EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH (CERN)

Submitted to: Phys. Rev. Lett.

CERN-EP-2021-065
May 28, 2021

Search for new phenomena in final states with two leptons and one or no b-tagged jets at $\sqrt{s} = 13$ TeV using the ATLAS detector

The ATLAS Collaboration

A search for new phenomena is presented in final states with two leptons and one or no b-tagged jets. The event selection requires the two leptons to have opposite charge, the same flavor (electrons or muons), and a large invariant mass. The analysis is based on the full Run-2 proton–proton collision dataset recorded at a center-of-mass energy of $\sqrt{s} = 13$ TeV by the ATLAS experiment at the LHC, corresponding to an integrated luminosity of 139 fb^{-1}. No significant deviation from the expected background is observed in the data. A four-fermion contact interaction between two quarks (b, s) and two leptons (ee or $\mu\mu$), inspired by the B-meson decay anomalies, is used as a benchmark signal model. This model is characterized by the energy scale and coupling, Λ and g_* respectively. Contact interactions with Λ/g_* lower than 2.0 (2.4) TeV are excluded for electrons (muons) at the 95% confidence level, still far below the value which is favored by the B-meson decay anomalies. In addition, model-independent limits are set as a function of the selection on the dilepton invariant mass, which allows the results to be reinterpreted in other signal scenarios.

Lepton flavor universality (LFU) is one of the fundamental predictions of the Standard Model (SM). LFU was tested extensively at LEP and SLD [1], and found to be compatible with the SM prediction. Several recent measurements hint at a possible violation of LFU in rare B-meson decays [2–13] into a K-meson and a pair of muons or electrons. Possible extensions to the SM suggest that the decay mechanism implies that physics beyond the SM (BSM) is present between the initial common state (b-quark) and the final state (s-quark and two charged electrons or muons). The BSM interaction can be modeled by using an effective field theory (EFT) with a four-point contact interaction between the common fermions involved ($bs\ell\ell$, $\ell = e, \mu$), where the scale and coupling of the underlying physics are denoted by Λ and g_*, respectively,[1] and can be searched for in final states with two opposite-charge and same-flavor leptons produced in association with exactly one b-quark or without any b-quarks. To explain the asymmetries measured in the B-meson decays, the $bs\ell\ell$ interaction would have to be different between electrons and muons. At tree level, there is no interference with the SM, and therefore it is neglected. The phenomenological framework for this analysis was suggested in Ref. [15]. The associated B-meson decay anomalies could correspond to a $bs\ell\ell$ operator with $\Lambda/g_* \approx 30$ TeV [16, 17], which is well beyond the discovery reach of the present search. Furthermore, other works showed that this unique signature provides enhanced sensitivity to other signal scenarios as well [14, 18]. Figure 1 shows Feynman diagrams for B-meson decays via the SM and via a $bs\ell\ell$ contact interaction, and for the production process via a $bs\ell\ell$ contact interaction in proton–proton (pp) collisions.

In this Letter, a search for new phenomena is presented, using pp collisions at a center-of-mass energy of $\sqrt{s} = 13$ TeV produced by the Large Hadron Collider (LHC). Data recorded by the ATLAS detector [19] during 2015–2018 are used, corresponding to an integrated luminosity of 139 fb^{-1}. Final states with two oppositely charged electrons or muons are considered separately, and further categorized into events with either no b-tagged jets or exactly one b-tagged jet. The $bs\ell\ell$ EFT is considered as a benchmark model, and model-independent results are also presented.

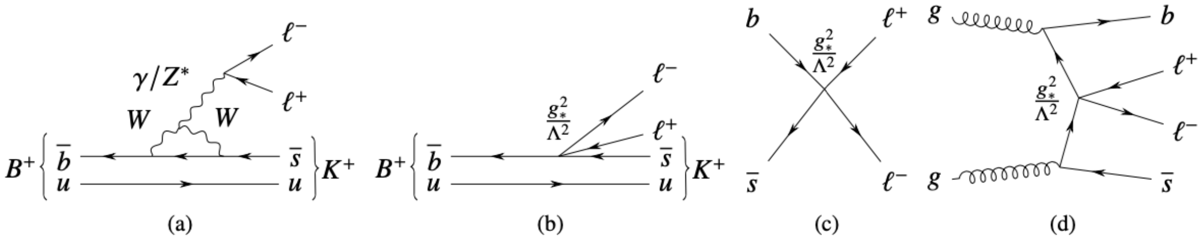
The ATLAS experiment at the LHC is a multipurpose particle detector with a forward–backward symmetric cylindrical geometry and a near 4π coverage in solid angle.[2] It consists of an inner tracking detector surrounded by a thin superconducting solenoid providing a 2 T axial magnetic field, electromagnetic and hadronic calorimeters, and a muon spectrometer. The inner tracking detector (ID) covers the pseudorapidity range $|\eta| < 2.5$. It consists of silicon pixel, silicon microstrip, and transition radiation tracking detectors, with a new innermost layer, the insertable B-layer, added to the pixel detector before Run 2 [20, 21]. Lead/liquid-argon (LAr) sampling calorimeters provide electromagnetic (EM) energy measurements with high granularity. A steel/scintillator-tile hadronic calorimeter covers the central pseudorapidity range ($|\eta| < 1.7$). The endcap and forward regions are instrumented with LAr calorimeters for EM and hadronic energy measurements up to $|\eta| = 4.9$. The muon spectrometer (MS) surrounds the calorimeters and is based on three large air-core toroidal superconducting 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.

Monte Carlo (MC) simulations are used to model the expected SM background and the benchmark signals. The Powheg Box v1 MC generator [22–25] was used to simulate at next-to-leading-order (NLO) accuracy

---

[1] For a discussion regarding the validity of the EFT parameter space see e.g. Ref. [14].

[2] ATLAS uses a right-handed coordinate system with its origin at the nominal interaction point (IP) in the center of the detector and the z-axis along the beam pipe. The x-axis points from the IP to the center of the LHC ring, and the y-axis points upwards. Cylindrical coordinates (r, ϕ) are used in the transverse plane, ϕ being the azimuthal angle around the z-axis. The pseudorapidity is defined in terms of the polar angle θ as $\eta = -\ln\tan(\theta/2)$. Angular distance is measured in units of $\Delta R \equiv \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2}$. The transverse momentum is defined as $p_{\mathrm{T}} = p\sin\theta = p/\cosh\eta$, and the transverse energy, E_{T}, is defined analogously.



(a) (b) (c) (d)

Figure 1: Representative Feynman diagrams for the decay of a B^+ meson to a K^+ meson in association with two leptons (a) in the SM and (b) in the EFT approach, and for production of two leptons via a $bs\ell\ell$ contact interaction in pp collisions (c) without and (d) with a b-jet in the final state.

in perturbative QCD the hard-scattering process of Z/γ^*-boson production and decay. It was interfaced to Pythia 8.186 to model the parton shower, hadronization, and underlying event, with parameters set according to the AZNLO tune [26]. The CT10 parton distribution function (PDF) set [27] was used for the hard scattering process, whereas the CTEQ6L1 PDF set [28] was used for the parton shower. The effect of QED final-state radiation (FSR) was simulated with Photos++ 3.52 [29, 30]. The use of Powheg Box was validated by a generator-level comparison with a sample produced by Sherpa 2.2.1 [31] using NLO matrix elements for up to two partons, and leading-order (LO) matrix elements for up to four partons calculated with the Comix [32] and OpenLoops 1 [33–35] libraries. Samples of diboson (W-boson) events, denoted by VV (W+jets), were simulated with Sherpa 2.2.2 (2.2.1) [31] using matrix elements at NLO accuracy in QCD with up to one (two) additional partons and up to three (four) additional parton emissions at LO, while additional corrections were calculated using the Comix [32] and OpenLoops 1 [33–35] libraries. The `NNPDF3.0nnlo` set of PDFs [36] was used for VV and W+jets productions. For both VV and W+jets, the matrix elements were matched with the Sherpa parton shower [37] using the MEPS@NLO prescription [38–41] and the parameter tune developed by the Sherpa authors. The W+jets samples were normalized to a next-to-next-to-leading-order (NNLO) prediction [42]. The production of $t\bar{t}$ and single-top-quark Wt events was modeled using the Powheg Box v2 generator at NLO with the `NNPDF3.0nlo` PDF set, and the h_{damp} parameter set to $1.5m_{\text{top}}$. Events were interfaced to Pythia 8.230 [43] to model the parton shower, hadronization, and underlying event, using the A14 parameter tune [44] and the `NNPDF2.3lo` set of PDFs. For Wt events, the diagram removal scheme [45] was used to remove interference with $t\bar{t}$ production. The production of $t\bar{t}V$ events was modeled using the MadGraph5_aMC@NLO v2.3.3 [46] generator at NLO with the `NNPDF3.0nlo` PDF set. The events were interfaced to Pythia 8.210 using the A14 tune and the `NNPDF2.3lo` PDF set. The EvtGen 1.2.0 (1.6.0) program [47] was used to decay bottom and charm hadrons for the $t\bar{t}V$ and Z/γ^* ($t\bar{t}$) processes. The $bs\ell\ell$ EFT signal was generated at LO with up to two partons in the final state by MadGraph5_aMC@NLO with the `NNPDF2.3lo` PDF set and the A14 tune of Pythia 8 parameters, using the CKKW-L merging algorithm [48] with a k_t-Durham parameter of 400 GeV. A model provided by the authors of Ref. [15] was used.[3] The cross section for the simulated signal with $\Lambda/g_* = 1$ TeV is 0.113 pb, for both electrons and muons. The ATLAS detector response was simulated with Geant4 [49, 50], except for signal samples, where a fast simulation [51] was used. The effect of multiple interactions in the same and neighboring bunch crossings (pileup) was modeled by overlaying simulated inelastic pp events generated by Pythia 8.186 [52] with the A3 tune [53] and the `NNPDF2.3lo` PDF set [36]. All MC distributions were reweighted so that the distribution of the average number of interactions per bunch crossing corresponds to the distribution in data.

Only events taken during stable beam conditions, and for which all relevant components of the detector

---

[3] The model can be found at the FeynRules database: http://feynrules.irmp.ucl.ac.be/wiki/FCNC4F.

were operational, are considered. Single-lepton triggers were used [54, 55], with p_{T} threshold of 60 GeV or 140 GeV for electrons, depending on the identification requirement, and 50 GeV for muons. Selected events must have a primary vertex with at least two tracks with a minimum p_{T} of 500 MeV, where the highest $\Sigma_{\mathrm{tracks}} p_{\mathrm{T}}^2$ vertex is chosen as the primary one [56].

Electrons are reconstructed [57] from energy clusters in the electromagnetic calorimeter with ID tracks matched to them, and are required to fulfill the "tight likelihood" identification criteria as well as calorimeter- and track-based isolation criteria. Electrons must have a minimum transverse energy of 30 GeV, and must be within the region $|\eta_{\mathrm{cluster}}| < 2.47$, excluding the barrel/endcap transition region, $1.37 < |\eta_{\mathrm{cluster}}| < 1.52$. Muons are reconstructed [58] from combined tracks in the MS and the ID with a minimum p_{T} of 30 GeV, must fulfill the "high-p_{T}" identification criteria, which aim to optimize the momentum resolution for tracks with high transverse momentum, and must be within the region $|\eta| < 2.5$. For muons, track-based isolation criteria are required based on the scalar sum of the transverse momenta of the ID tracks associated with the primary vertex, excluding the muon track itself. Muon (electron) candidates are required to originate from the primary vertex by requiring the significance of the track's transverse impact parameter calculated relative to the beam line, $d_0/\sigma(d_0)$, to be smaller than 3.0 (5.0). Furthermore, the longitudinal impact parameter z_0, defined as the difference between the z-coordinate of the point of closest approach to the beam line and the longitudinal position of the primary vertex, is required to satisfy $|z_0 \sin(\theta)| < 0.5$ mm. Jets are reconstructed from energy deposits in topological clusters of calorimeter cells [59] with the particle-flow algorithm [60, 61], with a radius parameter of 0.4, with energy calibrated at particle level [62] and are required to be within $|\eta| < 2.5$ and to have a minimum p_{T} of 30 GeV. For jets with $|\eta| < 2.4$ and $p_{\mathrm{T}} < 60$ GeV, pileup contributions are suppressed by the use of the jet vertex tagger [63]. Jets are identified as containing b-hadrons using the DL1 algorithm [64, 65], with a b-tagging efficiency of $\sim$77% for b-jets, and a rejection factor of $\sim$6 for c-jets and $\sim$110 for other light jets, based on simulated $t\bar{t}$ events. Finally, a sequential overlap-removal procedure is used, since a physics object can be reconstructed as several object types. The procedure is as follows: in the first step, electrons that share a track with a muon are removed; in the second step, any jet that has a ΔR to an electron that is smaller than 0.2 is removed; and in the third step, electrons are removed if they are geometrically closer than $\Delta R = 0.4$ to any remaining jet. Jets that have a $\Delta R < 0.04 + 10\ \mathrm{GeV}/p_{\mathrm{T}}(\mu)$ to a muon are removed if they have at most two associated tracks with $p_{\mathrm{T}}(\mathrm{track}) > 0.5$ GeV, otherwise the muon is removed.

Events are selected by requiring the presence of two same-flavor leptons (electrons or muons) with opposite electric charge, where at least one of the leptons is required to geometrically match the object which fired the trigger. To ensure high trigger efficiency, the p_{T} threshold for the leading lepton is raised to 65 GeV. Those selections are common to all of the regions defined in the analysis. Two channels are defined depending on the presence of a b-tagged jet, targeting two different production mechanisms. The b-veto category, also denoted by $e^+e^-/\mu^+\mu^- + 0b$, discards any event with a b-tagged jet, while the b-tag category, also denoted by $e^+e^-/\mu^+\mu^- + 1b$, requires exactly one b-tagged jet in each event. A set of signal regions (SRs) is defined with lower bounds on $m_{\ell\ell}$, $m_{\ell\ell}^{\mathrm{min}}$, ranging from 400 GeV to 3200 (2000) GeV for the b-veto (b-tag) category with a step size of 100 GeV, where each SR is defined by requiring $m_{\ell\ell} > m_{\ell\ell}^{\mathrm{min}}$. Control regions (CR) are defined in order to normalize the contribution of the two dominant background processes originating from $t\bar{t}$, Wt and $t\bar{t}V$, together denoted by "Top", and Z/γ^*+jets processes. The Z/γ^*+jets CRs (Z-CRs) are defined by requiring events to be within 130 GeV $< m_{\ell\ell} <$ 250 GeV, while the intermediate mass range, 250 GeV $< m_{\ell\ell} <$ 400 GeV, serves as a validation region (VR) to test the background modeling. For each Z-CR and VR the same splitting based on the presence of b-tagged jets as in the SRs is applied. Finally, a top-CR is constructed by requiring exactly two b-tagged jets and the dilepton invariant mass to satisfy $m_{\ell\ell} > 130$ GeV.

The regime with high invariant mass of the dilepton system, $m_{\ell\ell}$, in the Top background processes, suffers from having few events in the MC simulation. A fit-based extrapolation procedure is used to estimate the tails of the Top $m_{\ell\ell}$ distributions with functions which have been used in other ATLAS searches [66]:

$$f^{\mathrm{bkg1}}(m_{\ell\ell}) = \mathrm{e}^{-a} m_{\ell\ell}^{b} m_{\ell\ell}^{c\log(m_{\ell\ell})} \text{ and } f^{\mathrm{bkg2}}(m_{\ell\ell}) = \frac{a}{(m_{\ell\ell}+b)^{c}},$$

where a, b, c are free parameters. Several fits are performed by using both functions, while varying the start and end point of the fit range. A χ^2 test is performed in order to describe the level of agreement between the different fits and the MC prediction. The fit with the lowest χ^2 provides the nominal choice of the function parameters values while all other fits with χ^2 probability smaller than a fixed value are used for the uncertainty estimation. This fixed value is chosen such that near the transition point between the simulation and the extrapolation, the overall uncertainty accounted by the experimental and modeling systematic along with the MC statistic uncertainties on the simulated background, are similar to the resulting uncertainty on the extrapolation. Furthermore, checks are performed in order to make sure that the fitted function reproduces the MC event yields at lower values of $m_{\ell\ell}$ and that the cumulative distribution of the extrapolation is consistent with the small integrated event yields available in the MC samples. Finally, since the extrapolation is done for the combined Top sample, which includes all top-related processes, it was checked that those processes have a similar $m_{\ell\ell}$ shape within uncertainties. For the Top background extrapolation, the transition points between simulation and extrapolation in the $m_{\ell\ell}$ distribution are (1000, 1200, 1200/1300) GeV for the $(0, 1, 2)$-b-tagged jets selections, respectively, in the electron/muon channels.

The background contribution of events with reconstructed objects which have been misidentified as leptons, referred to as “Multijet”, is estimated using a data-driven approach. In the muon channel, this contribution is found to be negligible, while in the electron channel it is on the order of a few percent of the total background estimate. The matrix-method is used for the electron channel, similarly to the procedure described in Ref. [67]. The probabilities that a jet and a real electron satisfy the electron identification criteria are evaluated, for both the nominal and the “loose likelihood” identification criteria, while for the former no isolation criteria are applied. Then, these probabilities are used in order to estimate the Multijet contribution in the selected region. The Multijet background estimation suffers from having few events at high $m_{\ell\ell}$, and an extrapolation procedure similar to that for Top processes is used, with transition points at (800, 600, 600) GeV for the $(0, 1, 2)$-b-tagged jets selections, respectively.

Experimental systematic uncertainties, related to the modeling of the detector response in the simulation, are considered. The uncertainty in the combined 2015–2018 integrated luminosity is 1.7% [68]. Uncertainties in electron and muon trigger, reconstruction, and identification efficiencies, and energy and momentum calibration and resolution are derived from data using $Z \rightarrow \ell\ell$ and $J/\psi \rightarrow \ell\ell$ decays [57, 69]. Uncertainties in the jet energy scale and resolution are evaluated from MC simulations and from data using Multijet, Z + jets, and γ + jets events [62]. Uncertainties in the b-tagging efficiency are derived from data [70] for b-jets, c-jets, and other light jets. MC simulations are used to extrapolate the efficiencies to regions beyond the kinematic reach of each calibration. In order to assess the systematic uncertainty due to pileup, the reweighting to match simulation to data is varied within its uncertainty. Finally, the uncertainty related to the extrapolation of the Top and Multijet backgrounds is evaluated as described earlier in the text.

Theoretical systematic uncertainties, related to the modeling of the background processes in the MC simulation, are considered as well. The Z/γ^*+jets PDF variation uncertainty is estimated using the 90% confidence level (CL) CT14nnlo PDF error set, following Refs. [67, 71–73]. The uncertainty due to α_{s} is assessed by using the CT14nnlo PDF set where the value of α_{s} is shifted by as much as 0.003 from the

Table 1: Summary of the relative systematic uncertainties for signal regions with $m_{\ell\ell}^{\text{min}}$ = 2000 (1500) GeV before the fit is performed for the b-veto (b-tag) categories.

