Physics Letters B 763 (2016) 251–268

Contents lists available at ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

# Search for dark matter produced in association with a hadronically decaying vector boson in $pp$ collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector

The ATLAS Collaboration *

ARTICLE INFO

*Article history:*
Received 9 August 2016
Received in revised form 9 October 2016
Accepted 17 October 2016
Available online 20 October 2016
Editor: W.-D. Schlatter

ABSTRACT

A search is presented for dark matter produced in association with a hadronically decaying $W$ or $Z$ boson using 3.2 fb$^{-1}$ of $pp$ collisions at $\sqrt{s} = 13$ TeV recorded by the ATLAS detector at the Large Hadron Collider. Events with a hadronic jet compatible with a $W$ or $Z$ boson and with large missing transverse momentum are analysed. The data are consistent with the Standard Model predictions and are interpreted in terms of both an effective field theory and a simplified model containing dark matter.



Dark matter is the dominant component of matter in the universe, but its particle nature remains a mystery. Searches for a weakly interacting massive particle (WIMP), denoted by $\chi$, and for interactions between $\chi$ and Standard Model (SM) particles are a central component of the current set of dark-matter experiments.

At particle colliders, dark-matter particles may be produced in pairs via some unknown intermediate state. While in many models direct detection experiments have the greatest sensitivity for dark-matter masses $m_\chi$ between 10 and 100 GeV, searches for dark matter at particle colliders are most powerful for lower masses [1–3]. The final-state WIMPs are not directly detectable, but their presence can be inferred from the recoil against a visible particle [1]. Two example processes are shown in Fig. 1.

The Tevatron and LHC collaborations have reported limits on the cross section of $p\bar{p} \to \chi\bar{\chi} + X$ and $pp \to \chi\bar{\chi} + X$, respectively, where $X$ is a hadronic jet [1–3], a photon ($\gamma$) [4,5], a $W/Z$ boson [6,7], or a Higgs boson [8,9]. In many cases, results are reported in terms of limits on the parameters of an effective field theory (EFT) formulated as a four-point contact interaction [10–18] between quarks and WIMPs. For such models, the strongest limits come from data in which the recoiling object is a jet. In other models, however, the interaction is between dark matter and vector bosons [19], such that the primary discovery mode would be in final states such as those analysed here, where the recoiling object is a $W$ or $Z$ boson.

In this Letter, a search is reported for the production of a $W$ or $Z$ boson decaying hadronically (to $q\bar{q}'$ or $q\bar{q}$, respectively) and reconstructed as a single massive jet in association with large missing transverse momentum from the undetected $\chi\bar{\chi}$ particles in data collected by the ATLAS detector from $pp$ collisions with centre-of-mass energy $\sqrt{s} = 13$ TeV. This search is sensitive to WIMP pair production, as well as to other dark-matter-related models which predict invisible Higgs boson decays ($WH$ or $ZH$ production with $H \to \chi\bar{\chi}$).

The ATLAS detector [20] at the LHC covers the pseudorapidity[1] range $|\eta| < 4.9$ and the full azimuthal angle $\phi$. It consists of an inner tracking detector surrounded by a superconducting solenoid, electromagnetic and hadronic calorimeters, and an external muon spectrometer incorporating large superconducting toroidal magnets. A two-level trigger system is used to select interesting events to be recorded for subsequent offline analysis. Only data for which beams were stable and all subsystems described above were operational are used. Applying these requirements to $pp$ collision data, recorded during the 2015 LHC run, results in a data sample with a time-integrated luminosity of 3.2 fb$^{-1}$. The systematic uncertainty

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

* *E-mail address:* atlas.publications@cern.ch.

http://dx.doi.org/10.1016/j.physletb.2016.10.042

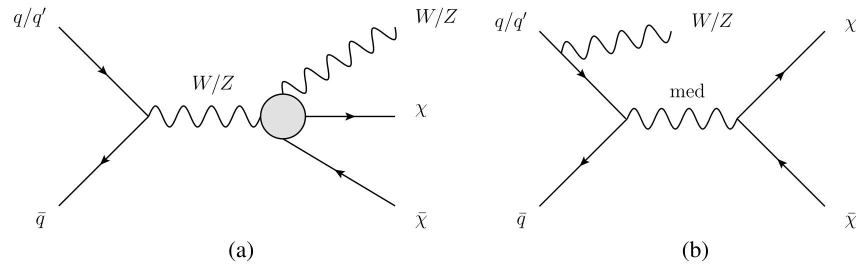



**Fig. 1.** Pair production of WIMPs ($\chi\bar{\chi}$) in proton–proton collisions at the LHC in association with a vector boson ($V$, meaning $W$ or $Z$) via two hypothetical processes: (a) production via an effective $VV\chi\chi$ interaction or (b) via a simplified model which includes an $s$-channel mediator.

of 2.1% in the luminosity is derived following the same methodology as that detailed in Ref. [21].

Three non-exclusive categories of jet candidates are built, each using the anti-$k_\perp$ clustering algorithm [22]. Two categories use clusters of energy deposits in calorimeter cells seeded by those with energies significantly above the measured noise and calibrated at the hadronic energy scale [25]. They are distinguished by their radius parameters; jets with radius parameter of 1.0 (0.4) are referred to as *large-R jets (narrow jets)*. Large and narrow jets can share a fraction of their energy deposits. A third type of jet candidate is reconstructed from inner-detector tracks using the anti-$k_\perp$ algorithm with $R = 0.2$, referred to as *track jets*. Large-$R$ jets are trimmed [26] to remove energy deposited by pile-up jets, the underlying event, and soft radiation. In this process, the constituents of large-$R$ jets are reclustered using the $k_\perp$ algorithm [23,24] with a distance parameter of 0.2, and subjets with transverse momentum $p_{\mathrm{T}}$ less than 5% of the large-$R$ jet $p_{\mathrm{T}}$ are removed. Large-$R$ jets are required to satisfy $p_{\mathrm{T}} > 200$ GeV and $|\eta| < 2.0$. These large-$R$ jets are intended to capture the hadronic products of both quarks from the decay of a $W$ or $Z$ boson, while the narrow jets and track jets are helpful in background suppression. The internal structure of the large-$R$ jet is characterized in terms of two quantities: $D_2$ [27,28], which identifies jets with two distinct concentrations of energy [29,30], and $m_{\mathrm{jet}}$, which is the calculated invariant mass of the jet. Narrow jets are required to satisfy $p_{\mathrm{T}} > 20$ GeV for $|\eta| < 2.5$ or $p_{\mathrm{T}} > 30$ GeV for $2.5 < |\eta| < 4.5$. Track jets are required to satisfy $p_{\mathrm{T}} > 10$ GeV and $|\eta| < 2.5$. For both the large-$R$ and narrow jets, jet momenta are calculated by performing a four-vector sum over these component clusters, treating each topological cluster [25] as an $(E, \vec{p})$ four-vector with zero mass, and are calibrated to the hadronic scale. For narrow jets, the direction of $\vec{p}$ is given by the line joining the reconstructed vertex with the barycentre of the energy cluster. The missing transverse momentum $\mathbf{E}_{\mathrm{T}}^{\mathrm{miss}}$ is calculated as the negative of the vector sum of the transverse momenta of reconstructed jets, leptons, and those tracks which are associated with the reconstructed vertex but not with any jet or lepton. A closely related quantity, $\mathbf{E}_{\mathrm{T,no}\mu}^{\mathrm{miss}}$, is calculated in the same way but excluding reconstructed muons. A third variant, $\mathbf{p}_{\mathrm{T}}^{\mathrm{miss}}$, is the missing transverse momentum measured using inner detector tracks. The magnitudes of the three missing-transverse-momentum variants are denoted by $E_{\mathrm{T}}^{\mathrm{miss}}$, $E_{\mathrm{T,no}\mu}^{\mathrm{miss}}$, and $p_{\mathrm{T}}^{\mathrm{miss}}$, respectively. Electrons, muons, jets, and $\mathbf{E}_{\mathrm{T}}^{\mathrm{miss}}$ are reconstructed as described in Refs. [25,31–33], respectively.

Candidate signal events are selected by an inclusive $E_{\mathrm{T}}^{\mathrm{miss}}$ trigger that is more than 99% efficient for events with $E_{\mathrm{T}}^{\mathrm{miss}} > 200$ GeV. Events triggered by detector noise and non-collision backgrounds are rejected as described in Ref. [34]. In addition, events are required to satisfy the requirements of $E_{\mathrm{T}}^{\mathrm{miss}} > 250$ GeV, no reconstructed electrons or muons, and at least one large-$R$ jet with $p_{\mathrm{T}} > 200$ GeV, $|\eta| < 2.0$, $m_{\mathrm{jet}}$ and $D_2$ consistent with a $W$ or $Z$ boson decay as in Ref. [35]. To further suppress backgrounds from multijet and $t\bar{t}$ production, events are required to satisfy $p_{\mathrm{T}}^{\mathrm{miss}} > 30$ GeV, a minimum azimuthal angular distance, $\Delta\phi$, of 0.6 between the $\mathbf{E}_{\mathrm{T}}^{\mathrm{miss}}$ and the nearest narrow jet, and $\Delta\phi(\mathbf{E}_{\mathrm{T}}^{\mathrm{miss}}, \mathbf{p}_{\mathrm{T}}^{\mathrm{miss}}) < \pi/2$. Within a fiducial volume defined at parton level by similar selection requirements (except those on $D_2$ and $p_{\mathrm{T}}^{\mathrm{miss}}$), the reconstruction efficiency for the signal models described above varies from 38% to 49%.

The dominant source of background events is $Z \to \nu\bar{\nu}$ production in association with jets. A secondary contribution comes from the production of jets in association with a leptonically decaying $W$ or $Z$ boson in which the charged leptons are not identified or the $\tau$ leptons decay hadronically. The third major background contribution comes from top-quark pair production. The kinematic distributions of these three largest backgrounds are estimated using simulated event samples but the normalization is determined using control regions where the dark-matter signal is expected to be negligible. Each control region requires $E_{\mathrm{T}}^{\mathrm{miss}} > 200$ GeV and $p_{\mathrm{T}}^{\mathrm{miss}} > 30$ GeV as well as one large-$R$ jet satisfying the substructure requirement on $D_2$ as applied in the signal region. The $Z$ boson control region requires exactly two muons with dimuon invariant mass $66 < m_{\mu\mu} < 116$ GeV. The $W$ boson (top quark) control region requires exactly one muon, and zero (at least one) $b$-tagged track jet not associated with the large-$R$ jet. Validation of the reconstruction of hadronic $W$ boson decays with large-$R$ jets is performed in the top-quark control region, as shown in Fig. 2, which also presents the distribution of the $D_2$ substructure variable. Other sources of background are diboson production and single-top-quark production. The contribution to the signal region from multijet production is negligible.

Samples of simulated $W$ + jets and $Z$ + jets events are generated using Sherpa 2.1.1 [36]. Matrix elements are calculated for up to two partons at next-to-leading order (NLO) and four partons at leading order (LO) using the Comix [37] and OpenLoops [38] matrix element generators and merged with the Sherpa parton shower [39] using the ME+PS@NLO prescription [40]. The CT10 [41] PDF set is used in conjunction with dedicated parton shower tuning developed by the Sherpa authors. The $W/Z$ production rates are normalized to a next-to-next-to-leading order (NNLO) calculation [42]. The production of $t\bar{t}$ and single-top processes, including $s$-channel, $t$-channel and $Wt$ production is modelled with the Powheg-Box v2 generator [43–45] interfaced to Pythia6.428 [46]. In these generators the CT10 and CTEQ6L1 [47] PDF sets are used, respectively. Top-quark pair production is normalized to NNLO with next-to-next-to-leading-logarithm corrections [48] in QCD while single-top processes are normalized at NLO [49,50] in QCD. The diboson ($WW, WZ, ZZ$) processes are simulated using Sherpa 2.1.1 with the CT10 PDF and normalized at NLO [51,52] in QCD. The multijet process is described using samples simulated with Pythia8.186 [53] and the NNPDF2.3LO [54] PDF at leading order in QCD; these multijet samples were used to develop the background estimation strategy but not for the final background prediction.

