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# Search for magnetic monopole pair production in ultraperipheral Pb+Pb collisions at $\sqrt{s_{\text{NN}}} = 5.36$ TeV with the ATLAS detector at the LHC

The ATLAS Collaboration

This Letter presents a search for highly ionizing magnetic monopoles in  $262 \mu\text{b}^{-1}$  of ultraperipheral Pb+Pb collision data at  $\sqrt{s_{\text{NN}}} = 5.36$  TeV collected by the ATLAS detector at the LHC. A new methodology that exploits the properties of clusters of hits reconstructed in the innermost silicon detector layers is introduced to study highly ionizing particles in heavy-ion data. No significant excess above the background, which is estimated using a data-driven technique, is observed. Using a nonperturbative semiclassical model, upper limits at 95% confidence level are set on the cross-section for pair production of monopoles with a single Dirac magnetic charge in the mass range of 20–150 GeV. The search significantly improves on the previous cross-section limits for production of low-mass monopoles in ultraperipheral Pb+Pb collisions.

Magnetic monopoles are hypothetical particles that carry isolated magnetic charge. The existence of a magnetically charged particle would restore symmetry to Maxwell's equations and explain why electric charge is quantized in nature, as shown by Dirac [1]. Dirac's argument predicts the magnetic charge of a monopole to be  $q_m = Ng_D$ , where  $N$  is an integer number,  $g_D = e/(2\alpha) \approx 68.5e$  is the Dirac elementary charge in cgs Gaussian units,  $\alpha$  is the fine-structure constant, and  $e$  is the elementary electric charge. Magnetic monopoles would manifest as highly ionizing particles, with unique trajectories in a magnetic field [2].

While monopoles appearing in grand unification theories typically have masses of the order of the unification scale ( $m \approx 10^{16}$  GeV) [3], some extensions of the Standard Model predict composite monopoles with masses near the TeV scale [4]. This improves the prospects for monopole production at existing colliders.

In ultrarelativistic heavy-ion collisions, the ion beams are accompanied by large electromagnetic (EM) fields (or equivalently, large photon fluxes). For photons emitted coherently by the entire nucleus, the flux is enhanced by a factor of  $Z^2$  (where  $Z$  is the charge of the nucleus), as compared with beams of protons. At impact parameters  $b$  larger than twice the nuclear radius,  $b > 2R_A$ , photon-induced reactions become the dominant interaction mechanism. These events, referred to as ultraperipheral collisions (UPC), have been used to study photon–nucleus (photonuclear) and photon–photon ( $\gamma\gamma$ ) collisions [5]. These events typically have features such as rapidity gaps and lower particle multiplicity, or exclusive final states with no extra particle production, that make them qualitatively different from nuclear collisions where hadronic interactions occur [6]. The interaction of strong magnetic fields in UPC can also give rise to the production of magnetic monopole-antimonopole pairs ( $M\bar{M}$ ). Using a simplified (leading order, LO) approach, the process corresponds to a  $\gamma\gamma$  fusion reaction,  $\gamma\gamma \rightarrow M\bar{M}$  [7].

The initial-photon energy spectra in UPC have a typical power-law behavior ( $E^{-1}$ ) up to energies of the order of  $E_{\max} \approx \gamma_L/R_A$  (where  $\gamma_L$  is the relativistic Lorentz factor of the ion). For Pb+Pb collisions at the Large Hadron Collider (LHC) at a nucleon–nucleon (NN) center-of-mass energy of  $\sqrt{s_{\text{NN}}} = 5.36$  TeV,  $E_{\max} \approx 85$  GeV, which implies that the UPC production cross-section for a final state with invariant mass  $m_X$  is suppressed for  $m_X > 170$  GeV.

Most searches for the direct production of magnetic monopoles at particle colliders have focused on collisions of elementary particles such as electrons or quarks, assuming pair production of spin-0 or spin- $\frac{1}{2}$  point-like monopoles via the Drell–Yan mechanism or  $\gamma\gamma$  fusion process [8–44]. However, due to the large coupling constant,  $1/(4\alpha) \approx 34$  [45], perturbative treatments in terms of Feynman diagrams are generally not well defined. Indeed, it has been argued that the production of composite monopoles from elementary-particle collisions is suppressed by a factor of  $e^{-4/\alpha} \approx 10^{-236}$  [46].

Magnetic monopoles could be produced in strong magnetic fields by a magnetic analogue of the Schwinger mechanism [47]. In this case, the  $M\bar{M}$  production cross-section can be computed nonperturbatively using semiclassical techniques such as the free-particle approximation (FPA) [48]. In the FPA model the formula for the total cross-section for magnetic monopole production in Pb+Pb UPC [48–50] is

$$\sigma_{\text{FPA}} = \frac{\omega}{m} \frac{2(q_m B)^4 R_{\text{Pb}}^4}{9\pi^2 m^4 \omega^2} \exp(-4m/\omega), \quad (1)$$

where  $m$  is the monopole mass,  $q_m$  is the magnetic charge,  $R_{\text{Pb}} = 6.62$  fm is the radius of a lead nucleus,  $B = 4.5 \cdot 10^{16}$  T is the peak magnetic field strength of the two nuclei at  $\sqrt{s_{\text{NN}}} = 5.36$  TeV, which occurs at  $b \approx 2R_{\text{Pb}}$ , and  $\omega = 1.19 \cdot 10^{26}$  s $^{-1}$  is the field inverse decay time. It should be noted that Eq. (1) was derived for scalar (spin-0) monopoles, and the effect of monopole spin should enhance the production cross-section [48]. Due to the coherence of the magnetic field, the potential  $e^{-4/\alpha}$  suppression is absent

for composite monopole production via the Schwinger formalism in UPC. This fact was used in the recent searches performed by the MoEDAL Collaboration in Pb+Pb collisions [50, 51]. It is also worth mentioning that while the quoted semiclassical calculations apply to elementary monopoles, the effects of finite monopole size are expected to enhance monopole production in these models [48].

This Letter presents a search for magnetic monopoles with  $|q_m| = 1g_D$  using  $262 \mu\text{b}^{-1}$  of UPC Pb+Pb collision data collected by the ATLAS detector at the LHC in 2023 at  $\sqrt{s_{\text{NN}}} = 5.36 \text{ TeV}$ . The ATLAS experiment [52, 53] is a multipurpose particle detector with cylindrical geometry [54], comprising an inner detector (ID) tracker surrounded by a thin superconducting solenoid, EM and hadronic calorimeters, and a muon spectrometer. A software suite [55] is used in Monte Carlo (MC) simulation, in the reconstruction and analysis of real and simulated data, in detector operations, and in the trigger and data acquisition systems of the experiment.

This analysis primarily makes use of the ID pixel detector and the zero-degree calorimeters (ZDC). The high-granularity silicon pixel detector surrounds the collision region. The innermost pixel-detector layer, the IBL, consists of 280 pixel-sensor modules that cover the region  $|\eta| < 3.03$ , and was installed at a mean distance of 3.3 cm from the beam axis before the start of Run 2 [56, 57]. In addition to the IBL, the pixel detector contains three other barrel layers and two endcaps with three disks each. It is followed by silicon microstrip (SCT) and transition radiation tracking detectors. ZDCs are located at  $z = \pm 140 \text{ m}$  from the interaction point, and detect neutral particles such as neutrons emitted from interacting nuclei.

Events of interest are selected by the first-level (L1) trigger system implemented in custom hardware, followed by selections made by algorithms implemented in software in the high-level trigger (HLT) [58]. In UPC, soft photons emitted by one lead nucleus can excite the other, typically through the giant dipole resonance [59], and induce the emission of one or more neutrons, each of which carries, on average, the full per-nucleon beam energy. This can give rise to three distinct EM breakup topologies:  $0n0n$  (no neutrons are emitted),  $0nXn$  (at least one neutron is emitted by exactly one nucleus) and  $XnXn$  (at least one neutron is emitted by each nucleus). They are shown schematically in Figure 1. This analysis exploits the  $XnXn$  topology, mainly due to limitations in triggering on monopole production. Since low-energy monopoles typically do not reach the ATLAS calorimeters, they do not produce any trigger signal there. Therefore, the only viable option is to trigger at L1 on the presence of forward neutrons in the ZDC. The primary trigger for this analysis requires a L1 signal consistent with the presence of one or more neutrons in both arms of the ZDC. In addition, the total transverse energy recorded in the calorimeter is required to be

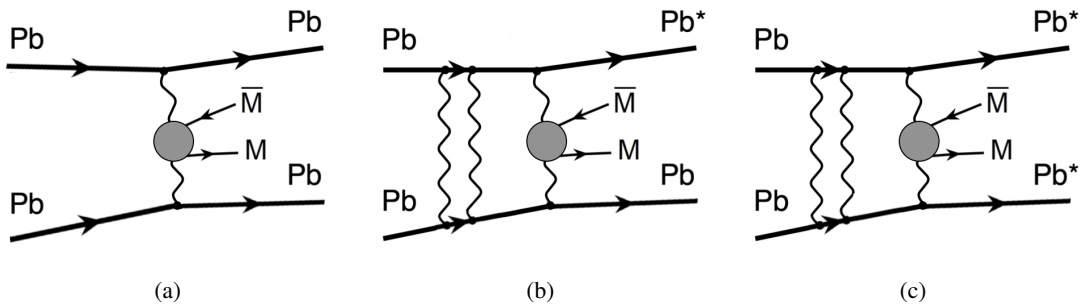


Figure 1: Schematic diagrams for magnetic monopole pair production in ultraperipheral Pb+Pb collisions for (a) no, (b) single and (c) mutual ion excitation due to extra soft-photon exchanges ( $0n0n$ ,  $0nXn$  and  $XnXn$  topologies, respectively). EM breakup of the ion, denoted by  $\text{Pb}^*$ , results in the production of forward neutrons, detectable in the ATLAS ZDC. The signal process in this study consists primarily of events having the  $XnXn$  topology (c).

