

UC Irvine

UC Irvine Previously Published Works

Title

Search for magnetic monopoles and stable particles with high electric charges in $s = 13$ TeV pp collisions with the ATLAS detector

Permalink

<https://escholarship.org/uc/item/04j711k6>

Journal

Journal of High Energy Physics, 2023(11)

ISSN

1126-6708

Authors

Aad, G
Abbott, B
Abeling, K
et al.

Publication Date

2023

DOI

10.1007/jhep11(2023)112

Copyright Information

This work is made available under the terms of a Creative Commons Attribution License, available at <https://creativecommons.org/licenses/by/4.0/>

Peer reviewed

Search for magnetic monopoles and stable particles with high electric charges in $\sqrt{s} = 13$ TeV pp collisions with the ATLAS detector



The ATLAS collaboration

E-mail: atlas.publications@cern.ch

ABSTRACT: We present a search for magnetic monopoles and high-electric-charge objects using LHC Run 2 $\sqrt{s} = 13$ TeV proton-proton collisions recorded by the ATLAS detector. A total integrated luminosity of 138 fb^{-1} was collected by a specialized trigger. No highly ionizing particle candidate was observed. Considering the Drell-Yan and photon-fusion pair production mechanisms as benchmark models, cross-section upper limits are presented for spin-0 and spin-1/2 magnetic monopoles of magnetic charge $1g_D$ and $2g_D$ and for high-electric-charge objects of electric charge $20 \leq |z| \leq 100$, for masses between 200 GeV and 4000 GeV. The search improves by approximately a factor of three the previous cross-section limits on the Drell-Yan production of magnetic monopoles and high-electric charge objects. Also, the first ATLAS limits on the photon-fusion pair production mechanism of magnetic monopoles and high-electric-charge objects are obtained.

KEYWORDS: Beyond Standard Model, Exotics, Hadron-Hadron Scattering

ARXIV EPRINT: [2308.04835](https://arxiv.org/abs/2308.04835)

Contents

1	Introduction	1
2	The ATLAS detector	3
3	Simulation	3
4	Signal selection	5
5	Background estimate	9
6	Systematic uncertainties	12
7	Upper cross-section and lower mass limits	13
8	Conclusions	16
	The ATLAS collaboration	25

1 Introduction

The magnetic monopole, an isolated magnetic charge, is appealing in that it restores the broken electric-magnetic dual symmetry in Maxwell’s equations. Furthermore, Dirac’s theory of magnetic monopoles [1, 2], which is compatible with quantum mechanics, offers an explanation for the quantization of electric charge. A Dirac magnetic monopole is a fundamental point particle that may take any spin or mass. In contrast, the monopoles predicted by Grand Unification Theories (GUTs) [3, 4], typically produced cosmologically via the Kibble mechanism [5], are extended objects with large mass $\sim 10^{17}$ GeV. Recent developments in extensions of the Standard Model [6–17] predict “electroweak” monopoles, which appear as gauge bosons of particle interactions before spontaneous symmetry breaking, and thus can have a mass as low as the TeV scale [8, 10–12].

Dirac’s quantization condition predicts that the magnetic charge g of a monopole is an integer multiple of the fundamental magnetic charge g_{D} , which is given by

$$g_{\text{D}} = \frac{e}{2\alpha} \approx 68.5e, \quad (1.1)$$

in natural SI units, where $\alpha \approx 1/137$ is the fine structure constant and e is the unsigned electron charge. This implies that the energy loss, or stopping power, of a high-velocity Dirac monopole of magnetic charge $|g| = g_{\text{D}}$ in matter is similar to that of an ion with electric charge $|z| = 68.5$, where z is in units of e . Hence, magnetic monopoles, along

with high-electric-charge objects (HECOs), such as strange and up-down quark matter [18–20], and Q-balls [21, 22], are collectively known as highly ionizing particles (HIPs). A consequence of the high ionization is the production of a large number of δ -rays, which are energetic electrons emitted along the HIP trajectory. The characteristic signature of HIPs, therefore, is high ionization coupled with a large number of δ -rays.

Searches for magnetic monopoles and HECOs have been extensively performed in cosmic rays [23–51] and at colliders [52–83], as reviewed in refs. [84–89]. Direct cosmic-ray searches look for signals of relic GUT monopoles produced in the early universe upon symmetry breaking [5] and nuclearites (nuggets of strange quark matter in collision with the Earth) that were either formed in the early universe or during collisions of neutron stars [90]. Limited by the collision energy, collider searches for HIPs target stable Dirac magnetic monopoles, Q-balls and quark matter with masses in the TeV range. Since the searches for monopoles of cosmological origin have limited sensitivity to TeV-mass HIPs, the cross-section limits for low-mass HIPs from searches at colliders are 6–9 orders of magnitude more stringent.

The first Large Hadron Collider (LHC) search for monopoles, carried out by the ATLAS Collaboration with 7 TeV proton-proton (pp) collision data in Run 1 [81], set a precedent for later LHC searches for HIPs [82, 83, 91–103]. The ATLAS monopole searches are complementary to those performed using the dedicated MoEDAL experiment at the LHC. While MoEDAL is able to probe magnetic charges up to $5g_D$ [97–101], its acceptance is limited by its forward location at $2 < \eta < 5$. Consequently, the ATLAS search, which considers $|\eta| < 1.375$, has significantly higher sensitivity for $1g_D$ and $2g_D$, the charge range in which it has a good acceptance. While ATLAS is sensitive to HECOs with electric charges up to $|z| = 100$, MoEDAL searches for HECOs with electric charges up to $|z| = 175$ [103]. MoEDAL has also searched for dyons (particles with both electric and magnetic charges) with magnetic charges up to $5g_D$ and electric charges up to $|z| = 200$ [102].

The ATLAS experiment has considered the highly ionizing signature to probe magnetic monopoles in the range $0.5g_D < |g| < 2g_D$ and HECOs in the range $20 \leq |z| \leq 100$ in previous searches [81–83], the most recent of which used 34.4 fb^{-1} of $\sqrt{s} = 13 \text{ TeV}$ pp collision data [83]. The present HIP search uses data from $\sqrt{s} = 13 \text{ TeV}$ LHC proton-proton collisions recorded by the ATLAS detector between 2015 and 2018 during Run 2. A custom HIP trigger was implemented in October 2015, and collected a total integrated luminosity of 138 fb^{-1} . The results presented supersede those of ref. [83], benefiting from a four-fold increase in data statistics and the addition of Z^0 exchange in the spin- $\frac{1}{2}$ Drell-Yan HECO production model [104]. New for this search are results for HIP production by the photon-fusion mechanism [104–108], which has a higher predicted cross-section than that of Drell-Yan production in $\sqrt{s} = 13 \text{ TeV}$ pp collisions, whereas the cross sections are comparable at $\sqrt{s} = 8 \text{ TeV}$.

The ATLAS detector is briefly covered in section 2, the production models and simulation are described in section 3, the signal selection is discussed in section 4, the method to estimate the background is presented in section 5, and the procedure to evaluate the systematic uncertainties is outlined in section 6. Finally, the results are presented in section 7, followed by the conclusions in section 8.

2 The ATLAS detector

The ATLAS detector [109] is a multipurpose particle detector with a forward-backward symmetric cylindrical geometry and a near 4π coverage in solid angle.¹ It comprises an inner tracking detector (ID) surrounded by a thin superconducting solenoid providing a 2 T axial magnetic field, electromagnetic and hadron calorimeters, and a muon spectrometer. To detect HIPs, it suffices to only consider the signals in the Transition Radiation Tracker (TRT) [110] and the electromagnetic (EM) calorimeter. The TRT has two sections: a barrel of radius $0.563 \text{ m} < r < 1.066 \text{ m}$ covering the pseudorapidity range $0 < |\eta| < 1.06$ and end-caps at either end of the barrel covering $0.77 < |\eta| < 2.0$. In the barrel the 4-mm diameter TRT straws are aligned parallel to the beam pipe, while in the end-caps they are in a radial array. The straws are filled with a Xenon- or Argon-gas-based mixture. An electron traversing the TRT induces transition radiation, which augments the energy recorded in a straw. The energy deposited in a straw by ionizing particles or transition radiation is compared with two energy thresholds, 200 eV and 6 keV (200 eV and 2 keV in Ar), to identify low threshold (LT) and high threshold (HT) hits, respectively. HT hits can indicate the passage of electrons or HIPs. Argon absorbs the transition radiation with a reduced efficiency relative to that of Xenon. Consequently, the HT hit probability for electrons is 50% lower in Ar than in Xe. However, the energy deposited by a HIP typically exceeds the high threshold in either gas.

The electromagnetic calorimeter, covering the $|\eta| < 1.475$ region, is composed of accordion-shaped lead absorbers and copper electrodes and filled with liquid Argon (LAr). The detector has four layers (labeled presampler, EM1, EM2 and EM3) of varying radiation depths at increasing radii from the beampipe, EM2 being the deepest ($16X_0$ to $20X_0$). The smallest sensor unit, called a cell, has different dimensions in each layer, e.g., $\Delta\eta \times \Delta\phi = 0.025 \times 0.025$ in EM2.

A two-level trigger system [111] is used to select events. The first-level trigger is implemented in hardware and uses a subset of the detector information to accept events at a rate below 100 kHz on average depending on the data-taking conditions. This is followed by a software-based high-level trigger (HLT) that reduces the rate of selected events to 1 kHz for offline storage. A custom HLT algorithm, explained in section 4, is used to recognize the highly ionizing signature of monopoles and HECOs. An extensive software suite [112] is used in data 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.

3 Simulation

Drell-Yan (DY) and photon fusion (PF) are considered as benchmark models for pair production of spin-0 and spin- $\frac{1}{2}$ HIPs. The model implementations are described in detail in ref. [104]. As a result of the high HIP charge, the charge-squared dependence of the HIP

¹ATLAS uses a right-handed coordinate system with its origin at the nominal interaction point (IP) in the center of the detector and the z axis coinciding with the axis of the beam pipe. The x axis points from the IP to the center of the LHC ring, and the y axis points upward. Cylindrical coordinates (r, ϕ) are used in the transverse plane, ϕ being the azimuthal angle around the beam pipe. The pseudorapidity is defined in terms of the polar angle θ as $\eta = -\ln \tan(\theta/2)$.

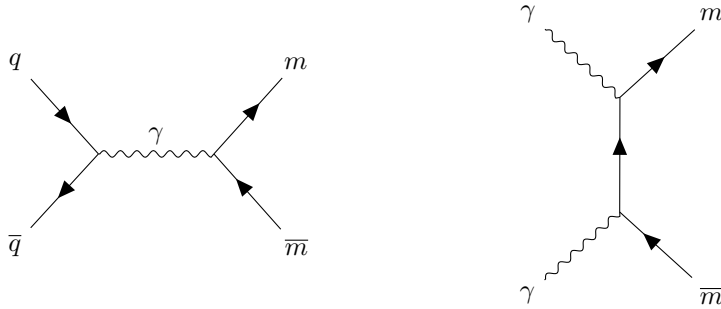


Figure 1. Feynman diagrams for Drell-Yan (left) and photon-fusion (right) pair-produced monopoles m . HECO production occurs by analogous diagrams. Other production modes not shown here, but which can be seen in ref. [104], include spin-0 HIP production by a four-point photon-fusion process and Drell-Yan production of spin- $\frac{1}{2}$ HECOs mediated by Z^0 exchange, in addition to photon exchange. Z^0 exchange is forbidden for spin-0 HECOs and for Dirac monopoles of either spin.

coupling to the gauge boson leads to divergences in the perturbative expansion beyond leading order [85]. To provide an approximation to these highly non-perturbative processes, only leading-order interactions, as described by the Feynman-like diagrams seen in figure 1, are considered. This approximation implies uncertainties in the pair-production cross section predictions and in the HIP kinematic distributions. The former are only used to derive mass limits for comparison with other experiments. The latter dictate the selection efficiencies. Since the interaction of the HIPs with the detector is spin-independent, a comparison of the selection efficiencies for spin-0 vs spin- $\frac{1}{2}$ HIPs provides a measure of how model uncertainties affect the search acceptance.

Monte Carlo (MC) samples are produced for both production models for magnetic monopoles with magnetic charges $|g| = g_D$ and $2g_D$ and HECOs with electric charges $|z| = 20, 40, 60, 80$ and 100 . In all cases, the masses considered are 200, 500, 1000, 1500, 2000, 2500, 3000 and 4000 GeV. The available energy of the interaction between two quarks in the collision sets the upper mass constraint. Because HIPs with mass below 200 GeV are more probable in softer pp collisions, in general they have lower kinetic energies and, consequently, poor selection efficiency. The leading-order benchmark models are implemented in MADGRAPH5_AMC@NLO 2.8.1 [113], which is used to generate the HIP pairs and to calculate the production cross sections. The events were interfaced to PYTHIA 8.244 [114, 115] to model the parton showering and hadronization, with parameter values set according to the A14 tune [116], and the NNPDF2.3LO [117] and LUXQED [118] parton distribution functions were used for DY and PF production, respectively.

To determine selection efficiencies, samples of 60 000 MC events of Drell-Yan spin- $\frac{1}{2}$ HIPs of a given mass and charge were simulated using GEANT4 [119] and processed with the ATLAS reconstruction software. The GEANT4 simulation describes the HIP ionization energy loss in the ATLAS detector, the δ -ray production and secondary ionization, and the monopole acceleration in the magnetic field. The standard Bethe-Bloch formula is used for ionization by HECOs, whereas a modified formula accounting for the velocity-dependent Lorentz force [120] is used for monopoles. In both cases, the energy loss by ionization is

proportional to the square of the charge. The simulation of highly ionizing particles in the ATLAS detector was validated by confirming the expected acceleration and trajectory in the magnetic field and the dependence of the ionization on the charge and on the speed of light fraction β . In addition, the simulation of the ionization and δ -ray production of HIPs in liquid argon was validated against published ion beam data in liquid argon [121]. These MC samples also include “pileup”, which are additional simulated minimum bias collisions overlaid on each event according to the distribution of the number of pp interactions per bunch crossing in the data.

Full simulation of HIP events is computationally intensive due to the high ionization and δ -ray production. Single-particle events have less detector activity than events with pair production from proton-proton collisions, and consequently can be abundantly produced at a reasonable cost of computational resources. Hence, the selection efficiencies of DY spin-0 HIPs and PF pair-produced HIPs of both spins are extrapolated by sampling model-independent efficiency maps based on the HIP kinematic properties, transverse kinetic energy $E_T^{\text{kin}} = E_{\text{kin}} \sin \theta$ and pseudorapidity $|\eta|$. The efficiency maps of a given mass and charge are derived from samples of 120 000 events comprising single monopoles or HECOs simulated using GEANT4, overlaid with pileup, and processed with the ATLAS reconstruction software. Given the statistics available in the single-particle samples, the bin size of the maps was optimized to ensure that most bins are populated.

4 Signal selection

The selection of HIP-like events exploits their characteristic signature in the ATLAS detector. When a HIP traverses a TRT straw, in addition to producing an HT hit, it generates many δ -rays, which in turn result in additional HT hits in neighbouring straws. In the mass and energy regime of this study, HIPs lose energy primarily via ionization, with radiation losses representing less than 5% of the total energy lost [122]. Consequently, since HIPs do not induce a shower in the EM calorimeter, their EM energy deposits have low lateral dispersion. The kinematic properties of the considered HIPs are such that most of them will stop before reaching the hadronic calorimeter. Consequently, the typical signature of a HIP in the ATLAS detector includes many TRT HT hits in a region aligned with a narrow high-energy deposit in the LAr EM calorimeter.

The HIP candidate selection begins with a custom HIP trigger. First, the standard first-level EM trigger requires an energy deposit of transverse energy $E_T > 22 \text{ GeV}$ in the EM calorimeter. The EM trigger rejects hadrons by vetoing candidates with $E_T < 50 \text{ GeV}$ in conjunction with an E_T -dependent minimum of 1 GeV to 2 GeV of energy in the hadronic calorimeter. The locations of any selected energy deposits determine regions of interest (ROI). The custom HIP HLT determines the number, $N_{\text{HT, trig}}$, of TRT HT hits and the fraction, $f_{\text{HT, trig}}$, of TRT hits that are HT hits in a 10 mrad $r - \phi$ wedge around the first-level ROI position. To control the rate while maintaining high signal efficiency for HIPs, the HIP HLT requires $N_{\text{HT, trig}} > 30$ and $f_{\text{HT, trig}} > 0.5$ in the wedge. In addition, it imposes a requirement on the pseudorapidity, $|\eta| < 1.7$, since the forward regions contain more multijet background events.

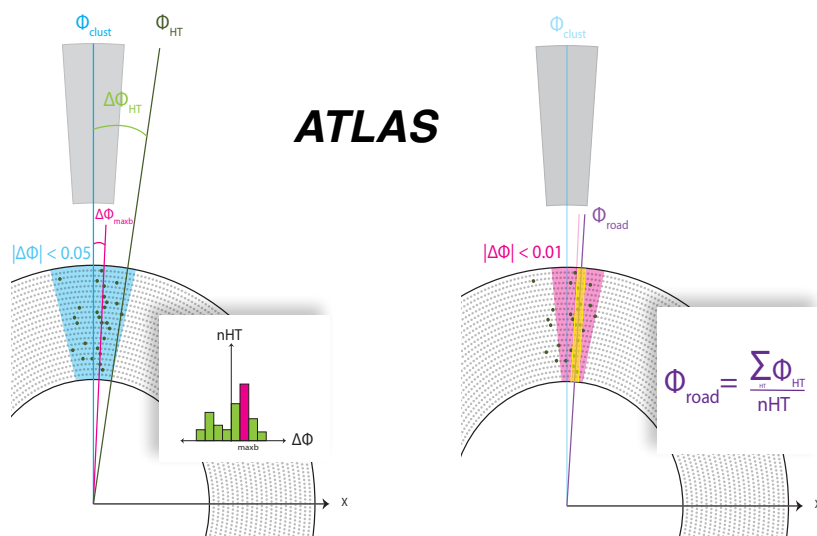


Figure 2. Schematic depicting the TRT road-centering and hit-counting algorithms for HIP candidates. Centering of the road happens in two stages. In the first stage (left), a ± 0.05 -rad wedge (shaded blue) is defined around the azimuthal angle ϕ_{clust} of the EM cluster (blue solid line). In that wedge, the HT hit ϕ_{HT} distribution with an 0.8-mrad bin size is determined. The center of the bin containing the largest number of HT hits defines the azimuthal angle ϕ_{maxb} (pink solid line). For the second stage (right), a new ± 0.01 -rad wedge (shaded pink) is centered around ϕ_{maxb} . The azimuthal angle ϕ_{road} (purple) is computed from the angular difference of each HT hit in this wedge with respect to ϕ_{clust} . The final ± 4 -mm road (shaded yellow) is defined around ϕ_{road} .

Events collected by the trigger are processed by the standard ATLAS reconstruction software, which performs a sophisticated topological clustering algorithm [123] in the calorimeter. A cluster is a group of cells, neighbouring in 3D, in which significant energy deposition is recorded. EM clusters with $E_T > 22$ GeV and $|\eta| < 1.375$ are considered as a starting point for HIP signal selection. The $|\eta| < 1.375$ requirement is needed to exclude the EM calorimeter end-caps, where the correlation between the final discriminating variables, described below, is enhanced.

This analysis does not use ATLAS track reconstruction for two main reasons: first, the trajectories of magnetic monopoles moving in a solenoidal magnetic field bend in the $r - z$ plane (unlike charged particles, which bend in the $r - \phi$ plane), and second, the presence of multiple δ -rays confuses the track fitting algorithm. Instead, HIPs are reconstructed in a manner similar to that of the HIP HLT: each EM cluster defines a starting ϕ position in the TRT for the hit-counting region; the ϕ position is fine-tuned to align with the region containing the highest number of HT hits; finally, an 8-mm-wide rectangular road in the barrel is centered on that new ϕ position. This road width is sufficient to capture energy deposited by the HIP and any δ -rays that may have penetrated a neighbouring TRT straw, but narrow enough to avoid counting nearby LT hits from pileup. In the end-cap, where the straws are radial, a 12 mrad $r - \phi$ wedge is used. The numbers of TRT LT and HT hits, N_{LT} and N_{HT} , respectively, in the road (wedge) aligned with the EM cluster are counted, as depicted in figure 2.

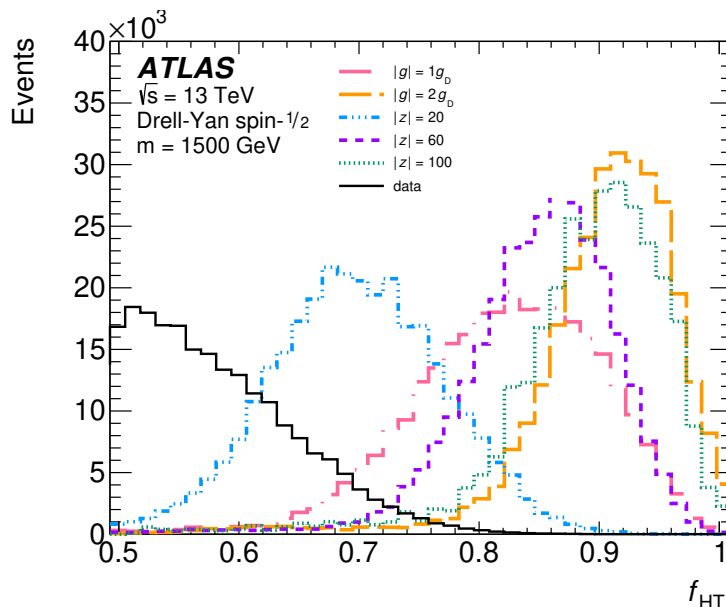


Figure 3. Distribution of the f_{HT} variable for events that passed the HIPTRT trigger and the criteria $|\eta| < 1.375$ and $N_{\text{HT}} > 30$. Only the TRT road candidate with the highest f_{HT} value in each event is included in the plot. The black distribution corresponds to 20% of the Run 2 data and the coloured distributions correspond to the mass 1500 GeV Drell-Yan spin- $\frac{1}{2}$ signal samples for various charges. All MC distributions have been normalized to the number of events in the data.

Two powerful variables distinguish HIP signal events from background. The fraction of all the TRT hits in the road (wedge) that exceed the high threshold, f_{HT} , is the first signal-discriminating variable, shown in figure 3. In the case where there are multiple HIP candidates in an event (this occurs for about 10% of the selected data events), the candidate with the highest f_{HT} value is selected. The second variable, w , reflects the lateral dispersion of the EM cluster, which is narrow for HIPs, since they do not induce an EM shower. Three variables, w_0 , w_1 and w_2 , are defined as the fractions of EM cluster energy (E_i) contained in the two most energetic cells in the presampler, the four most energetic cells in the EM1 layer, and the five most energetic cells in the EM2 layer, respectively, as depicted in figure 4. The variable w , shown in figure 5, is defined as the average of all w_i for which the energy E_i exceeds 10 GeV in each of the presampler and EM1 layers, and 5 GeV in the EM2 layer. In addition, it is required that one of E_0 and E_1 exceeds 10 GeV, as a HIP must pass through the presampler and EM1 layer to reach the EM2 layer and deposit energy there.

HIP candidates are identified by the signal discriminating criteria $f_{\text{HT}} \geq 0.77$ and $w \geq 0.93$. Optimal values of f_{HT} and w were obtained by comparing the signal efficiency for each DY spin- $\frac{1}{2}$ MC sample to the rejection of background, represented by a sample of one million pseudodata events prepared by sampling the 1D f_{HT} and w distributions in data and randomly pairing the values. Then, the weighted average of all f_{HT} and w values found for the different DY spin- $\frac{1}{2}$ MC samples was computed, where the weight was given by the efficiency for passing all the selection criteria before the discriminating variable cuts.

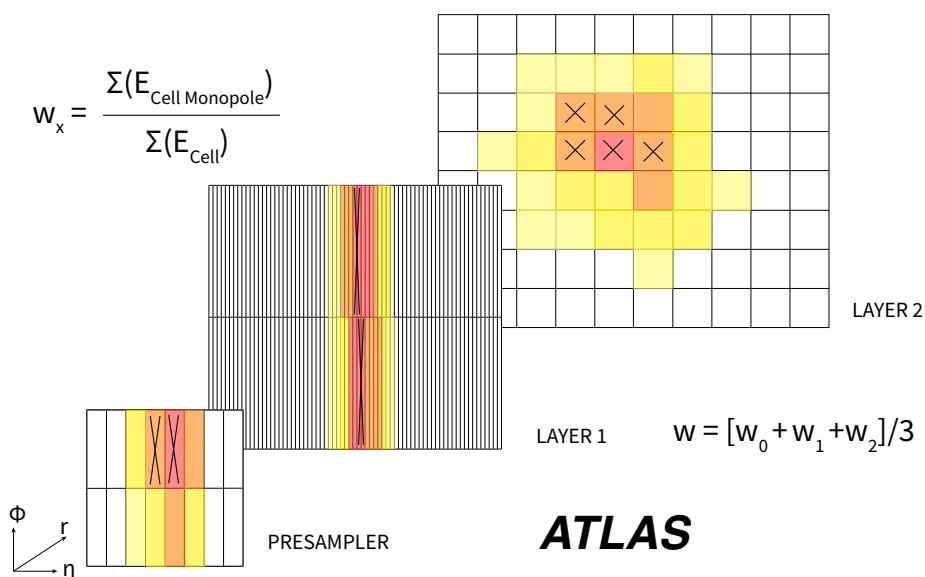


Figure 4. Illustration of example energy depositions in each layer of the EM calorimeter. Cells with higher energy deposits are shown in red, while lower energy deposits are yellow. Crosses represent the cells selected for their high-energy deposition for each layer for the computation of the w variable.

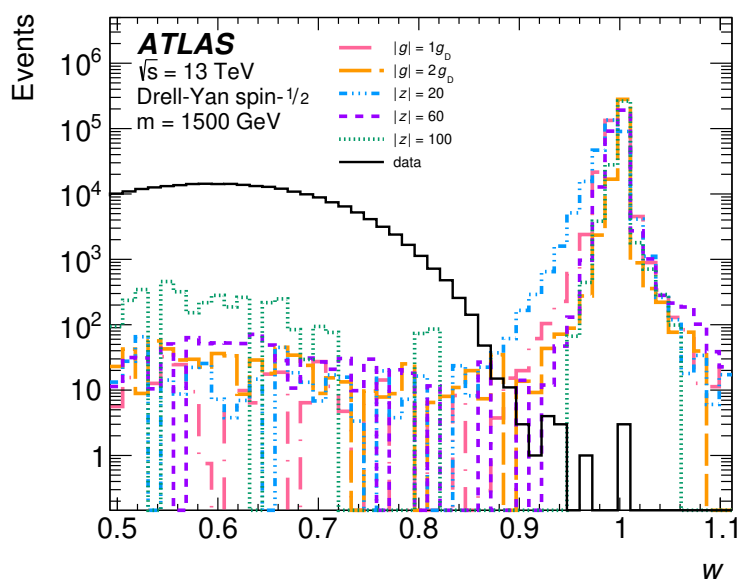


Figure 5. Distribution of the w variable for events that passed the HIPTRT trigger and the criteria $|\eta| < 1.375$ and $N_{\text{HT}} > 30$. Only the TRT road candidate with the highest f_{HT} value in each event is included in the plot. The black distribution corresponds to 20% of the Run 2 data and the coloured distributions correspond to the mass 1500 GeV Drell-Yan spin- $1/2$ signal samples for various charges. All MC distributions have been normalized to the number of events in the data.

region	A	B	C	D
events	0	9847	15	986500

Table 1. Data event yields in the signal region A and the three control regions, B, C and D.

The method used to extrapolate the selection efficiencies of DY spin-0 HIPs and PF HIPs of both spins is as follows. Given the E_T^{kin} and η values for each generated HIP, the corresponding bin in the appropriate efficiency map is identified and the efficiency is extracted. A random number r between 0 and 1 is generated and compared with this probability; if r is less than or equal to the efficiency, then the particle is considered to have passed the selection criteria. This process of extrapolating the selection efficiencies from the generator-level kinematics and the efficiency maps was validated using the fully simulated DY spin- $\frac{1}{2}$ samples.

The signal efficiencies for a given mass, charge and spin for each production mode are shown in figure 6. The selection efficiencies for spin-0 DY HIPs are higher than those for spin- $\frac{1}{2}$ DY HIPs because the former have more central $|\eta|$ and harder kinetic energy distributions. On the other hand, the selection efficiencies for spin-0 PF HIPs are lower than those for spin- $\frac{1}{2}$ PF HIPs, which have harder kinetic energy distributions. The HIP efficiencies are strongly correlated with charge and mass, with the selection of HIPs in the intermediate charge and mass ranges being the most efficient. In general, the high ionization of the higher charge HIPs is such that they stop before the EM calorimeter, whereas the lower charge HIPs may reach the hadronic calorimeter such that they are vetoed by the first-level trigger. The lower mass HIPs have lower efficiency because they have lower kinetic energies and may fail the first-level trigger, whereas higher mass HIPs may fail the trigger due to late arrival at the EM calorimeter.

5 Background estimate

Random combinations of rare processes, such as overlapping charged particles in multijet events and superpositions of high-energy electrons, can occasionally produce high f_{HT} and high w values. Considering how rare such events are, it is not practical to simulate a statistically significant MC sample. Instead, a data-driven ABCD background estimation approach is used. The 2D distribution of f_{HT} versus w for the HIP candidates, shown in figure 7, is divided into four regions: signal region A ($f_{\text{HT}} \geq 0.77$ and $w \geq 0.93$), which contains most of the signal events, and three neighboring control regions B ($f_{\text{HT}} \geq 0.77$ and $0.4 \leq w < 0.93$), C ($0.5 \leq f_{\text{HT}} < 0.77$ and $w \geq 0.93$) and D ($0.5 \leq f_{\text{HT}} < 0.77$ and $0.4 \leq w < 0.93$). If there is no correlation between the two discriminating variables, the estimate of expected background events in region A is calculated as $N_A^{\text{exp}} = N_B N_C / N_D$, where N_B , N_C and N_D are the numbers of events in regions B, C and D, respectively, as shown in table 1.

