



UvA-DARE (Digital Academic Repository)

Measurement of the inelastic proton-proton cross-section at $\sqrt{s} = 7$ TeV with the ATLAS detector

Aad, G.; et al., [Unknown]; Bentvelsen, S.; Colijn, A.P.; de Jong, P.; de Nooij, L.; Doxiadis, A.D.; Ferrari, P.; Garitaonandia, H.; Geerts, D.A.A.; Gosselink, M.; Kayl, M.S.; Koffeman, E.; Lee, H.; Linde, F.; Mechnich, J.; Mussche, I.; Ottersbach, J.P.; Tsiakiris, M.; van der Kraaij, E.; van der Leeuw, R.; van Kesteren, Z.; van Vulpen, I.; Vermeulen, J.C.; Vreeswijk, M.

DOI

[10.1038/ncomms1472](https://doi.org/10.1038/ncomms1472)

Publication date

2011

Document Version

Final published version

Published in

Nature Communications

[Link to publication](#)

Citation for published version (APA):

Aad, G., et al., U., Bentvelsen, S., Colijn, A. P., de Jong, P., de Nooij, L., Doxiadis, A. D., Ferrari, P., Garitaonandia, H., Geerts, D. A. A., Gosselink, M., Kayl, M. S., Koffeman, E., Lee, H., Linde, F., Mechnich, J., Mussche, I., Ottersbach, J. P., Tsiakiris, M., ... Vreeswijk, M. (2011). Measurement of the inelastic proton-proton cross-section at $\sqrt{s} = 7$ TeV with the ATLAS detector. *Nature Communications*, 2, Article 463. <https://doi.org/10.1038/ncomms1472>

General rights

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

Disclaimer/Complaints regulations

If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library, <https://uba.uva.nl/en/contact>, or a letter to: Library of the University of Amsterdam, Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.

ARTICLE

Received 5 Apr 2011 | Accepted 4 Aug 2011 | Published 6 Sep 2011

DOI:10.1038/ncomms1472

Measurement of the inelastic proton–proton cross-section at $\sqrt{s} = 7$ TeV with the ATLAS detector

The ATLAS Collaboration^{1,*}

The dependence of the rate of proton–proton interactions on the centre-of-mass collision energy, \sqrt{s} , is of fundamental importance for both hadron collider physics and particle astrophysics. The dependence cannot yet be calculated from first principles; therefore, experimental measurements are needed. Here we present the first measurement of the inelastic proton–proton interaction cross-section at a centre-of-mass energy, \sqrt{s} , of 7 TeV using the ATLAS detector at the Large Hadron Collider. Events are selected by requiring hits on scintillation counters mounted in the forward region of the detector. An inelastic cross-section of 60.3 ± 2.1 mb is measured for $\xi > 5 \times 10^{-6}$, where ξ is calculated from the invariant mass, M_x , of hadrons selected using the largest rapidity gap in the event. For diffractive events, this corresponds to requiring at least one of the dissociation masses to be larger than 15.7 GeV.

¹ EP-PH, CERN, ATLAS Secretariat, Geneva 1211, Switzerland. Correspondence and requests for materials should be addressed to Klaus Mönig (e-mail: atlas.publications@cern.ch). *A full list of authors for the ATLAS collaboration and their affiliations appears at the end of the paper.

Since the earliest days of particle physics, measurements of the total pp and $p\bar{p}$ cross-sections and their theoretical understanding have been topics of much interest¹. The cross-sections cannot yet be calculated by quantum chromodynamics, and many approaches have been used to describe the existing measurements. General arguments based on unitarity and analyticity imply a bound (the Froissart bound^{2,3}) on the high-energy behaviour of total hadronic cross-sections. This bound is independent of the details of the strong interaction dynamics and states that the total cross-section cannot rise faster than $\ln^2(s)$, where \sqrt{s} is the centre-of-mass energy. Recently, it has been extended to the inelastic cross-section⁴. Existing experimental data¹ show a rise in the hadronic cross-sections with s , but it is unclear whether the asymptotic behaviour has already been reached. In this letter, a direct measurement of the inelastic pp cross-section at the highest energy collider to date is presented. Measurements of the inelastic p -air cross-section in the multi-TeV regime are available from cosmic-ray shower detection experiments^{5–8}, and have been used to infer the pp cross-section albeit with significant uncertainties. The measurement presented here is of direct relevance for the modelling of high energy cosmic ray showers.

The most common models that describe the data up to $\sqrt{s} = 1.8$ TeV predict a rise of the total cross-section with a simple power law ($s^{\alpha(0)-1}$ where $\alpha(0)$ denotes the Pomeron-trajectory intercept)^{9–11} or with a power law depending on $\ln(s)$ (refs 12–16). Others employ quantum chromodynamics for aspects of the calculation^{17–20}. However, although the phenomenological description of the existing data is largely adequate, there are significant uncertainties on the extrapolation to higher energies, partly due to a long-standing 2.7σ discrepancy between the two highest energy collider measurements of the total $p\bar{p}$ cross-section by CDF²¹ and by E811 (ref. 22).

The inelastic pp cross-section at $\sqrt{s} = 7$ TeV is measured with data taken by the ATLAS experiment²³ at the Large Hadron Collider (LHC)²⁴. The data considered were collected during a single 8-hour fill beginning 31 March 2010, corresponding to an integrated luminosity of $20.3 \pm 0.7 \mu\text{b}^{-1}$ and a peak instantaneous luminosity of $1.2 \times 10^{27} \text{cm}^{-2} \text{s}^{-1}$. The mean number of interactions per crossing in this fill is ~ 0.01 . The analysis uses highly efficient scintillation counters, the minimum bias trigger scintillator (MBTS) detectors, to detect inelastic collisions. They are insensitive to diffractive dissociation processes in which the dissociation systems have small invariant masses, M_X . Their acceptance corresponds approximately to $\xi = M_X^2/s > 5 \times 10^{-6}$, equivalent to $M_X > 15.7 \text{ GeV}$ for $\sqrt{s} = 7$ TeV. The cross-section measurement presented here is restricted to this kinematic range. However, to compare the data with previous measurements, an extrapolation of the cross-section is performed to the full ξ range, $\xi > m_p^2/s$ where m_p is the proton mass.

Results

Acceptance determination. Monte Carlo (MC) simulations are used to determine the acceptance of the event selection and to assess systematic uncertainties. The detector response to the generated events is simulated using the ATLAS simulation²⁵ based on Geant4 (ref. 26), and both the simulated and data events are reconstructed and analysed with the same software. The Pythia6 (ref. 27), Pythia8 (ref. 28) and Phojet^{29,30} generators are used to predict properties of inelastic collisions. These generators distinguish between different processes that contribute to inelastic pp interactions: single dissociative (SD) processes, $pp \rightarrow pX$, in which one proton dissociates; double dissociative (DD) processes, $pp \rightarrow XY$, in which both protons dissociate with no net colour flow between the systems X and Y ; and non-diffractive (ND) processes in which colour flow is present between the two initial-state protons. The model by Schuler and Sjöstrand³¹, used by Pythia6 and Pythia8, predicts cross-sections of 48.5, 13.7 and 9.3 mb for the ND, SD and DD processes, respectively. Whereas the cross-sections used

by Pythia6 and Pythia8 are identical, they differ in the modelling of the hadronic final state. Phojet predicts the corresponding cross-sections as 61.6 mb (ND), 10.7 mb (SD) and 3.9 mb (DD). Because of differences in implementation of the interface between large ξ diffractive (SD and DD) processes and ND processes in Pythia and Phojet, the fractional contribution of these processes is a model-dependent quantity. Phojet also includes a 1.1 mb contribution from central diffraction (CD), $pp \rightarrow ppX$, a process not implemented in Pythia, wherein neither proton dissociates, but the Pomeron-trajectory exchange results in energy loss for the protons and the production of a central system of particles. The MC generators define the inelastic cross-section as the sum of these contributions, and thus Schuler and Sjöstrand (Phojet) predicts an inelastic cross-section of 71.5 mb (77.3 mb). Other recent predictions for this cross-section at $\sqrt{s} = 7$ TeV are 69 mb (ref. 15), 65–67 mb (ref. 17 and personal communication with the author), 68 mb (refs 18,19) and 60–75 mb (ref. 20).

Although the cross-section measured here is quoted for a restricted ξ -range, ξ is not directly measured. However, the η coverage of the MBTS implies a lower bound on the range of ξ -values for events that the detectors can observe. To study the acceptance as a function of ξ , MC generators are used. The variable ξ is defined at the particle level by dividing the final state particles from the MC generators into two systems, X and Y . The mean η of the two particles separated by the largest pseudorapidity gap in the event is used to assign all particles with greater pseudorapidity to one system and all particles with smaller pseudorapidity to the other³². The mass, $M_{X,Y}$, of each system is calculated, and the higher mass system is defined as X while the lower mass system is defined as Y . In the case of SD, Y is the non-dissociated proton. The variable ξ is then given by $\xi = M_X^2/s$ and it is bounded by the elastic limit, satisfying $\xi > m_p^2/s$. As expected from kinematic considerations, a strong correlation is observed, independently of the MC model used to determine ξ , between ξ and the pseudorapidity of the hadron from X that is farthest from the initial-state proton pseudorapidity. Therefore, the upper limit of the MBTS detector acceptance of $|\eta| < 3.84$ (see Methods) can be translated into a limit on the ξ of observed events. Thus the measurement is restricted in its ξ -range; there is no requirement on M_Y . Several models are used for the dependence of the diffractive cross-sections on ξ . The Schuler and Sjöstrand model has a relatively flat dependence on ξ , whereas the Phojet model predicts a slight decrease with decreasing ξ . Pythia8 has several extra predictions for the ξ -dependence of the diffractive cross-sections that are considered. In the low ξ regime, Bruni and Ingelman³³ predict a flat ξ -dependence whereas Donnachie and Landshoff (DL)³⁴ and Berger *et al.*³⁵ predict

$$\frac{d\sigma_{SD}}{d\xi} \propto \frac{1}{\xi^{1+\varepsilon}} \quad (1)$$

where $\varepsilon = \alpha(0) - 1$. Values of ε between 0.06 and 0.10, and of α' between 0.10 and 0.40 GeV^{-2} are considered for the DL model. α' is the slope of the Pomeron trajectory that is assumed to be linear such that $\alpha(t) = \alpha(0) + \alpha't$. The DL model with $\varepsilon = 0.085$ and $\alpha' = 0.25 \text{ GeV}^{-2}$ with Pythia8 fragmentation is the default model in this analysis, and the other models are used to assess uncertainties in the modelling of diffractive events.

Cross-section calculation elements. Experimentally the cross-section is calculated using

$$\sigma_{\text{inel}}(\xi > 5 \times 10^{-6}) = \frac{(N - N_{\text{BG}})}{\varepsilon_{\text{trig}} \times \int L dt} \times \frac{1 - f_{\xi < 5 \times 10^{-6}}}{\varepsilon_{\text{sel}}} \quad (2)$$

where N is the number of selected events, N_{BG} is the number of background events, $f_{\xi < 5 \times 10^{-6}}$ is the fraction of events that pass the event

selection but have $\xi < 5 \times 10^{-6}$, $\int L dt$ is the integrated luminosity, and ϵ_{trig} and ϵ_{sel} are the trigger and offline event selection efficiencies in the selected ξ -range. For $\xi = 5 \times 10^{-6}$, ϵ_{sel} is 50%, rising to nearly 100% for $\xi > 10^{-5}$. The dependence of the efficiency on ξ is similar for the SD and DD processes and for different MC generators. The measurement is quoted for $\xi > 5 \times 10^{-6}$ that gives the smallest correction factor, $(1 - f_{\xi < 5 \times 10^{-6}}) / \epsilon_{\text{sel}}$, and thus yields the smallest systematic uncertainty on the measurement due to the underlying ξ -distribution.

In this measurement, N_{BG} and ϵ_{trig} are determined directly from the data. The MBTS individual counter efficiencies in the MC simulation are tuned to match the observed efficiencies in data. Then ϵ_{sel} and $f_{\xi < 5 \times 10^{-6}}$ are taken from the tuned MC simulation. To reduce the uncertainties in the factors taken from MC simulation, the relative diffractive dissociation cross-section, $f_{\text{D}} = (\sigma_{\text{SD}} + \sigma_{\text{DD}} + \sigma_{\text{CD}}) / \sigma_{\text{inel}}$ for each generator is constrained. Each of these steps is described in detail below.

The MBTS functions as a trigger by determining the number of scintillation counters with a signal passing a leading-edge discriminator; in this analysis, at least one trigger signal must be present. In the offline reconstruction, the MBTS signals are fit to obtain the total charge and timing of the signal. The offline event selection requires at least two counters with a charge larger than 0.15 pC. This threshold is set to be well above the noise level, which is well described by a Gaussian centred at zero of width 0.02 pC. This inclusive sample contains 1,220,743 data events. To constrain the diffractive components, a subset of events that have at least two hits on one side of the MBTS detector and no hits on the opposing side (in z) are selected. In the data, 122,490 of these single-sided events are observed.

Backgrounds. Backgrounds arise from beam-related interactions, such as collisions of the beam with gas particles in the beam-pipe or with material upstream from the detector, and slowly-decaying, collision-induced radiation termed ‘afterglow’³⁶. Additionally, instrumental noise and cosmic rays provide backgrounds that were studied and found to be negligible for this analysis. The beam-related backgrounds are determined using the number of selected events collected in this fill with the non-colliding bunches, that is, when only one proton bunch was passing through ATLAS³⁷. They are normalized by the ratio of the number of protons in the colliding to the non-colliding bunches. The single-sided selection contains 422 ± 28 background events and the inclusive sample contains $N_{\text{BG}} = 1,574 \pm 54$ background events, corresponding to 0.3% and 0.1% of the total samples, respectively. In addition, there is an in-time afterglow component owing to the scattering of secondary low-energy particles produced in the same collision event that can give extra hits, causing low-activity events to migrate into the selected event sample. This contribution is evaluated to be at most 0.4% for the inclusive, and 3.6% for the single-sided samples, by examining the asymmetry of the absolute timing measurement of the MBTS counters. We conservatively assume a 100% uncertainty on both background sources that covers any residual impact of the afterglow on the background subtraction, any uncertainty in the beam current measurements and the uncertainty due to in-time afterglow. The resulting overall uncertainty on the number of background events N_{BG} is given by the quadratic sum of the two components and is 0.4%.

Detector efficiency and modelling. The trigger efficiency of the MBTS detector, with respect to the offline requirement, ϵ_{trig} , is measured to be $99.98^{+0.02}_{-0.12}\%$ (statistical errors) using events triggered randomly on colliding beams. The systematic uncertainty on ϵ_{trig} is determined using a second, independent trigger as reference. The difference between the two efficiency determinations leads to a 0.1% uncertainty on the cross-section measurement.

The data and MC simulation agreement in the MBTS counter response is checked using other detector subsystems with overlapping η ranges: charged particles reconstructed by the tracking detector ($2.09 < |\eta| < 2.5$), and calorimeter showers in the inner wheel of the electromagnetic calorimeter ($2.5 < |\eta| < 3.2$) and in the forward calorimeter ($3.1 < |\eta| < 3.84$). The efficiency with respect to a track (calorimeter energy deposit) to have a signal above the 0.15 pC threshold in the outer (inner) counters is on average 98.5% (97.5%) for the data and a constant 99.4% (98.7%) in the MC simulation. The individual counter efficiencies deviate by up to 2.0% (2.5%) from the average in the data. The MC simulation is corrected to match the data efficiency, and the maximum variations in the counter responses are considered as a systematic uncertainty. This results in a 0.1% uncertainty on the cross-section measurement.

The offline selection efficiency, ϵ_{sel} , depends on the amount of material traversed by particles before hitting the MBTS detector. The rate of photons (primarily from π^0 decays) converting to electrons that are subsequently detected by the MBTS increases with extra material, resulting in an increase of ϵ_{sel} . Second order effects arise from charged particles scattering out of the MBTS acceptance region (decreasing ϵ_{sel}), or charged particles scattering into the acceptance region (increasing $f_{\xi < 5 \times 10^{-6}}$). Within the tracking volume ($|\eta| < 2.5$), the material distribution has been studied using conversion electrons and $K_S^0 \rightarrow \pi^+ \pi^-$ decays, and is known to better than $\pm 5\%$ in the central region of the detector and to $\pm 30\%$ for $2.2 < |\eta| < 2.5$ (ref. 38). In the region $|\eta| > 2.5$, the material is dominated by the cooling and electrical services to the silicon pixel detector, and an uncertainty of $\pm 40\%$ is assumed. This is validated *in-situ* using the fraction of events wherein we observe significant energy in the forward calorimeters but no signal (above noise) in the MBTS detector. The resulting systematic uncertainty on the cross-section is 0.2%.

Misalignments of the MBTS detector with respect to the nominal centre of the detector could change the event selection efficiency for a particular value of ξ . Misalignments of up to 10 mm were considered and found to have a negligible impact. A misalignment of 10 mm is conservative compared with the survey precision and any known misalignments within the ATLAS experiment²³.

Fractional diffractive event contribution. The fractional contribution of diffractive events, f_{D} , is constrained by the ratio of single-sided to inclusive events, R_{ss} . The MC generators predict that less than 1% of the ND process pass the single-sided event selection, whereas 27–41% of the SD and DD processes pass the single-sided selection. For all models, the inclusive sample is dominated by ND events; therefore, the ratio of single-sided to inclusive events is sensitive to the relative fraction of diffractive events.

The measured R_{ss} in the data is $R_{\text{ss}} = [10.02 \pm 0.03(\text{stat.}) \pm 0.1(\text{sys.})]\%$, where the systematic error includes the uncertainties on the backgrounds, the MBTS response and the material.

Figure 1 compares the observed value of R_{ss} to the predictions of several models as a function of f_{D} . The intersection of the R_{ss} value measured in data with the prediction is used as the central value of f_{D} for each model. The systematic uncertainty on f_{D} is determined by the maximum and minimum values consistent with the 1σ uncertainty on the data when varying the double- to single-dissociation event ratio between 0 and 1. The resulting value using the default DL model is $f_{\text{D}} = 26.9^{+2.5}_{-1.0}\%$.

Uncertainty on acceptance. The acceptance calculation relies on the MC generators to provide an adequate description of the particle multiplicity in the acceptance region. The validity of the MC description is assessed by examining the hit multiplicity in the MBTS detector in the inclusive and single-sided event samples as shown in Figure 2. Whereas none of the generators gives a perfect

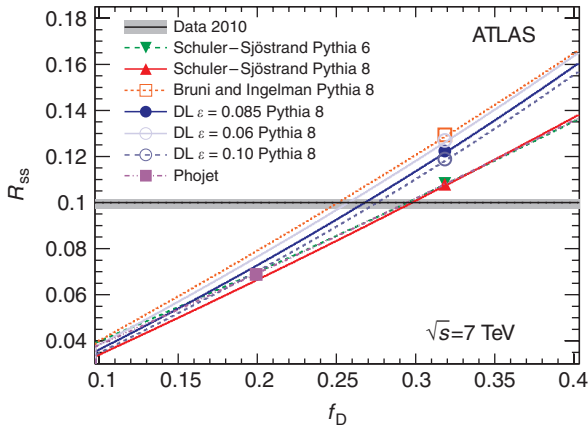


Figure 1 | Dependence of the fraction of single-sided events (R_{ss}) on the relative diffractive contribution (f_D). The ratio of the single-sided to inclusive event sample R_{ss} as a function of the fractional contribution of diffractive events, f_D , to the inelastic cross-section. The data value for R_{ss} is shown as the horizontal line with its systematic uncertainties (grey band). Also shown are predictions of several models as a function of an assumed value of f_D . For all three DL predictions, the α' value is 0.25 GeV^{-2} . The default f_D values are indicated by the markers; they are 32.2% for all models except Phojet that uses 20.2%.

description, the data lie between the models at low multiplicity that is most important for the measurement.

The inclusive sample, which is dominated by non-diffractive events, is reasonably well described by the MC. In addition, inclusive charged particle properties have been studied extensively in^{37,38} that show that the Monte Carlo generators describe the data well. Differences in the acceptance for non-diffractive events were studied with several variations of the Pythia6 tuning parameters and were shown to be negligible.

The single-sided sample is dominated by diffractive events. The default DL model describes it well, giving confidence in the diffractive modelling. We use the difference in the MC correction factor determined with Pythia8 and Pythia6 as the uncertainty due to the fragmentation model, leading to a 0.4% uncertainty on the cross-section. The maximum difference between the default DL model and all other models is taken as the uncertainty due to the underlying ξ distribution. Variations of α' have a negligible effect on the acceptance. Among all the models considered, the Phojet model gives the largest difference in the correction factor, leading to a 0.4% uncertainty on the cross-section.

