EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)

CERN-EP/2017-068
2018/03/13

CMS-HIG-16-027

Search for charged Higgs bosons produced via vector boson fusion and decaying into a pair of W and Z bosons using proton-proton collisions at $\sqrt{s} = 13\,\text{TeV}$

The CMS Collaboration*

arXiv:1705.02942v1 [hep-ex] 8 May 2017

Abstract

A search for charged Higgs bosons produced via vector boson fusion and decaying into W and Z bosons using proton-proton collisions at $\sqrt{s} = 13\,\text{TeV}$ is presented. The data sample corresponds to an integrated luminosity of $15.2\,\text{fb}^{-1}$ collected with the CMS detector in 2015 and 2016. The event selection requires three leptons (electrons or muons), two jets with large pseudorapidity separation and high dijet mass, and missing transverse momentum. The observation agrees with the standard model prediction. Limits on the vector boson fusion production cross section times branching fraction for new charged physical states are reported as a function of mass from 200 to 2000 GeV and interpreted in the context of Higgs triplet models.

Submitted to Physical Review Letters

© 2018 CERN for the benefit of the CMS Collaboration. CC-BY-3.0 license

*See Appendix A for the list of collaboration members

The discovery [1, 2] of a Higgs boson [3–8] at the CERN LHC marks an important milestone in the exploration of the electroweak (EW) sector of the standard model (SM) [9–11]. Many aspects of EW interactions at the energy scale of 1 TeV, however, remain to be explored. At the LHC, the study of vector boson scattering (VBS) may reveal hints to extensions of the SM. In particular, extended Higgs sectors with additional SU(2) doublets [12–15] or triplets [16–21] introduce couplings of vector bosons to heavy neutral or charged Higgs bosons.

Searches for charged Higgs bosons ($\mathrm{H}^{\pm}$) at the LHC currently focus on the production and the decay to fermions [22–30], well motivated by the minimal supersymmetric standard model [31]. In this model, the $\mathrm{H}^{\pm}\mathrm{tb}$ coupling is the strongest irrespective of the mass of the charged Higgs boson ($m(\mathrm{H}^{\pm})$) and $\tan\beta$, the ratio of the vacuum expectation values (vevs) of the two Higgs doublets. Couplings to vector bosons are however largely suppressed in these models.

Fermiophobic charged Higgs bosons appear in Higgs sectors extended by SU(2) triplets. Couplings to W and Z bosons are introduced at tree level. A prominent example is the Georgi–Machacek (GM) model [32], where real and complex Higgs triplets with high vevs are arranged to preserve custodial symmetry. In such models, the charged Higgs bosons are produced via vector boson fusion (VBF) and the couplings depend on $m(\mathrm{H}^{\pm})$ and the parameter $\sin\theta_{\mathrm{H}}$, or s_{H}, where s_{H}^2 denotes the fraction of the W boson mass squared generated by the vev of the triplets. The leading Feynman diagram for the production and decay is shown in Fig. 1.

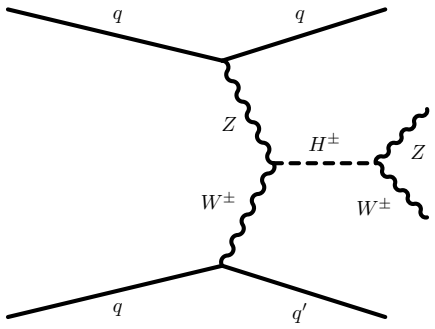


Figure 1: Feynman diagram showing the production of charged Higgs bosons via VBF.

In this Letter, we discuss the search for charged Higgs bosons that are produced via VBF and decay via couplings to W and Z bosons. The analysis is performed on a sample of proton-proton collisions collected at $\sqrt{s} = 13\,\mathrm{TeV}$ center-of-mass energy by the CMS experiment at the LHC. The data sample corresponds to integrated luminosities of 2.3 and 12.9 fb^{-1} recorded during the years 2015 and 2016, respectively. The search is performed using W and Z bosons decaying into electrons and muons. The event selection requires two jets with large pseudorapidity separation and high dijet mass to select a VBF topology. The data are compared to the predictions of the GM model for a charged Higgs boson mass range of $200 < m(\mathrm{H}^{\pm}) < 1000\,\mathrm{GeV}$. In addition, an exclusion limit on the VBF production cross section times branching fraction ($\mathcal{B}$) for $200 < m(\mathrm{H}^{\pm}) < 2000\,\mathrm{GeV}$ is derived. A similar search was performed by the ATLAS collaboration in proton-proton collisions at $\sqrt{s} = 8\,\mathrm{TeV}$ in the semi-leptonic ($\mathrm{WZ} \to \mathrm{qq}'\ell\ell$) final state [33].

The signal samples are produced with MADGRAPH5_aMC@NLO v2.2.2 [34]. The WZ production in association with two jets involving exclusively weak interactions at tree level is generated using MADGRAPH5_aMC@NLO and is referred to as EW WZ background. Two jet associated WZ production with both the strong and electroweak interaction vertices at tree level is simulated using POWHEG 2.0 [35–38] and is denoted as QCD WZ background. The Z+jets, $\mathrm{Z}\gamma$,

$t\bar{t}$, $t\bar{t}V$, VVV, where V refers to a W or Z boson, are produced using MADGRAPH5_aMC@NLO . The $gg \to ZZ$ process is generated with MCFM [39], while ZZ production via $q\bar{q}$ annihilation is simulated at next-to-leading order (NLO) with POWHEG. The PYTHIA 8 [40] package is used for parton showering, hadronization, and the underlying event simulation with parameters affecting the underlying event simulation set to the CUETP8M1 tune [41, 42]. The NNPDF 3.0 [43] set is used as the default set of parton distribution functions (PDFs). For all processes, the detector response is simulated using a detailed description of the CMS detector, based on the GEANT4 package [44], and event reconstruction is performed with the same algorithms as used for data. The simulated samples include additional interactions per bunch crossing (pileup) matching the observed multiplicity in the data of about 11 and 20 interactions per bunch crossing in 2015 and 2016, respectively.

Details of the CMS detector, its performance and the definition of the coordinate system can be found in Ref. [45]. The detector features a superconducting solenoid with a diameter of 6 m, providing a magnetic field of 3.8 T, and surrounding a silicon pixel and strip tracking detector, a lead tungstate electromagnetic calorimeter and a brass scintillator hadronic calorimeter. Gas ionization detectors embedded into the steel-flux return yokes, the muon system, are installed around the solenoid. The subdetectors are composed into a barrel and two endcap sections. The hadron forward calorimeter provides calorimetry to pseudorapidities from $|\eta| > 3$ to $|\eta| < 5$. A particle-flow technique is employed to identify and reconstruct the individual particles emerging from each collision [46, 47].

Electrons are reconstructed within $|\eta| < 2.5$. The reconstruction combines the information from clusters of energy deposits in the electromagnetic calorimeter and the trajectory in the tracker [48]. The selection criteria depend on transverse momentum p_T and $|\eta|$, and on a categorization based on observables sensitive to the amount of bremsstrahlung emitted. Muons are reconstructed within $|\eta| < 2.4$ [49]. The reconstruction combines the information from both the tracker and the muon spectrometer. Leptons are required to be isolated from other charged and neutral particles in the event. The lepton relative isolation is defined as the ratio of the p_T sum of charged hadrons and neutral particles within a cone of radius $\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} < 0.4$ (where ϕ is the azimuthal angle in radians) around the lepton and the lepton p_T. The relative isolation, corrected for pileup contributions, is required to be less than 6.5% (15%) for electrons (muons). Overall efficiencies of the reconstruction, identification, and isolation requirements for the prompt leptons are measured in data in several bins of p_T and $|\eta|$ using a "tag-and-probe" technique [50] applied to a sample of leptonically decaying Z boson events.

Jets are reconstructed using the anti-k_T clustering algorithm [51] with a distance parameter $R = 0.4$, as implemented in the FASTJET package [52, 53], and jet energy corrections are applied [54, 55]. To suppress the top quark background contribution in its decay to b quarks, the combined secondary vertex b tagging algorithm [56, 57] requirement is used corresponding to an efficiency of about 45% with a light flavor quark misidentification probability of 0.1%.

The missing transverse momentum vector $\vec{p}_T^{\,miss}$ is defined as the negative vectorial sum of the momenta of all reconstructed particles in an event projected onto the plane perpendicular to the beams, corrected for the pileup contribution [58]. Its magnitude is referred to as the p_T^{miss}.

Events are selected by the trigger system requiring the presence of one or two high p_T electrons or muons. The trigger efficiency is greater than 99% for events that pass all other selection criteria explained in the following. The selection of events aims to single out three-lepton events with the VBF topology. The event selection requires three lepton (electron or muon) candidates that meet the isolation and identification requirements. Two leptons are required to have $p_T > 20$ GeV and the third lepton is required to have $p_T > 10$ GeV. Events with an additional

fourth lepton with $p_T > 10\,\text{GeV}$ are rejected. Events are required to have at least two jets with $p_T > 30\,\text{GeV}$, and $|\eta| < 4.7$. The VBF topology is exploited by requiring that the two jets of highest p_T have large dijet mass, $m_{jj} > 500\,\text{GeV}$, and large pseudorapidity separation, $|\Delta\eta_{jj}| > 2.5$. To reconstruct a Z boson candidate a pair of same-flavor and opposite-charge leptons is required to have a dilepton invariant mass within 15 GeV of the nominal Z boson mass [59]. When there are two or more candidate pairs, the one with the mass closest to the nominal Z boson mass is chosen. The remaining lepton is associated with the W boson decay, and it is required to have $p_T > 20\,\text{GeV}$. The p_T^{miss} in the event is required to be larger than 30 GeV to select W boson decays. To reject the top-quark background, the event must not have jets passing the b-tagging selection.

After these requirements, the signal efficiency is about 10–15%, depending on $m(H^{\pm})$. For extraction of the signal, the shape of the distribution of the transverse mass variable (m_T) obtained from the WZ system is used

$$m_T(WZ) = \sqrt{(E_T(W) + E_T(Z))^2 - (\vec{p}_T(W) + \vec{p}_T(Z))^2},$$

where the $\vec{p}_T(W)$ is reconstructed from the vectorial sum of $\vec{p}_T^{\text{miss}}$ and the lepton $\vec{p}_T$, and $E_T(W)$ is calculated from the scalar sum of the lepton transverse energy and p_T^{miss}.

A combination of methods using control samples in the data and detailed simulation studies is used to estimate background contributions. The following background categories are considered: WZ, $ZZ \to 4\ell$, VVV, $Z\gamma$ and processes with nonprompt leptons.

The QCD and EW WZ background constitutes about 80% of the total expected SM background yield. The normalization of the QCD WZ background is obtained from a background-dominated sideband defined by the dijet variables outside of the search region where the expected signal yield is negligible: $100\,\text{GeV} < m_{jj} < 500\,\text{GeV}$ and $|\Delta\eta_{jj}| < 2.5$. In this phase-space region, expected background contributions from $ZZ \to 4\ell$, VVV productions and nonprompt leptons are subtracted from the number of events in data. The simulated sample of QCD WZ processes is then normalized to match the observed number of events in this control region. The estimated normalization of events is consistent with the SM prediction obtained using the POWHEG NLO cross section calculation. The EW WZ background is obtained at leading-order using the MADGRAPH5_aMC@NLO simulation and contributes about 30% to the overall WZ background processes.

The $ZZ \to 4\ell$, VVV and $Z\gamma$ contributions are estimated from simulated samples, with corrections to the lepton reconstruction, trigger and selection efficiencies, and momentum scale and resolution measurements estimated from data control samples. The overall expected contribution from these processes to the total background yield is about 10%, and the uncertainties in the estimates are dominated by the statistical component introduced by the number of simulated events passing the event selection requirements. The $ZZ \to 4\ell$ background is largely reduced by the p_T^{miss} requirement and the veto on events containing an additional lepton. The $q\bar{q} \to ZZ$ process is normalized to the next-to-next-to-leading order (NNLO) cross section prediction with a K-factor of 1.1 [60] and $gg \to ZZ$ at NLO with a K-factor of 1.7 [61].

