Published for SISSA by Springer

Received: August 3, 2023
Accepted: September 14, 2023
Published: September 28, 2023

JHEP09(2023)199

Measurement of the $B_s^0 \to \mu\mu$ effective lifetime with the ATLAS detector

The ATLAS collaboration

E-mail: atlas.publications@cern.ch

Abstract: This paper reports the first ATLAS measurement of the $B_s^0 \to \mu\mu$ effective lifetime. The measurement is based on the data collected in 2015–2016, amounting to $26.3\,\mathrm{fb}^{-1}$ of 13 TeV LHC proton-proton collisions. The proper decay-time distribution of 58 ± 13 background-subtracted signal candidates is fit with simulated signal templates parameterised as a function of the B_s^0 effective lifetime, with statistical uncertainties extracted through a Neyman construction. The resulting effective measurement of the $B_s^0 \to \mu\mu$ lifetime is $0.99^{+0.42}_{-0.07}\,(\mathrm{stat.}) \pm 0.17\,(\mathrm{syst.})$ ps and it is found to be consistent with the Standard Model.

Keywords: B Physics, Hadron-Hadron Scattering

ArXiv ePrint: 2308.01171

https://doi.org/10.1007/JHEP09(2023)199

Contents

1 Introduction

The Standard Model (SM) predicts that only the CP-odd heavy-mass eigenstate in the $B_s^0 - \bar{B}_s^0$ pair decays into a di-muon final state [1, 2]. This exclusivity does not generally hold when considering contributions Beyond the Standard Model (BSM) such as minimal supersymmetric Standard Model extensions [3], that can potentially perturb the effective lifetime in $B_s^0 \to \mu\mu$ decays. These perturbations can be significant also in absence of measurable BSM effects on the $B_s^0 \to \mu\mu$ branching fraction (BR). The effective $B_s^0 \to \mu\mu$ lifetime is defined as $\tau_{\mu\mu} = \frac{\int_0^\infty t\Gamma\left(B_s^0(t)\to\mu\mu\right) dt}{\int_0^\infty \Gamma\left(B_s^0(t)\to\mu\mu\right) dt}$, where t is the proper decay time of the B_s^0 and $\bar{B}_s^0$ mesons and $\Gamma\left(B_s\left(t\right) \to \mu\mu\right) = \Gamma\left(B_s^0\left(t\right) \to \mu\mu\right) + \Gamma\left(\bar{B}_s^0\left(t\right) \to \mu\mu\right)$. In the SM hypothesis $\tau_{\mu\mu}$ coincides with the lifetime of the heavy B_s^0 eigenstate $\tau_{B_s^H}$. The experimental average of the B_s^0–$\bar{B}_s^0$ lifetimes and their difference [4] yields the prediction $\tau_{\mu\mu}^{\mathrm{SM}} = (1.624 \pm 0.009)$ ps, with new physics effects perturbing it at most by the difference between the heavy and light eigenstate lifetimes (0.193 ps [4, 5]).

Previously, measurements of $\tau_{\mu\mu}$ (all largely consistent with the SM expectation) have been published by the CMS [6, 7] and LHCb [8, 9] collaborations, in conjunction with the latest results on the branching fractions BR $\left(B^0 \to \mu\mu\right)$ and BR $\left(B_s^0 \to \mu\mu\right)$. Experimental results on these branching fractions have been published also by the ATLAS collaboration [10–12]. A combination of the $\tau_{\mu\mu}$ measurements made by LHCb and CMS collaborations on their 2011–2016 datasets has also been published [13].

The ATLAS experiment [14] at the LHC is a multipurpose particle detector with a forward-backward symmetric cylindrical geometry and a near 4π coverage in solid angle.[1]

---

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

It consists of an inner tracking detector surrounded by a thin superconducting solenoid providing a 2 T axial magnetic field, electromagnetic and hadron calorimeters, and a muon spectrometer. The inner tracking detector covers the pseudorapidity range $|\eta| < 2.5$. It consists of silicon pixel, silicon microstrip, and transition radiation tracking detectors. Lead/liquid-argon (LAr) sampling calorimeters provide electromagnetic (EM) energy measurements with high granularity. A steel/scintillator-tile hadron calorimeter covers the central pseudorapidity range ($|\eta| < 1.7$). The endcap and forward regions are instrumented with LAr calorimeters for both the EM and hadronic energy measurements up to $|\eta| = 4.9$. The muon spectrometer surrounds the calorimeters and is based on three large superconducting air-core toroidal magnets with eight coils each. The field integral of the toroids ranges between 2.0 and 6.0 T m across most of the detector. The muon spectrometer includes a system of precision tracking chambers and fast detectors for triggering. A two-level trigger system is used to select events. The first-level trigger is implemented in hardware and uses a subset of the detector information to accept events at a rate below 100 kHz. This is followed by a software-based trigger that reduces the accepted event rate to 1 kHz on average depending on the data-taking conditions. An extensive software suite [15] 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.

2 Dataset and event selection

This analysis is based on the Run 2 data recorded in 2015 and 2016 from *pp* collisions at the LHC at a center-of-mass energy of $\sqrt{s} = 13$ TeV. Data used in the analysis were recorded during stable LHC beam periods. Data quality requirements were imposed, notably on the performance of the muon spectrometer, inner detector and calorimeter systems [16]. The total integrated luminosity collected by ATLAS in this period is $36.2\,\text{fb}^{-1}$ with an uncertainty of 2.1%. These values are determined using a methodology similar to that detailed in ref. [17], based on calibration of the luminosity scale using x–y beam-separation scans, and use the LUCID-2 detector [18] for the baseline luminosity measurement.

The data and Monte Carlo (MC) samples used in this analysis are identical to those of the ATLAS collaboration's most recent publication on the $B \to \mu\mu$ Branching Ratios (BR) [12], including the same per-event MC weights employed to correct data-MC discrepancies.

Together with di-muon signal candidates, the $B^{\pm} \to J/\psi(\to \mu^{+}\mu^{-})K^{\pm}$ signal (*reference channel*) is employed in the study of the analysis' systematic uncertainties. The data employed is collected with triggers subject to time-dependent pre-scales [19], affecting the signal and reference channel differently: accounting for these effects, the total effective integrated luminosity employed amounts to $26.3\,\text{fb}^{-1}$ for $(B_s^0 \to \mu\mu)$ and $15.1\,\text{fb}^{-1}$ for $(B^{\pm} \to J/\psi(\to \mu^{+}\mu^{-})K^{\pm})$.

B meson candidates are reconstructed based on a decay vertex fitted to two or three tracks for the signal and the reference channels respectively, depending on the decay process to be reconstructed. The invariant mass of each B candidate is calculated using muon trajectories measured by combining the information from the inner detector and the muon spectrometer to improve upon the mass resolution obtained from inner detector information only [20]. The coordinates of primary vertices are obtained from charged-particle tracks constrained to the luminous region of the colliding beams in the transverse plane, after excluding the tracks used in the signal candidates' reconstruction. The matching of a B candidate to a primary vertex is done by extrapolating the candidate trajectory to the point of closest approach to the beam axis, and choosing the primary vertex with the smallest separation along z. Ref. [12] verifies in simulation that this method matches the correct vertex with a probability above 99% for all relevant pile-up[2] conditions. The $B_s^0 \to \mu\mu$ candidate mass is obtained from the measured di-muon four-momentum, while its proper decay time is calculated as $\tilde{t}_{\mu^+\mu^-} = \frac{L_{xy} m^{\text{PDG}}_{B_s^0}}{p_{\text{T}}^{B_s^0}}$, where L_{xy} is the decay length projected along the reconstructed B_s^0 momentum in the transverse plane, $m^{\text{PDG}}_{B_s^0}$ the world averaged mass of B_s^0 mesons from ref. [5] and $p_{\text{T}}^{B_s^0}$ the magnitude of the candidate's reconstructed transverse momentum.

The same analysis selections as in ref. [12] are employed, including the same definition for the invariant mass signal-dominated ([5166−5526] MeV) and background-dominated ([4766−5166] MeV and [5526−5966] MeV) sideband regions. Invariant mass fits are performed in the [4766−5966] MeV range. As part of the event selection, the Boosted Decision Tree (BDT) from ref. [12] is employed to discriminate signal from the very large background: this BDT relies on 15 physical input variables related either to isolation properties of the B candidates and final state particles, or to topological and kinematic properties of the $B_s^0 \to \mu\mu$ decay (see ref. [12] for details).

The final event selection is simplified from multiple BDT output categories of ref. [12] to a single one. The requirement is chosen optimising the signal significance $\frac{S}{\sqrt{S+B}}$ in the [5166−5526] MeV candidate invariant mass range. The optimisation procedure is based on MC simulated events normalised to the SM expectation for the signal yield (S), and to background in a looser-BDT control region for the background yield (B). The background control region coincides with the *bin 0* BDT requirement (> 0.1439) employed in the BR analysis [12]. This requirement selects a background-dominated sample immediately next to the signal-sensitive BDT region. The control region is employed exclusively in this optimisation procedure.

The optimal BDT range is found to be [0.3650−1], corresponding to 49 signal and 27 background events expected — under the SM hypothesis — in the [5166−5526] MeV candidates' invariant mass range.

3 The effective lifetime measurement

After the event selection outlined in section 2, the invariant mass distribution of actual data candidates is shown in figure 1. The superimposed five parameters invariant mass fit is the result of an un-binned extended maximum likelihood fit to candidates in the [4766−5966] MeV mass region. The fit includes three PDF models, identical to what was

---

[2] The pile-up is defined as the average number of pp collisions in the same bunch crossing.

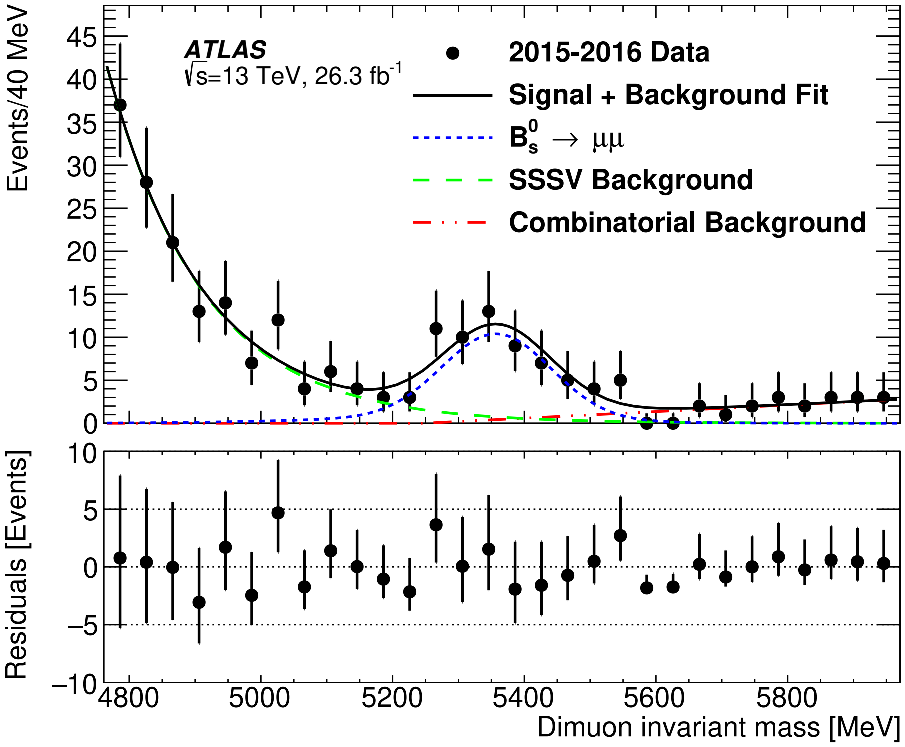

Figure 1. Invariant mass distribution of di-muon candidates passing the optimised BDT selection in the 2015–2016 dataset. The linear background component (red) is consistent in shape with simulations of di-muons originating from different b-quarks in $pp \to b\bar{b}$ processes. The exponentially falling background component (green) is instead consistent in shape with *Same Side Same Vertex* (SSSV) decays, i.e. muons corresponding to particles produced from the decay of a single b or $\bar{b}$ quark. The B_s^0 signal component is shown in blue.
The bottom panel reports the per-bin residuals, calculated as the difference between the top panel's data points and the black fit line.

used in the BR analysis [12] (which motivates the choice through MC studies). A double-Gaussian is employed to model the $B_s^0 \to \mu\mu$ signal. The background model includes an exponentially decaying component (to model *same-side same-vertex* (SSSV) B meson decays, i.e. muon pairs originating from a single B meson decay) and a linear contribution (to model the *combinatorial background*, i.e. random pairing of muons from $b\bar{b}$ decays). The latter component has a free slope and is imposed to be zero whenever the linear model would become negative. All yields and background shape parameters are unconstrained in the fit. Consistently with ref. [12], the relative fraction, mean and width of the signal Gaussian distributions are constrained to the fully simulated MC signal, within the detector mass-scale (±5 MeV) and mass-resolution (±5%) uncertainties. Additional resonant and non-resonant contributions are neglected in the fit model. The corresponding systematic uncertainties are evaluated by comparing the measurement shift using simulations that include these additional contributions, as explained in section 4. The fit yields 58±13 (stat. only) $B_s^0 \to \mu\mu$ signal events in the range [4766−5966] MeV.

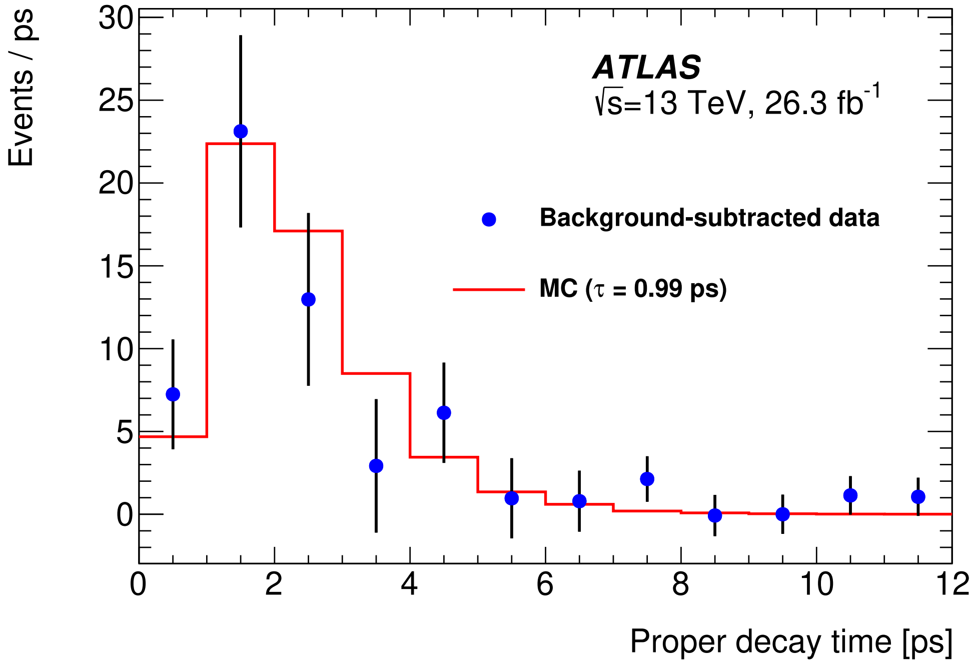

Figure 2. Signal proper decay time distribution extracted with the *sPlot* background subtraction procedure applied to the invariant mass fit illustrated in figure 1. The superimposed signal MC template is the result of the lifetime fit procedure discussed in the text. The uncertainties on the data points are calculated as Poisson fluctuations on the MC yield prediction (continuous red histogram) in the corresponding bin.

