Editors' Suggestion

Observation of $WW\gamma$ Production and Search for $H\gamma$ Production in Proton-Proton Collisions at $\sqrt{s} = 13$ TeV

A. Hayrapetyan *et al.*[*]
(CMS Collaboration)

(Received 8 October 2023; accepted 31 January 2024; published 19 March 2024)

The observation of $WW\gamma$ production in proton-proton collisions at a center-of-mass energy of 13 TeV with an integrated luminosity of 138 fb^{-1} is presented. The observed (expected) significance is 5.6 (5.1) standard deviations. Events are selected by requiring exactly two leptons (one electron and one muon) of opposite charge, moderate missing transverse momentum, and a photon. The measured fiducial cross section for $WW\gamma$ is $5.9 \pm 0.8(\text{stat}) \pm 0.8(\text{syst}) \pm 0.7(\text{modeling})$ fb, in agreement with the next-to-leading order quantum chromodynamics prediction. The analysis is extended with a search for the associated production of the Higgs boson and a photon, which is generated by a coupling of the Higgs boson to light quarks. The result is used to constrain the Higgs boson couplings to light quarks.

DOI: 10.1103/PhysRevLett.132.121901

Measurements of multiple electroweak (EW) bosons produced at a common interaction vertex are a key to understanding the EW sector of the standard model (SM). The non-Abelian structure of the EW interaction predicts the presence of self-interactions among the vector bosons (W, Z, γ), leading to a rich variety of multiboson production mechanisms. Many multiboson processes are currently accessible only at the CERN LHC given the energies and integrated luminosities required to observe them. The CMS and ATLAS Collaborations have both recently observed the simultaneous production of three massive gauge bosons [1,2]. Additionally, ATLAS has reported the observation of $WZ\gamma$ [3] with an observed significance of 6.3 standard deviations. The double-photon production processes $W\gamma\gamma$ and $Z\gamma\gamma$ have also been measured by both CMS and ATLAS [4–6]. Searches for $WW\gamma$ production have previously been conducted by both CMS and ATLAS at a center-of-mass energy of 8 TeV [7,8] where only upper limits were set because of a lack of statistical power and sensitivity.

Triboson production includes not only the interactions involving triple and quartic gauge couplings (TGCs and QGCs), but also the mediation of the Higgs boson (H), providing an opportunity to measure or constrain Yukawa couplings. Deviations from theoretical predictions in the triboson measurements could provide indirect evidence of new particles or new interactions. Recently, proposals to exploit $H\gamma$ production to probe Higgs boson couplings with light (c, s, u, and d) quarks have been published [9–11]. Since the gluon-initiated contribution $gg \to H\gamma$ vanishes according to Furry's theorem [9,12], $H\gamma$ inclusive production at the LHC is directly related to the Higgs boson Yukawa couplings to the light quarks. Various interpretations [13–15] of the light quark Yukawa couplings were previously proposed. Similarly, gluon fusion production can constrain the light quark Yukawa couplings [16]. Recently, CMS reported a direct constraint on the charm quark Yukawa coupling modifier of $1.1 < |\kappa_c| < 5.5$ at 95% confidence level (C.L.) [17] and ATLAS provided an upper bound of $|\kappa_c| < 8.5$ at 95% C.L. [18]. However, the upper bounds on the strange quark Yukawa coupling are presently significantly less stringent [19,20].

The EW $e^+\nu_e\mu^-\bar{\nu}_\mu\gamma$ and $\mu^+\nu_\mu e^-\bar{\nu}_e\gamma$ production in proton-proton (pp) collisions at leading order (LO) can proceed via (i) initial-state radiation (ISR) from one of the incoming quarks; (ii) final-state radiation (FSR) from the outgoing charged leptons; (iii) the WWZ or $WW\gamma$ TGC; (iv) the $WWZ\gamma$ or $WW\gamma\gamma$ QGC; and (v) the associated production of the Higgs boson and a photon. Figure 1 shows examples of these processes. At higher orders in quantum chromodynamics (QCD) [21], additional quarks can appear in the final state, and photons can arise via FSR from an outgoing quark or lepton.

This Letter reports a first observation of $WW\gamma$ production as well as a search for $H\gamma$ production generated through the Higgs boson interactions with light quarks. The measurements are based on $\sqrt{s} = 13$ TeV pp collision data collected with the CMS detector during 2016–2018, with an integrated luminosity of 138 fb^{-1}. Tabulated results are provided in HEPData [22].

The central feature of the CMS apparatus is a superconducting solenoid of 6 m internal diameter, providing a

[*]Full author list given at the end of the Letter.

Published by the American Physical Society under the terms of the Creative Commons Attribution 4.0 International license. Further distribution of this work must maintain attribution to the author(s) and the published article's title, journal citation, and DOI. Funded by SCOAP[3].

 © 2024 CERN, for the CMS Collaboration

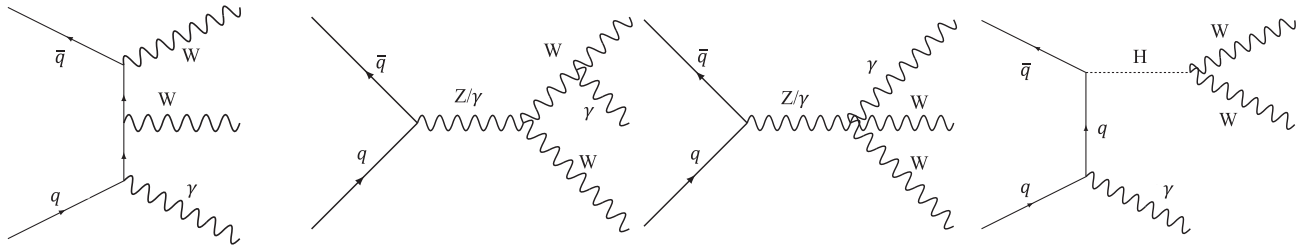

FIG. 1. Representative Feynman diagrams for the $WW\gamma$ process at LO, from left to right: ISR, TGC, QGC, and $H\gamma$ associated production.

magnetic field of 3.8 T. Within the magnetic field, there are silicon pixel and strip trackers plus several calorimeters, a lead tungstate crystal electromagnetic calorimeter (ECAL) and a brass-scintillator calorimeter; both of these are composed of a barrel and two end cap sections. The forward calorimeters extend the pseudorapidity (η) coverage provided by the barrel and end cap detectors. The particle-flow (PF) algorithm [23] reconstructs and identifies each individual particle in an event, with an optimized combination of information from the various elements of the CMS detector. Muons are detected in gas-ionization chambers embedded in the steel return yoke outside the solenoid. A detailed description of the CMS detector, together with a definition of the coordinate system used and the relevant kinematic variables, is reported in Ref. [24].

Electrons and photons are measured in the range of $|\eta| < 2.5$ corresponding to the acceptance of the tracker. The energy of an electron is obtained from a combination of three measurements: the electron momentum at the primary interaction vertex as determined by the tracker [25]; the energy of the corresponding ECAL cluster; and the energy sum of all bremsstrahlung photons spatially compatible with the original electron track. The photon momentum is determined by using an energy measurement in the ECAL cluster, which is inconsistent with any charged-particle track in the tracker [26]. Muons are measured within $|\eta| < 2.4$ and their momenta are determined by using a global fit of muon measurements in the gas-ionization chambers and matched tracks in the silicon tracker [27].

Jets are reconstructed from PF candidates [23] using the anti-k_T jet clustering algorithm with a distance parameter of 0.4 [28,29]. The energy is obtained within $|\eta| < 4.7$, from the corresponding corrected energy deposits in the ECAL and hadron calorimeters that are matched to charged hadron tracks in the tracker; it is corrected for (i) pileup (PU) from multiple interactions per proton bunch crossing in the colliding beams; (ii) nonuniformity of the detector response; and (iii) residual differences between data and simulation. The average neutral energy density from PU is estimated and subtracted from the reconstructed jet energies and the energy sum used in the calculation of lepton isolation [30]. Jets containing the decay of b quarks (b jets) are identified using the medium working point of the DeepJet algorithm [31] with a misidentification probability of 1%.

The missing transverse momentum vector ($\vec{p}_T^{\,\text{miss}}$) is computed as the negative vector transverse momentum ($\vec{p}_T$) sum of all PF candidates in an event [23] and its magnitude is denoted by p_T^{miss} [32]. The $\vec{p}_T^{\,\text{miss}}$ of an event is intended to represent the neutrinos associated with a single pp interaction within a bunch crossing. The $\vec{p}_T^{\,\text{miss}}$ is also modified to include corrections to the energy scale and resolution of the reconstructed jets in the event.

The $WW\gamma$ signal is simulated at next-to-LO (NLO) in QCD and includes intermediate τ decays. The $H\gamma$ signal is simulated at NLO in QCD for $c\bar{c}$ production and at LO using the Higgs effective Lagrangian model [33] for other light quarks where a generator-level cut of $p_T^{\gamma} > 5$ GeV is applied. The initial values of the quark masses are taken from the Particle Data Group [34] and a running coupling for the c quark is implemented. Both these simulations use the MadGraph5_aMC@NLO v2.6.5 [35] Monte Carlo event generator, and the Higgs boson decay modeled by the JHUGen v7.2.7 for the $H\gamma$ signal [36–39]. The parton showering and hadronization are performed using PYTHIA 8.226 [40], and the detector simulation is performed using GEANT4 v10.4.3 [41]. The PYTHIA8 CP5 underlying event tune [42] with NNPDF3.1 next-to-NLO parton distribution functions (PDFs) is used. Neither EW nor next-to-NLO QCD corrections are applied.

Background processes containing prompt leptons and a prompt photon, including $Z\gamma$ production, $t\bar{t}\gamma$ production, and associated production of a single top quark and W boson, are simulated using MadGraph5_aMC@NLO or POWHEG v2.0 [43–48] at NLO in QCD interfaced with PYTHIA8 for hadronization and fragmentation in a manner similar to that for the $WW\gamma$ signal sample. The background due to events containing nonprompt leptons and photons, including those from instrumental mismeasurements and genuine leptons or photons within jets, is estimated from data using a method similar to that of Ref. [49–51]. The relative contribution of events with well-isolated, high-quality leptons to less-isolated, lower-quality leptons is measured in a dijet control region (CR) in data as a function of the lepton $|\eta|$ and p_T, and corrected for prompt leptons and prompt photon conversions based on simulated samples. A similar procedure is applied for photons, based on a $W+$jets CR that excludes the signal region (SR). In the nonprompt-photon case, a fit to the width of the

photon ECAL shower is used to determine the nonprompt-photon fraction in the well-isolated, high-quality category, as described in Ref. [52]. Based on the matching to the generator level, the two procedures are combined to avoid double counting [49]. The SM contributions from other Higgs-related processes [53] are negligible.

Experimentally, we select $W^+W^-\gamma \to e^+\nu_e\mu^-\bar{\nu}_\mu\gamma$ and $\mu^+\nu_\mu e^-\bar{\nu}_e\gamma$ events, which pass the level-1 [54] and high-level [55] triggers that require an isolated muon and/or electron. We require the isolated electron and muon to satisfy additional identification criteria [26,27], a single reconstructed photon [26] must be present in the event, and the $p_{\mathrm{T}}^{\mathrm{miss}}$ must exceed 20 GeV. The photon must satisfy high performance identification requirements that correspond to a signal efficiency $>80\%$ [26]. Off-line kinematic requirements on the selected objects, based on the detector acceptance and the trigger thresholds, are $p_{\mathrm{T}}^{\gamma} > 20$ GeV, $|\eta^{\gamma}| < 2.5$, $|\eta^{e(\mu)}| < 2.5$ (2.4) and $p_{\mathrm{T}}^{e(\mu)} > 25$ (20) GeV. To reduce backgrounds from $WZ\gamma$ and relevant top quark processes, events are rejected that contain at least one b jet or an additional muon or electron with $p_{\mathrm{T}} > 10$ GeV passing looser criteria than those of the primary leptons. Moreover, it is required that $\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} > 0.5$, where $\Delta\phi$ and $\Delta\eta$ are the spatial separations in the azimuthal angle ϕ and η between leptons and photon. We further suppress background contributions by requiring the dilepton mass $(m_{\ell\ell}) > 10$ GeV, the transverse momentum $(p_{\mathrm{T}}^{\ell\ell}) > 15$ GeV, and the transverse mass, $m_{\mathrm{T}}^{WW} = \sqrt{2 p_{\mathrm{T}}^{\ell\ell} p_{\mathrm{T}}^{\mathrm{miss}} [1 - \cos\Delta\phi(\vec{p}_{\mathrm{T}}^{\ell\ell}, \vec{p}_{\mathrm{T}}^{\mathrm{miss}})]} > 10$ GeV.

A CR with charged leptons of the same sign, SS$WW\gamma$, is constructed to validate the nonprompt lepton background modeling. Another Topγ CR, dominated by events corresponding to top quark production, is used to validate the modeling of both nonprompt-lepton and nonprompt-photon backgrounds. These two CRs are included in the simultaneous maximum likelihood fit to constrain the estimates of these process rates. The selection for the SS$WW\gamma$ CR is the same as for the SR, except that the m_{T}^{WW} requirement is removed and the two leptons are required to have the same sign. The definition of the Topγ CR also follows closely that of the SR, except that at least one b-tagged jet with $p_{\mathrm{T}} > 20$ GeV is required and the m_{T}^{WW} requirement is removed.

The observed distributions in the SR of the invariant mass of the dilepton-photon system ($m_{\ell\ell\gamma}$) and m_{T}^{WW} are compared with the expected distributions before the fit in Fig. 2. The experimental data agree with the prediction within the uncertainties.

Various sources of systematic uncertainty are included in the fit as nuisance parameters and subject to log-normal constraints. Theoretical sources of systematic uncertainty include the choice of the renormalization and factorization scales, PDFs, and parton shower modeling. The two scales are varied by factors of 2 and 0.5 independently. The envelope of these variations, excluding the two extreme (2, 0.5) and (0.5, 2) cases, is assumed as the uncertainty. The systematic uncertainty due to PDFs is calculated using the PDF4LHC15_nnlo_30_pdfas PDF replicas, following the PDF4LHC group prescription [56–59]. Parton shower modeling uncertainties, which arise from the

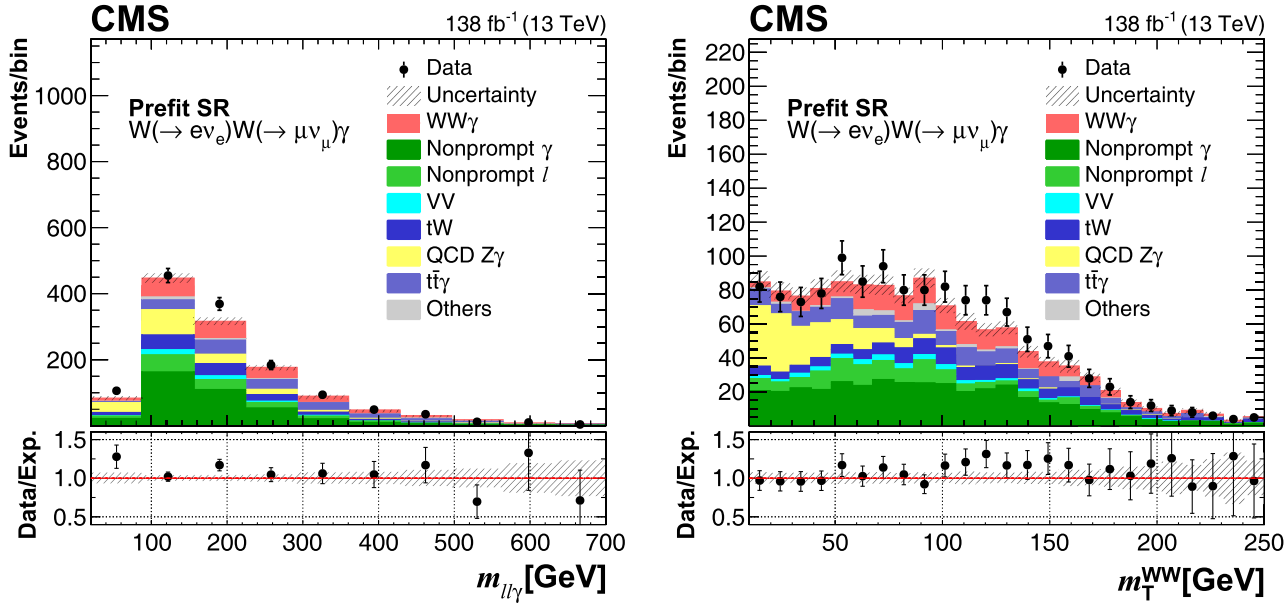

FIG. 2. The distributions of the invariant mass of the dilepton-photon system (left) and the transverse mass of the WW system (right) after the signal region selection and before the fit to the data. The black points with error bars represent the data and their statistical uncertainties, whereas the shaded band represents the Monte Carlo statistical uncertainties.