below 10 GeV. As the monopoles considered in this analysis have relatively low masses (below 150 GeV) and typically have low energy, they deposit their energy in the innermost parts of the ATLAS detector, primarily in the pixel detector, thereby producing a sizable number of  $\delta$ -electrons. The presence of more than 100 clusters of pixel hits is required in the HLT, with no specific selection on the presence of any charged-particle tracks. Due to the large cross-section for double EM dissociation [60] and limitations in the allowed data-recording rate at L1, the trigger was prescaled so that approximately one event in every six was saved, resulting in an effective integrated luminosity of  $262 \mu\text{b}^{-1}$ , compared to the  $1.67 \text{nb}^{-1}$  recorded by unprescaled triggers.

MC simulated signal samples were produced using a semiclassical (nonperturbative) approach based on the FPA model. The semiclassical approximation breaks down [50] for sufficiently light monopoles,  $m < 20 \text{ GeV}$  for 5.36 TeV Pb+Pb collisions, so monopole mass hypotheses below 20 GeV are not considered. For the distributions of monopole kinematic quantities, simplified predictions based on the FPA model are used to model back-to-back monopole pair production, in particular with isotropic polar angle distributions of the pairs and with a distribution of monopole momentum  $p$  that follows the relative probability [49]

$$d\sigma_{\text{FPA}}(|p|)/d\sigma_{\text{FPA}}(0) = \exp\left[-\frac{4}{\omega}\left(\sqrt{m^2 + |p|^2} - m\right)\right].$$

The same model was used in the MoEDAL analysis [50]. A monopole charge of  $|q_{\text{m}}| = 1g_{\text{D}}$  is set in all signal samples and the monopole masses considered are 20, 30, 40, 50, 60, 70, 90, 100, 120 and 150 GeV. The signal simulation setup includes all possible configurations for the EM breakup of the nuclei, as described below. A sample with no interacting particles was simulated as well, to mimic data events that contain only detector noise.

Signal efficiency estimates rely on an extension of the ATLAS detector simulation [61] based on GEANT4 [62]. This extension, originally developed for monopole searches in  $pp$  collisions [37–40], includes descriptions of monopole acceleration in the detector’s magnetic field, ionization energy losses in matter and  $\delta$ -electron production along the monopole’s trajectory.

In order to correct the signal MC simulation for the  $XnXn$  topology requirement, exclusive dilepton ( $e\bar{e}$  and  $\mu\bar{\mu}$ ) events from the process  $\gamma\gamma \rightarrow \ell\bar{\ell}$  are studied. Due to the relatively large instantaneous luminosity of Pb+Pb collisions at the LHC, additional neutrons might be generated in each bunch crossing and detected in one or both arms of the ZDC (EM pileup). This leads to an outflow of events, primarily from the  $0nXn$  category, to the  $XnXn$  category. To account for this effect in MC simulation, the yield of simulated signal events is scaled by the effective probability for the  $XnXn$  topology, parameterized as a function of total system mass  $m_X$  and system rapidity  $y_X$ :

$$p_{XnXn}^{\text{eff}}(m_X, y_X) = 0.8 \times (2f_{0nXn} p_{\text{EM}} + f_{XnXn})(1 + f_{\text{diss}}), \quad (2)$$

where  $f_{0nXn}$  and  $f_{XnXn}$  are the predicted fractions of events with single and double EM breakup, respectively,  $p_{\text{EM}}$  is the probability of having at least one neutron from EM pileup on a given detector side, and  $f_{\text{diss}}$  is the small fraction of dissociative (incoherent) events [63] from the  $\gamma^*\gamma \rightarrow \ell\bar{\ell}$  and  $\gamma^*\gamma^* \rightarrow \ell\bar{\ell}$  reactions, where  $\gamma^*$  denotes a virtual photon. The  $f_{0nXn}$  and  $f_{XnXn}$  values are based on the SUPERCHIC 4.2 MC predictions [64], and are provided differentially in dilepton invariant mass ( $m_{\ell\bar{\ell}}$ ) and dilepton absolute rapidity ( $|y_{\ell\bar{\ell}}|$ ). The value of  $p_{\text{EM}}$ , estimated as outlined in Ref. [65], is  $p_{\text{EM}} = 0.038$  for the signal trigger and 2023 Pb+Pb data-taking conditions. The value of  $f_{\text{diss}}$  for the  $XnXn$  selection is estimated to be  $f_{\text{diss}} = 0.13$ , based on the study of exclusive dimuon and dielectron events [65, 66]. A possible enhancement of the dissociative contribution at the largest considered monopole masses (due to very small

Pb+Pb impact parameters), leading to larger values of  $p_{XnXn}^{\text{eff}}$ , is conservatively neglected. The factor of 0.8 in Eq. (2) accounts for mismodeling of  $f_{0nXn}$  and  $f_{XnXn}$  in SUPERCHIC, based on the calculation in Ref. [64]. The model based on Eq. (2) is validated using UPC  $\gamma\gamma \rightarrow \ell\ell$  data and good agreement (within 10%) is found. The value of  $p_{XnXn}^{\text{eff}}$  is about 15% for  $m_X = 40$  GeV and grows to about 30% for  $m_X = 200$  GeV.

The backgrounds considered in this analysis are the background from particles produced in Pb+Pb interactions (collision background) and the beam-induced background (BIB). BIB is caused by beam particle losses in the LHC ring upstream of the ATLAS experiment, due to interactions with residual gas within the beam pipe or with machine elements [67–70]. It is characterized by particles moving almost parallel to the beam line.

A requirement of at most one reconstructed charged-particle track is used to suppress collision backgrounds and has only a minor impact on the signal efficiency because a monopole’s trajectory in the axial magnetic field provided by a solenoid is straight in the  $r-\phi$  plane and bends in the  $r-z$  plane [71] (whereas the opposite applies to electrically charged particles). Charged-particle tracks are required to pass the track selection, which is optimized to suppress combinatorial (fake) tracks in the dense track environment around Pb+Pb collisions [72], and to have transverse momentum  $p_T > 0.1$  GeV,  $|\eta| < 2.5$ , and a transverse impact parameter of  $|d_0| < 1$  mm calculated relative to the measured beam-line position.

Signal events are required to have at most one topological cluster of calorimeter-cell energy deposits [73]. These topoclusters must have transverse energy  $E_T > 0.1$  GeV and  $|\eta| < 4.9$ , and meet the cell significance criteria for the measured energy as outlined in Ref. [74] to suppress the contribution from electronic noise fluctuations.

Events are also required to have more than 150 pixel clusters [75],  $n_{\text{PixCl}} > 150$ , including more than 50 IBL clusters,  $n_{\text{IBLCl}} > 50$ . Clusters from the four pixel-sensor modules observed to have abnormal noise distributions in data are not considered in the cluster counting. Furthermore, events are rejected if the number of clusters in a particular module exceeds 90% of all pixel clusters in the event. The selection requirements imposed on tracks, topoclusters and pixel clusters fully suppress the collision background.

To further reduce the BIB, the azimuthal distribution of reconstructed pixel clusters is examined. A variable  $T$ , inspired by the *transverse thrust* [76], is defined as:

$$T = (1/n_{\text{PixCl}}) \sum_{i=1}^{n_{\text{PixCl}}} |\hat{r}_i \cdot \hat{n}|,$$

where  $\hat{r}_i$  is the direction (unit vector) of a given pixel cluster in the transverse plane with respect to the origin of the ATLAS coordinate system, and the transverse direction  $\hat{n}$  maximizes the expression and corresponds to an azimuthal angle  $\phi_T$ . The solution for  $\hat{n}$  (or  $\phi_T$ ) is found iteratively. The direction of  $\hat{n}$  roughly aligns in  $r-\phi$  with the monopole’s trajectory. The  $T$  variable has a maximum value of 1, for a set of fully aligned pixel clusters, and a minimum value of around  $2/\pi$ , for a uniform distribution of clusters in the transverse plane. Simulated signal events tend to have  $T$  values near unity, whereas the backgrounds with more uniform particle production in  $\phi$  concentrate at much lower  $T$  values, typically just above  $2/\pi$ . A requirement of  $T > 0.95$  is therefore used in the signal region (SR) selection, based on the simulated signal properties. The signal acceptance times efficiency of the SR selection varies between 4% and 0.2% for simulated events with low and high monopole masses, respectively, and is driven by the  $n_{\text{PixCl}} > 150$  requirement.

