

MIT Open Access Articles

First Measurement of Bose-Einstein Correlations in Proton-Proton Collisions at $\sqrt{s}=0.9$ and 2.36 TeV at the LHC

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

Citation: CMS Collaboration et al. "First Measurement of Bose-Einstein Correlations in Proton-Proton Collisions at $\sqrt{s}=0.9$ and 2.36 TeV at the LHC." Physical Review Letters 105, 032001 (2010) © 2010 CERN, for the CMS Collaboration.

As Published: <http://dx.doi.org/10.1103/PhysRevLett.105.032001>

Publisher: American Physical Society

Persistent URL: <http://hdl.handle.net/1721.1/60901>

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

Terms of Use: Article is made available in accordance with the publisher's policy and may be subject to US copyright law. Please refer to the publisher's site for terms of use.



First Measurement of Bose-Einstein Correlations in Proton-Proton Collisions at $\sqrt{s} = 0.9$ and 2.36 TeV at the LHC

V. Khachatryan *et al.**

(CMS Collaboration)

(Received 18 May 2010; published 13 July 2010)

Bose-Einstein correlations have been measured using samples of proton-proton collisions at 0.9 and 2.36 TeV center-of-mass energies, recorded by the CMS experiment at the CERN Large Hadron Collider. The signal is observed in the form of an enhancement of pairs of same-sign charged particles with small relative four-momentum. The size of the correlated particle emission region is seen to increase significantly with the particle multiplicity of the event.

DOI: 10.1103/PhysRevLett.105.032001

PACS numbers: 13.85.Hd

In particle collisions, the space-time structure of the hadronization source can be studied using measurements of Bose-Einstein correlations (BEC) between pairs of identical bosons. Since the first observation of BEC 50 years ago in proton-antiproton interactions [1], a number of measurements have been made by several experiments using different initial states; a detailed list of the experimental results can be found in [2,3]. Boson interferometry at the Large Hadron Collider provides a powerful tool to investigate the space-time structure of the particle emission source on femtometric length scales at different center-of-mass energies and with different initial states, using the same detector. This Letter reports the first measurements of BEC at the LHC with the CMS detector, namely, the first measurement in pp collisions at 0.9 TeV and the highest energy measurement at 2.36 TeV.

Constructive interference affects the joint probability for the emission of a pair of identical bosons with four-momenta p_1 and p_2 . Experimentally, the proximity in phase space between final-state particles is quantified by the Lorentz-invariant quantity $Q = \sqrt{-(p_1 - p_2)^2} = \sqrt{M^2 - 4m_\pi^2}$, where M is the invariant mass of the two particles, assumed to be pions with mass m_π . The BEC effect is observed as an enhancement at low Q of the ratio of the Q distributions for pairs of identical particles in the same event, and for pairs of particles in a reference sample that, by construction, is expected to include no BEC effect:

$$R(Q) = (dN/dQ)/(dN_{\text{ref}}/dQ), \quad (1)$$

which is then fitted with the parametrization

$$R(Q) = C[1 + \lambda\Omega(Qr)](1 + \delta Q). \quad (2)$$

In a static model of particle sources, $\Omega(Qr)$ is the Fourier

transform of the spatial distribution of the emission region of bosons with overlapping wave functions, characterized by an effective size r . It is often parametrized as an exponential function $\Omega(Qr) = e^{-Qr}$, or with a Gaussian form $\Omega(Qr) = e^{-(Qr)^2}$ (see [4] and references therein). The parameter λ reflects the BEC strength for incoherent boson emission from independent sources, δ accounts for long-range momentum correlations, and C is a normalization factor.

The data used for the present analysis were collected by the CMS experiment in December 2009 from proton-proton collisions at center-of-mass energies of 0.9 and 2.36 TeV. A detailed description of the CMS detector can be found in [5]. The central feature of the CMS apparatus is a superconducting solenoid of 6 m internal diameter, providing a uniform magnetic field of 3.8 T. The inner tracking system is the most relevant detector for the present analysis. It is composed of a pixel detector with three barrel layers at radii between 4.4 and 10.2 cm and a silicon strip tracker with 10 barrel detection layers extending outwards to a radius of 1.1 m. Each system is completed by two end caps, extending the acceptance up to a pseudorapidity $|\eta| = 2.5$. The transverse-momentum (p_T) resolution, for 1 GeV charged particles, is between 0.7% at $\eta = 0$ and 2% at $|\eta| = 2.5$. The events were selected by requiring activity in both beam scintillator counters [6]. A minimum-bias Monte Carlo (MC) sample was generated using PYTHIA (with D6T tune) [7] followed by full detector simulation based on the GEANT4 program [8]. Additional PYTHIA MC samples were generated to simulate BEC effects with both Gaussian and exponential forms of $\Omega(Qr)$.

Charged particles are required to have $p_T > 200$ MeV, which is sufficient for particles emitted from the interaction region to cross all three barrel layers of the pixel detector and ensure good two-track separation. Their pseudorapidity is required to satisfy $|\eta_{\text{track}}| < 2.4$. To ensure high purity of the primary track selection, the trajectories are required to be reconstructed in fits with more than 5 degrees of freedom (dof) and $\chi^2/N_{\text{dof}} < 5.0$. The transverse impact parameter with respect to the collision point is

*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. Further distribution of this work must maintain attribution to the author(s) and the published article's title, journal citation, and DOI.

required to satisfy $|d_{xy}| < 0.15$ cm. The innermost measured point of the track must be less than 20 cm from the beam axis, in order to reduce electrons and positrons from photon conversions in the detector material and secondary particles from the decay of long-lived hadrons (K_S^0 , Λ , etc.). In a total of 270 472 (13 548) events selected at 0.9 (2.36) TeV center-of-mass energy, 2 903 754 (188 140) tracks are accepted by these selection criteria.

All pairs of same-charge particles with Q between 0.02 and 2 GeV are used for the measurement. The lower limit is chosen to avoid cases of tracks that are duplicated or not well separated, while the upper limit extends far enough beyond the signal region to verify a good match between signal and reference samples. A study with simulated data shows that the ratio of the tracking efficiencies of particle pairs in the signal and in the reference samples is independent of Q in the measurement region.

Coulomb interactions between charged particles modify their relative momentum distribution. This effect, which differs for pairs with same charge (repulsion) and opposite charge (attraction), is corrected for by using Gamow factors [9]. As a cross-check, the enhancement in the production of opposite-charge particle pairs with small values of Q is measured in the data and is found to be reproduced by the Gamow factors to within $\pm 15\%$.

Different methods are designed to pair uncorrelated charged particles and to define reference samples used to extract the distribution in the denominator of Eq. (1).

Opposite-charge pairs.—This data set is a natural choice but contains resonances (η , ρ , ...) which are not present in the same-charge combinations.

Opposite-hemisphere pairs.—Tracks are paired after inverting in space the three-momentum of one of the two particles: $(E, \vec{p}) \rightarrow (E, -\vec{p})$; this procedure is applied to pairs with same and opposite charges.

Rotated particles.—Particle pairs are constructed after inverting the x and y components of the three-momentum of one of the two particles: $(p_x, p_y, p_z) \rightarrow (-p_x, -p_y, p_z)$.

Pairs from mixed events.—Particles from different events are combined with the following methods: (i) events are mixed at random, (ii) events with similar charged-particle multiplicity in the same η regions are selected, and (iii) events with an invariant mass of all charged particles similar to that of the signal are used to form the pairs.

As an example, the ratios $R(Q)$ obtained with the opposite-hemisphere, same-charge reference samples are shown in Fig. 1, both for data and for simulation without BEC. A significant excess at small values of Q is observed in the data. Additional details are given in [10].

In order to reduce the bias due to the construction of the reference samples, a double ratio \mathcal{R} is defined:

$$\mathcal{R}(Q) = \frac{R}{R_{MC}} = \left(\frac{dN/dQ}{dN_{ref}/dQ} \right) / \left(\frac{dN_{MC}/dQ}{dN_{MC,ref}/dQ} \right), \quad (3)$$

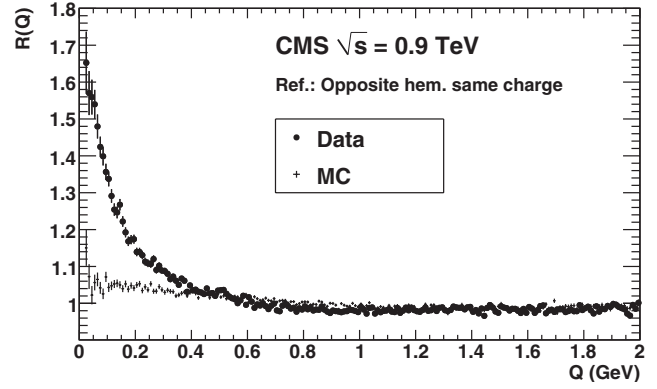


FIG. 1. Ratios $R(Q)$ obtained with the opposite-hemisphere, same-charge reference samples for data (dots) and MC calculations with no BEC effect (crosses).

where the subscripts “MC” and “MC, ref” refer to the corresponding distributions from the MC simulated data generated without BEC effects.

The results of fits of $\mathcal{R}(Q)$ based on the parametrization of Eq. (2) with $\Omega(Qr) = e^{-Qr}$ are given in Table I, both for 0.9 and 2.36 TeV data. In the case of the opposite-charge sample, it is found that the region with $0.6 < Q < 0.9$ GeV, containing a sizable contribution of pairs from $\rho \rightarrow \pi^+ \pi^-$ decays, is not well described by the MC calculations [10]. This region is therefore excluded from the fits with this reference sample and also with the combined sample defined below.

As a cross-check, the dE/dx [11] measurements of particles in the tracker are used to select a sample enriched in $\pi\pi$ pairs, and another sample with one of the particles not consistent with the pion hypothesis. Figure 2 presents the double ratios for these two samples at $\sqrt{s} = 0.9$ TeV, showing that an enhancement at small Q values is observed only in the case of identified $\pi\pi$ pairs.

As none of the definitions of the reference samples is preferable *a priori*, an additional, “combined” double ratio $\mathcal{R}^{\text{comb}}$ is formed, where the data and MC distributions are obtained by summing the Q distributions of the seven corresponding reference samples.

The distributions of $\mathcal{R}^{\text{comb}}$ for 0.9 and 2.36 TeV data are shown in Fig. 3, and the values of the fit parameters are given in Table I. A large correlation is found between the parameters λ and r , as well as between δ and C (correlation coefficients of 0.82 and -0.97 at 0.9 TeV, respectively). The data are described by Eq. (2) with an exponential form for $\Omega(Qr)$, as shown by the solid lines in Fig. 3 and confirmed by the fit probability (p value) in Table I. The fit with a Gaussian form, $\Omega(Qr) = e^{-(Qr)^2}$, which yields $\lambda = 0.32 \pm 0.01$, $r = 0.98 \pm 0.03$ fm, does not correctly describe the $\mathcal{R}(Q)$ distribution, as shown by the dashed lines in Fig. 3 and by a p value of 10^{-21} . Gaussian shape fits also proved to offer a poor description of the data in previous measurements [12–14].

TABLE I. Results of fits to the double ratios $\mathcal{R}(Q)$ for several reference samples, using the parametrization of Eq. (2) with the exponential form, for 0.9 TeV data (left) and 2.36 TeV data (right). Errors are statistical only, and quoted as if independent.

Reference sample	p value (%)	Results of fits to 0.9 TeV data					p value (%)	Results of fits to 2.36 TeV data				
		C	λ	r (fm)	δ (10^{-3} GeV $^{-1}$)			C	λ	r (fm)	δ (10^{-3} GeV $^{-1}$)	
Opposite charge	21.9	0.988 ± 0.003	0.56 ± 0.03	1.46 ± 0.06	-4 ± 2		57	1.004 ± 0.008	0.53 ± 0.08	1.65 ± 0.23	-16 ± 6	
Opposite hemisphere same charge	7.3	0.978 ± 0.003	0.63 ± 0.03	1.50 ± 0.06	11 ± 2		42	0.977 ± 0.006	0.68 ± 0.11	1.95 ± 0.24	15 ± 5	
Opposite hemisphere opposite charge	11.9	0.975 ± 0.003	0.59 ± 0.03	1.42 ± 0.06	13 ± 2		46	0.969 ± 0.005	0.70 ± 0.11	2.02 ± 0.23	24 ± 5	
Rotated	0.02	0.929 ± 0.003	0.68 ± 0.02	1.29 ± 0.04	58 ± 3		42	0.933 ± 0.007	0.61 ± 0.07	1.49 ± 0.15	58 ± 6	
Mixed events (random)	1.9	1.014 ± 0.002	0.62 ± 0.04	1.85 ± 0.09	-20 ± 2		23	1.041 ± 0.005	0.74 ± 0.15	2.78 ± 0.36	-40 ± 4	
Mixed events (same multiplicity)	12.2	0.981 ± 0.002	0.66 ± 0.03	1.72 ± 0.06	11 ± 2		35	0.974 ± 0.005	0.63 ± 0.10	2.01 ± 0.23	20 ± 5	
Mixed events (same mass)	1.7	0.976 ± 0.002	0.60 ± 0.03	1.59 ± 0.06	14 ± 2		73	0.964 ± 0.005	0.73 ± 0.11	2.18 ± 0.23	28 ± 5	
Combined	2.9	0.984 ± 0.002	0.63 ± 0.02	1.59 ± 0.05	8 ± 2		89	0.981 ± 0.005	0.66 ± 0.07	1.99 ± 0.18	13 ± 4	

Although the values of r obtained in the exponential fits cannot be compared directly with results obtained with a Gaussian function, it should be noted for comparison purposes that the first moment of the $\Omega(Qr)$ distribution corresponds to $1/r$ for an exponential shape and to $1/r\sqrt{\pi}$ for a Gaussian form. The first moments measured at the two energies are consistent within errors with most of the previous measurements [2,3]. Alternative functions, as defined in [13,15,16], also describe the data well with similar p values. In particular, for the Lévy parametrization $\Omega(Qr) = e^{-(Qr)^\alpha}$, the fitted values are $\lambda = 0.93 \pm 0.11$, $r = 2.46 \pm 0.38$ fm, and $\alpha = 0.76 \pm 0.06$, with a p value of 12.8%.