The ratio, N_B/N_D , called the transfer factor, is observed to fluctuate by up to 50% in bins of w . This is due to a mutual correlation of both variables, f_{HT} and w , with η , reflecting features in the detector structure, such as the barrel-end-cap transition region. The small effect of the non-uniformity on the search results can be evaluated by splitting the

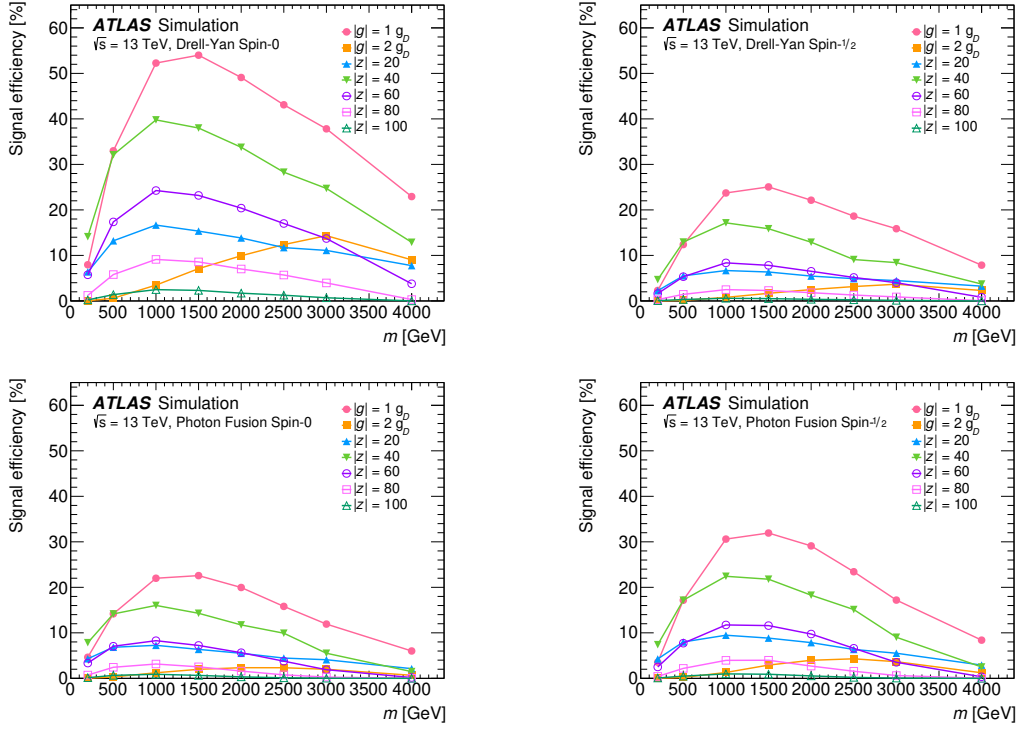


Figure 6. Selection efficiencies for Drell-Yan (top) and photon-fusion (bottom) pair-produced monopoles and HECOs, for spin-0 (left) and spin- $\frac{1}{2}$ (right). Only Drell-Yan spin- $\frac{1}{2}$ efficiencies come from fully simulated samples. Efficiencies for all other considered mechanisms are extrapolated from efficiency maps.

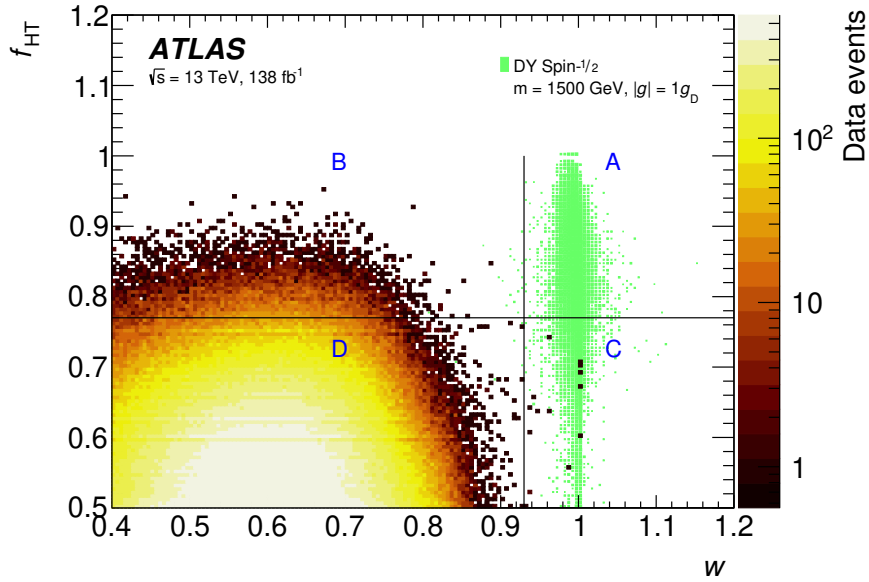


Figure 7. Two-dimensional distribution of the discriminators f_{HT} and w for the data and a representative signal sample (green). The signal (A) and control (B, C and D) regions are shown.

$ \eta $ range	mean transfer factor
0–0.32	$0.0087 \pm 0.0014(\text{stat.}) \pm 0.0066(\text{syst.})$
0.32–0.82	$0.00125 \pm 0.00005(\text{stat.}) \pm 0.00021(\text{syst.})$
0.82–1.375	$0.0158 \pm 0.0001(\text{stat.}) \pm 0.0027(\text{syst.})$

Table 2. Mean transfer factor for different $|\eta|$ regions. The variations in the statistical uncertainties reflect the η dependence of the selection efficiency. The root mean square of the constant fit to the N_B/N_D versus w distribution is assigned as the systematic uncertainty. Transfer factor fluctuations due to the low selection efficiency in the $|\eta| < 0.32$ region lead to a larger systematic uncertainty than in the other regions.

data into three $|\eta|$ ranges, resulting in a total of 12 orthogonal regions or bins on the ABCD plane. The mean transfer factor for each $|\eta|$ range (see table 2) is determined by fitting a constant to the N_B/N_D versus w distribution and used to obtain a background estimate N_A^{exp} for each $|\eta|$ -sliced ABCD plane. This gives rise to a relative systematic uncertainty of 30%, which is assigned to the final background estimate.

To ensure that the ABCD method yields a prediction of background events close to the actual number in the signal region, the method is validated as follows. Control region B is divided into validation regions B' ($w < 0.665$) and B'' ($w \geq 0.665$), containing 7684 and 2163 events, respectively. Validation regions D' and D'', containing 754 040 and 232 460 events, respectively, are similarly obtained from control region D. The background estimate $N_{B''}^{\text{exp}} = 2368$ for the number of events in region B'', found by computing $N_{B''}^{\text{exp}} = N_{B'} N_{D''} / N_{D'}$, is in reasonable agreement with the observed number of data events in that region.

The HIP signal leakage into the control regions B, C, and D, as seen in figure 7, could bias the background estimate and, hence, is considered for the fully simulated spin- $\frac{1}{2}$ DY pair-production MC samples. A background estimate accounting for signal leakage can be computed based on a simultaneous likelihood fit to signal and background of the ABCD plane. The inputs to this fit are the background estimated by the aforementioned method for the full η range, the number of data events in regions B, C and D, with a hypothesis of the number of events in region A, and the fraction of signal events in all regions. Thus, a likelihood function is constructed as a product of Poisson probabilities for all four regions, constrained by Gaussian distributions that take into account as nuisance parameters the signal efficiency systematic uncertainties, described in section 6, and the MC statistical uncertainties. By maximizing the likelihood function in the fit to the observed data, the background is estimated to be $N_A^{\text{exp}} = 0.15 \pm 0.04(\text{stat.}) \pm 0.05(\text{syst.})$, where the systematic uncertainty is that derived from the $|\eta|$ -sliced ABCD method and accounts for the transfer factor non-uniformity. This estimate is in agreement with the background estimate of the ABCD method.

The signal leakage of the spin-0 DY pair-produced HIPs and the PF pair-produced HIPs of either spin is not considered because it cannot be estimated using the extrapolation method described in section 4. The reason is that most signal events appear in the signal region A; consequently, single-particle samples many times larger than the existing samples

would be needed to sufficiently populate control region “efficiency” maps. Neglecting signal leakage does not introduce any significant bias into the limits for the alternative models presented in section 7, since an average relative discrepancy of less than 1% was found when comparing the limits computed considering signal leakage into the control regions to the limits obtained neglecting signal leakage for the DY spin- $\frac{1}{2}$ production mode.

6 Systematic uncertainties

There are various sources of uncertainty that arise in the computation of the signal selection efficiency, most of which are induced by possible imperfections of the HIP signal simulation. Uncertainties in the signal efficiencies are evaluated for each HIP charge, mass, spin and production mode, but only average relative uncertainties are reported here. Uncertainties evaluated in one direction are assumed to be symmetric.

There are several selection efficiency uncertainties associated with the simulation of the ionization process. These are quantified by simulating an alternative signal sample with modified parameters. The detector material mismodeling leads to the largest uncertainty, which inherits the dependence on the square of the charge from the ionization stopping power. Increasing the material in the ID and the EM calorimeter by one standard deviation (a 7.5% increase of the ID material [124], a 10% increase of the ID services material [124], and a 5% increase in the calorimeter presampler material) yields a relative uncertainty in the selection efficiency of 4% for $1g_D$ and 18% for $2g_D$ monopoles of mass 1500 GeV. On average across all monopole and HECO charges, the relative uncertainty is 9%. The δ -ray production is dictated by the dE/dx formulas for ionization by monopoles and HECOs, which have theoretical uncertainties of about 3% [120, 122] in the kinematic range considered in this analysis. By reducing the δ -ray production by 3% in the simulation, an average relative uncertainty of 2% is estimated. Another uncertainty is related to electron-ion recombination in the LAr EM calorimeter, which reduces the energy recorded compared to the energy deposited by a particle. While Birks’ law models this effect as a function of dE/dx [125], it overestimates the recombination effects at high dE/dx . A correction to Birks’ law for HIPs, as described in ref. [121], is implemented in the simulation. By varying this correction within its uncertainties, an average relative uncertainty of 8% is assigned.

The TRT occupancy (the fraction of TRT straws with hits in any event) is slightly underestimated in the simulation. This mismodeling affects the fraction of TRT HT hits used as a discriminating variable in the trigger and offline selections. Scaling the number of LT hits (those likely to come from pileup as opposed to HIPs or associated δ -rays) in each event by pileup-dependent ratios of TRT occupancy between data and simulation results, on average, in a relative systematic uncertainty of 2% in the selection efficiency. Similarly, a relative systematic uncertainty of 2% accounting for potential mismodeling of pileup is estimated with variations of the nominal pileup distribution within its uncertainty.

Slow-moving HIPs ($\beta < 0.37$) arrive at the EM calorimeter with a time delay of more than 10 ns with respect to the HIP production time. As a result, the first-level trigger may associate the calorimeter cluster with the next bunch crossing, leading to a reduction of the HIP selection efficiency by the HLT. However, this effect is not accurately simulated, such

that the trigger efficiency for slow-moving HIPs is overestimated. Therefore, the trigger efficiency loss is determined by rejecting the slow-moving HIPs at truth level, leading to a relative systematic uncertainty of 2% on average in the selection efficiency.

Finally, by comparing the efficiencies extrapolated from single-particle efficiency maps to those obtained using fully simulated MC spin- $\frac{1}{2}$ samples, an average relative systematic uncertainty of 1% in the selection efficiency is found for imprecise extrapolation of Drell-Yan spin-0 and photon-fusion efficiencies.

For each HIP charge, mass, spin and production mode, the systematic uncertainties described above are added in quadrature to obtain a final uncertainty on the signal efficiency. The limit-setting framework presented in section 7 also takes into account the 30% relative systematic uncertainty on the background estimate described in section 5 and the integrated luminosity uncertainty, which is 0.83%, estimated following the methods discussed in ref. [126].

7 Upper cross-section and lower mass limits

Consistent with the background expectation, no event is observed in the HIP signal region. Therefore, exclusion limits are set on all four signal models at 95% confidence level (CL) using the CL_S [127] frequentist framework implemented in RooStats [128]. The cross-section limits are obtained exploiting selection efficiencies and their corresponding uncertainties for each HIP signal sample, the systematic uncertainty on the background estimate, and the integrated luminosity uncertainty. A toys-based approach, with 5000 pseudoexperiments, is used to approximate the test-statistic distribution for each considered signal model. The likelihood function for DY spin- $\frac{1}{2}$ HIPs considers the signal leakage in the control regions, whereas only signal-region information is used for DY spin-0 pair-produced HIPs and PF pair-produced HIPs of both spins. Figures 8 and 9 show the observed 95% CL upper limits on the production cross sections, as a function of the HIP mass. Cross section limits for which the selection efficiency is below 0.1% are not reported, since the limited statistics preclude the evaluation of reliable systematic uncertainties in those cases. Lower mass limits derived for each production mode are shown in table 3. In cases where the cross section upper limit curve does not intersect the production cross section curve, the mass limit is set to the highest mass for which a cross section upper limit was determined. The photon-fusion mechanism provides more stringent mass limits than the Drell-Yan mechanism, as it has a higher predicted cross section. Given that the predicted cross sections can only be calculated at leading order, these mass limits primarily serve as benchmarks for comparison with other experiments, as shown in figure 10. The ATLAS cross-section limits for Drell-Yan production of HECOs in the range $20 \leq |z| \leq 100$ are several orders of magnitude better than those reported by MoEDAL in ref. [103], which considers 8 TeV pp collision data. While MoEDAL is the only experiment sensitive to magnetic charges in the range $3g_D \leq |g| \leq 5g_D$ [97–101], the present ATLAS search is able to set significantly better cross-section limits (one to two orders of magnitude) for $1g_D$ and $2g_D$.

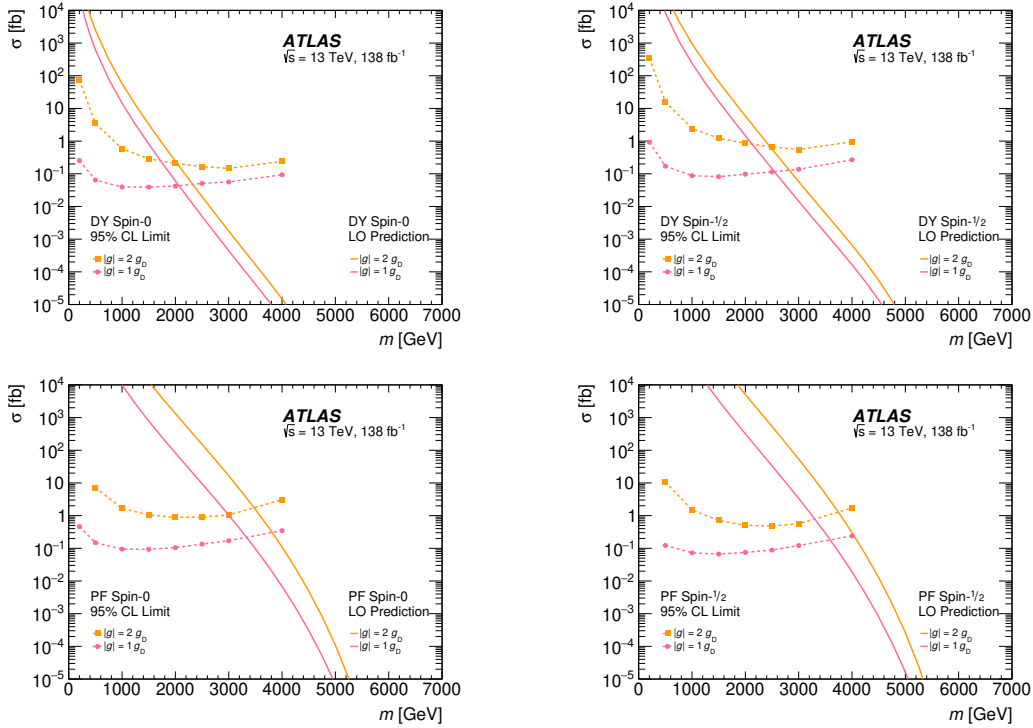


Figure 8. Observed 95% CL upper limits on the cross section for all masses and charges of Drell-Yan (top) and photon-fusion (bottom) pair-produced monopoles for spin-0 (left) and spin- $\frac{1}{2}$ (right). Mass points for which the selection efficiency is below 0.1% are not shown. The solid lines are the theoretical leading-order cross sections as a function of mass.

95% CL lower limits on the mass of HIPs [TeV]							
	$ g = 1g_D$	$ g = 2g_D$	$ z = 20$	$ z = 40$	$ z = 60$	$ z = 80$	$ z = 100$
DY spin-0	2.1	2.1	1.4	1.8	1.9	1.8	1.7
DY spin- $\frac{1}{2}$	2.6	2.5	1.8	2.2	2.2	2.1	1.9
PF spin-0	3.4	3.5	2.1	2.8	2.9	2.8	2.5
PF spin- $\frac{1}{2}$	3.6	3.7	2.5	3.1	3.1	3.0	2.5

Table 3. Lower limits on the mass of magnetic monopoles and HECOs (in TeV) at 95% confidence level in models of spin-0 and spin- $\frac{1}{2}$ Drell-Yan (DY) and photon-fusion (PF) pair production.

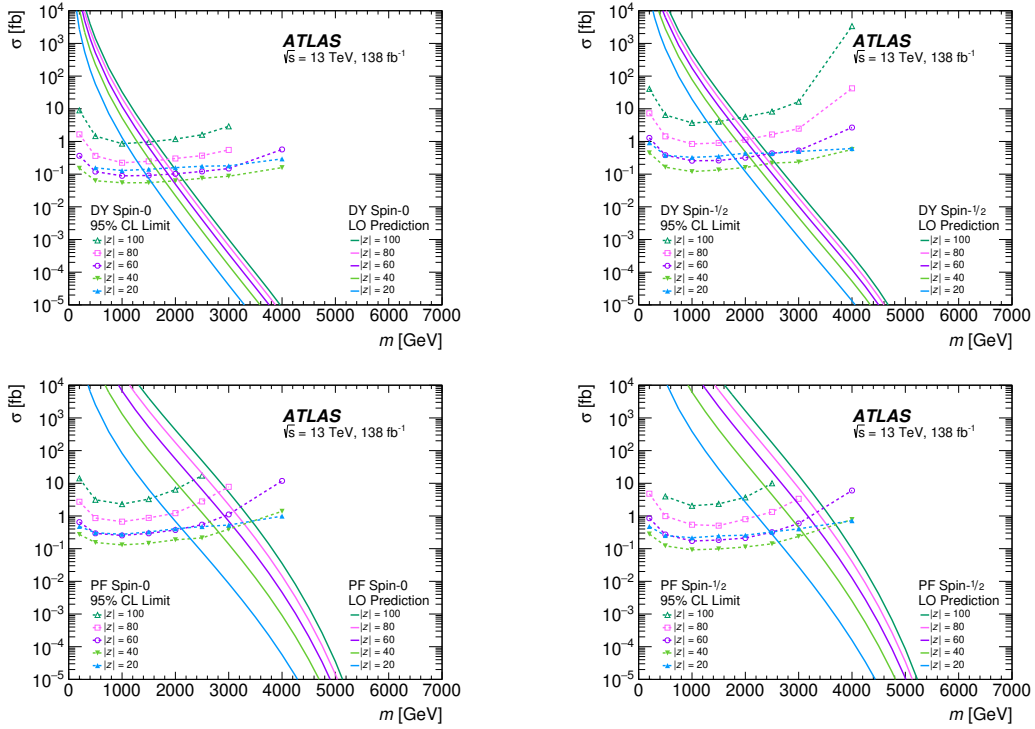


Figure 9. Observed 95% CL upper limits on the cross section for all masses and charges of Drell-Yan (top) and photon-fusion (bottom) pair-produced HECOs for spin-0 (left) and spin- $\frac{1}{2}$ (right). Mass points for which the selection efficiency is below 0.1% are not shown. The solid lines are the theoretical leading-order cross sections as a function of mass.

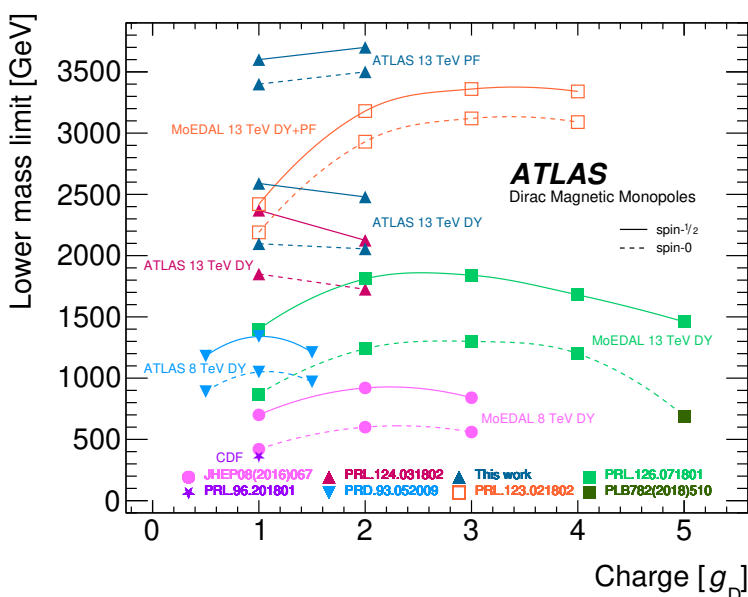


Figure 10. Comparison of the lower mass limits obtained by LHC searches in Run 1 and Run 2 pp collisions for Drell-Yan and photon-fusion pair-produced magnetic monopoles. A Tevatron measurement by CDF in $p\bar{p}$ collisions is also shown. The dashed and solid lines represent spin-0 and spin- $\frac{1}{2}$ measurements, respectively.

8 Conclusions

This paper presents a search for spin-0 and spin- $\frac{1}{2}$ magnetic monopoles and HECOs produced via the Drell-Yan and photon-fusion mechanisms using a dataset of 138 fb^{-1} of 13 TeV proton-proton collisions collected by the ATLAS detector between 2015 and 2018 during Run 2. Upper cross-section limits and lower mass limits computed at 95% confidence level are presented. The search improves by approximately a factor of three the cross-section limits on the Drell-Yan production of magnetic monopoles with magnetic charges $1g_D$ and $2g_D$ and HECOs in the range $20 \leq |z| \leq 100$ attained in the 2015/16 dataset alone. Also, the first ATLAS limits on the photon-fusion pair production mechanism of magnetic monopoles and HECOs are obtained.

Acknowledgments

We thank CERN for the very successful operation of the LHC, as well as the support staff from our institutions without whom ATLAS could not be operated efficiently.

We acknowledge the support of ANPCyT, Argentina; YerPhI, Armenia; ARC, Australia; BMWFW and FWF, Austria; ANAS, Azerbaijan; CNPq and FAPESP, Brazil; NSERC, NRC and CFI, Canada; CERN; ANID, Chile; CAS, MOST and NSFC, China; Minciencias, Colombia; MEYS CR, Czech Republic; DNRf and DNSRC, Denmark; IN2P3-CNRS and CEA-DRF/IRFU, France; SRNSFG, Georgia; BMBF, HGF and MPG, Germany; GSRI, Greece; RGC and Hong Kong SAR, China; ISF and Benoziyo Center, Israel; INFN,

Italy; MEXT and JSPS, Japan; CNRST, Morocco; NWO, Netherlands; RCN, Norway; MEiN, Poland; FCT, Portugal; MNE/IFA, Romania; MESTD, Serbia; MSSR, Slovakia; ARRS and MIZŠ, Slovenia; DSI/NRF, South Africa; MICINN, Spain; SRC and Wallenberg Foundation, Sweden; SERI, SNSF and Cantons of Bern and Geneva, Switzerland; MOST, Taiwan; TENMAK, Türkiye; STFC, United Kingdom; DOE and NSF, United States of America. In addition, individual groups and members have received support from BCKDF, CANARIE, Compute Canada and CRC, Canada; PRIMUS 21/SCI/017 and UNCE SCI/013, Czech Republic; COST, ERC, ERDF, Horizon 2020 and Marie Skłodowska-Curie Actions, European Union; Investissements d’Avenir Labex, Investissements d’Avenir IDEX and ANR, France; DFG and AvH Foundation, Germany; Herakleitos, Thales and Aristeia programmes co-financed by EU-ESF and the Greek NSRF, Greece; BSF-NSF and MINERVA, Israel; Norwegian Financial Mechanism 2014-2021, Norway; NCN and NAWA, Poland; La Caixa Banking Foundation, CERCA Programme Generalitat de Catalunya and PROMETEO and GenT Programmes Generalitat Valenciana, Spain; Göran Gustafssons Stiftelse, Sweden; The Royal Society and Leverhulme Trust, United Kingdom.

The crucial computing support from all WLCG partners is acknowledged gratefully, in particular from CERN, the ATLAS Tier-1 facilities at TRIUMF (Canada), NDGF (Denmark, Norway, Sweden), CC-IN2P3 (France), KIT/GridKA (Germany), INFN-CNAF (Italy), NL-T1 (Netherlands), PIC (Spain), ASGC (Taiwan), RAL (U.K.) and BNL (U.S.A.), the Tier-2 facilities worldwide and large non-WLCG resource providers. Major contributors of computing resources are listed in ref. [129].

Open Access. This article is distributed under the terms of the Creative Commons Attribution License ([CC-BY 4.0](https://creativecommons.org/licenses/by/4.0/)), which permits any use, distribution and reproduction in any medium, provided the original author(s) and source are credited.

References

- [1] P.A.M. Dirac, *Quantised singularities in the electromagnetic field*, *Proc. Roy. Soc. Lond. A* **133** (1931) 60 [[INSPIRE](#)].
- [2] P.A.M. Dirac, *The theory of magnetic poles*, *Phys. Rev.* **74** (1948) 817 [[INSPIRE](#)].
- [3] A.M. Polyakov, *Particle spectrum in quantum field theory*, *JETP Lett.* **20** (1974) 194 [[INSPIRE](#)].
- [4] G. ’t Hooft, *Magnetic monopoles in unified gauge theories*, *Nucl. Phys. B* **79** (1974) 276 [[INSPIRE](#)].
- [5] T.W.B. Kibble, *Topology of cosmic domains and strings*, *J. Phys. A* **9** (1976) 1387 [[INSPIRE](#)].
- [6] T.W. Kephart, G.K. Leontaris and Q. Shafi, *Magnetic monopoles and free fractionally charged states at accelerators and in cosmic rays*, *JHEP* **10** (2017) 176 [[arXiv:1707.08067](#)] [[INSPIRE](#)].
- [7] Y.M. Cho and D. Maison, *Monopole configuration in Weinberg-Salam model*, *Phys. Lett. B* **391** (1997) 360 [[hep-th/9601028](#)] [[INSPIRE](#)].
- [8] K. Kimm, J.H. Yoon and Y.M. Cho, *Finite energy electroweak dyon*, *Eur. Phys. J. C* **75** (2015) 67 [[arXiv:1305.1699](#)] [[INSPIRE](#)].

- [9] J. Ellis, N.E. Mavromatos and T. You, *The price of an electroweak monopole*, *Phys. Lett. B* **756** (2016) 29 [[arXiv:1602.01745](#)] [[INSPIRE](#)].
- [10] S. Arunasalam and A. Kobakhidze, *Electroweak monopoles and the electroweak phase transition*, *Eur. Phys. J. C* **77** (2017) 444 [[arXiv:1702.04068](#)] [[INSPIRE](#)].
- [11] J. Ellis, N.E. Mavromatos and T. You, *Light-by-light scattering constraint on Born-Infeld theory*, *Phys. Rev. Lett.* **118** (2017) 261802 [[arXiv:1703.08450](#)] [[INSPIRE](#)].
- [12] M. Arai, F. Blaschke, M. Eto and N. Sakai, *Localization of the Standard Model via the Higgs mechanism and a finite electroweak monopole from non-compact five dimensions*, *PTEP* **2018** (2018) 083B04 [[arXiv:1802.06649](#)] [[INSPIRE](#)].
- [13] N.E. Mavromatos and S. Sarkar, *Magnetic monopoles from global monopoles in the presence of a Kalb-Ramond field*, *Phys. Rev. D* **95** (2017) 104025 [[arXiv:1607.01315](#)] [[INSPIRE](#)].
- [14] N.E. Mavromatos and S. Sarkar, *Regularized Kalb-Ramond magnetic monopole with finite energy*, *Phys. Rev. D* **97** (2018) 125010 [[arXiv:1804.01702](#)] [[INSPIRE](#)].
- [15] Y.M. Cho, *Physical implications of electroweak monopole*, *Phil. Trans. Roy. Soc. Lond. A* **377** (2019) 20190038 [[INSPIRE](#)].
- [16] P.Q. Hung, *Topologically stable, finite-energy electroweak-scale monopoles*, *Nucl. Phys. B* **962** (2021) 115278 [[arXiv:2003.02794](#)] [[INSPIRE](#)].
- [17] J. Ellis, P.Q. Hung and N.E. Mavromatos, *An electroweak monopole, Dirac quantization and the weak mixing angle*, *Nucl. Phys. B* **969** (2021) 115468 [[arXiv:2008.00464](#)] [[INSPIRE](#)].
- [18] S.A. Chin and A.K. Kerman, *Possible longlived hyperstrange multi-quark droplets*, *Phys. Rev. Lett.* **43** (1979) 1292 [[INSPIRE](#)].
- [19] E. Farhi and R.L. Jaffe, *Strange matter*, *Phys. Rev. D* **30** (1984) 2379 [[INSPIRE](#)].
- [20] B. Holdom, J. Ren and C. Zhang, *Quark matter may not be strange*, *Phys. Rev. Lett.* **120** (2018) 222001 [[arXiv:1707.06610](#)] [[INSPIRE](#)].
- [21] S.R. Coleman, *Q-balls*, *Nucl. Phys. B* **262** (1985) 263 [*Addendum ibid.* **269** (1986) 744] [[INSPIRE](#)].
- [22] A. Kusenko, *Solitons in the supersymmetric extensions of the Standard Model*, *Phys. Lett. B* **405** (1997) 108 [[hep-ph/9704273](#)] [[INSPIRE](#)].
- [23] G. Battistoni et al., *Nucleon stability, magnetic monopoles and atmospheric neutrinos in the Mont Blanc experiment*, *Phys. Lett. B* **133** (1983) 454 [[INSPIRE](#)].
- [24] M.R. Krishnaswamy et al., *Limits on the flux of monopoles from the Kolar gold mine experiments*, *Phys. Lett. B* **142** (1984) 99 [[INSPIRE](#)].
- [25] S. Orito et al., *Search for supermassive relics with 2000 m² array of plastic track detector*, *Phys. Rev. Lett.* **66** (1991) 1951 [[INSPIRE](#)].
- [26] SOUDAN-2 collaboration, *A search for magnetic monopoles with the SOUDAN-2 detector*, *Phys. Rev. D* **46** (1992) 4846 [[INSPIRE](#)].
- [27] MACRO collaboration, *Search for slowly moving magnetic monopoles with the MACRO detector*, *Phys. Rev. Lett.* **72** (1994) 608 [[INSPIRE](#)].
- [28] MACRO collaboration, *Magnetic monopole search with the MACRO detector at Gran Sasso*, *Phys. Lett. B* **406** (1997) 249 [[INSPIRE](#)].