Inelastic cross-section. The final result for the measured inelastic cross-section is calculated using the default DL model of $\epsilon=0.085$ and $\alpha'=0.25$, which yields $f_D=26.9\%$, $\epsilon_{sel}=98.77\%$, and $f_{\xi < 5 \times 10^{-6}} = 0.96\%$. Together with $\epsilon_{trig}=99.98\%$, $N=1,220,743$, $N_{BG}=1,574$ and $\int Ldt = 20.25 \mu\text{b}^{-1}$ this results in $\sigma_{inel}(\xi > 5 \times 10^{-6}) = 60.3 \pm 0.05(\text{stat.}) \pm 0.5(\text{syst.}) \pm 2.1(\text{lumi.}) \text{ mb}$.

The systematic uncertainty includes all contributions discussed above and listed in Table 1. The dominant uncertainty arises from the luminosity calibration and is quoted separately.

Discussion

The measurement is compared with the predictions in Figure 3 and Table 2. The predictions by the Schuler-Sjöstrand model (66.4 mb) and the Phojet model (74.2 mb) are both higher than the data. The prediction of 51.8–56.2 mb by Ryskin *et al.*¹⁷ and personal communication, is slightly lower than the data.

To compare with previous measurements and analytic models, the fractional contribution to the inelastic cross-section of events

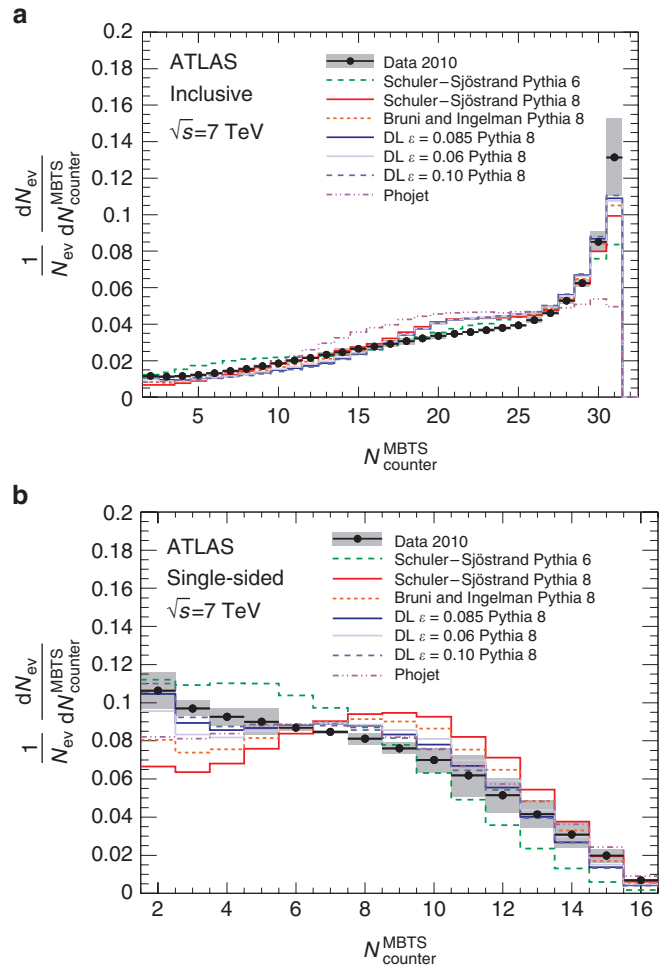


Figure 2 | MBTS multiplicity distributions. The MBTS multiplicity distribution in the data (filled circles) compared with MC expectations for the inclusive (a) and single-sided (b) samples for several MC models (histograms), using the fitted f_D values. The band around the data indicates the systematic uncertainty due to the MBTS detector response and the amount of material in front of the MBTS detector. For all three DL predictions, the α' value is 0.25 GeV^{-2} .

Table 1 | Systematic uncertainties.

Source	Uncertainty (%)
Trigger efficiency	0.1
MBTS response	0.1
Beam background	0.4
f_D	0.3
MC multiplicity	0.4
ξ -Distribution	0.4
Material	0.2
Luminosity	3.4
Total	3.5

Sources of systematic uncertainty and their effect on the cross-section measurement.

passing the $\xi > 5 \times 10^{-6}$ cut is determined from the models and used to extrapolate the measurement to the full inelastic cross-section. This fraction is 87.3% for the default model of DL with $\epsilon=0.085$ and $\alpha'=0.25$. The other models considered give fractions ranging from 96% (Phojet) to 86% (DL with $\epsilon=0.10$). Recent calculations also yield values between 79 and 84% (ref. 17). Thus

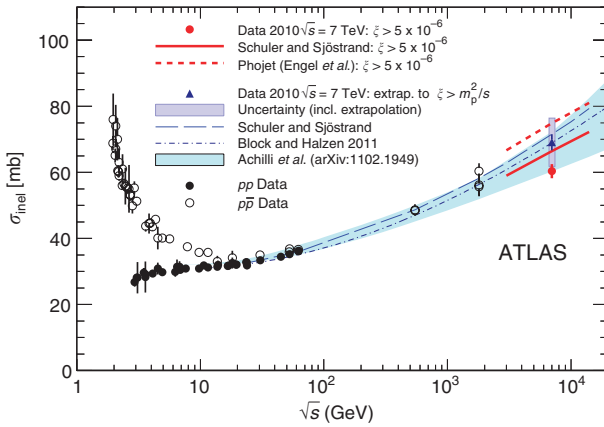


Figure 3 | The inelastic cross-section versus \sqrt{s} . The ATLAS measurement for $\xi > 5 \times 10^{-6}$ is shown as the red-filled circle and compared with the predictions of Schuler and Sjöstrand and Phojet for the same phase space. Data (filled circles for pp data and unfilled circles for $p\bar{p}$ data) from several experiments are compared with the predictions of the pp inelastic cross-section from Schuler and Sjöstrand³¹ (as used by Pythia), by Block and Halzen¹⁵ and by Achilli *et al.*²⁰ An extrapolation from the measured range of $\xi > 5 \times 10^{-6}$ to the full inelastic cross-section using the acceptance of $87 \pm 10\%$ is also shown (blue-filled triangle) based on the model by Donnachie and Landshoff for $\varepsilon = 0.085$ for $d\sigma/d\xi$. The experimental uncertainty is indicated by the error bar whereas the total (including the extrapolation uncertainty) is represented by the blue-shaded area.

87.3% is taken as the default value for this fraction and an uncertainty of 10% is taken because of the extrapolation uncertainty on the ξ -dependence. The resulting inelastic cross-section value is $\sigma_{\text{inel}} = 69.1 \pm 2.4(\text{exp.}) \pm 6.9(\text{extr.}) \text{ mb}$ where the experimental uncertainty includes the statistical and experimental systematic errors, and the extrapolation uncertainty results from the uncertainty on the ξ -dependence of the cross-section.

This result is shown in Figure 3 and compared with several theoretical predictions and a variety of data at lower \sqrt{s} . The measurement within the kinematic range $\xi > 5 \times 10^{-6}$ is significantly lower than the predictions of Schuler and Sjöstrand and Phojet. The extrapolated value agrees within the large extrapolation uncertainty with the predictions from Pythia, which uses a power law dependence on \sqrt{s} . It also agrees with Block and Halzen¹⁵ (which has a logarithmic \sqrt{s} dependence), and with other recent theoretical predictions that vary between 60 and 72 mb (refs 17–20). It should be stressed that this extrapolation relies on the prediction of the ξ -dependence of the cross-section.

The measurement and a variety of theoretical predictions are also summarized in Table 2.

In conclusion, a first measurement of the inelastic cross-section has been presented for pp collisions at $\sqrt{s} = 7$ TeV with a precision of 3.5%. The measurement is limited to the kinematic range corresponding to the detector acceptance: $\xi > 5 \times 10^{-6}$. Phenomenological predictions for both a power law dependence and a logarithmic rise of the cross-section with energy are consistent with the measurement.

Methods

The ATLAS detector. All measurements in this letter are made with the ATLAS detector, which is described in detail elsewhere²³. Here the detector coordinate system and sub-detectors relevant to this measurement are described.

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 aligned along the LHC beam pipe. The x -axis points from the interaction point to the centre of the LHC ring, and the y -axis points upward. Cylindrical coordinates (r, ϕ) are used in the transverse plane, ϕ being the azimuthal angle around the beam pipe. The pseudorapidity is defined in terms of the polar angle θ as $\eta = -\ln \tan(\theta/2)$.

Table 2 | Comparisons of the inelastic cross-section with predictions.

$\sigma(\xi > 5 \times 10^{-6}) \text{ (mb)}$	
ATLAS Data 2010	$60.33 \pm 2.10(\text{exp.})$
Schuler and Sjöstrand	66.4
Phojet	74.2
Ryskin <i>et al.</i>	51.8–56.2
$\sigma(\xi > m_p^2/s) \text{ (mb)}$	
ATLAS Data 2010	$69.1 \pm 2.4(\text{exp}) \pm 6.9(\text{extr.})$
Schuler and Sjöstrand	71.5
Phojet	77.3
Block and Halzen	69.0 ± 1.3
Ryskin <i>et al.</i>	65.2–67.1
Gotsman <i>et al.</i>	68
Achilli <i>et al.</i>	60–75

Measurement and theoretical predictions of the inelastic cross-section for the restricted kinematic range, $\xi > 5 \times 10^{-6}$, and for the full kinematic range, $\xi > m_p^2/s$. The experimental uncertainty (exp.) includes the statistical, systematic and luminosity uncertainties. The extrapolation uncertainty (extr.) only applies to the full kinematic range and is listed separately.

At the interaction point, the beam-line is surrounded by a tracking detector, which uses silicon pixel, silicon strip, and straw tube technologies, and is embedded in a 2-T magnetic field. The tracking system covers the pseudorapidity range $|\eta| < 2.5$. It is surrounded by electromagnetic and hadronic calorimeters covering $|\eta| < 3.2$, which are complemented by a forward hadronic calorimeter covering $3.1 < |\eta| < 4.9$. MBTS detectors, the primary detectors used in this measurement, are mounted in front of the endcap calorimeters on both sides of the interaction point at $z = \pm 3.56$ m and cover the range $2.09 < |\eta| < 3.84$. Each side consists of 16 independent counters divided into two rings; the inner 8 counters cover the rapidity range $2.83 < |\eta| < 3.84$ and the outer 8 counters cover the range $2.09 < |\eta| < 2.83$. Each individual counter spans 45° of the azimuthal angle (ϕ), and 31 out of 32 counters were operational.

The luminosity is measured using a Cherenkov light detector, LUCID, which is located at $z = \pm 17$ m. The luminosity calibration has been determined during dedicated van der Meer beam scans to a precision of 3.4% using the technique described in ref. 36.

References

- Nakamura, K., *et al.* & Particle Data Group. The review of particle physics Ch. 41, pg 385–401 *J. Phys. G* **37**, 075021 (2010).
- Froissart, M. Asymptotic behavior and subtractions in the Mandelstam representation. *Phys. Rev.* **3**, 1053–1057 (1961).
- Martin, A. Extension of the axiomatic analyticity domain of scattering amplitudes by unitarity-I. *Nuovo cimento* **42**, 930–953 (1966).
- Martin, A. Froissart bound for inelastic cross sections. *Phys. Rev. D* **80**, 065013–065018 (2009).
- Baltrusaitis, R. M. *et al.* Total Proton-Proton Cross Section at $s^{1/2}=30$ TeV. *Phys. Rev. Lett.* **52**, 1380–1383 (1984).
- Honda, M. *et al.* Inelastic cross section for p-air collisions from air shower experiments and total cross section for p-p collisions up to $\sqrt{s}=24$ TeV. *Phys. Rev. Lett.* **70**, 525–528 (1993).
- Nurenko, S. P. *et al.* Cosmic Ray Energy Spectrum in the Region of 10^{15} – 10^{17} eV. *Proceedings of 27th ICRC (Salt Lake City)* **1**, 372 (2001).
- Belov, K. & for the Hires Collaboration p-air Cross-Section Measurement at $10^{18.5}$ eV. *Nucl. Phys. B (Proc. Suppl.)* **151**, 197–204 (2006).
- Collins, P. D. B. *An Introduction to Regge Theory and High Energy Physics* (Cambridge University Press, 1977).
- Donnachie, A. & Landshoff, P. V. Total cross sections. *Phys. Lett. B* **296**, 227–232 (1992).
- Donnachie, A. & Landshoff, P. V. Does the hard pomeron obey Regge factorization? *Phys. Lett. B* **595**, 393–399 (2004).
- Block, M. M., Kang, K. & White, A. R. The current status of high-energy elastic scattering. *Int. J. Mod. Phys. A* **7**, 4449–4476 (1992).
- Block, M. M. & Cahn, R. N. High-Energy p anti-p and p p Forward Elastic Scattering and Total Cross-Sections. *Rev. Mod. Phys.* **57**, 563–712 (1985).
- Block, M. M. Hadronic forward scattering: Predictions for the Large Hadron Collider and cosmic rays. *Phys. Rep.* **436**, 71–215 (2006).
- Block, M. M. & Halzen, F. Forward hadronic scattering at 7 TeV: An update on predictions for the LHC. *Phys. Rev. D* **83**, 077901 (2011).
- Cudell, J. R., Kang, K. & Kim, S. K. Bounds on the soft pomeron intercept. *Phys. Lett. B* **395**, 311–331 (1997).
- Ryskin, M., Martin, A. & Khoze, V. High-energy strong interactions: from ‘hard’ to ‘soft’. *Eur. Phys. J.* **C71**, 1617–1653 (2011).

18. Gotsman, E., Levin, E., Maor, U. & Miller, J. S. A QCD motivated model for soft interactions at high energies. *Eur. Phys. J. C* **57**, 689–709 (2008).
19. Gotsman, E., Levin, E. & Maor, U. N=4 SYM and QCD motivated approach to soft interactions at high energies. *Eur. Phys. J. C* **71**, 1553–1589 (2011).
20. Achilli, A. *et al.* Total and inelastic cross-sections at LHC at CM energy of 7 TeV and beyond. *Phys. Rev. D* (in press).
21. Abe, F., *et al.* & CDF Collaboration. Measurement of the antiproton-proton total cross section at $s=546$ and 1800 GeV. *Phys. Rev. D* **50**, 5550–5561 (1994).
22. Avila, C., *et al.* & E811 Collaboration. A Measurement of the proton-antiproton total cross-section at $\sqrt{s}=1.8$ -TeV. *Phys. Lett. B* **445**, 419–422 (1999).
23. ATLAS Collaboration. The ATLAS Experiment at the CERN Large Hadron Collider. *JINST* **3**, S08003 (2008).
24. Evans, L., & Bryant, P. (ed.) LHC Machine. *JINST* **3**, S08001 (2008).
25. ATLAS Collaboration. The ATLAS Simulation Infrastructure. *Eur. Phys. J. C* **70**, 823–874 (2010).
26. Agostinelli, S., *et al.* & GEANT4 Collaboration GEANT4: A simulation toolkit. *Nucl. Instr. Meth. A* **506**, 250303 (2003).
27. PYTHIA version 6.421. Sjostrand, T., Mrenna, S. & Skands, P. PYTHIA 6.4 Physics and Manual. *JHEP* **05**, 026–602 (2006).
28. PYTHIA version 8.135. Sjostrand, T., Mrenna, S. & Skands, P. A Brief Introduction to PYTHIA 8.1. *Comput. Phys. Commun.* **178**, 852–867 (2008).
29. Engel, R. Photoproduction within the two component dual parton model. *Z. Phys. C* **66**, 203–214 (1995).
30. Engel, R. & Ranft, J. Hadronic photon-photon interactions at high energies. *Phys. Rev. D* **54**, 4244–4262 (1996).
31. Schuler, G. & Sjostrand, T. Hadronic diffractive cross sections and the rise of the total cross section. *Phys. Rev. D* **49**, 2257–2267 (1994).
32. Adloff, C., *et al.* & H1 Collaboration. Diffraction dissociation in photoproduction at HERA. *Z. Phys. C* **74**, 221–236 (1997).
33. Bruni, P. & Ingelman, G. Diffractive W and Z production at p anti-p colliders and the pomeron parton content. *Phys. Lett. B* **311**, 317–323 (1993).
34. Donnachie, A. & Landshoff, P. V. Elastic scattering and diffraction dissociation. *Nucl. Phys. B* **244**, 322–340 (1984).
35. Berger, E. L. *et al.* Diffractive hard scattering. *Nucl. Phys. B* **286**, 704–750 (1987).
36. ATLAS Collaboration. Luminosity determination in pp Collisions at $\sqrt{s}=7$ TeV using the ATLAS detector at the LHC. *Eur. Phys. J. C* **71**, 1630–1654 (2011).
37. ATLAS Collaboration. Charged-particle multiplicities in pp interactions at $\sqrt{s}=900$ GeV measured with the ATLAS detector at the LHC. *Phys. Lett. B* **688**, 21–42 (2010).
38. ATLAS Collaboration. Charged-particle multiplicities in pp interactions measured with the ATLAS detector at the LHC. *New J. Phys. B* **13**, 053033–053103 (2011).

Acknowledgements

We thank CERN for the efficient commissioning and operation of the LHC during this initial high-energy data-taking period as well as the support staff from our institutions without whom ATLAS could not be operated efficiently. We also thank T. Sjostrand, M. Ryskin and V. Khoze for their help on the theoretical aspects of the analysis. We acknowledge the support of ANPCyT, Argentina; YerPhI, Armenia; ARC, Australia; BMWF, Austria; ANAS, Azerbaijan; SSTC, Belarus; CNPq and FAPESP, Brazil; NSERC, NRC and CFI, Canada; CERN; CONICYT, Chile; CAS, MOST and NSFC, China; COLCIENCIAS, Colombia; MSMT CR, MPO CR and VSC CR, Czech Republic; DNRF, DNSRC and Lundbeck Foundation, Denmark; ARTEMIS, European Union; IN2P3-CNRS, CEA-DSM/IRFU, France; GNAS, Georgia; BMBF, DFG, HGF, MPG and AvH Foundation, Germany; GSRU, Greece; INFN, MINERVA, GIF, DIP and Beniyo Center, Israel; INFN, Italy; MEXT and JSPS, Japan; CNRST, Morocco; FOM and NWO, Netherlands; RCN, Norway; MNISW, Poland; GRICES and FCT, Portugal; MERYS (MECTS), Romania; MES of Russia and ROSATOM, Russian Federation; JINR; MSTU, Serbia; MSSR, Slovakia; ARRS and MVZT, Slovenia; DST/NRF, South Africa; MICINN, Spain; SRC and Wallenberg Foundation, Sweden; SER, SNSF and Cantons of Bern and Geneva, Switzerland; NSC, Taiwan; TAEK, Turkey; STFC, the Royal Society and Leverhulme Trust, United Kingdom; and DOE and NSF, United States of America. The crucial computing support from all WLCG partners is acknowledged gratefully, in particular from CERN and the ATLAS Tier-1 facilities at TRIUMF (Canada), NDGF (Denmark, Norway, Sweden), CC-IN2P3 (France), KIT/GridKA (Germany), INFN-CNAF (Italy), NL-T1 (Netherlands), PIC (Spain), ASGC (Taiwan), RAL (UK) and BNL (USA) and in the Tier-2 facilities worldwide.

Author contributions

All authors have contributed to the publication, being variously involved in designing and building the detector, writing offline software, operating and calibrating the detector and analysing the analysis of the processed data.

Additional information

Supplementary Information accompanies this paper at <http://www.nature.com/naturecommunications>

Competing financial interests: The authors declare no competing financial interests.

Reprints and permission information is available online at <http://npg.nature.com/reprintsandpermissions/>

How to cite this article: The ATLAS Collaboration, Measurement of the inelastic proton–proton cross-section at $\sqrt{s}=7$ TeV with the ATLAS detector. *Nat. Commun.* **2:463** doi: 10.1038/ncomms1472 (2011).

