EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)

FERMILAB-PUB-15-025-CMS

CERN-PH-EP/2015-003
2015/01/27

CMS-BPH-14-002

Measurement of the ratio $\mathcal{B}(\mathrm{B}_\mathrm{s}^0 \to \mathrm{J}/\psi\,\mathrm{f}_0(980))/\mathcal{B}(\mathrm{B}_\mathrm{s}^0 \to \mathrm{J}/\psi\,\phi(1020))$ in pp collisions at $\sqrt{s} = 7\,\mathrm{TeV}$

The CMS Collaboration*

arXiv:1501.06089v1 [hep-ex] 24 Jan 2015

Abstract

The ratio $R_{\mathrm{f}_0/\phi}$ of the branching fractions of the B_s^0 meson to the CP-odd eigenstate $\mathrm{J}/\psi\,\mathrm{f}_0(980)$ and to $\mathrm{J}/\psi\,\phi(1020)$ is measured, where $\mathrm{J}/\psi \to \mu^+\mu^-$, $\mathrm{f}_0 \to \pi^+\pi^-$, and $\phi \to \mathrm{K}^+\mathrm{K}^-$. The analysis is based on a data sample of pp collisions at a centre-of-mass energy of 7 TeV, collected by the CMS experiment, corresponding to an integrated luminosity of $5.3\,\mathrm{fb}^{-1}$. The result is $R_{\mathrm{f}_0/\phi} = 0.140 \pm 0.013 \pm 0.018$, where the first uncertainty is statistical and the second is systematic. This result is consistent with theoretical predictions and previous measurements of $R_{\mathrm{f}_0/\phi}$. It is the most precise measurement of the ratio to date.

Submitted to Physics Letters B

© 2015 CERN for the benefit of the CMS Collaboration. CC-BY-3.0 license

*See Appendix A for the list of collaboration members

1 Introduction

Since the observation of the decay $B_s^0 \to J/\psi\, f_0(980)$, with $J/\psi \to \mu^+\mu^-$ and $f_0 \to \pi^+\pi^-$ [1], this channel has been regarded with great interest in heavy-flavor physics. Given the quantum numbers $J^P = 0^+$ of the $f_0(980)$, the final state of this decay is a CP-odd eigenstate [2], allowing a measurement of the lifetime of the CP-odd part of the B_s^0 meson [3, 4]. This lifetime is needed to measure the mixing-induced CP-violating phase ϕ_s [5, 6] with a better precision than using only the decay $B_s^0 \to J/\psi\,\phi(1020)$ [7–11]. The phase ϕ_s is predicted to be small in the standard model (SM) [12], making its determination interesting because of the large enhancements that can be introduced by new physics [13, 14]. In what follows, we will refer to the $f_0(980)$ as f_0 and the $\phi(1020)$ as ϕ.

The $B_s^0 \to J/\psi\, f_0$ branching fraction can be used to reduce the uncertainty in ϕ_s when measured using $B_s^0 \to J/\psi\, K^+K^-$ decays, where $B_s^0 \to J/\psi\, f_0$, with $f_0 \to K^+K^-$, can contribute [15]. Furthermore, this branching fraction can help test [16] the theory in which the f_0 state is postulated to be a diquark-antidiquark (tetraquark) system [17] and new decay mechanisms can be involved [18]. This Letter presents the measurement of the ratio $R_{f_0/\phi}$ of the branching fractions $\mathcal{B}(B_s^0 \to J/\psi\, f_0)\mathcal{B}(f_0 \to \pi^+\pi^-)$ and $\mathcal{B}(B_s^0 \to J/\psi\,\phi)\mathcal{B}(\phi \to K^+K^-)$, where in both cases the J/ψ is detected through its decay to $\mu^+\mu^-$. It was recently measured by the LHCb experiment to be $0.162 \pm 0.022\,(\text{stat}) \pm 0.016\,(\text{syst})$ [1], which is consistent with the theoretical estimate of approximately 0.2 [19] and with results from several other experiments [3, 20]. Experimentally, the ratio $R_{f_0/\phi}$ is given by

$$R_{f_0/\phi} = \frac{\mathcal{B}(B_s^0 \to J/\psi\, f_0)\mathcal{B}(f_0 \to \pi^+\pi^-)}{\mathcal{B}(B_s^0 \to J/\psi\,\phi)\mathcal{B}(\phi \to K^+K^-)} = \frac{N_{\text{obs}}^{f_0}}{N_{\text{obs}}^{\phi}} \times \epsilon_{\text{reco}}^{\phi/f_0}, \tag{1}$$

where $N_{\text{obs}}^{f_0}$ and N_{obs}^{ϕ} are the observed yields of $B_s^0 \to J/\psi(\mu^+\mu^-)f_0$ with $f_0 \to \pi^+\pi^-$ and $B_s^0 \to J/\psi(\mu^+\mu^-)\phi$ with $\phi \to K^+K^-$ decays, respectively, and $\epsilon_{\text{reco}}^{\phi/f_0}$ is the ratio of the detection efficiencies for the B_s^0 decay mode with a ϕ to the decay mode with a f_0. Uncertainties in the b quark production cross section cancel in the ratio, as do those from the $J/\psi \to \mu^+\mu^-$ branching fraction and the integrated luminosity. Given the similar topologies of the two final states, the systematic uncertainties related to the tracking efficiency and the muon identification also cancel in the ratio.

2 CMS detector

The central feature of the CMS apparatus is a superconducting solenoid of 6 m internal diameter. Within the 3.8 T field volume are a silicon pixel and strip tracker, a lead tungstate crystal electromagnetic calorimeter, and a brass and scintillator hadron calorimeter, each composed of a barrel and two endcap sections. Muons are measured in the pseudorapidity range $|\eta| < 2.4$ in gas-ionization detectors embedded in the steel flux-return yoke outside the solenoid, which are made using three technologies: drift tubes, cathode strip chambers, and resistive-plate chambers. Extensive forward calorimetry complements the coverage provided by the barrel and endcap detectors. The main subdetectors used in this analysis are the silicon tracker and the muon systems.

The silicon tracker measures charged particles within the pseudorapidity range $|\eta| < 2.5$ and consists of 1440 silicon pixel and 15 148 silicon strip detector modules. Matching muons detected in the muon system to tracks measured in the silicon tracker results in a relative transverse momentum (p_T) resolution of 1–6%, for muons with $p_T < 100$ GeV [21].

The first level of the CMS trigger system, composed of custom hardware processors, uses information from the calorimeters and muon detectors to select the most interesting events in a fixed time interval of less than 4 μs. The high-level trigger (HLT) processor farm further decreases the event rate from around 100 kHz to around 400 Hz, before data storage.

A more detailed description of the CMS detector, together with a definition of the coordinate system used and the relevant kinematic variables, can be found in Ref. [22].

3 Event selection

The data sample used for this measurement was collected in 2011 by the CMS experiment at the CERN LHC in proton-proton collisions at a center-of-mass energy of 7 TeV and corresponds to an integrated luminosity of 5.3 fb^{-1}.

The search for $\mathrm{B}_\mathrm{s}^0 \to \mathrm{J}/\psi\,\mathrm{f}_0$ decays is performed in events with two muon candidates selected by the dimuon trigger at the HLT, requiring the muon pair to originate from a displaced vertex. The dimuon candidates are further required to comply with $\mathrm{L}_{xy}/\sigma_{xy} > 3$, where L_{xy} is the magnitude of the vector $\vec{\mathrm{L}}_{xy}$, which lies in a plane transverse to the beam axis and points from the interaction point to the dimuon vertex, and σ_{xy} is its uncertainty; $\cos\alpha_{\mathrm{J}/\psi} > 0.9$, where $\alpha_{\mathrm{J}/\psi}$ is the angle between the direction of the dimuon transverse momentum and $\vec{\mathrm{L}}_{xy}$; $p_\mathrm{T} > 4\,\text{GeV}$ and $|\eta| < 2.2$ for each muon candidate; $p_\mathrm{T} > 7\,\text{GeV}$ for the dimuon; the distance of closest approach of each muon track with respect to the other muon track $<0.5\,\text{cm}$.

Reconstruction of the $\mathrm{B}_\mathrm{s}^0 \to \mathrm{J}/\psi\,\mathrm{f}_0$ decays begins with the search for J/ψ candidates by combining two muons of opposite charge to form a vertex with a fit probability $>0.5\%$ and an invariant mass ($M_{\mathrm{J}/\psi}$) within $|M_{\mathrm{J}/\psi} - 3097.6\,\text{MeV}| < 150\,\text{MeV}$. To search for f_0 candidates, two tracks of opposite charge assumed to be pions are constrained to a vertex with a probability $>5\%$. One pion candidate must have $p_\mathrm{T} > 1\,\text{GeV}$ and the other $p_\mathrm{T} > 2.5\,\text{GeV}$. In addition, the f_0 candidate must have $p_\mathrm{T} > 3.5\,\text{GeV}$ and an invariant mass (M_{f_0}) in the range $|M_{\mathrm{f}_0} - 974\,\text{MeV}| < 50\,\text{MeV}$. The 974 MeV mass value is the fitted peak of the measured $\pi^+\pi^-$ invariant mass distribution for the signal events in data. This value is consistent with the f_0 mass from the PDG [23] and the LHCb measurement [1]. Finally, a vertex is formed with the J/ψ and f_0 candidates, constraining the dimuon mass to the nominal J/ψ mass [23]. The $\mathrm{B}_\mathrm{s}^0 \to \mathrm{J}/\psi\,\mathrm{f}_0$ candidates are required to have a vertex probability $>10\%$, $p_\mathrm{T} > 13\,\text{GeV}$, $\cos\alpha_{\mathrm{B}_\mathrm{s}^0} > 0.994$, where $\alpha_{\mathrm{B}_\mathrm{s}^0}$ is the angle between the direction of the B_s^0 transverse momentum and the vector $\vec{\mathrm{L}}_{xy}$, and a proper decay length $>100\,\mu\text{m}$. The proper decay length is defined as $(\vec{\mathrm{L}}_{xy} \cdot \vec{p}_\mathrm{T}\, M_\mathrm{B}/p_\mathrm{T}^2)$, where $\vec{p}_\mathrm{T}$ is the transverse momentum of the B_s^0 candidate and M_B is the world-average B_s^0 mass [23]. In the case of multiple B_s^0 candidates per event, the one with smallest B_s^0 vertex fit χ^2 is selected. The selection criteria for the B_s^0 candidates are established by maximizing $S/\sqrt{S+B}$, where S is the signal yield obtained from Monte Carlo (MC) simulation and B is the background yield taken from sideband regions, defined as the number of events with a $\mu^+\mu^-\pi^+\pi^-$ invariant mass in the range 5.27 to 5.30 GeV or 5.43 to 5.46 GeV.

The same procedure and selection criteria are applied to the reconstruction of the normalization channel $\mathrm{B}_\mathrm{s}^0 \to \mathrm{J}/\psi\,\phi$, except the ϕ mass window $|M_\phi - 1020\,\text{MeV}| < 10\,\text{MeV}$ is tighter than that for the f_0. In both decay channels, the S-wave contributions coming from $\mathrm{B}_\mathrm{s}^0 \to \mathrm{J}/\psi\,\pi^+\pi^-$ and $\mathrm{J}/\psi\,\mathrm{K}^+\mathrm{K}^-$, with nonresonant $\pi^+\pi^-$ and $\mathrm{K}^+\mathrm{K}^-$, are considered to be negligible [2, 24].

