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Search for resonant diboson production in the $\ell\ell q\bar{q}$ final state in pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector

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Abstract This paper reports on a search for narrow resonances in diboson production in the $\ell\ell q\bar{q}$ final state using pp collision data corresponding to an integrated luminosity of 20 fb^{-1} collected at $\sqrt{s} = 8$ TeV with the ATLAS detector at the Large Hadron Collider. No significant excess of data events over the Standard Model expectation is observed. Upper limits at the 95 % confidence level are set on the production cross section times branching ratio for Kaluza–Klein gravitons predicted by the Randall–Sundrum model and for Extended Gauge Model W' bosons. These results lead to the exclusion of mass values below 740 and 1590 GeV for the graviton and W' boson respectively.

1 Introduction

This paper presents a search for narrow diboson resonances in the semileptonic decay channel ZW or $ZZ \rightarrow \ell\ell q\bar{q}$ (where ℓ stands for electron or muon) in pp collision data corresponding to an integrated luminosity of 20 fb^{-1} recorded with the ATLAS detector at a centre-of-mass energy $\sqrt{s} = 8$ TeV at the Large Hadron Collider (LHC). This type of resonances appear in models such as Technicolor [1–3], Warped Extra Dimensions [4–6], and Grand Unified Theories [7–10]. The semileptonic decay channel has a relatively large branching ratio compared to the fully leptonic mode, while the requirement of the presence of two decay leptons can suppress the multijet background present in the fully hadronic mode. Additionally, the absence of neutrinos in the final state allows to reconstruct the invariant mass of the diboson system.

This analysis is optimized using two models with narrow resonances as benchmarks: spin-2 Kaluza–Klein (KK) gravitons ($G^* \rightarrow ZZ$), and spin-1 W' gauge bosons ($W' \rightarrow ZW$) of the Sequential Standard Model (SSM) with modified coupling to ZW, also referred to as the Extended Gauge Model (EGM) [11]. For both models, the W and Z bosons from resonance decays are longitudinally polarized over a pole mass range relevant to this analysis.

The KK graviton interpretation is based on an extended Randall–Sundrum (RS) model with a warped extra dimension in which the Standard Model (SM) fields can propagate [12]. This extended "bulk" RS model avoids constraints on the original RS model [4], referred to as RS1 hereafter, from limits on flavour-changing neutral currents and from electroweak precision tests. The bulk RS model is characterized by a dimensionless coupling constant $k/\bar{M}_{\rm Pl} \sim 1$ where k is the curvature of the warped extra dimension and $\bar{M}_{\rm Pl} = M_{\rm Pl}/\sqrt{8\pi}$ is the reduced Planck mass. The width relative to the mass of the bulk RS graviton with $k/\bar{M}_{\rm Pl} = 1$ varies between 3 and 6 % within the pole mass range of 300–2000 GeV.

The EGM introduces W' and Z' bosons with SM couplings to fermions and with the coupling strength of the heavy W' to WZ modified by a mixing factor $\xi = c \times (m_W/m_{W'})^2$ relative to the SM couplings, where m_W and $m_{W'}$ are the pole masses of the W and W' bosons respectively, and c is a coupling scaling factor. In this scenario the partial width of the W' boson to WZ scales linearly with $m_{W'}$, leading to a narrow resonance over the accessible mass range, in contrast to the SSM where the width grows rapidly as $m^5_{W'}$. For the simulated EGM W' samples used in the analysis, the natural W' width is about 3 % at a pole mass of 300 GeV and increases slightly to 4 % at a pole mass of 2000 GeV.

Previous searches for diboson resonances have been carried out using $p\bar{p}$ collision data at $\sqrt{s} = 1.96$ TeV at the Tevatron and pp collision data at $\sqrt{s} = 7$–8 TeV at the LHC. The D0 Collaboration searched for resonances in WW and ZW production [13,14] and excluded W' bosons in the mass range of 180–690 GeV and RS1 gravitons in the mass interval 300–754 GeV at the 95 % confidence level (CL). The CDF experiment searched for resonances in the ZZ decay channel and set limits on the production cross section of RS1 gravitons in the mass range 300–1000 GeV at the 95 % CL [15]. The ATLAS Collaboration reported searches for resonant ZZ ($\rightarrow \ell\ell\ell'\ell'$, $\ell\ell q\bar{q}$) [16], WW ($\rightarrow \ell\nu q\bar{q}$) [17] and WZ ($\rightarrow \ell\nu q\bar{q}$, $\ell\nu\ell'\ell'$) [17,18] production, and searches for new phenomena in high-mass WW ($\rightarrow \ell\nu\ell'\nu'$) processes [19]

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using pp collision data recorded at $\sqrt{s} = 7$ TeV, except for the $WZ \rightarrow \ell\nu\ell'\ell'$ search in Ref. [18], which used data recorded at $\sqrt{s} = 8$ TeV. Here ℓ' stands for an electron or muon. These studies excluded EGM W' bosons with masses up to 1.52 TeV for WZ final states, RS1 gravitons with masses up to 845 GeV for ZZ final states and up to 1.23 TeV for WW final states. The CMS Collaboration searched for ZZ and WW resonances in the semileptonic decay channel, setting exclusion limits on the production cross section of bulk RS gravitons [20]. In the fully hadronic channel, the CMS Collaboration excluded RS1 gravitons with $k/\bar{M}_{\rm Pl} = 0.1$ for masses up to 1.2 TeV, and W' bosons for masses up to 1.7 TeV [21]. Both of these searches implement jet substructure techniques to identify the event topology where the hadronic system from the decay of one or two gauge bosons is produced at high transverse momentum $p_{\rm T}$, resulting in a single reconstructed jet. In the analysis presented here, a similar technique has been used to identify hadronically decaying W or Z boson produced at high $p_{\rm T}$. This technique uses the characteristics of two cores ("subjets") inside a single reconstructed jet and allows for a significant improvement in acceptance and selection efficiency for high mass states with boosted W and Z bosons over the previous analysis [16].

2 Analysis

In this study, three optimized sets of selection criteria classify $ZW/ZZ \rightarrow \ell\ell q\bar{q}$ events into distinct kinematic regions, namely the "low-$p_{\rm T}$ resolved region" (LR), "high-$p_{\rm T}$ resolved region" (HR) and "merged region" (MR), based on the $p_{\rm T}$ of the dilepton and the hadronic system. In the LR and HR the hadronic boson decay is reconstructed as two distinct jets, whereas in the MR it is reconstructed as a single jet. In all three cases, the dilepton (hadronic system) mass is required to be consistent with the mass of the Z boson (W or Z boson). In the MR, additional jet substructure information, optimized for the identification of the hadronic decay of a longitudinally polarized high-$p_{\rm T}$ boson, is used to improve the sensitivity. Finally, the $\ell\ell q\bar{q}$ mass spectrum, reconstructed as the mass of the dilepton and the two-jet system in the LR and HR ($m_{\ell\ell jj}$) or the dilepton and the single-jet system in the MR ($m_{\ell\ell J}$), is examined for excesses with respect to the expectation from SM processes (background).

2.1 Detector and data sample

The ATLAS detector [22] consists of an inner detector (ID) providing charged particle tracking for the pseudorapidity[1] range $|\eta| < 2.5$, surrounded by a superconducting solenoid, electromagnetic and hadronic calorimeters with a coverage of $|\eta| < 4.9$, and a muon spectrometer (MS) with toroidal magnets that provides muon identification in the range $|\eta| < 2.7$.

This study uses an integrated luminosity of 20.3 fb^{-1} of pp collision data collected in 2012. The luminosity is derived from beam-separation scans [23] and has an uncertainty of 2.8 %. Events are selected with lepton triggers that require the presence of at least one lepton (electron or muon) with $p_{\rm T}$ above 24 GeV. The trigger efficiency for signal events that pass the selection criteria described in Sect. 2.3 is approximately 92 % for the muon channel and greater than 99 % for the electron channel.

Table 1 Theoretical production cross section times branching ratio $\sigma_{G^*}(pp \rightarrow G^*) \cdot {\rm BR}(G^* \rightarrow ZZ)$ with $k/\bar{M}_{\rm Pl} = 1.0$ and $\sigma_{W'}(pp \rightarrow W') \cdot {\rm BR}(W' \rightarrow ZW)$ with $c = 1$ for different pole masses of the resonances

Pole mass (GeV)	$\sigma_{G^*} \cdot$ BR (fb)	$\sigma_{W'} \cdot$ BR (fb)
500	540	4100
800	23	540
1400	0.44	33

2.2 Simulated event samples

To model the acceptance and the reconstructed mass spectra for narrow resonances, benchmark signal samples are generated with pole masses between 300 and 2000 GeV, in 100 GeV steps. Additional samples are generated between 350 and 950 GeV for the bulk RS G^* signal so that the mass gap is reduced to 50 GeV, which is comparable to the detector resolution of the reconstructed $\ell\ell q\bar{q}$ mass in this mass interval. The bulk RS G^* signal events are generated by CalcHEP [24] with $k/\bar{M}_{\rm Pl} = 1.0$, and the W' signal sample is generated with Pythia 8 [25], setting the coupling scale factor $c = 1$. The factorization and renormalization scales are set to the resonance mass. The hadronisation and fragmentation are modelled with Pythia 8 in both cases, and the CTEQ6L1 [26] (MSTW2008LO [27]) parton distribution functions (PDFs) are used for the G^* (W') signal. The W' production cross section is scaled to a next-to-next-to-leading-order (NNLO) calculation in α_s by ZWprod [28]. Calculated production cross section times branching ratio values for different pole masses are given in Table 1.