License: This work is licensed under a Creative Commons Attribution-NonCommercial-Share Alike 3.0 Unported License. To view a copy of this license, visit <http://creativecommons.org/licenses/by-nc-sa/3.0/>

G. Aad⁴⁸, B. Abbott¹¹¹, J. Abdallah¹¹, A.A. Abdelalim⁴⁹, A. Abdesselam¹¹⁸, O. Abdinov¹⁰, B. Abi¹¹², M. Abolins⁸⁸, H. Abramowicz¹⁵³, H. Abreu¹¹⁵, E. Acerbi^{89a,89b}, B.S. Acharya^{164a,164b}, D.L. Adams²⁴, T.N. Addy⁵⁶, J. Adelman¹⁷⁵, M. Aderholz⁹⁹, S. Adomeit⁹⁸, P. Adragna⁷⁵, T. Adye¹²⁹, S. Aefsky²², J.A. Aguilar-Saavedra^{124b,a}, M. Aharrouche⁸¹, S.P. Ahlen²¹, F. Ahles⁴⁸, A. Ahmad¹⁴⁸, M. Ahsan⁴⁰, G. Aielli^{133a,133b}, T. Akdogan^{18a}, T.P.A. Åkesson⁷⁹, G. Akimoto¹⁵⁵, A.V. Akimov⁹⁴, A. Akiyama⁶⁷, M.S. Alam¹, M.A. Alam⁷⁶, S. Albrand⁶⁵, M. Aleksan²⁹, I.N. Aleksandrov⁶⁵, F. Alessandria^{89a}, C. Alexa^{25a}, G. Alexander¹⁵³, G. Alexandre⁴⁹, T. Alexopoulos⁹, M. Alhrub²⁰, M. Aliev¹⁵, G. Alimonti^{89a}, J. Alison¹²⁰, M. Aliyev¹⁰, P.P. Allport⁷³, S.E. Allwood-Spiers⁵³, J. Almond⁸², A. Aloisio^{102a,102b}, R. Alon¹⁷¹, A. Alonso⁷⁹, M.G. Alviggi^{102a,102b}, K. Amako⁶⁶, P. Amaral²⁹, C. Amelung²², V.V. Ammosov¹²⁸, A. Amorim^{124a,b}, G. Amorós¹⁶⁷, N. Amram¹⁵³, C. Anastopoulos¹³⁹, T. Andeen³⁴, C.F. Anders²⁰, K.J. Anderson³⁰, A. Andreazza^{89a,89b}, V. Andrei^{58a}, M-L. Andrieux⁵⁵, X.S. Anduaga⁷⁰, A. Angerami³⁴, F. Anghinolfi²⁹, N. Anjos^{124a}, A. Annovi⁴⁷, A. Antonaki⁸, M. Antonelli⁴⁷, S. Antonelli^{19a,19b}, A. Antonov⁹⁶, J. Antos^{144b}, F. Anulli^{132a}, S. Aoun⁸³, L. Aperio Bella⁴, R. Apolle¹¹⁸, G. Arabidze⁸⁸, I. Aracena¹⁴³, Y. Arai⁶⁶, A.T.H. Arce⁴⁴, J.P. Archambault²⁸, S. Arfaoui^{29c}, J-F. Arguin¹⁴, E. Arik^{18a,3}, M. Arik^{18a}, A.J. Armbruster⁸⁷, O. Arnæz⁸¹, C. Arnault¹¹⁵, A. Artamonov⁹⁵, G. Artoni^{132a,132b}, D. Arutinov²⁰, S. Asai¹⁵⁵, R. Asfandiyarov¹⁷², S. Ask²⁷, B. Åsman^{146a,146b}, L. Asquith⁵, K. Assamagan²⁴, A. Astbury¹⁶⁹, A. Astvatsatourov⁵², G. Atoian¹⁷⁵, B. Aubert⁴, B. Auerbach¹⁷⁵, E. Auge¹¹⁵, K. Augsten¹²⁷, M. Auresseau^{145a}, N. Austin⁷³, R. Avramidou⁹, D. Axen¹⁶⁸, C. Ay⁵⁴, G. Azuelos^{93,d}, Y. Azuma¹⁵⁵, M.A. Baak²⁹, G. Baccaglioni^{89a}, C. Bacci^{134a,134b}, A.M. Bach¹⁴, H. Bachacou¹³⁶, K. Bachas²⁹, G. Bache²⁹, M. Backes⁴⁹, M. Backhaus²⁰, E. Badescu^{25a}, P. Bagnaia^{132a,132b}, S. Bahinipati², Y. Bai^{32a}, D.C. Bailey¹⁵⁸, T. Bain¹⁵⁸, J.T. Baines¹²⁹, O.K. Baker¹⁷⁵, M.D. Baker²⁴, S. Baker⁷⁷, F. Baltasar Dos Santos Pedrosa²⁹, E. Banas³⁸, P. Banerjee⁹³, Sw. Banerjee¹⁶⁹, D. Banfi²⁹, A. Bangert¹³⁷, V. Bansal¹⁶⁹, H.S. Bansil¹⁷, L. Barak¹⁷¹, S.P. Baranov⁹⁴, A. Barashkou⁶⁵, A. Barbaro Galtieri¹⁴, T. Barber²⁷, E.L. Barberio⁸⁶, D. Barberis^{50a,50b}, M. Barbero²⁰, D.Y. Bardin⁶⁵, T. Barillari¹⁹⁹, M. Barisonzi¹⁷⁴, T. Barklow¹⁴³, N. Barlow²⁷, B.M. Barnett¹²⁹, R.M. Barnett¹⁴, A. Baroncelli^{134a}, A.J. Barr¹¹⁸, F. Barreiro⁸⁰, J. Barreiro Guimarães da Costa⁵⁷, P. Barrillon¹¹⁵, R. Bartoldus¹⁴³, A.E. Barton⁷¹, D. Bartsch²⁰, V. Bartsch¹⁴⁹, R.L. Bates⁵³, L. Batkova^{144a}, J.R. Batley²⁷, A. Battaglia¹⁶, M. Battistin²⁹, G. Battistoni^{89a}, F. Bauer¹³⁶, H.S. Bawa^{143e}, B. Beare¹⁵⁸, T. Beau⁷⁸, P.H. Beauchemin¹¹⁸, R. Beccherle^{50a}, P. Bechtel⁴¹, H.P. Beck¹⁶, M. Beckingham⁴⁸, K.H. Becks¹⁷⁴, A.J. Beddall^{18c}, A. Beddall^{18c}, S. Bedikian¹⁷⁵, V.A. Bednyakov⁶⁵, C.P. Bee⁸³, M. Beggel²⁴, S. Behar Harpaz¹⁵², P.K. Behera⁶³, M. Beimforde⁹⁹, C. Belanger-Champagne¹⁶⁶, P.J. Bell⁴⁹, W.H. Bell⁴⁹, G. Bella¹⁵³, L. Bellagamba^{19a}, F. Bellina²⁹, M. Bellomo^{119a}, A. Belloni⁵⁷, O. Beloborodova¹⁰⁷, K. Belotskiy⁹⁶, O. Beltramello²⁹, S. Ben Ami¹⁵², O. Benary¹⁵³, D. Bencheikroun^{135a}, C. Benchouk⁸³, M. Bendel⁸¹, B.H. Benedict¹⁶³, N. Benekos¹⁶⁵, Y. Benhammou¹⁵³, D.P. Benjamin⁴⁴, M. Benoit¹¹⁵, J.R. Bensinger²², K. Benslama¹³⁰, S. Bentvelsen¹⁰⁵, D. Berge²⁹, E. Bergeas Kuitmann⁴¹, N. Berger⁴, F. Berghaus¹⁶⁹, E. Berglund⁴⁹, J. Beringer⁴, K. Bernardet⁸³, P. Bernat⁷⁷, R. Bernhard⁴⁸, C. Bernius²⁴, T. Berry⁷⁶, A. Bertin^{19a,19b}, F. Bertinelli²⁹, F. Bertolucci^{122a,122b}, M.I. Besana^{89a,89b}, N. Besson¹³⁶, S. Bethke⁹⁹, W. Bhimji⁴⁵, R.M. Bianchi²⁹, M. Bianco^{72a,72b}, O. Biebel⁹⁸, S.P. Bieniek⁷⁷, J. Biesiada¹⁴, M. Biglietti^{134a,134b}, H. Bilokon⁴⁷, M. Bindi^{19a,19b}, S. Binet¹¹⁵, A. Bingul^{18c}, C. Bini^{132a,132b}, C. Biscarat¹⁷⁷, U. Bitenc⁴⁸, K.M. Black²¹, R.E. Blair⁵, J.-B. Blanchard¹¹⁵, G. Blanchot²⁹, T. Blazek^{144a}, C. Blocker²², J. Blocki³⁸, A. Blondel⁴⁹, W. Blum⁸¹, U. Blumenschein⁵⁴, G.J. Bobbink¹⁰⁵, V.B. Bobrovnikov¹⁰⁷, S.S. Bocchetta⁷⁹, A. Bocchi⁴⁴, C.R. Boddy¹¹⁸, M. Boehler⁴¹, J. Boek¹⁷⁴, N. Boelaert³⁵, S. Böser⁷⁷, J.A. Bogaerts²⁹, A. Bogdanchikov¹⁰⁷, A. Bogouch^{90,3}, C. Bohm^{146a}, V. Boisvert⁷⁶, T. Bold^{163f}, V. Boldea^{25a}, N.M. Bolnet¹³⁶, M. Bona⁷⁵, V.G. Bondarenko⁹⁶, M. Boonekamp¹³⁶, G. Boorman⁷⁶, C.N. Booth¹³⁹, P. Booth¹³⁹, S. Bordon⁷⁸, C. Borer¹⁶, A. Borisov¹²⁸, G. Borissov⁷¹, I. Borjanovic^{12a}, S. Borroni^{132a,132b}, K. Bos¹⁰⁵, D. Boscherini^{19a},

