produced. The variable used is the three-dimensional impact parameter d_0, which is calculated as the distance between the line extrapolated from the reconstructed B_s^0 meson vertex in the direction of the B_s^0 momentum, and each PV candidate. The chosen PV is the one with the smallest d_0. Using MC simulation it was shown that the fraction of B_s^0 candidates that are assigned the wrong PV is less than 1% [18] and that the corresponding effect on the results is negligible. Finally, a requirement that the B_s^0 transverse momentum is greater than 10 GeV is applied. Figure 1 shows the reconstructed $J/\psi K^+K^-$ mass distribution and the result of an extended unbinned maximum-likelihood fit in the range (5150–5650) MeV, in which the signal is modeled by a sum of two Gaussian distributions and an exponential function is used to model the combinatorial background. The observed signal width is consistent with MC simulation. The fitted B_s^0 mass is $m_{\mathrm{fit}}(B_s^0) = 5366.6 \pm 0.1$ (stat) MeV, in agreement with the world average value 5366.89 ± 0.19 MeV [19]. For further investigation, only candidates with a reconstructed mass in the signal region 5346.6–5386.6 MeV are included, which gives $N(B_s^0) = 52750 \pm 280$ (stat) candidates.

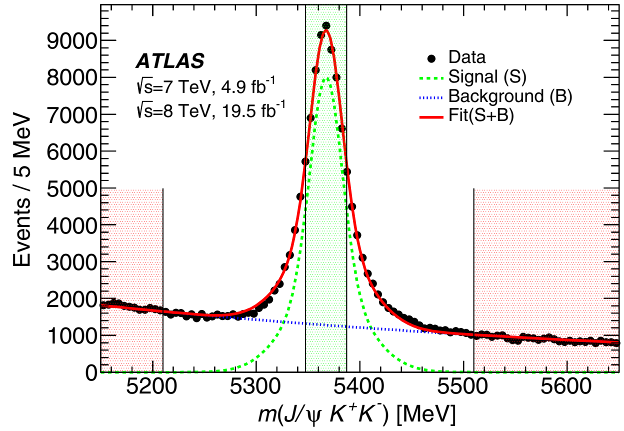

FIG. 1. The invariant mass distribution for $B_s^0 \to J/\psi\phi$ candidates satisfying the selection criteria. Data are shown as points and results of fits to signal (dashed), background (dotted), and the total fit (solid) are shown as lines. The two outer (red) shaded bands and the central (green) shaded band represent the mass sidebands and the signal region of B_s^0 meson candidates, respectively.

The $B_s^0\pi^\pm$ candidates are constructed by combining each of the tracks forming the selected PV with the selected B_s^0 candidate. Tracks that were already used to reconstruct the B_s^0 candidate and tracks identified as leptons (e or μ) are excluded, as well as tracks with transverse momentum $p_T < 500$ MeV. This p_T selection was chosen to maximize the ratio of the $B_s^0\pi^\pm$ signal to the background, based on MC simulation. Assigning the pion mass hypothesis to the tracks that pass these selection criteria, the mass $m(B_s^0\pi^\pm)$ is calculated as $m(J/\psi KK\pi^\pm) - m(J/\psi KK) + m_{\mathrm{fit}}(B_s^0)$, where $m_{\mathrm{fit}}(B_s^0) = 5366.6$ MeV. On average there are 1.8 $B_s^0\pi^\pm$ candidates in each selected event and all are retained for the analysis. A systematic study has shown that the effect on the results due to multiple candidates is negligible. The mass distribution of $B_s^0\pi^\pm$ candidates is fitted using an extended unbinned maximum-likelihood method. The probability density function (PDF) for the background component is defined as a threshold function:

$$F_{\mathrm{bck}}(m(B_s^0\pi^\pm)) = \left(\frac{m(B_s^0\pi^\pm) - m_{\mathrm{thr}}}{n}\right)^a \times \exp\left(\sum_{i=1}^{4} p_i \left(\frac{m(B_s^0\pi^\pm) - m_{\mathrm{thr}}}{n}\right)^i\right), \quad (2)$$

where $m_{\mathrm{thr}} = m_{\mathrm{fit}}(B_s^0) + m_\pi$ and n, a, and p_i are free parameters of the fit. The background PDF was tested using

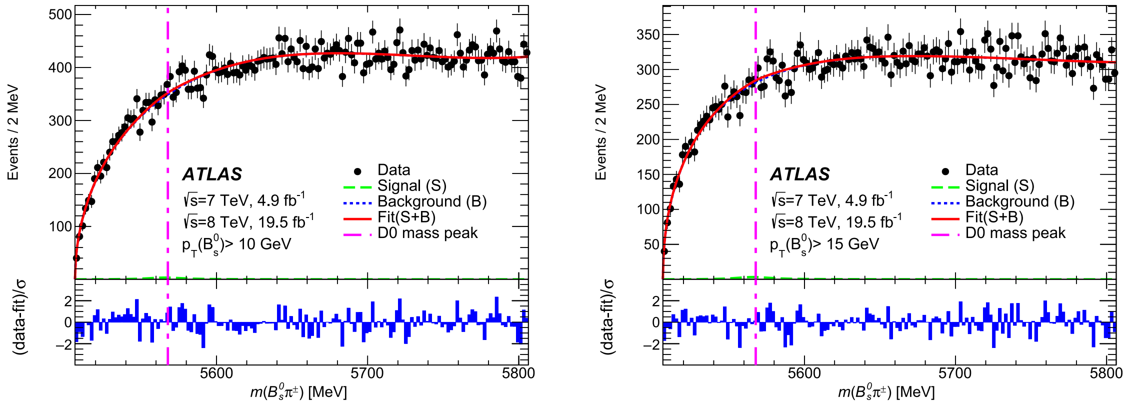

FIG. 2. Results of the fit to the $B_s^0\pi^\pm$ mass distribution for candidates with $p_T(B_s^0) > 10$ GeV (left) and $p_T(B_s^0) > 15$ GeV (right). The bottom panels show the difference between each data point and the fit divided by the statistical uncertainty of that point.

events with no real $B_s^0\pi^\pm$ candidates from two categories. The first background sample contains data events where $B_s^0\pi^\pm$ candidates are formed using "fake" B_s^0 mesons from the mass sidebands, shown in Fig. 1 by red shaded bands, defined as $5150 < m(J/\psi K^+K^-) < 5210$ MeV and $5510 < m(J/\psi K^+K^-) < 5650$ MeV. The second background sample is modeled using MC events containing only B_s^0 mesons not originating from the $B_s^0\pi^\pm$ signal, tuned to reproduce the B_s^0 transverse momentum distribution in data. In these events the B_s^0 meson is combined with each of the tracks originating from the selected PV. The first sample is normalized to the fitted number of B_s^0 background events in the B_s^0 mass signal region 5346.6–5386.6 MeV, while the second sample is normalized to the fitted number of B_s^0 signal events in the same region. The sum of these two distributions is consistent with the distribution of the data. The function in Eq. (2) describes both background distributions as well as their sum within uncertainties. The signal PDF $F_{\rm sig}(m(B_s^0\pi^\pm))$ is defined as a convolution of an S-wave Breit-Wigner PDF, defined in Eq. (1), and the detector resolution represented by a Gaussian function with a width that is calculated individually for each $B_s^0\pi^\pm$ candidate from the tracking and vertexing error matrices. Using MC and data samples, it has been verified that the per candidate mass resolutions are the same for the $B_s^0\pi^\pm$ signal and for the background events passing the selection criteria. The average resolution for the $B_s^0\pi^\pm$ signal, with the mass and width corresponding to those of the structure reported by the D0 Collaboration ($m_X = 5567.8$ MeV and $\Gamma_X = 21.9$ MeV), is 3.2 MeV. The full probability function used is

$$F(m(B_s^0\pi^\pm)) = N(X)F_{\rm sig}(m(B_s^0\pi^\pm)) + [N_{\rm can} - N(X)]F_{\rm bck}(m(B_s^0\pi^\pm)), \quad (3)$$

where $N(X)$ is the number of signal events and $N_{\rm can}$ is the number of all selected $B_s^0\pi^\pm$ candidates. The signal mass and width are fixed to the central values reported by the D0 Collaboration. Following other experiments, fits are performed for two subsets of $B_s^0\pi^\pm$ candidates, first with $p_T(B_s^0) > 10$ GeV and second with $p_T(B_s^0) > 15$ GeV. The results of the fits are shown in Fig. 2 and summarized in Table I. No significant $X(5568)$ signal is observed. Additional selections such as cuts on the angle between the momenta of the B_s^0 and $\pi^\pm$ candidates were investigated and did not produce evidence of a signal. These were found to introduce peaking background so are not included in the analysis. The yields $N(X)$ and $N(B_s^0)$ obtained from the fits are used to evaluate the X production rate relative to B_s^0, within the ATLAS acceptance, using the formula

$$\rho_X \equiv \frac{\sigma(pp \to X + \text{anything}) \times \mathcal{B}(X \to B_s^0\pi^\pm)}{\sigma(pp \to B_s^0 + \text{anything})} = \frac{N(X)}{N(B_s^0)} \times \frac{1}{\epsilon^{\rm rel}(X)}, \quad (4)$$

where σ represents the production cross section for each of the particles, within the ATLAS acceptance, and the relative efficiency $\epsilon^{\rm rel}(X) = \epsilon(X)/\epsilon(B_s^0)$ is the selection efficiency for the state X, decaying to $B_s^0\pi^\pm$, relative to that for the B_s^0 meson and accounts for the reconstruction and selection

TABLE I. Yields of B_s^0 and $X(5568)$ candidates obtained from the fits to the B_s^0 and $B_s^0\pi^\pm$ candidate mass distributions, with statistical uncertainties. The values given for $N(B_s^0)$ are those inside the B_s^0 signal window. The reported values for $X(5568)$ are obtained from the fits with signal mass and width parameters fixed to those reported by the D0 Collaboration. The relative efficiencies $\epsilon^{\rm rel}(X)$ and their uncertainties are described in the text.

$N(B_s^0)/10^3$	$p_T(B_s^0) > 10$ GeV	52.75 ± 0.28
	$p_T(B_s^0) > 15$ GeV	43.46 ± 0.24
$N(X)$	$p_T(B_s^0) > 10$ GeV	60 ± 140
	$p_T(B_s^0) > 15$ GeV	-30 ± 150
$\epsilon^{\rm rel}(X)$	$p_T(B_s^0) > 10$ GeV	0.53 ± 0.09
	$p_T(B_s^0) > 15$ GeV	0.60 ± 0.10

efficiency of the companion pion, including the soft pion acceptance.

The relative efficiency, $\epsilon^{\rm rel}(X)$, was determined using MC simulation of events containing $X \to B_s^0\pi^\pm$ and B_s^0 decays. In the ratio, the acceptance of the B_s^0 decay cancels, so the value to be determined is the pion reconstruction efficiency for $B_s^0\pi^\pm$ events in which the B_s^0 meson satisfies acceptance, reconstruction, and selection criteria. Based on MC events, $\epsilon^{\rm rel}(X)$ is determined as a function of $p_T(B_s^0)$ and of $m(B_s^0\pi^\pm)$. Using an MC-based function, the acceptance is determined individually for each $B_s^0\pi^\pm$ candidate, based on its measured values of $p_T(B_s^0)$ and $m(B_s^0\pi^\pm)$. The acceptance ratio, $\epsilon^{\rm rel}(X)$, is calculated as an average over the events included in the $m(B_s^0\pi^\pm)$ interval within which the search for a resonance is performed. The width of this interval is defined by a BW function convolved with the mass resolution function, with the start and end points of the range chosen to include 99% of the signal events. The uncertainty of $\epsilon^{\rm rel}(X)$ is calculated by varying the fitted parameters of the MC-based function used to describe the acceptance as a function of $p_T(B_s^0)$ within their uncertainties. Small variations of this function due to the pseudorapidity of the B_s^0 were investigated and are included in the systematic uncertainties. The error also includes the uncertainty in the number of data events used in the average and the statistical uncertainty in the $p_T(B_s^0)$ distribution of these events. The error in the pion reconstruction efficiency, arising from uncertainties in the amount of ID material, is found to have a negligible effect on ρ_X.

As no significant signal is observed, corresponding to the properties of the $X(5568)$ as reported by Ref. [1], upper limits are determined for the number of $B_s^0\pi^\pm$ signal events, $N(X)$, and for the relative production rate, ρ_X. These are calculated using the asymptotic approximation from the profile likelihood formalism [20] based on the CL_s frequentist method [21]. To establish the limit on the number of $B_s^0\pi^\pm$ signal events, the PDF models for signal and background, defined respectively by Eqs. (1) and (2), are used as inputs to the CL_s method. Without systematic uncertainties, the extracted upper limits at 95% C.L. are $N(X) < 264$ for $p_T(B_s^0) > 10$ GeV and $N(X) < 213$ for $p_T(B_s^0) > 15$ GeV. Systematic uncertainties affecting these limits are included in the determination of $N(X)$. To obtain results that can be compared to the state $X(5568)$ reported by the D0 Collaboration, systematic uncertainties are assigned by varying the values of m_X and Γ_X independently within Gaussian constraints, with uncertainties equal to those quoted in Ref. [1]. The default model of the X resonance, which is assumed to be spinless, is changed to a BW P-wave resonance. To include the systematic uncertainty due to the modeling of the background, the default PDF of Eq. (2) is replaced by a seventh-order Chebyshev polynomial, allowing more free parameters in the fit. For the detector resolution, the default per-candidate mass resolution model is replaced by the sum of three Gaussian functions with a common mean. The parameters used are determined from the $B_s^0\pi^\pm$ MC sample. Using these alternative models, upper limits that include systematic uncertainties are extracted, leading to values $N(X) < 382$ for $p_T(B_s^0) > 10$ GeV and $N(X) < 356$ for $p_T(B_s^0) > 15$ GeV. To extract the upper limits on ρ_X additional systematic uncertainties are included. The calculation of ρ_X also depends on the precision of extracting the number of B_s^0 signal events and the relative efficiency $\epsilon^{\rm rel}(X)$. To include these uncertainties, the central values and the uncertainties of the number of B_s^0 signal events and $\epsilon^{\rm rel}(X)$ are used to construct Gaussian constraints, which are included as additional inputs to the CL_s method. Both the statistical and systematic uncertainties are included after being summed in quadrature. For the B_s^0 signal, the default fit model of two Gaussian functions is changed to a triple Gaussian function and the change in the result is taken as a systematic uncertainty. The uncertainty due to the proper decay time requirement $t > 0.2$ ps was estimated by varying it within the time resolution and found to be negligible. The resulting upper limits at 95% C.L. are $\rho_X < 0.015$ for $p_T(B_s^0) > 10$ GeV and $\rho_X < 0.016$ for $p_T(B_s^0) > 15$ GeV. A hypothesis test is performed for the presence of a $B_s^0\pi^\pm$ peak for every 5 MeV step in its mass from 5550 to 5700 MeV, assuming a resonant state as described by Eq. (1), with a BW width of 21.9 MeV [1] and $p_T(B_s^0) >$ 10 GeV. For each $B_s^0\pi^\pm$ mass tested, $\epsilon^{\rm rel}(X)$ is calculated using the same method as for $X(5568)$. The values of $\epsilon^{\rm rel}(X)$ vary from 0.50 to 0.55 in the search interval. The upper limit of ρ_X at 95% C.L. is determined for each tested

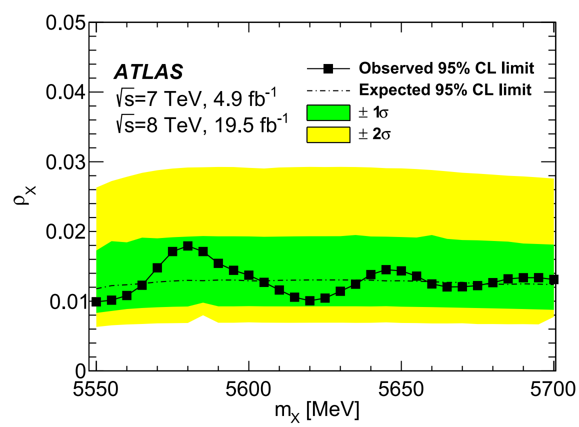

FIG. 3. Upper limits on ρ_X at 95% C.L. (black squares connected by line) at different masses of a hypothetical resonant state X decaying to $B_s^0\pi^\pm$, for events with $p_T(B_s^0) > 10$ GeV. A BW width of $21.9 \pm 6.4(\text{stat})^{+5.0}_{-2.5}(\text{syst})$ MeV is assumed, as reported by D0. The values include systematic uncertainties. The expected 95% C.L. upper limits (central black dot-dashed line) with $\pm1\sigma$ (green) and $\pm2\sigma$ (yellow) uncertainty bands on ρ_X are shown as a function of the assumed resonance mass.

mass. The same systematic uncertainties as in the determination of ρ_X for the state $X(5568)$ are included, with the exception of the $X(5568)$ mass uncertainty. The median expected upper limit at 95% C.L. as a function of the $B_s^0\pi^\pm$ mass is also determined with $\pm 1\sigma$ and $\pm 2\sigma$ error bands. The results are shown in Fig. 3.