TABLE I. The number of events in data and prediction after the fit to data in the SR, SS$WW\gamma$ CR, and Topγ CR. The uncertainties include both statistical and systematic contributions.

Process	SR (0 jet)	SR ($\geq$1 jet)	SR (total)	SSWWγ CR	Topγ CR
$WW\gamma$	122 ± 22	134 ± 26	256 ± 47	1.3 ± 0.2	12.9 ± 2.7
QCD $V\gamma$	72.0 ± 6.0	94.6 ± 9.3	164 ± 14	12.2 ± 2.3	12.6 ± 1.2
VV	15.1 ± 1.2	21.6 ± 2.3	36.7 ± 3.5	24.9 ± 1.7	2.0 ± 0.3
Top	56.6 ± 6.5	271 ± 27	328 ± 32	2.4 ± 0.6	2434 ± 85
Nonprompt ℓ	45.7 ± 4.0	77.1 ± 6.2	122.9 ± 9.7	197 ± 14	40 ± 11
Nonprompt γ	109.0 ± 8.4	300 ± 24	410 ± 32	19.8 ± 1.6	792 ± 62
Total	420 ± 17	898 ± 26	1318 ± 43	257 ± 14	3294 ± 57
Data	414	916	1330	259	3287

renormalization of QCD-induced ISR and FSR, are the dominant uncertainty in the measurement. Variations of the contributions of the ISR and FSR consist of 4 combinations made by keeping one constant and doubling or halving the other. Multiple experimental sources of systematic uncertainties are also included. The most significant contribution arises from the method used to estimate the nonprompt background (8%), followed by the b tagging efficiency (7%), and jet energy scale and resolution (5%), which also affect $\vec{p}_{\mathrm{T}}^{\,\mathrm{miss}}$. The uncertainties associated with the lepton and photon identification efficiencies, the lepton trigger, PU, and integrated luminosity [60–62] are also assessed. The statistical uncertainties from the limited size of the simulated signal and background samples are also included in the final fit.

The signal significance and strength are extracted from a binned maximum likelihood fit using two-dimensional distributions in bins of m_{T}^{WW} and $m_{\ell\ell\gamma}$, where the product of the Poisson probability mass functions for each bin forms the likelihood function. The $e\mu$ final states that result from the intermediate τ in our signal simulation, are treated as part of the signal in significance and strength extraction. A simultaneous fit including the SR and CRs is performed. Since background processes tend to be concentrated in the $\geq$1 jet region, the SR is divided into two categories based on jet multiplicity: 0 jet and $\geq$1 jet. The number of events in data and predictions after the fit to the data are listed in Table I. The observed (expected) signal significance from the fit is 5.6(5.1) standard deviations, corresponding to the observed distributions after the fit to the data shown in Fig. 3. The observed signal strength, $\mu_{\mathrm{obs}} = 1.11 \pm 0.16(\mathrm{stat}) \pm 0.15(\mathrm{syst}) \pm 0.13(\mathrm{modeling})$, is extracted in a fiducial region defined by applying the signal selection at particle level, without the requirements on b jets and additional leptons. The theoretical prediction for the $WW\gamma$ fiducial cross section is $5.33 \pm 0.34(\mathrm{scale}) \pm 0.05(\mathrm{PDF})$ fb at NLO QCD as evaluated by MadGraph5_aMC@NLO. The $WW\gamma$ measured cross section from the simultaneous

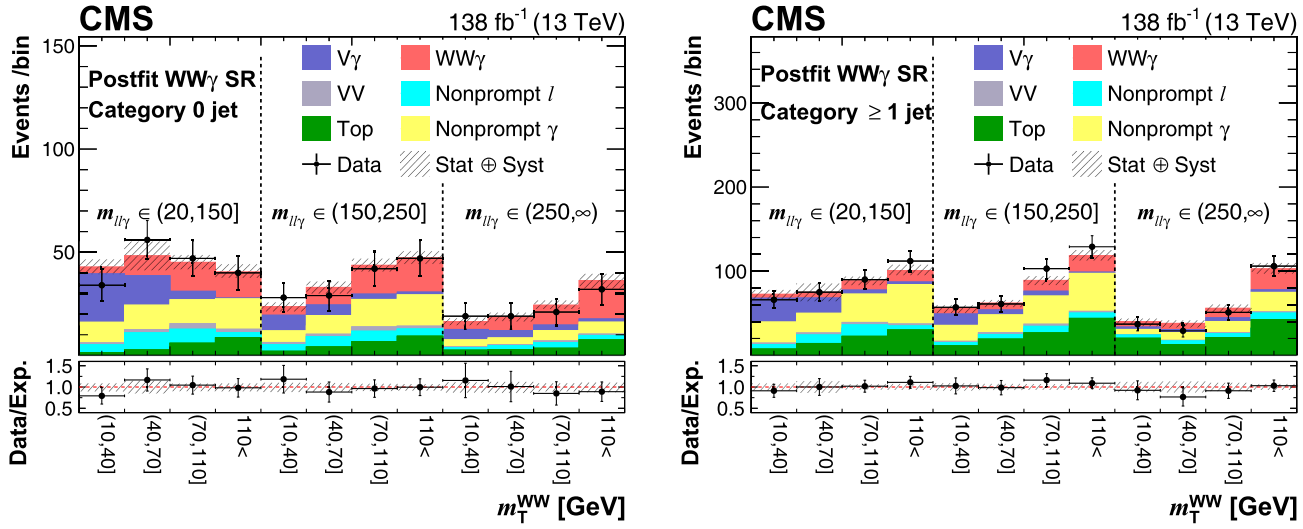

FIG. 3. The unrolled two-dimensional $m_{\mathrm{T}}^{WW} - m_{\ell\ell\gamma}$ distributions in category 0 jet (left) and $\geq$1 jet (right) after the fit to data. The data are compared with the sum of the signal and expected background. The black points with error bars represent the data and their statistical uncertainties, whereas the hatched bands represent the total uncertainties in the predictions.

TABLE II. Upper limits on the cross section and derived limits in terms of Yukawa coupling at 95% C.L. for $H\gamma$ production initiated by light quarks.

Process	σ upper limits obs. (exp.) [fb]	κ_q limits obs. (exp.) at 95% C.L.	$\bar{\kappa}_q$ limits obs. (exp.) at 95% C.L.
$u\bar{u} \to H + \gamma \to e\mu\nu_e\nu_\mu\gamma$	86 (67)	$\lvert\kappa_u\rvert \leq 16000$ (13000)	$\lvert\bar{\kappa}_u\rvert \leq 7.5$ (6.1)
$d\bar{d} \to H + \gamma \to e\mu\nu_e\nu_\mu\gamma$	72 (58)	$\lvert\kappa_d\rvert \leq 17000$ (14000)	$\lvert\bar{\kappa}_d\rvert \leq 16.6$ (14.7)
$s\bar{s} \to H + \gamma \to e\mu\nu_e\nu_\mu\gamma$	66 (49)	$\lvert\kappa_s\rvert \leq 1700$ (1300)	$\lvert\bar{\kappa}_s\rvert \leq 32.8$ (25.2)
$c\bar{c} \to H + \gamma \to e\mu\nu_e\nu_\mu\gamma$	88 (66)	$\lvert\kappa_c\rvert \leq 190$ (110)	$\lvert\bar{\kappa}_c\rvert \leq 43.2$ (25.0)

fit with the uncertainties divided into statistical, experimental, and theoretical modeling components is $\sigma = 5.9 \pm 0.8(\text{stat}) \pm 0.8(\text{syst}) \pm 0.7(\text{modeling})$ fb $= 5.9 \pm 1.3$ fb. The theoretical modeling uncertainties include the renormalization and factorization of QCD scales, PDFs, and parton shower modeling from all simulations.

We also search for the $H\gamma$ production mechanism shown in Fig. 1 with modified Higgs boson couplings to light quarks, which have different p_{T}^{γ} spectra and equivalently $H\gamma$ invariant mass compared with other anomalous $HZ\gamma$ coupling processes as described in Ref. [14]. The selection for this search is similar to the EW $WW\gamma$ signal selection but targets the Higgs boson characteristics by requiring $\Delta\phi_{\ell\ell} < 2.5$, $\Delta R_{\ell\ell} < 2.3$, and $\Delta R_{\ell\gamma} > 0.8$, since the two oppositely charged W bosons from the Higgs boson decay tend to have opposite spin orientation and the leptons from W bosons are likely to travel in the same direction [63]. Now the observed $WW\gamma$ is regarded as a background whose normalization floats and is constrained by incorporating the remaining $WW\gamma$ events and all CRs in the simultaneous fit. Since the $\Delta R_{\ell\ell}$ observable has good discrimination power [64], the profile likelihood ratio test statistic [65] is built separately for four processes in bins of $\Delta R_{\ell\ell}$ and m_{T}^{WW}, where $\Delta R_{\ell\ell}$ and m_{T}^{WW} are divided into bins of [0.5, 1.8, 2.0, 2.3) and [0, 10, 40, 70, 110, ∞), respectively. The upper limits on the $H\gamma$ cross sections at 95% C.L. are shown in Table II. The results can be interpreted as limits on the Higgs boson to light quarks Yukawa couplings κ_q [10], assuming that the light quark and the Higgs boson interaction vertex in Fig. 1 is the only parameter that does not behave according to the SM. The normalized light Yukawa couplings $\bar{\kappa}_q$ are also provided, which rescales κ_q into units of y_b^{SM} evaluated at scale $\mu = 125$ GeV as described in Ref. [66].

In summary, this Letter reports the first observation of $WW\gamma$ production in proton-proton collisions. The measurement uses a dataset collected by the CMS experiment at the LHC in 2016–2018 at a center-of-mass energy of 13 TeV, with an integrated luminosity of 138 fb^{-1}. The measured fiducial cross section for $WW\gamma$ production is 5.9 ± 1.3 fb, in agreement with the prediction at next-to-leading order in quantum chromodynamics. A search for the associated production of the Higgs boson and a photon is also performed using the Higgs boson decay to W^+W^-. A set of limits at 95% confidence level on the Higgs boson couplings to light quarks is reported.

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 centers and personnel of the Worldwide LHC Computing Grid and other centers 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, the CMS detector, and the supporting computing infrastructure provided by the following funding agencies: SC (Armenia), BMBWF and FWF (Austria); FNRS and FWO (Belgium); CNPq, CAPES, FAPERJ, FAPERGS, and FAPESP (Brazil); MES and BNSF (Bulgaria); CERN; CAS, MoST, and NSFC (China); MINCIENCIAS (Colombia); MSES and CSF (Croatia); RIF (Cyprus); SENESCYT (Ecuador); MoER, ERC PUT and ERDF (Estonia); Academy of Finland, MEC, and HIP (Finland); CEA and CNRS/IN2P3 (France); SRNSF (Georgia); BMBF, DFG, and HGF (Germany); GSRI (Greece); NKFIH (Hungary); DAE and DST (India); IPM (Iran); SFI (Ireland); INFN (Italy); MSIP and NRF (Republic of Korea); MES (Latvia); LAS (Lithuania); MOE and UM (Malaysia); BUAP, CINVESTAV, CONACYT, LNS, SEP, and UASLP-FAI (Mexico); MOS (Montenegro); MBIE (New Zealand); PAEC (Pakistan); MES and NSC (Poland); FCT (Portugal); MESTD (Serbia); MCIN/AEI and PCTI (Spain); MOSTR (Sri Lanka); Swiss Funding Agencies (Switzerland); MST (Taipei); MHESI and NSTDA (Thailand); TUBITAK and TENMAK (Turkey); NASU (Ukraine); STFC (United Kingdom); DOE and NSF (USA).

[1] CMS Collaboration, Observation of the production of three massive gauge bosons at $\sqrt{s} = 13$ TeV, Phys. Rev. Lett. **125**, 151802 (2020).

[2] ATLAS Collaboration, Observation of WWW production in pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector, Phys. Rev. Lett. **129**, 061803 (2022).

[3] ATLAS Collaboration, Observation of $WZ\gamma$ production in pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector, Phys. Rev. Lett. **132**, 021802 (2024).

[4] ATLAS Collaboration, Observation of $W\gamma\gamma$ triboson production in proton-proton collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector, Phys. Lett. B **848**, 138400 (2024).

[5] ATLAS Collaboration, Measurement of $Z\gamma\gamma$ production in pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector, Eur. Phys. J. C **83**, 539 (2023).

[6] CMS Collaboration, Measurements of the pp $\rightarrow W\gamma\gamma$ and pp $\rightarrow Z\gamma\gamma$ cross sections at $\sqrt{s} = 13$ TeV and limits on anomalous quartic gauge couplings, J. High Energy Phys. 10 (2021) 174.

[7] CMS Collaboration, Search for $WW\gamma$ and $WZ\gamma$ production and constraints on anomalous quartic gauge couplings in pp collisions at $\sqrt{s} = 8$ TeV, Phys. Rev. D **90**, 032008 (2014).

[8] ATLAS Collaboration, Study of $WW\gamma$ and $WZ\gamma$ production in pp collisions at $\sqrt{s} = 8$ TeV and search for anomalous quartic gauge couplings with the ATLAS experiment, Eur. Phys. J. C **77**, 646 (2017).

[9] H. Khanpour, S. Khatibi, and M. Mohammadi-Najafabadi, Probing Higgs boson couplings in $\mathrm{H} + \gamma$ production at the LHC, Phys. Lett. B **773**, 462 (2017).

[10] J. A. Aguilar-Saavedra, J. M. Cano, and J. M. No, More light on Higgs flavor at the LHC: Higgs boson couplings to light quarks through $h + \gamma$ production, Phys. Rev. D **103**, 095023 (2021).

[11] A. Falkowski, S. Ganguly, P. Gras, J. M. No, K. Tobioka, N. Vignaroli, and T. You, Light quark Yukawas in triboson final states, J. High Energy Phys. 04 (2021) 023.

[12] W. H. Furry, A symmetry theorem in the positron theory, Phys. Rev. **51**, 125 (1937).

[13] Y. Zhou, Probing anomalous couplings of the Higgs boson to weak bosons and fermions with precision calculations, thesis, Johns Hopkins University, 2019 [Report No. CERN-THESIS-2019-007].

[14] J. Davis, A. V. Gritsan, L. S. M. Guerra, S. Kyriacou, J. Roskes, and M. Schulze, Constraining anomalous Higgs boson couplings to virtual photons, Phys. Rev. D **105**, 096027 (2022).

[15] Y. Zhou, Constraining the Higgs boson coupling to light quarks in the $H \rightarrow ZZ$ final states, Phys. Rev. D **93**, 013019 (2016).

[16] LHC Higgs Cross Section Working Group, Handbook of LHC Higgs cross sections: 4. Deciphering the nature of the Higgs sector, CERN Report No. CERN-2017-002-M, 2016.

[17] CMS Collaboration, Search for Higgs boson decay to a charm quark-antiquark pair in proton-proton collisions at $\sqrt{s} = 13$ TeV, Phys. Rev. Lett. **131**, 061801 (2023).

[18] ATLAS Collaboration, Direct constraint on the Higgs-charm coupling from a search for Higgs boson decays into charm quarks with the ATLAS detector, Eur. Phys. J. C **82**, 717 (2022).

[19] J. Duarte-Campderros, G. Perez, M. Schlaffer, and A. Soffer, Probing the Higgs-strange quark coupling at e^+e^- colliders using light-jet flavor tagging, Phys. Rev. D **101**, 115005 (2020).

[20] ATLAS Collaboration, Search for exclusive Higgs and Z boson decays to $\phi\gamma$ and $\rho\gamma$ with the ATLAS detector, J. High Energy Phys. 07 (2018) 127.

[21] J.-W. Zhu, R.-Y. Zhang, W.-G. Ma, Q. Yang, and Y. Jiang, $WW\gamma$ production at hadron colliders with NLO QCD + EW corrections and parton shower effects, J. Phys. G **47**, 055006 (2020).

