



Measurement of the high-mass Drell–Yan differential cross-section in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector [☆]



ATLAS Collaboration ^{*}

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ABSTRACT

This Letter reports a measurement of the high-mass Drell–Yan differential cross-section in proton–proton collisions at a centre-of-mass energy of 7 TeV at the LHC. Based on an integrated luminosity of 4.9 fb^{-1} , the differential cross-section in the $Z/\gamma^* \rightarrow e^+e^-$ channel is measured with the ATLAS detector as a function of the invariant mass, m_{ee} , in the range $116 < m_{ee} < 1500$ GeV, for a fiducial region in which both the electron and the positron have transverse momentum $p_T > 25$ GeV and pseudorapidity $|\eta| < 2.5$. A comparison is made to various event generators and to the predictions of perturbative QCD calculations at next-to-next-to-leading order.

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1. Introduction

At hadron colliders, the Drell–Yan (DY) process [1], proceeding at tree level via the s -channel exchange of a virtual photon or Z boson, can produce charged lepton pairs over a wide range of invariant mass. The differential cross-section as a function of the invariant mass is described by perturbative QCD (pQCD) calculations at next-to-next-to-leading order (NNLO). Given the simple experimental signature and the low backgrounds, a small experimental uncertainty can be achieved on the measured invariant mass distribution allowing for a precision test of pQCD. The mass spectrum is also sensitive to the parton distribution functions (PDFs), in particular to the poorly known distribution of antiquarks at large x [2], where x can be interpreted, at leading order, as the fraction of the proton momentum carried by the interacting parton. Additionally, the production of DY dilepton pairs is a source of background for other Standard Model (SM) measurements, and the mass spectrum may be modified by new physics phenomena giving rise to, e.g., narrow resonances or an excess of high-mass pairs inconsistent with the known PDFs.

The differential cross-section for DY dilepton pair production in the high-mass range has been reported previously by the CMS [3], CDF [4] and D0 [5] Collaborations. With the ATLAS detector, total and differential cross-sections in a mass window of 66–116 GeV have been measured using the 2010 dataset [6]. In addition, searches for new physics in the high-mass range have been performed [7–9] and no deviations from the SM expectation were observed. This Letter reports an extension of these previous

analyses by providing a measurement of the DY cross-section, fully corrected for detector effects, in the dielectron channel as a function of the e^+e^- invariant mass, m_{ee} , up to 1500 GeV. To minimise model-dependent theoretical uncertainties, the cross-section is not extrapolated to the full phase space but is reported in a phase space only slightly extended with respect to the fiducial acceptance of the e^+ and e^- . The results are compared to NNLO pQCD calculations with next-to-leading-order (NLO) electroweak corrections from the FEWZ 3.1 [10,11] framework and to the predictions from three event generators.

2. The ATLAS detector

The ATLAS detector is described in detail in Ref. [12]. The two systems most relevant to this analysis are the inner tracking detector, surrounded by a superconducting solenoid providing a 2 T axial magnetic field, and the calorimeter. Charged-particle tracks and vertices are reconstructed with silicon pixel and microstrip detectors covering the pseudorapidity¹ range $|\eta| < 2.5$ and a straw-tube transition-radiation tracker covering $|\eta| < 2.0$. Within the region $|\eta| < 3.2$, electromagnetic calorimetry is provided by barrel and endcap detectors consisting of lead absorbers and liquid argon (LAr) as the active material, with fine lateral and longitudinal

¹ ATLAS uses a right-handed coordinate system with its origin at the nominal interaction point in the centre of the detector and the z -axis coinciding with the axis of the beam pipe. The x -axis points from the interaction point to the centre of the LHC ring, and the y -axis points upward. The pseudorapidity is defined in terms of the polar angle θ as $\eta = -\ln \tan(\theta/2)$, and ϕ is the azimuthal angle around the beam pipe with respect to the x -axis. The angular distance is defined as $\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2}$. Transverse momentum and energy are defined as $p_T = p \times \sin\theta$ and $E_T = E \times \sin\theta$, respectively.

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

segmentation within $|\eta| < 2.5$. The hadronic calorimeter is based on steel/scintillator tiles in the central region ($|\eta| < 1.7$) while the hadronic endcap calorimeters ($1.5 < |\eta| < 3.2$) use copper/LAr.

A three-level trigger system is used to select events. The first level is implemented in custom electronics and is followed by two software-based trigger levels. In 2011 the total output rate of events recorded for physics analysis was 200–300 Hz.

3. Simulated samples

Simulated data samples were generated in order to estimate backgrounds and correct the signal for the detector resolution, efficiency and acceptance. The PYTHIA 6.426 [13] and MC@NLO 4.02 [14] Monte Carlo (MC) generators were used to model the DY signal. In addition, SHERPA 1.3.1 [15] was used to produce signal samples with up to three additional partons, and the final result of the analysis is compared to the generator-level predictions from all three programs. MC@NLO was also used to simulate the $t\bar{t}$ background, while HERWIG 6.520 [16] was used for the diboson (WW , WZ or ZZ) backgrounds. MC@NLO was interfaced to HERWIG to model parton showers and fragmentation processes, and to JIMMY 4.31 [17] for underlying event simulation. All event generators were interfaced to PHOTOS 3.0 [18] to simulate QED final-state radiation (FSR), except for SHERPA which uses the method of Ref. [19].

The PYTHIA and HERWIG samples were generated using the modified leading-order (LO**) PDF set MRSTMCa1 [20] following the recommendations of Ref. [21], while the MC@NLO samples used the NLO CT10 [22] set. The SHERPA samples used the default CTEQ6L1 [23] PDF set of the generator.

All MC events were generated at $\sqrt{s} = 7$ TeV and include the full ATLAS detector simulation [24] based on GEANT4 [25]. Settings of MC parameters that describe properties of minimum bias events and the underlying event were chosen based on results from previous ATLAS measurements [26]. The effects of having on average nine interactions per bunch crossing (“pile-up”) were accounted for by overlaying simulated minimum bias events. To match the measured instantaneous luminosity profile of the LHC, MC events were reweighted to yield the same distribution of the mean number of interactions per bunch crossing as measured in data.

Several independent corrections were applied to the simulated samples, for the detector response, missing higher order terms in the generation of the signal events and for the modelling of the transverse momentum spectrum of the lepton pair. The electron² energy resolution was corrected to match that observed in data, following Ref. [27]. In addition, the efficiencies for electrons to pass requirements on the trigger, the reconstruction, and the particle identification in the MC simulation were corrected by scale factors, defined as the ratio of the measured efficiency in data to that in the simulation. The PYTHIA and MC@NLO signal predictions were reweighted to a NNLO pQCD calculation with m_{ee} -dependent K -factors obtained from a modified version of PHOZPR [28]. Additionally, NLO electroweak corrections, calculated using HORACE 3.1 [29], were applied to the PYTHIA MC sample. The $t\bar{t}$ sample was rescaled to its inclusive near-NNLO cross-section prediction [30,31] and the diboson samples were normalised to NLO cross-sections calculated using MCFM [32]. The PYTHIA signal MC sample was reweighted at generator level to a version that used an ATLAS tune found to yield a good agreement with the transverse momentum distribution of the Z boson observed in data [33]. This procedure gives an adequate description of the

transverse momentum distribution for the high m_{ee} region studied in this analysis.

4. Event selection

The analysis is based on the full 2011 data sample collected at $\sqrt{s} = 7$ TeV. The data were selected online by a trigger that required two electromagnetic (EM) energy deposits each with a transverse energy greater than 20 GeV. Applying trigger and data-quality requirements yields an integrated luminosity of $4.9 \pm 0.1 \text{ fb}^{-1}$. Events from these pp collisions are selected by requiring a collision vertex with at least three associated tracks, each with transverse momentum greater than 400 MeV. Events are then required to have at least two electron candidates as defined below.

Electron candidates are reconstructed from the energy deposits in the calorimeter matched to inner-detector tracks. The electron energy is measured in the calorimeter and its direction from the associated track. The calorimeter energy resolution is between 1% and 2% for high-energy electrons [27]. An energy scale correction obtained from an *in situ* calibration, using W/Z boson and J/ψ meson decays, following the recipe of Ref. [27], is applied to the data. The electron candidates are required to have a transverse energy $E_T > 25$ GeV and pseudorapidity $|\eta| < 2.47$, excluding the transition regions between the barrel and endcap calorimeters at $1.37 < |\eta| < 1.52$. They must satisfy the “medium” identification criteria based on shower shape, track-quality and track-cluster matching variables, which are inclusive of the shower shape criteria applied as part of the “loose” identification [27]. Additionally, the electron candidates must have an associated hit in the innermost pixel layer to suppress background from photon conversions.

If an event contains more than two electron candidates passing the above selection, the two with highest E_T are chosen. To further reduce the background from jet production, the leading (highest E_T) electron is required to be isolated by demanding that the sum of the transverse energy in the calorimeter cells in a cone of $\Delta R = 0.2$ around the electron direction is less than 7 GeV. This sum excludes the core of the electron energy deposition and is corrected for the E_T -dependent transverse shower leakage from the core, as well as for pile-up contributions.

After all selection requirements, a total of 26844 candidate events are found in the m_{ee} range considered. The dominant backgrounds are events containing one or two misidentified electron candidates, denoted W + jets and dijet. Other backgrounds arise from events containing two real electrons, originating from the dileptonic decays of pair-produced top quarks (denoted $t\bar{t}$) and from diboson production processes.

Of the dijet and W + jets background, the dijet component additionally contains multi-jet, heavy-flavour quark and γ + jet production. The W + jets includes pair-produced top quarks and single-top-quark production, where at least one electron comes from the misidentification of a jet or a heavy quark. A data-driven method is used to evaluate the sum of these components. The probability for a jet to be misidentified as an electron (the *fake rate*) is determined in an E_T - and η -dependent way from nine background-enriched samples recorded by different inclusive jet triggers. These triggers had E_T thresholds in the range 20–240 GeV, each with a different predefined rate achieved via the automatic rejection of a certain fraction of events, such that the nine samples were needed to collect sufficient background events over the full E_T range. In each of these jet-triggered samples, the fake rate is calculated as the fraction of electron candidates passing the “loose” identification requirement that also pass the “medium” requirement. Events containing electron candidates from W or Z boson decays are first removed by dedicated cuts in order to avoid bias from real electron contamination: W candidates are rejected by

² In the following electron can mean either electron or positron.

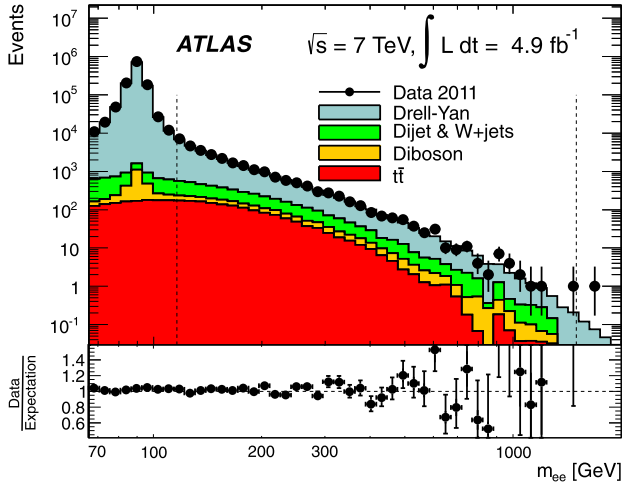


Fig. 1. Distribution of m_{ee} in data compared to the summed signal and background predictions, where the bin width is constant in $\log(m_{ee})$. The Drell–Yan signal is predicted from `PYTHIA` simulation and the combined dijet and W + jets contribution is estimated from data as described in the text. The dashed vertical lines indicate the mass range used for the differential cross-section measurement.

requiring low missing transverse energy and low transverse mass; and Z candidates are rejected if they contain two “medium” electrons. A weighted average of the fake rates obtained from the nine jet samples is then calculated. To estimate the total dijet plus W + jets background, a factor derived from the averaged fake rate is applied to events that pass the signal selection but with one or both electron candidates passing only the “loose” identification requirement and failing the “medium” requirement.

The $t\bar{t}$ and diboson backgrounds are estimated from MC simulation and account for up to 5% and 9% of the selected events, respectively. The overall level of agreement between data and the sum of the signal and background predictions is shown in Fig. 1.

5. Cross-section measurement

The differential cross-section, $d\sigma/dm_{ee}$, is measured in 13 bins of m_{ee} from 116 GeV to 1500 GeV in a fiducial region in which both electrons have transverse momentum $p_T > 25$ GeV and lie within $|\eta| < 2.5$. The cross-section and fiducial region are determined for two conventions regarding QED FSR corrections. For the Born-level result, the true (meaning without detector simulation) m_{ee} and electron kinematics are defined by the electrons originating from the Z/γ^* decay before FSR. At the *dressed* level, true final-state electrons after FSR are recombined with radiated photons within a cone of $\Delta R = 0.1$.

The cross-section is calculated from

$$\frac{d\sigma}{dm_{ee}} = \frac{N_{\text{data}} - N_{\text{bkg}}}{C_{\text{DY}} L_{\text{int}}} \frac{1}{\Gamma_{\text{bin}}}, \quad (1)$$

where N_{data} is the number of candidate events observed in a given bin of m_{ee} (of width Γ_{bin}), N_{bkg} is the total background in that bin and L_{int} is the integrated luminosity. The correction factor, C_{DY} , takes into account the efficiency of the signal selection and bin migration effects. It also includes the small extrapolation (about 10% to 13%) over the small region in $|\eta|$ that is excluded for reconstructed electron candidates ($1.37 < |\eta| < 1.52$ and $2.47 < |\eta| < 2.5$). The correction factor is defined as the number of MC-generated events that pass the signal selection in a bin of reconstructed m_{ee} , divided by the total number of generated events within the fiducial region, at the Born or dressed level, in the corresponding bin of true m_{ee} . It is obtained from the `PYTHIA` MC signal sample and corrected for differences in the reconstruction,

identification and trigger efficiencies between data and MC simulation. The value of C_{DY} varies from 0.55 (0.57) in the lowest bin to 0.70 (0.73) in the highest bin at the Born (dressed) level.

The m_{ee} resolution varies from approximately 3% at low m_{ee} to 1% at high m_{ee} . The purity, defined as the fraction of simulated events reconstructed in a given m_{ee} bin that have true m_{ee} in the same bin, ranges from 79% (82%) to 98% (98%) at the Born (dressed) level.

6. Systematic uncertainties

The main contributions to the systematic uncertainties are given in Table 1 and described below.

6.1. Background estimation

In the estimation of the dominant dijet and W + jets background, a systematic uncertainty of 11% is assigned to the E_T - and η -dependent fake rate, corresponding to the spread of this quantity as measured in the nine independent jet samples, in order to cover any possible bias introduced in the triggering of these background events. A further uncertainty on the fake rate of up to 11% arises due to the presence of remaining signal contamination in the background-enriched sample.

The total systematic uncertainty on the fake rate combines with a smaller effect (around 5%) from signal contamination in the sample where the fake rate is applied, to give a total uncertainty on the resulting background estimate of up to 16%. An additional systematic uncertainty can arise if the fake rate differs for different sources of fake electrons and the relative contribution of the different sources is not the same in the data sample where the fake rate is measured and the sample of events to which it is applied. It is found that b -jets have a higher fake rate than jets initiated by gluons or light quarks, but that the fraction of b -jets is small and similar in both samples. Conservatively taking this additional source of uncertainty into account, the overall uncertainty on the background is enlarged to 20%.

This 20% is added in quadrature to the statistical uncertainty of the sample to which the fake rate is applied; the latter uncertainty dominates in the highest two m_{ee} bins. The resulting overall uncertainty on the cross-section from the dijet and W + jets background varies between 1.3% and 7.9%, depending on m_{ee} .

Two alternative methods to estimate the dijet and W + jets background are considered as cross-checks. The first of these is similar to the baseline method but uses fake rates derived from loosely selected electrons collected by the EM signal trigger. Here the background-enriched sample is derived by employing a tag-and-probe technique selecting, among other requirements to suppress real electron contamination, a jet-like tag and a probe with the same charge. This method, being correlated to the baseline method due to the overlap of electron candidates passing the EM and jet triggers, yields very similar predictions with comparable systematic uncertainties. In the third method, the combined dijet plus W + jets background is estimated by performing a template fit to the isolation of the leading versus sub-leading electron. The background templates are obtained from data by reversing some of the identification requirements on one or both of the electrons, and the signal templates are made from the `PYTHIA` DY sample. No additional systematic uncertainty is assigned from the two cross-checks, as their results are in agreement with the baseline method.

The uncertainties on the diboson and $t\bar{t}$ background expectations include the theoretical uncertainties on their cross-sections, 5% for the dibosons [30] and 10% for $t\bar{t}$ [31]. At high m_{ee} , the statistical uncertainties on the simulated samples dominate,

Table 1

Summary of systematic uncertainties on the cross-section measurement, shown for the lowest and highest bin in m_{ee} . For some sources the lowest or highest uncertainty may lie in an intermediate bin. The data statistical uncertainties are also given for comparison.

Source of uncertainty	Uncertainty [%] in m_{ee} bin	
	116–130 GeV	1000–1500 GeV
Total background estimate (stat.)	0.1	7.6
Total background estimate (syst.)	1.3	3.1
Electron energy scale & resolution	2.1	3.3
Electron identification	2.3	2.5
Electron reconstruction	1.6	1.7
Bin-by-bin correction	1.5	1.5
Trigger efficiency	0.8	0.8
MC statistics (C_{DY} stat.)	0.7	0.4
MC modelling	0.2	0.3
Theoretical uncertainty	0.3	0.4
Total systematic uncertainty	4.2	9.8
Luminosity uncertainty	1.8	1.8
Data statistical uncertainty	1.1	50

exceeding 50% in the highest bin for both processes. The resulting uncertainty on the cross-section is small compared to the data-driven dijet and W + jets contributions, ranging from less than 0.3% at low m_{ee} to 2.0% in the highest m_{ee} bin. The uncertainty on the cross-section from the total background expectation is between 1.3% and 8.2%.

6.2. Electron reconstruction and identification

The reconstruction and identification efficiencies of electrons have been determined previously from data for electrons with E_T up to 50 GeV, using tag-and-probe methods in vector-boson decays, following the prescription of Ref. [27]. To extend the measurement range of the identification efficiency in E_T , a dedicated tag-and-probe measurement is made using $Z \rightarrow e^+e^-$ decays. It employs the isolation method, developed in Ref. [27] for $W \rightarrow e\nu$ final states, to estimate the background contamination. Here, η - and E_T -dependent background template distributions of the isolation are obtained from data by reversing some of the requirements applied in the electron identification criteria. The isolation quantity is defined in a similar way to that used in the selection of the leading electron in the signal sample. The background isolation templates are then normalised to data in the tail of the distributions where no contribution from signal is expected, both before and after applying the identification requirements, in order to estimate the background fraction in the probe sample. The identification efficiencies are found to be consistent with those obtained by the method of Ref. [27] in the common measurement range, and are stable for electrons with E_T up to 500 GeV.

The differences between the measured reconstruction and identification efficiencies and their values in MC simulation are taken as η - and E_T -dependent scale factors with which the MC-derived C_{DY} is corrected. An additional scale factor for the isolation requirement on the leading electron is also applied. Varying the scale factors for the electron reconstruction (identification) within their systematic uncertainties results in a change in the cross-section of up to 1.7% (2.6%).

