UNIVERSITY OF AMSTERDAM

UvA-DARE (Digital Academic Repository)

Search for quantum black-hole production in high-invariant-mass lepton+jet final states using pp collisions at √s = 8 TeV and the ATLAS detector

Aad, G.; et al., [Unknown]; Aben, R.; Beemster, L.J.; Bentvelsen, S.; Berge, D.; Berglund, E.; Bobbink, G.J.; Bos, K.; Boterenbrood, H.; Castelli, A.; Colijn, A.P.; de Jong, P.; de Nooij, L.; Deigaard, I.; Deluca, C.; Deviveiros, P.O.; Dhaliwal, S.; Ferrari, P.; Gadatsch, S.; Geerts, D.A.A.; Hartjes, F.; Hessey, N.P.; Hod, N.; Igonkina, O.; Kluit, P.; Koffeman, E.; Lee, H.; Lenz, T.; Linde, F.; Mahlstedt, J.; Mechnich, J.; Mussche, I.; Oussoren, K.P.; Pani, P.; Salek, D.; Valencic, N.; van der Deijl, P.C.; van der Geer, R.; van der Graaf, H.; van der Leeuw, R.; van Vulpen, I.; Verkerke, W.; Vermeulen, J.C.; Vranjes Milosavljevic, M.; Vreeswijk, M.; Weits, H.

DOI
10.1103/PhysRevLett.112.091804

Publication date
2014

Document Version
Final published version

Published in
Physical Review Letters

Link to publication

Citation for published version (APA):
Aad, G., et al., U., Aben, R., Beemster, L. J., Bentvelsen, S., Berge, D., Berglund, E., Bobbink, G. J., Bos, K., Boterenbrood, H., Castelli, A., Colijn, A. P., de Jong, P., de Nooij, L., Deigaard, I., Deluca, C., Deviveiros, P. O., Dhaliwal, S., Ferrari, P., ... Weits, H. (2014). Search for quantum black-hole production in high-invariant-mass lepton+jet final states using pp collisions at √s = 8 TeV and the ATLAS detector. *Physical Review Letters*, *112*(9), Article 091804. https://doi.org/10.1103/PhysRevLett.112.091804

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

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

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

Download date:15 Oct 2026

Search for Quantum Black Hole Production in High-Invariant-Mass Lepton + Jet Final States Using pp Collisions at $\sqrt{s} = 8$ TeV and the ATLAS Detector

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

(Received 8 November 2013; published 5 March 2014)

This Letter presents a search for quantum black-hole production using 20.3 fb^{-1} of data collected with the ATLAS detector in pp collisions at the LHC at $\sqrt{s} = 8$ TeV. The quantum black holes are assumed to decay into a final state characterized by a lepton (electron or muon) and a jet. In either channel, no event with a lepton-jet invariant mass of 3.5 TeV or more is observed, consistent with the expected background. Limits are set on the product of cross sections and branching fractions for the lepton + jet final states of quantum black holes produced in a search region for invariant masses above 1 TeV. The combined 95% confidence level upper limit on this product for quantum black holes with threshold mass above 3.5 TeV is 0.18 fb. This limit constrains the threshold quantum black-hole mass to be above 5.3 TeV in the model considered.

DOI: 10.1103/PhysRevLett.112.091804 PACS numbers: 13.85.Qk, 04.50.Cd, 04.50.Gh

Quantum black holes (QBHs) [1,2] are predicted in low-scale quantum gravity theories that offer solutions to the mass hierarchy problem of the standard model (SM) by lowering the scale of quantum gravity (M_D) from the Planck scale ($\sim 10^{16}$ TeV) to a value of about 1 TeV. In models with large extra dimensions such as the Arkani-Hamed–Dimopoulous–Dvali (ADD) model [3–5], only the gravitational field is allowed to penetrate the n extra dimensions, while all SM fields are localized in the usual four-dimensional space-time. QBHs with masses near M_D, postulated to conserve total angular momentum, color, and electric charge, may decay to two particles [2,6]. The behavior of QBHs is distinct from semiclassical black holes that decay via Hawking radiation to a large number of objects [7]. Searches for semiclassical black holes typically require three or more objects [8,9].

The quantum approximations used in the modeling of black hole production are valid when black hole masses are above a minimal threshold mass, M_{th}, which is taken to be equivalent to the QBH inverse gravitational radius. If the QBHs investigated in this Letter are accessible at the Large Hadron Collider (LHC) [10], they can produce lepton + jet final states [2,6], motivating this first dedicated search for high-invariant-mass final states with a single electron (e) or a single muon (μ), and at least one jet. Two-particle QBH decays to a final state consisting of a lepton and a quark-jet violate lepton and baryon number conservation, producing a distinctive signal for physics beyond the SM. Previous searches for QBHs relied on signatures such as dijet mass distributions [11,12], generic multiobject configurations [9], and photon + jet final states [13].

The largest QBH cross section for the final states considered is predicted for the collision of two u quarks (σ_{uu}), which produces charge $+4/3$ objects with equal branching fractions (BFs) of $\mathrm{BF}_{uu} = 11\%$ to each lepton + jet final state. The next largest cross sections are for charge $+1/3$ (ud) and $-2/3$ (dd) QBHs with lepton + jet BFs of $\mathrm{BF}_{ud} = 5.7\%$ and $\mathrm{BF}_{dd} = 6.7\%$ [6]. Processes with initial states having antiquarks and heavier sea quarks are suppressed by at least a factor of 100 and can be neglected. The QBH cross section is a steeply declining function of M_{th}, and has $\Sigma\sigma_{\mathrm{qq}} \times \mathrm{BF}_{\mathrm{qq}} \approx 8.6 \times 10^5$ fb, 8.9×10^2 fb and 0.75 fb for M_{th} of 1, 3, and 5 TeV, respectively [14].

The ATLAS detector [15] includes an inner tracker, covering a pseudorapidity [16] range $|\eta| < 2.5$, surrounded by a superconducting solenoid providing a 2 T central field. A liquid-argon (LAr) electromagnetic (EM) sampling calorimeter ($|\eta| < 3.2$), a scintillator-tile hadronic calorimeter ($|\eta| < 1.7$), a LAr hadronic calorimeter ($1.4 < |\eta| < 3.2$), and a LAr forward calorimeter ($3.1 < |\eta| < 4.9$) provide the energy measurements. The muon spectrometer consists of tracking chambers covering $|\eta| < 2.7$, and trigger chambers covering $|\eta| < 2.4$, in a magnetic field produced by a system of air-core toroids. Events considered in this analysis are required to have one high-transverse-momentum (high-p_{T}) lepton (e/μ) that passes requirements of the three-level trigger system [17]. The thresholds applied at the third trigger level are 60 and 36 GeV for electrons and muons, respectively. The analysis is based on the complete 2012 data set of pp collisions taken at a center-of-mass energy of $\sqrt{s} = 8$ TeV by the ATLAS detector at the LHC, corresponding to an integrated luminosity of 20.3 ± 0.6 fb^{-1} [18] after data-quality requirements.

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

Published by the American Physical Society under the terms of the Creative Commons Attribution 3.0 License. Further distribution of this work must maintain attribution to the author(s) and the published articles title, journal citation, and DOI.

 © 2014 CERN, for the ATLAS Collaboration

The event selection is designed to be efficient for generic lepton + jet final states and is based on leading-order simulated-signal QBH events obtained from the QBH1.04 generator [14], followed by parton showering and hadronization using PYTHIA8.165 [19]. The signal generator uses the MSTW2008LO [20] set of leading-order parton distribution functions (PDFs) with the AU2 underlying-event tune [21]. This Letter assumes the ADD model with $M_{\rm th} = M_D$, $n = 6$, and the QCD factorization scale for the PDFs set to the inverse gravitational radius [14]. Samples with $M_{\rm th}$ from 1 to 6 TeV, in steps of 0.5 TeV, are generated for both channels.

Events with a high-$p_{\rm T}$ lepton and one or more jets can also arise from electroweak (EW) processes including vector-boson production with additional jets, diboson (WW, WZ, ZZ), top-quark pair ($t\bar{t}$), and single top-quark (t or $\bar{t}$) production, and multijet processes including nonprompt leptons from semileptonic hadron decays and jets misidentified as leptons.

The EW background in the signal region (SR) is estimated using Monte Carlo (MC) samples normalized to data in control regions. All MC simulated samples are produced using the ATLAS detector simulation [22] based on GEANT4 [23]. The simulated events are reconstructed in the same manner as the data. The $t\bar{t}$ and single-top-quark events are simulated with MC@NLO4.06 [24] and AcerMC3.8 [25], respectively; the production of W + jets and Z + jets is simulated using ALPGEN2.14 [26]; and diboson production is simulated with SHERPA1.4.1 [27]. The leading-order CTEQ6L1 PDFs [28] are used for ALPGEN and AcerMC samples while the next-to-leading-order CT10 PDFs [29] are used for the SHERPA and MC@NLO samples. The generators for all samples except dibosons are interfaced to HERWIG6.520 [30,31] for parton showering and hadronization and to JIMMY4.31 [32] for the underlying-event model. The results of higher-order calculations are used to adjust the relative fractions of the simulated events as in Refs. [33,34]. Additional inelastic pp interactions, termed pileup, are included in the event simulation so as to match the distribution in the data (on average 21 interactions per bunch crossing).

Electron candidates are identified as localized depositions of energy in the EM calorimeter with $p_{{\rm T}e} > 130$ GeV and $|\eta| < 2.47$, excluding the barrel–end-cap transition region, $1.37 < |\eta| < 1.52$, and matched to a track reconstructed in the tracking detectors. Background from jets is reduced by requiring that the shower profiles are consistent with those of electrons [35]. Isolated electrons are selected by requiring the transverse energy deposited in a cone of radius $\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} = 0.3$ centered on the electron cluster, excluding the energy of the electron cluster itself, to be less than $0.0055 \times p_{{\rm T}e} + 3.5$ GeV after corrections for energy due to pileup and energy leakage from the electron cluster into the cone. This criterion provides nearly constant selection efficiency for signal events over the entire $p_{{\rm T}e}$ range explored and for all the pileup conditions.

Muon candidates are required to be detected in at least three layers of the muon spectrometer and to have $p_{{\rm T}\mu} > 130$ GeV and $|\eta| < 2.4$. Possible background from cosmic rays is reduced by requiring the transverse and longitudinal distances of closest approach to the interaction point to be smaller than 0.2 and 1.0 mm, respectively. Signal muons are required to be isolated such that $\sum p_{\rm T} < 0.05 \times p_{{\rm T}\mu}$, where $\sum p_{\rm T}$ is the sum of the $p_{\rm T}$ of the other tracks in a cone of radius $\Delta R = 0.3$ around the direction of the muon.

Jets are constructed from three-dimensional noise-suppressed clusters of calorimeter cells using the anti-k_t algorithm with a radius parameter of 0.4 [36,37]. Jet energies are corrected for losses in material in front of the active calorimeter layers, detector inhomogeneities, the noncompensating nature of the calorimeter, and pileup. Jet energies are calibrated using MC simulation and the combination of several *in situ* techniques applied to data [38–40]. All jets are required to have $p_{{\rm T}j} > 50$ GeV and $|\eta| < 2.5$. In addition, the most energetic jet is required to have $p_{{\rm T}j} > 130$ GeV.

The missing transverse momentum (with magnitude $E_{\rm T}^{\rm miss}$), used only in the background estimation, is calculated as the negative of the vectorial sum of calibrated clustered energy deposits in the calorimeters, and is corrected for the momenta of any reconstructed muons [41].

In the electron (muon) channel, events are required to have exactly one electron (muon). Multijet background can be reduced, with minimal loss in signal efficiency, by requiring the average value of η for the lepton and leading jet to satisfy $|\langle\eta\rangle| < 1.25$ and the difference between the lepton and leading jet η to satisfy $|\Delta\eta| < 1.5$. The signal lepton and jet are mostly back-to-back in ϕ and are required to satisfy $|\Delta\phi| > \pi/2$.

The invariant mass ($m_{\rm inv}$) is calculated from the lepton and highest-$p_{\rm T}$ jet. The SR is defined by a lower bound on $m_{\rm inv}$, $m_{\rm min}$, that accounts for experimental resolution. In the electron channel $m_{\rm min} = 0.9 M_{\rm th}$ is used. In the muon channel, the requirement is loosened at high invariant mass, as muon resolution has a term quadratic in $p_{{\rm T}\mu}$, resulting in $m_{\rm min} = [0.95 - 0.05 M_{\rm th}/1\ {\rm TeV}] M_{\rm th}$. A low-invariant-mass control region (LIMCR) is defined with $m_{\rm inv}$ between 400 and 900 GeV, which has a negligible contamination from a potential signal ($< 2\%$) for the lowest $M_{\rm th}$ considered.

The acceptance of the event selection is about 65%, based on generator-level quantities and calculated by imposing selection criteria that apply directly to phase space (lepton/jet η, lepton/jet $p_{\rm T}$, $\Delta\eta$, $\Delta\phi$, $\langle\eta\rangle$, and $m_{\rm inv}$). All other selection criteria, which in general correspond to event and object quality requirements, are used to calculate the experimental efficiency based on the events included in

the acceptance. The experimental efficiency falls from 89 (59)% to 81(50)% for masses from 1 to 6 TeV in the electron (muon) channel. The experimental efficiency in the muon channel is lower than that in the electron channel because more stringent requirements are applied to ensure the best possible resolution on m_{inv}. The cumulative signal efficiency is the product of the acceptance and experimental efficiency.

In the electron channel, the multijet background is characterized by small values of $E_{\text{T}}^{\text{miss}}$, while EW background events can have large $E_{\text{T}}^{\text{miss}}$ due to the production of high-momentum neutrinos. The discriminating power of $E_{\text{T}}^{\text{miss}}$ is used to determine the normalization of the two backgrounds to the data in the LIMCR. The multijet template is taken from data in which electron candidates pass relaxed identification criteria but fail the normal identification selection, and the EW template is taken from MC simulation where electron candidates pass the normal selection. The templates are fit to the $E_{\text{T}}^{\text{miss}}$ distribution in the interval [0,150] GeV in five separate detector-motivated regions of η, to determine normalization factors for both the multijet and EW backgrounds.

To extrapolate both the multijet and EW background to the SR, functions of the form $p_1 x^{p_2+p_3 \ln(x)}(1-x)^{p_4}$ (with $x = m_{\text{inv}}/\sqrt{s}$ and fit parameters p_1–p_4) [42] are used and the contributions are scaled by the corresponding normalization factor derived in the LIMCR. A simple power-law fit, with p_3 and p_4 fixed to zero, adequately describes both data and simulation. This is used as the baseline, while p_3 and p_4 are allowed to vary as part of the evaluation of the systematic uncertainty.

In the muon channel, the multijet and EW backgrounds can be discriminated on the basis of the transverse impact parameter (d_0) distribution of the muon since the multijet background is dominated by jets containing charm and bottom hadrons decaying to muons while EW backgrounds are dominated by prompt muons. The template for the EW background is selected using Z-boson decays to two muons while the template for the multijet background is taken from muons that fail the isolation requirement. Both templates are taken from data. The templates are fit to the d_0 distribution in the interval $[-0.1, +0.1]$ mm to determine the normalization factors. The fraction of multijet background, 0.046 ± 0.005, is neglected when extrapolating the background in SR. The procedure for extrapolating the EW background to the SR is the same as for the electron channel.

The background estimate in the SR, shown in Fig. 1, was not compared to data until the final fit method and parameters were fixed. The hatched area in Fig. 1 shows the total uncertainty in the background estimate, which is dominated by the systematic uncertainties. In extracting the limits, the fits described above are used to extrapolate the background into the high invariant-mass region.

