



Original citation:

ATLAS Collaboration (Including: Farrington, Sinead and Jones, G. (Graham)). (2013) A search for prompt lepton-jets in pp collisions at root s=7 TeV with the ATLAS detector. Physics Letters B, Volume 719 (Number 4-5). pp. 299-319

Permanent WRAP url:

<http://wrap.warwick.ac.uk/56441>

Copyright and reuse:

The Warwick Research Archive Portal (WRAP) makes this work of researchers of the University of Warwick available open access under the following conditions.

This article is made available under the Creative Commons Attribution License 3.0 and may be reused according to the conditions of the license. For more details see:

<http://creativecommons.org/licenses/by/3.0/>

A note on versions:

The version presented in WRAP is the published version, or, version of record, and may be cited as it appears here.

For more information, please contact the WRAP Team at: publications@warwick.ac.uk



<http://wrap.warwick.ac.uk/>



A search for prompt lepton-jets in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector[☆]

ATLAS Collaboration*

ARTICLE INFO

Article history:

Received 21 December 2012

Received in revised form 15 January 2013

Accepted 17 January 2013

Available online 26 January 2013

Editor: W.-D. Schlatter

ABSTRACT

We present a search for a light (mass < 2 GeV) boson predicted by Hidden Valley supersymmetric models that decays into a final state consisting of collimated muons or electrons, denoted “lepton-jets”. The analysis uses 5 fb^{-1} of $\sqrt{s} = 7$ TeV proton–proton collision data recorded by the ATLAS detector at the Large Hadron Collider to search for the following signatures: single lepton-jets with at least four muons; pairs of lepton-jets, each with two or more muons; and pairs of lepton-jets with two or more electrons. This study finds no statistically significant deviation from the Standard Model prediction and places 95% confidence-level exclusion limits on the production cross section times branching ratio of light bosons for several parameter sets of a Hidden Valley model.

© 2013 CERN. Published by Elsevier B.V. All rights reserved.

1. Introduction

A light boson at the GeV scale, in a model where a Hidden Valley sector is weakly coupled to the Standard Model (SM) sector [1–3], has been proposed to explain several recently observed anomalies in cosmic-ray and dark matter direct-detection experiments. These observations include an unexpected excess of cosmic electrons and/or positrons [4–7] and signals from certain dark matter direct-detection experiments [8–10]. The proposed boson could be created at particle accelerators and produce distinctive final states of tightly collimated “lepton-jets” consisting of close by electrons or muons [11–15]. Such lepton-jet decays are also a generically interesting signature that may be produced by rare decays of, for instance, Z or Higgs bosons [16]. Upper limits on lepton-jet production have already been set by previous analyses of collider data [17,18].

In Hidden Valley models, the universe consists of SM and supersymmetric (SUSY) particles, together with an additional spectrum of dark matter particles charged under a hidden gauge group (called the dark sector). Certain particles called messengers are charged under both the dark sector and the SM and SUSY gauge symmetries, permitting decay chains through the normal and dark sectors. For example, the lightest supersymmetric particle, which cannot decay to SM particles due to R-parity conservation, can decay into less-massive dark sector states ending with the lightest particle in the dark sector, a dark photon denoted γ_D . This dark photon can decay into light SM fermions by kinetic mixing [19] of the dark gauge sector and SM gauge symmetries. These models

aim to explain the excess of cosmic-ray positrons, in the absence of any observed proton excess, with a dark boson γ_D that has a mass below the proton–antiproton kinematic threshold of ~ 2 GeV. Such low-mass dark photons can decay to electrons, muons, and pions, whereas decays to protons are kinematically forbidden. Due to the boost of the γ_D , the light SM decay products are highly collimated, providing a striking signature for new physics.

The data is interpreted in a model where a pair of squarks is produced and each of the squarks cascade decays into dark sector particles, including one or more dark photons. The dark photons decay into pairs of leptons, forming lepton-jets. Additionally, dark sector particles may radiate multiple dark photons, increasing the lepton multiplicities and number of the lepton-jets [16]. The amount of radiation is determined by the dark sector gauge coupling parameter α_d . Setting $\alpha_d = 0.0$ results in a simple lepton-jet with two hard leptons. Larger values of α_d may produce lepton-jets with four, six, eight, or more prompt leptons from the decay of overlapping dark photons, albeit with reduced boost. The transverse momentum (p_T) of the leptons increases with dark photon mass, but decreases with α_d . This Letter considers values of α_d of 0.0, 0.1, and 0.3, and dark photon masses (m_{γ_D}) of 150, 300, and 500 MeV. For $m_{\gamma_D} = 150$ MeV, the dark photon is below the muon–antimuon threshold and can only decay to electrons. With $m_{\gamma_D} \geq 300$ MeV, the dark photon decays to electron and muon pairs. Additionally, for $m_{\gamma_D} = 500$ MeV, 20% of the decays produce pion pairs. These nine signal operating points cover a wide range of phase space from low-multiplicity lepton-jets containing leptons of only one flavour, to high-multiplicity lepton-jets containing a mix of electrons and muons.

The data samples used in this analysis were collected with the ATLAS detector during the 2011 run of the Large Hadron Collider at centre-of-mass energy $\sqrt{s} = 7$ TeV and correspond to 4.5 fb^{-1} .

* © CERN for the benefit of the ATLAS Collaboration.

* E-mail address: atlas.publications@cern.ch.

of integrated luminosity for the muon analyses and 4.8 fb^{-1} for the electron analysis [20,21], after their respective data quality requirements have been applied. This Letter considers lepton-jets in three signatures: single muon-jets with four or more muons, pairs of muon-jets each with two or more muons, and pairs of electron-jets each with two or more electrons. The selection is designed to enhance the signal relative to the SM backgrounds, the largest of which is multi-jet production. In multi-jet production the background arises from either real leptons from the decay of SM particles, from hadrons that are misidentified as leptons, or in the case of electrons, from photon conversions. All other SM background sources are expected to be negligible after the final selection cuts are applied. The multi-jet background is reduced through a variety of selection cuts, and the remaining background is estimated with two different data-driven techniques.

No requirements are made on the remaining activity in the event beyond the one or two lepton-jets in order to avoid introducing a strong model dependence in the analysis. For example, no cuts are made on the presence of other particles or jets, the event track multiplicity, or the presence of missing transverse energy.

2. The ATLAS detector

ATLAS is a general purpose detector [22] consisting of an inner tracking detector (ID) embedded in a 2 T solenoid, electromagnetic and hadronic calorimeters and a muon spectrometer (MS) employing toroidal magnets. The ID provides precision tracking of charged particles for $|\eta| < 2.5$ using silicon pixel and microstrip detectors and a straw-tube transition radiation tracker (TRT) that relies on transition radiation to distinguish electrons from pions in the range $|\eta| < 2.0$. Liquid argon (LAr) electromagnetic sampling calorimeters, with excellent energy and position resolution, cover the range $|\eta| < 3.2$ with a typical granularity of $\Delta\eta \times \Delta\phi$ of 0.025×0.025 . A scintillator-tile calorimeter, which is divided into a large barrel and two smaller extended-barrel cylinders, one on each side of the central barrel, provides hadronic calorimetry in the range $|\eta| < 1.7$. In the end-caps ($|\eta| > 1.5$), LAr is also used for the hadronic calorimeters, matching the outer $|\eta|$ limit of end-cap electromagnetic calorimeters. The LAr forward calorimeters provide both electromagnetic and hadronic energy measurements, and extend the coverage to $|\eta| = 4.9$. The calorimeter system has a minimum depth of 9.7 interaction lengths at $\eta = 0$. The MS covers $|\eta| < 2.7$ and provides triggering and precision tracking for muons.¹

A three-level trigger system is used to select events. The Level 1 (L1) trigger is implemented in hardware and uses information from the calorimeters and muon sub-detectors to reduce the event rate to a design value of at most 75 kHz. This is followed by two software-based trigger levels, Level 2 (L2) and Event Filter (EF), which together reduce the event rate to 300 Hz on average. The L1 trigger generates a list of Regions of Interest (RoI) η - ϕ coordinates with associated thresholds. The muon RoI have a spatial extent of 0.2 in $\Delta\eta$ and $\Delta\phi$ in the MS barrel, and 0.1 in the MS endcap. The electromagnetic calorimeter RoI have a spatial extent of 0.2 in $\Delta\eta$ and $\Delta\phi$. At L2, most reconstruction uses simplified algorithms running on data localized to an RoI which was reported by L1. At

the EF level, the trigger system has access to the full event for processing.

3. Event reconstruction and selection

The analysis used only data from stable running periods, and required events to have a primary collision vertex containing at least three tracks with $p_T > 400 \text{ MeV}$ in order to remove cosmic rays.

3.1. Electron-jet channel

Events containing electron-jets were selected using single electron triggers with an online p_T threshold of 20 or 22 GeV, the latter being used after there was a substantial increase in the instantaneous luminosity during 2011. To ensure proper modelling of the trigger acceptance, events were required to contain at least one reconstructed electron with $p_T > 35 \text{ GeV}$, above which the trigger efficiency is constant. The reconstructed electron was required to match an electron reconstructed above the p_T threshold in the trigger system with a separation in R ($\Delta R \equiv \sqrt{(\Delta\phi)^2 + (\Delta\eta)^2}$) less than 0.2.

The electron-jet candidates were built from electromagnetic clusters with minimum transverse energy $E_T > 10 \text{ GeV}$ inside the calorimeter fiducial region ($|\eta| < 2.47$, excluding the barrel/endcap transition region $1.37 < |\eta| < 1.52$ where there is substantial dead material that is difficult to model accurately). At least two tracks from the primary vertex (transverse impact parameter $|d_0| < 1 \text{ mm}$) having $p_T > 10 \text{ GeV}$ were required to have $\Delta R < 0.1$ of the cluster position in the second sampling layer of the calorimeter. Additional requirements were made on the number of hits along the track in the silicon pixel and silicon microstrip detectors to suppress backgrounds from photon conversions. The analysis required two lepton-jet candidates in each event, with one cluster matching the electron reconstructed in the trigger system. The invariant mass of the two highest- p_T tracks associated with each electron-jet had to be less than 2 GeV.

The background for the electron-jets analysis comes primarily from multi-jet events, and to a lesser extent from photon + jet events. Five variables were used to reduce the remaining background for electron-jet candidates. The electron cluster energy concentration shown in Fig. 1(a), $R_{\eta 2}$, must exceed 0.92. $R_{\eta 2}$ is defined as the ratio of total energy in 3×7 cells to the total energy in 7×7 cells in η - ϕ in the second sampling layer of the electromagnetic calorimeter. The electron cluster lateral shower width in the calorimeter, $w_{\eta 2}$, shown in Fig. 1(b), must be less than 0.0115, where

$$w_{\eta 2} = \sqrt{\frac{\sum_i E_i \times \eta_i^2}{\sum_i E_i}} - \left(\frac{\sum_i E_i \times \eta_i}{\sum_i E_i} \right)^2. \quad (1)$$

Here E_i and η_i represent the energy and pseudorapidity of the i th cell in a 3×5 η - ϕ window in the second sampling layer of the electromagnetic calorimeter. The ratio of the number of high-threshold hits [22], indicative of transition radiation, to the total number of hits from the TRT associated with each track, f_{HT} , was required to be greater than 0.05 to remove pions. The f_{HT} distribution per track is shown in Fig. 1(c). The sharp peak at zero arises from tracks matched to an electron candidate outside of the TRT acceptance. A scaled isolation variable is defined as the transverse energy within $0.1 < \Delta R < 0.4$ around the cluster divided by cluster E_T ; events were required to have scaled isolation below 30% as shown in Fig. 1(d). Finally, a requirement that the fraction of the lepton-jet energy found in the electromagnetic calorimeter, f_{EM} must be larger than 0.98, was used to reject activity from hadrons, as shown in Fig. 1(e).

¹ ATLAS uses a right-handed coordinate system with its origin at the nominal interaction point (IP) in the centre of the detector and the z-axis along the beam pipe. The x-axis points from the IP to the centre of the LHC ring, and the y-axis points upward. Cylindrical coordinates (r, ϕ) are used in the transverse plane, ϕ being the azimuthal angle around the beam pipe. The pseudorapidity is defined in terms of the polar angle θ as $\eta = -\ln \tan(\theta/2)$.

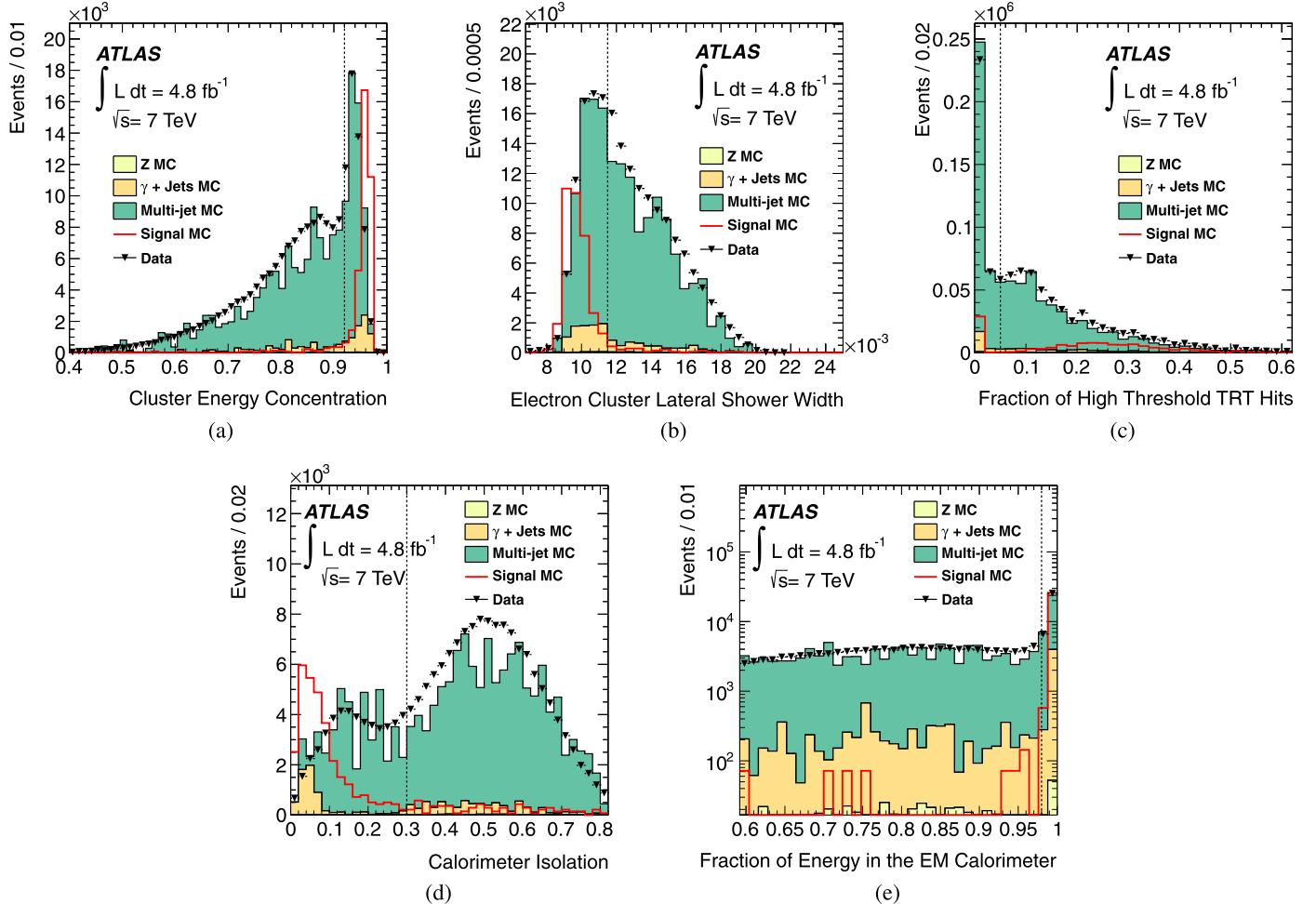


Fig. 1. Distributions of the five discriminating variables used after selection of events which have passed the trigger and contain two or more electron-jet candidates, shown separately for the multi-jet, $Z \rightarrow ee$ and $\gamma +$ jets backgrounds as well as for the signal sample with $\alpha_d = 0.0$ and $m_{\gamma\eta} = 150$ MeV. The signal MC normalization is arbitrary. The dashed black vertical line shows the cut values at (a) cluster energy concentration $R_{\eta 2} \geq 0.92$, (b) electron cluster lateral shower width $w_{\eta 2} \leq 0.0115$, (c) fraction of high threshold TRT hits $f_{HT} \geq 0.05$, (d) calorimeter isolation ≤ 0.3 , and (e) fraction of energy in the EM calorimeter $f_{EM} \geq 0.98$. The hadronic jet and $\gamma +$ jets distributions are shown here from PYTHIA MC for illustrative purposes.

3.2. Muon-jet channels

Single muon-jet events were selected from events satisfying a trigger with a single muon having more than 18 GeV in p_T . Candidates for double muon-jets were taken with either a single muon trigger with a p_T threshold of 18 GeV or a three-muon trigger with a p_T threshold of 6 GeV. The muon triggers were complementary, as the three-muon trigger has reduced efficiency for high- p_T muons from a single lepton-jet which may be too close together to produce more than one RoI.

Muon candidates must have been reconstructed in both the ID and the MS and have $|\eta| < 2.5$. Additional requirements were made on the number of associated hits in the silicon pixel and microstrip detectors, as well as on the number of track segments in the MS. The muons were required to come from the primary vertex by imposing a $|d_0| < 1$ mm cut on the tracks. The muon-jets were reconstructed in an iterative procedure using all candidate muons, by seeding the jet candidate with the highest- p_T muon, and adding all muons within $\Delta R = 0.1$. Additional jets were formed using the remaining muons, again seeding the muon-jet with the remaining highest- p_T muon. For the double muon-jet analysis, two muons with $p_T > 11$ GeV were required per jet with the additional requirement that the leading muon p_T be greater than 23 GeV for the single muon trigger events. For the single muon-jet analysis,

four muons were required per jet with $p_T > 19, 16, 14$ GeV, respectively, for the three highest- p_T muons, and $p_T > 4$ GeV for all additional muons.

Within a muon-jet, the two muons closest in p_T were required to have an invariant mass less than 2 GeV. A scaled isolation variable was formed by summing the E_T of all calorimeter cells within $\Delta R = 0.3$ of any of the muon-jet's component muons while excluding cells found within $\Delta R = 0.05$ of the muons, and dividing by the muon-jet p_T . The scaled isolation was required to be less than 0.3 (0.15) per muon-jet for the double (single) muon-jet analyses, to suppress muons from hadronic jets.

As noted earlier, a signature of the dark matter signal is a muon-jet composed of two or more muon tracks confined to a narrow cone. One source of collimated muons arises from the decay of low-mass states, since the opening angle is in inverse proportion to the Lorentz boost. The background from boosted low-mass states with an invariant mass less than 3.5 GeV is displayed in Fig. 2 showing the opening angle ΔR vs invariant mass for all dimuon pairs. This plot was produced using the same muon selection used for the muon-jet analysis, excluding the ΔR requirement. The invariant mass of muon pairs falls off smoothly, interrupted by easily observable narrow peaks produced by low-mass resonances such as ϕ (~ 1 GeV), and ω and ρ (~ 0.7 GeV). For smaller opening angles, $\Delta R \lesssim 0.03$, the low-mass resonances barely stand out from

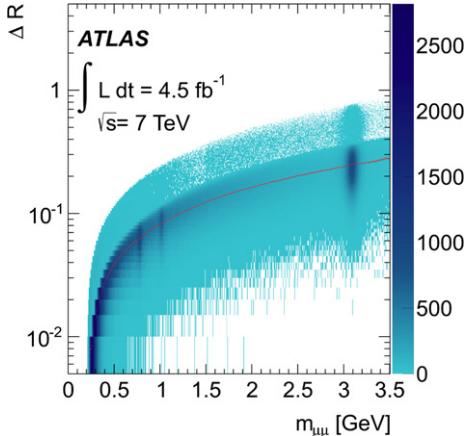


Fig. 2. The opening angle ΔR vs invariant mass for all muon pairs in the 4.5 fb^{-1} data sample. The overlaid red points show the profile of the ΔR distribution for each dimuon mass bin. The position of each point is the mean value of the vertical slice and its width is the RMS. The secondary distribution running along the top of the distribution arises from events with more than two muons, where a third muon triggers at a higher p_T , allowing for combinations of dimuon pairs with a larger opening angle. (For interpretation of the references to color in this figure, the reader is referred to the web version of this Letter.)

the rest of the background. It was not practical to exclude the ω/ρ and ϕ peak regions from the analysis. However, the J/ψ was removed for the electron-jet and muon-jet search by a 2 GeV mass cut. A second smoothly falling distribution is also visible in this figure from events with an additional three or more muons, one of which has a high enough p_T to fire the trigger, producing an additional combinatorial background.