The leading source of systematic uncertainty on the measurements arises from the fact that none of the reference samples is expected to give a perfect description of the Q distribution in the absence of BEC, and that none of them can be preferred or discarded *a priori*. The corresponding contribution to the systematic error is computed as the rms spread between the results obtained for the

different samples, i.e., $\pm 7\%$ for λ and $\pm 12\%$ for r . The systematic uncertainty related to the Coulomb corrections is computed by propagating the measured $\pm 15\%$ agreement margin, resulting in $\pm 2.8\%$ variation for λ and $\pm 0.8\%$ for r . The presence of a possible bias introduced by the track reconstruction and selection requirements was studied by comparing the results obtained at the generator and reconstruction levels in the MC simulation that incorporates BEC effects. The differences in the fitted parameter values for the different reference samples are smaller than the statistical errors, and no systematic bias is observed for r . No correction is therefore applied and no additional systematic error is included. For the 2.36 TeV data the same relative systematic uncertainties as for the 0.9 TeV

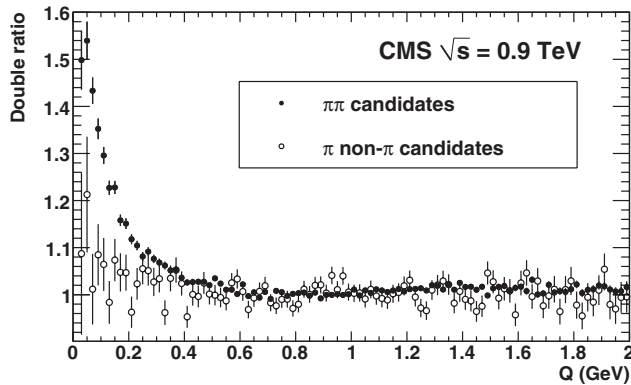


FIG. 2. Double ratios $\mathcal{R}(Q)$ for the 0.9 TeV data, using the opposite-hemisphere, same-charge reference samples for combinations enriched, using a dE/dx measurement, in pion-pion pairs (dots) and in pion-nonpion pairs (open circles), respectively.

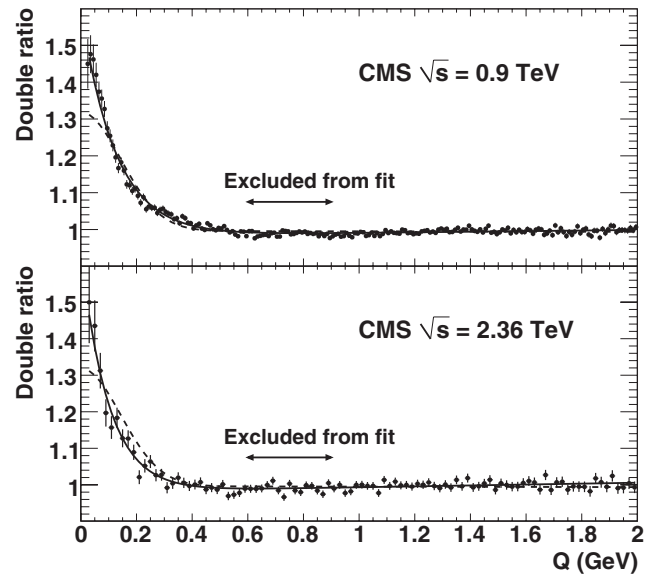


FIG. 3. Fits to the double ratios $\mathcal{R}^{\text{comb}}(Q)$ with exponential (solid lines) and Gaussian (dashed lines) functions, for 0.9 TeV (top panel) and 2.36 TeV (bottom panel) data. The range $0.6 < Q < 0.9$ GeV is excluded from the fits.

TABLE II. Results of the fits to the double ratio $\mathcal{R}^{\text{comb}}$ for the combined reference samples, using the parametrization of Eq. (2) with the exponential form, as a function of the charged-particle multiplicity in the event, for 0.9 TeV data. Errors are statistical only, except for λ and r where statistical (first error) and systematic (second error) uncertainties are given.

Multiplicity range	p value (%)	C	λ	r (fm)	δ (10^{-3} GeV^{-1})
2–9	97	0.90 ± 0.01	$0.89 \pm 0.05 \pm 0.20$	$1.00 \pm 0.07 \pm 0.05$	72 ± 12
10–14	38	0.97 ± 0.01	$0.64 \pm 0.04 \pm 0.09$	$1.28 \pm 0.08 \pm 0.09$	18 ± 5
15–19	27	0.96 ± 0.01	$0.60 \pm 0.04 \pm 0.10$	$1.40 \pm 0.10 \pm 0.05$	28 ± 5
20–29	24	0.99 ± 0.01	$0.59 \pm 0.05 \pm 0.17$	$1.98 \pm 0.14 \pm 0.45$	13 ± 3
30–79	28	1.00 ± 0.01	$0.69 \pm 0.09 \pm 0.17$	$2.76 \pm 0.25 \pm 0.44$	10 ± 3

results are used, in view of the reduced size of the sample and the larger statistical uncertainties of the fit results.

The BEC parameters measured with the combined reference sample are $\lambda = 0.625 \pm 0.021(\text{stat}) \pm 0.046(\text{syst})$ and $r = 1.59 \pm 0.05(\text{stat}) \pm 0.19(\text{syst})$ fm at 0.9 TeV and $\lambda = 0.663 \pm 0.073(\text{stat}) \pm 0.048(\text{syst})$ and $r = 1.99 \pm 0.18(\text{stat}) \pm 0.24(\text{syst})$ fm at 2.36 TeV.

The possible dependence of the BEC signal on various track and event observables has been studied. A significant dependence of r on the charged-particle multiplicity in the event is observed for all reference samples. Here, the only mixed-event reference sample used is the one constructed by combining charged particles from events in the same multiplicity range. The fit parameters for the combined reference sample are given in Table II and shown in Fig. 4 as a function of the track multiplicity for the 0.9 TeV data. As an example, the results for the opposite-hemisphere, same-charge reference sample are also shown in Fig. 4. The systematic errors on λ and r in each multi-

plicity bin are taken as the rms spread of the results obtained with the various reference samples. Because of the limited sample size of the 2.36 TeV data, only two multiplicity bins are considered, one for multiplicities smaller than 20 tracks, the other for multiplicities between 20 and 60 tracks. The values measured for the parameters with the combined reference samples are $\lambda = 0.65 \pm 0.08$ and $\lambda = 0.85 \pm 0.17$, and $r = 1.19 \pm 0.17$ fm and $r = 2.85 \pm 0.38$ fm for these two multiplicity bins, where the errors are statistical only. For comparison, the values obtained for the same multiplicity bins at 0.9 TeV are $\lambda = 0.65 \pm 0.02$ and $\lambda = 0.63 \pm 0.05$, and $r = 1.25 \pm 0.05$ fm and $r = 2.27 \pm 0.12$ fm, respectively. These measurements are consistent within errors. The dependence of r on multiplicity was already observed in previous measurements, as discussed in detail in [3].

In summary, Bose-Einstein correlations have been measured at the LHC by the CMS experiment in pp collisions at 0.9 and 2.36 TeV center-of-mass energies. The main systematic issue affecting BEC measurements was studied through the use of multiple reference samples to extract the signal. We have observed, for all reference samples, that the shape of the signal is not described by a Gaussian function, but rather by exponential or more complex functions. An increase of the effective size of the emission region with charged-particle multiplicity, disputed for a long time [3], is now very clearly observed in pp collisions with a single experiment.

We wish to 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 the following: 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); Academy of Sciences and NICPB (Estonia); Academy of Finland, ME, 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 (Korea); LAS (Lithuania); CINVESTAV, CONACYT, SEP, and UASLP-FAI (Mexico); PAEC (Pakistan); SCSR (Poland); FCT

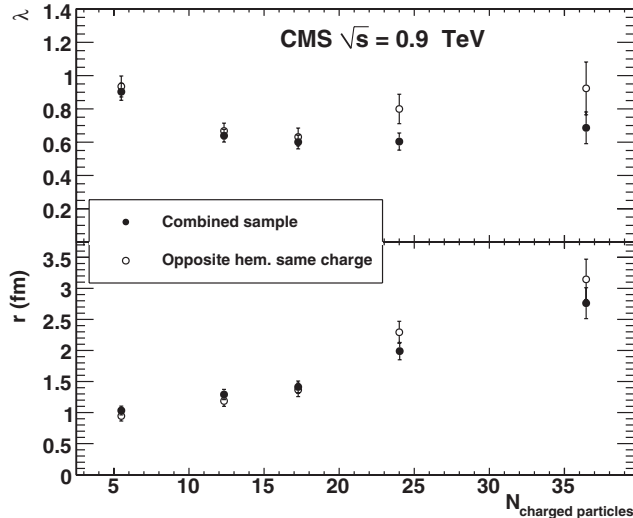


FIG. 4. Values of the λ (top panel) and r (bottom panel) parameters as a function of the charged-particle multiplicity in the event for combined (dots) and opposite-hemisphere, same-charge (open circles) reference samples, at 0.9 TeV. The errors shown are statistical only. The points are placed on the horizontal scale at the average of the multiplicity distribution in the corresponding bin.

(Portugal); JINR (Armenia, Belarus, Georgia, Ukraine, Uzbekistan); MST and MAE (Russia); MSTDS (Serbia); MICINN and CPAN (Spain); Swiss Funding Agencies (Switzerland); NSC (Taipei); TUBITAK and TAEK (Turkey); STFC (U.K.); and DOE and NSF (U.S.).

-
- [1] G. Goldhaber, W.B. Fowler, S. Goldhaber, T.F. Hoang, T.E. Kalogeropoulos, and W.M. Powell, *Phys. Rev. Lett.* **3**, 181 (1959).
- [2] G. Alexander, *Rep. Prog. Phys.* **66**, 481 (2003).
- [3] W. Kittel and E.A. De Wolf, *Soft Multihadron Dynamics* (World Scientific, Singapore, 2005).
- [4] G. Kozlov, O. Utyuzh, G. Wilk, and Z. Wlodarczyk, *Phys. At. Nucl.* **71**, 1502 (2008).
- [5] S. Chatrchyan *et al.* (CMS Collaboration), *JINST* **3**, S08004 (2008).
- [6] V. Khachatryan *et al.* (CMS Collaboration), *J. High Energy Phys.* **02** (2010) 041.
- [7] T. Sjostrand, S. Mrenna, and P. Skands, *J. High Energy Phys.* **05** (2006) 026.
- [8] T. Agostinelli *et al.*, *Nucl. Instrum. Methods Phys. Res., Sect. A* **506**, 250 (2003).
- [9] M. Gyulassy, S.K. Kauffmann, and L.W. Wilson, *Phys. Rev. C* **20**, 2267 (1979).
- [10] CMS Collaboration, CMS PAS Report No. QCD-10-003, 2010.
- [11] CMS Collaboration, CMS PAS Report No. TRK-10-001, 2010.
- [12] C. Adloff *et al.* (H1 Collaboration), *Z. Phys. C* **75**, 437 (1997).
- [13] G.A. Kozlov, L. Lovas, S. Tokar, Y.A. Boudagov, and A.N. Sissakian, [arXiv:hep-ph/0510027v2](https://arxiv.org/abs/hep-ph/0510027v2).
- [14] W.J. Metzger, T. Novak, W. Kittel, and T. Csorgo, *Int. J. Mod. Phys. E* **16**, 3224 (2007).
- [15] M. Biyajima, A. Bartl, T. Mizoguchi, N. Suzuki, and O. Terazawa, *Prog. Theor. Phys.* **84**, 931 (1990).
- [16] M. Biyajima, A. Bartl, T. Mizoguchi, N. Suzuki, and O. Terazawa, *Prog. Theor. Phys.* **88**, 157 (1992).
-