The proper decay time distribution in data is background-subtracted employing per-event weights calculated according to the *sPlot* technique [21]: signal and backgrounds weights are calculated from the result of the mass fit, yielding the background-subtracted distribution shown in figure 2. The lifetime measurement is obtained by minimising the binned χ^2 between the data histogram and lifetime-dependent pure signal MC templates extracted from MC simulated samples, as illustrated below in figure 3. The χ^2 calculation accounts for the statistical uncertainty on the weight-corrected MC as well as the Poissonian uncertainty in each data bin as expected from the predicted MC content for that bin. The MC templates, corresponding to different lifetimes, are generated as a function of the fit parameter $\tau_{\mu\mu}^{\text{Obs}}$ by re-weighting each signal MC event by the signal true proper decay time distribution. The evaluation of the $\tau_{\mu\mu}$ statistical sensitivity and of most systematic uncertainties relies on MC pseudo-experiments. These are based on generating the events in the phase space of di-muon mass and proper decay time, using analytical models for the signal and background components. The mass parameterisation of each of these components is consistent with the invariant mass fit, while the proper decay time distributions are empirically modelled with an exponential function (weighted by an error function in the case of the signal component) to take into account acceptance and efficiency effects. Finally, the distributions are convoluted with a Gaussian Probability Density Function

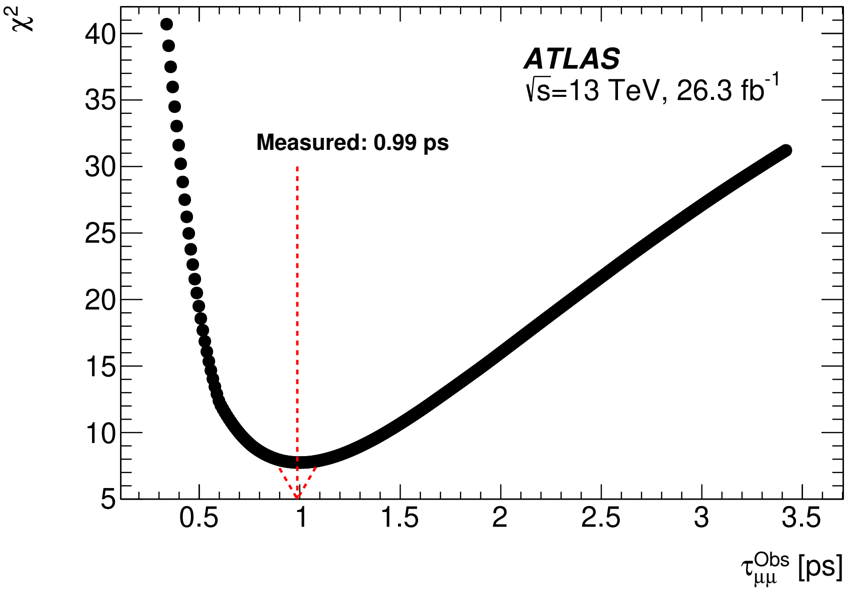

Figure 3. χ^2 scan vs MC lifetime. The minimum of the scan ($\chi^2/\mathrm{NDOF} = 7.7/11$), located at $\tau_{\mu\mu}^{\mathrm{Obs}} = 0.99\,\mathrm{ps}$, is used to determine the central value of the lifetime measured and is indicated by the red vertical dashed arrow.

(PDFs), representing the time resolution. The parameters of these models are fixed according to the signal and background components in MC simulated samples. The resulting shapes are verified to be consistent with the signal and background distributions obtained from data.

When extracting the $B_s^0 \to \mu\mu$ lifetime, the bin width of the proper decay time histogram is chosen for simplicity to be constant. The analysis procedure is applied to MC pseudo-experiments for different bin widths and fit ranges, choosing the optimal configuration to reach the best statistical uncertainty on $\tau_{\mu\mu}^{\mathrm{Obs}}$. A closure test is performed on MC pseudo-experiments generated at $\tau_{\mu\mu}^{\mathrm{True}} = \tau_{\mu\mu}^{\mathrm{SM}}$, yielding a bias on $\tau_{\mu\mu}^{\mathrm{Obs}}$ of $(82 \pm 4)\,\mathrm{fs}$. This bias is verified to arise from the low-statistics regime of the fit. $\tau_{\mu\mu}^{\mathrm{Obs}}$ is therefore redefined as $\tau_{\mu\mu}^{\mathrm{Obs}} - 82\,\mathrm{fs}$ and taken as the central value for the measurement, with the uncertainty estimated from a MC pseudo-experiments based Neyman construction [22]. As $\tau_{\mu\mu}^{\mathrm{True}}$ is varied in the range $[\tau_{B_s^L}, \tau_{B_s^H}]$ a 15 fs bias decrease is observed. This value is included as systematic uncertainty due to the fit bias lifetime dependency (see section 4).

Figure 3 reports the χ^2 scan as a function of $\tau_{\mu\mu}^{\mathrm{Obs}}$. The $\Delta\chi^2 = 1$ interval from this curve would not result in a reliable estimation of the $\tau_{\mu\mu}^{\mathrm{Obs}}$ statistical uncertainty with the non-Gaussian estimator used for the measurement. This uncertainty is instead derived from the Neyman CL band construction illustrated in figure 4. The χ^2 minimum and the Neyman belt construction yield $\tau_{\mu\mu}^{\mathrm{Obs}} = 0.99^{+0.42}_{-0.07}$ (stat. only) ps. The imbalance between positive and negative statistical uncertainties is already suggested by the asymmetry in the χ^2 scan of figure 3. The effect is further emphasised by the subtraction of the closure test bias.

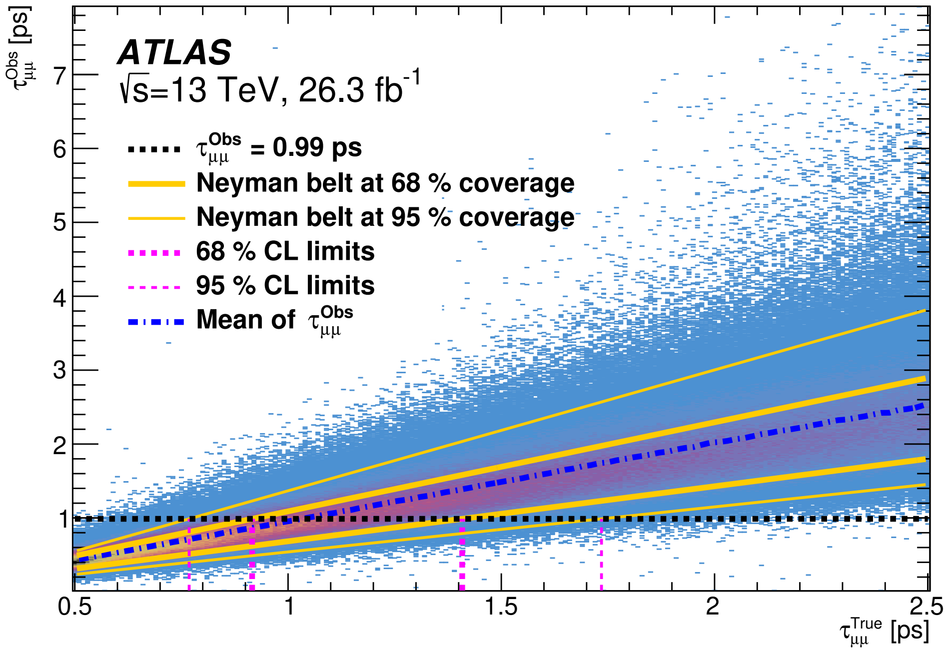

Figure 4. 68% and 95% CL bands obtained with a Neyman construction based on MC pseudo-experiments for the signal and background components. The yellow lines interpolate the band boundaries in order to smooth the effects of limited number of MC pseudo-experiments used. The dashed-dotted blue line corresponds to the average expected $\tau_{\mu\mu}^{\mathrm{Obs}}$ value at a given $\tau_{\mu\mu}^{\mathrm{True}}$ value. The horizontal dashed black line corresponds to the experimentally observed value of $\tau_{\mu\mu}^{\mathrm{Obs}} = 0.99\,\mathrm{ps}$, yielding a 68% CL band of $[0.92, 1.41]\,\mathrm{ps}$ (thick vertical dashed purple lines) and a 95% CL band of $[0.77, 1.73]\,\mathrm{ps}$ (thin vertical dashed purple lines). The same construction at the $\tau_{\mu\mu}^{\mathrm{Obs}}$ corresponding to $\tau_{\mu\mu}^{\mathrm{True}} = \tau_{\mu\mu}^{\mathrm{SM}}$ yields $[1.44, 2.26]\,\mathrm{ps}$ as 68% CL band.

4 Systematic uncertainties

Systematic uncertainties on $\tau_{\mu\mu}$ arise from fit-procedure assumptions, data-MC discrepancies and neglected backgrounds. These effects are discussed in detail below and estimated, unless otherwise specified, with the MC pseudo-experiments described above.

First, the fit procedure is based on a number of assumptions. The analytical models describing the *SSSV* and *combinatorial* backgrounds are replaced respectively with a Gaussian tail and an exponential function, yielding average shifts of 22 fs and 14 fs. A shift of 60 fs is observed when the number of *SSSV* background events is varied by ±100% in the simulation to account for normalisation assumptions. This variation is used without any further refinement as it is quite small compared to the expected statistical uncertainty although it is conservative with respect to the SSSV yield uncertainty (152 ± 13 events from the fit on data).

The *sPlot* re-weighting effectively subtracts the combinatorial background relying on an admixture of data events above and below the signal peak invariant mass region. A potential correlation between the background candidates' proper decay time and invariant mass is tested by repeating the fit and *sPlot* extraction of $\tau_{\mu\mu}$ on the same data, excluding in turn the upper or the lower sidebands. The largest shift observed for these two options is 56 fs and is taken as systematic uncertainty.

The nominal invariant mass fit does not take into account other b-hadron decays whose presence is considered as a source of systematic uncertainty. Each of these contributions is individually merged (in proportion to its expected SM yield after the analysis selection) with the normal MC pseudo-experiments, and the average difference in measured lifetime before and after this inclusion is measured for the semi-leptonic b-meson decays (2 fs), the two-body hadronic b-meson decays (3 fs), the inclusive $B_c^\pm$ decays (10 fs) and the $B^0 \to \mu\mu$ decays (16 fs).

The dominant data-MC systematic effect arises from the difference in vertex resolution between data and MC. This resolution tends to be underestimated in MC but is also distributed differently for the signal and reference channels. The effect is therefore estimated by measuring the $B^\pm \to J/\psi K^\pm$ lifetime on data and comparing the result against the world-average experimental value [4]. The measurement is performed applying to the reference channel the same fit procedure employed to extract $\tau_{\mu\mu}$. The average difference between the result obtained on $B^\pm \to J/\psi K^\pm$ data and MC pseudo-experiments is then measured in bins of proper decay length resolution ($\sigma_{L_{xy}}$). A bin-by-bin weighted average based on the proper decay length resolution distribution of the simulated $B_s^0 \to \mu\mu$ signal is performed to take into account differences between signal and reference channels. The final shift is found to be 134 fs. Aside from topological differences between the reference and signal channels, kinematical differences can also skew the measurement. The data/MC ratio for the $B^\pm \to J/\psi K^\pm$ signal di-muon pseudo-rapidity separation is applied to the $B_s^0 \to \mu\mu$ signal, yielding an additional shift of 6 fs. Uncertainties in the kinematic and reconstruction corrections (detailed in ref. [12]) applied to MC candidates are accounted for by repeating the measurement on MC pseudo-experiments with and without these corrections applied, observing a combined shift of 65 fs.

In this analysis the MC proper decay time fit templates are derived with the assumption that only the heavy B_s^0 mass eigenstate contributes to the decay, as predicted by the SM. The systematic effect due to this assumption is already included in the 15 fs systematic uncertainty ascribed to the fit bias lifetime dependency.

All the systematic effects discussed above are conservatively symmetrised and then combined in quadrature into an overall systematic uncertainty of 0.17 ps, yielding the ATLAS measurement of $\tau_{\mu\mu}^{\mathrm{Obs}} = 0.99^{+0.42}_{-0.07}$ (stat.) ± 0.17 (syst.) ps. The impact on $\tau_{\mu\mu}$ of the different sources of systematic uncertainties described above is reported in table 1.

5 Conclusions

This paper presents the first ATLAS measurement of the $B_s^0 \to \mu\mu$ effective lifetime, based on a fraction of the experiment's Run 2 dataset corresponding to 26.3 fb^{-1} of 13 TeV LHC proton-proton collisions. The result obtained is $\tau_{\mu\mu}^{\mathrm{Obs}} = 0.99^{+0.42}_{-0.07}\,(\mathrm{stat.}) \pm 0.17\,(\mathrm{syst.})$ ps. It is consistent with the SM prediction $\tau_{\mu\mu}^{\mathrm{SM}} = (1.624 \pm 0.009)$ ps [4] as well as with the other available experimental results.

JHEP09(2023)199

Uncertainty source	$\Delta\tau_{\mu\mu}^{\text{Obs}}$ [fs]
Data - MC discrepancies	134
SSSV lifetime model	60
Combinatorial lifetime model	56
B kinematic reweighting	55
B isolation reweighting	32
SSSV mass model	22
B_d background	16
Fit bias lifetime dependency and B_s^0 eigenstates admixture	15
Combinatorial mass model	14
Pileup reweighting	13
B_c background	10
Muon Δ_η correction	6
$B \to hh'$ background	3
Muon reconstruction SF reweighting	2
Semileptonic background	2
Trigger reweighting	1
Total	174

Table 1. Summary of the systematic uncertainty contributions affecting the $B_s^0 \to \mu\mu$ lifetime measurement. The last line represents the sum in quadrature of all systematic effects.

Acknowledgments

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

We acknowledge the support of ANPCyT, Argentina; YerPhI, Armenia; ARC, Australia; BMWFW and FWF, Austria; ANAS, Azerbaijan; CNPq and FAPESP, Brazil; NSERC, NRC and CFI, Canada; CERN; ANID, Chile; CAS, MOST and NSFC, China; Minciencias, Colombia; MEYS CR, Czech Republic; DNRF and DNSRC, Denmark; IN2P3-CNRS and CEA-DRF/IRFU, France; SRNSFG, Georgia; BMBF, HGF and MPG, Germany; GSRI, Greece; RGC and Hong Kong SAR, China; ISF and Benoziyo Center, Israel; INFN, Italy; MEXT and JSPS, Japan; CNRST, Morocco; NWO, Netherlands; RCN, Norway; MEiN, Poland; FCT, Portugal; MNE/IFA, Romania; MESTD, Serbia; MSSR, Slovakia; ARRS and MIZŠ, Slovenia; DSI/NRF, South Africa; MICINN, Spain; SRC and Wallenberg Foundation, Sweden; SERI, SNSF and Cantons of Bern and Geneva, Switzerland; MOST, Taiwan; TENMAK, Türkiye; STFC, United Kingdom; DOE and NSF, United States of America. In addition, individual groups and members have received support from BCKDF, CANARIE, Compute Canada and CRC, Canada; PRIMUS 21/SCI/017 and UNCE SCI/013, Czech Republic; COST, ERC, ERDF, Horizon 2020 and Marie Skłodowska-Curie Actions, European Union; Investissements d'Avenir Labex, Investissements d'Avenir Idex and ANR, France; DFG and AvH Foundation, Germany; Herakleitos, Thales and Aristeia programmes co-financed by EU-ESF and the Greek NSRF, Greece; BSF-NSF and MINERVA, Israel; Norwegian Financial Mechanism 2014-2021, Norway; NCN and NAWA, Poland; La Caixa Banking Foundation, CERCA Programme Generalitat de Catalunya and PROMETEO and GenT Programmes Generalitat Valenciana, Spain; Göran Gustafssons Stiftelse, Sweden; The Royal Society and Leverhulme Trust, United Kingdom.

The crucial computing support from all WLCG partners is acknowledged gratefully, in particular from CERN, the ATLAS Tier-1 facilities at TRIUMF (Canada), NDGF (Denmark, Norway, Sweden), CC-IN2P3 (France), KIT/GridKA (Germany), INFN-CNAF (Italy), NL-T1 (Netherlands), PIC (Spain), ASGC (Taiwan), RAL (UK) and BNL (USA), the Tier-2 facilities worldwide and large non-WLCG resource providers. Major contributors of computing resources are listed in ref. [23].

References

[1] M. Beneke, C. Bobeth and R. Szafron, *Power-enhanced leading-logarithmic QED corrections to* $B_q \to \mu^+\mu^-$, *JHEP* **10** (2019) 232 [`arXiv:1908.07011`] [*Erratum ibid.* **11** (2022) 099] [INSPIRE].

[2] K. De Bruyn et al., *Probing New Physics via the* $B_s^0 \to \mu^+\mu^-$ *Effective Lifetime*, *Phys. Rev. Lett.* **109** (2012) 041801 [`arXiv:1204.1737`] [INSPIRE].

[3] D.M. Straub, *New Physics Searches in Flavour Physics*, *Nuovo Cim. C* **035N1** (2012) 249 [`arXiv:1107.0266`] [INSPIRE].

[4] Heavy Flavor Averaging Group and HFLAV collaborations, *Averages of b-hadron, c-hadron, and* τ*-lepton properties as of 2021*, *Phys. Rev. D* **107** (2023) 052008 [`arXiv:2206.07501`] [INSPIRE].