4. Signal and background estimation

Both MC and data-driven methods were used for background and efficiency estimations. Various SM processes can mimic the signal due to misreconstructed objects, such as jets misidentified as electrons, or chance overlap of leptons. We have considered MC hadronic multi-jet events, $\gamma + \text{jets}$ events, $W \rightarrow \ell\nu + \text{jets}$, $Z \rightarrow \ell^+\ell^- + \text{jets}$, $t\bar{t}$ and diboson (WW , WZ , ZZ) events at $\sqrt{s} = 7 \text{ TeV}$. Pythia6 [23] was used for all samples except $t\bar{t}$, WW , WZ , ZZ for which MC@NLO [24] was used. The contribution from WZ and ZZ backgrounds, when one of the bosons is off-shell, was modeled with Sherpa [25]. Of all the backgrounds considered, only the hadronic multi-jet and $\gamma + \text{jets}$ events contribute significantly to the final background expectation. In addition, signal MC simulation was generated using MadGraph [26] with the CTEQ6L1 set of parton distribution functions [27], and a custom-made Mathematica [28] package to model the dark sector cascade decay described in Refs. [11,16], followed by Pythia6 for hadronization. All MC samples include the effect of multiple pp interactions per bunch crossing and are assigned an event weight such that the distribution of the number of pp interactions matches that in data. The mean momentum of the dark photons depends strongly on α_d and therefore the acceptance of the lepton-jets also depends on this parameter. At $\alpha_d = 0.0$ the mean momentum of the dark photon is 73, 76, and 82 GeV for $m_{\gamma_D} = 150, 300$, and 500 MeV, respectively, with no cuts applied. For $\alpha_d = 0.1$, the mean dark photon momentum decreases to 30.4, 35.9, and 41.6 GeV. At $\alpha_d = 0.3$ the mean values are 21.1, 25.7, and 30.9 GeV. All MC events were processed with the GEANT4 based ATLAS detector simulation [29,30] and then analyzed with the standard ATLAS reconstruction software.

Due to the very small acceptance for hadronic jets passing our signal criteria, $\mathcal{O}(10^{-3})$ to $\mathcal{O}(10^{-4})$ for jets with $50 < p_T < 400 \text{ GeV}$, there were too few MC events to accurately estimate

background yields. The background MC samples were used to help establish the event selection criteria, based on characteristics of the background. All the samples were required to satisfy the trigger conditions, with efficiencies ranging from 40% to 75% for the lepton-jet models considered.

4.1. Background estimation with the ABCD-likelihood method

In the lepton p_T and dilepton invariant mass ranges relevant to this study, the level of the background is best estimated using a data-driven method, rather than by MC simulation where the number of events is low and the backgrounds may be poorly modeled. This Letter uses an ABCD-likelihood method to determine the lepton-jet backgrounds which was cross-checked with a tag-and-probe fake-rate estimate. The traditional implementation of the ABCD method consists of using two uncorrelated or loosely correlated variables from the event selection to define four regions labeled A, B, C and D, as illustrated in Fig. 3. The background in the signal region is estimated by taking the ratio of events in the adjacent regions. This method breaks down in the presence of significant signal contamination in the side-band regions, or when there are too few events. The ABCD-likelihood method addresses both of these issues. A likelihood function, formed from the product of Poisson probability functions describing the signal and background expectations, is fit to all four of the regions simultaneously.

The likelihood takes the form:

$$L(n_A, n_B, n_C, n_D | \mu, \theta_\mu) = \prod_{i=A,B,C,D} \frac{e^{-\mu_i} \mu_i^{n_i}}{n_i!} \quad (2)$$

where n_A , n_B , n_C , and n_D are the numbers of events observed in each of the four regions, and μ_A , μ_B , μ_C , and μ_D are linear combinations of signal (μ) and multi-jet background (μ^U) expectations. In region A, the expected number of events $\mu_A = \mu^U + \mu$. In region B, $\mu_B = \mu^U \tau_B + \mu b$, where τ_B is the ratio of background events expected in region B to that in region A and b gives the signal contamination in region B. Similarly, the expected number of events in region C is expressed as $\mu_C = \mu^U \tau_C + \mu c$. In region D, $\mu_D = \mu^U \tau_B \tau_C + \mu d$, such that the multi-jet background contribution is determined using the product of the ratios. The signal contamination coefficients are taken from MC simulation for each signal sample, while μ^U and the τ_i values are allowed to float in a simultaneous fit to the four data regions.

For the electron-jet analysis, the ABCD-likelihood method used boundaries at $R_{\eta 2} = 0.92$ and $f_{EM} = 0.98$ on the second highest- E_T lepton-jet to define these four regions. In photon + jet events, the photon will typically deposit more energy in the EM calorimeter than the hadronic jet. Using the subleading cluster to estimate the background thus accounts for both the photon + jet and multi-jet backgrounds. The double (single) muon-jet analysis used the scaled isolation variable and the p_T cut on the fourth (third) muon in the event, associated with a muon-jet. The two-dimensional distributions with the A, B, C and D regions are shown in Fig. 3. In the absence of signal, the numbers of events predicted in region A for the single muon-jet channel, the double muon-jet channel, and the double electron-jet channel are 3.0 ± 1.0 , 0.5 ± 0.3 , and 15.2 ± 2.7 , respectively. The quoted errors are statistical only.

4.2. Background estimation using jet probabilities

Both the electron-jet and muon-jet analyses used a tag-and-probe method to cross-check the amount of background in the signal region using back-to-back hadronic jet pairs with $p_T > 30 \text{ GeV}$ and $|\Delta\phi| > 2$ but with different selection criteria.

For the electron-jet analysis, the tag was chosen by matching a jet with $f_{EM} < 0.9$ to a trigger jet. Using the highest- E_T

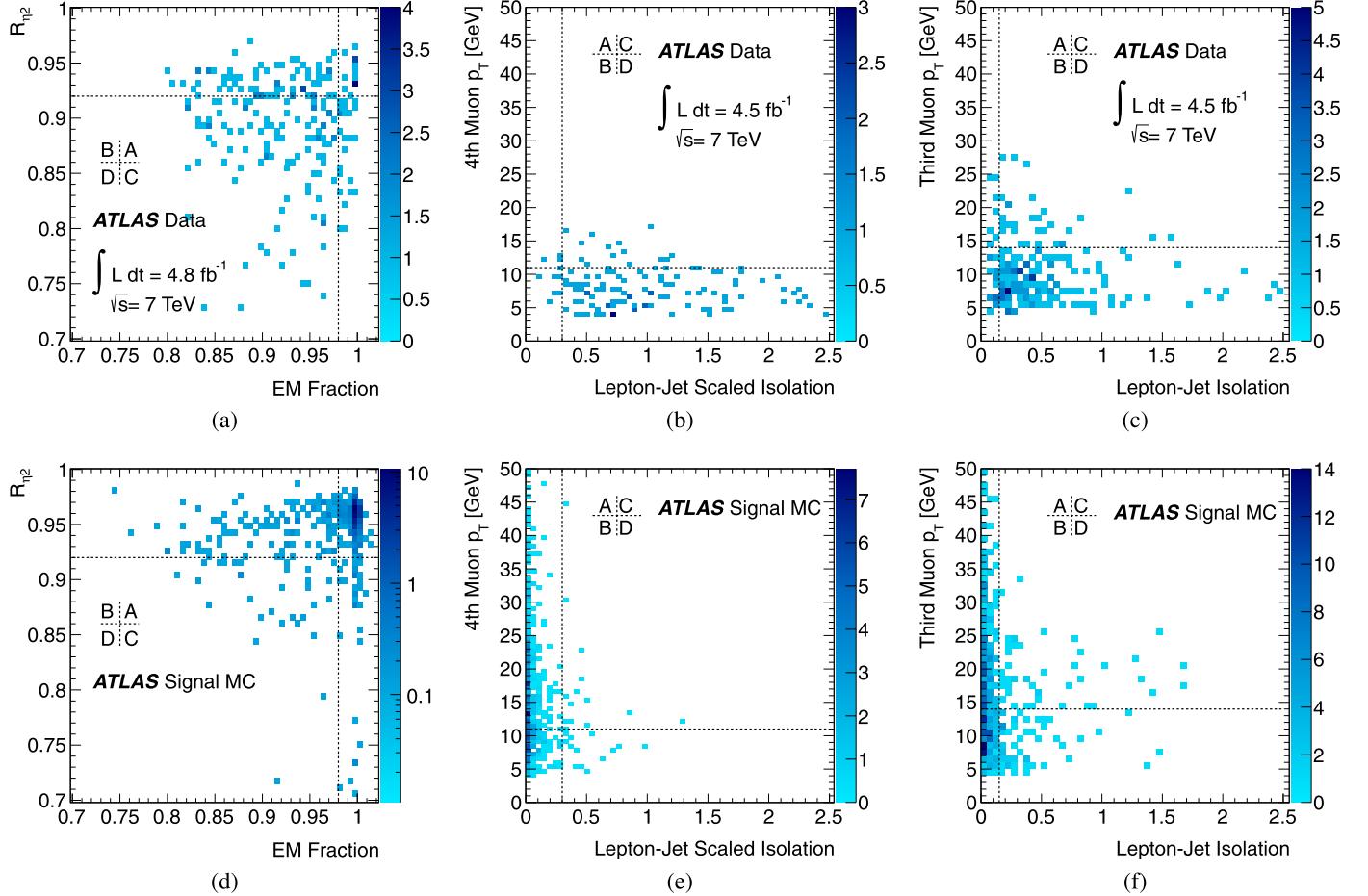


Fig. 3. Variables used for ABCD-likelihood method from data (top) and MC signal (bottom) using $\alpha_d = 0.1$ and $m_{\gamma_D} = 300$ MeV for the electron channel and $\alpha_d = 0.0$ and $m_{\gamma_D} = 300$ MeV for the two muon channels. The dashed black lines show the cuts used to define the four regions. Shown are (left) electron-jet: $R_{\eta 2}$ vs EM fraction; (centre) double muon-jet: scaled isolation vs p_T of the fourth muon; (right) single muon-jet: scaled isolation vs p_T of the third muon.

electromagnetic cluster within $\Delta R = 0.4$ of the probe jet as a seed for the electron-jet, the fake rate was extracted from the probe jets that satisfied the electron-jet criteria, as well as the probability for such electron-jets to pass the electron trigger. Jet triggers with different p_T thresholds were used to determine the rates over the full range of probe-jet p_T values. These probabilities were then used to calculate event weights for the inclusive multi-jet MC sample to estimate the number of events which would pass the electron trigger and electron-jet selection requirements. This method predicted $14.55^{+0.23}_{-0.04}$ background events after all analysis cuts were applied to the data. The quoted error is statistical only.

The double muon-jet analysis used two criteria to select either light-quark or b -quark jets by requiring that either the tag jets contain no muons and no b -tag, or the tag jets have a b -tag. The probe jets were then used to determine the probability that a hadronic jet could satisfy the muon selection criteria and the probability that it could satisfy the muon-jet selection criteria, as a function of the probe-jet p_T . The ratio of these two probabilities was used in events containing three muons (of which at least two formed a muon-jet and the third was embedded in a hadronic jet) to estimate the background from multi-jet production, accounting for the flavour of the hadronic jet. This method predicted 2.2 ± 0.9 events from multi-jet production. The quoted error is statistical only.

The fake rates for muon-jets and electron-jets were found to be consistent with those obtained from the ABCD-likelihood method, which were discussed in Section 4.1 and are summarized in Table 1. This cross-check thus validates the background estimates.

Table 1

The number of events in the signal region (A) observed in data and expected from background sources estimated with the ABCD-likelihood method. The quoted error is statistical only.

	Electron LJ	1 muon LJ	2 muon LJ
Data	15	7	3
All background	15.2 ± 2.7	3.0 ± 1.0	0.5 ± 0.3

Table 2

The acceptance times trigger, reconstruction, and selection efficiency ($A \times \epsilon$) expected in the signal region (A) from various signal hypotheses for the three different lepton-jet (LJ) channels. Note that the $m_{\gamma_D} = 150$ MeV dark photon cannot decay to muons.

α_d	m_{γ_D} [MeV]	Signal parameters	Electron LJ	1 muon LJ	2 muon LJ
			$A \times \epsilon$ [%]	$A \times \epsilon$ [%]	$A \times \epsilon$ [%]
0.0	150		3.01 ± 0.30		
0.0	300		2.7 ± 0.5	4.3 ± 0.9	9.2 ± 0.9
0.0	500		1.8 ± 0.5	1.7 ± 1.3	8.5 ± 1.1
0.10	150		2.69 ± 0.23		
0.10	300		1.04 ± 0.19	3.7 ± 0.5	7.10 ± 0.39
0.10	500		1.17 ± 0.23	5.0 ± 0.8	8.1 ± 0.6
0.30	150		2.49 ± 0.22		
0.30	300		0.80 ± 0.13	2.16 ± 0.29	7.47 ± 0.42
0.30	500		0.37 ± 0.10	3.16 ± 0.46	6.23 ± 0.43

Table 3

Contributions to the systematic uncertainty on the signal yields for the three different lepton-jet (LJ) channels given as percentages. A “NA” means this source does not apply.

	Electron LJ [%]	1 muon LJ [%]	2 muon LJ [%]
Luminosity	3.9	3.9	3.9
Trigger efficiency	1.5	2.0	3.6
Offline ΔR efficiency	13.0	10.7	10.7
Lepton momentum scale	0.6	1.0	1.0
Isolation	5.2	< 0.1	< 0.1
$R_{\eta 2}$ and $w_{\eta 2}$ efficiency	8.0	NA	NA
f_{HT} efficiency	1.0	NA	NA
f_{EM} efficiency	3.0	NA	NA
Muon momentum resolution	NA	< 1.0	< 1.0

5. Results and interpretation

Table 1 shows the number of events passing all analysis cuts compared to the background expectation from the ABCD-likelihood method. A slight excess is observed in both the single and the double muon-jet signal regions corresponding to p -values (the probability the background process would produce at least this many events) of 0.06 and 0.04, respectively. The acceptance times trigger, reconstruction, and selection efficiency for the various signal points are listed in **Table 2**. It ranges from about 0.4% to 10% depending on the model parameter α_d , the mass of the dark photon, and the analysis channel. The estimate of the background from the ABCD-likelihood method has a large statistical error, which reduces the expected sensitivity of the analysis. The systematic uncertainty on the ABCD-likelihood method due to correlation between the variables, 3% (4%) for the single (double) muon-jets channel, is small by comparison.

Table 3 lists the systematic uncertainties on the signal yields. The possible mismodelling of track reconstruction at very small opening angles (“Offline ΔR Efficiency” in **Table 3**) introduces a $\sim 10\%$ systematic error on the signal acceptance. The size of the systematic uncertainty on the acceptance was estimated by measuring the tracking efficiency using a tag-and-probe method with J/ψ data and MC. For $\Delta R > 0.05$ the data and MC agree to within $\sim 4\%$. However, a systematic variation of $\sim 10\%$ is observed in the efficiency for the smaller ΔR region, which is probably due to a slightly softer p_T distribution in the MC than in the data. Systematic errors are also assigned to the determination of the luminosity, the modelling of the trigger acceptance, the modelling of the lepton reconstruction efficiency, and the modelling of each of the analysis cuts.

The 95% confidence-level upper limits on the number of expected events from new phenomena producing collimated pairs of prompt leptons were calculated using the CLs method [31] with a log-likelihood ratio (LLR) test statistic. Ensembles of pseudo-experiments were generated for the signal-only hypothesis and the signal + background hypothesis, varying the LLR according to the statistical and systematic uncertainties. The upper limits were determined by performing a scan of p -values corresponding to LLR values larger than the one observed in data. For broad applicability, the limits are expressed in terms of the signal cross section times branching ratio to the final state under consideration, using the expected signal acceptance for each of the pairings of dark photon masses and dark sector gauge coupling parameter values in **Table 4**.

The observed limits in the electron-jets channel are in good agreement with the expected limits, and are the first inclusive study of prompt electron-jets at the LHC. The limits in the muon-jet channels are slightly higher than expected as a result of the slight excesses, but are within 2σ of the SM expectation for both channels. The limits on the production of prompt lepton-jets in

Table 4

Observed (expected) upper limits for cross section times branching ratio ($\sigma \times \text{BR}$) to the final state under consideration, in units of pb for the three different lepton-jet (LJ) channels.

Signal parameters		Electron LJ	1 muon LJ	2 muon LJ
α_d	m_{γ_D} [MeV]	Obs. (Exp.) pb	Obs. (Exp.) pb	Obs. (Exp.) pb
0.0	150	0.082 (0.082)	–	–
0.0	300	0.11 (0.11)	0.060 (0.035)	0.017 (0.011)
0.0	500	0.20 (0.21)	0.15 (0.090)	0.019 (0.012)
0.10	150	0.096 (0.10)	–	–
0.10	300	0.37 (0.37)	0.064 (0.036)	0.018 (0.011)
0.10	500	0.39 (0.39)	0.053 (0.035)	0.018 (0.011)
0.30	150	0.11 (0.11)	–	–
0.30	300	0.40 (0.40)	0.099 (0.055)	0.020 (0.012)
0.30	500	1.2 (1.2)	0.066 (0.043)	0.022 (0.015)

the muon-jet channel improve upon previous results by an order of magnitude.

6. Conclusions

A search for collimated pairs of muons or electrons, lepton-jets, has been performed using nearly 5 fb^{-1} of pp collisions at $\sqrt{s} = 7 \text{ TeV}$ recorded with the ATLAS detector at the LHC. Such final states have been proposed as a possible explanation of recently observed anomalies in cosmic-ray and dark matter direct-detection experiments. No significant excess of data compared to the SM expectation was observed in any of the three channels, and 95% confidence-level upper limits have been computed on the cross section times branching ratio for several parameter values of a Hidden Valley model. The limits range from 0.017 to 1.2 pb.

Acknowledgements

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; MERYS (MECTS), Romania; MES of Russia and ROSATOM, Russian Federation; JINR; MSTD, Serbia; MSSR, Slovakia; ARRS and MVZT, Slovenia; DST/NRF, South

Africa; MICINN, 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.

Open access

This article is published Open Access at sciedirect.com. It is distributed under the terms of the Creative Commons Attribution License 3.0, which permits unrestricted use, distribution, and reproduction in any medium, provided the original authors and source are credited.