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 M. Friedl,² R. Frühwirth,² V.M. Ghete,² J. Hammer,^{2,b} S. Häsnel,² M. Hoch,² N. Hörmann,² J. Hrubec,² M. Jeitler,² G. Kasieczka,² W. Kiesenhofer,² M. Krammer,² D. Liko,² I. Mikulec,² M. Pernicka,² H. Rohringer,² R. Schöffbeck,² J. Strauss,² A. Taurok,² F. Teischinger,² W. Waltenberger,² G. Walzel,² E. Widl,² C.-E. Wulz,² V. Mossolov,³ N. Shumeiko,³ J. Suarez Gonzalez,³ L. Benucci,⁴ L. Ceard,⁴ E.A. De Wolf,⁴ M. Hashemi,⁴ X. Janssen,⁴ T. Maes,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 V. Adler,⁵ S. Beauceron,⁵ S. Blyweert,⁵ J. D'Hondt,⁵ O. Devroede,⁵ A. Kalogeropoulos,⁵ J. Maes,⁵ M. Maes,⁵ S. Tavernier,⁵ W. Van Doninck,⁵ P. Van Mulders,⁵ I. Villella,⁵ E.C. Chabert,⁶ O. Charaf,⁶ B. Clerbaux,⁶ G. De Lentdecker,⁶ V. Dero,⁶ A.P.R. Gay,⁶ G.H. Hammad,⁶ P.E. Marage,⁶ C. Vander Velde,⁶ P. Vanlaer,⁶ J. Wickens,⁶ S. Costantini,⁷ M. Grunewald,⁷ B. Klein,⁷ A. Marinov,⁷ D. Ryckbosch,⁷ F. Thyssen,⁷ M. Tytgat,⁷ L. Vanelderen,⁷ P. Verwilligen,⁷ S. Walsh,⁷ N. Zaganidis,⁷ S. Basegmez,⁸ G. Bruno,⁸ J. Caudron,⁸ J. De Favereau De Jeneret,⁸ C. Delaere,⁸ P. Demin,⁸ D. Favart,⁸ A. Giammanco,⁸ G. Grégoire,⁸ J. Hollar,⁸ V. Lemaitre,⁸ O. Militaru,⁸ S. Ovyn,⁸ D. Pagano,⁸ A. Pin,⁸ K. Piotrkowski,^{8,b} L. Quertenmont,⁸ N. Schul,⁸ N. Beliy,⁹ T. Caebergs,⁹ E. Daubie,⁹ G.A. Alves,¹⁰ M.E. Pol,¹⁰ M.H.G. Souza,¹⁰ W. Carvalho,¹¹ E.M. Da Costa,¹¹ D. De Jesus Damiao,¹¹ C. De Oliveira Martins,¹¹ S. Fonseca De Souza,¹¹ L. Mundim,¹¹ V. Oguri,¹¹ A. Santoro,¹¹ S.M. Silva Do Amaral,¹¹ A. Sznajder,¹¹ F. Torres Da Silva De Araujo,¹¹ F.A. Dias,¹² M.A.F. Dias,¹² T.R. Fernandez Perez Tomei,¹² E.M. Gregores,¹² F. Marinho,¹² S.F. Novaes,¹² Sandra S. Padula,¹² N. Darmanov,^{13,b} L. Dimitrov,¹³ V. Genchev,^{13,b} P. Iaydjiev,¹³ S. Piperov,¹³ S. Stoykova,¹³ G. Sultanov,¹³ R. Trayanov,¹³ I. Vankov,¹³ M. Dyulendarova,¹⁴ R. Hadjiiska,¹⁴ V. Kozhuharov,¹⁴ L. Litov,¹⁴ E. Marinova,¹⁴ M. Mateev,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 J. Wang,¹⁵ J. Wang,¹⁵ X. Wang,¹⁵ Z. Wang,¹⁵ M. Yang,¹⁵ J. Zang,¹⁵ Z. Zhang,¹⁵ Y. Ban,¹⁶ S. Guo,¹⁶ Z. Hu,¹⁶ Y. Mao,¹⁶ S.J. Qian,¹⁶ H. Teng,¹⁶ B. Zhu,¹⁶ A. Cabrera,¹⁷ C.A. Carrillo Montoya,¹⁷ B. Gomez Moreno,¹⁷ A.A. Ocampo Rios,¹⁷ A.F. Osorio Oliveros,¹⁷ J.C. Sanabria,¹⁷ N. Godinovic,¹⁸ D. Lelas,¹⁸ K. Lelas,¹⁸ R. Plestina,^{18,c} D. Polic,¹⁸ I. Puljak,¹⁸ Z. Antunovic,¹⁹ M. Dzelalija,¹⁹ V. Brigljevic,²⁰ S. Duric,²⁰ K. Kadija,²⁰ S. Morovic,²⁰ A. Attikis,²¹ R. Fereos,²¹ M. Galanti,²¹ J. Mousa,²¹ C. Nicolaou,²¹ A. Papadakis,²¹ F. Ptochos,²¹ P.A. Razis,²¹ H. Rykaczewski,²¹ D. Tsiakkouri,²¹ Z. Zinonos,²¹ M. Mahmoud,²² A. Hektor,²³ M. Kadastik,²³ K. Kannike,²³ M. Müntel,²³ M. Raidal,²³ L. Rebane,²³ V. Azzolini,²⁴ P. Eerola,²⁴ S. Czellar,²⁵ J. Härkönen,²⁵ A. Heikkinen,²⁵ V. Karimäki,²⁵ R. Kinnunen,²⁵ J. Klem,²⁵ M.J. Kortelainen,²⁵ T. Lampén,²⁵ K. Lassila-Perini,²⁵ S. Lehti,²⁵ T. Lindén,²⁵ P. Luukka,²⁵ T. Mäenpää,²⁵ E. Tuominen,²⁵ J. Tuominiemi,²⁵ E. Tuovinen,²⁵ D. Ungaro,²⁵ L. Wendland,²⁵ K. Banzuzi,²⁶ A. Korpela,²⁶ T. Tuuva,²⁶ D. Sillou,²⁷ M. Besancon,²⁸ M. Dejardin,²⁸ D. Denegri,²⁸ J. Descamps,²⁸ B. Fabbro,²⁸ J.L. Faure,²⁸ F. Ferri,²⁸ S. Ganjour,²⁸ F.X. Gentit,²⁸ A. Givernaud,²⁸ P. Gras,²⁸ G. Hamel de Monchenault,²⁸ P. Jarry,²⁸ E. Locci,²⁸ J. Malcles,²⁸ M. Marionneau,²⁸ L. Millischer,²⁸ J. Rander,²⁸ A. Rosowsky,²⁸ D. Rousseau,²⁸ M. Titov,²⁸

- P. Verrecchia,²⁸ S. Baffioni,²⁹ L. Bianchini,²⁹ M. Bluj,^{29,d} C. Broutin,²⁹ P. Busson,²⁹ C. Charlot,²⁹ L. Dobrzynski,²⁹ S. Elgammal,²⁹ R. Granier de Cassagnac,²⁹ M. Haguenaue,²⁹ A. Kalinowski,²⁹ P. Miné,²⁹ P. Paganini,²⁹ D. Sabes,²⁹ Y. Sirois,²⁹ C. Thiebaux,²⁹ A. Zabi,²⁹ J.-L. Agram,³⁰ A. Besson,³⁰ D. Bloch,³⁰ D. Bodin,³⁰ J.-M. Brom,³⁰ M. Cardaci,³⁰ E. Conte,³⁰ F. Drouhin,³⁰ C. Ferro,³⁰ J.-C. Fontaine,³⁰ D. Gelé,³⁰ U. Goerlach,³⁰ S. Greder,³⁰ P. Juillot,³⁰ M. Karim,³⁰ A.-C. Le Bihan,³⁰ Y. Mikami,³⁰ J. Speck,³⁰ P. Van Hove,³⁰ F. Fassi,³¹ D. Mercier,³¹ C. Baty,³² N. Beaupere,³² M. Bedjidian,³² O. Bondu,³² G. Boudoul,³² D. Boumediene,³² H. Brun,³² N. Chanon,³² R. Chierici,³² D. Contardo,³² P. Depasse,³² H. El Mamouni,³² J. Fay,³² S. Gascon,³² B. Ille,³² T. Kurca,³² T. Le Grand,³² M. Lethuillier,³² L. Mirabito,³² S. Perries,³² V. Sordini,³² S. Tosi,³² Y. Tschudi,³² P. Verdier,³² H. Xiao,³² V. Roinishvili,³³ G. Anagnostou,³⁴ M. Edelhoff,³⁴ L. Feld,³⁴ N. Heracleous,³⁴ O. Hindrichs,³⁴ R. Jussen,³⁴ K. Klein,³⁴ J. Merz,³⁴ N. Mohr,³⁴ A. Ostapchuk,³⁴ A. Perieanu,³⁴ F. Raupach,³⁴ J. Sammet,³⁴ S. Schael,³⁴ D. Sprenger,³⁴ H. Weber,³⁴ M. Weber,³⁴ B. Wittmer,³⁴ O. Actis,³⁵ M. Ata,³⁵ W. Bender,³⁵ P. Biallass,³⁵ M. Erdmann,³⁵ J. Frangenheim,³⁵ T. Hebbeker,³⁵ A. Hinzmann,³⁵ K. Hoepfner,³⁵ C. Hof,³⁵ M. Kirsch,³⁵ T. Klimkovich,³⁵ P. Kreuzer,^{35,b} D. Lanske,^{35,a} C. Magass,³⁵ M. Merschmeyer,³⁵ A. Meyer,³⁵ P. Papacz,³⁵ H. Pieta,³⁵ H. Reithler,³⁵ S. A. Schmitz,³⁵ L. Sonnenschein,³⁵ M. Sowa,³⁵ J. Steggemann,³⁵ D. Teyssier,³⁵ C. Zeidler,³⁵ M. Bontenackels,³⁶ M. Davids,³⁶ M. Duda,³⁶ G. Flügge,³⁶ H. Geenen,³⁶ M. Giffels,³⁶ W. Haj Ahmad,³⁶ D. Heydhausen,³⁶ T. Kress,³⁶ Y. Kuessel,³⁶ A. Linn,³⁶ A. Nowack,³⁶ L. Perchalla,³⁶ O. Pooth,³⁶ P. Sauerland,³⁶ A. Stahl,³⁶ M. Thomas,³⁶ D. Tornier,³⁶ M. H. Zoeller,³⁶ M. Aldaya Martin,³⁷ W. Behrenhoff,³⁷ U. Behrens,³⁷ M. Bergholz,³⁷ K. Borras,³⁷ A. Campbell,³⁷ E. Castro,³⁷ D. Dammann,³⁷ G. Eckerlin,³⁷ A. Flossdorf,³⁷ G. Flucke,³⁷ A. Geiser,³⁷ J. Hauk,³⁷ H. Jung,³⁷ M. Kasemann,³⁷ I. Katkov,³⁷ C. Kleinwort,³⁷ H. Kluge,³⁷ A. Knutsson,³⁷ E. Kuznetsova,³⁷ W. Lange,³⁷ W. Lohmann,³⁷ R. Mankel,³⁷ M. Marienfeld,³⁷ I.-A. Melzer-Pellmann,³⁷ A. B. Meyer,³⁷ J. Mnich,³⁷ A. Mussgiller,³⁷ J. Olzem,³⁷ A. Parenti,³⁷ A. Raspereza,³⁷ R. Schmidt,³⁷ T. Schoerner-Sadenius,³⁷ N. Sen,³⁷ M. Stein,³⁷ J. Tomaszewska,³⁷ D. Volyanskyy,³⁷ C. Wissing,³⁷ C. Autermann,³⁸ J. Draeger,³⁸ D. Eckstein,³⁸ H. Enderle,³⁸ U. Gebbert,³⁸ K. Kaschube,³⁸ G. Kaussen,³⁸ R. Klanner,³⁸ B. Mura,³⁸ S. Naumann-Emme,³⁸ F. Nowak,³⁸ C. Sander,³⁸ H. Schettler,³⁸ P. Schleper,³⁸ M. Schröder,³⁸ T. Schum,³⁸ J. Schwandt,³⁸ H. Stadie,³⁸ G. Steinbrück,³⁸ J. Thomsen,³⁸ R. Wolf,³⁸ J. Bauer,³⁹ V. Buege,³⁹ A. Cakir,³⁹ T. Chwalek,³⁹ D. Daeuwel,³⁹ W. De Boer,³⁹ A. Dierlamm,³⁹ G. Dirkes,³⁹ M. Feindt,³⁹ J. Gruschke,³⁹ C. Hackstein,³⁹ F. Hartmann,³⁹ M. Heinrich,³⁹ H. Held,³⁹ K. H. Hoffmann,³⁹ S. Honc,³⁹ T. Kuhr,³⁹ D. Martschei,³⁹ S. Mueller,³⁹ Th. Müller,³⁹ M. Niegel,³⁹ O. Oberst,³⁹ A. Oehler,³⁹ J. Ott,³⁹ T. Peiffer,³⁹ D. Piparo,³⁹ G. Quast,³⁹ K. Rabbertz,³⁹ F. Ratnikov,³⁹ M. Renz,³⁹ A. Sabellek,³⁹ C. Saout,^{39,b} A. Scheurer,³⁹ P. Schieferdecker,³⁹ F.-P. Schilling,³⁹ G. Schott,³⁹ H. J. Simonis,³⁹ F. M. Stober,³⁹ D. Troendle,³⁹ J. Wagner-Kuhr,³⁹ M. Zeise,³⁹ V. Zhukov,^{39,e} E. B. Ziebarth,³⁹ G. Daskalakis,⁴⁰ T. Gerasis,⁴⁰ A. Kyriakis,⁴⁰ D. Loukas,⁴⁰ I. Manolakis,⁴⁰ A. Markou,⁴⁰ C. Markou,⁴⁰ C. Mavrommatis,⁴⁰ E. Petrakou,⁴⁰ L. Gouskos,⁴¹ P. Katsas,⁴¹ A. Panagiotou,^{41,b} I. Evangelou,⁴² P. Kokkas,⁴² N. Manthos,⁴² I. Papadopoulos,⁴² V. Patras,⁴² F. A. Triantis,⁴² A. Aranyi,⁴³ G. Bencze,⁴³ L. Boldizsar,⁴³ G. Debreczeni,⁴³ C. Hajdu,^{43,b} D. Horvath,^{43,f} A. Kapusi,⁴³ K. Krajczar,⁴³ A. Laszlo,⁴³ F. Sikler,⁴³ G. Vesztergombi,⁴³ N. Beni,⁴⁴ J. Molnar,⁴⁴ J. Palinkas,⁴⁴ Z. Szillasi,^{44,b} V. Veszpremi,⁴⁴ P. Raics,⁴⁵ Z. L. Trocsanyi,⁴⁵ B. Ujvari,⁴⁵ S. Bansal,⁴⁶ S. B. Beri,⁴⁶ V. Bhatnagar,⁴⁶ M. Jindal,⁴⁶ M. Kaur,⁴⁶ J. M. Kohli,⁴⁶ M. Z. Mehta,⁴⁶ N. Nishu,⁴⁶ L. K. Saini,⁴⁶ A. Sharma,⁴⁶ R. Sharma,⁴⁶ A. P. Singh,⁴⁶ J. B. Singh,⁴⁶ S. P. Singh,⁴⁶ S. Ahuja,⁴⁷ S. Bhattacharya,^{47,g} S. Chauhan,⁴⁷ B. C. Choudhary,⁴⁷ P. Gupta,⁴⁷ S. Jain,⁴⁷ S. Jain,⁴⁷ A. Kumar,⁴⁷ K. Ranjan,⁴⁷ R. K. Shivpuri,⁴⁷ R. K. Choudhury,⁴⁸ D. Dutta,⁴⁸ S. Kailas,⁴⁸ S. K. Kataria,⁴⁸ A. K. Mohanty,⁴⁸ L. M. Pant,⁴⁸ P. Shukla,⁴⁸ P. Suggisetti,⁴⁸ T. Aziz,⁴⁹ M. Guchait,^{49,h} A. Gurtu,⁴⁹ M. Maity,⁴⁹ D. Majumder,⁴⁹ G. Majumder,⁴⁹ K. Mazumdar,⁴⁹ G. B. Mohanty,⁴⁹ A. Saha,⁴⁹ K. Sudhakar,⁴⁹ N. Wickramage,⁴⁹ S. Banerjee,⁵⁰ S. Dugad,⁵⁰ N. K. Mondal,⁵⁰ H. Arfaei,⁵¹ H. Bakhshiansohi,⁵¹ A. Fahim,⁵¹ A. Jafari,⁵¹ M. Mohammadi Najafabadi,⁵¹ S. Paktinat Mehdiabadi,⁵¹ B. Safarzadeh,⁵¹ M. Zeinali,⁵¹ M. Abbrescia,^{52a,52b} L. Barbone,^{52a} A. Colaleo,^{52a} D. Creanza,^{52a,52c} N. De Filippis,^{52a} M. De Palma,^{52a,52b} A. Dimitrov,^{52a} F. Fedele,^{52a} L. Fiore,^{52a} G. Iaselli,^{52a,52c} L. Lusito,^{52a,52b,b} G. Maggi,^{52a,52c} M. Maggi,^{52a} N. Manna,^{52a,52b} B. Marangelli,^{52a,52b} S. My,^{52a,52c} S. Nuzzo,^{52a,52b} G. A. Pierro,^{52a} A. Pompili,^{52a,52b} G. Pugliese,^{52a,52c} F. Romano,^{52a,52c} G. Roselli,^{52a,52b} G. Selvaggi,^{52a,52b} L. Silvestris,^{52a} R. Trentadue,^{52a} S. Tupputi,^{52a,52b} G. Zito,^{52a} G. Abbiendi,^{53a} A. C. Benvenuti,^{53a} D. Bonacorsi,^{53a} S. Braibant-Giacomelli,^{53a,53b} P. Capiluppi,^{53a,53b} A. Castro,^{53a,53b} F. R. Cavallo,^{53a} G. Codispoti,^{53a,53b} M. Cuffiani,^{53a,53b} A. Fanfani,^{53a,53b} D. Fasanella,^{53a} P. Giacomelli,^{53a} M. Giunta,^{53a,b} C. Grandi,^{53a} S. Marcellini,^{53a} G. Masetti,^{53a,53b} A. Montanari,^{53a} F. L. Navarria,^{53a,53b} F. Odorici,^{53a} A. Perrotta,^{53a} A. M. Rossi,^{53a,53b} T. Rovelli,^{53a,53b} G. Siroli,^{53a,53b} R. Travaglini,^{53a,53b} S. Albergo,^{54a,54b} G. Cappello,^{54a,54b} M. Chiorboli,^{54a,54b}

