



## Letter

# Search for exclusive Higgs and $Z$ boson decays to $\omega\gamma$ and Higgs boson decays to $K^*\gamma$ with the ATLAS detector

The ATLAS Collaboration <sup>\*</sup>



## ARTICLE INFO

Editor: M. Doser

Dataset link: <https://hepdata.cedar.ac.uk>

## ABSTRACT

Searches for the exclusive decays of the Higgs boson to an  $\omega$  meson and a photon or a  $K^*$  meson and a photon can probe flavour-conserving and flavour-violating Higgs boson couplings to light quarks, respectively. Searches for these decays, along with the analogous  $Z$  boson decay to an  $\omega$  meson and a photon, are performed with a  $pp$  collision data sample corresponding to integrated luminosities of up to  $134 \text{ fb}^{-1}$  collected at  $\sqrt{s} = 13 \text{ TeV}$  with the ATLAS detector at the CERN Large Hadron Collider. The obtained 95% confidence-level upper limits on the respective branching fractions are  $B(H \rightarrow \omega\gamma) < 5.5 \times 10^{-4}$ ,  $B(H \rightarrow K^*\gamma) < 2.2 \times 10^{-4}$  and  $B(Z \rightarrow \omega\gamma) < 3.9 \times 10^{-6}$ . The limits for  $H \rightarrow \omega\gamma$  and  $Z \rightarrow \omega\gamma$  are 370 times and 140 times the Standard Model expected values, respectively. The result for  $Z \rightarrow \omega\gamma$  corresponds to a two-orders-of-magnitude improvement over the limit obtained by the DELPHI experiment at LEP.

## 1. Introduction

The discovery of a Higgs boson  $H$  with a mass of approximately  $m_H = 125 \text{ GeV}$  [1,2] by the ATLAS and CMS collaborations at the Large Hadron Collider (LHC) has led to a variety of measurements to determine its properties, which so far have found no deviations from the Standard Model (SM) [3,4]. In the SM, fermion masses are generated via Yukawa interactions between the Higgs and fermion fields. The Higgs boson couplings to the fermions are subject to substantial modifications in various theories beyond the SM [5]. Theories that modify the couplings of the Higgs boson to quarks include the Minimal Flavour Violation framework [6], the Froggatt–Nielsen mechanism [7], the Higgs-dependent Yukawa couplings model [8], the Randall–Sundrum family of models [9], and the possibility of the Higgs boson being a composite pseudo-Goldstone boson [10]. Measurements of Higgs boson production in association with top-quark pairs [11] and decays of Higgs bosons into pairs of  $\tau$ -leptons [11–13] or bottom-quarks [14,15] have been performed and were found to be consistent with the SM expectations, providing clarity on third-generation fermion interactions with the Higgs boson. Evidence has been reported for the Higgs boson coupling to the second generation through the  $H \rightarrow \mu^+\mu^-$  decay [16,17], but there is no further experimental evidence of interactions with fermions of the first and second generations. Searches have also been performed for the decay  $H \rightarrow c\bar{c}$  by the ATLAS and CMS collaborations [18–21].

Currently, the light ( $u$ ,  $d$ ,  $s$ ) quark couplings to the Higgs boson are loosely constrained by existing data on the total Higgs boson width and combined measurements of Higgs boson production and decays [3,4],

while the large multi-jet background at the LHC inhibits the study of such couplings with inclusive  $H \rightarrow q\bar{q}$  decays. Rare decays of the Higgs boson into a meson and a photon have been suggested as a probe of the couplings of the Higgs boson to light quarks. Higgs boson decays into a heavy quarkonium state,  $J/\psi$ ,  $\psi(2S)$  and  $Y(nS)$  with  $n = 1, 2, 3$ , and a photon have been suggested for probing the charm- and bottom-quark couplings to the Higgs boson [22–25]. These have already been searched for by the ATLAS and CMS collaborations [26–30]. Higgs boson decays into a  $\phi$  or  $\rho$  meson and a photon are potential probes for the  $u$ ,  $d$  and  $s$  quark couplings to the Higgs boson [31–33]. Searches have already been performed for these decays by the ATLAS Collaboration [34,35] and the CMS Collaboration [36]. The current constraints with the corresponding predictions are given in Ref. [37]. The partial widths for these decays are driven by two (interfering) contributions: one known as “direct”, which scales with the Yukawa couplings, and the other known as “indirect”, which mimics  $H \rightarrow \gamma\gamma$  but with one photon fragmenting into a quark–antiquark pair, forming the meson. These contributions are shown in Fig. 1. The interference between these two amplitudes is rather strong and typically destructive. In the case of the  $Y$  channel, almost complete destructive interference occurs, reversing the expected scaling with quark mass.

This paper describes a search for Higgs boson decays into the exclusive final states  $\omega\gamma$  and  $K^*\gamma$ . These decays can probe the flavour-conserving coupling of the Higgs boson to up and down quarks, and the flavour-violating coupling of the Higgs boson to down and strange quarks, respectively. Two calculations of the expected SM branching fractions for the  $\omega$  channel are available:  $B(H \rightarrow \omega\gamma) = (1.48 \pm 0.08) \times$

<sup>\*</sup> E-mail address: [atlas.publications@cern.ch](mailto:atlas.publications@cern.ch).

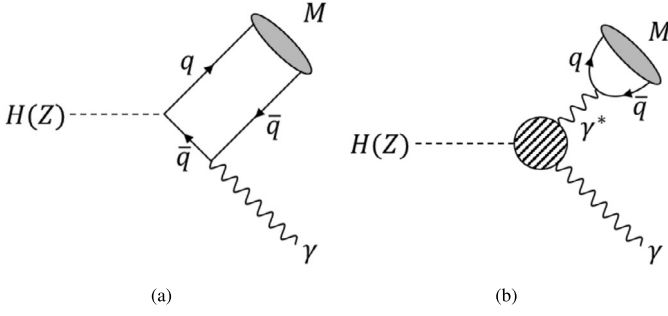


Fig. 1. Feynman diagrams for the (a) direct and (b) indirect contributions to the  $H/Z \rightarrow M\gamma$  decays.

$10^{-6}$  [31] and  $B(H \rightarrow \omega\gamma) = (1.6 \pm 0.2) \times 10^{-6}$  [32]. For the  $K^*\gamma$  decay, which arises from loop contributions, only the expected branching fraction of  $H \rightarrow d\bar{s} + \bar{d}s$  is available, with a value of  $B(H \rightarrow d\bar{s} + \bar{d}s) = 1.19 \times 10^{-11}$  [38]. The branching fraction for  $H \rightarrow K^*\gamma$  is expected to be much smaller. This is the first exclusive decay analysis to target flavour-changing interactions of the Higgs boson. Earlier searches for flavour-changing neutral currents via the top-quark decays  $t \rightarrow uH$  and  $t \rightarrow cH$  were performed by the ATLAS and CMS collaborations [39–42], with no evidence found for these decays.

The decay  $\omega \rightarrow \pi^+\pi^-\pi^0$  is used to reconstruct the  $\omega$  meson, and the decay  $K^* \rightarrow K^+\pi^-$  is used to reconstruct the  $K^*$  meson. The branching fractions of the respective meson decays are accounted for when calculating the expected signal yields. A search for the analogous decay of the  $Z$  boson into a  $\omega$  meson and a photon is also presented. The channel has been studied theoretically [25,43] as a unique precision test of the SM and the factorisation approach in quantum chromodynamics (QCD), in an environment where the power corrections in terms of the QCD energy scale divided by the mass of the vector boson are small [25]. The large  $Z$  boson production cross section at the LHC means that rare  $Z$  boson decays can be probed at branching fractions much smaller than for Higgs boson decays into the same final states. The SM branching fraction prediction for the decay considered in this paper is  $B(Z \rightarrow \omega\gamma) = (2.82 \pm 0.40) \times 10^{-8}$  [25]. A previous search was performed at the DELPHI experiment, yielding an upper limit on the branching fraction of  $B(Z \rightarrow \omega\gamma) < 6.5 \times 10^{-4}$  [44].

## 2. ATLAS detector

The ATLAS detector [45] is a multi-purpose particle physics detector with an approximately forward-backward symmetric cylindrical geometry and near  $4\pi$  coverage in solid angle.<sup>1</sup> It consists of an inner tracking detector surrounded by a thin superconducting solenoid, electromagnetic and hadronic calorimeters, and a muon spectrometer. The inner tracking detector (ID) covers the pseudorapidity range  $|\eta| < 2.5$ , and is surrounded by a thin superconducting solenoid providing a 2 T magnetic field. At small radii, a high-granularity silicon pixel detector covers the vertex region and typically provides three measurements per track. A new innermost pixel-detector layer, the insertable B-layer, was added before 13 TeV data-taking began in 2015 and provides an additional measurement at a radius of about 33 mm around a new and thinner beam pipe [46,47]. The pixel detectors are followed by a silicon microstrip tracker, which typically provides four space-point measurements per track. The silicon detectors are complemented by a gas-filled straw-tube transition radiation tracker, which enables

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

radially extended track reconstruction up to  $|\eta| = 2.0$ , with typically 35 measurements per track. The calorimeter system covers the pseudorapidity range  $|\eta| < 4.9$ . A high-granularity lead/liquid-argon (LAR) sampling electromagnetic calorimeter covers the region  $|\eta| < 3.2$ , with an additional thin LAR presampler covering  $|\eta| < 1.8$  to correct for energy losses upstream. The electromagnetic calorimeter is divided into a barrel section covering  $|\eta| < 1.475$  and two endcap sections covering  $1.375 < |\eta| < 3.2$ . For  $|\eta| < 2.5$  it is divided into three layers in depth, which are finely segmented in  $\eta$  and  $\phi$ . A steel/scintillator-tile calorimeter provides hadronic calorimetry in the range  $|\eta| < 1.7$ , while in the endcap region,  $1.5 < |\eta| < 3.2$ , a copper/LAR calorimeter is used. The solid-angle coverage is completed with forward copper/LAR and tungsten/LAR calorimeter modules in  $3.1 < |\eta| < 4.9$ , optimised for electromagnetic and hadronic measurements, respectively. The muon spectrometer surrounds the calorimeters and comprises separate trigger and high-precision tracking chambers measuring the deflection of muons in a magnetic field provided by three air-core superconducting toroids.

A two-level trigger and data acquisition system is used to provide an online selection and record events for offline analysis [48]. The level-1 trigger is implemented in hardware and uses a subset of detector information to reduce the event rate to 100 kHz or less from the maximum LHC collision rate of 40 MHz. It is followed by a software-based high-level trigger which filters events using the full detector information and records events for detailed offline analysis at an average rate of 1 kHz. An extensive software suite [49] 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. Data and Monte Carlo simulation

The searches are performed in two distinct decay modes,  $\omega\gamma$  and  $K^*\gamma$ , using a  $pp$  collision data sample collected at a centre-of-mass energy  $\sqrt{s} = 13$  TeV. Following the requirement that events must be collected under stable LHC beam conditions and that all relevant detector components are in good operating condition, the total integrated luminosity available is 89.5 and 134  $\text{fb}^{-1}$  for the  $\omega\gamma$  and  $K^*\gamma$  final states, respectively, with an uncertainty of 1.7% [50,51]. The data samples were recorded by a combination of dedicated triggers, which were integrated into the trigger menu at different times. This is reflected in the different integrated luminosities. Namely, the trigger for the  $\omega\gamma$  final state recorded data from July 2017 to the end of data taking in 2018, whilst the triggers for the  $K^*\gamma$  final state recorded data from May 2016 to the end of data taking in 2018. These require a photon at the level-1 trigger, and a photon and an isolated pair of ID tracks at the high-level trigger. At the high-level trigger, an isolated photon with a transverse momentum  $p_T^\gamma > 35$  GeV [48] is required in general, with the exception of data recorded for the  $K^*\gamma$  final state in 2017–2018, where the threshold was reduced to  $p_T^\gamma > 25$  GeV. For the ID tracks a modified version of the  $\tau$ -lepton trigger algorithms [52] is used. The triggers for the  $K^*\gamma$  final state require at least one track to have a  $p_T$  greater than 15 GeV, whilst the triggers for the  $\omega\gamma$  final state require at least one track to have a  $p_T$  greater than 25 GeV. In each case, the track is required to be associated with a topological cluster of calorimeter cells [53] with a transverse energy greater than 25 GeV. Different requirements on the invariant mass of the pair of tracks are applied, depending on the mass of each targeted meson. For  $\omega \rightarrow \pi^+\pi^-\pi^0$  an invariant mass of the pair of tracks in the range 279 to 648 MeV is required, under the charged-pion hypothesis. For  $K^* \rightarrow K^+\pi^-$  an invariant mass of 790 to 990 MeV, under the  $K^\pm\pi^\mp$  hypothesis, is required. The trigger efficiency with respect to the offline selection, as described in Section 4, is approximately 78% for the  $K^*\gamma$  final state and 52% for the  $\omega\gamma$  final state.

Higgs boson production through the gluon–gluon fusion ( $ggH$ ) and vector-boson fusion (VBF) processes was modelled up to next-to-leading order (NLO) in  $\alpha_s$  using the POWHEG BOX v4 Monte Carlo (MC) event generator [54–58]. POWHEG BOX v4 was interfaced with the PYTHIA

8.244 MC event generator [59,60] to model the parton shower, hadronisation and underlying event, with parameter values set according to the AZNLO tune [61] and using CTEQ6L1 parton distribution functions (PDFs) [62]. Additional contributions from the associated production of a Higgs boson and a  $W^\pm$  or  $Z$  boson (denoted by  $WH$  and  $ZH$ , respectively) were modelled by PYTHIA 8.244 with NNPDF2.3LO PDFs [63] and the A14 tune for hadronisation and the underlying event [64]. Higgs boson production through associated production with top quarks ( $t\bar{t}H$ ) was modelled using PYTHIA 8.244, and AMC@NLO to model the parton shower [65], again with the NNPDF2.3LO PDFs and A14 tune. The production rates and kinematic distributions for the SM Higgs boson with  $m_H = 125$  GeV are assumed throughout. These were obtained from Ref. [66] and are summarised below. The  $ggH$  production rate is normalised such that it reproduces the total cross section predicted by a next-to-next-to-next-to-leading-order QCD calculation with NLO electroweak corrections applied [67,68]. The VBF production rate is normalised to an approximate next-to-next-to-leading-order (NNLO) QCD cross section with NLO electroweak corrections applied [69–71]. The  $WH$  and  $ZH$  production rates are normalised to cross sections calculated at NNLO in QCD with NLO electroweak corrections [72] including the NLO QCD corrections for  $gg \rightarrow ZH$ . POWHEG BOX v4 was also used to model inclusive  $Z$  boson production with CT10 PDFs. PYTHIA 8.244 with CTEQ6L1 PDFs and the AZNLO tune was used to simulate the parton showering and hadronisation. The prediction is normalised to the total cross section obtained from the measurement in Ref. [73]. The Higgs and  $Z$  boson decays were simulated as a cascade of two- and three-body decays, accounting for angular momentum conservation. The meson invariant mass distributions were simulated by PYTHIA. The branching fraction for the decay  $\omega \rightarrow \pi^+ \pi^- \pi^0$  is  $(89.2 \pm 0.7)\%$ . The decay  $K^* \rightarrow K\pi$  has a branching fraction close to 100%, of which two-thirds correspond to decays to a charged kaon and a charged pion [74]. The simulated events were passed through a detailed GEANT4 simulation of the ATLAS detector [75,76] and processed with the same software used to reconstruct the data. Simulated additional  $pp$  collisions in the same or neighbouring bunch crossings (pile-up events) are also included and the distribution of these is matched to the conditions observed in the data.

#### 4. Object and event selections

The similarities of the final states in these searches allow common event selections to be used. A pair of oppositely charged reconstructed ID tracks is required for both, with the addition of a neutral pion in the reconstruction of the  $\omega\gamma$  final state.

Events with a  $pp$  interaction vertex reconstructed from at least two ID tracks with  $p_T > 500$  MeV are considered in the analysis. Within an event, the primary vertex is defined as the reconstructed vertex with the largest  $\sum p_T^2$  of associated ID tracks.

Photons are reconstructed from clusters of energy in the electromagnetic calorimeter. Reconstructed photon candidates are required to have  $p_T^\gamma > 35$  GeV,  $|\eta^\gamma| < 2.37$ , excluding the barrel/endcap calorimeter transition region  $1.37 < |\eta^\gamma| < 1.52$ , and to satisfy “tight” photon identification criteria [77]. An isolation requirement is imposed to further suppress contamination from jets. The sum of the transverse momenta of all tracks within  $\Delta R = \sqrt{(\Delta\phi)^2 + (\Delta\eta)^2} = 0.2$  of the photon direction, excluding those associated with the reconstructed photon, is required to be less than 5% of  $p_T^\gamma$ . Moreover, the sum of the transverse momenta of all calorimeter energy deposits within  $\Delta R = 0.4$  of the photon direction, excluding those associated with the reconstructed photon, is required to be less than  $2.45 \text{ GeV} + 0.022 \times p_T^\gamma$ . To mitigate the effects of multiple  $pp$  interactions in the same or neighbouring bunch crossings, only ID tracks consistent with originating from the primary vertex are considered in the photon track-based isolation. For the calorimeter-based isolation the effects of the underlying event and multiple  $pp$  interactions are also accounted for on an event-by-event basis using an average underlying-event energy density determined from data [77].

Charged-hadron candidates are reconstructed from ID tracks which are required to have  $|\eta| < 2.5$ ,  $p_T > 3$  GeV and to satisfy basic quality criteria, including a requirement on the number of hits in the silicon detectors [78]. For the  $\omega\gamma$  analysis, the combination of a pair of charged-hadron candidates with opposite charge and a neutral-pion candidate is denoted by  $\mathcal{M}$ , whereas for the  $K^*\gamma$  analysis,  $\mathcal{M}$  denotes the combination of a pair of charged-hadron candidates with opposite charge. Within a pair, the charged-hadron candidate with the higher  $p_T$ , referred to as the leading charged-hadron candidate, is required to have  $p_T > 20$  GeV for the  $K^*\gamma$  analysis and  $p_T > 25$  GeV for the  $\omega\gamma$  analysis. The selection of candidates for the charged-particle pair in  $\mathcal{M}$  is based on their invariant masses. Charged-hadron pairs satisfying these requirements are assumed to be a  $\pi^+\pi^-$  pair in the  $\omega\gamma$  analysis. In the  $K^*\gamma$  channel, tracks are assigned a particular mass hypothesis by calculating the invariant mass of the di-track system for both possible assignments ( $K/\pi$  or  $\pi/K$ ). The combination which results in an invariant mass closer to  $m_{K^*}$  is chosen. Additionally, the  $p_T$  of the di-track system must satisfy  $p_T > 35$  GeV. For the  $\omega\gamma$  channel, charged-hadron pairs with an invariant mass of 279 to 648 MeV are selected as candidates. For the  $K^*\gamma$  channel, charged-hadron pairs with an invariant mass of 790 to 990 MeV are selected as candidates. Selected charged-hadron pair candidates are required to satisfy an isolation requirement: the sum of the  $p_T$  of the reconstructed ID tracks from the primary vertex that are within  $\Delta R = 0.2$  of the leading charged-hadron candidate (excluding from the sum the charged-hadron candidate defining the pair) is required to be less than 10% of the  $p_T$  of the charged-hadron pair candidate for the  $\omega\gamma$  channel, and less than 20% for the  $K^*\gamma$  channel.

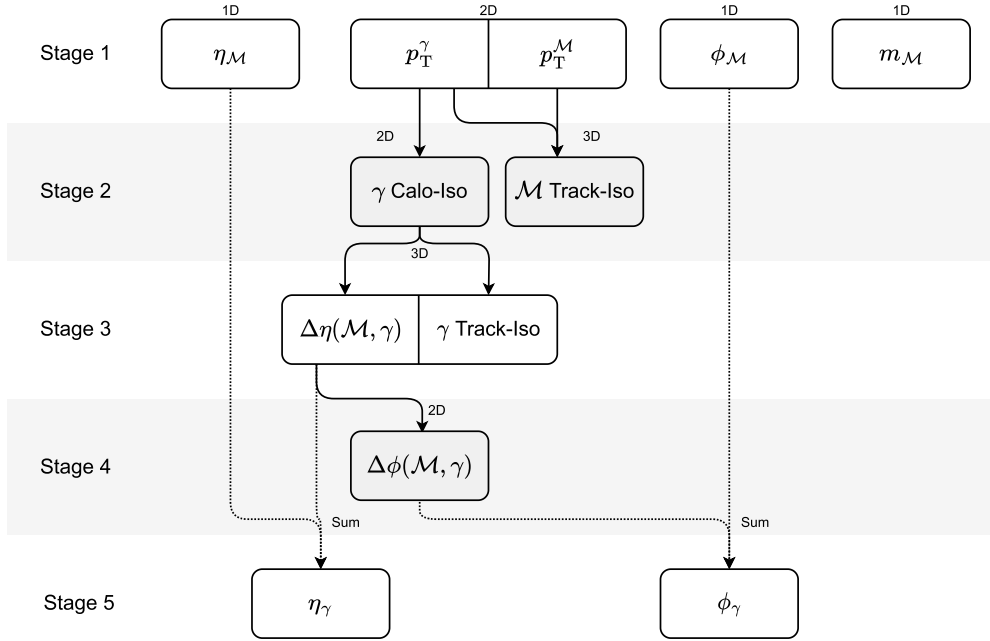
Neutral-pion candidates are expected to leave a signature of a pair of overlapping clusters in the electromagnetic calorimeter. In the case of  $H \rightarrow \omega\gamma$  decays, the  $\pi^0$  is expected to be very close in  $\Delta R$  to the  $\pi\pi$  system. Tau particle-flow object (TauPFO) algorithms [79] optimised to search for neutral pions in  $\tau$ -like decay signatures, using boosted decision trees, are used to reconstruct the neutral pion in the  $\omega$  decay. The  $\tau$ -jets are searched for, with no identification requirements, within  $\Delta R = 0.1$  of the  $\pi^+\pi^-$  system. The presence of neutral-pion particle-flow objects is then examined within each  $\tau$ -jet object. The closest particle-flow object consistent with a  $\pi^0$  is taken to be the  $\pi^0$  candidate, which is then added to the charged-hadron candidates to form  $\mathcal{M}$  for the  $\omega\gamma$  channel. An additional mass requirement of 650 to 850 MeV is then imposed on the fully reconstructed  $\omega$  meson.

The  $\mathcal{M}$  candidates are subsequently combined with the reconstructed photons. When multiple combinations are possible, a situation that arises only in a few percent of the events, the combination of the highest- $p_T$  photon and the  $\mathcal{M}$  candidate with an invariant mass closest to the respective meson mass is selected. The event is retained for further analysis if the requirement  $\Delta\phi(\mathcal{M}, \gamma) > \pi/2$  on the azimuthal angular separation between the meson candidate and the photon is satisfied. This selection defines the “signal region”.

For the  $\omega\gamma \rightarrow \pi^+ \pi^- \pi^0 \gamma$  final state, the total signal efficiency (kinematic acceptance, trigger and reconstruction efficiencies) is 2.2% and 0.4% for the Higgs and  $Z$  boson decays, respectively. The corresponding efficiency for the  $K^*\gamma$  final state in Higgs boson decay is 12.1%.<sup>2</sup> The difference in efficiency between the Higgs and  $Z$  boson decays arises primarily from the softer  $p_T$  distributions of the photon and charged-hadron candidates from  $Z \rightarrow \omega\gamma$  production. The efficiency difference between the two final states is due to the presence of the neutral pion in the decay of the  $\omega$ . This arises both from the reconstruction efficiency of the neutral pion itself, and from the softer  $p_T$  distributions of the charged hadrons in the decay of the  $\omega$  compared to the  $K^*$ , caused by the neutral pion taking a portion of the decay energy.

The Higgs boson signal  $m_{\mathcal{M}\gamma}$  distribution for the  $H \rightarrow \omega\gamma$  decay is modelled with a sum of a Crystal Ball distribution and a Gaussian dis-

<sup>2</sup> This efficiency is estimated with respect to  $K^*$  decays to a charged kaon and a charged pion.



**Fig. 2.** A schematic diagram showing the stages of the background model used for the analyses presented. Variables are drawn using a combination of 1D, 2D and 3D histograms in order to retain the correlations between them. Solid arrows correspond to where variables have been sampled from the previous stage. Dashed arrows correspond to where previous variables have been summed to produce a new variable. Joined cells indicate variables that have been simultaneously sampled from the previous stage.

tribution, while for  $H \rightarrow K^*\gamma$  a sum of two Gaussian probability density functions (pdf) with a common mean value is used. For the  $Z$  boson signal the  $m_{M\gamma}$  distribution is modelled with a double Voigtian pdf (a convolution of relativistic Breit-Wigner and Gaussian pdfs) corrected with a mass-dependent efficiency factor.

Additionally, sideband meson mass datasets are defined for both analyses, where the full set of selection criteria is imposed except for different invariant mass requirements on  $M$ . For the  $H \rightarrow \omega\gamma$  decay channel, the requirement is  $m_\omega < 650$  MeV or  $850$  MeV  $< m_\omega < 2000$  MeV. For  $H \rightarrow K^*\gamma$  the requirement is  $m_{K^*} < 790$  MeV or  $m_{K^*} > 990$  MeV. These requirements produce datasets that are orthogonal to the signal region, but still provide a useful description of the background processes.

## 5. Background estimation

For both the  $\omega\gamma$  and  $K^*\gamma$  final states, the main sources of background in the searches are events involving inclusive  $\gamma + \text{jet}$  or multi-jet processes, where an  $M$  system is reconstructed from ID tracks originating from a jet. From the selection criteria discussed earlier, the shape of this background exhibits a kinematic turn-on structure in the  $m_{M\gamma}$  distribution around 100 GeV, in the region of the  $Z$  boson signal, and a smoothly falling background in the region of the Higgs boson signal. These processes are modelled inclusively with a non-parametric data-driven approach using templates to describe the relevant distributions [80]. The background normalisation and shape are simultaneously extracted from a fit to the data. A similar procedure was used in the searches for Higgs and  $Z$  boson decays into  $\phi\gamma$  and  $\rho\gamma$  [34,35] and the searches for Higgs and  $Z$  boson decays into  $J/\psi\gamma$ ,  $\psi(2S)\gamma$  and  $Y(nS)\gamma$  [26–28].

### 5.1. Background modelling

The background modelling procedure for each final state uses a sample of approximately 16 000  $\pi^+\pi^-\pi^0\gamma$  and 280 000  $K^+\pi^-\gamma$  candidate events in data. These events pass all the kinematic selection requirements described previously, except that the photon and  $M$  candidates are not required to satisfy the nominal isolation requirements. This

selection defines the “generation region” (GR), which is background-dominated. From these events, pdfs are constructed to describe the distributions of the relevant kinematic and isolation variables and their most important correlations. In this way, in the absence of appropriate simulations, pseudocandidates are generated, from which the background shape in the discriminating variable is derived. This ensemble of pseudocandidates is produced by randomly sampling the distributions of the relevant kinematic and isolation variables, which are estimated from the data in the GR. Each pseudocandidate is described by  $M$  and  $\gamma$  four-momentum vectors and the associated  $M$  and photon isolation variables. The  $M$  four-momentum vector is constructed from sampled  $\eta_M$ ,  $\phi_M$ ,  $m_M$  and  $p_T^M$  values. For the  $\gamma$  four-momentum vector, the  $\eta_\gamma$  and  $\phi_\gamma$  values are determined from the sampled  $\Delta\phi(M, \gamma)$  and  $\Delta\eta(M, \gamma)$  values, whereas  $p_T^\gamma$  is sampled directly. The most important correlations among these kinematic and isolation variables in background events are retained in the generation of the pseudocandidates. This is achieved through the following sampling scheme, also depicted in Fig. 2, where the steps are performed sequentially, following the magnitude of the observed correlations:

i) Initially, values for  $p_T^M$  and  $p_T^\gamma$  are drawn from a two-dimensional pdf of  $(p_T^M, p_T^\gamma)$ . The values of  $\eta_M$  and the  $\phi$  angle of the meson are sampled from one-dimensional pdfs of the variables. Finally, a value for the meson mass is sampled from a one-dimensional pdf of  $m_M$ .

ii) The isolation of the meson candidate is sampled from a three-dimensional pdf based on the values of  $p_T^M$  and  $p_T^\gamma$  obtained in the previous step. Then, the photon’s relative calorimeter isolation is sampled from a two-dimensional pdf, based on the value of  $p_T^\gamma$  obtained in the previous step.

iii) From this value of the photon’s relative calorimeter isolation, the values of the pseudorapidity difference between the  $M$  and  $\gamma$  candidates,  $\Delta\eta(M, \gamma)$ , and the photon’s relative track isolation are sampled simultaneously from a three-dimensional pdf.

iv) The value of the azimuthal angular separation,  $\Delta\phi(M, \gamma)$ , is sampled from a two-dimensional pdf based on the value of  $\Delta\eta(M, \gamma)$  drawn in the previous step.

v) Given these sampled values, and the values sampled previously for  $\Delta\eta(M, \gamma)$  and  $\Delta\phi(M, \gamma)$ , the values of  $\eta_M$  and  $\phi_\gamma$  are then defined.

The nominal selection requirements are imposed on the ensemble, and the surviving pseudocandidates are used to construct templates for the  $m_{\mathcal{M}\gamma}$  distribution, which are then smoothed using Gaussian kernel density estimation [81]. Signal injection tests were performed to ensure that the background model is not affected by any potential signal contamination.

## 5.2. Background validation

To validate the background model, the  $m_{\mathcal{M}\gamma}$  distributions in validation regions, defined by kinematic and isolation requirements looser than the nominal signal requirements, are used to compare the prediction of the background model with the data. Three validation regions are defined, each based on the GR selection and adding one of the following: the meson isolation requirement (VR1), the calorimeter component of the photon isolation requirements (VR2a), or the track component of the photon isolation requirements (VR2b). The  $m_{\mathcal{M}\gamma}$  distributions in these validation regions are shown in Fig. 3. The background model is found to describe the data well in all regions within uncertainties.

To allow the shape of the background model for the three-body mass to adjust to the observed data, variations around the nominal shape are derived. Three variations are included to allow this adjustment to occur. Firstly, a scale variation of the  $p_T$  distribution of either  $\mathcal{M}$  or  $\gamma$  is used to allow the peak of the three-body mass distribution to shift upwards or downwards in mass. Secondly, a variation is produced via a polynomial distortion of the shape of the  $\Delta\phi(\mathcal{M}, \gamma)$  distribution, which allows the width of the three-body mass distribution to vary. Finally, a global tilt of the three-body mass distribution is included, which allows the model to account for slopes with respect to the data. The first two variations are simple alterations to the kinematics of the pseudocandidates, resulting in changes to the three-body mass distribution. The corresponding nuisance parameters are assigned a Gaussian constraint in the likelihood. The third variation is directly applied to the three-body mass template and is not constrained by a Gaussian term in the fit. The uncertainty band in Fig. 3 corresponds to the uncertainty envelope derived from these variations, which are set sufficiently large to allow the shape to adapt in the fit to the data.

## 6. Systematic uncertainties

The photon identification and isolation uncertainties are estimated to be 1.7% for the Higgs and  $Z$  boson signals. An uncertainty of 3.0% per  $\mathcal{M}$  candidate is assigned to the track reconstruction efficiency and accounts for effects associated with the modelling of ID material and also with the track reconstruction algorithms if there is a charged particle near the photon. This uncertainty is derived conservatively by assuming the uncertainty to be fully correlated between the two tracks of the  $\mathcal{M}$  candidate.