In conclusion, a search for a new state $X(5568)$ decaying to $B_s^0\pi^\pm$, with properties as reported by the D0 Collaboration, was performed by the ATLAS experiment at the LHC, using 4.9 fb^{-1} of pp collision data at 7 TeV and 19.5 fb^{-1} at 8 TeV. No significant signal was found. Within the acceptance in which this analysis is performed, upper limits on the number of signal events, $N(X)$, and on the X production rate relative to B_s^0 mesons, were determined at 95% C.L., resulting in $N(X) < 382$ and $\rho_X < 0.015$ for $p_T(B_s^0) > 10$ GeV, and $N(X) < 356$ and $\rho_X < 0.016$ for $p_T(B_s^0) > 15$ GeV. Limits are also set for potential $B_s^0\pi^\pm$ resonances in the mass range from 5550 to 5700 MeV. Across the full range, the upper limit set on ρ_X at 95% C.L. varies between 0.010 and 0.018, and does not exceed the $\pm 1\sigma$ error band from the expected limit.

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 and DNSRC, Denmark; IN2P3-CNRS, CEA-DRF/IRFU, France; SRNSFG, Georgia; BMBF, HGF, and MPG, Germany; GSRT, Greece; RGC, Hong Kong SAR, China; ISF, I-CORE and Benoziyo Center, Israel; INFN, Italy; MEXT and JSPS, Japan; CNRST, Morocco; NWO, Netherlands; RCN, Norway; MNiSW and NCN, Poland; FCT, Portugal; MNE/IFA, Romania; MES of Russia and NRC KI, Russian Federation; JINR; MESTD, Serbia; MSSR, Slovakia; ARRS and MIZŠ, Slovenia; DST/NRF, South Africa; MINECO, Spain; SRC and Wallenberg Foundation, Sweden; SERI, SNSF and Cantons of Bern and Geneva, Switzerland; MOST, Taiwan; TAEK, Turkey; STFC, United Kingdom; DOE and NSF, USA. In addition, individual groups and members have received support from BCKDF, the Canada Council, CANARIE, CRC, Compute Canada, FQRNT, and the Ontario Innovation Trust, Canada; EPLANET, ERC, ERDF, FP7, Horizon 2020 and Marie Skłodowska-Curie Actions, European Union; Investissements d'Avenir Labex and Idex, ANR, Région Auvergne and Fondation Partager le Savoir, France; DFG and AvH Foundation, Germany; Herakleitos, Thales and Aristeia programmes co-financed by EU-ESF and the Greek NSRF; BSF, GIF and Minerva, Israel; BRF, Norway; CERCA Programme Generalitat de Catalunya, Generalitat Valenciana, Spain; the Royal Society and Leverhulme Trust, United Kingdom. The crucial computing support from all WLCG partners is acknowledged gratefully, in particular from CERN, 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), the Tier-2 facilities worldwide and large non-WLCG resource providers. Major contributors of computing resources are listed in Ref. [22].

[1] D0 Collaboration, Evidence for a $B_s^0\pi^\pm$ State, Phys. Rev. Lett. **117**, 022003 (2016).

[2] W. Wang and R. Zhu, Can $X(5568)$ be a tetraquark state? Chin. Phys. C **40**, 093101 (2016).

[3] W. Chen, H. X. Chen, X. Liu, T. G. Steele, and S. L. Zhu, Decoding the $X(5568)$ as a Fully Open-Flavor $su\bar{b}\bar{d}$ Tetraquark State, Phys. Rev. Lett. **117**, 022002 (2016).

[4] Y.-R. Liu, X. Liu, and S.-L. Zhu, $X(5568)$ and its partner states, Phys. Rev. D **93**, 074023 (2016).

[5] Z.-G. Wang, Analysis of the strong decay $X(5568) \to B_s^0\pi^+$ with QCD sum rules, Eur. Phys. J. C **76**, 279 (2016).

[6] F. Stancu, $X(5568)$ as a $su\bar{d}\bar{b}$ tetraquark in a simple quark model, J. Phys. G **43**, 105001 (2016).

[7] D0 Collaboration, Study of the $X^\pm(5568)$ state with semileptonic decays of the B_s^0 meson, arXiv:1712.10176.

[8] LHCb Collaboration, Search for Structure in the $B_s^0\pi^\pm$ Invariant Mass Spectrum, Phys. Rev. Lett. **117**, 152003 (2016).

[9] CMS Collaboration, this issue, Search for the $X(5568)$ state decaying into $B_s^0\pi^\pm$ in proton–proton collisions at $\sqrt{s} = 8$ TeV, Phys. Rev. Lett. **120**, 202005 (2018).

[10] CDF Collaboration, preceding Letter, A Search for the exotic meson $X(5568)$ with the Collider Detector at Fermilab, Phys. Rev. Lett. **120**, 202006 (2018).

[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, ATL-PHYS-PUB-2011-009, 2011, https://cds.cern.ch/record/1363300.

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

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

[17] ATLAS Collaboration, Performance of the ATLAS muon trigger in pp collisions at $\sqrt{s} = 8$ TeV, Eur. Phys. J. C **75**, 120 (2015).

[18] ATLAS Collaboration, Measurement of the CP-violating phase ϕ_s and the B_s^0 meson decay width difference with $B_s^0 \to J/\psi\phi$ decays in ATLAS, J. High Energy Phys. 08 (2016) 147.

[19] C. Patrignani (Particle Data Group), Review of particle physics, Chin. Phys. C **40**, 100001 (2016).

[20] G. Cowan, K. Cranmer, E. Gross, and O. Vitells, Asymptotic formulae for likelihood-based tests of new physics, Eur. Phys. J. C **71**, 1554 (2011); Erratum, Eur. Phys. J. C **73**, 2501 (2013).

[21] A. L. Read, Presentation of search results: the CL_S technique, J. Phys. G **28**, 2693 (2002).

[22] ATLAS Collaboration, ATLAS Computing Acknowledgements, Report No. ATL-GEN-PUB-2016-002, https://cds.cern.ch/record/2202407.

M. Aaboud,[137d] G. Aad,[88] B. Abbott,[115] O. Abdinov,[12,a] B. Abeloos,[119] S. H. Abidi,[161] O. S. AbouZeid,[139] N. L. Abraham,[151] H. Abramowicz,[155] H. Abreu,[154] Y. Abulaiti,[148a,148b] B. S. Acharya,[167a,167b,b] S. Adachi,[157] L. Adamczyk,[41a] J. Adelman,[110] M. Adersberger,[102] T. Adye,[133] A. A. Affolder,[139] Y. Afik,[154] C. Agheorghiesei,[28c] J. A. Aguilar-Saavedra,[128a,128f] S. P. Ahlen,[24] F. Ahmadov,[68,c] G. Aielli,[135a,135b] S. Akatsuka,[71] H. Akerstedt,[148a,148b] T. P. A. Åkesson,[84] E. Akilli,[52] A. V. Akimov,[98] G. L. Alberghi,[22a,22b] J. Albert,[172] P. Albicocco,[50] M. J. Alconada Verzini,[74] S. Alderweireldt,[108] M. Aleksa,[32] I. N. Aleksandrov,[68] C. Alexa,[28b] G. Alexander,[155] T. Alexopoulos,[10] M. Alhroob,[115] B. Ali,[130] M. Aliev,[76a,76b] G. Alimonti,[94a] J. Alison,[33] S. P. Alkire,[38] B. M. M. Allbrooke,[151] B. W. Allen,[118] P. P. Allport,[19] A. Aloisio,[106a,106b] A. Alonso,[39] F. Alonso,[74] C. Alpigiani,[140] A. A. Alshehri,[56] M. I. Alstaty,[88] B. Alvarez Gonzalez,[32] D. Álvarez Piqueras,[170] M. G. Alviggi,[106a,106b] B. T. Amadio,[16] Y. Amaral Coutinho,[26a] C. Amelung,[25] D. Amidei,[92] S. P. Amor Dos Santos,[128a,128c] S. Amoroso,[32] C. Anastopoulos,[141] L. S. Ancu,[52] N. Andari,[19] T. Andeen,[11] C. F. Anders,[60b] J. K. Anders,[18] K. J. Anderson,[33] A. Andreazza,[94a,94b] V. Andrei,[60a] S. Angelidakis,[37] I. Angelozzi,[109] A. Angerami,[38] A. V. Anisenkov,[111,d] N. Anjos,[13] A. Annovi,[126a] C. Antel,[60a] M. Antonelli,[50] A. Antonov,[100,a] D. J. Antrim,[166] F. Anulli,[134a] M. Aoki,[69] L. Aperio Bella,[32] G. Arabidze,[93] Y. Arai,[69] J. P. Araque,[128a] V. Araujo Ferraz,[26a] A. T. H. Arce,[48] R. E. Ardell,[80] F. A. Arduh,[74] J-F. Arguin,[97] S. Argyropoulos,[66] M. Arik,[20a] A. J. Armbruster,[32] L. J. Armitage,[79] O. Arnaez,[161] H. Arnold,[51] M. Arratia,[30] O. Arslan,[23] A. Artamonov,[99,a] G. Artoni,[122] S. Artz,[86] S. Asai,[157] N. Asbah,[45] A. Ashkenazi,[155] L. Asquith,[151] K. Assamagan,[27] R. Astalos,[146a] M. Atkinson,[169] N. B. Atlay,[143] K. Augsten,[130] G. Avolio,[32] B. Axen,[16] M. K. Ayoub,[35a] G. Azuelos,[97,e] A. E. Baas,[60a] M. J. Baca,[19] H. Bachacou,[138] K. Bachas,[76a,76b] M. Backes,[122] P. Bagnaia,[134a,134b] M. Bahmani,[42] H. Bahrasemani,[144] J. T. Baines,[133] M. Bajic,[39] O. K. Baker,[179] P. J. Bakker,[109] D. Bakshi Gupta,[82] E. M. Baldin,[111,d] P. Balek,[175] F. Balli,[138] W. K. Balunas,[124] E. Banas,[42] A. Bandyopadhyay,[23] Sw. Banerjee,[176,f] A. A. E. Bannoura,[177] L. Barak,[155] E. L. Barberio,[91] D. Barberis,[53a,53b] M. Barbero,[88] T. Barillari,[103] M-S Barisits,[65] J. T. Barkeloo,[118] T. Barklow,[145] N. Barlow,[30] S. L. Barnes,[36b] B. M. Barnett,[133] R. M. Barnett,[16] Z. Barnovska-Blenessy,[36c] A. Baroncelli,[136a] G. Barone,[25] A. J. Barr,[122] L. Barranco Navarro,[170] F. Barreiro,[85] J. Barreiro Guimarães da Costa,[35a] R. Bartoldus,[145] A. E. Barton,[75] P. Bartos,[146a] A. Basalaev,[125] A. Bassalat,[119,g] R. L. Bates,[56] S. J. Batista,[161] J. R. Batley,[30] M. Battaglia,[139] M. Bauce,[134a,134b] F. Bauer,[138] K. T. Bauer,[166] H. S. Bawa,[145,h] J. B. Beacham,[113] M. D. Beattie,[75] T. Beau,[83] P. H. Beauchemin,[165] P. Bechtle,[23] H. P. Beck,[18,i] H. C. Beck,[58] K. Becker,[122] M. Becker,[86] C. Becot,[112] A. J. Beddall,[20e] A. Beddall,[20b] V. A. Bednyakov,[68] M. Bedognetti,[109] C. P. Bee,[150] T. A. Beermann,[32] M. Begalli,[26a] M. Begel,[27] J. K. Behr,[45] A. S. Bell,[81] G. Bella,[155] L. Bellagamba,[22a] A. Bellerive,[31] M. Bellomo,[154] K. Belotskiy,[100] O. Beltramello,[32] N. L. Belyaev,[100] O. Benary,[155,a] D. Benchekroun,[137a] M. Bender,[102] N. Benekos,[10] Y. Benhammou,[155] E. Benhar Noccioli,[179] J. Benitez,[66] D. P. Benjamin,[48] M. Benoit,[52] J. R. Bensinger,[25] S. Bentvelsen,[109] L. Beresford,[122] M. Beretta,[50] D. Berge,[109] E. Bergeaas Kuutmann,[168] N. Berger,[5] L. J. Bergsten,[25] J. Beringer,[16] S. Berlendis,[57] N. R. Bernard,[89] G. Bernardi,[83] C. Bernius,[145] F. U. Bernlochner,[23] T. Berry,[80] P. Berta,[86] C. Bertella,[35a] G. Bertoli,[148a,148b] I. A. Bertram,[75] C. Bertsche,[45] G. J. Besjes,[39] O. Bessidskaia Bylund,[148a,148b] M. Bessner,[45] N. Besson,[138] A. Bethani,[87] S. Bethke,[103] A. Betti,[23] A. J. Bevan,[79] J. Beyer,[103] R. M. Bianchi,[127] O. Biebel,[102] D. Biedermann,[17] R. Bielski,[87] K. Bierwagen,[86] N. V. Biesuz,[126a,126b] M. Biglietti,[136a] T. R. V. Billoud,[97] H. Bilokon,[50] M. Bindi,[58] A. Bingul,[20b] C. Bini,[134a,134b] S. Biondi,[22a,22b] T. Bisanz,[58] C. Bittrich,[47] D. M. Bjergaard,[48] J. E. Black,[145] K. M. Black,[24] R. E. Blair,[6] T. Blazek,[146a] I. Bloch,[45] C. Blocker,[25] A. Blue,[56] U. Blumenschein,[79] Dr. Blunier,[34a] G. J. Bobbink,[109] V. S. Bobrovnikov,[111,d] S. S. Bocchetta,[84] A. Bocci,[48] C. Bock,[102] M. Boehler,[51] D. Boerner,[177] D. Bogavac,[102] A. G. Bogdanchikov,[111] C. Bohm,[148a] V. Boisvert,[80] P. Bokan,[168,j] T. Bold,[41a] A. S. Boldyrev,[101] A. E. Bolz,[60b] M. Bomben,[83] M. Bona,[79] J. S. Bonilla,[118] M. Boonekamp,[138] A. Borisov,[132] G. Borissov,[75] J. Bortfeldt,[32] D. Bortoletto,[122] V. Bortolotto,[62a] D. Boscherini,[22a] M. Bosman,[13] J. D. Bossio Sola,[29] J. Boudreau,[127] E. V. Bouhova-Thacker,[75] D. Boumediene,[37] C. Bourdarios,[119] S. K. Boutle,[56] A. Boveia,[113] J. Boyd,[32] I. R. Boyko,[68] A. J. Bozson,[80] J. Bracinik,[19]

