Measurement of the Electron Charge Asymmetry in Inclusive W Production in pp Collisions at $\sqrt{s} = 7$ TeV

S. Chatrchyan *et al.**
(CMS Collaboration)

(Received 12 June 2012; published 11 September 2012)

A measurement of the electron charge asymmetry in inclusive $pp \to W + X \to e\nu + X$ production at $\sqrt{s} = 7$ TeV is presented based on data recorded by the CMS detector at the LHC and corresponding to an integrated luminosity of 840 pb^{-1}. The electron charge asymmetry reflects the unequal production of W^+ and W^- bosons in pp collisions. The electron charge asymmetry is measured in bins of the absolute value of electron pseudorapidity in the range of $|\eta| < 2.4$. The asymmetry rises from about 0.1 to 0.2 as a function of the pseudorapidity and is measured with a relative precision better than 7%. This measurement provides new stringent constraints for parton distribution functions.

DOI: 10.1103/PhysRevLett.109.111806 PACS numbers: 14.70.Fm, 12.15.−y, 13.85.Qk

The dominant mechanism for W boson production in pp collisions at the Large Hadron Collider (LHC) is the annihilation of a valence quark from one proton with a sea antiquark from the other. Because the proton contains two valence u quarks and one valence d quark, W^+ bosons are produced more frequently than W^- bosons. The Compact Muon Solenoid (CMS) Collaboration measured the ratio of the inclusive W^+ and W^- production cross sections at $\sqrt{s} = 7$ TeV at the LHC [1] to be in good agreement with the prediction of the standard model based on various parton distribution functions (PDFs) [2–7]. In this Letter, we present a further investigation of inclusive W^+ and W^- production in the $W \to e\nu$ decay channel. We measure the electron charge asymmetry, defined as

$$\mathcal{A}(\eta) = \frac{d\sigma/d\eta(W^+ \to e^+\nu) - d\sigma/d\eta(W^- \to e^-\bar{\nu})}{d\sigma/d\eta(W^+ \to e^+\nu) + d\sigma/d\eta(W^- \to e^-\bar{\nu})}, \quad (1)$$

where η is the electron pseudorapidity in the CMS lab frame [$\eta = -\ln\tan(\theta/2)$, θ is the polar angle, measured from the anticlockwise beam direction], and $d\sigma/d\eta$ is the differential cross section for electrons from W boson decays. Within the CMS tracker acceptance ($|\eta| < 2.5$), the asymmetry is expected to rise with increasing $|\eta|$ because the valence u quarks that produce the W^+ bosons tend to carry a higher fraction x of the proton momentum [8] than the valence d quarks that produce the W^- bosons. Measurements of the asymmetry provide constraints on the u, d, $\bar{u}$, and $\bar{d}$ PDFs in the range $10^{-3} < x < 10^{-1}$ and are complementary to measurements of deep inelastic scattering at HERA [4].

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

The lepton charge asymmetry and the W charge asymmetry have been studied in $p\bar{p}$ collisions by the CDF and D0 Collaborations at the Fermilab Tevatron collider [9,10]. The ATLAS and CMS Collaborations at the LHC reported measurements of the lepton charge asymmetry in the region $|\eta| < 2.5$ using the data collected during the 2010 LHC runs [11,12]. The LHCb Collaboration recently extended the measurement of the lepton charge asymmetry at the LHC to the $2.0 < \eta < 4.5$ region [13]. The NNPDF Collaboration estimated the impact of the CMS and ATLAS results on the PDFs [5]; the uncertainty on the light flavor and antiflavor distributions is reduced by 20% at $x \sim 10^{-3}$ and by 10%–25% at larger x values.

The results presented in this Letter significantly improve the measurement of the electron charge asymmetry in inclusive $pp \to W + X \to e\nu + X$ production at $\sqrt{s} = 7$ TeV and are based on a data sample corresponding to 840 pb^{-1} collected in spring 2011. This analysis uses the portion of the 2011 data set for which the single-electron trigger threshold was relatively low. Compared to the analysis performed in 2010 [12], the threshold on the electron transverse momentum (p_T) is increased from 25 to 35 GeV to match the higher trigger threshold for single electrons. The data sample is ~25 times larger than in 2010 and allows a reduction of many systematic uncertainties.

A detailed description of the CMS experiment can be found elsewhere [14]. The central feature of the CMS apparatus is a superconducting solenoid of 6 m internal diameter, 13 m in length, providing an axial field of 3.8 T. Within the field volume are the silicon pixel and strip tracker, the crystal electromagnetic calorimeter (ECAL), and the brass-scintillator hadron calorimeter. Muons are measured in gas-ionization detectors embedded in the steel return yoke of the solenoid. The most relevant subdetectors for this measurement are the ECAL and the tracking system. The electromagnetic calorimeter consists of nearly 76 000 lead tungstate crystals, which provide coverage in pseudorapidity $|\eta| < 1.48$ in the barrel region and

$1.48 < |\eta| < 3.00$ in two end cap regions. A preshower detector consisting of two planes of silicon sensors interleaved with a total of $3X_0$ of lead is located in front of the ECAL end caps. The energy resolution measured for electrons from Z decays varies across the acceptance of the ECAL. It is less than 2% in the central region of the ECAL barrel ($|\eta| < 1$), 3% in the outer barrel, and approximately 4%–5% in the end caps.

The $W \to e\nu$ candidates are characterized by a high-p_T electron accompanied by missing transverse energy $\not{E}_T$, due to the escaping neutrino. Experimentally, $\not{E}_T$ is determined as the magnitude of the negative vector sum of the transverse momenta of all particles reconstructed using a particle-flow algorithm [15] and, in this measurement, $\not{E}_T$ is used to separate signal from background on a statistical basis. The $W \to e\nu$ candidates used in this analysis were collected using a set of inclusive single-electron triggers that did not include $\not{E}_T$ requirements. Multijet and photon + jet production (QCD backgrounds) can give rise to high-p_T electron candidates and mimic W decays. Other background sources include Drell-Yan ($Z/\gamma^* \to \ell^+\ell^-$) and $W \to \tau\nu$ production [electroweak (EW) backgrounds], as well as top-quark pair ($t\bar{t}$) production.

Monte Carlo (MC) simulation samples are used to develop analysis techniques and estimate some of the background contributions. The signal and the EW backgrounds are simulated with the POWHEG [16] event generator interfaced with the CT10 [3] PDF model. The $t\bar{t}$ background is generated with the MADGRAPH [17] event generator interfaced with the CTEQ6L [18] PDF model. All generated events are passed through the CMS detector simulation using GEANT4 [19] and then processed with a reconstruction sequence identical to that used for collision data.

The selection criteria for electron identification are similar to those used in the W and Z cross section measurements [1]. A brief summary is given here for completeness. Electrons are identified as clusters of energy deposited in the ECAL fiducial volume matched to tracks from the silicon tracker. The tracks are reconstructed using a Gaussian sum filter (GSF) algorithm [20] that takes into account possible energy loss due to bremsstrahlung in the tracker layers. Particles misidentified as electrons are suppressed by requiring that the shower shape of the ECAL cluster be consistent with an electron candidate, and that the η and ϕ coordinates of the track trajectory extrapolated to the ECAL match those of the ECAL cluster. The azimuthal angle ϕ is measured in the plane perpendicular to the beam axis. Furthermore, electrons from W decay are expected to be isolated from other activity in the event. We therefore require that little transverse energy be observed in the ECAL, hadron calorimeter, and silicon tracking system within a cone $\Delta R < 0.3$ around the electron direction, where $\Delta R = \sqrt{(\Delta\phi)^2 + (\Delta\eta)^2}$ and where the calorimeter energy deposits and the track associated with the electron candidate are excluded.

A large fraction of electrons radiate photons, owing to the substantial amount of material in front of the ECAL detector. These photons may convert close to the original electron trajectory, leading to a non-negligible charge misidentification probability. Three different methods are used to determine the electron charge. First, the electron charge is determined by the signed curvature of the associated GSF track. Second, the charge is determined from the associated trajectory reconstructed in the silicon tracker using a Kalman filter algorithm [21]. Third, the electron charge is determined from the azimuthal angle between the vector joining the nominal interaction point and the ECAL cluster position and the vector joining the nominal interaction point and the innermost hit of the GSF track. It is required that all three charge determinations from these methods agree. This procedure significantly reduces the charge misidentification probability to 0.01% in the ECAL barrel and to 0.3% in the ECAL end caps. The electron pseudorapidity is measured from the GSF track at the pp interaction point; the uncertainty on η is negligible for this analysis.

The $W \to e\nu$ candidates are selected by requiring electrons to have transverse momentum $p_T > 35$ GeV, $|\eta| < 2.4$, and to be associated with one of the electron trigger candidates used to select the electron data set. The Drell-Yan production and $t\bar{t}$ backgrounds are suppressed by rejecting events that contain a second isolated electron or muon with $p_T > 15$ GeV and $|\eta| < 2.4$. According to MC simulations, the data sample of selected electrons consists of about 16% QCD background events, about 7.4% EW background events, and about 0.4% $t\bar{t}$ background events.

As the forward and backward hemispheres are equivalent in pp collisions, the asymmetry results are presented as a function of the absolute value of the electron pseudorapidity. The selected events are divided into bins of $|\eta|$ with bin width 0.2. The region of $|\eta|$ between 1.4 and 1.6 is excluded because the cables and services in the transition region between the ECAL barrel and end caps cause a significant reduction in the efficiency and purity of the W selection. A total of 1 229 315 $W^+ \to e^+\nu$ candidates and 991 256 $W^- \to e^-\bar{\nu}$ candidates are selected in the 11 bins of $|\eta|$.

A binned extended maximum-likelihood fit is performed to the $\not{E}_T$ distribution to estimate the $W \to e\nu$ signal yield for electrons (N^-) and positrons (N^+) in each pseudorapidity bin. The signal $\not{E}_T$ shape is derived from MC simulations with an event-by-event correction to account for differences in the energy scale and resolution between data and simulation inferred from the hadronic recoil energy distributions in $Z/\gamma^* \to e^+e^-$ events selected from data [22]. The shape of the QCD background is determined, for each charge, from a signal-free control sample obtained by inverting a subset of the electron identification criteria [1]. The $\not{E}_T$ shapes for other backgrounds

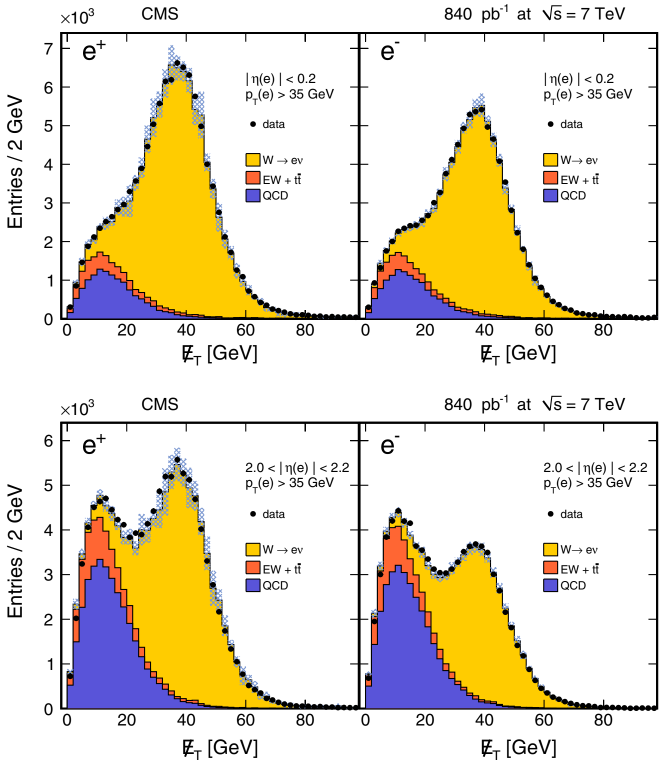

FIG. 1 (color online). Signal plus background fit to data $\not\!\!E_T$ distributions for positrons (left) and electrons (right) in data. Results are shown for the first pseudorapidity bin ($|\eta| < 0.2$, top) and for the tenth pseudorapidity bin ($2.0 < |\eta| < 2.2$, bottom). The hatched area represents the statistical and systematic uncertainties associated with the fitting procedure.

such as the Drell-Yan process, $t\bar{t}$, and $W \to \tau\nu$ are taken from MC simulations with a fixed normalization relative to the $W \to e\nu$ yields. The normalization factors are calculated from the predicted values of the cross sections at next-to-leading order (NLO). The yield of the QCD background and the yield of the $W \to e\nu$ signal ($N^{\pm}$) are free parameters in the fit. The results of the fits to the data are shown for the first ($|\eta| < 0.2$) and the tenth ($2.0 < |\eta| < 2.2$) pseudorapidity bins in Fig. 1. The uncertainty in each bin represents the systematic and statistical components associated with the $N^{\pm}$ extraction procedure. The ratio of the QCD background yields estimated from the fit to the $\not\!\!E_T$ distributions for positive and negative electrons is consistent with unity. The EW background yield for positive electrons is larger than for negative electrons because of the contribution of $W \to \tau\nu$ events. The charge asymmetry is obtained from the $(N^+ - N^-)/(N^+ + N^-)$ ratio.

TABLE I. Summary of the systematic uncertainties on the asymmetry. All values are given in units of 10^{-3}.