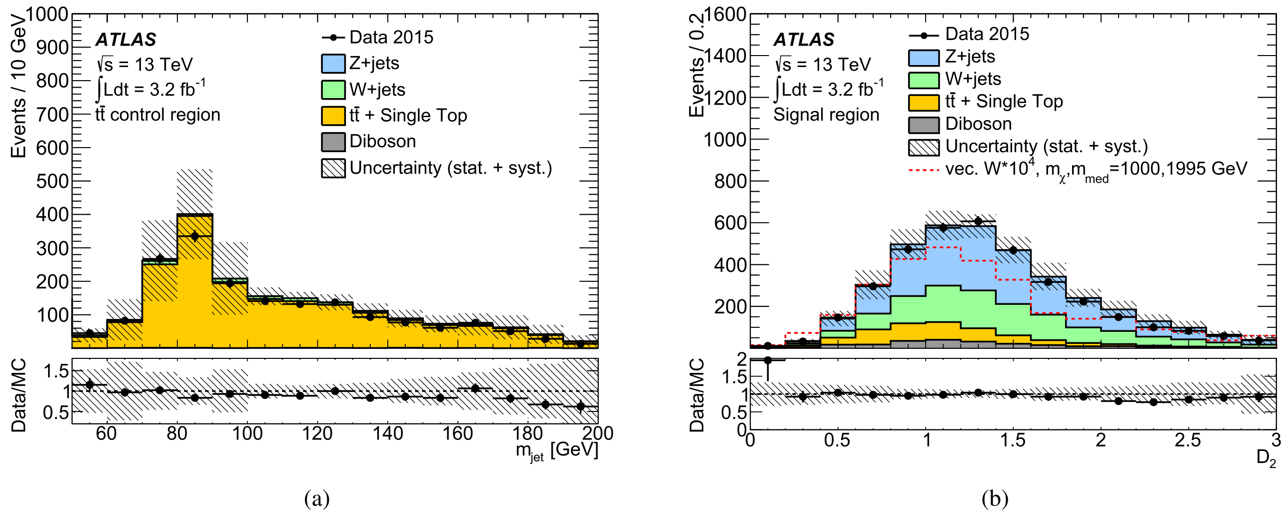



**Fig. 2.** Pane (a) Distribution of $m_{\text{jet}}$ in the data and for the predicted background in the top-quark control region. Pane (b) Distribution of jet substructure variable $D_2$ in the data and for the predicted background in events satisfying all signal region requirements other than those on $D_2$. Also shown is the distribution for the simplified model with a vector-boson mediator, scaled by a factor of $10^4$ for given values of $m_\chi$ and $m_{\text{med}}$, the mediator mass. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

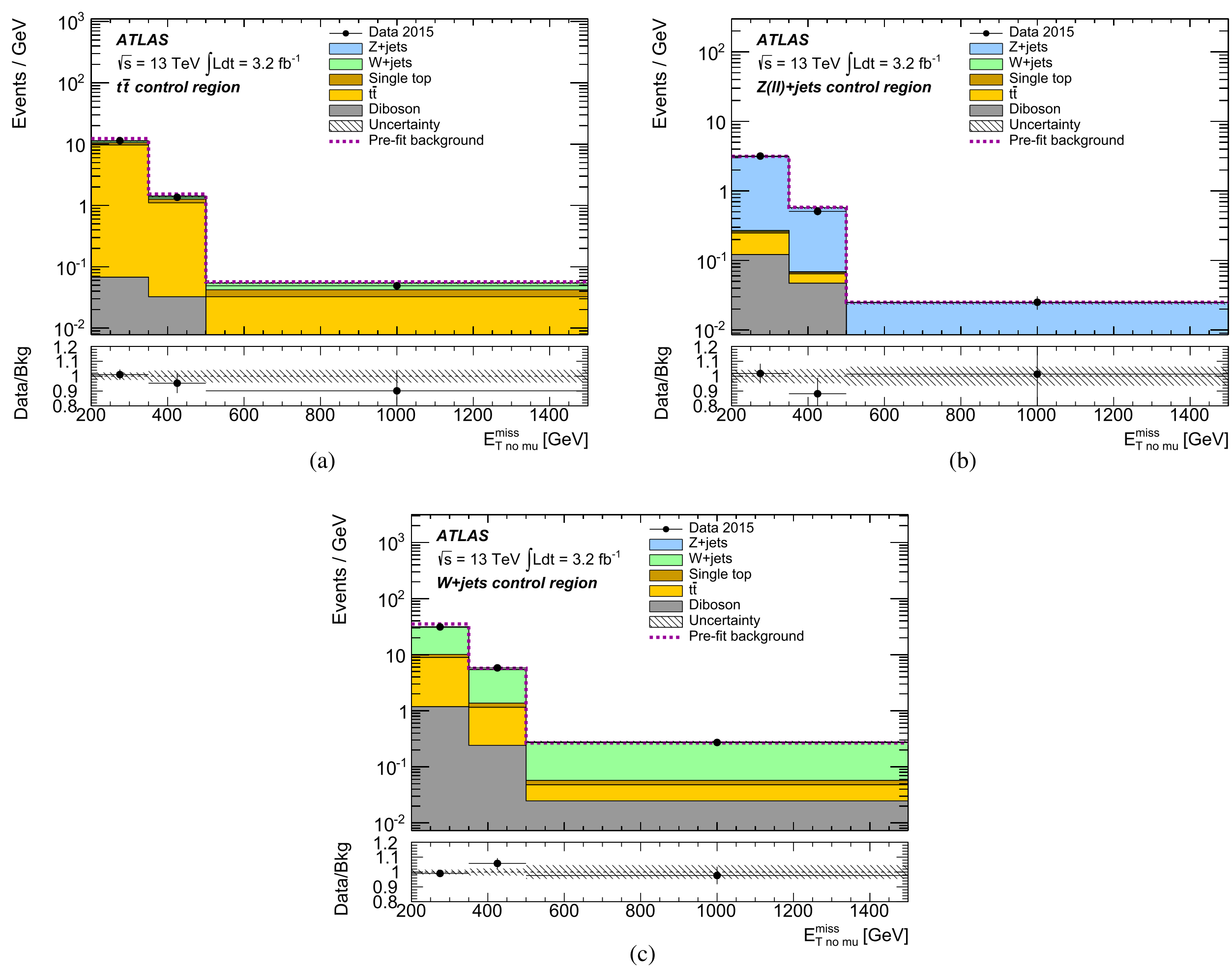



**Fig. 3.** The $E_{\text{T,no}\mu}^{\text{miss}}$ distribution of the events in the control regions after the profile-likelihood fit to the data under the background-only hypothesis. Pane (a) shows the $t\bar{t}$ control region, pane (b) shows the $Z$ + jets control region, and pane (c) shows the $W$ + jets control region. The total background prediction before the fit is shown as a dashed line. The inset at the bottom of each plot shows the ratio of the data to the total post-fit background. The hatched bands represent the total uncertainty in the background. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

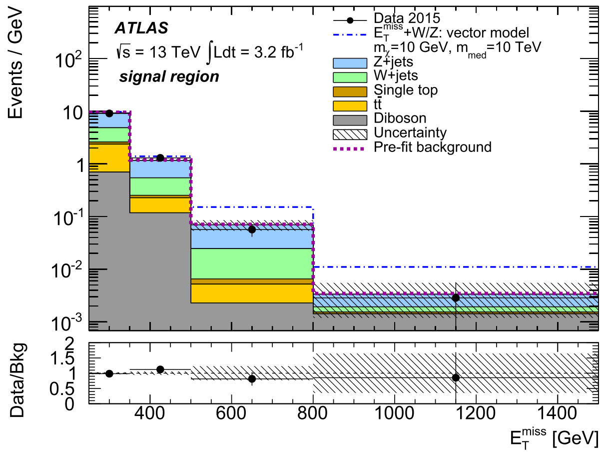



**Fig. 4.** The $E_T^{miss}$ distribution of the events in the signal region after the profile-likelihood fit to the data under the background-only hypothesis. The inset shows the ratio of the data to the total background. Also shown is the $E_T^{miss}$ distribution for the simplified model with a vector-boson mediator, scaled by a factor of $10^4$ for $m_\chi = 10$ GeV and $m_{med} = 10$ TeV. The total background before the fit is shown as a dashed line. The hatched bands represent the total uncertainty in the background. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Samples of simulated $W\chi\bar{\chi}$ and $Z\chi\bar{\chi}$ events are generated using MadGraph5_aMC@NLO [55], and the underlying event and parton showering are simulated with Pythia8.186 [53]. Two theoretical models are used as benchmarks: a seven-dimensional $VV\chi\chi$ EFT [19] model ($V$ meaning $W$ or $Z$) and a vector-mediated simplified model [56]. The strength of the EFT interaction is controlled by a mass scale, $M_\star$, and the strength of the simplified model interaction is controlled by the product of the couplings of the mediator to the SM and the dark matter (DM) particles, $g_{SM}g_{DM}$. The EFT model samples were generated with $M_\star = 3000$ GeV, and the simplified model samples were generated with couplings $g_{SM} = 0.25$ and $g_{DM} = 1$. The samples were generated as a function of dark-matter particle mass $m_\chi$ for the EFT model and in a grid of mediator mass $m_{med}$ and $m_\chi$ for the simplified model.

Major sources of systematic uncertainty are uncertainties in the modelling of large-$R$ jet observables, which have a 5–13% impact on the expected background and signal yields, and the energy scale of the narrow jets, which contribute a 1–5% uncertainty to the expected yields. Other sources of uncertainty include theoretical uncertainties in the simulated event samples used to model the background processes (1–10%), parton distribution functions (10–15%), and lepton reconstruction and identification efficiencies (up to 2%).

A profile-likelihood fit [57] to the $E_T^{miss}$ ($E_{T,no\mu}^{miss}$) distribution in the signal region (control regions) is used to constrain the $W$ boson, $Z$ boson, and $t\bar{t}$ backgrounds and extract the signal strength, $\mu$, for each model as an overall normalization factor for the signal prediction. Besides the signal strength, three overall normalization factors for the $W$ boson, $Z$ boson, and $t\bar{t}$ backgrounds are parameters in the fit. The diboson and single-top backgrounds are estimated from simulation, and the multijet background is negligible. The likelihood function is defined as the product of Poisson distributions over all bins in $E_T^{miss}$ and $E_{T,no\mu}^{miss}$, and the likelihood is simultaneously maximized over the signal and control regions.

Variations of the expected signal and background to allow for their systematic uncertainties are described with nuisance parameters constrained by Gaussian probability distribution functions, and correlations across signal and background processes and regions are taken into account.

**Table 1**
Predicted and observed number of events in the signal region. The yields and uncertainties of the backgrounds are shown after the profile-likelihood fit to the data under the background-only hypothesis. For comparison, the expected yield in the $VV\chi\chi$ EFT model with $M_\star = 600$ GeV and $m_\chi = 500$ GeV is $10.1 \pm 0.4$ events.

| Process | Events |
|---|---|
| $Z$ + jets | $544 \pm 33$ |
| $W$ + jets | $275 \pm 24$ |
| $t\bar{t}$ and single-top | $211 \pm 19$ |
| Diboson | $89 \pm 12$ |
| Total background | $1120 \pm 47$ |
| Data | 1121 |

**Table 2**
Background normalization factors relative to the initial theoretical prediction, extracted from the profile-likelihood fit under the background-only hypothesis.

| Process | Normalization factor |
|---|---|
| $Z$ + jets | $1.01 \pm 0.16$ |
| $W$ + jets | $0.90 \pm 0.16$ |
| $t\bar{t}$ | $0.91 \pm 0.18$ |

A background-only ($\mu = 0$) fit, shows no deviation from SM predictions, and Figs. 3 and 4 show kinematic distributions after the profile-likelihood fit. The floating background-normalization parameters are consistent with unity within one standard deviation. Tables 1 and 2 show the expected event yields after applying the signal selection and the background normalization scale factors, respectively. The values in these tables are estimated for the background-only hypothesis.

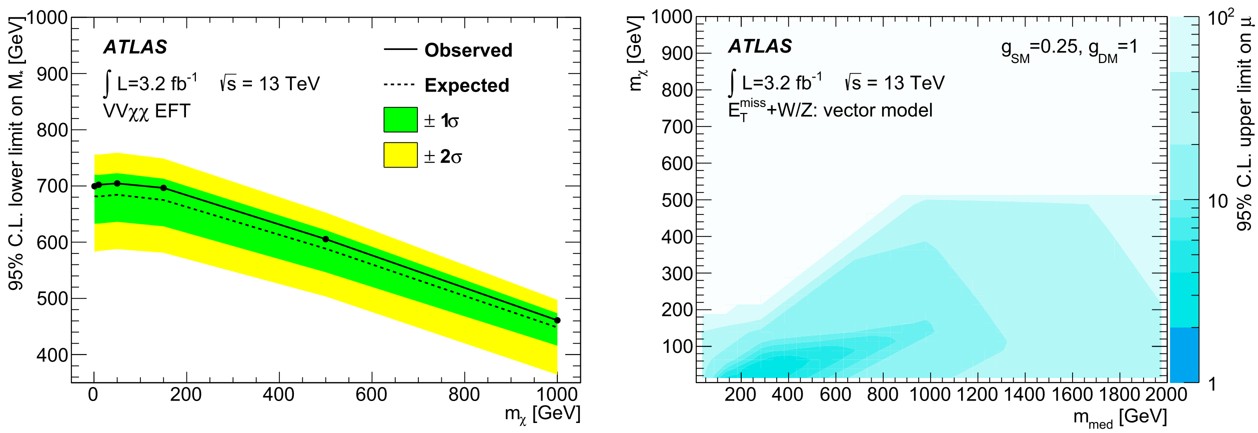
Upper limits at 95% confidence level (C.L.) on $\mu$ are calculated using the CL$_s$ method [58]. For the $VV\chi\chi$ EFT model, these limits are translated into constraints on the mass scale, $M_\star$. Fig. 5(a) shows the limit on the mass scale, $M_\star$, in the EFT model, as a function of $m_\chi$. Fig. 5(b) shows the limits on the signal strength, $\mu$, for a vector-mediated simplified model generated with couplings $g_{SM} = 0.25$ and $g_{DM} = 1$ in the plane of $m_\chi$ and $m_{med}$.