A. Brandt,[8] G. Brandt,[177] O. Brandt,[60a] F. Braren,[45] U. Bratzler,[158] B. Brau,[89] J. E. Brau,[118] W. D. Breaden Madden,[56] K. Brendlinger,[45] A. J. Brennan,[91] L. Brenner,[109] R. Brenner,[168] S. Bressler,[175] D. L. Briglin,[19] T. M. Bristow,[49] D. Britton,[56] D. Britzger,[60b] I. Brock,[23] R. Brock,[93] G. Brooijmans,[38] T. Brooks,[80] W. K. Brooks,[34b] E. Brost,[110] J. H Broughton,[19] P. A. Bruckman de Renstrom,[42] D. Bruncko,[146b] A. Bruni,[22a] G. Bruni,[22a] L. S. Bruni,[109] S. Bruno,[135a,135b] BH Brunt,[30] M. Bruschi,[22a] N. Bruscino,[127] P. Bryant,[33] L. Bryngemark,[45] T. Buanes,[15] Q. Buat,[144] P. Buchholz,[143] A. G. Buckley,[56] I. A. Budagov,[68] F. Buehrer,[51] M. K. Bugge,[121] O. Bulekov,[100] D. Bullock,[8] T. J. Burch,[110] S. Burdin,[77] C. D. Burgard,[109] A. M. Burger,[5] B. Burghgrave,[110] K. Burka,[42] S. Burke,[133] I. Burmeister,[46] J. T. P. Burr,[122] D. Büscher,[51] V. Büscher,[86] E. Buschmann,[58] P. Bussey,[56] J. M. Butler,[24] C. M. Buttar,[56] J. M. Butterworth,[81] P. Butti,[32] W. Buttinger,[27] A. Buzatu,[153] A. R. Buzykaev,[111,d] S. Cabrera Urbán,[170] D. Caforio,[130] H. Cai,[169] V. M. M. Cairo,[2] O. Cakir,[4a] N. Calace,[52] P. Calafiura,[16] A. Calandri,[88] G. Calderini,[83] P. Calfayan,[64] G. Callea,[40a,40b] L. P. Caloba,[26a] S. Calvente Lopez,[85] D. Calvet,[37] S. Calvet,[37] T. P. Calvet,[88] R. Camacho Toro,[33] S. Camarda,[32] P. Camarri,[135a,135b] D. Cameron,[121] R. Caminal Armadans,[169] C. Camincher,[57] S. Campana,[32] M. Campanelli,[81] A. Camplani,[94a,94b] A. Campoverde,[143] V. Canale,[106a,106b] M. Cano Bret,[36b] J. Cantero,[116] T. Cao,[155] M. D. M. Capeans Garrido,[32] I. Caprini,[28b] M. Caprini,[28b] M. Capua,[40a,40b] R. M. Carbone,[38] R. Cardarelli,[135a] F. Cardillo,[51] I. Carli,[131] T. Carli,[32] G. Carlino,[106a] B. T. Carlson,[127] L. Carminati,[94a,94b] R. M. D. Carney,[148a,148b] S. Caron,[108] E. Carquin,[34b] S. Carrá,[94a,94b] G. D. Carrillo-Montoya,[32] D. Casadei,[19] M. P. Casado,[13,k] A. F. Casha,[161] M. Casolino,[13] D. W. Casper,[166] R. Castelijn,[109] V. Castillo Gimenez,[170] N. F. Castro,[128a] A. Catinaccio,[32] J. R. Catmore,[121] A. Cattai,[32] J. Caudron,[23] V. Cavaliere,[169] E. Cavallaro,[13] D. Cavalli,[94a] M. Cavalli-Sforza,[13] V. Cavasinni,[126a,126b] E. Celebi,[20d] F. Ceradini,[136a,136b] L. Cerda Alberich,[170] A. S. Cerqueira,[26b] A. Cerri,[151] L. Cerrito,[135a,135b] F. Cerutti,[16] A. Cervelli,[22a,22b] S. A. Cetin,[20d] A. Chafaq,[137a] D. Chakraborty,[110] S. K. Chan,[59] W. S. Chan,[109] Y. L. Chan,[62a] P. Chang,[169] J. D. Chapman,[30] D. G. Charlton,[19] C. C. Chau,[31] C. A. Chavez Barajas,[151] S. Che,[113] S. Cheatham,[167a,167c] A. Chegwidden,[93] S. Chekanov,[6] S. V. Chekulaev,[163a] G. A. Chelkov,[68,l] M. A. Chelstowska,[32] C. Chen,[36c] C. Chen,[67] H. Chen,[27] J. Chen,[36c] J. Chen,[38] S. Chen,[35b] S. Chen,[157] X. Chen,[35c,m] Y. Chen,[70] H. C. Cheng,[92] H. J. Cheng,[35a,35d] A. Cheplakov,[68] E. Cheremushkina,[132] R. Cherkaoui El Moursli,[137e] E. Cheu,[7] K. Cheung,[63] L. Chevalier,[138] V. Chiarella,[50] G. Chiarelli,[126a] G. Chiodini,[76a] A. S. Chisholm,[32] A. Chitan,[28b] Y. H. Chiu,[172] M. V. Chizhov,[68] K. Choi,[64] A. R. Chomont,[37] S. Chouridou,[156] Y. S. Chow,[62a] V. Christodoulou,[81] M. C. Chu,[62a] J. Chudoba,[129] A. J. Chuinard,[90] J. J. Chwastowski,[42] L. Chytka,[117] A. K. Ciftci,[4a] D. Cinca,[46] V. Cindro,[78] I. A. Cioară,[23] A. Ciocio,[16] F. Cirotto,[106a,106b] Z. H. Citron,[175] M. Citterio,[94a] M. Ciubancan,[28b] A. Clark,[52] M. R. Clark,[38] P. J. Clark,[49] R. N. Clarke,[16] C. Clement,[148a,148b] Y. Coadou,[88] M. Cobal,[167a,167c] A. Coccaro,[52] J. Cochran,[67] L. Colasurdo,[108] B. Cole,[38] A. P. Colijn,[109] J. Collot,[57] P. Conde Muiño,[128a,128b] E. Coniavitis,[51] S. H. Connell,[147b] I. A. Connelly,[87] S. Constantinescu,[28b] G. Conti,[32] F. Conventi,[106a,n] A. M. Cooper-Sarkar,[122] F. Cormier,[171] K. J. R. Cormier,[161] M. Corradi,[134a,134b] E. E. Corrigan,[84] F. Corriveau,[90,o] A. Cortes-Gonzalez,[32] M. J. Costa,[170] D. Costanzo,[141] G. Cottin,[30] G. Cowan,[80] B. E. Cox,[87] K. Cranmer,[112] S. J. Crawley,[56] R. A. Creager,[124] G. Cree,[31] S. Crépé-Renaudin,[57] F. Crescioli,[83] W. A. Cribbs,[148a,148b] M. Cristinziani,[23] V. Croft,[112] G. Crosetti,[40a,40b] A. Cueto,[85] T. Cuhadar Donszelmann,[141] A. R. Cukierman,[145] J. Cummings,[179] M. Curatolo,[50] J. Cúth,[86] S. Czekierda,[42] P. Czodrowski,[32] G. D'amen,[22a,22b] S. D'Auria,[56] L. D'eramo,[83] M. D'Onofrio,[77] M. J. Da Cunha Sargedas De Sousa,[128a,128b] C. Da Via,[87] W. Dabrowski,[41a] T. Dado,[146a] S. Dahbi,[137e] T. Dai,[92] O. Dale,[15] F. Dallaire,[97] C. Dallapiccola,[89] M. Dam,[39] J. R. Dandoy,[124] M. F. Daneri,[29] N. P. Dang,[176,f] N. S. Dann,[87] M. Danninger,[171] M. Dano Hoffmann,[138] V. Dao,[150] G. Darbo,[53a] S. Darmora,[8] J. Dassoulas,[3] A. Dattagupta,[118] T. Daubney,[45] W. Davey,[23] C. David,[45] T. Davidek,[131] D. R. Davis,[48] P. Davison,[81] E. Dawe,[91] I. Dawson,[141] K. De,[8] R. de Asmundis,[106a] A. De Benedetti,[115] S. De Castro,[22a,22b] S. De Cecco,[83] N. De Groot,[108] P. de Jong,[109] H. De la Torre,[93] F. De Lorenzi,[67] A. De Maria,[58] D. De Pedis,[134a] A. De Salvo,[134a] U. De Sanctis,[135a,135b] A. De Santo,[151] K. De Vasconcelos Corga,[88] J. B. De Vivie De Regie,[119] R. Debbe,[27] C. Debenedetti,[139] D. V. Dedovich,[68] N. Dehghanian,[3] I. Deigaard,[109] M. Del Gaudio,[40a,40b] J. Del Peso,[85] D. Delgove,[119] F. Deliot,[138] C. M. Delitzsch,[7] A. Dell'Acqua,[32] L. Dell'Asta,[24] M. Della Pietra,[106a,106b] D. della Volpe,[52] M. Delmastro,[5] C. Delporte,[119] P. A. Delsart,[57] D. A. DeMarco,[161] S. Demers,[179] M. Demichev,[68] A. Demilly,[83] S. P. Denisov,[132] D. Denysiuk,[138] D. Derendarz,[42] J. E. Derkaoui,[137d] F. Derue,[83] P. Dervan,[77] K. Desch,[23] C. Deterre,[45] K. Dette,[161] M. R. Devesa,[29] P. O. Deviveiros,[32] A. Dewhurst,[133] S. Dhaliwal,[25] F. A. Di Bello,[52] A. Di Ciaccio,[135a,135b] L. Di Ciaccio,[5] W. K. Di Clemente,[124] C. Di Donato,[106a,106b] A. Di Girolamo,[32] B. Di Girolamo,[32] B. Di Micco,[136a,136b] R. Di Nardo,[32] K. F. Di Petrillo,[59] A. Di Simone,[51] R. Di Sipio,[161] D. Di Valentino,[31] C. Diaconu,[88] M. Diamond,[161] F. A. Dias,[39] M. A. Diaz,[34a] J. Dickinson,[16] E. B. Diehl,[92] J. Dietrich,[17] S. Díez Cornell,[45] A. Dimitrievska,[16] J. Dingfelder,[23] P. Dita,[28b] S. Dita,[28b] F. Dittus,[32]

F. Djama,[88] T. Djobava,[54b] J. I. Djuvsland,[60a] M. A. B. do Vale,[26c] M. Dobre,[28b] D. Dodsworth,[25] C. Doglioni,[84] J. Dolejsi,[131] Z. Dolezal,[131] M. Donadelli,[26d] S. Donati,[126a,126b] J. Donini,[37] J. Dopke,[133] A. Doria,[106a] M. T. Dova,[74] A. T. Doyle,[56] E. Drechsler,[58] M. Dris,[10] Y. Du,[36a] J. Duarte-Campderros,[155] F. Dubinin,[98] A. Dubreuil,[52] E. Duchovni,[175] G. Duckeck,[102] A. Ducourthial,[83] O. A. Ducu,[97,p] D. Duda,[109] A. Dudarev,[32] A. Chr. Dudder,[86] E. M. Duffield,[16] L. Duflot,[119] M. Dührssen,[32] C. Dulsen,[177] M. Dumancic,[175] A. E. Dumitriu,[28b,q] A. K. Duncan,[56] M. Dunford,[60a] A. Duperrin,[88] H. Duran Yildiz,[4a] M. Düren,[55] A. Durglishvili,[54b] D. Duschinger,[47] B. Dutta,[45] D. Duvnjak,[1] M. Dyndal,[45] B. S. Dziedzic,[42] C. Eckardt,[45] K. M. Ecker,[103] R. C. Edgar,[92] T. Eifert,[32] G. Eigen,[15] K. Einsweiler,[16] T. Ekelof,[168] M. El Kacimi,[137c] R. El Kosseifi,[88] V. Ellajosyula,[88] M. Ellert,[168] S. Elles,[5] F. Ellinghaus,[177] A. A. Elliot,[172] N. Ellis,[32] J. Elmsheuser,[27] M. Elsing,[32] D. Emeliyanov,[133] Y. Enari,[157] J. S. Ennis,[173] M. B. Epland,[48] J. Erdmann,[46] A. Ereditato,[18] M. Ernst,[27] S. Errede,[169] M. Escalier,[119] C. Escobar,[170] B. Esposito,[50] O. Estrada Pastor,[170] A. I. Etienvre,[138] E. Etzion,[155] H. Evans,[64] A. Ezhilov,[125] M. Ezzi,[137e] F. Fabbri,[22a,22b] L. Fabbri,[22a,22b] V. Fabiani,[108] G. Facini,[81] R. M. Fakhrutdinov,[132] S. Falciano,[134a] R. J. Falla,[81] J. Faltova,[32] Y. Fang,[35a] M. Fanti,[94a,94b] A. Farbin,[8] A. Farilla,[136a] E. M. Farina,[123a,123b] T. Farooque,[93] S. Farrell,[16] S. M. Farrington,[173] P. Farthouat,[32] F. Fassi,[137e] P. Fassnacht,[32] D. Fassouliotis,[9] M. Faucci Giannelli,[49] A. Favareto,[53a,53b] W. J. Fawcett,[122] L. Fayard,[119] O. L. Fedin,[125,r] W. Fedorko,[171] S. Feigl,[121] L. Feligioni,[88] C. Feng,[36a] E. J. Feng,[32] M. Feng,[48] M. J. Fenton,[56] A. B. Fenyuk,[132] L. Feremenga,[8] P. Fernandez Martinez,[170] J. Ferrando,[45] A. Ferrari,[168] P. Ferrari,[109] R. Ferrari,[123a] D. E. Ferreira de Lima,[60b] A. Ferrer,[170] D. Ferrere,[52] C. Ferretti,[92] F. Fiedler,[86] A. Filipčič,[78] M. Filipuzzi,[45] F. Filthaut,[108] M. Fincke-Keeler,[172] K. D. Finelli,[24] M. C. N. Fiolhais,[128a,128c,s] L. Fiorini,[170] C. Fischer,[13] J. Fischer,[177] W. C. Fisher,[93] N. Flaschel,[45] I. Fleck,[143] P. Fleischmann,[92] R. R. M. Fletcher,[124] T. Flick,[177] B. M. Flierl,[102] L. R. Flores Castillo,[62a] N. Fomin,[15] G. T. Forcolin,[87] A. Formica,[138] F. A. Förster,[13] A. Forti,[87] A. G. Foster,[19] D. Fournier,[119] H. Fox,[75] S. Fracchia,[141] P. Francavilla,[126a,126b] M. Franchini,[22a,22b] S. Franchino,[60a] D. Francis,[32] L. Franconi,[121] M. Franklin,[59] M. Frate,[166] M. Fraternali,[123a,123b] D. Freeborn,[81] S. M. Fressard-Batraneanu,[32] B. Freund,[97] W. S. Freund,[26a] D. Froidevaux,[32] J. A. Frost,[122] C. Fukunaga,[158] T. Fusayasu,[104] J. Fuster,[170] O. Gabizon,[154] A. Gabrielli,[22a,22b] A. Gabrielli,[16] G. P. Gach,[41a] S. Gadatsch,[32] S. Gadomski,[80] G. Gagliardi,[53a,53b] L. G. Gagnon,[97] C. Galea,[108] B. Galhardo,[128a,128c] E. J. Gallas,[122] B. J. Gallop,[133] P. Gallus,[130] G. Galster,[39] K. K. Gan,[113] S. Ganguly,[175] Y. Gao,[77] Y. S. Gao,[145,h] F. M. Garay Walls,[34a] C. García,[170] J. E. García Navarro,[170] J. A. García Pascual,[35a] M. Garcia-Sciveres,[16] R. W. Gardner,[33] N. Garelli,[145] V. Garonne,[121] K. Gasnikova,[45] C. Gatti,[50] A. Gaudiello,[53a,53b] G. Gaudio,[123a] I. L. Gavrilenko,[98] C. Gay,[171] G. Gaycken,[23] E. N. Gazis,[10] C. N. P. Gee,[133] J. Geisen,[58] M. Geisen,[86] M. P. Geisler,[60a] K. Gellerstedt,[148a,148b] C. Gemme,[53a] M. H. Genest,[57] C. Geng,[92] S. Gentile,[134a,134b] C. Gentsos,[156] S. George,[80] D. Gerbaudo,[13] G. Geßner,[46] S. Ghasemi,[143] M. Ghneimat,[23] B. Giacobbe,[22a] S. Giagu,[134a,134b] N. Giangiacomi,[22a,22b] P. Giannetti,[126a] S. M. Gibson,[80] M. Gignac,[171] M. Gilchriese,[16] D. Gillberg,[31] G. Gilles,[177] D. M. Gingrich,[3,e] M. P. Giordani,[167a,167c] F. M. Giorgi,[22a] P. F. Giraud,[138] P. Giromini,[59] G. Giugliarelli,[167a,167c] D. Giugni,[94a] F. Giuli,[122] M. Giulini,[60b] B. K. Gjelsten,[121] S. Gkaitatzis,[156] I. Gkialas,[9,t] E. L. Gkougkousis,[13] P. Gkountoumis,[10] L. K. Gladilin,[101] C. Glasman,[85] J. Glatzer,[13] P. C. F. Glaysher,[45] A. Glazov,[45] M. Goblirsch-Kolb,[25] J. Godlewski,[42] S. Goldfarb,[91] T. Golling,[52] D. Golubkov,[132] A. Gomes,[128a,128b,128d] R. Gonçalo,[128a] R. Goncalves Gama,[26a] J. Goncalves Pinto Firmino Da Costa,[138] G. Gonella,[51] L. Gonella,[19] A. Gongadze,[68] F. Gonnella,[19] J. L. Gonski,[59] S. González de la Hoz,[170] S. Gonzalez-Sevilla,[52] L. Goossens,[32] P. A. Gorbounov,[99] H. A. Gordon,[27] B. Gorini,[32] E. Gorini,[76a,76b] A. Gorišek,[78] A. T. Goshaw,[48] C. Gössling,[46] M. I. Gostkin,[68] C. A. Gottardo,[23] C. R. Goudet,[119] D. Goujdami,[137c] A. G. Goussiou,[140] N. Govender,[147b,u] C. Goy,[5] E. Gozani,[154] I. Grabowska-Bold,[41a] P. O. J. Gradin,[168] E. C. Graham,[77] J. Gramling,[166] E. Gramstad,[121] S. Grancagnolo,[17] V. Gratchev,[125] P. M. Gravila,[28f] C. Gray,[56] H. M. Gray,[16] Z. D. Greenwood,[82,v] C. Grefe,[23] K. Gregersen,[81] I. M. Gregor,[45] P. Grenier,[145] K. Grevtsov,[5] J. Griffiths,[8] A. A. Grillo,[139] K. Grimm,[75] S. Grinstein,[13,w] Ph. Gris,[37] J.-F. Grivaz,[119] S. Groh,[86] E. Gross,[175] J. Grosse-Knetter,[58] G. C. Grossi,[82] Z. J. Grout,[81] A. Grummer,[107] L. Guan,[92] W. Guan,[176] J. Guenther,[32] F. Guescini,[163a] D. Guest,[166] O. Gueta,[155] R. Gugel,[51] B. Gui,[113] E. Guido,[53a,53b] T. Guillemin,[5] S. Guindon,[32] U. Gul,[56] C. Gumpert,[32] J. Guo,[36b] W. Guo,[92] Y. Guo,[36c,x] R. Gupta,[43] S. Gurbuz,[20a] G. Gustavino,[115] B. J. Gutelman,[154] P. Gutierrez,[115] N. G. Gutierrez Ortiz,[81] C. Gutschow,[81] C. Guyot,[138] M. P. Guzik,[41a] C. Gwenlan,[122] C. B. Gwilliam,[77] A. Haas,[112] C. Haber,[16] H. K. Hadavand,[8] N. Haddad,[137e] A. Hadef,[88] S. Hageböck,[23] M. Hagihara,[164] H. Hakobyan,[180,a] M. Haleem,[45] J. Haley,[116] G. Halladjian,[93] G. D. Hallewell,[88] K. Hamacher,[177] P. Hamal,[117] K. Hamano,[172] A. Hamilton,[147a] G. N. Hamity,[141] P. G. Hamnett,[45] K. Han,[36c,y] L. Han,[36c] S. Han,[35a,35d] K. Hanagaki,[69,z] M. Hance,[139] D. M. Handl,[102] B. Haney,[124] R. Hankache,[83] P. Hanke,[60a] J. B. Hansen,[39] J. D. Hansen,[39] M. C. Hansen,[23] P. H. Hansen,[39] K. Hara,[164] A. S. Hard,[176] T. Harenberg,[177] F. Hariri,[119] S. Harkusha,[95]

