

MIT Open Access Articles

*Measurement of the $\lambda(1S)$, $\lambda(2S)$, and $\lambda(3S)$
Polarizations in pp Collisions at $\sqrt{s}=7$ TeV*

The MIT Faculty has made this article openly available. **Please share** how this access benefits you. Your story matters.

Citation: Chatrchyan, S., V. Khachatryan, A. M. Sirunyan, et al. Measurement of the $\lambda(1S)$, $\lambda(2S)$, and $\lambda(3S)$ Polarizations in Pp Collisions at $\text{Sqrt}[s]=7$ TeV. Physical Review Letters 110(8), 2013. © 2013 CERN, for the CMS Collaboration

As Published: <http://dx.doi.org/10.1103/PhysRevLett.110.081802>

Publisher: American Physical Society

Persistent URL: <http://hdl.handle.net/1721.1/78626>

Version: Final published version: final published article, as it appeared in a journal, conference proceedings, or other formally published context

Terms of use: Creative Commons Attribution 3.0



Measurement of the $Y(1S)$, $Y(2S)$, and $Y(3S)$ Polarizations in pp Collisions at $\sqrt{s} = 7$ TeV

S. Chatrchyan *et al.**

(CMS Collaboration)

(Received 13 September 2012; published 20 February 2013)

The polarizations of the $Y(1S)$, $Y(2S)$, and $Y(3S)$ mesons are measured in proton-proton collisions at $\sqrt{s} = 7$ TeV, using a data sample of $Y(nS) \rightarrow \mu^+ \mu^-$ decays collected by the CMS experiment, corresponding to an integrated luminosity of 4.9 fb^{-1} . The dimuon decay angular distributions are analyzed in three different polarization frames. The polarization parameters λ_ϑ , λ_φ , and $\lambda_{\vartheta\varphi}$, as well as the frame-invariant quantity $\vec{\lambda}$, are presented as a function of the $Y(nS)$ transverse momentum between 10 and 50 GeV, in the rapidity ranges $|y| < 0.6$ and $0.6 < |y| < 1.2$. No evidence of large transverse or longitudinal polarizations is seen in the explored kinematic region.

DOI: [10.1103/PhysRevLett.110.081802](https://doi.org/10.1103/PhysRevLett.110.081802)

PACS numbers: 13.20.Gd, 13.85.Qk, 13.88.+e

Studies of heavy-quarkonium production play a crucial role in the detailed investigation of quantum chromodynamics (QCD), from the hard region, where an expansion in the coupling constant is possible, to the soft region, dominated by nonperturbative effects [1]. Given their high mass, heavy-quarkonium states are approximately nonrelativistic systems, allowing the application of theoretical tools that simplify and constrain the analyses of nonperturbative effects [2]. The differential cross sections of J/ψ and Y mesons produced at Tevatron [3–5] and LHC [6–8] energies can be reproduced by calculations based on nonrelativistic QCD (NRQCD) [9], dominated by “color octet” production. However, the corresponding predictions [10] of strong transverse polarizations (dominant angular momentum component $J_z = \pm 1$ with respect to the quarkonium momentum direction) are in stark disagreement with the negligible polarizations measured for the J/ψ [11]. The Y satisfies the nonrelativistic approximation much better than the J/ψ , making the Y polarization a more decisive test of NRQCD, especially at asymptotically large transverse momentum, p_T . The existing measurements, however, are inconclusive, with the CDF [12] and D0 [13] results in mutual contradiction.

The polarization of the ($J^{PC} = 1^{--}$) Y states can be measured through the study of the angular distribution of the leptons produced in the $Y \rightarrow \mu^+ \mu^-$ decay [14],

$$W(\cos\vartheta, \varphi|\vec{\lambda}) \propto \frac{1}{(3 + \lambda_\vartheta)} (1 + \lambda_\vartheta \cos^2\vartheta + \lambda_\varphi \sin^2\vartheta \cos 2\varphi + \lambda_{\vartheta\varphi} \sin 2\vartheta \cos\varphi), \quad (1)$$

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

Published by the American Physical Society under the terms of the [Creative Commons Attribution 3.0 License](https://creativecommons.org/licenses/by/3.0/). Further distribution of this work must maintain attribution to the author(s) and the published article's title, journal citation, and DOI.

where ϑ and φ are the polar and azimuthal angles, respectively, of the μ^+ with respect to the z axis of the chosen polarization frame. As pointed out in Refs. [14–18], improved experimental measurements of quarkonium polarization require measuring all the angular distribution parameters, $\vec{\lambda} = (\lambda_\vartheta, \lambda_\varphi, \lambda_{\vartheta\varphi})$, in different polarization frames, as well as a frame-invariant polarization parameter, $\tilde{\lambda} = (\lambda_\vartheta + 3\lambda_\varphi)/(1 - \lambda_\varphi)$. This approach has already been followed in the $Y(nS)$ polarization analysis of CDF [12], and in some recent theory calculations [19].

This Letter presents the measurement of the polarizations of the $Y(nS)$ mesons produced in pp collisions at a center-of-mass energy of 7 TeV. The analysis is based on a dimuon sample collected by the CMS experiment at the LHC, corresponding to an integrated luminosity of 4.9 fb^{-1} and containing 252 000 $Y(1S)$, 94 000 $Y(2S)$, and 58 000 $Y(3S)$ mesons (after all selection criteria).

The analysis uses an unbinned likelihood approach, independent of assumptions on the production kinematics. The results are obtained in three frames, with different directions of the quantization axis: the center-of-mass helicity (HX) frame, where the polar axis coincides with the direction of the Y momentum; the Collins-Soper (CS) frame [20], whose axis is the average of the two beam directions in the Y rest frame; and the perpendicular helicity (PX) frame [21], orthogonal to the CS frame. The y axis of the polarization frame is taken, in all cases, to be in the direction of the vector product of the two beam directions, $\vec{P}_1 \times \vec{P}_2$ and $\vec{P}_2 \times \vec{P}_1$ for positive and negative rapidity, respectively.

The central feature of the CMS apparatus [22] is a superconducting solenoid of 6 m internal diameter, providing a 3.8 T field. The main subdetectors used in this analysis are the silicon tracker and the muon system. The silicon tracker, composed of pixel and strip detector modules, is immersed in the magnetic field and enables the measurement of charged-particle momenta over the pseudorapidity range $|\eta| < 2.5$. Muons are measured in the

range $|\eta| < 2.4$ using gas-ionization detectors embedded in the steel return yoke of the magnet and made using three technologies: drift tubes, cathode strip chambers, and resistive plate chambers. The events were collected using a two-level trigger system. The first level consists of custom hardware processors and uses information from the muon system to select events with two muons. The “high-level trigger” requires an opposite-sign muon pair with invariant mass $8.5 < M < 11.5$ GeV, $|y| < 1.25$, $p_T > 5$ or 7 GeV (depending on the instantaneous luminosity), and vertex fit χ^2 probability greater than 0.5%.

In the offline analysis, dimuons are formed by combining pairs of opposite-sign muons (tracks in the silicon tracker matched to tracks in the muon detectors) that satisfy several quality criteria, including the number of tracker hits, the muon-track fit quality, and the vicinity of the track to the closest primary vertex along the beam line. The selected muons are required to satisfy $|\eta| < 1.6$ and to have p_T above 4.5, 3.5, and 3.0 GeV for $|\eta| < 1.2$, $1.2 < |\eta| < 1.4$, and $1.4 < |\eta| < 1.6$, respectively, to ensure accurately measured muon detection efficiencies. Subsequent to the offline trigger confirmation, the combinatorial background from uncorrelated muons is reduced by requiring a dimuon vertex fit χ^2 probability larger than 1.0% and a distance between the dimuon vertex and the closest primary vertex less than twice its uncertainty. The analysis is performed in five dimuon p_T bins, of edges 10, 12, 16, 20, 30, and 50 GeV, and two $|y|$ ranges, 0.0–0.6 and 0.6–1.2.

The dimuon mass distribution, shown in Fig. 1, is well described by three Crystal-Ball functions [23] representing the Y peaks, and by a second-degree polynomial function determined from the low- and high-mass sidebands, located below the $Y(1S)$ and above the $Y(3S)$, respectively. The dimuon mass resolution is better than 70 MeV for $|y| < 0.6$, increasing to 95 MeV in the $0.6 < |y| < 1.2$ range, where the $Y(2S)$ and $Y(3S)$ peaks partially overlap.

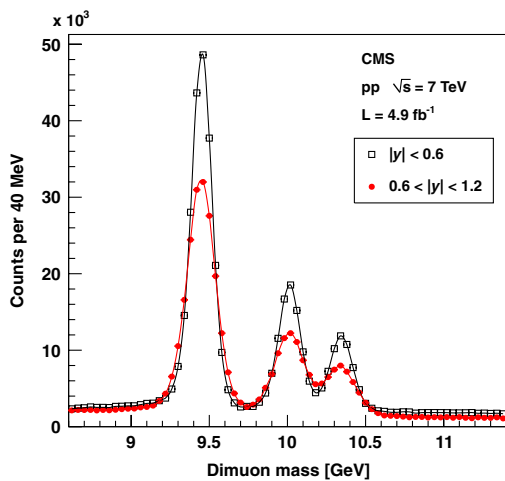


FIG. 1 (color online). Dimuon mass distributions in the Y region for $|y| < 0.6$ (open squares) and $0.6 < |y| < 1.2$ (closed circles).