Source	$e^+e^- + 0b\ (1b)$ [%]		$\mu^+\mu^- + 0b\ (1b)$ [%]	
	Signal $0b$ ($1b$)	Background $0b$ ($1b$)	Signal $0b$ ($1b$)	Background $0b$ ($1b$)
Luminosity	1.7 (1.7)	1.6 (1.5)	1.7 (1.7)	1.7 (1.7)
Pileup	<0.5 (<0.5)	<0.5 (0.7)	<0.5 (<0.5)	<0.5 (<0.5)
Leptons	8.7 (8.6)	8.6 (6.3)	8.5 (6.5)	9.1 (4.2)
Jets	<0.5 (1.8)	<0.5 (3.4)	<0.5 (1.6)	<0.5 (1.9)
b-tagging	<0.5 (1.4)	<0.5 (2.0)	<0.5 (1.4)	<0.5 (2.2)
Top bkg. extrapolation	-	3.5 (32.0)	-	<0.5 (36.0)
Multijet extrapolation	-	7.5 (15.0)	-	-
Top bkg. modeling	-	<0.5 (<0.5)	-	<0.5 (<0.5)
Z/γ^*+jets bkg. modeling	-	9.4 (4.3)	-	10.0 (5.5)
MC statistics	0.6 (0.8)	1.9 (3.5)	0.7 (1.0)	1.7 (2.4)
Total	8.9 (9.1)	15.0 (37.0)	8.7 (7.1)	14.0 (37.0)

nominal value $\alpha_{\text{s}}(m_Z) = 0.118$, while QCD scale uncertainties are obtained by varying the renormalization and factorization scales simultaneously by a factor of two up and down. Furthermore, the uncertainty due to the choice of PDF set is estimated by using the NNPDF3.0 PDF set instead of the nominal choice of CT14nnlo [73]. Corrections due to photon-induced processes are estimated using the MRST2004qed PDF set [74]. NLO electroweak corrections for Z/γ^*+jets are applied as well except for QED FSR. For $t\bar{t}$ and single-top-quark production, an uncertainty in the cross section originating from scale, PDF+α_{s} and top-quark-mass uncertainties is applied. The nominal sample is compared with a sample generated with MadGraph5_aMC@NLO to estimate the matrix-element uncertainty. For the parton-shower uncertainty, the nominal sample is compared with a sample simulated with Powheg Box interfaced to Herwig 7 [75]. To simulate higher parton radiation, the factorization and renormalization scales are varied by a factor of 0.5 in the matrix element while using the "up" variation from the A14 parameter tune in the parton shower. For lower parton radiation, the renormalization and factorization scales are varied by a factor of 2.0 while using the "down" variation in the parton shower. The impact of FSR is evaluated using parton-shower weights which vary the renormalization scale for QCD emission in the FSR by factors of 0.5 or 2.0. For $t\bar{t}$ and single-top-quark events, the PDF uncertainty is derived using 30 eigenvector variations as specified in Ref. [73], in order to account for distribution shape uncertainties. For $t\bar{t}$ production, the impact of factorization and renormalization scale uncertainties on the shapes of distributions is derived by varying those scales by a factor of 0.5 or 2.0 relative to the nominal selection. Finally, the nominal Wt sample is compared with a sample generated using the diagram subtraction scheme [45, 76].

The statistical uncertainties of the simulated event samples are also taken into account. Systematic uncertainties which are lower than 0.5% in a given region are not considered in the fit or in the limit derivation. Table 1 presents the systematic uncertainties for one signal region from each channel.

The signal and background yields are estimated using simultaneous maximum-likelihood fits of the signal-plus-background and background-only hypothesis. Systematic uncertainties are included as nuisance parameters (NPs), and are constrained in the fit. For each background in each region, an additional NP is included to cover the statistical uncertainty of the MC samples. Dedicated fit parameters are used as additional NPs to adjust the Top and Z/γ^*+jets background normalizations. A likelihood ratio test statistic is used to assess the compatibility of the data with the background-only hypothesis to derive limits on the BSM signals, following the procedure described in Ref. [77]. For setting exclusion limits on the signal, the $\mathrm{CL_s}$ method [78] is used. This method is performed separately for each of the b-tag and b-veto categories in the electron and muon channels, by considering a single-bin SR and the relevant CRs per category.

The data agree well with the SM prediction in all of the VRs after the fit. The post-fit $m_{\ell\ell}$ distributions in the SRs are presented in Figure 2 for the background-only hypothesis, while the fit is done only at the CRs (CR-only fit) and then used to estimate the background yields. The cumulative $m_{\ell\ell}$ distribution for the signal regions after the CR-only fit to the data are shown in Figure 3 together with the yields in the different control and validation regions. The largest deviation from the SM prediction is observed in the $e^+e^- + 1b$ category. Here, the local observed significance exceeds two standard deviations for $m_{\ell\ell}^{\mathrm{min}} = 1500$–$2000$ GeV, while $m_{\ell\ell}^{\mathrm{min}} = 1700$ GeV yields the largest observed local significance of 2.6 standard deviations from the prediction of the SM. The global significance for the largest local deviation is estimated by generating pseudo-experiments using all of the electron b-tag associated SRs, and found to be 1.5 standard deviations. In Figure 4, model-independent upper limits on the signal cross section times selection efficiency times detector acceptance ($\sigma_{\mathrm{vis}} = \sigma \cdot \epsilon \cdot \mathcal{A}$) are presented for each signal region selection. For the $bs\ell\ell$ benchmark model, the strongest expected limits on the signal are found with a selection of $m_{\ell\ell}^{\mathrm{min}} = 1900$ (1500) GeV in the $e^+e^- + 0b$ ($1b$) category, which corresponds to expected and observed lower limits on Λ/g_* of up to 2.2 (2.2) TeV and 2.0 (1.8) TeV, respectively, and with a selection of $m_{\ell\ell}^{\mathrm{min}} = 1800$ (1600) GeV in the $\mu^+\mu^- + 0b$ ($1b$) category, which corresponds to expected and observed lower limits on Λ/g_* of up to 2.1 (2.1) TeV and 2.4 (2.0) TeV, respectively. The excluded values of Λ/g_* are far below the value which is favored by the anomalies, which is ≈ 30 TeV.

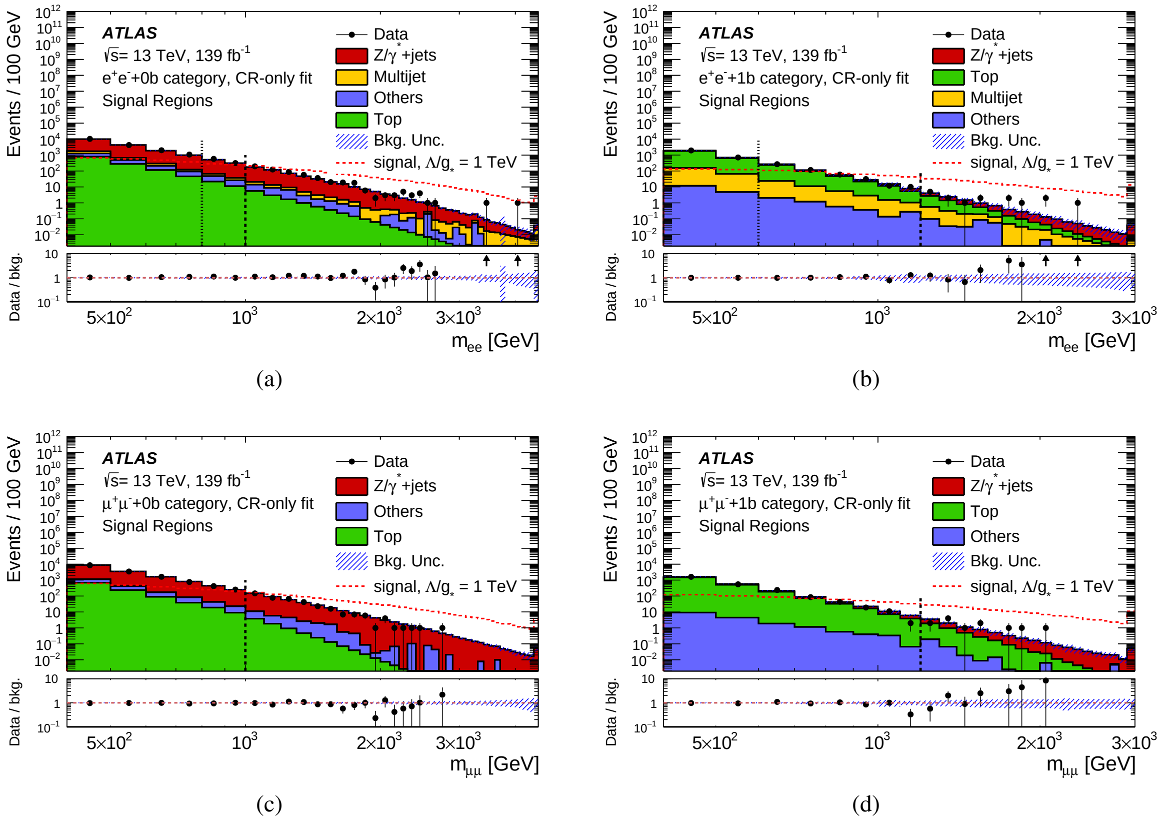
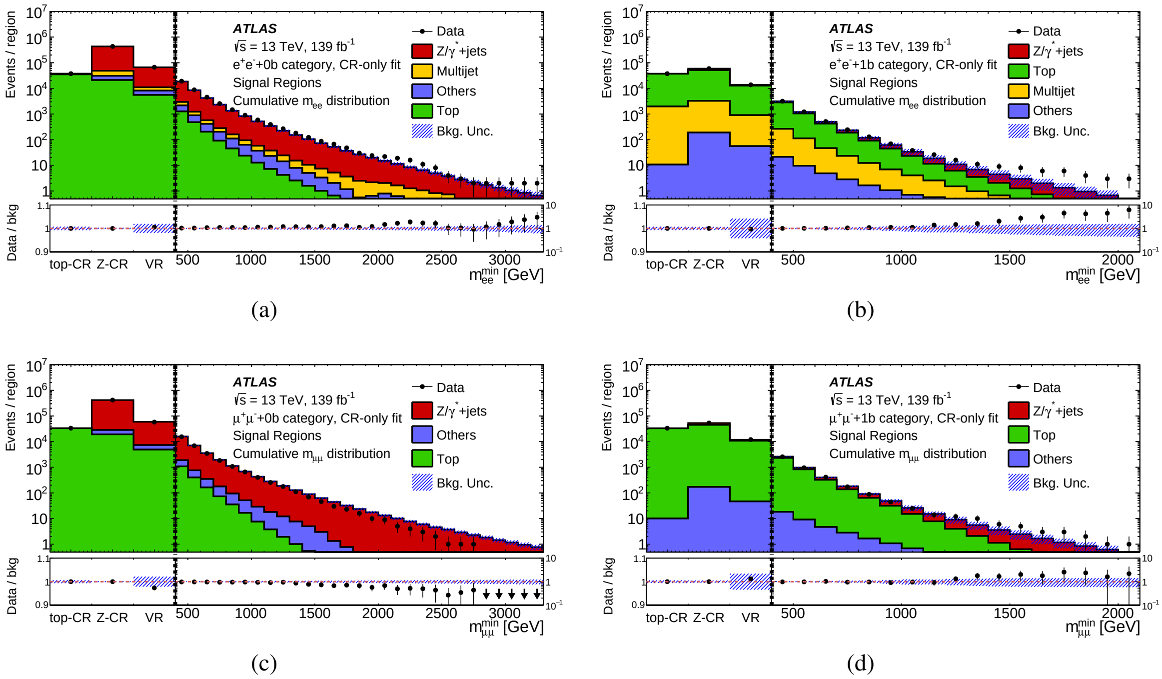


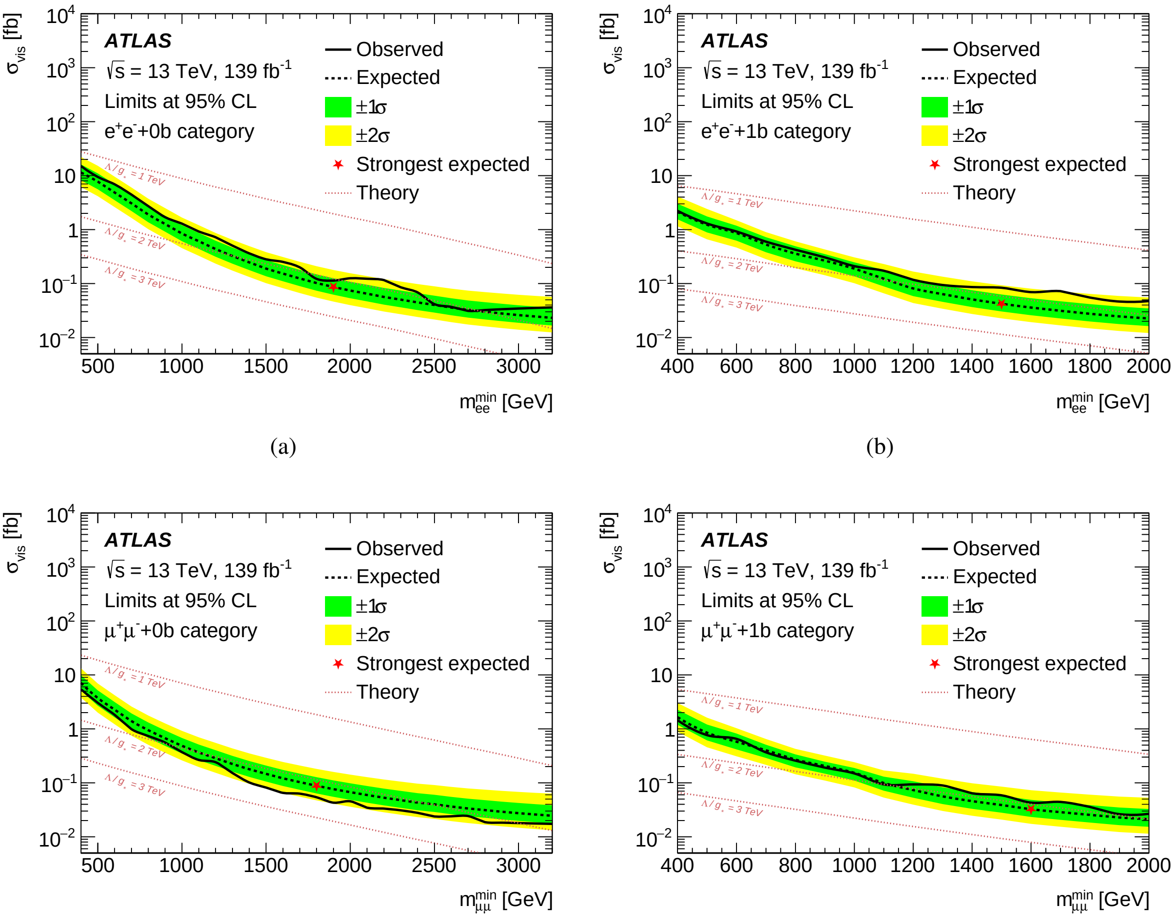
Figure 2: Data overlaid on SM background post-fit $m_{\ell\ell}$ distributions in the SRs of the (a) electron b-veto, (b) electron b-tag, (c) muon b-veto and (d) muon b-tag categories. "Others" refers to diboson and W+jets events. MC statistical uncertainties and systematic uncertainties are considered (hatched band). The pre-fit signal distribution is presented as well for a hypothesis of $\Lambda/g_* = 1$ TeV. The bottom panels show the ratio of the data to the background prediction, while the arrows correspond to bins where the ratio is beyond the limits of the figure. The last bin is an overflow bin, which contains the yields in the bins beyond it. The dashed and dotted lines mark the transition point where the extrapolation is used in the analysis for the Top and Multijet backgrounds, respectively.



(a) (b)

(c) (d)

Figure 3: Data overlaid on SM background post-fit yields in the regions of the (a) electron b-veto, (b) electron b-tag, (c) muon b-veto and (d) muon b-tag categories. “Others” refers to diboson and W+jets events. MC statistical uncertainties and systematic uncertainties are considered (hatched band). The left part of each figure presents the yields in the CRs and the VR of each category, while the right part presents the yields in the SRs of each category. The bottom panels show the ratio of the data to the background prediction, while the arrows correspond to bins where the ratio is beyond the limits of the figure. The range of the y-axis is different between the left and right parts of the bottom panels, and the latter is presented at logarithmic scale. For the SRs, as the distribution is cumulative, each bin is contained in and therefore correlated with the lower mass bins.



(a)

(b)

(c)

(d)

Figure 4: Model-independent observed (solid line) and expected (dashed line) upper limit on the visible cross section ($\sigma_{\text{vis}} = \sigma \cdot \epsilon \cdot \mathcal{A}$) for the (a) electron b-veto, (b) electron b-tag, (c) muon b-veto and (d) muon b-tag categories. The uncertainty bands around the expected limit represent the 68% and 95% confidence intervals. The theory lines (dotted lines) correspond to particular Λ/g_* values of the signal model, and the red marker presents the strongest expected lower limit on Λ/g_*.

In summary, a search for new phenomena was conducted in final states with two leptons and one or no b-tagged jets. Two categories were considered for both electron pairs and muon pairs: b-tag and b-veto final states. The analysis was conducted using 139 fb^{-1} of pp collision data at $\sqrt{s} = 13$ TeV recorded by the ATLAS detector at the Large Hadron Collider. No significant excess of events above the expected SM background is observed. Model-independent upper limits at 95% CL were set on the signal cross section in each of the signal regions. A first search for a $bs\ell\ell$ contact interaction is presented, and values of Λ/g_* smaller than 2.0 (2.4) TeV are excluded using the observed limits for electrons (muons) at 95% CL, which is still far below the value which has been predicted in order to explain the B-meson decay anomalies.

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; SSTC, Belarus; CNPq and FAPESP, Brazil; NSERC, NRC and CFI, Canada; CERN; ANID, Chile; CAS, MOST and NSFC, China; COLCIENCIAS, Colombia; MSMT CR, MPO CR and VSC CR, Czech Republic; DNRF and DNSRC, Denmark; IN2P3-CNRS and CEA-DRF/IRFU, France; SRNSFG, Georgia; BMBF, HGF and MPG, Germany; GSRT, Greece; RGC and Hong Kong SAR, China; ISF and Benoziyo Center, Israel; INFN, Italy; MEXT and JSPS, Japan; CNRST, Morocco; NWO, Netherlands; RCN, Norway; MNiSW and NCN, Poland; FCT, Portugal; MNE/IFA, Romania; JINR; MES of Russia and NRC KI, Russian Federation; MESTD, Serbia; MSSR, Slovakia; ARRS and MIZŠ, Slovenia; DST/NRF, South Africa; MICINN, Spain; SRC and Wallenberg Foundation, Sweden; SERI, SNSF and Cantons of Bern and Geneva, Switzerland; MOST, Taiwan; TAEK, Turkey; STFC, United Kingdom; DOE and NSF, United States of America. In addition, individual groups and members have received support from BCKDF, CANARIE, Compute Canada, CRC and IVADO, Canada; Beijing Municipal Science & Technology Commission, China; 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 GIF, Israel; 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. [79].