P. F. Harrison,[173] N. M. Hartmann,[102] Y. Hasegawa,[142] A. Hasib,[49] S. Hassani,[138] S. Haug,[18] R. Hauser,[93] L. Hauswald,[47] L. B. Havener,[38] M. Havranek,[130] C. M. Hawkes,[19] R. J. Hawkings,[32] D. Hayden,[93] C. P. Hays,[122] J. M. Hays,[79] H. S. Hayward,[77] S. J. Haywood,[133] T. Heck,[86] V. Hedberg,[84] L. Heelan,[8] S. Heer,[23] K. K. Heidegger,[51] S. Heim,[45] T. Heim,[16] B. Heinemann,[45,aa] J. J. Heinrich,[102] L. Heinrich,[112] C. Heinz,[55] J. Hejbal,[129] L. Helary,[32] A. Held,[171] S. Hellman,[148a,148b] C. Helsens,[32] R. C. W. Henderson,[75] Y. Heng,[176] S. Henkelmann,[171] A. M. Henriques Correia,[32] S. Henrot-Versille,[119] G. H. Herbert,[17] H. Herde,[25] V. Herget,[178] Y. Hernández Jiménez,[147c] H. Herr,[86] G. Herten,[51] R. Hertenberger,[102] L. Hervas,[32] T. C. Herwig,[124] G. G. Hesketh,[81] N. P. Hessey,[163a] J. W. Hetherly,[43] S. Higashino,[69] E. Higón-Rodriguez,[170] K. Hildebrand,[33] E. Hill,[172] J. C. Hill,[30] K. H. Hiller,[45] S. J. Hillier,[19] M. Hils,[47] I. Hinchliffe,[16] M. Hirose,[51] D. Hirschbuehl,[177] B. Hiti,[78] O. Hladik,[129] D. R. Hlaluku,[147c] X. Hoad,[49] J. Hobbs,[150] N. Hod,[163a] M. C. Hodgkinson,[141] P. Hodgson,[141] A. Hoecker,[32] M. R. Hoeferkamp,[107] F. Hoenig,[102] D. Hohn,[23] T. R. Holmes,[33] M. Holzbock,[102] M. Homann,[46] S. Honda,[164] T. Honda,[69] T. M. Hong,[127] B. H. Hooberman,[169] W. H. Hopkins,[118] Y. Horii,[105] A. J. Horton,[144] J-Y. Hostachy,[57] A. Hostiuc,[140] S. Hou,[153] A. Hoummada,[137a] J. Howarth,[87] J. Hoya,[74] M. Hrabovsky,[117] J. Hrdinka,[32] I. Hristova,[17] J. Hrivnac,[119] T. Hryn'ova,[5] A. Hrynevich,[96] P. J. Hsu,[63] S.-C. Hsu,[140] Q. Hu,[27] S. Hu,[36b] Y. Huang,[35a] Z. Hubacek,[130] F. Hubaut,[88] F. Huegging,[23] T. B. Huffman,[122] E. W. Hughes,[38] M. Huhtinen,[32] R. F. H. Hunter,[31] P. Huo,[150] A. M. Hupe,[31] N. Huseynov,[68,c] J. Huston,[93] J. Huth,[59] R. Hyneman,[92] G. Iacobucci,[52] G. Iakovidis,[27] I. Ibragimov,[143] L. Iconomidou-Fayard,[119] Z. Idrissi,[137e] P. Iengo,[32] O. Igonkina,[109,bb] T. Iizawa,[174] Y. Ikegami,[69] M. Ikeno,[69] Y. Ilchenko,[11,cc] D. Iliadis,[156] N. Ilic,[145] F. Iltzsche,[47] G. Introzzi,[123a,123b] P. Ioannou,[9,a] M. Iodice,[136a] K. Iordanidou,[38] V. Ippolito,[59] M. F. Isacson,[168] N. Ishijima,[120] M. Ishino,[157] M. Ishitsuka,[159] C. Issever,[122] S. Istin,[20a] F. Ito,[164] J. M. Iturbe Ponce,[62a] R. Iuppa,[162a,162b] H. Iwasaki,[69] J. M. Izen,[44] V. Izzo,[106a] S. Jabbar,[3] P. Jackson,[1] R. M. Jacobs,[23] V. Jain,[2] G. Jakel,[177] K. B. Jakobi,[86] K. Jakobs,[51] S. Jakobsen,[65] T. Jakoubek,[129] D. O. Jamin,[116] D. K. Jana,[82] R. Jansky,[52] J. Janssen,[23] M. Janus,[58] P. A. Janus,[41a] G. Jarlskog,[84] N. Javadov,[68,c] T. Javůrek,[51] M. Javurkova,[51] F. Jeanneau,[138] L. Jeanty,[16] J. Jejelava,[54a,dd] A. Jelinskas,[173] P. Jenni,[51,ee] C. Jeske,[173] S. Jézéquel,[5] H. Ji,[176] J. Jia,[150] H. Jiang,[67] Y. Jiang,[36c] Z. Jiang,[145] S. Jiggins,[81] J. Jimenez Pena,[170] S. Jin,[35b] A. Jinaru,[28b] O. Jinnouchi,[159] H. Jivan,[147c] P. Johansson,[141] K. A. Johns,[7] C. A. Johnson,[64] W. J. Johnson,[140] K. Jon-And,[148a,148b] R. W. L. Jones,[75] S. D. Jones,[151] S. Jones,[7] T. J. Jones,[77] J. Jongmanns,[60a] P. M. Jorge,[128a,128b] J. Jovicevic,[163a] X. Ju,[176] A. Juste Rozas,[13,w] A. Kaczmarska,[42] M. Kado,[119] H. Kagan,[113] M. Kagan,[145] S. J. Kahn,[88] T. Kaji,[174] E. Kajomovitz,[154] C. W. Kalderon,[84] A. Kaluza,[86] S. Kama,[43] A. Kamenshchikov,[132] L. Kanjir,[78] Y. Kano,[157] V. A. Kantserov,[100] J. Kanzaki,[69] B. Kaplan,[112] L. S. Kaplan,[176] D. Kar,[147c] K. Karakostas,[10] N. Karastathis,[10] M. J. Kareem,[163b] E. Karentzos,[10] S. N. Karpov,[68] Z. M. Karpova,[68] V. Kartvelishvili,[75] A. N. Karyukhin,[132] K. Kasahara,[164] L. Kashif,[176] R. D. Kass,[113] A. Kastanas,[149] Y. Kataoka,[157] C. Kato,[157] A. Katre,[52] J. Katzy,[45] K. Kawade,[70] K. Kawagoe,[73] T. Kawamoto,[157] G. Kawamura,[58] E. F. Kay,[77] V. F. Kazanin,[111,d] R. Keeler,[172] R. Kehoe,[43] J. S. Keller,[31] E. Kellermann,[84] J. J. Kempster,[80] J Kendrick,[19] H. Keoshkerian,[161] O. Kepka,[129] B. P. Kerševan,[78] S. Kersten,[177] R. A. Keyes,[90] M. Khader,[169] F. Khalil-zada,[12] A. Khanov,[116] A. G. Kharlamov,[111,d] T. Kharlamova,[111,d] A. Khodinov,[160] T. J. Khoo,[52] V. Khovanskiy,[99,a] E. Khramov,[68] J. Khubua,[54b,ff] S. Kido,[70] M. Kiehn,[52] C. R. Kilby,[80] H. Y. Kim,[8] S. H. Kim,[164] Y. K. Kim,[33] N. Kimura,[167a,167c] O. M. Kind,[17] B. T. King,[77] D. Kirchmeier,[47] J. Kirk,[133] A. E. Kiryunin,[103] T. Kishimoto,[157] D. Kisielewska,[41a] V. Kitali,[45] O. Kivernyk,[5] E. Kladiva,[146b] T. Klapdor-Kleingrothaus,[51] M. H. Klein,[92] M. Klein,[77] U. Klein,[77] K. Kleinknecht,[86] P. Klimek,[110] A. Klimentov,[27] R. Klingenberg,[46,a] T. Klingl,[23] T. Klioutchnikova,[32] F. F. Klitzner,[102] E.-E. Kluge,[60a] P. Kluit,[109] S. Kluth,[103] E. Kneringer,[65] E. B. F. G. Knoops,[88] A. Knue,[51] A. Kobayashi,[157] D. Kobayashi,[73] T. Kobayashi,[157] M. Kobel,[47] M. Kocian,[145] P. Kodys,[131] T. Koffas,[31] E. Koffeman,[109] N. M. Köhler,[103] T. Koi,[145] M. Kolb,[60b] I. Koletsou,[5] T. Kondo,[69] N. Kondrashova,[36b] K. Köneke,[51] A. C. König,[108] T. Kono,[69,gg] R. Konoplich,[112,hh] N. Konstantinidis,[81] B. Konya,[84] R. Kopeliansky,[64] S. Koperny,[41a] K. Korcyl,[42] K. Kordas,[156] A. Korn,[81] I. Korolkov,[13] E. V. Korolkova,[141] O. Kortner,[103] S. Kortner,[103] T. Kosek,[131] V. V. Kostyukhin,[23] A. Kotwal,[48] A. Koulouris,[10] A. Kourkoumeli-Charalampidi,[123a,123b] C. Kourkoumelis,[9] E. Kourlitis,[141] V. Kouskoura,[27] A. B. Kowalewska,[42] R. Kowalewski,[172] T. Z. Kowalski,[41a] C. Kozakai,[157] W. Kozanecki,[138] A. S. Kozhin,[132] V. A. Kramarenko,[101] G. Kramberger,[78] D. Krasnopevtsev,[100] M. W. Krasny,[83] A. Krasznahorkay,[32] D. Krauss,[103] J. A. Kremer,[41a] J. Kretzschmar,[77] K. Kreutzfeldt,[55] P. Krieger,[161] K. Krizka,[16] K. Kroeninger,[46] H. Kroha,[103] J. Kroll,[129] J. Kroll,[124] J. Kroseberg,[23] J. Krstic,[14] U. Kruchonak,[68] H. Krüger,[23] N. Krumnack,[67] M. C. Kruse,[48] T. Kubota,[91] H. Kucuk,[81] S. Kuday,[4b] J. T. Kuechler,[177] S. Kuehn,[32] A. Kugel,[60a] F. Kuger,[178] T. Kuhl,[45] V. Kukhtin,[68] R. Kukla,[88] Y. Kulchitsky,[95] S. Kuleshov,[34b] Y. P. Kulinich,[169] M. Kuna,[11] T. Kunigo,[71] A. Kupco,[129] T. Kupfer,[46] O. Kuprash,[155] H. Kurashige,[70]

