



CERN-PH-EP-2015-048

Submitted to: Physical Review Letters

---

**Measurements of the Total and Differential Higgs Boson  
Production Cross Sections Combining the  $H \rightarrow \gamma\gamma$  and  
 $H \rightarrow ZZ^* \rightarrow 4\ell$  Decay Channels at  $\sqrt{s} = 8$  TeV  
with the ATLAS Detector**

The ATLAS Collaboration

**Abstract**

Measurements of the total and differential cross sections of Higgs boson production are performed using  $20.3 \text{ fb}^{-1}$  of  $pp$  collisions produced by the Large Hadron Collider at a center-of-mass energy of  $\sqrt{s} = 8$  TeV and recorded by the ATLAS detector. Cross sections are obtained from measured  $H \rightarrow \gamma\gamma$  and  $H \rightarrow ZZ^* \rightarrow 4\ell$  event yields, which are combined accounting for detector efficiencies, fiducial acceptances and branching fractions. Differential cross sections are reported as a function of Higgs boson transverse momentum, Higgs boson rapidity, number of jets in the event, and transverse momentum of the leading jet. The total production cross section is determined to be  $\sigma_{pp \rightarrow H} = 33.0 \pm 5.3(\text{stat}) \pm 1.6(\text{sys}) \text{ pb}$ . The measurements are compared to state-of-the-art predictions.

# Measurements of the Total and Differential Higgs Boson Production Cross Sections Combining the $H \rightarrow \gamma\gamma$ and $H \rightarrow ZZ^* \rightarrow 4\ell$ Decay Channels at $\sqrt{s} = 8$ TeV with the ATLAS Detector

The ATLAS Collaboration  
(Dated: September 7, 2015)

Measurements of the total and differential cross sections of Higgs boson production are performed using  $20.3 \text{ fb}^{-1}$  of  $pp$  collisions produced by the Large Hadron Collider at a center-of-mass energy of  $\sqrt{s} = 8$  TeV and recorded by the ATLAS detector. Cross sections are obtained from measured  $H \rightarrow \gamma\gamma$  and  $H \rightarrow ZZ^* \rightarrow 4\ell$  event yields, which are combined accounting for detector efficiencies, fiducial acceptances and branching fractions. Differential cross sections are reported as a function of Higgs boson transverse momentum, Higgs boson rapidity, number of jets in the event, and transverse momentum of the leading jet. The total production cross section is determined to be  $\sigma_{pp \rightarrow H} = 33.0 \pm 5.3$  (stat)  $\pm 1.6$  (sys) pb. The measurements are compared to state-of-the-art predictions.

PACS numbers: 13.85.Lg, 13.85.Qk, 14.80.Bn

This Letter presents measurements of the total and differential cross sections of inclusive Higgs boson production using  $20.3 \text{ fb}^{-1}$  of  $pp$  collisions produced by the Large Hadron Collider (LHC) [1] at a center-of-mass energy of  $\sqrt{s} = 8$  TeV and recorded by the ATLAS detector [2]. The measured cross sections probe the properties of the Higgs boson and can be directly compared to the theoretical modeling of different Higgs boson production mechanisms, such as the most recent gluon fusion (ggF) QCD calculations. They can also be used to constrain new physics scenarios, for example using the effective field theory framework as proposed in Refs. [3–7]. The analysis uses event yields measured in the  $H \rightarrow \gamma\gamma$  and  $H \rightarrow ZZ^* \rightarrow 4\ell$  decays and detector efficiencies, both determined as described in Refs. [8, 9]. The statistical uncertainties on the Higgs boson signal yields in both channels are larger than the systematic uncertainties, while the total uncertainties in the two channels are similar. Combining the analyses improves the precision of the cross-section measurements by up to 40%, and by 25–30% on average, with respect to the corresponding measurements in the most precise individual channel.

Distributions of the differential  $pp \rightarrow H$  cross sections are reported as a function of the transverse momentum  $p_T^H$  and the rapidity  $|y^H|$  of the Higgs boson, the jet multiplicity  $N_{\text{jets}}$ , and the transverse momentum of the leading jet  $p_T^{\text{j1}}$ . The observables  $p_T^H$  and  $|y^H|$  describe the kinematics of the Higgs boson. They are sensitive to perturbative QCD modeling in ggF production, which is the dominant Higgs boson production mechanism in the Standard Model (SM). The  $|y^H|$  distribution furthermore offers a clean probe of the gluon parton distribution function (PDF) and will play a role in future PDF fits. The  $N_{\text{jets}}$  and  $p_T^{\text{j1}}$  observables probe the theoretical modeling of partonic radiation in ggF production as well as the overall rate and modeling of jets in vector-boson fusion (VBF) and associated Higgs boson production ( $VH$  and  $t\bar{t}H$ ). Jets produced in VBF,  $VH$  and  $t\bar{t}H$  processes tend

to have higher transverse momenta than those produced via ggF production, however the sensitivity to measuring these contributions is weak with the current amount of data.

Cross sections are extracted using a combined likelihood built from the signal yields in the  $H \rightarrow \gamma\gamma$  channel and the data and background yields in the  $H \rightarrow ZZ^* \rightarrow 4\ell$  channel, as well as detector efficiencies, fiducial acceptances and SM branching fractions [10]. A complementary approach, using a separate likelihood, measures the shape of the differential distributions by imposing a unity normalization constraint, which removes the implicit SM assumption on the branching fractions. For the extraction of the signal yields and the corrections of detector efficiencies, it is assumed that the signal in both channels is due to a narrow resonance with a mass  $m_H = 125.36 \pm 0.41$  GeV as measured by the ATLAS Collaboration [11]. The signal yield in the  $H \rightarrow \gamma\gamma$  channel is obtained from fits to the diphoton mass spectra [8], and from the background subtracted data yield in a  $m_{4\ell}$  mass window of 118 to 129 GeV for the  $H \rightarrow ZZ^* \rightarrow 4\ell$  channel [9]. The fiducial acceptance in both channels [8, 9] is derived using a set of Monte Carlo (MC) event generators. POWHEG-BOX [12–14], interfaced with PYTHIA8 [15] for showering, is used to generate ggF and VBF events, while PYTHIA8 is used to simulate  $VH$  and associated production with top quarks ( $t\bar{t}H$ ) and  $b$ -quarks ( $b\bar{b}H$ ). The fiducial acceptance for events with  $|y^H| < 1.2$  is approximately 72% for  $H \rightarrow \gamma\gamma$ , and 55–59% for  $H \rightarrow ZZ^* \rightarrow 4\ell$ . For higher  $|y^H|$ , the acceptance decreases to 35–38% in both channels. The fiducial acceptance is more constant as a function of the other variables and is in the range 56–62% for the  $H \rightarrow \gamma\gamma$  channel and 44–53% for the  $H \rightarrow ZZ^* \rightarrow 4\ell$  channel.

After correcting the differential cross sections and normalized shapes for fiducial acceptance and branching fractions, the corresponding measurements in both channels are found to be in good agreement with each other;  $p$ -values obtained from  $\chi^2$  compatibility tests are in the

range 56–99%.

In the binned maximum-likelihood fit, the statistical uncertainty of the  $H \rightarrow \gamma\gamma$  event yield is modeled using a Gaussian distribution, while the event yield in the  $H \rightarrow ZZ^* \rightarrow 4\ell$  channel follows a Poisson distribution due to the small sample size. Experimental and theoretical systematic uncertainties affecting the signal yields, detector efficiencies, branching fractions and fiducial acceptance corrections are taken into account in the likelihood as constrained nuisance parameters. Nuisance parameters describing the same uncertainty sources are treated as fully correlated between bins and channels. Systematic uncertainties on the  $H \rightarrow \gamma\gamma$  and  $H \rightarrow ZZ^* \rightarrow 4\ell$  background estimates and efficiency correction factors, as well as the uncertainty on the integrated luminosity, are described in detail in Refs. [8, 9]. The branching fraction uncertainty due to the assumed quark masses and other theoretical uncertainties are evaluated following the recommendations of Ref. [16], considering uncertainty correlations between the  $H \rightarrow \gamma\gamma$  and  $H \rightarrow ZZ^* \rightarrow 4\ell$  decay channels. Uncertainties on the acceptance correction related to the choice of PDF set are evaluated by taking the envelope of the sum in quadratures of eigenvector variations of the baseline (CT10 [17]) and the central values of alternative (MSTW2008NLO [18] and NNPDF2.3 [19]) PDF sets. Uncertainties on the acceptance correction associated with missing higher-order corrections are evaluated by varying the renormalization and factorization scales coherently and individually by factors of 0.5 and 2 from their nominal values, and by reweighting the  $p_T^H$  distribution from POWHEG-BOX to the prediction of the HRES 2.2 calculation [20, 21]. The envelope of the maximum deviation of the combined scale variations and the  $p_T^H$  reweighting is used as the systematic variation. To account for the uncertainty in the mass measurement, the Higgs boson mass is varied by  $\pm 0.4$  GeV. To assess the systematic uncertainty due to the assumption of SM cross-section fractions of the Higgs boson production modes, the VBF and  $VH$  fractions are varied by factors of 0.5 and 2 from the SM prediction and the fraction of  $t\bar{t}H$  is varied by factors of 0 and 5. These factors are based on current experimental bounds [22–26]. The total uncertainties on the acceptance correction range from 1% to 6%, depending on the channel, distribution and bin.

The total systematic uncertainties on the combined differential cross sections range from 4% to 12%, depending on the distribution and bin. For the kinematic variables  $p_T^H$  and  $|y^H|$ , the largest systematic uncertainties on the differential cross sections are due to the luminosity and the background estimates in both channels. For the jet variables  $N_{\text{jets}}$  and  $p_T^{j1}$ , the largest systematic uncertainties on the differential cross sections are due to the jet energy scale and resolution. In the shape combination, the normalization uncertainties including luminosity, branching fractions, and efficiency uncertainties do not apply.

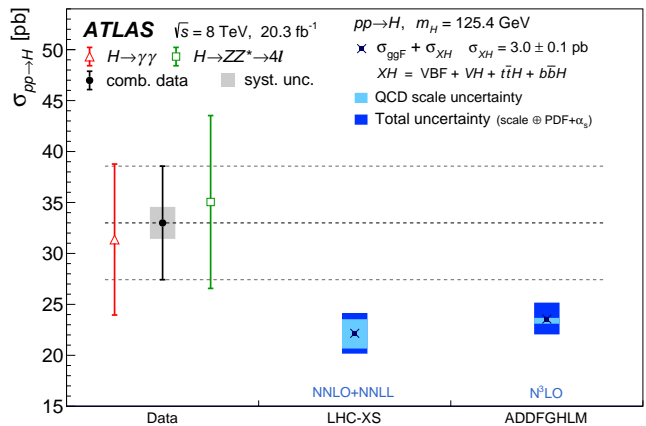


FIG. 1. Measured total cross section of Higgs boson production compared to two calculations of the ggF cross section. Contributions from other relevant Higgs boson production modes (VBF,  $VH$ ,  $t\bar{t}H$ ,  $b\bar{b}H$ ) are added using cross sections and uncertainties from Ref. [10]. Details of the predictions are presented in Table I.

Statistical uncertainties dominate all resulting distributions, ranging from 23% to 75%.

The total  $pp \rightarrow H$  cross section is determined in the

TABLE I. Summary of the ggF predictions used in the comparison with the measured cross sections. The second column states the order in QCD perturbation theory and which threshold resummation is applied, if any. Further details are provided in the footnotes. All predictions are for  $m_H = 125.4$  GeV and  $\sqrt{s} = 8$  TeV.

Total cross-section calculations	
LHC-XS [10]	NNLO+NNLL <sup>a,b,c</sup>
ADDFGHLM [27–30]	N <sup>3</sup> LO <sup>a,b,c</sup>
Analytical differential cross-section predictions	
HRES 2.2 [20, 21]	NNLO+NNLL <sup>a,e,f</sup>
STWZ [31], BLPTW [32]	NNLO+NNLL <sup>c,d,e,g,h</sup>
JetVHeto 2.0 [33–35]	NNLO+NNLL <sup>a,c,e</sup>
Monte Carlo event generators	
SHERPA 2.1.1 [36, 37]	$H + 0, 1, 2$ jets @NLO <sup>i,j</sup>
MG5_aMC@NLO [38, 39]	$H + 0, 1, 2$ jets @NLO <sup>i,k,l</sup>
POWHEG NNLOPS [40, 41]	NNLO <sub>≥0j</sub> , NLO <sub>≥1j</sub> <sup>e,l,m</sup>

- <sup>a</sup> Considers  $b$ - (and  $c$ -) quark masses in the  $gg \rightarrow H$  loop
- <sup>b</sup> Includes electroweak corrections
- <sup>c</sup> Based on MSTW2008nnlo [18] ( $\alpha_s$  from PDF set)
- <sup>d</sup> Uses  $\pi^2$ -resummed  $gg \rightarrow H$  form factor
- <sup>e</sup> NNLO refers to the total cross section
- <sup>f</sup> Based on the CT10nnlo PDF set
- <sup>g</sup> In the notation of Ref. [31], this corresponds to NNLL'
- <sup>h</sup> Includes 1-jet resummation included at NLL'+NLO
- <sup>i</sup> Based on the CT10nlo PDF set
- <sup>j</sup> Uses MEPS@NLO method and CKKW merging scheme [42–44]
- <sup>k</sup> Software version 2.2.1, NLO merged using FxFx scheme [39]
- <sup>l</sup> Interfaced with PYTHIA8 for parton showering
- <sup>m</sup> Uses MINLO method &  $y^H$  reweighting to HNNLO [41, 45, 46].

$H \rightarrow \gamma\gamma$  channel to be  $31.4 \pm 7.2$  (stat)  $\pm 1.6$  (sys) pb and in the  $H \rightarrow ZZ^* \rightarrow 4\ell$  channel to be  $35.0 \pm 8.4$  (stat)  $\pm 1.8$  (sys) pb. Combining the analyses yields  $\sigma_{pp \rightarrow H} = 33.0 \pm 5.3$  (stat)  $\pm 1.6$  (sys) pb. Figure 1 presents a comparison of these measurements with two ggF predictions to which contributions from other relevant Higgs boson production modes (VBF,  $VH$ ,  $t\bar{t}H$ ,  $b\bar{b}H$ ) are added using cross sections and uncertainties from Ref. [10]. The LHC-XS ggF prediction, recommended in Ref. [10], is accurate to next-to-next-to-leading order (NNLO) in QCD and utilises threshold resummation accurate to next-to-next-to-leading logarithms (NNLL). A significant effort has been undertaken by the theory community to provide ggF cross sections beyond this precision through various improvements in the perturbative calculations [31, 47–51]. Recently, the ADDFGHLM group has provided a fixed-order calculation accurate to next-to-next-to-next-leading order (N<sup>3</sup>LO) [27–30]. A PDF uncertainty of  $^{+7.5\%}_{-6.9\%}$  is assigned to the LHC-XS prediction, derived following the recommendations in Ref. [16]. This uncertainty is increased by  $^{+0.3\%}_{-0.1\%}$  for the ADDFGHLM prediction corresponding to the change in uncertainty of the MSTW2008nnlo PDF set when changing the calculation from NNLO to N<sup>3</sup>LO. The PDF uncertainty is treated as uncorrelated with the QCD scale uncertainty.

The central value of the measured total cross section is larger than the SM predictions presented in Fig. 1. A likelihood-ratio test statistic is used to quantify the agreement, using a bifurcated Gaussian to model the asymmetric theory uncertainties. The resulting  $p$ -values are 5.5% and 9.0% for the agreement between data and the predictions from LHC-XS and ADDFGHLM, respectively. The ratio of the measured cross section to the LHC-XS prediction is higher than the results presented in Refs. [22, 23, 58], which use an event categorization based on the expected SM yields in the different Higgs boson production modes.

The larger Higgs event yield observed in data motivates measurements of differential cross sections to investigate if the excess is localized to specific kinematic regions. Figure 2 shows the comparison of the combined cross sections in different inclusive and exclusive jet multiplicity bins with state-of-the-art predictions, including NLO-accurate multi-leg (ML) merged ggF MC event generators (further details are given in Table I). Jets are reconstructed using the anti- $k_t$  algorithm [52] with a radius parameter  $R = 0.4$  [53], and are required to have  $p_T > 30$  GeV and  $|y| < 4.4$ . Simulated particle-level jets are built from all particles with  $c\tau > 10$  mm excluding neutrinos, electrons and muons that do not originate from hadronic decays. Photons are excluded from jet-finding if they lie inside a cone of radius  $\Delta R < 0.1$  of an electron or muon, and neither the photon nor lepton originate from a hadron decay. To allow comparisons with the unfolded measurements, the analytical calculations are corrected for effects of hadronization and

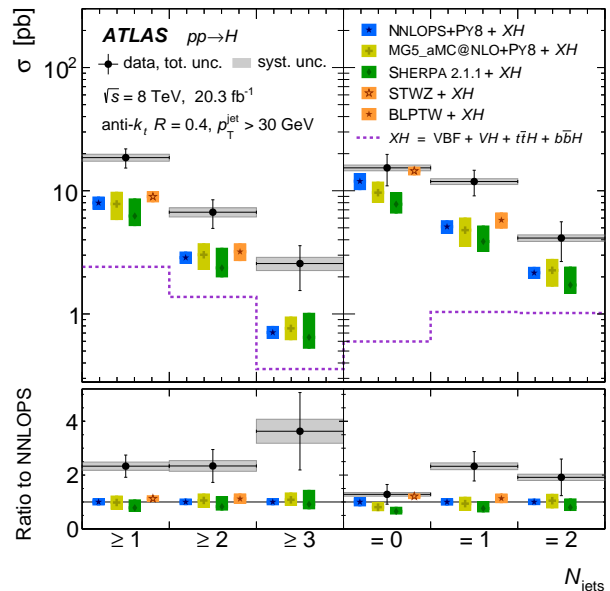


FIG. 2. Measured Higgs boson production cross sections in inclusive and exclusive jet multiplicity bins compared to different theoretical predictions (see Table I for details and references).

multiple particle interactions. These correction factors and their associated uncertainties are obtained using the PYTHIA8 and HERWIG [54] MC event generators with different tunes [55–57]. The total cross sections from the ML merged predictions are lower than from fully inclusive NNLO+NNLL calculations. However, for  $N_{\text{jets}} \geq 1$ , the MC predictions formally have NLO accuracy, which is the same as the analytical calculations. Contributions from other relevant Higgs boson production modes are generated using POWHEG for VBF and PYTHIA8 for  $VH$ ,  $t\bar{t}H$ , and  $b\bar{b}H$ , and are scaled to the cross sections in Ref. [10]. Uncertainties are assigned to all MC predictions from QCD scale and PDF variations. The ML-merged ggF predictions also have uncertainties due to the choice of merging scale. The SHERPA uncertainties further include resummation scale variations. The measured cross sections are higher than the predictions for all measured jet multiplicities. The poorest agreement between data and predictions can be found in the inclusive and exclusive 1-jet bins, with local  $p$ -values ranging between 0.1% and 3.6%. Normalizing the total expected cross section to the data results in an improved agreement for these bins, with local  $p$ -values ranging from 4–29%.

The combined differential cross sections as a function of  $p_T^H$ ,  $|y^H|$ , and  $p_T^{j1}$  are shown in Fig. 3 (left). The measured  $p_T^H$  and  $|y^H|$  distributions are compared to the HRES calculation and the  $p_T^{j1}$  measurement is compared to STWZ and JetVHeto predictions. Figure 3 (right) shows the comparisons of the normalized shapes to predictions from the MC event generators NNLOPS,

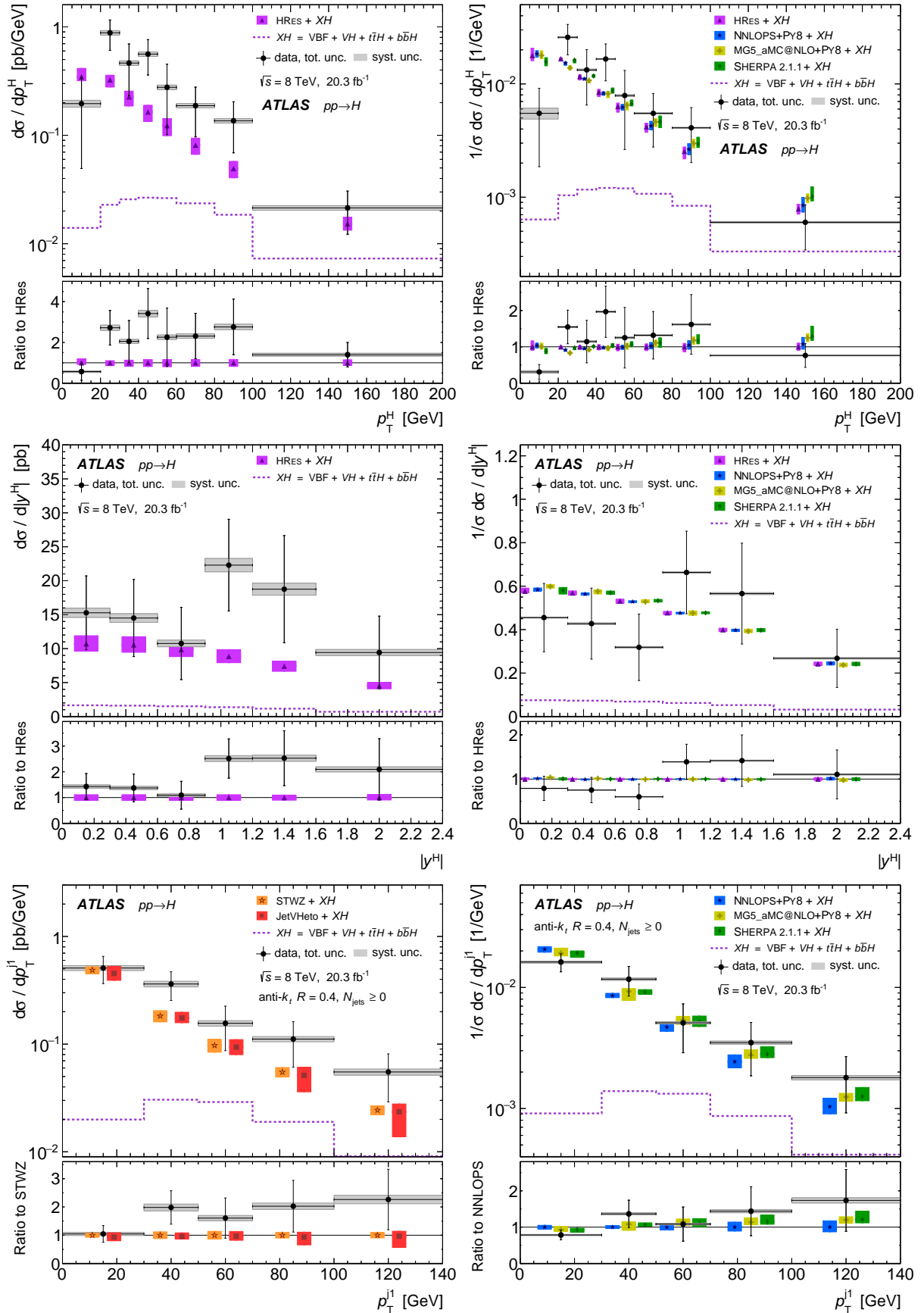


FIG. 3. Differential cross sections (left) and normalized cross-section shapes (right) for inclusive Higgs boson production measured by combining the  $H \rightarrow \gamma\gamma$  and  $H \rightarrow ZZ^* \rightarrow 4\ell$  channels. The measured variables are the Higgs boson transverse momentum  $p_T^H$  (top) and its rapidity  $|y^H|$  (middle), and the transverse momentum of the leading jet  $p_T^{j1}$  (bottom). The 0–30 GeV bin of the  $p_T^{j1}$  distributions corresponds to events without jets above 30 GeV. Various theoretical predictions are presented, using the same bin widths as the measurement.

SHERPA 2.1.1, and MG5\_aMC@NLO, as well as the HRES calculation. The uncertainties on the predicted shapes are evaluated following the same approach as for the differential cross-section predictions. They are derived from the impact of QCD scale, merging scale and PDF variations. The mean of the measured  $p_T^H$  distribution is  $40.1 \pm 3.0$  GeV, while the means of the MC predictions range from 34 to 37 GeV.

The  $p$ -values quantifying the compatibility of the measured cross sections and predictions range from 2% to 26%, and for the shapes from 8% to 88%. For the calculation of these values, the theory uncertainties are assumed to be Gaussian distributed and fully correlated between bins.

In conclusion, this Letter presents the first measurements of total and differential cross sections and shapes for inclusive  $pp \rightarrow H$  production. The measurements were performed in the  $H \rightarrow \gamma\gamma$  and  $H \rightarrow ZZ^* \rightarrow 4\ell$  channels using the full 2012 dataset, which consists of  $20.3 \text{ fb}^{-1}$  of  $pp$  collisions produced by the LHC at a center-of-mass energy of  $\sqrt{s} = 8$  TeV and recorded by the ATLAS detector. The results of the two channels are compatible and have similar precision. The measurements indicate that the total production cross section of the Higgs boson is larger, and that it is produced with larger transverse momentum and more associated jets than predicted by the current most advanced SM calculations, however more data is needed to confirm these observations.

We thank CERN for the very successful operation of the LHC, as well as the support staff from our institutions without whom ATLAS could not be operated efficiently.

We acknowledge the support of ANPCyT, Argentina; YerPhI, Armenia; ARC, Australia; BMWFW and FWF, Austria; ANAS, Azerbaijan; SSTC, Belarus; CNPq and FAPESP, Brazil; NSERC, NRC and CFI, Canada; CERN; CONICYT, Chile; CAS, MOST and NSFC, China; COLCIENCIAS, Colombia; MSMT CR, MPO CR and VSC CR, Czech Republic; DNRF, DNSRC and Lundbeck Foundation, Denmark; EPLANET, ERC and NSRF, European Union; IN2P3-CNRS, CEA-DSM/IRFU, France; GNSF, Georgia; BMBF, DFG, HGF, MPG and AvH Foundation, Germany; GSRT and NSRF, Greece; RGC, Hong Kong SAR, China; ISF, MINERVA, GIF, I-CORE and Benoziyo Center, Israel; INFN, Italy; MEXT and JSPS, Japan; CNRST, Morocco; FOM and NWO, Netherlands; BRF and RCN, Norway; MNiSW and NCN, Poland; GRICES and FCT, Portugal; MNE/IFA, Romania; MES of Russia and NRC KI, Russian Federation; JINR; MSTP, Serbia; MSSR, Slovakia; ARRS and MIZŠ, Slovenia; DST/NRF, South Africa; MINECO, Spain; SRC and Wallenberg Foundation, Sweden; SER, SNSF and Cantons of Bern and Geneva, Switzerland; NSC, Taiwan; TAEK, Turkey; STFC, the Royal Society and Leverhulme Trust, United

Kingdom; DOE and NSF, United States of America.

The crucial computing support from all WLCG partners is acknowledged gratefully, in particular from CERN and the ATLAS Tier-1 facilities at TRIUMF (Canada), NDGF (Denmark, Norway, Sweden), CC-IN2P3 (France), KIT/GridKA (Germany), INFN-CNAF (Italy), NL-T1 (Netherlands), PIC (Spain), ASGC (Taiwan), RAL (UK) and BNL (USA) and in the Tier-2 facilities worldwide.