$\|\eta\|$ bin	Signal yield	Energy scale and res.	Charge MisId.	Efficiency ratio
$0.0 < \|\eta\| < 0.2$	1.8	0.6	<0.1	4.5
$0.2 < \|\eta\| < 0.4$	2.5	0.6	<0.1	4.4
$0.4 < \|\eta\| < 0.6$	2.7	0.3	<0.1	4.4
$0.6 < \|\eta\| < 0.8$	2.5	0.3	<0.1	4.4
$0.8 < \|\eta\| < 1.0$	1.9	0.6	0.1	4.4
$1.0 < \|\eta\| < 1.2$	2.4	1.0	0.1	4.9
$1.2 < \|\eta\| < 1.4$	2.6	0.8	0.1	5.4
$1.6 < \|\eta\| < 1.8$	3.1	0.8	0.1	9.2
$1.8 < \|\eta\| < 2.0$	2.0	1.6	0.2	8.7
$2.0 < \|\eta\| < 2.2$	2.0	2.6	0.3	10.0
$2.2 < \|\eta\| < 2.4$	2.9	2.4	0.3	12.5

Two sources of systematic uncertainty are related to the signal $\not\!\!E_T$ shape, the PDF used to generate the events, and the uncertainty on the correction from the hadronic recoil applied to the signal $\not\!\!E_T$ shape. The PDF uncertainties and their effects on the measured asymmetries are evaluated using the prescription given by the PDF4LHC Working Group [23]. Uncertainties on the correction from the hadronic recoil obtained from data are also propagated to the asymmetry measurements. The systematic uncertainty due to the QCD background shape is evaluated by studying samples from different QCD background control regions.

TABLE II. Covariance matrix for the systematic uncertainties on the asymmetry. All values are given in units of 10^{-6}. The matrix is symmetric.

$\|\eta\|$ bin	[0.0, 0.2]	[0.2, 0.4]	[0.4, 0.6]	[0.6, 0.8]	[0.8, 1.0]	[1.0, 1.2]	[1.2, 1.4]	[1.6, 1.8]	[1.8, 2.0]	[2.0, 2.2]	[2.2, 2.4]
[0.0, 0.2]	23.7										
[0.2, 0.4]	2.6	26.2									
[0.4, 0.6]	2.2	2.6	26.6								
[0.6, 0.8]	2.5	2.9	2.6	25.6							
[0.8, 1.0]	2.7	3.1	2.8	3.3	23.3						
[1.0, 1.2]	2.9	3.3	2.9	3.4	3.9	30.8					
[1.2, 1.4]	2.9	3.4	3.2	3.7	4.2	4.5	36.5				
[1.6, 1.8]	2.9	3.2	2.9	3.3	3.7	4.1	4.3	94.9			
[1.8, 2.0]	2.8	3.0	2.5	2.8	3.4	4.0	3.7	3.8	82.4		
[2.0, 2.2]	3.1	3.9	3.3	3.7	4.6	5.7	5.8	5.1	6.2	110.7	
[2.2, 2.4]	4.2	4.7	4.1	4.7	5.6	6.8	6.7	6.2	7.0	10.3	171.0

The systematic uncertainty due to the modelling of Drell-Yan production, $t\bar{t}$, and $W \to \tau\nu$ is estimated by varying the relative normalization of the EW backgrounds to the $W \to e\nu$ yield by the uncertainty on the Drell-Yan production and $t\bar{t}$ cross sections, and the effect on the observed asymmetry is negligible. The values of $N^{\pm}$ from the fitting procedure are insensitive to the presence of pileup interactions because the $\not{E}_T$ distributions are obtained from data.

In order to compare our results directly to theoretical predictions, the observed charge asymmetry is corrected for three detector effects: (1) electron energy scale and resolution, (2) relative detection efficiency of positrons and electrons, and (3) electron charge misidentification.

The electron energy scale and resolution can bias the asymmetry because of the effect on electrons with transverse momentum close to the threshold value of 35 GeV. The electron energy scale and resolution are determined directly from the $Z/\gamma^* \to e^+e^-$ data and are used to adjust the simulated electron energy at the generator level. The correction to the measured charge asymmetry is estimated in each pseudorapidity bin by comparing the charge asymmetry as determined in the simulation with the resulting asymmetry after smearing. The corrections for the electron energy scale and resolution are found to fall between -4.4×10^{-3} and 0.2×10^{-3}. The uncertainties on the energy scale and resolutions are taken as sources for systematic uncertainties. The charge asymmetry is also corrected for final-state radiation, and the uncertainty on the correction is taken as an additional systematic uncertainty, which is summed in quadrature with the uncertainty on the electron energy scale and resolution.

Any efficiency difference between electrons and positrons would bias the measured charge asymmetry. The total electron efficiency (including electron reconstruction, identification, and trigger efficiencies) in each pseudorapidity bin is measured using the $Z/\gamma^* \to e^+e^-$ data, separately for e^- and e^+, using the tag-and-probe method [1]. The efficiency ratio is calculated and found to be between 0.96 and 1.03; the statistical uncertainties on the efficiency ratios (0.01–0.03) are treated as systematic uncertainties. This is the dominant systematic uncertainty in all the pseudorapidity bins.

The true charge asymmetry $\mathcal{A}$ is diluted because of charge misidentification, resulting in an observed asymmetry $\mathcal{A}^{\text{obs}} = \mathcal{A}(1 - 2w)$. The electron charge misidentification probability w is measured using $Z/\gamma^* \to e^+e^-$ events in data. The observed electron charge asymmetry is corrected for the charge misidentification probability as a function of $|\eta|$. The statistical uncertainty on the charge misidentification probability is taken as the systematic uncertainty.

Table I summarizes the systematic uncertainties in all the electron pseudorapidity bins. The full systematic covariance matrix is given in Table II.

TABLE III. Summary of the measured charge asymmetry results. The first uncertainty is statistical and the second is systematic. The theoretical predictions are obtained using MCFM interfaced with four different PDF models. The PDF uncertainties are estimated using the PDF reweighting technique. All values are in units of 10^{-3}.

$\vert\eta\vert$ bin	Measured	Theoretical predictions			
	Asymmetry $\mathcal{A}$	CT10	HERAPDF	MSTW	NNPDF
[0.0, 0.2]	$102 \pm 3 \pm 5$	109 ± 5	106^{+4}_{-8}	87^{+3}_{-5}	107 ± 5
[0.2, 0.4]	$111 \pm 3 \pm 5$	114 ± 5	110^{+4}_{-8}	89^{+3}_{-5}	110 ± 5
[0.4, 0.6]	$116 \pm 3 \pm 5$	119 ± 5	115^{+4}_{-8}	98^{+3}_{-5}	116 ± 5
[0.6, 0.8]	$123 \pm 3 \pm 5$	126 ± 5	122^{+4}_{-8}	103^{+3}_{-5}	123 ± 5
[0.8, 1.0]	$133 \pm 3 \pm 5$	138^{+5}_{-6}	132^{+4}_{-8}	115^{+4}_{-5}	134 ± 5
[1.0, 1.2]	$136 \pm 3 \pm 6$	146 ± 6	140^{+5}_{-8}	128^{+4}_{-5}	145 ± 5
[1.2, 1.4]	$156 \pm 3 \pm 6$	164^{+6}_{-7}	153^{+5}_{-7}	144 ± 5	158 ± 5
[1.6, 1.8]	$166 \pm 3 \pm 10$	195^{+8}_{-9}	181 ± 5	179 ± 5	190 ± 4
[1.8, 2.0]	$197 \pm 3 \pm 9$	207^{+8}_{-10}	196^{+4}_{-3}	200^{+6}_{-5}	206 ± 4
[2.0, 2.2]	$224 \pm 3 \pm 11$	224^{+8}_{-11}	211^{+5}_{-3}	213^{+6}_{-5}	219 ± 4
[2.2, 2.4]	$210 \pm 4 \pm 13$	241^{+8}_{-12}	225^{+9}_{-4}	231^{+6}_{-5}	231 ± 5

The measured charge asymmetry results are summarized in Table III with both statistical and systematic uncertainties shown. The statistical uncertainties in the various pseudorapidity bins are uncorrelated.

The experimental results are compared in Table III and in Fig. 2 to theoretical predictions obtained with the NLO MCFM [24] generator interfaced with CT10 [3], HERAPDF [4], NNPDF [5], and MSTW2008NLO [2] PDF models. The theoretical errors are estimated using the PDF reweighting technique [25]. The experimental data are in agreement with the predictions from CT10, NNPDF, and HERAPDF, while the predictions from

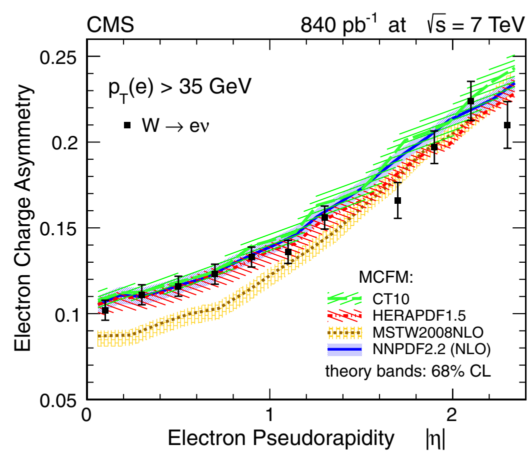

FIG. 2 (color online). Comparison of the measured electron asymmetry to the predictions of different PDF models for the electron $p_T > 35$ GeV. The error bars include both statistical and systematic uncertainties. The data points are placed in the center of the $|\eta|$ bins. The PDF uncertainty bands are estimated using the PDF reweighting technique and correspond to a 68% confidence level.

MSTW are systematically lower than the observed asymmetry in the region $|\eta| < 1.4$.

In summary, we have measured the electron charge asymmetry in the $W \to e\nu$ channel in a sample of proton-proton collisions at 7 TeV, corresponding to an integrated luminosity of 840 pb^{-1}. The measured asymmetry rises from about 0.1 to 0.2 as a function of the pseudorapidity, with an uncertainty that ranges from 0.006 in the central region to 0.014 in the ECAL end caps. This precise measurement of the electron charge asymmetry in inclusive W production at the LHC provides stringent constraints for parton distribution functions.

We congratulate our colleagues in the CERN accelerator departments for the excellent performance of the LHC machine. We thank the technical and administrative staff at CERN and other CMS institutes, and acknowledge support from FMSR (Austria); FNRS and FWO (Belgium); CNPq, CAPES, FAPERJ, and FAPESP (Brazil); MES (Bulgaria); CERN; CAS, MoST, and NSFC (China); COLCIENCIAS (Colombia); MSES (Croatia); RPF (Cyprus); MoER, SF0690030s09 and ERDF (Estonia); Academy of Finland, MEC, and HIP (Finland); CEA and CNRS/IN2P3 (France); BMBF, DFG, and HGF (Germany); GSRT (Greece); OTKA and NKTH (Hungary); DAE and DST (India); IPM (Iran); SFI (Ireland); INFN (Italy); NRF and WCU (Korea); LAS (Lithuania); CINVESTAV, CONACYT, SEP, and UASLP-FAI (Mexico); MSI (New Zealand); PAEC (Pakistan); MSHE and NSC (Poland); FCT (Portugal); JINR (Armenia, Belarus, Georgia, Ukraine, Uzbekistan); MON, RosAtom, RAS and RFBR (Russia); MSTD (Serbia); MICINN and CPAN (Spain); Swiss Funding Agencies (Switzerland); NSC (Taipei); TUBITAK and TAEK (Turkey); STFC (U.K.); DOE and NSF (U.S.).