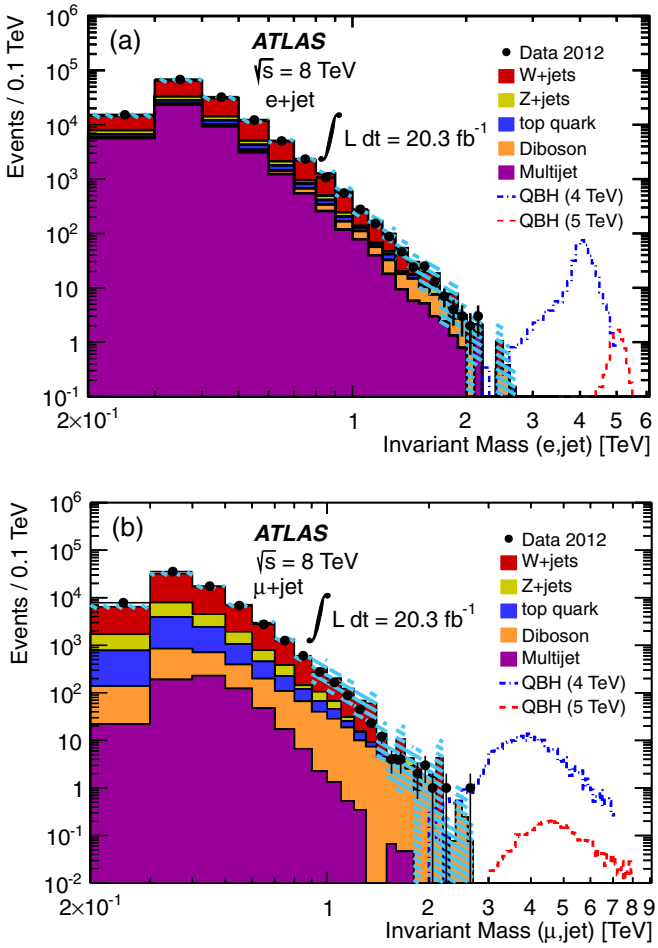

FIG. 1 (color online). Distribution of the invariant mass of the lepton and highest-p_{T} jet in (a) the electron + jet channel and (b) the muon + jet channel, for data (points with error bars) and for SM backgrounds (solid histograms). Overlaid are two examples of QBH signals. The sum of the uncertainties due to the finite MC sample size and from various sources of systematic uncertainty is shown by the hatched area. To extract the upper limit on the lepton + jet cross section, a fit to the invariant-mass distribution is performed, replacing the uncertainties due to MC sample size by the statistical uncertainties on the fit parameters.

The systematic uncertainties on the background are evaluated as a function of m_{inv}, and are dominated by uncertainties on the fits used to extrapolate the background to the highest m_{inv}, uncertainties on PDFs, and the choice of MC generator. Systematic uncertainties due to the choice of fitting functions are evaluated by fitting the m_{inv} spectrum with parameters p_3 and p_4 free and taking the difference between these fits and the fits with p_3 and p_4 fixed to zero. Additionally, SHERPA samples are used instead of ALPGEN and the fits are repeated. The uncertainty in the PDFs is estimated using a set of 44 PDF eigenvectors for CTEQ6.6 [43]. For each of the 44 sets, the background fits are repeated and the extrapolated backgrounds are estimated. To estimate the uncertainty in the multijet background in the electron channel, an alternative selection

TABLE I. Breakdown of relative systematic uncertainties on the SM background for the threshold mass $M_{\rm th} = 5$ TeV. The uncertainties are added in quadrature to obtain the total uncertainty.

Source	Electron + jet %		Muon + jet %	
Lepton reconstruction, scale, and resolution	+2	−1	+30	−7
Jet reconstruction, scale, and resolution	+31	−15	+5	−5
Multijet modeling	+27	−27	-	
PDF	+52	−33	+100	−69
Fit	+77	−77	+130	−71
Total	+100	−89	+170	−100

of background-enriched data events, based on photons, is used. The systematic uncertainties from the simulation of the detector response are associated with the jet and electron energy scales and resolutions, the muon momentum scale and resolution, and the trigger requirement. The combined uncertainty in the background prediction ranges from 16% (1 TeV) to 100% (6 TeV) for the electron channel and from 50% (1 TeV) to 170% (6 TeV) for the muon channel. Background systematic uncertainties for $M_{\rm th} = 5$ TeV are given in Table I.

Uncertainties on the signal efficiency in each of the mass bins are associated with the requirements on $\Delta\eta$, $\Delta\phi$, $\langle\eta\rangle$, $m_{\rm inv}$, and isolation. In addition, uncertainties on the detector simulation, mentioned above for the background, as well as the uncertainty in luminosity are taken into account. The combined uncertainty in the signal efficiency from these sources ranges from 3.5% at 1 TeV to 3.9% at 6 TeV for the electron channel and from 3.6% at 1 TeV to 5.6% at 6 TeV for the muon channel. The cumulative efficiency, shown in Table II, is taken from the signal MC simulation for charge $+4/3$ QBHs. The differences in the efficiency between the charge $+4/3$ state and the other charged states are much smaller than the uncertainties mentioned above and are neglected. The effect of the 0.65% uncertainty in the LHC beam energy [44] is to change the QBH production cross section. Since the QBH cross section is nearly constant in $M_{\rm th}/\sqrt{s}$ this is effectively an uncertainty in $M_{\rm th}$ and has a negligible effect on the limits.

The observed numbers of events and the expected backgrounds, shown in Table II, are in agreement within the total uncertainty. There is no evidence for any excess. Upper limits on $\Sigma\sigma_{\rm qq} \times {\rm BF}_{\rm qq}$ for the production of QBHs above $M_{\rm th}$ are determined in the interval 1–6 TeV assuming lepton universality and using the CLs method [45,46], which is designed to give conservative limits in cases where the observed background fluctuates below the expected values. The statistical combination of the channels employs a likelihood function constructed as the product of Poisson probability terms describing the total number of events observed in each channel. Systematic uncertainties are incorporated as nuisance parameters into the likelihood through their effect on the mean of the Poisson functions and through convolution with their assumed Gaussian distributions. Correlations between channels are taken into account.

TABLE II. Numbers of expected background (Expect.) and observed (Obs.) events, along with the cumulative signal efficiencies (Eff.), with uncertainties including both the statistical and systematic components for various values of $M_{\rm th}$. Numbers of events are integrated above the $m_{\rm inv}$ requirement for the given $M_{\rm th}$.

$M_{\rm th}$	Electron + jet Obs.	Expect.	Eff.	Muon + jet Obs.	Expect.	Eff.
TeV			%			%
1.0	1200	1210^{+230}_{-220}	57 ± 4	620	550 ± 280	38 ± 4
1.5	100	110 ± 40	57 ± 4	49	65^{+45}_{-40}	36 ± 4
2.0	12	19^{+13}_{-12}	56 ± 4	8	14^{+16}_{-14}	36 ± 4
2.5	0	$5.3^{+4.5}_{-3.9}$	55 ± 4	3	5^{+6}_{-5}	34 ± 4
3.0	0	$1.8^{+1.8}_{-1.6}$	54 ± 4	1	$2.1^{+2.9}_{-2.1}$	34 ± 4
3.5	0	$0.76^{+0.79}_{-0.67}$	54 ± 4	0	$1.0^{+1.6}_{-1.0}$	33 ± 4
4.0	0	$0.35^{+0.38}_{-0.34}$	53 ± 4	0	$0.57^{+0.94}_{-0.57}$	33 ± 5
5.0	0	$0.09^{+0.10}_{-0.09}$	52 ± 4	0	$0.24^{+0.39}_{-0.24}$	32 ± 5
6.0	0	$0.03^{+0.04}_{-0.03}$	52 ± 4	0	$0.13^{+0.22}_{-0.13}$	32 ± 6

Figure 2 shows the 95% confidence level (C.L.) combined lepton + jet upper limit on the cross section times

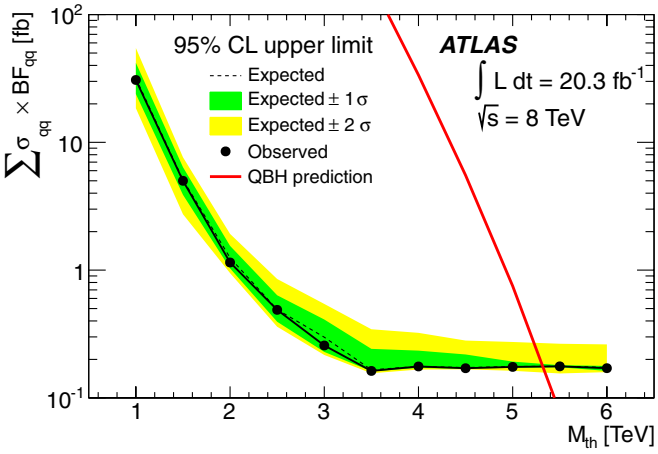

FIG. 2 (color online). The combined 95% C.L. upper limits on $\Sigma\sigma_{\rm qq} \times {\rm BF}_{\rm qq}$ for QBHs decaying to a lepton and jet, as a function of $M_{\rm th}$, assuming $M_{\rm D} = M_{\rm th}$ and $n = 6$ ADD extra dimensions. The limits take into account statistical and systematic uncertainties. Points along the solid black line indicate the mass of the signal where the limit is computed. Also shown are the $\pm 1\sigma$ and $\pm 2\sigma$ bands, indicating the underlying distribution of possible limit outcomes under the background-only hypothesis. The predicted cross section for QBHs is shown as the solid curve.

branching fraction for the production of QBHs as a function of M_{th}. Above 3.5 TeV, the limit is 0.18 fb. For the $n = 6$ QBH model assumed in this Letter, the 95% C.L. lower limit on M_{th} is 5.3 TeV. For $n = 2$, and all other model assumptions the same, the 95% C.L. lower limit on M_{th} is 4.7 TeV. Treating the channels separately, the 95% C.L. upper limit on the electron $(\mathrm{muon}) + \mathrm{jet}$ $\Sigma\sigma_{\mathrm{qq}} \times \mathrm{BF}_{\mathrm{qq}}$ above 3.5 TeV is 0.27 (0.49) fb, and the $n = 6$ lower limit on M_{th} is 5.2 (5.1) TeV.

In conclusion, a first search for two body lepton + jet final states with large invariant mass has been performed using 20.3 fb^{-1} of pp collisions recorded at $\sqrt{s} = 8$ TeV with the ATLAS detector at the LHC. In the invariant-mass region above 1 TeV the observed events are consistent with data-driven extrapolated backgrounds from the low-invariant-mass control region. Above 3.5 TeV the expected background drops below one event and the 95% C.L. upper limit on the electron $(\mathrm{muon}) + \mathrm{jet}$ $\Sigma\sigma_{\mathrm{qq}} \times \mathrm{BF}_{\mathrm{qq}}$ is 0.27 (0.49) fb. Assuming lepton universality, the 95% C.L. upper limit on the sum of the product of QBH lepton + jet production cross sections and branching fractions is 0.18 fb.

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; BMWF and FWF, Austria; ANAS, Azerbaijan; SSTC, Belarus; CNPq and FAPESP, Brazil; NSERC, NRC and CFI, Canada; CERN; CONICYT, Chile; CAS, MOST and NSFC, China; COLCIENCIAS, Colombia; MSMT CR, MPO CR and VSC CR, Czech Republic; DNRF, DNSRC and Lundbeck Foundation, Denmark; EPLANET, ERC and NSRF, European Union; IN2P3-CNRS, CEA-DSM/IRFU, France; GNSF, Georgia; BMBF, DFG, HGF, MPG and AvH Foundation, Germany; GSRT and NSRF, Greece; ISF, MINERVA, GIF, DIP and Benoziyo Center, Israel; INFN, Italy; MEXT and JSPS, Japan; CNRST, Morocco; FOM and NWO, Netherlands; BRF and RCN, Norway; MNiSW, Poland; GRICES and FCT, Portugal; MNE/IFA, Romania; MES of Russia and ROSATOM, Russian Federation; JINR; MSTD, Serbia; MSSR, Slovakia; ARRS and MIZŠ, Slovenia; DST/NRF, South Africa; MINECO, Spain; SRC and Wallenberg Foundation, Sweden; SER, SNSF and Cantons of Bern and Geneva, Switzerland; NSC, Taiwan; TAEK, Turkey; STFC, the Royal Society and Leverhulme Trust, United Kingdom; DOE and NSF, United States of America. The crucial computing support from all WLCG partners is acknowledged gratefully, in particular, from CERN and the ATLAS Tier-1 facilities at TRIUMF (Canada), NDGF (Denmark, Norway, Sweden), CC-IN2P3 (France), KIT/GridKA (Germany), INFN-CNAF (Italy), NL-T1 (Netherlands), PIC (Spain), ASGC (Taiwan), RAL (UK), and BNL (USA) and in the Tier-2 facilities worldwide.

[1] P. Meade and L. Randall, J. High Energy Phys. 05 (2008) 003.
[2] X. Calmet, W. Gong, and S. D. Hsu, Phys. Lett. B **668**, 20 (2008).
[3] N. Arkani-Hamed, S. Dimopoulos, and G. R. Dvali, Phys. Lett. B **429**, 263 (1998).
[4] I. Antoniadis, N. Arkani-Hamed, S. Dimopoulos, and G. R. Dvali, Phys. Lett. B **436**, 257 (1998).
[5] N. Arkani-Hamed, S. Dimopoulos, and G. R. Dvali, Phys. Rev. D **59**, 086004 (1999).
[6] D. M. Gingrich, J. Phys. G **37**, 105008 (2010).
[7] L. A. Anchordoqui, J. L. Feng, H. Goldberg, and A. D. Shapere, Phys. Rev. D **65**, 124027 (2002).
[8] ATLAS Collaboration, Phys. Lett. B **716**, 122 (2012).
[9] CMS Collaboration, J. High Energy Phys. 07 (2013) 178.
[10] L. Evans and P. Bryant, JINST **3**, S08001 (2008).
[11] ATLAS Collaboration, J. High Energy Phys. 01 (2013) 029.
[12] CMS Collaboration, J. High Energy Phys. 01 (2013) 013.
[13] ATLAS Collaboration, Phys. Lett. B **728**, 562 (2014).
[14] D. M. Gingrich, Comput. Phys. Commun. **181**, 1917 (2010).
[15] ATLAS Collaboration, JINST **3**, S08003 (2008).
[16] ATLAS uses a right-handed coordinate system with its origin at the nominal interaction point (IP) in the center of the detector and the z axis along the beam pipe. The x axis points from the IP to the center of the LHC ring, and the y axis points upward. The pseudorapidity is defined in terms of the polar angle θ as $\eta = -\ln\ \tan(\theta/2)$. Cylindrical coordinates (r, φ) are used in the transverse plane, ϕ being the azimuthal angle around the beam pipe, referred to the x axis.
[17] ATLAS Collaboration, Eur. Phys. J. C **72**, 1849 (2012).
[18] ATLAS Collaboration, Eur. Phys. J. C **73**, 2518 (2013).
[19] T. Sjostrand, S. Mrenna, and P. Z. Skands, Comput. Phys. Commun. **178**, 852 (2008).
[20] A. Martin, W. Stirling, R. Thorne, and G. Watt, Eur. Phys. J. C **63**, 189 (2009).
[21] ATLAS Collaboration, Report No. ATL-PHYS-PUB-2012-003, 2012, http://cds.cern.ch/record/1474107/.
[22] ATLAS Collaboration, Eur. Phys. J. C **70**, 823 (2010).
[23] GEANT4 Collaboration, Nucl. Instrum. Methods Phys. Res., Sect. A **506**, 250 (2003).
[24] S. Frixione, E. Laenen, P. Motylinski, C. White, and B. R. Webber, J. High Energy Phys. 07 (2008) 029.
[25] B. P. Kersevan and E. Richter-Was, Comput. Phys. Commun. **184**, 919 (2013).
[26] M. L. Mangano, F. Piccinini, A. D Polosa, M. Moretti, and R. Pittau, J. High Energy Phys. 07 (2003) 001.
[27] T. Gleisberg, S. Höche, F. Krauss, M. Schönherr, S. Schumann, F. Siegert, and J. Winter, J. High Energy Phys. 02 (2009) 007.
[28] J. Pumplin, D. R. Stump, J. Huston, H.-L. Lai, P. Nadolsky, and W.-K. Tung, J. High Energy Phys. 07 (2002) 012.
[29] H.-L. Lai, M. Guzzi, J. Huston, Z. Li, P. M. Nadolsky, J. Pumplin, and C.-P. Yuan, Phys. Rev. D **82**, 074024 (2010).
[30] G. Corcella, I. G. Knowles, G. Marchesini, S. Moretti, K. Odagiri, P. Richardson, M. H. Seymour, and B. R. Webber, J. High Energy Phys. 01 (2001) 010.
[31] ATLAS Collaboration, Report No. ATLAS-PUB-2011-008 2011, https://cds.cern.ch/record/1345343.