The main contributions to nonprompt leptons are from Z+jets and top-quark ($t\bar{t}$ and tW) events, where at least one of the jets or a constituent is misidentified as an isolated lepton. The dominant background at the final-selection level is Z+jets. According to the simulation, fewer than 10% of the background events with at least one nonprompt lepton come from top quark processes. Data control samples are used to estimate this background. Lepton candidates selected with loose identification requirements are defined in a sample of events dominated by dijet

production. The efficiency for candidates to pass the full lepton selection criteria is measured and is parametrized as a function of p_T and η. The calculated efficiencies are used as weights to extrapolate the yield of the sample of loose leptons to the sample of fully selected leptons. The background estimation method is validated on a nonprompt lepton W+jets and $t\bar{t}$ enriched sample, selected by inverting the Z boson mass or b tagging criteria, where good agreement between the data and prediction is observed.

Residual discrepancies in the lepton reconstruction, identification and trigger efficiencies between data and simulation are corrected by applying data-to-simulation scale factors measured using Z+jets events in the Z boson peak region [50] recorded with unbiased triggers. These factors depend on the lepton p_T and η and are within 2% of unity for electrons and muons. The experimental uncertainties in the lepton momentum scale and resolution, p_T^{miss} modeling, and jet energy scale are applied in simulated events by smearing and scaling the relevant observables and propagating the effects to the kinematic variables used in the analysis, in particular m_T. Uncertainties in the lepton momentum scale and resolution are smaller than 1% per lepton depending on the p_T and η of the lepton, and the effect on the yields at the analysis selection level is less than 1%. The uncertainties in the jet energy scale and resolution result in a 5% uncertainty in the signal yields. The uncertainty in the resolution of the p_T^{miss} measurement is 10%. Randomly smearing the measured p_T^{miss} by one standard deviation of the resolution gives rise to a 5% variation in the estimation of signal yields after the full selection. Uncertainties of 2.3% and 2.5% are assigned to the integrated luminosity measurements in the years 2015 and 2016, respectively [62, 63]. The effect of higher-order corrections to the signal cross section in the GM model is taken from Ref. [64]. The theoretical uncertainty is dominated by missing higher-order EW corrections estimated to be 7%. Uncertainties due to PDF choice and renormalization and factorization scales are 2–3% and less than 1%, respectively.

The uncertainty in the estimation of the expected number of QCD WZ events is 12%, which is estimated from the measured yields in the two-jet control region. An uncorrelated uncertainty of 30% is assigned on the normalization of WZ events produced via EW processes, estimated from variations of the renormalization and factorization scale. The total uncertainty in the prediction of the nonprompt background varies bin-by-bin in the m_T distribution between 30% and 80%, dominated by the low number of nonprompt leptons passing the sideband selection. A summary of the relative systematic uncertainties in the estimated signal and background yields is shown in Table 1.

Table 1: Relative systematic uncertainties in the estimated signal and background yields, in units of percent.

Source	Signal	WZ	VVV	Zγ	ZZ	Nonprompt
Integrated luminosity 2015 (2016)	2.3 (2.5)	—	2.3 (2.5)	2.3 (2.5)	2.3 (2.5)	—
Lepton efficiency	4.0	—	4.0	4.0	4.0	—
Lepton momentum scale	1.0	1.0	1.0	1.0	1.0	—
Jet momentum scale	5.0	8.0	6.0	30.0	13.0	—
p_T^{miss} resolution	5.0	1.7	1.0	—	7.0	—
b tagging	2.0	—	2.0	2.0	2.0	—
QCD (EW) WZ bkg. normalization	—	12 (30)	—	—	—	—
Nonprompt bkg. normalization	—	—	—	—	—	30–80
GM uncertainties	8	—	—	—	—	—

After applying the full selection, 9 and 62 events are selected in the data collected in 2015 and 2016, respectively. The data yield together with the SM expectation for the different processes is given in Table 2. The distribution of the m_T with bin boundaries given by $m_T =$

$[0, 100, 200, 400, 600, 800, 1000, 1200, 1500, \infty)$ GeV (the last bin is an overflow bin) is shown in Fig. 2. No event with $m_{\mathrm{T}}(\mathrm{WZ}) > 800$ GeV is observed in the data and overall agreement between the data and SM background prediction is observed.

A combined fit of the predicted signal and background yields in bins of m_{T} to the data is performed to derive expected and observed exclusion limits on $\sigma_{\mathrm{VBF}}(\mathrm{H}^{\pm})\,\mathcal{B}(\mathrm{H}^{\pm} \to \mathrm{WZ})$ at 95% confidence level using the $\mathrm{CL_s}$ method [65–67]. The exclusion limits as a function of $m(\mathrm{H}^{\pm})$ assuming a small intrinsic width for $\mathrm{H}^{\pm}$ are shown in Fig. 3 (left). Values for $\sigma_{\mathrm{VBF}}(\mathrm{H}^{\pm})\,\mathcal{B}(\mathrm{H}^{\pm} \to WZ)$ ranging from 573 fb at $m(\mathrm{H}^{\pm}) = 200$ GeV to 36 fb at $m(\mathrm{H}^{\pm}) = 2000$ GeV are excluded by the data.

The model-independent exclusion limits are compared to the predicted cross sections at NNLO in the GM model [64] in the s_{H}-$m(\mathrm{H}^{\pm})$ plane. For the probed parameter space and m_{T} distribution used for signal extraction, the varying width as a function of s_{H} is assumed to have negligible impact on the result. The value of the branching fraction $\mathcal{B}(\mathrm{H}^{\pm} \to \mathrm{WZ})$ is assumed to be one. In Fig. 3 (right), the excluded s_{H} values as a function of $m(\mathrm{H}^{\pm})$ are shown. The blue shaded region shows the parameter space for which the $\mathrm{H}^{\pm}$ total width exceeds 10% of $m(\mathrm{H}^{\pm})$, where the model is not applicable [64]. The observed limit excludes s_{H} values greater than 0.45, 0.81 and 0.66 at $m(\mathrm{H}^{\pm}) = 200$, 400 and 1000 GeV, respectively.

Table 2: Yields of selected events in 2015 and 2016 data, together with the expected yields from various background processes. The statistical and systematic uncertainties are shown. The signal yields are shown for values of $s_{\mathrm{H}} = 0.7$.

Dataset	2015	2016
Data	9	62
WZ	7.5 ± 0.5	44.4 ± 2.5
ZZ	0.2 ± 0.1	1.6 ± 0.1
VVV	0.8 ± 0.1	5.5 ± 0.3
$\mathrm{Z}\gamma$	0.2 ± 0.1	1.0 ± 0.4
Nonprompt	1.3 ± 0.5	7.4 ± 2.0
Total bkg.	10.0 ± 0.8	59.9 ± 3.5
Signal ($m(\mathrm{H}^{\pm}) = 700$ GeV)	0.9 ± 0.1	4.7 ± 0.5

In summary, we present a search for charged Higgs bosons produced via vector boson fusion and decaying into W and Z bosons in proton-proton collisions at $\sqrt{s} = 13$ TeV based on a sample corresponding to an integrated luminosity of 15.2 fb^{-1}. Events are required to have three leptons (electrons or muons), two jets with large pseudorapidity separation and high dijet mass, and missing transverse momentum. The number of events observed in the signal region agrees with the standard model prediction. The first limits on $\sigma_{\mathrm{VBF}}(\mathrm{H}^{\pm})\,\mathcal{B}(\mathrm{H}^{\pm} \to \mathrm{WZ})$ at $\sqrt{s} = 13$ TeV are obtained. The results are interpreted in the Georgi–Machacek model for which the most stringent limits are derived.

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 for delivering so effectively the computing infrastructure essential to our analyses. Finally, we acknowledge the enduring support for the construction and operation of the LHC and the CMS detector provided by the following funding agencies: BMWFW and FWF (Austria); FNRS and FWO (Belgium); CNPq, CAPES, FAPERJ, and FAPESP (Brazil); MES (Bulgaria); CERN; CAS, MoST, and NSFC (China); COLCIENCIAS (Colombia); MSES and CSF (Croatia); RPF

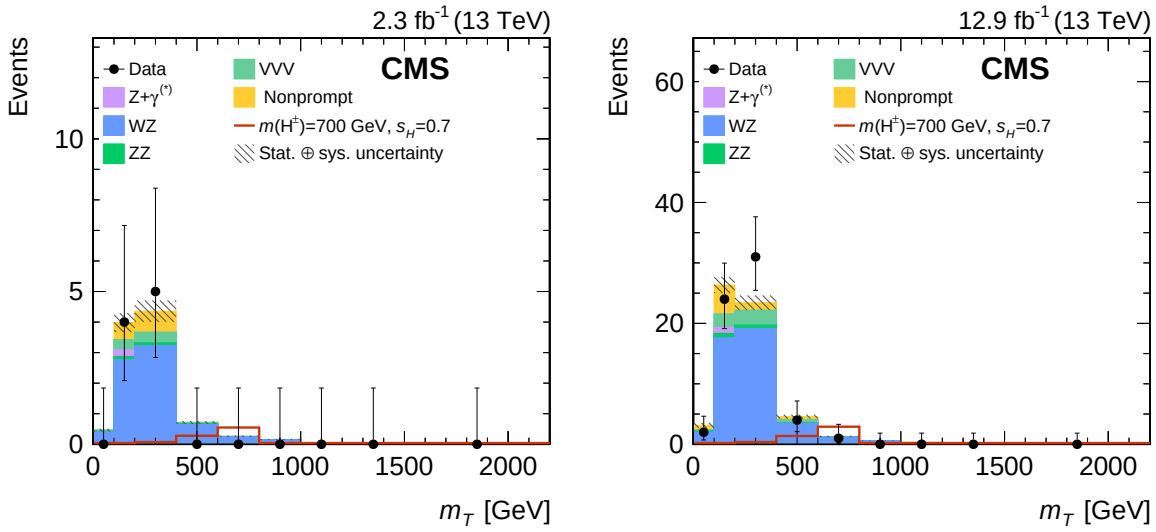


Figure 2: Transverse mass distributions after full selection, for data collected in 2015 (left) and 2016 (right). The background yield predictions correspond to the background-only hypothesis fit result. The signal distribution is shown for $m(\mathrm{H}^{\pm}) = 700\,\mathrm{GeV}$ and the cross-section prediction in the GM model at $s_{\mathrm{H}} = 0.7$.

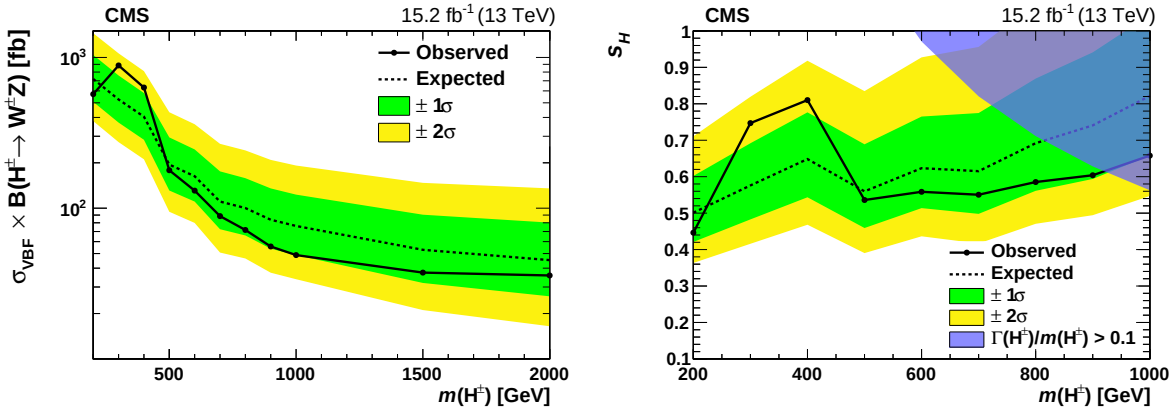


Figure 3: Expected and observed exclusion limits at 95% confidence level as a function of $m(\mathrm{H}^{\pm})$ for $\sigma_{\mathrm{VBF}}(\mathrm{H}^{\pm})\,\mathcal{B}(\mathrm{H}^{\pm} \to \mathrm{WZ})$ (left) and on the ratio of vacuum expectation values in the GM model (right) for $15.2\,\mathrm{fb}^{-1}$ of proton-proton collisions at 13 TeV collected in 2015 and 2016. The blue shaded area covers the theoretically not allowed parameter space [64].