- [29] MACRO collaboration, *Nuclearite search with the macro detector at Gran Sasso*, *Eur. Phys. J. C* **13** (2000) 453 [[hep-ex/9904031](#)] [[INSPIRE](#)].
- [30] MACRO collaboration, *Final results of magnetic monopole searches with the MACRO experiment*, *Eur. Phys. J. C* **25** (2002) 511 [[hep-ex/0207020](#)] [[INSPIRE](#)].
- [31] Y.F. Novoseltsev et al., *A search for massive magnetic monopoles at the Baksan Underground Scintillation Telescope (BUST)*, *Nucl. Phys. B Proc. Suppl.* **151** (2006) 337 [[INSPIRE](#)].
- [32] BAIKAL collaboration, *Search for relativistic magnetic monopoles with the Baikal neutrino telescope*, *Astropart. Phys.* **29** (2008) 366 [[INSPIRE](#)].
- [33] S. Balestra et al., *Magnetic monopole search at high altitude with the SLIM experiment*, *Eur. Phys. J. C* **55** (2008) 57 [[arXiv:0801.4913](#)] [[INSPIRE](#)].
- [34] SLIM collaboration, *Results of the search for strange quark matter and Q-balls with the SLIM experiment*, *Eur. Phys. J. C* **57** (2008) 525 [[arXiv:0805.1797](#)] [[INSPIRE](#)].
- [35] D.P. Hogan et al., *Relativistic magnetic monopole flux constraints from RICE*, *Phys. Rev. D* **78** (2008) 075031 [[arXiv:0806.2129](#)] [[INSPIRE](#)].
- [36] R. Abbasi et al., *Search for relativistic magnetic monopoles with the AMANDA-II neutrino telescope*, *Eur. Phys. J. C* **69** (2010) 361 [[INSPIRE](#)].
- [37] ANITA-II collaboration, *Ultra-relativistic magnetic monopole search with the ANITA-II balloon-borne radio interferometer*, *Phys. Rev. D* **83** (2011) 023513 [[arXiv:1008.1282](#)] [[INSPIRE](#)].
- [38] PIERRE AUGER collaboration, *Search for ultrarelativistic magnetic monopoles with the Pierre Auger Observatory*, *Phys. Rev. D* **94** (2016) 082002 [[arXiv:1609.04451](#)] [[INSPIRE](#)].
- [39] ANTARES collaboration, *Search for relativistic magnetic monopoles with the ANTARES neutrino telescope*, *Astropart. Phys.* **35** (2012) 634 [[arXiv:1110.2656](#)] [[INSPIRE](#)].
- [40] ANTARES collaboration, *Search for relativistic magnetic monopoles with five years of the ANTARES detector data*, *JHEP* **07** (2017) 054 [[arXiv:1703.00424](#)] [[INSPIRE](#)].
- [41] ANTARES collaboration, *Nuclearite search with ANTARES*, *2021 JINST* **16** C09010 [[arXiv:2107.13479](#)] [[INSPIRE](#)].
- [42] ANTARES collaboration, *Search for relativistic magnetic monopoles with ten years of the ANTARES detector data*, *2021 JINST* **16** C11004 [[INSPIRE](#)].
- [43] ANTARES collaboration, *Search for magnetic monopoles with ten years of the ANTARES neutrino telescope*, *JHEAp* **34** (2022) 1 [[arXiv:2202.13786](#)] [[INSPIRE](#)].
- [44] ANTARES collaboration, *Limits on the nuclearite flux using the ANTARES neutrino telescope*, *JCAP* **01** (2023) 012 [[arXiv:2208.11689](#)] [[INSPIRE](#)].
- [45] ICECUBE collaboration, *Search for relativistic magnetic monopoles with IceCube*, *Phys. Rev. D* **87** (2013) 022001 [[arXiv:1208.4861](#)] [[INSPIRE](#)].
- [46] ICECUBE collaboration, *New limit for mildly relativistic magnetic monopoles obtained with IceCube*, *PoS ICRC2015* (2016) 1061 [[INSPIRE](#)].
- [47] ICECUBE collaboration, *Searches for relativistic magnetic monopoles in IceCube*, *Eur. Phys. J. C* **76** (2016) 133 [[arXiv:1511.01350](#)] [[INSPIRE](#)].
- [48] ICECUBE collaboration, *Searches for magnetic monopoles with IceCube*, *EPJ Web Conf.* **168** (2018) 04010 [[INSPIRE](#)].

- [49] ICECUBE collaboration, *Search for relativistic magnetic monopoles with eight years of IceCube data*, *Phys. Rev. Lett.* **128** (2022) 051101 [[arXiv:2109.13719](#)] [[INSPIRE](#)].
- [50] Z. Wang, *Search for magnetic monopoles with the NOvA far detector*, Ph.D. thesis, [University of Virginia](#), Charlottesville, VA, U.S.A. (2015) [[INSPIRE](#)].
- [51] NOvA collaboration, *Search for slow magnetic monopoles with the NOvA detector on the surface*, *Phys. Rev. D* **103** (2021) 012007 [[arXiv:2009.04867](#)] [[INSPIRE](#)].
- [52] P. Musset, M. Price and E. Lohrmann, *Search for magnetic monopoles in electron-positron collisions at 34 GeV center-of-mass energy*, *Phys. Lett. B* **128** (1983) 333 [[INSPIRE](#)].
- [53] K. Kinoshita, P.B. Price and D. Fryberger, *Search for highly ionizing particles in e^+e^- collisions at $\sqrt{s} = 29$ GeV*, *Phys. Rev. Lett.* **48** (1982) 77 [[INSPIRE](#)].
- [54] D. Fryberger, T.E. Coan, K. Kinoshita and P.B. Price, *Search for highly ionizing particles in e^+e^- collisions at $\sqrt{s} = 29$ GeV*, *Phys. Rev. D* **29** (1984) 1524 [[INSPIRE](#)].
- [55] CLEO collaboration, *Search for magnetically charged particles produced in e^+e^- annihilations at $\sqrt{s} = 10.6$ GeV*, *Phys. Rev. D* **35** (1987) 1081 [[INSPIRE](#)].
- [56] TASSO collaboration, *A search for particles with magnetic charge produced in e^+e^- annihilations at $\sqrt{s} = 35$ GeV*, *Z. Phys. C* **38** (1988) 543 [[INSPIRE](#)].
- [57] K. Kinoshita et al., *Search for highly ionizing particles in e^+e^- annihilations at $\sqrt{s} = 50$ – 52 GeV*, *Phys. Rev. Lett.* **60** (1988) 1610 [[INSPIRE](#)].
- [58] K. Kinoshita et al., *Search for highly ionizing particles in e^+e^- annihilations at $\sqrt{s} = 50$ – 60.8 GeV*, *Phys. Lett. B* **228** (1989) 543 [[INSPIRE](#)].
- [59] OPAL collaboration, *Search for Dirac magnetic monopoles in e^+e^- collisions with the OPAL detector at LEP2*, *Phys. Lett. B* **663** (2008) 37 [[arXiv:0707.0404](#)] [[INSPIRE](#)].
- [60] K. Kinoshita et al., *Search for highly ionizing particles in e^+e^- annihilations at $\sqrt{s} = 91.1$ GeV*, *Phys. Rev. D* **46** (1992) R881 [[INSPIRE](#)].
- [61] J.L. Pinfold et al., *A search for highly ionizing particles produced at the OPAL intersection point at LEP*, *Phys. Lett. B* **316** (1993) 407 [[INSPIRE](#)].
- [62] H1 collaboration, *A direct search for stable magnetic monopoles produced in positron-proton collisions at HERA*, *Eur. Phys. J. C* **41** (2005) 133 [[hep-ex/0501039](#)] [[INSPIRE](#)].
- [63] K. Johnsen, *CERN Intersecting Storage Rings (ISR)*, *Proc. Nat. Acad. Sci.* **70** (1973) 619 [[INSPIRE](#)].
- [64] CDF collaboration, *Direct search for Dirac magnetic monopoles in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV*, *Phys. Rev. Lett.* **96** (2006) 201801 [[hep-ex/0509015](#)] [[INSPIRE](#)].
- [65] G.R. Kalbfleisch et al., *Limits on production of magnetic monopoles utilizing samples from the D0 and CDF detectors at the Tevatron*, *Phys. Rev. D* **69** (2004) 052002 [[hep-ex/0306045](#)] [[INSPIRE](#)].
- [66] G.R. Kalbfleisch et al., *Improved experimental limits on the production of magnetic monopoles*, *Phys. Rev. Lett.* **85** (2000) 5292 [[hep-ex/0005005](#)] [[INSPIRE](#)].
- [67] D0 collaboration, *A search for heavy point-like Dirac monopoles*, *Phys. Rev. Lett.* **81** (1998) 524 [[hep-ex/9803023](#)] [[INSPIRE](#)].
- [68] P.B. Price, G.-X. Ren and K. Kinoshita, *Search for highly ionizing particles at the Fermilab proton anti-proton collider*, *Phys. Rev. Lett.* **59** (1987) 2523 [[INSPIRE](#)].

- [69] P.B. Price, G.R. Jing and K. Kinoshita, *High luminosity search for highly ionizing particles at the Fermilab collider*, *Phys. Rev. Lett.* **65** (1990) 149 [INSPIRE].
- [70] M. Bertani et al., *Search for magnetic monopoles at the Tevatron collider*, *EPL* **12** (1990) 613 [INSPIRE].
- [71] H. Hoffmann et al., *A new search for magnetic monopoles at the CERN ISR with plastic detectors*, *Lett. Nuovo Cim.* **23** (1978) 357 [INSPIRE].
- [72] R.A. Carrigan Jr., B.P. Strauss and G. Giacomelli, *Search for magnetic monopoles at the CERN Intersecting Storage Rings*, *Phys. Rev. D* **17** (1978) 1754 [INSPIRE].
- [73] B. Aubert, P. Musset, M. Price and J.P. Vialle, *Search for magnetic monopoles in proton-anti-proton interactions at 540 GeV center-of-mass energy*, *Phys. Lett. B* **120** (1983) 465 [INSPIRE].
- [74] R.A. Carrigan, F.A. Nezrick and B.P. Strauss, *Search for magnetic monopole production by 300 GeV protons*, *Phys. Rev. D* **8** (1973) 3717 [INSPIRE].
- [75] R.A. Carrigan Jr., F.A. Nezrick and B.P. Strauss, *Extension of Fermi national accelerator laboratory magnetic monopole search to 400 GeV*, *Phys. Rev. D* **10** (1974) 3867 [INSPIRE].
- [76] Y.D. He, *Search for a Dirac magnetic monopole in high-energy nucleus-nucleus collisions*, *Phys. Rev. Lett.* **79** (1997) 3134 [INSPIRE].
- [77] STAR collaboration, *Strangelet search in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV*, *Phys. Rev. C* **76** (2007) 011901 [nucl-ex/0511047] [INSPIRE].
- [78] E886 collaboration, *Strangelet search and light nucleus production in relativistic Si+Pt and Au+Pt collisions*, *Phys. Rev. C* **54** (1996) R15 [INSPIRE].
- [79] E864 collaboration, *Negatively charged strangelet search using the E864 spectrometer at the AGS*, *J. Phys. G* **25** (1999) 411 [hep-ex/9811049] [INSPIRE].
- [80] E864 collaboration, *Search for positively charged strangelets and other related results with E864 at the AGS*, *J. Phys. G* **25** (1999) 403 [nucl-ex/9811006] [INSPIRE].
- [81] ATLAS collaboration, *Search for magnetic monopoles in $\sqrt{s} = 7$ TeV pp collisions with the ATLAS detector*, *Phys. Rev. Lett.* **109** (2012) 261803 [arXiv:1207.6411] [INSPIRE].
- [82] ATLAS collaboration, *Search for magnetic monopoles and stable particles with high electric charges in 8 TeV pp collisions with the ATLAS detector*, *Phys. Rev. D* **93** (2016) 052009 [arXiv:1509.08059] [INSPIRE].
- [83] ATLAS collaboration, *Search for magnetic monopoles and stable high-electric-charge objects in 13 TeV proton-proton collisions with the ATLAS detector*, *Phys. Rev. Lett.* **124** (2020) 031802 [arXiv:1905.10130] [INSPIRE].
- [84] G. Giacomelli and L. Patrizii, *Magnetic monopole searches*, *ICTP Lect. Notes Ser.* **14** (2003) 121 [hep-ex/0302011] [INSPIRE].
- [85] K.A. Milton, *Theoretical and experimental status of magnetic monopoles*, *Rept. Prog. Phys.* **69** (2006) 1637 [hep-ex/0602040] [INSPIRE].
- [86] S. Burdin et al., *Non-collider searches for stable massive particles*, *Phys. Rept.* **582** (2015) 1 [arXiv:1410.1374] [INSPIRE].
- [87] L. Patrizii and M. Spurio, *Status of searches for magnetic monopoles*, *Ann. Rev. Nucl. Part. Sci.* **65** (2015) 279 [arXiv:1510.07125] [INSPIRE].

- [88] L. Patrizii, Z. Sahnoun and V. Togo, *Searches for cosmic magnetic monopoles: past, present and future*, *Phil. Trans. Roy. Soc. Lond. A* **377** (2019) 20180328 [INSPIRE].
- [89] N.E. Mavromatos and V.A. Mitsou, *Magnetic monopoles revisited: models and searches at colliders and in the cosmos*, *Int. J. Mod. Phys. A* **35** (2020) 2030012 [arXiv:2005.05100] [INSPIRE].
- [90] A. De Rújula and S.L. Glashow, *Nuclearites: a novel form of cosmic radiation*, *Nature* **312** (1984) 734 [INSPIRE].
- [91] ATLAS collaboration, *Search for long-lived, multi-charged particles in pp collisions at $\sqrt{s} = 7$ TeV using the ATLAS detector*, *Phys. Lett. B* **722** (2013) 305 [arXiv:1301.5272] [INSPIRE].
- [92] ATLAS collaboration, *Search for heavy long-lived multi-charged particles in pp collisions at $\sqrt{s} = 8$ TeV using the ATLAS detector*, *Eur. Phys. J. C* **75** (2015) 362 [arXiv:1504.04188] [INSPIRE].
- [93] ATLAS collaboration, *Search for heavy long-lived multicharged particles in proton-proton collisions at $\sqrt{s} = 13$ TeV using the ATLAS detector*, *Phys. Rev. D* **99** (2019) 052003 [arXiv:1812.03673] [INSPIRE].
- [94] ATLAS collaboration, *Search for heavy long-lived multi-charged particles in the full LHC run 2 pp collision data at $\sqrt{s} = 13$ TeV using the ATLAS detector*, arXiv:2303.13613 [INSPIRE].
- [95] CMS collaboration, *Searches for long-lived charged particles in pp collisions at $\sqrt{s} = 7$ and 8 TeV*, *JHEP* **07** (2013) 122 [Erratum *ibid.* **11** (2022) 149] [arXiv:1305.0491] [INSPIRE].
- [96] CMS collaboration, *Search for long-lived charged particles in proton-proton collisions at $\sqrt{s} = 13$ TeV*, *Phys. Rev. D* **94** (2016) 112004 [arXiv:1609.08382] [INSPIRE].
- [97] MoEDAL collaboration, *Search for magnetic monopoles with the MoEDAL prototype trapping detector in 8 TeV proton-proton collisions at the LHC*, *JHEP* **08** (2016) 067 [arXiv:1604.06645] [INSPIRE].
- [98] MoEDAL collaboration, *Search for magnetic monopoles with the MoEDAL forward trapping detector in 13 TeV proton-proton collisions at the LHC*, *Phys. Rev. Lett.* **118** (2017) 061801 [arXiv:1611.06817] [INSPIRE].
- [99] MoEDAL collaboration, *Search for magnetic monopoles with the MoEDAL forward trapping detector in 2.11 fb^{-1} of 13 TeV proton-proton collisions at the LHC*, *Phys. Lett. B* **782** (2018) 510 [arXiv:1712.09849] [INSPIRE].
- [100] MoEDAL collaboration, *Magnetic monopole search with the full MoEDAL trapping detector in 13 TeV pp collisions interpreted in photon-fusion and Drell-Yan production*, *Phys. Rev. Lett.* **123** (2019) 021802 [arXiv:1903.08491] [INSPIRE].
- [101] MoEDAL collaboration, *Search for magnetic monopoles produced via the Schwinger mechanism*, *Nature* **602** (2022) 63 [arXiv:2106.11933] [INSPIRE].
- [102] MoEDAL collaboration, *First search for dyons with the full MoEDAL trapping detector in 13 TeV pp collisions*, *Phys. Rev. Lett.* **126** (2021) 071801 [arXiv:2002.00861] [INSPIRE].
- [103] MoEDAL collaboration, *Search for highly-ionizing particles in pp collisions at the LHC's run-1 using the prototype MoEDAL detector*, *Eur. Phys. J. C* **82** (2022) 694 [arXiv:2112.05806] [INSPIRE].

- [104] W.Y. Song and W. Taylor, *Pair production of magnetic monopoles and stable high-electric-charge objects in proton-proton and heavy-ion collisions*, *J. Phys. G* **49** (2022) 045002 [[arXiv:2107.10789](#)] [[INSPIRE](#)].
- [105] Y. Kurochkin et al., *On production of magnetic monopoles via $\gamma\gamma$ fusion at high energy pp collisions*, *Mod. Phys. Lett. A* **21** (2006) 2873 [[INSPIRE](#)].
- [106] T. Dougall and S.D. Wick, *Dirac magnetic monopole production from photon fusion in proton collisions*, *Eur. Phys. J. A* **39** (2009) 213 [[arXiv:0706.1042](#)] [[INSPIRE](#)].
- [107] L.N. Epele et al., *Looking for magnetic monopoles at LHC with diphoton events*, *Eur. Phys. J. Plus* **127** (2012) 60 [[arXiv:1205.6120](#)] [[INSPIRE](#)].
- [108] S. Baines et al., *Monopole production via photon fusion and Drell-Yan processes: MadGraph implementation and perturbativity via velocity-dependent coupling and magnetic moment as novel features*, *Eur. Phys. J. C* **78** (2018) 966 [*Erratum ibid.* **79** (2019) 166] [[arXiv:1808.08942](#)] [[INSPIRE](#)].
- [109] ATLAS collaboration, *The ATLAS experiment at the CERN Large Hadron Collider*, **2008 JINST** **3** S08003 [[INSPIRE](#)].
- [110] ATLAS collaboration, *Performance of the ATLAS transition radiation tracker in run 1 of the LHC: tracker properties*, **2017 JINST** **12** P05002 [[arXiv:1702.06473](#)] [[INSPIRE](#)].
- [111] ATLAS collaboration, *Performance of the ATLAS trigger system in 2015*, *Eur. Phys. J. C* **77** (2017) 317 [[arXiv:1611.09661](#)] [[INSPIRE](#)].
- [112] ATLAS collaboration, *The ATLAS collaboration software and firmware*, **ATL-SOFT-PUB-2021-001**, CERN, Geneva, Switzerland (2021).
- [113] J. Alwall et al., *The automated computation of tree-level and next-to-leading order differential cross sections, and their matching to parton shower simulations*, *JHEP* **07** (2014) 079 [[arXiv:1405.0301](#)] [[INSPIRE](#)].
- [114] T. Sjöstrand et al., *An introduction to PYTHIA 8.2*, *Comput. Phys. Commun.* **191** (2015) 159 [[arXiv:1410.3012](#)] [[INSPIRE](#)].
- [115] T. Sjöstrand, S. Mrenna and P.Z. Skands, *PYTHIA 6.4 physics and manual*, *JHEP* **05** (2006) 026 [[hep-ph/0603175](#)] [[INSPIRE](#)].
- [116] ATLAS collaboration, *ATLAS Pythia 8 tunes to 7 TeV data*, **ATL-PHYS-PUB-2014-021**, CERN, Geneva, Switzerland (2014).
- [117] S. Carrazza, S. Forte and J. Rojo, *Parton distributions and event generators*, in the proceedings of the 43rd international symposium on multiparticle dynamics, (2013), p. 89 [[arXiv:1311.5887](#)] [[INSPIRE](#)].
- [118] A.V. Manohar, P. Nason, G.P. Salam and G. Zanderighi, *The photon content of the proton*, *JHEP* **12** (2017) 046 [[arXiv:1708.01256](#)] [[INSPIRE](#)].
- [119] GEANT4 collaboration, *GEANT4 — a simulation toolkit*, *Nucl. Instrum. Meth. A* **506** (2003) 250 [[INSPIRE](#)].
- [120] S.P. Ahlen, *Stopping power formula for magnetic monopoles*, *Phys. Rev. D* **17** (1978) 229 [[INSPIRE](#)].
- [121] S. Burdin, M. Horbatsch and W. Taylor, *A correction to Birks' law in liquid argon ionization chamber simulations for highly ionizing particles*, *Nucl. Instrum. Meth. A* **664** (2012) 111 [[INSPIRE](#)].

- [122] S.P. Ahlen, *Theoretical and experimental aspects of the energy loss of relativistic heavily ionizing particles*, *Rev. Mod. Phys.* **52** (1980) 121 [[INSPIRE](#)].
- [123] ATLAS collaboration, *Topological cell clustering in the ATLAS calorimeters and its performance in LHC run 1*, *Eur. Phys. J. C* **77** (2017) 490 [[arXiv:1603.02934](#)] [[INSPIRE](#)].
- [124] ATLAS collaboration, *Study of the material of the ATLAS inner detector for run 2 of the LHC, 2017 JINST* **12** P12009 [[arXiv:1707.02826](#)] [[INSPIRE](#)].
- [125] J.B. Birks, *Theory of the response of organic scintillation crystals to short-range particles*, *Phys. Rev.* **86** (1952) 569.
- [126] ATLAS collaboration, *Luminosity determination in pp collisions at $\sqrt{s} = 13$ TeV using the ATLAS detector at the LHC*, [arXiv:2212.09379](#).
- [127] A.L. Read, *Presentation of search results: the CL_s technique*, *J. Phys. G* **28** (2002) 2693 [[INSPIRE](#)].
- [128] W. Verkerke and D. Kirkby, *The RooFit toolkit for data modeling*, in *Conference in Computing in High Energy and nuclear Physics (CHEP03)*, (2003) [[physics/0306116](#)].
- [129] ATLAS collaboration, *ATLAS computing acknowledgements*, [ATL-SOFT-PUB-2023-001](#), CERN, Geneva, Switzerland (2023).

The ATLAS collaboration

G. Aad [ID](#)¹⁰², B. Abbott [ID](#)¹²⁰, K. Abeling [ID](#)⁵⁵, N.J. Abicht [ID](#)⁴⁹, S.H. Abidi [ID](#)²⁹,
A. Abouhorma [ID](#)^{35e}, H. Abramowicz [ID](#)¹⁵¹, H. Abreu [ID](#)¹⁵⁰, Y. Abulaiti [ID](#)¹¹⁷,
B.S. Acharya [ID](#)^{69a,69b,q}, C. Adam Bourdarios [ID](#)⁴, L. Adamczyk [ID](#)^{86a}, S.V. Addepalli [ID](#)²⁶,
M.J. Addison [ID](#)¹⁰¹, J. Adelman [ID](#)¹¹⁵, A. Adiguzel [ID](#)^{21c}, T. Adye [ID](#)¹³⁴, A.A. Affolder [ID](#)¹³⁶,
Y. Afik [ID](#)³⁶, M.N. Agaras [ID](#)¹³, J. Agarwala [ID](#)^{73a,73b}, A. Aggarwal [ID](#)¹⁰⁰, C. Agheorghiesei [ID](#)^{27c},
A. Ahmad [ID](#)³⁶, F. Ahmadov [ID](#)^{38,ak}, W.S. Ahmed [ID](#)¹⁰⁴, S. Ahuja [ID](#)⁹⁵, X. Ai [ID](#)^{62a}, G. Aielli [ID](#)^{76a,76b},
A. Aikot [ID](#)¹⁶³, M. Ait Tamlihat [ID](#)^{35e}, B. Aitbenchikh [ID](#)^{35a}, I. Aizenberg [ID](#)¹⁶⁹, M. Akbiyik [ID](#)¹⁰⁰,
T.P.A. Åkesson [ID](#)⁹⁸, A.V. Akimov [ID](#)³⁷, D. Akiyama [ID](#)¹⁶⁸, N.N. Akolkar [ID](#)²⁴, K. Al Khoury [ID](#)⁴¹,
G.L. Alberghi [ID](#)^{23b}, J. Albert [ID](#)¹⁶⁵, P. Albicocco [ID](#)⁵³, G.L. Albouy [ID](#)⁶⁰, S. Alderweireldt [ID](#)⁵²,
M. Aleksa [ID](#)³⁶, I.N. Aleksandrov [ID](#)³⁸, C. Alexa [ID](#)^{27b}, T. Alexopoulos [ID](#)¹⁰, F. Alfonsi [ID](#)^{23b},
M. Algren [ID](#)⁵⁶, M. Alhroob [ID](#)¹²⁰, B. Ali [ID](#)¹³², H.M.J. Ali [ID](#)⁹¹, S. Ali [ID](#)¹⁴⁸, S.W. Alibocus [ID](#)⁹²,
M. Aliev [ID](#)¹⁴⁵, G. Alimonti [ID](#)^{71a}, W. Alkahi [ID](#)⁵⁵, C. Allaire [ID](#)⁶⁶, B.M.M. Allbrooke [ID](#)¹⁴⁶,
J.F. Allen [ID](#)⁵², C.A. Allendes Flores [ID](#)^{137f}, P.P. Allport [ID](#)²⁰, A. Aloisio [ID](#)^{72a,72b}, F. Alonso [ID](#)⁹⁰,
C. Alpigiani [ID](#)¹³⁸, M. Alvarez Estevez [ID](#)⁹⁹, A. Alvarez Fernandez [ID](#)¹⁰⁰, M. Alves Cardoso [ID](#)⁵⁶,
M.G. Alviggi [ID](#)^{72a,72b}, M. Aly [ID](#)¹⁰¹, Y. Amaral Coutinho [ID](#)^{83b}, A. Ambler [ID](#)¹⁰⁴, C. Amelung [ID](#)³⁶,
M. Amerl [ID](#)¹⁰¹, C.G. Ames [ID](#)¹⁰⁹, D. Amidei [ID](#)¹⁰⁶, S.P. Amor Dos Santos [ID](#)^{130a}, K.R. Amos [ID](#)¹⁶³,
V. Ananiev [ID](#)¹²⁵, C. Anastopoulos [ID](#)¹³⁹, T. Andeen [ID](#)¹¹, J.K. Anders [ID](#)³⁶, S.Y. Andrean [ID](#)^{47a,47b},
A. Andreatta [ID](#)^{71a,71b}, S. Angelidakis [ID](#)⁹, A. Angerami [ID](#)^{41,ao}, A.V. Anisenkov [ID](#)³⁷, A. Annovi [ID](#)^{74a},
C. Antel [ID](#)⁵⁶, M.T. Anthony [ID](#)¹³⁹, E. Antipov [ID](#)¹⁴⁵, M. Antonelli [ID](#)⁵³, F. Anulli [ID](#)^{75a}, M. Aoki [ID](#)⁸⁴,
T. Aoki [ID](#)¹⁵³, J.A. Aparisi Pozo [ID](#)¹⁶³, M.A. Aparo [ID](#)¹⁴⁶, L. Aperio Bella [ID](#)⁴⁸, C. Appelt [ID](#)¹⁸,
A. Apyan [ID](#)²⁶, N. Aranzabal [ID](#)³⁶, S.J. Arbiol Val [ID](#)⁸⁷, C. Arcangeletti [ID](#)⁵³, A.T.H. Arce [ID](#)⁵¹,
E. Arena [ID](#)⁹², J-F. Arguin [ID](#)¹⁰⁸, S. Argyropoulos [ID](#)⁵⁴, J.-H. Arling [ID](#)⁴⁸, O. Arnaez [ID](#)⁴,
H. Arnold [ID](#)¹¹⁴, G. Artoni [ID](#)^{75a,75b}, H. Asada [ID](#)¹¹¹, K. Asai [ID](#)¹¹⁸, S. Asai [ID](#)¹⁵³, N.A. Asbah [ID](#)⁶¹,
J. Assahsah [ID](#)^{35d}, K. Assamagan [ID](#)²⁹, R. Astalos [ID](#)^{28a}, S. Atashi [ID](#)¹⁶⁰, R.J. Atkin [ID](#)^{33a},
M. Atkinson [ID](#)¹⁶², H. Atmani [ID](#)^{35f}, P.A. Atmasiddha [ID](#)¹⁰⁶, K. Augsten [ID](#)¹³², S. Auricchio [ID](#)^{72a,72b},
A.D. Auriol [ID](#)²⁰, V.A. Austrup [ID](#)¹⁰¹, G. Avolio [ID](#)³⁶, K. Axiotis [ID](#)⁵⁶, G. Azuelos [ID](#)^{108,aw},
D. Babal [ID](#)^{28b}, H. Bachacou [ID](#)¹³⁵, K. Bachas [ID](#)^{152,w}, A. Bachiu [ID](#)³⁴, F. Backman [ID](#)^{47a,47b},
A. Badea [ID](#)⁶¹, P. Bagnaia [ID](#)^{75a,75b}, M. Bahmani [ID](#)¹⁸, A.J. Bailey [ID](#)¹⁶³, V.R. Bailey [ID](#)¹⁶²,
J.T. Baines [ID](#)¹³⁴, L. Baines [ID](#)⁹⁴, O.K. Baker [ID](#)¹⁷², E. Bakos [ID](#)¹⁵, D. Bakshi Gupta [ID](#)⁸,
V. Balakrishnan [ID](#)¹²⁰, R. Balasubramanian [ID](#)¹¹⁴, E.M. Baldin [ID](#)³⁷, P. Balek [ID](#)^{86a},
E. Ballabene [ID](#)^{23b,23a}, F. Balli [ID](#)¹³⁵, L.M. Baltés [ID](#)^{63a}, W.K. Balunas [ID](#)³², J. Balz [ID](#)¹⁰⁰,
E. Banas [ID](#)⁸⁷, M. Bandieramonte [ID](#)¹²⁹, A. Bandyopadhyay [ID](#)²⁴, S. Bansal [ID](#)²⁴, L. Barak [ID](#)¹⁵¹,
M. Barakat [ID](#)⁴⁸, E.L. Barberio [ID](#)¹⁰⁵, D. Barberis [ID](#)^{57b,57a}, M. Barbero [ID](#)¹⁰², M.Z. Barel [ID](#)¹¹⁴,
K.N. Barends [ID](#)^{33a}, T. Barillari [ID](#)¹¹⁰, M-S. Barisits [ID](#)³⁶, T. Barklow [ID](#)¹⁴³, P. Baron [ID](#)¹²²,
D.A. Baron Moreno [ID](#)¹⁰¹, A. Baroncelli [ID](#)^{62a}, G. Barone [ID](#)²⁹, A.J. Barr [ID](#)¹²⁶, J.D. Barr [ID](#)⁹⁶,
L. Barranco Navarro [ID](#)^{47a,47b}, F. Barreiro [ID](#)⁹⁹, J. Barreiro Guimarães da Costa [ID](#)^{14a},
U. Barron [ID](#)¹⁵¹, M.G. Barros Teixeira [ID](#)^{130a}, S. Barsov [ID](#)³⁷, F. Bartels [ID](#)^{63a}, R. Bartoldus [ID](#)¹⁴³,
A.E. Barton [ID](#)⁹¹, P. Bartos [ID](#)^{28a}, A. Basan [ID](#)^{100,af}, M. Baselga [ID](#)⁴⁹, A. Bassalat [ID](#)^{66,b},
M.J. Basso [ID](#)^{156a}, C.R. Basson [ID](#)¹⁰¹, R.L. Bates [ID](#)⁵⁹, S. Batlamous [ID](#)^{35e}, J.R. Batley [ID](#)³²,
B. Batool [ID](#)¹⁴¹, M. Battaglia [ID](#)¹³⁶, D. Battulga [ID](#)¹⁸, M. Bauce [ID](#)^{75a,75b}, M. Bauer [ID](#)³⁶, P. Bauer [ID](#)²⁴,
L.T. Bazzano Hurrell [ID](#)³⁰, J.B. Beacham [ID](#)⁵¹, T. Beau [ID](#)¹²⁷, J.Y. Beaucamp [ID](#)⁹⁰,