[22] HEPData record for this analysis (2023).

[23] CMS Collaboration, Particle-flow reconstruction and global event description with the CMS detector, J. Instrum. **12**, P10003 (2017).

[24] CMS Collaboration, The CMS experiment at the CERN LHC, J. Instrum. **3**, S08004 (2008).

[25] CMS Collaboration, Measurement of electroweak WZ boson production and search for new physics in WZ + two jets events in pp collisions at $\sqrt{s} = 13$ TeV, Phys. Lett. B **795**, 281 (2019).

[26] CMS Collaboration, Electron and photon reconstruction and identification with the CMS experiment at the CERN LHC, J. Instrum. **16**, P05014 (2021).

[27] CMS Collaboration, Performance of the CMS muon detector and muon reconstruction with proton-proton collisions at $\sqrt{s} = 13$ TeV, J. Instrum. **13**, P06015 (2018).

[28] M. Cacciari, G. P. Salam, and G. Soyez, The anti-k_T jet clustering algorithm, J. High Energy Phys. 04 (2008) 063.

[29] M. Cacciari, G. P. Salam, and G. Soyez, FastJet user manual, Eur. Phys. J. C **72**, 1896 (2012).

[30] M. Cacciari and G. P. Salam, Pileup subtraction using jet areas, Phys. Lett. B **659**, 119 (2008).

[31] E. Bols, J. Kieseler, M. Verzetti, M. Stoye, and A. Stakia, Jet flavour classification using DeepJet, J. Instrum. **15**, P12012 (2020).

[32] CMS Collaboration, Performance of missing transverse momentum reconstruction in proton-proton collisions at $\sqrt{s} = 13$ TeV using the CMS detector, J. Instrum. **14**, P07004 (2019).

[33] A. Alloul, B. Fuks, and V. Sanz, Phenomenology of the Higgs effective Lagrangian via FEYNRULES, J. High Energy Phys. 04 (2014) 110.

[34] P. A. Zyla *et al.* (Particle Data Group), Review of particle physics, Prog. Theor. Exp. Phys. **2020**, 083C01 (2020).

[35] J. Alwall, R. Frederix, S. Frixione, V. Hirschi, F. Maltoni, O. Mattelaer, H.-S. Shao, T. Stelzer, P. Torielli, and M. Zaro, The automated computation of tree-level and next-to-leading order differential cross sections, and their matching to parton shower simulations, J. High Energy Phys. 07 (2014) 079.

[36] Y. Gao, A. V. Gritsan, Z. Guo, K. Melnikov, M. Schulze, and N. V. Tran, Spin determination of single-produced resonances at hadron colliders, Phys. Rev. D **81**, 075022 (2010).

[37] S. Bolognesi, Y. Gao, A. V. Gritsan, K. Melnikov, M. Schulze, N. V. Tran, and A. Whitbeck, Spin and parity of a single-produced resonance at the LHC, Phys. Rev. D **86**, 095031 (2012).

[38] I. Anderson, S. Bolognesi, F. Caola, Y. Gao, A. V. Gritsan, C. B. Martin, K. Melnikov, M. Schulze, N. V. Tran, A. Whitbeck, and Y. Zhou, Constraining anomalous HVV interactions at proton and lepton colliders, Phys. Rev. D **89**, 035007 (2014).

[39] A. V. Gritsan, R. Röntsch, M. Schulze, and M. Xiao, Constraining anomalous Higgs boson couplings to the heavy flavor fermions using matrix element techniques, Phys. Rev. D **94**, 055023 (2016).

[40] T. Sjöstrand, S. Ask, J. R. Christiansen, R. Corke, N. Desai, P. Ilten, S. Mrenna, S. Prestel, C. O. Rasmussen, and P. Z. Skands, An introduction to PYTHIA8.2, Comput. Phys. Commun. **191**, 159 (2015).
[41] S. Agostinelli *et al.* (GEANT4 Collaboration), GEANT4—a simulation toolkit, Nucl. Instrum. Methods Phys. Res., Sect. A **506**, 250 (2003).
[42] CMS Collaboration, Extraction and validation of a new set of CMS PYTHIA8 tunes from underlying-event measurements, Eur. Phys. J. C **80**, 4 (2020).
[43] P. Nason, A new method for combining NLO QCD with shower Monte Carlo algorithms, J. High Energy Phys. 11 (2004) 040.
[44] S. Frixione, P. Nason, and C. Oleari, Matching NLO QCD computations with parton shower simulations: The POWHEG method, J. High Energy Phys. 11 (2007) 070.
[45] S. Alioli, P. Nason, C. Oleari, and E. Re, A general framework for implementing NLO calculations in shower Monte Carlo programs: The POWHEG BOX, J. High Energy Phys. 06 (2010) 043.
[46] S. Alioli, K. Hamilton, P. Nason, C. Oleari, and E. Re, Jet pair production in POWHEG, J. High Energy Phys. 04 (2011) 081.
[47] S. Alioli, P. Nason, C. Oleari, and E. Re, NLO Higgs boson production via gluon fusion matched with shower in POWHEG, J. High Energy Phys. 04 (2009) 002.
[48] E. Bagnaschi, G. Degrassi, P. Slavich, and A. Vicini, Higgs production via gluon fusion in the POWHEG approach in the SM and in the MSSM, J. High Energy Phys. 02 (2012) 088.
[49] CMS Collaboration, Measurement of the Wγ production cross section in proton-proton collisions at $\sqrt{s} = 13$ TeV and constraints on effective field theory coefficients, Phys. Rev. Lett. **126**, 252002 (2021).
[50] CMS Collaboration, Measurement of the electroweak production of Wγ in association with two jets in proton-proton collisions at $\sqrt{s} = 13$ TeV, Phys. Rev. D **108**, 032017 (2023).
[51] CMS Collaboration, Measurement of the electroweak production of $Z\gamma$ and two jets in proton-proton collisions at $\sqrt{s} = 13$ TeV and constraints on anomalous quartic gauge couplings, Phys. Rev. D **104**, 072001 (2021).
[52] CMS Collaboration, Measurement of the cross section for electroweak production of a Z boson, a photon and two jets in proton-proton collisions at $\sqrt{s} = 13$ TeV and constraints on anomalous quartic couplings, J. High Energy Phys. 06 (2020) 076.
[53] E. Gabrielli, B. Mele, F. Piccinini, and R. Pittau, Asking for an extra photon in Higgs production at the LHC and beyond, J. High Energy Phys. 07 (2016) 003.
[54] CMS Collaboration, Performance of the CMS level-1 trigger in proton-proton collisions at $\sqrt{s} = 13$ TeV, J. Instrum. **15**, P10017 (2020).
[55] CMS Collaboration, The CMS trigger system, J. Instrum. **12**, P01020 (2017).
[56] J. Butterworth *et al.*, PDF4LHC recommendations for LHC Run II, J. Phys. G **43**, 023001 (2016).
[57] L. A. Harland-Lang, A. D. Martin, P. Motylinski, and R. S. Thorne, Parton distributions in the LHC era: MMHT 2014 PDFs, Eur. Phys. J. C **75**, 204 (2015).
[58] R. D. Ball *et al.* (NNPDF Collaboration), Parton distributions for the LHC Run II, J. High Energy Phys. 04 (2015) 040.
[59] S. Dulat, T.-J. Hou, J. Gao, M. Guzzi, J. Huston, P. Nadolsky, J. Pumplin, C. Schmidt, D. Stump, and C.-P. Yuan, New parton distribution functions from a global analysis of quantum chromodynamics, Phys. Rev. D **93**, 033006 (2016).
[60] CMS Collaboration, Precision luminosity measurement in proton-proton collisions at $\sqrt{s} = 13$ TeV in 2015 and 2016 at CMS, Eur. Phys. J. C **81**, 800 (2021).
[61] CMS Collaboration, CMS luminosity measurement for the 2017 data-taking period at $\sqrt{s} = 13$ TeV, CMS Physics Analysis Summary Report No. CMS-PAS-LUM-17-004, 2018, https://cds.cern.ch/record/2621960.
[62] CMS Collaboration, CMS luminosity measurement for the 2018 data-taking period at $\sqrt{s} = 13$ TeV, CMS Physics Analysis Summary Report No. CMS-PAS-LUM-18-002, 2019, https://cds.cern.ch/record/2676164.
[63] M. Dittmar and H. Dreiner, How to find a Higgs boson with a mass between 155 and 180 GeV at the LHC, Phys. Rev. D **55**, 167 (1997).
[64] M. Duehrssen, Study of Higgs bosons in the WW final state and development of a fast calorimeter simulation for the ATLAS experiment, Ph.D. thesis, Freiburg University, 2009 [Report No. CERN-THESIS-2010-061], https://cds.cern.ch/record/1261372.
[65] ATLAS and CMS Collaborations, and LHC Higgs Combination Group, Procedure for the LHC Higgs boson search combination in Summer 2011, CMS Physics Analysis Note Reports No. CMS-NOTE-2011-005, No. ATL-PHYS-PUB-2011-11, 2011, https://cds.cern.ch/record/1379837.
[66] F. Yu, Phenomenology of enhanced light quark Yukawa couplings and the $W^{\pm}h$ charge asymmetry, J. High Energy Phys. 02 (2017) 083.

A. Hayrapetyan,[1] A. Tumasyan,[1,b] W. Adam,[2] J. W. Andrejkovic,[2] T. Bergauer,[2] S. Chatterjee,[2] K. Damanakis,[2] M. Dragicevic,[2] A. Escalante Del Valle,[2] P. S. Hussain,[2] M. Jeitler,[2,c] N. Krammer,[2] D. Liko,[2] I. Mikulec,[2] J. Schieck,[2,c] R. Schöfbeck,[2] D. Schwarz,[2] M. Sonawane,[2] S. Templ,[2] W. Waltenberger,[2] C.-E. Wulz,[2,c] M. R. Darwish,[3,d] T. Janssen,[3] P. Van Mechelen,[3] E. S. Bols,[4] J. D'Hondt,[4] S. Dansana,[4] A. De Moor,[4] M. Delcourt,[4] H. El Faham,[4] S. Lowette,[4] I. Makarenko,[4] D. Müller,[4] A. R. Sahasransu,[4] S. Tavernier,[4] M. Tytgat,[4,e] S. Van Putte,[4] D. Vannerom,[4] B. Clerbaux,[5] G. De Lentdecker,[5] L. Favart,[5] D. Hohov,[5] J. Jaramillo,[5] A. Khalilzadeh,[5] K. Lee,[5] M. Mahdavikhorrami,[5] A. Malara,[5] S. Paredes,[5] L. Pétré,[5] N. Postiau,[5]

L. Thomas,[5] M. Vanden Bemden,[5] C. Vander Velde,[5] P. Vanlaer,[5] M. De Coen,[6] D. Dobur,[6] Y. Hong,[6] J. Knolle,[6] L. Lambrecht,[6] G. Mestdach,[6] C. Rendón,[6] A. Samalan,[6] K. Skovpen,[6] N. Van Den Bossche,[6] L. Wezenbeek,[6] A. Benecke,[7] G. Bruno,[7] C. Caputo,[7] C. Delaere,[7] I. S. Donertas,[7] A. Giammanco,[7] K. Jaffel,[7] Sa. Jain,[7] V. Lemaitre,[7] J. Lidrych,[7] P. Mastrapasqua,[7] K. Mondal,[7] T. T. Tran,[7] S. Wertz,[7] G. A. Alves,[8] E. Coelho,[8] C. Hensel,[8] T. Menezes De Oliveira,[8] A. Moraes,[8] P. Rebello Teles,[8] M. Soeiro,[8] W. L. Aldá Júnior,[9] M. Alves Gallo Pereira,[9] M. Barroso Ferreira Filho,[9] H. Brandao Malbouisson,[9] W. Carvalho,[9] J. Chinellato,[9,f] E. M. Da Costa,[9] G. G. Da Silveira,[9,g] D. De Jesus Damiao,[9] S. Fonseca De Souza,[9] J. Martins,[9,h] C. Mora Herrera,[9] K. Mota Amarilo,[9] L. Mundim,[9] H. Nogima,[9] A. Santoro,[9] S. M. Silva Do Amaral,[9] A. Sznajder,[9] M. Thiel,[9] A. Vilela Pereira,[9] C. A. Bernardes,[10,g] L. Calligaris,[10] T. R. Fernandez Perez Tomei,[10] E. M. Gregores,[10] P. G. Mercadante,[10] S. F. Novaes,[10] B. Orzari,[10] Sandra S. Padula,[10] A. Aleksandrov,[11] G. Antchev,[11] R. Hadjiiska,[11] P. Iaydjiev,[11] M. Misheva,[11] M. Shopova,[11] G. Sultanov,[11] A. Dimitrov,[12] T. Ivanov,[12] L. Litov,[12] B. Pavlov,[12] P. Petkov,[12] A. Petrov,[12] E. Shumka,[12] S. Keshri,[13] S. Thakur,[13] T. Cheng,[14] Q. Guo,[14] T. Javaid,[14] M. Mittal,[14] L. Yuan,[14] G. Bauer,[15,i,j] Z. Hu,[15] K. Yi,[15,i,k] G. M. Chen,[16,l] H. S. Chen,[16,l] M. Chen,[16,l] F. Iemmi,[16] C. H. Jiang,[16] A. Kapoor,[16] H. Liao,[16] Z.-A. Liu,[16,m] F. Monti,[16] M. A. Shahzad,[16,l] R. Sharma,[16] J. N. Song,[16,m] J. Tao,[16] C. Wang,[16,l] J. Wang,[16] Z. Wang,[16,l] H. Zhang,[16] A. Agapitos,[17] Y. Ban,[17] Z. Guan,[17] A. Levin,[17] C. Li,[17] Q. Li,[17] X. Lyu,[17] Y. Mao,[17] S. J. Qian,[17] X. Sun,[17] D. Wang,[17] H. Yang,[17] C. Zhou,[17] Z. You,[18] N. Lu,[19] D. Leggat,[20] H. Okawa,[20] Y. Zhang,[20] Z. Lin,[21] C. Lu,[21] M. Xiao,[21] C. Avila,[22] D. A. Barbosa Trujillo,[22] A. Cabrera,[22] C. Florez,[22] J. Fraga,[22] J. A. Reyes Vega,[22] J. Mejia Guisao,[23] F. Ramirez,[23] M. Rodriguez,[23] J. D. Ruiz Alvarez,[23] D. Giljanovic,[24] N. Godinovic,[24] D. Lelas,[24] A. Sculac,[24] M. Kovac,[25] T. Sculac,[25] P. Bargassa,[26] V. Brigljevic,[26] B. K. Chitroda,[26] D. Ferencek,[26] S. Mishra,[26] A. Starodumov,[26,n] T. Susa,[26] A. Attikis,[27] K. Christoforou,[27] S. Konstantinou,[27] J. Mousa,[27] C. Nicolaou,[27] F. Ptochos,[27] P. A. Razis,[27] H. Rykaczewski,[27] H. Saka,[27] A. Stepennov,[27] M. Finger,[28] M. Finger Jr.,[28] A. Kveton,[28] E. Ayala,[29] E. Carrera Jarrin,[30] A. A. Abdelalim,[31,o,p] E. Salama,[31,q,r] M. Abdullah Al-Mashad,[32] M. A. Mahmoud,[32] R. K. Dewanjee,[33,s] K. Ehataht,[33] M. Kadastik,[33] T. Lange,[33] S. Nandan,[33] C. Nielsen,[33] J. Pata,[33] M. Raidal,[33] L. Tani,[33] C. Veelken,[33] H. Kirschenmann,[34] K. Osterberg,[34] M. Voutilainen,[34] S. Bharthuar,[35] E. Brücken,[35] F. Garcia,[35] J. Havukainen,[35] K. T. S. Kallonen,[35] M. S. Kim,[35] R. Kinnunen,[35] T. Lampén,[35] K. Lassila-Perini,[35] S. Lehti,[35] T. Lindén,[35] M. Lotti,[35] L. Martikainen,[35] M. Myllymäki,[35] M. m. Rantanen,[35] H. Siikonen,[35] E. Tuominen,[35] J. Tuominiemi,[35] P. Luukka,[36] H. Petrow,[36] T. Tuuva,[36,a] M. Besancon,[37] F. Couderc,[37] M. Dejardin,[37] D. Denegri,[37] J. L. Faure,[37] F. Ferri,[37] S. Ganjour,[37] P. Gras,[37] G. Hamel de Monchenault,[37] V. Lohezic,[37] J. Malcles,[37] J. Rander,[37] A. Rosowsky,[37] M. Ö. Sahin,[37] A. Savoy-Navarro,[37,t] P. Simkina,[37] M. Titov,[37] C. Baldenegro Barrera,[38] F. Beaudette,[38] A. Buchot Perraguin,[38] P. Busson,[38] A. Cappati,[38] C. Charlot,[38] F. Damas,[38] O. Davignon,[38] A. De Wit,[38] G. Falmagne,[38] B. A. Fontana Santos Alves,[38] S. Ghosh,[38] A. Gilbert,[38] R. Granier de Cassagnac,[38] A. Hakimi,[38] B. Harikrishnan,[38] L. Kalipoliti,[38] G. Liu,[38] J. Motta,[38] M. Nguyen,[38] C. Ochando,[38] L. Portales,[38] R. Salerno,[38] U. Sarkar,[38] J. B. Sauvan,[38] Y. Sirois,[38] A. Tarabini,[38] E. Vernazza,[38] A. Zabi,[38] A. Zghiche,[38] J.-L. Agram,[39,u] J. Andrea,[39] D. Apparu,[39] D. Bloch,[39] J.-M. Brom,[39] E. C. Chabert,[39] C. Collard,[39] S. Falke,[39] U. Goerlach,[39] C. Grimault,[39] R. Haeberle,[39] A.-C. Le Bihan,[39] M. A. Sessini,[39] P. Van Hove,[39] S. Beauceron,[40] B. Blancon,[40] G. Boudoul,[40] N. Chanon,[40] J. Choi,[40] D. Contardo,[40] P. Depasse,[40] C. Dozen,[40,v] H. El Mamouni,[40] J. Fay,[40] S. Gascon,[40] M. Gouzevitch,[40] C. Greenberg,[40] G. Grenier,[40] B. Ille,[40] I. B. Laktineh,[40] M. Lethuillier,[40] L. Mirabito,[40] S. Perries,[40] M. Vander Donckt,[40] P. Verdier,[40] J. Xiao,[40] D. Chokheli,[41] I. Lomidze,[41] Z. Tsamalaidze,[41,n] V. Botta,[42] L. Feld,[42] K. Klein,[42] M. Lipinski,[42] D. Meuser,[42] A. Pauls,[42] N. Röwert,[42] M. Teroerde,[42] S. Diekmann,[43] A. Dodonova,[43] N. Eich,[43] D. Eliseev,[43] F. Engelke,[43] M. Erdmann,[43] P. Fackeldey,[43] B. Fischer,[43] T. Hebbeker,[43] K. Hoepfner,[43] F. Ivone,[43] A. Jung,[43] M. y. Lee,[43] L. Mastrolorenzo,[43] M. Merschmeyer,[43] A. Meyer,[43] S. Mukherjee,[43] D. Noll,[43] A. Novak,[43] F. Nowotny,[43] A. Pozdnyakov,[43] Y. Rath,[43] W. Redjeb,[43] F. Rehm,[43] H. Reithler,[43] V. Sarkisovi,[43] A. Schmidt,[43] S. C. Schuler,[43] A. Sharma,[43] A. Stein,[43] F. Torres Da Silva De Araujo,[43,w] L. Vigilante,[43] S. Wiedenbeck,[43] S. Zaleski,[43] C. Dziwok,[44] G. Flügge,[44] W. Haj Ahmad,[44,x] T. Kress,[44] A. Nowack,[44] O. Pooth,[44] A. Stahl,[44] T. Ziemons,[44] A. Zotz,[44] H. Aarup Petersen,[45] M. Aldaya Martin,[45] J. Alimena,[45] S. Amoroso,[45] Y. An,[45] S. Baxter,[45] M. Bayatmakou,[45] H. Becerril Gonzalez,[45] O. Behnke,[45] A. Belvedere,[45] S. Bhattacharya,[45] F. Blekman,[45,y]