(Cyprus); SENESCYT (Ecuador); MoER, ERC IUT and ERDF (Estonia); Academy of Finland, MEC, and HIP (Finland); CEA and CNRS/IN2P3 (France); BMBF, DFG, and HGF (Germany); GSRT (Greece); OTKA and NIH (Hungary); DAE and DST (India); IPM (Iran); SFI (Ireland); INFN (Italy); MSIP and NRF (Republic of Korea); LAS (Lithuania); MOE and UM (Malaysia); BUAP, CINVESTAV, CONACYT, LNS, SEP, and UASLP-FAI (Mexico); MBIE (New Zealand); PAEC (Pakistan); MSHE and NSC (Poland); FCT (Portugal); JINR (Dubna); MON, RosAtom, RAS and RFBR (Russia); MESTD (Serbia); SEIDI and CPAN (Spain); Swiss Funding Agencies (Switzerland); MST (Taipei); ThEPCenter, IPST, STAR and NSTDA (Thailand); TUBITAK and TAEK (Turkey); NASU and SFFR (Ukraine); STFC (United Kingdom); DOE and NSF (USA).

References

[1] ATLAS Collaboration, "Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC", *Phys. Lett. B* **716** (2012) 1, doi:10.1016/j.physletb.2012.08.020, arXiv:1207.7214.

[2] CMS Collaboration, "Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC", *Phys. Lett. B* **716** (2012) 30, doi:10.1016/j.physletb.2012.08.021, arXiv:1207.7235.

[3] F. Englert and R. Brout, "Broken Symmetry and the Mass of Gauge Vector Mesons", *Phys. Rev. Lett.* **13** (1964) 321, doi:10.1103/PhysRevLett.13.321.

[4] P. W. Higgs, "Broken Symmetries, Massless Particles and Gauge Fields", *Phys. Rev. Lett.* **12** (1964) 132, doi:10.1016/0031-9163(64)91136-9.

[5] P. W. Higgs, "Broken Symmetries and the Masses of Gauge Bosons", *Phys. Rev. Lett.* **13** (1964) 508, doi:10.1103/PhysRevLett.13.508.

[6] G. S. Guralnik, C. R. Hagen, and T. W. B. Kibble, "Global Conservation Laws and Massless Particles", *Phys. Rev. Lett.* **13** (1964) 585, doi:10.1103/PhysRevLett.13.585.

[7] P. W. Higgs, "Spontaneous Symmetry Breakdown without Massless Bosons", *Phys. Rev.* **145** (1966) 1156, doi:10.1103/PhysRev.145.1156.

[8] T. W. B. Kibble, "Symmetry Breaking in Non-Abelian Gauge Theories", *Phys. Rev.* **155** (1967) 1554, doi:10.1103/PhysRev.155.1554.

[9] S. L. Glashow, "Partial-symmetries of weak interactions", *Nucl. Phys.* **22** (1961) 579, doi:10.1016/0029-5582(61)90469-2.

[10] S. Weinberg, "A Model of Leptons", *Phys. Rev. Lett.* **19** (1967) 1264, doi:10.1103/PhysRevLett.19.1264.

[11] A. Salam, "Weak and electromagnetic interactions", in *Elementary particle physics: relativistic groups and analyticity*, N. Svartholm, ed., p. 367. Almquvist & Wiskell, 1968. Proceedings of the eighth Nobel symposium.

[12] T. D. Lee, "A Theory of Spontaneous T Violation", *Phys. Rev. D* **8** (1973) 1226, doi:10.1103/PhysRevD.8.1226.

[13] P. Fayet, "A gauge theory of weak and electromagnetic interactions with spontaneous parity breaking", *Nucl. Phys. B* **78** (1974) 14, doi:10.1016/0550-3213(74)90113-8.

[14] N. Craig and S. Thomas, "Exclusive signals of an extended Higgs sector", *JHEP* **11** (2012) 083, doi:10.1007/JHEP11(2012)083, arXiv:1207.4835.

[15] G. C. Branco et al., "Theory and phenomenology of two-Higgs-doublet models", *Phys. Rep.* **516** (2012) 1, doi:10.1016/j.physrep.2012.02.002, arXiv:1106.0034.

[16] W. Konetschny and W. Kummer, "Nonconservation of total lepton number with scalar bosons", *Phys. Lett. B* **70** (1977) 433, doi:10.1016/0370-2693(77)90407-5.

[17] M. Magg and C. Wetterich, "Neutrino mass problem and gauge hierarchy", *Phys. Lett. B* **94** (1980) 61, doi:10.1016/0370-2693(80)90825-4.

[18] T. P. Cheng and L.-F. Li, "Neutrino masses, mixings, and oscillations in SU(2)×U(1) models of electroweak interactions", *Phys. Rev. D* **22** (1980) 2860, doi:10.1103/PhysRevD.22.2860.

[19] J. Schechter and J. W. F. Valle, "Neutrino masses in SU(2) ⊗ U(1) theories", *Phys. Rev. D* **22** (1980) 2227, doi:10.1103/PhysRevD.22.2227.

[20] Ch. Englert, E. Re, and M. Spannowsky, "Triplet Higgs boson collider phenomenology after the LHC", *Phys. Rev. D* **87** (2013) 095014, doi:10.1103/PhysRevD.87.095014, arXiv:1302.6505.

[21] Ch. Englert, E. Re, and M. Spannowsky, "Pinning down Higgs triplets at the LHC", *Phys. Rev. D* **88** (2013) 035024, doi:10.1103/PhysRevD.88.035024, arXiv:1306.6228.

[22] ATLAS Collaboration, "Search for charged Higgs bosons decaying via $H^+ \to \tau\nu$ in top quark pair events using pp collision data at $\sqrt{s} = 7$ TeV with the ATLAS detector", *JHEP* **06** (2012) 039, doi:10.1007/JHEP06(2012)039, arXiv:1204.2760.

[23] ATLAS Collaboration, "Search for charged Higgs bosons through the violation of lepton universality in $t\bar{t}$ events using pp collision data at $\sqrt{s} = 7$ TeV with the ATLAS experiment", *JHEP* **03** (2013) 076, doi:10.1007/JHEP03(2013)076, arXiv:1212.3572.

[24] ATLAS Collaboration, "Search for charged Higgs bosons decaying via $H^\pm \to \tau^\pm\nu$ in fully hadronic final states using pp collision data at $\sqrt{s} = 8$ TeV with the ATLAS detector", *JHEP* **03** (2015) 088, doi:10.1007/JHEP03(2015)088, arXiv:1412.6663.

[25] CMS Collaboration, "Search for a light charged Higgs boson in top quark decays in pp collisions at $\sqrt{s} = 7$ TeV", *JHEP* **07** (2012) 143, doi:10.1007/JHEP07(2012)143, arXiv:1205.5736.

[26] ATLAS Collaboration, "Search for charged Higgs bosons in the $H^\pm \to tb$ decay channel in pp collisions at $\sqrt{s} = 8$ TeV using the ATLAS detector", *JHEP* **03** (2016) 127, doi:10.1007/JHEP03(2016)127, arXiv:1512.03704.

[27] CMS Collaboration, "Search for a charged Higgs boson in pp collisions at $\sqrt{s} = 8$ TeV", *JHEP* **11** (2015) 018, doi:10.1007/JHEP11(2015)018, arXiv:1508.07774.

[28] ATLAS Collaboration, "Search for a light charged Higgs boson in the decay channel $H^+ \to c\bar{s}$ in $t\bar{t}$ events using pp collisions at $\sqrt{s}$ = 7 TeV with the ATLAS detector", *Eur. Phys. J.* **73** (2013) 2465, doi:10.1140/epjc/s10052-013-2465-z, arXiv:1302.3694.

[29] CMS Collaboration, "Search for a light charged Higgs boson decaying to $c\bar{s}$ in pp collisions at $\sqrt{s} = 8$ TeV", *JHEP* **12** (2015) 178, doi:10.1007/JHEP12(2015)178, arXiv:1510.04252.

[30] ATLAS Collaboration, "Search for charged Higgs bosons produced in association with a top quark and decaying via $H^{\pm} \to \tau\nu$ using pp collision data recorded at $\sqrt{s} = 13$ TeV by the ATLAS detector", *Phys. Lett. B* **759** (2016) 555, doi:10.1016/j.physletb.2016.06.017, arXiv:1603.09203.

[31] S. Dimopoulos and H. Georgi, "Softly broken supersymmetry and SU(5)", *Nucl. Phys. B* **193** (1981) 150, doi:10.1016/0550-3213(81)90522-8.

[32] H. Georgi and M. Machacek, "Doubly charged Higgs bosons", *Nucl. Phys. B* **262** (1985) 463, doi:10.1016/0550-3213(85)90325-6.

[33] ATLAS Collaboration, "Search for a Charged Higgs Boson Produced in the Vector-Boson Fusion Mode with Decay $H^{\pm} \to W^{\pm}Z$ using pp Collisions at $\sqrt{s} = 8$ TeV with the ATLAS Experiment", *Phys. Rev. Lett.* **114** (2015) 231801, doi:10.1103/PhysRevLett.114.231801, arXiv:1503.04233.

[34] J. Alwall et al., "The automated computation of tree-level and next-to-leading order differential cross sections, and their matching to parton shower simulations", *JHEP* **07** (2014) 079, doi:10.1007/JHEP07(2014)079, arXiv:1405.0301.

[35] S. Alioli, P. Nason, C. Oleari, and E. Re, "NLO vector-boson production matched with shower in POWHEG", *JHEP* **07** (2008) 060, doi:10.1088/1126-6708/2008/07/060, arXiv:0805.4802.

[36] P. Nason, "A new method for combining NLO QCD with shower Monte Carlo algorithms", *JHEP* **11** (2004) 040, doi:10.1088/1126-6708/2004/11/040, arXiv:hep-ph/0409146.

[37] S. Frixione, P. Nason, and C. Oleari, "Matching NLO QCD computations with parton shower simulations: the POWHEG method", *JHEP* **11** (2007) 070, doi:10.1088/1126-6708/2007/11/070, arXiv:0709.2092.

[38] S. Alioli, P. Nason, C. Oleari, and E. Re, "A general framework for implementing NLO calculations in shower Monte Carlo programs: the POWHEG BOX", *JHEP* **06** (2010) 043, doi:10.1007/JHEP06(2010)043, arXiv:1002.2581.

[39] J. M. Campbell and R. K. Ellis, "MCFM for the Tevatron and the LHC", *Nucl. Phys. Proc. Suppl.* **205** (2010) 10, doi:10.1016/j.nuclphysbps.2010.08.011, arXiv:1007.3492.

[40] T. Sjöstrand et al., "An introduction to PYTHIA 8.2", *Comput. Phys. Commun.* **191** (2015) 159, doi:10.1016/j.cpc.2015.01.024, arXiv:1410.3012.

[41] P. Skands, S. Carrazza, and J. Rojo, "Tuning PYTHIA 8.1: the Monash 2013 tune", *Eur. Phys. J. C* **74** (2014) 3024, doi:10.1140/epjc/s10052-014-3024-y, arXiv:1404.5630.

[42] CMS Collaboration, "Event generator tunes obtained from underlying event and multiparton scattering measurements", *Eur. Phys. J. C* **76** (2016) 155, doi:10.1140/epjc/s10052-016-3988-x, arXiv:1512.00815.

[43] NNPDF Collaboration, "Parton distributions for the LHC Run II", *JHEP* **04** (2015) 040, doi:10.1007/JHEP04(2015)040, arXiv:1410.8849.

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

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

[46] CMS Collaboration, "Particle-Flow Event Reconstruction in CMS and Performance for Jets, Taus, and $E_{\mathrm{T}}^{\mathrm{miss}}$", CMS Physics Analysis Summary CMS-PAS-PFT-09-001, 2009.