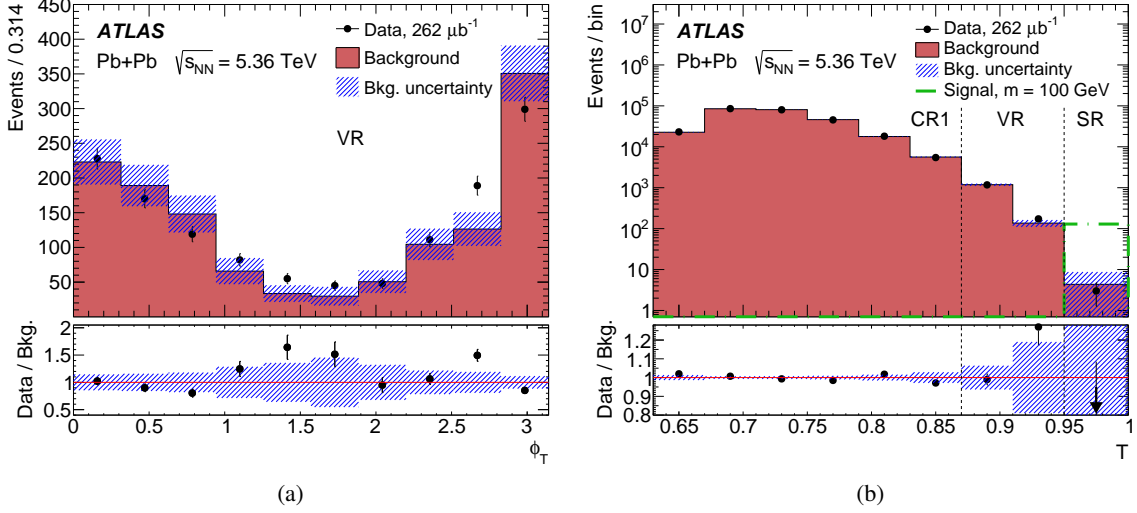


Figure 2: (a)  $\phi_T$  distribution for data in the VR and (b)  $T$  distribution for data in CR1, the VR, and the SR. Data (markers) are shown together with the estimated background (filled histograms). The distributions for background use events from CR2 scaled as described in the text. The lower panels show the ratio of data to the estimated background. The shaded bands represent the statistical uncertainty of the background. In (b) the green dotted-dashed line shows the representative signal contribution for a monopole of mass 100 GeV, and the arrow in the ratio plot is for the point that is outside the range.

The background yield in this analysis is estimated using a fully data-driven method. A control region (CR1) is defined by requiring  $T \leq 0.87$ . It is observed that the event characteristics in CR1 are consistent with those of BIB. Since the BIB typically results in asymmetric event activity, an additional control region (CR2) enriched in BIB is defined from events passing a supporting trigger that selects events with ZDC activity on one side and no activity on the opposite side. The same event selection criteria as for the SR, except no requirement on  $T$  and a different topocluster requirement, are applied to CR2. To help enrich the CR2 sample in BIB events and consequently reduce the signal contamination, only events with 1–3 topoclusters are used, with at least one out-of-time energy deposit in the calorimeter, i.e. a topocluster with reconstructed time more than 10 ns before the bunch-crossing time. The presence of topoclusters with negative reconstructed time is one of the characteristic features of BIB [67]. The signal contamination in both CR1 and CR2 is studied in the MC simulated samples and is found to be negligible.

Events in CR2 are used to extrapolate the background contribution from CR1 to SR, by using the relation:  $N_{\text{bkg}}^{\text{SR}} = (N^{\text{CR1}}/N_{T<0.87}^{\text{CR2}})N_{T>0.95}^{\text{CR2}}$ , where  $N^{\text{CR1}}$  is the event yield in CR1, and  $N_{T<0.87}^{\text{CR2}}$  ( $N_{T>0.95}^{\text{CR2}}$ ) is the number of CR2 events having  $T < 0.87$  ( $T > 0.95$ ). To cross-check this procedure, a validation region (VR) is defined by requiring  $0.87 < T \leq 0.95$ . Figure 2(a) shows the  $\phi_T$  distributions in the VR. The CR2-based background estimate describes the data adequately. The enhanced event activity at  $\phi_T \approx 0$  and  $\phi_T \approx \pi$  is characteristic of BIB [67, 68].

The number of pixel clusters is correlated with the number of SCT space points [77],  $n_{\text{SCTsp}}$ . To address a small discrepancy between the CR1 and CR2  $n_{\text{SCTsp}}$  distributions at low  $n_{\text{SCTsp}}$ , extra reweighting of the  $n_{\text{SCTsp}}$  distribution is performed for events in CR2 to better match the distribution observed in CR1. The correction applied to the  $n_{\text{SCTsp}}$  distribution improves the modeling of the  $n_{\text{PixCl}}$  distribution. This correction changes the shape of the  $T$  distribution by a few percent at low  $T$  and by about 10% at high  $T$ .

Figure 2(b) shows the  $T$  distribution in CR1, the VR, and the SR. The background in the SR is estimated to be  $4 \pm 4$  (stat.) events.

The systematic uncertainties that were considered are related to the modeling of the detector response to the monopole, the overall noise level in the pixel detector, potential mismodeling of the  $XnXn$  selection, the background uncertainty, and the luminosity uncertainty. Uncertainties evaluated in one direction are assumed to be symmetric.

The uncertainty due to the ID material modeling in the GEANT4 simulation is accounted for by comparing the signal efficiency with its value in alternative signal samples. These samples differ by having modified descriptions of the ATLAS ID geometry: the passive material of the ID is scaled by 5%, the passive material of the IBL is scaled by 10%, or the passive material in the services region is scaled by 25%. These variations capture the full range of data–MC differences observed in studies of the ID material [78]. The changes in signal yield depend on the monopole mass hypothesis and range from 3% to 20% for the lowest and highest mass points, respectively.

The kinetic energy threshold below which  $\delta$ -electrons are not propagated explicitly in the ATLAS simulation depends on the GEANT4 “range cut” parameter [79]. Reducing the value of this parameter by a factor of five produces less than a 3% signal yield change, which is taken as a systematic uncertainty.

The  $dE/dx$  formulas for ionization by monopoles (Bethe–Ahlen theory) have theoretical uncertainties of about  $\pm 3\%$  in the kinematic region considered in this analysis [80]. Alternative signal samples where  $\delta$ -electron production is reduced by 3% were therefore simulated. This results in a 1%–4% decrease in signal yield for the mass range considered, which is included as a systematic uncertainty.

Noise activity in the pixel detector is somewhat mismodeled in the simulation. Less activity is observed in MC simulated events with no interacting particles than in “empty” single-EM-dissociation (single-EMD) data events (with no tracks or topoclusters) selected by an unbiased trigger. To obtain better data–MC agreement, the MC simulated “empty” events are overlaid, on an event-by-event basis, with additional pixel clusters randomly assigned to pixel-cluster positions seen in “empty” single-EMD data events. The same degree of pixel-cluster overlay is then applied in MC signal events, resulting in a 1%–2% decrease in signal yield, which is taken as a systematic uncertainty. A similar procedure is used to estimate calorimeter noise, resulting in a 1% decrease in signal yield.

To cover the  $XnXn$  selection modeling, a 20% uncertainty is assigned to  $p_{XnXn}^{\text{eff}}$ . A value of 20% is chosen to primarily cover the 10%–20% differences observed between the  $f_{0nXn}$  and  $f_{XnXn}$  values in ATLAS data and those predicted by SUPERCHIC 4.2 [64]. It also covers differences between SUPERCHIC and alternative STARLIGHT [81] or GAMMA-UPC [82] predictions for  $f_{0nXn}$  and  $f_{XnXn}$ .

The difference between the background estimates from the reweighted and non-reweighted  $n_{\text{SCTsp}}$  distributions in CR2 is taken as a systematic uncertainty in the background estimate. The reweighting of other distributions that show slight differences between CR1 and CR2 has a negligible impact on the background estimate.

The uncertainty in the integrated luminosity of the data sample is 3.5%. It is derived from the calibration of the luminosity following a methodology similar to that detailed in Ref. [83], and using the LUCID-2 detector [84] for the baseline luminosity measurements. The total systematic uncertainty affecting the selection efficiency varies between 21% (lowest masses) and 38% (highest masses).