M. Bosman¹¹, H. Boterenbrood¹⁰⁵, D. Botterill²⁹, J. Bouchami⁹³, J. Boudreau¹²³, E.V. Bouhova-Thacker⁷¹, C. Boulahouache¹²³, C. Bourdarios¹¹⁵, N. Bousson⁸³, A. Boveia³⁰, J. Boyd²⁹, I.R. Boyko⁶⁵, N.I. Bozhko¹²⁸, I. Bozovic-Jelisavcic^{12b}, J. Bracinik¹⁷, A. Braem²⁹, P. Branchini^{134a}, G.W. Brandenburg⁵⁷, A. Brandt⁷, G. Brandt¹⁵, O. Brandt⁵⁴, U. Bratzler¹⁵⁶, B. Brau⁸⁴, J.E. Brau¹¹⁴, H.M. Braun¹⁷⁴, B. Brelier¹⁵⁸, J. Bremer²⁹, R. Brenner¹⁶⁶, S. Bressler¹⁵², D. Breton¹¹⁵, N.D. Brett¹¹⁸, D. Britton⁵³, F.M. Brochu²⁷, I. Brock²⁰, R. Brock⁸⁸, T.J. Brodbeck⁷¹, E. Brodet¹⁵³, F. Broggi^{89a}, C. Bromberg⁸⁸, G. Brooijmans³⁴, W.K. Brooks^{31b}, G. Brown⁸², H. Brown⁷, E. Brubaker³⁰, P.A. Bruckman de Renstrom³⁸, D. Bruncko^{144b}, R. Bruneliere⁴⁸, S. Brunet⁶¹, A. Bruni^{19a}, G. Bruni^{19a}, M. Bruschi^{19a}, T. Buanes¹³, F. Bucci⁴⁹, J. Buchanan¹¹⁸, N.J. Buchanan², P. Buchholz¹⁴¹, R.M. Buckingham¹¹⁸, A.G. Buckley⁴⁵, S.I. Buda^{25a}, I.A. Budagov⁶⁵, B. Budick¹⁰⁸, V. Büscher⁸¹, L. Bugge¹¹⁷, D. Buira-Clark¹¹⁸, E.J. Buis¹⁰⁵, O. Bulekov⁹⁶, M. Bunse⁴², T. Buran¹¹⁷, H. Burckhart²⁹, S. Burdin⁷³, T. Burgess¹³, S. Burke¹²⁹, E. Busato³³, P. Bussey³³, C.P. Buszello¹⁶⁶, F. Butin²⁹, B. Butler¹⁴³, J.M. Butler²¹, C.M. Buttar⁵³, J.M. Butterworth⁷⁷, W. Buttinger²⁷, T. Byatt⁷⁷, S. Cabrera Urbán¹⁶⁷, D. Caforio^{19a,19b}, O. Cakir^{3a}, P. Calafiura¹⁴, G. Calderini⁷⁸, P. Calfayan⁹⁸, R. Calkins¹⁰⁶, L.P. Caloba^{23a}, R. Caloi^{132a,132b}, D. Calvet³³, S. Calvet³³, R. Camacho Toro³³, A. Camard⁷⁸, P. Camarri^{133a,133b}, M. Cambiaghi^{119a,119b}, D. Cameron¹¹⁷, J. Cammin²⁰, S. Campana²⁹, M. Campanelli⁷⁷, V. Canale^{102a,102b}, F. Canelli³⁰, A. Canepa^{159a}, J. Cantero⁸⁰, L. Capasso^{102a,102b}, M.D.M. Capeans Garrido²⁹, I. Caprini^{25a}, M. Caprini^{25a}, D. Capriotti⁹⁹, M. Capua^{36a,36b}, R. Caputo¹⁴⁸, C. Caramarcu^{25a}, R. Cardarelli^{133a}, T. Carli²⁹, G. Carlino^{102a}, L. Carminati^{89a,89b}, B. Caron^{159a}, S. Caron⁴⁸, C. Carpentieri⁴⁸, G.D. Carrillo Montoya¹⁷², A.A. Carter⁷⁵, J.R. Carter²⁷, J. Carvalho^{124a,g}, D. Casadei¹⁰⁸, M.P. Casado¹¹, M. Cascella^{122a,122b}, C. Caso^{50a,50b,1}, A.M. Castaneda Hernandez¹⁷², E. Castaneda-Miranda¹⁷², V. Castillo Gimenez¹⁶⁷, N.F. Castro^{124a}, G. Cataldi^{72a}, F. Cataneo²⁹, A. Catinaccio²⁹, J.R. Catmore⁷¹, A. Cattai²⁹, G. Cattani^{133a,133b}, S. Caughnon⁸⁸, D. Cauz^{164a,164c}, A. Cavallari^{132a,132b}, P. Cavalleri⁷⁸, D. Cavalli^{89a}, M. Cavalli-Sforza¹¹, V. Cavasinni^{122a,122b}, A. Cazzato^{72a,72b}, F. Ceradini^{134a,134b}, A.S. Cerqueira^{23a}, A. Cerri²⁹, L. Cerrito⁷⁵, F. Cerutti⁴⁷, S.A. Cetin^{18b}, F. Cevenini^{102a,102b}, A. Chafaq^{135a}, D. Chakraborty¹⁰⁶, K. Chan², B. Chapleau⁸⁵, J.D. Chapman²⁷, J.W. Chapman⁸⁷, E. Chareyre⁷⁸, D.G. Charlton¹⁷, V. Chavda⁸², S. Cheatham⁷¹, S. Chekanov⁵, S.V. Chekulav^{159a}, G.A. Chelkov⁶⁵, M.A. Chelstowska¹⁰⁴, C. Chen⁶⁴, H. Chen²⁴, L. Chen², S. Chen^{32c}, T. Chen^{32c}, X. Chen⁷², S. Cheng^{32a}, A. Cheplakov⁶⁵, V.F. Chepurinov⁶⁵, R. Cherkaoui El Moursli^{135e}, V. Chernyatin²⁴, E. Cheu⁶, S.L. Cheung¹⁵⁸, L. Chevalier¹³⁶, G. Chiefari^{102a,102b}, L. Chikovani⁵¹, J.T. Childers^{58a}, A. Chilingarov⁷¹, G. Chiodini^{72a}, M.V. Chizhov⁶⁵, G. Choudalakis³⁰, S. Chouridou¹³⁷, I.A. Christidi⁷⁷, A. Christov⁴⁸, D. Chromek-Burckhart²⁹, M.L. Chu¹⁵¹, J. Chudoba¹²⁵, G. Ciapetti^{132a,132b}, K. Ciba³⁷, A.K. Ciftci^{3a}, R. Ciftci^{3a}, D. Cinca³³, V. Cindro⁷⁴, M.D. Ciobotaru¹⁶³, C. Ciocca^{19a,19b}, A. Ciocio¹⁴, M. Cirilli⁸⁷, M. Ciubancan^{25a}, A. Clark⁴⁹, P.J. Clark⁴⁵, W. Cleland¹²³, J.C. Clemens⁸³, B. Clement⁵⁵, C. Clement^{146a,146b}, R.W. Clifft¹²⁹, Y. Coadou⁸³, M. Cobal^{164a,164c}, A. Coccaro^{50a,50b}, J. Cochran⁶⁴, P. Coe¹¹⁸, J.G. Cogan¹⁴³, J. Coggeshall¹⁶⁵, E. Cogneras¹⁷⁷, C.D. Cojocar²⁸, J. Colas⁴, A.P. Colijn¹⁰⁵, C. Collard¹¹⁵, N.J. Collins¹⁷, C. Collins-Tooth⁵³, J. Collot⁵⁵, G. Colon⁸⁴, G. Comune⁸⁸, P. Conde Muiño^{124a}, E. Coniavitis¹¹⁸, M.C. Conidi¹¹, M. Consonni¹⁰⁴, S. Constantinescu^{25a}, C. Conta^{119a,119b}, F. Conventi^{102a,h}, J. Cook²⁹, M. Cooke¹⁴, B.D. Cooper⁷⁷, A.M. Cooper-Sarkar¹¹⁸, N.J. Cooper-Smith⁷⁶, K. Copic³⁴, T. Cornelissen^{50a,50b}, M. Corradi^{19a}, F. Corrivae⁸⁵ⁱ, A. Cortes-Gonzalez¹⁶⁵, G. Cortiana⁹⁹, G. Costa^{89a}, M.J. Costa¹⁶⁷, D. Costanzo¹³⁹, T. Costin³⁰, D. Côte²⁹, R. Coura Torres^{23a}, L. Courneyea¹⁶⁹, G. Cowan⁷⁶, C. Cowden²⁷, B.E. Cox⁸², K. Cranmer¹⁰⁸, F. Crescioli^{122a,122b}, M. Cristinziani²⁰, G. Crosetti^{36a,36b}, R. Crupi^{72a,72b}, S. Crépe-Renaudin⁵⁵, C.-M. Cuciuc^{25a}, C. Cuenca Almenar¹⁷⁵, T. Cuhadar Donszelmann¹³⁹, S. Cuneo^{50a,50b}, M. Curatolo⁴⁷, C.J. Curtis¹⁷, P. Cwetanski⁶¹, H. Czirr¹⁴¹, Z. Czyczula¹¹⁷, S. D'Auria⁵³, M. D'Onofrio⁷³, A. D'Orazio^{132a,132b}, A. Da Rocha Gesualdi Mello^{23a}, P.V.M. Da Silva^{23a}, C. Da Via⁸², W. Dabrowski³⁷, A. Dahlhoff⁴⁸, T. Dai⁸⁷, C. Dallapiccola⁸⁴, M. Dam³⁵, M. Dameri^{150a,50b}, D.S. Damiani¹³⁷, H.O. Danielsson²⁹, R. Dankers¹⁰⁵, D. Dannheim⁹⁹, V. Dao⁴⁹, G. Darbo^{50a}, G.L. Darlea^{25b}, C. Daum¹⁰⁵, J.P. Dauvergne²⁹, W. Davey⁸⁶, T. Davidek¹²⁶, N. Davidson⁸⁶, R. Davidson⁷¹, M. Davies⁹³, A.R. Davison⁷⁷, E. Dawe¹⁴², I. Dawson¹³⁹, J.W. Dawson^{5,‡}, R.K. Daya³⁹, K. De⁷, R. de Asmundis^{102a}, S. De Castro^{19a,19b}, P.E. De Castro Faria Salgado²⁴, S. De Cecco⁷⁸, J. de Graat⁹⁸, N. De Groot¹⁰⁴, P. de Jong¹⁰⁵, C. De La Taille¹¹⁵, H. De la Torre⁸⁰, B. De Lotto^{164a,164c}, L. De Mora⁷¹, L. De Nooij¹⁰⁵, M. De Oliveira Branco²⁹, D. De Pedis^{132a}, P. de Saintignon⁵⁵, A. De Salvo^{132a}, U. De Sanctis^{164a,164c}, A. De Sato¹⁴⁹, J.B. De Vivie De Regie¹¹⁵, S. Dean⁷⁷, D.V. Dedovich⁶⁵, J. Degenhardt¹²⁰, M. Dehchar¹¹⁸, M. Deile⁹⁸, C. Del Papa^{164a,164c}, J. Del Peso⁸⁰, T. Del Prete^{122a,122b}, A. Dell'Acqua²⁹, L. Dell'Asta^{89a,89b}, M. Della Pietra^{102a,h}, D. della Volpe^{102a,102b}, M. Delmastro²⁹, P. Delpierre⁸³, N. Delruelle²⁹, P.A. Delsart⁵⁵, C. Deluca⁴⁸, S. Demers¹⁷⁵, M. Demichev⁶⁵, B. Demirköz^{11j}, J. Deng¹⁶³, S.P. Denisov¹²⁸, D. Derendarz³⁸, J.E. Derkaoui^{135d}, F. Derue⁷⁸, P. Dervan⁷³, K. Desch²⁰, E. Devetak¹⁴⁸, P.O. Deviveiros¹⁵⁸, A. Dewhurst¹²⁹, B. DeWilde¹⁴⁸, S. Dhaliwal¹⁵⁸, R. Dhullipudi^{24,k}, A. Di Ciaccio^{133a,133b}, L. Di Ciaccio⁴, A. Di Girolamo²⁹, B. Di Girolamo²⁹, S. Di Luise^{134a,134b}, A. Di Mattia⁸⁸, B. Di Micco²⁹, R. Di Nardo^{133a,133b}, A. Di Simone^{133a,133b}, R. Di Sipio^{19a,19b}, M.A. Diaz^{31a}, F. Diblen^{18c}, E.B. Diehl⁸⁷, H. Dietl⁹⁹, J. Dietrich⁴⁸, T.A. Dietzsch^{58a}, S. Diglio¹¹⁵, K. Dindar Yagci³⁹, J. Dingfelder²⁰, C. Dionisi^{132a,132b}, P. Dita^{25a}, S. Dita^{25a}, F. Dittus²⁹, F. Djama⁸³, R. Djilkibaev¹⁰⁸, T. Djobava⁵¹, M.A.B. do Vale^{23a}, A. Do Valle Wemans^{124a}, T.K.O. Doan⁴, M. Dobbs⁸⁵, R. Dobinson^{29,‡}, D. Dobos⁴², E. Dobson²⁹, M. Dobson¹⁶³, J. Dodd³⁴, O.B. Dogan^{18a,‡}, C. Doglioni¹¹⁸, T. Doherty⁵³, Y. Doi^{66,‡}, J. Dolejsi¹²⁶, I. Dolenc⁷⁴, Z. Dolezal¹²⁶, B.A. Dolgoshein^{96,‡}, T. Dohmae¹⁵⁵, M. Donadelli^{23b}, M. Donega¹²⁰, J. Donini⁵⁵, J. Dopke²⁹, A. Doria^{102a}, A. Dos Anjos¹⁷², M. Dosil¹¹, A. Dotti^{122a,122b}, M.T. Dova⁷⁰, J.D. Dowell¹⁷, A.D. Doxiadis¹⁰⁵, A.T. Doyle⁵³, Z. Drasal¹²⁶, J. Drees¹⁷⁴, N. Dressandt¹²⁰, H. Drevermann²⁹, C. Driouchi¹³⁵, M. Dris⁹, J.G. Drohan⁷⁷, J. Dubbert⁹⁹, T. Dubbs¹³⁹, S. Dube¹⁴, E. Duchovni¹⁷¹, G. Duckeck⁹⁸, A. Dudarev²⁹, F. Dudziak⁶⁴, M. Dührsen²⁹, I.P. Duerdoth⁸², L. Duflot¹¹⁵, M.-A. Dufour⁸⁵, M. Dunford²⁹, H. Duran Yildiz^{3b}, R. Duxfield¹³⁹, M. Dwuznik³⁷, F. Dydak²⁹, D. Dzahini⁵⁵, M. Düren⁵², W.L. Ebenstein⁴⁴, J. Ebke⁹⁸, S. Eckert⁴⁸, S. Eckweiler⁸¹, K. Edmonds⁸¹, C.A. Edwards⁷⁶, W. Ehrenfeld⁴¹, T. Ehrich⁹⁹, T. Eifer²⁹, G. Eigen¹³, K. Einsweiler¹⁴, E. Eisenhandler⁷⁵, T. Ekelof¹⁶⁶, M. El Kacimi^{135c}, M. Ellert¹⁶⁶, S. Elles⁴, F. Ellinghaus⁸¹, K. Ellis⁷⁵, N. Ellis²⁹, J. Elmsheuser⁹⁸, M. Elsing²⁹, R. Ely¹⁴, D. Emelianov¹²⁹, R. Engelmann¹⁴⁸, A. Engl⁹⁸, B. Epp⁶², A. Eppig⁸⁷, J. Erdmann⁵⁴, A. Ereditato¹⁶, D. Eriksson^{146a}, J. Ernst¹, M. Ernst²⁴, J. Erwein¹³⁶, D. Errede¹⁶⁵, S. Errede¹⁶⁵, E. Ertel⁸¹, M. Escalier¹¹⁵, C. Escobar¹⁶⁷, X. Espinal Curull¹¹, B. Esposito⁴⁷, F. Etienne⁸³, A.I. Etiennev¹³⁶, E. Etzion¹⁵³, D. Evangelakou⁵⁴, H. Evans⁶¹, L. Fabbri^{19a,19b}, C. Fabre²⁹, R.M. Fakhruddinov¹²⁸, S. Falciano^{132a}, A.C. Falou¹¹⁵, Y. Fang¹⁷², M. Fant^{89a,89b}, A. Farbin⁷, A. Farilla^{134a}, J. Farley¹⁴⁸, T. Farrow¹⁵⁸, S.M. Farrington¹¹⁸, P. Farthouat²⁹, D. Fasching¹⁷², P. Fassnacht²⁹, D. Fassouliotis⁸, B. Fatholahzadeh¹⁵⁸, A. Favareto^{89a,89b}, L. Fayard¹¹⁵, S. Fazio^{36a,36b}, R. Febbraro³³, P. Federic^{144a}, O.L. Fedin¹²¹, I. Fedorko²⁹, W. Fedorko⁸⁸, M. Fehling-Kaschek⁴⁸, L. Feligioni⁸³, D. Fellmann⁵, C.U. Felzmann⁸⁶, C. Feng^{32d}, E.J. Feng³⁰, A.B. Fenuyk¹⁷¹, F. Ferencei^{144b}, J. Ferland⁹³, W. Fernando¹⁰⁹, S. Ferrag⁵³, J. Ferrando⁵³, V. Ferrara⁴¹, A. Ferrari¹⁶⁶, P. Ferrari¹⁰⁵, R. Ferrari^{119a}, A. Ferrer¹⁶⁷, M.L. Ferrer⁴⁷, D. Ferrere⁴⁹, C. Ferretti⁸⁷, A. Ferretto Parodi^{50a,50b}, M. Fiascaris³⁰, F. Fiedler⁸¹, A. Filipčić⁷⁴, A. Filipipas⁹, F. Filthaut¹⁰⁴, M. Fincke-Keeler¹⁶⁹, M.C.N. Fiolhais^{124a,g}, L. Fiorini¹¹, A. Firan³⁹, G. Fischer⁴¹, P. Fischer²⁰, M.J. Fisher¹⁰⁹, S.M. Fisher¹²⁹, J. Flammer²⁹, M. Flechl⁴⁸, I. Fleck¹⁴¹, J. Fleckner⁸¹, P. Fleischmann¹⁷³, S. Fleischmann¹⁷⁴, T. Flick¹⁷⁴, L.R. Flores Castillo¹⁷², M.J. Flowerdew⁹⁹, F. Föhlich^{58a}, M. Fokitis⁹, T. Fonseca Martin¹⁶, D.A. Forbush¹³⁸, A. Formica¹³⁶, A. Forti⁸², D. Fortin^{159a}, J.M. Foster⁸², D. Fournier¹¹⁵, A. Foussat²⁹, A.J. Fowler⁴⁴, K. Fowler¹³⁷, H. Fox⁷¹, P. Francavilla^{122a,122b}, S. Franchino^{119a,119b}, D. Francis²⁹, T. Frank¹⁷¹, M. Franklin⁵⁷, S. Franz²⁹, M. Fraternali^{119a,119b}, S. Fratina¹²⁰, S.T. French²⁷, R. Froesch²⁹, D. Froidevaux²⁹, J.A. Frost²⁷, C. Fukunaga¹⁵⁶, E. Fullana Torregrosa²⁹, J. Fuster¹⁶⁷, C. Gabaldon²⁹, O. Gabizon¹⁷¹, T. Gadfort²⁴, S. Gadomski⁴⁹, G. Gagliardi^{50a,50b}, P. Gagnon⁶¹, C. Galea⁹⁸, E.J. Gallas¹¹⁸, M.V. Gallas²⁹, V. Gallo¹⁶, B.J. Gallop¹²⁹, P. Gallus¹²⁵, E. Galyaev⁴⁰, K.K. Gan¹⁰⁹, Y.S. Gao^{143e}, V.A. Gapienko¹²⁸, A. Gaponenko¹⁴, F. Garberon¹⁷⁵, M. Garcia-Sciveres¹⁴, C. García¹⁶⁷, J.E. García Navarro⁴⁹, R.W. Gardner³⁰, N. Garelli²⁹, H. Garitavandian¹⁰⁵, V. Garonne²⁹, J. Garvey¹⁷, C. Gatti⁴⁷, G. Gaudio^{119a}, O. Gaumer⁴⁹, B. Gaur¹⁴¹, L. Gauthier¹³⁶, I.L. Gavrilenco⁹⁴, C. Gay¹⁶⁸, G. Gaycken²⁰, J.-C. Gayde²⁹, E.N. Gazis⁹, P. Ge^{32d}, C.N.P. Gee¹²⁹, D.A.A. Geerts¹⁰⁵, Ch. Geich-Gimbel²⁰, K. Gellerstedt^{146a,146b}, C. Gemme^{50a}, A. Gemmel⁵³, M.H. Genest⁹⁸, S. Gentile^{132a,132b}, M. George⁵⁴, S. George⁷⁶, P. Gerlach¹⁷⁴, A. Gershon¹⁵³, C. Geweniger^{58a}, H. Ghazlane^{135b}, P. Ghez⁴, N. Ghodbane³³, B. Giacobbe^{19a}, S. Giagu^{132a,132b}, V. Giakoumopoulou⁸, V. Giangiobbe^{122a,122b}, F. Gianotti²⁹, B. Gibbard²⁴, A. Gibson¹⁵⁸, S.M. Gibson²⁹, G.F. Gieraltowski⁵¹, L.M. Gilbert¹¹⁸, M. Gilchriese¹⁴, V. Gilevsky⁹¹, D. Gillberg²⁸, A.R. Gillman¹²⁹, D.M. Gingrich^{2,d}, J. Ginzburg¹⁵³, N. Giokaris⁸, R. Giordano^{102a,102b}, F.M. Giorgi¹⁵, P. Giovannini⁹⁹, P.F. Giraud¹³⁶, D. Giugni^{89a}, M. Giunta^{132a,132b}, P. Giusti^{19a}, B.K. Gjelsten¹¹⁷, L.K. Gladilin⁹⁷, C. Glasman⁸⁰, J. Glatzer⁴⁸, A. Glazov⁴¹, K.W. Glitza¹⁷⁴, G.L. Glonti⁶⁵, J. Godfrey¹⁴², J. Godlewski²⁹, M. Goebel⁴¹, T. Göpfert⁴³, C. Goeringer⁸¹, C. Gössling⁴², T. Göttfert⁹⁹, S. Goldfarb⁸⁷, D. Goldin³⁹, T. Golling¹⁷⁵, S.N. Golovina¹²⁸, A. Gomes^{124a,b}, L.S. Gomez Fajardo⁴¹, R. Gonçalo⁷⁶,

