Observation of Coherent $\phi(1020)$ Meson Photoproduction in Ultraperipheral PbPb Collisions at $\sqrt{s_{\mathrm{NN}}} = 5.36$ TeV

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The first observation of coherent $\phi(1020)$ meson photoproduction off heavy nuclei is presented using ultraperipheral lead-lead collisions at a center-of-mass energy per nucleon pair of 5.36 TeV. The data were collected by the CMS experiment and correspond to an integrated luminosity of 1.62 μb^{-1}. The $\phi(1020)$ meson signals are reconstructed via the K^+K^- decay channel. The production cross section is presented as a function of the $\phi(1020)$ meson rapidity in the range $0.3 < |y| < 1.0$, probing gluons that carry a fraction of the nucleon momentum (x) around 10^{-4}. The observed cross section exhibits little dependence on rapidity and is significantly suppressed, by a factor of ~5, compared to a baseline model that treats a nucleus as a collection of free nucleons. Theoretical models that incorporate the nuclear shadowing effect generally provide a better description of the $\phi(1020)$ data than those incorporating gluon saturation. This study establishes a powerful new tool for exploring nuclear effects and nuclear gluonic structure in the small-x regime at a unique energy scale bridging the perturbative and nonperturbative quantum chromodynamics domains.

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Understanding the fundamental structure of nuclear matter is a central goal of quantum chromodynamics (QCD). At high energies or small x values, where x represents the momentum fraction carried by a parton within a nucleon, gluon densities rise rapidly, leading to gluon dominance in the partonic structure [1]. It is theorized that this growth of gluon density is primarily driven by gluon splitting; however, at small x, nonlinear effects such as gluon recombination are predicted to counterbalance this increase, leading to the phenomenon of "gluon saturation" [2,3]. Heavy nuclei, with significantly higher gluon densities than free nucleons, provide an ideal setting to investigate this phenomenon [4]. Furthermore, nuclear shadowing, which may arise from coherent multinucleon interactions, can also reduce the effective gluon density in nuclei compared to that in free nucleons, thereby also influencing small-x physics [5]. A combined treatment of gluon saturation and nuclear shadowing, though challenging, would be valuable for future theoretical developments.

In ultraperipheral collisions (UPCs) of high-energy heavy ions, a photon emitted by one nucleus can fluctuate into a virtual quark-antiquark pair and interact diffractively with the other nucleus, producing a vector meson (VM) such as a $\rho(770)^0$, $\phi(1020)$, J/ψ, or Υ meson [6–19]. In what follows, the $\phi(1020)$ meson will be referred to as the ϕ meson. This photoproduction process is sensitive to the nuclear gluon distribution [20,21]. If the photon interacts with the entire nucleus, the process is called coherent; if it interacts with its internal constituents, it is called incoherent. At the leading order in perturbative QCD (pQCD), the cross section for coherent VM production scales as $\sigma_{\mathrm{VM}} \propto [xG(x, Q^2)]^2$, where $G(x, Q^2)$ is the gluon density at an energy scale Q^2 that is often taken to be $\sim(Q_0^2 + m_{\mathrm{VM}}^2)$, with $Q_0 \sim 0$ GeV for quasi-real photons [4,22,23]. The VM mass (m_{VM}) is therefore the primary determinant of the energy scale in QCD calculations. The onset of gluon saturation and the applicability of pQCD are highly sensitive to this scale.

While the J/ψ meson probes gluon distributions at relatively large scales ($Q^2 \gtrsim 10\ \mathrm{GeV}^2$), the ϕ meson, composed of a strange quark-antiquark pair with a mass of 1.019 GeV [24], probes an intermediate regime where both perturbative and nonperturbative QCD dynamics are relevant. Varying the vector-meson mass effectively scans different interaction scales, providing sensitivity to the transition between dilute and dense gluonic matter. Because gluon-saturation models feature an explicit saturation scale $Q_s(x, A)$, whereas nuclear-shadowing models do not, the ϕ meson offers a unique test of their scale dependence. Measuring the coherent photoproduction of ϕ mesons is challenging due to the very low transverse momentum of the decay kaons ($p_{\mathrm{T}}^{\mathrm{trk}} < 0.15$ GeV), which

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limits the detector acceptance and particle identification efficiency. This has prevented ϕ mesons from being used as probes in previous UPC studies.

This Letter presents the first measurement of coherent ϕ meson photoproduction in heavy ion UPCs. The ϕ meson is reconstructed via the decay channel $\phi \to K^+K^-$ using PbPb collision data collected by the CMS detector at the CERN LHC at a center-of-mass energy per nucleon pair of $\sqrt{s_{NN}} = 5.36$ TeV. The dataset corresponds to an integrated luminosity of $1.62 \pm 0.10\ \mu b^{-1}$. The differential cross section is reported as a function of ϕ meson rapidity for the range $0.3 < |y| < 1.0$, probing x values around 10^{-4}. Acceptance and efficiency limitations in reconstructing $K^\pm$ mesons restrict the measurable coherent ϕ meson yield to this rapidity range. The results are compared with a wide range of theoretical predictions that include gluon saturation or nuclear shadowing effects. The tabulated results are provided in the HEPData record [25].

The central feature of the CMS apparatus [26] is a superconducting solenoid with an internal diameter of 6 m, providing a magnetic field of 3.8 T. Within the solenoid volume are a silicon pixel and strip tracker [27], a lead tungstate crystal electromagnetic calorimeter [28], and a brass and scintillator hadron calorimeter, each composed of a barrel and two end cap sections, providing pseudorapidity (η) coverage $|\eta| < 3.0$. The hadron forward (HF) calorimeter [29] is divided into two halves, one on either side of the interaction region, with each half segmented in $0.175 \times 0.175 (\Delta\eta \times \Delta\phi)$ "towers." This detector extends the η coverage provided by the barrel and end cap detectors into the range $3.0 < |\eta| < 5.2$. The CMS apparatus can be used to detect and identify electrons, muons, photons, and hadrons [27–30]. The silicon pixel and strip tracker is capable of reconstructing charged particles with p_T^{trk} values down to 0.05 GeV. A more detailed description of the CMS detector, together with a definition of the coordinate system used and the relevant kinematic variables, can be found in Refs. [26,31].

Events are selected using a zero-bias trigger with an additional online requirement of at least one reconstructed pixel track, achieving about 90% efficiency for detecting at least one daughter kaon from a ϕ meson in the analysis phase space. In a subsequent off-line selection, events must have a primary interaction vertex, formed by at least two tracks coming from the collision, that is within 25 cm along the beam axis and within 2 cm in the transverse plane from the detector center.