[5] Particle Data Group collaboration, *Review of Particle Physics*, *PTEP* **2022** (2022) 083C01 [INSPIRE].

[6] CMS collaboration, *Measurement of properties of* $B_\mathrm{s}^0 \to \mu^+\mu^-$ *decays and search for* $B^0 \to \mu^+\mu^-$ *with the CMS experiment*, *JHEP* **04** (2020) 188 [`arXiv:1910.12127`] [INSPIRE].

[7] CMS collaboration, *Measurement of the* $B_\mathrm{S}^0 \to \mu^+\mu^-$ *decay properties and search for the* $B^0 \to \mu^+\mu^-$ *decay in proton-proton collisions at* $\sqrt{s} = 13$ *TeV*, *Phys. Lett. B* **842** (2023) 137955 [`arXiv:2212.10311`] [INSPIRE].

[8] LHCb collaboration, *Measurement of the* $B_s^0 \to \mu^+\mu^-$ *branching fraction and effective lifetime and search for* $B^0 \to \mu^+\mu^-$ *decays*, *Phys. Rev. Lett.* **118** (2017) 191801 [`arXiv:1703.05747`] [INSPIRE].

[9] LHCb collaboration, *Analysis of Neutral B-Meson Decays into Two Muons*, *Phys. Rev. Lett.* **128** (2022) 041801 [`arXiv:2108.09284`] [INSPIRE].

[10] ATLAS collaboration, *Search for the decay* $B_s^0 \to \mu\mu$ *with the ATLAS detector*, *Phys. Lett. B* **713** (2012) 387 [`arXiv:1204.0735`] [INSPIRE].

[11] ATLAS collaboration, *Study of the rare decays of B_s^0 and B^0 into muon pairs from data collected during the LHC Run 1 with the ATLAS detector*, *Eur. Phys. J. C* **76** (2016) 513 [`arXiv:1604.04263`] [INSPIRE].

[12] ATLAS collaboration, *Study of the rare decays of B_s^0 and B^0 mesons into muon pairs using data collected during 2015 and 2016 with the ATLAS detector*, *JHEP* **04** (2019) 098 [`arXiv:1812.03017`] [INSPIRE].

[13] ATLAS, CMS and LHC collaborations, *Combination of the ATLAS, CMS and LHCb results on the $B^0_{(s)} \to \mu^+\mu^-$ decays*, CMS-PAS-BPH-20-003; LHCb-CONF-2020-002; ATLAS-CONF-2020-049 (2020) [INSPIRE].

[14] ATLAS collaboration, *The ATLAS Experiment at the CERN Large Hadron Collider*, 2008 *JINST* **3** S08003 [INSPIRE].

[15] ATLAS collaboration, *The ATLAS Collaboration Software and Firmware*, ATL-SOFT-PUB-2021-001 (2021).

[16] ATLAS collaboration, *ATLAS data quality operations and performance for 2015–2018 data-taking*, 2020 *JINST* **15** P04003 [`arXiv:1911.04632`] [INSPIRE].

[17] ATLAS collaboration, *Luminosity determination in pp collisions at $\sqrt{s} = 8$ TeV using the ATLAS detector at the LHC*, *Eur. Phys. J. C* **76** (2016) 653 [`arXiv:1608.03953`] [INSPIRE].

[18] G. Avoni et al., *The new LUCID-2 detector for luminosity measurement and monitoring in ATLAS*, 2018 *JINST* **13** P07017 [INSPIRE].

[19] ATLAS collaboration, *Performance of the ATLAS Trigger System in 2015*, *Eur. Phys. J. C* **77** (2017) 317 [`arXiv:1611.09661`] [INSPIRE].

[20] ATLAS collaboration, *Measurement of the muon reconstruction performance of the ATLAS detector using 2011 and 2012 LHC proton-proton collision data*, *Eur. Phys. J. C* **74** (2014) 3130 [`arXiv:1407.3935`] [INSPIRE].

[21] M. Pivk and F.R. Le Diberder, *SPlot: A Statistical tool to unfold data distributions*, *Nucl. Instrum. Meth. A* **555** (2005) 356 [`physics/0402083`] [INSPIRE].

[22] J. Neyman, *Outline of a Theory of Statistical Estimation Based on the Classical Theory of Probability*, *Phil. Trans. Roy. Soc. Lond. A* **236** (1937) 333 [INSPIRE].

[23] ATLAS collaboration, *ATLAS Computing Acknowledgements*, ATL-SOFT-PUB-2021-003 (2021) [INSPIRE].

The ATLAS collaboration

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

M. Bauce[75a,75b], M. Bauer[36], P. Bauer[24], L.T. Bazzano Hurrell[30], J.B. Beacham[51], T. Beau[127], J.Y. Beaucamp[90], P.H. Beauchemin[158], F. Becherer[54], P. Bechtle[24], H.P. Beck[19,u], K. Becker[167], A.J. Beddall[82], V.A. Bednyakov[38], C.P. Bee[145], L.J. Beemster[15], T.A. Beermann[36], M. Begalli[83d], M. Begel[29], A. Behera[145], J.K. Behr[48], J.F. Beirer[55], F. Beisiegel[24], M. Belfkir[159], G. Bella[151], L. Bellagamba[23b], A. Bellerive[34], P. Bellos[20], K. Beloborodov[37], D. Benchekroun[35a], F. Bendebba[35a], Y. Benhammou[151], M. Benoit[29], J.R. Bensinger[26], S. Bentvelsen[114], L. Beresford[48], M. Beretta[53], E. Bergeaas Kuutmann[161], N. Berger[4], B. Bergmann[132], J. Beringer[17a], G. Bernardi[5], C. Bernius[143], F.U. Bernlochner[24], F. Bernon[36,102], A. Berrocal Guardia[13], T. Berry[95], P. Berta[133], A. Berthold[50], I.A. Bertram[91], S. Bethke[110], A. Betti[75a,75b], A.J. Bevan[94], N.K. Bhalla[54], M. Bhamjee[33c], S. Bhatta[145], D.S. Bhattacharya[166], P. Bhattarai[143], V.S. Bhopatkar[121], R. Bi[29,az], R.M. Bianchi[129], G. Bianco[23b,23a], O. Biebel[109], R. Bielski[123], M. Biglietti[77a], M. Bindi[55], A. Bingul[21b], C. Bini[75a,75b], A. Biondini[92], C.J. Birch-sykes[101], G.A. Bird[20,134], M. Birman[169], M. Biros[133], S. Biryukov[146], T. Bisanz[49], E. Bisceglie[43b,43a], J.P. Biswal[134], D. Biswas[141], A. Bitadze[101], K. Bjørke[125], I. Bloch[48], C. Blocker[26], A. Blue[59], U. Blumenschein[94], J. Blumenthal[100], G.J. Bobbink[114], V.S. Bobrovnikov[37], M. Boehler[54], B. Boehm[166], D. Bogavac[36], A.G. Bogdanchikov[37], C. Bohm[47a], V. Boisvert[95], P. Bokan[48], T. Bold[86a], M. Bomben[5], M. Bona[94], M. Boonekamp[135], C.D. Booth[95], A.G. Borbély[59,at], I.S. Bordulev[37], H.M. Borecka-Bielska[108], G. Borissov[91], D. Bortoletto[126], D. Boscherini[23b], M. Bosman[13], J.D. Bossio Sola[36], K. Bouaouda[35a], N. Bouchhar[163], J. Boudreau[129], E.V. Bouhova-Thacker[91], D. Boumediene[40], R. Bouquet[165], A. Boveia[119], J. Boyd[36], D. Boye[29], I.R. Boyko[38], J. Bracinik[20], N. Brahimi[62d], G. Brandt[171], O. Brandt[32], F. Braren[48], B. Brau[103], J.E. Brau[123], R. Brener[169], L. Brenner[114], R. Brenner[161], S. Bressler[169], D. Britton[59], D. Britzger[110], I. Brock[24], G. Brooijmans[41], W.K. Brooks[137f], E. Brost[29], L.M. Brown[165,n], L.E. Bruce[61], T.L. Bruckler[126], P.A. Bruckman de Renstrom[87], B. Brüers[48], A. Bruni[23b], G. Bruni[23b], M. Bruschi[23b], N. Bruscino[75a,75b], T. Buanes[16], Q. Buat[138], D. Buchin[110], A.G. Buckley[59], O. Bulekov[37], B.A. Bullard[143], S. Burdin[92], C.D. Burgard[49], A.M. Burger[40], B. Burghgrave[8], O. Burlayenko[54], J.T.P. Burr[32], C.D. Burton[11], J.C. Burzynski[142], E.L. Busch[41], V. Büscher[100], P.J. Bussey[59], J.M. Butler[25], C.M. Buttar[59], J.M. Butterworth[96], W. Buttinger[134], C.J. Buxo Vazquez[107], A.R. Buzykaev[37], S. Cabrera Urbán[163], L. Cadamuro[66], D. Caforio[58], H. Cai[129], Y. Cai[14a,14e], Y. Cai[14c], V.M.M. Cairo[36], O. Cakir[3a], N. Calace[36], P. Calafiura[17a], G. Calderini[127], P. Calfayan[68], G. Callea[59], L.P. Caloba[83b], D. Calvet[40], S. Calvet[40], T.P. Calvet[102], M. Calvetti[74a,74b], R. Camacho Toro[127], S. Camarda[36], D. Camarero Munoz[26], P. Camarri[76a,76b], M.T. Camerlingo[72a,72b], D. Cameron[36,h], C. Camincher[165], M. Campanelli[96], A. Camplani[42], V. Canale[72a,72b], A. Canesse[104], J. Cantero[163], Y. Cao[162], F. Capocasa[26], M. Capua[43b,43a], A. Carbone[71a,71b], R. Cardarelli[76a], J.C.J. Cardenas[8], F. Cardillo[163], G. Carducci[43b,43a], T. Carli[36], G. Carlino[72a], J.I. Carlotto[13], B.T. Carlson[129,x], E.M. Carlson[165,156a], L. Carminati[71a,71b], A. Carnelli[135],

M. Carnesale[75a,75b], S. Caron[113], E. Carquin[137f], S. Carrá[71a,71b], G. Carratta[23b,23a], F. Carrio Argos[33g], J.W.S. Carter[155], T.M. Carter[52], M.P. Casado[13,k], M. Caspar[48], F.L. Castillo[4], L. Castillo Garcia[13], V. Castillo Gimenez[163], N.F. Castro[130a,130e], A. Catinaccio[36], J.R. Catmore[125], V. Cavaliere[29], N. Cavalli[23b,23a], V. Cavasinni[74a,74b], Y.C. Cekmecelioglu[48], E. Celebi[21a], F. Celli[126], M.S. Centonze[70a,70b], V. Cepaitis[56], K. Cerny[122], A.S. Cerqueira[83a], A. Cerri[146], L. Cerrito[76a,76b], F. Cerutti[17a], B. Cervato[141], A. Cervelli[23b], G. Cesarini[53], S.A. Cetin[82], Z. Chadi[35a], D. Chakraborty[115], J. Chan[170], W.Y. Chan[153], J.D. Chapman[32], E. Chapon[135], B. Chargeishvili[149b], D.G. Charlton[20], T.P. Charman[94], M. Chatterjee[19], C. Chauhan[133], S. Chekanov[6], S.V. Chekulaev[156a], G.A. Chelkov[38,a], A. Chen[106], B. Chen[151], B. Chen[165], H. Chen[14c], H. Chen[29], J. Chen[62c], J. Chen[142], M. Chen[126], S. Chen[153], S.J. Chen[14c], X. Chen[62c,135], X. Chen[14b,av], Y. Chen[62a], C.L. Cheng[170], H.C. Cheng[64a], S. Cheong[143], A. Cheplakov[38], E. Cheremushkina[48], E. Cherepanova[114], R. Cherkaoui El Moursli[35e], E. Cheu[7], K. Cheung[65], L. Chevalier[135], V. Chiarella[53], G. Chiarelli[74a], N. Chiedde[102], G. Chiodini[70a], A.S. Chisholm[20], A. Chitan[27b], M. Chitishvili[163], M.V. Chizhov[38], K. Choi[11], A.R. Chomont[75a,75b], Y. Chou[103], E.Y.S. Chow[113], T. Chowdhury[33g], K.L. Chu[169], M.C. Chu[64a], X. Chu[14a,14e], J. Chudoba[131], J.J. Chwastowski[87], D. Cieri[110], K.M. Ciesla[86a], V. Cindro[93], A. Ciocio[17a], F. Cirotto[72a,72b], Z.H. Citron[169,o], M. Citterio[71a], D.A. Ciubotaru[27b], B.M. Ciungu[155], A. Clark[56], P.J. Clark[52], C. Clarry[155], J.M. Clavijo Columbie[48], S.E. Clawson[48], C. Clement[47a,47b], J. Clercx[48], L. Clissa[23b,23a], Y. Coadou[102], M. Cobal[69a,69c], A. Coccaro[57b], R.F. Coelho Barrue[130a], R. Coelho Lopes De Sa[103], S. Coelli[71a], H. Cohen[151], A.E.C. Coimbra[71a,71b], B. Cole[41], J. Collot[60], P. Conde Muiño[130a,130g], M.P. Connell[33c], S.H. Connell[33c], I.A. Connelly[59], E.I. Conroy[126], F. Conventi[72a,ax], H.G. Cooke[20], A.M. Cooper-Sarkar[126], A. Cordeiro Oudot Choi[127], L.D. Corpe[40], M. Corradi[75a,75b], F. Corriveau[104,ai], A. Cortes-Gonzalez[18], M.J. Costa[163], F. Costanza[4], D. Costanzo[139], B.M. Cote[119], G. Cowan[95], K. Cranmer[170], D. Cremonini[23b,23a], S. Crépé-Renaudin[60], F. Crescioli[127], M. Cristinziani[141], M. Cristoforetti[78a,78b], V. Croft[114], J.E. Crosby[121], G. Crosetti[43b,43a], A. Cueto[99], T. Cuhadar Donszelmann[160], H. Cui[14a,14e], Z. Cui[7], W.R. Cunningham[59], F. Curcio[43b,43a], P. Czodrowski[36], M.M. Czurylo[63b], M.J. Da Cunha Sargedas De Sousa[57b,57a], J.V. Da Fonseca Pinto[83b], C. Da Via[101], W. Dabrowski[86a], T. Dado[49], S. Dahbi[33g], T. Dai[106], D. Dal Santo[19], C. Dallapiccola[103], M. Dam[42], G. D’amen[29], V. D’Amico[109], J. Damp[100], J.R. Dandoy[128], M.F. Daneri[30], M. Danninger[142], V. Dao[36], G. Darbo[57b], S. Darmora[6], S.J. Das[29,az], S. D’Auria[71a,71b], C. David[156b], T. Davidek[133], B. Davis-Purcell[34], I. Dawson[94], H.A. Day-hall[132], K. De[8], R. De Asmundis[72a], N. De Biase[48], S. De Castro[23b,23a], N. De Groot[113], P. de Jong[114], H. De la Torre[115], A. De Maria[14c], A. De Salvo[75a], U. De Sanctis[76a,76b], A. De Santo[146], J.B. De Vivie De Regie[60], D.V. Dedovich[38], J. Degens[114], A.M. Deiana[44], F. Del Corso[23b,23a], J. Del Peso[99], F. Del Rio[63a], F. Deliot[135], C.M. Delitzsch[49], M. Della Pietra[72a,72b], D. Della Volpe[56], A. Dell’Acqua[36], L. Dell’Asta[71a,71b], M. Delmastro[4], P.A. Delsart[60], S. Demers[172], M. Demichev[38], S.P. Denisov[37],