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

The main background sources are Z bosons produced in association with jets (Z + jets), followed by top-quark pair and non-resonant vector-boson pair production. The contribution from multijet events is negligible after the selection cuts described in Sect. 2.3. All background estimates are based on simulation. Additionally, the main background source, Z + jets, is estimated using constraints from data as described in Sect. 2.4. The Z + jets background is modelled by the SHERPA generator [29] with CT10 PDFs [30]. The top pair, s-channel single-top and Wt processes are modelled by the MC@NLO [31–34] generator with CT10 PDFs, interfaced to HERWIG [35,36] for hadronisation and JIMMY [37] for modelling of the underlying event. The top pair production cross section is calculated at NNLO in QCD including resummation of next-to-next-to-leading logarithmic soft gluon terms with Top++2.0 [38–43]. The t-channel single-top events are generated by AcerMC [44] with CTEQ6L1 PDFs and PYTHIA 6 [45] for hadronisation. The diboson events are produced with the HERWIG generator and CTEQ6L1 PDFs. The diboson production cross sections are normalized to predictions at next-to-leading-order accuracy as calculated with [46]. Generated events are processed with the ATLAS detector simulation program [47] based on the GEANT4 package [48]. Effects from additional inelastic pp interactions (pile-up) occurring in the same bunch crossing are taken into account by overlaying minimum-bias events simulated by PYTHIA 8.

2.3 Object and event selection

Electron candidates are selected from energy clusters in the electromagnetic calorimeter according to the medium criteria of Ref. [49], which impose requirements on the shower profile and demand an associated ID track. Offline reconstructed electrons are required to have $p_{\mathrm{T}} > 25$ GeV and $|\eta| < 2.47$. The transition region between the barrel and endcaps ($1.37 < |\eta| < 1.52$) exhibits degraded energy resolution and is therefore excluded.

Muon candidates are reconstructed by combining ID and MS tracks which have consistent position, charge and momentum measurements [50]. The muon candidates are required to have $p_{\mathrm{T}} > 25$ GeV and $|\eta| < 2.4$.

A primary vertex reconstructed from at least three well-reconstructed charged particle tracks, each with $p_{\mathrm{T}} > 400$ MeV, is required in order to remove non-collision background. If an event contains more than one primary vertex candidate, the vertex with the highest Σp_{T}^2 of the associated tracks is selected. To ensure that both electrons or muons originate from the primary vertex, it is required that the product of the longitudinal impact parameter (z_0) and the sine of the polar angle of the candidate (θ) satisfies $|z_0 \sin(\theta)| < 0.5$ mm, and that the ratio of the transverse impact parameter (d_0) to its uncertainty (σ_{d_0}) for electrons (muons) fulfils $|d_0|/\sigma_{d_0} < 6$ (3.5). In addition, the lepton candidates are required to be isolated from other tracks and calorimetric activity. The scalar sum of the transverse momenta of tracks within a cone of size $\Delta R \equiv \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} = 0.2$ around the lepton track is required to be less than 15 % of the candidate p_{T}. Similarly, the sum of transverse energy deposits in the calorimeter within a cone of size $\Delta R = 0.2$, excluding the transverse energy due to the lepton, and corrected for the expected pile-up contribution, is required to be less than 30 % of the candidate p_{T} (calorimetric isolation).

To improve the acceptance for events with boosted Z bosons, with $p_{\mathrm{T}} > 800$ GeV, the isolation method is modified for dilepton objects: a dilepton track isolation variable is calculated for each lepton of a like-flavour pair by subtracting the p_{T} of the paired lepton from the p_{T} sum described above if it falls inside the isolation cone of the lepton under consideration. The modified scalar sum p_{T} variable for the dilepton isolation is required to be less than 15 % of the lepton p_{T}, as in the standard track isolation. The calorimetric isolation requirements are dropped if $\Delta R(\ell\ell) < 0.25$.

Jets are reconstructed from clusters of calorimeter cells using the anti-k_t algorithm [51,52] with a distance parameter $R = 0.4$. Jets are required to be in the range $|\eta| < 2.1$ and to have $p_{\mathrm{T}} > 30$ GeV after correcting for energy losses in passive material, the non-compensating response of the calorimeter and extra energy due to event pile-up [53]. Furthermore, for jets with $p_{\mathrm{T}} < 50$ GeV, the scalar sum p_{T} of associated tracks from the primary vertex is required to be at least 50 % of the scalar sum p_{T} of all associated tracks to suppress jets from pile-up interactions. The selected anti-k_t jets are referred to as small-R jets and denoted by "j" hereafter.

For resonances with a mass above about 900 GeV, the $q\bar{q}$ pair is often merged into a single jet and the fraction of merged $q\bar{q}$ pairs increases with the resonance mass. Such jets are reconstructed with the Cambridge–Aachen jet clustering algorithm [54] with a distance parameter $R = 1.2$. To exploit the characteristics of the decay of the massive boson into a $q\bar{q}$ pair, these jets are further required to pass a splitting and filtering algorithm similar to the algorithm described in Ref. [55] but optimized for the identification of very high-p_{T} boson decays [56]. These jets are required to be within $|\eta| < 1.2$ and to have $p_{\mathrm{T}} > 100$ GeV, and are referred to as large-R jets or "J" hereafter.

Events which contain exactly two electrons or muons satisfying the above criteria are selected if at least one is associated with a lepton trigger candidate. To select lepton pairs originating from a Z boson decay, the dilepton invariant mass ($m_{\ell\ell}$) is required to be in the range 66 GeV $< m_{\ell\ell} <$ 116 GeV. The $m_{\ell\ell}$ cut range is chosen to be wide to enhance the signal sensitivity, given that the dominant background is from the Z + jets processes and a narrower cut would not provide additional discrimination power. Muon-pair events are further required to have muons of opposite charge. The

Table 2 Event yields in signal regions for data, expected backgrounds, and G^* and W' signals. The statistical and systematic uncertainties are given separately (in this order), except for the total background where the combined statistical and systematic uncertainty before (unconstrained) and after (constrained) the fit to the data in the signal regions is shown. The signal mass points correspond to 500 (LR), 800 (HR), 1400 (MR) GeV

Sample	LR	HR	MR
Z + jets	$9460 \pm 40 \pm 660$	$591 \pm 4 \pm 15$	$20.9 \pm 0.3 \pm 2.3$
$WW/WZ/ZZ$	$234 \pm 4 \pm 22$	$20.6 \pm 0.3 \pm 1.4$	$1.38 \pm 0.02 \pm 0.13$
$t\bar{t}$ + Single t	$175.3 \pm 9.2 \pm 9.9$	–	–
Total (unconstrained)	9870 ± 690	612 ± 17	22.3 ± 2.5
Total (constrained)	9730 ± 98	608.8 ± 3.8	21.80 ± 0.46
Data	9728	619	25
G^* signal	$1097 \pm 17 \pm 63$	$14.27 \pm 0.19 \pm 0.76$	$0.0995 \pm 0.0013 \pm 0.0059$
W' signal	$1950 \pm 40 \pm 140$	$145.0 \pm 2.3 \pm 8.1$	$3.64 \pm 0.06 \pm 0.31$

opposite charge requirement is not required for electron-pair events because of a higher charge misidentification rate for high-p_{T} electrons.

The three selection regions are differentiated by the p_{T} ranges for the leptonic Z decay candidate ($p_{\mathrm{T}}^{\ell\ell}$) and hadronic jet system, namely $p_{\mathrm{T}}^{\ell\ell} > 400$ GeV and $p_{\mathrm{T}}^{J} > 400$ GeV for the large-R jet in the MR, and $p_{\mathrm{T}}^{\ell\ell} > 100$ (250) GeV and $p_{\mathrm{T}}^{jj} > 100$ (250) GeV for the two small-R jets at low (high) p_{T} in the LR (HR). The mass of the hadronic jet system is required to be in the range 70 GeV $< m_{jj/J} <$ 110 GeV for both the hadronic W and Z decay candidates in all three regions. In the MR, the large-R jet is split into subjets using an algorithm described in Ref. [55]. However, in contrast to the configuration used in Ref. [55], the mass relation between the large-R jet and subjets, the mass drop, is not imposed. A subjet momentum balance variable is defined as $\sqrt{y_{\mathrm{f}}} = \min(p_{\mathrm{T}}^{j1}, p_{\mathrm{T}}^{j2})\Delta R_{12}/m_{12}$, where p_{T}^{j1} and p_{T}^{j2} are the transverse momenta of the two leading subjets, ΔR_{12} is their separation and m_{12} is their mass. To suppress jets from gluon radiation and splitting, the subjet momentum balance is required to be $\sqrt{y_{\mathrm{f}}} > 0.45$. Events are classified by sequentially applying the criteria for the MR, HR, and LR, thus assigning each event exclusively to one region. Overall, the signal acceptance times efficiency after all selection requirements increases from 5 to 10 % at $m_{G^*} = 300$ GeV to a plateau of 30–35 % above $m_{G^*} = 500$ GeV for a signal sample of $G^* \to ZZ \to \ell\ell q\bar{q}$. The improvement in acceptance compared to the previous analysis [16] ranges up to a factor of five for masses above 1.5 TeV.