4 Results

The signal yields of both decay channels are extracted using unbinned maximum-likelihood fits of the mass distributions. The invariant mass distribution of the $J/\psi(\mu^+\mu^-)f_0(\pi^+\pi^-)$ candidates is shown in Fig. 1. It is fit with a superposition of a Gaussian function representing the signal, a polynomial function to account for the combinatorial background, and another Gaussian function for any possible peaking background. The latter models resonant structures that could appear in the left sideband of the $J/\psi(\mu^+\mu^-)f_0(\pi^+\pi^-)$ signal mass owing to the misidentification of a kaon as a pion coming from decays such as $B^0 \to J/\psi K^*(892)(K^+\pi^-)$ and $B_s^0 \to J/\psi K^+K^-$. In addition, $B^+ \to J/\psi K^+(\pi^+)$ decays can be a source of background when combined with an extra background pion candidate. When allowing all parameters to float, the fit returns $N_{\rm obs}^{f_0} = 873 \pm 49$ events and a B_s^0 mass of 5369.1 ± 0.9 MeV, with a resolution of 15.9 ± 0.9 MeV, where the uncertainties are statistical only. The mean and the resolution of the B_s^0 are consistent with the MC simulation.

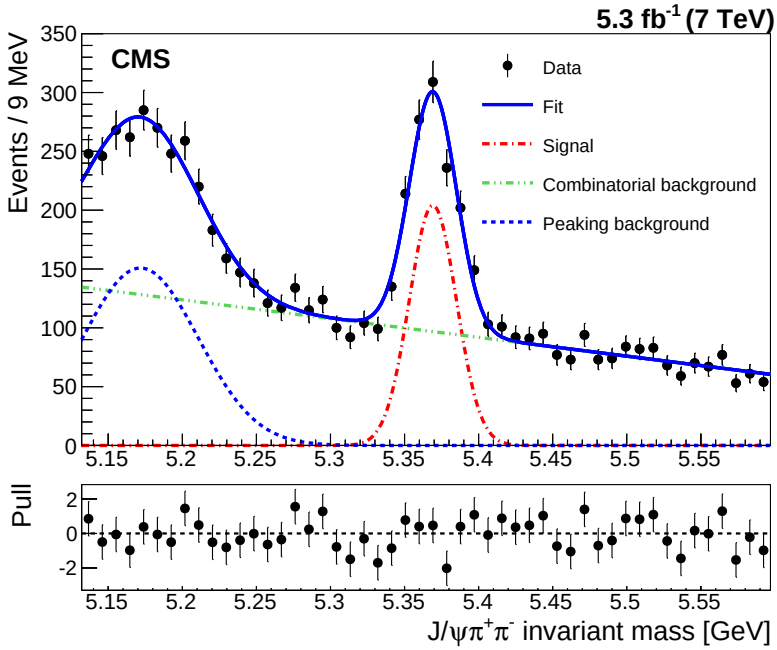

Figure 1: Invariant mass distribution of the $B_s^0 \to J/\psi(\mu^+\mu^-)f_0(\pi^+\pi^-)$ candidates (filled circles). The signal is modelled as a Gaussian (dot-dashed line), the combinatorial background as a first-order polynomial function (dashed-double-dotted line), and the peaking background by a Gaussian (dotted line). The result of the total fit is shown with the solid line. The bottom plot shows the pull, which is the deviation of the data from the fit divided by the uncertainty in the data.

The $J/\psi(\mu^+\mu^-)\phi(K^+K^-)$ invariant mass distribution is modelled by two Gaussian functions for the signal and a constant function for the combinatorial background. A signal yield of $N_{\rm obs}^{\phi} = 8377 \pm 107$ events is obtained, with a B_s^0 mass of 5366.8 ± 0.2 MeV and a resolution of 17.1 ± 0.1 MeV, which are consistent with the MC simulation. The corresponding invariant mass distribution is presented in Fig. 2.

Using the MC simulation, the detection efficiencies for the two processes are calculated as the ratio of the reconstructed and generated yields. The B_s^0 meson production is simulated using PYTHIA 6.4.24 [25] and its decays simulated with EVTGEN [26]. The decay model used for the

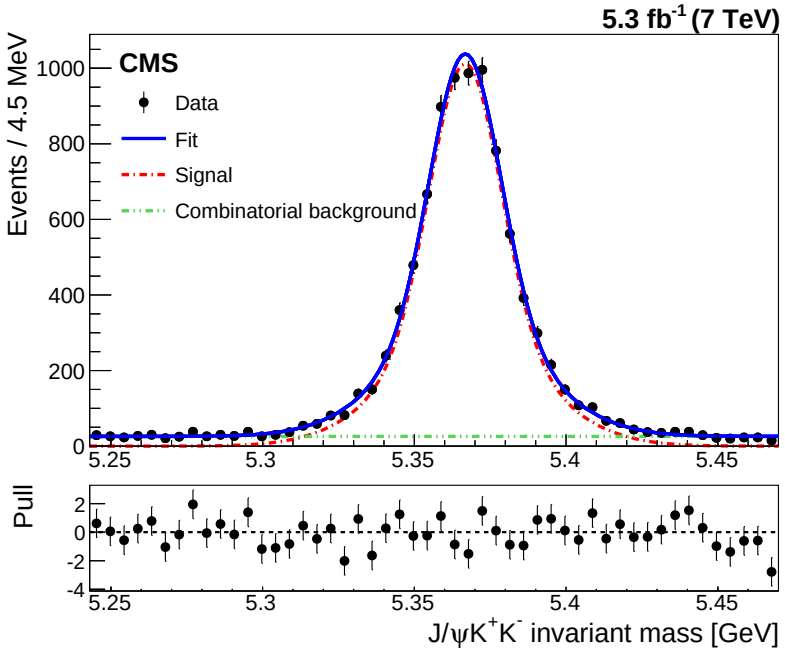

Figure 2: Invariant mass distribution of the $B_s^0 \to J/\psi(\mu^+\mu^-)\phi(K^+K^-)$ candidates (black filled circles). The signal model is a double Gaussian (dot-dashed line), while the combinatorial background model is a constant function (dash-double-dotted line). The total fit is represented by the solid line. The bottom plot shows the ratio of the deviation of the data to the fit and the statistical uncertainty in the data.

$B_s^0 \to J/\psi\, f_0$ decay is a phase-space model reweighted to reflect the spin-1 structure of the $J/\psi \to \mu^+\mu^-$ decay. The corresponding models for the $B_s^0 \to J/\psi\,\phi$ decay are: a pseudoscalar-vector-vector with CP violation [27, 28] for the B_s^0 decay; a vector-lepton-lepton model with radiation (PHOTOS) [29] for the $J/\psi \to \mu^+\mu^-$ decay; and a vector-scalar-scalar model [26] for the $\phi \to K^+K^-$ decay. The events are processed with a GEANT4-based detector simulation [30] and the same reconstruction algorithms used on data. In order to validate the MC simulation samples, relevant kinematic and geometric variables of both simulated decay channels are compared with the data after background subtraction and found to be in agreement. For example, Fig. 3 compares the p_T and invariant mass distributions of the $f_0(\pi^+\pi^-)$ candidates for background-subtracted data and MC simulation. The f_0 width was set to 50 MeV in the MC simulation. The ratio of the detection efficiencies for the two B_s^0 decays is measured to be $\epsilon_{\rm reco}^{\phi/f_0} = 1.344 \pm 0.095$, where the uncertainty is statistical. This uncertainty is included in the final statistical uncertainty of the ratio measurement. Using the corresponding values of $N_{\rm obs}^{f_0}$, $N_{\rm obs}^{\phi}$, and $\epsilon_{\rm reco}^{\phi/f_0}$ in Eq. (1), we measure $R_{f_0/\phi} = 0.140 \pm 0.013$, where the uncertainty is statistical.

The stability of the $R_{f_0/\phi}$ measurement is verified with control checks using different run periods, selection criteria, and geometric acceptances. To study possible effects from varying run conditions, the value of $R_{f_0/\phi}$ is determined for two subsamples, found by dividing the data into two. The ratio is also measured after changing the selection criteria for the proper decay length and p_T of the B_s^0 candidates and the p_T of the leading and subleading pion candidates, and by using different azimuthal angle and η requirements for the muons. None of these cross-checks revealed any statistically significant biases.

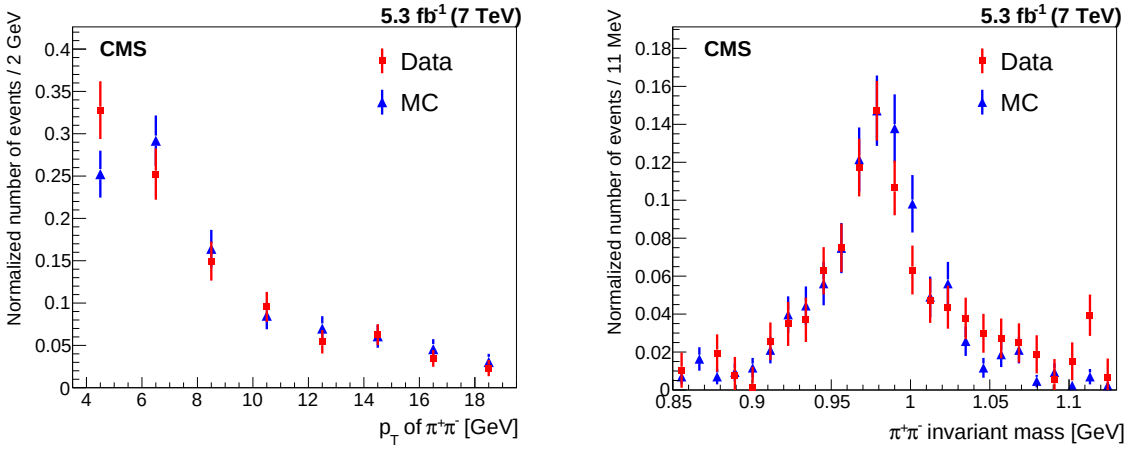

Figure 3: Comparison of normalized MC simulation (triangles) and background-subtracted data (squared) for the p_{T} (left) and invariant mass (right) distributions of the $\mathrm{f}_0(\pi^+\pi^-)$ candidates.

5 Systematic uncertainties

Potential systematic uncertainties in the measurement of $R_{\mathrm{f}_0/\phi}$ come from sources such as the signal yield extraction procedure, data selection effects caused by the f_0 mass window, and the relative efficiency estimation.

Systematic uncertainties in the signal yield extraction are estimated by changing the modeling of the signal and the background invariant mass distributions in the likelihood fits. For the case of the $\mathrm{J}/\psi\,\pi^+\pi^-$ mass distribution the signal shape is changed to a double-Gaussian function and the background to an exponential function, while for the $\mathrm{J}/\psi\,\mathrm{K}^+\mathrm{K}^-$ mass distribution the signal is changed to a Gaussian function and its background is modelled as a first-order polynomial function. These changes lead to a maximum variation of 2.1% in $R_{\mathrm{f}_0/\phi}$.

To estimate the possible contribution of unknown background in the f_0 mass region that could affect the $\mathrm{B}_\mathrm{s}^0 \to \mathrm{J}/\psi\,\mathrm{f}_0$ yield, the f_0 mass window is widened from 50 to 100 MeV around the f_0 mass, resulting in a variation in $R_{\mathrm{f}_0/\phi}$ of 6.4%.

The poorly known f_0 natural width can affect the estimate of $\epsilon_{\mathrm{reco}}^{\phi/\mathrm{f}_0}$, an input to the determination of $R_{\mathrm{f}_0/\phi}$, as shown in Eq. (1). In the MC simulation used to estimate the ratio of the efficiencies, the f_0 width was set to 50 MeV. This value was varied by ± 10 MeV, resulting in a systematic uncertainty of 8.6% in $R_{\mathrm{f}_0/\phi}$.

In addition, different decay models used in the signal MC generation could influence the estimated detection efficiency. For both channels the decay models are set to phase space instead of the default decay models, leading to a 6.2% systematic uncertainty in $R_{\mathrm{f}_0/\phi}$.

Combining these uncertainties in quadrature leads to a total systematic uncertainty of 12.6%.