[32] J. Butterworth, J. R. Forshaw, and M. Seymour, Z. Phys. C **72**, 637 (1996).
[33] R. Hamberg, W. L. van Neerven, and T. Matsuura, Nucl. Phys. **B359**, 343 (1991).
[34] Q. Seth, G. Ryan, L. Ye, and P. Frank, Comput. Phys. Commun. **184**, 209 (2013).
[35] ATLAS Collaboration, Eur. Phys. J. C **72**, 1909 (2012).
[36] M. Cacciari, G. P. Salam, and G. Soyez, J. High Energy Phys. 04 (2008) 063.
[37] M. Cacciari and G. P. Salam, Phys. Lett. B **641**, 57 (2006).
[38] ATLAS Collaboration, Eur. Phys. J. C **73**, 2304 (2013).
[39] M. Cacciari, G. P. Salam, and G. Soyez, J. High Energy Phys. 04 (2008) 005.
[40] M. Cacciari, G. P. Salam, and S. Sapeta, J. High Energy Phys. 04 (2010) 065.
[41] ATLAS Collaboration, Eur. Phys. J. C **72**, 1844 (2012).
[42] R. M. Harris and K. Kousouris, Int. J. Mod. Phys. A **26**, 5005 (2011).
[43] P. M. Nadolsky, H.-L. Lai, Q.-H. Cao, J. Huston, J. Pumplin, D. Stump, W.-K. Tung, and C.-P. Yuan, Phys. Rev. D **78**, 013004 (2008).
[44] J. Wenninger, Report No. CERN-ATS-2013-040, 2013, http://cds.cern.ch/record/1546734.
[45] T. Junk, Nucl. Instrum. Methods Phys. Res., Sect. A **434**, 435 (1999).
[46] A. L. Read, J. Phys. G **28**, 2693 (2002).

G. Aad,[48] T. Abajyan,[21] B. Abbott,[112] J. Abdallah,[152] S. Abdel Khalek,[116] O. Abdinov,[11] R. Aben,[106] B. Abi,[113] M. Abolins,[89] O. S. AbouZeid,[159] H. Abramowicz,[154] H. Abreu,[137] Y. Abulaiti,[147a,147b] B. S. Acharya,[165a,165b,b] L. Adamczyk,[38a] D. L. Adams,[25] T. N. Addy,[56] J. Adelman,[177] S. Adomeit,[99] T. Adye,[130] S. Aefsky,[23] T. Agatonovic-Jovin,[13b] J. A. Aguilar-Saavedra,[125b,c] M. Agustoni,[17] S. P. Ahlen,[22] A. Ahmad,[149] F. Ahmadov,[64,d] G. Aielli,[134a,134b] T. P. A. Åkesson,[80] G. Akimoto,[156] A. V. Akimov,[95] M. A. Alam,[76] J. Albert,[170] S. Albrand,[55] M. J. Alconada Verzini,[70] M. Aleksa,[30] I. N. Aleksandrov,[64] C. Alexa,[26a] G. Alexander,[154] G. Alexandre,[49] T. Alexopoulos,[10] M. Alhroob,[165a,165c] G. Alimonti,[90a] L. Alio,[84] J. Alison,[31] B. M. M. Allbrooke,[18] L. J. Allison,[71] P. P. Allport,[73] S. E. Allwood-Spiers,[53] J. Almond,[83] A. Aloisio,[103a,103b] R. Alon,[173] A. Alonso,[36] F. Alonso,[70] A. Altheimer,[35] B. Alvarez Gonzalez,[89] M. G. Alviggi,[103a,103b] K. Amako,[65] Y. Amaral Coutinho,[24a] C. Amelung,[23] V. V. Ammosov,[129,a] S. P. Amor Dos Santos,[125a] A. Amorim,[125a,e] S. Amoroso,[48] N. Amram,[154] G. Amundsen,[23] C. Anastopoulos,[30] L. S. Ancu,[17] N. Andari,[30] T. Andeen,[35] C. F. Anders,[58b] G. Anders,[58a] K. J. Anderson,[31] A. Andreazza,[90a,90b] V. Andrei,[58a] X. S. Anduaga,[70] S. Angelidakis,[9] P. Anger,[44] A. Angerami,[35] F. Anghinolfi,[30] A. V. Anisenkov,[108] N. Anjos,[125a] A. Annovi,[47] A. Antonaki,[9] M. Antonelli,[47] A. Antonov,[97] J. Antos,[145b] F. Anulli,[133a] M. Aoki,[65] L. Aperio Bella,[18] R. Apolle,[119,f] G. Arabidze,[89] I. Aracena,[144] Y. Arai,[65] A. T. H. Arce,[45] J-F. Arguin,[94] S. Argyropoulos,[42] E. Arik,[19a,a] M. Arik,[19a] A. J. Armbruster,[88] O. Arnaez,[82] V. Arnal,[81] O. Arslan,[21] A. Artamonov,[96] G. Artoni,[23] S. Asai,[156] N. Asbah,[94] S. Ask,[28] B. Åsman,[147a,147b] L. Asquith,[6] K. Assamagan,[25] R. Astalos,[145a] A. Astbury,[170] M. Atkinson,[166] N. B. Atlay,[142] B. Auerbach,[6] E. Auge,[116] K. Augsten,[127] M. Aurousseau,[146b] G. Avolio,[30] G. Azuelos,[94,g] Y. Azuma,[156] M. A. Baak,[30] C. Bacci,[135a,135b] A. M. Bach,[15] H. Bachacou,[137] K. Bachas,[155] M. Backes,[30] M. Backhaus,[21] J. Backus Mayes,[144] E. Badescu,[26a] P. Bagiacchi,[133a,133b] P. Bagnaia,[133a,133b] Y. Bai,[33a] D. C. Bailey,[159] T. Bain,[35] J. T. Baines,[130] O. K. Baker,[177] S. Baker,[77] P. Balek,[128] F. Balli,[137] E. Banas,[39] Sw. Banerjee,[174] D. Banfi,[30] A. Bangert,[151] V. Bansal,[170] H. S. Bansil,[18] L. Barak,[173] S. P. Baranov,[95] T. Barber,[48] E. L. Barberio,[87] D. Barberis,[50a,50b] M. Barbero,[84] T. Barillari,[100] M. Barisonzi,[176] T. Barklow,[144] N. Barlow,[28] B. M. Barnett,[130] R. M. Barnett,[15] A. Baroncelli,[135a] G. Barone,[49] A. J. Barr,[119] F. Barreiro,[81] J. Barreiro Guimarães da Costa,[57] R. Bartoldus,[144] A. E. Barton,[71] P. Bartos,[145a] V. Bartsch,[150] A. Bassalat,[116] A. Basye,[166] R. L. Bates,[53] L. Batkova,[145a] J. R. Batley,[28] M. Battistin,[30] F. Bauer,[137] H. S. Bawa,[144,h] T. Beau,[79] P. H. Beauchemin,[162] R. Beccherle,[123a,123b] P. Bechtle,[21] H. P. Beck,[17] K. Becker,[176] S. Becker,[99] M. Beckingham,[139] A. J. Beddall,[19c] A. Beddall,[19c] S. Bedikian,[177] V. A. Bednyakov,[64] C. P. Bee,[149] L. J. Beemster,[106] T. A. Beermann,[176] M. Begel,[25] K. Behr,[119] C. Belanger-Champagne,[86] P. J. Bell,[49] W. H. Bell,[49] G. Bella,[154] L. Bellagamba,[20a] A. Bellerive,[29] M. Bellomo,[85] A. Belloni,[57] O. L. Beloborodova,[108,i] K. Belotskiy,[97] O. Beltramello,[30] O. Benary,[154] D. Benchekroun,[136a] K. Bendtz,[147a,147b] N. Benekos,[166] Y. Benhammou,[154] E. Benhar Noccioli,[49] J. A. Benitez Garcia,[160b] D. P. Benjamin,[45] J. R. Bensinger,[23] K. Benslama,[131] S. Bentvelsen,[106] D. Berge,[106] E. Bergeaas Kuutmann,[16] N. Berger,[5] F. Berghaus,[170] E. Berglund,[106] J. Beringer,[15] C. Bernard,[22] P. Bernat,[77] C. Bernius,[78] F. U. Bernlochner,[170] T. Berry,[76] P. Berta,[128] C. Bertella,[84] F. Bertolucci,[123a,123b] M. I. Besana,[90a] G. J. Besjes,[105] O. Bessidskaia,[147a,147b] N. Besson,[137] S. Bethke,[100] W. Bhimji,[46] R. M. Bianchi,[124] L. Bianchini,[23] M. Bianco,[30] O. Biebel,[99] S. P. Bieniek,[77] K. Bierwagen,[54] J. Biesiada,[15] M. Biglietti,[135a] J. Bilbao De Mendizabal,[49] H. Bilokon,[47] M. Bindi,[20a,20b] S. Binet,[116] A. Bingul,[19c] C. Bini,[133a,133b] B. Bittner,[100] C. W. Black,[151] J. E. Black,[144] K. M. Black,[22] D. Blackburn,[139] R. E. Blair,[6] J.-B. Blanchard,[137] T. Blazek,[145a]

I. Bloch,[42] C. Blocker,[23] W. Blum,[82,a] U. Blumenschein,[54] G. J. Bobbink,[106] V. S. Bobrovnikov,[108] S. S. Bocchetta,[80] A. Bocci,[45] C. R. Boddy,[119] M. Boehler,[48] J. Boek,[176] T. T. Boek,[176] J. A. Bogaerts,[30] A. G. Bogdanchikov,[108] A. Bogouch,[91,a] C. Bohm,[147a] J. Bohm,[126] V. Boisvert,[76] T. Bold,[38a] V. Boldea,[26a] A. S. Boldyrev,[98] N. M. Bolnet,[137] M. Bomben,[79] M. Bona,[75] M. Boonekamp,[137] A. Borisov,[129] G. Borissov,[71] M. Borri,[83] S. Borroni,[42] J. Bortfeldt,[99] V. Bortolotto,[135a,135b] K. Bos,[106] D. Boscherini,[20a] M. Bosman,[12] H. Boterenbrood,[106] J. Bouchami,[94] J. Boudreau,[124] E. V. Bouhova-Thacker,[71] D. Boumediene,[34] C. Bourdarios,[116] N. Bousson,[84] S. Boutouil,[136d] A. Boveia,[31] J. Boyd,[30] I. R. Boyko,[64] I. Bozovic-Jelisavcic,[13b] J. Bracinik,[18] P. Branchini,[135a] A. Brandt,[8] G. Brandt,[15] O. Brandt,[58a] U. Bratzler,[157] B. Brau,[85] J. E. Brau,[115] H. M. Braun,[176,a] S. F. Brazzale,[165a,165c] B. Brelier,[159] K. Brendlinger,[121] A. J. Brennan,[87] R. Brenner,[167] S. Bressler,[173] K. Bristow,[146c] T. M. Bristow,[46] D. Britton,[53] F. M. Brochu,[28] I. Brock,[21] R. Brock,[89] C. Bromberg,[89] J. Bronner,[100] G. Brooijmans,[35] T. Brooks,[76] W. K. Brooks,[32b] J. Brosamer,[15] E. Brost,[115] G. Brown,[83] J. Brown,[55] P. A. Bruckman de Renstrom,[39] D. Bruncko,[145b] R. Bruneliere,[48] S. Brunet,[60] A. Bruni,[20a] G. Bruni,[20a] M. Bruschi,[20a] L. Bryngemark,[80] T. Buanes,[14] Q. Buat,[55] F. Bucci,[49] P. Buchholz,[142] R. M. Buckingham,[119] A. G. Buckley,[46] S. I. Buda,[26a] I. A. Budagov,[64] B. Budick,[109] F. Buehrer,[48] L. Bugge,[118] M. K. Bugge,[118] O. Bulekov,[97] A. C. Bundock,[73] M. Bunse,[43] H. Burckhart,[30] S. Burdin,[73] B. Burghgrave,[107] S. Burke,[130] I. Burmeister,[43] E. Busato,[34] V. Büscher,[82] P. Bussey,[53] C. P. Buszello,[167] B. Butler,[57] J. M. Butler,[22] A. I. Butt,[3] C. M. Buttar,[53] J. M. Butterworth,[77] W. Buttinger,[28] A. Buzatu,[53] M. Byszewski,[10] S. Cabrera Urbán,[168] D. Caforio,[20a,20b] O. Cakir,[4a] P. Calafiura,[15] G. Calderini,[79] P. Calfayan,[99] R. Calkins,[107] L. P. Caloba,[24a] R. Caloi,[133a,133b] D. Calvet,[34] S. Calvet,[34] R. Camacho Toro,[49] P. Camarri,[134a,134b] D. Cameron,[118] L. M. Caminada,[15] R. Caminal Armadans,[12] S. Campana,[30] M. Campanelli,[77] A. Campoverde,[149] V. Canale,[103a,103b] F. Canelli,[31] A. Canepa,[160a] J. Cantero,[81] R. Cantrill,[76] T. Cao,[40] M. D. M. Capeans Garrido,[30] I. Caprini,[26a] M. Caprini,[26a] M. Capua,[37a,37b] R. Caputo,[82] R. Cardarelli,[134a] T. Carli,[30] G. Carlino,[103a] L. Carminati,[90a,90b] S. Caron,[105] E. Carquin,[32a] G. D. Carrillo-Montoya,[146c] A. A. Carter,[75] J. R. Carter,[28] J. Carvalho,[125a,j] D. Casadei,[77] M. P. Casado,[12] E. Castaneda-Miranda,[146b] A. Castelli,[106] V. Castillo Gimenez,[168] N. F. Castro,[125a] P. Catastini,[57] A. Catinaccio,[30] J. R. Catmore,[71] A. Cattai,[30] G. Cattani,[134a,134b] S. Caughron,[89] V. Cavaliere,[166] D. Cavalli,[90a] M. Cavalli-Sforza,[12] V. Cavasinni,[123a,123b] F. Ceradini,[135a,135b] B. Cerio,[45] K. Cerny,[128] A. S. Cerqueira,[24b] A. Cerri,[150] L. Cerrito,[75] F. Cerutti,[15] M. Cerv,[30] A. Cervelli,[17] S. A. Cetin,[19b] A. Chafaq,[136a] D. Chakraborty,[107] I. Chalupkova,[128] K. Chan,[3] P. Chang,[166] B. Chapleau,[86] J. D. Chapman,[28] D. Charfeddine,[116] D. G. Charlton,[18] V. Chavda,[83] C. A. Chavez Barajas,[30] S. Cheatham,[86] S. Chekanov,[6] S. V. Chekulaev,[160a] G. A. Chelkov,[64] M. A. Chelstowska,[88] C. Chen,[63] H. Chen,[25] K. Chen,[149] L. Chen,[33d,k] S. Chen,[33c] X. Chen,[146c] Y. Chen,[35] H. C. Cheng,[88] Y. Cheng,[31] A. Cheplakov,[64] R. Cherkaoui El Moursli,[136e] V. Chernyatin,[25,a] E. Cheu,[7] L. Chevalier,[137] V. Chiarella,[47] G. Chiefari,[103a,103b] J. T. Childers,[30] A. Chilingarov,[71] G. Chiodini,[72a] A. S. Chisholm,[18] R. T. Chislett,[77] A. Chitan,[26a] M. V. Chizhov,[64] S. Chouridou,[9] B. K. B. Chow,[99] I. A. Christidi,[77] D. Chromek-Burckhart,[30] M. L. Chu,[152] J. Chudoba,[126] G. Ciapetti,[133a,133b] A. K. Ciftci,[4a] R. Ciftci,[4a] D. Cinca,[62] V. Cindro,[74] A. Ciocio,[15] P. Cirkovic,[13b] Z. H. Citron,[173] M. Citterio,[90a] M. Ciubancan,[26a] A. Clark,[49] P. J. Clark,[46] R. N. Clarke,[15] W. Cleland,[124] J. C. Clemens,[84] B. Clement,[55] C. Clement,[147a,147b] Y. Coadou,[84] M. Cobal,[165a,165c] A. Coccaro,[139] J. Cochran,[63] L. Coffey,[23] J. G. Cogan,[144] J. Coggeshall,[166] B. Cole,[35] S. Cole,[107] A. P. Colijn,[106] C. Collins-Tooth,[53] J. Collot,[55] T. Colombo,[58c] G. Colon,[85] G. Compostella,[100] P. Conde Muiño,[125a] E. Coniavitis,[167] M. C. Conidi,[12] I. A. Connelly,[76] S. M. Consonni,[90a,90b] V. Consorti,[48] S. Constantinescu,[26a] C. Conta,[120a,120b] G. Conti,[57] F. Conventi,[103a,l] M. Cooke,[15] B. D. Cooper,[77] A. M. Cooper-Sarkar,[119] N. J. Cooper-Smith,[76] K. Copic,[15] T. Cornelissen,[176] M. Corradi,[20a] F. Corriveau,[86,m] A. Corso-Radu,[164] A. Cortes-Gonzalez,[12] G. Cortiana,[100] G. Costa,[90a] M. J. Costa,[168] R. Costa Batalha Pedro,[125a] D. Costanzo,[140] D. Côté,[8] G. Cottin,[32a] G. Cowan,[76] B. E. Cox,[83] K. Cranmer,[109] G. Cree,[29] S. Crépé-Renaudin,[55] F. Crescioli,[79] M. Crispin Ortuzar,[119] M. Cristinziani,[21] G. Crosetti,[37a,37b] C.-M. Cuciuc,[26a] C. Cuenca Almenar,[177] T. Cuhadar Donszelmann,[140] J. Cummings,[177] M. Curatolo,[47] C. Cuthbert,[151] H. Czirr,[142] P. Czodrowski,[3] Z. Czyczula,[177] S. D'Auria,[53] M. D'Onofrio,[73] A. D'Orazio,[133a,133b] M. J. Da Cunha Sargedas De Sousa,[125a] C. Da Via,[83] W. Dabrowski,[38a] A. Dafinca,[119] T. Dai,[88] F. Dallaire,[94] C. Dallapiccola,[85] M. Dam,[36] A. C. Daniells,[18] M. Dano Hoffmann,[36] V. Dao,[105] G. Darbo,[50a] G. L. Darlea,[26c] S. Darmora,[8] J. A. Dassoulas,[42] W. Davey,[21] C. David,[170] T. Davidek,[128] E. Davies,[119,f] M. Davies,[94] O. Davignon,[79] A. R. Davison,[77] Y. Davygora,[58a] E. Dawe,[143] I. Dawson,[140] R. K. Daya-Ishmukhametova,[23] K. De,[8] R. de Asmundis,[103a] S. De Castro,[20a,20b] S. De Cecco,[79] J. de Graat,[99] N. De Groot,[105] P. de Jong,[106] C. De La Taille,[116] H. De la Torre,[81] F. De Lorenzi,[63] L. De Nooij,[106] D. De Pedis,[133a] A. De Salvo,[133a] U. De Sanctis,[165a,165c] A. De Santo,[150] J. B. De Vivie De Regie,[116] G. De Zorzi,[133a,133b] W. J. Dearnaley,[71] R. Debbe,[25] C. Debenedetti,[46]