Within a ± 1 standard deviation (σ) window around the $Y(nS)$ masses, the cross feed between the $Y(2S)$ and $Y(3S)$ is below 4%, and the background fractions are 4%–8%, 9%–18%, and 12%–28% (increasing with decreasing p_T), for the $Y(1S)$, $Y(2S)$, and $Y(3S)$, respectively.

The single-muon detection efficiencies are measured with a “tag-and-probe” technique [24] using event samples collected with dedicated triggers enriched in dimuons from J/ψ decays. The trigger and reconstruction efficiencies must be accurately determined to avoid biases on the angular distributions, which could mimic polarization effects. The technique has been validated in the fiducial region of the analysis with detailed Monte Carlo (MC) simulation studies. The single-muon efficiencies are measured and parametrized as a function of p_T in eight η bins. Their uncertainties, reflecting the statistical precision of the calibration samples and possible imperfections of the parametrization, contribute to the systematic uncertainty on the final results. The dimuon trigger and the selection criteria applied at the dimuon level could potentially introduce muon-pair correlations, making the dimuon detection efficiencies different from the product of the efficiencies of the two single muons. Detailed MC simulations show that such correlations are essentially independent of $\cos\vartheta$ and φ , in the phase space selected for the measurement. Residual effects are incorporated into the systematic uncertainty.

A fit to the dimuon mass distribution provides the fraction of background events, f_B , under each of the three Y mass peaks, for a given definition of the signal region. The angular distributions of these background events are modeled as weighted sums of the distributions measured in the mass sidebands (defined with negligible signal contamination), with weights derived under the assumption that they change monotonically with dimuon mass. The background dimuons are subtracted on an event-by-event basis using the likelihood ratio $L_B/L_{(S+B)}$, where both likelihoods are functions of the variables p_T , $|y|$, M , $\cos\vartheta$, and φ . L_B is the likelihood of an event to be background, reflecting the background model, and $L_{(S+B)}$ is its likelihood to be either signal or background, reflecting the distribution of the measured events. A fraction f_B of events distributed according to the $(p_T, |y|, M, \cos\vartheta, \varphi)$ distribution of the background model is removed from the data sample.

The posterior probability distribution (PPD) for the average values of the Y polarization parameters ($\vec{\lambda}$) inside a particular kinematic cell is then defined as a product over the remaining (“signal-like”) events (i),

$$\mathcal{P}(\vec{\lambda}) = \prod_i \mathcal{E}(\vec{p}_1^{(i)}, \vec{p}_2^{(i)}), \quad (2)$$

where \mathcal{E} represents the event probability distribution as a function of the muon momenta $\vec{p}_{1,2}$ in event i . The priors are assumed to be uniform in the full parameter space. Unlike most polarization analyses, we do not use simulated $(\cos\vartheta, \varphi)$ acceptance and efficiency maps, averaged over

all events in the considered kinematic cell. Instead, the procedure exploits the efficiency measurement as a function of muon momenta, attributing to each event a probability dependent on the full event kinematics (not only $\cos\vartheta$ and φ) and on the values of the polarization parameters. The event probability is defined as

$$\mathcal{E}(\vec{p}_1, \vec{p}_2) = \frac{1}{\mathcal{N}(\vec{\lambda})} W(\cos\vartheta, \varphi|\vec{\lambda})\epsilon(\vec{p}_1, \vec{p}_2), \quad (3)$$

where $\epsilon(\vec{p}_1, \vec{p}_2)$ is the detection efficiency. The normalization factor $\mathcal{N}(\vec{\lambda})$ is calculated by integrating $W \cdot \epsilon$ over $\cos\vartheta$ and φ uniformly, using $(p_T, |y|, M)$ distributions determined from the background-subtracted data.

The background subtraction procedure is repeated 50 times to evaluate the statistical fluctuations associated with its random nature and the final PPD is obtained as the average of the 50 individual PPDs.

The analysis framework, including the effects of the detection efficiencies, has been tested with pseudoexperiments based on simulated samples. Each test involves 50 pseudoexperiments and evaluates a specific systematic uncertainty. The pseudosamples are individually generated and reconstructed, leading to statistically independent determinations of the polarization parameters. The difference between the median of the 50 results and the injected polarization parameters provides the systematic uncertainty corresponding to the effect under study. The reliability of the method to extract the signal polarization is evaluated for several signal and background polarization scenarios. The influence of a possible residual bias from muon or dimuon efficiencies, stemming from the tag-and-probe measurement precision or from the efficiency parametrization, is evaluated by applying uncertainty-based changes to the efficiencies used in the extraction of the polarization parameters. The monotonicity hypothesis in the data-driven modeling of the background angular distribution under the $Y(nS)$ peaks has been tested by varying the signal region from $\pm 3\sigma$ to $\pm 1\sigma$ around the $Y(nS)$ masses (with corresponding corrections determined from a simple simulation of two-body decay kinematics). Despite significant changes in f_B [from 40% to 28% for the $Y(3S)$ at low p_T and $|y| < 0.6$, for instance], the results remain essentially identical for all three states. Larger variations are observed by modifying the relative weights of the low- and high-mass sidebands in the background model composition. A conservative range of hypotheses is considered, such as assuming that the background under the $Y(1S)$ [$Y(3S)$] peak resembles exclusively the low-mass [high-mass] sideband, or assuming that it is reproduced by an equal mixture of the two sideband distributions. While there is no dominant source of systematic uncertainty in the $Y(1S)$ case, the total systematic uncertainty of the $Y(2S)$ and $Y(3S)$ states is dominated by the background model uncertainty, especially at low p_T . At high p_T , the statistical uncertainties dominate. For example, the statistical uncertainties in λ_ϑ (PX) at $|y| < 0.6$ for the $Y(1S)$ [$Y(3S)$] are of order 0.1 [0.2] at both low and high p_T ;

the corresponding systematic uncertainties have a similar magnitude at low p_T and are two [three] times smaller at high p_T .

Each PPD is broadened by the effects of systematic uncertainties, which are included by convolution. One- and two-dimensional projections of each final PPD are calculated by numerical integration. The highest posterior probability in each one-dimensional projection is used to estimate the best value of the associated polarization parameter. Intervals $[\lambda_1, \lambda_2]$ corresponding to a given confidence level (CL), are calculated by identifying two regions of the parameter space, $[-\infty, \lambda_1]$ and $[\lambda_2, \infty]$, each containing $0.5(1 - \text{CL})\%$ of the one-dimensional projection of the PPD. Figure 2 shows two projections of the final PPD for the $Y(1S)$ at $|y| < 0.6$ and $30 < p_T < 50$ GeV, displaying the 68.3% and 99.7% CL contours for the CS and HX frames.

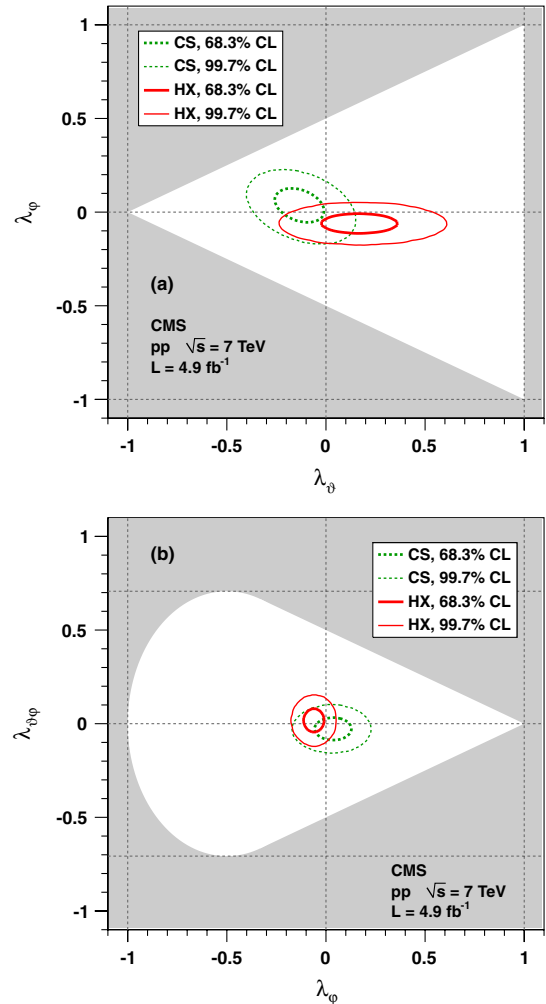


FIG. 2 (color online). Two-dimensional projections of the PPD in the λ_φ vs λ_ϑ (a) and $\lambda_{\vartheta\varphi}$ vs λ_φ (b) planes, for $Y(1S)$ with $|y| < 0.6$ and $30 < p_T < 50$ GeV. The 68.3% and 99.7% CL contours are shown for the CS and HX frames. The shaded areas represent physically forbidden regions of parameter space [18].