To select UPC events, the largest energy deposit in any of the HF calorimeter towers must fall below a tower specific threshold determined from empty bunch crossing events. This eliminates nearly all hadronic events while maintaining negligible loss of UPC signal efficiency [32]. Furthermore, events are required to have exactly two "high purity tracks" (as defined in Ref. [27]) with opposite electric charges, and with $p_T^{\text{trk}} > 0.05$ GeV and $|\eta| < 2.4$.

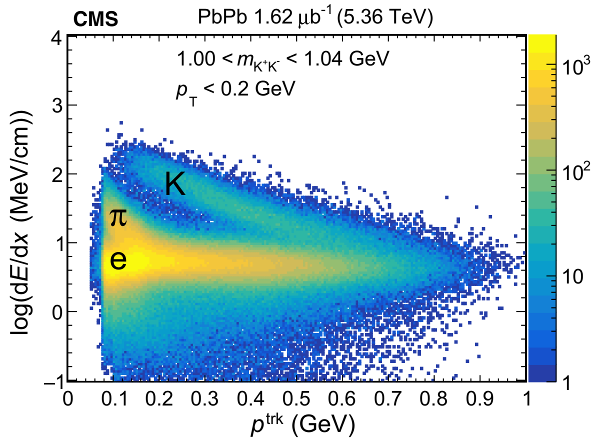

FIG. 1. The $\log(\mathrm{d}E/\mathrm{d}x)$ distribution of daughter tracks of coherent ϕ candidates with $p_T < 0.2$ GeV, selected within the signal invariant mass region, as a function of the daughter track total momentum, p^{trk}.

The kaon identification is performed using the energy loss information ($\mathrm{d}E/\mathrm{d}x$) measured by the pixel detector, as illustrated in Fig. 1, following a probability-based method described in Refs. [33,34]. Here and throughout the rest of the Letter, p_T refers to the transverse momentum of the K^+K^- pair.

The probability of producing an energy loss value ε at a total momentum p^{trk} for a given charged particle species k (k can be $\pi^\pm$, $K^\pm$, proton p, or antiproton $\bar{p}$) can be approximated by

$$P_k(\varepsilon|p^{\text{trk}}) = \frac{1}{\sqrt{2\pi}\sigma_k} \exp\left(-\frac{(\varepsilon - \mu_k)^2}{2\sigma_k^2}\right), \quad (1)$$

where $\varepsilon = \log(\mathrm{d}E/\mathrm{d}x)$, and μ_k and σ_k are the corresponding values for the momentum dependent mean and width, respectively, of the ε distribution for species k. As the pair production of p and $\bar{p}$ is strongly suppressed because of the lack of coupling to VM photoproductions in UPC events [6], the selected two-track events mainly contain pions and kaons. To select high-quality K^+K^- events, each track is required to satisfy $P_K(\varepsilon|p^{\text{trk}}) > 10P_\pi(\varepsilon|p^{\text{trk}})$.

The K^+K^- pairs with an invariant mass within a range of $0.98 < m_{K^+K^-} < 1.15$ GeV are selected for the signal extraction of ϕ mesons. These K^+K^- pairs mainly include both $\phi \to K^+K^-$ decays and direct K^+K^- pairs from photon-nuclear interactions. Direct pairs are produced when a photon fluctuates into a virtual K^+K^- pair and elastically scatters off the target nucleus, forming a real K^+K^- pair. These pairs contribute as a smooth continuum background in the $m_{K^+K^-}$ distribution. Contamination from misidentified $\pi^+\pi^-$ pairs originating from coherently produced ρ decays and direct $\pi^+\pi^-$ pairs is estimated by assigning the K mass to the charged pions produced in Monte Carlo (MC) samples. The pion pair contamination

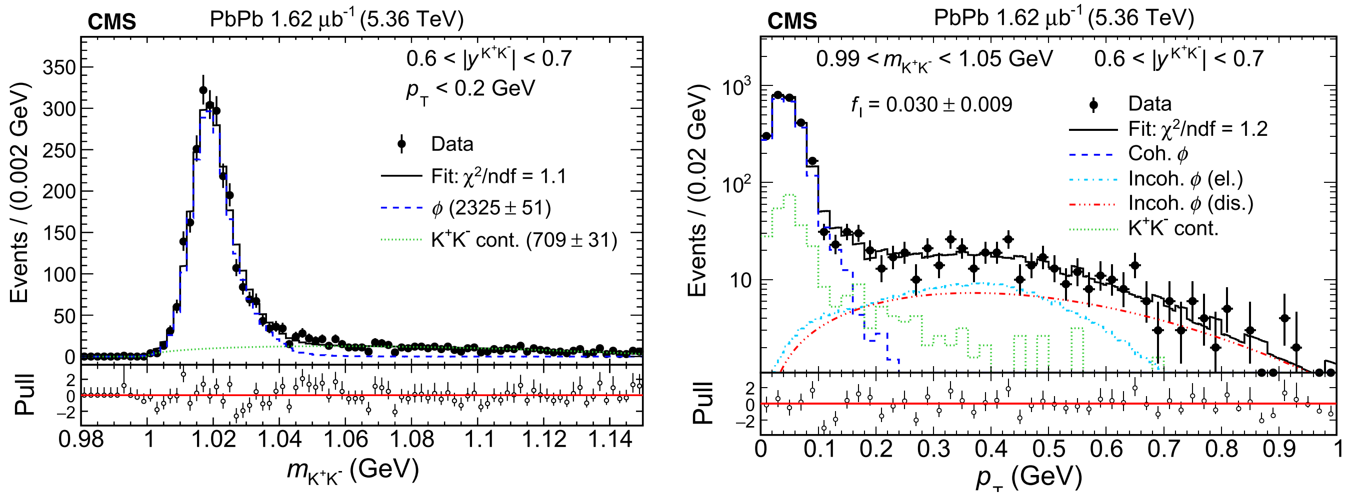

FIG. 2. Examples of the invariant mass ($m_{K^+K^-}$) distribution in the coherent process dominant region of pair $p_T < 0.2$ GeV (left) and the pair p_T distribution in the ϕ meson mass window $0.99 < m_{K^+K^-} < 1.05$ GeV (right). The curves show results of the template fit, including the coherent (Coh.) ϕ, incoherent (Incoh.) ϕ for both elastic (el.) and dissociative (dis.) processes, and the direct K^+K^- continuum (cont.). The error bars represent statistical uncertainties (σ_{Data}). The bottom panels show fit pulls, $(\mathrm{Data} - \mathrm{Fit})/\sigma_{\mathrm{Data}}$, with red lines at zero.

contributes only a negligible ~0.01% to the total observed yield in the signal mass range.