- S. Costa,^{54a,54b} A. Tricomi,^{54a,54b} C. Tuve,^{54a} G. Barbagli,^{55a} G. Broccolo,^{55a,55b} V. Ciulli,^{55a,55b} C. Civinini,^{55a}
 R. D'Alessandro,^{55a,55b} E. Focardi,^{55a,55b} S. Frosali,^{55a,55b} E. Gallo,^{55a} C. Genta,^{55a,55b} P. Lenzi,^{55a,55b,b}
 M. Meschini,^{55a} S. Paoletti,^{55a} G. Sguazzoni,^{55a} A. Tropiano,^{55a} L. Benussi,⁵⁶ S. Bianco,⁵⁶ S. Colafranceschi,⁵⁶
 F. Fabbri,⁵⁶ D. Piccolo,⁵⁶ P. Fabbriatore,⁵⁷ R. Musenich,⁵⁷ A. Benaglia,^{58a,58b} G. B. Cerati,^{58a,58b,b} F. De Guio,^{58a,58b}
 L. Di Matteo,^{58a,58b} A. Ghezzi,^{58a,58b,b} P. Govoni,^{58a,58b} M. Malberti,^{58a,58b,b} S. Malvezzi,^{58a} A. Martelli,^{58a,58b,c}
 A. Massironi,^{58a,58b} D. Menasce,^{58a} V. Miccio,^{58a,58b} L. Moroni,^{58a} P. Negri,^{58a,58b} M. Paganoni,^{58a,58b} D. Pedrini,^{58a}
 S. Ragazzi,^{58a,58b} N. Redaelli,^{58a} S. Sala,^{58a} R. Salerno,^{58a,58b} T. Tabarelli de Fatis,^{58a,58b} V. Tancini,^{58a,58b}
 S. Taroni,^{58a,58b} S. Buontempo,^{59a} A. Cimmino,^{59a,59b} A. De Cosa,^{59a,59b,b} M. De Gruttola,^{59a,59b,b} F. Fabozzi,^{59a}
 A. O. M. Iorio,^{59a} L. Lista,^{59a} P. Noli,^{59a,59b} P. Paolucci,^{59a} P. Azzi,^{60a} N. Bacchetta,^{60a} P. Bellan,^{60a,60b,b}
 D. Bisello,^{60a,60b} R. Carlin,^{60a,60b} P. Checchia,^{60a} E. Conti,^{60a} M. De Mattia,^{60a,60b} T. Dorigo,^{60a} U. Dosselli,^{60a}
 F. Gasparini,^{60a,60b} U. Gasparini,^{60a,60b} P. Giubilato,^{60a,60b} A. Gresele,^{60a,60c} S. Lacaprara,^{60a} I. Lazzizzera,^{60a,60c}
 M. Margoni,^{60a,60b} M. Mazzucato,^{60a} A. T. Meneguzzo,^{60a,60b} M. Nespolo,^{60a} L. Perrozzi,^{60a} N. Pozzobon,^{60a,60b}
 P. Ronchese,^{60a,60b} F. Simonetto,^{60a,60b} E. Torassa,^{60a} M. Tosi,^{60a,60b} S. Vanini,^{60a,60b} P. Zotto,^{60a,60b}
 G. Zumerle,^{60a,60b} P. Baesso,^{61a,61b} U. Berzano,^{61a} C. Riccardi,^{61a,61b} P. Torre,^{61a,61b} P. Vitulo,^{61a,61b} C. Viviani,^{61a,61b}
 M. Biasini,^{62a,62b} G. M. Bilei,^{62a} B. Caponeri,^{62a,62b} L. Fanò,^{62a} P. Lariccia,^{62a,62b} A. Lucaroni,^{62a,62b}
 G. Mantovani,^{62a,62b} M. Menichelli,^{62a} A. Nappi,^{62a,62b} A. Santocchia,^{62a,62b} L. Servoli,^{62a} M. Valdata,^{62a}
 R. Volpe,^{62a,62b,b} P. Azzurri,^{63a,63c} G. Bagliesi,^{63a} J. Bernardini,^{63a,63b,b} T. Boccali,^{63a} R. Castaldi,^{63a}
 R. T. Dagnolo,^{63a,63c} R. Dell'Orso,^{63a} F. Fiori,^{63a,63b} L. Foà,^{63a,63c} A. Giassi,^{63a} A. Kraan,^{63a} F. Ligabue,^{63a,63c}
 T. Lomtadze,^{63a} L. Martini,^{63a} A. Messineo,^{63a,63b} F. Palla,^{63a} F. Palmonari,^{63a} G. Segneri,^{63a} A. T. Serban,^{63a}
 P. Spagnolo,^{63a,b} R. Tenchini,^{63a,b} G. Tonelli,^{63a,63b,b} A. Venturi,^{63a} P. G. Verdini,^{63a} L. Barone,^{64a,64b}
 F. Cavallari,^{64a,b} D. Del Re,^{64a,64b} E. Di Marco,^{64a,64b} M. Diemoz,^{64a} D. Franci,^{64a,64b} M. Grassi,^{64a} E. Longo,^{64a,64b}
 G. Organtini,^{64a,64b} A. Palma,^{64a,64b} F. Pandolfi,^{64a,64b} R. Paramatti,^{64a,b} S. Rahatlou,^{64a,64b,b} N. Amapane,^{65a,65b}
 R. Arcidiacono,^{65a,65b} S. Argiro,^{65a,65b} M. Arneodo,^{65a,65c} C. Biino,^{65a} C. Botta,^{65a,65b} N. Cartiglia,^{65a}
 R. Castello,^{65a,65b} M. Costa,^{65a,65b} N. Demaria,^{65a} A. Graziano,^{65a,65b} C. Mariotti,^{65a} M. Marone,^{65a,65b} S. Maselli,^{65a}
 E. Migliore,^{65a,65b} G. Mila,^{65a,65b} V. Monaco,^{65a,65b} M. Musich,^{65a,65b} M. M. Obertino,^{65a,65c} N. Pastrone,^{65a}
 M. Pelliccioni,^{65a,65b,b} A. Romero,^{65a,65b} M. Ruspà,^{65a,65c} R. Sacchi,^{65a,65b} A. Solano,^{65a,65b} A. Staiano,^{65a}
 D. Trocino,^{65a,65b} A. Vilela Pereira,^{65a,65b,b} F. Ambroglini,^{66a,66b} S. Belforte,^{66a} F. Cossutti,^{66a} G. Della Ricca,^{66a,66b}
 B. Gobbo,^{66a} D. Montanino,^{66a} A. Penzo,^{66a} S. Chang,⁶⁷ J. Chung,⁶⁷ D. H. Kim,⁶⁷ G. N. Kim,⁶⁷ J. E. Kim,⁶⁷
 D. J. Kong,⁶⁷ H. Park,⁶⁷ D. C. Son,⁶⁷ Zero Kim,⁶⁸ J. Y. Kim,⁶⁸ S. Song,⁶⁸ B. Hong,⁶⁹ H. Kim,⁶⁹ J. H. Kim,⁶⁹
 T. J. Kim,⁶⁹ K. S. Lee,⁶⁹ D. H. Moon,⁶⁹ S. K. Park,⁶⁹ H. B. Rhee,⁶⁹ K. S. Sim,⁶⁹ M. Choi,⁷⁰ S. Kang,⁷⁰ H. Kim,⁷⁰
 C. Park,⁷⁰ I. C. Park,⁷⁰ S. Park,⁷⁰ S. Choi,⁷¹ Y. Choi,⁷¹ Y. K. Choi,⁷¹ J. Goh,⁷¹ J. Lee,⁷¹ S. Lee,⁷¹ H. Seo,⁷¹ I. Yu,⁷¹
 M. Janulis,⁷² D. Martisiute,⁷² P. Petrov,⁷² T. Sabonis,⁷² H. Castilla Valdez,^{73,b} E. De La Cruz Burelo,⁷³
 R. Lopez-Fernandez,⁷³ A. Sánchez Hernández,⁷³ L. M. Villaseñor-Cendejas,⁷³ S. Carrillo Moreno,⁷⁴
 H. A. Salazar Ibarguen,⁷⁵ E. Casimiro Linares,⁷⁶ A. Morelos Pineda,⁷⁶ M. A. Reyes-Santos,⁷⁶ P. Allfrey,⁷⁷
 D. Krofcheck,⁷⁷ J. Tam,⁷⁷ P. H. Butler,⁷⁸ T. Signal,⁷⁸ J. C. Williams,⁷⁸ M. Ahmad,⁷⁹ I. Ahmed,⁷⁹ M. I. Asghar,⁷⁹
 H. R. Hoorani,⁷⁹ W. A. Khan,⁷⁹ T. Khurshid,⁷⁹ S. Qazi,⁷⁹ M. Cwiok,⁸⁰ W. Dominik,⁸⁰ K. Doroba,⁸⁰ M. Konecki,⁸⁰
 J. Krolikowski,⁸⁰ T. Frueboes,⁸¹ R. Gokiel,⁸¹ M. Górski,⁸¹ M. Kazana,⁸¹ K. Nawrocki,⁸¹ M. Szleper,⁸¹
 G. Wrochna,⁸¹ P. Zalewski,⁸¹ N. Almeida,⁸² A. David,⁸² P. Faccioli,⁸² P. G. Ferreira Parracho,⁸² M. Gallinaro,⁸²
 G. Mini,⁸² P. Musella,⁸² A. Nayak,⁸² L. Raposo,⁸² P. Q. Ribeiro,⁸² J. Seixas,⁸² P. Silva,⁸² D. Soares,⁸² J. Varela,^{82,b}
 H. K. Wöhri,⁸² I. Altsybeev,⁸³ I. Belotelov,⁸³ P. Bunin,⁸³ M. Finger,⁸³ M. Finger, Jr.,⁸³ I. Golutvin,⁸³ A. Kameney,⁸³
 V. Karjavin,⁸³ G. Kozlov,⁸³ A. Lanev,⁸³ P. Moisezenz,⁸³ V. Palichik,⁸³ V. Perelygin,⁸³ S. Shmatov,⁸³ V. Smirnov,⁸³
 A. Volodko,⁸³ A. Zarubin,⁸³ N. Bondar,⁸⁴ V. Golovtsov,⁸⁴ Y. Ivanov,⁸⁴ V. Kim,⁸⁴ P. Levchenko,⁸⁴ I. Smirnov,⁸⁴
 V. Sulimov,⁸⁴ L. Uvarov,⁸⁴ S. Vasilov,⁸⁴ A. Vorobyev,⁸⁴ Yu. Andreev,⁸⁵ S. Gninenko,⁸⁵ N. Golubev,⁸⁵ M. Kirsanov,⁸⁵
 N. Krasnikov,⁸⁵ V. Matveev,⁸⁵ A. Pashenkov,⁸⁵ A. Toropin,⁸⁵ S. Troitsky,⁸⁵ V. Epshteyn,⁸⁶ V. Gavrilov,⁸⁶ N. Ilina,⁸⁶
 V. Kaftanov,^{86,a} M. Kossov,^{86,b} A. Krohotin,⁸⁶ S. Kuleshov,⁸⁶ A. Oulianov,⁸⁶ G. Safronov,⁸⁶ S. Semenov,⁸⁶
 I. Shreyber,⁸⁶ V. Stolin,⁸⁶ E. Vlasov,⁸⁶ A. Zhokin,⁸⁶ E. Boos,⁸⁷ M. Dubinin,^{87,i} L. Dudko,⁸⁷ A. Ershov,⁸⁷
 A. Gribushin,⁸⁷ O. Kodolova,⁸⁷ I. Lokhtin,⁸⁷ S. Obraztsov,⁸⁷ S. Petrushanko,⁸⁷ L. Sarycheva,⁸⁷ V. Savrin,⁸⁷
 A. Snigirev,⁸⁷ V. Andreev,⁸⁸ I. Dremin,⁸⁸ M. Kirakosyan,⁸⁸ S. V. Rusakov,⁸⁸ A. Vinogradov,⁸⁸ I. Azhgirey,⁸⁹
 S. Bitioukov,⁸⁹ K. Datsko,⁸⁹ V. Grishin,^{89,b} V. Kachanov,⁸⁹ D. Konstantinov,⁸⁹ V. Krychkin,⁸⁹ V. Petrov,⁸⁹
 R. Ryutin,⁸⁹ S. Slabospitsky,⁸⁹ A. Sobol,⁸⁹ A. Sytine,⁸⁹ L. Tourtchanovitch,⁸⁹ S. Troshin,⁸⁹ N. Tyurin,⁸⁹
 A. Uzunian,⁸⁹ A. Volkov,⁸⁹ P. Adzic,⁹⁰ M. Djordjevic,⁹⁰ D. Krpic,⁹⁰ D. Maletic,⁹⁰ J. Milosevic,⁹⁰ J. Puzovic,⁹⁰