L. D'Eramo[40], D. Derendarz[87], F. Derue[127], P. Dervan[92], K. Desch[24], C. Deutsch[24], F.A. Di Bello[57b,57a], A. Di Ciaccio[76a,76b], L. Di Ciaccio[4], A. Di Domenico[75a,75b], C. Di Donato[72a,72b], A. Di Girolamo[36], G. Di Gregorio[36], A. Di Luca[78a,78b], B. Di Micco[77a,77b], R. Di Nardo[77a,77b], C. Diaconu[102], M. Diamantopoulou[34], F.A. Dias[114], T. Dias Do Vale[142], M.A. Diaz[137a,137b], F.G. Diaz Capriles[24], M. Didenko[163], E.B. Diehl[106], L. Diehl[54], S. Díez Cornell[48], C. Diez Pardos[141], C. Dimitriadi[161,24,161], A. Dimitrievska[17a], J. Dingfelder[24], I-M. Dinu[27b], S.J. Dittmeier[63b], F. Dittus[36], F. Djama[102], T. Djobava[149b], J.I. Djuvsland[16], C. Doglioni[101,98], A. Dohnalova[28a], J. Dolejsi[133], Z. Dolezal[133], K.M. Dona[39], M. Donadelli[83c], B. Dong[107], J. Donini[40], A. D'Onofrio[77a,77b], M. D'Onofrio[92], J. Dopke[134], A. Doria[72a], N. Dos Santos Fernandes[130a], P. Dougan[101], M.T. Dova[90], A.T. Doyle[59], M.A. Draguet[126], E. Dreyer[169], I. Drivas-koulouris[10], M. Drnevich[117], A.S. Drobac[158], M. Drozdova[56], D. Du[62a], T.A. du Pree[114], F. Dubinin[37], M. Dubovsky[28a], E. Duchovni[169], G. Duckeck[109], O.A. Ducu[27b], D. Duda[52], A. Dudarev[36], E.R. Duden[26], M. D'uffizi[101], L. Duflot[66], M. Dührssen[36], C. Dülsen[171], A.E. Dumitriu[27b], M. Dunford[63a], S. Dungs[49], K. Dunne[47a,47b], A. Duperrin[102], H. Duran Yildiz[3a], M. Düren[58], A. Durglishvili[149b], B.L. Dwyer[115], G.I. Dyckes[17a], M. Dyndal[86a], B.S. Dziedzic[87], Z.O. Earnshaw[146], G.H. Eberwein[126], B. Eckerova[28a], S. Eggebrecht[55], E. Egidio Purcino De Souza[127], L.F. Ehrke[56], G. Eigen[16], K. Einsweiler[17a], T. Ekelof[161], P.A. Ekman[98], S. El Farkh[35b], Y. El Ghazali[35b], H. El Jarrari[35e,148], A. El Moussaouy[108,ab], V. Ellajosyula[161], M. Ellert[161], F. Ellinghaus[171], N. Ellis[36], J. Elmsheuser[29], M. Elsing[36], D. Emeliyanov[134], Y. Enari[153], I. Ene[17a], S. Epari[13], J. Erdmann[49], P.A. Erland[87], M. Errenst[171], M. Escalier[66], C. Escobar[163], E. Etzion[151], G. Evans[130a], H. Evans[68], L.S. Evans[95], M.O. Evans[146], A. Ezhilov[37], S. Ezzarqtouni[35a], F. Fabbri[59], L. Fabbri[23b,23a], G. Facini[96], V. Fadeyev[136], R.M. Fakhrutdinov[37], S. Falciano[75a], L.F. Falda Ulhoa Coelho[36], P.J. Falke[24], J. Faltova[133], C. Fan[162], Y. Fan[14a], Y. Fang[14a,14e], M. Fanti[71a,71b], M. Faraj[69a,69b], Z. Farazpay[97], A. Farbin[8], A. Farilla[77a], T. Farooque[107], S.M. Farrington[52], F. Fassi[35e], D. Fassouliotis[9], M. Faucci Giannelli[76a,76b], W.J. Fawcett[32], L. Fayard[66], P. Federic[133], P. Federicova[131], O.L. Fedin[37,a], G. Fedotov[37], M. Feickert[170], L. Feligioni[102], D.E. Fellers[123], C. Feng[62b], M. Feng[14b], Z. Feng[114], M.J. Fenton[160], A.B. Fenyuk[37], L. Ferencz[48], R.A.M. Ferguson[91], S.I. Fernandez Luengo[137f], P. Fernandez Martinez[13], M.J.V. Fernoux[102], J. Ferrando[48], A. Ferrari[161], P. Ferrari[114,113], R. Ferrari[73a], D. Ferrere[56], C. Ferretti[106], F. Fiedler[100], P. Fiedler[132], A. Filipčič[93], E.K. Filmer[1], F. Filthaut[113], M.C.N. Fiolhais[130a,130c,d], L. Fiorini[163], W.C. Fisher[107], T. Fitschen[101], P.M. Fitzhugh[135], I. Fleck[141], P. Fleischmann[106], T. Flick[171], M. Flores[33d,ap], L.R. Flores Castillo[64a], L. Flores Sanz De Acedo[36], F.M. Follega[78a,78b], N. Fomin[16], J.H. Foo[155], B.C. Forland[68], A. Formica[135], A.C. Forti[101], E. Fortin[36], A.W. Fortman[61], M.G. Foti[17a], L. Fountas[9,l], D. Fournier[66], H. Fox[91], P. Francavilla[74a,74b], S. Francescato[61], S. Franchellucci[56], M. Franchini[23b,23a], S. Franchino[63a], D. Francis[36], L. Franco[113], V. Franco Lima[36], L. Franconi[48], M. Franklin[61], G. Frattari[26], A.C. Freegard[94], W.S. Freund[83b], Y.Y. Frid[151],

J. Friend[59], N. Fritzsche[50], A. Froch[54], D. Froidevaux[36], J.A. Frost[126], Y. Fu[62a], S. Fuenzalida Garrido[137f], M. Fujimoto[118,aq], E. Fullana Torregrosa[163,*], K.Y. Fung[64a], E. Furtado De Simas Filho[83b], M. Furukawa[153], J. Fuster[163], A. Gabrielli[23b,23a], A. Gabrielli[155], P. Gadow[36], G. Gagliardi[57b,57a], L.G. Gagnon[17a], E.J. Gallas[126], B.J. Gallop[134], K.K. Gan[119], S. Ganguly[153], Y. Gao[52], F.M. Garay Walls[137a,137b], B. Garcia[29,az], C. García[163], A. Garcia Alonso[114], A.G. Garcia Caffaro[172], J.E. García Navarro[163], M. Garcia-Sciveres[17a], G.L. Gardner[128], R.W. Gardner[39], N. Garelli[158], D. Garg[80], R.B. Garg[143,t], J.M. Gargan[52], C.A. Garner[155], C.M. Garvey[33a], P. Gaspar[83b], V.K. Gassmann[158], G. Gaudio[73a], V. Gautam[13], P. Gauzzi[75a,75b], I.L. Gavrilenko[37], A. Gavrilyuk[37], C. Gay[164], G. Gaycken[48], E.N. Gazis[10], A.A. Geanta[27b], C.M. Gee[136], C. Gemme[57b], M.H. Genest[60], S. Gentile[75a,75b], A.D. Gentry[112], S. George[95], W.F. George[20], T. Geralis[46], P. Gessinger-Befurt[36], M.E. Geyik[171], M. Ghani[167], M. Ghneimat[141], K. Ghorbanian[94], A. Ghosal[141], A. Ghosh[160], A. Ghosh[7], B. Giacobbe[23b], S. Giagu[75a,75b], T. Giani[114], P. Giannetti[74a], A. Giannini[62a], S.M. Gibson[95], M. Gignac[136], D.T. Gil[86b], A.K. Gilbert[86a], B.J. Gilbert[41], D. Gillberg[34], G. Gilles[114], N.E.K. Gillwald[48], L. Ginabat[127], D.M. Gingrich[2,aw], M.P. Giordani[69a,69c], P.F. Giraud[135], G. Giugliarelli[69a,69c], D. Giugni[71a], F. Giuli[36], I. Gkialas[9,l], L.K. Gladilin[37], C. Glasman[99], G.R. Gledhill[123], G. Glemža[48], M. Glisic[123], I. Gnesi[43b,g], Y. Go[29,az], M. Goblirsch-Kolb[36], B. Gocke[49], D. Godin[108], B. Gokturk[21a], S. Goldfarb[105], T. Golling[56], M.G.D. Gololo[33g], D. Golubkov[37], J.P. Gombas[107], A. Gomes[130a,130b], G. Gomes Da Silva[141], A.J. Gomez Delegido[163], R. Gonçalo[130a,130c], G. Gonella[123], L. Gonella[20], A. Gongadze[149c], F. Gonnella[20], J.L. Gonski[41], R.Y. González Andana[52], S. González de la Hoz[163], S. Gonzalez Fernandez[13], R. Gonzalez Lopez[92], C. Gonzalez Renteria[17a], M.V. Gonzalez Rodrigues[48], R. Gonzalez Suarez[161], S. Gonzalez-Sevilla[56], G.R. Gonzalvo Rodriguez[163], L. Goossens[36], B. Gorini[36], E. Gorini[70a,70b], A. Gorišek[93], T.C. Gosart[128], A.T. Goshaw[51], M.I. Gostkin[38], S. Goswami[121], C.A. Gottardo[36], S.A. Gotz[109], M. Gouighri[35b], V. Goumarre[48], A.G. Goussiou[138], N. Govender[33c], I. Grabowska-Bold[86a], K. Graham[34], E. Gramstad[125], S. Grancagnolo[70a,70b], M. Grandi[146], C.M. Grant[1,135], P.M. Gravila[27f], F.G. Gravili[70a,70b], H.M. Gray[17a], M. Greco[70a,70b], C. Grefe[24], I.M. Gregor[48], P. Grenier[143], S.G. Grewe[110], C. Grieco[13], A.A. Grillo[136], K. Grimm[31], S. Grinstein[13,ad], J.-F. Grivaz[66], E. Gross[169], J. Grosse-Knetter[55], C. Grud[106], J.C. Grundy[126], L. Guan[106], W. Guan[29], C. Gubbels[164], J.G.R. Guerrero Rojas[163], G. Guerrieri[69a,69c], F. Guescini[110], R. Gugel[100], J.A.M. Guhit[106], A. Guida[18], T. Guillemin[4], E. Guilloton[167,134], S. Guindon[36], F. Guo[14a,14e], J. Guo[62c], L. Guo[48], Y. Guo[106], R. Gupta[48], R. Gupta[129], S. Gurbuz[24], S.S. Gurdasani[54], G. Gustavino[36], M. Guth[56], P. Gutierrez[120], L.F. Gutierrez Zagazeta[128], M. Gutsche[50], C. Gutschow[96], C. Gwenlan[126], C.B. Gwilliam[92], E.S. Haaland[125], A. Haas[117], M. Habedank[48], C. Haber[17a], H.K. Hadavand[8], A. Hadef[100], S. Hadzic[110], A.I. Hagan[91], J.J. Hahn[141], E.H. Haines[96], M. Haleem[166], J. Haley[121], J.J. Hall[139], G.D. Hallewell[102], L. Halser[19], K. Hamano[165], M. Hamer[24], G.N. Hamity[52], E.J. Hampshire[95], J. Han[62b], K. Han[62a], L. Han[14c], L. Han[62a], S. Han[17a], Y.F. Han[155],

K. Hanagaki[84], M. Hance[136], D.A. Hangal[41,ao], H. Hanif[142], M.D. Hank[128], R. Hankache[101], J.B. Hansen[42], J.D. Hansen[42], P.H. Hansen[42], K. Hara[157], D. Harada[56], T. Harenberg[171], S. Harkusha[37], M.L. Harris[103], Y.T. Harris[126], J. Harrison[13], N.M. Harrison[119], P.F. Harrison[167], N.M. Hartman[110], N.M. Hartmann[109], Y. Hasegawa[140], R. Hauser[107], C.M. Hawkes[20], R.J. Hawkings[36], Y. Hayashi[153], S. Hayashida[111], D. Hayden[107], C. Hayes[106], R.L. Hayes[114], C.P. Hays[126], J.M. Hays[94], H.S. Hayward[92], F. He[62a], M. He[14a,14e], Y. He[154], Y. He[48], N.B. Heatley[94], V. Hedberg[98], A.L. Heggelund[125], N.D. Hehir[94], C. Heidegger[54], K.K. Heidegger[54], W.D. Heidorn[81], J. Heilman[34], S. Heim[48], T. Heim[17a], J.G. Heinlein[128], J.J. Heinrich[123], L. Heinrich[110,au], J. Hejbal[131], L. Helary[48], A. Held[170], S. Hellesund[16], C.M. Helling[164], S. Hellman[47a,47b], R.C.W. Henderson[91], L. Henkelmann[32], A.M. Henriques Correia[36], H. Herde[98], Y. Hernández Jiménez[145], L.M. Herrmann[24], T. Herrmann[50], G. Herten[54], R. Hertenberger[109], L. Hervas[36], M.E. Hesping[100], N.P. Hessey[156a], H. Hibi[85], E. Hill[155], S.J. Hillier[20], J.R. Hinds[107], F. Hinterkeuser[24], M. Hirose[124], S. Hirose[157], D. Hirschbuehl[171], T.G. Hitchings[101], B. Hiti[93], J. Hobbs[145], R. Hobincu[27e], N. Hod[169], M.C. Hodgkinson[139], B.H. Hodkinson[32], A. Hoecker[36], J. Hofer[48], T. Holm[24], M. Holzbock[110], L.B.A.H. Hommels[32], B.P. Honan[101], J. Hong[62c], T.M. Hong[129], B.H. Hooberman[162], W.H. Hopkins[6], Y. Horii[111], S. Hou[148], A.S. Howard[93], J. Howarth[59], J. Hoya[6], M. Hrabovsky[122], A. Hrynevich[48], T. Hryn'ova[4], P.J. Hsu[65], S.-C. Hsu[138], Q. Hu[62a], Y.F. Hu[14a,14e], S. Huang[64b], X. Huang[14c], X. Huang[14a,14e], Y. Huang[139,m], Y. Huang[14a], Z. Huang[101], Z. Hubacek[132], M. Huebner[24], F. Huegging[24], T.B. Huffman[126], C.A. Hugli[48], M. Huhtinen[36], S.K. Huiberts[16], R. Hulsken[104], N. Huseynov[12], J. Huston[107], J. Huth[61], R. Hyneman[143], G. Iacobucci[56], G. Iakovidis[29], I. Ibragimov[141], L. Iconomidou-Fayard[66], P. Iengo[72a,72b], R. Iguchi[153], T. Iizawa[126,r], Y. Ikegami[84], N. Ilic[155], H. Imam[35a], M. Ince Lezki[56], T. Ingebretsen Carlson[47a,47b], G. Introzzi[73a,73b], M. Iodice[77a], V. Ippolito[75a,75b], R.K. Irwin[92], M. Ishino[153], W. Islam[170], C. Issever[18,48], S. Istin[21a,bb], H. Ito[168], J.M. Iturbe Ponce[64a], R. Iuppa[78a,78b], A. Ivina[169], J.M. Izen[45], V. Izzo[72a], P. Jacka[131,132], P. Jackson[1], R.M. Jacobs[48], B.P. Jaeger[142], C.S. Jagfeld[109], G. Jain[156a], P. Jain[54], K. Jakobs[54], T. Jakoubek[169], J. Jamieson[59], K.W. Janas[86a], M. Javurkova[103], F. Jeanneau[135], L. Jeanty[123], J. Jejelava[149a,al], P. Jenni[54,i], C.E. Jessiman[34], S. Jézéquel[4], C. Jia[62b], J. Jia[145], X. Jia[61], X. Jia[14a,14e], Z. Jia[14c], S. Jiggins[48], J. Jimenez Pena[13], S. Jin[14c], A. Jinaru[27b], O. Jinnouchi[154], P. Johansson[139], K.A. Johns[7], J.W. Johnson[136], D.M. Jones[32], E. Jones[48], P. Jones[32], R.W.L. Jones[91], T.J. Jones[92], H.L. Joos[55,36], R. Joshi[119], J. Jovicevic[15], X. Ju[17a], J.J. Junggeburth[103,v], T. Junkermann[63a], A. Juste Rozas[13,ad], M.K. Juzek[87], S. Kabana[137e], A. Kaczmarska[87], M. Kado[110], H. Kagan[119], M. Kagan[143], A. Kahn[41], A. Kahn[128], C. Kahra[100], T. Kaji[153], E. Kajomovitz[150], N. Kakati[169], I. Kalaitzidou[54], C.W. Kalderon[29], A. Kamenshchikov[155], N.J. Kang[136], D. Kar[33g], K. Karava[126], M.J. Kareem[156b], E. Karentzos[54], I. Karkanias[152], O. Karkout[114], S.N. Karpov[38], Z.M. Karpova[38], V. Kartvelishvili[91], A.N. Karyukhin[37], E. Kasimi[152], J. Katzy[48], S. Kaur[34], K. Kawade[140], M.P. Kawale[120], C. Kawamoto[88],