- 
- [1] L. Evans and P. Bryant, *JINST* **3** (2008) S08001.
  - [2] ATLAS Collaboration, *JINST* **3** (2008) S08003.
  - [3] G. Giudice, C. Grojean, A. Pomarol, and R. Rattazzi, *J. High Energy Phys.* **06** (2007) 045, [arXiv:hep-ph/0703164 \[hep-ph\]](#).
  - [4] B. Grzadkowski, M. Iskrzynski, M. Misiak, and J. Rosiek, *J. High Energy Phys.* **10** (2010) 085, [arXiv:1008.4884 \[hep-ph\]](#).
  - [5] R. Contino, M. Ghezzi, C. Grojean, M. Muhlleitner, and M. Spira, *J. High Energy Phys.* **07** (2013) 035, [arXiv:1303.3876 \[hep-ph\]](#).
  - [6] J. Ellis, V. Sanz, and T. You, *J. High Energy Phys.* **03** (2015) 157, [arXiv:1410.7703 \[hep-ph\]](#).
  - [7] C. Englert and M. Spannowsky, *Phys. Lett.* **B 740** (2015) 8–15, [arXiv:1408.5147 \[hep-ph\]](#).
  - [8] ATLAS Collaboration, *J. High Energy Phys.* **09** (2014) 112, [arXiv:1407.4222 \[hep-ex\]](#).
  - [9] ATLAS Collaboration, *Phys. Lett.* **B 738** (2014) 234–253, [arXiv:1408.3226 \[hep-ex\]](#).
  - [10] LHC Higgs cross section working group, S. Dittmaier, C. Mariotti, G. Passarino, and R. Tanaka (Eds.), CERN-2011-002 (2011), [arXiv:1101.0593 \[hep-ph\]](#).
  - [11] ATLAS Collaboration, *Phys. Rev.* **D 90** (2014) 052004, [arXiv:1406.3827 \[hep-ex\]](#).
  - [12] P. Nason, *J. High Energy Phys.* **11** (2004) 040, [arXiv:hep-ph/0409146](#).
  - [13] S. Frixione, P. Nason, and C. Oleari, *J. High Energy Phys.* **11** (2007) 070, [arXiv:0709.2092 \[hep-ph\]](#).
  - [14] S. Alioli, P. Nason, C. Oleari, and E. Re, *J. High Energy Phys.* **06** (2010) 043, [arXiv:1002.2581 \[hep-ph\]](#).
  - [15] T. Sjöstrand, S. Mrenna, and P. Z. Skands, *Comput. Phys. Commun.* **178** (2008) 852–867, [arXiv:0710.3820 \[hep-ph\]](#).
  - [16] LHC Higgs Cross Section Working Group, S. Heinemeyer, C. Mariotti, G. Passarino, and R. Tanaka (Eds.), CERN-2013-004 (2013), [arXiv:1307.1347 \[hep-ph\]](#).
  - [17] H.-L. Lai et al., *Phys. Rev.* **D 82** (2010) 074024, [arXiv:1007.2241 \[hep-ph\]](#).
  - [18] A. D. Martin, W. J. Stirling, R. S. Thorne, and G. Watt, *Eur. Phys. J.* **C 63** (2009) 189–285, [arXiv:0901.0002 \[hep-ph\]](#).
  - [19] R. D. Ball et al., *Nucl. Phys.* **B 849** (2011) 296–363, [arXiv:1101.1300 \[hep-ph\]](#).
  - [20] D. de Florian, G. Ferrera, M. Grazzini, and D. Tommasini, *J. High Energy Phys.* **06** (2012) 132, [arXiv:1203.6321 \[hep-ph\]](#).
  - [21] M. Grazzini and H. Sargsyan, *J. High Energy Phys.* **09** (2013) 129, [arXiv:1306.4581 \[hep-ph\]](#).

- [22] ATLAS Collaboration, Phys. Rev. **D 90** (2014) 112015, [arXiv:1408.7084 \[hep-ex\]](#).
- [23] ATLAS Collaboration, Phys. Rev. **D 91** (2015) 012006, [arXiv:1408.5191 \[hep-ex\]](#).
- [24] ATLAS Collaboration, [arXiv:1412.2641 \[hep-ex\]](#).
- [25] ATLAS Collaboration, Phys. Lett. **B 740** (2015) 222–242, [arXiv:1409.3122 \[hep-ex\]](#).
- [26] CMS Collaboration, J. High Energy Phys. **09** (2014) 087, [arXiv:1408.1682 \[hep-ex\]](#).
- [27] C. Anastasiou, S. Buehler, F. Herzog, and A. Lazopoulos, J. High Energy Phys. **12** (2011) 058, [arXiv:1107.0683 \[hep-ph\]](#).
- [28] C. Anastasiou, C. Duhr, F. Dulat, E. Furlan, T. Gehrmann, F. Herzog, and B. Mistlberger, Phys. Lett. **B 737** (2014) 325–328, [arXiv:1403.4616 \[hep-ph\]](#). Predictions quoted in this paper derived by the authors using `ihixs 2.0`.
- [29] C. Anastasiou, C. Duhr, F. Dulat, E. Furlan, T. Gehrmann, F. Herzog, and B. Mistlberger, [arXiv:1411.3584 \[hep-ph\]](#).
- [30] C. Anastasiou, C. Duhr, F. Dulat, F. Herzog, and B. Mistlberger, [arXiv:1503.06056 \[hep-ph\]](#).
- [31] I. W. Stewart, F. J. Tackmann, J. R. Walsh, and S. Zuberi, Phys. Rev. **D 89** (2014) 054001, [arXiv:1307.1808 \[hep-ph\]](#). Prediction quoted in this paper derived by the authors.
- [32] R. Boughezal, X. Liu, F. Petriello, F. J. Tackmann, and J. R. Walsh, Phys. Rev. **D 89** (2014) 074044, [arXiv:1312.4535 \[hep-ph\]](#). Predictions quoted in this paper derived by the authors.
- [33] A. Banfi, P. F. Monni, G. P. Salam, and G. Zanderighi, Phys. Rev. Lett. **109** (2012) 202001, [arXiv:1206.4998 \[hep-ph\]](#).
- [34] A. Banfi, G. P. Salam, and G. Zanderighi, J. High Energy Phys. **06** (2012) 159, [arXiv:1203.5773 \[hep-ph\]](#).
- [35] A. Banfi, P. F. Monni, and G. Zanderighi, J. High Energy Phys. **01** (2014) 097, [arXiv:1308.4634 \[hep-ph\]](#).
- [36] T. Gleisberg et al., J. High Energy Phys. **02** (2009) 007, [arXiv:0811.4622 \[hep-ph\]](#).
- [37] S. Hoeche, F. Krauss, and M. Schönherr, Phys. Rev. **D 90** (2014) 014012, [arXiv:1401.7971 \[hep-ph\]](#). Predictions quoted in this paper derived by the authors.
- [38] J. Alwall et al., J. High Energy Phys. **07** (2014) 079, [arXiv:1405.0301 \[hep-ph\]](#). Predictions quoted in this paper derived by the authors.
- [39] R. Frederix and S. Frixione, J. High Energy Phys. **12** (2012) 061, [arXiv:1209.6215 \[hep-ph\]](#).
- [40] K. Hamilton, P. Nason, E. Re, and G. Zanderighi, J. High Energy Phys. **10** (2013) 222, [arXiv:1309.0017 \[hep-ph\]](#).
- [41] S. Catani and M. Grazzini, Phys. Rev. Lett. **98** (2007) 222002, [arXiv:hep-ph/0703012](#).
- [42] S. Hoeche, F. Krauss, S. Schumann, and F. Siegert, J. High Energy Phys. **05** (2009) 053, [arXiv:0903.1219 \[hep-ph\]](#).
- [43] S. Catani, F. Krauss, R. Kuhn, and B. Webber, J. High Energy Phys. **11** (2001) 063, [arXiv:hep-ph/0109231 \[hep-ph\]](#).
- [44] S. Hoeche, F. Krauss, M. Schönherr, and F. Siegert, J. High Energy Phys. **04** (2013) 027, [arXiv:1207.5030 \[hep-ph\]](#).
- [45] M. Grazzini, J. High Energy Phys. **02** (08) 043, [arXiv:0801.3232 \[hep-ph\]](#).
- [46] M. Grazzini and H. Sargsyan, J. High Energy Phys. **09** (2013) 129, [arXiv:1306.4581 \[hep-ph\]](#).
- [47] V. Ahrens, T. Becher, M. Neubert, and L. L. Yang, Phys. Lett. **B 698** (2011) 271–274, [arXiv:1008.3162 \[hep-ph\]](#). Prediction quoted in this paper derived by the authors using the `RGHiggs 1.1` program.
- [48] D. de Florian, J. Mazzitelli, S. Moch, and A. Vogt, J. High Energy Phys. **10** (2014) 176, [arXiv:1408.6277 \[hep-ph\]](#). Prediction quoted in this paper provided by the authors.
- [49] R. D. Ball, M. Bonvini, S. Forte, S. Marzani, and G. Ridolfi, Nucl. Phys. **B 874** (2013) 746–772, [arXiv:1303.3590 \[hep-ph\]](#).
- [50] M. Bonvini, R. D. Ball, S. Forte, S. Marzani, and G. Ridolfi, J. Phys. **G 41** (2014) 095002, [arXiv:1404.3204 \[hep-ph\]](#). Prediction quoted in this paper derived by the authors using the `ggHiggs 2.0` and `ResHiggs 2.2` programs.
- [51] M. Bonvini and S. Marzani, J. High Energy Phys. **09** (2014) 007, [arXiv:1405.3654 \[hep-ph\]](#).
- [52] M. Cacciari, G. P. Salam, and G. Soyez, J. High Energy Phys. **04** (2008) 063, [arXiv:0802.1189 \[hep-ph\]](#).
- [53] ATLAS uses a right-handed coordinate system with its origin at the nominal interaction point (IP) in the center of the detector and the  $z$ -axis along the beam pipe. The  $x$ -axis points from the IP to the center of the LHC ring, and the  $y$ -axis points upward. Cylindrical coordinates  $(r, \phi)$  are used in the transverse plane,  $\phi$  being the azimuthal angle around the beam pipe. The pseudorapidity is defined in terms of the polar angle  $\theta$  as  $\eta = -2 \ln \tan(\theta/2)$ .
- [54] G. Corcella et al., J. High Energy Phys. **01** (2001) 010.
- [55] ATLAS Collaboration, ATL-PHYS-PUB-2011-014. <https://cds.cern.ch/record/1400677>.
- [56] ATLAS Collaboration, ATL-PHYS-PUB-2011-009. <https://cds.cern.ch/record/1363300>.
- [57] ATLAS Collaboration, ATL-PHYS-PUB-2011-008. <https://cds.cern.ch/record/1345343>.
- [58] V. Khachatryan et al. [CMS Collaboration], Eur. Phys. J. C **75**, no. 5, 212 (2015) [arXiv:1412.8662 \[hep-ex\]](#).

# The ATLAS Collaboration

G. Aad<sup>85</sup>, B. Abbott<sup>113</sup>, J. Abdallah<sup>152</sup>, O. Abidinov<sup>11</sup>, R. Aben<sup>107</sup>, M. Abolins<sup>90</sup>, O.S. AbouZeid<sup>159</sup>, H. Abramowicz<sup>154</sup>, H. Abreu<sup>153</sup>, R. Abreu<sup>30</sup>, Y. Abulaiti<sup>147a,147b</sup>, B.S. Acharya<sup>165a,165b,a</sup>, L. Adamczyk<sup>38a</sup>, D.L. Adams<sup>25</sup>, J. Adelman<sup>108</sup>, S. Adomeit<sup>100</sup>, T. Adye<sup>131</sup>, A.A. Affolder<sup>74</sup>, T. Agatonovic-Jovin<sup>13</sup>, J.A. Aguilar-Saavedra<sup>126a,126f</sup>, M. Agustoni<sup>17</sup>, S.P. Ahlen<sup>22</sup>, F. Ahmadov<sup>65,b</sup>, G. Aielli<sup>134a,134b</sup>, H. Akerstedt<sup>147a,147b</sup>, T.P.A. Åkesson<sup>81</sup>, G. Akimoto<sup>156</sup>, A.V. Akimov<sup>96</sup>, G.L. Alberghi<sup>20a,20b</sup>, J. Albert<sup>170</sup>, S. Albrand<sup>55</sup>, M.J. Alconada Verzini<sup>71</sup>, M. Aleksa<sup>30</sup>, I.N. Aleksandrov<sup>65</sup>, C. Alexa<sup>26a</sup>, G. Alexander<sup>154</sup>, T. Alexopoulos<sup>10</sup>, M. Alhroob<sup>113</sup>, G. Alimonti<sup>91a</sup>, L. Alio<sup>85</sup>, J. Alison<sup>31</sup>, S.P. Alkire<sup>35</sup>, B.M.M. Allbrooke<sup>18</sup>, P.P. Allport<sup>74</sup>, A. Aloisio<sup>104a,104b</sup>, A. Alonso<sup>36</sup>, F. Alonso<sup>71</sup>, C. Alpigiani<sup>76</sup>, A. Altheimer<sup>35</sup>, B. Alvarez Gonzalez<sup>90</sup>, D. Álvarez Piqueras<sup>168</sup>, M.G. Alviggi<sup>104a,104b</sup>, K. Amako<sup>66</sup>, Y. Amaral Coutinho<sup>24a</sup>, C. Amelung<sup>23</sup>, D. Amidei<sup>89</sup>, S.P. Amor Dos Santos<sup>126a,126c</sup>, A. Amorim<sup>126a,126b</sup>, S. Amoroso<sup>48</sup>, N. Amram<sup>154</sup>, G. Amundsen<sup>23</sup>, C. Anastopoulos<sup>140</sup>, L.S. Ancu<sup>49</sup>, N. Andari<sup>30</sup>, T. Andeen<sup>35</sup>, C.F. Anders<sup>58b</sup>, G. Anders<sup>30</sup>, K.J. Anderson<sup>31</sup>, A. Andreazza<sup>91a,91b</sup>, V. Andrei<sup>58a</sup>, S. Angelidakis<sup>9</sup>, I. Angelozzi<sup>107</sup>, P. Anger<sup>44</sup>, A. Angerami<sup>35</sup>, F. Anghinolfi<sup>30</sup>, A.V. Anisenkov<sup>109,c</sup>, N. Anjos<sup>12</sup>, A. Annovi<sup>124a,124b</sup>, M. Antonelli<sup>47</sup>, A. Antonov<sup>98</sup>, J. Antos<sup>145b</sup>, F. Anulli<sup>133a</sup>, M. Aoki<sup>66</sup>, L. Aperio Bella<sup>18</sup>, G. Arabidze<sup>90</sup>, Y. Arai<sup>66</sup>, J.P. Araque<sup>126a</sup>, A.T.H. Arce<sup>45</sup>, F.A. Arduh<sup>71</sup>, J-F. Arguin<sup>95</sup>, S. Argyropoulos<sup>42</sup>, M. Arik<sup>19a</sup>, A.J. Armbruster<sup>30</sup>, O. Arnaez<sup>30</sup>, V. Arnal<sup>82</sup>, H. Arnold<sup>48</sup>, M. Arratia<sup>28</sup>, O. Arslan<sup>21</sup>, A. Artamonov<sup>97</sup>, G. Artoni<sup>23</sup>, S. Asai<sup>156</sup>, N. Asbah<sup>42</sup>, A. Ashkenazi<sup>154</sup>, B. Åsman<sup>147a,147b</sup>, L. Asquith<sup>150</sup>, K. Assamagan<sup>25</sup>, R. Astalos<sup>145a</sup>, M. Atkinson<sup>166</sup>, N.B. Atlay<sup>142</sup>, B. Auerbach<sup>6</sup>, K. Augsten<sup>128</sup>, M. Auresseau<sup>146b</sup>, G. Avolio<sup>30</sup>, B. Axen<sup>15</sup>, M.K. Ayoub<sup>117</sup>, G. Azuelos<sup>95,d</sup>, M.A. Baak<sup>30</sup>, A.E. Baas<sup>58a</sup>, C. Bacci<sup>135a,135b</sup>, H. Bachacou<sup>137</sup>, K. Bachas<sup>155</sup>, M. Backes<sup>30</sup>, M. Backhaus<sup>30</sup>, E. Badescu<sup>26a</sup>, P. Bagiacchi<sup>133a,133b</sup>, P. Bagnaia<sup>133a,133b</sup>, Y. Bai<sup>33a</sup>, T. Bain<sup>35</sup>, J.T. Baines<sup>131</sup>, O.K. Baker<sup>177</sup>, P. Balek<sup>129</sup>, T. Balestri<sup>149</sup>, F. Balli<sup>84</sup>, E. Banas<sup>39</sup>, Sw. Banerjee<sup>174</sup>, A.A.E. Bannoura<sup>176</sup>, H.S. Bansil<sup>18</sup>, L. Barak<sup>30</sup>, S.P. Baranov<sup>96</sup>, E.L. Barberio<sup>88</sup>, D. Barberis<sup>50a,50b</sup>, M. Barbero<sup>85</sup>, T. Barillari<sup>101</sup>, M. Barisonzi<sup>165a,165b</sup>, T. Barklow<sup>144</sup>, N. Barlow<sup>28</sup>, S.L. Barnes<sup>84</sup>, B.M. Barnett<sup>131</sup>, R.M. Barnett<sup>15</sup>, Z. Barnovska<sup>5</sup>, A. Baroncelli<sup>135a</sup>, G. Barone<sup>49</sup>, A.J. Barr<sup>120</sup>, F. Barreiro<sup>82</sup>, J. Barreiro Guimarães da Costa<sup>57</sup>, R. Bartoldus<sup>144</sup>, A.E. Barton<sup>72</sup>, P. Bartos<sup>145a</sup>, A. Bassalat<sup>117</sup>, A. Basye<sup>166</sup>, R.L. Bates<sup>53</sup>, S.J. Batista<sup>159</sup>, J.R. Batley<sup>28</sup>, M. Battaglia<sup>138</sup>, M. Bauge<sup>133a,133b</sup>, F. Bauer<sup>137</sup>, H.S. Bawa<sup>144,e</sup>, J.B. Beacham<sup>111</sup>, M.D. Beattie<sup>72</sup>, T. Beau<sup>80</sup>, P.H. Beauchemin<sup>162</sup>, R. Beccherle<sup>124a,124b</sup>, P. Bechtel<sup>21</sup>, H.P. Beck<sup>17,f</sup>, K. Becker<sup>120</sup>, M. Becker<sup>83</sup>, S. Becker<sup>100</sup>, M. Beckingham<sup>171</sup>, C. Becot<sup>117</sup>, A.J. Beddall<sup>19c</sup>, A. Beddall<sup>19c</sup>, V.A. Bednyakov<sup>65</sup>, C.P. Bee<sup>149</sup>, L.J. Beemster<sup>107</sup>, T.A. Beermann<sup>176</sup>, M. Begel<sup>25</sup>, J.K. Behr<sup>120</sup>, C. Belanger-Champagne<sup>87</sup>, W.H. Bell<sup>49</sup>, G. Bella<sup>154</sup>, L. Bellagamba<sup>20a</sup>, A. Bellerive<sup>29</sup>, M. Bellomo<sup>86</sup>, K. Belotskiy<sup>98</sup>, O. Beltramello<sup>30</sup>, O. Benary<sup>154</sup>, D. Benchekroun<sup>136a</sup>, M. Bender<sup>100</sup>, K. Bendtz<sup>147a,147b</sup>, N. Benekos<sup>10</sup>, Y. Benhammou<sup>154</sup>, E. Benhar Nocchioli<sup>49</sup>, J.A. Benitez Garcia<sup>160b</sup>, D.P. Benjamin<sup>45</sup>, J.R. Bensinger<sup>23</sup>, S. Bentvelsen<sup>107</sup>, L. Beresford<sup>120</sup>, M. Beretta<sup>47</sup>, D. Berge<sup>107</sup>, E. Bergeaas Kuutmann<sup>167</sup>, N. Berger<sup>5</sup>, F. Berghaus<sup>170</sup>, J. Beringer<sup>15</sup>, C. Bernard<sup>22</sup>, N.R. Bernard<sup>86</sup>, C. Bernius<sup>110</sup>, F.U. Bernlochner<sup>21</sup>, T. Berry<sup>77</sup>, P. Berta<sup>129</sup>, C. Bertella<sup>83</sup>, G. Bertoli<sup>147a,147b</sup>, F. Bertolucci<sup>124a,124b</sup>, C. Bertsche<sup>113</sup>, D. Bertsche<sup>113</sup>, M.I. Besana<sup>91a</sup>, G.J. Besjes<sup>106</sup>, O. Bessidskaia Bylund<sup>147a,147b</sup>, M. Bessner<sup>42</sup>, N. Besson<sup>137</sup>, C. Betancourt<sup>48</sup>, S. Bethke<sup>101</sup>, A.J. Bevan<sup>76</sup>, W. Bhimji<sup>46</sup>, R.M. Bianchi<sup>125</sup>, L. Bianchini<sup>23</sup>, M. Bianco<sup>30</sup>, O. Biebel<sup>100</sup>, S.P. Bieniek<sup>78</sup>, M. Biglietti<sup>135a</sup>, J. Bilbao De Mendizabal<sup>49</sup>, H. Bilokon<sup>47</sup>, M. Bindl<sup>54</sup>, S. Binet<sup>117</sup>, A. Bingul<sup>19c</sup>, C. Bini<sup>133a,133b</sup>, C.W. Black<sup>151</sup>, J.E. Black<sup>144</sup>, K.M. Black<sup>22</sup>, D. Blackburn<sup>139</sup>, R.E. Blair<sup>6</sup>, J.-B. Blanchard<sup>137</sup>, J.E. Blanco<sup>77</sup>, T. Blazek<sup>145a</sup>, I. Bloch<sup>42</sup>, C. Blocker<sup>23</sup>, W. Blum<sup>83,\*</sup>, U. Blumenschein<sup>54</sup>, G.J. Bobbink<sup>107</sup>, V.S. Bobrovnikov<sup>109,c</sup>, S.S. Bocchetta<sup>81</sup>, A. Bocci<sup>45</sup>, C. Bock<sup>100</sup>, M. Boehler<sup>48</sup>, J.A. Bogaerts<sup>30</sup>, A.G. Bogdanchikov<sup>109</sup>, C. Bohm<sup>147a</sup>, V. Boisvert<sup>77</sup>, T. Bold<sup>38a</sup>, V. Boldea<sup>26a</sup>, A.S. Boldyrev<sup>99</sup>, M. Bomben<sup>80</sup>, M. Bona<sup>76</sup>, M. Boonekamp<sup>137</sup>, A. Borisov<sup>130</sup>, G. Borissov<sup>72</sup>, S. Borroni<sup>42</sup>, J. Bortfeldt<sup>100</sup>, V. Bortolotto<sup>60a,60b,60c</sup>, K. Bos<sup>107</sup>, D. Boscherini<sup>20a</sup>, M. Bosman<sup>12</sup>, J. Boudreau<sup>125</sup>, J. Bouffard<sup>2</sup>, E.V. Bouhova-Thacker<sup>72</sup>, D. Boumediene<sup>34</sup>, C. Bourdarios<sup>117</sup>, N. Bousson<sup>114</sup>, A. Boveia<sup>30</sup>, J. Boyd<sup>30</sup>, I.R. Boyko<sup>65</sup>, I. Bozic<sup>13</sup>, J. Bracinik<sup>18</sup>, A. Brandt<sup>8</sup>, G. Brandt<sup>15</sup>, O. Brandt<sup>58a</sup>, U. Bratzler<sup>157</sup>, B. Brau<sup>86</sup>, J.E. Brau<sup>116</sup>, H.M. Braun<sup>176,\*</sup>, S.F. Brazzale<sup>165a,165c</sup>, K. Brendlinger<sup>122</sup>, A.J. Brennan<sup>88</sup>, L. Brenner<sup>107</sup>, R. Brenner<sup>167</sup>, S. Bressler<sup>173</sup>, K. Bristow<sup>146c</sup>, T.M. Bristow<sup>46</sup>, D. Britton<sup>53</sup>, D. Britzger<sup>42</sup>, F.M. Brochu<sup>28</sup>, I. Brock<sup>21</sup>, R. Brock<sup>90</sup>, J. Bronner<sup>101</sup>, G. Brooijmans<sup>35</sup>, T. Brooks<sup>77</sup>, W.K. Brooks<sup>32b</sup>, J. Brosamer<sup>15</sup>, E. Brost<sup>116</sup>, J. Brown<sup>55</sup>, P.A. Bruckman de Renstrom<sup>39</sup>, D. Bruncko<sup>145b</sup>, R. Brunelieire<sup>48</sup>, A. Bruni<sup>20a</sup>, G. Bruni<sup>20a</sup>, M. Bruschi<sup>20a</sup>, L. Bryngemark<sup>81</sup>, T. Buanes<sup>14</sup>, Q. Buat<sup>143</sup>, P. Buchholz<sup>142</sup>, A.G. Buckley<sup>53</sup>, S.I. Buda<sup>26a</sup>, I.A. Budagov<sup>65</sup>, F. Buehrer<sup>48</sup>, L. Bugge<sup>119</sup>, M.K. Bugge<sup>119</sup>, O. Bulekov<sup>98</sup>, H. Burckhart<sup>30</sup>, S. Burdin<sup>74</sup>, B. Burghgrave<sup>108</sup>, S. Burke<sup>131</sup>, I. Burmeister<sup>43</sup>, E. Busato<sup>34</sup>, D. Büscher<sup>48</sup>, V. Büscher<sup>83</sup>, P. Bussey<sup>53</sup>, C.P. Buszello<sup>167</sup>, J.M. Butler<sup>22</sup>, A.I. Butt<sup>3</sup>, C.M. Buttar<sup>53</sup>, J.M. Butterworth<sup>78</sup>, P. Butti<sup>107</sup>, W. Buttinger<sup>25</sup>, A. Buzatu<sup>53</sup>, R. Buzykaev<sup>109,c</sup>, S. Cabrera Urbán<sup>168</sup>, D. Caforio<sup>128</sup>, O. Cakir<sup>4a</sup>, P. Calafiura<sup>15</sup>, A. Calandri<sup>137</sup>, G. Calderini<sup>80</sup>, P. Calfayan<sup>100</sup>,