J. Goncalves Pinto Firmino Da Costa⁴¹, L. Gonella²⁰, A. Gonidec²⁹, S. Gonzalez¹⁷², S. González de la Hoz¹⁶⁷, M.L. Gonzalez Silva²⁶, S. Gonzalez-Sevilla⁴⁹, J.J. Goodson¹⁴⁸, L. Goossens²⁹, P.A. Gorbounov⁹⁵, H.A. Gordon²⁴, I. Gorelov¹⁰³, G. Gorfine¹⁷⁴, B. Gorini²⁹, E. Gorini^{172a,72b}, A. Gorišek⁷⁴, E. Gornicki³⁸, S.A. Gorokhov¹²⁸, V.N. Goryachev¹²⁸, B. Gosdzik⁴¹, M. Gosselink¹⁰⁵, I. Gostkin⁶⁵, M. Gouanère⁴, I. Gough Eschrich¹⁶³, M. Goughrih^{135a}, D. Goujdami^{135c}, M.P. Goulette⁴⁹, A.G. Goussiou¹³⁸, C. Goy⁴, I. Grabowska-Bold^{163f}, V. Grabski¹⁷⁶, P. Grafström²⁹, C. Grah¹⁷⁴, K.-J. Grah¹⁴⁷, F. Grancagnolo^{72a}, S. Grancagnolo¹⁵, V. Grassi¹⁴⁸, V. Gratchev¹²¹, N. Grau³⁴, H.M. Gray²⁹, J.A. Gray¹⁴⁸, E. Graziani^{134a}, O.G. Grebenyuk¹²¹, D. Greenfield¹²⁹, T. Greenshaw⁷³, Z.D. Greenwood^{24k}, I.M. Gregor⁴¹, P. Grenier¹⁴³, E. Griesmayer⁴⁶, J. Griffiths¹³⁸, N. Grigalashvili⁶⁵, A.A. Grillo¹³⁷, S. Grinstein¹¹, P.L.Y. Gris³³, Y.V. Grishkevich⁹⁷, J.-F. Grivaz¹¹⁵, J. Grognuz²⁹, M. Groh⁹⁹, E. Gross¹⁷¹, J. Grosse-Knetter⁵⁴, J. Groth-Jensen⁷⁹, M. Gruwe²⁹, K. Grybel¹⁴¹, V.J. Guarino⁵, D. Guest¹⁷, C. Guicheney³³, A. Guida^{72a,72b}, T. Guillemin⁴, S. Guindon⁵⁴, H. Guler⁸⁵ⁱ, J. Gunther¹²⁵, B. Guo¹⁵⁸, J. Guo³⁴, A. Gupta³⁰, Y. Gusakov⁶⁵, V.N. Gushchin¹²⁸, A. Gutierrez⁹³, P. Gutierrez¹¹¹, N. Guttman¹⁵³, O. Gutzwiller¹⁷², C. Guyot¹³⁶, C. Gwenlan¹¹⁸, C.B. Gwilliam⁷³, A. Haas¹⁴³, S. Haas²⁹, C. Haber¹⁴, R. Hackenberg²⁴, H.K. Hadavand³⁹, D.R. Hadley¹⁷, P. Haefner⁹⁹, F. Hahn²⁹, S. Haider²⁹, Z. Hajduk³⁸, H. Hakobyan¹⁷⁶, J. Haller⁵⁴, K. Hamacher¹⁷⁴, P. Hamal¹¹³, A. Hamilton⁴⁹, S. Hamilton¹⁶¹, H. Han^{32a}, L. Han^{32b}, K. Hanagaki¹¹⁶, M. Hance¹²⁰, C. Handel⁸¹, P. Hanke^{58a}, C.J. Hansen¹⁶⁶, J.R. Hansen³⁵, J.B. Hansen³⁵, J.D. Hansen³⁵, P.H. Hansen³⁵, P. Hansson¹⁴³, K. Hara¹⁶⁰, G.A. Hare¹³⁷, T. Harenberg¹⁷⁴, S. Harkusha⁹⁰, D. Harper⁸⁷, R.D. Harrington²¹, O.M. Harris¹³⁸, K. Harrison¹⁷, J. Hartert⁴⁸, F. Hartjes¹⁰⁵, T. Haruyama⁶⁶, A. Harvey⁵⁶, S. Hasegawa¹⁰¹, Y. Hasegawa¹⁴⁰, S. Hassani¹³⁶, M. Hatch²⁹, D. Hauff⁹⁹, S. Haug²⁶, M. Hauschild²⁹, R. Hauser⁸⁸, M. Havranek²⁰, B.M. Hawes¹¹⁸, C.M. Hawkes¹⁷, R.J. Hawkins²⁹, D. Hawkins¹⁶³, T. Hayakawa⁶⁷, D. Hayden⁷⁶, H.S. Hayward⁷³, S.J. Haywood¹²⁹, E. Hazen²¹, M. He^{32d}, S.J. Head¹⁷, V. Hedberg⁷⁹, L. Heelan⁷, S. Heim⁸⁸, B. Heinemann¹⁴, S. Heisterkamp³⁵, L. Helary⁴, M. Heldmann⁴⁸, M. Heller¹¹⁵, S. Hellman^{146a,146b}, C. Helsen¹¹, R.C.W. Henderson⁷¹, M. Henke^{58a}, A. Henrichs⁵⁴, A.M. Henriques Correia²⁹, S. Henrot-Versille¹¹⁵, F. Henry-Couannier⁸³, C. Hensel⁵⁴, T. Henß¹⁷⁴, C.M. Hernandez⁷, Y. Hernández Jiménez¹⁶⁷, R. Herrberg¹⁵, A.D. Hershenhorn¹⁵², G. Herten⁴⁸, R. Hertenberger⁹⁸, L. Hervas²⁹, N.P. Hessey¹⁰⁵, A. Hidvegi^{146a}, E. Higón-Rodríguez¹⁶⁷, D. Hill⁵, J.C. Hill²⁷, N. Hill⁵, K.H. Hiller⁴¹, S. Hillert²⁰, S.J. Hillier¹⁷, I. Hinchliffe¹⁴, E. Hines¹²⁰, M. Hirose¹¹⁶, F. Hirsch⁴², D. Hirschbuehl¹⁷⁴, J. Hobbs¹⁴⁸, N. Hod¹⁵³, M.C. Hodgkinson¹³⁹, P. Hodgson¹³⁹, A. Hoecker²⁹, M.R. Hoferkamp¹⁰³, J. Hoffman³⁹, D. Hoffmann⁸³, M. Hohlfeld⁸¹, M. Holder¹⁴¹, A. Holmes¹¹⁸, S.O. Holmgren^{146a}, T. Holy¹²⁷, J.L. Holzbauer⁸⁸, Y. Homma⁶⁷, L. Hooft van Huysduynen¹⁰⁸, T. Horazdovsky¹²⁷, C. Horn¹⁴³, S. Horner⁴⁸, K. Horton¹¹⁸, J.-Y. Hostachy⁵⁵, S. Hou¹⁵¹, M.A. Houlden⁷³, A. Houmada^{135a}, J. Howarth⁸², D.F. Howell¹¹⁸, I. Hristova⁴¹, J. Hrivnac¹¹⁵, I. Hruska¹²⁵, T. Hryn'ova⁴, P.J. Hsu¹⁷⁵, S.-C. Hsu¹⁴, G.S. Huang¹¹¹, Z. Hubacek¹²⁷, F. Hubaut⁸³, F. Huegging²⁰, T.B. Huffman¹¹⁸, E.W. Hughes³⁴, G. Hughes⁷¹, R.E. Hughes-Jones⁸², M. Huhtinen²⁹, P. Hurst⁵⁷, M. Hurwitz¹⁴, U. Husemann⁴¹, N. Huseynov^{65m}, J. Huston⁸⁸, J. Huth⁵⁷, G. Iacobucci^{102a}, G. Iakovidis⁹, M. Ibbotson⁸², I. Ibragimov¹⁴¹, R. Ichimiya⁶⁷, L. Icomonidou-Fayard¹¹⁵, J. Idarraga¹¹⁵, M. Idzik³⁷, P. Iengo^{102a,102b}, O. Igonkina¹⁰⁵, Y. Ikegami¹⁶⁶, M. Ikeno⁶⁶, Y. Ilchenko³⁹, D. Iliadis¹⁵⁴, D. Imbault⁷⁸, M. Imhaeuser¹⁷⁴, M. Imori¹⁵⁵, T. Ince²⁰, J. Inigo-Golfín²⁹, P. Ioannou⁸, M. Iodice^{134a}, G. Ionescu⁴, A. Irls Quiles¹⁶⁷, K. Ishii⁶⁶, A. Ishikawa⁶⁷, M. Ishino⁶⁶, R. Ishmukhametov³⁹, C. Issever¹¹⁸, S. Istin^{18a}, Y. Itoh¹⁰¹, A.V. Ivashin¹²⁸, W. Iwanski³⁸, H. Iwasaki⁶⁶, J.M. Izen⁴⁰, V. Izzo^{102a}, B. Jackson¹²⁰, J.N. Jackson⁷³, P. Jackson¹⁴³, M.R. Jaekel²⁹, V. Jain⁶¹, K. Jakobs⁴⁸, S. Jakobsen³⁵, J. Jakubek¹²⁷, D.K. Jana¹¹¹, E. Jankowski¹⁵⁸, E. Jansen⁷⁷, A. Jantsch⁹⁹, M. Janus²⁰, G. Jarlskog⁷⁹, L. Jeanty⁵⁷, K. Jelen³⁷, I. Jen-La Plante³⁰, P. Jenni²⁹, A. Jeremie⁴, P. Jež³⁵, S. Jézéquel⁴, M.K. Jha^{19a}, H. Ji¹⁷², W. Ji⁸¹, J. Jia¹⁴⁸, Y. Jiang^{32b}, M. Jimenez Belenguer⁴¹, G. Jin^{32b}, S. Jin^{32a}, O. Jinnouchi¹⁵⁷, M.D. Joergensen³⁵, D. Joffe³⁹, L.G. Johansen¹³, M. Johansen^{146a,146b}, K.E. Johansson^{146a}, P. Johansson¹³⁹, S. Johnert⁴¹, K.A. Johns⁶, K. Jon-And^{146a,146b}, G. Jones⁸², R.W.L. Jones⁷¹, T.W. Jones⁷⁷, T.J. Jones⁷³, O. Jonsson²⁹, C. Joram²⁹, P.M. Jorge^{124ab}, J. Joseph¹⁴, X. Ju¹³⁰, V. Juranek¹²⁵, P. Jussel⁶², V.V. Kabachenko¹²⁸, S. Kabana¹⁶, M. Kaci¹⁶⁷, A. Kaczmarek³⁸, P. Kadlecik³⁵, M. Kado¹¹⁵, H. Kagan¹⁰⁹, M. Kagan⁸⁷, S. Kaiser⁹⁹, E. Kajomovitz¹⁵², S. Kalinin¹⁷⁴, L.V. Kalinovskaya⁶⁵, S. Kama³⁹, N. Kanaya¹⁵⁵, M. Kaneda¹⁵⁵, T. Kanno¹⁵⁷, V.A. Kantserov⁹⁶, J. Kanzaki⁶⁶, B. Kaplan¹⁷⁵, A. Kapliy³⁰, J. Kaplon²⁹, D. Kar⁴³, M. Karagoz¹¹⁸, M. Karnevskiy⁴¹, K. Karr⁵, M. Kartvelishvili⁷¹, A.N. Karyukhin¹²⁸, L. Kashif¹⁷², A. Kasmi³⁹, R.D. Kass¹⁰⁹, A. Kastanas¹³, M. Kataoka⁴, Y. Kataoka¹⁵⁵, E. Katsoufis⁹, J. Katzy⁴¹, V. Kaushik⁶, K. Kawagoe⁶⁷, T. Kawamoto¹⁵⁵, G. Kawamura⁸¹, M.S. Kay¹⁰⁵, V.A. Kazanin¹⁰⁷, M.Y. Kazarinov⁶⁵, S.I. Kazi⁸⁶, J.R. Keates⁸², R. Keeler¹⁶⁹, R. Kehoe³⁹, M. Keil⁵⁴, G.D. Kekelidze⁶⁵, M. Kelly⁸², J. Kennedy⁹⁸, C.J. Kenney¹⁴³, M. Kenyon⁵³, O. Kepka¹²⁵, N. Kerschen²⁹, B.P. Kerševan⁷⁴, S. Kersten¹⁷⁴, K. Kessoku¹⁵⁵, C. Ketterer⁴⁸, M. Khakzad²⁸, F. Khalil-zada¹⁰, H. Khandanyan¹⁶⁵, A. Khanov¹¹², D. Kharchenko⁶⁵, A. Khodinov¹⁴⁸, A.G. Kholodenko¹²⁸, A. Khomich^{58a}, T.J. Khoo²⁷, G. Khorauli²⁰, A. Khoroshilov¹⁷⁴, N. Khovanskiy⁶⁵, V. Khovanskiy⁹⁵, E. Khranov⁶⁵, J. Khubua⁵¹, G. Kilvington⁷⁶, H. Kim⁷, M.S. Kim², P.C. Kim¹⁴³, S.H. Kim¹⁶⁰, N. Kimura¹⁷⁰, O. Kind¹⁵, B.T. King⁷³, M. King⁶⁷, R.S.B. King¹¹⁸, J. Kirk¹²⁹, G.P. Kirsch¹¹⁸, L.E. Kirsch²², A.E. Kiryunin⁹⁹, D. Kisielewska³⁷, T. Kittelmann¹²³, A.M. Kiver¹²⁸, H. Kiyamura⁶⁷, E. Kladiava^{144b}, J. Klaiber-Lodewigs⁴², M. Klein⁷³, U. Klein⁷³, K. Kleinknecht⁸¹, M. Klemetti⁸⁵, A. Klier¹⁷¹, A. Klimentov²⁴, R. Klingenberg⁴², E.B. Klinkby³⁵, T. Klioutchnikova²⁹, P.F. Klok¹⁰⁴, S. Klous¹⁰⁵, E.-E. Kluge^{58a}, T. Kluge⁷³, P. Kluit¹⁰⁵, S. Kluth⁹⁹, E. Kneringer⁶², J. Knobloch²⁹, E.B.F.G. Knoops⁸³, A. Knue⁵⁴, B.R. Ko⁴⁴, T. Kobayashi¹⁵⁵, M. Kobel⁴³, B. Koblitz²⁹, M. Kocian¹⁴³, A. Kocnar¹¹³, P. Kodys¹²⁶, K. Köneke²⁹, A.C. König¹⁰⁴, S. Koenig⁸¹, L. Köpcke⁸¹, F. Koetsveld¹⁰⁴, P. Koesvarko²⁰, T. Koffas²⁹, E. Koffman¹⁰⁵, F. Kohn⁵⁴, Z. Kohout¹²⁷, T. Kohriki⁶⁶, T. Koil¹⁴³, T. Kokott²⁰, G.M. Kolachev¹⁰⁷, H. Kolanoski¹⁵, V. Kolesnikov⁶⁵, I. Koleskou^{89a}, J. Koll⁸⁸, D. Kollar²⁹, M. Kollerfarth⁴⁸, S.D. Kolya⁸², A.A. Komar⁹⁴, J.R. Komaragiri¹⁴², T. Kondo⁶⁶, T. Kono⁴¹ⁿ, A.I. Kononov⁴⁸, R. Konoplich^{108o}, N. Konstantinidis⁷⁷, A. Kootz¹⁷⁴, S. Koperny³⁷, S.V. Kopikov¹²⁸, K. Korcyl⁸⁸, K. Kordas¹⁵⁴, V. Koreshev¹²⁸, A. Korn¹⁴, A. Korol¹⁰⁷, I. Korolkov¹¹, E.V. Korolkova¹³⁹, V.A. Korotkov¹²⁸, O. Kortner⁹⁹, S. Kortner⁹⁹, V.V. Kostyukhin²⁰, M.J. Kotamäki²⁹, S. Kotov⁹⁹, V.M. Kotov⁶⁵, A. Kotwal⁴⁴, C. Kourkoumelis⁸, V. Kouskoura¹⁵⁴, A. Koutsman¹⁰⁵, R. Kowalewski¹⁶⁹, T.Z. Kowalski³⁷, W. Kozanecki¹³⁶, A.S. Kozhin¹²⁸, V. Kral¹²⁷, V.A. Kramarenko⁹⁷, G. Kramberger⁷⁴, O. Krasel⁴², M.W. Krasny⁷⁸, A. Krasznahorkay¹⁰⁸, J. Kraus⁸⁸, A. Kreisel¹⁵³, F. Krejci¹²⁷, J. Kretzschmar⁷³, N. Krieger⁵⁴, P. Krieger¹⁵⁸, K. Kroeninger⁵⁴, H. Kroha⁹⁹, J. Kroll¹²⁰, J. Kroseberg²⁰, J. Krstic^{12a}, U. Kruchonak⁶⁵, H. Krüger²⁰, Z.V. Krumshcheyn⁶⁵, A. Kruth²⁰, T. Kubota¹⁵⁵, S. Kuehn⁴⁸, A. Kugel^{58c}, T. Kuhl¹⁷⁴, D. Kuhn⁶², V. Kukhtin⁶⁵, Y. Kulchitsky⁹⁰, S. Kuleshov^{31b}, C. Kummer⁹⁸, M. Kuna⁷⁸, N. Kundu¹¹⁸, J. Kunkle¹²⁰, A. Kupco¹²⁵, H. Kurashige⁶⁷, M. Kurata¹⁶⁰, Y.A. Kurochkin⁹⁰, V. Kus¹²⁵, W. Kuykendall³⁸, M. Kuze¹⁵⁷, P. Kuzhir⁹¹, O. Kvasnicka¹²⁵, J. Kvita²⁹, R. Kwee¹⁵, A. La Rosa²⁹, L. La Rotonda^{36a,36b}, L. Labarga⁸⁰, J. Labbe⁴, S. Lablak^{135a}, C. Lacasta¹⁶⁷, F. Lacava^{132a,132b}, H. Lacker¹⁵, D. Lacour⁷⁸, V.P.R. Lacuesta¹⁶⁷, E. Ladygin⁶⁵, R. Lafaye⁴, B. Laforge⁷⁸, T. Lagouri⁸⁰, S. Lai⁴⁸, E. Laisne⁵⁵, M. Lamanna²⁹, C.L. Lampen⁶, W. Lamp¹⁶, E. Lancon¹³⁶, U. Landgraf⁴⁸, M.P.J. Landon⁷⁵, H. Landsman¹⁵², J.L. Lane⁸², C. Lange⁴¹, A.J. Lankford¹⁶³, F. Lanni²⁴, K. Lantzsch²⁹, V.V. Lapin¹²⁸ⁱ, S. Laplace⁷⁸, C. Lapoire²⁰, J.F. Laporte¹³⁶, T. Lari^{89a}, A.V. Larionov¹²⁸, A. Larner¹¹⁸, C. Lasseur²⁹, M. Lassnig²⁹, W. Lau¹¹⁸, P. Laurelli⁴⁷, A. Lavorato¹¹⁸, W. Lavrijsen¹⁴, P. Laycock⁷³, A.B. Lazarev⁶⁵, A. Lazzaro^{89a,89b}, O. Le Dortz⁷⁸, E. Le Guirrec⁸³, C. Le Maner¹⁵⁸, E. Le Menedeu¹³⁶, A. Lebedev⁶⁴, C. Lebel⁹³, T. LeCompte⁵, F. Ledroit-Guillon⁵⁵, H. Lee¹⁰⁵, J.S.H. Lee¹⁵⁰, S.C. Lee¹⁵¹, L. Lee¹⁷⁵, M. Lefebvre¹⁶⁹, M. Legendre¹³⁶, A. Leger⁴⁹, B.C. LeGeyt¹²⁰, F. Legger⁹⁸, C. Leggett¹⁴, M. Lehmacher²⁰, G. Lehmann Miotto²⁹, X. Lei⁶, M.A.L. Leite^{23b}, R. Leitner¹²⁶, D. Lellouch¹⁷¹, J. Lellouch⁷⁸, M. Leltchouk³⁴, V. Lendermann^{58a}, K.J.C. Leney^{145b}, T. Lenz¹⁷⁴, G. Lenzen¹⁷⁴, B. Lenzi¹³⁶, K. Leonhardt⁴³, S. Leontsinis⁹, C. Leroy⁹³, J.-R. Lessard¹⁶⁹, J. Lesse^{146a}, C.G. Lester²⁷, A. Leung Fook Cheong¹⁷², J. Levêque⁴, D. Levin⁸⁷, L.J. Levinson¹⁷¹, M.S. Levitski¹²⁸, M. Lewandowska²¹, G.H. Lewis¹⁰⁸, A.M. Leyko²⁰, M. Leyton¹⁵, B. Li⁸³, H. Li¹⁷², S. Li^{32b}, X. Li⁸⁷, Z. Liang³⁹, Z. Liang^{118p}, B. Liberti^{133a}, P. Lichard²⁹, M. Lichtnecker⁹⁸, K. Lie¹⁶⁵, W. Liebig¹³, R. Lifshitz¹⁵², J.N. Lilley¹⁷, C. Limbach²⁰, A. Limosan⁸⁶, M. Limper⁶³, S.C. Lin^{151a}, F. Linde¹⁰⁵, J.T. Linnemann⁸⁸, E. Lipelce¹²⁰, L. Lipnicka¹³, T.M. Liss¹⁶⁵, D. Lissauer²⁴, A. Lister⁴⁹, A.M. Litke¹³⁷, C. Liu²⁸, D. Liu^{151r}, H. Liu⁸⁷, J.B. Liu⁸⁷, M. Liu^{32b}, S. Liu², Y. Liu^{32b}, M. Livan^{119a,119b}, S.S.A. Livermore¹¹⁸, A. Lleres⁵⁵, J. Llorente Merino⁸⁰, S.L. Lloyd⁷⁵, E. Lobodzinska⁴¹, P. Loch⁶, W.S. Lockman¹³⁷, S. Lockwitz¹⁷⁵, T. Loddenkoetter²⁰, F.K. Loebinger⁸², A. Loginov¹⁷⁵, C.W. Loh¹⁶⁸, T. Lohse¹⁵, K. Lohwasser⁴⁸, M. Lokajicek¹²⁵, J. Loken¹¹⁸, V.P. Lombardo⁴, R.E. Long⁷¹, L. Lopes^{124a,b}, D. Lopez Mateos^{34s}, M. Losada¹⁶², P. Loscutoff¹⁴, F. Lo Sterzo^{132a,132b}, M.J. Losty^{159a}, X. Lou⁴⁰, A. Lounis¹¹⁵, K.F. Loureiro¹⁶², J. Love²¹, P.A. Love⁷¹, A.J. Lowe^{143e}, F. Lu^{32a}, L. Lu³⁹, H.J. Lubatti¹³⁸, C. Luci^{132a,132b}, A. Lucotte⁵⁵, A. Ludwig⁴³, D. Ludwig⁴¹, I. Ludwig⁴⁸, J. Ludwig⁴⁸, F. Luehring⁶¹, G. Luijckx¹⁰⁵, D. Lumb⁴⁸, L. Luminari^{132a}, E. Lund¹¹⁷, B. Lund-Jensen¹⁴⁷, B. Lundberg⁷⁹, J. Lundberg^{146a,146b}, J. Lundquist³⁵, M. Lungwitz⁸¹, A. Lupi^{122a,122b}, G. Lutz⁹⁹, D. Lynn²⁴, J. Lys¹⁴, E. Lytken⁷⁹, H. Ma²⁴, L.L. Ma¹⁷², J.A. Macana Goia⁹³, G. Maccarrone⁴⁷, A. Macchiolo⁹⁹, B. Maček⁷⁴,