[47] CMS Collaboration, "Commissioning of the particle-flow event reconstruction with the first LHC collisions recorded in the CMS detector", CMS Physics Analysis Summary CMS-PAS-PFT-10-001, 2010.

[48] CMS Collaboration, "Performance of electron reconstruction and selection with the CMS detector in proton-proton collisions at $\sqrt{s} = 8$ TeV", *JINST* **10** (2015) P06005, doi:10.1088/1748-0221/10/06/P06005, arXiv:1502.02701.

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

[50] CMS Collaboration, "Measurements of inclusive W and Z cross sections in pp collisions at $\sqrt{s} = 7$ TeV", *JHEP* **01** (2011) 080, doi:10.1007/JHEP01(2011)080, arXiv:1012.2466.

[51] M. Cacciari, G. P. Salam, and G. Soyez, "The anti-k_t jet clustering algorithm", *JHEP* **04** (2008) 063, doi:10.1088/1126-6708/2008/04/063, arXiv:0802.1189.

[52] M. Cacciari, G. P. Salam, and G. Soyez, "FastJet user manual", *Eur. Phys. J. C* **72** (2012) 1896, doi:10.1140/epjc/s10052-012-1896-2, arXiv:1111.6097.

[53] M. Cacciari, G. P. Salam, "Dispelling the N^3 myth for the k_{t} jet-finder", *Phys. Lett. B* **641** (2006) 57, doi:10.1016/j.physletb.2006.08.037, arXiv:hep-ph/0512210.

[54] CMS Collaboration, "Determination of jet energy calibration and transverse momentum resolution in CMS", *JINST* **6** (2011) P11002, doi:10.1088/1748-0221/6/11/P11002, arXiv:1107.4277.

[55] CMS Collaboration, "Jet energy scale and resolution in the CMS experiment in pp collisions at 8 TeV", *JINST* **12** (2017) 02014, doi:10.1088/1748-0221/12/02/P02014, arXiv:1607.03663.

[56] CMS Collaboration, "Identification of b-quark jets with the CMS experiment", *JINST* **8** (2013) P04013, doi:10.1088/1748-0221/8/04/P04013, arXiv:1211.4462.

[57] CMS Collaboration, "Identification of b quark jets at the CMS Experiment in the LHC Run 2", CMS Physics Analysis Summary CMS-PAS-BTV-15-001, 2016.

[58] M. Cacciari and G. P. Salam, "Pileup subtraction using jet areas", *Phys. Lett. B* **659** (2008) 119, doi:10.1016/j.physletb.2007.09.077, arXiv:0707.1378.

[59] Particle Data Group Collaboration, "Review of Particle Physics", *Chin. Phys. C* **40** (2016) 100001, doi:10.1088/1674-1137/40/10/100001.

[60] F. Cascioli et al., "ZZ production at hadron colliders in NNLO QCD", *Phys. Lett. B* **735** (2014) 311, doi:10.1016/j.physletb.2014.06.056, arXiv:1405.2219.

[61] F. Caola, K. Melnikov, R. Röntsch, and L. Tancredi, "QCD corrections to ZZ production in gluon fusion at the LHC", *Phys. Rev. D* **92** (2015) 094028, doi:10.1103/PhysRevD.92.094028, arXiv:1509.06734.

[62] CMS Collaboration, "CMS luminosity measurement for the 2015 data-taking period", CMS Physics Analysis Summary CMS-PAS-LUM-15-001, 2017.

[63] CMS Collaboration, "CMS luminosity measurement for the 2016 data-taking period", CMS Physics Analysis Summary CMS-PAS-LUM-17-001, 2017.

[64] M. Zaro and H. Logan, "Recommendations for the interpretation of LHC searches for H_5^0, $H_5^\pm$, and $H_5^{\pm\pm}$ in vector boson fusion with decays to vector boson pairs", CERN Report LHCHXSWG-2015-001, 2015.

[65] T. Junk, "Confidence level computation for combining searches with small statistics", *Nucl. Instrum. Meth. A* **434** (1999) 435, doi:10.1016/S0168-9002(99)00498-2, arXiv:hep-ex/9902006.

[66] A. L. Read, "Presentation of search results: the CL_s technique", *J. Phys. G* **28** (2002) 2693, doi:10.1088/0954-3899/28/10/313.

[67] G. Cowan, K. Cranmer, E. Gross, and O. Vitells, "Asymptotic formulae for likelihood-based tests of new physics", *Eur. Phys. J. C* **71** (2011) 1554, doi:10.1140/epjc/s10052-011-1554-0, arXiv:1007.1727. [Erratum: *Eur. Phys. J. C* **73** (2013) 2501].

A The CMS Collaboration

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

Institut für Hochenergiephysik, Wien, Austria
W. Adam, E. Asilar, T. Bergauer, J. Brandstetter, E. Brondolin, M. Dragicevic, J. Erö, M. Flechl, M. Friedl, R. Frühwirth[1], V.M. Ghete, C. Hartl, N. Hörmann, J. Hrubec, M. Jeitler[1], A. König, I. Krätschmer, D. Liko, T. Matsushita, I. Mikulec, D. Rabady, N. Rad, B. Rahbaran, H. Rohringer, J. Schieck[1], J. Strauss, W. Waltenberger, C.-E. Wulz[1]

Institute for Nuclear Problems, Minsk, Belarus
O. Dvornikov, V. Makarenko, V. Mossolov, J. Suarez Gonzalez, V. Zykunov

National Centre for Particle and High Energy Physics, Minsk, Belarus
N. Shumeiko

Universiteit Antwerpen, Antwerpen, Belgium
S. Alderweireldt, E.A. De Wolf, X. Janssen, J. Lauwers, M. Van De Klundert, H. Van Haevermaet, P. Van Mechelen, N. Van Remortel, A. Van Spilbeeck

Vrije Universiteit Brussel, Brussel, Belgium
S. Abu Zeid, F. Blekman, J. D'Hondt, N. Daci, I. De Bruyn, K. Deroover, S. Lowette, S. Moortgat, L. Moreels, A. Olbrechts, Q. Python, K. Skovpen, S. Tavernier, W. Van Doninck, P. Van Mulders, I. Van Parijs

Université Libre de Bruxelles, Bruxelles, Belgium
H. Brun, B. Clerbaux, G. De Lentdecker, H. Delannoy, G. Fasanella, L. Favart, R. Goldouzian, A. Grebenyuk, G. Karapostoli, T. Lenzi, A. Léonard, J. Luetic, T. Maerschalk, A. Marinov, A. Randle-conde, T. Seva, C. Vander Velde, P. Vanlaer, D. Vannerom, R. Yonamine, F. Zenoni, F. Zhang[2]

Ghent University, Ghent, Belgium
T. Cornelis, D. Dobur, A. Fagot, M. Gul, I. Khvastunov, D. Poyraz, S. Salva, R. Schöfbeck, M. Tytgat, W. Van Driessche, W. Verbeke, N. Zaganidis

Université Catholique de Louvain, Louvain-la-Neuve, Belgium
H. Bakhshiansohi, O. Bondu, S. Brochet, G. Bruno, A. Caudron, S. De Visscher, C. Delaere, M. Delcourt, B. Francois, A. Giammanco, A. Jafari, M. Komm, G. Krintiras, V. Lemaitre, A. Magitteri, A. Mertens, M. Musich, K. Piotrzkowski, L. Quertenmont, M. Vidal Marono, S. Wertz

Université de Mons, Mons, Belgium
N. Beliy

Centro Brasileiro de Pesquisas Fisicas, Rio de Janeiro, Brazil
W.L. Aldá Júnior, F.L. Alves, G.A. Alves, L. Brito, C. Hensel, A. Moraes, M.E. Pol, P. Rebello Teles

Universidade do Estado do Rio de Janeiro, Rio de Janeiro, Brazil
E. Belchior Batista Das Chagas, W. Carvalho, J. Chinellato[3], A. Custódio, E.M. Da Costa, G.G. Da Silveira[4], D. De Jesus Damiao, C. De Oliveira Martins, S. Fonseca De Souza, L.M. Huertas Guativa, H. Malbouisson, D. Matos Figueiredo, C. Mora Herrera, L. Mundim, H. Nogima, W.L. Prado Da Silva, A. Santoro, A. Sznajder, E.J. Tonelli Manganote[3], F. Torres Da Silva De Araujo, A. Vilela Pereira

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

Institute for Nuclear Research and Nuclear Energy, Sofia, Bulgaria
A. Aleksandrov, R. Hadjiiska, P. Iaydjiev, M. Rodozov, S. Stoykova, G. Sultanov, M. Vutova

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

Beihang University, Beijing, China
W. Fang[5], X. Gao[5]

Institute of High Energy Physics, Beijing, China
M. Ahmad, J.G. Bian, G.M. Chen, H.S. Chen, M. Chen, Y. Chen, T. Cheng, C.H. Jiang, D. Leggat, Z. Liu, F. Romeo, M. Ruan, S.M. Shaheen, A. Spiezia, J. Tao, C. Wang, Z. Wang, E. Yazgan, H. Zhang, J. Zhao

State Key Laboratory of Nuclear Physics and Technology, Peking University, Beijing, China
Y. Ban, G. Chen, Q. Li, S. Liu, Y. Mao, S.J. Qian, D. Wang, Z. Xu

Universidad de Los Andes, Bogota, Colombia
C. Avila, A. Cabrera, L.F. Chaparro Sierra, C. Florez, J.P. Gomez, C.F. González Hernández, J.D. Ruiz Alvarez[6], J.C. Sanabria

University of Split, Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, Split, Croatia
N. Godinovic, D. Lelas, I. Puljak, P.M. Ribeiro Cipriano, T. Sculac

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

Institute Rudjer Boskovic, Zagreb, Croatia
V. Brigljevic, D. Ferencek, K. Kadija, B. Mesic, T. Susa

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

Charles University, Prague, Czech Republic
M. Finger[7], M. Finger Jr.[7]

Universidad San Francisco de Quito, Quito, Ecuador
E. Carrera Jarrin

Academy of Scientific Research and Technology of the Arab Republic of Egypt, Egyptian Network of High Energy Physics, Cairo, Egypt
A.A. Abdelalim[8,9], Y. Mohammed[10], E. Salama[11,12]

National Institute of Chemical Physics and Biophysics, Tallinn, Estonia
M. Kadastik, L. Perrini, M. Raidal, A. Tiko, C. Veelken

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

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

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

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

Laboratoire Leprince-Ringuet, Ecole polytechnique, CNRS/IN2P3, Université Paris-Saclay, Palaiseau, France
A. Abdulsalam, I. Antropov, S. Baffioni, F. Beaudette, P. Busson, L. Cadamuro, E. Chapon, C. Charlot, O. Davignon, R. Granier de Cassagnac, M. Jo, S. Lisniak, A. Lobanov, P. Miné, M. Nguyen, C. Ochando, G. Ortona, P. Paganini, P. Pigard, S. Regnard, R. Salerno, Y. Sirois, A.G. Stahl Leiton, T. Strebler, Y. Yilmaz, A. Zabi, A. Zghiche

Université de Strasbourg, CNRS, IPHC UMR 7178, F-67000 Strasbourg, France
J.-L. Agram[13], J. Andrea, D. Bloch, J.-M. Brom, M. Buttignol, E.C. Chabert, N. Chanon, C. Collard, E. Conte[13], X. Coubez, J.-C. Fontaine[13], D. Gelé, U. Goerlach, A.-C. Le Bihan, P. Van Hove

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

Université de Lyon, Université Claude Bernard Lyon 1, CNRS-IN2P3, Institut de Physique Nucléaire de Lyon, Villeurbanne, France
S. Beauceron, C. Bernet, G. Boudoul, C.A. Carrillo Montoya, R. Chierici, D. Contardo, B. Courbon, P. Depasse, H. El Mamouni, J. Fay, L. Finco, S. Gascon, M. Gouzevitch, G. Grenier, B. Ille, F. Lagarde, I.B. Laktineh, M. Lethuillier, L. Mirabito, A.L. Pequegnot, S. Perries, A. Popov[14], V. Sordini, M. Vander Donckt, P. Verdier, S. Viret

Georgian Technical University, Tbilisi, Georgia
A. Khvedelidze[7]