The ATLAS Collaboration

G. Aad[99], B. Abbott[124], D.C. Abbott[100], A. Abed Abud[34], K. Abeling[51], D.K. Abhayasinghe[91], S.H. Abidi[27], H. Abramowicz[157], H. Abreu[156], Y. Abulaiti[5], A.C. Abusleme Hoffman[142a], B.S. Acharya[64a,64b,p], B. Achkar[51], C. Adam Bourdarios[4], L. Adamczyk[81a], L. Adamek[162], J. Adelman[117], A. Adiguzel[11c,ad], S. Adorni[52], T. Adye[139], A.A. Affolder[141], Y. Afik[156], C. Agapopoulou[62], M.N. Agaras[12], J. Agarwala[68a,68b], A. Aggarwal[115], C. Agheorghiesei[25c], J.A. Aguilar-Saavedra[135f,135a,ac], A. Ahmad[34], F. Ahmadov[77], W.S. Ahmed[101], X. Ai[44], G. Aielli[71a,71b], S. Akatsuka[83], M. Akbiyik[97], T.P.A. Åkesson[94], A.V. Akimov[108], K. Al Khoury[37], G.L. Alberghi[21b,21a], J. Albert[171], M.J. Alconada Verzini[86], S. Alderweireldt[48], M. Aleksa[34], I.N. Aleksandrov[77], C. Alexa[25b], T. Alexopoulos[9], A. Alfonsi[116], F. Alfonsi[21b,21a], M. Alhroob[124], B. Ali[137], S. Ali[154], M. Aliev[161], G. Alimonti[66a], C. Allaire[34], B.M.M. Allbrooke[152], P.P. Allport[19], A. Aloisio[67a,67b], F. Alonso[86], C. Alpigiani[144], E. Alunno Camelia[71a,71b], M. Alvarez Estevez[96], M.G. Alviggi[67a,67b], Y. Amaral Coutinho[78b], A. Ambler[101], L. Ambroz[130], C. Amelung[34], D. Amidei[103], S.P. Amor Dos Santos[135a], S. Amoroso[44], C.S. Amrouche[52], C. Anastopoulos[145], T. Andeen[10], J.K. Anders[18], S.Y. Andrean[43a,43b], A. Andreazza[66a,66b], V. Andrei[59a], S. Angelidakis[8], A. Angerami[37], A.V. Anisenkov[118b,118a], A. Annovi[69a], C. Antel[52], M.T. Anthony[145], E. Antipov[125], M. Antonelli[49], D.J.A. Antrim[16], F. Anulli[70a], M. Aoki[79], J.A. Aparisi Pozo[169], M.A. Aparo[152], L. Aperio Bella[44], N. Aranzabal[34], V. Araujo Ferraz[78a], C. Arcangeletti[49], A.T.H. Arce[47], E. Arena[88], J-F. Arguin[107], S. Argyropoulos[50], J.-H. Arling[44], A.J. Armbruster[34], O. Arnaez[162], H. Arnold[34], Z.P. Arrubarrena Tame[111], G. Artoni[130], H. Asada[113], K. Asai[122], S. Asai[159], N.A. Asbah[57], L. Asquith[152], J. Assahsah[33e], K. Assamagan[27], R. Astalos[26a], R.J. Atkin[31a], M. Atkinson[168], N.B. Atlay[17], H. Atmani[58b], P.A. Atmasiddha[103], K. Augsten[137], S. Auricchio[67a,67b], V.A. Austrup[177], G. Avolio[34], M.K. Ayoub[13c], G. Azuelos[107,ai], D. Babal[26a], H. Bachacou[140], K. Bachas[158], F. Backman[43a,43b], A. Badea[57], P. Bagnaia[70a,70b], H. Bahrasemani[148], A.J. Bailey[169], V.R. Bailey[168], J.T. Baines[139], C. Bakalis[9], O.K. Baker[178], P.J. Bakker[116], E. Bakos[14], D. Bakshi Gupta[7], S. Balaji[153], R. Balasubramanian[116], E.M. Baldin[118b,118a], P. Balek[138], E. Ballabene[66a,66b], F. Balli[140], W.K. Balunas[130], J. Balz[97], E. Banas[82], M. Bandieramonte[134], A. Bandyopadhyay[17], L. Barak[157], E.L. Barberio[102], D. Barberis[53b,53a], M. Barbero[99], G. Barbour[92], K.N. Barends[31a], T. Barillari[112], M-S. Barisits[34], T. Barklow[149], B.M. Barnett[139], R.M. Barnett[16], A. Baroncelli[58a], G. Barone[27], A.J. Barr[130], L. Barranco Navarro[43a,43b], F. Barreiro[96], J. Barreiro Guimarães da Costa[13a], U. Barron[157], S. Barsov[133], F. Bartels[59a], R. Bartoldus[149], G. Bartolini[99], A.E. Barton[87], P. Bartos[26a], A. Basalaev[44], A. Basan[97], I. Bashta[72a,72b], A. Bassalat[62], M.J. Basso[162], C.R. Basson[98], R.L. Bates[55], S. Batlamous[33f], J.R. Batley[30], B. Batool[147], M. Battaglia[141], M. Bauce[70a,70b], F. Bauer[140,*], P. Bauer[22], H.S. Bawa[29], A. Bayirli[11c], J.B. Beacham[47], T. Beau[131], P.H. Beauchemin[165], F. Becherer[50], P. Bechtle[22], H.P. Beck[18,r], K. Becker[173], C. Becot[44], A.J. Beddall[11a], V.A. Bednyakov[77], C.P. Bee[151], T.A. Beermann[177], M. Begalli[78b], M. Begel[27], A. Behera[151], J.K. Behr[44], C. Beirao Da Cruz E Silva[34], J.F. Beirer[51,34], F. Beisiegel[22], M. Belfkir[4], G. Bella[157], L. Bellagamba[21b], A. Bellerive[32], P. Bellos[19], K. Beloborodov[118b,118a], K. Belotskiy[109], N.L. Belyaev[109], D. Benchekroun[33a], Y. Benhammou[157], D.P. Benjamin[27], M. Benoit[27], J.R. Bensinger[24], S. Bentvelsen[116], L. Beresford[34], M. Beretta[49], D. Berge[17], E. Bergeaas Kuutmann[167], N. Berger[4], B. Bergmann[137], L.J. Bergsten[24], J. Beringer[16], S. Berlendis[6], G. Bernardi[131], C. Bernius[149], F.U. Bernlochner[22], T. Berry[91], P. Berta[44], A. Berthold[46], I.A. Bertram[87], S. Bethke[112], A. Betti[40], A.J. Bevan[90], S. Bhatta[151], D.S. Bhattacharya[172], P. Bhattarai[24], V.S. Bhopatkar[5], R.M. Bianchi[134], O. Biebel[111], R. Bielski[34], M. Biglietti[72a], T.R.V. Billoud[137], M. Bindi[51], A. Bingul[11d], C. Bini[70a,70b], S. Biondi[21b,21a], C.J. Birch-sykes[98], G.A. Bird[19,139], M. Birman[175], T. Bisanz[34], J.P. Biswal[2], D. Biswas[176,k], A. Bitadze[98], C. Bittrich[46], K. Bjørke[129], I. Bloch[44], C. Blocker[24], A. Blue[55], U. Blumenschein[90], G.J. Bobbink[116], V.S. Bobrovnikov[118b,118a], D. Bogavac[12], A.G. Bogdanchikov[118b,118a], C. Bohm[43a], V. Boisvert[91], P. Bokan[44], T. Bold[81a], M. Bomben[131], M. Bona[90], M. Boonekamp[140], C.D. Booth[91], A.G. Borbély[55], H.M. Borecka-Bielska[107], L.S. Borgna[92], G. Borissov[87], D. Bortoletto[130], D. Boscherini[21b], M. Bosman[12], J.D. Bossio Sola[101], K. Bouaouda[33a], J. Boudreau[134], E.V. Bouhova-Thacker[87], D. Boumediene[36], R. Bouquet[131], A. Boveia[123], J. Boyd[34], D. Boye[27], I.R. Boyko[77], A.J. Bozson[91], J. Bracinik[19], N. Brahimi[58d,58c], G. Brandt[177], O. Brandt[30], F. Braren[44], B. Brau[100], J.E. Brau[127], K. Brendlinger[44], R. Brener[175], L. Brenner[34], R. Brenner[167], S. Bressler[175], B. Brickwedde[97], D.L. Briglin[19], D. Britton[55], D. Britzger[112], I. Brock[22], R. Brock[104], G. Brooijmans[37], W.K. Brooks[142d], E. Brost[27], P.A. Bruckman de Renstrom[82], B. Brüers[44], D. Bruncko[26b], A. Bruni[21b], G. Bruni[21b], M. Bruschi[21b], N. Bruscino[70a,70b], L. Bryngemark[149], T. Buanes[15], Q. Buat[151], P. Buchholz[147], A.G. Buckley[55], I.A. Budagov[77], M.K. Bugge[129], O. Bulekov[109], B.A. Bullard[57], T.J. Burch[117], S. Burdin[88], C.D. Burgard[44], A.M. Burger[125], B. Burghgrave[7], J.T.P. Burr[44], C.D. Burton[10], J.C. Burzynski[100], V. Büscher[97], P.J. Bussey[55], J.M. Butler[23], C.M. Buttar[55], J.M. Butterworth[92], W. Buttinger[139], C.J. Buxo Vazquez[104], A.R. Buzykaev[118b,118a], G. Cabras[21b,21a], S. Cabrera Urbán[169], D. Caforio[54], H. Cai[134], V.M.M. Cairo[149], O. Cakir[3a], N. Calace[34], P. Calafiura[16], G. Calderini[131], P. Calfayan[63], G. Callea[55], L.P. Caloba[78b], A. Caltabiano[71a,71b], S. Calvente Lopez[96], D. Calvet[36], S. Calvet[36], T.P. Calvet[99], M. Calvetti[69a,69b], R. Camacho Toro[131], S. Camarda[34], D. Camarero Munoz[96], P. Camarri[71a,71b], M.T. Camerlingo[72a,72b], D. Cameron[129], C. Camincher[171], M. Campanelli[92], A. Camplani[38], V. Canale[67a,67b], A. Canesse[101], M. Cano Bret[75], J. Cantero[125], Y. Cao[168], M. Capua[39b,39a], A. Carbone[66a,66b], R. Cardarelli[71a], F. Cardillo[169], G. Carducci[39b,39a], T. Carli[34], G. Carlino[67a], B.T. Carlson[134], E.M. Carlson[171,163a], L. Carminati[66a,66b], M. Carnesale[70a,70b], R.M.D. Carney[149], S. Caron[115], E. Carquin[142d], S. Carrá[44], G. Carratta[21b,21a], J.W.S. Carter[162], T.M. Carter[48], D. Casadei[31c], M.P. Casado[12,h], A.F. Casha[162], E.G. Castiglia[178], F.L. Castillo[59a], L. Castillo Garcia[12], V. Castillo Gimenez[169], N.F. Castro[135a,135e], A. Catinaccio[34], J.R. Catmore[129], A. Cattai[34], V. Cavaliere[27], N. Cavalli[21b,21a], V. Cavasinni[69a,69b], E. Celebi[11b], F. Celli[130], K. Cerny[126], A.S. Cerqueira[78a], A. Cerri[152], L. Cerrito[71a,71b], F. Cerutti[16], A. Cervelli[21b,21a], S.A. Cetin[11b], Z. Chadi[33a], D. Chakraborty[117], M. Chala[135f], J. Chan[176], W.Y. Chan[88], J.D. Chapman[30], B. Chargeishvili[155b], D.G. Charlton[19], T.P. Charman[90], M. Chatterjee[18], C.C. Chau[32], S. Chekanov[5], S.V. Chekulaev[163a], G.A. Chelkov[77,af], A. Chen[103], B. Chen[157], C. Chen[58a], C.H. Chen[76], H. Chen[13c], H. Chen[27], J. Chen[58a], J. Chen[37], J. Chen[24], S. Chen[132], S.J. Chen[13c], X. Chen[13b], Y. Chen[58a], Y-H. Chen[44], C.L. Cheng[176], H.C. Cheng[60a], H.J. Cheng[13a], A. Cheplakov[77], E. Cheremushkina[44], R. Cherkaoui El Moursli[33f], E. Cheu[6], K. Cheung[61], L. Chevalier[140], V. Chiarella[49], G. Chiarelli[69a], G. Chiodini[65a], A.S. Chisholm[19], A. Chitan[25b], I. Chiu[159], Y.H. Chiu[171], M.V. Chizhov[77,t], K. Choi[10], A.R. Chomont[70a,70b], Y. Chou[100], Y.S. Chow[116], L.D. Christopher[31f], M.C. Chu[60a], X. Chu[13a,13d], J. Chudoba[136], J.J. Chwastowski[82], D. Cieri[112], K.M. Ciesla[82], V. Cindro[89], I.A. Cioară[25b], A. Ciocio[16], F. Cirotto[67a,67b], Z.H. Citron[175,l], M. Citterio[66a], D.A. Ciubotaru[25b], B.M. Ciungu[162], A. Clark[52], P.J. Clark[48], J.M. Clavijo Columbie[44], S.E. Clawson[98], C. Clement[43a,43b], L. Clissa[21b,21a], Y. Coadou[99], M. Cobal[64a,64c], A. Coccaro[53b], J. Cochran[76], R.F. Coelho Barrue[135a], R. Coelho Lopes De Sa[100], S. Coelli[66a], H. Cohen[157], A.E.C. Coimbra[34], B. Cole[37], J. Collot[56], P. Conde Muiño[135a,135h], S.H. Connell[31c], I.A. Connelly[55], E.I. Conroy[130], F. Conventi[67a,aj], H.G. Cooke[19], A.M. Cooper-Sarkar[130], F. Cormier[170], L.D. Corpe[34], M. Corradi[70a,70b], E.E. Corrigan[94], F. Corriveau[101,aa], M.J. Costa[169], F. Costanza[4], D. Costanzo[145], B.M. Cote[123], G. Cowan[91], J.W. Cowley[30], J. Crane[98], K. Cranmer[121], R.A. Creager[132], S. Crépé-Renaudin[56], F. Crescioli[131], M. Cristinziani[147], M. Cristoforetti[73a,73b,b], V. Croft[165], G. Crosetti[39b,39a], A. Cueto[4], T. Cuhadar Donszelmann[166], H. Cui[13a,13d], A.R. Cukierman[149], W.R. Cunningham[55], S. Czekierda[82], P. Czodrowski[34], M.M. Czurylo[59b], M.J. Da Cunha Sargedas De Sousa[58a], J.V. Da Fonseca Pinto[78b], C. Da Via[98], W. Dabrowski[81a], T. Dado[45], S. Dahbi[31f], T. Dai[103], C. Dallapiccola[100], M. Dam[38], G. D’amen[27], V. D’Amico[72a,72b], J. Damp[97], J.R. Dandoy[132], M.F. Daneri[28], M. Danninger[148], V. Dao[34],