In conclusion, this Letter reports ATLAS limits on dark-matter production in events with a hadronically decaying $W$ or $Z$ boson and large missing transverse momentum. These limits from 3.2 fb$^{-1}$ of 13 TeV $pp$ collisions at the LHC improve on earlier ATLAS results. No statistically significant excess is observed over the Standard Model prediction.

## Acknowledgements

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

We acknowledge the support of ANPCyT, Argentina; YerPhI, Armenia; ARC, Australia; BMWFW and FWF, Austria; ANAS, Azerbaijan; SSTC, Belarus; CNPq and FAPESP, Brazil; NSERC, NRC and CFI, Canada; CERN; CONICYT, Chile; CAS, MOST and NSFC, China; COLCIENCIAS, Colombia; MSMT CR, MPO CR and VSC CR, Czech Republic; DNRF and DNSRC, Denmark; IN2P3-CNRS, CEA-DSM/IRFU, France; GNSF, Georgia; BMBF, HGF, and MPG, Germany; GSRT, Greece; RGC, Hong Kong SAR, China; ISF, I-CORE and Benoziyo Center, Israel; INFN, Italy; MEXT and JSPS, Japan; CNRST, Morocco; FOM and NWO, Netherlands; RCN, Norway; MNiSW and NCN, Poland; FCT, Portugal; MNE/IFA, Romania; MES of Russia and NRC KI, Russian Federation; JINR; MESTD, Serbia; MSSR, Slovakia; ARRS and MIZŠ, Slovenia; DST/NRF, South Africa; MINECO, Spain; SRC and Wallenberg Foundation, Sweden; SERI, SNSF and Cantons




(a) (b)

**Fig. 5.** Pane (a) shows the limit on the mass scale, $M_\star$, of the $VV\chi\chi$ EFT model. Pane (b) shows the observed limit on the signal strength, $\mu$, of the vector-mediated simplified model in the plane of the dark-matter particle mass, $m_\chi$, and the mediator mass, $m_{\rm med}$; white areas indicate an upper limit at $\mu \geq 100$. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

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, the Canada Council, CANARIE, CRC, Compute Canada, FQRNT, and the Ontario Innovation Trust, Canada; EPLANET, ERC, FP7, Horizon 2020 and Marie Skłodowska-Curie Actions, European Union; Investissements d'Avenir Labex and Idex, ANR, Région Auvergne and Fondation Partager le Savoir, France; DFG and AvH Foundation, Germany; Herakleitos, Thales and Aristeia programmes co-financed by EU-ESF and the Greek NSRF; BSF, GIF and Minerva, Israel; BRF, Norway; Generalitat de Catalunya, Generalitat Valenciana, Spain; 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. [59].

## References

[1] CDF Collaboration, T. Aaltonen, et al., A search for dark matter in events with one jet and missing transverse energy in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV, Phys. Rev. Lett. 108 (2012) 211804, arXiv:1203.0742.
[2] CMS Collaboration, Search for dark matter, extra dimensions, and unparticles in monojet events in proton–proton collisions at $\sqrt{s} = 8$ TeV, Eur. Phys. J. C 75 (2015) 235, arXiv:1408.3583.
[3] ATLAS Collaboration, Search for new phenomena in final states with an energetic jet and large missing transverse momentum in $pp$ collisions at $\sqrt{s} =$ 13 TeV using the ATLAS detector, arXiv:1604.07773, 2016.
[4] ATLAS Collaboration, Search for dark matter candidates and large extra dimensions in events with a photon and missing transverse momentum in $pp$ collision data at $\sqrt{s} = 7$ TeV with the ATLAS detector, Phys. Rev. Lett. 110 (2013) 011802, arXiv:1209.4625.
[5] CMS Collaboration, Search for new phenomena in monophoton final states in proton–proton collisions at $\sqrt{s} = 8$ TeV, Phys. Lett. B 755 (2016) 102–124, arXiv:1410.8812.
[6] ATLAS Collaboration, Search for dark matter in events with a $Z$ boson and missing transverse momentum in $pp$ collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector, Phys. Rev. D 90 (2014) 012004, arXiv:1404.0051.
[7] ATLAS Collaboration, Search for dark matter in events with a hadronically decaying $W$ or $Z$ boson and missing transverse momentum in $pp$ collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector, Phys. Rev. Lett. 112 (2014) 041802, arXiv:1309.4017.
[8] ATLAS Collaboration, Search for dark matter in events with missing transverse momentum and a Higgs boson decaying to two photons in $pp$ collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector, Phys. Rev. Lett. 115 (2015) 131801, arXiv:1506.01081.
[9] ATLAS Collaboration, Search for dark matter produced in association with a Higgs boson decaying to two bottom quarks in $pp$ collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector, Phys. Rev. D 93 (2015) 072007, arXiv:1510.06218.
[10] Q.H. Cao, et al., Effective dark matter model: relic density, CDMS II, Fermi LAT and LHC, J. High Energy Phys. 08 (2011) 018, arXiv:0912.4511.
[11] M. Beltran, et al., Maverick dark matter at colliders, J. High Energy Phys. 09 (2010) 037, arXiv:1002.4137.
[12] J. Goodman, et al., Constraints on light Majorana dark matter from colliders, Phys. Lett. B 695 (2011) 185, arXiv:1005.1286.
[13] Y. Bai, P.J. Fox, R. Harnik, The tevatron at the frontier of dark matter direct detection, J. High Energy Phys. 12 (2010) 048, arXiv:1005.3797.
[14] J. Goodman, et al., Constraints on dark matter from colliders, Phys. Rev. D 82 (2010) 116010, arXiv:1008.1783.
[15] A. Rajaraman, et al., LHC bounds on interactions of dark matter, Phys. Rev. D 84 (2011) 095013, arXiv:1108.1196.
[16] P.J. Fox, et al., Missing energy signatures of dark matter at the LHC, Phys. Rev. D 85 (2012) 056011, arXiv:1109.4398.
[17] K. Cheung, et al., Global constraints on effective dark matter interactions: relic density, direct detection, indirect detection, and collider, J. Cosmol. Astropart. Phys. 1205 (2012) 001, arXiv:1201.3402.
[18] R.C. Cotta, et al., Bounds on dark matter interactions with electroweak gauge bosons, Phys. Rev. D 88 (2013) 116009, arXiv:1210.0525.
[19] L.M. Carpenter, et al., Collider searches for dark matter in events with a $Z$ boson and missing energy, Phys. Rev. D 87 (2013) 074005, arXiv:1212.3352.
[20] ATLAS Collaboration, The ATLAS experiment at the CERN Large Hadron Collider, J. Instrum. 3 (2008) S08003.
[21] ATLAS Collaboration, Improved luminosity determination in $pp$ collisions at $\sqrt{s} = 7$ TeV using the ATLAS detector at the LHC, Eur. Phys. J. C 73 (2013) 2518, arXiv:1302.4393.
[22] M. Cacciari, G.P. Salam, G. Soyez, The anti-$k_t$ jet clustering algorithm, J. High Energy Phys. 04 (2008) 063, arXiv:0802.1189.
[23] S.D. Ellis, D.E. Soper, Successive combination jet algorithm for hadron collisions, Phys. Rev. D 48 (7) (1993) 3160–3166.
[24] S. Catani, et al., Longitudinally-invariant $k_\perp$-clustering algorithms for hadron–hadron collisions, Nucl. Phys. B (ISSN 0550-3213) 406 (1993) 187–224.
[25] ATLAS Collaboration, Jet energy measurement with the ATLAS detector in proton–proton collisions at $\sqrt{s} = 7$ TeV, Eur. Phys. J. C 73 (2013) 2304, arXiv:1112.6426.
[26] D. Krohn, J. Thaler, L.-T. Wang, Jet trimming, J. High Energy Phys. 02 (2010) 084, arXiv:0912.1342.
[27] A.J. Larkoski, I. Moult, D. Neill, Power counting to better jet observables, J. High Energy Phys. 12 (2014) 009, arXiv:1409.6298.
[28] A.J. Larkoski, G.P. Salam, J. Thaler, Energy correlation functions for jet substructure, J. High Energy Phys. 06 (2013) 108, arXiv:1305.0007.
[29] ATLAS Collaboration, Performance of jet substructure techniques for large-$R$ jets in proton–proton collisions at $\sqrt{s} = 7$ TeV using the ATLAS detector, J. High Energy Phys. 09 (2013) 076, arXiv:1306.4945.
[30] ATLAS Collaboration, Performance of jet substructure techniques in early $\sqrt{s} = 13$ TeV $pp$ collisions with the ATLAS detector, ATLAS-CONF-2015-035, http://cdsweb.cern.ch/record/2041462.
[31] ATLAS Collaboration, Electron performance measurements with the ATLAS detector using the 2010 LHC proton–proton collision data, Eur. Phys. J. C 72 (2012) 1909, arXiv:1110.3174.

[32] 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.
[33] ATLAS Collaboration, Performance of missing transverse momentum reconstruction in proton–proton collisions at 7 TeV with ATLAS, Eur. Phys. J. C 72 (2012) 1844, arXiv:1108.5602.
[34] ATLAS Collaboration, Search for dark matter candidates and large extra dimensions in events with a jet and missing transverse momentum with the ATLAS detector, J. High Energy Phys. 04 (2013) 075, arXiv:1210.4491.
[35] Searches for heavy diboson resonances in $pp$ collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector, J. High Energy Phys. 1609 (2016) 173, arXiv:1606.04833.
[36] T. Gleisberg, et al., Event generation with SHERPA 1.1, J. High Energy Phys. 02 (2009) 007, arXiv:0811.4622.
[37] T. Gleisberg, S. Höche, Comix, a new matrix element generator, J. High Energy Phys. 12 (2008) 039, arXiv:0808.3674.
[38] F. Cascioli, P. Maierhofer, S. Pozzorini, Scattering amplitudes with open loops, Phys. Rev. Lett. 108 (2012) 111601, arXiv:1111.5206.
[39] S. Schumann, F. Krauss, A parton shower algorithm based on Catani–Seymour dipole factorisation, J. High Energy Phys. 03 (2008) 038, arXiv:0709.1027.
[40] S. Höche, et al., QCD matrix elements + parton showers: the NLO case, J. High Energy Phys. 04 (2013) 027, arXiv:1207.5030.
[41] H.-L. Lai, et al., New parton distributions for collider physics, Phys. Rev. D 82 (2010) 074024, arXiv:1007.2241.
[42] K. Melnikov, F. Petriello, Electroweak gauge boson production at hadron colliders through $\mathcal{O}(\alpha_s^2)$, Phys. Rev. D 74 (11) (2006) 114017.
[43] P. Nason, A new method for combining NLO QCD with shower Monte Carlo algorithms, J. High Energy Phys. 11 (2004) 040, arXiv:hep-ph/0409146.
[44] S. Frixione, P. Nason, C. Oleari, Matching NLO QCD computations with parton shower simulations: the POWHEG method, J. High Energy Phys. 11 (2007) 070, arXiv:0709.2092.
[45] S. Alioli, et al., A general framework for implementing NLO calculations in shower Monte Carlo programs: the POWHEG BOX, J. High Energy Phys. 06 (2010) 043, arXiv:1002.2581.
[46] T. Sjöstrand, S. Mrenna, P.Z. Skands, PYTHIA 6.4 physics and manual, J. High Energy Phys. 05 (2006) 026, arXiv:hep-ph/0603175.
[47] J. Pumplin, et al., New generation of parton distributions with uncertainties from global QCD analysis, J. High Energy Phys. 07 (2002) 012, arXiv:hep-ph/0201195.
[48] M. Czakon, P. Fiedler, A. Mitov, The total top quark pair production cross-section at hadron colliders through $\mathcal{O}(\alpha_S^4)$, Phys. Rev. Lett. 110 (2013) 252004, arXiv:1303.6254.
[49] S. Alioli, et al., NLO single-top production matched with shower in POWHEG: $s$- and $t$-channel contributions, J. High Energy Phys. 09 (2009) 111; J. High Energy Phys. 02 (2010) 011 (Erratum), arXiv:0907.4076.
[50] E. Re, Single-top $Wt$-channel production matched with parton showers using the POWHEG method, Eur. Phys. J. C 71 (2011) 1547, arXiv:1009.2450.
[51] J.M. Campbell, R. Ellis, MCFM for the Tevatron and the LHC, Nucl. Phys., Proc. Suppl. 205–206 (2010) 10, arXiv:1007.3492.
[52] J.M. Campbell, R.K. Ellis, C. Williams, Vector boson pair production at the LHC, J. High Energy Phys. 07 (2011) 018, arXiv:1105.0020.
[53] T. Sjöstrand, S. Mrenna, P.Z. Skands, A brief introduction to PYTHIA 8.1, Comput. Phys. Commun. 178 (2008) 852–867, arXiv:0710.3820.
[54] R.D. Ball, et al., Parton distributions with LHC data, Nucl. Phys. B 867 (2013) 244–289, arXiv:1207.1303.
[55] J. Alwall, et al., The automated computation of tree-level and next-to-leading order differential cross sections, and their matching to parton shower simulations, J. High Energy Phys. 07 (2014) 079, arXiv:1405.0301.
[56] D. Abercrombie, et al., Dark matter benchmark models for early LHC Run-2 searches: report of the ATLAS/CMS dark matter forum, arXiv:1507.00966, 2015.
[57] G. Cowan, et al., Asymptotic formulae for likelihood-based tests of new physics, Eur. Phys. J. C 71 (2011) 1554, arXiv:1007.1727.
[58] A.L. Read, Presentation of search results: the $CL_s$ technique, J. Phys. G 28 (2002) 2693–2704.
[59] ATLAS Collaboration, ATLAS computing acknowledgements 2016–2017, ATL-GEN-PUB-2016-002, http://cds.cern.ch/record/2202407, 2016.