- M. Aguilar-Benitez,⁹¹ J. Alcaraz Maestre,⁹¹ P. Arce,⁹¹ C. Battilana,⁹¹ E. Calvo,⁹¹ M. Cepeda,⁹¹ M. Cerrada,⁹¹ M. Chamizo Llatas,⁹¹ N. Colino,⁹¹ B. De La Cruz,⁹¹ C. Diez Pardos,⁹¹ C. Fernandez Bedoya,⁹¹ J. P. Fernández Ramos,⁹¹ A. Ferrando,⁹¹ J. Flix,⁹¹ M. C. Fouz,⁹¹ P. Garcia-Abia,⁹¹ O. Gonzalez Lopez,⁹¹ S. Goy Lopez,⁹¹ J. M. Hernandez,⁹¹ M. I. Josa,⁹¹ G. Merino,⁹¹ J. Puerta Pelayo,⁹¹ I. Redondo,⁹¹ L. Romero,⁹¹ J. Santaolalla,⁹¹ C. Willmott,⁹¹ C. Albajar,⁹² J. F. de Trocóniz,⁹² J. Cuevas,⁹³ J. Fernandez Menendez,⁹³ I. Gonzalez Caballero,⁹³ L. Lloret Iglesias,⁹³ J. M. Vizan Garcia,⁹³ I. J. Cabrillo,⁹⁴ A. Calderon,⁹⁴ S. H. Chuang,⁹⁴ I. Diaz Merino,⁹⁴ C. Diez Gonzalez,⁹⁴ J. Duarte Campderros,⁹⁴ M. Fernandez,⁹⁴ G. Gomez,⁹⁴ J. Gonzalez Sanchez,⁹⁴ R. Gonzalez Suarez,⁹⁴ C. Jorda,⁹⁴ P. Lobelle Pardo,⁹⁴ A. Lopez Virto,⁹⁴ J. Marco,⁹⁴ R. Marco,⁹⁴ C. Martinez Rivero,⁹⁴ P. Martinez Ruiz del Arbol,⁹⁴ F. Matorras,⁹⁴ T. Rodrigo,⁹⁴ A. Ruiz Jimeno,⁹⁴ L. Scodellaro,⁹⁴ M. Sobron Sanudo,⁹⁴ I. Vila,⁹⁴ R. Vilar Cortabitarte,⁹⁴ D. Abbaneo,⁹⁵ E. Auffray,⁹⁵ P. Baillon,⁹⁵ A. H. Ball,⁹⁵ D. Barney,⁹⁵ F. Beaudette,^{95,c} R. Bellan,⁹⁵ D. Benedetti,⁹⁵ C. Bernet,^{95,c} W. Bialas,⁹⁵ P. Bloch,⁹⁵ A. Bocci,⁹⁵ S. Bolognesi,⁹⁵ H. Breuer,⁹⁵ G. Bruna,⁹⁵ K. Bunkowski,⁹⁵ T. Camporesi,⁹⁵ E. Cano,⁹⁵ A. Cattai,⁹⁵ G. Cerminara,⁹⁵ T. Christiansen,⁹⁵ J. A. Coarasa Perez,⁹⁵ R. Covarelli,⁹⁵ B. Curé,⁹⁵ T. Dahms,⁹⁵ A. De Roeck,⁹⁵ A. Elliott-Peisert,⁹⁵ W. Funk,⁹⁵ A. Gaddi,⁹⁵ S. Gennai,⁹⁵ H. Gerwig,⁹⁵ D. Gigi,⁹⁵ K. Gill,⁹⁵ D. Giordano,⁹⁵ F. Glege,⁹⁵ R. Gomez-Reino Garrido,⁹⁵ S. Gowdy,⁹⁵ L. Guiducci,⁹⁵ M. Hansen,⁹⁵ C. Hartl,⁹⁵ J. Harvey,⁹⁵ B. Hegner,⁹⁵ C. Henderson,⁹⁵ H. F. Hoffmann,⁹⁵ A. Honma,⁹⁵ V. Innocente,⁹⁵ P. Janot,⁹⁵ P. Lecoq,⁹⁵ C. Leonidopoulos,⁹⁵ C. Lourenço,⁹⁵ A. Macpherson,⁹⁵ T. Mäki,⁹⁵ L. Malgeri,⁹⁵ M. Mannelli,⁹⁵ L. Masetti,⁹⁵ G. Mavromanolakis,⁹⁵ F. Meijers,⁹⁵ S. Mersi,⁹⁵ E. Meschi,⁹⁵ R. Moser,⁹⁵ M. U. Mozer,⁹⁵ M. Mulders,⁹⁵ E. Nesvold,^{95,b} L. Orsini,⁹⁵ E. Perez,⁹⁵ A. Petrilli,⁹⁵ A. Pfeiffer,⁹⁵ M. Pierini,⁹⁵ M. Pimiä,⁹⁵ A. Racz,⁹⁵ G. Rolandi,⁹⁵ C. Rovelli,^{95,j} M. Rovere,⁹⁵ H. Sakulin,⁹⁵ C. Schäfer,⁹⁵ C. Schwick,⁹⁵ I. Segoni,⁹⁵ A. Sharma,⁹⁵ P. Siegrist,⁹⁵ M. Simon,⁹⁵ P. Spicas,^{95,k} D. Spiga,⁹⁵ M. Spiropulu,^{95,i} F. Stöckli,⁹⁵ P. Traczyk,⁹⁵ P. Tropea,⁹⁵ A. Tsiros,⁹⁵ G. I. Veres,⁹⁵ P. Vichoudis,⁹⁵ M. Voutilainen,⁹⁵ W. D. Zeuner,⁹⁵ W. Bertl,⁹⁶ K. Deiters,⁹⁶ W. Erdmann,⁹⁶ K. Gabathuler,⁹⁶ R. Horisberger,⁹⁶ Q. Ingram,⁹⁶ H. C. Kaestli,⁹⁶ S. König,⁹⁶ D. Kotlinski,⁹⁶ U. Langenegger,⁹⁶ F. Meier,⁹⁶ D. Renker,⁹⁶ T. Rohe,⁹⁶ J. Sibille,^{96,l} A. Starodumov,^{96,m} L. Caminada,^{97,n} Z. Chen,⁹⁷ S. Cittolin,⁹⁷ G. Dissertori,⁹⁷ M. Dittmar,⁹⁷ J. Eugster,⁹⁷ K. Freudenreich,⁹⁷ C. Grab,⁹⁷ A. Hervé,⁹⁷ W. Hintz,⁹⁷ P. Lecomte,⁹⁷ W. Lustermann,⁹⁷ C. Marchica,^{97,n} P. Meridiani,⁹⁷ P. Milenovic,^{97,o} F. Moortgat,⁹⁷ A. Nardulli,⁹⁷ P. Nef,⁹⁷ F. Nessi-Tedaldi,⁹⁷ L. Pape,⁹⁷ F. Pauss,⁹⁷ T. Punz,⁹⁷ A. Rizzi,⁹⁷ F. J. Ronga,⁹⁷ L. Sala,⁹⁷ A. K. Sanchez,⁹⁷ M.-C. Sawley,⁹⁷ D. Schinzel,⁹⁷ B. Stieger,⁹⁷ L. Tauscher,^{97,a} A. Thea,⁹⁷ K. Theofilatos,⁹⁷ D. Treille,⁹⁷ M. Weber,⁹⁷ L. Wehrli,⁹⁷ J. Weng,⁹⁷ C. Amsler,⁹⁸ V. Chiochia,⁹⁸ S. De Visscher,⁹⁸ M. Ivova Rikova,⁹⁸ B. Millan Mejias,⁹⁸ C. Regenfus,⁹⁸ P. Robmann,⁹⁸ T. Rommelskirchen,⁹⁸ A. Schmidt,⁹⁸ D. Tsirigkas,⁹⁸ L. Wilke,⁹⁸ Y. H. Chang,⁹⁹ K. H. Chen,⁹⁹ W. T. Chen,⁹⁹ A. Go,⁹⁹ C. M. Kuo,⁹⁹ S. W. Li,⁹⁹ W. Lin,⁹⁹ M. H. Liu,⁹⁹ Y. J. Lu,⁹⁹ J. H. Wu,⁹⁹ S. S. Yu,⁹⁹ P. Bartalini,¹⁰⁰ P. Chang,¹⁰⁰ Y. H. Chang,¹⁰⁰ Y. W. Chang,¹⁰⁰ Y. Chao,¹⁰⁰ K. F. Chen,¹⁰⁰ W.-S. Hou,¹⁰⁰ Y. Hsiung,¹⁰⁰ K. Y. Kao,¹⁰⁰ Y. J. Lei,¹⁰⁰ S. W. Lin,¹⁰⁰ R.-S. Lu,¹⁰⁰ J. G. Shiu,¹⁰⁰ Y. M. Tzeng,¹⁰⁰ K. Ueno,¹⁰⁰ C. C. Wang,¹⁰⁰ M. Wang,¹⁰⁰ J. T. Wei,¹⁰⁰ A. Adiguzel,¹⁰¹ A. Ayhan,¹⁰¹ M. N. Bakirci,¹⁰¹ S. Cerci,¹⁰¹ Z. Demir,¹⁰¹ C. Dozen,¹⁰¹ I. Dumanoglu,¹⁰¹ E. Eskut,¹⁰¹ S. Girgis,¹⁰¹ G. Gökbulut,¹⁰¹ Y. Güler,¹⁰¹ E. Garpinar,¹⁰¹ I. Hos,¹⁰¹ E. E. Kangal,¹⁰¹ T. Karaman,¹⁰¹ A. Kayis Topaksu,¹⁰¹ A. Nart,¹⁰¹ G. Öngüt,¹⁰¹ K. Ozdemir,¹⁰¹ S. Ozturk,¹⁰¹ A. Polatöz,¹⁰¹ O. Sahin,¹⁰¹ O. Sengul,¹⁰¹ K. Sogut,¹⁰¹ B. Tali,¹⁰¹ H. Topakli,¹⁰¹ D. Uzun,¹⁰¹ L. N. Vergili,¹⁰¹ M. Vergili,¹⁰¹ C. Zorbilmez,¹⁰¹ I. V. Akin,¹⁰² T. Aliev,¹⁰² S. Bilmis,¹⁰² M. Deniz,¹⁰² H. Gamsizkan,¹⁰² A. M. Guler,¹⁰² K. Ocalan,¹⁰² A. Ozpineci,¹⁰² M. Serin,¹⁰² R. Sever,¹⁰² U. E. Surat,¹⁰² E. Yildirim,¹⁰² M. Zeyrek,¹⁰² M. Deliomeroğlu,¹⁰³ D. Demir,¹⁰³ E. Gülmez,¹⁰³ A. Halu,¹⁰³ B. Isildak,¹⁰³ M. Kaya,¹⁰³ O. Kaya,¹⁰³ M. Özbek,¹⁰³ S. Ozkorucuklu,¹⁰³ N. Sonmez,¹⁰³ L. Levchuk,¹⁰⁴ P. Bell,¹⁰⁵ F. Bostock,¹⁰⁵ J. J. Brooke,¹⁰⁵ T. L. Cheng,¹⁰⁵ D. Cussans,¹⁰⁵ R. Frazier,¹⁰⁵ J. Goldstein,¹⁰⁵ M. Hansen,¹⁰⁵ G. P. Heath,¹⁰⁵ H. F. Heath,¹⁰⁵ C. Hill,¹⁰⁵ B. Huckvale,¹⁰⁵ J. Jackson,¹⁰⁵ L. Kreczko,¹⁰⁵ C. K. Mackay,¹⁰⁵ S. Metson,¹⁰⁵ D. M. Newbold,^{105,p} K. Nirunpong,¹⁰⁵ V. J. Smith,¹⁰⁵ S. Ward,¹⁰⁵ L. Basso,¹⁰⁶ K. W. Bell,¹⁰⁶ A. Belyaev,¹⁰⁶ C. Brew,¹⁰⁶ R. M. Brown,¹⁰⁶ B. Camanzi,¹⁰⁶ D. J. A. Cockerill,¹⁰⁶ J. A. Coughlan,¹⁰⁶ K. Harder,¹⁰⁶ S. Harper,¹⁰⁶ B. W. Kennedy,¹⁰⁶ E. Olaiya,¹⁰⁶ D. Petyt,¹⁰⁶ B. C. Radburn-Smith,¹⁰⁶ C. H. Shepherd-Themistocleous,¹⁰⁶ I. R. Tomalin,¹⁰⁶ W. J. Womersley,¹⁰⁶ S. D. Worm,¹⁰⁶ R. Bainbridge,¹⁰⁷ G. Ball,¹⁰⁷ J. Ballin,¹⁰⁷ R. Beuselinck,¹⁰⁷ O. Buchmuller,¹⁰⁷ D. Colling,¹⁰⁷ N. Cripps,¹⁰⁷ M. Cutajar,¹⁰⁷ G. Davies,¹⁰⁷ M. Della Negra,¹⁰⁷ C. Foudas,¹⁰⁷ J. Fulcher,¹⁰⁷ D. Futyan,¹⁰⁷ A. Guneratne Bryer,¹⁰⁷ G. Hall,¹⁰⁷ Z. Hatherell,¹⁰⁷ J. Hays,¹⁰⁷ G. Iles,¹⁰⁷ G. Karapostoli,¹⁰⁷ L. Lyons,¹⁰⁷ A.-M. Magnan,¹⁰⁷ J. Marrouche,¹⁰⁷ R. Nandi,¹⁰⁷ J. Nash,¹⁰⁷ A. Nikitenko,^{107,m} A. Papageorgiou,¹⁰⁷ M. Pesaresi,¹⁰⁷ K. Petridis,¹⁰⁷ M. Pioppi,^{107,q} D. M. Raymond,¹⁰⁷ N. Rompotis,¹⁰⁷ A. Rose,¹⁰⁷ M. J. Ryan,¹⁰⁷ C. Seez,¹⁰⁷ P. Sharp,¹⁰⁷ A. Sparrow,¹⁰⁷ M. Stoye,¹⁰⁷ A. Tapper,¹⁰⁷

