Letter

Test of lepton flavor universality in semileptonic B_c^+ meson decays in proton-proton collisions at $\sqrt{s} = 13$ TeV

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A measurement of the ratio of branching fractions $R(J/\psi) = \mathcal{B}(B_c^+ \to J/\psi\tau^+\nu_\tau)/\mathcal{B}(B_c^+ \to J/\psi\mu^+\nu_\mu)$ in the $J/\psi \to \mu^+\mu^-$, $\tau^+ \to \mu^+\nu_\mu\bar{\nu}_\tau$ decay channel is presented. This measurement uses a sample of proton-proton collision data collected at a center-of-mass energy of 13 TeV by the CMS experiment in 2018, corresponding to an integrated luminosity of 59.7 fb^{-1}. The measured ratio, $R(J/\psi) = 0.17^{+0.18}_{-0.17}(\text{stat})^{+0.21}_{-0.22}(\text{syst})^{+0.19}_{-0.18}(\text{theo}) = 0.17 \pm 0.33$, agrees with the value of 0.2582 ± 0.0038 predicted by the standard model, which assumes lepton flavor universality. By testing lepton flavor universality, this measurement is a probe of new physics using B_c^+ mesons, which are currently only produced at the LHC.

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In the standard model (SM), the three lepton families have the same couplings for electroweak interactions, an accidental symmetry known as lepton flavor universality (LFU). Differences in decay rates between processes that differ solely by lepton flavor thus originate only from the different lepton masses.

Several beyond the SM (BSM) models that contain additional particles and nontrivial flavor interactions, such as an extended Higgs sector [1,2], leptoquarks [3], or an extended gauge sector [4], predict LFU violation. To date, no direct evidence for the existence of BSM particles has been found, and constraints are set on these models, e.g., in Refs. [5–7]. However, even if they are too heavy to be produced at existing colliders, BSM particles could still contribute via virtual interactions and alter the decay rates predicted by the SM.

Lepton flavor universality has been confirmed in leptonic Z and W boson decays down to the per-mille level [8–12] and, in recent years, has been extensively tested in semileptonic b hadron (H_b) decays through the measurement of ratios of branching fractions. In particular, the *BABAR* [13], Belle [14,15], and LHCb [16–18] collaborations investigated the $R(D^*) = \mathcal{B}(B^0 \to D^{*-}\tau^+\nu_\tau)/\mathcal{B}(B^0 \to D^{*-}\mu^+\nu_\mu)$ ratio, observing a combined value of $R(D^*) = 0.295 \pm 0.014$, 3.2 standard deviations above the SM expected value of 0.254 ± 0.005 [19]. In this Letter, charge conjugate states are implied.

The same, possibly nonuniversal, lepton couplings in $b \to c\ell\nu_\ell$ transitions can also be experimentally tested in semitauonic decays from H_b hadrons other than B^0. In this Letter, we present the measurement of the ratio

$$R(J/\psi) = \frac{\mathcal{B}(B_c^+ \to J/\psi\tau^+\nu_\tau)}{\mathcal{B}(B_c^+ \to J/\psi\mu^+\nu_\mu)}.$$

A recent calculation predicts a value of $R(J/\psi) = 0.2582 \pm 0.0038$ [20], which is consistent with earlier estimates [21–24]. Since B_c^+ mesons cannot be produced at the existing B factories, this ratio has not been extensively explored. The only measurement to date, by the LHCb Collaboration [25], reports a two standard deviation excess over the SM prediction. The present measurement, which is also provided in a HEPData record [26], uses a sample of proton-proton collision data collected at a center-of-mass energy of 13 TeV by the CMS experiment in 2018, corresponding to an integrated luminosity of 59.7 fb^{-1} [27].

The CMS apparatus [28] is a multipurpose, nearly hermetic detector, designed to trigger on [29,30] and identify electrons, muons, photons, and (charged and neutral) hadrons [31–33]. A global "particle-flow" 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 particles are used to build τ leptons, jets, and missing transverse momentum, defined as the negative vector sum of the

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transverse momenta of all the reconstructed candidates in an event [35–38].

The analysis reconstructs both the $B_c^+ \to J/\psi\tau^+\nu_\tau$ and $B_c^+ \to J/\psi\mu^+\nu_\mu$ signals in the $J/\psi \to \mu^+\mu^-$ and $\tau^+ \to \mu^+\nu_\mu\bar{\nu}_\tau$ decay chains, thus resulting in the identical visible products $(\mu^+\mu^-)\mu^+$ for both processes, where the muon not originating from the J/ψ meson decay is referred to as the "third" muon. The signal final states differ in the number of neutrinos and the muon topology, owing to the tau lepton lifetime. Several background contributions are considered: processes where the J/ψ meson and the third muon come from either the same or different b hadrons (including a B_c^+ meson, excluding the signal modes), events where a hadron is misidentified as the third muon, and three-muon events with two unrelated opposite-charge muons with invariant mass $m_{\mu\mu}$ close to that of the J/ψ meson. Backgrounds are estimated from data control regions (CRs) or, when not possible, from simulations complemented with inputs from data. The expected signal and background contributions are fitted to data to extract $R(J/\psi)$ through a maximum likelihood binned fit.

Events are retained if they satisfy triggers requiring three muons with $p_T > 5$, 3.5 and 2 GeV, all within pseudorapidity $|\eta| < 2.5$, the invariant mass of at least one opposite-charge muon pair to lie between 2.95 and 3.25 GeV, consistent with the world-average J/ψ meson mass $m_{J/\psi} = 3.097$ GeV [39], and the corresponding p value of the dimuon vertex fit greater than 0.5%.