Three data events were found in the SR. This is consistent with the estimate of  $4 \pm 4$  (stat.)  $\pm 1$  (syst.) background events. Consequently, exclusion limits are set at 95% confidence level (CL) using the  $\text{CL}_s$

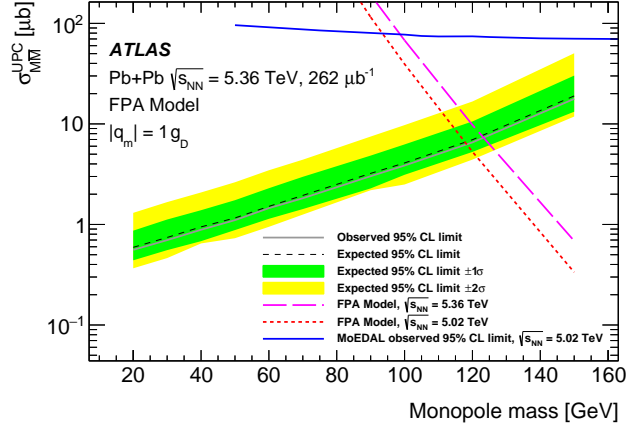


Figure 3: Expected and observed upper limits on the monopole pair-production cross-section in Pb+Pb UPC at  $\sqrt{s_{\text{NN}}} = 5.36$  TeV for  $|q_m| = 1g_D$  and assuming the FPA model. The gray solid line (black dashed line) represents observed (expected) limits, whereas the darker and lighter shaded bands around the expected limits represent the  $\pm 1\sigma$  and  $\pm 2\sigma$  intervals, respectively. The limits are compared with FPA model predictions (dashed lines) and the observed limits by MoEDAL for  $|q_m| = 1g_D$  at a lower center-of-mass energy of  $\sqrt{s_{\text{NN}}} = 5.02$  TeV [50] (blue line).

method [85] implemented in RooStats [86]. The cross-section limits are obtained by exploiting the selection efficiency and its uncertainty for each signal sample, the systematic uncertainty of the background estimate, and the integrated luminosity’s uncertainty. Limits are calculated using the pseudo-experiment approach, with 20000 “toys” per mass point. Figure 3 shows the obtained 95% CL limits. These results are compared with the FPA model predictions [48] (Eq. (1)) and with the observed limits MoEDAL [50] obtained using the trapping technique [87]. The present search excludes monopoles with masses below 120 GeV, and significantly improves on the previous cross-section limits reported by MoEDAL.

In conclusion, this Letter presents a search for magnetic monopoles with mass in the range 20–150 GeV in ultraperipheral heavy-ion collisions using  $262 \mu\text{b}^{-1}$  of Pb+Pb collision data at  $\sqrt{s_{\text{NN}}} = 5.36$  TeV collected by the ATLAS detector at the LHC. This analysis uses an alternative way of detecting low-mass monopoles in heavy-ion collisions, complementary to the trapping technique used by the MoEDAL experiment. The targeted monopole signature is based on high ionization in the ATLAS pixel detector. The background is mainly beam-induced, and its yield is estimated using a data-driven procedure. No excess of events over the expected background is observed. The derived upper limits on monopole pair-production cross-sections, based on a non-perturbative semiclassical model and derived at 95% confidence level, are more stringent than the recently reported limits from MoEDAL, also using Pb+Pb collisions. Monopoles with a single Dirac magnetic charge and mass below 120 GeV are excluded.

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## The ATLAS Collaboration

G. Aad <sup>105</sup>, E. Aakvaag <sup>17</sup>, B. Abbott <sup>124</sup>, S. Abdelhameed <sup>120a</sup>, K. Abeling <sup>57</sup>, N.J. Abicht <sup>51</sup>, S.H. Abidi <sup>30</sup>, M. Aboeela <sup>46</sup>, A. Aboulhorma <sup>36e</sup>, H. Abramowicz <sup>155</sup>, H. Abreu <sup>154</sup>, Y. Abulaiti <sup>121</sup>, B.S. Acharya <sup>71a,71b,k</sup>, A. Ackermann <sup>65a</sup>, C. Adam Bourdarios <sup>4</sup>, L. Adamczyk <sup>88a</sup>, S.V. Addepalli <sup>27</sup>, M.J. Addison <sup>104</sup>, J. Adelman <sup>119</sup>, A. Adiguzel <sup>22c</sup>, T. Adye <sup>138</sup>, A.A. Affolder <sup>140</sup>, Y. Afik <sup>41</sup>, M.N. Agaras <sup>13</sup>, A. Aggarwal <sup>103</sup>, C. Agheorghiesei <sup>28c</sup>, F. Ahmadov <sup>40,y</sup>, S. Ahuja <sup>98</sup>, X. Ai <sup>64e</sup>, G. Aielli <sup>78a,78b</sup>, A. Aikot <sup>168</sup>, M. Ait Tamlihat <sup>36e</sup>, B. Aitbenkikh <sup>36a</sup>, M. Akbiyik <sup>103</sup>, T.P.A. Åkesson <sup>101</sup>, A.V. 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





















































































































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A. Moussa [ID](#)<sup>36d</sup>, Y. Moyal [ID](#)<sup>174</sup>, E.J.W. Moyses [ID](#)<sup>106</sup>, O. Mtintsilana [ID](#)<sup>34g</sup>, S. Muanza [ID](#)<sup>105</sup>,  
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 M. Verducci [ID<sup>76a,76b</sup>](#), C. Vergis [ID<sup>97</sup>](#), M. Verissimo De Araujo [ID<sup>85b</sup>](#), W. Verkerke [ID<sup>118</sup>](#),  
 J.C. Vermeulen [ID<sup>118</sup>](#), C. Vernieri [ID<sup>147</sup>](#), M. Vessella [ID<sup>106</sup>](#), M.C. Vetterli [ID<sup>146,ac</sup>](#), A. Vgenopoulos [ID<sup>103</sup>](#),  
 N. Viaux Maira [ID<sup>141f</sup>](#), T. Vickey [ID<sup>143</sup>](#), O.E. Vickey Boeriu [ID<sup>143</sup>](#), G.H.A. Viehhauser [ID<sup>130</sup>](#), L. Vignani [ID<sup>65b</sup>](#),  
 M. Vigl [ID<sup>113</sup>](#), M. Villa [ID<sup>24b,24a</sup>](#), M. Villaplana Perez [ID<sup>168</sup>](#), E.M. Villhauer [ID<sup>54</sup>](#), E. Vilucchi [ID<sup>55</sup>](#),  
 M.G. Vincter [ID<sup>35</sup>](#), A. Visibile [ID<sup>118</sup>](#), C. Vittori [ID<sup>37</sup>](#), I. Vivarelli [ID<sup>24b,24a</sup>](#), E. Voevodina [ID<sup>113</sup>](#), F. Vogel [ID<sup>112</sup>](#),  
 J.C. Voigt [ID<sup>52</sup>](#), P. Vokac [ID<sup>136</sup>](#), Yu. Volkotrub [ID<sup>88b</sup>](#), E. Von Toerne [ID<sup>25</sup>](#), A. Vorlander [ID<sup>176</sup>](#),  
 B. Vormwald [ID<sup>37</sup>](#), V. Vorobel [ID<sup>137</sup>](#), K. Vorobev [ID<sup>39</sup>](#), M. Vos [ID<sup>168</sup>](#), K. Voss [ID<sup>145</sup>](#), M. Vozak [ID<sup>118</sup>](#),  
 L. Vozdecky [ID<sup>124</sup>](#), N. Vranjes [ID<sup>16</sup>](#), M. Vranjes Milosavljevic [ID<sup>16</sup>](#), M. Vreeswijk [ID<sup>118</sup>](#), N.K. Vu [ID<sup>64d,64c</sup>](#),  
 R. Vuillermet [ID<sup>37</sup>](#), O. Vujinovic [ID<sup>103</sup>](#), I. Vukotic [ID<sup>41</sup>](#), I.K. Vyas [ID<sup>35</sup>](#), S. Wada [ID<sup>161</sup>](#), C. Wagner [ID<sup>147</sup>](#),  
 J.M. Wagner [ID<sup>18a</sup>](#), W. Wagner [ID<sup>176</sup>](#), S. Wahdan [ID<sup>176</sup>](#), H. Wahlberg [ID<sup>93</sup>](#), C.H. Waits [ID<sup>124</sup>](#), J. Walder [ID<sup>138</sup>](#),  
 R. Walker [ID<sup>112</sup>](#), W. Walkowiak [ID<sup>145</sup>](#), A. Wall [ID<sup>132</sup>](#), E.J. Wallin [ID<sup>101</sup>](#), T. Wamorkar [ID<sup>6</sup>](#), A.Z. Wang [ID<sup>140</sup>](#),  
 C. Wang [ID<sup>103</sup>](#), C. Wang [ID<sup>11</sup>](#), H. Wang [ID<sup>18a</sup>](#), J. Wang [ID<sup>66c</sup>](#), P. Wang [ID<sup>99</sup>](#), R. Wang [ID<sup>63</sup>](#), R. Wang [ID<sup>6</sup>](#),  
 S.M. Wang [ID<sup>152</sup>](#), S. Wang [ID<sup>14</sup>](#), T. Wang [ID<sup>64a</sup>](#), W.T. Wang [ID<sup>82</sup>](#), W. Wang [ID<sup>14</sup>](#), X. Wang [ID<sup>115a</sup>](#),  
 X. Wang [ID<sup>167</sup>](#), X. Wang [ID<sup>64c</sup>](#), Y. Wang [ID<sup>64d</sup>](#), Y. Wang [ID<sup>115a</sup>](#), Y. Wang [ID<sup>64a</sup>](#), Z. Wang [ID<sup>109</sup>](#),  
 Z. Wang [ID<sup>64d,53,64c</sup>](#), Z. Wang [ID<sup>109</sup>](#), A. Warburton [ID<sup>107</sup>](#), R.J. Ward [ID<sup>21</sup>](#), N. Warrack [ID<sup>61</sup>](#),  
 S. Waterhouse [ID<sup>98</sup>](#), A.T. Watson [ID<sup>21</sup>](#), H. Watson [ID<sup>54</sup>](#), M.F. Watson [ID<sup>21</sup>](#), E. Watton [ID<sup>61,138</sup>](#), G. Watts [ID<sup>142</sup>](#),  
 B.M. Waugh [ID<sup>99</sup>](#), J.M. Webb [ID<sup>56</sup>](#), C. Weber [ID<sup>30</sup>](#), H.A. Weber [ID<sup>19</sup>](#), M.S. Weber [ID<sup>20</sup>](#), S.M. Weber [ID<sup>65a</sup>](#),  
 C. Wei [ID<sup>64a</sup>](#), Y. Wei [ID<sup>56</sup>](#), A.R. Weidberg [ID<sup>130</sup>](#), E.J. Weik [ID<sup>121</sup>](#), J. Weingarten [ID<sup>51</sup>](#), C. Weiser [ID<sup>56</sup>](#),  
 C.J. Wells [ID<sup>50</sup>](#), T. Wenaus [ID<sup>30</sup>](#), B. Wendland [ID<sup>51</sup>](#), T. Wengler [ID<sup>37</sup>](#), N.S. Wenke [ID<sup>113</sup>](#), N. Wermes [ID<sup>25</sup>](#),  
 M. Wessels [ID<sup>65a</sup>](#), A.M. Wharton [ID<sup>94</sup>](#), A.S. White [ID<sup>63</sup>](#), A. White [ID<sup>8</sup>](#), M.J. White [ID<sup>1</sup>](#), D. Whiteson [ID<sup>163</sup>](#),  
 L. Wickremasinghe [ID<sup>128</sup>](#), W. Wiedenmann [ID<sup>175</sup>](#), M. Wielers [ID<sup>138</sup>](#), C. Wiglesworth [ID<sup>44</sup>](#), D.J. Wilbern [ID<sup>124</sup>](#),  
 H.G. Wilkens [ID<sup>37</sup>](#), J.J.H. Wilkinson [ID<sup>33</sup>](#), D.M. Williams [ID<sup>43</sup>](#), H.H. Williams [ID<sup>132</sup>](#), S. Williams [ID<sup>33</sup>](#),