[1] S. Chatrchyan *et al.* (CMS Collaboration), J. High Energy Phys. 10 (2011) 132.
[2] A. D. Martin, W. J. Stirling, R. S. Thorne, and G. Watt, Eur. Phys. J. C **63**, 189 (2009).
[3] H.-L. Lai, M. Guzzi, J. Huston, Z. Li, P. M. Nadolsky, J. Pumplin, and C.-P. Yuan, Phys. Rev. D **82**, 074024 (2010).
[4] F. D. Aaron *et al.* (H1 and ZEUS Collaborations), J. High Energy Phys. 01 (2010) 109.
[5] R. D. Ball, V. Bertone, F. Cerutti, L. Del Debbio, S. Forte, A. Guffanti, N. P. Hartland, J. I. Latorre, J. Rojo, and M. Ubiali, Nucl. Phys. **B855**, 608 (2012).
[6] S. Alekhin, J. Blumlein, S. Klein, and S. Moch, Phys. Rev. D **81**, 014032 (2010).
[7] P. Jimenez-Delgado and E. Reya, Phys. Rev. D **79**, 074023 (2009).
[8] J. D. Bjorken and E. A. Paschos, Phys. Rev. **185**, 1975 (1969).
[9] T. Aaltonen *et al.* (CDF Collaboration), Phys. Rev. Lett. **102**, 181801 (2009).
[10] V. M. Abazov *et al.* (D0 Collaboration), Phys. Rev. Lett. **101**, 211801 (2008).
[11] G. Aad *et al.* (ATLAS Collaboration), Phys. Lett. B **701**, 31 (2011).
[12] S. Chatrchyan *et al.* (CMS Collaboration), J. High Energy Phys. 04 (2011) 050.
[13] R. Aaij *et al.* (LHCb Collaboration), J. High Energy Phys. 06 (2012) 058.
[14] S. Chatrchyan *et al.* (CMS Collaboration), JINST **3**, S08004 (2008).
[15] CMS Collaboration, CMS Physics Analysis Summary Report No. CMS-PAS-PFT-10-003, 2010, http://cdsweb.cern.ch/record/1279347.
[16] S. Frixione, P. Nason, and C. Oleari, J. High Energy Phys., 11 (2007) 070.
[17] J. Alwall, M. Herquet, F. Maltoni, O. Mattelaer, and T. Stelzer, J. High Energy Phys. 06 (2011) 128.
[18] J. Pumplin, D. R. Stump, J. Huston, H. L. Lai, P. M. Nadolsky and W.-K. Tung, J. High Energy Phys. 07 (2002) 012.
[19] S. Agostinelli *et al.* (GEANT4 Collaboration), Nucl. Instrum. Methods Phys. Res., Sect. A **506**, 250 (2003).
[20] W. Adam, R. Frühwirth, A. Strandlie, and T. Todorov, CMS Note Report No. 2005/001, 2005, http://cdsweb.cern.ch/record/815410.
[21] V. Khachatryan *et al.* (CMS Collaboration), Eur. Phys. J. C **70**, 1165 (2010).
[22] CMS Collaboration, CMS Physics Analysis Summary Report No. CMS-PAS-JME-10-005, 2010, http://cdsweb.cern.ch/record/1294501.
[23] M. Botje, J. Butterworth, A. Cooper-Sarkar, A. de Roeck, and J. Feltesse *et al.*, arXiv:1101.0538.
[24] J. M. Campbell and R. K. Ellis, Phys. Rev. D **62**, 114012 (2000).
[25] D. Bourilkov, R. C. Group, and M. R. Whalley, arXiv:hep-ph/0605240.

S. Chatrchyan,[1] V. Khachatryan,[1] A. M. Sirunyan,[1] A. Tumasyan,[1] W. Adam,[2] T. Bergauer,[2] M. Dragicevic,[2] J. Erö,[2] C. Fabjan,[2,b] M. Friedl,[2] R. Frühwirth,[2,b] V. M. Ghete,[2] J. Hammer,[2] N. Hörmann,[2] J. Hrubec,[2] M. Jeitler,[2,b] W. Kiesenhofer,[2] V. Knünz,[2] M. Krammer,[2,b] D. Liko,[2] I. Mikulec,[2] M. Pernicka,[2,a] B. Rahbaran,[2] C. Rohringer,[2] H. Rohringer,[2] R. Schöfbeck,[2] J. Strauss,[2] A. Taurok,[2] P. Wagner,[2] W. Waltenberger,[2] G. Walzel,[2] E. Widl,[2] C.-E. Wulz,[2,b] V. Mossolov,[3] N. Shumeiko,[3] J. Suarez Gonzalez,[3] S. Bansal,[4] T. Cornelis,[4] E. A. De Wolf,[4] X. Janssen,[4] S. Luyckx,[4] T. Maes,[4] L. Mucibello,[4] S. Ochesanu,[4] B. Roland,[4] R. Rougny,[4] M. Selvaggi,[4] Z. Staykova,[4] H. Van Haevermaet,[4] P. Van Mechelen,[4] N. Van Remortel,[4] A. Van Spilbeeck,[4] F. Blekman,[5] S. Blyweert,[5] J. D'Hondt,[5] R. Gonzalez Suarez,[5] A. Kalogeropoulos,[5] M. Maes,[5] A. Olbrechts,[5] W. Van Doninck,[5]

P. Van Mulders,[5] G. P. Van Onsem,[5] I. Villella,[5] O. Charaf,[6] B. Clerbaux,[6] G. De Lentdecker,[6] V. Dero,[6] A. P. R. Gay,[6] T. Hreus,[6] A. Léonard,[6] P. E. Marage,[6] T. Reis,[6] L. Thomas,[6] C. Vander Velde,[6] P. Vanlaer,[6] J. Wang,[6] V. Adler,[7] K. Beernaert,[7] A. Cimmino,[7] S. Costantini,[7] G. Garcia,[7] M. Grunewald,[7] B. Klein,[7] J. Lellouch,[7] A. Marinov,[7] J. Mccartin,[7] A. A. Ocampo Rios,[7] D. Ryckbosch,[7] N. Strobbe,[7] F. Thyssen,[7] M. Tytgat,[7] L. Vanelderen,[7] P. Verwilligen,[7] S. Walsh,[7] E. Yazgan,[7] N. Zaganidis,[7] S. Basegmez,[8] G. Bruno,[8] R. Castello,[8] A. Caudron,[8] L. Ceard,[8] C. Delaere,[8] T. du Pree,[8] D. Favart,[8] L. Forthomme,[8] A. Giammanco,[8,c] J. Hollar,[8] V. Lemaitre,[8] J. Liao,[8] O. Militaru,[8] C. Nuttens,[8] D. Pagano,[8] L. Perrini,[8] A. Pin,[8] K. Piotrzkowski,[8] N. Schul,[8] J. M. Vizan Garcia,[8] N. Beliy,[9] T. Caebergs,[9] E. Daubie,[9] G. H. Hammad,[9] G. A. Alves,[10] M. Correa Martins Junior,[10] D. De Jesus Damiao,[10] T. Martins,[10] M. E. Pol,[10] M. H. G. Souza,[10] W. L. Aldá Júnior,[11] W. Carvalho,[11] A. Custódio,[11] E. M. Da Costa,[11] C. De Oliveira Martins,[11] S. Fonseca De Souza,[11] D. Matos Figueiredo,[11] L. Mundim,[11] H. Nogima,[11] V. Oguri,[11] W. L. Prado Da Silva,[11] A. Santoro,[11] L. Soares Jorge,[11] A. Sznajder,[11] C. A. Bernardes,[12,d] F. A. Dias,[12,e] T. R. Fernandez Perez Tomei,[12] E. M. Gregores,[12,d] C. Lagana,[12] F. Marinho,[12] P. G. Mercadante,[12,d] S. F. Novaes,[12] Sandra S. Padula,[12] V. Genchev,[13,f] P. Iaydjiev,[13,f] S. Piperov,[13] M. Rodozov,[13] S. Stoykova,[13] G. Sultanov,[13] V. Tcholakov,[13] R. Trayanov,[13] M. Vutova,[13] A. Dimitrov,[14] R. Hadjiiska,[14] V. Kozhuharov,[14] L. Litov,[14] B. Pavlov,[14] P. Petkov,[14] J. G. Bian,[15] G. M. Chen,[15] H. S. Chen,[15] C. H. Jiang,[15] D. Liang,[15] S. Liang,[15] X. Meng,[15] J. Tao,[15] J. Wang,[15] X. Wang,[15] Z. Wang,[15] H. Xiao,[15] M. Xu,[15] J. Zang,[15] Z. Zhang,[15] C. Asawatangtrakuldee,[16] Y. Ban,[16] S. Guo,[16] Y. Guo,[16] W. Li,[16] S. Liu,[16] Y. Mao,[16] S. J. Qian,[16] H. Teng,[16] S. Wang,[16] B. Zhu,[16] W. Zou,[16] C. Avila,[17] J. P. Gomez,[17] B. Gomez Moreno,[17] A. F. Osorio Oliveros,[17] J. C. Sanabria,[17] N. Godinovic,[18] D. Lelas,[18] R. Plestina,[18,g] D. Polic,[18] I. Puljak,[18,f] Z. Antunovic,[19] M. Kovac,[19] V. Brigljevic,[20] S. Duric,[20] K. Kadija,[20] J. Luetic,[20] S. Morovic,[20] A. Attikis,[21] M. Galanti,[21] G. Mavromanolakis,[21] J. Mousa,[21] C. Nicolaou,[21] F. Ptochos,[21] P. A. Razis,[21] M. Finger,[22] M. Finger, Jr.,[22] Y. Assran,[23,h] S. Elgammal,[23,i] A. Ellithi Kamel,[23,j] S. Khalil,[23,i] M. A. Mahmoud,[23,k] A. Radi,[23,l,m] M. Kadastik,[24] M. Müntel,[24] M. Raidal,[24] L. Rebane,[24] A. Tiko,[24] V. Azzolini,[25] P. Eerola,[25] G. Fedi,[25] M. Voutilainen,[25] J. Härkönen,[26] A. Heikkinen,[26] V. Karimäki,[26] R. Kinnunen,[26] M. J. Kortelainen,[26] T. Lampén,[26] K. Lassila-Perini,[26] S. Lehti,[26] T. Lindén,[26] P. Luukka,[26] T. Mäenpää,[26] T. Peltola,[26] E. Tuominen,[26] J. Tuominiemi,[26] E. Tuovinen,[26] D. Ungaro,[26] L. Wendland,[26] K. Banzuzi,[27] A. Karjalainen,[27] A. Korpela,[27] T. Tuuva,[27] M. Besancon,[28] S. Choudhury,[28] M. Dejardin,[28] D. Denegri,[28] B. Fabbro,[28] J. L. Faure,[28] F. Ferri,[28] S. Ganjour,[28] A. Givernaud,[28] P. Gras,[28] G. Hamel de Monchenault,[28] P. Jarry,[28] E. Locci,[28] J. Malcles,[28] L. Millischer,[28] A. Nayak,[28] J. Rander,[28] A. Rosowsky,[28] I. Shreyber,[28] M. Titov,[28] S. Baffioni,[29] F. Beaudette,[29] L. Benhabib,[29] L. Bianchini,[29] M. Bluj,[29,n] C. Broutin,[29] P. Busson,[29] C. Charlot,[29] N. Daci,[29] T. Dahms,[29] L. Dobrzynski,[29] R. Granier de Cassagnac,[29] M. Haguenauer,[29] P. Miné,[29] C. Mironov,[29] M. Nguyen,[29] C. Ochando,[29] P. Paganini,[29] D. Sabes,[29] R. Salerno,[29] Y. Sirois,[29] C. Veelken,[29] A. Zabi,[29] J.-L. Agram,[30,o] J. Andrea,[30] D. Bloch,[30] D. Bodin,[30] J.-M. Brom,[30] M. Cardaci,[30] E. C. Chabert,[30] C. Collard,[30] E. Conte,[30,o] F. Drouhin,[30,o] C. Ferro,[30] J.-C. Fontaine,[30,o] D. Gelé,[30] U. Goerlach,[30] P. Juillot,[30] A.-C. Le Bihan,[30] P. Van Hove,[30] F. Fassi,[31] D. Mercier,[31] S. Beauceron,[32] N. Beaupere,[32] O. Bondu,[32] G. Boudoul,[32] H. Brun,[32] J. Chasserat,[32] R. Chierici,[32,f] D. Contardo,[32] P. Depasse,[32] H. El Mamouni,[32] J. Fay,[32] S. Gascon,[32] M. Gouzevitch,[32] B. Ille,[32] T. Kurca,[32] M. Lethuillier,[32] L. Mirabito,[32] S. Perries,[32] V. Sordini,[32] S. Tosi,[32] Y. Tschudi,[32] P. Verdier,[32] S. Viret,[32] Z. Tsamalaidze,[33,p] G. Anagnostou,[34] S. Beranek,[34] M. Edelhoff,[34] L. Feld,[34] N. Heracleous,[34] O. Hindrichs,[34] R. Jussen,[34] K. Klein,[34] J. Merz,[34] A. Ostapchuk,[34] A. Perieanu,[34] F. Raupach,[34] J. Sammet,[34] S. Schael,[34] D. Sprenger,[34] H. Weber,[34] B. Wittmer,[34] V. Zhukov,[34,q] M. Ata,[35] J. Caudron,[35] E. Dietz-Laursonn,[35] D. Duchardt,[35] M. Erdmann,[35] R. Fischer,[35] A. Güth,[35] T. Hebbeker,[35] C. Heidemann,[35] K. Hoepfner,[35] D. Klingebiel,[35] P. Kreuzer,[35] J. Lingemann,[35] C. Magass,[35] M. Merschmeyer,[35] A. Meyer,[35] M. Olschewski,[35] P. Papacz,[35] H. Pieta,[35] H. Reithler,[35] S. A. Schmitz,[35] L. Sonnenschein,[35] J. Steggemann,[35] D. Teyssier,[35] M. Weber,[35] M. Bontenackels,[36] V. Cherepanov,[36] G. Flügge,[36] H. Geenen,[36] M. Geisler,[36] W. Haj Ahmad,[36] F. Hoehle,[36] B. Kargoll,[36] T. Kress,[36] Y. Kuessel,[36] A. Nowack,[36] L. Perchalla,[36] O. Pooth,[36] J. Rennefeld,[36] P. Sauerland,[36] A. Stahl,[36] M. Aldaya Martin,[37] J. Behr,[37] W. Behrenhoff,[37] U. Behrens,[37] M. Bergholz,[37,r] A. Bethani,[37] K. Borras,[37] A. Burgmeier,[37] A. Cakir,[37] L. Calligaris,[37] A. Campbell,[37] E. Castro,[37] F. Costanza,[37] D. Dammann,[37] G. Eckerlin,[37] D. Eckstein,[37] G. Flucke,[37] A. Geiser,[37] I. Glushkov,[37] P. Gunnellini,[37] S. Habib,[37] J. Hauk,[37] G. Hellwig,[37] H. Jung,[37,f] M. Kasemann,[37] P. Katsas,[37] C. Kleinwort,[37] H. Kluge,[37] A. Knutsson,[37] M. Krämer,[37] D. Krücker,[37] E. Kuznetsova,[37] W. Lange,[37] W. Lohmann,[37,r] B. Lutz,[37] R. Mankel,[37] I. Marfin,[37] M. Marienfeld,[37] I.-A. Melzer-Pellmann,[37] A. B. Meyer,[37] J. Mnich,[37] A. Mussgiller,[37] S. Naumann-Emme,[37] J. Olzem,[37] H. Perrey,[37] A. Petrukhin,[37] D. Pitzl,[37] A. Raspereza,[37] P. M. Ribeiro Cipriano,[37]