References

- [1] N. Arkani-Hamed, N. Weiner, JHEP 0812 (2008) 104, arXiv:0810.0714, <http://dx.doi.org/10.1088/1126-6708/2008/12/104>.
- [2] N. Arkani-Hamed, N. Weiner, Phys. Rev. D 79 (2009) 015014, arXiv:0810.0713, <http://dx.doi.org/10.1103/PhysRevD.79.015014>.
- [3] M.J. Strassler, Possible effects of a hidden valley on supersymmetric phenomenology, arXiv:hep-ph/0607160.
- [4] S. Barwick, et al., Astrophys. J. 482 (1997) L191, arXiv:astro-ph/9703192, <http://dx.doi.org/10.1086/310706>.
- [5] A.A. Abdo, et al., Phys. Rev. Lett. 102 (2009) 181101, arXiv:0905.0025, <http://dx.doi.org/10.1103/PhysRevLett.102.181101>.
- [6] O. Adriani, et al., Nature 458 (2009) 607, arXiv:0810.4995, <http://dx.doi.org/10.1038/nature07942>.
- [7] J. Chang, J. Adams, H. Ahn, G. Bashindzhyan, M. Christl, et al., Nature 456 (2008) 362, <http://dx.doi.org/10.1038/nature07477>.
- [8] R. Bernabei, et al., Eur. Phys. J. C 67 (2010) 39, arXiv:1002.1028, <http://dx.doi.org/10.1140/epjc/s10052-010-1303-9>.
- [9] C. Aalseth, et al., Phys. Rev. Lett. 106 (2011) 131301, arXiv:1002.4703, <http://dx.doi.org/10.1103/PhysRevLett.106.131301>.
- [10] G. Angloher, M. Bauer, I. Bavykina, A. Bento, C. Bucci, et al., Results from 730 kg days of the CRESST-II Dark Matter Search, arXiv:1109.0702, 2012, <http://dx.doi.org/10.1140/epjc/s10052-012-1971-8>.
- [11] M. Baumgart, C. Cheung, J.T. Ruderman, L.-T. Wang, I. Yavin, JHEP 0904 (2009) 014, arXiv:0901.0283, <http://dx.doi.org/10.1088/1126-6708/2009/04/014>.
- [12] D.S. Alves, S.R. Behbahani, P. Schuster, J.G. Wacker, Phys. Lett. B 692 (2010) 323, arXiv:0903.3945, <http://dx.doi.org/10.1016/j.physletb.2010.08.006>.
- [13] G.D. Kribs, T.S. Roy, J. Terning, K.M. Zurek, Phys. Rev. D 81 (2010) 095001, arXiv:0909.2034, <http://dx.doi.org/10.1103/PhysRevD.81.095001>.
- [14] A. Katz, R. Sundrum, JHEP 0906 (2009) 003, arXiv:0902.3271, <http://dx.doi.org/10.1088/1126-6708/2009/06/003>.
- [15] A. Falkowski, J.T. Ruderman, T. Volansky, J. Zupan, JHEP 1005 (2010) 077, arXiv:1002.2952, [http://dx.doi.org/10.1007/JHEP05\(2010\)077](http://dx.doi.org/10.1007/JHEP05(2010)077).
- [16] C. Cheung, J.T. Ruderman, L.-T. Wang, I. Yavin, JHEP 1004 (2010) 116, arXiv:0909.0290, [http://dx.doi.org/10.1007/JHEP04\(2010\)116](http://dx.doi.org/10.1007/JHEP04(2010)116).
- [17] CMS Collaboration, JHEP 1107 (2011) 098, arXiv:1106.2375, [http://dx.doi.org/10.1007/JHEP07\(2011\)098](http://dx.doi.org/10.1007/JHEP07(2011)098).
- [18] D0 Collaboration, V.M. Abazov, et al., Phys. Rev. Lett. 105 (2010) 211802, arXiv:1008.3356, <http://dx.doi.org/10.1103/PhysRevLett.105.211802>.
- [19] B. Holdom, Phys. Lett. B 166 (1986) 196, [http://dx.doi.org/10.1016/0370-2693\(86\)91377-8](http://dx.doi.org/10.1016/0370-2693(86)91377-8).
- [20] ATLAS Collaboration, Eur. Phys. J. C 71 (2011) 1630, arXiv:1101.2185, <http://dx.doi.org/10.1140/epjc/s10052-011-1630-5>.
- [21] ATLAS Collaboration, Luminosity determination in pp collisions at $\sqrt{s} = 7$ TeV using the ATLAS detector in 2011, <http://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2011-116/>, August 2011.
- [22] ATLAS Collaboration, JINST 3 (2008) S08003, <http://dx.doi.org/10.1088/1748-0221/3/08/S08003>.
- [23] T. Sjostrand, S. Mrenna, P.Z. Skands, JHEP 0605 (2006) 026, arXiv:hep-ph/0603175, <http://dx.doi.org/10.1088/1126-6708/2006/05/026>.
- [24] S. Frixione, B.R. Webber, JHEP 0206 (2002) 029, arXiv:hep-ph/0204244, <http://dx.doi.org/10.1088/1126-6708/2002/06/029>.
- [25] T. Gleisberg, S. Hoeche, F. Krauss, M. Schonherr, S. Schumann, et al., JHEP 0902 (2009) 007, arXiv:0811.4622, <http://dx.doi.org/10.1088/1126-6708/2009/02/007>.
- [26] J. Alwall, P. Artoisenet, S. de Visscher, C. Duhr, R. Frederix, et al., AIP Conf. Proc. 1078 (2009) 84, arXiv:0809.2410, <http://dx.doi.org/10.1063/1.3052056>.
- [27] J. Pumplin, D. Stump, J. Huston, H. Lai, P.M. Nadolsky, et al., JHEP 0207 (2002) 012, arXiv:hep-ph/0201195, <http://dx.doi.org/10.1088/1126-6708/2002/07/012>.
- [28] Wolfram Research, Inc., Mathematica Edition: Version 7.0, Wolfram Research, Inc., Champaign, Illinois, 2008.
- [29] S. Agostinelli, Nucl. Instrum. Methods Phys. Res. Sect. A: Accelerators, Spectrometers, Detectors and Associated Equipment 506 (3) (2003) 250, [http://dx.doi.org/10.1016/S0168-9002\(03\)01368-8](http://dx.doi.org/10.1016/S0168-9002(03)01368-8).
- [30] ATLAS Collaboration, Eur. Phys. J. C 70 (2010) 823, arXiv:1005.4568, <http://dx.doi.org/10.1140/epjc/s10052-010-1429-9>.
- [31] A.L. Read, J. Phys. G 28 (2002) 2693, <http://dx.doi.org/10.1088/0954-3899/28/10/313>.

ATLAS Collaboration

- G. Aad⁴⁸, T. Abajyan²¹, B. Abbott¹¹¹, J. Abdallah¹², S. Abdel Khalek¹¹⁵, A.A. Abdelalim⁴⁹, O. Abdinov¹¹, R. Aben¹⁰⁵, B. Abi¹¹², M. Abolins⁸⁸, O.S. AbouZeid¹⁵⁸, H. Abramowicz¹⁵³, H. Abreu¹³⁶, B.S. Acharya^{164a,164b,a}, L. Adamczyk³⁸, D.L. Adams²⁵, T.N. Addy⁵⁶, J. Adelman¹⁷⁶, S. Adomeit⁹⁸, P. Adragna⁷⁵, T. Adye¹²⁹, S. Aefsky²³, J.A. Aguilar-Saavedra^{124b,b}, M. Agustoni¹⁷, S.P. Ahlen²², F. Ahles⁴⁸, A. Ahmad¹⁴⁸, M. Ahsan⁴¹, G. Aielli^{133a,133b}, T.P.A. Åkesson⁷⁹, G. Akimoto¹⁵⁵, A.V. Akimov⁹⁴, M.A. Alam⁷⁶, J. Albert¹⁶⁹, S. Albrand⁵⁵, M. Aleksa³⁰, I.N. Aleksandrov⁶⁴, F. Alessandria^{89a}, C. Alexa^{26a}, G. Alexander¹⁵³, G. Alexandre⁴⁹, T. Alexopoulos¹⁰, M. Alhroob^{164a,164c}, M. Aliev¹⁶, G. Alimonti^{89a}, J. Alison¹²⁰, B.M.M. Allbrooke¹⁸, L.J. Allison⁷¹, P.P. Allport⁷³, S.E. Allwood-Spiers⁵³, J. Almond⁸², A. Aloisio^{102a,102b}, R. Alon¹⁷², A. Alonso⁷⁹, F. Alonso⁷⁰, A. Altheimer³⁵, B. Alvarez Gonzalez⁸⁸, M.G. Alviggi^{102a,102b}, K. Amako⁶⁵, C. Amelung²³, V.V. Ammosov^{128,*}, S.P. Amor Dos Santos^{124a}, A. Amorim^{124a,c}, S. Amoroso⁴⁸, N. Amram¹⁵³, C. Anastopoulos³⁰, L.S. Ancu¹⁷, N. Andari¹¹⁵, T. Andeen³⁵, C.F. Anders^{58b}, G. Anders^{58a}, K.J. Anderson³¹, A. Andreazza^{89a,89b}, V. Andrei^{58a}, M-L. Andrieux⁵⁵, X.S. Anduaga⁷⁰, S. Angelidakis⁹, P. Anger⁴⁴, A. Angerami³⁵, F. Anghinolfi³⁰, A. Anisenkov¹⁰⁷, N. Anjos^{124a}, A. Annovi⁴⁷, A. Antonaki⁹, M. Antonelli⁴⁷, A. Antonov⁹⁶, J. Antos^{144b}, F. Anulli^{132a}, M. Aoki¹⁰¹, S. Aoun⁸³, L. Aperio Bella⁵, R. Apolle^{118,d}, G. Arabidze⁸⁸, I. Aracena¹⁴³, Y. Arai⁶⁵, A.T.H. Arce⁴⁵, S. Arfaoui¹⁴⁸, J-F. Arguin⁹³, S. Argyropoulos⁴², E. Arik^{19a,*}, M. Arik^{19a}, A.J. Armbruster⁸⁷, O. Arnaez⁸¹, V. Arnal⁸⁰, A. Artamonov⁹⁵, G. Artoni^{132a,132b}, D. Arutinov²¹, S. Asai¹⁵⁵, S. Ask²⁸, B. Åsman^{146a,146b}, L. Asquith⁶, K. Assamagan^{25,e}, A. Astbury¹⁶⁹, M. Atkinson¹⁶⁵, B. Aubert⁵, E. Auge¹¹⁵, K. Augsten¹²⁶, M. Aurousseau^{145a}, G. Avolio³⁰, D. Axen¹⁶⁸, G. Azuelos^{93,f},

- Y. Azuma ¹⁵⁵, M.A. Baak ³⁰, G. Baccaglioni ^{89a}, C. Bacci ^{134a,134b}, A.M. Bach ¹⁵, H. Bachacou ¹³⁶,
 K. Bachas ¹⁵⁴, M. Backes ⁴⁹, M. Backhaus ²¹, J. Backus Mayes ¹⁴³, E. Badescu ^{26a}, P. Bagnaia ^{132a,132b},
 Y. Bai ^{33a}, D.C. Bailey ¹⁵⁸, T. Bain ³⁵, J.T. Baines ¹²⁹, O.K. Baker ¹⁷⁶, S. Baker ⁷⁷, P. Balek ¹²⁷, E. Banas ³⁹,
 P. Banerjee ⁹³, Sw. Banerjee ¹⁷³, D. Banfi ³⁰, A. Bangert ¹⁵⁰, V. Bansal ¹⁶⁹, H.S. Bansil ¹⁸, L. Barak ¹⁷²,
 S.P. Baranov ⁹⁴, T. Barber ⁴⁸, E.L. Barberio ⁸⁶, D. Barberis ^{50a,50b}, M. Barbero ²¹, D.Y. Bardin ⁶⁴, T. Barillari ⁹⁹,
 M. Barisonzi ¹⁷⁵, T. Barklow ¹⁴³, N. Barlow ²⁸, B.M. Barnett ¹²⁹, R.M. Barnett ¹⁵, A. Baroncelli ^{134a},
 G. Barone ⁴⁹, A.J. Barr ¹¹⁸, F. Barreiro ⁸⁰, J. Barreiro Guimaraes da Costa ⁵⁷, R. Bartoldus ¹⁴³, A.E. Barton ⁷¹,
 V. Bartsch ¹⁴⁹, A. Basye ¹⁶⁵, R.L. Bates ⁵³, L. Batkova ^{144a}, J.R. Batley ²⁸, A. Battaglia ¹⁷, M. Battistin ³⁰,
 F. Bauer ¹³⁶, H.S. Bawa ^{143,g}, S. Beale ⁹⁸, T. Beau ⁷⁸, P.H. Beauchemin ¹⁶¹, R. Becccherle ^{50a}, P. Bechtle ²¹,
 H.P. Beck ¹⁷, K. Becker ¹⁷⁵, S. Becker ⁹⁸, M. Beckingham ¹³⁸, K.H. Becks ¹⁷⁵, A.J. Beddall ^{19c}, A. Beddall ^{19c},
 S. Bedikian ¹⁷⁶, V.A. Bednyakov ⁶⁴, C.P. Bee ⁸³, L.J. Beemster ¹⁰⁵, M. Begel ²⁵, S. Behar Harpaz ¹⁵²,
 P.K. Behera ⁶², M. Beimforde ⁹⁹, C. Belanger-Champagne ⁸⁵, P.J. Bell ⁴⁹, W.H. Bell ⁴⁹, G. Bella ¹⁵³,
 L. Bellagamba ^{20a}, M. Bellomo ³⁰, A. Belloni ⁵⁷, O. Beloborodova ^{107,h}, K. Belotskiy ⁹⁶, O. Beltramello ³⁰,
 O. Benary ¹⁵³, D. Benchekroun ^{135a}, K. Bendtz ^{146a,146b}, N. Benekos ¹⁶⁵, Y. Benhammou ¹⁵³,
 E. Benhar Noccioli ⁴⁹, J.A. Benitez Garcia ^{159b}, D.P. Benjamin ⁴⁵, M. Benoit ¹¹⁵, J.R. Bensinger ²³,
 K. Benslama ¹³⁰, S. Bentvelsen ¹⁰⁵, D. Berge ³⁰, E. Bergeaas Kuutmann ⁴², N. Berger ⁵, F. Berghaus ¹⁶⁹,
 E. Berglund ¹⁰⁵, J. Beringer ¹⁵, P. Bernat ⁷⁷, R. Bernhard ⁴⁸, C. Bernius ²⁵, T. Berry ⁷⁶, C. Bertella ⁸³,
 A. Bertin ^{20a,20b}, F. Bertolucci ^{122a,122b}, M.I. Besana ^{89a,89b}, G.J. Besjes ¹⁰⁴, N. Besson ¹³⁶, S. Bethke ⁹⁹,
 W. Bhimji ⁴⁶, R.M. Bianchi ³⁰, L. Bianchini ²³, M. Bianco ^{72a,72b}, O. Biebel ⁹⁸, S.P. Bieniek ⁷⁷,
 K. Bierwagen ⁵⁴, J. Biesiada ¹⁵, M. Biglietti ^{134a}, H. Bilokon ⁴⁷, M. Bindl ^{20a,20b}, S. Binet ¹¹⁵, A. Bingul ^{19c},
 C. Bini ^{132a,132b}, C. Biscarat ¹⁷⁸, B. Bittner ⁹⁹, C.W. Black ¹⁵⁰, K.M. Black ²², R.E. Blair ⁶, J.-B. Blanchard ¹³⁶,
 T. Blazek ^{144a}, I. Bloch ⁴², C. Blocker ²³, J. Blocki ³⁹, W. Blum ⁸¹, U. Blumenschein ⁵⁴, G.J. Bobbink ¹⁰⁵,
 V.S. Bobrovnikov ¹⁰⁷, S.S. Bocchetta ⁷⁹, A. Bocci ⁴⁵, C.R. Boddy ¹¹⁸, M. Boehler ⁴⁸, J. Boek ¹⁷⁵, T.T. Boek ¹⁷⁵,
 N. Boelaert ³⁶, J.A. Bogaerts ³⁰, A. Bogdanchikov ¹⁰⁷, A. Bogouch ^{90,*}, C. Bohm ^{146a}, J. Bohm ¹²⁵,
 V. Boisvert ⁷⁶, T. Bold ³⁸, V. Boldea ^{26a}, N.M. Bolnet ¹³⁶, M. Bomben ⁷⁸, M. Bona ⁷⁵, M. Boonekamp ¹³⁶,
 S. Bordoni ⁷⁸, C. Borer ¹⁷, A. Borisov ¹²⁸, G. Borissov ⁷¹, I. Borjanovic ^{13a}, M. Borri ⁸², S. Borroni ⁴²,
 J. Bortfeldt ⁹⁸, V. Bortolotto ^{134a,134b}, K. Bos ¹⁰⁵, D. Boscherini ^{20a}, M. Bosman ¹², H. Boterenbrood ¹⁰⁵,
 J. Bouchami ⁹³, J. Boudreau ¹²³, E.V. Bouhova-Thacker ⁷¹, D. Boumediene ³⁴, C. Bourdarios ¹¹⁵,
 N. Bousson ⁸³, A. Boveia ³¹, J. Boyd ³⁰, I.R. Boyko ⁶⁴, I. Bozovic-Jelisavcic ^{13b}, J. Bracinik ¹⁸, P. Branchini ^{134a},
 A. Brandt ⁸, G. Brandt ¹¹⁸, O. Brandt ⁵⁴, U. Bratzler ¹⁵⁶, B. Brau ⁸⁴, J.E. Brau ¹¹⁴, H.M. Braun ^{175,*},
 S.F. Brazzale ^{164a,164c}, B. Brelier ¹⁵⁸, J. Bremer ³⁰, K. Brendlinger ¹²⁰, R. Brenner ¹⁶⁶, S. Bressler ¹⁷²,
 T.M. Bristow ^{145b}, D. Britton ⁵³, F.M. Brochu ²⁸, I. Brock ²¹, R. Brock ⁸⁸, F. Broggi ^{89a}, C. Bromberg ⁸⁸,
 J. Bronner ⁹⁹, G. Brooijmans ³⁵, T. Brooks ⁷⁶, W.K. Brooks ^{32b}, G. Brown ⁸², P.A. Bruckman de Renstrom ³⁹,
 D. Bruncko ^{144b}, R. Bruneliere ⁴⁸, S. Brunet ⁶⁰, A. Bruni ^{20a}, G. Bruni ^{20a}, M. Bruschi ^{20a}, L. Bryngemark ⁷⁹,
 T. Buanes ¹⁴, Q. Buat ⁵⁵, F. Bucci ⁴⁹, J. Buchanan ¹¹⁸, P. Buchholz ¹⁴¹, R.M. Buckingham ¹¹⁸, A.G. Buckley ⁴⁶,
 S.I. Buda ^{26a}, I.A. Budagov ⁶⁴, B. Budick ¹⁰⁸, V. Büscher ⁸¹, L. Bugge ¹¹⁷, O. Bulekov ⁹⁶, A.C. Bundock ⁷³,
 M. Bunse ⁴³, T. Buran ¹¹⁷, H. Burckhart ³⁰, S. Burdin ⁷³, T. Burgess ¹⁴, S. Burke ¹²⁹, E. Busato ³⁴, P. Bussey ⁵³,
 C.P. Buszello ¹⁶⁶, B. Butler ¹⁴³, J.M. Butler ²², C.M. Buttar ⁵³, J.M. Butterworth ⁷⁷, W. Buttinger ²⁸,
 M. Byszewski ³⁰, S. Cabrera Urbán ¹⁶⁷, D. Caforio ^{20a,20b}, O. Cakir ^{4a}, P. Calafiura ¹⁵, G. Calderini ⁷⁸,
 P. Calfayan ⁹⁸, R. Calkins ¹⁰⁶, L.P. Caloba ^{24a}, R. Caloi ^{132a,132b}, D. Calvet ³⁴, S. Calvet ³⁴, R. Camacho Toro ³⁴,
 P. Camarri ^{133a,133b}, D. Cameron ¹¹⁷, L.M. Caminada ¹⁵, R. Caminal Armadans ¹², S. Campana ³⁰,
 M. Campanelli ⁷⁷, V. Canale ^{102a,102b}, F. Canelli ³¹, A. Canepa ^{159a}, J. Cantero ⁸⁰, R. Cantrill ⁷⁶,
 M.D.M. Capeans Garrido ³⁰, I. Caprini ^{26a}, M. Caprini ^{26a}, D. Capriotti ⁹⁹, M. Capua ^{37a,37b}, R. Caputo ⁸¹,
 R. Cardarelli ^{133a}, T. Carli ³⁰, G. Carlino ^{102a}, L. Carminati ^{89a,89b}, S. Caron ¹⁰⁴, E. Carquin ^{32b},
 G.D. Carrillo-Montoya ^{145b}, A.A. Carter ⁷⁵, J.R. Carter ²⁸, J. Carvalho ^{124a,i}, D. Casadei ¹⁰⁸, M.P. Casado ¹²,
 M. Cascella ^{122a,122b}, C. Caso ^{50a,50b,*}, A.M. Castaneda Hernandez ^{173,j}, E. Castaneda-Miranda ¹⁷³,
 V. Castillo Gimenez ¹⁶⁷, N.F. Castro ^{124a}, G. Cataldi ^{72a}, P. Catastini ⁵⁷, A. Catinaccio ³⁰, J.R. Catmore ³⁰,
 A. Cattai ³⁰, G. Cattani ^{133a,133b}, S. Caughron ⁸⁸, V. Cavalieri ¹⁶⁵, P. Cavalleri ⁷⁸, D. Cavalli ^{89a},
 M. Cavalli-Sforza ¹², V. Cavasinni ^{122a,122b}, F. Ceradini ^{134a,134b}, A.S. Cerqueira ^{24b}, A. Cerri ¹⁵, L. Cerrito ⁷⁵,
 F. Cerutti ¹⁵, S.A. Cetin ^{19b}, A. Chafaq ^{135a}, D. Chakraborty ¹⁰⁶, I. Chalupkova ¹²⁷, K. Chan ³, P. Chang ¹⁶⁵,
 B. Chapleau ⁸⁵, J.D. Chapman ²⁸, J.W. Chapman ⁸⁷, D.G. Charlton ¹⁸, V. Chavda ⁸², C.A. Chavez Barajas ³⁰,
 S. Cheatham ⁸⁵, S. Chekanov ⁶, S.V. Chekulaev ^{159a}, G.A. Chelkov ⁶⁴, M.A. Chelstowska ¹⁰⁴, C. Chen ⁶³,