S. Willocq <sup>106</sup>, B.J. Wilson <sup>104</sup>, P.J. Windischhofer <sup>41</sup>, F.I. Winkel <sup>31</sup>, F. Winklmeier <sup>127</sup>, B.T. Winter <sup>56</sup>, J.K. Winter <sup>104</sup>, M. Wittgen<sup>147</sup>, M. Wobisch <sup>100</sup>, T. Wojtkowski<sup>62</sup>, Z. Wolffs <sup>118</sup>, J. Wollrath<sup>37</sup>, M.W. Wolter <sup>89</sup>, H. Wolters <sup>134a,134c</sup>, M.C. Wong<sup>140</sup>, E.L. Woodward <sup>43</sup>, S.D. Worm <sup>50</sup>, B.K. Wosiek <sup>89</sup>, K.W. Woźniak <sup>89</sup>, S. Wozniowski <sup>57</sup>, K. Wraight <sup>61</sup>, C. Wu <sup>21</sup>, M. Wu <sup>115b</sup>, M. Wu <sup>117</sup>, S.L. Wu <sup>175</sup>, X. Wu <sup>58</sup>, Y. Wu <sup>64a</sup>, Z. Wu <sup>4</sup>, J. Wuerzinger <sup>113,aa</sup>, T.R. Wyatt <sup>104</sup>, B.M. Wynne <sup>54</sup>, S. Xella <sup>44</sup>, L. Xia <sup>115a</sup>, M. Xia <sup>15</sup>, M. Xie <sup>64a</sup>, S. Xin <sup>14,115c</sup>, A. Xiong <sup>127</sup>, J. Xiong <sup>18a</sup>, D. Xu <sup>14</sup>, H. Xu <sup>64a</sup>, L. Xu <sup>64a</sup>, R. Xu <sup>132</sup>, T. Xu <sup>109</sup>, Y. Xu <sup>142</sup>, Z. Xu <sup>54</sup>, Z. Xu<sup>115a</sup>, B. Yabsley <sup>151</sup>, S. Yacoub <sup>34a</sup>, Y. Yamaguchi <sup>86</sup>, E. Yamashita <sup>157</sup>, H. Yamauchi <sup>161</sup>, T. Yamazaki <sup>18a</sup>, Y. Yamazaki <sup>87</sup>, S. Yan <sup>61</sup>, Z. Yan <sup>106</sup>, H.J. Yang <sup>64c,64d</sup>, H.T. Yang <sup>64a</sup>, S. Yang <sup>64a</sup>, T. Yang <sup>66c</sup>, X. Yang <sup>37</sup>, X. Yang <sup>14</sup>, Y. Yang <sup>46</sup>, Y. Yang<sup>64a</sup>, W-M. Yao <sup>18a</sup>, H. Ye <sup>115a</sup>, H. Ye <sup>57</sup>, J. Ye <sup>14</sup>, S. Ye <sup>30</sup>, X. Ye <sup>64a</sup>, Y. Yeh <sup>99</sup>, I. Yeletsikh <sup>40</sup>, B. Yeo <sup>18b</sup>, M.R. Yexley <sup>99</sup>, T.P. Yildirim <sup>130</sup>, P. Yin <sup>43</sup>, K. Yorita <sup>173</sup>, S. Younas <sup>28b</sup>, C.J.S. Young <sup>37</sup>, C. Young <sup>147</sup>, C. Yu <sup>14,115c</sup>, Y. Yu <sup>64a</sup>, J. Yuan <sup>14,115c</sup>, M. Yuan <sup>109</sup>, R. Yuan <sup>64d,64c</sup>, L. Yue <sup>99</sup>, M. Zaazoua <sup>64a</sup>, B. Zabinski <sup>89</sup>, E. Zaid<sup>54</sup>, Z.K. Zak <sup>89</sup>, T. Zakareishvili <sup>168</sup>, S. Zambito <sup>58</sup>, J.A. Zamora Saa <sup>141d,141b</sup>, J. Zang <sup>157</sup>, D. Zanzi <sup>56</sup>, O. Zaplatilek <sup>136</sup>, C. Zeitnitz <sup>176</sup>, H. Zeng <sup>14</sup>, J.C. Zeng <sup>167</sup>, D.T. Zenger Jr <sup>27</sup>, O. Zenin <sup>39</sup>, T. Ženiš <sup>29a</sup>, S. Zenz <sup>97</sup>, S. Zerradi <sup>36a</sup>, D. Zerwas <sup>68</sup>, M. Zhai <sup>14,115c</sup>, D.F. Zhang <sup>143</sup>, J. Zhang <sup>64b</sup>, J. Zhang <sup>6</sup>, K. Zhang <sup>14,115c</sup>, L. Zhang <sup>64a</sup>, L. Zhang <sup>115a</sup>, P. Zhang <sup>14,115c</sup>, R. Zhang <sup>175</sup>, S. Zhang <sup>109</sup>, S. Zhang <sup>92</sup>, T. Zhang <sup>157</sup>, X. Zhang <sup>64c</sup>, Y. Zhang <sup>142</sup>, Y. Zhang <sup>99</sup>, Y. Zhang <sup>115a</sup>, Z. Zhang <sup>18a</sup>, Z. Zhang <sup>64b</sup>, Z. Zhang <sup>68</sup>, H. Zhao <sup>142</sup>, T. Zhao <sup>64b</sup>, Y. Zhao <sup>140</sup>, Z. Zhao <sup>64a</sup>, Z. Zhao <sup>64a</sup>, A. Zhemchugov <sup>40</sup>, J. Zheng <sup>115a</sup>, K. Zheng <sup>167</sup>, X. Zheng <sup>64a</sup>, Z. Zheng <sup>147</sup>, D. Zhong <sup>167</sup>, B. Zhou <sup>109</sup>, H. Zhou <sup>7</sup>, N. Zhou <sup>64c</sup>, Y. Zhou<sup>15</sup>, Y. Zhou <sup>115a</sup>, Y. Zhou<sup>7</sup>, C.G. Zhu <sup>64b</sup>, J. Zhu <sup>109</sup>, X. Zhu <sup>64d</sup>, Y. Zhu <sup>64c</sup>, Y. Zhu <sup>64a</sup>, X. Zhuang <sup>14</sup>, K. Zhukov <sup>70</sup>, N.I. Zimine <sup>40</sup>, J. Zinsser <sup>65b</sup>, M. Ziolkowski <sup>145</sup>, L. Živković <sup>16</sup>, A. Zoccoli <sup>24b,24a</sup>, K. Zoch <sup>63</sup>, T.G. Zorbas <sup>143</sup>, O. Zormpa <sup>48</sup>, W. Zou <sup>43</sup>, L. Zwalinski <sup>37</sup>.

<sup>1</sup>Department of Physics, University of Adelaide, Adelaide; Australia.

<sup>2</sup>Department of Physics, University of Alberta, Edmonton AB; Canada.

<sup>3</sup>(<sup>a</sup>)Department of Physics, Ankara University, Ankara; (<sup>b</sup>)Division of Physics, TOBB University of Economics and Technology, Ankara; Türkiye.

<sup>4</sup>LAPP, Université Savoie Mont Blanc, CNRS/IN2P3, Annecy; France.

