Searches for Pair-Produced Multijet Resonances Using Data Scouting in Proton-Proton Collisions at $\sqrt{s} = 13$ TeV

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

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Searches for pair-produced multijet signatures using data corresponding to an integrated luminosity of 128 fb^{-1} of proton-proton collisions at $\sqrt{s} = 13$ TeV are presented. A data scouting technique is employed to record events with low jet scalar transverse momentum sum values. The electroweak production of particles predicted in R-parity violating supersymmetric models is probed for the first time with fully hadronic final states. This is the first search for prompt hadronically decaying mass-degenerate higgsinos, and extends current exclusions on R-parity violating top squarks and gluinos.

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Discovery of the Higgs boson [1–3] completed the standard model (SM), but many phenomena in particle physics remain unexplained [4–7]. Diverse theories of physics beyond the SM (BSM) have been proposed. Many posit the existence of new resonances that would be produced in high-energy proton-proton (pp) collisions and subsequently decay to multiquark final states [7,8]. This Letter presents searches for pair-produced BSM particles promptly decaying to two or three quarks. Pair-produced R-parity violating (RPV) supersymmetric (SUSY) particles, which each decay to pairs or triplets of quarks (q), namely higgsinos ($\tilde{h} \to qqq$), top squarks ($\tilde{t} \to qq$), and gluinos ($\tilde{g} \to qqq$) are used as benchmark models [7]. The searches are based on data from pp collisions at the CERN LHC, collected with the CMS detector in 2016–2018, corresponding to an integrated luminosity of 128 fb^{-1} [9–11].

The high center-of-mass energy of 13 TeV of these pp collisions at the LHC can result in low-mass resonances produced with significant Lorentz boosts, such that the hadronization products of the individual final-state quarks overlap in the detector. The resulting signatures are large-radius jets with identifiable substructure. The searches presented in this Letter consider three experimental signatures: pairs of large-radius jets with substructure consistent with three underlying quarks (henceforth called "merged trijets"), pairs of large-radius jets with two-quark substructure (henceforth called *merged dijets*), and pairs of well-resolved triplets of jets (henceforth called "resolved trijets"). Simplified diagrams of the production of each signature are shown in Fig. 1. The first two signatures are sensitive to both $\tilde{h}$ and $\tilde{t}$ pair production, while the third is sensitive to $\tilde{g}$ pair production.

While the three signatures are analyzed independently, the three analyses use similar techniques for signal selection and share a single method for estimating the dominant background from quantum chromodynamic (QCD) multijet processes. In particular, the analyses use the CMS "scouting dataset" [12,13], in which only the event data reconstructed by the high-level trigger (HLT, described below) is retained. The resulting reduced event size allows for higher event rates at lower energy thresholds, thus increasing the sensitivity of searches for lower resonance masses. Jet substructure variables developed explicitly for data scouting are used to reduce the QCD background. The fully hadronic decay of the SM production of top quark-antiquark pairs ($t\bar{t}$) is an irreducible background to the paired trijet search. Similarly, events containing hadronically decaying Z or W bosons are a background to the paired dijet search. These three resonant backgrounds are estimated from simulations.

Searches for pairs of BSM particles, each decaying to three resolved jets, have been performed by the CDF [14], ATLAS [15,16], and CMS [17–19] collaborations. Searches for pairs of particles, which each decay to two quarks, have also been reported by the ATLAS [20–22] and CMS [23,24] collaborations. While this Letter does not present a search for resolved paired dijet resonances, such searches have been performed with the same dataset [23–26]. However, no searches have previously been conducted for the production of prompt mass-degenerate RPV higgsinos with a fully hadronic decay or at $\sqrt{s} = 13$ TeV for the production of RPV gluinos with masses below 200 GeV. The searches presented in this Letter are the first to probe these regimes. Tabulated results for this analysis are provided in the HEPData record [27].

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

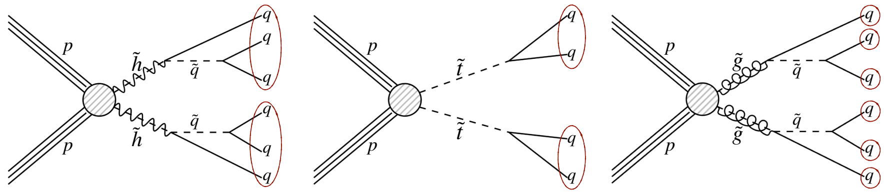

FIG. 1. Benchmark RPV SUSY models for merged trijets (left), merged dijets (middle), and resolved trijets (right). The red circles group the final state quarks (or antiquarks) according to the expected jet clustering of their hadronization products.

The CMS apparatus [28] is a multipurpose, nearly hermetic detector, designed to trigger on [29,30] and identify electrons, muons, photons, and hadrons [31–33]. A global "particle-flow" (PF) algorithm [34] aims to reconstruct all individual particles in an event, combining information provided by the all-silicon inner tracker and by the crystal electromagnetic and brass-scintillator hadron calorimeters, operating inside a 3.8 T superconducting solenoid, with data from the gas-ionization muon detectors embedded in the flux-return yoke outside the solenoid. The reconstructed particle candidates are used to build τ leptons, jets, and missing transverse momentum [35–37].

While the LHC provides collisions every 25 ns, the CMS detector and data acquisition systems do not have the bandwidth to record every event. Instead, events of interest are selected using a two-tiered trigger system. 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 within a fixed latency of about 4 μs [29]. The second level, known as the HLT, consists of a farm of processors running a version of the PF algorithm optimized for fast processing, and reduces the event rate to around 1 kHz before data storage [30]. If the partial reconstruction by the HLT indicates that the event has passed some specific requirements, such as the scalar sum of the transverse momenta (p_T) of jets in the event (H_T) being above some threshold, the event is fully reconstructed and stored for offline analysis.

To handle the high multijet production rates of the LHC, the threshold for standard trigger selection based purely on H_T was set to 800 GeV in 2016 and 1.05 TeV in 2017–2018. For the range of new particle masses considered in this Letter, the resonances rarely decay to jets with sufficient p_T for the events to meet these thresholds. To allow analyses targeting low-mass final states to overcome these limitations, CMS implemented data scouting, in which only the objects reconstructed at the HLT are saved for further analysis [13]. In particular, the analyses use a dataset of scouting events with $H_T > 410$ GeV [12,34]. Data scouting allows CMS to collect data at a rate much higher than that possible with standard triggers. During one of the highest instantaneous luminosity data collection periods, the scouting triggers used in these searches were able to collect data at 1.8 kHz, while the rate for comparable standard triggers was 400 Hz. The data size of scouting events is approximately 60 times smaller than that of standard events.

Pair production of RPV SUSY particles is used as the benchmark model for these analyses, where gluinos and higgsinos decay to the three-jet final state and top squarks decay to the dijet final state. Signal events are generated using MadGraph5_aMC@NLO2.6.5 [38] with up to one additional jet using the MLM matching procedure [39]. The masses of virtual squarks in gluino decays are set to sufficiently high values that the gluinos decay without an internal resonance. The natural width of the RPV higgsinos, RPV gluinos, and RPV top squarks is assumed to be much smaller than the experimental resolution. QCD and $t\bar{t}$ events, as well as events with W and Z bosons produced in association with extra jets ($W/Z +$ jets) are simulated, with MadGraph5_aMC@NLO2.6.5. QCD and $W/Z +$ jets events are simulated at leading order with up to four extra partons in the matrix element calculations, while $t\bar{t}$ events are simulated at next-to-leading order.

All samples were interfaced with PYTHIA8.212 [40] with CP5 as the underlying event tune [41] using the parton distribution function set NNPDF3.1NNLO [42]. The interaction of particles with the detector is simulated using the GEANT4 toolkit [43]. The effects of particles from additional pp interactions in the same or adjacent bunch crossings (pileup) are incorporated by overlaying minimum bias events, simulated with PYTHIA, on the hard scattering interactions, with the multiplicity distribution of these additional interactions matching that observed in data. The QCD simulation is only used to optimize the event selection procedure for each analysis. The QCD background for each search is estimated using Gaussian process (GP) regression as described below [44].