- H. Chen ²⁵, S. Chen ^{33c}, X. Chen ¹⁷³, Y. Chen ³⁵, Y. Cheng ³¹, A. Cheplakov ⁶⁴, R. Cherkaoui El Moursli ^{135e}, V. Chernyatin ²⁵, E. Cheu ⁷, S.L. Cheung ¹⁵⁸, L. Chevalier ¹³⁶, G. Chiefari ^{102a,102b}, L. Chikovani ^{51a,*}, 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, G. Choudalakis ³¹, S. Chouridou ¹³⁷, I.A. Christidi ⁷⁷, A. Christov ⁴⁸, D. Chromek-Burckhart ³⁰, M.L. Chu ¹⁵¹, J. Chudoba ¹²⁵, G. Ciapetti ^{132a,132b}, A.K. Ciftci ^{4a}, R. Ciftci ^{4a}, D. Cinca ³⁴, V. Cindro ⁷⁴, A. Ciocio ¹⁵, M. Cirilli ⁸⁷, P. Cirkovic ^{13b}, Z.H. Citron ¹⁷², M. Citterio ^{89a}, M. Ciubancan ^{26a}, A. Clark ⁴⁹, P.J. Clark ⁴⁶, R.N. Clarke ¹⁵, W. Cleland ¹²³, J.C. Clemens ⁸³, B. Clement ⁵⁵, C. Clement ^{146a,146b}, Y. Coadou ⁸³, M. Cobal ^{164a,164c}, A. Coccato ¹³⁸, J. Cochran ⁶³, L. Coffey ²³, J.G. Cogan ¹⁴³, J. Coggeshall ¹⁶⁵, J. Colas ⁵, S. Cole ¹⁰⁶, A.P. Colijn ¹⁰⁵, N.J. Collins ¹⁸, C. Collins-Tooth ⁵³, J. Collot ⁵⁵, T. Colombo ^{119a,119b}, G. Colon ⁸⁴, G. Compostella ⁹⁹, P. Conde Muñoz ^{124a}, E. Coniavitis ¹⁶⁶, M.C. Conidi ¹², S.M. Consonni ^{89a,89b}, V. Consorti ⁴⁸, S. Constantinescu ^{26a}, C. Conta ^{119a,119b}, G. Conti ⁵⁷, F. Conventi ^{102a,k}, M. Cooke ¹⁵, B.D. Cooper ⁷⁷, A.M. Cooper-Sarkar ¹¹⁸, K. Copic ¹⁵, T. Cornelissen ¹⁷⁵, M. Corradi ^{20a}, F. Corriveau ^{85,l}, A. Cortes-Gonzalez ¹⁶⁵, G. Cortiana ⁹⁹, G. Costa ^{89a}, M.J. Costa ¹⁶⁷, D. Costanzo ¹³⁹, D. Côté ³⁰, L. Courneyea ¹⁶⁹, G. Cowan ⁷⁶, B.E. Cox ⁸², K. Cranmer ¹⁰⁸, F. Crescioli ⁷⁸, M. Cristinziani ²¹, G. Crosetti ^{37a,37b}, S. Crépé-Renaudin ⁵⁵, C.-M. Cuciuc ^{26a}, C. Cuenca Almenar ¹⁷⁶, T. Cuhadar Donszelmann ¹³⁹, J. Cummings ¹⁷⁶, M. Curatolo ⁴⁷, C.J. Curtis ¹⁸, C. Cuthbert ¹⁵⁰, P. Cwetanski ⁶⁰, H. Czirr ¹⁴¹, P. Czodrowski ⁴⁴, Z. Czyczula ¹⁷⁶, S. D'Auria ⁵³, M. D'Onofrio ⁷³, A. D'Orazio ^{132a,132b}, M.J. Da Cunha Sargedas De Sousa ^{124a}, C. Da Via ⁸², W. Dabrowski ³⁸, A. Dafinca ¹¹⁸, T. Dai ⁸⁷, F. Dallaire ⁹³, C. Dallapiccola ⁸⁴, M. Dam ³⁶, M. Dameri ^{50a,50b}, D.S. Damiani ¹³⁷, H.O. Danielsson ³⁰, V. Dao ¹⁰⁴, G. Darbo ^{50a}, G.L. Darlea ^{26b}, J.A. Dassoulas ⁴², W. Davey ²¹, T. Davidek ¹²⁷, N. Davidson ⁸⁶, R. Davidson ⁷¹, E. Davies ^{118,d}, M. Davies ⁹³, O. Davignon ⁷⁸, A.R. Davison ⁷⁷, Y. Davygora ^{58a}, E. Dawe ¹⁴², I. Dawson ¹³⁹, R.K. Daya-Ishmukhametova ²³, K. De ⁸, R. de Asmundis ^{102a}, S. De Castro ^{20a,20b}, S. De Cecco ⁷⁸, J. de Graat ⁹⁸, N. De Groot ¹⁰⁴, P. de Jong ¹⁰⁵, C. De La Taille ¹¹⁵, H. De la Torre ⁸⁰, F. De Lorenzi ⁶³, L. De Nooij ¹⁰⁵, D. De Pedis ^{132a}, A. De Salvo ^{132a}, U. De Sanctis ^{164a,164c}, A. De Santo ¹⁴⁹, J.B. De Vivie De Regie ¹¹⁵, G. De Zorzi ^{132a,132b}, W.J. Dearnaley ⁷¹, R. Debbe ²⁵, C. Debenedetti ⁴⁶, B. Dechenaux ⁵⁵, D.V. Dedovich ⁶⁴, J. Degenhardt ¹²⁰, J. Del Peso ⁸⁰, T. Del Prete ^{122a,122b}, T. Delemontex ⁵⁵, M. Deliyergiyev ⁷⁴, A. Dell'Acqua ³⁰, L. Dell'Asta ²², M. Della Pietra ^{102a,k}, D. della Volpe ^{102a,102b}, M. Delmastro ⁵, P.A. Delsart ⁵⁵, C. Deluca ¹⁰⁵, S. Demers ¹⁷⁶, M. Demichev ⁶⁴, B. Demirköz ^{12,m}, S.P. Denisov ¹²⁸, D. Derendarz ³⁹, J.E. Derkaoui ^{135d}, F. Derue ⁷⁸, P. Dervan ⁷³, K. Desch ²¹, E. Devetak ¹⁴⁸, P.O. Deviveiros ¹⁰⁵, A. Dewhurst ¹²⁹, B. DeWilde ¹⁴⁸, S. Dhaliwal ¹⁵⁸, R. Dhullipudi ^{25,n}, A. Di Ciaccio ^{133a,133b}, L. Di Ciaccio ⁵, C. Di Donato ^{102a,102b}, A. Di Girolamo ³⁰, B. Di Girolamo ³⁰, S. Di Luise ^{134a,134b}, A. Di Mattia ¹⁵², B. Di Micco ³⁰, R. Di Nardo ⁴⁷, A. Di Simone ^{133a,133b}, R. Di Sipio ^{20a,20b}, M.A. Diaz ^{32a}, E.B. Diehl ⁸⁷, J. Dietrich ⁴², T.A. Dietzsch ^{58a}, S. Diglio ⁸⁶, K. Dindar Yagci ⁴⁰, J. Dingfelder ²¹, F. Dinut ^{26a}, C. Dionisi ^{132a,132b}, P. Dita ^{26a}, S. Dita ^{26a}, F. Dittus ³⁰, F. Djama ⁸³, T. Djobava ^{51b}, M.A.B. do Vale ^{24c}, A. Do Valle Wemans ^{124a,o}, T.K.O. Doan ⁵, M. Dobbs ⁸⁵, D. Dobos ³⁰, E. Dobson ^{30,p}, J. Dodd ³⁵, C. Doglioni ⁴⁹, T. Doherty ⁵³, Y. Doi ^{65,*}, J. Dolejsi ¹²⁷, Z. Dolezal ¹²⁷, B.A. Dolgoshein ^{96,*}, T. Dohmae ¹⁵⁵, M. Donadelli ^{24d}, J. Donini ³⁴, J. Dopke ³⁰, A. Doria ^{102a}, A. Dos Anjos ¹⁷³, A. Dotti ^{122a,122b}, M.T. Dova ⁷⁰, A.D. Doxiadis ¹⁰⁵, A.T. Doyle ⁵³, N. Dressnandt ¹²⁰, M. Dris ¹⁰, J. Dubbert ⁹⁹, S. Dube ¹⁵, E. Dubreuil ³⁴, E. Duchovni ¹⁷², G. Duckeck ⁹⁸, D. Duda ¹⁷⁵, A. Dudarev ³⁰, F. Dudziak ⁶³, M. Dührssen ³⁰, I.P. Duerdorff ⁸², L. Duflot ¹¹⁵, M-A. Dufour ⁸⁵, L. Duguid ⁷⁶, M. Dunford ^{58a}, H. Duran Yildiz ^{4a}, R. Duxfield ¹³⁹, M. Dwuznik ³⁸, M. Düren ⁵², W.L. Ebenstein ⁴⁵, J. Ebke ⁹⁸, S. Eckweiler ⁸¹, W. Edson ², C.A. Edwards ⁷⁶, N.C. Edwards ⁵³, W. Ehrenfeld ²¹, T. Eifert ¹⁴³, G. Eigen ¹⁴, K. Einsweiler ¹⁵, E. Eisenhandler ⁷⁵, T. Ekelof ¹⁶⁶, M. El Kacimi ^{135c}, M. Ellert ¹⁶⁶, S. Elles ⁵, F. Ellinghaus ⁸¹, K. Ellis ⁷⁵, N. Ellis ³⁰, J. Elmshausen ⁹⁸, M. Elsing ³⁰, D. Emeliyanov ¹²⁹, R. Engelmann ¹⁴⁸, A. Engl ⁹⁸, B. Epp ⁶¹, J. Erdmann ¹⁷⁶, A. Ereditato ¹⁷, D. Eriksson ^{146a}, J. Ernst ², M. Ernst ²⁵, J. Ernwein ¹³⁶, D. Errede ¹⁶⁵, S. Errede ¹⁶⁵, E. Ertel ⁸¹, M. Escalier ¹¹⁵, H. Esch ⁴³, C. Escobar ¹²³, X. Espinal Curull ¹², B. Esposito ⁴⁷, F. Etienne ⁸³, A.I. Etienvre ¹³⁶, E. Etzion ¹⁵³, D. Evangelakou ⁵⁴, H. Evans ⁶⁰, L. Fabbri ^{20a,20b}, C. Fabre ³⁰, R.M. Fakhrutdinov ¹²⁸, S. Falciano ^{132a}, Y. Fang ^{33a}, M. Fanti ^{89a,89b}, A. Farbin ⁸, A. Farilla ^{134a}, J. Farley ¹⁴⁸, T. Farooque ¹⁵⁸, S. Farrell ¹⁶³, S.M. Farrington ¹⁷⁰, P. Farthouat ³⁰, F. Fassi ¹⁶⁷, P. Fassnacht ³⁰, D. Fassouliotis ⁹, B. Fatholahzadeh ¹⁵⁸, A. Favareto ^{89a,89b}, L. Fayard ¹¹⁵, P. Federic ^{144a}, O.L. Fedin ¹²¹, W. Fedorko ¹⁶⁸, M. Fehling-Kaschek ⁴⁸, L. Feligioni ⁸³, C. Feng ^{33d}, E.J. Feng ⁶, A.B. Fenyuk ¹²⁸, J. Ferencei ^{144b}, W. Fernando ⁶, S. Ferrag ⁵³, J. Ferrando ⁵³, V. Ferrara ⁴², A. Ferrari ¹⁶⁶, P. Ferrari ¹⁰⁵,

- R. Ferrari ^{119a}, D.E. Ferreira de Lima ⁵³, A. Ferrer ¹⁶⁷, D. Ferrere ⁴⁹, C. Ferretti ⁸⁷, A. Ferretto Parodi ^{50a,50b}, M. Fiascaris ³¹, F. Fiedler ⁸¹, A. Filipčič ⁷⁴, F. Filthaut ¹⁰⁴, M. Fincke-Keeler ¹⁶⁹, M.C.N. Fiolhais ^{124a,i}, L. Fiorini ¹⁶⁷, A. Firan ⁴⁰, G. Fischer ⁴², M.J. Fisher ¹⁰⁹, E.A. Fitzgerald ²³, M. Flechl ⁴⁸, I. Fleck ¹⁴¹, J. Fleckner ⁸¹, P. Fleischmann ¹⁷⁴, S. Fleischmann ¹⁷⁵, G. Fletcher ⁷⁵, T. Flick ¹⁷⁵, A. Floderus ⁷⁹, L.R. Flores Castillo ¹⁷³, A.C. Florez Bustos ^{159b}, M.J. Flowerdew ⁹⁹, T. Fonseca Martin ¹⁷, A. Formica ¹³⁶, A. Forti ⁸², D. Fortin ^{159a}, D. Fournier ¹¹⁵, A.J. Fowler ⁴⁵, H. Fox ⁷¹, P. Francavilla ¹², M. Franchini ^{20a,20b}, S. Franchino ^{119a,119b}, D. Francis ³⁰, T. Frank ¹⁷², M. Franklin ⁵⁷, S. Franz ³⁰, M. Fraternali ^{119a,119b}, S. Fratina ¹²⁰, S.T. French ²⁸, C. Friedrich ⁴², F. Friedrich ⁴⁴, D. Froidevaux ³⁰, J.A. Frost ²⁸, C. Fukunaga ¹⁵⁶, E. Fullana Torregrosa ¹²⁷, B.G. Fulsom ¹⁴³, J. Fuster ¹⁶⁷, C. Gabaldon ³⁰, O. Gabizon ¹⁷², T. Gadfort ²⁵, S. Gadomski ⁴⁹, G. Gagliardi ^{50a,50b}, P. Gagnon ⁶⁰, C. Galea ⁹⁸, B. Galhardo ^{124a}, E.J. Gallas ¹¹⁸, V. Gallo ¹⁷, B.J. Gallop ¹²⁹, P. Gallus ¹²⁶, K.K. Gan ¹⁰⁹, Y.S. Gao ^{143,g}, A. Gaponenko ¹⁵, F. Garberson ¹⁷⁶, M. Garcia-Sciveres ¹⁵, C. García ¹⁶⁷, J.E. García Navarro ¹⁶⁷, R.W. Gardner ³¹, N. Garelli ¹⁴³, V. Garonne ³⁰, C. Gatti ⁴⁷, G. Gaudio ^{119a}, B. Gaur ¹⁴¹, L. Gauthier ¹³⁶, P. Gauzzi ^{132a,132b}, I.L. Gavrilenko ⁹⁴, C. Gay ¹⁶⁸, G. Gaycken ²¹, E.N. Gazis ¹⁰, P. Ge ^{33d}, Z. Gecse ¹⁶⁸, C.N.P. Gee ¹²⁹, D.A.A. Geerts ¹⁰⁵, Ch. Geich-Gimbel ²¹, K. Gellerstedt ^{146a,146b}, C. Gemme ^{50a}, A. Gemmell ⁵³, M.H. Genest ⁵⁵, S. Gentile ^{132a,132b}, M. George ⁵⁴, S. George ⁷⁶, D. Gerbaudo ¹², P. Gerlach ¹⁷⁵, A. Gershon ¹⁵³, C. Geweniger ^{58a}, H. Ghazlane ¹³⁵, N. Ghodbane ³⁴, B. Giacobbe ^{20a}, S. Giagu ^{132a,132b}, V. Giangiobbe ¹², F. Gianotti ³⁰, B. Gibbard ²⁵, A. Gibson ¹⁵⁸, S.M. Gibson ³⁰, M. Gilchriese ¹⁵, D. Gillberg ³⁰, A.R. Gillman ¹²⁹, D.M. Gingrich ^{3,f}, J. Ginzburg ¹⁵³, N. Giokaris ⁹, M.P. Giordani ^{164c}, R. Giordano ^{102a,102b}, F.M. Giorgi ¹⁶, P. Giovannini ⁹⁹, P.F. Giraud ¹³⁶, D. Giugni ^{89a}, M. Giunta ⁹³, B.K. Gjelsten ¹¹⁷, L.K. Gladilin ⁹⁷, C. Glasman ⁸⁰, J. Glatzer ²¹, A. Glazov ⁴², G.L. Glonti ⁶⁴, J.R. Goddard ⁷⁵, J. Godfrey ¹⁴², J. Godlewski ³⁰, M. Goebel ⁴², T. Göpfert ⁴⁴, C. Goeringer ⁸¹, C. Gössling ⁴³, S. Goldfarb ⁸⁷, T. Golling ¹⁷⁶, D. Golubkov ¹²⁸, A. Gomes ^{124a,c}, L.S. Gomez Fajardo ⁴², R. Gonçalo ⁷⁶, J. Goncalves Pinto Firmino Da Costa ⁴², L. Gonella ²¹, S. González de la Hoz ¹⁶⁷, G. Gonzalez Parra ¹², M.L. Gonzalez Silva ²⁷, S. Gonzalez-Sevilla ⁴⁹, J.J. Goodson ¹⁴⁸, L. Goossens ³⁰, P.A. Gorbounov ⁹⁵, H.A. Gordon ²⁵, I. Gorelov ¹⁰³, G. Gorfine ¹⁷⁵, B. Gorini ³⁰, E. Gorini ^{72a,72b}, A. Gorišek ⁷⁴, E. Gornicki ³⁹, A.T. Goshaw ⁶, M. Gosselink ¹⁰⁵, M.I. Gostkin ⁶⁴, I. Gough Eschrich ¹⁶³, M. Gouighri ^{135a}, D. Goujdami ^{135c}, M.P. Goulette ⁴⁹, A.G. Goussiou ¹³⁸, C. Goy ⁵, S. Gozpinar ²³, I. Grabowska-Bold ³⁸, P. Grafström ^{20a,20b}, K.-J. Grahn ⁴², E. Gramstad ¹¹⁷, F. Grancagnolo ^{72a}, S. Grancagnolo ¹⁶, V. Grassi ¹⁴⁸, V. Gratchev ¹²¹, H.M. Gray ³⁰, J.A. Gray ¹⁴⁸, E. Graziani ^{134a}, O.G. Grebenyuk ¹²¹, T. Greenshaw ⁷³, Z.D. Greenwood ^{25,n}, K. Gregersen ³⁶, I.M. Gregor ⁴², P. Grenier ¹⁴³, J. Griffiths ⁸, N. Grigalashvili ⁶⁴, A.A. Grillo ¹³⁷, K. Grimm ⁷¹, S. Grinstein ¹², Ph. Gris ³⁴, Y.V. Grishkevich ⁹⁷, J.-F. Grivaz ¹¹⁵, A. Grohsjean ⁴², E. Gross ¹⁷², J. Grosse-Knetter ⁵⁴, J. Groth-Jensen ¹⁷², K. Grybel ¹⁴¹, D. Guest ¹⁷⁶, C. Guicheney ³⁴, E. Guido ^{50a,50b}, T. Guillemin ¹¹⁵, S. Guindon ⁵⁴, U. Gul ⁵³, J. Gunther ¹²⁵, B. Guo ¹⁵⁸, J. Guo ³⁵, P. Gutierrez ¹¹¹, N. Guttman ¹⁵³, O. Gutzwiler ¹⁷³, C. Guyot ¹³⁶, C. Gwenlan ¹¹⁸, C.B. Gwilliam ⁷³, A. Haas ¹⁰⁸, S. Haas ³⁰, C. Haber ¹⁵, H.K. Hadavand ⁸, D.R. Hadley ¹⁸, P. Haefner ²¹, F. Hahn ³⁰, Z. Hajduk ³⁹, H. Hakobyan ¹⁷⁷, D. Hall ¹¹⁸, G. Halladjian ⁶², K. Hamacher ¹⁷⁵, P. Hamal ¹¹³, K. Hamano ⁸⁶, M. Hamer ⁵⁴, A. Hamilton ^{145b,q}, S. Hamilton ¹⁶¹, L. Han ^{33b}, K. Hanagaki ¹¹⁶, K. Hanawa ¹⁶⁰, M. Hance ¹⁵, C. Handel ⁸¹, P. Hanke ^{58a}, J.R. Hansen ³⁶, J.B. Hansen ³⁶, J.D. Hansen ³⁶, P.H. Hansen ³⁶, P. Hansson ¹⁴³, K. Hara ¹⁶⁰, T. Harenberg ¹⁷⁵, S. Harkusha ⁹⁰, D. Harper ⁸⁷, R.D. Harrington ⁴⁶, O.M. Harris ¹³⁸, J. Hartert ⁴⁸, F. Hartjes ¹⁰⁵, T. Haruyama ⁶⁵, A. Harvey ⁵⁶, S. Hasegawa ¹⁰¹, Y. Hasegawa ¹⁴⁰, S. Hassani ¹³⁶, S. Haug ¹⁷, M. Hauschild ³⁰, R. Hauser ⁸⁸, M. Havranek ²¹, C.M. Hawkes ¹⁸, R.J. Hawkings ³⁰, A.D. Hawkins ⁷⁹, T. Hayakawa ⁶⁶, T. Hayashi ¹⁶⁰, D. Hayden ⁷⁶, C.P. Hays ¹¹⁸, H.S. Hayward ⁷³, S.J. Haywood ¹²⁹, S.J. Head ¹⁸, V. Hedberg ⁷⁹, L. Heelan ⁸, S. Heim ¹²⁰, B. Heinemann ¹⁵, S. Heisterkamp ³⁶, L. Helary ²², C. Heller ⁹⁸, M. Heller ³⁰, S. Hellman ^{146a,146b}, D. Hellmich ²¹, C. Helsens ¹², R.C.W. Henderson ⁷¹, M. Henke ^{58a}, A. Henrichs ¹⁷⁶, A.M. Henriques Correia ³⁰, S. Henrot-Versille ¹¹⁵, C. Hensel ⁵⁴, C.M. Hernandez ⁸, Y. Hernández Jiménez ¹⁶⁷, R. Herrberg ¹⁶, G. Herten ⁴⁸, R. Hertenberger ⁹⁸, L. Hervas ³⁰, G.G. Hesketh ⁷⁷, N.P. Hessey ¹⁰⁵, R. Hickling ⁷⁵, E. Higón-Rodriguez ¹⁶⁷, J.C. Hill ²⁸, K.H. Hiller ⁴², S. Hillert ²¹, S.J. Hillier ¹⁸, I. Hinchliffe ¹⁵, E. Hines ¹²⁰, M. Hirose ¹¹⁶, F. Hirsch ⁴³, D. Hirschbuehl ¹⁷⁵, J. Hobbs ¹⁴⁸, N. Hod ¹⁵³, M.C. Hodgkinson ¹³⁹, P. Hodgson ¹³⁹, A. Hoecker ³⁰, M.R. Hoeferkamp ¹⁰³, J. Hoffman ⁴⁰, D. Hoffmann ⁸³, M. Hohlfeld ⁸¹, M. Holder ¹⁴¹, S.O. Holmgren ^{146a}, T. Holy ¹²⁶, J.L. Holzbauer ⁸⁸, T.M. Hong ¹²⁰, L. Hooft van Huysduynen ¹⁰⁸, S. Horner ⁴⁸, J.-Y. Hostachy ⁵⁵, S. Hou ¹⁵¹, A. Hoummada ^{135a}, J. Howard ¹¹⁸,