P.H. Beauchemin [ID](#)¹⁵⁸, F. Becherer [ID](#)⁵⁴, P. Bechtle [ID](#)²⁴, H.P. Beck [ID](#)^{19,u}, K. Becker [ID](#)¹⁶⁷,
 A.J. Beddall [ID](#)⁸², V.A. Bednyakov [ID](#)³⁸, C.P. Bee [ID](#)¹⁴⁵, L.J. Beemster¹⁵, T.A. Beermann [ID](#)³⁶,
 M. Begalli [ID](#)^{83d}, M. Begel [ID](#)²⁹, A. Behera [ID](#)¹⁴⁵, J.K. Behr [ID](#)⁴⁸, J.F. Beirer [ID](#)⁵⁵, F. Beisiegel [ID](#)²⁴,
 M. Belfkir [ID](#)¹⁵⁹, G. Bella [ID](#)¹⁵¹, L. Bellagamba [ID](#)^{23b}, A. Bellerive [ID](#)³⁴, P. Bellos [ID](#)²⁰,
 K. Beloborodov [ID](#)³⁷, D. Benchekroun [ID](#)^{35a}, F. Bendebba [ID](#)^{35a}, Y. Benhammou [ID](#)¹⁵¹, M. Benoit [ID](#)²⁹,
 J.R. Bensinger [ID](#)²⁶, S. Bentvelsen [ID](#)¹¹⁴, L. Beresford [ID](#)⁴⁸, M. Beretta [ID](#)⁵³,
 E. Bergeas Kuutmann [ID](#)¹⁶¹, N. Berger [ID](#)⁴, B. Bergmann [ID](#)¹³², J. Beringer [ID](#)^{17a}, G. Bernardi [ID](#)⁵,
 C. Bernius [ID](#)¹⁴³, F.U. Bernlochner [ID](#)²⁴, F. Bernon [ID](#)^{36,102}, T. Berry [ID](#)⁹⁵, P. Berta [ID](#)¹³³,
 A. Berthold [ID](#)⁵⁰, I.A. Bertram [ID](#)⁹¹, S. Bethke [ID](#)¹¹⁰, A. Betti [ID](#)^{75a,75b}, A.J. Bevan [ID](#)⁹⁴,
 N.K. Bhalla [ID](#)⁵⁴, M. Bhamjee [ID](#)^{33c}, S. Bhatta [ID](#)¹⁴⁵, D.S. Bhattacharya [ID](#)¹⁶⁶, P. Bhattarai [ID](#)¹⁴³,
 V.S. Bhopatkar [ID](#)¹²¹, R. Bi^{29,az}, R.M. Bianchi [ID](#)¹²⁹, G. Bianco [ID](#)^{23b,23a}, O. Biebel [ID](#)¹⁰⁹,
 R. Bielski [ID](#)¹²³, M. Biglietti [ID](#)^{77a}, M. Bindi [ID](#)⁵⁵, A. Bingul [ID](#)^{21b}, C. Bini [ID](#)^{75a,75b}, A. Biondini [ID](#)⁹²,
 C.J. Birch-sykes [ID](#)¹⁰¹, G.A. Bird [ID](#)^{20,134}, M. Birman [ID](#)¹⁶⁹, M. Biros [ID](#)¹³³, S. Biryukov [ID](#)¹⁴⁶,
 T. Bisanz [ID](#)⁴⁹, E. Bisceglie [ID](#)^{43b,43a}, J.P. Biswal [ID](#)¹³⁴, D. Biswas [ID](#)¹⁴¹, A. Bitadze [ID](#)¹⁰¹,
 K. Bjørke [ID](#)¹²⁵, I. Bloch [ID](#)⁴⁸, C. Blocker [ID](#)²⁶, A. Blue [ID](#)⁵⁹, U. Blumenschein [ID](#)⁹⁴,
 J. Blumenthal [ID](#)¹⁰⁰, G.J. Bobbink [ID](#)¹¹⁴, V.S. Bobrovnikov [ID](#)³⁷, M. Boehler [ID](#)⁵⁴, B. Boehm [ID](#)¹⁶⁶,
 D. Bogavac [ID](#)³⁶, A.G. Bogdanchikov [ID](#)³⁷, C. Bohm [ID](#)^{47a}, V. Boisvert [ID](#)⁹⁵, P. Bokan [ID](#)⁴⁸,
 T. Bold [ID](#)^{86a}, M. Bomben [ID](#)⁵, M. Bona [ID](#)⁹⁴, M. Boonekamp [ID](#)¹³⁵, C.D. Booth [ID](#)⁹⁵,
 A.G. Borbély [ID](#)^{59,at}, I.S. Bordulev [ID](#)³⁷, H.M. Borecka-Bielska [ID](#)¹⁰⁸, G. Borissov [ID](#)⁹¹,
 D. Bortoletto [ID](#)¹²⁶, D. Boscherini [ID](#)^{23b}, M. Bosman [ID](#)¹³, J.D. Bossio Sola [ID](#)³⁶, K. Bouaouda [ID](#)^{35a},
 N. Bouchhar [ID](#)¹⁶³, J. Boudreau [ID](#)¹²⁹, E.V. Bouhova-Thacker [ID](#)⁹¹, D. Boumediene [ID](#)⁴⁰,
 R. Bouquet [ID](#)¹⁶⁵, A. Boveia [ID](#)¹¹⁹, J. Boyd [ID](#)³⁶, D. Boye [ID](#)²⁹, I.R. Boyko [ID](#)³⁸, J. Bracinik [ID](#)²⁰,
 N. Brahimi [ID](#)^{62d}, G. Brandt [ID](#)¹⁷¹, O. Brandt [ID](#)³², F. Braren [ID](#)⁴⁸, B. Brau [ID](#)¹⁰³, J.E. Brau [ID](#)¹²³,
 R. Brenner [ID](#)¹⁶⁹, L. Brenner [ID](#)¹¹⁴, R. Brenner [ID](#)¹⁶¹, S. Bressler [ID](#)¹⁶⁹, D. Britton [ID](#)⁵⁹,
 D. Britzger [ID](#)¹¹⁰, I. Brock [ID](#)²⁴, G. Brooijmans [ID](#)⁴¹, W.K. Brooks [ID](#)^{137f}, E. Brost [ID](#)²⁹,
 L.M. Brown [ID](#)^{165,n}, L.E. Bruce [ID](#)⁶¹, T.L. Bruckler [ID](#)¹²⁶, P.A. Bruckman de Renstrom [ID](#)⁸⁷,
 B. Brüers [ID](#)⁴⁸, A. Bruni [ID](#)^{23b}, G. Bruni [ID](#)^{23b}, M. Bruschi [ID](#)^{23b}, N. Brusino [ID](#)^{75a,75b}, T. Buanes [ID](#)¹⁶,
 Q. Buat [ID](#)¹³⁸, D. Buchin [ID](#)¹¹⁰, A.G. Buckley [ID](#)⁵⁹, O. Bulekov [ID](#)³⁷, B.A. Bullard [ID](#)¹⁴³, S. Burdin [ID](#)⁹²,
 C.D. Burgard [ID](#)⁴⁹, A.M. Burger [ID](#)⁴⁰, B. Burghgrave [ID](#)⁸, O. Burlayenko [ID](#)⁵⁴, J.T.P. Burr [ID](#)³²,
 C.D. Burton [ID](#)¹¹, J.C. Burzynski [ID](#)¹⁴², E.L. Busch [ID](#)⁴¹, V. Büscher [ID](#)¹⁰⁰, P.J. Bussey [ID](#)⁵⁹,
 J.M. Butler [ID](#)²⁵, C.M. Buttar [ID](#)⁵⁹, J.M. Butterworth [ID](#)⁹⁶, W. Buttinger [ID](#)¹³⁴,
 C.J. Buxo Vazquez¹⁰⁷, A.R. Buzykaev [ID](#)³⁷, S. Cabrera Urbán [ID](#)¹⁶³, L. Cadamuro [ID](#)⁶⁶,
 D. Caforio [ID](#)⁵⁸, H. Cai [ID](#)¹²⁹, Y. Cai [ID](#)^{14a,14e}, Y. Cai [ID](#)^{14c}, V.M.M. Cairo [ID](#)³⁶, O. Cakir [ID](#)^{3a},
 N. Calace [ID](#)³⁶, P. Calafiura [ID](#)^{17a}, G. Calderini [ID](#)¹²⁷, P. Calfayan [ID](#)⁶⁸, G. Callea [ID](#)⁵⁹, L.P. Caloba [ID](#)^{83b},
 D. Calvet [ID](#)⁴⁰, S. Calvet [ID](#)⁴⁰, T.P. Calvet [ID](#)¹⁰², M. Calvetti [ID](#)^{74a,74b}, R. Camacho Toro [ID](#)¹²⁷,
 S. Camarda [ID](#)³⁶, D. Camarero Munoz [ID](#)²⁶, P. Camarri [ID](#)^{76a,76b}, M.T. Camerlingo [ID](#)^{72a,72b},
 D. Cameron [ID](#)^{36,h}, C. Camincher [ID](#)¹⁶⁵, M. Campanelli [ID](#)⁹⁶, A. Camplani [ID](#)⁴², V. Canale [ID](#)^{72a,72b},
 A. Canesse [ID](#)¹⁰⁴, J. Cantero [ID](#)¹⁶³, Y. Cao [ID](#)¹⁶², F. Capocasa [ID](#)²⁶, M. Capua [ID](#)^{43b,43a},
 A. Carbone [ID](#)^{71a,71b}, R. Cardarelli [ID](#)^{76a}, J.C.J. Cardenas [ID](#)⁸, F. Cardillo [ID](#)¹⁶³, G. Carducci [ID](#)^{43b,43a},
 T. Carli [ID](#)³⁶, G. Carlino [ID](#)^{72a}, J.I. Carlotto [ID](#)¹³, B.T. Carlson [ID](#)^{129,x}, E.M. Carlson [ID](#)^{165,156a},
 L. Carminati [ID](#)^{71a,71b}, A. Carnelli [ID](#)¹³⁵, M. Carnesale [ID](#)^{75a,75b}, S. Caron [ID](#)¹¹³, E. Carquin [ID](#)^{137f},
 S. Carrá [ID](#)^{71a,71b}, G. Carratta [ID](#)^{23b,23a}, F. Carrio Argos [ID](#)^{33g}, J.W.S. Carter [ID](#)¹⁵⁵, T.M. Carter [ID](#)⁵²,
 M.P. Casado [ID](#)^{13,k}, M. Caspar [ID](#)⁴⁸, F.L. Castillo [ID](#)⁴, L. Castillo Garcia [ID](#)¹³,

V. Castillo Gimenez [ID](#)¹⁶³, N.F. Castro [ID](#)^{130a,130e}, A. Catinaccio [ID](#)³⁶, J.R. Catmore [ID](#)¹²⁵,
V. Cavaliere [ID](#)²⁹, N. Cavalli [ID](#)^{23b,23a}, V. Cavasinni [ID](#)^{74a,74b}, Y.C. Cekmecelioglu [ID](#)⁴⁸, E. Celebi [ID](#)^{21a},
F. Celli [ID](#)¹²⁶, M.S. Centonze [ID](#)^{70a,70b}, V. Cepaitis [ID](#)⁵⁶, K. Cerny [ID](#)¹²², A.S. Cerqueira [ID](#)^{83a},
A. Cerri [ID](#)¹⁴⁶, L. Cerrito [ID](#)^{76a,76b}, F. Cerutti [ID](#)^{17a}, B. Cervato [ID](#)¹⁴¹, A. Cervelli [ID](#)^{23b},
G. Cesarini [ID](#)⁵³, S.A. Cetin [ID](#)⁸², Z. Chadi [ID](#)^{35a}, D. Chakraborty [ID](#)¹¹⁵, J. Chan [ID](#)¹⁷⁰,
W.Y. Chan [ID](#)¹⁵³, J.D. Chapman [ID](#)³², E. Chapon [ID](#)¹³⁵, B. Chargeishvili [ID](#)^{149b}, D.G. Charlton [ID](#)²⁰,
T.P. Charman [ID](#)⁹⁴, M. Chatterjee [ID](#)¹⁹, C. Chauhan [ID](#)¹³³, S. Chekanov [ID](#)⁶, S.V. Chekulaev [ID](#)^{156a},
G.A. Chelkov [ID](#)^{38,a}, A. Chen [ID](#)¹⁰⁶, B. Chen [ID](#)¹⁵¹, B. Chen [ID](#)¹⁶⁵, H. Chen [ID](#)^{14c}, H. Chen [ID](#)²⁹,
J. Chen [ID](#)^{62c}, J. Chen [ID](#)¹⁴², M. Chen [ID](#)¹²⁶, S. Chen [ID](#)¹⁵³, S.J. Chen [ID](#)^{14c}, X. Chen [ID](#)^{62c,135},
X. Chen [ID](#)^{14b,av}, Y. Chen [ID](#)^{62a}, C.L. Cheng [ID](#)¹⁷⁰, H.C. Cheng [ID](#)^{64a}, S. Cheong [ID](#)¹⁴³,
A. Cheplakov [ID](#)³⁸, E. Cheremushkina [ID](#)⁴⁸, E. Cherepanova [ID](#)¹¹⁴, R. Cherkaoui El Moursli [ID](#)^{35e},
E. Cheu [ID](#)⁷, K. Cheung [ID](#)⁶⁵, L. Chevalier [ID](#)¹³⁵, V. Chiarella [ID](#)⁵³, G. Chiarelli [ID](#)^{74a}, N. Chiedde [ID](#)¹⁰²,
G. Chiodini [ID](#)^{70a}, A.S. Chisholm [ID](#)²⁰, A. Chitan [ID](#)^{27b}, M. Chitishvili [ID](#)¹⁶³, M.V. Chizhov [ID](#)³⁸,
K. Choi [ID](#)¹¹, A.R. Chomont [ID](#)^{75a,75b}, Y. Chou [ID](#)¹⁰³, E.Y.S. Chow [ID](#)¹¹³, T. Chowdhury [ID](#)^{33g},
K.L. Chu [ID](#)¹⁶⁹, M.C. Chu [ID](#)^{64a}, X. Chu [ID](#)^{14a,14e}, J. Chudoba [ID](#)¹³¹, J.J. Chwastowski [ID](#)⁸⁷,
D. Cieri [ID](#)¹¹⁰, K.M. Ciesla [ID](#)^{86a}, V. Cindro [ID](#)⁹³, A. Ciocio [ID](#)^{17a}, F. Ciotto [ID](#)^{72a,72b},
Z.H. Citron [ID](#)^{169,o}, M. Citterio [ID](#)^{71a}, D.A. Ciubotaru [ID](#)^{27b}, B.M. Ciungu [ID](#)¹⁵⁵, A. Clark [ID](#)⁵⁶,
P.J. Clark [ID](#)⁵², C. Clarry [ID](#)¹⁵⁵, J.M. Clavijo Columbie [ID](#)⁴⁸, S.E. Clawson [ID](#)⁴⁸, C. Clement [ID](#)^{47a,47b},
J. Clercx [ID](#)⁴⁸, L. Clissa [ID](#)^{23b,23a}, Y. Coadou [ID](#)¹⁰², M. Cobal [ID](#)^{69a,69c}, A. Coccaro [ID](#)^{57b},
R.F. Coelho Barrue [ID](#)^{130a}, R. Coelho Lopes De Sa [ID](#)¹⁰³, S. Coelli [ID](#)^{71a}, H. Cohen [ID](#)¹⁵¹,
A.E.C. Coimbra [ID](#)^{71a,71b}, B. Cole [ID](#)⁴¹, J. Collot [ID](#)⁶⁰, P. Conde Muiño [ID](#)^{130a,130g}, M.P. Connell [ID](#)^{33c},
S.H. Connell [ID](#)^{33c}, I.A. Connelly [ID](#)⁵⁹, E.I. Conroy [ID](#)¹²⁶, F. Conventi [ID](#)^{72a,ax}, H.G. Cooke [ID](#)²⁰,
A.M. Cooper-Sarkar [ID](#)¹²⁶, A. Cordeiro Oudot Choi [ID](#)¹²⁷, L.D. Corpe [ID](#)⁴⁰, M. Corradi [ID](#)^{75a,75b},
F. Corriveau [ID](#)^{104,ai}, A. Cortes-Gonzalez [ID](#)¹⁸, M.J. Costa [ID](#)¹⁶³, F. Costanza [ID](#)⁴, D. Costanzo [ID](#)¹³⁹,
B.M. Cote [ID](#)¹¹⁹, G. Cowan [ID](#)⁹⁵, K. Cranmer [ID](#)¹⁷⁰, D. Cremonini [ID](#)^{23b,23a}, S. Crépé-Renaudin [ID](#)⁶⁰,
F. Crescioli [ID](#)¹²⁷, M. Cristinziani [ID](#)¹⁴¹, M. Cristoforetti [ID](#)^{78a,78b}, V. Croft [ID](#)¹¹⁴, J.E. Crosby [ID](#)¹²¹,
G. Crosetti [ID](#)^{43b,43a}, A. Cueto [ID](#)⁹⁹, T. Cuhadar Donszelmann [ID](#)¹⁶⁰, H. Cui [ID](#)^{14a,14e}, Z. Cui [ID](#)⁷,
W.R. Cunningham [ID](#)⁵⁹, F. Curcio [ID](#)^{43b,43a}, P. Czodrowski [ID](#)³⁶, M.M. Czurylo [ID](#)^{63b},
M.J. Da Cunha Sargedas De Sousa [ID](#)^{57b,57a}, J.V. Da Fonseca Pinto [ID](#)^{83b}, C. Da Via [ID](#)¹⁰¹,
W. Dabrowski [ID](#)^{86a}, T. Dado [ID](#)⁴⁹, S. Dahbi [ID](#)^{33g}, T. Dai [ID](#)¹⁰⁶, D. Dal Santo [ID](#)¹⁹,
C. Dallapiccola [ID](#)¹⁰³, M. Dam [ID](#)⁴², G. D’amen [ID](#)²⁹, V. D’Amico [ID](#)¹⁰⁹, J. Damp [ID](#)¹⁰⁰,
J.R. Dandoy [ID](#)¹²⁸, M.F. Daneri [ID](#)³⁰, M. Danninger [ID](#)¹⁴², V. Dao [ID](#)³⁶, G. Darbo [ID](#)^{57b},
S. Darmora [ID](#)⁶, S.J. Das [ID](#)^{29,az}, S. D’Auria [ID](#)^{71a,71b}, C. David [ID](#)^{156b}, T. Davidek [ID](#)¹³³,
B. Davis-Purcell [ID](#)³⁴, I. Dawson [ID](#)⁹⁴, H.A. Day-hall [ID](#)¹³², K. De [ID](#)⁸, R. De Asmundis [ID](#)^{72a},
N. De Biase [ID](#)⁴⁸, S. De Castro [ID](#)^{23b,23a}, N. De Groot [ID](#)¹¹³, P. de Jong [ID](#)¹¹⁴, H. De la Torre [ID](#)¹¹⁵,
A. De Maria [ID](#)^{14c}, A. De Salvo [ID](#)^{75a}, U. De Sanctis [ID](#)^{76a,76b}, A. De Santo [ID](#)¹⁴⁶,
J.B. De Vivie De Regie [ID](#)⁶⁰, D.V. Dedovich [ID](#)³⁸, J. Degens [ID](#)¹¹⁴, A.M. Deiana [ID](#)⁴⁴,
F. Del Corso [ID](#)^{23b,23a}, J. Del Peso [ID](#)⁹⁹, F. Del Rio [ID](#)^{63a}, F. Deliot [ID](#)¹³⁵, C.M. Delitzsch [ID](#)⁴⁹,
M. Della Pietra [ID](#)^{72a,72b}, D. Della Volpe [ID](#)⁵⁶, A. Dell’Acqua [ID](#)³⁶, L. Dell’Asta [ID](#)^{71a,71b},
M. Delmastro [ID](#)⁴, P.A. Delsart [ID](#)⁶⁰, S. Demers [ID](#)¹⁷², M. Demichev [ID](#)³⁸, S.P. Denisov [ID](#)³⁷,
L. D’Eramo [ID](#)⁴⁰, D. Derendarz [ID](#)⁸⁷, F. Derue [ID](#)¹²⁷, P. Dervan [ID](#)⁹², K. Desch [ID](#)²⁴, C. Deutsch [ID](#)²⁴,
F.A. Di Bello [ID](#)^{57b,57a}, A. Di Ciaccio [ID](#)^{76a,76b}, L. Di Ciaccio [ID](#)⁴, A. Di Domenico [ID](#)^{75a,75b},
C. Di Donato [ID](#)^{72a,72b}, A. Di Girolamo [ID](#)³⁶, G. Di Gregorio [ID](#)³⁶, A. Di Luca [ID](#)^{78a,78b},

B. Di Micco [ID](#)^{77a,77b}, R. Di Nardo [ID](#)^{77a,77b}, C. Diaconu [ID](#)¹⁰², M. Diamantopoulou [ID](#)³⁴,
 F.A. Dias [ID](#)¹¹⁴, T. Dias Do Vale [ID](#)¹⁴², M.A. Diaz [ID](#)^{137a,137b}, F.G. Diaz Capriles [ID](#)²⁴,
 M. Didenko [ID](#)¹⁶³, E.B. Diehl [ID](#)¹⁰⁶, L. Diehl [ID](#)⁵⁴, S. Díez Cornell [ID](#)⁴⁸, C. Díez Pardos [ID](#)¹⁴¹,
 C. Dimitriadi [ID](#)^{161,24,161}, A. Dimitrievska [ID](#)^{17a}, J. Dingfelder [ID](#)²⁴, I-M. Dinu [ID](#)^{27b},
 S.J. Dittmeier [ID](#)^{63b}, F. Dittus [ID](#)³⁶, F. Djama [ID](#)¹⁰², T. Djobava [ID](#)^{149b}, J.I. Djuvsland [ID](#)¹⁶,
 C. Doglioni [ID](#)^{101,98}, A. Dohnalova [ID](#)^{28a}, J. Dolejsi [ID](#)¹³³, Z. Dolezal [ID](#)¹³³, K.M. Dona [ID](#)³⁹,
 M. Donadelli [ID](#)^{83c}, B. Dong [ID](#)¹⁰⁷, J. Donini [ID](#)⁴⁰, A. D’Onofrio [ID](#)^{77a,77b}, M. D’Onofrio [ID](#)⁹²,
 J. Dopke [ID](#)¹³⁴, A. Doria [ID](#)^{72a}, N. Dos Santos Fernandes [ID](#)^{130a}, P. Dougan [ID](#)¹⁰¹, M.T. Dova [ID](#)⁹⁰,
 A.T. Doyle [ID](#)⁵⁹, M.A. Draguet [ID](#)¹²⁶, E. Dreyer [ID](#)¹⁶⁹, I. Drivas-koulouris [ID](#)¹⁰, M. Drnević [ID](#)¹¹⁷,
 A.S. Drobac [ID](#)¹⁵⁸, M. Drozdova [ID](#)⁵⁶, D. Du [ID](#)^{62a}, T.A. du Pree [ID](#)¹¹⁴, F. Dubinin [ID](#)³⁷,
 M. Dubovsky [ID](#)^{28a}, E. Duchovni [ID](#)¹⁶⁹, G. Duckeck [ID](#)¹⁰⁹, O.A. Ducu [ID](#)^{27b}, D. Duda [ID](#)⁵²,
 A. Dudarev [ID](#)³⁶, E.R. Duden [ID](#)²⁶, M. D’uffizi [ID](#)¹⁰¹, L. Duflot [ID](#)⁶⁶, M. Dührssen [ID](#)³⁶, C. Dülsen [ID](#)¹⁷¹,
 A.E. Dumitriu [ID](#)^{27b}, M. Dunford [ID](#)^{63a}, S. Dungs [ID](#)⁴⁹, K. Dunne [ID](#)^{47a,47b}, A. Duperrin [ID](#)¹⁰²,
 H. Duran Yildiz [ID](#)^{3a}, M. Düren [ID](#)⁵⁸, A. Durglishvili [ID](#)^{149b}, B.L. Dwyer [ID](#)¹¹⁵, G.I. Dyckes [ID](#)^{17a},
 M. Dyndal [ID](#)^{86a}, B.S. Dziedzic [ID](#)⁸⁷, Z.O. Earnshaw [ID](#)¹⁴⁶, G.H. Eberwein [ID](#)¹²⁶, B. Eckerova [ID](#)^{28a},
 S. Eggebrecht [ID](#)⁵⁵, E. Egidio Purcino De Souza [ID](#)¹²⁷, L.F. Ehrke [ID](#)⁵⁶, G. Eigen [ID](#)¹⁶,
 K. Einsweiler [ID](#)^{17a}, T. Ekelof [ID](#)¹⁶¹, P.A. Ekman [ID](#)⁹⁸, S. El Farkh [ID](#)^{35b}, Y. El Ghazali [ID](#)^{35b},
 H. El Jarrari [ID](#)^{35e,148}, A. El Moussaouy [ID](#)^{108,ab}, V. Ellajosyula [ID](#)¹⁶¹, M. Ellert [ID](#)¹⁶¹,
 F. Ellinghaus [ID](#)¹⁷¹, N. Ellis [ID](#)³⁶, J. Elmsheuser [ID](#)²⁹, M. Elsing [ID](#)³⁶, D. Emelianov [ID](#)¹³⁴,
 Y. Enari [ID](#)¹⁵³, I. Ene [ID](#)^{17a}, S. Epari [ID](#)¹³, J. Erdmann [ID](#)⁴⁹, P.A. Erland [ID](#)⁸⁷, M. Errenst [ID](#)¹⁷¹,
 M. Escalier [ID](#)⁶⁶, C. Escobar [ID](#)¹⁶³, E. Etzion [ID](#)¹⁵¹, G. Evans [ID](#)^{130a}, H. Evans [ID](#)⁶⁸, L.S. Evans [ID](#)⁹⁵,
 M.O. Evans [ID](#)¹⁴⁶, A. Ezhilov [ID](#)³⁷, S. Ezzarqtouni [ID](#)^{35a}, F. Fabbri [ID](#)⁵⁹, L. Fabbri [ID](#)^{23b,23a},
 G. Facini [ID](#)⁹⁶, V. Fadeyev [ID](#)¹³⁶, R.M. Fakhрутdinov [ID](#)³⁷, S. Falciano [ID](#)^{75a},
 L.F. Falda Ulhoa Coelho [ID](#)³⁶, P.J. Falke [ID](#)²⁴, J. Faltova [ID](#)¹³³, C. Fan [ID](#)¹⁶², Y. Fan [ID](#)^{14a},
 Y. Fang [ID](#)^{14a,14e}, M. Fanti [ID](#)^{71a,71b}, M. Faraj [ID](#)^{69a,69b}, Z. Farazpay [ID](#)⁹⁷, A. Farbin [ID](#)⁸,
 A. Farilla [ID](#)^{77a}, T. Faroouque [ID](#)¹⁰⁷, S.M. Farrington [ID](#)⁵², F. Fassi [ID](#)^{35e}, D. Fassouliotis [ID](#)⁹,
 M. Fauci Giannelli [ID](#)^{76a,76b}, W.J. Fawcett [ID](#)³², L. Fayard [ID](#)⁶⁶, P. Federic [ID](#)¹³³, P. Federicova [ID](#)¹³¹,
 O.L. Fedin [ID](#)^{37,a}, G. Fedotov [ID](#)³⁷, M. Feickert [ID](#)¹⁷⁰, L. Feligioni [ID](#)¹⁰², D.E. Fellers [ID](#)¹²³,
 C. Feng [ID](#)^{62b}, M. Feng [ID](#)^{14b}, Z. Feng [ID](#)¹¹⁴, M.J. Fenton [ID](#)¹⁶⁰, A.B. Fenyuk [ID](#)³⁷, L. Ferencz [ID](#)⁴⁸,
 R.A.M. Ferguson [ID](#)⁹¹, S.I. Fernandez Luengo [ID](#)^{137f}, P. Fernandez Martinez [ID](#)¹³,
 M.J.V. Fernoux [ID](#)¹⁰², J. Ferrando [ID](#)⁴⁸, A. Ferrari [ID](#)¹⁶¹, P. Ferrari [ID](#)^{114,113}, R. Ferrari [ID](#)^{73a},
 D. Ferrere [ID](#)⁵⁶, C. Ferretti [ID](#)¹⁰⁶, F. Fiedler [ID](#)¹⁰⁰, P. Fiedler [ID](#)¹³², A. Filipčić [ID](#)⁹³, E.K. Filmer [ID](#)¹,
 F. Filthaut [ID](#)¹¹³, M.C.N. Fiolhais [ID](#)^{130a,130c,d}, L. Fiorini [ID](#)¹⁶³, W.C. Fisher [ID](#)¹⁰⁷, T. Fitschen [ID](#)¹⁰¹,
 P.M. Fitzhugh [ID](#)¹³⁵, I. Fleck [ID](#)¹⁴¹, P. Fleischmann [ID](#)¹⁰⁶, T. Flick [ID](#)¹⁷¹, M. Flores [ID](#)^{33d,ap},
 L.R. Flores Castillo [ID](#)^{64a}, L. Flores Sanz De Acedo [ID](#)³⁶, F.M. Follega [ID](#)^{78a,78b}, N. Fomin [ID](#)¹⁶,
 J.H. Foo [ID](#)¹⁵⁵, B.C. Forland [ID](#)⁶⁸, A. Formica [ID](#)¹³⁵, A.C. Forti [ID](#)¹⁰¹, E. Fortin [ID](#)³⁶, A.W. Fortman [ID](#)⁶¹,
 M.G. Foti [ID](#)^{17a}, L. Fountas [ID](#)^{9,l}, D. Fournier [ID](#)⁶⁶, H. Fox [ID](#)⁹¹, P. Francavilla [ID](#)^{74a,74b},
 S. Francescato [ID](#)⁶¹, S. Franchellucci [ID](#)⁵⁶, M. Franchini [ID](#)^{23b,23a}, S. Franchino [ID](#)^{63a}, D. Francis [ID](#)³⁶,
 L. Franco [ID](#)¹¹³, V. Franco Lima [ID](#)³⁶, L. Franconi [ID](#)⁴⁸, M. Franklin [ID](#)⁶¹, G. Frattari [ID](#)²⁶,
 A.C. Freegard [ID](#)⁹⁴, W.S. Freund [ID](#)^{83b}, Y.Y. Frid [ID](#)¹⁵¹, J. Friend [ID](#)⁵⁹, N. Fritzsche [ID](#)⁵⁰, A. Froch [ID](#)⁵⁴,
 D. Froidevaux [ID](#)³⁶, J.A. Frost [ID](#)¹²⁶, Y. Fu [ID](#)^{62a}, M. Fujimoto [ID](#)^{118,aq}, E. Fullana Torregrosa [ID](#)^{163,*},
 K.Y. Fung [ID](#)^{64a}, E. Furtado De Simas Filho [ID](#)^{83b}, M. Furukawa [ID](#)¹⁵³, J. Fuster [ID](#)¹⁶³,
 A. Gabrielli [ID](#)^{23b,23a}, A. Gabrielli [ID](#)¹⁵⁵, P. Gadow [ID](#)³⁶, G. Gagliardi [ID](#)^{57b,57a}, L.G. Gagnon [ID](#)^{17a},