B. Dechenaux,[55] D. V. Dedovich,[64] J. Degenhardt,[121] I. Deigaard,[106] J. Del Peso,[81] T. Del Prete,[123a,123b] T. Delemontex,[55] F. Deliot,[137] M. Deliyergiyev,[74] A. Dell'Acqua,[30] L. Dell'Asta,[22] M. Della Pietra,[103a,l] D. della Volpe,[49] M. Delmastro,[5] P. A. Delsart,[55] C. Deluca,[106] S. Demers,[177] M. Demichev,[64] A. Demilly,[79] B. Demirkoz,[12,n] S. P. Denisov,[129] D. Derendarz,[39] J. E. Derkaoui,[136d] F. Derue,[79] P. Dervan,[73] K. Desch,[21] P. O. Deviveiros,[106] A. Dewhurst,[130] S. Dhaliwal,[106] A. Di Ciaccio,[134a,134b] L. Di Ciaccio,[5] C. Di Donato,[103a,103b] A. Di Girolamo,[30] B. Di Girolamo,[30] A. Di Mattia,[153] B. Di Micco,[135a,135b] R. Di Nardo,[47] A. Di Simone,[48] R. Di Sipio,[20a,20b] D. Di Valentino,[29] M. A. Diaz,[32a] E. B. Diehl,[88] J. Dietrich,[42] T. A. Dietzsch,[58a] S. Diglio,[87] A. Dimitrievska,[13a] K. Dindar Yagci,[40] J. Dingfelder,[21] C. Dionisi,[133a,133b] P. Dita,[26a] S. Dita,[26a] F. Dittus,[30] F. Djama,[84] T. Djobava,[51b] M. A. B. do Vale,[24c] A. Do Valle Wemans,[125a,o] T. K. O. Doan,[5] D. Dobos,[30] E. Dobson,[77] C. Doglioni,[49] T. Doherty,[53] T. Dohmae,[156] J. Dolejsi,[128] Z. Dolezal,[128] B. A. Dolgoshein,[97,a] M. Donadelli,[24d] S. Donati,[123a,123b] P. Dondero,[120a,120b] J. Donini,[34] J. Dopke,[30] A. Doria,[103a] A. Dos Anjos,[174] A. Dotti,[123a,123b] M. T. Dova,[70] A. T. Doyle,[53] M. Dris,[10] J. Dubbert,[88] S. Dube,[15] E. Dubreuil,[34] E. Duchovni,[173] G. Duckeck,[99] O. A. Ducu,[26a] D. Duda,[176] A. Dudarev,[30] F. Dudziak,[63] L. Duflot,[116] L. Duguid,[76] M. Dührssen,[30] M. Dunford,[58a] H. Duran Yildiz,[4a] M. Düren,[52] M. Dwuznik,[38a] J. Ebke,[99] W. Edson,[2] C. A. Edwards,[76] N. C. Edwards,[46] W. Ehrenfeld,[21] T. Eifert,[144] G. Eigen,[14] K. Einsweiler,[15] T. Ekelof,[167] M. El Kacimi,[136c] M. Ellert,[167] S. Elles,[5] F. Ellinghaus,[82] K. Ellis,[75] N. Ellis,[30] J. Elmsheuser,[99] M. Elsing,[30] D. Emeliyanov,[130] Y. Enari,[156] O. C. Endner,[82] M. Endo,[117] R. Engelmann,[149] J. Erdmann,[177] A. Ereditato,[17] D. Eriksson,[147a] G. Ernis,[176] J. Ernst,[2] M. Ernst,[25] J. Ernwein,[137] D. Errede,[166] S. Errede,[166] E. Ertel,[82] M. Escalier,[116] H. Esch,[43] C. Escobar,[124] X. Espinal Curull,[12] B. Esposito,[47] F. Etienne,[84] A. I. Etienvre,[137] E. Etzion,[154] D. Evangelakou,[54] H. Evans,[60] L. Fabbri,[20a,20b] G. Facini,[30] R. M. Fakhrutdinov,[129] S. Falciano,[133a] Y. Fang,[33a] M. Fanti,[90a,90b] A. Farbin,[8] A. Farilla,[135a] T. Farooque,[12] S. Farrell,[164] S. M. Farrington,[171] P. Farthouat,[30] F. Fassi,[168] P. Fassnacht,[30] D. Fassouliotis,[9] B. Fatholahzadeh,[159] A. Favareto,[50a,50b] L. Fayard,[116] P. Federic,[145a] O. L. Fedin,[122] W. Fedorko,[169] M. Fehling-Kaschek,[48] S. Feigl,[30] L. Feligioni,[84] C. Feng,[33d] E. J. Feng,[6] H. Feng,[88] A. B. Fenyuk,[129] S. Fernandez Perez,[30] W. Fernando,[6] S. Ferrag,[53] J. Ferrando,[53] V. Ferrara,[42] A. Ferrari,[167] P. Ferrari,[106] R. Ferrari,[120a] D. E. Ferreira de Lima,[53] A. Ferrer,[168] D. Ferrere,[49] C. Ferretti,[88] A. Ferretto Parodi,[50a,50b] M. Fiascaris,[31] F. Fiedler,[82] A. Filipčič,[74] M. Filipuzzi,[42] F. Filthaut,[105] M. Fincke-Keeler,[170] K. D. Finelli,[45] M. C. N. Fiolhais,[125a,j] L. Fiorini,[168] A. Firan,[40] J. Fischer,[176] M. J. Fisher,[110] E. A. Fitzgerald,[23] M. Flechl,[48] I. Fleck,[142] P. Fleischmann,[175] S. Fleischmann,[176] G. T. Fletcher,[140] G. Fletcher,[75] T. Flick,[176] A. Floderus,[80] L. R. Flores Castillo,[174] A. C. Florez Bustos,[160b] M. J. Flowerdew,[100] A. Formica,[137] A. Forti,[83] D. Fortin,[160a] D. Fournier,[116] H. Fox,[71] P. Francavilla,[12] M. Franchini,[20a,20b] S. Franchino,[30] D. Francis,[30] M. Franklin,[57] S. Franz,[61] M. Fraternali,[120a,120b] S. Fratina,[121] S. T. French,[28] C. Friedrich,[42] F. Friedrich,[44] D. Froidevaux,[30] J. A. Frost,[28] C. Fukunaga,[157] E. Fullana Torregrosa,[128] B. G. Fulsom,[144] J. Fuster,[168] C. Gabaldon,[55] O. Gabizon,[173] A. Gabrielli,[20a,20b] A. Gabrielli,[133a,133b] S. Gadatsch,[106] T. Gadfort,[25] S. Gadomski,[49] G. Gagliardi,[50a,50b] P. Gagnon,[60] C. Galea,[105] B. Galhardo,[125a] E. J. Gallas,[119] V. Gallo,[17] B. J. Gallop,[130] P. Gallus,[127] G. Galster,[36] K. K. Gan,[110] R. P. Gandrajula,[62] J. Gao,[33b,k] Y. S. Gao,[144,h] F. M. Garay Walls,[46] F. Garberson,[177] C. García,[168] J. E. García Navarro,[168] M. Garcia-Sciveres,[15] R. W. Gardner,[31] N. Garelli,[144] V. Garonne,[30] C. Gatti,[47] G. Gaudio,[120a] B. Gaur,[142] L. Gauthier,[94] P. Gauzzi,[133a,133b] I. L. Gavrilenko,[95] C. Gay,[169] G. Gaycken,[21] E. N. Gazis,[10] P. Ge,[33d,p] Z. Gecse,[169] C. N. P. Gee,[130] D. A. A. Geerts,[106] Ch. Geich-Gimbel,[21] K. Gellerstedt,[147a,147b] C. Gemme,[50a] A. Gemmell,[53] M. H. Genest,[55] S. Gentile,[133a,133b] M. George,[54] S. George,[76] D. Gerbaudo,[164] A. Gershon,[154] H. Ghazlane,[136b] N. Ghodbane,[34] B. Giacobbe,[20a] S. Giagu,[133a,133b] V. Giangiobbe,[12] P. Giannetti,[123a,123b] F. Gianotti,[30] B. Gibbard,[25] S. M. Gibson,[76] M. Gilchriese,[15] T. P. S. Gillam,[28] D. Gillberg,[30] A. R. Gillman,[130] D. M. Gingrich,[3,g] N. Giokaris,[9] M. P. Giordani,[165a,165c] R. Giordano,[103a,103b] F. M. Giorgi,[16] P. Giovannini,[100] P. F. Giraud,[137] D. Giugni,[90a] C. Giuliani,[48] M. Giunta,[94] B. K. Gjelsten,[118] I. Gkialas,[155,q] L. K. Gladilin,[98] C. Glasman,[81] J. Glatzer,[21] A. Glazov,[42] G. L. Glonti,[64] M. Goblirsch-Kolb,[100] J. R. Goddard,[75] J. Godfrey,[143] J. Godlewski,[30] C. Goeringer,[82] S. Goldfarb,[88] T. Golling,[177] D. Golubkov,[129] A. Gomes,[125a,e] L. S. Gomez Fajardo,[42] R. Gonçalo,[76] J. Goncalves Pinto Firmino Da Costa,[42] L. Gonella,[21] S. González de la Hoz,[168] G. Gonzalez Parra,[12] M. L. Gonzalez Silva,[27] S. Gonzalez-Sevilla,[49] L. Goossens,[30] P. A. Gorbounov,[96] H. A. Gordon,[25] I. Gorelov,[104] G. Gorfine,[176] B. Gorini,[30] E. Gorini,[72a,72b] A. Gorišek,[74] E. Gornicki,[39] A. T. Goshaw,[6] C. Gössling,[43] M. I. Gostkin,[64] M. Gouighri,[136a] D. Goujdami,[136c] M. P. Goulette,[49] A. G. Goussiou,[139] C. Goy,[5] S. Gozpinar,[23] H. M. X. Grabas,[137] L. Graber,[54] I. Grabowska-Bold,[38a] P. Grafström,[20a,20b] K-J. Grahn,[42] J. Gramling,[49] E. Gramstad,[118] F. Grancagnolo,[72a] S. Grancagnolo,[16] V. Grassi,[149] V. Gratchev,[122] H. M. Gray,[30] J. A. Gray,[149] E. Graziani,[135a] O. G. Grebenyuk,[122] Z. D. Greenwood,[78,r] K. Gregersen,[36] I. M. Gregor,[42] P. Grenier,[144] J. Griffiths,[8] N. Grigalashvili,[64] A. A. Grillo,[138]