L. L. Kurchaninov,[163a] Y. A. Kurochkin,[95] M. G. Kurth,[35a,35d] E. S. Kuwertz,[172] M. Kuze,[159] J. Kvita,[117] T. Kwan,[172] A. La Rosa,[103] J. L. La Rosa Navarro,[26d] L. La Rotonda,[40a,40b] F. La Ruffa,[40a,40b] C. Lacasta,[170] F. Lacava,[134a,134b] J. Lacey,[45] D. P. J. Lack,[87] H. Lacker,[17] D. Lacour,[83] E. Ladygin,[68] R. Lafaye,[5] B. Laforge,[83] S. Lai,[58] S. Lammers,[64] W. Lampl,[7] E. Lançon,[27] U. Landgraf,[51] M. P. J. Landon,[79] M. C. Lanfermann,[52] V. S. Lang,[45] J. C. Lange,[13] R. J. Langenberg,[32] A. J. Lankford,[166] F. Lanni,[27] K. Lantzsch,[23] A. Lanza,[123a] A. Lapertosa,[53a,53b] S. Laplace,[83] J. F. Laporte,[138] T. Lari,[94a] F. Lasagni Manghi,[22a,22b] M. Lassnig,[32] T. S. Lau,[62a] P. Laurelli,[50] A. T. Law,[139] P. Laycock,[77] T. Lazovich,[59] M. Lazzaroni,[94a,94b] B. Le,[91] O. Le Dortz,[83] E. Le Guirriec,[88] E. P. Le Quilleuc,[138] M. LeBlanc,[7] T. LeCompte,[6] F. Ledroit-Guillon,[57] C. A. Lee,[27] G. R. Lee,[34a] S. C. Lee,[153] L. Lee,[59] B. Lefebvre,[90] G. Lefebvre,[83] M. Lefebvre,[172] F. Legger,[102] C. Leggett,[16] G. Lehmann Miotto,[32] X. Lei,[7] W. A. Leight,[45] M. A. L. Leite,[26d] R. Leitner,[131] D. Lellouch,[175] B. Lemmer,[58] K. J. C. Leney,[81] T. Lenz,[23] B. Lenzi,[32] R. Leone,[7] S. Leone,[126a] C. Leonidopoulos,[49] G. Lerner,[151] C. Leroy,[97] R. Les,[161] A. A. J. Lesage,[138] C. G. Lester,[30] M. Levchenko,[125] J. Levêque,[5] D. Levin,[92] L. J. Levinson,[175] M. Levy,[19] D. Lewis,[79] B. Li,[36c,x] C.-Q. Li,[36c] H. Li,[150] L. Li,[36b] Q. Li,[35a,35d] Q. Li,[36c] S. Li,[48] X. Li,[36b] Y. Li,[143] Z. Liang,[35a] B. Liberti,[135a] A. Liblong,[161] K. Lie,[62c] A. Limosani,[152] C. Y. Lin,[30] K. Lin,[93] S. C. Lin,[182] T. H. Lin,[86] R. A. Linck,[64] B. E. Lindquist,[150] A. E. Lionti,[52] E. Lipeles,[124] A. Lipniacka,[15] M. Lisovyi,[60b] T. M. Liss,[169,ii] A. Lister,[171] A. M. Litke,[139] B. Liu,[67] H. Liu,[92] H. Liu,[27] J. K. K. Liu,[122] J. B. Liu,[36c] K. Liu,[88] L. Liu,[169] M. Liu,[36c] Y. L. Liu,[36c] Y. Liu,[36c] M. Livan,[123a,123b] A. Lleres,[57] J. Llorente Merino,[35a] S. L. Lloyd,[79] C. Y. Lo,[62b] F. Lo Sterzo,[43] E. M. Lobodzinska,[45] P. Loch,[7] F. K. Loebinger,[87] A. Loesle,[51] K. M. Loew,[25] T. Lohse,[17] K. Lohwasser,[141] M. Lokajicek,[129] B. A. Long,[24] J. D. Long,[169] R. E. Long,[75] L. Longo,[76a,76b] K. A. Looper,[113] J. A. Lopez,[34b] I. Lopez Paz,[13] A. Lopez Solis,[83] J. Lorenz,[102] N. Lorenzo Martinez,[5] M. Losada,[21] P. J. Lösel,[102] X. Lou,[35a] A. Lounis,[119] J. Love,[6] P. A. Love,[75] H. Lu,[62a] N. Lu,[92] Y. J. Lu,[63] H. J. Lubatti,[140] C. Luci,[134a,134b] A. Lucotte,[57] C. Luedtke,[51] F. Luehring,[64] W. Lukas,[65] L. Luminari,[134a] B. Lund-Jensen,[149] M. S. Lutz,[89] P. M. Luzi,[83] D. Lynn,[27] R. Lysak,[129] E. Lytken,[84] F. Lyu,[35a] V. Lyubushkin,[68] H. Ma,[27] L. L. Ma,[36a] Y. Ma,[36a] G. Maccarrone,[50] A. Macchiolo,[103] C. M. Macdonald,[141] B. Maček,[78] J. Machado Miguens,[124,128b] D. Madaffari,[170] R. Madar,[37] W. F. Mader,[47] A. Madsen,[45] N. Madysa,[47] J. Maeda,[70] S. Maeland,[15] T. Maeno,[27] A. S. Maevskiy,[101] V. Magerl,[51] C. Maiani,[119] C. Maidantchik,[26a] T. Maier,[102] A. Maio,[128a,128b,128d] O. Majersky,[146a] S. Majewski,[118] Y. Makida,[69] N. Makovec,[119] B. Malaescu,[83] Pa. Malecki,[42] V. P. Maleev,[125] F. Malek,[57] U. Mallik,[66] D. Malon,[6] C. Malone,[30] S. Maltezos,[10] S. Malyukov,[32] J. Mamuzic,[170] G. Mancini,[50] I. Mandić,[78] J. Maneira,[128a,128b] L. Manhaes de Andrade Filho,[26b] J. Manjarres Ramos,[47] K. H. Mankinen,[84] A. Mann,[102] A. Manousos,[32] B. Mansoulie,[138] J. D. Mansour,[35a] R. Mantifel,[90] M. Mantoani,[58] S. Manzoni,[94a,94b] L. Mapelli,[32] G. Marceca,[29] L. March,[52] L. Marchese,[122] G. Marchiori,[83] M. Marcisovsky,[129] C. A. Marin Tobon,[32] M. Marjanovic,[37] D. E. Marley,[92] F. Marroquim,[26a] S. P. Marsden,[87] Z. Marshall,[16] M. U. F Martensson,[168] S. Marti-Garcia,[170] C. B. Martin,[113] T. A. Martin,[173] V. J. Martin,[49] B. Martin dit Latour,[15] M. Martinez,[13,w] V. I. Martinez Outschoorn,[169] S. Martin-Haugh,[133] V. S. Martoiu,[28b] A. C. Martyniuk,[81] A. Marzin,[32] L. Masetti,[86] T. Mashimo,[157] R. Mashinistov,[98] J. Masik,[87] A. L. Maslennikov,[111,d] L. H. Mason,[91] L. Massa,[135a,135b] P. Mastrandrea,[5] A. Mastroberardino,[40a,40b] T. Masubuchi,[157] P. Mättig,[177] J. Maurer,[28b] S. J. Maxfield,[77] D. A. Maximov,[111,d] R. Mazini,[153] I. Maznas,[156] S. M. Mazza,[94a,94b] N. C. Mc Fadden,[107] G. Mc Goldrick,[161] S. P. Mc Kee,[92] A. McCarn,[92] R. L. McCarthy,[150] T. G. McCarthy,[103] L. I. McClymont,[81] E. F. McDonald,[91] J. A. Mcfayden,[32] G. Mchedlidze,[58] S. J. McMahon,[133] P. C. McNamara,[91] C. J. McNicol,[173] R. A. McPherson,[172,o] Z. A. Meadows,[89] S. Meehan,[140] T. J. Megy,[51] S. Mehlhase,[102] A. Mehta,[77] T. Meideck,[57] K. Meier,[60a] B. Meirose,[44] D. Melini,[170,jj] B. R. Mellado Garcia,[147c] J. D. Mellenthin,[58] M. Melo,[146a] F. Meloni,[18] A. Melzer,[23] S. B. Menary,[87] L. Meng,[77] X. T. Meng,[92] A. Mengarelli,[22a,22b] S. Menke,[103] E. Meoni,[40a,40b] S. Mergelmeyer,[17] C. Merlassino,[18] P. Mermod,[52] L. Merola,[106a,106b] C. Meroni,[94a] F. S. Merritt,[33] A. Messina,[134a,134b] J. Metcalfe,[6] A. S. Mete,[166] C. Meyer,[124] J-P. Meyer,[138] J. Meyer,[109] H. Meyer Zu Theenhausen,[60a] F. Miano,[151] R. P. Middleton,[133] S. Miglioranzi,[53a,53b] L. Mijović,[49] G. Mikenberg,[175] M. Mikestikova,[129] M. Mikuž,[78] M. Milesi,[91] A. Milic,[161] D. A. Millar,[79] D. W. Miller,[33] A. Milov,[175] D. A. Milstead,[148a,148b] A. A. Minaenko,[132] I. A. Minashvili,[54b] A. I. Mincer,[112] B. Mindur,[41a] M. Mineev,[68] Y. Minegishi,[157] Y. Ming,[176] L. M. Mir,[13] A. Mirto,[76a,76b] K. P. Mistry,[124] T. Mitani,[174] J. Mitrevski,[102] V. A. Mitsou,[170] A. Miucci,[18] P. S. Miyagawa,[141] A. Mizukami,[69] J. U. Mjörnmark,[84] T. Mkrtchyan,[180] M. Mlynarikova,[131] T. Moa,[148a,148b] K. Mochizuki,[97] P. Mogg,[51] S. Mohapatra,[38] S. Molander,[148a,148b] R. Moles-Valls,[23] M. C. Mondragon,[93] K. Mönig,[45] J. Monk,[39] E. Monnier,[88] A. Montalbano,[150] J. Montejo Berlingen,[32] F. Monticelli,[74] S. Monzani,[94a] R. W. Moore,[3] N. Morange,[119] D. Moreno,[21] M. Moreno Llácer,[32] P. Morettini,[53a] M. Morgenstern,[109] S. Morgenstern,[32] D. Mori,[144] T. Mori,[157] M. Morii,[59] M. Morinaga,[174] V. Morisbak,[121] A. K. Morley,[32] G. Mornacchi,[32]

J. D. Morris,[79] L. Morvaj,[150] P. Moschovakos,[10] M. Mosidze,[54b] H. J. Moss,[141] J. Moss,[145,kk] K. Motohashi,[159] R. Mount,[145] E. Mountricha,[27] E. J. W. Moyse,[89] S. Muanza,[88] F. Mueller,[103] J. Mueller,[127] R. S. P. Mueller,[102] D. Muenstermann,[75] P. Mullen,[56] G. A. Mullier,[18] F. J. Munoz Sanchez,[87] W. J. Murray,[173,133] H. Musheghyan,[32] M. Muškinja,[78] C. Mwewa,[147a] A. G. Myagkov,[132,ll] J. Myers,[118] M. Myska,[130] B. P. Nachman,[16] O. Nackenhorst,[46] K. Nagai,[122] R. Nagai,[69,gg] K. Nagano,[69] Y. Nagasaka,[61] K. Nagata,[164] M. Nagel,[51] E. Nagy,[88] A. M. Nairz,[32] Y. Nakahama,[105] K. Nakamura,[69] T. Nakamura,[157] I. Nakano,[114] R. F. Naranjo Garcia,[45] R. Narayan,[11] D. I. Narrias Villar,[60a] I. Naryshkin,[125] T. Naumann,[45] G. Navarro,[21] R. Nayyar,[7] H. A. Neal,[92] P. Yu. Nechaeva,[98] T. J. Neep,[138] A. Negri,[123a,123b] M. Negrini,[22a] S. Nektarijevic,[108] C. Nellist,[58] A. Nelson,[166] M. E. Nelson,[122] S. Nemecek,[129] P. Nemethy,[112] M. Nessi,[32,mm] M. S. Neubauer,[169] M. Neumann,[177] P. R. Newman,[19] T. Y. Ng,[62c] Y. S. Ng,[17] T. Nguyen Manh,[97] R. B. Nickerson,[122] R. Nicolaidou,[138] J. Nielsen,[139] N. Nikiforou,[11] V. Nikolaenko,[132,ll] I. Nikolic-Audit,[83] K. Nikolopoulos,[19] P. Nilsson,[27] Y. Ninomiya,[69] A. Nisati,[134a] N. Nishu,[36b] R. Nisius,[103] I. Nitsche,[46] T. Nitta,[174] T. Nobe,[157] Y. Noguchi,[71] M. Nomachi,[120] I. Nomidis,[31] M. A. Nomura,[27] T. Nooney,[79] M. Nordberg,[32] N. Norjoharuddeen,[122] O. Novgorodova,[47] R. Novotny,[130] M. Nozaki,[69] L. Nozka,[117] K. Ntekas,[166] E. Nurse,[81] F. Nuti,[91] K. O'Connor,[25] D. C. O'Neil,[144] A. A. O'Rourke,[45] V. O'Shea,[56] F. G. Oakham,[31,e] H. Oberlack,[103] T. Obermann,[23] J. Ocariz,[83] A. Ochi,[70] I. Ochoa,[38] J. P. Ochoa-Ricoux,[34a] S. Oda,[73] S. Odaka,[69] A. Oh,[87] S. H. Oh,[48] C. C. Ohm,[149] H. Ohman,[168] H. Oide,[53a,53b] H. Okawa,[164] Y. Okumura,[157] T. Okuyama,[69] A. Olariu,[28b] L. F. Oleiro Seabra,[128a] S. A. Olivares Pino,[34a] D. Oliveira Damazio,[27] J. L. Oliver,[1] M. J. R. Olsson,[33] A. Olszewski,[42] J. Olszowska,[42] A. Onofre,[128a,128e] K. Onogi,[105] P. U. E. Onyisi,[11,cc] H. Oppen,[121] M. J. Oreglia,[33] Y. Oren,[155] D. Orestano,[136a,136b] E. C. Orgill,[87] N. Orlando,[62b] R. S. Orr,[161] B. Osculati,[53a,53b,a] R. Ospanov,[36c] G. Otero y Garzon,[29] H. Otono,[73] M. Ouchrif,[137d] F. Ould-Saada,[121] A. Ouraou,[138] K. P. Oussoren,[109] Q. Ouyang,[35a] M. Owen,[56] R. E. Owen,[19] V. E. Ozcan,[20a] N. Ozturk,[8] K. Pachal,[144] A. Pacheco Pages,[13] L. Pacheco Rodriguez,[138] C. Padilla Aranda,[13] S. Pagan Griso,[16] M. Paganini,[179] F. Paige,[27] G. Palacino,[64] S. Palazzo,[40a,40b] S. Palestini,[32] M. Palka,[41b] D. Pallin,[37] E. St. Panagiotopoulou,[10] I. Panagoulias,[10] C. E. Pandini,[52] J. G. Panduro Vazquez,[80] P. Pani,[32] S. Panitkin,[27] D. Pantea,[28b] L. Paolozzi,[52] Th. D. Papadopoulou,[10] K. Papageorgiou,[9,t] A. Paramonov,[6] D. Paredes Hernandez,[62b] A. J. Parker,[75] M. A. Parker,[30] K. A. Parker,[45] F. Parodi,[53a,53b] J. A. Parsons,[38] U. Parzefall,[51] V. R. Pascuzzi,[161] J. M. Pasner,[139] E. Pasqualucci,[134a] S. Passaggio,[53a] Fr. Pastore,[80] S. Pataraia,[86] J. R. Pater,[87] T. Pauly,[32] B. Pearson,[103] S. Pedraza Lopez,[170] R. Pedro,[128a,128b] S. V. Peleganchuk,[111,d] O. Penc,[129] C. Peng,[35a,35d] H. Peng,[36c] J. Penwell,[64] B. S. Peralva,[26b] M. M. Perego,[138] D. V. Perepelitsa,[27] F. Peri,[17] L. Perini,[94a,94b] H. Pernegger,[32] S. Perrella,[106a,106b] R. Peschke,[45] V. D. Peshekhonov,[68,a] K. Peters,[45] R. F. Y. Peters,[87] B. A. Petersen,[32] T. C. Petersen,[39] E. Petit,[57] A. Petridis,[1] C. Petridou,[156] P. Petroff,[119] E. Petrolo,[134a] M. Petrov,[122] F. Petrucci,[136a,136b] N. E. Pettersson,[89] A. Peyaud,[138] R. Pezoa,[34b] T. Pham,[91] F. H. Phillips,[93] P. W. Phillips,[133] G. Piacquadio,[150] E. Pianori,[173] A. Picazio,[89] M. A. Pickering,[122] R. Piegaia,[29] J. E. Pilcher,[33] A. D. Pilkington,[87] M. Pinamonti,[135a,135b] J. L. Pinfold,[3] H. Pirumov,[45] M. Pitt,[175] M.-A. Pleier,[27] V. Pleskot,[86] E. Plotnikova,[68] D. Pluth,[67] P. Podberezko,[111] R. Poettgen,[84] R. Poggi,[123a,123b] L. Poggioli,[119] I. Pogrebnyak,[93] D. Pohl,[23] I. Pokharel,[58] G. Polesello,[123a] A. Poley,[45] A. Policicchio,[40a,40b] R. Polifka,[32] A. Polini,[22a] C. S. Pollard,[45] V. Polychronakos,[27] K. Pommès,[32] D. Ponomarenko,[100] L. Pontecorvo,[134a] G. A. Popeneciu,[28d] D. M. Portillo Quintero,[83] S. Pospisil,[130] K. Potamianos,[45] I. N. Potrap,[68] C. J. Potter,[30] H. Potti,[11] T. Poulsen,[84] J. Poveda,[32] M. E. Pozo Astigarraga,[32] P. Pralavorio,[88] S. Prell,[67] D. Price,[87] M. Primavera,[76a] S. Prince,[90] N. Proklova,[100] K. Prokofiev,[62c] F. Prokoshin,[34b] S. Protopopescu,[27] J. Proudfoot,[6] M. Przybycien,[41a] A. Puri,[169] P. Puzo,[119] J. Qian,[92] Y. Qin,[87] A. Quadt,[58] M. Queitsch-Maitland,[45] D. Quilty,[56] S. Raddum,[121] V. Radeka,[27] V. Radescu,[122] S. K. Radhakrishnan,[150] P. Radloff,[118] P. Rados,[91] F. Ragusa,[94a,94b] G. Rahal,[181] J. A. Raine,[87] S. Rajagopalan,[27] T. Rashid,[119] S. Raspopov,[5] M. G. Ratti,[94a,94b] D. M. Rauch,[45] F. Rauscher,[102] S. Rave,[86] I. Ravinovich,[175] J. H. Rawling,[87] M. Raymond,[32] A. L. Read,[121] N. P. Readioff,[57] M. Reale,[76a,76b] D. M. Rebuzzi,[123a,123b] A. Redelbach,[178] G. Redlinger,[27] R. Reece,[139] R. G. Reed,[147c] K. Reeves,[44] L. Rehnisch,[17] J. Reichert,[124] A. Reiss,[86] C. Rembser,[32] H. Ren,[35a,35d] M. Rescigno,[134a] S. Resconi,[94a] E. D. Resseguie,[124] S. Rettie,[171] E. Reynolds,[19] O. L. Rezanova,[111,d] P. Reznicek,[131] R. Rezvani,[97] R. Richter,[103] S. Richter,[81] E. Richter-Was,[41b] O. Ricken,[23] M. Ridel,[83] P. Rieck,[103] C. J. Riegel,[177] J. Rieger,[58] O. Rifki,[115] M. Rijssenbeek,[150] A. Rimoldi,[123a,123b] M. Rimoldi,[18] L. Rinaldi,[22a] G. Ripellino,[149] B. Ristić,[32] E. Ritsch,[32] I. Riu,[13] J. C. Rivera Vergara,[34a] F. Rizatdinova,[116] E. Rizvi,[79] C. Rizzi,[13] R. T. Roberts,[87] S. H. Robertson,[90,o] A. Robichaud-Veronneau,[90] D. Robinson,[30] J. E. M. Robinson,[45] A. Robson,[56] E. Rocco,[86] C. Roda,[126a,126b] Y. Rodina,[88,nn] S. Rodriguez Bosca,[170] A. Rodriguez Perez,[13] D. Rodriguez Rodriguez,[170] A. M. Rodríguez Vera,[163b] S. Roe,[32] C. S. Rogan,[59] O. Røhne,[121] J. Roloff,[59] A. Romaniouk,[100] M. Romano,[22a,22b] S. M. Romano Saez,[37] E. Romero Adam,[170] N. Rompotis,[77] M. Ronzani,[51] L. Roos,[83] S. Rosati,[134a]