G. Darbo[53b], S. Darmora[5], S. D’Auria[66a,66b], C. David[163b], T. Davidek[138], D.R. Davis[47], B. Davis-Purcell[32], I. Dawson[90], K. De[7], R. De Asmundis[67a], M. De Beurs[116], S. De Castro[21b,21a], N. De Groot[115], P. de Jong[116], H. De la Torre[104], A. De Maria[13c], D. De Pedis[70a], A. De Salvo[70a], U. De Sanctis[71a,71b], A. De Santo[152], J.B. De Vivie De Regie[56], D.V. Dedovich[77], J. Degens[116], A.M. Deiana[40], J. Del Peso[96], Y. Delabat Diaz[44], F. Deliot[140], C.M. Delitzsch[6], M. Della Pietra[67a,67b], D. Della Volpe[52], A. Dell’Acqua[34], L. Dell’Asta[66a,66b], M. Delmastro[4], P.A. Delsart[56], S. Demers[178], M. Demichev[77], S.P. Denisov[119], L. D’Eramo[117], D. Derendarz[82], J.E. Derkaoui[33e], F. Derue[131], P. Dervan[88], K. Desch[22], K. Dette[162], C. Deutsch[22], P.O. Deviveiros[34], F.A. Di Bello[70a,70b], A. Di Ciaccio[71a,71b], L. Di Ciaccio[4], C. Di Donato[67a,67b], A. Di Girolamo[34], G. Di Gregorio[69a,69b], A. Di Luca[73a,73b], B. Di Micco[72a,72b], R. Di Nardo[72a,72b], C. Diaconu[99], F.A. Dias[116], T. Dias Do Vale[135a], M.A. Diaz[142a], F.G. Diaz Capriles[22], J. Dickinson[16], M. Didenko[169], E.B. Diehl[103], J. Dietrich[17], S. Díez Cornell[44], C. Diez Pardos[147], A. Dimitrievska[16], W. Ding[13b], J. Dingfelder[22], I-M. Dinu[25b], S.J. Dittmeier[59b], F. Dittus[34], F. Djama[99], T. Djobava[155b], J.I. Djuvsland[15], M.A.B. Do Vale[143], C. Doglioni[94], J. Dolejsi[138], Z. Dolezal[138], M. Donadelli[78c], B. Dong[58c], J. Donini[36], A. D’onofrio[13c], M. D’Onofrio[88], J. Dopke[139], A. Doria[67a], M.T. Dova[86], A.T. Doyle[55], E. Drechsler[148], E. Dreyer[148], T. Dreyer[51], A.S. Drobac[165], D. Du[58b], T.A. du Pree[116], F. Dubinin[108], M. Dubovsky[26a], A. Dubreuil[52], E. Duchovni[175], G. Duckeck[111], O.A. Ducu[34,25b], D. Duda[112], A. Dudarev[34], M. D’uffizi[98], L. Duflot[62], M. Dührssen[34], C. Dülsen[177], A.E. Dumitriu[25b], M. Dunford[59a], S. Dungs[45], A. Duperrin[99], H. Duran Yildiz[3a], M. Düren[54], A. Durglishvili[155b], B. Dutta[44], D. Duvnjak[1], G.I. Dyckes[132], M. Dyndal[81a], S. Dysch[98], B.S. Dziedzic[82], B. Eckerova[26a], M.G. Eggleston[47], E. Egidio Purcino De Souza[78b], L.F. Ehrke[52], T. Eifert[7], G. Eigen[15], K. Einsweiler[16], T. Ekelof[167], Y. El Ghazali[33b], H. El Jarrari[33f], A. El Moussaouy[33a], V. Ellajosyula[167], M. Ellert[167], F. Ellinghaus[177], A.A. Elliot[90], N. Ellis[34], J. Elmsheuser[27], M. Elsing[34], D. Emeliyanov[139], A. Emerman[37], Y. Enari[159], J. Erdmann[45], A. Ereditato[18], P.A. Erland[82], M. Errenst[177], M. Escalier[62], C. Escobar[169], O. Estrada Pastor[169], E. Etzion[157], G. Evans[135a], H. Evans[63], M.O. Evans[152], A. Ezhilov[133], F. Fabbri[55], L. Fabbri[21b,21a], V. Fabiani[115], G. Facini[173], V. Fadeyev[141], R.M. Fakhrutdinov[119], S. Falciano[70a], P.J. Falke[22], S. Falke[34], J. Faltova[138], Y. Fan[13a], Y. Fang[13a], Y. Fang[13a], G. Fanourakis[42], M. Fanti[66a,66b], M. Faraj[58c], A. Farbin[7], A. Farilla[72a], E.M. Farina[68a,68b], T. Farooque[104], S.M. Farrington[48], P. Farthouat[34], F. Fassi[33f], D. Fassouliotis[8], M. Faucci Giannelli[71a,71b], W.J. Fawcett[30], L. Fayard[62], O.L. Fedin[133,q], A. Fehr[18], M. Feickert[168], L. Feligioni[99], A. Fell[145], C. Feng[58b], M. Feng[13b], M.J. Fenton[166], A.B. Fenyuk[119], S.W. Ferguson[41], J. Ferrando[44], A. Ferrari[167], P. Ferrari[116], R. Ferrari[68a], D. Ferrere[52], C. Ferretti[103], F. Fiedler[97], A. Filipčič[89], F. Filthaut[115], M.C.N. Fiolhais[135a,135c,a], L. Fiorini[169], F. Fischer[147], J. Fischer[97], W.C. Fisher[104], T. Fitschen[19], I. Fleck[147], P. Fleischmann[103], T. Flick[177], B.M. Flierl[111], L. Flores[132], L.R. Flores Castillo[60a], F.M. Follega[73a,73b], N. Fomin[15], J.H. Foo[162], G.T. Forcolin[73a,73b], B.C. Forland[63], A. Formica[140], F.A. Förster[12], A.C. Forti[98], E. Fortin[99], M.G. Foti[130], D. Fournier[62], H. Fox[87], P. Francavilla[69a,69b], S. Francescato[70a,70b], M. Franchini[21b,21a], S. Franchino[59a], D. Francis[34], L. Franco[4], L. Franconi[18], M. Franklin[57], G. Frattari[70a,70b], A.C. Freegard[90], P.M. Freeman[19], B. Freund[107], W.S. Freund[78b], E.M. Freundlich[45], D. Froidevaux[34], J.A. Frost[130], Y. Fu[58a], M. Fujimoto[122], E. Fullana Torregrosa[169], J. Fuster[169], A. Gabrielli[21b,21a], A. Gabrielli[34], P. Gadow[44], G. Gagliardi[53b,53a], L.G. Gagnon[16], G.E. Gallardo[130], E.J. Gallas[130], B.J. Gallop[139], R. Gamboa Goni[90], K.K. Gan[123], S. Ganguly[175], J. Gao[58a], Y. Gao[48], Y.S. Gao[29,n], F.M. Garay Walls[142a], C. García[169], J.E. García Navarro[169], J.A. García Pascual[13a], M. Garcia-Sciveres[16], R.W. Gardner[35], D. Garg[75], S. Gargiulo[50], C.A. Garner[162], V. Garonne[129], S.J. Gasiorowski[144], P. Gaspar[78b], G. Gaudio[68a], P. Gauzzi[70a,70b], I.L. Gavrilenko[108], A. Gavrilyuk[120], C. Gay[170], G. Gaycken[44], E.N. Gazis[9], A.A. Geanta[25b], C.M. Gee[141], C.N.P. Gee[139], J. Geisen[94], M. Geisen[97], C. Gemme[53b], M.H. Genest[56], S. Gentile[70a,70b], S. George[91], T. Geralis[42], L.O. Gerlach[51], P. Gessinger-Befurt[97], M. Ghasemi Bostanabad[171], M. Ghneimat[147], A. Ghosh[166], A. Ghosh[75], B. Giacobbe[21b], S. Giagu[70a,70b], N. Giangiacomi[162], P. Giannetti[69a], A. Giannini[67a,67b], S.M. Gibson[91], M. Gignac[141], D.T. Gil[81b], B.J. Gilbert[37], D. Gillberg[32], G. Gilles[177], N.E.K. Gillwald[44], D.M. Gingrich[2,ai], M.P. Giordani[64a,64c], P.F. Giraud[140], G. Giugliarelli[64a,64c], D. Giugni[66a], F. Giuli[71a,71b], I. Gkialas[8,i], E.L. Gkougkousis[12], P. Gkountoumis[9], L.K. Gladilin[110], C. Glasman[96], G.R. Gledhill[127], M. Glisic[127], I. Gnesi[39b,d], M. Goblirsch-Kolb[24], D. Godin[107], S. Goldfarb[102], T. Golling[52], D. Golubkov[119], J.P. Gombas[104], A. Gomes[135a,135b], R. Goncalves Gama[51], R. Gonçalo[135a,135c], G. Gonella[127], L. Gonella[19], A. Gongadze[77], F. Gonnella[19], J.L. Gonski[37], S. González de la Hoz[169], S. Gonzalez Fernandez[12], R. Gonzalez Lopez[88], C. Gonzalez Renteria[16], R. Gonzalez Suarez[167], S. Gonzalez-Sevilla[52], G.R. Gonzalvo Rodriguez[169], R.Y. González Andana[142a], L. Goossens[34], N.A. Gorasia[19], P.A. Gorbounov[120], H.A. Gordon[27], B. Gorini[34], E. Gorini[65a,65b], A. Gorišek[89], A.T. Goshaw[47], M.I. Gostkin[77], C.A. Gottardo[115], M. Gouighri[33b], V. Goumarre[44], A.G. Goussiou[144], N. Govender[31c], C. Goy[4], I. Grabowska-Bold[81a], K. Graham[32], E. Gramstad[129], S. Grancagnolo[17], M. Grandi[152], V. Gratchev[133], P.M. Gravila[25f], F.G. Gravili[65a,65b], H.M. Gray[16], C. Grefe[22], I.M. Gregor[44], P. Grenier[149], K. Grevtsov[44], C. Grieco[12], N.A. Grieser[124], A.A. Grillo[141], K. Grimm[29,m], S. Grinstein[12,x], J.-F. Grivaz[62], S. Groh[97], E. Gross[175], J. Grosse-Knetter[51], Z.J. Grout[92], C. Grud[103], A. Grummer[114], J.C. Grundy[130], L. Guan[103], W. Guan[176], C. Gubbels[170], J. Guenther[34], J.G.R. Guerrero Rojas[169], F. Guescini[112], D. Guest[17], R. Gugel[97], A. Guida[44], T. Guillemin[4], S. Guindon[34], J. Guo[58c], L. Guo[62], Y. Guo[103], R. Gupta[44], S. Gurbuz[22], G. Gustavino[124], M. Guth[50], P. Gutierrez[124], L.F. Gutierrez Zagazeta[132], C. Gutschow[92], C. Guyot[140], C. Gwenlan[130], C.B. Gwilliam[88], E.S. Haaland[129], A. Haas[121], M.H. Habedank[17], C. Haber[16], H.K. Hadavand[7], A. Hadef[97], M. Haleem[172], J. Haley[125], J.J. Hall[145], G. Halladjian[104], G.D. Hallewell[99], L. Halser[18], K. Hamano[171], H. Hamdaoui[33f], M. Hamer[22], G.N. Hamity[48], K. Han[58a], L. Han[13c], L. Han[58a], S. Han[16], Y.F. Han[162], K. Hanagaki[79,v], M. Hance[141], M.D. Hank[35], R. Hankache[98], E. Hansen[94], J.B. Hansen[38], J.D. Hansen[38], M.C. Hansen[22], P.H. Hansen[38], K. Hara[164], T. Harenberg[177], S. Harkusha[105], Y.T. Harris[130], P.F. Harrison[173], N.M. Hartman[149], N.M. Hartmann[111], Y. Hasegawa[146], A. Hasib[48], S. Hassani[140], S. Haug[18], R. Hauser[104], M. Havranek[137], C.M. Hawkes[19], R.J. Hawkings[34], S. Hayashida[113], D. Hayden[104], C. Hayes[103], R.L. Hayes[170], C.P. Hays[130], J.M. Hays[90], H.S. Hayward[88], S.J. Haywood[139], F. He[58a], Y. He[160], Y. He[131], M.P. Heath[48], V. Hedberg[94], A.L. Heggelund[129], N.D. Hehir[90], C. Heidegger[50], K.K. Heidegger[50], W.D. Heidorn[76], J. Heilman[32], S. Heim[44], T. Heim[16], B. Heinemann[44,ag], J.G. Heinlein[132], J.J. Heinrich[127], L. Heinrich[34], J. Hejbal[136], L. Helary[44], A. Held[121], S. Hellesund[129], C.M. Helling[141], S. Hellman[43a,43b], C. Helsens[34], R.C.W. Henderson[87], L. Henkelmann[30], A.M. Henriques Correia[34], H. Herde[149], Y. Hernández Jiménez[151], M.G. Herrmann[111], T. Herrmann[46], G. Herten[50], R. Hertenberger[111], L. Hervas[34], N.P. Hessey[163a], H. Hibi[80], S. Higashino[79], E. Higón-Rodriguez[169], K.K. Hill[27], K.H. Hiller[44], S.J. Hillier[19], M. Hils[46], I. Hinchliffe[16], F. Hinterkeuser[22], M. Hirose[128], S. Hirose[164], D. Hirschbuehl[177], B. Hiti[89], O. Hladik[136], J. Hobbs[151], R. Hobincu[25e], N. Hod[175], M.C. Hodgkinson[145], B.H. Hodkinson[30], A. Hoecker[34], J. Hofer[44], D. Hohn[50], T. Holm[22], T.R. Holmes[35], M. Holzbock[112], L.B.A.H. Hommels[30], B.P. Honan[98], T.M. Hong[134], J.C. Honig[50], A. Hönle[112], B.H. Hooberman[168], W.H. Hopkins[5], Y. Horii[113], P. Horn[46], L.A. Horyn[35], S. Hou[154], J. Howarth[55], J. Hoya[86], M. Hrabovsky[126], A. Hrynevich[106], T. Hryn’ova[4], P.J. Hsu[61], S.-C. Hsu[144], Q. Hu[37], S. Hu[58c], Y.F. Hu[13a,13d,ak], D.P. Huang[92], X. Huang[13c], Y. Huang[58a], Y. Huang[13a], Z. Hubacek[137], F. Hubaut[99], M. Huebner[22], F. Huegging[22], T.B. Huffman[130], M. Huhtinen[34], R. Hulsken[56], N. Huseynov[77,ab], J. Huston[104], J. Huth[57], R. Hyneman[149], S. Hyrych[26a], G. Iacobucci[52], G. Iakovidis[27], I. Ibragimov[147], L. Iconomidou-Fayard[62], P. Iengo[34], R. Ignazzi[38], R. Iguchi[159], T. Iizawa[52], Y. Ikegami[79], N. Ilic[162,162], H. Imam[33a], T. Ingebretsen Carlson[43a,43b], G. Introzzi[68a,68b], M. Iodice[72a], V. Ippolito[70a,70b], M. Ishino[159], W. Islam[125], C. Issever[17,44], S. Istin[11c,al], J.M. Iturbe Ponce[60a], R. Iuppa[73a,73b], A. Ivina[175], J.M. Izen[41], V. Izzo[67a], P. Jacka[136], P. Jackson[1], R.M. Jacobs[44], B.P. Jaeger[148], C.S. Jagfeld[111], G. Jäkel[177], K.B. Jakobi[97], K. Jakobs[50], T. Jakoubek[175], J. Jamieson[55], K.W. Janas[81a], G. Jarlskog[94], A.E. Jaspan[88], N. Javadov[77,ab], M. Javurkova[100], F. Jeanneau[140], L. Jeanty[127], J. Jejelava[155a], P. Jenni[50,e], S. Jézéquel[4], J. Jia[151], Z. Jia[13c], Y. Jiang[58a], S. Jiggins[50], J. Jimenez Pena[112], S. Jin[13c], A. Jinaru[25b], O. Jinnouchi[160],

P. Johansson[145], K.A. Johns[6], E. Jones[173], R.W.L. Jones[87], T.J. Jones[88], J. Jovicevic[51], X. Ju[16], J.J. Junggeburth[34], A. Juste Rozas[12,x], A. Kaczmarska[82], M. Kado[70a,70b], H. Kagan[123], M. Kagan[149], A. Kahn[37], C. Kahra[97], T. Kaji[174], E. Kajomovitz[156], C.W. Kalderon[27], A. Kaluza[97], M. Kaneda[159], N.J. Kang[141], S. Kang[76], Y. Kano[113], J. Kanzaki[79], D. Kar[31f], K. Karava[130], M.J. Kareem[163b], I. Karkanias[158], S.N. Karpov[77], Z.M. Karpova[77], V. Kartvelishvili[87], A.N. Karyukhin[119], E. Kasimi[158], C. Kato[58d], J. Katzy[44], K. Kawade[146], K. Kawagoe[85], T. Kawamoto[140], G. Kawamura[51], E.F. Kay[171], F.I. Kaya[165], S. Kazakos[12], V.F. Kazanin[118b,118a], Y. Ke[151], J.M. Keaveney[31a], R. Keeler[171], J.S. Keller[32], D. Kelsey[152], J.J. Kempster[19], K.E. Kennedy[37], O. Kepka[136], S. Kersten[177], B.P. Kerševan[89], S. Ketabchi Haghighat[162], M. Khandoga[131], A. Khanov[125], A.G. Kharlamov[118b,118a], T. Kharlamova[118b,118a], E.E. Khoda[170], T.J. Khoo[17], G. Khoriauli[172], E. Khramov[77], J. Khubua[155b], S. Kido[80], M. Kiehn[34], A. Kilgallon[127], E. Kim[160], Y.K. Kim[35], N. Kimura[92], A. Kirchhoff[51], D. Kirchmeier[46], J. Kirk[139], A.E. Kiryunin[112], T. Kishimoto[159], D.P. Kisliuk[162], V. Kitali[44], C. Kitsaki[9], O. Kivernyk[22], T. Klapdor-Kleingrothaus[50], M. Klassen[59a], C. Klein[32], L. Klein[172], M.H. Klein[103], M. Klein[88], U. Klein[88], P. Klimek[34], A. Klimentov[27], F. Klimpel[34], T. Klingl[22], T. Klioutchnikova[34], F.F. Klitzner[111], P. Kluit[116], S. Kluth[112], E. Kneringer[74], T.M. Knight[162], A. Knue[50], D. Kobayashi[85], M. Kobel[46], M. Kocian[149], P. Kodys[138], D.M. Koeck[152], P.T. Koenig[22], T. Koffas[32], N.M. Köhler[34], M. Kolb[140], I. Koletsou[4], T. Komarek[126], K. Köneke[50], A.X.Y. Kong[1], T. Kono[122], V. Konstantinides[92], N. Konstantinidis[92], B. Konya[94], R. Kopeliansky[63], S. Koperny[81a], K. Korcyl[82], K. Kordas[158], G. Koren[157], A. Korn[92], S. Korn[51], I. Korolkov[12], E.V. Korolkova[145], N. Korotkova[110], B. Kortman[116], O. Kortner[112], S. Kortner[112], V.V. Kostyukhin[145,161], A. Kotsokechagia[62], A. Kotwal[47], A. Koulouris[34], A. Kourkoumeli-Charalampidi[68a,68b], C. Kourkoumelis[8], E. Kourlitis[5], R. Kowalewski[171], W. Kozanecki[140], A.S. Kozhin[119], V.A. Kramarenko[110], G. Kramberger[89], D. Krasnopevtsev[58a], M.W. Krasny[131], A. Krasznahorkay[34], J.A. Kremer[97], J. Kretzschmar[88], K. Kreul[17], P. Krieger[162], F. Krieter[111], S. Krishnamurthy[100], A. Krishnan[59b], M. Krivos[138], K. Krizka[16], K. Kroeninger[45], H. Kroha[112], J. Kroll[136], J. Kroll[132], K.S. Krowpman[104], U. Kruchonak[77], H. Krüger[22], N. Krumnack[76], M.C. Kruse[47], J.A. Krzysiak[82], A. Kubota[160], O. Kuchinskaia[161], S. Kuday[3b], D. Kuechler[44], J.T. Kuechler[44], S. Kuehn[34], T. Kuhl[44], V. Kukhtin[77], Y. Kulchitsky[105,ae], S. Kuleshov[142b], M. Kumar[31f], N. Kumari[99], M. Kuna[56], A. Kupco[136], T. Kupfer[45], O. Kuprash[50], H. Kurashige[80], L.L. Kurchaninov[163a], Y.A. Kurochkin[105], A. Kurova[109], M.G. Kurth[13a,13d], E.S. Kuwertz[34], M. Kuze[160], A.K. Kvam[144], J. Kvita[126], T. Kwan[101], C. Lacasta[169], F. Lacava[70a,70b], H. Lacker[17], D. Lacour[131], N.N. Lad[92], E. Ladygin[77], R. Lafaye[4], B. Laforge[131], T. Lagouri[142c], S. Lai[51], I.K. Lakomiec[81a], N. Lalloue[56], J.E. Lambert[124], S. Lammers[63], W. Lampl[6], C. Lampoudis[158], E. Lançon[27], U. Landgraf[50], M.P.J. Landon[90], V.S. Lang[50], J.C. Lange[51], R.J. Langenberg[100], A.J. Lankford[166], F. Lanni[27], K. Lantzsch[22], A. Lanza[68a], A. Lapertosa[53b,53a], J.F. Laporte[140], T. Lari[66a], F. Lasagni Manghi[21b,21a], M. Lassnig[34], V. Latonova[136], T.S. Lau[60a], A. Laudrain[97], A. Laurier[32], M. Lavorgna[67a,67b], S.D. Lawlor[91], M. Lazzaroni[66a,66b], B. Le[98], B. Leban[89], A. Lebedev[76], M. LeBlanc[34], T. LeCompte[5], F. Ledroit-Guillon[56], A.C.A. Lee[92], C.A. Lee[27], G.R. Lee[15], L. Lee[57], S.C. Lee[154], S. Lee[76], L.L. Leeuw[31c], B. Lefebvre[163a], H.P. Lefebvre[91], M. Lefebvre[171], C. Leggett[16], K. Lehmann[148], N. Lehmann[18], G. Lehmann Miotto[34], W.A. Leight[44], A. Leisos[158,w], M.A.L. Leite[78c], C.E. Leitgeb[44], R. Leitner[138], K.J.C. Leney[40], T. Lenz[22], S. Leone[69a], C. Leonidopoulos[48], A. Leopold[131], C. Leroy[107], R. Les[104], C.G. Lester[30], M. Levchenko[133], J. Levêque[4], D. Levin[103], L.J. Levinson[175], D.J. Lewis[19], B. Li[13b], B. Li[58b], C. Li[58a], C-Q. Li[58c,58d], H. Li[58a], H. Li[58b], J. Li[58c], K. Li[144], L. Li[58c], M. Li[13a,13d], Q.Y. Li[58a], S. Li[58d,c], X. Li[44], Y. Li[44], Z. Li[58b], Z. Li[130], Z. Li[101], Z. Li[88], Z. Liang[13a], M. Liberatore[44], B. Liberti[71a], K. Lie[60c], K. Lin[104], R.A. Linck[63], R.E. Lindley[6], J.H. Lindon[2], A. Linss[44], A.L. Lionti[52], E. Lipeles[132], A. Lipniacka[15], T.M. Liss[168,ah], A. Lister[170], J.D. Little[7], B. Liu[13a], B.X. Liu[148], J.B. Liu[58a], J.K.K. Liu[35], K. Liu[58d,58c], M. Liu[58a], M.Y. Liu[58a], P. Liu[13a], X. Liu[58a], Y. Liu[44], Y. Liu[13c,13d], Y.L. Liu[103], Y.W. Liu[58a], M. Livan[68a,68b], A. Lleres[56], J. Llorente Merino[148], S.L. Lloyd[90], E.M. Lobodzinska[44],