K. Grimm,[71] S. Grinstein,[12,s] Ph. Gris,[34] Y. V. Grishkevich,[98] J.-F. Grivaz,[116] J. P. Grohs,[44] A. Grohsjean,[42] E. Gross,[173] J. Grosse-Knetter,[54] G. C. Grossi,[134a,134b] J. Groth-Jensen,[173] Z. J. Grout,[150] K. Grybel,[142] L. Guan,[33b] F. Guescini,[49] D. Guest,[177] O. Gueta,[154] C. Guicheney,[34] E. Guido,[50a,50b] T. Guillemin,[116] S. Guindon,[2] U. Gul,[53] C. Gumpert,[44] J. Gunther,[127] J. Guo,[35] S. Gupta,[119] P. Gutierrez,[112] N. G. Gutierrez Ortiz,[53] C. Gutschow,[77] N. Guttman,[154] C. Guyot,[137] C. Gwenlan,[119] C. B. Gwilliam,[73] A. Haas,[109] C. Haber,[15] H. K. Hadavand,[8] P. Haefner,[21] S. Hageboeck,[21] Z. Hajduk,[39] H. Hakobyan,[178] M. Haleem,[42] D. Hall,[119] G. Halladjian,[89] K. Hamacher,[176] P. Hamal,[114] K. Hamano,[87] M. Hamer,[54] A. Hamilton,[146a,t] S. Hamilton,[162] L. Han,[33b] K. Hanagaki,[117] K. Hanawa,[156] M. Hance,[15] P. Hanke,[58a] J. R. Hansen,[36] J. B. Hansen,[36] J. D. Hansen,[36] P. H. Hansen,[36] P. Hansson,[144] K. Hara,[161] A. S. Hard,[174] T. Harenberg,[176] S. Harkusha,[91] D. Harper,[88] R. D. Harrington,[46] O. M. Harris,[139] P. F. Harrison,[171] F. Hartjes,[106] A. Harvey,[56] S. Hasegawa,[102] Y. Hasegawa,[141] S. Hassani,[137] S. Haug,[17] M. Hauschild,[30] R. Hauser,[89] M. Havranek,[21] C. M. Hawkes,[18] R. J. Hawkings,[30] A. D. Hawkins,[80] T. Hayashi,[161] D. Hayden,[89] C. P. Hays,[119] H. S. Hayward,[73] S. J. Haywood,[130] S. J. Head,[18] T. Heck,[82] V. Hedberg,[80] L. Heelan,[8] S. Heim,[121] T. Heim,[176] B. Heinemann,[15] L. Heinrich,[109] S. Heisterkamp,[36] J. Hejbal,[126] L. Helary,[22] C. Heller,[99] M. Heller,[30] S. Hellman,[147a,147b] D. Hellmich,[21] C. Helsens,[30] J. Henderson,[119] R. C. W. Henderson,[71] C. Hengler,[42] A. Henrichs,[177] A. M. Henriques Correia,[30] S. Henrot-Versille,[116] C. Hensel,[54] G. H. Herbert,[16] Y. Hernández Jiménez,[168] R. Herrberg-Schubert,[16] G. Herten,[48] R. Hertenberger,[99] L. Hervas,[30] G. G. Hesketh,[77] N. P. Hessey,[106] R. Hickling,[75] E. Higón-Rodriguez,[168] J. C. Hill,[28] K. H. Hiller,[42] S. Hillert,[21] S. J. Hillier,[18] I. Hinchliffe,[15] E. Hines,[121] M. Hirose,[117] D. Hirschbuehl,[176] J. Hobbs,[149] N. Hod,[106] M. C. Hodgkinson,[140] P. Hodgson,[140] A. Hoecker,[30] M. R. Hoeferkamp,[104] J. Hoffman,[40] D. Hoffmann,[84] J. I. Hofmann,[58a] M. Hohlfeld,[82] T. R. Holmes,[15] T. M. Hong,[121] L. Hooft van Huysduynen,[109] J-Y. Hostachy,[55] S. Hou,[152] A. Hoummada,[136a] J. Howard,[119] J. Howarth,[83] M. Hrabovsky,[114] I. Hristova,[16] J. Hrivnac,[116] T. Hryn'ova,[5] P. J. Hsu,[82] S.-C. Hsu,[139] D. Hu,[35] X. Hu,[25] Y. Huang,[146c] Z. Hubacek,[30] F. Hubaut,[84] F. Huegging,[21] A. Huettmann,[42] T. B. Huffman,[119] E. W. Hughes,[35] G. Hughes,[71] M. Huhtinen,[30] T. A. Hülsing,[82] M. Hurwitz,[15] N. Huseynov,[64,d] J. Huston,[89] J. Huth,[57] G. Iacobucci,[49] G. Iakovidis,[10] I. Ibragimov,[142] L. Iconomidou-Fayard,[116] J. Idarraga,[116] E. Ideal,[177] P. Iengo,[103a] O. Igonkina,[106] T. Iizawa,[172] Y. Ikegami,[65] K. Ikematsu,[142] M. Ikeno,[65] D. Iliadis,[155] N. Ilic,[159] Y. Inamaru,[66] T. Ince,[100] P. Ioannou,[9] M. Iodice,[135a] K. Iordanidou,[9] V. Ippolito,[133a,133b] A. Irles Quiles,[168] C. Isaksson,[167] M. Ishino,[67] M. Ishitsuka,[158] R. Ishmukhametov,[110] C. Issever,[119] S. Istin,[19a] J. M. Iturbe Ponce,[83] A. V. Ivashin,[129] W. Iwanski,[39] H. Iwasaki,[65] J. M. Izen,[41] V. Izzo,[103a] B. Jackson,[121] J. N. Jackson,[73] M. Jackson,[73] P. Jackson,[1] M. R. Jaekel,[30] V. Jain,[2] K. Jakobs,[48] S. Jakobsen,[36] T. Jakoubek,[126] J. Jakubek,[127] D. O. Jamin,[152] D. K. Jana,[78] E. Jansen,[77] H. Jansen,[30] J. Janssen,[21] M. Janus,[171] G. Jarlskog,[80] L. Jeanty,[15] G.-Y. Jeng,[151] I. Jen-La Plante,[31] D. Jennens,[87] P. Jenni,[48,u] J. Jentzsch,[43] C. Jeske,[171] S. Jézéquel,[5] M. K. Jha,[20a] H. Ji,[174] W. Ji,[82] J. Jia,[149] Y. Jiang,[33b] M. Jimenez Belenguer,[42] S. Jin,[33a] A. Jinaru,[26a] O. Jinnouchi,[158] M. D. Joergensen,[36] D. Joffe,[40] K. E. Johansson,[147a] P. Johansson,[140] K. A. Johns,[7] K. Jon-And,[147a,147b] G. Jones,[171] R. W. L. Jones,[71] T. J. Jones,[73] P. M. Jorge,[125a] K. D. Joshi,[83] J. Jovicevic,[148] X. Ju,[174] C. A. Jung,[43] R. M. Jungst,[30] P. Jussel,[61] A. Juste Rozas,[12,s] M. Kaci,[168] A. Kaczmarska,[39] M. Kado,[116] H. Kagan,[110] M. Kagan,[144] E. Kajomovitz,[45] S. Kama,[40] N. Kanaya,[156] M. Kaneda,[30] S. Kaneti,[28] T. Kanno,[158] V. A. Kantserov,[97] J. Kanzaki,[65] B. Kaplan,[109] A. Kapliy,[31] D. Kar,[53] K. Karakostas,[10] N. Karastathis,[10] M. Karnevskiy,[82] S. N. Karpov,[64] K. Karthik,[109] V. Kartvelishvili,[71] A. N. Karyukhin,[129] L. Kashif,[174] G. Kasieczka,[58b] R. D. Kass,[110] A. Kastanas,[14] Y. Kataoka,[156] A. Katre,[49] J. Katzy,[42] V. Kaushik,[7] K. Kawagoe,[69] T. Kawamoto,[156] G. Kawamura,[54] S. Kazama,[156] V. F. Kazanin,[108] M. Y. Kazarinov,[64] R. Keeler,[170] P. T. Keener,[121] R. Kehoe,[40] M. Keil,[54] J. S. Keller,[139] H. Keoshkerian,[5] O. Kepka,[126] B. P. Kerševan,[74] S. Kersten,[176] K. Kessoku,[156] J. Keung,[159] F. Khalil-zada,[11] H. Khandanyan,[147a,147b] A. Khanov,[113] D. Kharchenko,[64] A. Khodinov,[97] A. Khomich,[58a] T. J. Khoo,[28] G. Khoriauli,[21] A. Khoroshilov,[176] V. Khovanskiy,[96] E. Khramov,[64] J. Khubua,[51b] H. Kim,[147a,147b] S. H. Kim,[161] N. Kimura,[172] O. Kind,[16] B. T. King,[73] M. King,[168] R. S. B. King,[119] S. B. King,[169] J. Kirk,[130] A. E. Kiryunin,[100] T. Kishimoto,[66] D. Kisielewska,[38a] T. Kitamura,[66] T. Kittelmann,[124] K. Kiuchi,[161] E. Kladiva,[145b] M. Klein,[73] U. Klein,[73] K. Kleinknecht,[82] P. Klimek,[147a,147b] A. Klimentov,[25] R. Klingenberg,[43] J. A. Klinger,[83] E. B. Klinkby,[36] T. Klioutchnikova,[30] P. F. Klok,[105] E.-E. Kluge,[58a] P. Kluit,[106] S. Kluth,[100] E. Kneringer,[61] E. B. F. G. Knoops,[84] A. Knue,[53] T. Kobayashi,[156] M. Kobel,[44] M. Kocian,[144] P. Kodys,[128] S. Koenig,[82] P. Koevesarki,[21] T. Koffas,[29] E. Koffeman,[106] L. A. Kogan,[119] S. Kohlmann,[176] Z. Kohout,[127] T. Kohriki,[65] T. Koi,[144] H. Kolanoski,[16] I. Koletsou,[5] J. Koll,[89] A. A. Komar,[95,a] Y. Komori,[156] T. Kondo,[65] K. Köneke,[48] A. C. König,[105] T. Kono,[65,v] R. Konoplich,[109,w] N. Konstantinidis,[77] R. Kopeliansky,[153] S. Koperny,[38a] L. Köpke,[82] A. K. Kopp,[48] K. Korcyl,[39] K. Kordas,[155] A. Korn,[46] A. A. Korol,[108] I. Korolkov,[12] E. V. Korolkova,[140] V. A. Korotkov,[129] O. Kortner,[100] S. Kortner,[100]

V. V. Kostyukhin,[21] S. Kotov,[100] V. M. Kotov,[64] A. Kotwal,[45] C. Kourkoumelis,[9] V. Kouskoura,[155] A. Koutsman,[160a] R. Kowalewski,[170] T. Z. Kowalski,[38a] W. Kozanecki,[137] A. S. Kozhin,[129] V. Kral,[127] V. A. Kramarenko,[98] G. Kramberger,[74] D. Krasnopevtsev,[97] M. W. Krasny,[79] A. Krasznahorkay,[30] J. K. Kraus,[21] A. Kravchenko,[25] S. Kreiss,[109] J. Kretzschmar,[73] K. Kreutzfeldt,[52] N. Krieger,[54] P. Krieger,[159] K. Kroeninger,[54] H. Kroha,[100] J. Kroll,[121] J. Kroseberg,[21] J. Krstic,[13a] U. Kruchonak,[64] H. Krüger,[21] T. Kruker,[17] N. Krumnack,[63] Z. V. Krumshteyn,[64] A. Kruse,[174] M. C. Kruse,[45] M. Kruskal,[22] T. Kubota,[87] S. Kuday,[4a] S. Kuehn,[48] A. Kugel,[58c] T. Kuhl,[42] V. Kukhtin,[64] Y. Kulchitsky,[91] S. Kuleshov,[32b] M. Kuna,[133a,133b] J. Kunkle,[121] A. Kupco,[126] H. Kurashige,[66] Y. A. Kurochkin,[91] R. Kurumida,[66] V. Kus,[126] E. S. Kuwertz,[148] M. Kuze,[158] J. Kvita,[143] A. La Rosa,[49] L. La Rotonda,[37a,37b] L. Labarga,[81] S. Lablak,[136a] C. Lacasta,[168] F. Lacava,[133a,133b] J. Lacey,[29] H. Lacker,[16] D. Lacour,[79] V. R. Lacuesta,[168] E. Ladygin,[64] R. Lafaye,[5] B. Laforge,[79] T. Lagouri,[177] S. Lai,[48] H. Laier,[58a] E. Laisne,[55] L. Lambourne,[77] C. L. Lampen,[7] W. Lampl,[7] E. Lançon,[137] U. Landgraf,[48] M. P. J. Landon,[75] V. S. Lang,[58a] C. Lange,[42] A. J. Lankford,[164] F. Lanni,[25] K. Lantzsch,[30] A. Lanza,[120a] S. Laplace,[79] C. Lapoire,[21] J. F. Laporte,[137] T. Lari,[90a] A. Larner,[119] M. Lassnig,[30] P. Laurelli,[47] V. Lavorini,[37a,37b] W. Lavrijsen,[15] P. Laycock,[73] B. T. Le,[55] O. Le Dortz,[79] E. Le Guirriec,[84] E. Le Menedeu,[12] T. LeCompte,[6] F. Ledroit-Guillon,[55] C. A. Lee,[152] H. Lee,[106] J. S. H. Lee,[117] S. C. Lee,[152] L. Lee,[177] G. Lefebvre,[79] M. Lefebvre,[170] F. Legger,[99] C. Leggett,[15] A. Lehan,[73] M. Lehmacher,[21] G. Lehmann Miotto,[30] X. Lei,[7] A. G. Leister,[177] M. A. L. Leite,[24d] R. Leitner,[128] D. Lellouch,[173] B. Lemmer,[54] K. J. C. Leney,[146c] T. Lenz,[106] G. Lenzen,[176] B. Lenzi,[30] R. Leone,[7] K. Leonhardt,[44] S. Leontsinis,[10] C. Leroy,[94] C. G. Lester,[28] C. M. Lester,[121] J. Levêque,[5] D. Levin,[88] L. J. Levinson,[173] A. Lewis,[119] G. H. Lewis,[109] A. M. Leyko,[21] M. Leyton,[16] B. Li,[33b,x] B. Li,[84] H. Li,[149] H. L. Li,[31] S. Li,[45] X. Li,[88] Z. Liang,[119,y] H. Liao,[34] B. Liberti,[134a] P. Lichard,[30] K. Lie,[166] J. Liebal,[21] W. Liebig,[14] C. Limbach,[21] A. Limosani,[87] M. Limper,[62] S. C. Lin,[152,z] F. Linde,[106] B. E. Lindquist,[149] J. T. Linnemann,[89] E. Lipeles,[121] A. Lipniacka,[14] M. Lisovyi,[42] T. M. Liss,[166] D. Lissauer,[25] A. Lister,[169] A. M. Litke,[138] B. Liu,[152] D. Liu,[152] J. B. Liu,[33b] K. Liu,[33b,aa] L. Liu,[88] M. Liu,[45] M. Liu,[33b] Y. Liu,[33b] M. Livan,[120a,120b] S. S. A. Livermore,[119] A. Lleres,[55] J. Llorente Merino,[81] S. L. Lloyd,[75] F. Lo Sterzo,[152] E. Lobodzinska,[42] P. Loch,[7] W. S. Lockman,[138] T. Loddenkoetter,[21] F. K. Loebinger,[83] A. E. Loevschall-Jensen,[36] A. Loginov,[177] C. W. Loh,[169] T. Lohse,[16] K. Lohwasser,[48] M. Lokajicek,[126] V. P. Lombardo,[5] J. D. Long,[88] R. E. Long,[71] L. Lopes,[125a] D. Lopez Mateos,[57] B. Lopez Paredes,[140] J. Lorenz,[99] N. Lorenzo Martinez,[116] M. Losada,[163] P. Loscutoff,[15] M. J. Losty,[160a,a] X. Lou,[41] A. Lounis,[116] J. Love,[6] P. A. Love,[71] A. J. Lowe,[144,h] F. Lu,[33a] H. J. Lubatti,[139] C. Luci,[133a,133b] A. Lucotte,[55] D. Ludwig,[42] I. Ludwig,[48] F. Luehring,[60] W. Lukas,[61] L. Luminari,[133a] J. Lundberg,[147a,147b] O. Lundberg,[147a,147b] B. Lund-Jensen,[148] M. Lungwitz,[82] D. Lynn,[25] R. Lysak,[126] E. Lytken,[80] H. Ma,[25] L. L. Ma,[33d] G. Maccarrone,[47] A. Macchiolo,[100] B. Maček,[74] J. Machado Miguens,[125a] D. Macina,[30] R. Mackeprang,[36] R. Madar,[48] H. J. Maddocks,[71] W. F. Mader,[44] A. Madsen,[167] M. Maeno,[8] T. Maeno,[25] L. Magnoni,[164] E. Magradze,[54] K. Mahboubi,[48] J. Mahlstedt,[106] S. Mahmoud,[73] G. Mahout,[18] C. Maiani,[137] C. Maidantchik,[24a] A. Maio,[125a,e] S. Majewski,[115] Y. Makida,[65] N. Makovec,[116] P. Mal,[137,bb] B. Malaescu,[79] Pa. Malecki,[39] V. P. Maleev,[122] F. Malek,[55] U. Mallik,[62] D. Malon,[6] C. Malone,[144] S. Maltezos,[10] V. M. Malyshev,[108] S. Malyukov,[30] J. Mamuzic,[13b] B. Mandelli,[30] L. Mandelli,[90a] I. Mandić,[74] R. Mandrysch,[62] J. Maneira,[125a] A. Manfredini,[100] L. Manhaes de Andrade Filho,[24b] J. A. Manjarres Ramos,[137] A. Mann,[99] P. M. Manning,[138] A. Manousakis-Katsikakis,[9] B. Mansoulie,[137] R. Mantifel,[86] L. Mapelli,[30] L. March,[168] J. F. Marchand,[29] F. Marchese,[134a,134b] G. Marchiori,[79] M. Marcisovsky,[126] C. P. Marino,[170] C. N. Marques,[125a] F. Marroquim,[24a] Z. Marshall,[15] L. F. Marti,[17] S. Marti-Garcia,[168] B. Martin,[30] B. Martin,[89] J. P. Martin,[94] T. A. Martin,[171] V. J. Martin,[46] B. Martin dit Latour,[49] H. Martinez,[137] M. Martinez,[12,s] S. Martin-Haugh,[130] A. C. Martyniuk,[77] M. Marx,[139] F. Marzano,[133a] A. Marzin,[112] L. Masetti,[82] T. Mashimo,[156] R. Mashinistov,[95] J. Masik,[83] A. L. Maslennikov,[108] I. Massa,[20a,20b] N. Massol,[5] P. Mastrandrea,[149] A. Mastroberardino,[37a,37b] T. Masubuchi,[156] H. Matsunaga,[156] T. Matsushita,[66] P. Mättig,[176] S. Mättig,[42] J. Mattmann,[82] C. Mattravers,[119,f] J. Maurer,[84] S. J. Maxfield,[73] D. A. Maximov,[108,i] R. Mazini,[152] L. Mazzaferro,[134a,134b] G. Mc Goldrick,[159] S. P. Mc Kee,[88] A. McCarn,[88] R. L. McCarthy,[149] T. G. McCarthy,[29] N. A. McCubbin,[130] K. W. McFarlane,[56,a] J. A. Mcfayden,[140] G. Mchedlidze,[54] T. Mclaughlan,[18] S. J. McMahon,[130] R. A. McPherson,[170,m] A. Meade,[85] J. Mechnich,[106] M. Mechtel,[176] M. Medinnis,[42] S. Meehan,[31] R. Meera-Lebbai,[112] S. Mehlhase,[36] A. Mehta,[73] K. Meier,[58a] C. Meineck,[99] B. Meirose,[80] C. Melachrinos,[31] B. R. Mellado Garcia,[146c] F. Meloni,[90a,90b] L. Mendoza Navas,[163] A. Mengarelli,[20a,20b] S. Menke,[100] E. Meoni,[162] K. M. Mercurio,[57] S. Mergelmeyer,[21] N. Meric,[137] P. Mermod,[49] L. Merola,[103a,103b] C. Meroni,[90a] F. S. Merritt,[31] H. Merritt,[110] A. Messina,[30,cc] J. Metcalfe,[25] A. S. Mete,[164] C. Meyer,[82] C. Meyer,[31] J-P. Meyer,[137] J. Meyer,[30] J. Meyer,[54] R. P. Middleton,[130] S. Migas,[73] L. Mijović,[137] G. Mikenberg,[173] M. Mikestikova,[126] M. Mikuž,[74] D. W. Miller,[31] C. Mills,[57] A. Milov,[173] D. A. Milstead,[147a,147b] D. Milstein,[173]