T. Kawamoto[135], E.F. Kay[36], F.I. Kaya[158], S. Kazakos[107], V.F. Kazanin[37], Y. Ke[145],
J.M. Keaveney[33a], R. Keeler[165], G.V. Kehris[61], J.S. Keller[34], A.S. Kelly[96],
J.J. Kempster[146], K.E. Kennedy[41], P.D. Kennedy[100], O. Kepka[131], B.P. Kerridge[167],
S. Kersten[171], B.P. Kerševan[93], S. Keshri[66], L. Keszeghova[28a],
S. Ketabchi Haghighat[155], R.A. Khan[129], M. Khandoga[127], A. Khanov[121],
A.G. Kharlamov[37], T. Kharlamova[37], E.E. Khoda[138], M. Kholodenko[37], T.J. Khoo[18],
G. Khoriauli[166], J. Khubua[149b], Y.A.R. Khwaira[66], A. Kilgallon[123], D.W. Kim[47a,47b],
Y.K. Kim[39], N. Kimura[96], M.K. Kingston[55], A. Kirchhoff[55], C. Kirfel[24], F. Kirfel[24],
J. Kirk[134], A.E. Kiryunin[110], C. Kitsaki[10], O. Kivernyk[24], M. Klassen[63a], C. Klein[34],
L. Klein[166], M.H. Klein[106], M. Klein[92], S.B. Klein[56], U. Klein[92], P. Klimek[36],
A. Klimentov[29], T. Klioutchnikova[36], P. Kluit[114], S. Kluth[110], E. Kneringer[79],
T.M. Knight[155], A. Knue[49], R. Kobayashi[88], D. Kobylianskii[169], S.F. Koch[126],
M. Kocian[143], P. Kodyš[133], D.M. Koeck[123], P.T. Koenig[24], T. Koffas[34], O. Kolay[50],
M. Kolb[135], I. Koletsou[4], T. Komarek[122], K. Köneke[54], A.X.Y. Kong[1], T. Kono[118],
N. Konstantinidis[96], P. Kontaxakis[56], B. Konya[98], R. Kopeliansky[68], S. Koperny[86a],
K. Korcyl[87], K. Kordas[152,f], G. Koren[151], A. Korn[96], S. Korn[55], I. Korolkov[13],
N. Korotkova[37], B. Kortman[114], O. Kortner[110], S. Kortner[110], W.H. Kostecka[115],
V.V. Kostyukhin[141], A. Kotsokechagia[135], A. Kotwal[51], A. Koulouris[36],
A. Kourkoumeli-Charalampidi[73a,73b], C. Kourkoumelis[9], E. Kourlitis[110,au],
O. Kovanda[146], R. Kowalewski[165], W. Kozanecki[135], A.S. Kozhin[37],
V.A. Kramarenko[37], G. Kramberger[93], P. Kramer[100], M.W. Krasny[127],
A. Krasznahorkay[36], J.W. Kraus[171], J.A. Kremer[48], T. Kresse[50], J. Kretzschmar[92],
K. Kreul[18], P. Krieger[155], S. Krishnamurthy[103], M. Krivos[133], K. Krizka[20],
K. Kroeninger[49], H. Kroha[110], J. Kroll[131], J. Kroll[128], K.S. Krowpman[107],
U. Kruchonak[38], H. Krüger[24], N. Krumnack[81], M.C. Kruse[51], J.A. Krzysiak[87],
O. Kuchinskaia[37], S. Kuday[3a], S. Kuehn[36], R. Kuesters[54], T. Kuhl[48], V. Kukhtin[38],
Y. Kulchitsky[37,a], S. Kuleshov[137d,137b], M. Kumar[33g], N. Kumari[48], A. Kupco[131],
T. Kupfer[49], A. Kupich[37], O. Kuprash[54], H. Kurashige[85], L.L. Kurchaninov[156a],
O. Kurdysh[66], Y.A. Kurochkin[37], A. Kurova[37], M. Kuze[154], A.K. Kvam[103],
J. Kvita[122], T. Kwan[104], N.G. Kyriacou[106], L.A.O. Laatu[102], C. Lacasta[163],
F. Lacava[75a,75b], H. Lacker[18], D. Lacour[127], N.N. Lad[96], E. Ladygin[38], B. Laforge[127],
T. Lagouri[137e], F.Z. Lahbabi[35a], S. Lai[55], I.K. Lakomiec[86a], N. Lalloue[60],
J.E. Lambert[165,n], S. Lammers[68], W. Lampl[7], C. Lampoudis[152,f], A.N. Lancaster[115],
E. Lançon[29], U. Landgraf[54], M.P.J. Landon[94], V.S. Lang[54], R.J. Langenberg[103],
O.K.B. Langrekken[125], A.J. Lankford[160], F. Lanni[36], K. Lantzsch[24], A. Lanza[73a],
A. Lapertosa[57b,57a], J.F. Laporte[135], T. Lari[71a], F. Lasagni Manghi[23b], M. Lassnig[36],
V. Latonova[131], A. Laudrain[100], A. Laurier[150], S.D. Lawlor[139], Z. Lawrence[101],
M. Lazzaroni[71a,71b], B. Le[101], E.M. Le Boulicaut[51], B. Leban[93], A. Lebedev[81],
M. LeBlanc[101,as], F. Ledroit-Guillon[60], A.C.A. Lee[96], S.C. Lee[148], S. Lee[47a,47b],
T.F. Lee[92], L.L. Leeuw[33c], H.P. Lefebvre[95], M. Lefebvre[165], C. Leggett[17a],
G. Lehmann Miotto[36], M. Leigh[56], W.A. Leight[103], W. Leinonen[113], A. Leisos[152,ac],
M.A.L. Leite[83c], C.E. Leitgeb[48], R. Leitner[133], K.J.C. Leney[44], T. Lenz[24],
S. Leone[74a], C. Leonidopoulos[52], A. Leopold[144], C. Leroy[108], R. Les[107],

C.G. Lester[32], M. Levchenko[37], J. Levêque[4], D. Levin[106], L.J. Levinson[169], M.P. Lewicki[87], D.J. Lewis[4], A. Li[5], B. Li[62b], C. Li[62a], C-Q. Li[62c], H. Li[62a], H. Li[62b], H. Li[14c], H. Li[14b], H. Li[62b], J. Li[62c], K. Li[138], L. Li[62c], M. Li[14a,14e], Q.Y. Li[62a], S. Li[14a,14e], S. Li[62d,62c,e], T. Li[5,c], X. Li[104], Z. Li[126], Z. Li[104], Z. Li[92], Z. Li[14a,14e], S. Liang[14a,14e], Z. Liang[14a], M. Liberatore[135,am], B. Liberti[76a], K. Lie[64c], J. Lieber Marin[83b], H. Lien[68], K. Lin[107], R.E. Lindley[7], J.H. Lindon[2], E. Lipeles[128], A. Lipniacka[16], A. Lister[164], J.D. Little[4], B. Liu[14a], B.X. Liu[142], D. Liu[62d,62c], J.B. Liu[62a], J.K.K. Liu[32], K. Liu[62d,62c], M. Liu[62a], M.Y. Liu[62a], P. Liu[14a], Q. Liu[62d,138,62c], X. Liu[62a], Y. Liu[14d,14e], Y.L. Liu[62b], Y.W. Liu[62a], J. Llorente Merino[142], S.L. Lloyd[94], E.M. Lobodzinska[48], P. Loch[7], T. Lohse[18], K. Lohwasser[139], E. Loiacono[48], M. Lokajicek[131,*], J.D. Lomas[20], J.D. Long[162], I. Longarini[160], L. Longo[70a,70b], R. Longo[162], I. Lopez Paz[67], A. Lopez Solis[48], J. Lorenz[109], N. Lorenzo Martinez[4], A.M. Lory[109], O. Loseva[37], X. Lou[47a,47b], X. Lou[14a,14e], A. Lounis[66], J. Love[6], P.A. Love[91], G. Lu[14a,14e], M. Lu[80], S. Lu[128], Y.J. Lu[65], H.J. Lubatti[138], C. Luci[75a,75b], F.L. Lucio Alves[14c], A. Lucotte[60], F. Luehring[68], I. Luise[145], O. Lukianchuk[66], O. Lundberg[144], B. Lund-Jensen[144], N.A. Luongo[123], M.S. Lutz[151], A.B. Lux[25], D. Lynn[29], H. Lyons[92], R. Lysak[131], E. Lytken[98], V. Lyubushkin[38], T. Lyubushkina[38], M.M. Lyukova[145], H. Ma[29], K. Ma[62a], L.L. Ma[62b], Y. Ma[121], D.M. Mac Donell[165], G. Maccarrone[53], J.C. MacDonald[100], P.C. Machado De Abreu Farias[83b], R. Madar[40], W.F. Mader[50], T. Madula[96], J. Maeda[85], T. Maeno[29], H. Maguire[139], V. Maiboroda[135], A. Maio[130a,130b,130d], K. Maj[86a], O. Majersky[48], S. Majewski[123], N. Makovec[66], V. Maksimovic[15], B. Malaescu[127], Pa. Malecki[87], V.P. Maleev[37], F. Malek[60], M. Mali[93], D. Malito[95,s], U. Mallik[80], S. Maltezos[10], S. Malyukov[38], J. Mamuzic[13], G. Mancini[53], G. Manco[73a,73b], J.P. Mandalia[94], I. Mandić[93], L. Manhaes de Andrade Filho[83a], I.M. Maniatis[169], J. Manjarres Ramos[102,an], D.C. Mankad[169], A. Mann[109], B. Mansoulie[135], S. Manzoni[36], X. Mapekula[33c], A. Marantis[152,ac], G. Marchiori[5], M. Marcisovsky[131], C. Marcon[71a,71b], M. Marinescu[20], M. Marjanovic[120], E.J. Marshall[91], Z. Marshall[17a], S. Marti-Garcia[163], T.A. Martin[167], V.J. Martin[52], B. Martin dit Latour[16], L. Martinelli[75a,75b], M. Martinez[13,ad], P. Martinez Agullo[163], V.I. Martinez Outschoorn[103], P. Martinez Suarez[13], S. Martin-Haugh[134], V.S. Martoiu[27b], A.C. Martyniuk[96], A. Marzin[36], D. Mascione[78a,78b], L. Masetti[100], T. Mashimo[153], J. Masik[101], A.L. Maslennikov[37], L. Massa[23b], P. Massarotti[72a,72b], P. Mastrandrea[74a,74b], A. Mastroberardino[43b,43a], T. Masubuchi[153], T. Mathisen[161], J. Matousek[133], N. Matsuzawa[153], J. Maurer[27b], B. Maček[93], D.A. Maximov[37], R. Mazini[148], I. Maznas[152], M. Mazza[107], S.M. Mazza[136], E. Mazzeo[71a,71b], C. Mc Ginn[29], J.P. Mc Gowan[104], S.P. Mc Kee[106], E.F. McDonald[105], A.E. McDougall[114], J.A. Mcfayden[146], R.P. McGovern[128], G. Mchedlidze[149b], R.P. Mckenzie[33g], T.C. Mclachlan[48], D.J. Mclaughlin[96], S.J. McMahon[134], C.M. Mcpartland[92], R.A. McPherson[165,ai], S. Mehlhase[109], A. Mehta[92], D. Melini[150], B.R. Mellado Garcia[33g], A.H. Melo[55], F. Meloni[48], A.M. Mendes Jacques Da Costa[101], H.Y. Meng[155], L. Meng[91], S. Menke[110], M. Mentink[36], E. Meoni[43b,43a],

C. Merlassino[126], L. Merola[72a,72b], C. Meroni[71a,71b], G. Merz[106], O. Meshkov[37], J. Metcalfe[6], A.S. Mete[6], C. Meyer[68], J-P. Meyer[135], R.P. Middleton[134], L. Mijović[52], G. Mikenberg[169], M. Mikestikova[131], M. Mikuž[93], H. Mildner[100], A. Milic[36], C.D. Milke[44], D.W. Miller[39], L.S. Miller[34], A. Milov[169], D.A. Milstead[47a,47b], T. Min[14c], A.A. Minaenko[37], I.A. Minashvili[149b], L. Mince[59], A.I. Mincer[117], B. Mindur[86a], M. Mineev[38], Y. Mino[88], L.M. Mir[13], M. Miralles Lopez[163], M. Mironova[17a], A. Mishima[153], M.C. Missio[113], A. Mitra[167], V.A. Mitsou[163], Y. Mitsumori[111], O. Miu[155], P.S. Miyagawa[94], T. Mkrtchyan[63a], M. Mlinarevic[96], T. Mlinarevic[96], M. Mlynarikova[36], S. Mobius[19], P. Moder[48], P. Mogg[109], A.F. Mohammed[14a,14e], S. Mohapatra[41], G. Mokgatitswane[33g], L. Moleri[169], B. Mondal[141], S. Mondal[132], G. Monig[146], K. Mönig[48], E. Monnier[102], L. Monsonis Romero[163], J. Montejo Berlingen[13], M. Montella[119], F. Montereali[77a,77b], F. Monticelli[90], S. Monzani[69a,69c], N. Morange[66], A.L. Moreira De Carvalho[130a], M. Moreno Llácer[163], C. Moreno Martinez[56], P. Morettini[57b], S. Morgenstern[36], M. Morii[61], M. Morinaga[153], A.K. Morley[36], F. Morodei[75a,75b], L. Morvaj[36], P. Moschovakos[36], B. Moser[36], M. Mosidze[149b], T. Moskalets[54], P. Moskvitina[113], J. Moss[31,p], E.J.W. Moyse[103], O. Mtintsilana[33g], S. Muanza[102], J. Mueller[129], D. Muenstermann[91], R. Müller[19], G.A. Mullier[161], A.J. Mullin[32], J.J. Mullin[128], D.P. Mungo[155], D. Munoz Perez[163], F.J. Munoz Sanchez[101], M. Murin[101], W.J. Murray[167,134], A. Murrone[71a,71b], M. Muškinja[17a], C. Mwewa[29], A.G. Myagkov[37,a], A.J. Myers[8], G. Myers[68], M. Myska[132], B.P. Nachman[17a], O. Nackenhorst[49], A. Nag[50], K. Nagai[126], K. Nagano[84], J.L. Nagle[29,az], E. Nagy[102], A.M. Nairz[36], Y. Nakahama[84], K. Nakamura[84], K. Nakkalil[5], H. Nanjo[124], R. Narayan[44], E.A. Narayanan[112], I. Naryshkin[37], M. Naseri[34], S. Nasri[159], C. Nass[24], G. Navarro[22a], J. Navarro-Gonzalez[163], R. Nayak[151], A. Nayaz[18], P.Y. Nechaeva[37], F. Nechansky[48], L. Nedic[126], T.J. Neep[20], A. Negri[73a,73b], M. Negrini[23b], C. Nellist[114], C. Nelson[104], K. Nelson[106], S. Nemecek[131], M. Nessi[36,j], M.S. Neubauer[162], F. Neuhaus[100], J. Neundorf[48], R. Newhouse[164], P.R. Newman[20], C.W. Ng[129], Y.W.Y. Ng[48], B. Ngair[35e], H.D.N. Nguyen[108], R.B. Nickerson[126], R. Nicolaidou[135], J. Nielsen[136], M. Niemeyer[55], J. Niermann[55,36], N. Nikiforou[36], V. Nikolaenko[37,a], I. Nikolic-Audit[127], K. Nikolopoulos[20], P. Nilsson[29], I. Ninca[48], H.R. Nindhito[56], G. Ninio[151], A. Nisati[75a], N. Nishu[2], R. Nisius[110], J-E. Nitschke[50], E.K. Nkadimeng[33g], T. Nobe[153], D.L. Noel[32], T. Nommensen[147], M.B. Norfolk[139], R.R.B. Norisam[96], B.J. Norman[34], J. Novak[93], T. Novak[48], L. Novotny[132], R. Novotny[112], L. Nozka[122], K. Ntekas[160], N.M.J. Nunes De Moura Junior[83b], E. Nurse[96], J. Ocariz[127], A. Ochi[85], I. Ochoa[130a], S. Oerdek[48,y], J.T. Offermann[39], A. Ogrodnik[133], A. Oh[101], C.C. Ohm[144], H. Oide[84], R. Oishi[153], M.L. Ojeda[48], M.W. O'Keefe[92], Y. Okumura[153], L.F. Oleiro Seabra[130a], S.A. Olivares Pino[137d], D. Oliveira Damazio[29], D. Oliveira Goncalves[83a], J.L. Oliver[160], Ö.O. Öncel[54], A.P. O'Neill[19], A. Onofre[130a,130e], P.U.E. Onyisi[11], M.J. Oreglia[39], G.E. Orellana[90], D. Orestano[77a,77b], N. Orlando[13], R.S. Orr[155], V. O'Shea[59], L.M. Osojnak[128], R. Ospanov[62a], G. Otero y Garzon[30], H. Otono[89], P.S. Ott[63a], G.J. Ottino[17a], M. Ouchrif[35d], J. Ouellette[29], F. Ould-Saada[125], M. Owen[59], R.E. Owen[134],