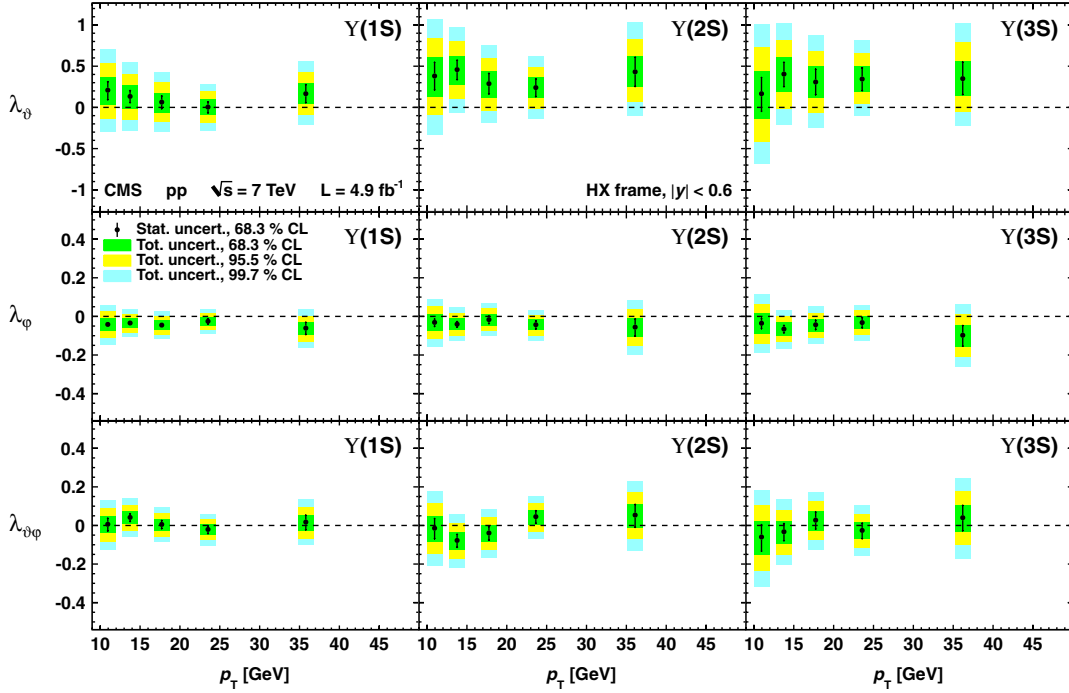


FIG. 3 (color online). Values of the λ_θ (top), λ_ϕ (middle), and $\lambda_{\theta\phi}$ (bottom) parameters for the $Y(1S)$ (left), $Y(2S)$ (middle), and $Y(3S)$ (right), in the HX frame, as a function of the Y p_T for $|y| < 0.6$. The error bars indicate the 68.3% CL interval when neglecting the systematic uncertainties. The three bands represent the 68.3%, 95.5%, and 99.7% CL intervals of the total uncertainties. The points are placed at the average p_T of each bin.

Figure 3 shows, for the rapidity range 0.0–0.6, one-dimensional profiles (68.3%, 95.5%, and 99.7% CL intervals) of the PPDs of the parameters λ_θ , λ_ϕ , and $\lambda_{\theta\phi}$, for the $Y(1S)$, $Y(2S)$, and $Y(3S)$ states, in the HX frame. Similar values are obtained in the 0.6–1.2 rapidity range (see the Supplemental Material [25]). Figure 4 displays the corresponding results for the frame-invariant parameter $\tilde{\lambda}$, including also the CS and PX values. The results obtained in the three frames are in good agreement, as required in the

absence of unaccounted for systematic effects. Complete tables of results for λ_θ , λ_ϕ , $\lambda_{\theta\phi}$, and $\tilde{\lambda}$, for the three Y states and in the three frames considered in this analysis, are available in the Supplemental Material [25].

All the polarization parameters are compatible with zero or small values in the three polarization frames, excluding that a significant polarization could remain undetected because of smearing effects induced by unfortunate frame choices. The indication that the $Y(nS)$ resonances are

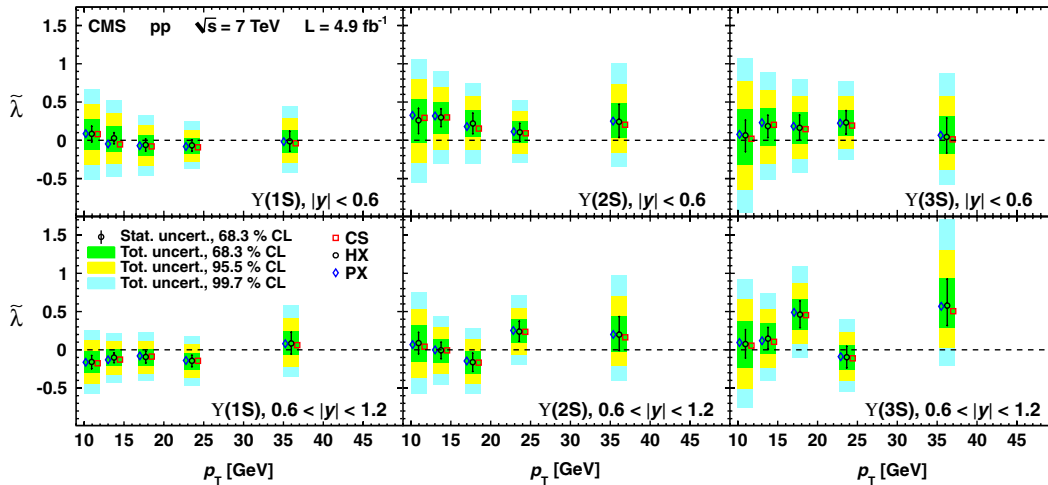


FIG. 4 (color online). Values of $\tilde{\lambda}$ for the $Y(1S)$, $Y(2S)$, and $Y(3S)$ states (left to right), in the HX, CS, and PX frames, for the $|y| < 0.6$ (top) and $0.6 < |y| < 1.2$ (bottom) ranges. The bands and error bars have the same meaning as in the previous figure.

produced as an unpolarized mixture might be related to the fact that the measurements do not distinguish directly produced Y mesons from those produced in the decays of heavier (P -wave) bottomonium states.

In summary, the polarizations of the $Y(nS)$ mesons produced in pp collisions at $\sqrt{s} = 7$ TeV have been determined as a function of the Y p_T in two rapidity ranges and in three different polarization frames, using both frame-dependent and frame-independent parameters. The results exclude large transverse or longitudinal $Y(nS)$ polarizations, beyond the p_T and y ranges probed by previous experiments, especially for the $Y(3S)$ state, less affected by feeddown decays, and are in disagreement with theoretical expectations for high-energy hadron collisions [10,26].

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: BMWF and FWF (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, and Uzbekistan); MON, RosAtom, RAS, and RFBR (Russia); MSTD (Serbia); SEIDI and CPAN (Spain); Swiss Funding Agencies (Switzerland); NSC (Taipei); TUBITAK and TAEK (Turkey); STFC (United Kingdom); and DOE and NSF (USA).

-
- [1] N. Brambilla *et al.* (Quarkonium Working Group), [arXiv: hep-ph/0412158](https://arxiv.org/abs/hep-ph/0412158).
 [2] N. Brambilla *et al.*, *Eur. Phys. J. C* **71**, 1534 (2011).
 [3] D. Acosta *et al.* (CDF Collaboration), *Phys. Rev. D* **71**, 032001 (2005).