A. A. Minaenko,[129] M. Miñano Moya,[168] I. A. Minashvili,[64] A. I. Mincer,[109] B. Mindur,[38a] M. Mineev,[64] Y. Ming,[174] L. M. Mir,[12] G. Mirabelli,[133a] T. Mitani,[172] J. Mitrevski,[99] V. A. Mitsou,[168] S. Mitsui,[65] A. Miucci,[49] P. S. Miyagawa,[140] J. U. Mjörnmark,[80] T. Moa,[147a,147b] V. Moeller,[28] S. Mohapatra,[35] W. Mohr,[48] S. Molander,[147a,147b] R. Moles-Valls,[168] K. Mönig,[42] C. Monini,[55] J. Monk,[36] E. Monnier,[84] J. Montejo Berlingen,[12] F. Monticelli,[70] S. Monzani,[20a,20b] R. W. Moore,[3] C. Mora Herrera,[49] A. Moraes,[53] N. Morange,[62] J. Morel,[54] D. Moreno,[82] M. Moreno Llácer,[54] P. Morettini,[50a] M. Morgenstern,[44] M. Morii,[57] S. Moritz,[82] A. K. Morley,[148] G. Mornacchi,[30] J. D. Morris,[75] L. Morvaj,[102] H. G. Moser,[100] M. Mosidze,[51b] J. Moss,[110] R. Mount,[144] E. Mountricha,[25] S. V. Mouraviev,[95,a] E. J. W. Moyse,[85] S. G. Muanza,[84] R. D. Mudd,[18] F. Mueller,[58a] J. Mueller,[124] K. Mueller,[21] T. Mueller,[28] T. Mueller,[82] D. Muenstermann,[49] Y. Munwes,[154] J. A. Murillo Quijada,[18] W. J. Murray,[171,f] I. Mussche,[106] E. Musto,[153] A. G. Myagkov,[129,dd] M. Myska,[126] O. Nackenhorst,[54] J. Nadal,[54] K. Nagai,[61] R. Nagai,[158] Y. Nagai,[84] K. Nagano,[65] A. Nagarkar,[110] Y. Nagasaka,[59] M. Nagel,[100] A. M. Nairz,[30] Y. Nakahama,[30] K. Nakamura,[65] T. Nakamura,[156] I. Nakano,[111] H. Namasivayam,[41] G. Nanava,[21] A. Napier,[162] R. Narayan,[58b] M. Nash,[77,f] T. Nattermann,[21] T. Naumann,[42] G. Navarro,[163] R. Nayyar,[7] H. A. Neal,[88] P. Yu. Nechaeva,[95] T. J. Neep,[83] A. Negri,[120a,120b] G. Negri,[30] M. Negrini,[20a] S. Nektarijevic,[49] A. Nelson,[164] T. K. Nelson,[144] S. Nemecek,[126] P. Nemethy,[109] A. A. Nepomuceno,[24a] M. Nessi,[30,ee] M. S. Neubauer,[166] M. Neumann,[176] A. Neusiedl,[82] R. M. Neves,[109] P. Nevski,[25] F. M. Newcomer,[121] P. R. Newman,[18] D. H. Nguyen,[6] V. Nguyen Thi Hong,[137] R. B. Nickerson,[119] R. Nicolaidou,[137] B. Nicquevert,[30] J. Nielsen,[138] N. Nikiforou,[35] A. Nikiforov,[16] V. Nikolaenko,[129,dd] I. Nikolic-Audit,[79] K. Nikolics,[49] K. Nikolopoulos,[18] P. Nilsson,[8] Y. Ninomiya,[156] A. Nisati,[133a] R. Nisius,[100] T. Nobe,[158] L. Nodulman,[6] M. Nomachi,[117] I. Nomidis,[155] S. Norberg,[112] M. Nordberg,[30] J. Novakova,[128] M. Nozaki,[65] L. Nozka,[114] K. Ntekas,[10] A.-E. Nuncio-Quiroz,[21] G. Nunes Hanninger,[87] T. Nunnemann,[99] E. Nurse,[77] F. Nuti,[87] B. J. O'Brien,[46] F. O'grady,[7] D. C. O'Neil,[143] V. O'Shea,[53] F. G. Oakham,[29,g] H. Oberlack,[100] J. Ocariz,[79] A. Ochi,[66] M. I. Ochoa,[77] S. Oda,[69] S. Odaka,[65] H. Ogren,[60] A. Oh,[83] S. H. Oh,[45] C. C. Ohm,[30] T. Ohshima,[102] W. Okamura,[117] H. Okawa,[25] Y. Okumura,[31] T. Okuyama,[156] A. Olariu,[26a] A. G. Olchevski,[64] S. A. Olivares Pino,[46] D. Oliveira Damazio,[25] E. Oliver Garcia,[168] D. Olivito,[121] A. Olszewski,[39] J. Olszowska,[39] A. Onofre,[125a,ff] P. U. E. Onyisi,[31,gg] C. J. Oram,[160a] M. J. Oreglia,[31] Y. Oren,[154] D. Orestano,[135a,135b] N. Orlando,[72a,72b] C. Oropeza Barrera,[53] R. S. Orr,[159] B. Osculati,[50a,50b] R. Ospanov,[121] G. Otero y Garzon,[27] H. Otono,[69] M. Ouchrif,[136d] E. A. Ouellette,[170] F. Ould-Saada,[118] A. Ouraou,[137] K. P. Oussoren,[106] Q. Ouyang,[33a] A. Ovcharova,[15] M. Owen,[83] S. Owen,[140] V. E. Ozcan,[19a] N. Ozturk,[8] K. Pachal,[119] A. Pacheco Pages,[12] C. Padilla Aranda,[12] S. Pagan Griso,[15] E. Paganis,[140] C. Pahl,[100] F. Paige,[25] P. Pais,[85] K. Pajchel,[118] G. Palacino,[160b] S. Palestini,[30] D. Pallin,[34] A. Palma,[125a] J. D. Palmer,[18] Y. B. Pan,[174] E. Panagiotopoulou,[10] J. G. Panduro Vazquez,[76] P. Pani,[106] N. Panikashvili,[88] S. Panitkin,[25] D. Pantea,[26a] Th. D. Papadopoulou,[10] K. Papageorgiou,[155,q] A. Paramonov,[6] D. Paredes Hernandez,[34] M. A. Parker,[28] F. Parodi,[50a,50b] J. A. Parsons,[35] U. Parzefall,[48] E. Pasqualucci,[133a] S. Passaggio,[50a] A. Passeri,[135a] F. Pastore,[135a,135b,a] Fr. Pastore,[76] G. Pásztor,[49,hh] S. Pataraia,[176] N. D. Patel,[151] J. R. Pater,[83] S. Patricelli,[103a,103b] T. Pauly,[30] J. Pearce,[170] M. Pedersen,[118] S. Pedraza Lopez,[168] S. V. Peleganchuk,[108] D. Pelikan,[167] H. Peng,[33b] B. Penning,[31] J. Penwell,[60] D. V. Perepelitsa,[35] E. Perez Codina,[160a] M. T. Pérez García-Estañ,[168] V. Perez Reale,[35] L. Perini,[90a,90b] H. Pernegger,[30] R. Perrino,[72a] R. Peschke,[42] V. D. Peshekhonov,[64] K. Peters,[30] R. F. Y. Peters,[54,ii] B. A. Petersen,[30] J. Petersen,[30] T. C. Petersen,[36] E. Petit,[42] A. Petridis,[147a,147b] C. Petridou,[155] E. Petrolo,[133a] F. Petrucci,[135a,135b] M. Petteni,[143] R. Pezoa,[32b] P. W. Phillips,[130] G. Piacquadio,[144] E. Pianori,[171] A. Picazio,[49] E. Piccaro,[75] M. Piccinini,[20a,20b] S. M. Piec,[42] R. Piegaia,[27] D. T. Pignotti,[110] J. E. Pilcher,[31] A. D. Pilkington,[77] J. Pina,[125a,e] M. Pinamonti,[165a,165c,jj] A. Pinder,[119] J. L. Pinfold,[3] A. Pingel,[36] B. Pinto,[125a] C. Pizio,[90a,90b] M.-A. Pleier,[25] V. Pleskot,[128] E. Plotnikova,[64] P. Plucinski,[147a,147b] S. Poddar,[58a] F. Podlyski,[34] R. Poettgen,[82] L. Poggioli,[116] D. Pohl,[21] M. Pohl,[49] G. Polesello,[120a] A. Policicchio,[37a,37b] R. Polifka,[159] A. Polini,[20a] C. S. Pollard,[45] V. Polychronakos,[25] D. Pomeroy,[23] K. Pommès,[30] L. Pontecorvo,[133a] B. G. Pope,[89] G. A. Popeneciu,[26b] D. S. Popovic,[13a] A. Poppleton,[30] X. Portell Bueso,[12] G. E. Pospelov,[100] S. Pospisil,[127] K. Potamianos,[15] I. N. Potrap,[64] C. J. Potter,[150] C. T. Potter,[115] G. Poulard,[30] J. Poveda,[60] V. Pozdnyakov,[64] R. Prabhu,[77] P. Pralavorio,[84] A. Pranko,[15] S. Prasad,[30] R. Pravahan,[8] S. Prell,[63] D. Price,[83] J. Price,[73] L. E. Price,[6] D. Prieur,[124] M. Primavera,[72a] M. Proissl,[46] K. Prokofiev,[109] F. Prokoshin,[32b] E. Protopapadaki,[137] S. Protopopescu,[25] J. Proudfoot,[6] X. Prudent,[44] M. Przybycien,[38a] H. Przysiezniak,[5] S. Psoroulas,[21] E. Ptacek,[115] E. Pueschel,[85] D. Puldon,[149] M. Purohit,[25,kk] P. Puzo,[116] Y. Pylypchenko,[62] J. Qian,[88] A. Quadt,[54] D. R. Quarrie,[15] W. B. Quayle,[165a,165b] D. Quilty,[53] V. Radeka,[25] V. Radescu,[42] S. K. Radhakrishnan,[149] P. Radloff,[115] F. Ragusa,[90a,90b] G. Rahal,[179] S. Rajagopalan,[25] M. Rammensee,[48] M. Rammes,[142] A. S. Randle-Conde,[40] C. Rangel-Smith,[79] K. Rao,[164] F. Rauscher,[99] T. C. Rave,[48] T. Ravenscroft,[53] M. Raymond,[30] A. L. Read,[118] D. M. Rebuzzi,[120a,120b] A. Redelbach,[175]