6.3. Energy scale and resolution

Both the scale and resolution corrections, estimated from $Z \rightarrow e^+e^-$ events, are varied in the simulation within their uncertainties. The overall effect on the cross-section is between 1.0% and 3.3%.

Table 2

Measured differential cross-sections $\frac{d\sigma}{dm_{ee}}$ (in pb/GeV) at the Born and dressed levels for DY production of e^+e^- pairs in the fiducial region (electron $p_T > 25$ GeV and $|\eta| < 2.5$) with statistical (stat.) and systematic (syst.) uncertainties in %. The 1.8% luminosity uncertainty is not included.

m_{ee} [GeV]	$\frac{d\sigma}{dm_{ee}}$ (Born)		Stat. err. [%]	Syst. err. [%]
	$\frac{d\sigma}{dm_{ee}}$ (Born)	$\frac{d\sigma}{dm_{ee}}$ (dressed)		
116–130	2.24×10^{-1}	2.15×10^{-1}	1.1	4.2
130–150	1.02×10^{-1}	9.84×10^{-2}	1.4	4.3
150–170	5.12×10^{-2}	4.93×10^{-2}	2.0	4.6
170–190	2.84×10^{-2}	2.76×10^{-2}	2.7	4.7
190–210	1.87×10^{-2}	1.82×10^{-2}	3.0	5.3
210–230	1.07×10^{-2}	1.04×10^{-2}	4.4	6.1
230–250	8.23×10^{-3}	7.98×10^{-3}	5.2	5.9
250–300	4.66×10^{-3}	4.52×10^{-3}	4.3	5.8
300–400	1.70×10^{-3}	1.65×10^{-3}	5.1	5.9
400–500	4.74×10^{-4}	4.58×10^{-4}	9.4	6.3
500–700	1.46×10^{-4}	1.41×10^{-4}	11	5.7
700–1000	2.21×10^{-5}	2.13×10^{-5}	24	7.5
1000–1500	2.88×10^{-6}	2.76×10^{-6}	50	9.8

6.4. Bin-by-bin correction

The results obtained from the bin-by-bin correction are cross-checked using an iterative Bayesian approach [34] and found to be consistent. In addition, a consistency test is performed by correcting the MC@NLO signal sample using the PYTHIA-derived C_{DY} factor. The discrepancy between the sample corrected in this way and the true MC@NLO sample is about 1.5%. This is due to the slightly different shapes of the m_{ee} distribution from the two generators, considered to represent the possible shape difference between data and the PYTHIA simulation. This is conservatively added as a systematic uncertainty on the cross-section in all m_{ee} bins.

6.5. Trigger efficiency

Scale factors to account for the difference in the EM signal-trigger efficiency between data and simulation are obtained by measuring the efficiency in data and MC events using a tag-and-probe method. The $Z \rightarrow e^+e^-$ events are tagged by selecting events passing a single-electron trigger, thus providing one electron probe free of trigger bias to test against the signal-trigger requirements. The scale factors are very close to unity, and the effect on the cross-section of varying them within their systematic uncertainties is approximately 1%.

6.6. MC statistics and MC modelling

The finite number of events in the MC samples from which the C_{DY} factor is derived contribute an uncertainty of up to 2.4% on C_{DY} and the computed cross-section. Systematic uncertainties are associated with the use of the K -factors and with the reweighting of the PYTHIA signal MC events in order to better match the transverse momentum distribution of the Z bosons and the mean number of interactions per bunch crossing in the data. The effect of a further reweighting of the vertex position distribution in the z direction, not applied by default when calculating C_{DY} , is also taken as an uncertainty. These uncertainties enter into the calculation of C_{DY} and result in an overall uncertainty on the cross-section of less than 1%. Excellent agreement in the FSR predictions between PHOTOS and SANC [35,36] has been shown [37] and uncertainties related to the modelling of the detector response to low-energy photons from FSR are negligible.

6.7. Theoretical uncertainties

Several theoretical uncertainties apply to the extrapolation of the cross-section in $|\eta|$ from the measured region to the fiducial

region and thus contribute to an additional uncertainty on C_{DY} . To evaluate the effect of the choice of PDF, the calculation of C_{DY} using PYTHIA with its default PDF (MRSTMCa1) is compared to that obtained after reweighting to CT10 (NLO) and HERAPDF1.5 [38] (NLO). The largest difference between the reweighted results and the default is taken as the systematic uncertainty, and amounts to 0.2%. A further systematic uncertainty is calculated using the MC@NLO sample reweighted to the 52 CT10 eigenvector error sets, the result being 0.5% at most. Finally, comparisons are made between PYTHIA reweighted to the CT10 PDF and MC@NLO (which uses as default CT10), and cross-checked using FEWZ 2.1 at NLO using the CT10 PDF. The effect is at most 0.3%. These systematic uncertainties, which each have a different dependence on m_{ee} , are added in quadrature and together give a 0.2–0.5% uncertainty on the cross-section.

The contributions from the above sources of systematic uncertainty to the uncertainty on the measured cross-section are summarised in Table 1 for the lowest and highest bin in the m_{ee} range considered. The overall systematic uncertainty, excluding the luminosity uncertainty of 1.8% [39], rises from 4.2% in the lowest m_{ee} bin to 9.8% in the highest m_{ee} bin. The data statistical uncertainties increase from 1.1% to 50%.

7. Results and comparison to theory

The cross-sections obtained in the fiducial region (electron $p_T > 25$ GeV and $|\eta| < 2.5$) at the Born and dressed levels are given in Table 2. The difference between the two results is at most 4%. The precision of the measurement is limited by the statistical uncertainty on the data for $m_{ee} > 400$ GeV.

Fig. 2 shows the results at the dressed level, where they are compared to the predictions from PYTHIA, MC@NLO and SHERPA. No corrections have been applied to the generator-level predictions; instead, the prediction of each generator has been scaled globally to match the total number of events observed in data. The resulting scale factors are 1.23 for PYTHIA, 1.08 for MC@NLO and 1.39 for SHERPA. As expected, the only prediction at NLO in pQCD, from the MC@NLO generator, yields the scale factor closest to unity. The overall shape of the m_{ee} distribution from all three generators is consistent with the data.

Fig. 3 shows the differential cross-section at the Born level compared to calculations in the FEWZ 3.1 framework using various recent NNLO PDFs. The FEWZ 3.1 framework allows the (N)NLO QCD corrections to lepton pair production to be combined with the NLO electroweak corrections. It has been verified at NLO in QCD that the choice of the electroweak scheme, G_μ or $\alpha(m_Z)$ as introduced in Ref. [40], has an effect of at most 0.4% on the calculated cross-section after applying NLO electroweak corrections. The electroweak-corrected NNLO QCD predictions shown are calculated using the G_μ scheme. The electroweak corrections include a positive contribution from the irreducible, non-resonant photon-induced background, i.e., $\gamma\gamma \rightarrow e^+e^-$. This contribution is estimated at leading order (LO) using the MRST2004qed [41] PDF, currently the only set available that includes QED corrections to the proton PDF, by taking the average of the predictions obtained under the current and constituent quark mass schemes. The symmetric difference between the average and either scheme is assigned as the corresponding uncertainty on this additive correction, being approximately 50% and representing a 3% uncertainty on the cross-section prediction in the highest m_{ee} bin. The electroweak and photon-induced corrections were verified by SANC [35,36]. An additional small correction arises from single-boson production in which the final-state charged lepton radiates a real W or Z boson [42]. This is estimated using MADGRAPH 5 [43],

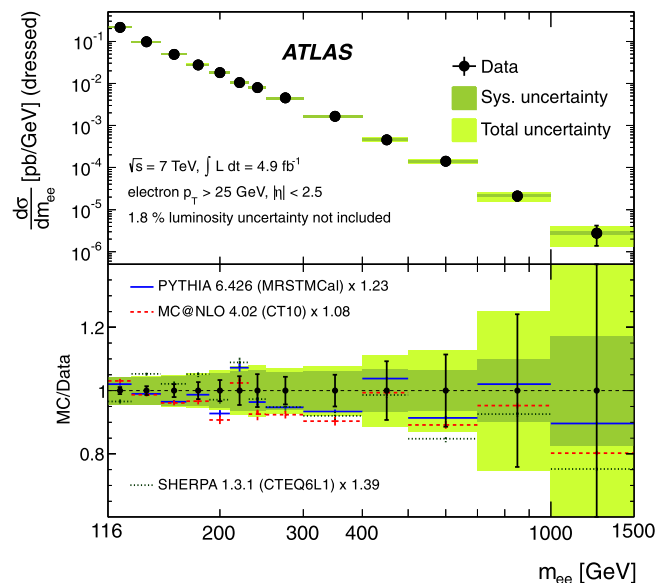


Fig. 2. Measured differential cross-section at the dressed level within the fiducial region (electron $p_T > 25$ GeV and $|\eta| < 2.5$) with statistical (error bars), systematic (dark shaded), and combined statistical and systematic (total, light shaded) uncertainties, excluding the 1.8% uncertainty on the luminosity. In the lower panel, the measurement is compared to the predictions of the PYTHIA, MC@NLO and SHERPA MC generators including their statistical uncertainties. No corrections have been applied to the cross-section predictions of the generators. Instead, the predictions of each generator have been scaled by a global factor as indicated on the ratio plots to match the total number of events observed in data.

following the prescription outlined in Ref. [42], to be at most 2%, in the highest m_{ee} bin.

It can be seen in Fig. 3 that the deviations between the MSTW2008 [2] and the CT10 [22], HERAPDF1.5 [38] and NNPDF2.3 [44] predictions are covered by the total uncertainty band assigned to the MSTW2008 prediction, which is dominated by the combined 68% confidence level (CL) PDF and α_s variation. At low m_{ee} the ABM11 [45] prediction lies above this theoretical uncertainty band, in part due to the ABM11 PDF set using a value of α_s outside of the 68% CL variation. The renormalisation and factorisation scale uncertainties contribute at most 1% to the theoretical uncertainty band in the highest m_{ee} bin, having been evaluated by varying both scales up or down together by a factor of two, using VRAP [46]. The size of the photon-induced contribution is similar to the sum of the PDF, α_s and scale uncertainties as can be seen in the lower panel of Fig. 3(left), where the nominal calculation using the MSTW2008 PDF set is compared to the case where this contribution is not taken into account.

In the region where the precision of the measurement is limited by systematic uncertainties, $m_{ee} < 400$ GeV, the data generally lie above the FEWZ calculations. However, assuming that all systematic uncertainties, except those of statistical origin on the background and on C_{DY} (Table 1), are fully correlated bin-to-bin, the comparison between data and the different predictions over the full mass range yields chi-squared values of 13.9 for MSTW2008, 18.9 for CT10, 13.5 for HERAPDF1.5, 14.7 for ABM11 and 14.8 for NNPDF2.3, for the 13 data points, indicating compatibility between the theory and data.

8. Summary

Using 4.9 fb^{-1} of data from pp collisions at a centre-of-mass energy of $\sqrt{s} = 7$ TeV, the invariant mass distribution of e^+e^- pairs from DY production has been measured at ATLAS in the range $116 < m_{ee} < 1500$ GeV, for electrons with $p_T > 25$ GeV and

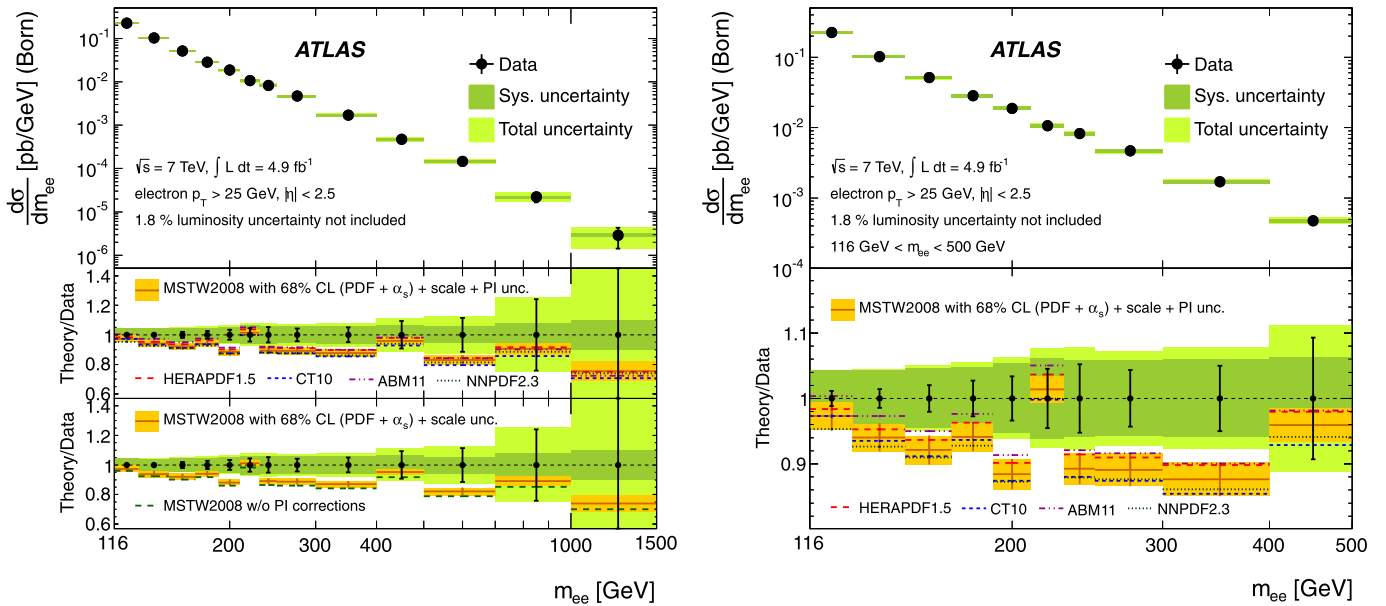


Fig. 3. Measured differential cross-section at the Born level within the fiducial region (electron $p_T > 25$ GeV and $|\eta| < 2.5$) with statistical (error bars), systematic (dark shaded), and combined statistical and systematic (total, light shaded) uncertainties, excluding the 1.8% uncertainty on the luminosity. The measurement is compared to FEWZ 3.1 calculations at NNLO QCD with NLO electroweak corrections using the G_{μ} electroweak parameter scheme. The predictions include an additional small correction from single-boson production in which the final-state charged lepton radiates a real W or Z boson. On the left, in the upper ratio plot, the photon-induced (PI) corrections have been added to the predictions obtained from the MSTW2008, HERAPDF1.5, CT10, ABM11 and NNPDF2.3 NNLO PDFs, and for the MSTW2008 prediction the total uncertainty band arising from the PDF, α_s , renormalisation and factorisation scale, and photon-induced uncertainties is drawn. The lower ratio plot shows the influence of the photon-induced corrections on the MSTW2008 prediction, the uncertainty band including only the PDF, α_s and scale uncertainties. On the right, the results are shown for a restricted range of m_{ee} .

$|\eta| < 2.5$. Comparisons have been made to the predictions of the PYTHIA, MC@NLO and SHERPA MC generators, after scaling them globally to match the total number of events observed in data. The MC predictions are consistent with the shape of the measured m_{ee} distribution. The predictions of the FEWZ 3.1 framework using five PDF sets at NNLO have also been studied. The framework combines calculations at NNLO QCD with NLO electroweak corrections, to which LO photon-induced corrections and real W and Z boson emission in single-boson production have been added. The resulting predictions for all PDFs are consistent with the measured differential cross-section, although the data are systematically above the theory. The data have the potential to constrain PDFs, in particular for antiquarks at large x , in the context of a PDF fit involving the world data sensitive to the proton structure.

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G. Aad⁴⁸, T. Abajyan²¹, B. Abbott¹¹², J. Abdallah¹², S. Abdel Khalek¹¹⁶, A.A. Abdelalim⁴⁹, O. Abidinov¹¹, R. Aben¹⁰⁶, B. Abi¹¹³, M. Abolins⁸⁹, O.S. AbouZeid¹⁵⁹, H. Abramowicz¹⁵⁴, H. Abreu¹³⁷, Y. Abulaiti^{147a,147b}, B.S. Acharya^{165a,165b,a}, L. Adamczyk^{38a}, D.L. Adams²⁵, T.N. Addy⁵⁶, J. Adelman¹⁷⁷, S. Adomeit⁹⁹, T. Adye¹³⁰, S. Aefsky²³, J.A. Aguilar-Saavedra^{125b,b}, M. Agustoni¹⁷, S.P. Ahlen²², F. Ahles⁴⁸, A. Ahmad¹⁴⁹, M. Ahsan⁴¹, G. Aielli^{134a,134b}, T.P.A. Åkesson⁸⁰, G. Akimoto¹⁵⁶, A.V. Akimov⁹⁵, M.A. Alam⁷⁶, J. Albert¹⁷⁰, S. Albrand⁵⁵, M.J. Alconada Verzini⁷⁰, M. Aleksa³⁰, I.N. Aleksandrov⁶⁴, F. Alessandria^{90a}, C. Alexa^{26a}, G. Alexander¹⁵⁴, G. Alexandre⁴⁹, T. Alexopoulos¹⁰, M. Alhroob^{165a,165c}, M. Aliev¹⁶, G. Alimonti^{90a}, J. Alison³¹, B.M.M. Allbrooke¹⁸, L.J. Allison⁷¹, P.P. Allport⁷³, S.E. Allwood-Spiers⁵³, J. Almond⁸³, A. Aloisio^{103a,103b}, R. Alon¹⁷³, A. Alonso³⁶, F. Alonso⁷⁰, A. Altheimer³⁵, B. Alvarez Gonzalez⁸⁹, M.G. Alviggi^{103a,103b}, K. Amako⁶⁵, Y. Amaral Coutinho^{24a}, C. Amelung²³, V.V. Ammosov^{129,*}, S.P. Amor Dos Santos^{125a}, A. Amorim^{125a,c}, S. Amoroso⁴⁸, N. Amram¹⁵⁴, C. Anastopoulos³⁰, L.S. Ancu¹⁷, N. Andari³⁰, T. Andeen³⁵, C.F. Anders^{58b}, G. Anders^{58a}, K.J. Anderson³¹, A. Andreazza^{90a,90b}, V. Andrei^{58a}, X.S. Anduaga⁷⁰, S. Angelidakis⁹, P. Anger⁴⁴, A. Angerami³⁵, F. Anghinolfi³⁰, A. Anisenkov¹⁰⁸, N. Anjos^{125a}, A. Annovi⁴⁷, A. Antonaki⁹, M. Antonelli⁴⁷, A. Antonov⁹⁷, J. Antos^{145b}, F. Anulli^{133a}, M. Aoki¹⁰², L. Aperio Bella¹⁸, R. Apolle^{119,d}, G. Arabidze⁸⁹, I. Aracena¹⁴⁴, Y. Arai⁶⁵, A.T.H. Arce⁴⁵, S. Arfaoui¹⁴⁹, J-F. Arguin⁹⁴, S. Argyropoulos⁴², E. Arik^{19a,*}, M. Arik^{19a}, A.J. Armbruster⁸⁸, O. Arnaez⁸², V. Arnal⁸¹, A. Artamonov⁹⁶, G. Artoni^{133a,133b}, D. Arutinov²¹, S. Asai¹⁵⁶, N. Asbah⁹⁴, S. Ask²⁸, B. Åsman^{147a,147b}, L. Asquith⁶, K. Assamagan²⁵, R. Astalos^{145a}, A. Astbury¹⁷⁰, M. Atkinson¹⁶⁶, B. Auerbach⁶, E. Auge¹¹⁶, K. Augsten¹²⁷, M. Aurousseau^{146b}, G. Avolio³⁰, D. Axen¹⁶⁹, G. Azuelos^{94,e}, Y. Azuma¹⁵⁶, M.A. Baak³⁰, C. Bacci^{135a,135b}, A.M. Bach¹⁵, H. Bachacou¹³⁷, K. Bachas¹⁵⁵, M. Backes⁴⁹, M. Backhaus²¹, J. Backus Mayes¹⁴⁴, E. Badescu^{26a}, P. Bagiachi^{133a,133b}, P. Bagnaia^{133a,133b}, Y. Bai^{33a}, D.C. Bailey¹⁵⁹, T. Bain³⁵, J.T. Baines¹³⁰, O.K. Baker¹⁷⁷, S. Baker⁷⁷, P. Balek¹²⁸, F. Balli¹³⁷, E. Banas³⁹, P. Banerjee⁹⁴, Sw. Banerjee¹⁷⁴, D. Banfi³⁰, A. Bangert¹⁵¹, V. Bansal¹⁷⁰, H.S. Bansil¹⁸, L. Barak¹⁷³, S.P. Baranov⁹⁵, T. Barber⁴⁸, E.L. Barberio⁸⁷, D. Barberis^{50a,50b}, M. Barbero⁸⁴, D.Y. Bardin⁶⁴, T. Barillari¹⁰⁰, M. Barisonzi¹⁷⁶, T. Barklow¹⁴⁴, N. Barlow²⁸, B.M. Barnett¹³⁰, R.M. Barnett¹⁵, A. Baroncelli^{135a}, G. Barone⁴⁹, A.J. Barr¹¹⁹, F. Barreiro⁸¹, J. Barreiro Guimarães da Costa⁵⁷, R. Bartoldus¹⁴⁴, A.E. Barton⁷¹, V. Bartsch¹⁵⁰,