In the offline data analysis, further requirements are applied to events satisfying the trigger selection. The J/ψ candidates are required to have a vertex fit p value above 1% and a reconstructed mass within 50 MeV of $m_{J/\psi}$ if all muons have $|\eta| < 1$, 100 MeV if they have $|\eta| > 1$, or 70 MeV otherwise. In each event, the three muon candidates must have $p_T > 4$ GeV and $|\eta| < 2.4$, and at least one must have $p_T > 6$ GeV. The two muons forming the J/ψ candidate must satisfy the "medium" working point of the standard CMS muon identification algorithm [32].

For each 3μ candidate, its corresponding primary vertex (PV) is defined as the one with the shortest longitudinal distance with respect to the J/ψ meson momentum direction backpropagated onto the beam line. The transverse impact parameter (defined as the distance of closest approach of the particle's trajectory to the beam line) of each muon track is required to be smaller than 0.5 mm to ensure its compatibility with coming from a decay of a B_c^+ meson. For any pair of muons, the absolute difference between their longitudinal impact parameters must be smaller than 2 mm to further reduce accidental combinations of muons coming from different PVs. Finally, the three muons are required to have a vertex fit p value above 0.01%, with the two muons forming the J/ψ candidate constrained to the J/ψ mass.

Kinematical variables sensitive to the large mass difference between tau leptons and muons and to the presence of two additional neutrinos in the $\tau^+ \to \mu^+\nu_\mu\bar{\nu}_\tau$ decay allow disentangling the two signals and help to identify and reduce backgrounds. The determination of such variables benefits from the knowledge of the original B_c^+ candidate 4-momentum in the laboratory frame ($p_{B_c^+}$), which can only be inferred indirectly, due to undetected neutrinos. The B_c^+ 4-momentum is estimated from the 3μ candidate 4-momentum $p_{3\mu}^{\text{vis}}$ and mass $m_{3\mu}^{\text{vis}}$ as $p_{B_c^+} = (m_{B_c^+}/m_{3\mu}^{\text{vis}})p_{3\mu}^{\text{vis}}$, where $m_{B_c^+}$ is the B_c^+ meson mass [39]. The direction of $p_{B_c^+}$ is therefore assumed to be aligned with that of $p_{3\mu}^{\text{vis}}$. A variable that efficiently discriminates between the final states of the two signal decays is the squared 4-momentum transfer to the lepton system $q^2 = (p_{B_c^+} - p_{J/\psi})^2$, where $p_{J/\psi}$ is the 4-momentum of the J/ψ candidate. In addition, two topological observables are also used: IP3D/σ_{IP3D}, where the three-dimensional impact parameter (IP3D) is the shortest distance from the third muon track to the J/ψ vertex with a sign depending on whether the trajectory of the third muon reaches the minimum distance before or after the J/ψ vertex along the J/ψ candidate momentum direction and σ_{IP3D} is its uncertainty, and $L_{xy}/\sigma_{L_{xy}}$, where L_{xy} is the distance between the J/ψ meson decay vertex and beam line in the transverse plane and $\sigma_{L_{xy}}$ is its uncertainty.

Simulated samples are used to model all contributions yielding a J/ψ meson in association with a genuine μ^+ from either the same or different decay chains, as opposed to a misidentified muon (misID), defined as a muon from K^+ or π^+ decays, photon conversions, or misreconstructed hadrons. Processes with misID or where the J/ψ candidate arises from accidental muon pairs are estimated from data, as discussed later. Two separate Monte Carlo (MC) samples describe decays initiated by a B_c^+ meson or another H_b.

In the first sample, B_c^+ mesons are generated with the dedicated BCVEGPY 2.2b [40] software. Decays of interest are forced using EVTGEN 1.6.0 [41], and the event hadronization is handled by Pythia 8.240 [42]. The set of forced decays includes the signal channels, $B_c^+ \to J/\psi\mu^+\nu_\mu$ and $B_c^+ \to J/\psi\tau^+\nu_\tau$ [all τ^+ decays are allowed and $\mathcal{B}(\tau^+ \to \mu^+\nu_\mu\nu_\tau) = 17.41\%$], $c\bar{c}$ states that decay into the J/ψ meson, and other $B_c^+ \to J/\psi D_{(s)}^{(*)}X$ decays, where X indicates up to two extra hadrons. The only feed-down processes with sizable contributions after the final selection are $B_c^+ \to \psi(2S)\mu^+\nu_\mu$, $B_c^+ \to \chi_{c1}(1P)\mu^+\nu_\mu$, and $B_c^+ \to \chi_{c2}(1P)\mu^+\nu_\mu$. While $B_c^+ \to \psi(2S)\tau^+\nu_\tau$ is also considered in the analysis, its final yield is negligible. The branching fractions of the various forced decays are expressed relative to $\mathcal{B}(B_c^+ \to J/\psi\mu^+\nu_\mu)$ and fixed to their measured values [39,43–46] or, lacking thereof, to theoretical predictions or upper limits. The properties of the interaction between the B_c^+ meson constituent quarks are described by form factors, which govern the decay kinematics and therefore impact the q^2 observable. In this sample, for the $B_c^+ \to J/\psi\tau^+\nu_\tau$ and $B_c^+ \to J/\psi\mu^+\nu_\mu$

processes, the form factors predicted in Ref. [47] are used. A generator-level reweighting procedure based on the Hammer package [48] is employed to update the form factors to more recent predictions based on the lattice quantum chromodynamics for semileptonic $b \to c\ell\nu$ transitions [49].