K. Borras,[45,z] D. Brunner,[45] A. Campbell,[45] A. Cardini,[45] C. Cheng,[45] F. Colombina,[45] S. Consuegra Rodríguez,[45] G. Correia Silva,[45] M. De Silva,[45] G. Eckerlin,[45] D. Eckstein,[45] L. I. Estevez Banos,[45] O. Filatov,[45] E. Gallo,[45,y] A. Geiser,[45] A. Giraldi,[45] G. Greau,[45] V. Guglielmi,[45] M. Guthoff,[45] A. Hinzmann,[45] A. Jafari,[45,aa] L. Jeppe,[45] N. Z. Jomhari,[45] B. Kaech,[45] M. Kasemann,[45] H. Kaveh,[45] C. Kleinwort,[45] R. Kogler,[45] M. Komm,[45] D. Krücker,[45] W. Lange,[45] D. Leyva Pernia,[45] K. Lipka,[45,bb] W. Lohmann,[45,cc] R. Mankel,[45] I.-A. Melzer-Pellmann,[45] M. Mendizabal Morentin,[45] J. Metwally,[45] A. B. Meyer,[45] G. Milella,[45] A. Mussgiller,[45] A. Nürnberg,[45] Y. Otarid,[45] D. Pérez Adán,[45] E. Ranken,[45] A. Raspereza,[45] B. Ribeiro Lopes,[45] J. Rübenach,[45] A. Saggio,[45] M. Scham,[45,dd,z] V. Scheurer,[45] S. Schnake,[45,z] P. Schütze,[45] C. Schwanenberger,[45,y] D. Selivanova,[45] M. Shchedrolosiev,[45] R. E. Sosa Ricardo,[45] L. P. Sreelatha Pramod,[45] D. Stafford,[45] F. Vazzoler,[45] A. Ventura Barroso,[45] R. Walsh,[45] Q. Wang,[45] Y. Wen,[45] K. Wichmann,[45] L. Wiens,[45,z] C. Wissing,[45] S. Wuchterl,[45] Y. Yang,[45] A. Zimermmane Castro Santos,[45] A. Albrecht,[46] S. Albrecht,[46] M. Antonello,[46] S. Bein,[46] L. Benato,[46] M. Bonanomi,[46] P. Connor,[46] M. Eich,[46] K. El Morabit,[46] Y. Fischer,[46] A. Fröhlich,[46] C. Garbers,[46] E. Garutti,[46] A. Grohsjean,[46] M. Hajheidari,[46] J. Haller,[46] H. R. Jabusch,[46] G. Kasieczka,[46] P. Keicher,[46] R. Klanner,[46] W. Korcari,[46] T. Kramer,[46] V. Kutzner,[46] F. Labe,[46] J. Lange,[46] A. Lobanov,[46] C. Matthies,[46] A. Mehta,[46] L. Moureaux,[46] M. Mrowietz,[46] A. Nigamova,[46] Y. Nissan,[46] A. Paasch,[46] K. J. Pena Rodriguez,[46] T. Quadfasel,[46] B. Raciti,[46] M. Rieger,[46] D. Savoiu,[46] J. Schindler,[46] P. Schleper,[46] M. Schröder,[46] J. Schwandt,[46] M. Sommerhalder,[46] H. Stadie,[46] G. Steinbrück,[46] A. Tews,[46] M. Wolf,[46] S. Brommer,[47] M. Burkart,[47] E. Butz,[47] T. Chwalek,[47] A. Dierlamm,[47] A. Droll,[47] N. Faltermann,[47] M. Giffels,[47] A. Gottmann,[47] F. Hartmann,[47,ee] R. Hofsaess,[47] M. Horzela,[47] U. Husemann,[47] M. Klute,[47] R. Koppenhöfer,[47] M. Link,[47] A. Lintuluoto,[47] S. Maier,[47] S. Mitra,[47] M. Mormile,[47] Th. Müller,[47] M. Neukum,[47] M. Oh,[47] G. Quast,[47] K. Rabbertz,[47] B. Regnery,[47] N. Shadskiy,[47] I. Shvetsov,[47] H. J. Simonis,[47] N. Trevisani,[47] R. Ulrich,[47] J. van der Linden,[47] R. F. Von Cube,[47] M. Wassmer,[47] S. Wieland,[47] F. Wittig,[47] R. Wolf,[47] S. Wunsch,[47] X. Zuo,[47] G. Anagnostou,[48] P. Assiouras,[48] G. Daskalakis,[48] A. Kyriakis,[48] A. Papadopoulos,[48,ee] A. Stakia,[48] D. Karasavvas,[49] P. Kontaxakis,[49] G. Melachroinos,[49] A. Panagiotou,[49] I. Papavergou,[49] I. Paraskevas,[49] N. Saoulidou,[49] K. Theofilatos,[49] E. Tziaferi,[49] K. Vellidis,[49] I. Zisopoulos,[49] G. Bakas,[50] T. Chatzistavrou,[50] G. Karapostoli,[50] K. Kousouris,[50] I. Papakrivopoulos,[50] E. Siamarkou,[50] G. Tsipolitis,[50] A. Zacharopoulou,[50] K. Adamidis,[51] I. Bestintzanos,[51] I. Evangelou,[51] C. Foudas,[51] P. Gianneios,[51] C. Kamtsikis,[51] P. Katsoulis,[51] P. Kokkas,[51] P. G. Kosmoglou Kioseoglou,[51] N. Manthos,[51] I. Papadopoulos,[51] J. Strologas,[51] M. Bartók,[52,ff] C. Hajdu,[52] D. Horvath,[52,gg,hh] F. Sikler,[52] V. Veszpremi,[52] M. Csanád,[53] K. Farkas,[53] M. M. A. Gadallah,[53,ii] Á. Kadlecsik,[53] P. Major,[53] K. Mandal,[53] G. Pásztor,[53] A. J. Rádl,[53,jj] G. I. Veres,[53] P. Raics,[54] B. Ujvari,[54,kk] G. Zilizi,[54] G. Bencze,[55] S. Czellar,[55] J. Karancsi,[55,ff] J. Molnar,[55] Z. Szillasi,[55] T. Csorgo,[56,jj] F. Nemes,[56,jj] T. Novak,[56] J. Babbar,[57] S. Bansal,[57] S. B. Beri,[57] V. Bhatnagar,[57] G. Chaudhary,[57] S. Chauhan,[57] N. Dhingra,[57,ll] R. Gupta,[57] A. Kaur,[57] A. Kaur,[57] H. Kaur,[57] M. Kaur,[57] S. Kumar,[57] P. Kumari,[57] M. Meena,[57] K. Sandeep,[57] T. Sheokand,[57] J. B. Singh,[57,mm] A. Singla,[57] A. Ahmed,[58] A. Bhardwaj,[58] A. Chhetri,[58] B. C. Choudhary,[58] A. Kumar,[58] M. Naimuddin,[58] K. Ranjan,[58] S. Saumya,[58] S. Acharya,[59] S. Baradia,[59] S. Barman,[59,nn] S. Bhattacharya,[59] D. Bhowmik,[59] S. Dutta,[59] S. Dutta,[59] B. Gomber,[59,oo] P. Palit,[59] G. Saha,[59] B. Sahu,[59,oo] S. Sarkar,[59] M. M. Ameen,[60] P. K. Behera,[60] S. C. Behera,[60] S. Chatterjee,[60] P. Jana,[60] P. Kalbhor,[60] J. R. Komaragiri,[60,pp] D. Kumar,[60,pp] L. Panwar,[60,pp] R. Pradhan,[60] P. R. Pujahari,[60] N. R. Saha,[60] A. Sharma,[60] A. K. Sikdar,[60] S. Verma,[60] T. Aziz,[61] I. Das,[61] S. Dugad,[61] M. Kumar,[61] G. B. Mohanty,[61] P. Suryadevara,[61] A. Bala,[62] S. Banerjee,[62] R. M. Chatterjee,[62] M. Guchait,[62] S. Karmakar,[62] S. Kumar,[62] G. Majumder,[62] K. Mazumdar,[62] S. Mukherjee,[62] A. Thachayath,[62] S. Bahinipati,[63,qq] A. K. Das,[63] C. Kar,[63] D. Maity,[63,rr] P. Mal,[63] T. Mishra,[63] V. K. Muraleedharan Nair Bindhu,[63,rr] K. Naskar,[63,rr] A. Nayak,[63,rr] P. Sadangi,[63] P. Saha,[63] S. K. Swain,[63] S. Varghese,[63,rr] D. Vats,[63,rr] A. Alpana,[64] S. Dube,[64] B. Kansal,[64] A. Laha,[64] A. Rastogi,[64] S. Sharma,[64] H. Bakhshiansohi,[65,ss] E. Khazaie,[65,tt] M. Zeinali,[65,uu] S. Chenarani,[66,vv] S. M. Etesami,[66] M. Khakzad,[66] M. Mohammadi Najafabadi,[66] M. Grunewald,[67] M. Abbrescia,[68a,68b] R. Aly,[68a,68c,o] A. Colaleo,[68a,68b] D. Creanza,[68a,68c] B. D` Anzi,[68a,68b] N. De Filippis,[68a,68c] M. De Palma,[68a,68b] A. Di Florio,[68a,68c] W. Elmetenawee,[68a,68b,o] L. Fiore,[68a] G. Iaselli,[68a,68c] G. Maggi,[68a,68c] M. Maggi,[68a] I. Margjeka,[68a,68b] V. Mastrapasqua,[68a,68b] S. My,[68a,68b] S. Nuzzo,[68a,68b] A. Pellecchia,[68a,68b] A. Pompili,[68a,68b] G. Pugliese,[68a,68c] R. Radogna,[68a] G. Ramirez-Sanchez,[68a,68c] D. Ramos,[68a] A. Ranieri,[68a] L. Silvestris,[68a]

