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Measurements of the Electroweak Diboson Production Cross Sections in Proton-Proton Collisions at $\sqrt{s} = 5.02$ TeV Using Leptonic Decays

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

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The first measurements of diboson production cross sections in proton-proton interactions at a center-of-mass energy of 5.02 TeV are reported. They are based on data collected with the CMS detector at the LHC, corresponding to an integrated luminosity of 302 pb^{-1}. Events with two, three, or four charged light leptons (electrons or muons) in the final state are analyzed. The WW, WZ, and ZZ total cross sections are measured as $\sigma_{WW} = 37.0^{+5.5}_{-5.2}(\mathrm{stat})^{+2.7}_{-2.6}(\mathrm{syst})$ pb, $\sigma_{WZ} = 6.4^{+2.5}_{-2.1}(\mathrm{stat})^{+0.5}_{-0.3}(\mathrm{syst})$ pb, and $\sigma_{ZZ} = 5.3^{+2.5}_{-2.1}(\mathrm{stat})^{+0.5}_{-0.4}(\mathrm{syst})$ pb. All measurements are in good agreement with theoretical calculations at combined next-to-next-to-leading order quantum chromodynamics and next-to-leading order electroweak accuracy.

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The study of diboson production at the CERN LHC is an important test of the standard model (SM) of particle physics because of its sensitivity to the self-interactions between gauge bosons via trilinear gauge couplings [1]. Understanding diboson production is also important for Higgs boson measurements and for a multitude of beyond-the-SM searches where these diboson processes represent irreducible background contributions. The CMS and ATLAS Collaborations have measured diboson production cross sections in proton-proton (pp) collisions at center-of-mass energies of 7, 8, and 13 TeV [2–18]. In this Letter, we present the first measurements of electroweak diboson production cross sections at $\sqrt{s} = 5.02$ TeV. All measurements are performed with pp collision data corresponding to an integrated luminosity of 302 pb^{-1}, collected in November 2017 with the CMS detector [19] at the LHC. The maximum instantaneous luminosity delivered by the LHC during this period was $1.37 \times 10^{33}\ \mathrm{cm}^{-2}\,\mathrm{s}^{-1}$, and the mean number of pp interactions per bunch crossing, assuming a total inelastic cross section of 65 mb, was 2.0.

The central feature of the CMS apparatus is a superconducting solenoid of 6 m internal diameter, providing a magnetic field of 3.8 T. Within the solenoid volume are a silicon pixel and strip tracker, a lead tungstate crystal electromagnetic calorimeter (ECAL), and a brass and scintillator hadron calorimeter (HCAL), each composed of a barrel and two end cap sections. Forward calorimeters extend the pseudorapidity (η) coverage provided by the barrel and end cap detectors. Muons are detected in gas-ionization chambers embedded in the steel flux-return yoke outside the solenoid. A more detailed description of the CMS detector, together with a definition of the coordinate system used and the relevant kinematic variables, is reported in Ref. [19].

Signal and background processes are simulated by using several Monte Carlo (MC) generators. The propagation of the generated particles through the CMS detector and the modeling of the detector response is performed using GEANT4 [20], assuming alignment and calibration from real data. Simulated signal events are generated at next-to-leading order (NLO) in perturbative quantum chromodynamics (QCD) and dynamic renormalization and factorization scales using POWHEG (v2) [21–23]. The WW, WZ, and ZZ signal cross sections are scaled from NLO to next-to-next-to-leading order (NNLO) using MATRIX calculations [24]. The MADGRAPH5_aMC@NLO [25] generator is used to simulate W and $Z/\gamma^* +$ jets at NLO. The simulation includes up to two extra partons at the matrix element level and uses the FxFx merging scheme [26]. Simulated top quark events—top quark pair production ($t\bar{t}$) and single top quark processes—are also generated using POWHEG. All the events are then interfaced with PYTHIA 8 (v8.2) [27] for parton showering, hadronization, and the underlying event simulation, using the CP5 tune [28,29]. The NNPDF3.1 [30] NNLO parton distribution functions (PDFs) are used. The simulated samples include pileup collisions.

The particle-flow (PF) algorithm [31] reconstructs and identifies each individual particle in an event, with an optimized combination of information from the various elements of the CMS detector. The energy of photons is obtained from the ECAL measurement. The energy of electrons is determined from a combination of the electron momentum at the primary interaction vertex as determined by the tracker, the energy of the corresponding ECAL

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

cluster, and the energy sum of all bremsstrahlung photons spatially compatible with originating from the electron track. The energy of muons is obtained from the curvature of the corresponding track. The energy of charged hadrons is determined from a combination of their momentum measured in the tracker and the matching ECAL and HCAL energy deposits, corrected for the response function of the calorimeters to hadronic showers. Finally, the energy of neutral hadrons is obtained from the corresponding corrected ECAL and HCAL energies. For each event, hadronic jets are clustered from these reconstructed particles using the anti-k_T algorithm [32,33] with a distance parameter of 0.4. Jet momentum is determined as the vectorial sum of all particle momenta in the jet, and, based on simulation, is typically within 5% to 10% of the true momentum over the entire transverse momentum (p_T) spectrum and detector acceptance. The missing transverse momentum vector $\vec{p}_T^{\text{miss}}$ is computed as the negative vector p_T sum of all the PF candidates in an event, and its magnitude is denoted as p_T^{miss} [34]. The $\vec{p}_T^{\text{miss}}$ is modified to account for corrections to the energy scale of the reconstructed jets in the event [35]. The candidate vertex with the largest value of summed physics-object p_T^2 is the primary pp interaction vertex. The physics objects used to calculate the primary vertex are the leptons, jets and the p_T^{miss} associated with this event.

Electrons are identified with a multivariate analysis (MVA) discriminant [36,37] and are required to have a p_T larger than 8 GeV and $|\eta| < 2.5$. Electrons matched to a secondary vertex consistent with a photon conversion or having at least one missing hit in the pixel tracking system are vetoed. Muons are identified as tracks in the central tracker consistent with either a track or several hits in the muon system, and associated with calorimeter deposits compatible with the muon hypothesis. Reconstructed muons are required to have $p_T > 8$ GeV and $|\eta| < 2.4$, and must fulfill criteria on the geometrical matching between the tracker and the muon track, and the quality of the global fit [38]. An upper threshold of 0.4 on the relative isolation (as defined in Ref. [39]), is applied for both electrons and muons. Lepton candidates are selected if the transverse (longitudinal) impact parameter with respect to the primary vertex does not exceed 0.05 (0.1) cm. Identification criteria are specifically designed to separate prompt leptons—electrons and muons from the decay of a W or Z boson either directly or mediated by a leptonic τ decay—from leptons that arise from other sources, such as c or b decays. Two lepton categories, loose and tight, are defined. The loose identification criteria refer to the requirements presented above and are used to provisionally select all leptons in the events. The tight selection is based on an MVA discriminant—a gradient boosted decision tree—trained to separate between prompt and nonprompt lepton sources [40] and includes, in addition to the loose selection, (i) a tighter upper threshold on the relative isolation (0.085 for electrons and 0.325 for electrons and muons), and (ii) a threshold on the b-tagging DEEPJET discriminator [41–43] for any jet that contains a lepton to reduce the $t\bar{t}$ background. Jets with $p_{\mathrm{T}} > 25$ GeV and $|\eta| < 2.4$ which do not overlap ($\Delta R < 0.4$) with a lepton passing the loose criteria are selected.

Events of interest are selected using a two-tiered trigger system [44]. The first level (L1), composed of custom hardware processors, uses information from the calorimeters and muon detectors to select events at a rate of around 100 kHz. The second level, known as the high-level trigger, consists of a farm of processors running a version of the full event reconstruction software optimized for fast processing, and reduces the event rate to around 1 kHz before data storage. Events that pass at least one single-lepton trigger with p_T thresholds of 17 (electrons) or 12 (muons) GeV are selected. Candidate events are further required to have at least two loose leptons (electrons or muons, ℓ) with a minimal invariant mass of any lepton pair greater than 12 GeV.

The WW signal region (SR) requirements are exactly two tight leptons with opposite charge and different flavor; the p_T of the leading (subleading) lepton > 20 (10) GeV; the p_T of the dilepton system > 20 GeV; the azimuthal separation between the two leptons > 2.8 radians; and the transverse mass of any combination of a lepton with the $\vec{p}_T^{\text{miss}} > 20$ GeV. In addition, events with jets are rejected.

For the WZ measurement two SRs are defined: one with three leptons (3ℓ) and another with two muons with the same electric charge (2μss). In the 3ℓ category, events with exactly three loose leptons with at least one opposite-sign same-flavor (OSSF) pair are selected. To exploit the characteristic kinematics of on-shell WZ production, an algorithm is applied to tag the two leptons from the Z boson decay (ℓ_Z and ℓ'_Z) and that of the W boson decay (ℓ_W). If only one OSSF lepton pair occurs in the event, the leptons corresponding to it are tagged as ℓ_Z and ℓ'_Z, whereas the different flavor one is tagged as ℓ_W. If multiple OSSF pairs are found, the OSSF lepton pair with invariant mass closest to that of the Z boson is selected for the $\ell_Z\,\ell'_Z$ pair. Then, a p_T threshold of 8 GeV is imposed. Additional selection criteria are applied to increase the purity of WZ events. The invariant mass of the ℓ_Z and ℓ'_Z lepton pair must be consistent with the Z boson mass, $|m_{\ell_Z\ell'_Z} - 91.2\ \text{GeV}| < 30$ GeV. The two same-sign leptons are required to pass the tight lepton requirements, the p_T of ℓ_W must be > 20 GeV, and the invariant mass of the three lepton system must be > 100 GeV. For the 2μss category, events with two tight muons and zero jets are selected. The p_T of the leading (subleading) muon must be >20 (10) GeV. To ensure a high-quality charge measurement, the relative uncertainty in the curvature of the muon track must be $< 20\%$. Additionally, a minimal requirement of $p_T^{\text{miss}} > 25$ GeV is included.

For the ZZ measurement, two categories are defined: one with four leptons (4ℓ) and another with two leptons ($2\ell 2\nu$). For the 4ℓ category, exactly four loose leptons with $p_T > 8$ GeV are required. For the $2\ell 2\nu$ category, events with exactly two tight OSSF leptons are selected. The p_T of the leading (subleading) lepton must be >20 (10) GeV. The invariant mass of the leptons must be close to the Z boson peak, $|m_{\ell,\ell'} - 91.2\ \mathrm{GeV}| < 10$ GeV. The axial p_T^{miss} in the event [9], which expresses the p_T projection of the neutrino pair of the invisibly decaying Z boson onto the p_T direction of the Z boson decaying to charged leptons, must exceed 50 GeV. The relative difference between p_T^{miss} and the dilepton p_T with respect to the dilepton p_T must be smaller than 0.3 [9]. Events with jets are rejected.