G. Redlinger,[25] R. Reece,[138] K. Reeves,[41] L. Rehnisch,[16] A. Reinsch,[115] H. Reisin,[27] M. Relich,[164] C. Rembser,[30] Z. L. Ren,[152] A. Renaud,[116] M. Rescigno,[133a] S. Resconi,[90a] B. Resende,[137] P. Reznicek,[99] R. Rezvani,[94] R. Richter,[100] M. Ridel,[79] P. Rieck,[16] M. Rijssenbeek,[149] A. Rimoldi,[120a,120b] L. Rinaldi,[20a] E. Ritsch,[61] I. Riu,[12] F. Rizatdinova,[113] E. Rizvi,[75] S. H. Robertson,[86,m] A. Robichaud-Veronneau,[119] D. Robinson,[28] J. E. M. Robinson,[83] A. Robson,[53] J. G. Rocha de Lima,[107] C. Roda,[123a,123b] D. Roda Dos Santos,[126] L. Rodrigues,[30] S. Roe,[30] O. Røhne,[118] S. Rolli,[162] A. Romaniouk,[97] M. Romano,[20a,20b] G. Romeo,[27] E. Romero Adam,[168] N. Rompotis,[139] L. Roos,[79] E. Ros,[168] S. Rosati,[133a] K. Rosbach,[49] A. Rose,[150] M. Rose,[76] P. L. Rosendahl,[14] O. Rosenthal,[142] V. Rossetti,[147a,147b] E. Rossi,[103a,103b] L. P. Rossi,[50a] R. Rosten,[139] M. Rotaru,[26a] I. Roth,[173] J. Rothberg,[139] D. Rousseau,[116] C. R. Royon,[137] A. Rozanov,[84] Y. Rozen,[153] X. Ruan,[146c] F. Rubbo,[12] I. Rubinskiy,[42] V. I. Rud,[98] C. Rudolph,[44] M. S. Rudolph,[159] F. Rühr,[7] A. Ruiz-Martinez,[63] Z. Rurikova,[48] N. A. Rusakovich,[64] A. Ruschke,[99] J. P. Rutherfoord,[7] N. Ruthmann,[48] P. Ruzicka,[126] Y. F. Ryabov,[122] M. Rybar,[128] G. Rybkin,[116] N. C. Ryder,[119] A. F. Saavedra,[151] S. Sacerdoti,[27] A. Saddique,[3] I. Sadeh,[154] H. F-W. Sadrozinski,[138] R. Sadykov,[64] F. Safai Tehrani,[133a] H. Sakamoto,[156] Y. Sakurai,[172] G. Salamanna,[75] A. Salamon,[134a] M. Saleem,[112] D. Salek,[106] P. H. Sales De Bruin,[139] D. Salihagic,[100] A. Salnikov,[144] J. Salt,[168] B. M. Salvachua Ferrando,[6] D. Salvatore,[37a,37b] F. Salvatore,[150] A. Salvucci,[105] A. Salzburger,[30] D. Sampsonidis,[155] A. Sanchez,[103a,103b] J. Sánchez,[168] V. Sanchez Martinez,[168] H. Sandaker,[14] H. G. Sander,[82] M. P. Sanders,[99] M. Sandhoff,[176] T. Sandoval,[28] C. Sandoval,[165a,165b] R. Sandstroem,[100] D. P. C. Sankey,[130] A. Sansoni,[47] C. Santoni,[34] R. Santonico,[134a,134b] H. Santos,[125a] I. Santoyo Castillo,[150] K. Sapp,[124] A. Sapronov,[64] J. G. Saraiva,[125a] E. Sarkisyan-Grinbaum,[8] B. Sarrazin,[21] G. Sartisohn,[176] O. Sasaki,[65] Y. Sasaki,[156] I. Satsounkevitch,[91] G. Sauvage,[5,a] E. Sauvan,[5] J. B. Sauvan,[116] P. Savard,[159,g] D. O. Savu,[30] C. Sawyer,[119] L. Sawyer,[78,r] D. H. Saxon,[53] J. Saxon,[121] C. Sbarra,[20a] A. Sbrizzi,[3] T. Scanlon,[30] D. A. Scannicchio,[164] M. Scarcella,[151] J. Schaarschmidt,[173] P. Schacht,[100] D. Schaefer,[121] A. Schaelicke,[46] S. Schaepe,[21] S. Schaetzel,[58b] U. Schäfer,[82] A. C. Schaffer,[116] D. Schaile,[99] R. D. Schamberger,[149] V. Scharf,[58a] V. A. Schegelsky,[122] D. Scheirich,[128] M. Schernau,[164] M. I. Scherzer,[35] C. Schiavi,[50a,50b] J. Schieck,[99] C. Schillo,[48] M. Schioppa,[37a,37b] S. Schlenker,[30] E. Schmidt,[48] K. Schmieden,[30] C. Schmitt,[82] C. Schmitt,[99] S. Schmitt,[58b] B. Schneider,[17] Y. J. Schnellbach,[73] U. Schnoor,[44] L. Schoeffel,[137] A. Schoening,[58b] B. D. Schoenrock,[89] A. L. S. Schorlemmer,[54] M. Schott,[82] D. Schouten,[160a] J. Schovancova,[25] M. Schram,[86] S. Schramm,[159] M. Schreyer,[175] C. Schroeder,[82] N. Schroer,[58c] N. Schuh,[82] M. J. Schultens,[21] H.-C. Schultz-Coulon,[58a] H. Schulz,[16] M. Schumacher,[48] B. A. Schumm,[138] Ph. Schune,[137] A. Schwartzman,[144] Ph. Schwegler,[100] Ph. Schwemling,[137] R. Schwienhorst,[89] J. Schwindling,[137] T. Schwindt,[21] M. Schwoerer,[5] F. G. Sciacca,[17] E. Scifo,[116] G. Sciolla,[23] W. G. Scott,[130] F. Scuri,[123a,123b] F. Scutti,[21] J. Searcy,[88] G. Sedov,[42] E. Sedykh,[122] S. C. Seidel,[104] A. Seiden,[138] F. Seifert,[127] J. M. Seixas,[24a] G. Sekhniaidze,[103a] S. J. Sekula,[40] K. E. Selbach,[46] D. M. Seliverstov,[122] G. Sellers,[73] M. Seman,[145b] N. Semprini-Cesari,[20a,20b] C. Serfon,[30] L. Serin,[116] L. Serkin,[54] T. Serre,[84] R. Seuster,[160a] H. Severini,[112] F. Sforza,[100] A. Sfyrla,[30] E. Shabalina,[54] M. Shamim,[115] L. Y. Shan,[33a] J. T. Shank,[22] Q. T. Shao,[87] M. Shapiro,[15] P. B. Shatalov,[96] K. Shaw,[165a,165c] P. Sherwood,[77] S. Shimizu,[66] C. O. Shimmin,[164] M. Shimojima,[101] T. Shin,[56] M. Shiyakova,[64] A. Shmeleva,[95] M. J. Shochet,[31] D. Short,[119] S. Shrestha,[63] E. Shulga,[97] M. A. Shupe,[7] S. Shushkevich,[42] P. Sicho,[126] D. Sidorov,[113] A. Sidoti,[133a] F. Siegert,[48] Dj. Sijacki,[13a] O. Silbert,[173] J. Silva,[125a] Y. Silver,[154] D. Silverstein,[144] S. B. Silverstein,[147a] V. Simak,[127] O. Simard,[5] Lj. Simic,[13a] S. Simion,[116] E. Simioni,[82] B. Simmons,[77] R. Simoniello,[90a,90b] M. Simonyan,[36] P. Sinervo,[159] N. B. Sinev,[115] V. Sipica,[142] G. Siragusa,[175] A. Sircar,[78] A. N. Sisakyan,[64,a] S. Yu. Sivoklokov,[98] J. Sjölin,[147a,147b] T. B. Sjursen,[14] L. A. Skinnari,[15] H. P. Skottowe,[57] K. Yu. Skovpen,[108] P. Skubic,[112] M. Slater,[18] T. Slavicek,[127] K. Sliwa,[162] V. Smakhtin,[173] B. H. Smart,[46] L. Smestad,[118] S. Yu. Smirnov,[97] Y. Smirnov,[97] L. N. Smirnova,[98,ll] O. Smirnova,[80] K. M. Smith,[53] M. Smizanska,[71] K. Smolek,[127] A. A. Snesarev,[95] G. Snidero,[75] J. Snow,[112] S. Snyder,[25] R. Sobie,[170,m] F. Socher,[44] J. Sodomka,[127] A. Soffer,[154] D. A. Soh,[152,y] C. A. Solans,[30] M. Solar,[127] J. Solc,[127] E. Yu. Soldatov,[97] U. Soldevila,[168] E. Solfaroli Camillocci,[133a,133b] A. A. Solodkov,[129] O. V. Solovyanov,[129] V. Solovyev,[122] N. Soni,[1] A. Sood,[15] V. Sopko,[127] B. Sopko,[127] M. Sosebee,[8] R. Soualah,[165a,165c] P. Soueid,[94] A. M. Soukharev,[108] D. South,[42] S. Spagnolo,[72a,72b] F. Spanò,[76] W. R. Spearman,[57] R. Spighi,[20a] G. Spigo,[30] M. Spousta,[128] T. Spreitzer,[159] B. Spurlock,[8] R. D. St. Denis,[53] J. Stahlman,[121] R. Stamen,[58a] E. Stanecka,[39] R. W. Stanek,[6] C. Stanescu,[135a] M. Stanescu-Bellu,[42] M. M. Stanitzki,[42] S. Stapnes,[118] E. A. Starchenko,[129] J. Stark,[55] P. Staroba,[126] P. Starovoitov,[42] R. Staszewski,[39] P. Stavina,[145a,a] G. Steele,[53] P. Steinbach,[44] P. Steinberg,[25] I. Stekl,[127] B. Stelzer,[143] H. J. Stelzer,[89] O. Stelzer-Chilton,[160a] H. Stenzel,[52] S. Stern,[100] G. A. Stewart,[30] J. A. Stillings,[21] M. C. Stockton,[86] M. Stoebe,[86] K. Stoerig,[48] G. Stoicea,[26a] S. Stonjek,[100] A. R. Stradling,[8] A. Straessner,[44] J. Strandberg,[148] S. Strandberg,[147a,147b] A. Strandlie,[118] E. Strauss,[144] M. Strauss,[112] P. Strizenec,[145b] R. Ströhmer,[175] D. M. Strom,[115]

R. Stroynowski,[40] S. A. Stucci,[17] B. Stugu,[14] I. Stumer,[25,a] J. Stupak,[149] N. A. Styles,[42] D. Su,[144] J. Su,[124] HS. Subramania,[3] R. Subramaniam,[78] A. Succurro,[12] Y. Sugaya,[117] C. Suhr,[107] M. Suk,[127] V. V. Sulin,[95] S. Sultansoy,[4c] T. Sumida,[67] X. Sun,[55] J. E. Sundermann,[48] K. Suruliz,[140] G. Susinno,[37a,37b] M. R. Sutton,[150] Y. Suzuki,[65] M. Svatos,[126] S. Swedish,[169] M. Swiatlowski,[144] I. Sykora,[145a] T. Sykora,[128] D. Ta,[89] K. Tackmann,[42] J. Taenzer,[159] A. Taffard,[164] R. Tafirout,[160a] N. Taiblum,[154] Y. Takahashi,[102] H. Takai,[25] R. Takashima,[68] H. Takeda,[66] T. Takeshita,[141] Y. Takubo,[65] M. Talby,[84] A. A. Talyshev,[108,i] J. Y. C. Tam,[175] M. C. Tamsett,[78,mm] K. G. Tan,[87] J. Tanaka,[156] R. Tanaka,[116] S. Tanaka,[132] S. Tanaka,[65] A. J. Tanasijczuk,[143] K. Tani,[66] N. Tannoury,[84] S. Tapprogge,[82] S. Tarem,[153] F. Tarrade,[29] G. F. Tartarelli,[90a] P. Tas,[128] M. Tasevsky,[126] T. Tashiro,[67] E. Tassi,[37a,37b] A. Tavares Delgado,[125a] Y. Tayalati,[136d] C. Taylor,[77] F. E. Taylor,[93] G. N. Taylor,[87] W. Taylor,[160b] F. A. Teischinger,[30] M. Teixeira Dias Castanheira,[75] P. Teixeira-Dias,[76] K. K. Temming,[48] H. Ten Kate,[30] P. K. Teng,[152] S. Terada,[65] K. Terashi,[156] J. Terron,[81] S. Terzo,[100] M. Testa,[47] R. J. Teuscher,[159,m] J. Therhaag,[21] T. Theveneaux-Pelzer,[34] S. Thoma,[48] J. P. Thomas,[18] J. Thomas-Wilsker,[76] E. N. Thompson,[35] P. D. Thompson,[18] P. D. Thompson,[159] A. S. Thompson,[53] L. A. Thomsen,[36] E. Thomson,[121] M. Thomson,[28] W. M. Thong,[87] R. P. Thun,[88,a] F. Tian,[35] M. J. Tibbetts,[15] T. Tic,[126] V. O. Tikhomirov,[95,nn] Yu. A. Tikhonov,[108,i] S. Timoshenko,[97] E. Tiouchichine,[84] P. Tipton,[177] S. Tisserant,[84] T. Todorov,[5] S. Todorova-Nova,[128] B. Toggerson,[164] J. Tojo,[69] S. Tokár,[145a] K. Tokushuku,[65] K. Tollefson,[89] L. Tomlinson,[83] M. Tomoto,[102] L. Tompkins,[31] K. Toms,[104] N. D. Topilin,[64] E. Torrence,[115] H. Torres,[143] E. Torró Pastor,[168] J. Toth,[84,hh] F. Touchard,[84] D. R. Tovey,[140] H. L. Tran,[116] T. Trefzger,[175] L. Tremblet,[30] A. Tricoli,[30] I. M. Trigger,[160a] S. Trincaz-Duvoid,[79] M. F. Tripiana,[70] N. Triplett,[25] W. Trischuk,[159] B. Trocmé,[55] C. Troncon,[90a] M. Trottier-McDonald,[143] M. Trovatelli,[135a,135b] P. True,[89] M. Trzebinski,[39] A. Trzupek,[39] C. Tsarouchas,[30] J. C-L. Tseng,[119] P. V. Tsiareshka,[91] D. Tsionou,[137] G. Tsipolitis,[10] N. Tsirintanis,[9] S. Tsiskaridze,[12] V. Tsiskaridze,[48] E. G. Tskhadadze,[51a] I. I. Tsukerman,[96] V. Tsulaia,[15] J.-W. Tsung,[21] S. Tsuno,[65] D. Tsybychev,[149] A. Tua,[140] A. Tudorache,[26a] V. Tudorache,[26a] A. N. Tuna,[121] S. A. Tupputi,[20a,20b] S. Turchikhin,[98,ll] D. Turecek,[127] I. Turk Cakir,[4d] R. Turra,[90a,90b] P. M. Tuts,[35] A. Tykhonov,[74] M. Tylmad,[147a,147b] M. Tyndel,[130] K. Uchida,[21] I. Ueda,[156] R. Ueno,[29] M. Ughetto,[84] M. Ugland,[14] M. Uhlenbrock,[21] F. Ukegawa,[161] G. Unal,[30] A. Undrus,[25] G. Unel,[164] F. C. Ungaro,[48] Y. Unno,[65] D. Urbaniec,[35] P. Urquijo,[21] G. Usai,[8] A. Usanova,[61] L. Vacavant,[84] V. Vacek,[127] B. Vachon,[86] N. Valencic,[106] S. Valentinetti,[20a,20b] A. Valero,[168] L. Valery,[34] S. Valkar,[128] E. Valladolid Gallego,[168] S. Vallecorsa,[49] J. A. Valls Ferrer,[168] R. Van Berg,[121] P. C. Van Der Deijl,[106] R. van der Geer,[106] H. van der Graaf,[106] R. Van Der Leeuw,[106] D. van der Ster,[30] N. van Eldik,[30] P. van Gemmeren,[6] J. Van Nieuwkoop,[143] I. van Vulpen,[106] M. C. van Woerden,[30] M. Vanadia,[133a,133b] W. Vandelli,[30] A. Vaniachine,[6] P. Vankov,[42] F. Vannucci,[79] G. Vardanyan,[178] R. Vari,[133a] E. W. Varnes,[7] T. Varol,[85] D. Varouchas,[15] A. Vartapetian,[8] K. E. Varvell,[151] V. I. Vassilakopoulos,[56] F. Vazeille,[34] T. Vazquez Schroeder,[54] J. Veatch,[7] F. Veloso,[125a] S. Veneziano,[133a] A. Ventura,[72a,72b] D. Ventura,[85] M. Venturi,[48] N. Venturi,[159] A. Venturini,[23] V. Vercesi,[120a] M. Verducci,[139] W. Verkerke,[106] J. C. Vermeulen,[106] A. Vest,[44] M. C. Vetterli,[143,g] O. Viazlo,[80] I. Vichou,[166] T. Vickey,[146c,oo] O. E. Vickey Boeriu,[146c] G. H. A. Viehhauser,[119] S. Viel,[169] R. Vigne,[30] M. Villa,[20a,20b] M. Villaplana Perez,[168] E. Vilucchi,[47] M. G. Vincter,[29] V. B. Vinogradov,[64] J. Virzi,[15] O. Vitells,[173] I. Vivarelli,[150] F. Vives Vaque,[3] S. Vlachos,[10] D. Vladoiu,[99] M. Vlasak,[127] A. Vogel,[21] P. Vokac,[127] G. Volpi,[47] M. Volpi,[87] H. von der Schmitt,[100] H. von Radziewski,[48] E. von Toerne,[21] V. Vorobel,[128] M. Vos,[168] R. Voss,[30] J. H. Vossebeld,[73] N. Vranjes,[137] M. Vranjes Milosavljevic,[106] V. Vrba,[126] M. Vreeswijk,[106] T. Vu Anh,[48] R. Vuillermet,[30] I. Vukotic,[31] Z. Vykydal,[127] W. Wagner,[176] P. Wagner,[21] S. Wahrmund,[44] J. Wakabayashi,[102] J. Walder,[71] R. Walker,[99] W. Walkowiak,[142] R. Wall,[177] P. Waller,[73] B. Walsh,[177] C. Wang,[152] C. Wang,[45] H. Wang,[15] H. Wang,[40] J. Wang,[152] J. Wang,[33a] K. Wang,[86] R. Wang,[104] S. M. Wang,[152] T. Wang,[21] X. Wang,[177] A. Warburton,[86] C. P. Ward,[28] D. R. Wardrope,[77] M. Warsinsky,[48] A. Washbrook,[46] C. Wasicki,[42] I. Watanabe,[66] P. M. Watkins,[18] A. T. Watson,[18] I. J. Watson,[151] M. F. Watson,[18] G. Watts,[139] S. Watts,[83] A. T. Waugh,[151] B. M. Waugh,[77] S. Webb,[83] M. S. Weber,[17] S. W. Weber,[175] J. S. Webster,[31] A. R. Weidberg,[119] P. Weigell,[100] J. Weingarten,[54] C. Weiser,[48] H. Weits,[106] P. S. Wells,[30] T. Wenaus,[25] D. Wendland,[16] Z. Weng,[152,y] T. Wengler,[30] S. Wenig,[30] N. Wermes,[21] M. Werner,[48] P. Werner,[30] M. Wessels,[58a] J. Wetter,[162] K. Whalen,[29] A. White,[8] M. J. White,[1] R. White,[32b] S. White,[123a,123b] D. Whiteson,[164] D. Whittington,[60] D. Wicke,[176] F. J. Wickens,[130] W. Wiedenmann,[174] M. Wielers,[80,f] P. Wienemann,[21] C. Wiglesworth,[36] L. A. M. Wiik-Fuchs,[21] P. A. Wijeratne,[77] A. Wildauer,[100] M. A. Wildt,[42,pp] H. G. Wilkens,[30] J. Z. Will,[99] H. H. Williams,[121] S. Williams,[28] S. Willocq,[85] J. A. Wilson,[18] A. Wilson,[88] I. Wingerter-Seez,[5] S. Winkelmann,[48] F. Winklmeier,[115] M. Wittgen,[144] T. Wittig,[43] J. Wittkowski,[99] S. J. Wollstadt,[82] M. W. Wolter,[39] H. Wolters,[125a,j] B. K. Wosiek,[39] J. Wotschack,[30] M. J. Woudstra,[83] K. W. Wozniak,[39] K. Wraight,[53] M. Wright,[53] S. L. Wu,[174] X. Wu,[49] Y. Wu,[88] E. Wulf,[35] T. R. Wyatt,[83] B. M. Wynne,[46]