K. Rosbach,[51] P. Rose,[139] N.-A. Rosien,[58] E. Rossi,[106a,106b] L. P. Rossi,[53a] J. H. N. Rosten,[30] R. Rosten,[140] M. Rotaru,[28b] J. Rothberg,[140] D. Rousseau,[119] D. Roy,[147c] A. Rozanov,[88] Y. Rozen,[154] X. Ruan,[147c] F. Rubbo,[145] F. Rühr,[51] A. Ruiz-Martinez,[31] Z. Rurikova,[51] N. A. Rusakovich,[68] H. L. Russell,[90] J. P. Rutherfoord,[7] N. Ruthmann,[32] E. M. Rüttinger,[45] Y. F. Ryabov,[125] M. Rybar,[169] G. Rybkin,[119] S. Ryu,[6] A. Ryzhov,[132] G. F. Rzehorz,[58] A. F. Saavedra,[152] G. Sabato,[109] S. Sacerdoti,[29] H. F-W. Sadrozinski,[139] R. Sadykov,[68] F. Safai Tehrani,[134a] P. Saha,[110] M. Sahinsoy,[60a] M. Saimpert,[45] M. Saito,[157] T. Saito,[157] H. Sakamoto,[157] Y. Sakurai,[174] G. Salamanna,[136a,136b] J. E. Salazar Loyola,[34b] D. Salek,[109] P. H. Sales De Bruin,[168] D. Salihagic,[103] A. Salnikov,[145] J. Salt,[170] D. Salvatore,[40a,40b] F. Salvatore,[151] A. Salvucci,[62a,62b,62c] A. Salzburger,[32] D. Sammel,[51] D. Sampsonidis,[156] D. Sampsonidou,[156] J. Sánchez,[170] A. Sanchez Pineda,[167a,167c] H. Sandaker,[121] R. L. Sandbach,[79] C. O. Sander,[45] M. Sandhoff,[177] C. Sandoval,[21] D. P. C. Sankey,[133] M. Sannino,[53a,53b] Y. Sano,[105] A. Sansoni,[50] C. Santoni,[37] H. Santos,[128a] I. Santoyo Castillo,[151] A. Sapronov,[68] J. G. Saraiva,[128a,128d] O. Sasaki,[69] K. Sato,[164] E. Sauvan,[5] G. Savage,[80] P. Savard,[161,e] N. Savic,[103] R. Sawada,[157] C. Sawyer,[133] L. Sawyer,[82,v] C. Sbarra,[22a] A. Sbrizzi,[22a,22b] T. Scanlon,[81] D. A. Scannicchio,[166] J. Schaarschmidt,[140] P. Schacht,[103] B. M. Schachtner,[102] D. Schaefer,[33] L. Schaefer,[124] J. Schaeffer,[86] S. Schaepe,[32] U. Schäfer,[86] A. C. Schaffer,[119] D. Schaile,[102] R. D. Schamberger,[150] V. A. Schegelsky,[125] D. Scheirich,[131] F. Schenck,[17] M. Schernau,[166] C. Schiavi,[53a,53b] S. Schier,[139] L. K. Schildgen,[23] C. Schillo,[51] E. J. Schioppa,[32] M. Schioppa,[40a,40b] S. Schlenker,[32] K. R. Schmidt-Sommerfeld,[103] K. Schmieden,[32] C. Schmitt,[86] S. Schmitt,[45] S. Schmitz,[86] U. Schnoor,[51] L. Schoeffel,[138] A. Schoening,[60b] B. D. Schoenrock,[93] E. Schopf,[23] M. Schott,[86] J. F. P. Schouwenberg,[108] J. Schovancova,[32] S. Schramm,[52] N. Schuh,[86] A. Schulte,[86] M. J. Schultens,[23] H.-C. Schultz-Coulon,[60a] M. Schumacher,[51] B. A. Schumm,[139] Ph. Schune,[138] A. Schwartzman,[145] T. A. Schwarz,[92] H. Schweiger,[87] Ph. Schwemling,[138] R. Schwienhorst,[93] J. Schwindling,[138] A. Sciandra,[23] G. Sciolla,[25] M. Scornajenghi,[40a,40b] F. Scuri,[126a] F. Scutti,[91] J. Searcy,[92] P. Seema,[23] S. C. Seidel,[107] A. Seiden,[139] J. M. Seixas,[26a] G. Sekhniaidze,[106a] K. Sekhon,[92] S. J. Sekula,[43] N. Semprini-Cesari,[22a,22b] S. Senkin,[37] C. Serfon,[121] L. Serin,[119] L. Serkin,[167a,167b] M. Sessa,[136a,136b] R. Seuster,[172] H. Severini,[115] T. Šfiligoj,[78] F. Sforza,[165] A. Sfyrla,[52] E. Shabalina,[58] N. W. Shaikh,[148a,148b] L. Y. Shan,[35a] R. Shang,[169] J. T. Shank,[24] M. Shapiro,[16] P. B. Shatalov,[99] K. Shaw,[167a,167b] S. M. Shaw,[87] A. Shcherbakova,[148a,148b] C. Y. Shehu,[151] Y. Shen,[115] N. Sherafati,[31] A. D. Sherman,[24] P. Sherwood,[81] L. Shi,[153,oo] S. Shimizu,[70] C. O. Shimmin,[179] M. Shimojima,[104] I. P. J. Shipsey,[122] S. Shirabe,[73] M. Shiyakova,[68,pp] J. Shlomi,[175] A. Shmeleva,[98] D. Shoaleh Saadi,[97] M. J. Shochet,[33] S. Shojaii,[91] D. R. Shope,[115] S. Shrestha,[113] E. Shulga,[100] M. A. Shupe,[7] P. Sicho,[129] A. M. Sickles,[169] P. E. Sidebo,[149] E. Sideras Haddad,[147c] O. Sidiropoulou,[178] A. Sidoti,[22a,22b] F. Siegert,[47] Dj. Sijacki,[14] J. Silva,[128a,128d] M. Silva Jr.,[176] S. B. Silverstein,[148a] V. Simak,[130] L. Simic,[68] S. Simion,[119] E. Simioni,[86] B. Simmons,[81] M. Simon,[86] P. Sinervo,[161] N. B. Sinev,[118] M. Sioli,[22a,22b] G. Siragusa,[178] I. Siral,[92] S. Yu. Sivoklokov,[101] J. Sjölin,[148a,148b] M. B. Skinner,[75] P. Skubic,[115] M. Slater,[19] T. Slavicek,[130] M. Slawinska,[42] K. Sliwa,[165] R. Slovak,[131] V. Smakhtin,[175] B. H. Smart,[5] J. Smiesko,[146a] N. Smirnov,[100] S. Yu. Smirnov,[100] Y. Smirnov,[100] L. N. Smirnova,[101,qq] O. Smirnova,[84] J. W. Smith,[58] M. N. K. Smith,[38] R. W. Smith,[38] M. Smizanska,[75] K. Smolek,[130] A. A. Snesarev,[98] I. M. Snyder,[118] S. Snyder,[27] R. Sobie,[172,o] F. Socher,[47] A. M. Soffa,[166] A. Soffer,[155] A. Søgaard,[49] D. A. Soh,[153] G. Sokhrannyi,[78] C. A. Solans Sanchez,[32] M. Solar,[130] E. Yu. Soldatov,[100] U. Soldevila,[170] A. A. Solodkov,[132] A. Soloshenko,[68] O. V. Solovyanov,[132] V. Solovyev,[125] P. Sommer,[141] H. Son,[165] W. Song,[133] A. Sopczak,[130] D. Sosa,[60b] C. L. Sotiropoulou,[126a,126b] S. Sottocornola,[123a,123b] R. Soualah,[167a,167c] A. M. Soukharev,[111,d] D. South,[45] B. C. Sowden,[80] S. Spagnolo,[76a,76b] M. Spalla,[126a,126b] M. Spangenberg,[173] F. Spanò,[80] D. Sperlich,[17] F. Spettel,[103] T. M. Spieker,[60a] R. Spighi,[22a] G. Spigo,[32] L. A. Spiller,[91] M. Spousta,[131] R. D. St. Denis,[56,a] A. Stabile,[94a,94b] R. Stamen,[60a] S. Stamm,[17] E. Stanecka,[42] R. W. Stanek,[6] C. Stanescu,[136a] M. M. Stanitzki,[45] B. S. Stapf,[109] S. Stapnes,[121] E. A. Starchenko,[132] G. H. Stark,[33] J. Stark,[57] S. H Stark,[39] P. Staroba,[129] P. Starovoitov,[60a] S. Stärz,[32] R. Staszewski,[42] M. Stegler,[45] P. Steinberg,[27] B. Stelzer,[144] H. J. Stelzer,[32] O. Stelzer-Chilton,[163a] H. Stenzel,[55] T. J. Stevenson,[79] G. A. Stewart,[56] M. C. Stockton,[118] M. Stoebe,[90] G. Stoicea,[28b] P. Stolte,[58] S. Stonjek,[103] A. R. Stradling,[8] A. Straessner,[47] M. E. Stramaglia,[18] J. Strandberg,[149] S. Strandberg,[148a,148b] M. Strauss,[115] P. Strizenec,[146b] R. Ströhmer,[178] D. M. Strom,[118] R. Stroynowski,[43] A. Strubig,[49] S. A. Stucci,[27] B. Stugu,[15] N. A. Styles,[45] D. Su,[145] J. Su,[127] S. Suchek,[60a] Y. Sugaya,[120] M. Suk,[130] V. V. Sulin,[98] DMS Sultan,[52] S. Sultansoy,[4c] T. Sumida,[71] S. Sun,[92] X. Sun,[3] K. Suruliz,[151] C. J. E. Suster,[152] M. R. Sutton,[151] S. Suzuki,[69] M. Svatos,[129] M. Swiatlowski,[33] S. P. Swift,[2] A. Sydorenko,[86] I. Sykora,[146a] T. Sykora,[131] D. Ta,[51] K. Tackmann,[45] J. Taenzer,[155] A. Taffard,[166] R. Tafirout,[163a] E. Tahirovic,[79] N. Taiblum,[155] H. Takai,[27] R. Takashima,[72] E. H. Takasugi,[103] K. Takeda,[70] T. Takeshita,[142] Y. Takubo,[69] M. Talby,[88] A. A. Talyshev,[111,d] J. Tanaka,[157] M. Tanaka,[159] R. Tanaka,[119] R. Tanioka,[70] B. B. Tannenwald,[113] S. Tapia Araya,[34b] S. Tapprogge,[86] S. Tarem,[154]