Most background contributions, including photon conversions, charge mismeasurement, and those processes yielding prompt leptons in the final state, such as $t\bar{t}$, single top, Drell-Yan (DY), and diboson production, are estimated from simulation. Backgrounds involving one or more nonprompt leptons are estimated from simulation aided by control samples in data in those categories with two leptons in the final state and exclusively from simulation otherwise. Nonprompt-lepton background sources are composed of processes in which at least one of the final-state leptons does not come from the decay of a W or Z boson either directly or mediated by a leptonic τ decay. Dominant SM sources of nonprompt background depend on the specific decay channel: $Z+$jets and dileptonic $t\bar{t}$ production for those channels with at least three leptons, $W+$jets and semileptonic $t\bar{t}$ for channels with two leptons in the final state. The nonprompt-lepton contribution is estimated using a lepton misidentification rate method [45] based on the misidentification rate measured in a simulated $t\bar{t}$ sample and applied to control region data. The main background contributions differ in each SR because of the different final states under study. The dominant background contributions for the WW measurement come from nonprompt lepton and top quark production processes. For the WZ 3ℓ, the background is mainly arising from $Z+$jets. For the WZ 2μss and ZZ $2\ell2\nu$ SRs the main background is nonprompt leptons. The ZZ 4ℓ SR is very clean with a small background contribution of nonprompt leptons.

Although the measurements presented in this Letter are dominated by the statistical limitation of the size of the data set, the impact of different sources of systematic uncertainties is studied.

The lepton identification scale factors are estimated using the tag-and-probe method [46] as a function of the lepton p_T and η for loose and tight electrons and muons. These scale factors are close to 1 and have an uncertainty of the order of 1–3%, except for a few bins limited by statistics. Corrections to the jet energy scale are applied to data and simulation separately as η- and p_T-dependent corrections. Jet energy corrections are derived from simulation to bring the measured response of jets to that of particle-level jets on average. In situ measurements of the momentum balance in dijet, photon $+$ jet, $Z+$jet, and multijet events are used to correct any residual differences in jet energy scale in data and simulation [35]. The jet energy resolution amounts typically to 15% at 10 GeV and 8% at 100 GeV. During the 2017 data taking, a gradual shift in the input timing of the ECAL L1 trigger in the region of $|\eta| > 2.0$ caused a trigger inefficiency of 1%–4%. Correction factors were computed from data and applied to the acceptance evaluated by simulation. For the selected events the trigger efficiency is very close to 1 in all channels, and no further correction is applied to the simulation. The relative difference between the trigger efficiency estimated in the WW, WZ, and ZZ samples and 100% is used as an uncertainty in the respective cross section measurement.

The uncertainty arising from the choice of PDF is determined by reweighting the sample of simulated diboson events according to the 32 replica PDF sets from PDF4LHC15 [47]. The envelope of the variations in the signal yields is used as the estimate of the uncertainty. The systematic bias due to the missing higher-order diagrams in POWHEG is estimated by varying the default renormalization and factorization scale choices independently by a factor of 2 or 1/2. The uncertainty is assigned from the maximum difference in the signal yields for each variation, excluding the two extreme up or down combinations, with the nominal values.

The uncertainty assigned to the nonprompt lepton contribution in the two-lepton categories is based on the differences between the lepton misidentification rate estimated for all flavor jets, and the b-flavor jets and light-flavor jets, separately. The uncertainty affects mostly electrons: a 30% uncertainty is used per electron and 15% per muon in the categories with two leptons in the final state. Normalization uncertainties of 30% for conversions, 20% for nonprompt leptons, charge mismeasurement, and diboson, and 10% for top quark and DY processes are assigned.

An uncertainty of 1.9% in the integrated luminosity, estimated offline using the methodology described in Ref. [48], is applied as a global normalization uncertainty for all processes.

The statistical uncertainties due to the limited size of the MC samples are treated according to the Barlow-Beeston method [49]; individual nuisance parameters (per process and per channel) are used when the corresponding expected amount of events in the bin is smaller than 10 events.

A summary of the expected event yields for signal and each of the background processes, and the observed data in the WW SR is shown in Table I. For the other SRs, the expected event yields for signal and the total background, and the observed data, are shown in Table II.

The cross sections are measured in regions, called total regions, defined to provide a measurement without any detector acceptance requirements. As outlined below, each channel has a different total region defined at generator level with dressed leptons (the momenta of generator-level photons within a cone of $\Delta R(\ell,\gamma) < 0.1$ is added to the

TABLE I. Expected event yields in the WW SR and observed number of events. The uncertainties correspond to the statistical and systematic component, respectively.

Source	Number of events
Top quark	$9.0 \pm 0.1 \pm 1.1$
$WZ + ZZ$	$5.6 \pm 1.0 \pm 1.1$
Drell–Yan	$1.8 \pm 0.5 \pm 0.2$
Conversions	$2.7 \pm 0.7 \pm 0.7$
Nonprompt ℓ	$11.2 \pm 1.3 \pm 3.4$
Background	$30.3 \pm 1.9 \pm 3.9$
WW signal	$55.2 \pm 0.3 \pm 1.8$
Data	101

lepton momenta). All total regions are defined as excluding events containing any OSSF lepton pair with invariant mass below 4 GeV. For the WW total region, no further requirements are applied. For the WZ total region, an additional kinematic requirement is imposed that selects events consistent with the on-shell Z boson production: $60 < m_{\ell_Z,\ell'_Z} < 120$ GeV. For the ZZ total region, this additional kinematic requirement is applied to both Z boson candidates. The lepton tagging algorithm defined above to assign leptons to either the W or Z boson decay is applied. In the case of the ZZ $2\ell2\nu$ SR, one Z boson is reconstructed from the two leptons and the other from the neutrinos.

The total cross section, σ, is computed as

$$\sigma = \frac{N_{\text{signal}}^{\text{SR}}}{\mathcal{B}(W \to \ell\nu \text{ or } Z \to \ell\ell)\mathcal{B}(W \to \ell\nu \text{ or } Z \to \ell\ell)\epsilon\mathcal{L}}, \tag{1}$$

where $\mathcal{L}$ is the total integrated luminosity, ϵ is the efficiency of the lepton reconstruction and the additional phase space requirements, and $N_{\text{signal}}^{\text{SR}}$ is the number of obtained signal events, estimated for each SR by performing a maximum likelihood fit to the yields with a single free-floating parameter that corresponds to the normalization of the signal process. The efficiency values are computed using the signal simulated samples as the ratio of the number of events that fulfill the SR requirements over those that only pass the total region ones. An extrapolation from the lepton final state to the total production cross section is done by dividing by the branching fractions ($\mathcal{B}$) of each of the W and/or Z bosons to leptons, which are taken from Ref. [50]. The distributions of the dilepton p_T and W boson transverse mass in the WW and WZ 3ℓ signal region, respectively, are shown in Fig. 1. Good agreement between the observed data and prefit and postfit predictions is found in all channels.

TABLE II. Expected event yields for the signal and total background in the WZ and ZZ SRs, and observed number of events. The uncertainties correspond to the statistical and systematic component, respectively.

SR	Background	Signal	Data
WZ 3ℓ	$4.0 \pm 0.6 \pm 0.4$	$14.8 \pm 0.1 \pm 0.6$	12
WZ 2μss	$0.6 \pm 0.1 \pm 0.1$	$3.2 \pm 0.8 \pm 0.2$	4
ZZ 4ℓ	$0.5 \pm 0.2 \pm 0.1$	$2.5 \pm 0.0 \pm 0.1$	3
ZZ $2\ell2\nu$	$4.8 \pm 0.3 \pm 0.7$	$3.8 \pm 0.0 \pm 0.2$	12

The uncertainties derived above are propagated to the final result through the numerator of Eq. (1). The measured values for the WW, WZ, and ZZ total cross sections, shown in Fig. 2, are

$$\begin{aligned}
\sigma_{WW} &= 37.0^{+5.5}_{-5.2}(\text{stat})^{+2.7}_{-2.6}(\text{syst}) = 37.0^{+6.2}_{-5.8}\ \text{pb},\\
\sigma_{WZ} &= 6.4^{+2.5}_{-2.1}(\text{stat})^{+0.5}_{-0.3}(\text{syst}) = 6.4^{+2.5}_{-2.1}\ \text{pb},\\
\sigma_{ZZ} &= 5.3^{+2.5}_{-2.1}(\text{stat})^{+0.5}_{-0.4}(\text{syst}) = 5.3^{+2.6}_{-2.1}\ \text{pb},
\end{aligned}$$

respectively. Figure 2 also presents a summary of the diboson production cross section measurements at different center-of-mass energies and a comparison with fixed-order predictions produced via the MATRIX framework [24]. For the WZ measurement, the result is consistent with the SM prediction within two standard deviations. The calculations are performed with the NNPDF31_nnlo_as_0118_luxqed [51] PDF set (NNPDF31_nnlo_as_0118_luxqed_nf4 for WW production). The quark-induced processes are calculated at NNLO in QCD and NLO in electroweak (EW) corrections. For the WW and ZZ processes, the gluon induced contribution is calculated at NLO in QCD [52].

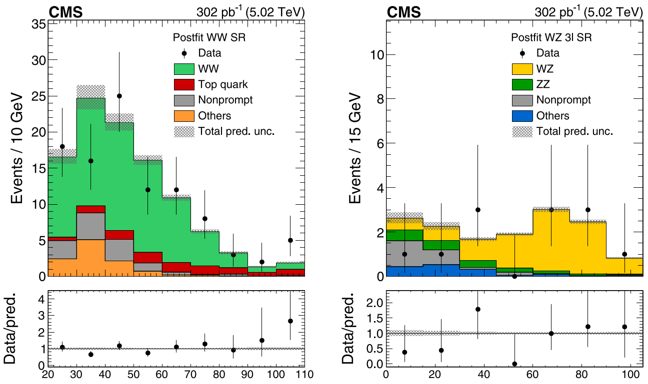

FIG. 1. Distribution of the dilepton p_T in the WW signal region (left). Events from DY, conversions, and diboson processes are grouped into the “Others” category. Distribution of the W boson transverse mass in the WZ 3ℓ signal region (right). Events from conversions, and DY processes are grouped into the Others category. The vertical error bars represent the statistical uncertainty in the data and the shaded band the uncertainty in the prediction. The signal contributions are scaled to the measured cross sections (postfit).

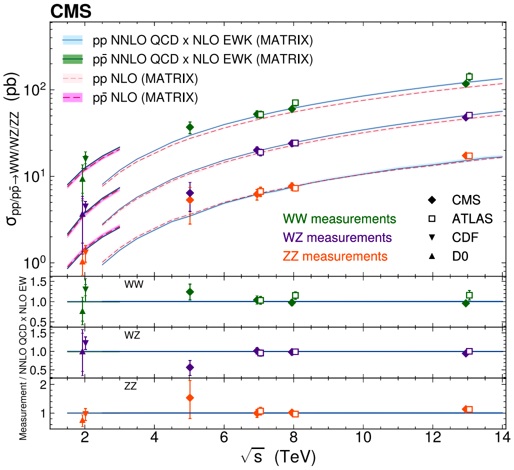

FIG. 2. Results obtained in this analysis and other diboson production cross section measurements at different center-of-mass energies for the CMS [11–18], ATLAS [2–10], CDF [54,55], and D0 [56–58] Collaborations are presented, and compared with the NNLO QCD × NLO EW and NLO predictions from MATRIX. The vertical error bars represent the uncertainty in the measured cross section.

Photon-induced contributions are included at up to NLO EW. The quark-induced NNLO QCD and NLO EW contributions are combined multiplicatively (NNLO QCD × NLO EW), and the gluon- and photon-induced contributions are combined additively, following the procedure described in Ref. [53].

The diboson production cross sections are measured for the first time at a new energy, 5.02 TeV, using data collected with the CMS detector corresponding to an integrated luminosity of 302 pb^{-1}. The analysis is performed in the leptonic decays of the W and Z bosons with at least two leptons in the final state. The measured total cross sections are consistent with theoretical calculations at combined next-to-next-to-leading order quantum chromodynamics and next-to-leading order electroweak accuracy.