Tbilisi State University, Tbilisi, Georgia
Z. Tsamalaidze[7]

RWTH Aachen University, I. Physikalisches Institut, Aachen, Germany
C. Autermann, S. Beranek, L. Feld, M.K. Kiesel, K. Klein, M. Lipinski, M. Preuten, C. Schomakers, J. Schulz, T. Verlage

RWTH Aachen University, III. Physikalisches Institut A, Aachen, Germany
A. Albert, M. Brodski, E. Dietz-Laursonn, D. Duchardt, M. Endres, M. Erdmann, S. Erdweg, T. Esch, R. Fischer, A. Güth, M. Hamer, T. Hebbeker, C. Heidemann, K. Hoepfner, S. Knutzen, M. Merschmeyer, A. Meyer, P. Millet, S. Mukherjee, M. Olschewski, K. Padeken, T. Pook, M. Radziej, H. Reithler, M. Rieger, F. Scheuch, L. Sonnenschein, D. Teyssier, S. Thüer

RWTH Aachen University, III. Physikalisches Institut B, Aachen, Germany
V. Cherepanov, G. Flügge, B. Kargoll, T. Kress, A. Künsken, J. Lingemann, T. Müller, A. Nehrkorn, A. Nowack, C. Pistone, O. Pooth, A. Stahl[15]

Deutsches Elektronen-Synchrotron, Hamburg, Germany
M. Aldaya Martin, T. Arndt, C. Asawatangtrakuldee, K. Beernaert, O. Behnke, U. Behrens, A.A. Bin Anuar, K. Borras[16], A. Campbell, P. Connor, C. Contreras-Campana, F. Costanza, C. Diez Pardos, G. Dolinska, G. Eckerlin, D. Eckstein, T. Eichhorn, E. Eren, E. Gallo[17], J. Garay Garcia, A. Geiser, A. Gizhko, J.M. Grados Luyando, A. Grohsjean, P. Gunnellini, A. Harb, J. Hauk, M. Hempel[18], H. Jung, A. Kalogeropoulos, O. Karacheban[18], M. Kasemann, J. Keaveney, C. Kleinwort, I. Korol, D. Krücker, W. Lange, A. Lelek, T. Lenz, J. Leonard, K. Lipka, W. Lohmann[18], R. Mankel, I.-A. Melzer-Pellmann, A.B. Meyer, G. Mittag, J. Mnich, A. Mussgiller, E. Ntomari, D. Pitzl, R. Placakyte, A. Raspereza, B. Roland, M.Ö. Sahin, P. Saxena, T. Schoerner-Sadenius, S. Spannagel, N. Stefaniuk, G.P. Van Onsem, R. Walsh, C. Wissing

University of Hamburg, Hamburg, Germany
V. Blobel, M. Centis Vignali, A.R. Draeger, T. Dreyer, E. Garutti, D. Gonzalez, J. Haller, M. Hoffmann, A. Junkes, R. Klanner, R. Kogler, N. Kovalchuk, S. Kurz, T. Lapsien, I. Marchesini, D. Marconi, M. Meyer, M. Niedziela, D. Nowatschin, F. Pantaleo[15], T. Peiffer, A. Perieanu, C. Scharf, P. Schleper, A. Schmidt, S. Schumann, J. Schwandt, J. Sonneveld, H. Stadie, G. Steinbrück, F.M. Stober, M. Stöver, H. Tholen, D. Troendle, E. Usai, L. Vanelderen, A. Vanhoefer, B. Vormwald

Institut für Experimentelle Kernphysik, Karlsruhe, Germany
M. Akbiyik, C. Barth, S. Baur, C. Baus, J. Berger, E. Butz, R. Caspart, T. Chwalek, F. Colombo, W. De Boer, A. Dierlamm, S. Fink, B. Freund, R. Friese, M. Giffels, A. Gilbert, P. Goldenzweig, D. Haitz, F. Hartmann[15], S.M. Heindl, U. Husemann, F. Kassel[15], I. Katkov[14], S. Kudella, H. Mildner, M.U. Mozer, Th. Müller, M. Plagge, G. Quast, K. Rabbertz, S. Röcker, F. Roscher, M. Schröder, I. Shvetsov, G. Sieber, H.J. Simonis, R. Ulrich, S. Wayand, M. Weber, T. Weiler, S. Williamson, C. Wöhrmann, R. Wolf

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

National and Kapodistrian University of Athens, Athens, Greece
S. Kesisoglou, A. Panagiotou, N. Saoulidou, E. Tziaferi

National Technical University of Athens, Athens, Greece
K. Kousouris

University of Ioánnina, Ioánnina, Greece
I. Evangelou, G. Flouris, C. Foudas, P. Kokkas, N. Loukas, N. Manthos, I. Papadopoulos, E. Paradas, F.A. Triantis

MTA-ELTE Lendület CMS Particle and Nuclear Physics Group, Eötvös Loránd University, Budapest, Hungary
N. Filipovic, G. Pasztor

Wigner Research Centre for Physics, Budapest, Hungary
G. Bencze, C. Hajdu, D. Horvath[19], F. Sikler, V. Veszpremi, G. Vesztergombi[20], A.J. Zsigmond

Institute of Nuclear Research ATOMKI, Debrecen, Hungary
N. Beni, S. Czellar, J. Karancsi[21], A. Makovec, J. Molnar, Z. Szillasi

Institute of Physics, University of Debrecen, Debrecen, Hungary
M. Bartók[20], P. Raics, Z.L. Trocsanyi, B. Ujvari

Indian Institute of Science (IISc), Bangalore, India
S. Choudhury, J.R. Komaragiri

National Institute of Science Education and Research, Bhubaneswar, India
S. Bahinipati[22], S. Bhowmik[23], P. Mal, K. Mandal, A. Nayak[24], D.K. Sahoo[22], N. Sahoo, S.K. Swain

Panjab University, Chandigarh, India
S. Bansal, S.B. Beri, V. Bhatnagar, R. Chawla, U.Bhawandeep, A.K. Kalsi, A. Kaur, M. Kaur, R. Kumar, P. Kumari, A. Mehta, M. Mittal, J.B. Singh, G. Walia

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

Saha Institute of Nuclear Physics, Kolkata, India
R. Bhattacharya, S. Bhattacharya, K. Chatterjee, S. Dey, S. Dutt, S. Dutta, S. Ghosh, N. Majumdar, A. Modak, K. Mondal, S. Mukhopadhyay, S. Nandan, A. Purohit, A. Roy, D. Roy, S. Roy Chowdhury, S. Sarkar, M. Sharan, S. Thakur

Indian Institute of Technology Madras, Madras, India
P.K. Behera

Bhabha Atomic Research Centre, Mumbai, India
R. Chudasama, D. Dutta, V. Jha, V. Kumar, A.K. Mohanty[15], P.K. Netrakanti, L.M. Pant, P. Shukla, A. Topkar

Tata Institute of Fundamental Research-A, Mumbai, India
T. Aziz, S. Dugad, G. Kole, B. Mahakud, S. Mitra, G.B. Mohanty, B. Parida, N. Sur, B. Sutar

Tata Institute of Fundamental Research-B, Mumbai, India
S. Banerjee, R.K. Dewanjee, S. Ganguly, M. Guchait, Sa. Jain, S. Kumar, M. Maity[23], G. Majumder, K. Mazumdar, T. Sarkar[23], N. Wickramage[25]

Indian Institute of Science Education and Research (IISER), Pune, India
S. Chauhan, S. Dube, V. Hegde, A. Kapoor, K. Kothekar, S. Pandey, A. Rane, S. Sharma

Institute for Research in Fundamental Sciences (IPM), Tehran, Iran
S. Chenarani[26], E. Eskandari Tadavani, S.M. Etesami[26], M. Khakzad, M. Mohammadi Najafabadi, M. Naseri, S. Paktinat Mehdiabadi[27], F. Rezaei Hosseinabadi, B. Safarzadeh[28], M. Zeinali

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

INFN Sezione di Bari [a], Università di Bari [b], Politecnico di Bari [c], Bari, Italy
M. Abbrescia[a,b], C. Calabria[a,b], C. Caputo[a,b], A. Colaleo[a], D. Creanza[a,c], L. Cristella[a,b], N. De Filippis[a,c], M. De Palma[a,b], L. Fiore[a], G. Iaselli[a,c], G. Maggi[a,c], M. Maggi[a], G. Miniello[a,b], S. My[a,b], S. Nuzzo[a,b], A. Pompili[a,b], G. Pugliese[a,c], R. Radogna[a,b], A. Ranieri[a], G. Selvaggi[a,b], A. Sharma[a], L. Silvestris[a,15], R. Venditti[a,b], P. Verwilligen[a]

INFN Sezione di Bologna [a], Università di Bologna [b], Bologna, Italy
G. Abbiendi[a], C. Battilana, D. Bonacorsi[a,b], S. Braibant-Giacomelli[a,b], L. Brigliadori[a,b],

R. Campanini[a,b], P. Capiluppi[a,b], A. Castro[a,b], F.R. Cavallo[a], S.S. Chhibra[a,b], G. Codispoti[a,b], M. Cuffiani[a,b], G.M. Dallavalle[a], F. Fabbri[a], A. Fanfani[a,b], D. Fasanella[a,b], P. Giacomelli[a], C. Grandi[a], L. Guiducci[a,b], S. Marcellini[a], G. Masetti[a], A. Montanari[a], F.L. Navarria[a,b], A. Perrotta[a], A.M. Rossi[a,b], T. Rovelli[a,b], G.P. Siroli[a,b], N. Tosi[a,b,15]

INFN Sezione di Catania [a], Università di Catania [b], Catania, Italy
S. Albergo[a,b], S. Costa[a,b], A. Di Mattia[a], F. Giordano[a,b], R. Potenza[a,b], A. Tricomi[a,b], C. Tuve[a,b]

INFN Sezione di Firenze [a], Università di Firenze [b], Firenze, Italy
G. Barbagli[a], V. Ciulli[a,b], C. Civinini[a], R. D'Alessandro[a,b], E. Focardi[a,b], P. Lenzi[a,b], M. Meschini[a], S. Paoletti[a], L. Russo[a,29], G. Sguazzoni[a], D. Strom[a], L. Viliani[a,b,15]

INFN Laboratori Nazionali di Frascati, Frascati, Italy
L. Benussi, S. Bianco, F. Fabbri, D. Piccolo, F. Primavera[15]

INFN Sezione di Genova [a], Università di Genova [b], Genova, Italy
V. Calvelli[a,b], F. Ferro[a], M.R. Monge[a,b], E. Robutti[a], S. Tosi[a,b]

INFN Sezione di Milano-Bicocca [a], Università di Milano-Bicocca [b], Milano, Italy
L. Brianza[a,b,15], F. Brivio[a,b], V. Ciriolo, M.E. Dinardo[a,b], S. Fiorendi[a,b,15], S. Gennai[a], A. Ghezzi[a,b], P. Govoni[a,b], M. Malberti[a,b], S. Malvezzi[a], R.A. Manzoni[a,b], D. Menasce[a], L. Moroni[a], M. Paganoni[a,b], D. Pedrini[a], S. Pigazzini[a,b], S. Ragazzi[a,b], T. Tabarelli de Fatis[a,b]

INFN Sezione di Napoli [a], Università di Napoli 'Federico II' [b], Napoli, Italy, Università della Basilicata [c], Potenza, Italy, Università G. Marconi [d], Roma, Italy
S. Buontempo[a], N. Cavallo[a,c], G. De Nardo[a,b], S. Di Guida[a,d,15], F. Fabozzi[a,c], F. Fienga[a,b], A.O.M. Iorio[a,b], L. Lista[a], S. Meola[a,d,15], P. Paolucci[a,15], C. Sciacca[a,b], F. Thyssen[a]