S. Tournier,¹⁰⁷ M. Vazquez Acosta,¹⁰⁷ T. Virdee,^{107,b} S. Wakefield,¹⁰⁷ D. Wardrope,¹⁰⁷ T. Whyntie,¹⁰⁷ M. Barrett,¹⁰⁸ M. Chadwick,¹⁰⁸ J.E. Cole,¹⁰⁸ P.R. Hobson,¹⁰⁸ A. Khan,¹⁰⁸ P. Kyberd,¹⁰⁸ D. Leslie,¹⁰⁸ I.D. Reid,¹⁰⁸ L. Teodorescu,¹⁰⁸ T. Bose,¹⁰⁹ A. Clough,¹⁰⁹ A. Heister,¹⁰⁹ J. St. John,¹⁰⁹ P. Lawson,¹⁰⁹ D. Lazic,¹⁰⁹ J. Rohlf,¹⁰⁹ L. Sulak,¹⁰⁹ J. Andrea,¹¹⁰ A. Avetisyan,¹¹⁰ S. Bhattacharya,¹¹⁰ J.P. Chou,¹¹⁰ D. Cutts,¹¹⁰ S. Esen,¹¹⁰ U. Heintz,¹¹⁰ S. Jabeen,¹¹⁰ G. Kukartsev,¹¹⁰ G. Landsberg,¹¹⁰ M. Narain,¹¹⁰ D. Nguyen,¹¹⁰ T. Speer,¹¹⁰ K.V. Tsang,¹¹⁰ M.A. Borgia,¹¹¹ R. Breedon,¹¹¹ M. Calderon De La Barca Sanchez,¹¹¹ D. Cebra,¹¹¹ M. Chertok,¹¹¹ J. Conway,¹¹¹ P.T. Cox,¹¹¹ J. Dolen,¹¹¹ R. Erbacher,¹¹¹ E. Friis,¹¹¹ W. Ko,¹¹¹ A. Kopecky,¹¹¹ R. Lander,¹¹¹ H. Liu,¹¹¹ S. Maruyama,¹¹¹ T. Miceli,¹¹¹ M. Nikolic,¹¹¹ D. Pellett,¹¹¹ J. Robles,¹¹¹ T. Schwarz,¹¹¹ M. Searle,¹¹¹ J. Smith,¹¹¹ M. Squires,¹¹¹ M. Tripathi,¹¹¹ R. Vasquez Sierra,¹¹¹ C. Veelken,¹¹¹ V. Andreev,¹¹² K. Arisaka,¹¹² D. Cline,¹¹² R. Cousins,¹¹² A. Deisher,¹¹² S. Erhan,^{112,b} C. Farrell,¹¹² M. Felcini,¹¹² J. Hauser,¹¹² M. Ignatenko,¹¹² C. Jarvis,¹¹² C. Plager,¹¹² G. Rakness,¹¹² P. Schlein,^{112,a} J. Tucker,¹¹² V. Valuev,¹¹² R. Wallny,¹¹² J. Babb,¹¹³ R. Clare,¹¹³ J. Ellison,¹¹³ J.W. Gary,¹¹³ G. Hanson,¹¹³ G.Y. Jeng,¹¹³ S.C. Kao,¹¹³ F. Liu,¹¹³ H. Liu,¹¹³ A. Luthra,¹¹³ H. Nguyen,¹¹³ G. Pasztor,^{113,r} A. Satpathy,¹¹³ B.C. Shen,^{113,a} R. Stringer,¹¹³ J. Sturdy,¹¹³ S. Sumowidagdo,¹¹³ R. Wilken,¹¹³ S. Wimpenny,¹¹³ W. Andrews,¹¹⁴ J.G. Branson,¹¹⁴ E. Dusenberre,¹¹⁴ D. Evans,¹¹⁴ F. Golf,¹¹⁴ A. Holzner,¹¹⁴ R. Kelley,¹¹⁴ M. Lebourgeois,¹¹⁴ J. Letts,¹¹⁴ B. Mangano,¹¹⁴ J. Muelmenstaedt,¹¹⁴ S. Padhi,¹¹⁴ C. Palmer,¹¹⁴ G. Petrucciani,¹¹⁴ H. Pi,¹¹⁴ M. Pieri,¹¹⁴ R. Ranieri,¹¹⁴ M. Sani,¹¹⁴ V. Sharma,^{114,b} S. Simon,¹¹⁴ Y. Tu,¹¹⁴ A. Vartak,¹¹⁴ F. Würthwein,¹¹⁴ A. Yagil,¹¹⁴ D. Barge,¹¹⁵ M. Blume,¹¹⁵ C. Campagnari,¹¹⁵ M. D'Alfonso,¹¹⁵ T. Danielson,¹¹⁵ J. Garbersen,¹¹⁵ J. Incandela,¹¹⁵ C. Justus,¹¹⁵ P. Kalavase,¹¹⁵ S.A. Koay,¹¹⁵ D. Kovalskyi,¹¹⁵ V. Krutelyov,¹¹⁵ J. Lamb,¹¹⁵ S. Lowette,¹¹⁵ V. Pavlunin,¹¹⁵ F. Rebassoo,¹¹⁵ J. Ribnik,¹¹⁵ J. Richman,¹¹⁵ R. Rossin,¹¹⁵ D. Stuart,¹¹⁵ W. To,¹¹⁵ J.R. Vlimant,¹¹⁵ M. Witherell,¹¹⁵ A. Bornheim,¹¹⁶ J. Bunn,¹¹⁶ M. Gataullin,¹¹⁶ D. Kcira,¹¹⁶ V. Litvine,¹¹⁶ Y. Ma,¹¹⁶ H.B. Newman,¹¹⁶ C. Rogan,¹¹⁶ K. Shin,¹¹⁶ V. Timciuc,¹¹⁶ J. Veverka,¹¹⁶ R. Wilkinson,¹¹⁶ Y. Yang,¹¹⁶ R.Y. Zhu,¹¹⁶ B. Akgun,¹¹⁷ R. Carroll,¹¹⁷ T. Ferguson,¹¹⁷ D.W. Jang,¹¹⁷ S.Y. Jun,¹¹⁷ M. Paulini,¹¹⁷ J. Russ,¹¹⁷ N. Terentyev,¹¹⁷ H. Vogel,¹¹⁷ I. Vorobiev,¹¹⁷ J.P. Cumalat,¹¹⁸ M.E. Dinardo,¹¹⁸ B.R. Drell,¹¹⁸ W.T. Ford,¹¹⁸ B. Heyburn,¹¹⁸ E. Luigi Lopez,¹¹⁸ U. Nauenberg,¹¹⁸ J.G. Smith,¹¹⁸ K. Stenson,¹¹⁸ K.A. Ulmer,¹¹⁸ S.R. Wagner,¹¹⁸ S.L. Zang,¹¹⁸ L. Agostino,¹¹⁹ J. Alexander,¹¹⁹ F. Blekman,¹¹⁹ A. Chatterjee,¹¹⁹ S. Das,¹¹⁹ N. Eggert,¹¹⁹ L.J. Fields,¹¹⁹ L.K. Gibbons,¹¹⁹ B. Heltsley,¹¹⁹ W. Hopkins,¹¹⁹ A. Khukhunaishvili,¹¹⁹ B. Kreis,¹¹⁹ V. Kuznetsov,¹¹⁹ G. Nicolas Kaufman,¹¹⁹ J.R. Patterson,¹¹⁹ D. Puigh,¹¹⁹ D. Riley,¹¹⁹ A. Ryd,¹¹⁹ X. Shi,¹¹⁹ W. Sun,¹¹⁹ W.D. Teo,¹¹⁹ J. Thom,¹¹⁹ J. Thompson,¹¹⁹ J. Vaughan,¹¹⁹ Y. Weng,¹¹⁹ P. Wittich,¹¹⁹ A. Biselli,¹²⁰ G. Cirino,¹²⁰ D. Winn,¹²⁰ S. Abdullin,¹²¹ M. Albrow,¹²¹ J. Anderson,¹²¹ G. Apollinari,¹²¹ M. Atac,¹²¹ J.A. Bakken,¹²¹ S. Banerjee,¹²¹ L.A.T. Bauerdick,¹²¹ A. Beretvas,¹²¹ J. Berryhill,¹²¹ P.C. Bhat,¹²¹ I. Bloch,¹²¹ F. Borchering,¹²¹ K. Burkett,¹²¹ J.N. Butler,¹²¹ V. Chetluru,¹²¹ H.W.K. Cheung,¹²¹ F. Chlebana,¹²¹ S. Cihangir,¹²¹ M. Demarteau,¹²¹ D.P. Eartly,¹²¹ V.D. Elvira,¹²¹ I. Fisk,¹²¹ J. Freeman,¹²¹ Y. Gao,¹²¹ E. Gottschalk,¹²¹ D. Green,¹²¹ O. Gutsche,¹²¹ A. Hahn,¹²¹ J. Hanlon,¹²¹ R.M. Harris,¹²¹ E. James,¹²¹ H. Jensen,¹²¹ M. Johnson,¹²¹ U. Joshi,¹²¹ R. Khatiwada,¹²¹ B. Kilminster,¹²¹ B. Klima,¹²¹ K. Kousouris,¹²¹ S. Kunori,¹²¹ S. Kwan,¹²¹ P. Limon,¹²¹ R. Lipton,¹²¹ J. Lykken,¹²¹ K. Maeshima,¹²¹ J.M. Marraffino,¹²¹ D. Mason,¹²¹ P. McBride,¹²¹ T. McCauley,¹²¹ T. Miao,¹²¹ K. Mishra,¹²¹ S. Mrenna,¹²¹ Y. Musienko,^{121,s} C. Newman-Holmes,¹²¹ V. O'Dell,¹²¹ S. Popescu,¹²¹ R. Pordes,¹²¹ O. Prokofyev,¹²¹ N. Saoulidou,¹²¹ E. Sexton-Kennedy,¹²¹ S. Sharma,¹²¹ R.P. Smith,^{121,a} A. Soha,¹²¹ W.J. Spalding,¹²¹ L. Spiegel,¹²¹ P. Tan,¹²¹ L. Taylor,¹²¹ S. Tkaczyk,¹²¹ L. Uplegger,¹²¹ E.W. Vaandering,¹²¹ R. Vidal,¹²¹ J. Whitmore,¹²¹ W. Wu,¹²¹ F. Yumiceva,¹²¹ J.C. Yun,¹²¹ D. Acosta,¹²² P. Avery,¹²² D. Bourilkov,¹²² M. Chen,¹²² G.P. Di Giovanni,¹²² D. Dobur,¹²² A. Drozdetskiy,¹²² R.D. Field,¹²² Y. Fu,¹²² I.K. Furic,¹²² J. Gartner,¹²² B. Kim,¹²² S. Klimenko,¹²² J. Konigsberg,¹²² A. Korytov,¹²² K. Kotov,¹²² A. Kropivnitskaya,¹²² T. Kypreos,¹²² K. Matchev,¹²² G. Mitselmakher,¹²² Y. Pakhotin,¹²² J. Piedra Gomez,¹²² C. Prescott,¹²² R. Remington,¹²² M. Schmitt,¹²² B. Scurlock,¹²² P. Sellers,¹²² D. Wang,¹²² J. Yelton,¹²² M. Zakaria,¹²² C. Ceron,¹²³ V. Gaultney,¹²³ L. Kramer,¹²³ L.M. Lebolo,¹²³ S. Linn,¹²³ P. Markowitz,¹²³ G. Martinez,¹²³ D. Mesa,¹²³ J.L. Rodriguez,¹²³ T. Adams,¹²⁴ A. Askew,¹²⁴ J. Chen,¹²⁴ B. Diamond,¹²⁴ S.V. Gleyzer,¹²⁴ J. Haas,¹²⁴ S. Hagopian,¹²⁴ V. Hagopian,¹²⁴ M. Jenkins,¹²⁴ K.F. Johnson,¹²⁴ H. Prosper,¹²⁴ S. Sekmen,¹²⁴ V. Veeraraghavan,¹²⁴ M.M. Baarmand,¹²⁵ S. Guragain,¹²⁵ M. Hohlmann,¹²⁵ H. Kalakhety,¹²⁵ H. Mermerkaya,¹²⁵ R. Ralich,¹²⁵ I. Vodopiyarov,¹²⁵ M.R. Adams,¹²⁶ I.M. Anghel,¹²⁶ L. Apanasevich,¹²⁶ V.E. Bazterra,¹²⁶ R.R. Betts,¹²⁶ J. Callner,¹²⁶ R. Cavanaugh,¹²⁶ C. Dragoiu,¹²⁶ E.J. Garcia-Solis,¹²⁶ C.E. Gerber,¹²⁶ D.J. Hofman,¹²⁶ S. Khalatian,¹²⁶ F. Lacroix,¹²⁶ E. Shabalina,¹²⁶ A. Smoron,¹²⁶ D. Strom,¹²⁶ N. Varelas,¹²⁶ U. Akgun,¹²⁷ E.A. Albayrak,¹²⁷ B. Bilki,¹²⁷ K. Cankocak,¹²⁷ W. Clarida,¹²⁷ F. Duru,¹²⁷ C.K. Lae,¹²⁷ E. McCliment,¹²⁷