In the second sample, $\mathrm{H}_b \to J/\psi(\to \mu^+\mu^-) + \mu^+$ processes are simulated. The third muon can come from either the same H_b as the J/ψ meson or an unrelated source. The Pythia generator is used to produce and hadronize b quark pairs into H_b; then, EVTGEN is used to enforce decays of interest. To improve the generation efficiency, H_b are forced to decay in modes that contain a J/ψ meson (including feed-downs). The list of H_b that are subject to forced decays includes B^+, B^0, B^0_s, Λ^0_b, Ξ^-_b, Ξ^0_b, Σ^-_b, and Ω^-_b and corresponds to all H_b that can give rise to a J/ψ meson in at least one decay mode, based on Ref. [39], except for B^+_c decays, as discussed earlier. Five excited $c\bar{c}$ resonances, $\psi(2S)$, $\psi(3770)$, $\chi_{c0}(1P)$, $\chi_{c1}(1P)$, and $\chi_{c2}(1P)$ are forced to decay in modes with a J/ψ meson, if they come from an H_b. The relative proportions between different decays are preserved. The majority (98%) of $\mathrm{H}_b \to J/\psi(\to \mu^+\mu^-) + \mu^+$ backgrounds arise from the accidental pairing of a J/ψ and a μ^+ candidate from different decay chains, which can therefore populate the $m(3\mu) > m_{B^+_c}$ CR, otherwise kinematically forbidden for both $B^+_c \to J/\psi\tau^+\nu_\tau$ and $B^+_c \to J/\psi\mu^+\nu_\mu$ decays. This signal-depleted, background-enriched region is used in the fit to determine the yield of the H_b background, without relying on the precise knowledge of the $b\bar{b}$ cross section.

For both MC samples, additional proton-proton collisions within the same or adjacent bunch crossings (pileup), drawn from a large minimum bias sample produced with Pythia, are superimposed on the simulated $b\bar{b}$ event. Final-state photon radiation is generated using the PHOTOS 3.61 toolkit [50]. The Geant4 package [51] is used to model the interaction of the generated particles with the CMS detector, and the samples are processed through the standard CMS reconstruction software.

Despite the excellent muon identification performance of CMS, the largest background source corresponds to events where the third muon comes from charged pion or kaon decays. This background component, referred to as "misID background," is estimated *in situ* from CRs in data. This background is reduced primarily through the optimization of the identification and isolation requirements imposed on the third muon. Since both signals have low multiplicity, the third muon is expected to be more isolated from additional nearby particles in signal events than in H_b decays with several hadrons in the final state. The standard CMS relative muon isolation (I^{rel}) [32], defined as the sum of the transverse momenta of all the hadrons coming from the PV in a cone of $\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2} = 0.3$, and a multivariate muon identification algorithm [52] (ID) are used.

The shape and yield of the misID background contribution in the signal region (SR), where the third muon satisfies both the isolation ($I^{\mathrm{rel}} < 0.2$) and identification ($\mathrm{ID} = 1$) criteria, are predicted through a data-driven method based on three background-enriched CRs: $I^{\mathrm{rel}} < 0.2$ and $\mathrm{ID} \neq 1$, $I^{\mathrm{rel}} > 0.2$ and $\mathrm{ID} = 1$, and $I^{\mathrm{rel}} > 0.2$ and $\mathrm{ID} \neq 1$. First, the probability for a misID hadron to satisfy $I^{\mathrm{rel}} < 0.2$ is measured using events with $\mathrm{ID} \neq 1$. This multiple-dimension distribution is fit with a neural network (NN) binary classifier to accurately model the dependence on several kinematical and topological observables and ensure its applicability to a different phase space. The NN uses ten inputs, comprising the muon p_T and $|\eta|$, secondary vertex displacement, and the kinematical observables of the three-muon candidate, and the two classes are defined by $I^{\mathrm{rel}} < 0.2$ or > 0.2. The NN output is then interpreted as a probability and used as a per-event weight to be applied to events with $\mathrm{ID} = 1$ and $I^{\mathrm{rel}} > 0.2$. In this region, both data and simulated samples with a genuine third muon are weighted, and the histogram of the latter is subtracted from the former to obtain the misID-background prediction in the SR. The subtraction is implemented in the fit model for each bin in the histograms, such that variations in the MC distributions are propagated to the misID background. The method is validated in a background-dominated CR ($I^{\mathrm{rel}} > 1.5$) by comparing the predicted and actual misID-background distributions for several kinematical observables.

An additional combinatorial background originates from three-muon events where two unrelated, opposite-charge muons with $m_{\mu\mu}$ close to $m_{J/\psi}$ are selected. The distributions for this background are modeled from a low $m_{\mu\mu}$ data CR, away from the J/ψ peak. As q^2 is kinematically constrained by $m_{\mu\mu}$, combinatorial dimuon events in the CR present a q^2 distribution different to that of those in the SR. Therefore, to predict the q^2 shape of this background in the SR, the 4-momenta of dimuon events in the CR are scaled by the ratio of the known $m_{J/\psi}$ to the average $m_{\mu\mu}$ in the CR. The corresponding yield is derived from integrating the background function, obtained from a fit to the $m_{\mu\mu}$ distribution, in a narrow range around $m_{J/\psi}$. This method is validated in data by comparing the observed q^2 distribution of the dimuon combinatorial background in the upper sideband to the prediction obtained from events in the lower sideband.