- [4] D. Acosta *et al.* (CDF Collaboration) *Phys. Rev. Lett.* **88**, 161802 (2002).
 [5] V.M. Abazov *et al.* (D0 Collaboration), *Phys. Rev. Lett.* **94**, 232001 (2005).
 [6] S. Chatrchyan *et al.* (CMS Collaboration), *J. High Energy Phys.* **02** (2012) 011.
 [7] R. Aaij *et al.* (LHCb Collaboration), *Eur. Phys. J. C* **72**, 2025 (2012).
 [8] V. Khachatryan *et al.* (CMS Collaboration), *Phys. Rev. D* **83**, 112004 (2011).
 [9] G. T. Bodwin, E. Braaten, and G. P. Lepage, *Phys. Rev. D* **51**, 1125 (1995).
 [10] B. Gong, J.-X. Wang, and H.-F. Zhang, *Phys. Rev. D* **83**, 114021 (2011).
 [11] A. Abulencia *et al.* (CDF Collaboration), *Phys. Rev. Lett.* **99**, 132001 (2007).
 [12] T. Aaltonen *et al.* (CDF Collaboration), *Phys. Rev. Lett.* **108**, 151802 (2012).
 [13] V.M. Abazov *et al.* (D0 Collaboration), *Phys. Rev. Lett.* **101**, 182004 (2008).
 [14] P. Faccioli, C. Lourenço, J. Seixas, and H. K. Wöhri, *Eur. Phys. J. C* **69**, 657 (2010).
 [15] P. Faccioli, C. Lourenço, J. Seixas, and H. K. Wöhri, *Phys. Rev. Lett.* **102**, 151802 (2009).
 [16] P. Faccioli, C. Lourenço, and J. Seixas, *Phys. Rev. Lett.* **105**, 061601 (2010).
 [17] P. Faccioli, C. Lourenço, and J. Seixas, *Phys. Rev. D* **81**, 111502(R) (2010).
 [18] P. Faccioli, C. Lourenço, J. Seixas, and H. K. Wöhri, *Phys. Rev. D* **83**, 056008 (2011).
 [19] S. P. Baranov, A. V. Lipatov, and N. P. Zotov, *Phys. Rev. D* **85**, 014034 (2012).
 [20] J. C. Collins and D. E. Soper, *Phys. Rev. D* **16**, 2219 (1977).
 [21] E. Braaten, D. Kang, J. Lee, and C. Yu, *Phys. Rev. D* **79**, 014025 (2009).
 [22] S. Chatrchyan *et al.* (CMS Collaboration), *JINST* **3**, S08004 (2008).
 [23] M. J. Oreglia, Ph.D. thesis, Stanford University, 1980, SLAC Report SLACR-236.
 [24] V. Khachatryan *et al.* (CMS Collaboration), *J. High Energy Phys.* **01** (2011) 080.
 [25] See Supplemental Material at <http://link.aps.org/supplemental/10.1103/PhysRevLett.110.081802> for the numerical values corresponding to the results presented in this Letter.
 [26] P. Artoisenet, J. Campbell, J. P. Lansberg, F. Maltoni, and F. Tramontano, *Phys. Rev. Lett.* **101**, 152001 (2008).

S. Chatrchyan,¹ V. Khachatryan,¹ A. M. Sirunyan,¹ A. Tumasyan,¹ W. Adam,² E. Aguilo,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} I. Krätschmer,² 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 W. Waltenberger,² C.-E. Wulz,^{2,b} V. Mossolov,³ N. Shumeiko,³ J. Suarez Gonzalez,³ M. Bansal,⁴ S. Bansal,⁴ T. Cornelis,⁴ E. A. De Wolf,⁴ X. Janssen,⁴ S. Luyckx,⁴ L. Mucibello,⁴ S. Ochesanu,⁴ B. Roland,⁴ R. Rougny,⁴ M. Selvaggi,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. Vilella,⁵ 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 A. Mohammadi,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 S. Walsh,⁷ E. Yazgan,⁷ N. Zaganidis,⁷ S. Basegmez,⁸ G. Bruno,⁸ R. Castello,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. Lemaître,⁸ J. Liao,⁸ O. Militaru,⁸ C. Nuttens,⁸ D. Pagano,⁸ A. Pin,⁸ K. Piotrkowski,⁸ J. M. Vizan Garcia,⁸ N. Belyi,⁹ T. Caeberts,⁹ E. Daubie,⁹ G. H. Hammad,⁹ G. A. Alves,¹⁰ M. Correa Martins Junior,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 D. De Jesus Damiao,¹¹ C. De Oliveira Martins,¹¹ S. Fonseca De Souza,¹¹ H. Malbouisson,¹¹ M. Malek,¹¹ D. Matos Figueiredo,¹¹ L. Mundim,¹¹ H. Nogima,¹¹ W. L. Prado Da Silva,¹¹ A. Santoro,¹¹ L. Soares Jorge,¹¹ A. Sznajder,¹¹ A. Vilela Pereira,¹¹ T. S. Anjos,^{12,d} 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 Y. Guo,¹⁶ W. Li,¹⁶ S. Liu,¹⁶ Y. Mao,¹⁶ S. J. Qian,¹⁶ H. Teng,¹⁶ D. Wang,¹⁶ L. Zhang,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 D. Mekterovic,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 P. Eerola,²⁵ G. Fedir,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 M. Titov,²⁸ S. Baffioni,²⁹ F. Beaudette,²⁹ L. Benhabib,²⁹ L. Bianchini,²⁹ M. Bluj,^{29,n} P. Busson,²⁹ C. Charlot,²⁹ N. Daci,²⁹ T. Dahms,²⁹ M. Dalchenko,²⁹ L. Dobrzynski,²⁹ A. Florent,²⁹ R. Granier de Cassagnac,²⁹ M. Hagnauer,²⁹ P. Miné,²⁹ C. Mironov,²⁹ I. N. Naranjo,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} 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 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 L. Sgandurra,³² V. Sordini,³² Y. Tschudi,³² P. Verdier,³² S. Viret,³² Z. Tsamalaidze,^{33,p} C. Autermann,³⁴ S. Beranek,³⁴ B. Calpas,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 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 S. Thüer,³⁵ M. Weber,³⁵ M. Bontenackels,³⁶ V. Cherepanov,³⁶ Y. Erdogan,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 J. Lingemann,^{36,f} A. Nowack,³⁶ L. Perchalla,³⁶ O. Pooth,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 C. Diez Pardos,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 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 J. Leonard,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 O. Novgorodova,³⁷ J. Olzem,³⁷ H. Perrey,³⁷ A. Petrukhin,³⁷ D. Pitzl,³⁷ A. Raspereza,³⁷ P. M. Ribeiro Cipriano,³⁷ C. Riedl,³⁷ E. Ron,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
V. Blobel,³⁸ H. Enderle,³⁸ J. Erfle,³⁸ U. Gebbert,³⁸ M. Görner,³⁸ M. Gosselink,³⁸ J. Haller,³⁸ T. Hermanns,³⁸
R. S. Höing,³⁸ K. Kaschube,³⁸ G. Kaussen,³⁸ H. Kirschenmann,³⁸ R. Klanner,³⁸ J. Lange,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 J. Sibille,^{38,s} V. Sola,³⁸ H. Stadie,³⁸ G. Steinbrück,³⁸ J. Thomsen,³⁸ L. Vanelderden,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,f} T. Haut,^{39,f} M. Heinrich,³⁹ H. Held,³⁹ K. H. Hoffmann,³⁹
U. Husemann,³⁹ I. Katkov,^{39,q} J. R. Komaragiri,³⁹ P. Lobelle Pardo,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 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. Anagnostou,⁴⁰ 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
P. Kokkas,⁴² N. Manthos,⁴² I. Papadopoulos,⁴² V. Patras,⁴² G. Bencze,⁴³ C. Hajdu,⁴³ P. Hidas,⁴³ D. Horvath,^{43,t}
F. Sikler,⁴³ V. Veszpremi,⁴³ G. Vesztergombi,^{43,u} 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. Kaur,⁴⁶ M. Z. Mehta,⁴⁶ N. Nishu,⁴⁶ L. K. Saini,⁴⁶ A. Sharma,⁴⁶ J. B. Singh,⁴⁶ Ashok Kumar,⁴⁷ Arun Kumar,⁴⁷
S. Ahuja,⁴⁷ A. Bhardwaj,⁴⁷ B. C. Choudhary,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 D. Dutta,⁴⁹ S. Kailas,⁴⁹ V. Kumar,⁴⁹ A. K. Mohanty,^{49,f} L. M. Pant,⁴⁹
P. Shukla,⁴⁹ T. Aziz,⁵⁰ S. Ganguly,⁵⁰ M. Guchait,^{50,v} A. Gurtu,^{50,w} M. Maity,^{50,x} 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,y}
H. Bakhshiansohi,⁵² S. M. Etesami,^{52,z} A. Fahim,^{52,y} M. Hashemi,^{52,aa} H. Hesari,⁵² A. Jafari,⁵² M. Khakzad,⁵²
M. Mohammadi Najafabadi,⁵² S. Paktinat Mehdiabadi,⁵² B. Safarzadeh,^{52,bb} M. Zeinali,⁵² 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} G. Maggi,^{53a,53c} M. Maggi,^{53a} B. Marangelli,^{53a,53b} S. My,^{53a,53c}
S. Nuzzo,^{53a,53b} N. Pacifico,^{53a} A. Pompili,^{53a,53b} G. Pugliese,^{53a,53c} G. Selvaggi,^{53a,53b} L. Silvestris,^{53a}
G. Singh,^{53a,53b} R. Venditti,^{53a,53b} P. Verwilligen,^{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}
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. P. Siroli,^{54a,54b} N. Tosi,^{54a} 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,56b} L. Benussi,⁵⁷ S. Bianco,⁵⁷ S. Colafranceschi,^{57,cc}
F. Fabbri,⁵⁷ D. Piccolo,⁵⁷ P. Fabricatore,^{58a} R. Musenich,^{58a} S. Tosi,^{58a,58b} A. Benaglia,^{59a} 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} 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}
N. Cavallo,^{60a,dd} A. De Cosa,^{60a,60b,f} O. Dogangun,^{60a,60b} F. Fabozzi,^{60a,dd} A. O. M. Iorio,^{60a,60b} L. Lista,^{60a}
S. Meola,^{60a,ee} M. Merola,^{60a} P. Paolucci,^{60a,f} P. Azzi,^{61a} N. Bacchetta,^{61a,f} P. Bellan,^{61a,61b} 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} M. Nespolo,^{61a,f} J. Pazzini,^{61a,61b} P. Ronchese,^{61a,61b} F. Simonetto,^{61a,61b} E. Torassa,^{61a}
S. Vanini,^{61a,61b} P. Zotto,^{61a,61b} 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} G. Mantovani,^{63a,63b}
M. Menichelli,^{63a} A. Nappi,^{63a,63b,a} F. Romeo,^{63a,63b} A. Saha,^{63a} A. Santocchia,^{63a,63b} A. Spiezia,^{63a,63b}
S. Taroni,^{63a,63b} P. Azzurri,^{64a,64c} G. Bagliesi,^{64a} T. Boccali,^{64a} G. Broccolo,^{64a,64c} R. Castaldi,^{64a}
R. T. D'Agnoles,^{64a,64c,f} 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,ff} A. Messineo,^{64a,64b} F. Palla,^{64a} A. Rizzi,^{64a,64b} A. T. Serban,^{64a,gg} P. Spagnolo,^{64a}