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[1] K. Hagiwara, S. Ishihara, R. Szalapski, and D. Zeppenfeld, Low-energy effects of new interactions in the electroweak boson sector, Phys. Rev. D **48**, 2182 (1993).

[2] ATLAS Collaboration, Measurement of W^+W^- production in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector and limits on anomalous WWZ and WWγ couplings, Phys. Rev. D **87**, 112001 (2013); Erratum, Phys. Rev. D **88**, 079906 (2013).

[3] ATLAS Collaboration, Measurement of total and differential W^+W^- production cross sections in proton-proton collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector and limits on anomalous triple-gauge-boson couplings, J. High Energy Phys. 09 (2016) 029.

[4] ATLAS Collaboration, Measurement of the W^+W^- production cross section in pp collisions at a centre-of-mass energy of $\sqrt{s} = 13$ TeV with the ATLAS experiment, Phys. Lett. B **773**, 354 (2017).

[5] ATLAS Collaboration, Measurement of WZ production in proton-proton collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector, Eur. Phys. J. C **72**, 2173 (2012).

[6] ATLAS Collaboration, Measurements of $W^{\pm}Z$ production cross sections in pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector and limits on anomalous gauge boson self-couplings, Phys. Rev. D **93**, 092004 (2016).

[7] ATLAS Collaboration, Measurement of $W^{\pm}Z$ production cross sections and gauge boson polarisation in pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector, Eur. Phys. J. C **79**, 535 (2019).

[8] ATLAS Collaboration, Measurement of ZZ production in pp collisions at $\sqrt{s} = 7$ TeV and limits on anomalous ZZZ and $ZZ\gamma$ couplings with the ATLAS detector, J. High Energy Phys. 03 (2013) 128.

[9] ATLAS Collaboration, Measurement of the ZZ production cross section in proton-proton collisions at $\sqrt{s} = 8$ TeV using the $ZZ \to \ell^-\ell^+\ell'^-\ell'^+$ and $ZZ \to \ell^-\ell^+\nu\bar{\nu}$ channels with the ATLAS detector, J. High Energy Phys. 01 (2017) 099.

[10] ATLAS Collaboration, $ZZ \to \ell^+\ell^-\ell'^+\ell'^-$ cross-section measurements and search for anomalous triple gauge couplings in 13 TeV pp collisions with the ATLAS detector, Phys. Rev. D **97**, 032005 (2018).

[11] CMS Collaboration, Measurement of the W^+W^- cross section in pp collisions at $\sqrt{s} = 7$ TeV and limits on anomalous WWγ and WWZ couplings, Eur. Phys. J. C **73**, 2610 (2013).

[12] CMS Collaboration, Measurement of the W^+W^- cross section in pp collisions at $\sqrt{s} = 8$ TeV and limits on anomalous gauge couplings, Eur. Phys. J. C **76**, 401 (2016).

[13] CMS Collaboration, W^+W^- boson pair production in proton-proton collisions at $\sqrt{s} = 13$ TeV, Phys. Rev. D **102**, 092001 (2020).

[14] CMS Collaboration, Measurement of the WZ production cross section in pp collisions at $\sqrt{s} = 7$ and 8 TeV and search for anomalous triple gauge couplings at $\sqrt{s} = 8$ TeV, Eur. Phys. J. C **77**, 236 (2017).

[15] CMS Collaboration, Measurements of the pp → WZ inclusive and differential production cross section and constraints on charged anomalous triple gauge couplings at $\sqrt{s} = 13$ TeV, J. High Energy Phys. 04 (2019) 122.

[16] CMS Collaboration, Measurement of the ZZ production cross section and search for anomalous couplings in $2\ell 2\ell'$ final states in pp collisions at $\sqrt{s} = 7$ TeV, J. High Energy Phys. 01 (2013) 063.

[17] CMS Collaboration, Measurement of the pp → ZZ production cross section and constraints on anomalous triple gauge couplings in four-lepton final states at $\sqrt{s} = 8$ TeV, Phys. Lett. B **740**, 250 (2015); Erratum, Phys. Lett. B **757**, 569 (2016).

[18] CMS Collaboration, Measurements of pp → ZZ production cross sections and constraints on anomalous triple gauge couplings at $\sqrt{s} = 13$ TeV, Eur. Phys. J. C **81**, 200 (2021).

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

[20] S. Agostinelli *et al.* (GEANT4 Collaboration), GEANT4—a simulation toolkit, Nucl. Instrum. Methods Phys. Res., Sect. A **506**, 250 (2003).

[21] P. Nason, A new method for combining NLO QCD with shower Monte Carlo algorithms, J. High Energy Phys. 11 (2004) 040.

[22] 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.

[23] 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.

[24] M. Grazzini, S. Kallweit, and M. Wiesemann, Fully differential NNLO computations with MATRIX, Eur. Phys. J. C **78**, 537 (2018).

[25] 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.

[26] R. Frederix and S. Frixione, Merging meets matching in MC@NLO, J. High Energy Phys. 12 (2012) 61.

[27] 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 PYTHIA 8.2, Comput. Phys. Commun. **191**, 159 (2015).

[28] P. Skands, S. Carrazza, and J. Rojo, Tuning PYTHIA 8.1: the Monash 2013 tune, Eur. Phys. J. C **74**, 3024 (2014).

[29] CMS Collaboration, Extraction and validation of a new set of CMS PYTHIA8 tunes from underlying-event measurements, Eur. Phys. J. C **80**, 4 (2020).

[30] R. D. Ball *et al.* (NNPDF Collaboration), Parton distributions from high-precision collider data, Eur. Phys. J. C **77**, 663 (2017).

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

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

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

[34] 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).

[35] CMS Collaboration, Jet energy scale and resolution in the CMS experiment in pp collisions at 8 TeV, J. Instrum. **12**, P02014 (2017).

[36] CMS Collaboration, Performance of electron reconstruction and selection with the CMS detector in proton-proton collisions at $\sqrt{s} = 8$ TeV, J. Instrum. **10**, P06005 (2015).

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

[38] 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).

[39] CMS Collaboration, Search for new physics in same-sign dilepton events in proton–proton collisions at $\sqrt{s} = 13$ TeV, Eur. Phys. J. C **76**, 439 (2016).

[40] CMS Collaboration, Measurement of the Higgs boson production rate in association with top quarks in final states with electrons, muons, and hadronically decaying tau leptons at $\sqrt{s} = 13$ TeV, Eur. Phys. J. C **81**, 378 (2021).

[41] CMS Collaboration, Identification of heavy-flavour jets with the CMS detector in pp collisions at 13 TeV, J. Instrum. **13**, P05011 (2018).

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

[43] CMS Collaboration, Performance of the DeepJet b tagging algorithm using 41.9 fb^{-1} of data from proton-proton collisions at 13 TeV with phase 1 CMS detector, CMS Detector Performance Note, Report No. CMS-DP-2018-058, 2018, http://cds.cern.ch/record/2646773.

[44] CMS Collaboration, The CMS trigger system, J. Instrum. **12**, P01020 (2017).

[45] CMS Collaboration, Evidence for associated production of a Higgs boson with a top quark pair in final states with

electrons, muons, and hadronically decaying τ leptons at $\sqrt{s} = 13$ TeV, J. High Energy Phys. 08 (2018) 066.

[46] CMS Collaboration, Measurements of inclusive W and Z cross sections in pp collisions at $\sqrt{s} = 7$ TeV, J. High Energy Phys. 01 (2011) 080.

[47] J. Butterworth *et al.*, PDF4LHC recommendations for LHC Run II, J. Phys. G **43**, 023001 (2016).

[48] CMS Collaboration, Luminosity measurement in proton-proton collisions at 5.02 TeV in 2017 at CMS, CMS Physics Analysis Summary, Report No. CMS-PAS-LUM-19-001, 2021, http://cds.cern.ch/record/2765655.

[49] R. J. Barlow and C. Beeston, Fitting using finite Monte Carlo samples, Comput. Phys. Commun. **77**, 219 (1993).

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

[51] V. Bertone, S. Carrazza, N. P. Hartland, and J. Rojo (NNPDF Collaboration), Illuminating the photon content of the proton within a global PDF analysis, SciPost Phys. **5**, 008 (2018).

[52] M. Grazzini, S. Kallweit, M. Wiesemann, and J. Y. Yook, *ZZ* production at the LHC: NLO QCD corrections to the loop-induced gluon fusion channel, J. High Energy Phys. 03 (2019) 070.

[53] M. Grazzini, S. Kallweit, J. M. Lindert, S. Pozzorini, and M. Wiesemann, NNLO QCD + NLO EW with Matrix + OpenLoops: Precise predictions for vector-boson pair production, J. High Energy Phys. 02 (2020) 087.

[54] T. A. Aaltonen *et al.* (CDF Collaboration), Measurement of the WW and WZ production cross section using final states with a charged lepton and heavy-flavor jets in the full CDF Run II data set, Phys. Rev. D **94**, 032008 (2016).

[55] T. A. Aaltonen *et al.* (CDF Collaboration), Measurement of the ZZ production cross section using the full CDF II data set, Phys. Rev. D **89**, 112001 (2014).

[56] V. M. Abazov *et al.* (D0 Collaboration), Measurements of WW and WZ Production in W + jets Final States in $p\bar{p}$ Collisions, Phys. Rev. Lett. **108**, 181803 (2012).

[57] V. M. Abazov *et al.* (D0 Collaboration), A measurement of the WZ and ZZ production cross sections using leptonic final states in 8.6 fb^{-1} of $p\bar{p}$ collisions, Phys. Rev. D **85**, 112005 (2012).

[58] V. M. Abazov *et al.* (D0 Collaboration), Measurement of the ZZ production cross section and search for the standard model Higgs boson in the four lepton final state in $p\bar{p}$ collisions, Phys. Rev. D **88**, 032008 (2013).