J. Machado Miguens^{124a}, D. Macina⁴⁹, R. Mackeprang³⁵, R.J. Madaras¹⁴, W.F. Mader⁴³, R. Maenner^{58c}, T. Maeno²⁴, P. Mättig¹⁷⁴, S. Mättig⁴¹, P.J. Magalhaes Martins^{124a,g}, L. Magnoni²⁹, E. Magradze⁵⁴, Y. Mahalalel¹⁵³, K. Mahboubi¹⁴⁸, G. Mahout¹⁷, C. Maiani^{132a,132b}, C. Maidantchik^{23a}, A. Maio^{124a,b}, S. Majewski²⁴, Y. Makida⁶⁶, N. Makovec¹¹⁵, P. Mal⁶, Pa. Malecki³⁸, P. Malecki³⁸, V.P. Maleev²¹, F. Malek⁵⁵, U. Mallik⁶³, D. Malon⁵, S. Maltezos⁹, V. Malyshev¹⁰⁷, S. Malyukov²⁹, R. Mameghani⁹⁸, J. Mamuzic^{12b}, A. Manabe⁶⁶, L. Mandelli^{89a}, I. Mandić⁷⁴, R. Mandrysch¹⁵, J. Maneira^{124a}, P.S. Mangedard⁸⁸, I.D. Manjavizde⁶⁵, A. Mann⁵⁴, P.M. Manning¹³⁷, A. Manousakis-Katsikakis⁸, B. Mansoulie³⁶, A. Manz⁹⁹, A. Mapelli²⁹, L. Mapelli²⁹, L. March⁸⁰, J.F. Marchand²⁹, F. Marchese^{133a,133b}, G. Marchiori⁷⁸, M. Marcisovsky¹²⁵, A. Marin^{21,2}, C.P. Marino⁶¹, F. Marroquin^{23a}, R. Marshall⁸², Z. Marshall^{34,5}, F.K. Martens¹⁵⁸, S. Marti-Garcia¹⁶⁷, A.J. Martin¹⁷⁵, B. Martin²⁹, B. Martin⁸⁸, F.F. Martin¹²⁰, J.P. Martin⁹³, Ph. Martin⁵⁵, T.A. Martin¹⁷, B. Martin dit Latour⁴⁹, M. Martinez¹¹, V. Martinez Outschoorn⁵⁷, A.C. Martyniuk⁸², M. Marx⁸², F. Marzano^{132a}, A. Marzin¹¹¹, L. Masetti⁸¹, T. Mashimo¹⁵⁵, R. Mashinistov⁹⁴, J. Masik⁸², A.L. Maslennikov¹⁰⁷, M. Maß⁴², I. Massa^{19a,19b}, G. Massaro¹⁰⁵, N. Massol⁴, A. Mastroberardino^{36a,36b}, T. Masubuchi¹⁵⁵, M. Mathes²⁰, P. Matricon¹¹⁵, H. Matsumoto¹¹⁵, H. Matsunaga¹¹⁵, T. Matsushita⁶⁷, C. Mattravers^{118,t}, J.M. Maignan²⁹, S.J. Maxfield⁷³, D.A. Maximov¹⁰⁷, E.N. May⁵, A. Mayne¹³⁹, R. Mazini¹¹⁵¹, M. Mazur²⁰, M. Mazzanti^{89a}, E. Mazzoni^{1122a,122b}, S.P. Mc Kee⁸⁷, A. McCarn¹⁶⁵, R.L. McCarthy¹⁴⁸, T.G. McCarthy²⁸, N.A. McCubbin¹²⁹, K.W. McFarlane⁵⁶, J.A. McFayden¹³⁹, H. McGlone⁵³, G. Mchedlidze⁵¹, R.A. McLaren²⁹, T. McLaughlin¹⁷, S.J. McMahon¹²⁹, R.A. McPherson^{169,i}, A. Meade⁸⁴, J. Mechnich¹⁰⁵, M. Mechtel¹⁷⁴, M. Medinnis⁴¹, R. Meera-Lebbai¹¹¹, T. Meguro¹¹⁶, R. Mehdiyev⁹³, S. Mehlhase³⁵, A. Mehta⁷³, K. Meier^{58a}, J. Meinhardt⁴⁸, B. Meirose⁷⁹, C. Melachrinou³⁰, B.R. Mellado Garcia¹⁷², L. Mendoza Navas¹⁶², Z. Meng^{151,r}, A. Mengarelli^{19a,19b}, S. Menke⁹⁹, C. Menot²⁹, E. Meoni¹¹, K.M. Mercurio⁵⁷, P. Mermod¹¹⁸, L. Merola^{102a,102b}, C. Meroni^{89a}, F.S. Merritt³⁰, A. Messina²⁹, J. Metcalfe¹⁰³, A.S. Mete⁶⁴, S. Meuser²⁰, C. Meyer⁸¹, J.-P. Meyer¹³⁶, J. Meyer¹⁷¹, J. Meyer⁵⁴, T.C. Meyer²⁹, W.T. Meyer⁶⁴, J. Miao^{32d}, S. Michal²⁹, L. Micu^{32d}, R.P. Middleton¹²⁹, P. Miele²⁹, S. Migas⁷³, L. Mijovic⁴¹, G. Mikenberg¹⁷¹, M. Mikestikova¹²⁵, B. Mikulec⁴⁹, M. Mikuž⁷⁴, D.W. Miller¹⁴³, R.J. Miller⁸⁸, W.J. Mills¹⁶⁸, C. Mills⁵⁷, A. Milov¹⁷¹, D.A. Milstead^{146a,146b}, D. Milstein¹⁷¹, A.A. Minaenko¹²⁸, M. Miñano¹⁶⁷, I.A. Minashvili⁶⁵, A.I. Mincer¹⁰⁸, B. Mindur³⁷, M. Mineev⁶⁵, Y. Ming¹³⁰, L.M. Mir¹¹, G. Mirabelli^{132a}, L. Miralles Verge¹¹, A. Misiejuk⁷⁶, J. Mitrevski¹³⁷, G.Y. Mitrofanov¹²⁸, V.A. Mitsou¹⁶⁷, S. Mitsui⁶⁶, P.S. Miyagawa⁸², K. Miyazaki⁶⁷, J.U. Mjörnmark⁷⁹, T. Moa^{146a,146b}, P. Mockett¹³⁸, S. Moed⁵⁷, V. Moeller²⁷, K. Mönig⁴¹, N. Möser²⁰, S. Mohapatra¹⁴⁸, B. Mohn¹³, W. Mohr⁴⁸, S. Mohrdieck-Möck⁹⁹, A.M. Moiseev^{128,2}, R. Moles-Valls¹⁶⁷, J. Molina-Perez²⁹, L. Moneta⁴⁹, J. Monk⁷⁷, E. Monnier⁸³, S. Montesano^{89a,89b}, F. Monticelli⁷⁰, S. Monzani^{19a,19b}, R.W. Moore², G.F. Moorhead⁸⁶, C. Mora Herrera⁴⁹, A. Moraes⁵³, A. Morais^{124a,b}, N. Morange³⁶, G. Morello^{36a,36b}, D. Moreno⁸¹, M. Moreno Llacer¹⁶⁷, P. Morettini^{50a}, M. Morii⁵⁷, J. Morin⁷⁵, Y. Morita⁶⁶, A.K. Morley²⁹, G. Mornacchi²⁹, M.-C. Morone⁴⁹, S.V. Morozov⁹⁶, J.D. Morris⁷⁵, H.G. Moser⁹⁹, M. Mosidze⁵¹, J. Moss¹⁰⁹, R. Mount¹⁴³, E. Mountricha⁹, S.V. Mouraviev⁹⁴, E.J.W. Moyses⁸⁴, M. Mudrinic^{12b}, F. Mueller^{58a}, J. Mueller¹²³, K. Mueller²⁰, T.A. Müller⁹⁸, D. Muenstermann²⁹, A. Muijs¹⁰⁵, A. Muir¹⁶⁸, Y. Munwes¹⁵³, K. Murakami⁶⁶, W.J. Murray¹²⁹, I. Müssche¹⁰⁵, E. Musto^{102a,102b}, A.G. Myagkov¹²⁸, M. Myska¹²⁵, J. Nadal¹¹, K. Nagai¹⁶⁰, K. Nagano⁶⁶, Y. Nagasaka⁶⁰, A.M. Nairz²⁹, Y. Nakahama¹¹⁵, K. Nakamura¹⁵⁵, I. Nakano¹¹⁰, G. Nanava²⁰, A. Napier¹⁶¹, M. Nash^{77,1}, N.R. Nation²¹, T. Nattermann²⁰, T. Naumann⁴¹, G. Navarro¹⁶², H.A. Neal⁸⁷, E. Nebot⁸⁰, P.Yu. Nechaeva⁹⁴, A. Negri^{119a,119b}, G. Negri²⁹, S. Nektarijevic⁴⁹, A. Nelson⁶⁴, S. Nelson¹⁴³, T.K. Nelson¹⁴³, S. Nemecek¹²⁵, P. Nemethy¹⁰⁸, A.A. Nepomuceno^{23a}, M. Nessi^{29,u}, S.Y. Nesterov¹²¹, M.S. Neubauer¹⁶⁵, A. Neusiedl⁸¹, R.M. Neves¹⁰⁸, P. Nevski²⁴, P.R. Newman¹⁷, R.B. Nickerson¹¹⁸, R. Nicolaidou¹³⁶, L. Nicolas¹³⁹, B. Nicquevert²⁹, F. Niedercorn¹¹⁵, J. Nielsen¹³⁷, T. Niinikoski²⁹, A. Nikiforov¹⁵, V. Nikolaenko¹²⁸, K. Nikolaev⁶⁵, I. Nikolic-Audit⁷⁸, K. Nikolopoulos²⁴, H. Nilsen⁴⁸, P. Nilsson⁷, Y. Ninomiya¹⁵⁵, A. Nisati^{132a}, T. Nishiyama⁶⁷, R. Nisius⁹⁹, L. Nodulman⁵, M. Nomachi¹¹⁶, I. Nomidis¹⁵⁴, H. Nomoto¹⁵⁵, M. Nordberg²⁹, B. Nordkvist^{146a,146b}, P.R. Norton¹²⁹, J. Novakova¹²⁶, M. Nozaki⁶⁶, M. Nožička⁴¹, L. Nozka¹¹³, I.M. Nugent^{159a}, A.-E. Nuncio-Quiroz²⁰, G. Nunes Hanninger²⁰, T. Nunnemann⁹⁸, E. Nurse⁷⁷, T. Nyman²⁹, B.J. O'Brien⁴⁵, S.W. O'Neale^{17,2}, D.C. O'Neil¹⁴², V. O'Shea⁵³, F.G. Oakham^{28,d}, H. Oberlack⁹⁹, J. Ocariz⁷⁸, A. Ochi⁶⁷, S. Oda¹⁵⁵, S. Odaka⁶⁶, J. Odier⁸³, H. Ogren⁶¹, A. Oh⁸², S.H. Oh⁴⁴, C.C. Ohm^{146a,146b}, T. Ohshima¹⁰¹, H. Ohshita¹⁴⁰, T.K. Ohshka¹⁶⁷, T. Ohsugi⁵⁹, S. Okada⁶⁷, H. Okawa¹⁶³, Y. Okumura¹⁰¹, T. Okuyama¹⁵⁵, M. Olcese^{50a}, A.G. Olchevski⁶⁵, M. Oliveira^{124a,g}, D. Oliveira Damazio²⁴, E. Oliver Garcia¹⁶⁷, D. Olivito¹²⁰, A. Olszewski³⁸, J. Olszowska³⁸, C. Omachi¹⁶⁷, A. Onofre^{124a,v}, P.U.E. Onyisi³⁰, C.J. Oram^{159a}, M.J. Oreglia³⁰, F. Orellana⁴⁹, Y. Oren¹⁵³, D. Orestano^{134a,134b}, I. Orlov¹⁰⁷, C. Oropeza Barrera⁵³, R.S. Orr¹⁵⁸, E.O. Ortega¹³⁰, B. Osculati^{50a,50b}, R. Osipov¹²⁰, C. Osuna¹¹, G. Otero y Garzon²⁶, J.P. Ottersbach¹⁰⁵, M. Ouchrif^{135d}, F. Ould-Saada¹¹⁷, A. Ouraou¹³⁶, Q. Ouyang^{32a}, M. Owen⁸², S. Owen¹³⁹, O.K. Øye¹³, V.E. Ozcan^{18a}, N. Ozturk⁷, A. Pacheco Pages¹¹, C. Padilla Aranda¹¹, E. Paganis¹³⁹, F. Paige²⁴, K. Pajchel¹¹⁷, S. Palestini²⁹, D. Pallin³³, A. Palma^{124a,b}, J.D. Palmer¹⁷, Y.B. Pan¹⁷², E. Panagiotopoulou⁹, B. Panes^{31a}, N. Panikashvili⁸⁷, S. Panitkin²⁴, D. Pantea^{25a}, M. Panuskova¹²⁵, V. Paolone¹²³, A. Paoloni^{133a,133b}, A. Papadellis^{146a}, Th.D. Papadopolou⁹, A. Paramonov⁵, W. Park^{24,w}, M.A. Parker²⁷, F. Parodi^{50a,50b}, J.A. Parsons³⁴, U. Parzefall⁴⁸, E. Pasqualucci^{132a}, A. Passeri^{134a}, F. Pastore^{134a,134b}, Fr. Pastore²⁹, G. Pásztor^{49,x}, S. Pataria¹⁷², N. Patel¹⁵⁰, J.R. Pater⁸², S. Patricelli^{102a,102b}, T. Paval²⁹, M. Pecsny^{144a}, M.I. Pedraza Morales¹⁷², S.V. Peleganchuk¹⁰⁷, H. Peng¹⁷², R. Pengo²⁹, A. Penson³⁴, J. Penwell⁶¹, M. Perantoni^{123a}, K. Perez^{34,5}, T. Perez Cauchati⁴¹, E. Perez Codina¹¹, M.T. Pérez García-Estañ¹⁶⁷, V. Perez Reale³⁴, I. Peric²⁰, L. Perini^{89a,89b}, H. Pernegger²⁹, R. Perrino^{72a}, P. Perrodo⁴, S. Persebe^{3a}, V.D. Peschkhonov⁶⁵, O. Peters¹⁰⁵, B.A. Petersen²⁹, F. Petersen²⁹, T.C. Petersen³⁵, E. Petit⁸³, A. Petridis¹⁵⁴, C. Petridou¹⁵⁴, E. Petrolo^{132a}, F. Petrucci^{134a,134b}, D. Petschull⁴¹, M. Petten¹⁴², R. Pezosa^{31b}, A. Phan⁸⁶, A.W. Phillips²⁷, P.W. Phillips¹²⁹, G. Piacquadio²⁹, E. Piccaro⁷⁵, M. Piccinini^{19a,19b}, A. Pickford⁵³, S.M. Piec⁴¹, R. Piegaia²⁶, J.E. Pilcher³⁰, A.D. Pilkington⁸², J. Pina^{124a,b}, M. Pinamonti^{164a,164c}, A. Pinder¹¹⁸, J.L. Pinfold², J. Ping^{32c}, B. Pinto^{124a,b}, O. Pirotte²⁹, C. Pizio^{89a,89b}, R. Placakyte⁴¹, M. Plamondon¹⁶⁹, W.G. Plano⁸², M.-A. Pleier²⁴, A.V. Pleskach¹²⁸, A. Poblaguev²⁴, S. Poddar^{58a}, F. Podlyski³³, L. Poggioli¹¹⁵, T. Poghosyan²⁰, M. Pohl⁴⁹, F. Polci⁵⁵, G. Polesello^{119a}, A. Policicchio¹³⁸, A. Polini^{19a}, J. Poll⁷⁵, V. Polychronakos²⁴, D.M. Pomaredé³⁶, D. Pomeroy²², K. Pommès²⁹, L. Pontecorvo^{132a}, B.G. Pope⁸⁸, G.A. Popenciu^{25a}, D.S. Popovic^{12a}, A. Poppleton²⁹, X. Portell Bueso⁴⁸, R. Porter¹⁶³, C. Posch²¹, G.E. Pospelov⁹⁹, S. Pospisil¹²⁷, I.N. Potrap⁹⁹, C.J. Potter¹⁴⁹, C.T. Potter¹¹⁴, G. Poulard²⁹, J. Poveda¹⁷², R. Prabhu⁷⁷, P. Pralavorio⁸³, S. Prasad⁵⁷, R. Pravahan⁷, S. Prell⁶⁴, K. Pretz¹¹⁶, L. Pribyl²⁹, D. Price⁶¹, L.E. Price⁵, M.J. Price²⁹, P.M. Prichard⁷³, D. Prieur¹²³, M. Primavera^{172a}, K. Prokofiev¹⁰⁸, F. Prokoshin^{31b}, S. Protopopescu²⁴, J. Proudfoot⁵⁵, X. Prudent⁴³, H. Przysiecki⁴, S. Psoroulas¹⁵, E. Ptacek¹¹⁴, J. Purdham⁸⁷, M. Purohit^{24,w}, P. Puzo¹⁵⁵, Y. Pylypchenko¹¹⁷, J. Qian⁸⁷, Z. Qian⁸³, Z. Qin⁴¹, A. Quadt⁵⁴, D.R. Quarrie¹⁴, W.B. Quayle¹⁷², F. Quinonez^{31a}, M. Raas¹⁰⁴, V. Radescu^{58b}, B. Radics²⁰, T. Rador^{18a}, F. Ragusa^{89a,89b}, G. Raha¹⁷⁷, A.M. Rahimi¹⁰⁹, D. Rahm²⁴, S. Rajagopalan²⁴, M. Rammensee⁴⁸, M. Rammes¹⁴¹, M. Ramstedt^{146a,146b}, K. Randrianarivony²⁸, P.N. Ratoff⁷¹, F. Rauscher⁹⁸, E. Rauter⁹⁹, M. Raymond²⁹, A.L. Read¹¹⁷, D.M. Rebuffi^{119a,119b}, A. Redelbach¹⁷³, G. Redlinger²⁴, R. Reece¹²⁰, K. Reeves⁴⁰, A. Reichold¹⁰⁵, E. Reinherz-Aronis¹⁵³, A. Reinsch¹¹⁴, I. Reisinger⁴², D. Reljic^{12a}, C. Rember²⁹, Z.L. Ren¹⁵¹, A. Renaud¹¹⁵, P. Renkel³⁹, B. Rensch³⁵, M. Rescigno^{132a}, S. Resconi^{89a}, B. Resende¹³⁶, P. Reznicek⁹⁸, R. Rezvani¹⁵⁸, A. Richards⁷⁷, R. Richter⁹⁹, E. Richter-Was^{38,y}, M. Ridet⁷⁸, S. Rieke⁸¹, M. Rijpstra¹⁰⁵, M. Rijssenbeek¹⁴⁸, A. Rimoldi^{119a,119b}, L. Rinaldi^{19a}, R.R. Rios³⁹, I. Riu¹¹, G. Rivoltella^{89a,89b}, F. Rizatdinova¹¹², E. Rizvi⁷⁵, S.H. Robertson⁸⁵ⁱ, A. Robichaud-Veronneau⁴⁹, D. Robinson²⁷, J.E.M. Robinson⁷⁷, M. Robinson¹¹⁴, A. Robson⁵³, J.G. Rocha de Lima¹⁰⁶, C. Roda^{122a,122b}, D. Roda Dos Santos²⁹, S. Rodier⁸⁰, D. Rodriguez¹⁶², Y. Rodriguez Garcia¹⁵, A. Roe⁵⁴, S. Roe²⁹, O. Røhne¹¹⁷, V.A. Rojo¹, S. Rolfi¹⁶¹, A. Romaniouk⁹⁶, V.M. Romanov⁶⁵, G. Romeo²⁶, D. Romero Maltrana^{31a}, L. Roos⁷⁸, E. Ros¹⁶⁷, S. Rosati^{132a,132b}, K. Rosbach⁴⁹, M. Rose⁷⁹, G.A. Rosenbaum¹⁵⁸, E.I. Rosenber⁶⁴, P.L. Rosendahl¹³, L. Rossette⁴⁹, V. Rossetti¹¹, E. Rossi^{102a,102b}, L.P. Rossi^{50a}, L. Rossi^{89a,89b}, M. Rotaru^{25a}, I. Roth¹⁷¹, J. Rothberg¹³⁸, D. Rousseau¹¹⁵, C.R. Royon¹³⁶, A. Rozanov⁸³, Y. Rozen¹⁵², X. Ruan¹¹⁵, I. Rubinsky⁴¹, B. Ruckert⁹⁸, N. Ruckstuhl¹⁰⁵, V.I. Rud⁹⁷, G. Rudolph⁶², F. Rühr⁶, F. Ruggieri^{134a,134b}, A. Ruiz-Martinez⁶⁴, E. Rulikowska-Zarebska³⁷, V. Rumiantsev^{91,2}, L. Rummyantsev⁶⁵, K. Runge⁴⁸, O. Runolfsson²⁰, Z. Rurikova⁴⁸, N.A. Rusakovich⁶⁵, D.R. Rust⁶¹, J.P. Rutherford⁶, C. Ruwiedel¹⁴, P. Ruzicka¹²⁵, Y.F. Ryabov¹²¹, V. Ryadovikov¹²⁸, P. Ryan⁸⁸, M. Rybar¹²⁶, G. Rybkin¹¹⁵, N.C. Ryder¹¹⁸, S. Rzaeva¹⁰, A.F. Saavedra¹⁵⁰, I. Sadeh¹⁵³, H.F.-W. Sadrozinski¹³⁷, R. Sadykov⁶⁵, F. Safai Tehrani^{132a,132b}, H. Sakamoto¹⁵⁵, G. Salamanna¹⁰⁵, A. Salamon^{133a}, M. Saleem¹¹¹, D. Salihagic⁹⁹, A. Salnikov¹⁴³, J. Salt¹⁶⁷, B.M. Salvachua Ferrando⁵, D. Salvatore^{36a,36b}, F. Salvatore¹⁴⁹, A. Salzburger²⁹, D. Sampsonidis¹⁵⁴, B.H. Samset¹¹⁷, H. Sandaker¹³, H.G. Sander⁸¹, M.P. Sanders⁹⁸, M. Sandhoff¹⁷⁴, P. Sandhu¹⁵⁸, T. Sandoval²⁷, R. Sandstrom¹⁰⁵, S. Sandvoss¹⁷⁴, D.P.C. Sankey¹²⁹,