6 Summary

Using data collected by the CMS experiment in proton-proton collisions at $\sqrt{s} = 7$ TeV, corresponding to an integrated luminosity of $5.3\,\mathrm{fb}^{-1}$, 873 ± 49 events of $\mathrm{B}_\mathrm{s}^0 \to \mathrm{J}/\psi(\mu^+\mu^-)\mathrm{f}_0(\pi^+\pi^-)$ and 8377 ± 107 events of $\mathrm{B}_\mathrm{s}^0 \to \mathrm{J}/\psi(\mu^+\mu^-)\phi(\mathrm{K}^+\mathrm{K}^-)$ are observed. The ratio of the branching fraction of $\mathrm{B}_\mathrm{s}^0 \to \mathrm{J}/\psi(\mu^+\mu^-)\mathrm{f}_0(\pi^+\pi^-)$ to the branching fraction of $\mathrm{B}_\mathrm{s}^0 \to \mathrm{J}/\psi(\mu^+\mu^-)\phi(\mathrm{K}^+\mathrm{K}^-)$,

$R_{f_0/\phi}$, is found to be

$$\frac{\mathcal{B}(B_s^0 \to J/\psi\, f_0)\mathcal{B}(f_0 \to \pi^+\pi^-)}{\mathcal{B}(B_s^0 \to J/\psi\, \phi)\mathcal{B}(\phi \to K^+K^-)} = 0.140 \pm 0.013\,(\text{stat}) \pm 0.018\,(\text{syst}). \quad (2)$$

This result is consistent with the theoretical prediction of about 0.2 [19] and with previous measurements [1, 3, 20]. It is the most precise measurement of the ratio to date.

Acknowledgments

We congratulate our colleagues in the CERN accelerator departments for the excellent performance of the LHC and thank the technical and administrative staffs at CERN and at other CMS institutes for their contributions to the success of the CMS effort. In addition, we gratefully acknowledge the computing centres and personnel of the Worldwide LHC Computing Grid for delivering so effectively the computing infrastructure essential to our analyses. Finally, we acknowledge the enduring support for the construction and operation of the LHC and the CMS detector provided by the following funding agencies: BMWFW and FWF (Austria); FNRS and FWO (Belgium); CNPq, CAPES, FAPERJ, and FAPESP (Brazil); MES (Bulgaria); CERN; CAS, MoST, and NSFC (China); COLCIENCIAS (Colombia); MSES and CSF (Croatia); RPF (Cyprus); MoER, ERC IUT and ERDF (Estonia); Academy of Finland, MEC, and HIP (Finland); CEA and CNRS/IN2P3 (France); BMBF, DFG, and HGF (Germany); GSRT (Greece); OTKA and NIH (Hungary); DAE and DST (India); IPM (Iran); SFI (Ireland); INFN (Italy); MSIP and NRF (Republic of Korea); LAS (Lithuania); MOE and UM (Malaysia); CINVESTAV, CONACYT, SEP, and UASLP-FAI (Mexico); MBIE (New Zealand); PAEC (Pakistan); MSHE and NSC (Poland); FCT (Portugal); JINR (Dubna); MON, RosAtom, RAS and RFBR (Russia); MESTD (Serbia); SEIDI and CPAN (Spain); Swiss Funding Agencies (Switzerland); MST (Taipei); ThEPCenter, IPST, STAR and NSTDA (Thailand); TUBITAK and TAEK (Turkey); NASU and SFFR (Ukraine); STFC (United Kingdom); DOE and NSF (USA).

Individuals have received support from the Marie-Curie programme and the European Research Council and EPLANET (European Union); the Leventis Foundation; the A. P. Sloan Foundation; the Alexander von Humboldt Foundation; the Belgian Federal Science Policy Office; the Fonds pour la Formation à la Recherche dans l'Industrie et dans l'Agriculture (FRIA-Belgium); the Agentschap voor Innovatie door Wetenschap en Technologie (IWT-Belgium); the Ministry of Education, Youth and Sports (MEYS) of the Czech Republic; the Council of Science and Industrial Research, India; the HOMING PLUS programme of Foundation for Polish Science, cofinanced from European Union, Regional Development Fund; the Compagnia di San Paolo (Torino); the Consorzio per la Fisica (Trieste); MIUR project 20108T4XTM (Italy); the Thalis and Aristeia programmes cofinanced by EU-ESF and the Greek NSRF; and the National Priorities Research Program by Qatar National Research Fund.

References

[1] LHCb Collaboration, "First observation of $B_s^0 \to J/\psi\, f_0(980)$ decays", *Phys. Lett. B* **698** (2011) 115, doi:10.1016/j.physletb.2011.03.006, arXiv:1102.0206.

[2] LHCb Collaboration, "Analysis of the resonant components in $\overline{B}_s^0 \to J/\psi\, \pi^+\pi^-$", *Phys. Rev. D* **86** (2012) 052006, doi:10.1103/PhysRevD.86.052006, arXiv:1204.5643.

[3] CDF Collaboration, "Measurement of branching ratio and B_s^0 lifetime in the decay $B_s^0 \to J/\psi\, f_0(980)$ at CDF", *Phys. Rev. D* **84** (2011) 052012, doi:10.1103/PhysRevD.84.052012, arXiv:1106.3682.

[4] LHCb Collaboration, "Measurement of the B_s^0 effective lifetime in the $J/\psi\, f_0(980)$ final state", *Phys. Rev. Lett.* **109** (2012) 152002, doi:10.1103/PhysRevLett.109.152002, arXiv:1207.0878.

[5] LHCb Collaboration, "Measurement of the CP-violating phase ϕ_s in $\overline{B}_s^0 \to J/\psi\, f_0(980)$", *Phys. Lett. B* **707** (2012) 497, doi:10.1016/j.physletb.2012.01.017, arXiv:1112.3056.

[6] LHCb Collaboration, "Measurement of the CP-violating phase ϕ_s in $\overline{B}_s^0 \to J/\psi\, \pi^+\pi^-$ decays", *Phys. Lett. B* **736** (2014) 186, doi:10.1016/j.physletb.2014.06.079, arXiv:1405.4140.

[7] D0 Collaboration, "Measurement of B_s^0 mixing parameters from the flavor-tagged decay $B_s^0 \to J/\psi\, \phi$", *Phys. Rev. Lett.* **101** (2008) 241801, doi:10.1103/PhysRevLett.101.241801, arXiv:0802.2255.

[8] CDF Collaboration, "First flavor-tagged determination of bounds on mixing-induced CP violation in $B_s^0 \to J/\psi\, \phi$ decays", *Phys. Rev. Lett.* **100** (2008) 161802, doi:10.1103/PhysRevLett.100.161802, arXiv:0712.2397.

[9] D0 Collaboration, "Measurement of the CP-violating phase $\phi_s^{J/\psi\,\phi}$ using the flavor-tagged decay $B_s^0 \to J/\psi\, \phi$ in 8 fb^{-1} of $p\overline{p}$ collisions", *Phys. Rev. D.* **85** (2012) 032006, doi:10.1103/PhysRevD.85.032006, arXiv:1109.3166.

[10] LHCb Collaboration, "Measurement of the CP-violating phase ϕ_s in the decay $B_s^0 \to J/\psi\, \phi$", *Phys. Rev. Lett.* **108** (2012) 101803, doi:10.1103/PhysRevLett.108.101803, arXiv:1112.3183.

[11] ATLAS Collaboration, "Time-dependent angular analysis of the decay $B_s^0 \to J/\psi\, \phi$ and extraction of $\Delta\Gamma_s$ and the *CP*-violating weak phase ϕ_s by ATLAS", *JHEP* **12** (2012) 072, doi:10.1007/JHEP12(2012)072, arXiv:1208.0572.

[12] J. Charles et al., "Predictions of selected flavour observables within the standard model", *Phys. Rev. D* **84** (2011) 033005, doi:10.1103/PhysRevD.84.033005, arXiv:1106.4041.

[13] P. Ball and R. Fleischer, "Probing new physics through B mixing: Status, benchmarks and prospects", *Eur. Phys. J. C* **48** (2006) 413, doi:10.1140/epjc/s10052-006-0034-4, arXiv:hep-ph/0604249.

[14] A. Lenz, "Unparticle physics effects in B_s-$\overline{B}_s$ mixing", *Phys. Rev. D* **76** (2007) 065006, doi:10.1103/PhysRevD.76.065006, arXiv:0707.1535.

[15] O. Leitner, J.-P. Dedonder, B. Loiseau, and B. El-Bennich, "Scalar resonance effects on the B_s-$\overline{B}_s$ mixing angle", *Phys. Rev. D* **82** (2010) 076006, doi:10.1103/PhysRevD.82.076006, arXiv:1003.5980.

[16] LHCb Collaboration, "Measurement of the resonant and *CP* components in $\overline{B}_s^0 \to J/\psi\, \pi^+\pi^-$ decays", *Phys. Rev. D* **90** (2014) 012003, doi:10.1103/PhysRevD.90.012003, arXiv:1404.5673.

[17] S. Stone and L. Zhang, "Use of $B_s^0 \to J/\psi f_0$ decays to discern the $q\bar{q}$ or tetraquark nature of scalar mesons", *Phys. Rev. Lett.* **111** (2013) 062001, doi:10.1103/PhysRevLett.111.062001, arXiv:1305.6554.

[18] R. Fleischer, R. Knegjens, and G. Ricciardi, "Anatomy of $B_{s,d}^0 \to J/\psi f_0(980)$", *Eur. Phys. J. C* **71** (2011) 1832, doi:10.1140/epjc/s10052-011-1832-x, arXiv:1109.1112.

[19] S. Stone and L. Zhang, "S-waves and the measurement of CP-violating phases in B_s decays", *Phys. Rev. D* **79** (2009) 074024, doi:10.1103/PhysRevD.79.074024, arXiv:0812.2832.

[20] D0 Collaboration, "Measurement of the relative branching ratio of $B_s^0 \to J/\psi f_0(980)$ to $B_s^0 \to J/\psi \phi$", *Phys. Rev. D* **85** (2012) 011103, doi:10.1103/PhysRevD.85.011103, arXiv:1110.4272.

[21] CMS Collaboration, "Performance of CMS muon reconstruction in pp collision events at $\sqrt{s} = 7$ TeV", *JINST* **7** (2012) P10002, doi:10.1088/1748-0221/7/10/P10002, arXiv:1206.4071.

[22] CMS Collaboration, "The CMS experiment at the CERN LHC", *JINST* **03** (2008) S08004, doi:10.1088/1748-0221/3/08/S08004.

[23] Particle Data Group, J. Beringer et al., "Review of Particle Physics", *Phys. Rev. D* **86** (2012) 010001, doi:10.1103/PhysRevD.86.010001.

[24] CDF Collaboration, "Measurement of the Bottom-Strange Meson Mixing Phase in the Full CDF data set", *Phys. Rev. Lett.* **109** (2012) 171802, doi:10.1103/PhysRevLett.109.171802, arXiv:1208.2967.

[25] T. Sjöstrand, S. Mrenna, and P. Skands, "PYTHIA 6.4 physics and manual", *JHEP* **05** (2006) 026, doi:10.1088/1126-6708/2006/05/026, arXiv:hep-ph/0603175.

[26] D. Lange, "The EvtGen particle decay simulation package", *Nucl. Instrum. Meth. A* **462** (2001) 152, doi:10.1016/S0168-9002(01)00089-4.

[27] I. Dunietz et al., "How to extract CP-violating asymmetries from angular correlations", *Phys. Rev. D* **43** (1991) 2193, doi:10.1103/PhysRevD.43.2193.

[28] BABAR Collaboration, "Measurement of the $B \to J/\psi K^*(892)$ decay amplitudes", *Phys. Rev. Lett.* **87** (2001) 241801, doi:10.1103/PhysRevLett.87.241801, arXiv:hep-ex/0107049.

[29] P. Golonka and Z. Was, "PHOTOS Monte Carlo: a precision tool for QED corrections in Z and W decays", *Eur. Phys. J. C* **45** (2006) 97, doi:10.1140/epjc/s2005-02396-4, arXiv:hep-ph/0506026.