A. Tumasyan,[1] W. Adam,[2] J. W. Andrejkovic,[2] T. Bergauer,[2] S. Chatterjee,[2] M. Dragicevic,[2] A. Escalante Del Valle,[2] R. Frühwirth,[2,b] M. Jeitler,[2,b] N. Krammer,[2] L. Lechner,[2] D. Liko,[2] I. Mikulec,[2] P. Paulitsch,[2] F. M. Pitters,[2] J. Schieck,[2,b] R. Schöfbeck,[2] M. Spanring,[2] S. Templ,[2] W. Waltenberger,[2] C.-E. Wulz,[2,b] V. Chekhovsky,[3] A. Litomin,[3] V. Makarenko,[3] M. R. Darwish,[4,c] E. A. De Wolf,[4] X. Janssen,[4] T. Kello,[4,d] A. Lelek,[4] H. Rejeb Sfar,[4] P. Van Mechelen,[4] S. Van Putte,[4] N. Van Remortel,[4] F. Blekman,[5] E. S. Bols,[5] J. D'Hondt,[5] J. De Clercq,[5] M. Delcourt,[5] H. El Faham,[5] S. Lowette,[5] S. Moortgat,[5] A. Morton,[5] D. Müller,[5] A. R. Sahasransu,[5] S. Tavernier,[5] W. Van Doninck,[5] P. Van Mulders,[5] D. Beghin,[6] B. Bilin,[6] B. Clerbaux,[6] G. De Lentdecker,[6] L. Favart,[6] A. Grebenyuk,[6] A. K. Kalsi,[6] K. Lee,[6] M. Mahdavikhorrami,[6] I. Makarenko,[6] L. Moureaux,[6] L. Pétré,[6] A. Popov,[6] N. Postiau,[6] E. Starling,[6] L. Thomas,[6] M. Vanden Bemden,[6] C. Vander Velde,[6] P. Vanlaer,[6] D. Vannerom,[6] L. Wezenbeek,[6] T. Cornelis,[7] D. Dobur,[7] J. Knolle,[7] L. Lambrecht,[7] G. Mestdach,[7] M. Niedziela,[7] C. Roskas,[7] A. Samalan,[7] K. Skovpen,[7] M. Tytgat,[7] W. Verbeke,[7] B. Vermassen,[7] M. Vit,[7] A. Bethani,[8] G. Bruno,[8] F. Bury,[8] C. Caputo,[8] P. David,[8] C. Delaere,[8] I. S. Donertas,[8] A. Giammanco,[8] K. Jaffel,[8] Sa. Jain,[8] V. Lemaitre,[8] K. Mondal,[8] J. Prisciandaro,[8] A. Taliercio,[8] M. Teklishyn,[8] T. T. Tran,[8] P. Vischia,[8] S. Wertz,[8] G. A. Alves,[9] C. Hensel,[9] A. Moraes,[9] W. L. Aldá Júnior,[10] M. Alves Gallo Pereira,[10] M. Barroso Ferreira Filho,[10] H. Brandao Malbouisson,[10] W. Carvalho,[10] J. Chinellato,[10,e] E. M. Da Costa,[10] G. G. Da Silveira,[10,f] D. De Jesus Damiao,[10] S. Fonseca De Souza,[10] D. Matos Figueiredo,[10] C. Mora Herrera,[10] K. Mota Amarilo,[10] L. Mundim,[10] H. Nogima,[10] P. Rebello Teles,[10] A. Santoro,[10] S. M. Silva Do Amaral,[10] A. Sznajder,[10] M. Thiel,[10] F. Torres Da Silva De Araujo,[10] A. Vilela Pereira,[10] C. A. Bernardes,[11a,f] L. Calligaris,[11a] T. R. Fernandez Perez Tomei,[11a] E. M. Gregores,[11a,11b] D. S. Lemos,[11a] P. G. Mercadante,[11a,11b] S. F. Novaes,[11a] Sandra S. Padula,[11a] A. Aleksandrov,[12] G. Antchev,[12] R. Hadjiiska,[12] P. Iaydjiev,[12] M. Misheva,[12] M. Rodozov,[12] M. Shopova,[12] G. Sultanov,[12] A. Dimitrov,[13] T. Ivanov,[13] L. Litov,[13] B. Pavlov,[13] P. Petkov,[13] A. Petrov,[13] T. Cheng,[14] Q. Guo,[14] T. Javaid,[14,g] M. Mittal,[14] H. Wang,[14] L. Yuan,[14] M. Ahmad,[15] G. Bauer,[15] C. Dozen,[15,h] Z. Hu,[15] J. Martins,[15,i] Y. Wang,[15] K. Yi,[15,j,k] E. Chapon,[16] G. M. Chen,[16,g] H. S. Chen,[16,g] M. Chen,[16] F. Iemmi,[16] A. Kapoor,[16] D. Leggat,[16] H. Liao,[16] Z.-A. Liu,[16,g] V. Milosevic,[16] F. Monti,[16] R. Sharma,[16] J. Tao,[16] J. Thomas-Wilsker,[16] J. Wang,[16] H. Zhang,[16] S. Zhang,[16,g] J. Zhao,[16] A. Agapitos,[17] Y. Ban,[17] C. Chen,[17] A. Levin,[17] Q. Li,[17] X. Lyu,[17] Y. Mao,[17] S. J. Qian,[17] D. Wang,[17] Q. Wang,[17] J. Xiao,[17] M. Lu,[18] Z. You,[18] X. Gao,[19,d] H. Okawa,[19] Z. Lin,[20] M. Xiao,[20] C. Avila,[21] A. Cabrera,[21] C. Florez,[21] J. Fraga,[21] A. Sarkar,[21] M. A. Segura Delgado,[21] J. Mejia Guisao,[22] F. Ramirez,[22] J. D. Ruiz Alvarez,[22] C. A. Salazar González,[22] D. Giljanovic,[23]

N. Godinovic,[23] D. Lelas,[23] I. Puljak,[23] Z. Antunovic,[24] M. Kovac,[24] T. Sculac,[24] V. Brigljevic,[25] D. Ferencek,[25] D. Majumder,[25] M. Roguljic,[25] A. Starodumov,[25,l] T. Susa,[25] A. Attikis,[26] K. Christoforou,[26] E. Erodotou,[26] A. Ioannou,[26] G. Kole,[26] M. Kolosova,[26] S. Konstantinou,[26] J. Mousa,[26] C. Nicolaou,[26] F. Ptochos,[26] P. A. Razis,[26] H. Rykaczewski,[26] H. Saka,[26] M. Finger,[27,m] M. Finger Jr.,[27,m] A. Kveton,[27] E. Ayala,[28] E. Carrera Jarrin,[29] A. A. Abdelalim,[30,n,o] Y. Assran,[30,p,q] Y. Assran,[30,p,q] A. Lotfy,[31] M. A. Mahmoud,[31] S. Bhowmik,[32] R. K. Dewanjee,[32] K. Ehataht,[32] M. Kadastik,[32] S. Nandan,[32] C. Nielsen,[32] J. Pata,[32] M. Raidal,[32] L. Tani,[32] C. Veelken,[32] P. Eerola,[33] L. Forthomme,[33] H. Kirschenmann,[33] K. Osterberg,[33] M. Voutilainen,[33] S. Bharthuar,[34] E. Brücken,[34] F. Garcia,[34] J. Havukainen,[34] M. S. Kim,[34] R. Kinnunen,[34] T. Lampén,[34] K. Lassila-Perini,[34] S. Lehti,[34] T. Lindén,[34] M. Lotti,[34] L. Martikainen,[34] M. Myllymäki,[34] J. Ott,[34] H. Siikonen,[34] E. Tuominen,[34] J. Tuominiemi,[34] P. Luukka,[35] H. Petrow,[35] T. Tuuva,[35] C. Amendola,[36] M. Besancon,[36] F. Couderc,[36] M. Dejardin,[36] D. Denegri,[36] J. L. Faure,[36] F. Ferri,[36] S. Ganjour,[36] A. Givernaud,[36] P. Gras,[36] G. Hamel de Monchenault,[36] P. Jarry,[36] B. Lenzi,[36] E. Locci,[36] J. Malcles,[36] J. Rander,[36] A. Rosowsky,[36] M. Ö. Sahin,[36] A. Savoy-Navarro,[36,r] M. Titov,[36] G. B. Yu,[36] S. Ahuja,[37] F. Beaudette,[37] M. Bonanomi,[37] A. Buchot Perraguin,[37] P. Busson,[37] A. Cappati,[37] C. Charlot,[37] O. Davignon,[37] B. Diab,[37] G. Falmagne,[37] S. Ghosh,[37] R. Granier de Cassagnac,[37] A. Hakimi,[37] I. Kucher,[37] M. Nguyen,[37] C. Ochando,[37] P. Paganini,[37] J. Rembser,[37] R. Salerno,[37] J. B. Sauvan,[37] Y. Sirois,[37] A. Zabi,[37] A. Zghiche,[37] J.-L. Agram,[38,s] J. Andrea,[38] D. Apparu,[38] D. Bloch,[38] G. Bourgatte,[38] J.-M. Brom,[38] E. C. Chabert,[38] C. Collard,[38] D. Darej,[38] J.-C. Fontaine,[38,s] U. Goerlach,[38] C. Grimault,[38] A.-C. Le Bihan,[38] E. Nibigira,[38] P. Van Hove,[38] E. Asilar,[39] S. Beauceron,[39] C. Bernet,[39] G. Boudoul,[39] C. Camen,[39] A. Carle,[39] N. Chanon,[39] D. Contardo,[39] P. Depasse,[39] H. El Mamouni,[39] J. Fay,[39] S. Gascon,[39] M. Gouzevitch,[39] B. Ille,[39] I. B. Laktineh,[39] H. Lattaud,[39] A. Lesauvage,[39] M. Lethuillier,[39] L. Mirabito,[39] S. Perries,[39] K. Shchablo,[39] V. Sordini,[39] L. Torterotot,[39] G. Touquet,[39] M. Vander Donckt,[39] S. Viret,[39] A. Khvedelidze,[40,m] I. Lomidze,[40] Z. Tsamalaidze,[40,m] L. Feld,[41] K. Klein,[41] M. Lipinski,[41] D. Meuser,[41] A. Pauls,[41] M. P. Rauch,[41] N. Röwert,[41] J. Schulz,[41] M. Teroerde,[41] A. Dodonova,[42] D. Eliseev,[42] M. Erdmann,[42] P. Fackeldey,[42] B. Fischer,[42] S. Ghosh,[42] T. Hebbeker,[42] K. Hoepfner,[42] F. Ivone,[42] H. Keller,[42] L. Mastrolorenzo,[42] M. Merschmeyer,[42] A. Meyer,[42] G. Mocellin,[42] S. Mondal,[42] S. Mukherjee,[42] D. Noll,[42] A. Novak,[42] T. Pook,[42] A. Pozdnyakov,[42] Y. Rath,[42] H. Reithler,[42] J. Roemer,[42] A. Schmidt,[42] S. C. Schuler,[42] A. Sharma,[42] L. Vigilante,[42] S. Wiedenbeck,[42] S. Zaleski,[42] C. Dziwok,[43] G. Flügge,[43] W. Haj Ahmad,[43,t] O. Hlushchenko,[43] T. Kress,[43] A. Nowack,[43] C. Pistone,[43] O. Pooth,[43] D. Roy,[43] H. Sert,[43] A. Stahl,[43,u] T. Ziemons,[43] H. Aarup Petersen,[44] M. Aldaya Martin,[44] P. Asmuss,[44] I. Babounikau,[44] S. Baxter,[44] O. Behnke,[44] A. Bermúdez Martínez,[44] S. Bhattacharya,[44] A. A. Bin Anuar,[44] K. Borras,[44,v] V. Botta,[44] D. Brunner,[44] A. Campbell,[44] A. Cardini,[44] C. Cheng,[44] F. Colombina,[44] S. Consuegra Rodríguez,[44] G. Correia Silva,[44] V. Danilov,[44] L. Didukh,[44] G. Eckerlin,[44] D. Eckstein,[44] L. I. Estevez Banos,[44] O. Filatov,[44] E. Gallo,[44,w] A. Geiser,[44] A. Giraldi,[44] A. Grohsjean,[44] M. Guthoff,[44] A. Jafari,[44,x] N. Z. Jomhari,[44] H. Jung,[44] A. Kasem,[44,v] M. Kasemann,[44] H. Kaveh,[44] C. Kleinwort,[44] D. Krücker,[44] W. Lange,[44] J. Lidrych,[44] K. Lipka,[44] W. Lohmann,[44,y] R. Mankel,[44] I.-A. Melzer-Pellmann,[44] J. Metwally,[44] A. B. Meyer,[44] M. Meyer,[44] J. Mnich,[44] A. Mussgiller,[44] Y. Otarid,[44] D. Pérez Adán,[44] D. Pitzl,[44] A. Raspereza,[44] B. Ribeiro Lopes,[44] J. Rübenach,[44] A. Saggio,[44] A. Saibel,[44] M. Savitskyi,[44] M. Scham,[44] V. Scheurer,[44] C. Schwanenberger,[44,w] A. Singh,[44] R. E. Sosa Ricardo,[44] D. Stafford,[44] N. Tonon,[44] O. Turkot,[44] M. Van De Klundert,[44] R. Walsh,[44] D. Walter,[44] Y. Wen,[44] K. Wichmann,[44] L. Wiens,[44] C. Wissing,[44] S. Wuchterl,[44] R. Aggleton,[45] S. Albrecht,[45] S. Bein,[45] L. Benato,[45] A. Benecke,[45] P. Connor,[45] K. De Leo,[45] M. Eich,[45] F. Feindt,[45] A. Fröhlich,[45] C. Garbers,[45] E. Garutti,[45] P. Gunnellini,[45] J. Haller,[45] A. Hinzmann,[45] G. Kasieczka,[45] R. Klanner,[45] R. Kogler,[45] T. Kramer,[45] V. Kutzner,[45] J. Lange,[45] T. Lange,[45] A. Lobanov,[45] A. Malara,[45] A. Nigamova,[45] K. J. Pena Rodriguez,[45] O. Rieger,[45] P. Schleper,[45] M. Schröder,[45] J. Schwandt,[45] D. Schwarz,[45] J. Sonneveld,[45] H. Stadie,[45] G. Steinbrück,[45] A. Tews,[45] B. Vormwald,[45] I. Zoi,[45] J. Bechtel,[46] T. Berger,[46] E. Butz,[46] R. Caspart,[46] T. Chwalek,[46] W. De Boer,[46,a] A. Dierlamm,[46] A. Droll,[46] K. El Morabit,[46] N. Faltermann,[46] M. Giffels,[46] J. o. Gosewisch,[46] A. Gottmann,[46] F. Hartmann,[46,u] C. Heidecker,[46] U. Husemann,[46] I. Katkov,[46,z] P. Keicher,[46] R. Koppenhöfer,[46] S. Maier,[46] M. Metzler,[46] S. Mitra,[46] Th. Müller,[46] M. Neukum,[46] A. Nürnberg,[46] G. Quast,[46] K. Rabbertz,[46] J. Rauser,[46] D. Savoiu,[46] M. Schnepf,[46] D. Seith,[46] I. Shvetsov,[46] H. J. Simonis,[46] R. Ulrich,[46] J. Van Der Linden,[46] R. F. Von Cube,[46] M. Wassmer,[46] M. Weber,[46] S. Wieland,[46] R. Wolf,[46] S. Wozniewski,[46] S. Wunsch,[46] G. Anagnostou,[47] G. Daskalakis,[47] T. Geralis,[47] A. Kyriakis,[47] D. Loukas,[47] A. Stakia,[47] M. Diamantopoulou,[48] D. Karasavvas,[48] G. Karathanasis,[48] P. Kontaxakis,[48] C. K. Koraka,[48] A. Manousakis-Katsikakis,[48] A. Panagiotou,[48] I. Papavergou,[48] N. Saoulidou,[48] K. Theofilatos,[48] E. Tziaferi,[48] K. Vellidis,[48] E. Vourliotis,[48] G. Bakas,[49] K. Kousouris,[49] I. Papakrivopoulos,[49] G. Tsipolitis,[49] A. Zacharopoulou,[49] I. Evangelou,[50] C. Foudas,[50] P. Gianneios,[50] P. Katsoulis,[50]