**The ATLAS Collaboration**

M. Aaboud [136d], G. Aad [87], B. Abbott [114], J. Abdallah [8], O. Abdinov [12], B. Abeloos [118], R. Aben [108], O.S. AbouZeid [138], N.L. Abraham [152], H. Abramowicz [156], H. Abreu [155], R. Abreu [117], Y. Abulaiti [149a,149b], B.S. Acharya [168a,168b,a], S. Adachi [158], L. Adamczyk [40a], D.L. Adams [27], J. Adelman [109], S. Adomeit [101], T. Adye [132], A.A. Affolder [76], T. Agatonovic-Jovin [14], J. Agricola [56], J.A. Aguilar-Saavedra [127a,127f], S.P. Ahlen [24], F. Ahmadov [67,b], G. Aielli [134a,134b], H. Akerstedt [149a,149b], T.P.A. Åkesson [83], A.V. Akimov [97], G.L. Alberghi [22a,22b], J. Albert [173], S. Albrand [57], M.J. Alconada Verzini [73], M. Aleksa [32], I.N. Aleksandrov [67], C. Alexa [28b], G. Alexander [156], T. Alexopoulos [10], M. Alhroob [114], B. Ali [129], M. Aliev [75a,75b], G. Alimonti [93a], J. Alison [33], S.P. Alkire [37], B.M.M. Allbrooke [152], B.W. Allen [117], P.P. Allport [19], A. Aloisio [105a,105b], A. Alonso [38], F. Alonso [73], C. Alpigiani [139], A.A. Alshehri [55], M. Alstaty [87], B. Alvarez Gonzalez [32], D. Álvarez Piqueras [171], M.G. Alviggi [105a,105b], B.T. Amadio [16], K. Amako [68], Y. Amaral Coutinho [26a], C. Amelung [25], D. Amidei [91], S.P. Amor Dos Santos [127a,127c], A. Amorim [127a,127b], S. Amoroso [32], G. Amundsen [25], C. Anastopoulos [142], L.S. Ancu [51], N. Andari [19], T. Andeen [11], C.F. Anders [60b], G. Anders [32], J.K. Anders [76], K.J. Anderson [33], A. Andreazza [93a,93b], V. Andrei [60a], S. Angelidakis [9], I. Angelozzi [108], P. Anger [46], A. Angerami [37], F. Anghinolfi [32], A.V. Anisenkov [110,c], N. Anjos [13], A. Annovi [125a,125b], C. Antel [60a], M. Antonelli [49], A. Antonov [99,*], F. Anulli [133a], M. Aoki [68], L. Aperio Bella [19], G. Arabidze [92], Y. Arai [68], J.P. Araque [127a], A.T.H. Arce [47], F.A. Arduh [73], J-F. Arguin [96], S. Argyropoulos [65], M. Arik [20a], A.J. Armbruster [146], L.J. Armitage [78], O. Arnaez [32], H. Arnold [50], M. Arratia [30], O. Arslan [23], A. Artamonov [98], G. Artoni [121], S. Artz [85], S. Asai [158], N. Asbah [44], A. Ashkenazi [156], B. Åsman [149a,149b], L. Asquith [152], K. Assamagan [27], R. Astalos [147a], M. Atkinson [170], N.B. Atlay [144], K. Augsten [129], G. Avolio [32], B. Axen [16], M.K. Ayoub [118], G. Azuelos [96,d], M.A. Baak [32], A.E. Baas [60a], M.J. Baca [19], H. Bachacou [137], K. Bachas [75a,75b], M. Backes [121], M. Backhaus [32], P. Bagiacchi [133a,133b], P. Bagnaia [133a,133b], Y. Bai [35a], J.T. Baines [132], O.K. Baker [180], E.M. Baldin [110,c], P. Balek [176], T. Balestri [151], F. Balli [137], W.K. Balunas [123], E. Banas [41], Sw. Banerjee [177,e], A.A.E. Bannoura [179], L. Barak [32], E.L. Barberio [90], D. Barberis [52a,52b], M. Barbero [87], T. Barillari [102], M-S Barisits [32], T. Barklow [146], N. Barlow [30], S.L. Barnes [86], B.M. Barnett [132], R.M. Barnett [16], Z. Barnovska-Blenessy [5], A. Baroncelli [135a], G. Barone [25], A.J. Barr [121], L. Barranco Navarro [171], F. Barreiro [84], J. Barreiro Guimarães da Costa [35a], R. Bartoldus [146], A.E. Barton [74], P. Bartos [147a], A. Basalaev [124], A. Bassalat [118,f], R.L. Bates [55], S.J. Batista [162], J.R. Batley [30], M. Battaglia [138],

M. Bauce [133a,133b], F. Bauer [137], H.S. Bawa [146,g], J.B. Beacham [112], M.D. Beattie [74], T. Beau [82], P.H. Beauchemin [166], P. Bechtle [23], H.P. Beck [18,h], K. Becker [121], M. Becker [85], M. Beckingham [174], C. Becot [111], A.J. Beddall [20e], A. Beddall [20b], V.A. Bednyakov [67], M. Bedognetti [108], C.P. Bee [151], L.J. Beemster [108], T.A. Beermann [32], M. Begel [27], J.K. Behr [44], C. Belanger-Champagne [89], A.S. Bell [80], G. Bella [156], L. Bellagamba [22a], A. Bellerive [31], M. Bellomo [88], K. Belotskiy [99], O. Beltramello [32], N.L. Belyaev [99], O. Benary [156,*], D. Benchekroun [136a], M. Bender [101], K. Bendtz [149a,149b], N. Benekos [10], Y. Benhammou [156], E. Benhar Noccioli [180], J. Benitez [65], D.P. Benjamin [47], J.R. Bensinger [25], S. Bentvelsen [108], L. Beresford [121], M. Beretta [49], D. Berge [108], E. Bergeaas Kuutmann [169], N. Berger [5], J. Beringer [16], S. Berlendis [57], N.R. Bernard [88], C. Bernius [111], F.U. Bernlochner [23], T. Berry [79], P. Berta [130], C. Bertella [85], G. Bertoli [149a,149b], F. Bertolucci [125a,125b], I.A. Bertram [74], C. Bertsche [44], D. Bertsche [114], G.J. Besjes [38], O. Bessidskaia Bylund [149a,149b], M. Bessner [44], N. Besson [137], C. Betancourt [50], A. Bethani [57], S. Bethke [102], A.J. Bevan [78], R.M. Bianchi [126], L. Bianchini [25], M. Bianco [32], O. Biebel [101], D. Biedermann [17], R. Bielski [86], N.V. Biesuz [125a,125b], M. Biglietti [135a], J. Bilbao De Mendizabal [51], T.R.V. Billoud [96], H. Bilokon [49], M. Bindi [56], S. Binet [118], A. Bingul [20b], C. Bini [133a,133b], S. Biondi [22a,22b], T. Bisanz [56], D.M. Bjergaard [47], C.W. Black [153], J.E. Black [146], K.M. Black [24], D. Blackburn [139], R.E. Blair [6], J.-B. Blanchard [137], T. Blazek [147a], I. Bloch [44], C. Blocker [25], A. Blue [55], W. Blum [85,*], U. Blumenschein [56], S. Blunier [34a], G.J. Bobbink [108], V.S. Bobrovnikov [110,c], S.S. Bocchetta [83], A. Bocci [47], C. Bock [101], M. Boehler [50], D. Boerner [179], J.A. Bogaerts [32], D. Bogavac [14], A.G. Bogdanchikov [110], C. Bohm [149a], V. Boisvert [79], P. Bokan [14], T. Bold [40a], A.S. Boldyrev [168a,168c], M. Bomben [82], M. Bona [78], M. Boonekamp [137], A. Borisov [131], G. Borissov [74], J. Bortfeldt [32], D. Bortoletto [121], V. Bortolotto [62a,62b,62c], K. Bos [108], D. Boscherini [22a], M. Bosman [13], J.D. Bossio Sola [29], J. Boudreau [126], J. Bouffard [2], E.V. Bouhova-Thacker [74], D. Boumediene [36], C. Bourdarios [118], S.K. Boutle [55], A. Boveia [32], J. Boyd [32], I.R. Boyko [67], J. Bracinik [19], A. Brandt [8], G. Brandt [56], O. Brandt [60a], U. Bratzler [159], B. Brau [88], J.E. Brau [117], W.D. Breaden Madden [55], K. Brendlinger [123], A.J. Brennan [90], L. Brenner [108], R. Brenner [169], S. Bressler [176], T.M. Bristow [48], D. Britton [55], D. Britzger [44], F.M. Brochu [30], I. Brock [23], R. Brock [92], G. Brooijmans [37], T. Brooks [79], W.K. Brooks [34b], J. Brosamer [16], E. Brost [109], J.H Broughton [19], P.A. Bruckman de Renstrom [41], D. Bruncko [147b], R. Bruneliere [50], A. Bruni [22a], G. Bruni [22a], L.S. Bruni [108], BH Brunt [30], M. Bruschi [22a], N. Bruscino [23], P. Bryant [33], L. Bryngemark [83], T. Buanes [15], Q. Buat [145], P. Buchholz [144], A.G. Buckley [55], I.A. Budagov [67], F. Buehrer [50], M.K. Bugge [120], O. Bulekov [99], D. Bullock [8], H. Burckhart [32], S. Burdin [76], C.D. Burgard [50], B. Burghgrave [109], K. Burka [41], S. Burke [132], I. Burmeister [45], J.T.P. Burr [121], E. Busato [36], D. Büscher [50], V. Büscher [85], P. Bussey [55], J.M. Butler [24], C.M. Buttar [55], J.M. Butterworth [80], P. Butti [108], W. Buttinger [27], A. Buzatu [55], A.R. Buzykaev [110,c], S. Cabrera Urbán [171], D. Caforio [129], V.M. Cairo [39a,39b], O. Cakir [4a], N. Calace [51], P. Calafiura [16], A. Calandri [87], G. Calderini [82], P. Calfayan [101], G. Callea [39a,39b], L.P. Caloba [26a], S. Calvente Lopez [84], D. Calvet [36], S. Calvet [36], T.P. Calvet [87], R. Camacho Toro [33], S. Camarda [32], P. Camarri [134a,134b], D. Cameron [120], R. Caminal Armadans [170], C. Camincher [57], S. Campana [32], M. Campanelli [80], A. Camplani [93a,93b], A. Campoverde [144], V. Canale [105a,105b], A. Canepa [164a], M. Cano Bret [141], J. Cantero [115], T. Cao [42], M.D.M. Capeans Garrido [32], I. Caprini [28b], M. Caprini [28b], M. Capua [39a,39b], R.M. Carbone [37], R. Cardarelli [134a], F. Cardillo [50], I. Carli [130], T. Carli [32], G. Carlino [105a], L. Carminati [93a,93b], S. Caron [107], E. Carquin [34b], G.D. Carrillo-Montoya [32], J.R. Carter [30], J. Carvalho [127a,127c], D. Casadei [19], M.P. Casado [13,i], M. Casolino [13], D.W. Casper [167], E. Castaneda-Miranda [148a], R. Castelijn [108], A. Castelli [108], V. Castillo Gimenez [171], N.F. Castro [127a,j], A. Catinaccio [32], J.R. Catmore [120], A. Cattai [32], J. Caudron [23], V. Cavaliere [170], E. Cavallaro [13], D. Cavalli [93a], M. Cavalli-Sforza [13], V. Cavasinni [125a,125b], F. Ceradini [135a,135b], L. Cerda Alberich [171], B.C. Cerio [47], A.S. Cerqueira [26b], A. Cerri [152], L. Cerrito [134a,134b], F. Cerutti [16], M. Cerv [32], A. Cervelli [18], S.A. Cetin [20d], A. Chafaq [136a], D. Chakraborty [109], S.K. Chan [58], Y.L. Chan [62a], P. Chang [170], J.D. Chapman [30], D.G. Charlton [19], A. Chatterjee [51], C.C. Chau [162], C.A. Chavez Barajas [152], S. Che [112], S. Cheatham [168a,168c], A. Chegwidden [92], S. Chekanov [6], S.V. Chekulaev [164a], G.A. Chelkov [67,k], M.A. Chelstowska [91], C. Chen [66], H. Chen [27], K. Chen [151], S. Chen [35b], S. Chen [158], X. Chen [35c], Y. Chen [69], H.C. Cheng [91], H.J Cheng [35a], Y. Cheng [33], A. Cheplakov [67], E. Cheremushkina [131], R. Cherkaoui El Moursli [136e], V. Chernyatin [27,*], E. Cheu [7], L. Chevalier [137], V. Chiarella [49], G. Chiarelli [125a,125b], G. Chiodini [75a], A.S. Chisholm [32], A. Chitan [28b], M.V. Chizhov [67], K. Choi [63], A.R. Chomont [36], S. Chouridou [9], B.K.B. Chow [101], V. Christodoulou [80], D. Chromek-Burckhart [32], J. Chudoba [128], A.J. Chuinard [89], J.J. Chwastowski [41],