P. Loch[6], S. Loffredo[71a,71b], T. Lohse[17], K. Lohwasser[145], M. Lokajicek[136], J.D. Long[168], R.E. Long[87], I. Longarini[70a,70b], L. Longo[34], R. Longo[168], I. Lopez Paz[12], A. Lopez Solis[44], J. Lorenz[111], N. Lorenzo Martinez[4], A.M. Lory[111], A. Lösle[50], X. Lou[43a,43b], X. Lou[13a], A. Lounis[62], J. Love[5], P.A. Love[87], J.J. Lozano Bahilo[169], G. Lu[13a], M. Lu[58a], S. Lu[132], Y.J. Lu[61], H.J. Lubatti[144], C. Luci[70a,70b], F.L. Lucio Alves[13c], A. Lucotte[56], F. Luehring[63], I. Luise[151], L. Luminari[70a], B. Lund-Jensen[150], N.A. Luongo[127], M.S. Lutz[157], D. Lynn[27], H. Lyons[88], R. Lysak[136], E. Lytken[94], F. Lyu[13a], V. Lyubushkin[77], T. Lyubushkina[77], H. Ma[27], L.L. Ma[58b], Y. Ma[92], D.M. Mac Donell[171], G. Maccarrone[49], C.M. Macdonald[145], J.C. MacDonald[145], R. Madar[36], W.F. Mader[46], M. Madugoda Ralalage Don[125], N. Madysa[46], J. Maeda[80], T. Maeno[27], M. Maerker[46], V. Magerl[50], J. Magro[64a,64c], D.J. Mahon[37], C. Maidantchik[78b], A. Maio[135a,135b,135d], K. Maj[81a], O. Majersky[26a], S. Majewski[127], N. Makovec[62], B. Malaescu[131], Pa. Malecki[82], V.P. Maleev[133], F. Malek[56], D. Malito[39b,39a], U. Mallik[75], C. Malone[30], S. Maltezos[9], S. Malyukov[77], J. Mamuzic[169], G. Mancini[49], J.P. Mandalia[90], I. Mandić[89], L. Manhaes de Andrade Filho[78a], I.M. Maniatis[158], M. Manisha[140], J. Manjarres Ramos[46], A. Mann[111], B. Mansoulie[140], I. Manthos[158], S. Manzoni[116], A. Marantis[158,w], L. Marchese[130], G. Marchiori[131], M. Marcisovsky[136], L. Marcoccia[71a,71b], C. Marcon[94], M. Marjanovic[124], Z. Marshall[16], S. Marti-Garcia[169], T.A. Martin[173], V.J. Martin[48], B. Martin dit Latour[15], L. Martinelli[70a,70b], M. Martinez[12,x], P. Martinez Agullo[169], V.I. Martinez Outschoorn[100], S. Martin-Haugh[139], V.S. Martoiu[25b], A.C. Martyniuk[92], A. Marzin[34], S.R. Maschek[112], L. Masetti[97], T. Mashimo[159], J. Masik[98], A.L. Maslennikov[118b,118a], L. Massa[21b,21a], P. Massarotti[67a,67b], P. Mastrandrea[69a,69b], A. Mastroberardino[39b,39a], T. Masubuchi[159], D. Matakias[27], T. Mathisen[167], N. Matsuzawa[159], J. Maurer[25b], B. Maček[89], D.A. Maximov[118b,118a], R. Mazini[154], I. Maznas[158], S.M. Mazza[141], C. Mc Ginn[27], J.P. Mc Gowan[101], S.P. Mc Kee[103], T.G. McCarthy[112], W.P. McCormack[16], E.F. McDonald[102], A.E. McDougall[116], J.A. Mcfayden[152], G. Mchedlidze[155b], M.A. McKay[40], K.D. McLean[171], S.J. McMahon[139], P.C. McNamara[102], R.A. McPherson[171,aa], Z.A. Meadows[100], T. Megy[36], S. Mehlhase[111], A. Mehta[88], B. Meirose[41], D. Melini[156], B.R. Mellado Garcia[31f], F. Meloni[44], A. Melzer[22], E.D. Mendes Gouveia[135a], A.M. Mendes Jacques Da Costa[19], H.Y. Meng[162], L. Meng[34], S. Menke[112], M. Mentink[34], E. Meoni[39b,39a], S.A.M. Merkt[134], C. Merlassino[130], P. Mermod[52,*], L. Merola[67a,67b], C. Meroni[66a], G. Merz[103], O. Meshkov[110,108], J.K.R. Meshreki[147], J. Metcalfe[5], A.S. Mete[5], C. Meyer[63], J-P. Meyer[140], M. Michetti[17], R.P. Middleton[139], L. Mijović[48], G. Mikenberg[175], M. Mikestikova[136], M. Mikuž[89], H. Mildner[145], A. Milic[162], C.D. Milke[40], D.W. Miller[35], L.S. Miller[32], A. Milov[175], D.A. Milstead[43a,43b], A.A. Minaenko[119], I.A. Minashvili[155b], L. Mince[55], A.I. Mincer[121], B. Mindur[81a], M. Mineev[77], Y. Mino[83], L.M. Mir[12], M. Miralles Lopez[169], M. Mironova[130], T. Mitani[174], V.A. Mitsou[169], M. Mittal[58c], O. Miu[162], P.S. Miyagawa[90], Y. Miyazaki[85], A. Mizukami[79], J.U. Mjörnmark[94], T. Mkrtchyan[59a], M. Mlynarikova[117], T. Moa[43a,43b], S. Mobius[51], K. Mochizuki[107], P. Moder[44], P. Mogg[111], A.F. Mohammed[13a], S. Mohapatra[37], G. Mokgatitswane[31f], B. Mondal[147], S. Mondal[137], K. Mönig[44], E. Monnier[99], A. Montalbano[148], J. Montejo Berlingen[34], M. Montella[123], F. Monticelli[86], N. Morange[62], A.L. Moreira De Carvalho[135a], M. Moreno Llácer[169], C. Moreno Martinez[12], P. Morettini[53b], M. Morgenstern[156], S. Morgenstern[173], D. Mori[148], M. Morii[57], M. Morinaga[159], V. Morisbak[129], A.K. Morley[34], A.P. Morris[92], L. Morvaj[34], P. Moschovakos[34], B. Moser[116], M. Mosidze[155b], T. Moskalets[50], P. Moskvitina[115], J. Moss[29,o], E.J.W. Moyse[100], S. Muanza[99], J. Mueller[134], D. Muenstermann[87], G.A. Mullier[94], J.J. Mullin[132], D.P. Mungo[66a,66b], J.L. Munoz Martinez[12], F.J. Munoz Sanchez[98], M. Murin[98], P. Murin[26b], W.J. Murray[173,139], A. Murrone[66a,66b], J.M. Muse[124], M. Muškinja[16], C. Mwewa[27], A.G. Myagkov[119,af], A.A. Myers[134], G. Myers[63], M. Myska[137], B.P. Nachman[16], O. Nackenhorst[45], A.Nag Nag[46], K. Nagai[130], K. Nagano[79], J.L. Nagle[27], E. Nagy[99], A.M. Nairz[34], Y. Nakahama[113], K. Nakamura[79], H. Nanjo[128], F. Napolitano[59a], R. Narayan[40], I. Naryshkin[133], M. Naseri[32], C. Nass[22], T. Naumann[44], G. Navarro[20a], J. Navarro-Gonzalez[169], P.Y. Nechaeva[108], F. Nechansky[44], T.J. Neep[19], A. Negri[68a,68b], M. Negrini[21b],

C. Nellist[115], C. Nelson[101], K. Nelson[103], M.E. Nelson[43a,43b], S. Nemecek[136], M. Nessi[34,g], M.S. Neubauer[168], F. Neuhaus[97], J. Neundorf[44], R. Newhouse[170], P.R. Newman[19], C.W. Ng[134], Y.S. Ng[17], Y.W.Y. Ng[166], B. Ngair[33f], H.D.N. Nguyen[99], T. Nguyen Manh[107], R.B. Nickerson[130], R. Nicolaidou[140], D.S. Nielsen[38], J. Nielsen[141], M. Niemeyer[51], N. Nikiforou[10], V. Nikolaenko[119,af], I. Nikolic-Audit[131], K. Nikolopoulos[19], P. Nilsson[27], H.R. Nindhito[52], A. Nisati[70a], N. Nishu[2], R. Nisius[112], T. Nitta[174], T. Nobe[159], D.L. Noel[30], Y. Noguchi[83], I. Nomidis[131], M.A. Nomura[27], M.B. Norfolk[145], R.R.B. Norisam[92], J. Novak[89], T. Novak[44], O. Novgorodova[46], L. Novotny[137], R. Novotny[114], L. Nozka[126], K. Ntekas[166], E. Nurse[92], F.G. Oakham[32,ai], J. Ocariz[131], A. Ochi[80], I. Ochoa[135a], J.P. Ochoa-Ricoux[142a], K. O'Connor[24], S. Oda[85], S. Odaka[79], S. Oerdek[167], A. Ogrodnik[81a], A. Oh[98], C.C. Ohm[150], H. Oide[160], R. Oishi[159], M.L. Ojeda[162], Y. Okazaki[83], M.W. O'Keefe[88], Y. Okumura[159], A. Olariu[25b], L.F. Oleiro Seabra[135a], S.A. Olivares Pino[142c], D. Oliveira Damazio[27], D. Oliveira Goncalves[78a], J.L. Oliver[1], M.J.R. Olsson[166], A. Olszewski[82], J. Olszowska[82], Ö.O. Öncel[22], D.C. O'Neil[148], A.P. O'neill[130], A. Onofre[135a,135e], P.U.E. Onyisi[10], H. Oppen[129], R.G. Oreamuno Madriz[117], M.J. Oreglia[35], G.E. Orellana[86], D. Orestano[72a,72b], N. Orlando[12], R.S. Orr[162], V. O'Shea[55], R. Ospanov[58a], G. Otero y Garzon[28], H. Otono[85], P.S. Ott[59a], G.J. Ottino[16], M. Ouchrif[33e], J. Ouellette[27], F. Ould-Saada[129], A. Ouraou[140,*], Q. Ouyang[13a], M. Owen[55], R.E. Owen[139], V.E. Ozcan[11c], N. Ozturk[7], S. Ozturk[11c], J. Pacalt[126], H.A. Pacey[30], K. Pachal[47], A. Pacheco Pages[12], C. Padilla Aranda[12], S. Pagan Griso[16], G. Palacino[63], S. Palazzo[48], S. Palestini[34], M. Palka[81b], P. Palni[81a], D.K. Panchal[10], C.E. Pandini[52], J.G. Panduro Vazquez[91], P. Pani[44], G. Panizzo[64a,64c], L. Paolozzi[52], C. Papadatos[107], S. Parajuli[40], A. Paramonov[5], C. Paraskevopoulos[9], D. Paredes Hernandez[60b], S.R. Paredes Saenz[130], B. Parida[175], T.H. Park[162], A.J. Parker[29], M.A. Parker[30], F. Parodi[53b,53a], E.W. Parrish[117], J.A. Parsons[37], U. Parzefall[50], L. Pascual Dominguez[157], V.R. Pascuzzi[16], F. Pasquali[116], E. Pasqualucci[70a], S. Passaggio[53b], F. Pastore[91], P. Pasuwan[43a,43b], J.R. Pater[98], A. Pathak[176], J. Patton[88], T. Pauly[34], J. Pearkes[149], M. Pedersen[129], L. Pedraza Diaz[115], R. Pedro[135a], T. Peiffer[51], S.V. Peleganchuk[118b,118a], O. Penc[136], C. Peng[60b], H. Peng[58a], M. Penzin[161], B.S. Peralva[78a], M.M. Perego[62], A.P. Pereira Peixoto[135a], L. Pereira Sanchez[43a,43b], D.V. Perepelitsa[27], E. Perez Codina[163a], M. Perganti[9], L. Perini[66a,66b], H. Pernegger[34], S. Perrella[34], A. Perrevoort[116], K. Peters[44], R.F.Y. Peters[98], B.A. Petersen[34], T.C. Petersen[38], E. Petit[99], V. Petousis[137], C. Petridou[158], P. Petroff[62], F. Petrucci[72a,72b], M. Pettee[178], N.E. Pettersson[34], K. Petukhova[138], A. Peyaud[140], R. Pezoa[142d], L. Pezzotti[68a,68b], G. Pezzullo[178], T. Pham[102], P.W. Phillips[139], M.W. Phipps[168], G. Piacquadio[151], E. Pianori[16], F. Piazza[66a,66b], A. Picazio[100], R. Piegaia[28], D. Pietreanu[25b], J.E. Pilcher[35], A.D. Pilkington[98], M. Pinamonti[64a,64c], J.L. Pinfold[2], C. Pitman Donaldson[92], D.A. Pizzi[32], L. Pizzimento[71a,71b], A. Pizzini[116], M.-A. Pleier[27], V. Plesanovs[50], V. Pleskot[138], E. Plotnikova[77], P. Podberezko[118b,118a], R. Poettgen[94], R. Poggi[52], L. Poggioli[131], I. Pogrebnyak[104], D. Pohl[22], I. Pokharel[51], G. Polesello[68a], A. Poley[148,163a], A. Policicchio[70a,70b], R. Polifka[138], A. Polini[21b], C.S. Pollard[44], Z.B. Pollock[123], V. Polychronakos[27], D. Ponomarenko[109], L. Pontecorvo[34], S. Popa[25a], G.A. Popeneciu[25d], L. Portales[4], D.M. Portillo Quintero[56], S. Pospisil[137], P. Postolache[25c], K. Potamianos[130], I.N. Potrap[77], C.J. Potter[30], H. Potti[1], T. Poulsen[44], J. Poveda[169], T.D. Powell[145], M.E. Pozo Astigarraga[34], A. Prades Ibanez[169], P. Pralavorio[99], M.M. Prapa[42], S. Prell[76], D. Price[98], M. Primavera[65a], M.A. Principe Martin[96], M.L. Proffitt[144], N. Proklova[109], K. Prokofiev[60c], F. Prokoshin[77], S. Protopopescu[27], J. Proudfoot[5], M. Przybycien[81a], D. Pudzha[133], P. Puzo[62], D. Pyatiizbyantseva[109], J. Qian[103], Y. Qin[98], A. Quadt[51], M. Queitsch-Maitland[34], G. Rabanal Bolanos[57], F. Ragusa[66a,66b], G. Rahal[95], J.A. Raine[52], S. Rajagopalan[27], K. Ran[13a,13d], D.F. Rassloff[59a], D.M. Rauch[44], S. Rave[97], B. Ravina[55], I. Ravinovich[175], M. Raymond[34], A.L. Read[129], N.P. Readioff[145], D.M. Rebuzzi[68a,68b], G. Redlinger[27], K. Reeves[41], D. Reikher[157], A. Reiss[97], A. Rej[147], C. Rembser[34], A. Renardi[44], M. Renda[25b], M.B. Rendel[112], A.G. Rennie[55], S. Resconi[66a], E.D. Resseguie[16], S. Rettie[92], B. Reynolds[123], E. Reynolds[19], M. Rezaei Estabragh[177], O.L. Rezanova[118b,118a], P. Reznicek[138], E. Ricci[73a,73b], R. Richter[112], S. Richter[44],