INFN Sezione di Padova [a], Università di Padova [b], Padova, Italy, Università di Trento [c], Trento, Italy
P. Azzi[a,15], N. Bacchetta[a], L. Benato[a,b], D. Bisello[a,b], A. Boletti[a,b], R. Carlin[a,b], A. Carvalho Antunes De Oliveira[a,b], P. Checchia[a], M. Dall'Osso[a,b], P. De Castro Manzano[a], T. Dorigo[a], F. Gasparini[a,b], U. Gasparini[a,b], A. Gozzelino[a], S. Lacaprara[a], M. Margoni[a,b], A.T. Meneguzzo[a,b], J. Pazzini[a,b], N. Pozzobon[a,b], P. Ronchese[a,b], R. Rossin[a,b], F. Simonetto[a,b], E. Torassa[a], M. Zanetti[a,b], P. Zotto[a,b], G. Zumerle[a,b]

INFN Sezione di Pavia [a], Università di Pavia [b], Pavia, Italy
A. Braghieri[a], F. Fallavollita[a,b], A. Magnani[a,b], P. Montagna[a,b], S.P. Ratti[a,b], V. Re[a], M. Ressegotti, C. Riccardi[a,b], P. Salvini[a], I. Vai[a,b], P. Vitulo[a,b]

INFN Sezione di Perugia [a], Università di Perugia [b], Perugia, Italy
L. Alunni Solestizi[a,b], G.M. Bilei[a], D. Ciangottini[a,b], L. Fanò[a,b], P. Lariccia[a,b], R. Leonardi[a,b], G. Mantovani[a,b], V. Mariani[a,b], M. Menichelli[a], A. Saha[a], A. Santocchia[a,b]

INFN Sezione di Pisa [a], Università di Pisa [b], Scuola Normale Superiore di Pisa [c], Pisa, Italy
K. Androsov[a], P. Azzurri[a,15], G. Bagliesi[a], J. Bernardini[a], T. Boccali[a], R. Castaldi[a], M.A. Ciocci[a,b], R. Dell'Orso[a], G. Fedi[a], A. Giassi[a], M.T. Grippo[a,29], F. Ligabue[a,c], T. Lomtadze[a], L. Martini[a,b], A. Messineo[a,b], F. Palla[a], A. Rizzi[a,b], A. Savoy-Navarro[a,30], P. Spagnolo[a], R. Tenchini[a], G. Tonelli[a,b], A. Venturi[a], P.G. Verdini[a]

INFN Sezione di Roma [a], Sapienza Università di Roma [b], Rome, Italy
L. Barone[a,b], F. Cavallari[a], M. Cipriani[a,b], D. Del Re[a,b,15], M. Diemoz[a], S. Gelli[a,b], E. Longo[a,b], F. Margaroli[a,b], B. Marzocchi[a,b], P. Meridiani[a], G. Organtini[a,b], R. Paramatti[a,b], F. Preiato[a,b], S. Rahatlou[a,b], C. Rovelli[a], F. Santanastasio[a,b]

INFN Sezione di Torino [a], Università di Torino [b], Torino, Italy, Università del Piemonte Orientale [c], Novara, Italy
N. Amapane[a,b], R. Arcidiacono[a,c,15], S. Argiro[a,b], M. Arneodo[a,c], N. Bartosik[a], R. Bellan[a,b], C. Biino[a], N. Cartiglia[a], F. Cenna[a,b], M. Costa[a,b], R. Covarelli[a,b], A. Degano[a,b], N. Demaria[a], B. Kiani[a,b], C. Mariotti[a], S. Maselli[a], E. Migliore[a,b], V. Monaco[a,b], E. Monteil[a,b], M. Monteno[a], M.M. Obertino[a,b], L. Pacher[a,b], N. Pastrone[a], M. Pelliccioni[a], G.L. Pinna Angioni[a,b], F. Ravera[a,b], A. Romero[a,b], M. Ruspa[a,c], R. Sacchi[a,b], K. Shchelina[a,b], V. Sola[a], A. Solano[a,b], A. Staiano[a], P. Traczyk[a,b]

INFN Sezione di Trieste [a], Università di Trieste [b], Trieste, Italy
S. Belforte[a], M. Casarsa[a], F. Cossutti[a], G. Della Ricca[a,b], A. Zanetti[a]

Kyungpook National University, Daegu, Korea
D.H. Kim, G.N. Kim, M.S. Kim, J. Lee, S. Lee, S.W. Lee, Y.D. Oh, S. Sekmen, D.C. Son, Y.C. Yang

Chonbuk National University, Jeonju, Korea
A. Lee

Chonnam National University, Institute for Universe and Elementary Particles, Kwangju, Korea
H. Kim

Hanyang University, Seoul, Korea
J.A. Brochero Cifuentes, J. Goh, T.J. Kim

Korea University, Seoul, Korea
S. Cho, S. Choi, Y. Go, D. Gyun, S. Ha, B. Hong, Y. Jo, Y. Kim, K. Lee, K.S. Lee, S. Lee, J. Lim, S.K. Park, Y. Roh

Seoul National University, Seoul, Korea
J. Almond, J. Kim, H. Lee, S.B. Oh, B.C. Radburn-Smith, S.h. Seo, U.K. Yang, H.D. Yoo, G.B. Yu

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

Sungkyunkwan University, Suwon, Korea
Y. Choi, C. Hwang, J. Lee, I. Yu

Vilnius University, Vilnius, Lithuania
V. Dudenas, A. Juodagalvis, J. Vaitkus

National Centre for Particle Physics, Universiti Malaya, Kuala Lumpur, Malaysia
I. Ahmed, Z.A. Ibrahim, M.A.B. Md Ali[31], F. Mohamad Idris[32], W.A.T. Wan Abdullah, M.N. Yusli, Z. Zolkapli

Centro de Investigacion y de Estudios Avanzados del IPN, Mexico City, Mexico
H. Castilla-Valdez, E. De La Cruz-Burelo, I. Heredia-De La Cruz[33], R. Lopez-Fernandez, R. Magaña Villalba, J. Mejia Guisao, A. Sanchez-Hernandez

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

Benemerita Universidad Autonoma de Puebla, Puebla, Mexico
S. Carpinteyro, I. Pedraza, H.A. Salazar Ibarguen, C. Uribe Estrada

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

University of Auckland, Auckland, New Zealand
D. Krofcheck

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

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

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

Institute of Experimental Physics, Faculty of Physics, University of Warsaw, Warsaw, Poland
K. Bunkowski, A. Byszuk[34], K. Doroba, A. Kalinowski, M. Konecki, J. Krolikowski, M. Misiura, M. Olszewski, A. Pyskir, M. Walczak

Laboratório de Instrumentação e Física Experimental de Partículas, Lisboa, Portugal
P. Bargassa, C. Beirão Da Cruz E Silva, B. Calpas, A. Di Francesco, P. Faccioli, M. Gallinaro, J. Hollar, N. Leonardo, L. Lloret Iglesias, M.V. Nemallapudi, J. Seixas, O. Toldaiev, D. Vadruccio, J. Varela

Joint Institute for Nuclear Research, Dubna, Russia
S. Afanasiev, P. Bunin, M. Gavrilenko, I. Golutvin, I. Gorbunov, A. Kamenev, V. Karjavin, A. Lanev, A. Malakhov, V. Matveev[35,36], V. Palichik, V. Perelygin, S. Shmatov, S. Shulha, N. Skatchkov, V. Smirnov, N. Voytishin, A. Zarubin

Petersburg Nuclear Physics Institute, Gatchina (St. Petersburg), Russia
L. Chtchipounov, V. Golovtsov, Y. Ivanov, V. Kim[37], E. Kuznetsova[38], V. Murzin, V. Oreshkin, V. Sulimov, A. Vorobyev

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

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

Moscow Institute of Physics and Technology, Moscow, Russia
T. Aushev, A. Bylinkin[36]

National Research Nuclear University 'Moscow Engineering Physics Institute' (MEPhI), Moscow, Russia
R. Chistov[39], M. Danilov[39], S. Polikarpov

P.N. Lebedev Physical Institute, Moscow, Russia
V. Andreev, M. Azarkin[36], I. Dremin[36], M. Kirakosyan, A. Leonidov[36], A. Terkulov

Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia
A. Baskakov, A. Belyaev, E. Boos, V. Bunichev, M. Dubinin[40], L. Dudko, A. Gribushin, V. Klyukhin, O. Kodolova, I. Lokhtin, I. Miagkov, S. Obraztsov, M. Perfilov, S. Petrushanko, V. Savrin

Novosibirsk State University (NSU), Novosibirsk, Russia
V. Blinov[41], Y.Skovpen[41], D. Shtol[41]

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

University of Belgrade, Faculty of Physics and Vinca Institute of Nuclear Sciences, Belgrade, Serbia
P. Adzic[42], P. Cirkovic, D. Devetak, M. Dordevic, J. Milosevic, V. Rekovic

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

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

Universidad de Oviedo, Oviedo, Spain
J. Cuevas, C. Erice, J. Fernandez Menendez, I. Gonzalez Caballero, J.R. González Fernández, E. Palencia Cortezon, S. Sanchez Cruz, I. Suárez Andrés, P. Vischia, J.M. Vizan Garcia

Instituto de Física de Cantabria (IFCA), CSIC-Universidad de Cantabria, Santander, Spain
I.J. Cabrillo, A. Calderon, E. Curras, M. Fernandez, J. Garcia-Ferrero, G. Gomez, A. Lopez Virto, J. Marco, C. Martinez Rivero, F. Matorras, J. Piedra Gomez, T. Rodrigo, A. Ruiz-Jimeno, L. Scodellaro, N. Trevisani, I. Vila, R. Vilar Cortabitarte

CERN, European Organization for Nuclear Research, Geneva, Switzerland
D. Abbaneo, E. Auffray, G. Auzinger, P. Baillon, A.H. Ball, D. Barney, P. Bloch, A. Bocci, C. Botta, T. Camporesi, R. Castello, M. Cepeda, G. Cerminara, Y. Chen, A. Cimmino, D. d'Enterria, A. Dabrowski, V. Daponte, A. David, M. De Gruttola, A. De Roeck, E. Di Marco[43], M. Dobson, B. Dorney, T. du Pree, M. Dünser, N. Dupont, A. Elliott-Peisert, P. Everaerts, S. Fartoukh, G. Franzoni, J. Fulcher, W. Funk, D. Gigi, K. Gill, M. Girone, F. Glege, D. Gulhan, S. Gundacker, M. Guthoff, P. Harris, J. Hegeman, V. Innocente, P. Janot, J. Kieseler, H. Kirschenmann, V. Knünz, A. Kornmayer[15], M.J. Kortelainen, M. Krammer[1], C. Lange, P. Lecoq, C. Lourenço, M.T. Lucchini, L. Malgeri, M. Mannelli, A. Martelli, F. Meijers, J.A. Merlin, S. Mersi, E. Meschi, P. Milenovic[44], F. Moortgat, S. Morovic, M. Mulders, H. Neugebauer, S. Orfanelli, L. Orsini, L. Pape, E. Perez, M. Peruzzi, A. Petrilli, G. Petrucciani, A. Pfeiffer, M. Pierini, A. Racz, T. Reis, G. Rolandi[45], M. Rovere, H. Sakulin, J.B. Sauvan, C. Schäfer, C. Schwick, M. Seidel, M. Selvaggi, A. Sharma, P. Silva, P. Sphicas[46], J. Steggemann, M. Stoye, Y. Takahashi, M. Tosi, D. Treille, A. Triossi, A. Tsirou, V. Veckalns[47], G.I. Veres[20], M. Verweij, N. Wardle, H.K. Wöhri, A. Zagozdzinska[34], W.D. Zeuner

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

Institute for Particle Physics, ETH Zurich, Zurich, Switzerland
F. Bachmair, L. Bäni, L. Bianchini, B. Casal, G. Dissertori, M. Dittmar, M. Donegà, C. Grab,

C. Heidegger, D. Hits, J. Hoss, G. Kasieczka, W. Lustermann, B. Mangano, M. Marionneau, P. Martinez Ruiz del Arbol, M. Masciovecchio, M.T. Meinhard, D. Meister, F. Micheli, P. Musella, F. Nessi-Tedaldi, F. Pandolfi, J. Pata, F. Pauss, G. Perrin, L. Perrozzi, M. Quittnat, M. Rossini, M. Schönenberger, A. Starodumov[48], V.R. Tavolaro, K. Theofilatos, R. Wallny