P. Squillacioti,^{64a,f} R. Tenchini,^{64a} G. Tonelli,^{64a,64b} A. Venturi,^{64a} P. G. Verdini,^{64a} L. Barone,^{65a,65b} F. Cavallari,^{65a} D. Del Re,^{65a,65b} M. Diemoz,^{65a} C. Fanelli,^{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} N. Cartiglia,^{66a} S. Casasso,^{66a,66b} M. Costa,^{66a,66b} N. Demaria,^{66a} 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} A. Solano,^{66a,66b} A. Staiano,^{66a} S. Belforte,^{67a} V. Candelise,^{67a,67b} M. Casarsa,^{67a} 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} T. Y. Kim,⁶⁸ S. K. Nam,⁶⁸ S. Chang,⁶⁹ D. H. Kim,⁶⁹ G. N. Kim,⁶⁹ D. J. Kong,⁶⁹ H. Park,⁶⁹ D. C. Son,⁶⁹ T. Son,⁶⁹ J. Y. Kim,⁷⁰ Zero J. Kim,⁷⁰ S. Song,⁷⁰ S. Choi,⁷¹ D. Gyun,⁷¹ B. Hong,⁷¹ M. Jo,⁷¹ H. Kim,⁷¹ T. J. Kim,⁷¹ K. S. Lee,⁷¹ D. H. Moon,⁷¹ S. K. Park,⁷¹ M. Choi,⁷² J. H. Kim,⁷² C. Park,⁷² I. C. Park,⁷² S. Park,⁷² G. Ryu,⁷² Y. Choi,⁷³ Y. K. Choi,⁷³ J. Goh,⁷³ M. S. Kim,⁷³ E. Kwon,⁷³ B. Lee,⁷³ J. Lee,⁷³ S. Lee,⁷³ H. Seo,⁷³ I. Yu,⁷³ M. J. Bilinskas,⁷⁴ I. Grigelionis,⁷⁴ M. Janulis,⁷⁴ A. Juodagalvis,⁷⁴ H. Castilla-Valdez,⁷⁵ E. De La Cruz-Burelo,⁷⁵ I. Heredia-de La Cruz,⁷⁵ R. Lopez-Fernandez,⁷⁵ J. Martínez-Ortega,⁷⁵ A. Sánchez-Hernández,⁷⁵ L. M. Villasenor-Cendejas,⁷⁵ S. Carrillo Moreno,⁷⁶ F. Vazquez Valencia,⁷⁶ H. A. Salazar Ibarguen,⁷⁷ E. Casimiro Linares,⁷⁸ A. Morelos Pineda,⁷⁸ M. A. Reyes-Santos,⁷⁸ D. Krofcheck,⁷⁹ A. J. Bell,⁸⁰ P. H. Butler,⁸⁰ R. Doesburg,⁸⁰ S. Reucroft,⁸⁰ H. Silverwood,⁸⁰ M. Ahmad,⁸¹ M. I. Asghar,⁸¹ J. Butt,⁸¹ H. R. Hoorani,⁸¹ S. Khalid,⁸¹ W. A. Khan,⁸¹ T. Khurshid,⁸¹ S. Qazi,⁸¹ M. A. Shah,⁸¹ M. Shoaib,⁸¹ H. Bialkowska,⁸² B. Boimska,⁸² T. Frueboes,⁸² M. Górski,⁸² M. Kazana,⁸² K. Nawrocki,⁸² K. Romanowska-Rybinska,⁸² M. Szeleper,⁸² G. Wrochna,⁸² P. Zalewski,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 M. Misiura,⁸³ N. Almeida,⁸⁴ P. Bargassa,⁸⁴ A. David,⁸⁴ P. Faccioli,⁸⁴ P. G. Ferreira Parracho,⁸⁴ M. Gallinaro,⁸⁴ J. Seixas,⁸⁴ J. Varela,⁸⁴ P. Vischia,⁸⁴ I. Belotelov,⁸⁵ P. Bunin,⁸⁵ M. Gavrilenko,⁸⁵ I. Golutvin,⁸⁵ I. Gorbunov,⁸⁵ A. Kamenev,⁸⁵ V. Karjavin,⁸⁵ G. Kozlov,⁸⁵ A. Lanev,⁸⁵ A. Malakhov,⁸⁵ P. Moisezen,⁸⁵ V. Palichik,⁸⁵ V. Perelygin,⁸⁵ S. Shmatov,⁸⁵ V. Smirnov,⁸⁵ A. Volodko,⁸⁵ A. Zarubin,⁸⁵ S. Evstyukhin,⁸⁶ V. Golovtsov,⁸⁶ Y. Ivanov,⁸⁶ V. Kim,⁸⁶ P. Levchenko,⁸⁶ V. Murzin,⁸⁶ V. Oreshkin,⁸⁶ I. Smirnov,⁸⁶ V. Sulimov,⁸⁶ L. Uvarov,⁸⁶ S. Vavilov,⁸⁶ A. Vorobyev,⁸⁶ An. Vorobyev,⁸⁶ Yu. Andreev,⁸⁷ A. Dermenev,⁸⁷ S. Gninenko,⁸⁷ N. Golubev,⁸⁷ M. Kirsanov,⁸⁷ N. Krasnikov,⁸⁷ V. Matveev,⁸⁷ A. Pashenkov,⁸⁷ D. Tlisov,⁸⁷ A. Toropin,⁸⁷ V. Epshteyn,⁸⁸ M. Erofeeva,⁸⁸ V. Gavrilov,⁸⁸ M. Kossov,⁸⁸ N. Lychkovskaya,⁸⁸ V. Popov,⁸⁸ G. Safronov,⁸⁸ S. Semenov,⁸⁸ I. Shreyber,⁸⁸ V. Stolin,⁸⁸ E. Vlasov,⁸⁸ A. Zhokin,⁸⁸ A. Belyaev,⁸⁹ E. Boos,⁸⁹ M. Dubinin,^{89,e} L. Dudko,⁸⁹ A. Ershov,⁸⁹ A. Gribushin,⁸⁹ V. Klyukhin,⁸⁹ O. Kodolova,⁸⁹ I. Lokhtin,⁸⁹ A. Markina,⁸⁹ S. Obraztsov,⁸⁹ M. Perfilov,⁸⁹ S. Petrushanko,⁸⁹ A. Popov,⁸⁹ L. Sarycheva,^{89,a} V. Savrin,⁸⁹ A. Snigirev,⁸⁹ V. Andreev,⁹⁰ M. Azarkin,⁹⁰ I. Dremin,⁹⁰ M. Kirakosyan,⁹⁰ A. Leonidov,⁹⁰ G. Mesyats,⁹⁰ S. V. Rusakov,⁹⁰ A. Vinogradov,⁹⁰ I. Azhgirey,⁹¹ I. Bayshev,⁹¹ S. Bitioukov,⁹¹ V. Grishin,^{91,f} V. Kachanov,⁹¹ D. Konstantinov,⁹¹ V. Krychkin,⁹¹ V. Petrov,⁹¹ R. Ryutin,⁹¹ A. Sobol,⁹¹ L. Tourtchanovitch,⁹¹ S. Troshin,⁹¹ N. Tyurin,⁹¹ A. Uzunian,⁹¹ A. Volkov,⁹¹ P. Adzic,^{92,hh} M. Djordjevic,⁹² M. Ekmedzic,⁹² D. Krpic,^{92,hh} J. Milosevic,⁹² M. Aguilar-Benitez,⁹³ J. Alcaraz Maestre,⁹³ P. Arce,⁹³ C. Battilana,⁹³ E. Calvo,⁹³ M. Cerrada,⁹³ M. Chamizo Llatas,⁹³ N. Colino,⁹³ B. De La Cruz,⁹³ A. Delgado Peris,⁹³ D. Domínguez Vázquez,⁹³ C. Fernandez Bedoya,⁹³ J. P. Fernández Ramos,⁹³ A. Ferrando,⁹³ J. Flix,⁹³ M. C. Fouz,⁹³ P. Garcia-Abia,⁹³ O. Gonzalez Lopez,⁹³ S. Goy Lopez,⁹³ J. M. Hernandez,⁹³ M. I. Josa,⁹³ G. Merino,⁹³ J. Puerta Pelayo,⁹³ A. Quintario Olmeda,⁹³ I. Redondo,⁹³ L. Romero,⁹³ J. Santaolalla,⁹³ M. S. Soares,⁹³ C. Willmott,⁹³ C. Albajar,⁹⁴ G. Codispoti,⁹⁴ J. F. de Trocóniz,⁹⁴ H. Brun,⁹⁵ J. Cuevas,⁹⁵ J. Fernandez Menendez,⁹⁵ S. Folgueras,⁹⁵ I. Gonzalez Caballero,⁹⁵ L. Lloret Iglesias,⁹⁵ J. Piedra Gomez,⁹⁵ J. A. Brochero Cifuentes,⁹⁶ I. J. Cabrillo,⁹⁶ A. Calderon,⁹⁶ S. H. Chuang,⁹⁶ J. Duarte Campderros,⁹⁶ M. Felcini,^{96,ii} M. Fernandez,⁹⁶ G. Gomez,⁹⁶ J. Gonzalez Sanchez,⁹⁶ A. Graziano,⁹⁶ C. Jorda,⁹⁶ A. Lopez Virto,⁹⁶ J. Marco,⁹⁶ R. Marco,⁹⁶ C. Martinez Rivero,⁹⁶ F. Matorras,⁹⁶ F. J. Munoz Sanchez,⁹⁶ T. Rodrigo,⁹⁶ A. Y. Rodríguez-Marrero,⁹⁶ A. Ruiz-Jimeno,⁹⁶ L. Scodellaro,⁹⁶ I. Vila,⁹⁶ R. Vilar Cortabitarte,⁹⁶ D. Abbaneo,⁹⁷ E. Auffray,⁹⁷ G. Auzinger,⁹⁷ M. Bachtis,⁹⁷ P. Baillon,⁹⁷ A. H. Ball,⁹⁷ D. Barney,⁹⁷ J. F. Benitez,⁹⁷ C. Bernet,^{97,g} G. Bianchi,⁹⁷ P. Bloch,⁹⁷ A. Bocci,⁹⁷ A. Bonato,⁹⁷ C. Botta,⁹⁷ H. Breuker,⁹⁷ T. Camporesi,⁹⁷ G. Cerminara,⁹⁷ T. Christiansen,⁹⁷ J. A. Coarasa Perez,⁹⁷ D. D'Enterria,⁹⁷ A. Dabrowski,⁹⁷ A. De Roeck,⁹⁷ S. Di Guida,⁹⁷ M. Dobson,⁹⁷ N. Dupont-Sagorin,⁹⁷ A. Elliott-Peisert,⁹⁷ B. Frisch,⁹⁷ W. Funk,⁹⁷ G. Georgiou,⁹⁷ M. Giffels,⁹⁷ D. Gigi,⁹⁷ K. Gill,⁹⁷ D. Giordano,⁹⁷ M. Girone,⁹⁷ M. Giunta,⁹⁷ F. Glege,⁹⁷ R. Gomez-Reino Garrido,⁹⁷ P. Govoni,⁹⁷ S. Gowdy,⁹⁷ R. Guida,⁹⁷ S. Gundacker,⁹⁷ M. Hansen,⁹⁷ P. Harris,⁹⁷ C. Hartl,⁹⁷ J. Harvey,⁹⁷ B. Hegner,⁹⁷ A. Hinzmann,⁹⁷ V. Innocente,⁹⁷ P. Janot,⁹⁷ K. Kaadze,⁹⁷ E. Karavakis,⁹⁷