The systematic uncertainty in the expected signal yield arising from the photon component of the trigger efficiency is estimated to be 0.7% [82]. Uncertainties to account for the “ $\tau$ ”-component of the trigger turn on are assigned in accord with the studies described in Ref. [83], and are 7.3% (2.1%) for the  $H(Z) \rightarrow \omega\gamma$  channels, and 4.1% for the  $H \rightarrow K^*\gamma$  channel.

The Higgs boson production cross sections and decay branching fractions, as well as their uncertainties, are taken from Refs. [5,84,85]. The effect of QCD scale uncertainties on the cross section for a 125 GeV  $H$  boson [5] amounts to a 5.0% uncertainty. The uncertainties in the production cross section due to uncertainties in the PDFs and the strong coupling constant,  $\alpha_s$ , are combined for the separate processes and amount to 2.9%. The shape component of the uncertainties was found to be negligible. The efficiency to reconstruct the neutral pion in the decay using the TauPFO algorithms is approximately 65%. The uncertainty in this reconstruction efficiency, based on Ref. [77], is 5.0%.

**Table 1**

Numbers of observed and expected background events for the  $m_{\mathcal{M}\gamma}$  ranges of interest. Each expected background and the corresponding uncertainty of its mean is obtained from a background-only fit to the data; the uncertainty does not take into account statistical fluctuations in each mass range. Expected  $Z$  and Higgs boson signal contributions, with their corresponding total systematic uncertainty, are shown for reference branching fractions of  $10^{-6}$  and  $10^{-4}$ , respectively. Entries are marked with a dash when there is no signal of that type in the specified range.

Channel	Mass range [GeV]	Observed (Expected) background	$H$ signal $B = 10^{-4}$	$Z$ signal $B = 10^{-6}$
$H \rightarrow \omega\gamma$	115–135	686 (730 $\pm$ 17)	9 $\pm$ 1	–
$Z \rightarrow \omega\gamma$	80–100	388 (386 $\pm$ 16)	–	18 $\pm$ 2
$H \rightarrow K^*\gamma$	120–130	9526 (9630 $\pm$ 50)	53 $\pm$ 4	–

**Table 2**

Expected and observed branching fraction limits at the 95% CL for  $H/Z \rightarrow \omega\gamma$  and  $H \rightarrow K^*\gamma$ .

Channel	95% CL upper limit	
	Expected	Observed
$H \rightarrow \omega\gamma$ [ $10^{-4}$ ]	10.4 $^{+3.8}_{-2.9}$	5.5
$Z \rightarrow \omega\gamma$ [ $10^{-6}$ ]	4.7 $^{+2.0}_{-1.3}$	3.9
$H \rightarrow K^*\gamma$ [ $10^{-4}$ ]	3.7 $^{+1.5}_{-1.0}$	2.2

The shape of the background model is allowed to vary around the nominal shape, and the parameters controlling these systematic variations are treated as nuisance parameters in the maximum-likelihood fit used to extract the signal and background yields, as described in Section 5.2.

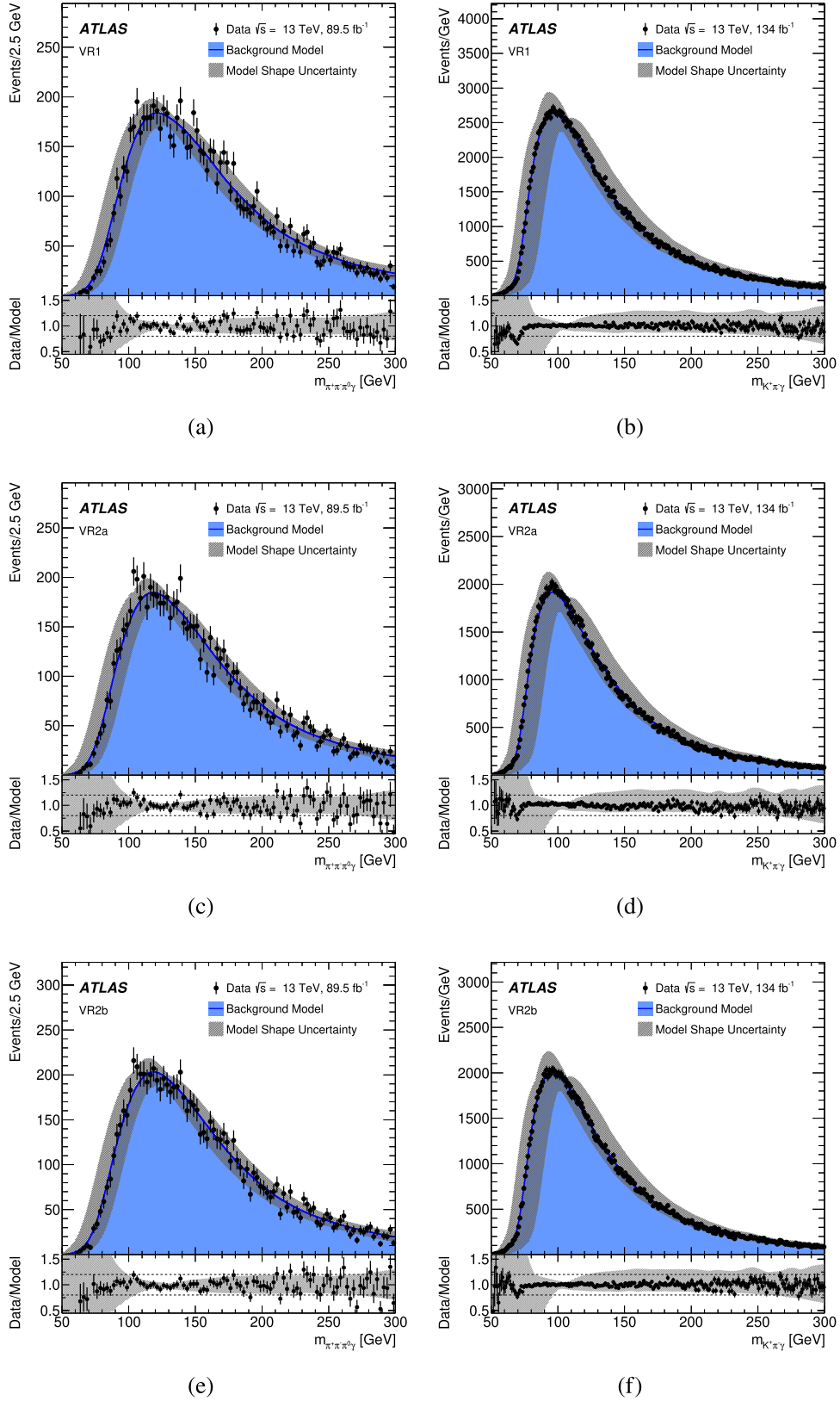
## 7. Results

After the full selection is applied, 4264 events are observed in the  $H/Z \rightarrow \omega\gamma$  signal region, and 114 707 events are observed in the  $H \rightarrow K^*\gamma$  signal region. The data are compared with background and signal predictions using an unbinned maximum-likelihood fit to the  $m_{\mathcal{M}\gamma}$  distribution. The parameters of interest are the Higgs and  $Z$  boson signal normalisations. Systematic uncertainties are modelled using additional nuisance parameters in the fit; in particular, the background normalisation is a free parameter in the model. The fit uses the selected events with  $m_{\mathcal{M}\gamma} < 300$  GeV. Upper limits are set on the branching fractions for the Higgs and  $Z$  boson decays into  $\mathcal{M}\gamma$  using the CL<sub>s</sub> modified frequentist formalism [86] with the profile-likelihood-ratio test statistic and the asymptotic approximations derived in Ref. [87]. For the upper limits on the branching fractions, the SM production cross section is assumed for the Higgs boson, while the ATLAS measurement of the inclusive  $Z$  boson cross section is used for the  $Z$  boson signal, as discussed in Section 6. Tests of the fit on sideband meson-mass data demonstrate good agreement and modelling of the background processes and serve as further validation of the background modelling.

The expected and observed numbers of background events within regions of  $m_{\mathcal{M}\gamma}$  around the Higgs and  $Z$  boson masses are given in Table 1. The expected numbers of background events are taken from background-only fits. Table 1 also shows the expected number of signal events for branching fractions near the sensitivity of the analyses. Fits to the signal region data are shown in Fig. 4. Signals are shown normalised to branching fraction values of the order of the expected sensitivity. The observed and expected limits are summarised in Table 2.

## 8. Conclusion

A search for the decays  $H/Z \rightarrow \omega\gamma$  and  $H \rightarrow K^*\gamma$  has been performed with 13 TeV  $pp$  collision data samples collected with the AT-



**Fig. 3.** Distributions of ((a), (c), (e))  $m_{\pi^+\pi^-\pi^0\gamma}$  and ((b), (d), (f))  $m_{K^+\pi^-\gamma}$  in data compared with the prediction of the background model for the VR1, VR2a and VR2b validation regions. The background model is normalised to the observed number of events within the region shown. The uncertainty band corresponds to the uncertainty envelope derived from variations in the background modelling procedure, described in Section 5. The ratio of the data to the background model is shown below the distributions.

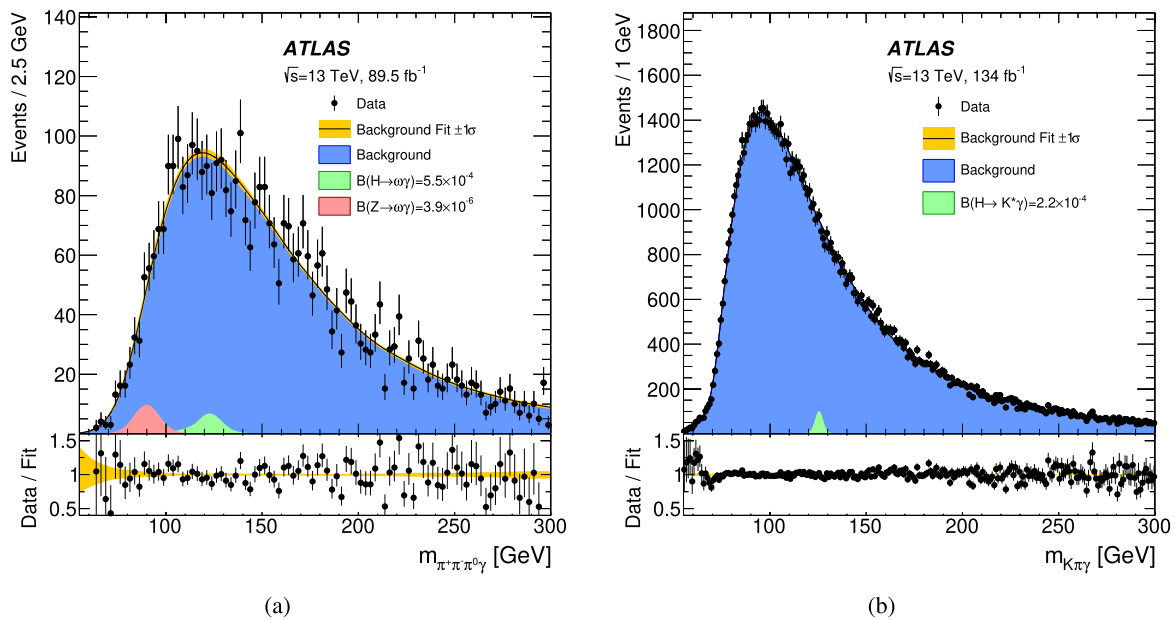


Fig. 4. Background-only fits performed in the signal region for the (a)  $\omega\gamma$  and (b)  $K^*\gamma$  final states. The branching fraction of each of the signals is set to the observed 95% CL upper limit. The yellow band represents the uncertainty in the fit arising from the constrained background shape systematic uncertainties.

LAS detector at the LHC corresponding to integrated luminosities of  $89.5 \text{ fb}^{-1}$  and  $134 \text{ fb}^{-1}$  respectively. The  $\omega$  and  $K^*$  mesons are reconstructed via their dominant decays into  $\pi^+\pi^-\pi^0$  and  $K^+\pi^\pm$  final states, respectively. The background model is derived using a fully data-driven approach and validated in a number of different regions. No significant excess of events above the SM background expectations is observed. The obtained 95% CL upper limits are  $B(H \rightarrow \omega\gamma) < 5.5 \times 10^{-4}$  ( $370 \times \text{SM}$ ),  $B(Z \rightarrow \omega\gamma) < 3.9 \times 10^{-6}$  ( $140 \times \text{SM}$ ), and  $B(H \rightarrow K^*\gamma) < 2.2 \times 10^{-4}$ . The result for  $Z \rightarrow \omega\gamma$  corresponds to a two-orders-of-magnitude improvement over the previously set limit at DELPHI.

#### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

#### Data availability

The data for this manuscript are not available. The values in the plots and tables associated to this article are stored in HEPDATA (<https://hepdata.cedar.ac.uk>).

#### Acknowledgements

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 Benozziyo 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, ICSC-NextGenerationEU 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 (UK) and BNL (USA), the Tier-2 facilities worldwide and large non-WLCG resource providers. Major contributors of computing resources are listed in Ref. [88].

#### References

- [1] ATLAS Collaboration, Observation of a new particle in the search for the standard model Higgs boson with the ATLAS detector at the LHC, *Phys. Lett. B* 716 (2012) 1, arXiv:1207.7214 [hep-ex].
- [2] CMS Collaboration, Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC, *Phys. Lett. B* 716 (2012) 30, arXiv:1207.7235 [hep-ex].
- [3] ATLAS Collaboration, A detailed map of Higgs boson interactions by the ATLAS experiment ten years after the discovery, *Nature* 607 (2022) 52, arXiv:2207.00092 [hep-ex].
- [4] CMS Collaboration, A portrait of the Higgs boson by the CMS experiment ten years after the discovery, *Nature* 607 (2022) 60, arXiv:2207.00043 [hep-ex].
- [5] LHC Higgs Cross Section Working Group, S. Heinemeyer, C. Mariotti, G. Passarino, Tanaka (Eds.), *Handbook of LHC Higgs Cross Sections: 3. Higgs Properties*, CERN, Geneva, 2013, CERN-2013-004, arXiv:1307.1347 [hep-ph].
- [6] G. D'Ambrosio, G.F. Giudice, G. Isidori, A. Strumia, Minimal flavor violation: an effective field theory approach, *Nucl. Phys. B* 645 (2002) 155, arXiv:hep-ph/0207036 [hep-ph].
- [7] C.D. Froggatt, H.B. Nielsen, Hierarchy of quark masses, cabibbo angles and CP violation, *Nucl. Phys. B* 147 (1979) 277.
- [8] G.F. Giudice, O. Lebedev, Higgs-dependent Yukawa couplings, *Phys. Lett. B* 665 (2008) 79, arXiv:0804.1753 [hep-ph].

- [9] L. Randall, R. Sundrum, Large mass hierarchy from a small extra dimension, *Phys. Rev. Lett.* 83 (1999) 3370, arXiv:hep-ph/9905221 [hep-ph].
- [10] M.J. Dugan, H. Georgi, D.B. Kaplan, Anatomy of a composite Higgs model, *Nucl. Phys. B* 254 (1985) 299.
- [11] ATLAS and CMS Collaborations, Measurements of the Higgs boson production and decay rates and constraints on its couplings from a combined ATLAS and CMS analysis of the LHC  $pp$  collision data at  $\sqrt{s} = 7$  and  $8\text{ TeV}$ , *J. High Energy Phys.* 08 (2016) 045, arXiv:1606.02266 [hep-ex].
- [12] ATLAS Collaboration, Evidence for the Higgs-boson Yukawa coupling to tau leptons with the ATLAS detector, *J. High Energy Phys.* 04 (2015) 117, arXiv:1501.04943 [hep-ex].
- [13] CMS Collaboration, Evidence for the  $125\text{ GeV}$  Higgs boson decaying to a pair of  $\tau$  leptons, *J. High Energy Phys.* 05 (2014) 104, arXiv:1401.5041 [hep-ex].
- [14] ATLAS Collaboration, Evidence for the  $H \rightarrow b\bar{b}$  decay with the ATLAS detector, *J. High Energy Phys.* 12 (2017) 024, arXiv:1708.03299 [hep-ex].
- [15] CMS Collaboration, Evidence for the Higgs boson decay to a bottom quark–antiquark pair, *Phys. Lett. B* 780 (2018) 501, arXiv:1709.07497 [hep-ex].
- [16] CMS Collaboration, Evidence for Higgs boson decay to a pair of muons, *J. High Energy Phys.* 01 (2021) 148, arXiv:2009.04363 [hep-ex].
- [17] ATLAS Collaboration, A search for the dimuon decay of the standard model Higgs boson with the ATLAS detector, *Phys. Lett. B* 812 (2021) 135980, arXiv:2007.07830 [hep-ex].
- [18] ATLAS Collaboration, Search for the decay of the Higgs boson to charm quarks with the ATLAS experiment, *Phys. Rev. Lett.* 120 (2018) 211802, arXiv:1802.04329 [hep-ex].
- [19] ATLAS Collaboration, Direct constraint on the Higgs-charm coupling from a search for Higgs boson decays into charm quarks with the ATLAS detector, *Eur. Phys. J. C* 82 (2022) 717, arXiv:2201.11428 [hep-ex].
- [20] CMS Collaboration, A search for the standard model Higgs boson decaying to charm quarks, *J. High Energy Phys.* 03 (2020) 131, arXiv:1912.01662 [hep-ex].
- [21] CMS Collaboration, Search for Higgs boson decay to a charm quark–antiquark pair in proton–proton collisions at  $\sqrt{s} = 13\text{ TeV}$ , *Phys. Rev. Lett.* 131 (2022) 061801, arXiv:2205.05550 [hep-ex].
- [22] M. Doroshenko, V. Kartvelishvili, E. Chikovani, S. Esakiya, Vector quarkonium in decays of heavy Higgs particles, *Yad. Fiz.* 46 (1987) 864.
- [23] G. Bodwin, F. Petriello, S. Stoynev, M. Velasco, Higgs boson decays to quarkonia and the  $H\bar{c}c$  coupling, *Phys. Rev. D* 88 (2013) 053003, arXiv:1306.5770 [hep-ph].
- [24] G.T. Bodwin, H.S. Chung, J.-H. Ee, J. Lee, F. Petriello, Relativistic corrections to Higgs-boson decays to quarkonia, *Phys. Rev. D* 90 (2014) 113010, arXiv:1407.6695 [hep-ph].
- [25] Y. Grossman, M. König, M. Neubert, Exclusive radiative decays of W and Z bosons in QCD factorization, *J. High Energy Phys.* 04 (2015) 101, arXiv:1501.06569 [hep-ph].
- [26] ATLAS Collaboration, Search for Higgs and Z boson decays to  $J/\psi\gamma$  and  $Y(nS)\gamma$  with the ATLAS detector, *Phys. Rev. Lett.* 114 (2015) 121801, arXiv:1501.03276 [hep-ex].
- [27] ATLAS Collaboration, Searches for exclusive Higgs and Z boson decays into  $J/\psi\gamma$ ,  $\psi(2S)\gamma$ , and  $Y(nS)\gamma$  at  $\sqrt{s} = 13\text{ TeV}$  with the ATLAS detector, *Phys. Lett. B* 786 (2018) 134, arXiv:1807.00802 [hep-ex].
- [28] ATLAS Collaboration, Searches for exclusive Higgs and Z boson decays into a vector quarkonium state and a photon using  $139\text{ fb}^{-1}$  of ATLAS  $\sqrt{s} = 13\text{ TeV}$  proton–proton collision data, *Eur. Phys. J. C* 83 (2023) 781, arXiv:2208.03122 [hep-ex].
- [29] CMS Collaboration, Search for a Higgs boson decaying into  $\gamma^*\gamma \rightarrow \ell\ell\gamma$  with low dilepton mass in  $pp$  collisions at  $\sqrt{s} = 8\text{ TeV}$ , *Phys. Lett. B* 753 (2016) 341, arXiv:1507.03031 [hep-ex].
- [30] CMS Collaboration, Search for rare decays of Z and Higgs bosons to  $J/\psi$  and a photon in proton–proton collisions at  $\sqrt{s} = 13\text{ TeV}$ , *Eur. Phys. J. C* 79 (2019) 94, arXiv:1810.10056 [hep-ex].
- [31] M. König, M. Neubert, Exclusive radiative Higgs decays as probes of light-quark Yukawa couplings, *J. High Energy Phys.* 08 (2015) 012, arXiv:1505.03870 [hep-ph].
- [32] A.L. Kagan, et al., Exclusive window onto Higgs Yukawa couplings, *Phys. Rev. Lett.* 114 (2015) 101802, arXiv:1406.1722 [hep-ph].
- [33] G. Perez, Y. Soreq, E. Stamou, K. Tobioka, Prospects for measuring the Higgs boson coupling to light quarks, *Phys. Rev. D* 93 (2016) 013001, arXiv:1505.06689 [hep-ph].
- [34] ATLAS Collaboration, Search for Higgs and Z boson decays to  $\phi\gamma$  with the ATLAS detector, *Phys. Rev. Lett.* 117 (2016) 111802, arXiv:1607.03400 [hep-ex].
- [35] ATLAS Collaboration, Search for exclusive Higgs and Z boson decays to  $\phi\gamma$  and  $\rho\gamma$  with the ATLAS detector, *J. High Energy Phys.* 07 (2018) 127, arXiv:1712.02758 [hep-ex].
- [36] CMS Collaboration, Search for decays of the  $125\text{ GeV}$  Higgs boson into a Z boson and a  $\rho$  or  $\phi$  meson, *J. High Energy Phys.* 11 (2020) 039, arXiv:2007.05122 [hep-ex].
- [37] ATLAS Collaboration, Summary of ATLAS searches for Higgs and Z boson decays to a meson and a photon, ATL-PHYS-PUB-2023-004, <https://cds.cern.ch/record/2851888>, 2023.
- [38] J.I. Aranda, G. González-Estrada, J. Montaña, F. Ramírez-Zavaleta, E.S. Tututi, Revisiting the rare  $H \rightarrow q_i q_j$  decays in the standard model, *J. Phys. G* 47 (2020) 125001, arXiv:2009.07166 [hep-ph].
- [39] ATLAS Collaboration, Search for top quark decays  $t \rightarrow qH$ , with  $H \rightarrow \gamma\gamma$ , in  $\sqrt{s} = 13\text{ TeV}$   $pp$  collisions using the ATLAS detector, *J. High Energy Phys.* 10 (2017) 129, arXiv:1707.01404 [hep-ex].
- [40] ATLAS Collaboration, Search for flavor-changing neutral currents in top quark decays  $t \rightarrow Hc$  and  $t \rightarrow Hu$  in multilepton final states in proton–proton collisions at  $\sqrt{s} = 13\text{ TeV}$  with the ATLAS detector, *Phys. Rev. D* 98 (2018) 032002, arXiv:1805.03483 [hep-ex].
- [41] CMS Collaboration, Search for flavor-changing neutral current interactions of the top quark and the Higgs boson decaying to a bottom quark–antiquark pair at  $\sqrt{s} = 13\text{ TeV}$ , *J. High Energy Phys.* 02 (2021) 169, arXiv:2112.09734 [hep-ex].
- [42] CMS Collaboration, Search for flavor-changing neutral current interactions of the top quark and Higgs boson in final states with two photons in proton–proton collisions at  $\sqrt{s} = 13\text{ TeV}$ , *Phys. Rev. Lett.* 129 (2022) 032001, arXiv:2111.02219 [hep-ex].
- [43] T.-C. Huang, F. Petriello, Rare exclusive decays of the Z boson revisited, *Phys. Rev. D* 92 (2015) 014007, arXiv:1411.5924 [hep-ph].
- [44] DELPHI Collaboration, Measurement of the  $e^+e^- \rightarrow \gamma\gamma(\gamma)$  cross section at LEP energies, *Phys. Lett. B* 327 (1994) 386.
- [45] ATLAS Collaboration, The ATLAS experiment at the CERN large hadron collider, *J. Instrum.* 3 (2008) S08003.
- [46] ATLAS Collaboration, ATLAS insertable B-layer: technical design report, ATLAS-TDR-19; CERN-LHCC-2010-013, <https://cds.cern.ch/record/1291633>, 2010; Addendum: ATLAS-TDR-19-ADD-1; CERN-LHCC-2012-009, <https://cds.cern.ch/record/1451888>, 2012.
- [47] B. Abbott, et al., Production and integration of the ATLAS insertable B-layer, *J. Instrum.* 13 (2018) T05008, arXiv:1803.00844 [physics.ins-det].
- [48] ATLAS Collaboration, Performance of the ATLAS trigger system in 2015, *Eur. Phys. J. C* 77 (2017) 317, arXiv:1611.09661 [hep-ex].
- [49] ATLAS Collaboration, The ATLAS collaboration software and firmware, ATL-SOFT-PUB-2021-001, <https://cds.cern.ch/record/2767187>, 2021.
- [50] ATLAS Collaboration, Luminosity determination in  $pp$  collisions at  $\sqrt{s} = 8\text{ TeV}$  using the ATLAS detector at the LHC, *Eur. Phys. J. C* 76 (2016) 653, arXiv:1608.03953 [hep-ex].
- [51] ATLAS Collaboration, Luminosity determination in  $pp$  collisions at  $\sqrt{s} = 13\text{ TeV}$  using the ATLAS detector at the LHC, ATLAS-CONF-2019-021, <https://cds.cern.ch/record/2677054>, 2019.
- [52] ATLAS Collaboration, The ATLAS tau trigger in run 2, ATLAS-CONF-2017-061, <https://cds.cern.ch/record/2274201>, 2017.
- [53] 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 [hep-ex].
- [54] P. Nason, A new method for combining NLO QCD with shower Monte Carlo algorithms, *J. High Energy Phys.* 11 (2004) 040, arXiv:hep-ph/0409146.
- [55] S. Frixione, P. Nason, C. Oleari, Matching NLO QCD computations with parton shower simulations: the POWHEG method, *J. High Energy Phys.* 11 (2007) 070, arXiv:0709.2092 [hep-ph].
- [56] S. Alioli, P. Nason, C. Oleari, E. Re, A general framework for implementing NLO calculations in shower Monte Carlo programs: the POWHEG BOX, *J. High Energy Phys.* 06 (2010) 043, arXiv:1002.2581 [hep-ph].
- [57] S. Alioli, P. Nason, C. Oleari, E. Re, NLO Higgs boson production via gluon fusion matched with shower in POWHEG, *J. High Energy Phys.* 04 (2009) 080, arXiv:0812.0578 [hep-ph].
- [58] P. Nason, C. Oleari, NLO Higgs boson production via vector-boson fusion matched with shower in POWHEG, *J. High Energy Phys.* 02 (2010) 037, arXiv:0911.5299 [hep-ph].
- [59] T. Sjöstrand, S. Mrenna, P.Z. Skands, A brief introduction to PYTHIA 8.1, *Comput. Phys. Commun.* 178 (2008) 852, arXiv:0710.3820 [hep-ph].
- [60] T. Sjöstrand, S. Mrenna, P.Z. Skands, PYTHIA 6.4 physics and manual, *J. High Energy Phys.* 05 (2006) 026, arXiv:hep-ph/0603175.
- [61] ATLAS Collaboration, Measurement of the Z/ $\gamma^*$  boson transverse momentum distribution in  $pp$  collisions at  $\sqrt{s} = 7\text{ TeV}$  with the ATLAS detector, *J. High Energy Phys.* 09 (2014) 145, arXiv:1406.3660 [hep-ex].
- [62] J. Pumplin, et al., New generation of parton distributions with uncertainties from global QCD analysis, *J. High Energy Phys.* 07 (2002) 012, arXiv:hep-ph/0201195 [hep-ph].
- [63] R.D. Ball, et al., Parton distributions with LHC data, *Nucl. Phys. B* 867 (2013) 244, arXiv:1207.1303 [hep-ph].
- [64] ATLAS Collaboration, ATLAS Pythia 8 tunes to 7 TeV data, ATL-PHYS-PUB-2014-021, <https://cds.cern.ch/record/1966419>, 2014.
- [65] 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, *J. High Energy Phys.* 07 (2014) 079, arXiv:1405.0301 [hep-ph].
- [66] LHC Higgs cross section working group, S. Dittmaier, C. Mariotti, G. Passarino, Tanaka (Eds.), Handbook of LHC Higgs Cross Sections: 2. Differential Distributions, 2012, CERN-2012-002, arXiv:1201.3084 [hep-ph].
- [67] S. Actis, G. Passarino, C. Sturm, S. Uccirati, NLO electroweak corrections to Higgs boson production at hadron colliders, *Phys. Lett. B* 670 (2008) 12, arXiv:0809.1301 [hep-ph].
- [68] C. Anastasiou, R. Boughezal, F. Petriello, Mixed QCD-electroweak corrections to Higgs boson production in gluon fusion, *J. High Energy Phys.* 04 (2009) 003, arXiv:0811.3458 [hep-ph].
- [69] M. Ciccolini, A. Denner, S. Dittmaier, Strong and electroweak corrections to the production of a Higgs boson + 2 jets via weak interactions at the large hadron collider, *Phys. Rev. Lett.* 99 (2007) 161803, arXiv:0707.0381 [hep-ph].



- [70] M. Ciccolini, A. Denner, S. Dittmaier, Electroweak and QCD corrections to Higgs production via vector-boson fusion at the LHC, *Phys. Rev. D* 77 (2008) 013002, arXiv:0710.4749 [hep-ph].
- [71] P. Bolzoni, F. Maltoni, S.-O. Moch, M. Zaro, Higgs boson production via vector-boson fusion at next-to-next-to-leading order in QCD, *Phys. Rev. Lett.* 105 (2010) 011801, arXiv:1003.4451 [hep-ph].
- [72] O. Brein, A. Djouadi, R. Harlander, NNLO QCD corrections to the Higgs-strahlung processes at hadron colliders, *Phys. Lett. B* 579 (2004) 149, arXiv:hep-ph/0307206.
- [73] ATLAS Collaboration, Measurement of  $W^\pm$  and Z-boson production cross sections in  $pp$  collisions at  $\sqrt{s} = 13 \text{ TeV}$  with the ATLAS detector, *Phys. Lett. B* 759 (2016) 601, arXiv:1603.09222 [hep-ex].
- [74] Particle Data Group, Review of particle physics, *Chin. Phys. C* 38 (2014) 090001.
- [75] S. Agostinelli, et al., GEANT4: a simulation toolkit, *Nucl. Instrum. Methods A* 506 (2003) 250.
- [76] ATLAS Collaboration, The ATLAS simulation infrastructure, *Eur. Phys. J. C* 70 (2010) 823, arXiv:1005.4568.
- [77] ATLAS Collaboration, Measurement of the photon identification efficiencies with the ATLAS detector using LHC run 2 data collected in 2015 and 2016, *Eur. Phys. J. C* 79 (2019) 205, arXiv:1810.05087 [hep-ex].
- [78] ATLAS Collaboration, Early inner detector tracking performance in the 2015 data at  $\sqrt{s} = 13 \text{ TeV}$ , <https://cds.cern.ch/record/2110140>, 2015.
- [79] ATLAS Collaboration, Reconstruction of hadronic decay products of tau leptons with the ATLAS experiment, *Eur. Phys. J. C* 76 (2016) 295, arXiv:1512.05955 [hep-ex].
- [80] A. Chisholm, et al., Non-parametric data-driven background modelling using conditional probabilities, *J. High Energy Phys.* 10 (2022) 001, arXiv:2112.00650 [hep-ex].
- [81] K.S. Cranmer, Kernel estimation in high-energy physics, *Comput. Phys. Commun.* 136 (2001) 198, arXiv:hep-ex/0011057 [hep-ex].
- [82] ATLAS Collaboration, Performance of electron and photon triggers in ATLAS during LHC run 2, *Eur. Phys. J. C* 80 (2020) 47, arXiv:1909.00761 [hep-ex].
- [83] ATLAS Collaboration, Measurement of the energy response of the ATLAS calorimeter to charged pions from  $W^\pm \rightarrow \tau^\pm (\rightarrow \pi^\pm \nu_\tau) \nu_\tau$  events in run 2 data, *Eur. Phys. J. C* 82 (2021) 223, arXiv:2108.09043 [hep-ex].
- [84] LHC Higgs cross section working group, S. Dittmaier, C. Mariotti, G. Passarino, R. Tanaka (Eds.), Handbook of LHC Higgs Cross Sections: 1. Inclusive Observables, 2011, arXiv:1101.0593 [hep-ph].
- [85] LHC Higgs cross section working group, S. Dittmaier, C. Mariotti, G. Passarino, R. Tanaka (Eds.), Handbook of LHC Higgs Cross Sections: 2. Differential Distributions, 2012, CERN-2012-002, arXiv:1201.3084 [hep-ph].
- [86] A.L. Read, Presentation of search results: the CL(s) technique, in: M.R. Whalley, L. Lyons (Eds.), *J. Phys. G* 28 (2002) 2693.
- [87] G. Cowan, K. Cranmer, E. Gross, O. Vitells, Asymptotic formulae for likelihood-based tests of new physics, *Eur. Phys. J. C* 71 (2011) 1554, arXiv:1007.1727 [physics.data-an].
- [88] ATLAS Collaboration, ATLAS computing acknowledgements, ATL-SOFT-PUB-2023-001, <https://cds.cern.ch/record/2869272>, 2023.