[30] GEANT4 Collaboration, "Geant4—a simulation toolkit", *Nucl. Instrum. Meth. A* **506** (2003) 250, doi:10.1016/S0168-9002(03)01368-8.

A The CMS Collaboration

Yerevan Physics Institute, Yerevan, Armenia
V. Khachatryan, A.M. Sirunyan, A. Tumasyan

Institut für Hochenergiephysik der OeAW, Wien, Austria
W. Adam, T. Bergauer, M. Dragicevic, J. Erö, M. Friedl, R. Frühwirth[1], V.M. Ghete, C. Hartl, N. Hörmann, J. Hrubec, M. Jeitler[1], W. Kiesenhofer, V. Knünz, M. Krammer[1], I. Krätschmer, D. Liko, I. Mikulec, D. Rabady[2], B. Rahbaran, H. Rohringer, R. Schöfbeck, J. Strauss, W. Treberer-Treberspurg, W. Waltenberger, C.-E. Wulz[1]

National Centre for Particle and High Energy Physics, Minsk, Belarus
V. Mossolov, N. Shumeiko, J. Suarez Gonzalez

Universiteit Antwerpen, Antwerpen, Belgium
S. Alderweireldt, S. Bansal, T. Cornelis, E.A. De Wolf, X. Janssen, A. Knutsson, J. Lauwers, S. Luyckx, S. Ochesanu, R. Rougny, M. Van De Klundert, H. Van Haevermaet, P. Van Mechelen, N. Van Remortel, A. Van Spilbeeck

Vrije Universiteit Brussel, Brussel, Belgium
F. Blekman, S. Blyweert, J. D'Hondt, N. Daci, N. Heracleous, J. Keaveney, S. Lowette, M. Maes, A. Olbrechts, Q. Python, D. Strom, S. Tavernier, W. Van Doninck, P. Van Mulders, G.P. Van Onsem, I. Villella

Université Libre de Bruxelles, Bruxelles, Belgium
C. Caillol, B. Clerbaux, G. De Lentdecker, D. Dobur, L. Favart, A.P.R. Gay, A. Grebenyuk, A. Léonard, A. Mohammadi, L. Perniè[2], A. Randle-conde, T. Reis, T. Seva, L. Thomas, C. Vander Velde, P. Vanlaer, J. Wang, F. Zenoni

Ghent University, Ghent, Belgium
V. Adler, K. Beernaert, L. Benucci, A. Cimmino, S. Costantini, S. Crucy, A. Fagot, G. Garcia, J. Mccartin, A.A. Ocampo Rios, D. Poyraz, D. Ryckbosch, S. Salva Diblen, M. Sigamani, N. Strobbe, F. Thyssen, M. Tytgat, E. Yazgan, N. Zaganidis

Université Catholique de Louvain, Louvain-la-Neuve, Belgium
S. Basegmez, C. Beluffi[3], G. Bruno, R. Castello, A. Caudron, L. Ceard, G.G. Da Silveira, C. Delaere, T. du Pree, D. Favart, L. Forthomme, A. Giammanco[4], J. Hollar, A. Jafari, P. Jez, M. Komm, V. Lemaitre, C. Nuttens, D. Pagano, L. Perrini, A. Pin, K. Piotrzkowski, A. Popov[5], L. Quertenmont, M. Selvaggi, M. Vidal Marono, J.M. Vizan Garcia

Université de Mons, Mons, Belgium
N. Beliy, T. Caebergs, E. Daubie, G.H. Hammad

Centro Brasileiro de Pesquisas Fisicas, Rio de Janeiro, Brazil
W.L. Aldá Júnior, G.A. Alves, L. Brito, M. Correa Martins Junior, T. Dos Reis Martins, J. Molina, C. Mora Herrera, M.E. Pol, P. Rebello Teles

Universidade do Estado do Rio de Janeiro, Rio de Janeiro, Brazil
W. Carvalho, J. Chinellato[6], A. Custódio, E.M. Da Costa, D. De Jesus Damiao, C. De Oliveira Martins, S. Fonseca De Souza, H. Malbouisson, D. Matos Figueiredo, L. Mundim, H. Nogima, W.L. Prado Da Silva, J. Santaolalla, A. Santoro, A. Sznajder, E.J. Tonelli Manganote[6], A. Vilela Pereira

Universidade Estadual Paulista [a], Universidade Federal do ABC [b], São Paulo, Brazil
C.A. Bernardes[b], S. Dogra[a], T.R. Fernandez Perez Tomei[a], E.M. Gregores[b], P.G. Mercadante[b], S.F. Novaes[a], Sandra S. Padula[a]

Institute for Nuclear Research and Nuclear Energy, Sofia, Bulgaria
A. Aleksandrov, V. Genchev[2], R. Hadjiiska, P. Iaydjiev, A. Marinov, S. Piperov, M. Rodozov, S. Stoykova, G. Sultanov, M. Vutova

University of Sofia, Sofia, Bulgaria
A. Dimitrov, I. Glushkov, L. Litov, B. Pavlov, P. Petkov

Institute of High Energy Physics, Beijing, China
J.G. Bian, G.M. Chen, H.S. Chen, M. Chen, T. Cheng, R. Du, C.H. Jiang, R. Plestina[7], F. Romeo, J. Tao, Z. Wang

State Key Laboratory of Nuclear Physics and Technology, Peking University, Beijing, China
C. Asawatangtrakuldee, Y. Ban, S. Liu, Y. Mao, S.J. Qian, D. Wang, Z. Xu, L. Zhang, W. Zou

Universidad de Los Andes, Bogota, Colombia
C. Avila, A. Cabrera, L.F. Chaparro Sierra, C. Florez, J.P. Gomez, B. Gomez Moreno, J.C. Sanabria

University of Split, Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, Split, Croatia
N. Godinovic, D. Lelas, D. Polic, I. Puljak

University of Split, Faculty of Science, Split, Croatia
Z. Antunovic, M. Kovac

Institute Rudjer Boskovic, Zagreb, Croatia
V. Brigljevic, K. Kadija, J. Luetic, D. Mekterovic, L. Sudic

University of Cyprus, Nicosia, Cyprus
A. Attikis, G. Mavromanolakis, J. Mousa, C. Nicolaou, F. Ptochos, P.A. Razis, H. Rykaczewski

Charles University, Prague, Czech Republic
M. Bodlak, M. Finger, M. Finger Jr.[8]

Academy of Scientific Research and Technology of the Arab Republic of Egypt, Egyptian Network of High Energy Physics, Cairo, Egypt
Y. Assran[9], A. Ellithi Kamel[10], M.A. Mahmoud[11], A. Radi[12,13]

National Institute of Chemical Physics and Biophysics, Tallinn, Estonia
M. Kadastik, M. Murumaa, M. Raidal, A. Tiko

Department of Physics, University of Helsinki, Helsinki, Finland
P. Eerola, M. Voutilainen

Helsinki Institute of Physics, Helsinki, Finland
J. Härkönen, V. Karimäki, R. Kinnunen, M.J. Kortelainen, T. Lampén, K. Lassila-Perini, S. Lehti, T. Lindén, P. Luukka, T. Mäenpää, T. Peltola, E. Tuominen, J. Tuominiemi, E. Tuovinen, L. Wendland

Lappeenranta University of Technology, Lappeenranta, Finland
J. Talvitie, T. Tuuva

DSM/IRFU, CEA/Saclay, Gif-sur-Yvette, France
M. Besancon, F. Couderc, M. Dejardin, D. Denegri, B. Fabbro, J.L. Faure, C. Favaro, F. Ferri, S. Ganjour, A. Givernaud, P. Gras, G. Hamel de Monchenault, P. Jarry, E. Locci, J. Malcles, J. Rander, A. Rosowsky, M. Titov

Laboratoire Leprince-Ringuet, Ecole Polytechnique, IN2P3-CNRS, Palaiseau, France
S. Baffioni, F. Beaudette, P. Busson, E. Chapon, C. Charlot, T. Dahms, M. Dalchenko, L. Dobrzynski, N. Filipovic, A. Florent, R. Granier de Cassagnac, L. Mastrolorenzo, P. Miné, I.N. Naranjo, M. Nguyen, C. Ochando, G. Ortona, P. Paganini, S. Regnard, R. Salerno, J.B. Sauvan, Y. Sirois, C. Veelken, Y. Yilmaz, A. Zabi

Institut Pluridisciplinaire Hubert Curien, Université de Strasbourg, Université de Haute Alsace Mulhouse, CNRS/IN2P3, Strasbourg, France
J.-L. Agram[14], J. Andrea, A. Aubin, D. Bloch, J.-M. Brom, E.C. Chabert, C. Collard, E. Conte[14], J.-C. Fontaine[14], D. Gelé, U. Goerlach, C. Goetzmann, A.-C. Le Bihan, K. Skovpen, P. Van Hove

Centre de Calcul de l'Institut National de Physique Nucleaire et de Physique des Particules, CNRS/IN2P3, Villeurbanne, France
S. Gadrat

Université de Lyon, Université Claude Bernard Lyon 1, CNRS-IN2P3, Institut de Physique Nucléaire de Lyon, Villeurbanne, France
S. Beauceron, N. Beaupere, C. Bernet[7], G. Boudoul[2], E. Bouvier, S. Brochet, C.A. Carrillo Montoya, J. Chasserat, R. Chierici, D. Contardo[2], B. Courbon, P. Depasse, H. El Mamouni, J. Fan, J. Fay, S. Gascon, M. Gouzevitch, B. Ille, T. Kurca, M. Lethuillier, L. Mirabito, A.L. Pequegnot, S. Perries, J.D. Ruiz Alvarez, D. Sabes, L. Sgandurra, V. Sordini, M. Vander Donckt, P. Verdier, S. Viret, H. Xiao

Institute of High Energy Physics and Informatization, Tbilisi State University, Tbilisi, Georgia
Z. Tsamalaidze[8]

RWTH Aachen University, I. Physikalisches Institut, Aachen, Germany
C. Autermann, S. Beranek, M. Bontenackels, M. Edelhoff, L. Feld, A. Heister, K. Klein, M. Lipinski, A. Ostapchuk, M. Preuten, F. Raupach, J. Sammet, S. Schael, J.F. Schulte, H. Weber, B. Wittmer, V. Zhukov[5]

RWTH Aachen University, III. Physikalisches Institut A, Aachen, Germany
M. Ata, M. Brodski, E. Dietz-Laursonn, D. Duchardt, M. Erdmann, R. Fischer, A. Güth, T. Hebbeker, C. Heidemann, K. Hoepfner, D. Klingebiel, S. Knutzen, P. Kreuzer, M. Merschmeyer, A. Meyer, P. Millet, M. Olschewski, K. Padeken, P. Papacz, H. Reithler, S.A. Schmitz, L. Sonnenschein, D. Teyssier, S. Thüer

RWTH Aachen University, III. Physikalisches Institut B, Aachen, Germany
V. Cherepanov, Y. Erdogan, G. Flügge, H. Geenen, M. Geisler, W. Haj Ahmad, F. Hoehle, B. Kargoll, T. Kress, Y. Kuessel, A. Künsken, J. Lingemann[2], A. Nowack, I.M. Nugent, C. Pistone, O. Pooth, A. Stahl

Deutsches Elektronen-Synchrotron, Hamburg, Germany
M. Aldaya Martin, I. Asin, N. Bartosik, J. Behr, U. Behrens, A.J. Bell, A. Bethani, K. Borras, A. Burgmeier, A. Cakir, L. Calligaris, A. Campbell, S. Choudhury, F. Costanza, C. Diez Pardos, G. Dolinska, S. Dooling, T. Dorland, G. Eckerlin, D. Eckstein, T. Eichhorn, G. Flucke, J. Garay Garcia, A. Geiser, A. Gizhko, P. Gunnellini, J. Hauk, M. Hempel[15], H. Jung, A. Kalogeropoulos, O. Karacheban[15], M. Kasemann, P. Katsas, J. Kieseler, C. Kleinwort, I. Korol,