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M. Raymond,[145] A. Richards,[145] A. Rose,[145] E. Scott,[145] C. Seez,[145] A. Shtipliyski,[145] A. Tapper,[145] K. Uchida,[145] T. Virdee,[145,u] M. Vojinovic,[145] N. Wardle,[145] S. N. Webb,[145] D. Winterbottom,[145] A. G. Zecchinelli,[145] K. Coldham,[146] J. E. Cole,[146] A. Khan,[146] P. Kyberd,[146] I. D. Reid,[146] L. Teodorescu,[146] S. Zahid,[146] S. Abdullin,[147] A. Brinkerhoff,[147] B. Caraway,[147] J. Dittmann,[147] K. Hatakeyama,[147] A. R. Kanuganti,[147] B. McMaster,[147] N. Pastika,[147] M. Saunders,[147] S. Sawant,[147] C. Sutantawibul,[147] J. Wilson,[147] R. Bartek,[148] A. Dominguez,[148] R. Uniyal,[148]

A. M. Vargas Hernandez,[148] A. Buccilli,[149] S. I. Cooper,[149] D. Di Croce,[149] S. V. Gleyzer,[149] C. Henderson,[149] C. U. Perez,[149] P. Rumerio,[149,jjjj] C. West,[149] A. Akpinar,[150] A. Albert,[150] D. Arcaro,[150] C. Cosby,[150] Z. Demiragli,[150] E. Fontanesi,[150] D. Gastler,[150] J. Rohlf,[150] K. Salyer,[150] D. Sperka,[150] D. Spitzbart,[150] I. Suarez,[150] A. Tsatsos,[150] S. Yuan,[150] D. Zou,[150] G. Benelli,[151] B. Burkle,[151] X. Coubez,[151,v] D. Cutts,[151] M. Hadley,[151] U. Heintz,[151] J. M. Hogan,[151,kkkk] G. Landsberg,[151] K. T. Lau,[151] M. Lukasik,[151] J. Luo,[151] M. Narain,[151] S. Sagir,[151,llll] E. Usai,[151] W. Y. Wong,[151] X. Yan,[151] D. Yu,[151] W. Zhang,[151] J. Bonilla,[152] C. Brainerd,[152] R. Breedon,[152] M. Calderon De La Barca Sanchez,[152] M. Chertok,[152] J. Conway,[152] P. T. Cox,[152] R. Erbacher,[152] G. Haza,[152] F. Jensen,[152] O. Kukral,[152] R. Lander,[152] M. Mulhearn,[152] D. Pellett,[152] B. Regnery,[152] D. Taylor,[152] Y. Yao,[152] F. Zhang,[152] M. Bachtis,[153] R. Cousins,[153] A. Datta,[153] D. Hamilton,[153] J. Hauser,[153] M. Ignatenko,[153] M. A. Iqbal,[153] T. Lam,[153] W. A. Nash,[153] S. Regnard,[153] D. Saltzberg,[153] B. Stone,[153] V. Valuev,[153] K. Burt,[154] Y. Chen,[154] R. Clare,[154] J. W. Gary,[154] M. Gordon,[154] G. Hanson,[154] G. Karapostoli,[154] O. R. Long,[154] N. Manganelli,[154] M. Olmedo Negrete,[154] W. Si,[154] S. Wimpenny,[154] Y. Zhang,[154] J. G. Branson,[155] P. Chang,[155] S. Cittolin,[155] S. Cooperstein,[155] N. Deelen,[155] D. Diaz,[155] J. Duarte,[155] R. Gerosa,[155] L. Giannini,[155] D. Gilbert,[155] J. Guiang,[155] R. Kansal,[155] V. Krutelyov,[155] R. Lee,[155] J. Letts,[155] M. Masciovecchio,[155] S. May,[155] M. Pieri,[155] B. V. Sathia Narayanan,[155] V. Sharma,[155] M. Tadel,[155] A. Vartak,[155] F. Würthwein,[155] Y. Xiang,[155] A. Yagil,[155] N. Amin,[156] C. Campagnari,[156] M. Citron,[156] A. Dorsett,[156] V. Dutta,[156] J. Incandela,[156] M. Kilpatrick,[156] J. Kim,[156] B. Marsh,[156] H. Mei,[156] M. Oshiro,[156] M. Quinnan,[156] J. Richman,[156] U. Sarica,[156] J. Sheplock,[156] D. Stuart,[156] S. Wang,[156] A. Bornheim,[157] O. Cerri,[157] I. Dutta,[157] J. M. Lawhorn,[157] N. Lu,[157] J. Mao,[157] H. B. Newman,[157] T. Q. Nguyen,[157] M. Spiropulu,[157] J. R. Vlimant,[157] C. Wang,[157] S. Xie,[157] Z. Zhang,[157] R. Y. Zhu,[157] J. Alison,[158] S. An,[158] M. B. Andrews,[158] P. Bryant,[158] T. Ferguson,[158] A. Harilal,[158] C. Liu,[158] T. Mudholkar,[158] M. Paulini,[158] A. Sanchez,[158] J. P. Cumalat,[159] W. T. Ford,[159] A. Hassani,[159] E. MacDonald,[159] R. Patel,[159] A. Perloff,[159] C. Savard,[159] K. Stenson,[159] K. A. Ulmer,[159] S. R. Wagner,[159] J. Alexander,[160] S. Bright-thonney,[160] Y. Cheng,[160] D. J. Cranshaw,[160] S. Hogan,[160] J. Monroy,[160] J. R. Patterson,[160] D. Quach,[160] J. Reichert,[160] M. Reid,[160] A. Ryd,[160] W. Sun,[160] J. Thom,[160] P. Wittich,[160] R. Zou,[160] M. Albrow,[161] M. Alyari,[161] G. Apollinari,[161] A. Apresyan,[161] A. Apyan,[161] S. Banerjee,[161] L. A. T. Bauerdick,[161] D. Berry,[161] J. Berryhill,[161] P. C. Bhat,[161] K. Burkett,[161] J. N. Butler,[161] A. Canepa,[161] G. B. Cerati,[161] H. W. K. Cheung,[161] F. Chlebana,[161] M. Cremonesi,[161] K. F. Di Petrillo,[161] V. D. Elvira,[161] Y. Feng,[161] J. Freeman,[161] Z. Gecse,[161] L. Gray,[161] D. Green,[161] S. Grünendahl,[161] O. Gutsche,[161] R. M. Harris,[161] R. Heller,[161] T. C. Herwig,[161] J. Hirschauer,[161] B. Jayatilaka,[161] S. Jindariani,[161] M. Johnson,[161] U. Joshi,[161] T. Klijnsma,[161] B. Klima,[161] K. H. M. Kwok,[161] S. Lammel,[161] D. Lincoln,[161] R. Lipton,[161] T. Liu,[161] C. Madrid,[161] K. Maeshima,[161] C. Mantilla,[161] D. Mason,[161] P. McBride,[161] P. Merkel,[161] S. Mrenna,[161] S. Nahn,[161] J. Ngadiuba,[161] V. O'Dell,[161] V. Papadimitriou,[161] K. Pedro,[161] C. Pena,[161,fff] O. Prokofyev,[161] F. Ravera,[161] A. Reinsvold Hall,[161] L. Ristori,[161] B. Schneider,[161] E. Sexton-Kennedy,[161] N. Smith,[161] A. Soha,[161] W. J. Spalding,[161] L. Spiegel,[161] S. Stoynev,[161] J. Strait,[161] L. Taylor,[161] S. Tkaczyk,[161] N. V. Tran,[161] L. Uplegger,[161] E. W. Vaandering,[161] H. A. Weber,[161] D. Acosta,[162] P. Avery,[162] D. Bourilkov,[162] L. Cadamuro,[162] V. Cherepanov,[162] F. Errico,[162] R. D. Field,[162] D. Guerrero,[162] B. M. Joshi,[162] M. Kim,[162] E. Koenig,[162] J. Konigsberg,[162] A. Korytov,[162] K. H. Lo,[162] K. Matchev,[162] N. Menendez,[162] G. Mitselmakher,[162] A. Muthirakalayil Madhu,[162] N. Rawal,[162] D. Rosenzweig,[162] S. Rosenzweig,[162] K. Shi,[162] J. Sturdy,[162] J. Wang,[162] E. Yigitbasi,[162] X. Zuo,[162] T. Adams,[163] A. Askew,[163] R. Habibullah,[163] V. Hagopian,[163] K. F. Johnson,[163] R. Khurana,[163] T. Kolberg,[163] G. Martinez,[163] H. Prosper,[163] C. Schiber,[163] O. Viazlo,[163] R. Yohay,[163] J. Zhang,[163] M. M. Baarmand,[164] S. Butalla,[164] T. Elkafrawy,[164,mmmm] M. Hohlmann,[164] R. Kumar Verma,[164] D. Noonan,[164] M. Rahmani,[164] F. Yumiceva,[164] M. R. Adams,[165] H. Becerril Gonzalez,[165] R. Cavanaugh,[165] X. Chen,[165] S. Dittmer,[165] O. Evdokimov,[165] C. E. Gerber,[165] D. A. Hangal,[165] D. J. Hofman,[165] A. H. Merrit,[165] C. Mills,[165] G. Oh,[165] T. Roy,[165] S. Rudrabhatla,[165] M. B. Tonjes,[165] N. Varelas,[165] J. Viinikainen,[165] X. Wang,[165] Z. Wu,[165] Z. Ye,[165] M. Alhusseini,[166] K. Dilsiz,[166,nnnn] R. P. Gandrajula,[166] O. K. Köseyan,[166] J.-P. Merlo,[166] A. Mestvirishvili,[166,oooo] J. Nachtman,[166] H. Ogul,[166,pppp] Y. Onel,[166] A. Penzo,[166] C. Snyder,[166] E. Tiras,[166,qqqq] O. Amram,[167] B. Blumenfeld,[167] L. Corcodilos,[167] J. Davis,[167] M. Eminizer,[167] A. V. Gritsan,[167] S. Kyriacou,[167] P. Maksimovic,[167] J. Roskes,[167] M. Swartz,[167] T. Á. Vámi,[167] A. Abreu,[168] J. Anguiano,[168] C. Baldenegro Barrera,[168] P. Baringer,[168] A. Bean,[168] A. Bylinkin,[168] Z. Flowers,[168] T. Isidori,[168] S. Khalil,[168] J. King,[168] G. Krintiras,[168] A. Kropivnitskaya,[168] M. Lazarovits,[168] C. Lindsey,[168] J. Marquez,[168] N. Minafra,[168] M. Murray,[168] M. Nickel,[168] C. Rogan,[168] C. Royon,[168] R. Salvatico,[168] S. Sanders,[168] E. Schmitz,[168] C. Smith,[168] J. D. Tapia Takaki,[168] Q. Wang,[168] Z. Warner,[168] J. Williams,[168] G. Wilson,[168] S. Duric,[169] A. Ivanov,[169] K. Kaadze,[169] D. Kim,[169] Y. Maravin,[169] T. Mitchell,[169] A. Modak,[169] K. Nam,[169] F. Rebassoo,[170] D. Wright,[170] E. Adams,[171] A. Baden,[171] O. Baron,[171] A. Belloni,[171]