K. Kousouris,⁹⁷ P. Lecoq,⁹⁷ Y.-J. Lee,⁹⁷ P. Lenzi,⁹⁷ C. Lourenço,⁹⁷ N. Magini,⁹⁷ T. Mäki,⁹⁷ M. Malberti,⁹⁷
 L. Malgeri,⁹⁷ M. Mannelli,⁹⁷ L. Masetti,⁹⁷ F. Meijers,⁹⁷ S. Mersi,⁹⁷ E. Meschi,⁹⁷ R. Moser,⁹⁷ M. U. Mozer,⁹⁷
 M. Mulders,⁹⁷ P. Musella,⁹⁷ E. Nesvold,⁹⁷ T. Orimoto,⁹⁷ L. Orsini,⁹⁷ E. Palencia Cortezon,⁹⁷ E. Perez,⁹⁷
 L. Perrozzi,⁹⁷ A. Petrilli,⁹⁷ A. Pfeiffer,⁹⁷ M. Pierini,⁹⁷ M. Pimiä,⁹⁷ D. Piparo,⁹⁷ G. Polese,⁹⁷ L. Quertenmont,⁹⁷
 A. Racz,⁹⁷ W. Reece,⁹⁷ J. Rodrigues Antunes,⁹⁷ G. Rolandi,^{97,ji} C. Rovelli,^{97,kk} M. Rovere,⁹⁷ H. Sakulin,⁹⁷
 F. Santanastasio,⁹⁷ C. Schäfer,⁹⁷ C. Schwick,⁹⁷ I. Segoni,⁹⁷ S. Sekmen,⁹⁷ A. Sharma,⁹⁷ P. Siegrist,⁹⁷ P. Silva,⁹⁷
 M. Simon,⁹⁷ P. Sphicas,^{97,li} D. Spiga,⁹⁷ A. Tsiroiu,⁹⁷ G. I. Veres,^{97,u} J. R. Vlimant,⁹⁷ H. K. Wöhri,⁹⁷ S. D. Worm,^{97,mm}
 W. D. Zeuner,⁹⁷ W. Bertl,⁹⁸ K. Deiters,⁹⁸ W. Erdmann,⁹⁸ K. Gabathuler,⁹⁸ R. Horisberger,⁹⁸ Q. Ingram,⁹⁸
 H. C. Kaestli,⁹⁸ S. König,⁹⁸ D. Kotlinski,⁹⁸ U. Langenegger,⁹⁸ F. Meier,⁹⁸ D. Renker,⁹⁸ T. Rohe,⁹⁸ L. Bäni,⁹⁹
 P. Bortignon,⁹⁹ M. A. Buchmann,⁹⁹ B. Casal,⁹⁹ N. Chanon,⁹⁹ A. Deisher,⁹⁹ G. Dissertori,⁹⁹ M. Dittmar,⁹⁹
 M. Donegà,⁹⁹ M. Dünser,⁹⁹ J. Eugster,⁹⁹ K. Freudenreich,⁹⁹ C. Grab,⁹⁹ D. Hits,⁹⁹ P. Lecomte,⁹⁹ W. Lustermann,⁹⁹
 A. C. Marini,⁹⁹ P. Martinez Ruiz del Arbol,⁹⁹ N. Mohr,⁹⁹ F. Moortgat,⁹⁹ C. Nägeli,^{99,nn} P. Nef,⁹⁹ F. Nessi-Tedaldi,⁹⁹
 F. Pandolfi,⁹⁹ L. Pape,⁹⁹ F. Pauss,⁹⁹ M. Peruzzi,⁹⁹ F. J. Ronga,⁹⁹ M. Rossini,⁹⁹ L. Sala,⁹⁹ A. K. Sanchez,⁹⁹
 A. Starodumov,^{99,oo} B. Stieger,⁹⁹ M. Takahashi,⁹⁹ L. Tauscher,^{99,a} A. Thea,⁹⁹ K. Theofilatos,⁹⁹ D. Treille,⁹⁹
 C. Urscheler,⁹⁹ R. Wallny,⁹⁹ H. A. Weber,⁹⁹ L. Wehrli,⁹⁹ C. Amsler,^{100,pp} V. Chiochia,¹⁰⁰ S. De Visscher,¹⁰⁰
 C. Favaro,¹⁰⁰ M. Ivova Rikova,¹⁰⁰ B. Kilminster,¹⁰⁰ B. Millan Mejias,¹⁰⁰ P. Otiougova,¹⁰⁰ P. Robmann,¹⁰⁰
 H. Snoek,¹⁰⁰ S. Tupputi,¹⁰⁰ M. Verzetti,¹⁰⁰ Y. H. Chang,¹⁰¹ K. H. Chen,¹⁰¹ C. Ferro,¹⁰¹ C. M. Kuo,¹⁰¹ S. W. Li,¹⁰¹
 W. Lin,¹⁰¹ Y. J. Lu,¹⁰¹ A. P. Singh,¹⁰¹ R. Volpe,¹⁰¹ S. S. Yu,¹⁰¹ P. Bartalini,¹⁰² P. Chang,¹⁰² Y. H. Chang,¹⁰²
 Y. W. Chang,¹⁰² Y. Chao,¹⁰² K. F. Chen,¹⁰² C. Dietz,¹⁰² U. Grundler,¹⁰² W.-S. Hou,¹⁰² Y. Hsiung,¹⁰² K. Y. Kao,¹⁰²
 Y. J. Lei,¹⁰² R.-S. Lu,¹⁰² D. Majumder,¹⁰² E. Petrakou,¹⁰² X. Shi,¹⁰² J. G. Shiu,¹⁰² Y. M. Tzeng,¹⁰² X. Wan,¹⁰²
 M. Wang,¹⁰² B. Asavapibhop,¹⁰³ N. Srimanobhas,¹⁰³ A. Adiguzel,¹⁰⁴ M. N. Bakirci,^{104,qq} S. Cerci,^{104,rr} C. Dozen,¹⁰⁴
 I. Dumanoglu,¹⁰⁴ E. Eskut,¹⁰⁴ S. Girgis,¹⁰⁴ G. Gokbulut,¹⁰⁴ E. Garpinar,¹⁰⁴ I. Hos,¹⁰⁴ E. E. Kangal,¹⁰⁴ T. Karaman,¹⁰⁴
 G. Karapinar,^{104,ss} A. Kayis Topaksu,¹⁰⁴ G. Onengut,¹⁰⁴ K. Ozdemir,¹⁰⁴ S. Ozturk,^{104,tt} A. Polatoz,¹⁰⁴ K. Sogut,^{104,uu}
 D. Sunar Cerci,^{104,rr} B. Tali,^{104,rr} H. Topakli,^{104,qq} 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,vv}
 M. Kaya,^{106,ww} O. Kaya,^{106,ww} S. Ozkorucuklu,^{106,xx} N. Sonmez,^{106,yy} K. Cankocak,¹⁰⁷ L. Levchuk,¹⁰⁸
 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,mm} K. Nirunpong,¹⁰⁹ A. Poll,¹⁰⁹
 S. Senkin,¹⁰⁹ V. J. Smith,¹⁰⁹ T. Williams,¹⁰⁹ L. Basso,^{110,zz} K. W. Bell,¹¹⁰ A. Belyaev,^{110,zz} 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 M. Pesaresi,¹¹¹ K. Petridis,¹¹¹ M. Pioppi,^{111,aaa}
 D. M. Raymond,¹¹¹ S. Rogerson,¹¹¹ A. Rose,¹¹¹ M. J. Ryan,¹¹¹ C. Seez,¹¹¹ P. Sharp,^{111,a} A. Sparrow,¹¹¹ M. Stoye,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 O. Charaf,¹¹⁴
 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
 G. Christopher,¹¹⁶ D. Cutts,¹¹⁶ Z. Demiragli,¹¹⁶ A. Ferapontov,¹¹⁶ A. Garabedian,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 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 O. Mall,¹¹⁷ T. Miceli,¹¹⁷ D. Pellett,¹¹⁷ F. Ricci-tam,¹¹⁷ B. Rutherford,¹¹⁷
 M. Searle,¹¹⁷ J. Smith,¹¹⁷ M. Squires,¹¹⁷ M. Tripathi,¹¹⁷ R. Vasquez Sierra,¹¹⁷ R. Yohay,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 G. Rakness,¹¹⁸ P. Schlein,^{118,a} P. Traczyk,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 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 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,bbb} 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 F. Golf,¹²¹ J. Incandela,¹²¹ C. Justus,¹²¹ P. Kalavase,¹²¹ D. Kovalskiy,¹²¹ V. Krutelyov,¹²¹ S. Lowette,¹²¹ R. Magaña Villalba,¹²¹ N. Mccoll,¹²¹ V. Pavlunin,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 M. Spiropulu,¹²² V. Timciuc,¹²² J. Veverka,¹²² R. Wilkinson,¹²² S. Xie,¹²² Y. Yang,¹²² R. Y. Zhu,¹²² V. Azzolini,¹²³ A. Calamba,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 W. T. Ford,¹²⁴ A. Gaz,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. Tucker,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 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. Klima,¹²⁷ S. Kunori,¹²⁷ S. Kwan,¹²⁷ C. Leonidopoulos,^{127,ccc} J. Linacre,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,ddd} 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 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 J. C. Yun,¹²⁷ D. Acosta,¹²⁸ P. Avery,¹²⁸ D. Bourilkov,¹²⁸ M. Chen,¹²⁸ T. Cheng,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,eee} G. Mitselmakher,¹²⁸ L. Muniz,¹²⁸ M. Park,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 S. Hewamanage,¹²⁹ L. M. Lebolo,¹²⁹ S. Linn,¹²⁹ P. Markowitz,¹²⁹ G. Martinez,¹²⁹ J. L. Rodriguez,¹²⁹ 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. Vodopiyarov,¹³¹ F. Yumiceva,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 O. Evdokimov,¹³² L. Gauthier,¹³² C. E. Gerber,¹³² D. J. Hofman,¹³² S. Khalatyan,¹³² F. Lacroix,¹³² C. O'Brien,¹³² C. Silkworth,¹³² D. Strom,¹³² P. Turner,¹³² N. Varelas,¹³² U. Akgun,¹³³ E. A. Albayrak,¹³³ B. Bilki,^{133,fff} W. Clarida,¹³³ F. Duru,¹³³ J.-P. Merlo,¹³³ H. Mermerkaya,^{133,ggg} A. Mestvirishvili,¹³³ A. Moeller,¹³³ J. Nachtman,¹³³ C. R. Newsom,¹³³ E. Norbeck,¹³³ Y. Onel,¹³³ F. Ozok,^{133,hhh} S. Sen,¹³³ P. Tan,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 M. Swartz,¹³⁴ A. Whitbeck,¹³⁴ P. Baringer,¹³⁵ A. Bean,¹³⁵ G. Benelli,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 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 F. Rebassoo,¹³⁷ D. Wright,¹³⁷ A. Baden,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. Skuja,¹³⁸ J. Temple,¹³⁸ M. B. Tonjes,¹³⁸ S. C. Tonwar,¹³⁸ A. Apyan,¹³⁹ 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 Y. Kim,¹³⁹ M. Klute,¹³⁹ K. Krajczar,^{139,iii} A. Levin,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 M. Yang,¹³⁹ Y. Yilmaz,¹³⁹ A. S. Yoon,¹³⁹ M. Zanetti,¹³⁹ V. Zhukova,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 D. R. Claes,¹⁴² A. Dominguez,¹⁴² M. Eads,¹⁴² J. Keller,¹⁴² I. Kravchenko,¹⁴² J. Lazo-Flores,¹⁴² S. Malik,¹⁴² G. R. Snow,¹⁴² A. Godshalk,¹⁴³ I. Iashvili,¹⁴³ S. Jain,¹⁴³ A. Kharchilava,¹⁴³ A. Kumar,¹⁴³ S. Rappoccio,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 K. A. Hahn,¹⁴⁵ A. Kubik,¹⁴⁵ L. Lusito,¹⁴⁵ N. Mucia,¹⁴⁵ N. Odell,¹⁴⁵ R. A. Oforzynski,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 K. M. Chan,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 M. Planer,¹⁴⁶ R. Ruchti,¹⁴⁶ J. Slaunwhite,¹⁴⁶ N. Valls,¹⁴⁶ M. Wayne,¹⁴⁶ M. Wolf,¹⁴⁶ B. Bylsma,¹⁴⁷ L. S. Durkin,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 E. Berry,¹⁴⁸ P. Elmer,¹⁴⁸ V. Halyo,¹⁴⁸ P. Hebda,¹⁴⁸ J. Hegeman,¹⁴⁸ A. Hunt,¹⁴⁸ P. Jindal,¹⁴⁸ S. A. Koay,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 E. Brownson,¹⁴⁹ A. Lopez,¹⁴⁹ H. Mendez,¹⁴⁹ J. E. Ramirez Vargas,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 B. Akgun,¹⁵² C. Boulahouache,¹⁵² K. M. Ecklund,¹⁵² F. J. M. Geurts,¹⁵² W. Li,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 T. Ferbel,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. Goulios,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 M. Walker,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 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 C. Dragoiu,¹⁵⁸ P. R. Duderø,¹⁵⁸ C. Jeong,¹⁵⁸ K. Kovitanggoon,¹⁵⁸ S. W. Lee,¹⁵⁸ T. Libeiro,¹⁵⁸ Y. Roh,¹⁵⁸ I. Volobouev,¹⁵⁸ E. Appelt,¹⁵⁹ A. G. Delannoy,¹⁵⁹ C. Florez,¹⁵⁹ S. Greene,¹⁵⁹ A. Gurrola,¹⁵⁹ W. Johns,¹⁵⁹ P. Kurt,¹⁵⁹ C. Maguire,¹⁵⁹ A. Melo,¹⁵⁹ M. Sharma,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 S. Gollapinni,¹⁶¹ R. Harr,¹⁶¹ P. E. Karchin,¹⁶¹ C. Kottachchi Kankanamge Don,¹⁶¹ P. Lamichhane,¹⁶¹ A. Sakharov,¹⁶¹ M. Anderson,¹⁶² D. Belknap,¹⁶² L. Borrello,¹⁶² D. Carlsmith,¹⁶² M. Cepeda,¹⁶² S. Dasu,¹⁶² E. Friis,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 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. Swanson¹⁶²