All the PF candidates in an event are clustered into jets using FastJet [45,46] with the anti-k_T algorithm [47] and distance parameters of 0.4 and 0.8 (AK4 and AK8 jets) for the resolved and merged categories, respectively. The jet energies are corrected to compensate for the combined response functions of the CMS calorimeters and the effects of pileup [36,48]. Jets in data are further corrected to account for the residual difference between simulation and data. The corrections are derived from data that has undergone full offline reconstruction, with small residual corrections appropriate for the HLT reconstruction used in scouting dataset. The tight jet identification criteria [49] are applied to remove poorly reconstructed jets and calorimeter noise misidentified as jets.

TABLE I. Selection requirements for the resolved trijet resonance search listed for the three regions of three-jet resonance mass.

Region	Trijet mass (GeV)	6th jet p_T (GeV)	$D^2_{[(6,3)+(3,2)]}$	A_m	Δ (GeV)	$D^2_{[3,2]}$
1	200–500	>40	<1.25	<0.25	>250	<0.05
2	500–900	>50	<1.00	<0.175	>180	<0.175
3	900–2000	>100	<0.9	<0.15	>150	<0.2

The trimming algorithm described in Ref. [50] is applied to the AK8 jets. This algorithm clusters the constituents of the jet into smaller jets with radius of 0.2 using the k_T algorithm. Clusters with p_T smaller than 3% of the original jet p_T are removed. This trimming procedure reduces contributions from soft QCD radiation, pileup, and particles from the underlying event to the jet mass m. After trimming m is further corrected so that the top quark mass distribution observed in data matches that from $t\bar{t}$ simulation.

In the merged analyses, jet substructure variables [51] are used to separate signal jets (AK8 jets containing the hadronization of multiple quarks) from the QCD background. In particular, the variables τ_{32} [51] and N_2^1 [52] are used to identify resonances decaying to three or two quarks with merged final states, respectively. These variables have lower values when evaluated on jets resulting from overlapping quark decays, and higher values for jets initiated by a single quark or gluon. These substructure variables are correlated with the kinematic properties of the jet, such that imposing a selection based on them can preferentially enhance regions of the background mass distributions. To avoid these correlations, the "designed decorrelated tagger" (DDT) [53] procedure is used to reduce the dependence of the variables on the p_T and $\rho = \ln(m^2/p_T^2)$ of the jets. The decorrelation is achieved by varying the substructure variables in each p_T and ρ bin such that 5% of simulated QCD events are allowed in each bin. The resulting variables are called $N^1_{2,\mathrm{DDT}}$ and $\tau_{32,\mathrm{DDT}}$. This methodology has been used in several searches performed by the CMS Collaboration [54–56]. Both the leading and subleading jets are required to have $\tau_{32,\mathrm{DDT}} < 0$ or $N^1_{2,\mathrm{DDT}} < 0$, for selecting pair-produced resonances decaying to three or two quarks, respectively.

For the merged resonance searches, only the leading two AK8 jets in the events are considered. To ensure that the analyses only consider events for which the trigger is fully efficient, each jet is required to have $p_T > 300$ GeV and $|\eta| < 2.4$. The mass asymmetry between the leading jet (j_1) and subleading jet (j_2) sorted by jet p_T, $A_m \equiv |m(j_1) - m(j_2)|/(m(j_1) + m(j_2))$ is required to be less than 0.15.

For the resolved analysis, a neural network (NN) based quark-gluon discriminator (QGD) is used to distinguish gluon-initiated AK4 jets from the quark-initiated AK4 jets expected for trijet resonances. The network's architecture is based on the "particle-flow network" as described in Ref. [57]. The NN inputs are the normalized four-momenta information (p_T, η, ϕ, m) along with the particle type of each jet constituent. Each constituent's p_T is divided by the p_T of the entire jet. The NN is trained on an equal number of quark and gluon jets, sampled from the QCD simulation using truth-level information, for a total of 900 000 jets. The NN outputs a QGD score between 0 and 1, with 1 corresponding to more quarklike jets. The analysis uses loose, medium, and tight QGD selections corresponding to the quark jet acceptance and gluon jet rejection rates of 98% and 31%, 83% and 70%, and 61% and 87%, respectively. The tight and loose selections are optimized for best quark jet acceptance and gluon jet rejections efficiencies, respectively.

The analyses must contend with immense background from QCD multijet processes. In the case of the merged signatures, jet substructure is used to suppress this background. The sensitivity of the resolved trijet search is improved by using the QGD with the jet-ensemble technique, which examines all possible combinations of three jets as described in Ref. [19]. The remaining QCD background in the analyses is estimated using GP regression [58], a technique for fitting data without assuming a prior for functional form, utilized for these kinds of searches for the first time. Backgrounds from $t\bar{t}$ are estimated using Monte Carlo (MC) simulation.

Events in the resolved trijets search are divided into three regions, based on the targeted gluino mass. The three mass ranges are given in Table I. For all three search regions, in the event reconstruction all AK4 jets that pass the thresholds of $p_T > 30$ GeV and $|\eta| < 2.4$ are initially considered. The events are required to have a total $H_T > 600$ GeV, to ensure a fully efficient trigger. Jets that fail the loose quark threshold of the QGD are rejected, and every event is required to have at least six jets passing this selection criteria. In events with more than six jets, it was found that restricting the set of considered jets to the six with the highest p_T maximized the sensitivity of the analysis. These six jets are grouped into combinations of three, making twenty triplets, and ten triplet pairs.

The final selection for each of the three gluino mass regions is based on six variables, as described in Ref. [19]. The lowest p_T of the six jets must be above a given threshold. The event-level Dalitz variable $D^2_{[(6,3)+(3,2)]}$,

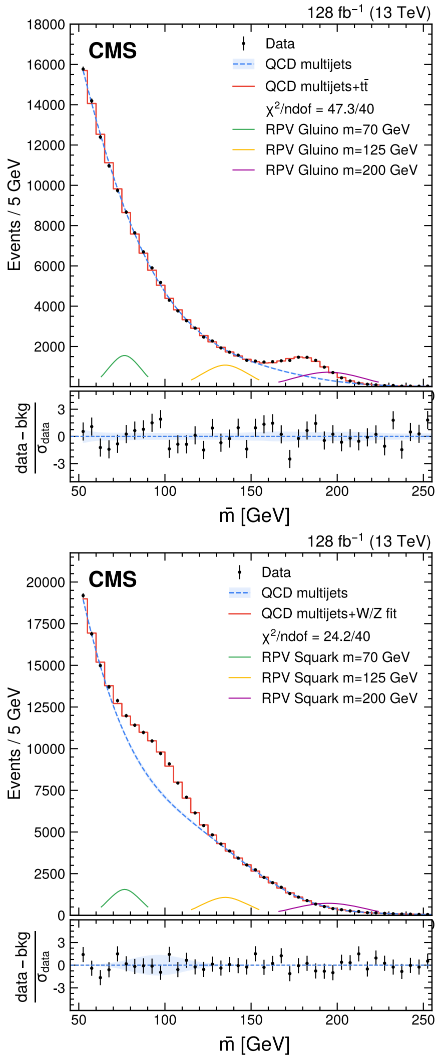

FIG. 2. The distribution of average jet mass in the data (points), for the search for pair-produced merged resonances decaying to trijets (upper) and dijets (lower), compared to a background-only prediction from GP regression (blue), and the full background fit including simulations (red) of SM resonances from $t\bar{t}$ (upper) and $W/Z+\text{jets}$ (lower). Also shown are the expected shapes of signals from R-parity violating gluinos or squarks with resonance masses 70 (green), 125 (yellow), and 200 GeV (purple), with arbitrary normalizations. The bottom panel shows the difference between the data and the final background estimate, divided by the statistical uncertainty of the data in each bin, with fit uncertainty shown in blue.

which measures the geometric spread in the six-jet topology, cannot exceed a given threshold. The A_m value between the constituent triplet objects cannot exceed a predefined threshold. A variable $\Delta \equiv p_{T_{jjj}} - m_{jjj}$, is defined for triplets from the remaining pairs. Trijets from QCD multijets have a low value of Δ, as $p_{T_{jjj}}$ and m_{jjj} scale with each other. A triplet-level requirement on the Dalitz variable $D^2_{[3,2]}$ is imposed to enforce a symmetry of decay in the triplets. Finally, all jets within the triplets passing the above criteria are required to pass the medium QGD selection and at least one jet must pass the tight QGD selection. The selection variables were optimized individually for each of the three gluino mass ranges. The values of the relevant thresholds are shown in Table I. Events must have at least one such triplet, and if multiple jet triplets in an event fulfill these requirements, all such trijet combinations are considered in the final distribution of reconstructed gluino masses.