L. Chytka [116], G. Ciapetti [133a,133b], A.K. Ciftci [4a], D. Cinca [45], V. Cindro [77], I.A. Cioara [23], C. Ciocca [22a,22b], A. Ciocio [16], F. Cirotto [105a,105b], Z.H. Citron [176], M. Citterio [93a], M. Ciubancan [28b], A. Clark [51], B.L. Clark [58], M.R. Clark [37], P.J. Clark [48], R.N. Clarke [16], C. Clement [149a,149b], Y. Coadou [87], M. Cobal [168a,168c], A. Coccaro [51], J. Cochran [66], L. Colasurdo [107], B. Cole [37], A.P. Colijn [108], J. Collot [57], T. Colombo [167], G. Compostella [102], P. Conde Muiño [127a,127b], E. Coniavitis [50], S.H. Connell [148b], I.A. Connelly [79], V. Consorti [50], S. Constantinescu [28b], G. Conti [32], F. Conventi [105a,l], M. Cooke [16], B.D. Cooper [80], A.M. Cooper-Sarkar [121], K.J.R. Cormier [162], T. Cornelissen [179], M. Corradi [133a,133b], F. Corriveau [89,m], A. Cortes-Gonzalez [32], G. Cortiana [102], G. Costa [93a], M.J. Costa [171], D. Costanzo [142], G. Cottin [30], G. Cowan [79], B.E. Cox [86], K. Cranmer [111], S.J. Crawley [55], G. Cree [31], S. Crépé-Renaudin [57], F. Crescioli [82], W.A. Cribbs [149a,149b], M. Crispin Ortuzar [121], M. Cristinziani [23], V. Croft [107], G. Crosetti [39a,39b], A. Cueto [84], T. Cuhadar Donszelmann [142], J. Cummings [180], M. Curatolo [49], J. Cúth [85], H. Czirr [144], P. Czodrowski [3], G. D'amen [22a,22b], S. D'Auria [55], M. D'Onofrio [76], M.J. Da Cunha Sargedas De Sousa [127a,127b], C. Da Via [86], W. Dabrowski [40a], T. Dado [147a], T. Dai [91], O. Dale [15], F. Dallaire [96], C. Dallapiccola [88], M. Dam [38], J.R. Dandoy [33], N.P. Dang [50], A.C. Daniells [19], N.S. Dann [86], M. Danninger [172], M. Dano Hoffmann [137], V. Dao [50], G. Darbo [52a], S. Darmora [8], J. Dassoulas [3], A. Dattagupta [117], W. Davey [23], C. David [173], T. Davidek [130], M. Davies [156], P. Davison [80], E. Dawe [90], I. Dawson [142], K. De [8], R. de Asmundis [105a], A. De Benedetti [114], S. De Castro [22a,22b], S. De Cecco [82], N. De Groot [107], P. de Jong [108], H. De la Torre [92], F. De Lorenzi [66], A. De Maria [56], D. De Pedis [133a], A. De Salvo [133a], U. De Sanctis [152], A. De Santo [152], J.B. De Vivie De Regie [118], W.J. Dearnaley [74], R. Debbe [27], C. Debenedetti [138], D.V. Dedovich [67], N. Dehghanian [3], I. Deigaard [108], M. Del Gaudio [39a,39b], J. Del Peso [84], T. Del Prete [125a,125b], D. Delgove [118], F. Deliot [137], C.M. Delitzsch [51], A. Dell'Acqua [32], L. Dell'Asta [24], M. Dell'Orso [125a,125b], M. Della Pietra [105a,l], D. della Volpe [51], M. Delmastro [5], P.A. Delsart [57], D.A. DeMarco [162], S. Demers [180], M. Demichev [67], A. Demilly [82], S.P. Denisov [131], D. Denysiuk [137], D. Derendarz [41], J.E. Derkaoui [136d], F. Derue [82], P. Dervan [76], K. Desch [23], C. Deterre [44], K. Dette [45], P.O. Deviveiros [32], A. Dewhurst [132], S. Dhaliwal [25], A. Di Ciaccio [134a,134b], L. Di Ciaccio [5], W.K. Di Clemente [123], C. Di Donato [133a,133b], A. Di Girolamo [32], B. Di Girolamo [32], B. Di Micco [135a,135b], R. Di Nardo [32], A. Di Simone [50], R. Di Sipio [162], D. Di Valentino [31], C. Diaconu [87], M. Diamond [162], F.A. Dias [48], M.A. Diaz [34a], E.B. Diehl [91], J. Dietrich [17], S. Díez Cornell [44], A. Dimitrievska [14], J. Dingfelder [23], P. Dita [28b], S. Dita [28b], F. Dittus [32], F. Djama [87], T. Djobava [53b], J.I. Djuvsland [60a], M.A.B. do Vale [26c], D. Dobos [32], M. Dobre [28b], C. Doglioni [83], J. Dolejsi [130], Z. Dolezal [130], M. Donadelli [26d], S. Donati [125a,125b], P. Dondero [122a,122b], J. Donini [36], J. Dopke [132], A. Doria [105a], M.T. Dova [73], A.T. Doyle [55], E. Drechsler [56], M. Dris [10], Y. Du [140], J. Duarte-Campderros [156], E. Duchovni [176], G. Duckeck [101], O.A. Ducu [96,n], D. Duda [108], A. Dudarev [32], A. Chr. Dudder [85], E.M. Duffield [16], L. Duflot [118], M. Dührssen [32], M. Dumancic [176], M. Dunford [60a], H. Duran Yildiz [4a], M. Düren [54], A. Durglishvili [53b], D. Duschinger [46], B. Dutta [44], M. Dyndal [44], C. Eckardt [44], K.M. Ecker [102], R.C. Edgar [91], N.C. Edwards [48], T. Eifert [32], G. Eigen [15], K. Einsweiler [16], T. Ekelof [169], M. El Kacimi [136c], V. Ellajosyula [87], M. Ellert [169], S. Elles [5], F. Ellinghaus [179], A.A. Elliot [173], N. Ellis [32], J. Elmsheuser [27], M. Elsing [32], D. Emeliyanov [132], Y. Enari [158], O.C. Endner [85], J.S. Ennis [174], J. Erdmann [45], A. Ereditato [18], G. Ernis [179], J. Ernst [2], M. Ernst [27], S. Errede [170], E. Ertel [85], M. Escalier [118], H. Esch [45], C. Escobar [126], B. Esposito [49], A.I. Etienvre [137], E. Etzion [156], H. Evans [63], A. Ezhilov [124], M. Ezzi [136e], F. Fabbri [22a,22b], L. Fabbri [22a,22b], G. Facini [33], R.M. Fakhrutdinov [131], S. Falciano [133a], R.J. Falla [80], J. Faltova [32], Y. Fang [35a], M. Fanti [93a,93b], A. Farbin [8], A. Farilla [135a], C. Farina [126], E.M. Farina [122a,122b], T. Farooque [13], S. Farrell [16], S.M. Farrington [174], P. Farthouat [32], F. Fassi [136e], P. Fassnacht [32], D. Fassouliotis [9], M. Faucci Giannelli [79], A. Favareto [52a,52b], W.J. Fawcett [121], L. Fayard [118], O.L. Fedin [124,o], W. Fedorko [172], S. Feigl [120], L. Feligioni [87], C. Feng [140], E.J. Feng [32], H. Feng [91], A.B. Fenyuk [131], L. Feremenga [8], P. Fernandez Martinez [171], S. Fernandez Perez [13], J. Ferrando [44], A. Ferrari [169], P. Ferrari [108], R. Ferrari [122a], D.E. Ferreira de Lima [60b], A. Ferrer [171], D. Ferrere [51], C. Ferretti [91], A. Ferretto Parodi [52a,52b], F. Fiedler [85], A. Filipčič [77], M. Filipuzzi [44], F. Filthaut [107], M. Fincke-Keeler [173], K.D. Finelli [153], M.C.N. Fiolhais [127a,127c], L. Fiorini [171], A. Firan [42], A. Fischer [2], C. Fischer [13], J. Fischer [179], W.C. Fisher [92], N. Flaschel [44], I. Fleck [144], P. Fleischmann [91], G.T. Fletcher [142], R.R.M. Fletcher [123], T. Flick [179], L.R. Flores Castillo [62a], M.J. Flowerdew [102], G.T. Forcolin [86], A. Formica [137], A. Forti [86], A.G. Foster [19], D. Fournier [118], H. Fox [74], S. Fracchia [13], P. Francavilla [82], M. Franchini [22a,22b], D. Francis [32], L. Franconi [120], M. Franklin [58], M. Frate [167], M. Fraternali [122a,122b], D. Freeborn [80], S.M. Fressard-Batraneanu [32], F. Friedrich [46], D. Froidevaux [32], J.A. Frost [121], C. Fukunaga [159],