2.4 Background and event yield

The simulation of the main background source (Z + jets) is corrected using data. The normalization and $m_{\ell\ell jj/J}$ shape corrections of the simulated Z + jets background sample is determined from data in a control region defined by all selection cuts but with an inverted cut on $m_{jj/J}$, namely $m_{jj/J} < 70$ GeV or $m_{jj/J} > 110$ GeV, in the resolved and merged regions, respectively. The normalization corrections, obtained as the ratio of event yields in the data and Z + jets simulated samples for the electron and muon channel, after removing contributions from subdominant backgrounds from the data spectrum, range between 2 and 10 %. The $m_{\ell\ell jj/J}$ shape correction is well reproduced with a linear fit to the ratio of data to Z+jets background, derived for each signal region after combining the electron and muon channels. This results in bin-by-bin corrections of up to 7 % in the LR, 3 % in the HR, and 22 % in the MR. The other backgrounds, from diboson and top production, are taken from simulation without applying corrections from data control regions.

The event yield in the three signal regions is summarized in Table 2. The total event yield with combined statistical and systematic uncertainties is given before and after the simultaneous fit to the three signal regions (cf. Sect. 3).

2.5 Systematic uncertainties

The main systematic uncertainty on the $m_{\ell\ell jj/J}$ spectrum comes from the uncertainty in the Z+jets background modelling. The normalization uncertainty of the Z + jets background is estimated from the relative difference between the normalization corrections derived from the nominal control region ($m_{jj/J} < 70$ GeV or $>$ 110 GeV) and either the lower or higher mass region, taking the larger of the two as an estimate of the systematic uncertainty. If the resulting uncertainty is smaller than the statistical uncertainty of the normalization correction from the nominal control region, the latter is used as the systematic uncertainty. The uncertainty of the shape correction is estimated from the uncertainty on the slope parameter of the linear fit and is treated as uncorrelated with respect to the normalization uncertainty. The combined normalization and shape uncertainties vary as a function of $m_{\ell\ell jj/J}$ and range from 6 to 9 % in the LR, 2 to 8 % in the HR, and 11 to 47 % in the MR. For all simulated samples, detector performance-related systematic uncertainties including the small-R jet energy scale and resolution, large-R jet energy, mass and momentum-balance scales and resolutions, the lepton reconstruction and identification efficiencies, and lepton momentum scales and resolutions are also considered. The large-R jet energy and mass scale uncertainties are evaluated by comparing the ratio of calorimeter-based to track-based measurements in dijet data and simulated events, and are validated using a data sample of high-p_T W bosons produced in association with jets. A Kolmogorov–Smirnov (KS) test [57] is then performed between the nominal and systematically varied distributions for a given systematic uncertainty source to determine if it has a sizeable effect on the shape of background and signal estimations. Only significant systematic effects are retained in the analysis by requiring a KS probability of less then 10 %. For the normalization, if the event yield changes by more than half the statistical uncertainty of the nominal yield, the systematic uncertainty is included.

Uncertainties on signal acceptance due to PDF sets, renormalization and factorization scale choices, initial- and final-state gluon radiation (ISR/FSR) modelling, and LHC beam energy uncertainty are also considered. The PDF uncertainties are estimated by taking the acceptance difference between CTEQL1 and MSTW2008LO PDFs and adding it in quadrature to the difference between MSTW2008LO error sets. The uncertainties due to the scale and ISR/FSR modelling are estimated by varying relevant parameters in PYTHIA 8 by a factor of 2.0 and 0.5. The beam energy systematic uncertainty is assessed with simulation by varying the beam energy within the measured uncertainty of 0.66 % [58], leading to at most a 1 % effect on acceptance. The dominant uncertainty comes from ISR/FSR modelling and is approximately 5 %.

3 Results

The invariant mass of the diboson system is reconstructed from the $\ell\ell jj$ or $\ell\ell J$ system. The reconstructed $m_{\ell\ell jj/J}$ distributions for data and simulated background events in the three signal regions are shown in Fig. 1 for the combined electron and muon channels. Good agreement is observed between the data and the background predictions, with p value[2] ranging from 0.98 to 0.10, and the results are presented as 95 % confidence level upper limits on the production cross section times branching ratio for the G^* and W' models. The upper limits are determined using the CL_S modified frequentist formalism [59] with a profile likelihood test statistic [60].

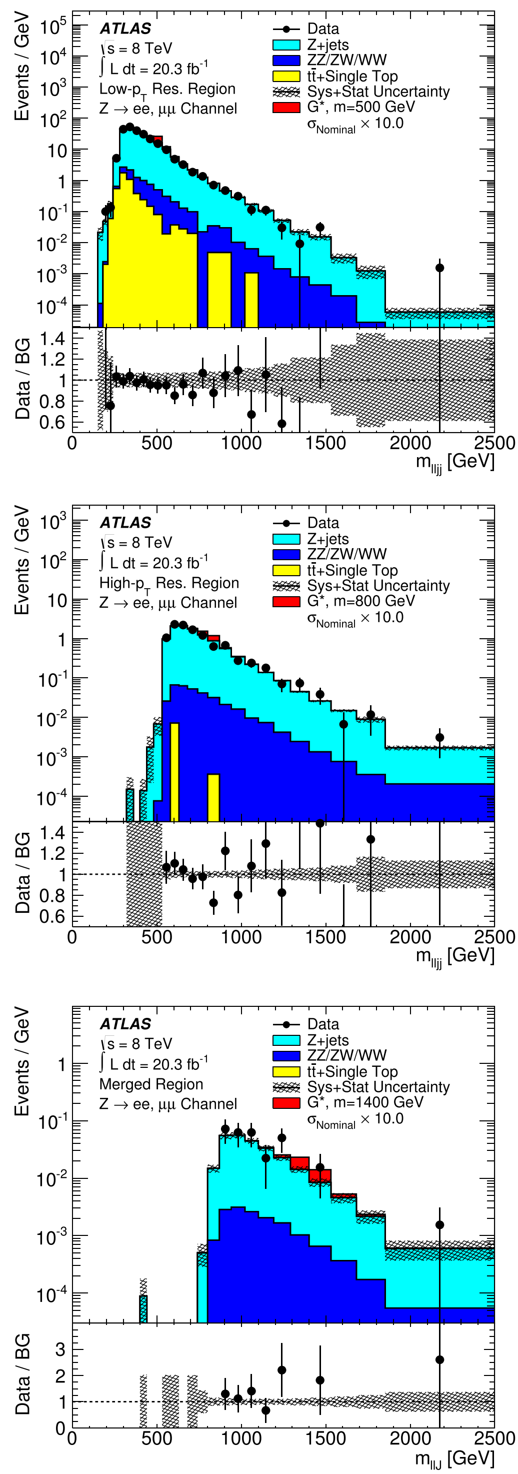

Fig. 1 Reconstructed $\ell\ell jj$ or $\ell\ell J$ mass distributions in the data and for background after all the selection cuts are applied in the three kinematic regions referred to as the LR (*top*), HR (*middle*) and MR (*bottom*) in the text. The shaded regions show the full background uncertainty obtained by adding statistical and systematic uncertainties in quadrature, including the constraints on the background from the data control regions and before the fit to the data in the signal regions (cf. unconstrained case in Table 2). Also shown are the G^* signal yields expected for masses of 500, 800 and 1400 GeV with the production cross sections scaled by a factor 10

[2] The p value is the probability that the background can produce a fluctuation greater than or equal to the excess observed in data.