The GP regression technique is used to estimate the dominant background from QCD [44]. Unlike the rigid constraints imposed by conventional curve fitting approaches, GP is a flexible alternative that does not specify a parametric functional form, instead providing a probability distribution over possible functions that fit the data [58]. The GP regression is defined using a kernel that directly encodes an understanding of the underlying physics, manifesting as controlled covariance among the bin counts [59]. In these analyses the radial bias function kernel is used to model the QCD multijet invariant mass distributions, as described in Ref. [44]. This kernel describes the correlation between bins in the mass spectra by assigning an exponential weight that falls with the square of their separation. Use of the GP regression technique was previously observed to give accurately modeled multijet mass distributions [59]. The signal shapes are modeled by Gaussian distributions. A bias test was performed at various masses by injecting signal shapes to validate the fitting procedure, and yielded no indication of significant bias in the signal extraction process. The background contributions from processes with SM multijet resonances ($t\bar{t}$, $W/Z+\text{jets}$) are taken from simulation, with their cross sections constrained by the GP regression in data. All other SM background contributions are found to be negligible.

For the merged trijet and merged dijet searches, this background estimation procedure is applied to the average jet mass [$\bar{m} = (m_1 + m_2)/2$] distribution of events passing the selection criteria for pair-produced merged resonances decaying to three or two quarks, respectively, as illustrated in Fig. 2. Similarly, in the resolved trijet search, this background estimation procedure is applied to the individual trijet invariant mass (m_{jjj}) distributions for jet triplets passing the selection criteria, as illustrated in Fig. 3. The GP regression and added $t\bar{t}$ and W/Z simulations describe the data well, with p values using a χ^2 metric of 0.75, 0.12, and 0.97 for the three regions of the resolved trijet search, and 0.21 and 0.96 for the merged trijet and merged dijet searches, respectively.

The strength of the selection criteria is indicated by the clear observation of the $t\bar{t}$ and W/Z signals in the merged trijet and dijet resonance search (Fig. 2) and of the $t\bar{t}$ signal in the resolved trijet search (Fig. 3). The rates of $t\bar{t}$ and W/Z production observed in the trijet and dijet searches are within 7% and 6% of SM expectations, respectively.

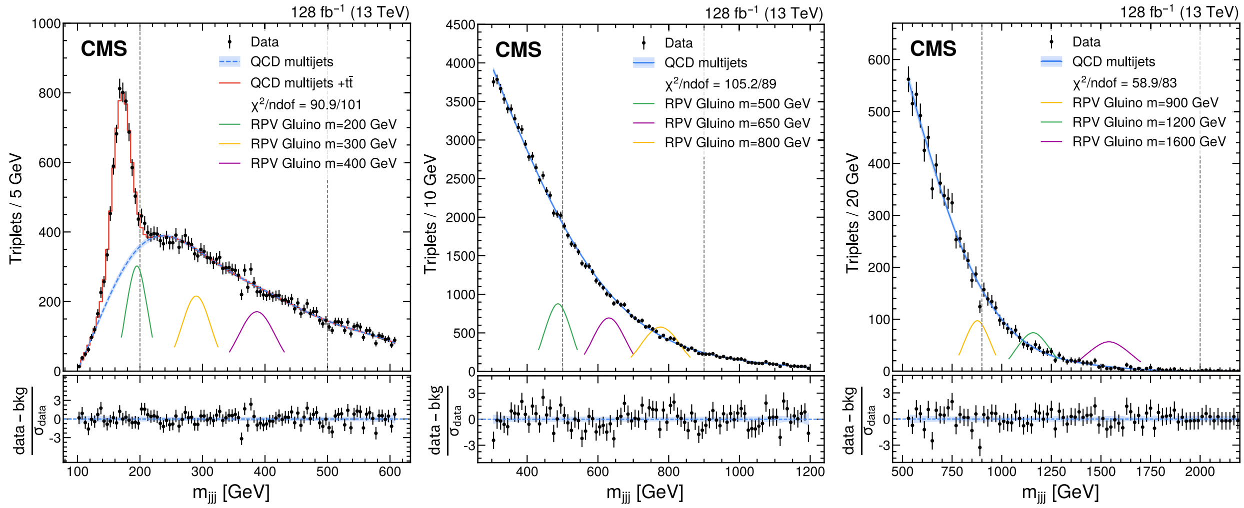

FIG. 3. The distribution of trijet mass in the data (points), for the three search regions (left, middle, and right) for pair-produced resolved resonances decaying to trijets, compared to a background-only fit from GP regression (blue), and (left) the full background fit including simulation of a SM resonance from $t\bar{t}$ production (red). Also shown are the expected shapes of signals from R-parity violating gluinos at various masses (green, yellow, and purple), with arbitrary normalizations. The search range is indicated by the vertical dashed lines. The bottom panel shows the difference in each bin between the data and the final background estimate, divided by the statistical uncertainty of the data, with fit uncertainty shown in blue.

The widths of the Gaussian distributions used to model the signal are extracted from the mass spectra of the simulated higgsinos, top squarks, and gluinos. We observed an effectively linear relation between the width of the Gaussian and the resonance mass for our search ranges. The widths are found to be 9.1% and 7.5% of resonance mass in the merged and resolved searches, respectively. The search is performed by fitting these signal templates and the backgrounds simultaneously to the data using a Bayesian approach described in detail below. No significant deviation from the SM is found; the largest excess occurs at a reconstructed trijet mass of approximately 720 GeV as shown in Fig. 3 (middle) and has a local significance of 2.6 standard deviations. This corresponds to a gluino mass of 770 GeV.

This analysis uses a Bayesian procedure with a uniform prior signal strength to evaluate significance and determine the 95% confidence level (CL) upper limit [60,61]. The Markov chain MC method is used to marginalize the nuisance parameters [44,62]. The Markov chain MC sampling procedure is applied to 1000 pseudo datasets. The posterior distributions from these are used to obtain the estimated limits.

The uncertainty in the selection efficiency of the substructure variables is measured using semileptonic decays of $t\bar{t}$. This is the dominant systematic uncertainty. The uncertainty in the integrated luminosity measurement also contributes to the uncertainty in the signal rate. The contribution from the choice of parton distribution functions for the signal simulations was found to have a negligible effect. All the signal rate uncertainties are modeled with log-normal probability density functions. The uncertainties arising from the jet energy corrections and the uncertainty in the jet energy resolution both affect the shape of the signal. These are modeled as nuisance parameters affecting the mean and width of the signal, respectively. The nuisance parameters corresponding to the signal and background shape uncertainties are modeled with Gaussian probability density functions. The shape and rate uncertainties that affect the signal also affect the $t\bar{t}$ and W/Z backgrounds. The standard deviations for all nuisance parameters are shown in Table II.

Upper limits on the product of production cross section, branching fraction, and acceptance for each signature are shown in Fig. 4. The results were compared to asymptotic $\mathrm{CL_s}$ [63–65] limits for a subset of signal masses and were found to be in close agreement. The acceptance after all selection criteria varies between 10^{-5} and 6×10^{-5}, 4×10^{-5} and 1.7×10^{-4}, and 2×10^{-3} and 6×10^{-2} for the

TABLE II. Summary of the systematic uncertainties in the signal yield and shape, for the searches for merged three- and two-quark and resolved trijet resonances.