E.J. Gallas [ID](#)¹²⁶, B.J. Gallop [ID](#)¹³⁴, K.K. Gan [ID](#)¹¹⁹, S. Ganguly [ID](#)¹⁵³, Y. Gao [ID](#)⁵²,
 F.M. Garay Walls [ID](#)^{137a,137b}, B. Garcia^{29,az}, C. García [ID](#)¹⁶³, A. Garcia Alonso [ID](#)¹¹⁴,
 A.G. Garcia Caffaro [ID](#)¹⁷², J.E. García Navarro [ID](#)¹⁶³, M. Garcia-Sciveres [ID](#)^{17a}, G.L. Gardner [ID](#)¹²⁸,
 R.W. Gardner [ID](#)³⁹, N. Garelli [ID](#)¹⁵⁸, D. Garg [ID](#)⁸⁰, R.B. Garg [ID](#)^{143,t}, J.M. Gargan⁵², C.A. Garner¹⁵⁵,
 C.M. Garvey [ID](#)^{33a}, P. Gaspar [ID](#)^{83b}, V.K. Gassmann¹⁵⁸, G. Gaudio [ID](#)^{73a}, V. Gautam¹³,
 P. Gauzzi [ID](#)^{75a,75b}, I.L. Gavrilenko [ID](#)³⁷, A. Gavriluk [ID](#)³⁷, C. Gay [ID](#)¹⁶⁴, G. Gaycken [ID](#)⁴⁸,
 E.N. Gazis [ID](#)¹⁰, A.A. Geanta [ID](#)^{27b}, C.M. Gee [ID](#)¹³⁶, C. Gemme [ID](#)^{57b}, M.H. Genest [ID](#)⁶⁰,
 S. Gentile [ID](#)^{75a,75b}, A.D. Gentry [ID](#)¹¹², S. George [ID](#)⁹⁵, W.F. George [ID](#)²⁰, T. Gerialis [ID](#)⁴⁶,
 P. Gessinger-Befurt [ID](#)³⁶, M.E. Geyik [ID](#)¹⁷¹, M. Ghani [ID](#)¹⁶⁷, M. Ghneimat [ID](#)¹⁴¹, K. Ghorbanian [ID](#)⁹⁴,
 A. Ghosal [ID](#)¹⁴¹, A. Ghosh [ID](#)¹⁶⁰, A. Ghosh [ID](#)⁷, B. Giacobbe [ID](#)^{23b}, S. Giagu [ID](#)^{75a,75b}, T. Giani¹¹⁴,
 P. Giannetti [ID](#)^{74a}, A. Giannini [ID](#)^{62a}, S.M. Gibson [ID](#)⁹⁵, M. Gignac [ID](#)¹³⁶, D.T. Gil [ID](#)^{86b},
 A.K. Gilbert [ID](#)^{86a}, B.J. Gilbert [ID](#)⁴¹, D. Gillberg [ID](#)³⁴, G. Gilles [ID](#)¹¹⁴, N.E.K. Gillwald [ID](#)⁴⁸,
 L. Ginabat [ID](#)¹²⁷, D.M. Gingrich [ID](#)^{2,aw}, M.P. Giordani [ID](#)^{69a,69c}, P.F. Giraud [ID](#)¹³⁵,
 G. Giugliarelli [ID](#)^{69a,69c}, D. Giugni [ID](#)^{71a}, F. Giuli [ID](#)³⁶, I. Gkialas [ID](#)^{9,l}, L.K. Gladilin [ID](#)³⁷,
 C. Glasman [ID](#)⁹⁹, G.R. Gledhill [ID](#)¹²³, G. Glemža [ID](#)⁴⁸, M. Glisic¹²³, I. Gnesi [ID](#)^{43b,g}, Y. Go [ID](#)^{29,az},
 M. Goblirsch-Kolb [ID](#)³⁶, B. Gocke [ID](#)⁴⁹, D. Godin¹⁰⁸, B. Gokturk [ID](#)^{21a}, S. Goldfarb [ID](#)¹⁰⁵,
 T. Golling [ID](#)⁵⁶, M.G.D. Gololo^{33g}, D. Golubkov [ID](#)³⁷, J.P. Gombas [ID](#)¹⁰⁷, A. Gomes [ID](#)^{130a,130b},
 G. Gomes Da Silva [ID](#)¹⁴¹, A.J. Gomez Delegido [ID](#)¹⁶³, R. Gonçalo [ID](#)^{130a,130c}, G. Gonella [ID](#)¹²³,
 L. Gonella [ID](#)²⁰, A. Gongadze [ID](#)^{149c}, F. Gonnella [ID](#)²⁰, J.L. Gonski [ID](#)⁴¹, R.Y. González Andana [ID](#)⁵²,
 S. González de la Hoz [ID](#)¹⁶³, S. Gonzalez Fernandez [ID](#)¹³, R. Gonzalez Lopez [ID](#)⁹²,
 C. Gonzalez Renteria [ID](#)^{17a}, M.V. Gonzalez Rodrigues [ID](#)⁴⁸, R. Gonzalez Suarez [ID](#)¹⁶¹,
 S. Gonzalez-Sevilla [ID](#)⁵⁶, G.R. Gonzalvo Rodriguez [ID](#)¹⁶³, L. Goossens [ID](#)³⁶, B. Gorini [ID](#)³⁶,
 E. Gorini [ID](#)^{70a,70b}, A. Gorišek [ID](#)⁹³, T.C. Gosart [ID](#)¹²⁸, A.T. Goshaw [ID](#)⁵¹, M.I. Gostkin [ID](#)³⁸,
 S. Goswami [ID](#)¹²¹, C.A. Gottardo [ID](#)³⁶, S.A. Gotz [ID](#)¹⁰⁹, M. Goughri [ID](#)^{35b}, V. Goumarre [ID](#)⁴⁸,
 A.G. Goussiou [ID](#)¹³⁸, N. Govender [ID](#)^{33c}, I. Grabowska-Bold [ID](#)^{86a}, K. Graham [ID](#)³⁴,
 E. Gramstad [ID](#)¹²⁵, S. Grancagnolo [ID](#)^{70a,70b}, M. Grandi [ID](#)¹⁴⁶, C.M. Grant^{1,135}, P.M. Gravila [ID](#)^{27f},
 F.G. Gravili [ID](#)^{70a,70b}, H.M. Gray [ID](#)^{17a}, M. Greco [ID](#)^{70a,70b}, C. Grefe [ID](#)²⁴, I.M. Gregor [ID](#)⁴⁸,
 P. Grenier [ID](#)¹⁴³, S.G. Grewe¹¹⁰, C. Grieco [ID](#)¹³, A.A. Grillo [ID](#)¹³⁶, K. Grimm [ID](#)³¹, S. Grinstein [ID](#)^{13,ad},
 J.-F. Grivaz [ID](#)⁶⁶, E. Gross [ID](#)¹⁶⁹, J. Grosse-Knetter [ID](#)⁵⁵, C. Grud¹⁰⁶, J.C. Grundy [ID](#)¹²⁶,
 L. Guan [ID](#)¹⁰⁶, W. Guan [ID](#)²⁹, C. Gubbels [ID](#)¹⁶⁴, J.G.R. Guerrero Rojas [ID](#)¹⁶³, G. Guerrieri [ID](#)^{69a,69c},
 F. Guescini [ID](#)¹¹⁰, R. Gugel [ID](#)¹⁰⁰, J.A.M. Guhit [ID](#)¹⁰⁶, A. Guida [ID](#)¹⁸, T. Guillemin [ID](#)⁴,
 E. Guilloton [ID](#)^{167,134}, S. Guindon [ID](#)³⁶, F. Guo [ID](#)^{14a,14e}, J. Guo [ID](#)^{62c}, L. Guo [ID](#)⁴⁸, Y. Guo [ID](#)¹⁰⁶,
 R. Gupta [ID](#)⁴⁸, S. Gurbuz [ID](#)²⁴, S.S. Gurdasani [ID](#)⁵⁴, G. Gustavino [ID](#)³⁶, M. Guth [ID](#)⁵⁶,
 P. Gutierrez [ID](#)¹²⁰, L.F. Gutierrez Zagazeta [ID](#)¹²⁸, M. Gutsche [ID](#)⁵⁰, C. Gutschow [ID](#)⁹⁶,
 C. Gwenlan [ID](#)¹²⁶, C.B. Gwilliam [ID](#)⁹², E.S. Haaland [ID](#)¹²⁵, A. Haas [ID](#)¹¹⁷, M. Habedank [ID](#)⁴⁸,
 C. Haber [ID](#)^{17a}, H.K. Hadavand [ID](#)⁸, A. Hadeef [ID](#)¹⁰⁰, S. Hadzic [ID](#)¹¹⁰, A.I. Hagan⁹¹, J.J. Hahn [ID](#)¹⁴¹,
 E.H. Haines [ID](#)⁹⁶, M. Haleem [ID](#)¹⁶⁶, J. Haley [ID](#)¹²¹, J.J. Hall [ID](#)¹³⁹, G.D. Hallewell [ID](#)¹⁰², L. Halser [ID](#)¹⁹,
 K. Hamano [ID](#)¹⁶⁵, M. Hamer [ID](#)²⁴, G.N. Hamity [ID](#)⁵², E.J. Hampshire [ID](#)⁹⁵, J. Han [ID](#)^{62b}, K. Han [ID](#)^{62a},
 L. Han [ID](#)^{14c}, L. Han [ID](#)^{62a}, S. Han [ID](#)^{17a}, Y.F. Han [ID](#)¹⁵⁵, K. Hanagaki [ID](#)⁸⁴, M. Hance [ID](#)¹³⁶,
 D.A. Hangal [ID](#)^{41,ao}, H. Hanif [ID](#)¹⁴², M.D. Hank [ID](#)¹²⁸, R. Hankache [ID](#)¹⁰¹, J.B. Hansen [ID](#)⁴²,
 J.D. Hansen [ID](#)⁴², P.H. Hansen [ID](#)⁴², K. Hara [ID](#)¹⁵⁷, D. Harada [ID](#)⁵⁶, T. Harenberg [ID](#)¹⁷¹,
 S. Harkusha [ID](#)³⁷, M.L. Harris [ID](#)¹⁰³, Y.T. Harris [ID](#)¹²⁶, J. Harrison [ID](#)¹³, N.M. Harrison [ID](#)¹¹⁹,
 P.F. Harrison¹⁶⁷, N.M. Hartman [ID](#)¹¹⁰, N.M. Hartmann [ID](#)¹⁰⁹, Y. Hasegawa [ID](#)¹⁴⁰, R. Hauser [ID](#)¹⁰⁷,

C.M. Hawkes [ID](#)²⁰, R.J. Hawkins [ID](#)³⁶, Y. Hayashi [ID](#)¹⁵³, S. Hayashida [ID](#)¹¹¹, D. Hayden [ID](#)¹⁰⁷, C. Hayes [ID](#)¹⁰⁶, R.L. Hayes [ID](#)¹¹⁴, C.P. Hays [ID](#)¹²⁶, J.M. Hays [ID](#)⁹⁴, H.S. Hayward [ID](#)⁹², F. He [ID](#)^{62a}, M. He [ID](#)^{14a,14e}, Y. He [ID](#)¹⁵⁴, Y. He [ID](#)⁴⁸, N.B. Heatley [ID](#)⁹⁴, V. Hedberg [ID](#)⁹⁸, A.L. Heggelund [ID](#)¹²⁵, N.D. Hehir [ID](#)⁹⁴, C. Heidegger [ID](#)⁵⁴, K.K. Heidegger [ID](#)⁵⁴, W.D. Heidorn [ID](#)⁸¹, J. Heilman [ID](#)³⁴, S. Heim [ID](#)⁴⁸, T. Heim [ID](#)^{17a}, J.G. Heinlein [ID](#)¹²⁸, J.J. Heinrich [ID](#)¹²³, L. Heinrich [ID](#)^{110,au}, J. Hejbal [ID](#)¹³¹, L. Helary [ID](#)⁴⁸, A. Held [ID](#)¹⁷⁰, S. Hellesund [ID](#)¹⁶, C.M. Helling [ID](#)¹⁶⁴, S. Hellman [ID](#)^{47a,47b}, R.C.W. Henderson [ID](#)⁹¹, L. Henkelmann [ID](#)³², A.M. Henriques Correia [ID](#)³⁶, H. Herde [ID](#)⁹⁸, Y. Hernández Jiménez [ID](#)¹⁴⁵, L.M. Herrmann [ID](#)²⁴, T. Herrmann [ID](#)⁵⁰, G. Herten [ID](#)⁵⁴, R. Hertenberger [ID](#)¹⁰⁹, L. Hervas [ID](#)³⁶, M.E. Hespington [ID](#)¹⁰⁰, N.P. Hessey [ID](#)^{156a}, H. Hibi [ID](#)⁸⁵, E. Hill [ID](#)¹⁵⁵, S.J. Hillier [ID](#)²⁰, J.R. Hinds [ID](#)¹⁰⁷, F. Hinterkeuser [ID](#)²⁴, M. Hirose [ID](#)¹²⁴, S. Hirose [ID](#)¹⁵⁷, D. Hirschbuehl [ID](#)¹⁷¹, T.G. Hitchings [ID](#)¹⁰¹, B. Hiti [ID](#)⁹³, J. Hobbs [ID](#)¹⁴⁵, R. Hobincu [ID](#)^{27e}, N. Hod [ID](#)¹⁶⁹, M.C. Hodgkinson [ID](#)¹³⁹, B.H. Hodgkinson [ID](#)³², A. Hoecker [ID](#)³⁶, J. Hofer [ID](#)⁴⁸, T. Holm [ID](#)²⁴, M. Holzbock [ID](#)¹¹⁰, L.B.A.H. Hommels [ID](#)³², B.P. Honan [ID](#)¹⁰¹, J. Hong [ID](#)^{62c}, T.M. Hong [ID](#)¹²⁹, B.H. Hooberman [ID](#)¹⁶², W.H. Hopkins [ID](#)⁶, Y. Horii [ID](#)¹¹¹, S. Hou [ID](#)¹⁴⁸, A.S. Howard [ID](#)⁹³, J. Howarth [ID](#)⁵⁹, J. Hoya [ID](#)⁶, M. Hrabovsky [ID](#)¹²², A. Hrynevich [ID](#)⁴⁸, T. Hryn'ova [ID](#)⁴, P.J. Hsu [ID](#)⁶⁵, S.-C. Hsu [ID](#)¹³⁸, Q. Hu [ID](#)^{62a}, Y.F. Hu [ID](#)^{14a,14e}, S. Huang [ID](#)^{64b}, X. Huang [ID](#)^{14c}, X. Huang [ID](#)^{14a,14e}, Y. Huang [ID](#)^{139,m}, Y. Huang [ID](#)^{14a}, Z. Huang [ID](#)¹⁰¹, Z. Hubacek [ID](#)¹³², M. Huebner [ID](#)²⁴, F. Huegging [ID](#)²⁴, T.B. Huffman [ID](#)¹²⁶, C.A. Hugli [ID](#)⁴⁸, M. Huhtinen [ID](#)³⁶, S.K. Huiberts [ID](#)¹⁶, R. Hulsken [ID](#)¹⁰⁴, N. Huseynov [ID](#)¹², J. Huston [ID](#)¹⁰⁷, J. Huth [ID](#)⁶¹, R. Hyneman [ID](#)¹⁴³, G. Iacobucci [ID](#)⁵⁶, G. Iakovidis [ID](#)²⁹, I. Ibragimov [ID](#)¹⁴¹, L. Iconomidou-Fayard [ID](#)⁶⁶, P. Iengo [ID](#)^{72a,72b}, R. Iguchi [ID](#)¹⁵³, T. Iizawa [ID](#)^{126,r}, Y. Ikegami [ID](#)⁸⁴, N. Ilic [ID](#)¹⁵⁵, H. Imam [ID](#)^{35a}, M. Ince Lezki [ID](#)⁵⁶, T. Ingebretsen Carlson [ID](#)^{47a,47b}, G. Introzzi [ID](#)^{73a,73b}, M. Iodice [ID](#)^{77a}, V. Ippolito [ID](#)^{75a,75b}, R.K. Irwin [ID](#)⁹², M. Ishino [ID](#)¹⁵³, W. Islam [ID](#)¹⁷⁰, C. Issever [ID](#)^{18,48}, S. Istin [ID](#)^{21a,bb}, H. Ito [ID](#)¹⁶⁸, J.M. Iturbe Ponce [ID](#)^{64a}, R. Iuppa [ID](#)^{78a,78b}, A. Ivina [ID](#)¹⁶⁹, J.M. Izen [ID](#)⁴⁵, V. Izzo [ID](#)^{72a}, P. Jacka [ID](#)^{131,132}, P. Jackson [ID](#)¹, R.M. Jacobs [ID](#)⁴⁸, B.P. Jaeger [ID](#)¹⁴², C.S. Jagfeld [ID](#)¹⁰⁹, G. Jain [ID](#)^{156a}, P. Jain [ID](#)⁵⁴, K. Jakobs [ID](#)⁵⁴, T. Jakoubek [ID](#)¹⁶⁹, J. Jamieson [ID](#)⁵⁹, K.W. Janas [ID](#)^{86a}, M. Javurkova [ID](#)¹⁰³, F. Jeanneau [ID](#)¹³⁵, L. Jeanty [ID](#)¹²³, J. Jejelava [ID](#)^{149a,al}, P. Jenni [ID](#)^{54,i}, C.E. Jessiman [ID](#)³⁴, S. Jézéquel [ID](#)⁴, C. Jia [ID](#)^{62b}, J. Jia [ID](#)¹⁴⁵, X. Jia [ID](#)⁶¹, X. Jia [ID](#)^{14a,14e}, Z. Jia [ID](#)^{14c}, S. Jiggins [ID](#)⁴⁸, J. Jimenez Pena [ID](#)¹³, S. Jin [ID](#)^{14c}, A. Jinaru [ID](#)^{27b}, O. Jinnouchi [ID](#)¹⁵⁴, P. Johansson [ID](#)¹³⁹, K.A. Johns [ID](#)⁷, J.W. Johnson [ID](#)¹³⁶, D.M. Jones [ID](#)³², E. Jones [ID](#)⁴⁸, P. Jones [ID](#)³², R.W.L. Jones [ID](#)⁹¹, T.J. Jones [ID](#)⁹², H.L. Joos [ID](#)^{55,36}, R. Joshi [ID](#)¹¹⁹, J. Jovicevic [ID](#)¹⁵, X. Ju [ID](#)^{17a}, J.J. Junggeburth [ID](#)^{103,v}, T. Junkermann [ID](#)^{63a}, A. Juste Rozas [ID](#)^{13,ad}, M.K. Juzek [ID](#)⁸⁷, S. Kabana [ID](#)^{137e}, A. Kaczmarek [ID](#)⁸⁷, M. Kado [ID](#)¹¹⁰, H. Kagan [ID](#)¹¹⁹, M. Kagan [ID](#)¹⁴³, A. Kahn [ID](#)⁴¹, A. Kahn [ID](#)¹²⁸, C. Kahra [ID](#)¹⁰⁰, T. Kajji [ID](#)¹⁵³, E. Kajomovitz [ID](#)¹⁵⁰, N. Kakati [ID](#)¹⁶⁹, I. Kalaitzidou [ID](#)⁵⁴, C.W. Kalderon [ID](#)²⁹, A. Kamenshchikov [ID](#)¹⁵⁵, N.J. Kang [ID](#)¹³⁶, D. Kar [ID](#)^{33g}, K. Karava [ID](#)¹²⁶, M.J. Kareem [ID](#)^{156b}, E. Karentzos [ID](#)⁵⁴, I. Karkanas [ID](#)¹⁵², O. Karkout [ID](#)¹¹⁴, S.N. Karpov [ID](#)³⁸, Z.M. Karpova [ID](#)³⁸, V. Kartvelishvili [ID](#)⁹¹, A.N. Karyukhin [ID](#)³⁷, E. Kasimi [ID](#)¹⁵², J. Katzy [ID](#)⁴⁸, S. Kaur [ID](#)³⁴, K. Kawade [ID](#)¹⁴⁰, M.P. Kawale [ID](#)¹²⁰, C. Kawamoto [ID](#)⁸⁸, T. Kawamoto [ID](#)¹³⁵, E.F. Kay [ID](#)³⁶, F.I. Kaya [ID](#)¹⁵⁸, S. Kazakos [ID](#)¹⁰⁷, V.F. Kazanin [ID](#)³⁷, Y. Ke [ID](#)¹⁴⁵, J.M. Keaveney [ID](#)^{33a}, R. Keeler [ID](#)¹⁶⁵, G.V. Kehris [ID](#)⁶¹, J.S. Keller [ID](#)³⁴, A.S. Kelly [ID](#)⁹⁶, J.J. Kempster [ID](#)¹⁴⁶, K.E. Kennedy [ID](#)⁴¹, P.D. Kennedy [ID](#)¹⁰⁰, O. Kepka [ID](#)¹³¹, B.P. Kerridge [ID](#)¹⁶⁷, S. Kersten [ID](#)¹⁷¹, B.P. Kerševan [ID](#)⁹³, S. Keshri [ID](#)⁶⁶, L. Keszeghova [ID](#)^{28a}, S. Ketabchi Haghighat [ID](#)¹⁵⁵, R.A. Khan [ID](#)¹²⁹,

M. Khandoga [ID](#)¹²⁷, A. Khanov [ID](#)¹²¹, A.G. Kharlamov [ID](#)³⁷, T. Kharlamova [ID](#)³⁷, E.E. Khoda [ID](#)¹³⁸, M. Kholodenko [ID](#)³⁷, T.J. Khoo [ID](#)¹⁸, G. Khoriauli [ID](#)¹⁶⁶, J. Khubua [ID](#)^{149b}, Y.A.R. Khwaira [ID](#)⁶⁶, A. Kilgallon [ID](#)¹²³, D.W. Kim [ID](#)^{47a,47b}, Y.K. Kim [ID](#)³⁹, N. Kimura [ID](#)⁹⁶, M.K. Kingston [ID](#)⁵⁵, A. Kirchhoff [ID](#)⁵⁵, C. Kirfel [ID](#)²⁴, F. Kirfel [ID](#)²⁴, J. Kirk [ID](#)¹³⁴, A.E. Kiryunin [ID](#)¹¹⁰, C. Kitsaki [ID](#)¹⁰, O. Kivernyk [ID](#)²⁴, M. Klassen [ID](#)^{63a}, C. Klein [ID](#)³⁴, L. Klein [ID](#)¹⁶⁶, M.H. Klein [ID](#)¹⁰⁶, M. Klein [ID](#)⁹², S.B. Klein [ID](#)⁵⁶, U. Klein [ID](#)⁹², P. Klimek [ID](#)³⁶, A. Klimentov [ID](#)²⁹, T. Klioutchnikova [ID](#)³⁶, P. Kluit [ID](#)¹¹⁴, S. Kluth [ID](#)¹¹⁰, E. Kneringer [ID](#)⁷⁹, T.M. Knight [ID](#)¹⁵⁵, A. Knue [ID](#)⁴⁹, R. Kobayashi [ID](#)⁸⁸, D. Kobylanski [ID](#)¹⁶⁹, S.F. Koch [ID](#)¹²⁶, M. Kocian [ID](#)¹⁴³, P. Kodyš [ID](#)¹³³, D.M. Koeck [ID](#)¹²³, P.T. Koenig [ID](#)²⁴, T. Koffas [ID](#)³⁴, M. Kolb [ID](#)¹³⁵, I. Koletsou [ID](#)⁴, T. Komarek [ID](#)¹²², K. Köneke [ID](#)⁵⁴, A.X.Y. Kong [ID](#)¹, T. Kono [ID](#)¹¹⁸, N. Konstantinidis [ID](#)⁹⁶, P. Kontaxakis [ID](#)⁵⁶, B. Konya [ID](#)⁹⁸, R. Kopeliansky [ID](#)⁶⁸, S. Koperny [ID](#)^{86a}, K. Korcyl [ID](#)⁸⁷, K. Kordas [ID](#)^{152,f}, G. Koren [ID](#)¹⁵¹, A. Korn [ID](#)⁹⁶, S. Korn [ID](#)⁵⁵, I. Korolkov [ID](#)¹³, N. Korotkova [ID](#)³⁷, B. Kortman [ID](#)¹¹⁴, O. Kortner [ID](#)¹¹⁰, S. Kortner [ID](#)¹¹⁰, W.H. Kostecka [ID](#)¹¹⁵, V.V. Kostyukhin [ID](#)¹⁴¹, A. Kotskechagia [ID](#)¹³⁵, A. Kotwal [ID](#)⁵¹, A. Koulouris [ID](#)³⁶, A. Kourkouveli-Charalampidi [ID](#)^{73a,73b}, C. Kourkoumelis [ID](#)⁹, E. Kourlitis [ID](#)^{110,au}, O. Kovanda [ID](#)¹⁴⁶, R. Kowalewski [ID](#)¹⁶⁵, W. Kozanecki [ID](#)¹³⁵, A.S. Kozhin [ID](#)³⁷, V.A. Kramarenko [ID](#)³⁷, G. Kramberger [ID](#)⁹³, P. Kramer [ID](#)¹⁰⁰, M.W. Krasny [ID](#)¹²⁷, A. Krasznahorkay [ID](#)³⁶, J.W. Kraus [ID](#)¹⁷¹, J.A. Kremer [ID](#)⁴⁸, T. Kresse [ID](#)⁵⁰, J. Kretzschmar [ID](#)⁹², K. Kreul [ID](#)¹⁸, P. Krieger [ID](#)¹⁵⁵, S. Krishnamurthy [ID](#)¹⁰³, M. Krivos [ID](#)¹³³, K. Krizka [ID](#)²⁰, K. Kroeninger [ID](#)⁴⁹, H. Kroha [ID](#)¹¹⁰, J. Kroll [ID](#)¹³¹, J. Kroll [ID](#)¹²⁸, K.S. Krowpman [ID](#)¹⁰⁷, U. Kruchonak [ID](#)³⁸, H. Krüger [ID](#)²⁴, N. Krumnack [ID](#)⁸¹, M.C. Kruse [ID](#)⁵¹, J.A. Krzysiak [ID](#)⁸⁷, O. Kuchinskaia [ID](#)³⁷, S. Kuday [ID](#)^{3a}, S. Kuehn [ID](#)³⁶, R. Kuesters [ID](#)⁵⁴, T. Kuhl [ID](#)⁴⁸, V. Kukhtin [ID](#)³⁸, Y. Kulchitsky [ID](#)^{37,a}, S. Kuleshov [ID](#)^{137d,137b}, M. Kumar [ID](#)^{33g}, N. Kumari [ID](#)⁴⁸, A. Kupco [ID](#)¹³¹, T. Kupfer [ID](#)⁴⁹, A. Kupich [ID](#)³⁷, O. Kuprash [ID](#)⁵⁴, H. Kurashige [ID](#)⁸⁵, L.L. Kurchaninov [ID](#)^{156a}, O. Kurdysh [ID](#)⁶⁶, Y.A. Kurochkin [ID](#)³⁷, A. Kurova [ID](#)³⁷, M. Kuze [ID](#)¹⁵⁴, A.K. Kvam [ID](#)¹⁰³, J. Kvitka [ID](#)¹²², T. Kwan [ID](#)¹⁰⁴, N.G. Kyriacou [ID](#)¹⁰⁶, L.A.O. Laatu [ID](#)¹⁰², C. Lacasta [ID](#)¹⁶³, F. Lacava [ID](#)^{75a,75b}, H. Lacker [ID](#)¹⁸, D. Lacour [ID](#)¹²⁷, N.N. Lad [ID](#)⁹⁶, E. Ladygin [ID](#)³⁸, B. Laforge [ID](#)¹²⁷, T. Lagouri [ID](#)^{137e}, F.Z. Lahbabi [ID](#)^{35a}, S. Lai [ID](#)⁵⁵, I.K. Lakomic [ID](#)^{86a}, N. Lalloue [ID](#)⁶⁰, J.E. Lambert [ID](#)^{165,n}, S. Lammers [ID](#)⁶⁸, W. Lampl [ID](#)⁷, C. Lampoudis [ID](#)^{152,f}, A.N. Lancaster [ID](#)¹¹⁵, E. Lançon [ID](#)²⁹, U. Landgraf [ID](#)⁵⁴, M.P.J. Landon [ID](#)⁹⁴, V.S. Lang [ID](#)⁵⁴, R.J. Langenberg [ID](#)¹⁰³, O.K.B. Langrekken [ID](#)¹²⁵, A.J. Lankford [ID](#)¹⁶⁰, F. Lanni [ID](#)³⁶, K. Lantzsch [ID](#)²⁴, A. Lanza [ID](#)^{73a}, A. Lapertosa [ID](#)^{57b,57a}, J.F. Laporte [ID](#)¹³⁵, T. Lari [ID](#)^{71a}, F. Lasagni Manghi [ID](#)^{23b}, M. Lassnig [ID](#)³⁶, V. Latonova [ID](#)¹³¹, A. Laudrain [ID](#)¹⁰⁰, A. Laurier [ID](#)¹⁵⁰, S.D. Lawlor [ID](#)¹³⁹, Z. Lawrence [ID](#)¹⁰¹, M. Lazzaroni [ID](#)^{71a,71b}, B. Le [ID](#)¹⁰¹, E.M. Le Boulicaut [ID](#)⁵¹, B. Leban [ID](#)⁹³, A. Lebedev [ID](#)⁸¹, M. LeBlanc [ID](#)^{101,as}, F. Ledroit-Guillon [ID](#)⁶⁰, A.C.A. Lee [ID](#)⁹⁶, S.C. Lee [ID](#)¹⁴⁸, S. Lee [ID](#)^{47a,47b}, T.F. Lee [ID](#)⁹², L.L. Leeuw [ID](#)^{33c}, H.P. Lefebvre [ID](#)⁹⁵, M. Lefebvre [ID](#)¹⁶⁵, C. Leggett [ID](#)^{17a}, G. Lehmann Miotto [ID](#)³⁶, M. Leigh [ID](#)⁵⁶, W.A. Leight [ID](#)¹⁰³, W. Leinonen [ID](#)¹¹³, A. Leisos [ID](#)^{152,ac}, M.A.L. Leite [ID](#)^{83c}, C.E. Leitgeb [ID](#)⁴⁸, R. Leitner [ID](#)¹³³, K.J.C. Leney [ID](#)⁴⁴, T. Lenz [ID](#)²⁴, S. Leone [ID](#)^{74a}, C. Leonidopoulos [ID](#)⁵², A. Leopold [ID](#)¹⁴⁴, C. Leroy [ID](#)¹⁰⁸, R. Les [ID](#)¹⁰⁷, C.G. Lester [ID](#)³², M. Levchenko [ID](#)³⁷, J. Levêque [ID](#)⁴, D. Levin [ID](#)¹⁰⁶, L.J. Levinson [ID](#)¹⁶⁹, M.P. Lewicki [ID](#)⁸⁷, D.J. Lewis [ID](#)⁴, A. Li [ID](#)⁵, B. Li [ID](#)^{62b}, C. Li [ID](#)^{62a}, C-Q. Li [ID](#)^{62c}, H. Li [ID](#)^{62a}, H. Li [ID](#)^{62b}, H. Li [ID](#)^{14c}, H. Li [ID](#)^{14b}, H. Li [ID](#)^{62b}, J. Li [ID](#)^{62c}, K. Li [ID](#)¹³⁸, L. Li [ID](#)^{62c}, M. Li [ID](#)^{14a,14e}, Q.Y. Li [ID](#)^{62a}, S. Li [ID](#)^{14a,14e}, S. Li [ID](#)^{62d,62c,e}, T. Li [ID](#)^{5,c}, X. Li [ID](#)¹⁰⁴, Z. Li [ID](#)¹²⁶, Z. Li [ID](#)¹⁰⁴, Z. Li [ID](#)⁹², Z. Li [ID](#)^{14a,14e}, S. Liang [ID](#)^{14a,14e}, Z. Liang [ID](#)^{14a}, M. Liberatore [ID](#)^{135,am}, B. Liberti [ID](#)^{76a}, K. Lie [ID](#)^{64c}, J. Lieber Marin [ID](#)^{83b}, H. Lien [ID](#)⁶⁸, K. Lin [ID](#)¹⁰⁷, R.E. Lindley [ID](#)⁷, J.H. Lindon [ID](#)², E. Lipeles [ID](#)¹²⁸,