The ϕ meson raw yield (N_ϕ^{raw}) is extracted via a χ^2 template fit to the $m_{K^+K^-}$ distribution in the low K^+K^- transverse momentum region $p_T < 0.2$ GeV, where the coherent process dominates, as illustrated in Fig. 2 (left). The signal template shape of coherent ϕ meson production is obtained from the STARlight (v3.30) event generator [35], together with a full CMS detector simulation, as implemented with Geant4 [36]. Similar to previous studies [37–39], the continuum background of direct K^+K^- pairs is described by an empirical function $f_{\mathrm{bkg}}(m) = A(m - 2m_K)^{1/2} + B(m - 2m_K)^{3/2}$, where A and B are free parameters. This function accounts for the experimental threshold effects near twice the kaon mass. A recent ALICE study [40] reported a hint of enhanced direct K^+K^- yield in the mass range $1.1 < m_{K^+K^-} < 1.4$ GeV with a significance of 2.1σ. This enhancement is attributed to potential interference effects between $\phi \to K^+K^-$ decay and direct K^+K^- production. However, the absence of a direct ϕ meson measurement prevents a definitive conclusion regarding this explanation. A theoretical study [41] suggests that such interference effects are negligible near the ϕ meson peak and become significant only at higher masses ($m_{K^+K^-} > 1.2$ GeV). In this analysis, the χ^2/ndf (where ndf is the number of degrees of freedom) value and the pull distribution, as shown in the lower panel of Fig. 2 (left), indicate that the fit without incorporating interference effects provides an accurate description of the data. This observation is consistent with the expectation of Ref. [41].

The extracted N_ϕ^{raw} value includes contributions from both coherent and incoherent photoproduction. The fraction of the incoherent contribution (f_I) is determined by fits to the pair p_T distributions within the ϕ mass window. Incoherent processes can be either elastic or dissociative, depending on whether the interacting nucleon remains intact or dissociates after the interaction, respectively. The template p_T shapes of coherent and elastic incoherent ϕ meson photoproduction processes are from the STARlight simulations. The p_T distribution of the dissociative incoherent process is described by the function $\mathrm{d}N/\mathrm{d}p_T \approx p_T e^{b_{\mathrm{pd}} p_T^2}$, as employed by the ZEUS experiment [42], where b_{pd} is a free parameter in the fit. The p_T distribution of the K^+K^- continuum is obtained from the higher-sideband region of the ϕ signal peak ($1.05 < m_{K^+K^-} < 1.15$ GeV), while its normalization factor is fixed to the yield within the ϕ mass window determined in the full p_T range up to 1 GeV. The default configuration of STARlight does not perfectly simulate the p_T spectra of coherent VM photoproductions observed in recent measurements [12,15,16,43–45]. In Ref. [43], it was pointed out that this issue can be overcome by enlarging the nuclear radius parameter. Changing the Pb radius parameter from 6.67 to 8.67 fm allows STARlight to match the measured ϕ p_T spectra and, consequently, the larger radius value is used here. In the fit, the normalization factors are free for the coherent, elastic incoherent and dissociative incoherent ϕ meson photoproduction. The incoherent contamination fraction can be obtained as $f_I = [N_{\mathrm{incoh}}^{\mathrm{el}} + N_{\mathrm{incoh}}^{\mathrm{dis}}]/N_{\mathrm{coh}}$ in the low-p_T (< 0.2 GeV) region. A representative fit to the p_T spectrum of the K^+K^- pairs within the ϕ meson mass window is shown in Fig. 2 (right). The extracted f_I values in different rapidity intervals are found to be in the range 3%–5%.

The differential cross section of coherent ϕ meson photoproduction is determined using the expression

$$\frac{d\sigma_{\phi}^{\mathrm{coh}}}{dy} = \frac{N_{\phi}^{\mathrm{raw}}}{(1+f_{\mathrm{I}})(\mathcal{A}\epsilon)_{\phi}\mathcal{B}_{\phi\to K^+K^-}\mathcal{L}_{\mathrm{int}}\Delta y}, \qquad (2)$$

where N_{ϕ}^{raw} is the ϕ meson yield extracted within $p_{\mathrm{T}} < 0.2$ GeV, f_{I} is the incoherent fraction, $(\mathcal{A}\epsilon)_{\phi}$ is the product of detector acceptance and efficiency for reconstructing the coherent ϕ meson photoproduction, $\mathcal{B}_{\phi\to K^+K^-} = (49.1 \pm 0.5)\%$ is the world-average branching fraction [24], Δy is the width of the rapidity interval, and $\mathcal{L}_{\mathrm{int}}$ is the integrated luminosity of the data sample. The $(\mathcal{A}\epsilon)_{\phi}$ factor is determined from simulation, with values between 12% and 36% for the ϕ meson rapidity range of $0.3 < |y| < 1.0$. The dominant efficiency loss arises from the requirement on the minimum number of hits per track. This condition is less often satisfied for tracks at mid-rapidity, where large curvature in the strong magnetic field reduces the number of tracker hits. Additional corrections using the “tag-and-probe” (TnP) method [46,47] are applied to account for data-to-simulation discrepancies in the description of the online trigger and kaon reconstruction efficiencies. In this approach, one kaon track from $\phi \to K^+K^-$ decays is tightly selected (“tag”), while the second (“probe”) is a loosely reconstructed pixel-seed track used to determine the probability of satisfying the online trigger, as well as the off-line full reconstruction and PID criteria. The resulting scale factors are about 0.85 in the ϕ meson rapidity range. The reported cross section does not include contributions from coincident ultraperipheral collisions; any residual effect ($< 2\%$) is included in the systematic uncertainty.

Systematic uncertainties are evaluated by taking the maximum deviation from the nominal result for each given uncertainty source. The uncertainties are 6.4% in the integrated luminosity and 1% in the $\mathcal{B}_{\phi\to K^+K^-}$ [24]. Uncertainties propagated from the TnP scaling factors are estimated to be 2%–6%. The threshold energies in the HF calorimeter used to reject hadronic contamination are tightened on both sides, which leads to a 2%–3% uncertainty. The uncertainty from the raw signal yield extraction is evaluated by using the alternative background model employed in Ref. [38] and by varying the range of the $m_{K^+K^-}$ for the fit. Overall, the uncertainties from signal yield extraction are found to be 3%–6%. The systematic uncertainty in the incoherent fraction is estimated by (i) using the coherent ϕ meson production template with the default nuclear parameters in STARlight, (ii) varying the range of the mass sideband for the K^+K^- continuum template, and (iii) removing the elastic incoherent ϕ template from the fit for the incoherent fraction estimation. The uncertainty from the incoherent fraction is less than 1%. Individual sources of systematic uncertainties are added in quadrature to obtain the total systematic uncertainty of 7%–10%.