K.Y. Oyulmaz[21a], V.E. Ozcan[21a], F. Ozturk[87], N. Ozturk[8], S. Ozturk[82],
H.A. Pacey[126], A. Pacheco Pages[13], C. Padilla Aranda[13], G. Padovano[75a,75b],
S. Pagan Griso[17a], G. Palacino[68], A. Palazzo[70a,70b], S. Palestini[36], J. Pan[172],
T. Pan[64a], D.K. Panchal[11], C.E. Pandini[114], J.G. Panduro Vazquez[95], H.D. Pandya[1],
H. Pang[14b], P. Pani[48], G. Panizzo[69a,69c], L. Paolozzi[56], C. Papadatos[108],
S. Parajuli[44], A. Paramonov[6], C. Paraskevopoulos[10], D. Paredes Hernandez[64b],
K.R. Park[41], T.H. Park[155], M.A. Parker[32], F. Parodi[57b,57a], E.W. Parrish[115],
V.A. Parrish[52], J.A. Parsons[41], U. Parzefall[54], B. Pascual Dias[108],
L. Pascual Dominguez[151], E. Pasqualucci[75a], S. Passaggio[57b], F. Pastore[95],
P. Pasuwan[47a,47b], P. Patel[87], U.M. Patel[51], J.R. Pater[101], T. Pauly[36], J. Pearkes[143],
M. Pedersen[125], R. Pedro[130a], S.V. Peleganchuk[37], O. Penc[36], E.A. Pender[52],
K.E. Penski[109], M. Penzin[37], B.S. Peralva[83d], A.P. Pereira Peixoto[60],
L. Pereira Sanchez[47a,47b], D.V. Perepelitsa[29,az], E. Perez Codina[156a], M. Perganti[10],
L. Perini[71a,71b,*], H. Pernegger[36], O. Perrin[40], K. Peters[48], R.F.Y. Peters[101],
B.A. Petersen[36], T.C. Petersen[42], E. Petit[102], V. Petousis[132], C. Petridou[152,f],
A. Petrukhin[141], M. Pettee[17a], N.E. Pettersson[36], A. Petukhov[37], K. Petukhova[133],
R. Pezoa[137f], L. Pezzotti[36], G. Pezzullo[172], T.M. Pham[170], T. Pham[105],
P.W. Phillips[134], G. Piacquadio[145], E. Pianori[17a], F. Piazza[123], R. Piegaia[30],
D. Pietreanu[27b], A.D. Pilkington[101], M. Pinamonti[69a,69c], J.L. Pinfold[2],
B.C. Pinheiro Pereira[130a], A.E. Pinto Pinoargote[100,135], L. Pintucci[69a,69c], K.M. Piper[146],
A. Pirttikoski[56], D.A. Pizzi[34], L. Pizzimento[64b], A. Pizzini[114], M.-A. Pleier[29],
V. Plesanovs[54], V. Pleskot[133], E. Plotnikova[38], G. Poddar[4], R. Poettgen[98],
L. Poggioli[127], I. Pokharel[55], S. Polacek[133], G. Polesello[73a], A. Poley[142,156a],
R. Polifka[132], A. Polini[23b], C.S. Pollard[167], Z.B. Pollock[119], V. Polychronakos[29],
E. Pompa Pacchi[75a,75b], D. Ponomarenko[113], L. Pontecorvo[36], S. Popa[27a],
G.A. Popeneciu[27d], A. Poreba[36], D.M. Portillo Quintero[156a], S. Pospisil[132],
M.A. Postill[139], P. Postolache[27c], K. Potamianos[167], P.A. Potepa[86a], I.N. Potrap[38],
C.J. Potter[32], H. Potti[1], T. Poulsen[48], J. Poveda[163], M.E. Pozo Astigarraga[36],
A. Prades Ibanez[163], J. Pretel[54], D. Price[101], M. Primavera[70a],
M.A. Principe Martin[99], R. Privara[122], T. Procter[59], M.L. Proffitt[138], N. Proklova[128],
K. Prokofiev[64c], G. Proto[110], S. Protopopescu[29], J. Proudfoot[6], M. Przybycien[86a],
W.W. Przygoda[86b], J.E. Puddefoot[139], D. Pudzha[37], D. Pyatiizbyantseva[37], J. Qian[106],
D. Qichen[101], Y. Qin[101], T. Qiu[52], A. Quadt[55], M. Queitsch-Maitland[101],
G. Quetant[56], R.P. Quinn[164], G. Rabanal Bolanos[61], D. Rafanoharana[54],
F. Raffaeli[76b], F. Ragusa[71a,71b], J.L. Rainbolt[39], J.A. Raine[56], S. Rajagopalan[29],
E. Ramakoti[37], I.A. Ramirez-Berend[34], K. Ran[48,14e], N.P. Rapheeha[33g], H. Rasheed[27b],
V. Raskina[127], D.F. Rassloff[63a], S. Rave[100], B. Ravina[55], I. Ravinovich[169],
M. Raymond[36], A.L. Read[125], N.P. Readioff[139], D.M. Rebuzzi[73a,73b], G. Redlinger[29],
A.S. Reed[110], K. Reeves[26], J.A. Reidelsturz[171,aa], D. Reikher[151], A. Rej[49,z],
C. Rembser[36], A. Renardi[48], M. Renda[27b], M.B. Rendel[110], F. Renner[48],
A.G. Rennie[160], A.L. Rescia[48], S. Resconi[71a], M. Ressegotti[57b,57a], S. Rettie[36],
J.G. Reyes Rivera[107], E. Reynolds[17a], O.L. Rezanova[37], P. Reznicek[133], N. Ribaric[91],
E. Ricci[78a,78b], R. Richter[110], S. Richter[47a,47b], E. Richter-Was[86b], M. Ridel[127],

S. Ridouani[35d], P. Rieck[117], P. Riedler[36], E.M. Riefel[47a,47b], J.O. Rieger[114],
M. Rijssenbeek[145], A. Rimoldi[73a,73b], M. Rimoldi[36], L. Rinaldi[23b,23a], T.T. Rinn[29],
M.P. Rinnagel[109], G. Ripellino[161], I. Riu[13], P. Rivadeneira[48], J.C. Rivera Vergara[165],
F. Rizatdinova[121], E. Rizvi[94], B.A. Roberts[167], B.R. Roberts[17a], S.H. Robertson[104,ai],
D. Robinson[32], C.M. Robles Gajardo[137f], M. Robles Manzano[100], A. Robson[59],
A. Rocchi[76a,76b], C. Roda[74a,74b], S. Rodriguez Bosca[63a], Y. Rodriguez Garcia[22a],
A. Rodriguez Rodriguez[54], A.M. Rodríguez Vera[156b], S. Roe[36], J.T. Roemer[160],
A.R. Roepe-Gier[136], J. Roggel[171], O. Røhne[125], R.A. Rojas[103], C.P.A. Roland[127],
J. Roloff[29], A. Romaniouk[37], E. Romano[73a,73b], M. Romano[23b],
A.C. Romero Hernandez[162], N. Rompotis[92], L. Roos[127], S. Rosati[75a], B.J. Rosser[39],
E. Rossi[126], E. Rossi[72a,72b], L.P. Rossi[57b], L. Rossini[54], R. Rosten[119], M. Rotaru[27b],
B. Rottler[54], C. Rougier[102,an], D. Rousseau[66], D. Rousso[32], A. Roy[162],
S. Roy-Garand[155], A. Rozanov[102], Z.M.A. Rozario[59], Y. Rozen[150], X. Ruan[33g],
A. Rubio Jimenez[163], A.J. Ruby[92], V.H. Ruelas Rivera[18], T.A. Ruggeri[1],
A. Ruggiero[126], A. Ruiz-Martinez[163], A. Rummler[36], Z. Rurikova[54], N.A. Rusakovich[38],
H.L. Russell[165], G. Russo[75a,75b], J.P. Rutherfoord[7], S. Rutherford Colmenares[32],
K. Rybacki[91], M. Rybar[133], E.B. Rye[125], A. Ryzhov[44], J.A. Sabater Iglesias[56],
P. Sabatini[163], L. Sabetta[75a,75b], H.F-W. Sadrozinski[136], F. Safai Tehrani[75a],
B. Safarzadeh Samani[134], M. Safdari[143], S. Saha[165], M. Sahinsoy[110], M. Saimpert[135],
M. Saito[153], T. Saito[153], D. Salamani[36], A. Salnikov[143], J. Salt[163],
A. Salvador Salas[151], D. Salvatore[43b,43a], F. Salvatore[146], A. Salzburger[36],
D. Sammel[54], D. Sampsonidis[152,f], D. Sampsonidou[123], J. Sánchez[163],
A. Sanchez Pineda[4], V. Sanchez Sebastian[163], H. Sandaker[125], C.O. Sander[48],
J.A. Sandesara[103], M. Sandhoff[171], C. Sandoval[22b], D.P.C. Sankey[134], T. Sano[88],
A. Sansoni[53], L. Santi[75a,75b], C. Santoni[40], H. Santos[130a,130b], S.N. Santpur[17a],
A. Santra[169], K.A. Saoucha[116b], J.G. Saraiva[130a,130d], J. Sardain[7], O. Sasaki[84],
K. Sato[157], C. Sauer[63b], F. Sauerburger[54], E. Sauvan[4], P. Savard[155,aw], R. Sawada[153],
C. Sawyer[134], L. Sawyer[97], I. Sayago Galvan[163], C. Sbarra[23b], A. Sbrizzi[23b,23a],
T. Scanlon[96], J. Schaarschmidt[138], P. Schacht[110], U. Schäfer[100], A.C. Schaffer[66,44],
D. Schaile[109], R.D. Schamberger[145], C. Scharf[18], M.M. Schefer[19], V.A. Schegelsky[37],
D. Scheirich[133], F. Schenck[18], M. Schernau[160], C. Scheulen[55], C. Schiavi[57b,57a],
E.J. Schioppa[70a,70b], M. Schioppa[43b,43a], B. Schlag[143,t], K.E. Schleicher[54],
S. Schlenker[36], J. Schmeing[171], M.A. Schmidt[171], K. Schmieden[100], C. Schmitt[100],
N. Schmitt[100], S. Schmitt[48], L. Schoeffel[135], A. Schoening[63b], P.G. Scholer[54],
E. Schopf[126], M. Schott[100], J. Schovancova[36], S. Schramm[56], F. Schroeder[171],
T. Schroer[56], H-C. Schultz-Coulon[63a], M. Schumacher[54], B.A. Schumm[136],
Ph. Schune[135], A.J. Schuy[138], H.R. Schwartz[136], A. Schwartzman[143], T.A. Schwarz[106],
Ph. Schwemling[135], R. Schwienhorst[107], A. Sciandra[136], G. Sciolla[26], F. Scuri[74a],
C.D. Sebastiani[92], K. Sedlaczek[115], P. Seema[18], S.C. Seidel[112], A. Seiden[136],
B.D. Seidlitz[41], C. Seitz[48], J.M. Seixas[83b], G. Sekhniaidze[72a], S.J. Sekula[44],
L. Selem[60], N. Semprini-Cesari[23b,23a], D. Sengupta[56], V. Senthilkumar[163], L. Serin[66],
L. Serkin[69a,69b], M. Sessa[76a,76b], H. Severini[120], F. Sforza[57b,57a], A. Sfyrla[56],
E. Shabalina[55], R. Shaheen[144], J.D. Shahinian[128], D. Shaked Renous[169], L.Y. Shan[14a],

M. Shapiro[17a], A. Sharma[36], A.S. Sharma[164], P. Sharma[80], S. Sharma[48], P.B. Shatalov[37], K. Shaw[146], S.M. Shaw[101], A. Shcherbakova[37], Q. Shen[62c,5], P. Sherwood[96], L. Shi[96], X. Shi[14a], C.O. Shimmin[172], J.D. Shinner[95], I.P.J. Shipsey[126], S. Shirabe[56,j], M. Shiyakova[38,ag], J. Shlomi[169], M.J. Shochet[39], J. Shojaii[105], D.R. Shope[125], B. Shrestha[120], S. Shrestha[119,ba], E.M. Shrif[33g], M.J. Shroff[165], P. Sicho[131], A.M. Sickles[162], E. Sideras Haddad[33g], A. Sidoti[23b], F. Siegert[50], Dj. Sijacki[15], R. Sikora[86a], F. Sili[90], J.M. Silva[20], M.V. Silva Oliveira[29], S.B. Silverstein[47a], S. Simion[66], R. Simoniello[36], E.L. Simpson[59], H. Simpson[146], L.R. Simpson[106], N.D. Simpson[98], S. Simsek[82], S. Sindhu[55], P. Sinervo[155], S. Singh[155], S. Sinha[48], S. Sinha[101], M. Sioli[23b,23a], I. Siral[36], E. Sitnikova[48], S.Yu. Sivoklokov[37,*], J. Sjölin[47a,47b], A. Skaf[55], E. Skorda[20,ar], P. Skubic[120], M. Slawinska[87], V. Smakhtin[169], B.H. Smart[134], J. Smiesko[36], S.Yu. Smirnov[37], Y. Smirnov[37], L.N. Smirnova[37,a], O. Smirnova[98], A.C. Smith[41], E.A. Smith[39], H.A. Smith[126], J.L. Smith[92], R. Smith[143], M. Smizanska[91], K. Smolek[132], A.A. Snesarev[37], S.R. Snider[155], H.L. Snoek[114], S. Snyder[29], R. Sobie[165,ai], A. Soffer[151], C.A. Solans Sanchez[36], E.Yu. Soldatov[37], U. Soldevila[163], A.A. Solodkov[37], S. Solomon[26], A. Soloshenko[38], K. Solovieva[54], O.V. Solovyanov[40], V. Solovyev[37], P. Sommer[36], A. Sonay[13], W.Y. Song[156b], J.M. Sonneveld[114], A. Sopczak[132], A.L. Sopio[96], F. Sopkova[28b], I.R. Sotarriva Alvarez[154], V. Sothilingam[63a], S. Sottocornola[68], R. Soualah[116b], Z. Soumaimi[35e], D. South[48], N. Soybelman[169], S. Spagnolo[70a,70b], M. Spalla[110], D. Sperlich[54], G. Spigo[36], S. Spinali[91], D.P. Spiteri[59], M. Spousta[133], E.J. Staats[34], A. Stabile[71a,71b], R. Stamen[63a], A. Stampekis[20], M. Standke[24], E. Stanecka[87], M.V. Stange[50], B. Stanislaus[17a], M.M. Stanitzki[48], B. Stapf[48], E.A. Starchenko[37], G.H. Stark[136], J. Stark[102,an], D.M. Starko[156b], P. Staroba[131], P. Starovoitov[63a], S. Stärz[104], R. Staszewski[87], G. Stavropoulos[46], J. Steentoft[161], P. Steinberg[29], B. Stelzer[142,156a], H.J. Stelzer[129], O. Stelzer-Chilton[156a], H. Stenzel[58], T.J. Stevenson[146], G.A. Stewart[36], J.R. Stewart[121], M.C. Stockton[36], G. Stoicea[27b], M. Stolarski[130a], S. Stonjek[110], A. Straessner[50], J. Strandberg[144], S. Strandberg[47a,47b], M. Stratmann[171], M. Strauss[120], T. Strebler[102], P. Strizenec[28b], R. Ströhmer[166], D.M. Strom[123], L.R. Strom[48], R. Stroynowski[44], A. Strubig[47a,47b], S.A. Stucci[29], B. Stugu[16], J. Stupak[120], N.A. Styles[48], D. Su[143], S. Su[62a], W. Su[62d], X. Su[62a,66], K. Sugizaki[153], V.V. Sulin[37], M.J. Sullivan[92], D.M.S. Sultan[78a,78b], L. Sultanaliyeva[37], S. Sultansoy[3b], T. Sumida[88], S. Sun[106], S. Sun[170], O. Sunneborn Gudnadottir[161], N. Sur[102], M.R. Sutton[146], H. Suzuki[157], M. Svatos[131], M. Swiatlowski[156a], T. Swirski[166], I. Sykora[28a], M. Sykora[133], T. Sykora[133], D. Ta[100], K. Tackmann[48,ae], A. Taffard[160], R. Tafirout[156a], J.S. Tafoya Vargas[66], E.P. Takeva[52], Y. Takubo[84], M. Talby[102], A.A. Talyshev[37], K.C. Tam[64b], N.M. Tamir[151], A. Tanaka[153], J. Tanaka[153], R. Tanaka[66], M. Tanasini[57b,57a], Z. Tao[164], S. Tapia Araya[137f], S. Tapprogge[100], A. Tarek Abouelfadl Mohamed[107], S. Tarem[150], K. Tariq[14a], G. Tarna[102,27b], G.F. Tartarelli[71a], P. Tas[133], M. Tasevsky[131], E. Tassi[43b,43a], A.C. Tate[162], G. Tateno[153], Y. Tayalati[35e,ah], G.N. Taylor[105], W. Taylor[156b], A.S. Tee[170], R. Teixeira De Lima[143], P. Teixeira-Dias[95], J.J. Teoh[155], K. Terashi[153], J. Terron[99], S. Terzo[13], M. Testa[53], R.J. Teuscher[155,ai], A. Thaler[79], O. Theiner[56],