C. Riedl,[37] M. Rosin,[37] J. Salfeld-Nebgen,[37] R. Schmidt,[37,r] T. Schoerner-Sadenius,[37] N. Sen,[37] A. Spiridonov,[37] M. Stein,[37] R. Walsh,[37] C. Wissing,[37] C. Autermann,[38] V. Blobel,[38] S. Bobrovskyi,[38] J. Draeger,[38] H. Enderle,[38] J. Erfle,[38] U. Gebbert,[38] M. Görner,[38] T. Hermanns,[38] R. S. Höing,[38] K. Kaschube,[38] G. Kaussen,[38] H. Kirschenmann,[38] R. Klanner,[38] J. Lange,[38] B. Mura,[38] F. Nowak,[38] T. Peiffer,[38] N. Pietsch,[38] D. Rathjens,[38] C. Sander,[38] H. Schettler,[38] P. Schleper,[38] E. Schlieckau,[38] A. Schmidt,[38] M. Schröder,[38] T. Schum,[38] M. Seidel,[38] H. Stadie,[38] G. Steinbrück,[38] J. Thomsen,[38] C. Barth,[39] J. Berger,[39] C. Böser,[39] T. Chwalek,[39] W. De Boer,[39] A. Descroix,[39] A. Dierlamm,[39] M. Feindt,[39] M. Guthoff,[39,f] C. Hackstein,[39] F. Hartmann,[39] T. Hauth,[39,f] M. Heinrich,[39] H. Held,[39] K. H. Hoffmann,[39] S. Honc,[39] I. Katkov,[39,q] J. R. Komaragiri,[39] D. Martschei,[39] S. Mueller,[39] Th. Müller,[39] M. Niegel,[39] A. Nürnberg,[39] O. Oberst,[39] A. Oehler,[39] J. Ott,[39] G. Quast,[39] K. Rabbertz,[39] F. Ratnikov,[39] N. Ratnikova,[39] S. Röcker,[39] A. Scheurer,[39] F.-P. Schilling,[39] G. Schott,[39] H. J. Simonis,[39] F. M. Stober,[39] D. Troendle,[39] R. Ulrich,[39] J. Wagner-Kuhr,[39] S. Wayand,[39] T. Weiler,[39] M. Zeise,[39] G. Daskalakis,[40] T. Geralis,[40] S. Kesisoglou,[40] A. Kyriakis,[40] D. Loukas,[40] I. Manolakos,[40] A. Markou,[40] C. Markou,[40] C. Mavrommatis,[40] E. Ntomari,[40] L. Gouskos,[41] T. J. Mertzimekis,[41] A. Panagiotou,[41] N. Saoulidou,[41] I. Evangelou,[42] C. Foudas,[42,f] P. Kokkas,[42] N. Manthos,[42] I. Papadopoulos,[42] V. Patras,[42] G. Bencze,[43] C. Hajdu,[43,f] P. Hidas,[43] D. Horvath,[43,s] F. Sikler,[43] V. Veszpremi,[43] G. Vesztergombi,[43,t] N. Beni,[44] S. Czellar,[44] J. Molnar,[44] J. Palinkas,[44] Z. Szillasi,[44] J. Karancsi,[45] P. Raics,[45] Z. L. Trocsanyi,[45] B. Ujvari,[45] S. B. Beri,[46] V. Bhatnagar,[46] N. Dhingra,[46] R. Gupta,[46] M. Jindal,[46] M. Kaur,[46] M. Z. Mehta,[46] N. Nishu,[46] L. K. Saini,[46] A. Sharma,[46] J. Singh,[46] S. Ahuja,[47] A. Bhardwaj,[47] B. C. Choudhary,[47] A. Kumar,[47] A. Kumar,[47] S. Malhotra,[47] M. Naimuddin,[47] K. Ranjan,[47] V. Sharma,[47] R. K. Shivpuri,[47] S. Banerjee,[48] S. Bhattacharya,[48] S. Dutta,[48] B. Gomber,[48] Sa. Jain,[48] Sh. Jain,[48] R. Khurana,[48] S. Sarkar,[48] M. Sharan,[48] A. Abdulsalam,[49] R. K. Choudhury,[49] D. Dutta,[49] S. Kailas,[49] V. Kumar,[49] P. Mehta,[49] A. K. Mohanty,[49,f] L. M. Pant,[49] P. Shukla,[49] T. Aziz,[50] S. Ganguly,[50] M. Guchait,[50,u] M. Maity,[50,v] G. Majumder,[50] K. Mazumdar,[50] G. B. Mohanty,[50] B. Parida,[50] K. Sudhakar,[50] N. Wickramage,[50] S. Banerjee,[51] S. Dugad,[51] H. Arfaei,[52] H. Bakhshiansohi,[52,w] S. M. Etesami,[52,x] A. Fahim,[52,w] M. Hashemi,[52] A. Jafari,[52,w] M. Khakzad,[52] A. Mohammadi,[52,y] M. Mohammadi Najafabadi,[52] S. Paktinat Mehdiabadi,[52] B. Safarzadeh,[52,z] M. Zeinali,[52,x] M. Abbrescia,[53a,53b] L. Barbone,[53a,53b] C. Calabria,[53a,53b,f] S. S. Chhibra,[53a,53b] A. Colaleo,[53a] D. Creanza,[53a,53c] N. De Filippis,[53a,53c,f] M. De Palma,[53a,53b] L. Fiore,[53a] G. Iaselli,[53a,53c] L. Lusito,[53a,53b] G. Maggi,[53a,53c] M. Maggi,[53a] B. Marangelli,[53a,53b] S. My,[53a,53c] S. Nuzzo,[53a,53b] N. Pacifico,[53a,53b] A. Pompili,[53a,53b] G. Pugliese,[53a,53c] G. Selvaggi,[53a,53b] L. Silvestris,[53a] G. Singh,[53a,53b] R. Venditti,[53a] G. Zito,[53a] G. Abbiendi,[54a] A. C. Benvenuti,[54a] D. Bonacorsi,[54a,54b] S. Braibant-Giacomelli,[54a,54b] L. Brigliadori,[54a,54b] P. Capiluppi,[54a,54b] A. Castro,[54a,54b] F. R. Cavallo,[54a] M. Cuffiani,[54a,54b] G. M. Dallavalle,[54a] F. Fabbri,[54a] A. Fanfani,[54a,54b] D. Fasanella,[54a,54b,f] P. Giacomelli,[54a] C. Grandi,[54a] L. Guiducci,[54a,54b] S. Marcellini,[54a] G. Masetti,[54a] M. Meneghelli,[54a,54b,f] A. Montanari,[54a] F. L. Navarria,[54a,54b] F. Odorici,[54a] A. Perrotta,[54a] F. Primavera,[54a,54b] A. M. Rossi,[54a,54b] T. Rovelli,[54a,54b] G. Siroli,[54a,54b] R. Travaglini,[54a,54b] S. Albergo,[55a,55b] G. Cappello,[55a,55b] M. Chiorboli,[55a,55b] S. Costa,[55a,55b] R. Potenza,[55a,55b] A. Tricomi,[55a,55b] C. Tuve,[55a,55b] G. Barbagli,[56a] V. Ciulli,[56a,56b] C. Civinini,[56a] R. D'Alessandro,[56a,56b] E. Focardi,[56a,56b] S. Frosali,[56a,56b] E. Gallo,[56a] S. Gonzi,[56a,56b] M. Meschini,[56a] S. Paoletti,[56a] G. Sguazzoni,[56a] A. Tropiano,[56a,f] L. Benussi,[57] S. Bianco,[57] S. Colafranceschi,[57,aa] F. Fabbri,[57] D. Piccolo,[57] P. Fabbricatore,[58] R. Musenich,[58] A. Benaglia,[59a,59b,f] F. De Guio,[59a,59b] L. Di Matteo,[59a,59b,f] S. Fiorendi,[59a,59b] S. Gennai,[59a,f] A. Ghezzi,[59a,59b] S. Malvezzi,[59a] R. A. Manzoni,[59a,59b] A. Martelli,[59a,59b] A. Massironi,[59a,59b,f] D. Menasce,[59a] L. Moroni,[59a] M. Paganoni,[59a,59b] D. Pedrini,[59a] S. Ragazzi,[59a,59b] N. Redaelli,[59a] S. Sala,[59a] T. Tabarelli de Fatis,[59a,59b] S. Buontempo,[60a] C. A. Carrillo Montoya,[60a,f] N. Cavallo,[60a,bb] A. De Cosa,[60a,60b,f] O. Dogangun,[60a,60b] F. Fabozzi,[60a,bb] A. O. M. Iorio,[60a] L. Lista,[60a] S. Meola,[60a,cc] M. Merola,[60a,60b] P. Paolucci,[60a,f] P. Azzi,[61a] N. Bacchetta,[61a,f] D. Bisello,[61a,61b] A. Branca,[61a,f] R. Carlin,[61a,61b] P. Checchia,[61a] T. Dorigo,[61a] U. Dosselli,[61a] F. Gasparini,[61a,61b] U. Gasparini,[61a,61b] A. Gozzelino,[61a] K. Kanishchev,[61a,61c] S. Lacaprara,[61a] I. Lazzizzera,[61a,61c] M. Margoni,[61a,61b] A. T. Meneguzzo,[61a,61b] J. Pazzini,[61a] N. Pozzobon,[61a,61b] P. Ronchese,[61a,61b] F. Simonetto,[61a,61b] E. Torassa,[61a] M. Tosi,[61a,61b,f] S. Vanini,[61a,61b] P. Zotto,[61a,61b] A. Zucchetta,[61a] G. Zumerle,[61a,61b] M. Gabusi,[62a,62b] S. P. Ratti,[62a,62b] C. Riccardi,[62a,62b] P. Torre,[62a,62b] P. Vitulo,[62a,62b] M. Biasini,[63a,63b] G. M. Bilei,[63a] L. Fanò,[63a,63b] P. Lariccia,[63a,63b] A. Lucaroni,[63a,63b,f] G. Mantovani,[63a,63b] M. Menichelli,[63a] A. Nappi,[63a,63b] F. Romeo,[63a,63b] A. Saha,[63a] A. Santocchia,[63a,63b] S. Taroni,[63a,63b,f] P. Azzurri,[64a,64c] G. Bagliesi,[64a] T. Boccali,[64a] G. Broccolo,[64a,64c] R. Castaldi,[64a] R. T. D'Agnolo,[64a,64c] R. Dell'Orso,[64a] F. Fiori,[64a,64b,f] L. Foà,[64a,64c] A. Giassi,[64a] A. Kraan,[64a] F. Ligabue,[64a,64c] T. Lomtadze,[64a] L. Martini,[64a,dd] A. Messineo,[64a,64b] F. Palla,[64a] A. Rizzi,[64a,64b] A. T. Serban,[64a,ee]