<sup>5</sup>APC, Université Paris Cité, CNRS/IN2P3, Paris; France.

<sup>6</sup>High Energy Physics Division, Argonne National Laboratory, Argonne IL; United States of America.

<sup>7</sup>Department of Physics, University of Arizona, Tucson AZ; United States of America.

<sup>8</sup>Department of Physics, University of Texas at Arlington, Arlington TX; United States of America.

<sup>9</sup>Physics Department, National and Kapodistrian University of Athens, Athens; Greece.

<sup>10</sup>Physics Department, National Technical University of Athens, Zografou; Greece.

<sup>11</sup>Department of Physics, University of Texas at Austin, Austin TX; United States of America.

<sup>12</sup>Institute of Physics, Azerbaijan Academy of Sciences, Baku; Azerbaijan.

<sup>13</sup>Institut de Física d'Altes Energies (IFAE), Barcelona Institute of Science and Technology, Barcelona; Spain.

<sup>14</sup>Institute of High Energy Physics, Chinese Academy of Sciences, Beijing; China.

<sup>15</sup>Physics Department, Tsinghua University, Beijing; China.

<sup>16</sup>Institute of Physics, University of Belgrade, Belgrade; Serbia.

<sup>17</sup>Department for Physics and Technology, University of Bergen, Bergen; Norway.

<sup>18</sup>(<sup>a</sup>)Physics Division, Lawrence Berkeley National Laboratory, Berkeley CA; (<sup>b</sup>)University of California, Berkeley CA; United States of America.

- <sup>19</sup>Institut für Physik, Humboldt Universität zu Berlin, Berlin; Germany.
- <sup>20</sup>Albert Einstein Center for Fundamental Physics and Laboratory for High Energy Physics, University of Bern, Bern; Switzerland.
- <sup>21</sup>School of Physics and Astronomy, University of Birmingham, Birmingham; United Kingdom.
- <sup>22</sup>(<sup>a</sup>) Department of Physics, Bogazici University, Istanbul; (<sup>b</sup>) Department of Physics Engineering, Gaziantep University, Gaziantep; (<sup>c</sup>) Department of Physics, Istanbul University, Istanbul; Türkiye.
- <sup>23</sup>(<sup>a</sup>) Facultad de Ciencias y Centro de Investigaciones, Universidad Antonio Nariño, Bogotá; (<sup>b</sup>) Departamento de Física, Universidad Nacional de Colombia, Bogotá; Colombia.
- <sup>24</sup>(<sup>a</sup>) Dipartimento di Fisica e Astronomia A. Righi, Università di Bologna, Bologna; (<sup>b</sup>) INFN Sezione di Bologna; Italy.
- <sup>25</sup>Physikalisches Institut, Universität Bonn, Bonn; Germany.
- <sup>26</sup>Department of Physics, Boston University, Boston MA; United States of America.
- <sup>27</sup>Department of Physics, Brandeis University, Waltham MA; United States of America.
- <sup>28</sup>(<sup>a</sup>) Transilvania University of Brasov, Brasov; (<sup>b</sup>) Horia Hulubei National Institute of Physics and Nuclear Engineering, Bucharest; (<sup>c</sup>) Department of Physics, Alexandru Ioan Cuza University of Iasi, Iasi; (<sup>d</sup>) National Institute for Research and Development of Isotopic and Molecular Technologies, Physics Department, Cluj-Napoca; (<sup>e</sup>) National University of Science and Technology Politehnica, Bucharest; (<sup>f</sup>) West University in Timisoara, Timisoara; (<sup>g</sup>) Faculty of Physics, University of Bucharest, Bucharest; Romania.
- <sup>29</sup>(<sup>a</sup>) Faculty of Mathematics, Physics and Informatics, Comenius University, Bratislava; (<sup>b</sup>) Department of Subnuclear Physics, Institute of Experimental Physics of the Slovak Academy of Sciences, Kosice; Slovak Republic.
- <sup>30</sup>Physics Department, Brookhaven National Laboratory, Upton NY; United States of America.
- <sup>31</sup>Universidad de Buenos Aires, Facultad de Ciencias Exactas y Naturales, Departamento de Física, y CONICET, Instituto de Física de Buenos Aires (IFIBA), Buenos Aires; Argentina.
- <sup>32</sup>California State University, CA; United States of America.
- <sup>33</sup>Cavendish Laboratory, University of Cambridge, Cambridge; United Kingdom.
- <sup>34</sup>(<sup>a</sup>) Department of Physics, University of Cape Town, Cape Town; (<sup>b</sup>) iThemba Labs, Western Cape; (<sup>c</sup>) Department of Mechanical Engineering Science, University of Johannesburg, Johannesburg; (<sup>d</sup>) National Institute of Physics, University of the Philippines Diliman (Philippines); (<sup>e</sup>) University of South Africa, Department of Physics, Pretoria; (<sup>f</sup>) University of Zululand, KwaDlangezwa; (<sup>g</sup>) School of Physics, University of the Witwatersrand, Johannesburg; South Africa.
- <sup>35</sup>Department of Physics, Carleton University, Ottawa ON; Canada.
- <sup>36</sup>(<sup>a</sup>) Faculté des Sciences Ain Chock, Université Hassan II de Casablanca; (<sup>b</sup>) Faculté des Sciences, Université Ibn-Tofail, Kénitra; (<sup>c</sup>) Faculté des Sciences Semlalia, Université Cadi Ayyad, LPHEA-Marrakech; (<sup>d</sup>) LPMR, Faculté des Sciences, Université Mohamed Premier, Oujda; (<sup>e</sup>) Faculté des sciences, Université Mohammed V, Rabat; (<sup>f</sup>) Institute of Applied Physics, Mohammed VI Polytechnic University, Ben Guerir; Morocco.
- <sup>37</sup>CERN, Geneva; Switzerland.
- <sup>38</sup>Affiliated with an institute formerly covered by a cooperation agreement with CERN.
- <sup>39</sup>Affiliated with an institute covered by a cooperation agreement with CERN.
- <sup>40</sup>Affiliated with an international laboratory covered by a cooperation agreement with CERN.
- <sup>41</sup>Enrico Fermi Institute, University of Chicago, Chicago IL; United States of America.
- <sup>42</sup>LPC, Université Clermont Auvergne, CNRS/IN2P3, Clermont-Ferrand; France.
- <sup>43</sup>Nevis Laboratory, Columbia University, Irvington NY; United States of America.
- <sup>44</sup>Niels Bohr Institute, University of Copenhagen, Copenhagen; Denmark.
- <sup>45</sup>(<sup>a</sup>) Dipartimento di Fisica, Università della Calabria, Rende; (<sup>b</sup>) INFN Gruppo Collegato di Cosenza, Laboratori Nazionali di Frascati; Italy.