Source of uncertainty	Effect	Merged trijets	Merged dijets	Resolved trijets
Trigger efficiency	Yield	2.5%	2.5%	2.5%
Acceptance	Yield	5%	5%	5%
Jet energy corrections	Mean	3.5%	3.5%	3.5%
Jet energy resolution	Width	12%	12%	12%
QGD efficiency	Yield	…	…	5%
$\tau_{32,\mathrm{DDT}}$ efficiency	Yield	4%	…	…
$N^1_{2,\mathrm{DDT}}$ efficiency	Yield	…	20%	…

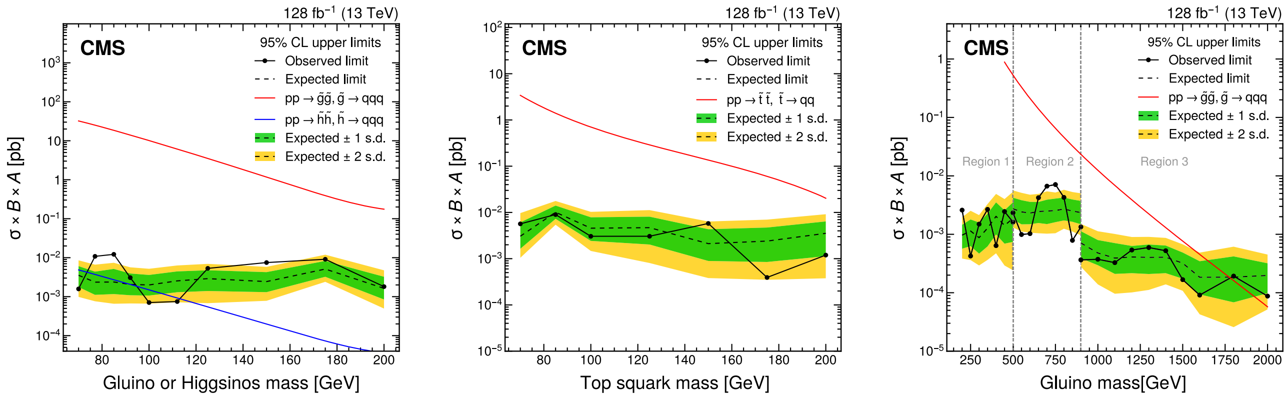

FIG. 4. Observed limits (points) and expected limits (dashed curves) on the product of the production cross section (σ), branching fraction (B), and acceptance (A) for pair-produced merged trijets (left), merged dijets (middle), and pair-produced resolved trijets (right). The vertical lines on the resolved three-quark resonance limits (right) indicate the different search regions. The limits are compared to theoretical predictions for the pair production of R-parity violating gluinos (red in left and right), mass degenerate higgsinos (blue in left), and top squarks (red in middle).

merged three-quark, merged two-quark, and resolved three-quark resonance searches, respectively. The substructure requirements in merged resonance searches, and the Δ selection in the resolved trijet search are the principal causes of the diminished acceptance rates. The upper limits are compared to predictions for RPV gluinos, RPV top squarks, and mass-degenerate RPV higgsinos [66], assuming a 100% branching fraction to quarks. The merged trijet resonance search sets the first limits on mass degenerate RPV higgsinos, excluding masses between 70 and 75 GeV and between 95 and 112 GeV at 95% C.L. The merged dijet resonance search excludes RPV top squarks with masses between 70 and 200 GeV at 95% C.L., extending the exclusion to lower mass and yielding higher sensitivity than previous results [24]. Finally, the trijet searches exclude RPV gluinos with masses between 70 GeV and 1.7 TeV, and supersede earlier results [19].

In summary, a search has been performed for pair-produced multijet resonances using data scouting, where the jets in the final state can be either merged or resolved individually. This search accurately reconstructs the hadronic decays of the top quark and W, Z bosons, in agreement with SM expectations. New, additional resonances were not observed, with the largest excess consistent with a three-jet resonance mass of 770 GeV, but with a local significance of only 2.6 standard deviations. This search extends the previous limits on R-parity violating models of top squarks and gluinos, and sets the first exclusion limits on R-parity violating mass-degenerate, prompt, and hadronically decaying higgsinos.

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[1] CMS Collaboration, Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC, Phys. Lett. B **716**, 30 (2012).

[2] CMS Collaboration, Observation of a new boson with mass near 125 GeV in pp collisions at $\sqrt{s} = 7$ and 8 TeV, J. High Energy Phys. 06 (2013) 081.

[3] 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**, 1 (2012).

[4] Y. Fukuda *et al.* (Super-Kamiokande Collaboration), Evidence for oscillation of atmospheric neutrinos, Phys. Rev. Lett. **81**, 1562 (1998).

[5] B. Abi *et al.* (Muon $g-2$ Collaboration), Measurement of the positive muon anomalous magnetic moment to 0.46 ppm, Phys. Rev. Lett. **126**, 141801 (2021).

[6] LHCb Collaboration, Test of lepton universality in beauty-quark decays, Nat. Phys. **18**, 277 (2022).

[7] R. Barbier, C. Bérat, M. Besançon, M. Chemtob, A. Deandrea, E. Dudas, P. Fayet, S. Lavignac, G. Moreau, E. Perez, and Y. Sirois, R-parity violating supersymmetry, Phys. Rep. **420**, 1 (2005).

[8] H. Easa, T. Gregoire, and D. Stolarski, New limits on coloured three jet resonances, J. High Energy Phys. 09 (2020) 131.

[9] CMS Collaboration, Precision luminosity measurement in proton-proton collisions at $\sqrt{s} = 13$ TeV in 2015 and 2016 at CMS, Eur. Phys. J. C **81**, 800 (2021).

[10] CMS Collaboration, CMS luminosity measurement for the 2017 data-taking period at $\sqrt{s} = 13$ TeV, CMS Physics Analysis Summary CMS-PAS-LUM-17-004, 2018, https://cds.cern.ch/record/2621960.

[11] CMS Collaboration, CMS luminosity measurement for the 2018 data-taking period at $\sqrt{s} = 13$ TeV, CMS Physics Analysis Summary CMS-PAS-LUM-18-002, 2019, https://cds.cern.ch/record/2676164.

[12] CMS Collaboration, Data scouting: A new trigger paradigm, in *5th Large Hadron Collider Physics Conference* (2017), arXiv:1708.06925.

[13] CMS Collaboration, Enriching the physics program of the CMS experiment via data scouting and data parking, arXiv:2403.16134.

[14] T. Aaltonen *et al.* (CDF Collaboration), First search for multijet resonances in $\sqrt{s} = 1.96$ TeV $p\bar{p}$ collisions, Phys. Rev. Lett. **107**, 042001 (2011).

[15] ATLAS Collaboration, Search for massive supersymmetric particles decaying to many jets using the ATLAS detector in pp collisions at $\sqrt{s} = 8$ TeV, Phys. Rev. D **91**, 112016 (2015); **93**, 039901(E) (2016).

[16] ATLAS Collaboration, Search for R-parity-violating supersymmetric particles in multi-jet final states produced in p-p collisions at $\sqrt{s} = 13$ TeV using the ATLAS detector at the LHC, Phys. Lett. B **785**, 136 (2018).

[17] CMS Collaboration, Search for three-jet resonances in pp collisions at $\sqrt{s} = 7$ TeV, Phys. Lett. B **718**, 329 (2012).

[18] CMS Collaboration, Searches for light- and heavy-flavour three-jet resonances in pp collisions at $\sqrt{s} = 8$ TeV, Phys. Lett. B **730**, 193 (2014).

[19] CMS Collaboration, Search for pair-produced three-jet resonances in proton-proton collisions at $\sqrt{s} = 13$ TeV, Phys. Rev. D **99**, 012010 (2019).

[20] ATLAS Collaboration, A search for top squarks with R-parity-violating decays to all-hadronic final states with the ATLAS detector in $\sqrt{s} = 8$ TeV proton-proton collisions, J. High Energy Phys. 06 (2016) 067.

[21] ATLAS Collaboration, A search for pair-produced resonances in four-jet final states at $\sqrt{s} = 13$ TeV with the ATLAS detector, Eur. Phys. J. C **78**, 250 (2018).

[22] ATLAS Collaboration, Search for pair production of massive particles decaying into three quarks with the ATLAS detector in $\sqrt{s} = 7$ TeV pp collisions at the LHC, J. High Energy Phys. 12 (2012) 086.

[23] CMS Collaboration, Search for pair-produced resonances decaying to jet pairs in proton–proton collisions at $\sqrt{s} = 8$ TeV, Phys. Lett. B **747**, 98 (2015).

[24] CMS Collaboration, Search for pair-produced resonances decaying to quark pairs in proton-proton collisions at $\sqrt{s} = 13$ TeV, Phys. Rev. D **98**, 112014 (2018).