Universität Zürich, Zurich, Switzerland
T.K. Aarrestad, C. Amsler[49], L. Caminada, M.F. Canelli, A. De Cosa, S. Donato, C. Galloni, A. Hinzmann, T. Hreus, B. Kilminster, J. Ngadiuba, D. Pinna, G. Rauco, P. Robmann, D. Salerno, C. Seitz, Y. Yang, A. Zucchetta

National Central University, Chung-Li, Taiwan
V. Candelise, T.H. Doan, Sh. Jain, R. Khurana, M. Konyushikhin, C.M. Kuo, W. Lin, A. Pozdnyakov, S.S. Yu

National Taiwan University (NTU), Taipei, Taiwan
Arun Kumar, P. Chang, Y.H. Chang, Y. Chao, K.F. Chen, P.H. Chen, F. Fiori, W.-S. Hou, Y. Hsiung, Y.F. Liu, R.-S. Lu, M. Miñano Moya, E. Paganis, A. Psallidas, J.f. Tsai

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

Cukurova University, Physics Department, Science and Art Faculty, Adana, Turkey
A. Adiguzel, F. Boran, S. Cerci[50], S. Damarseckin, Z.S. Demiroglu, C. Dozen, I. Dumanoglu, S. Girgis, G. Gokbulut, Y. Guler, I. Hos[51], E.E. Kangal[52], O. Kara, A. Kayis Topaksu, U. Kiminsu, M. Oglakci, G. Onengut[53], K. Ozdemir[54], D. Sunar Cerci[50], H. Topakli[55], S. Turkcapar, I.S. Zorbakir, C. Zorbilmez

Middle East Technical University, Physics Department, Ankara, Turkey
B. Bilin, B. Isildak[56], G. Karapinar[57], M. Yalvac, M. Zeyrek

Bogazici University, Istanbul, Turkey
E. Gülmez, M. Kaya[58], O. Kaya[59], E.A. Yetkin[60], T. Yetkin[61]

Istanbul Technical University, Istanbul, Turkey
A. Cakir, K. Cankocak, S. Sen[62]

Institute for Scintillation Materials of National Academy of Science of Ukraine, Kharkov, Ukraine
B. Grynyov

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

University of Bristol, Bristol, United Kingdom
R. Aggleton, F. Ball, L. Beck, J.J. Brooke, D. Burns, E. Clement, D. Cussans, H. Flacher, J. Goldstein, M. Grimes, G.P. Heath, H.F. Heath, J. Jacob, L. Kreczko, C. Lucas, D.M. Newbold[63], S. Paramesvaran, A. Poll, T. Sakuma, S. Seif El Nasr-storey, D. Smith, V.J. Smith

Rutherford Appleton Laboratory, Didcot, United Kingdom
K.W. Bell, A. Belyaev[64], C. Brew, R.M. Brown, L. Calligaris, D. Cieri, D.J.A. Cockerill, J.A. Coughlan, K. Harder, S. Harper, E. Olaiya, D. Petyt, C.H. Shepherd-Themistocleous, A. Thea, I.R. Tomalin, T. Williams

Imperial College, London, United Kingdom
M. Baber, R. Bainbridge, O. Buchmuller, A. Bundock, S. Casasso, M. Citron, D. Colling, L. Corpe, P. Dauncey, G. Davies, A. De Wit, M. Della Negra, R. Di Maria, P. Dunne,

A. Elwood, D. Futyan, Y. Haddad, G. Hall, G. Iles, T. James, R. Lane, C. Laner, L. Lyons, A.-M. Magnan, S. Malik, L. Mastrolorenzo, J. Nash, A. Nikitenko[48], J. Pela, B. Penning, M. Pesaresi, D.M. Raymond, A. Richards, A. Rose, E. Scott, C. Seez, S. Summers, A. Tapper, K. Uchida, M. Vazquez Acosta[65], T. Virdee[15], J. Wright, S.C. Zenz

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

Baylor University, Waco, USA
A. Borzou, K. Call, J. Dittmann, K. Hatakeyama, H. Liu, N. Pastika

Catholic University of America, Washington, USA
R. Bartek, A. Dominguez

The University of Alabama, Tuscaloosa, USA
A. Buccilli, S.I. Cooper, C. Henderson, P. Rumerio, C. West

Boston University, Boston, USA
D. Arcaro, A. Avetisyan, T. Bose, D. Gastler, D. Rankin, C. Richardson, J. Rohlf, L. Sulak, D. Zou

Brown University, Providence, USA
G. Benelli, D. Cutts, A. Garabedian, J. Hakala, U. Heintz, J.M. Hogan, O. Jesus, K.H.M. Kwok, E. Laird, G. Landsberg, Z. Mao, M. Narain, S. Piperov, S. Sagir, E. Spencer, R. Syarif

University of California, Davis, Davis, USA
R. Breedon, D. Burns, M. Calderon De La Barca Sanchez, S. Chauhan, M. Chertok, J. Conway, R. Conway, P.T. Cox, R. Erbacher, C. Flores, G. Funk, M. Gardner, W. Ko, R. Lander, C. Mclean, M. Mulhearn, D. Pellett, J. Pilot, S. Shalhout, M. Shi, J. Smith, M. Squires, D. Stolp, K. Tos, M. Tripathi

University of California, Los Angeles, USA
M. Bachtis, C. Bravo, R. Cousins, A. Dasgupta, A. Florent, J. Hauser, M. Ignatenko, N. Mccoll, D. Saltzberg, C. Schnaible, V. Valuev, M. Weber

University of California, Riverside, Riverside, USA
E. Bouvier, K. Burt, R. Clare, J. Ellison, J.W. Gary, S.M.A. Ghiasi Shirazi, G. Hanson, J. Heilman, P. Jandir, E. Kennedy, F. Lacroix, O.R. Long, M. Olmedo Negrete, M.I. Paneva, A. Shrinivas, W. Si, H. Wei, S. Wimpenny, B. R. Yates

University of California, San Diego, La Jolla, USA
J.G. Branson, G.B. Cerati, S. Cittolin, M. Derdzinski, R. Gerosa, A. Holzner, D. Klein, V. Krutelyov, J. Letts, I. Macneill, D. Olivito, S. Padhi, M. Pieri, M. Sani, V. Sharma, S. Simon, M. Tadel, A. Vartak, S. Wasserbaech[66], C. Welke, J. Wood, F. Würthwein, A. Yagil, G. Zevi Della Porta

University of California, Santa Barbara - Department of Physics, Santa Barbara, USA
N. Amin, R. Bhandari, J. Bradmiller-Feld, C. Campagnari, A. Dishaw, V. Dutta, M. Franco Sevilla, C. George, F. Golf, L. Gouskos, J. Gran, R. Heller, J. Incandela, S.D. Mullin, A. Ovcharova, H. Qu, J. Richman, D. Stuart, I. Suarez, J. Yoo

California Institute of Technology, Pasadena, USA
D. Anderson, J. Bendavid, A. Bornheim, J. Bunn, J.M. Lawhorn, A. Mott, H.B. Newman, C. Pena, M. Spiropulu, J.R. Vlimant, S. Xie, R.Y. Zhu

Carnegie Mellon University, Pittsburgh, USA
M.B. Andrews, T. Ferguson, M. Paulini, J. Russ, M. Sun, H. Vogel, I. Vorobiev, M. Weinberg

University of Colorado Boulder, Boulder, USA
J.P. Cumalat, W.T. Ford, F. Jensen, A. Johnson, M. Krohn, S. Leontsinis, T. Mulholland, K. Stenson, S.R. Wagner

Cornell University, Ithaca, USA
J. Alexander, J. Chaves, J. Chu, S. Dittmer, K. Mcdermott, N. Mirman, J.R. Patterson, A. Rinkevicius, A. Ryd, L. Skinnari, L. Soffi, S.M. Tan, Z. Tao, J. Thom, J. Tucker, P. Wittich, M. Zientek

Fairfield University, Fairfield, USA
D. Winn

Fermi National Accelerator Laboratory, Batavia, USA
S. Abdullin, M. Albrow, G. Apollinari, A. Apresyan, S. Banerjee, L.A.T. Bauerdick, A. Beretvas, J. Berryhill, P.C. Bhat, G. Bolla, K. Burkett, J.N. Butler, H.W.K. Cheung, F. Chlebana, S. Cihangir†, M. Cremonesi, J. Duarte, V.D. Elvira, I. Fisk, J. Freeman, E. Gottschalk, L. Gray, D. Green, S. Grünendahl, O. Gutsche, R.M. Harris, S. Hasegawa, J. Hirschauer, Z. Hu, B. Jayatilaka, S. Jindariani, M. Johnson, U. Joshi, B. Klima, B. Kreis, S. Lammel, J. Linacre, D. Lincoln, R. Lipton, M. Liu, T. Liu, R. Lopes De Sá, J. Lykken, K. Maeshima, N. Magini, J.M. Marraffino, S. Maruyama, D. Mason, P. McBride, P. Merkel, S. Mrenna, S. Nahn, V. O'Dell, K. Pedro, O. Prokofyev, G. Rakness, L. Ristori, E. Sexton-Kennedy, A. Soha, W.J. Spalding, L. Spiegel, S. Stoynev, J. Strait, N. Strobbe, L. Taylor, S. Tkaczyk, N.V. Tran, L. Uplegger, E.W. Vaandering, C. Vernieri, M. Verzocchi, R. Vidal, M. Wang, H.A. Weber, A. Whitbeck, Y. Wu

University of Florida, Gainesville, USA
D. Acosta, P. Avery, P. Bortignon, D. Bourilkov, A. Brinkerhoff, A. Carnes, M. Carver, D. Curry, S. Das, R.D. Field, I.K. Furic, J. Konigsberg, A. Korytov, J.F. Low, P. Ma, K. Matchev, H. Mei, G. Mitselmakher, D. Rank, L. Shchutska, D. Sperka, L. Thomas, J. Wang, S. Wang, J. Yelton

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

Florida State University, Tallahassee, USA
A. Ackert, T. Adams, A. Askew, S. Bein, S. Hagopian, V. Hagopian, K.F. Johnson, T. Kolberg, T. Perry, H. Prosper, A. Santra, R. Yohay

Florida Institute of Technology, Melbourne, USA
M.M. Baarmand, V. Bhopatkar, S. Colafranceschi, M. Hohlmann, D. Noonan, T. Roy, F. Yumiceva

University of Illinois at Chicago (UIC), Chicago, USA
M.R. Adams, L. Apanasevich, D. Berry, R.R. Betts, R. Cavanaugh, X. Chen, O. Evdokimov, C.E. Gerber, D.A. Hangal, D.J. Hofman, K. Jung, J. Kamin, I.D. Sandoval Gonzalez, H. Trauger, N. Varelas, H. Wang, Z. Wu, J. Zhang

The University of Iowa, Iowa City, USA
B. Bilki[67], W. Clarida, K. Dilsiz, S. Durgut, R.P. Gandrajula, M. Haytmyradov, V. Khristenko, J.-P. Merlo, H. Mermerkaya[68], A. Mestvirishvili, A. Moeller, J. Nachtman, H. Ogul, Y. Onel, F. Ozok[69], A. Penzo, C. Snyder, E. Tiras, J. Wetzel, K. Yi

Johns Hopkins University, Baltimore, USA
B. Blumenfeld, A. Cocoros, N. Eminizer, D. Fehling, L. Feng, A.V. Gritsan, P. Maksimovic, J. Roskes, U. Sarica, M. Swartz, M. Xiao, C. You

The University of Kansas, Lawrence, USA
A. Al-bataineh, P. Baringer, A. Bean, S. Boren, J. Bowen, J. Castle, L. Forthomme, S. Khalil, A. Kropivnitskaya, D. Majumder, W. Mcbrayer, M. Murray, S. Sanders, R. Stringer, J.D. Tapia Takaki, Q. Wang

Kansas State University, Manhattan, USA
A. Ivanov, K. Kaadze, Y. Maravin, A. Mohammadi, L.K. Saini, N. Skhirtladze, S. Toda