A. Basye ¹⁶⁶, R.L. Bates ⁵³, L. Batkova ^{145a}, J.R. Batley ²⁸, A. Battaglia ¹⁷, M. Battistin ³⁰,
 F. Bauer ¹³⁷, H.S. Bawa ^{144,f}, S. Beale ⁹⁹, T. Beau ⁷⁹, P.H. Beauchemin ¹⁶², R. Beccherle ^{50a},
 P. Bechtel ²¹, H.P. Beck ¹⁷, K. Becker ¹⁷⁶, S. Becker ⁹⁹, M. Beckingham ¹³⁹, K.H. Becks ¹⁷⁶,
 A.J. Beddall ^{19c}, A. Beddall ^{19c}, S. Bedikian ¹⁷⁷, V.A. Bednyakov ⁶⁴, C.P. Bee ⁸⁴,
 L.J. Beemster ¹⁰⁶, T.A. Beermann ¹⁷⁶, M. Begel ²⁵, C. Belanger-Champagne ⁸⁶, P.J. Bell ⁴⁹,
 W.H. Bell ⁴⁹, G. Bella ¹⁵⁴, L. Bellagamba ^{20a}, A. Bellerive ²⁹, M. Bellomo ³⁰, A. Belloni ⁵⁷,
 O. Beloborodova ^{108,g}, K. Belotskiy ⁹⁷, O. Beltramello ³⁰, O. Benary ¹⁵⁴, D. Benchekroun ^{136a},
 K. Bendtz ^{147a,147b}, N. Benekos ¹⁶⁶, Y. Benhammou ¹⁵⁴, E. Benhar Noccioli ⁴⁹,
 J.A. Benitez Garcia ^{160b}, D.P. Benjamin ⁴⁵, J.R. Bensinger ²³, K. Benslama ¹³¹,
 S. Bentvelsen ¹⁰⁶, D. Berge ³⁰, E. Bergeaas Kuutmann ¹⁶, N. Berger ⁵, F. Berghaus ¹⁷⁰,
 E. Berglund ¹⁰⁶, J. Beringer ¹⁵, P. Bernat ⁷⁷, R. Bernhard ⁴⁸, C. Bernius ⁷⁸,
 F.U. Bernlochner ¹⁷⁰, T. Berry ⁷⁶, C. Bertella ⁸⁴, F. Bertolucci ^{123a,123b}, M.I. Besana ^{90a,90b},
 G.J. Besjes ¹⁰⁵, N. Besson ¹³⁷, S. Bethke ¹⁰⁰, W. Bhimji ⁴⁶, R.M. Bianchi ¹²⁴, L. Bianchini ²³,
 M. Bianco ^{72a,72b}, O. Biebel ⁹⁹, S.P. Bieniek ⁷⁷, K. Bierwagen ⁵⁴, J. Biesiada ¹⁵,
 M. Biglietti ^{135a}, H. Bilokon ⁴⁷, M. Bindi ^{20a,20b}, S. Binet ¹¹⁶, A. Bingul ^{19c}, C. Bini ^{133a,133b},
 B. Bittner ¹⁰⁰, C.W. Black ¹⁵¹, J.E. Black ¹⁴⁴, K.M. Black ²², D. Blackburn ¹³⁹, R.E. Blair ⁶,
 J.-B. Blanchard ¹³⁷, T. Blazek ^{145a}, I. Bloch ⁴², C. Blocker ²³, J. Blocki ³⁹, W. Blum ⁸²,
 U. Blumenschein ⁵⁴, G.J. Bobbink ¹⁰⁶, V.S. Bobrovnikov ¹⁰⁸, S.S. Bocchetta ⁸⁰, A. Bocci ⁴⁵,
 C.R. Boddy ¹¹⁹, M. Boehler ⁴⁸, J. Boek ¹⁷⁶, T.T. Boek ¹⁷⁶, N. Boelaert ³⁶, J.A. Bogaerts ³⁰,
 A. Bogdanchikov ¹⁰⁸, A. Bogouch ^{91,*}, C. Bohm ^{147a}, J. Bohm ¹²⁶, V. Boisvert ⁷⁶, T. Bold ^{38a},
 V. Boldea ^{26a}, N.M. Bolnet ¹³⁷, M. Bomben ⁷⁹, M. Bona ⁷⁵, M. Boonekamp ¹³⁷, S. Bordoni ⁷⁹,
 C. Borer ¹⁷, A. Borisov ¹²⁹, G. Borissov ⁷¹, M. Borri ⁸³, S. Borroni ⁴², J. Bortfeldt ⁹⁹,
 V. Bortolotto ^{135a,135b}, K. Bos ¹⁰⁶, D. Boscherini ^{20a}, M. Bosman ¹², H. Boterenbrood ¹⁰⁶,
 J. Bouchami ⁹⁴, J. Boudreau ¹²⁴, E.V. Bouhova-Thacker ⁷¹, D. Boumediene ³⁴,
 C. Bourdarios ¹¹⁶, N. Bousson ⁸⁴, S. Boutouil ^{136d}, A. Boveia ³¹, J. Boyd ³⁰, I.R. Boyko ⁶⁴,
 I. Bozovic-Jelisavcic ^{13b}, J. Bracinik ¹⁸, P. Branchini ^{135a}, A. Brandt ⁸, G. Brandt ¹⁵,
 O. Brandt ⁵⁴, U. Bratzler ¹⁵⁷, B. Brau ⁸⁵, J.E. Brau ¹¹⁵, H.M. Braun ^{176,*}, S.F. Brazzale ^{165a,165c},
 B. Brelief ¹⁵⁹, J. Bremer ³⁰, K. Brendlinger ¹²¹, R. Brenner ¹⁶⁷, S. Bressler ¹⁷³,
 T.M. Bristow ^{146c}, D. Britton ⁵³, F.M. Brochu ²⁸, I. Brock ²¹, R. Brock ⁸⁹, F. Broggi ^{90a},
 C. Bromberg ⁸⁹, J. Bronner ¹⁰⁰, G. Brooijmans ³⁵, T. Brooks ⁷⁶, W.K. Brooks ^{32b}, E. Brost ¹¹⁵,
 G. Brown ⁸³, P.A. Bruckman de Renstrom ³⁹, D. Bruncko ^{145b}, R. Bruneliere ⁴⁸, S. Brunet ⁶⁰,
 A. Bruni ^{20a}, G. Bruni ^{20a}, M. Bruschi ^{20a}, L. Bryngemark ⁸⁰, T. Buanes ¹⁴, Q. Buat ⁵⁵,
 F. Bucci ⁴⁹, J. Buchanan ¹¹⁹, P. Buchholz ¹⁴², R.M. Buckingham ¹¹⁹, A.G. Buckley ⁴⁶,
 S.I. Buda ^{26a}, I.A. Budagov ⁶⁴, B. Budick ¹⁰⁹, L. Bugge ¹¹⁸, O. Bulekov ⁹⁷, A.C. Bundock ⁷³,
 M. Bunse ⁴³, T. Buran ^{118,*}, H. Burckhart ³⁰, S. Burdin ⁷³, T. Burgess ¹⁴, S. Burke ¹³⁰,
 E. Busato ³⁴, V. Büscher ⁸², P. Bussey ⁵³, C.P. Buszello ¹⁶⁷, B. Butler ⁵⁷, J.M. Butler ²²,
 C.M. Buttar ⁵³, J.M. Butterworth ⁷⁷, W. Buttinger ²⁸, M. Byszewski ¹⁰, S. Cabrera Urbán ¹⁶⁸,
 D. Caforio ^{20a,20b}, O. Cakir ^{4a}, P. Calafiura ¹⁵, G. Calderini ⁷⁹, P. Calfayan ⁹⁹, R. Calkins ¹⁰⁷,
 L.P. Caloba ^{24a}, R. Caloi ^{133a,133b}, D. Calvet ³⁴, S. Calvet ³⁴, R. Camacho Toro ⁴⁹,
 P. Camarri ^{134a,134b}, D. Cameron ¹¹⁸, L.M. Caminada ¹⁵, R. Caminal Armadans ¹²,
 S. Campana ³⁰, M. Campanelli ⁷⁷, V. Canale ^{103a,103b}, F. Canelli ³¹, A. Canepa ^{160a},
 J. Cantero ⁸¹, R. Cantrill ⁷⁶, T. Cao ⁴⁰, M.D.M. Capeans Garrido ³⁰, I. Caprini ^{26a},
 M. Caprini ^{26a}, D. Capriotti ¹⁰⁰, M. Capua ^{37a,37b}, R. Caputo ⁸², R. Cardarelli ^{134a}, T. Carli ³⁰,
 G. Carlino ^{103a}, L. Carminati ^{90a,90b}, S. Caron ¹⁰⁵, E. Carquin ^{32b}, G.D. Carrillo-Montoya ^{146c},
 A.A. Carter ⁷⁵, J.R. Carter ²⁸, J. Carvalho ^{125a,h}, D. Casadei ¹⁰⁹, M.P. Casado ¹²,
 M. Cascella ^{123a,123b}, C. Caso ^{50a,50b,*}, E. Castaneda-Miranda ¹⁷⁴, A. Castelli ¹⁰⁶,
 V. Castillo Gimenez ¹⁶⁸, N.F. Castro ^{125a}, G. Cataldi ^{72a}, P. Catastini ⁵⁷, A. Catinaccio ³⁰,
 J.R. Catmore ³⁰, A. Cattai ³⁰, G. Cattani ^{134a,134b}, S. Caughron ⁸⁹, V. Cavaliere ¹⁶⁶,
 D. Cavalli ^{90a}, M. Cavalli-Sforza ¹², V. Cavasinni ^{123a,123b}, F. Ceradini ^{135a,135b}, B. Cerio ⁴⁵,
 A.S. Cerqueira ^{24b}, A. Cerri ¹⁵, L. Cerrito ⁷⁵, F. Cerutti ¹⁵, A. Cervelli ¹⁷, S.A. Cetin ^{19b},
 A. Chafaq ^{136a}, D. Chakraborty ¹⁰⁷, I. Chalupkova ¹²⁸, K. Chan ³, P. Chang ¹⁶⁶, B. Chapleau ⁸⁶,
 J.D. Chapman ²⁸, J.W. Chapman ⁸⁸, D.G. Charlton ¹⁸, V. Chavda ⁸³, C.A. Chavez Barajas ³⁰,

S. Cheatham⁸⁶, S. Chekanov⁶, S.V. Chekulaev^{160a}, G.A. Chelkov⁶⁴, M.A. Chelstowska¹⁰⁵, C. Chen⁶³, H. Chen²⁵, S. Chen^{33c}, X. Chen¹⁷⁴, Y. Chen³⁵, Y. Cheng³¹, A. Cheplakov⁶⁴, R. Cherkaoui El Moursli^{136e}, V. Chernyatin²⁵, E. Cheu⁷, S.L. Cheung¹⁵⁹, L. Chevalier¹³⁷, V. Chiarella⁴⁷, G. Chiefari^{103a,103b}, J.T. Childers³⁰, A. Chilingarov⁷¹, G. Chiodini^{72a}, A.S. Chisholm¹⁸, R.T. Chislett⁷⁷, A. Chitan^{26a}, M.V. Chizhov⁶⁴, G. Choudalakis³¹, S. Chouridou⁹, B.K.B. Chow⁹⁹, I.A. Christidi⁷⁷, A. Christov⁴⁸, D. Chromek-Burckhart³⁰, M.L. Chu¹⁵², J. Chudoba¹²⁶, G. Ciapetti^{133a,133b}, A.K. Ciftci^{4a}, R. Ciftci^{4a}, D. Cinca⁶², V. Cindro⁷⁴, A. Ciocio¹⁵, M. Cirilli⁸⁸, P. Cirkovic^{13b}, Z.H. Citron¹⁷³, M. Citterio^{90a}, M. Ciubancan^{26a}, A. Clark⁴⁹, P.J. Clark⁴⁶, R.N. Clarke¹⁵, J.C. Clemens⁸⁴, B. Clement⁵⁵, C. Clement^{147a,147b}, Y. Coadou⁸⁴, M. Cobal^{165a,165c}, A. Coccaro¹³⁹, J. Cochran⁶³, S. Coelli^{90a}, L. Coffey²³, J.G. Cogan¹⁴⁴, J. Coggeshall¹⁶⁶, J. Colas⁵, S. Cole¹⁰⁷, A.P. Colijn¹⁰⁶, N.J. Collins¹⁸, C. Collins-Tooth⁵³, J. Collot⁵⁵, T. Colombo^{120a,120b}, G. Colon⁸⁵, G. Compostella¹⁰⁰, P. Conde Muiño^{125a}, E. Coniavitis¹⁶⁷, M.C. Conidi¹², S.M. Consonni^{90a,90b}, V. Consorti⁴⁸, S. Constantinescu^{26a}, C. Conta^{120a,120b}, G. Conti⁵⁷, F. Conventi^{103a,i}, M. Cooke¹⁵, B.D. Cooper⁷⁷, A.M. Cooper-Sarkar¹¹⁹, N.J. Cooper-Smith⁷⁶, K. Copic¹⁵, T. Cornelissen¹⁷⁶, M. Corradi^{20a}, F. Corriveau^{86,j}, A. Corso-Radu¹⁶⁴, A. Cortes-Gonzalez¹⁶⁶, G. Cortiana¹⁰⁰, G. Costa^{90a}, M.J. Costa¹⁶⁸, D. Costanzo¹⁴⁰, D. Côté³⁰, G. Cottin^{32a}, L. Courneyea¹⁷⁰, G. Cowan⁷⁶, B.E. Cox⁸³, K. Cranmer¹⁰⁹, S. Crépe-Renaudin⁵⁵, F. Crescioli⁷⁹, M. Cristinziani²¹, G. Crosetti^{37a,37b}, C.-M. Cuciuc^{26a}, C. Cuenca Almenar¹⁷⁷, T. Cuhadar Donszelmann¹⁴⁰, J. Cummings¹⁷⁷, M. Curatolo⁴⁷, C.J. Curtis¹⁸, C. Cuthbert¹⁵¹, H. Czirr¹⁴², P. Czodrowski⁴⁴, Z. Czyczula¹⁷⁷, S. D'Auria⁵³, M. D'Onofrio⁷³, A. D'Orazio^{133a,133b}, M.J. Da Cunha Sargedas De Sousa^{125a}, C. Da Via⁸³, W. Dabrowski^{38a}, A. Dafinca¹¹⁹, T. Dai⁸⁸, F. Dallaire⁹⁴, C. Dallapiccola⁸⁵, M. Dam³⁶, D.S. Damiani¹³⁸, A.C. Daniells¹⁸, H.O. Danielsson³⁰, V. Dao¹⁰⁵, G. Darbo^{50a}, G.L. Darlea^{26c}, S. Darmora⁸, J.A. Dassoulas⁴², W. Davey²¹, T. Davidek¹²⁸, N. Davidson⁸⁷, E. Davies^{119,d}, M. Davies⁹⁴, O. Davignon⁷⁹, A.R. Davison⁷⁷, Y. Davygora^{58a}, E. Dawe¹⁴³, I. Dawson¹⁴⁰, R.K. Daya-Ishmukhametova²³, K. De⁸, R. de Asmundis^{103a}, S. De Castro^{20a,20b}, S. De Cecco⁷⁹, J. de Graat⁹⁹, N. De Groot¹⁰⁵, P. de Jong¹⁰⁶, C. De La Taille¹¹⁶, H. De la Torre⁸¹, F. De Lorenzi⁶³, L. De Nooij¹⁰⁶, D. De Pedis^{133a}, A. De Salvo^{133a}, U. De Sanctis^{165a,165c}, A. De Santo¹⁵⁰, J.B. De Vivie De Regie¹¹⁶, G. De Zorzi^{133a,133b}, W.J. Dearnaley⁷¹, R. Debbé²⁵, C. Debenedetti⁴⁶, B. Dechenaux⁵⁵, D.V. Dedovich⁶⁴, J. Degenhardt¹²¹, J. Del Peso⁸¹, T. Del Prete^{123a,123b}, T. Delemontex⁵⁵, M. Deliyergiyev⁷⁴, A. Dell'Acqua³⁰, L. Dell'Asta²², M. Della Pietra^{103a,i}, D. della Volpe^{103a,103b}, M. Delmastro⁵, P.A. Delsart⁵⁵, C. Deluca¹⁰⁶, S. Demers¹⁷⁷, M. Demichev⁶⁴, A. Demilly⁷⁹, B. Demirköz^{12,k}, S.P. Denisov¹²⁹, D. Derendarz³⁹, J.E. Derkaoui^{136d}, F. Derue⁷⁹, P. Dervan⁷³, K. Desch²¹, P.O. Deviveiros¹⁰⁶, A. Dewhurst¹³⁰, B. DeWilde¹⁴⁹, S. Dhaliwal¹⁰⁶, R. Dhullipudi^{78,l}, A. Di Ciaccio^{134a,134b}, L. Di Ciaccio⁵, C. Di Donato^{103a,103b}, A. Di Girolamo³⁰, B. Di Girolamo³⁰, S. Di Luise^{135a,135b}, A. Di Mattia¹⁵³, B. Di Micco^{135a,135b}, R. Di Nardo⁴⁷, A. Di Simone^{134a,134b}, R. Di Sipio^{20a,20b}, M.A. Diaz^{32a}, E.B. Diehl⁸⁸, J. Dietrich⁴², T.A. Dietzsch^{58a}, S. Diglio⁸⁷, K. Dindar Yagci⁴⁰, J. Dingfelder²¹, F. Dinut^{26a}, C. Dionisi^{133a,133b}, P. Dita^{26a}, S. Dita^{26a}, F. Dittus³⁰, F. Djama⁸⁴, T. Djobava^{51b}, M.A.B. do Vale^{24c}, A. Do Valle Wemans^{125a,m}, T.K.O. Doan⁵, D. Dobos³⁰, E. Dobson⁷⁷, J. Dodd³⁵, C. Doglioni⁴⁹, T. Doherty⁵³, T. Dohmae¹⁵⁶, Y. Doi^{65,*}, J. Dolejsi¹²⁸, Z. Dolezal¹²⁸, B.A. Dolgoshein^{97,*}, M. Donadelli^{24d}, J. Donini³⁴, J. Dopke³⁰, A. Doria^{103a}, A. Dos Anjos¹⁷⁴, A. Dotti^{123a,123b}, M.T. Dova⁷⁰, A.T. Doyle⁵³, M. Dris¹⁰, J. Dubbert⁸⁸, S. Dube¹⁵, E. Dubreuil³⁴, E. Duchovni¹⁷³, G. Duckeck⁹⁹, D. Duda¹⁷⁶, A. Dudarev³⁰, F. Dudziak⁶³, L. Duflot¹¹⁶, M.-A. Dufour⁸⁶, L. Duguid⁷⁶, M. Dührssen³⁰, M. Dunford^{58a}, H. Duran Yildiz^{4a}, M. Düren⁵², M. Dwuznik^{38a}, J. Ebke⁹⁹, S. Eckweiler⁸², W. Edson², C.A. Edwards⁷⁶, N.C. Edwards⁵³, W. Ehrenfeld²¹, T. Eifert¹⁴⁴, G. Eigen¹⁴, K. Einsweiler¹⁵, E. Eisenhandler⁷⁵, T. Ekelof¹⁶⁷, M. El Kacimi^{136c}, M. Ellert¹⁶⁷, S. Elles⁵, F. Ellinghaus⁸², K. Ellis⁷⁵, N. Ellis³⁰, J. Elmsheuser⁹⁹, M. Elsing³⁰, D. Emeliyanov¹³⁰, Y. Enari¹⁵⁶,