## The ATLAS Collaboration

G. Aad<sup>90</sup>, B. Abbott<sup>120</sup>, K. Abeling<sup>55</sup>, S.H. Abidi<sup>29</sup>, A. Abouhorma<sup>35e</sup>, H. Abramowicz<sup>151</sup>, H. Abreu<sup>150</sup>, Y. Abulaiti<sup>117</sup>, A.C. Abusleme Hoffman<sup>137a</sup>, B.S. Acharya<sup>69a,69b</sup>, C. Adam Bourdarios<sup>4</sup>, L. Adamczyk<sup>85a</sup>, L. Adamek<sup>155</sup>, S.V. Addepalli<sup>26</sup>, J. Adelman<sup>115</sup>, A. Adiguzel<sup>21c</sup>, S. Adorni<sup>56</sup>, T. Adye<sup>134</sup>, A.A. Affolder<sup>136</sup>, Y. Afik<sup>36</sup>, M.N. Agarar<sup>13</sup>, J. Agarwala<sup>73a,73b</sup>, A. Aggarwal<sup>101</sup>, C. Agheorghiesei<sup>27c</sup>, J.A. Aguilar-Saavedra<sup>130f</sup>, A. Ahmad<sup>36</sup>, F. Ahmadov<sup>38</sup>, W.S. Ahmed<sup>104</sup>, S. Ahuja<sup>96</sup>, X. Ai<sup>48</sup>, G. Aielli<sup>76a,76b</sup>, M. Ait Tamliah<sup>35e</sup>, B. Aitbenkikh<sup>35a</sup>, I. Aizenberg<sup>169</sup>, M. Akbiyik<sup>101</sup>, T.P.A. Åkesson<sup>99</sup>, A.V. Akimov<sup>37</sup>, K. Al Khoury<sup>41</sup>, G.L. Alberghi<sup>23b</sup>, J. Albert<sup>165</sup>, P. Albicocco<sup>53</sup>, S. Alderweireldt<sup>52</sup>, M. Aleksa<sup>36</sup>, I.N. Aleksandrov<sup>38</sup>, C. Alexa<sup>27b</sup>, T. Alexopoulos<sup>10</sup>, A. Alfonsi<sup>114</sup>, F. Alfonsi<sup>23b</sup>, M. Alhroob<sup>120</sup>, B. Ali<sup>132</sup>, S. Ali<sup>148</sup>, M. Aliev<sup>37</sup>, G. Alimonti<sup>71a</sup>, W. Alkakhri<sup>55</sup>, C. Allaire<sup>66</sup>, B.M.M. Allbrooke<sup>146</sup>, C.A. Allendes Flores<sup>137f</sup>, P.P. Allport<sup>20</sup>, A. Aloisio<sup>72a,72b</sup>, F. Alonso<sup>91</sup>, C. Alpigiani<sup>138</sup>, M. Alvarez Estevez<sup>100</sup>, A. Alvarez Fernandez<sup>101</sup>, M.G. Alviggi<sup>72a,72b</sup>, M. Aly<sup>102</sup>, Y. Amaral Coutinho<sup>82b</sup>, A. Ambler<sup>104</sup>, C. Amelung<sup>36</sup>, M. Amerl<sup>102</sup>, C.G. Ames<sup>109</sup>, D. Amidei<sup>106</sup>, S.P. Amor Dos Santos<sup>130a</sup>, K.R. Amos<sup>163</sup>, V. Ananiev<sup>125</sup>, C. Anastopoulos<sup>139</sup>, T. Andeen<sup>11</sup>, J.K. Anders<sup>36</sup>, S.Y. Andreev<sup>47a,47b</sup>, A. Andreazza<sup>71a,71b</sup>, S. Angelidakis<sup>9</sup>, A. Angerami<sup>41</sup>, A.V. Anisenkov<sup>37</sup>, A. Annovi<sup>74a</sup>, C. Antel<sup>56</sup>, M.T. Anthony<sup>139</sup>, E. Antipov<sup>145</sup>, M. Antonelli<sup>53</sup>, D.J.A. Antrim<sup>17a</sup>, F. Anulli<sup>75a</sup>, M. Aoki<sup>83</sup>, T. Aoki<sup>153</sup>, J.A. Aparisi Pozo<sup>163</sup>, M.A. Aparo<sup>146</sup>, L. Aperio Bella<sup>48</sup>, C. Appelt<sup>18</sup>, N. Aranzabal<sup>36</sup>, V. Araujo Ferraz<sup>82a</sup>, C. Arcangeletti<sup>53</sup>, A.T.H. Arce<sup>51</sup>, E. Arena<sup>93</sup>, J-F. Arguin<sup>108</sup>, S. Argyropoulos<sup>54</sup>, J.-H. Arling<sup>48</sup>, A.J. Armbruster<sup>36</sup>, O. Arnaez<sup>4</sup>, H. Arnold<sup>114</sup>, Z.P. Arrubarrena Tame<sup>109</sup>, G. Artoni<sup>75a,75b</sup>, H. Asada<sup>111</sup>, K. Asai<sup>118</sup>, S. Asai<sup>153</sup>, N.A. Asbah<sup>61</sup>, J. Assahsah<sup>35d</sup>, K. Assamagan<sup>29</sup>, R. Astalos<sup>28a</sup>, R.J. Atkin<sup>33a</sup>, M. Atkinson<sup>162</sup>, N.B. Atlay<sup>18</sup>, H. Atmani<sup>62b</sup>, P.A. Atmasiddha<sup>106</sup>, K. Augsten<sup>132</sup>, S. Auricchio<sup>72a,72b</sup>, A.D. Auriol<sup>20</sup>, V.A. Austrup<sup>171</sup>, G. Avner<sup>150</sup>, G. Avolio<sup>36</sup>, K. Axiotis<sup>56</sup>, G. Azuelos<sup>108</sup>, D. Babal<sup>28a</sup>, H. Bachacou<sup>135</sup>, K. Bachas<sup>152</sup>, A. Bachiou<sup>34</sup>, F. Backman<sup>47a,47b</sup>, A. Badea<sup>61</sup>, P. Bagnaia<sup>75a,75b</sup>, M. Bahmani<sup>18</sup>, A.J. Bailey<sup>163</sup>, V.R. Bailey<sup>162</sup>, J.T. Baines<sup>134</sup>, C. Bakalis<sup>10</sup>, O.K. Baker<sup>172</sup>, E. Bakos<sup>15</sup>, D. Bakshi Gupta<sup>8</sup>, R. Balasubramanian<sup>114</sup>, E.M. Baldin<sup>37</sup>, P. Balek<sup>133</sup>, E. Ballabene<sup>71a,71b</sup>, F. Balli<sup>135</sup>, L.M. Baltos<sup>63a</sup>, W.K. Balunas<sup>32</sup>, J. Balz<sup>101</sup>, E. Banas<sup>86</sup>, M. Bandieramonte<sup>129</sup>, A. Bandyopadhyay<sup>24</sup>, S. Bansal<sup>24</sup>, L. Barak<sup>151</sup>, E.L. Barberio<sup>105</sup>, D. Barberis<sup>57b,57a</sup>, M. Barbero<sup>90</sup>, G. Barbour<sup>97</sup>, K.N. Barends<sup>33a</sup>, T. Barillari<sup>110</sup>, M-S. Barisits<sup>36</sup>,

T. Barklow <sup>143, [id](#)</sup>, P. Baron <sup>122, [id](#)</sup>, D.A. Baron Moreno <sup>102, [id](#)</sup>, A. Baroncelli <sup>62a, [id](#)</sup>, G. Barone <sup>29, [id](#)</sup>, A.J. Barr <sup>126, [id](#)</sup>, L. Barranco Navarro <sup>47a,47b, [id](#)</sup>, F. Barreiro <sup>100, [id](#)</sup>, J. Barreiro Guimarães da Costa <sup>14a, [id](#)</sup>, U. Barron <sup>151, [id](#)</sup>, M.G. Barros Teixeira <sup>130a, [id](#)</sup>, S. Barsov <sup>37, [id](#)</sup>, F. Bartels <sup>63a, [id](#)</sup>, R. Bartoldus <sup>143, [id](#)</sup>, A.E. Barton <sup>92, [id](#)</sup>, P. Bartos <sup>28a, [id](#)</sup>, A. Basan <sup>101, [id](#)</sup>, M. Baselga <sup>49, [id](#)</sup>, I. Bashta <sup>77a,77b, [id](#)</sup>, A. Bassalat <sup>66, [id](#), [b](#)</sup>, M.J. Basso <sup>155, [id](#)</sup>, C.R. Basson <sup>102, [id](#)</sup>, R.L. Bates <sup>59, [id](#)</sup>, S. Batlamous <sup>35e, [id](#)</sup>, J.R. Batley <sup>32, [id](#)</sup>, B. Batool <sup>141, [id](#)</sup>, M. Battaglia <sup>136, [id](#)</sup>, D. Battulga <sup>18, [id](#)</sup>, M. Bauce <sup>75a,75b, [id](#)</sup>, P. Bauer <sup>24, [id](#)</sup>, J.B. Beacham <sup>51, [id](#)</sup>, T. Beau <sup>127, [id](#)</sup>, P.H. Beauchemin <sup>158, [id](#)</sup>, F. Becherer <sup>54, [id](#)</sup>, P. Bechtel <sup>24, [id](#)</sup>, H.P. Beck <sup>19, [id](#), [r](#)</sup>, K. Becker <sup>167, [id](#)</sup>, A.J. Beddall <sup>21d, [id](#)</sup>, V.A. Bednyakov <sup>38, [id](#)</sup>, C.P. Bee <sup>145, [id](#)</sup>, L.J. Beemster <sup>15, [id](#)</sup>, T.A. Beermann <sup>36, [id](#)</sup>, M. Begalli <sup>82d, [id](#)</sup>, M. Begel <sup>29, [id](#)</sup>, A. Behera <sup>145, [id](#)</sup>, J.K. Behr <sup>48, [id](#)</sup>, C. Beirao Da Cruz E Silva <sup>36, [id](#)</sup>, J.F. Beirer <sup>55,36, [id](#)</sup>, F. Beisiegel <sup>24, [id](#)</sup>, M. Belfkir <sup>159, [id](#)</sup>, G. Bella <sup>151, [id](#)</sup>, L. Bellagamba <sup>23b, [id](#)</sup>, A. Bellerive <sup>34, [id](#)</sup>, P. Bellos <sup>20, [id](#)</sup>, K. Beloborodov <sup>37, [id](#)</sup>, N.L. Belyaev <sup>37, [id](#)</sup>, D. Bencheekroun <sup>35a, [id](#)</sup>, F. Bendebba <sup>35a, [id](#)</sup>, Y. Benhammou <sup>151, [id](#)</sup>, M. Benoit <sup>29, [id](#)</sup>, J.R. Bensinger <sup>26, [id](#)</sup>, S. Bentvelsen <sup>114, [id](#)</sup>, L. Beresford <sup>36, [id](#)</sup>, M. Beretta <sup>53, [id](#)</sup>, E. Bergeaas Kuutmann <sup>161, [id](#)</sup>, N. Berger <sup>4, [id](#)</sup>, B. Bergmann <sup>132, [id](#)</sup>, J. Beringer <sup>17a, [id](#)</sup>, S. Berlendis <sup>7, [id](#)</sup>, G. Bernardi <sup>5, [id](#)</sup>, C. Bernius <sup>143, [id](#)</sup>, F.U. Bernlochner <sup>24, [id](#)</sup>, T. Berry <sup>96, [id](#)</sup>, P. Berta <sup>133, [id](#)</sup>, A. Berthold <sup>50, [id](#)</sup>, I.A. Bertram <sup>92, [id](#)</sup>, S. Bethke <sup>110, [id](#)</sup>, A. Betti <sup>75a,75b, [id](#)</sup>, A.J. Bevan <sup>95, [id](#)</sup>, M. Bhamjee <sup>33c, [id](#)</sup>, S. Bhatta <sup>145, [id](#)</sup>, D.S. Bhattacharya <sup>166, [id](#)</sup>, P. Bhattarai <sup>26, [id](#)</sup>, V.S. Bhopatkar <sup>121, [id](#)</sup>, R. Bi <sup>29, [al](#)</sup>, R.M. Bianchi <sup>129, [id](#)</sup>, O. Biebel <sup>109, [id](#)</sup>, R. Bielski <sup>123, [id](#)</sup>, M. Biglietti <sup>77a, [id](#)</sup>, T.R.V. Billoud <sup>132, [id](#)</sup>, M. Bindi <sup>55, [id](#)</sup>, A. Bingul <sup>21b, [id](#)</sup>, C. Bini <sup>75a,75b, [id](#)</sup>, A. Biondini <sup>93, [id](#)</sup>, C.J. Birch-sykes <sup>102, [id](#)</sup>, G.A. Bird <sup>20,134, [id](#)</sup>, M. Birman <sup>169, [id](#)</sup>, M. Biros <sup>133, [id](#)</sup>, T. Bisanz <sup>36, [id](#)</sup>, E. Bisceglie <sup>43b,43a, [id](#)</sup>, D. Biswas <sup>170, [id](#)</sup>, A. Bitadze <sup>102, [id](#)</sup>, K. Björke <sup>125, [id](#)</sup>, I. Bloch <sup>48, [id](#)</sup>, C. Blocker <sup>26, [id](#)</sup>, A. Blue <sup>59, [id](#)</sup>, U. Blumenschein <sup>95, [id](#)</sup>, J. Blumenthal <sup>101, [id](#)</sup>, G.J. Bobbink <sup>114, [id](#)</sup>, V.S. Bobrovnikov <sup>37, [id](#)</sup>, M. Boehler <sup>54, [id](#)</sup>, D. Bogavac <sup>36, [id](#)</sup>, A.G. Bogdanchikov <sup>37, [id](#)</sup>, C. Boehm <sup>47a, [id](#)</sup>, V. Boisvert <sup>96, [id](#)</sup>, P. Bokan <sup>48, [id](#)</sup>, T. Bold <sup>85a, [id](#)</sup>, M. Bomben <sup>5, [id](#)</sup>, M. Bona <sup>95, [id](#)</sup>, M. Boonekamp <sup>135, [id](#)</sup>, C.D. Booth <sup>96, [id](#)</sup>, A.G. Borbély <sup>59, [id](#)</sup>, H.M. Borecka-Bielska <sup>108, [id](#)</sup>, L.S. Borgna <sup>97, [id](#)</sup>, G. Borissov <sup>92, [id](#)</sup>, D. Bortoletto <sup>126, [id](#)</sup>, D. Boscherini <sup>23b, [id](#)</sup>, M. Bosman <sup>13, [id](#)</sup>, J.D. Bossio Sola <sup>36, [id](#)</sup>, K. Bouaouda <sup>35a, [id](#)</sup>, N. Bouchhar <sup>163, [id](#)</sup>, J. Boudreau <sup>129, [id](#)</sup>, E.V. Bouhova-Thacker <sup>92, [id](#)</sup>, D. Boumediene <sup>40, [id](#)</sup>, R. Bouquet <sup>5, [id](#)</sup>, A. Boveia <sup>119, [id](#)</sup>, J. Boyd <sup>36, [id](#)</sup>, D. Boye <sup>29, [id](#)</sup>, I.R. Boyko <sup>38, [id](#)</sup>, J. Bracinik <sup>20, [id](#)</sup>, N. Brahimi <sup>62d, [id](#)</sup>, G. Brandt <sup>171, [id](#)</sup>, O. Brandt <sup>32, [id](#)</sup>, F. Braren <sup>48, [id](#)</sup>, B. Brau <sup>103, [id](#)</sup>, J.E. Brau <sup>123, [id](#)</sup>, K. Brendlinger <sup>48, [id](#)</sup>, R. Brenner <sup>169, [id](#)</sup>, L. Brenner <sup>114, [id](#)</sup>, R. Brenner <sup>161, [id](#)</sup>, S. Bressler <sup>169, [id](#)</sup>, D. Britton <sup>59, [id](#)</sup>, D. Britzger <sup>110, [id](#)</sup>, I. Brock <sup>24, [id](#)</sup>, G. Brooijmans <sup>41, [id](#)</sup>, W.K. Brooks <sup>137f, [id](#)</sup>, E. Brost <sup>29, [id](#)</sup>, L.M. Brown <sup>165, [id](#)</sup>, T.L. Bruckler <sup>126, [id](#)</sup>, P.A. Bruckman de Renstrom <sup>86, [id](#)</sup>, B. Brüers <sup>48, [id](#)</sup>, D. Bruncko <sup>28b, [id](#), [\\*](#)</sup>, A. Bruni <sup>23b, [id](#)</sup>, G. Bruni <sup>23b, [id](#)</sup>, M. Bruschi <sup>23b, [id](#)</sup>, N. Brusino <sup>75a,75b, [id](#)</sup>, T. Buanes <sup>16, [id](#)</sup>, Q. Buat <sup>138, [id](#)</sup>, A.G. Buckley <sup>59, [id](#)</sup>, I.A. Budagov <sup>38, [id](#), [\\*](#)</sup>, M.K. Bugge <sup>125, [id](#)</sup>, O. Bulekov <sup>37, [id](#)</sup>, B.A. Bullard <sup>143, [id](#)</sup>, S. Burdin <sup>93, [id](#)</sup>, C.D. Burgard <sup>49, [id](#)</sup>, A.M. Burger <sup>40, [id](#)</sup>, B. Burghgrave <sup>8, [id](#)</sup>, J.T.P. Burr <sup>32, [id](#)</sup>, C.D. Burton <sup>11, [id](#)</sup>, J.C. Burzynski <sup>142, [id](#)</sup>, E.L. Busch <sup>41, [id](#)</sup>, V. Büscher <sup>101, [id](#)</sup>, P.J. Bussey <sup>59, [id](#)</sup>, J.M. Butler <sup>25, [id](#)</sup>, C.M. Buttar <sup>59, [id](#)</sup>, J.M. Butterworth <sup>97, [id](#)</sup>, W. Buttinger <sup>134, [id](#)</sup>, C.J. Buxo Vazquez <sup>107, [id](#)</sup>, A.R. Buzykaev <sup>37, [id](#)</sup>, G. Cabras <sup>23b, [id](#)</sup>, S. Cabrera Urbán <sup>163, [id](#)</sup>, D. Caforio <sup>58, [id](#)</sup>, H. Cai <sup>129, [id](#)</sup>, Y. Cai <sup>14a,14d, [id](#)</sup>, V.M.M. Cairo <sup>36, [id](#)</sup>, O. Cakir <sup>3a, [id](#)</sup>, N. Calace <sup>36, [id](#)</sup>, P. Calafiura <sup>17a, [id](#)</sup>, G. Calderini <sup>127, [id](#)</sup>, P. Calfayan <sup>68, [id](#)</sup>, G. Callea <sup>59, [id](#)</sup>, L.P. Caloba <sup>82b, [id](#)</sup>, D. Calvet <sup>40, [id](#)</sup>, S. Calvet <sup>40, [id](#)</sup>, T.P. Calvet <sup>90, [id](#)</sup>, M. Calvetti <sup>74a,74b, [id](#)</sup>, R. Camacho Toro <sup>127, [id](#)</sup>, S. Camarda <sup>36, [id](#)</sup>, D. Camarero Munoz <sup>26, [id](#)</sup>, P. Camarri <sup>76a,76b, [id](#)</sup>, M.T. Camerlingo <sup>72a,72b, [id](#)</sup>, D. Cameron <sup>125, [id](#)</sup>, C. Camincher <sup>165, [id](#)</sup>, M. Campanelli <sup>97, [id](#)</sup>, A. Camplani <sup>42, [id](#)</sup>, V. Canale <sup>72a,72b, [id](#)</sup>, A. Canesse <sup>104, [id](#)</sup>, M. Cano Bret <sup>80, [id](#)</sup>, J. Cantero <sup>163, [id](#)</sup>, Y. Cao <sup>162, [id](#)</sup>, F. Capocasa <sup>26, [id](#)</sup>, M. Capua <sup>43b,43a, [id](#)</sup>, A. Carbone <sup>71a,71b, [id](#)</sup>, R. Cardarelli <sup>76a, [id](#)</sup>, J.C.J. Cardenas <sup>8, [id](#)</sup>, F. Cardillo <sup>163, [id](#)</sup>, T. Carli <sup>36, [id](#)</sup>, G. Carlino <sup>72a, [id](#)</sup>, J.I. Carlotto <sup>13, [id](#)</sup>, B.T. Carlson <sup>129, [id](#), [r](#)</sup>, E.M. Carlson <sup>165,156a, [id](#)</sup>, L. Carminati <sup>71a,71b, [id](#)</sup>, M. Carnesale <sup>75a,75b, [id](#)</sup>, S. Caron <sup>113, [id](#)</sup>, E. Carquin <sup>137f, [id](#)</sup>, S. Carrá <sup>71a,71b, [id](#)</sup>, G. Carratta <sup>23b,23a, [id](#)</sup>, F. Carrio Argos <sup>33g, [id](#)</sup>, J.W.S. Carter <sup>155, [id](#)</sup>, T.M. Carter <sup>52, [id](#)</sup>, M.P. Casado <sup>13, [id](#), [j](#)</sup>, A.F. Casha <sup>155, [id](#)</sup>, M. Caspar <sup>48, [id](#)</sup>,

E.G. Castiglia <sup>172, [id](#)</sup>, F.L. Castillo <sup>63a, [id](#)</sup>, L. Castillo Garcia <sup>13, [id](#)</sup>, V. Castillo Gimenez <sup>163, [id](#)</sup>, N.F. Castro <sup>130a, 130e, [id](#)</sup>,  
A. Catinaccio <sup>36, [id](#)</sup>, J.R. Catmore <sup>125, [id](#)</sup>, V. Cavaliere <sup>29, [id](#)</sup>, N. Cavalli <sup>23b, 23a, [id](#)</sup>, V. Cavasinni <sup>74a, 74b, [id](#)</sup>,  
E. Celebi <sup>21a, [id](#)</sup>, F. Celli <sup>126, [id](#)</sup>, M.S. Centonze <sup>70a, 70b, [id](#)</sup>, K. Cerny <sup>122, [id](#)</sup>, A.S. Cerqueira <sup>82a, [id](#)</sup>, A. Cerri <sup>146, [id](#)</sup>,  
L. Cerrito <sup>76a, 76b, [id](#)</sup>, F. Cerutti <sup>17a, [id](#)</sup>, A. Cervelli <sup>23b, [id](#)</sup>, G. Cesarini <sup>53, [id](#)</sup>, S.A. Cetin <sup>21d, [id](#)</sup>, Z. Chadi <sup>35a, [id](#)</sup>,  
D. Chakraborty <sup>115, [id](#)</sup>, M. Chala <sup>130f, [id](#)</sup>, J. Chan <sup>170, [id](#)</sup>, W.Y. Chan <sup>153, [id](#)</sup>, J.D. Chapman <sup>32, [id](#)</sup>, B. Chargeishvili <sup>149b, [id](#)</sup>,  
D.G. Charlton <sup>20, [id](#)</sup>, T.P. Charman <sup>95, [id](#)</sup>, M. Chatterjee <sup>19, [id](#)</sup>, C. Chauhan <sup>133, [id](#)</sup>, S. Chekanov <sup>6, [id](#)</sup>,  
S.V. Chekulaev <sup>156a, [id](#)</sup>, G.A. Chelkov <sup>38, [id](#), [a](#)</sup>, A. Chen <sup>106, [id](#)</sup>, B. Chen <sup>151, [id](#)</sup>, B. Chen <sup>165, [id](#)</sup>, H. Chen <sup>14c, [id](#)</sup>,  
H. Chen <sup>29, [id](#)</sup>, J. Chen <sup>62c, [id](#)</sup>, J. Chen <sup>142, [id](#)</sup>, S. Chen <sup>153, [id](#)</sup>, S.J. Chen <sup>14c, [id](#)</sup>, X. Chen <sup>62c, [id](#)</sup>, X. Chen <sup>14b, [id](#), [ah](#)</sup>,  
Y. Chen <sup>62a, [id](#)</sup>, C.L. Cheng <sup>170, [id](#)</sup>, H.C. Cheng <sup>64a, [id](#)</sup>, S. Cheong <sup>143, [id](#)</sup>, A. Cheplakov <sup>38, [id](#)</sup>, E. Cheremushkina <sup>48, [id](#)</sup>,  
E. Cherepanova <sup>114, [id](#)</sup>, R. Cherkaoui El Moursli <sup>35e, [id](#)</sup>, E. Cheu <sup>7, [id](#)</sup>, K. Cheung <sup>65, [id](#)</sup>, L. Chevalier <sup>135, [id](#)</sup>,  
V. Chiarella <sup>53, [id](#)</sup>, G. Chiarelli <sup>74a, [id](#)</sup>, N. Chiedde <sup>90, [id](#)</sup>, G. Chiodini <sup>70a, [id](#)</sup>, A.S. Chisholm <sup>20, [id](#)</sup>, A. Chitan <sup>27b, [id](#)</sup>,  
M. Chitishvili <sup>163, [id](#)</sup>, M.V. Chizhov <sup>38, [id](#)</sup>, K. Choi <sup>11, [id](#)</sup>, A.R. Chomont <sup>75a, 75b, [id](#)</sup>, Y. Chou <sup>103, [id](#)</sup>, E.Y.S. Chow <sup>114, [id](#)</sup>,  
T. Chowdhury <sup>33g, [id](#)</sup>, L.D. Christopher <sup>33g, [id](#)</sup>, K.L. Chu <sup>64a, [id](#)</sup>, M.C. Chu <sup>64a, [id](#)</sup>, X. Chu <sup>14a, 14d, [id](#)</sup>, J. Chudoba <sup>131, [id](#)</sup>,  
J.J. Chwastowski <sup>86, [id](#)</sup>, D. Cieri <sup>110, [id](#)</sup>, K.M. Ciesla <sup>85a, [id](#)</sup>, V. Cindro <sup>94, [id](#)</sup>, A. Ciocio <sup>17a, [id](#)</sup>, F. Ciotto <sup>72a, 72b, [id](#)</sup>,  
Z.H. Citron <sup>169, [id](#), [m](#)</sup>, M. Citterio <sup>71a, [id](#)</sup>, D.A. Ciubotaru <sup>27b, [id](#)</sup>, B.M. Ciungu <sup>155, [id](#)</sup>, A. Clark <sup>56, [id](#)</sup>, P.J. Clark <sup>52, [id](#)</sup>,  
J.M. Clavijo Columbie <sup>48, [id](#)</sup>, S.E. Clawson <sup>102, [id](#)</sup>, C. Clement <sup>47a, 47b, [id](#)</sup>, J. Clercx <sup>48, [id](#)</sup>, L. Clissa <sup>23b, 23a, [id](#)</sup>,  
Y. Coadou <sup>90, [id](#)</sup>, M. Cobal <sup>69a, 69c, [id](#)</sup>, A. Coccaro <sup>57b, [id](#)</sup>, R.F. Coelho Barrue <sup>130a, [id](#)</sup>, R. Coelho Lopes De Sa <sup>103, [id](#)</sup>,  
S. Coelli <sup>71a, [id](#)</sup>, H. Cohen <sup>151, [id](#)</sup>, A.E.C. Coimbra <sup>71a, 71b, [id](#)</sup>, B. Cole <sup>41, [id](#)</sup>, J. Collot <sup>60, [id](#)</sup>, P. Conde Muiño <sup>130a, 130g, [id](#)</sup>,  
M.P. Connell <sup>33c, [id](#)</sup>, S.H. Connell <sup>33c, [id](#)</sup>, I.A. Connelly <sup>59, [id](#)</sup>, E.I. Conroy <sup>126, [id](#)</sup>, F. Conventi <sup>72a, [id](#), [aj](#)</sup>, H.G. Cooke <sup>20, [id](#)</sup>,  
A.M. Cooper-Sarkar <sup>126, [id](#)</sup>, F. Cormier <sup>164, [id](#)</sup>, L.D. Corpe <sup>36, [id](#)</sup>, M. Corradi <sup>75a, 75b, [id](#)</sup>, F. Corriveau <sup>104, [id](#), [z](#)</sup>,  
A. Cortes-Gonzalez <sup>18, [id](#)</sup>, M.J. Costa <sup>163, [id](#)</sup>, F. Costanza <sup>4, [id](#)</sup>, D. Costanzo <sup>139, [id](#)</sup>, B.M. Cote <sup>119, [id](#)</sup>, G. Cowan <sup>96, [id](#)</sup>,  
J.W. Cowley <sup>32, [id](#)</sup>, K. Cranmer <sup>117, [id](#)</sup>, S. Crépe-Renaudin <sup>60, [id](#)</sup>, F. Crescioli <sup>127, [id](#)</sup>, M. Cristinziani <sup>141, [id](#)</sup>,  
M. Cristoforetti <sup>78a, 78b, [id](#), [d](#)</sup>, V. Croft <sup>114, [id](#)</sup>, G. Crosetti <sup>43b, 43a, [id](#)</sup>, A. Cueto <sup>36, [id](#)</sup>, T. Cuhadar Donszelmann <sup>160, [id](#)</sup>,  
H. Cui <sup>14a, 14d, [id](#)</sup>, Z. Cui <sup>7, [id](#)</sup>, W.R. Cunningham <sup>59, [id](#)</sup>, F. Curcio <sup>43b, 43a, [id](#)</sup>, P. Czodrowski <sup>36, [id](#)</sup>, M.M. Czurylo <sup>63b, [id](#)</sup>,  
M.J. Da Cunha Sargedas De Sousa <sup>62a, [id](#)</sup>, J.V. Da Fonseca Pinto <sup>82b, [id](#)</sup>, C. Da Via <sup>102, [id](#)</sup>, W. Dabrowski <sup>85a, [id](#)</sup>,  
T. Dado <sup>49, [id](#)</sup>, S. Dahbi <sup>33g, [id](#)</sup>, T. Dai <sup>106, [id](#)</sup>, C. Dallapiccola <sup>103, [id](#)</sup>, M. Dam <sup>42, [id](#)</sup>, G. D'amen <sup>29, [id](#)</sup>, V. D'Amico <sup>109, [id](#)</sup>,  
J. Damp <sup>101, [id](#)</sup>, J.R. Dandoy <sup>128, [id](#)</sup>, M.F. Daneri <sup>30, [id](#)</sup>, M. Danninger <sup>142, [id](#)</sup>, V. Dao <sup>36, [id](#)</sup>, G. Darbo <sup>57b, [id](#)</sup>,  
S. Darmora <sup>6, [id](#)</sup>, S.J. Das <sup>29, [id](#), [al](#)</sup>, S. D'Auria <sup>71a, 71b, [id](#)</sup>, C. David <sup>156b, [id](#)</sup>, T. Davidek <sup>133, [id](#)</sup>, B. Davis-Purcell <sup>34, [id](#)</sup>,  
I. Dawson <sup>95, [id](#)</sup>, K. De <sup>8, [id](#)</sup>, R. De Asmundis <sup>72a, [id](#)</sup>, N. De Biase <sup>48, [id](#)</sup>, S. De Castro <sup>23b, 23a, [id](#)</sup>, N. De Groot <sup>113, [id](#)</sup>,  
P. de Jong <sup>114, [id](#)</sup>, H. De la Torre <sup>107, [id](#)</sup>, A. De Maria <sup>14c, [id](#)</sup>, A. De Salvo <sup>75a, [id](#)</sup>, U. De Sanctis <sup>76a, 76b, [id](#)</sup>,  
A. De Santo <sup>146, [id](#)</sup>, J.B. De Vivie De Regie <sup>60, [id](#)</sup>, D.V. Dedovich <sup>38, [id](#)</sup>, J. Degen <sup>114, [id](#)</sup>, A.M. Deiana <sup>44, [id](#)</sup>,  
F. Del Corso <sup>23b, 23a, [id](#)</sup>, J. Del Peso <sup>100, [id](#)</sup>, F. Del Rio <sup>63a, [id](#)</sup>, F. Deliot <sup>135, [id](#)</sup>, C.M. Delitzsch <sup>49, [id](#)</sup>,  
M. Della Pietra <sup>72a, 72b, [id](#)</sup>, D. Della Volpe <sup>56, [id](#)</sup>, A. Dell'Acqua <sup>36, [id](#)</sup>, L. Dell'Asta <sup>71a, 71b, [id](#)</sup>, M. Delmastro <sup>4, [id](#)</sup>,  
P.A. Delsart <sup>60, [id](#)</sup>, S. Demers <sup>172, [id](#)</sup>, M. Demichev <sup>38, [id](#)</sup>, S.P. Denisov <sup>37, [id](#)</sup>, L. D'Eramo <sup>115, [id](#)</sup>, D. Derendarz <sup>86, [id](#)</sup>,  
F. Derue <sup>127, [id](#)</sup>, P. Dervan <sup>93, [id](#)</sup>, K. Desch <sup>24, [id](#)</sup>, K. Dette <sup>155, [id](#)</sup>, C. Deutsch <sup>24, [id](#)</sup>, F.A. Di Bello <sup>57b, 57a, [id](#)</sup>,  
A. Di Ciaccio <sup>76a, 76b, [id](#)</sup>, L. Di Ciaccio <sup>4, [id](#)</sup>, A. Di Domenico <sup>75a, 75b, [id](#)</sup>, C. Di Donato <sup>72a, 72b, [id](#)</sup>, A. Di Girolamo <sup>36, [id](#)</sup>,  
G. Di Gregorio <sup>5, [id](#)</sup>, A. Di Luca <sup>78a, 78b, [id](#)</sup>, B. Di Micco <sup>77a, 77b, [id](#)</sup>, R. Di Nardo <sup>77a, 77b, [id](#)</sup>, C. Diaconu <sup>90, [id](#)</sup>,  
F.A. Dias <sup>114, [id](#)</sup>, T. Dias Do Vale <sup>142, [id](#)</sup>, M.A. Diaz <sup>137a, 137b, [id](#)</sup>, F.G. Diaz Capriles <sup>24, [id](#)</sup>, M. Didenko <sup>163, [id](#)</sup>,  
E.B. Diehl <sup>106, [id](#)</sup>, L. Diehl <sup>54, [id](#)</sup>, S. Díez Cornell <sup>48, [id](#)</sup>, C. Diez Pardos <sup>141, [id](#)</sup>, C. Dimitriadi <sup>24, 161, [id](#)</sup>,  
A. Dimitrievska <sup>17a, [id](#)</sup>, J. Dingfelder <sup>24, [id](#)</sup>, I-M. Dinu <sup>27b, [id](#)</sup>, S.J. Dittmeier <sup>63b, [id](#)</sup>, F. Dittus <sup>36, [id](#)</sup>, F. Djama <sup>90, [id](#)</sup>,  
T. Djobava <sup>149b, [id](#)</sup>, J.I. Djuvsland <sup>16, [id](#)</sup>, C. Doglioni <sup>102, 99, [id](#)</sup>, J. Dolejsi <sup>133, [id](#)</sup>, Z. Dolezal <sup>133, [id](#)</sup>, M. Donadelli <sup>82c, [id](#)</sup>,  
B. Dong <sup>107, [id](#)</sup>, J. Donini <sup>40, [id](#)</sup>, A. D'Onofrio <sup>77a, 77b, [id](#)</sup>, M. D'Onofrio <sup>93, [id](#)</sup>, J. Dopke <sup>134, [id](#)</sup>, A. Doria <sup>72a, [id](#)</sup>,  
M.T. Dova <sup>91, [id](#)</sup>, A.T. Doyle <sup>59, [id](#)</sup>, M.A. Draguet <sup>126, [id](#)</sup>, E. Drechsler <sup>142, [id](#)</sup>, E. Dreyer <sup>169, [id](#)</sup>, I. Drivas-koulouris <sup>10, [id](#)</sup>,