F. M. Simone,[68a,68b] Ü. Sözbilir,[68a] A. Stamerra,[68a] R. Venditti,[68a] P. Verwilligen,[68a] A. Zaza,[68a,68b] G. Abbiendi,[69a] C. Battilana,[69a,69b] D. Bonacorsi,[69a,69b] L. Borgonovi,[69a] R. Campanini,[69a,69b] P. Capiluppi,[69a,69b] A. Castro,[69a,69b] F. R. Cavallo,[69a] M. Cuffiani,[69a,69b] G. M. Dallavalle,[69a] T. Diotalevi,[69a,69b] F. Fabbri,[69a] A. Fanfani,[69a,69b] D. Fasanella,[69a,69b] P. Giacomelli,[69a] L. Giommi,[69a,69b] C. Grandi,[69a] L. Guiducci,[69a,69b] S. Lo Meo,[69a,ww] L. Lunerti,[69a,69b] G. Masetti,[69a] F. L. Navarria,[69a,69b] A. Perrotta,[69a] F. Primavera,[69a,69b] A. M. Rossi,[69a,69b] T. Rovelli,[69a,69b] G. P. Siroli,[69a,69b] S. Costa,[70a,70b,xx] A. Di Mattia,[70a] R. Potenza,[70a,70b] A. Tricomi,[70a,70b,xx] C. Tuve,[70a,70b] G. Barbagli,[71a] G. Bardelli,[71a,71b] B. Camaiani,[71a,71b] A. Cassese,[71a] R. Ceccarelli,[71a] V. Ciulli,[71a,71b] C. Civinini,[71a] R. D'Alessandro,[71a,71b] E. Focardi,[71a,71b] G. Latino,[71a,71b] P. Lenzi,[71a,71b] M. Lizzo,[71a] M. Meschini,[71a] S. Paoletti,[71a] A. Papanastassiou,[71a,71b] G. Sguazzoni,[71a] L. Viliani,[71a] L. Benussi,[72] S. Bianco,[72] S. Meola,[72,yy] D. Piccolo,[72] P. Chatagnon,[73a] F. Ferro,[73a] E. Robutti,[73a] S. Tosi,[73a,73b] A. Benaglia,[74a] G. Boldrini,[74a] F. Brivio,[74a] F. Cetorelli,[74a] F. De Guio,[74a,74b] M. E. Dinardo,[74a,74b] P. Dini,[74a] S. Gennai,[74a] A. Ghezzi,[74a,74b] P. Govoni,[74a,74b] L. Guzzi,[74a] M. T. Lucchini,[74a,74b] M. Malberti,[74a] S. Malvezzi,[74a] A. Massironi,[74a] D. Menasce,[74a] L. Moroni,[74a] M. Paganoni,[74a,74b] D. Pedrini,[74a] B. S. Pinolini,[74a] S. Ragazzi,[74a,74b] N. Redaelli,[74a] T. Tabarelli de Fatis,[74a,74b] D. Zuolo,[74a] S. Buontempo,[75a] A. Cagnotta,[75a,75b] F. Carnevali,[75a,75b] N. Cavallo,[75a,75c] A. De Iorio,[75a,75b] F. Fabozzi,[75a,75c] A. O. M. Iorio,[75a,75b] L. Lista,[75a,75b,zz] P. Paolucci,[75a,ee] B. Rossi,[75a] C. Sciacca,[75a,75b] R. Ardino,[76a] P. Azzi,[76a] N. Bacchetta,[76a,aaa] D. Bisello,[76a,76b] P. Bortignon,[76a] A. Bragagnolo,[76a,76b] R. Carlin,[76a,76b] P. Checchia,[76a] T. Dorigo,[76a] F. Fanzago,[76a] F. Gasparini,[76a,76b] F. Gonella,[76a] G. Grosso,[76a] L. Layer,[76a,bbb] E. Lusiani,[76a] M. Margoni,[76a,76b] A. T. Meneguzzo,[76a,76b] M. Migliorini,[76a,76b] J. Pazzini,[76a,76b] P. Ronchese,[76a,76b] R. Rossin,[76a,76b] F. Simonetto,[76a,76b] G. Strong,[76a] M. Tosi,[76a,76b] A. Triossi,[76a,76b] S. Ventura,[76a] H. Yarar,[76a,76b] M. Zanetti,[76a,76b] P. Zotto,[76a,76b] A. Zucchetta,[76a,76b] S. Abu Zeid,[77a,r] C. Aimè,[77a,77b] A. Braghieri,[77a] S. Calzaferri,[77a,77b] D. Fiorina,[77a,77b] P. Montagna,[77a,77b] V. Re,[77a] C. Riccardi,[77a,77b] P. Salvini,[77a] I. Vai,[77a,77b] P. Vitulo,[77a,77b] S. Ajmal,[78a,78b] P. Asenov,[78a,ccc] G. M. Bilei,[78a] D. Ciangottini,[78a,78b] L. Fanò,[78a,78b] M. Magherini,[78a,78b] G. Mantovani,[78a,78b] V. Mariani,[78a,78b] M. Menichelli,[78a] F. Moscatelli,[78a,ccc] A. Piccinelli,[78a,78b] M. Presilla,[78a,78b] A. Rossi,[78a,78b] A. Santocchia,[78a,78b] D. Spiga,[78a] T. Tedeschi,[78a,78b] P. Azzurri,[79a] G. Bagliesi,[79a] R. Bhattacharya,[79a] L. Bianchini,[79a,79b] T. Boccali,[79a] E. Bossini,[79a] D. Bruschini,[79a,79c] R. Castaldi,[79a] M. A. Ciocci,[79a,79b] M. Cipriani,[79a,79b] V. D'Amante,[79a,79d] R. Dell'Orso,[79a] S. Donato,[79a] A. Giassi,[79a] F. Ligabue,[79a,79c] D. Matos Figueiredo,[79a] A. Messineo,[79a,79b] M. Musich,[79a,79b] F. Palla,[79a] S. Parolia,[79a] A. Rizzi,[79a,79b] G. Rolandi,[79a,79c] S. Roy Chowdhury,[79a] T. Sarkar,[79a] A. Scribano,[79a] P. Spagnolo,[79a] R. Tenchini,[79a,79b] G. Tonelli,[79a,79b] N. Turini,[79a,79d] A. Venturi,[79a] P. G. Verdini,[79a] P. Barria,[80a] M. Campana,[80a,80b] F. Cavallari,[80a] L. Cunqueiro Mendez,[80a,80b] D. Del Re,[80a,80b] E. Di Marco,[80a] M. Diemoz,[80a] F. Errico,[80a,80b] E. Longo,[80a,80b] P. Meridiani,[80a] J. Mijuskovic,[80a,80b] G. Organtini,[80a,80b] F. Pandolfi,[80a] R. Paramatti,[80a,80b] C. Quaranta,[80a,80b] S. Rahatlou,[80a,80b] C. Rovelli,[80a] F. Santanastasio,[80a,80b] L. Soffi,[80a] R. Tramontano,[80a,80b] N. Amapane,[81a,81b] R. Arcidiacono,[81a,81c] S. Argiro,[81a,81b] M. Arneodo,[81a,81c] N. Bartosik,[81a] R. Bellan,[81a,81b] A. Bellora,[81a,81b] C. Biino,[81a] N. Cartiglia,[81a] M. Costa,[81a,81b] R. Covarelli,[81a,81b] N. Demaria,[81a] L. Finco,[81a] M. Grippo,[81a,81b] B. Kiani,[81a,81b] F. Legger,[81a] F. Luongo,[81a,81b] C. Mariotti,[81a] S. Maselli,[81a] A. Mecca,[81a,81b] E. Migliore,[81a,81b] M. Monteno,[81a] R. Mulargia,[81a] M. M. Obertino,[81a,81b] G. Ortona,[81a] L. Pacher,[81a,81b] N. Pastrone,[81a] M. Pelliccioni,[81a] M. Ruspa,[81a,81c] F. Siviero,[81a,81b] V. Sola,[81a,81b] A. Solano,[81a,81b] D. Soldi,[81a,81b] A. Staiano,[81a] C. Tarricone,[81a,81b] M. Tornago,[81a,81b] D. Trocino,[81a] G. Umoret,[81a,81b] E. Vlasov,[81a,81b] S. Belforte,[82a] V. Candelise,[82a,82b] M. Casarsa,[82a] F. Cossutti,[82a] K. De Leo,[82a,82b] G. Della Ricca,[82a,82b] S. Dogra,[83] J. Hong,[83] C. Huh,[83] B. Kim,[83] D. H. Kim,[83] J. Kim,[83] H. Lee,[83] S. W. Lee,[83] C. S. Moon,[83] Y. D. Oh,[83] S. I. Pak,[83] M. S. Ryu,[83] S. Sekmen,[83] Y. C. Yang,[83] G. Bak,[84] P. Gwak,[84] H. Kim,[84] D. H. Moon,[84] E. Asilar,[85] D. Kim,[85] T. J. Kim,[85] J. A. Merlin,[85] J. Park,[85] S. Choi,[86] S. Han,[86] B. Hong,[86] K. Lee,[86] K. S. Lee,[86] S. Lee,[86] J. Park,[86] S. K. Park,[86] J. Yoo,[86] J. Goh,[87] H. S. Kim,[88] Y. Kim,[88] S. Lee,[88] J. Almond,[89] J. H. Bhyun,[89] J. Choi,[89] W. Jun,[89] J. Kim,[89] J. S. Kim,[89] S. Ko,[89] H. Kwon,[89] H. Lee,[89] J. Lee,[89] J. Lee,[89] S. Lee,[89] B. H. Oh,[89] S. B. Oh,[89] H. Seo,[89] U. K. Yang,[89] I. Yoon,[89] W. Jang,[90] D. Y. Kang,[90] Y. Kang,[90] S. Kim,[90] B. Ko,[90] J. S. H. Lee,[90] Y. Lee,[90] I. C. Park,[90] Y. Roh,[90] I. J. Watson,[90] S. Yang,[90] S. Ha,[91] H. D. Yoo,[91] M. Choi,[92] M. R. Kim,[92] H. Lee,[92] Y. Lee,[92] I. Yu,[92] T. Beyrouthy,[93] Y. Maghrbi,[93] K. Dreimanis,[94] A. Gaile,[94] G. Pikurs,[94] A. Potrebko,[94] M. Seidel,[94]

V. Veckalns,[94,ddd] N. R. Strautnieks,[95] M. Ambrozas,[96] A. Juodagalvis,[96] A. Rinkevicius,[96] G. Tamulaitis,[96] N. Bin Norjoharuddeen,[97] I. Yusuff,[97,eee] Z. Zolkapli,[97] J. F. Benitez,[98] A. Castaneda Hernandez,[98] H. A. Encinas Acosta,[98] L. G. Gallegos Maríñez,[98] M. León Coello,[98] J. A. Murillo Quijada,[98] A. Sehrawat,[98] L. Valencia Palomo,[98] G. Ayala,[99] H. Castilla-Valdez,[99] E. De La Cruz-Burelo,[99] I. Heredia-De La Cruz,[99,fff] R. Lopez-Fernandez,[99] C. A. Mondragon Herrera,[99] A. Sánchez Hernández,[99] C. Oropeza Barrera,[100] M. Ramírez García,[100] I. Bautista,[101] I. Pedraza,[101] H. A. Salazar Ibarguen,[101] C. Uribe Estrada,[101] I. Bubanja,[102] N. Raicevic,[102] P. H. Butler,[103] A. Ahmad,[104] M. I. Asghar,[104] A. Awais,[104] M. I. M. Awan,[104] H. R. Hoorani,[104] W. A. Khan,[104] V. Avati,[105] L. Grzanka,[105] M. Malawski,[105] H. Bialkowska,[106] M. Bluj,[106] B. Boimska,[106] M. Górski,[106] M. Kazana,[106] M. Szleper,[106] P. Zalewski,[106] K. Bunkowski,[107] K. Doroba,[107] A. Kalinowski,[107] M. Konecki,[107] J. Krolikowski,[107] A. Muhammad,[107] K. Pozniak,[108] W. Zabolotny,[108] M. Araujo,[109] D. Bastos,[109] C. Beirão Da Cruz E Silva,[109] A. Boletti,[109] M. Bozzo,[109] P. Faccioli,[109] M. Gallinaro,[109] J. Hollar,[109] N. Leonardo,[109] T. Niknejad,[109] A. Petrilli,[109] M. Pisano,[109] J. Seixas,[109] J. Varela,[109] P. Adzic,[110] P. Milenovic,[110] M. Dordevic,[111] J. Milosevic,[111] V. Rekovic,[111] M. Aguilar-Benitez,[112] J. Alcaraz Maestre,[112] M. Barrio Luna,[112] Cristina F. Bedoya,[112] M. Cepeda,[112] M. Cerrada,[112] N. Colino,[112] B. De La Cruz,[112] A. Delgado Peris,[112] D. Fernández Del Val,[112] J. P. Fernández Ramos,[112] J. Flix,[112] M. C. Fouz,[112] O. Gonzalez Lopez,[112] S. Goy Lopez,[112] J. M. Hernandez,[112] M. I. Josa,[112] J. León Holgado,[112] D. Moran,[112] C. M. Morcillo Perez,[112] Á. Navarro Tobar,[112] C. Perez Dengra,[112] A. Pérez-Calero Yzquierdo,[112] J. Puerta Pelayo,[112] I. Redondo,[112] D. D. Redondo Ferrero,[112] L. Romero,[112] S. Sánchez Navas,[112] L. Urda Gómez,[112] J. Vazquez Escobar,[112] C. Willmott,[112] J. F. de Trocóniz,[113] B. Alvarez Gonzalez,[114] J. Cuevas,[114] J. Fernandez Menendez,[114] S. Folgueras,[114] I. Gonzalez Caballero,[114] J. R. González Fernández,[114] E. Palencia Cortezon,[114] C. Ramón Álvarez,[114] V. Rodríguez Bouza,[114] A. Soto Rodríguez,[114] A. Trapote,[114] C. Vico Villalba,[114] P. Vischia,[114] S. Bhowmik,[115] S. Blanco Fernández,[115] J. A. Brochero Cifuentes,[115] I. J. Cabrillo,[115] A. Calderon,[115] J. Duarte Campderros,[115] M. Fernandez,[115] C. Fernandez Madrazo,[115] G. Gomez,[115] C. Lasaosa García,[115] C. Martinez Rivero,[115] P. Martinez Ruiz del Arbol,[115] F. Matorras,[115] P. Matorras Cuevas,[115] E. Navarrete Ramos,[115] J. Piedra Gomez,[115] C. Prieels,[115] L. Scodellaro,[115] I. Vila,[115] J. M. Vizan Garcia,[115] M. K. Jayananda,[116] B. Kailasapathy,[116,ggg] D. U. J. Sonnadara,[116] D. D. C. Wickramarathna,[116] W. G. D. Dharmaratna,[117] K. Liyanage,[117] N. Perera,[117] N. Wickramage,[117] D. Abbaneo,[118] C. Amendola,[118] E. Auffray,[118] G. Auzinger,[118] J. Baechler,[118] D. Barney,[118] A. Bermúdez Martínez,[118] M. Bianco,[118] B. Bilin,[118] A. A. Bin Anuar,[118] A. Bocci,[118] E. Brondolin,[118] C. Caillol,[118] T. Camporesi,[118] G. Cerminara,[118] N. Chernyavskaya,[118] D. d'Enterria,[118] A. Dabrowski,[118] A. David,[118] A. De Roeck,[118] M. M. Defranchis,[118] M. Deile,[118] M. Dobson,[118] F. Fallavollita,[118,hhh] L. Forthomme,[118] G. Franzoni,[118] W. Funk,[118] S. Giani,[118] D. Gigi,[118] K. Gill,[118] F. Glege,[118] L. Gouskos,[118] M. Haranko,[118] J. Hegeman,[118] V. Innocente,[118] T. James,[118] P. Janot,[118] J. Kieseler,[118] S. Laurila,[118] P. Lecoq,[118] E. Leutgeb,[118] C. Lourenço,[118] B. Maier,[118] L. Malgeri,[118] M. Mannelli,[118] A. C. Marini,[118] F. Meijers,[118] S. Mersi,[118] E. Meschi,[118] V. Milosevic,[118] F. Moortgat,[118] M. Mulders,[118] S. Orfanelli,[118] F. Pantaleo,[118] M. Peruzzi,[118] G. Petrucciani,[118] A. Pfeiffer,[118] M. Pierini,[118] D. Piparo,[118] H. Qu,[118] D. Rabady,[118] G. Reales Gutiérrez,[118] M. Rovere,[118] H. Sakulin,[118] S. Scarfi,[118] M. Selvaggi,[118] A. Sharma,[118] K. Shchelina,[118] P. Silva,[118] P. Sphicas,[118,iii] A. G. Stahl Leiton,[118] A. Steen,[118] S. Summers,[118] D. Treille,[118] P. Tropea,[118] A. Tsirou,[118] D. Walter,[118] J. Wanczyk,[118,jjj] K. A. Wozniak,[118,kkk] P. Zehetner,[118] P. Zejdl,[118] W. D. Zeuner,[118] T. Bevilacqua,[119,lll] L. Caminada,[119,lll] A. Ebrahimi,[119] W. Erdmann,[119] R. Horisberger,[119] Q. Ingram,[119] H. C. Kaestli,[119] D. Kotlinski,[119] C. Lange,[119] M. Missiroli,[119,lll] L. Noehte,[119,lll] T. Rohe,[119] T. K. Aarrestad,[120] K. Androsov,[120,jjj] M. Backhaus,[120] A. Calandri,[120] C. Cazzaniga,[120] K. Datta,[120] A. De Cosa,[120] G. Dissertori,[120] M. Dittmar,[120] M. Donegà,[120] F. Eble,[120] M. Galli,[120] K. Gedia,[120] F. Glessgen,[120] C. Grab,[120] D. Hits,[120] W. Lustermann,[120] A.-M. Lyon,[120] R. A. Manzoni,[120] M. Marchegiani,[120] L. Marchese,[120] C. Martin Perez,[120] A. Mascellani,[120,jjj] F. Nessi-Tedaldi,[120] F. Pauss,[120] V. Perovic,[120] S. Pigazzini,[120] M. G. Ratti,[120] M. Reichmann,[120] C. Reissel,[120] T. Reitenspiess,[120] B. Ristic,[120] F. Riti,[120] D. Ruini,[120] D. A. Sanz Becerra,[120] R. Seidita,[120] J. Steggemann,[120,jjj] D. Valsecchi,[120] R. Wallny,[120] C. Amsler,[121,mmm] P. Bärtschi,[121] C. Botta,[121] D. Brzhechko,[121] M. F. Canelli,[121] K. Cormier,[121] R. Del Burgo,[121] J. K. Heikkilä,[121] M. Huwiler,[121] W. Jin,[121] A. Jofrehei,[121] B. Kilminster,[121] S. Leontsinis,[121] S. P. Liechti,[121]