- J. Howarth⁸², I. Hristova¹⁶, J. Hrivnac¹¹⁵, T. Hryvn'ova⁵, P.J. Hsu⁸¹, S.-C. Hsu¹³⁸, D. Hu³⁵, Z. Hubacek³⁰, F. Hubaut⁸³, F. Huegging²¹, A. Huettmann⁴², T.B. Huffman¹¹⁸, E.W. Hughes³⁵, G. Hughes⁷¹, M. Huhtinen³⁰, M. Hurwitz¹⁵, N. Huseynov^{64,r}, J. Huston⁸⁸, J. Huth⁵⁷, G. Iacobucci⁴⁹, G. Iakovidis¹⁰, M. Ibbotson⁸², I. Ibragimov¹⁴¹, L. Iconomidou-Fayard¹¹⁵, J. Idarraga¹¹⁵, P. Iengo^{102a}, O. Igonkina¹⁰⁵, Y. Ikegami⁶⁵, M. Ikeno⁶⁵, D. Iliadis¹⁵⁴, N. Illic¹⁵⁸, T. Ince⁹⁹, P. Ioannou⁹, M. Iodice^{134a}, K. Iordanidou⁹, V. Ippolito^{132a,132b}, A. Irles Quiles¹⁶⁷, C. Isaksson¹⁶⁶, M. Ishino⁶⁷, M. Ishitsuka¹⁵⁷, R. Ishmukhametov¹⁰⁹, C. Issever¹¹⁸, S. Istin^{19a}, A.V. Ivashin¹²⁸, W. Iwanski⁶⁵, J.M. Izen⁴¹, V. Izzo^{102a}, B. Jackson¹²⁰, J.N. Jackson⁷³, P. Jackson¹, M.R. Jaekel³⁰, V. Jain², K. Jakobs⁴⁸, S. Jakobsen³⁶, T. Jakoubek¹²⁵, J. Jakubek¹²⁶, D.O. Jamin¹⁵¹, D.K. Jana¹¹¹, E. Jansen⁷⁷, H. Jansen³⁰, J. Janssen²¹, A. Jantsch⁹⁹, M. Janus⁴⁸, R.C. Jared¹⁷³, G. Jarlskog⁷⁹, L. Jeanty⁵⁷, I. Jen-La Plante³¹, G.-Y. Jeng¹⁵⁰, D. Jennens⁸⁶, P. Jenni³⁰, A.E. Loevschall-Jensen³⁶, P. Jež³⁶, S. Jézéquel⁵, M.K. Jha^{20a}, H. Ji¹⁷³, W. Ji⁸¹, J. Jia¹⁴⁸, Y. Jiang^{33b}, M. Jimenez Belenguer⁴², S. Jin^{33a}, O. Jinnouchi¹⁵⁷, M.D. Joergensen³⁶, D. Joffe⁴⁰, M. Johansen^{146a,146b}, K.E. Johansson^{146a}, P. Johansson¹³⁹, S. Johnert⁴², K.A. Johns⁷, K. Jon-And^{146a,146b}, G. Jones¹⁷⁰, R.W.L. Jones⁷¹, T.J. Jones⁷³, C. Joram³⁰, P.M. Jorge^{124a}, K.D. Joshi⁸², J. Jovicevic¹⁴⁷, T. Jovin^{13b}, X. Ju¹⁷³, C.A. Jung⁴³, R.M. Jungst³⁰, V. Juranek¹²⁵, P. Jussel⁶¹, A. Juste Rozas¹², S. Kabana¹⁷, M. Kaci¹⁶⁷, A. Kaczmarśka³⁹, P. Kadlecik³⁶, M. Kado¹¹⁵, H. Kagan¹⁰⁹, M. Kagan⁵⁷, E. Kajomovitz¹⁵², S. Kalinin¹⁷⁵, L.V. Kalinovskaya⁶⁴, S. Kama⁴⁰, N. Kanaya¹⁵⁵, M. Kaneda³⁰, S. Kaneti²⁸, T. Kanno¹⁵⁷, V.A. Kantserov⁹⁶, J. Kanzaki⁶⁵, B. Kaplan¹⁰⁸, A. Kapliy³¹, D. Kar⁵³, M. Karagounis²¹, K. Karakostas¹⁰, M. Karnevskiy^{58b}, V. Kartvelishvili⁷¹, A.N. Karyukhin¹²⁸, L. Kashif¹⁷³, G. Kasieczka^{58b}, R.D. Kass¹⁰⁹, A. Kastanas¹⁴, M. Kataoka⁵, Y. Kataoka¹⁵⁵, J. Katzy⁴², V. Kaushik⁷, K. Kawagoe⁶⁹, T. Kawamoto¹⁵⁵, G. Kawamura⁸¹, S. Kazama¹⁵⁵, V.F. Kazanin¹⁰⁷, M.Y. Kazarinov⁶⁴, R. Keeler¹⁶⁹, P.T. Keener¹²⁰, R. Kehoe⁴⁰, M. Keil⁵⁴, G.D. Kekelidze⁶⁴, J.S. Keller¹³⁸, M. Kenyon⁵³, H. Keoshkerian⁵, O. Kepka¹²⁵, N. Kerschen³⁰, B.P. Kerševan⁷⁴, S. Kersten¹⁷⁵, K. Kessoku¹⁵⁵, J. Keung¹⁵⁸, F. Khalil-zada¹¹, H. Khandanyan^{146a,146b}, A. Khanov¹¹², D. Kharchenko⁶⁴, A. Khodinov⁹⁶, A. Khomich^{58a}, T.J. Khoo²⁸, G. Khoriauli²¹, A. Khoroshilov¹⁷⁵, V. Khovanskiy⁹⁵, E. Khramov⁶⁴, J. Khubua^{51b}, H. Kim^{146a,146b}, S.H. Kim¹⁶⁰, N. Kimura¹⁷¹, O. Kind¹⁶, B.T. King⁷³, M. King⁶⁶, R.S.B. King¹¹⁸, J. Kirk¹²⁹, A.E. Kiryunin⁹⁹, T. Kishimoto⁶⁶, D. Kisielewska³⁸, T. Kitamura⁶⁶, T. Kittelmann¹²³, K. Kiuchi¹⁶⁰, E. Kladiva^{144b}, M. Klein⁷³, U. Klein⁷³, K. Kleinknecht⁸¹, M. Klemetti⁸⁵, A. Klier¹⁷², P. Klimek^{146a,146b}, A. Klimentov²⁵, R. Klingenberg⁴³, J.A. Klinger⁸², E.B. Klinkby³⁶, T. Klioutchnikova³⁰, P.F. Klok¹⁰⁴, S. Klous¹⁰⁵, E.-E. Kluge^{58a}, T. Kluge⁷³, P. Kluit¹⁰⁵, S. Kluth⁹⁹, E. Knerner⁶¹, E.B.F.G. Knoops⁸³, A. Knue⁵⁴, B.R. Ko⁴⁵, T. Kobayashi¹⁵⁵, M. Kobel⁴⁴, M. Kocian¹⁴³, P. Kodys¹²⁷, K. Köneke³⁰, A.C. König¹⁰⁴, S. Koenig⁸¹, L. Köpke⁸¹, F. Koetsveld¹⁰⁴, P. Koevesarki²¹, T. Koffas²⁹, E. Koffeman¹⁰⁵, L.A. Kogan¹¹⁸, S. Kohlmann¹⁷⁵, F. Kohn⁵⁴, Z. Kohout¹²⁶, T. Kohriki⁶⁵, T. Koi¹⁴³, G.M. Kolachev^{107,*}, H. Kolanoski¹⁶, V. Kolesnikov⁶⁴, I. Koletsou^{89a}, J. Koll⁸⁸, A.A. Komar⁹⁴, Y. Komori¹⁵⁵, T. Kondo⁶⁵, T. Kono^{42,s}, A.I. Kononov⁴⁸, R. Konoplich^{108,t}, N. Konstantinidis⁷⁷, R. Kopeliansky¹⁵², S. Koperny³⁸, K. Korcyl³⁹, K. Kordas¹⁵⁴, A. Korn¹¹⁸, A. Korol¹⁰⁷, I. Korolkov¹², E.V. Korolkova¹³⁹, V.A. Korotkov¹²⁸, O. Kortner⁹⁹, S. Kortner⁹⁹, V.V. Kostyukhin²¹, S. Kotov⁹⁹, V.M. Kotov⁶⁴, A. Kotwal⁴⁵, C. Kourkoumelis⁹, V. Kouskoura¹⁵⁴, A. Koutsman^{159a}, R. Kowalewski¹⁶⁹, T.Z. Kowalski³⁸, W. Kozanecki¹³⁶, A.S. Kozhin¹²⁸, V. Kral¹²⁶, V.A. Kramarenko⁹⁷, G. Kramberger⁷⁴, M.W. Krasny⁷⁸, A. Krasznahorkay¹⁰⁸, J.K. Kraus²¹, A. Kravchenko²⁵, S. Kreiss¹⁰⁸, F. Krejci¹²⁶, J. Kretzschmar⁷³, K. Kreutzfeldt⁵², N. Krieger⁵⁴, P. Krieger¹⁵⁸, K. Kroeninger⁵⁴, H. Kroha⁹⁹, J. Kroll¹²⁰, J. Kroeseberg²¹, J. Krstic^{13a}, U. Kruchonak⁶⁴, H. Krüger²¹, T. Kruker¹⁷, N. Krumnack⁶³, Z.V. Krumshteyn⁶⁴, M.K. Kruse⁴⁵, T. Kubota⁸⁶, S. Kuday^{4a}, S. Kuehn⁴⁸, A. Kugel^{58c}, T. Kuhl⁴², V. Kukhtin⁶⁴, Y. Kulchitsky⁹⁰, S. Kuleshov^{32b}, M. Kuna⁷⁸, J. Kunkle¹²⁰, A. Kupco¹²⁵, H. Kurashige⁶⁶, M. Kurata¹⁶⁰, Y.A. Kurochkin⁹⁰, V. Kus¹²⁵, E.S. Kuwertz¹⁴⁷, M. Kuze¹⁵⁷, J. Kvita¹⁴², R. Kwee¹⁶, A. La Rosa⁴⁹, L. La Rotonda^{37a,37b}, L. Labarga⁸⁰, S. Lablak^{135a}, C. Lacasta¹⁶⁷, F. Lacava^{132a,132b}, J. Lacev²⁹, H. Lacker¹⁶, D. Lacour⁷⁸, V.R. Lacuesta¹⁶⁷, E. Ladygin⁶⁴, R. Lafaye⁵, B. Laforge⁷⁸, T. Lagouri¹⁷⁶, S. Lai⁴⁸, E. Laisne⁵⁵, L. Lambourne⁷⁷, C.L. Lampen⁷, W. Lampl⁷, E. Lancon¹³⁶, U. Landgraf⁴⁸, M.P.J. Landon⁷⁵, V.S. Lang^{58a}, C. Lange⁴², A.J. Lankford¹⁶³, F. Lanni²⁵, K. Lantzsch³⁰, A. Lanza^{119a}, S. Laplace⁷⁸, C. Lapoire²¹, J.F. Laporte¹³⁶, T. Lari^{89a}, A. Larner¹¹⁸, M. Lassnig³⁰, P. Laurelli⁴⁷, V. Lavorini^{37a,37b}, W. Lavrijsen¹⁵, P. Laycock⁷³, O. Le Dortz⁷⁸, E. Le Guirriec⁸³, E. Le Menedeu¹², T. LeCompte⁶, F. Ledroit-Guillon⁵⁵, H. Lee¹⁰⁵, J.S.H. Lee¹¹⁶, S.C. Lee¹⁵¹, L. Lee¹⁷⁶, M. Lefebvre¹⁶⁹, M. Legendre¹³⁶, F. Leggett¹⁵, C. Leggett⁹⁸, M. Lehmacner²¹,

- G. Lehmann Miotto ³⁰, A.G. Leister ¹⁷⁶, M.A.L. Leite ^{24d}, R. Leitner ¹²⁷, D. Lellouch ¹⁷², B. Lemmer ⁵⁴,
 V. Lendermann ^{58a}, K.J.C. Leney ^{145b}, T. Lenz ¹⁰⁵, G. Lenzen ¹⁷⁵, B. Lenzi ³⁰, K. Leonhardt ⁴⁴, S. Leontsinis ¹⁰,
 F. Lepold ^{58a}, C. Leroy ⁹³, J.-R. Lessard ¹⁶⁹, C.G. Lester ²⁸, C.M. Lester ¹²⁰, J. Levêque ⁵, D. Levin ⁸⁷,
 L.J. Levinson ¹⁷², A. Lewis ¹¹⁸, G.H. Lewis ¹⁰⁸, A.M. Leyko ²¹, M. Leyton ¹⁶, B. Li ^{33b}, B. Li ⁸³, H. Li ¹⁴⁸,
 H.L. Li ³¹, S. Li ^{33b,u}, X. Li ⁸⁷, Z. Liang ^{118,v}, H. Liao ³⁴, B. Liberti ^{133a}, P. Lichard ³⁰, K. Lie ¹⁶⁵, W. Liebig ¹⁴,
 C. Limbach ²¹, A. Limosani ⁸⁶, M. Limper ⁶², S.C. Lin ^{151,w}, F. Linde ¹⁰⁵, J.T. Linnemann ⁸⁸, E. Lipeles ¹²⁰,
 A. Lipniacka ¹⁴, T.M. Liss ¹⁶⁵, D. Lissauer ²⁵, A. Lister ⁴⁹, A.M. Litke ¹³⁷, D. Liu ¹⁵¹, J.B. Liu ^{33b}, L. Liu ⁸⁷,
 M. Liu ^{33b}, Y. Liu ^{33b}, M. Livan ^{119a,119b}, S.S.A. Livermore ¹¹⁸, A. Lleres ⁵⁵, J. Llorente Merino ⁸⁰,
 S.L. Lloyd ⁷⁵, E. Lobodzinska ⁴², P. Loch ⁷, W.S. Lockman ¹³⁷, T. Loddenkoetter ²¹, F.K. Loebinger ⁸²,
 A. Loginov ¹⁷⁶, C.W. Loh ¹⁶⁸, T. Lohse ¹⁶, K. Lohwasser ⁴⁸, M. Lokajicek ¹²⁵, V.P. Lombardo ⁵, R.E. Long ⁷¹,
 L. Lopes ^{124a}, D. Lopez Mateos ⁵⁷, J. Lorenz ⁹⁸, N. Lorenzo Martinez ¹¹⁵, M. Losada ¹⁶², P. Loscutoff ¹⁵,
 F. Lo Sterzo ^{132a,132b}, M.J. Losty ^{159a,*}, X. Lou ⁴¹, A. Lounis ¹¹⁵, K.F. Loureiro ¹⁶², J. Love ⁶, P.A. Love ⁷¹,
 A.J. Lowe ^{143,g}, F. Lu ^{33a}, H.J. Lubatti ¹³⁸, C. Luci ^{132a,132b}, A. Lucotte ⁵⁵, D. Ludwig ⁴², I. Ludwig ⁴⁸,
 J. Ludwig ⁴⁸, F. Luehring ⁶⁰, G. Luijckx ¹⁰⁵, W. Lukas ⁶¹, L. Luminari ^{132a}, E. Lund ¹¹⁷, B. Lund-Jensen ¹⁴⁷,
 B. Lundberg ⁷⁹, J. Lundberg ^{146a,146b}, O. Lundberg ^{146a,146b}, J. Lundquist ³⁶, M. Lungwitz ⁸¹, D. Lynn ²⁵,
 E. Lytken ⁷⁹, H. Ma ²⁵, L.L. Ma ¹⁷³, G. Maccarrone ⁴⁷, A. Macchiolo ⁹⁹, B. Maček ⁷⁴,
 J. Machado Miguens ^{124a}, D. Macina ³⁰, R. Mackeprang ³⁶, R.J. Madaras ¹⁵, H.J. Maddocks ⁷¹, W.F. Mader ⁴⁴,
 T. Maeno ²⁵, P. Mättig ¹⁷⁵, S. Mättig ⁴², L. Magnoni ¹⁶³, E. Magradze ⁵⁴, K. Mahboubi ⁴⁸, J. Mahlstedt ¹⁰⁵,
 S. Mahmoud ⁷³, G. Mahout ¹⁸, C. Maiani ¹³⁶, C. Maidantchik ^{24a}, A. Maio ^{124a,c}, S. Majewski ²⁵,
 Y. Makida ⁶⁵, N. Makovec ¹¹⁵, P. Mal ¹³⁶, B. Malaescu ⁷⁸, Pa. Malecki ³⁹, P. Malecki ³⁹, V.P. Maleev ¹²¹,
 F. Malek ⁵⁵, U. Mallik ⁶², D. Malon ⁶, C. Malone ¹⁴³, S. Maltezos ¹⁰, V. Malyshev ¹⁰⁷, S. Malyukov ³⁰,
 J. Mamuzic ^{13b}, A. Manabe ⁶⁵, L. Mandelli ^{89a}, I. Mandić ⁷⁴, R. Mandrysch ⁶², J. Maneira ^{124a},
 A. Manfredini ⁹⁹, L. Manhaes de Andrade Filho ^{24b}, J.A. Manjarres Ramos ¹³⁶, A. Mann ⁹⁸,
 P.M. Manning ¹³⁷, A. Manousakis-Katsikakis ⁹, B. Mansoulie ¹³⁶, R. Mantifel ⁸⁵, A. Mapelli ³⁰, L. Mapelli ³⁰,
 L. March ¹⁶⁷, J.F. Marchand ²⁹, F. Marchese ^{133a,133b}, G. Marchiori ⁷⁸, M. Marcisovsky ¹²⁵, C.P. Marino ¹⁶⁹,
 F. Marroquim ^{24a}, Z. Marshall ³⁰, L.F. Marti ¹⁷, S. Marti-Garcia ¹⁶⁷, B. Martin ³⁰, B. Martin ⁸⁸, J.P. Martin ⁹³,
 T.A. Martin ¹⁸, V.J. Martin ⁴⁶, B. Martin dit Latour ⁴⁹, S. Martin-Haugh ¹⁴⁹, H. Martinez ¹³⁶, M. Martinez ¹²,
 V. Martinez Outschoorn ⁵⁷, A.C. Martyniuk ¹⁶⁹, M. Marx ⁸², F. Marzano ^{132a}, A. Marzin ¹¹¹, L. Masetti ⁸¹,
 T. Mashimo ¹⁵⁵, R. Mashinistov ⁹⁴, J. Masik ⁸², A.L. Maslennikov ¹⁰⁷, I. Massa ^{20a,20b}, G. Massaro ¹⁰⁵,
 N. Massol ⁵, P. Mastrandrea ¹⁴⁸, A. Mastroberardino ^{37a,37b}, T. Masubuchi ¹⁵⁵, H. Matsunaga ¹⁵⁵,
 T. Matsushita ⁶⁶, C. Mattravers ^{118,d}, J. Maurer ⁸³, S.J. Maxfield ⁷³, D.A. Maximov ^{107,h}, R. Mazini ¹⁵¹,
 M. Mazur ²¹, L. Mazzaferro ^{133a,133b}, M. Mazzanti ^{89a}, J. Mc Donald ⁸⁵, S.P. Mc Kee ⁸⁷, A. McCarn ¹⁶⁵,
 R.L. McCarthy ¹⁴⁸, T.G. McCarthy ²⁹, N.A. McCubbin ¹²⁹, K.W. McFarlane ^{56,*}, J.A. McFayden ¹³⁹,
 G. Mchedlidze ^{51b}, T. McLaughlan ¹⁸, S.J. McMahon ¹²⁹, R.A. McPherson ^{169,l}, A. Meade ⁸⁴, J. Mechlich ¹⁰⁵,
 M. Mechtel ¹⁷⁵, M. Medinnis ⁴², S. Meehan ³¹, R. Meera-Lebbai ¹¹¹, T. Meguro ¹¹⁶, S. Mehlhase ³⁶,
 A. Mehta ⁷³, K. Meier ^{58a}, B. Meirose ⁷⁹, C. Melachrinos ³¹, B.R. Mellado Garcia ¹⁷³, F. Meloni ^{89a,89b},
 L. Mendoza Navas ¹⁶², Z. Meng ^{151,x}, A. Mengarelli ^{20a,20b}, S. Menke ⁹⁹, E. Meoni ¹⁶¹, K.M. Mercurio ⁵⁷,
 P. Mermod ⁴⁹, L. Merola ^{102a,102b}, C. Meroni ^{89a}, F.S. Merritt ³¹, H. Merritt ¹⁰⁹, A. Messina ^{30,y},
 J. Metcalfe ²⁵, A.S. Mete ¹⁶³, C. Meyer ⁸¹, C. Meyer ³¹, J.-P. Meyer ¹³⁶, J. Meyer ¹⁷⁴, J. Meyer ⁵⁴, S. Michal ³⁰,
 L. Micu ^{26a}, R.P. Middleton ¹²⁹, S. Migas ⁷³, L. Mijović ¹³⁶, G. Mikenberg ¹⁷², M. Mikestikova ¹²⁵,
 M. Mikuž ⁷⁴, D.W. Miller ³¹, R.J. Miller ⁸⁸, W.J. Mills ¹⁶⁸, C. Mills ⁵⁷, A. Milov ¹⁷², D.A. Milstead ^{146a,146b},
 D. Milstein ¹⁷², A.A. Minaenko ¹²⁸, M. Miñano Moya ¹⁶⁷, I.A. Minashvili ⁶⁴, A.I. Mincer ¹⁰⁸, B. Mindur ³⁸,
 M. Mineev ⁶⁴, Y. Ming ¹⁷³, L.M. Mir ¹², G. Mirabelli ^{132a}, J. Mitrevski ¹³⁷, V.A. Mitsou ¹⁶⁷, S. Mitsui ⁶⁵,
 P.S. Miyagawa ¹³⁹, J.U. Mjörnmark ⁷⁹, T. Moa ^{146a,146b}, V. Moeller ²⁸, K. Möning ⁴², N. Möser ²¹,
 S. Mohapatra ¹⁴⁸, W. Mohr ⁴⁸, R. Moles-Valls ¹⁶⁷, A. Molfetas ³⁰, J. Monk ⁷⁷, E. Monnier ⁸³,
 J. Montejo Berlingen ¹², F. Monticelli ⁷⁰, S. Monzani ^{20a,20b}, R.W. Moore ³, G.F. Moorhead ⁸⁶,
 C. Mora Herrera ⁴⁹, A. Moraes ⁵³, N. Morange ¹³⁶, J. Morel ⁵⁴, G. Morello ^{37a,37b}, D. Moreno ⁸¹,
 M. Moreno Llácer ¹⁶⁷, P. Morettini ^{50a}, M. Morgenstern ⁴⁴, M. Morii ⁵⁷, A.K. Morley ³⁰, G. Mornacchi ³⁰,
 J.D. Morris ⁷⁵, L. Morvaj ¹⁰¹, H.G. Moser ⁹⁹, M. Mosidze ^{51b}, J. Moss ¹⁰⁹, R. Mount ¹⁴³, E. Mountricha ^{10,z},
 S.V. Mouraviev ^{94,*}, E.J.W. Moyse ⁸⁴, F. Mueller ^{58a}, J. Mueller ¹²³, K. Mueller ²¹, T.A. Müller ⁹⁸,
 T. Mueller ⁸¹, D. Muenstermann ³⁰, Y. Munwes ¹⁵³, W.J. Murray ¹²⁹, I. Mussche ¹⁰⁵, E. Musto ¹⁵²,
 A.G. Myagkov ¹²⁸, M. Myska ¹²⁵, O. Nackenhorst ⁵⁴, J. Nadal ¹², K. Nagai ¹⁶⁰, R. Nagai ¹⁵⁷, K. Nagano ⁶⁵,