A. Lipniacka [ID](#)¹⁶, A. Lister [ID](#)¹⁶⁴, J.D. Little [ID](#)⁴, B. Liu [ID](#)^{14a}, B.X. Liu [ID](#)¹⁴², D. Liu [ID](#)^{62d,62c},
 J.B. Liu [ID](#)^{62a}, J.K.K. Liu [ID](#)³², K. Liu [ID](#)^{62d,62c}, M. Liu [ID](#)^{62a}, M.Y. Liu [ID](#)^{62a}, P. Liu [ID](#)^{14a},
 Q. Liu [ID](#)^{62d,138,62c}, X. Liu [ID](#)^{62a}, Y. Liu [ID](#)^{14d,14e}, Y.L. Liu [ID](#)^{62b}, Y.W. Liu [ID](#)^{62a},
 J. Llorente Merino [ID](#)¹⁴², S.L. Lloyd [ID](#)⁹⁴, E.M. Lobodzinska [ID](#)⁴⁸, P. Loch [ID](#)⁷, T. Lohse [ID](#)¹⁸,
 K. Lohwasser [ID](#)¹³⁹, E. Loiacono [ID](#)⁴⁸, M. Lokajicek [ID](#)^{131,*}, J.D. Lomas [ID](#)²⁰, J.D. Long [ID](#)¹⁶²,
 I. Longarini [ID](#)¹⁶⁰, L. Longo [ID](#)^{70a,70b}, R. Longo [ID](#)¹⁶², I. Lopez Paz [ID](#)⁶⁷, A. Lopez Solis [ID](#)⁴⁸,
 J. Lorenz [ID](#)¹⁰⁹, N. Lorenzo Martinez [ID](#)⁴, A.M. Lory [ID](#)¹⁰⁹, O. Loseva [ID](#)³⁷, X. Lou [ID](#)^{47a,47b},
 X. Lou [ID](#)^{14a,14e}, A. Lounis [ID](#)⁶⁶, J. Love [ID](#)⁶, P.A. Love [ID](#)⁹¹, G. Lu [ID](#)^{14a,14e}, M. Lu [ID](#)⁸⁰, S. Lu [ID](#)¹²⁸,
 Y.J. Lu [ID](#)⁶⁵, H.J. Lubatti [ID](#)¹³⁸, C. Luci [ID](#)^{75a,75b}, F.L. Lucio Alves [ID](#)^{14c}, A. Lucotte [ID](#)⁶⁰,
 F. Luehring [ID](#)⁶⁸, I. Luise [ID](#)¹⁴⁵, O. Lukianchuk [ID](#)⁶⁶, O. Lundberg [ID](#)¹⁴⁴, B. Lund-Jensen [ID](#)¹⁴⁴,
 N.A. Luongo [ID](#)¹²³, M.S. Lutz [ID](#)¹⁵¹, A.B. Lux [ID](#)²⁵, D. Lynn [ID](#)²⁹, H. Lyons⁹², R. Lysak [ID](#)¹³¹,
 E. Lytken [ID](#)⁹⁸, V. Lyubushkin [ID](#)³⁸, T. Lyubushkina [ID](#)³⁸, M.M. Lyukova [ID](#)¹⁴⁵, H. Ma [ID](#)²⁹, K. Ma^{62a},
 L.L. Ma [ID](#)^{62b}, Y. Ma [ID](#)¹²¹, D.M. Mac Donell [ID](#)¹⁶⁵, G. Maccarrone [ID](#)⁵³, J.C. MacDonald [ID](#)¹⁰⁰,
 P.C. Machado De Abreu Farias [ID](#)^{83b}, R. Madar [ID](#)⁴⁰, W.F. Mader [ID](#)⁵⁰, T. Madula [ID](#)⁹⁶,
 J. Maeda [ID](#)⁸⁵, T. Maeno [ID](#)²⁹, H. Maguire [ID](#)¹³⁹, V. Maiboroda [ID](#)¹³⁵, A. Maio [ID](#)^{130a,130b,130d},
 K. Maj [ID](#)^{86a}, O. Majersky [ID](#)⁴⁸, S. Majewski [ID](#)¹²³, N. Makovec [ID](#)⁶⁶, V. Maksimovic [ID](#)¹⁵,
 B. Malaescu [ID](#)¹²⁷, Pa. Malecki [ID](#)⁸⁷, V.P. Maleev [ID](#)³⁷, F. Malek [ID](#)⁶⁰, M. Mali [ID](#)⁹³, D. Malito [ID](#)^{95,s},
 U. Mallik [ID](#)⁸⁰, S. Maltezos¹⁰, S. Malyukov³⁸, J. Mamuzic [ID](#)¹³, G. Mancini [ID](#)⁵³, G. Manco [ID](#)^{73a,73b},
 J.P. Mandalia [ID](#)⁹⁴, I. Mandić [ID](#)⁹³, L. Manhaes de Andrade Filho [ID](#)^{83a}, I.M. Maniatis [ID](#)¹⁶⁹,
 J. Manjarres Ramos [ID](#)^{102,an}, D.C. Mankad [ID](#)¹⁶⁹, A. Mann [ID](#)¹⁰⁹, B. Mansoulie [ID](#)¹³⁵, S. Manzoni [ID](#)³⁶,
 X. Mapekula [ID](#)^{33c}, A. Marantis [ID](#)^{152,ac}, G. Marchiori [ID](#)⁵, M. Marcisovsky [ID](#)¹³¹, C. Marcon [ID](#)^{71a,71b},
 M. Marinescu [ID](#)²⁰, M. Marjanovic [ID](#)¹²⁰, E.J. Marshall [ID](#)⁹¹, Z. Marshall [ID](#)^{17a}, S. Marti-Garcia [ID](#)¹⁶³,
 T.A. Martin [ID](#)¹⁶⁷, V.J. Martin [ID](#)⁵², B. Martin dit Latour [ID](#)¹⁶, L. Martinelli [ID](#)^{75a,75b},
 M. Martinez [ID](#)^{13,ad}, P. Martinez Agullo [ID](#)¹⁶³, V.I. Martinez Outschoorn [ID](#)¹⁰³,
 P. Martinez Suarez [ID](#)¹³, S. Martin-Haugh [ID](#)¹³⁴, V.S. Martoiu [ID](#)^{27b}, A.C. Martyniuk [ID](#)⁹⁶,
 A. Marzin [ID](#)³⁶, D. Mascione [ID](#)^{78a,78b}, L. Masetti [ID](#)¹⁰⁰, T. Mashimo [ID](#)¹⁵³, J. Masik [ID](#)¹⁰¹,
 A.L. Maslennikov [ID](#)³⁷, L. Massa [ID](#)^{23b}, P. Massarotti [ID](#)^{72a,72b}, P. Mastrandrea [ID](#)^{74a,74b},
 A. Mastroberardino [ID](#)^{43b,43a}, T. Masubuchi [ID](#)¹⁵³, T. Mathisen [ID](#)¹⁶¹, J. Matousek [ID](#)¹³³,
 N. Matsuzawa¹⁵³, J. Maurer [ID](#)^{27b}, B. Maček [ID](#)⁹³, D.A. Maximov [ID](#)³⁷, R. Mazini [ID](#)¹⁴⁸,
 I. Maznas [ID](#)¹⁵², M. Mazza [ID](#)¹⁰⁷, S.M. Mazza [ID](#)¹³⁶, E. Mazzeo [ID](#)^{71a,71b}, C. Mc Ginn [ID](#)²⁹,
 J.P. Mc Gowan [ID](#)¹⁰⁴, S.P. Mc Kee [ID](#)¹⁰⁶, E.F. McDonald [ID](#)¹⁰⁵, A.E. McDougall [ID](#)¹¹⁴,
 J.A. Mcfayden [ID](#)¹⁴⁶, R.P. McGovern [ID](#)¹²⁸, G. Mchedlidze [ID](#)^{149b}, R.P. Mckenzie [ID](#)^{33g},
 T.C. Mclachlan [ID](#)⁴⁸, D.J. Mclaughlin [ID](#)⁹⁶, S.J. McMahan [ID](#)¹³⁴, C.M. Mcpartland [ID](#)⁹²,
 R.A. McPherson [ID](#)^{165,ai}, S. Mehlhase [ID](#)¹⁰⁹, A. Mehta [ID](#)⁹², D. Melini [ID](#)¹⁵⁰,
 B.R. Mellado Garcia [ID](#)^{33g}, A.H. Melo [ID](#)⁵⁵, F. Meloni [ID](#)⁴⁸, A.M. Mendes Jacques Da Costa [ID](#)¹⁰¹,
 H.Y. Meng [ID](#)¹⁵⁵, L. Meng [ID](#)⁹¹, S. Menke [ID](#)¹¹⁰, M. Mentink [ID](#)³⁶, E. Meoni [ID](#)^{43b,43a},
 C. Merlassino [ID](#)¹²⁶, L. Merola [ID](#)^{72a,72b}, C. Meroni [ID](#)^{71a,71b}, G. Merz¹⁰⁶, O. Meshkov [ID](#)³⁷,
 J. Metcalfe [ID](#)⁶, A.S. Mete [ID](#)⁶, C. Meyer [ID](#)⁶⁸, J-P. Meyer [ID](#)¹³⁵, R.P. Middleton [ID](#)¹³⁴, L. Mijović [ID](#)⁵²,
 G. Mikenberg [ID](#)¹⁶⁹, M. Mikestikova [ID](#)¹³¹, M. Mikuž [ID](#)⁹³, H. Mildner [ID](#)¹⁰⁰, A. Milic [ID](#)³⁶,
 C.D. Milke [ID](#)⁴⁴, D.W. Miller [ID](#)³⁹, L.S. Miller [ID](#)³⁴, A. Milov [ID](#)¹⁶⁹, D.A. Milstead^{47a,47b}, T. Min^{14c},
 A.A. Minaenko [ID](#)³⁷, I.A. Minashvili [ID](#)^{149b}, L. Mince [ID](#)⁵⁹, A.I. Mincer [ID](#)¹¹⁷, B. Mindur [ID](#)^{86a},
 M. Mineev [ID](#)³⁸, Y. Mino [ID](#)⁸⁸, L.M. Mir [ID](#)¹³, M. Miralles Lopez [ID](#)¹⁶³, M. Mironova [ID](#)^{17a},
 A. Mishima¹⁵³, M.C. Missio [ID](#)¹¹³, A. Mitra [ID](#)¹⁶⁷, V.A. Mitsou [ID](#)¹⁶³, Y. Mitsumori [ID](#)¹¹¹,



























































O. Miu [155](#), P.S. Miyagawa [94](#), T. Mkrtchyan [63a](#), M. Mlinarevic [96](#), T. Mlinarevic [96](#), M. Mlynarikova [36](#), S. Mobius [19](#), P. Moder [48](#), P. Mogg [109](#), A.F. Mohammed [14a,14e](#), S. Mohapatra [41](#), G. Mokgatitswane [33g](#), L. Moleri [169](#), B. Mondal [141](#), S. Mondal [132](#), G. Monig [146](#), K. Mönig [48](#), E. Monnier [102](#), L. Monsonis Romero [163](#), J. Montejo Berlingen [13](#), M. Montella [119](#), F. Montekali [77a,77b](#), F. Monticelli [90](#), S. Monzani [69a,69c](#), N. Morange [66](#), A.L. Moreira De Carvalho [130a](#), M. Moreno Llácer [163](#), C. Moreno Martinez [56](#), P. Morettini [57b](#), S. Morgenstern [36](#), M. Morii [61](#), M. Morinaga [153](#), A.K. Morley [36](#), F. Morodei [75a,75b](#), L. Morvaj [36](#), P. Moschovakos [36](#), B. Moser [36](#), M. Mosidze [149b](#), T. Moskalets [54](#), P. Moskvitina [113](#), J. Moss [31,p](#), E.J.W. Moyse [103](#), O. Mtintsilana [33g](#), S. Muanza [102](#), J. Mueller [129](#), D. Muenstermann [91](#), R. Müller [19](#), G.A. Mullier [161](#), A.J. Mullin [32](#), J.J. Mullin [128](#), D.P. Mungo [155](#), D. Munoz Perez [163](#), F.J. Munoz Sanchez [101](#), M. Murin [101](#), W.J. Murray [167,134](#), A. Murrone [71a,71b](#), M. Muškinja [17a](#), C. Mwewa [29](#), A.G. Myagkov [37,a](#), A.J. Myers [8](#), G. Myers [68](#), M. Myska [132](#), B.P. Nachman [17a](#), O. Nackenhorst [49](#), A. Nag [50](#), K. Nagai [126](#), K. Nagano [84](#), J.L. Nagle [29,az](#), E. Nagy [102](#), A.M. Nairz [36](#), Y. Nakahama [84](#), K. Nakamura [84](#), K. Nakkalil [5](#), H. Nanjo [124](#), R. Narayan [44](#), E.A. Narayanan [112](#), I. Naryshkin [37](#), M. Naseri [34](#), S. Nasri [159](#), C. Nass [24](#), G. Navarro [22a](#), J. Navarro-Gonzalez [163](#), R. Nayak [151](#), A. Nayaz [18](#), P.Y. Nechaeva [37](#), F. Nechansky [48](#), L. Nedic [126](#), T.J. Neep [20](#), A. Negri [73a,73b](#), M. Negrini [23b](#), C. Nellist [114](#), C. Nelson [104](#), K. Nelson [106](#), S. Nemecek [131](#), M. Nessi [36,j](#), M.S. Neubauer [162](#), F. Neuhaus [100](#), J. Neundorff [48](#), R. Newhouse [164](#), P.R. Newman [20](#), C.W. Ng [129](#), Y.W.Y. Ng [48](#), B. Ngair [35e](#), H.D.N. Nguyen [108](#), R.B. Nickerson [126](#), R. Nicolaidou [135](#), J. Nielsen [136](#), M. Niemeyer [55](#), J. Niermann [55,36](#), N. Nikiforou [36](#), V. Nikolaenko [37,a](#), I. Nikolic-Audit [127](#), K. Nikolopoulos [20](#), P. Nilsson [29](#), I. Ninca [48](#), H.R. Nindhito [56](#), G. Ninio [151](#), A. Nisati [75a](#), N. Nishu [2](#), R. Nisius [110](#), J-E. Nitschke [50](#), E.K. Nkadimeng [33g](#), T. Nobe [153](#), D.L. Noel [32](#), T. Nommensen [147](#), M.B. Norfolk [139](#), R.R.B. Norisam [96](#), B.J. Norman [34](#), J. Novak [93](#), T. Novak [48](#), L. Novotny [132](#), R. Novotny [112](#), L. Nozka [122](#), K. Ntekas [160](#), N.M.J. Nunes De Moura Junior [83b](#), E. Nurse [96](#), J. Ocariz [127](#), A. Ochi [85](#), I. Ochoa [130a](#), S. Oerdek [48,y](#), J.T. Offermann [39](#), A. Ogrodnik [133](#), A. Oh [101](#), C.C. Ohm [144](#), H. Oide [84](#), R. Oishi [153](#), M.L. Ojeda [48](#), M.W. O’Keefe [92](#), Y. Okumura [153](#), L.F. Oleiro Seabra [130a](#), S.A. Olivares Pino [137d](#), D. Oliveira Damazio [29](#), D. Oliveira Goncalves [83a](#), J.L. Oliver [160](#), Ö.O. Öncel [54](#), A.P. O’Neill [19](#), A. Onofre [130a,130e](#), P.U.E. Onyisi [11](#), M.J. Oreglia [39](#), G.E. Orellana [90](#), D. Orestano [77a,77b](#), N. Orlando [13](#), R.S. Orr [155](#), V. O’Shea [59](#), L.M. Osojnak [128](#), R. Ospanov [62a](#), G. Otero y Garzon [30](#), H. Otono [89](#), P.S. Ott [63a](#), G.J. Ottino [17a](#), M. Ouchrif [35d](#), J. Ouellette [29](#), F. Ould-Saada [125](#), M. Owen [59](#), R.E. Owen [134](#), K.Y. Oyulmaz [21a](#), V.E. Ozcan [21a](#), F. Ozturk [87](#), N. Ozturk [8](#), S. Ozturk [82](#), H.A. Pacey [126](#), A. Pacheco Pages [13](#), C. Padilla Aranda [13](#), G. Padovano [75a,75b](#), S. Pagan Griso [17a](#), G. Palacino [68](#), A. Palazzo [70a,70b](#), S. Palestini [36](#), J. Pan [172](#), T. Pan [64a](#), D.K. Panchal [11](#), C.E. Pandini [114](#), J.G. Panduro Vazquez [95](#), H.D. Pandya [1](#), H. Pang [14b](#), P. Pani [48](#), G. Panizzo [69a,69c](#), L. Paolozzi [56](#), C. Papadatos [108](#), S. Parajuli [44](#), A. Paramonov [6](#), C. Paraskevopoulos [10](#), D. Paredes Hernandez [64b](#), K.R. Park [41](#), T.H. Park [155](#), M.A. Parker [32](#), F. Parodi [57b,57a](#), E.W. Parrish [115](#), V.A. Parrish [52](#), J.A. Parsons [41](#), U. Parzefall [54](#), B. Pascual Dias [108](#), L. Pascual Dominguez [151](#),

E. Pasqualucci [ID](#)^{75a}, S. Passaggio [ID](#)^{57b}, F. Pastore [ID](#)⁹⁵, P. Pasuwan [ID](#)^{47a,47b}, P. Patel [ID](#)⁸⁷,
 U.M. Patel [ID](#)⁵¹, J.R. Pater [ID](#)¹⁰¹, T. Pauly [ID](#)³⁶, J. Pearkes [ID](#)¹⁴³, M. Pedersen [ID](#)¹²⁵, R. Pedro [ID](#)^{130a},
 S.V. Peleganchuk [ID](#)³⁷, O. Penc [ID](#)³⁶, E.A. Pender [ID](#)⁵², K.E. Pensi [ID](#)¹⁰⁹, M. Penzin [ID](#)³⁷,
 B.S. Peralva [ID](#)^{83d}, A.P. Pereira Peixoto [ID](#)⁶⁰, L. Pereira Sanchez [ID](#)^{47a,47b}, D.V. Perepelitsa [ID](#)^{29,az},
 E. Perez Codina [ID](#)^{156a}, M. Perganti [ID](#)¹⁰, L. Perini [ID](#)^{71a,71b,*}, H. Pernegger [ID](#)³⁶, O. Perrin [ID](#)⁴⁰,
 K. Peters [ID](#)⁴⁸, R.F.Y. Peters [ID](#)¹⁰¹, B.A. Petersen [ID](#)³⁶, T.C. Petersen [ID](#)⁴², E. Petit [ID](#)¹⁰²,
 V. Petousis [ID](#)¹³², C. Petridou [ID](#)^{152,f}, A. Petrukhin [ID](#)¹⁴¹, M. Pettee [ID](#)^{17a}, N.E. Pettersson [ID](#)³⁶,
 A. Petukhov [ID](#)³⁷, K. Petukhova [ID](#)¹³³, R. Pezoa [ID](#)^{137f}, L. Pezzotti [ID](#)³⁶, G. Pezzullo [ID](#)¹⁷²,
 T.M. Pham [ID](#)¹⁷⁰, T. Pham [ID](#)¹⁰⁵, P.W. Phillips [ID](#)¹³⁴, G. Piacquadio [ID](#)¹⁴⁵, E. Pianori [ID](#)^{17a},
 F. Piazza [ID](#)¹²³, R. Piegai [ID](#)³⁰, D. Pietreanu [ID](#)^{27b}, A.D. Pilkington [ID](#)¹⁰¹, M. Pinamonti [ID](#)^{69a,69c},
 J.L. Pinfold [ID](#)², B.C. Pinheiro Pereira [ID](#)^{130a}, A.E. Pinto Pinoargote [ID](#)^{100,135}, L. Pintucci [ID](#)^{69a,69c},
 K.M. Piper [ID](#)¹⁴⁶, A. Pirttikoski [ID](#)⁵⁶, D.A. Pizzi [ID](#)³⁴, L. Pizzimento [ID](#)^{64b}, A. Pizzini [ID](#)¹¹⁴,
 M.-A. Pleier [ID](#)²⁹, V. Plesanovs⁵⁴, V. Pleskot [ID](#)¹³³, E. Plotnikova³⁸, G. Poddar [ID](#)⁴, R. Poettgen [ID](#)⁹⁸,
 L. Poggioli [ID](#)¹²⁷, I. Pokharel [ID](#)⁵⁵, S. Polacek [ID](#)¹³³, G. Polesello [ID](#)^{73a}, A. Poley [ID](#)^{142,156a},
 R. Polifka [ID](#)¹³², A. Polini [ID](#)^{23b}, C.S. Pollard [ID](#)¹⁶⁷, Z.B. Pollock [ID](#)¹¹⁹, V. Polychronakos [ID](#)²⁹,
 E. Pompa Pacchi [ID](#)^{75a,75b}, D. Ponomarenko [ID](#)¹¹³, L. Pontecorvo [ID](#)³⁶, S. Popa [ID](#)^{27a},
 G.A. Popeneciu [ID](#)^{27d}, A. Poreba [ID](#)³⁶, D.M. Portillo Quintero [ID](#)^{156a}, S. Pospisil [ID](#)¹³²,
 M.A. Postill [ID](#)¹³⁹, P. Postolache [ID](#)^{27c}, K. Potamianos [ID](#)¹⁶⁷, P.A. Potepa [ID](#)^{86a}, I.N. Potrap [ID](#)³⁸,
 C.J. Potter [ID](#)³², H. Potti [ID](#)¹, T. Poulsen [ID](#)⁴⁸, J. Poveda [ID](#)¹⁶³, M.E. Pozo Astigarraga [ID](#)³⁶,
 A. Prades Ibanez [ID](#)¹⁶³, J. Pretel [ID](#)⁵⁴, D. Price [ID](#)¹⁰¹, M. Primavera [ID](#)^{70a}, M.A. Principe Martin [ID](#)⁹⁹,
 R. Privara [ID](#)¹²², T. Procter [ID](#)⁵⁹, M.L. Proffitt [ID](#)¹³⁸, N. Proklova [ID](#)¹²⁸, K. Prokofiev [ID](#)^{64c},
 G. Proto [ID](#)¹¹⁰, S. Protopopescu [ID](#)²⁹, J. Proudfoot [ID](#)⁶, M. Przybycien [ID](#)^{86a}, W.W. Przygoda [ID](#)^{86b},
 J.E. Puddefoot [ID](#)¹³⁹, D. Pudzha [ID](#)³⁷, D. Pyatiizbyantseva [ID](#)³⁷, J. Qian [ID](#)¹⁰⁶, D. Qichen [ID](#)¹⁰¹,
 Y. Qin [ID](#)¹⁰¹, T. Qiu [ID](#)⁵², A. Quadt [ID](#)⁵⁵, M. Queitsch-Maitland [ID](#)¹⁰¹, G. Quetant [ID](#)⁵⁶,
 R.P. Quinn [ID](#)¹⁶⁴, G. Rabanal Bolanos [ID](#)⁶¹, D. Rafanoharana [ID](#)⁵⁴, F. Ragusa [ID](#)^{71a,71b},
 J.L. Rainbolt [ID](#)³⁹, J.A. Raine [ID](#)⁵⁶, S. Rajagopalan [ID](#)²⁹, E. Ramakoti [ID](#)³⁷, K. Ran [ID](#)^{48,14e},
 N.P. Rapheeha [ID](#)^{33g}, H. Rasheed [ID](#)^{27b}, V. Raskina [ID](#)¹²⁷, D.F. Rassloff [ID](#)^{63a}, S. Rave [ID](#)¹⁰⁰,
 B. Ravina [ID](#)⁵⁵, I. Ravinovich [ID](#)¹⁶⁹, M. Raymond [ID](#)³⁶, A.L. Read [ID](#)¹²⁵, N.P. Readioff [ID](#)¹³⁹,
 D.M. Rebutzi [ID](#)^{73a,73b}, G. Redlinger [ID](#)²⁹, A.S. Reed [ID](#)¹¹⁰, K. Reeves [ID](#)²⁶, J.A. Reidelsturz [ID](#)^{171,aa},
 D. Reikher [ID](#)¹⁵¹, A. Rej [ID](#)^{49,z}, C. Rembser [ID](#)³⁶, A. Renardi [ID](#)⁴⁸, M. Renda [ID](#)^{27b}, M.B. Rendel¹¹⁰,
 F. Renner [ID](#)⁴⁸, A.G. Rennie [ID](#)¹⁶⁰, A.L. Rescia [ID](#)⁴⁸, S. Resconi [ID](#)^{71a}, M. Ressegotti [ID](#)^{57b,57a},
 S. Rettie [ID](#)³⁶, J.G. Reyes Rivera [ID](#)¹⁰⁷, E. Reynolds [ID](#)^{17a}, O.L. Rezanova [ID](#)³⁷, P. Reznicek [ID](#)¹³³,
 N. Ribaric [ID](#)⁹¹, E. Ricci [ID](#)^{78a,78b}, R. Richter [ID](#)¹¹⁰, S. Richter [ID](#)^{47a,47b}, E. Richter-Was [ID](#)^{86b},
 M. Ridel [ID](#)¹²⁷, S. Ridouani [ID](#)^{35d}, P. Rieck [ID](#)¹¹⁷, P. Riedler [ID](#)³⁶, E.M. Riefel [ID](#)^{47a,47b}, J.O. Rieger¹¹⁴,
 M. Rijssenbeek [ID](#)¹⁴⁵, A. Rimoldi [ID](#)^{73a,73b}, M. Rimoldi [ID](#)³⁶, L. Rinaldi [ID](#)^{23b,23a}, T.T. Rinn [ID](#)²⁹,
 M.P. Rinnagel [ID](#)¹⁰⁹, G. Ripellino [ID](#)¹⁶¹, I. Riu [ID](#)¹³, P. Rivadeneira [ID](#)⁴⁸, J.C. Rivera Vergara [ID](#)¹⁶⁵,
 F. Rizatdinova [ID](#)¹²¹, E. Rizvi [ID](#)⁹⁴, B.A. Roberts [ID](#)¹⁶⁷, B.R. Roberts [ID](#)^{17a}, S.H. Robertson [ID](#)^{104,ai},
 D. Robinson [ID](#)³², C.M. Robles Gajardo^{137f}, M. Robles Manzano [ID](#)¹⁰⁰, A. Robson [ID](#)⁵⁹,
 A. Rocchi [ID](#)^{76a,76b}, C. Roda [ID](#)^{74a,74b}, S. Rodriguez Bosca [ID](#)^{63a}, Y. Rodriguez Garcia [ID](#)^{22a},
 A. Rodriguez Rodriguez [ID](#)⁵⁴, A.M. Rodríguez Vera [ID](#)^{156b}, S. Roe³⁶, J.T. Roemer [ID](#)¹⁶⁰,
 A.R. Roepe-Gier [ID](#)¹³⁶, J. Roggel [ID](#)¹⁷¹, O. Røhne [ID](#)¹²⁵, R.A. Rojas [ID](#)¹⁰³, C.P.A. Roland [ID](#)¹²⁷,
 J. Roloff [ID](#)²⁹, A. Romaniouk [ID](#)³⁷, E. Romano [ID](#)^{73a,73b}, M. Romano [ID](#)^{23b},
 A.C. Romero Hernandez [ID](#)¹⁶², N. Rompotis [ID](#)⁹², L. Roos [ID](#)¹²⁷, S. Rosati [ID](#)^{75a}, B.J. Rosser [ID](#)³⁹,