A.S. Drobac <sup>158, [id](#)</sup>, M. Drozdova <sup>56, [id](#)</sup>, D. Du <sup>62a, [id](#)</sup>, T.A. du Pree <sup>114, [id](#)</sup>, F. Dubinin <sup>37, [id](#)</sup>, M. Dubovsky <sup>28a, [id](#)</sup>, E. Duchovni <sup>169, [id](#)</sup>, G. Duckeck <sup>109, [id](#)</sup>, O.A. Ducu <sup>27b, [id](#)</sup>, D. Duda <sup>110, [id](#)</sup>, A. Dudarev <sup>36, [id](#)</sup>, E.R. Duden <sup>26, [id](#)</sup>, M. D'uffizi <sup>102, [id](#)</sup>, L. Dufлот <sup>66, [id](#)</sup>, M. Dürrssen <sup>36, [id](#)</sup>, C. Dülse <sup>171, [id](#)</sup>, A.E. Dumitriu <sup>27b, [id](#)</sup>, M. Dunford <sup>63a, [id](#)</sup>, S. Dungs <sup>49, [id](#)</sup>, K. Dunne <sup>47a,47b, [id](#)</sup>, A. Duperrin <sup>90, [id](#)</sup>, H. Duran Yildiz <sup>3a, [id](#)</sup>, M. Düren <sup>58, [id](#)</sup>, A. Durglishvili <sup>149b, [id](#)</sup>, B.L. Dwyer <sup>115, [id](#)</sup>, G.I. Dyckes <sup>17a, [id](#)</sup>, M. Dyndal <sup>85a, [id](#)</sup>, S. Dysch <sup>102, [id](#)</sup>, B.S. Dziedzic <sup>86, [id](#)</sup>, Z.O. Earnshaw <sup>146, [id](#)</sup>, B. Eckerova <sup>28a, [id](#)</sup>, S. Eggebrecht <sup>55, [id](#)</sup>, M.G. Eggleston <sup>51</sup>, E. Egidio Purcino De Souza <sup>127, [id](#)</sup>, L.F. Ehrke <sup>56, [id](#)</sup>, G. Eigen <sup>16, [id](#)</sup>, K. Einsweiler <sup>17a, [id](#)</sup>, T. Ekelof <sup>161, [id](#)</sup>, P.A. Ekman <sup>99, [id](#)</sup>, Y. El Ghazali <sup>35b, [id](#)</sup>, H. El Jarrari <sup>35e,148, [id](#)</sup>, A. El Moussaouy <sup>35a, [id](#)</sup>, V. Ellajosyula <sup>161, [id](#)</sup>, M. Ellert <sup>161, [id](#)</sup>, F. Ellinghaus <sup>171, [id](#)</sup>, A.A. Elliot <sup>95, [id](#)</sup>, N. Ellis <sup>36, [id](#)</sup>, J. Elmsheuser <sup>29, [id](#)</sup>, M. Elsing <sup>36, [id](#)</sup>, D. Emeliyanov <sup>134, [id](#)</sup>, Y. Enari <sup>153, [id](#)</sup>, I. Ene <sup>17a, [id](#)</sup>, S. Epari <sup>13, [id](#)</sup>, J. Erdmann <sup>49, [id](#)</sup>, P.A. Erland <sup>86, [id](#)</sup>, M. Errenst <sup>171, [id](#)</sup>, M. Escalier <sup>66, [id](#)</sup>, C. Escobar <sup>163, [id](#)</sup>, E. Etzion <sup>151, [id](#)</sup>, G. Evans <sup>130a, [id](#)</sup>, H. Evans <sup>68, [id](#)</sup>, M.O. Evans <sup>146, [id](#)</sup>, A. Ezhilov <sup>37, [id](#)</sup>, S. Ezzarqtouni <sup>35a, [id](#)</sup>, F. Fabbri <sup>59, [id](#)</sup>, L. Fabbri <sup>23b,23a, [id](#)</sup>, G. Facini <sup>97, [id](#)</sup>, V. Fadeyev <sup>136, [id](#)</sup>, R.M. Fakhrutdinov <sup>37, [id](#)</sup>, S. Falciano <sup>75a, [id](#)</sup>, L.F. Falda Ulhoa Coelho <sup>36, [id](#)</sup>, P.J. Falke <sup>24, [id](#)</sup>, S. Falke <sup>36, [id](#)</sup>, J. Faltova <sup>133, [id](#)</sup>, Y. Fan <sup>14a, [id](#)</sup>, Y. Fang <sup>14a,14d, [id](#)</sup>, M. Fanti <sup>71a,71b, [id](#)</sup>, M. Faraj <sup>69a,69b, [id](#)</sup>, Z. Farazpay <sup>98, [id](#)</sup>, A. Farbin <sup>8, [id](#)</sup>, A. Farilla <sup>77a, [id](#)</sup>, T. Farooque <sup>107, [id](#)</sup>, S.M. Farrington <sup>52, [id](#)</sup>, F. Fassi <sup>35e, [id](#)</sup>, D. Fassouliotis <sup>9, [id](#)</sup>, M. Faucci Giannelli <sup>76a,76b, [id](#)</sup>, W.J. Fawcett <sup>32, [id](#)</sup>, L. Fayard <sup>66, [id](#)</sup>, P. Federic <sup>133, [id](#)</sup>, P. Federicova <sup>131, [id](#)</sup>, O.L. Fedin <sup>37, [id](#)</sup>, G. Fedotov <sup>37, [id](#)</sup>, M. Feickert <sup>170, [id](#)</sup>, L. Feligioni <sup>90, [id](#)</sup>, A. Fell <sup>139, [id](#)</sup>, D.E. Fellers <sup>123, [id](#)</sup>, C. Feng <sup>62b, [id](#)</sup>, M. Feng <sup>14b, [id](#)</sup>, Z. Feng <sup>114, [id](#)</sup>, M.J. Fenton <sup>160, [id](#)</sup>, A.B. Fenyuk <sup>37</sup>, L. Ferencz <sup>48, [id](#)</sup>, R.A.M. Ferguson <sup>92, [id](#)</sup>, S.I. Fernandez Luengo <sup>137f, [id](#)</sup>, J. Ferrando <sup>48, [id](#)</sup>, A. Ferrari <sup>161, [id](#)</sup>, P. Ferrari <sup>114,113, [id](#)</sup>, R. Ferrari <sup>73a, [id](#)</sup>, D. Ferrere <sup>56, [id](#)</sup>, C. Ferretti <sup>106, [id](#)</sup>, F. Fiedler <sup>101, [id](#)</sup>, A. Filipčič <sup>94, [id](#)</sup>, E.K. Filmer <sup>1, [id](#)</sup>, F. Filthaut <sup>113, [id](#)</sup>, M.C.N. Fiolhais <sup>130a,130c, [id](#)</sup>, L. Fiorini <sup>163, [id](#)</sup>, F. Fischer <sup>141, [id](#)</sup>, W.C. Fisher <sup>107, [id](#)</sup>, T. Fitschen <sup>102, [id](#)</sup>, I. Fleck <sup>141, [id](#)</sup>, P. Fleischmann <sup>106, [id](#)</sup>, T. Flick <sup>171, [id](#)</sup>, L. Flores <sup>128, [id](#)</sup>, M. Flores <sup>33d, [id](#)</sup>, L.R. Flores Castillo <sup>64a, [id](#)</sup>, F.M. Follega <sup>78a,78b, [id](#)</sup>, N. Fomin <sup>16, [id](#)</sup>, J.H. Foo <sup>155, [id](#)</sup>, B.C. Forland <sup>68</sup>, A. Formica <sup>135, [id](#)</sup>, A.C. Forti <sup>102, [id](#)</sup>, E. Fortin <sup>90, [id](#)</sup>, A.W. Fortman <sup>61, [id](#)</sup>, M.G. Foti <sup>17a, [id](#)</sup>, L. Fountas <sup>9, [id](#)</sup>, D. Fournier <sup>66, [id](#)</sup>, H. Fox <sup>92, [id](#)</sup>, P. Francavilla <sup>74a,74b, [id](#)</sup>, S. Francescato <sup>61, [id](#)</sup>, S. Franchellucci <sup>56, [id](#)</sup>, M. Franchini <sup>23b,23a, [id](#)</sup>, S. Franchino <sup>63a, [id](#)</sup>, D. Francis <sup>36</sup>, L. Franco <sup>113, [id](#)</sup>, L. Franconi <sup>19, [id](#)</sup>, M. Franklin <sup>61, [id](#)</sup>, G. Frattari <sup>26, [id](#)</sup>, A.C. Freegard <sup>95, [id](#)</sup>, W.S. Freund <sup>82b, [id](#)</sup>, Y.Y. Frid <sup>151, [id](#)</sup>, N. Fritzsche <sup>50, [id](#)</sup>, A. Froch <sup>54, [id](#)</sup>, D. Froidevaux <sup>36, [id](#)</sup>, J.A. Frost <sup>126, [id](#)</sup>, Y. Fu <sup>62a, [id](#)</sup>, M. Fujimoto <sup>118, [id](#)</sup>, E. Fullana Torregrosa <sup>163, [id](#)</sup>, E. Furtado De Simas Filho <sup>82b, [id](#)</sup>, J. Fuster <sup>163, [id](#)</sup>, A. Gabrielli <sup>23b,23a, [id](#)</sup>, A. Gabrielli <sup>155, [id](#)</sup>, P. Gadow <sup>48, [id](#)</sup>, G. Gagliardi <sup>57b,57a, [id](#)</sup>, L.G. Gagnon <sup>17a, [id](#)</sup>, G.E. Gallardo <sup>126, [id](#)</sup>, E.J. Gallas <sup>126, [id](#)</sup>, B.J. Gallop <sup>134, [id](#)</sup>, R. Gamboa Goni <sup>95, [id](#)</sup>, K.K. Gan <sup>119, [id](#)</sup>, S. Ganguly <sup>153, [id](#)</sup>, J. Gao <sup>62a, [id](#)</sup>, Y. Gao <sup>52, [id](#)</sup>, F.M. Garay Walls <sup>137a,137b, [id](#)</sup>, B. Garcia <sup>29, [id](#)</sup>, C. García <sup>163, [id](#)</sup>, J.E. García Navarro <sup>163, [id](#)</sup>, M. Garcia-Sciveres <sup>17a, [id](#)</sup>, R.W. Gardner <sup>39, [id](#)</sup>, D. Garg <sup>80, [id](#)</sup>, R.B. Garg <sup>143, [id](#)</sup>, C.A. Garner <sup>155</sup>, S.J. Gasiorowski <sup>138, [id](#)</sup>, P. Gaspar <sup>82b, [id](#)</sup>, G. Gaudio <sup>73a, [id](#)</sup>, V. Gautam <sup>13</sup>, P. Gauzzi <sup>75a,75b, [id](#)</sup>, I.L. Gavrilenko <sup>37, [id](#)</sup>, A. Gavrilyuk <sup>37, [id](#)</sup>, C. Gay <sup>164, [id](#)</sup>, G. Gaycken <sup>48, [id](#)</sup>, E.N. Gazis <sup>10, [id](#)</sup>, A.A. Geanta <sup>27b,27e, [id](#)</sup>, C.M. Gee <sup>136, [id](#)</sup>, C. Gemme <sup>57b, [id](#)</sup>, M.H. Genest <sup>60, [id](#)</sup>, S. Gentile <sup>75a,75b, [id](#)</sup>, S. George <sup>96, [id](#)</sup>, W.F. George <sup>20, [id](#)</sup>, T. Gerialis <sup>46, [id](#)</sup>, L.O. Gerlach <sup>55</sup>, P. Gessinger-Befurt <sup>36, [id](#)</sup>, M.E. Geyik <sup>171, [id](#)</sup>, M. Ghneimat <sup>141, [id](#)</sup>, K. Ghorbanian <sup>95, [id](#)</sup>, A. Ghosal <sup>141, [id](#)</sup>, A. Ghosh <sup>160, [id](#)</sup>, A. Ghosh <sup>7, [id](#)</sup>, B. Giacobbe <sup>23b, [id](#)</sup>, S. Giagu <sup>75a,75b, [id](#)</sup>, P. Giannetti <sup>74a, [id](#)</sup>, A. Giannini <sup>62a, [id](#)</sup>, S.M. Gibson <sup>96, [id](#)</sup>, M. Gignac <sup>136, [id](#)</sup>, D.T. Gil <sup>85b, [id](#)</sup>, A.K. Gilbert <sup>85a, [id](#)</sup>, B.J. Gilbert <sup>41, [id](#)</sup>, D. Gillberg <sup>34, [id](#)</sup>, G. Gilles <sup>114, [id](#)</sup>, N.E.K. Gillwald <sup>48, [id](#)</sup>, L. Ginabat <sup>127, [id](#)</sup>, D.M. Gingrich <sup>2, [id](#)</sup>, M.P. Giordani <sup>69a,69c, [id](#)</sup>, P.F. Giraud <sup>135, [id](#)</sup>, G. Giugliarelli <sup>69a,69c, [id](#)</sup>, D. Giugni <sup>71a, [id](#)</sup>, F. Giuli <sup>36, [id](#)</sup>, I. Gkialas <sup>9, [id](#)</sup>, L.K. Gladilin <sup>37, [id](#)</sup>, C. Glasman <sup>100, [id](#)</sup>, G.R. Gledhill <sup>123, [id](#)</sup>, M. Glisic <sup>123</sup>, I. Gnesi <sup>43b, [id](#)</sup>, Y. Go <sup>29, [id](#)</sup>, M. Goblirsch-Kolb <sup>26, [id](#)</sup>, B. Gocke <sup>49, [id](#)</sup>, D. Godin <sup>108</sup>, B. Gokturk <sup>21a, [id](#)</sup>, S. Goldfarb <sup>105, [id](#)</sup>, T. Golling <sup>56, [id](#)</sup>, M.G.D. Gololo <sup>33g</sup>, D. Golubkov <sup>37, [id](#)</sup>, J.P. Gombas <sup>107, [id](#)</sup>, A. Gomes <sup>130a,130b, [id](#)</sup>, G. Gomes Da Silva <sup>141, [id](#)</sup>, A.J. Gomez Delegido <sup>163, [id](#)</sup>, R. Gonçalo <sup>130a,130c, [id](#)</sup>, G. Gonella <sup>123, [id](#)</sup>, L. Gonella <sup>20, [id](#)</sup>,

A. Gongadze <sup>38, [ib](#)</sup>, F. Gonnella <sup>20, [ib](#)</sup>, J.L. Gonski <sup>41, [ib](#)</sup>, R.Y. González Andana <sup>52, [ib](#)</sup>, S. González de la Hoz <sup>163, [ib](#)</sup>,  
 S. Gonzalez Fernandez <sup>13, [ib](#)</sup>, R. Gonzalez Lopez <sup>93, [ib](#)</sup>, C. Gonzalez Renteria <sup>17a, [ib](#)</sup>, R. Gonzalez Suarez <sup>161, [ib](#)</sup>,  
 S. Gonzalez-Sevilla <sup>56, [ib](#)</sup>, G.R. Gonzalvo Rodriguez <sup>163, [ib](#)</sup>, L. Goossens <sup>36, [ib](#)</sup>, P.A. Gorbounov <sup>37, [ib](#)</sup>, B. Gorini <sup>36, [ib](#)</sup>,  
 E. Gorini <sup>70a,70b, [ib](#)</sup>, A. Gorišek <sup>94, [ib](#)</sup>, A.T. Goshaw <sup>51, [ib](#)</sup>, M.I. Gostkin <sup>38, [ib](#)</sup>, S. Goswami <sup>121, [ib](#)</sup>, C.A. Gottardo <sup>36, [ib](#)</sup>,  
 M. Gouighri <sup>35b, [ib](#)</sup>, V. Goumarre <sup>48, [ib](#)</sup>, A.G. Goussiou <sup>138, [ib](#)</sup>, N. Govender <sup>33c, [ib](#)</sup>, I. Grabowska-Bold <sup>85a, [ib](#)</sup>,  
 K. Graham <sup>34, [ib](#)</sup>, E. Gramstad <sup>125, [ib](#)</sup>, S. Grancagnolo <sup>18, [ib](#)</sup>, M. Grandi <sup>146, [ib](#)</sup>, V. Gratchev <sup>37, [\\*](#)</sup>, P.M. Gravila <sup>27f, [ib](#)</sup>,  
 F.G. Gravili <sup>70a,70b, [ib](#)</sup>, H.M. Gray <sup>17a, [ib](#)</sup>, M. Greco <sup>70a,70b, [ib](#)</sup>, C. Grefe <sup>24, [ib](#)</sup>, I.M. Gregor <sup>48, [ib](#)</sup>, P. Grenier <sup>143, [ib](#)</sup>,  
 C. Grieco <sup>13, [ib](#)</sup>, A.A. Grillo <sup>136, [ib](#)</sup>, K. Grimm <sup>31, [ib](#)</sup>, S. Grinstein <sup>13, [ib](#)</sup>, J.-F. Grivaz <sup>66, [ib](#)</sup>, E. Gross <sup>169, [ib](#)</sup>,  
 J. Grosse-Knetter <sup>55, [ib](#)</sup>, C. Grud <sup>106, [ib](#)</sup>, J.C. Grundy <sup>126, [ib](#)</sup>, L. Guan <sup>106, [ib](#)</sup>, W. Guan <sup>29, [ib](#)</sup>, C. Gubbels <sup>164, [ib](#)</sup>,  
 J.G.R. Guerrero Rojas <sup>163, [ib](#)</sup>, G. Guerrieri <sup>69a,69b, [ib](#)</sup>, F. Guescini <sup>110, [ib](#)</sup>, R. Gugel <sup>101, [ib](#)</sup>, J.A.M. Guhit <sup>106, [ib](#)</sup>,  
 A. Guida <sup>48, [ib](#)</sup>, T. Guillemin <sup>4, [ib](#)</sup>, E. Guillon <sup>167,134, [ib](#)</sup>, S. Guindon <sup>36, [ib](#)</sup>, F. Guo <sup>14a,14d, [ib](#)</sup>, J. Guo <sup>62c, [ib](#)</sup>, L. Guo <sup>66, [ib](#)</sup>,  
 Y. Guo <sup>106, [ib](#)</sup>, R. Gupta <sup>48, [ib](#)</sup>, S. Gurbuz <sup>24, [ib](#)</sup>, S.S. Gurdasani <sup>54, [ib](#)</sup>, G. Gustavino <sup>36, [ib](#)</sup>, M. Guth <sup>56, [ib](#)</sup>,  
 P. Gutierrez <sup>120, [ib](#)</sup>, L.F. Gutierrez Zagazeta <sup>128, [ib](#)</sup>, C. Gutsche <sup>97, [ib](#)</sup>, C. Gwenlan <sup>126, [ib](#)</sup>, C.B. Gwilliam <sup>93, [ib](#)</sup>,  
 E.S. Haaland <sup>125, [ib](#)</sup>, A. Haas <sup>117, [ib](#)</sup>, M. Habedank <sup>48, [ib](#)</sup>, C. Haber <sup>17a, [ib](#)</sup>, H.K. Hadavand <sup>8, [ib](#)</sup>, A. Hadeef <sup>101, [ib](#)</sup>,  
 S. Hadzic <sup>110, [ib](#)</sup>, E.H. Haines <sup>97, [ib](#)</sup>, M. Haleem <sup>166, [ib](#)</sup>, J. Haley <sup>121, [ib](#)</sup>, J.J. Hall <sup>139, [ib](#)</sup>, G.D. Hallowell <sup>90, [ib](#)</sup>,  
 L. Halser <sup>19, [ib](#)</sup>, K. Hamano <sup>165, [ib](#)</sup>, H. Hamdaoui <sup>35c, [ib](#)</sup>, M. Hamer <sup>24, [ib](#)</sup>, G.N. Hamity <sup>52, [ib](#)</sup>, E.J. Hampshire <sup>96, [ib](#)</sup>,  
 J. Han <sup>62b, [ib](#)</sup>, K. Han <sup>62a, [ib](#)</sup>, L. Han <sup>14c, [ib](#)</sup>, L. Han <sup>62a, [ib](#)</sup>, S. Han <sup>17a, [ib](#)</sup>, Y.F. Han <sup>155, [ib](#)</sup>, K. Hanagaki <sup>83, [ib](#)</sup>,  
 M. Hance <sup>136, [ib](#)</sup>, D.A. Hangal <sup>41, [ib](#)</sup>, H. Hanif <sup>142, [ib](#)</sup>, M.D. Hank <sup>128, [ib](#)</sup>, R. Hankache <sup>102, [ib](#)</sup>, J.B. Hansen <sup>42, [ib](#)</sup>,  
 J.D. Hansen <sup>42, [ib](#)</sup>, P.H. Hansen <sup>42, [ib](#)</sup>, K. Hara <sup>157, [ib](#)</sup>, D. Harada <sup>56, [ib](#)</sup>, T. Harenberg <sup>171, [ib](#)</sup>, S. Harkusha <sup>37, [ib](#)</sup>,  
 Y.T. Harris <sup>126, [ib](#)</sup>, N.M. Harrison <sup>119, [ib](#)</sup>, P.F. Harrison <sup>167, [ib](#)</sup>, N.M. Hartman <sup>143, [ib](#)</sup>, N.M. Hartmann <sup>109, [ib](#)</sup>,  
 Y. Hasegawa <sup>140, [ib](#)</sup>, A. Hasib <sup>52, [ib](#)</sup>, S. Haug <sup>19, [ib](#)</sup>, R. Hauser <sup>107, [ib](#)</sup>, M. Havranek <sup>132, [ib](#)</sup>, C.M. Hawkes <sup>20, [ib](#)</sup>,  
 R.J. Hawkings <sup>36, [ib](#)</sup>, S. Hayashida <sup>111, [ib](#)</sup>, D. Hayden <sup>107, [ib](#)</sup>, C. Hayes <sup>106, [ib](#)</sup>, R.L. Hayes <sup>114, [ib](#)</sup>, C.P. Hays <sup>126, [ib](#)</sup>,  
 J.M. Hays <sup>95, [ib](#)</sup>, H.S. Hayward <sup>93, [ib](#)</sup>, F. He <sup>62a, [ib](#)</sup>, Y. He <sup>154, [ib](#)</sup>, Y. He <sup>127, [ib](#)</sup>, N.B. Heatley <sup>95, [ib](#)</sup>, V. Hedberg <sup>99, [ib](#)</sup>,  
 A.L. Heggelund <sup>125, [ib](#)</sup>, N.D. Hehir <sup>95, [ib](#)</sup>, C. Heidegger <sup>54, [ib](#)</sup>, K.K. Heidegger <sup>54, [ib](#)</sup>, W.D. Heidorn <sup>81, [ib](#)</sup>,  
 J. Heilman <sup>34, [ib](#)</sup>, S. Heim <sup>48, [ib](#)</sup>, T. Heim <sup>17a, [ib](#)</sup>, J.G. Heinlein <sup>128, [ib](#)</sup>, J.J. Heinrich <sup>123, [ib](#)</sup>, L. Heinrich <sup>110, [ib](#)</sup>,  
 J. Hejbal <sup>131, [ib](#)</sup>, L. Helary <sup>48, [ib](#)</sup>, A. Held <sup>170, [ib](#)</sup>, S. Hellesund <sup>16, [ib](#)</sup>, C.M. Helling <sup>164, [ib](#)</sup>, S. Hellman <sup>47a,47b, [ib](#)</sup>,  
 C. Hensens <sup>36, [ib](#)</sup>, R.C.W. Henderson <sup>92, [ib](#)</sup>, L. Henkelmann <sup>32, [ib](#)</sup>, A.M. Henriques Correia <sup>36, [ib](#)</sup>, H. Herde <sup>99, [ib](#)</sup>,  
 Y. Hernández Jiménez <sup>145, [ib](#)</sup>, L.M. Herrmann <sup>24, [ib](#)</sup>, T. Herrmann <sup>50, [ib](#)</sup>, G. Herten <sup>54, [ib](#)</sup>, R. Hertenberger <sup>109, [ib](#)</sup>,  
 L. Hervas <sup>36, [ib](#)</sup>, N.P. Hessey <sup>156a, [ib](#)</sup>, H. Hibi <sup>84, [ib](#)</sup>, S.J. Hillier <sup>20, [ib](#)</sup>, F. Hinterkeuser <sup>24, [ib](#)</sup>, M. Hirose <sup>124, [ib](#)</sup>,  
 S. Hirose <sup>157, [ib](#)</sup>, D. Hirschbuehl <sup>171, [ib](#)</sup>, T.G. Hitchings <sup>102, [ib](#)</sup>, B. Hiti <sup>94, [ib](#)</sup>, J. Hobbs <sup>145, [ib](#)</sup>, R. Hobincu <sup>27e, [ib](#)</sup>,  
 N. Hod <sup>169, [ib](#)</sup>, M.C. Hodgkinson <sup>139, [ib](#)</sup>, B.H. Hodgkinson <sup>32, [ib](#)</sup>, A. Hoecker <sup>36, [ib](#)</sup>, J. Hofer <sup>48, [ib](#)</sup>, T. Holm <sup>24, [ib](#)</sup>,  
 M. Holzbock <sup>110, [ib](#)</sup>, L.B.A.H. Hommels <sup>32, [ib](#)</sup>, B.P. Honan <sup>102, [ib](#)</sup>, J. Hong <sup>62c, [ib](#)</sup>, T.M. Hong <sup>129, [ib](#)</sup>, J.C. Honig <sup>54, [ib](#)</sup>,  
 B.H. Hooberman <sup>162, [ib](#)</sup>, W.H. Hopkins <sup>6, [ib](#)</sup>, Y. Horii <sup>111, [ib](#)</sup>, S. Hou <sup>148, [ib](#)</sup>, A.S. Howard <sup>94, [ib](#)</sup>, J. Howarth <sup>59, [ib](#)</sup>,  
 J. Hoya <sup>6, [ib](#)</sup>, M. Hrabovsky <sup>122, [ib](#)</sup>, A. Hrynevich <sup>48, [ib](#)</sup>, T. Hryn'ova <sup>4, [ib](#)</sup>, P.J. Hsu <sup>65, [ib](#)</sup>, S.-C. Hsu <sup>138, [ib](#)</sup>, Q. Hu <sup>41, [ib](#)</sup>,  
 Y.F. Hu <sup>14a,14d, [ib](#)</sup>, D.P. Huang <sup>97, [ib](#)</sup>, S. Huang <sup>64b, [ib](#)</sup>, X. Huang <sup>14c, [ib](#)</sup>, Y. Huang <sup>62a, [ib](#)</sup>, Y. Huang <sup>14a, [ib](#)</sup>,  
 Z. Huang <sup>102, [ib](#)</sup>, Z. Hubacek <sup>132, [ib](#)</sup>, M. Huebner <sup>24, [ib](#)</sup>, F. Huegging <sup>24, [ib](#)</sup>, T.B. Huffman <sup>126, [ib](#)</sup>, M. Huhtinen <sup>36, [ib](#)</sup>,  
 S.K. Huiberts <sup>16, [ib](#)</sup>, R. Hulsken <sup>104, [ib](#)</sup>, N. Huseynov <sup>12, [ib](#)</sup>, J. Huston <sup>107, [ib](#)</sup>, J. Huth <sup>61, [ib](#)</sup>, R. Hyneman <sup>143, [ib](#)</sup>,  
 G. Iacobucci <sup>56, [ib](#)</sup>, G. Iakovidis <sup>29, [ib](#)</sup>, I. Ibragimov <sup>141, [ib](#)</sup>, L. Iconomidou-Fayard <sup>66, [ib](#)</sup>, P. Iengo <sup>72a,72b, [ib](#)</sup>,  
 R. Iguchi <sup>153, [ib](#)</sup>, T. Iizawa <sup>56, [ib](#)</sup>, Y. Ikegami <sup>83, [ib](#)</sup>, A. Ilg <sup>19, [ib](#)</sup>, N. Ilic <sup>155, [ib](#)</sup>, H. Imam <sup>35a, [ib](#)</sup>,  
 T. Ingebretsen Carlson <sup>47a,47b, [ib](#)</sup>, G. Introzzi <sup>73a,73b, [ib](#)</sup>, M. Iodice <sup>77a, [ib](#)</sup>, V. Ippolito <sup>75a,75b, [ib](#)</sup>, M. Ishino <sup>153, [ib](#)</sup>,  
 W. Islam <sup>170, [ib](#)</sup>, C. Issever <sup>18,48, [ib](#)</sup>, S. Istin <sup>21a, [ib](#)</sup>, H. Ito <sup>168, [ib](#)</sup>, J.M. Iturbe Ponce <sup>64a, [ib](#)</sup>, R. Iuppa <sup>78a,78b, [ib](#)</sup>,  
 A. Ivina <sup>169, [ib](#)</sup>, J.M. Izen <sup>45, [ib](#)</sup>, V. Izzo <sup>72a, [ib](#)</sup>, P. Jacka <sup>131,132, [ib](#)</sup>, P. Jackson <sup>1, [ib](#)</sup>, R.M. Jacobs <sup>48, [ib](#)</sup>, B.P. Jaeger <sup>142, [ib](#)</sup>,  
 C.S. Jagfeld <sup>109, [ib](#)</sup>, P. Jain <sup>54, [ib](#)</sup>, G. Jäkel <sup>171, [ib](#)</sup>, K. Jakobs <sup>54, [ib](#)</sup>, T. Jakoubek <sup>169, [ib](#)</sup>, J. Jamieson <sup>59, [ib](#)</sup>,