P. Spagnolo,[64a] P. Squillacioti,[64a,f] R. Tenchini,[64a] G. Tonelli,[64a,64b,f] A. Venturi,[64a,f] P. G. Verdini,[64a] L. Barone,[65a,65b] F. Cavallari,[65a] D. Del Re,[65a,65b,f] M. Diemoz,[65a] M. Grassi,[65a,65b,f] E. Longo,[65a,65b] P. Meridiani,[65a,f] F. Micheli,[65a,65b] S. Nourbakhsh,[65a,65b] G. Organtini,[65a,65b] R. Paramatti,[65a] S. Rahatlou,[65a,65b] M. Sigamani,[65a] L. Soffi,[65a,65b] N. Amapane,[66a,66b] R. Arcidiacono,[66a,66c] S. Argiro,[66a,66b] M. Arneodo,[66a,66c] C. Biino,[66a] C. Botta,[66a,66b] N. Cartiglia,[66a] M. Costa,[66a,66b] N. Demaria,[66a] A. Graziano,[66a,66b] C. Mariotti,[66a,f] S. Maselli,[66a] E. Migliore,[66a,66b] V. Monaco,[66a,66b] M. Musich,[66a,f] M. M. Obertino,[66a,66c] N. Pastrone,[66a] M. Pelliccioni,[66a] A. Potenza,[66a,66b] A. Romero,[66a,66b] M. Ruspa,[66a,66c] R. Sacchi,[66a,66b] V. Sola,[66a,66b] A. Solano,[66a,66b] A. Staiano,[66a] A. Vilela Pereira,[66a] S. Belforte,[67a] V. Candelise,[67a,67b] F. Cossutti,[67a] G. Della Ricca,[67a,67b] B. Gobbo,[67a] M. Marone,[67a,67b,f] D. Montanino,[67a,67b,f] A. Penzo,[67a] A. Schizzi,[67a,67b] S. G. Heo,[68] T. Y. Kim,[68] S. K. Nam,[68] S. Chang,[69] J. Chung,[69] D. H. Kim,[69] G. N. Kim,[69] D. J. Kong,[69] H. Park,[69] S. R. Ro,[69] D. C. Son,[69] T. Son,[69] J. Y. Kim,[70] Zero J. Kim,[70] S. Song,[70] H. Y. Jo,[71] S. Choi,[72] D. Gyun,[72] B. Hong,[72] M. Jo,[72] H. Kim,[72] T. J. Kim,[72] K. S. Lee,[72] D. H. Moon,[72] S. K. Park,[72] M. Choi,[73] S. Kang,[73] J. H. Kim,[73] C. Park,[73] I. C. Park,[73] S. Park,[73] G. Ryu,[73] Y. Cho,[74] Y. Choi,[74] Y. K. Choi,[74] J. Goh,[74] M. S. Kim,[74] E. Kwon,[74] B. Lee,[74] J. Lee,[74] S. Lee,[74] H. Seo,[74] I. Yu,[74] M. J. Bilinskas,[75] I. Grigelionis,[75] M. Janulis,[75] A. Juodagalvis,[75] H. Castilla-Valdez,[76] E. De La Cruz-Burelo,[76] I. Heredia-de La Cruz,[76] R. Lopez-Fernandez,[76] R. Magaña Villalba,[76] J. Martínez-Ortega,[76] A. Sánchez-Hernández,[76] L. M. Villasenor-Cendejas,[76] S. Carrillo Moreno,[77] F. Vazquez Valencia,[77] H. A. Salazar Ibarguen,[78] E. Casimiro Linares,[79] A. Morelos Pineda,[79] M. A. Reyes-Santos,[79] D. Krofcheck,[80] A. J. Bell,[81] P. H. Butler,[81] R. Doesburg,[81] S. Reucroft,[81] H. Silverwood,[81] M. Ahmad,[82] M. I. Asghar,[82] H. R. Hoorani,[82] S. Khalid,[82] W. A. Khan,[82] T. Khurshid,[82] S. Qazi,[82] M. A. Shah,[82] M. Shoaib,[82] G. Brona,[83] K. Bunkowski,[83] M. Cwiok,[83] W. Dominik,[83] K. Doroba,[83] A. Kalinowski,[83] M. Konecki,[83] J. Krolikowski,[83] H. Bialkowska,[84] B. Boimska,[84] T. Frueboes,[84] R. Gokieli,[84] M. Górski,[84] M. Kazana,[84] K. Nawrocki,[84] K. Romanowska-Rybinska,[84] M. Szleper,[84] G. Wrochna,[84] P. Zalewski,[84] N. Almeida,[85] P. Bargassa,[85] A. David,[85] P. Faccioli,[85] M. Fernandes,[85] P. G. Ferreira Parracho,[85] M. Gallinaro,[85] J. Seixas,[85] J. Varela,[85] P. Vischia,[85] I. Belotelov,[86] P. Bunin,[86] M. Gavrilenko,[86] I. Golutvin,[86] I. Gorbunov,[86] A. Kamenev,[86] V. Karjavin,[86] G. Kozlov,[86] A. Lanev,[86] A. Malakhov,[86] P. Moisenz,[86] V. Palichik,[86] V. Perelygin,[86] S. Shmatov,[86] V. Smirnov,[86] A. Volodko,[86] A. Zarubin,[86] S. Evstyukhin,[87] V. Golovtsov,[87] Y. Ivanov,[87] V. Kim,[87] P. Levchenko,[87] V. Murzin,[87] V. Oreshkin,[87] I. Smirnov,[87] V. Sulimov,[87] L. Uvarov,[87] S. Vavilov,[87] A. Vorobyev,[87] An. Vorobyev,[87] Yu. Andreev,[88] A. Dermenev,[88] S. Gninenko,[88] N. Golubev,[88] M. Kirsanov,[88] N. Krasnikov,[88] V. Matveev,[88] A. Pashenkov,[88] D. Tlisov,[88] A. Toropin,[88] V. Epshteyn,[89] M. Erofeeva,[89] V. Gavrilov,[89] M. Kossov,[89,f] N. Lychkovskaya,[89] V. Popov,[89] G. Safronov,[89] S. Semenov,[89] V. Stolin,[89] E. Vlasov,[89] A. Zhokin,[89] A. Belyaev,[90] E. Boos,[90] M. Dubinin,[90,e] L. Dudko,[90] A. Ershov,[90] A. Gribushin,[90] V. Klyukhin,[90] O. Kodolova,[90] I. Lokhtin,[90] A. Markina,[90] S. Obraztsov,[90] M. Perfilov,[90] S. Petrushanko,[90] A. Popov,[90] L. Sarycheva,[90,a] V. Savrin,[90] A. Snigirev,[90] V. Andreev,[91] M. Azarkin,[91] I. Dremin,[91] M. Kirakosyan,[91] A. Leonidov,[91] G. Mesyats,[91] S. V. Rusakov,[91] A. Vinogradov,[91] I. Azhgirey,[92] I. Bayshev,[92] S. Bitioukov,[92] V. Grishin,[92,f] V. Kachanov,[92] D. Konstantinov,[92] A. Korablev,[92] V. Krychkine,[92] V. Petrov,[92] R. Ryutin,[92] A. Sobol,[92] L. Tourtchanovitch,[92] S. Troshin,[92] N. Tyurin,[92] A. Uzunian,[92] A. Volkov,[92] P. Adzic,[93,ff] M. Djordjevic,[93] M. Ekmedzic,[93] D. Krpic,[93,ff] J. Milosevic,[93] M. Aguilar-Benitez,[94] J. Alcaraz Maestre,[94] P. Arce,[94] C. Battilana,[94] E. Calvo,[94] M. Cerrada,[94] M. Chamizo Llatas,[94] N. Colino,[94] B. De La Cruz,[94] A. Delgado Peris,[94] C. Diez Pardos,[94] D. Domínguez Vázquez,[94] C. Fernandez Bedoya,[94] J. P. Fernández Ramos,[94] A. Ferrando,[94] J. Flix,[94] M. C. Fouz,[94] P. Garcia-Abia,[94] O. Gonzalez Lopez,[94] S. Goy Lopez,[94] J. M. Hernandez,[94] M. I. Josa,[94] G. Merino,[94] J. Puerta Pelayo,[94] A. Quintario Olmeda,[94] I. Redondo,[94] L. Romero,[94] J. Santaolalla,[94] M. S. Soares,[94] C. Willmott,[94] C. Albajar,[95] G. Codispoti,[95] J. F. de Trocóniz,[95] J. Cuevas,[96] J. Fernandez Menendez,[96] S. Folgueras,[96] I. Gonzalez Caballero,[96] L. Lloret Iglesias,[96] J. Piedra Gomez,[96,gg] J. A. Brochero Cifuentes,[97] I. J. Cabrillo,[97] A. Calderon,[97] S. H. Chuang,[97] J. Duarte Campderros,[97] M. Felcini,[97,hh] M. Fernandez,[97] G. Gomez,[97] J. Gonzalez Sanchez,[97] C. Jorda,[97] P. Lobelle Pardo,[97] A. Lopez Virto,[97] J. Marco,[97] R. Marco,[97] C. Martinez Rivero,[97] F. Matorras,[97] F. J. Munoz Sanchez,[97] T. Rodrigo,[97] A. Y. Rodríguez-Marrero,[97] A. Ruiz-Jimeno,[97] L. Scodellaro,[97] M. Sobron Sanudo,[97] I. Vila,[97] R. Vilar Cortabitarte,[97] D. Abbaneo,[98] E. Auffray,[98] G. Auzinger,[98] P. Baillon,[98] A. H. Ball,[98] D. Barney,[98] C. Bernet,[98,g] G. Bianchi,[98] P. Bloch,[98] A. Bocci,[98] A. Bonato,[98] H. Breuker,[98] T. Camporesi,[98] G. Cerminara,[98] T. Christiansen,[98] J. A. Coarasa Perez,[98] D. D'Enterria,[98] A. Dabrowski,[98] A. De Roeck,[98] S. Di Guida,[98] M. Dobson,[98] N. Dupont-Sagorin,[98] A. Elliott-Peisert,[98] B. Frisch,[98] W. Funk,[98] G. Georgiou,[98] M. Giffels,[98] D. Gigi,[98] K. Gill,[98] D. Giordano,[98] M. Giunta,[98] F. Glege,[98]