D. Krücker, W. Lange, J. Leonard, K. Lipka, A. Lobanov, W. Lohmann[15], B. Lutz, R. Mankel, I. Marfin[15], I.-A. Melzer-Pellmann, A.B. Meyer, G. Mittag, J. Mnich, A. Mussgiller, S. Naumann-Emme, A. Nayak, E. Ntomari, H. Perrey, D. Pitzl, R. Placakyte, A. Raspereza, P.M. Ribeiro Cipriano, B. Roland, E. Ron, M.Ö. Sahin, J. Salfeld-Nebgen, P. Saxena, T. Schoerner-Sadenius, M. Schröder, C. Seitz, S. Spannagel, A.D.R. Vargas Trevino, R. Walsh, C. Wissing

University of Hamburg, Hamburg, Germany
V. Blobel, M. Centis Vignali, A.R. Draeger, J. Erfle, E. Garutti, K. Goebel, M. Görner, J. Haller, M. Hoffmann, R.S. Höing, A. Junkes, H. Kirschenmann, R. Klanner, R. Kogler, T. Lapsien, T. Lenz, I. Marchesini, D. Marconi, J. Ott, T. Peiffer, A. Perieanu, N. Pietsch, J. Poehlsen, T. Poehlsen, D. Rathjens, C. Sander, H. Schettler, P. Schleper, E. Schlieckau, A. Schmidt, M. Seidel, V. Sola, H. Stadie, G. Steinbrück, D. Troendle, E. Usai, L. Vanelderen, A. Vanhoefer

Institut für Experimentelle Kernphysik, Karlsruhe, Germany
C. Barth, C. Baus, J. Berger, C. Böser, E. Butz, T. Chwalek, W. De Boer, A. Descroix, A. Dierlamm, M. Feindt, F. Frensch, M. Giffels, A. Gilbert, F. Hartmann[2], T. Hauth, U. Husemann, I. Katkov[5], A. Kornmayer[2], P. Lobelle Pardo, M.U. Mozer, T. Müller, Th. Müller, A. Nürnberg, G. Quast, K. Rabbertz, S. Röcker, H.J. Simonis, F.M. Stober, R. Ulrich, J. Wagner-Kuhr, S. Wayand, T. Weiler, R. Wolf

Institute of Nuclear and Particle Physics (INPP), NCSR Demokritos, Aghia Paraskevi, Greece
G. Anagnostou, G. Daskalakis, T. Geralis, V.A. Giakoumopoulou, A. Kyriakis, D. Loukas, A. Markou, C. Markou, A. Psallidas, I. Topsis-Giotis

University of Athens, Athens, Greece
A. Agapitos, S. Kesisoglou, A. Panagiotou, N. Saoulidou, E. Stiliaris, E. Tziaferi

University of Ioánnina, Ioánnina, Greece
X. Aslanoglou, I. Evangelou, G. Flouris, C. Foudas, P. Kokkas, N. Manthos, I. Papadopoulos, E. Paradas, J. Strologas

Wigner Research Centre for Physics, Budapest, Hungary
G. Bencze, C. Hajdu, P. Hidas, D. Horvath[16], F. Sikler, V. Veszpremi, G. Vesztergombi[17], A.J. Zsigmond

Institute of Nuclear Research ATOMKI, Debrecen, Hungary
N. Beni, S. Czellar, J. Karancsi[18], J. Molnar, J. Palinkas, Z. Szillasi

University of Debrecen, Debrecen, Hungary
A. Makovec, P. Raics, Z.L. Trocsanyi, B. Ujvari

National Institute of Science Education and Research, Bhubaneswar, India
S.K. Swain

Panjab University, Chandigarh, India
S.B. Beri, V. Bhatnagar, R. Gupta, U.Bhawandeep, A.K. Kalsi, M. Kaur, R. Kumar, M. Mittal, N. Nishu, J.B. Singh

University of Delhi, Delhi, India
Ashok Kumar, Arun Kumar, S. Ahuja, A. Bhardwaj, B.C. Choudhary, A. Kumar, S. Malhotra, M. Naimuddin, K. Ranjan, V. Sharma

Saha Institute of Nuclear Physics, Kolkata, India
S. Banerjee, S. Bhattacharya, K. Chatterjee, S. Dutta, B. Gomber, Sa. Jain, Sh. Jain, R. Khurana, A. Modak, S. Mukherjee, D. Roy, S. Sarkar, M. Sharan

Bhabha Atomic Research Centre, Mumbai, India
A. Abdulsalam, D. Dutta, V. Kumar, A.K. Mohanty[2], L.M. Pant, P. Shukla, A. Topkar

Tata Institute of Fundamental Research, Mumbai, India
T. Aziz, S. Banerjee, S. Bhowmik[19], R.M. Chatterjee, R.K. Dewanjee, S. Dugad, S. Ganguly, S. Ghosh, M. Guchait, A. Gurtu[20], G. Kole, S. Kumar, M. Maity[19], G. Majumder, K. Mazumdar, G.B. Mohanty, B. Parida, K. Sudhakar, N. Wickramage[21]

Indian Institute of Science Education and Research (IISER), Pune, India
S. Sharma

Institute for Research in Fundamental Sciences (IPM), Tehran, Iran
H. Bakhshiansohi, H. Behnamian, S.M. Etesami[22], A. Fahim[23], R. Goldouzian, M. Khakzad, M. Mohammadi Najafabadi, M. Naseri, S. Paktinat Mehdiabadi, F. Rezaei Hosseinabadi, B. Safarzadeh[24], M. Zeinali

University College Dublin, Dublin, Ireland
M. Felcini, M. Grunewald

INFN Sezione di Bari [a], Università di Bari [b], Politecnico di Bari [c], Bari, Italy
M. Abbrescia[a,b], C. Calabria[a,b], S.S. Chhibra[a,b], A. Colaleo[a], D. Creanza[a,c], L. Cristella[a,b], N. De Filippis[a,c], M. De Palma[a,b], L. Fiore[a], G. Iaselli[a,c], G. Maggi[a,c], M. Maggi[a], S. My[a,c], S. Nuzzo[a,b], A. Pompili[a,b], G. Pugliese[a,c], R. Radogna[a,b,2], G. Selvaggi[a,b], A. Sharma[a], L. Silvestris[a,2], R. Venditti[a,b], P. Verwilligen[a]

INFN Sezione di Bologna [a], Università di Bologna [b], Bologna, Italy
G. Abbiendi[a], A.C. Benvenuti[a], D. Bonacorsi[a,b], S. Braibant-Giacomelli[a,b], L. Brigliadori[a,b], R. Campanini[a,b], P. Capiluppi[a,b], A. Castro[a,b], F.R. Cavallo[a], G. Codispoti[a,b], M. Cuffiani[a,b], G.M. Dallavalle[a], F. Fabbri[a], A. Fanfani[a,b], D. Fasanella[a,b], P. Giacomelli[a], C. Grandi[a], L. Guiducci[a,b], S. Marcellini[a], G. Masetti[a], A. Montanari[a], F.L. Navarria[a,b], A. Perrotta[a], A.M. Rossi[a,b], T. Rovelli[a,b], G.P. Siroli[a,b], N. Tosi[a,b], R. Travaglini[a,b]

INFN Sezione di Catania [a], Università di Catania [b], CSFNSM [c], Catania, Italy
S. Albergo[a,b], G. Cappello[a], M. Chiorboli[a,b], S. Costa[a,b], F. Giordano[a,2], R. Potenza[a,b], A. Tricomi[a,b], C. Tuve[a,b]

INFN Sezione di Firenze [a], Università di Firenze [b], Firenze, Italy
G. Barbagli[a], V. Ciulli[a,b], C. Civinini[a], R. D'Alessandro[a,b], E. Focardi[a,b], E. Gallo[a], S. Gonzi[a,b], V. Gori[a,b], P. Lenzi[a,b], M. Meschini[a], S. Paoletti[a], G. Sguazzoni[a], A. Tropiano[a,b]

INFN Laboratori Nazionali di Frascati, Frascati, Italy
L. Benussi, S. Bianco, F. Fabbri, D. Piccolo

INFN Sezione di Genova [a], Università di Genova [b], Genova, Italy
R. Ferretti[a,b], F. Ferro[a], M. Lo Vetere[a,b], E. Robutti[a], S. Tosi[a,b]

INFN Sezione di Milano-Bicocca [a], Università di Milano-Bicocca [b], Milano, Italy
M.E. Dinardo[a,b], S. Fiorendi[a,b], S. Gennai[a,2], R. Gerosa[a,b,2], A. Ghezzi[a,b], P. Govoni[a,b], M.T. Lucchini[a,b,2], S. Malvezzi[a], R.A. Manzoni[a,b], A. Martelli[a,b], B. Marzocchi[a,b,2], D. Menasce[a], L. Moroni[a], M. Paganoni[a,b], D. Pedrini[a], S. Ragazzi[a,b], N. Redaelli[a], T. Tabarelli de Fatis[a,b]

INFN Sezione di Napoli [a], Università di Napoli 'Federico II' [b], Università della Basilicata (Potenza) [c], Università G. Marconi (Roma) [d], Napoli, Italy
S. Buontempo[a], N. Cavallo[a,c], S. Di Guida[a,d,2], F. Fabozzi[a,c], A.O.M. Iorio[a,b], L. Lista[a], S. Meola[a,d,2], M. Merola[a], P. Paolucci[a,2]

INFN Sezione di Padova [a], Università di Padova [b], Università di Trento (Trento) [c], Padova, Italy
P. Azzi[a], N. Bacchetta[a], D. Bisello[a,b], R. Carlin[a,b], P. Checchia[a], M. Dall'Osso[a,b], T. Dorigo[a], F. Gasparini[a,b], U. Gasparini[a,b], A. Gozzelino[a], M. Gulmini[a,25], K. Kanishchev[a,c], S. Lacaprara[a], M. Margoni[a,b], A.T. Meneguzzo[a,b], M. Passaseo[a], J. Pazzini[a,b], N. Pozzobon[a,b], P. Ronchese[a,b], F. Simonetto[a,b], E. Torassa[a], M. Tosi[a,b], P. Zotto[a,b], A. Zucchetta[a,b], G. Zumerle[a,b]

INFN Sezione di Pavia [a], Università di Pavia [b], Pavia, Italy
M. Gabusi[a,b], S.P. Ratti[a,b], V. Re[a], C. Riccardi[a,b], P. Salvini[a], P. Vitulo[a,b]

INFN Sezione di Perugia [a], Università di Perugia [b], Perugia, Italy
M. Biasini[a,b], G.M. Bilei[a], D. Ciangottini[a,b,2], L. Fanò[a,b], P. Lariccia[a,b], G. Mantovani[a,b], M. Menichelli[a], A. Saha[a], A. Santocchia[a,b], A. Spiezia[a,b,2]

INFN Sezione di Pisa [a], Università di Pisa [b], Scuola Normale Superiore di Pisa [c], Pisa, Italy
K. Androsov[a,26], P. Azzurri[a], G. Bagliesi[a], J. Bernardini[a], T. Boccali[a], G. Broccolo[a,c], R. Castaldi[a], M.A. Ciocci[a,26], R. Dell'Orso[a], S. Donato[a,c,2], G. Fedi, F. Fiori[a,c], L. Foà[a,c], A. Giassi[a], M.T. Grippo[a,26], F. Ligabue[a,c], T. Lomtadze[a], L. Martini[a,b], A. Messineo[a,b], C.S. Moon[a,27], F. Palla[a,2], A. Rizzi[a,b], A. Savoy-Navarro[a,28], A.T. Serban[a], P. Spagnolo[a], P. Squillacioti[a,26], R. Tenchini[a], G. Tonelli[a,b], A. Venturi[a], P.G. Verdini[a], C. Vernieri[a,c]