J.-P. Merlo,¹²⁷ A. Mestvirishvili,¹²⁷ A. Moeller,¹²⁷ J. Nachtman,¹²⁷ C.R. Newsom,¹²⁷ E. Norbeck,¹²⁷ J. Olson,¹²⁷ Y. Onel,¹²⁷ F. Ozok,¹²⁷ S. Sen,¹²⁷ J. Wetzel,¹²⁷ T. Yetkin,¹²⁷ K. Yi,¹²⁷ B.A. Barnett,¹²⁸ B. Blumenfeld,¹²⁸ A. Bonato,¹²⁸ C. Eskew,¹²⁸ D. Fehling,¹²⁸ G. Giurgiu,¹²⁸ A.V. Gritsan,¹²⁸ Z.J. Guo,¹²⁸ G. Hu,¹²⁸ P. Maksimovic,¹²⁸ S. Rappoccio,¹²⁸ M. Swartz,¹²⁸ N.V. Tran,¹²⁸ A. Whitbeck,¹²⁸ P. Baringer,¹²⁹ A. Bean,¹²⁹ G. Benelli,¹²⁹ O. Grachov,¹²⁹ M. Murray,¹²⁹ V. Radicci,¹²⁹ S. Sanders,¹²⁹ J.S. Wood,¹²⁹ V. Zhukova,¹²⁹ D. Bandurin,¹³⁰ T. Bolton,¹³⁰ I. Chakaberia,¹³⁰ A. Ivanov,¹³⁰ K. Kaadze,¹³⁰ Y. Maravin,¹³⁰ S. Shrestha,¹³⁰ I. Svintradze,¹³⁰ Z. Wan,¹³⁰ J. Gronberg,¹³¹ D. Lange,¹³¹ D. Wright,¹³¹ D. Baden,¹³² M. Boutemour,¹³² S.C. Eno,¹³² D. Ferencek,¹³² N.J. Hadley,¹³² R.G. Kellogg,¹³² M. Kirn,¹³² A. Mignerey,¹³² K. Rossato,¹³² P. Rumerio,¹³² F. Santanastasio,¹³² A. Skuja,¹³² J. Temple,¹³² M.B. Tonjes,¹³² S.C. Tonwar,¹³² E. Twedt,¹³² B. Alver,¹³³ G. Bauer,¹³³ J. Bendavid,¹³³ W. Busza,¹³³ E. Butz,¹³³ I.A. Cali,¹³³ M. Chan,¹³³ D. D'Enterria,¹³³ P. Everaerts,¹³³ G. Gomez Ceballos,¹³³ M. Goncharov,¹³³ K.A. Hahn,¹³³ P. Harris,¹³³ Y. Kim,¹³³ M. Klute,¹³³ Y.-J. Lee,¹³³ W. Li,¹³³ C. Loizides,¹³³ P.D. Luckey,¹³³ T. Ma,¹³³ S. Nahn,¹³³ C. Paus,¹³³ C. Roland,¹³³ G. Roland,¹³³ M. Rudolph,¹³³ G.S.F. Stephans,¹³³ K. Sumorok,¹³³ K. Sung,¹³³ E.A. Wenger,¹³³ B. Wyslouch,¹³³ S. Xie,¹³³ Y. Yilmaz,¹³³ A.S. Yoon,¹³³ M. Zanetti,¹³³ P. Cole,¹³⁴ S.I. Cooper,¹³⁴ P. Cushman,¹³⁴ B. Dahmes,¹³⁴ A. De Benedetti,¹³⁴ P.R. Duderod,¹³⁴ G. Franzoni,¹³⁴ J. Haupt,¹³⁴ K. Klapoetke,¹³⁴ Y. Kubota,¹³⁴ J. Mans,¹³⁴ V. Rekovic,¹³⁴ R. Rusack,¹³⁴ M. Sasseville,¹³⁴ A. Singovsky,¹³⁴ L.M. Cremaldi,¹³⁵ R. Godang,¹³⁵ R. Kroeger,¹³⁵ L. Perera,¹³⁵ R. Rahmat,¹³⁵ D.A. Sanders,¹³⁵ P. Sonnek,¹³⁵ D. Summers,¹³⁵ K. Bloom,¹³⁶ S. Bose,¹³⁶ J. Butt,¹³⁶ D.R. Claes,¹³⁶ A. Dominguez,¹³⁶ M. Eads,¹³⁶ J. Keller,¹³⁶ T. Kelly,¹³⁶ I. Kravchenko,¹³⁶ J. Lazo-Flores,¹³⁶ C. Lundstedt,¹³⁶ H. Malbouisson,¹³⁶ S. Malik,¹³⁶ G.R. Snow,¹³⁶ U. Baur,¹³⁷ I. Iashvili,¹³⁷ A. Kharchilava,¹³⁷ A. Kumar,¹³⁷ K. Smith,¹³⁷ M. Strang,¹³⁷ J. Zennaro,¹³⁷ G. Alverson,¹³⁸ E. Barberis,¹³⁸ D. Baumgartel,¹³⁸ O. Boeriu,¹³⁸ S. Reucroft,¹³⁸ J. Swain,¹³⁸ D. Wood,¹³⁸ J. Zhang,¹³⁸ A. Anastassov,¹³⁹ A. Kubik,¹³⁹ R.A. Ofierzynski,¹³⁹ A. Pozdnyakov,¹³⁹ M. Schmitt,¹³⁹ S. Stoynev,¹³⁹ M. Velasco,¹³⁹ S. Won,¹³⁹ L. Antonelli,¹⁴⁰ D. Berry,¹⁴⁰ M. Hildreth,¹⁴⁰ C. Jessop,¹⁴⁰ D.J. Karmgard,¹⁴⁰ J. Kolb,¹⁴⁰ T. Kolberg,¹⁴⁰ K. Lannon,¹⁴⁰ S. Lynch,¹⁴⁰ N. Marinelli,¹⁴⁰ D.M. Morse,¹⁴⁰ R. Ruchti,¹⁴⁰ J. Slaunwhite,¹⁴⁰ N. Valls,¹⁴⁰ J. Warchol,¹⁴⁰ M. Wayne,¹⁴⁰ J. Ziegler,¹⁴⁰ B. Bylsma,¹⁴¹ L.S. Durkin,¹⁴¹ J. Gu,¹⁴¹ P. Killewald,¹⁴¹ T.Y. Ling,¹⁴¹ G. Williams,¹⁴¹ N. Adam,¹⁴² E. Berry,¹⁴² P. Elmer,¹⁴² D. Gerbaudo,¹⁴² V. Halyo,¹⁴² A. Hunt,¹⁴² J. Jones,¹⁴² E. Laird,¹⁴² D. Lopes Pegna,¹⁴² D. Marlow,¹⁴² T. Medvedeva,¹⁴² M. Mooney,¹⁴² J. Olsen,¹⁴² P. Piroué,¹⁴² D. Stickland,¹⁴² C. Tully,¹⁴² J.S. Werner,¹⁴² A. Zuranski,¹⁴² J.G. Acosta,¹⁴³ X.T. Huang,¹⁴³ A. Lopez,¹⁴³ H. Mendez,¹⁴³ S. Oliveros,¹⁴³ J.E. Ramirez Vargas,¹⁴³ A. Zatserklyaniy,¹⁴³ E. Alagoz,¹⁴⁴ V.E. Barnes,¹⁴⁴ G. Bolla,¹⁴⁴ L. Borrello,¹⁴⁴ D. Bortoletto,¹⁴⁴ A. Everett,¹⁴⁴ A.F. Garfinkel,¹⁴⁴ Z. Gecse,¹⁴⁴ L. Gutay,¹⁴⁴ M. Jones,¹⁴⁴ O. Koybasi,¹⁴⁴ A.T. Laasanen,¹⁴⁴ N. Leonardo,¹⁴⁴ C. Liu,¹⁴⁴ V. Maroussov,¹⁴⁴ P. Merkel,¹⁴⁴ D.H. Miller,¹⁴⁴ N. Neumeister,¹⁴⁴ K. Potamianos,¹⁴⁴ I. Shipsey,¹⁴⁴ D. Silvers,¹⁴⁴ H.D. Yoo,¹⁴⁴ J. Zablocki,¹⁴⁴ Y. Zheng,¹⁴⁴ P. Jindal,¹⁴⁵ N. Parashar,¹⁴⁵ V. Cuplov,¹⁴⁶ K.M. Ecklund,¹⁴⁶ F.J.M. Geurts,¹⁴⁶ J.H. Liu,¹⁴⁶ J. Morales,¹⁴⁶ B.P. Padley,¹⁴⁶ R. Redjimi,¹⁴⁶ J. Roberts,¹⁴⁶ B. Betchart,¹⁴⁷ A. Bodek,¹⁴⁷ Y.S. Chung,¹⁴⁷ P. de Barbaro,¹⁴⁷ R. Demina,¹⁴⁷ H. Flacher,¹⁴⁷ A. Garcia-Bellido,¹⁴⁷ Y. Gotra,¹⁴⁷ J. Han,¹⁴⁷ A. Harel,¹⁴⁷ D.C. Miner,¹⁴⁷ D. Orbaker,¹⁴⁷ G. Petrillo,¹⁴⁷ D. Vishnevskiy,¹⁴⁷ M. Zielinski,¹⁴⁷ A. Bhatti,¹⁴⁸ L. Demortier,¹⁴⁸ K. Goulanos,¹⁴⁸ K. Hatakeyama,¹⁴⁸ G. Lungu,¹⁴⁸ C. Mesropian,¹⁴⁸ M. Yan,¹⁴⁸ O. Atramentov,¹⁴⁹ Y. Gershtein,¹⁴⁹ R. Gray,¹⁴⁹ E. Halkiadakis,¹⁴⁹ D. Hidas,¹⁴⁹ D. Hits,¹⁴⁹ A. Lath,¹⁴⁹ K. Rose,¹⁴⁹ S. Schnetzer,¹⁴⁹ S. Somalwar,¹⁴⁹ R. Stone,¹⁴⁹ S. Thomas,¹⁴⁹ G. Cerizza,¹⁵⁰ M. Hollingsworth,¹⁵⁰ S. Spanier,¹⁵⁰ Z.C. Yang,¹⁵⁰ A. York,¹⁵⁰ J. Asaadi,¹⁵¹ R. Eusebi,¹⁵¹ J. Gilmore,¹⁵¹ A. Gurrola,¹⁵¹ T. Kamon,¹⁵¹ V. Khotilovich,¹⁵¹ R. Montalvo,¹⁵¹ C.N. Nguyen,¹⁵¹ J. Pivarski,¹⁵¹ A. Safonov,¹⁵¹ S. Sengupta,¹⁵¹ D. Toback,¹⁵¹ M. Weinberger,¹⁵¹ N. Akchurin,¹⁵² C. Bardak,¹⁵² J. Damgov,¹⁵² C. Jeong,¹⁵² K. Kovitanggoon,¹⁵² S.W. Lee,¹⁵² P. Mane,¹⁵² Y. Roh,¹⁵² A. Sill,¹⁵² I. Volobouev,¹⁵² R. Wigmans,¹⁵² E. Yazgan,¹⁵² E. Appelt,¹⁵³ E. Brownson,¹⁵³ D. Engh,¹⁵³ C. Florez,¹⁵³ W. Gabella,¹⁵³ W. Johns,¹⁵³ P. Kurt,¹⁵³ C. Maguire,¹⁵³ A. Melo,¹⁵³ P. Sheldon,¹⁵³ J. Velkovska,¹⁵³ M.W. Arenton,¹⁵⁴ M. Balazs,¹⁵⁴ M. Buehler,¹⁵⁴ S. Conetti,¹⁵⁴ B. Cox,¹⁵⁴ R. Hirosky,¹⁵⁴ A. Ledovskoy,¹⁵⁴ C. Neu,¹⁵⁴ R. Yohay,¹⁵⁴ S. Gollapinni,¹⁵⁵ K. Gunthoti,¹⁵⁵ R. Harr,¹⁵⁵ P.E. Karchin,¹⁵⁵ M. Mattson,¹⁵⁵ C. Milstène,¹⁵⁵ A. Sakharov,¹⁵⁵ M. Anderson,¹⁵⁶ M. Bachtis,¹⁵⁶ J.N. Bellinger,¹⁵⁶ D. Carlsmith,¹⁵⁶ S. Dasu,¹⁵⁶ S. Dutta,¹⁵⁶ J. Efron,¹⁵⁶ L. Gray,¹⁵⁶ K.S. Grogg,¹⁵⁶ M. Grothe,¹⁵⁶ M. Herndon,¹⁵⁶ P. Klabbers,¹⁵⁶ J. Klukas,¹⁵⁶ A. Lanaro,¹⁵⁶ C. Lazaridis,¹⁵⁶ J. Leonard,¹⁵⁶ D. Lomidze,¹⁵⁶ R. Loveless,¹⁵⁶ A. Mohapatra,¹⁵⁶ G. Polese,¹⁵⁶ D. Reeder,¹⁵⁶ A. Savin,¹⁵⁶ W.H. Smith,¹⁵⁶ J. Swanson,¹⁵⁶ and M. Weinberg¹⁵⁶