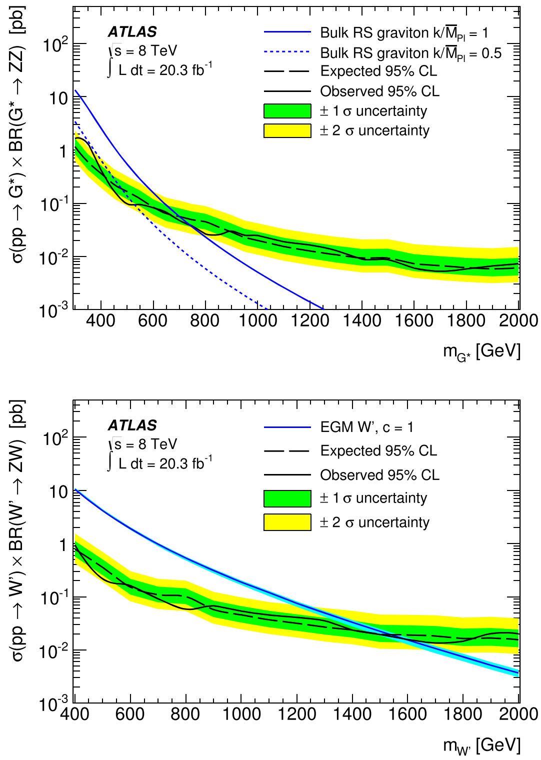

Fig. 2 Observed and expected 95 % CL upper limits on the cross section times branching fraction as a function of the resonance pole mass for the G^* (*top*) and EGM W' (*bottom*). The LO (NNLO) theoretical cross sections for G^* (EGM W') production with $k/\bar{M}_{\rm Pl} = 0.5$ and 1.0 ($c = 1$) are also shown. The band around the W' cross section represents the theoretical uncertainty on the NNLO calculation. The *inner* and *outer* bands on the expected limits represent $\pm 1\sigma$ and $\pm 2\sigma$ variations respectively

The test statistic is evaluated with a maximum likelihood fit of signal models and background predictions to the reconstructed $m_{\ell\ell jj/J}$ spectra shown in Fig. 1. Systematic uncertainties and their correlations are taken into account as nuisance parameters with Gaussian constraints. The likelihood fit, which takes into account correlations between the systematic uncertainties, is performed for signal pole masses ranging between 300 and 850 GeV for the LR, 550 and 1800 GeV for the HR and 800 and 2000 GeV for the MR. Overlapping regions are fit simultaneously.

Figure 2 shows 95 % CL upper limits on the production cross section times branching fraction into ZZ or ZW as a function of the resonance pole mass. The theoretical predictions for the EGM W' and the bulk RS G^* with two different values of the coupling constant, shown in the figure, allow the extraction of observed (expected) lower mass limits of 1590 (1540) GeV for the W', and 740 and 540 (700 and 490) GeV for the G^* with $k/\bar{M}_{\rm Pl} = 1.0$ and 0.5 respectively. The most powerful search regions are the LR for masses below 550 GeV, the HR from 500 to 850 GeV and the MR for higher masses.

4 Conclusion

In summary, a search for narrow, heavy resonances produced in pp collisions and decaying to diboson final states at the Large Hadron Collider has been performed. The data sample analysed, corresponding to an integrated luminosity of 20 fb^{-1} at $\sqrt{s} = 8$ TeV, was recorded with the ATLAS detector. No significant excess over the Standard Model background expectation was found. Upper limits on the production cross section times branching ratio and mass exclusion limits are derived for W' bosons in the theoretical framework of an Extended Gauge Model and for gravitons in warped extra dimensions in the context of the bulk Randall–Sundrum model. The results represent a significant improvement over previously reported limits by ATLAS [16] due to increased pp collision energy and data set size as well as the development of new techniques to analyse heavily boosted decays of bosons.

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ATLAS Collaboration

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Di Ciaccio[134a,134b], L. Di Ciaccio[5], A. Di Domenico[133a,133b], C. Di Donato[103a,103b], A. Di Girolamo[30], B. Di Girolamo[30], A. Di Mattia[153], B. Di Micco[135a,135b], R. Di Nardo[47], A. Di Simone[48], R. Di Sipio[20a,20b], D. Di Valentino[29], F. A. Dias[46], M. A. Diaz[32a], E. B. Diehl[88], J. Dietrich[42], T. A. Dietzsch[58a], S. Diglio[84], A. Dimitrievska[13a], J. Dingfelder[21], C. Dionisi[133a,133b], P. Dita[26a], S. Dita[26a], F. Dittus[30], F. Djama[84], T. Djobava[51b], M. A. B. do Vale[24c], A. Do Valle Wemans[125a,125g], D. Dobos[30], C. Doglioni[49], T. Doherty[53], T. Dohmae[156], J. Dolejsi[128], Z. Dolezal[128], B. A. Dolgoshein[97,*], M. Donadelli[24d], S. Donati[123a,123b], P. Dondero[120a,120b], J. Donini[34], J. Dopke[130], A. Doria[103a], M. T. Dova[70], A. T. Doyle[53], M. Dris[10], J. Dubbert[88], S. Dube[15], E. Dubreuil[34], E. Duchovni[173], G. Duckeck[99], O. A. Ducu[26a], D. Duda[176], A. Dudarev[30], F. Dudziak[63], L. Duflot[116], L. Duguid[76], M. Dührssen[30], M. Dunford[58a], H. Duran Yildiz[4a], M. Düren[52], A. Durglishvili[51b], M. Dwuznik[38a], M. Dyndal[38a], J. Ebke[99], W. Edson[2], N. C. Edwards[46], W. Ehrenfeld[21], T. Eifert[144], G. Eigen[14], K. Einsweiler[15], T. Ekelof[167], M. El Kacimi[136c], M. Ellert[167], S. Elles[5], F. Ellinghaus[82], N. Ellis[30], J. Elmsheuser[99], M. Elsing[30], D. Emeliyanov[130], Y. Enari[156], O. C. Endner[82], M. Endo[117], R. Engelmann[149], J. Erdmann[177], A. Ereditato[17], D. Eriksson[147a], G. Ernis[176], J. Ernst[2], M. Ernst[25], J. Erwein[137], D. Errede[166], S. Errede[166], E. Ertel[82], M. Escalier[116], H. Esch[43], C. Escobar[124], B. Esposito[47], A. I. Etienvre[137], E. Etzion[154], H. Evans[60], A. Ezhilov[122], L. Fabbri[20a,20b], G. Facini[31], R. M. Fakhrutdinov[129], S. Falciano[133a], R. J. Falla[77], J. Faltova[128], Y. Fang[33a], M. Fanti[90a,90b], A. Farbin[8], A. Farilla[135a], T. Farooque[12],