- A. Nagarkar ¹⁰⁹, Y. Nagasaka ⁵⁹, M. Nagel ⁹⁹, A.M. Nairz ³⁰, Y. Nakahama ³⁰, K. Nakamura ¹⁵⁵,
 T. Nakamura ¹⁵⁵, I. Nakano ¹¹⁰, G. Nanava ²¹, A. Napier ¹⁶¹, R. Narayan ^{58b}, M. Nash ^{77,d}, T. Nattermann ²¹,
 T. Naumann ⁴², G. Navarro ¹⁶², H.A. Neal ⁸⁷, P.Yu. Nechaeva ⁹⁴, T.J. Neep ⁸², A. Negri ^{119a,119b}, G. Negri ³⁰,
 M. Negrini ^{20a}, S. Nektarijevic ⁴⁹, A. Nelson ¹⁶³, T.K. Nelson ¹⁴³, S. Nemecek ¹²⁵, P. Nemethy ¹⁰⁸,
 A.A. Nepomuceno ^{24a}, M. Nessi ^{30,aa}, M.S. Neubauer ¹⁶⁵, M. Neumann ¹⁷⁵, A. Neusiedl ⁸¹, R.M. Neves ¹⁰⁸,
 P. Nevski ²⁵, F.M. Newcomer ¹²⁰, P.R. Newman ¹⁸, V. Nguyen Thi Hong ¹³⁶, R.B. Nickerson ¹¹⁸,
 R. Nicolaïdou ¹³⁶, B. Nicquevert ³⁰, F. Niedercorn ¹¹⁵, J. Nielsen ¹³⁷, N. Nikiforou ³⁵, A. Nikiforov ¹⁶,
 V. Nikolaenko ¹²⁸, I. Nikolic-Audit ⁷⁸, K. Nikolics ⁴⁹, K. Nikolopoulos ¹⁸, H. Nilsen ⁴⁸, P. Nilsson ⁸,
 Y. Ninomiya ¹⁵⁵, A. Nisati ^{132a}, R. Nisius ⁹⁹, T. Nobe ¹⁵⁷, L. Nodulman ⁶, M. Nomachi ¹¹⁶, I. Nomidis ¹⁵⁴,
 S. Norberg ¹¹¹, M. Nordberg ³⁰, J. Novakova ¹²⁷, M. Nozaki ⁶⁵, L. Nozka ¹¹³, A.-E. Nuncio-Quiroz ²¹,
 G. Nunes Hanninger ⁸⁶, T. Nunnemann ⁹⁸, E. Nurse ⁷⁷, B.J. O'Brien ⁴⁶, D.C. O'Neil ¹⁴², V. O'Shea ⁵³,
 L.B. Oakes ⁹⁸, F.G. Oakham ^{29,f}, H. Oberlack ⁹⁹, J. Ocariz ⁷⁸, A. Ochi ⁶⁶, S. Oda ⁶⁹, S. Odaka ⁶⁵, J. Odier ⁸³,
 H. Ogren ⁶⁰, A. Oh ⁸², S.H. Oh ⁴⁵, C.C. Ohm ³⁰, T. Ohshima ¹⁰¹, W. Okamura ¹¹⁶, H. Okawa ²⁵,
 Y. Okumura ³¹, T. Okuyama ¹⁵⁵, A. Olariu ^{26a}, A.G. Olchevski ⁶⁴, S.A. Olivares Pino ^{32a}, M. Oliveira ^{124a,i},
 D. Oliveira Damazio ²⁵, E. Oliver Garcia ¹⁶⁷, D. Olivito ¹²⁰, A. Olszewski ³⁹, J. Olszowska ³⁹,
 A. Onofre ^{124a,ab}, P.U.E. Onyisi ^{31,ac}, C.J. Oram ^{159a}, M.J. Oreglia ³¹, Y. Oren ¹⁵³, D. Orestano ^{134a,134b},
 N. Orlando ^{72a,72b}, C. Oropeza Barrera ⁵³, R.S. Orr ¹⁵⁸, B. Osculati ^{50a,50b}, R. Ospanov ¹²⁰, C. Osuna ¹²,
 G. Otero y Garzon ²⁷, J.P. Ottersbach ¹⁰⁵, M. Ouchrif ^{135d}, E.A. Ouellette ¹⁶⁹, F. Ould-Saada ¹¹⁷,
 A. Ouraou ¹³⁶, Q. Ouyang ^{33a}, A. Ovcharova ¹⁵, M. Owen ⁸², S. Owen ¹³⁹, V.E. Ozcan ^{19a}, N. Ozturk ⁸,
 A. Pacheco Pages ¹², C. Padilla Aranda ¹², S. Pagan Griso ¹⁵, E. Paganis ¹³⁹, C. Pahl ⁹⁹, F. Paige ²⁵, P. Pais ⁸⁴,
 K. Pajchel ¹¹⁷, G. Palacino ^{159b}, C.P. Paleari ⁷, S. Palestini ³⁰, D. Pallin ³⁴, A. Palma ^{124a}, J.D. Palmer ¹⁸,
 Y.B. Pan ¹⁷³, E. Panagiotopoulou ¹⁰, J.G. Panduro Vazquez ⁷⁶, P. Pani ¹⁰⁵, N. Panikashvili ⁸⁷, S. Panitkin ²⁵,
 D. Pantea ^{26a}, A. Papadelis ^{146a}, Th.D. Papadopoulou ¹⁰, A. Paramonov ⁶, D. Paredes Hernandez ³⁴,
 W. Park ^{25,ad}, M.A. Parker ²⁸, F. Parodi ^{50a,50b}, J.A. Parsons ³⁵, U. Parzefall ⁴⁸, S. Pashapour ⁵⁴,
 E. Pasqualucci ^{132a}, S. Passaggio ^{50a}, A. Passeri ^{134a}, F. Pastore ^{134a,134b,*}, Fr. Pastore ⁷⁶, G. Pásztor ^{49,ae},
 S. Pataraia ¹⁷⁵, N. Patel ¹⁵⁰, J.R. Pater ⁸², S. Patricelli ^{102a,102b}, T. Pauly ³⁰, S. Pedraza Lopez ¹⁶⁷,
 M.I. Pedraza Morales ¹⁷³, S.V. Peleganchuk ¹⁰⁷, D. Pelikan ¹⁶⁶, H. Peng ^{33b}, B. Penning ³¹, A. Penson ³⁵,
 J. Penwell ⁶⁰, M. Perantoni ^{24a}, K. Perez ^{35,af}, T. Perez Cavalcanti ⁴², E. Perez Codina ^{159a},
 M.T. Pérez García-Estañ ¹⁶⁷, V. Perez Reale ³⁵, L. Perini ^{89a,89b}, H. Pernegger ³⁰, R. Perrino ^{72a}, P. Perrodo ⁵,
 V.D. Peshekhonov ⁶⁴, K. Peters ³⁰, B.A. Petersen ³⁰, J. Petersen ³⁰, T.C. Petersen ³⁶, E. Petit ⁵, A. Petridis ¹⁵⁴,
 C. Petridou ¹⁵⁴, E. Petrolo ^{132a}, F. Petracci ^{134a,134b}, D. Petschull ⁴², M. Petteni ¹⁴², R. Pezoa ^{32b}, A. Phan ⁸⁶,
 P.W. Phillips ¹²⁹, G. Piacquadio ³⁰, A. Picazio ⁴⁹, E. Piccaro ⁷⁵, M. Piccinini ^{20a,20b}, S.M. Piec ⁴², R. Piegaia ²⁷,
 D.T. Pignotti ¹⁰⁹, J.E. Pilcher ³¹, A.D. Pilkington ⁸², J. Pina ^{124a,c}, M. Pinamonti ^{164a,164c}, A. Pinder ¹¹⁸,
 J.L. Pinfold ³, A. Pingel ³⁶, B. Pinto ^{124a}, C. Pizio ^{89a,89b}, M.-A. Pleier ²⁵, E. Plotnikova ⁶⁴, A. Poblahuev ²⁵,
 S. Poddar ^{58a}, F. Podlaski ³⁴, L. Poggioli ¹¹⁵, D. Pohl ²¹, M. Pohl ⁴⁹, G. Polesello ^{119a}, A. Policicchio ^{37a,37b},
 R. Polifka ¹⁵⁸, A. Polini ^{20a}, J. Poll ⁷⁵, V. Polychronakos ²⁵, D. Pomeroy ²³, K. Pommès ³⁰, L. Pontecorvo ^{132a},
 B.G. Pope ⁸⁸, G.A. Popeneiciu ^{26a}, D.S. Popovic ^{13a}, A. Poppleton ³⁰, X. Portell Bueso ³⁰, G.E. Pospelov ⁹⁹,
 S. Pospisil ¹²⁶, I.N. Potrap ⁹⁹, C.J. Potter ¹⁴⁹, C.T. Potter ¹¹⁴, G. Poulard ³⁰, J. Poveda ⁶⁰, V. Pozdnyakov ⁶⁴,
 R. Prabhu ⁷⁷, P. Pralavorio ⁸³, A. Pranko ¹⁵, S. Prasad ³⁰, R. Pravahan ²⁵, S. Prell ⁶³, K. Pretzl ¹⁷, D. Price ⁶⁰,
 J. Price ⁷³, L.E. Price ⁶, D. Prieur ¹²³, M. Primavera ^{72a}, K. Prokofiev ¹⁰⁸, F. Prokoshin ^{32b}, S. Protopopescu ²⁵,
 J. Proudfoot ⁶, X. Prudent ⁴⁴, M. Przybycien ³⁸, H. Przysiezniak ⁵, S. Psoroulas ²¹, E. Ptacek ¹¹⁴,
 E. Pueschel ⁸⁴, D. Puldon ¹⁴⁸, J. Purdham ⁸⁷, M. Purohit ^{25,ad}, P. Puzo ¹¹⁵, Y. Pylypchenko ⁶², J. Qian ⁸⁷,
 A. Quadt ⁵⁴, D.R. Quarrie ¹⁵, W.B. Quayle ¹⁷³, M. Raas ¹⁰⁴, V. Radeka ²⁵, V. Radescu ⁴², P. Radloff ¹¹⁴,
 F. Ragusa ^{89a,89b}, G. Rahal ¹⁷⁸, A.M. Rahimi ¹⁰⁹, D. Rahm ²⁵, S. Rajagopalan ²⁵, M. Rammensee ⁴⁸,
 M. Rammes ¹⁴¹, A.S. Randle-Conde ⁴⁰, K. Randrianarivony ²⁹, K. Rao ¹⁶³, F. Rauscher ⁹⁸, T.C. Rave ⁴⁸,
 M. Raymond ³⁰, A.L. Read ¹¹⁷, D.M. Rebuzzi ^{119a,119b}, A. Redelbach ¹⁷⁴, G. Redlinger ²⁵, R. Reece ¹²⁰,
 K. Reeves ⁴¹, A. Reinsch ¹¹⁴, I. Reisinger ⁴³, C. Rembser ³⁰, Z.L. Ren ¹⁵¹, A. Renaud ¹¹⁵, M. Rescigno ^{132a},
 S. Resconi ^{89a}, B. Resende ¹³⁶, P. Reznicek ⁹⁸, R. Rezvani ¹⁵⁸, R. Richter ⁹⁹, E. Richter-Was ^{5,ag}, M. Ridel ⁷⁸,
 M. Rijssenbeek ¹⁴⁸, A. Rimoldi ^{119a,119b}, L. Rinaldi ^{20a}, R.R. Rios ⁴⁰, E. Ritsch ⁶¹, I. Riu ¹²,
 G. Rivoltella ^{89a,89b}, F. Rizatdinova ¹¹², E. Rizvi ⁷⁵, S.H. Robertson ^{85,l}, A. Robichaud-Veronneau ¹¹⁸,
 D. Robinson ²⁸, J.E.M. Robinson ⁸², A. Robson ⁵³, J.G. Rocha de Lima ¹⁰⁶, C. Roda ^{122a,122b},
 D. Roda Dos Santos ³⁰, A. Roe ⁵⁴, S. Roe ³⁰, O. Røhne ¹¹⁷, S. Rolli ¹⁶¹, A. Romanouk ⁹⁶, M. Romano ^{20a,20b},