S. C. Eno,[171] N. J. Hadley,[171] S. Jabeen,[171] R. G. Kellogg,[171] T. Koeth,[171] A. C. Mignerey,[171] S. Nabili,[171] C. Palmer,[171] M. Seidel,[171] A. Skuja,[171] L. Wang,[171] K. Wong,[171] D. Abercrombie,[172] G. Andreassi,[172] R. Bi,[172] S. Brandt,[172] W. Busza,[172] I. A. Cali,[172] Y. Chen,[172] M. D'Alfonso,[172] J. Eysermans,[172] C. Freer,[172] G. Gomez Ceballos,[172] M. Goncharov,[172] P. Harris,[172] M. Hu,[172] M. Klute,[172] D. Kovalskyi,[172] J. Krupa,[172] Y.-J. Lee,[172] B. Maier,[172] C. Mironov,[172] C. Paus,[172] D. Rankin,[172] C. Roland,[172] G. Roland,[172] Z. Shi,[172] G. S. F. Stephans,[172] K. Tatar,[172] J. Wang,[172] Z. Wang,[172] B. Wyslouch,[172] R. M. Chatterjee,[173] A. Evans,[173] P. Hansen,[173] J. Hiltbrand,[173] Sh. Jain,[173] M. Krohn,[173] Y. Kubota,[173] J. Mans,[173] M. Revering,[173] R. Rusack,[173] R. Saradhy,[173] N. Schroeder,[173] N. Strobbe,[173] M. A. Wadud,[173] K. Bloom,[174] M. Bryson,[174] S. Chauhan,[174] D. R. Claes,[174] C. Fangmeier,[174] L. Finco,[174] F. Golf,[174] C. Joo,[174] I. Kravchenko,[174] M. Musich,[174] I. Reed,[174] J. E. Siado,[174] G. R. Snow,[174,a] W. Tabb,[174] F. Yan,[174] G. Agarwal,[175] H. Bandyopadhyay,[175] L. Hay,[175] I. Iashvili,[175] A. Kharchilava,[175] C. McLean,[175] D. Nguyen,[175] J. Pekkanen,[175] S. Rappoccio,[175] A. Williams,[175] G. Alverson,[176] E. Barberis,[176] Y. Haddad,[176] A. Hortiangtham,[176] J. Li,[176] G. Madigan,[176] B. Marzocchi,[176] D. M. Morse,[176] V. Nguyen,[176] T. Orimoto,[176] A. Parker,[176] L. Skinnari,[176] A. Tishelman-Charny,[176] T. Wamorkar,[176] B. Wang,[176] A. Wisecarver,[176] D. Wood,[176] S. Bhattacharya,[177] J. Bueghly,[177] Z. Chen,[177] A. Gilbert,[177] T. Gunter,[177] K. A. Hahn,[177] Y. Liu,[177] N. Odell,[177] M. H. Schmitt,[177] M. Velasco,[177] R. Band,[178] R. Bucci,[178] A. Das,[178] N. Dev,[178] R. Goldouzian,[178] M. Hildreth,[178] K. Hurtado Anampa,[178] C. Jessop,[178] K. Lannon,[178] J. Lawrence,[178] N. Loukas,[178] D. Lutton,[178] N. Marinelli,[178] I. Mcalister,[178] T. McCauley,[178] F. Meng,[178] K. Mohrman,[178] Y. Musienko,[178,yy] R. Ruchti,[178] P. Siddireddy,[178] A. Townsend,[178] M. Wayne,[178] A. Wightman,[178] M. Wolf,[178] M. Zarucki,[178] L. Zygala,[178] B. Bylsma,[179] B. Cardwell,[179] L. S. Durkin,[179] B. Francis,[179] C. Hill,[179] M. Nunez Ornelas,[179] K. Wei,[179] B. L. Winer,[179] B. R. Yates,[179] F. M. Addesa,[180] B. Bonham,[180] P. Das,[180] G. Dezoort,[180] P. Elmer,[180] A. Frankenthal,[180] B. Greenberg,[180] N. Haubrich,[180] S. Higginbotham,[180] A. Kalogeropoulos,[180] G. Kopp,[180] S. Kwan,[180] D. Lange,[180] M. T. Lucchini,[180] D. Marlow,[180] K. Mei,[180] I. Ojalvo,[180] J. Olsen,[180] D. Stickland,[180] C. Tully,[180] S. Malik,[181] S. Norberg,[181] A. S. Bakshi,[182] V. E. Barnes,[182] R. Chawla,[182] S. Das,[182] L. Gutay,[182] M. Jones,[182] A. W. Jung,[182] S. Karmarkar,[182] M. Liu,[182] G. Negro,[182] N. Neumeister,[182] G. Paspalaki,[182] C. C. Peng,[182] S. Piperov,[182] A. Purohit,[182] J. F. Schulte,[182] M. Stojanovic,[182,r] J. Thieman,[182] F. Wang,[182] R. Xiao,[182] W. Xie,[182] J. Dolen,[183] N. Parashar,[183] A. Baty,[184] M. Decaro,[184] S. Dildick,[184] K. M. Ecklund,[184] S. Freed,[184] P. Gardner,[184] F. J. M. Geurts,[184] A. Kumar,[184] W. Li,[184] B. P. Padley,[184] R. Redjimi,[184] W. Shi,[184] A. G. Stahl Leiton,[184] S. Yang,[184] L. Zhang,[184] Y. Zhang,[184] A. Bodek,[185] P. de Barbaro,[185] R. Demina,[185] J. L. Dulemba,[185] C. Fallon,[185] T. Ferbel,[185] M. Galanti,[185] A. Garcia-Bellido,[185] O. Hindrichs,[185] A. Khukhunaishvili,[185] E. Ranken,[185] R. Taus,[185] B. Chiarito,[186] J. P. Chou,[186] A. Gandrakota,[186] Y. Gershtein,[186] E. Halkiadakis,[186] A. Hart,[186] M. Heindl,[186] O. Karacheban,[186,y] I. Laflotte,[186] A. Lath,[186] R. Montalvo,[186] K. Nash,[186] M. Osherson,[186] S. Salur,[186] S. Schnetzer,[186] S. Somalwar,[186] R. Stone,[186] S. A. Thayil,[186] S. Thomas,[186] H. Wang,[186] H. Acharya,[187] A. G. Delannoy,[187] S. Spanier,[187] O. Bouhali,[188,rrrr] M. Dalchenko,[188] A. Delgado,[188] R. Eusebi,[188] J. Gilmore,[188] T. Huang,[188] T. Kamon,[188,ssss] H. Kim,[188] S. Luo,[188] S. Malhotra,[188] R. Mueller,[188] D. Overton,[188] D. Rathjens,[188] A. Safonov,[188] N. Akchurin,[189] J. Damgov,[189] V. Hegde,[189] S. Kunori,[189] K. Lamichhane,[189] S. W. Lee,[189] T. Mengke,[189] S. Muthumuni,[189] T. Peltola,[189] I. Volobouev,[189] Z. Wang,[189] A. Whitbeck,[189] E. Appelt,[190] S. Greene,[190] A. Gurrola,[190] W. Johns,[190] A. Melo,[190] H. Ni,[190] K. Padeken,[190] F. Romeo,[190] P. Sheldon,[190] S. Tuo,[190] J. Velkovska,[190] M. W. Arenton,[191] B. Cox,[191] G. Cummings,[191] J. Hakala,[191] R. Hirosky,[191] M. Joyce,[191] A. Ledovskoy,[191] A. Li,[191] C. Neu,[191] B. Tannenwald,[191] S. White,[191] E. Wolfe,[191] N. Poudyal,[192] K. Black,[193] T. Bose,[193] J. Buchanan,[193] C. Caillol,[193] S. Dasu,[193] I. De Bruyn,[193] P. Everaerts,[193] F. Fienga,[193] C. Galloni,[193] H. He,[193] M. Herndon,[193] A. Hervé,[193] U. Hussain,[193] A. Lanaro,[193] A. Loeliger,[193] R. Loveless,[193] J. Madhusudanan Sreekala,[193] A. Mallampalli,[193] A. Mohammadi,[193] D. Pinna,[193] A. Savin,[193] V. Shang,[193] V. Sharma,[193] W. H. Smith,[193] D. Teague,[193] S. Trembath-Reichert,[193] and W. Vetens[193]