R. Gomez-Reino Garrido,[98] P. Govoni,[98] S. Gowdy,[98] R. Guida,[98] M. Hansen,[98] P. Harris,[98] C. Hartl,[98] J. Harvey,[98] B. Hegner,[98] A. Hinzmann,[98] V. Innocente,[98] P. Janot,[98] K. Kaadze,[98] E. Karavakis,[98] K. Kousouris,[98] P. Lecoq,[98] Y.-J. Lee,[98] P. Lenzi,[98] C. Lourenço,[98] T. Mäki,[98] M. Malberti,[98] L. Malgeri,[98] M. Mannelli,[98] L. Masetti,[98] F. Meijers,[98] S. Mersi,[98] E. Meschi,[98] R. Moser,[98] M. U. Mozer,[98] M. Mulders,[98] P. Musella,[98] E. Nesvold,[98] T. Orimoto,[98] L. Orsini,[98] E. Palencia Cortezon,[98] E. Perez,[98] L. Perrozzi,[98] A. Petrilli,[98] A. Pfeiffer,[98] M. Pierini,[98] M. Pimiä,[98] D. Piparo,[98] G. Polese,[98] L. Quertenmont,[98] A. Racz,[98] W. Reece,[98] J. Rodrigues Antunes,[98] G. Rolandi,[98,ii] T. Rommerskirchen,[98] C. Rovelli,[98,jj] M. Rovere,[98] H. Sakulin,[98] F. Santanastasio,[98] C. Schäfer,[98] C. Schwick,[98] I. Segoni,[98] S. Sekmen,[98] A. Sharma,[98] P. Siegrist,[98] P. Silva,[98] M. Simon,[98] P. Sphicas,[98,kk] D. Spiga,[98] M. Spiropulu,[98,e] M. Stoye,[98] A. Tsirou,[98] G. I. Veres,[98,t] J. R. Vlimant,[98] H. K. Wöhri,[98] S. D. Worm,[98,ll] W. D. Zeuner,[98] W. Bertl,[99] K. Deiters,[99] W. Erdmann,[99] K. Gabathuler,[99] R. Horisberger,[99] Q. Ingram,[99] H. C. Kaestli,[99] S. König,[99] D. Kotlinski,[99] U. Langenegger,[99] F. Meier,[99] D. Renker,[99] T. Rohe,[99] J. Sibille,[99,mm] L. Bäni,[100] P. Bortignon,[100] M. A. Buchmann,[100] B. Casal,[100] N. Chanon,[100] A. Deisher,[100] G. Dissertori,[100] M. Dittmar,[100] M. Dünser,[100] J. Eugster,[100] K. Freudenreich,[100] C. Grab,[100] D. Hits,[100] P. Lecomte,[100] W. Lustermann,[100] A. C. Marini,[100] P. Martinez Ruiz del Arbol,[100] N. Mohr,[100] F. Moortgat,[100] C. Nägeli,[100,nn] P. Nef,[100] F. Nessi-Tedaldi,[100] F. Pandolfi,[100] L. Pape,[100] F. Pauss,[100] M. Peruzzi,[100] F. J. Ronga,[100] M. Rossini,[100] L. Sala,[100] A. K. Sanchez,[100] A. Starodumov,[100,oo] B. Stieger,[100] M. Takahashi,[100] L. Tauscher,[100,a] A. Thea,[100] K. Theofilatos,[100] D. Treille,[100] C. Urscheler,[100] R. Wallny,[100] H. A. Weber,[100] L. Wehrli,[100] E. Aguilo,[101] C. Amsler,[101] V. Chiochia,[101] S. De Visscher,[101] C. Favaro,[101] M. Ivova Rikova,[101] B. Millan Mejias,[101] P. Otiougova,[101] P. Robmann,[101] H. Snoek,[101] S. Tupputi,[101] M. Verzetti,[101] Y. H. Chang,[102] K. H. Chen,[102] C. M. Kuo,[102] S. W. Li,[102] W. Lin,[102] Z. K. Liu,[102] Y. J. Lu,[102] D. Mekterovic,[102] A. P. Singh,[102] R. Volpe,[102] S. S. Yu,[102] P. Bartalini,[103] P. Chang,[103] Y. H. Chang,[103] Y. W. Chang,[103] Y. Chao,[103] K. F. Chen,[103] C. Dietz,[103] U. Grundler,[103] W.-S. Hou,[103] Y. Hsiung,[103] K. Y. Kao,[103] Y. J. Lei,[103] R.-S. Lu,[103] D. Majumder,[103] E. Petrakou,[103] X. Shi,[103] J. G. Shiu,[103] Y. M. Tzeng,[103] X. Wan,[103] M. Wang,[103] A. Adiguzel,[104] M. N. Bakirci,[104,pp] S. Cerci,[104,qq] C. Dozen,[104] I. Dumanoglu,[104] E. Eskut,[104] S. Girgis,[104] G. Gokbulut,[104] E. Gurpinar,[104] I. Hos,[104] E. E. Kangal,[104] G. Karapinar,[104] A. Kayis Topaksu,[104] G. Onengut,[104] K. Ozdemir,[104] S. Ozturk,[104,rr] A. Polatoz,[104] K. Sogut,[104,ss] D. Sunar Cerci,[104,qq] B. Tali,[104,qq] H. Topakli,[104,pp] L. N. Vergili,[104] M. Vergili,[104] I. V. Akin,[105] T. Aliev,[105] B. Bilin,[105] S. Bilmis,[105] M. Deniz,[105] H. Gamsizkan,[105] A. M. Guler,[105] K. Ocalan,[105] A. Ozpineci,[105] M. Serin,[105] R. Sever,[105] U. E. Surat,[105] M. Yalvac,[105] E. Yildirim,[105] M. Zeyrek,[105] E. Gülmez,[106] B. Isildak,[106,tt] M. Kaya,[106,uu] O. Kaya,[106,uu] S. Ozkorucuklu,[106,vv] N. Sonmez,[106,ww] K. Cankocak,[107] L. Levchuk,[108] F. Bostock,[109] J. J. Brooke,[109] E. Clement,[109] D. Cussans,[109] H. Flacher,[109] R. Frazier,[109] J. Goldstein,[109] M. Grimes,[109] G. P. Heath,[109] H. F. Heath,[109] L. Kreczko,[109] S. Metson,[109] D. M. Newbold,[109,ll] K. Nirunpong,[109] A. Poll,[109] S. Senkin,[109] V. J. Smith,[109] T. Williams,[109] L. Basso,[110,xx] K. W. Bell,[110] A. Belyaev,[110,xx] C. Brew,[110] R. M. Brown,[110] D. J. A. Cockerill,[110] J. A. Coughlan,[110] K. Harder,[110] S. Harper,[110] J. Jackson,[110] B. W. Kennedy,[110] E. Olaiya,[110] D. Petyt,[110] B. C. Radburn-Smith,[110] C. H. Shepherd-Themistocleous,[110] I. R. Tomalin,[110] W. J. Womersley,[110] R. Bainbridge,[111] G. Ball,[111] R. Beuselinck,[111] O. Buchmuller,[111] D. Colling,[111] N. Cripps,[111] M. Cutajar,[111] P. Dauncey,[111] G. Davies,[111] M. Della Negra,[111] W. Ferguson,[111] J. Fulcher,[111] D. Futyan,[111] A. Gilbert,[111] A. Guneratne Bryer,[111] G. Hall,[111] Z. Hatherell,[111] J. Hays,[111] G. Iles,[111] M. Jarvis,[111] G. Karapostoli,[111] L. Lyons,[111] A.-M. Magnan,[111] J. Marrouche,[111] B. Mathias,[111] R. Nandi,[111] J. Nash,[111] A. Nikitenko,[111,oo] A. Papageorgiou,[111] J. Pela,[111,f] M. Pesaresi,[111] K. Petridis,[111] M. Pioppi,[111,yy] D. M. Raymond,[111] S. Rogerson,[111] A. Rose,[111] M. J. Ryan,[111] C. Seez,[111] P. Sharp,[111,a] A. Sparrow,[111] A. Tapper,[111] M. Vazquez Acosta,[111] T. Virdee,[111] S. Wakefield,[111] N. Wardle,[111] T. Whyntie,[111] M. Chadwick,[112] J. E. Cole,[112] P. R. Hobson,[112] A. Khan,[112] P. Kyberd,[112] D. Leggat,[112] D. Leslie,[112] W. Martin,[112] I. D. Reid,[112] P. Symonds,[112] L. Teodorescu,[112] M. Turner,[112] K. Hatakeyama,[113] H. Liu,[113] T. Scarborough,[113] C. Henderson,[114] P. Rumerio,[114] A. Avetisyan,[115] T. Bose,[115] C. Fantasia,[115] A. Heister,[115] J. St. John,[115] P. Lawson,[115] D. Lazic,[115] J. Rohlf,[115] D. Sperka,[115] L. Sulak,[115] J. Alimena,[116] S. Bhattacharya,[116] D. Cutts,[116] A. Ferapontov,[116] U. Heintz,[116] S. Jabeen,[116] G. Kukartsev,[116] E. Laird,[116] G. Landsberg,[116] M. Luk,[116] M. Narain,[116] D. Nguyen,[116] M. Segala,[116] T. Sinthuprasith,[116] T. Speer,[116] K. V. Tsang,[116] R. Breedon,[117] G. Breto,[117] M. Calderon De La Barca Sanchez,[117] S. Chauhan,[117] M. Chertok,[117] J. Conway,[117] R. Conway,[117] P. T. Cox,[117] J. Dolen,[117] R. Erbacher,[117] M. Gardner,[117] R. Houtz,[117] W. Ko,[117] A. Kopecky,[117] R. Lander,[117] T. Miceli,[117] D. Pellett,[117] B. Rutherford,[117] M. Searle,[117] J. Smith,[117] M. Squires,[117] M. Tripathi,[117] R. Vasquez Sierra,[117] V. Andreev,[118] D. Cline,[118] R. Cousins,[118] J. Duris,[118] S. Erhan,[118] P. Everaerts,[118] C. Farrell,[118] J. Hauser,[118] M. Ignatenko,[118] C. Jarvis,[118] C. Plager,[118]

G. Rakness,[118] P. Schlein,[118,a] J. Tucker,[118] V. Valuev,[118] M. Weber,[118] J. Babb,[119] R. Clare,[119] M. E. Dinardo,[119] J. Ellison,[119] J. W. Gary,[119] F. Giordano,[119] G. Hanson,[119] G. Y. Jeng,[119,zz] H. Liu,[119] O. R. Long,[119] A. Luthra,[119] H. Nguyen,[119] S. Paramesvaran,[119] J. Sturdy,[119] S. Sumowidagdo,[119] R. Wilken,[119] S. Wimpenny,[119] W. Andrews,[120] J. G. Branson,[120] G. B. Cerati,[120] S. Cittolin,[120] D. Evans,[120] F. Golf,[120] A. Holzner,[120] R. Kelley,[120] M. Lebourgeois,[120] J. Letts,[120] I. Macneill,[120] B. Mangano,[120] S. Padhi,[120] C. Palmer,[120] G. Petrucciani,[120] M. Pieri,[120] M. Sani,[120] V. Sharma,[120] S. Simon,[120] E. Sudano,[120] M. Tadel,[120] Y. Tu,[120] A. Vartak,[120] S. Wasserbaech,[120,aaa] F. Würthwein,[120] A. Yagil,[120] J. Yoo,[120] D. Barge,[121] R. Bellan,[121] C. Campagnari,[121] M. D'Alfonso,[121] T. Danielson,[121] K. Flowers,[121] P. Geffert,[121] J. Incandela,[121] C. Justus,[121] P. Kalavase,[121] S. A. Koay,[121] D. Kovalskyi,[121] V. Krutelyov,[121] S. Lowette,[121] N. Mccoll,[121] V. Pavlunin,[121] F. Rebassoo,[121] J. Ribnik,[121] J. Richman,[121] R. Rossin,[121] D. Stuart,[121] W. To,[121] C. West,[121] A. Apresyan,[122] A. Bornheim,[122] Y. Chen,[122] E. Di Marco,[122] J. Duarte,[122] M. Gataullin,[122] Y. Ma,[122] A. Mott,[122] H. B. Newman,[122] C. Rogan,[122] V. Timciuc,[122] P. Traczyk,[122] J. Veverka,[122] R. Wilkinson,[122] Y. Yang,[122] R. Y. Zhu,[122] B. Akgun,[123] R. Carroll,[123] T. Ferguson,[123] Y. Iiyama,[123] D. W. Jang,[123] Y. F. Liu,[123] M. Paulini,[123] H. Vogel,[123] I. Vorobiev,[123] J. P. Cumalat,[124] B. R. Drell,[124] C. J. Edelmaier,[124] W. T. Ford,[124] A. Gaz,[124] B. Heyburn,[124] E. Luiggi Lopez,[124] J. G. Smith,[124] K. Stenson,[124] K. A. Ulmer,[124] S. R. Wagner,[124] J. Alexander,[125] A. Chatterjee,[125] N. Eggert,[125] L. K. Gibbons,[125] B. Heltsley,[125] A. Khukhunaishvili,[125] B. Kreis,[125] N. Mirman,[125] G. Nicolas Kaufman,[125] J. R. Patterson,[125] A. Ryd,[125] E. Salvati,[125] W. Sun,[125] W. D. Teo,[125] J. Thom,[125] J. Thompson,[125] J. Vaughan,[125] Y. Weng,[125] L. Winstrom,[125] P. Wittich,[125] D. Winn,[126] S. Abdullin,[127] M. Albrow,[127] J. Anderson,[127] L. A. T. Bauerdick,[127] A. Beretvas,[127] J. Berryhill,[127] P. C. Bhat,[127] I. Bloch,[127] K. Burkett,[127] J. N. Butler,[127] V. Chetluru,[127] H. W. K. Cheung,[127] F. Chlebana,[127] V. D. Elvira,[127] I. Fisk,[127] J. Freeman,[127] Y. Gao,[127] D. Green,[127] O. Gutsche,[127] J. Hanlon,[127] R. M. Harris,[127] J. Hirschauer,[127] B. Hooberman,[127] S. Jindariani,[127] M. Johnson,[127] U. Joshi,[127] B. Kilminster,[127] B. Klima,[127] S. Kunori,[127] S. Kwan,[127] C. Leonidopoulos,[127] D. Lincoln,[127] R. Lipton,[127] J. Lykken,[127] K. Maeshima,[127] J. M. Marraffino,[127] S. Maruyama,[127] D. Mason,[127] P. McBride,[127] K. Mishra,[127] S. Mrenna,[127] Y. Musienko,[127,bbb] C. Newman-Holmes,[127] V. O'Dell,[127] O. Prokofyev,[127] E. Sexton-Kennedy,[127] S. Sharma,[127] W. J. Spalding,[127] L. Spiegel,[127] P. Tan,[127] L. Taylor,[127] S. Tkaczyk,[127] N. V. Tran,[127] L. Uplegger,[127] E. W. Vaandering,[127] R. Vidal,[127] J. Whitmore,[127] W. Wu,[127] F. Yang,[127] F. Yumiceva,[127] J. C. Yun,[127] D. Acosta,[128] P. Avery,[128] D. Bourilkov,[128] M. Chen,[128] S. Das,[128] M. De Gruttola,[128] G. P. Di Giovanni,[128] D. Dobur,[128] A. Drozdetskiy,[128] R. D. Field,[128] M. Fisher,[128] Y. Fu,[128] I. K. Furic,[128] J. Gartner,[128] J. Hugon,[128] B. Kim,[128] J. Konigsberg,[128] A. Korytov,[128] A. Kropivnitskaya,[128] T. Kypreos,[128] J. F. Low,[128] K. Matchev,[128] P. Milenovic,[128,ccc] G. Mitselmakher,[128] L. Muniz,[128] R. Remington,[128] A. Rinkevicius,[128] P. Sellers,[128] N. Skhirtladze,[128] M. Snowball,[128] J. Yelton,[128] M. Zakaria,[128] V. Gaultney,[129] L. M. Lebolo,[129] S. Linn,[129] P. Markowitz,[129] G. Martinez,[129] J. L. Rodriguez,[129] J. R. Adams,[130] T. Adams,[130] A. Askew,[130] J. Bochenek,[130] J. Chen,[130] B. Diamond,[130] S. V. Gleyzer,[130] J. Haas,[130] S. Hagopian,[130] V. Hagopian,[130] M. Jenkins,[130] K. F. Johnson,[130] H. Prosper,[130] V. Veeraraghavan,[130] M. Weinberg,[130] M. M. Baarmand,[131] B. Dorney,[131] M. Hohlmann,[131] H. Kalakhety,[131] I. Vodopiyanov,[131] M. R. Adams,[132] I. M. Anghel,[132] L. Apanasevich,[132] Y. Bai,[132] V. E. Bazterra,[132] R. R. Betts,[132] I. Bucinskaite,[132] J. Callner,[132] R. Cavanaugh,[132] C. Dragoiu,[132] O. Evdokimov,[132] L. Gauthier,[132] C. E. Gerber,[132] D. J. Hofman,[132] S. Khalatyan,[132] F. Lacroix,[132] M. Malek,[132] C. O'Brien,[132] C. Silkworth,[132] D. Strom,[132] N. Varelas,[132] U. Akgun,[133] E. A. Albayrak,[133] B. Bilki,[133,ddd] W. Clarida,[133] F. Duru,[133] S. Griffiths,[133] J.-P. Merlo,[133] H. Mermerkaya,[133,eee] A. Mestvirishvili,[133] A. Moeller,[133] J. Nachtman,[133] C. R. Newsom,[133] E. Norbeck,[133] Y. Onel,[133] F. Ozok,[133] S. Sen,[133] E. Tiras,[133] J. Wetzel,[133] T. Yetkin,[133] K. Yi,[133] B. A. Barnett,[134] B. Blumenfeld,[134] S. Bolognesi,[134] D. Fehling,[134] G. Giurgiu,[134] A. V. Gritsan,[134] Z. J. Guo,[134] G. Hu,[134] P. Maksimovic,[134] S. Rappoccio,[134] M. Swartz,[134] A. Whitbeck,[134] P. Baringer,[135] A. Bean,[135] G. Benelli,[135] O. Grachov,[135] R. P. Kenny Iii,[135] M. Murray,[135] D. Noonan,[135] S. Sanders,[135] R. Stringer,[135] G. Tinti,[135] J. S. Wood,[135] V. Zhukova,[135] A. F. Barfuss,[136] T. Bolton,[136] I. Chakaberia,[136] A. Ivanov,[136] S. Khalil,[136] M. Makouski,[136] Y. Maravin,[136] S. Shrestha,[136] I. Svintradze,[136] J. Gronberg,[137] D. Lange,[137] D. Wright,[137] A. Baden,[138] M. Boutemeur,[138] B. Calvert,[138] S. C. Eno,[138] J. A. Gomez,[138] N. J. Hadley,[138] R. G. Kellogg,[138] M. Kirn,[138] T. Kolberg,[138] Y. Lu,[138] M. Marionneau,[138] A. C. Mignerey,[138] K. Pedro,[138] A. Peterman,[138] A. Skuja,[138] J. Temple,[138] M. B. Tonjes,[138] S. C. Tonwar,[138] E. Twedt,[138] G. Bauer,[139] J. Bendavid,[139] W. Busza,[139] E. Butz,[139] I. A. Cali,[139] M. Chan,[139] V. Dutta,[139] G. Gomez Ceballos,[139] M. Goncharov,[139] K. A. Hahn,[139] Y. Kim,[139] M. Klute,[139] K. Krajczar,[139,fff] W. Li,[139] P. D. Luckey,[139] T. Ma,[139] S. Nahn,[139] C. Paus,[139] D. Ralph,[139] C. Roland,[139] G. Roland,[139] M. Rudolph,[139]