INFN Sezione di Roma [a], Università di Roma [b], Roma, Italy
L. Barone[a,b], F. Cavallari[a], G. D'imperio[a,b], D. Del Re[a,b], M. Diemoz[a], C. Jorda[a], E. Longo[a,b], F. Margaroli[a,b], P. Meridiani[a], F. Micheli[a,b,2], G. Organtini[a,b], R. Paramatti[a], S. Rahatlou[a,b], C. Rovelli[a], F. Santanastasio[a,b], L. Soffi[a,b], P. Traczyk[a,b,2]

INFN Sezione di Torino [a], Università di Torino [b], Università del Piemonte Orientale (Novara) [c], Torino, Italy
N. Amapane[a,b], R. Arcidiacono[a,c], S. Argiro[a,b], M. Arneodo[a,c], R. Bellan[a,b], C. Biino[a], N. Cartiglia[a], S. Casasso[a,b,2], M. Costa[a,b], R. Covarelli, A. Degano[a,b], N. Demaria[a], L. Finco[a,b,2], C. Mariotti[a], S. Maselli[a], E. Migliore[a,b], V. Monaco[a,b], M. Musich[a], M.M. Obertino[a,c], L. Pacher[a,b], N. Pastrone[a], M. Pelliccioni[a], G.L. Pinna Angioni[a,b], A. Potenza[a,b], A. Romero[a,b], M. Ruspa[a,c], R. Sacchi[a,b], A. Solano[a,b], A. Staiano[a], U. Tamponi[a]

INFN Sezione di Trieste [a], Università di Trieste [b], Trieste, Italy
S. Belforte[a], V. Candelise[a,b,2], M. Casarsa[a], F. Cossutti[a], G. Della Ricca[a,b], B. Gobbo[a], C. La Licata[a,b], M. Marone[a,b], A. Schizzi[a,b], T. Umer[a,b], A. Zanetti[a]

Kangwon National University, Chunchon, Korea
S. Chang, A. Kropivnitskaya, S.K. Nam

Kyungpook National University, Daegu, Korea
D.H. Kim, G.N. Kim, M.S. Kim, D.J. Kong, S. Lee, Y.D. Oh, H. Park, A. Sakharov, D.C. Son

Chonbuk National University, Jeonju, Korea
T.J. Kim, M.S. Ryu

Chonnam National University, Institute for Universe and Elementary Particles, Kwangju, Korea
J.Y. Kim, D.H. Moon, S. Song

Korea University, Seoul, Korea
S. Choi, D. Gyun, B. Hong, M. Jo, H. Kim, Y. Kim, B. Lee, K.S. Lee, S.K. Park, Y. Roh

Seoul National University, Seoul, Korea
H.D. Yoo

University of Seoul, Seoul, Korea
M. Choi, J.H. Kim, I.C. Park, G. Ryu

Sungkyunkwan University, Suwon, Korea
Y. Choi, Y.K. Choi, J. Goh, D. Kim, E. Kwon, J. Lee, I. Yu

Vilnius University, Vilnius, Lithuania
A. Juodagalvis

National Centre for Particle Physics, Universiti Malaya, Kuala Lumpur, Malaysia
J.R. Komaragiri, M.A.B. Md Ali, W.A.T. Wan Abdullah

Centro de Investigacion y de Estudios Avanzados del IPN, Mexico City, Mexico
E. Casimiro Linares, H. Castilla-Valdez, E. De La Cruz-Burelo, I. Heredia-de La Cruz, A. Hernandez-Almada, R. Lopez-Fernandez, A. Sanchez-Hernandez

Universidad Iberoamericana, Mexico City, Mexico
S. Carrillo Moreno, F. Vazquez Valencia

Benemerita Universidad Autonoma de Puebla, Puebla, Mexico
I. Pedraza, H.A. Salazar Ibarguen

Universidad Autónoma de San Luis Potosí, San Luis Potosí, Mexico
A. Morelos Pineda

University of Auckland, Auckland, New Zealand
D. Krofcheck

University of Canterbury, Christchurch, New Zealand
P.H. Butler, S. Reucroft

National Centre for Physics, Quaid-I-Azam University, Islamabad, Pakistan
A. Ahmad, M. Ahmad, Q. Hassan, H.R. Hoorani, W.A. Khan, T. Khurshid, M. Shoaib

National Centre for Nuclear Research, Swierk, Poland
H. Bialkowska, M. Bluj, B. Boimska, T. Frueboes, M. Górski, M. Kazana, K. Nawrocki, K. Romanowska-Rybinska, M. Szleper, P. Zalewski

Institute of Experimental Physics, Faculty of Physics, University of Warsaw, Warsaw, Poland
G. Brona, K. Bunkowski, M. Cwiok, W. Dominik, K. Doroba, A. Kalinowski, M. Konecki, J. Krolikowski, M. Misiura, M. Olszewski

Laboratório de Instrumentação e Física Experimental de Partículas, Lisboa, Portugal
P. Bargassa, C. Beirão Da Cruz E Silva, P. Faccioli, P.G. Ferreira Parracho, M. Gallinaro, L. Lloret Iglesias, F. Nguyen, J. Rodrigues Antunes, J. Seixas, J. Varela, P. Vischia

Joint Institute for Nuclear Research, Dubna, Russia
M. Gavrilenko, I. Golutvin, A. Kamenev, V. Karjavin, V. Konoplyanikov, V. Korenkov, G. Kozlov, A. Lanev, A. Malakhov, V. Matveev[29], V.V. Mitsyn, P. Moisenz, V. Palichik, V. Perelygin, S. Shmatov, V. Smirnov, E. Tikhonenko, A. Zarubin

Petersburg Nuclear Physics Institute, Gatchina (St. Petersburg), Russia
V. Golovtsov, Y. Ivanov, V. Kim[30], E. Kuznetsova, P. Levchenko, V. Murzin, V. Oreshkin, I. Smirnov, V. Sulimov, L. Uvarov, S. Vavilov, A. Vorobyev, An. Vorobyev

Institute for Nuclear Research, Moscow, Russia
Yu. Andreev, A. Dermenev, S. Gninenko, N. Golubev, M. Kirsanov, N. Krasnikov, A. Pashenkov, D. Tlisov, A. Toropin

Institute for Theoretical and Experimental Physics, Moscow, Russia
V. Epshteyn, V. Gavrilov, N. Lychkovskaya, V. Popov, I. Pozdnyakov, G. Safronov, S. Semenov, A. Spiridonov, V. Stolin, E. Vlasov, A. Zhokin

P.N. Lebedev Physical Institute, Moscow, Russia
V. Andreev, M. Azarkin[31], I. Dremin[31], M. Kirakosyan, A. Leonidov[31], G. Mesyats, S.V. Rusakov, A. Vinogradov

Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia
A. Belyaev, E. Boos, M. Dubinin[32], L. Dudko, A. Ershov, A. Gribushin, V. Klyukhin, O. Kodolova, I. Lokhtin, S. Obraztsov, S. Petrushanko, V. Savrin, A. Snigirev

State Research Center of Russian Federation, Institute for High Energy Physics, Protvino, Russia
I. Azhgirey, I. Bayshev, S. Bitioukov, V. Kachanov, A. Kalinin, D. Konstantinov, V. Krychkine, V. Petrov, R. Ryutin, A. Sobol, L. Tourtchanovitch, S. Troshin, N. Tyurin, A. Uzunian, A. Volkov

University of Belgrade, Faculty of Physics and Vinca Institute of Nuclear Sciences, Belgrade, Serbia
P. Adzic[33], M. Ekmedzic, J. Milosevic, V. Rekovic

Centro de Investigaciones Energéticas Medioambientales y Tecnológicas (CIEMAT), Madrid, Spain
J. Alcaraz Maestre, C. Battilana, E. Calvo, M. Cerrada, M. Chamizo Llatas, N. Colino, B. De La Cruz, A. Delgado Peris, D. Domínguez Vázquez, A. Escalante Del Valle, C. Fernandez Bedoya, J.P. Fernández Ramos, J. Flix, M.C. Fouz, P. Garcia-Abia, O. Gonzalez Lopez, S. Goy Lopez, J.M. Hernandez, M.I. Josa, E. Navarro De Martino, A. Pérez-Calero Yzquierdo, J. Puerta Pelayo, A. Quintario Olmeda, I. Redondo, L. Romero, M.S. Soares

Universidad Autónoma de Madrid, Madrid, Spain
C. Albajar, J.F. de Trocóniz, M. Missiroli, D. Moran

Universidad de Oviedo, Oviedo, Spain
H. Brun, J. Cuevas, J. Fernandez Menendez, S. Folgueras, I. Gonzalez Caballero

Instituto de Física de Cantabria (IFCA), CSIC-Universidad de Cantabria, Santander, Spain
J.A. Brochero Cifuentes, I.J. Cabrillo, A. Calderon, J. Duarte Campderros, M. Fernandez, G. Gomez, A. Graziano, A. Lopez Virto, J. Marco, R. Marco, C. Martinez Rivero, F. Matorras, F.J. Munoz Sanchez, J. Piedra Gomez, T. Rodrigo, A.Y. Rodríguez-Marrero, A. Ruiz-Jimeno, L. Scodellaro, I. Vila, R. Vilar Cortabitarte

CERN, European Organization for Nuclear Research, Geneva, Switzerland
D. Abbaneo, E. Auffray, G. Auzinger, M. Bachtis, P. Baillon, A.H. Ball, D. Barney, A. Benaglia, J. Bendavid, L. Benhabib, J.F. Benitez, P. Bloch, A. Bocci, A. Bonato, O. Bondu, C. Botta, H. Breuker, T. Camporesi, G. Cerminara, S. Colafranceschi[34], M. D'Alfonso, D. d'Enterria, A. Dabrowski, A. David, F. De Guio, A. De Roeck, S. De Visscher, E. Di Marco, M. Dobson,

M. Dordevic, B. Dorney, N. Dupont-Sagorin, A. Elliott-Peisert, G. Franzoni, W. Funk, D. Gigi, K. Gill, D. Giordano, M. Girone, F. Glege, R. Guida, S. Gundacker, M. Guthoff, J. Hammer, M. Hansen, P. Harris, J. Hegeman, V. Innocente, P. Janot, K. Kousouris, K. Krajczar, P. Lecoq, C. Lourenço, N. Magini, L. Malgeri, M. Mannelli, J. Marrouche, L. Masetti, F. Meijers, S. Mersi, E. Meschi, F. Moortgat, S. Morovic, M. Mulders, L. Orsini, L. Pape, E. Perez, A. Petrilli, G. Petrucciani, A. Pfeiffer, M. Pimiä, D. Piparo, M. Plagge, A. Racz, G. Rolandi[35], M. Rovere, H. Sakulin, C. Schäfer, C. Schwick, A. Sharma, P. Siegrist, P. Silva, M. Simon, P. Sphicas[36], D. Spiga, J. Steggemann, B. Stieger, M. Stoye, Y. Takahashi, D. Treille, A. Tsirou, G.I. Veres[17], N. Wardle, H.K. Wöhri, H. Wollny, W.D. Zeuner

Paul Scherrer Institut, Villigen, Switzerland
W. Bertl, K. Deiters, W. Erdmann, R. Horisberger, Q. Ingram, H.C. Kaestli, D. Kotlinski, U. Langenegger, D. Renker, T. Rohe

Institute for Particle Physics, ETH Zurich, Zurich, Switzerland
F. Bachmair, L. Bäni, L. Bianchini, M.A. Buchmann, B. Casal, N. Chanon, G. Dissertori, M. Dittmar, M. Donegà, M. Dünser, P. Eller, C. Grab, D. Hits, J. Hoss, G. Kasieczka, W. Lustermann, B. Mangano, A.C. Marini, M. Marionneau, P. Martinez Ruiz del Arbol, M. Masciovecchio, D. Meister, N. Mohr, P. Musella, C. Nägeli[37], F. Nessi-Tedaldi, F. Pandolfi, F. Pauss, L. Perrozzi, M. Peruzzi, M. Quittnat, L. Rebane, M. Rossini, A. Starodumov[38], M. Takahashi, K. Theofilatos, R. Wallny, H.A. Weber