- G. Romeo ²⁷, E. Romero Adam ¹⁶⁷, N. Rompotis ¹³⁸, L. Roos ⁷⁸, E. Ros ¹⁶⁷, S. Rosati ^{132a}, K. Rosbach ⁴⁹,
A. Rose ¹⁴⁹, M. Rose ⁷⁶, G.A. Rosenbaum ¹⁵⁸, P.L. Rosendahl ¹⁴, O. Rosenthal ¹⁴¹, L. Rosselet ⁴⁹,
V. Rossetti ¹², E. Rossi ^{132a,132b}, L.P. Rossi ^{50a}, M. Rotaru ^{26a}, I. Roth ¹⁷², J. Rothberg ¹³⁸, D. Rousseau ¹¹⁵,
C.R. Royon ¹³⁶, A. Rozanov ⁸³, Y. Rozen ¹⁵², X. Ruan ^{33a,ah}, F. Rubbo ¹², I. Rubinskiy ⁴², N. Ruckstuhl ¹⁰⁵,
V.I. Rud ⁹⁷, C. Rudolph ⁴⁴, F. Rühr ⁷, A. Ruiz-Martinez ⁶³, L. Rumyantsev ⁶⁴, Z. Rurikova ⁴⁸,
N.A. Rusakovich ⁶⁴, A. Ruschke ⁹⁸, J.P. Rutherford ⁷, N. Ruthmann ⁴⁸, P. Ruzicka ¹²⁵, Y.F. Ryabov ¹²¹,
M. Rybar ¹²⁷, G. Rybkin ¹¹⁵, N.C. Ryder ¹¹⁸, A.F. Saavedra ¹⁵⁰, I. Sadeh ¹⁵³, H.F-W. Sadrozinski ¹³⁷,
R. Sadykov ⁶⁴, F. Safai Tehrani ^{132a}, H. Sakamoto ¹⁵⁵, G. Salamanna ⁷⁵, A. Salamon ^{133a}, M. Saleem ¹¹¹,
D. Salek ³⁰, D. Salihagic ⁹⁹, A. Salnikov ¹⁴³, J. Salt ¹⁶⁷, B.M. Salvachua Ferrando ⁶, D. Salvatore ^{37a,37b},
F. Salvatore ¹⁴⁹, A. Salvucci ¹⁰⁴, A. Salzburger ³⁰, D. Sampsonidis ¹⁵⁴, B.H. Samset ¹¹⁷, A. Sanchez ^{102a,102b},
V. Sanchez Martinez ¹⁶⁷, H. Sandaker ¹⁴, H.G. Sander ⁸¹, M.P. Sanders ⁹⁸, M. Sandhoff ¹⁷⁵, T. Sandoval ²⁸,
C. Sandoval ¹⁶², R. Sandstroem ⁹⁹, D.P.C. Sankey ¹²⁹, A. Sansoni ⁴⁷, C. Santamarina Rios ⁸⁵, C. Santoni ³⁴,
R. Santonicò ^{133a,133b}, H. Santos ^{124a}, I. Santoyo Castillo ¹⁴⁹, J.G. Saraiva ^{124a}, T. Sarangi ¹⁷³,
E. Sarkisyan-Grinbaum ⁸, B. Sarrazin ²¹, F. Sarri ^{122a,122b}, G. Sartisohn ¹⁷⁵, O. Sasaki ⁶⁵, Y. Sasaki ¹⁵⁵,
N. Sasao ⁶⁷, I. Satsounkevitch ⁹⁰, G. Sauvage ^{5,*}, E. Sauvan ⁵, J.B. Sauvan ¹¹⁵, P. Savard ^{158,f}, V. Savinov ¹²³,
D.O. Savu ³⁰, L. Sawyer ^{25,n}, D.H. Saxon ⁵³, J. Saxon ¹²⁰, C. Sbarra ^{20a}, A. Sbrizzi ^{20a,20b}, D.A. Scannicchio ¹⁶³,
M. Scarella ¹⁵⁰, J. Schaarschmidt ¹¹⁵, P. Schacht ⁹⁹, D. Schaefer ¹²⁰, U. Schäfer ⁸¹, A. Schaelicke ⁴⁶,
S. Schaepe ²¹, S. Schaetzl ^{58b}, A.C. Schaffer ¹¹⁵, D. Schaile ⁹⁸, R.D. Schamberger ¹⁴⁸, V. Scharf ^{58a},
V.A. Schegelsky ¹²¹, D. Scheirich ⁸⁷, M. Schernau ¹⁶³, M.I. Scherzer ³⁵, C. Schiavi ^{50a,50b}, J. Schieck ⁹⁸,
M. Schioppa ^{37a,37b}, S. Schlenker ³⁰, E. Schmidt ⁴⁸, K. Schmieden ²¹, C. Schmitt ⁸¹, S. Schmitt ^{58b},
B. Schneider ¹⁷, U. Schnoor ⁴⁴, L. Schoeffel ¹³⁶, A. Schoening ^{58b}, A.L.S. Schorlemmer ⁵⁴, M. Schott ³⁰,
D. Schouten ^{159a}, J. Schovancova ¹²⁵, M. Schram ⁸⁵, C. Schroeder ⁸¹, N. Schroer ^{58c}, M.J. Schultens ²¹,
J. Schultes ¹⁷⁵, H.-C. Schultz-Coulon ^{58a}, H. Schulz ¹⁶, M. Schumacher ⁴⁸, B.A. Schumm ¹³⁷, Ph. Schune ¹³⁶,
A. Schwartzman ¹⁴³, Ph. Schwegler ⁹⁹, Ph. Schwemling ⁷⁸, R. Schwienhorst ⁸⁸, J. Schwindling ¹³⁶,
T. Schwindt ²¹, M. Schwoerer ⁵, F.G. Sciaccà ¹⁷, E. Scifo ¹¹⁵, G. Sciolla ²³, W.G. Scott ¹²⁹, J. Searcy ¹¹⁴,
G. Sedov ⁴², E. Sedykh ¹²¹, S.C. Seidel ¹⁰³, A. Seiden ¹³⁷, F. Seifert ⁴⁴, J.M. Seixas ^{24a}, G. Sekhniaidze ^{102a},
S.J. Sekula ⁴⁰, K.E. Selbach ⁴⁶, D.M. Seliverstov ¹²¹, B. Sellden ^{146a}, G. Sellers ⁷³, M. Seman ^{144b},
N. Semprini-Cesari ^{20a,20b}, C. Serfon ³⁰, L. Serin ¹¹⁵, L. Serkin ⁵⁴, R. Seuster ^{159a}, H. Severini ¹¹¹, A. Sfyrla ³⁰,
E. Shabalina ⁵⁴, M. Shamim ¹¹⁴, L.Y. Shan ^{33a}, J.T. Shank ²², Q.T. Shao ⁸⁶, M. Shapiro ¹⁵, P.B. Shatalov ⁹⁵,
K. Shaw ^{164a,164c}, D. Sherman ¹⁷⁶, P. Sherwood ⁷⁷, S. Shimizu ¹⁰¹, M. Shimojima ¹⁰⁰, T. Shin ⁵⁶,
M. Shiyakova ⁶⁴, A. Shmeleva ⁹⁴, M.J. Shochet ³¹, D. Short ¹¹⁸, S. Shrestha ⁶³, E. Shulga ⁹⁶, M.A. Shupe ⁷,
P. Sicho ¹²⁵, A. Sidoti ^{132a}, F. Siegert ⁴⁸, Dj. Sijacki ^{13a}, O. Silbert ¹⁷², J. Silva ^{124a}, Y. Silver ¹⁵³,
D. Silverstein ¹⁴³, S.B. Silverstein ^{146a}, V. Simak ¹²⁶, O. Simard ¹³⁶, Lj. Simic ^{13a}, S. Simion ¹¹⁵, E. Simioni ⁸¹,
B. Simmons ⁷⁷, R. Simoniello ^{89a,89b}, M. Simonyan ³⁶, P. Sinervo ¹⁵⁸, N.B. Sinev ¹¹⁴, V. Sipica ¹⁴¹,
G. Siragusa ¹⁷⁴, A. Sircar ²⁵, A.N. Sisakyan ^{64,*}, S.Yu. Sivoklokov ⁹⁷, J. Sjölin ^{146a,146b}, T.B. Sjursen ¹⁴,
L.A. Skinnari ¹⁵, H.P. Skottowe ⁵⁷, K. Skovpen ¹⁰⁷, P. Skubic ¹¹¹, M. Slater ¹⁸, T. Slavicek ¹²⁶, K. Sliwa ¹⁶¹,
V. Smakhtin ¹⁷², B.H. Smart ⁴⁶, L. Smestad ¹¹⁷, S.Yu. Smirnov ⁹⁶, Y. Smirnov ⁹⁶, L.N. Smirnova ⁹⁷,
O. Smirnova ⁷⁹, B.C. Smith ⁵⁷, K.M. Smith ⁵³, M. Smizanska ⁷¹, K. Smolek ¹²⁶, A.A. Snesarev ⁹⁴,
S.W. Snow ⁸², J. Snow ¹¹¹, S. Snyder ²⁵, R. Sobie ^{169,l}, J. Sodomka ¹²⁶, A. Soffer ¹⁵³, C.A. Solans ³⁰,
M. Solar ¹²⁶, J. Solc ¹²⁶, E.Yu. Soldatov ⁹⁶, U. Soldevila ¹⁶⁷, E. Solfaroli Camillocci ^{132a,132b},
A.A. Solodkov ¹²⁸, O.V. Solovyanov ¹²⁸, V. Solovyev ¹²¹, N. Soni ¹, A. Sood ¹⁵, V. Sopko ¹²⁶, B. Sopko ¹²⁶,
M. Sosebee ⁸, R. Soualah ^{164a,164c}, P. Soueid ⁹³, A. Soukharev ¹⁰⁷, D. South ⁴², S. Spagnolo ^{72a,72b},
F. Spanò ⁷⁶, R. Spighi ^{20a}, G. Spigo ³⁰, R. Spiwoks ³⁰, M. Spousta ^{127,ai}, T. Spreitzer ¹⁵⁸, B. Spurlock ⁸,
R.D. St. Denis ⁵³, J. Stahlman ¹²⁰, R. Stamen ^{58a}, E. Stancka ³⁹, R.W. Stanek ⁶, C. Stanescu ^{134a},
M. Stanescu-Bellu ⁴², M.M. Stanitzki ⁴², S. Stapnes ¹¹⁷, E.A. Starchenko ¹²⁸, J. Stark ⁵⁵, P. Staroba ¹²⁵,
P. Starovoitov ⁴², R. Staszewski ³⁹, A. Staude ⁹⁸, P. Stavina ^{144a,*}, G. Steele ⁵³, P. Steinbach ⁴⁴,
P. Steinberg ²⁵, I. Stekl ¹²⁶, B. Stelzer ¹⁴², H.J. Stelzer ⁸⁸, O. Stelzer-Chilton ^{159a}, H. Stenzel ⁵², S. Stern ⁹⁹,
G.A. Stewart ³⁰, J.A. Stillings ²¹, M.C. Stockton ⁸⁵, M. Stoebe ⁸⁵, K. Stoerig ⁴⁸, G. Stoica ^{26a}, S. Stonjek ⁹⁹,
P. Strachota ¹²⁷, A.R. Stradling ⁸, A. Straessner ⁴⁴, J. Strandberg ¹⁴⁷, S. Strandberg ^{146a,146b}, A. Strandlie ¹¹⁷,
M. Strang ¹⁰⁹, E. Strauss ¹⁴³, M. Strauss ¹¹¹, P. Strizenec ^{144b}, R. Ströhmer ¹⁷⁴, D.M. Strom ¹¹⁴,
J.A. Strong ^{76,*}, R. Stroynowski ⁴⁰, B. Stugu ¹⁴, I. Stumer ^{25,*}, J. Stupak ¹⁴⁸, P. Sturm ¹⁷⁵, N.A. Styles ⁴²,
D.A. Soh ^{151,v}, D. Su ¹⁴³, HS. Subramania ³, R. Subramaniam ²⁵, A. Succurro ¹², Y. Sugaya ¹¹⁶, C. Suhr ¹⁰⁶,

- M. Suk ¹²⁷, V.V. Sulin ⁹⁴, S. Sultansoy ^{4d}, T. Sumida ⁶⁷, X. Sun ⁵⁵, J.E. Sundermann ⁴⁸, K. Suruliz ¹³⁹, G. Susinno ^{37a,37b}, M.R. Sutton ¹⁴⁹, Y. Suzuki ⁶⁵, Y. Suzuki ⁶⁶, M. Svatos ¹²⁵, S. Swedish ¹⁶⁸, I. Sykora ^{144a}, T. Sykora ¹²⁷, J. Sánchez ¹⁶⁷, D. Ta ¹⁰⁵, K. Tackmann ⁴², A. Taffard ¹⁶³, R. Tafirout ^{159a}, N. Taiblum ¹⁵³, Y. Takahashi ¹⁰¹, H. Takai ²⁵, R. Takashima ⁶⁸, H. Takeda ⁶⁶, T. Takeshita ¹⁴⁰, Y. Takubo ⁶⁵, M. Talby ⁸³, A. Talyshев ^{107,h}, M.C. Tamsett ²⁵, K.G. Tan ⁸⁶, J. Tanaka ¹⁵⁵, R. Tanaka ¹¹⁵, S. Tanaka ¹³¹, S. Tanaka ⁶⁵, A.J. Tanasijczuk ¹⁴², K. Tani ⁶⁶, N. Tannoury ⁸³, S. Tapprogge ⁸¹, D. Tardif ¹⁵⁸, S. Tarem ¹⁵², F. Tarrade ²⁹, G.F. Tartarelli ^{89a}, P. Tas ¹²⁷, M. Tasevsky ¹²⁵, E. Tassi ^{37a,37b}, Y. Tayalati ^{135d}, C. Taylor ⁷⁷, F.E. Taylor ⁹², G.N. Taylor ⁸⁶, W. Taylor ^{159b}, M. Teinturier ¹¹⁵, F.A. Teischinger ³⁰, M. Teixeira Dias Castanheira ⁷⁵, P. Teixeira-Dias ⁷⁶, K.K. Temming ⁴⁸, H. Ten Kate ³⁰, P.K. Teng ¹⁵¹, S. Terada ⁶⁵, K. Terashi ¹⁵⁵, J. Terron ⁸⁰, M. Testa ⁴⁷, R.J. Teuscher ^{158,l}, J. Therhaag ²¹, T. Theveneaux-Pelzer ⁷⁸, S. Thoma ⁴⁸, J.P. Thomas ¹⁸, E.N. Thompson ³⁵, P.D. Thompson ¹⁸, P.D. Thompson ¹⁵⁸, A.S. Thompson ⁵³, L.A. Thomsen ³⁶, E. Thomson ¹²⁰, M. Thomson ²⁸, W.M. Thong ⁸⁶, R.P. Thun ⁸⁷, F. Tian ³⁵, M.J. Tibbetts ¹⁵, T. Tic ¹²⁵, V.O. Tikhomirov ⁹⁴, Y.A. Tikhonov ^{107,h}, S. Timoshenko ⁹⁶, E. Tiouchichine ⁸³, P. Tipton ¹⁷⁶, S. Tisserant ⁸³, T. Todorov ⁵, S. Todorova-Nova ¹⁶¹, B. Togerson ¹⁶³, J. Tojo ⁶⁹, S. Tokár ^{144a}, K. Tokushuku ⁶⁵, K. Tollefson ⁸⁸, M. Tomoto ¹⁰¹, L. Tompkins ³¹, K. Tomis ¹⁰³, A. Tonoyan ¹⁴, C. Topfel ¹⁷, N.D. Topilin ⁶⁴, E. Torrence ¹¹⁴, H. Torres ⁷⁸, E. Torró Pastor ¹⁶⁷, J. Toth ^{83,ae}, F. Touchard ⁸³, D.R. Tovey ¹³⁹, T. Trefzger ¹⁷⁴, L. Tremblet ³⁰, A. Tricoli ³⁰, I.M. Trigger ^{159a}, S. Trincaz-Duvoid ⁷⁸, M.F. Tripiana ⁷⁰, N. Triplett ²⁵, W. Trischuk ¹⁵⁸, B. Trocmé ⁵⁵, C. Troncon ^{89a}, M. Trottier-McDonald ¹⁴², P. True ⁸⁸, M. Trzebinski ³⁹, A. Trzupek ³⁹, C. Tsarouchas ³⁰, J.-C.-L. Tseng ¹¹⁸, M. Tsiakiris ¹⁰⁵, P.V. Tsiareshka ⁹⁰, D. Tsionou ^{5,aj}, G. Tsipolitis ¹⁰, S. Tsiskaridze ¹², V. Tsiskaridze ⁴⁸, E.G. Tskhadadze ^{51a}, I.I. Tsukerman ⁹⁵, V. Tsulaia ¹⁵, J.-W. Tsung ²¹, S. Tsuno ⁶⁵, D. Tsybychev ¹⁴⁸, A. Tua ¹³⁹, A. Tudorache ^{26a}, V. Tudorache ^{26a}, J.M. Tuggle ³¹, M. Turala ³⁹, D. Turecek ¹²⁶, I. Turk Cakir ^{4e}, R. Turra ^{89a,89b}, P.M. Tuts ³⁵, A. Tykhonov ⁷⁴, M. Tylmad ^{146a,146b}, M. Tyndel ¹²⁹, G. Tzanakos ⁹, K. Uchida ²¹, I. Ueda ¹⁵⁵, R. Ueno ²⁹, M. Ughetto ⁸³, M. Ugland ¹⁴, M. Uhlenbrock ²¹, F. Ukegawa ¹⁶⁰, G. Unal ³⁰, A. Undrus ²⁵, G. Unel ¹⁶³, Y. Unno ⁶⁵, D. Urbaniec ³⁵, P. Urquijo ²¹, G. Usai ⁸, L. Vacavant ⁸³, V. Vacek ¹²⁶, B. Vachon ⁸⁵, S. Vahsen ¹⁵, S. Valentinetto ^{20a,20b}, A. Valero ¹⁶⁷, L. Valery ³⁴, S. Valkar ¹²⁷, E. Valladolid Gallego ¹⁶⁷, S. Vallecorsa ¹⁵², J.A. Valls Ferrer ¹⁶⁷, R. Van Berg ¹²⁰, P.C. Van Der Deijl ¹⁰⁵, R. van der Geer ¹⁰⁵, H. van der Graaf ¹⁰⁵, R. Van Der Leeuw ¹⁰⁵, E. van der Poel ¹⁰⁵, D. van der Ster ³⁰, N. van Eldik ³⁰, P. van Gemmeren ⁶, J. Van Nieuwkoop ¹⁴², I. van Vulpen ¹⁰⁵, M. Vanadia ⁹⁹, W. Vandelli ³⁰, A. Vaniachine ⁶, P. Vankov ⁴², F. Vannucci ⁷⁸, R. Vari ^{132a}, E.W. Varnes ⁷, T. Varol ⁸⁴, D. Varouchas ¹⁵, A. Vartapetian ⁸, K.E. Varvell ¹⁵⁰, V.I. Vassilakopoulos ⁵⁶, F. Vazeille ³⁴, T. Vazquez Schroeder ⁵⁴, G. Vegni ^{89a,89b}, J.J. Veillet ¹¹⁵, F. Veloso ^{124a}, R. Veness ³⁰, S. Veneziano ^{132a}, A. Ventura ^{72a,72b}, D. Ventura ⁸⁴, M. Venturi ⁴⁸, N. Venturi ¹⁵⁸, V. Vercesi ^{119a}, M. Verducci ¹³⁸, W. Verkerke ¹⁰⁵, J.C. Vermeulen ¹⁰⁵, A. Vest ⁴⁴, M.C. Vetterli ^{142,f}, I. Vichou ¹⁶⁵, T. Vickey ^{145b,ak}, O.E. Vickey Boeriu ^{145b}, G.H.A. Viehhauser ¹¹⁸, S. Viel ¹⁶⁸, M. Villa ^{20a,20b}, M. Villaplana Perez ¹⁶⁷, E. Vilucchi ⁴⁷, M.G. Vincter ²⁹, E. Vinek ³⁰, V.B. Vinogradov ⁶⁴, M. Virchaux ^{136,*}, J. Virzi ¹⁵, O. Vitells ¹⁷², M. Viti ⁴², I. Vivarelli ⁴⁸, F. Vives Vaque ³, S. Vlachos ¹⁰, D. Vladoiu ⁹⁸, M. Vlasak ¹²⁶, A. Vogel ²¹, P. Vokac ¹²⁶, G. Volpi ⁴⁷, M. Volpi ⁸⁶, G. Volpini ^{89a}, H. von der Schmitt ⁹⁹, H. von Radziewski ⁴⁸, E. von Toerne ²¹, V. Vorobel ¹²⁷, V. Vorwerk ¹², M. Vos ¹⁶⁷, R. Voss ³⁰, J.H. Vossebeld ⁷³, N. Vranjes ¹³⁶, M. Vranjes Milosavljevic ¹⁰⁵, V. Vrba ¹²⁵, M. Vreeswijk ¹⁰⁵, T. Vu Anh ⁴⁸, R. Vuillermet ³⁰, I. Vukotic ³¹, W. Wagner ¹⁷⁵, P. Wagner ²¹, H. Wahlen ¹⁷⁵, S. Wahrmund ⁴⁴, J. Wakabayashi ¹⁰¹, S. Walch ⁸⁷, J. Walder ⁷¹, R. Walker ⁹⁸, W. Walkowiak ¹⁴¹, R. Wall ¹⁷⁶, P. Waller ⁷³, B. Walsh ¹⁷⁶, C. Wang ⁴⁵, H. Wang ¹⁷³, H. Wang ⁴⁰, J. Wang ¹⁵¹, J. Wang ^{33a}, R. Wang ¹⁰³, S.M. Wang ¹⁵¹, T. Wang ²¹, A. Warburton ⁸⁵, 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 ¹⁵⁰, M.F. Watson ¹⁸, G. Watts ¹³⁸, S. Watts ⁸², A.T. Waugh ¹⁵⁰, B.M. Waugh ⁷⁷, M.S. Weber ¹⁷, J.S. Webster ³¹, A.R. Weidberg ¹¹⁸, P. Weigell ⁹⁹, J. Weingarten ⁵⁴, C. Weiser ⁴⁸, P.S. Wells ³⁰, T. Wenaus ²⁵, D. Wendland ¹⁶, Z. Weng ^{151,v}, T. Wengler ³⁰, S. Wenig ³⁰, N. Wermes ²¹, M. Werner ⁴⁸, P. Werner ³⁰, M. Werth ¹⁶³, M. Wessels ^{58a}, J. Wetter ¹⁶¹, C. Weydert ⁵⁵, K. Whalen ²⁹, A. White ⁸, M.J. White ⁸⁶, S. White ^{122a,122b}, S.R. Whitehead ¹¹⁸, D. Whiteson ¹⁶³, D. Whittington ⁶⁰, D. Wicke ¹⁷⁵, F.J. Wickens ¹²⁹, W. Wiedenmann ¹⁷³, M. Wieler ¹²⁹, P. Wienemann ²¹, C. Wiglesworth ⁷⁵, L.A.M. Wiik-Fuchs ²¹, P.A. Wijeratne ⁷⁷, A. Wildauer ⁹⁹, M.A. Wildt ^{42,s}, I. Wilhelm ¹²⁷, H.G. Wilkens ³⁰, J.Z. Will ⁹⁸, E. Williams ³⁵, H.H. Williams ¹²⁰, S. Williams ²⁸, W. Willis ³⁵, S. Willocq ⁸⁴, J.A. Wilson ¹⁸, M.G. Wilson ¹⁴³, A. Wilson ⁸⁷, I. Wingerter-Seez ⁵,

S. Winkelmann⁴⁸, F. Winklmeier³⁰, M. Wittgen¹⁴³, S.J. Wollstadt⁸¹, M.W. Wolter³⁹, H. Wolters^{124a,i}, W.C. Wong⁴¹, G. Wooden⁸⁷, B.K. Wosiek³⁹, J. Wotschack³⁰, M.J. Woudstra⁸², K.W. Wozniak³⁹, K. Wright⁵³, M. Wright⁵³, B. Wrona⁷³, S.L. Wu¹⁷³, X. Wu⁴⁹, Y. Wu^{33b,al}, E. Wulf³⁵, B.M. Wynne⁴⁶, S. Xella³⁶, M. Xiao¹³⁶, S. Xie⁴⁸, C. Xu^{33b,z}, D. Xu^{33a}, L. Xu^{33b}, B. Yabsley¹⁵⁰, S. Yacoob^{145a,am}, M. Yamada⁶⁵, H. Yamaguchi¹⁵⁵, A. Yamamoto⁶⁵, K. Yamamoto⁶³, S. Yamamoto¹⁵⁵, T. Yamamura¹⁵⁵, T. Yamanaka¹⁵⁵, K. Yamauchi¹⁰¹, T. Yamazaki¹⁵⁵, Y. Yamazaki⁶⁶, Z. Yan²², H. Yang^{33e}, H. Yang¹⁷³, U.K. Yang⁸², Y. Yang¹⁰⁹, Z. Yang^{146a,146b}, S. Yanush⁹¹, L. Yao^{33a}, Y. Yasu⁶⁵, E. Yatsenko⁴², J. Ye⁴⁰, S. Ye²⁵, A.L. Yen⁵⁷, M. Yilmaz^{4c}, R. Yoosoofmiya¹²³, K. Yorita¹⁷¹, R. Yoshida⁶, K. Yoshihara¹⁵⁵, C. Young¹⁴³, C.J. Young¹¹⁸, S. Youssef²², D. Yu²⁵, D.R. Yu¹⁵, J. Yu⁸, J. Yu¹¹², L. Yuan⁶⁶, A. Yurkewicz¹⁰⁶, B. Zabinski³⁹, R. Zaidan⁶², A.M. Zaitsev¹²⁸, L. Zanello^{132a,132b}, D. Zanzi⁹⁹, A. Zaytsev²⁵, C. Zeitnitz¹⁷⁵, M. Zeman¹²⁶, A. Zemla³⁹, O. Zenin¹²⁸, T. Ženiš^{144a}, Z. Zinonos^{122a,122b}, D. Zerwas¹¹⁵, G. Zevi della Porta⁵⁷, D. Zhang⁸⁷, H. Zhang⁸⁸, J. Zhang⁶, X. Zhang^{33d}, Z. Zhang¹¹⁵, L. Zhao¹⁰⁸, Z. Zhao^{33b}, A. Zhemchugov⁶⁴, J. Zhong¹¹⁸, B. Zhou⁸⁷, N. Zhou¹⁶³, Y. Zhou¹⁵¹, C.G. Zhu^{33d}, H. Zhu⁴², J. Zhu⁸⁷, Y. Zhu^{33b}, X. Zhuang⁹⁸, V. Zhuravlov⁹⁹, A. Zibell⁹⁸, D. Ziemska⁶⁰, N.I. Zimin⁶⁴, R. Zimmermann²¹, S. Zimmermann²¹, S. Zimmermann⁴⁸, M. Ziolkowski¹⁴¹, R. Zitoun⁵, L. Živković³⁵, V.V. Zmouchko^{128,*}, G. Zobernig¹⁷³, A. Zoccoli^{20a,20b}, M. zur Nedden¹⁶, V. Zutshi¹⁰⁶, L. Zwalski³⁰