G. S. F. Stephans,[139] F. Stöckli,[139] K. Sumorok,[139] K. Sung,[139] D. Velicanu,[139] E. A. Wenger,[139] R. Wolf,[139] B. Wyslouch,[139] S. Xie,[139] M. Yang,[139] Y. Yilmaz,[139] A. S. Yoon,[139] M. Zanetti,[139] S. I. Cooper,[140] B. Dahmes,[140] A. De Benedetti,[140] G. Franzoni,[140] A. Gude,[140] S. C. Kao,[140] K. Klapoetke,[140] Y. Kubota,[140] J. Mans,[140] N. Pastika,[140] R. Rusack,[140] M. Sasseville,[140] A. Singovsky,[140] N. Tambe,[140] J. Turkewitz,[140] L. M. Cremaldi,[141] R. Kroeger,[141] L. Perera,[141] R. Rahmat,[141] D. A. Sanders,[141] E. Avdeeva,[142] K. Bloom,[142] S. Bose,[142] J. Butt,[142] D. R. Claes,[142] A. Dominguez,[142] M. Eads,[142] J. Keller,[142] I. Kravchenko,[142] J. Lazo-Flores,[142] H. Malbouisson,[142] S. Malik,[142] G. R. Snow,[142] U. Baur,[143] A. Godshalk,[143] I. Iashvili,[143] S. Jain,[143] A. Kharchilava,[143] A. Kumar,[143] S. P. Shipkowski,[143] K. Smith,[143] G. Alverson,[144] E. Barberis,[144] D. Baumgartel,[144] M. Chasco,[144] J. Haley,[144] D. Nash,[144] D. Trocino,[144] D. Wood,[144] J. Zhang,[144] A. Anastassov,[145] A. Kubik,[145] N. Mucia,[145] N. Odell,[145] R. A. Ofierzynski,[145] B. Pollack,[145] A. Pozdnyakov,[145] M. Schmitt,[145] S. Stoynev,[145] M. Velasco,[145] S. Won,[145] L. Antonelli,[146] D. Berry,[146] A. Brinkerhoff,[146] M. Hildreth,[146] C. Jessop,[146] D. J. Karmgard,[146] J. Kolb,[146] K. Lannon,[146] W. Luo,[146] S. Lynch,[146] N. Marinelli,[146] D. M. Morse,[146] T. Pearson,[146] R. Ruchti,[146] J. Slaunwhite,[146] N. Valls,[146] M. Wayne,[146] M. Wolf,[146] B. Bylsma,[147] L. S. Durkin,[147] A. Hart,[147] C. Hill,[147] R. Hughes,[147] K. Kotov,[147] T. Y. Ling,[147] D. Puigh,[147] M. Rodenburg,[147] C. Vuosalo,[147] G. Williams,[147] B. L. Winer,[147] N. Adam,[148] E. Berry,[148] P. Elmer,[148] D. Gerbaudo,[148] V. Halyo,[148] P. Hebda,[148] J. Hegeman,[148] A. Hunt,[148] P. Jindal,[148] D. Lopes Pegna,[148] P. Lujan,[148] D. Marlow,[148] T. Medvedeva,[148] M. Mooney,[148] J. Olsen,[148] P. Piroué,[148] X. Quan,[148] A. Raval,[148] H. Saka,[148] D. Stickland,[148] C. Tully,[148] J. S. Werner,[148] A. Zuranski,[148] J. G. Acosta,[149] E. Brownson,[149] X. T. Huang,[149] A. Lopez,[149] H. Mendez,[149] S. Oliveros,[149] J. E. Ramirez Vargas,[149] A. Zatserklyaniy,[149] E. Alagoz,[150] V. E. Barnes,[150] D. Benedetti,[150] G. Bolla,[150] D. Bortoletto,[150] M. De Mattia,[150] A. Everett,[150] Z. Hu,[150] M. Jones,[150] O. Koybasi,[150] M. Kress,[150] A. T. Laasanen,[150] N. Leonardo,[150] V. Maroussov,[150] P. Merkel,[150] D. H. Miller,[150] N. Neumeister,[150] I. Shipsey,[150] D. Silvers,[150] A. Svyatkovskiy,[150] M. Vidal Marono,[150] H. D. Yoo,[150] J. Zablocki,[150] Y. Zheng,[150] S. Guragain,[151] N. Parashar,[151] A. Adair,[152] C. Boulahouache,[152] K. M. Ecklund,[152] F. J. M. Geurts,[152] B. P. Padley,[152] R. Redjimi,[152] J. Roberts,[152] J. Zabel,[152] B. Betchart,[153] A. Bodek,[153] Y. S. Chung,[153] R. Covarelli,[153] P. de Barbaro,[153] R. Demina,[153] Y. Eshaq,[153] A. Garcia-Bellido,[153] P. Goldenzweig,[153] J. Han,[153] A. Harel,[153] D. C. Miner,[153] D. Vishnevskiy,[153] M. Zielinski,[153] A. Bhatti,[154] R. Ciesielski,[154] L. Demortier,[154] K. Goulianos,[154] G. Lungu,[154] S. Malik,[154] C. Mesropian,[154] S. Arora,[155] A. Barker,[155] J. P. Chou,[155] C. Contreras-Campana,[155] E. Contreras-Campana,[155] D. Duggan,[155] D. Ferencek,[155] Y. Gershtein,[155] R. Gray,[155] E. Halkiadakis,[155] D. Hidas,[155] A. Lath,[155] S. Panwalkar,[155] M. Park,[155] R. Patel,[155] V. Rekovic,[155] J. Robles,[155] K. Rose,[155] S. Salur,[155] S. Schnetzer,[155] C. Seitz,[155] S. Somalwar,[155] R. Stone,[155] S. Thomas,[155] G. Cerizza,[156] M. Hollingsworth,[156] S. Spanier,[156] Z. C. Yang,[156] A. York,[156] R. Eusebi,[157] W. Flanagan,[157] J. Gilmore,[157] T. Kamon,[157,ggg] V. Khotilovich,[157] R. Montalvo,[157] I. Osipenkov,[157] Y. Pakhotin,[157] A. Perloff,[157] J. Roe,[157] A. Safonov,[157] T. Sakuma,[157] S. Sengupta,[157] I. Suarez,[157] A. Tatarinov,[157] D. Toback,[157] N. Akchurin,[158] J. Damgov,[158] P. R. Dudero,[158] C. Jeong,[158] K. Kovitanggoon,[158] S. W. Lee,[158] T. Libeiro,[158] Y. Roh,[158] I. Volobouev,[158] E. Appelt,[159] C. Florez,[159] S. Greene,[159] A. Gurrola,[159] W. Johns,[159] C. Johnston,[159] P. Kurt,[159] C. Maguire,[159] A. Melo,[159] P. Sheldon,[159] B. Snook,[159] S. Tuo,[159] J. Velkovska,[159] M. W. Arenton,[160] M. Balazs,[160] S. Boutle,[160] B. Cox,[160] B. Francis,[160] J. Goodell,[160] R. Hirosky,[160] A. Ledovskoy,[160] C. Lin,[160] C. Neu,[160] J. Wood,[160] R. Yohay,[160] S. Gollapinni,[161] R. Harr,[161] P. E. Karchin,[161] C. Kottachchi Kankanamge Don,[161] P. Lamichhane,[161] A. Sakharov,[161] M. Anderson,[162] M. Bachtis,[162] D. Belknap,[162] L. Borrello,[162] D. Carlsmith,[162] M. Cepeda,[162] S. Dasu,[162] L. Gray,[162] K. S. Grogg,[162] M. Grothe,[162] R. Hall-Wilton,[162] M. Herndon,[162] A. Hervé,[162] P. Klabbers,[162] J. Klukas,[162] A. Lanaro,[162] C. Lazaridis,[162] J. Leonard,[162] R. Loveless,[162] A. Mohapatra,[162] I. Ojalvo,[162] F. Palmonari,[162] G. A. Pierro,[162] I. Ross,[162] A. Savin,[162] W. H. Smith,[162] and J. Swanson[162]

(CMS Collaboration)

[1]*Yerevan Physics Institute, Yerevan, Armenia*
[2]*Institut für Hochenergiephysik der OeAW, Wien, Austria*
[3]*National Centre for Particle and High Energy Physics, Minsk, Belarus*
[4]*Universiteit Antwerpen, Antwerpen, Belgium*
[5]*Vrije Universiteit Brussel, Brussel, Belgium*
[6]*Université Libre de Bruxelles, Bruxelles, Belgium*
[7]*Ghent University, Ghent, Belgium*

[8]*Université Catholique de Louvain, Louvain-la-Neuve, Belgium*
[9]*Université de Mons, Mons, Belgium*
[10]*Centro Brasileiro de Pesquisas Fisicas, Rio de Janeiro, Brazil*
[11]*Universidade do Estado do Rio de Janeiro, Rio de Janeiro, Brazil*
[12]*Instituto de Fisica Teorica, Universidade Estadual Paulista, Sao Paulo, Brazil*
[13]*Institute for Nuclear Research and Nuclear Energy, Sofia, Bulgaria*
[14]*University of Sofia, Sofia, Bulgaria*
[15]*Institute of High Energy Physics, Beijing, China*
[16]*State Key Lab. of Nucl. Phys. and Tech., Peking University, Beijing, China*
[17]*Universidad de Los Andes, Bogota, Colombia*
[18]*Technical University of Split, Split, Croatia*
[19]*University of Split, Split, Croatia*
[20]*Institute Rudjer Boskovic, Zagreb, Croatia*
[21]*University of Cyprus, Nicosia, Cyprus*
[22]*Charles University, Prague, Czech Republic*
[23]*Academy of Scientific Research and Technology of the Arab Republic of Egypt, Egyptian Network of High Energy Physics, Cairo, Egypt*
[24]*National Institute of Chemical Physics and Biophysics, Tallinn, Estonia*
[25]*Department of Physics, University of Helsinki, Helsinki, Finland*
[26]*Helsinki Institute of Physics, Helsinki, Finland*
[27]*Lappeenranta University of Technology, Lappeenranta, Finland*
[28]*DSM/IRFU, CEA/Saclay, Gif-sur-Yvette, France*
[29]*Laboratoire Leprince-Ringuet, Ecole Polytechnique, IN2P3-CNRS, Palaiseau, France*
[30]*Institut Pluridisciplinaire Hubert Curien, Université de Strasbourg, Université de Haute Alsace Mulhouse, CNRS/IN2P3, Strasbourg, France*
[31]*Centre de Calcul de l'Institut National de Physique Nucleaire et de Physique des Particules (IN2P3), Villeurbanne, France*
[32]*Université de Lyon, Université Claude Bernard Lyon 1, CNRS-IN2P3, Institut de Physique Nucléaire de Lyon, Villeurbanne, France*
[33]*Institute of High Energy Physics and Informatization, Tbilisi State University, Tbilisi, Georgia*
[34]*RWTH Aachen University, I. Physikalisches Institut, Aachen, Germany*
[35]*RWTH Aachen University, III. Physikalisches Institut A, Aachen, Germany*
[36]*RWTH Aachen University, III. Physikalisches Institut B, Aachen, Germany*
[37]*Deutsches Elektronen-Synchrotron, Hamburg, Germany*
[38]*University of Hamburg, Hamburg, Germany*
[39]*Institut für Experimentelle Kernphysik, Karlsruhe, Germany*
[40]*Institute of Nuclear Physics "Demokritos", Aghia Paraskevi, Greece*
[41]*University of Athens, Athens, Greece*
[42]*University of Ioánnina, Ioánnina, Greece*
[43]*KFKI Research Institute for Particle and Nuclear Physics, Budapest, Hungary*
[44]*Institute of Nuclear Research ATOMKI, Debrecen, Hungary*
[45]*University of Debrecen, Debrecen, Hungary*
[46]*Panjab University, Chandigarh, India*
[47]*University of Delhi, Delhi, India*
[48]*Saha Institute of Nuclear Physics, Kolkata, India*
[49]*Bhabha Atomic Research Centre, Mumbai, India*
[50]*Tata Institute of Fundamental Research - EHEP, Mumbai, India*
[51]*Tata Institute of Fundamental Research - HECR, Mumbai, India*
[52]*Institute for Research in Fundamental Sciences (IPM), Tehran, Iran*
[53a]*INFN Sezione di Bari, Bari, Italy*
[53b]*Università di Bari, Bari, Italy*
[53c]*Politecnico di Bari, Bari, Italy*
[54a]*INFN Sezione di Bologna, Bologna, Italy*
[54b]*Università di Bologna, Bologna, Italy*
[55a]*INFN Sezione di Catania, Catania, Italy*
[55b]*Università di Catania, Catania, Italy*
[56a]*INFN Sezione di Firenze, Firenze, Italy*
[56b]*Università di Firenze, Firenze, Italy*
[57]*INFN Laboratori Nazionali di Frascati, Frascati, Italy*
[58]*INFN Sezione di Genova, Genova, Italy*
[59a]*INFN Sezione di Milano-Bicocca, Milano, Italy*
[59b]*Università di Milano-Bicocca, Milano, Italy*
[60a]*INFN Sezione di Napoli, Napoli, Italy*