Lawrence Livermore National Laboratory, Livermore, USA
F. Rebassoo, D. Wright

University of Maryland, College Park, USA
C. Anelli, A. Baden, O. Baron, A. Belloni, B. Calvert, S.C. Eno, C. Ferraioli, N.J. Hadley, S. Jabeen, G.Y. Jeng, R.G. Kellogg, J. Kunkle, A.C. Mignerey, F. Ricci-Tam, Y.H. Shin, A. Skuja, M.B. Tonjes, S.C. Tonwar

Massachusetts Institute of Technology, Cambridge, USA
D. Abercrombie, B. Allen, A. Apyan, V. Azzolini, R. Barbieri, A. Baty, R. Bi, K. Bierwagen, S. Brandt, W. Busza, I.A. Cali, M. D'Alfonso, Z. Demiragli, G. Gomez Ceballos, M. Goncharov, D. Hsu, Y. Iiyama, G.M. Innocenti, M. Klute, D. Kovalskyi, K. Krajczar, Y.S. Lai, Y.-J. Lee, A. Levin, P.D. Luckey, B. Maier, A.C. Marini, C. Mcginn, C. Mironov, S. Narayanan, X. Niu, C. Paus, C. Roland, G. Roland, J. Salfeld-Nebgen, G.S.F. Stephans, K. Tatar, D. Velicanu, J. Wang, T.W. Wang, B. Wyslouch

University of Minnesota, Minneapolis, USA
A.C. Benvenuti, R.M. Chatterjee, A. Evans, P. Hansen, S. Kalafut, S.C. Kao, Y. Kubota, Z. Lesko, J. Mans, S. Nourbakhsh, N. Ruckstuhl, R. Rusack, N. Tambe, J. Turkewitz

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

University of Nebraska-Lincoln, Lincoln, USA
E. Avdeeva, K. Bloom, D.R. Claes, C. Fangmeier, R. Gonzalez Suarez, R. Kamalieddin, I. Kravchenko, A. Malta Rodrigues, J. Monroy, J.E. Siado, G.R. Snow, B. Stieger

State University of New York at Buffalo, Buffalo, USA
M. Alyari, J. Dolen, A. Godshalk, C. Harrington, I. Iashvili, D. Nguyen, A. Parker, S. Rappoccio, B. Roozbahani

Northeastern University, Boston, USA
G. Alverson, E. Barberis, A. Hortiangtham, A. Massironi, D.M. Morse, D. Nash, T. Orimoto, R. Teixeira De Lima, D. Trocino, R.-J. Wang, D. Wood

Northwestern University, Evanston, USA
S. Bhattacharya, O. Charaf, K.A. Hahn, N. Mucia, N. Odell, B. Pollack, M.H. Schmitt, K. Sung, M. Trovato, M. Velasco

University of Notre Dame, Notre Dame, USA
N. Dev, M. Hildreth, K. Hurtado Anampa, C. Jessop, D.J. Karmgard, N. Kellams, K. Lannon, N. Marinelli, F. Meng, C. Mueller, Y. Musienko[35], M. Planer, A. Reinsvold, R. Ruchti, N. Rupprecht, G. Smith, S. Taroni, M. Wayne, M. Wolf, A. Woodard

The Ohio State University, Columbus, USA
J. Alimena, L. Antonelli, B. Bylsma, L.S. Durkin, S. Flowers, B. Francis, A. Hart, C. Hill, W. Ji, B. Liu, W. Luo, D. Puigh, B.L. Winer, H.W. Wulsin

Princeton University, Princeton, USA
S. Cooperstein, O. Driga, P. Elmer, J. Hardenbrook, P. Hebda, D. Lange, J. Luo, D. Marlow, T. Medvedeva, K. Mei, I. Ojalvo, J. Olsen, C. Palmer, P. Piroué, D. Stickland, A. Svyatkovskiy, C. Tully

University of Puerto Rico, Mayaguez, USA
S. Malik

Purdue University, West Lafayette, USA
A. Barker, V.E. Barnes, S. Folgueras, L. Gutay, M.K. Jha, M. Jones, A.W. Jung, A. Khatiwada, D.H. Miller, N. Neumeister, J.F. Schulte, J. Sun, F. Wang, W. Xie

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

Rice University, Houston, USA
A. Adair, B. Akgun, Z. Chen, K.M. Ecklund, F.J.M. Geurts, M. Guilbaud, W. Li, B. Michlin, M. Northup, B.P. Padley, J. Roberts, J. Rorie, Z. Tu, J. Zabel

University of Rochester, Rochester, USA
B. Betchart, A. Bodek, P. de Barbaro, R. Demina, Y.t. Duh, T. Ferbel, M. Galanti, A. Garcia-Bellido, J. Han, O. Hindrichs, A. Khukhunaishvili, K.H. Lo, P. Tan, M. Verzetti

Rutgers, The State University of New Jersey, Piscataway, USA
A. Agapitos, J.P. Chou, Y. Gershtein, T.A. Gómez Espinosa, E. Halkiadakis, M. Heindl, E. Hughes, S. Kaplan, R. Kunnawalkam Elayavalli, S. Kyriacou, A. Lath, R. Montalvo, K. Nash, M. Osherson, H. Saka, S. Salur, S. Schnetzer, D. Sheffield, S. Somalwar, R. Stone, S. Thomas, P. Thomassen, M. Walker

University of Tennessee, Knoxville, USA
A.G. Delannoy, M. Foerster, J. Heideman, G. Riley, K. Rose, S. Spanier, K. Thapa

Texas A&M University, College Station, USA
O. Bouhali[70], A. Celik, M. Dalchenko, M. De Mattia, A. Delgado, S. Dildick, R. Eusebi, J. Gilmore, T. Huang, E. Juska, T. Kamon[71], R. Mueller, Y. Pakhotin, R. Patel, A. Perloff, L. Perniè, D. Rathjens, A. Safonov, A. Tatarinov, K.A. Ulmer

Texas Tech University, Lubbock, USA
N. Akchurin, J. Damgov, F. De Guio, C. Dragoiu, P.R. Dudero, J. Faulkner, E. Gurpinar, S. Kunori, K. Lamichhane, S.W. Lee, T. Libeiro, T. Peltola, S. Undleeb, I. Volobouev, Z. Wang

Vanderbilt University, Nashville, USA
S. Greene, A. Gurrola, R. Janjam, W. Johns, C. Maguire, A. Melo, H. Ni, P. Sheldon, S. Tuo, J. Velkovska, Q. Xu

University of Virginia, Charlottesville, USA
M.W. Arenton, P. Barria, B. Cox, R. Hirosky, A. Ledovskoy, H. Li, C. Neu, T. Sinthuprasith, X. Sun, Y. Wang, E. Wolfe, F. Xia

Wayne State University, Detroit, USA
C. Clarke, R. Harr, P.E. Karchin, J. Sturdy, S. Zaleski

University of Wisconsin - Madison, Madison, WI, USA
D.A. Belknap, J. Buchanan, C. Caillol, S. Dasu, L. Dodd, S. Duric, B. Gomber, M. Grothe, M. Herndon, A. Hervé, U. Hussain, P. Klabbers, A. Lanaro, A. Levine, K. Long, R. Loveless, G.A. Pierro, G. Polese, T. Ruggles, A. Savin, N. Smith, W.H. Smith, D. Taylor, N. Woods

†: Deceased
1: Also at Vienna University of Technology, Vienna, Austria
2: Also at State Key Laboratory of Nuclear Physics and Technology, Peking University, Beijing, China
3: Also at Universidade Estadual de Campinas, Campinas, Brazil
4: Also at Universidade Federal de Pelotas, Pelotas, Brazil
5: Also at Université Libre de Bruxelles, Bruxelles, Belgium
6: Also at Universidad de Antioquia, Medellin, Colombia
7: Also at Joint Institute for Nuclear Research, Dubna, Russia
8: Also at Helwan University, Cairo, Egypt
9: Now at Zewail City of Science and Technology, Zewail, Egypt
10: Now at Fayoum University, El-Fayoum, Egypt
11: Also at British University in Egypt, Cairo, Egypt
12: Now at Ain Shams University, Cairo, Egypt
13: Also at Université de Haute Alsace, Mulhouse, France
14: Also at Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia
15: Also at CERN, European Organization for Nuclear Research, Geneva, Switzerland
16: Also at RWTH Aachen University, III. Physikalisches Institut A, Aachen, Germany
17: Also at University of Hamburg, Hamburg, Germany
18: Also at Brandenburg University of Technology, Cottbus, Germany
19: Also at Institute of Nuclear Research ATOMKI, Debrecen, Hungary
20: Also at MTA-ELTE Lendület CMS Particle and Nuclear Physics Group, Eötvös Loránd University, Budapest, Hungary
21: Also at Institute of Physics, University of Debrecen, Debrecen, Hungary
22: Also at Indian Institute of Technology Bhubaneswar, Bhubaneswar, India
23: Also at University of Visva-Bharati, Santiniketan, India
24: Also at Institute of Physics, Bhubaneswar, India
25: Also at University of Ruhuna, Matara, Sri Lanka
26: Also at Isfahan University of Technology, Isfahan, Iran
27: Also at Yazd University, Yazd, Iran
28: Also at Plasma Physics Research Center, Science and Research Branch, Islamic Azad University, Tehran, Iran
29: Also at Università degli Studi di Siena, Siena, Italy
30: Also at Purdue University, West Lafayette, USA
31: Also at International Islamic University of Malaysia, Kuala Lumpur, Malaysia
32: Also at Malaysian Nuclear Agency, MOSTI, Kajang, Malaysia
33: Also at Consejo Nacional de Ciencia y Tecnología, Mexico city, Mexico
34: Also at Warsaw University of Technology, Institute of Electronic Systems, Warsaw, Poland
35: Also at Institute for Nuclear Research, Moscow, Russia
36: Now at National Research Nuclear University 'Moscow Engineering Physics Institute' (MEPhI), Moscow, Russia
37: Also at St. Petersburg State Polytechnical University, St. Petersburg, Russia
38: Also at University of Florida, Gainesville, USA
39: Also at P.N. Lebedev Physical Institute, Moscow, Russia
40: Also at California Institute of Technology, Pasadena, USA
41: Also at Budker Institute of Nuclear Physics, Novosibirsk, Russia
42: Also at Faculty of Physics, University of Belgrade, Belgrade, Serbia
43: Also at INFN Sezione di Roma; Sapienza Università di Roma, Rome, Italy

44: Also at University of Belgrade, Faculty of Physics and Vinca Institute of Nuclear Sciences, Belgrade, Serbia
45: Also at Scuola Normale e Sezione dell'INFN, Pisa, Italy
46: Also at National and Kapodistrian University of Athens, Athens, Greece
47: Also at Riga Technical University, Riga, Latvia
48: Also at Institute for Theoretical and Experimental Physics, Moscow, Russia
49: Also at Albert Einstein Center for Fundamental Physics, Bern, Switzerland
50: Also at Adiyaman University, Adiyaman, Turkey
51: Also at Istanbul Aydin University, Istanbul, Turkey
52: Also at Mersin University, Mersin, Turkey
53: Also at Cag University, Mersin, Turkey
54: Also at Piri Reis University, Istanbul, Turkey
55: Also at Gaziosmanpasa University, Tokat, Turkey
56: Also at Ozyegin University, Istanbul, Turkey
57: Also at Izmir Institute of Technology, Izmir, Turkey
58: Also at Marmara University, Istanbul, Turkey
59: Also at Kafkas University, Kars, Turkey
60: Also at Istanbul Bilgi University, Istanbul, Turkey
61: Also at Yildiz Technical University, Istanbul, Turkey
62: Also at Hacettepe University, Ankara, Turkey
63: Also at Rutherford Appleton Laboratory, Didcot, United Kingdom
64: Also at School of Physics and Astronomy, University of Southampton, Southampton, United Kingdom
65: Also at Instituto de Astrofísica de Canarias, La Laguna, Spain
66: Also at Utah Valley University, Orem, USA
67: Also at BEYKENT UNIVERSITY, Istanbul, Turkey
68: Also at Erzincan University, Erzincan, Turkey
69: Also at Mimar Sinan University, Istanbul, Istanbul, Turkey
70: Also at Texas A&M University at Qatar, Doha, Qatar
71: Also at Kyungpook National University, Daegu, Korea