S. Farrell[15], S. M. Farrington[171], P. Farthouat[30], F. Fassi[136e], P. Fassnacht[30], D. Fassouliotis[9], A. Favareto[50a,50b], L. Fayard[116], P. Federic[145a], O. L. Fedin[122,k], W. Fedorko[169], M. Fehling-Kaschek[48], S. Feigl[30], L. Feligioni[84], C. Feng[33d], E. J. Feng[6], H. Feng[88], A. B. Fenyuk[129], S. Fernandez Perez[30], S. Ferrag[53], J. Ferrando[53], A. Ferrari[167], P. Ferrari[106], R. Ferrari[120a], D. E. Ferreira de Lima[53], A. Ferrer[168], D. Ferrere[49], C. Ferretti[88], A. Ferretto Parodi[50a,50b], M. Fiascaris[31], F. Fiedler[82], A. Filipčič[74], M. Filipuzzi[42], F. Filthaut[105], M. Fincke-Keeler[170], K. D. Finelli[151], M. C. N. Fiolhais[125a,125c], L. Fiorini[168], A. Firan[40], A. Fischer[2], J. Fischer[176], W. C. Fisher[89], E. A. Fitzgerald[23], M. Flechl[48], I. Fleck[142], P. Fleischmann[88], S. Fleischmann[176], G. T. Fletcher[140], G. Fletcher[75], T. Flick[176], A. Floderus[80], L. R. Flores Castillo[174,l], A. C. Florez Bustos[160b], M. J. Flowerdew[100], A. Formica[137], A. Forti[83], D. Fortin[160a], D. Fournier[116], H. Fox[71], S. Fracchia[12], P. Francavilla[79], M. Franchini[20a,20b], S. Franchino[30], D. Francis[30], L. Franconi[118], M. Franklin[57], S. Franz[61], M. Fraternali[120a,120b], S. T. French[28], C. Friedrich[42], F. Friedrich[44], D. Froidevaux[30], J. A. Frost[28], C. Fukunaga[157], E. Fullana Torregrosa[82], B. G. Fulsom[144], J. Fuster[168], C. Gabaldon[55], O. Gabizon[176], A. Gabrielli[20a,20b], A. Gabrielli[133a,133b], S. Gadatsch[106], S. Gadomski[49], G. Gagliardi[50a,50b], P. Gagnon[60], C. Galea[105], B. Galhardo[125a,125c], E. J. Gallas[119], V. Gallo[17], B. J. Gallop[130], P. Gallus[127], G. Galster[36], K. K. Gan[110], J. Gao[33b,h], Y. S. Gao[144,f], F. M. Garay Walls[46], F. Garberson[177], C. García[168], J. E. García Navarro[168], M. Garcia-Sciveres[15], R. W. Gardner[31], N. Garelli[144], V. Garonne[30], C. Gatti[47], G. Gaudio[120a], B. Gaur[142], L. Gauthier[94], P. Gauzzi[133a,133b], I. L. Gavrilenko[95], C. Gay[169], G. Gaycken[21], E. N. Gazis[10], P. Ge[33d], Z. Gecse[169], C. N. P. Gee[130], D. A. A. Geerts[106], Ch. Geich-Gimbel[21], K. Gellerstedt[147a,147b], C. Gemme[50a], A. Gemmell[53], M. H. Genest[55], S. Gentile[133a,133b], M. George[54], S. George[76], D. Gerbaudo[164], A. Gershon[154], H. Ghazlane[136b], N. Ghodbane[34], B. Giacobbe[20a], S. Giagu[133a,133b], V. Giangiobbe[12], P. Giannetti[123a,123b], F. Gianotti[30], B. Gibbard[25], S. M. Gibson[76], M. Gilchriese[15], T. P. S. Gillam[28], D. Gillberg[30], G. Gilles[34], D. M. Gingrich[3,e], N. Giokaris[9], M. P. Giordani[165a,165c], R. Giordano[103a,103b], F. M. Giorgi[20a], F. M. Giorgi[16], P. F. Giraud[137], D. Giugni[90a], C. Giuliani[48], M. Giulini[58b], B. K. Gjelsten[118], S. Gkaitatzis[155], I. Gkialas[155,m], L. K. Gladilin[98], C. Glasman[81], J. Glatzer[30], P. C. F. Glaysher[46], A. Glazov[42], G. L. Glonti[64], M. Goblirsch-Kolb[100], J. R. Goddard[75], J. Godlewski[30], C. Goeringer[82], S. Goldfarb[88], T. Golling[177], D. Golubkov[129], A. Gomes[125a,125b,125d], L. S. Gomez Fajardo[42], R. Gonçalo[125a], J. Goncalves Pinto Firmino Da Costa[137], L. Gonella[21], S. González de la Hoz[168], G. Gonzalez Parra[12], S. Gonzalez-Sevilla[49], L. Goossens[30], P. A. Gorbounov[96], H. A. Gordon[25], I. Gorelov[104], B. Gorini[30], E. Gorini[72a,72b], A. Gorišek[74], E. Gornicki[39], A. T. Goshaw[6], C. Gössling[43], M. I. Gostkin[64], M. Gouighri[136a], D. Goujdami[136c], M. P. Goulette[49], A. G. Goussiou[139], C. Goy[5], S. Gozpinar[23], H. M. X. Grabas[137], L. Graber[54], I. Grabowska-Bold[38a], P. Grafström[20a,20b], K-J. Grahn[42], J. Gramling[49], E. Gramstad[118], S. Grancagnolo[16], V. Grassi[149], V. Gratchev[122], H. M. Gray[30], E. Graziani[135a], O. G. Grebenyuk[122], Z. D. Greenwood[78,n], K. Gregersen[77], I. M. Gregor[42], P. Grenier[144], J. Griffiths[8], A. A. Grillo[138], K. Grimm[71], S. Grinstein[12,o], Ph. Gris[34], Y. V. Grishkevich[98], J.-F. Grivaz[116], J. P. Grohs[44], A. Grohsjean[42], E. Gross[173], J. Grosse-Knetter[54], G. C. Grossi[134a,134b], J. Groth-Jensen[173], Z. J. Grout[150], L. Guan[33b], J. Guenther[127], F. Guescini[49], D. Guest[177], O. Gueta[154], C. Guicheney[34], E. Guido[50a,50b], T. Guillemin[116], S. Guindon[2], U. Gul[53], C. Gumpert[44], J. Guo[35], S. Gupta[119], P. Gutierrez[112], N. G. Gutierrez Ortiz[53], C. Gutschow[77], N. Guttman[154], C. Guyot[137], C. Gwenlan[119], C. B. Gwilliam[73], A. Haas[109], C. Haber[15], H. K. Hadavand[8], N. Haddad[136e], P. Haefner[21], S. Hageböeck[21], Z. Hajduk[39], H. Hakobyan[178], M. Haleem[42], D. Hall[119], G. Halladjian[89], K. Hamacher[176], P. Hamal[114], K. Hamano[170], M. Hamer[54], A. Hamilton[146a], S. Hamilton[162], G. N. Hamity[146c], P. G. Hamnett[42], L. Han[33b], K. Hanagaki[117], K. Hanawa[156], M. Hance[15], P. Hanke[58a], R. Hanna[137], J. B. Hansen[36], J. D. Hansen[36], P. H. Hansen[36], K. Hara[161], A. S. Hard[174], T. Harenberg[176], F. Hariri[116], S. Harkusha[91], D. Harper[88], R. D. Harrington[46], O. M. Harris[139], P. F. Harrison[171], F. Hartjes[106], M. Hasegawa[66], S. Hasegawa[102], Y. Hasegawa[141], A. Hasib[112], S. Hassani[137], S. Haug[17], M. Hauschild[30], R. Hauser[89], M. Havranek[126], C. M. Hawkes[18], R. J. Hawkings[30], A. D. Hawkins[80], T. Hayashi[161], D. Hayden[89], C. P. Hays[119], H. S. Hayward[73], S. J. Haywood[130], S. J. Head[18], T. Heck[82], V. Hedberg[80], L. Heelan[8], S. Heim[121], T. Heim[176], B. Heinemann[15], L. Heinrich[109], J. Hejbal[126], L. Helary[22], C. Heller[99], M. Heller[30], S. Hellman[147a,147b], D. Hellmich[21], C. Helsens[30], J. Henderson[119], R. C. W. Henderson[71], Y. Heng[174], C. Hengler[42], A. Henrichs[177], A. M. Henriques Correia[30], S. Henrot-Versille[116], C. Hensel[54], G. H. Herbert[16], Y. Hernández Jiménez[168], R. Herrberg-Schubert[16], G. Herten[48], R. Hertenberger[99], L. Hervas[30], G. G. Hesketh[77], N. P. Hessey[106], R. Hickling[75], E. Higón-Rodriguez[168], E. Hill[170], J. C. Hill[28], K. H. Hiller[42], S. Hillert[21], S. J. Hillier[18], I. Hinchliffe[15], E. Hines[121], M. Hirose[158], D. Hirschbuehl[176], J. Hobbs[149], N. Hod[106], M. C. Hodgkinson[140], P. Hodgson[140], A. Hoecker[30], M. R. Hoeferkamp[104], F. Hoenig[99], J. Hoffman[40], D. Hoffmann[84], J. I. Hofmann[58a], M. Hohlfeld[82], T. R. Holmes[15], T. M. Hong[121], L. Hooft van Huysduynen[109], W. H. Hopkins[115], Y. Horii[102], J-Y. Hostachy[55], S. Hou[152], A. Hoummada[136a], J. Howard[119], J. Howarth[42], M. Hrabovsky[114], I. Hristova[16], J. Hrivnac[116], T. Hryn'ova[5], C. Hsu[146c], P. J. Hsu[82], S.-C. Hsu[139], D. Hu[35], X. Hu[88], Y. Huang[42], Z. Hubacek[30], F. Hubaut[84], F. Huegging[21], T. B. Huffman[119], E. W. Hughes[35], G. Hughes[71], M. Huhtinen[30], T. A. Hülsing[82], M. Hurwitz[15], N. Huseynov[64,b], J. Huston[89], J. Huth[57], G. Iacobucci[49], G. Iakovidis[10], I. Ibragimov[142],