L.P. Caloba<sup>24a</sup>, D. Calvet<sup>34</sup>, S. Calvet<sup>34</sup>, R. Camacho Toro<sup>49</sup>, S. Camarda<sup>42</sup>, D. Cameron<sup>119</sup>, L.M. Caminada<sup>15</sup>, R. Caminal Armadans<sup>12</sup>, S. Campana<sup>30</sup>, M. Campanelli<sup>78</sup>, A. Campoverde<sup>149</sup>, V. Canale<sup>104a,104b</sup>, A. Canepa<sup>160a</sup>, M. Cano Bret<sup>76</sup>, J. Cantero<sup>82</sup>, R. Cantrill<sup>126a</sup>, T. Cao<sup>40</sup>, M.D.M. Capeans Garrido<sup>30</sup>, I. Caprini<sup>26a</sup>, M. Caprini<sup>26a</sup>, M. Capua<sup>37a,37b</sup>, R. Caputo<sup>83</sup>, R. Cardarelli<sup>134a</sup>, T. Carli<sup>30</sup>, G. Carlino<sup>104a</sup>, L. Carminati<sup>91a,91b</sup>, S. Caron<sup>106</sup>, E. Carquin<sup>32a</sup>, G.D. Carrillo-Montoya<sup>8</sup>, J.R. Carter<sup>28</sup>, J. Carvalho<sup>126a,126c</sup>, D. Casadei<sup>78</sup>, M.P. Casado<sup>12</sup>, M. Casolino<sup>12</sup>, E. Castaneda-Miranda<sup>146b</sup>, A. Castelli<sup>107</sup>, V. Castillo Gimenez<sup>168</sup>, N.F. Castro<sup>126a,g</sup>, P. Catastini<sup>57</sup>, A. Catinaccio<sup>30</sup>, J.R. Catmore<sup>119</sup>, A. Cattai<sup>30</sup>, J. Caudron<sup>83</sup>, V. Cavaliere<sup>166</sup>, D. Cavalli<sup>91a</sup>, M. Cavalli-Sforza<sup>12</sup>, V. Cavasinni<sup>124a,124b</sup>, F. Ceradini<sup>135a,135b</sup>, B.C. Cerio<sup>45</sup>, K. Cerny<sup>129</sup>, A.S. Cerqueira<sup>24b</sup>, A. Cerri<sup>150</sup>, L. Cerrito<sup>76</sup>, F. Cerutti<sup>15</sup>, M. Cerv<sup>30</sup>, A. Cervelli<sup>17</sup>, S.A. Cetin<sup>19b</sup>, A. Chafaq<sup>136a</sup>, D. Chakraborty<sup>108</sup>, I. Chalupkova<sup>129</sup>, P. Chang<sup>166</sup>, B. Chapleau<sup>87</sup>, J.D. Chapman<sup>28</sup>, D.G. Charlton<sup>18</sup>, C.C. Chau<sup>159</sup>, C.A. Chavez Barajas<sup>150</sup>, S. Cheatham<sup>153</sup>, A. Chegwiddden<sup>90</sup>, S. Chekanov<sup>6</sup>, S.V. Chekulaev<sup>160a</sup>, G.A. Chelkov<sup>65,h</sup>, M.A. Chelstowska<sup>89</sup>, C. Chen<sup>64</sup>, H. Chen<sup>25</sup>, K. Chen<sup>149</sup>, L. Chen<sup>33d,i</sup>, S. Chen<sup>33c</sup>, X. Chen<sup>33f</sup>, Y. Chen<sup>67</sup>, H.C. Cheng<sup>89</sup>, Y. Cheng<sup>31</sup>, A. Cheplakov<sup>65</sup>, E. Cheremushkina<sup>130</sup>, R. Cherkaoui El Moursli<sup>136e</sup>, V. Chernyatin<sup>25,\*</sup>, E. Cheu<sup>7</sup>, L. Chevalier<sup>137</sup>, V. Chiarella<sup>47</sup>, J.T. Childers<sup>6</sup>, G. Chiodini<sup>73a</sup>, A.S. Chisholm<sup>18</sup>, R.T. Chislett<sup>78</sup>, A. Chitan<sup>26a</sup>, M.V. Chizhov<sup>65</sup>, K. Choi<sup>61</sup>, S. Chouridou<sup>9</sup>, B.K.B. Chow<sup>100</sup>, V. Christodoulou<sup>78</sup>, D. Chromek-Burckhart<sup>30</sup>, M.L. Chu<sup>152</sup>, J. Chudoba<sup>127</sup>, A.J. Chuinard<sup>87</sup>, J.J. Chwastowski<sup>39</sup>, L. Chytka<sup>115</sup>, G. Ciapetti<sup>133a,133b</sup>, A.K. Ciftci<sup>4a</sup>, D. Cinca<sup>53</sup>, V. Cindro<sup>75</sup>, I.A. Cioara<sup>21</sup>, A. Ciocio<sup>15</sup>, Z.H. Citron<sup>173</sup>, M. Ciubancan<sup>26a</sup>, A. Clark<sup>49</sup>, B.L. Clark<sup>57</sup>, P.J. Clark<sup>46</sup>, R.N. Clarke<sup>15</sup>, W. Cleland<sup>125</sup>, C. Clement<sup>147a,147b</sup>, Y. Coadou<sup>85</sup>, M. Cobal<sup>165a,165c</sup>, A. Coccaro<sup>139</sup>, J. Cochran<sup>64</sup>, L. Coffey<sup>23</sup>, J.G. Cogan<sup>144</sup>, B. Cole<sup>35</sup>, S. Cole<sup>108</sup>, A.P. Colijn<sup>107</sup>, J. Collot<sup>55</sup>, T. Colombo<sup>58c</sup>, G. Compostella<sup>101</sup>, P. Conde Muiño<sup>126a,126b</sup>, E. Coniavitis<sup>48</sup>, S.H. Connell<sup>146b</sup>, I.A. Connelly<sup>77</sup>, S.M. Consonni<sup>91a,91b</sup>, V. Consorti<sup>48</sup>, S. Constantinescu<sup>26a</sup>, C. Conta<sup>121a,121b</sup>, G. Conti<sup>30</sup>, F. Conventi<sup>104a,j</sup>, M. Cooke<sup>15</sup>, B.D. Cooper<sup>78</sup>, A.M. Cooper-Sarkar<sup>120</sup>, K. Copic<sup>15</sup>, T. Cornelissen<sup>176</sup>, M. Corradi<sup>20a</sup>, F. Corriveau<sup>87,k</sup>, A. Corso-Radu<sup>164</sup>, A. Cortes-Gonzalez<sup>12</sup>, G. Cortiana<sup>101</sup>, G. Costa<sup>91a</sup>, M.J. Costa<sup>168</sup>, D. Costanzo<sup>140</sup>, D. Côté<sup>8</sup>, G. Cottin<sup>28</sup>, G. Cowan<sup>77</sup>, B.E. Cox<sup>84</sup>, K. Crammer<sup>110</sup>, G. Cree<sup>29</sup>, S. Crépe-Renaudin<sup>55</sup>, F. Crescioli<sup>80</sup>, W.A. Cribbs<sup>147a,147b</sup>, M. Crispin Ortuzar<sup>120</sup>, M. Cristinziani<sup>21</sup>, V. Croft<sup>106</sup>, G. Crosetti<sup>37a,37b</sup>, T. Cuhadar Donszelmann<sup>140</sup>, J. Cummings<sup>177</sup>, M. Curatolo<sup>47</sup>, C. Cuthbert<sup>151</sup>, H. Czirr<sup>142</sup>, P. Czodrowski<sup>3</sup>, S. D'Auria<sup>53</sup>, M. D'Onofrio<sup>74</sup>, M.J. Da Cunha Sargedas De Sousa<sup>126a,126b</sup>, C. Da Via<sup>84</sup>, W. Dabrowski<sup>38a</sup>, A. Dafinca<sup>120</sup>, T. Dai<sup>89</sup>, O. Dale<sup>14</sup>, F. Dallaire<sup>95</sup>, C. Dallapiccola<sup>86</sup>, M. Dam<sup>36</sup>, J.R. Dandoy<sup>31</sup>, A.C. Daniells<sup>18</sup>, M. Danninger<sup>169</sup>, M. Dano Hoffmann<sup>137</sup>, V. Dao<sup>48</sup>, G. Darbo<sup>50a</sup>, S. Darmora<sup>8</sup>, J. Dassoulas<sup>3</sup>, A. Dattagupta<sup>61</sup>, W. Davey<sup>21</sup>, C. David<sup>170</sup>, T. Davidek<sup>129</sup>, E. Davies<sup>120,l</sup>, M. Davies<sup>154</sup>, P. Davison<sup>78</sup>, Y. Davygora<sup>58a</sup>, E. Dawe<sup>88</sup>, I. Dawson<sup>140</sup>, R.K. Daya-Ishmukhametova<sup>86</sup>, K. De<sup>8</sup>, R. de Asmundis<sup>104a</sup>, S. De Castro<sup>20a,20b</sup>, S. De Cecco<sup>80</sup>, N. De Groot<sup>106</sup>, P. de Jong<sup>107</sup>, H. De la Torre<sup>82</sup>, F. De Lorenzi<sup>64</sup>, L. De Nooij<sup>107</sup>, D. De Pedis<sup>133a</sup>, A. De Salvo<sup>133a</sup>, U. De Sanctis<sup>150</sup>, A. De Santo<sup>150</sup>, J.B. De Vivie De Regie<sup>117</sup>, W.J. Dearnaley<sup>72</sup>, R. Debbe<sup>25</sup>, C. Debenedetti<sup>138</sup>, D.V. Dedovich<sup>65</sup>, I. Deigaard<sup>107</sup>, J. Del Peso<sup>82</sup>, T. Del Prete<sup>124a,124b</sup>, D. Delgove<sup>117</sup>, F. Deliot<sup>137</sup>, C.M. Delitzsch<sup>49</sup>, M. Deliyergiyev<sup>75</sup>, A. Dell'Acqua<sup>30</sup>, L. Dell'Asta<sup>22</sup>, M. Dell'Orso<sup>124a,124b</sup>, M. Della Pietra<sup>104a,j</sup>, D. della Volpe<sup>49</sup>, M. Delmastro<sup>5</sup>, P.A. Delsart<sup>55</sup>, C. Deluca<sup>107</sup>, D.A. DeMarco<sup>159</sup>, S. Demers<sup>177</sup>, M. Demichev<sup>65</sup>, A. Demilly<sup>80</sup>, S.P. Denisov<sup>130</sup>, D. Derendarz<sup>39</sup>, J.E. Derkaoui<sup>136d</sup>, F. Derue<sup>80</sup>, P. Dervan<sup>74</sup>, K. Desch<sup>21</sup>, C. Deterre<sup>42</sup>, P.O. Deviveiros<sup>30</sup>, A. Dewhurst<sup>131</sup>, S. Dhaliwal<sup>107</sup>, A. Di Ciaccio<sup>134a,134b</sup>, L. Di Ciaccio<sup>5</sup>, A. Di Domenico<sup>133a,133b</sup>, C. Di Donato<sup>104a,104b</sup>, A. Di Girolamo<sup>30</sup>, B. Di Girolamo<sup>30</sup>, A. Di Mattia<sup>153</sup>, B. Di Micco<sup>135a,135b</sup>, R. Di Nardo<sup>47</sup>, A. Di Simone<sup>48</sup>, R. Di Sipio<sup>159</sup>, D. Di Valentino<sup>29</sup>, C. Diaconu<sup>85</sup>, M. Diamond<sup>159</sup>, F.A. Dias<sup>46</sup>, M.A. Diaz<sup>32a</sup>, E.B. Diehl<sup>89</sup>, J. Dietrich<sup>16</sup>, S. Diglio<sup>85</sup>, A. Dimitrievska<sup>13</sup>, J. Dingfelder<sup>21</sup>, P. Dita<sup>26a</sup>, S. Dita<sup>26a</sup>, F. Dittus<sup>30</sup>, F. Djama<sup>85</sup>, T. Djobava<sup>51b</sup>, J.I. Djuvsland<sup>58a</sup>, M.A.B. do Vale<sup>24c</sup>, D. Dobos<sup>30</sup>, M. Dobre<sup>26a</sup>, C. Doglioni<sup>49</sup>, T. Dohmae<sup>156</sup>, J. Dolejsi<sup>129</sup>, Z. Dolezal<sup>129</sup>, B.A. Dolgoshein<sup>98,\*</sup>, M. Donadelli<sup>24d</sup>, S. Donati<sup>124a,124b</sup>, P. Dondero<sup>121a,121b</sup>, J. Donini<sup>34</sup>, J. Dopke<sup>131</sup>, A. Doria<sup>104a</sup>, M.T. Dova<sup>71</sup>, A.T. Doyle<sup>53</sup>, E. Drechsler<sup>54</sup>, M. Dris<sup>10</sup>, E. Dubreuil<sup>34</sup>, E. Duchovni<sup>173</sup>, G. Duckeck<sup>100</sup>, O.A. Ducu<sup>26a,85</sup>, D. Duda<sup>176</sup>, A. Dudarev<sup>30</sup>, L. Dufflot<sup>117</sup>, L. Duguid<sup>77</sup>, M. Dührssen<sup>30</sup>, M. Dunford<sup>58a</sup>, H. Duran Yildiz<sup>4a</sup>, M. Düren<sup>52</sup>, A. Durglishvili<sup>51b</sup>, D. Duschinger<sup>44</sup>, M. Dyndal<sup>38a</sup>, C. Eckardt<sup>42</sup>, K.M. Ecker<sup>101</sup>, W. Edson<sup>2</sup>, N.C. Edwards<sup>46</sup>, W. Ehrenfeld<sup>21</sup>, T. Eifert<sup>30</sup>, G. Eigen<sup>14</sup>, K. Einsweiler<sup>15</sup>, T. Ekelof<sup>167</sup>, M. El Kacimi<sup>136c</sup>, M. Ellert<sup>167</sup>, S. Elles<sup>5</sup>, F. Ellinghaus<sup>83</sup>, A.A. Elliot<sup>170</sup>, N. Ellis<sup>30</sup>, J. Elmsheuser<sup>100</sup>, M. Elsing<sup>30</sup>, D. Emelianov<sup>131</sup>, Y. Enari<sup>156</sup>, O.C. Endner<sup>83</sup>, M. Endo<sup>118</sup>, R. Engelmann<sup>149</sup>, J. Erdmann<sup>43</sup>, A. Ereditato<sup>17</sup>, G. Ernis<sup>176</sup>, J. Ernst<sup>2</sup>, M. Ernst<sup>25</sup>, S. Errede<sup>166</sup>, E. Ertel<sup>83</sup>, M. Escalier<sup>117</sup>, H. Esch<sup>43</sup>, C. Escobar<sup>125</sup>, B. Esposito<sup>47</sup>, A.I. Etienvre<sup>137</sup>, E. Etzion<sup>154</sup>, H. Evans<sup>61</sup>, A. Ezhilov<sup>123</sup>, L. Fabbri<sup>20a,20b</sup>, G. Facini<sup>31</sup>, R.M. Fakhruddinov<sup>130</sup>, S. Falciano<sup>133a</sup>, R.J. Falla<sup>78</sup>, J. Faltova<sup>129</sup>, Y. Fang<sup>33a</sup>, M. Fanti<sup>91a,91b</sup>, A. Farbin<sup>8</sup>, A. Farilla<sup>135a</sup>, T. Farooque<sup>12</sup>, S. Farrell<sup>15</sup>, S.M. Farrington<sup>171</sup>, P. Farthouat<sup>30</sup>, F. Fassi<sup>136e</sup>, P. Fassnacht<sup>30</sup>, D. Fassouliotis<sup>9</sup>, M. Fauci Giannelli<sup>77</sup>, A. Favareto<sup>50a,50b</sup>, L. Fayard<sup>117</sup>, P. Federic<sup>145a</sup>, O.L. Fedin<sup>123,m</sup>, W. Fedorko<sup>169</sup>, S. Feigl<sup>30</sup>, L. Feligioni<sup>85</sup>, C. Feng<sup>33d</sup>, E.J. Feng<sup>6</sup>, H. Feng<sup>89</sup>, A.B. Fenyuk<sup>130</sup>, P. Fernandez Martinez<sup>168</sup>, S. Fernandez Perez<sup>30</sup>, S. Ferrag<sup>53</sup>, J. Ferrando<sup>53</sup>, A. Ferrari<sup>167</sup>, P. Ferrari<sup>107</sup>,

R. Ferrari<sup>121a</sup>, D.E. Ferreira de Lima<sup>53</sup>, A. Ferrer<sup>168</sup>, D. Ferrere<sup>49</sup>, C. Ferretti<sup>89</sup>, A. Ferretto Parodi<sup>50a,50b</sup>, M. Fiascaris<sup>31</sup>, F. Fiedler<sup>83</sup>, A. Filipčić<sup>75</sup>, M. Filipuzzi<sup>42</sup>, F. Filthaut<sup>106</sup>, M. Fincke-Keeler<sup>170</sup>, K.D. Finelli<sup>151</sup>, M.C.N. Fiolhais<sup>126a,126c</sup>, L. Fiorini<sup>168</sup>, A. Firan<sup>40</sup>, A. Fischer<sup>2</sup>, C. Fischer<sup>12</sup>, J. Fischer<sup>176</sup>, W.C. Fisher<sup>90</sup>, E.A. Fitzgerald<sup>23</sup>, M. Flechl<sup>48</sup>, I. Fleck<sup>142</sup>, P. Fleischmann<sup>89</sup>, S. Fleischmann<sup>176</sup>, G.T. Fletcher<sup>140</sup>, G. Fletcher<sup>76</sup>, T. Flick<sup>176</sup>, A. Floderus<sup>81</sup>, L.R. Flores Castillo<sup>60a</sup>, M.J. Flowerdew<sup>101</sup>, A. Formica<sup>137</sup>, A. Forti<sup>84</sup>, D. Fournier<sup>117</sup>, H. Fox<sup>72</sup>, S. Fracchia<sup>12</sup>, P. Francavilla<sup>80</sup>, M. Franchini<sup>20a,20b</sup>, D. Francis<sup>30</sup>, L. Franconi<sup>119</sup>, M. Franklin<sup>57</sup>, M. Fraternali<sup>121a,121b</sup>, D. Freeborn<sup>78</sup>, S.T. French<sup>28</sup>, F. Friedrich<sup>44</sup>, D. Froidevaux<sup>30</sup>, J.A. Frost<sup>120</sup>, C. Fukunaga<sup>157</sup>, E. Fullana Torregrosa<sup>83</sup>, B.G. Fulsom<sup>144</sup>, J. Fuster<sup>168</sup>, C. Gabaldon<sup>55</sup>, O. Gabizon<sup>176</sup>, A. Gabrielli<sup>20a,20b</sup>, A. Gabrielli<sup>133a,133b</sup>, S. Gadatsch<sup>107</sup>, S. Gadomski<sup>49</sup>, G. Gagliardi<sup>50a,50b</sup>, P. Gagnon<sup>61</sup>, C. Galea<sup>106</sup>, B. Galhardo<sup>126a,126c</sup>, E.J. Gallas<sup>120</sup>, B.J. Gallop<sup>131</sup>, P. Gallus<sup>128</sup>, G. Galster<sup>36</sup>, K.K. Gan<sup>111</sup>, J. Gao<sup>33b,85</sup>, Y. Gao<sup>46</sup>, Y.S. Gao<sup>144,e</sup>, F.M. Garay Walls<sup>46</sup>, F. Garbersen<sup>177</sup>, C. García<sup>168</sup>, J.E. García Navarro<sup>168</sup>, M. Garcia-Sciveres<sup>15</sup>, R.W. Gardner<sup>31</sup>, N. Garelli<sup>144</sup>, V. Garonne<sup>119</sup>, C. Gatti<sup>47</sup>, A. Gaudiello<sup>50a,50b</sup>, G. Gaudio<sup>121a</sup>, B. Gaur<sup>142</sup>, L. Gauthier<sup>95</sup>, P. Gauzzi<sup>133a,133b</sup>, I.L. Gavrilenko<sup>96</sup>, C. Gay<sup>169</sup>, G. Gaycken<sup>21</sup>, E.N. Gazis<sup>10</sup>, P. Ge<sup>33d</sup>, Z. Gecse<sup>169</sup>, C.N.P. Gee<sup>131</sup>, D.A.A. Geerts<sup>107</sup>, Ch. Geich-Gimbel<sup>21</sup>, M.P. Geisler<sup>58a</sup>, C. Gemme<sup>50a</sup>, M.H. Genest<sup>55</sup>, S. Gentile<sup>133a,133b</sup>, M. George<sup>54</sup>, S. George<sup>77</sup>, D. Gerbaudo<sup>164</sup>, A. Gershon<sup>154</sup>, H. Ghazlane<sup>136b</sup>, B. Giacobbe<sup>20a</sup>, S. Giagu<sup>133a,133b</sup>, V. Giangiobbe<sup>12</sup>, P. Giannetti<sup>124a,124b</sup>, B. Gibbard<sup>25</sup>, S.M. Gibson<sup>77</sup>, M. Gilchriese<sup>15</sup>, T.P.S. Gillam<sup>28</sup>, D. Gillberg<sup>30</sup>, G. Gilles<sup>34</sup>, D.M. Gingrich<sup>3,d</sup>, N. Giokaris<sup>9</sup>, M.P. Giordani<sup>165a,165c</sup>, F.M. Giorgi<sup>20a</sup>, F.M. Giorgi<sup>16</sup>, P.F. Giraud<sup>137</sup>, P. Giromini<sup>47</sup>, D. Giugni<sup>91a</sup>, C. Giuliani<sup>48</sup>, M. Giulini<sup>58b</sup>, B.K. Gjelsten<sup>119</sup>, S. Gkaitatzis<sup>155</sup>, I. Gkialas<sup>155</sup>, E.L. Gkoukousis<sup>117</sup>, L.K. Gladilin<sup>99</sup>, C. Glasman<sup>82</sup>, J. Glatzer<sup>30</sup>, P.C.F. Glaysler<sup>46</sup>, A. Glazov<sup>42</sup>, M. Goblirsch-Kolb<sup>101</sup>, J.R. Goddard<sup>76</sup>, J. Godlewski<sup>39</sup>, S. Goldfarb<sup>89</sup>, T. Golling<sup>49</sup>, D. Golubkov<sup>130</sup>, A. Gomes<sup>126a,126b,126d</sup>, R. Gonçalo<sup>126a</sup>, J. Goncalves Pinto Firmino Da Costa<sup>137</sup>, L. Gonella<sup>21</sup>, S. González de la Hoz<sup>168</sup>, G. Gonzalez Parra<sup>12</sup>, S. Gonzalez-Sevilla<sup>49</sup>, L. Goossens<sup>30</sup>, P.A. Gorbounov<sup>97</sup>, H.A. Gordon<sup>25</sup>, I. Gorelov<sup>105</sup>, B. Gorini<sup>30</sup>, E. Gorini<sup>73a,73b</sup>, A. Gorišek<sup>75</sup>, E. Gornicki<sup>39</sup>, A.T. Goshaw<sup>45</sup>, C. Gössling<sup>43</sup>, M.I. Gostkin<sup>65</sup>, D. Goujdami<sup>136c</sup>, A.G. Goussiou<sup>139</sup>, N. Govender<sup>146b</sup>, H.M.X. Grabas<sup>138</sup>, L. Graber<sup>54</sup>, I. Grabowska-Bold<sup>38a</sup>, P. Grafström<sup>20a,20b</sup>, K-J. Grahn<sup>42</sup>, J. Gramling<sup>49</sup>, E. Gramstad<sup>119</sup>, S. Grancagnolo<sup>16</sup>, V. Grassi<sup>149</sup>, V. Gratchev<sup>123</sup>, H.M. Gray<sup>30</sup>, E. Graziani<sup>135a</sup>, Z.D. Greenwood<sup>79,n</sup>, K. Gregersen<sup>78</sup>, I.M. Gregor<sup>42</sup>, P. Grenier<sup>144</sup>, J. Griffiths<sup>8</sup>, A.A. Grillo<sup>138</sup>, K. Grimm<sup>72</sup>, S. Grinstein<sup>12,o</sup>, Ph. Gris<sup>34</sup>, J.-F. Grivaz<sup>117</sup>, J.P. Grohs<sup>44</sup>, A. Grohsjean<sup>42</sup>, E. Gross<sup>173</sup>, J. Grosse-Knetter<sup>54</sup>, G.C. Grossi<sup>79</sup>, Z.J. Grout<sup>150</sup>, L. Guan<sup>33b</sup>, J. Guenther<sup>128</sup>, F. Guescini<sup>49</sup>, D. Guest<sup>177</sup>, O. Gueta<sup>154</sup>, E. Guido<sup>50a,50b</sup>, T. Guillemin<sup>117</sup>, S. Guindon<sup>2</sup>, U. Gul<sup>53</sup>, C. Gumpert<sup>44</sup>, J. Guo<sup>33e</sup>, S. Gupta<sup>120</sup>, P. Gutierrez<sup>113</sup>, N.G. Gutierrez Ortiz<sup>53</sup>, C. Gutsche<sup>44</sup>, C. Guyot<sup>137</sup>, C. Gwenlan<sup>120</sup>, C.B. Gwilliam<sup>74</sup>, A. Haas<sup>110</sup>, C. Haber<sup>15</sup>, H.K. Hadavand<sup>8</sup>, N. Haddad<sup>136e</sup>, P. Haefner<sup>21</sup>, S. Hageböck<sup>21</sup>, Z. Hajduk<sup>39</sup>, H. Hakobyan<sup>178</sup>, M. Haleem<sup>42</sup>, J. Haley<sup>114</sup>, D. Hall<sup>120</sup>, G. Halladjian<sup>90</sup>, G.D. Hallewell<sup>85</sup>, K. Hamacher<sup>176</sup>, P. Hamal<sup>115</sup>, K. Hamano<sup>170</sup>, M. Hamer<sup>54</sup>, A. Hamilton<sup>146a</sup>, S. Hamilton<sup>162</sup>, G.N. Hamity<sup>146c</sup>, P.G. Hamnett<sup>42</sup>, L. Han<sup>33b</sup>, K. Hanagaki<sup>118</sup>, K. Hanawa<sup>156</sup>, M. Hance<sup>15</sup>, B. Haney<sup>122</sup>, P. Hanke<sup>58a</sup>, R. Hanna<sup>137</sup>, J.B. Hansen<sup>36</sup>, J.D. Hansen<sup>36</sup>, M.C. Hansen<sup>21</sup>, P.H. Hansen<sup>36</sup>, K. Hara<sup>161</sup>, A.S. Hard<sup>174</sup>, T. Harenberg<sup>176</sup>, F. Hariri<sup>117</sup>, S. Harkusha<sup>92</sup>, R.D. Harrington<sup>46</sup>, P.F. Harrison<sup>171</sup>, F. Hartjes<sup>107</sup>, M. Hasegawa<sup>67</sup>, S. Hasegawa<sup>103</sup>, Y. Hasegawa<sup>141</sup>, A. Hasib<sup>113</sup>, S. Hassani<sup>137</sup>, S. Haug<sup>17</sup>, R. Hauser<sup>90</sup>, L. Hauswald<sup>44</sup>, M. Havranek<sup>127</sup>, C.M. Hawkes<sup>18</sup>, R.J. Hawkings<sup>30</sup>, A.D. Hawkins<sup>81</sup>, T. Hayashi<sup>161</sup>, D. Hayden<sup>90</sup>, C.P. Hays<sup>120</sup>, J.M. Hays<sup>76</sup>, H.S. Hayward<sup>74</sup>, S.J. Haywood<sup>131</sup>, S.J. Head<sup>18</sup>, T. Heck<sup>83</sup>, V. Hedberg<sup>81</sup>, L. Heelan<sup>8</sup>, S. Heim<sup>122</sup>, T. Heim<sup>176</sup>, B. Heinemann<sup>15</sup>, L. Heinrich<sup>110</sup>, J. Hejbal<sup>127</sup>, L. Helary<sup>22</sup>, S. Hellman<sup>147a,147b</sup>, D. Hellmich<sup>21</sup>, C. Helsen<sup>30</sup>, J. Henderson<sup>120</sup>, R.C.W. Henderson<sup>72</sup>, Y. Heng<sup>174</sup>, C. Hengler<sup>42</sup>, A. Henrichs<sup>177</sup>, A.M. Henriques Correia<sup>30</sup>, S. Henrot-Versille<sup>117</sup>, G.H. Herbert<sup>16</sup>, Y. Hernández Jiménez<sup>168</sup>, R. Herrberg-Schubert<sup>16</sup>, G. Herten<sup>48</sup>, R. Hertenberger<sup>100</sup>, L. Hervas<sup>30</sup>, G.G. Hesketh<sup>78</sup>, N.P. Hesse<sup>107</sup>, J.W. Hetherly<sup>40</sup>, R. Hickling<sup>76</sup>, E. Higón-Rodríguez<sup>168</sup>, E. Hill<sup>170</sup>, J.C. Hill<sup>28</sup>, K.H. Hiller<sup>42</sup>, S.J. Hillier<sup>18</sup>, I. Hinchliffe<sup>15</sup>, E. Hines<sup>122</sup>, R.R. Hinman<sup>15</sup>, M. Hirose<sup>158</sup>, D. Hirschbuehl<sup>176</sup>, J. Hobbs<sup>149</sup>, N. Hod<sup>107</sup>, M.C. Hodgkinson<sup>140</sup>, P. Hodgson<sup>140</sup>, A. Hoecker<sup>30</sup>, M.R. Hoferkamp<sup>105</sup>, F. Hoenig<sup>100</sup>, M. Hohlfeld<sup>83</sup>, D. Hohn<sup>21</sup>, T.R. Holmes<sup>15</sup>, T.M. Hong<sup>122</sup>, L. Hooft van Huysduynen<sup>110</sup>, W.H. Hopkins<sup>116</sup>, Y. Horii<sup>103</sup>, A.J. Horton<sup>143</sup>, J.-Y. Hostachy<sup>55</sup>, S. Hou<sup>152</sup>, A. Hoummada<sup>136a</sup>, J. Howard<sup>120</sup>, J. Howarth<sup>42</sup>, M. Hrabovsky<sup>115</sup>, I. Hristova<sup>16</sup>, J. Hrivnac<sup>117</sup>, T. Hryn'ova<sup>5</sup>, A. Hrynevich<sup>93</sup>, C. Hsu<sup>146c</sup>, P.J. Hsu<sup>152,p</sup>, S.-C. Hsu<sup>139</sup>, D. Hu<sup>35</sup>, Q. Hu<sup>33b</sup>, X. Hu<sup>89</sup>, Y. Huang<sup>42</sup>, Z. Hubacek<sup>30</sup>, F. Hubaut<sup>85</sup>, F. Huegging<sup>21</sup>, T.B. Huffman<sup>120</sup>, E.W. Hughes<sup>35</sup>, G. Hughes<sup>72</sup>, M. Huhtinen<sup>30</sup>, T.A. Hülsing<sup>83</sup>, N. Huseynov<sup>65,b</sup>, J. Huston<sup>90</sup>, J. Huth<sup>57</sup>, G. Iacobucci<sup>49</sup>, G. Iakovidis<sup>25</sup>, I. Ibragimov<sup>142</sup>, L. Iconomidou-Fayard<sup>117</sup>, E. Ideal<sup>177</sup>, Z. Idrissi<sup>136e</sup>, P. Iengo<sup>30</sup>, O. Igonkina<sup>107</sup>, T. Iizawa<sup>172</sup>, Y. Ikegami<sup>66</sup>, K. Ikematsu<sup>142</sup>, M. Ikeno<sup>66</sup>, Y. Ilchenko<sup>31,q</sup>, D. Iliadis<sup>155</sup>, N. Ilic<sup>159</sup>, Y. Inamaru<sup>67</sup>, T. Ince<sup>101</sup>, P. Ioannou<sup>9</sup>, M. Iodice<sup>135a</sup>, K. Iordanidou<sup>35</sup>, V. Ippolito<sup>57</sup>, A. Irls Quiles<sup>168</sup>, C. Isaksson<sup>167</sup>, M. Ishino<sup>68</sup>, M. Ishitsuka<sup>158</sup>, R. Ishmukhametov<sup>111</sup>, C. Issever<sup>120</sup>, S. Istin<sup>19a</sup>, J.M. Iturbe Ponce<sup>84</sup>, R. Iuppa<sup>134a,134b</sup>, J. Ivarsson<sup>81</sup>, W. Iwanski<sup>39</sup>, H. Iwasaki<sup>66</sup>, J.M. Izen<sup>41</sup>, V. Izzo<sup>104a</sup>, S. Jabbar<sup>3</sup>, B. Jackson<sup>122</sup>, M. Jackson<sup>74</sup>, P. Jackson<sup>1</sup>, M.R. Jaekel<sup>30</sup>, V. Jain<sup>2</sup>, K. Jakobs<sup>48</sup>,