K.W. Janas<sup>85a, [id](#)</sup>, A.E. Jaspan<sup>93, [id](#)</sup>, M. Javurkova<sup>103, [id](#)</sup>, F. Jeanneau<sup>135, [id](#)</sup>, L. Jeanty<sup>123, [id](#)</sup>, J. Jejelava<sup>149a, [id](#), [ac](#)</sup>,  
 P. Jenni<sup>54, [id](#), [h](#)</sup>, C.E. Jessiman<sup>34, [id](#)</sup>, S. Jézéquel<sup>4, [id](#)</sup>, C. Jia<sup>62b, [id](#)</sup>, J. Jia<sup>145, [id](#)</sup>, X. Jia<sup>61, [id](#)</sup>, X. Jia<sup>14a, 14d, [id](#)</sup>, Z. Jia<sup>14c, [id](#)</sup>,  
 Y. Jiang<sup>62a, [id](#)</sup>, S. Jiggins<sup>48, [id](#)</sup>, J. Jimenez Pena<sup>110, [id](#)</sup>, S. Jin<sup>14c, [id](#)</sup>, A. Jinaru<sup>27b, [id](#)</sup>, O. Jinnouchi<sup>154, [id](#)</sup>,  
 P. Johansson<sup>139, [id](#)</sup>, K.A. Johns<sup>7, [id](#)</sup>, J.W. Johnson<sup>136, [id](#)</sup>, D.M. Jones<sup>32, [id](#)</sup>, E. Jones<sup>167, [id](#)</sup>, P. Jones<sup>32, [id](#)</sup>,  
 R.W.L. Jones<sup>92, [id](#)</sup>, T.J. Jones<sup>93, [id](#)</sup>, R. Joshi<sup>119, [id](#)</sup>, J. Jovicevic<sup>15, [id](#)</sup>, X. Ju<sup>17a, [id](#)</sup>, J.J. Junggeburth<sup>36, [id](#)</sup>,  
 T. Junkermann<sup>63a, [id](#)</sup>, A. Juste Rozas<sup>13, [id](#), [v](#)</sup>, S. Kabana<sup>137e, [id](#)</sup>, A. Kaczmarska<sup>86, [id](#)</sup>, M. Kado<sup>110, [id](#)</sup>, H. Kagan<sup>119, [id](#)</sup>,  
 M. Kagan<sup>143, [id](#)</sup>, A. Kahn<sup>41, [id](#)</sup>, A. Kahn<sup>128, [id](#)</sup>, C. Kahra<sup>101, [id](#)</sup>, T. Kaji<sup>168, [id](#)</sup>, E. Kajomovitz<sup>150, [id](#)</sup>, N. Kakati<sup>169, [id](#)</sup>,  
 C.W. Kalderon<sup>29, [id](#)</sup>, A. Kamenshchikov<sup>155, [id](#)</sup>, S. Kanayama<sup>154, [id](#)</sup>, N.J. Kang<sup>136, [id](#)</sup>, D. Kar<sup>33g, [id](#)</sup>, K. Karava<sup>126, [id](#)</sup>,  
 M.J. Kareem<sup>156b, [id](#)</sup>, E. Karentzos<sup>54, [id](#)</sup>, I. Karkanias<sup>152, [id](#), [f](#)</sup>, S.N. Karpov<sup>38, [id](#)</sup>, Z.M. Karpova<sup>38, [id](#)</sup>,  
 V. Kartvelishvili<sup>92, [id](#)</sup>, A.N. Karyukhin<sup>37, [id](#)</sup>, E. Kasimi<sup>152, [id](#), [f](#)</sup>, J. Katzy<sup>48, [id](#)</sup>, S. Kaur<sup>34, [id](#)</sup>, K. Kawade<sup>140, [id](#)</sup>,  
 T. Kawamoto<sup>135, [id](#)</sup>, G. Kawamura<sup>55, [id](#)</sup>, E.F. Kay<sup>165, [id](#)</sup>, F.I. Kaya<sup>158, [id](#)</sup>, S. Kazakos<sup>13, [id](#)</sup>, V.F. Kazanin<sup>37, [id](#)</sup>,  
 Y. Ke<sup>145, [id](#)</sup>, J.M. Keaveney<sup>33a, [id](#)</sup>, R. Keeler<sup>165, [id](#)</sup>, G.V. Kehris<sup>61, [id](#)</sup>, J.S. Keller<sup>34, [id](#)</sup>, A.S. Kelly<sup>97, [id](#)</sup>, D. Kelsey<sup>146, [id](#)</sup>,  
 J.J. Kempster<sup>146, [id](#)</sup>, K.E. Kennedy<sup>41, [id](#)</sup>, P.D. Kennedy<sup>101, [id](#)</sup>, O. Kepka<sup>131, [id](#)</sup>, B.P. Kerridge<sup>167, [id](#)</sup>, S. Kersten<sup>171, [id](#)</sup>,  
 B.P. Kerševan<sup>94, [id](#)</sup>, S. Keshri<sup>66, [id](#)</sup>, L. Keszeghova<sup>28a, [id](#)</sup>, S. Ketabchi Haghighat<sup>155, [id](#)</sup>, M. Khandoga<sup>127, [id](#)</sup>,  
 A. Khanov<sup>121, [id](#)</sup>, A.G. Kharlamov<sup>37, [id](#)</sup>, T. Kharlamova<sup>37, [id](#)</sup>, E.E. Khoda<sup>138, [id](#)</sup>, T.J. Khoo<sup>18, [id](#)</sup>, G. Khoriauli<sup>166, [id](#)</sup>,  
 J. Khubua<sup>149b, [id](#)</sup>, Y.A.R. Khwaira<sup>66, [id](#)</sup>, M. Kiehn<sup>36, [id](#)</sup>, A. Kilgallon<sup>123, [id](#)</sup>, D.W. Kim<sup>47a, 47b, [id](#)</sup>, E. Kim<sup>154, [id](#)</sup>,  
 Y.K. Kim<sup>39, [id](#)</sup>, N. Kimura<sup>97, [id](#)</sup>, A. Kirchhoff<sup>55, [id](#)</sup>, C. Kirfel<sup>24, [id](#)</sup>, J. Kirk<sup>134, [id](#)</sup>, A.E. Kiryunin<sup>110, [id](#)</sup>,  
 T. Kishimoto<sup>153, [id](#)</sup>, D.P. Kisiuk<sup>155, [id](#)</sup>, C. Kitsaki<sup>10, [id](#)</sup>, O. Kivernyk<sup>24, [id](#)</sup>, M. Klassen<sup>63a, [id](#)</sup>, C. Klein<sup>34, [id](#)</sup>,  
 L. Klein<sup>166, [id](#)</sup>, M.H. Klein<sup>106, [id](#)</sup>, M. Klein<sup>93, [id](#)</sup>, S.B. Klein<sup>56, [id](#)</sup>, U. Klein<sup>93, [id](#)</sup>, P. Klimek<sup>36, [id](#)</sup>, A. Klimentov<sup>29, [id](#)</sup>,  
 F. Klimpel<sup>110, [id](#)</sup>, T. Klioutchnikova<sup>36, [id](#)</sup>, P. Kluit<sup>114, [id](#)</sup>, S. Kluth<sup>110, [id](#)</sup>, E. Kneringer<sup>79, [id](#)</sup>, T.M. Knight<sup>155, [id](#)</sup>,  
 A. Knue<sup>54, [id](#)</sup>, R. Kobayashi<sup>87, [id](#)</sup>, M. Kocian<sup>143, [id](#)</sup>, P. Kodyš<sup>133, [id](#)</sup>, D.M. Koeck<sup>146, [id](#)</sup>, P.T. Koenig<sup>24, [id](#)</sup>,  
 T. Koffas<sup>34, [id](#)</sup>, M. Kolb<sup>135, [id](#)</sup>, I. Koletsou<sup>4, [id](#)</sup>, T. Komarek<sup>122, [id](#)</sup>, K. Köneke<sup>54, [id](#)</sup>, A.X.Y. Kong<sup>1, [id](#)</sup>, T. Kono<sup>118, [id](#)</sup>,  
 N. Konstantinidis<sup>97, [id](#)</sup>, B. Konya<sup>99, [id](#)</sup>, R. Kopeliansky<sup>68, [id](#)</sup>, S. Koperny<sup>85a, [id](#)</sup>, K. Korcyl<sup>86, [id](#)</sup>, K. Kordas<sup>152, [id](#), [f](#)</sup>,  
 G. Koren<sup>151, [id](#)</sup>, A. Korn<sup>97, [id](#)</sup>, S. Korn<sup>55, [id](#)</sup>, I. Korolkov<sup>13, [id](#)</sup>, N. Korotkova<sup>37, [id](#)</sup>, B. Kortman<sup>114, [id](#)</sup>,  
 O. Kortner<sup>110, [id](#)</sup>, S. Kortner<sup>110, [id](#)</sup>, W.H. Kostecka<sup>115, [id](#)</sup>, V.V. Kostyukhin<sup>141, [id](#)</sup>, A. Kotskechagia<sup>135, [id](#)</sup>,  
 A. Kotwal<sup>51, [id](#)</sup>, A. Koulouris<sup>36, [id](#)</sup>, A. Kourkoumeli-Charalampidi<sup>73a, 73b, [id](#)</sup>, C. Kourkoumelis<sup>9, [id](#)</sup>, E. Kourlitis<sup>6, [id](#)</sup>,  
 O. Kovanda<sup>146, [id](#)</sup>, R. Kowalewski<sup>165, [id](#)</sup>, W. Kozanecki<sup>135, [id](#)</sup>, A.S. Kozhin<sup>37, [id](#)</sup>, V.A. Kramarenko<sup>37, [id](#)</sup>,  
 G. Kramberger<sup>94, [id](#)</sup>, P. Kramer<sup>101, [id](#)</sup>, M.W. Krasny<sup>127, [id](#)</sup>, A. Krasznahorkay<sup>36, [id](#)</sup>, J.A. Kremer<sup>101, [id](#)</sup>,  
 T. Kresse<sup>50, [id](#)</sup>, J. Kretschmar<sup>93, [id](#)</sup>, K. Kreul<sup>18, [id](#)</sup>, P. Krieger<sup>155, [id](#)</sup>, S. Krishnamurthy<sup>103, [id](#)</sup>, M. Krivos<sup>133, [id](#)</sup>,  
 K. Krizka<sup>20, [id](#)</sup>, K. Kroeninger<sup>49, [id](#)</sup>, H. Kroha<sup>110, [id](#)</sup>, J. Kroll<sup>131, [id](#)</sup>, J. Kroll<sup>128, [id](#)</sup>, K.S. Krowpman<sup>107, [id](#)</sup>,  
 U. Kruchonak<sup>38, [id](#)</sup>, H. Krüger<sup>24, [id](#)</sup>, N. Krumnack<sup>81, [id](#)</sup>, M.C. Kruse<sup>51, [id](#)</sup>, J.A. Krzysiak<sup>86, [id](#)</sup>, O. Kuchinskaia<sup>37, [id](#)</sup>,  
 S. Kудay<sup>3a, [id](#)</sup>, S. Kuehn<sup>36, [id](#)</sup>, R. Kuesters<sup>54, [id](#)</sup>, T. Kuhl<sup>48, [id](#)</sup>, V. Kukhtin<sup>38, [id](#)</sup>, Y. Kulchitsky<sup>37, [id](#), [a](#)</sup>,  
 S. Kuleshov<sup>137d, 137b, [id](#)</sup>, M. Kumar<sup>33g, [id](#)</sup>, N. Kumari<sup>90, [id](#)</sup>, A. Kupco<sup>131, [id](#)</sup>, T. Kupfer<sup>49, [id](#)</sup>, A. Kupich<sup>37, [id](#)</sup>,  
 O. Kuprash<sup>54, [id](#)</sup>, H. Kurashige<sup>84, [id](#)</sup>, L.L. Kurchaninov<sup>156a, [id](#)</sup>, Y.A. Kurochkin<sup>37, [id](#)</sup>, A. Kurova<sup>37, [id](#)</sup>, M. Kuze<sup>154, [id](#)</sup>,  
 A.K. Kvam<sup>103, [id](#)</sup>, J. Kvita<sup>122, [id](#)</sup>, T. Kwan<sup>104, [id](#)</sup>, N.G. Kyriacou<sup>106, [id](#)</sup>, L.A.O. Laatu<sup>90, [id](#)</sup>, C. Lacasta<sup>163, [id](#)</sup>,  
 F. Lacava<sup>75a, 75b, [id](#)</sup>, H. Lacker<sup>18, [id](#)</sup>, D. Lacour<sup>127, [id](#)</sup>, N.N. Lad<sup>97, [id](#)</sup>, E. Ladygin<sup>38, [id](#)</sup>, B. Laforge<sup>127, [id](#)</sup>,  
 T. Lagouri<sup>137e, [id](#)</sup>, S. Lai<sup>55, [id](#)</sup>, I.K. Lakomic<sup>85a, [id](#)</sup>, N. Lalloue<sup>60, [id](#)</sup>, J.E. Lambert<sup>120, [id](#)</sup>, S. Lammers<sup>68, [id](#)</sup>,  
 W. Lampl<sup>7, [id](#)</sup>, C. Lampoudis<sup>152, [id](#), [f](#)</sup>, A.N. Lancaster<sup>115, [id](#)</sup>, E. Lançon<sup>29, [id](#)</sup>, U. Landgraf<sup>54, [id](#)</sup>, M.P.J. Landon<sup>95, [id](#)</sup>,  
 V.S. Lang<sup>54, [id](#)</sup>, R.J. Langenberg<sup>103, [id](#)</sup>, A.J. Lankford<sup>160, [id](#)</sup>, F. Lanni<sup>36, [id](#)</sup>, K. Lantzsck<sup>24, [id](#)</sup>, A. Lanza<sup>73a, [id](#)</sup>,  
 A. Lapertosa<sup>57b, 57a, [id](#)</sup>, J.F. Laporte<sup>135, [id](#)</sup>, T. Lari<sup>71a, [id](#)</sup>, F. Lasagni Manghi<sup>23b, [id](#)</sup>, M. Lassnig<sup>36, [id](#)</sup>, V. Latonova<sup>131, [id](#)</sup>,  
 A. Laudrain<sup>101, [id](#)</sup>, A. Laurier<sup>150, [id](#)</sup>, S.D. Lawlor<sup>96, [id](#)</sup>, Z. Lawrence<sup>102, [id](#)</sup>, M. Lazzaroni<sup>71a, 71b, [id](#)</sup>, B. Le<sup>102, [id](#)</sup>,  
 E.M. Le Boulicaut<sup>51, [id](#)</sup>, B. Leban<sup>94, [id](#)</sup>, A. Lebedev<sup>81, [id](#)</sup>, M. LeBlanc<sup>36, [id](#)</sup>, F. Ledroit-Guillon<sup>60, [id](#)</sup>, A.C.A. Lee<sup>97, [id](#)</sup>,  
 G.R. Lee<sup>16, [id](#)</sup>, S.C. Lee<sup>148, [id](#)</sup>, S. Lee<sup>47a, 47b, [id](#)</sup>, T.F. Lee<sup>93, [id](#)</sup>, L.L. Leeuw<sup>33c, [id](#)</sup>, H.P. Lefebvre<sup>96, [id](#)</sup>, M. Lefebvre<sup>165, [id](#)</sup>,

C. Leggett <sup>17a, [id](#)</sup>, K. Lehmann <sup>142, [id](#)</sup>, G. Lehmann Miotto <sup>36, [id](#)</sup>, M. Leigh <sup>56, [id](#)</sup>, W.A. Leight <sup>103, [id](#)</sup>, A. Leisos <sup>152, [id](#), [u](#)</sup>, M.A.L. Leite <sup>82c, [id](#)</sup>, C.E. Leitgeb <sup>48, [id](#)</sup>, R. Leitner <sup>133, [id](#)</sup>, K.J.C. Leney <sup>44, [id](#)</sup>, T. Lenz <sup>24, [id](#)</sup>, S. Leone <sup>74a, [id](#)</sup>, C. Leonidopoulos <sup>52, [id](#)</sup>, A. Leopold <sup>144, [id](#)</sup>, C. Leroy <sup>108, [id](#)</sup>, R. Les <sup>107, [id](#)</sup>, C.G. Lester <sup>32, [id](#)</sup>, M. Levchenko <sup>37, [id](#)</sup>, J. Levêque <sup>4, [id](#)</sup>, D. Levin <sup>106, [id](#)</sup>, L.J. Levinson <sup>169, [id](#)</sup>, M.P. Lewicki <sup>86, [id](#)</sup>, D.J. Lewis <sup>4, [id](#)</sup>, A. Li <sup>5, [id](#)</sup>, B. Li <sup>62b, [id](#)</sup>, C. Li <sup>62a</sup>, C-Q. Li <sup>62c, [id](#)</sup>, H. Li <sup>62a, [id](#)</sup>, H. Li <sup>62b, [id](#)</sup>, H. Li <sup>14c, [id](#)</sup>, H. Li <sup>62b, [id](#)</sup>, J. Li <sup>62c, [id](#)</sup>, K. Li <sup>138, [id](#)</sup>, L. Li <sup>62c, [id](#)</sup>, M. Li <sup>14a, 14d, [id](#)</sup>, Q.Y. Li <sup>62a, [id](#)</sup>, S. Li <sup>14a, 14d, [id](#)</sup>, S. Li <sup>62d, 62c, [id](#), [e](#)</sup>, T. Li <sup>62b, [id](#)</sup>, X. Li <sup>104, [id](#)</sup>, Z. Li <sup>62b, [id](#)</sup>, Z. Li <sup>126, [id](#)</sup>, Z. Li <sup>104, [id](#)</sup>, Z. Li <sup>93, [id](#)</sup>, Z. Li <sup>14a, 14d, [id](#)</sup>, Z. Liang <sup>14a, [id](#)</sup>, M. Liberatore <sup>48, [id](#)</sup>, B. Liberti <sup>76a, [id](#)</sup>, K. Lie <sup>64c, [id](#)</sup>, J. Lieber Marin <sup>82b, [id](#)</sup>, H. Lien <sup>68, [id](#)</sup>, K. Lin <sup>107, [id](#)</sup>, R.A. Linck <sup>68, [id](#)</sup>, R.E. Lindley <sup>7, [id](#)</sup>, J.H. Lindon <sup>2, [id](#)</sup>, A. Linss <sup>48, [id](#)</sup>, E. Lipeles <sup>128, [id](#)</sup>, A. Lipniacka <sup>16, [id](#)</sup>, A. Lister <sup>164, [id](#)</sup>, J.D. Little <sup>4, [id](#)</sup>, B. Liu <sup>14a, [id](#)</sup>, B.X. Liu <sup>142, [id](#)</sup>, D. Liu <sup>62d, 62c, [id](#)</sup>, J.B. Liu <sup>62a, [id](#)</sup>, J.K.K. Liu <sup>32, [id](#)</sup>, K. Liu <sup>62d, 62c, [id](#)</sup>, M. Liu <sup>62a, [id](#)</sup>, M.Y. Liu <sup>62a, [id](#)</sup>, P. Liu <sup>14a, [id](#)</sup>, Q. Liu <sup>62d, 138, 62c, [id](#)</sup>, X. Liu <sup>62a, [id](#)</sup>, Y. Liu <sup>14c, 14d, [id](#)</sup>, Y.L. Liu <sup>106, [id](#)</sup>, Y.W. Liu <sup>62a, [id](#)</sup>, J. Llorente Merino <sup>142, [id](#)</sup>, S.L. Lloyd <sup>95, [id](#)</sup>, E.M. Lobodzinska <sup>48, [id](#)</sup>, P. Loch <sup>7, [id](#)</sup>, S. Loffredo <sup>76a, 76b, [id](#)</sup>, T. Lohse <sup>18, [id](#)</sup>, K. Lohwasser <sup>139, [id](#)</sup>, E. Loiacono <sup>48, [id](#)</sup>, M. Lokajicek <sup>131, [id](#), [\\*](#)</sup>, J.D. Long <sup>162, [id](#)</sup>, I. Longarini <sup>160, [id](#)</sup>, L. Longo <sup>70a, 70b, [id](#)</sup>, R. Longo <sup>162, [id](#)</sup>, I. Lopez Paz <sup>67, [id](#)</sup>, A. Lopez Solis <sup>48, [id](#)</sup>, J. Lorenz <sup>109, [id](#)</sup>, N. Lorenzo Martinez <sup>4, [id](#)</sup>, A.M. Lory <sup>109, [id](#)</sup>, X. Lou <sup>47a, 47b, [id](#)</sup>, X. Lou <sup>14a, 14d, [id](#)</sup>, A. Lounis <sup>66, [id](#)</sup>, J. Love <sup>6, [id](#)</sup>, P.A. Love <sup>92, [id](#)</sup>, G. Lu <sup>14a, 14d, [id](#)</sup>, M. Lu <sup>80, [id](#)</sup>, S. Lu <sup>128, [id](#)</sup>, Y.J. Lu <sup>65, [id](#)</sup>, H.J. Lubatti <sup>138, [id](#)</sup>, C. Luci <sup>75a, 75b, [id](#)</sup>, F.L. Lucio Alves <sup>14c, [id](#)</sup>, A. Lucotte <sup>60, [id](#)</sup>, F. Luehring <sup>68, [id](#)</sup>, I. Luise <sup>145, [id](#)</sup>, O. Lukianchuk <sup>66, [id](#)</sup>, O. Lundberg <sup>144, [id](#)</sup>, B. Lund-Jensen <sup>144, [id](#)</sup>, N.A. Luongo <sup>123, [id](#)</sup>, M.S. Lutz <sup>151, [id](#)</sup>, D. Lynn <sup>29, [id](#)</sup>, H. Lyons <sup>93</sup>, R. Lysak <sup>131, [id](#)</sup>, E. Lytken <sup>99, [id](#)</sup>, V. Lyubushkin <sup>38, [id](#)</sup>, T. Lyubushkina <sup>38, [id](#)</sup>, M.M. Lyukova <sup>145, [id](#)</sup>, H. Ma <sup>29, [id](#)</sup>, L.L. Ma <sup>62b, [id](#)</sup>, Y. Ma <sup>97, [id](#)</sup>, D.M. Mac Donell <sup>165, [id](#)</sup>, G. Maccarrone <sup>53, [id](#)</sup>, J.C. MacDonald <sup>139, [id](#)</sup>, R. Madar <sup>40, [id](#)</sup>, W.F. Mader <sup>50, [id](#)</sup>, J. Maeda <sup>84, [id](#)</sup>, T. Maeno <sup>29, [id](#)</sup>, M. Maerker <sup>50, [id](#)</sup>, H. Maguire <sup>139, [id](#)</sup>, A. Maio <sup>130a, 130b, 130d, [id](#)</sup>, K. Maj <sup>85a, [id](#)</sup>, O. Majersky <sup>48, [id](#)</sup>, S. Majewski <sup>123, [id](#)</sup>, N. Makovec <sup>66, [id](#)</sup>, V. Maksimovic <sup>15, [id](#)</sup>, B. Malaescu <sup>127, [id](#)</sup>, Pa. Malecki <sup>86, [id](#)</sup>, V.P. Maleev <sup>37, [id](#)</sup>, F. Malek <sup>60, [id](#)</sup>, D. Malito <sup>43b, 43a, [id](#)</sup>, U. Mallik <sup>80, [id](#)</sup>, C. Malone <sup>32, [id](#)</sup>, S. Maltezos <sup>10</sup>, S. Malyukov <sup>38</sup>, J. Mamuzic <sup>13, [id](#)</sup>, G. Mancini <sup>53, [id](#)</sup>, G. Manco <sup>73a, 73b, [id](#)</sup>, J.P. Mandalia <sup>95, [id](#)</sup>, I. Mandić <sup>94, [id](#)</sup>, L. Manhaes de Andrade Filho <sup>82a, [id](#)</sup>, I.M. Maniatis <sup>169, [id](#)</sup>, J. Manjarres Ramos <sup>90, [id](#), [ad](#)</sup>, D.C. Mankad <sup>169, [id](#)</sup>, A. Mann <sup>109, [id](#)</sup>, B. Mansoulie <sup>135, [id](#)</sup>, S. Manzoni <sup>36, [id](#)</sup>, A. Marantis <sup>152, [id](#), [u](#)</sup>, G. Marchiori <sup>5, [id](#)</sup>, M. Marcisovsky <sup>131, [id](#)</sup>, C. Marcon <sup>71a, 71b, [id](#)</sup>, M. Marinescu <sup>20, [id](#)</sup>, M. Marjanovic <sup>120, [id](#)</sup>, E.J. Marshall <sup>92, [id](#)</sup>, Z. Marshall <sup>17a, [id](#)</sup>, S. Marti-Garcia <sup>163, [id](#)</sup>, T.A. Martin <sup>167, [id](#)</sup>, V.J. Martin <sup>52, [id](#)</sup>, B. Martin dit Latour <sup>16, [id](#)</sup>, L. Martinelli <sup>75a, 75b, [id](#)</sup>, M. Martinez <sup>13, [id](#), [v](#)</sup>, P. Martinez Agullo <sup>163, [id](#)</sup>, V.I. Martinez Outschoorn <sup>103, [id](#)</sup>, P. Martinez Suarez <sup>13, [id](#)</sup>, S. Martin-Haugh <sup>134, [id](#)</sup>, V.S. Martoiu <sup>27b, [id](#)</sup>, A.C. Martyniuk <sup>97, [id](#)</sup>, A. Marzin <sup>36, [id](#)</sup>, S.R. Maschek <sup>110, [id](#)</sup>, D. Mascione <sup>78a, 78b, [id](#)</sup>, L. Masetti <sup>101, [id](#)</sup>, T. Mashimo <sup>153, [id](#)</sup>, J. Masik <sup>102, [id](#)</sup>, A.L. Maslennikov <sup>37, [id](#)</sup>, L. Massa <sup>23b, [id](#)</sup>, P. Massarotti <sup>72a, 72b, [id](#)</sup>, P. Mastrandrea <sup>74a, 74b, [id](#)</sup>, A. Mastroberardino <sup>43b, 43a, [id](#)</sup>, T. Masubuchi <sup>153, [id](#)</sup>, T. Mathisen <sup>161, [id](#)</sup>, N. Matsuzawa <sup>153</sup>, J. Maurer <sup>27b, [id](#)</sup>, B. Maček <sup>94, [id](#)</sup>, D.A. Maximov <sup>37, [id](#)</sup>, R. Mazini <sup>148, [id](#)</sup>, I. Maznas <sup>152, [id](#), [f](#)</sup>, M. Mazza <sup>107, [id](#)</sup>, S.M. Mazza <sup>136, [id](#)</sup>, C. Mc Ginn <sup>29, [id](#)</sup>, J.P. Mc Gowan <sup>104, [id](#)</sup>, S.P. Mc Kee <sup>106, [id](#)</sup>, E.F. McDonald <sup>105, [id](#)</sup>, A.E. McDougall <sup>114, [id](#)</sup>, J.A. MCFayden <sup>146, [id](#)</sup>, G. Mchedlidze <sup>149b, [id](#)</sup>, R.P. McKenzie <sup>33g, [id](#)</sup>, T.C. McLachlan <sup>48, [id](#)</sup>, D.J. McLaughlin <sup>97, [id](#)</sup>, K.D. McLean <sup>165, [id](#)</sup>, S.J. McMahon <sup>134, [id](#)</sup>, P.C. McNamara <sup>105, [id](#)</sup>, C.M. Mcpartland <sup>93, [id](#)</sup>, R.A. McPherson <sup>165, [id](#), [z](#)</sup>, T. Megy <sup>40, [id](#)</sup>, S. Mehlhase <sup>109, [id](#)</sup>, A. Mehta <sup>93, [id](#)</sup>, D. Melini <sup>150, [id](#)</sup>, B.R. Mellado Garcia <sup>33g, [id](#)</sup>, A.H. Melo <sup>55, [id](#)</sup>, F. Meloni <sup>48, [id](#)</sup>, A.M. Mendes Jacques Da Costa <sup>102, [id](#)</sup>, H.Y. Meng <sup>155, [id](#)</sup>, L. Meng <sup>92, [id](#)</sup>, S. Menke <sup>110, [id](#)</sup>, M. Mentink <sup>36, [id](#)</sup>, E. Meoni <sup>43b, 43a, [id](#)</sup>, C. Merlassino <sup>126, [id](#)</sup>, L. Merola <sup>72a, 72b, [id](#)</sup>, C. Meroni <sup>71a, 71b, [id](#)</sup>, G. Merz <sup>106</sup>, O. Meshkov <sup>37, [id](#)</sup>, J. Metcalfe <sup>6, [id](#)</sup>, A.S. Mete <sup>6, [id](#)</sup>, C. Meyer <sup>68, [id](#)</sup>, J-P. Meyer <sup>135, [id](#)</sup>, R.P. Middleton <sup>134, [id](#)</sup>, L. Mijović <sup>52, [id](#)</sup>, G. Mikenberg <sup>169, [id](#)</sup>, M. Mikestikova <sup>131, [id](#)</sup>, M. Mikuž <sup>94, [id](#)</sup>, H. Mildner <sup>139, [id](#)</sup>, A. Milic <sup>36, [id](#)</sup>, C.D. Milke <sup>44, [id](#)</sup>, D.W. Miller <sup>39, [id](#)</sup>, L.S. Miller <sup>34, [id](#)</sup>, A. Milov <sup>169, [id](#)</sup>, D.A. Milstead <sup>47a, 47b</sup>, T. Min <sup>14c</sup>, A.A. Minaenko <sup>37, [id](#)</sup>, I.A. Minashvili <sup>149b, [id](#)</sup>, L. Mince <sup>59, [id](#)</sup>, A.I. Mincer <sup>117, [id](#)</sup>, B. Mindur <sup>85a, [id](#)</sup>, M. Mineev <sup>38, [id](#)</sup>, Y. Mino <sup>87, [id](#)</sup>, L.M. Mir <sup>13, [id](#)</sup>, M. Miralles Lopez <sup>163, [id](#)</sup>, M. Mironova <sup>126, [id](#)</sup>, M.C. Missio <sup>113, [id](#)</sup>, T. Mitani <sup>168, [id](#)</sup>,