[25] CMS Collaboration, Search for pair-produced dijet resonances in four-jet final states in pp collisions at $\sqrt{s} = 7$ TeV, Phys. Rev. Lett. **110**, 141802 (2013).

[26] CMS Collaboration, Search for resonant and nonresonant production of pairs of dijet resonances in proton-proton collisions at $\sqrt{s} = 13$ TeV, J. High Energy Phys. 07 (2023) 161.

[27] HEPData record for this analysis (2024), 10.17182/hepdata.150407.

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

[29] CMS Collaboration, Performance of the CMS level-1 trigger in proton-proton collisions at $\sqrt{s} = 13$ TeV, J. Instrum. **15**, P10017 (2020).

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

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

[32] 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).

[33] CMS Collaboration, Description and performance of track and primary-vertex reconstruction with the CMS tracker, J. Instrum. **9**, P10009 (2014).

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

[35] CMS Collaboration, Performance of reconstruction and identification of τ leptons decaying to hadrons and ν_τ in pp collisions at $\sqrt{s} = 13$ TeV, J. Instrum. **13**, P10005 (2018).

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

[37] 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).

[38] J. Alwall, R. Frederix, S. Frixione, V. Hirschi, F. Maltoni, O. Mattelaer, H.-S. Shao, T. Stelzer, P. Torrielli, 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.

[39] J. Alwall, S. Höche, F. Krauss, N. Lavesson, L. Lönnblad, F. Maltoni, M. L. Mangano, M. Moretti, C. G. Papadopoulos,

F. Piccinini, S. Schumann, M. Treccani, J. Winter, and M. Worek, Comparative study of various algorithms for the merging of parton showers and matrix elements in hadronic collisions, Eur. Phys. J. C **53**, 473 (2008).
[40] T. Sjöstrand, S. Ask, J. R. Christiansen, R. Corke, N. Desai, P. Ilten, S. Mrenna, S. Prestel, C. O. Rasmussen, and P. Z. Skands, An introduction to PYTHIA8.2, Comput. Phys. Commun. **191**, 159 (2015).
[41] CMS Collaboration, Extraction and validation of a new set of CMS PYTHIA8 tunes from underlying-event measurements, Eur. Phys. J. C **80**, 4 (2020).
[42] R. D. Ball *et al.* (NNPDF Collaboration), Parton distributions for the LHC Run II, J. High Energy Phys. 04 (2015) 040.
[43] S. Agostinelli *et al.* (GEANT4 Collaboration), GEANT4—a simulation toolkit, Nucl. Instrum. Methods Phys. Res., Sect. A **506**, 250 (2003).
[44] A. Gandrakota, A. Lath, A. V. Morozov, and S. Murthy, Model selection and signal extraction using Gaussian process regression, J. High Energy Phys. 02 (2023) 230.
[45] M. Cacciari, G. P. Salam, and G. Soyez, FastJet user manual, Eur. Phys. J. C **72**, 1896 (2012).
[46] M. Cacciari and G. P. Salam, Dispelling the N^3 myth for the k_t jet-finder, Phys. Lett. B **641**, 57 (2006).
[47] M. Cacciari, G. P. Salam, and G. Soyez, The anti-k_T jet clustering algorithm, J. High Energy Phys. 04 (2008) 063.
[48] CMS Collaboration, Pileup mitigation at CMS in 13 TeV data, J. Instrum. **15**, P09018 (2020).
[49] CMS Collaboration, Jet algorithms performance in 13 TeV data, CMS Physics Analysis Summary CMS-PAS-JME-16-003 (2017), https://cds.cern.ch/record/2256875.
[50] D. Krohn, J. Thaler, and L.-T. Wang, Jet trimming, J. High Energy Phys. 02 (2018) 084.
[51] J. Thaler and K. Van Tilburg, Identifying boosted objects with N-subjettiness, J. High Energy Phys. 03 (2011) 015.
[52] I. Moult, L. Necib, and J. Thaler, New angles on energy correlation functions, J. High Energy Phys. 12 (2016) 153.
[53] J. Dolen, P. Harris, S. Marzani, S. Rappoccio, and N. Tran, Thinking outside the ROCs: Designing decorrelated taggers (DDT) for jet substructure, J. High Energy Phys. 05 (2016) 156.
[54] CMS Collaboration, Search for low mass vector resonances decaying into quark-antiquark pairs in proton-proton collisions at $\sqrt{s} = 13$ TeV, J. High Energy Phys. 01 (2018) 097.
[55] CMS Collaboration, Search for low mass vector resonances decaying into quark-antiquark pairs in proton-proton collisions at $\sqrt{s} = 13$ TeV, Phys. Rev. D **100**, 112007 (2019).
[56] CMS Collaboration, Search for low-mass quark-antiquark resonances produced in association with a photon at $\sqrt{s} = 13$ TeV, Phys. Rev. Lett. **123**, 231803 (2019).
[57] P. T. Komiske, E. M. Metodiev, and J. Thaler, Energy flow networks: Deep sets for particle jets, J. High Energy Phys. 01 (2019) 121.
[58] C. E. Rasmussen and C. K. I. Williams, *Gaussian Processes for Machine Learning* (The MIT Press, Cambridge, MA, 2005).
[59] M. Frate, K. Cranmer, S. Kalia, A. Vandenberg-Rodes, and D. Whiteson, Modeling smooth backgrounds and generic localized signals with Gaussian processes, arXiv:1709.05681.
[60] G. Cowan (Particle Data Group), Statistics, Chap. 39; C. Patrignani *et al.*, Review of particle physics, Chin. Phys. C **40**, 100001 (2016).
[61] ATLAS, CMS, and LHC Higgs Combination Group Collaborations, Procedure for the LHC Higgs boson search combination in Summer 2011, Technical Report No. CMS-NOTE-2011-005, ATL-PHYS-PUB-2011-11, CERN, Geneva, Switzerland, 2011, https://cds.cern.ch/record/1379837.
[62] D. Foreman-Mackey, D. W. Hogg, D. Lang, and J. Goodman, emcee: The MCMC hammer, Publ. Astron. Soc. Pac. **125**, 306 (2013).
[63] G. Cowan, K. Cranmer, E. Gross, and O. Vitells, Asymptotic formulae for likelihood-based tests of new physics, Eur. Phys. J. C **71**, 1554 (2011); **73**, 2501(E) (2013).
[64] A. L. Read, Presentation of search results: The CL_s technique, J. Phys. G **28**, 2693 (2002).
[65] T. Junk, Confidence level computation for combining searches with small statistics, Nucl. Instrum. Methods Phys. Res., Sect. A **434**, 435 (1999).
[66] C. Borschensky, M. Krämer, A. Kulesza, M. Mangano, S. Padhi, T. Plehn, and X. Portell, Squark and gluino production cross sections in pp collisions at $\sqrt{s} = 13$, 14, 33 and 100 TeV, Eur. Phys. J. C **74**, 3174 (2014).

A. Hayrapetyan,[1] A. Tumasyan,[1,b] W. Adam,[2] J. W. Andrejkovic,[2] T. Bergauer,[2] S. Chatterjee,[2] K. Damanakis,[2] M. Dragicevic,[2] P. S. Hussain,[2] M. Jeitler,[2,c] N. Krammer,[2] A. Li,[2] D. Liko,[2] I. Mikulec,[2] J. Schieck,[2,c] R. Schöfbeck,[2] D. Schwarz,[2] M. Sonawane,[2] S. Templ,[2] W. Waltenberger,[2] C.-E. Wulz,[2,c] M. R. Darwish,[3,d] T. Janssen,[3] P. Van Mechelen,[3] N. Breugelmans,[4] J. D'Hondt,[4] S. Dansana,[4] A. De Moor,[4] M. Delcourt,[4] F. Heyen,[4] S. Lowette,[4] I. Makarenko,[4] D. Müller,[4] S. Tavernier,[4] M. Tytgat,[4,e] G. P. Van Onsem,[4] S. Van Putte,[4] D. Vannerom,[4] B. Clerbaux,[5] A. K. Das,[5] G. De Lentdecker,[5] H. Evard,[5] L. Favart,[5] P. Gianneios,[5] D. Hohov,[5] J. Jaramillo,[5] A. Khalilzadeh,[5] F. A. Khan,[5] K. Lee,[5] M. Mahdavikhorrami,[5] A. Malara,[5] S. Paredes,[5] L. Thomas,[5] M. Vanden Bemden,[5] C. Vander Velde,[5] P. Vanlaer,[5] M. De Coen,[6] D. Dobur,[6] G. Gokbulut,[6] Y. Hong,[6] J. Knolle,[6] L. Lambrecht,[6] D. Marckx,[6] G. Mestdach,[6] K. Mota Amarilo,[6] C. Rendón,[6] A. Samalan,[6] K. Skovpen,[6] N. Van Den Bossche,[6] J. van der Linden,[6] L. Wezenbeek,[6] A. Benecke,[7] A. Bethani,[7] G. Bruno,[7]