S. Jakobsen<sup>30</sup>, T. Jakoubek<sup>127</sup>, J. Jakubek<sup>128</sup>, D.O. Jamin<sup>152</sup>, D.K. Jana<sup>79</sup>, E. Jansen<sup>78</sup>, R.W. Jansky<sup>62</sup>,  
 J. Janssen<sup>21</sup>, M. Janus<sup>171</sup>, G. Jarlskog<sup>81</sup>, N. Javadov<sup>65,b</sup>, T. Javůrek<sup>48</sup>, L. Jeanty<sup>15</sup>, J. Jejelava<sup>51a,r</sup>, G.-Y. Jeng<sup>151</sup>,  
 D. Jennens<sup>88</sup>, P. Jenni<sup>48,s</sup>, J. Jentzsch<sup>43</sup>, C. Jeske<sup>171</sup>, S. Jézéquel<sup>5</sup>, H. Ji<sup>174</sup>, J. Jia<sup>149</sup>, Y. Jiang<sup>33b</sup>, S. Jiggins<sup>78</sup>,  
 J. Jimenez Pena<sup>168</sup>, S. Jin<sup>33a</sup>, A. Jinaru<sup>26a</sup>, O. Jinnouchi<sup>158</sup>, M.D. Joergensen<sup>36</sup>, P. Johansson<sup>140</sup>, K.A. Johns<sup>7</sup>,  
 K. Jon-And<sup>147a,147b</sup>, G. Jones<sup>171</sup>, R.W.L. Jones<sup>72</sup>, T.J. Jones<sup>74</sup>, J. Jongmanns<sup>58a</sup>, P.M. Jorge<sup>126a,126b</sup>, K.D. Joshi<sup>84</sup>,  
 J. Jovicevic<sup>160a</sup>, X. Ju<sup>174</sup>, C.A. Jung<sup>43</sup>, P. Jussel<sup>62</sup>, A. Juste Rozas<sup>12,o</sup>, M. Kaci<sup>168</sup>, A. Kaczmarzka<sup>39</sup>, M. Kado<sup>117</sup>,  
 H. Kagan<sup>111</sup>, M. Kagan<sup>144</sup>, S.J. Kahn<sup>85</sup>, E. Kajomovitz<sup>45</sup>, C.W. Kalderon<sup>120</sup>, S. Kama<sup>40</sup>, A. Kamenshchikov<sup>130</sup>,  
 N. Kanaya<sup>156</sup>, M. Kaneda<sup>30</sup>, S. Kaneti<sup>28</sup>, V.A. Kantserov<sup>98</sup>, J. Kanzaki<sup>66</sup>, B. Kaplan<sup>110</sup>, A. Kapliyi<sup>31</sup>, D. Kar<sup>53</sup>,  
 K. Karakostas<sup>10</sup>, A. Karamaoun<sup>3</sup>, N. Karastathis<sup>10,107</sup>, M.J. Kareem<sup>54</sup>, M. Karnevskiy<sup>83</sup>, S.N. Karpov<sup>65</sup>,  
 Z.M. Karpova<sup>65</sup>, K. Karthik<sup>110</sup>, V. Kartvelishvili<sup>72</sup>, A.N. Karyukhin<sup>130</sup>, L. Kashif<sup>174</sup>, R.D. Kass<sup>111</sup>, A. Kastanas<sup>14</sup>,  
 Y. Kataoka<sup>156</sup>, A. Katre<sup>49</sup>, J. Katzy<sup>42</sup>, K. Kawagoe<sup>70</sup>, T. Kawamoto<sup>156</sup>, G. Kawamura<sup>54</sup>, S. Kazama<sup>156</sup>,  
 V.F. Kazanin<sup>109,c</sup>, M.Y. Kazarinov<sup>65</sup>, R. Keeler<sup>170</sup>, R. Kehoe<sup>40</sup>, J.S. Keller<sup>42</sup>, J.J. Kempster<sup>77</sup>, H. Keoshkerian<sup>84</sup>,  
 O. Kepka<sup>127</sup>, B.P. Kerševan<sup>75</sup>, S. Kersten<sup>176</sup>, R.A. Keyes<sup>87</sup>, F. Khalil-zada<sup>11</sup>, H. Khandanyan<sup>147a,147b</sup>,  
 A. Khanov<sup>114</sup>, A.G. Kharlamov<sup>109,c</sup>, T.J. Khoo<sup>28</sup>, V. Khovanskiy<sup>97</sup>, E. Khramov<sup>65</sup>, J. Khubua<sup>51b,t</sup>, H.Y. Kim<sup>8</sup>,  
 H. Kim<sup>147a,147b</sup>, S.H. Kim<sup>161</sup>, Y. Kim<sup>31</sup>, N. Kimura<sup>155</sup>, O.M. Kind<sup>16</sup>, B.T. King<sup>74</sup>, M. King<sup>168</sup>, R.S.B. King<sup>120</sup>,  
 S.B. King<sup>169</sup>, J. Kirk<sup>131</sup>, A.E. Kiryunin<sup>101</sup>, T. Kishimoto<sup>67</sup>, D. Kisielewska<sup>38a</sup>, F. Kiss<sup>48</sup>, K. Kiuchi<sup>161</sup>,  
 O. Kivernyk<sup>137</sup>, E. Kladiva<sup>145b</sup>, M.H. Klein<sup>35</sup>, M. Klein<sup>74</sup>, U. Klein<sup>74</sup>, K. Kleinknecht<sup>83</sup>, P. Klimek<sup>147a,147b</sup>,  
 A. Klimentov<sup>25</sup>, R. Klingenberg<sup>43</sup>, J.A. Klinger<sup>84</sup>, T. Klioutchnikova<sup>30</sup>, P.F. Klok<sup>106</sup>, E.-E. Kluge<sup>58a</sup>, P. Kluit<sup>107</sup>,  
 S. Kluth<sup>101</sup>, E. Kneringer<sup>62</sup>, E.B.F.G. Knoops<sup>85</sup>, A. Knue<sup>53</sup>, D. Kobayashi<sup>158</sup>, T. Kobayashi<sup>156</sup>, M. Kobel<sup>44</sup>,  
 M. Kocian<sup>144</sup>, P. Kodys<sup>129</sup>, T. Koffas<sup>29</sup>, E. Koffeman<sup>107</sup>, L.A. Kogan<sup>120</sup>, S. Kohlmann<sup>176</sup>, Z. Kohout<sup>128</sup>,  
 T. Kohriki<sup>66</sup>, T. Koi<sup>144</sup>, H. Kolanoski<sup>16</sup>, I. Koletsou<sup>5</sup>, A.A. Komar<sup>96,\*</sup>, Y. Komori<sup>156</sup>, T. Kondo<sup>66</sup>,  
 N. Kondrashova<sup>42</sup>, K. Köneke<sup>48</sup>, A.C. König<sup>106</sup>, S. König<sup>83</sup>, T. Kono<sup>66,u</sup>, R. Konoplich<sup>110,v</sup>, N. Konstantinidis<sup>78</sup>,  
 R. Kopeliansky<sup>153</sup>, S. Koperny<sup>38a</sup>, L. Köpke<sup>83</sup>, A.K. Kopp<sup>48</sup>, K. Korcyl<sup>39</sup>, K. Kordas<sup>155</sup>, A. Korn<sup>78</sup>,  
 A.A. Korol<sup>109,c</sup>, I. Korolkov<sup>12</sup>, E.V. Korolkova<sup>140</sup>, O. Kortner<sup>101</sup>, S. Kortner<sup>101</sup>, T. Kosek<sup>129</sup>, V.V. Kostyukhin<sup>21</sup>,  
 V.M. Kotov<sup>65</sup>, A. Kotwal<sup>145</sup>, A. Kourkoumeli-Charalampidi<sup>155</sup>, C. Kourkoumelis<sup>9</sup>, V. Kouskoura<sup>25</sup>,  
 A. Koutsman<sup>160a</sup>, R. Kowalewski<sup>170</sup>, T.Z. Kowalski<sup>38a</sup>, W. Kozanecki<sup>137</sup>, A.S. Kozhin<sup>130</sup>, V.A. Kramarenko<sup>99</sup>,  
 G. Kramberger<sup>75</sup>, D. Krasnopevtsev<sup>98</sup>, A. Krasznahorkay<sup>30</sup>, J.K. Kraus<sup>21</sup>, A. Kravchenko<sup>25</sup>, S. Kreiss<sup>110</sup>,  
 M. Kretz<sup>58c</sup>, J. Kretzschmar<sup>74</sup>, K. Kreutzfeldt<sup>52</sup>, P. Krieger<sup>159</sup>, K. Krizka<sup>31</sup>, K. Kroeninger<sup>43</sup>, H. Kroha<sup>101</sup>,  
 J. Kroll<sup>122</sup>, J. Kroseberg<sup>21</sup>, J. Krstic<sup>13</sup>, U. Kruchonak<sup>65</sup>, H. Krüger<sup>21</sup>, N. Krumnack<sup>64</sup>, Z.V. Krumshteyn<sup>65</sup>,  
 A. Kruse<sup>174</sup>, M.C. Kruse<sup>45</sup>, M. Kruskal<sup>22</sup>, T. Kubota<sup>88</sup>, H. Kucuk<sup>78</sup>, S. Kuday<sup>4c</sup>, S. Kuehn<sup>48</sup>, A. Kugel<sup>58c</sup>,  
 F. Kuger<sup>175</sup>, A. Kuhl<sup>138</sup>, T. Kuhl<sup>42</sup>, V. Kukhtin<sup>65</sup>, Y. Kulchitsky<sup>92</sup>, S. Kuleshov<sup>32b</sup>, M. Kuna<sup>133a,133b</sup>, T. Kunigo<sup>68</sup>,  
 A. Kupco<sup>127</sup>, H. Kurashige<sup>67</sup>, Y.A. Kurochkin<sup>92</sup>, R. Kurumida<sup>67</sup>, V. Kus<sup>127</sup>, E.S. Kuwertz<sup>148</sup>, M. Kuze<sup>158</sup>,  
 J. Kvita<sup>115</sup>, T. Kwan<sup>170</sup>, D. Kyriazopoulos<sup>140</sup>, A. La Rosa<sup>49</sup>, J.L. La Rosa Navarro<sup>24d</sup>, L. La Rotonda<sup>37a,37b</sup>,  
 C. Lacasta<sup>168</sup>, F. Lacava<sup>133a,133b</sup>, J. Lacey<sup>29</sup>, H. Lacker<sup>16</sup>, D. Lacour<sup>80</sup>, V.R. Lacuesta<sup>168</sup>, E. Ladygin<sup>65</sup>, R. Lafaye<sup>5</sup>,  
 B. Laforge<sup>80</sup>, T. Lagouri<sup>177</sup>, S. Lai<sup>48</sup>, L. Lambourne<sup>78</sup>, S. Lammers<sup>61</sup>, C.L. Lampen<sup>7</sup>, W. Lampl<sup>7</sup>, E. Lançon<sup>137</sup>,  
 U. Landgraf<sup>48</sup>, M.P.J. Landon<sup>76</sup>, V.S. Lang<sup>58a</sup>, J.C. Lange<sup>12</sup>, A.J. Lankford<sup>164</sup>, F. Lanni<sup>25</sup>, K. Lantzsch<sup>30</sup>,  
 S. Laplace<sup>80</sup>, C. Lapoire<sup>30</sup>, J.F. Laporte<sup>137</sup>, T. Lari<sup>91a</sup>, F. Lasagni Manghi<sup>20a,20b</sup>, M. Lassnig<sup>30</sup>, P. Laurelli<sup>47</sup>,  
 W. Lavrijsen<sup>15</sup>, A.T. Law<sup>138</sup>, P. Laycock<sup>74</sup>, O. Le Dortz<sup>80</sup>, E. Le Guirriec<sup>85</sup>, E. Le Menedeu<sup>12</sup>, M. LeBlanc<sup>170</sup>,  
 T. LeCompte<sup>6</sup>, F. Ledroit-Guillon<sup>55</sup>, C.A. Lee<sup>146b</sup>, S.C. Lee<sup>152</sup>, L. Lee<sup>1</sup>, G. Lefebvre<sup>80</sup>, M. Lefebvre<sup>170</sup>, F. Legger<sup>100</sup>,  
 C. Leggett<sup>15</sup>, A. Lehan<sup>74</sup>, G. Lehmann Miotto<sup>30</sup>, X. Lei<sup>7</sup>, W.A. Leight<sup>29</sup>, A. Leisos<sup>155</sup>, A.G. Leister<sup>177</sup>,  
 M.A.L. Leite<sup>24d</sup>, R. Leitner<sup>129</sup>, D. Lellouch<sup>173</sup>, B. Lemmer<sup>54</sup>, K.J.C. Leney<sup>78</sup>, T. Lenz<sup>21</sup>, B. Lenzi<sup>30</sup>, R. Leone<sup>7</sup>,  
 S. Leone<sup>124a,124b</sup>, C. Leonidopoulos<sup>46</sup>, S. Leontsinis<sup>10</sup>, C. Leroy<sup>95</sup>, C.G. Lester<sup>28</sup>, M. Levchenko<sup>123</sup>, J. Levêque<sup>5</sup>,  
 D. Levin<sup>89</sup>, L.J. Levinson<sup>173</sup>, M. Levy<sup>18</sup>, A. Lewis<sup>120</sup>, A.M. Leyko<sup>21</sup>, M. Leyton<sup>41</sup>, B. Li<sup>33b,w</sup>, H. Li<sup>149</sup>, H.L. Li<sup>31</sup>,  
 L. Li<sup>45</sup>, L. Li<sup>33e</sup>, S. Li<sup>45</sup>, Y. Li<sup>33c,x</sup>, Z. Liang<sup>138</sup>, H. Liao<sup>34</sup>, B. Liberti<sup>134a</sup>, A. Liblong<sup>159</sup>, P. Lichard<sup>30</sup>, K. Lie<sup>166</sup>,  
 J. Liebal<sup>21</sup>, W. Liebig<sup>14</sup>, C. Limbach<sup>21</sup>, A. Limosani<sup>151</sup>, S.C. Lin<sup>152,y</sup>, T.H. Lin<sup>83</sup>, F. Linde<sup>107</sup>, B.E. Lindquist<sup>149</sup>,  
 J.T. Linnemann<sup>90</sup>, E. Lipeles<sup>122</sup>, A. Lipniacka<sup>14</sup>, M. Lisovyi<sup>42</sup>, T.M. Liss<sup>166</sup>, D. Lissauer<sup>25</sup>, A. Lister<sup>169</sup>,  
 A.M. Litke<sup>138</sup>, B. Liu<sup>152,z</sup>, D. Liu<sup>152</sup>, J. Liu<sup>85</sup>, J.B. Liu<sup>33b</sup>, K. Liu<sup>85</sup>, L. Liu<sup>166</sup>, M. Liu<sup>45</sup>, M. Liu<sup>33b</sup>, Y. Liu<sup>33b</sup>,  
 M. Livan<sup>121a,121b</sup>, A. Lleres<sup>55</sup>, J. Llorente Merino<sup>82</sup>, S.L. Lloyd<sup>76</sup>, F. Lo Sterzo<sup>152</sup>, E. Lobodzinska<sup>42</sup>, P. Loch<sup>7</sup>,  
 W.S. Lockman<sup>138</sup>, F.K. Loebinger<sup>84</sup>, A.E. Loevschall-Jensen<sup>36</sup>, A. Loginov<sup>177</sup>, T. Lohse<sup>16</sup>, K. Lohwasser<sup>42</sup>,  
 M. Lokajicek<sup>127</sup>, B.A. Long<sup>22</sup>, J.D. Long<sup>89</sup>, R.E. Long<sup>72</sup>, K.A. Looper<sup>111</sup>, L. Lopes<sup>126a</sup>, D. Lopez Mateos<sup>57</sup>,  
 B. Lopez Paredes<sup>140</sup>, I. Lopez Paz<sup>12</sup>, J. Lorenz<sup>100</sup>, N. Lorenzo Martinez<sup>61</sup>, M. Losada<sup>163</sup>, P. Loscutoff<sup>15</sup>,  
 P.J. Lösel<sup>100</sup>, X. Lou<sup>33a</sup>, A. Lounis<sup>117</sup>, J. Love<sup>6</sup>, P.A. Love<sup>72</sup>, N. Lu<sup>89</sup>, H.J. Lubatti<sup>139</sup>, C. Luci<sup>133a,133b</sup>,  
 A. Lucotte<sup>55</sup>, F. Luehring<sup>61</sup>, W. Lukas<sup>62</sup>, L. Luminari<sup>133a</sup>, O. Lundberg<sup>147a,147b</sup>, B. Lund-Jensen<sup>148</sup>, M. Lungwitz<sup>83</sup>,  
 D. Lynn<sup>25</sup>, R. Lysak<sup>127</sup>, E. Lytken<sup>81</sup>, H. Ma<sup>25</sup>, L.L. Ma<sup>33d</sup>, G. Maccarrone<sup>47</sup>, A. Macchiolo<sup>101</sup>, C.M. Macdonald<sup>140</sup>,  
 J. Machado Miguens<sup>122,126b</sup>, D. Macina<sup>30</sup>, D. Madaffari<sup>85</sup>, R. Madar<sup>34</sup>, H.J. Maddocks<sup>72</sup>, W.F. Mader<sup>44</sup>,  
 A. Madsen<sup>167</sup>, S. Maeland<sup>14</sup>, T. Maeno<sup>25</sup>, A. Maevskiy<sup>99</sup>, E. Magradze<sup>54</sup>, K. Mahboubi<sup>48</sup>, J. Mahlstedt<sup>107</sup>,