Universität Zürich, Zurich, Switzerland
C. Amsler[39], M.F. Canelli, V. Chiochia, A. De Cosa, A. Hinzmann, T. Hreus, B. Kilminster, C. Lange, J. Ngadiuba, D. Pinna, P. Robmann, F.J. Ronga, S. Taroni, Y. Yang

National Central University, Chung-Li, Taiwan
M. Cardaci, K.H. Chen, C. Ferro, C.M. Kuo, W. Lin, Y.J. Lu, R. Volpe, S.S. Yu

National Taiwan University (NTU), Taipei, Taiwan
P. Chang, Y.H. Chang, Y. Chao, K.F. Chen, P.H. Chen, C. Dietz, U. Grundler, W.-S. Hou, Y.F. Liu, R.-S. Lu, M. Miñano Moya, E. Petrakou, Y.M. Tzeng, R. Wilken

Chulalongkorn University, Faculty of Science, Department of Physics, Bangkok, Thailand
B. Asavapibhop, G. Singh, N. Srimanobhas, N. Suwonjandee

Cukurova University, Adana, Turkey
A. Adiguzel, M.N. Bakirci[40], S. Cerci[41], C. Dozen, I. Dumanoglu, E. Eskut, S. Girgis, G. Gokbulut, Y. Guler, E. Gurpinar, I. Hos, E.E. Kangal[42], A. Kayis Topaksu, G. Onengut[43], K. Ozdemir[44], S. Ozturk[40], A. Polatoz, D. Sunar Cerci[41], B. Tali[41], H. Topakli[40], M. Vergili, C. Zorbilmez

Middle East Technical University, Physics Department, Ankara, Turkey
I.V. Akin, B. Bilin, S. Bilmis, H. Gamsizkan[45], B. Isildak[46], G. Karapinar[47], K. Ocalan[48], S. Sekmen, U.E. Surat, M. Yalvac, M. Zeyrek

Bogazici University, Istanbul, Turkey
E.A. Albayrak[49], E. Gülmez, M. Kaya[50], O. Kaya[51], T. Yetkin[52]

Istanbul Technical University, Istanbul, Turkey
K. Cankocak, F.I. Vardarlı

National Scientific Center, Kharkov Institute of Physics and Technology, Kharkov, Ukraine
L. Levchuk, P. Sorokin

University of Bristol, Bristol, United Kingdom
J.J. Brooke, E. Clement, D. Cussans, H. Flacher, J. Goldstein, M. Grimes, G.P. Heath, H.F. Heath, J. Jacob, L. Kreczko, C. Lucas, Z. Meng, D.M. Newbold[53], S. Paramesvaran, A. Poll, T. Sakuma, S. Seif El Nasr-storey, S. Senkin, V.J. Smith

Rutherford Appleton Laboratory, Didcot, United Kingdom
K.W. Bell, A. Belyaev[54], C. Brew, R.M. Brown, D.J.A. Cockerill, J.A. Coughlan, K. Harder, S. Harper, E. Olaiya, D. Petyt, C.H. Shepherd-Themistocleous, A. Thea, I.R. Tomalin, T. Williams, W.J. Womersley, S.D. Worm

Imperial College, London, United Kingdom
M. Baber, R. Bainbridge, O. Buchmuller, D. Burton, D. Colling, N. Cripps, P. Dauncey, G. Davies, M. Della Negra, P. Dunne, A. Elwood, W. Ferguson, J. Fulcher, D. Futyan, G. Hall, G. Iles, M. Jarvis, G. Karapostoli, M. Kenzie, R. Lane, R. Lucas[53], L. Lyons, A.-M. Magnan, S. Malik, B. Mathias, J. Nash, A. Nikitenko[38], J. Pela, M. Pesaresi, K. Petridis, D.M. Raymond, S. Rogerson, A. Rose, C. Seez, P. Sharp[†], A. Tapper, M. Vazquez Acosta, T. Virdee, S.C. Zenz

Brunel University, Uxbridge, United Kingdom
J.E. Cole, P.R. Hobson, A. Khan, P. Kyberd, D. Leggat, D. Leslie, I.D. Reid, P. Symonds, L. Teodorescu, M. Turner

Baylor University, Waco, USA
J. Dittmann, K. Hatakeyama, A. Kasmi, H. Liu, N. Pastika, T. Scarborough, Z. Wu

The University of Alabama, Tuscaloosa, USA
O. Charaf, S.I. Cooper, C. Henderson, P. Rumerio

Boston University, Boston, USA
A. Avetisyan, T. Bose, C. Fantasia, P. Lawson, C. Richardson, J. Rohlf, J. St. John, L. Sulak

Brown University, Providence, USA
J. Alimena, E. Berry, S. Bhattacharya, G. Christopher, D. Cutts, Z. Demiragli, N. Dhingra, A. Ferapontov, A. Garabedian, U. Heintz, E. Laird, G. Landsberg, Z. Mao, M. Narain, S. Sagir, T. Sinthuprasith, T. Speer, J. Swanson

University of California, Davis, Davis, USA
R. Breedon, G. Breto, M. Calderon De La Barca Sanchez, S. Chauhan, M. Chertok, J. Conway, R. Conway, P.T. Cox, R. Erbacher, M. Gardner, W. Ko, R. Lander, M. Mulhearn, D. Pellett, J. Pilot, F. Ricci-Tam, S. Shalhout, J. Smith, M. Squires, D. Stolp, M. Tripathi, S. Wilbur, R. Yohay

University of California, Los Angeles, USA
R. Cousins, P. Everaerts, C. Farrell, J. Hauser, M. Ignatenko, G. Rakness, E. Takasugi, V. Valuev, M. Weber

University of California, Riverside, Riverside, USA
K. Burt, R. Clare, J. Ellison, J.W. Gary, G. Hanson, J. Heilman, M. Ivova Rikova, P. Jandir, E. Kennedy, F. Lacroix, O.R. Long, A. Luthra, M. Malberti, M. Olmedo Negrete, A. Shrinivas, S. Sumowidagdo, S. Wimpenny

University of California, San Diego, La Jolla, USA
J.G. Branson, G.B. Cerati, S. Cittolin, R.T. D'Agnolo, A. Holzner, R. Kelley, D. Klein, J. Letts, I. Macneill, D. Olivito, S. Padhi, C. Palmer, M. Pieri, M. Sani, V. Sharma, S. Simon, M. Tadel, Y. Tu, A. Vartak, C. Welke, F. Würthwein, A. Yagil, G. Zevi Della Porta

University of California, Santa Barbara, Santa Barbara, USA
D. Barge, J. Bradmiller-Feld, C. Campagnari, T. Danielson, A. Dishaw, V. Dutta, K. Flowers, M. Franco Sevilla, P. Geffert, C. George, F. Golf, L. Gouskos, J. Incandela, C. Justus, N. Mccoll, S.D. Mullin, J. Richman, D. Stuart, W. To, C. West, J. Yoo

California Institute of Technology, Pasadena, USA
A. Apresyan, A. Bornheim, J. Bunn, Y. Chen, J. Duarte, A. Mott, H.B. Newman, C. Pena, M. Pierini, M. Spiropulu, J.R. Vlimant, R. Wilkinson, S. Xie, R.Y. Zhu

Carnegie Mellon University, Pittsburgh, USA
V. Azzolini, A. Calamba, B. Carlson, T. Ferguson, Y. Iiyama, M. Paulini, J. Russ, H. Vogel, I. Vorobiev

University of Colorado at Boulder, Boulder, USA
J.P. Cumalat, W.T. Ford, A. Gaz, M. Krohn, E. Luiggi Lopez, U. Nauenberg, J.G. Smith, K. Stenson, S.R. Wagner

Cornell University, Ithaca, USA
J. Alexander, A. Chatterjee, J. Chaves, J. Chu, S. Dittmer, N. Eggert, N. Mirman, G. Nicolas Kaufman, J.R. Patterson, A. Ryd, E. Salvati, L. Skinnari, W. Sun, W.D. Teo, J. Thom, J. Thompson, J. Tucker, Y. Weng, L. Winstrom, P. Wittich

Fairfield University, Fairfield, USA
D. Winn

Fermi National Accelerator Laboratory, Batavia, USA
S. Abdullin, M. Albrow, J. Anderson, G. Apollinari, L.A.T. Bauerdick, A. Beretvas, J. Berryhill, P.C. Bhat, G. Bolla, K. Burkett, J.N. Butler, H.W.K. Cheung, F. Chlebana, S. Cihangir, V.D. Elvira, I. Fisk, J. Freeman, E. Gottschalk, L. Gray, D. Green, S. Grünendahl, O. Gutsche, J. Hanlon, D. Hare, R.M. Harris, J. Hirschauer, B. Hooberman, S. Jindariani, M. Johnson, U. Joshi, B. Klima, B. Kreis, S. Kwan[†], J. Linacre, D. Lincoln, R. Lipton, T. Liu, R. Lopes De Sá, J. Lykken, K. Maeshima, J.M. Marraffino, V.I. Martinez Outschoorn, S. Maruyama, D. Mason, P. McBride, P. Merkel, K. Mishra, S. Mrenna, S. Nahn, C. Newman-Holmes, V. O'Dell, O. Prokofyev, E. Sexton-Kennedy, A. Soha, W.J. Spalding, L. Spiegel, L. Taylor, S. Tkaczyk, N.V. Tran, L. Uplegger, E.W. Vaandering, R. Vidal, A. Whitbeck, J. Whitmore, F. Yang

University of Florida, Gainesville, USA
D. Acosta, P. Avery, P. Bortignon, D. Bourilkov, M. Carver, D. Curry, S. Das, M. De Gruttola, G.P. Di Giovanni, R.D. Field, M. Fisher, I.K. Furic, J. Hugon, J. Konigsberg, A. Korytov, T. Kypreos, J.F. Low, K. Matchev, H. Mei, P. Milenovic[55], G. Mitselmakher, L. Muniz, A. Rinkevicius, L. Shchutska, M. Snowball, D. Sperka, J. Yelton, M. Zakaria

Florida International University, Miami, USA
S. Hewamanage, S. Linn, P. Markowitz, G. Martinez, J.L. Rodriguez

Florida State University, Tallahassee, USA
J.R. Adams, T. Adams, A. Askew, J. Bochenek, B. Diamond, J. Haas, S. Hagopian, V. Hagopian, K.F. Johnson, H. Prosper, V. Veeraraghavan, M. Weinberg

Florida Institute of Technology, Melbourne, USA
M.M. Baarmand, M. Hohlmann, H. Kalakhety, F. Yumiceva

University of Illinois at Chicago (UIC), Chicago, USA
M.R. Adams, L. Apanasevich, D. Berry, R.R. Betts, I. Bucinskaite, R. Cavanaugh, O. Evdokimov,

L. Gauthier, C.E. Gerber, D.J. Hofman, P. Kurt, C. O'Brien, I.D. Sandoval Gonzalez, C. Silkworth, P. Turner, N. Varelas

The University of Iowa, Iowa City, USA
B. Bilki[56], W. Clarida, K. Dilsiz, M. Haytmyradov, J.-P. Merlo, H. Mermerkaya[57], A. Mestvirishvili, A. Moeller, J. Nachtman, H. Ogul, Y. Onel, F. Ozok[49], A. Penzo, R. Rahmat, S. Sen, P. Tan, E. Tiras, J. Wetzel, K. Yi

Johns Hopkins University, Baltimore, USA
I. Anderson, B.A. Barnett, B. Blumenfeld, S. Bolognesi, D. Fehling, A.V. Gritsan, P. Maksimovic, C. Martin, M. Swartz, M. Xiao

The University of Kansas, Lawrence, USA
P. Baringer, A. Bean, G. Benelli, C. Bruner, J. Gray, R.P. Kenny III, D. Majumder, M. Malek, M. Murray, D. Noonan, S. Sanders, J. Sekaric, R. Stringer, Q. Wang, J.S. Wood