A. Mitra <sup>167, [id](#)</sup>, V.A. Mitsou <sup>163, [id](#)</sup>, O. Miu <sup>155, [id](#)</sup>, P.S. Miyagawa <sup>95, [id](#)</sup>, Y. Miyazaki <sup>89</sup>, A. Mizukami <sup>83, [id](#)</sup>,  
 T. Mkrтчhyan <sup>63a, [id](#)</sup>, M. Mlinarevic <sup>97, [id](#)</sup>, T. Mlinarevic <sup>97, [id](#)</sup>, M. Mlynarikova <sup>36, [id](#)</sup>, S. Mobius <sup>55, [id](#)</sup>,  
 K. Mochizuki <sup>108, [id](#)</sup>, P. Moder <sup>48, [id](#)</sup>, P. Mogg <sup>109, [id](#)</sup>, A.F. Mohammed <sup>14a,14d, [id](#)</sup>, S. Mohapatra <sup>41, [id](#)</sup>,  
 G. Mokgatitswane <sup>33g, [id](#)</sup>, B. Mondal <sup>141, [id](#)</sup>, S. Mondal <sup>132, [id](#)</sup>, K. Mönig <sup>48, [id](#)</sup>, E. Monnier <sup>90, [id](#)</sup>,  
 L. Monsonis Romero <sup>163</sup>, J. Montejo Berlingen <sup>83, [id](#)</sup>, M. Montella <sup>119, [id](#)</sup>, F. Monticelli <sup>91, [id](#)</sup>, N. Morange <sup>66, [id](#)</sup>,  
 A.L. Moreira De Carvalho <sup>130a, [id](#)</sup>, M. Moreno Llácer <sup>163, [id](#)</sup>, C. Moreno Martinez <sup>56, [id](#)</sup>, P. Morettini <sup>57b, [id](#)</sup>,  
 S. Morgenstern <sup>167, [id](#)</sup>, M. Morii <sup>61, [id](#)</sup>, M. Morinaga <sup>153, [id](#)</sup>, A.K. Morley <sup>36, [id](#)</sup>, F. Morodei <sup>75a,75b, [id](#)</sup>, L. Morvaj <sup>36, [id](#)</sup>,  
 P. Moschovakos <sup>36, [id](#)</sup>, B. Moser <sup>36, [id](#)</sup>, M. Mosidze <sup>149b</sup>, T. Moskalets <sup>54, [id](#)</sup>, P. Moskvitina <sup>113, [id](#)</sup>, J. Moss <sup>31, [id](#), [o](#)</sup>,  
 E.J.W. Moyse <sup>103, [id](#)</sup>, O. Mtintsilana <sup>33g, [id](#)</sup>, S. Muanza <sup>90, [id](#)</sup>, J. Mueller <sup>129, [id](#)</sup>, D. Muenstermann <sup>92, [id](#)</sup>,  
 R. Müller <sup>19, [id](#)</sup>, G.A. Mullier <sup>161, [id](#)</sup>, J.J. Mullin <sup>128</sup>, D.P. Mungo <sup>155, [id](#)</sup>, J.L. Munoz Martinez <sup>13, [id](#)</sup>,  
 D. Munoz Perez <sup>163, [id](#)</sup>, F.J. Munoz Sanchez <sup>102, [id](#)</sup>, M. Murin <sup>102, [id](#)</sup>, W.J. Murray <sup>167,134, [id](#)</sup>, A. Murrone <sup>71a,71b, [id](#)</sup>,  
 J.M. Muse <sup>120, [id](#)</sup>, M. Muškinja <sup>17a, [id](#)</sup>, C. Mwewa <sup>29, [id](#)</sup>, A.G. Myagkov <sup>37, [id](#), [a](#)</sup>, A.J. Myers <sup>8, [id](#)</sup>, A.A. Myers <sup>129</sup>,  
 G. Myers <sup>68, [id](#)</sup>, M. Myska <sup>132, [id](#)</sup>, B.P. Nachman <sup>17a, [id](#)</sup>, O. Nackenhorst <sup>49, [id](#)</sup>, A. Nag <sup>50, [id](#)</sup>, K. Nagai <sup>126, [id](#)</sup>,  
 K. Nagano <sup>83, [id](#)</sup>, J.L. Nagle <sup>29, [id](#), [al](#)</sup>, E. Nagy <sup>90, [id](#)</sup>, A.M. Nairz <sup>36, [id](#)</sup>, Y. Nakahama <sup>83, [id](#)</sup>, K. Nakamura <sup>83, [id](#)</sup>,  
 H. Nanjo <sup>124, [id](#)</sup>, R. Narayan <sup>44, [id](#)</sup>, E.A. Narayanan <sup>112, [id](#)</sup>, I. Naryshkin <sup>37, [id](#)</sup>, M. Naseri <sup>34, [id](#)</sup>, C. Nass <sup>24, [id](#)</sup>,  
 G. Navarro <sup>22a, [id](#)</sup>, J. Navarro-Gonzalez <sup>163, [id](#)</sup>, R. Nayak <sup>151, [id](#)</sup>, A. Nayaz <sup>18, [id](#)</sup>, P.Y. Nechaeva <sup>37, [id](#)</sup>,  
 F. Nechansky <sup>48, [id](#)</sup>, L. Nedic <sup>126, [id](#)</sup>, T.J. Neep <sup>20, [id](#)</sup>, A. Negri <sup>73a,73b, [id](#)</sup>, M. Negrini <sup>23b, [id](#)</sup>, C. Nellist <sup>114, [id](#)</sup>,  
 C. Nelson <sup>104, [id](#)</sup>, K. Nelson <sup>106, [id](#)</sup>, S. Nemecek <sup>131, [id](#)</sup>, M. Nessi <sup>36, [id](#), [i](#)</sup>, M.S. Neubauer <sup>162, [id](#)</sup>, F. Neuhaus <sup>101, [id](#)</sup>,  
 J. Neundorff <sup>48, [id](#)</sup>, R. Newhouse <sup>164, [id](#)</sup>, P.R. Newman <sup>20, [id](#)</sup>, C.W. Ng <sup>129, [id](#)</sup>, Y.W.Y. Ng <sup>48, [id](#)</sup>, B. Ngair <sup>35e, [id](#)</sup>,  
 H.D.N. Nguyen <sup>108, [id](#)</sup>, R.B. Nickerson <sup>126, [id](#)</sup>, R. Nicolaidou <sup>135, [id](#)</sup>, J. Nielsen <sup>136, [id](#)</sup>, M. Niemeyer <sup>55, [id](#)</sup>,  
 N. Nikiporou <sup>36, [id](#)</sup>, V. Nikolaenko <sup>37, [id](#), [a](#)</sup>, I. Nikolic-Audit <sup>127, [id](#)</sup>, K. Nikolopoulos <sup>20, [id](#)</sup>, P. Nilsson <sup>29, [id](#)</sup>, I. Ninca <sup>48, [id](#)</sup>,  
 H.R. Nindhito <sup>56, [id](#)</sup>, G. Ninio <sup>151, [id](#)</sup>, A. Nisati <sup>75a, [id](#)</sup>, N. Nishu <sup>2, [id](#)</sup>, R. Nisius <sup>110, [id](#)</sup>, J-E. Nitschke <sup>50, [id](#)</sup>,  
 E.K. Nkadimeng <sup>33g, [id](#)</sup>, S.J. Noacco Rosende <sup>91, [id](#)</sup>, T. Nobe <sup>153, [id](#)</sup>, D.L. Noel <sup>32, [id](#)</sup>, Y. Noguchi <sup>87, [id](#)</sup>,  
 T. Nommensen <sup>147, [id](#)</sup>, M.A. Nomura <sup>29</sup>, M.B. Norfolk <sup>139, [id](#)</sup>, R.R.B. Norisam <sup>97, [id](#)</sup>, B.J. Norman <sup>34, [id](#)</sup>, J. Novak <sup>94, [id](#)</sup>,  
 T. Novak <sup>48, [id](#)</sup>, L. Novotny <sup>132, [id](#)</sup>, R. Novotny <sup>112, [id](#)</sup>, L. Nozka <sup>122, [id](#)</sup>, K. Ntekas <sup>160, [id](#)</sup>,  
 N.M.J. Nunes De Moura Junior <sup>82b, [id](#)</sup>, E. Nurse <sup>97</sup>, J. Ocariz <sup>127, [id](#)</sup>, A. Ochi <sup>84, [id](#)</sup>, I. Ochoa <sup>130a, [id](#)</sup>, S. Oerdek <sup>161, [id](#)</sup>,  
 J.T. Offermann <sup>39, [id](#)</sup>, A. Ogrodnik <sup>85a, [id](#)</sup>, A. Oh <sup>102, [id](#)</sup>, C.C. Ohm <sup>144, [id](#)</sup>, H. Oide <sup>83, [id](#)</sup>, R. Oishi <sup>153, [id](#)</sup>,  
 M.L. Ojeda <sup>48, [id](#)</sup>, Y. Okazaki <sup>87, [id](#)</sup>, M.W. O’Keefe <sup>93</sup>, Y. Okumura <sup>153, [id](#)</sup>, L.F. Oleiro Seabra <sup>130a, [id](#)</sup>,  
 S.A. Olivares Pino <sup>137d, [id](#)</sup>, D. Oliveira Damazio <sup>29, [id](#)</sup>, D. Oliveira Goncalves <sup>82a, [id](#)</sup>, J.L. Oliver <sup>160, [id](#)</sup>,  
 M.J.R. Olsson <sup>160, [id](#)</sup>, A. Olszewski <sup>86, [id](#)</sup>, J. Olszowska <sup>86, [id](#), [\\*](#)</sup>, Ö.O. Öncel <sup>54, [id](#)</sup>, D.C. O’Neil <sup>142, [id](#)</sup>, A.P. O’Neill <sup>19, [id](#)</sup>,  
 A. Onofre <sup>130a,130e, [id](#)</sup>, P.U.E. Onyisi <sup>11, [id](#)</sup>, M.J. Oreglia <sup>39, [id](#)</sup>, G.E. Orellana <sup>91, [id](#)</sup>, D. Orestano <sup>77a,77b, [id](#)</sup>,  
 N. Orlando <sup>13, [id](#)</sup>, R.S. Orr <sup>155, [id](#)</sup>, V. O’Shea <sup>59, [id](#)</sup>, R. Ospanov <sup>62a, [id](#)</sup>, G. Otero y Garzon <sup>30, [id](#)</sup>, H. Otono <sup>89, [id](#)</sup>,  
 P.S. Ott <sup>63a, [id](#)</sup>, G.J. Ottino <sup>17a, [id](#)</sup>, M. Ouchrif <sup>35d, [id](#)</sup>, J. Ouellette <sup>29, [id](#)</sup>, F. Ould-Saada <sup>125, [id](#)</sup>, M. Owen <sup>59, [id](#)</sup>,  
 R.E. Owen <sup>134, [id](#)</sup>, K.Y. Oyulmaz <sup>21a, [id](#)</sup>, V.E. Ozcan <sup>21a, [id](#)</sup>, N. Ozturk <sup>8, [id](#)</sup>, S. Ozturk <sup>21d, [id](#)</sup>, H.A. Pacey <sup>32, [id](#)</sup>,  
 A. Pacheco Pages <sup>13, [id](#)</sup>, C. Padilla Aranda <sup>13, [id](#)</sup>, G. Padovano <sup>75a,75b, [id](#)</sup>, S. Pagan Griso <sup>17a, [id](#)</sup>, G. Palacino <sup>68, [id](#)</sup>,  
 A. Palazzo <sup>70a,70b, [id](#)</sup>, S. Palestini <sup>36, [id](#)</sup>, J. Pan <sup>172, [id](#)</sup>, T. Pan <sup>64a, [id](#)</sup>, D.K. Panchal <sup>11, [id](#)</sup>, C.E. Pandini <sup>114, [id](#)</sup>,  
 J.G. Panduro Vazquez <sup>96, [id](#)</sup>, H. Pang <sup>14b, [id](#)</sup>, P. Pani <sup>48, [id](#)</sup>, G. Panizzo <sup>69a,69c, [id](#)</sup>, L. Paolozzi <sup>56, [id](#)</sup>, C. Papadatos <sup>108, [id](#)</sup>,  
 S. Parajuli <sup>44, [id](#)</sup>, A. Paramonov <sup>6, [id](#)</sup>, C. Paraskevopoulos <sup>10, [id](#)</sup>, D. Paredes Hernandez <sup>64b, [id](#)</sup>, T.H. Park <sup>155, [id](#)</sup>,  
 M.A. Parker <sup>32, [id](#)</sup>, F. Parodi <sup>57b,57a, [id](#)</sup>, E.W. Parrish <sup>115, [id](#)</sup>, V.A. Parrish <sup>52, [id](#)</sup>, J.A. Parsons <sup>41, [id](#)</sup>, U. Parzefall <sup>54, [id](#)</sup>,  
 B. Pascual Dias <sup>108, [id](#)</sup>, L. Pascual Dominguez <sup>151, [id](#)</sup>, F. Pasquali <sup>114, [id](#)</sup>, E. Pasqualucci <sup>75a, [id](#)</sup>, S. Passaggio <sup>57b, [id](#)</sup>,  
 F. Pastore <sup>96, [id](#)</sup>, P. Pasuwan <sup>47a,47b, [id](#)</sup>, P. Patel <sup>86, [id](#)</sup>, U.M. Patel <sup>51, [id](#)</sup>, J.R. Pater <sup>102, [id](#)</sup>, T. Pauly <sup>36, [id](#)</sup>,  
 J. Pearkes <sup>143, [id](#)</sup>, M. Pedersen <sup>125, [id](#)</sup>, R. Pedro <sup>130a, [id](#)</sup>, S.V. Peleganchuk <sup>37, [id](#)</sup>, O. Penc <sup>36, [id](#)</sup>, E.A. Pender <sup>52, [id](#)</sup>,  
 H. Peng <sup>62a, [id](#)</sup>, K.E. Pensi <sup>109, [id](#)</sup>, M. Penzin <sup>37, [id](#)</sup>, B.S. Peralva <sup>82d, [id](#)</sup>, A.P. Pereira Peixoto <sup>60, [id](#)</sup>,



L. Pereira Sanchez <sup>47a,47b, [id](#)</sup>, D.V. Perepelitsa <sup>29, [id](#), [al](#)</sup>, E. Perez Codina <sup>156a, [id](#)</sup>, M. Perganti <sup>10, [id](#)</sup>, L. Perini <sup>71a,71b, [id](#), \*</sup>,  
H. Pernegger <sup>36, [id](#)</sup>, A. Perrevoort <sup>113, [id](#)</sup>, O. Perrin <sup>40, [id](#)</sup>, K. Peters <sup>48, [id](#)</sup>, R.F.Y. Peters <sup>102, [id](#)</sup>, B.A. Petersen <sup>36, [id](#)</sup>,  
T.C. Petersen <sup>42, [id](#)</sup>, E. Petit <sup>90, [id](#)</sup>, V. Petousis <sup>132, [id](#)</sup>, C. Petridou <sup>152, [id](#), [f](#)</sup>, A. Petrukhin <sup>141, [id](#)</sup>, M. Pettee <sup>17a, [id](#)</sup>,  
N.E. Pettersson <sup>36, [id](#)</sup>, A. Petukhov <sup>37, [id](#)</sup>, K. Petukhova <sup>133, [id](#)</sup>, A. Peyaud <sup>135, [id](#)</sup>, R. Pezoa <sup>137f, [id](#)</sup>, L. Pezzotti <sup>36, [id](#)</sup>,  
G. Pezzullo <sup>172, [id](#)</sup>, T.M. Pham <sup>170, [id](#)</sup>, T. Pham <sup>105, [id](#)</sup>, P.W. Phillips <sup>134, [id](#)</sup>, M.W. Phipps <sup>162, [id](#)</sup>, G. Piacquadio <sup>145, [id](#)</sup>,  
E. Pianori <sup>17a, [id](#)</sup>, F. Piazza <sup>71a,71b, [id](#)</sup>, R. Piegaia <sup>30, [id](#)</sup>, D. Pietreanu <sup>27b, [id](#)</sup>, A.D. Pilkington <sup>102, [id](#)</sup>,  
M. Pinamonti <sup>69a,69c, [id](#)</sup>, J.L. Pinfold <sup>2, [id](#)</sup>, B.C. Pinheiro Pereira <sup>130a, [id](#)</sup>, C. Pitman Donaldson <sup>97</sup>, D.A. Pizzi <sup>34, [id](#)</sup>,  
L. Pizzimento <sup>76a,76b, [id](#)</sup>, A. Pizzini <sup>114, [id](#)</sup>, M.-A. Pleier <sup>29, [id](#)</sup>, V. Plesanovs <sup>54</sup>, V. Pleskot <sup>133, [id](#)</sup>, E. Plotnikova <sup>38</sup>,  
G. Poddar <sup>4, [id](#)</sup>, R. Poettgen <sup>99, [id](#)</sup>, L. Poggioli <sup>127, [id](#)</sup>, D. Pohl <sup>24, [id](#)</sup>, I. Pokharel <sup>55, [id](#)</sup>, S. Polacek <sup>133, [id](#)</sup>,  
G. Polesello <sup>73a, [id](#)</sup>, A. Poley <sup>142,156a, [id](#)</sup>, R. Polifka <sup>132, [id](#)</sup>, A. Polini <sup>23b, [id](#)</sup>, C.S. Pollard <sup>167, [id](#)</sup>, Z.B. Pollock <sup>119, [id](#)</sup>,  
V. Polychronakos <sup>29, [id](#)</sup>, E. Pompa Pacchi <sup>75a,75b, [id](#)</sup>, D. Ponomarenko <sup>113, [id](#)</sup>, L. Pontecorvo <sup>36, [id](#)</sup>, S. Popa <sup>27a, [id](#)</sup>,  
G.A. Popeneciu <sup>27d, [id](#)</sup>, D.M. Portillo Quintero <sup>156a, [id](#)</sup>, S. Pospisil <sup>132, [id](#)</sup>, P. Postolache <sup>27c, [id](#)</sup>, K. Potamianos <sup>126, [id](#)</sup>,  
P.A. Potepa <sup>85a, [id](#)</sup>, I.N. Potrap <sup>38, [id](#)</sup>, C.J. Potter <sup>32, [id](#)</sup>, H. Potti <sup>1, [id](#)</sup>, T. Poulsen <sup>48, [id](#)</sup>, J. Poveda <sup>163, [id](#)</sup>,  
M.E. Pozo Astigarraga <sup>36, [id](#)</sup>, A. Prades Ibanez <sup>163, [id](#)</sup>, M.M. Prapa <sup>46, [id](#)</sup>, J. Pretel <sup>54, [id](#)</sup>, D. Price <sup>102, [id](#)</sup>,  
M. Primavera <sup>70a, [id](#)</sup>, M.A. Principe Martin <sup>100, [id](#)</sup>, R. Privara <sup>122, [id](#)</sup>, M.L. Proffitt <sup>138, [id](#)</sup>, N. Proklova <sup>128, [id](#)</sup>,  
K. Prokofiev <sup>64c, [id](#)</sup>, G. Proto <sup>76a,76b, [id](#)</sup>, S. Protopopescu <sup>29, [id](#)</sup>, J. Proudfoot <sup>6, [id](#)</sup>, M. Przybycien <sup>85a, [id](#)</sup>,  
W.W. Przygoda <sup>85b, [id](#)</sup>, J.E. Puddefoot <sup>139, [id](#)</sup>, D. Pudzha <sup>37, [id](#)</sup>, D. Pyatiizbyantseva <sup>37, [id](#)</sup>, J. Qian <sup>106, [id](#)</sup>,  
D. Qichen <sup>102, [id](#)</sup>, Y. Qin <sup>102, [id](#)</sup>, T. Qiu <sup>52, [id](#)</sup>, A. Quadt <sup>55, [id](#)</sup>, M. Queitsch-Maitland <sup>102, [id](#)</sup>, G. Quetant <sup>56, [id](#)</sup>,  
G. Rabanal Bolanos <sup>61, [id](#)</sup>, D. Rafanoharana <sup>54, [id](#)</sup>, F. Ragusa <sup>71a,71b, [id](#)</sup>, J.L. Rainbolt <sup>39, [id](#)</sup>, J.A. Raine <sup>56, [id](#)</sup>,  
S. Rajagopalan <sup>29, [id](#)</sup>, E. Ramakoti <sup>37, [id](#)</sup>, K. Ran <sup>48,14d, [id](#)</sup>, N.P. Rapheeha <sup>33g, [id](#)</sup>, V. Raskina <sup>127, [id](#)</sup>, D.F. Rassloff <sup>63a, [id](#)</sup>,  
S. Rave <sup>101, [id](#)</sup>, B. Ravina <sup>55, [id](#)</sup>, I. Ravinovich <sup>169, [id](#)</sup>, M. Raymond <sup>36, [id](#)</sup>, A.L. Read <sup>125, [id](#)</sup>, N.P. Readioff <sup>139, [id](#)</sup>,  
D.M. Rebuffi <sup>73a,73b, [id](#)</sup>, G. Redlinger <sup>29, [id](#)</sup>, K. Reeves <sup>45, [id](#)</sup>, J.A. Reidelsturz <sup>171, [id](#)</sup>, D. Reikher <sup>151, [id](#)</sup>, A. Rej <sup>141, [id](#)</sup>,  
C. Rembser <sup>36, [id](#)</sup>, A. Renardi <sup>48, [id](#)</sup>, M. Renda <sup>27b, [id](#)</sup>, M.B. Rendel <sup>110</sup>, F. Renner <sup>48, [id](#)</sup>, A.G. Rennie <sup>59, [id](#)</sup>,  
S. Resconi <sup>71a, [id](#)</sup>, M. Ressegotti <sup>57b,57a, [id](#)</sup>, E.D. Resseguie <sup>17a, [id](#)</sup>, S. Rettie <sup>36, [id](#)</sup>, J.G. Reyes Rivera <sup>107, [id](#)</sup>,  
B. Reynolds <sup>119</sup>, E. Reynolds <sup>17a, [id](#)</sup>, M. Rezaei Estabragh <sup>171, [id](#)</sup>, O.L. Rezanova <sup>37, [id](#)</sup>, P. Reznicek <sup>133, [id](#)</sup>,  
N. Ribaric <sup>92, [id](#)</sup>, E. Ricci <sup>78a,78b, [id](#)</sup>, R. Richter <sup>110, [id](#)</sup>, S. Richter <sup>47a,47b, [id](#)</sup>, E. Richter-Was <sup>85b, [id](#)</sup>, M. Ridel <sup>127, [id](#)</sup>,  
S. Ridouani <sup>35d, [id](#)</sup>, P. Rieck <sup>117, [id](#)</sup>, P. Riedler <sup>36, [id](#)</sup>, M. Rijssenbeek <sup>145, [id](#)</sup>, A. Rimoldi <sup>73a,73b, [id](#)</sup>, M. Rimoldi <sup>48, [id](#)</sup>,  
L. Rinaldi <sup>23b,23a, [id](#)</sup>, T.T. Rinn <sup>29, [id](#)</sup>, M.P. Rinnagel <sup>109, [id](#)</sup>, G. Ripellino <sup>161, [id](#)</sup>, I. Riu <sup>13, [id](#)</sup>, P. Rivadeneira <sup>48, [id](#)</sup>,  
J.C. Rivera Vergara <sup>165, [id](#)</sup>, F. Rizatdinova <sup>121, [id](#)</sup>, E. Rizvi <sup>95, [id](#)</sup>, C. Rizzi <sup>56, [id](#)</sup>, B.A. Roberts <sup>167, [id](#)</sup>, B.R. Roberts <sup>17a, [id](#)</sup>,  
S.H. Robertson <sup>104, [id](#), [z](#)</sup>, M. Robin <sup>48, [id](#)</sup>, D. Robinson <sup>32, [id](#)</sup>, C.M. Robles Gajardo <sup>137f</sup>, M. Robles Manzano <sup>101, [id](#)</sup>,  
A. Robson <sup>59, [id](#)</sup>, A. Rocchi <sup>76a,76b, [id](#)</sup>, C. Roda <sup>74a,74b, [id](#)</sup>, S. Rodriguez Bosca <sup>63a, [id](#)</sup>, Y. Rodriguez Garcia <sup>22a, [id](#)</sup>,  
A. Rodriguez Rodriguez <sup>54, [id](#)</sup>, A.M. Rodríguez Vera <sup>156b, [id](#)</sup>, S. Roe <sup>36</sup>, J.T. Roemer <sup>160, [id](#)</sup>, A.R. Roepe-Gier <sup>136, [id](#)</sup>,  
J. Roggel <sup>171, [id](#)</sup>, O. Røhne <sup>125, [id](#)</sup>, R.A. Rojas <sup>103, [id](#)</sup>, B. Roland <sup>54, [id](#)</sup>, C.P.A. Roland <sup>68, [id](#)</sup>, J. Roloff <sup>29, [id](#)</sup>,  
A. Romaniouk <sup>37, [id](#)</sup>, E. Romano <sup>73a,73b, [id](#)</sup>, M. Romano <sup>23b, [id](#)</sup>, A.C. Romero Hernandez <sup>162, [id](#)</sup>, N. Rompotis <sup>93, [id](#)</sup>,  
L. Roos <sup>127, [id](#)</sup>, S. Rosati <sup>75a, [id](#)</sup>, B.J. Rosser <sup>39, [id](#)</sup>, E. Rossi <sup>4, [id](#)</sup>, E. Rossi <sup>72a,72b, [id](#)</sup>, L.P. Rossi <sup>57b, [id](#)</sup>, L. Rossini <sup>48, [id](#)</sup>,  
R. Rosten <sup>119, [id](#)</sup>, M. Rotaru <sup>27b, [id](#)</sup>, B. Rottler <sup>54, [id](#)</sup>, C. Rougier <sup>90, [id](#), [ad](#)</sup>, D. Rousseau <sup>66, [id](#)</sup>, D. Rousso <sup>32, [id](#)</sup>,  
G. Rovelli <sup>73a,73b, [id](#)</sup>, A. Roy <sup>162, [id](#)</sup>, S. Roy-Garand <sup>155, [id](#)</sup>, A. Rozanov <sup>90, [id](#)</sup>, Y. Rozen <sup>150, [id](#)</sup>, X. Ruan <sup>33g, [id](#)</sup>,  
A. Rubio Jimenez <sup>163, [id](#)</sup>, A.J. Ruby <sup>93, [id](#)</sup>, V.H. Ruelas Rivera <sup>18, [id](#)</sup>, T.A. Ruggeri <sup>1, [id](#)</sup>, F. Rühr <sup>54, [id](#)</sup>,  
A. Ruiz-Martinez <sup>163, [id](#)</sup>, A. Rummler <sup>36, [id](#)</sup>, Z. Rurikova <sup>54, [id](#)</sup>, N.A. Rusakovich <sup>38, [id](#)</sup>, H.L. Russell <sup>165, [id](#)</sup>,  
J.P. Rutherford <sup>7, [id](#)</sup>, K. Rybacki <sup>92</sup>, M. Rybar <sup>133, [id](#)</sup>, E.B. Rye <sup>125, [id](#)</sup>, A. Ryzhov <sup>37, [id](#)</sup>, J.A. Sabater Iglesias <sup>56, [id](#)</sup>,  
P. Sabatini <sup>163, [id](#)</sup>, L. Sabetta <sup>75a,75b, [id](#)</sup>, H.F.W. Sadrozinski <sup>136, [id](#)</sup>, F. Safai Tehrani <sup>75a, [id](#)</sup>,  
B. Safarzadeh Samani <sup>146, [id](#)</sup>, M. Safdari <sup>143, [id](#)</sup>, S. Saha <sup>104, [id](#)</sup>, M. Sahinsoy <sup>110, [id](#)</sup>, M. Saimpert <sup>135, [id](#)</sup>, M. Saito <sup>153, [id](#)</sup>,  
T. Saito <sup>153, [id](#)</sup>, D. Salamani <sup>36, [id](#)</sup>, A. Salnikov <sup>143, [id](#)</sup>, J. Salt <sup>163, [id](#)</sup>, A. Salvador Salas <sup>13, [id](#)</sup>, D. Salvatore <sup>43b,43a, [id](#)</sup>,