C. Maiani<sup>137</sup>, C. Maidantchik<sup>24a</sup>, A.A. Maier<sup>101</sup>, T. Maier<sup>100</sup>, A. Maio<sup>126a,126b,126d</sup>, S. Majewski<sup>116</sup>, Y. Makida<sup>66</sup>, N. Makovec<sup>117</sup>, B. Malaescu<sup>80</sup>, Pa. Malecki<sup>39</sup>, V.P. Maleev<sup>123</sup>, F. Malek<sup>55</sup>, U. Mallik<sup>63</sup>, D. Malon<sup>6</sup>, C. Malone<sup>144</sup>, S. Maltezos<sup>10</sup>, V.M. Malyshev<sup>109</sup>, S. Malyukov<sup>30</sup>, J. Mamuzic<sup>42</sup>, G. Mancini<sup>47</sup>, B. Mandelli<sup>30</sup>, L. Mandelli<sup>91a</sup>, I. Mandić<sup>75</sup>, R. Mandrysch<sup>63</sup>, J. Maneira<sup>126a,126b</sup>, A. Manfredini<sup>101</sup>, L. Manhaes de Andrade Filho<sup>24b</sup>, J. Manjarres Ramos<sup>160b</sup>, A. Mann<sup>100</sup>, P.M. Manning<sup>138</sup>, A. Manousakis-Katsikakis<sup>9</sup>, B. Mansoulie<sup>137</sup>, R. Mantifel<sup>87</sup>, M. Mantoani<sup>54</sup>, L. Mapelli<sup>30</sup>, L. March<sup>146c</sup>, G. Marchiori<sup>80</sup>, M. Marcisovsky<sup>127</sup>, C.P. Marino<sup>170</sup>, M. Marjanovic<sup>13</sup>, F. Marroquin<sup>24a</sup>, S.P. Marsden<sup>84</sup>, Z. Marshall<sup>15</sup>, L.F. Marti<sup>17</sup>, S. Marti-Garcia<sup>168</sup>, B. Martin<sup>90</sup>, T.A. Martin<sup>171</sup>, V.J. Martin<sup>46</sup>, B. Martin dit Latour<sup>14</sup>, M. Martinez<sup>12,o</sup>, S. Martin-Haugh<sup>131</sup>, V.S. Martoiu<sup>26a</sup>, A.C. Martyniuk<sup>78</sup>, M. Marx<sup>139</sup>, F. Marzano<sup>133a</sup>, A. Marzin<sup>30</sup>, L. Masetti<sup>83</sup>, T. Mashimo<sup>156</sup>, R. Mashinistov<sup>96</sup>, J. Masik<sup>84</sup>, A.L. Maslennikov<sup>109,c</sup>, I. Massa<sup>20a,20b</sup>, L. Massa<sup>20a,20b</sup>, N. Massol<sup>5</sup>, P. Mastrandrea<sup>149</sup>, A. Mastroberardino<sup>37a,37b</sup>, T. Masubuchi<sup>156</sup>, P. Mättig<sup>176</sup>, J. Mattmann<sup>83</sup>, J. Maurer<sup>26a</sup>, S.J. Maxfield<sup>74</sup>, D.A. Maximov<sup>109,c</sup>, R. Mazini<sup>152</sup>, S.M. Mazza<sup>91a,91b</sup>, L. Mazzaferro<sup>134a,134b</sup>, G. Mc Goldrick<sup>159</sup>, S.P. Mc Kee<sup>89</sup>, A. McCarn<sup>89</sup>, R.L. McCarthy<sup>149</sup>, T.G. McCarthy<sup>29</sup>, N.A. McCubbin<sup>131</sup>, K.W. McFarlane<sup>56,\*</sup>, J.A. Mcfayden<sup>78</sup>, G. Mchedlidze<sup>54</sup>, S.J. McMahon<sup>131</sup>, R.A. McPherson<sup>170,k</sup>, M. Medinnis<sup>42</sup>, S. Meehan<sup>146a</sup>, S. Mehlhase<sup>100</sup>, A. Mehta<sup>74</sup>, K. Meier<sup>58a</sup>, C. Meineck<sup>100</sup>, B. Meirose<sup>41</sup>, B.R. Mellado Garcia<sup>146c</sup>, F. Meloni<sup>17</sup>, A. Mengarelli<sup>20a,20b</sup>, S. Menke<sup>101</sup>, E. Meoni<sup>162</sup>, K.M. Mercurio<sup>57</sup>, S. Mergelmeyer<sup>21</sup>, P. Mermod<sup>49</sup>, L. Merola<sup>104a,104b</sup>, C. Meroni<sup>91a</sup>, F.S. Merritt<sup>31</sup>, A. Messina<sup>133a,133b</sup>, J. Metcalfe<sup>25</sup>, A.S. Mete<sup>164</sup>, C. Meyer<sup>83</sup>, C. Meyer<sup>122</sup>, J-P. Meyer<sup>137</sup>, J. Meyer<sup>107</sup>, R.P. Middleton<sup>131</sup>, S. Miglioranzi<sup>165a,165c</sup>, L. Mijović<sup>21</sup>, G. Mikenberg<sup>173</sup>, M. Mikestikova<sup>127</sup>, M. Mikuš<sup>75</sup>, M. Milesi<sup>88</sup>, A. Milic<sup>30</sup>, D.W. Miller<sup>31</sup>, C. Mills<sup>46</sup>, A. Milov<sup>173</sup>, D.A. Milstead<sup>147a,147b</sup>, A.A. Minaenko<sup>130</sup>, Y. Minami<sup>156</sup>, I.A. Minashvili<sup>65</sup>, A.I. Mincer<sup>110</sup>, B. Mindur<sup>38a</sup>, M. Mineev<sup>65</sup>, Y. Ming<sup>174</sup>, L.M. Mir<sup>12</sup>, T. Mitani<sup>172</sup>, J. Mitrevski<sup>100</sup>, V.A. Mitsou<sup>168</sup>, A. Miucci<sup>49</sup>, P.S. Miyagawa<sup>140</sup>, J.U. Mjörnmark<sup>81</sup>, T. Moad<sup>147a,147b</sup>, K. Mochizuki<sup>85</sup>, S. Mohapatra<sup>35</sup>, W. Mohr<sup>48</sup>, S. Molander<sup>147a,147b</sup>, R. Moles-Valls<sup>168</sup>, K. Mönig<sup>42</sup>, C. Monini<sup>55</sup>, J. Monk<sup>36</sup>, E. Monnier<sup>85</sup>, J. Montejo Berlingen<sup>12</sup>, F. Monticelli<sup>71</sup>, S. Monzani<sup>133a,133b</sup>, R.W. Moore<sup>3</sup>, N. Morange<sup>117</sup>, D. Moreno<sup>163</sup>, M. Moreno Llacer<sup>54</sup>, P. Morettini<sup>50a</sup>, M. Morgenstern<sup>44</sup>, M. Morii<sup>57</sup>, M. Morinaga<sup>156</sup>, V. Morisbak<sup>119</sup>, S. Moritz<sup>83</sup>, A.K. Morley<sup>148</sup>, G. Mornacchi<sup>30</sup>, J.D. Morris<sup>76</sup>, S.S. Mortensen<sup>36</sup>, A. Morton<sup>53</sup>, L. Morvaj<sup>103</sup>, M. Mosidze<sup>51b</sup>, J. Moss<sup>111</sup>, K. Motohashi<sup>158</sup>, R. Mount<sup>144</sup>, E. Mountricha<sup>25</sup>, S.V. Mouraviev<sup>96,\*</sup>, E.J.W. Moyses<sup>86</sup>, S. Muanza<sup>85</sup>, R.D. Mudd<sup>18</sup>, F. Mueller<sup>101</sup>, J. Mueller<sup>125</sup>, K. Mueller<sup>21</sup>, R.S.P. Mueller<sup>100</sup>, T. Mueller<sup>28</sup>, D. Muenstermann<sup>49</sup>, P. Mullen<sup>53</sup>, Y. Munwes<sup>154</sup>, J.A. Murillo Quijada<sup>18</sup>, W.J. Murray<sup>171,131</sup>, H. Musheghyan<sup>54</sup>, E. Musto<sup>153</sup>, A.G. Myagkov<sup>130,aa</sup>, M. Myska<sup>128</sup>, O. Nackenhorst<sup>54</sup>, J. Nadal<sup>54</sup>, K. Nagai<sup>120</sup>, R. Nagai<sup>158</sup>, Y. Nagai<sup>85</sup>, K. Nagano<sup>66</sup>, A. Nagarkar<sup>111</sup>, Y. Nagasaka<sup>59</sup>, K. Nagata<sup>161</sup>, M. Nagel<sup>101</sup>, E. Nagy<sup>85</sup>, A.M. Nairz<sup>30</sup>, Y. Nakahama<sup>30</sup>, K. Nakamura<sup>66</sup>, T. Nakamura<sup>156</sup>, I. Nakano<sup>112</sup>, H. Namasivayam<sup>41</sup>, R.F. Naranjo Garcia<sup>42</sup>, R. Narayan<sup>58b</sup>, T. Naumann<sup>42</sup>, G. Navarro<sup>163</sup>, R. Nayyar<sup>7</sup>, H.A. Neal<sup>89</sup>, P.Yu. Nechaeva<sup>96</sup>, T.J. Neep<sup>84</sup>, P.D. Nef<sup>144</sup>, A. Negri<sup>121a,121b</sup>, M. Negrini<sup>20a</sup>, S. Nektarijevic<sup>106</sup>, C. Nellist<sup>117</sup>, A. Nelson<sup>164</sup>, S. Nemecek<sup>127</sup>, P. Nemethy<sup>110</sup>, A.A. Nepomuceno<sup>24a</sup>, M. Nessi<sup>30,ab</sup>, M.S. Neubauer<sup>166</sup>, M. Neumann<sup>176</sup>, R.M. Neves<sup>110</sup>, P. Nevski<sup>25</sup>, P.R. Newman<sup>18</sup>, D.H. Nguyen<sup>6</sup>, R.B. Nickerson<sup>120</sup>, R. Nicolaidou<sup>137</sup>, B. Nicquevert<sup>30</sup>, J. Nielsen<sup>138</sup>, N. Nikiforou<sup>35</sup>, A. Nikiforov<sup>16</sup>, V. Nikolaenko<sup>130,aa</sup>, I. Nikolic-Audit<sup>80</sup>, K. Nikolopoulos<sup>18</sup>, J.K. Nilsen<sup>119</sup>, P. Nilsson<sup>25</sup>, Y. Ninomiya<sup>156</sup>, A. Nisati<sup>133a</sup>, R. Nisius<sup>101</sup>, T. Nobe<sup>158</sup>, M. Nomachi<sup>118</sup>, I. Nomidis<sup>29</sup>, T. Nooney<sup>76</sup>, S. Norberg<sup>113</sup>, M. Nordberg<sup>30</sup>, O. Novgorodova<sup>44</sup>, S. Nowak<sup>101</sup>, M. Nozaki<sup>66</sup>, L. Nozka<sup>115</sup>, K. Ntekas<sup>10</sup>, G. Nunes Hanninger<sup>88</sup>, T. Nunnemann<sup>100</sup>, E. Nurse<sup>78</sup>, F. Nuti<sup>88</sup>, B.J. O'Brien<sup>46</sup>, F. O'grady<sup>7</sup>, D.C. O'Neil<sup>143</sup>, V. O'Shea<sup>53</sup>, F.G. Oakham<sup>29,d</sup>, H. Oberlack<sup>101</sup>, T. Obermann<sup>21</sup>, J. Ocariz<sup>80</sup>, A. Ochi<sup>67</sup>, I. Ochoa<sup>78</sup>, J.P. Ochoa-Ricoux<sup>32a</sup>, S. Oda<sup>70</sup>, S. Odaka<sup>66</sup>, H. Ogren<sup>61</sup>, A. Oh<sup>84</sup>, S.H. Oh<sup>45</sup>, C.C. Ohm<sup>15</sup>, H. Ohman<sup>167</sup>, H. Oide<sup>30</sup>, W. Okamura<sup>118</sup>, H. Okawa<sup>161</sup>, Y. Okumura<sup>31</sup>, T. Okuyama<sup>156</sup>, A. Olariu<sup>26a</sup>, S.A. Olivares Pino<sup>46</sup>, D. Oliveira Damazio<sup>25</sup>, E. Oliver Garcia<sup>168</sup>, A. Olszewski<sup>39</sup>, J. Olszowska<sup>39</sup>, A. Onofre<sup>126a,126e</sup>, P.U.E. Onyisi<sup>31,q</sup>, C.J. Oram<sup>160a</sup>, M.J. Oreglia<sup>31</sup>, Y. Oren<sup>154</sup>, D. Orestano<sup>135a,135b</sup>, N. Orlando<sup>155</sup>, C. Oropeza Barrera<sup>53</sup>, R.S. Orr<sup>159</sup>, B. Osculati<sup>50a,50b</sup>, R. Ospanov<sup>84</sup>, G. Otero y Garzon<sup>27</sup>, H. Otono<sup>70</sup>, M. Ouchrif<sup>136d</sup>, E.A. Ouellette<sup>170</sup>, F. Ould-Saada<sup>119</sup>, A. Ouraou<sup>137</sup>, K.P. Oussoren<sup>107</sup>, Q. Ouyang<sup>33a</sup>, A. Ovcharova<sup>15</sup>, M. Owen<sup>53</sup>, R.E. Owen<sup>18</sup>, V.E. Ozcan<sup>19a</sup>, N. Ozturk<sup>8</sup>, K. Pachal<sup>120</sup>, A. Pacheco Pages<sup>12</sup>, C. Padilla Aranda<sup>12</sup>, M. Pagáčová<sup>48</sup>, S. Pagan Griso<sup>15</sup>, E. Paganis<sup>140</sup>, C. Pahl<sup>101</sup>, F. Paige<sup>25</sup>, P. Pais<sup>86</sup>, K. Pajchel<sup>119</sup>, G. Palacino<sup>160b</sup>, S. Palestini<sup>30</sup>, M. Palka<sup>38b</sup>, D. Pallin<sup>34</sup>, A. Palma<sup>126a,126b</sup>, Y.B. Pan<sup>174</sup>, E. Panagiotopoulou<sup>10</sup>, C.E. Pandini<sup>80</sup>, J.G. Panduro Vazquez<sup>77</sup>, P. Pani<sup>147a,147b</sup>, S. Panitkin<sup>25</sup>, D. Pantea<sup>26a</sup>, L. Paolozzi<sup>134a,134b</sup>, Th.D. Papadopoulos<sup>10</sup>, K. Papageorgiou<sup>155</sup>, A. Paramonov<sup>6</sup>, D. Paredes Hernandez<sup>155</sup>, M.A. Parker<sup>28</sup>, K.A. Parker<sup>140</sup>, F. Parodi<sup>50a,50b</sup>, J.A. Parsons<sup>35</sup>, U. Parzefall<sup>48</sup>, E. Pasqualucci<sup>133a</sup>, S. Passaggio<sup>50a</sup>, F. Pastore<sup>135a,135b,\*</sup>, Fr. Pastore<sup>77</sup>, G. Pásztor<sup>29</sup>, S. Pataraja<sup>176</sup>, N.D. Patel<sup>151</sup>, J.R. Pater<sup>84</sup>, T. Pauly<sup>30</sup>, J. Pearce<sup>170</sup>, B. Pearson<sup>113</sup>, L.E. Pedersen<sup>36</sup>, M. Pedersen<sup>119</sup>, S. Pedraza Lopez<sup>168</sup>, R. Pedro<sup>126a,126b</sup>, S.V. Peleganchuk<sup>109</sup>, D. Pelikan<sup>167</sup>, H. Peng<sup>33b</sup>, B. Penning<sup>31</sup>, J. Penwell<sup>61</sup>, D.V. Perepelitsa<sup>25</sup>, E. Perez Codina<sup>160a</sup>, M.T. Pérez García-Están<sup>168</sup>, L. Perini<sup>91a,91b</sup>, H. Pernegger<sup>30</sup>, S. Perrella<sup>104a,104b</sup>, R. Peschke<sup>42</sup>, V.D. Peshekhonov<sup>65</sup>, K. Peters<sup>30</sup>, R.F.Y. Peters<sup>84</sup>,

B.A. Petersen<sup>30</sup>, T.C. Petersen<sup>36</sup>, E. Petit<sup>42</sup>, A. Petridis<sup>147a,147b</sup>, C. Petridou<sup>155</sup>, E. Petrolo<sup>133a</sup>, F. Petrucci<sup>135a,135b</sup>,  
 N.E. Pettersson<sup>158</sup>, R. Pezoa<sup>32b</sup>, P.W. Phillips<sup>131</sup>, G. Piacquadio<sup>144</sup>, E. Pianori<sup>171</sup>, A. Picazio<sup>49</sup>, E. Piccaro<sup>76</sup>,  
 M. Piccinini<sup>20a,20b</sup>, M.A. Pickering<sup>120</sup>, R. Piegaia<sup>27</sup>, D.T. Pignotti<sup>111</sup>, J.E. Pilcher<sup>31</sup>, A.D. Pilkington<sup>84</sup>,  
 J. Pina<sup>126a,126b,126d</sup>, M. Pinamonti<sup>165a,165c,ac</sup>, J.L. Pinfeld<sup>3</sup>, A. Pingel<sup>36</sup>, B. Pinto<sup>126a</sup>, S. Pires<sup>80</sup>, M. Pitt<sup>173</sup>,  
 C. Pizio<sup>91a,91b</sup>, L. Plazak<sup>145a</sup>, M.-A. Pleier<sup>25</sup>, V. Pleskot<sup>129</sup>, E. Plotnikova<sup>65</sup>, P. Plucinski<sup>147a,147b</sup>, D. Pluth<sup>64</sup>,  
 R. Poettgen<sup>83</sup>, L. Poggioli<sup>117</sup>, D. Pohl<sup>21</sup>, G. Polesello<sup>121a</sup>, A. Policicchio<sup>37a,37b</sup>, R. Polifka<sup>159</sup>, A. Polini<sup>20a</sup>,  
 C.S. Pollard<sup>53</sup>, V. Polychronakos<sup>25</sup>, K. Pommès<sup>30</sup>, L. Pontecorvo<sup>133a</sup>, B.G. Pope<sup>90</sup>, G.A. Popeneciu<sup>26b</sup>,  
 D.S. Popovic<sup>13</sup>, A. Poppleton<sup>30</sup>, S. Pospisil<sup>128</sup>, K. Potamianos<sup>15</sup>, I.N. Potrap<sup>65</sup>, C.J. Potter<sup>150</sup>, C.T. Potter<sup>116</sup>,  
 G. Poulard<sup>30</sup>, J. Poveda<sup>30</sup>, V. Pozdnyakov<sup>65</sup>, P. Pralavorio<sup>85</sup>, A. Pranko<sup>15</sup>, S. Prasad<sup>30</sup>, S. Prell<sup>64</sup>, D. Price<sup>84</sup>,  
 L.E. Price<sup>6</sup>, M. Primavera<sup>73a</sup>, S. Prince<sup>87</sup>, M. Proissl<sup>46</sup>, K. Prokofiev<sup>60c</sup>, F. Prokoshin<sup>32b</sup>, E. Protopapadaki<sup>137</sup>,  
 S. Protopopescu<sup>25</sup>, J. Proudfoot<sup>6</sup>, M. Przybycien<sup>38a</sup>, E. Ptacek<sup>116</sup>, D. Puddu<sup>135a,135b</sup>, E. Pueschel<sup>86</sup>, D. Puldon<sup>149</sup>,  
 M. Purohit<sup>25,ad</sup>, P. Puza<sup>117</sup>, J. Qian<sup>89</sup>, G. Qin<sup>53</sup>, Y. Qin<sup>84</sup>, A. Quadt<sup>54</sup>, D.R. Quarrie<sup>15</sup>, W.B. Quayle<sup>165a,165b</sup>,  
 M. Queitsch-Maitland<sup>84</sup>, D. Quilty<sup>53</sup>, S. Raddum<sup>119</sup>, V. Radeka<sup>25</sup>, V. Radescu<sup>42</sup>, S.K. Radhakrishnan<sup>149</sup>,  
 P. Radloff<sup>116</sup>, P. Rados<sup>88</sup>, F. Ragusa<sup>91a,91b</sup>, G. Rahal<sup>179</sup>, S. Rajagopalan<sup>25</sup>, M. Rammensee<sup>30</sup>, C. Rangel-Smith<sup>167</sup>,  
 F. Rauscher<sup>100</sup>, S. Rave<sup>83</sup>, T. Ravenscroft<sup>53</sup>, M. Raymond<sup>30</sup>, A.L. Read<sup>119</sup>, N.P. Readioff<sup>74</sup>, D.M. Rebuffi<sup>121a,121b</sup>,  
 A. Redelbach<sup>175</sup>, G. Redlinger<sup>25</sup>, R. Reece<sup>138</sup>, K. Reeves<sup>41</sup>, L. Rehnisch<sup>16</sup>, H. Reisin<sup>27</sup>, M. Relich<sup>164</sup>, C. Rembser<sup>30</sup>,  
 H. Ren<sup>33a</sup>, A. Renaud<sup>117</sup>, M. Rescigno<sup>133a</sup>, S. Resconi<sup>91a</sup>, O.L. Rezanova<sup>109,c</sup>, P. Reznicek<sup>129</sup>, R. Rezvani<sup>95</sup>,  
 R. Richter<sup>101</sup>, S. Richter<sup>78</sup>, E. Richter-Was<sup>38b</sup>, O. Ricken<sup>21</sup>, M. Ridel<sup>80</sup>, P. Rieck<sup>16</sup>, C.J. Riegel<sup>176</sup>, J. Rieger<sup>54</sup>,  
 M. Rijssenbeek<sup>149</sup>, A. Rimoldi<sup>121a,121b</sup>, L. Rinaldi<sup>20a</sup>, B. Ristic<sup>49</sup>, E. Ritsch<sup>62</sup>, I. Riu<sup>12</sup>, F. Rizatdinova<sup>114</sup>,  
 E. Rizvi<sup>76</sup>, S.H. Robertson<sup>87,k</sup>, A. Robichaud-Veronneau<sup>87</sup>, D. Robinson<sup>28</sup>, J.E.M. Robinson<sup>84</sup>, A. Robson<sup>53</sup>,  
 C. Roda<sup>124a,124b</sup>, S. Roe<sup>30</sup>, O. Røhne<sup>119</sup>, S. Rolli<sup>162</sup>, A. Romaniouk<sup>98</sup>, M. Romano<sup>20a,20b</sup>, S.M. Romano Saez<sup>34</sup>,  
 E. Romero Adam<sup>168</sup>, N. Rompotis<sup>139</sup>, M. Ronzani<sup>48</sup>, L. Roos<sup>80</sup>, E. Ros<sup>168</sup>, S. Rosati<sup>133a</sup>, K. Rosbach<sup>48</sup>, P. Rose<sup>138</sup>,  
 P.L. Rosendahl<sup>14</sup>, O. Rosenthal<sup>142</sup>, V. Rossetti<sup>147a,147b</sup>, E. Rossi<sup>104a,104b</sup>, L.P. Rossi<sup>50a</sup>, R. Rosten<sup>139</sup>, M. Rotaru<sup>26a</sup>,  
 I. Roth<sup>173</sup>, J. Rothberg<sup>139</sup>, D. Rousseau<sup>117</sup>, C.R. Royon<sup>137</sup>, A. Rozanov<sup>85</sup>, Y. Rozen<sup>153</sup>, X. Ruan<sup>146c</sup>, F. Rubbo<sup>144</sup>,  
 I. Rubinskiy<sup>42</sup>, V.I. Rud<sup>99</sup>, C. Rudolph<sup>44</sup>, M.S. Rudolph<sup>159</sup>, F. Rühr<sup>48</sup>, A. Ruiz-Martinez<sup>30</sup>, Z. Rurikova<sup>48</sup>,  
 N.A. Rusakovich<sup>65</sup>, A. Ruschke<sup>100</sup>, H.L. Russell<sup>139</sup>, J.P. Rutherford<sup>7</sup>, N. Ruthmann<sup>48</sup>, Y.F. Ryabov<sup>123</sup>,  
 M. Rybar<sup>129</sup>, G. Rybkin<sup>117</sup>, N.C. Ryder<sup>120</sup>, A.F. Saavedra<sup>151</sup>, G. Sabato<sup>107</sup>, S. Sacerdoti<sup>27</sup>, A. Saddique<sup>3</sup>,  
 H.F.-W. Sadrozinski<sup>138</sup>, R. Sadykov<sup>65</sup>, F. Safai Tehrani<sup>133a</sup>, M. Saimpert<sup>137</sup>, H. Sakamoto<sup>156</sup>, Y. Sakurai<sup>172</sup>,  
 G. Salamanna<sup>135a,135b</sup>, A. Salamon<sup>134a</sup>, M. Saleem<sup>113</sup>, D. Salek<sup>107</sup>, P.H. Sales De Bruin<sup>139</sup>, D. Salihagic<sup>101</sup>,  
 A. Salnikov<sup>144</sup>, J. Salt<sup>168</sup>, D. Salvatore<sup>37a,37b</sup>, F. Salvatore<sup>150</sup>, A. Salvucci<sup>106</sup>, A. Salzburger<sup>30</sup>, D. Sampsonidis<sup>155</sup>,  
 A. Sanchez<sup>104a,104b</sup>, J. Sánchez<sup>168</sup>, V. Sanchez Martinez<sup>168</sup>, H. Sandaker<sup>14</sup>, R.L. Sandbach<sup>76</sup>, H.G. Sander<sup>83</sup>,  
 M.P. Sanders<sup>100</sup>, M. Sandhoff<sup>176</sup>, C. Sandoval<sup>163</sup>, R. Sandstroem<sup>101</sup>, D.P.C. Sankey<sup>131</sup>, M. Sannino<sup>50a,50b</sup>,  
 A. Sansoni<sup>47</sup>, C. Santoni<sup>34</sup>, R. Santonico<sup>134a,134b</sup>, H. Santos<sup>126a</sup>, I. Santoyo Castillo<sup>150</sup>, K. Sapp<sup>125</sup>, A. Saprnov<sup>65</sup>,  
 J.G. Saraiva<sup>126a,126d</sup>, B. Sarrazin<sup>21</sup>, O. Sasaki<sup>66</sup>, Y. Sasaki<sup>156</sup>, K. Sato<sup>161</sup>, G. Sauvage<sup>5,\*</sup>, E. Sauvan<sup>5</sup>, G. Savage<sup>77</sup>,  
 P. Savard<sup>159,d</sup>, C. Sawyer<sup>120</sup>, L. Sawyer<sup>79,n</sup>, J. Saxon<sup>31</sup>, C. Sbarra<sup>20a</sup>, A. Sbrizzi<sup>20a,20b</sup>, T. Scanlon<sup>78</sup>,  
 D.A. Scannicchio<sup>164</sup>, M. Scarcella<sup>151</sup>, V. Scarfone<sup>37a,37b</sup>, J. Schaarschmidt<sup>173</sup>, P. Schacht<sup>101</sup>, D. Schaefer<sup>30</sup>,  
 R. Schaefer<sup>42</sup>, J. Schaeffer<sup>83</sup>, S. Schaepe<sup>21</sup>, S. Schaezel<sup>58b</sup>, U. Schäfer<sup>83</sup>, A.C. Schaffer<sup>117</sup>, D. Schaille<sup>100</sup>,  
 R.D. Schamberger<sup>149</sup>, V. Scharf<sup>58a</sup>, V.A. Schegelsky<sup>123</sup>, D. Scheirich<sup>129</sup>, M. Schernau<sup>164</sup>, C. Schiavi<sup>50a,50b</sup>,  
 C. Schillo<sup>48</sup>, M. Schioppa<sup>37a,37b</sup>, S. Schlenker<sup>30</sup>, E. Schmidt<sup>48</sup>, K. Schmieden<sup>30</sup>, C. Schmitt<sup>83</sup>, S. Schmitt<sup>58b</sup>,  
 S. Schmitt<sup>42</sup>, B. Schneider<sup>160a</sup>, Y.J. Schnellbach<sup>74</sup>, U. Schnoor<sup>44</sup>, L. Schoeffel<sup>137</sup>, A. Schoening<sup>58b</sup>,  
 B.D. Schoenrock<sup>90</sup>, E. Schopf<sup>21</sup>, A.L.S. Schorlemmer<sup>54</sup>, M. Schott<sup>83</sup>, D. Schouten<sup>160a</sup>, J. Schovancova<sup>8</sup>,  
 S. Schramm<sup>159</sup>, M. Schreyer<sup>175</sup>, C. Schroeder<sup>83</sup>, N. Schuh<sup>83</sup>, M.J. Schultens<sup>21</sup>, H.-C. Schultz-Coulon<sup>58a</sup>, H. Schulz<sup>16</sup>,  
 M. Schumacher<sup>48</sup>, B.A. Schumm<sup>138</sup>, Ph. Schune<sup>137</sup>, C. Schwanenberger<sup>84</sup>, A. Schwartzman<sup>144</sup>, T.A. Schwarz<sup>89</sup>,  
 Ph. Schwegler<sup>101</sup>, Ph. Schwemling<sup>137</sup>, R. Schwienhorst<sup>90</sup>, J. Schwindling<sup>137</sup>, T. Schwindt<sup>21</sup>, M. Schwoerer<sup>5</sup>,  
 F.G. Sciacca<sup>17</sup>, E. Scifo<sup>117</sup>, G. Sciolla<sup>23</sup>, F. Scuri<sup>124a,124b</sup>, F. Scutti<sup>21</sup>, J. Searcy<sup>89</sup>, G. Sedov<sup>42</sup>, E. Sedykh<sup>123</sup>,  
 P. Seema<sup>21</sup>, S.C. Seidel<sup>105</sup>, A. Seiden<sup>138</sup>, F. Seifert<sup>128</sup>, J.M. Seixas<sup>24a</sup>, G. Sekhniaidze<sup>104a</sup>, S.J. Sekula<sup>40</sup>,  
 K.E. Selbach<sup>46</sup>, D.M. Seliverstov<sup>123,\*</sup>, N. Semprini-Cesari<sup>20a,20b</sup>, C. Serfon<sup>30</sup>, L. Serin<sup>117</sup>, L. Serkin<sup>165a,165b</sup>,  
 T. Serre<sup>85</sup>, R. Seuster<sup>160a</sup>, H. Severini<sup>113</sup>, T. Sfiligoj<sup>75</sup>, F. Sforza<sup>101</sup>, A. Sfyrly<sup>30</sup>, E. Shabalina<sup>54</sup>, M. Shamim<sup>116</sup>,  
 L.Y. Shan<sup>33a</sup>, R. Shang<sup>166</sup>, J.T. Shank<sup>22</sup>, M. Shapiro<sup>15</sup>, P.B. Shatalov<sup>97</sup>, K. Shaw<sup>165a,165b</sup>, S.M. Shaw<sup>84</sup>,  
 A. Shcherbakova<sup>147a,147b</sup>, C.Y. Shehu<sup>150</sup>, P. Sherwood<sup>78</sup>, L. Shi<sup>152,ae</sup>, S. Shimizu<sup>67</sup>, C.O. Shimmin<sup>164</sup>,  
 M. Shimojima<sup>102</sup>, M. Shiyakova<sup>65</sup>, A. Shmeleva<sup>96</sup>, D. Shoaleh Saadi<sup>95</sup>, M.J. Shochet<sup>31</sup>, S. Shojaii<sup>91a,91b</sup>,  
 S. Shrestha<sup>111</sup>, E. Shulga<sup>98</sup>, M.A. Shupe<sup>7</sup>, S. Shushkevich<sup>42</sup>, P. Sicho<sup>127</sup>, O. Sidiropoulou<sup>175</sup>, D. Sidorov<sup>114</sup>,  
 A. Sidoti<sup>20a,20b</sup>, F. Siegert<sup>44</sup>, Dj. Sijacki<sup>13</sup>, J. Silva<sup>126a,126d</sup>, Y. Silver<sup>154</sup>, S.B. Silverstein<sup>147a</sup>, V. Simak<sup>128</sup>,  
 O. Simard<sup>5</sup>, Lj. Simic<sup>13</sup>, S. Simion<sup>117</sup>, E. Simioni<sup>83</sup>, B. Simmons<sup>78</sup>, D. Simon<sup>34</sup>, R. Simoniello<sup>91a,91b</sup>, P. Sinervo<sup>159</sup>,  
 N.B. Sinev<sup>116</sup>, G. Siragusa<sup>175</sup>, A.N. Sisakyan<sup>65,\*</sup>, S.Yu. Sivoklov<sup>99</sup>, J. Sjölín<sup>147a,147b</sup>, T.B. Sjurson<sup>14</sup>,  
 M.B. Skinner<sup>72</sup>, H.P. Skottowe<sup>57</sup>, P. Skubic<sup>113</sup>, M. Slater<sup>18</sup>, T. Slavicek<sup>128</sup>, M. Slawinska<sup>107</sup>, K. Sliwa<sup>162</sup>,