G. F. Tartarelli,[94a] P. Tas,[131] M. Tasevsky,[129] T. Tashiro,[71] E. Tassi,[40a,40b] A. Tavares Delgado,[128a,128b] Y. Tayalati,[137e] A. C. Taylor,[107] A. J. Taylor,[49] G. N. Taylor,[91] P. T. E. Taylor,[91] W. Taylor,[163b] P. Teixeira-Dias,[80] D. Temple,[144] H. Ten Kate,[32] P. K. Teng,[153] J. J. Teoh,[120] F. Tepel,[177] S. Terada,[69] K. Terashi,[157] J. Terron,[85] S. Terzo,[13] M. Testa,[50] R. J. Teuscher,[161,o] S. J. Thais,[179] T. Theveneaux-Pelzer,[88] F. Thiele,[39] J. P. Thomas,[19] J. Thomas-Wilsker,[80] P. D. Thompson,[19] A. S. Thompson,[56] L. A. Thomsen,[179] E. Thomson,[124] Y. Tian,[38] R. E. Ticse Torres,[58] V. O. Tikhomirov,[98,rr] Yu. A. Tikhonov,[111,d] S. Timoshenko,[100] P. Tipton,[179] S. Tisserant,[88] K. Todome,[159] S. Todorova-Nova,[5] S. Todt,[47] J. Tojo,[73] S. Tokár,[146a] K. Tokushuku,[69] E. Tolley,[113] L. Tomlinson,[87] M. Tomoto,[105] L. Tompkins,[145,ss] K. Toms,[107] B. Tong,[59] P. Tornambe,[51] E. Torrence,[118] H. Torres,[47] E. Torró Pastor,[140] J. Toth,[88,tt] F. Touchard,[88] D. R. Tovey,[141] C. J. Treado,[112] T. Trefzger,[178] F. Tresoldi,[151] A. Tricoli,[27] I. M. Trigger,[163a] S. Trincaz-Duvoid,[83] M. F. Tripiana,[13] W. Trischuk,[161] B. Trocmé,[57] A. Trofymov,[45] C. Troncon,[94a] M. Trovatelli,[172] L. Truong,[147b] M. Trzebinski,[42] A. Trzupek,[42] K. W. Tsang,[62a] J. C-L. Tseng,[122] P. V. Tsiareshka,[95] N. Tsirintanis,[9] S. Tsiskaridze,[13] V. Tsiskaridze,[51] E. G. Tskhadadze,[54a] I. I. Tsukerman,[99] V. Tsulaia,[16] S. Tsuno,[69] D. Tsybychev,[150] Y. Tu,[62b] A. Tudorache,[28b] V. Tudorache,[28b] T. T. Tulbure,[28a] A. N. Tuna,[59] S. Turchikhin,[68] D. Turgeman,[175] I. Turk Cakir,[4b,uu] R. Turra,[94a] P. M. Tuts,[38] G. Ucchielli,[22a,22b] I. Ueda,[69] M. Ughetto,[148a,148b] F. Ukegawa,[164] G. Unal,[32] A. Undrus,[27] G. Unel,[166] F. C. Ungaro,[91] Y. Unno,[69] K. Uno,[157] J. Urban,[146b] P. Urquijo,[91] P. Urrejola,[86] G. Usai,[8] J. Usui,[69] L. Vacavant,[88] V. Vacek,[130] B. Vachon,[90] K. O. H. Vadla,[121] A. Vaidya,[81] C. Valderanis,[102] E. Valdes Santurio,[148a,148b] M. Valente,[52] S. Valentinetti,[22a,22b] A. Valero,[170] L. Valéry,[13] A. Vallier,[5] J. A. Valls Ferrer,[170] W. Van Den Wollenberg,[109] H. van der Graaf,[109] P. van Gemmeren,[6] J. Van Nieuwkoop,[144] I. van Vulpen,[109] M. C. van Woerden,[109] M. Vanadia,[135a,135b] W. Vandelli,[32] A. Vaniachine,[160] P. Vankov,[109] G. Vardanyan,[180] R. Vari,[134a] E. W. Varnes,[7] C. Varni,[53a,53b] T. Varol,[43] D. Varouchas,[119] A. Vartapetian,[8] K. E. Varvell,[152] J. G. Vasquez,[179] G. A. Vasquez,[34b] F. Vazeille,[37] D. Vazquez Furelos,[13] T. Vazquez Schroeder,[90] J. Veatch,[58] V. Veeraraghavan,[7] L. M. Veloce,[161] F. Veloso,[128a,128c] S. Veneziano,[134a] A. Ventura,[76a,76b] M. Venturi,[172] N. Venturi,[32] V. Vercesi,[123a] M. Verducci,[136a,136b] W. Verkerke,[109] A. T. Vermeulen,[109] J. C. Vermeulen,[109] M. C. Vetterli,[144,e] N. Viaux Maira,[34b] O. Viazlo,[84] I. Vichou,[169,a] T. Vickey,[141] O. E. Vickey Boeriu,[141] G. H. A. Viehhauser,[122] S. Viel,[16] L. Vigani,[122] M. Villa,[22a,22b] M. Villaplana Perez,[94a,94b] E. Vilucchi,[50] M. G. Vincter,[31] V. B. Vinogradov,[68] A. Vishwakarma,[45] C. Vittori,[22a,22b] I. Vivarelli,[151] S. Vlachos,[10] M. Vogel,[177] P. Vokac,[130] G. Volpi,[13] S. E. von Buddenbrock,[147c] H. von der Schmitt,[103] E. von Toerne,[23] V. Vorobel,[131] K. Vorobev,[100] M. Vos,[170] R. Voss,[32] J. H. Vossebeld,[77] N. Vranjes,[14] M. Vranjes Milosavljevic,[14] V. Vrba,[130] M. Vreeswijk,[109] R. Vuillermet,[32] I. Vukotic,[33] P. Wagner,[23] W. Wagner,[177] J. Wagner-Kuhr,[102] H. Wahlberg,[74] S. Wahrmund,[47] K. Wakamiya,[70] J. Walder,[75] R. Walker,[102] W. Walkowiak,[143] V. Wallangen,[148a,148b] A. M. Wang,[59] C. Wang,[36a,q] F. Wang,[176] H. Wang,[16] H. Wang,[3] J. Wang,[60b] J. Wang,[152] Q. Wang,[115] R.-J. Wang,[83] R. Wang,[6] S. M. Wang,[153] T. Wang,[38] W. Wang,[153,vv] W. Wang,[36c,ww] Z. Wang,[36b] C. Wanotayaroj,[45] A. Warburton,[90] C. P. Ward,[30] D. R. Wardrope,[81] A. Washbrook,[49] P. M. Watkins,[19] A. T. Watson,[19] M. F. Watson,[19] G. Watts,[140] S. Watts,[87] B. M. Waugh,[81] A. F. Webb,[11] S. Webb,[86] M. S. Weber,[18] S. M. Weber,[60a] S. A. Weber,[31] J. S. Webster,[6] A. R. Weidberg,[122] B. Weinert,[64] J. Weingarten,[58] M. Weirich,[86] C. Weiser,[51] P. S. Wells,[32] T. Wenaus,[27] T. Wengler,[32] S. Wenig,[32] N. Wermes,[23] M. D. Werner,[67] P. Werner,[32] M. Wessels,[60a] T. D. Weston,[18] K. Whalen,[118] N. L. Whallon,[140] A. M. Wharton,[75] A. S. White,[92] A. White,[8] M. J. White,[1] R. White,[34b] D. Whiteson,[166] B. W. Whitmore,[75] F. J. Wickens,[133] W. Wiedenmann,[176] M. Wielers,[133] C. Wiglesworth,[39] L. A. M. Wiik-Fuchs,[51] A. Wildauer,[103] F. Wilk,[87] H. G. Wilkens,[32] H. H. Williams,[124] S. Williams,[30] C. Willis,[93] S. Willocq,[89] J. A. Wilson,[19] I. Wingerter-Seez,[5] E. Winkels,[151] F. Winklmeier,[118] O. J. Winston,[151] B. T. Winter,[23] M. Wittgen,[145] M. Wobisch,[82,v] A. Wolf,[86] T. M. H. Wolf,[109] R. Wolff,[88] M. W. Wolter,[42] H. Wolters,[128a,128c] V. W. S. Wong,[171] N. L. Woods,[139] S. D. Worm,[19] B. K. Wosiek,[42] J. Wotschack,[32] K. W. Wozniak,[42] M. Wu,[33] S. L. Wu,[176] X. Wu,[52] Y. Wu,[92] T. R. Wyatt,[87] B. M. Wynne,[49] S. Xella,[39] Z. Xi,[92] L. Xia,[35c] D. Xu,[35a] L. Xu,[27] T. Xu,[138] W. Xu,[92] B. Yabsley,[152] S. Yacoob,[147a] K. Yajima,[120] D. P. Yallup,[81] D. Yamaguchi,[159] Y. Yamaguchi,[159] A. Yamamoto,[69] T. Yamanaka,[157] F. Yamane,[70] M. Yamatani,[157] T. Yamazaki,[157] Y. Yamazaki,[70] Z. Yan,[24] H. Yang,[36b] H. Yang,[16] S. Yang,[66] Y. Yang,[153] Z. Yang,[15] W-M. Yao,[16] Y. C. Yap,[45] Y. Yasu,[69] E. Yatsenko,[5] K. H. Yau Wong,[23] J. Ye,[43] S. Ye,[27] I. Yeletskikh,[68] E. Yigitbasi,[24] E. Yildirim,[86] K. Yorita,[174] K. Yoshihara,[124] C. Young,[145] C. J. S. Young,[32] J. Yu,[8] J. Yu,[67] S. P. Y. Yuen,[23] I. Yusuff,[30,xx] B. Zabinski,[42] G. Zacharis,[10] R. Zaidan,[13] A. M. Zaitsev,[132,ll] N. Zakharchuk,[45] J. Zalieckas,[15] A. Zaman,[150] S. Zambito,[59] D. Zanzi,[32] C. Zeitnitz,[177] G. Zemaityte,[122] J. C. Zeng,[169] Q. Zeng,[145] O. Zenin,[132] T. Ženiš,[146a] D. Zerwas,[119] D. Zhang,[36a] D. Zhang,[92] F. Zhang,[176] G. Zhang,[36c,ww] H. Zhang,[119] J. Zhang,[6] L. Zhang,[51] L. Zhang,[36c] M. Zhang,[169] P. Zhang,[35b] R. Zhang,[23] R. Zhang,[36c,q] X. Zhang,[36a] Y. Zhang,[35a,35d] Z. Zhang,[119] X. Zhao,[43] Y. Zhao,[36a,y] Z. Zhao,[36c] A. Zhemchugov,[68]

B. Zhou,[92] C. Zhou,[176] L. Zhou,[43] M. Zhou,[35a,35d] M. Zhou,[150] N. Zhou,[36b] Y. Zhou,[7] C. G. Zhu,[36a] H. Zhu,[35a] J. Zhu,[92] Y. Zhu,[36c] X. Zhuang,[35a] K. Zhukov,[98] A. Zibell,[178] D. Zieminska,[64] N. I. Zimine,[68] S. Zimmermann,[51] Z. Zinonos,[103] M. Zinser,[86] M. Ziolkowski,[143] L. Živković,[14] G. Zobernig,[176] A. Zoccoli,[22a,22b] R. Zou,[33] M. zur Nedden,[17] and L. Zwalinski[32]

(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, National and Kapodistrian University of Athens, Athens, Greece*
[10]*Physics Department, National Technical University of Athens, Zografou, Greece*
[11]*Department of Physics, The University of Texas at Austin, Austin, Texas, USA*
[12]*Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan*
[13]*Institut de Física d'Altes Energies (IFAE), The Barcelona Institute of Science and Technology, Barcelona, Spain*
[14]*Institute of Physics, University of Belgrade, Belgrade, Serbia*
[15]*Department for Physics and Technology, University of Bergen, Bergen, Norway*
[16]*Physics Division, Lawrence Berkeley National Laboratory and University of California, Berkeley, California, USA*
[17]*Department of Physics, Humboldt University, Berlin, Germany*
[18]*Albert Einstein Center for Fundamental Physics and Laboratory for High Energy Physics, University of Bern, Bern, Switzerland*
[19]*School of Physics and Astronomy, University of Birmingham, Birmingham, United Kingdom*
[20a]*Department of Physics, Bogazici University, Istanbul, Turkey*
[20b]*Department of Physics Engineering, Gaziantep University, Gaziantep, Turkey*
[20d]*Istanbul Bilgi University, Faculty of Engineering and Natural Sciences, Istanbul, Turkey*
[20e]*Bahcesehir University, Faculty of Engineering and Natural Sciences, Istanbul, Turkey*
[21]*Centro de Investigaciones, Universidad Antonio Narino, Bogota, Colombia*
[22a]*INFN Sezione di Bologna, Italy*
[22b]*Dipartimento di Fisica e Astronomia, Università di Bologna, Bologna, Italy*
[23]*Physikalisches Institut, University of Bonn, Bonn, Germany*
[24]*Department of Physics, Boston University, Boston, Massachusetts, USA*
[25]*Department of Physics, Brandeis University, Waltham, Massachusetts, USA*
[26a]*Universidade Federal do Rio De Janeiro COPPE/EE/IF, Rio de Janeiro, Brazil*
[26b]*Electrical Circuits Department, Federal University of Juiz de Fora (UFJF), Juiz de Fora, Brazil*
[26c]*Federal University of Sao Joao del Rei (UFSJ), Sao Joao del Rei, Brazil*
[26d]*Instituto de Fisica, Universidade de Sao Paulo, Sao Paulo, Brazil*
[27]*Physics Department, Brookhaven National Laboratory, Upton, New York, USA*
[28a]*Transilvania University of Brasov, Brasov, Romania*
[28b]*Horia Hulubei National Institute of Physics and Nuclear Engineering, Bucharest, Romania*
[28c]*Department of Physics, Alexandru Ioan Cuza University of Iasi, Iasi, Romania*
[28d]*National Institute for Research and Development of Isotopic and Molecular Technologies, Physics Department, Cluj Napoca, Romania*
[28e]*University Politehnica Bucharest, Bucharest, Romania*
[28f]*West University in Timisoara, Timisoara, Romania*
[29]*Departamento de Física, Universidad de Buenos Aires, Buenos Aires, Argentina*
[30]*Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom*
[31]*Department of Physics, Carleton University, Ottawa, Ontario, Canada*
[32]*CERN, Geneva, Switzerland*
[33]*Enrico Fermi Institute, University of Chicago, Chicago, Illinois, USA*
[34a]*Departamento de Física, Pontificia Universidad Católica de Chile, Santiago, Chile*
[34b]*Departamento de Física, Universidad Técnica Federico Santa María, Valparaíso, Chile*
[35a]*Institute of High Energy Physics, Chinese Academy of Sciences, Beijing, China*

[35b]Department of Physics, Nanjing University, Jiangsu, China
[35c]Physics Department, Tsinghua University, Beijing 100084, China
[35d]University of Chinese Academy of Science (UCAS), Beijing, China
[36a]School of Physics, Shandong University, Shandong, China
[36b]School of Physics and Astronomy, Key Laboratory for Particle Physics, Astrophysics and Cosmology, Ministry of Education; Shanghai Key Laboratory for Particle Physics and Cosmology, Shanghai Jiao Tong University, China
[36c]Department of Modern Physics and State Key Laboratory of Particle Detection and Electronics, University of Science and Technology of China, Anhui, China
[37]Université Clermont Auvergne, CNRS/IN2P3, LPC, Clermont-Ferrand, France
[38]Nevis Laboratory, Columbia University, Irvington, New York, USA
[39]Niels Bohr Institute, University of Copenhagen, Kobenhavn, Denmark
[40a]INFN Gruppo Collegato di Cosenza, Laboratori Nazionali di Frascati, Italy
[40b]Dipartimento di Fisica, Università della Calabria, Rende, Italy
[41a]AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Krakow, Poland
[41b]Marian Smoluchowski Institute of Physics, Jagiellonian University, Krakow, Poland
[42]Institute of Nuclear Physics Polish Academy of Sciences, Krakow, Poland
[43]Physics Department, Southern Methodist University, Dallas, Texas, USA
[44]Physics Department, University of Texas at Dallas, Richardson, Texas, USA
[45]DESY, Hamburg and Zeuthen, Germany
[46]Lehrstuhl für Experimentelle Physik IV, Technische Universität Dortmund, Dortmund, Germany
[47]Institut für Kern- und Teilchenphysik, Technische Universität Dresden, Dresden, Germany
[48]Department of Physics, Duke University, Durham, North Carolina, USA
[49]SUPA - School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom
[50]INFN e Laboratori Nazionali di Frascati, Frascati, Italy
[51]Fakultät für Mathematik und Physik, Albert-Ludwigs-Universität, Freiburg, Germany
[52]Departement de Physique Nucleaire et Corpusculaire, Université de Genève, Geneva, Switzerland
[53a]INFN Sezione di Genova, Italy
[53b]Dipartimento di Fisica, Università di Genova, Genova, Italy
[54a]E. Andronikashvili Institute of Physics, Iv. Javakhishvili Tbilisi State University, Tbilisi, Georgia
[54b]High Energy Physics Institute, Tbilisi State University, Tbilisi, Georgia
[55]II Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen, Germany
[56]SUPA - School of Physics and Astronomy, University of Glasgow, Glasgow, United Kingdom
[57]Laboratoire de Physique Subatomique et de Cosmologie, Université Grenoble-Alpes, CNRS/IN2P3, Grenoble, France
[58]II Physikalisches Institut, Georg-August-Universität, Göttingen, Germany
[59]Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge, Massachusetts, USA
[60a]Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany
[60b]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany
[61]Faculty of Applied Information Science, Hiroshima Institute of Technology, Hiroshima, Japan
[62a]Department of Physics, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong, China
[62b]Department of Physics, The University of Hong Kong, Hong Kong, China
[62c]Department of Physics and Institute for Advanced Study, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, China
[63]Department of Physics, National Tsing Hua University, Hsinchu, Taiwan
[64]Department of Physics, Indiana University, Bloomington, Indiana, USA
[65]Institut für Astro- und Teilchenphysik, Leopold-Franzens-Universität, Innsbruck, Austria
[66]University of Iowa, Iowa City, Iowa, USA
[67]Department of Physics and Astronomy, Iowa State University, Ames, Iowa, USA
[68]Joint Institute for Nuclear Research, JINR Dubna, Dubna, Russia
[69]KEK, High Energy Accelerator Research Organization, Tsukuba, Japan
[70]Graduate School of Science, Kobe University, Kobe, Japan
[71]Faculty of Science, Kyoto University, Kyoto, Japan
[72]Kyoto University of Education, Kyoto, Japan
[73]Research Center for Advanced Particle Physics and Department of Physics, Kyushu University, Fukuoka, Japan
[74]Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata, Argentina
[75]Physics Department, Lancaster University, Lancaster, United Kingdom
[76a]INFN Sezione di Lecce, Italy
[76b]Dipartimento di Matematica e Fisica, Università del Salento, Lecce, Italy
[77]Oliver Lodge Laboratory, University of Liverpool, Liverpool, United Kingdom
[78]Department of Experimental Particle Physics, Jožef Stefan Institute and Department of Physics, University of Ljubljana, Ljubljana, Slovenia