N. Themistokleous[52], T. Theveneaux-Pelzer[102], O. Thielmann[171], D.W. Thomas[95],
J.P. Thomas[20], E.A. Thompson[17a], P.D. Thompson[20], E. Thomson[128], Y. Tian[55],
V. Tikhomirov[37,a], Yu.A. Tikhonov[37], S. Timoshenko[37], D. Timoshyn[133], E.X.L. Ting[1],
P. Tipton[172], S.H. Tlou[33g], A. Tnourji[40], K. Todome[154], S. Todorova-Nova[133],
S. Todt[50], M. Togawa[84], J. Tojo[89], S. Tokár[28a], K. Tokushuku[84], O. Toldaiev[68],
R. Tombs[32], M. Tomoto[84,111], L. Tompkins[143,t], K.W. Topolnicki[86b], E. Torrence[123],
H. Torres[102,an], E. Torró Pastor[163], M. Toscani[30], C. Tosciri[39], M. Tost[11],
D.R. Tovey[139], A. Traeet[16], I.S. Trandafir[27b], T. Trefzger[166], A. Tricoli[29],
I.M. Trigger[156a], S. Trincaz-Duvoid[127], D.A. Trischuk[26], B. Trocmé[60], C. Troncon[71a],
L. Truong[33c], M. Trzebinski[87], A. Trzupek[87], F. Tsai[145], M. Tsai[106], A. Tsiamis[152,f],
P.V. Tsiareshka[37], S. Tsigaridas[156a], A. Tsirigotis[152,ac], V. Tsiskaridze[155],
E.G. Tskhadadze[149a], M. Tsopoulou[152,f], Y. Tsujikawa[88], I.I. Tsukerman[37],
V. Tsulaia[17a], S. Tsuno[84], O. Tsur[150], K. Tsuri[118], D. Tsybychev[145], Y. Tu[64b],
A. Tudorache[27b], V. Tudorache[27b], A.N. Tuna[36], S. Turchikhin[57b,57a], I. Turk Cakir[3a],
R. Turra[71a], T. Turtuvshin[38,aj], P.M. Tuts[41], S. Tzamarias[152,f], P. Tzanis[10],
E. Tzovara[100], F. Ukegawa[157], P.A. Ulloa Poblete[137c,137b], E.N. Umaka[29], G. Unal[36],
M. Unal[11], A. Undrus[29], G. Unel[160], J. Urban[28b], P. Urquijo[105], P. Urrejola[137a],
G. Usai[8], R. Ushioda[154], M. Usman[108], Z. Uysal[21b], V. Vacek[132], B. Vachon[104],
K.O.H. Vadla[125], T. Vafeiadis[36], A. Vaitkus[96], C. Valderanis[109],
E. Valdes Santurio[47a,47b], M. Valente[156a], S. Valentinetti[23b,23a], A. Valero[163],
E. Valiente Moreno[163], A. Vallier[102,an], J.A. Valls Ferrer[163], D.R. Van Arneman[114],
T.R. Van Daalen[138], A. Van Der Graaf[49], P. Van Gemmeren[6], M. Van Rijnbach[125,36],
S. Van Stroud[96], I. Van Vulpen[114], M. Vanadia[76a,76b], W. Vandelli[36],
M. Vandenbroucke[135], E.R. Vandewall[121], D. Vannicola[151], L. Vannoli[57b,57a],
R. Vari[75a], E.W. Varnes[7], C. Varni[17b], T. Varol[148], D. Varouchas[66], L. Varriale[163],
K.E. Varvell[147], M.E. Vasile[27b], L. Vaslin[84], G.A. Vasquez[165], A. Vasyukov[38],
F. Vazeille[40], T. Vazquez Schroeder[36], J. Veatch[31], V. Vecchio[101], M.J. Veen[103],
I. Veliscek[126], L.M. Veloce[155], F. Veloso[130a,130c], S. Veneziano[75a], A. Ventura[70a,70b],
S. Ventura Gonzalez[135], A. Verbytskyi[110], M. Verducci[74a,74b], C. Vergis[24],
M. Verissimo De Araujo[83b], W. Verkerke[114], J.C. Vermeulen[114], C. Vernieri[143],
M. Vessella[103], M.C. Vetterli[142,aw], A. Vgenopoulos[152,f], N. Viaux Maira[137f],
T. Vickey[139], O.E. Vickey Boeriu[139], G.H.A. Viehhauser[126], L. Vigani[63b],
M. Villa[23b,23a], M. Villaplana Perez[163], E.M. Villhauer[52], E. Vilucchi[53], M.G. Vincter[34],
G.S. Virdee[20], A. Vishwakarma[52], A. Visibile[114], C. Vittori[36], I. Vivarelli[146],
E. Voevodina[110], F. Vogel[109], J.C. Voigt[50], P. Vokac[132], Yu. Volkotrub[86a],
J. Von Ahnen[48], E. Von Toerne[24], B. Vormwald[36], V. Vorobel[133], K. Vorobev[37],
M. Vos[163], K. Voss[141], J.H. Vossebeld[92], M. Vozak[114], L. Vozdecky[94], N. Vranjes[15],
M. Vranjes Milosavljevic[15], M. Vreeswijk[114], R. Vuillermet[36], O. Vujinovic[100],
I. Vukotic[39], S. Wada[157], C. Wagner[103], J.M. Wagner[17a], W. Wagner[171], S. Wahdan[171],
H. Wahlberg[90], M. Wakida[111], J. Walder[134], R. Walker[109], W. Walkowiak[141],
A. Wall[128], T. Wamorkar[6], A.Z. Wang[136], C. Wang[100], C. Wang[62c], H. Wang[17a],
J. Wang[64a], R.-J. Wang[100], R. Wang[61], R. Wang[6], S.M. Wang[148], S. Wang[62b],
T. Wang[62a], W.T. Wang[80], W. Wang[14a], X. Wang[14c], X. Wang[162], X. Wang[62c],

Y. Wang[62d], Y. Wang[14c], Z. Wang[106], Z. Wang[62d,51,62c], Z. Wang[106],
A. Warburton[104], R.J. Ward[20], N. Warrack[59], A.T. Watson[20], H. Watson[59],
M.F. Watson[20], E. Watton[59,134], G. Watts[138], B.M. Waugh[96], C. Weber[29],
H.A. Weber[18], M.S. Weber[19], S.M. Weber[63a], C. Wei[62a], Y. Wei[126], A.R. Weidberg[126],
E.J. Weik[117], J. Weingarten[49], M. Weirich[100], C. Weiser[54], C.J. Wells[48],
T. Wenaus[29], B. Wendland[49], T. Wengler[36], N.S. Wenke[110], N. Wermes[24],
M. Wessels[63a], A.M. Wharton[91], A.S. White[61], A. White[8], M.J. White[1],
D. Whiteson[160], L. Wickremasinghe[124], W. Wiedenmann[170], C. Wiel[50], M. Wielers[134],
C. Wiglesworth[42], D.J. Wilbern[120], H.G. Wilkens[36], D.M. Williams[41], H.H. Williams[128],
S. Williams[32], S. Willocq[103], B.J. Wilson[101], P.J. Windischhofer[39], F.I. Winkel[30],
F. Winklmeier[123], B.T. Winter[54], J.K. Winter[101], M. Wittgen[143], M. Wobisch[97],
Z. Wolffs[114], J. Wollrath[160], M.W. Wolter[87], H. Wolters[130a,130c], A.F. Wongel[48],
E.L. Woodward[41], S.D. Worm[48], B.K. Wosiek[87], K.W. Woźniak[87], S. Wozniewski[55],
K. Wraight[59], C. Wu[20], J. Wu[14a,14e], M. Wu[64a], M. Wu[113], S.L. Wu[170], X. Wu[56],
Y. Wu[62a], Z. Wu[135], J. Wuerzinger[110,au], T.R. Wyatt[101], B.M. Wynne[52], S. Xella[42],
L. Xia[14c], M. Xia[14b], J. Xiang[64c], M. Xie[62a], X. Xie[62a], S. Xin[14a,14e], A. Xiong[123],
J. Xiong[17a], I. Xiotidis[146], D. Xu[14a], H. Xu[62a], L. Xu[62a], R. Xu[128], T. Xu[106],
Y. Xu[14b], Z. Xu[52], B. Yabsley[147], S. Yacoob[33a], Y. Yamaguchi[154], E. Yamashita[153],
H. Yamauchi[157], T. Yamazaki[17a], Y. Yamazaki[85], J. Yan[62c], S. Yan[126], Z. Yan[25],
H.J. Yang[62c,62d], H.T. Yang[62a], S. Yang[62a], T. Yang[64c], X. Yang[36], X. Yang[14a],
Y. Yang[44], Y. Yang[62a], Z. Yang[62a], W-M. Yao[17a], Y.C. Yap[48], H. Ye[14c], H. Ye[55],
J. Ye[14a], S. Ye[29], X. Ye[62a], Y. Yeh[96], I. Yeletskikh[38], B.K. Yeo[17b], M.R. Yexley[96],
P. Yin[41], K. Yorita[168], S. Younas[27b], C.J.S. Young[36], C. Young[143], C. Yu[14a,14e,ay],
Y. Yu[62a], M. Yuan[106], R. Yuan[62b], L. Yue[96], M. Zaazoua[62a], B. Zabinski[87],
E. Zaid[52], T. Zakareishvili[149b], N. Zakharchuk[34], S. Zambito[56], J.A. Zamora Saa[137d,137b],
J. Zang[153], D. Zanzi[54], O. Zaplatilek[132], C. Zeitnitz[171], H. Zeng[14a], J.C. Zeng[162],
D.T. Zenger Jr[26], O. Zenin[37], T. Ženiš[28a], S. Zenz[94], S. Zerradi[35a], D. Zerwas[66],
M. Zhai[14a,14e], B. Zhang[14c], D.F. Zhang[139], J. Zhang[62b], J. Zhang[6], K. Zhang[14a,14e],
L. Zhang[14c], P. Zhang[14a,14e], R. Zhang[170], S. Zhang[106], S. Zhang[44], T. Zhang[153],
X. Zhang[62c], X. Zhang[62b], Y. Zhang[62c,5], Y. Zhang[96], Y. Zhang[14c], Z. Zhang[17a],
Z. Zhang[66], H. Zhao[138], P. Zhao[51], T. Zhao[62b], Y. Zhao[136], Z. Zhao[62a],
A. Zhemchugov[38], J. Zheng[14c], K. Zheng[162], X. Zheng[62a], Z. Zheng[143], D. Zhong[162],
B. Zhou[106], H. Zhou[7], N. Zhou[62c], Y. Zhou[7], C.G. Zhu[62b], J. Zhu[106], Y. Zhu[62c],
Y. Zhu[62a], X. Zhuang[14a], K. Zhukov[37], V. Zhulanov[37], N.I. Zimine[38], J. Zinsser[63b],
M. Ziolkowski[141], L. Živković[15], A. Zoccoli[23b,23a], K. Zoch[61], T.G. Zorbas[139],
O. Zormpa[46], W. Zou[41], L. Zwalinski[36]

[1] *Department of Physics, University of Adelaide, Adelaide; Australia*
[2] *Department of Physics, University of Alberta, Edmonton AB; Canada*
[3] (a)*Department of Physics, Ankara University, Ankara;*(b)*Division of Physics, TOBB University of Economics and Technology, Ankara; Türkiye*
[4] *LAPP, Université Savoie Mont Blanc, CNRS/IN2P3, Annecy; France*
[5] *APC, Université Paris Cité, CNRS/IN2P3, Paris; France*
[6] *High Energy Physics Division, Argonne National Laboratory, Argonne IL; U.S.A.*

[7] *Department of Physics, University of Arizona, Tucson AZ; U.S.A.*

[8] *Department of Physics, University of Texas at Arlington, Arlington TX; U.S.A.*

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

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

[11] *Department of Physics, University of Texas at Austin, Austin TX; U.S.A.*

[12] *Institute of Physics, Azerbaijan Academy of Sciences, Baku; Azerbaijan*

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

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

[15] *Institute of Physics, University of Belgrade, Belgrade; Serbia*

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

[17] *(a) Physics Division, Lawrence Berkeley National Laboratory, Berkeley CA; (b) University of California, Berkeley CA; U.S.A.*

[18] *Institut für Physik, Humboldt Universität zu Berlin, Berlin; Germany*

[19] *Albert Einstein Center for Fundamental Physics and Laboratory for High Energy Physics, University of Bern, Bern; Switzerland*

[20] *School of Physics and Astronomy, University of Birmingham, Birmingham; U.K.*

[21] *(a) Department of Physics, Bogazici University, Istanbul; (b) Department of Physics Engineering, Gaziantep University, Gaziantep; (c) Department of Physics, Istanbul University, Istanbul; Türkiye*

[22] *(a) Facultad de Ciencias y Centro de Investigaciónes, Universidad Antonio Nariño, Bogotá; (b) Departamento de Física, Universidad Nacional de Colombia, Bogotá; (c) Pontificia Universidad Javeriana, Bogota; Colombia*

[23] *(a) Dipartimento di Fisica e Astronomia A. Righi, Università di Bologna, Bologna; (b) INFN Sezione di Bologna; Italy*

[24] *Physikalisches Institut, Universität Bonn, Bonn; Germany*

[25] *Department of Physics, Boston University, Boston MA; U.S.A.*

[26] *Department of Physics, Brandeis University, Waltham MA; U.S.A.*

[27] *(a) Transilvania University of Brasov, Brasov; (b) Horia Hulubei National Institute of Physics and Nuclear Engineering, Bucharest; (c) Department of Physics, Alexandru Ioan Cuza University of Iasi, Iasi; (d) National Institute for Research and Development of Isotopic and Molecular Technologies, Physics Department, Cluj-Napoca; (e) University Politehnica Bucharest, Bucharest; (f) West University in Timisoara, Timisoara; (g) Faculty of Physics, University of Bucharest, Bucharest; Romania*

[28] *(a) Faculty of Mathematics, Physics and Informatics, Comenius University, Bratislava; (b) Department of Subnuclear Physics, Institute of Experimental Physics of the Slovak Academy of Sciences, Kosice; Slovak Republic*

[29] *Physics Department, Brookhaven National Laboratory, Upton NY; U.S.A.*

[30] *Universidad de Buenos Aires, Facultad de Ciencias Exactas y Naturales, Departamento de Física, y CONICET, Instituto de Física de Buenos Aires (IFIBA), Buenos Aires; Argentina*

[31] *California State University, CA; U.S.A.*

[32] *Cavendish Laboratory, University of Cambridge, Cambridge; U.K.*

[33] *(a) Department of Physics, University of Cape Town, Cape Town; (b) iThemba Labs, Western Cape; (c) Department of Mechanical Engineering Science, University of Johannesburg, Johannesburg; (d) National Institute of Physics, University of the Philippines Diliman (Philippines); (e) University of South Africa, Department of Physics, Pretoria; (f) University of Zululand, KwaDlangezwa; (g) School of Physics, University of the Witwatersrand, Johannesburg; South Africa*

[34] *Department of Physics, Carleton University, Ottawa ON; Canada*

[35] *(a) Faculté des Sciences Ain Chock, Réseau Universitaire de Physique des Hautes Energies — Université Hassan II, Casablanca; (b) Faculté des Sciences, Université Ibn-Tofail, Kénitra; (c) Faculté des Sciences Semlalia, Université Cadi Ayyad, LPHEA-Marrakech; (d) LPMR, Faculté des Sciences,*