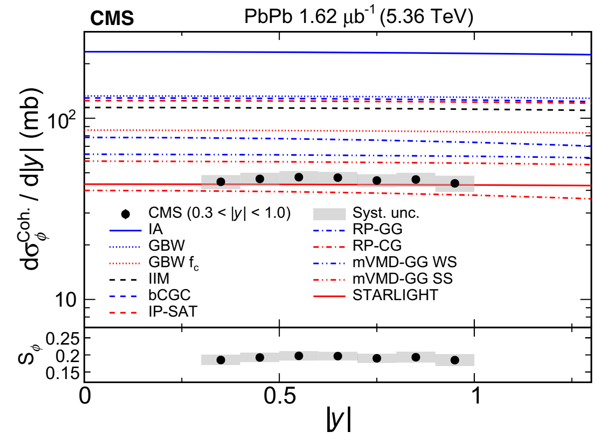

FIG. 3. The differential cross section of coherent ϕ meson photoproduction as a function of rapidity in the range $0.3 < |y| < 1.0$ (top panel). Vertical bars and shaded bands indicate statistical and systematic uncertainties, respectively. Theoretical predictions shown include the impulse approximation (IA) [35], color dipole models (IIM [53], bCGC [54], IP-SAT [55,56], GBW and GBW f$_c$ [57,58]), reggeometric pomeron (RP) models with classical Glauber and Gribov-Glauber approaches [23,59], the modified VMD (mVMD) model with GG and strong or weak shadowing (SS or WS) [50], and STARlight with CG [35]. The bottom panel shows the data-to-IA ratio.

The differential cross section for coherent ϕ meson photoproduction over the rapidity range $0.3 < |y| < 1.0$ is shown in Fig. 3. The characteristic x values of the probed gluons in a given $|y|$ interval can be obtained using

$$x = \frac{m_{\phi}}{\sqrt{s_{\mathrm{NN}}}}\exp(\pm y), \qquad (3)$$

where the sign of y corresponds to the rapidity sign of the photon-emitting nucleus in the laboratory frame [20,43,48,49]. However, in symmetric UPCs, the photon emitter cannot be definitively identified [20,50]. Consequently, the cross section values at each $|y|$ represent the average contributions from $+y$ and $-y$, without separating individual contributions. The x values corresponding to the $|y|$ coverage are around 10^{-4}, falling within the range explored in recent measurements [43,51], where the coherent J/ψ meson photoproduction cross section exhibits strong nuclear suppression effects [52].

The data are compared to various theoretical models, all of which are constrained to photoproduction data off protons from HERA [37], either directly or via fitted parameterizations (as in the case of STARlight). A baseline model, referred to as the impulse approximation (IA), represents the direct sum of coherent contributions by treating the nucleus as a simple collection of free nucleons [50,60]. To quantify the impact of nuclear modifications on coherent ϕ meson photoproduction, a nuclear suppression factor, S_{ϕ}, is defined as the ratio of the measured cross section to the IA prediction [50]. The extracted S_ϕ values, as shown in the bottom panel of Fig. 3, are found to be ~0.18–0.20 across the entire $|y|$ range. This observation provides strong evidence that coherent ϕ meson photoproduction undergoes significant nuclear suppression. Moreover, the value of S_ϕ is approximately half of $S^{J/\psi}$ (0.41 ± 0.05) within the $0 < |y| < 0.8$ range, as reported by the ALICE experiment [16] with PbPb UPCs at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV. The greater suppression of the ϕ meson confirms the mass dependence in coherent VM photoproductions [5,54,61].

Theoretical calculations that include gluon-saturation effects at small x are performed within the color glass condensate (CGC) framework [3] using the color-dipole formalism [62]. Three representative approaches are compared with the data. The Iancu-Itakura-Munier (IIM) model [53] interpolates between the Balitsky-Fadin-Kuraev-Lipatov [63–65] and Balitsky-Kovchegov [65–67] equations, the bCGC model [54] adds impact-parameter dependence to the saturation scale, and the IP-SAT model [55,56] employs an eikonalized dipole amplitude based on a DGLAP-evolved gluon density [68–70]. All three models overpredict the measured coherent ϕ photoproduction cross section off lead nuclei by a factor of $2.6 - 3.0$.

Notably, a theoretical study [58], based on a framework similar to the bCGC model and known as the Golec-Biernat-Wusthoff (GBW) model, specifically investigates non-pQCD corrections to the photon wave function within the color dipole formalism. The predictions without and with these corrections, referred to as GBW and GBW f_c, respectively, are shown in Fig. 3. The inclusion of non-pQCD corrections results in an additional reduction of approximately 40% in the predicted cross sections, but the predictions still overestimate the data by a factor of about 2.

In contrast to gluon-saturation models, another class of calculations accounts for nonlinear QCD effects at small x through *nuclear shadowing*. These models generally use the vector meson dominance (VMD) picture [71] combined with either the classical Glauber (CG) [72] or the Gribov-Glauber (GG) [73] formalism to describe multiple scatterings of the virtual vector meson in the nucleus. While CG includes only elastic interactions, GG extends the treatment to inelastic channels. The reggeometric Pomeron (RP) model [23,59] combines VMD with both CG and GG schemes, with the latter predicting cross sections roughly twice as large. The CG-based results and the modified VMD (mVMD) approach with strong or weak shadowing scenarios [50] describe the data more closely, though they still overshoot by 25%–35%. Predictions from the STARlight model [35], which employs VMD with the CG formalism, agree with the measurements within a few percent, despite its known limitations for coherent $\rho(770)^0$ and J/ψ production [16,18,43,51,74,75].

In summary, the first measurement of coherent $\phi(1020)$ meson photoproduction off a heavy nucleus has been performed by the CMS experiment in ultraperipheral lead-lead collisions at a center-of-mass energy per nucleon pair of 5.36 TeV. The production cross section is reported in the ϕ meson rapidity range $0.3 < |y| < 1.0$, probing gluons within the lead nucleus having x values around 10^{-4} at an intermediate energy scale set by the ϕ meson mass. This places it in a unique regime between perturbative and nonperturbative quantum chromodynamics. The cross section is found to be significantly suppressed by a factor of ~5 compared to an impulse approximation model that treats a nucleus as a collection of free nucleons. Models that account for nuclear shadowing effects generally provide better predictions of the data compared to those that incorporate gluon saturation effects. The measurement of coherent ϕ meson photoproduction off a heavy nucleus establishes a powerful new tool for exploring nuclear effects and nuclear gluonic structure in the small-x regime.