- <sup>46</sup>Physics Department, Southern Methodist University, Dallas TX; United States of America.
- <sup>47</sup>Physics Department, University of Texas at Dallas, Richardson TX; United States of America.
- <sup>48</sup>National Centre for Scientific Research "Demokritos", Agia Paraskevi; Greece.
- <sup>49</sup>(<sup>a</sup>)Department of Physics, Stockholm University; (<sup>b</sup>)Oskar Klein Centre, Stockholm; Sweden.
- <sup>50</sup>Deutsches Elektronen-Synchrotron DESY, Hamburg and Zeuthen; Germany.
- <sup>51</sup>Fakultät Physik, Technische Universität Dortmund, Dortmund; Germany.
- <sup>52</sup>Institut für Kern- und Teilchenphysik, Technische Universität Dresden, Dresden; Germany.
- <sup>53</sup>Department of Physics, Duke University, Durham NC; United States of America.
- <sup>54</sup>SUPA - School of Physics and Astronomy, University of Edinburgh, Edinburgh; United Kingdom.
- <sup>55</sup>INFN e Laboratori Nazionali di Frascati, Frascati; Italy.
- <sup>56</sup>Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Freiburg; Germany.
- <sup>57</sup>II. Physikalisches Institut, Georg-August-Universität Göttingen, Göttingen; Germany.
- <sup>58</sup>Département de Physique Nucléaire et Corpusculaire, Université de Genève, Genève; Switzerland.
- <sup>59</sup>(<sup>a</sup>)Dipartimento di Fisica, Università di Genova, Genova; (<sup>b</sup>)INFN Sezione di Genova; Italy.
- <sup>60</sup>II. Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen; Germany.
- <sup>61</sup>SUPA - School of Physics and Astronomy, University of Glasgow, Glasgow; United Kingdom.
- <sup>62</sup>LPSC, Université Grenoble Alpes, CNRS/IN2P3, Grenoble INP, Grenoble; France.
- <sup>63</sup>Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge MA; United States of America.
- <sup>64</sup>(<sup>a</sup>)Department of Modern Physics and State Key Laboratory of Particle Detection and Electronics, University of Science and Technology of China, Hefei; (<sup>b</sup>)Institute of Frontier and Interdisciplinary Science and Key Laboratory of Particle Physics and Particle Irradiation (MOE), Shandong University, Qingdao; (<sup>c</sup>)School of Physics and Astronomy, Shanghai Jiao Tong University, Key Laboratory for Particle Astrophysics and Cosmology (MOE), SKLPPC, Shanghai; (<sup>d</sup>)Tsung-Dao Lee Institute, Shanghai; (<sup>e</sup>)School of Physics and Microelectronics, Zhengzhou University; China.
- <sup>65</sup>(<sup>a</sup>)Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Heidelberg; (<sup>b</sup>)Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg; Germany.
- <sup>66</sup>(<sup>a</sup>)Department of Physics, Chinese University of Hong Kong, Shatin, N.T., Hong Kong; (<sup>b</sup>)Department of Physics, University of Hong Kong, Hong Kong; (<sup>c</sup>)Department of Physics and Institute for Advanced Study, Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong; China.
- <sup>67</sup>Department of Physics, National Tsing Hua University, Hsinchu; Taiwan.
- <sup>68</sup>IJCLab, Université Paris-Saclay, CNRS/IN2P3, 91405, Orsay; France.
- <sup>69</sup>Centro Nacional de Microelectrónica (IMB-CNM-CSIC), Barcelona; Spain.
- <sup>70</sup>Department of Physics, Indiana University, Bloomington IN; United States of America.
- <sup>71</sup>(<sup>a</sup>)INFN Gruppo Collegato di Udine, Sezione di Trieste, Udine; (<sup>b</sup>)ICTP, Trieste; (<sup>c</sup>)Dipartimento Politecnico di Ingegneria e Architettura, Università di Udine, Udine; Italy.
- <sup>72</sup>(<sup>a</sup>)INFN Sezione di Lecce; (<sup>b</sup>)Dipartimento di Matematica e Fisica, Università del Salento, Lecce; Italy.
- <sup>73</sup>(<sup>a</sup>)INFN Sezione di Milano; (<sup>b</sup>)Dipartimento di Fisica, Università di Milano, Milano; Italy.
- <sup>74</sup>(<sup>a</sup>)INFN Sezione di Napoli; (<sup>b</sup>)Dipartimento di Fisica, Università di Napoli, Napoli; Italy.
- <sup>75</sup>(<sup>a</sup>)INFN Sezione di Pavia; (<sup>b</sup>)Dipartimento di Fisica, Università di Pavia, Pavia; Italy.
- <sup>76</sup>(<sup>a</sup>)INFN Sezione di Pisa; (<sup>b</sup>)Dipartimento di Fisica E. Fermi, Università di Pisa, Pisa; Italy.
- <sup>77</sup>(<sup>a</sup>)INFN Sezione di Roma; (<sup>b</sup>)Dipartimento di Fisica, Sapienza Università di Roma, Roma; Italy.
- <sup>78</sup>(<sup>a</sup>)INFN Sezione di Roma Tor Vergata; (<sup>b</sup>)Dipartimento di Fisica, Università di Roma Tor Vergata, Roma; Italy.
- <sup>79</sup>(<sup>a</sup>)INFN Sezione di Roma Tre; (<sup>b</sup>)Dipartimento di Matematica e Fisica, Università Roma Tre, Roma; Italy.
- <sup>80</sup>(<sup>a</sup>)INFN-TIFPA; (<sup>b</sup>)Università degli Studi di Trento, Trento; Italy.

- <sup>81</sup>Universität Innsbruck, Department of Astro and Particle Physics, Innsbruck; Austria.
- <sup>82</sup>University of Iowa, Iowa City IA; United States of America.
- <sup>83</sup>Department of Physics and Astronomy, Iowa State University, Ames IA; United States of America.
- <sup>84</sup>Istinye University, Sariyer, Istanbul; Türkiye.
- <sup>85</sup>(<sup>a</sup>) Departamento de Engenharia Elétrica, Universidade Federal de Juiz de Fora (UFJF), Juiz de Fora; (<sup>b</sup>) Universidade Federal do Rio De Janeiro COPPE/EE/IF, Rio de Janeiro; (<sup>c</sup>) Instituto de Física, Universidade de São Paulo, São Paulo; (<sup>d</sup>) Rio de Janeiro State University, Rio de Janeiro; (<sup>e</sup>) Federal University of Bahia, Bahia; Brazil.
- <sup>86</sup>KEK, High Energy Accelerator Research Organization, Tsukuba; Japan.
- <sup>87</sup>Graduate School of Science, Kobe University, Kobe; Japan.
- <sup>88</sup>(<sup>a</sup>) AGH University of Krakow, Faculty of Physics and Applied Computer Science, Krakow; (<sup>b</sup>) Marian Smoluchowski Institute of Physics, Jagiellonian University, Krakow; Poland.
- <sup>89</sup>Institute of Nuclear Physics Polish Academy of Sciences, Krakow; Poland.
- <sup>90</sup>Faculty of Science, Kyoto University, Kyoto; Japan.
- <sup>91</sup>Research Center for Advanced Particle Physics and Department of Physics, Kyushu University, Fukuoka ; Japan.
- <sup>92</sup>L2IT, Université de Toulouse, CNRS/IN2P3, UPS, Toulouse; France.
- <sup>93</sup>Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata; Argentina.
- <sup>94</sup>Physics Department, Lancaster University, Lancaster; United Kingdom.
- <sup>95</sup>Oliver Lodge Laboratory, University of Liverpool, Liverpool; United Kingdom.
- <sup>96</sup>Department of Experimental Particle Physics, Jožef Stefan Institute and Department of Physics, University of Ljubljana, Ljubljana; Slovenia.
- <sup>97</sup>School of Physics and Astronomy, Queen Mary University of London, London; United Kingdom.
- <sup>98</sup>Department of Physics, Royal Holloway University of London, Egham; United Kingdom.
- <sup>99</sup>Department of Physics and Astronomy, University College London, London; United Kingdom.
- <sup>100</sup>Louisiana Tech University, Ruston LA; United States of America.
- <sup>101</sup>Fysiska institutionen, Lunds universitet, Lund; Sweden.
- <sup>102</sup>Departamento de Física Teórica C-15 and CIAFF, Universidad Autónoma de Madrid, Madrid; Spain.
- <sup>103</sup>Institut für Physik, Universität Mainz, Mainz; Germany.
- <sup>104</sup>School of Physics and Astronomy, University of Manchester, Manchester; United Kingdom.
- <sup>105</sup>CPPM, Aix-Marseille Université, CNRS/IN2P3, Marseille; France.
- <sup>106</sup>Department of Physics, University of Massachusetts, Amherst MA; United States of America.
- <sup>107</sup>Department of Physics, McGill University, Montreal QC; Canada.
- <sup>108</sup>School of Physics, University of Melbourne, Victoria; Australia.
- <sup>109</sup>Department of Physics, University of Michigan, Ann Arbor MI; United States of America.
- <sup>110</sup>Department of Physics and Astronomy, Michigan State University, East Lansing MI; United States of America.
- <sup>111</sup>Group of Particle Physics, University of Montreal, Montreal QC; Canada.
- <sup>112</sup>Fakultät für Physik, Ludwig-Maximilians-Universität München, München; Germany.
- <sup>113</sup>Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), München; Germany.
- <sup>114</sup>Graduate School of Science and Kobayashi-Maskawa Institute, Nagoya University, Nagoya; Japan.
- <sup>115</sup>(<sup>a</sup>) Department of Physics, Nanjing University, Nanjing; (<sup>b</sup>) School of Science, Shenzhen Campus of Sun Yat-sen University; (<sup>c</sup>) University of Chinese Academy of Science (UCAS), Beijing; China.
- <sup>116</sup>Department of Physics and Astronomy, University of New Mexico, Albuquerque NM; United States of America.
- <sup>117</sup>Institute for Mathematics, Astrophysics and Particle Physics, Radboud University/Nikhef, Nijmegen; Netherlands.