A. Macchiolo,[121] P. Meiring,[121] V. M. Mikuni,[121] U. Molinatti,[121] I. Neutelings,[121] A. Reimers,[121] P. Robmann,[121] S. Sanchez Cruz,[121] K. Schweiger,[121] M. Senger,[121] Y. Takahashi,[121] C. Adloff,[122,nnn] C. M. Kuo,[122] W. Lin,[122] P. K. Rout,[122] P. C. Tiwari,[122,pp] S. S. Yu,[122] L. Ceard,[123] Y. Chao,[123] K. F. Chen,[123] P. s. Chen,[123] Z. g. Chen,[123] W.-S. Hou,[123] T. h. Hsu,[123] Y. w. Kao,[123] R. Khurana,[123] G. Kole,[123] Y. y. Li,[123] R.-S. Lu,[123] E. Paganis,[123] A. Psallidas,[123] X. f. Su,[123] J. Thomas-Wilsker,[123] H. y. Wu,[123] E. Yazgan,[123] C. Asawatangtrakuldee,[124] N. Srimanobhas,[124] V. Wachirapusitanand,[124] D. Agyel,[125] F. Boran,[125] Z. S. Demiroglu,[125] F. Dolek,[125] I. Dumanoglu,[125,ooo] E. Eskut,[125] Y. Guler,[125,ppp] E. Gurpinar Guler,[125,ppp] C. Isik,[125] O. Kara,[125] A. Kayis Topaksu,[125] U. Kiminsu,[125] G. Onengut,[125] K. Ozdemir,[125,qqq] A. Polatoz,[125] B. Tali,[125,rrr] U. G. Tok,[125] S. Turkcapar,[125] E. Uslan,[125] I. S. Zorbakir,[125] K. Ocalan,[126,sss] M. Yalvac,[126,ttt] B. Akgun,[127] I. O. Atakisi,[127] E. Gülmez,[127] M. Kaya,[127,uuu] O. Kaya,[127,vvv] S. Tekten,[127,www] A. Cakir,[128] K. Cankocak,[128,ooo] Y. Komurcu,[128] S. Sen,[128,xxx] O. Aydilek,[129] S. Cerci,[129,rrr] V. Epshteyn,[129] B. Hacisahinoglu,[129] I. Hos,[129,yyy] B. Isildak,[129,zzz] B. Kaynak,[129] S. Ozkorucuklu,[129] O. Potok,[129] H. Sert,[129] C. Simsek,[129] D. Sunar Cerci,[129,rrr] C. Zorbilmez,[129] A. Boyaryntsev,[130] B. Grynyov,[130] L. Levchuk,[131] D. Anthony,[132] J. J. Brooke,[132] A. Bundock,[132] F. Bury,[132] E. Clement,[132] D. Cussans,[132] H. Flacher,[132] M. Glowacki,[132] J. Goldstein,[132] H. F. Heath,[132] L. Kreczko,[132] B. Krikler,[132] S. Paramesvaran,[132] S. Seif El Nasr-Storey,[132] V. J. Smith,[132] N. Stylianou,[132,aaaa] K. Walkingshaw Pass,[132] R. White,[132] A. H. Ball,[133] K. W. Bell,[133] A. Belyaev,[133,bbbb] C. Brew,[133] R. M. Brown,[133] D. J. A. Cockerill,[133] C. Cooke,[133] K. V. Ellis,[133] K. Harder,[133] S. Harper,[133] M.-L. Holmberg,[133,cccc] Sh. Jain,[133] J. Linacre,[133] K. Manolopoulos,[133] D. M. Newbold,[133] E. Olaiya,[133] D. Petyt,[133] T. Reis,[133] G. Salvi,[133] T. Schuh,[133] C. H. Shepherd-Themistocleous,[133] I. R. Tomalin,[133] T. Williams,[133] R. Bainbridge,[134] P. Bloch,[134] C. E. Brown,[134] O. Buchmuller,[134] V. Cacchio,[134] C. A. Carrillo Montoya,[134] G. S. Chahal,[134,dddd] D. Colling,[134] J. S. Dancu,[134] P. Dauncey,[134] G. Davies,[134] J. Davies,[134] M. Della Negra,[134] S. Fayer,[134] G. Fedi,[134] G. Hall,[134] M. H. Hassanshahi,[134] A. Howard,[134] G. Iles,[134] M. Knight,[134] J. Langford,[134] L. Lyons,[134] A.-M. Magnan,[134] S. Malik,[134] A. Martelli,[134] M. Mieskolainen,[134] J. Nash,[134,eeee] M. Pesaresi,[134] B. C. Radburn-Smith,[134] A. Richards,[134] A. Rose,[134] C. Seez,[134] R. Shukla,[134] A. Tapper,[134] K. Uchida,[134] G. P. Uttley,[134] L. H. Vage,[134] T. Virdee,[134,ee] M. Vojinovic,[134] N. Wardle,[134] D. Winterbottom,[134] K. Coldham,[135] J. E. Cole,[135] A. Khan,[135] P. Kyberd,[135] I. D. Reid,[135] S. Abdullin,[136] A. Brinkerhoff,[136] B. Caraway,[136] J. Dittmann,[136] K. Hatakeyama,[136] J. Hiltbrand,[136] A. R. Kanuganti,[136] B. McMaster,[136] M. Saunders,[136] S. Sawant,[136] C. Sutantawibul,[136] M. Toms,[136,n] J. Wilson,[136] R. Bartek,[137] A. Dominguez,[137] C. Huerta Escamilla,[137] A. E. Simsek,[137] R. Uniyal,[137] A. M. Vargas Hernandez,[137] R. Chudasama,[138] S. I. Cooper,[138] S. V. Gleyzer,[138] C. U. Perez,[138] P. Rumerio,[138,ffff] E. Usai,[138] C. West,[138] R. Yi,[138] A. Akpinar,[139] A. Albert,[139] D. Arcaro,[139] C. Cosby,[139] Z. Demiragli,[139] C. Erice,[139] E. Fontanesi,[139] D. Gastler,[139] S. Jeon,[139] J. Rohlf,[139] K. Salyer,[139] D. Sperka,[139] D. Spitzbart,[139] I. Suarez,[139] A. Tsatsos,[139] S. Yuan,[139] G. Benelli,[140] X. Coubez,[140,z] D. Cutts,[140] M. Hadley,[140] U. Heintz,[140] J. M. Hogan,[140,gggg] T. Kwon,[140] G. Landsberg,[140] K. T. Lau,[140] D. Li,[140] J. Luo,[140] S. Mondal,[140] M. Narain,[140,a] N. Pervan,[140] S. Sagir,[140,hhhh] F. Simpson,[140] M. Stamenkovic,[140] W. Y. Wong,[140] X. Yan,[140] W. Zhang,[140] S. Abbott,[141] J. Bonilla,[141] C. Brainerd,[141] R. Breedon,[141] M. Calderon De La Barca Sanchez,[141] M. Chertok,[141] M. Citron,[141] J. Conway,[141] P. T. Cox,[141] R. Erbacher,[141] G. Haza,[141] F. Jensen,[141] O. Kukral,[141] G. Mocellin,[141] M. Mulhearn,[141] D. Pellett,[141] W. Wei,[141] Y. Yao,[141] F. Zhang,[141] M. Bachtis,[142] R. Cousins,[142] A. Datta,[142] J. Hauser,[142] M. Ignatenko,[142] M. A. Iqbal,[142] T. Lam,[142] E. Manca,[142] W. A. Nash,[142] D. Saltzberg,[142] B. Stone,[142] V. Valuev,[142] R. Clare,[143] M. Gordon,[143] G. Hanson,[143] W. Si,[143] S. Wimpenny,[143,a] J. G. Branson,[144] S. Cittolin,[144] S. Cooperstein,[144] D. Diaz,[144] J. Duarte,[144] R. Gerosa,[144] L. Giannini,[144] J. Guiang,[144] R. Kansal,[144] V. Krutelyov,[144] R. Lee,[144] J. Letts,[144] M. Masciovecchio,[144] F. Mokhtar,[144] M. Pieri,[144] M. Quinnan,[144] B. V. Sathia Narayanan,[144] V. Sharma,[144] M. Tadel,[144] E. Vourliotis,[144] F. Würthwein,[144] Y. Xiang,[144] A. Yagil,[144] A. Barzdukas,[145] L. Brennan,[145] C. Campagnari,[145] G. Collura,[145] A. Dorsett,[145] J. Incandela,[145] M. Kilpatrick,[145] J. Kim,[145] A. J. Li,[145] P. Masterson,[145] H. Mei,[145] M. Oshiro,[145] J. Richman,[145] U. Sarica,[145] R. Schmitz,[145] F. Setti,[145] J. Sheplock,[145] D. Stuart,[145] S. Wang,[145] A. Bornheim,[146] O. Cerri,[146] A. Latorre,[146] J. M. Lawhorn,[146] J. Mao,[146] H. B. Newman,[146] T. Q. Nguyen,[146] M. Spiropulu,[146] J. R. Vlimant,[146] C. Wang,[146] S. Xie,[146] R. Y. Zhu,[146] J. Alison,[147] S. An,[147] M. B. Andrews,[147] P. Bryant,[147] V. Dutta,[147] T. Ferguson,[147] A. Harilal,[147] C. Liu,[147] T. Mudholkar,[147]

S. Murthy,[147] M. Paulini,[147] A. Roberts,[147] A. Sanchez,[147] W. Terrill,[147] J. P. Cumalat,[148] W. T. Ford,[148] A. Hassani,[148] G. Karathanasis,[148] E. MacDonald,[148] N. Manganelli,[148] F. Marini,[148] A. Perloff,[148] C. Savard,[148] N. Schonbeck,[148] K. Stenson,[148] K. A. Ulmer,[148] S. R. Wagner,[148] N. Zipper,[148] J. Alexander,[149] S. Bright-Thonney,[149] X. Chen,[149] D. J. Cranshaw,[149] J. Fan,[149] X. Fan,[149] D. Gadkari,[149] S. Hogan,[149] J. Monroy,[149] J. R. Patterson,[149] J. Reichert,[149] M. Reid,[149] A. Ryd,[149] J. Thom,[149] P. Wittich,[149] R. Zou,[149] M. Albrow,[150] M. Alyari,[150] O. Amram,[150] G. Apollinari,[150] A. Apresyan,[150] L. A. T. Bauerdick,[150] D. Berry,[150] J. Berryhill,[150] P. C. Bhat,[150] K. Burkett,[150] J. N. Butler,[150] A. Canepa,[150] G. B. Cerati,[150] H. W. K. Cheung,[150] F. Chlebana,[150] G. Cummings,[150] J. Dickinson,[150] I. Dutta,[150] V. D. Elvira,[150] Y. Feng,[150] J. Freeman,[150] A. Gandrakota,[150] Z. Gecse,[150] L. Gray,[150] D. Green,[150] A. Grummer,[150] S. Grünendahl,[150] D. Guerrero,[150] O. Gutsche,[150] R. M. Harris,[150] R. Heller,[150] T. C. Herwig,[150] J. Hirschauer,[150] L. Horyn,[150] B. Jayatilaka,[150] S. Jindariani,[150] M. Johnson,[150] U. Joshi,[150] T. Klijnsma,[150] B. Klima,[150] K. H. M. Kwok,[150] S. Lammel,[150] D. Lincoln,[150] R. Lipton,[150] T. Liu,[150] C. Madrid,[150] K. Maeshima,[150] C. Mantilla,[150] D. Mason,[150] P. McBride,[150] P. Merkel,[150] S. Mrenna,[150] S. Nahn,[150] J. Ngadiuba,[150] D. Noonan,[150] V. Papadimitriou,[150] N. Pastika,[150] K. Pedro,[150] C. Pena,[150,iiii] F. Ravera,[150] A. Reinsvold Hall,[150,jjjj] L. Ristori,[150] E. Sexton-Kennedy,[150] N. Smith,[150] A. Soha,[150] L. Spiegel,[150] S. Stoynev,[150] J. Strait,[150] L. Taylor,[150] S. Tkaczyk,[150] N. V. Tran,[150] L. Uplegger,[150] E. W. Vaandering,[150] I. Zoi,[150] C. Aruta,[151] P. Avery,[151] D. Bourilkov,[151] L. Cadamuro,[151] P. Chang,[151] V. Cherepanov,[151] R. D. Field,[151] E. Koenig,[151] M. Kolosova,[151] J. Konigsberg,[151] A. Korytov,[151] K. H. Lo,[151] K. Matchev,[151] N. Menendez,[151] G. Mitselmakher,[151] A. Muthirakalayil Madhu,[151] N. Rawal,[151] D. Rosenzweig,[151] S. Rosenzweig,[151] K. Shi,[151] J. Wang,[151] T. Adams,[152] A. Al Kadhim,[152] A. Askew,[152] N. Bower,[152] R. Habibullah,[152] V. Hagopian,[152] R. Hashmi,[152] R. S. Kim,[152] S. Kim,[152] T. Kolberg,[152] G. Martinez,[152] H. Prosper,[152] P. R. Prova,[152] O. Viazlo,[152] M. Wulansatiti,[152] R. Yohay,[152] J. Zhang,[152] B. Alsufyani,[153] M. M. Baarmand,[153] S. Butalla,[153] T. Elkafrawy,[153,r] M. Hohlmann,[153] R. Kumar Verma,[153] M. Rahmani,[153] M. R. Adams,[154] C. Bennett,[154] R. Cavanaugh,[154] S. Dittmer,[154] R. Escobar Franco,[154] O. Evdokimov,[154] C. E. Gerber,[154] D. J. Hofman,[154] J. h. Lee,[154] D. S. Lemos,[154] A. H. Merrit,[154] C. Mills,[154] S. Nanda,[154] G. Oh,[154] B. Ozek,[154] D. Pilipovic,[154] T. Roy,[154] S. Rudrabhatla,[154] M. B. Tonjes,[154] N. Varelas,[154] X. Wang,[154] Z. Ye,[154] J. Yoo,[154] M. Alhusseini,[155] D. Blend,[155] K. Dilsiz,[155,kkkk] L. Emediato,[155] G. Karaman,[155] O. K. Köseyan,[155] J.-P. Merlo,[155] A. Mestvirishvili,[155,llll] J. Nachtman,[155] O. Neogi,[155] H. Ogul,[155,mmmm] Y. Onel,[155] A. Penzo,[155] C. Snyder,[155] E. Tiras,[155,nnnn] B. Blumenfeld,[156] L. Corcodilos,[156] J. Davis,[156] A. V. Gritsan,[156] L. Kang,[156] S. Kyriacou,[156] P. Maksimovic,[156] M. Roguljic,[156] J. Roskes,[156] S. Sekhar,[156] M. Swartz,[156] T. Á. Vámi,[156] A. Abreu,[157] L. F. Alcerro Alcerro,[157] J. Anguiano,[157] P. Baringer,[157] A. Bean,[157] Z. Flowers,[157] D. Grove,[157] J. King,[157] G. Krintiras,[157] M. Lazarovits,[157] C. Le Mahieu,[157] C. Lindsey,[157] J. Marquez,[157] N. Minafra,[157] M. Murray,[157] M. Nickel,[157] M. Pitt,[157] S. Popescu,[157,oooo] C. Rogan,[157] C. Royon,[157] R. Salvatico,[157] S. Sanders,[157] C. Smith,[157] Q. Wang,[157] G. Wilson,[157] B. Allmond,[158] A. Ivanov,[158] K. Kaadze,[158] A. Kalogeropoulos,[158] D. Kim,[158] Y. Maravin,[158] K. Nam,[158] J. Natoli,[158] D. Roy,[158] G. Sorrentino,[158] F. Rebassoo,[159] D. Wright,[159] E. Adams,[160] A. Baden,[160] O. Baron,[160] A. Belloni,[160] A. Bethani,[160] Y. M. Chen,[160] S. C. Eno,[160] N. J. Hadley,[160] S. Jabeen,[160] R. G. Kellogg,[160] T. Koeth,[160] Y. Lai,[160] S. Lascio,[160] A. C. Mignerey,[160] S. Nabili,[160] C. Palmer,[160] C. Papageorgakis,[160] M. M. Paranjpe,[160] L. Wang,[160] K. Wong,[160] J. Bendavid,[161] W. Busza,[161] I. A. Cali,[161] Y. Chen,[161] M. D'Alfonso,[161] J. Eysermans,[161] C. Freer,[161] G. Gomez-Ceballos,[161] M. Goncharov,[161] P. Harris,[161] D. Hoang,[161] D. Kovalskyi,[161] J. Krupa,[161] L. Lavezzo,[161] Y.-J. Lee,[161] K. Long,[161] C. Mironov,[161] C. Paus,[161] D. Rankin,[161] C. Roland,[161] G. Roland,[161] S. Rothman,[161] Z. Shi,[161] G. S. F. Stephans,[161] J. Wang,[161] Z. Wang,[161] B. Wyslouch,[161] T. J. Yang,[161] B. Crossman,[162] B. M. Joshi,[162] C. Kapsiak,[162] M. Krohn,[162] D. Mahon,[162] J. Mans,[162] B. Marzocchi,[162] S. Pandey,[162] M. Revering,[162] R. Rusack,[162] R. Saradhy,[162] N. Schroeder,[162] N. Strobbe,[162] M. A. Wadud,[162] L. M. Cremaldi,[163] K. Bloom,[164] M. Bryson,[164] D. R. Claes,[164] C. Fangmeier,[164] F. Golf,[164] J. Hossain,[164] C. Joo,[164] I. Kravchenko,[164] I. Reed,[164] J. E. Siado,[164] G. R. Snow,[164,a] W. Tabb,[164] A. Vagnerini,[164] A. Wightman,[164] F. Yan,[164] D. Yu,[164] A. G. Zecchinelli,[164] G. Agarwal,[165] H. Bandyopadhyay,[165] L. Hay,[165] I. Iashvili,[165] A. Kharchilava,[165] C. McLean,[165] M. Morris,[165] D. Nguyen,[165] J. Pekkanen,[165] S. Rappoccio,[165] H. Rejeb Sfar,[165] A. Williams,[165]