O.C. Endner⁸², R. Engelmann¹⁴⁹, A. Engl⁹⁹, J. Erdmann¹⁷⁷, A. Ereditato¹⁷,
D. Eriksson^{147a}, J. Ernst², M. Ernst²⁵, J. Ernwein¹³⁷, D. Errede¹⁶⁶, S. Errede¹⁶⁶, E. Ertel⁸²,
M. Escalier¹¹⁶, H. Esch⁴³, C. Escobar¹²⁴, X. Espinal Curull¹², B. Esposito⁴⁷, F. Etienne⁸⁴,
A.I. Etievre¹³⁷, E. Etzion¹⁵⁴, D. Evangelakou⁵⁴, H. Evans⁶⁰, L. Fabbri^{20a,20b}, C. Fabre³⁰,
G. Facini³⁰, R.M. Fakhruddinov¹²⁹, S. Falciano^{133a}, Y. Fang^{33a}, M. Fanti^{90a,90b}, A. Farbin⁸,
A. Farilla^{135a}, T. Farooque¹⁵⁹, S. Farrell¹⁶⁴, S.M. Farrington¹⁷¹, P. Farthouat³⁰, F. Fassi¹⁶⁸,
P. Fassnacht³⁰, D. Fassouliotis⁹, B. Fatholahzadeh¹⁵⁹, A. Favareto^{90a,90b}, L. Fayard¹¹⁶,
P. Federic^{145a}, O.L. Fedin¹²², W. Fedorko¹⁶⁹, M. Fehling-Kaschek⁴⁸, L. Feligioni⁸⁴,
C. Feng^{33d}, E.J. Feng⁶, H. Feng⁸⁸, A.B. Fenyuk¹²⁹, J. Ferencei^{145b}, W. Fernando⁶,
S. Ferrag⁵³, J. Ferrando⁵³, V. Ferrara⁴², A. Ferrari¹⁶⁷, P. Ferrari¹⁰⁶, R. Ferrari^{120a},
D.E. Ferreira de Lima⁵³, A. Ferrer¹⁶⁸, D. Ferrere⁴⁹, C. Ferretti⁸⁸, A. Ferretto Parodi^{50a,50b},
M. Fiascaris³¹, F. Fiedler⁸², A. Filipčič⁷⁴, F. Filthaut¹⁰⁵, M. Fincke-Keeler¹⁷⁰, K.D. Finelli⁴⁵,
M.C.N. Fiolhais^{125a,h}, L. Fiorini¹⁶⁸, A. Firan⁴⁰, J. Fischer¹⁷⁶, M.J. Fisher¹¹⁰,
E.A. Fitzgerald²³, M. Flechl⁴⁸, I. Fleck¹⁴², P. Fleischmann¹⁷⁵, S. Fleischmann¹⁷⁶,
G.T. Fletcher¹⁴⁰, G. Fletcher⁷⁵, T. Flick¹⁷⁶, A. Floderus⁸⁰, L.R. Flores Castillo¹⁷⁴,
A.C. Florez Bustos^{160b}, M.J. Flowerdew¹⁰⁰, T. Fonseca Martin¹⁷, A. Formica¹³⁷, A. Forti⁸³,
D. Fortin^{160a}, D. Fournier¹¹⁶, H. Fox⁷¹, P. Francavilla¹², M. Franchini^{20a,20b},
S. Franchino³⁰, D. Francis³⁰, M. Franklin⁵⁷, S. Franz³⁰, M. Fraternali^{120a,120b},
S. Fratina¹²¹, S.T. French²⁸, C. Friedrich⁴², F. Friedrich⁴⁴, D. Froidevaux³⁰, J.A. Frost²⁸,
C. Fukunaga¹⁵⁷, E. Fullana Torregrosa¹²⁸, B.G. Fulson¹⁴⁴, J. Fuster¹⁶⁸, C. Gabaldon³⁰,
O. Gabizon¹⁷³, A. Gabrielli^{20a,20b}, A. Gabrielli^{133a,133b}, S. Gadatsch¹⁰⁶, T. Gadfort²⁵,
S. Gadomski⁴⁹, G. Gagliardi^{50a,50b}, P. Gagnon⁶⁰, C. Galea⁹⁹, B. Galhardo^{125a},
E.J. Gallas¹¹⁹, V. Gallo¹⁷, B.J. Gallop¹³⁰, P. Gallus¹²⁷, K.K. Gan¹¹⁰, R.P. Gandrajula⁶²,
Y.S. Gao^{144.f}, A. Gaponenko¹⁵, F.M. Garay Walls⁴⁶, F. Garbersson¹⁷⁷, C. García¹⁶⁸,
J.E. García Navarro¹⁶⁸, M. Garcia-Sciveres¹⁵, R.W. Gardner³¹, N. Garelli¹⁴⁴, V. Garonne³⁰,
C. Gatti⁴⁷, G. Gaudio^{120a}, B. Gaur¹⁴², L. Gauthier⁹⁴, P. Gauzzi^{133a,133b}, I.L. Gavrilenko⁹⁵,
C. Gay¹⁶⁹, G. Gaycken²¹, E.N. Gazis¹⁰, P. Ge^{33d,n}, Z. Gece¹⁶⁹, C.N.P. Gee¹³⁰,
D.A.A. Geerts¹⁰⁶, Ch. Geich-Gimbel²¹, K. Gellerstedt^{147a,147b}, C. Gemme^{50a},
A. Gemmell⁵³, M.H. Genest⁵⁵, S. Gentile^{133a,133b}, M. George⁵⁴, S. George⁷⁶,
D. Gerbaudo¹⁶⁴, A. Gershon¹⁵⁴, H. Ghazlane^{136b}, N. Ghodbane³⁴, B. Giacobbe^{20a},
S. Giagu^{133a,133b}, V. Giangiobbe¹², P. Giannetti^{123a,123b}, F. Gianotti³⁰, B. Gibbard²⁵,
A. Gibson¹⁵⁹, S.M. Gibson⁷⁶, M. Gilchriese¹⁵, T.P.S. Gillam²⁸, D. Gillberg³⁰,
A.R. Gillman¹³⁰, D.M. Gingrich^{3,e}, N. Giokaris⁹, M.P. Giordani^{165c}, R. Giordano^{103a,103b},
F.M. Giorgi¹⁶, P. Giovannini¹⁰⁰, P.F. Giraud¹³⁷, D. Giugni^{90a}, C. Giuliani⁴⁸, M. Giunta⁹⁴,
B.K. Gjelsten¹¹⁸, I. Gkialas^{155,o}, L.K. Gladilin⁹⁸, C. Glasman⁸¹, J. Glatzer²¹, A. Glazov⁴²,
G.L. Glonti⁶⁴, J.R. Goddard⁷⁵, J. Godfrey¹⁴³, J. Godlewski³⁰, M. Goebel⁴², C. Goeringer⁸²,
S. Goldfarb⁸⁸, T. Golling¹⁷⁷, D. Golubkov¹²⁹, A. Gomes^{125a,c}, L.S. Gomez Fajardo⁴²,
R. Gonçalo⁷⁶, J. Goncalves Pinto Firmino Da Costa⁴², L. Gonella²¹,
S. González de la Hoz¹⁶⁸, G. Gonzalez Parra¹², M.L. Gonzalez Silva²⁷,
S. Gonzalez-Sevilla⁴⁹, J.J. Goodson¹⁴⁹, L. Goossens³⁰, P.A. Gorbounov⁹⁶, H.A. Gordon²⁵,
I. Gorelov¹⁰⁴, G. Gorfine¹⁷⁶, B. Gorini³⁰, E. Gorini^{72a,72b}, A. Gorišek⁷⁴, E. Gornicki³⁹,
A.T. Goshaw⁶, C. Gössling⁴³, M.I. Gostkin⁶⁴, I. Gough Eschrich¹⁶⁴, M. Gouighri^{136a},
D. Goujdami^{136c}, M.P. Goulette⁴⁹, A.G. Goussiou¹³⁹, C. Goy⁵, S. Gozpinar²³, L. Graber⁵⁴,
I. Grabowska-Bold^{38a}, P. Grafström^{20a,20b}, K-J. Grahn⁴², E. Gramstad¹¹⁸,
F. Grancagnolo^{72a}, S. Grancagnolo¹⁶, V. Grassi¹⁴⁹, V. Gratchev¹²², H.M. Gray³⁰,
J.A. Gray¹⁴⁹, E. Graziani^{135a}, O.G. Grebenyuk¹²², T. Greenshaw⁷³, Z.D. Greenwood^{78,l},
K. Gregersen³⁶, I.M. Gregor⁴², P. Grenier¹⁴⁴, J. Griffiths⁸, N. Grigalashvili⁶⁴,
A.A. Grillo¹³⁸, K. Grimm⁷¹, S. Grinstein¹², Ph. Gris³⁴, Y.V. Grishkevich⁹⁸, J.-F. Grivaz¹¹⁶,
J.P. Grohs⁴⁴, A. Grohsjean⁴², E. Gross¹⁷³, J. Grosse-Knetter⁵⁴, J. Groth-Jensen¹⁷³,
K. Grybel¹⁴², F. Guescini⁴⁹, D. Guest¹⁷⁷, O. Gueta¹⁵⁴, C. Guicheney³⁴, E. Guido^{50a,50b},
T. Guillemin¹¹⁶, S. Guindon², U. Gul⁵³, J. Gunther¹²⁷, J. Guo³⁵, P. Gutierrez¹¹²,
N. Guttman¹⁵⁴, O. Gutzwiller¹⁷⁴, C. Guyot¹³⁷, C. Gwenlan¹¹⁹, C.B. Gwilliam⁷³,

A. Haas¹⁰⁹, S. Haas³⁰, C. Haber¹⁵, H.K. Hadavand⁸, P. Haefner²¹, Z. Hajduk³⁹,
 H. Hakobyan¹⁷⁸, D. Hall¹¹⁹, G. Halladjian⁶², K. Hamacher¹⁷⁶, P. Hamal¹¹⁴, K. Hamano⁸⁷,
 M. Hamer⁵⁴, A. Hamilton^{146a,p}, S. Hamilton¹⁶², L. Han^{33b}, K. Hanagaki¹¹⁷, K. Hanawa¹⁶¹,
 M. Hance¹⁵, C. Handel⁸², P. Hanke^{58a}, J.R. Hansen³⁶, J.B. Hansen³⁶, J.D. Hansen³⁶,
 P.H. Hansen³⁶, P. Hansson¹⁴⁴, K. Hara¹⁶¹, A.S. Hard¹⁷⁴, T. Harenberg¹⁷⁶, S. Harkusha⁹¹,
 D. Harper⁸⁸, R.D. Harrington⁴⁶, O.M. Harris¹³⁹, J. Hartert⁴⁸, F. Hartjes¹⁰⁶, T. Haruyama⁶⁵,
 A. Harvey⁵⁶, S. Hasegawa¹⁰², Y. Hasegawa¹⁴¹, S. Hassani¹³⁷, S. Haug¹⁷, M. Hauschild³⁰,
 R. Hauser⁸⁹, M. Havranek²¹, C.M. Hawkes¹⁸, R.J. Hawkins³⁰, A.D. Hawkins⁸⁰,
 T. Hayakawa⁶⁶, T. Hayashi¹⁶¹, D. Hayden⁷⁶, C.P. Hays¹¹⁹, H.S. Hayward⁷³,
 S.J. Haywood¹³⁰, S.J. Head¹⁸, T. Heck⁸², V. Hedberg⁸⁰, L. Heelan⁸, S. Heim¹²¹,
 B. Heinemann¹⁵, S. Heisterkamp³⁶, J. Hejbal¹²⁶, L. Helary²², C. Heller⁹⁹, M. Heller³⁰,
 S. Hellman^{147a,147b}, D. Hellmich²¹, C. Hensens³⁰, J. Henderson¹¹⁹, R.C.W. Henderson⁷¹,
 M. Henke^{58a}, A. Henrichs¹⁷⁷, A.M. Henriques Correia³⁰, S. Henrot-Versille¹¹⁶,
 C. Hensel⁵⁴, G.H. Herbert¹⁶, C.M. Hernandez⁸, Y. Hernández Jiménez¹⁶⁸,
 R. Herrberg-Schubert¹⁶, G. Herten⁴⁸, R. Hertenberger⁹⁹, L. Hervas³⁰, G.G. Hesketh⁷⁷,
 N.P. Hessey¹⁰⁶, R. Hickling⁷⁵, E. Higón-Rodríguez¹⁶⁸, J.C. Hill²⁸, K.H. Hiller⁴², S. Hillert²¹,
 S.J. Hillier¹⁸, I. Hinchliffe¹⁵, E. Hines¹²¹, M. Hirose¹¹⁷, D. Hirschbuehl¹⁷⁶, J. Hobbs¹⁴⁹,
 N. Hod¹⁰⁶, M.C. Hodgkinson¹⁴⁰, P. Hodgson¹⁴⁰, A. Hoecker³⁰, M.R. Hoferkamp¹⁰⁴,
 J. Hoffman⁴⁰, D. Hoffmann⁸⁴, J.I. Hofmann^{58a}, M. Hohlfield⁸², S.O. Holmgren^{147a},
 J.L. Holzbauer⁸⁹, T.M. Hong¹²¹, L. Hooft van Huysduynen¹⁰⁹, J-Y. Hostachy⁵⁵, S. Hou¹⁵²,
 A. Hoummada^{136a}, J. Howard¹¹⁹, J. Howarth⁸³, M. Hrabovsky¹¹⁴, I. Hristova¹⁶,
 J. Hrivnac¹¹⁶, T. Hryn'ova⁵, P.J. Hsu⁸², S.-C. Hsu¹³⁹, D. Hu³⁵, X. Hu²⁵, Z. Hubacek³⁰,
 F. Hubaut⁸⁴, F. Huegging²¹, A. Huettmann⁴², T.B. Huffman¹¹⁹, E.W. Hughes³⁵,
 G. Hughes⁷¹, M. Huhtinen³⁰, T.A. Hülsing⁸², M. Hurwitz¹⁵, N. Huseynov^{64,q}, J. Huston⁸⁹,
 J. Huth⁵⁷, G. Iacobucci⁴⁹, G. Iakovidis¹⁰, I. Ibragimov¹⁴², L. Iconomidou-Fayard¹¹⁶,
 J. Idarraga¹¹⁶, P. Iengo^{103a}, O. Igonkina¹⁰⁶, Y. Ikegami⁶⁵, K. Ikematsu¹⁴², M. Ikeno⁶⁵,
 D. Iliadis¹⁵⁵, N. Ilic¹⁵⁹, T. Ince¹⁰⁰, P. Ioannou⁹, M. Iodice^{135a}, K. Iordanidou⁹,
 V. Ippolito^{133a,133b}, A. Irlles Quiles¹⁶⁸, C. Isaksson¹⁶⁷, M. Ishino⁶⁷, M. Ishitsuka¹⁵⁸,
 R. Ishmukhametov¹¹⁰, C. Issever¹¹⁹, S. Istin^{19a}, A.V. Ivashin¹²⁹, W. Iwanski³⁹,
 H. Iwasaki⁶⁵, J.M. Izen⁴¹, V. Izzo^{103a}, B. Jackson¹²¹, J.N. Jackson⁷³, P. Jackson¹,
 M.R. Jaekel³⁰, V. Jain², K. Jakobs⁴⁸, S. Jakobsen³⁶, T. Jakoubek¹²⁶, J. Jakubek¹²⁷,
 D.O. Jamin¹⁵², D.K. Jana¹¹², E. Jansen⁷⁷, H. Jansen³⁰, J. Janssen²¹, A. Jantsch¹⁰⁰,
 M. Janus⁴⁸, R.C. Jared¹⁷⁴, G. Jarlskog⁸⁰, L. Jeanty⁵⁷, G.-Y. Jeng¹⁵¹, I. Jen-La Plante³¹,
 D. Jennens⁸⁷, P. Jenni³⁰, J. Jentsch⁴³, C. Jeske¹⁷¹, P. Jež³⁶, S. Jézéquel⁵, M.K. Jha^{20a},
 H. Ji¹⁷⁴, W. Ji⁸², J. Jia¹⁴⁹, Y. Jiang^{33b}, M. Jimenez Belenguer⁴², S. Jin^{33a}, O. Jinnouchi¹⁵⁸,
 M.D. Joergensen³⁶, D. Joffe⁴⁰, M. Johansen^{147a,147b}, K.E. Johansson^{147a}, P. Johansson¹⁴⁰,
 S. Johnert⁴², K.A. Johns⁷, K. Jon-And^{147a,147b}, G. Jones¹⁷¹, R.W.L. Jones⁷¹, T.J. Jones⁷³,
 P.M. Jorge^{125a}, K.D. Joshi⁸³, J. Jovicevic¹⁴⁸, T. Jovin^{13b}, X. Ju¹⁷⁴, C.A. Jung⁴³,
 R.M. Jungst³⁰, P. Jussel⁶¹, A. Juste Rozas¹², S. Kabana¹⁷, M. Kaci¹⁶⁸, A. Kaczmarska³⁹,
 P. Kadlecik³⁶, M. Kado¹¹⁶, H. Kagan¹¹⁰, M. Kagan⁵⁷, E. Kajomovitz¹⁵³, S. Kalinin¹⁷⁶,
 S. Kama⁴⁰, N. Kanaya¹⁵⁶, M. Kaneda³⁰, S. Kaneti²⁸, T. Kanno¹⁵⁸, V.A. Kantserov⁹⁷,
 J. Kanzaki⁶⁵, B. Kaplan¹⁰⁹, A. Kapliy³¹, D. Kar⁵³, K. Karakostas¹⁰, M. Karnevskiy⁸²,
 V. Kartvelishvili⁷¹, A.N. Karyukhin¹²⁹, L. Kashif¹⁷⁴, G. Kasielczka^{58b}, R.D. Kass¹¹⁰,
 A. Kastanas¹⁴, Y. Kataoka¹⁵⁶, J. Katzy⁴², V. Kaushik⁷, K. Kawagoe⁶⁹, T. Kawamoto¹⁵⁶,
 G. Kawamura⁵⁴, S. Kazama¹⁵⁶, V.F. Kazanin¹⁰⁸, M.Y. Kazarinov⁶⁴, R. Keeler¹⁷⁰,
 P.T. Keener¹²¹, R. Kehoe⁴⁰, M. Keil⁵⁴, J.S. Keller¹³⁹, H. Keoshkerian⁵, O. Kepka¹²⁶,
 B.P. Kerševan⁷⁴, S. Kersten¹⁷⁶, K. Kessoku¹⁵⁶, J. Keung¹⁵⁹, F. Khalil-zada¹¹,
 H. Khandanyan^{147a,147b}, A. Khanov¹¹³, D. Kharchenko⁶⁴, A. Khodinov⁹⁷, A. Khomich^{58a},
 T.J. Khoo²⁸, G. Khorialauli²¹, A. Khoroshilov¹⁷⁶, V. Khovanskiy⁹⁶, E. Khramov⁶⁴,
 J. Khubua^{51b}, H. Kim^{147a,147b}, S.H. Kim¹⁶¹, N. Kimura¹⁷², O. Kind¹⁶, B.T. King⁷³,
 M. King⁶⁶, R.S.B. King¹¹⁹, S.B. King¹⁶⁹, J. Kirk¹³⁰, A.E. Kiryunin¹⁰⁰, T. Kishimoto⁶⁶,
 D. Kisielewska^{38a}, T. Kitamura⁶⁶, T. Kittelmann¹²⁴, K. Kiuchi¹⁶¹, E. Kladiva^{145b},