¹ School of Chemistry and Physics, University of Adelaide, Adelaide, Australia² Physics Department, SUNY Albany, Albany, NY, United States³ Department of Physics, University of Alberta, Edmonton, AB, Canada⁴ (a) Department of Physics, Ankara University, Ankara; (b) Department of Physics, Dumlupinar University, Kutahya; (c) Department of Physics, Gazi University, Ankara; (d) Division of Physics, TOBB University of Economics and Technology, Ankara; (e) Turkish Atomic Energy Authority, Ankara, Turkey⁵ LAPP, CNRS/IN2P3 and Université de Savoie, Annecy-le-Vieux, France⁶ High Energy Physics Division, Argonne National Laboratory, Argonne, IL, United States⁷ Department of Physics, University of Arizona, Tucson, AZ, United States⁸ Department of Physics, The University of Texas at Arlington, Arlington, TX, United States⁹ Physics Department, University of Athens, Athens, Greece¹⁰ Physics Department, National Technical University of Athens, Zografou, Greece¹¹ Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan¹² Institut de Física d'Altes Energies and Departament de Física de la Universitat Autònoma de Barcelona and ICREA, Barcelona, Spain¹³ (a) Institute of Physics, University of Belgrade, Belgrade; (b) Vinca Institute of Nuclear Sciences, University of Belgrade, Belgrade, Serbia¹⁴ Department for Physics and Technology, University of Bergen, Bergen, Norway¹⁵ Physics Division, Lawrence Berkeley National Laboratory and University of California, Berkeley, CA, United States¹⁶ Department of Physics, Humboldt University, Berlin, Germany¹⁷ Albert Einstein Center for Fundamental Physics and Laboratory for High Energy Physics, University of Bern, Bern, Switzerland¹⁸ School of Physics and Astronomy, University of Birmingham, Birmingham, United Kingdom¹⁹ (a) Department of Physics, Bogazici University, Istanbul; (b) Division of Physics, Dogus University, Istanbul; (c) Department of Physics Engineering, Gaziantep University, Gaziantep; (d) Department of Physics, Istanbul Technical University, Istanbul, Turkey²⁰ (a) INFN Sezione di Bologna; (b) Dipartimento di Fisica, Università di Bologna, Bologna, Italy²¹ Physikalisches Institut, University of Bonn, Bonn, Germany²² Department of Physics, Boston University, Boston, MA, United States²³ Department of Physics, Brandeis University, Waltham, MA, United States²⁴ (a) Universidade Federal do Rio De Janeiro COPPE/EE/IF, Rio de Janeiro; (b) Federal University of Juiz de Fora (UFJF), Juiz de Fora; (c) Federal University of Sao Joao del Rei (UFSJ), Sao Joao del Rei; (d) Instituto de Física, Universidade de São Paulo, São Paulo, Brazil²⁵ Physics Department, Brookhaven National Laboratory, Upton, NY, United States²⁶ (a) National Institute of Physics and Nuclear Engineering, Bucharest; (b) University Politehnica Bucharest, Bucharest; (c) West University in Timisoara, Timisoara, Romania²⁷ Departamento de Física, Universidad de Buenos Aires, Buenos Aires, Argentina²⁸ Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom²⁹ Department of Physics, Carleton University, Ottawa, ON, Canada³⁰ CERN, Geneva, Switzerland³¹ Enrico Fermi Institute, University of Chicago, Chicago, IL, United States³² (a) Departamento de Física, Pontifícia Universidad Católica de Chile, Santiago; (b) Departamento de Física, Universidad Técnica Federico Santa María, Valparaíso, Chile³³ (a) Institute of High Energy Physics, Chinese Academy of Sciences, Beijing; (b) Department of Modern Physics, University of Science and Technology of China, Anhui; (c) Department of Physics, Nanjing University, Jiangsu; (d) School of Physics, Shandong University, Shandong; (e) Physics Department, Shanghai Jiao Tong University, Shanghai, China³⁴ Laboratoire de Physique Corpusculaire, Clermont Université and Université Blaise Pascal and CNRS/IN2P3, Clermont-Ferrand, France³⁵ Nevis Laboratory, Columbia University, Irvington, NY, United States³⁶ Niels Bohr Institute, University of Copenhagen, Kobenhavn, Denmark³⁷ (a) INFN Gruppo Collegato di Cosenza; (b) Dipartimento di Fisica, Università della Calabria, Arcavata di Rende, Italy³⁸ AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Krakow, Poland³⁹ The Henryk Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences, Krakow, Poland⁴⁰ Physics Department, Southern Methodist University, Dallas, TX, United States⁴¹ Physics Department, University of Texas at Dallas, Richardson, TX, United States⁴² DESY, Hamburg and Zeuthen, Germany⁴³ Institut für Experimentelle Physik IV, Technische Universität Dortmund, Dortmund, Germany⁴⁴ Institut für Kern- und Teilchenphysik, Technical University Dresden, Dresden, Germany⁴⁵ Department of Physics, Duke University, Durham, NC, United States⁴⁶ SUPA – School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom⁴⁷ INFN Laboratori Nazionali di Frascati, Frascati, Italy⁴⁸ Fakultät für Mathematik und Physik, Albert-Ludwigs-Universität, Freiburg, Germany⁴⁹ Section de Physique, Université de Genève, Geneva, Switzerland⁵⁰ (a) INFN Sezione di Genova; (b) Dipartimento di Fisica, Università di Genova, Genova, Italy

- ⁵¹ (a) *E. Andronikashvili Institute of Physics, Iv. Javakhishvili Tbilisi State University, Tbilisi;* (b) *High Energy Physics Institute, Tbilisi State University, Tbilisi, Georgia*
- ⁵² *II Physikalischs Institut, Justus-Liebig-Universität Giessen, Giessen, Germany*
- ⁵³ *SUPA – School of Physics and Astronomy, University of Glasgow, Glasgow, United Kingdom*
- ⁵⁴ *II Physikalischs 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, VA, United States*
- ⁵⁷ *Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge, MA, United States*
- ⁵⁸ (a) *Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Heidelberg;* (b) *Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg;* (c) *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, IN, United States*
- ⁶¹ *Institut für Astro- und Teilchenphysik, Leopold-Franzens-Universität, Innsbruck, Austria*
- ⁶² *University of Iowa, Iowa City, IA, United States*
- ⁶³ *Department of Physics and Astronomy, Iowa State University, Ames, IA, United States*
- 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*
- ⁷² (a) *INFN Sezione di Lecce;* (b) *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 *Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France*
- ⁷⁹ *Fysiska institutionen, Lunds universitet, Lund, Sweden*
- ⁸⁰ *Departamento de Física Teórica C-15, Universidad Autónoma de Madrid, Madrid, Spain*
- ⁸¹ *Institut für Physik, Universität Mainz, Mainz, Germany*
- ⁸² *School of Physics and Astronomy, University of Manchester, Manchester, United Kingdom*
- ⁸³ *CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France*
- ⁸⁴ *Department of Physics, University of Massachusetts, Amherst, MA, United States*
- ⁸⁵ *Department of Physics, McGill University, Montreal, QC, Canada*
- ⁸⁶ *School of Physics, University of Melbourne, Victoria, Australia*
- ⁸⁷ *Department of Physics, The University of Michigan, Ann Arbor, MI, United States*
- ⁸⁸ *Department of Physics and Astronomy, Michigan State University, East Lansing, MI, United States*
- ⁸⁹ (a) *INFN Sezione di Milano;* (b) *Dipartimento di Fisica, Università di Milano, Milano, Italy*
- ⁹⁰ *B.I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk, Belarus*
- ⁹¹ *National Scientific and Educational Centre for Particle and High Energy Physics, Minsk, Belarus*
- ⁹² *Department of Physics, Massachusetts Institute of Technology, Cambridge, MA, United States*
- ⁹³ *Group of Particle Physics, University of Montreal, Montreal, QC, Canada*
- ⁹⁴ *P.N. Lebedev Institute of Physics, Academy of Sciences, Moscow, Russia*
- ⁹⁵ *Institute for Theoretical and Experimental Physics (ITEP), Moscow, Russia*
- ⁹⁶ *Moscow Engineering and Physics Institute (MEPhI), Moscow, Russia*
- ⁹⁷ *Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia*
- ⁹⁸ *Fakultät für Physik, Ludwig-Maximilians-Universität München, München, Germany*
- ⁹⁹ *Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), München, Germany*
- ¹⁰⁰ *Nagasaki Institute of Applied Science, Nagasaki, Japan*
- ¹⁰¹ *Graduate School of Science and Kobayashi-Maskawa Institute, Nagoya University, Nagoya, Japan*
- ¹⁰² (a) *INFN Sezione di Napoli;* (b) *Dipartimento di Scienze Fisiche, Università di Napoli, Napoli, Italy*
- ¹⁰³ *Department of Physics and Astronomy, University of New Mexico, Albuquerque, NM, United States*
- ¹⁰⁴ *Institute for Mathematics, Astrophysics and Particle Physics, Radboud University Nijmegen/Nikhef, Nijmegen, Netherlands*
- ¹⁰⁵ *Nikhef National Institute for Subatomic Physics and University of Amsterdam, Amsterdam, Netherlands*
- ¹⁰⁶ *Department of Physics, Northern Illinois University, DeKalb, IL, United States*
- ¹⁰⁷ *Budker Institute of Nuclear Physics, SB RAS, Novosibirsk, Russia*
- ¹⁰⁸ *Department of Physics, New York University, New York, NY, United States*
- ¹⁰⁹ *Ohio State University, Columbus, OH, United States*
- ¹¹⁰ *Faculty of Science, Okayama University, Okayama, Japan*
- ¹¹¹ *Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman, OK, United States*
- ¹¹² *Department of Physics, Oklahoma State University, Stillwater, OK, United States*
- ¹¹³ *Palacký University, RCPMT, Olomouc, Czech Republic*
- ¹¹⁴ *Center for High Energy Physics, University of Oregon, Eugene, OR, United States*
- ¹¹⁵ *LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France*
- ¹¹⁶ *Graduate School of Science, Osaka University, Osaka, Japan*
- ¹¹⁷ *Department of Physics, University of Oslo, Oslo, Norway*
- ¹¹⁸ *Department of Physics, Oxford University, Oxford, United Kingdom*
- ¹¹⁹ (a) *INFN Sezione di Pavia;* (b) *Dipartimento di Fisica, Università di Pavia, Pavia, Italy*
- ¹²⁰ *Department of Physics, University of Pennsylvania, Philadelphia, PA, United States*
- ¹²¹ *Petersburg Nuclear Physics Institute, Gatchina, Russia*
- ¹²² (a) *INFN Sezione di Pisa;* (b) *Dipartimento di Fisica E. Fermi, Università di Pisa, Pisa, Italy*
- ¹²³ *Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh, PA, United States*
- ¹²⁴ (a) *Laboratorio de Instrumentacão e Física Experimental de Partículas – LIP, Lisboa, Portugal;* (b) *Departamento de Física Teórica y del Cosmos and CAFPE, Universidad de Granada, Granada, Spain*
- ¹²⁵ *Institute of Physics, Academy of Sciences of the Czech Republic, Praha, Czech Republic*
- ¹²⁶ *Czech Technical University in Prague, Praha, Czech Republic*
- ¹²⁷ *Faculty of Mathematics and Physics, Charles University in Prague, Praha, Czech Republic*

- 128 State Research Center Institute for High Energy Physics, Protvino, Russia
 129 Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom
 130 Physics Department, University of Regina, Regina, SK, Canada
 131 Ritsumeikan University, Kusatsu, Shiga, Japan
 132 ^(a) INFN Sezione di Roma I; ^(b) Dipartimento di Fisica, Università La Sapienza, Roma, Italy
 133 ^(a) INFN Sezione di Roma Tor Vergata; ^(b) Dipartimento di Fisica, Università di Roma Tor Vergata, Roma, Italy
 134 ^(a) INFN Sezione di Roma Tre; ^(b) Dipartimento di Fisica, Università Roma Tre, Roma, Italy
 135 ^(a) Faculté des Sciences Ain Chock, Réseau Universitaire de Physique des Hautes Energies – Université Hassan II, Casablanca; ^(b) Centre National de l'Energie des Sciences Techniques Nucléaires, Rabat; ^(c) Faculté des Sciences Semlalia, Université Cadi Ayyad, LPHEA, Marrakech; ^(d) Faculté des Sciences, Université Mohamed Premier and LPTPM, Oujda; ^(e) Faculté des sciences, Université Mohammed V-Agdal, Rabat, Morocco
 136 DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat à l'Energie Atomique et aux Energies Alternatives), Gif-sur-Yvette, France
 137 Santa Cruz Institute for Particle Physics, University of California Santa Cruz, Santa Cruz, CA, United States
 138 Department of Physics, University of Washington, Seattle, WA, United States
 139 Department of Physics and Astronomy, University of Sheffield, Sheffield, United Kingdom
 140 Department of Physics, Shinshu University, Nagano, Japan
 141 Fachbereich Physik, Universität Siegen, Siegen, Germany
 142 Department of Physics, Simon Fraser University, Burnaby, BC, Canada
 143 SLAC National Accelerator Laboratory, Stanford, CA, United States
 144 ^(a) Faculty of Mathematics, Physics & Informatics, Comenius University, Bratislava; ^(b) Department of Subnuclear Physics, Institute of Experimental Physics of the Slovak Academy of Sciences, Kosice, Slovak Republic
 145 ^(a) Department of Physics, University of Johannesburg, Johannesburg; ^(b) School of Physics, University of the Witwatersrand, Johannesburg, South Africa
 146 ^(a) Department of Physics, Stockholm University; ^(b) The Oskar Klein Centre, Stockholm, Sweden
 147 Physics Department, Royal Institute of Technology, Stockholm, Sweden
 148 Departments of Physics & Astronomy and Chemistry, Stony Brook University, Stony Brook, NY, United States
 149 Department of Physics and Astronomy, University of Sussex, Brighton, United Kingdom
 150 School of Physics, University of Sydney, Sydney, Australia
 151 Institute of Physics, Academia Sinica, Taipei, Taiwan
 152 Department of Physics, Technion: Israel Institute of Technology, Haifa, Israel
 153 Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel
 154 Department of Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece
 155 International Center for Elementary Particle Physics and Department of Physics, The University of Tokyo, Tokyo, Japan
 156 Graduate School of Science and Technology, Tokyo Metropolitan University, Tokyo, Japan
 157 Department of Physics, Tokyo Institute of Technology, Tokyo, Japan
 158 Department of Physics, University of Toronto, Toronto, ON, Canada
 159 ^(a) TRIUMF, Vancouver, BC; ^(b) Department of Physics and Astronomy, York University, Toronto, ON, Canada
 160 Faculty of Pure and Applied Sciences, University of Tsukuba, Tsukuba, Japan
 161 Department of Physics and Astronomy, Tufts University, Medford, MA, United States
 162 Centro de Investigaciones, Universidad Antonio Narino, Bogota, Colombia
 163 Department of Physics and Astronomy, University of California Irvine, Irvine, CA, United States
 164 ^(a) INFN Gruppo Collegato di Udine; ^(b) ICTP, Trieste; ^(c) Dipartimento di Chimica, Fisica e Ambiente, Università di Udine, Udine, Italy
 165 Department of Physics, University of Illinois, Urbana, IL, United States
 166 Department of Physics and Astronomy, University of Uppsala, Uppsala, Sweden
 167 Instituto de Física Corpuscular (IFIC) and Departamento de Física Atómica, Molecular y Nuclear and Departamento de Ingeniería Electrónica and Instituto de Microelectrónica de Barcelona (IMB-CNM), University of Valencia and CSIC, Valencia, Spain
 168 Department of Physics, University of British Columbia, Vancouver, BC, Canada
 169 Department of Physics and Astronomy, University of Victoria, Victoria, BC, Canada
 170 Department of Physics, University of Warwick, Coventry, United Kingdom
 171 Waseda University, Tokyo, Japan
 172 Department of Particle Physics, The Weizmann Institute of Science, Rehovot, Israel
 173 Department of Physics, University of Wisconsin, Madison, WI, United States
 174 Fakultät für Physik und Astronomie, Julius-Maximilians-Universität, Würzburg, Germany
 175 Fachbereich C Physik, Bergische Universität Wuppertal, Wuppertal, Germany
 176 Department of Physics, Yale University, New Haven, CT, United States
 177 Yerevan Physics Institute, Yerevan, Armenia
 178 Centre de Calcul de l'Institut National de Physique Nucléaire et de Physique des Particules (IN2P3), Villeurbanne, France

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

^b Also at Laboratorio de Instrumentacão e Física Experimental de Partículas – LIP, Lisboa, Portugal.

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

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

^e Also at Department of Physics, University of Johannesburg, Johannesburg, South Africa.

^f Also at TRIUMF, Vancouver, BC, Canada.

^g Also at Department of Physics, California State University, Fresno, CA, United States.

^h Also at Novosibirsk State University, Novosibirsk, Russia.

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

^j Also at Department of Physics, UASLP, San Luis Potosí, Mexico.

^k Also at Università di Napoli Parthenope, Napoli, Italy.

^l Also at Institute of Particle Physics (IPP), Canada.

^m Also at Department of Physics, Middle East Technical University, Ankara, Turkey.

ⁿ Also at Louisiana Tech University, Ruston, LA, United States.

^o Also at Departamento de Física and CEFITEC of Faculdade de Ciencias e Tecnologia, Universidade Nova de Lisboa, Caparica, Portugal.

^p Also at Department of Physics and Astronomy, University College London, London, United Kingdom.

^q Also at Department of Physics, University of Cape Town, Cape Town, South Africa.

^r Also at Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan.

^s Also at Institut für Experimentalphysik, Universität Hamburg, Hamburg, Germany.

^t Also at Manhattan College, New York, NY, United States.

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

- ^v Also at School of Physics and Engineering, Sun Yat-sen University, Guangzhou, China.
- ^w Also at Academia Sinica Grid Computing, Institute of Physics, Academia Sinica, Taipei, Taiwan.
- ^x Also at School of Physics, Shandong University, Shandong, China.
- ^y Also at Dipartimento di Fisica, Università La Sapienza, Roma, Italy.
- ^z Also at 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.
- ^{aa} Also at Section de Physique, Université de Genève, Geneva, Switzerland.
- ^{ab} Also at Departamento de Física, Universidade de Minho, Braga, Portugal.
- ^{ac} Also at Department of Physics, The University of Texas at Austin, Austin, TX, United States.
- ^{ad} Also at Department of Physics and Astronomy, University of South Carolina, Columbia, SC, United States.
- ^{ae} Also at Institute for Particle and Nuclear Physics, Wigner Research Centre for Physics, Budapest, Hungary.
- ^{af} Also at California Institute of Technology, Pasadena, CA, United States.
- ^{ag} Also at Institute of Physics, Jagiellonian University, Krakow, Poland.
- ^{ah} Also at LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France.
- ^{ai} Also at Nevis Laboratory, Columbia University, Irvington, NY, United States.
- ^{aj} Also at Department of Physics and Astronomy, University of Sheffield, Sheffield, United Kingdom.
- ^{ak} Also at Department of Physics, Oxford University, Oxford, United Kingdom.
- ^{al} Also at Department of Physics, The University of Michigan, Ann Arbor, MI, United States.
- ^{am} Also at Discipline of Physics, University of KwaZulu-Natal, Durban, South Africa.
- * Deceased.