Kansas State University, Manhattan, USA
I. Chakaberia, A. Ivanov, K. Kaadze, S. Khalil, M. Makouski, Y. Maravin, L.K. Saini, N. Skhirtladze, I. Svintradze

Lawrence Livermore National Laboratory, Livermore, USA
J. Gronberg, D. Lange, F. Rebassoo, D. Wright

University of Maryland, College Park, USA
A. Baden, A. Belloni, B. Calvert, S.C. Eno, J.A. Gomez, N.J. Hadley, S. Jabeen, R.G. Kellogg, T. Kolberg, Y. Lu, A.C. Mignerey, K. Pedro, A. Skuja, M.B. Tonjes, S.C. Tonwar

Massachusetts Institute of Technology, Cambridge, USA
A. Apyan, R. Barbieri, K. Bierwagen, W. Busza, I.A. Cali, L. Di Matteo, G. Gomez Ceballos, M. Goncharov, D. Gulhan, M. Klute, Y.S. Lai, Y.-J. Lee, A. Levin, P.D. Luckey, C. Paus, D. Ralph, C. Roland, G. Roland, G.S.F. Stephans, K. Sumorok, D. Velicanu, J. Veverka, B. Wyslouch, M. Yang, M. Zanetti, V. Zhukova

University of Minnesota, Minneapolis, USA
B. Dahmes, A. Gude, S.C. Kao, K. Klapoetke, Y. Kubota, J. Mans, S. Nourbakhsh, R. Rusack, A. Singovsky, N. Tambe, J. Turkewitz

University of Mississippi, Oxford, USA
J.G. Acosta, S. Oliveros

University of Nebraska-Lincoln, Lincoln, USA
E. Avdeeva, K. Bloom, S. Bose, D.R. Claes, A. Dominguez, R. Gonzalez Suarez, J. Keller, D. Knowlton, I. Kravchenko, J. Lazo-Flores, F. Meier, F. Ratnikov, G.R. Snow, M. Zvada

State University of New York at Buffalo, Buffalo, USA
J. Dolen, A. Godshalk, I. Iashvili, A. Kharchilava, A. Kumar, S. Rappoccio

Northeastern University, Boston, USA
G. Alverson, E. Barberis, D. Baumgartel, M. Chasco, A. Massironi, D.M. Morse, D. Nash, T. Orimoto, D. Trocino, R.-J. Wang, D. Wood, J. Zhang

Northwestern University, Evanston, USA
K.A. Hahn, A. Kubik, N. Mucia, N. Odell, B. Pollack, A. Pozdnyakov, M. Schmitt, S. Stoynev, K. Sung, M. Velasco, S. Won

University of Notre Dame, Notre Dame, USA
A. Brinkerhoff, K.M. Chan, A. Drozdetskiy, M. Hildreth, C. Jessop, D.J. Karmgard, N. Kellams, K. Lannon, S. Lynch, N. Marinelli, Y. Musienko[29], T. Pearson, M. Planer, R. Ruchti, G. Smith, N. Valls, M. Wayne, M. Wolf, A. Woodard

The Ohio State University, Columbus, USA
L. Antonelli, J. Brinson, B. Bylsma, L.S. Durkin, S. Flowers, A. Hart, C. Hill, R. Hughes, K. Kotov, T.Y. Ling, W. Luo, D. Puigh, M. Rodenburg, B.L. Winer, H. Wolfe, H.W. Wulsin

Princeton University, Princeton, USA
O. Driga, P. Elmer, J. Hardenbrook, P. Hebda, S.A. Koay, P. Lujan, D. Marlow, T. Medvedeva, M. Mooney, J. Olsen, P. Piroué, X. Quan, H. Saka, D. Stickland[2], C. Tully, J.S. Werner, A. Zuranski

University of Puerto Rico, Mayaguez, USA
E. Brownson, S. Malik, H. Mendez, J.E. Ramirez Vargas

Purdue University, West Lafayette, USA
V.E. Barnes, D. Benedetti, D. Bortoletto, M. De Mattia, L. Gutay, Z. Hu, M.K. Jha, M. Jones, K. Jung, M. Kress, N. Leonardo, D.H. Miller, N. Neumeister, F. Primavera, B.C. Radburn-Smith, X. Shi, I. Shipsey, D. Silvers, A. Svyatkovskiy, F. Wang, W. Xie, L. Xu, J. Zablocki

Purdue University Calumet, Hammond, USA
N. Parashar, J. Stupak

Rice University, Houston, USA
A. Adair, B. Akgun, K.M. Ecklund, F.J.M. Geurts, W. Li, B. Michlin, B.P. Padley, R. Redjimi, J. Roberts, J. Zabel

University of Rochester, Rochester, USA
B. Betchart, A. Bodek, P. de Barbaro, R. Demina, Y. Eshaq, T. Ferbel, M. Galanti, A. Garcia-Bellido, P. Goldenzweig, J. Han, A. Harel, O. Hindrichs, A. Khukhunaishvili, S. Korjenevski, G. Petrillo, M. Verzetti, D. Vishnevskiy

The Rockefeller University, New York, USA
R. Ciesielski, L. Demortier, K. Goulianos, C. Mesropian

Rutgers, The State University of New Jersey, Piscataway, USA
S. Arora, A. Barker, J.P. Chou, C. Contreras-Campana, E. Contreras-Campana, D. Duggan, D. Ferencek, Y. Gershtein, R. Gray, E. Halkiadakis, D. Hidas, S. Kaplan, A. Lath, S. Panwalkar, M. Park, S. Salur, S. Schnetzer, D. Sheffield, S. Somalwar, R. Stone, S. Thomas, P. Thomassen, M. Walker

University of Tennessee, Knoxville, USA
K. Rose, S. Spanier, A. York

Texas A&M University, College Station, USA
O. Bouhali[58], A. Castaneda Hernandez, S. Dildick, R. Eusebi, W. Flanagan, J. Gilmore, T. Kamon[59], V. Khotilovich, V. Krutelyov, R. Montalvo, I. Osipenkov, Y. Pakhotin, R. Patel, A. Perloff, J. Roe, A. Rose, A. Safonov, I. Suarez, A. Tatarinov, K.A. Ulmer

Texas Tech University, Lubbock, USA
N. Akchurin, C. Cowden, J. Damgov, C. Dragoiu, P.R. Dudero, J. Faulkner, K. Kovitanggoon, S. Kunori, S.W. Lee, T. Libeiro, I. Volobouev

Vanderbilt University, Nashville, USA
E. Appelt, A.G. Delannoy, S. Greene, A. Gurrola, W. Johns, C. Maguire, Y. Mao, A. Melo, M. Sharma, P. Sheldon, B. Snook, S. Tuo, J. Velkovska

University of Virginia, Charlottesville, USA
M.W. Arenton, S. Boutle, B. Cox, B. Francis, J. Goodell, R. Hirosky, A. Ledovskoy, H. Li, C. Lin, C. Neu, E. Wolfe, J. Wood

Wayne State University, Detroit, USA
C. Clarke, R. Harr, P.E. Karchin, C. Kottachchi Kankanamge Don, P. Lamichhane, J. Sturdy

University of Wisconsin, Madison, USA
D.A. Belknap, D. Carlsmith, M. Cepeda, S. Dasu, L. Dodd, S. Duric, E. Friis, R. Hall-Wilton, M. Herndon, A. Hervé, P. Klabbers, A. Lanaro, C. Lazaridis, A. Levine, R. Loveless, A. Mohapatra, I. Ojalvo, T. Perry, G.A. Pierro, G. Polese, I. Ross, T. Sarangi, A. Savin, W.H. Smith, D. Taylor, C. Vuosalo, N. Woods

†: Deceased
1: Also at Vienna University of Technology, Vienna, Austria
2: Also at CERN, European Organization for Nuclear Research, Geneva, Switzerland
3: Also at Institut Pluridisciplinaire Hubert Curien, Université de Strasbourg, Université de Haute Alsace Mulhouse, CNRS/IN2P3, Strasbourg, France
4: Also at National Institute of Chemical Physics and Biophysics, Tallinn, Estonia
5: Also at Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia
6: Also at Universidade Estadual de Campinas, Campinas, Brazil
7: Also at Laboratoire Leprince-Ringuet, Ecole Polytechnique, IN2P3-CNRS, Palaiseau, France
8: Also at Joint Institute for Nuclear Research, Dubna, Russia
9: Also at Suez University, Suez, Egypt
10: Also at Cairo University, Cairo, Egypt
11: Also at Fayoum University, El-Fayoum, Egypt
12: Also at British University in Egypt, Cairo, Egypt
13: Now at Ain Shams University, Cairo, Egypt
14: Also at Université de Haute Alsace, Mulhouse, France
15: Also at Brandenburg University of Technology, Cottbus, Germany
16: Also at Institute of Nuclear Research ATOMKI, Debrecen, Hungary
17: Also at Eötvös Loránd University, Budapest, Hungary
18: Also at University of Debrecen, Debrecen, Hungary
19: Also at University of Visva-Bharati, Santiniketan, India
20: Now at King Abdulaziz University, Jeddah, Saudi Arabia
21: Also at University of Ruhuna, Matara, Sri Lanka
22: Also at Isfahan University of Technology, Isfahan, Iran
23: Also at University of Tehran, Department of Engineering Science, Tehran, Iran
24: Also at Plasma Physics Research Center, Science and Research Branch, Islamic Azad University, Tehran, Iran
25: Also at Laboratori Nazionali di Legnaro dell'INFN, Legnaro, Italy
26: Also at Università degli Studi di Siena, Siena, Italy
27: Also at Centre National de la Recherche Scientifique (CNRS) - IN2P3, Paris, France
28: Also at Purdue University, West Lafayette, USA
29: Also at Institute for Nuclear Research, Moscow, Russia
30: Also at St. Petersburg State Polytechnical University, St. Petersburg, Russia

31: Also at National Research Nuclear University "Moscow Engineering Physics Institute" (MEPhI), Moscow, Russia
32: Also at California Institute of Technology, Pasadena, USA
33: Also at Faculty of Physics, University of Belgrade, Belgrade, Serbia
34: Also at Facoltà Ingegneria, Università di Roma, Roma, Italy
35: Also at Scuola Normale e Sezione dell'INFN, Pisa, Italy
36: Also at University of Athens, Athens, Greece
37: Also at Paul Scherrer Institut, Villigen, Switzerland
38: Also at Institute for Theoretical and Experimental Physics, Moscow, Russia
39: Also at Albert Einstein Center for Fundamental Physics, Bern, Switzerland
40: Also at Gaziosmanpasa University, Tokat, Turkey
41: Also at Adiyaman University, Adiyaman, Turkey
42: Also at Mersin University, Mersin, Turkey
43: Also at Cag University, Mersin, Turkey
44: Also at Piri Reis University, Istanbul, Turkey
45: Also at Anadolu University, Eskisehir, Turkey
46: Also at Ozyegin University, Istanbul, Turkey
47: Also at Izmir Institute of Technology, Izmir, Turkey
48: Also at Necmettin Erbakan University, Konya, Turkey
49: Also at Mimar Sinan University, Istanbul, Istanbul, Turkey
50: Also at Marmara University, Istanbul, Turkey
51: Also at Kafkas University, Kars, Turkey
52: Also at Yildiz Technical University, Istanbul, Turkey
53: Also at Rutherford Appleton Laboratory, Didcot, United Kingdom
54: Also at School of Physics and Astronomy, University of Southampton, Southampton, United Kingdom
55: Also at University of Belgrade, Faculty of Physics and Vinca Institute of Nuclear Sciences, Belgrade, Serbia
56: Also at Argonne National Laboratory, Argonne, USA
57: Also at Erzincan University, Erzincan, Turkey
58: Also at Texas A&M University at Qatar, Doha, Qatar
59: Also at Kyungpook National University, Daegu, Korea