Before performing the final fit to data, events are classified in seven pairs of nonoverlapping categories. In each pair, categories differ only by the third muon passing or failing the isolation requirement. This split is instrumental to the misID background *in situ* evaluation: the fail-isolation category corresponds to the CR where misID probability weights are applied to predict the misID background in the pass-isolation SR. The $L_{xy}/\sigma_{L_{xy}}$ or the q^2 observable is used in the final fit for categories designed to

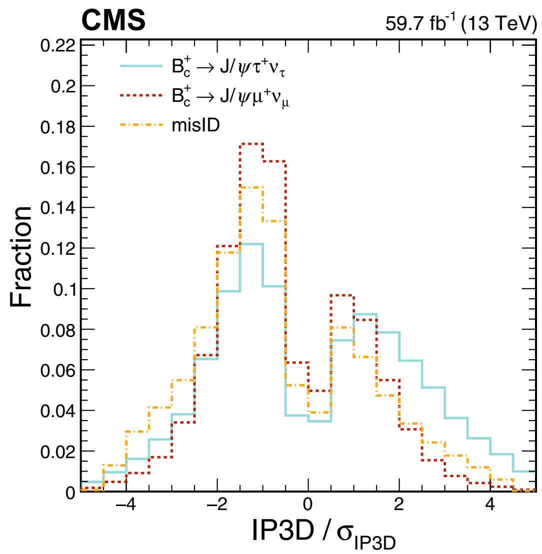

FIG. 1. Normalized distributions of the IP3D/σ_{IP3D} observable for the $B_c^+ \to J/\psi\mu^+\nu_\mu$ and $B_c^+ \to J/\psi\tau^+\nu_\tau$ signal channels and the misID background. Events are selected in the region $m(3\mu) < m_{B_c^+}$. The first and last bins contain underflow and overflow events, respectively.

constrain the misID and H_b backgrounds or isolate the signals, respectively, as each provides the optimal separation between the relevant processes. The four categories enriched in $B_c^+ \to J/\psi\tau^+\nu_\tau$ events leverage the IP3D/σ_{IP3D} variable to enhance the τ lepton signal sensitivity, as the muon from the τ lepton decay is displaced with respect to the B_c^+ vertex, because of the measurable τ lepton lifetime, as shown in Fig. 1. Further details are summarized in Table I.

A binned maximum-likelihood fit is performed simultaneously to all categories, using the CMS statistical analysis tool Combine [53], to extract $R(J/\psi)$ directly. Since the B_c^+ meson production cross section cancels in the $R(J/\psi)$ ratio, a single scale parameter, which is left floating in the fit, is assigned to all B_c^+-initiated processes. Because of the large $B_c^+ \to J/\psi\mu^+\nu_\mu$ yield, this parameter is strongly constrained in the fit, and its impact is negligible. The H_b background normalization is free to vary independently from that of the B_c^+ signal and is constrained in the $m(3\mu) > m_{B_c^+}$ category. The combinatorial background normalization can be varied in the fit within the uncertainty obtained from the dimuon fit described earlier.

Several systematic uncertainties, which can affect both yields and shapes of the different components, are incorporated into the fit as nuisance parameters and simultaneously fitted through the likelihood profiling method [54]. The most relevant uncertainties pertain to the B_c^+ form factors, the misID background estimate, the finite size of the MC samples, and the mismodeling of IP3D/σ_{IP3D} and $L_{xy}/\sigma_{L_{xy}}$ in simulated events.

Theoretical uncertainties in the form factors are the single dominant source of uncertainty in $R(J/\psi)$ because of their effect on the q^2 observable. They consist of ten independent shape variations simultaneously affecting the $B_c^+ \to J/\psi\tau^+\nu_\tau$ and $B_c^+ \to J/\psi\mu^+\nu_\mu$ processes, corresponding to the principal components of the correlation matrix of the form factor coefficients presented in Ref. [49].

Uncertainties in the dominant misID background significantly affect the measurement accuracy. The misID background estimate is subject to the limited number of events in the isolation-failing CRs, the statistical uncertainty of the NN training dataset and its contamination from processes with genuine muons, and the finite number of events in the validation region. Furthermore, the choice of the nominal method over possible alternatives is considered as a source of uncertainty. These uncertainty sources are accounted for as follows. An overall 13% normalization uncertainty, derived from residual nonclosure in the validation test in the $I^{\mathrm{rel}} > 1.5$ control region, is applied to all categories. The difference between the nominal and an alternative estimate (based on the probability for a misID muon to satisfy the identification requirement instead of isolation) and the effect of varying the MC normalization in

TABLE I. Summary of the category pair definitions and respective observables used in the fit. Each pair is also divided by passing or failing the isolation criterion. The first four category pairs are enriched in $B_c^+ \to J/\psi\tau^+\nu_\tau$, the following two enriched in $B_c^+ \to J/\psi\mu^+\nu_\mu$, and the last one enriched in misID and H_b background events.

Category pair definitions			
$m(3\mu)$	q^2	IP3D/σ_{IP3D}	Fit observable
$<m_{B_c^+}$	$>5.5\ \mathrm{GeV}^2$	<-2	q^2
		-2–0	
		0–2	
		>2	
$<m_{B_c^+}$	$<4.5\ \mathrm{GeV}^2$	<0	$L_{xy}/\sigma_{L_{xy}}$
		>0	
$>m_{B_c^+}$	...	...	$L_{xy}/\sigma_{L_{xy}}$

TABLE II. Leading systematic uncertainties for the measurement of $R(J/\psi)$. The second column reports the uncertainty type: shape (S) or normalization (N). The last column shows the resulting uncertainty in the $R(J/\psi)$ measurement.