E. Richter-Was[81b], M. Ridel[131], P. Rieck[112], P. Riedler[34], O. Rifki[44], M. Rijssenbeek[151], A. Rimoldi[68a,68b], M. Rimoldi[44], L. Rinaldi[21b], T.T. Rinn[168], M.P. Rinnagel[111], G. Ripellino[150], I. Riu[12], P. Rivadeneira[44], J.C. Rivera Vergara[171], F. Rizatdinova[125], E. Rizvi[90], C. Rizzi[52], B.A. Roberts[173], S.H. Robertson[101,aa], M. Robin[44], D. Robinson[30], C.M. Robles Gajardo[142d], M. Robles Manzano[97], A. Robson[55], A. Rocchi[71a,71b], C. Roda[69a,69b], S. Rodriguez Bosca[59a], A. Rodriguez Rodriguez[50], A.M. Rodríguez Vera[163b], S. Roe[34], J. Roggel[177], O. Røhne[129], R.A. Rojas[142d], B. Roland[50], C.P.A. Roland[63], J. Roloff[27], A. Romaniouk[109], M. Romano[21b,21a], N. Rompotis[88], M. Ronzani[121], L. Roos[131], S. Rosati[70a], G. Rosin[100], B.J. Rosser[132], E. Rossi[162], E. Rossi[4], E. Rossi[67a,67b], L.P. Rossi[53b], L. Rossini[44], R. Rosten[123], M. Rotaru[25b], B. Rottler[50], D. Rousseau[62], D. Rousso[30], G. Rovelli[68a,68b], A. Roy[10], A. Rozanov[99], Y. Rozen[156], X. Ruan[31f], A.J. Ruby[88], T.A. Ruggeri[1], F. Rühr[50], A. Ruiz-Martinez[169], A. Rummler[34], Z. Rurikova[50], N.A. Rusakovich[77], H.L. Russell[34], L. Rustige[36], J.P. Rutherfoord[6], M. Rybar[138], E.B. Rye[129], A. Ryzhov[119], J.A. Sabater Iglesias[44], P. Sabatini[169], L. Sabetta[70a,70b], H.F-W. Sadrozinski[141], R. Sadykov[77], F. Safai Tehrani[70a], B. Safarzadeh Samani[152], M. Safdari[149], P. Saha[117], S. Saha[101], M. Sahinsoy[112], A. Sahu[177], M. Saimpert[140], M. Saito[159], T. Saito[159], D. Salamani[52], G. Salamanna[72a,72b], A. Salnikov[149], J. Salt[169], A. Salvador Salas[12], D. Salvatore[39b,39a], F. Salvatore[152], A. Salzburger[34], D. Sammel[50], D. Sampsonidis[158], D. Sampsonidou[58d,58c], J. Sánchez[169], A. Sanchez Pineda[4], V. Sanchez Sebastian[169], H. Sandaker[129], C.O. Sander[44], I.G. Sanderswood[87], J.A. Sandesara[100], M. Sandhoff[177], C. Sandoval[20b], D.P.C. Sankey[139], M. Sannino[53b,53a], Y. Sano[113], A. Sansoni[49], C. Santoni[36], H. Santos[135a,135b], S.N. Santpur[16], A. Santra[175], K.A. Saoucha[145], A. Sapronov[77], J.G. Saraiva[135a,135d], O. Sasaki[79], K. Sato[164], C. Sauer[59b], F. Sauerburger[50], E. Sauvan[4], P. Savard[162,ai], R. Sawada[159], C. Sawyer[139], L. Sawyer[93], I. Sayago Galvan[169], C. Sbarra[21b], A. Sbrizzi[64a,64c], T. Scanlon[92], J. Schaarschmidt[144], P. Schacht[112], D. Schaefer[35], L. Schaefer[132], U. Schäfer[97], A.C. Schaffer[62], D. Schaile[111], R.D. Schamberger[151], E. Schanet[111], C. Scharf[17], N. Scharmberg[98], V.A. Schegelsky[133], D. Scheirich[138], F. Schenck[17], M. Schernau[166], C. Schiavi[53b,53a], L.K. Schildgen[22], Z.M. Schillaci[24], E.J. Schioppa[65a,65b], M. Schioppa[39b,39a], B. Schlag[97], K.E. Schleicher[50], S. Schlenker[34], K. Schmieden[97], C. Schmitt[97], S. Schmitt[44], L. Schoeffel[140], A. Schoening[59b], P.G. Scholer[50], E. Schopf[130], M. Schott[97], J. Schovancova[34], S. Schramm[52], F. Schroeder[177], H-C. Schultz-Coulon[59a], M. Schumacher[50], B.A. Schumm[141], Ph. Schune[140], A. Schwartzman[149], T.A. Schwarz[103], Ph. Schwemling[140], R. Schwienhorst[104], A. Sciandra[141], G. Sciolla[24], F. Scuri[69a], F. Scutti[102], C.D. Sebastiani[88], K. Sedlaczek[45], P. Seema[17], S.C. Seidel[114], A. Seiden[141], B.D. Seidlitz[27], T. Seiss[35], C. Seitz[44], J.M. Seixas[78b], G. Sekhniaidze[67a], S.J. Sekula[40], L.P. Selem[4], N. Semprini-Cesari[21b,21a], S. Sen[47], C. Serfon[27], L. Serin[62], L. Serkin[64a,64b], M. Sessa[58a], H. Severini[124], S. Sevova[149], F. Sforza[53b,53a], A. Sfyrla[52], E. Shabalina[51], R. Shaheen[150], J.D. Shahinian[132], N.W. Shaikh[43a,43b], D. Shaked Renous[175], L.Y. Shan[13a], M. Shapiro[16], A. Sharma[34], A.S. Sharma[1], S. Sharma[44], P.B. Shatalov[120], K. Shaw[152], S.M. Shaw[98], P. Sherwood[92], L. Shi[92], C.O. Shimmin[178], Y. Shimogama[174], J.D. Shinner[91], I.P.J. Shipsey[130], S. Shirabe[52], M. Shiyakova[77], J. Shlomi[175], M.J. Shochet[35], J. Shojaii[102], D.R. Shope[150], S. Shrestha[123], E.M. Shrif[31f], M.J. Shroff[171], E. Shulga[175], P. Sicho[136], A.M. Sickles[168], E. Sideras Haddad[31f], A. Sidoti[21b,21a], F. Siegert[46], Dj. Sijacki[14], M.V. Silva Oliveira[34], S.B. Silverstein[43a], S. Simion[62], R. Simoniello[34], S. Simsek[11b], P. Sinervo[162], V. Sinetckii[110], S. Singh[148], S. Sinha[44], S. Sinha[31f], M. Sioli[21b,21a], I. Siral[127], S.Yu. Sivoklokov[110], J. Sjölin[43a,43b], A. Skaf[51], E. Skorda[94], P. Skubic[124], M. Slawinska[82], K. Sliwa[165], V. Smakhtin[175], B.H. Smart[139], J. Smiesko[138], S.Yu. Smirnov[109], Y. Smirnov[109], L.N. Smirnova[110,s], O. Smirnova[94], E.A. Smith[35], H.A. Smith[130], M. Smizanska[87], K. Smolek[137], A. Smykiewicz[82], A.A. Snesarev[108], H.L. Snoek[116], S. Snyder[27], R. Sobie[171,aa], A. Soffer[157], F. Sohns[51], C.A. Solans Sanchez[34], E.Yu. Soldatov[109], U. Soldevila[169], A.A. Solodkov[119], S. Solomon[50], A. Soloshenko[77], O.V. Solovyanov[119], V. Solovyev[133], P. Sommer[145], H. Son[165], A. Sonay[12], W.Y. Song[163b], A. Sopczak[137], A.L. Sopio[92], F. Sopkova[26b], S. Sottocornola[68a,68b],

R. Soualah[64a,64c], A.M. Soukharev[118b,118a], Z. Soumaimi[33f], D. South[44], S. Spagnolo[65a,65b], M. Spalla[112], M. Spangenberg[173], F. Spanò[91], D. Sperlich[50], T.M. Spieker[59a], G. Spigo[34], M. Spina[152], M. Spousta[138], A. Stabile[66a,66b], B.L. Stamas[117], R. Stamen[59a], M. Stamenkovic[116], A. Stampekis[19], M. Standke[22], E. Stanecka[82], B. Stanislaus[34], M.M. Stanitzki[44], M. Stankaityte[130], B. Stapf[44], E.A. Starchenko[119], G.H. Stark[141], J. Stark[99], D.M. Starko[163b], P. Staroba[136], P. Starovoitov[59a], S. Stärz[101], R. Staszewski[82], G. Stavropoulos[42], P. Steinberg[27], A.L. Steinhebel[127], B. Stelzer[148,163a], H.J. Stelzer[134], O. Stelzer-Chilton[163a], H. Stenzel[54], T.J. Stevenson[152], G.A. Stewart[34], M.C. Stockton[34], G. Stoicea[25b], M. Stolarski[135a], S. Stonjek[112], A. Straessner[46], J. Strandberg[150], S. Strandberg[43a,43b], M. Strauss[124], T. Strebler[99], P. Strizenec[26b], R. Ströhmer[172], D.M. Strom[127], L.R. Strom[44], R. Stroynowski[40], A. Strubig[43a,43b], S.A. Stucci[27], B. Stugu[15], J. Stupak[124], N.A. Styles[44], D. Su[149], S. Su[58a], W. Su[58d,144,58c], X. Su[58a], N.B. Suarez[134], K. Sugizaki[159], V.V. Sulin[108], M.J. Sullivan[88], D.M.S. Sultan[52], S. Sultansoy[3c], T. Sumida[83], S. Sun[103], S. Sun[176], X. Sun[98], O. Sunneborn Gudnadottir[167], C.J.E. Suster[153], M.R. Sutton[152], M. Svatos[136], M. Swiatlowski[163a], T. Swirski[172], I. Sykora[26a], M. Sykora[138], T. Sykora[138], D. Ta[97], K. Tackmann[44,y], A. Taffard[166], R. Tafirout[163a], E. Tagiev[119], R.H.M. Taibah[131], R. Takashima[84], K. Takeda[80], T. Takeshita[146], E.P. Takeva[48], Y. Takubo[79], M. Talby[99], A.A. Talyshev[118b,118a], K.C. Tam[60b], N.M. Tamir[157], A. Tanaka[159], J. Tanaka[159], R. Tanaka[62], Z. Tao[170], S. Tapia Araya[168], S. Tapprogge[97], A. Tarek Abouelfadl Mohamed[104], S. Tarem[156], K. Tariq[58b], G. Tarna[25b,f], G.F. Tartarelli[66a], P. Tas[138], M. Tasevsky[136], E. Tassi[39b,39a], G. Tateno[159], Y. Tayalati[33f], G.N. Taylor[102], W. Taylor[163b], H. Teagle[88], A.S. Tee[176], R. Teixeira De Lima[149], P. Teixeira-Dias[91], H. Ten Kate[34], J.J. Teoh[116], K. Terashi[159], J. Terron[96], S. Terzo[12], M. Testa[49], R.J. Teuscher[162,aa], N. Themistokleous[48], T. Theveneaux-Pelzer[17], O. Thielmann[177], D.W. Thomas[91], J.P. Thomas[19], E.A. Thompson[44], P.D. Thompson[19], E. Thomson[132], E.J. Thorpe[90], Y. Tian[51], V.O. Tikhomirov[108], Yu.A. Tikhonov[118b,118a], S. Timoshenko[109], P. Tipton[178], S. Tisserant[99], S.H. Tlou[31f], A. Tnourji[36], K. Todome[21b,21a], S. Todorova-Nova[138], S. Todt[46], M. Togawa[79], J. Tojo[85], S. Tokár[26a], K. Tokushuku[79], E. Tolley[123], R. Tombs[30], M. Tomoto[79,113], L. Tompkins[149], P. Tornambe[100], E. Torrence[127], H. Torres[46], E. Torró Pastor[169], M. Toscani[28], C. Tosciri[35], J. Toth[99,z], D.R. Tovey[145], A. Traeet[15], C.J. Treado[121], T. Trefzger[172], A. Tricoli[27], I.M. Trigger[163a], S. Trincaz-Duvoid[131], D.A. Trischuk[170], W. Trischuk[162], B. Trocmé[56], A. Trofymov[62], C. Troncon[66a], F. Trovato[152], L. Truong[31c], M. Trzebinski[82], A. Trzupek[82], F. Tsai[151], A. Tsiamis[158], P.V. Tsiareshka[105,ae], A. Tsirigotis[158,w], V. Tsiskaridze[151], E.G. Tskhadadze[155a], M. Tsopoulou[158], I.I. Tsukerman[120], V. Tsulaia[16], S. Tsuno[79], O. Tsur[156], D. Tsybychev[151], Y. Tu[60b], A. Tudorache[25b], V. Tudorache[25b], A.N. Tuna[34], S. Turchikhin[77], D. Turgeman[175], I. Turk Cakir[3b,u], R.J. Turner[19], R. Turra[66a], P.M. Tuts[37], S. Tzamarias[158], P. Tzanis[9], E. Tzovara[97], K. Uchida[159], F. Ukegawa[164], G. Unal[34], M. Unal[10], A. Undrus[27], G. Unel[166], F.C. Ungaro[102], J. Urban[26b], P. Urquijo[102], G. Usai[7], R. Ushioda[160], M. Usman[107], Z. Uysal[11d], V. Vacek[137], B. Vachon[101], K.O.H. Vadla[129], T. Vafeiadis[34], C. Valderanis[111], E. Valdes Santurio[43a,43b], M. Valente[163a], S. Valentinetti[21b,21a], A. Valero[169], L. Valéry[44], R.A. Vallance[19], A. Vallier[99], J.A. Valls Ferrer[169], T.R. Van Daalen[12], P. Van Gemmeren[5], S. Van Stroud[92], I. Van Vulpen[116], M. Vanadia[71a,71b], W. Vandelli[34], M. Vandenbroucke[140], E.R. Vandewall[125], D. Vannicola[70a,70b], L. Vannoli[53b,53a], R. Vari[70a], E.W. Varnes[6], C. Varni[53b,53a], T. Varol[154], D. Varouchas[62], K.E. Varvell[153], M.E. Vasile[25b], L. Vaslin[36], G.A. Vasquez[171], F. Vazeille[36], D. Vazquez Furelos[12], T. Vazquez Schroeder[34], J. Veatch[51], V. Vecchio[98], M.J. Veen[116], I. Veliscek[130], L.M. Veloce[162], F. Veloso[135a,135c], S. Veneziano[70a], A. Ventura[65a,65b], A. Verbytskyi[112], M. Verducci[69a,69b], C. Vergis[22], M. Verissimo De Araujo[78b], W. Verkerke[116], A.T. Vermeulen[116], J.C. Vermeulen[116], C. Vernieri[149], P.J. Verschuuren[91], M.L. Vesterbacka[121], M.C. Vetterli[148,ai], N. Viaux Maira[142d], T. Vickey[145], O.E. Vickey Boeriu[145], G.H.A. Viehhauser[130], L. Vigani[59b], M. Villa[21b,21a], M. Villaplana Perez[169], E.M. Villhauer[48], E. Vilucchi[49], M.G. Vincter[32], G.S. Virdee[19], A. Vishwakarma[48], C. Vittori[21b,21a], I. Vivarelli[152], V. Vladimirov[173], E. Voevodina[112], M. Vogel[177], P. Vokac[137], J. Von Ahnen[44], S.E. von Buddenbrock[31f], E. Von Toerne[22], V. Vorobel[138], K. Vorobev[109],

M. Vos[169], J.H. Vossebeld[88], M. Vozak[98], N. Vranjes[14], M. Vranjes Milosavljevic[14], V. Vrba[137,*], M. Vreeswijk[116], N.K. Vu[99], R. Vuillermet[34], I. Vukotic[35], S. Wada[164], C. Wagner[100], P. Wagner[22], W. Wagner[177], S. Wahdan[177], H. Wahlberg[86], R. Wakasa[164], M. Wakida[113], V.M. Walbrecht[112], J. Walder[139], R. Walker[111], S.D. Walker[91], W. Walkowiak[147], A.M. Wang[57], A.Z. Wang[176], C. Wang[58a], C. Wang[58c], H. Wang[16], J. Wang[60a], P. Wang[40], R.-J. Wang[97], R. Wang[57], R. Wang[117], S.M. Wang[154], S. Wang[58b], T. Wang[58a], W.T. Wang[58a], W.X. Wang[58a], X. Wang[168], Y. Wang[58a], Z. Wang[103], C. Wanotayaroj[34], A. Warburton[101], C.P. Ward[30], R.J. Ward[19], N. Warrack[55], A.T. Watson[19], M.F. Watson[19], G. Watts[144], B.M. Waugh[92], A.F. Webb[10], C. Weber[27], M.S. Weber[18], S.M. Weber[59a], C. Wei[58a], Y. Wei[130], A.R. Weidberg[130], J. Weingarten[45], M. Weirich[97], C. Weiser[50], P.S. Wells[34], T. Wenaus[27], B. Wendland[45], T. Wengler[34], S. Wenig[34], N. Wermes[22], M. Wessels[59a], K. Whalen[127], A.M. Wharton[87], A.S. White[57], A. White[7], M.J. White[1], D. Whiteson[166], W. Wiedenmann[176], C. Wiel[46], M. Wielers[139], N. Wieseotte[97], C. Wiglesworth[38], L.A.M. Wiik-Fuchs[50], D.J. Wilbern[124], H.G. Wilkens[34], L.J. Wilkins[91], D.M. Williams[37], H.H. Williams[132], S. Williams[30], S. Willocq[100], P.J. Windischhofer[130], I. Wingerter-Seez[4], F. Winklmeier[127], B.T. Winter[50], M. Wittgen[149], M. Wobisch[93], R. Wölker[130], J. Wollrath[166], M.W. Wolter[82], H. Wolters[135a,135c], V.W.S. Wong[170], A.F. Wongel[44], S.D. Worm[44], B.K. Wosiek[82], K.W. Woźniak[82], K. Wraight[55], J. Wu[13a,13d], S.L. Wu[176], X. Wu[52], Y. Wu[58a], Z. Wu[140,58a], J. Wuerzinger[130], T.R. Wyatt[98], B.M. Wynne[48], S. Xella[38], J. Xiang[60c], X. Xiao[103], X. Xie[58a], I. Xiotidis[152], D. Xu[13a], H. Xu[58a], H. Xu[58a], L. Xu[58a], R. Xu[132], W. Xu[103], Y. Xu[13b], Z. Xu[58b], Z. Xu[149], B. Yabsley[153], S. Yacoob[31a], N. Yamaguchi[85], Y. Yamaguchi[160], M. Yamatani[159], H. Yamauchi[164], T. Yamazaki[16], Y. Yamazaki[80], J. Yan[58c], Z. Yan[23], H.J. Yang[58c,58d], H.T. Yang[16], S. Yang[58a], T. Yang[60c], X. Yang[58a], X. Yang[13a], Y. Yang[159], Z. Yang[103,58a], W-M. Yao[16], Y.C. Yap[44], H. Ye[13c], J. Ye[40], S. Ye[27], I. Yeletskikh[77], M.R. Yexley[87], P. Yin[37], K. Yorita[174], K. Yoshihara[76], C.J.S. Young[34], C. Young[149], R. Yuan[58b,j], X. Yue[59a], M. Zaazoua[33f], B. Zabinski[82], G. Zacharis[9], E. Zaffaroni[52], J. Zahreddine[99], A.M. Zaitsev[119,af], T. Zakareishvili[155b], N. Zakharchuk[32], S. Zambito[34], D. Zanzi[50], S.V. Zeißner[45], C. Zeitnitz[177], G. Zemaityte[130], J.C. Zeng[168], O. Zenin[119], T. Ženiš[26a], S. Zenz[90], S. Zerradi[33a], D. Zerwas[62], M. Zgubič[130], B. Zhang[13c], D.F. Zhang[13b], G. Zhang[13b], J. Zhang[5], K. Zhang[13a], L. Zhang[13c], M. Zhang[168], R. Zhang[176], S. Zhang[103], X. Zhang[58c], X. Zhang[58b], Z. Zhang[62], P. Zhao[47], Y. Zhao[141], Z. Zhao[58a], A. Zhemchugov[77], Z. Zheng[103], D. Zhong[168], B. Zhou[103], C. Zhou[176], H. Zhou[6], N. Zhou[58c], Y. Zhou[6], C.G. Zhu[58b], C. Zhu[13a,13d], H.L. Zhu[58a], H. Zhu[13a], J. Zhu[103], Y. Zhu[58a], X. Zhuang[13a], K. Zhukov[108], V. Zhulanov[118b,118a], D. Zieminska[63], N.I. Zimine[77], S. Zimmermann[50,*], M. Ziolkowski[147], L. Živković[14], A. Zoccoli[21b,21a], K. Zoch[52], T.G. Zorbas[145], O. Zormpa[42], W. Zou[37], L. Zwalinski[34].