L. Iconomidou-Fayard[116], E. Ideal[177], P. Iengo[103a], O. Igonkina[106], T. Iizawa[172], Y. Ikegami[65], K. Ikematsu[142], M. Ikeno[65], Y. Ilchenko[31,p], D. Iliadis[155], N. Ilic[159], Y. Inamaru[66], T. Ince[100], P. Ioannou[9], M. Iodice[135a], K. Iordanidou[9], V. Ippolito[57], A. Irles Quiles[168], C. Isaksson[167], M. Ishino[67], M. Ishitsuka[158], R. Ishmukhametov[110], C. Issever[119], S. Istin[19a], J. M. Iturbe Ponce[83], R. Iuppa[134a,134b], J. Ivarsson[80], W. Iwanski[39], H. Iwasaki[65], J. M. Izen[41], V. Izzo[103a], B. Jackson[121], M. Jackson[73], P. Jackson[1], M. R. Jaekel[30], V. Jain[2], K. Jakobs[48], S. Jakobsen[30], T. Jakoubek[126], J. Jakubek[127], D. O. Jamin[152], D. K. Jana[78], E. Jansen[77], H. Jansen[30], J. Janssen[21], M. Janus[171], G. Jarlskog[80], N. Javadov[64,b], T. Javůrek[48], L. Jeanty[15], J. Jejelava[51a,q], G.-Y. Jeng[151], D. Jennens[87], P. Jenni[48,r], J. Jentzsch[43], C. Jeske[171], S. Jézéquel[5], H. Ji[174], J. Jia[149], Y. Jiang[33b], M. Jimenez Belenguer[42], S. Jin[33a], A. Jinaru[26a], O. Jinnouchi[158], M. D. Joergensen[36], K. E. Johansson[147a,147b], P. Johansson[140], K. A. Johns[7], K. Jon-And[147a,147b], G. Jones[171], R. W. L. Jones[71], T. J. Jones[73], J. Jongmanns[58a], P. M. Jorge[125a,125b], K. D. Joshi[83], J. Jovicevic[148], X. Ju[174], C. A. Jung[43], R. M. Jungst[30], P. Jussel[61], A. Juste Rozas[12,o], M. Kaci[168], A. Kaczmarska[39], M. Kado[116], H. Kagan[110], M. Kagan[144], E. Kajomovitz[45], C. W. Kalderon[119], S. Kama[40], A. Kamenshchikov[129], N. Kanaya[156], M. Kaneda[30], S. Kaneti[28], V. A. Kantserov[97], J. Kanzaki[65], B. Kaplan[109], A. Kapliy[31], D. Kar[53], K. Karakostas[10], N. Karastathis[10], M. J. Kareem[54], M. Karnevskiy[82], S. N. Karpov[64], Z. M. Karpova[64], K. Karthik[109], V. Kartvelishvili[71], A. N. Karyukhin[129], L. Kashif[174], G. Kasieczka[58b], R. D. Kass[110], A. Kastanas[14], Y. Kataoka[156], A. Katre[49], J. Katzy[42], V. Kaushik[7], K. Kawagoe[69], T. Kawamoto[156], G. Kawamura[54], S. Kazama[156], V. F. Kazanin[108], M. Y. Kazarinov[64], R. Keeler[170], R. Kehoe[40], M. Keil[54], J. S. Keller[42], J. J. Kempster[76], H. Keoshkerian[5], O. Kepka[126], B. P. Kerševan[74], S. Kersten[176], K. Kessoku[156], J. Keung[159], F. Khalil-zada[11], H. Khandanyan[147a,147b], A. Khanov[113], A. Khodinov[97], A. Khomich[58a], T. J. Khoo[28], G. Khoriauli[21], A. Khoroshilov[176], V. Khovanskiy[96], E. Khramov[64], J. Khubua[51b], H. Y. Kim[8], H. Kim[147a,147b], S. H. Kim[161], N. Kimura[172], O. Kind[16], B. T. King[73], M. King[168], R. S. B. King[119], S. B. King[169], J. Kirk[130], A. E. Kiryunin[100], T. Kishimoto[66], D. Kisielewska[38a], F. Kiss[48], T. Kittelmann[124], K. Kiuchi[161], E. Kladiva[145b], M. Klein[73], U. Klein[73], K. Kleinknecht[82], P. Klimek[147a,147b], A. Klimentov[25], R. Klingenberg[43], J. A. Klinger[83], T. Klioutchnikova[30], P. F. Klok[105], E.-E. Kluge[58a], P. Kluit[106], S. Kluth[100], E. Kneringer[61], E. B. F. G. Knoops[84], A. Knue[53], D. Kobayashi[158], T. Kobayashi[156], M. Kobel[44], M. Kocian[144], P. Kodys[128], P. Koevesarki[21], T. Koffas[29], E. Koffeman[106], L. A. Kogan[119], S. Kohlmann[176], Z. Kohout[127], T. Kohriki[65], T. Koi[144], H. Kolanoski[16], I. Koletsou[5], J. Koll[89], A. A. Komar[95,*], Y. Komori[156], T. Kondo[65], N. Kondrashova[42], K. Köneke[48], A. C. König[105], S. König[82], T. Kono[65,s], R. Konoplich[109,t], N. Konstantinidis[77], R. Kopeliansky[153], S. Koperny[38a], L. Köpke[82], A. K. Kopp[48], K. Korcyl[39], K. Kordas[155], A. Korn[77], A. A. Korol[108,c], I. Korolkov[12], E. V. Korolkova[140], V. A. Korotkov[129], O. Kortner[100], S. Kortner[100], V. V. Kostyukhin[21], V. M. Kotov[64], A. Kotwal[45], C. Kourkoumelis[9], V. Kouskoura[155], A. Koutsman[160a], R. Kowalewski[170], T. Z. Kowalski[38a], W. Kozanecki[137], A. S. Kozhin[129], V. Kral[127], V. A. Kramarenko[98], G. Kramberger[74], D. Krasnopevtsev[97], M. W. Krasny[79], A. Krasznahorkay[30], J. K. Kraus[21], A. Kravchenko[25], S. Kreiss[109], M. Kretz[58c], J. Kretzschmar[73], K. Kreutzfeldt[52], P. Krieger[159], K. Kroeninger[54], H. Kroha[100], J. Kroll[121], J. Kroseberg[21], J. Krstic[13a], U. Kruchonak[64], H. Krüger[21], T. Kruker[17], N. Krumnack[63], Z. V. Krumshteyn[64], A. Kruse[174], M. C. Kruse[45], M. Kruskal[22], T. Kubota[87], S. Kuday[4a], S. Kuehn[48], A. Kugel[58c], A. Kuhl[138], T. Kuhl[42], V. Kukhtin[64], Y. Kulchitsky[91], S. Kuleshov[32b], M. Kuna[133a,133b], J. Kunkle[121], A. Kupco[126], H. Kurashige[66], Y. A. Kurochkin[91], R. Kurumida[66], V. Kus[126], E. S. Kuwertz[148], M. Kuze[158], J. Kvita[114], A. La Rosa[49], L. La Rotonda[37a,37b], C. Lacasta[168], F. Lacava[133a,133b], J. Lacey[29], H. Lacker[16], D. Lacour[79], V. R. Lacuesta[168], E. Ladygin[64], R. Lafaye[5], B. Laforge[79], T. Lagouri[177], S. Lai[48], H. Laier[58a], L. Lambourne[77], S. Lammers[60], C. L. Lampen[7], W. Lampl[7], E. Lançon[137], U. Landgraf[48], M. P. J. Landon[75], V. S. Lang[58a], A. J. Lankford[164], F. Lanni[25], K. Lantzsch[30], S. Laplace[79], C. Lapoire[21], J. F. Laporte[137], T. Lari[90a], F. Lasagni Manghi[20a,20b], M. Lassnig[30], P. Laurelli[47], W. Lavrijsen[15], A. T. Law[138], P. Laycock[73], O. Le Dortz[79], E. Le Guirriec[84], E. Le Menedeu[12], T. LeCompte[6], F. Ledroit-Guillon[55], C. A. Lee[152], H. Lee[106], J. S. H. Lee[117], S. C. Lee[152], L. Lee[1], G. Lefebvre[79], M. Lefebvre[170], F. Legger[99], C. Leggett[15], A. Lehan[73], M. Lehmacher[21], G. Lehmann Miotto[30], X. Lei[7], W. A. Leight[29], A. Leisos[155], A. G. Leister[177], M. A. L. Leite[24d], R. Leitner[128], D. Lellouch[173], B. Lemmer[54], K. J. C. Leney[77], T. Lenz[21], G. Lenzen[176], B. Lenzi[30], R. Leone[7], S. Leone[123a,123b], C. Leonidopoulos[46], S. Leontsinis[10], C. Leroy[94], C. G. Lester[28], C. M. Lester[121], M. Levchenko[122], J. Levêque[5], D. Levin[88], L. J. Levinson[173], M. Levy[18], A. Lewis[119], G. H. Lewis[109], A. M. Leyko[21], M. Leyton[41], B. Li[33b,u], B. Li[84], H. Li[149], H. L. Li[31], L. Li[45], L. Li[33e], S. Li[45], Y. Li[33c,v], Z. Liang[138], H. Liao[34], B. Liberti[134a], P. Lichard[30], K. Lie[166], J. Liebal[21], W. Liebig[14], C. Limbach[21], A. Limosani[87], S. C. Lin[152,w], T. H. Lin[82], F. Linde[106], B. E. Lindquist[149], J. T. Linnemann[89], E. Lipeles[121], A. Lipniacka[14], M. Lisovyi[42], T. M. Liss[166], D. Lissauer[25], A. Lister[169], A. M. Litke[138], B. Liu[152], D. Liu[152], J. B. Liu[33b], K. Liu[33b,x], L. Liu[88], M. Liu[45], M. Liu[33b], Y. Liu[33b], M. Livan[120a,120b], S. S. A. Livermore[119], A. Lleres[55], J. Llorente Merino[81], S. L. Lloyd[75], F. Lo Sterzo[152], E. Lobodzinska[42], P. Loch[7], W. S. Lockman[138], T. Loddenkoetter[21], F. K. Loebinger[83], A. E. Loevschall-Jensen[36], A. Loginov[177], T. Lohse[16], K. Lohwasser[42], M. Lokajicek[126], V. P. Lombardo[5], B. A. Long[22], J. D. Long[88], R. E. Long[71], L. Lopes[125a], D. Lopez Mateos[57], B. Lopez Paredes[140],