(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 Físicas, 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 Laboratory of Nuclear Physics and Technology, 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, CNRS/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*
- ^{58a}*INFN Sezione di Genova, Genova, Italy*
- ^{58b}*Università 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
⁶⁸Kangwon National University, Chunchon, Korea
⁶⁹Kyungpook National University, Daegu, Korea
⁷⁰Chonnam National University, Institute for Universe and Elementary Particles, Kwangju, Korea
⁷¹Korea University, Seoul, Korea
⁷²University of Seoul, Seoul, Korea
⁷³Sungkyunkwan University, Suwon, Korea
⁷⁴Vilnius University, Vilnius, Lithuania
⁷⁵Centro de Investigacion y de Estudios Avanzados del IPN, Mexico City, Mexico
⁷⁶Universidad Iberoamericana, Mexico City, Mexico
⁷⁷Benemerita Universidad Autonoma de Puebla, Puebla, Mexico
⁷⁸Universidad Autónoma de San Luis Potosí, San Luis Potosí, Mexico
⁷⁹University of Auckland, Auckland, New Zealand
⁸⁰University of Canterbury, Christchurch, New Zealand
⁸¹National Centre for Physics, Quaid-I-Azam University, Islamabad, Pakistan
⁸²National Centre for Nuclear Research, Swierk, Poland
⁸³Institute of Experimental Physics, Faculty of Physics, University of Warsaw, Warsaw, Poland
⁸⁴Laboratório de Instrumentação e Física Experimental de Partículas, Lisboa, Portugal
⁸⁵Joint Institute for Nuclear Research, Dubna, Russia
⁸⁶Petersburg Nuclear Physics Institute, Gatchina (St. Petersburg), Russia
⁸⁷Institute for Nuclear Research, Moscow, Russia
⁸⁸Institute for Theoretical and Experimental Physics, Moscow, Russia
⁸⁹Moscow State University, Moscow, Russia
⁹⁰P.N. Lebedev Physical Institute, Moscow, Russia
⁹¹State Research Center of Russian Federation, Institute for High Energy Physics, Protvino, Russia
⁹²University of Belgrade, Faculty of Physics and Vinca Institute of Nuclear Sciences, Belgrade, Serbia
⁹³Centro de Investigaciones Energéticas Medioambientales y Tecnológicas (CIEMAT), Madrid, Spain
⁹⁴Universidad Autónoma de Madrid, Madrid, Spain
⁹⁵Universidad de Oviedo, Oviedo, Spain
⁹⁶Instituto de Física de Cantabria (IFCA), CSIC-Universidad de Cantabria, Santander, Spain
⁹⁷CERN, European Organization for Nuclear Research, Geneva, Switzerland
⁹⁸Paul Scherrer Institut, Villigen, Switzerland
⁹⁹Institute for Particle Physics, ETH Zurich, Zurich, Switzerland
¹⁰⁰Universität Zürich, Zurich, Switzerland
¹⁰¹National Central University, Chung-Li, Taiwan
¹⁰²National Taiwan University (NTU), Taipei, Taiwan
¹⁰³Chulalongkorn University, Bangkok, Thailand
¹⁰⁴Cukurova University, Adana, Turkey
¹⁰⁵Middle East Technical University, Physics Department, Ankara, Turkey
¹⁰⁶Bogazici University, Istanbul, Turkey
¹⁰⁷Istanbul Technical University, Istanbul, Turkey
¹⁰⁸National Scientific Center, Kharkov Institute of Physics and Technology, Kharkov, Ukraine
¹⁰⁹University of Bristol, Bristol, United Kingdom
¹¹⁰Rutherford Appleton Laboratory, Didcot, United Kingdom
¹¹¹Imperial College, London, United Kingdom
¹¹²Brunel University, Uxbridge, United Kingdom
¹¹³Baylor 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, Pennsylvania, 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, Florida, 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, Oxford, 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, USA*
¹⁵⁰*Purdue University, West Lafayette, Indiana, USA*
¹⁵¹*Purdue University Calumet, Hammond, Indiana, 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*