[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)Istanbul Aydin University, Application and Research Center for Advanced Studies, Istanbul;(c)Division of Physics, TOBB University of Economics and Technology, Ankara; Turkey.
[4]LAPP, Univ. Savoie Mont Blanc, CNRS/IN2P3, Annecy ; France.
[5]High Energy Physics Division, Argonne National Laboratory, Argonne IL; United States of America.
[6]Department of Physics, University of Arizona, Tucson AZ; United States of America.
[7]Department of Physics, University of Texas at Arlington, Arlington TX; United States of America.
[8]Physics Department, National and Kapodistrian University of Athens, Athens; Greece.
[9]Physics Department, National Technical University of Athens, Zografou; Greece.
[10]Department of Physics, University of Texas at Austin, Austin TX; United States of America.
[11](a)Bahcesehir University, Faculty of Engineering and Natural Sciences, Istanbul;(b)Istanbul Bilgi University, Faculty of Engineering and Natural Sciences, Istanbul;(c)Department of Physics, Bogazici University, Istanbul;(d)Department of Physics Engineering, Gaziantep University, Gaziantep; Turkey.

[12]Institut de Física d'Altes Energies (IFAE), Barcelona Institute of Science and Technology, Barcelona; Spain.
[13](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)University of Chinese Academy of Science (UCAS), Beijing; China.
[14]Institute of Physics, University of Belgrade, Belgrade; Serbia.
[15]Department for Physics and Technology, University of Bergen, Bergen; Norway.
[16]Physics Division, Lawrence Berkeley National Laboratory and University of California, Berkeley CA; United States of America.
[17]Institut für Physik, Humboldt Universität zu Berlin, Berlin; Germany.
[18]Albert Einstein Center for Fundamental Physics and Laboratory for High Energy Physics, University of Bern, Bern; Switzerland.
[19]School of Physics and Astronomy, University of Birmingham, Birmingham; United Kingdom.
[20](a)Facultad de Ciencias y Centro de Investigaciónes, Universidad Antonio Nariño, Bogotá;(b)Departamento de Física, Universidad Nacional de Colombia, Bogotá, Colombia; Colombia.
[21](a)INFN Bologna and Universita' di Bologna, Dipartimento di Fisica;(b)INFN Sezione di Bologna; Italy.
[22]Physikalisches Institut, Universität Bonn, Bonn; Germany.
[23]Department of Physics, Boston University, Boston MA; United States of America.
[24]Department of Physics, Brandeis University, Waltham MA; United States of America.
[25](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; Romania.
[26](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.
[27]Physics Department, Brookhaven National Laboratory, Upton NY; United States of America.
[28]Departamento de Física, Universidad de Buenos Aires, Buenos Aires; Argentina.
[29]California State University, CA; United States of America.
[30]Cavendish Laboratory, University of Cambridge, Cambridge; United Kingdom.
[31](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;(e)University of South Africa, Department of Physics, Pretoria;(f)School of Physics, University of the Witwatersrand, Johannesburg; South Africa.
[32]Department of Physics, Carleton University, Ottawa ON; Canada.
[33](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)Moroccan Foundation for Advanced Science Innovation and Research (MAScIR), Rabat;(e)LPMR, Faculté des Sciences, Université Mohamed Premier, Oujda;(f)Faculté des sciences, Université Mohammed V, Rabat; Morocco.
[34]CERN, Geneva; Switzerland.
[35]Enrico Fermi Institute, University of Chicago, Chicago IL; United States of America.
[36]LPC, Université Clermont Auvergne, CNRS/IN2P3, Clermont-Ferrand; France.
[37]Nevis Laboratory, Columbia University, Irvington NY; United States of America.
[38]Niels Bohr Institute, University of Copenhagen, Copenhagen; Denmark.

[39](a)Dipartimento di Fisica, Università della Calabria, Rende;(b)INFN Gruppo Collegato di Cosenza, Laboratori Nazionali di Frascati; Italy.
[40]Physics Department, Southern Methodist University, Dallas TX; United States of America.
[41]Physics Department, University of Texas at Dallas, Richardson TX; United States of America.
[42]National Centre for Scientific Research "Demokritos", Agia Paraskevi; Greece.
[43](a)Department of Physics, Stockholm University;(b)Oskar Klein Centre, Stockholm; Sweden.
[44]Deutsches Elektronen-Synchrotron DESY, Hamburg and Zeuthen; Germany.
[45]Lehrstuhl für Experimentelle Physik IV, Technische Universität Dortmund, Dortmund; Germany.
[46]Institut für Kern- und Teilchenphysik, Technische Universität Dresden, Dresden; Germany.
[47]Department of Physics, Duke University, Durham NC; United States of America.
[48]SUPA - School of Physics and Astronomy, University of Edinburgh, Edinburgh; United Kingdom.
[49]INFN e Laboratori Nazionali di Frascati, Frascati; Italy.
[50]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Freiburg; Germany.
[51]II. Physikalisches Institut, Georg-August-Universität Göttingen, Göttingen; Germany.
[52]Département de Physique Nucléaire et Corpusculaire, Université de Genève, Genève; Switzerland.
[53](a)Dipartimento di Fisica, Università di Genova, Genova;(b)INFN Sezione di Genova; Italy.
[54]II. Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen; Germany.
[55]SUPA - School of Physics and Astronomy, University of Glasgow, Glasgow; United Kingdom.
[56]LPSC, Université Grenoble Alpes, CNRS/IN2P3, Grenoble INP, Grenoble; France.
[57]Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge MA; United States of America.
[58](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.
[59](a)Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Heidelberg;(b)Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg; Germany.
[60](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.
[61]Department of Physics, National Tsing Hua University, Hsinchu; Taiwan.
[62]IJCLab, Université Paris-Saclay, CNRS/IN2P3, 91405, Orsay; France.
[63]Department of Physics, Indiana University, Bloomington IN; United States of America.
[64](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.
[65](a)INFN Sezione di Lecce;(b)Dipartimento di Matematica e Fisica, Università del Salento, Lecce; Italy.
[66](a)INFN Sezione di Milano;(b)Dipartimento di Fisica, Università di Milano, Milano; Italy.
[67](a)INFN Sezione di Napoli;(b)Dipartimento di Fisica, Università di Napoli, Napoli; Italy.
[68](a)INFN Sezione di Pavia;(b)Dipartimento di Fisica, Università di Pavia, Pavia; Italy.
[69](a)INFN Sezione di Pisa;(b)Dipartimento di Fisica E. Fermi, Università di Pisa, Pisa; Italy.
[70](a)INFN Sezione di Roma;(b)Dipartimento di Fisica, Sapienza Università di Roma, Roma; Italy.
[71](a)INFN Sezione di Roma Tor Vergata;(b)Dipartimento di Fisica, Università di Roma Tor Vergata, Roma; Italy.
[72](a)INFN Sezione di Roma Tre;(b)Dipartimento di Matematica e Fisica, Università Roma Tre, Roma; Italy.
[73](a)INFN-TIFPA;(b)Università degli Studi di Trento, Trento; Italy.
[74]Institut für Astro- und Teilchenphysik, Leopold-Franzens-Universität, Innsbruck; Austria.

[75]University of Iowa, Iowa City IA; United States of America.
[76]Department of Physics and Astronomy, Iowa State University, Ames IA; United States of America.
[77]Joint Institute for Nuclear Research, Dubna; Russia.
[78](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; Brazil.
[79]KEK, High Energy Accelerator Research Organization, Tsukuba; Japan.
[80]Graduate School of Science, Kobe University, Kobe; Japan.
[81](a)AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Krakow;(b)Marian Smoluchowski Institute of Physics, Jagiellonian University, Krakow; Poland.
[82]Institute of Nuclear Physics Polish Academy of Sciences, Krakow; Poland.
[83]Faculty of Science, Kyoto University, Kyoto; Japan.
[84]Kyoto University of Education, Kyoto; Japan.
[85]Research Center for Advanced Particle Physics and Department of Physics, Kyushu University, Fukuoka ; Japan.
[86]Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata; Argentina.
[87]Physics Department, Lancaster University, Lancaster; United Kingdom.
[88]Oliver Lodge Laboratory, University of Liverpool, Liverpool; United Kingdom.
[89]Department of Experimental Particle Physics, Jožef Stefan Institute and Department of Physics, University of Ljubljana, Ljubljana; Slovenia.
[90]School of Physics and Astronomy, Queen Mary University of London, London; United Kingdom.
[91]Department of Physics, Royal Holloway University of London, Egham; United Kingdom.
[92]Department of Physics and Astronomy, University College London, London; United Kingdom.
[93]Louisiana Tech University, Ruston LA; United States of America.
[94]Fysiska institutionen, Lunds universitet, Lund; Sweden.
[95]Centre de Calcul de l'Institut National de Physique Nucléaire et de Physique des Particules (IN2P3), Villeurbanne; France.
[96]Departamento de Física Teorica C-15 and CIAFF, Universidad Autónoma de Madrid, Madrid; Spain.
[97]Institut für Physik, Universität Mainz, Mainz; Germany.
[98]School of Physics and Astronomy, University of Manchester, Manchester; United Kingdom.
[99]CPPM, Aix-Marseille Université, CNRS/IN2P3, Marseille; France.
[100]Department of Physics, University of Massachusetts, Amherst MA; United States of America.
[101]Department of Physics, McGill University, Montreal QC; Canada.
[102]School of Physics, University of Melbourne, Victoria; Australia.
[103]Department of Physics, University of Michigan, Ann Arbor MI; United States of America.
[104]Department of Physics and Astronomy, Michigan State University, East Lansing MI; United States of America.
[105]B.I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk; Belarus.
[106]Research Institute for Nuclear Problems of Byelorussian State University, Minsk; Belarus.
[107]Group of Particle Physics, University of Montreal, Montreal QC; Canada.
[108]P.N. Lebedev Physical Institute of the Russian Academy of Sciences, Moscow; Russia.
[109]National Research Nuclear University MEPhI, Moscow; Russia.
[110]D.V. Skobeltsyn Institute of Nuclear Physics, M.V. Lomonosov Moscow State University, Moscow; Russia.
[111]Fakultät für Physik, Ludwig-Maximilians-Universität München, München; Germany.
[112]Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), München; Germany.
[113]Graduate School of Science and Kobayashi-Maskawa Institute, Nagoya University, Nagoya; Japan.

[114]Department of Physics and Astronomy, University of New Mexico, Albuquerque NM; United States of America.
[115]Institute for Mathematics, Astrophysics and Particle Physics, Radboud University/Nikhef, Nijmegen; Netherlands.
[116]Nikhef National Institute for Subatomic Physics and University of Amsterdam, Amsterdam; Netherlands.
[117]Department of Physics, Northern Illinois University, DeKalb IL; United States of America.
[118](a)Budker Institute of Nuclear Physics and NSU, SB RAS, Novosibirsk;(b)Novosibirsk State University Novosibirsk; Russia.
[119]Institute for High Energy Physics of the National Research Centre Kurchatov Institute, Protvino; Russia.
[120]Institute for Theoretical and Experimental Physics named by A.I. Alikhanov of National Research Centre "Kurchatov Institute", Moscow; Russia.
[121]Department of Physics, New York University, New York NY; United States of America.
[122]Ochanomizu University, Otsuka, Bunkyo-ku, Tokyo; Japan.
[123]Ohio State University, Columbus OH; United States of America.
[124]Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman OK; United States of America.
[125]Department of Physics, Oklahoma State University, Stillwater OK; United States of America.
[126]Palacký University, Joint Laboratory of Optics, Olomouc; Czech Republic.
[127]Institute for Fundamental Science, University of Oregon, Eugene, OR; United States of America.
[128]Graduate School of Science, Osaka University, Osaka; Japan.
[129]Department of Physics, University of Oslo, Oslo; Norway.
[130]Department of Physics, Oxford University, Oxford; United Kingdom.
[131]LPNHE, Sorbonne Université, Université de Paris, CNRS/IN2P3, Paris; France.
[132]Department of Physics, University of Pennsylvania, Philadelphia PA; United States of America.
[133]Konstantinov Nuclear Physics Institute of National Research Centre "Kurchatov Institute", PNPI, St. Petersburg; Russia.
[134]Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh PA; United States of America.
[135](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)Dep Física and CEFITEC of Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Caparica;(h)Instituto Superior Técnico, Universidade de Lisboa, Lisboa; Portugal.
[136]Institute of Physics of the Czech Academy of Sciences, Prague; Czech Republic.
[137]Czech Technical University in Prague, Prague; Czech Republic.
[138]Charles University, Faculty of Mathematics and Physics, Prague; Czech Republic.
[139]Particle Physics Department, Rutherford Appleton Laboratory, Didcot; United Kingdom.
[140]IRFU, CEA, Université Paris-Saclay, Gif-sur-Yvette; France.
[141]Santa Cruz Institute for Particle Physics, University of California Santa Cruz, Santa Cruz CA; United States of America.
[142](a)Departamento de Física, Pontificia Universidad Católica de Chile, Santiago;(b)Universidad Andres Bello, Department of Physics, Santiago;(c)Instituto de Alta Investigación, Universidad de Tarapacá, Arica;(d)Departamento de Física, Universidad Técnica Federico Santa María, Valparaíso; Chile.
[143]Universidade Federal de São João del Rei (UFSJ), São João del Rei; Brazil.

[144]Department of Physics, University of Washington, Seattle WA; United States of America.
[145]Department of Physics and Astronomy, University of Sheffield, Sheffield; United Kingdom.
[146]Department of Physics, Shinshu University, Nagano; Japan.
[147]Department Physik, Universität Siegen, Siegen; Germany.
[148]Department of Physics, Simon Fraser University, Burnaby BC; Canada.
[149]SLAC National Accelerator Laboratory, Stanford CA; United States of America.
[150]Department of Physics, Royal Institute of Technology, Stockholm; Sweden.
[151]Departments of Physics and Astronomy, Stony Brook University, Stony Brook NY; United States of America.
[152]Department of Physics and Astronomy, University of Sussex, Brighton; United Kingdom.
[153]School of Physics, University of Sydney, Sydney; Australia.
[154]Institute of Physics, Academia Sinica, Taipei; Taiwan.
[155](a)E. Andronikashvili Institute of Physics, Iv. Javakhishvili Tbilisi State University, Tbilisi;(b)High Energy Physics Institute, Tbilisi State University, Tbilisi; Georgia.
[156]Department of Physics, Technion, Israel Institute of Technology, Haifa; Israel.
[157]Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv; Israel.
[158]Department of Physics, Aristotle University of Thessaloniki, Thessaloniki; Greece.
[159]International Center for Elementary Particle Physics and Department of Physics, University of Tokyo, Tokyo; Japan.
[160]Department of Physics, Tokyo Institute of Technology, Tokyo; Japan.
[161]Tomsk State University, Tomsk; Russia.
[162]Department of Physics, University of Toronto, Toronto ON; Canada.
[163](a)TRIUMF, Vancouver BC;(b)Department of Physics and Astronomy, York University, Toronto ON; Canada.
[164]Division of Physics and Tomonaga Center for the History of the Universe, Faculty of Pure and Applied Sciences, University of Tsukuba, Tsukuba; Japan.
[165]Department of Physics and Astronomy, Tufts University, Medford MA; United States of America.
[166]Department of Physics and Astronomy, University of California Irvine, Irvine CA; United States of America.
[167]Department of Physics and Astronomy, University of Uppsala, Uppsala; Sweden.
[168]Department of Physics, University of Illinois, Urbana IL; United States of America.
[169]Instituto de Física Corpuscular (IFIC), Centro Mixto Universidad de Valencia - CSIC, Valencia; Spain.
[170]Department of Physics, University of British Columbia, Vancouver BC; Canada.
[171]Department of Physics and Astronomy, University of Victoria, Victoria BC; Canada.
[172]Fakultät für Physik und Astronomie, Julius-Maximilians-Universität Würzburg, Würzburg; Germany.
[173]Department of Physics, University of Warwick, Coventry; United Kingdom.
[174]Waseda University, Tokyo; Japan.
[175]Department of Particle Physics and Astrophysics, Weizmann Institute of Science, Rehovot; Israel.
[176]Department of Physics, University of Wisconsin, Madison WI; United States of America.
[177]Fakultät für Mathematik und Naturwissenschaften, Fachgruppe Physik, Bergische Universität Wuppertal, Wuppertal; Germany.
[178]Department of Physics, Yale University, New Haven CT; United States of America.
[a] Also at Borough of Manhattan Community College, City University of New York, New York NY; United States of America.
[b] Also at Bruno Kessler Foundation, Trento; Italy.
[c] Also at Center for High Energy Physics, Peking University; China.
[d] Also at Centro Studi e Ricerche Enrico Fermi; Italy.

[e] Also at CERN, Geneva; Switzerland.
[f] Also at CPPM, Aix-Marseille Université, CNRS/IN2P3, Marseille; France.
[g] Also at Département de Physique Nucléaire et Corpusculaire, Université de Genève, Genève; Switzerland.
[h] Also at Departament de Fisica de la Universitat Autonoma de Barcelona, Barcelona; Spain.
[i] Also at Department of Financial and Management Engineering, University of the Aegean, Chios; Greece.
[j] Also at Department of Physics and Astronomy, Michigan State University, East Lansing MI; United States of America.
[k] Also at Department of Physics and Astronomy, University of Louisville, Louisville, KY; United States of America.
[l] Also at Department of Physics, Ben Gurion University of the Negev, Beer Sheva; Israel.
[m] Also at Department of Physics, California State University, East Bay; United States of America.
[n] Also at Department of Physics, California State University, Fresno; United States of America.
[o] Also at Department of Physics, California State University, Sacramento; United States of America.
[p] Also at Department of Physics, King's College London, London; United Kingdom.
[q] Also at Department of Physics, St. Petersburg State Polytechnical University, St. Petersburg; Russia.
[r] Also at Department of Physics, University of Fribourg, Fribourg; Switzerland.
[s] Also at Faculty of Physics, M.V. Lomonosov Moscow State University, Moscow; Russia.
[t] Also at Faculty of Physics, Sofia University, 'St. Kliment Ohridski', Sofia; Bulgaria.
[u] Also at Giresun University, Faculty of Engineering, Giresun; Turkey.
[v] Also at Graduate School of Science, Osaka University, Osaka; Japan.
[w] Also at Hellenic Open University, Patras; Greece.
[x] Also at Institucio Catalana de Recerca i Estudis Avancats, ICREA, Barcelona; Spain.
[y] Also at Institut für Experimentalphysik, Universität Hamburg, Hamburg; Germany.
[z] Also at Institute for Particle and Nuclear Physics, Wigner Research Centre for Physics, Budapest; Hungary.
[aa] Also at Institute of Particle Physics (IPP); Canada.
[ab] Also at Institute of Physics, Azerbaijan Academy of Sciences, Baku; Azerbaijan.
[ac] Also at Instituto de Fisica Teorica, IFT-UAM/CSIC, Madrid; Spain.
[ad] Also at Istanbul University, Dept. of Physics, Istanbul; Turkey.
[ae] Also at Joint Institute for Nuclear Research, Dubna; Russia.
[af] Also at Moscow Institute of Physics and Technology State University, Dolgoprudny; Russia.
[ag] Also at Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Freiburg; Germany.
[ah] Also at The City College of New York, New York NY; United States of America.
[ai] Also at TRIUMF, Vancouver BC; Canada.
[aj] Also at Universita di Napoli Parthenope, Napoli; Italy.
[ak] Also at University of Chinese Academy of Sciences (UCAS), Beijing; China.
[al] Also at Yeditepe University, Physics Department, Istanbul; Turkey.
[*] Deceased

References

[1] S. Schael et al., *Precision electroweak measurements on the Z resonance*, Phys. Rept. **427** (2006) 257, arXiv: `hep-ex/0509008 [hep-ex]`.