(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 Física Teórica, Universidade Estadual Paulista, São 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, Bogotá, 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*Academy of Scientific Research and Technology of the Arab Republic of Egypt, Egyptian Network of High Energy Physics, Cairo, Egypt*
- ²³*National Institute of Chemical Physics and Biophysics, Tallinn, Estonia*
- ²⁴*Department of Physics, University of Helsinki, Helsinki, Finland*
- ²⁵*Helsinki Institute of Physics, Helsinki, Finland*
- ²⁶*Lappeenranta University of Technology, Lappeenranta, Finland*
- ²⁷*Laboratoire d'Annecy-le-Vieux de Physique des Particules, IN2P3-CNRS, Annecy-le-Vieux, France*
- 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 Nucléaire 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*E. Andronikashvili Institute of Physics, Academy of Science, 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*Bhabha Atomic Research Centre, Mumbai, India*
- ⁴⁹*Tata Institute of Fundamental Research–EHEP, Mumbai, India*
- ⁵⁰*Tata Institute of Fundamental Research–HECR, Mumbai, India*
- ⁵¹*Institute for Studies in Theoretical Physics & Mathematics (IPM), Tehran, Iran*
- ^{52a}*INFN Sezione di Bari, Bari, Italy*
- ^{52b}*Università di Bari, Bari, Italy*
- ^{52c}*Politecnico di Bari, Bari, Italy*
- ^{53a}*INFN Sezione di Bologna, Bologna, Italy*
- ^{53b}*Università di Bologna, Bologna, Italy*
- ^{54a}*INFN Sezione di Catania, Catania, Italy*
- ^{54b}*Università di Catania, Catania, Italy*
- ^{55a}*INFN Sezione di Firenze, Firenze, Italy*

- ^{55b}*Università di Firenze, Firenze, Italy*
⁵⁶*INFN Laboratori Nazionali di Frascati, Frascati, Italy*
⁵⁷*INFN Sezione di Genova, Genova, Italy*
^{58a}*INFN Sezione di Milano-Bicocca, Milano, Italy*
^{58b}*Università di Milano-Bicocca, Milano, Italy*
^{59a}*INFN Sezione di Napoli, Napoli, Italy*
^{59b}*Università di Napoli "Federico II," Napoli, Italy*
^{60a}*INFN Sezione di Padova, Padova, Italy*
^{60b}*Università di Padova, Padova, Italy*
^{60c}*Università di Trento (Trento), Padova, Italy*
^{61a}*INFN Sezione di Pavia, Pavia, Italy*
^{61b}*Università di Pavia, Pavia, Italy*
^{62a}*INFN Sezione di Perugia, Perugia, Italy*
^{62b}*Università di Perugia, Perugia, Italy*
^{63a}*INFN Sezione di Pisa, Pisa, Italy*
^{63b}*Università di Pisa, Pisa, Italy*
^{63c}*Scuola Normale Superiore di Pisa, Pisa, Italy*
^{64a}*INFN Sezione di Roma, Roma, Italy*
^{64b}*Università di Roma "La Sapienza," Roma, Italy*
^{65a}*INFN Sezione di Torino, Torino, Italy*
^{65b}*Università di Torino, Torino, Italy*
^{65c}*Università del Piemonte Orientale (Novara), Torino, Italy*
^{66a}*INFN Sezione di Trieste, Trieste, Italy*
^{66b}*Università di Trieste, Trieste, Italy*
⁶⁷*Kyungpook National University, Daegu, Korea*
⁶⁸*Chonnam National University, Institute for Universe and Elementary Particles, Kwangju, Korea*
⁶⁹*Korea University, Seoul, Korea*
⁷⁰*University of Seoul, Seoul, Korea*
⁷¹*Sungkyunkwan University, Suwon, Korea*
⁷²*Vilnius University, Vilnius, Lithuania*
⁷³*Centro de Investigacion y de Estudios Avanzados del IPN, Mexico City, Mexico*
⁷⁴*Universidad Iberoamericana, Mexico City, Mexico*
⁷⁵*Benemerita Universidad Autonoma de Puebla, Puebla, Mexico*
⁷⁶*Universidad Autónoma de San Luis Potosí, San Luis Potosí, Mexico*
⁷⁷*University of Auckland, Auckland, New Zealand*
⁷⁸*University of Canterbury, Christchurch, New Zealand*
⁷⁹*National Centre for Physics, Quaid-I-Azam University, Islamabad, Pakistan*
⁸⁰*Institute of Experimental Physics, Warsaw, Poland*
⁸¹*Soltan Institute for Nuclear Studies, Warsaw, Poland*
⁸²*Laboratório de Instrumentação e Física Experimental de Partículas, Lisboa, Portugal*
⁸³*Joint Institute for Nuclear Research, Dubna, Russia*
⁸⁴*Petersburg Nuclear Physics Institute, Gatchina (St. Petersburg), Russia*
⁸⁵*Institute for Nuclear Research, Moscow, Russia*
⁸⁶*Institute for Theoretical and Experimental Physics, Moscow, Russia*
⁸⁷*Moscow State University, Moscow, Russia*
⁸⁸*P. N. Lebedev Physical Institute, Moscow, Russia*
⁸⁹*State Research Center of Russian Federation, Institute for High Energy Physics, Protvino, Russia*
⁹⁰*Vinca Institute of Nuclear Sciences, Belgrade, Serbia*
⁹¹*Centro de Investigaciones Energéticas Medioambientales y Tecnológicas (CIEMAT), Madrid, Spain*
⁹²*Universidad Autónoma de Madrid, Madrid, Spain*
⁹³*Universidad de Oviedo, Oviedo, Spain*
⁹⁴*Instituto de Física de Cantabria (IFCA), CSIC-Universidad de Cantabria, Santander, Spain*
⁹⁵*CERN, European Organization for Nuclear Research, Geneva, Switzerland*
⁹⁶*Paul Scherrer Institut, Villigen, Switzerland*
⁹⁷*Institute for Particle Physics, ETH Zurich, Zurich, Switzerland*
⁹⁸*Universität Zürich, Zurich, Switzerland*
⁹⁹*National Central University, Chung-Li, Taiwan*
¹⁰⁰*National Taiwan University (NTU), Taipei, Taiwan*
¹⁰¹*Cukurova University, Adana, Turkey*
¹⁰²*Physics Department, Middle East Technical University, Ankara, Turkey*
¹⁰³*Department of Physics, Bogaziçi University, Istanbul, Turkey*

- ¹⁰⁴*National Scientific Center, Kharkov Institute of Physics and Technology, Kharkov, Ukraine*
- ¹⁰⁵*University of Bristol, Bristol, United Kingdom*
- ¹⁰⁶*Rutherford Appleton Laboratory, Didcot, United Kingdom*
- ¹⁰⁷*Imperial College, University of London, London, United Kingdom*
- ¹⁰⁸*Brunel University, Uxbridge, United Kingdom*
- ¹⁰⁹*Boston University, Boston, Massachusetts 02215, USA*
- ¹¹⁰*Brown University, Providence, Rhode Island 02912, USA*
- ¹¹¹*University of California, Davis, Davis, California 95616, USA*
- ¹¹²*University of California, Los Angeles, Los Angeles, California 90095, USA*
- ¹¹³*University of California, Riverside, Riverside, California 92521, USA*
- ¹¹⁴*University of California, San Diego, La Jolla, California 92093, USA*
- ¹¹⁵*University of California, Santa Barbara, Santa Barbara, California 93106, USA*
- ¹¹⁶*California Institute of Technology, Pasadena, California 91125, USA*
- ¹¹⁷*Carnegie Mellon University, Pittsburgh, Pennsylvania 15213, USA*
- ¹¹⁸*University of Colorado at Boulder, Boulder, Colorado 80309, USA*
- ¹¹⁹*Cornell University, Ithaca, New York 14853-5001, USA*
- ¹²⁰*Fairfield University, Fairfield, Connecticut 06824, USA*
- ¹²¹*Fermi National Accelerator Laboratory, Batavia, Illinois 60510-0500, USA*
- ¹²²*University of Florida, Gainesville, Florida 32611-8440, USA*
- ¹²³*Florida International University, Miami, Florida 33199, USA*
- ¹²⁴*Florida State University, Tallahassee, Florida 32306-4350, USA*
- ¹²⁵*Florida Institute of Technology, Melbourne, Florida 32901, USA*
- ¹²⁶*University of Illinois at Chicago (UIC), Chicago, Illinois 60607-7059, USA*
- ¹²⁷*The University of Iowa, Iowa City, Iowa 52242-1479, USA*
- ¹²⁸*Johns Hopkins University, Baltimore, Maryland 21218, USA*
- ¹²⁹*The University of Kansas, Lawrence, Kansas 66045, USA*
- ¹³⁰*Kansas State University, Manhattan, Kansas 66506, USA*
- ¹³¹*Lawrence Livermore National Laboratory, Livermore, California 94720, USA*
- ¹³²*University of Maryland, College Park, Maryland 20742, USA*
- ¹³³*Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA*
- ¹³⁴*University of Minnesota, Minneapolis, Minnesota 55455, USA*
- ¹³⁵*University of Mississippi, University, Mississippi 38677, USA*
- ¹³⁶*University of Nebraska–Lincoln, Lincoln, Nebraska 68588-0111, USA*
- ¹³⁷*State University of New York at Buffalo, Buffalo, New York 14260-1500, USA*
- ¹³⁸*Northeastern University, Boston, Massachusetts 02115, USA*
- ¹³⁹*Northwestern University, Evanston, Illinois 60208-3112, USA*
- ¹⁴⁰*University of Notre Dame, Notre Dame, Indiana 46556, USA*
- ¹⁴¹*The Ohio State University, Columbus, Ohio 43210, USA*
- ¹⁴²*Princeton University, Princeton, New Jersey 08544-0708, USA*
- ¹⁴³*University of Puerto Rico, Mayaguez, Puerto Rico 00680*
- ¹⁴⁴*Purdue University, West Lafayette, Indiana 47907-1396, USA*
- ¹⁴⁵*Purdue University Calumet, Hammond, Indiana 46323, USA*
- ¹⁴⁶*Rice University, Houston, Texas 77251-1892, USA*
- ¹⁴⁷*University of Rochester, Rochester, New York 14627-0171, USA*
- ¹⁴⁸*The Rockefeller University, New York, New York 10021-6399, USA*
- ¹⁴⁹*Rutgers, The State University of New Jersey, Piscataway, New Jersey 08854-8019, USA*
- ¹⁵⁰*University of Tennessee, Knoxville, Tennessee 37996-1200, USA*
- ¹⁵¹*Texas A&M University, College Station, Texas 77843-4242, USA*
- ¹⁵²*Texas Tech University, Lubbock, Texas 79409-1051, USA*
- ¹⁵³*Vanderbilt University, Nashville, Tennessee 37235, USA*
- ¹⁵⁴*University of Virginia, Charlottesville, Virginia 22901, USA*
- ¹⁵⁵*Wayne State University, Detroit, Michigan 48202, USA*
- ¹⁵⁶*University of Wisconsin, Madison, Wisconsin 53706, USA*

^aDeceased.

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

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

^dAlso at Soltan Institute for Nuclear Studies, Warsaw, Poland.

^eAlso at Moscow State University, Moscow, Russia.

^fAlso at Institute of Nuclear Research ATOMKI, Debrecen, Hungary.

^gAlso at University of California, San Diego, La Jolla, CA, USA.

^hAlso at Tata Institute of Fundamental Research–HECR, Mumbai, India.

ⁱAlso at California Institute of Technology, Pasadena, CA, USA.

^jAlso at INFN Sezione di Roma, Università di Roma “La Sapienza,” Roma, Italy.

^kAlso at University of Athens, Athens, Greece.

^lAlso at The University of Kansas, Lawrence, KS, USA.

^mAlso at Institute for Theoretical and Experimental Physics, Moscow, Russia.

ⁿAlso at Paul Scherrer Institut, Villigen, Switzerland.

^oAlso at Vinca Institute of Nuclear Sciences, Belgrade, Serbia.

^pAlso at Rutherford Appleton Laboratory, Didcot, United Kingdom.

^qAlso at INFN Sezione di Perugia, Università di Perugia, Perugia, Italy.

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

^sAlso at Institute for Nuclear Research, Moscow, Russia.