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Data availability—Release and preservation of data used by the CMS Collaboration as the basis for publications is

guided by the CMS data preservation, re-use, and open access policy [76].

[1] H1 and ZEUS Collaborations, Combination of measurements of inclusive deep inelastic $e^{\pm}p$ scattering cross sections and QCD analysis of HERA data, Eur. Phys. J. C **75**, 580 (2015).

[2] E. Iancu and R. Venugopalan, The color glass condensate and high-energy scattering in QCD, in *Quark-Gluon Plasma 3* (World Scientific, Singapore, 2004), p. 249.

[3] F. Gelis, E. Iancu, J. Jalilian-Marian, and R. Venugopalan, The color glass condensate, Annu. Rev. Nucl. Part. Sci. **60**, 463 (2010).

[4] A. Accardi *et al.*, Electron Ion Collider: The next QCD frontier: Understanding the glue that binds us all, Eur. Phys. J. A **52**, 268 (2016).

[5] L. Frankfurt, M. Strikman, and C. Weiss, Small-x physics: From HERA to LHC and beyond, Annu. Rev. Nucl. Part. Sci. **55**, 403 (2005).

[6] A. J. Baltz, G. Baur, D. Denterria, L. Frankfurt, F. Gelis, V. Guzey, K. Hencken, Y. Kharlov, M. Klasen, and S. Klein, The physics of ultraperipheral collisions at the LHC, Phys. Rep. **458**, 1 (2008).

[7] L. Adamczyk *et al.* (STAR Collaboration), Coherent diffractive photoproduction of ρ^0 mesons on gold nuclei at 200 GeV/nucleon-pair at the Relativistic Heavy Ion Collider, Phys. Rev. C **96**, 054904 (2017).

[8] S. Afanasiev *et al.* (PHENIX Collaboration), Photoproduction of J/ψ and of high mass e^+e^- in ultra-peripheral Au + Au collisions at $\sqrt{s_{NN}} = 200$ GeV, Phys. Lett. B **679**, 321 (2009).

[9] ALICE Collaboration, Exclusive J/ψ photoproduction off protons in ultra-peripheral p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, Phys. Rev. Lett. **113**, 232504 (2014).

[10] CMS Collaboration, Measurement of exclusive Υ photoproduction from protons in pPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, Eur. Phys. J. C **79**, 277 (2019).

[11] CMS Collaboration, Measurement of exclusive $\rho(770)^0$ photoproduction in ultraperipheral pPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, Eur. Phys. J. C **79**, 702 (2019).

[12] STAR Collaboration, Tomography of ultrarelativistic nuclei with polarized photon-gluon collisions, Sci. Adv. **9**, eabq3903 (2023).

[13] ALICE Collaboration, Coherent J/ψ photoproduction in ultra-peripheral PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV, Phys. Lett. B **718**, 1273 (2013).

[14] ALICE Collaboration, Charmonium and e^+e^- pair photoproduction at mid-rapidity in ultra-peripheral PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV, Eur. Phys. J. C **73**, 2617 (2013).

[15] ALICE Collaboration, Coherent J/ψ photoproduction at forward rapidity in ultra-peripheral Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, Phys. Lett. B **798**, 134926 (2019).

[16] ALICE Collaboration, Coherent J/ψ and $\psi(2s)$ photoproduction at midrapidity in ultra-peripheral Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, Eur. Phys. J. C **81**, 712 (2021).

[17] CMS Collaboration, Coherent J/ψ photoproduction in ultra-peripheral PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV with the CMS experiment, Phys. Lett. B **772**, 489 (2017).

[18] LHCb Collaboration, Study of coherent J/ψ production in lead-lead collisions at $\sqrt{s_{NN}} = 5$ TeV, J. High Energy Phys. 07 (2022) 117.

[19] LHCb Collaboration, Study of exclusive photoproduction of charmonium in ultra-peripheral lead-lead collisions, J. High Energy Phys. 06 (2023) 146.

[20] V. Guzey, M. Strikman, and M. Zhalov, Disentangling coherent and incoherent quasielastic J/ψ photoproduction on nuclei by neutron tagging in ultraperipheral ion collisions at the LHC, Eur. Phys. J. C **74**, 2942 (2014).

[21] S. R. Klein and P. Steinberg, Photonuclear and two-photon interactions at high-energy nuclear colliders, Annu. Rev. Nucl. Part. Sci. **70**, 323 (2020).

[22] M. Klein and R. Yoshida, Collider physics at HERA, Prog. Part. Nucl. Phys. **61**, 343 (2008).

[23] L. Jenkovszky, É. S. Rocha, and M. V. T. Machado, Light vector meson photoproduction in ultraperipheral heavy-ion collisions at the LHC within the Reggeometric Pomeron approach, Astron. Nachr. **344**, e220117 (2023).

[24] Particle Data Group, Review of particle physics, Phys. Rev. D **110**, 030001 (2024).

[25] HEPData record for this analysis, 10.17182/hepdata.156183 (2025).

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

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

[28] CMS Collaboration, Electron and photon reconstruction and identification with the CMS experiment at the CERN LHC, J. Instrum. **16**, P05014 (2020).

[29] G. Bayatian *et al.*, Design, performance and calibration of the CMS forward calorimeter wedges, Eur. Phys. J. C **53**, 139 (2008).

[30] 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).

[31] CMS Collaboration, Development of the CMS detector for the CERN LHC Run 3, J. Instrum. **19**, P05064 (2023).

[32] CMS Collaboration, Observation of forward neutron multiplicity dependence of dimuon acoplanarity in ultraperipheral PbPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, Phys. Rev. Lett. **127**, 122001 (2021).

[33] CMS Collaboration, Study of the inclusive production of charged pions, kaons, and protons in pp collisions at $\sqrt{s} = 0.9$, 2.76, and 7 TeV, Eur. Phys. J. C **72**, 2164 (2012).

[34] CMS and TOTEM Collaborations, Nonresonant central exclusive production of charged-hadron pairs in proton-proton collisions at $\sqrt{s} = 13$ TeV, Phys. Rev. D **109**, 112013 (2024).

[35] S. R. Klein, J. Nystrand, J. Seger, Y. Gorbunov, and J. Butterworth, STARlight: A Monte Carlo simulation program for ultra-peripheral collisions of relativistic ions, Comput. Phys. Commun. **212**, 258 (2017).

[36] S. Agostinelli *et al.* (Geant4 Collaboration), Geant4—a simulation toolkit, Nucl. Instrum. Methods Phys. Res., Sect. A **506**, 250 (2003).

[37] M. Derrick *et al.* (ZEUS Collaboration), Measurement of elastic ϕ photoproduction at HERA, Phys. Lett. B **377**, 259 (1996).