(CMS Collaboration)

[1]*Yerevan Physics Institute, Yerevan, Armenia*
[2]*Institut für Hochenergiephysik, Wien, Austria*
[3]*Institute for Nuclear Problems, Minsk, Belarus*
[4]*Universiteit Antwerpen, Antwerpen, Belgium*
[5]*Vrije Universiteit Brussel, Brussel, Belgium*
[6]*Université Libre de Bruxelles, Bruxelles, Belgium*

[7]*Ghent University, Ghent, Belgium*
[8]*Université Catholique de Louvain, Louvain-la-Neuve, Belgium*
[9]*Centro Brasileiro de Pesquisas Fisicas, Rio de Janeiro, Brazil*
[10]*Universidade do Estado do Rio de Janeiro, Rio de Janeiro, Brazil*
[11a]*Universidade Estadual Paulista, São Paulo, Brazil*
[11b]*Universidade Federal do ABC, São Paulo, Brazil*
[12]*Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Sofia, Bulgaria*
[13]*University of Sofia, Sofia, Bulgaria*
[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]*Institute of Modern Physics and Key Laboratory of Nuclear Physics and Ion-beam Application (MOE) - Fudan University, Shanghai, China*
[20]*Zhejiang University, Hangzhou, China*
[21]*Universidad de Los Andes, Bogota, Colombia*
[22]*Universidad de Antioquia, Medellin, Colombia*
[23]*University of Split, Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, Split, Croatia*
[24]*University of Split, Faculty of Science, Split, Croatia*
[25]*Institute Rudjer Boskovic, Zagreb, Croatia*
[26]*University of Cyprus, Nicosia, Cyprus*
[27]*Charles University, Prague, Czech Republic*
[28]*Escuela Politecnica Nacional, Quito, Ecuador*
[29]*Universidad San Francisco de Quito, Quito, Ecuador*
[30]*Academy of Scientific Research and Technology of the Arab Republic of Egypt, Egyptian Network of High Energy Physics, Cairo, Egypt*
[31]*Center for High Energy Physics (CHEP-FU), Fayoum University, El-Fayoum, Egypt*
[32]*National Institute of Chemical Physics and Biophysics, Tallinn, Estonia*
[33]*Department of Physics, University of Helsinki, Helsinki, Finland*
[34]*Helsinki Institute of Physics, Helsinki, Finland*
[35]*Lappeenranta University of Technology, Lappeenranta, Finland*
[36]*IRFU, CEA, Université Paris-Saclay, Gif-sur-Yvette, France*
[37]*Laboratoire Leprince-Ringuet, CNRS/IN2P3, Ecole Polytechnique, Institut Polytechnique de Paris, Palaiseau, France*
[38]*Université de Strasbourg, CNRS, IPHC UMR 7178, Strasbourg, France*
[39]*Institut de Physique des 2 Infinis de Lyon (IP2I), Villeurbanne, France*
[40]*Georgian Technical University, Tbilisi, Georgia*
[41]*RWTH Aachen University, I. Physikalisches Institut, Aachen, Germany*
[42]*RWTH Aachen University, III. Physikalisches Institut A, Aachen, Germany*
[43]*RWTH Aachen University, III. Physikalisches Institut B, Aachen, Germany*
[44]*Deutsches Elektronen-Synchrotron, Hamburg, Germany*
[45]*University of Hamburg, Hamburg, Germany*
[46]*Karlsruher Institut fuer Technologie, Karlsruhe, Germany*
[47]*Institute of Nuclear and Particle Physics (INPP), NCSR Demokritos, Aghia Paraskevi, Greece*
[48]*National and Kapodistrian University of Athens, Athens, Greece*
[49]*National Technical University of Athens, Athens, Greece*
[50]*University of Ioánnina, Ioánnina, Greece*
[51]*MTA-ELTE Lendület CMS Particle and Nuclear Physics Group, Eötvös Loránd University, Budapest, Hungary*
[52]*Wigner Research Centre for Physics, Budapest, Hungary*
[53]*Institute of Nuclear Research ATOMKI, Debrecen, Hungary*
[54]*Institute of Physics, University of Debrecen, Debrecen, Hungary*
[55]*Karoly Robert Campus, MATE Institute of Technology, Gyöngyös, Hungary*
[56]*Indian Institute of Science (IISc), Bangalore, India*
[57]*National Institute of Science Education and Research, HBNI, Bhubaneswar, India*
[58]*Panjab University, Chandigarh, India*
[59]*University of Delhi, Delhi, India*
[60]*Saha Institute of Nuclear Physics, HBNI, Kolkata, India*
[61]*Indian Institute of Technology Madras, Madras, India*
[62]*Bhabha Atomic Research Centre, Mumbai, India*
[63]*Tata Institute of Fundamental Research-A, Mumbai, India*

[64]*Tata Institute of Fundamental Research-B, Mumbai, India*
[65]*Indian Institute of Science Education and Research (IISER), Pune, India*
[66]*Department of Physics, Isfahan University of Technology, Isfahan, Iran*
[67]*Institute for Research in Fundamental Sciences (IPM), Tehran, Iran*
[68]*University College Dublin, Dublin, Ireland*
[69a]*INFN Sezione di Bari, Bari, Italy*
[69b]*Università di Bari, Bari, Italy*
[69c]*Politecnico di Bari, Bari, Italy*
[70a]*INFN Sezione di Bologna, Bologna, Italy*
[70b]*Università di Bologna, Bologna, Italy*
[71a]*INFN Sezione di Catania, Catania, Italy*
[71b]*Università di Catania, Catania, Italy*
[72a]*INFN Sezione di Firenze, Firenze, Italy*
[72b]*Università di Firenze, Firenze, Italy*
[73]*INFN Laboratori Nazionali di Frascati, Frascati, Italy*
[74a]*INFN Sezione di Genova, Genova, Italy*
[74b]*Università di Genova, Genova, Italy*
[75a]*INFN Sezione di Milano-Bicocca, Milano, Italy*
[75b]*Università di Milano-Bicocca, Milano, Italy*
[76a]*INFN Sezione di Napoli, Napoli, Italy*
[76b]*Università di Napoli 'Federico II', Napoli, Italy*
[76c]*Università della Basilicata, Potenza, Italy*
[76d]*Università G. Marconi, Roma, Italy*
[77a]*INFN Sezione di Padova, Padova, Italy*
[77b]*Università di Padova, Padova, Italy*
[77c]*Università di Trento, Trento, Italy*
[78a]*INFN Sezione di Pavia, Pavia, Italy*
[78b]*Università di Pavia, Pavia, Italy*
[79a]*INFN Sezione di Perugia, Perugia, Italy*
[79b]*Università di Perugia, Perugia, Italy*
[80a]*INFN Sezione di Pisa, Pisa Italy*
[80b]*Università di Pisa, Pisa Italy*
[80c]*Scuola Normale Superiore di Pisa, Pisa Italy*
[80d]*Università di Siena, Siena, Italy*
[81a]*INFN Sezione di Roma, Rome, Italy*
[81b]*Sapienza Università di Roma, Rome, Italy*
[82a]*INFN Sezione di Torino, Torino, Italy*
[82b]*Università di Torino, Torino, Italy*
[82c]*Università del Piemonte Orientale, Novara, Italy*
[83a]*INFN Sezione di Trieste, Trieste, Italy*
[83b]*Università di Trieste, Trieste, Italy*
[84]*Kyungpook National University, Daegu, Korea*
[85]*Chonnam National University, Institute for Universe and Elementary Particles, Kwangju, Korea*
[86]*Hanyang University, Seoul, Korea*
[87]*Korea University, Seoul, Korea*
[88]*Kyung Hee University, Department of Physics, Seoul, Republic of Korea*
[89]*Sejong University, Seoul, Korea*
[90]*Seoul National University, Seoul, Korea*
[91]*University of Seoul, Seoul, Korea*
[92]*Yonsei University, Department of Physics, Seoul, Korea*
[93]*Sungkyunkwan University, Suwon, Korea*
[94]*College of Engineering and Technology, American University of the Middle East (AUM), Egaila, Kuwait*
[95]*Riga Technical University, 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 Auckland, Auckland, New Zealand*
[104]*University of Canterbury, Christchurch, New Zealand*
[105]*National Centre for Physics, Quaid-I-Azam University, Islamabad, Pakistan*
[106]*AGH University of Science and Technology Faculty of Computer Science, Electronics and Telecommunications, Krakow, Poland*
[107]*National Centre for Nuclear Research, Swierk, Poland*
[108]*Institute of Experimental Physics, Faculty of Physics, University of Warsaw, Warsaw, Poland*
[109]*Laboratório de Instrumentação e Física Experimental de Partículas, Lisboa, Portugal*
[110]*Joint Institute for Nuclear Research, Dubna, Russia*
[111]*Petersburg Nuclear Physics Institute, Gatchina (St. Petersburg), Russia*
[112]*Institute for Nuclear Research, Moscow, Russia*
[113]*Institute for Theoretical and Experimental Physics named by A.I. Alikhanov of NRC 'Kurchatov Institute', Moscow, Russia*
[114]*Moscow Institute of Physics and Technology, Moscow, Russia*
[115]*National Research Nuclear University 'Moscow Engineering Physics Institute' (MEPhI), Moscow, Russia*
[116]*P.N. Lebedev Physical Institute, Moscow, Russia*
[117]*Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia*
[118]*Novosibirsk State University (NSU), Novosibirsk, Russia*
[119]*Institute for High Energy Physics of National Research Centre 'Kurchatov Institute', Protvino, Russia*
[120]*National Research Tomsk Polytechnic University, Tomsk, Russia*
[121]*Tomsk State University, Tomsk, Russia*
[122]*University of Belgrade: Faculty of Physics and VINCA Institute of Nuclear Sciences, Belgrade, Serbia*
[123]*Centro de Investigaciones Energéticas Medioambientales y Tecnológicas (CIEMAT), Madrid, Spain*
[124]*Universidad Autónoma de Madrid, Madrid, Spain*
[125]*Universidad de Oviedo, Instituto Universitario de Ciencias y Tecnologías Espaciales de Asturias (ICTEA), Oviedo, Spain*
[126]*Instituto de Física de Cantabria (IFCA), CSIC-Universidad de Cantabria, Santander, Spain*
[127]*University of Colombo, Colombo, Sri Lanka*
[128]*University of Ruhuna, Department of Physics, Matara, Sri Lanka*
[129]*CERN, European Organization for Nuclear Research, Geneva, Switzerland*
[130]*Paul Scherrer Institut, Villigen, Switzerland*
[131]*ETH Zurich - Institute for Particle Physics and Astrophysics (IPA), Zurich, Switzerland*
[132]*Universität Zürich, Zurich, Switzerland*
[133]*National Central University, Chung-Li, Taiwan*
[134]*National Taiwan University (NTU), Taipei, Taiwan*
[135]*Chulalongkorn University, Faculty of Science, Department of Physics, Bangkok, Thailand*
[136]*Çukurova University, Physics Department, Science and Art Faculty, Adana, Turkey*
[137]*Middle East Technical University, Physics Department, Ankara, Turkey*
[138]*Bogazici University, Istanbul, Turkey*
[139]*Istanbul Technical University, Istanbul, Turkey*
[140]*Istanbul University, Istanbul, Turkey*
[141]*Institute for Scintillation Materials of National Academy of Science of Ukraine, Kharkov, Ukraine*
[142]*National Scientific Center, Kharkov Institute of Physics and Technology, Kharkov, Ukraine*
[143]*University of Bristol, Bristol, United Kingdom*
[144]*Rutherford Appleton Laboratory, Didcot, United Kingdom*
[145]*Imperial College, London, United Kingdom*
[146]*Brunel University, Uxbridge, United Kingdom*
[147]*Baylor University, Waco, Texas, USA*
[148]*Catholic University of America, Washington, DC, USA*
[149]*The University of Alabama, Tuscaloosa, Alabama, USA*
[150]*Boston University, Boston, Massachusetts, USA*
[151]*Brown University, Providence, Rhode Island, USA*
[152]*University of California, Davis, Davis, California, USA*
[153]*University of California, Los Angeles, California, USA*
[154]*University of California, Riverside, Riverside, California, USA*
[155]*University of California, San Diego, La Jolla, California, USA*
[156]*University of California, Santa Barbara - Department of Physics, Santa Barbara, California, USA*
[157]*California Institute of Technology, Pasadena, California, USA*
[158]*Carnegie Mellon University, Pittsburgh, Pennsylvania, USA*
[159]*University of Colorado Boulder, Boulder, Colorado, USA*
[160]*Cornell University, Ithaca, New York, USA*
[161]*Fermi National Accelerator Laboratory, Batavia, Illinois, USA*
[162]*University of Florida, Gainesville, Florida, USA*