- <sup>118</sup>Nikhef National Institute for Subatomic Physics and University of Amsterdam, Amsterdam; Netherlands.
- <sup>119</sup>Department of Physics, Northern Illinois University, DeKalb IL; United States of America.
- <sup>120</sup>(<sup>a</sup>)New York University Abu Dhabi, Abu Dhabi;(<sup>b</sup>)United Arab Emirates University, Al Ain; United Arab Emirates.
- <sup>121</sup>Department of Physics, New York University, New York NY; United States of America.
- <sup>122</sup>Ochanomizu University, Otsuka, Bunkyo-ku, Tokyo; Japan.
- <sup>123</sup>Ohio State University, Columbus OH; United States of America.
- <sup>124</sup>Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman OK; United States of America.
- <sup>125</sup>Department of Physics, Oklahoma State University, Stillwater OK; United States of America.
- <sup>126</sup>Palacký University, Joint Laboratory of Optics, Olomouc; Czech Republic.
- <sup>127</sup>Institute for Fundamental Science, University of Oregon, Eugene, OR; United States of America.
- <sup>128</sup>Graduate School of Science, Osaka University, Osaka; Japan.
- <sup>129</sup>Department of Physics, University of Oslo, Oslo; Norway.
- <sup>130</sup>Department of Physics, Oxford University, Oxford; United Kingdom.
- <sup>131</sup>LPNHE, Sorbonne Université, Université Paris Cité, CNRS/IN2P3, Paris; France.
- <sup>132</sup>Department of Physics, University of Pennsylvania, Philadelphia PA; United States of America.
- <sup>133</sup>Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh PA; United States of America.
- <sup>134</sup>(<sup>a</sup>)Laboratório de Instrumentação e Física Experimental de Partículas - LIP, Lisboa;(<sup>b</sup>)Departamento de Física, Faculdade de Ciências, Universidade de Lisboa, Lisboa;(<sup>c</sup>)Departamento de Física, Universidade de Coimbra, Coimbra;(<sup>d</sup>)Centro de Física Nuclear da Universidade de Lisboa, Lisboa;(<sup>e</sup>)Departamento de Física, Universidade do Minho, Braga;(<sup>f</sup>)Departamento de Física Teórica y del Cosmos, Universidad de Granada, Granada (Spain);(<sup>g</sup>)Departamento de Física, Instituto Superior Técnico, Universidade de Lisboa, Lisboa; Portugal.
- <sup>135</sup>Institute of Physics of the Czech Academy of Sciences, Prague; Czech Republic.
- <sup>136</sup>Czech Technical University in Prague, Prague; Czech Republic.
- <sup>137</sup>Charles University, Faculty of Mathematics and Physics, Prague; Czech Republic.
- <sup>138</sup>Particle Physics Department, Rutherford Appleton Laboratory, Didcot; United Kingdom.
- <sup>139</sup>IRFU, CEA, Université Paris-Saclay, Gif-sur-Yvette; France.
- <sup>140</sup>Santa Cruz Institute for Particle Physics, University of California Santa Cruz, Santa Cruz CA; United States of America.
- <sup>141</sup>(<sup>a</sup>)Departamento de Física, Pontificia Universidad Católica de Chile, Santiago;(<sup>b</sup>)Millennium Institute for Subatomic physics at high energy frontier (SAPHIR), Santiago;(<sup>c</sup>)Instituto de Investigación Multidisciplinario en Ciencia y Tecnología, y Departamento de Física, Universidad de La Serena;(<sup>d</sup>)Universidad Andres Bello, Department of Physics, Santiago;(<sup>e</sup>)Instituto de Alta Investigación, Universidad de Tarapacá, Arica;(<sup>f</sup>)Departamento de Física, Universidad Técnica Federico Santa María, Valparaíso; Chile.
- <sup>142</sup>Department of Physics, University of Washington, Seattle WA; United States of America.
- <sup>143</sup>Department of Physics and Astronomy, University of Sheffield, Sheffield; United Kingdom.
- <sup>144</sup>Department of Physics, Shinshu University, Nagano; Japan.
- <sup>145</sup>Department Physik, Universität Siegen, Siegen; Germany.
- <sup>146</sup>Department of Physics, Simon Fraser University, Burnaby BC; Canada.
- <sup>147</sup>SLAC National Accelerator Laboratory, Stanford CA; United States of America.
- <sup>148</sup>Department of Physics, Royal Institute of Technology, Stockholm; Sweden.
- <sup>149</sup>Departments of Physics and Astronomy, Stony Brook University, Stony Brook NY; United States of

America.

<sup>150</sup>Department of Physics and Astronomy, University of Sussex, Brighton; United Kingdom.

<sup>151</sup>School of Physics, University of Sydney, Sydney; Australia.

<sup>152</sup>Institute of Physics, Academia Sinica, Taipei; Taiwan.

<sup>153</sup>(<sup>a</sup>) E. Andronikashvili Institute of Physics, Iv. Javakhishvili Tbilisi State University, Tbilisi; (<sup>b</sup>) High Energy Physics Institute, Tbilisi State University, Tbilisi; (<sup>c</sup>) University of Georgia, Tbilisi; Georgia.

<sup>154</sup>Department of Physics, Technion, Israel Institute of Technology, Haifa; Israel.

<sup>155</sup>Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv; Israel.

<sup>156</sup>Department of Physics, Aristotle University of Thessaloniki, Thessaloniki; Greece.

<sup>157</sup>International Center for Elementary Particle Physics and Department of Physics, University of Tokyo, Tokyo; Japan.

<sup>158</sup>Department of Physics, Tokyo Institute of Technology, Tokyo; Japan.

<sup>159</sup>Department of Physics, University of Toronto, Toronto ON; Canada.

<sup>160</sup>(<sup>a</sup>) TRIUMF, Vancouver BC; (<sup>b</sup>) Department of Physics and Astronomy, York University, Toronto ON; Canada.

<sup>161</sup>Division of Physics and Tomonaga Center for the History of the Universe, Faculty of Pure and Applied Sciences, University of Tsukuba, Tsukuba; Japan.

<sup>162</sup>Department of Physics and Astronomy, Tufts University, Medford MA; United States of America.

<sup>163</sup>Department of Physics and Astronomy, University of California Irvine, Irvine CA; United States of America.

<sup>164</sup>University of West Attica, Athens; Greece.

<sup>165</sup>University of Sharjah, Sharjah; United Arab Emirates.

<sup>166</sup>Department of Physics and Astronomy, University of Uppsala, Uppsala; Sweden.

<sup>167</sup>Department of Physics, University of Illinois, Urbana IL; United States of America.

<sup>168</sup>Instituto de Física Corpuscular (IFIC), Centro Mixto Universidad de Valencia - CSIC, Valencia; Spain.

<sup>169</sup>Department of Physics, University of British Columbia, Vancouver BC; Canada.

<sup>170</sup>Department of Physics and Astronomy, University of Victoria, Victoria BC; Canada.

<sup>171</sup>Fakultät für Physik und Astronomie, Julius-Maximilians-Universität Würzburg, Würzburg; Germany.

<sup>172</sup>Department of Physics, University of Warwick, Coventry; United Kingdom.

<sup>173</sup>Waseda University, Tokyo; Japan.

<sup>174</sup>Department of Particle Physics and Astrophysics, Weizmann Institute of Science, Rehovot; Israel.

<sup>175</sup>Department of Physics, University of Wisconsin, Madison WI; United States of America.

<sup>176</sup>Fakultät für Mathematik und Naturwissenschaften, Fachgruppe Physik, Bergische Universität Wuppertal, Wuppertal; Germany.

<sup>177</sup>Department of Physics, Yale University, New Haven CT; United States of America.

<sup>178</sup>Yerevan Physics Institute, Yerevan; Armenia.

<sup>a</sup> Also Affiliated with an institute covered by a cooperation agreement with CERN.

<sup>b</sup> Also at An-Najah National University, Nablus; Palestine.

<sup>c</sup> Also at Borough of Manhattan Community College, City University of New York, New York NY; United States of America.

<sup>d</sup> Also at Center for Interdisciplinary Research and Innovation (CIRI-AUTH), Thessaloniki; Greece.

<sup>e</sup> Also at CERN, Geneva; Switzerland.

<sup>f</sup> Also at CMD-AC UNEC Research Center, Azerbaijan State University of Economics (UNEC); Azerbaijan.

<sup>g</sup> Also at Département de Physique Nucléaire et Corpusculaire, Université de Genève, Genève; Switzerland.

<sup>h</sup> Also at Departament de Física de la Universitat Autònoma de Barcelona, Barcelona; Spain.



- i* Also at Department of Financial and Management Engineering, University of the Aegean, Chios; Greece.
- j* Also at Department of Physics, California State University, Sacramento; United States of America.
- k* Also at Department of Physics, King's College London, London; United Kingdom.
- l* Also at Department of Physics, Stanford University, Stanford CA; United States of America.
- m* Also at Department of Physics, Stellenbosch University; South Africa.
- n* Also at Department of Physics, University of Fribourg, Fribourg; Switzerland.
- o* Also at Department of Physics, University of Thessaly; Greece.
- p* Also at Department of Physics, Westmont College, Santa Barbara; United States of America.
- q* Also at Faculty of Physics, Sofia University, 'St. Kliment Ohridski', Sofia; Bulgaria.
- r* Also at Hellenic Open University, Patras; Greece.
- s* Also at Imam Mohammad Ibn Saud Islamic University; Saudi Arabia.
- t* Also at Institucio Catalana de Recerca i Estudis Avancats, ICREA, Barcelona; Spain.
- u* Also at Institut für Experimentalphysik, Universität Hamburg, Hamburg; Germany.
- v* Also at Institute for Nuclear Research and Nuclear Energy (INRNE) of the Bulgarian Academy of Sciences, Sofia; Bulgaria.
- w* Also at Institute of Applied Physics, Mohammed VI Polytechnic University, Ben Guerir; Morocco.
- x* Also at Institute of Particle Physics (IPP); Canada.
- y* Also at Institute of Physics, Azerbaijan Academy of Sciences, Baku; Azerbaijan.
- z* Also at National Institute of Physics, University of the Philippines Diliman (Philippines); Philippines.
- aa* Also at Technical University of Munich, Munich; Germany.
- ab* Also at The Collaborative Innovation Center of Quantum Matter (CICQM), Beijing; China.
- ac* Also at TRIUMF, Vancouver BC; Canada.
- ad* Also at Università di Napoli Parthenope, Napoli; Italy.
- ae* Also at University of Colorado Boulder, Department of Physics, Colorado; United States of America.
- af* Also at Washington College, Chestertown, MD; United States of America.
- ag* Also at Yeditepe University, Physics Department, Istanbul; Türkiye.
- \* Deceased