Contribution	Type	Uncertainty (10^{-2})
Form factor (theory)	S	19
misID statistical	S (bin by bin)	13
misID systematic	N, S	8, 0.7
Finite MC size	S (bin by bin)	9
Topological	S	9
Efficiencies	N	6
Total systematic uncertainty		28

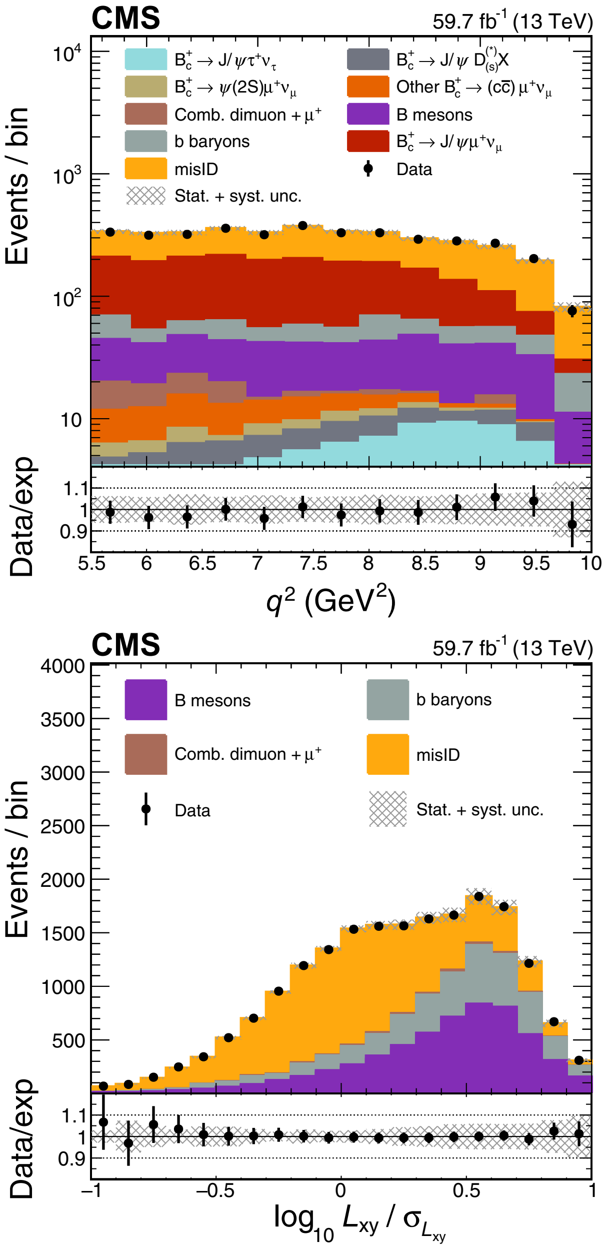

FIG. 2. Distributions of the q^2 observable in the signal-enriched category, defined by $m(3\mu) < m_{B_c^+}$ in the bin of $q^2 > 5.5\ \mathrm{GeV}^2$ and $\mathrm{IP3D}/\sigma_{\mathrm{IP3D}} > 2$ (upper) and of the $L_{xy}/\sigma_{L_{xy}}$ observable in the category defined by $m(3\mu) > m_{B_c^+}$ (lower). In each panel, data are compared to the best-fit results. The ratio between the data and the expected sum of signal and background contributions is shown in the lower panel of each observable. The postfit total uncertainty in the expectation is represented by the hashed band.

the region where the misID probability is measured are included as two additional shape uncertainties. Lastly, misID statistical shape uncertainties, which can vary for each bin independently, are added to account for the impact of the limited-size sample used for the misID background estimate validation.

Uncertainties due to the limited number of events in the simulated samples are implemented as bin-by-bin shape variations. An uncertainty of 5% in each of the topological quantities $\mathrm{IP3D}/\sigma_{\mathrm{IP3D}}$ and $L_{xy}/\sigma_{L_{xy}}$, estimated from discrepancies between data and MC in CRs, is also implemented as a shape uncertainty and applied to all MC-based distributions. The former results in an event migration between the four categories with higher signal sensitivity, thus explaining its sizable impact.

Uncertainties in trigger, muon ID, and isolation efficiencies (6.6%) are also considered in the fit. Other considered systematic uncertainties are found to be negligible.

From the maximum likelihood fit to the data, we measure

$$R(J/\psi) = 0.17^{+0.18}_{-0.17}(\mathrm{stat})^{+0.21}_{-0.22}(\mathrm{syst})^{+0.19}_{-0.18}(\mathrm{theo}),$$

where the statistical, experimental systematic, and form factor uncertainties are reported separately. A further breakdown of the systematic uncertainties is given in Table II.

The observed yields of the $B_c^+ \to J/\psi\tau^+\nu_\tau$ and $B_c^+ \to J/\psi\mu^+\nu_\mu$ processes are 430 ± 570 and 43100 ± 4900 events, respectively. The distributions where the nuisance parameters, $R(J/\psi)$, and their uncertainties are fixed at their best-fit value (postfit) are presented in Fig. 2, for the most signal-sensitive category (upper) and for one background-enriched auxiliary category (lower).

In summary, using data collected by the CMS experiment in 2018 at a center-of-mass energy of 13 TeV, corresponding to 59.7 fb^{-1} of integrated luminosity, we measured the ratio of two branching fractions:

$$R(J/\psi) = \frac{\mathcal{B}(B_c^+ \to J/\psi\tau^+\nu_\tau)}{\mathcal{B}(B_c^+ \to J/\psi\mu^+\nu_\mu)} = 0.17 \pm 0.33.$$

The result agrees with the standard model value 0.2582 ± 0.0038 [20] and with the LHCb measurement $0.71 \pm 0.17(\mathrm{stat}) \pm 0.18(\mathrm{syst})$ [25]. This measurement is the first contribution from a general-purpose experiment to the lepton flavor universality tests in B_c^+ meson decays, presently only accessible at hadron colliders.