G. Alverson,[166] E. Barberis,[166] Y. Haddad,[166] Y. Han,[166] A. Krishna,[166] J. Li,[166] M. Lu,[166] G. Madigan,[166] D. M. Morse,[166] V. Nguyen,[166] T. Orimoto,[166] A. Parker,[166] L. Skinnari,[166] A. Tishelman-Charny,[166] B. Wang,[166] D. Wood,[166] S. Bhattacharya,[167] J. Bueghly,[167] Z. Chen,[167] K. A. Hahn,[167] Y. Liu,[167] Y. Miao,[167] D. G. Monk,[167] M. H. Schmitt,[167] A. Taliercio,[167] M. Velasco,[167] R. Band,[168] R. Bucci,[168] S. Castells,[168] M. Cremonesi,[168] A. Das,[168] R. Goldouzian,[168] M. Hildreth,[168] K. W. Ho,[168] K. Hurtado Anampa,[168] C. Jessop,[168] K. Lannon,[168] J. Lawrence,[168] N. Loukas,[168] L. Lutton,[168] J. Mariano,[168] N. Marinelli,[168] I. Mcalister,[168] T. McCauley,[168] C. Mcgrady,[168] K. Mohrman,[168] C. Moore,[168] Y. Musienko,[168,n] H. Nelson,[168] M. Osherson,[168] R. Ruchti,[168] A. Townsend,[168] M. Wayne,[168] H. Yockey,[168] M. Zarucki,[168] L. Zygala,[168] A. Basnet,[169] B. Bylsma,[169] M. Carrigan,[169] L. S. Durkin,[169] C. Hill,[169] M. Joyce,[169] A. Lesauvage,[169] M. Nunez Ornelas,[169] K. Wei,[169] B. L. Winer,[169] B. R. Yates,[169] F. M. Addesa,[170] H. Bouchamaoui,[170] P. Das,[170] G. Dezoort,[170] P. Elmer,[170] A. Frankenthal,[170] B. Greenberg,[170] N. Haubrich,[170] S. Higginbotham,[170] G. Kopp,[170] S. Kwan,[170] D. Lange,[170] A. Loeliger,[170] D. Marlow,[170] I. Ojalvo,[170] J. Olsen,[170] D. Stickland,[170] C. Tully,[170] S. Malik,[171] A. S. Bakshi,[172] V. E. Barnes,[172] S. Chandra,[172] R. Chawla,[172] S. Das,[172] A. Gu,[172] L. Gutay,[172] M. Jones,[172] A. W. Jung,[172] D. Kondratyev,[172] A. M. Koshy,[172] M. Liu,[172] G. Negro,[172] N. Neumeister,[172] G. Paspalaki,[172] S. Piperov,[172] A. Purohit,[172] J. F. Schulte,[172] M. Stojanovic,[172] J. Thieman,[172] A. K. Virdi,[172] F. Wang,[172] W. Xie,[172] J. Dolen,[173] N. Parashar,[173] A. Pathak,[173] D. Acosta,[174] A. Baty,[174] T. Carnahan,[174] S. Dildick,[174] K. M. Ecklund,[174] P. J. Fernández Manteca,[174] S. Freed,[174] P. Gardner,[174] F. J. M. Geurts,[174] A. Kumar,[174] W. Li,[174] O. Miguel Colin,[174] B. P. Padley,[174] R. Redjimi,[174] J. Rotter,[174] E. Yigitbasi,[174] Y. Zhang,[174] A. Bodek,[175] P. de Barbaro,[175] R. Demina,[175] J. L. Dulemba,[175] C. Fallon,[175] A. Garcia-Bellido,[175] O. Hindrichs,[175] A. Khukhunaishvili,[175] P. Parygin,[175,n] E. Popova,[175,n] R. Taus,[175] G. P. Van Onsem,[175] K. Goulianos,[176] B. Chiarito,[177] J. P. Chou,[177] Y. Gershtein,[177] E. Halkiadakis,[177] A. Hart,[177] M. Heindl,[177] D. Jaroslawski,[177] O. Karacheban,[177,cc] I. Laflotte,[177] A. Lath,[177] R. Montalvo,[177] K. Nash,[177] H. Routray,[177] S. Salur,[177] S. Schnetzer,[177] S. Somalwar,[177] R. Stone,[177] S. A. Thayil,[177] S. Thomas,[177] J. Vora,[177] H. Wang,[177] H. Acharya,[178] D. Ally,[178] A. G. Delannoy,[178] S. Fiorendi,[178] T. Holmes,[178] N. Karunarathna,[178] L. Lee,[178] E. Nibigira,[178] S. Spanier,[178] D. Aebi,[179] M. Ahmad,[179] O. Bouhali,[179,pppp] M. Dalchenko,[179] R. Eusebi,[179] J. Gilmore,[179] T. Huang,[179] T. Kamon,[179,qqqq] H. Kim,[179] S. Luo,[179] S. Malhotra,[179] R. Mueller,[179] D. Overton,[179] D. Rathjens,[179] A. Safonov,[179] N. Akchurin,[180] J. Damgov,[180] V. Hegde,[180] A. Hussain,[180] Y. Kazhykarim,[180] K. Lamichhane,[180] S. W. Lee,[180] A. Mankel,[180] T. Mengke,[180] S. Muthumuni,[180] T. Peltola,[180] I. Volobouev,[180] A. Whitbeck,[180] E. Appelt,[181] S. Greene,[181] A. Gurrola,[181] W. Johns,[181] R. Kunnawalkam Elayavalli,[181] A. Melo,[181] F. Romeo,[181] P. Sheldon,[181] S. Tuo,[181] J. Velkovska,[181] J. Viinikainen,[181] B. Cardwell,[182] B. Cox,[182] J. Hakala,[182] R. Hirosky,[182] A. Ledovskoy,[182] A. Li,[182] C. Neu,[182] C. E. Perez Lara,[182] P. E. Karchin,[183] A. Aravind,[184] S. Banerjee,[184] K. Black,[184] T. Bose,[184] S. Dasu,[184] I. De Bruyn,[184] P. Everaerts,[184] C. Galloni,[184] H. He,[184] M. Herndon,[184] A. Herve,[184] C. K. Koraka,[184] A. Lanaro,[184] R. Loveless,[184] J. Madhusudanan Sreekala,[184] A. Mallampalli,[184] A. Mohammadi,[184] S. Mondal,[184] G. Parida,[184] D. Pinna,[184] A. Savin,[184] V. Shang,[184] V. Sharma,[184] W. H. Smith,[184] D. Teague,[184] H. F. Tsoi,[184] W. Vetens,[184] A. Warden,[184] S. Afanasiev,[185] V. Andreev,[185] Yu. Andreev,[185] T. Aushev,[185] M. Azarkin,[185] A. Babaev,[185] A. Belyaev,[185] V. Blinov,[185,n] E. Boos,[185] V. Borshch,[185] D. Budkouski,[185] V. Bunichev,[185] V. Chekhovsky,[185] R. Chistov,[185,n] M. Danilov,[185,n] A. Dermenev,[185] T. Dimova,[185,n] D. Druzhkin,[185,rrrr] M. Dubinin,[185,iiii] L. Dudko,[185] G. Gavrilov,[185] V. Gavrilov,[185] S. Gninenko,[185] V. Golovtcov,[185] N. Golubev,[185] I. Golutvin,[185] I. Gorbunov,[185] A. Gribushin,[185] Y. Ivanov,[185] V. Kachanov,[185] L. Kardapoltsev,[185,n] V. Karjavine,[185] A. Karneyeu,[185] V. Kim,[185,n] M. Kirakosyan,[185] D. Kirpichnikov,[185] M. Kirsanov,[185] V. Klyukhin,[185] O. Kodolova,[185,ssss] D. Konstantinov,[185] V. Korenkov,[185] A. Kozyrev,[185,n] N. Krasnikov,[185] A. Lanev,[185] P. Levchenko,[185,tttt] O. Lukina,[185] N. Lychkovskaya,[185] V. Makarenko,[185] A. Malakhov,[185] V. Matveev,[185,n] V. Murzin,[185] A. Nikitenko,[185,uuuu,ssss] S. Obraztsov,[185] V. Oreshkin,[185] V. Palichik,[185] V. Perelygin,[185] S. Petrushanko,[185] S. Polikarpov,[185,n] V. Popov,[185] O. Radchenko,[185,n] M. Savina,[185] V. Savrin,[185] V. Shalaev,[185] S. Shmatov,[185] S. Shulha,[185] Y. Skovpen,[185,n] S. Slabospitskii,[185] V. Smirnov,[185] A. Snigirev,[185] D. Sosnov,[185] V. Sulimov,[185] E. Tcherniaev,[185] A. Terkulov,[185] O. Teryaev,[185] I. Tlisova,[185] A. Toropin,[185] L. Uvarov,[185]

A. Uzunian,[185] A. Vorobyev,[185,a] N. Voytishin,[185] B. S. Yuldashev,[185,vvvv] A. Zarubin,[185] I. Zhizhin,[185] and A. Zhokin[185]

(CMS Collaboration)

[1]*Yerevan Physics Institute, Yerevan, Armenia*
[2]*Institut für Hochenergiephysik, Vienna, Austria*
[3]*Universiteit Antwerpen, Antwerpen, Belgium*
[4]*Vrije Universiteit Brussel, Brussel, Belgium*
[5]*Université Libre de Bruxelles, Bruxelles, Belgium*
[6]*Ghent University, Ghent, Belgium*
[7]*Université Catholique de Louvain, Louvain-la-Neuve, Belgium*
[8]*Centro Brasileiro de Pesquisas Fisicas, Rio de Janeiro, Brazil*
[9]*Universidade do Estado do Rio de Janeiro, Rio de Janeiro, Brazil*
[10]*Universidade Estadual Paulista, Universidade Federal do ABC, São Paulo, Brazil*
[11]*Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Sofia, Bulgaria*
[12]*University of Sofia, Sofia, Bulgaria*
[13]*Instituto De Alta Investigación, Universidad de Tarapacá, Casilla 7 D, Arica, Chile*
[14]*Beihang University, Beijing, China*
[15]*Department of Physics, Tsinghua University, Beijing, China*
[16]*Institute of High Energy Physics, Beijing, China*
[17]*State Key Laboratory of Nuclear Physics and Technology, Peking University, Beijing, China*
[18]*Sun Yat-Sen University, Guangzhou, China*
[19]*University of Science and Technology of China, Hefei, China*
[20]*Institute of Modern Physics and Key Laboratory of Nuclear Physics and Ion-beam Application (MOE) - Fudan University, Shanghai, China*
[21]*Zhejiang University, Hangzhou, Zhejiang, China*
[22]*Universidad de Los Andes, Bogota, Colombia*
[23]*Universidad de Antioquia, Medellin, Colombia*
[24]*University of Split, Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, Split, Croatia*
[25]*University of Split, Faculty of Science, Split, Croatia*
[26]*Institute Rudjer Boskovic, Zagreb, Croatia*
[27]*University of Cyprus, Nicosia, Cyprus*
[28]*Charles University, Prague, Czech Republic*
[29]*Escuela Politecnica Nacional, Quito, Ecuador*
[30]*Universidad San Francisco de Quito, Quito, Ecuador*
[31]*Academy of Scientific Research and Technology of the Arab Republic of Egypt, Egyptian Network of High Energy Physics, Cairo, Egypt*
[32]*Center for High Energy Physics (CHEP-FU), Fayoum University, El-Fayoum, Egypt*
[33]*National Institute of Chemical Physics and Biophysics, Tallinn, Estonia*
[34]*Department of Physics, University of Helsinki, Helsinki, Finland*
[35]*Helsinki Institute of Physics, Helsinki, Finland*
[36]*Lappeenranta-Lahti University of Technology, Lappeenranta, Finland*
[37]*IRFU, CEA, Université Paris-Saclay, Gif-sur-Yvette, France*
[38]*Laboratoire Leprince-Ringuet, CNRS/IN2P3, Ecole Polytechnique, Institut Polytechnique de Paris, Palaiseau, France*
[39]*Université de Strasbourg, CNRS, IPHC UMR 7178, Strasbourg, France*
[40]*Institut de Physique des 2 Infinis de Lyon (IP2I), Villeurbanne, France*
[41]*Georgian Technical University, Tbilisi, Georgia*
[42]*RWTH Aachen University, I. Physikalisches Institut, Aachen, Germany*
[43]*RWTH Aachen University, III. Physikalisches Institut A, Aachen, Germany*
[44]*RWTH Aachen University, III. Physikalisches Institut B, Aachen, Germany*
[45]*Deutsches Elektronen-Synchrotron, Hamburg, Germany*
[46]*University of Hamburg, Hamburg, Germany*
[47]*Karlsruher Institut fuer Technologie, Karlsruhe, Germany*
[48]*Institute of Nuclear and Particle Physics (INPP), NCSR Demokritos, Aghia Paraskevi, Greece*
[49]*National and Kapodistrian University of Athens, Athens, Greece*
[50]*National Technical University of Athens, Athens, Greece*
[51]*University of Ioánnina, Ioánnina, Greece*

[52]HUN-REN Wigner Research Centre for Physics, Budapest, Hungary
[53]MTA-ELTE Lendület CMS Particle and Nuclear Physics Group, Eötvös Loránd University, Budapest, Hungary
[54]Faculty of Informatics, University of Debrecen, Debrecen, Hungary
[55]Institute of Nuclear Research ATOMKI, Debrecen, Hungary
[56]Karoly Robert Campus, MATE Institute of Technology, Gyongyos, Hungary
[57]Panjab University, Chandigarh, India
[58]University of Delhi, Delhi, India
[59]Saha Institute of Nuclear Physics, HBNI, Kolkata, India
[60]Indian Institute of Technology Madras, Madras, India
[61]Tata Institute of Fundamental Research-A, Mumbai, India
[62]Tata Institute of Fundamental Research-B, Mumbai, India
[63]National Institute of Science Education and Research, An OCC of Homi Bhabha National Institute, Bhubaneswar, Odisha, India
[64]Indian Institute of Science Education and Research (IISER), Pune, India
[65]Isfahan University of Technology, Isfahan, Iran
[66]Institute for Research in Fundamental Sciences (IPM), Tehran, Iran
[67]University College Dublin, Dublin, Ireland
[68a]INFN Sezione di Bari, Bari, Italy
[68b]Università di Bari, Bari, Italy
[68c]Politecnico di Bari, Bari, Italy
[69a]INFN Sezione di Bologna, Bologna, Italy
[69b]Università di Bologna, Bologna, Italy
[70a]INFN Sezione di Catania, Catania, Italy
[70b]Università di Catania, Catania, Italy
[71a]INFN Sezione di Firenze, Firenze, Italy
[71b]Università di Firenze, Firenze, Italy
[72]INFN Laboratori Nazionali di Frascati, Frascati, Italy
[73a]INFN Sezione di Genova, Genova, Italy
[73b]Università di Genova, Genova, Italy
[74a]INFN Sezione di Milano-Bicocca, Milano, Italy
[74b]Università di Milano-Bicocca, Milano, Italy
[75a]INFN Sezione di Napoli, Napoli, Italy
[75b]Università di Napoli 'Federico II', Napoli, Italy
[75c]Università della Basilicata, Potenza, Italy
[75d]Università G. Marconi, Roma, Italy
[76a]INFN Sezione di Padova, Padova, Italy
[76b]Università di Padova, Padova, Italy
[76c]Università di Trento, Trento, Italy
[77a]INFN Sezione di Pavia, Pavia, Italy
[77b]Università di Pavia, Pavia, Italy
[78a]INFN Sezione di Perugia, Perugia, Italy
[78b]Università di Perugia, Perugia, Italy
[79a]INFN Sezione di Pisa, Pisa, Italy
[79b]Università di Pisa, Pisa, Italy
[79c]Scuola Normale Superiore di Pisa, Pisa, Italy
[79d]Università di Siena, Siena, Italy
[80a]INFN Sezione di Roma, Roma, Italy
[80b]Sapienza Università di Roma, Roma, Italy
[81a]INFN Sezione di Torino, Torino, Italy
[81b]Università di Torino, Torino, Italy
[81c]Università del Piemonte Orientale, Novara, Italy
[82a]INFN Sezione di Trieste, Trieste, Italy
[82b]Università di Trieste, Trieste, Italy
[83]Kyungpook National University, Daegu, Korea
[84]Chonnam National University, Institute for Universe and Elementary Particles, Kwangju, Korea
[85]Hanyang University, Seoul, Korea
[86]Korea University, Seoul, Korea
[87]Kyung Hee University, Department of Physics, Seoul, Korea
[88]Sejong University, Seoul, Korea
[89]Seoul National University, Seoul, Korea