[79]School of Physics and Astronomy, Queen Mary University of London, London, United Kingdom
[80]Department of Physics, Royal Holloway University of London, Surrey, United Kingdom
[81]Department of Physics and Astronomy, University College London, London, United Kingdom
[82]Louisiana Tech University, Ruston, Louisiana, USA
[83]Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France
[84]Fysiska institutionen, Lunds universitet, Lund, Sweden
[85]Departamento de Fisica Teorica C-15, Universidad Autonoma de Madrid, Madrid, Spain
[86]Institut für Physik, Universität Mainz, Mainz, Germany
[87]School of Physics and Astronomy, University of Manchester, Manchester, United Kingdom
[88]CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France
[89]Department of Physics, University of Massachusetts, Amherst, Massachusetts, USA
[90]Department of Physics, McGill University, Montreal, Quebec, Canada
[91]School of Physics, University of Melbourne, Victoria, Australia
[92]Department of Physics, The University of Michigan, Ann Arbor, Michigan, USA
[93]Department of Physics and Astronomy, Michigan State University, East Lansing, Michigan, USA
[94a]INFN Sezione di Milano, Italy
[94b]Dipartimento di Fisica, Università di Milano, Milano, Italy
[95]B.I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk, Republic of Belarus
[96]Research Institute for Nuclear Problems of Byelorussian State University, Minsk, Republic of Belarus
[97]Group of Particle Physics, University of Montreal, Montreal, Quebec, Canada
[98]P.N. Lebedev Physical Institute of the Russian Academy of Sciences, Moscow, Russia
[99]Institute for Theoretical and Experimental Physics (ITEP), Moscow, Russia
[100]National Research Nuclear University MEPhI, Moscow, Russia
[101]D.V. Skobeltsyn Institute of Nuclear Physics, M.V. Lomonosov Moscow State University, Moscow, Russia
[102]Fakultät für Physik, Ludwig-Maximilians-Universität München, München, Germany
[103]Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), München, Germany
[104]Nagasaki Institute of Applied Science, Nagasaki, Japan
[105]Graduate School of Science and Kobayashi-Maskawa Institute, Nagoya University, Nagoya, Japan
[106a]INFN Sezione di Napoli, Italy
[106b]Dipartimento di Fisica, Università di Napoli, Napoli, Italy
[107]Department of Physics and Astronomy, University of New Mexico, Albuquerque, New Mexico, USA
[108]Institute for Mathematics, Astrophysics and Particle Physics, Radboud University Nijmegen/Nikhef, Nijmegen, Netherlands
[109]Nikhef National Institute for Subatomic Physics and University of Amsterdam, Amsterdam, Netherlands
[110]Department of Physics, Northern Illinois University, DeKalb, Illinois, USA
[111]Budker Institute of Nuclear Physics, SB RAS, Novosibirsk, Russia
[112]Department of Physics, New York University, New York, New York, USA
[113]The Ohio State University, Columbus, Ohio, USA
[114]Faculty of Science, Okayama University, Okayama, Japan
[115]Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman, Oklahoma, USA
[116]Department of Physics, Oklahoma State University, Stillwater, Oklahoma, USA
[117]Palacký University, RCPTM, Olomouc, Czech Republic
[118]Center for High Energy Physics, University of Oregon, Eugene, Oregon, USA
[119]LAL, Univ. Paris-Sud, CNRS/IN2P3, Université Paris-Saclay, Orsay, France
[120]Graduate School of Science, Osaka University, Osaka, Japan
[121]Department of Physics, University of Oslo, Oslo, Norway
[122]Department of Physics, Oxford University, Oxford, United Kingdom
[123a]INFN Sezione di Pavia, Italy
[123b]Dipartimento di Fisica, Università di Pavia, Pavia, Italy
[124]Department of Physics, University of Pennsylvania, Philadelphia, Pennsylvania, USA
[125]National Research Centre "Kurchatov Institute" B.P. Konstantinov Petersburg Nuclear Physics Institute, St. Petersburg, Russia
[126a]INFN Sezione di Pisa, Italy
[126b]Dipartimento di Fisica E. Fermi, Università di Pisa, Pisa, Italy
[127]Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh, Pennsylvania, USA
[128a]Laboratório de Instrumentação e Física Experimental de Partículas - LIP, Lisboa, Portugal
[128b]Faculdade de Ciências, Universidade de Lisboa, Lisboa, Portugal
[128c]Department of Physics, University of Coimbra, Coimbra, Portugal
[128d]Centro de Física Nuclear da Universidade de Lisboa, Lisboa, Portugal
[128e]Departamento de Fisica, Universidade do Minho, Braga, Portugal
[128f]Departamento de Fisica Teorica y del Cosmos, Universidad de Granada, Granada, Portugal
[128g]Dep Fisica and CEFITEC of Faculdade de Ciencias e Tecnologia, Universidade Nova de Lisboa, Caparica, Portugal

[129]*Institute of Physics, Academy of Sciences of the Czech Republic, Praha, Czech Republic*
[130]*Czech Technical University in Prague, Praha, Czech Republic*
[131]*Charles University, Faculty of Mathematics and Physics, Prague, Czech Republic*
[132]*State Research Center Institute for High Energy Physics (Protvino), NRC KI, Russia*
[133]*Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom*
[134a]*INFN Sezione di Roma, Italy*
[134b]*Dipartimento di Fisica, Sapienza Università di Roma, Roma, Italy*
[135a]*INFN Sezione di Roma Tor Vergata, Italy*
[135b]*Dipartimento di Fisica, Università di Roma Tor Vergata, Roma, Italy*
[136a]*INFN Sezione di Roma Tre, Italy*
[136b]*Dipartimento di Matematica e Fisica, Università Roma Tre, Roma, Italy*
[137a]*Faculté des Sciences Ain Chock, Réseau Universitaire de Physique des Hautes Energies - Université Hassan II, Casablanca, Morocco*
[137b]*Centre National de l'Energie des Sciences Techniques Nucleaires, Rabat, Morocco*
[137c]*Faculté des Sciences Semlalia, Université Cadi Ayyad, LPHEA-Marrakech, Morocco*
[137d]*Faculté des Sciences, Université Mohamed Premier and LPTPM, Oujda, Morocco*
[137e]*Faculté des sciences, Université Mohammed V, Rabat, Morocco*
[138]*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*
[139]*Santa Cruz Institute for Particle Physics, University of California Santa Cruz, Santa Cruz, California, USA*
[140]*Department of Physics, University of Washington, Seattle, Washington, USA*
[141]*Department of Physics and Astronomy, University of Sheffield, Sheffield, United Kingdom*
[142]*Department of Physics, Shinshu University, Nagano, Japan*
[143]*Department Physik, Universität Siegen, Siegen, Germany*
[144]*Department of Physics, Simon Fraser University, Burnaby, British Columbia, Canada*
[145]*SLAC National Accelerator Laboratory, Stanford, California, USA*
[146a]*Faculty of Mathematics, Physics & Informatics, Comenius University, Bratislava, Slovak Republic*
[146b]*Department of Subnuclear Physics, Institute of Experimental Physics of the Slovak Academy of Sciences, Kosice, Slovak Republic*
[147a]*Department of Physics, University of Cape Town, Cape Town, South Africa*
[147b]*Department of Physics, University of Johannesburg, Johannesburg, South Africa*
[147c]*School of Physics, University of the Witwatersrand, Johannesburg, South Africa*
[148a]*Department of Physics, Stockholm University, Sweden*
[148b]*The Oskar Klein Centre, Stockholm, Sweden*
[149]*Physics Department, Royal Institute of Technology, Stockholm, Sweden*
[150]*Departments of Physics & Astronomy and Chemistry, Stony Brook University, Stony Brook, New York, USA*
[151]*Department of Physics and Astronomy, University of Sussex, Brighton, United Kingdom*
[152]*School of Physics, University of Sydney, Sydney, Australia*
[153]*Institute of Physics, Academia Sinica, Taipei, Taiwan*
[154]*Department of Physics, Technion: Israel Institute of Technology, Haifa, Israel*
[155]*Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel*
[156]*Department of Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece*
[157]*International Center for Elementary Particle Physics and Department of Physics, The University of Tokyo, Tokyo, Japan*
[158]*Graduate School of Science and Technology, Tokyo Metropolitan University, Tokyo, Japan*
[159]*Department of Physics, Tokyo Institute of Technology, Tokyo, Japan*
[160]*Tomsk State University, Tomsk, Russia*
[161]*Department of Physics, University of Toronto, Toronto, Ontario, Canada*
[162a]*INFN-TIFPA, Italy*
[162b]*University of Trento, Trento, Italy*
[163a]*TRIUMF, Vancouver, British Columbia, Canada*
[163b]*Department of Physics and Astronomy, York University, Toronto, Ontario, Canada*
[164]*Faculty of Pure and Applied Sciences, and Center for Integrated Research in Fundamental Science and Engineering, University of Tsukuba, Tsukuba, Japan*
[165]*Department of Physics and Astronomy, Tufts University, Medford, Massachusetts, USA*
[166]*Department of Physics and Astronomy, University of California Irvine, Irvine, California, USA*
[167a]*INFN Gruppo Collegato di Udine, Sezione di Trieste, Udine, Italy*
[167b]*ICTP, Trieste, Italy*
[167c]*Dipartimento di Chimica, Fisica e Ambiente, Università di Udine, Udine, Italy*
[168]*Department of Physics and Astronomy, University of Uppsala, Uppsala, Sweden*
[169]*Department of Physics, University of Illinois, Urbana, Illinois, USA*
[170]*Instituto de Fisica Corpuscular (IFIC), Centro Mixto Universidad de Valencia - CSIC, Spain*

[171]Department of Physics, University of British Columbia, Vancouver, British Columbia, Canada
[172]Department of Physics and Astronomy, University of Victoria, Victoria, British Columbia, Canada
[173]Department of Physics, University of Warwick, Coventry, United Kingdom
[174]Waseda University, Tokyo, Japan
[175]Department of Particle Physics, The Weizmann Institute of Science, Rehovot, Israel
[176]Department of Physics, University of Wisconsin, Madison, Wisconsin, USA
[177]Fakultät für Mathematik und Naturwissenschaften, Fachgruppe Physik, Bergische Universität Wuppertal, Wuppertal, Germany
[178]Fakultät für Physik und Astronomie, Julius-Maximilians-Universität, Würzburg, Germany
[179]Department of Physics, Yale University, New Haven, Connecticut, USA
[180]Yerevan Physics Institute, Yerevan, Armenia
[181]Centre de Calcul de l'Institut National de Physique Nucléaire et de Physique des Particules (IN2P3), Villeurbanne, France
[182]Academia Sinica Grid Computing, Institute of Physics, Academia Sinica, Taipei, Taiwan

[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, British Columbia, Canada.
[f]Also at Department of Physics & Astronomy, University of Louisville, Louisville, KY, USA.
[g]Also at Physics Department, An-Najah National University, Nablus, Palestine.
[h]Also at Department of Physics, California State University, Fresno, CA, USA.
[i]Also at Department of Physics, University of Fribourg, Fribourg, Switzerland.
[j]Also at II Physikalisches Institut, Georg-August-Universität, Göttingen, Germany.
[k]Also at Departament de Fisica de la Universitat Autonoma de Barcelona, Barcelona, Spain.
[l]Also at Tomsk State University, Tomsk, and Moscow Institute of Physics and Technology State University, Dolgoprudny, Russia.
[m]Also at The Collaborative Innovation Center of Quantum Matter (CICQM), Beijing, China.
[n]Also at Universita di Napoli Parthenope, Napoli, Italy.
[o]Also at Institute of Particle Physics (IPP), Canada.
[p]Also at Horia Hulubei National Institute of Physics and Nuclear Engineering, Bucharest, Romania.
[q]Also at CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France.
[r]Also at Department of Physics, St. Petersburg State Polytechnical University, St. Petersburg, Russia.
[s]Also at Borough of Manhattan Community College, City University of New York, New York City, NY, USA.
[t]Also at Department of Financial and Management Engineering, University of the Aegean, Chios, Greece.
[u]Also at Centre for High Performance Computing, CSIR Campus, Rosebank, Cape Town, South Africa.
[v]Also at Louisiana Tech University, Ruston, LA, USA.
[w]Also at Institucio Catalana de Recerca i Estudis Avancats, ICREA, Barcelona, Spain.
[x]Also at Department of Physics, The University of Michigan, Ann Arbor, MI, USA.
[y]Also at LAL, Univ. Paris-Sud, CNRS/IN2P3, Université Paris-Saclay, Orsay, France.
[z]Also at Graduate School of Science, Osaka University, Osaka, Japan.
[aa]Also at Fakultät für Mathematik und Physik, Albert-Ludwigs-Universität, Freiburg, Germany.
[bb]Also at Institute for Mathematics, Astrophysics and Particle Physics, Radboud University Nijmegen/Nikhef, Nijmegen, Netherlands.
[cc]Also at Department of Physics, The University of Texas at Austin, Austin, TX, USA.
[dd]Also at Institute of Theoretical Physics, Ilia State University, Tbilisi, Georgia.
[ee]Also at CERN, Geneva, Switzerland.
[ff]Also at Georgian Technical University (GTU), Tbilisi, Georgia.
[gg]Also at Ochadai Academic Production, Ochanomizu University, Tokyo, Japan.
[hh]Also at Manhattan College, New York, NY, USA.
[ii]Also at The City College of New York, New York, NY, USA.
[jj]Also at Departamento de Fisica Teorica y del Cosmos, Universidad de Granada, Granada, Portugal.
[kk]Also at Department of Physics, California State University, Sacramento, CA, USA.
[ll]Also at Moscow Institute of Physics and Technology State University, Dolgoprudny, Russia.
[mm]Also at Departement de Physique Nucleaire et Corpusculaire, Université de Genève, Geneva, Switzerland.
[nn]Also at Institut de Física d'Altes Energies (IFAE), The Barcelona Institute of Science and Technology, Barcelona, Spain.
[oo]Also at School of Physics, Sun Yat-sen University, Guangzhou, China.
[pp]Also at Institute for Nuclear Research and Nuclear Energy (INRNE) of the Bulgarian Academy of Sciences, Sofia, Bulgaria.
[qq]Also at Faculty of Physics, M. V. Lomonosov Moscow State University, Moscow, Russia.
[rr]Also at National Research Nuclear University MEPhI, Moscow, Russia.
[ss]Also at Department of Physics, Stanford University, Stanford, CA, USA.
[tt]Also at Institute for Particle and Nuclear Physics, Wigner Research Centre for Physics, Budapest, Hungary.

[uu]Also at Giresun University, Faculty of Engineering, Turkey.
[vv]Also at Department of Physics, Nanjing University, Jiangsu, China.
[ww]Also at Institute of Physics, Academia Sinica, Taipei, Taiwan.
[xx]Also at University of Malaya, Department of Physics, Kuala Lumpur, Malaysia.