V. Smakhtin<sup>173</sup>, B.H. Smart<sup>46</sup>, L. Smestad<sup>14</sup>, S.Yu. Smirnov<sup>98</sup>, Y. Smirnov<sup>98</sup>, L.N. Smirnova<sup>99,af</sup>, O. Smirnova<sup>81</sup>, M.N.K. Smith<sup>35</sup>, M. Smizanska<sup>72</sup>, K. Smolek<sup>128</sup>, A.A. Snesarev<sup>96</sup>, G. Snidero<sup>76</sup>, S. Snyder<sup>25</sup>, R. Sobie<sup>170,k</sup>, F. Socher<sup>44</sup>, A. Soffer<sup>154</sup>, D.A. Soh<sup>152,ae</sup>, C.A. Solans<sup>30</sup>, M. Solar<sup>128</sup>, J. Solc<sup>128</sup>, E.Yu. Soldatov<sup>98</sup>, U. Soldevila<sup>168</sup>, A.A. Solodkov<sup>130</sup>, A. Soloshenko<sup>65</sup>, O.V. Solovyanov<sup>130</sup>, V. Solovyevev<sup>123</sup>, P. Sommer<sup>48</sup>, H.Y. Song<sup>33b</sup>, N. Soni<sup>1</sup>, A. Sood<sup>15</sup>, A. Sopczak<sup>128</sup>, B. Sopko<sup>128</sup>, V. Sopko<sup>128</sup>, V. Sorin<sup>12</sup>, D. Sosa<sup>58b</sup>, M. Sosebee<sup>8</sup>, C.L. Sotiropoulou<sup>124a,124b</sup>, R. Soualah<sup>165a,165c</sup>, P. Soueid<sup>95</sup>, A.M. Soukharev<sup>109,c</sup>, D. South<sup>42</sup>, S. Spagnolo<sup>73a,73b</sup>, M. Spalla<sup>124a,124b</sup>, F. Spanò<sup>77</sup>, W.R. Spearman<sup>57</sup>, F. Spettel<sup>101</sup>, R. Spighi<sup>20a</sup>, G. Spigo<sup>30</sup>, L.A. Spiller<sup>88</sup>, M. Spousta<sup>129</sup>, T. Spreitzer<sup>159</sup>, R.D. St. Denis<sup>53,\*</sup>, S. Staerz<sup>44</sup>, J. Stahlman<sup>122</sup>, R. Stamen<sup>58a</sup>, S. Stamm<sup>16</sup>, E. Stanecka<sup>39</sup>, C. Stanescu<sup>135a</sup>, M. Stanescu-Bellu<sup>42</sup>, M.M. Stanitzki<sup>42</sup>, S. Stapnes<sup>119</sup>, E.A. Starchenko<sup>130</sup>, J. Stark<sup>55</sup>, P. Staroba<sup>127</sup>, P. Starovoitov<sup>42</sup>, R. Staszewski<sup>39</sup>, P. Stavina<sup>145a,\*</sup>, P. Steinberg<sup>25</sup>, B. Stelzer<sup>143</sup>, H.J. Stelzer<sup>30</sup>, O. Stelzer-Chilton<sup>160a</sup>, H. Stenzel<sup>52</sup>, S. Stern<sup>101</sup>, G.A. Stewart<sup>53</sup>, J.A. Stillings<sup>21</sup>, M.C. Stockton<sup>87</sup>, M. Stoebe<sup>87</sup>, G. Stoicea<sup>26a</sup>, P. Stolte<sup>54</sup>, S. Stonjek<sup>101</sup>, A.R. Stradling<sup>8</sup>, A. Straessner<sup>44</sup>, M.E. Stramaglia<sup>17</sup>, J. Strandberg<sup>148</sup>, S. Strandberg<sup>147a,147b</sup>, A. Strandlie<sup>119</sup>, E. Strauss<sup>144</sup>, M. Strauss<sup>113</sup>, P. Strizenec<sup>145b</sup>, R. Ströhmer<sup>175</sup>, D.M. Strom<sup>116</sup>, R. Stroynowski<sup>40</sup>, A. Strubig<sup>106</sup>, S.A. Stucci<sup>17</sup>, B. Stugu<sup>14</sup>, N.A. Styles<sup>42</sup>, D. Su<sup>144</sup>, J. Su<sup>125</sup>, R. Subramaniam<sup>79</sup>, A. Succurro<sup>12</sup>, Y. Sugaya<sup>118</sup>, C. Suhr<sup>108</sup>, M. Suk<sup>128</sup>, V.V. Sulin<sup>96</sup>, S. Sultansoy<sup>4d</sup>, T. Sumida<sup>68</sup>, S. Sun<sup>57</sup>, X. Sun<sup>33a</sup>, J.E. Sundermann<sup>48</sup>, K. Suruliz<sup>150</sup>, G. Susinno<sup>37a,37b</sup>, M.R. Sutton<sup>150</sup>, S. Suzuki<sup>66</sup>, Y. Suzuki<sup>66</sup>, M. Svatos<sup>127</sup>, S. Swedish<sup>169</sup>, M. Swiatlowski<sup>144</sup>, I. Sykora<sup>145a</sup>, T. Sykora<sup>129</sup>, D. Ta<sup>90</sup>, C. Taccini<sup>135a,135b</sup>, K. Tackmann<sup>42</sup>, J. Taenzer<sup>159</sup>, A. Taffard<sup>164</sup>, R. Tafirout<sup>160a</sup>, N. Taiblum<sup>154</sup>, H. Takai<sup>25</sup>, R. Takashima<sup>69</sup>, H. Takeda<sup>67</sup>, T. Takeshita<sup>141</sup>, Y. Takubo<sup>66</sup>, M. Talby<sup>85</sup>, A.A. Talyshev<sup>109,c</sup>, J.Y.C. Tam<sup>175</sup>, K.G. Tan<sup>88</sup>, J. Tanaka<sup>156</sup>, R. Tanaka<sup>117</sup>, S. Tanaka<sup>132</sup>, S. Tanaka<sup>66</sup>, B.B. Tannenwald<sup>111</sup>, N. Tannoury<sup>21</sup>, S. Tapprogge<sup>83</sup>, S. Tarem<sup>153</sup>, F. Tarrade<sup>29</sup>, G.F. Tartarelli<sup>91a</sup>, P. Tas<sup>129</sup>, M. Tasevsky<sup>127</sup>, T. Tashiro<sup>68</sup>, E. Tassi<sup>37a,37b</sup>, A. Tavares Delgado<sup>126a,126b</sup>, Y. Tayalati<sup>136d</sup>, F.E. Taylor<sup>94</sup>, G.N. Taylor<sup>88</sup>, W. Taylor<sup>160b</sup>, F.A. Teischinger<sup>30</sup>, M. Teixeira Dias Castanheira<sup>76</sup>, P. Teixeira-Dias<sup>77</sup>, K.K. Temming<sup>48</sup>, H. Ten Kate<sup>30</sup>, P.K. Teng<sup>152</sup>, J.J. Teoh<sup>118</sup>, F. Tepel<sup>176</sup>, S. Terada<sup>66</sup>, K. Terashi<sup>156</sup>, J. Terron<sup>82</sup>, S. Terzo<sup>101</sup>, M. Testa<sup>47</sup>, R.J. Teuscher<sup>159,k</sup>, J. Therhaag<sup>21</sup>, T. Theveneaux-Pelzer<sup>34</sup>, J.P. Thomas<sup>18</sup>, J. Thomas-Wilsker<sup>77</sup>, E.N. Thompson<sup>35</sup>, P.D. Thompson<sup>18</sup>, R.J. Thompson<sup>84</sup>, A.S. Thompson<sup>53</sup>, L.A. Thomsen<sup>36</sup>, E. Thomson<sup>122</sup>, M. Thomson<sup>28</sup>, R.P. Thun<sup>89,\*</sup>, M.J. Tibbetts<sup>15</sup>, R.E. Ticse Torres<sup>85</sup>, V.O. Tikhomirov<sup>96,ag</sup>, Yu.A. Tikhonov<sup>109,c</sup>, S. Timoshenko<sup>98</sup>, E. Tiouchichine<sup>85</sup>, P. Tipton<sup>177</sup>, S. Tisserant<sup>85</sup>, T. Todorov<sup>5,\*</sup>, S. Todorova-Nova<sup>129</sup>, J. Tojo<sup>70</sup>, S. Tokár<sup>145a</sup>, K. Tokushuku<sup>66</sup>, K. Tollefson<sup>90</sup>, E. Tolley<sup>57</sup>, L. Tomlinson<sup>84</sup>, M. Tomoto<sup>103</sup>, L. Tompkins<sup>144,ah</sup>, K. Toms<sup>105</sup>, E. Torrence<sup>116</sup>, H. Torres<sup>143</sup>, E. Torrò Pastor<sup>168</sup>, J. Toth<sup>85,ai</sup>, F. Touchard<sup>85</sup>, D.R. Tovey<sup>140</sup>, T. Trefzger<sup>175</sup>, L. Tremblet<sup>30</sup>, A. Tricoli<sup>30</sup>, I.M. Trigger<sup>160a</sup>, S. Trincaz-Duvold<sup>80</sup>, M.F. Tripiana<sup>12</sup>, W. Trischuk<sup>159</sup>, B. Trocme<sup>55</sup>, C. Troncon<sup>91a</sup>, M. Trottier-McDonald<sup>15</sup>, M. Trovatelli<sup>135a,135b</sup>, P. True<sup>90</sup>, M. Trzebinski<sup>39</sup>, A. Trzupek<sup>39</sup>, C. Tsarouchas<sup>30</sup>, J.C.-L. Tseng<sup>120</sup>, P.V. Tsiarehshka<sup>92</sup>, D. Tsionou<sup>155</sup>, G. Tsiopolitis<sup>10</sup>, N. Tsirintanis<sup>9</sup>, S. Tsiskaridze<sup>12</sup>, V. Tsiskaridze<sup>48</sup>, E.G. Tskhadadze<sup>51a</sup>, I.I. Tsukerman<sup>97</sup>, V. Tsulaia<sup>15</sup>, S. Tsuno<sup>66</sup>, D. Tsybychev<sup>149</sup>, A. Tudorache<sup>26a</sup>, V. Tudorache<sup>26a</sup>, A.N. Tuna<sup>122</sup>, S.A. Tupputi<sup>20a,20b</sup>, S. Turchikhin<sup>99,af</sup>, D. Turecek<sup>128</sup>, R. Turra<sup>91a,91b</sup>, A.J. Turvey<sup>40</sup>, P.M. Tuts<sup>35</sup>, A. Tykhonov<sup>49</sup>, M. Tylmad<sup>147a,147b</sup>, M. Tyndel<sup>131</sup>, I. Ueda<sup>156</sup>, R. Ueno<sup>29</sup>, M. Ughetto<sup>147a,147b</sup>, M. Uglan<sup>14</sup>, M. Uhlenbrock<sup>21</sup>, F. Ukegawa<sup>161</sup>, G. Unal<sup>30</sup>, A. Undrus<sup>25</sup>, G. Unel<sup>164</sup>, F.C. Ungaro<sup>48</sup>, Y. Unno<sup>66</sup>, C. Unverdorben<sup>100</sup>, J. Urban<sup>145b</sup>, P. Urquijo<sup>88</sup>, P. Urrejola<sup>83</sup>, G. Usai<sup>8</sup>, A. Usanova<sup>62</sup>, L. Vacavant<sup>85</sup>, V. Vacek<sup>128</sup>, B. Vachon<sup>87</sup>, C. Valderanis<sup>83</sup>, N. Valencic<sup>107</sup>, S. Valentineti<sup>20a,20b</sup>, A. Valero<sup>168</sup>, L. Valery<sup>12</sup>, S. Valkar<sup>129</sup>, E. Valladolid Gallego<sup>168</sup>, S. Vallecorsa<sup>49</sup>, J.A. Valls Ferrer<sup>168</sup>, W. Van Den Wollenberg<sup>107</sup>, P.C. Van Der Deijl<sup>107</sup>, R. van der Geer<sup>107</sup>, H. van der Graaf<sup>107</sup>, R. Van Der Leeuw<sup>107</sup>, N. van Eldik<sup>153</sup>, P. van Gemmeren<sup>6</sup>, J. Van Nieuwkoop<sup>143</sup>, I. van Vulpen<sup>107</sup>, M.C. van Woerden<sup>30</sup>, M. Vanadia<sup>133a,133b</sup>, W. Vandelli<sup>30</sup>, R. Vanguri<sup>122</sup>, A. Vaniachine<sup>6</sup>, F. Vannucci<sup>80</sup>, G. Vardanyan<sup>178</sup>, R. Vari<sup>133a</sup>, E.W. Varnes<sup>7</sup>, T. Varol<sup>40</sup>, D. Varouchas<sup>80</sup>, A. Vartapetian<sup>8</sup>, K.E. Varvell<sup>151</sup>, F. Vazeille<sup>34</sup>, T. Vazquez Schroeder<sup>87</sup>, J. Veatch<sup>7</sup>, F. Veloso<sup>126a,126c</sup>, T. Velz<sup>21</sup>, S. Veneziano<sup>133a</sup>, A. Ventura<sup>73a,73b</sup>, D. Ventura<sup>86</sup>, M. Venturi<sup>170</sup>, N. Venturi<sup>159</sup>, A. Venturini<sup>23</sup>, V. Vercesi<sup>121a</sup>, M. Verducci<sup>133a,133b</sup>, W. Verkerke<sup>107</sup>, J.C. Vermeulen<sup>107</sup>, A. Vest<sup>44</sup>, M.C. Vetterli<sup>143,d</sup>, O. Viazlo<sup>81</sup>, I. Vichou<sup>166</sup>, T. Vickey<sup>140</sup>, O.E. Vickey Boeriu<sup>140</sup>, G.H.A. Viehhauser<sup>120</sup>, S. Viel<sup>15</sup>, R. Vigne<sup>30</sup>, M. Villa<sup>20a,20b</sup>, M. Villaplana Perez<sup>91a,91b</sup>, E. Vilucchi<sup>47</sup>, M.G. Vincter<sup>29</sup>, V.B. Vinogradov<sup>65</sup>, I. Vivarelli<sup>150</sup>, F. Vives Vaque<sup>3</sup>, S. Vlachos<sup>10</sup>, D. Vladoiu<sup>100</sup>, M. Vlasak<sup>128</sup>, M. Vogel<sup>32a</sup>, P. Vokac<sup>128</sup>, G. Volpi<sup>124a,124b</sup>, M. Volpi<sup>88</sup>, H. von der Schmitt<sup>101</sup>, H. von Radziewski<sup>48</sup>, E. von Toerne<sup>21</sup>, V. Vorobel<sup>129</sup>, K. Vorobev<sup>98</sup>, M. Vos<sup>168</sup>, R. Voss<sup>30</sup>, J.H. Vosseveld<sup>74</sup>, N. Vranjes<sup>13</sup>, M. Vranjes Milosavljevic<sup>13</sup>, V. Vrba<sup>127</sup>, M. Vreeswijk<sup>107</sup>, R. Vuillermet<sup>30</sup>, I. Vukotic<sup>31</sup>, Z. Vykydal<sup>128</sup>, P. Wagner<sup>21</sup>, W. Wagner<sup>176</sup>, H. Wahlberg<sup>71</sup>, S. Wahrenmund<sup>44</sup>, J. Wakabayashi<sup>103</sup>, J. Walder<sup>72</sup>, R. Walker<sup>100</sup>, W. Walkowiak<sup>142</sup>, C. Wang<sup>33c</sup>, F. Wang<sup>174</sup>, H. Wang<sup>15</sup>, H. Wang<sup>40</sup>, J. Wang<sup>42</sup>, J. Wang<sup>33a</sup>, K. Wang<sup>87</sup>, R. Wang<sup>6</sup>, S.M. Wang<sup>152</sup>, T. Wang<sup>21</sup>, X. Wang<sup>177</sup>, C. Wanotayaroj<sup>116</sup>, A. Warburton<sup>87</sup>, C.P. Ward<sup>28</sup>, D.R. Wardrope<sup>78</sup>, M. Warsinsky<sup>48</sup>, A. Washbrook<sup>46</sup>, C. Wasicki<sup>42</sup>, P.M. Watkins<sup>18</sup>, A.T. Watson<sup>18</sup>, I.J. Watson<sup>151</sup>, M.F. Watson<sup>18</sup>, G. Watts<sup>139</sup>, S. Watts<sup>84</sup>,

B.M. Waugh<sup>78</sup>, S. Webb<sup>84</sup>, M.S. Weber<sup>17</sup>, S.W. Weber<sup>175</sup>, J.S. Webster<sup>31</sup>, A.R. Weidberg<sup>120</sup>, B. Weinert<sup>61</sup>, J. Weingarten<sup>54</sup>, C. Weiser<sup>48</sup>, H. Weits<sup>107</sup>, P.S. Wells<sup>30</sup>, T. Wenaus<sup>25</sup>, T. Wengler<sup>30</sup>, S. Wenig<sup>30</sup>, N. Wermes<sup>21</sup>, M. Werner<sup>48</sup>, P. Werner<sup>30</sup>, M. Wessels<sup>58a</sup>, J. Wetter<sup>162</sup>, K. Whalen<sup>29</sup>, A.M. Wharton<sup>72</sup>, A. White<sup>8</sup>, M.J. White<sup>1</sup>, R. White<sup>32b</sup>, S. White<sup>124a,124b</sup>, D. Whiteson<sup>164</sup>, F.J. Wickens<sup>131</sup>, W. Wiedenmann<sup>174</sup>, M. Wieler<sup>131</sup>, P. Wienemann<sup>21</sup>, C. Wiglesworth<sup>36</sup>, L.A.M. Wiik-Fuchs<sup>21</sup>, A. Wildauer<sup>101</sup>, H.G. Wilkens<sup>30</sup>, H.H. Williams<sup>122</sup>, S. Williams<sup>107</sup>, C. Willis<sup>90</sup>, S. Willocq<sup>86</sup>, A. Wilson<sup>89</sup>, J.A. Wilson<sup>18</sup>, I. Wingerter-Seetz<sup>5</sup>, F. Winklmeier<sup>116</sup>, B.T. Winter<sup>21</sup>, M. Wittgen<sup>144</sup>, J. Wittkowski<sup>100</sup>, S.J. Wollstadt<sup>83</sup>, M.W. Wolter<sup>39</sup>, H. Wolters<sup>126a,126c</sup>, B.K. Wosiek<sup>39</sup>, J. Wotschack<sup>30</sup>, M.J. Woudstra<sup>84</sup>, K.W. Wozniak<sup>39</sup>, M. Wu<sup>55</sup>, M. Wu<sup>31</sup>, S.L. Wu<sup>174</sup>, X. Wu<sup>49</sup>, Y. Wu<sup>89</sup>, T.R. Wyatt<sup>84</sup>, B.M. Wynne<sup>46</sup>, S. Xella<sup>36</sup>, D. Xu<sup>33a</sup>, L. Xu<sup>33b,aj</sup>, B. Yabsley<sup>151</sup>, S. Yacoob<sup>146b,ak</sup>, R. Yakabe<sup>67</sup>, M. Yamada<sup>66</sup>, Y. Yamaguchi<sup>118</sup>, A. Yamamoto<sup>66</sup>, S. Yamamoto<sup>156</sup>, T. Yamanaka<sup>156</sup>, K. Yamauchi<sup>103</sup>, Y. Yamazaki<sup>67</sup>, Z. Yan<sup>22</sup>, H. Yang<sup>33e</sup>, H. Yang<sup>174</sup>, Y. Yang<sup>152</sup>, L. Yao<sup>33a</sup>, W.-M. Yao<sup>15</sup>, Y. Yasu<sup>66</sup>, E. Yatsenko<sup>42</sup>, K.H. Yau Wong<sup>21</sup>, J. Ye<sup>40</sup>, S. Ye<sup>25</sup>, I. Yeletskikh<sup>65</sup>, A.L. Yen<sup>57</sup>, E. Yildirim<sup>42</sup>, K. Yorita<sup>172</sup>, R. Yoshida<sup>6</sup>, K. Yoshihara<sup>122</sup>, C. Young<sup>144</sup>, C.J.S. Young<sup>30</sup>, S. Youssef<sup>22</sup>, D.R. Yu<sup>15</sup>, J. Yu<sup>8</sup>, J.M. Yu<sup>89</sup>, J. Yu<sup>114</sup>, L. Yuan<sup>67</sup>, A. Yurkewicz<sup>108</sup>, I. Yusuff<sup>28,al</sup>, B. Zabinski<sup>39</sup>, R. Zaidan<sup>63</sup>, A.M. Zaitsev<sup>130,aa</sup>, J. Zalieckas<sup>14</sup>, A. Zaman<sup>149</sup>, S. Zambito<sup>23</sup>, L. Zanello<sup>133a,133b</sup>, D. Zanzi<sup>88</sup>, C. Zeitnitz<sup>176</sup>, M. Zeman<sup>128</sup>, A. Zemla<sup>38a</sup>, K. Zengel<sup>23</sup>, O. Zenin<sup>130</sup>, T. Ženiš<sup>145a</sup>, D. Zerwas<sup>117</sup>, D. Zhang<sup>89</sup>, F. Zhang<sup>174</sup>, J. Zhang<sup>6</sup>, L. Zhang<sup>48</sup>, R. Zhang<sup>33b</sup>, X. Zhang<sup>33d</sup>, Z. Zhang<sup>117</sup>, X. Zhao<sup>40</sup>, Y. Zhao<sup>33d,117</sup>, Z. Zhao<sup>33b</sup>, A. Zhemchugov<sup>65</sup>, J. Zhong<sup>120</sup>, B. Zhou<sup>89</sup>, C. Zhou<sup>45</sup>, L. Zhou<sup>35</sup>, L. Zhou<sup>40</sup>, N. Zhou<sup>164</sup>, C.G. Zhu<sup>33d</sup>, H. Zhu<sup>33a</sup>, J. Zhu<sup>89</sup>, Y. Zhu<sup>33b</sup>, X. Zhuang<sup>33a</sup>, K. Zhukov<sup>96</sup>, A. Zibell<sup>175</sup>, D. Zieminska<sup>61</sup>, N.I. Zimine<sup>65</sup>, C. Zimmermann<sup>83</sup>, R. Zimmermann<sup>21</sup>, S. Zimmermann<sup>48</sup>, Z. Zinonos<sup>54</sup>, M. Zinser<sup>83</sup>, M. Ziolkowski<sup>142</sup>, L. Živković<sup>13</sup>, G. Zobernig<sup>174</sup>, A. Zoccoli<sup>20a,20b</sup>, M. zur Nedden<sup>16</sup>, G. Zurzolo<sup>104a,104b</sup>, L. Zwalinski<sup>30</sup>.

<sup>1</sup> Department of Physics, University of Adelaide, Adelaide, Australia

<sup>2</sup> Physics Department, SUNY Albany, Albany NY, United States of America

<sup>3</sup> Department of Physics, University of Alberta, Edmonton AB, Canada

<sup>4</sup> (a) Department of Physics, Ankara University, Ankara; (c) Istanbul Aydin University, Istanbul; (d) Division of Physics, TOBB University of Economics and Technology, Ankara, Turkey

<sup>5</sup> LAPP, CNRS/IN2P3 and Université Savoie Mont Blanc, Annecy-le-Vieux, France

<sup>6</sup> High Energy Physics Division, Argonne National Laboratory, Argonne IL, United States of America

<sup>7</sup> Department of Physics, University of Arizona, Tucson AZ, United States of America

<sup>8</sup> Department of Physics, The University of Texas at Arlington, Arlington TX, United States of America

<sup>9</sup> Physics Department, University of Athens, Athens, Greece

<sup>10</sup> Physics Department, National Technical University of Athens, Zografou, Greece

<sup>11</sup> Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan

<sup>12</sup> Institut de Física d'Altes Energies and Departament de Física de la Universitat Autònoma de Barcelona, Barcelona, Spain

<sup>13</sup> Institute of Physics, University of Belgrade, Belgrade, Serbia

<sup>14</sup> Department for Physics and Technology, University of Bergen, Bergen, Norway

<sup>15</sup> Physics Division, Lawrence Berkeley National Laboratory and University of California, Berkeley CA, United States of America

<sup>16</sup> Department of Physics, Humboldt University, Berlin, Germany

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

<sup>18</sup> School of Physics and Astronomy, University of Birmingham, Birmingham, United Kingdom

<sup>19</sup> (a) Department of Physics, Bogazici University, Istanbul; (b) Department of Physics, Dogus University, Istanbul;

(c) Department of Physics Engineering, Gaziantep University, Gaziantep, Turkey

<sup>20</sup> (a) INFN Sezione di Bologna; (b) Dipartimento di Fisica e Astronomia, Università di Bologna, Bologna, Italy

<sup>21</sup> Physikalisches Institut, University of Bonn, Bonn, Germany

<sup>22</sup> Department of Physics, Boston University, Boston MA, United States of America

<sup>23</sup> Department of Physics, Brandeis University, Waltham MA, United States of America

<sup>24</sup> (a) Universidade Federal do Rio De Janeiro COPPE/EE/IF, Rio de Janeiro; (b) Electrical Circuits Department, Federal University of Juiz de Fora (UFJF), Juiz de Fora; (c) Federal University of Sao Joao del Rei (UFSJ), Sao Joao del Rei; (d) Instituto de Fisica, Universidade de Sao Paulo, Sao Paulo, Brazil

<sup>25</sup> Physics Department, Brookhaven National Laboratory, Upton NY, United States of America

<sup>26</sup> (a) National Institute of Physics and Nuclear Engineering, Bucharest; (b) National Institute for Research and Development of Isotopic and Molecular Technologies, Physics Department, Cluj Napoca; (c) University Politehnica

- Bucharest, Bucharest; <sup>(d)</sup> West University in Timisoara, Timisoara, Romania
- <sup>27</sup> Departamento de Física, Universidad de Buenos Aires, Buenos Aires, Argentina
- <sup>28</sup> Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom
- <sup>29</sup> Department of Physics, Carleton University, Ottawa ON, Canada
- <sup>30</sup> CERN, Geneva, Switzerland
- <sup>31</sup> Enrico Fermi Institute, University of Chicago, Chicago IL, United States of America
- <sup>32</sup> <sup>(a)</sup> Departamento de Física, Pontificia Universidad Católica de Chile, Santiago; <sup>(b)</sup> Departamento de Física, Universidad Técnica Federico Santa María, Valparaíso, Chile
- <sup>33</sup> <sup>(a)</sup> Institute of High Energy Physics, Chinese Academy of Sciences, Beijing; <sup>(b)</sup> Department of Modern Physics, University of Science and Technology of China, Anhui; <sup>(c)</sup> Department of Physics, Nanjing University, Jiangsu; <sup>(d)</sup> School of Physics, Shandong University, Shandong; <sup>(e)</sup> Department of Physics and Astronomy, Shanghai Key Laboratory for Particle Physics and Cosmology, Shanghai Jiao Tong University, Shanghai; <sup>(f)</sup> Physics Department, Tsinghua University, Beijing 100084, China
- <sup>34</sup> Laboratoire de Physique Corpusculaire, Clermont Université and Université Blaise Pascal and CNRS/IN2P3, Clermont-Ferrand, France
- <sup>35</sup> Nevis Laboratory, Columbia University, Irvington NY, United States of America
- <sup>36</sup> Niels Bohr Institute, University of Copenhagen, Kobenhavn, Denmark
- <sup>37</sup> <sup>(a)</sup> INFN Gruppo Collegato di Cosenza, Laboratori Nazionali di Frascati; <sup>(b)</sup> Dipartimento di Fisica, Università della Calabria, Rende, Italy
- <sup>38</sup> <sup>(a)</sup> AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Krakow; <sup>(b)</sup> Marian Smoluchowski Institute of Physics, Jagiellonian University, Krakow, Poland
- <sup>39</sup> Institute of Nuclear Physics Polish Academy of Sciences, Krakow, Poland
- <sup>40</sup> Physics Department, Southern Methodist University, Dallas TX, United States of America
- <sup>41</sup> Physics Department, University of Texas at Dallas, Richardson TX, United States of America
- <sup>42</sup> DESY, Hamburg and Zeuthen, Germany
- <sup>43</sup> Institut für Experimentelle Physik IV, Technische Universität Dortmund, Dortmund, Germany
- <sup>44</sup> Institut für Kern- und Teilchenphysik, Technische Universität Dresden, Dresden, Germany
- <sup>45</sup> Department of Physics, Duke University, Durham NC, United States of America
- <sup>46</sup> SUPA - School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom
- <sup>47</sup> INFN Laboratori Nazionali di Frascati, Frascati, Italy
- <sup>48</sup> Fakultät für Mathematik und Physik, Albert-Ludwigs-Universität, Freiburg, Germany
- <sup>49</sup> Section de Physique, Université de Genève, Geneva, Switzerland
- <sup>50</sup> <sup>(a)</sup> INFN Sezione di Genova; <sup>(b)</sup> Dipartimento di Fisica, Università di Genova, Genova, Italy
- <sup>51</sup> <sup>(a)</sup> E. Andronikashvili Institute of Physics, Iv. Javakishvili Tbilisi State University, Tbilisi; <sup>(b)</sup> High Energy Physics Institute, Tbilisi State University, Tbilisi, Georgia
- <sup>52</sup> II Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen, Germany
- <sup>53</sup> SUPA - School of Physics and Astronomy, University of Glasgow, Glasgow, United Kingdom
- <sup>54</sup> II Physikalisches Institut, Georg-August-Universität, Göttingen, Germany
- <sup>55</sup> Laboratoire de Physique Subatomique et de Cosmologie, Université Grenoble-Alpes, CNRS/IN2P3, Grenoble, France
- <sup>56</sup> Department of Physics, Hampton University, Hampton VA, United States of America
- <sup>57</sup> Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge MA, United States of America
- <sup>58</sup> <sup>(a)</sup> Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Heidelberg; <sup>(b)</sup> Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg; <sup>(c)</sup> ZITI Institut für technische Informatik, Ruprecht-Karls-Universität Heidelberg, Mannheim, Germany
- <sup>59</sup> Faculty of Applied Information Science, Hiroshima Institute of Technology, Hiroshima, Japan
- <sup>60</sup> <sup>(a)</sup> Department of Physics, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong; <sup>(b)</sup> Department of Physics, The University of Hong Kong, Hong Kong; <sup>(c)</sup> Department of Physics, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, China
- <sup>61</sup> Department of Physics, Indiana University, Bloomington IN, United States of America
- <sup>62</sup> Institut für Astro- und Teilchenphysik, Leopold-Franzens-Universität, Innsbruck, Austria
- <sup>63</sup> University of Iowa, Iowa City IA, United States of America
- <sup>64</sup> Department of Physics and Astronomy, Iowa State University, Ames IA, United States of America
- <sup>65</sup> Joint Institute for Nuclear Research, JINR Dubna, Dubna, Russia
- <sup>66</sup> KEK, High Energy Accelerator Research Organization, Tsukuba, Japan
- <sup>67</sup> Graduate School of Science, Kobe University, Kobe, Japan