We congratulate our colleagues in the CERN accelerator departments for the excellent performance of the LHC and thank the technical and administrative staffs at CERN and at other CMS institutes for their contributions to the success of the CMS effort. In addition, we gratefully acknowledge the computing centers and personnel of the Worldwide LHC Computing Grid and other centers for delivering so effectively the computing infrastructure essential to our analyses. Finally, we acknowledge the enduring support for the construction and operation of the LHC, the CMS detector, and the supporting computing infrastructure provided by the following funding agencies: SC (Armenia), BMBWF and FWF (Austria); FNRS and FWO (Belgium);

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[1] M. Tanaka, Charged Higgs effects on exclusive semitauonic B decays, Z. Phys. C **67**, 321 (1995).

[2] A. Crivellin, C. Greub, and A. Kokulu, Explaining $B \to D\tau\nu$, $B \to D^*\tau\nu$ and $B \to \tau\nu$ in a two Higgs doublet model of type III, Phys. Rev. D **86**, 054014 (2012).

[3] M. Freytsis, Z. Ligeti, and J. T. Ruderman, Flavor models for $\bar{B} \to D^{(*)}\tau\bar{\nu}$, Phys. Rev. D **92**, 054018 (2015).

[4] A. Crivellin, G. D'Ambrosio, and J. Heeck, Addressing the LHC flavor anomalies with horizontal gauge symmetries, Phys. Rev. D **91**, 075006 (2015).

[5] ATLAS Collaboration, Search for new phenomena in pp collisions in final states with tau leptons, b-jets, and missing transverse momentum with the ATLAS detector, Phys. Rev. D **104**, 112005 (2021).

[6] CMS Collaboration, Search for new particles in events with energetic jets and large missing transverse momentum in proton-proton collisions at $\sqrt{s} = 13$ TeV, J. High Energy Phys. 11 (2021) 153.

[7] CMS Collaboration, Search for heavy resonances and quantum black holes in $e\mu$, $e\tau$, and $\mu\tau$ final states in proton-proton collisions at $\sqrt{s} = 13$ TeV, J. High Energy Phys. 05 (2023) 227.

[8] C. Albajar *et al.* (UA1 Collaboration), Studies of intermediate vector boson production and decay in UA1 at the CERN proton-antiproton collider, Z. Phys. C **44**, 15 (1989).

[9] ALEPH, DELPHI, L3, OPAL and SLD Collaborations, and LEP Electroweak, SLD Electroweak and SLD Heavy Flavour Working Groups, Precision electroweak measurements on the Z resonance, Phys. Rep. **427**, 257 (2006).

[10] ATLAS Collaboration, Precision measurement and interpretation of inclusive W^+, W^- and Z/γ^* production cross sections with the ATLAS detector, Eur. Phys. J. C **77**, 367 (2017).

[11] ATLAS Collaboration, Test of the universality of τ and μ lepton couplings in W-boson decays with the ATLAS detector, Nat. Phys. **17**, 813 (2021).

[12] CMS Collaboration, Precision measurement of the W boson decay branching fractions in proton-proton collisions at $\sqrt{s} = 13$ TeV, Phys. Rev. D **105**, 072008 (2022).

[13] J. P. Lees *et al.* (*BABAR* Collaboration), Measurement of an excess of $\bar{B} \to D^{(*)}\tau^-\bar{\nu}_\tau$ decays and implications for charged Higgs bosons, Phys. Rev. D **88**, 072012 (2013).

[14] M. Huschle *et al.* (Belle Collaboration), Measurement of the branching ratio of $\bar{B} \to D^{(*)}\tau^-\bar{\nu}_\tau$ relative to $\bar{B} \to D^{(*)}\ell^-\bar{\nu}_\ell$ decays with hadronic tagging at Belle, Phys. Rev. D **92**, 072014 (2015).

[15] Y. Sato *et al.* (Belle Collaboration), Measurement of the branching ratio of $\bar{B}^0 \to D^{*+}\tau^-\bar{\nu}_\tau$ relative to $\bar{B}^0 \to D^{*+}\ell^-\bar{\nu}_\ell$ decays with a semileptonic tagging method, Phys. Rev. D **94**, 072007 (2016).

[16] LHCb Collaboration, Measurement of the ratio of branching fractions $\mathcal{B}(\bar{B}^0 \to D^{*+}\tau^-\bar{\nu}_\tau)/\mathcal{B}(\bar{B}^0 \to D^{*+}\mu^-\bar{\nu}_\mu)$, Phys. Rev. Lett. **115**, 111803 (2015); **115**, 159901(E) (2015).

[17] LHCb Collaboration, Measurement of the ratio of the $B^0 \to D^{*-}\tau^+\nu_\tau$ and $B^0 \to D^{*-}\mu^+\nu_\mu$ branching fractions using three-prong τ-lepton decays, Phys. Rev. Lett. **120**, 171802 (2018).

[18] LHCb Collaboration, Measurement of the ratios of branching fractions $\mathcal{R}(D^*)$ and $\mathcal{R}(D^0)$, Phys. Rev. Lett. **131**, 111802 (2023).

[19] Y. Amhis *et al.* (HFLAV Collaboration), Averages of b-hadron, c-hadron, and τ-lepton properties as of 2021, Phys. Rev. D **107**, 052008 (2023).

[20] J. Harrison, C. T. H. Davies, and A. Lytle (LATTICE-HPQCD Collaboration), $R(J/\psi)$ and $B_c^- \to J/\psi\ell^-\bar{\nu}_\ell$ lepton flavor universality violating observables from lattice QCD, Phys. Rev. Lett. **125**, 222003 (2020).