F. Salvatore <sup>146, [ib](#)</sup>, A. Salzburger <sup>36, [ib](#)</sup>, D. Sammel <sup>54, [ib](#)</sup>, D. Sampsonidis <sup>152, [ib](#), [f](#)</sup>, D. Sampsonidou <sup>62d,62c, [ib](#)</sup>, J. Sánchez <sup>163, [ib](#)</sup>, A. Sanchez Pineda <sup>4, [ib](#)</sup>, V. Sanchez Sebastian <sup>163, [ib](#)</sup>, H. Sandaker <sup>125, [ib](#)</sup>, C.O. Sander <sup>48, [ib](#)</sup>, J.A. Sandesara <sup>103, [ib](#)</sup>, M. Sandhoff <sup>171, [ib](#)</sup>, C. Sandoval <sup>22b, [ib](#)</sup>, D.P.C. Sankey <sup>134, [ib](#)</sup>, T. Sano <sup>87, [ib](#)</sup>, A. Sansoni <sup>53, [ib](#)</sup>, L. Santi <sup>75a,75b, [ib](#)</sup>, C. Santoni <sup>40, [ib](#)</sup>, H. Santos <sup>130a,130b, [ib](#)</sup>, S.N. Santpur <sup>17a, [ib](#)</sup>, A. Santra <sup>169, [ib](#)</sup>, K.A. Saoucha <sup>139, [ib](#)</sup>, J.G. Saraiva <sup>130a,130d, [ib](#)</sup>, J. Sardain <sup>7, [ib](#)</sup>, O. Sasaki <sup>83, [ib](#)</sup>, K. Sato <sup>157, [ib](#)</sup>, C. Sauer <sup>63b, [ib](#)</sup>, F. Sauerburger <sup>54, [ib](#)</sup>, E. Sauvan <sup>4, [ib](#)</sup>, P. Savard <sup>155, [ib](#), [ai](#)</sup>, R. Sawada <sup>153, [ib](#)</sup>, C. Sawyer <sup>134, [ib](#)</sup>, L. Sawyer <sup>98, [ib](#)</sup>, I. Sayago Galvan <sup>163, [ib](#)</sup>, C. Sbarra <sup>23b, [ib](#)</sup>, A. Sbrizzi <sup>23b,23a, [ib](#)</sup>, T. Scanlon <sup>97, [ib](#)</sup>, J. Schaarschmidt <sup>138, [ib](#)</sup>, P. Schacht <sup>110, [ib](#)</sup>, D. Schaefer <sup>39, [ib](#)</sup>, U. Schäfer <sup>101, [ib](#)</sup>, A.C. Schaffer <sup>66,44, [ib](#)</sup>, D. Schaile <sup>109, [ib](#)</sup>, R.D. Schamberger <sup>145, [ib](#)</sup>, E. Schanet <sup>109, [ib](#)</sup>, C. Scharf <sup>18, [ib](#)</sup>, M.M. Schefer <sup>19, [ib](#)</sup>, V.A. Schegelsky <sup>37, [ib](#)</sup>, D. Scheirich <sup>133, [ib](#)</sup>, F. Schenck <sup>18, [ib](#)</sup>, M. Schernau <sup>160, [ib](#)</sup>, C. Scheulen <sup>55, [ib](#)</sup>, C. Schiavi <sup>57b,57a, [ib](#)</sup>, Z.M. Schillaci <sup>26, [ib](#)</sup>, E.J. Schioppa <sup>70a,70b, [ib](#)</sup>, M. Schioppa <sup>43b,43a, [ib](#)</sup>, B. Schlag <sup>101, [ib](#)</sup>, K.E. Schleicher <sup>54, [ib](#)</sup>, S. Schlenker <sup>36, [ib](#)</sup>, J. Schmeing <sup>171, [ib](#)</sup>, M.A. Schmidt <sup>171, [ib](#)</sup>, K. Schmieden <sup>101, [ib](#)</sup>, C. Schmitt <sup>101, [ib](#)</sup>, S. Schmitt <sup>48, [ib](#)</sup>, L. Schoeffel <sup>135, [ib](#)</sup>, A. Schoening <sup>63b, [ib](#)</sup>, P.G. Scholer <sup>54, [ib](#)</sup>, E. Schopf <sup>126, [ib](#)</sup>, M. Schott <sup>101, [ib](#)</sup>, J. Schovancova <sup>36, [ib](#)</sup>, S. Schramm <sup>56, [ib](#)</sup>, F. Schroeder <sup>171, [ib](#)</sup>, H-C. Schultz-Coulon <sup>63a, [ib](#)</sup>, M. Schumacher <sup>54, [ib](#)</sup>, B.A. Schumm <sup>136, [ib](#)</sup>, Ph. Schune <sup>135, [ib](#)</sup>, H.R. Schwartz <sup>136, [ib](#)</sup>, A. Schwartzman <sup>143, [ib](#)</sup>, T.A. Schwarz <sup>106, [ib](#)</sup>, Ph. Schwemling <sup>135, [ib](#)</sup>, R. Schwienhorst <sup>107, [ib](#)</sup>, A. Sciandra <sup>136, [ib](#)</sup>, G. Sciolla <sup>26, [ib](#)</sup>, F. Scuri <sup>74a, [ib](#)</sup>, F. Scutti <sup>105, [ib](#)</sup>, C.D. Sebastiani <sup>93, [ib](#)</sup>, K. Sedlaczek <sup>49, [ib](#)</sup>, P. Seema <sup>18, [ib](#)</sup>, S.C. Seidel <sup>112, [ib](#)</sup>, A. Seiden <sup>136, [ib](#)</sup>, B.D. Seidlitz <sup>41, [ib](#)</sup>, C. Seitz <sup>48, [ib](#)</sup>, J.M. Seixas <sup>82b, [ib](#)</sup>, G. Sekhniaidze <sup>72a, [ib](#)</sup>, S.J. Sekula <sup>44, [ib](#)</sup>, L. Selem <sup>4, [ib](#)</sup>, N. Semprini-Cesari <sup>23b,23a, [ib](#)</sup>, S. Sen <sup>51, [ib](#)</sup>, D. Sengupta <sup>56, [ib](#)</sup>, V. Senthilkumar <sup>163, [ib](#)</sup>, L. Serin <sup>66, [ib](#)</sup>, L. Serkin <sup>69a,69b, [ib](#)</sup>, M. Sessa <sup>77a,77b, [ib](#)</sup>, H. Severini <sup>120, [ib](#)</sup>, F. Sforza <sup>57b,57a, [ib](#)</sup>, A. Sfyra <sup>56, [ib](#)</sup>, E. Shabalina <sup>55, [ib](#)</sup>, R. Shaheen <sup>144, [ib](#)</sup>, J.D. Shahinian <sup>128, [ib](#)</sup>, D. Shaked Renous <sup>169, [ib](#)</sup>, L.Y. Shan <sup>14a, [ib](#)</sup>, M. Shapiro <sup>17a, [ib](#)</sup>, A. Sharma <sup>36, [ib](#)</sup>, A.S. Sharma <sup>164, [ib](#)</sup>, P. Sharma <sup>80, [ib](#)</sup>, S. Sharma <sup>48, [ib](#)</sup>, P.B. Shatalov <sup>37, [ib](#)</sup>, K. Shaw <sup>146, [ib](#)</sup>, S.M. Shaw <sup>102, [ib](#)</sup>, Q. Shen <sup>62c,5, [ib](#)</sup>, P. Sherwood <sup>97, [ib](#)</sup>, L. Shi <sup>97, [ib](#)</sup>, C.O. Shimmin <sup>172, [ib](#)</sup>, Y. Shimogama <sup>168, [ib](#)</sup>, J.D. Shinner <sup>96, [ib](#)</sup>, I.P.J. Shipsey <sup>126, [ib](#)</sup>, S. Shirabe <sup>60, [ib](#)</sup>, M. Shiyakova <sup>38, [ib](#), [x](#)</sup>, J. Shlomi <sup>169, [ib](#)</sup>, M.J. Shochet <sup>39, [ib](#)</sup>, J. Shojaii <sup>105, [ib](#)</sup>, D.R. Shope <sup>125, [ib](#)</sup>, S. Shrestha <sup>119, [ib](#), [am](#)</sup>, E.M. Shrif <sup>33g, [ib](#)</sup>, M.J. Shroff <sup>165, [ib](#)</sup>, P. Sicho <sup>131, [ib](#)</sup>, A.M. Sickles <sup>162, [ib](#)</sup>, E. Sideras Haddad <sup>33g, [ib](#)</sup>, A. Sidoti <sup>23b, [ib](#)</sup>, F. Siegert <sup>50, [ib](#)</sup>, Dj. Sijacki <sup>15, [ib](#)</sup>, R. Sikora <sup>85a, [ib](#)</sup>, F. Sili <sup>91, [ib](#)</sup>, J.M. Silva <sup>20, [ib](#)</sup>, M.V. Silva Oliveira <sup>36, [ib](#)</sup>, S.B. Silverstein <sup>47a, [ib](#)</sup>, S. Simion <sup>66, [ib](#)</sup>, R. Simoniello <sup>36, [ib](#)</sup>, E.L. Simpson <sup>59, [ib](#)</sup>, H. Simpson <sup>146, [ib](#)</sup>, L.R. Simpson <sup>106, [ib](#)</sup>, N.D. Simpson <sup>99, [ib](#)</sup>, S. Simsek <sup>21d, [ib](#)</sup>, S. Sindhu <sup>55, [ib](#)</sup>, P. Sinervo <sup>155, [ib](#)</sup>, S. Singh <sup>142, [ib](#)</sup>, S. Singh <sup>155, [ib](#)</sup>, S. Sinha <sup>48, [ib](#)</sup>, S. Sinha <sup>33g, [ib](#)</sup>, M. Sioli <sup>23b,23a, [ib](#)</sup>, I. Siral <sup>36, [ib](#)</sup>, S.Yu. Sivoklokov <sup>37, [ib](#), [\\*](#)</sup>, J. Sjölin <sup>47a,47b, [ib](#)</sup>, A. Skaf <sup>55, [ib](#)</sup>, E. Skorda <sup>99, [ib](#)</sup>, P. Skubic <sup>120, [ib](#)</sup>, M. Slawinska <sup>86, [ib](#)</sup>, V. Smakhtin <sup>169, [ib](#)</sup>, B.H. Smart <sup>134, [ib](#)</sup>, J. Smiesko <sup>36, [ib](#)</sup>, S.Yu. Smirnov <sup>37, [ib](#)</sup>, Y. Smirnov <sup>37, [ib](#)</sup>, L.N. Smirnova <sup>37, [ib](#), [a](#)</sup>, O. Smirnova <sup>99, [ib](#)</sup>, A.C. Smith <sup>41, [ib](#)</sup>, E.A. Smith <sup>39, [ib](#)</sup>, H.A. Smith <sup>126, [ib](#)</sup>, J.L. Smith <sup>93, [ib](#)</sup>, R. Smith <sup>143, [ib](#)</sup>, M. Smizanska <sup>92, [ib](#)</sup>, K. Smolek <sup>132, [ib](#)</sup>, A. Smykiewicz <sup>86, [ib](#)</sup>, A.A. Snesarev <sup>37, [ib](#)</sup>, H.L. Snoek <sup>114, [ib](#)</sup>, S. Snyder <sup>29, [ib](#)</sup>, R. Sobie <sup>165, [ib](#), [z](#)</sup>, A. Soffer <sup>151, [ib](#)</sup>, C.A. Solans Sanchez <sup>36, [ib](#)</sup>, E.Yu. Soldatov <sup>37, [ib](#)</sup>, U. Soldevila <sup>163, [ib](#)</sup>, A.A. Solodkov <sup>37, [ib](#)</sup>, S. Solomon <sup>54, [ib](#)</sup>, A. Soloshenko <sup>38, [ib](#)</sup>, K. Solovieva <sup>54, [ib](#)</sup>, O.V. Solovyanov <sup>40, [ib](#)</sup>, V. Solovyev <sup>37, [ib](#)</sup>, P. Sommer <sup>36, [ib](#)</sup>, A. Sonay <sup>13, [ib](#)</sup>, W.Y. Song <sup>156b, [ib](#)</sup>, J.M. Sonneveld <sup>114, [ib](#)</sup>, A. Sopczak <sup>132, [ib](#)</sup>, A.L. Soppio <sup>97, [ib](#)</sup>, F. Sopkova <sup>28b, [ib](#)</sup>, V. Sothilingam <sup>63a, [ib](#)</sup>, S. Sottocornola <sup>68, [ib](#)</sup>, R. Soualah <sup>116b, [ib](#)</sup>, Z. Soumami <sup>35e, [ib](#)</sup>, D. South <sup>48, [ib](#)</sup>, S. Spagnolo <sup>70a,70b, [ib](#)</sup>, M. Spalla <sup>110, [ib](#)</sup>, D. Sperlich <sup>54, [ib](#)</sup>, G. Spigo <sup>36, [ib](#)</sup>, M. Spina <sup>146, [ib](#)</sup>, S. Spinali <sup>92, [ib](#)</sup>, D.P. Spiteri <sup>59, [ib](#)</sup>, M. Spousta <sup>133, [ib](#)</sup>, E.J. Staats <sup>34, [ib](#)</sup>, A. Stabile <sup>71a,71b, [ib](#)</sup>, R. Stamen <sup>63a, [ib](#)</sup>, M. Stamenkovic <sup>114, [ib](#)</sup>, A. Stampekis <sup>20, [ib](#)</sup>, M. Standke <sup>24, [ib](#)</sup>, E. Stanecka <sup>86, [ib](#)</sup>, M.V. Stange <sup>50, [ib](#)</sup>, B. Stanislaus <sup>17a, [ib](#)</sup>, M.M. Stanitzki <sup>48, [ib](#)</sup>, M. Stankaityte <sup>126, [ib](#)</sup>, B. Stapf <sup>48, [ib](#)</sup>, E.A. Starchenko <sup>37, [ib](#)</sup>, G.H. Stark <sup>136, [ib](#)</sup>, J. Stark <sup>90, [ib](#), [ad](#)</sup>, D.M. Starke <sup>156b, [ib](#)</sup>, P. Staroba <sup>131, [ib](#)</sup>, P. Starovoitov <sup>63a, [ib](#)</sup>, S. Stärz <sup>104, [ib](#)</sup>, R. Staszewski <sup>86, [ib](#)</sup>, G. Stavropoulos <sup>46, [ib](#)</sup>, J. Steentoft <sup>161, [ib](#)</sup>, P. Steinberg <sup>29, [ib](#)</sup>, B. Stelzer <sup>142,156a, [ib](#)</sup>, H.J. Stelzer <sup>129, [ib](#)</sup>, O. Stelzer-Chilton <sup>156a, [ib](#)</sup>, H. Stenzel <sup>58, [ib](#)</sup>, T.J. Stevenson <sup>146, [ib](#)</sup>, G.A. Stewart <sup>36, [ib](#)</sup>, J.R. Stewart <sup>121, [ib](#)</sup>, M.C. Stockton <sup>36, [ib](#)</sup>, G. Stoicea <sup>27b, [ib](#)</sup>, M. Stolarski <sup>130a, [ib](#)</sup>, S. Stonjek <sup>110, [ib](#)</sup>, A. Straessner <sup>50, [ib](#)</sup>,

J. Strandberg <sup>144, [id](#)</sup>, S. Strandberg <sup>47a,47b, [id](#)</sup>, M. Strauss <sup>120, [id](#)</sup>, T. Strebler <sup>90, [id](#)</sup>, P. Strizenec <sup>28b, [id](#)</sup>, R. Ströhmer <sup>166, [id](#)</sup>, D.M. Strom <sup>123, [id](#)</sup>, L.R. Strom <sup>48, [id](#)</sup>, R. Stroynowski <sup>44, [id](#)</sup>, A. Strubig <sup>47a,47b, [id](#)</sup>, S.A. Stucci <sup>29, [id](#)</sup>, B. Stugu <sup>16, [id](#)</sup>, J. Stupak <sup>120, [id](#)</sup>, N.A. Styles <sup>48, [id](#)</sup>, D. Su <sup>143, [id](#)</sup>, S. Su <sup>62a, [id](#)</sup>, W. Su <sup>62d,138,62c, [id](#)</sup>, X. Su <sup>62a,66, [id](#)</sup>, K. Sugizaki <sup>153, [id](#)</sup>, V.V. Sulin <sup>37, [id](#)</sup>, M.J. Sullivan <sup>93, [id](#)</sup>, D.M.S. Sultan <sup>78a,78b, [id](#)</sup>, L. Sultanaliev <sup>37, [id](#)</sup>, S. Sultansoy <sup>3b, [id](#)</sup>, T. Sumida <sup>87, [id](#)</sup>, S. Sun <sup>106, [id](#)</sup>, S. Sun <sup>170, [id](#)</sup>, O. Sunneborn Gudnadottir <sup>161, [id](#)</sup>, M.R. Sutton <sup>146, [id](#)</sup>, M. Svatos <sup>131, [id](#)</sup>, M. Swiatlowski <sup>156a, [id](#)</sup>, T. Swirski <sup>166, [id](#)</sup>, I. Sykora <sup>28a, [id](#)</sup>, M. Sykora <sup>133, [id](#)</sup>, T. Sykora <sup>133, [id](#)</sup>, D. Ta <sup>101, [id](#)</sup>, K. Tackmann <sup>48, [id](#)</sup>, A. Taffard <sup>160, [id](#)</sup>, R. Tafirout <sup>156a, [id](#)</sup>, J.S. Tafoya Vargas <sup>66, [id](#)</sup>, R.H.M. Taibah <sup>127, [id](#)</sup>, R. Takashima <sup>88, [id](#)</sup>, E.P. Takeva <sup>52, [id](#)</sup>, Y. Takubo <sup>83, [id](#)</sup>, M. Talby <sup>90, [id](#)</sup>, A.A. Talyshev <sup>37, [id](#)</sup>, K.C. Tam <sup>64b, [id](#)</sup>, N.M. Tamir <sup>151, [id](#)</sup>, A. Tanaka <sup>153, [id](#)</sup>, J. Tanaka <sup>153, [id](#)</sup>, R. Tanaka <sup>66, [id](#)</sup>, M. Tanasini <sup>57b,57a, [id](#)</sup>, J. Tang <sup>62c, [id](#)</sup>, Z. Tao <sup>164, [id](#)</sup>, S. Tapia Araya <sup>137f, [id](#)</sup>, S. Tapprogge <sup>101, [id](#)</sup>, A. Tarek Abouelfadl Mohamed <sup>107, [id](#)</sup>, S. Tarem <sup>150, [id](#)</sup>, K. Tariq <sup>62b, [id](#)</sup>, G. Tarna <sup>90,27b, [id](#)</sup>, G.F. Tartarelli <sup>71a, [id](#)</sup>, P. Tas <sup>133, [id](#)</sup>, M. Tasevsky <sup>131, [id](#)</sup>, E. Tassi <sup>43b,43a, [id](#)</sup>, A.C. Tate <sup>162, [id](#)</sup>, G. Taten <sup>153, [id](#)</sup>, Y. Tayalati <sup>35e, [id](#)</sup>, G.N. Taylor <sup>105, [id](#)</sup>, W. Taylor <sup>156b, [id](#)</sup>, H. Teagle <sup>93, [id](#)</sup>, A.S. Tee <sup>170, [id](#)</sup>, R. Teixeira De Lima <sup>143, [id](#)</sup>, P. Teixeira-Dias <sup>96, [id](#)</sup>, J.J. Teoh <sup>155, [id](#)</sup>, K. Terashi <sup>153, [id](#)</sup>, J. Terron <sup>100, [id](#)</sup>, S. Terzo <sup>13, [id](#)</sup>, M. Testa <sup>53, [id](#)</sup>, R.J. Teuscher <sup>155, [id](#)</sup>, A. Thaler <sup>79, [id](#)</sup>, O. Theiner <sup>56, [id](#)</sup>, N. Themistokleous <sup>52, [id](#)</sup>, T. Theveneaux-Pelzer <sup>90, [id](#)</sup>, O. Thielmann <sup>171, [id](#)</sup>, D.W. Thomas <sup>96, [id](#)</sup>, J.P. Thomas <sup>20, [id](#)</sup>, E.A. Thompson <sup>17a, [id](#)</sup>, P.D. Thompson <sup>20, [id](#)</sup>, E. Thomson <sup>128, [id](#)</sup>, E.J. Thorpe <sup>95, [id](#)</sup>, Y. Tian <sup>55, [id](#)</sup>, V. Tikhomirov <sup>37, [id](#)</sup>, Yu.A. Tikhonov <sup>37, [id](#)</sup>, S. Timoshenko <sup>37, [id](#)</sup>, E.X.L. Ting <sup>1, [id](#)</sup>, P. Tipton <sup>172, [id](#)</sup>, S.H. Tlou <sup>33g, [id](#)</sup>, A. Tmourji <sup>40, [id](#)</sup>, K. Todome <sup>23b,23a, [id](#)</sup>, S. Todorova-Nova <sup>133, [id](#)</sup>, S. Todt <sup>50, [id](#)</sup>, M. Togawa <sup>83, [id](#)</sup>, J. Tojo <sup>89, [id](#)</sup>, S. Tokár <sup>28a, [id](#)</sup>, K. Tokushuku <sup>83, [id](#)</sup>, O. Toldaiev <sup>68, [id](#)</sup>, R. Tombs <sup>32, [id](#)</sup>, M. Tomoto <sup>83,111, [id](#)</sup>, L. Tompkins <sup>143, [id](#)</sup>, K.W. Topolnicki <sup>85b, [id](#)</sup>, P. Tornambe <sup>103, [id](#)</sup>, E. Torrence <sup>123, [id](#)</sup>, H. Torres <sup>50, [id](#)</sup>, E. Torró Pastor <sup>163, [id](#)</sup>, M. Toscani <sup>30, [id](#)</sup>, C. Toscirri <sup>39, [id](#)</sup>, M. Tost <sup>11, [id](#)</sup>, D.R. Tovey <sup>139, [id](#)</sup>, A. Traet <sup>16, [id](#)</sup>, I.S. Trandafir <sup>27b, [id](#)</sup>, T. Trefzger <sup>166, [id](#)</sup>, A. Tricoli <sup>29, [id](#)</sup>, I.M. Trigger <sup>156a, [id](#)</sup>, S. Trincaz-Duvold <sup>127, [id](#)</sup>, D.A. Trischuk <sup>26, [id](#)</sup>, B. Trocmé <sup>60, [id](#)</sup>, C. Troncon <sup>71a, [id](#)</sup>, L. Truong <sup>33c, [id](#)</sup>, M. Trzebinski <sup>86, [id](#)</sup>, A. Trzupek <sup>86, [id](#)</sup>, F. Tsai <sup>145, [id](#)</sup>, M. Tsai <sup>106, [id](#)</sup>, A. Tsiamis <sup>152, [id](#)</sup>, P.V. Tsiarehka <sup>37, [id](#)</sup>, S. Tsigaridas <sup>156a, [id](#)</sup>, A. Tsigirotis <sup>152, [id](#)</sup>, V. Tsiskaridze <sup>145, [id](#)</sup>, E.G. Tskhadadze <sup>149a, [id](#)</sup>, M. Tsopoulou <sup>152, [id](#)</sup>, Y. Tsujikawa <sup>87, [id](#)</sup>, I.I. Tsukerman <sup>37, [id](#)</sup>, V. Tsulaia <sup>17a, [id](#)</sup>, S. Tsuno <sup>83, [id](#)</sup>, O. Tsur <sup>150, [id](#)</sup>, D. Tsybychev <sup>145, [id](#)</sup>, Y. Tu <sup>64b, [id](#)</sup>, A. Tudorache <sup>27b, [id](#)</sup>, V. Tudorache <sup>27b, [id](#)</sup>, A.N. Tuna <sup>36, [id](#)</sup>, S. Turchikhin <sup>38, [id](#)</sup>, I. Turk Cakir <sup>3a, [id](#)</sup>, R. Turra <sup>71a, [id](#)</sup>, T. Turtuvshin <sup>38, [id](#)</sup>, P.M. Tuts <sup>41, [id](#)</sup>, S. Tzamarias <sup>152, [id](#)</sup>, P. Tzanis <sup>10, [id](#)</sup>, E. Tzovara <sup>101, [id](#)</sup>, K. Uchida <sup>153, [id](#)</sup>, F. Ukegawa <sup>157, [id](#)</sup>, P.A. Ulloa Poblete <sup>137c, [id](#)</sup>, E.N. Umaka <sup>29, [id](#)</sup>, G. Unal <sup>36, [id](#)</sup>, M. Unal <sup>11, [id](#)</sup>, A. Undrus <sup>29, [id](#)</sup>, G. Unel <sup>160, [id](#)</sup>, J. Urban <sup>28b, [id](#)</sup>, P. Urquijo <sup>105, [id](#)</sup>, G. Usai <sup>8, [id](#)</sup>, R. Ushioda <sup>154, [id](#)</sup>, M. Usman <sup>108, [id](#)</sup>, Z. Uysal <sup>21b, [id](#)</sup>, L. Vacavant <sup>90, [id](#)</sup>, V. Vacek <sup>132, [id](#)</sup>, B. Vachon <sup>104, [id](#)</sup>, K.O.H. Vadla <sup>125, [id](#)</sup>, T. Vafeiadis <sup>36, [id](#)</sup>, A. Vaitkus <sup>97, [id](#)</sup>, C. Valderanis <sup>109, [id](#)</sup>, E. Valdes Santurio <sup>47a,47b, [id](#)</sup>, M. Valente <sup>156a, [id](#)</sup>, S. Valentinetti <sup>23b,23a, [id](#)</sup>, A. Valero <sup>163, [id](#)</sup>, A. Vallier <sup>90, [id](#)</sup>, J.A. Valls Ferrer <sup>163, [id](#)</sup>, D.R. Van Arneeman <sup>114, [id](#)</sup>, T.R. Van Daalen <sup>138, [id](#)</sup>, P. Van Gemmeren <sup>6, [id](#)</sup>, M. Van Rijnbach <sup>125,36, [id](#)</sup>, S. Van Stroud <sup>97, [id](#)</sup>, I. Van Vulpen <sup>114, [id](#)</sup>, M. Vanadia <sup>76a,76b, [id](#)</sup>, W. Vandelli <sup>36, [id](#)</sup>, M. Vandenbroucke <sup>135, [id](#)</sup>, E.R. Vandewall <sup>121, [id](#)</sup>, D. Vannicola <sup>151, [id](#)</sup>, L. Vannoli <sup>57b,57a, [id](#)</sup>, R. Vari <sup>75a, [id](#)</sup>, E.W. Varnes <sup>7, [id](#)</sup>, C. Varni <sup>17a, [id](#)</sup>, T. Varol <sup>148, [id](#)</sup>, D. Varouchas <sup>66, [id](#)</sup>, L. Varriale <sup>163, [id](#)</sup>, K.E. Varvell <sup>147, [id](#)</sup>, M.E. Vasile <sup>27b, [id](#)</sup>, L. Vaslin <sup>40, [id](#)</sup>, G.A. Vasquez <sup>165, [id](#)</sup>, F. Vazeille <sup>40, [id](#)</sup>, T. Vazquez Schroeder <sup>36, [id](#)</sup>, J. Veatch <sup>31, [id](#)</sup>, V. Vecchio <sup>102, [id](#)</sup>, M.J. Veen <sup>103, [id](#)</sup>, I. Veliscek <sup>126, [id](#)</sup>, L.M. Veloce <sup>155, [id](#)</sup>, F. Veloso <sup>130a,130c, [id](#)</sup>, S. Veneziano <sup>75a, [id](#)</sup>, A. Ventura <sup>70a,70b, [id](#)</sup>, A. Verbytskyi <sup>110, [id](#)</sup>, M. Verducci <sup>74a,74b, [id](#)</sup>, C. Vergis <sup>24, [id](#)</sup>, M. Verissimo De Araujo <sup>82b, [id](#)</sup>, W. Verkerke <sup>114, [id](#)</sup>, J.C. Vermeulen <sup>114, [id](#)</sup>, C. Vernieri <sup>143, [id](#)</sup>, P.J. Verschuuren <sup>96, [id](#)</sup>, M. Vessella <sup>103, [id](#)</sup>, M.C. Vetterli <sup>142, [id](#)</sup>, A. Vgenopoulos <sup>152, [id](#)</sup>, N. Viaux Maira <sup>137f, [id](#)</sup>, T. Vickey <sup>139, [id](#)</sup>, O.E. Vickey Boeriu <sup>139, [id](#)</sup>, G.H.A. Viehhauser <sup>126, [id](#)</sup>, L. Vigani <sup>63b, [id](#)</sup>, M. Villa <sup>23b,23a, [id](#)</sup>, M. Villaplana Perez <sup>163, [id](#)</sup>, E.M. Villhauer <sup>52, [id](#)</sup>, E. Vilucchi <sup>53, [id](#)</sup>, M.G. Vinciter <sup>34, [id](#)</sup>, G.S. Virdee <sup>20, [id](#)</sup>, A. Vishwakarma <sup>52, [id](#)</sup>, C. Vittori <sup>36, [id](#)</sup>, I. Vivarelli <sup>146, [id](#)</sup>, V. Vladimirov <sup>167, [id](#)</sup>, E. Voevodina <sup>110, [id](#)</sup>, F. Vogel <sup>109, [id](#)</sup>, P. Vokac <sup>132, [id](#)</sup>, J. Von Ahnen <sup>48, [id](#)</sup>,