C. Caputo,[7] J. De Favereau De Jeneret,[7] C. Delaere,[7] I. S. Donertas,[7] A. Giammanco,[7] A. O. Guzel,[7] Sa. Jain,[7] V. Lemaitre,[7] J. Lidrych,[7] P. Mastrapasqua,[7] T. T. Tran,[7] S. Wertz,[7] G. A. Alves,[8] E. Coelho,[8] C. Hensel,[8] T. Menezes De Oliveira,[8] A. Moraes,[8] P. Rebello Teles,[8] M. Soeiro,[8] A. Vilela Pereira,[8,f] W. L. Aldá Júnior,[9] M. Alves Gallo Pereira,[9] M. Barroso Ferreira Filho,[9] H. Brandao Malbouisson,[9] W. Carvalho,[9] J. Chinellato,[9,g] E. M. Da Costa,[9] G. G. Da Silveira,[9,h] D. De Jesus Damiao,[9] S. Fonseca De Souza,[9] R. Gomes De Souza,[9] M. Macedo,[9] J. Martins,[9,i] C. Mora Herrera,[9] L. Mundim,[9] H. Nogima,[9] J. P. Pinheiro,[9] A. Santoro,[9] A. Sznajder,[9] M. Thiel,[9] C. A. Bernardes,[10,h] L. Calligaris,[10] T. R. Fernandez Perez Tomei,[10] E. M. Gregores,[10] I. Maietto Silverio,[10] P. G. Mercadante,[10] S. F. Novaes,[10] B. Orzari,[10] Sandra S. Padula,[10] A. Aleksandrov,[11] G. Antchev,[11] R. Hadjiiska,[11] P. Iaydjiev,[11] M. Misheva,[11] M. Shopova,[11] G. Sultanov,[11] A. Dimitrov,[12] L. Litov,[12] B. Pavlov,[12] P. Petkov,[12] A. Petrov,[12] E. Shumka,[12] S. Keshri,[13] S. Thakur,[13] T. Cheng,[14] T. Javaid,[14] L. Yuan,[14] Z. Hu,[15] Z. Liang,[15] J. Liu,[15] K. Yi,[15,j,k] G. M. Chen,[16,l] H. S. Chen,[16,l] M. Chen,[16,l] F. Iemmi,[16] C. H. Jiang,[16] A. Kapoor,[16,m] H. Liao,[16] Z.-A. Liu,[16,n] R. Sharma,[16,o] J. N. Song,[16,n] J. Tao,[16] C. Wang,[16,l] J. Wang,[16] Z. Wang,[16,l] H. Zhang,[16] J. Zhao,[16] A. Agapitos,[17] Y. Ban,[17] S. Deng,[17] B. Guo,[17] A. Levin,[17] C. Li,[17] Q. Li,[17] Y. Mao,[17] S. Qian,[17] S. J. Qian,[17] X. Sun,[17] D. Wang,[17] H. Yang,[17] L. Zhang,[17] Y. Zhao,[17] C. Zhou,[17] S. Yang,[18] Z. You,[19] K. Jaffel,[20] N. Lu,[20] G. Bauer,[21,p] B. Li,[21] J. Zhang,[21] X. Gao,[22,q] Z. Lin,[23] C. Lu,[23] M. Xiao,[23] C. Avila,[24] D. A. Barbosa Trujillo,[24] A. Cabrera,[24] C. Florez,[24] J. Fraga,[24] J. A. Reyes Vega,[24] F. Ramirez,[25] M. Rodriguez,[25] A. A. Ruales Barbosa,[25] J. D. Ruiz Alvarez,[25] D. Giljanovic,[26] N. Godinovic,[26] D. Lelas,[26] A. Sculac,[26] M. Kovac,[27] A. Petkovic,[27] T. Sculac,[27] P. Bargassa,[28] V. Brigljevic,[28] B. K. Chitroda,[28] D. Ferencek,[28] K. Jakovcic,[28] S. Mishra,[28] A. Starodumov,[28,r] T. Susa,[28] A. Attikis,[29] K. Christoforou,[29] A. Hadjiagapiou,[29] C. Leonidou,[29] J. Mousa,[29] C. Nicolaou,[29] L. Paizanos,[29] F. Ptochos,[29] P. A. Razis,[29] H. Rykaczewski,[29] H. Saka,[29] A. Stepennov,[29] M. Finger,[30] M. Finger Jr.,[30] A. Kveton,[30] E. Carrera Jarrin,[31] Y. Assran,[32,s,t] B. El-mahdy,[32] S. Elgammal,[32,t] A. Lotfy,[33] M. A. Mahmoud,[33] K. Ehataht,[34] M. Kadastik,[34] T. Lange,[34] S. Nandan,[34] C. Nielsen,[34] J. Pata,[34] M. Raidal,[34] L. Tani,[34] C. Veelken,[34] H. Kirschenmann,[35] K. Osterberg,[35] M. Voutilainen,[35] S. Bharthuar,[36] E. Brücken,[36] F. Garcia,[36] P. Inkaew,[36] K. T. S. Kallonen,[36] R. Kinnunen,[36] T. Lampén,[36] K. Lassila-Perini,[36] S. Lehti,[36] T. Lindén,[36] L. Martikainen,[36] M. Myllymäki,[36] M. m. Rantanen,[36] H. Siikonen,[36] J. Tuominiemi,[36] P. Luukka,[37] H. Petrow,[37] M. Besancon,[38] F. Couderc,[38] M. Dejardin,[38] D. Denegri,[38] J. L. Faure,[38] F. Ferri,[38] S. Ganjour,[38] P. Gras,[38] G. Hamel de Monchenault,[38] V. Lohezic,[38] J. Malcles,[38] F. Orlandi,[38] L. Portales,[38] J. Rander,[38] A. Rosowsky,[38] M. Ö. Sahin,[38] A. Savoy-Navarro,[38,u] P. Simkina,[38] M. Titov,[38] M. Tornago,[38] F. Beaudette,[39] P. Busson,[39] A. Cappati,[39] C. Charlot,[39] M. Chiusi,[39] F. Damas,[39] O. Davignon,[39] A. De Wit,[39] I. T. Ehle,[39] B. A. Fontana Santos Alves,[39] S. Ghosh,[39] A. Gilbert,[39] R. Granier de Cassagnac,[39] A. Hakimi,[39] B. Harikrishnan,[39] L. Kalipoliti,[39] G. Liu,[39] M. Nguyen,[39] C. Ochando,[39] R. Salerno,[39] J. B. Sauvan,[39] Y. Sirois,[39] E. Vernazza,[39] A. Zabi,[39] A. Zghiche,[39] J.-L. Agram,[40,v] J. Andrea,[40] D. Apparu,[40] D. Bloch,[40] J.-M. Brom,[40] E. C. Chabert,[40] C. Collard,[40] S. Falke,[40] U. Goerlach,[40] R. Haeberle,[40] A.-C. Le Bihan,[40] M. Meena,[40] O. Poncet,[40] G. Saha,[40] M. A. Sessini,[40] P. Van Hove,[40] P. Vaucelle,[40] D. Amram,[41] S. Beauceron,[41] B. Blancon,[41] G. Boudoul,[41] N. Chanon,[41] D. Contardo,[41] P. Depasse,[41] C. Dozen,[41,w] H. El Mamouni,[41] J. Fay,[41] S. Gascon,[41] M. Gouzevitch,[41] C. Greenberg,[41] G. Grenier,[41] B. Ille,[41] E. Jourd`huy,[41] I. B. Laktineh,[41] M. Lethuillier,[41] L. Mirabito,[41] S. Perries,[41] A. Purohit,[41] M. Vander Donckt,[41] P. Verdier,[41] J. Xiao,[41] A. Khvedelidze,[42,r] I. Lomidze,[42] Z. Tsamalaidze,[42,r] V. Botta,[43] L. Feld,[43] K. Klein,[43] M. Lipinski,[43] D. Meuser,[43] A. Pauls,[43] N. Röwert,[43] M. Teroerde,[43] S. Diekmann,[44] A. Dodonova,[44] N. Eich,[44] D. Eliseev,[44] F. Engelke,[44] J. Erdmann,[44] M. Erdmann,[44] P. Fackeldey,[44] B. Fischer,[44] T. Hebbeker,[44] K. Hoepfner,[44] F. Ivone,[44] A. Jung,[44] M. y. Lee,[44] F. Mausolf,[44] M. Merschmeyer,[44] A. Meyer,[44] S. Mukherjee,[44] D. Noll,[44] F. Nowotny,[44] A. Pozdnyakov,[44] Y. Rath,[44] W. Redjeb,[44] F. Rehm,[44] H. Reithler,[44] V. Sarkisovi,[44] A. Schmidt,[44] A. Sharma,[44] J. L. Spah,[44] A. Stein,[44] F. Torres Da Silva De Araujo,[44,x] S. Wiedenbeck,[44] S. Zaleski,[44] C. Dziwok,[45] G. Flügge,[45] T. Kress,[45] A. Nowack,[45] O. Pooth,[45] A. Stahl,[45] T. Ziemons,[45] A. Zotz,[45] H. Aarup Petersen,[46] M. Aldaya Martin,[46] J. Alimena,[46] S. Amoroso,[46] Y. An,[46] J. Bach,[46] S. Baxter,[46] M. Bayatmakou,[46] H. Becerril Gonzalez,[46] O. Behnke,[46] A. Belvedere,[46] S. Bhattacharya,[46] F. Blekman,[46,y] K. Borras,[46,z] A. Campbell,[46] A. Cardini,[46] C. Cheng,[46] F. Colombina,[46] S. Consuegra Rodríguez,[46] G. Correia Silva,[46] M. De Silva,[46] G. Eckerlin,[46] D. Eckstein,[46] L. I. Estevez Banos,[46]