M. Klein⁷³, U. Klein⁷³, K. Kleinknecht⁸², M. Klemetti⁸⁶, A. Klier¹⁷³, P. Klimek^{147a,147b},
A. Klimentov²⁵, R. Klingenberg⁴³, J.A. Klinger⁸³, E.B. Klinkby³⁶, T. Klioutchnikova³⁰,
P.F. Klok¹⁰⁵, E.-E. Kluge^{58a}, P. Kluit¹⁰⁶, S. Kluth¹⁰⁰, E. Kneringer⁶¹, E.B.F.G. Knoops⁸⁴,
A. Knue⁵⁴, B.R. Ko⁴⁵, T. Kobayashi¹⁵⁶, M. Kobel⁴⁴, M. Kocian¹⁴⁴, P. Kodys¹²⁸, S. Koenig⁸²,
F. Koetsveld¹⁰⁵, P. Koevesarki²¹, T. Koffas²⁹, E. Koffeman¹⁰⁶, L.A. Kogan¹¹⁹,
S. Kohlmann¹⁷⁶, F. Kohn⁵⁴, Z. Kohout¹²⁷, T. Kohriki⁶⁵, T. Koi¹⁴⁴, H. Kolanoski¹⁶,
I. Koletsou^{90a}, J. Koll⁸⁹, A.A. Komar⁹⁵, Y. Komori¹⁵⁶, T. Kondo⁶⁵, K. Köneke³⁰,
A.C. König¹⁰⁵, T. Kono^{42,r}, A.I. Kononov⁴⁸, R. Konoplich^{109,s}, N. Konstantinidis⁷⁷,
R. Kopeliansky¹⁵³, S. Koperny^{38a}, L. Köpke⁸², A.K. Kopp⁴⁸, K. Korcyl³⁹, K. Kordas¹⁵⁵,
A. Korn⁴⁶, A. Korol¹⁰⁸, I. Korolkov¹², E.V. Korolkova¹⁴⁰, V.A. Korotkov¹²⁹, O. Kortner¹⁰⁰,
S. Kortner¹⁰⁰, V.V. Kostyukhin²¹, S. Kotov¹⁰⁰, V.M. Kotov⁶⁴, A. Kotwal⁴⁵,
C. Kourkoumelis⁹, V. Kouskoura¹⁵⁵, A. Koutsman^{160a}, R. Kowalewski¹⁷⁰, T.Z. Kowalski^{38a},
W. Kozanecki¹³⁷, A.S. Kozhin¹²⁹, V. Kral¹²⁷, V.A. Kramarenko⁹⁸, G. Kramberger⁷⁴,
M.W. Krasny⁷⁹, A. Krasznahorkay¹⁰⁹, J.K. Kraus²¹, A. Kravchenko²⁵, S. Kreiss¹⁰⁹,
J. Kretschmar⁷³, K. Kreutzfeldt⁵², N. Krieger⁵⁴, P. Krieger¹⁵⁹, K. Kroeninger⁵⁴,
H. Kroha¹⁰⁰, J. Kroll¹²¹, J. Kroseberg²¹, J. Krstic^{13a}, U. Kruchonak⁶⁴, H. Krüger²¹,
T. Kruker¹⁷, N. Krumnack⁶³, Z.V. Krumshteyn⁶⁴, A. Kruse¹⁷⁴, M.K. Kruse⁴⁵, M. Kruskal²²,
T. Kubota⁸⁷, S. Kudah^{4a}, S. Kuehn⁴⁸, A. Kugel^{58c}, T. Kuhl⁴², V. Kukhtin⁶⁴, Y. Kulchitsky⁹¹,
S. Kuleshov^{32b}, M. Kuna⁷⁹, J. Kunkle¹²¹, A. Kupco¹²⁶, H. Kurashige⁶⁶, M. Kurata¹⁶¹,
Y.A. Kurochkin⁹¹, V. Kus¹²⁶, E.S. Kuwertz¹⁴⁸, M. Kuze¹⁵⁸, J. Kvita¹⁴³, R. Kwee¹⁶,
A. La Rosa⁴⁹, L. La Rotonda^{37a,37b}, L. Labarga⁸¹, S. Lablak^{136a}, C. Lacasta¹⁶⁸,
F. Lacava^{133a,133b}, J. Lacey²⁹, H. Lacker¹⁶, D. Lacour⁷⁹, V.R. Lacuesta¹⁶⁸, E. Ladygin⁶⁴,
R. Lafaye⁵, B. Laforge⁷⁹, T. Lagouri¹⁷⁷, S. Lai⁴⁸, H. Laier^{58a}, E. Laisne⁵⁵, L. Lambourne⁷⁷,
C.L. Lampen⁷, W. Lampl⁷, E. Lançon¹³⁷, U. Landgraf⁴⁸, M.P.J. Landon⁷⁵, V.S. Lang^{58a},
C. Lange⁴², A.J. Lankford¹⁶⁴, F. Lanni²⁵, K. Lantsch³⁰, A. Lanza^{120a}, S. Laplace⁷⁹,
C. Lapoire²¹, J.F. Laporte¹³⁷, T. Lari^{90a}, A. Larner¹¹⁹, M. Lassnig³⁰, P. Laurelli⁴⁷,
V. Lavorini^{37a,37b}, W. Lavrijsen¹⁵, P. Laycock⁷³, O. Le Dortz⁷⁹, E. Le Guirriec⁸⁴,
E. Le Menedeu¹², T. LeCompte⁶, F. Ledroit-Guillon⁵⁵, H. Lee¹⁰⁶, J.S.H. Lee¹¹⁷, S.C. Lee¹⁵²,
L. Lee¹⁷⁷, G. Lefebvre⁷⁹, M. Lefebvre¹⁷⁰, M. Legendre¹³⁷, F. Legger⁹⁹, C. Leggett¹⁵,
M. Lehmacher²¹, G. Lehmann Miotto³⁰, A.G. Leister¹⁷⁷, M.A.L. Leite^{24d}, R. Leitner¹²⁸,
D. Lellouch¹⁷³, B. Lemmer⁵⁴, V. Lendermann^{58a}, K.J.C. Leney^{146c}, T. Lenz¹⁰⁶,
G. Lenzen¹⁷⁶, B. Lenzi³⁰, K. Leonhardt⁴⁴, S. Leontsinis¹⁰, F. Lepold^{58a}, C. Leroy⁹⁴,
J-R. Lessard¹⁷⁰, C.G. Lester²⁸, C.M. Lester¹²¹, J. Levêque⁵, D. Levin⁸⁸, L.J. Levinson¹⁷³,
A. Lewis¹¹⁹, G.H. Lewis¹⁰⁹, A.M. Leyko²¹, M. Leyton¹⁶, B. Li^{33b}, B. Li⁸⁴, H. Li¹⁴⁹,
H.L. Li³¹, S. Li^{33b,t}, X. Li⁸⁸, Z. Liang^{119,u}, H. Liao³⁴, B. Liberti^{134a}, P. Lichard³⁰, K. Lie¹⁶⁶,
J. Liebal²¹, W. Liebig¹⁴, C. Limbach²¹, A. Limosani⁸⁷, M. Limper⁶², S.C. Lin^{152,v},
F. Linde¹⁰⁶, B.E. Lindquist¹⁴⁹, J.T. Linnemann⁸⁹, E. Lipeles¹²¹, A. Lipniacka¹⁴,
M. Lisovyi⁴², T.M. Liss¹⁶⁶, D. Lissauer²⁵, A. Lister¹⁶⁹, A.M. Litke¹³⁸, D. Liu¹⁵², J.B. Liu^{33b},
K. Liu^{33b,w}, L. Liu⁸⁸, M. Liu⁴⁵, M. Liu^{33b}, Y. Liu^{33b}, M. Livan^{120a,120b}, S.S.A. Livermore¹¹⁹,
A. Lleres⁵⁵, J. Llorente Merino⁸¹, S.L. Lloyd⁷⁵, F. Lo Sterzo^{133a,133b}, E. Lobodzinska⁴²,
P. Loch⁷, W.S. Lockman¹³⁸, T. Lodenkoetter²¹, F.K. Loebinger⁸³, A.E. Loevschall-Jensen³⁶,
A. Loginov¹⁷⁷, C.W. Loh¹⁶⁹, T. Lohse¹⁶, K. Lohwasser⁴⁸, M. Lokajicek¹²⁶, V.P. Lombardo⁵,
R.E. Long⁷¹, L. Lopes^{125a}, D. Lopez Mateos⁵⁷, J. Lorenz⁹⁹, N. Lorenzo Martinez¹¹⁶,
M. Losada¹⁶³, P. Loscutoff¹⁵, M.J. Losty^{160a,*}, X. Lou⁴¹, A. Lounis¹¹⁶, K.F. Loureiro¹⁶³,
J. Love⁶, P.A. Love⁷¹, A.J. Lowe^{144,f}, F. Lu^{33a}, H.J. Lubatti¹³⁹, C. Luci^{133a,133b}, A. Lucotte⁵⁵,
D. Ludwig⁴², I. Ludwig⁴⁸, J. Ludwig⁴⁸, F. Luehring⁶⁰, W. Lukas⁶¹, L. Luminari^{133a},
E. Lund¹¹⁸, J. Lundberg^{147a,147b}, O. Lundberg^{147a,147b}, B. Lund-Jensen¹⁴⁸, J. Lundquist³⁶,
M. Lungwitz⁸², D. Lynn²⁵, R. Lysak¹²⁶, E. Lytken⁸⁰, H. Ma²⁵, L.L. Ma¹⁷⁴,
G. Maccarrone⁴⁷, A. Macchiolo¹⁰⁰, B. Maček⁷⁴, J. Machado Miguens^{125a}, D. Macina³⁰,
R. Mackeprang³⁶, R. Madar⁴⁸, R.J. Madaras¹⁵, H.J. Maddocks⁷¹, W.F. Mader⁴⁴,
A. Madsen¹⁶⁷, M. Maeno⁵, T. Maeno²⁵, L. Magnoni¹⁶⁴, E. Magradze⁵⁴, K. Mahboubi⁴⁸,
J. Mahlstedt¹⁰⁶, S. Mahmoud⁷³, G. Mahout¹⁸, C. Maiani¹³⁷, C. Maidantchik^{24a},

A. Maio ^{125a,c}, S. Majewski ¹¹⁵, Y. Makida ⁶⁵, N. Makovec ¹¹⁶, P. Mal ^{137,x}, B. Malaescu ⁷⁹,
 Pa. Malecki ³⁹, P. Malecki ³⁹, V.P. Maleev ¹²², F. Malek ⁵⁵, U. Mallik ⁶², D. Malon ⁶,
 C. Malone ¹⁴⁴, S. Maltezos ¹⁰, V. Malyshev ¹⁰⁸, S. Malyukov ³⁰, J. Mamuzic ^{13b},
 L. Mandelli ^{90a}, I. Mandić ⁷⁴, R. Mandrysch ⁶², J. Maneira ^{125a}, A. Manfredini ¹⁰⁰,
 L. Manhaes de Andrade Filho ^{24b}, J.A. Manjarres Ramos ¹³⁷, A. Mann ⁹⁹, P.M. Manning ¹³⁸,
 A. Manousakis-Katsikakis ⁹, B. Mansoulie ¹³⁷, R. Mantifel ⁸⁶, L. Mapelli ³⁰, L. March ¹⁶⁸,
 J.F. Marchand ²⁹, F. Marchese ^{134a,134b}, G. Marchiori ⁷⁹, M. Marcisovsky ¹²⁶, C.P. Marino ¹⁷⁰,
 C.N. Marques ^{125a}, F. Marroquim ^{24a}, Z. Marshall ¹²¹, L.F. Marti ¹⁷, S. Marti-Garcia ¹⁶⁸,
 B. Martin ³⁰, B. Martin ⁸⁹, J.P. Martin ⁹⁴, T.A. Martin ¹⁷¹, V.J. Martin ⁴⁶,
 B. Martin dit Latour ⁴⁹, H. Martinez ¹³⁷, M. Martinez ¹², S. Martin-Haugh ¹⁵⁰,
 A.C. Martyniuk ¹⁷⁰, M. Marx ⁸³, F. Marzano ^{133a}, A. Marzin ¹¹², L. Masetti ⁸², T. Mashimo ¹⁵⁶,
 R. Mashinistov ⁹⁵, J. Masik ⁸³, A.L. Maslennikov ¹⁰⁸, I. Massa ^{20a,20b}, N. Massol ⁵,
 P. Mastrandrea ¹⁴⁹, A. Mastroberardino ^{37a,37b}, T. Masubuchi ¹⁵⁶, H. Matsunaga ¹⁵⁶,
 T. Matsushita ⁶⁶, P. Mättig ¹⁷⁶, S. Mättig ⁴², C. Mattravers ^{119,d}, J. Maurer ⁸⁴, S.J. Maxfield ⁷³,
 D.A. Maximov ^{108,g}, R. Mazini ¹⁵², M. Mazur ²¹, L. Mazzaferro ^{134a,134b}, M. Mazzanti ^{90a},
 S.P. Mc Kee ⁸⁸, A. McCarn ¹⁶⁶, R.L. McCarthy ¹⁴⁹, T.G. McCarthy ²⁹, N.A. McCubbin ¹³⁰,
 K.W. McFarlane ^{56,*}, J.A. MCFayden ¹⁴⁰, G. Mchedlize ^{51b}, T. McLaughlan ¹⁸,
 S.J. McMahon ¹³⁰, R.A. McPherson ^{170,j}, A. Meade ⁸⁵, J. Mechnich ¹⁰⁶, M. Mechtel ¹⁷⁶,
 M. Medinnis ⁴², S. Meehan ³¹, R. Meera-Lebbai ¹¹², T. Meguro ¹¹⁷, S. Mehlhase ³⁶,
 A. Mehta ⁷³, K. Meier ^{58a}, C. Meineck ⁹⁹, B. Meirose ⁸⁰, C. Melachrinou ³¹,
 B.R. Mellado Garcia ^{146c}, F. Meloni ^{90a,90b}, L. Mendoza Navas ¹⁶³, A. Mengarelli ^{20a,20b},
 S. Menke ¹⁰⁰, E. Meoni ¹⁶², K.M. Mercurio ⁵⁷, N. Meric ¹³⁷, P. Mermod ⁴⁹, L. Merola ^{103a,103b},
 C. Meroni ^{90a}, F.S. Merritt ³¹, H. Merritt ¹¹⁰, A. Messina ^{30,y}, J. Metcalfe ²⁵, A.S. Mete ¹⁶⁴,
 C. Meyer ⁸², C. Meyer ³¹, J-P. Meyer ¹³⁷, J. Meyer ³⁰, J. Meyer ⁵⁴, S. Michal ³⁰,
 R.P. Middleton ¹³⁰, S. Migas ⁷³, L. Mijović ¹³⁷, G. Mikenberg ¹⁷³, M. Mikestikova ¹²⁶,
 M. Mikuž ⁷⁴, D.W. Miller ³¹, W.J. Mills ¹⁶⁹, C. Mills ⁵⁷, A. Milov ¹⁷³, D.A. Milstead ^{147a,147b},
 D. Milstein ¹⁷³, A.A. Minaenko ¹²⁹, M. Miñano Moya ¹⁶⁸, I.A. Minashvili ⁶⁴, A.I. Mincer ¹⁰⁹,
 B. Mindur ^{38a}, M. Mineev ⁶⁴, Y. Ming ¹⁷⁴, L.M. Mir ¹², G. Mirabelli ^{133a}, J. Mitrevski ¹³⁸,
 V.A. Mitsou ¹⁶⁸, S. Mitsui ⁶⁵, P.S. Miyagawa ¹⁴⁰, J.U. Mjörnmark ⁸⁰, T. Moa ^{147a,147b},
 V. Moeller ²⁸, S. Mohapatra ¹⁴⁹, W. Mohr ⁴⁸, R. Moles-Valls ¹⁶⁸, A. Molfetas ³⁰, K. Mönig ⁴²,
 C. Monini ⁵⁵, J. Monk ³⁶, E. Monnier ⁸⁴, J. Montejo Berlingen ¹², F. Monticelli ⁷⁰,
 S. Monzani ^{20a,20b}, R.W. Moore ³, C. Mora Herrera ⁴⁹, A. Moraes ⁵³, N. Morange ⁶²,
 J. Morel ⁵⁴, D. Moreno ⁸², M. Moreno Llácer ¹⁶⁸, P. Morettini ^{50a}, M. Morgenstern ⁴⁴,
 M. Morii ⁵⁷, S. Moritz ⁸², A.K. Morley ³⁰, G. Mornacchi ³⁰, J.D. Morris ⁷⁵, L. Morvaj ¹⁰²,
 N. Möser ²¹, H.G. Moser ¹⁰⁰, M. Mosidze ^{51b}, J. Moss ¹¹⁰, R. Mount ¹⁴⁴, E. Mountricha ^{10,z},
 S.V. Mouraviev ^{95,*}, E.J.W. Moyses ⁸⁵, R.D. Mudd ¹⁸, F. Mueller ^{58a}, J. Mueller ¹²⁴,
 K. Mueller ²¹, T. Mueller ²⁸, T. Mueller ⁸², D. Muenstermann ³⁰, Y. Munwes ¹⁵⁴,
 J.A. Murillo Quijada ¹⁸, W.J. Murray ¹³⁰, I. Mussche ¹⁰⁶, E. Musto ¹⁵³, A.G. Myagkov ^{129,aa},
 M. Myska ¹²⁶, O. Nackenhorst ⁵⁴, J. Nadal ¹², K. Nagai ¹⁶¹, R. Nagai ¹⁵⁸, Y. Nagai ⁸⁴,
 K. Nagano ⁶⁵, A. Nagarkar ¹¹⁰, Y. Nagasaka ⁵⁹, M. Nagel ¹⁰⁰, A.M. Nairz ³⁰, Y. Nakahama ³⁰,
 K. Nakamura ⁶⁵, T. Nakamura ¹⁵⁶, I. Nakano ¹¹¹, H. Namasivayam ⁴¹, G. Nanava ²¹,
 A. Napier ¹⁶², R. Narayan ^{58b}, M. Nash ^{77,d}, T. Nattermann ²¹, T. Naumann ⁴², G. Navarro ¹⁶³,
 H.A. Neal ⁸⁸, P.Yu. Nechaeva ⁹⁵, T.J. Neep ⁸³, A. Negri ^{120a,120b}, G. Negri ³⁰, M. Negrini ^{20a},
 S. Nektarijevic ⁴⁹, A. Nelson ¹⁶⁴, T.K. Nelson ¹⁴⁴, S. Nemecek ¹²⁶, P. Nemethy ¹⁰⁹,
 A.A. Nepomuceno ^{24a}, M. Nessi ^{30,ab}, M.S. Neubauer ¹⁶⁶, M. Neumann ¹⁷⁶, A. Neusiedl ⁸²,
 R.M. Neves ¹⁰⁹, P. Nevski ²⁵, F.M. Newcomer ¹²¹, P.R. Newman ¹⁸, D.H. Nguyen ⁶,
 V. Nguyen Thi Hong ¹³⁷, R.B. Nickerson ¹¹⁹, R. Nicolaidou ¹³⁷, B. Nicquevert ³⁰,
 F. Niedercorn ¹¹⁶, J. Nielsen ¹³⁸, N. Nikiforou ³⁵, A. Nikiforov ¹⁶, V. Nikolaenko ^{129,aa},
 I. Nikolic-Audit ⁷⁹, K. Nikolics ⁴⁹, K. Nikolopoulos ¹⁸, P. Nilsson ⁸, Y. Ninomiya ¹⁵⁶,
 A. Nisati ^{133a}, R. Nisius ¹⁰⁰, T. Nobe ¹⁵⁸, L. Nodulman ⁶, M. Nomachi ¹¹⁷, I. Nomidis ¹⁵⁵,
 S. Norberg ¹¹², M. Nordberg ³⁰, J. Novakova ¹²⁸, M. Nozaki ⁶⁵, L. Nozka ¹¹⁴,
 A.-E. Nuncio-Quiroz ²¹, G. Nunes Hanninger ⁸⁷, T. Nunnemann ⁹⁹, E. Nurse ⁷⁷,