I. Lopez Paz[12], J. Lorenz[99], N. Lorenzo Martinez[60], M. Losada[163], P. Loscutoff[15], X. Lou[41], A. Lounis[116], J. Love[6], P. A. Love[71], A. J. Lowe[144,f], F. Lu[33a], N. Lu[88], H. J. Lubatti[139], C. Luci[133a,133b], A. Lucotte[55], F. Luehring[60], W. Lukas[61], L. Luminari[133a], O. Lundberg[147a,147b], B. Lund-Jensen[148], M. Lungwitz[82], D. Lynn[25], R. Lysak[126], E. Lytken[80], H. Ma[25], L. L. Ma[33d], G. Maccarrone[47], A. Macchiolo[100], J. Machado Miguens[125a,125b], D. Macina[30], D. Madaffari[84], R. Madar[48], H. J. Maddocks[71], W. F. Mader[44], A. Madsen[167], M. Maeno[8], T. Maeno[25], A. Maevskiy[98], E. Magradze[54], K. Mahboubi[48], J. Mahlstedt[106], S. Mahmoud[73], C. Maiani[137], C. Maidantchik[24a], A. A. Maier[100], A. Maio[125a,125b,125d], S. Majewski[115], Y. Makida[65], N. Makovec[116], P. Mal[137,y], B. Malaescu[79], Pa. Malecki[39], V. P. Maleev[122], F. Malek[55], U. Mallik[62], D. Malon[6], C. Malone[144], S. Maltezos[10], V. M. Malyshev[108], S. Malyukov[30], J. Mamuzic[13b], B. Mandelli[30], L. Mandelli[90a], I. Mandić[74], R. Mandrysch[62], J. Maneira[125a,125b], A. Manfredini[100], L. Manhaes de Andrade Filho[24b], J. A. Manjarres Ramos[160b], A. Mann[99], P. M. Manning[138], A. Manousakis-Katsikakis[9], B. Mansoulie[137], R. Mantifel[86], L. Mapelli[30], L. March[146c], J. F. Marchand[29], G. Marchiori[79], M. Marcisovsky[126], C. P. Marino[170], M. Marjanovic[13a], C. N. Marques[125a], F. Marroquim[24a], S. P. Marsden[83], Z. Marshall[15], L. F. Marti[17], S. Marti-Garcia[168], B. Martin[30], B. Martin[89], T. A. Martin[171], V. J. Martin[46], B. Martin dit Latour[14], H. Martinez[137], M. Martinez[12,o], S. Martin-Haugh[130], A. C. Martyniuk[77], M. Marx[139], F. Marzano[133a], A. Marzin[30], L. Masetti[82], T. Mashimo[156], R. Mashinistov[95], J. Masik[83], A. L. Maslennikov[108c], I. Massa[20a,20b], L. Massa[20a,20b], N. Massol[5], P. Mastrandrea[149], A. Mastroberardino[37a,37b], T. Masubuchi[156], P. Mättig[176], J. Mattmann[82], J. Maurer[26a], S. J. Maxfield[73], D. A. Maximov[108,c], R. Mazini[152], L. Mazzaferro[134a,134b], G. Mc Goldrick[159], S. P. Mc Kee[88], A. McCarn[88], R. L. McCarthy[149], T. G. McCarthy[29], N. A. McCubbin[130], K. W. McFarlane[56,*], J. A. Mcfayden[77], G. Mchedlidze[54], S. J. McMahon[130], R. A. McPherson[170,j], J. Mechnich[106], M. Medinnis[42], S. Meehan[31], S. Mehlhase[99], A. Mehta[73], K. Meier[58a], C. Meineck[99], B. Meirose[80], C. Melachrinos[31], B. R. Mellado Garcia[146c], F. Meloni[17], A. Mengarelli[20a,20b], S. Menke[100], E. Meoni[162], K. M. Mercurio[57], S. Mergelmeyer[21], N. Meric[137], P. Mermod[49], L. Merola[103a,103b], C. Meroni[90a], F. S. Merritt[31], H. Merritt[110], A. Messina[30,z], J. Metcalfe[25], A. S. Mete[164], C. Meyer[82], C. Meyer[121], J-P. Meyer[137], J. Meyer[30], R. P. Middleton[130], S. Migas[73], L. Mijović[21], G. Mikenberg[173], M. Mikestikova[126], M. Mikuž[74], A. Milic[30], D. W. Miller[31], C. Mills[46], A. Milov[173], D. A. Milstead[147a,147b], D. Milstein[173], A. A. Minaenko[129], Y. Minami[156], I. A. Minashvili[64], A. I. Mincer[109], B. Mindur[38a], M. Mineev[64], Y. Ming[174], L. M. Mir[12], G. Mirabelli[133a], T. Mitani[172], J. Mitrevski[99], V. A. Mitsou[168], S. Mitsui[65], A. Miucci[49], P. S. Miyagawa[140], J. U. Mjörnmark[80], T. Moa[147a,147b], K. Mochizuki[84], S. Mohapatra[35], W. Mohr[48], S. Molander[147a,147b], R. Moles-Valls[168], K. Mönig[42], C. Monini[55], J. Monk[36], E. Monnier[84], J. Montejo Berlingen[12], F. Monticelli[70], S. Monzani[133a,133b], R. W. Moore[3], N. Morange[62], D. Moreno[82], M. Moreno Llácer[54], P. Morettini[50a], M. Morgenstern[44], M. Morii[57], S. Moritz[82], A. K. Morley[148], G. Mornacchi[30], J. D. Morris[75], L. Morvaj[102], H. G. Moser[100], M. Mosidze[51b], J. Moss[110], K. Motohashi[158], R. Mount[144], E. Mountricha[25], S. V. Mouraviev[95,*], E. J. W. Moyse[85], S. Muanza[84], R. D. Mudd[18], F. Mueller[58a], J. Mueller[124], K. Mueller[21], T. Mueller[28], T. Mueller[82], D. Muenstermann[49], Y. Munwes[154], J. A. Murillo Quijada[18], W. J. Murray[130,171], H. Musheghyan[54], E. Musto[153], A. G. Myagkov[129,aa], M. Myska[127], O. Nackenhorst[54], J. Nadal[54], K. Nagai[61], R. Nagai[158], Y. Nagai[84], K. Nagano[65], A. Nagarkar[110], Y. Nagasaka[59], M. Nagel[100], A. M. Nairz[30], Y. Nakahama[30], K. Nakamura[65], T. Nakamura[156], I. Nakano[111], H. Namasivayam[41], G. Nanava[21], R. Narayan[58b], T. Nattermann[21], T. Naumann[42], G. Navarro[163], R. Nayyar[7], H. A. Neal[88], P. Yu. Nechaeva[95], T. J. Neep[83], P. D. Nef[144], A. Negri[120a,120b], G. Negri[30], M. Negrini[20a], S. Nektarijevic[49], C. Nellist[116], A. Nelson[164], T. K. Nelson[144], S. Nemecek[126], P. Nemethy[109], A. A. Nepomuceno[24a], M. Nessi[30,ab], M. S. Neubauer[166], M. Neumann[176], R. M. Neves[109], P. Nevski[25], P. R. Newman[18], D. H. Nguyen[6], R. B. Nickerson[119], R. 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Onyisi[31,p], C. J. Oram[160a], M. J. Oreglia[31], Y. Oren[154], D. Orestano[135a,135b], N. Orlando[72a,72b], C. Oropeza Barrera[53], R. S. Orr[159], B. Osculati[50a,50b], R. Ospanov[121], G. Otero y Garzon[27], H. Otono[69], M. Ouchrif[136d], E. A. Ouellette[170], F. Ould-Saada[118], A. Ouraou[137], K. P. Oussoren[106], Q. Ouyang[33a], A. Ovcharova[15], M. Owen[83], V. E. Ozcan[19a], N. Ozturk[8], K. Pachal[119], A. Pacheco Pages[12], C. Padilla Aranda[12], M. Pagáčová[48], S. Pagan Griso[15], E. Paganis[140], C. Pahl[100], F. Paige[25], P. Pais[85], K. Pajchel[118], G. Palacino[160b], S. Palestini[30], M. Palka[38b], D. Pallin[34], A. Palma[125a,125b], J. D. Palmer[18], Y. B. Pan[174], E. Panagiotopoulou[10], J. G. Panduro Vazquez[76], P. Pani[106], N. Panikashvili[88], S. Panitkin[25], D. Pantea[26a], L. Paolozzi[134a,134b], Th. D. Papadopoulou[10], K. Papageorgiou[155,m], A. Paramonov[6], D. Paredes Hernandez[34], M. A. Parker[28], F. Parodi[50a,50b], J. A. Parsons[35], U. Parzefall[48],