A. Sansoni⁴⁷, C. Santamarina Rios⁸⁵, C. Santoni³³, R. Santonicio^{133a,133b}, H. Santos^{124a}, J.G. Saraiva^{124a,b}, T. Sarangi¹¹⁷², E. Sarkisyan-Grinbaum⁷, F. Sarri^{122a,122b}, G. Sartisohn¹⁷⁴, O. Sasaki⁶⁶, T. Sasaki⁶⁶, N. Sasao⁶⁸, I. Satsounkevitch⁹⁰, G. Sauvage⁴, J.B. Sauvan¹¹⁵, P. Savard^{158,d}, V. Savinov¹²³, D.O. Savu²⁹, P. Savva⁹, L. Sawyer^{24,k}, D.H. Saxon⁵³, L.P. Says³³, C. Sbarra^{19a,19b}, A. Sbrizzi^{19a,19b}, O. Scallion⁹³, D.A. Scannicchio¹⁶³, J. Schaarschmidt¹¹⁵, P. Schacht⁹⁹, U. Schäfer⁸¹, S. Schaepe²⁰, S. Schaezel^{58b}, A.C. Schaffer¹¹⁵, D. Schaille⁹⁸, R.D. Schamberger¹⁴⁸, A.G. Schamov¹⁰⁷, V. Scharf^{58a}, V.A. Schegelsky¹²¹, D. Scheirich⁸⁷, M.I. Scherzer¹⁴, C. Schiavi^{50a,50b}, J. Schieck⁹⁸, M. Schioppa^{36a,36b}, S. Schlenker²⁹, J.L. Schlereth⁵, E. Schmidt⁴⁸, M.P. Schmidt^{175,3}, K. Schmieden²⁰, C. Schmitt⁸¹, M. Schmitz²⁰, A. Schöning^{58b}, M. Schott²⁹, D. Schouten¹⁴², J. Schovancova¹²⁵, M. Schram⁸⁵, C. Schroeder⁸¹, N. Schroer^{58c}, S. Schuh²⁹, G. Schuler²⁹, J. Schultes¹⁷⁴, H.-C. Schultz-Coulon¹⁸, H. Schulz¹⁵, J.W. Schumacher²⁰, M. Schumacher⁴⁸, B.A. Schumm¹³⁷, Ph. Schune¹³⁶, C. Schwabenberger⁸², A. Schwartzman¹⁴³, Ph. Schwemling⁷⁸, R. Schwienerhorst⁸⁸, R. Schwierz⁴³, J. Schwindling¹³⁶, W.G. Scott¹²⁹, J. Searcy¹¹⁴, E. Sedyk¹²¹, E. Segura¹¹, S.C. Seidel¹⁰³, A. Seiden¹³⁷, F. Seifert⁴³, J.M. Seixas^{23a}, G. Sekhniaidze^{102a}, D.M. Seliverstov¹²¹, B. Sellend^{146a}, G. Sellers⁷³, M. Seman^{144b}, N. Semprini-Cesari^{19a,19b}, C. Serfon⁹⁸, L. Serin¹¹⁵, R. Seuster⁹⁹, H. Severini¹¹¹, M.E. Seviour⁸⁶, A. Sfyra²⁹, E. Shabalina⁵⁴, M. Shamim¹¹⁴, L.Y. Shan^{32a}, J.T. Shank²¹, Q.T. Shao⁸⁶, M. Shapiro¹⁴, P.B. Shatalov⁹⁵, L. Shaver⁶, C. Shaw⁵³, K. Shaw^{164a,164c}, D. Sherman¹⁷⁵, P. Sherwood⁷⁷, A. Shibata¹⁰⁸, S. Shimizu²⁹, M. Shimojima¹⁰⁰, T. Shin⁵⁶, A. Shmeleva⁹⁴, M.J. Shochet³⁰, D. Short¹¹⁸, M.A. Shupe⁶, P. Sicho¹²⁵, A. Sidoti^{132a,132b}, A. Siebel¹⁷⁴, F. Siegert⁴⁸, J. Siegrist¹⁴, D.J. Sijacki^{12a}, O. Silbert¹⁷¹, J. Silva^{124a,b}, Y. Silver¹⁵³, D. Silverstein¹⁴³, S.B. Silverstein^{146a}, V. Simak¹²⁷, O. Simard³⁶, Lj. Simic^{12a}, S. Simion¹¹⁵, B. Simmons⁷⁷, M. Simonyan³⁵, P. Sinervo¹⁵⁸, N.B. Sinev¹¹⁴, V. Sipica¹⁴¹, G. Siragusa⁸¹, A.N. Sisakyan⁶⁵, S.Yu. Sivoklov⁹⁷, J. Sjölin^{146a,146b}, T.B. Sjrnsen¹³, L.A. Skinnari¹⁴, K. Skovpen¹⁰⁷, P. Skubic¹¹¹, N. Skvorodnev²², M. Slater¹⁷, T. Slavicek¹²⁷, K. Sliwa⁶¹, T.J. Sloan⁷¹, J. Sloper²⁹, V. Smakhtin¹⁷¹, S.Yu. Smirnov⁹⁶, L.N. Smirnova⁹⁷, O. Smirnova⁷⁹, B.C. Smith⁵⁷, D. Smith¹⁴³, K.M. Smith⁵³, M. Smizanska⁷¹, K. Smolek¹²⁷, A.A. Snesarev⁹⁴, S.W. Snow⁸², J. Snow¹¹¹, J. Snuverink¹⁰⁵, S. Snyder²⁴, M. Soares^{124a}, R. Sobie^{169j}, J. Sodomka¹²⁷, A. Soffer¹⁵³, C.A. Solans¹⁶⁷, M. Solar¹²⁷, J. Solc¹²⁷, E. Soldatov⁹⁶, U. Soldevila¹⁶⁷, E. Solfaroli Camillocci^{132a,132b}, A.A. Solodkov¹²⁸, O.V. Solovyanov¹²⁸, J. Sondericker²⁴, N. Soni², V. Sopko¹²⁷, M. Sorb^{89a,89b}, M. Sosebee⁷, A. Soukharev¹⁰⁷, S. Spagnolo^{72a,72b}, F. Spanò³⁴, R. Spighi^{19a}, G. Spigo²⁹, F. Spila^{132a,132b}, E. Spiriti^{134a}, R. Spiwoaks²⁹, M. Spousta¹²⁶, T. Spreitzer¹⁵⁸, B. Spurlock⁷, R.D. St. Denis⁵³, T. Stahl¹⁴¹, J. Stahlman¹²⁰, R. Stamen^{58a}, E. Stanecka²⁹, R.W. Stanek⁵, C. Stanescu^{134a}, S. Stapnes¹¹⁷, E.A. Starchenko¹²⁸, J. Stark⁵⁵, P. Staroba¹²⁵, P. Starovoitov⁹¹, A. Stauder⁹⁸, P. Stavina^{144a}, G. Stavropoulos¹⁴, G. Steele⁵³, P. Steinbach⁴³, P. Steinberg²⁴, I. Stelk¹²⁷, B. Stelzer¹⁴², H.J. Stelzer⁴¹, O. Stelzer-Chilton^{159a}, H. Stenzel⁵², K. Stevenson⁷⁵, G.A. Stewart⁵³, J.A. Stillings²⁰, T. Stockmanns²⁰, M.C. Stockton²⁹, K. Stoerig⁴⁸, G. Stoica^{25a}, S. Stonjek⁹⁹, P. Strachota¹²⁶, A.R. Stradling⁷, A. Straessner⁴³, J. Strandberg³⁷, S. Strandberg^{146a,146b}, A. Strandlie¹¹⁷, M. Strang¹⁰⁹, E. Strauss¹⁴³, M. Strauss¹¹¹, P. Strizenc^{144b}, R. Ströhmer¹⁷³, D.M. Strom¹¹⁴, J.A. Strong^{76,3}, R. Stroynskii³⁹, J. Strube¹²⁹, B. Stugu¹³, I. Stumer^{24,3}, J. Stupak¹⁴⁸, P. Sturm¹⁷⁴, D.A. Soh^{151,p}, D. Su¹⁴³, H.S. Subramania², A. Succurro¹¹, Y. Sugaya¹¹⁶, T. Sugimoto¹⁰¹, C. Suhr¹⁰⁶, K. Suita⁶⁷, M. Suk¹²⁶, V.V. Sulin⁹⁴, S. Sultansorg^{3d}, T. Sumida²⁹, X. Sun⁵⁵, J.E. Sundermann⁴⁸, K. Suruliz^{164a,164b}, S. Sushkov¹¹, G. Susinno^{36a,36b}, M.R. Sutton¹³⁹, Y. Suzuki¹⁶⁶, M. Svatos¹²⁵, Yu.M. Sviridov¹²⁸, S. Swedish¹⁶⁸, I. Sykora^{144a}, D. Sykora¹²⁶, B. Szeeles²⁹, J. Sánchez¹⁶⁷, D. Tai¹⁰⁵, K. Tackmann⁴¹, A. Taffard¹⁶³, R. Tafirout^{159a}, A. Taga¹¹⁷, N. Taiblum¹⁵³, Y. Takahashi¹⁰¹, H. Takai²⁴, R. Takashima⁶⁹, H. Takeda⁶⁷, T. Takeshita¹⁴⁰, M. Talby⁸³, A. Talyshiev¹⁰⁷, M.C. Tamsett²⁴, J. Tanaka¹⁵⁵, R. Tanaka¹¹⁵, S. Tanaka¹³¹, S. Tanaka⁶⁶, Y. Tanaka¹⁰⁰, K. Tani⁶⁷, N. Tannoury⁸³, G.P. Tappern²⁹, S. Tapprogge⁸¹, D. Tardif¹⁵⁸, S. Tarem¹⁵², F. Tarrade²⁴, G.F. Tartarelli^{89a}, P. Tas¹²⁶, M. Tasevsky¹²⁵, E. Tassi^{36a,36b}, M. Tatarikhanov¹⁴, C. Taylor⁷⁷, F.E. Taylor⁹², G.N. Taylor⁸⁶, W. Taylor^{159b}, M. Teixeira Dias Castanheira⁷⁵, P. Teixeira-Dias⁷⁶, K.K. Temming⁴⁸, H. Ten Kate²⁹, P.K. Teng¹⁵¹, S. Terada⁶⁶, K. Terashi¹⁵⁵, J. Terron⁸⁰, M. Terwort^{41,n}, M. Testa⁴⁷, R.J. Teuscher^{158,i}, C.M. Tevlin⁸², J. Thadome¹⁷⁴, J. Therhaag²⁰, T. Theveneaux-Pelzer⁷⁸, M. Thioly¹⁷⁵, S. Thoma⁴⁸, J.P. Thomas¹⁷, E.N. Thompson⁸⁴, P.D. Thompson¹⁷, P.D. Thompson¹⁵⁸, A.S. Thompson⁵³, E. Thomson¹²⁰, M. Thomson²⁷, R.P. Thun⁸⁷, T. Tic¹²⁵, V.O. Tikhomirov⁹⁴, Y.A. Tikhonov¹⁰⁷, C.J.W.P. Timmermans¹⁰⁴, P. Tipton¹⁷⁵, F.J. Tique Aires Viegas²⁹, S. Tisserant⁸³, J. Tobias⁴⁸, B. Toczek³⁷, T. Todorov⁴, S. Todorova-Nova¹⁶¹, B. Toggerson¹⁶³, J. Tojo⁶⁶, S. Tokár^{144a}, K. Tokunaga⁶⁷, K. Tokushuku⁶⁶, K. Tollefson⁸⁸, M. Tomoto¹⁰¹, L.T. Tompkins¹⁴, K. Toms¹⁰³, G. Tong^{32a}, A. Tonoyan¹³, C. Topfel¹⁶, N.D. Topilin⁶⁵, I. Torchiani²⁹, E. Torrence¹¹⁴, E. Torró Pastor¹⁶⁷, J. Toth^{83,x}, F. Touchard⁸³, D.R. Tovey¹³⁹, T. Traynor⁷⁵, T. Trefzger¹⁷³, J. Treis²⁰, L. Tremblet²⁹, A. Tricoli²⁹, I.M. Trigger^{159a}, S. Trinczay-Duvoid⁷⁸, T.N. Trinh⁷⁸, M.F. Tripiana⁷⁰, N. Triplett⁶⁴, W. Trischuk⁵⁸, A. Trivedi^{24,w}, B. Trocme⁵⁵, C. Troncon^{89a}, M. Trotter-McDonald¹⁴², A. Trzupek³⁸, C. Tsarouchas²⁹, J.C.-L. Tseng¹¹⁸, M. Tsiakiris¹⁰⁵, P.V. Tsiarshka⁹⁰, D. Tsiou⁴, G. Tsipolitis⁹, V. Tsiskaridze⁴⁸, E.G. Tskhadadze⁵¹, I.I. Tsukerman⁹⁵, V. Tsulaia¹²³, J.-W. Tsung²⁰, S. Tsuno⁶⁶, D. Tsybychev¹⁴⁸, A. Tua¹³⁹, J.M. Tuggle³⁰, M. Turala³⁸, D. Turecek¹²⁷, I. Turk Cakir^{3e}, E. Turlay¹⁰⁵, R. Turra^{89a,89b}, P.M. Tuts³⁴, A. Tykhonov⁷⁴, M. Tylmad^{146a,146b}, M. Tyndel¹²⁹, H. Tyrvaiven²⁹, G. Tzanakos⁸, K. Uchida²⁰, I. Ueda¹⁵⁵, R. Ueno²⁸, M. Ugland¹³, M. Uhlenbrock²⁰, M. Uhrmacher⁵⁴, F. Ukegawa¹⁶⁰, G. Unal²⁹, D.G. Underwood⁵, A. Undrus²⁴, G. Unel¹⁶³, Y. Unno⁶⁶, D. Urbaniec³⁴, E. Urkovsky¹⁵³, P. Urrejola^{31a}, G. Usai⁷, M. Uslenghi^{119a,119b}, L. Vacavant⁸³, V. Vacek¹²⁷, B. Vachon⁸⁵, S. Vahsen¹⁴, C. Valderanis⁹⁹, J. Valenta¹²⁵, P. Valente^{132a}, S. Valentini^{19a,19b}, S. Valkar¹²⁶, E. Valladolid Gallego¹⁶⁷, S. Vallecorsa¹⁵², J.A. Valls Ferrer¹⁶⁷, H. van der Graaf¹⁰⁵, E. van der Kraaij¹⁰⁵, R. Van Der Leeuw¹⁰⁵, E. van der Poel¹⁰⁵, D. van der Ster²⁹, B. Van Eijk¹⁰⁵, N. van Eldik⁸⁴, P. van Gemmeren⁵, Z. van Kesteren¹⁰⁵, I. van Vulpen¹⁰⁵, W. Vandell²⁹, G. Vandoni²⁹, A. Vaniachine⁵, P. Vankov⁴¹, F. Vannucci⁷⁸, F. Varela Rodriguez²⁹, R. Vari^{132a}, E.W. Varnes⁶, D. Varouchas¹⁴, A. Vartapetian⁷, K.E. Varvell¹⁵⁰, V.I. Vassilakopoulos⁵⁶, F. Vazeille³³, G. Vegni^{89a,89b}, J.J. Veillet¹¹⁵, C. Vellidis⁸, F. Veloso^{124a}, R. Veness²⁹, S. Veneziano^{132a}, A. Ventura^{72a,72b}, D. Ventura¹³⁸, M. Venturi¹⁶, V. Vercesi^{119a}, M. Verducci¹³⁸, W. Verkerke¹⁰⁵, J.C. Vermeulen¹⁰⁵, A. Vest⁴³, M.C. Vetterli^{142,d}, I. Vichou¹⁶⁵, T. Vickey^{145b,z}, G.H.A. Viehhauser¹¹⁸, S. Viel¹⁶⁸, M. Villa^{19a,19b}, M. Villaplana Perez¹⁶⁷, E. Vilucchi⁴⁷, M.G. Vinciter²⁸, E. Vinek²⁹, V.B. Vinogradov⁶⁵, M. Virchaux^{136,3}, S. Viret³³, J. Virzi¹⁴, A. Vitale^{19a,19b}, O. Vitells¹⁷¹, M. Viti⁴¹, I. Vivarelli⁴⁸, F. Vives Vaque¹¹, S. Vlachos⁹, M. Vlasak¹²⁷, N. Vlasov²⁰, A. Vogel²⁰, P. Vokac¹²⁷, G. Volpi⁴⁷, M. Volpi¹¹, G. Volpini^{89a}, H. von der Schmitt⁹⁹, J. von Loeben⁹⁹, H. von Radziewski⁴⁸, E. von Toerne²⁰, V. Vorobel¹²⁶, A.P. Vorobiev¹²⁸, V. Vorwerk¹¹, M. Vos¹⁶⁷, R. Voss²⁹, T.T. Voss¹⁷⁴, J.H. Vosseveld⁷³, A.S. Vovenko¹²⁸, N. Vranjes^{12a}, M. Vranjes Milosavljevic^{12a}, V. Vrba¹²⁵, M. Vreeswijk¹⁰⁵, T. Vu Anh⁸¹, R. Vuillermet²⁹, I. Vukotic¹¹⁵, W. Wagner¹⁷⁴, P. Wagner¹²⁰, H. Wahlen¹⁷⁴, J. Wakabayashi¹⁰¹, J. Walbersloh⁴², S. Walch⁸⁷, J. Walder⁷¹, R. Walker⁹⁸, W. Walkowiak¹⁴¹, R. Wall¹⁷⁵, P. Waller⁷³, C. Wang⁴⁴, H. Wang¹⁷², H. Wang^{32b}, J. Wang¹⁵¹, J. Wang^{32d}, J.C. Wang¹³⁸, R. Wang¹⁰³, S.M. Wang¹⁵¹, A. Warburton⁸⁵, C.P. Ward²⁷, M. Warsinsky⁴⁸, P.M. Watkins¹⁷, A.T. Watson¹⁷, M.F. Watson¹⁷, G. Watts¹³⁸, S. Watts⁸², A.T. Waugh¹⁵⁰, B.M. Waugh⁷⁷, J. Weber⁴², M. Weber²⁹, M.S. Weber¹⁶, P. Weber⁵⁴, A.R. Weidberg¹¹⁸, P. Weigell⁹⁹, J. Weingarten⁵⁴, C. Weiser⁴⁸, H. Wellenstein²², P.S. Wells²⁹, M. Wen⁴⁷, T. Wenaus²⁴, S. Wendler¹²³, Z. Weng^{151,p}, T. Wengler²⁹, S. Wenig²⁹, N. Wermes²⁰, M. Werner⁴⁸, P. Werner²⁹, M. Werth¹⁶³, M. Wessels^{58a}, C. Weydert⁵⁵, K. Whalen²⁸, S.J. Wheeler-Ellis¹⁶³, S.P. Whitaker²¹, A. White⁷, M.J. White⁸⁶, S. White²⁴, S.R. Whitehead¹¹⁸, D. Whiteson¹⁶³, D. Whittington⁶¹, F. Wicke¹¹⁵, D. Wicke¹⁷⁴, F.J. Wickens¹²⁹, W. Wiedenmann¹⁷², M. Wieler¹²⁹, P. Wienemann²⁰, C. Wigglesworth⁷³, L.A.M. Wiik⁴⁸, P.A. Wijeratne⁷⁷, A. Wildauer¹⁶⁷, M.A. Wildt^{41,n}, I. Wilhelm¹²⁶, H.G. Wilkens²⁹, J.Z. Will⁹⁸, E. Williams³⁴, H.H. Williams¹²⁰, W. Willis³⁴, S. Willocq⁸⁴, J.A. Wilson¹⁷, M.G. Wilson¹⁴³, A. Wilson⁸⁷, I. Wingerter-Seez⁴, S. Winkelmann⁴⁸, F. Winklmeier²⁹, M. Wittgen¹⁴³, M.W. Wolter³⁸, H. Wolters^{124a,g}, G. Wooden¹¹⁸, B.K. Wosiek³⁸, J. Wotschack²⁹, M.J. Woudstra⁸⁴, K. Wraight⁵³, C. Wright⁵³, B. Wrona⁷³, S.L. Wu¹⁷², X. Wu⁴⁹, Y. Wu^{32b}, E. Wulf³⁴, R. Wunstorff⁴², B.M. Wynne⁴⁵, L. Xaplanteris⁹, S. Xella³⁵, S. Xie⁴⁸, Y. Xie^{32a}, C. Xu^{32b}, D. Xu¹³⁹, G. Xu^{32a}, B. Yabsley⁶⁰, M. Yamada⁶⁶, A. Yamamoto⁶⁶, K. Yamamoto⁶⁴, S. Yamamoto¹⁵⁵, T. Yamamura¹⁵⁵, J. Yamaoka⁴⁴, T. Yamazaki¹⁵⁵, Y. Yamazaki¹⁶⁷, Z. Yan²¹, H. Yang⁸⁷, U.K. Yang⁸², Y. Yang⁶¹, Y. Yang^{32a}, Z. Yang^{146a,146b}, S. Yanush⁹¹, W.-M. Yao¹⁴, Y. Yao¹⁴, Y. Yasu⁶⁶, G.V. Ybeys Smith¹³⁰, J. Ye³⁹, S. Ye²⁴, M. Yilmaz^{3c}, R. Yoosofmiya¹²³, K. Yorita¹⁷⁰, R. Yoshida⁵, C. Young¹⁴³, S. Youssef²¹, D. Yu²⁴, J. Yu⁷, J. Yu^{32c,aa}, L. Yuan^{32a,ab}, A. Yurkewicz¹⁴⁸, V.G. Zaets¹²⁸, R. Zaidan⁶³, A.M. Zaitsev¹²⁸, Z. Zajacova²⁹, Yo.K. Zalite¹²¹, L. Zanello^{132a,132b}, P. Zarzhitsky³⁹, A. Zaytsev¹⁰⁷, C. Zeitnitz¹⁷⁴, M. Zeller¹⁷⁵, P.F. Zema²⁹, A. Zemla³⁸, C. Zender²⁰, A.V. Zenin¹²⁸, O. Zenin¹²⁸, T. Ženiš^{144a}, Z. Zenonos^{122a,122b}, S. Zenz¹⁴, D. Zerwas¹¹⁵, G. Zevi della Porta⁵⁷, Z. Zhan^{32d}, D. Zhang^{32b}, H. Zhang⁸⁸, J. Zhang⁵, X. Zhang^{32d}, Z. Zhang¹¹⁵, L. Zhao¹⁰⁸, T. Zhao¹³⁸, Z. Zhao^{32b}, A. Zhemchugov⁶⁵, S. Zheng^{32a}, J. Zhong^{151,ac}, B. Zhou⁸⁷, N. Zhou¹⁶³, Y. Zhou¹⁵¹, C.G. Zhu^{32d}, H. Zhu⁴¹, Y. Zhu¹⁷², X. Zhuang⁹⁸, V. Zhuravlov⁹⁹, D. Zieminska⁶¹, R. Zimmermann²⁰, S. Zimmermann²⁰, S. Zimmermann⁴⁸, M. Ziolkowski¹⁴¹, R. Zitoun⁴, L. Živković³⁴, V.V. Zmouchko^{128,3}, G. Zobernig¹⁷², A. Zoccoli^{19a,19b}, Y. Zolnierowski⁴, A. Zsenei²⁹, M. zur Nedden¹⁵, V. Zutshi¹⁰⁶, L. Zwalinski²⁹.