O. Filatov,[46] E. Gallo,[46,y] A. Geiser,[46] V. Guglielmi,[46] M. Guthoff,[46] A. Hinzmann,[46] L. Jeppe,[46] B. Kaech,[46] M. Kasemann,[46] C. Kleinwort,[46] R. Kogler,[46] M. Komm,[46] D. Krücker,[46] W. Lange,[46] D. Leyva Pernia,[46] K. Lipka,[46,aa] W. Lohmann,[46,bb] F. Lorkowski,[46] R. Mankel,[46] I.-A. Melzer-Pellmann,[46] M. Mendizabal Morentin,[46] A. B. Meyer,[46] G. Milella,[46] K. Moral Figueroa,[46] A. Mussgiller,[46] L. P. Nair,[46] J. Niedziela,[46] A. Nürnberg,[46] Y. Otarid,[46] J. Park,[46] D. Pérez Adán,[46] E. Ranken,[46] A. Raspereza,[46] D. Rastorguev,[46] J. Rübenach,[46] L. Rygaard,[46] A. Saggio,[46] M. Scham,[46,cc,z] S. Schnake,[46,z] P. Schütze,[46] C. Schwanenberger,[46,y] D. Selivanova,[46] K. Sharko,[46] M. Shchedrolosiev,[46] D. Stafford,[46] F. Vazzoler,[46] A. Ventura Barroso,[46] R. Walsh,[46] D. Wang,[46] Q. Wang,[46] Y. Wen,[46] K. Wichmann,[46] L. Wiens,[46,z] C. Wissing,[46] Y. Yang,[46] A. Zimermmane Castro Santos,[46] A. Albrecht,[47] S. Albrecht,[47] M. Antonello,[47] S. Bein,[47] L. Benato,[47] S. Bollweg,[47] M. Bonanomi,[47] P. Connor,[47] K. El Morabit,[47] Y. Fischer,[47] E. Garutti,[47] A. Grohsjean,[47] J. Haller,[47] H. R. Jabusch,[47] G. Kasieczka,[47] P. Keicher,[47] R. Klanner,[47] W. Korcari,[47] T. Kramer,[47] C. c. Kuo,[47] V. Kutzner,[47] F. Labe,[47] J. Lange,[47] A. Lobanov,[47] C. Matthies,[47] L. Moureaux,[47] M. Mrowietz,[47] A. Nigamova,[47] Y. Nissan,[47] A. Paasch,[47] K. J. Pena Rodriguez,[47] T. Quadfasel,[47] B. Raciti,[47] M. Rieger,[47] D. Savoiu,[47] J. Schindler,[47] P. Schleper,[47] M. Schröder,[47] J. Schwandt,[47] M. Sommerhalder,[47] H. Stadie,[47] G. Steinbrück,[47] A. Tews,[47] M. Wolf,[47] S. Brommer,[48] M. Burkart,[48] E. Butz,[48] T. Chwalek,[48] A. Dierlamm,[48] A. Droll,[48] N. Faltermann,[48] M. Giffels,[48] A. Gottmann,[48] F. Hartmann,[48,dd] R. Hofsaess,[48] M. Horzela,[48] U. Husemann,[48] J. Kieseler,[48] M. Klute,[48] R. Koppenhöfer,[48] J. M. Lawhorn,[48] M. Link,[48] A. Lintuluoto,[48] B. Maier,[48] S. Maier,[48] S. Mitra,[48] M. Mormile,[48] Th. Müller,[48] M. Neukum,[48] M. Oh,[48] E. Pfeffer,[48] M. Presilla,[48] G. Quast,[48] K. Rabbertz,[48] B. Regnery,[48] N. Shadskiy,[48] I. Shvetsov,[48] H. J. Simonis,[48] L. Sowa,[48] L. Stockmeier,[48] K. Tauqeer,[48] M. Toms,[48] N. Trevisani,[48] R. F. Von Cube,[48] M. Wassmer,[48] S. Wieland,[48] F. Wittig,[48] R. Wolf,[48] X. Zuo,[48] G. Anagnostou,[49] G. Daskalakis,[49] A. Kyriakis,[49] A. Papadopoulos,[49,dd] A. Stakia,[49] P. Kontaxakis,[50] G. Melachroinos,[50] Z. Painesis,[50] A. Panagiotou,[50] I. Papavergou,[50] I. Paraskevas,[50] N. Saoulidou,[50] K. Theofilatos,[50] E. Tziaferi,[50] K. Vellidis,[50] I. Zisopoulos,[50] G. Bakas,[51] T. Chatzistavrou,[51] G. Karapostoli,[51] K. Kousouris,[51] I. Papakrivopoulos,[51] E. Siamarkou,[51] G. Tsipolitis,[51] A. Zacharopoulou,[51] K. Adamidis,[52] I. Bestintzanos,[52] I. Evangelou,[52] C. Foudas,[52] C. Kamtsikis,[52] P. Katsoulis,[52] P. 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Konstantinov,[187] V. Korenkov,[187] A. Kozyrev,[187,r] N. Krasnikov,[187] A. Lanev,[187] P. Levchenko,[187,rrrr] N. Lychkovskaya,[187] V. Makarenko,[187] A. Malakhov,[187] V. Matveev,[187,r] V. Murzin,[187] A. Nikitenko,[187,ssss,qqqq] S. Obraztsov,[187] V. Oreshkin,[187] V. Palichik,[187] V. Perelygin,[187] M. Perfilov,[187] S. Polikarpov,[187,r] V. Popov,[187] O. Radchenko,[187,r] M. Savina,[187] V. Savrin,[187] V. Shalaev,[187] S. Shmatov,[187] S. Shulha,[187] Y. Skovpen,[187,r] S. Slabospitskii,[187] V. Smirnov,[187] A. Snigirev,[187]

D. Sosnov,[187] V. Sulimov,[187] E. Tcherniaev,[187] A. Terkulov,[187] O. Teryaev,[187] I. Tlisova,[187] A. Toropin,[187] L. Uvarov,[187] A. Uzunian,[187] A. Vorobyev,[187,a] N. Voytishin,[187] B. S. Yuldashev,[187,tttt] A. Zarubin,[187] I. Zhizhin,[187] and A. Zhokin[187]