B.J. O'Brien⁴⁶, D.C. O'Neil¹⁴³, V. O'Shea⁵³, L.B. Oakes⁹⁹, F.G. Oakham^{29,e}, H. Oberlack¹⁰⁰,
 J. Ocariz⁷⁹, A. Ochi⁶⁶, M.I. Ochoa⁷⁷, S. Oda⁶⁹, S. Odaka⁶⁵, J. Odier⁸⁴, H. Ogren⁶⁰,
 A. Oh⁸³, S.H. Oh⁴⁵, C.C. Ohm³⁰, T. Ohshima¹⁰², W. Okamura¹¹⁷, H. Okawa²⁵,
 Y. Okumura³¹, T. Okuyama¹⁵⁶, A. Olariu^{26a}, A.G. Olchevski⁶⁴, S.A. Olivares Pino⁴⁶,
 M. Oliveira^{125a,h}, D. Oliveira Damazio²⁵, E. Oliver Garcia¹⁶⁸, D. Olivito¹²¹, A. Olszewski³⁹,
 J. Olszowska³⁹, A. Onofre^{125a,ac}, P.U.E. Onyisi^{31,ad}, C.J. Oram^{160a}, M.J. Oreglia³¹,
 Y. Oren¹⁵⁴, D. Orestano^{135a,135b}, N. Orlando^{72a,72b}, C. Oropeza Barrera⁵³, R.S. Orr¹⁵⁹,
 B. Osculati^{50a,50b}, R. Ospanov¹²¹, G. Otero y Garzon²⁷, J.P. Ottersbach¹⁰⁶, M. Ouchrif^{136d},
 E.A. Ouellette¹⁷⁰, F. Ould-Saada¹¹⁸, A. Ouraou¹³⁷, Q. Ouyang^{33a}, A. Ovcharova¹⁵,
 M. Owen⁸³, S. Owen¹⁴⁰, V.E. Ozcan^{19a}, N. Ozturk⁸, A. Pacheco Pages¹²,
 C. Padilla Aranda¹², S. Pagan Griso¹⁵, E. Paganis¹⁴⁰, C. Pahl¹⁰⁰, F. Paige²⁵, P. Pais⁸⁵,
 K. Pajchel¹¹⁸, G. Palacino^{160b}, C.P. Paleari⁷, S. Palestini³⁰, D. Pallin³⁴, A. Palma^{125a},
 J.D. Palmer¹⁸, Y.B. Pan¹⁷⁴, E. Panagiotopoulou¹⁰, J.G. Panduro Vazquez⁷⁶, P. Pani¹⁰⁶,
 N. Panikashvili⁸⁸, S. Panitkin²⁵, D. Pantea^{26a}, A. Papadelis^{147a}, Th.D. Papadopoulou¹⁰,
 K. Papageorgiou^{155,o}, A. Paramonov⁶, D. Paredes Hernandez³⁴, W. Park^{25,ae},
 M.A. Parker²⁸, F. Parodi^{50a,50b}, J.A. Parsons³⁵, U. Parzefall⁴⁸, S. Pashapour⁵⁴,
 E. Pasqualucci^{133a}, S. Passaggio^{50a}, A. Passeri^{135a}, F. Pastore^{135a,135b,*}, Fr. Pastore⁷⁶,
 G. Pásztor^{49,af}, S. Patarai¹⁷⁶, N.D. Patel¹⁵¹, J.R. Pater⁸³, S. Patricelli^{103a,103b}, T. Pauly³⁰,
 J. Pearce¹⁷⁰, M. Pedersen¹¹⁸, S. Pedraza Lopez¹⁶⁸, M.I. Pedraza Morales¹⁷⁴,
 S.V. Peleganchuk¹⁰⁸, D. Pelikan¹⁶⁷, H. Peng^{33b}, B. Penning³¹, A. Penson³⁵, J. Penwell⁶⁰,
 T. Perez Cavalcanti⁴², E. Perez Codina^{160a}, M.T. Pérez García-Estañ¹⁶⁸, V. Perez Reale³⁵,
 L. Perini^{90a,90b}, H. Pernegger³⁰, R. Perrino^{72a}, P. Perrodo⁵, V.D. Peshekhonov⁶⁴,
 K. Peters³⁰, R.F.Y. Peters^{54,ag}, B.A. Petersen³⁰, J. Petersen³⁰, T.C. Petersen³⁶, E. Petit⁵,
 A. Petridis^{147a,147b}, C. Petridou¹⁵⁵, E. Petrolo^{133a}, F. Petrucci^{135a,135b}, D. Petschull⁴²,
 M. Petteni¹⁴³, R. Pezoa^{32b}, A. Phan⁸⁷, P.W. Phillips¹³⁰, G. Piacquadio¹⁴⁴, E. Pianori¹⁷¹,
 A. Picazio⁴⁹, E. Piccaro⁷⁵, M. Piccinini^{20a,20b}, S.M. Piec⁴², R. Piegai²⁷, D.T. Pignotti¹¹⁰,
 J.E. Pilcher³¹, A.D. Pilkington⁷⁷, J. Pina^{125a,c}, M. Pinamonti^{165a,165c,ah}, A. Pinder¹¹⁹,
 J.L. Pinfold³, A. Pingel³⁶, B. Pinto^{125a}, C. Pizio^{90a,90b}, M.-A. Pleier²⁵, V. Pleskot¹²⁸,
 E. Plotnikova⁶⁴, P. Plucinski^{147a,147b}, S. Poddar^{58a}, F. Podlyski³⁴, R. Poettgen⁸²,
 L. Poggioli¹¹⁶, D. Pohl²¹, M. Pohl⁴⁹, G. Polesello^{120a}, A. Policicchio^{37a,37b}, R. Polifka¹⁵⁹,
 A. Polini^{20a}, V. Polychronakos²⁵, D. Pomeroy²³, K. Pommès³⁰, L. Pontecorvo^{133a},
 B.G. Pope⁸⁹, G.A. Popeneciu^{26b}, D.S. Popovic^{13a}, A. Poppleton³⁰, X. Portell Bueso¹²,
 G.E. Pospelov¹⁰⁰, S. Pospisil¹²⁷, I.N. Potrap⁶⁴, C.J. Potter¹⁵⁰, C.T. Potter¹¹⁵, G. Poulard³⁰,
 J. Poveda⁶⁰, V. Pozdnyakov⁶⁴, R. Prabhu⁷⁷, P. Pralavorio⁸⁴, A. Pranko¹⁵, S. Prasad³⁰,
 R. Pravahan²⁵, S. Prell⁶³, K. Pretzl¹⁷, D. Price⁶⁰, J. Price⁷³, L.E. Price⁶, D. Prieur¹²⁴,
 M. Primavera^{72a}, M. Proissl⁴⁶, K. Prokofiev¹⁰⁹, F. Prokoshin^{32b}, E. Protopapadaki¹³⁷,
 S. Protopopescu²⁵, J. Proudfoot⁶, X. Prudent⁴⁴, M. Przybycien^{38a}, H. Przysiezniak⁵,
 S. Psoroulas²¹, E. Ptacek¹¹⁵, E. Pueschel⁸⁵, D. Puldon¹⁴⁹, M. Purohit^{25,ae}, P. Puzo¹¹⁶,
 Y. Pylypchenko⁶², J. Qian⁸⁸, A. Quadt⁵⁴, D.R. Quarrie¹⁵, W.B. Quayle¹⁷⁴, D. Quilty⁵³,
 M. Raas¹⁰⁵, V. Radeka²⁵, V. Radescu⁴², P. Radloff¹¹⁵, F. Ragusa^{90a,90b}, G. Rahal¹⁷⁹,
 S. Rajagopalan²⁵, M. Rammensee⁴⁸, M. Rammes¹⁴², A.S. Randle-Conde⁴⁰,
 K. Randrianarivony²⁹, C. Rangel-Smith⁷⁹, K. Rao¹⁶⁴, F. Rauscher⁹⁹, T.C. Rave⁴⁸,
 T. Ravenscroft⁵³, M. Raymond³⁰, A.L. Read¹¹⁸, D.M. Rebuffi^{120a,120b}, A. Redelbach¹⁷⁵,
 G. Redlinger²⁵, R. Reece¹²¹, K. Reeves⁴¹, A. Reinsch¹¹⁵, I. Reisinger⁴³, M. Relich¹⁶⁴,
 C. Rembser³⁰, Z.L. Ren¹⁵², A. Renaud¹¹⁶, M. Rescigno^{133a}, S. Resconi^{90a}, B. Resende¹³⁷,
 P. Reznicek⁹⁹, R. Rezvani⁹⁴, R. Richter¹⁰⁰, E. Richter-Was^{38b}, M. Ridel⁷⁹, P. Rieck¹⁶,
 M. Rijssenbeek¹⁴⁹, A. Rimoldi^{120a,120b}, L. Rinaldi^{20a}, R.R. Rios⁴⁰, E. Ritsch⁶¹, I. Riu¹²,
 G. Rivoltella^{90a,90b}, F. Rizatdinova¹¹³, E. Rizvi⁷⁵, S.H. Robertson^{86,j},
 A. Robichaud-Veronneau¹¹⁹, D. Robinson²⁸, J.E.M. Robinson⁸³, A. Robson⁵³,
 J.G. Rocha de Lima¹⁰⁷, C. Roda^{123a,123b}, D. Roda Dos Santos³⁰, A. Roe⁵⁴, S. Roe³⁰,
 O. Røhne¹¹⁸, S. Rolli¹⁶², A. Romaniouk⁹⁷, M. Romano^{20a,20b}, G. Romeo²⁷,
 E. Romero Adam¹⁶⁸, N. Rompotis¹³⁹, L. Roos⁷⁹, E. Ros¹⁶⁸, S. Rosati^{133a}, K. Rosbach⁴⁹,

A. Rose¹⁵⁰, M. Rose⁷⁶, G.A. Rosenbaum¹⁵⁹, P.L. Rosendahl¹⁴, O. Rosenthal¹⁴²,
 V. Rossetti¹², E. Rossi^{133a,133b}, L.P. Rossi^{50a}, M. Rotaru^{26a}, I. Roth¹⁷³, J. Rothberg¹³⁹,
 D. Rousseau¹¹⁶, C.R. Royon¹³⁷, A. Rozanov⁸⁴, Y. Rozen¹⁵³, X. Ruan^{146c}, F. Rubbo¹²,
 I. Rubinskiy⁴², N. Ruckstuhl¹⁰⁶, V.I. Rud⁹⁸, C. Rudolph⁴⁴, M.S. Rudolph¹⁵⁹, F. Rühr⁷,
 A. Ruiz-Martinez⁶³, L. Rumyantsev⁶⁴, Z. Rurikova⁴⁸, N.A. Rusakovich⁶⁴, A. Ruschke⁹⁹,
 J.P. Rutherford⁷, N. Ruthmann⁴⁸, P. Ruzicka¹²⁶, Y.F. Ryabov¹²², M. Rybar¹²⁸,
 G. Rybkin¹¹⁶, N.C. Ryder¹¹⁹, A.F. Saavedra¹⁵¹, A. Saddique³, I. Sadeh¹⁵⁴,
 H.F.-W. Sadrozinski¹³⁸, R. Sadykov⁶⁴, F. Safai Tehrani^{133a}, H. Sakamoto¹⁵⁶,
 G. Salamanna⁷⁵, A. Salamon^{134a}, M. Saleem¹¹², D. Salek³⁰, D. Salihagic¹⁰⁰,
 A. Salnikov¹⁴⁴, J. Salt¹⁶⁸, B.M. Salvachua Ferrando⁶, D. Salvatore^{37a,37b}, F. Salvatore¹⁵⁰,
 A. Salvucci¹⁰⁵, A. Salzburger³⁰, D. Sampsonidis¹⁵⁵, A. Sanchez^{103a,103b}, J. Sánchez¹⁶⁸,
 V. Sanchez Martinez¹⁶⁸, H. Sandaker¹⁴, H.G. Sander⁸², M.P. Sanders⁹⁹, M. Sandhoff¹⁷⁶,
 T. Sandoval²⁸, C. Sandoval¹⁶³, R. Sandstroem¹⁰⁰, D.P.C. Sankey¹³⁰, A. Sansoni⁴⁷,
 C. Santoni³⁴, R. Santonico^{134a,134b}, H. Santos^{125a}, I. Santoyo Castillo¹⁵⁰, K. Sapp¹²⁴,
 J.G. Saraiva^{125a}, T. Sarangi¹⁷⁴, E. Sarkisyan-Grinbaum⁸, B. Sarrazin²¹, F. Sarri^{123a,123b},
 G. Sartisohn¹⁷⁶, O. Sasaki⁶⁵, Y. Sasaki¹⁵⁶, N. Sasao⁶⁷, I. Satsounkevitch⁹¹, G. Sauvage^{5,*},
 E. Sauvan⁵, J.B. Sauvan¹¹⁶, P. Savard^{159,e}, V. Savinov¹²⁴, D.O. Savu³⁰, C. Sawyer¹¹⁹,
 L. Sawyer^{78,l}, D.H. Saxon⁵³, J. Saxon¹²¹, C. Sbarra^{20a}, A. Sbrizzi³, D.A. Scannicchio¹⁶⁴,
 M. Scarcella¹⁵¹, J. Schaarschmidt¹¹⁶, P. Schacht¹⁰⁰, D. Schaefer¹²¹, A. Schaelicke⁴⁶,
 S. Schaepe²¹, S. Schaetzel^{58b}, U. Schäfer⁸², A.C. Schaffer¹¹⁶, D. Schaile⁹⁹,
 R.D. Schamberger¹⁴⁹, V. Scharf^{58a}, V.A. Schegelsky¹²², D. Scheirich⁸⁸, M. Schernau¹⁶⁴,
 M.I. Scherzer³⁵, C. Schiavi^{50a,50b}, J. Schieck⁹⁹, C. Schillo⁴⁸, M. Schioppa^{37a,37b},
 S. Schlenker³⁰, E. Schmidt⁴⁸, K. Schmieden²¹, C. Schmitt⁸², C. Schmitt⁹⁹, S. Schmitt^{58b},
 B. Schneider¹⁷, Y.J. Schnellbach⁷³, U. Schnoor⁴⁴, L. Schoeffel¹³⁷, A. Schoening^{58b},
 A.L.S. Schorlemmer⁵⁴, M. Schott⁸², D. Schouten^{160a}, J. Schovancova¹²⁶, M. Schram⁸⁶,
 C. Schroeder⁸², N. Schroer^{58c}, M.J. Schultens²¹, H.-C. Schultz-Coulon^{58a}, H. Schulz¹⁶,
 M. Schumacher⁴⁸, B.A. Schumm¹³⁸, Ph. Schune¹³⁷, A. Schwartzman¹⁴⁴, Ph. Schwegler¹⁰⁰,
 Ph. Schwemling¹³⁷, R. Schwienhorst⁸⁹, J. Schwindling¹³⁷, T. Schwindt²¹, M. Schwoerer⁵,
 F.G. Sciacca¹⁷, E. Scifo¹¹⁶, G. Sciolla²³, W.G. Scott¹³⁰, F. Scutti²¹, J. Searcy⁸⁸, G. Sedov⁴²,
 E. Sedykh¹²², S.C. Seidel¹⁰⁴, A. Seiden¹³⁸, F. Seifert⁴⁴, J.M. Seixas^{24a}, G. Sekhniaidze^{103a},
 S.J. Sekula⁴⁰, K.E. Selbach⁴⁶, D.M. Seliverstov¹²², G. Sellers⁷³, M. Seman^{145b},
 N. Semprini-Cesari^{20a,20b}, C. Serfon³⁰, L. Serin¹¹⁶, L. Serkin⁵⁴, T. Serre⁸⁴, R. Seuster^{160a},
 H. Severini¹¹², A. Sfyrla³⁰, E. Shabalina⁵⁴, M. Shamim¹¹⁵, L.Y. Shan^{33a}, J.T. Shank²²,
 Q.T. Shao⁸⁷, M. Shapiro¹⁵, P.B. Shatalov⁹⁶, K. Shaw^{165a,165c}, P. Sherwood⁷⁷, S. Shimizu¹⁰²,
 M. Shimojima¹⁰¹, T. Shin⁵⁶, M. Shiyakova⁶⁴, A. Shmeleva⁹⁵, M.J. Shochet³¹, D. Short¹¹⁹,
 S. Shrestha⁶³, E. Shulga⁹⁷, M.A. Shupe⁷, P. Sicho¹²⁶, A. Sidoti^{133a}, F. Siegert⁴⁸,
 Dj. Sijacki^{13a}, O. Silbert¹⁷³, J. Silva^{125a}, Y. Silver¹⁵⁴, D. Silverstein¹⁴⁴, S.B. Silverstein^{147a},
 V. Simak¹²⁷, O. Simard⁵, Lj. Simic^{13a}, S. Simion¹¹⁶, E. Simioni⁸², B. Simmons⁷⁷,
 R. Simoniello^{90a,90b}, M. Simonyan³⁶, P. Sinervo¹⁵⁹, N.B. Sinev¹¹⁵, V. Sipica¹⁴²,
 G. Siragusa¹⁷⁵, A. Sircar⁷⁸, A.N. Sisakyan^{64,*}, S.Yu. Sivoklov⁹⁸, J. Sjölin^{147a,147b},
 T.B. Sjursen¹⁴, L.A. Skinnari¹⁵, H.P. Skottowe⁵⁷, K. Skovpen¹⁰⁸, P. Skubic¹¹², M. Slater¹⁸,
 T. Slavicek¹²⁷, K. Sliwa¹⁶², V. Smakhtin¹⁷³, B.H. Smart⁴⁶, L. Smestad¹¹⁸, S.Yu. Smirnov⁹⁷,
 Y. Smirnov⁹⁷, L.N. Smirnova^{98,ai}, O. Smirnova⁸⁰, K.M. Smith⁵³, M. Smizanska⁷¹,
 K. Smolek¹²⁷, A.A. Snesarev⁹⁵, G. Snidero⁷⁵, J. Snow¹¹², S. Snyder²⁵, R. Sobie^{170,j},
 J. Sodomka¹²⁷, A. Soffer¹⁵⁴, D.A. Soh^{152,u}, C.A. Solans³⁰, M. Solar¹²⁷, J. Solc¹²⁷,
 E.Yu. Soldatov⁹⁷, U. Soldevila¹⁶⁸, E. Solfaroli Camillocci^{133a,133b}, A.A. Solodkov¹²⁹,
 O.V. Solovyanov¹²⁹, V. Solovyev¹²², N. Soni¹, A. Sood¹⁵, V. Sopko¹²⁷, B. Sopko¹²⁷,
 M. Sosebee⁸, R. Soualah^{165a,165c}, P. Soueid⁹⁴, A. Soukharev¹⁰⁸, D. South⁴²,
 S. Spagnolo^{72a,72b}, F. Spanò⁷⁶, R. Spighi^{20a}, G. Spigo³⁰, R. Spiwoks³⁰, M. Spusta^{128,aj},
 T. Spreitzer¹⁵⁹, B. Spurlock⁸, R.D. St. Denis⁵³, J. Stahlman¹²¹, R. Stamen^{58a}, E. Stanecka³⁹,
 R.W. Stanek⁶, C. Stancu^{135a}, M. Stancu-Bellu⁴², M.M. Stanitzki⁴², S. Stapnes¹¹⁸,
 E.A. Starchenko¹²⁹, J. Stark⁵⁵, P. Staroba¹²⁶, P. Starovoitov⁴², R. Staszewski³⁹, A. Staude⁹⁹,