E. Pasqualucci[133a], S. Passaggio[50a], A. Passeri[135a], F. Pastore[135a,135b,*], Fr. Pastore[76], G. Pásztor[29], S. Pataraia[176], N. D. Patel[151], J. R. Pater[83], S. Patricelli[103a,103b], T. Pauly[30], J. Pearce[170], L. E. Pedersen[36], M. Pedersen[118], S. Pedraza Lopez[168], R. Pedro[125a,125b], S. V. Peleganchuk[108], D. Pelikan[167], H. Peng[33b], B. Penning[31], J. Penwell[60], D. V. Perepelitsa[25], E. Perez Codina[160a], M. T. Pérez García-Estañ[168], V. Perez Reale[35], L. Perini[90a,90b], H. Pernegger[30], S. Perrella[103a,103b], R. Perrino[72a], R. Peschke[42], V. D. Peshekhonov[64], K. Peters[30], R. F. Y. Peters[83], B. A. Petersen[30], T. C. Petersen[36], E. Petit[42], A. Petridis[147a,147b], C. Petridou[155], E. Petrolo[133a], F. Petrucci[135a,135b], N. E. Pettersson[158], R. Pezoa[32b], P. W. Phillips[130], G. Piacquadio[144], E. Pianori[171], A. Picazio[49], E. Piccaro[75], M. Piccinini[20a,20b], R. Piegaia[27], D. T. Pignotti[110], J. E. Pilcher[31], A. D. Pilkington[77], J. Pina[125a,125b,125d], M. Pinamonti[165a,165c,ac], A. Pinder[119], J. L. Pinfold[3], A. Pingel[36], B. Pinto[125a], S. Pires[79], M. Pitt[173], C. Pizio[90a,90b], L. Plazak[145a], M.-A. Pleier[25], V. Pleskot[128], E. Plotnikova[64], P. Plucinski[147a,147b], S. Poddar[58a], F. Podlyski[34], R. Poettgen[82], L. Poggioli[116], D. Pohl[21], M. Pohl[49], G. Polesello[120a], A. Policicchio[37a,37b], R. Polifka[159], A. Polini[20a], C. S. Pollard[45], V. Polychronakos[25], K. Pommès[30], L. Pontecorvo[133a], B. G. Pope[89], G. A. Popeneciu[26b], D. S. Popovic[13a], A. Poppleton[30], X. Portell Bueso[12], S. Pospisil[127], K. Potamianos[15], I. N. Potrap[64], C. J. Potter[150], C. T. Potter[115], G. Poulard[30], J. Poveda[60], V. Pozdnyakov[64], P. Pralavorio[84], A. Pranko[15], S. Prasad[30], R. Pravahan[8], S. Prell[63], D. Price[83], J. Price[73], L. E. Price[6], D. Prieur[124], M. Primavera[72a], M. Proissl[46], K. Prokofiev[47], F. Prokoshin[32b], E. Protopapadaki[137], S. Protopopescu[25], J. Proudfoot[6], M. Przybycien[38a], H. Przysiezniak[5], E. Ptacek[115], D. Puddu[135a,135b], E. Pueschel[85], D. Puldon[149], M. Purohit[25,ad], P. Puzo[116], J. Qian[88], G. Qin[53], Y. Qin[83], A. Quadt[54], D. R. Quarrie[15], W. B. Quayle[165a,165b], M. Queitsch-Maitland[83], D. Quilty[53], A. Qureshi[160b], V. Radeka[25], V. Radescu[42], S. K. Radhakrishnan[149], P. Radloff[115], P. Rados[87], F. Ragusa[90a,90b], G. Rahal[179], S. Rajagopalan[25], M. Rammensee[30], A. S. Randle-Conde[40], C. Rangel-Smith[167], K. Rao[164], F. Rauscher[99], T. C. Rave[48], T. Ravenscroft[53], M. Raymond[30], A. L. Read[118], N. P. Readioff[73], D. M. Rebuzzi[120a,120b], A. Redelbach[175], G. Redlinger[25], R. Reece[138], K. Reeves[41], L. Rehnisch[16], H. Reisin[27], M. Relich[164], C. Rembser[30], H. Ren[33a], Z. L. Ren[152], A. Renaud[116], M. Rescigno[133a], S. Resconi[90a], O. L. Rezanova[108,c], P. Reznicek[128], R. Rezvani[94], R. Richter[100], M. Ridel[79], P. Rieck[16], J. Rieger[54], M. Rijssenbeek[149], A. Rimoldi[120a,120b], L. Rinaldi[20a], E. Ritsch[61], I. Riu[12], F. Rizatdinova[113], E. Rizvi[75], S. H. Robertson[86,j], A. Robichaud-Veronneau[86], D. Robinson[28], J. E. M. Robinson[83], A. Robson[53], C. Roda[123a,123b], L. Rodrigues[30], S. Roe[30], O. Røhne[118], S. Rolli[162], A. Romaniouk[97], M. Romano[20a,20b], E. Romero Adam[168], N. Rompotis[139], M. Ronzani[48], L. Roos[79], E. Ros[168], S. Rosati[133a], K. Rosbach[49], M. Rose[76], P. Rose[138], P. L. Rosendahl[14], O. Rosenthal[142], V. Rossetti[147a,147b], E. Rossi[103a,103b], L. P. Rossi[50a], R. Rosten[139], M. Rotaru[26a], I. Roth[173], J. Rothberg[139], D. Rousseau[116], C. R. Royon[137], A. Rozanov[84], Y. Rozen[153], X. Ruan[146c], F. Rubbo[12], I. Rubinskiy[42], V. I. Rud[98], C. Rudolph[44], M. S. Rudolph[159], F. Rühr[48], A. Ruiz-Martinez[30], Z. Rurikova[48], N. A. Rusakovich[64], A. Ruschke[99], J. P. Rutherfoord[7], N. Ruthmann[48], Y. F. Ryabov[122], M. Rybar[128], G. Rybkin[116], N. C. Ryder[119], A. F. Saavedra[151], S. Sacerdoti[27], A. Saddique[3], I. Sadeh[154], H. F-W. Sadrozinski[138], R. Sadykov[64], F. Safai Tehrani[133a], H. Sakamoto[156], Y. Sakurai[172], G. Salamanna[135a,135b], A. Salamon[134a], M. Saleem[112], D. Salek[106], P. H. Sales De Bruin[139], D. Salihagic[100], A. Salnikov[144], J. Salt[168], D. Salvatore[37a,37b], F. Salvatore[150], A. Salvucci[105], A. Salzburger[30], D. Sampsonidis[155], A. Sanchez[103a,103b], J. Sánchez[168], V. Sanchez Martinez[168], H. Sandaker[14], R. L. Sandbach[75], H. G. Sander[82], M. P. Sanders[99], M. Sandhoff[176], T. Sandoval[28], C. Sandoval[163], R. Sandstroem[100], D. P. C. Sankey[130], A. Sansoni[47], C. Santoni[34], R. Santonico[134a,134b], H. Santos[125a], I. Santoyo Castillo[150], K. Sapp[124], A. Sapronov[64], J. G. Saraiva[125a,125d], B. Sarrazin[21], G. Sartisohn[176], O. Sasaki[65], Y. Sasaki[156], G. Sauvage[5,*], E. Sauvan[5], P. Savard[159,e], D. O. Savu[30], C. Sawyer[119], L. Sawyer[78,n], D. H. Saxon[53], J. Saxon[121], C. Sbarra[20a], A. Sbrizzi[20a,20b], T. Scanlon[77], D. A. Scannicchio[164], M. Scarcella[151], V. Scarfone[37a,37b], J. Schaarschmidt[173], P. Schacht[100], D. Schaefer[30], R. Schaefer[42], S. Schaepe[21], S. Schaetzel[58b], U. Schäfer[82], A. C. Schaffer[116], D. Schaile[99], R. D. Schamberger[149], V. Scharf[58a], V. A. Schegelsky[122], D. Scheirich[128], M. Schernau[164], M. I. Scherzer[35], C. Schiavi[50a,50b], J. Schieck[99], C. Schillo[48], M. Schioppa[37a,37b], S. Schlenker[30], E. Schmidt[48], K. Schmieden[30], C. Schmitt[82], S. Schmitt[58b], B. Schneider[17], Y. J. Schnellbach[73], U. Schnoor[44], L. Schoeffel[137], A. Schoening[58b], B. D. Schoenrock[89], A. L. S. Schorlemmer[54], M. Schott[82], D. Schouten[160a], J. Schovancova[25], S. Schramm[159], M. Schreyer[175], C. Schroeder[82], N. Schuh[82], M. J. Schultens[21], H.-C. Schultz-Coulon[58a], H. Schulz[16], M. Schumacher[48], B. A. Schumm[138], Ph. Schune[137], C. Schwanenberger[83], A. Schwartzman[144], T. A. Schwarz[88], Ph. Schwegler[100], Ph. Schwemling[137], R. Schwienhorst[89], J. Schwindling[137], T. Schwindt[21], M. Schwoerer[5], F. G. Sciacca[17], E. Scifo[116], G. Sciolla[23], W. G. Scott[130], F. Scuri[123a,123b], F. Scutti[21], J. Searcy[88], G. Sedov[42], E. Sedykh[122], S. C. Seidel[104], A. Seiden[138], F. Seifert[127], J. M. Seixas[24a], G. Sekhniaidze[103a], S. J. Sekula[40], K. E. Selbach[46], D. M. Seliverstov[122,*], G. Sellers[73], N. Semprini-Cesari[20a,20b], C. Serfon[30], L. Serin[116], L. Serkin[54], T. Serre[84], R. Seuster[160a], H. Severini[112], T. Sfiligoj[74], F. Sforza[100], A. Sfyrla[30], E. Shabalina[54], M. Shamim[115], L. Y. Shan[33a], R. Shang[166], J. T. Shank[22], M. Shapiro[15], P. B. Shatalov[96], K. Shaw[165a,165b], C. Y. Shehu[150], P. Sherwood[77], L. Shi[152,ae], S. Shimizu[66], C. O. Shimmin[164], M. Shimojima[101], M. Shiyakova[64], A. Shmeleva[95], M. J. Shochet[31], D. Short[119], S. Shrestha[63],

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