S. Xella,[36] M. Xiao,[137] D. Xu,[33a] L. Xu,[33b,qq] B. Yabsley,[151] S. Yacoob,[146b,rr] M. Yamada,[65] H. Yamaguchi,[156] Y. Yamaguchi,[156] A. Yamamoto,[65] K. Yamamoto,[63] S. Yamamoto,[156] T. Yamamura,[156] T. Yamanaka,[156] K. Yamauchi,[102] Y. Yamazaki,[66] Z. Yan,[22] H. Yang,[33e] H. Yang,[174] U. K. Yang,[83] Y. Yang,[110] S. Yanush,[92] L. Yao,[33a] Y. Yasu,[65] E. Yatsenko,[42] K. H. Yau Wong,[21] J. Ye,[40] S. Ye,[25] A. L. Yen,[57] E. Yildirim,[42] M. Yilmaz,[4b] R. Yoosoofmiya,[124] K. Yorita,[172] R. Yoshida,[6] K. Yoshihara,[156] C. Young,[144] C. J. S. Young,[30] S. Youssef,[22] D. R. Yu,[15] J. Yu,[8] J. M. Yu,[88] J. Yu,[113] L. Yuan,[66] A. Yurkewicz,[107] B. Zabinski,[39] R. Zaidan,[62] A. M. Zaitsev,[129,dd] A. Zaman,[149] S. Zambito,[23] L. Zanello,[133a,133b] D. Zanzi,[100] A. Zaytsev,[25] C. Zeitnitz,[176] M. Zeman,[127] A. Zemla,[38a] K. Zengel,[23] O. Zenin,[129] T. Ženiš,[145a] D. Zerwas,[116] G. Zevi della Porta,[57] D. Zhang,[88] H. Zhang,[89] J. Zhang,[6] L. Zhang,[152] X. Zhang,[33d] Z. Zhang,[116] Z. Zhao,[33b] A. Zhemchugov,[64] J. Zhong,[119] B. Zhou,[88] L. Zhou,[35] N. Zhou,[164] C. G. Zhu,[33d] H. Zhu,[33a] J. Zhu,[88] Y. Zhu,[33b] X. Zhuang,[33a] A. Zibell,[99] D. Zieminska,[60] N. I. Zimin,[64] C. Zimmermann,[82] R. Zimmermann,[21] S. Zimmermann,[21] S. Zimmermann,[48] Z. Zinonos,[54] M. Ziolkowski,[142] R. Zitoun,[5] L. Živković,[35] G. Zobernig,[174] A. Zoccoli,[20a,20b] M. zur Nedden,[16] G. Zurzolo,[103a,103b] V. Zutshi[107] and L. Zwalinski[30]

(ATLAS Collaboration)

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

[29]Department of Physics, Carleton University, Ottawa, Ontario, Canada
[30]CERN, Geneva, Switzerland
[31]Enrico Fermi Institute, University of Chicago, Chicago, Illinois, USA
[32a]Departamento de Física, Pontificia Universidad Católica de Chile, Santiago, Chile
[32b]Departamento de Física, Universidad Técnica Federico Santa María, Valparaíso, Chile
[33a]Institute of High Energy Physics, Chinese Academy of Sciences, Beijing, China
[33b]Department of Modern Physics, University of Science and Technology of China, Anhui, China
[33c]Department of Physics, Nanjing University, Jiangsu, China
[33d]School of Physics, Shandong University, Shandong, China
[33e]Physics Department, Shanghai Jiao Tong University, Shanghai, China
[34]Laboratoire de Physique Corpusculaire, Clermont Université and Université Blaise Pascal and CNRS/IN2P3, Clermont-Ferrand, France
[35]Nevis Laboratory, Columbia University, Irvington, New York, USA
[36]Niels Bohr Institute, University of Copenhagen, Kobenhavn, Denmark
[37a]INFN Gruppo Collegato di Cosenza, Laboratori Nazionali di Frascati, Rende, Italy
[37b]Dipartimento di Fisica, Università della Calabria, Rende, Italy
[38a]AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Krakow, Poland
[38b]Marian Smoluchowski Institute of Physics, Jagiellonian University, Krakow, Poland
[39]The Henryk Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences, Krakow, Poland
[40]Physics Department, Southern Methodist University, Dallas, Texas, USA
[41]Physics Department, University of Texas at Dallas, Richardson, Texas, USA
[42]DESY, Hamburg and Zeuthen, Germany
[43]Institut für Experimentelle Physik IV, Technische Universität Dortmund, Dortmund, Germany
[44]Institut für Kern- und Teilchenphysik, Technische Universität Dresden, Dresden, Germany
[45]Department of Physics, Duke University, Durham, North Carolina, USA
[46]SUPA–School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom
[47]INFN Laboratori Nazionali di Frascati, Frascati, Italy
[48]Fakultät für Mathematik und Physik, Albert-Ludwigs-Universität, Freiburg, Germany
[49]Section de Physique, Université de Genève, Geneva, Switzerland
[50a]INFN Sezione di Genova, Italy
[50b]Dipartimento di Fisica, Università di Genova, Genova, Italy
[51a]E. Andronikashvili Institute of Physics, Ivane Javakhishvili Tbilisi State University, Tbilisi, Georgia
[51b]High Energy Physics Institute, Tbilisi State University, Tbilisi, Georgia
[52]II Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen, Germany
[53]SUPA–School of Physics and Astronomy, University of Glasgow, Glasgow, United Kingdom
[54]II Physikalisches Institut, Georg-August-Universität, Göttingen, Germany
[55]Laboratoire de Physique Subatomique et de Cosmologie, Université Joseph Fourier and CNRS/IN2P3 and Institut National Polytechnique de Grenoble, Grenoble, France
[56]Department of Physics, Hampton University, Hampton, Virginia, USA
[57]Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge, Massachusetts, USA
[58a]Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany
[58b]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany
[58c]ZITI Institut für technische Informatik, Ruprecht-Karls-Universität Heidelberg, Mannheim, Germany
[59]Faculty of Applied Information Science, Hiroshima Institute of Technology, Hiroshima, Japan
[60]Department of Physics, Indiana University, Bloomington, Indiana, USA
[61]Institut für Astro- und Teilchenphysik, Leopold-Franzens-Universität, Innsbruck, Austria
[62]University of Iowa, Iowa City, Iowa, USA
[63]Department of Physics and Astronomy, Iowa State University, Ames, Iowa, USA
[64]Joint Institute for Nuclear Research, JINR Dubna, Dubna, Russia
[65]KEK, High Energy Accelerator Research Organization, Tsukuba, Japan
[66]Graduate School of Science, Kobe University, Kobe, Japan
[67]Faculty of Science, Kyoto University, Kyoto, Japan
[68]Kyoto University of Education, Kyoto, Japan
[69]Department of Physics, Kyushu University, Fukuoka, Japan
[70]Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata, Argentina
[71]Physics Department, Lancaster University, Lancaster, United Kingdom
[72a]INFN Sezione di Lecce, Italy
[72b]Dipartimento di Matematica e Fisica, Università del Salento, Lecce, Italy
[73]Oliver Lodge Laboratory, University of Liverpool, Liverpool, United Kingdom
[74]Department of Physics, Jožef Stefan Institute and University of Ljubljana, Ljubljana, Slovenia

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

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

[173]Department of Particle Physics, The Weizmann Institute of Science, Rehovot, Israel
[174]Department of Physics, University of Wisconsin, Madison, Wisconsin, USA
[175]Fakultät für Physik und Astronomie, Julius-Maximilians-Universität, Würzburg, Germany
[176]Fachbereich C Physik, Bergische Universität Wuppertal, Wuppertal, Germany
[177]Department of Physics, Yale University, New Haven, Connecticut, USA
[178]Yerevan Physics Institute, Yerevan, Armenia
[179]Centre de Calcul de l'Institut National de Physique Nucléaire et de Physique des Particules (IN2P3), Villeurbanne, France

[a]Deceased.
[b]Also at Department of Physics, King's College London, London, United Kingdom.
[c]Also at Laboratorio de Instrumentacao e Fisica Experimental de Particulas - LIP, Lisboa, Portugal.
[d]Also at Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan.
[e]Also at Faculdade de Ciencias and CFNUL, Universidade de Lisboa, Lisboa, Portugal.
[f]Also at Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom.
[g]Also at TRIUMF, Vancouver BC, Canada.
[h]Also at Department of Physics, California State University, Fresno CA, USA.
[i]Also at Novosibirsk State University, Novosibirsk, Russia.
[j]Also at Department of Physics, University of Coimbra, Coimbra, Portugal.
[k]Also at CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France.
[l]Also at Università di Napoli Parthenope, Napoli, Italy.
[m]Also at Institute of Particle Physics (IPP), Canada.
[n]Also at Department of Physics, Middle East Technical University, Ankara, Turkey.
[o]Also at Dep Fisica and CEFITEC of Faculdade de Ciencias e Tecnologia, Universidade Nova de Lisboa, Caparica, Portugal.
[p]Also at Department of Physics and Astronomy, Michigan State University, East Lansing MI, USA.
[q]Also at Department of Financial and Management Engineering, University of the Aegean, Chios, Greece.
[r]Also at Louisiana Tech University, Ruston LA, USA.
[s]Also at Institucio Catalana de Recerca i Estudis Avancats, ICREA, Barcelona, Spain.
[t]Also at Department of Physics, University of Cape Town, Cape Town, South Africa.
[u]Also at CERN, Geneva, Switzerland.
[v]Also at Ochadai Academic Production, Ochanomizu University, Tokyo, Japan.
[w]Also at Manhattan College, New York NY, USA.
[x]Also at Institute of Physics, Academia Sinica, Taipei, Taiwan.
[y]Also at School of Physics and Engineering, Sun Yat-sen University, Guanzhou, China.
[z]Also at Academia Sinica Grid Computing, Institute of Physics, Academia Sinica, Taipei, Taiwan.
[aa]Also at Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France.
[bb]Also at School of Physical Sciences, National Institute of Science Education and Research, Bhubaneswar, India.
[cc]Also at Dipartimento di Fisica, Università La Sapienza, Roma, Italy.
[dd]Also at Moscow Institute of Physics and Technology State University, Dolgoprudny, Russia.
[ee]Also at Section de Physique, Université de Genève, Geneva, Switzerland.
[ff]Also at Departamento de Fisica, Universidade de Minho, Braga, Portugal.
[gg]Also at Department of Physics, The University of Texas at Austin, Austin TX, USA.
[hh]Also at Institute for Particle and Nuclear Physics, Wigner Research Centre for Physics, Budapest, Hungary.
[ii]Also at DESY, Hamburg and Zeuthen, Germany.
[jj]Also at International School for Advanced Studies (SISSA), Trieste, Italy.
[kk]Also at Department of Physics and Astronomy, University of South Carolina, Columbia SC, USA.
[ll]Also at Faculty of Physics, M.V.Lomonosov Moscow State University, Moscow, Russia.
[mm]Also at Physics Department, Brookhaven National Laboratory, Upton NY, USA.
[nn]Also at Moscow Engineering and Physics Institute (MEPhI), Moscow, Russia.
[oo]Also at Department of Physics, Oxford University, Oxford, United Kingdom.
[pp]Also at Institut für Experimentalphysik, Universität Hamburg, Hamburg, Germany.
[qq]Also at Department of Physics, The University of Michigan, Ann Arbor MI, USA.
[rr]Also at Discipline of Physics, University of KwaZulu-Natal, Durban, South Africa.