P. Stavina ^{145a,*}, G. Steele ⁵³, P. Steinbach ⁴⁴, P. Steinberg ²⁵, I. Stekl ¹²⁷, B. Stelzer ¹⁴³,
 H.J. Stelzer ⁸⁹, O. Stelzer-Chilton ^{160a}, H. Stenzel ⁵², S. Stern ¹⁰⁰, G.A. Stewart ³⁰,
 J.A. Stillings ²¹, M.C. Stockton ⁸⁶, M. Stoebe ⁸⁶, K. Stoerig ⁴⁸, G. Stoicea ^{26a}, S. Stonjek ¹⁰⁰,
 A.R. Stradling ⁸, A. Straessner ⁴⁴, J. Strandberg ¹⁴⁸, S. Strandberg ^{147a,147b}, A. Strandlie ¹¹⁸,
 M. Strang ¹¹⁰, E. Strauss ¹⁴⁴, M. Strauss ¹¹², P. Strizenec ^{145b}, R. Ströhmer ¹⁷⁵,
 D.M. Strom ¹¹⁵, J.A. Strong ^{76,*}, R. Stroynowski ⁴⁰, B. Stugu ¹⁴, I. Stumer ^{25,*}, J. Stupak ¹⁴⁹,
 P. Sturm ¹⁷⁶, N.A. Styles ⁴², D. Su ¹⁴⁴, HS. Subramania ³, R. Subramaniam ⁷⁸, A. Succurro ¹²,
 Y. Sugaya ¹¹⁷, C. Suhr ¹⁰⁷, M. Suk ¹²⁷, V.V. Sulin ⁹⁵, S. Sultansoy ^{4c}, T. Sumida ⁶⁷, X. Sun ⁵⁵,
 J.E. Sundermann ⁴⁸, K. Suruliz ¹⁴⁰, G. Susinno ^{37a,37b}, M.R. Sutton ¹⁵⁰, Y. Suzuki ⁶⁵,
 Y. Suzuki ⁶⁶, M. Svatos ¹²⁶, S. Swedish ¹⁶⁹, M. Swiatlowski ¹⁴⁴, I. Sykora ^{145a}, T. Sykora ¹²⁸,
 D. Ta ¹⁰⁶, K. Tackmann ⁴², A. Taffard ¹⁶⁴, R. Tafirout ^{160a}, N. Taiblum ¹⁵⁴, Y. Takahashi ¹⁰²,
 H. Takai ²⁵, R. Takashima ⁶⁸, H. Takeda ⁶⁶, T. Takeshita ¹⁴¹, Y. Takubo ⁶⁵, M. Talby ⁸⁴,
 A. Talyshev ^{108.g}, J.Y.C. Tam ¹⁷⁵, M.C. Tamsett ^{78.ak}, K.G. Tan ⁸⁷, J. Tanaka ¹⁵⁶, R. Tanaka ¹¹⁶,
 S. Tanaka ¹³², S. Tanaka ⁶⁵, A.J. Tanasijczuk ¹⁴³, K. Tani ⁶⁶, N. Tannoury ⁸⁴, S. Tapprogge ⁸²,
 S. Tarem ¹⁵³, F. Tarrade ²⁹, G.F. Tartarelli ^{90a}, P. Tas ¹²⁸, M. Tasevsky ¹²⁶, T. Tashiro ⁶⁷,
 E. Tassi ^{37a,37b}, Y. Tayalati ^{136d}, C. Taylor ⁷⁷, F.E. Taylor ⁹³, G.N. Taylor ⁸⁷, W. Taylor ^{160b},
 M. Teinturier ¹¹⁶, F.A. Teischinger ³⁰, M. Teixeira Dias Castanheira ⁷⁵, P. Teixeira-Dias ⁷⁶,
 K.K. Temming ⁴⁸, H. Ten Kate ³⁰, P.K. Teng ¹⁵², S. Terada ⁶⁵, K. Terashi ¹⁵⁶, J. Terron ⁸¹,
 M. Testa ⁴⁷, R.J. Teuscher ^{159.j}, J. Therhaag ²¹, T. Theveneaux-Pelzer ³⁴, S. Thoma ⁴⁸,
 J.P. Thomas ¹⁸, E.N. Thompson ³⁵, P.D. Thompson ¹⁸, P.D. Thompson ¹⁵⁹, A.S. Thompson ⁵³,
 L.A. Thomsen ³⁶, E. Thomson ¹²¹, M. Thomson ²⁸, W.M. Thong ⁸⁷, R.P. Thun ^{88,*}, F. Tian ³⁵,
 M.J. Tibbetts ¹⁵, T. Tic ¹²⁶, V.O. Tikhomirov ⁹⁵, Y.A. Tikhonov ^{108.g}, S. Timoshenko ⁹⁷,
 E. Tiouchichine ⁸⁴, P. Tipton ¹⁷⁷, S. Tisserant ⁸⁴, T. Todorov ⁵, S. Todorova-Nova ¹⁶²,
 B. Toggerson ¹⁶⁴, J. Tojo ⁶⁹, S. Tokár ^{145a}, K. Tokushuku ⁶⁵, K. Tollefson ⁸⁹, L. Tomlinson ⁸³,
 M. Tomoto ¹⁰², L. Tompkins ³¹, K. Toms ¹⁰⁴, A. Tonoyan ¹⁴, C. Topfel ¹⁷, N.D. Topilin ⁶⁴,
 E. Torrence ¹¹⁵, H. Torres ⁷⁹, E. Torró Pastor ¹⁶⁸, J. Toth ^{84.af}, F. Touchard ⁸⁴, D.R. Tovey ¹⁴⁰,
 H.L. Tran ¹¹⁶, T. Trefzger ¹⁷⁵, L. Tremblet ³⁰, A. Tricoli ³⁰, I.M. Trigger ^{160a},
 S. Trincaz-Duvoid ⁷⁹, M.F. Tripiana ⁷⁰, N. Triplett ²⁵, W. Trischuk ¹⁵⁹, B. Trocmé ⁵⁵,
 C. Troncon ^{90a}, M. Trottier-McDonald ¹⁴³, M. Trovatelli ^{135a,135b}, P. True ⁸⁹, M. Trzebinski ³⁹,
 A. Trzupek ³⁹, C. Tsarouchas ³⁰, J.C.-L. Tseng ¹¹⁹, M. Tsiakiris ¹⁰⁶, P.V. Tsiarehka ⁹¹,
 D. Tsionou ¹³⁷, G. Tsipolitis ¹⁰, S. Tsiskaridze ¹², V. Tsiskaridze ⁴⁸, E.G. Tskhadadze ^{51a},
 I.I. Tsukerman ⁹⁶, V. Tsulaia ¹⁵, J.-W. Tsung ²¹, S. Tsuno ⁶⁵, D. Tsybychev ¹⁴⁹, A. Tua ¹⁴⁰,
 A. Tudorache ^{26a}, V. Tudorache ^{26a}, J.M. Tuggle ³¹, A.N. Tuna ¹²¹, M. Turala ³⁹,
 D. Turecek ¹²⁷, I. Turk Cakir ^{4d}, R. Turra ^{90a,90b}, P.M. Tuts ³⁵, A. Tykhonov ⁷⁴,
 M. Tylmad ^{147a,147b}, M. Tyndel ¹³⁰, K. Uchida ²¹, I. Ueda ¹⁵⁶, R. Ueno ²⁹, M. Ughetto ⁸⁴,
 M. Uglan ¹⁴, M. Uhlenbrock ²¹, F. Ukegawa ¹⁶¹, G. Unal ³⁰, A. Undrus ²⁵, G. Unel ¹⁶⁴,
 F.C. Ungaro ⁴⁸, Y. Unno ⁶⁵, D. Urbaniec ³⁵, P. Urquijo ²¹, G. Usai ⁸, L. Vacavant ⁸⁴,
 V. Vacek ¹²⁷, B. Vachon ⁸⁶, S. Vahsen ¹⁵, N. Valencic ¹⁰⁶, S. Valentinetti ^{20a,20b}, A. Valero ¹⁶⁸,
 L. Valery ³⁴, S. Valkar ¹²⁸, E. Valladolid Gallego ¹⁶⁸, S. Vallecorsa ¹⁵³, J.A. Valls Ferrer ¹⁶⁸,
 R. Van Berg ¹²¹, P.C. Van Der Deijl ¹⁰⁶, R. van der Geer ¹⁰⁶, H. van der Graaf ¹⁰⁶,
 R. Van Der Leeuw ¹⁰⁶, D. van der Ster ³⁰, N. van Eldik ³⁰, P. van Gemmeren ⁶,
 J. Van Nieuwkoop ¹⁴³, I. van Vulpen ¹⁰⁶, M. Vanadia ¹⁰⁰, W. Vandelli ³⁰, A. Vaniachine ⁶,
 P. Vankov ⁴², F. Vannucci ⁷⁹, R. Vari ^{133a}, E.W. Varnes ⁷, T. Varol ⁸⁵, D. Varouchas ¹⁵,
 A. Vartapetian ⁸, K.E. Varvell ¹⁵¹, V.I. Vassilakopoulos ⁵⁶, F. Vazeille ³⁴,
 T. Vazquez Schroeder ⁵⁴, F. Veloso ^{125a}, S. Veneziano ^{133a}, A. Ventura ^{72a,72b}, D. Ventura ⁸⁵,
 M. Venturi ⁴⁸, N. Venturi ¹⁵⁹, V. Vercesi ^{120a}, M. Verducci ¹³⁹, W. Verkerke ¹⁰⁶,
 J.C. Vermeulen ¹⁰⁶, A. Vest ⁴⁴, M.C. Vetterli ^{143.e}, I. Vichou ¹⁶⁶, T. Vickey ^{146c.al},
 O.E. Vickey Boeriu ^{146c}, G.H.A. Viehhauser ¹¹⁹, S. Viel ¹⁶⁹, M. Villa ^{20a,20b},
 M. Villaplana Perez ¹⁶⁸, E. Vilucchi ⁴⁷, M.G. Vincter ²⁹, V.B. Vinogradov ⁶⁴, J. Virzi ¹⁵,
 O. Vitells ¹⁷³, M. Viti ⁴², I. Vivarelli ⁴⁸, F. Vives Vaque ³, S. Vlachos ¹⁰, D. Vladioiu ⁹⁹,
 M. Vlasak ¹²⁷, A. Vogel ²¹, P. Vokac ¹²⁷, G. Volpi ⁴⁷, M. Volpi ⁸⁷, G. Volpini ^{90a},
 H. von der Schmitt ¹⁰⁰, H. von Radziewski ⁴⁸, E. von Toerne ²¹, V. Vorobel ¹²⁸, M. Vos ¹⁶⁸,

R. Voss³⁰, J.H. Vosseveld⁷³, N. Vranjes¹³⁷, M. Vranjes Milosavljevic¹⁰⁶, V. Vrba¹²⁶,
M. Vreeswijk¹⁰⁶, T. Vu Anh⁴⁸, R. Vuillermet³⁰, I. Vukotic³¹, Z. Vykydal¹²⁷, W. Wagner¹⁷⁶,
P. Wagner²¹, S. Wahrmund⁴⁴, J. Wakabayashi¹⁰², S. Walch⁸⁸, J. Walder⁷¹, R. Walker⁹⁹,
W. Walkowiak¹⁴², R. Wall¹⁷⁷, P. Waller⁷³, B. Walsh¹⁷⁷, C. Wang⁴⁵, H. Wang¹⁷⁴,
H. Wang⁴⁰, J. Wang¹⁵², J. Wang^{33a}, K. Wang⁸⁶, R. Wang¹⁰⁴, S.M. Wang¹⁵², T. Wang²¹,
X. Wang¹⁷⁷, A. Warburton⁸⁶, C.P. Ward²⁸, D.R. Wardrope⁷⁷, M. Warsinsky⁴⁸,
A. Washbrook⁴⁶, C. Wasicki⁴², I. Watanabe⁶⁶, P.M. Watkins¹⁸, A.T. Watson¹⁸,
I.J. Watson¹⁵¹, M.F. Watson¹⁸, G. Watts¹³⁹, S. Watts⁸³, A.T. Waugh¹⁵¹, B.M. Waugh⁷⁷,
M.S. Weber¹⁷, J.S. Webster³¹, A.R. Weidberg¹¹⁹, P. Weigell¹⁰⁰, J. Weingarten⁵⁴,
C. Weiser⁴⁸, P.S. Wells³⁰, T. Wenaus²⁵, D. Wendland¹⁶, Z. Weng^{152,u}, T. Wengler³⁰,
S. Wenig³⁰, N. Wermes²¹, M. Werner⁴⁸, P. Werner³⁰, M. Werth¹⁶⁴, M. Wessels^{58a},
J. Wetter¹⁶², K. Whalen²⁹, A. White⁸, M.J. White⁸⁷, R. White^{32b}, S. White^{123a,123b},
S.R. Whitehead¹¹⁹, D. Whiteson¹⁶⁴, D. Whittington⁶⁰, D. Wicke¹⁷⁶, F.J. Wickens¹³⁰,
W. Wiedenmann¹⁷⁴, M. Wielers^{80,d}, P. Wienemann²¹, C. Wiglesworth³⁶,
L.A.M. Wiik-Fuchs²¹, P.A. Wijeratne⁷⁷, A. Wildauer¹⁰⁰, M.A. Wildt^{42,r}, I. Wilhelm¹²⁸,
H.G. Wilkens³⁰, J.Z. Will⁹⁹, E. Williams³⁵, H.H. Williams¹²¹, S. Williams²⁸, W. Willis^{35,*},
S. Willocq⁸⁵, J.A. Wilson¹⁸, A. Wilson⁸⁸, I. Wingerter-Seez⁵, S. Winkelmann⁴⁸,
F. Winklmeier³⁰, M. Wittgen¹⁴⁴, T. Wittig⁴³, J. Wittkowski⁹⁹, S.J. Wollstadt⁸²,
M.W. Wolter³⁹, H. Wolters^{125a,h}, W.C. Wong⁴¹, G. Wooden⁸⁸, B.K. Wosiek³⁹,
J. Wotschack³⁰, M.J. Woudstra⁸³, K.W. Wozniak³⁹, K. Wraight⁵³, M. Wright⁵³,
B. Wrona⁷³, S.L. Wu¹⁷⁴, X. Wu⁴⁹, Y. Wu⁸⁸, E. Wulf³⁵, B.M. Wynne⁴⁶, S. Xella³⁶,
M. Xiao¹³⁷, S. Xie⁴⁸, C. Xu^{33b,z}, D. Xu^{33a}, L. Xu^{33b}, B. Yabsley¹⁵¹, S. Yacoob^{146b,am},
M. Yamada⁶⁵, H. Yamaguchi¹⁵⁶, Y. Yamaguchi¹⁵⁶, A. Yamamoto⁶⁵, K. Yamamoto⁶³,
S. Yamamoto¹⁵⁶, T. Yamamura¹⁵⁶, T. Yamanaka¹⁵⁶, K. Yamauchi¹⁰², T. Yamazaki¹⁵⁶,
Y. Yamazaki⁶⁶, Z. Yan²², H. Yang^{33e}, H. Yang¹⁷⁴, U.K. Yang⁸³, Y. Yang¹¹⁰, Z. Yang^{147a,147b},
S. Yanush⁹², L. Yao^{33a}, Y. Yasu⁶⁵, E. Yatsenko⁴², K.H. Yau Wong²¹, J. Ye⁴⁰, S. Ye²⁵,
A.L. Yen⁵⁷, E. Yildirim⁴², M. Yilmaz^{4b}, R. Yoosofmiya¹²⁴, K. Yorita¹⁷², R. Yoshida⁶,
K. Yoshihara¹⁵⁶, C. Young¹⁴⁴, C.J.S. Young¹¹⁹, S. Youssef²², D. Yu²⁵, D.R. Yu¹⁵, J. Yu⁸,
J. Yu¹¹³, L. Yuan⁶⁶, A. Yurkewicz¹⁰⁷, B. Zabinski³⁹, R. Zaidan⁶², A.M. Zaitsev^{129,aa},
S. Zambito²³, L. Zanello^{133a,133b}, D. Zanzi¹⁰⁰, A. Zaytsev²⁵, C. Zeitnitz¹⁷⁶, M. Zeman¹²⁷,
A. Zemla³⁹, O. Zenin¹²⁹, T. Ženiš^{145a}, D. Zerwas¹¹⁶, G. Zevi della Porta⁵⁷, D. Zhang⁸⁸,
H. Zhang⁸⁹, J. Zhang⁶, L. Zhang¹⁵², X. Zhang^{33d}, Z. Zhang¹¹⁶, Z. Zhao^{33b},
A. Zhemchugov⁶⁴, J. Zhong¹¹⁹, B. Zhou⁸⁸, N. Zhou¹⁶⁴, Y. Zhou¹⁵², C.G. Zhu^{33d}, H. Zhu⁴²,
J. Zhu⁸⁸, Y. Zhu^{33b}, X. Zhuang^{33a}, A. Zibell⁹⁹, D. Zieminska⁶⁰, N.I. Zimin⁶⁴,
C. Zimmermann⁸², R. Zimmermann²¹, S. Zimmermann²¹, S. Zimmermann⁴⁸,
Z. Zinonos^{123a,123b}, M. Ziolkowski¹⁴², R. Zitoun⁵, L. Živković³⁵, V.V. Zmouchko^{129,*},
G. Zobernig¹⁷⁴, A. Zoccoli^{20a,20b}, M. zur Nedden¹⁶, V. Zutshi¹⁰⁷, L. Zwalinski³⁰