E. Fullana Torregrosa [85], T. Fusayasu [103], J. Fuster [171], C. Gabaldon [57], O. Gabizon [179], A. Gabrielli [22a,22b], A. Gabrielli [16], G.P. Gach [40a], S. Gadatsch [32], S. Gadomski [79], G. Gagliardi [52a,52b], L.G. Gagnon [96], P. Gagnon [63], C. Galea [107], B. Galhardo [127a,127c], E.J. Gallas [121], B.J. Gallop [132], P. Gallus [129], G. Galster [38], K.K. Gan [112], J. Gao [59], Y. Gao [48], Y.S. Gao [146,g], F.M. Garay Walls [48], C. García [171], J.E. García Navarro [171], M. Garcia-Sciveres [16], R.W. Gardner [33], N. Garelli [146], V. Garonne [120], A. Gascon Bravo [44], K. Gasnikova [44], C. Gatti [49], A. Gaudiello [52a,52b], G. Gaudio [122a], L. Gauthier [96], I.L. Gavrilenko [97], C. Gay [172], G. Gaycken [23], E.N. Gazis [10], Z. Gecse [172], C.N.P. Gee [132], Ch. Geich-Gimbel [23], M. Geisen [85], M.P. Geisler [60a], K. Gellerstedt [149a,149b], C. Gemme [52a], M.H. Genest [57], C. Geng [59,p], S. Gentile [133a,133b], C. Gentsos [157], S. George [79], D. Gerbaudo [13], A. Gershon [156], S. Ghasemi [144], M. Ghneimat [23], B. Giacobbe [22a], S. Giagu [133a,133b], P. Giannetti [125a,125b], B. Gibbard [27], S.M. Gibson [79], M. Gignac [172], M. Gilchriese [16], T.P.S. Gillam [30], D. Gillberg [31], G. Gilles [179], D.M. Gingrich [3,d], N. Giokaris [9], M.P. Giordani [168a,168c], F.M. Giorgi [22a], F.M. Giorgi [17], P.F. Giraud [137], P. Giromini [58], D. Giugni [93a], F. Giuli [121], C. Giuliani [102], M. Giulini [60b], B.K. Gjelsten [120], S. Gkaitatzis [157], I. Gkialas [157], E.L. Gkougkousis [118], L.K. Gladilin [100], C. Glasman [84], J. Glatzer [50], P.C.F. Glaysher [48], A. Glazov [44], M. Goblirsch-Kolb [25], J. Godlewski [41], S. Goldfarb [90], T. Golling [51], D. Golubkov [131], A. Gomes [127a,127b,127d], R. Gonçalo [127a], J. Goncalves Pinto Firmino Da Costa [137], G. Gonella [50], L. Gonella [19], A. Gongadze [67], S. González de la Hoz [171], G. Gonzalez Parra [13], S. Gonzalez-Sevilla [51], L. Goossens [32], P.A. Gorbounov [98], H.A. Gordon [27], I. Gorelov [106], B. Gorini [32], E. Gorini [75a,75b], A. Gorišek [77], E. Gornicki [41], A.T. Goshaw [47], C. Gössling [45], M.I. Gostkin [67], C.R. Goudet [118], D. Goujdami [136c], A.G. Goussiou [139], N. Govender [148b,q], E. Gozani [155], L. Graber [56], I. Grabowska-Bold [40a], P.O.J. Gradin [57], P. Grafström [22a,22b], J. Gramling [51], E. Gramstad [120], S. Grancagnolo [17], V. Gratchev [124], P.M. Gravila [28e], H.M. Gray [32], E. Graziani [135a], Z.D. Greenwood [81,r], C. Grefe [23], K. Gregersen [80], I.M. Gregor [44], P. Grenier [146], K. Grevtsov [5], J. Griffiths [8], A.A. Grillo [138], K. Grimm [74], S. Grinstein [13,s], Ph. Gris [36], J.-F. Grivaz [118], S. Groh [85], J.P. Grohs [46], E. Gross [176], J. Grosse-Knetter [56], G.C. Grossi [81], Z.J. Grout [80], L. Guan [91], W. Guan [177], J. Guenther [64], F. Guescini [51], D. Guest [167], O. Gueta [156], E. Guido [52a,52b], T. Guillemin [5], S. Guindon [2], U. Gul [55], C. Gumpert [32], J. Guo [141], Y. Guo [59,p], R. Gupta [42], S. Gupta [121], G. Gustavino [133a,133b], P. Gutierrez [114], N.G. Gutierrez Ortiz [80], C. Gutschow [46], C. Guyot [137], C. Gwenlan [121], C.B. Gwilliam [76], A. Haas [111], C. Haber [16], H.K. Hadavand [8], N. Haddad [136e], A. Hadef [87], S. Hageböck [23], M. Hagihara [165], Z. Hajduk [41], H. Hakobyan [181,*], M. Haleem [44], J. Haley [115], G. Halladjian [92], G.D. Hallewell [87], K. Hamacher [179], P. Hamal [116], K. Hamano [173], A. Hamilton [148a], G.N. Hamity [142], P.G. Hamnett [44], L. Han [59], K. Hanagaki [68,t], K. Hanawa [158], M. Hance [138], B. Haney [123], P. Hanke [60a], R. Hanna [137], J.B. Hansen [38], J.D. Hansen [38], M.C. Hansen [23], P.H. Hansen [38], K. Hara [165], A.S. Hard [177], T. Harenberg [179], F. Hariri [118], S. Harkusha [94], R.D. Harrington [48], P.F. Harrison [174], F. Hartjes [108], N.M. Hartmann [101], M. Hasegawa [69], Y. Hasegawa [143], A. Hasib [114], S. Hassani [137], S. Haug [18], R. Hauser [92], L. Hauswald [46], M. Havranek [128], C.M. Hawkes [19], R.J. Hawkings [32], D. Hayakawa [160], D. Hayden [92], C.P. Hays [121], J.M. Hays [78], H.S. Hayward [76], S.J. Haywood [132], S.J. Head [19], T. Heck [85], V. Hedberg [83], L. Heelan [8], S. Heim [123], T. Heim [16], B. Heinemann [16], J.J. Heinrich [101], L. Heinrich [111], C. Heinz [54], J. Hejbal [128], L. Helary [32], S. Hellman [149a,149b], C. Helsens [32], J. Henderson [121], R.C.W. Henderson [74], Y. Heng [177], S. Henkelmann [172], A.M. Henriques Correia [32], S. Henrot-Versille [118], G.H. Herbert [17], H. Herde [25], V. Herget [178], Y. Hernández Jiménez [171], G. Herten [50], R. Hertenberger [101], L. Hervas [32], G.G. Hesketh [80], N.P. Hessey [108], J.W. Hetherly [42], R. Hickling [78], E. Higón-Rodriguez [171], E. Hill [173], J.C. Hill [30], K.H. Hiller [44], S.J. Hillier [19], I. Hinchliffe [16], E. Hines [123], R.R. Hinman [16], M. Hirose [50], D. Hirschbuehl [179], J. Hobbs [151], N. Hod [164a], M.C. Hodgkinson [142], P. Hodgson [142], A. Hoecker [32], M.R. Hoeferkamp [106], F. Hoenig [101], D. Hohn [23], T.R. Holmes [16], M. Homann [45], T. Honda [68], T.M. Hong [126], B.H. Hooberman [170], W.H. Hopkins [117], Y. Horii [104], A.J. Horton [145], J-Y. Hostachy [57], S. Hou [154], A. Hoummada [136a], J. Howarth [44], J. Hoya [73], M. Hrabovsky [116], I. Hristova [17], J. Hrivnac [118], T. Hryn'ova [5], A. Hrynevich [95], C. Hsu [148c], P.J. Hsu [154,u], S.-C. Hsu [139], Q. Hu [59], S. Hu [141], Y. Huang [44], Z. Hubacek [129], F. Hubaut [87], F. Huegging [23], T.B. Huffman [121], E.W. Hughes [37], G. Hughes [74], M. Huhtinen [32], P. Huo [151], N. Huseynov [67,b], J. Huston [92], J. Huth [58], G. Iacobucci [51], G. Iakovidis [27], I. Ibragimov [144], L. Iconomidou-Fayard [118], E. Ideal [180], Z. Idrissi [136e], P. Iengo [32], O. Igonkina [108,v], T. Iizawa [175], Y. Ikegami [68], M. Ikeno [68], Y. Ilchenko [11,w], D. Iliadis [157], N. Ilic [146], T. Ince [102], G. Introzzi [122a,122b], P. Ioannou [9,*], M. Iodice [135a], K. Iordanidou [37], V. Ippolito [58], N. Ishijima [119], M. Ishino [158], M. Ishitsuka [160], R. Ishmukhametov [112], C. Issever [121],

S. Istin [20a], F. Ito [165], J.M. Iturbe Ponce [86], R. Iuppa [163a,163b], W. Iwanski [64], H. Iwasaki [68], J.M. Izen [43], V. Izzo [105a], S. Jabbar [3], B. Jackson [123], P. Jackson [1], V. Jain [2], K.B. Jakobi [85], K. Jakobs [50], S. Jakobsen [32], T. Jakoubek [128], D.O. Jamin [115], D.K. Jana [81], R. Jansky [64], J. Janssen [23], M. Janus [56], G. Jarlskog [83], N. Javadov [67,b], T. Javůrek [50], F. Jeanneau [137], L. Jeanty [16], G.-Y. Jeng [153], D. Jennens [90], P. Jenni [50,x], C. Jeske [174], S. Jézéquel [5], H. Ji [177], J. Jia [151], H. Jiang [66], Y. Jiang [59], S. Jiggins [80], J. Jimenez Pena [171], S. Jin [35a], A. Jinaru [28b], O. Jinnouchi [160], H. Jivan [148c], P. Johansson [142], K.A. Johns [7], W.J. Johnson [139], K. Jon-And [149a,149b], G. Jones [174], R.W.L. Jones [74], S. Jones [7], T.J. Jones [76], J. Jongmanns [60a], P.M. Jorge [127a,127b], J. Jovicevic [164a], X. Ju [177], A. Juste Rozas [13,s], M.K. Köhler [176], A. Kaczmarska [41], M. Kado [118], H. Kagan [112], M. Kagan [146], S.J. Kahn [87], T. Kaji [175], E. Kajomovitz [47], C.W. Kalderon [121], A. Kaluza [85], S. Kama [42], A. Kamenshchikov [131], N. Kanaya [158], S. Kaneti [30], L. Kanjir [77], V.A. Kantserov [99], J. Kanzaki [68], B. Kaplan [111], L.S. Kaplan [177], A. Kapliy [33], D. Kar [148c], K. Karakostas [10], A. Karamaoun [3], N. Karastathis [10], M.J. Kareem [56], E. Karentzos [10], M. Karnevskiy [85], S.N. Karpov [67], Z.M. Karpova [67], K. Karthik [111], V. Kartvelishvili [74], A.N. Karyukhin [131], K. Kasahara [165], L. Kashif [177], R.D. Kass [112], A. Kastanas [15], Y. Kataoka [158], C. Kato [158], A. Katre [51], J. Katzy [44], K. Kawade [104], K. Kawagoe [72], T. Kawamoto [158], G. Kawamura [56], V.F. Kazanin [110,c], R. Keeler [173], R. Kehoe [42], J.S. Keller [44], J.J. Kempster [79], H. Keoshkerian [162], O. Kepka [128], B.P. Kerševan [77], S. Kersten [179], R.A. Keyes [89], M. Khader [170], F. Khalil-zada [12], A. Khanov [115], A.G. Kharlamov [110,c], T. Kharlamova [110], T.J. Khoo [51], V. Khovanskiy [98], E. Khramov [67], J. Khubua [53b,y], S. Kido [69], C.R. Kilby [79], H.Y. Kim [8], S.H. Kim [165], Y.K. Kim [33], N. Kimura [157], O.M. Kind [17], B.T. King [76], M. King [171], J. Kirk [132], A.E. Kiryunin [102], T. Kishimoto [158], D. Kisielewska [40a], F. Kiss [50], K. Kiuchi [165], O. Kivernyk [137], E. Kladiva [147b], M.H. Klein [37], M. Klein [76], U. Klein [76], K. Kleinknecht [85], P. Klimek [109], A. Klimentov [27], R. Klingenberg [45], J.A. Klinger [142], T. Klioutchnikova [32], E.-E. Kluge [60a], P. Kluit [108], S. Kluth [102], J. Knapik [41], E. Kneringer [64], E.B.F.G. Knoops [87], A. Knue [55], A. Kobayashi [158], D. Kobayashi [160], T. Kobayashi [158], M. Kobel [46], M. Kocian [146], P. Kodys [130], N.M. Koehler [102], T. Koffas [31], E. Koffeman [108], T. Koi [146], H. Kolanoski [17], M. Kolb [60b], I. Koletsou [5], A.A. Komar [97,*], Y. Komori [158], T. Kondo [68], N. Kondrashova [44], K. Köneke [50], A.C. König [107], T. Kono [68,z], R. Konoplich [111,aa], N. Konstantinidis [80], R. Kopeliansky [63], S. Koperny [40a], L. Köpke [85], A.K. Kopp [50], K. Korcyl [41], K. Kordas [157], A. Korn [80], A.A. Korol [110,c], I. Korolkov [13], E.V. Korolkova [142], O. Kortner [102], S. Kortner [102], T. Kosek [130], V.V. Kostyukhin [23], A. Kotwal [47], A. Kourkoumeli-Charalampidi [122a,122b], C. Kourkoumelis [9], V. Kouskoura [27], A.B. Kowalewska [41], R. Kowalewski [173], T.Z. Kowalski [40a], C. Kozakai [158], W. Kozanecki [137], A.S. Kozhin [131], V.A. Kramarenko [100], G. Kramberger [77], D. Krasnopevtsev [99], M.W. Krasny [82], A. Krasznahorkay [32], A. Kravchenko [27], M. Kretz [60c], J. Kretzschmar [76], K. Kreutzfeldt [54], P. Krieger [162], K. Krizka [33], K. Kroeninger [45], H. Kroha [102], J. Kroll [123], J. Kroseberg [23], J. Krstic [14], U. Kruchonak [67], H. Krüger [23], N. Krumnack [66], M.C. Kruse [47], M. Kruskal [24], T. Kubota [90], H. Kucuk [80], S. Kuday [4b], J.T. Kuechler [179], S. Kuehn [50], A. Kugel [60c], F. Kuger [178], A. Kuhl [138], T. Kuhl [44], V. Kukhtin [67], R. Kukla [137], Y. Kulchitsky [94], S. Kuleshov [34b], M. Kuna [133a,133b], T. Kunigo [70], A. Kupco [128], H. Kurashige [69], Y.A. Kurochkin [94], V. Kus [128], E.S. Kuwertz [173], M. Kuze [160], J. Kvita [116], T. Kwan [173], D. Kyriazopoulos [142], A. La Rosa [102], J.L. La Rosa Navarro [26d], L. La Rotonda [39a,39b], C. Lacasta [171], F. Lacava [133a,133b], J. Lacey [31], H. Lacker [17], D. Lacour [82], V.R. Lacuesta [171], E. Ladygin [67], R. Lafaye [5], B. Laforge [82], T. Lagouri [180], S. Lai [56], S. Lammers [63], W. Lampl [7], E. Lançon [137], U. Landgraf [50], M.P.J. Landon [78], M.C. Lanfermann [51], V.S. Lang [60a], J.C. Lange [13], A.J. Lankford [167], F. Lanni [27], K. Lantzsch [23], A. Lanza [122a], S. Laplace [82], C. Lapoire [32], J.F. Laporte [137], T. Lari [93a], F. Lasagni Manghi [22a,22b], M. Lassnig [32], P. Laurelli [49], W. Lavrijsen [16], A.T. Law [138], P. Laycock [76], T. Lazovich [58], M. Lazzaroni [93a,93b], B. Le [90], O. Le Dortz [82], E. Le Guirriec [87], E.P. Le Quilleuc [137], M. LeBlanc [173], T. LeCompte [6], F. Ledroit-Guillon [57], C.A. Lee [27], S.C. Lee [154], L. Lee [1], B. Lefebvre [89], G. Lefebvre [82], M. Lefebvre [173], F. Legger [101], C. Leggett [16], A. Lehan [76], G. Lehmann Miotto [32], X. Lei [7], W.A. Leight [31], A.G. Leister [180], M.A.L. Leite [26d], R. Leitner [130], D. Lellouch [176], B. Lemmer [56], K.J.C. Leney [80], T. Lenz [23], B. Lenzi [32], R. Leone [7], S. Leone [125a,125b], C. Leonidopoulos [48], S. Leontsinis [10], G. Lerner [152], C. Leroy [96], A.A.J. Lesage [137], C.G. Lester [30], M. Levchenko [124], J. Levêque [5], D. Levin [91], L.J. Levinson [176], M. Levy [19], D. Lewis [78], A.M. Leyko [23], M. Leyton [43], B. Li [59,p], C. Li [59], H. Li [151], H.L. Li [33], L. Li [47], L. Li [141], Q. Li [35a], S. Li [47], X. Li [86], Y. Li [144], Z. Liang [35a], B. Liberti [134a], A. Liblong [162], P. Lichard [32], K. Lie [170], J. Liebal [23], W. Liebig [15], A. Limosani [153], S.C. Lin [154,ab], T.H. Lin [85], B.E. Lindquist [151], A.E. Lionti [51], E. Lipeles [123], A. Lipniacka [15], M. Lisovyi [60b], T.M. Liss [170], A. Lister [172], A.M. Litke [138], B. Liu [154,ac],