[38] T. Mibe *et al.* (CLAS Collaboration), First measurement of coherent ϕ-meson photoproduction on deuteron at low energies, Phys. Rev. C **76**, 052202 (2007).

[39] CMS Collaboration, Multiplicity and rapidity dependence of strange hadron production in pp, pPb, and PbPb collisions at the LHC, Phys. Lett. B **768**, 103 (2017).

[40] ALICE Collaboration, Photoproduction of K^+K^- pairs in ultraperipheral collisions, Phys. Rev. Lett. **132**, 222303 (2024).

[41] M. G. Ryskin and Y. M. Shabelski, Elastic ρ' and ϕ meson photoproduction and electroproduction with nonresonant background, Phys. At. Nucl. **62**, 980 (1999), [arXiv:hep-ph/9712437].

[42] J. Breitweg *et al.* (ZEUS Collaboration), Measurement of diffractive photoproduction of vector mesons at large momentum transfer at HERA, Eur. Phys. J. C **14**, 213 (2000).

[43] CMS Collaboration, Probing small Bjorken-x nuclear gluonic structure via coherent J/ψ photoproduction in ultraperipheral Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV, Phys. Rev. Lett. **131**, 262301 (2023).

[44] ALICE Collaboration, Coherent ρ^0 photoproduction in ultra-peripheral Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV, J. High Energy Phys. 09 (2015) 095.

[45] ALICE Collaboration, First measurement of coherent ρ^0 photoproduction in ultra-peripheral Xe-Xe collisions at $\sqrt{s_{\mathrm{NN}}} = 5.44$ TeV, Phys. Lett. B **820**, 136481 (2021).

[46] CMS Collaboration, Performance of CMS muon reconstruction in pp collision events at $\sqrt{s} = 7$ TeV, J. Instrum. **7**, P10002 (2012).

[47] CMS Collaboration, Measurement of the inclusive W and Z production cross sections in pp collisions at $\sqrt{s} = 7$ TeV, J. High Energy Phys. 10 (2011) 132.

[48] S. P. Jones, A. D. Martin, M. G. Ryskin, and T. Teubner, Probes of the small x gluon via exclusive J/ψ and Υ production at HERA and the LHC, J. High Energy Phys. 11 (2013) 085.

[49] CMS Collaboration, Probing gluon fluctuations in nuclei with the first energy-dependent measurement of incoherent J/ψ photoproduction in ultraperipheral PbPb collisions, Phys. Rev. Lett. **135**, 112301 (2025).

[50] V. Guzey, E. Kryshen, and M. Zhalov, Coherent photoproduction of vector mesons in ultraperipheral heavy ion collisions: Update for run 2 at the CERN Large Hadron Collider, Phys. Rev. C **93**, 055206 (2016).

[51] ALICE Collaboration, Energy dependence of coherent photonuclear production of J/ψ mesons in ultra-peripheral Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV, J. High Energy Phys. 10 (2023) 119.

[52] H. Mäntysaari, J. Penttala, F. Salazar, and B. Schenke, Finite-size effects on small-x evolution and saturation in proton and nuclear targets, Phys. Rev. D **111**, 054033 (2025).

[53] E. Iancu, K. Itakura, and S. Munier, Saturation and BFKL dynamics in the HERA data at small x, Phys. Lett. B **590**, 199 (2004).

[54] H. Kowalski, L. Motyka, and G. Watt, Exclusive diffractive processes at HERA within the dipole picture, Phys. Rev. D **74**, 074016 (2006).

[55] J. Bartels, K. Golec-Biernat, and H. Kowalski, A modification of the saturation model: DGLAP evolution, Phys. Rev. D **66**, 014001 (2002).

[56] A. H. Rezaeian, M. Siddikov, M. Van de Klundert, and R. Venugopalan, Analysis of combined HERA data in the impact-parameter dependent saturation model, Phys. Rev. D **87**, 034002 (2013).

[57] K. Golec-Biernat and M. Wüsthoff, Saturation effects in deep inelastic scattering at low Q^2 and its implications on diffraction, Phys. Rev. D **59**, 014017 (1998).

[58] V. P. Goncalves and B. D. Moreira, A phenomenological analysis of the nonperturbative QCD contributions for the photon wave function, Eur. Phys. J. C **80**, 492 (2020).

[59] L. Jenkovszky, E. S. Rocha and M. V. T. Rocha, Investigating exclusive ρ^0 photoproduction within the Regge phenomenology approach, Phys. Lett. B **835**, 137585 (2022).

[60] S. Klein and J. Nystrand, Exclusive vector meson production in relativistic heavy ion collisions, Phys. Rev. C **60**, 014903 (1999).

[61] J. R. Forshaw and G. Shaw, Gluon saturation in the colour dipole model?, J. High Energy Phys. 12 (2024) 052.

[62] V. P. Goncalves, M. V. T. Machado, B. D. Moreira, F. S. Navarra, and G. S. dos Santos, Color dipole predictions for the exclusive vector meson photoproduction in pp, pPb, and PbPb collisions at run 2 LHC energies, Phys. Rev. D **96**, 094027 (2017).

[63] E. A. Kuraev, L. N. Lipatov, and V. S. Fadin, The Pomeranchuk singularity in non-Abelian gauge theories, Sov. Phys. JETP **45**, 199 (1977), http://www.jetp.ras.ru/cgi-bin/e/index/e/45/2/p199?a=list.

[64] I. I. Balitsky and L. N. Lipatov, The pomeranchuk singularity in quantum chromodynamics, Sov. J. Nucl. Phys. **28**, 822 (1978).

[65] Y. V. Kovchegov, Small x F_2 structure function of a nucleus including multiple pomeron exchanges, Phys. Rev. D **60**, 034008 (1999).

[66] I. Balitsky, Operator expansion for high-energy scattering, Nucl. Phys. **B463**, 99 (1996).

[67] Y. V. Kovchegov, Unitarization of the BFKL pomeron on a nucleus, Phys. Rev. D **61**, 074018 (2000).

[68] V. N. Gribov and L. N. Lipatov, Deep inelastic ep scattering in perturbation theory, Sov. J. Nucl. Phys. **15**, 438 (1972).

[69] G. Altarelli and G. Parisi, Asymptotic freedom in parton language, Nucl. Phys. **B126**, 298 (1977).

[70] Y. L. Dokshitzer, Calculation of the structure functions for deep inelastic scattering and e^+e^- annihilation by perturbation theory in quantum chromodynamics, Sov. Phys. JETP **46**, 641 (1977), http://www.jetp.ras.ru/cgi-bin/dn/e_046_04_0641.pdf.