- <sup>68</sup> Faculty of Science, Kyoto University, Kyoto, Japan
- <sup>69</sup> Kyoto University of Education, Kyoto, Japan
- <sup>70</sup> Department of Physics, Kyushu University, Fukuoka, Japan
- <sup>71</sup> Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata, Argentina
- <sup>72</sup> Physics Department, Lancaster University, Lancaster, United Kingdom
- <sup>73</sup> <sup>(a)</sup> INFN Sezione di Lecce; <sup>(b)</sup> Dipartimento di Matematica e Fisica, Università del Salento, Lecce, Italy
- <sup>74</sup> Oliver Lodge Laboratory, University of Liverpool, Liverpool, United Kingdom
- <sup>75</sup> Department of Physics, Jožef Stefan Institute and University of Ljubljana, Ljubljana, Slovenia
- <sup>76</sup> School of Physics and Astronomy, Queen Mary University of London, London, United Kingdom
- <sup>77</sup> Department of Physics, Royal Holloway University of London, Surrey, United Kingdom
- <sup>78</sup> Department of Physics and Astronomy, University College London, London, United Kingdom
- <sup>79</sup> Louisiana Tech University, Ruston LA, United States of America
- <sup>80</sup> Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France
- <sup>81</sup> Fysiska institutionen, Lunds universitet, Lund, Sweden
- <sup>82</sup> Departamento de Física Teórica C-15, Universidad Autónoma de Madrid, Madrid, Spain
- <sup>83</sup> Institut für Physik, Universität Mainz, Mainz, Germany
- <sup>84</sup> School of Physics and Astronomy, University of Manchester, Manchester, United Kingdom
- <sup>85</sup> CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France
- <sup>86</sup> Department of Physics, University of Massachusetts, Amherst MA, United States of America
- <sup>87</sup> Department of Physics, McGill University, Montreal QC, Canada
- <sup>88</sup> School of Physics, University of Melbourne, Victoria, Australia
- <sup>89</sup> Department of Physics, The University of Michigan, Ann Arbor MI, United States of America
- <sup>90</sup> Department of Physics and Astronomy, Michigan State University, East Lansing MI, United States of America
- <sup>91</sup> <sup>(a)</sup> INFN Sezione di Milano; <sup>(b)</sup> Dipartimento di Fisica, Università di Milano, Milano, Italy
- <sup>92</sup> B.I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk, Republic of Belarus
- <sup>93</sup> National Scientific and Educational Centre for Particle and High Energy Physics, Minsk, Republic of Belarus
- <sup>94</sup> Department of Physics, Massachusetts Institute of Technology, Cambridge MA, United States of America
- <sup>95</sup> Group of Particle Physics, University of Montreal, Montreal QC, Canada
- <sup>96</sup> P.N. Lebedev Institute of Physics, Academy of Sciences, Moscow, Russia
- <sup>97</sup> Institute for Theoretical and Experimental Physics (ITEP), Moscow, Russia
- <sup>98</sup> National Research Nuclear University MEPhI, Moscow, Russia
- <sup>99</sup> D.V. Skobel'syn Institute of Nuclear Physics, M.V. Lomonosov Moscow State University, Moscow, Russia
- <sup>100</sup> Fakultät für Physik, Ludwig-Maximilians-Universität München, München, Germany
- <sup>101</sup> Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), München, Germany
- <sup>102</sup> Nagasaki Institute of Applied Science, Nagasaki, Japan
- <sup>103</sup> Graduate School of Science and Kobayashi-Maskawa Institute, Nagoya University, Nagoya, Japan
- <sup>104</sup> <sup>(a)</sup> INFN Sezione di Napoli; <sup>(b)</sup> Dipartimento di Fisica, Università di Napoli, Napoli, Italy
- <sup>105</sup> Department of Physics and Astronomy, University of New Mexico, Albuquerque NM, United States of America
- <sup>106</sup> Institute for Mathematics, Astrophysics and Particle Physics, Radboud University Nijmegen/Nikhef, Nijmegen, Netherlands
- <sup>107</sup> Nikhef National Institute for Subatomic Physics and University of Amsterdam, Amsterdam, Netherlands
- <sup>108</sup> Department of Physics, Northern Illinois University, DeKalb IL, United States of America
- <sup>109</sup> Budker Institute of Nuclear Physics, SB RAS, Novosibirsk, Russia
- <sup>110</sup> Department of Physics, New York University, New York NY, United States of America
- <sup>111</sup> Ohio State University, Columbus OH, United States of America
- <sup>112</sup> Faculty of Science, Okayama University, Okayama, Japan
- <sup>113</sup> Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman OK, United States of America
- <sup>114</sup> Department of Physics, Oklahoma State University, Stillwater OK, United States of America
- <sup>115</sup> Palacký University, RCPTM, Olomouc, Czech Republic
- <sup>116</sup> Center for High Energy Physics, University of Oregon, Eugene OR, United States of America
- <sup>117</sup> LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France
- <sup>118</sup> Graduate School of Science, Osaka University, Osaka, Japan
- <sup>119</sup> Department of Physics, University of Oslo, Oslo, Norway
- <sup>120</sup> Department of Physics, Oxford University, Oxford, United Kingdom

- 121 <sup>(a)</sup> INFN Sezione di Pavia; <sup>(b)</sup> Dipartimento di Fisica, Università di Pavia, Pavia, Italy  
 122 Department of Physics, University of Pennsylvania, Philadelphia PA, United States of America  
 123 Petersburg Nuclear Physics Institute, Gatchina, Russia  
 124 <sup>(a)</sup> INFN Sezione di Pisa; <sup>(b)</sup> Dipartimento di Fisica E. Fermi, Università di Pisa, Pisa, Italy  
 125 Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh PA, United States of America  
 126 <sup>(a)</sup> Laboratorio de Instrumentacao e Fisica Experimental de Particulas - LIP, Lisboa; <sup>(b)</sup> Faculdade de Ciências, Universidade de Lisboa, Lisboa; <sup>(c)</sup> Department of Physics, University of Coimbra, Coimbra; <sup>(d)</sup> Centro de Física Nuclear da Universidade de Lisboa, Lisboa; <sup>(e)</sup> Departamento de Física, Universidade do Minho, Braga; <sup>(f)</sup> Departamento de Física Teórica y del Cosmos and CAFPE, Universidad de Granada, Granada (Spain); <sup>(g)</sup> Dep Física and CEFITEC of Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Caparica, Portugal  
 127 Institute of Physics, Academy of Sciences of the Czech Republic, Praha, Czech Republic  
 128 Czech Technical University in Prague, Praha, Czech Republic  
 129 Faculty of Mathematics and Physics, Charles University in Prague, Praha, Czech Republic  
 130 State Research Center Institute for High Energy Physics, Protvino, Russia  
 131 Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom  
 132 Ritsumeikan University, Kusatsu, Shiga, Japan  
 133 <sup>(a)</sup> INFN Sezione di Roma; <sup>(b)</sup> Dipartimento di Fisica, Sapienza Università di Roma, Roma, Italy  
 134 <sup>(a)</sup> INFN Sezione di Roma Tor Vergata; <sup>(b)</sup> Dipartimento di Fisica, Università di Roma Tor Vergata, Roma, Italy  
 135 <sup>(a)</sup> INFN Sezione di Roma Tre; <sup>(b)</sup> Dipartimento di Matematica e Fisica, Università Roma Tre, Roma, Italy  
 136 <sup>(a)</sup> Faculté des Sciences Ain Chock, Réseau Universitaire de Physique des Hautes Energies - Université Hassan II, Casablanca; <sup>(b)</sup> Centre National de l'Energie des Sciences Techniques Nucleaires, Rabat; <sup>(c)</sup> Faculté des Sciences Semlalia, Université Cadi Ayyad, LPHEA-Marrakech; <sup>(d)</sup> Faculté des Sciences, Université Mohamed Premier and LPTPM, Oujda; <sup>(e)</sup> Faculté des sciences, Université Mohammed V-Agdal, Rabat, Morocco  
 137 DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat à l'Energie Atomique et aux Energies Alternatives), Gif-sur-Yvette, France  
 138 Santa Cruz Institute for Particle Physics, University of California Santa Cruz, Santa Cruz CA, United States of America  
 139 Department of Physics, University of Washington, Seattle WA, United States of America  
 140 Department of Physics and Astronomy, University of Sheffield, Sheffield, United Kingdom  
 141 Department of Physics, Shinshu University, Nagano, Japan  
 142 Fachbereich Physik, Universität Siegen, Siegen, Germany  
 143 Department of Physics, Simon Fraser University, Burnaby BC, Canada  
 144 SLAC National Accelerator Laboratory, Stanford CA, United States of America  
 145 <sup>(a)</sup> Faculty of Mathematics, Physics & Informatics, Comenius University, Bratislava; <sup>(b)</sup> Department of Subnuclear Physics, Institute of Experimental Physics of the Slovak Academy of Sciences, Kosice, Slovak Republic  
 146 <sup>(a)</sup> Department of Physics, University of Cape Town, Cape Town; <sup>(b)</sup> Department of Physics, University of Johannesburg, Johannesburg; <sup>(c)</sup> School of Physics, University of the Witwatersrand, Johannesburg, South Africa  
 147 <sup>(a)</sup> Department of Physics, Stockholm University; <sup>(b)</sup> The Oskar Klein Centre, Stockholm, Sweden  
 148 Physics Department, Royal Institute of Technology, Stockholm, Sweden  
 149 Departments of Physics & Astronomy and Chemistry, Stony Brook University, Stony Brook NY, United States of America  
 150 Department of Physics and Astronomy, University of Sussex, Brighton, United Kingdom  
 151 School of Physics, University of Sydney, Sydney, Australia  
 152 Institute of Physics, Academia Sinica, Taipei, Taiwan  
 153 Department of Physics, Technion: Israel Institute of Technology, Haifa, Israel  
 154 Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel  
 155 Department of Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece  
 156 International Center for Elementary Particle Physics and Department of Physics, The University of Tokyo, Tokyo, Japan  
 157 Graduate School of Science and Technology, Tokyo Metropolitan University, Tokyo, Japan  
 158 Department of Physics, Tokyo Institute of Technology, Tokyo, Japan  
 159 Department of Physics, University of Toronto, Toronto ON, Canada  
 160 <sup>(a)</sup> TRIUMF, Vancouver BC; <sup>(b)</sup> Department of Physics and Astronomy, York University, Toronto ON, Canada  
 161 Faculty of Pure and Applied Sciences, University of Tsukuba, Tsukuba, Japan  
 162 Department of Physics and Astronomy, Tufts University, Medford MA, United States of America  
 163 Centro de Investigaciones, Universidad Antonio Narino, Bogota, Colombia

- <sup>164</sup> Department of Physics and Astronomy, University of California Irvine, Irvine CA, United States of America
- <sup>165</sup> <sup>(a)</sup> INFN Gruppo Collegato di Udine, Sezione di Trieste, Udine; <sup>(b)</sup> ICTP, Trieste; <sup>(c)</sup> Dipartimento di Chimica, Fisica e Ambiente, Università di Udine, Udine, Italy
- <sup>166</sup> Department of Physics, University of Illinois, Urbana IL, United States of America
- <sup>167</sup> Department of Physics and Astronomy, University of Uppsala, Uppsala, Sweden
- <sup>168</sup> Instituto de Física Corpuscular (IFIC) and Departamento de Física Atómica, Molecular y Nuclear and Departamento de Ingeniería Electrónica and Instituto de Microelectrónica de Barcelona (IMB-CNM), University of Valencia and CSIC, Valencia, Spain
- <sup>169</sup> Department of Physics, University of British Columbia, Vancouver BC, Canada
- <sup>170</sup> Department of Physics and Astronomy, University of Victoria, Victoria BC, Canada
- <sup>171</sup> Department of Physics, University of Warwick, Coventry, United Kingdom
- <sup>172</sup> Waseda University, Tokyo, Japan
- <sup>173</sup> Department of Particle Physics, The Weizmann Institute of Science, Rehovot, Israel
- <sup>174</sup> Department of Physics, University of Wisconsin, Madison WI, United States of America
- <sup>175</sup> Fakultät für Physik und Astronomie, Julius-Maximilians-Universität, Würzburg, Germany
- <sup>176</sup> Fachbereich C Physik, Bergische Universität Wuppertal, Wuppertal, Germany
- <sup>177</sup> Department of Physics, Yale University, New Haven CT, United States of America
- <sup>178</sup> Yerevan Physics Institute, Yerevan, Armenia
- <sup>179</sup> Centre de Calcul de l'Institut National de Physique Nucléaire et de Physique des Particules (IN2P3), Villeurbanne, France
- <sup>a</sup> Also at Department of Physics, King's College London, London, United Kingdom
- <sup>b</sup> Also at Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan
- <sup>c</sup> Also at Novosibirsk State University, Novosibirsk, Russia
- <sup>d</sup> Also at TRIUMF, Vancouver BC, Canada
- <sup>e</sup> Also at Department of Physics, California State University, Fresno CA, United States of America
- <sup>f</sup> Also at Department of Physics, University of Fribourg, Fribourg, Switzerland
- <sup>g</sup> Also at Departamento de Física e Astronomia, Faculdade de Ciências, Universidade do Porto, Portugal
- <sup>h</sup> Also at Tomsk State University, Tomsk, Russia
- <sup>i</sup> Also at CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France
- <sup>j</sup> Also at Università di Napoli Parthenope, Napoli, Italy
- <sup>k</sup> Also at Institute of Particle Physics (IPP), Canada
- <sup>l</sup> Also at Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom
- <sup>m</sup> Also at Department of Physics, St. Petersburg State Polytechnical University, St. Petersburg, Russia
- <sup>n</sup> Also at Louisiana Tech University, Ruston LA, United States of America
- <sup>o</sup> Also at Institutio Catalana de Recerca i Estudis Avancats, ICREA, Barcelona, Spain
- <sup>p</sup> Also at Department of Physics, National Tsing Hua University, Taiwan
- <sup>q</sup> Also at Department of Physics, The University of Texas at Austin, Austin TX, United States of America
- <sup>r</sup> Also at Institute of Theoretical Physics, Ilia State University, Tbilisi, Georgia
- <sup>s</sup> Also at CERN, Geneva, Switzerland
- <sup>t</sup> Also at Georgian Technical University (GTU), Tbilisi, Georgia
- <sup>u</sup> Also at Ochadai Academic Production, Ochanomizu University, Tokyo, Japan
- <sup>v</sup> Also at Manhattan College, New York NY, United States of America
- <sup>w</sup> Also at Institute of Physics, Academia Sinica, Taipei, Taiwan
- <sup>x</sup> Also at LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France
- <sup>y</sup> Also at Academia Sinica Grid Computing, Institute of Physics, Academia Sinica, Taipei, Taiwan
- <sup>z</sup> Also at School of Physics, Shandong University, Shandong, China
- <sup>aa</sup> Also at Moscow Institute of Physics and Technology State University, Dolgoprudny, Russia
- <sup>ab</sup> Also at Section de Physique, Université de Genève, Geneva, Switzerland
- <sup>ac</sup> Also at International School for Advanced Studies (SISSA), Trieste, Italy
- <sup>ad</sup> Also at Department of Physics and Astronomy, University of South Carolina, Columbia SC, United States of America
- <sup>ae</sup> Also at School of Physics and Engineering, Sun Yat-sen University, Guangzhou, China
- <sup>af</sup> Also at Faculty of Physics, M.V.Lomonosov Moscow State University, Moscow, Russia
- <sup>ag</sup> Also at National Research Nuclear University MEPhI, Moscow, Russia
- <sup>ah</sup> Also at Department of Physics, Stanford University, Stanford CA, United States of America
- <sup>ai</sup> Also at Institute for Particle and Nuclear Physics, Wigner Research Centre for Physics, Budapest, Hungary

<sup>aj</sup> Also at Department of Physics, The University of Michigan, Ann Arbor MI, United States of America

<sup>ak</sup> Also at Discipline of Physics, University of KwaZulu-Natal, Durban, South Africa

<sup>al</sup> Also at University of Malaya, Department of Physics, Kuala Lumpur, Malaysia

\* Deceased

## SUPPLEMENTAL MATERIAL

The fiducial cross section  $\sigma_i$  in a given bin  $i$  can be expressed as

$$\sigma_i = \frac{n_i}{\mathcal{L} \mathcal{B} \alpha_i c_i} = \frac{\sigma_{\text{fid},i}}{\mathcal{B} \alpha_i}, \quad (1)$$

where  $n_i$  is the measured Higgs boson signal yield,  $\mathcal{L}$  is the integrated luminosity ( $20.3 \text{ fb}^{-1}$  for this analysis),  $\mathcal{B}$  is the branching ratio (0.228% for  $H \rightarrow \gamma\gamma$  and 0.0129% for  $H \rightarrow ZZ^* \rightarrow 4\ell$ ,  $\ell = e$  or  $\mu$ ),  $\alpha_i$  is the fiducial acceptance and  $c_i$  is a correction factor for detector effects, primarily accounting for reconstruction efficiency but also for bin-to-bin migration. For  $H \rightarrow ZZ^* \rightarrow 4\ell$ , the signal yield is defined as the number of observed events  $n_{\text{data}}$  in a window around the Higgs boson mass peak minus the background estimate:  $n_i = n_{\text{data},i} - n_{\text{bkg},i}$ , while for  $H \rightarrow \gamma\gamma$ , the signal yield is extracted from a simultaneous signal+background fit of the  $m_{\gamma\gamma}$  distribution. The correction factors for detector effects  $c_i$ , along with their systematic uncertainties are taken from the differential cross section measurements in the individual channels [8, 9]. The differential cross section is defined as the fiducial cross section divided by the bin width.

TABLE II. Fiducial acceptance factors in percent for the  $H \rightarrow ZZ^* \rightarrow 4\ell$  measurement with associated uncertainties. The binning is the same as in Fig. 4.

Bin	1	2	3	4	5
Incl.	$46.7 \pm 1.1$				
$N_{\text{jets}}$	$45.0 \pm 1.1$	$47.8 \pm 1.0$	$49.8 \pm 1.3$	$50.0 \pm 1.9$	
$p_{\text{T}}^{\text{j1}}$	$45.0 \pm 1.1$	$46.2 \pm 0.8$	$47.7 \pm 0.8$	$50.3 \pm 0.7$	
$ y^{\text{H}} $	$59.2 \pm 0.9$	$58.7 \pm 0.7$	$57.9 \pm 0.8$	$55.3 \pm 0.6$	$34.8 \pm 0.8$
$p_{\text{T}}^{\text{H}}$	$44.4 \pm 1.0$	$45.2 \pm 0.9$	$47.6 \pm 0.7$	$52.9 \pm 0.7$	

TABLE III. Fiducial acceptance factors in percent for the  $H \rightarrow \gamma\gamma$  measurement with associated uncertainties. The binning is the same as in Fig. 4.

Bin	1	2	3	4	5	6	7	8
Incl.	$60.4 \pm 1.2$							
$N_{\text{jets}}$	$62.1 \pm 1.4$	$59.1 \pm 0.7$	$58.4 \pm 1.4$	$55.9 \pm 3.5$				
$p_{\text{T}}^{\text{j1}}$	$62.1 \pm 1.4$	$58.9 \pm 0.9$	$57.4 \pm 0.9$	$57.2 \pm 0.9$	$58.3 \pm 1.6$			
$ y^{\text{H}} $	$71.5 \pm 1.2$	$71.6 \pm 1.2$	$71.7 \pm 1.2$	$71.5 \pm 1.2$	$67.7 \pm 1.3$	$37.7 \pm 0.5$		
$p_{\text{T}}^{\text{H}}$	$62.2 \pm 1.1$	$62.2 \pm 1.2$	$60.6 \pm 1.3$	$59.3 \pm 1.1$	$57.9 \pm 1.2$	$57.5 \pm 0.9$	$56.7 \pm 1.1$	$58.6 \pm 1.0$

## Fiducial acceptance

For each bin  $i$ , the acceptance factor for each decay channel is defined as

$$\alpha_i = \frac{\sigma_{\text{fid},i}}{\sigma_{\text{incl},i}}. \quad (2)$$

The fiducial acceptances for both channels and all measured distributions are presented in Fig. 4 and Tables II and III. They are based on Eq. 2 and derived using the Higgs MC samples described in the text. For  $p_{\text{T}}^{\text{H}}$  and  $|y^{\text{H}}|$ ,  $\alpha_i$  is the probability for an event to pass the fiducial requirements. The acceptance is lower for  $H \rightarrow ZZ^* \rightarrow 4\ell$  than for  $H \rightarrow \gamma\gamma$  since it is less likely for four decay products to fulfill the fiducial requirements. For the jet variables  $p_{\text{T}}^{\text{j1}}$  and  $N_{\text{jets}}$ , an additional migration effect enters due to overlap between jets and the Higgs boson decay products, which affects the fiducial regions differently than the total phase space, where no Higgs boson decay products need to be considered. The fiducial acceptance falls off steeply as the Higgs boson rapidity increases, as both fiducial definitions include pseudo-rapidity requirements on the Higgs boson decay products.

## Additional figures

Figure 5 presents the measured jet multiplicity distributions. The lower two subfigures include the individual  $H \rightarrow \gamma\gamma$  and  $H \rightarrow ZZ^* \rightarrow 4\ell$  measurements. Figure 6 presents the same six distributions as shown in Fig. 3, but with the individual channel measurements overlaid.

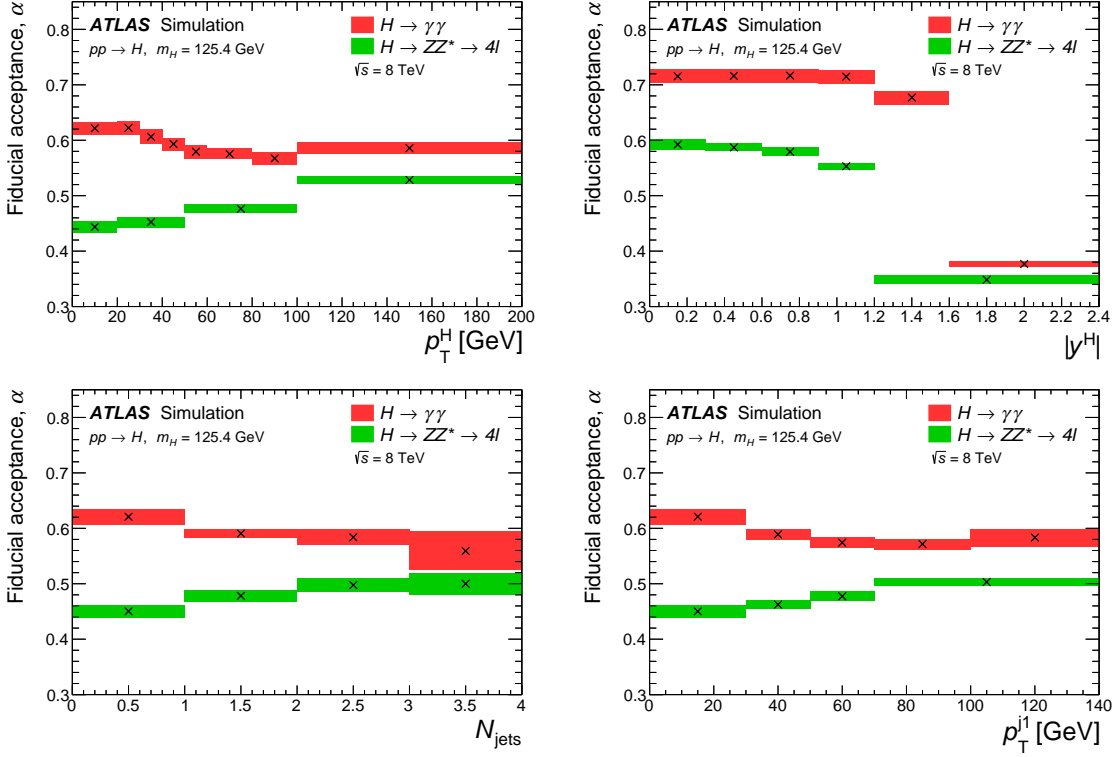


FIG. 4. Fiducial acceptances mapping each measured bin of the  $p_T^H$ ,  $|y^H|$ ,  $N_{\text{jets}}$ , and  $p_T^{j1}$  distributions from the inclusive phase space to the respective fiducial regions. The factors are derived using POWHEG for ggF and VBF production and PYTHIA8 for  $VH$ ,  $t\bar{t}H$ , and  $b\bar{b}H$ . The width of the band indicates the uncertainty from five sources: missing higher order corrections, PDF variations, changing the Higgs boson mass and the production mode composition, and variations of the hadronization/underlying event tunes (see main text for further details). The PDF uncertainty is the largest individual contribution to the total uncertainty.