D. Liu [154], H. Liu [91], H. Liu [27], J. Liu [87], J.B. Liu [59], K. Liu [87], L. Liu [170], M. Liu [47], M. Liu [59], Y.L. Liu [59], Y. Liu [59], M. Livan [122a,122b], A. Lleres [57], J. Llorente Merino [35a], S.L. Lloyd [78], F. Lo Sterzo [154], E.M. Lobodzinska [44], P. Loch [7], W.S. Lockman [138], F.K. Loebinger [86], A.E. Loevschall-Jensen [38], K.M. Loew [25], A. Loginov [180,*], T. Lohse [17], K. Lohwasser [44], M. Lokajicek [128], B.A. Long [24], J.D. Long [170], R.E. Long [74], L. Longo [75a,75b], K.A. Looper [112], J.A. López [34b], D. Lopez Mateos [58], B. Lopez Paredes [142], I. Lopez Paz [13], A. Lopez Solis [82], J. Lorenz [101], N. Lorenzo Martinez [63], M. Losada [21], P.J. Lösel [101], X. Lou [35a], A. Lounis [118], J. Love [6], P.A. Love [74], H. Lu [62a], N. Lu [91], H.J. Lubatti [139], C. Luci [133a,133b], A. Lucotte [57], C. Luedtke [50], F. Luehring [63], W. Lukas [64], L. Luminari [133a], O. Lundberg [149a,149b], B. Lund-Jensen [150], P.M. Luzi [82], D. Lynn [27], R. Lysak [128], E. Lytken [83], V. Lyubushkin [67], H. Ma [27], L.L. Ma [140], Y. Ma [140], G. Maccarrone [49], A. Macchiolo [102], C.M. Macdonald [142], B. Maček [77], J. Machado Miguens [123,127b], D. Madaffari [87], R. Madar [36], H.J. Maddocks [169], W.F. Mader [46], A. Madsen [44], J. Maeda [69], S. Maeland [15], T. Maeno [27], A. Maevskiy [100], E. Magradze [56], J. Mahlstedt [108], C. Maiani [118], C. Maidantchik [26a], A.A. Maier [102], T. Maier [101], A. Maio [127a,127b,127d], S. Majewski [117], Y. Makida [68], N. Makovec [118], B. Malaescu [82], Pa. Malecki [41], V.P. Maleev [124], F. Malek [57], U. Mallik [65], D. Malon [6], C. Malone [146], C. Malone [30], S. Maltezos [10], S. Malyukov [32], J. Mamuzic [171], G. Mancini [49], L. Mandelli [93a], I. Mandić [77], J. Maneira [127a,127b], L. Manhaes de Andrade Filho [26b], J. Manjarres Ramos [164b], A. Mann [101], A. Manousos [32], B. Mansoulie [137], J.D. Mansour [35a], R. Mantifel [89], M. Mantoani [56], S. Manzoni [93a,93b], L. Mapelli [32], G. Marceca [29], L. March [51], G. Marchiori [82], M. Marcisovsky [128], M. Marjanovic [14], D.E. Marley [91], F. Marroquim [26a], S.P. Marsden [86], Z. Marshall [16], S. Marti-Garcia [171], B. Martin [92], T.A. Martin [174], V.J. Martin [48], B. Martin dit Latour [15], M. Martinez [13,s], V.I. Martinez Outschoorn [170], S. Martin-Haugh [132], V.S. Martoiu [28b], A.C. Martyniuk [80], A. Marzin [32], L. Masetti [85], T. Mashimo [158], R. Mashinistov [97], J. Masik [86], A.L. Maslennikov [110,c], I. Massa [22a,22b], L. Massa [22a,22b], P. Mastrandrea [5], A. Mastroberardino [39a,39b], T. Masubuchi [158], P. Mättig [179], J. Mattmann [85], J. Maurer [28b], S.J. Maxfield [76], D.A. Maximov [110,c], R. Mazini [154], S.M. Mazza [93a,93b], N.C. Mc Fadden [106], G. Mc Goldrick [162], S.P. Mc Kee [91], A. McCarn [91], R.L. McCarthy [151], T.G. McCarthy [102], L.I. McClymont [80], E.F. McDonald [90], J.A. Mcfayden [80], G. Mchedlidze [56], S.J. McMahon [132], R.A. McPherson [173,m], M. Medinnis [44], S. Meehan [139], S. Mehlhase [101], A. Mehta [76], K. Meier [60a], C. Meineck [101], B. Meirose [43], D. Melini [171], B.R. Mellado Garcia [148c], M. Melo [147a], F. Meloni [18], A. Mengarelli [22a,22b], S. Menke [102], E. Meoni [166], S. Mergelmeyer [17], P. Mermod [51], L. Merola [105a,105b], C. Meroni [93a], F.S. Merritt [33], A. Messina [133a,133b], J. Metcalfe [6], A.S. Mete [167], C. Meyer [85], C. Meyer [123], J-P. Meyer [137], J. Meyer [108], H. Meyer Zu Theenhausen [60a], F. Miano [152], R.P. Middleton [132], S. Miglioranzi [52a,52b], L. Mijović [48], G. Mikenberg [176], M. Mikestikova [128], M. Mikuž [77], M. Milesi [90], A. Milic [64], D.W. Miller [33], C. Mills [48], A. Milov [176], D.A. Milstead [149a,149b], A.A. Minaenko [131], Y. Minami [158], I.A. Minashvili [67], A.I. Mincer [111], B. Mindur [40a], M. Mineev [67], Y. Minegishi [158], Y. Ming [177], L.M. Mir [13], K.P. Mistry [123], T. Mitani [175], J. Mitrevski [101], V.A. Mitsou [171], A. Miucci [18], P.S. Miyagawa [142], J.U. Mjörnmark [83], M. Mlynarikova [130], T. Moa [149a,149b], K. Mochizuki [96], S. Mohapatra [37], S. Molander [149a,149b], R. Moles-Valls [23], R. Monden [70], M.C. Mondragon [92], K. Mönig [44], J. Monk [38], E. Monnier [87], A. Montalbano [151], J. Montejo Berlingen [32], F. Monticelli [73], S. Monzani [93a,93b], R.W. Moore [3], N. Morange [118], D. Moreno [21], M. Moreno Llácer [56], P. Morettini [52a], S. Morgenstern [32], D. Mori [145], T. Mori [158], M. Morii [58], M. Morinaga [158], V. Morisbak [120], S. Moritz [85], A.K. Morley [153], G. Mornacchi [32], J.D. Morris [78], S.S. Mortensen [38], L. Morvaj [151], M. Mosidze [53b], J. Moss [146,ad], K. Motohashi [160], R. Mount [146], E. Mountricha [27], E.J.W. Moyse [88], S. Muanza [87], R.D. Mudd [19], F. Mueller [102], J. Mueller [126], R.S.P. Mueller [101], T. Mueller [30], D. Muenstermann [74], P. Mullen [55], G.A. Mullier [18], F.J. Munoz Sanchez [86], J.A. Murillo Quijada [19], W.J. Murray [174,132], H. Musheghyan [56], M. Muškinja [77], A.G. Myagkov [131,ae], M. Myska [129], B.P. Nachman [146], O. Nackenhorst [51], K. Nagai [121], R. Nagai [68,z], K. Nagano [68], Y. Nagasaka [61], K. Nagata [165], M. Nagel [50], E. Nagy [87], A.M. Nairz [32], Y. Nakahama [104], K. Nakamura [68], T. Nakamura [158], I. Nakano [113], H. Namasivayam [43], R.F. Naranjo Garcia [44], R. Narayan [11], D.I. Narrias Villar [60a], I. Naryshkin [124], T. Naumann [44], G. Navarro [21], R. Nayyar [7], H.A. Neal [91], P.Yu. Nechaeva [97], T.J. Neep [86], A. Negri [122a,122b], M. Negrini [22a], S. Nektarijevic [107], C. Nellist [118], A. Nelson [167], S. Nemecek [128], P. Nemethy [111], A.A. Nepomuceno [26a], M. Nessi [32,af], M.S. Neubauer [170], M. Neumann [179], R.M. Neves [111], P. Nevski [27], P.R. Newman [19], D.H. Nguyen [6], T. Nguyen Manh [96], R.B. Nickerson [121], R. Nicolaidou [137], J. Nielsen [138], A. Nikiforov [17], V. Nikolaenko [131,ae], I. Nikolic-Audit [82], K. Nikolopoulos [19], J.K. Nilsen [120], P. Nilsson [27],