^aDeceased.

^bAlso at Vienna University of Technology, Vienna, Austria.

^cAlso at National Institute of Chemical Physics and Biophysics, Tallinn, Estonia.

^dAlso at Universidade Federal do ABC, Santo Andre, Brazil.

^eAlso at California Institute of Technology, Pasadena, CA, USA.

^fAlso at CERN, European Organization for Nuclear Research, Geneva, Switzerland.

^gAlso at Laboratoire Leprince-Ringuet, Ecole Polytechnique, IN2P3-CNRS, Palaiseau, France.

^hAlso at Suez Canal University, Suez, Egypt.

ⁱAlso at Zewail City of Science and Technology, Zewail, Egypt.

^jAlso at Cairo University, Cairo, Egypt.

- ^kAlso at Fayoum University, El-Fayoum, Egypt.
- ^lAlso at British University, Cairo, Egypt.
- ^mNow at Ain Shams University, Cairo, Egypt.
- ⁿAlso at National Centre for Nuclear Research, Swierk, Poland.
- ^oAlso at Université de Haute-Alsace, Mulhouse, France.
- ^pAlso at Joint Institute for Nuclear Research, Dubna, Russia.
- ^qAlso at Moscow State University, Moscow, Russia.
- ^rAlso at Brandenburg University of Technology, Cottbus, Germany.
- ^sAlso at The University of Kansas, Lawrence, KS, USA.
- ^tAlso at Institute of Nuclear Research ATOMKI, Debrecen, Hungary.
- ^uAlso at Eötvös Loránd University, Budapest, Hungary.
- ^vAlso at Tata Institute of Fundamental Research-HECR, Mumbai, India.
- ^wNow at King Abdulaziz University, Jeddah, Saudi Arabia.
- ^xAlso at University of Visva-Bharati, Santiniketan, India.
- ^yAlso at Sharif University of Technology, Tehran, Iran.
- ^zAlso at Isfahan University of Technology, Isfahan, Iran.
- ^{aa}Also at Shiraz University, Shiraz, Iran.
- ^{bb}Also at Plasma Physics Research Center, Science and Research Branch, Islamic Azad University, Tehran, Iran.
- ^{cc}Also at Facoltà Ingegneria Università di Roma, Roma, Italy.
- ^{dd}Also at Università della Basilicata, Potenza, Italy.
- ^{ee}Also at Università degli Studi Guglielmo Marconi, Roma, Italy.
- ^{ff}Also at Università degli Studi di Siena, Siena, Italy.
- ^{gg}Also at University of Bucharest, Faculty of Physics, Bucuresti-Magurele, Romania.
- ^{hh}Also at Faculty of Physics of University of Belgrade, Belgrade, Serbia.
- ⁱⁱAlso at University of California, Los Angeles, Los Angeles, CA, USA.
- ^{jj}Also at Scuola Normale e Sezione dell' INFN, Pisa, Italy.
- ^{kk}Also at INFN Sezione di Roma, Università di Roma "La Sapienza", Roma, Italy.
- ^{ll}Also at University of Athens, Athens, Greece.
- ^{mm}Also at Rutherford Appleton Laboratory, Didcot, United Kingdom.
- ⁿⁿAlso at Paul Scherrer Institut, Villigen, Switzerland.
- ^{oo}Also at Institute for Theoretical and Experimental Physics, Moscow, Russia.
- ^{pp}Also at Albert Einstein Center for Fundamental Physics, Bern, Switzerland.
- ^{qq}Also at Gaziosmanpasa University, Tokat, Turkey.
- ^{rr}Also at Adiyaman University, Adiyaman, Turkey.
- ^{ss}Also at Izmir Institute of Technology, Izmir, Turkey.
- ^{tt}Also at The University of Iowa, Iowa City, IA, USA.
- ^{uu}Also at Mersin University, Mersin, Turkey.
- ^{vv}Also at Ozyegin University, Istanbul, Turkey.
- ^{ww}Also at Kafkas University, Kars, Turkey.
- ^{xx}Also at Suleyman Demirel University, Isparta, Turkey.
- ^{yy}Also at Ege University, Izmir, Turkey.
- ^{zz}Also at School of Physics and Astronomy, University of Southampton, Southampton, United Kingdom.
- ^{aaa}Also at INFN Sezione di Perugia, Università di Perugia, Perugia, Italy.
- ^{bbb}Also at Utah Valley University, Orem, UT, USA.
- ^{ccc}Now at University of Edinburgh, Scotland, Edinburgh, United Kingdom.
- ^{ddd}Also at Institute for Nuclear Research, Moscow, Russia.
- ^{eee}Also at University of Belgrade, Faculty of Physics and Vinca Institute of Nuclear Sciences, Belgrade, Serbia.
- ^{fff}Also at Argonne National Laboratory, Argonne, IL, USA.
- ^{ggg}Also at Erzincan University, Erzincan, Turkey.
- ^{hhh}Also at Mimar Sinan University, Istanbul, Istanbul, Turkey.
- ⁱⁱⁱAlso at KFKI Research Institute for Particle and Nuclear Physics, Budapest, Hungary.
- ^{jjj}Also at Kyungpook National University, Daegu, Korea.