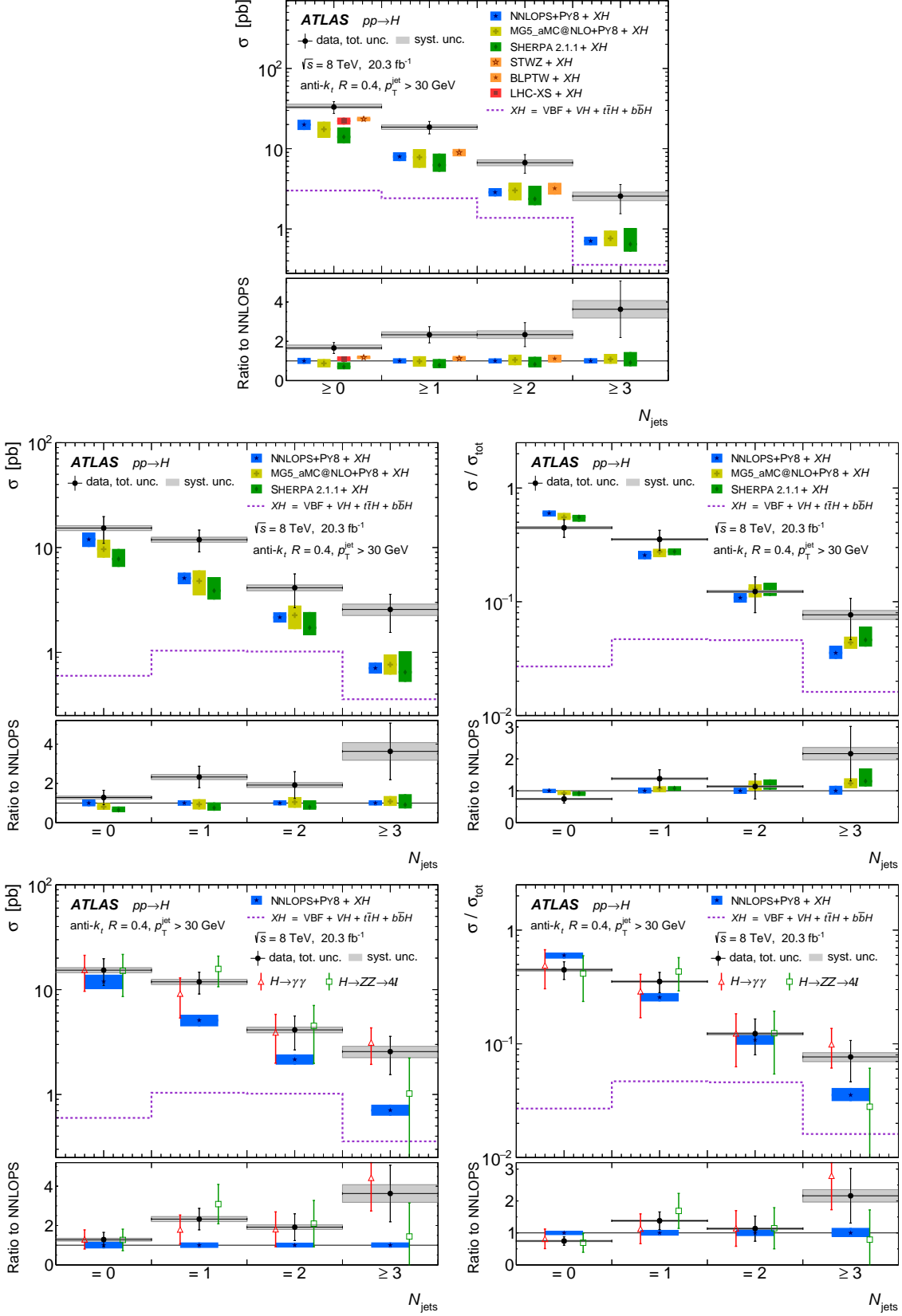


FIG. 5. Absolute and fractional cross sections in bins of jet multiplicity for inclusive Higgs boson production at  $\sqrt{s} = 8$  TeV measured by combining the  $H \rightarrow \gamma\gamma$  and  $H \rightarrow ZZ^* \rightarrow 4\ell$  analyses using  $20.3 \text{ fb}^{-1}$  of  $pp$  collisions. The top plot shows the cross section in inclusive jet bins, while the other plots have exclusive jet binning (except for the  $\geq 3$  jets bin). In the lower two plots, the cross sections of the two channels are shown individually, defined by the fiducial cross sections corrected for acceptance and branching ratio (see Eq. 1). These cross sections have partially correlated systematic uncertainties that are considered in the combined measurement.

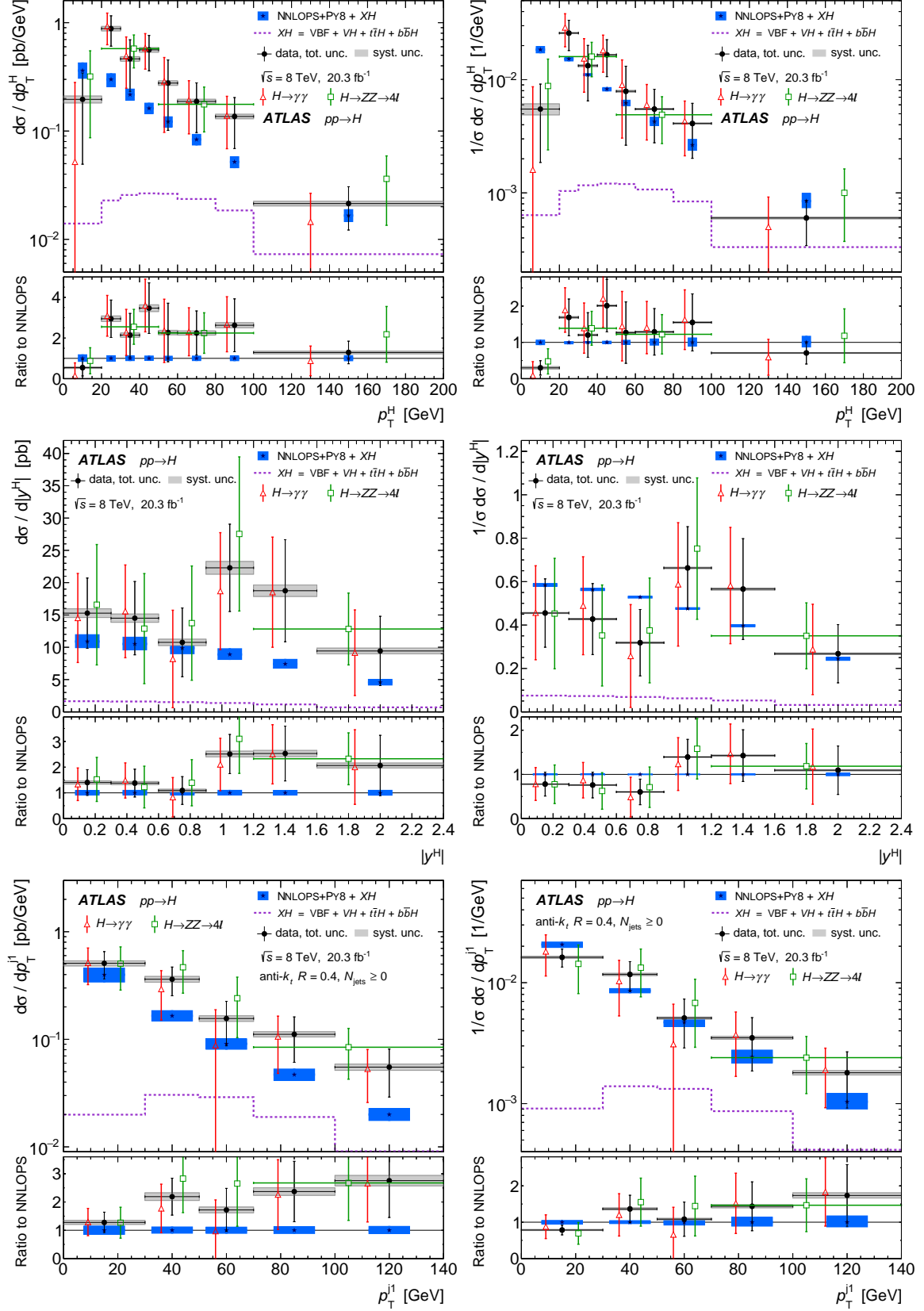


FIG. 6. Differential cross sections (left) and shapes (right) of the Higgs boson transverse momentum (top), absolute rapidity (middle) and leading jet transverse momentum (bottom) of inclusive Higgs boson production at  $\sqrt{s} = 8$  TeV measured in the  $H \rightarrow \gamma\gamma$  and  $H \rightarrow ZZ^* \rightarrow 4\ell$  final states using  $20.3 \text{ fb}^{-1}$  of  $pp$  collisions. Both the combined measurements as well as the individual channels are shown.



### Result tables

Tables IV–VII present the measured differential cross sections and Tables VIII–XI report the corresponding shape measurements.

TABLE IV. Measured cross section in bins of  $p_T^H$ . The first uncertainty is statistical, the second is systematic.

Bins [GeV]	$d\sigma/dp_T^H$ [pb/GeV]		
0–20	$0.20 \pm 0.15$	$\pm 0.01$	
20–30	$0.88 \pm 0.27$	$\pm 0.04$	
30–40	$0.46 \pm 0.23$	$\pm 0.02$	
40–50	$0.56 \pm 0.20$	$\pm 0.03$	
50–60	$0.28 \pm 0.18$	$\pm 0.01$	
60–80	$0.188 \pm 0.090$	$\pm 0.009$	
80–100	$0.136 \pm 0.067$	$\pm 0.006$	
100–200	$0.0214 \pm 0.0091 \pm 0.0010$		

TABLE V. Measured cross section in bins of  $|y^H|$ . The first uncertainty is statistical, the second is systematic.

Bins	$d\sigma/d y^H $ [pb]	
0.0–0.3	$15.3 \pm 5.4$	$\pm 0.7$
0.3–0.6	$14.5 \pm 5.6$	$\pm 0.6$
0.6–0.9	$10.8 \pm 5.3$	$\pm 0.5$
0.9–1.2	$22.3 \pm 6.7$	$\pm 1.0$
1.2–1.6	$18.8 \pm 7.9$	$\pm 0.9$
1.6–2.4	$9.4 \pm 5.3$	$\pm 0.4$

TABLE VI. Measured cross section in bins of  $N_{\text{jets}}$ . The first uncertainty is statistical, the second is systematic.

Bins	$d\sigma/dN_{\text{jets}}$ [pb]		
0	$15.3 \pm 4.3$	$\pm 0.8$	
1	$11.9 \pm 2.7$	$\pm 0.6$	
2	$4.1 \pm 1.5$	$\pm 0.3$	
$\geq 3$	$2.57 \pm 0.97 \pm 0.32$		

TABLE VII. Measured cross section in bins of  $p_T^{j1}$ . The first uncertainty is statistical, the second is systematic.

Bins [GeV]	$d\sigma/dp_T^{j1}$ [pb/GeV]		
0–30	$0.51 \pm 0.14$	$\pm 0.03$	
30–50	$0.36 \pm 0.11$	$\pm 0.02$	
50–70	$0.156 \pm 0.069$	$\pm 0.009$	
70–100	$0.111 \pm 0.050$	$\pm 0.006$	
100–140	$0.055 \pm 0.026 \pm 0.004$		

TABLE VIII. Measured fractions in bins of  $p_T^H$ . The first uncertainty is statistical, the second is systematic.

Bins [GeV]	$1/\sigma d\sigma/dp_T^H$ [1/GeV]		
0–20	$0.0055 \pm 0.0036$	$\pm 0.0006$	
20–30	$0.0258 \pm 0.0077$	$\pm 0.0003$	
30–40	$0.0133 \pm 0.0068$	$\pm 0.0002$	
40–50	$0.0166 \pm 0.0060$	$\pm 0.0002$	
50–60	$0.0079 \pm 0.0053$	$\pm 0.0001$	
60–80	$0.0055 \pm 0.0027$	$\pm 0.0001$	
80–100	$0.0041 \pm 0.0021$	$\pm 0.0000$	
100–200	$0.00060 \pm 0.00026 \pm 0.00001$		

TABLE IX. Measured fractions in bins of  $|y^H|$ . The first uncertainty is statistical, the second is systematic.

Bins	$1/\sigma d\sigma/d y^H $	
0.0–0.3	$0.46 \pm 0.16$	$\pm 0.00$
0.3–0.6	$0.43 \pm 0.16$	$\pm 0.00$
0.6–0.9	$0.32 \pm 0.15$	$\pm 0.00$
0.9–1.2	$0.66 \pm 0.19$	$\pm 0.00$
1.2–1.6	$0.57 \pm 0.23$	$\pm 0.00$
1.6–2.4	$0.27 \pm 0.13$	$\pm 0.00$

TABLE X. Measured fractions in bins of  $N_{\text{jets}}$ . The first uncertainty is statistical, the second is systematic.

Bins	$1/\sigma d\sigma/dN_{\text{jets}}$	
0	$0.447 \pm 0.078$	$\pm 0.010$
1	$0.353 \pm 0.071$	$\pm 0.005$
2	$0.123 \pm 0.043$	$\pm 0.003$
$\geq 3$	$0.077 \pm 0.029 \pm 0.007$	

TABLE XI. Measured fractions in bins of  $p_T^{j1}$ . The first uncertainty is statistical, the second is systematic.

Bins [GeV]	$1/\sigma d\sigma/dp_T^{j1}$ [1/GeV]		
0–30	$0.0162 \pm 0.0027$	$\pm 0.0003$	
30–50	$0.0117 \pm 0.0032$	$\pm 0.0002$	
50–70	$0.0051 \pm 0.0022$	$\pm 0.0001$	
70–100	$0.0035 \pm 0.0016$	$\pm 0.0001$	
100–140	$0.00180 \pm 0.00088 \pm 0.00007$		

### Uncertainty correlation tables

Tables XII–XV contain the correlation matrices of the differential cross section measurements and Tables XVI–XIX those of the differential shape measurements.

TABLE XII. Correlation matrix for the total uncertainty of the differential cross-section measurement in bins of  $p_T^H$ .

	Bin 1	Bin 2	Bin 3	Bin 4	Bin 5	Bin 6	Bin 7	Bin 8
Bin 1	1.00	0.01	0.01	0.01	0.00	0.01	0.01	0.01
Bin 2	0.01	1.00	-0.13	-0.10	0.01	0.01	0.01	0.02
Bin 3	0.01	-0.13	1.00	-0.08	0.01	0.01	0.01	0.01
Bin 4	0.01	-0.10	-0.08	1.00	0.01	0.01	0.01	0.01
Bin 5	0.00	0.01	0.01	0.01	1.00	-0.16	-0.11	0.01
Bin 6	0.01	0.01	0.01	0.01	-0.16	1.00	-0.11	0.01
Bin 7	0.01	0.01	0.01	0.01	-0.11	-0.11	1.00	0.01
Bin 8	0.01	0.02	0.01	0.01	0.01	0.01	0.01	1.00

TABLE XIII. Correlation matrix for the total uncertainty of the differential cross-section measurement in bins of  $|y^H|$ .

	Bin 1	Bin 2	Bin 3	Bin 4	Bin 5	Bin 6
Bin 1	1.00	0.01	0.01	0.02	0.01	0.01
Bin 2	0.01	1.00	0.01	0.02	0.01	0.01
Bin 3	0.01	0.01	1.00	0.01	0.01	0.01
Bin 4	0.02	0.02	0.01	1.00	0.02	0.01
Bin 5	0.01	0.01	0.01	0.02	1.00	-0.28
Bin 6	0.01	0.01	0.01	0.01	-0.28	1.00

TABLE XIV. Correlation matrix for the total uncertainty of the differential cross-section measurement in bins of  $N_{\text{jets}}$ .

	Bin 1	Bin 2	Bin 3	Bin 4
Bin 1	1.00	0.03	-0.02	0.02
Bin 2	0.03	1.00	-0.04	0.05
Bin 3	-0.02	-0.04	1.00	-0.04
Bin 4	0.02	0.05	-0.04	1.00

TABLE XV. Correlation matrix for the total uncertainty of the differential cross-section measurement in bins of  $p_T^{j1}$ .

	Bin 1	Bin 2	Bin 3	Bin 4	Bin 5
Bin 1	1.00	0.03	0.02	0.02	0.01
Bin 2	0.03	1.00	0.02	0.02	0.02
Bin 3	0.02	0.02	1.00	0.02	0.01
Bin 4	0.02	0.02	0.02	1.00	-0.19
Bin 5	0.01	0.02	0.01	-0.19	1.00

TABLE XVI. Correlation matrix for the total uncertainty of the differential shape measurement in bins of  $p_T^H$ .

	Bin 1	Bin 2	Bin 3	Bin 4	Bin 5	Bin 6	Bin 7	Bin 8
Bin 1	1.00	-0.28	-0.22	-0.18	-0.16	-0.17	-0.11	-0.12
Bin 2	-0.28	1.00	-0.34	-0.28	-0.11	-0.11	-0.08	-0.08
Bin 3	-0.22	-0.34	1.00	-0.21	-0.08	-0.09	-0.06	-0.06
Bin 4	-0.18	-0.28	-0.21	1.00	-0.07	-0.07	-0.05	-0.05
Bin 5	-0.16	-0.11	-0.08	-0.07	1.00	-0.26	-0.18	-0.04
Bin 6	-0.17	-0.11	-0.09	-0.07	-0.26	1.00	-0.18	-0.05
Bin 7	-0.11	-0.08	-0.06	-0.05	-0.18	-0.18	1.00	-0.03
Bin 8	-0.12	-0.08	-0.06	-0.05	-0.04	-0.05	-0.03	1.00

TABLE XVII. Correlation matrix for the total uncertainty of the differential shape measurement in bins of  $|y^H|$ .

	Bin 1	Bin 2	Bin 3	Bin 4	Bin 5	Bin 6
Bin 1	1.00	-0.09	-0.09	-0.11	-0.10	-0.21
Bin 2	-0.09	1.00	-0.09	-0.12	-0.11	-0.22
Bin 3	-0.09	-0.09	1.00	-0.11	-0.10	-0.21
Bin 4	-0.11	-0.12	-0.11	1.00	-0.13	-0.27
Bin 5	-0.10	-0.11	-0.10	-0.13	1.00	-0.66
Bin 6	-0.21	-0.22	-0.21	-0.27	-0.66	1.00

TABLE XVIII. Correlation matrix for the total uncertainty of the differential shape measurement in bins of  $N_{\text{jets}}$ .

	Bin 1	Bin 2	Bin 3	Bin 4
Bin 1	1.00	-0.77	-0.37	-0.26
Bin 2	-0.77	1.00	-0.16	-0.11
Bin 3	-0.37	-0.16	1.00	-0.05
Bin 4	-0.26	-0.11	-0.05	1.00

TABLE XIX. Correlation matrix for the total uncertainty of the differential shape measurement in bins of  $p_T^{j1}$ .

	Bin 1	Bin 2	Bin 3	Bin 4	Bin 5
Bin 1	1.00	-0.63	-0.38	-0.36	-0.20
Bin 2	-0.63	1.00	-0.12	-0.11	-0.06
Bin 3	-0.38	-0.12	1.00	-0.07	-0.04
Bin 4	-0.36	-0.11	-0.07	1.00	-0.28
Bin 5	-0.20	-0.06	-0.04	-0.28	1.00

## Gluon fusion cross section

Figure 7 shows the measurement of the Higgs boson production cross section compared to a range of theory predictions, including LHC-XS, the result used by the ATLAS and CMS collaboration in Run 1, for which the ggF part is accurate to NNLO+NNLL in QCD [10], as well as ggF cross section calculations that attempt to go beyond NNLO, including the recently completed full N<sup>3</sup>LO prediction. Details about the various predictions are presented in Table XX, and the central values and a breakdown of the uncertainties of the calculations as well as the measurement are reported in Table XXI.

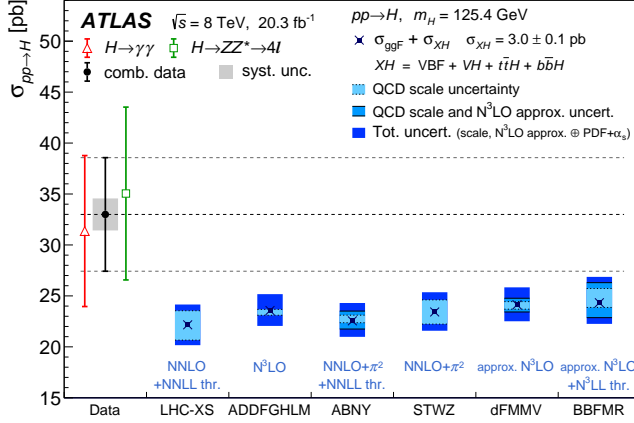


FIG. 7. Measured total cross section of Higgs boson production compared to different theoretical calculations.

TABLE XX. Summary of the ggF predictions used in the comparison with the measured cross sections. The second column states the order in QCD perturbation theory and which threshold resummation is applied, if any. Further details are provided in the footnotes. All predictions are for  $m_H = 125.4$  GeV and  $\sqrt{s} = 8$  TeV.

Total cross-section calculations	
LHC-XS [10]	NNLO+NNLL <sup>a,b,c</sup>
ADDFGHLM [27–30]	N <sup>3</sup> LO <sup>a,b,c</sup>
ABNY [47]	NNLO+NNLL <sup>a,b,c,d,e</sup>
STWZ [31]	NNLO <sup>c,d</sup>
dFMMV [48]	approx. N <sup>3</sup> LO <sup>c</sup>
BBFMR [49–51]	approx. N <sup>3</sup> LO+N <sup>3</sup> LL <sup>a,b,c</sup>

<sup>a</sup> Considers  $b$ - (and  $c$ -) quark masses in the  $gg \rightarrow H$  loop

<sup>b</sup> Includes electroweak corrections

<sup>c</sup> Based on MSTW2008nnlo [18] ( $\alpha_s$  from PDF set)

<sup>d</sup> Uses  $\pi^2$ -resummed  $gg \rightarrow H$  form factor

<sup>e</sup> In the counting of Ref. [47], the result has N<sup>3</sup>LL accuracy

For the predictions, uncertainties from renormalization, factorization and, where appropriate, resummation scale variations as well as uncertainties due to approximation or missing terms beyond NNLO are pro-

TABLE XXI. Central values and uncertainties for the different ggF predictions and the data.

Name	$\sigma_{gg \rightarrow H}$ [pb]	
Data– $XH^a$	$30.0 \pm 5.3$ (stat)	$\pm 1.6$ (sys)
LHC-XS	$19.15^{+1.38}_{-1.49}$ (scale)	$^{+1.44}_{-1.32}$ (pdf)
ADDFGHLM	$20.55^{+0.04}_{-0.45}$ (scale)	$^{+1.60}_{-1.44}$ (pdf)
ABNY	$19.54^{+0.55}_{-0.14}$ (scale)	$^{+1.47}_{-1.35}$ (pdf) $\pm 0.78$ (appr.)
STWZ	$20.41 \pm 1.18$ (scale)	$^{+1.53}_{-1.41}$ (pdf)
dFMMV	$21.12^{+0.29}_{-0.42}$ (scale)	$^{+1.58}_{-1.46}$ (pdf) $\pm 0.56$ (appr.)
BBFMR	$21.32^{+1.39}_{-0.45}$ (scale)	$^{+1.60}_{-1.47}$ (pdf) $\pm 1.39$ (appr.)

<sup>a</sup> Non-ggF cross section

$\sigma_{XH} = 3.01^{+0.05}_{-0.06}$  (scale)  $\pm 0.09$  (pdf) pb, subtracted from the measured inclusive cross section:  $33.0 \pm 5.3$  (stat)  $\pm 1.6$  (sys) pb.

vided separately for each prediction. The same relative PDF uncertainty of  $^{+7.5}_{-6.9}\%$  is assigned to all ggF predictions, except for the ADDFGHLM prediction for which this uncertainty is increased to  $^{+7.8}_{-7.0}\%$  corresponding to the change in MSTW2008nnlo uncertainty observed by the group when changing the matrix element from NNLO to N<sup>3</sup>LO. The non-ggF contribution ( $\sigma_{XH} = 3.01^{+0.05}_{-0.06}$  (scale)  $\pm 0.09$  (pdf) pb,  $XH = VBF + VH + t\bar{t}H + b\bar{b}H$ ) is added to the ggF predictions to be able to compare to the data in Fig. 7.

As detailed in Table XX, all inclusive predictions use the same PDF set but differ in the perturbative calculation. Four of the predictions apply both electroweak corrections and consider finite  $b$ - and  $c$ -quark masses. These corrections have non-negligible impacts on the ggF cross section; the electroweak correction results in an increase of approximately 5%, while the bottom and charm corrections give a  $O(5 - 10\%)$  reduction depending on precisely how they have been implemented in the calculations. They therefore have an opposite effect on the total cross section such that their numerical effects partially cancel. The STWZ and dFMMV predictions consider neither of these corrections.

The calculations take different approaches to approximately evaluate the ggF cross section beyond NNLO. Therefore the preferred scale for each calculation differs, and the choice of scale and the precise scale variations applied was left to the authors of the calculations. The LHC-XS, ABNY, STWZ, and BBFMR predictions use a central scale of  $\mu_0 = m_H$  as their overall scale, while dFMMV and ADDFGHLM use  $\mu_0 = m_H/2$ .

### Compatibility between predictions and data

Tables XXII and XXIII present compatibility tests between the differential predictions and the measured cross sections and shapes respectively. The theory uncertainties are assumed to be Gaussian and to be fully correlated between bins.

TABLE XXII.  $p$ -values quantifying the compatibility between predictions and the data for the differential cross sections. The theory uncertainties are assumed to be Gaussian and to be fully correlated between bins.

	$p_T^H$	$ y^H $	$p_T^{j1}$
HRES	2%	14%	-
STWZ	-	-	26%
JetVHeto	-	-	24%

TABLE XXIII.  $p$ -values quantifying the compatibility between predictions and data for the differential shapes. The theory uncertainties are assumed to be Gaussian distributed and fully correlated between bins.

	$p_T^H$	$ y^H $	$p_T^{j1}$
HRES	15%	64%	-
NNLOPS	10%	64%	64%
SHERPA 2.1.1	22%	63%	88%
MG5_aMC@NLO	8%	60%	88%

### Non-perturbative correction factors

Table XXIV presents multiplicative non-perturbative correction factors and associated uncertainties that are applied to correct analytical parton-level predictions presented in this Letter to particle level. These corrections account for hadronization and multiple parton interactions, and are derived based on a number of underlying event and showering tunes applied to the Higgs boson production MC samples used in the analysis.

TABLE XXIV. Non-perturbative factors in percent with systematic uncertainties, accounting for the impact of hadronization and underlying event.

Bin	1	2	3	4	5	6	7	8
$p_T^H$	$99.5 \pm 1.0$	$100.5 \pm 1.3$	$99.9 \pm 1.1$	$99.9 \pm 1.4$	$100.2 \pm 1.4$	$99.9 \pm 1.1$	$100.4 \pm 1.5$	$100.0 \pm 1.0$
$ y^H $	$100.0 \pm 0.8$	$100.1 \pm 0.7$	$99.8 \pm 0.7$	$100.1 \pm 0.8$	$100.0 \pm 0.7$	$99.8 \pm 0.6$		
$N_{\text{jets, excl}}$	$100.6 \pm 2.1$	$99.8 \pm 2.9$	$99.3 \pm 5.0$	$96.7 \pm 6.7$				
$N_{\text{jets, incl}}$	$100.0 \pm 0.0$	$99.2 \pm 2.5$	$98.7 \pm 5.3$	$96.8 \pm 6.7$				
$p_T^{j1}$	$100.6 \pm 2.1$	$99.6 \pm 2.6$	$99.2 \pm 2.9$	$99.1 \pm 3.2$	$98.7 \pm 3.6$			