¹ School of Chemistry and Physics, University of Adelaide, Adelaide, Australia

² Physics Department, SUNY Albany, Albany, NY, United States

³ Department of Physics, University of Alberta, Edmonton, AB, Canada

⁴ ^(a) Department of Physics, Ankara University, Ankara; ^(b) Department of Physics, Gazi University, Ankara; ^(c) Division of Physics, TOBB University of Economics and Technology, Ankara; ^(d) Turkish Atomic Energy Authority, Ankara, Turkey

⁵ LAPP, CNRS/IN2P3 and Université de Savoie, Annecy-le-Vieux, France

⁶ High Energy Physics Division, Argonne National Laboratory, Argonne, IL, United States

⁷ Department of Physics, University of Arizona, Tucson, AZ, United States

⁸ Department of Physics, The University of Texas at Arlington, Arlington, TX, United States

⁹ Physics Department, University of Athens, Athens, Greece

¹⁰ Physics Department, National Technical University of Athens, Zografou, Greece

¹¹ Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan

¹² Institut de Física d'Altes Energies and Departament de Física de la Universitat Autònoma de Barcelona and ICREA, Barcelona, Spain

¹³ ^(a) Institute of Physics, University of Belgrade, Belgrade; ^(b) Vinca Institute of Nuclear Sciences, University of Belgrade, Belgrade, Serbia

¹⁴ Department for Physics and Technology, University of Bergen, Bergen, Norway

¹⁵ Physics Division, Lawrence Berkeley National Laboratory and University of California, Berkeley, CA, United States

¹⁶ Department of Physics, Humboldt University, Berlin, Germany

¹⁷ Albert Einstein Center for Fundamental Physics and Laboratory for High Energy Physics, University of Bern, Bern, Switzerland

¹⁸ School of Physics and Astronomy, University of Birmingham, Birmingham, United Kingdom

¹⁹ ^(a) Department of Physics, Bogazici University, Istanbul; ^(b) Department of Physics, Dogus University, Istanbul; ^(c) Department of Physics Engineering, Gaziantep University, Gaziantep, Turkey

²⁰ ^(a) INFN Sezione di Bologna; ^(b) Dipartimento di Fisica e Astronomia, Università di Bologna, Bologna, Italy

- ²¹ Physikalisches Institut, University of Bonn, Bonn, Germany
- ²² Department of Physics, Boston University, Boston, MA, United States
- ²³ Department of Physics, Brandeis University, Waltham, MA, United States
- ²⁴ ^(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 Fisica, Universidade de Sao Paulo, Sao Paulo, Brazil
- ²⁵ Physics Department, Brookhaven National Laboratory, Upton, NY, United States
- ²⁶ ^(a) National Institute of Physics and Nuclear Engineering, Bucharest; ^(b) National Institute for Research and Development of Isotopic and Molecular Technologies, Physics Department, Cluj Napoca; ^(c) University Politehnica Bucharest, Bucharest; ^(d) West University in Timisoara, Timisoara, Romania
- ²⁷ Departamento de Fisica, Universidad de Buenos Aires, Buenos Aires, Argentina
- ²⁸ Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom
- ²⁹ Department of Physics, Carleton University, Ottawa ON, Canada
- ³⁰ CERN, Geneva, Switzerland
- ³¹ Enrico Fermi Institute, University of Chicago, Chicago, IL, United States
- ³² ^(a) Departamento de Fisica, Pontificia Universidad Católica de Chile, Santiago; ^(b) Departamento de Fisica, Universidad Técnica Federico Santa María, Valparaíso, Chile
- ³³ ^(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, China
- ³⁴ Laboratoire de Physique Corpusculaire, Clermont Université and Université Blaise Pascal and CNRS/IN2P3, Clermont-Ferrand, France
- ³⁵ Nevis Laboratory, Columbia University, Irvington, NY, United States
- ³⁶ Niels Bohr Institute, University of Copenhagen, Kobenhavn, Denmark
- ³⁷ ^(a) INFN Gruppo Collegato di Cosenza; ^(b) Dipartimento di Fisica, Università della Calabria, Rende, Italy
- ³⁸ ^(a) AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Krakow; ^(b) Marian Smoluchowski Institute of Physics, Jagiellonian University, Krakow, Poland
- ³⁹ The Henryk Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences, Krakow, Poland
- ⁴⁰ Physics Department, Southern Methodist University, Dallas, TX, United States
- ⁴¹ Physics Department, University of Texas at Dallas, Richardson, TX, United States
- ⁴² DESY, Hamburg and Zeuthen, Germany
- ⁴³ Institut für Experimentelle Physik IV, Technische Universität Dortmund, Dortmund, Germany
- ⁴⁴ Institut für Kern- und Teilchenphysik, Technical University Dresden, Dresden, Germany
- ⁴⁵ Department of Physics, Duke University, Durham, NC, United States
- ⁴⁶ SUPA – School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom
- ⁴⁷ INFN Laboratori Nazionali di Frascati, Frascati, Italy
- ⁴⁸ Fakultät für Mathematik und Physik, Albert-Ludwigs-Universität, Freiburg, Germany
- ⁴⁹ Section de Physique, Université de Genève, Geneva, Switzerland
- ⁵⁰ ^(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 Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen, Germany
- ⁵³ SUPA – School of Physics and Astronomy, University of Glasgow, Glasgow, United Kingdom
- ⁵⁴ II Physikalisches Institut, Georg-August-Universität, Göttingen, Germany
- ⁵⁵ Laboratoire de Physique Subatomique et de Cosmologie, Université Joseph Fourier and CNRS/IN2P3 and Institut National Polytechnique de Grenoble, Grenoble, France
- ⁵⁶ Department of Physics, Hampton University, Hampton, 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 Fisica 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 Louisiana Tech University, Ruston, LA, United States
- ⁷⁹ Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France
- ⁸⁰ Fysiska institutionen, Lunds universitet, Lund, Sweden
- ⁸¹ Departamento de Fisica Teorica C-15, Universidad Autonoma de Madrid, Madrid, Spain
- ⁸² Institut für Physik, Universität Mainz, Mainz, Germany
- ⁸³ School of Physics and Astronomy, University of Manchester, Manchester, United Kingdom
- ⁸⁴ CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France
- ⁸⁵ Department of Physics, University of Massachusetts, Amherst, MA, United States
- ⁸⁶ Department of Physics, McGill University, Montreal, QC, Canada
- ⁸⁷ School of Physics, University of Melbourne, Victoria, Australia
- ⁸⁸ Department of Physics, The University of Michigan, Ann Arbor, MI, United States
- ⁸⁹ Department of Physics and Astronomy, Michigan State University, East Lansing, MI, United States
- ⁹⁰ ^(a) INFN Sezione di Milano; ^(b) Dipartimento di Fisica, Università di Milano, Milano, Italy

- ⁹¹ B.I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk, Belarus
- ⁹² National Scientific and Educational Centre for Particle and High Energy Physics, Minsk, Belarus
- ⁹³ Department of Physics, Massachusetts Institute of Technology, Cambridge, MA, United States
- ⁹⁴ Group of Particle Physics, University of Montreal, Montreal, QC, Canada
- ⁹⁵ P.N. Lebedev Institute of Physics, Academy of Sciences, Moscow, Russia
- ⁹⁶ Institute for Theoretical and Experimental Physics (ITEP), Moscow, Russia
- ⁹⁷ Moscow Engineering and Physics Institute (MEPhI), Moscow, Russia
- ⁹⁸ D.V. Skobeltsyn Institute of Nuclear Physics, M.V. Lomonosov Moscow State University, Moscow, Russia
- ⁹⁹ Fakultät für Physik, Ludwig-Maximilians-Universität München, München, Germany
- ¹⁰⁰ Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), München, Germany
- ¹⁰¹ Nagasaki Institute of Applied Science, Nagasaki, Japan
- ¹⁰² Graduate School of Science and Kobayashi-Maskawa Institute, Nagoya University, Nagoya, Japan
- ¹⁰³ ^(a) INFN Sezione di Napoli; ^(b) Dipartimento di Scienze Fisiche, Università di Napoli, Napoli, Italy
- ¹⁰⁴ Department of Physics and Astronomy, University of New Mexico, Albuquerque, NM, United States
- ¹⁰⁵ Institute for Mathematics, Astrophysics and Particle Physics, Radboud University Nijmegen/Nikhef, Nijmegen, Netherlands
- ¹⁰⁶ Nikhef National Institute for Subatomic Physics and University of Amsterdam, Amsterdam, Netherlands
- ¹⁰⁷ Department of Physics, Northern Illinois University, DeKalb, IL, United States
- ¹⁰⁸ Budker Institute of Nuclear Physics, SB RAS, Novosibirsk, Russia
- ¹⁰⁹ Department of Physics, New York University, New York, NY, United States
- ¹¹⁰ Ohio State University, Columbus, OH, United States
- ¹¹¹ Faculty of Science, Okayama University, Okayama, Japan
- ¹¹² Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman, OK, United States
- ¹¹³ Department of Physics, Oklahoma State University, Stillwater, OK, United States
- ¹¹⁴ Palacký University, RCPTM, Olomouc, Czech Republic
- ¹¹⁵ Center for High Energy Physics, University of Oregon, Eugene, OR, United States
- ¹¹⁶ LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France
- ¹¹⁷ Graduate School of Science, Osaka University, Osaka, Japan
- ¹¹⁸ Department of Physics, University of Oslo, Oslo, Norway
- ¹¹⁹ Department of Physics, Oxford University, Oxford, United Kingdom
- ¹²⁰ ^(a) INFN Sezione di Pavia; ^(b) Dipartimento di Fisica, Università di Pavia, Pavia, Italy
- ¹²¹ Department of Physics, University of Pennsylvania, Philadelphia, PA, United States
- ¹²² Petersburg Nuclear Physics Institute, Gatchina, Russia
- ¹²³ ^(a) INFN Sezione di Pisa; ^(b) Dipartimento di Fisica E. Fermi, Università di Pisa, Pisa, Italy
- ¹²⁴ Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh, PA, United States
- ¹²⁵ ^(a) Laboratório de Instrumentação e Física Experimental de Partículas – LIP, Lisboa, Portugal; ^(b) Departamento de Física Teórica y del Cosmos and CAFPE, Universidad de Granada, Granada, Spain
- ¹²⁶ Institute of Physics, Academy of Sciences of the Czech Republic, Praha, Czech Republic
- ¹²⁷ Czech Technical University in Prague, Praha, Czech Republic
- ¹²⁸ Faculty of Mathematics and Physics, Charles University in Prague, Praha, Czech Republic
- ¹²⁹ State Research Center Institute for High Energy Physics, Protvino, Russia
- ¹³⁰ Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom
- ¹³¹ Physics Department, University of Regina, Regina, SK, Canada
- ¹³² Ritsumeikan University, Kusatsu, Shiga, Japan
- ¹³³ ^(a) INFN Sezione di Roma I; ^(b) Dipartimento di Fisica, Università La Sapienza, Roma, Italy
- ¹³⁴ ^(a) INFN Sezione di Roma Tor Vergata; ^(b) Dipartimento di Fisica, Università di Roma Tor Vergata, Roma, Italy
- ¹³⁵ ^(a) INFN Sezione di Roma Tre; ^(b) Dipartimento di Matematica e Fisica, Università Roma Tre, Roma, Italy
- ¹³⁶ ^(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 Nucleaires, 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
- ¹³⁷ DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l’Univers), CEA Saclay (Commissariat à l’Energie Atomique et aux Energies Alternatives), Gif-sur-Yvette, France
- ¹³⁸ Santa Cruz Institute for Particle Physics, University of California Santa Cruz, Santa Cruz, CA, United States
- ¹³⁹ Department of Physics, University of Washington, Seattle, WA, United States
- ¹⁴⁰ Department of Physics and Astronomy, University of Sheffield, Sheffield, United Kingdom
- ¹⁴¹ Department of Physics, Shinshu University, Nagano, Japan
- ¹⁴² Fachbereich Physik, Universität Siegen, Siegen, Germany
- ¹⁴³ Department of Physics, Simon Fraser University, Burnaby, BC, Canada
- ¹⁴⁴ SLAC National Accelerator Laboratory, Stanford, CA, United States
- ¹⁴⁵ ^(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
- ¹⁴⁶ ^(a) Department of Physics, University of Cape Town, Cape Town; ^(b) Department of Physics, University of Johannesburg, Johannesburg; ^(c) School of Physics, University of the Witwatersrand, Johannesburg, South Africa
- ¹⁴⁷ ^(a) Department of Physics, Stockholm University; ^(b) The Oskar Klein Centre, Stockholm, Sweden
- ¹⁴⁸ Physics Department, Royal Institute of Technology, Stockholm, Sweden
- ¹⁴⁹ Departments of Physics & Astronomy and Chemistry, Stony Brook University, Stony Brook, NY, United States
- ¹⁵⁰ Department of Physics and Astronomy, University of Sussex, Brighton, United Kingdom
- ¹⁵¹ School of Physics, University of Sydney, Sydney, Australia
- ¹⁵² Institute of Physics, Academia Sinica, Taipei, Taiwan
- ¹⁵³ Department of Physics, Technion: Israel Institute of Technology, Haifa, Israel
- ¹⁵⁴ Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel
- ¹⁵⁵ Department of Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece
- ¹⁵⁶ International Center for Elementary Particle Physics and Department of Physics, The University of Tokyo, Tokyo, Japan
- ¹⁵⁷ Graduate School of Science and Technology, Tokyo Metropolitan University, Tokyo, Japan
- ¹⁵⁸ Department of Physics, Tokyo Institute of Technology, Tokyo, Japan
- ¹⁵⁹ Department of Physics, University of Toronto, Toronto, ON, Canada
- ¹⁶⁰ ^(a) TRIUMF, Vancouver, BC; ^(b) Department of Physics and Astronomy, York University, Toronto, ON, Canada
- ¹⁶¹ Faculty of Pure and Applied Sciences, University of Tsukuba, Tsukuba, Japan
- ¹⁶² Department of Physics and Astronomy, Tufts University, Medford, MA, United States
- ¹⁶³ Centro de Investigaciones, Universidad Antonio Narino, Bogota, Colombia

- ¹⁶⁴ Department of Physics and Astronomy, University of California Irvine, Irvine, CA, United States
¹⁶⁵ ^(a) INFN Gruppo Collegato di Udine; ^(b) ICTP, Trieste; ^(c) Dipartimento di Chimica, Fisica e Ambiente, Università di Udine, Udine, Italy
¹⁶⁶ Department of Physics, University of Illinois, Urbana, IL, United States
¹⁶⁷ Department of Physics and Astronomy, University of Uppsala, Uppsala, Sweden
¹⁶⁸ Instituto de Física Corpuscular (IFIC) and Departamento de Física Atómica, Molecular y Nuclear and Departamento de Ingeniería Electrónica and Instituto de Microelectrónica de Barcelona (IMB-CNM), University of Valencia and CSIC, Valencia, Spain
¹⁶⁹ Department of Physics, University of British Columbia, Vancouver, BC, Canada
¹⁷⁰ Department of Physics and Astronomy, University of Victoria, Victoria, BC, Canada
¹⁷¹ Department of Physics, University of Warwick, Coventry, United Kingdom
¹⁷² Waseda University, Tokyo, Japan
¹⁷³ Department of Particle Physics, The Weizmann Institute of Science, Rehovot, Israel
¹⁷⁴ Department of Physics, University of Wisconsin, Madison, WI, United States
¹⁷⁵ Fakultät für Physik und Astronomie, Julius-Maximilians-Universität, Würzburg, Germany
¹⁷⁶ Fachbereich C Physik, Bergische Universität Wuppertal, Wuppertal, Germany
¹⁷⁷ Department of Physics, Yale University, New Haven, CT, United States
¹⁷⁸ Yerevan Physics Institute, Yerevan, Armenia
¹⁷⁹ Centre de Calcul de l'Institut National de Physique Nucléaire et de Physique des Particules (IN2P3), Villeurbanne, France

- ^a Also at Department of Physics, King's College London, London, United Kingdom.
^b Also at Laboratório de Instrumentação e Física Experimental de Partículas – LIP, Lisboa, Portugal.
^c Also at Faculdade de Ciências and CFNUL, Universidade de Lisboa, Lisboa, Portugal.
^d Also at Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom.
^e Also at TRIUMF, Vancouver, BC, Canada.
^f Also at Department of Physics, California State University, Fresno, CA, United States.
^g Also at Novosibirsk State University, Novosibirsk, Russia.
^h Also at Department of Physics, University of Coimbra, Coimbra, Portugal.
ⁱ Also at Università di Napoli Parthenope, Napoli, Italy.
^j Also at Institute of Particle Physics (IPP), Canada.
^k Also at Department of Physics, Middle East Technical University, Ankara, Turkey.
^l Also at Louisiana Tech University, Ruston, LA, United States.
^m Also at Dep Física and CEFITEC of Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Caparica, Portugal.
ⁿ Also at Department of Physics and Astronomy, Michigan State University, East Lansing, MI, United States.
^o Also at Department of Financial and Management Engineering, University of the Aegean, Chios, Greece.
^p Also at Department of Physics, University of Cape Town, Cape Town, South Africa.
^q Also at Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan.
^r Also at Institut für Experimentalphysik, Universität Hamburg, Hamburg, Germany.
^s Also at Manhattan College, New York, NY, United States.
^t Also at CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France.
^u Also at School of Physics and Engineering, Sun Yat-sen University, Guanzhou, China.
^v Also at Academia Sinica Grid Computing, Institute of Physics, Academia Sinica, Taipei, Taiwan.
^w Also at Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France.
^x Also at School of Physical Sciences, National Institute of Science Education and Research, Bhubaneswar, India.
^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 Moscow Institute of Physics and Technology State University, Dolgoprudny, Russia.
^{ab} Also at Section de Physique, Université de Genève, Geneva, Switzerland.
^{ac} Also at Departamento de Física, Universidade de Minho, Braga, Portugal.
^{ad} Also at Department of Physics, The University of Texas at Austin, Austin, TX, United States.
^{ae} Also at Department of Physics and Astronomy, University of South Carolina, Columbia, SC, United States.
^{af} Also at Institute for Particle and Nuclear Physics, Wigner Research Centre for Physics, Budapest, Hungary.
^{ag} Also at DESY, Hamburg and Zeuthen, Germany.
^{ah} Also at International School for Advanced Studies (SISSA), Trieste, Italy.
^{ai} Also at Faculty of Physics, M.V.Lomonosov Moscow State University, Moscow, Russia.
^{aj} Also at Nevis Laboratory, Columbia University, Irvington, NY, United States.
^{ak} Also at Physics Department, Brookhaven National Laboratory, Upton, NY, United States.
^{al} Also at Department of Physics, Oxford University, Oxford, United Kingdom.
^{am} Also at Discipline of Physics, University of KwaZulu-Natal, Durban, South Africa.
^{*} Deceased.