Université Mohamed Premier, Oujda;(e) Faculté des sciences, Université Mohammed V, Rabat;(f) Institute of Applied Physics, Mohammed VI Polytechnic University, Ben Guerir; Morocco
[36] CERN, Geneva; Switzerland
[37] Affiliated with an institute covered by a cooperation agreement with CERN
[38] Affiliated with an international laboratory covered by a cooperation agreement with CERN
[39] Enrico Fermi Institute, University of Chicago, Chicago IL; U.S.A.
[40] LPC, Université Clermont Auvergne, CNRS/IN2P3, Clermont-Ferrand; France
[41] Nevis Laboratory, Columbia University, Irvington NY; U.S.A.
[42] Niels Bohr Institute, University of Copenhagen, Copenhagen; Denmark
[43] (a) Dipartimento di Fisica, Università della Calabria, Rende;(b) INFN Gruppo Collegato di Cosenza, Laboratori Nazionali di Frascati; Italy
[44] Physics Department, Southern Methodist University, Dallas TX; U.S.A.
[45] Physics Department, University of Texas at Dallas, Richardson TX; U.S.A.
[46] National Centre for Scientific Research "Demokritos", Agia Paraskevi; Greece
[47] (a) Department of Physics, Stockholm University;(b) Oskar Klein Centre, Stockholm; Sweden
[48] Deutsches Elektronen-Synchrotron DESY, Hamburg and Zeuthen; Germany
[49] Fakultät Physik , Technische Universität Dortmund, Dortmund; Germany
[50] Institut für Kern- und Teilchenphysik, Technische Universität Dresden, Dresden; Germany
[51] Department of Physics, Duke University, Durham NC; U.S.A.
[52] SUPA — School of Physics and Astronomy, University of Edinburgh, Edinburgh; U.K.
[53] INFN e Laboratori Nazionali di Frascati, Frascati; Italy
[54] Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Freiburg; Germany
[55] II. Physikalisches Institut, Georg-August-Universität Göttingen, Göttingen; Germany
[56] Département de Physique Nucléaire et Corpusculaire, Université de Genève, Genève; Switzerland
[57] (a) Dipartimento di Fisica, Università di Genova, Genova;(b) INFN Sezione di Genova; Italy
[58] II. Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen; Germany
[59] SUPA — School of Physics and Astronomy, University of Glasgow, Glasgow; U.K.
[60] LPSC, Université Grenoble Alpes, CNRS/IN2P3, Grenoble INP, Grenoble; France
[61] Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge MA; U.S.A.
[62] (a) Department of Modern Physics and State Key Laboratory of Particle Detection and Electronics, University of Science and Technology of China, Hefei;(b) Institute of Frontier and Interdisciplinary Science and Key Laboratory of Particle Physics and Particle Irradiation (MOE), Shandong University, Qingdao;(c) School of Physics and Astronomy, Shanghai Jiao Tong University, Key Laboratory for Particle Astrophysics and Cosmology (MOE), SKLPPC, Shanghai;(d) Tsung-Dao Lee Institute, Shanghai; China
[63] (a) Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Heidelberg;(b) Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg; Germany
[64] (a) Department of Physics, Chinese University of Hong Kong, Shatin, N.T., Hong Kong;(b) Department of Physics, University of Hong Kong, Hong Kong;(c) Department of Physics and Institute for Advanced Study, Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong; China
[65] Department of Physics, National Tsing Hua University, Hsinchu; Taiwan
[66] IJCLab, Université Paris-Saclay, CNRS/IN2P3, 91405, Orsay; France
[67] Centro Nacional de Microelectrónica (IMB-CNM-CSIC), Barcelona; Spain
[68] Department of Physics, Indiana University, Bloomington IN; U.S.A.
[69] (a) INFN Gruppo Collegato di Udine, Sezione di Trieste, Udine;(b) ICTP, Trieste;(c) Dipartimento Politecnico di Ingegneria e Architettura, Università di Udine, Udine; Italy
[70] (a) INFN Sezione di Lecce;(b) Dipartimento di Matematica e Fisica, Università del Salento, Lecce; Italy
[71] (a) INFN Sezione di Milano;(b) Dipartimento di Fisica, Università di Milano, Milano; Italy
[72] (a) INFN Sezione di Napoli;(b) Dipartimento di Fisica, Università di Napoli, Napoli; Italy
[73] (a) INFN Sezione di Pavia;(b) Dipartimento di Fisica, Università di Pavia, Pavia; Italy
[74] (a) INFN Sezione di Pisa;(b) Dipartimento di Fisica E. Fermi, Università di Pisa, Pisa; Italy

[75] (a) *INFN Sezione di Roma;* (b) *Dipartimento di Fisica, Sapienza Università di Roma, Roma; Italy*
[76] (a) *INFN Sezione di Roma Tor Vergata;* (b) *Dipartimento di Fisica, Università di Roma Tor Vergata, Roma; Italy*
[77] (a) *INFN Sezione di Roma Tre;* (b) *Dipartimento di Matematica e Fisica, Università Roma Tre, Roma; Italy*
[78] (a) *INFN-TIFPA;* (b) *Università degli Studi di Trento, Trento; Italy*
[79] *Universität Innsbruck, Department of Astro and Particle Physics, Innsbruck; Austria*
[80] *University of Iowa, Iowa City IA; U.S.A.*
[81] *Department of Physics and Astronomy, Iowa State University, Ames IA; U.S.A.*
[82] *Istinye University, Sariyer, Istanbul; Türkiye*
[83] (a) *Departamento de Engenharia Elétrica, Universidade Federal de Juiz de Fora (UFJF), Juiz de Fora;* (b) *Universidade Federal do Rio De Janeiro COPPE/EE/IF, Rio de Janeiro;* (c) *Instituto de Física, Universidade de São Paulo, São Paulo;* (d) *Rio de Janeiro State University, Rio de Janeiro; Brazil*
[84] *KEK, High Energy Accelerator Research Organization, Tsukuba; Japan*
[85] *Graduate School of Science, Kobe University, Kobe; Japan*
[86] (a) *AGH University of Krakow, Faculty of Physics and Applied Computer Science, Krakow;* (b) *Marian Smoluchowski Institute of Physics, Jagiellonian University, Krakow; Poland*
[87] *Institute of Nuclear Physics Polish Academy of Sciences, Krakow; Poland*
[88] *Faculty of Science, Kyoto University, Kyoto; Japan*
[89] *Research Center for Advanced Particle Physics and Department of Physics, Kyushu University, Fukuoka; Japan*
[90] *Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata; Argentina*
[91] *Physics Department, Lancaster University, Lancaster; U.K.*
[92] *Oliver Lodge Laboratory, University of Liverpool, Liverpool; U.K.*
[93] *Department of Experimental Particle Physics, Jožef Stefan Institute and Department of Physics, University of Ljubljana, Ljubljana; Slovenia*
[94] *School of Physics and Astronomy, Queen Mary University of London, London; U.K.*
[95] *Department of Physics, Royal Holloway University of London, Egham; U.K.*
[96] *Department of Physics and Astronomy, University College London, London; U.K.*
[97] *Louisiana Tech University, Ruston LA; U.S.A.*
[98] *Fysiska institutionen, Lunds universitet, Lund; Sweden*
[99] *Departamento de Física Teorica C-15 and CIAFF, Universidad Autónoma de Madrid, Madrid; Spain*
[100] *Institut für Physik, Universität Mainz, Mainz; Germany*
[101] *School of Physics and Astronomy, University of Manchester, Manchester; U.K.*
[102] *CPPM, Aix-Marseille Université, CNRS/IN2P3, Marseille; France*
[103] *Department of Physics, University of Massachusetts, Amherst MA; U.S.A.*
[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; U.S.A.*
[107] *Department of Physics and Astronomy, Michigan State University, East Lansing MI; U.S.A.*
[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; U.S.A.*
[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; U.S.A.*
[116] (a) *New York University Abu Dhabi, Abu Dhabi;* (b) *University of Sharjah, Sharjah; United Arab Emirates*

[117] *Department of Physics, New York University, New York NY; U.S.A.*
[118] *Ochanomizu University, Otsuka, Bunkyo-ku, Tokyo; Japan*
[119] *Ohio State University, Columbus OH; U.S.A.*
[120] *Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman OK; U.S.A.*
[121] *Department of Physics, Oklahoma State University, Stillwater OK; U.S.A.*
[122] *Palacký University, Joint Laboratory of Optics, Olomouc; Czech Republic*
[123] *Institute for Fundamental Science, University of Oregon, Eugene, OR; U.S.A.*
[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; U.K.*
[127] *LPNHE, Sorbonne Université, Université Paris Cité, CNRS/IN2P3, Paris; France*
[128] *Department of Physics, University of Pennsylvania, Philadelphia PA; U.S.A.*
[129] *Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh PA; U.S.A.*
[130] (a) *Laboratório de Instrumentação e Física Experimental de Partículas — LIP, Lisboa;* (b) *Departamento de Física, Faculdade de Ciências, Universidade de Lisboa, Lisboa;* (c) *Departamento de Física, Universidade de Coimbra, Coimbra;* (d) *Centro de Física Nuclear da Universidade de Lisboa, Lisboa;* (e) *Departamento de Física, Universidade do Minho, Braga;* (f) *Departamento de Física Teórica y del Cosmos, Universidad de Granada, Granada (Spain);* (g) *Departamento de Física, Instituto Superior Técnico, Universidade de Lisboa, Lisboa; Portugal*
[131] *Institute of Physics of the Czech Academy of Sciences, Prague; Czech Republic*
[132] *Czech Technical University in Prague, Prague; Czech Republic*
[133] *Charles University, Faculty of Mathematics and Physics, Prague; Czech Republic*
[134] *Particle Physics Department, Rutherford Appleton Laboratory, Didcot; U.K.*
[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; U.S.A.*
[137] (a) *Departamento de Física, Pontificia Universidad Católica de Chile, Santiago;* (b) *Millennium Institute for Subatomic physics at high energy frontier (SAPHIR), Santiago;* (c) *Instituto de Investigación Multidisciplinario en Ciencia y Tecnología, y Departamento de Física, Universidad de La Serena;* (d) *Universidad Andres Bello, Department of Physics, Santiago;* (e) *Instituto de Alta Investigación, Universidad de Tarapacá, Arica;* (f) *Departamento de Física, Universidad Técnica Federico Santa María, Valparaíso; Chile*
[138] *Department of Physics, University of Washington, Seattle WA; U.S.A.*
[139] *Department of Physics and Astronomy, University of Sheffield, Sheffield; U.K.*
[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; U.S.A.*
[144] *Department of Physics, Royal Institute of Technology, Stockholm; Sweden*
[145] *Departments of Physics and Astronomy, Stony Brook University, Stony Brook NY; U.S.A.*
[146] *Department of Physics and Astronomy, University of Sussex, Brighton; U.K.*
[147] *School of Physics, University of Sydney, Sydney; Australia*
[148] *Institute of Physics, Academia Sinica, Taipei; Taiwan*
[149] (a) *E. Andronikashvili Institute of Physics, Iv. Javakhishvili Tbilisi State University, Tbilisi;* (b) *High Energy Physics Institute, Tbilisi State University, Tbilisi;* (c) *University of Georgia, Tbilisi; Georgia*
[150] *Department of Physics, Technion, Israel Institute of Technology, Haifa; Israel*
[151] *Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv; Israel*
[152] *Department of Physics, Aristotle University of Thessaloniki, Thessaloniki; Greece*
[153] *International Center for Elementary Particle Physics and Department of Physics, University of Tokyo, Tokyo; Japan*
[154] *Department of Physics, Tokyo Institute of Technology, Tokyo; Japan*

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

[a] *Also Affiliated with an institute covered by a cooperation agreement with CERN*
[b] *Also at An-Najah National University, Nablus; Palestine*
[c] *Also at APC, Université Paris Cité, CNRS/IN2P3, Paris; France*
[d] *Also at Borough of Manhattan Community College, City University of New York, New York NY; U.S.A.*
[e] *Also at Center for High Energy Physics, Peking University; China*
[f] *Also at Center for Interdisciplinary Research and Innovation (CIRI-AUTH), Thessaloniki; Greece*
[g] *Also at Centro Studi e Ricerche Enrico Fermi; Italy*
[h] *Also at CERN Tier-0; Switzerland*
[i] *Also at CERN, Geneva; Switzerland*
[j] *Also at Département de Physique Nucléaire et Corpusculaire, Université de Genève, Genève; Switzerland*
[k] *Also at Departament de Fisica de la Universitat Autonoma de Barcelona, Barcelona; Spain*
[l] *Also at Department of Financial and Management Engineering, University of the Aegean, Chios; Greece*
[m] *Also at Department of Physics and Astronomy, University of Sheffield, Sheffield; U.K.*
[n] *Also at Department of Physics and Astronomy, University of Victoria, Victoria BC; Canada*
[o] *Also at Department of Physics, Ben Gurion University of the Negev, Beer Sheva; Israel*
[p] *Also at Department of Physics, California State University, Sacramento; U.S.A.*
[q] *Also at Department of Physics, King's College London, London; U.K.*
[r] *Also at Department of Physics, Oxford University, Oxford; U.K.*
[s] *Also at Department of Physics, Royal Holloway University of London, Egham; U.K.*
[t] *Also at Department of Physics, Stanford University, Stanford CA; U.S.A.*
[u] *Also at Department of Physics, University of Fribourg, Fribourg; Switzerland*
[v] *Also at Department of Physics, University of Massachusetts, Amherst MA; U.S.A.*
[w] *Also at Department of Physics, University of Thessaly; Greece*
[x] *Also at Department of Physics, Westmont College, Santa Barbara; U.S.A.*
[y] *Also at Deutsches Elektronen-Synchrotron DESY, Hamburg and Zeuthen; Germany*
[z] *Also at Fakultät Physik , Technische Universität Dortmund, Dortmund; Germany*

[aa] *Also at Fakultät für Mathematik und Naturwissenschaften, Fachgruppe Physik, Bergische Universität Wuppertal, Wuppertal; Germany*

[ab] *Also at Group of Particle Physics, University of Montreal, Montreal QC; Canada*

[ac] *Also at Hellenic Open University, Patras; Greece*

[ad] *Also at Institucio Catalana de Recerca i Estudis Avancats, ICREA, Barcelona; Spain*

[ae] *Also at Institut für Experimentalphysik, Universität Hamburg, Hamburg; Germany*

[af] *Also at Institut für Physik, Universität Mainz, Mainz; Germany*

[ag] *Also at Institute for Nuclear Research and Nuclear Energy (INRNE) of the Bulgarian Academy of Sciences, Sofia; Bulgaria*

[ah] *Also at Institute of Applied Physics, Mohammed VI Polytechnic University, Ben Guerir; Morocco*

[ai] *Also at Institute of Particle Physics (IPP); Canada*

[aj] *Also at Institute of Physics and Technology, Ulaanbaatar; Mongolia*

[ak] *Also at Institute of Physics, Azerbaijan Academy of Sciences, Baku; Azerbaijan*

[al] *Also at Institute of Theoretical Physics, Ilia State University, Tbilisi; Georgia*

[am] *Also at IRFU, CEA, Université Paris-Saclay, Gif-sur-Yvette; France*

[an] *Also at L2IT, Université de Toulouse, CNRS/IN2P3, UPS, Toulouse; France*

[ao] *Also at Lawrence Livermore National Laboratory, Livermore; U.S.A.*

[ap] *Also at National Institute of Physics, University of the Philippines Diliman (Philippines); Philippines*

[aq] *Also at Ochanomizu University, Otsuka, Bunkyo-ku, Tokyo; Japan*

[ar] *Also at School of Physics and Astronomy, University of Birmingham, Birmingham; U.K.*

[as] *Also at School of Physics and Astronomy, University of Manchester, Manchester; U.K.*

[at] *Also at SUPA — School of Physics and Astronomy, University of Glasgow, Glasgow; U.K.*

[au] *Also at Technical University of Munich, Munich; Germany*

[av] *Also at The Collaborative Innovation Center of Quantum Matter (CICQM), Beijing; China*

[aw] *Also at TRIUMF, Vancouver BC; Canada*

[ax] *Also at Università di Napoli Parthenope, Napoli; Italy*

[ay] *Also at University of Chinese Academy of Sciences (UCAS), Beijing; China*

[az] *Also at University of Colorado Boulder, Department of Physics, Colorado; U.S.A.*

[ba] *Also at Washington College, Chestertown, MD; U.S.A.*

[bb] *Also at Yeditepe University, Physics Department, Istanbul; Türkiye*

[*] *Deceased*