[2] LHCb Collaboration, *Test of lepton universality with $B^0 \to K^{*0}\ell^+\ell^-$ decays*, JHEP **08** (2017) 055, arXiv: `1705.05802 [hep-ex]`.

[3] LHCb Collaboration, *Search for lepton-universality violation in $B^+ \to K^+\ell^+\ell^-$ decays*, Phys. Rev. Lett. **122** (2019) 191801, arXiv: `1903.09252 [hep-ex]`.

[4] LHCb Collaboration, *Test of lepton universality with $\Lambda_b^0 \to pK^-\ell^+\ell^-$ decays*, JHEP **05** (2020) 040, arXiv: `1912.08139 [hep-ex]`.

[5] BaBar Collaboration, *Measurement of branching fractions and rate asymmetries in the rare decays $B \to K^{(*)}\ell^+\ell^-$*, Phys. Rev. D **86** (2012) 032012, arXiv: `1204.3933 [hep-ex]`.

[6] Belle Collaboration, *Test of lepton-flavor universality in $B \to K^*\ell^+\ell^-$ decays at Belle*, (2019), arXiv: `1904.02440 [hep-ex]`.

[7] S. Choudhury et al., *Test of lepton flavor universality and search for lepton flavor violation in $B \to K\ell\ell$ decays*, JHEP **03** (2021) 105, arXiv: `1908.01848 [hep-ex]`.

[8] LHCb Collaboration, *Differential branching fractions and isospin asymmetries of $B \to K^{(*)}\mu^+\mu^-$ decays*, JHEP **06** (2014) 133, arXiv: `1403.8044 [hep-ex]`.

[9] LHCb Collaboration, *Angular analysis and differential branching fraction of the decay $B_s^0 \to \phi\mu^+\mu^-$*, JHEP **09** (2015) 179, arXiv: `1506.08777 [hep-ex]`.

[10] LHCb Collaboration, *Differential branching fraction and angular analysis of $\Lambda_b^0 \to \Lambda\mu^+\mu^-$ decays*, JHEP **06** (2015) 115, [Erratum: JHEP 09, 145 (2018)], arXiv: `1503.07138 [hep-ex]`.

[11] LHCb Collaboration, *Measurements of the S-wave fraction in $B^0 \to K^+\pi^-\mu^+\mu^-$ decays and the $B^0 \to K^*(892)^0\mu^+\mu^-$ differential branching fraction*, JHEP **11** (2016) 047, [Erratum: JHEP 04, (2017) 142], arXiv: `1606.04731 [hep-ex]`.

[12] R. Aaij et al., *Measurement of CP-Averaged Observables in the $B^0 \to K^{*0}\mu^+\mu^-$ Decay*, Phys. Rev. Lett. **125** (2020) 011802, arXiv: `2003.04831 [hep-ex]`.

[13] LHCb Collaboration, *Angular analysis of the $B^0 \to K^{*0}\mu^+\mu^-$ decay using 3 fb^{-1} of integrated luminosity*, JHEP **02** (2016) 104, arXiv: `1512.04442 [hep-ex]`.

[14] Y. Afik, S. Bar-Shalom, J. Cohen, and Y. Rozen, *Searching for New Physics with $b\bar{b}\ell^+\ell^-$ contact interactions*, Phys. Lett. B **807** (2020) 135541, arXiv: `1912.00425 [hep-ex]`.

[15] Y. Afik, J. Cohen, E. Gozani, E. Kajomovitz, and Y. Rozen, *Establishing a search for $b \to s\ell^+\ell^-$ anomalies at the LHC*, JHEP **08** (2018) 056, arXiv: `1805.11402 [hep-ph]`.

[16] M. Algueró et al.,
Emerging patterns of New Physics with and without Lepton Flavour Universal contributions,
Eur. Phys. J. C **79** (2019) 714, [Addendum: Eur. Phys. J. C 80, (2020) 511],
arXiv: `1903.09578 [hep-ph]`.

[17] A. Greljo and D. Marzocca, *High-p_T dilepton tails and flavor physics*,
Eur. Phys. J. C **77** (2017) 548, arXiv: `1704.09015 [hep-ph]`.

[18] Y. Afik, S. Bar-Shalom, A. Soni, and J. Wudka,
New flavor physics in di- and tri-lepton events from single-top at the LHC and beyond, (2021),
arXiv: `2101.05286 [hep-ph]`.

[19] ATLAS Collaboration, *The ATLAS Experiment at the CERN Large Hadron Collider*,
JINST **3** (2008) S08003.

[20] ATLAS Collaboration, *ATLAS Insertable B-Layer Technical Design Report*,
ATLAS-TDR-19; CERN-LHCC-2010-013, 2010,
URL: `https://cds.cern.ch/record/1291633`.

[21] B. Abbott et al., *Production and integration of the ATLAS Insertable B-Layer*,
JINST **13** (2018) T05008, arXiv: `1803.00844 [physics.ins-det]`.

[22] P. Nason, *A new method for combining NLO QCD with shower Monte Carlo algorithms*,
JHEP **11** (2004) 040, arXiv: `hep-ph/0409146`.

[23] S. Frixione, P. Nason, and C. Oleari,
Matching NLO QCD computations with parton shower simulations: the POWHEG method,
JHEP **11** (2007) 070, arXiv: `0709.2092 [hep-ph]`.

[24] S. Alioli, P. Nason, C. Oleari, and E. Re, *A general framework for implementing NLO calculations in shower Monte Carlo programs: the POWHEG BOX*, JHEP **06** (2010) 043,
arXiv: `1002.2581 [hep-ph]`.

[25] S. Alioli, P. Nason, C. Oleari, and E. Re,
NLO vector-boson production matched with shower in POWHEG, JHEP **07** (2008) 060,
arXiv: `0805.4802 [hep-ph]`.

[26] ATLAS Collaboration, *Measurement of the Z/γ^* boson transverse momentum distribution in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector*, JHEP **09** (2014) 145,
arXiv: `1406.3660 [hep-ex]`.

[27] H.-L. Lai, M. Guzzi, J. Huston, Z. Li, P. M. Nadolsky, et al.,
New parton distributions for collider physics, Phys. Rev. D **82** (2010) 074024,
arXiv: `1007.2241 [hep-ph]`.

[28] J. Pumplin et al.,
New Generation of Parton Distributions with Uncertainties From Global QCD Analysis,
JHEP **07** (2002) 012, arXiv: `hep-ph/0201195`.

[29] P. Golonka and Z. Was,
PHOTOS Monte Carlo: a precision tool for QED corrections in Z and W decays,
Eur. Phys. J. C **45** (2006) 97, arXiv: `hep-ph/0506026 [hep-ph]`.

[30] N. Davidson, T. Przedzinski, and Z. Was,
PHOTOS interface in C++: Technical and physics documentation,
Comput. Phys. Commun. **199** (2016) 86, arXiv: `1011.0937 [hep-ph]`.

[31] E. Bothmann et al., *Event generation with Sherpa 2.2*, SciPost Phys. **7** (2019) 034, arXiv: `1905.09127 [hep-ph]`.

[32] T. Gleisberg and S. Höche, *Comix, a new matrix element generator*, JHEP **12** (2008) 039, arXiv: `0808.3674 [hep-ph]`.

[33] F. Buccioni et al., *OpenLoops 2*, Eur. Phys. J. C **79** (2019) 866, arXiv: `1907.13071 [hep-ph]`.

[34] F. Cascioli, P. Maierhofer, and S. Pozzorini, *Scattering Amplitudes with Open Loops*, Phys. Rev. Lett. **108** (2012) 111601, arXiv: `1111.5206 [hep-ph]`.

[35] A. Denner, S. Dittmaier, and L. Hofer, *Collier: A fortran-based complex one-loop lIbrary in extended regularizations*, Comput. Phys. Commun. **212** (2017) 220, arXiv: `1604.06792 [hep-ph]`.

[36] NNPDF Collaboration, R.D. Ball et al., *Parton distributions for the LHC run II*, JHEP **04** (2015) 040, arXiv: `1410.8849 [hep-ph]`.

[37] S. Schumann and F. Krauss, *A parton shower algorithm based on Catani-Seymour dipole factorisation*, JHEP **03** (2008) 038, arXiv: `0709.1027 [hep-ph]`.

[38] S. Hoeche, F. Krauss, M. Schonherr, and F. Siegert, *A critical appraisal of NLO+PS matching methods*, JHEP **09** (2012) 049, arXiv: `1111.1220 [hep-ph]`.

[39] S. Hoeche, F. Krauss, M. Schonherr, and F. Siegert, *QCD matrix elements + parton showers. The NLO case*, JHEP **04** (2013) 027, arXiv: `1207.5030 [hep-ph]`.

[40] S. Catani, F. Krauss, R. Kuhn, and B. Webber, *QCD Matrix Elements + Parton Showers*, JHEP **11** (2001) 063, arXiv: `hep-ph/0109231`.

[41] S. Höche, F. Krauss, S. Schumann, and F. Siegert, *QCD matrix elements and truncated showers*, JHEP **05** (2009) 053, arXiv: `0903.1219 [hep-ph]`.

[42] C. Anastasiou, L. J. Dixon, K. Melnikov, and F. Petriello, *High precision QCD at hadron colliders: Electroweak gauge boson rapidity distributions at NNLO*, Phys. Rev. D **69** (2004) 094008, arXiv: `hep-ph/0312266`.

[43] T. Sjöstrand et al., *An introduction to PYTHIA 8.2*, Comput. Phys. Commun. **191** (2015) 159, arXiv: `1410.3012 [hep-ph]`.

[44] ATLAS Collaboration, *ATLAS Pythia 8 tunes to* 7 *TeV data*, ATL-PHYS-PUB-2014-021, 2014, URL: `https://cds.cern.ch/record/1966419`.

[45] S. Frixione, E. Laenen, P. Motylinski, B. R. Webber, and C. D. White, *Single-top hadroproduction in association with a W boson*, JHEP **07** (2008) 029, arXiv: `0805.3067 [hep-ph]`.

[46] J. Alwall, R. Frederix, S. Frixione, V. Hirschi, F. Maltoni, et al., *The automated computation of tree-level and next-to-leading order differential cross sections, and their matching to parton shower simulations*, JHEP **07** (2014) 079, arXiv: `1405.0301 [hep-ph]`.

[47] D. J. Lange, *The EvtGen particle decay simulation package*, Nucl. Instrum. Meth. A **462** (2001) 152.

[48] L. Lönnblad and S. Prestel, *Matching tree-level matrix elements with interleaved showers*, JHEP **03** (2012) 019, arXiv: `1109.4829 [hep-ph]`.

[49] S. Agostinelli et al., *Geant4–a simulation toolkit*, Nucl. Instrum. Meth. A **506** (2003) 250.

[50] ATLAS Collaboration, *The ATLAS Simulation Infrastructure*, Eur. Phys. J. C **70** (2010) 823, arXiv: `1005.4568 [physics.ins-det]`.

[51] ATLAS Collaboration, *The simulation principle and performance of the ATLAS fast calorimeter simulation FastCaloSim*, ATL-PHYS-PUB-2010-013, 2010, URL: `https://cds.cern.ch/record/1300517`.

[52] T. Sjöstrand, S. Mrenna, and P. Z. Skands, *A brief introduction to PYTHIA 8.1*, Comput. Phys. Commun. **178** (2008) 852, arXiv: `0710.3820 [hep-ph]`.

[53] ATLAS Collaboration, *The Pythia 8 A3 tune description of ATLAS minimum bias and inelastic measurements incorporating the Donnachie–Landshoff diffractive model*, ATL-PHYS-PUB-2016-017, 2016, URL: `https://cds.cern.ch/record/2206965`.

[54] ATLAS Collaboration, *Performance of electron and photon triggers in ATLAS during LHC Run 2*, Eur. Phys. J. C **80** (2020) 47, arXiv: `1909.00761 [hep-ex]`.

[55] ATLAS Collaboration, *Performance of the ATLAS muon triggers in Run 2*, JINST **15** (2020) P09015, arXiv: `2004.13447 [hep-ex]`.

[56] ATLAS Collaboration, *Vertex Reconstruction Performance of the ATLAS Detector at* $\sqrt{s} = 13$ *TeV*, ATL-PHYS-PUB-2015-026, 2015, URL: `https://cds.cern.ch/record/2037717`.

[57] ATLAS Collaboration, *Electron and photon performance measurements with the ATLAS detector using the 2015–2017 LHC proton–proton collision data*, JINST **14** (2019) P12006, arXiv: `1908.00005 [hep-ex]`.

[58] ATLAS Collaboration, *Muon reconstruction and identification efficiency in ATLAS using the full Run 2 pp collision data set at* $\sqrt{s} = 13$ *TeV*, (2020), arXiv: `2012.00578 [hep-ex]`.

[59] ATLAS Collaboration, *Topological cell clustering in the ATLAS calorimeters and its performance in LHC Run 1*, Eur. Phys. J. C **77** (2017) 490, arXiv: `1603.02934 [hep-ex]`.

[60] ATLAS Collaboration, *Jet reconstruction and performance using particle flow with the ATLAS Detector*, Eur. Phys. J. C **77** (2017) 466, arXiv: `1703.10485 [hep-ex]`.

[61] M. Cacciari, G. P. Salam, and G. Soyez, *The anti-*k_t *jet clustering algorithm*, JHEP **04** (2008) 063, arXiv: `0802.1189 [hep-ph]`.

[62] ATLAS Collaboration, *Jet energy scale and resolution measured in proton–proton collisions at* $\sqrt{s} = 13$ *TeV with the ATLAS detector*, (2020), arXiv: `2007.02645 [hep-ex]`.

[63] ATLAS Collaboration, *Performance of pile-up mitigation techniques for jets in pp collisions at* $\sqrt{s} = 8$ *TeV using the ATLAS detector*, Eur. Phys. J. C **76** (2016) 581, arXiv: `1510.03823 [hep-ex]`.

[64] ATLAS Collaboration, *Optimisation and performance studies of the ATLAS b-tagging algorithms for the 2017-18 LHC run*, ATL-PHYS-PUB-2017-013, 2017, URL: `https://cds.cern.ch/record/2273281`.

[65] ATLAS Collaboration, *Performance of b-jet identification in the ATLAS experiment*, JINST **11** (2016) P04008, arXiv: `1512.01094 [hep-ex]`.

[66] ATLAS Collaboration, *Search for a heavy charged boson in events with a charged lepton and missing transverse momentum from pp collisions at* $\sqrt{s} = 13$ *TeV with the ATLAS detector*, Phys. Rev. D **100** (2019) 052013, arXiv: `1906.05609 [hep-ex]`.

[67] ATLAS Collaboration, *Search for new high-mass phenomena in the dilepton final state using* $36\,fb^{-1}$ *of proton–proton collision data at* $\sqrt{s} = 13$ *TeV with the ATLAS detector*, JHEP **10** (2017) 182, arXiv: `1707.02424 [hep-ex]`.

[68] ATLAS Collaboration, *Luminosity determination in pp collisions at* $\sqrt{s} = 13$ *TeV using the ATLAS detector at the LHC*, ATLAS-CONF-2019-021, 2019, URL: `https://cds.cern.ch/record/2677054`.

[69] ATLAS Collaboration, *Muon reconstruction performance of the ATLAS detector in proton–proton collision data at* $\sqrt{s} = 13$ *TeV*, Eur. Phys. J. C **76** (2016) 292, arXiv: `1603.05598 [hep-ex]`.

[70] ATLAS Collaboration, *ATLAS b-jet identification performance and efficiency measurement with* $t\bar{t}$ *events in pp collisions at* $\sqrt{s} = 13$ *TeV*, Eur. Phys. J. C **79** (2019) 970, arXiv: `1907.05120 [hep-ex]`.

[71] ATLAS Collaboration, *Search for high-mass dilepton resonances in pp collisions at* $\sqrt{s} = 8$ *TeV with the ATLAS detector*, Phys. Rev. D **90** (2014) 052005, arXiv: `1405.4123 [hep-ex]`.

[72] J. Gao and P. Nadolsky, *A meta-analysis of parton distribution functions*, JHEP **07** (2014) 035, arXiv: `1401.0013 [hep-ph]`.

[73] J. Butterworth et al., *PDF4LHC recommendations for LHC Run II*, J. Phys. G **43** (2016) 023001, arXiv: `1510.03865 [hep-ph]`.

[74] A. D. Martin, R. G. Roberts, W. J. Stirling, and R. S. Thorne, *Parton distributions incorporating QED contributions*, Eur. Phys. J. C **39** (2005) 155, arXiv: `hep-ph/0411040`.

[75] J. Bellm et al., *Herwig 7.0/Herwig++ 3.0 release note*, Eur. Phys. J. C **76** (2016) 196, arXiv: `1512.01178 [hep-ph]`.

[76] ATLAS Collaboration, *Studies on top-quark Monte Carlo modelling for Top2016*, ATL-PHYS-PUB-2016-020, 2016, URL: `https://cds.cern.ch/record/2216168`.

[77] G. Cowan, K. Cranmer, E. Gross, and O. Vitells, *Asymptotic formulae for likelihood-based tests of new physics*, Eur. Phys. J. C **71** (2011) 1554, [Erratum: Eur.Phys.J.C 73, 2501 (2013)], arXiv: `1007.1727 [physics.data-an]`.

[78] A. L. Read, *Presentation of search results: The* CL_s *technique*, J. Phys. G **28** (2002) 2693, ed. by M. Whalley and L. Lyons.

[79] ATLAS Collaboration, *ATLAS Computing Acknowledgements*, ATL-SOFT-PUB-2020-001, URL: `https://cds.cern.ch/record/2717821`.