[21] A. Y. Anisimov, I. M. Narodetskii, C. Semay, and B. Silvestre-Brac, The B_c meson lifetime in the light-front constituent quark model, Phys. Lett. B **452**, 129 (1999).

[22] M. A. Ivanov, J. G. Korner, and P. Santorelli, Exclusive semileptonic and nonleptonic decays of the B_c meson, Phys. Rev. D **73**, 054024 (2006).

[23] E. Hernandez, J. Nieves, and J. M. Verde-Velasco, Study of exclusive semileptonic and non-leptonic decays of B_c^- in a nonrelativistic quark model, Phys. Rev. D **74**, 074008 (2006).

[24] K. Azizi, Y. Sarac, and H. Sundu, Lepton flavor universality violation in semileptonic tree level weak transitions, Phys. Rev. D **99**, 113004 (2019).

[25] LHCb Collaboration, Measurement of the ratio of branching fractions $\mathcal{B}(B_c^+ \to J/\psi\tau^+\nu_\tau)/\mathcal{B}(B_c^+ \to J/\psi\mu^+\nu_\mu)$, Phys. Rev. Lett. **120**, 121801 (2018).

[26] HEPData record for this analysis, 10.17182/hepdata.153486 (2024).

[27] CMS Collaboration, CMS luminosity measurement for the 2018 data-taking period at $\sqrt{s} = 13$ TeV, CMS physics analysis summary Report No. CMS-PAS-LUM-18-002, 2019, https://cds.cern.ch/record/2676164.
[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, Identification of hadronic tau lepton decays using a deep neural network, J. Instrum. **17**, P07023 (2022).
[37] CMS Collaboration, Jet energy scale and resolution in the CMS experiment in pp collisions at 8 TeV, J. Instrum. **12**, P02014 (2017).
[38] 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).
[39] Particle Data Group, Review of particle physics, Prog. Theor. Exp. Phys. **2022**, 083C01 (2022).
[40] C.-H. Chang, X.-Y. Wang, and X.-G. Wu, BCVEGPY2.2: A newly upgraded version for hadronic production of the meson $\mathrm{B_c}$ and its excited states, Comput. Phys. Commun. **197**, 335 (2015).
[41] D. J. Lange, The EVTGEN particle decay simulation package, Nucl. Instrum. Methods Phys. Res., Sect. A **462**, 152 (2001).
[42] T. Sjöstrand, S. Ask, J. R. Christiansen, R. Corke, N. Desai, P. Ilten, S. Mrenna, S. Prestel, C. O. Rasmussen, and P. Z. Skands, An introduction to Pythia 8.2, Comput. Phys. Commun. **191**, 159 (2015).
[43] LHCb Collaboration, Measurement of the B_c^- meson production fraction and asymmetry in 7 and 13 TeV pp collisions, Phys. Rev. D **100**, 112006 (2019).
[44] LHCb Collaboration, Observation of $B_c^+ \to J/\psi D_s^+$ and $B_c^+ \to J/\psi D_s^{*+}$ decays, Phys. Rev. D **87**, 112012 (2013); **89**, 019901(E) (2014).
[45] ATLAS Collaboration, Study of the $B_c^+ \to J/\psi D_s^+$ and $B_c^+ \to J/\psi D_s^{*+}$ decays with the ATLAS detector, Eur. Phys. J. C **76**, 4 (2016).
[46] LHCb Collaboration, Observation of $B_c^+ \to J/\psi D^{(*)} K^{(*)}$ decays, Phys. Rev. D **95**, 032005 (2017).
[47] V. V. Kiselev, A. K. Likhoded, and A. I. Onishchenko, Semileptonic B_c-meson decays in sum rules of QCD and NRQCD, Nucl. Phys. **B569**, 473 (2000).
[48] F. U. Bernlochner, S. Duell, Z. Ligeti, M. Papucci, and D. J. Robinson, Das ist der Hammer: Consistent new physics interpretations of semileptonic decays, Eur. Phys. J. C **80**, 883 (2020).
[49] T. D. Cohen, H. Lamm, and R. F. Lebed, Precision model-independent bounds from a global analysis of $b \to c\ell\nu$ form factors, Phys. Rev. D **100**, 094503 (2019).
[50] E. Barberio and Z. Wąs, PHOTOS—a universal Monte Carlo for QED radiative corrections: version 2.0, Comput. Phys. Commun. **79**, 291 (1994).
[51] S. Agostinelli *et al.* (GEANT4 Collaboration), Geant4—a simulation toolkit, Nucl. Instrum. Methods Phys. Res., Sect. A **506**, 250 (2003).
[52] CMS Collaboration, Measurement of the $\mathrm{B_s^0} \to \mu^+\mu^-$ decay properties and search for the $\mathrm{B^0} \to \mu^+\mu^-$ decay in proton-proton collisions at $\sqrt{s} = 13$ TeV, Phys. Lett. B **842**, 137955 (2023).
[53] CMS Collaboration, The CMS statistical analysis and combination tool: Combine, Comput. Software Big Sci. **8**, 19 (2024).
[54] CMS Collaboration, Precise determination of the mass of the Higgs boson and tests of compatibility of its couplings with the standard model predictions using proton collisions at 7 and 8 TeV, Eur. Phys. J. C **75**, 212 (2015).