E. Rossi [ID](#)¹²⁶, E. Rossi [ID](#)^{72a,72b}, L.P. Rossi [ID](#)^{57b}, L. Rossini [ID](#)⁵⁴, R. Rosten [ID](#)¹¹⁹, M. Rotaru [ID](#)^{27b},
 B. Rottler [ID](#)⁵⁴, C. Rougier [ID](#)^{102,an}, D. Rousseau [ID](#)⁶⁶, D. Rouso [ID](#)³², A. Roy [ID](#)¹⁶²,
 S. Roy-Garand [ID](#)¹⁵⁵, A. Rozanov [ID](#)¹⁰², Y. Rozen [ID](#)¹⁵⁰, X. Ruan [ID](#)^{33g}, A. Rubio Jimenez [ID](#)¹⁶³,
 A.J. Ruby [ID](#)⁹², V.H. Ruelas Rivera [ID](#)¹⁸, T.A. Ruggeri [ID](#)¹, A. Ruggiero [ID](#)¹²⁶, A. Ruiz-Martinez [ID](#)¹⁶³,
 A. Rummler [ID](#)³⁶, Z. Rurikova [ID](#)⁵⁴, N.A. Rusakovich [ID](#)³⁸, H.L. Russell [ID](#)¹⁶⁵, G. Russo [ID](#)^{75a,75b},
 J.P. Rutherford [ID](#)⁷, S. Rutherford Colmenares [ID](#)³², K. Rybacki⁹¹, M. Rybar [ID](#)¹³³, E.B. Rye [ID](#)¹²⁵,
 A. Ryzhov [ID](#)⁴⁴, J.A. Sabater Iglesias [ID](#)⁵⁶, P. Sabatini [ID](#)¹⁶³, L. Sabetta [ID](#)^{75a,75b},
 H.F-W. Sadrozinski [ID](#)¹³⁶, F. Safai Tehrani [ID](#)^{75a}, B. Safarzadeh Samani [ID](#)¹³⁴, M. Safdari [ID](#)¹⁴³,
 S. Saha [ID](#)¹⁶⁵, M. Sahinsoy [ID](#)¹¹⁰, M. Saimpert [ID](#)¹³⁵, M. Saito [ID](#)¹⁵³, T. Saito [ID](#)¹⁵³, D. Salamani [ID](#)³⁶,
 A. Salnikov [ID](#)¹⁴³, J. Salt [ID](#)¹⁶³, A. Salvador Salas [ID](#)¹⁵¹, D. Salvatore [ID](#)^{43b,43a}, F. Salvatore [ID](#)¹⁴⁶,
 A. Salzburger [ID](#)³⁶, D. Sammel [ID](#)⁵⁴, D. Sampsonidis [ID](#)^{152,f}, D. Sampsonidou [ID](#)¹²³, J. Sánchez [ID](#)¹⁶³,
 A. Sanchez Pineda [ID](#)⁴, V. Sanchez Sebastian [ID](#)¹⁶³, H. Sandaker [ID](#)¹²⁵, C.O. Sander [ID](#)⁴⁸,
 J.A. Sandesara [ID](#)¹⁰³, M. Sandhoff [ID](#)¹⁷¹, C. Sandoval [ID](#)^{22b}, D.P.C. Sankey [ID](#)¹³⁴, T. Sano [ID](#)⁸⁸,
 A. Sansoni [ID](#)⁵³, L. Santi [ID](#)^{75a,75b}, C. Santoni [ID](#)⁴⁰, H. Santos [ID](#)^{130a,130b}, S.N. Santpur [ID](#)^{17a},
 A. Santra [ID](#)¹⁶⁹, K.A. Saoucha [ID](#)^{116b}, J.G. Saraiva [ID](#)^{130a,130d}, J. Sardain [ID](#)⁷, O. Sasaki [ID](#)⁸⁴,
 K. Sato [ID](#)¹⁵⁷, C. Sauer^{63b}, F. Sauerburger [ID](#)⁵⁴, E. Sauvan [ID](#)⁴, P. Savard [ID](#)^{155,aw}, R. Sawada [ID](#)¹⁵³,
 C. Sawyer [ID](#)¹³⁴, L. Sawyer [ID](#)⁹⁷, I. Sayago Galvan¹⁶³, C. Sbarra [ID](#)^{23b}, A. Sbrizzi [ID](#)^{23b,23a},
 T. Scanlon [ID](#)⁹⁶, J. Schaarschmidt [ID](#)¹³⁸, P. Schacht [ID](#)¹¹⁰, U. Schäfer [ID](#)¹⁰⁰, A.C. Schaffer [ID](#)^{66,44},
 D. Schaile [ID](#)¹⁰⁹, R.D. Schamberger [ID](#)¹⁴⁵, C. Scharf [ID](#)¹⁸, M.M. Schefer [ID](#)¹⁹, V.A. Schegelsky [ID](#)³⁷,
 D. Scheirich [ID](#)¹³³, F. Schenck [ID](#)¹⁸, M. Schernau [ID](#)¹⁶⁰, C. Scheulen [ID](#)⁵⁵, C. Schiavi [ID](#)^{57b,57a},
 E.J. Schioppa [ID](#)^{70a,70b}, M. Schioppa [ID](#)^{43b,43a}, B. Schlag [ID](#)^{143,t}, K.E. Schleicher [ID](#)⁵⁴, S. Schlenker [ID](#)³⁶,
 J. Schmeing [ID](#)¹⁷¹, M.A. Schmidt [ID](#)¹⁷¹, K. Schmieden [ID](#)¹⁰⁰, C. Schmitt [ID](#)¹⁰⁰, N. Schmitt [ID](#)¹⁰⁰,
 S. Schmitt [ID](#)⁴⁸, L. Schoeffel [ID](#)¹³⁵, A. Schoening [ID](#)^{63b}, P.G. Scholer [ID](#)⁵⁴, E. Schopf [ID](#)¹²⁶,
 M. Schott [ID](#)¹⁰⁰, J. Schovancova [ID](#)³⁶, S. Schramm [ID](#)⁵⁶, F. Schroeder [ID](#)¹⁷¹, T. Schroer [ID](#)⁵⁶,
 H-C. Schultz-Coulon [ID](#)^{63a}, M. Schumacher [ID](#)⁵⁴, B.A. Schumm [ID](#)¹³⁶, Ph. Schune [ID](#)¹³⁵,
 A.J. Schuy [ID](#)¹³⁸, H.R. Schwartz [ID](#)¹³⁶, A. Schwartzman [ID](#)¹⁴³, T.A. Schwarz [ID](#)¹⁰⁶,
 Ph. Schwemling [ID](#)¹³⁵, R. Schwienhorst [ID](#)¹⁰⁷, A. Sciandra [ID](#)¹³⁶, G. Sciolla [ID](#)²⁶, F. Scuri [ID](#)^{74a},
 C.D. Sebastiani [ID](#)⁹², K. Sedlaczek [ID](#)¹¹⁵, P. Seema [ID](#)¹⁸, S.C. Seidel [ID](#)¹¹², A. Seiden [ID](#)¹³⁶,
 B.D. Seidlitz [ID](#)⁴¹, C. Seitz [ID](#)⁴⁸, J.M. Seixas [ID](#)^{83b}, G. Sekhniaidze [ID](#)^{72a}, S.J. Sekula [ID](#)⁴⁴,
 L. Selem [ID](#)⁶⁰, N. Semprini-Cesari [ID](#)^{23b,23a}, D. Sengupta [ID](#)⁵⁶, V. Senthilkumar [ID](#)¹⁶³, L. Serin [ID](#)⁶⁶,
 L. Serkin [ID](#)^{69a,69b}, M. Sessa [ID](#)^{76a,76b}, H. Severini [ID](#)¹²⁰, F. Sforza [ID](#)^{57b,57a}, A. Sfyrta [ID](#)⁵⁶,
 E. Shabalina [ID](#)⁵⁵, R. Shaheen [ID](#)¹⁴⁴, J.D. Shahinian [ID](#)¹²⁸, D. Shaked Renous [ID](#)¹⁶⁹, L.Y. Shan [ID](#)^{14a},
 M. Shapiro [ID](#)^{17a}, A. Sharma [ID](#)³⁶, A.S. Sharma [ID](#)¹⁶⁴, P. Sharma [ID](#)⁸⁰, S. Sharma [ID](#)⁴⁸,
 P.B. Shatalov [ID](#)³⁷, K. Shaw [ID](#)¹⁴⁶, S.M. Shaw [ID](#)¹⁰¹, A. Shcherbakova [ID](#)³⁷, Q. Shen [ID](#)^{62c,5},
 P. Sherwood [ID](#)⁹⁶, L. Shi [ID](#)⁹⁶, X. Shi [ID](#)^{14a}, C.O. Shimmin [ID](#)¹⁷², J.D. Shinner [ID](#)⁹⁵, I.P.J. Shipsey [ID](#)¹²⁶,
 S. Shirabe [ID](#)^{56,j}, M. Shiyakova [ID](#)^{38,ag}, J. Shlomi [ID](#)¹⁶⁹, M.J. Shochet [ID](#)³⁹, J. Shojaii [ID](#)¹⁰⁵,
 D.R. Shope [ID](#)¹²⁵, B. Shrestha [ID](#)¹²⁰, S. Shrestha [ID](#)^{119,ba}, E.M. Shrif [ID](#)^{33g}, M.J. Shroff [ID](#)¹⁶⁵,
 P. Sicho [ID](#)¹³¹, A.M. Sickles [ID](#)¹⁶², E. Sideras Haddad [ID](#)^{33g}, A. Sidoti [ID](#)^{23b}, F. Siegert [ID](#)⁵⁰,
 Dj. Sijacki [ID](#)¹⁵, R. Sikora [ID](#)^{86a}, F. Sili [ID](#)⁹⁰, J.M. Silva [ID](#)²⁰, M.V. Silva Oliveira [ID](#)²⁹,
 S.B. Silverstein [ID](#)^{47a}, S. Simion⁶⁶, R. Simoniello [ID](#)³⁶, E.L. Simpson [ID](#)⁵⁹, H. Simpson [ID](#)¹⁴⁶,
 L.R. Simpson [ID](#)¹⁰⁶, N.D. Simpson⁹⁸, S. Simsek [ID](#)⁸², S. Sindhu [ID](#)⁵⁵, P. Sinervo [ID](#)¹⁵⁵, S. Singh [ID](#)¹⁵⁵,
 S. Sinha [ID](#)⁴⁸, S. Sinha [ID](#)¹⁰¹, M. Sioli [ID](#)^{23b,23a}, I. Siral [ID](#)³⁶, E. Sitnikova [ID](#)⁴⁸, S.Yu. Sivoklov [ID](#)^{37,*},
 J. Sjölin [ID](#)^{47a,47b}, A. Skaf [ID](#)⁵⁵, E. Skorda [ID](#)^{20,ar}, P. Skubic [ID](#)¹²⁰, M. Slawinska [ID](#)⁸⁷, V. Smakhtin¹⁶⁹,

B.H. Smart [ID](#)¹³⁴, J. Smiesko [ID](#)³⁶, S.Yu. Smirnov [ID](#)³⁷, Y. Smirnov [ID](#)³⁷, L.N. Smirnova [ID](#)^{37,a}, O. Smirnova [ID](#)⁹⁸, A.C. Smith [ID](#)⁴¹, E.A. Smith [ID](#)³⁹, H.A. Smith [ID](#)¹²⁶, J.L. Smith [ID](#)⁹², R. Smith [ID](#)¹⁴³, M. Smizanska [ID](#)⁹¹, K. Smolek [ID](#)¹³², A.A. Snesev [ID](#)³⁷, S.R. Snider [ID](#)¹⁵⁵, H.L. Snoek [ID](#)¹¹⁴, S. Snyder [ID](#)²⁹, R. Sobie [ID](#)^{165,ai}, A. Soffer [ID](#)¹⁵¹, C.A. Solans Sanchez [ID](#)³⁶, E.Yu. Soldatov [ID](#)³⁷, U. Soldevila [ID](#)¹⁶³, A.A. Solodkov [ID](#)³⁷, S. Solomon [ID](#)²⁶, A. Soloshenko [ID](#)³⁸, K. Solovieva [ID](#)⁵⁴, O.V. Solovyanov [ID](#)⁴⁰, V. Solovyev [ID](#)³⁷, P. Sommer [ID](#)³⁶, A. Sonay [ID](#)¹³, W.Y. Song [ID](#)^{156b}, J.M. Sonneveld [ID](#)¹¹⁴, A. Sopczak [ID](#)¹³², A.L. Sopio [ID](#)⁹⁶, F. Sopkova [ID](#)^{28b}, I.R. Sotarriva Alvarez [ID](#)¹⁵⁴, V. Sothilingam [ID](#)^{63a}, S. Sottocornola [ID](#)⁶⁸, R. Soualah [ID](#)^{116b}, Z. Soumami [ID](#)^{35e}, D. South [ID](#)⁴⁸, N. Soybelman [ID](#)¹⁶⁹, S. Spagnolo [ID](#)^{70a,70b}, M. Spalla [ID](#)¹¹⁰, D. Sperlich [ID](#)⁵⁴, G. Spigo [ID](#)³⁶, S. Spinali [ID](#)⁹¹, D.P. Spiteri [ID](#)⁵⁹, M. Spousta [ID](#)¹³³, E.J. Staats [ID](#)³⁴, A. Stabile [ID](#)^{71a,71b}, R. Stamen [ID](#)^{63a}, A. Stampekis [ID](#)²⁰, M. Standke [ID](#)²⁴, E. Stanecka [ID](#)⁸⁷, M.V. Stange [ID](#)⁵⁰, B. Stanislaus [ID](#)^{17a}, M.M. Stanitzki [ID](#)⁴⁸, B. Stapf [ID](#)⁴⁸, E.A. Starchenko [ID](#)³⁷, G.H. Stark [ID](#)¹³⁶, J. Stark [ID](#)^{102,an}, D.M. Starko [ID](#)^{156b}, P. Staroba [ID](#)¹³¹, P. Starovoitov [ID](#)^{63a}, S. Stärz [ID](#)¹⁰⁴, R. Staszewski [ID](#)⁸⁷, G. Stavropoulos [ID](#)⁴⁶, J. Steentoft [ID](#)¹⁶¹, P. Steinberg [ID](#)²⁹, B. Stelzer [ID](#)^{142,156a}, H.J. Stelzer [ID](#)¹²⁹, O. Stelzer-Chilton [ID](#)^{156a}, H. Stenzel [ID](#)⁵⁸, T.J. Stevenson [ID](#)¹⁴⁶, G.A. Stewart [ID](#)³⁶, J.R. Stewart [ID](#)¹²¹, M.C. Stockton [ID](#)³⁶, G. Stoicea [ID](#)^{27b}, M. Stolarski [ID](#)^{130a}, S. Stonjek [ID](#)¹¹⁰, A. Straessner [ID](#)⁵⁰, J. Strandberg [ID](#)¹⁴⁴, S. Strandberg [ID](#)^{47a,47b}, M. Stratmann [ID](#)¹⁷¹, M. Strauss [ID](#)¹²⁰, T. Strebler [ID](#)¹⁰², P. Strizenc [ID](#)^{28b}, R. Ströhmer [ID](#)¹⁶⁶, D.M. Strom [ID](#)¹²³, L.R. Strom [ID](#)⁴⁸, R. Stroynowski [ID](#)⁴⁴, A. Strubig [ID](#)^{47a,47b}, S.A. Stucci [ID](#)²⁹, B. Stugu [ID](#)¹⁶, J. Stupak [ID](#)¹²⁰, N.A. Styles [ID](#)⁴⁸, D. Su [ID](#)¹⁴³, S. Su [ID](#)^{62a}, W. Su [ID](#)^{62d}, X. Su [ID](#)^{62a,66}, K. Sugizaki [ID](#)¹⁵³, V.V. Sulin [ID](#)³⁷, M.J. Sullivan [ID](#)⁹², D.M.S. Sultan [ID](#)^{78a,78b}, L. Sultanaliyeva [ID](#)³⁷, S. Sultansoy [ID](#)^{3b}, T. Sumida [ID](#)⁸⁸, S. Sun [ID](#)¹⁰⁶, S. Sun [ID](#)¹⁷⁰, O. Sunneborn Gudnadottir [ID](#)¹⁶¹, N. Sur [ID](#)¹⁰², M.R. Sutton [ID](#)¹⁴⁶, H. Suzuki [ID](#)¹⁵⁷, M. Svatos [ID](#)¹³¹, M. Swiatlowski [ID](#)^{156a}, T. Swirski [ID](#)¹⁶⁶, I. Sykora [ID](#)^{28a}, M. Sykora [ID](#)¹³³, T. Sykora [ID](#)¹³³, D. Ta [ID](#)¹⁰⁰, K. Tackmann [ID](#)^{48,ae}, A. Taffard [ID](#)¹⁶⁰, R. Tafirout [ID](#)^{156a}, J.S. Tafoya Vargas [ID](#)⁶⁶, E.P. Takeva [ID](#)⁵², Y. Takubo [ID](#)⁸⁴, M. Talby [ID](#)¹⁰², A.A. Talyshev [ID](#)³⁷, K.C. Tam [ID](#)^{64b}, N.M. Tamir [ID](#)¹⁵¹, A. Tanaka [ID](#)¹⁵³, J. Tanaka [ID](#)¹⁵³, R. Tanaka [ID](#)⁶⁶, M. Tanasini [ID](#)^{57b,57a}, Z. Tao [ID](#)¹⁶⁴, S. Tapia Araya [ID](#)^{137f}, S. Tapprogge [ID](#)¹⁰⁰, A. Tarek Abouelfadl Mohamed [ID](#)¹⁰⁷, S. Tarem [ID](#)¹⁵⁰, K. Tariq [ID](#)^{14a}, G. Tarna [ID](#)^{102,27b}, G.F. Tartarelli [ID](#)^{71a}, P. Tas [ID](#)¹³³, M. Tasevsky [ID](#)¹³¹, E. Tassi [ID](#)^{43b,43a}, A.C. Tate [ID](#)¹⁶², G. Tateno [ID](#)¹⁵³, Y. Tayalati [ID](#)^{35e,ah}, G.N. Taylor [ID](#)¹⁰⁵, W. Taylor [ID](#)^{156b}, A.S. Tee [ID](#)¹⁷⁰, R. Teixeira De Lima [ID](#)¹⁴³, P. Teixeira-Dias [ID](#)⁹⁵, J.J. Teoh [ID](#)¹⁵⁵, K. Terashi [ID](#)¹⁵³, J. Terron [ID](#)⁹⁹, S. Terzo [ID](#)¹³, M. Testa [ID](#)⁵³, R.J. Teuscher [ID](#)^{155,ai}, A. Thaler [ID](#)⁷⁹, O. Theiner [ID](#)⁵⁶, N. Themistokleous [ID](#)⁵², T. Theveneaux-Pelzer [ID](#)¹⁰², O. Thielmann [ID](#)¹⁷¹, D.W. Thomas [ID](#)⁹⁵, J.P. Thomas [ID](#)²⁰, E.A. Thompson [ID](#)^{17a}, P.D. Thompson [ID](#)²⁰, E. Thomson [ID](#)¹²⁸, Y. Tian [ID](#)⁵⁵, V. Tikhomirov [ID](#)^{37,a}, Yu.A. Tikhonov [ID](#)³⁷, S. Timoshenko [ID](#)³⁷, D. Timoshyn [ID](#)¹³³, E.X.L. Ting [ID](#)¹, P. Tipton [ID](#)¹⁷², S.H. Tlou [ID](#)^{33g}, A. Thourji [ID](#)⁴⁰, K. Todome [ID](#)¹⁵⁴, S. Todorova-Nova [ID](#)¹³³, S. Todt [ID](#)⁵⁰, M. Togawa [ID](#)⁸⁴, J. Tojo [ID](#)⁸⁹, S. Tokár [ID](#)^{28a}, K. Tokushuku [ID](#)⁸⁴, O. Toldaiev [ID](#)⁶⁸, R. Tombs [ID](#)³², M. Tomoto [ID](#)^{84,111}, L. Tompkins [ID](#)^{143,t}, K.W. Topolnicki [ID](#)^{86b}, E. Torrence [ID](#)¹²³, H. Torres [ID](#)^{102,an}, E. Torró Pastor [ID](#)¹⁶³, M. Toscani [ID](#)³⁰, C. Toscirci [ID](#)³⁹, M. Tost [ID](#)¹¹, D.R. Tovey [ID](#)¹³⁹, A. Traeet [ID](#)¹⁶, I.S. Trandafir [ID](#)^{27b}, T. Trefzger [ID](#)¹⁶⁶, A. Tricoli [ID](#)²⁹, I.M. Trigger [ID](#)^{156a}, S. Trincaz-Duvold [ID](#)¹²⁷, D.A. Trischuk [ID](#)²⁶, B. Trocme [ID](#)⁶⁰, C. Troncon [ID](#)^{71a}, L. Truong [ID](#)^{33c}, M. Trzebinski [ID](#)⁸⁷, A. Trzupek [ID](#)⁸⁷, F. Tsai [ID](#)¹⁴⁵, M. Tsai [ID](#)¹⁰⁶, A. Tsiamis [ID](#)^{152,f}, P.V. Tsiarehka [ID](#)³⁷, S. Tsigaridas [ID](#)^{156a}, A. Tsirigotis [ID](#)^{152,ac}, V. Tsiskaridze [ID](#)¹⁵⁵, E.G. Tskhadadze [ID](#)^{149a},

M. Tsopoulou [ID](#)^{152,f}, Y. Tsujikawa [ID](#)⁸⁸, I.I. Tsukerman [ID](#)³⁷, V. Tsulaia [ID](#)^{17a}, S. Tsuno [ID](#)⁸⁴,
 O. Tsur [ID](#)¹⁵⁰, K. Tsur [ID](#)¹¹⁸, D. Tsybychev [ID](#)¹⁴⁵, Y. Tu [ID](#)^{64b}, A. Tudorache [ID](#)^{27b}, V. Tudorache [ID](#)^{27b},
 A.N. Tuna [ID](#)³⁶, S. Turchikhin [ID](#)^{57b,57a}, I. Turk Cakir [ID](#)^{3a}, R. Turra [ID](#)^{71a}, T. Turtuvshin [ID](#)^{38,aj},
 P.M. Tuts [ID](#)⁴¹, S. Tzamarias [ID](#)^{152,f}, P. Tzanis [ID](#)¹⁰, E. Tzovara [ID](#)¹⁰⁰, F. Ukegawa [ID](#)¹⁵⁷,
 P.A. Ulloa Poblete [ID](#)^{137c,137b}, E.N. Umaka [ID](#)²⁹, G. Unal [ID](#)³⁶, M. Unal [ID](#)¹¹, A. Undrus [ID](#)²⁹,
 G. Unel [ID](#)¹⁶⁰, J. Urban [ID](#)^{28b}, P. Urquijo [ID](#)¹⁰⁵, P. Urrejola [ID](#)^{137a}, G. Usai [ID](#)⁸, R. Ushioda [ID](#)¹⁵⁴,
 M. Usman [ID](#)¹⁰⁸, Z. Uysal [ID](#)^{21b}, V. Vacek [ID](#)¹³², B. Vachon [ID](#)¹⁰⁴, K.O.H. Vadla [ID](#)¹²⁵,
 T. Vafeiadis [ID](#)³⁶, A. Vaitkus [ID](#)⁹⁶, C. Valderanis [ID](#)¹⁰⁹, E. Valdes Santurio [ID](#)^{47a,47b}, M. Valente [ID](#)^{156a},
 S. Valentineti [ID](#)^{23b,23a}, A. Valero [ID](#)¹⁶³, E. Valiente Moreno [ID](#)¹⁶³, A. Vallier [ID](#)^{102,an},
 J.A. Valls Ferrer [ID](#)¹⁶³, D.R. Van Arneman [ID](#)¹¹⁴, T.R. Van Daalen [ID](#)¹³⁸, A. Van Der Graaf [ID](#)⁴⁹,
 P. Van Gemmeren [ID](#)⁶, M. Van Rijnbach [ID](#)^{125,36}, S. Van Stroud [ID](#)⁹⁶, I. Van Vulpen [ID](#)¹¹⁴,
 M. Vanadia [ID](#)^{76a,76b}, W. Vandelli [ID](#)³⁶, M. Vandenbroucke [ID](#)¹³⁵, E.R. Vandewall [ID](#)¹²¹,
 D. Vannicola [ID](#)¹⁵¹, L. Vannoli [ID](#)^{57b,57a}, R. Vari [ID](#)^{75a}, E.W. Varnes [ID](#)⁷, C. Varni [ID](#)^{17b}, T. Varol [ID](#)¹⁴⁸,
 D. Varouchas [ID](#)⁶⁶, L. Varriale [ID](#)¹⁶³, K.E. Varvell [ID](#)¹⁴⁷, M.E. Vasile [ID](#)^{27b}, L. Vaslin [ID](#)⁸⁴,
 G.A. Vasquez [ID](#)¹⁶⁵, A. Vasyukov [ID](#)³⁸, F. Vazeille [ID](#)⁴⁰, T. Vazquez Schroeder [ID](#)³⁶, J. Veatch [ID](#)³¹,
 V. Vecchio [ID](#)¹⁰¹, M.J. Veen [ID](#)¹⁰³, I. Veliscek [ID](#)¹²⁶, L.M. Veloce [ID](#)¹⁵⁵, F. Veloso [ID](#)^{130a,130c},
 S. Veneziano [ID](#)^{75a}, A. Ventura [ID](#)^{70a,70b}, S. Ventura Gonzalez [ID](#)¹³⁵, A. Verbytskyi [ID](#)¹¹⁰,
 M. Verducci [ID](#)^{74a,74b}, C. Vergis [ID](#)²⁴, M. Verissimo De Araujo [ID](#)^{83b}, W. Verkerke [ID](#)¹¹⁴,
 J.C. Vermeulen [ID](#)¹¹⁴, C. Vernieri [ID](#)¹⁴³, M. Vessella [ID](#)¹⁰³, M.C. Vetterli [ID](#)^{142,aw},
 A. Vgenopoulos [ID](#)^{152,f}, N. Viaux Maira [ID](#)^{137f}, T. Vickey [ID](#)¹³⁹, O.E. Vickey Boeriu [ID](#)¹³⁹,
 G.H.A. Viehhauser [ID](#)¹²⁶, L. Vignani [ID](#)^{63b}, M. Villa [ID](#)^{23b,23a}, M. Villaplana Perez [ID](#)¹⁶³,
 E.M. Villhauer [ID](#)⁵², E. Vilucchi [ID](#)⁵³, M.G. Vincter [ID](#)³⁴, G.S. Virdee [ID](#)²⁰, A. Vishwakarma [ID](#)⁵²,
 A. Visibile [ID](#)¹¹⁴, C. Vittori [ID](#)³⁶, I. Vivarelli [ID](#)¹⁴⁶, E. Voevodina [ID](#)¹¹⁰, F. Vogel [ID](#)¹⁰⁹, J.C. Voigt [ID](#)⁵⁰,
 P. Vokac [ID](#)¹³², Yu. Volkotrub [ID](#)^{86a}, J. Von Ahnen [ID](#)⁴⁸, E. Von Toerne [ID](#)²⁴, B. Vormwald [ID](#)³⁶,
 V. Vorobel [ID](#)¹³³, K. Vorobev [ID](#)³⁷, M. Vos [ID](#)¹⁶³, K. Voss [ID](#)¹⁴¹, J.H. Vossebeld [ID](#)⁹², M. Vozak [ID](#)¹¹⁴,
 L. Vozdecky [ID](#)⁹⁴, N. Vranjes [ID](#)¹⁵, M. Vranjes Milosavljevic [ID](#)¹⁵, M. Vreeswijk [ID](#)¹¹⁴,
 R. Vuillermet [ID](#)³⁶, O. Vujanovic [ID](#)¹⁰⁰, I. Vukotic [ID](#)³⁹, S. Wada [ID](#)¹⁵⁷, C. Wagner [ID](#)¹⁰³,
 J.M. Wagner [ID](#)^{17a}, W. Wagner [ID](#)¹⁷¹, S. Wahdan [ID](#)¹⁷¹, H. Wahlberg [ID](#)⁹⁰, M. Wakida [ID](#)¹¹¹,
 J. Walder [ID](#)¹³⁴, R. Walker [ID](#)¹⁰⁹, W. Walkowiak [ID](#)¹⁴¹, A. Wall [ID](#)¹²⁸, T. Wamorkar [ID](#)⁶,
 A.Z. Wang [ID](#)¹³⁶, C. Wang [ID](#)¹⁰⁰, C. Wang [ID](#)^{62c}, H. Wang [ID](#)^{17a}, J. Wang [ID](#)^{64a}, R.-J. Wang [ID](#)¹⁰⁰,
 R. Wang [ID](#)⁶¹, R. Wang [ID](#)⁶, S.M. Wang [ID](#)¹⁴⁸, S. Wang [ID](#)^{62b}, T. Wang [ID](#)^{62a}, W.T. Wang [ID](#)⁸⁰,
 W. Wang [ID](#)^{14a}, X. Wang [ID](#)^{14c}, X. Wang [ID](#)¹⁶², X. Wang [ID](#)^{62c}, Y. Wang [ID](#)^{62d}, Y. Wang [ID](#)^{14c},
 Z. Wang [ID](#)¹⁰⁶, Z. Wang [ID](#)^{62d,51,62c}, Z. Wang [ID](#)¹⁰⁶, A. Warburton [ID](#)¹⁰⁴, R.J. Ward [ID](#)²⁰,
 N. Warrack [ID](#)⁵⁹, A.T. Watson [ID](#)²⁰, H. Watson [ID](#)⁵⁹, M.F. Watson [ID](#)²⁰, E. Watton [ID](#)^{59,134},
 G. Watts [ID](#)¹³⁸, B.M. Waugh [ID](#)⁹⁶, C. Weber [ID](#)²⁹, H.A. Weber [ID](#)¹⁸, M.S. Weber [ID](#)¹⁹,
 S.M. Weber [ID](#)^{63a}, C. Wei [ID](#)^{62a}, Y. Wei [ID](#)¹²⁶, A.R. Weidberg [ID](#)¹²⁶, E.J. Weik [ID](#)¹¹⁷,
 J. Weingarten [ID](#)⁴⁹, M. Weirich [ID](#)¹⁰⁰, C. Weiser [ID](#)⁵⁴, C.J. Wells [ID](#)⁴⁸, T. Wenaus [ID](#)²⁹,
 B. Wendland [ID](#)⁴⁹, T. Wengler [ID](#)³⁶, N.S. Wenke [ID](#)¹¹⁰, N. Wermes [ID](#)²⁴, M. Wessels [ID](#)^{63a},
 A.M. Wharton [ID](#)⁹¹, A.S. White [ID](#)⁶¹, A. White [ID](#)⁸, M.J. White [ID](#)¹, D. Whiteson [ID](#)¹⁶⁰,
 L. Wickremasinghe [ID](#)¹²⁴, W. Wiedenmann [ID](#)¹⁷⁰, C. Wiel [ID](#)⁵⁰, M. Wielers [ID](#)¹³⁴, C. Wiglesworth [ID](#)⁴²,
 D.J. Wilbern [ID](#)¹²⁰, H.G. Wilkens [ID](#)³⁶, D.M. Williams [ID](#)⁴¹, H.H. Williams [ID](#)¹²⁸, S. Williams [ID](#)³²,
 S. Willocq [ID](#)¹⁰³, B.J. Wilson [ID](#)¹⁰¹, P.J. Windischhofer [ID](#)³⁹, F.I. Winkel [ID](#)³⁰, F. Winklmeier [ID](#)¹²³,
 B.T. Winter [ID](#)⁵⁴, J.K. Winter [ID](#)¹⁰¹, M. Wittgen [ID](#)¹⁴³, M. Wobisch [ID](#)⁹⁷, Z. Wolffs [ID](#)¹¹⁴, J. Wollrath [ID](#)¹⁶⁰,