[90]University of Seoul, Seoul, Korea
[91]Yonsei University, Department of Physics, Seoul, Korea
[92]Sungkyunkwan University, Suwon, Korea
[93]College of Engineering and Technology, American University of the Middle East (AUM), Dasman, Kuwait
[94]Riga Technical University, Riga, Latvia
[95]University of Latvia (LU), Riga, Latvia
[96]Vilnius University, Vilnius, Lithuania
[97]National Centre for Particle Physics, Universiti Malaya, Kuala Lumpur, Malaysia
[98]Universidad de Sonora (UNISON), Hermosillo, Mexico
[99]Centro de Investigacion y de Estudios Avanzados del IPN, Mexico City, Mexico
[100]Universidad Iberoamericana, Mexico City, Mexico
[101]Benemerita Universidad Autonoma de Puebla, Puebla, Mexico
[102]University of Montenegro, Podgorica, Montenegro
[103]University of Canterbury, Christchurch, New Zealand
[104]National Centre for Physics, Quaid-I-Azam University, Islamabad, Pakistan
[105]AGH University of Krakow, Faculty of Computer Science, Electronics and Telecommunications, Krakow, Poland
[106]National Centre for Nuclear Research, Swierk, Poland
[107]Institute of Experimental Physics, Faculty of Physics, University of Warsaw, Warsaw, Poland
[108]Warsaw University of Technology, Warsaw, Poland
[109]Laboratório de Instrumentação e Física Experimental de Partículas, Lisboa, Portugal
[110]Faculty of Physics, University of Belgrade, Belgrade, Serbia
[111]VINCA Institute of Nuclear Sciences, University of Belgrade, Belgrade, Serbia
[112]Centro de Investigaciones Energéticas Medioambientales y Tecnológicas (CIEMAT), Madrid, Spain
[113]Universidad Autónoma de Madrid, Madrid, Spain
[114]Universidad de Oviedo, Instituto Universitario de Ciencias y Tecnologías Espaciales de Asturias (ICTEA), Oviedo, Spain
[115]Instituto de Física de Cantabria (IFCA), CSIC-Universidad de Cantabria, Santander, Spain
[116]University of Colombo, Colombo, Sri Lanka
[117]University of Ruhuna, Department of Physics, Matara, Sri Lanka
[118]CERN, European Organization for Nuclear Research, Geneva, Switzerland
[119]Paul Scherrer Institut, Villigen, Switzerland
[120]ETH Zurich - Institute for Particle Physics and Astrophysics (IPA), Zurich, Switzerland
[121]Universität Zürich, Zurich, Switzerland
[122]National Central University, Chung-Li, Taiwan
[123]National Taiwan University (NTU), Taipei, Taiwan
[124]High Energy Physics Research Unit, Department of Physics, Faculty of Science, Chulalongkorn University, Bangkok, Thailand
[125]Çukurova University, Physics Department, Science and Art Faculty, Adana, Turkey
[126]Middle East Technical University, Physics Department, Ankara, Turkey
[127]Bogazici University, Istanbul, Turkey
[128]Istanbul Technical University, Istanbul, Turkey
[129]Istanbul University, Istanbul, Turkey
[130]Institute for Scintillation Materials of National Academy of Science of Ukraine, Kharkiv, Ukraine
[131]National Science Centre, Kharkiv Institute of Physics and Technology, Kharkiv, Ukraine
[132]University of Bristol, Bristol, United Kingdom
[133]Rutherford Appleton Laboratory, Didcot, United Kingdom
[134]Imperial College, London, United Kingdom
[135]Brunel University, Uxbridge, United Kingdom
[136]Baylor University, Waco, Texas, USA
[137]Catholic University of America, Washington, DC, USA
[138]The University of Alabama, Tuscaloosa, Alabama, USA
[139]Boston University, Boston, Massachusetts, USA
[140]Brown University, Providence, Rhode Island, USA
[141]University of California, Davis, Davis, California, USA
[142]University of California, Los Angeles, California, USA
[143]University of California, Riverside, Riverside, California, USA
[144]University of California, San Diego, La Jolla, California, USA
[145]University of California, Santa Barbara - Department of Physics, Santa Barbara, California, USA
[146]California Institute of Technology, Pasadena, California, USA
[147]Carnegie Mellon University, Pittsburgh, Pennsylvania, USA
[148]University of Colorado Boulder, Boulder, Colorado, USA

[149]Cornell University, Ithaca, New York, USA
[150]Fermi National Accelerator Laboratory, Batavia, Illinois, USA
[151]University of Florida, Gainesville, Florida, USA
[152]Florida State University, Tallahassee, Florida, USA
[153]Florida Institute of Technology, Melbourne, Florida, USA
[154]University of Illinois Chicago, Chicago, USA, Chicago, USA
[155]The University of Iowa, Iowa City, Iowa, USA
[156]Johns Hopkins University, Baltimore, Maryland, USA
[157]The University of Kansas, Lawrence, Kansas, USA
[158]Kansas State University, Manhattan, Kansas, USA
[159]Lawrence Livermore National Laboratory, Livermore, California, USA
[160]University of Maryland, College Park, Maryland, USA
[161]Massachusetts Institute of Technology, Cambridge, Massachusetts, USA
[162]University of Minnesota, Minneapolis, Minnesota, USA
[163]University of Mississippi, Oxford, Mississippi, USA
[164]University of Nebraska-Lincoln, Lincoln, Nebraska, USA
[165]State University of New York at Buffalo, Buffalo, New York, USA
[166]Northeastern University, Boston, Massachusetts, USA
[167]Northwestern University, Evanston, Illinois, USA
[168]University of Notre Dame, Notre Dame, Indiana, USA
[169]The Ohio State University, Columbus, Ohio, USA
[170]Princeton University, Princeton, New Jersey, USA
[171]University of Puerto Rico, Mayaguez, Puerto Rico, USA
[172]Purdue University, West Lafayette, Indiana, USA
[173]Purdue University Northwest, Hammond, Indiana, USA
[174]Rice University, Houston, Texas, USA
[175]University of Rochester, Rochester, New York, USA
[176]The Rockefeller University, New York, New York, USA
[177]Rutgers, The State University of New Jersey, Piscataway, New Jersey, USA
[178]University of Tennessee, Knoxville, Tennessee, USA
[179]Texas A&M University, College Station, Texas, USA
[180]Texas Tech University, Lubbock, Texas, USA
[181]Vanderbilt University, Nashville, Tennessee, USA
[182]University of Virginia, Charlottesville, Virginia, USA
[183]Wayne State University, Detroit, Michigan, USA
[184]University of Wisconsin - Madison, Madison, Wisconsin, USA
[185]An institute or international laboratory covered by a cooperation agreement with CERN

[a]Deceased.
[b]Also at Yerevan State University, Yerevan, Armenia.
[c]Also at TU Wien, Vienna, Austria.
[d]Also at Institute of Basic and Applied Sciences, Faculty of Engineering, Arab Academy for Science, Technology and Maritime Transport, Alexandria, Egypt.
[e]Also at Ghent University, Ghent, Belgium.
[f]Also at Universidade Estadual de Campinas, Campinas, Brazil.
[g]Also at Federal University of Rio Grande do Sul, Porto Alegre, Brazil.
[h]Also at UFMS, Nova Andradina, Brazil.
[i]Also at Nanjing Normal University, Nanjing, China.
[j]Also at Henan Normal University, Xinxiang, China.
[k]Also at The University of Iowa, Iowa City, Iowa, USA.
[l]Also at University of Chinese Academy of Sciences, Beijing, China.
[m]Also at University of Chinese Academy of Sciences, Beijing, China.
[n]Also at Another institute or international laboratory covered by a cooperation agreement with CERN.
[o]Also at Helwan University, Cairo, Egypt.
[p]Also at Zewail City of Science and Technology, Zewail, Egypt.
[q]Also at British University in Egypt, Cairo, Egypt.
[r]Also at Ain Shams University, Cairo, Egypt.
[s]Also at Birla Institute of Technology, Mesra, Mesra, India.
[t]Also at Purdue University, West Lafayette, Indiana, USA.
[u]Also at Université de Haute Alsace, Mulhouse, France.

[v]Also at Department of Physics, Tsinghua University, Beijing, China.
[w]Also at The University of the State of Amazonas, Manaus, Brazil.
[x]Also at Erzincan Binali Yildirim University, Erzincan, Turkey.
[y]Also at University of Hamburg, Hamburg, Germany.
[z]Also at RWTH Aachen University, III. Physikalisches Institut A, Aachen, Germany.
[aa]Also at Isfahan University of Technology, Isfahan, Iran.
[bb]Also at Bergische University Wuppertal (BUW), Wuppertal, Germany.
[cc]Also at Brandenburg University of Technology, Cottbus, Germany.
[dd]Also at Forschungszentrum Jülich, Juelich, Germany.
[ee]Also at CERN, European Organization for Nuclear Research, Geneva, Switzerland.
[ff]Also at Institute of Physics, University of Debrecen, Debrecen, Hungary.
[gg]Also at Institute of Nuclear Research ATOMKI, Debrecen, Hungary.
[hh]Also at Universitatea Babes-Bolyai—Facultatea de Fizica, Cluj-Napoca, Romania.
[ii]Also at Physics Department, Faculty of Science, Assiut University, Assiut, Egypt.
[jj]Also at HUN-REN Wigner Research Centre for Physics, Budapest, Hungary.
[kk]Also at Faculty of Informatics, University of Debrecen, Debrecen, Hungary.
[ll]Also at Punjab Agricultural University, Ludhiana, India.
[mm]Also at UPES—University of Petroleum and Energy Studies, Dehradun, India.
[nn]Also at University of Visva-Bharati, Santiniketan, India.
[oo]Also at University of Hyderabad, Hyderabad, India.
[pp]Also at Indian Institute of Science (IISc), Bangalore, India.
[qq]Also at IIT Bhubaneswar, Bhubaneswar, India.
[rr]Also at Institute of Physics, Bhubaneswar, India.
[ss]Also at Deutsches Elektronen-Synchrotron, Hamburg, Germany.
[tt]Also at Department of Physics, Isfahan University of Technology, Isfahan, Iran.
[uu]Also at Sharif University of Technology, Tehran, Iran.
[vv]Also at Department of Physics, University of Science and Technology of Mazandaran, Behshahr, Iran.
[ww]Also at Italian National Agency for New Technologies, Energy and Sustainable Economic Development, Bologna, Italy.
[xx]Also at Centro Siciliano di Fisica Nucleare e di Struttura Della Materia, Catania, Italy.
[yy]Also at Università degli Studi Guglielmo Marconi, Roma, Italy.
[zz]Also at Scuola Superiore Meridionale, Università di Napoli 'Federico II', Napoli, Italy.
[aaa]Also at Fermi National Accelerator Laboratory, Batavia, Illinois, USA.
[bbb]Also at Università di Napoli 'Federico II', Napoli, Italy.
[ccc]Also at Consiglio Nazionale delle Ricerche—Istituto Officina dei Materiali, Perugia, Italy.
[ddd]Also at Riga Technical University, Riga, Latvia.
[eee]Also at Department of Applied Physics, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, Bangi, Malaysia.
[fff]Also at Consejo Nacional de Ciencia y Tecnología, Mexico City, Mexico.
[ggg]Also at Trincomalee Campus, Eastern University, Sri Lanka, Nilaveli, Sri Lanka.
[hhh]Also at INFN Sezione di Pavia, Università di Pavia, Pavia, Italy.
[iii]Also at National and Kapodistrian University of Athens, Athens, Greece.
[jjj]Also at Ecole Polytechnique Fédérale Lausanne, Lausanne, Switzerland.
[kkk]Also at University of Vienna Faculty of Computer Science, Vienna, Austria.
[lll]Also at Universität Zürich, Zurich, Switzerland.
[mmm]Also at Stefan Meyer Institute for Subatomic Physics, Vienna, Austria.
[nnn]Also at Laboratoire d'Annecy-le-Vieux de Physique des Particules, IN2P3-CNRS, Annecy-le-Vieux, France.
[ooo]Also at Near East University, Research Center of Experimental Health Science, Mersin, Turkey.
[ppp]Also at Konya Technical University, Konya, Turkey.
[qqq]Also at Izmir Bakircay University, Izmir, Turkey.
[rrr]Also at Adiyaman University, Adiyaman, Turkey.
[sss]Also at Necmettin Erbakan University, Konya, Turkey.
[ttt]Also at Bozok Universitetesi Rektörlügü, Yozgat, Turkey.
[uuu]Also at Marmara University, Istanbul, Turkey.
[vvv]Also at Milli Savunma University, Istanbul, Turkey.
[www]Also at Kafkas University, Kars, Turkey.
[xxx]Also at Hacettepe University, Ankara, Turkey.
[yyy]Also at Istanbul University—Cerrahpasa, Faculty of Engineering, Istanbul, Turkey.
[zzz]Also at Yildiz Technical University, Istanbul, Turkey.
[aaaa]Also at Vrije Universiteit Brussel, Brussel, Belgium.
[bbbb]Also at School of Physics and Astronomy, University of Southampton, Southampton, United Kingdom.
[cccc]Also at University of Bristol, Bristol, United Kingdom.

[dddd]Also at IPPP Durham University, Durham, United Kingdom.
[eeee]Also at Monash University, Faculty of Science, Clayton, Australia.
[ffff]Also at Università di Torino, Torino, Italy.
[gggg]Also at Bethel University, St. Paul, Minnesota, USA.
[hhhh]Also at Karamanoğlu Mehmetbey University, Karaman, Turkey.
[iiii]Also at California Institute of Technology, Pasadena, California, USA.
[jjjj]Also at United States Naval Academy, Annapolis, Maryland, USA.
[kkkk]Also at Bingol University, Bingol, Turkey.
[llll]Also at Georgian Technical University, Tbilisi, Georgia.
[mmmm]Also at Sinop University, Sinop, Turkey.
[nnnn]Also at Erciyes University, Kayseri, Turkey.
[oooo]Also at Horia Hulubei National Institute of Physics and Nuclear Engineering (IFIN-HH), Bucharest, Romania.
[pppp]Also at Texas A&M University at Qatar, Doha, Qatar.
[qqqq]Also at Kyungpook National University, Daegu, Korea.
[rrrr]Also at Universiteit Antwerpen, Antwerpen, Belgium.
[ssss]Also at Yerevan Physics Institute, Yerevan, Armenia.
[tttt]Also at Northeastern University, Boston, Massachusetts, USA.
[uuuu]Also at Imperial College, London, United Kingdom.
[vvvv]Also at Institute of Nuclear Physics of the Uzbekistan Academy of Sciences, Tashkent, Uzbekistan.