- ¹University at Albany, Albany, New York, USA.
- ²Department of Physics, University of Alberta, Edmonton, Alberta, Canada.
- ^{3(a)}Department of Physics, Ankara University, Ankara, Turkey; ^(b)Department of Physics, Dumlupinar University, Kutahya, Turkey; ^(c)Department of Physics, Gazi University, Ankara, Turkey; ^(d)Division of Physics, TOBB University of Economics and Technology, Ankara, Turkey; ^(e)Turkish Atomic Energy Authority, Ankara, Turkey.
- ⁴LAPP, CNRS/IN2P3 and Université de Savoie, Annecy-le-Vieux, France.
- ⁵High Energy Physics Division, Argonne National Laboratory, Argonne, Illinois, USA.
- ⁶Department of Physics, University of Arizona, Tucson, Arizona, USA.
- ⁷Department of Physics, The University of Texas at Arlington, Arlington, Texas, USA.
- ⁸Physics Department, University of Athens, Athens, Greece.
- ⁹Physics Department, National Technical University of Athens, Zografou, Greece.
- ¹⁰Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan.
- ¹¹Institut de Física d'Altes Energies and Universitat Autònoma de Barcelona and ICREA, Barcelona, Spain.
- ^{12(a)}Institute of Physics, University of Belgrade, Belgrade; ^(b)Vinca Institute of Nuclear Sciences, Belgrade, Serbia.
- ¹³Department for Physics and Technology, University of Bergen, Bergen, Norway.
- ¹⁴Physics Division, Lawrence Berkeley National Laboratory and University of California, Berkeley, California, USA.
- ¹⁵Department of Physics, Humboldt University, Berlin, Germany.
- ¹⁶Albert Einstein Center for Fundamental Physics and Laboratory for High Energy Physics, University of Bern, Bern, Switzerland.
- ¹⁷School of Physics and Astronomy, University of Birmingham, Birmingham, UK.
- ^{18(a)}Department of Physics, Bogazici University, Istanbul; ^(b)Division of Physics, Dogus University, Istanbul, Turkey; ^(c)Department of Physics Engineering, Gaziantep University, Gaziantep, Turkey; ^(d)Department of Physics, Istanbul Technical University, Istanbul, Turkey.
- ^{19(a)}INFN Sezione di Bologna, Bologna, Italy; ^(b)Dipartimento di Fisica, Università di Bologna, Bologna, Italy.
- ²⁰Physikalisches Institut, University of Bonn, Bonn, Germany.
- ²¹Department of Physics, Boston University, Boston, Massachusetts, USA.
- ²²Department of Physics, Brandeis University, Waltham, Massachusetts, USA.
- ^{23(a)}Universidade Federal do Rio De Janeiro COPPE/EE/IF, Rio de Janeiro, Brazil; ^(b)Instituto de Física, Universidade de Sao Paulo, Sao Paulo, Brazil.
- ²⁴Physics Department, Brookhaven National Laboratory, Upton, New York, USA.
- ^{25(a)}National Institute of Physics and Nuclear Engineering, Bucharest, Romania; ^(b)University Politehnica Bucharest, Bucharest, Romania; ^(c)West University in Timisoara, Timisoara, Romania.
- ²⁶Departamento de Física, Universidad de Buenos Aires, Buenos Aires, Argentina.
- ²⁷Cavendish Laboratory, University of Cambridge, Cambridge, UK.
- ²⁸Department of Physics, Carleton University, Ottawa, Ontario, Canada.
- ²⁹CERN, Geneva, Switzerland.
- ³⁰Enrico Fermi Institute, University of Chicago, Chicago, Illinois, USA.
- ^{31(a)}Departamento de Física, Pontificia Universidad Católica de Chile, Santiago, Chile; ^(b)Departamento de Física, Universidad Técnica Federico Santa María, Valparaíso, Chile.
- ^{32(a)}Institute of High Energy Physics, Chinese Academy of Sciences, Beijing, China; ^(b)Department of Modern Physics, University of Science and Technology of China, Anhui, China; ^(c)Department of Physics, Nanjing University, Jiangsu, China; ^(d)High Energy Physics Group, Shandong University, Shandong, China.
- ³³Laboratoire de Physique Corpusculaire, Clermont Université and Université Blaise Pascal and CNRS/IN2P3, Aubiere Cedex, France.
- ³⁴Nevis Laboratory, Columbia University, Irvington, New York, USA.
- ³⁵Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark.
- ^{36(a)}INFN Gruppo Collegato di Cosenza, Arcavata di Rende, Italy; ^(b)Dipartimento di Fisica, Università della Calabria, Arcavata di Rende, Italy.
- ³⁷Faculty of Physics and Applied Computer Science, AGH-University of Science and Technology, Krakow, Poland.
- ³⁸The Henryk Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences, Krakow, Poland.
- ³⁹Physics Department, Southern Methodist University, Dallas, Texas, USA.
- ⁴⁰Physics Department, University of Texas at Dallas, Richardson, Texas, USA.
- ⁴¹DESY, Hamburg and Zeuthen, Germany.
- ⁴²Institut für Experimentelle Physik IV, Technische Universität Dortmund, Dortmund, Germany.
- ⁴³Institut für Kern- und Teilchenphysik, Technical University Dresden, Dresden, Germany.
- ⁴⁴Department of Physics, Duke University, Durham, North Carolina, USA.
- ⁴⁵SUPA—School of Physics and Astronomy, University of Edinburgh, Edinburgh, UK.
- ⁴⁶Fachhochschule Wiener Neustadt, Wiener Neustadt, Austria.
- ⁴⁷INFN Laboratori Nazionali di Frascati, Frascati, Italy.
- ⁴⁸Fakultät für Mathematik und Physik, Albert-Ludwigs-Universität, Freiburg i.Br., Germany.
- ⁴⁹Section de Physique, Université de Genève, Geneva, Switzerland.
- ^{50(a)}INFN Sezione di Genova, Genova, Italy; ^(b)Dipartimento di Fisica, Università di Genova, Genova, Italy.
- ⁵¹Institute of Physics and HEP Institute, Georgian Academy of Sciences and Tbilisi State University, Tbilisi, Georgia.
- ⁵²II Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen, Germany.
- ⁵³SUPA—School of Physics and Astronomy, University of Glasgow, Glasgow, UK.
- ⁵⁴II Physikalisches Institut, Georg-August-Universität, Göttingen, Germany.
- ⁵⁵Laboratoire de Physique Subatomique et de Cosmologie, Université Joseph Fourier and CNRS/IN2P3 and Institut National Polytechnique de Grenoble, Grenoble, France.
- ⁵⁶Department of Physics, Hampton University, Hampton, Virginia, USA.
- ⁵⁷Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge, Massachusetts, USA.
- ^{58(a)}Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany; ^(b)Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany; ^(c)ZITI Institut für technische Informatik, Ruprecht-Karls-Universität Heidelberg, Mannheim, Germany.

- ⁵⁹Faculty of Science, Hiroshima University, Hiroshima, Japan.
- ⁶⁰Faculty of Applied Information Science, Hiroshima Institute of Technology, Hiroshima, Japan.
- ⁶¹Department of Physics, Indiana University, Bloomington, Indiana, USA.
- ⁶²Institut für Astro- und Teilchenphysik, Leopold-Franzens-Universität, Innsbruck, Austria.
- ⁶³University of Iowa, Iowa City, Iowa, USA.
- ⁶⁴Department of Physics and Astronomy, Iowa State University, Ames, Iowa, USA.
- ⁶⁵Joint Institute for Nuclear Research, JINR Dubna, Dubna, Russia.
- ⁶⁶KEK, High Energy Accelerator Research Organization, Tsukuba, Japan.
- ⁶⁷Graduate School of Science, Kobe University, Kobe, Japan.
- ⁶⁸Faculty of Science, Kyoto University, Kyoto, Japan.
- ⁶⁹Kyoto University of Education, Kyoto, Japan.
- ⁷⁰Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata, Argentina.
- ⁷¹Physics Department, Lancaster University, Lancaster, UK.
- ^{72(a)}INFN Sezione di Lecce, Lecce, Italy; ^(b)Dipartimento di Fisica, Università del Salento, Lecce, Italy.
- ⁷³Oliver Lodge Laboratory, University of Liverpool, Liverpool, UK.
- ⁷⁴Department of Physics, Jožef Stefan Institute and University of Ljubljana, Ljubljana, Slovenia.
- ⁷⁵Department of Physics, Queen Mary University of London, London, UK.
- ⁷⁶Department of Physics, Royal Holloway University of London, Surrey, UK.
- ⁷⁷Department of Physics and Astronomy, University College London, London, UK.
- ⁷⁸Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France.
- ⁷⁹Fysiska institutionen, Lunds universitet, Lund, Sweden.
- ⁸⁰Departamento de Física Teórica C-15, Universidad Autónoma de Madrid, Madrid, Spain.
- ⁸¹Institut für Physik, Universität Mainz, Mainz, Germany.
- ⁸²School of Physics and Astronomy, University of Manchester, Manchester, UK.
- ⁸³CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France.
- ⁸⁴Department of Physics, University of Massachusetts, Amherst, Massachusetts, USA.
- ⁸⁵Department of Physics, McGill University, Montreal, Québec, Canada.
- ⁸⁶School of Physics, University of Melbourne, Victoria, Australia.
- ⁸⁷Department of Physics, The University of Michigan, Ann Arbor, Michigan, USA.
- ⁸⁸Department of Physics and Astronomy, Michigan State University, East Lansing, Michigan, USA.
- ^{89(a)}INFN Sezione di Milano, Milano, Italy; ^(b)Dipartimento di Fisica, Università di Milano, Milano, Italy.
- ⁹⁰B.I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk, Republic of Belarus.
- ⁹¹National Scientific and Educational Centre for Particle and High Energy Physics, Minsk, Republic of Belarus.
- ⁹²Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA.
- ⁹³Group of Particle Physics, University of Montreal, Montreal, Québec, Canada.
- ⁹⁴P.N. Lebedev Institute of Physics, Academy of Sciences, Moscow, Russia.
- ⁹⁵Institute for Theoretical and Experimental Physics (ITEP), Moscow, Russia.
- ⁹⁶Moscow Engineering and Physics Institute (MEPhI), Moscow, Russia.
- ⁹⁷Skobel'syn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia.
- ⁹⁸Fakultät für Physik, Ludwig-Maximilians-Universität München, München, Germany.
- ⁹⁹Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), München, Germany.
- ¹⁰⁰Nagasaki Institute of Applied Science, Nagasaki, Japan.
- ¹⁰¹Graduate School of Science, Nagoya University, Nagoya, Japan.
- ^{102(a)}INFN Sezione di Napoli; ^(b)Dipartimento di Scienze Fisiche, Università di Napoli, Napoli, Italy.
- ¹⁰³Department of Physics and Astronomy, University of New Mexico, Albuquerque, NM, USA.
- ¹⁰⁴Institute for Mathematics, Astrophysics and Particle Physics, Radboud University Nijmegen/Nikhef, Nijmegen, Netherlands.
- ¹⁰⁵Nikhef National Institute for Subatomic Physics and University of Amsterdam, Amsterdam, Netherlands.
- ¹⁰⁶Department of Physics, Northern Illinois University, DeKalb, Illinois, USA.
- ¹⁰⁷Budker Institute of Nuclear Physics (BINP), Novosibirsk, Russia.
- ¹⁰⁸Department of Physics, New York University, New York, New York, USA.
- ¹⁰⁹Ohio State University, Columbus, Ohio, USA.
- ¹¹⁰Faculty of Science, Okayama University, Okayama, Japan.
- ¹¹¹Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman, Oklahoma, USA.
- ¹¹²Department of Physics, Oklahoma State University, Stillwater, Oklahoma, USA.
- ¹¹³Palacký University, RCPTM, Olomouc, Czech Republic.
- ¹¹⁴Center for High Energy Physics, University of Oregon, Eugene, Oregon, USA.
- ¹¹⁵LAL, Univ. Paris-Sud and CNRS/IN2P3, Orsay, France.
- ¹¹⁶Graduate School of Science, Osaka University, Osaka, Japan.
- ¹¹⁷Department of Physics, University of Oslo, Oslo, Norway.
- ¹¹⁸Department of Physics, Oxford University, Oxford, UK.
- ^{119(a)}INFN Sezione di Pavia, Pavia, Italy; ^(b)Dipartimento di Fisica Nucleare e Teorica, Università di Pavia, Pavia, Italy.
- ¹²⁰Department of Physics, University of Pennsylvania, Philadelphia, Pennsylvania, USA.
- ¹²¹Petersburg Nuclear Physics Institute, Gatchina, Russia.
- ^{122(a)}INFN Sezione di Pisa, Pisa, Italy; ^(b)Dipartimento di Fisica E. Fermi, Università di Pisa, Pisa, Italy.
- ¹²³Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh, Pennsylvania, USA.

- ^{124(a)}Laboratorio de Instrumentacao e Fisica Experimental de Particulas - LIP, Lisboa, Portugal; ^(b)Departamento de Fisica Teorica y del Cosmos and CAFPE, Universidad de Granada, Granada, Spain.
- ¹²⁵Institute of Physics, Academy of Sciences of the Czech Republic, Praha, Czech Republic.
- ¹²⁶Faculty of Mathematics and Physics, Charles University in Prague, Praha, Czech Republic.
- ¹²⁷Czech Technical University in Prague, Praha, Czech Republic.
- ¹²⁸State Research Center Institute for High Energy Physics, Protvino, Russia.
- ¹²⁹Particle Physics Department, Rutherford Appleton Laboratory, Didcot, UK.
- ¹³⁰Physics Department, University of Regina, Regina, Saskatchewan, Canada.
- ¹³¹Ritsumeikan University, Kusatsu, Shiga, Japan.
- ^{132(a)}INFN Sezione di Roma I, Roma, Italy; ^(b)Dipartimento di Fisica, Università La Sapienza, Roma, Italy.
- ^{133(a)}INFN Sezione di Roma Tor Vergata, Roma, Italy; ^(b)Dipartimento di Fisica, Università di Roma Tor Vergata, Roma, Italy.
- ^{134(a)}INFN Sezione di Roma Tre, Roma, Italy; ^(b)Dipartimento di Fisica, Università Roma Tre, Roma, Italy.
- ^{135(a)}Faculté des Sciences Ain Chock, Réseau Universitaire de Physique des Hautes Energies - Université Hassan II, Casablanca, Morocco; ^(b)Centre National de l'Énergie des Sciences Techniques Nucleaires, Rabat, Morocco; ^(c)Université Cadi Ayyad, Faculté des sciences Semlalia Département de Physique, B.P. 2390 Marrakech 40000, Morocco; ^(d)Faculté des Sciences, Université Mohamed Premier and LPTPM, Oujda, Morocco; ^(e)Faculté des Sciences, Université Mohammed V, Rabat, Morocco.
- ¹³⁶DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat a l'Énergie Atomique), Gif-sur-Yvette, France.
- ¹³⁷Santa Cruz Institute for Particle Physics, University of California Santa Cruz, Santa Cruz, California, USA.
- ¹³⁸Department of Physics, University of Washington, Seattle, Washington, USA.
- ¹³⁹Department of Physics and Astronomy, University of Sheffield, Sheffield, UK.
- ¹⁴⁰Department of Physics, Shinshu University, Nagano, Japan.
- ¹⁴¹Fachbereich Physik, Universität Siegen, Siegen, Germany.
- ¹⁴²Department of Physics, Simon Fraser University, Burnaby, British Columbia, Canada.
- ¹⁴³SLAC National Accelerator Laboratory, Stanford, California, USA.
- ^{144(a)}Faculty of Mathematics, Physics & Informatics, Comenius University, Bratislava, Slovak Republic; ^(b)Department of Subnuclear Physics, Institute of Experimental Physics of the Slovak Academy of Sciences, Kosice, Slovak Republic.
- ^{145(a)}Department of Physics, University of Johannesburg, Johannesburg, South Africa; ^(b)School of Physics, University of the Witwatersrand, Johannesburg, South Africa.
- ^{146(a)}Department of Physics, Stockholm University, Stockholm, Sweden; ^(b)The Oskar Klein Centre, Stockholm, Sweden.
- ¹⁴⁷Physics Department, Royal Institute of Technology, Stockholm, Sweden.
- ¹⁴⁸Department of Physics and Astronomy, Stony Brook University, Stony Brook, New York, USA.
- ¹⁴⁹Department of Physics and Astronomy, University of Sussex, Brighton, UK.
- ¹⁵⁰School of Physics, University of Sydney, Sydney, Australia.
- ¹⁵¹Institute of Physics, Academia Sinica, Taipei, Taiwan.
- ¹⁵²Department of Physics, Technion: Israel Inst. of Technology, Haifa, Israel.
- ¹⁵³Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel.
- ¹⁵⁴Department of Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece.
- ¹⁵⁵International Center for Elementary Particle Physics and Department of Physics, The University of Tokyo, Tokyo, Japan.
- ¹⁵⁶Graduate School of Science and Technology, Tokyo Metropolitan University, Tokyo, Japan.
- ¹⁵⁷Department of Physics, Tokyo Institute of Technology, Tokyo, Japan.
- ¹⁵⁸Department of Physics, University of Toronto, Toronto, Ontario, Canada.
- ^{159(a)}TRIUMF, Vancouver British Columbia, Canada; ^(b)Department of Physics and Astronomy, York University, Toronto, Ontario, Canada.
- ¹⁶⁰Institute of Pure and Applied Sciences, University of Tsukuba, Ibaraki, Japan.
- ¹⁶¹Science and Technology Center, Tufts University, Medford, Massachusetts, USA.
- ¹⁶²Centro de Investigaciones, Universidad Antonio Narino, Bogota, Colombia.
- ¹⁶³Department of Physics and Astronomy, University of California Irvine, Irvine, California, USA.
- ^{164(a)}INFN Gruppo Collegato di Udine, Udine, Italy; ^(b)ICTP, Trieste; ^(c)Dipartimento di Fisica, Università di Udine, Udine, Italy.
- ¹⁶⁵Department of Physics, University of Illinois, Urbana, Illinois, USA.
- ¹⁶⁶Department of Physics and Astronomy, University of Uppsala, Uppsala, Sweden.
- ¹⁶⁷Instituto 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.
- ¹⁶⁸Department of Physics, University of British Columbia, Vancouver, British Columbia, Canada.
- ¹⁶⁹Department of Physics and Astronomy, University of Victoria, Victoria, British Columbia, Canada.
- ¹⁷⁰Waseda University, Tokyo, Japan.
- ¹⁷¹Department of Particle Physics, The Weizmann Institute of Science, Rehovot, Israel.
- ¹⁷²Department of Physics, University of Wisconsin, Madison, Wisconsin, USA.
- ¹⁷³Fakultät für Physik und Astronomie, Julius-Maximilians-Universität, Würzburg, Germany.
- ¹⁷⁴Fachbereich C Physik, Bergische Universität Wuppertal, Wuppertal, Germany.
- ¹⁷⁵Department of Physics, Yale University, New Haven, Connecticut, USA.
- ¹⁷⁶Yerevan Physics Institute, Yerevan, Armenia.
- ¹⁷⁷Domaine scientifique de la Doua, Centre de Calcul CNRS/IN2P3, Villeurbanne Cedex, France.
- ^aAlso at Laboratorio de Instrumentacao e Fisica Experimental de Particulas - LIP, Lisboa, Portugal.
- ^bAlso at Faculdade de Ciencias and CFNUL, Universidade de Lisboa, Lisboa, Portugal.
- ^cAlso at CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France.
- ^dAlso at TRIUMF, Vancouver, British Columbia, Canada.
- ^eAlso at Department of Physics, California State University, Fresno, California, USA.

^fAlso at Faculty of Physics and Applied Computer Science, AGH-University of Science and Technology, Krakow, Poland.

^gAlso at Department of Physics, University of Coimbra, Coimbra, Portugal.

^hAlso at Università di Napoli Parthenope, Napoli, Italy.

ⁱAlso at Institute of Particle Physics (IPP), Canada.

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

^kAlso at Louisiana Tech University, Ruston, Louisiana, USA.

^lAlso at Group of Particle Physics, University of Montreal, Montreal, Québec, Canada.

^mAlso at Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan.

ⁿAlso at Institut für Experimentalphysik, Universität Hamburg, Hamburg, Germany.

^oAlso at Manhattan College, New York, New York, USA.

^pAlso at School of Physics and Engineering, Sun Yat-sen University, Guanzhou, China.

^qAlso at Academia Sinica Grid Computing, Institute of Physics, Academia Sinica, Taipei, Taiwan.

^rAlso at High Energy Physics Group, Shandong University, Shandong, China.

^sAlso at California Institute of Technology, Pasadena, California, USA.

^tAlso at Particle Physics Department, Rutherford Appleton Laboratory, Didcot, UK.

^uAlso at Section de Physique, Université de Genève, Geneva, Switzerland.

^vAlso at Departamento de Física, Universidade de Minho, Braga, Portugal.

^wAlso at Department of Physics and Astronomy, University of South Carolina, Columbia, South Carolina, USA.

^xAlso at KFKI Research Institute for Particle and Nuclear Physics, Budapest, Hungary.

^yAlso at Institute of Physics, Jagiellonian University, Krakow, Poland.

^zAlso at Department of Physics, Oxford University, Oxford, UK.

^{aa}Also at DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat à l'Energie Atomique), Gif-sur-Yvette, France.

^{ab}Also at Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France.

^{ac}Also at Department of Physics, Nanjing University, Jiangsu, China.

‡Deceased.