(CMS Collaboration)

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

[50]National and Kapodistrian University of Athens, Athens, Greece
[51]National Technical University of Athens, Athens, Greece
[52]University of Ioánnina, Ioánnina, Greece
[53]HUN-REN Wigner Research Centre for Physics, Budapest, Hungary
[54]MTA-ELTE Lendület CMS Particle and Nuclear Physics Group, Eötvös Loránd University, Budapest, Hungary
[55]Faculty of Informatics, University of Debrecen, Debrecen, Hungary
[56]Institute of Nuclear Research ATOMKI, Debrecen, Hungary
[57]Karoly Robert Campus, MATE Institute of Technology, Gyongyos, Hungary
[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]Tata Institute of Fundamental Research-A, Mumbai, India
[63]Tata Institute of Fundamental Research-B, Mumbai, India
[64]National Institute of Science Education and Research, An OCC of Homi Bhabha National Institute, Bhubaneswar, Odisha, India
[65]Indian Institute of Science Education and Research (IISER), Pune, India
[66]Isfahan University of Technology, Isfahan, Iran
[67]Institute for Research in Fundamental Sciences (IPM), Tehran, Iran
[68]University College Dublin, Dublin, Ireland
[69]INFN Sezione di Bari, Università di Bari, Politecnico di Bari, Bari, Italy
[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]Scuola Superiore Meridionale (SSM), Napoli, 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, Roma, Italy
[81b]Sapienza Università di Roma, Roma, 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]Department of Mathematics and Physics - GWNU, Gangneung, Korea
[86]Chonnam National University, Institute for Universe and Elementary Particles, Kwangju, Korea
[87]Hanyang University, Seoul, Korea

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

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

[a]Deceased.
[b]Also at Yerevan State University, Yerevan, Armenia.
[c]Also at TU Wien, Vienna, Austria.
[d]Also at Institute of Basic and Applied Sciences, Faculty of Engineering, Arab Academy for Science, Technology and Maritime Transport, Alexandria, Egypt.
[e]Also at Ghent University, Ghent, Belgium.
[f]Also at Universidade do Estado do Rio de Janeiro, Rio de Janeiro, Brazil.
[g]Also at Universidade Estadual de Campinas, Campinas, Brazil.
[h]Also at Federal University of Rio Grande do Sul, Porto Alegre, Brazil.
[i]Also at UFMS, Nova Andradina, Brazil.
[j]Also at Nanjing Normal University, Nanjing, China.
[k]Also at The University of Iowa, Iowa City, Iowa, USA.
[l]Also at University of Chinese Academy of Sciences, Beijing, China.
[m]Also at China Center of Advanced Science and Technology, Beijing, China.
[n]Also at University of Chinese Academy of Sciences, Beijing, China.
[o]Also at China Spallation Neutron Source, Guangdong, China.
[p]Also at Henan Normal University, Xinxiang, China.
[q]Also at Université Libre de Bruxelles, Bruxelles, Belgium.
[r]Also at Another institute or international laboratory covered by a cooperation agreement with CERN.

[s]Also at Suez University, Suez, Egypt.
[t]Also at British University in Egypt, Cairo, Egypt.
[u]Also at Purdue University, West Lafayette, Indiana, USA.
[v]Also at Université de Haute Alsace, Mulhouse, France.
[w]Also at Department of Physics, Tsinghua University, Beijing, China.
[x]Also at The University of the State of Amazonas, Manaus, Brazil.
[y]Also at University of Hamburg, Hamburg, Germany.
[z]Also at RWTH Aachen University, III. Physikalisches Institut A, Aachen, Germany.
[aa]Also at Bergische University Wuppertal (BUW), Wuppertal, Germany.
[bb]Also at Brandenburg University of Technology, Cottbus, Germany.
[cc]Also at Forschungszentrum Jülich, Juelich, Germany.
[dd]Also at CERN, European Organization for Nuclear Research, Geneva, Switzerland.
[ee]Also at Institute of Physics, University of Debrecen, Debrecen, Hungary.
[ff]Also at Institute of Nuclear Research ATOMKI, Debrecen, Hungary.
[gg]Also at Universitatea Babes-Bolyai—Facultatea de Fizica, Cluj-Napoca, Romania.
[hh]Also at MTA-ELTE Lendület CMS Particle and Nuclear Physics Group, Eötvös Loránd University, Budapest, Hungary.
[ii]Also at HUN-REN Wigner Research Centre for Physics, Budapest, Hungary.
[jj]Also at Physics Department, Faculty of Science, Assiut University, Assiut, Egypt.
[kk]Also at Punjab Agricultural University, Ludhiana, India.
[ll]Also at University of Visva-Bharati, Santiniketan, India.
[mm]Also at Indian Institute of Science (IISc), Bangalore, India.
[nn]Also at IIT Bhubaneswar, Bhubaneswar, India.
[oo]Also at Institute of Physics, Bhubaneswar, India.
[pp]Also at University of Hyderabad, Hyderabad, India.
[qq]Also at Deutsches Elektronen-Synchrotron, Hamburg, Germany.
[rr]Also at Isfahan University of Technology, Isfahan, Iran.
[ss]Also at Sharif University of Technology, Tehran, Iran.
[tt]Also at Department of Physics, University of Science and Technology of Mazandaran, Behshahr, Iran.
[uu]Also at Department of Physics, Isfahan University of Technology, Isfahan, Iran.
[vv]Also at Department of Physics, Faculty of Science, Arak University, ARAK, Iran.
[ww]Also at Italian National Agency for New Technologies, Energy and Sustainable Economic Development, Bologna, Italy.
[xx]Also at Centro Siciliano di Fisica Nucleare e di Struttura Della Materia, Catania, Italy.
[yy]Also at Università degli Studi Guglielmo Marconi, Roma, Italy.
[zz]Also at Scuola Superiore Meridionale, Università di Napoli ‘Federico II’, Napoli, Italy.
[aaa]Also at Fermi National Accelerator Laboratory, Batavia, Illinois, USA.
[bbb]Also at Consiglio Nazionale delle Ricerche—Istituto Officina dei Materiali, Perugia, Italy.
[ccc]Also at Department of Applied Physics, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, Bangi, Malaysia.
[ddd]Also at Consejo Nacional de Ciencia y Tecnología, Mexico City, Mexico.
[eee]Also at Trincomalee Campus, Eastern University, Sri Lanka, Nilaveli, Sri Lanka.
[fff]Also at Saegis Campus, Nugegoda, Sri Lanka.
[ggg]Also at National and Kapodistrian University of Athens, Athens, Greece.
[hhh]Also at Ecole Polytechnique Fédérale Lausanne, Lausanne, Switzerland.
[iii]Also at Universität Zürich, Zurich, Switzerland.
[jjj]Also at Stefan Meyer Institute for Subatomic Physics, Vienna, Austria.
[kkk]Also at Laboratoire d’Annecy-le-Vieux de Physique des Particules, IN2P3-CNRS, Annecy-le-Vieux, France.
[lll]Also at Near East University, Research Center of Experimental Health Science, Mersin, Turkey.
[mmm]Also at Konya Technical University, Konya, Turkey.
[nnn]Also at Izmir Bakircay University, Izmir, Turkey.
[ooo]Also at Adiyaman University, Adiyaman, Turkey.
[ppp]Also at Bozok Universitetesi Rektörlügü, Yozgat, Turkey.
[qqq]Also at Marmara University, Istanbul, Turkey.
[rrr]Also at Milli Savunma University, Istanbul, Turkey.
[sss]Also at Kafkas University, Kars, Turkey.
[ttt]Also at stanbul Okan University, Istanbul, Turkey.
[uuu]Also at Hacettepe University, Ankara, Turkey.
[vvv]Also at Erzincan Binali Yildirim University, Erzincan, Turkey.
[www]Also at Istanbul University—Cerrahpasa, Faculty of Engineering, Istanbul, Turkey.
[xxx]Also at Yildiz Technical University, Istanbul, Turkey.
[yyy]Also at Vrije Universiteit Brussel, Brussel, Belgium.
[zzz]Also at School of Physics and Astronomy, University of Southampton, Southampton, United Kingdom.

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