[71] T. H. Bauer, R. D. Spital, D. R. Yennie, and F. M. Pipkin, The hadronic properties of the photon in high-energy interactions, Rev. Mod. Phys. **50**, 261 (1978).

[72] V. N. Gribov, Glauber corrections and the interaction between high-energy hadrons and nuclei, Sov. Phys. JETP **29**, 483 (1969), http://jetp.ras.ru/cgi-bin/dn/e_029_03_0483.pdf.

[73] R. J. Glauber and G. Matthiae, High-energy scattering of protons by nuclei, Nucl. Phys. **B21**, 135 (1970).

[74] ALICE Collaboration, Coherent photoproduction of ρ^0 vector mesons in ultra-peripheral Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, J. High Energy Phys. 06 (2020) 035.
[75] M. I. Abdulhamid *et al.* (STAR Collaboration), Observation of strong nuclear suppression in exclusive J/ψ photoproduction in Au + Au ultraperipheral collisions at RHIC, Phys. Rev. Lett. **133**, 052301 (2024).
[76] CMS data availability statement, 10.7483/OPENDATA.CMS.1BNU.8V1W.

V. Chekhovsky,[1] A. Hayrapetyan,[1] V. Makarenko,[1] A. Tumasyan,[1,b] W. Adam,[2] J. W. Andrejkovic,[2] L. Benato,[2] T. Bergauer,[2] K. Damanakis,[2] M. Dragicevic,[2] C. Giordano,[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,c] D. Schwarz,[2] M. Sonawane,[2] W. Waltenberger,[2] C.-E. Wulz,[2,c] T. Janssen,[3] H. Kwon,[3] T. Van Laer,[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] Y. Hong,[4] S. Lowette,[4] I. Makarenko,[4] D. Müller,[4] S. Tavernier,[4] M. Tytgat,[4,d] G. P. Van Onsem,[4] S. Van Putte,[4] D. Vannerom,[4] B. Bilin,[5] B. Clerbaux,[5] A. K. Das,[5] I. De Bruyn,[5] G. De Lentdecker,[5] H. Evard,[5] L. Favart,[5] P. Gianneios,[5] A. Khalilzadeh,[5] F. A. Khan,[5] A. Malara,[5] M. A. Shahzad,[5] L. Thomas,[5] M. Vanden Bemden,[5] C. Vander Velde,[5] P. Vanlaer,[5] F. Zhang,[5] M. De Coen,[6] D. Dobur,[6] G. Gokbulut,[6] J. Knolle,[6] L. Lambrecht,[6] D. Marckx,[6] K. Skovpen,[6] N. Van Den Bossche,[6] J. van der Linden,[6] J. Vandenbroeck,[6] L. Wezenbeek,[6] S. Bein,[7] A. Benecke,[7] A. Bethani,[7] G. Bruno,[7] A. Cappati,[7] J. De Favereau De Jeneret,[7] C. Delaere,[7] A. Giammanco,[7] A. O. Guzel,[7] Sa. Jain,[7] V. Lemaitre,[7] J. Lidrych,[7] P. Mastrapasqua,[7] S. Turkcapar,[7] G. A. Alves,[8] E. Coelho,[8] G. Correia Silva,[8] C. Hensel,[8] T. Menezes De Oliveira,[8] C. Mora Herrera,[8,e] P. Rebello Teles,[8] M. Soeiro,[8] E. J. Tonelli Manganote,[8,f] A. Vilela Pereira,[8,e] W. L. Aldá Júnior,[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] S. S. Jesus,[9] T. Laux Kuhn,[9,h] M. Macedo,[9] K. Mota Amarilo,[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] V. Scheurer,[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] D. Laroze,[13] S. Thakur,[13] T. Cheng,[14] T. Javaid,[14] L. Yuan,[14] Z. Hu,[15] Z. Liang,[15] J. Liu,[15] G. M. Chen,[16,i] H. S. Chen,[16,i] M. Chen,[16,i] Q. Hou,[16] F. Iemmi,[16] C. H. Jiang,[16] A. Kapoor,[16,j] H. Liao,[16] Z.-A. Liu,[16,k] R. Sharma,[16,k] J. N. Song,[16,k] J. Tao,[16] C. Wang,[16,i] J. Wang,[16] H. Zhang,[16] J. Zhao,[16] A. Agapitos,[17] Y. Ban,[17] A. Carvalho Antunes De Oliveira,[17] S. Deng,[17] B. Guo,[17] C. Jiang,[17] A. Levin,[17] C. Li,[17] Q. Li,[17] Y. Mao,[17] S. Qian,[17] S. J. Qian,[17] X. Qin,[17] X. Sun,[17] D. Wang,[17] H. Yang,[17] Y. Zhao,[17] C. Zhou,[17] S. Yang,[18] Z. Ye,[18] Z. You,[19] K. Jaffel,[20] N. Lu,[20] G. Bauer,[21,l] B. Li,[21,m] H. Wang,[21] K. Yi,[21,n] J. Zhang,[21] Y. Li,[22] 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] J. Jaramillo,[25] C. Rendón,[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] A. Starodumov,[28] 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. Ayala,[31] E. Carrera Jarrin,[32] B. El-mahdy,[33] S. Khalil,[33,o] E. Salama,[33,p,q] M. Abdullah Al-Mashad,[34] M. A. Mahmoud,[34] K. Ehataht,[35] M. Kadastik,[35] T. Lange,[35] C. Nielsen,[35] J. Pata,[35] M. Raidal,[35] L. Tani,[35] C. Veelken,[35] K. Osterberg,[36] M. Voutilainen,[36] N. Bin Norjoharuddeen,[37] E. Brücken,[37] F. Garcia,[37] P. Inkaew,[37] K. T. S. Kallonen,[37] T. Lampén,[37] K. Lassila-Perini,[37] S. Lehti,[37] T. Lindén,[37] M. Myllymäki,[37] M. m. Rantanen,[37] S. Saariokari,[37] J. Tuominiemi,[37] H. Kirschenmann,[38] P. Luukka,[38] H. Petrow,[38] M. Besancon,[39] F. Couderc,[39] M. Dejardin,[39] D. Denegri,[39] J. L. Faure,[39] F. Ferri,[39] S. Ganjour,[39] P. Gras,[39] G. Hamel de Monchenault,[39] M. Kumar,[39] V. Lohezic,[39] J. Malcles,[39] F. Orlandi,[39] L. Portales,[39] A. Rosowsky,[39] M. Ö. Sahin,[39] A. Savoy-Navarro,[39,r] P. Simkina,[39] M. Titov,[39] M. Tornago,[39] F. Beaudette,[40] G. Boldrini,[40] P. Busson,[40] C. Charlot,[40] M. Chiusi,[40] T. D. Cuisset,[40] F. Damas,[40] O. Davignon,[40]