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] E. S. Bols,[4] J. D'Hondt,[4] S. Dansana,[4] A. De Moor,[4] M. Delcourt,[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] Y. Hong,[6] J. Knolle,[6] L. Lambrecht,[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]

C. Delaere,[7] I. S. Donertas,[7] A. Giammanco,[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] W. L. Aldá Júnior,[9] M. Alves Gallo Pereira,[9] M. Barroso Ferreira Filho,[9] H. Brandao Malbouisson,[9] W. Carvalho,[9] J. Chinellato,[9,f] E. M. Da Costa,[9] G. G. Da Silveira,[9,g] D. De Jesus Damiao,[9] S. Fonseca De Souza,[9] R. Gomes De Souza,[9] M. Macedo,[9] J. Martins,[9,h] C. Mora Herrera,[9] L. Mundim,[9] H. Nogima,[9] J. P. Pinheiro,[9] A. Santoro,[9] A. Sznajder,[9] M. Thiel,[9] A. Vilela Pereira,[9] C. A. Bernardes,[10,g] L. Calligaris,[10] T. R. Fernandez Perez Tomei,[10] E. M. Gregores,[10] P. G. Mercadante,[10] S. F. Novaes,[10] B. Orzari,[10] Sandra S. Padula,[10] A. Aleksandrov,[11] G. Antchev,[11] R. Hadjiiska,[11] P. Iaydjiev,[11] M. Misheva,[11] M. Shopova,[11] G. Sultanov,[11] A. Dimitrov,[12] 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] J. Liu,[15] K. Yi,[15,i,j] G. M. Chen,[16,k] H. S. Chen,[16,k] M. Chen,[16,k] F. Iemmi,[16] C. H. Jiang,[16] A. Kapoor,[16,l] H. Liao,[16] Z.-A. Liu,[16,m] R. Sharma,[16,n] J. N. Song,[16,m] J. Tao,[16] C. Wang,[16,k] J. Wang,[16] Z. Wang,[16,k] H. Zhang,[16] A. Agapitos,[17] Y. Ban,[17] A. Levin,[17] C. Li,[17] Q. Li,[17] Y. Mao,[17] S. J. Qian,[17] X. Sun,[17] D. Wang,[17] H. Yang,[17] L. Zhang,[17] C. Zhou,[17] Z. You,[18] K. Jaffel,[19] N. Lu,[19] G. Bauer,[20,o] X. Gao,[21,p] Z. Lin,[22] C. Lu,[22] M. Xiao,[22] C. Avila,[23] D. A. Barbosa Trujillo,[23] A. Cabrera,[23] C. Florez,[23] J. Fraga,[23] J. A. Reyes Vega,[23] J. Mejia Guisao,[24] F. Ramirez,[24] M. Rodriguez,[24] J. D. Ruiz Alvarez,[24] D. Giljanovic,[25] N. Godinovic,[25] D. Lelas,[25] A. Sculac,[25] M. Kovac,[26] A. Petkovic,[26] T. Sculac,[26] P. Bargassa,[27] V. Brigljevic,[27] B. K. Chitroda,[27] D. Ferencek,[27] K. Jakovcic,[27] S. Mishra,[27] A. Starodumov,[27,q] T. Susa,[27] A. Attikis,[28] K. Christoforou,[28] A. Hadjiagapiou,[28] J. Mousa,[28] C. Nicolaou,[28] L. Paizanos,[28] F. Ptochos,[28] P. A. Razis,[28] H. Rykaczewski,[28] H. Saka,[28] A. Stepennov,[28] M. Finger,[29] M. Finger Jr.,[29] A. Kveton,[29] E. Ayala,[30] E. Carrera Jarrin,[31] H. Abdalla,[32,r] Y. Assran,[32,s,t] A. Lotfy,[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] 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] E. Tuominen,[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] A. Buchot Perraguin,[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] J. Motta,[39] M. Nguyen,[39] C. Ochando,[39] R. Salerno,[39] J. B. Sauvan,[39] Y. Sirois,[39] A. Tarabini,[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] C. Grimault,[40] R. Haeberle,[40] A.-C. Le Bihan,[40] M. Meena,[40] G. Saha,[40] M. A. Sessini,[40] P. Van Hove,[40] 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] 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] I. Lomidze,[42] T. Toriashvili,[42,x] Z. Tsamalaidze,[42,q] 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] U. Sarkar,[44] V. Sarkisovi,[44] A. Schmidt,[44] A. Sharma,[44] J. L. Spah,[44] A. Stein,[44] F. Torres Da Silva De Araujo,[44,y] S. Wiedenbeck,[44] S. Zaleski,[44] C. Dziwok,[45] G. Flügge,[45] W. Haj Ahmad,[45,z] 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] S. Baxter,[46] M. Bayatmakou,[46] H. Becerril Gonzalez,[46] O. Behnke,[46] A. Belvedere,[46] S. Bhattacharya,[46] F. Blekman,[46,aa] K. Borras,[46,bb] 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,aa] A. Geiser,[46] A. Giraldi,[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,cc] W. Lohmann,[46,dd] F. Lorkowski,[46] R. Mankel,[46] I.-A. Melzer-Pellmann,[46] M. Mendizabal Morentin,[46] A. B. Meyer,[46] G. Milella,[46] A. Mussgiller,[46] L. P. Nair,[46] A. Nürnberg,[46] Y. Otarid,[46] J. Park,[46] D. Pérez Adán,[46] E. Ranken,[46] A. Raspereza,[46] D. Rastorguev,[46] B. Ribeiro Lopes,[46] J. Rübenach,[46] A. Saggio,[46] M. Scham,[46,ee,bb] S. Schnake,[46,bb] P. Schütze,[46] C. Schwanenberger,[46,aa] D. Selivanova,[46] K. Sharko,[46] M. Shchedrolosiev,[46] R. E. Sosa Ricardo,[46] D. Stafford,[46] F. Vazzoler,[46] A. Ventura Barroso,[46] R. Walsh,[46] Q. Wang,[46] Y. Wen,[46] K. Wichmann,[46] L. Wiens,[46,bb] 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] 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,ff] 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. 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