E. Von Toerne<sup>24, [id](#)</sup>, B. Vormwald<sup>36, [id](#)</sup>, V. Vorobel<sup>133, [id](#)</sup>, K. Vorobev<sup>37, [id](#)</sup>, M. Vos<sup>163, [id](#)</sup>, K. Voss<sup>141, [id](#)</sup>, J.H. Vossebeld<sup>93, [id](#)</sup>, M. Vozak<sup>114, [id](#)</sup>, L. Vozdecky<sup>95, [id](#)</sup>, N. Vranjes<sup>15, [id](#)</sup>, M. Vranjes Milosavljevic<sup>15, [id](#)</sup>, M. Vreeswijk<sup>114, [id](#)</sup>, R. Vuillemet<sup>36, [id](#)</sup>, O. Vujanovic<sup>101, [id](#)</sup>, I. Vukotic<sup>39, [id](#)</sup>, S. Wada<sup>157, [id](#)</sup>, C. Wagner<sup>103</sup>, J.M. Wagner<sup>17a, [id](#)</sup>, W. Wagner<sup>171, [id](#)</sup>, S. Wahdan<sup>171, [id](#)</sup>, H. Wahlberg<sup>91, [id](#)</sup>, R. Wakasa<sup>157, [id](#)</sup>, M. Wakida<sup>111, [id](#)</sup>, J. Walder<sup>134, [id](#)</sup>, R. Walker<sup>109, [id](#)</sup>, W. Walkowiak<sup>141, [id](#)</sup>, A.M. Wang<sup>61, [id](#)</sup>, A.Z. Wang<sup>170, [id](#)</sup>, C. Wang<sup>101, [id](#)</sup>, C. Wang<sup>62c, [id](#)</sup>, H. Wang<sup>17a, [id](#)</sup>, J. Wang<sup>64a, [id](#)</sup>, R.-J. Wang<sup>101, [id](#)</sup>, R. Wang<sup>61, [id](#)</sup>, R. Wang<sup>6, [id](#)</sup>, S.M. Wang<sup>148, [id](#)</sup>, S. Wang<sup>62b, [id](#)</sup>, T. Wang<sup>62a, [id](#)</sup>, W.T. Wang<sup>80, [id](#)</sup>, X. Wang<sup>14c, [id](#)</sup>, X. Wang<sup>162, [id](#)</sup>, X. Wang<sup>62c, [id](#)</sup>, Y. Wang<sup>62d, [id](#)</sup>, Y. Wang<sup>14c, [id](#)</sup>, Z. Wang<sup>106, [id](#)</sup>, Z. Wang<sup>62d,51,62c, [id](#)</sup>, Z. Wang<sup>106, [id](#)</sup>, A. Warburton<sup>104, [id](#)</sup>, R.J. Ward<sup>20, [id](#)</sup>, N. Warrack<sup>59, [id](#)</sup>, A.T. Watson<sup>20, [id](#)</sup>, H. Watson<sup>59, [id](#)</sup>, M.F. Watson<sup>20, [id](#)</sup>, G. Watts<sup>138, [id](#)</sup>, B.M. Waugh<sup>97, [id](#)</sup>, C. Weber<sup>29, [id](#)</sup>, H.A. Weber<sup>18, [id](#)</sup>, M.S. Weber<sup>19, [id](#)</sup>, S.M. Weber<sup>63a, [id](#)</sup>, C. Wei<sup>62a, [id](#)</sup>, Y. Wei<sup>126, [id](#)</sup>, A.R. Weidberg<sup>126, [id](#)</sup>, E.J. Weik<sup>117, [id](#)</sup>, J. Weingarten<sup>49, [id](#)</sup>, M. Weirich<sup>101, [id](#)</sup>, C. Weiser<sup>54, [id](#)</sup>, C.J. Wells<sup>48, [id](#)</sup>, T. Wenaus<sup>29, [id](#)</sup>, B. Wendland<sup>49, [id](#)</sup>, T. Wengler<sup>36, [id](#)</sup>, N.S. Wenke<sup>110</sup>, N. Wermes<sup>24, [id](#)</sup>, M. Wessels<sup>63a, [id](#)</sup>, K. Whalen<sup>123, [id](#)</sup>, A.M. Wharton<sup>92, [id](#)</sup>, A.S. White<sup>61, [id](#)</sup>, A. White<sup>8, [id](#)</sup>, M.J. White<sup>1, [id](#)</sup>, D. Whiteson<sup>160, [id](#)</sup>, L. Wickremasinghe<sup>124, [id](#)</sup>, W. Wiedenmann<sup>170, [id](#)</sup>, C. Wiel<sup>50, [id](#)</sup>, M. Wielers<sup>134, [id](#)</sup>, C. Wiglesworth<sup>42, [id](#)</sup>, L.A.M. Wiik-Fuchs<sup>54, [id](#)</sup>, D.J. Wilbern<sup>120</sup>, H.G. Wilkens<sup>36, [id](#)</sup>, D.M. Williams<sup>41, [id](#)</sup>, H.H. Williams<sup>128</sup>, S. Williams<sup>32, [id](#)</sup>, S. Willocq<sup>103, [id](#)</sup>, B.J. Wilson<sup>102, [id](#)</sup>, P.J. Windischhofer<sup>39, [id](#)</sup>, F. Winklmeier<sup>123, [id](#)</sup>, B.T. Winter<sup>54, [id](#)</sup>, J.K. Winter<sup>102, [id](#)</sup>, M. Wittgen<sup>143</sup>, M. Wobisch<sup>98, [id](#)</sup>, R. Wölker<sup>126, [id](#)</sup>, J. Wollrath<sup>160</sup>, M.W. Wolter<sup>86, [id](#)</sup>, H. Wolters<sup>130a,130c, [id](#)</sup>, V.W.S. Wong<sup>164, [id](#)</sup>, A.F. Wongel<sup>48, [id](#)</sup>, S.D. Worm<sup>48, [id](#)</sup>, B.K. Wosiek<sup>86, [id](#)</sup>, K.W. Woźniak<sup>86, [id](#)</sup>, K. Wraight<sup>59, [id](#)</sup>, J. Wu<sup>14a,14d, [id](#)</sup>, M. Wu<sup>64a, [id](#)</sup>, M. Wu<sup>113, [id](#)</sup>, S.L. Wu<sup>170, [id](#)</sup>, X. Wu<sup>56, [id](#)</sup>, Y. Wu<sup>62a, [id](#)</sup>, Z. Wu<sup>135,62a, [id](#)</sup>, J. Wuerzinger<sup>110, [id](#)</sup>, T.R. Wyatt<sup>102, [id](#)</sup>, B.M. Wynne<sup>52, [id](#)</sup>, S. Xella<sup>42, [id](#)</sup>, L. Xia<sup>14c, [id](#)</sup>, M. Xia<sup>14b, [id](#)</sup>, J. Xiang<sup>64c, [id](#)</sup>, X. Xiao<sup>106, [id](#)</sup>, M. Xie<sup>62a, [id](#)</sup>, X. Xie<sup>62a, [id](#)</sup>, S. Xin<sup>14a,14d, [id](#)</sup>, J. Xiong<sup>17a, [id](#)</sup>, I. Xiotidis<sup>146</sup>, D. Xu<sup>14a, [id](#)</sup>, H. Xu<sup>62a, [id](#)</sup>, H. Xu<sup>62a, [id](#)</sup>, L. Xu<sup>62a, [id](#)</sup>, R. Xu<sup>128, [id](#)</sup>, T. Xu<sup>106, [id](#)</sup>, Y. Xu<sup>14b, [id](#)</sup>, Z. Xu<sup>62b, [id](#)</sup>, Z. Xu<sup>14a, [id](#)</sup>, B. Yabsley<sup>147, [id](#)</sup>, S. Yacoub<sup>33a, [id](#)</sup>, N. Yamaguchi<sup>89, [id](#)</sup>, Y. Yamaguchi<sup>154, [id](#)</sup>, H. Yamauchi<sup>157, [id](#)</sup>, T. Yamazaki<sup>17a, [id](#)</sup>, Y. Yamazaki<sup>84, [id](#)</sup>, J. Yan<sup>62c, [id](#)</sup>, S. Yan<sup>126, [id](#)</sup>, Z. Yan<sup>25, [id](#)</sup>, H.J. Yang<sup>62c,62d, [id](#)</sup>, H.T. Yang<sup>62a, [id](#)</sup>, S. Yang<sup>62a, [id](#)</sup>, T. Yang<sup>64c, [id](#)</sup>, X. Yang<sup>62a, [id](#)</sup>, X. Yang<sup>14a, [id](#)</sup>, Y. Yang<sup>44, [id](#)</sup>, Y. Yang<sup>62a, [id](#)</sup>, Z. Yang<sup>62a,106, [id](#)</sup>, W-M. Yao<sup>17a, [id](#)</sup>, Y.C. Yap<sup>48, [id](#)</sup>, H. Ye<sup>14c, [id](#)</sup>, H. Ye<sup>55, [id](#)</sup>, J. Ye<sup>44, [id](#)</sup>, S. Ye<sup>29, [id](#)</sup>, X. Ye<sup>62a, [id](#)</sup>, Y. Yeh<sup>97, [id](#)</sup>, I. Yeletsikh<sup>38, [id](#)</sup>, B.K. Yeo<sup>17a, [id](#)</sup>, M.R. Yexley<sup>92, [id](#)</sup>, P. Yin<sup>41, [id](#)</sup>, K. Yorita<sup>168, [id](#)</sup>, S. Younas<sup>27b, [id](#)</sup>, C.J.S. Young<sup>54, [id](#)</sup>, C. Young<sup>143, [id](#)</sup>, Y. Yu<sup>62a, [id](#)</sup>, M. Yuan<sup>106, [id](#)</sup>, R. Yuan<sup>62b, [id](#)</sup>, L. Yue<sup>97, [id](#)</sup>, M. Zaazoua<sup>35e, [id](#)</sup>, B. Zabinski<sup>86, [id](#)</sup>, E. Zaid<sup>52</sup>, T. Zakareishvili<sup>149b, [id](#)</sup>, N. Zakharchuk<sup>34, [id](#)</sup>, S. Zambito<sup>56, [id](#)</sup>, J.A. Zamora Saa<sup>137d,137b, [id](#)</sup>, J. Zang<sup>153, [id](#)</sup>, D. Zanzi<sup>54, [id](#)</sup>, O. Zaplatilek<sup>132, [id](#)</sup>, C. Zeitnitz<sup>171, [id](#)</sup>, H. Zeng<sup>14a, [id](#)</sup>, J.C. Zeng<sup>162, [id](#)</sup>, D.T. Zenger Jr<sup>26, [id](#)</sup>, O. Zenin<sup>37, [id](#)</sup>, T. Ženiš<sup>28a, [id](#)</sup>, S. Zenz<sup>95, [id](#)</sup>, S. Zerradi<sup>35a, [id](#)</sup>, D. Zerwas<sup>66, [id](#)</sup>, M. Zhai<sup>14a,14d, [id](#)</sup>, B. Zhang<sup>14c, [id](#)</sup>, D.F. Zhang<sup>139, [id](#)</sup>, J. Zhang<sup>62b, [id](#)</sup>, J. Zhang<sup>6, [id](#)</sup>, K. Zhang<sup>14a,14d, [id](#)</sup>, L. Zhang<sup>14c, [id](#)</sup>, P. Zhang<sup>14a,14d</sup>, R. Zhang<sup>170, [id](#)</sup>, S. Zhang<sup>106, [id](#)</sup>, T. Zhang<sup>153, [id](#)</sup>, X. Zhang<sup>62c, [id](#)</sup>, X. Zhang<sup>62b, [id](#)</sup>, Y. Zhang<sup>62c,5, [id](#)</sup>, Z. Zhang<sup>17a, [id](#)</sup>, Z. Zhang<sup>66, [id](#)</sup>, H. Zhao<sup>138, [id](#)</sup>, P. Zhao<sup>51, [id](#)</sup>, T. Zhao<sup>62b, [id](#)</sup>, Y. Zhao<sup>136, [id](#)</sup>, Z. Zhao<sup>62a, [id](#)</sup>, A. Zhemchugov<sup>38, [id](#)</sup>, X. Zheng<sup>62a, [id](#)</sup>, Z. Zheng<sup>143, [id](#)</sup>, D. Zhong<sup>162, [id](#)</sup>, B. Zhou<sup>106</sup>, C. Zhou<sup>170, [id](#)</sup>, H. Zhou<sup>7, [id](#)</sup>, N. Zhou<sup>62c, [id](#)</sup>, Y. Zhou<sup>7</sup>, C.G. Zhu<sup>62b, [id](#)</sup>, H.L. Zhu<sup>62a, [id](#)</sup>, J. Zhu<sup>106, [id](#)</sup>, Y. Zhu<sup>62c, [id](#)</sup>, Y. Zhu<sup>62a, [id](#)</sup>, X. Zhuang<sup>14a, [id](#)</sup>, K. Zhukov<sup>37, [id](#)</sup>, V. Zhulanov<sup>37, [id](#)</sup>, N.I. Zimine<sup>38, [id](#)</sup>, J. Zinsser<sup>63b, [id](#)</sup>, M. Ziolkowski<sup>141, [id](#)</sup>, L. Živković<sup>15, [id](#)</sup>, A. Zoccoli<sup>23b,23a, [id](#)</sup>, K. Zoch<sup>56, [id](#)</sup>, T.G. Zorbas<sup>139, [id](#)</sup>, O. Zormpa<sup>46, [id](#)</sup>, W. Zou<sup>41, [id](#)</sup>, L. Zwalinski<sup>36, [id](#)</sup>

<sup>1</sup> Department of Physics, University of Adelaide, Adelaide; Australia<sup>2</sup> Department of Physics, University of Alberta, Edmonton AB; Canada<sup>3</sup> (a) Department of Physics, Ankara University, Ankara; (b) Division of Physics, TOBB University of Economics and Technology, Ankara; Türkiye<sup>4</sup> LAPP, Université Savoie Mont Blanc, CNRS/IN2P3, Annecy; France<sup>5</sup> APC, Université Paris Cité, CNRS/IN2P3, Paris; France<sup>6</sup> High Energy Physics Division, Argonne National Laboratory, Argonne IL; United States of America<sup>7</sup> Department of Physics, University of Arizona, Tucson AZ; United States of America<sup>8</sup> Department of Physics, University of Texas at Arlington, Arlington TX; United States of America<sup>9</sup> Physics Department, National and Kapodistrian University of Athens, Athens; Greece

- <sup>10</sup> Physics Department, National Technical University of Athens, Zografou; Greece
- <sup>11</sup> Department of Physics, University of Texas at Austin, Austin TX; United States of America
- <sup>12</sup> Institute of Physics, Azerbaijan Academy of Sciences, Baku; Azerbaijan
- <sup>13</sup> Institut de Física d'Altes Energies (IFAE), Barcelona Institute of Science and Technology, Barcelona; Spain
- <sup>14</sup> <sup>(a)</sup> Institute of High Energy Physics, Chinese Academy of Sciences, Beijing; <sup>(b)</sup> Physics Department, Tsinghua University, Beijing; <sup>(c)</sup> Department of Physics, Nanjing University, Nanjing;
- <sup>(d)</sup> University of Chinese Academy of Science (UCAS), Beijing; China
- <sup>15</sup> Institute of Physics, University of Belgrade, Belgrade; Serbia
- <sup>16</sup> Department for Physics and Technology, University of Bergen, Bergen; Norway
- <sup>17</sup> <sup>(a)</sup> Physics Division, Lawrence Berkeley National Laboratory, Berkeley CA; <sup>(b)</sup> University of California, Berkeley CA; United States of America
- <sup>18</sup> Institut für Physik, Humboldt Universität zu Berlin, Berlin; Germany
- <sup>19</sup> Albert Einstein Center for Fundamental Physics and Laboratory for High Energy Physics, University of Bern, Bern; Switzerland
- <sup>20</sup> School of Physics and Astronomy, University of Birmingham, Birmingham; United Kingdom
- <sup>21</sup> <sup>(a)</sup> Department of Physics, Bogazici University, Istanbul; <sup>(b)</sup> Department of Physics Engineering, Gaziantep University, Gaziantep; <sup>(c)</sup> Department of Physics, Istanbul University, Istanbul;
- <sup>(d)</sup> Istinye University, Sariyer, Istanbul; Türkiye
- <sup>22</sup> <sup>(a)</sup> Facultad de Ciencias y Centro de Investigaciones, Universidad Antonio Nariño, Bogotá; <sup>(b)</sup> Departamento de Física, Universidad Nacional de Colombia, Bogotá; Colombia
- <sup>23</sup> <sup>(a)</sup> Dipartimento di Fisica e Astronomia A. Righi, Università di Bologna, Bologna; <sup>(b)</sup> INFN Sezione di Bologna; Italy
- <sup>24</sup> Physikalisches Institut, Universität Bonn, Bonn; Germany
- <sup>25</sup> Department of Physics, Boston University, Boston MA; United States of America
- <sup>26</sup> Department of Physics, Brandeis University, Waltham MA; United States of America
- <sup>27</sup> <sup>(a)</sup> Transilvania University of Brasov, Brasov; <sup>(b)</sup> Horia Hulubei National Institute of Physics and Nuclear Engineering, Bucharest; <sup>(c)</sup> Department of Physics, Alexandru Ioan Cuza University of Iasi, Iasi; <sup>(d)</sup> National Institute for Research and Development of Isotopic and Molecular Technologies, Physics Department, Cluj-Napoca; <sup>(e)</sup> University Politehnica Bucharest, Bucharest; <sup>(f)</sup> West University in Timisoara, Timisoara; <sup>(g)</sup> Faculty of Physics, University of Bucharest, Bucharest; Romania
- <sup>28</sup> <sup>(a)</sup> Faculty of Mathematics, Physics and Informatics, Comenius University, Bratislava; <sup>(b)</sup> Department of Subnuclear Physics, Institute of Experimental Physics of the Slovak Academy of Sciences, Kosice; Slovak Republic
- <sup>29</sup> Physics Department, Brookhaven National Laboratory, Upton NY; United States of America
- <sup>30</sup> Universidad de Buenos Aires, Facultad de Ciencias Exactas y Naturales, Departamento de Física, y CONICET, Instituto de Física de Buenos Aires (IFIBA), Buenos Aires; Argentina
- <sup>31</sup> California State University, CA; United States of America
- <sup>32</sup> Cavendish Laboratory, University of Cambridge, Cambridge; United Kingdom
- <sup>33</sup> <sup>(a)</sup> Department of Physics, University of Cape Town, Cape Town; <sup>(b)</sup> iThemba Labs, Western Cape; <sup>(c)</sup> Department of Mechanical Engineering Science, University of Johannesburg, Johannesburg;
- <sup>(d)</sup> National Institute of Physics, University of the Philippines Diliman (Philippines); <sup>(e)</sup> University of South Africa, Department of Physics, Pretoria; <sup>(f)</sup> University of Zululand, KwaDlangezwa;
- <sup>(g)</sup> School of Physics, University of the Witwatersrand, Johannesburg; South Africa
- <sup>34</sup> Department of Physics, Carleton University, Ottawa ON; Canada
- <sup>35</sup> <sup>(a)</sup> Faculté des Sciences Ain Chock, Réseau Universitaire de Physique des Hautes Energies - Université Hassan II, Casablanca; <sup>(b)</sup> Faculté des Sciences, Université Ibn-Tofail, Kénitra; <sup>(c)</sup> Faculté des Sciences Semlalia, Université Cadi Ayyad, LPHEA-Marrakech; <sup>(d)</sup> LPMR, Faculté des Sciences, Université Mohamed Premier, Oujda; <sup>(e)</sup> Faculté des sciences, Université Mohammed V, Rabat;
- <sup>(f)</sup> Institute of Applied Physics, Mohammed VI Polytechnic University, Ben Guerir; Morocco
- <sup>36</sup> CERN, Geneva; Switzerland
- <sup>37</sup> Affiliated with an institute covered by a cooperation agreement with CERN
- <sup>38</sup> Affiliated with an international laboratory covered by a cooperation agreement with CERN
- <sup>39</sup> Enrico Fermi Institute, University of Chicago, Chicago IL; United States of America
- <sup>40</sup> LPC, Université Clermont Auvergne, CNRS/IN2P3, Clermont-Ferrand; France
- <sup>41</sup> Nevis Laboratory, Columbia University, Irvington NY; United States of America
- <sup>42</sup> Niels Bohr Institute, University of Copenhagen, Copenhagen; Denmark
- <sup>43</sup> <sup>(a)</sup> Dipartimento di Fisica, Università della Calabria, Rende; <sup>(b)</sup> INFN Gruppo Collegato di Cosenza, Laboratori Nazionali di Frascati; Italy
- <sup>44</sup> Physics Department, Southern Methodist University, Dallas TX; United States of America
- <sup>45</sup> Physics Department, University of Texas at Dallas, Richardson TX; United States of America
- <sup>46</sup> National Centre for Scientific Research "Demokritos", Agia Paraskevi; Greece
- <sup>47</sup> <sup>(a)</sup> Department of Physics, Stockholm University; <sup>(b)</sup> Oskar Klein Centre, Stockholm; Sweden
- <sup>48</sup> Deutsches Elektronen-Synchrotron DESY, Hamburg and Zeuthen; Germany
- <sup>49</sup> Fakultät Physik, Technische Universität Dortmund, Dortmund; Germany
- <sup>50</sup> Institut für Kern- und Teilchenphysik, Technische Universität Dresden, Dresden; Germany
- <sup>51</sup> Department of Physics, Duke University, Durham NC; United States of America
- <sup>52</sup> SUPA - School of Physics and Astronomy, University of Edinburgh, Edinburgh; United Kingdom
- <sup>53</sup> INFN e Laboratori Nazionali di Frascati, Frascati; Italy
- <sup>54</sup> Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Freiburg; Germany
- <sup>55</sup> II. Physikalisches Institut, Georg-August-Universität Göttingen, Göttingen; Germany
- <sup>56</sup> Département de Physique Nucléaire et Corpusculaire, Université de Genève, Genève; Switzerland
- <sup>57</sup> <sup>(a)</sup> Dipartimento di Fisica, Università di Genova, Genova; <sup>(b)</sup> INFN Sezione di Genova; Italy
- <sup>58</sup> II. Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen; Germany
- <sup>59</sup> SUPA - School of Physics and Astronomy, University of Glasgow, Glasgow; United Kingdom
- <sup>60</sup> LPSC, Université Grenoble Alpes, CNRS/IN2P3, Grenoble INP, Grenoble; France
- <sup>61</sup> Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge MA; United States of America
- <sup>62</sup> <sup>(a)</sup> Department of Modern Physics and State Key Laboratory of Particle Detection and Electronics, University of Science and Technology of China, Hefei; <sup>(b)</sup> Institute of Frontier and Interdisciplinary Science and Key Laboratory of Particle Physics and Particle Irradiation (MOE), Shandong University, Qingdao; <sup>(c)</sup> School of Physics and Astronomy, Shanghai Jiao Tong University, Key Laboratory for Particle Astrophysics and Cosmology (MOE), SKLPPC, Shanghai; <sup>(d)</sup> Tsung-Dao Lee Institute, Shanghai; China
- <sup>63</sup> Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Heidelberg; <sup>(b)</sup> Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg; Germany
- <sup>64</sup> <sup>(a)</sup> Department of Physics, Chinese University of Hong Kong, Shatin, N.T., Hong Kong; <sup>(b)</sup> Department of Physics, University of Hong Kong, Hong Kong; <sup>(c)</sup> Department of Physics and Institute for Advanced Study, Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong; China
- <sup>65</sup> Department of Physics, National Tsing Hua University, Hsinchu; Taiwan
- <sup>66</sup> IJCLab, Université Paris-Saclay, CNRS/IN2P3, 91405, Orsay; France
- <sup>67</sup> Centro Nacional de Microelectrónica (IMB-CNM-CSIC), Barcelona; Spain
- <sup>68</sup> Department of Physics, Indiana University, Bloomington IN; United States of America
- <sup>69</sup> <sup>(a)</sup> INFN Gruppo Collegato di Udine, Sezione di Trieste, Udine; <sup>(b)</sup> ICTP, Trieste; <sup>(c)</sup> Dipartimento Politecnico di Ingegneria e Architettura, Università di Udine, Udine; Italy
- <sup>70</sup> <sup>(a)</sup> INFN Sezione di Lecce; <sup>(b)</sup> Dipartimento di Matematica e Fisica, Università del Salento, Lecce; Italy
- <sup>71</sup> <sup>(a)</sup> INFN Sezione di Milano; <sup>(b)</sup> Dipartimento di Fisica, Università di Milano, Milano; Italy
- <sup>72</sup> <sup>(a)</sup> INFN Sezione di Napoli; <sup>(b)</sup> Dipartimento di Fisica, Università di Napoli, Napoli; Italy
- <sup>73</sup> <sup>(a)</sup> INFN Sezione di Pavia; <sup>(b)</sup> Dipartimento di Fisica, Università di Pavia, Pavia; Italy
- <sup>74</sup> <sup>(a)</sup> INFN Sezione di Pisa; <sup>(b)</sup> Dipartimento di Fisica E. Fermi, Università di Pisa, Pisa; Italy
- <sup>75</sup> <sup>(a)</sup> INFN Sezione di Roma; <sup>(b)</sup> Dipartimento di Fisica, Sapienza Università di Roma, Roma; Italy
- <sup>76</sup> <sup>(a)</sup> INFN Sezione di Roma Tor Vergata; <sup>(b)</sup> Dipartimento di Fisica, Università di Roma Tor Vergata, Roma; Italy
- <sup>77</sup> <sup>(a)</sup> INFN Sezione di Roma Tre; <sup>(b)</sup> Dipartimento di Matematica e Fisica, Università Roma Tre, Roma; Italy

- 78 <sup>(a)</sup> INFN-TIFPA; <sup>(b)</sup> 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 <sup>(a)</sup> Departamento de Engenharia Elétrica, Universidade Federal de Juiz de Fora (UFJF), Juiz de Fora; <sup>(b)</sup> Universidade Federal do Rio De Janeiro COPPE/EE/IF, Rio de Janeiro; <sup>(c)</sup> Instituto de Física, Universidade de São Paulo, São Paulo; <sup>(d)</sup> Rio de Janeiro State University, Rio de Janeiro; Brazil
- 83 KEK, High Energy Accelerator Research Organization, Tsukuba; Japan
- 84 Graduate School of Science, Kobe University, Kobe; Japan
- 85 <sup>(a)</sup> AGH University of Krakow, Faculty of Physics and Applied Computer Science, Krakow; <sup>(b)</sup> Marian Smoluchowski Institute of Physics, Jagiellonian University, Krakow; Poland
- 86 Institute of Nuclear Physics Polish Academy of Sciences, Krakow; Poland
- 87 Faculty of Science, Kyoto University, Kyoto; Japan
- 88 Kyoto University of Education, Kyoto; Japan
- 89 Research Center for Advanced Particle Physics and Department of Physics, Kyushu University, Fukuoka; Japan
- 90 CPPM, Aix-Marseille Université, CNRS/IN2P3, Marseille; France
- 91 Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata; Argentina
- 92 Physics Department, Lancaster University, Lancaster; United Kingdom
- 93 Oliver Lodge Laboratory, University of Liverpool, Liverpool; United Kingdom
- 94 Department of Experimental Particle Physics, Jožef Stefan Institute and Department of Physics, University of Ljubljana, Ljubljana; Slovenia
- 95 School of Physics and Astronomy, Queen Mary University of London, London; United Kingdom
- 96 Department of Physics, Royal Holloway University of London, Egham; United Kingdom
- 97 Department of Physics and Astronomy, University College London, London; United Kingdom
- 98 Louisiana Tech University, Ruston LA; United States of America
- 99 Fysiska institutionen, Lunds universitet, Lund; Sweden
- 100 Departamento de Física Teórica C-15 and CIAFF, Universidad Autónoma de Madrid, Madrid; Spain
- 101 Institut für Physik, Universität Mainz, Mainz; Germany
- 102 School of Physics and Astronomy, University of Manchester, Manchester; United Kingdom
- 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 <sup>(a)</sup> New York University Abu Dhabi, Abu Dhabi; <sup>(b)</sup> 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 <sup>(a)</sup> Laboratório de Instrumentação e Física Experimental de Partículas - LIP, Lisboa; <sup>(b)</sup> Departamento de Física, Faculdade de Ciências, Universidade de Lisboa, Lisboa; <sup>(c)</sup> Departamento de Física, Universidade de Coimbra, Coimbra; <sup>(d)</sup> Centro de Física Nuclear da Universidade de Lisboa, Lisboa; <sup>(e)</sup> Departamento de Física, Universidade do Minho, Braga; <sup>(f)</sup> Departamento de Física Teórica y del Cosmos, Universidad de Granada, Granada (Spain); <sup>(g)</sup> Departamento de Física, Instituto Superior Técnico, Universidade de Lisboa, Lisboa; Portugal
- 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 <sup>(a)</sup> Departamento de Física, Pontificia Universidad Católica de Chile, Santiago; <sup>(b)</sup> Millennium Institute for Subatomic physics at high energy frontier (SAPHIR), Santiago; <sup>(c)</sup> Instituto de Investigación Multidisciplinario en Ciencia y Tecnología, y Departamento de Física, Universidad de La Serena; <sup>(d)</sup> Universidad Andres Bello, Department of Physics, Santiago; <sup>(e)</sup> Instituto de Alta Investigación, Universidad de Tarapacá, Arica; <sup>(f)</sup> Departamento de Física, Universidad Técnica Federico Santa María, Valparaíso; Chile
- 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 <sup>(a)</sup> E. Andronikashvili Institute of Physics, Iv. Javakishvili Tbilisi State University, Tbilisi; <sup>(b)</sup> High Energy Physics Institute, Tbilisi State University, Tbilisi; <sup>(c)</sup> 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

- <sup>152</sup> Department of Physics, Aristotle University of Thessaloniki, Thessaloniki; Greece  
<sup>153</sup> International Center for Elementary Particle Physics and Department of Physics, University of Tokyo, Tokyo; Japan  
<sup>154</sup> Department of Physics, Tokyo Institute of Technology, Tokyo; Japan  
<sup>155</sup> Department of Physics, University of Toronto, Toronto ON; Canada  
<sup>156</sup> <sup>(a)</sup> TRIUMF, Vancouver BC; <sup>(b)</sup> Department of Physics and Astronomy, York University, Toronto ON; Canada  
<sup>157</sup> Division of Physics and Tomonaga Center for the History of the Universe, Faculty of Pure and Applied Sciences, University of Tsukuba, Tsukuba; Japan  
<sup>158</sup> Department of Physics and Astronomy, Tufts University, Medford MA; United States of America  
<sup>159</sup> United Arab Emirates University, Al Ain; United Arab Emirates  
<sup>160</sup> Department of Physics and Astronomy, University of California Irvine, Irvine CA; United States of America  
<sup>161</sup> Department of Physics and Astronomy, University of Uppsala, Uppsala; Sweden  
<sup>162</sup> Department of Physics, University of Illinois, Urbana IL; United States of America  
<sup>163</sup> Instituto de Física Corpuscular (IFIC), Centro Mixto Universidad de Valencia - CSIC, Valencia; Spain  
<sup>164</sup> Department of Physics, University of British Columbia, Vancouver BC; Canada  
<sup>165</sup> Department of Physics and Astronomy, University of Victoria, Victoria BC; Canada  
<sup>166</sup> Fakultät für Physik und Astronomie, Julius-Maximilians-Universität Würzburg, Würzburg; Germany  
<sup>167</sup> Department of Physics, University of Warwick, Coventry; United Kingdom  
<sup>168</sup> Waseda University, Tokyo; Japan  
<sup>169</sup> Department of Particle Physics and Astrophysics, Weizmann Institute of Science, Rehovot; Israel  
<sup>170</sup> Department of Physics, University of Wisconsin, Madison WI; United States of America  
<sup>171</sup> Fakultät für Mathematik und Naturwissenschaften, Fachgruppe Physik, Bergische Universität Wuppertal, Wuppertal; Germany  
<sup>172</sup> Department of Physics, Yale University, New Haven CT; United States of America

- <sup>a</sup> Also Affiliated with an institute covered by a cooperation agreement with CERN.  
<sup>b</sup> Also at An-Najah National University, Nablus; Palestine.  
<sup>c</sup> Also at Borough of Manhattan Community College, City University of New York, New York NY; United States of America.  
<sup>d</sup> Also at Bruno Kessler Foundation, Trento; Italy.  
<sup>e</sup> Also at Center for High Energy Physics, Peking University; China.  
<sup>f</sup> Also at Center for Interdisciplinary Research and Innovation (CIRI-AUTH), Thessaloniki; Greece.  
<sup>g</sup> Also at Centro Studi e Ricerche Enrico Fermi; Italy.  
<sup>h</sup> Also at CERN, Geneva; Switzerland.  
<sup>i</sup> Also at Département de Physique Nucléaire et Corpusculaire, Université de Genève, Genève; Switzerland.  
<sup>j</sup> Also at Departament de Física de la Universitat Autònoma de Barcelona, Barcelona; Spain.  
<sup>k</sup> Also at Department of Financial and Management Engineering, University of the Aegean, Chios; Greece.  
<sup>l</sup> Also at Department of Physics and Astronomy, Michigan State University, East Lansing MI; United States of America.  
<sup>m</sup> Also at Department of Physics, Ben Gurion University of the Negev, Beer Sheva; Israel.  
<sup>n</sup> Also at Department of Physics, California State University, East Bay; United States of America.  
<sup>o</sup> Also at Department of Physics, California State University, Sacramento; United States of America.  
<sup>p</sup> Also at Department of Physics, King's College London, London; United Kingdom.  
<sup>q</sup> Also at Department of Physics, Stanford University, Stanford CA; United States of America.  
<sup>r</sup> Also at Department of Physics, University of Fribourg, Fribourg; Switzerland.  
<sup>s</sup> Also at Department of Physics, University of Thessaly; Greece.  
<sup>t</sup> Also at Department of Physics, Westmont College, Santa Barbara; United States of America.  
<sup>u</sup> Also at Hellenic Open University, Patras; Greece.  
<sup>v</sup> Also at Institutio Catalana de Recerca i Estudis Avancats, ICREA, Barcelona; Spain.  
<sup>w</sup> Also at Institut für Experimentalphysik, Universität Hamburg, Hamburg; Germany.  
<sup>x</sup> Also at Institute for Nuclear Research and Nuclear Energy (INRNE) of the Bulgarian Academy of Sciences, Sofia; Bulgaria.  
<sup>y</sup> Also at Institute of Applied Physics, Mohammed VI Polytechnic University, Ben Guerir; Morocco.  
<sup>z</sup> Also at Institute of Particle Physics (IPP); Canada.  
<sup>aa</sup> Also at Institute of Physics and Technology, Ulaanbaatar; Mongolia.  
<sup>ab</sup> Also at Institute of Physics, Azerbaijan Academy of Sciences, Baku; Azerbaijan.  
<sup>ac</sup> Also at Institute of Theoretical Physics, Ilija State University, Tbilisi; Georgia.  
<sup>ad</sup> Also at LZIT, Université de Toulouse, CNRS/IN2P3, UPS, Toulouse; France.  
<sup>ae</sup> Also at Lawrence Livermore National Laboratory, Livermore; United States of America.  
<sup>af</sup> Also at National Institute of Physics, University of the Philippines Diliman (Philippines); Philippines.  
<sup>ag</sup> Also at Technical University of Munich, Munich; Germany.  
<sup>ah</sup> Also at The Collaborative Innovation Center of Quantum Matter (CICQM), Beijing; China.  
<sup>ai</sup> Also at TRIUMF, Vancouver BC; Canada.  
<sup>aj</sup> Also at Università di Napoli Parthenope, Napoli; Italy.  
<sup>ak</sup> Also at University of Chinese Academy of Sciences (UCAS), Beijing; China.  
<sup>al</sup> Also at University of Colorado Boulder, Department of Physics, Colorado; United States of America.  
<sup>am</sup> Also at Washington College, Maryland; United States of America.  
<sup>an</sup> Also at Yeditepe University, Physics Department, Istanbul; Türkiye.  
<sup>\*</sup> Deceased.