A. De Wit,[40] I. T. Ehle,[40] B. A. Fontana Santos Alves,[40] S. Ghosh,[40] A. Gilbert,[40] R. Granier de Cassagnac,[40] B. Harikrishnan,[40] L. Kalipoliti,[40] G. Liu,[40] M. Manoni,[40] M. Nguyen,[40] S. Obraztsov,[40] C. Ochando,[40] R. Salerno,[40] J. B. Sauvan,[40] Y. Sirois,[40] G. Sokmen,[40] L. Urda Gómez,[40] E. Vernazza,[40] A. Zabi,[40] A. Zghiche,[40] J.-L. Agram,[41,s] J. Andrea,[41] D. Bloch,[41] J.-M. Brom,[41] E. C. Chabert,[41] C. Collard,[41] S. Falke,[41] U. Goerlach,[41] R. Haeberle,[41] A.-C. Le Bihan,[41] M. Meena,[41] O. Poncet,[41] G. Saha,[41] M. A. Sessini,[41] P. Van Hove,[41] P. Vaucelle,[41] A. Di Florio,[42] D. Amram,[43] S. Beauceron,[43] B. Blancon,[43] G. Boudoul,[43] N. Chanon,[43] D. Contardo,[43] P. Depasse,[43] C. Dozen,[43,t] H. El Mamouni,[43] J. Fay,[43] S. Gascon,[43] M. Gouzevitch,[43] C. Greenberg,[43] G. Grenier,[43] B. Ille,[43] E. Jourd‘huy,[43] I. B. Laktineh,[43] M. Lethuillier,[43] L. Mirabito,[43] S. Perries,[43] A. Purohit,[43] M. Vander Donckt,[43] P. Verdier,[43] J. Xiao,[43] I. Lomidze,[44] T. Toriashvili,[44,u] Z. Tsamalaidze,[44,v] V. Botta,[45] S. Consuegra Rodríguez,[45] L. Feld,[45] K. Klein,[45] M. Lipinski,[45] D. Meuser,[45] A. Pauls,[45] D. Pérez Adán,[45] N. Röwert,[45] M. Teroerde,[45] S. Diekmann,[46] A. Dodonova,[46] N. Eich,[46] D. Eliseev,[46] F. Engelke,[46] J. Erdmann,[46] M. Erdmann,[46] B. Fischer,[46] T. Hebbeker,[46] K. Hoepfner,[46] F. Ivone,[46] A. Jung,[46] N. Kumar,[46] M. y. Lee,[46] F. Mausolf,[46] M. Merschmeyer,[46] A. Meyer,[46] F. Nowotny,[46] A. Pozdnyakov,[46] Y. Rath,[46] W. Redjeb,[46] F. Rehm,[46] H. Reithler,[46] V. Sarkisovi,[46] A. Schmidt,[46] C. Seth,[46] A. Sharma,[46] J. L. Spah,[46] F. Torres Da Silva De Araujo,[46,w] S. Wiedenbeck,[46] S. Zaleski,[46] C. Dziwok,[47] G. Flügge,[47] T. Kress,[47] A. Nowack,[47] O. Pooth,[47] A. Stahl,[47] T. Ziemons,[47] A. Zotz,[47] H. Aarup Petersen,[48] M. Aldaya Martin,[48] J. Alimena,[48] S. Amoroso,[48] Y. An,[48] J. Bach,[48] S. Baxter,[48] M. Bayatmakou,[48] H. Becerril Gonzalez,[48] O. Behnke,[48] A. Belvedere,[48] F. Blekman,[48,x] K. Borras,[48,y] A. Campbell,[48] A. Cardini,[48] S. Chatterjee,[48] F. Colombina,[48] M. De Silva,[48] G. Eckerlin,[48] D. Eckstein,[48] E. Gallo,[48,x] A. Geiser,[48] V. Guglielmi,[48] M. Guthoff,[48] A. Hinzmann,[48] L. Jeppe,[48] B. Kaech,[48] M. Kasemann,[48] C. Kleinwort,[48] R. Kogler,[48] M. Komm,[48] D. Krücker,[48] W. Lange,[48] D. Leyva Pernia,[48] K. Lipka,[48,z] W. Lohmann,[48,aa] F. Lorkowski,[48] R. Mankel,[48] I.-A. Melzer-Pellmann,[48] M. Mendizabal Morentin,[48] A. B. Meyer,[48] G. Milella,[48] K. Moral Figueroa,[48] A. Mussgiller,[48] L. P. Nair,[48] J. Niedziela,[48] A. Nürnberg,[48] J. Park,[48] E. Ranken,[48] A. Raspereza,[48] D. Rastorguev,[48] J. Rübenach,[48] L. Rygaard,[48] M. Scham,[48,bb,y] S. Schnake,[48,y] P. Schütze,[48] C. Schwanenberger,[48,x] D. Selivanova,[48] K. Sharko,[48] M. Shchedrolosiev,[48] D. Stafford,[48] F. Vazzoler,[48] A. Ventura Barroso,[48] R. Walsh,[48] D. Wang,[48] Q. Wang,[48] K. Wichmann,[48] L. Wiens,[48,y] C. Wissing,[48] Y. Yang,[48] S. Zakharov,[48] A. Zimermmane Castro Santos,[48] A. Albrecht,[49] S. Albrecht,[49] M. Antonello,[49] S. Bollweg,[49] M. Bonanomi,[49] P. Connor,[49] K. El Morabit,[49] Y. Fischer,[49] E. Garutti,[49] A. Grohsjean,[49] J. Haller,[49] D. Hundhausen,[49] H. R. Jabusch,[49] G. Kasieczka,[49] P. Keicher,[49] R. Klanner,[49] W. Korcari,[49] T. Kramer,[49] C. c. Kuo,[49] V. Kutzner,[49] F. Labe,[49] J. Lange,[49] A. Lobanov,[49] C. Matthies,[49] L. Moureaux,[49] M. Mrowietz,[49] A. Nigamova,[49] K. Nikolopoulos,[49] Y. Nissan,[49] A. Paasch,[49] K. J. Pena Rodriguez,[49] T. Quadfasel,[49] B. Raciti,[49] M. Rieger,[49] D. Savoiu,[49] J. Schindler,[49] P. Schleper,[49] M. Schröder,[49] J. Schwandt,[49] M. Sommerhalder,[49] H. Stadie,[49] G. Steinbrück,[49] A. Tews,[49] B. Wiederspan,[49] M. Wolf,[49] S. Brommer,[50] E. Butz,[50] Y. M. Chen,[50] T. 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