[163]*Florida State University, Tallahassee, Florida, USA*
[164]*Florida Institute of Technology, Melbourne, Florida, USA*
[165]*University of Illinois at Chicago (UIC), Chicago, Illinois, USA*
[166]*The University of Iowa, Iowa City, Iowa, USA*
[167]*Johns Hopkins University, Baltimore, Maryland, USA*
[168]*The University of Kansas, Lawrence, Kansas, USA*
[169]*Kansas State University, Manhattan, Kansas, USA*
[170]*Lawrence Livermore National Laboratory, Livermore, California, USA*
[171]*University of Maryland, College Park, Maryland, USA*
[172]*Massachusetts Institute of Technology, Cambridge, Massachusetts, USA*
[173]*University of Minnesota, Minneapolis, Minnesota, USA*
[174]*University of Nebraska-Lincoln, Lincoln, Nebraska, USA*
[175]*State University of New York at Buffalo, Buffalo, New York, USA*
[176]*Northeastern University, Boston, Massachusetts, USA*
[177]*Northwestern University, Evanston, Illinois, USA*
[178]*University of Notre Dame, Notre Dame, Indiana, USA*
[179]*The Ohio State University, Columbus, Ohio, USA*
[180]*Princeton University, Princeton, New Jersey, USA*
[181]*University of Puerto Rico, Mayaguez, Puerto Rico, USA*
[182]*Purdue University, West Lafayette, Indiana, USA*
[183]*Purdue University Northwest, Hammond, Indiana, USA*
[184]*Rice University, Houston, Texas, USA*
[185]*University of Rochester, Rochester, New York, USA*
[186]*Rutgers, The State University of New Jersey, Piscataway, New Jersey, USA*
[187]*University of Tennessee, Knoxville, Tennessee, USA*
[188]*Texas A&M University, College Station, Texas, USA*
[189]*Texas Tech University, Lubbock, Texas, USA*
[190]*Vanderbilt University, Nashville, Tennessee, USA*
[191]*University of Virginia, Charlottesville, Virginia, USA*
[192]*Wayne State University, Detroit, Michigan, USA*
[193]*University of Wisconsin - Madison, Madison, WI, Wisconsin, USA*

[a] Deceased.
[b] Also at TU Wien, Vienna, Austria.
[c] Also at Institute of Basic and Applied Sciences, Faculty of Engineering, Arab Academy for Science, Technology and Maritime Transport, Alexandria, Egypt.
[d] Also at Université Libre de Bruxelles, Bruxelles, Belgium.
[e] Also at Universidade Estadual de Campinas, Campinas, Brazil.
[f] Also at Federal University of Rio Grande do Sul, Porto Alegre, Brazil.
[g] Also at University of Chinese Academy of Sciences, Beijing, China.
[h] Also at Department of Physics, Tsinghua University, Beijing, China.
[i] Also at Universidade Federal do Mato Grosso do Sul, Nova Andradina, Mato Grosso do Sul, Brazil.
[j] Also at The University of Iowa, Iowa City, Iowa, USA.
[k] Also at Nanjing Normal University Department of Physics, Nanjing, China.
[l] Also at Institute for Theoretical and Experimental Physics named by A.I. Alikhanov of NRC ‘Kurchatov Institute’, Moscow, Russia.
[m] Also at Joint Institute for Nuclear Research, Dubna, Russia.
[n] Also at Helwan University, Cairo, Egypt.
[o] Also at Zewail City of Science and Technology, Zewail, Egypt.
[p] Also at Suez University, Suez, Egypt.
[q] Also at British University in Egypt, Cairo, Egypt.
[r] Also at Purdue University, West Lafayette, Indiana, USA.
[s] Also at Université de Haute Alsace, Mulhouse, France.
[t] Also at Erzincan Binali Yildirim University, Erzincan, Turkey.
[u] Also at CERN, European Organization for Nuclear Research, Geneva, Switzerland.
[v] Also at RWTH Aachen University, III. Physikalisches Institut A, Aachen, Germany.
[w] Also at University of Hamburg, Hamburg, Germany.
[x] Also at Department of Physics, Isfahan University of Technology, Isfahan, Iran.
[y] Also at Brandenburg University of Technology, Cottbus, Germany.
[z] Also at Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia.

[aa] Also at Physics Department, Faculty of Science, Assiut University.
[bb] Also at Karoly Robert Campus, MATE Institute of Technology.
[cc] Also at Institute of Physics, University of Debrecen, Debrecen, Hungary.
[dd] Also at Institute of Nuclear Research ATOMKI, Debrecen, Hungary.
[ee] Also at MTA-ELTE Lendület CMS Particle and Nuclear Physics Group, Eötvös Loránd University, Budapest, Hungary.
[ff] Also at Wigner Research Centre for Physics, Budapest, Hungary.
[gg] Also at IIT Bhubaneswar, Bhubaneswar, India.
[hh] Also at Institute of Physics, Bhubaneswar, India.
[ii] Also at G.H.G. Khalsa College, Punjab, India.
[jj] Also at Shoolini University, Solan, India.
[kk] Also at University of Hyderabad, Hyderabad, India.
[ll] Also at University of Visva-Bharati, Santiniketan, India.
[mm] Also at Indian Institute of Technology (IIT), Mumbai, India.
[nn] Also at Deutsches Elektronen-Synchrotron, Hamburg, Germany.
[oo] Also at Sharif University of Technology, Tehran, Iran.
[pp] Also at Department of Physics, University of Science and Technology of Mazandaran, Behshahr, Iran.
[qq] Also at INFN Sezione di Bari, Università di Bari, Politecnico di Bari, Bari, Italy.
[rr] Also at Italian National Agency for New Technologies, Energy and Sustainable Economic Development.
[ss] Also at Centro Siciliano di Fisica Nucleare e di Struttura Della Materia.
[tt] Also at Università di Napoli 'Federico II'.
[uu] Also at Consiglio Nazionale delle Ricerche - Istituto Officina dei Materiali.
[vv] Also at Riga Technical University, Riga, Latvia.
[ww] Also at Consejo Nacional de Ciencia y Tecnología, Mexico City, Mexico.
[xx] Also at IRFU, CEA, Université Paris-Saclay, Gif-sur-Yvette, France.
[yy] Also at Institute for Nuclear Research, Moscow, Russia.
[zz] Also at National Research Nuclear University 'Moscow Engineering Physics Institute' (MEPhI), Moscow, Russia.
[aaa] Also at Institute of Nuclear Physics of the Uzbekistan Academy of Sciences, Tashkent, Uzbekistan.
[bbb] Also at St. Petersburg State Polytechnical University, St. Petersburg, Russia.
[ccc] Also at University of Florida, Gainesville, Florida, USA.
[ddd] Also at Imperial College, London, United Kingdom.
[eee] Also at P.N. Lebedev Physical Institute, Moscow, Russia.
[fff] Also at California Institute of Technology, Pasadena, California, USA.
[ggg] Also at Budker Institute of Nuclear Physics, Novosibirsk, Russia.
[hhh] Also at Faculty of Physics, University of Belgrade, Belgrade, Serbia.
[iii] Also at Trincomalee Campus, Eastern University, Sri Lanka.
[jjj] Also at INFN Sezione di Pavia, Università di Pavia, Pavia, Italy.
[kkk] Also at National and Kapodistrian University of Athens, Athens, Greece.
[lll] Also at Ecole Polytechnique Fédérale Lausanne, Lausanne, Switzerland.
[mmm] Also at Universität Zürich, Zurich, Switzerland.
[nnn] Also at Stefan Meyer Institute for Subatomic Physics, Vienna, Austria.
[ooo] Also at Laboratoire d'Annecy-le-Vieux de Physique des Particules, IN2P3-CNRS, Annecy-le-Vieux, France.
[ppp] Also at Şırnak University.
[qqq] Also at Near East University, Research Center of Experimental Health Science, Nicosia, Turkey.
[rrr] Also at Konya Technical University.
[sss] Also at Istanbul University - Cerrahpasa, Faculty of Engineering.
[ttt] Also at Piri Reis University, Istanbul, Turkey.
[uuu] Also at Adiyaman University, Adiyaman, Turkey.
[vvv] Also at Ozyegin University, Istanbul, Turkey.
[www] Also at Izmir Institute of Technology, Izmir, Turkey.
[xxx] Also at Necmettin Erbakan University, Konya, Turkey.
[yyy] Also at Bozok Universitetesi Rektörlügü, Yozgat, Turkey.
[zzz] Also at Marmara University, Istanbul, Turkey.
[aaaa] Also at Milli Savunma University.
[bbbb] Also at Kafkas University, Kars, Turkey.
[cccc] Also at Istanbul Bilgi University, Istanbul, Turkey.
[dddd] Also at Hacettepe University, Ankara, Turkey.
[eeee] Also at Rutherford Appleton Laboratory, Didcot, United Kingdom.
[ffff] Also at Vrije Universiteit Brussel, Brussel, Belgium.
[gggg] Also at School of Physics and Astronomy, University of Southampton, Southampton, United Kingdom.
[hhhh] Also at IPPP Durham University.

[iiii] Also at Monash University, Faculty of Science, Clayton, Australia.
[jjjj] Also at Università di Torino.
[kkkk] Also at Bethel University, St. Paul, Minneapolis, USA.
[llll] Also at Karamanoğlu Mehmetbey University, Karaman, Turkey.
[mmmm] Also at Ain Shams University, Cairo, Egypt.
[nnnn] Also at Bingol University, Bingol, Turkey.
[oooo] Also at Georgian Technical University, Tbilisi, Georgia.
[pppp] Also at Sinop University, Sinop, Turkey.
[qqqq] Also at Erciyes University.
[rrrr] Also at Texas A&M University at Qatar, Doha, Qatar.
[ssss] Also at Kyungpook National University, Daegu, Korea.