M.W. Wolter ⁸⁷, H. Wolters ^{130a,130c}, A.F. Wongel ⁴⁸, E.L. Woodward ⁴¹, S.D. Worm ⁴⁸, B.K. Wosiek ⁸⁷, K.W. Woźniak ⁸⁷, S. Wozniowski ⁵⁵, K. Wraight ⁵⁹, C. Wu ²⁰, J. Wu ^{14a,14e}, M. Wu ^{64a}, M. Wu ¹¹³, S.L. Wu ¹⁷⁰, X. Wu ⁵⁶, Y. Wu ^{62a}, Z. Wu ¹³⁵, J. Wuerzinger ^{110,au}, T.R. Wyatt ¹⁰¹, B.M. Wynne ⁵², S. Xella ⁴², L. Xia ^{14c}, M. Xia ^{14b}, J. Xiang ^{64c}, M. Xie ^{62a}, X. Xie ^{62a}, S. Xin ^{14a,14e}, A. Xiong ¹²³, J. Xiong ^{17a}, D. Xu ^{14a}, H. Xu ^{62a}, L. Xu ^{62a}, R. Xu ¹²⁸, T. Xu ¹⁰⁶, Y. Xu ^{14b}, Z. Xu ⁵², Z. Xu ^{14a}, Z. Xu ^{14c}, B. Yabsley ¹⁴⁷, S. Yacoob ^{33a}, Y. Yamaguchi ¹⁵⁴, E. Yamashita ¹⁵³, H. Yamauchi ¹⁵⁷, T. Yamazaki ^{17a}, Y. Yamazaki ⁸⁵, J. Yan ^{62c}, S. Yan ¹²⁶, Z. Yan ²⁵, H.J. Yang ^{62c,62d}, H.T. Yang ^{62a}, S. Yang ^{62a}, T. Yang ^{64c}, X. Yang ³⁶, X. Yang ^{14a}, Y. Yang ⁴⁴, Y. Yang ^{62a}, Z. Yang ^{62a}, W-M. Yao ^{17a}, Y.C. Yap ⁴⁸, H. Ye ^{14c}, H. Ye ⁵⁵, J. Ye ^{14a}, S. Ye ²⁹, X. Ye ^{62a}, Y. Yeh ⁹⁶, I. Yeletsikh ³⁸, B.K. Yeo ^{17b}, M.R. Yexley ⁹⁶, P. Yin ⁴¹, K. Yorita ¹⁶⁸, S. Younas ^{27b}, C.J.S. Young ³⁶, C. Young ¹⁴³, C. Yu ^{14a,14e,ay}, Y. Yu ^{62a}, M. Yuan ¹⁰⁶, R. Yuan ^{62b}, L. Yue ⁹⁶, M. Zaazoua ^{62a}, B. Zabinski ⁸⁷, E. Zaid ⁵², T. Zakareishvili ^{149b}, N. Zakharchuk ³⁴, S. Zambito ⁵⁶, J.A. Zamora Saa ^{137d,137b}, J. Zang ¹⁵³, D. Zanzi ⁵⁴, O. Zaplatilek ¹³², C. Zeitnitz ¹⁷¹, H. Zeng ^{14a}, J.C. Zeng ¹⁶², D.T. Zenger Jr ²⁶, O. Zenin ³⁷, T. Ženiš ^{28a}, S. Zenz ⁹⁴, S. Zerradi ^{35a}, D. Zerwas ⁶⁶, M. Zhai ^{14a,14e}, B. Zhang ^{14c}, D.F. Zhang ¹³⁹, J. Zhang ^{62b}, J. Zhang ⁶, K. Zhang ^{14a,14e}, L. Zhang ^{14c}, P. Zhang ^{14a,14e}, R. Zhang ¹⁷⁰, S. Zhang ¹⁰⁶, S. Zhang ⁴⁴, T. Zhang ¹⁵³, X. Zhang ^{62c}, X. Zhang ^{62b}, Y. Zhang ^{62c,5}, Y. Zhang ⁹⁶, Y. Zhang ^{14c}, Z. Zhang ^{17a}, Z. Zhang ⁶⁶, H. Zhao ¹³⁸, P. Zhao ⁵¹, T. Zhao ^{62b}, Y. Zhao ¹³⁶, Z. Zhao ^{62a}, A. Zhemchugov ³⁸, J. Zheng ^{14c}, K. Zheng ¹⁶², X. Zheng ^{62a}, Z. Zheng ¹⁴³, D. Zhong ¹⁶², B. Zhou ¹⁰⁶, H. Zhou ⁷, N. Zhou ^{62c}, Y. Zhou ⁷, C.G. Zhu ^{62b}, J. Zhu ¹⁰⁶, Y. Zhu ^{62c}, Y. Zhu ^{62a}, X. Zhuang ^{14a}, K. Zhukov ³⁷, V. Zhulanov ³⁷, N.I. Zimine ³⁸, J. Zinsser ^{63b}, M. Ziolkowski ¹⁴¹, L. Živković ¹⁵, A. Zoccoli ^{23b,23a}, K. Zoch ⁶¹, T.G. Zorbas ¹³⁹, O. Zormpa ⁴⁶, W. Zou ⁴¹, L. Zwalinski ³⁶

¹ Department of Physics, University of Adelaide, Adelaide; Australia

² Department of Physics, University of Alberta, Edmonton AB; Canada

³ ^(a) Department of Physics, Ankara University, Ankara; ^(b) Division of Physics, TOBB University of Economics and Technology, Ankara; Türkiye

⁴ LAPP, Université Savoie Mont Blanc, CNRS/IN2P3, Annecy; France

⁵ APC, Université Paris Cité, CNRS/IN2P3, Paris; France

⁶ High Energy Physics Division, Argonne National Laboratory, Argonne IL; United States of America

⁷ Department of Physics, University of Arizona, Tucson AZ; United States of America

⁸ Department of Physics, University of Texas at Arlington, Arlington TX; United States of America

⁹ Physics Department, National and Kapodistrian University of Athens, Athens; Greece

¹⁰ Physics Department, National Technical University of Athens, Zografou; Greece

¹¹ Department of Physics, University of Texas at Austin, Austin TX; United States of America

¹² Institute of Physics, Azerbaijan Academy of Sciences, Baku; Azerbaijan

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

¹⁴ ^(a) Institute of High Energy Physics, Chinese Academy of Sciences, Beijing; ^(b) Physics Department, Tsinghua University, Beijing; ^(c) Department of Physics, Nanjing University, Nanjing; ^(d) School of Science, Shenzhen Campus of Sun Yat-sen University; ^(e) University of Chinese Academy of Science (UCAS), Beijing; China

¹⁵ Institute of Physics, University of Belgrade, Belgrade; Serbia

¹⁶ Department for Physics and Technology, University of Bergen, Bergen; Norway

- ¹⁷ ^(a) *Physics Division, Lawrence Berkeley National Laboratory, Berkeley CA;* ^(b) *University of California, Berkeley CA; United States of America*
- ¹⁸ *Institut für Physik, Humboldt Universität zu Berlin, Berlin; Germany*
- ¹⁹ *Albert Einstein Center for Fundamental Physics and Laboratory for High Energy Physics, University of Bern, Bern; Switzerland*
- ²⁰ *School of Physics and Astronomy, University of Birmingham, Birmingham; United Kingdom*
- ²¹ ^(a) *Department of Physics, Bogazici University, Istanbul;* ^(b) *Department of Physics Engineering, Gaziantep University, Gaziantep;* ^(c) *Department of Physics, Istanbul University, Istanbul; Türkiye*
- ²² ^(a) *Facultad de Ciencias y Centro de Investigaciones, Universidad Antonio Nariño, Bogotá;* ^(b) *Departamento de Física, Universidad Nacional de Colombia, Bogotá; Colombia*
- ²³ ^(a) *Dipartimento di Fisica e Astronomia A. Righi, Università di Bologna, Bologna;* ^(b) *INFN Sezione di Bologna; Italy*
- ²⁴ *Physikalisches Institut, Universität Bonn, Bonn; Germany*
- ²⁵ *Department of Physics, Boston University, Boston MA; United States of America*
- ²⁶ *Department of Physics, Brandeis University, Waltham MA; United States of America*
- ²⁷ ^(a) *Transilvania University of Brasov, Brasov;* ^(b) *Horia Hulubei National Institute of Physics and Nuclear Engineering, Bucharest;* ^(c) *Department of Physics, Alexandru Ioan Cuza University of Iasi, Iasi;* ^(d) *National Institute for Research and Development of Isotopic and Molecular Technologies, Physics Department, Cluj-Napoca;* ^(e) *University Politehnica Bucharest, Bucharest;* ^(f) *West University in Timisoara, Timisoara;* ^(g) *Faculty of Physics, University of Bucharest, Bucharest; Romania*
- ²⁸ ^(a) *Faculty of Mathematics, Physics and Informatics, Comenius University, Bratislava;* ^(b) *Department of Subnuclear Physics, Institute of Experimental Physics of the Slovak Academy of Sciences, Kosice; Slovak Republic*
- ²⁹ *Physics Department, Brookhaven National Laboratory, Upton NY; United States of America*
- ³⁰ *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*
- ³¹ *California State University, CA; United States of America*
- ³² *Cavendish Laboratory, University of Cambridge, Cambridge; United Kingdom*
- ³³ ^(a) *Department of Physics, University of Cape Town, Cape Town;* ^(b) *iThemba Labs, Western Cape;* ^(c) *Department of Mechanical Engineering Science, University of Johannesburg, Johannesburg;* ^(d) *National Institute of Physics, University of the Philippines Diliman (Philippines);* ^(e) *University of South Africa, Department of Physics, Pretoria;* ^(f) *University of Zululand, KwaDlangezwa;* ^(g) *School of Physics, University of the Witwatersrand, Johannesburg; South Africa*
- ³⁴ *Department of Physics, Carleton University, Ottawa ON; Canada*
- ³⁵ ^(a) *Faculté des Sciences Ain Chock, Réseau Universitaire de Physique des Hautes Energies — Université Hassan II, Casablanca;* ^(b) *Faculté des Sciences, Université Ibn-Tofail, Kénitra;* ^(c) *Faculté des Sciences Semlalia, Université Cadi Ayyad, LPHEA-Marrakech;* ^(d) *LPMR, Faculté des Sciences, Université Mohamed Premier, Oujda;* ^(e) *Faculté des sciences, Université Mohammed V, Rabat;* ^(f) *Institute of Applied Physics, Mohammed VI Polytechnic University, Ben Guerir; Morocco*
- ³⁶ *CERN, Geneva; Switzerland*
- ³⁷ *Affiliated with an institute covered by a cooperation agreement with CERN*
- ³⁸ *Affiliated with an international laboratory covered by a cooperation agreement with CERN*
- ³⁹ *Enrico Fermi Institute, University of Chicago, Chicago IL; United States of America*
- ⁴⁰ *LPC, Université Clermont Auvergne, CNRS/IN2P3, Clermont-Ferrand; France*
- ⁴¹ *Nevis Laboratory, Columbia University, Irvington NY; United States of America*
- ⁴² *Niels Bohr Institute, University of Copenhagen, Copenhagen; Denmark*
- ⁴³ ^(a) *Dipartimento di Fisica, Università della Calabria, Rende;* ^(b) *INFN Gruppo Collegato di Cosenza, Laboratori Nazionali di Frascati; Italy*
- ⁴⁴ *Physics Department, Southern Methodist University, Dallas TX; United States of America*
- ⁴⁵ *Physics Department, University of Texas at Dallas, Richardson TX; United States of America*
- ⁴⁶ *National Centre for Scientific Research “Demokritos”, Agia Paraskevi; Greece*
- ⁴⁷ ^(a) *Department of Physics, Stockholm University;* ^(b) *Oskar Klein Centre, Stockholm; Sweden*

- ⁴⁸ Deutsches Elektronen-Synchrotron DESY, Hamburg and Zeuthen; Germany
- ⁴⁹ Fakultät Physik, Technische Universität Dortmund, Dortmund; Germany
- ⁵⁰ Institut für Kern- und Teilchenphysik, Technische Universität Dresden, Dresden; Germany
- ⁵¹ Department of Physics, Duke University, Durham NC; United States of America
- ⁵² SUPA — School of Physics and Astronomy, University of Edinburgh, Edinburgh; United Kingdom
- ⁵³ INFN e Laboratori Nazionali di Frascati, Frascati; Italy
- ⁵⁴ Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Freiburg; Germany
- ⁵⁵ II. Physikalisches Institut, Georg-August-Universität Göttingen, Göttingen; Germany
- ⁵⁶ Département de Physique Nucléaire et Corpusculaire, Université de Genève, Genève; Switzerland
- ⁵⁷ ^(a) Dipartimento di Fisica, Università di Genova, Genova; ^(b) INFN Sezione di Genova; Italy
- ⁵⁸ II. Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen; Germany
- ⁵⁹ SUPA — School of Physics and Astronomy, University of Glasgow, Glasgow; United Kingdom
- ⁶⁰ LPSC, Université Grenoble Alpes, CNRS/IN2P3, Grenoble INP, Grenoble; France
- ⁶¹ Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge MA; United States of America
- ⁶² ^(a) Department of Modern Physics and State Key Laboratory of Particle Detection and Electronics, University of Science and Technology of China, Hefei; ^(b) Institute of Frontier and Interdisciplinary Science and Key Laboratory of Particle Physics and Particle Irradiation (MOE), Shandong University, Qingdao; ^(c) School of Physics and Astronomy, Shanghai Jiao Tong University, Key Laboratory for Particle Astrophysics and Cosmology (MOE), SKLPPC, Shanghai; ^(d) Tsung-Dao Lee Institute, Shanghai; China
- ⁶³ ^(a) Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Heidelberg; ^(b) Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg; Germany
- ⁶⁴ ^(a) Department of Physics, Chinese University of Hong Kong, Shatin, N.T., Hong Kong; ^(b) Department of Physics, University of Hong Kong, Hong Kong; ^(c) Department of Physics and Institute for Advanced Study, Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong; China
- ⁶⁵ Department of Physics, National Tsing Hua University, Hsinchu; Taiwan
- ⁶⁶ IJCLab, Université Paris-Saclay, CNRS/IN2P3, 91105, Orsay; France
- ⁶⁷ Centro Nacional de Microelectrónica (IMB-CNM-CSIC), Barcelona; Spain
- ⁶⁸ Department of Physics, Indiana University, Bloomington IN; United States of America
- ⁶⁹ ^(a) INFN Gruppo Collegato di Udine, Sezione di Trieste, Udine; ^(b) ICTP, Trieste; ^(c) Dipartimento Politecnico di Ingegneria e Architettura, Università di Udine, Udine; Italy
- ⁷⁰ ^(a) INFN Sezione di Lecce; ^(b) Dipartimento di Matematica e Fisica, Università del Salento, Lecce; Italy
- ⁷¹ ^(a) INFN Sezione di Milano; ^(b) Dipartimento di Fisica, Università di Milano, Milano; Italy
- ⁷² ^(a) INFN Sezione di Napoli; ^(b) Dipartimento di Fisica, Università di Napoli, Napoli; Italy
- ⁷³ ^(a) INFN Sezione di Pavia; ^(b) Dipartimento di Fisica, Università di Pavia, Pavia; Italy
- ⁷⁴ ^(a) INFN Sezione di Pisa; ^(b) Dipartimento di Fisica E. Fermi, Università di Pisa, Pisa; Italy
- ⁷⁵ ^(a) INFN Sezione di Roma; ^(b) Dipartimento di Fisica, Sapienza Università di Roma, Roma; Italy
- ⁷⁶ ^(a) INFN Sezione di Roma Tor Vergata; ^(b) Dipartimento di Fisica, Università di Roma Tor Vergata, Roma; Italy
- ⁷⁷ ^(a) INFN Sezione di Roma Tre; ^(b) Dipartimento di Matematica e Fisica, Università Roma Tre, Roma; Italy
- ⁷⁸ ^(a) INFN-TIFPA; ^(b) Università degli Studi di Trento, Trento; Italy
- ⁷⁹ Universität Innsbruck, Department of Astro and Particle Physics, Innsbruck; Austria
- ⁸⁰ University of Iowa, Iowa City IA; United States of America
- ⁸¹ Department of Physics and Astronomy, Iowa State University, Ames IA; United States of America
- ⁸² Istinye University, Sariyer, Istanbul; Türkiye
- ⁸³ ^(a) Departamento de Engenharia Elétrica, Universidade Federal de Juiz de Fora (UFJF), Juiz de Fora; ^(b) Universidade Federal do Rio De Janeiro COPPE/EE/IF, Rio de Janeiro; ^(c) Instituto de Física, Universidade de São Paulo, São Paulo; ^(d) Rio de Janeiro State University, Rio de Janeiro; Brazil
- ⁸⁴ KEK, High Energy Accelerator Research Organization, Tsukuba; Japan
- ⁸⁵ Graduate School of Science, Kobe University, Kobe; Japan

- ⁸⁶ ^(a) AGH University of Krakow, Faculty of Physics and Applied Computer Science, Krakow; ^(b) Marian Smoluchowski Institute of Physics, Jagiellonian University, Krakow; Poland
- ⁸⁷ Institute of Nuclear Physics Polish Academy of Sciences, Krakow; Poland
- ⁸⁸ Faculty of Science, Kyoto University, Kyoto; Japan
- ⁸⁹ Research Center for Advanced Particle Physics and Department of Physics, Kyushu University, Fukuoka; Japan
- ⁹⁰ Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata; Argentina
- ⁹¹ Physics Department, Lancaster University, Lancaster; United Kingdom
- ⁹² Oliver Lodge Laboratory, University of Liverpool, Liverpool; United Kingdom
- ⁹³ Department of Experimental Particle Physics, Jožef Stefan Institute and Department of Physics, University of Ljubljana, Ljubljana; Slovenia
- ⁹⁴ School of Physics and Astronomy, Queen Mary University of London, London; United Kingdom
- ⁹⁵ Department of Physics, Royal Holloway University of London, Egham; United Kingdom
- ⁹⁶ Department of Physics and Astronomy, University College London, London; United Kingdom
- ⁹⁷ Louisiana Tech University, Ruston LA; United States of America
- ⁹⁸ Fysiska institutionen, Lunds universitet, Lund; Sweden
- ⁹⁹ Departamento de Física Teórica C-15 and CIAFF, Universidad Autónoma de Madrid, Madrid; Spain
- ¹⁰⁰ Institut für Physik, Universität Mainz, Mainz; Germany
- ¹⁰¹ School of Physics and Astronomy, University of Manchester, Manchester; United Kingdom
- ¹⁰² CPPM, Aix-Marseille Université, CNRS/IN2P3, Marseille; France
- ¹⁰³ Department of Physics, University of Massachusetts, Amherst MA; United States of America
- ¹⁰⁴ Department of Physics, McGill University, Montreal QC; Canada
- ¹⁰⁵ School of Physics, University of Melbourne, Victoria; Australia
- ¹⁰⁶ Department of Physics, University of Michigan, Ann Arbor MI; United States of America
- ¹⁰⁷ Department of Physics and Astronomy, Michigan State University, East Lansing MI; United States of America
- ¹⁰⁸ Group of Particle Physics, University of Montreal, Montreal QC; Canada
- ¹⁰⁹ Fakultät für Physik, Ludwig-Maximilians-Universität München, München; Germany
- ¹¹⁰ Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), München; Germany
- ¹¹¹ Graduate School of Science and Kobayashi-Maskawa Institute, Nagoya University, Nagoya; Japan
- ¹¹² Department of Physics and Astronomy, University of New Mexico, Albuquerque NM; United States of America
- ¹¹³ Institute for Mathematics, Astrophysics and Particle Physics, Radboud University/Nikhef, Nijmegen; Netherlands
- ¹¹⁴ Nikhef National Institute for Subatomic Physics and University of Amsterdam, Amsterdam; Netherlands
- ¹¹⁵ Department of Physics, Northern Illinois University, DeKalb IL; United States of America
- ¹¹⁶ ^(a) New York University Abu Dhabi, Abu Dhabi; ^(b) University of Sharjah, Sharjah; United Arab Emirates
- ¹¹⁷ Department of Physics, New York University, New York NY; United States of America
- ¹¹⁸ Ochanomizu University, Otsuka, Bunkyo-ku, Tokyo; Japan
- ¹¹⁹ Ohio State University, Columbus OH; United States of America
- ¹²⁰ Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman OK; United States of America
- ¹²¹ Department of Physics, Oklahoma State University, Stillwater OK; United States of America
- ¹²² Palacký University, Joint Laboratory of Optics, Olomouc; Czech Republic
- ¹²³ Institute for Fundamental Science, University of Oregon, Eugene, OR; United States of America
- ¹²⁴ Graduate School of Science, Osaka University, Osaka; Japan
- ¹²⁵ Department of Physics, University of Oslo, Oslo; Norway
- ¹²⁶ Department of Physics, Oxford University, Oxford; United Kingdom
- ¹²⁷ LPNHE, Sorbonne Université, Université Paris Cité, CNRS/IN2P3, Paris; France
- ¹²⁸ Department of Physics, University of Pennsylvania, Philadelphia PA; United States of America
- ¹²⁹ Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh PA; United States of America

- ¹³⁰ ^(a) *Laboratório de Instrumentação e Física Experimental de Partículas — LIP, Lisboa;* ^(b) *Departamento de Física, Faculdade de Ciências, Universidade de Lisboa, Lisboa;* ^(c) *Departamento de Física, Universidade de Coimbra, Coimbra;* ^(d) *Centro de Física Nuclear da Universidade de Lisboa, Lisboa;* ^(e) *Departamento de Física, Universidade do Minho, Braga;* ^(f) *Departamento de Física Teórica y del Cosmos, Universidad de Granada, Granada (Spain);* ^(g) *Departamento de Física, Instituto Superior Técnico, Universidade de Lisboa, Lisboa; Portugal*
- ¹³¹ *Institute of Physics of the Czech Academy of Sciences, Prague; Czech Republic*
- ¹³² *Czech Technical University in Prague, Prague; Czech Republic*
- ¹³³ *Charles University, Faculty of Mathematics and Physics, Prague; Czech Republic*
- ¹³⁴ *Particle Physics Department, Rutherford Appleton Laboratory, Didcot; United Kingdom*
- ¹³⁵ *IRFU, CEA, Université Paris-Saclay, Gif-sur-Yvette; France*
- ¹³⁶ *Santa Cruz Institute for Particle Physics, University of California Santa Cruz, Santa Cruz CA; United States of America*
- ¹³⁷ ^(a) *Departamento de Física, Pontificia Universidad Católica de Chile, Santiago;* ^(b) *Millennium Institute for Subatomic physics at high energy frontier (SAPHIR), Santiago;* ^(c) *Instituto de Investigación Multidisciplinario en Ciencia y Tecnología, y Departamento de Física, Universidad de La Serena;* ^(d) *Universidad Andres Bello, Department of Physics, Santiago;* ^(e) *Instituto de Alta Investigación, Universidad de Tarapacá, Arica;* ^(f) *Departamento de Física, Universidad Técnica Federico Santa María, Valparaíso; Chile*
- ¹³⁸ *Department of Physics, University of Washington, Seattle WA; United States of America*
- ¹³⁹ *Department of Physics and Astronomy, University of Sheffield, Sheffield; United Kingdom*
- ¹⁴⁰ *Department of Physics, Shinshu University, Nagano; Japan*
- ¹⁴¹ *Department Physik, Universität Siegen, Siegen; Germany*
- ¹⁴² *Department of Physics, Simon Fraser University, Burnaby BC; Canada*
- ¹⁴³ *SLAC National Accelerator Laboratory, Stanford CA; United States of America*
- ¹⁴⁴ *Department of Physics, Royal Institute of Technology, Stockholm; Sweden*
- ¹⁴⁵ *Departments of Physics and Astronomy, Stony Brook University, Stony Brook NY; United States of America*
- ¹⁴⁶ *Department of Physics and Astronomy, University of Sussex, Brighton; United Kingdom*
- ¹⁴⁷ *School of Physics, University of Sydney, Sydney; Australia*
- ¹⁴⁸ *Institute of Physics, Academia Sinica, Taipei; Taiwan*
- ¹⁴⁹ ^(a) *E. Andronikashvili Institute of Physics, Iv. Javakishvili Tbilisi State University, Tbilisi;* ^(b) *High Energy Physics Institute, Tbilisi State University, Tbilisi;* ^(c) *University of Georgia, Tbilisi; Georgia*
- ¹⁵⁰ *Department of Physics, Technion, Israel Institute of Technology, Haifa; Israel*
- ¹⁵¹ *Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv; Israel*
- ¹⁵² *Department of Physics, Aristotle University of Thessaloniki, Thessaloniki; Greece*
- ¹⁵³ *International Center for Elementary Particle Physics and Department of Physics, University of Tokyo, Tokyo; Japan*
- ¹⁵⁴ *Department of Physics, Tokyo Institute of Technology, Tokyo; Japan*
- ¹⁵⁵ *Department of Physics, University of Toronto, Toronto ON; Canada*
- ¹⁵⁶ ^(a) *TRIUMF, Vancouver BC;* ^(b) *Department of Physics and Astronomy, York University, Toronto ON; Canada*
- ¹⁵⁷ *Division of Physics and Tomonaga Center for the History of the Universe, Faculty of Pure and Applied Sciences, University of Tsukuba, Tsukuba; Japan*
- ¹⁵⁸ *Department of Physics and Astronomy, Tufts University, Medford MA; United States of America*
- ¹⁵⁹ *United Arab Emirates University, Al Ain; United Arab Emirates*
- ¹⁶⁰ *Department of Physics and Astronomy, University of California Irvine, Irvine CA; United States of America*
- ¹⁶¹ *Department of Physics and Astronomy, University of Uppsala, Uppsala; Sweden*
- ¹⁶² *Department of Physics, University of Illinois, Urbana IL; United States of America*
- ¹⁶³ *Instituto de Física Corpuscular (IFIC), Centro Mixto Universidad de Valencia — CSIC, Valencia; Spain*
- ¹⁶⁴ *Department of Physics, University of British Columbia, Vancouver BC; Canada*

- ¹⁶⁵ *Department of Physics and Astronomy, University of Victoria, Victoria BC; Canada*
- ¹⁶⁶ *Fakultät für Physik und Astronomie, Julius-Maximilians-Universität Würzburg, Würzburg; Germany*
- ¹⁶⁷ *Department of Physics, University of Warwick, Coventry; United Kingdom*
- ¹⁶⁸ *Waseda University, Tokyo; Japan*
- ¹⁶⁹ *Department of Particle Physics and Astrophysics, Weizmann Institute of Science, Rehovot; Israel*
- ¹⁷⁰ *Department of Physics, University of Wisconsin, Madison WI; United States of America*
- ¹⁷¹ *Fakultät für Mathematik und Naturwissenschaften, Fachgruppe Physik, Bergische Universität Wuppertal, Wuppertal; Germany*
- ¹⁷² *Department of Physics, Yale University, New Haven CT; United States of America*
- ^a *Also Affiliated with an institute covered by a cooperation agreement with CERN*
- ^b *Also at An-Najah National University, Nablus; Palestine*
- ^c *Also at APC, Université Paris Cité, CNRS/IN2P3, Paris; France*
- ^d *Also at Borough of Manhattan Community College, City University of New York, New York NY; United States of America*
- ^e *Also at Center for High Energy Physics, Peking University; China*
- ^f *Also at Center for Interdisciplinary Research and Innovation (CIRI-AUTH), Thessaloniki; Greece*
- ^g *Also at Centro Studi e Ricerche Enrico Fermi; Italy*
- ^h *Also at CERN Tier-0; Switzerland*
- ⁱ *Also at CERN, Geneva; Switzerland*
- ^j *Also at Département de Physique Nucléaire et Corpusculaire, Université de Genève, Genève; Switzerland*
- ^k *Also at Departament de Física de la Universitat Autònoma de Barcelona, Barcelona; Spain*
- ^l *Also at Department of Financial and Management Engineering, University of the Aegean, Chios; Greece*
- ^m *Also at Department of Physics and Astronomy, University of Sheffield, Sheffield; United Kingdom*
- ⁿ *Also at Department of Physics and Astronomy, University of Victoria, Victoria BC; Canada*
- ^o *Also at Department of Physics, Ben Gurion University of the Negev, Beer Sheva; Israel*
- ^p *Also at Department of Physics, California State University, Sacramento; United States of America*
- ^q *Also at Department of Physics, King's College London, London; United Kingdom*
- ^r *Also at Department of Physics, Oxford University, Oxford; United Kingdom*
- ^s *Also at Department of Physics, Royal Holloway University of London, Egham; United Kingdom*
- ^t *Also at Department of Physics, Stanford University, Stanford CA; United States of America*
- ^u *Also at Department of Physics, University of Fribourg, Fribourg; Switzerland*
- ^v *Also at Department of Physics, University of Massachusetts, Amherst MA; United States of America*
- ^w *Also at Department of Physics, University of Thessaly; Greece*
- ^x *Also at Department of Physics, Westmont College, Santa Barbara; United States of America*
- ^y *Also at Deutsches Elektronen-Synchrotron DESY, Hamburg and Zeuthen; Germany*
- ^z *Also at Fakultät Physik, Technische Universität Dortmund, Dortmund; Germany*
- ^{aa} *Also at Fakultät für Mathematik und Naturwissenschaften, Fachgruppe Physik, Bergische Universität Wuppertal, Wuppertal; Germany*
- ^{ab} *Also at Group of Particle Physics, University of Montreal, Montreal QC; Canada*
- ^{ac} *Also at Hellenic Open University, Patras; Greece*
- ^{ad} *Also at Institutio Catalana de Recerca i Estudis Avancats, ICREA, Barcelona; Spain*
- ^{ae} *Also at Institut für Experimentalphysik, Universität Hamburg, Hamburg; Germany*
- ^{af} *Also at Institut für Physik, Universität Mainz, Mainz; Germany*
- ^{ag} *Also at Institute for Nuclear Research and Nuclear Energy (INRNE) of the Bulgarian Academy of Sciences, Sofia; Bulgaria*
- ^{ah} *Also at Institute of Applied Physics, Mohammed VI Polytechnic University, Ben Guerir; Morocco*
- ^{ai} *Also at Institute of Particle Physics (IPP); Canada*
- ^{aj} *Also at Institute of Physics and Technology, Ulaanbaatar; Mongolia*
- ^{ak} *Also at Institute of Physics, Azerbaijan Academy of Sciences, Baku; Azerbaijan*
- ^{al} *Also at Institute of Theoretical Physics, Ilia State University, Tbilisi; Georgia*
- ^{am} *Also at IRFU, CEA, Université Paris-Saclay, Gif-sur-Yvette; France*
- ^{an} *Also at L2IT, Université de Toulouse, CNRS/IN2P3, UPS, Toulouse; France*

- ^{a_o} Also at Lawrence Livermore National Laboratory, Livermore; United States of America
- ^{a_p} Also at National Institute of Physics, University of the Philippines Diliman (Philippines); Philippines
- ^{a_q} Also at Ochanomizu University, Otsuka, Bunkyo-ku, Tokyo; Japan
- ^{a_r} Also at School of Physics and Astronomy, University of Birmingham, Birmingham; United Kingdom
- ^{a_s} Also at School of Physics and Astronomy, University of Manchester, Manchester; United Kingdom
- ^{a_t} Also at SUPA — School of Physics and Astronomy, University of Glasgow, Glasgow; United Kingdom
- ^{a_u} Also at Technical University of Munich, Munich; Germany
- ^{a_v} Also at The Collaborative Innovation Center of Quantum Matter (CICQM), Beijing; China
- ^{a_w} Also at TRIUMF, Vancouver BC; Canada
- ^{a_x} Also at Università di Napoli Parthenope, Napoli; Italy
- ^{a_y} Also at University of Chinese Academy of Sciences (UCAS), Beijing; China
- ^{a_z} Also at University of Colorado Boulder, Department of Physics, Colorado; United States of America
- ^{b_a} Also at Washington College, Chestertown, MD; United States of America
- ^{b_b} Also at Yeditepe University, Physics Department, Istanbul; Türkiye
- * Deceased