[60b]Università di Napoli "Federico II", Napoli, Italy
[61a]INFN Sezione di Padova, Padova, Italy
[61b]Università di Padova, Padova, Italy
[61c]Università di Trento (Trento), Padova, Italy
[62a]INFN Sezione di Pavia, Pavia, Italy
[62b]Università di Pavia, Pavia, Italy
[63a]INFN Sezione di Perugia, Perugia, Italy
[63b]Università di Perugia, Perugia, Italy
[64a]INFN Sezione di Pisa, Pisa, Italy
[64b]Università di Pisa, Pisa, Italy
[64c]Scuola Normale Superiore di Pisa, Pisa, Italy
[65a]INFN Sezione di Roma, Roma, Italy
[65b]Università di Roma "La Sapienza", Roma, Italy
[66a]INFN Sezione di Torino, Torino, Italy
[66b]Università di Torino, Torino, Italy
[66c]Università del Piemonte Orientale (Novara), Torino, Italy
[67a]INFN Sezione di Trieste, Trieste, Italy
[67b]Università di Trieste, Trieste, Italy
[68]Kangwon National University, Chunchon, Korea
[69]Kyungpook National University, Daegu, Korea
[70]Chonnam National University, Institute for Universe and Elementary Particles, Kwangju, Korea
[71]Konkuk University, Seoul, Korea
[72]Korea University, Seoul, Korea
[73]University of Seoul, Seoul, Korea
[74]Sungkyunkwan University, Suwon, Korea
[75]Vilnius University, Vilnius, Lithuania
[76]Centro de Investigacion y de Estudios Avanzados del IPN, Mexico City, Mexico
[77]Universidad Iberoamericana, Mexico City, Mexico
[78]Benemerita Universidad Autonoma de Puebla, Puebla, Mexico
[79]Universidad Autónoma de San Luis Potosí, San Luis Potosí, Mexico
[80]University of Auckland, Auckland, New Zealand
[81]University of Canterbury, Christchurch, New Zealand
[82]National Centre for Physics, Quaid-I-Azam University, Islamabad, Pakistan
[83]Institute of Experimental Physics, Faculty of Physics, University of Warsaw, Warsaw, Poland
[84]Soltan Institute for Nuclear Studies, Warsaw, Poland
[85]Laboratório de Instrumentação e Física Experimental de Partículas, Lisboa, Portugal
[86]Joint Institute for Nuclear Research, Dubna, Russia
[87]Petersburg Nuclear Physics Institute, Gatchina (St Petersburg), Russia
[88]Institute for Nuclear Research, Moscow, Russia
[89]Institute for Theoretical and Experimental Physics, Moscow, Russia
[90]Moscow State University, Moscow, Russia
[91]P.N. Lebedev Physical Institute, Moscow, Russia
[92]State Research Center of Russian Federation, Institute for High Energy Physics, Protvino, Russia
[93]University of Belgrade, Faculty of Physics and Vinca Institute of Nuclear Sciences, Belgrade, Serbia
[94]Centro de Investigaciones Energéticas Medioambientales y Tecnológicas (CIEMAT), Madrid, Spain
[95]Universidad Autónoma de Madrid, Madrid, Spain
[96]Universidad de Oviedo, Oviedo, Spain
[97]Instituto de Física de Cantabria (IFCA), CSIC-Universidad de Cantabria, Santander, Spain
[98]CERN, European Organization for Nuclear Research, Geneva, Switzerland
[99]Paul Scherrer Institut, Villigen, Switzerland
[100]Institute for Particle Physics, ETH Zurich, Zurich, Switzerland
[101]Universität Zürich, Zurich, Switzerland
[102]National Central University, Chung-Li, Taiwan
[103]National Taiwan University (NTU), Taipei, Taiwan
[104]Cukurova University, Adana, Turkey
[105]Middle East Technical University, Physics Department, Ankara, Turkey
[106]Bogazici University, Istanbul, Turkey
[107]Istanbul Technical University, Istanbul, Turkey
[108]National Scientific Center, Kharkov Institute of Physics and Technology, Kharkov, Ukraine
[109]University of Bristol, Bristol, United Kingdom
[110]Rutherford Appleton Laboratory, Didcot, United Kingdom

[111]*Imperial College, London, United Kingdom*
[112]*Brunel University, Uxbridge, United Kingdom*
[113]*Baylor University, Waco, Texas, USA*
[114]*The University of Alabama, Tuscaloosa, Alabama, USA*
[115]*Boston University, Boston, Massachusetts, USA*
[116]*Brown University, Providence, Rhode Island, USA*
[117]*University of California, Davis, Davis, California, USA*
[118]*University of California, Los Angeles, Los Angeles, California, USA*
[119]*University of California, Riverside, Riverside, California, USA*
[120]*University of California, San Diego, La Jolla, California, USA*
[121]*University of California, Santa Barbara, Santa Barbara,California, USA*
[122]*California Institute of Technology, Pasadena, California, USA*
[123]*Carnegie Mellon University, Pittsburgh, Philadelphia, USA*
[124]*University of Colorado at Boulder, Boulder, Colorado, USA*
[125]*Cornell University, Ithaca, New York, USA*
[126]*Fairfield University, Fairfield, Connecticut, USA*
[127]*Fermi National Accelerator Laboratory, Batavia, Illinois, USA*
[128]*University of Florida, Gainesville, USA*
[129]*Florida International University, Miami, Florida, USA*
[130]*Florida State University, Tallahassee, Florida, USA*
[131]*Florida Institute of Technology, Melbourne, Florida, USA*
[132]*University of Illinois at Chicago (UIC), Chicago, Illinois, USA*
[133]*The University of Iowa, Iowa City, Iowa, USA*
[134]*Johns Hopkins University, Baltimore, maryland, USA*
[135]*The University of Kansas, Lawrence, Kansas, USA*
[136]*Kansas State University, Manhattan, Kansas, USA*
[137]*Lawrence Livermore National Laboratory, Livermore, California, USA*
[138]*University of Maryland, College Park, Maryland, USA*
[139]*Massachusetts Institute of Technology, Cambridge, Massachusetts, USA*
[140]*University of Minnesota, Minneapolis, Minnesota, USA*
[141]*University of Mississippi, University, Mississippi, USA*
[142]*University of Nebraska-Lincoln, Lincoln, Nebraska, USA*
[143]*State University of New York at Buffalo, Buffalo, New York, USA*
[144]*Northeastern University, Boston, Massachusetts, USA*
[145]*Northwestern University, Evanston, Illinois, USA*
[146]*University of Notre Dame, Notre Dame, Indiana, USA*
[147]*The Ohio State University, Columbus, Ohio, USA*
[148]*Princeton University, Princeton, New Jersey, USA*
[149]*University of Puerto Rico, Mayaguez, Puerto Rico*
[150]*Purdue University, West Lafayette, Indiana, USA*
[151]*Purdue University Calumet, Indiana, Hammond, USA*
[152]*Rice University, Houston, Texas, USA*
[153]*University of Rochester, Rochester, New York, USA*
[154]*The Rockefeller University, New York, New York, USA*
[155]*Rutgers, the State University of New Jersey, Piscataway, New Jersey, USA*
[156]*University of Tennessee, Knoxville, Tennessee, USA*
[157]*Texas A&M University, College Station, Texas. USA*
[158]*Texas Tech University, Lubbock, Texas, USA*
[159]*Vanderbilt University, Nashville, Tennessee, USA*
[160]*University of Virginia, Charlottesville, Virginia, USA*
[161]*Wayne State University, Detroit, Michigan, USA*
[162]*University of Wisconsin, Madison, Wisconsin, USA*

[a]Deceased.
[b]Also at Vienna University of Technology, Vienna, Austria.
[c]Also at National Institute of Chemical Physics and Biophysics, Tallinn, Estonia.
[d]Also at Universidade Federal do ABC, Santo Andre, Brazil.
[e]Also at California Institute of Technology, Pasadena, CA, USA.
[f]Also at CERN, European Organization for Nuclear Research, Geneva, Switzerland.
[g]Also at Laboratoire Leprince-Ringuet, Ecole Polytechnique, IN2P3-CNRS, Palaiseau, France.

[h]Also at Suez Canal University, Suez, Egypt.
[i]Also at Zewail City of Science and Technology, Zewail, Egypt.
[j]Also at Cairo University, Cairo, Egypt.
[k]Also at Fayoum University, El-Fayoum, Egypt.
[l]Also at Ain Shams University, Cairo, Egypt.
[m]Now at British University, Cairo, Egypt.
[n]Also at Soltan Institute for Nuclear Studies, Warsaw, Poland.
[o]Also at Université de Haute-Alsace, Mulhouse, France.
[p]Now at Joint Institute for Nuclear Research, Dubna, Russia.
[q]Also at Moscow State University, Moscow, Russia.
[r]Also at Brandenburg University of Technology, Cottbus, Germany.
[s]Also at Institute of Nuclear Research ATOMKI, Debrecen, Hungary.
[t]Also at Eötvös Loránd University, Budapest, Hungary.
[u]Also at Tata Institute of Fundamental Research - HECR, Mumbai, India.
[v]Also at University of Visva-Bharati, Santiniketan, India.
[w]Also at Sharif University of Technology, Tehran, Iran.
[x]Also at Isfahan University of Technology, Isfahan, Iran.
[y]Also at Shiraz University, Shiraz, Iran.
[z]Also at Plasma Physics Research Center, Science and Research Branch, Islamic Azad University, Teheran, Iran.
[aa]Also at Facoltà Ingegneria Università di Roma, Roma, Italy.
[bb]Also at Università della Basilicata, Potenza, Italy.
[cc]Also at Università degli Studi Guglielmo Marconi, Roma, Italy.
[dd]Also at Università degli studi di Siena, Siena, Italy.
[ee]Also at University of Bucharest, Faculty of Physics, Bucuresti-Magurele, Romania.
[ff]Also at Faculty of Physics of University of Belgrade, Belgrade, Serbia.
[gg]Also at University of Florida, Gainesville, FL, USA.
[hh]Also at University of California, Los Angeles, Los Angeles, CA, USA.
[ii]Also at Scuola Normale e Sezione dell' INFN, Pisa, Italy.
[jj]Also at INFN Sezione di Roma, Università di Roma "La Sapienza", Roma, Italy.
[kk]Also at University of Athens, Athens, Greece.
[ll]Also at Rutherford Appleton Laboratory, Didcot, United Kingdom.
[mm]Also at The University of Kansas, Lawrence, KS, USA.
[nn]Also at Paul Scherrer Institut, Villigen, Switzerland.
[oo]Also at Institute for Theoretical and Experimental Physics, Moscow, Russia.
[pp]Also at Gaziosmanpasa University, Tokat, Turkey.
[qq]Also at Adiyaman University, Adiyaman, Turkey.
[rr]Also at The University of Iowa, Iowa City, IA, USA.
[ss]Also at Mersin University, Mersin, Turkey.
[tt]Also at Ozyegin University, Istanbul, Turkey.
[uu]Also at Kafkas University, Kars, Turkey.
[vv]Also at Suleyman Demirel University, Isparta, Turkey.
[ww]Also at Ege University, Izmir, Turkey.
[xx]Also at School of Physics and Astronomy, University of Southampton, Southampton, United Kingdom.
[yy]Also at INFN Sezione di Perugia, Università di Perugia, Perugia, Italy.
[zz]Also at University of Sydney, Sydney, Australia.
[aaa]Also at Utah Valley University, Orem, UT. USA.
[bbb]Also at Institute for Nuclear Research, Moscow, Russia.
[ccc]Also at University of Belgrade, Faculty of Physics and Vinca Institute of Nuclear Sciences, Belgrade, Serbi.a
[ddd]Also at Argonne National Laboratory, Argonne, IL, USA.
[eee]Also at Erzincan University, Erzincan, Turkey.
[fff]Also at KFKI Research Institute for Particle and Nuclear Physics, Budapest, Hungary.
[ggg]Also at Kyungpook National University, Daegu, Korea.