Y. Ninomiya [158], A. Nisati [133a], R. Nisius [102], T. Nobe [158], M. Nomachi [119], I. Nomidis [31], T. Nooney [78], S. Norberg [114], M. Nordberg [32], N. Norjoharuddeen [121], O. Novgorodova [46], S. Nowak [102], M. Nozaki [68], L. Nozka [116], K. Ntekas [167], E. Nurse [80], F. Nuti [90], F. O'grady [7], D.C. O'Neil [145], A.A. O'Rourke [44], V. O'Shea [55], F.G. Oakham [31,d], H. Oberlack [102], T. Obermann [23], J. Ocariz [82], A. Ochi [69], I. Ochoa [37], J.P. Ochoa-Ricoux [34a], S. Oda [72], S. Odaka [68], H. Ogren [63], A. Oh [86], S.H. Oh [47], C.C. Ohm [16], H. Ohman [169], H. Oide [32], H. Okawa [165], Y. Okumura [158], T. Okuyama [68], A. Olariu [28b], L.F. Oleiro Seabra [127a], S.A. Olivares Pino [48], D. Oliveira Damazio [27], A. Olszewski [41], J. Olszowska [41], A. Onofre [127a,127e], K. Onogi [104], P.U.E. Onyisi [11,w], M.J. Oreglia [33], Y. Oren [156], D. Orestano [135a,135b], N. Orlando [62b], R.S. Orr [162], B. Osculati [52a,52b,*], R. Ospanov [86], G. Otero y Garzon [29], H. Otono [72], M. Ouchrif [136d], F. Ould-Saada [120], A. Ouraou [137], K.P. Oussoren [108], Q. Ouyang [35a], M. Owen [55], R.E. Owen [19], V.E. Ozcan [20a], N. Ozturk [8], K. Pachal [145], A. Pacheco Pages [13], L. Pacheco Rodriguez [137], C. Padilla Aranda [13], M. Pagáčová [50], S. Pagan Griso [16], M. Paganini [180], F. Paige [27], P. Pais [88], K. Pajchel [120], G. Palacino [164b], S. Palazzo [39a,39b], S. Palestini [32], M. Palka [40b], D. Pallin [36], E.St. Panagiotopoulou [10], C.E. Pandini [82], J.G. Panduro Vazquez [79], P. Pani [149a,149b], S. Panitkin [27], D. Pantea [28b], L. Paolozzi [51], Th.D. Papadopoulou [10], K. Papageorgiou [157], A. Paramonov [6], D. Paredes Hernandez [180], A.J. Parker [74], M.A. Parker [30], K.A. Parker [142], F. Parodi [52a,52b], J.A. Parsons [37], U. Parzefall [50], V.R. Pascuzzi [162], E. Pasqualucci [133a], S. Passaggio [52a], Fr. Pastore [79], G. Pásztor [31,ag], S. Pataraia [179], J.R. Pater [86], T. Pauly [32], J. Pearce [173], B. Pearson [114], L.E. Pedersen [38], M. Pedersen [120], S. Pedraza Lopez [171], R. Pedro [127a,127b], S.V. Peleganchuk [110,c], O. Penc [128], C. Peng [35a], H. Peng [59], J. Penwell [63], B.S. Peralva [26b], M.M. Perego [137], D.V. Perepelitsa [27], E. Perez Codina [164a], L. Perini [93a,93b], H. Pernegger [32], S. Perrella [105a,105b], R. Peschke [44], V.D. Peshekhonov [67], K. Peters [44], R.F.Y. Peters [86], B.A. Petersen [32], T.C. Petersen [38], E. Petit [57], A. Petridis [1], C. Petridou [157], P. Petroff [118], E. Petrolo [133a], M. Petrov [121], F. Petrucci [135a,135b], N.E. Pettersson [88], A. Peyaud [137], R. Pezoa [34b], P.W. Phillips [132], G. Piacquadio [146,ah], E. Pianori [174], A. Picazio [88], E. Piccaro [78], M. Piccinini [22a,22b], M.A. Pickering [121], R. Piegaia [29], J.E. Pilcher [33], A.D. Pilkington [86], A.W.J. Pin [86], M. Pinamonti [168a,168c,ai], J.L. Pinfold [3], A. Pingel [38], S. Pires [82], H. Pirumov [44], M. Pitt [176], L. Plazak [147a], M.-A. Pleier [27], V. Pleskot [85], E. Plotnikova [67], P. Plucinski [92], D. Pluth [66], R. Poettgen [149a,149b], L. Poggioli [118], D. Pohl [23], G. Polesello [122a], A. Poley [44], A. Policicchio [39a,39b], R. Polifka [162], A. Polini [22a], C.S. Pollard [55], V. Polychronakos [27], K. Pommès [32], L. Pontecorvo [133a], B.G. Pope [92], G.A. Popeneciu [28c], A. Poppleton [32], S. Pospisil [129], K. Potamianos [16], I.N. Potrap [67], C.J. Potter [30], C.T. Potter [117], G. Poulard [32], J. Poveda [32], V. Pozdnyakov [67], M.E. Pozo Astigarraga [32], P. Pralavorio [87], A. Pranko [16], S. Prell [66], D. Price [86], L.E. Price [6], M. Primavera [75a], S. Prince [89], K. Prokofiev [62c], F. Prokoshin [34b], S. Protopopescu [27], J. Proudfoot [6], M. Przybycien [40a], D. Puddu [135a,135b], M. Purohit [27,aj], P. Puzo [118], J. Qian [91], G. Qin [55], Y. Qin [86], A. Quadt [56], W.B. Quayle [168a,168b], M. Queitsch-Maitland [86], D. Quilty [55], S. Raddum [120], V. Radeka [27], V. Radescu [121], S.K. Radhakrishnan [151], P. Radloff [117], P. Rados [90], F. Ragusa [93a,93b], G. Rahal [182], J.A. Raine [86], S. Rajagopalan [27], M. Rammensee [32], C. Rangel-Smith [169], M.G. Ratti [93a,93b], F. Rauscher [101], S. Rave [85], T. Ravenscroft [55], I. Ravinovich [176], M. Raymond [32], A.L. Read [120], N.P. Readioff [76], M. Reale [75a,75b], D.M. Rebuzzi [122a,122b], A. Redelbach [178], G. Redlinger [27], R. Reece [138], R.G. Reed [148c], K. Reeves [43], L. Rehnisch [17], J. Reichert [123], A. Reiss [85], C. Rembser [32], H. Ren [35a], M. Rescigno [133a], S. Resconi [93a], O.L. Rezanova [110,c], P. Reznicek [130], R. Rezvani [96], R. Richter [102], S. Richter [80], E. Richter-Was [40b], O. Ricken [23], M. Ridel [82], P. Rieck [17], C.J. Riegel [179], J. Rieger [56], O. Rifki [114], M. Rijssenbeek [151], A. Rimoldi [122a,122b], M. Rimoldi [18], L. Rinaldi [22a], B. Ristić [51], E. Ritsch [32], I. Riu [13], F. Rizatdinova [115], E. Rizvi [78], C. Rizzi [13], S.H. Robertson [89,m], A. Robichaud-Veronneau [89], D. Robinson [30], J.E.M. Robinson [44], A. Robson [55], C. Roda [125a,125b], Y. Rodina [87,ak], A. Rodriguez Perez [13], D. Rodriguez Rodriguez [171], S. Roe [32], C.S. Rogan [58], O. Røhne [120], A. Romaniouk [99], M. Romano [22a,22b], S.M. Romano Saez [36], E. Romero Adam [171], N. Rompotis [139], M. Ronzani [50], L. Roos [82], E. Ros [171], S. Rosati [133a], K. Rosbach [50], P. Rose [138], N.-A. Rosien [56], V. Rossetti [149a,149b], E. Rossi [105a,105b], L.P. Rossi [52a], J.H.N. Rosten [30], R. Rosten [139], M. Rotaru [28b], I. Roth [176], J. Rothberg [139], D. Rousseau [118], A. Rozanov [87], Y. Rozen [155], X. Ruan [148c], F. Rubbo [146], M.S. Rudolph [162], F. Rühr [50], A. Ruiz-Martinez [31], Z. Rurikova [50], N.A. Rusakovich [67], A. Ruschke [101], H.L. Russell [139], J.P. Rutherfoord [7], N. Ruthmann [32], Y.F. Ryabov [124], M. Rybar [170], G. Rybkin [118], S. Ryu [6], A. Ryzhov [131], G.F. Rzehorz [56], A.F. Saavedra [153], G. Sabato [108], S. Sacerdoti [29], H.F-W. Sadrozinski [138], R. Sadykov [67], F. Safai Tehrani [133a], P. Saha [109], M. Sahinsoy [60a], M. Saimpert [137], T. Saito [158], H. Sakamoto [158], Y. Sakurai [175], G. Salamanna [135a,135b], A. Salamon [134a,134b], J.E. Salazar Loyola [34b], D. Salek [108], P.H. Sales De Bruin [139], D. Salihagic [102], A. Salnikov [146], J. Salt [171], D. Salvatore [39a,39b], F. Salvatore [152], A. Salvucci [62a,62b,62c], A. Salzburger [32], D. Sammel [50], D. Sampsonidis [157], J. Sánchez [171], V. Sanchez Martinez [171], A. Sanchez Pineda [105a,105b], H. Sandaker [120], R.L. Sandbach [78], H.G. Sander [85], M. Sandhoff [179], C. Sandoval [21], D.P.C. Sankey [132], M. Sannino [52a,52b], A. Sansoni [49], C. Santoni [36], R. Santonico [134a,134b], H. Santos [127a], I. Santoyo Castillo [152], K. Sapp [126], A. Sapronov [67], J.G. Saraiva [127a,127d], B. Sarrazin [23], O. Sasaki [68], K. Sato [165], E. Sauvan [5], G. Savage [79], P. Savard [162,d], N. Savic [102], C. Sawyer [132], L. Sawyer [81,r], J. Saxon [33], C. Sbarra [22a], A. Sbrizzi [22a,22b], T. Scanlon [80], D.A. Scannicchio [167], M. Scarcella [153], V. Scarfone [39a,39b], J. Schaarschmidt [176], P. Schacht [102], B.M. Schachtner [101], D. Schaefer [32], L. Schaefer [123], R. Schaefer [44], J. Schaeffer [85], S. Schaepe [23], S. Schaetzel [60b], U. Schäfer [85], A.C. Schaffer [118], D. Schaile [101], R.D. Schamberger [151], V. Scharf [60a], V.A. Schegelsky [124], D. Scheirich [130], M. Schernau [167], C. Schiavi [52a,52b], S. Schier [138], C. Schillo [50], M. Schioppa [39a,39b], S. Schlenker [32], K.R. Schmidt-Sommerfeld [102], K. Schmieden [32], C. Schmitt [85], S. Schmitt [44], S. Schmitz [85], B. Schneider [164a], U. Schnoor [50], L. Schoeffel [137], A. Schoening [60b], B.D. Schoenrock [92], E. Schopf [23], M. Schott [85], J.F.P. Schouwenberg [107], J. Schovancova [8], S. Schramm [51], M. Schreyer [178], N. Schuh [85], A. Schulte [85], M.J. Schultens [23], H.-C. Schultz-Coulon [60a], H. Schulz [17], M. Schumacher [50], B.A. Schumm [138], Ph. Schune [137], A. Schwartzman [146], T.A. Schwarz [91], H. Schweiger [86], Ph. Schwemling [137], R. Schwienhorst [92], J. Schwindling [137], T. Schwindt [23], G. Sciolla [25], F. Scuri [125a,125b], F. Scutti [90], J. Searcy [91], P. Seema [23], S.C. Seidel [106], A. Seiden [138], F. Seifert [129], J.M. Seixas [26a], G. Sekhniaidze [105a], K. Sekhon [91], S.J. Sekula [42], D.M. Seliverstov [124,*], N. Semprini-Cesari [22a,22b], C. Serfon [120], L. Serin [118], L. Serkin [168a,168b], M. Sessa [135a,135b], R. Seuster [173], H. Severini [114], T. Sfiligoj [77], F. Sforza [32], A. Sfyrla [51], E. Shabalina [56], N.W. Shaikh [149a,149b], L.Y. Shan [35a], R. Shang [170], J.T. Shank [24], M. Shapiro [16], P.B. Shatalov [98], K. Shaw [168a,168b], S.M. Shaw [86], A. Shcherbakova [149a,149b], C.Y. Shehu [152], P. Sherwood [80], L. Shi [154,al], S. Shimizu [69], C.O. Shimmin [167], M. Shimojima [103], S. Shirabe [72], M. Shiyakova [67,am], A. Shmeleva [97], D. Shoaleh Saadi [96], M.J. Shochet [33], S. Shojaii [93a,93b], D.R. Shope [114], S. Shrestha [112], E. Shulga [99], M.A. Shupe [7], P. Sicho [128], A.M. Sickles [170], P.E. Sidebo [150], O. Sidiropoulou [178], D. Sidorov [115], A. Sidoti [22a,22b], F. Siegert [46], Dj. Sijacki [14], J. Silva [127a,127d], S.B. Silverstein [149a], V. Simak [129], Lj. Simic [14], S. Simion [118], E. Simioni [85], B. Simmons [80], D. Simon [36], M. Simon [85], P. Sinervo [162], N.B. Sinev [117], M. Sioli [22a,22b], G. Siragusa [178], S.Yu. Sivoklokov [100], J. Sjölin [149a,149b], M.B. Skinner [74], H.P. Skottowe [58], P. Skubic [114], M. Slater [19], T. Slavicek [129], M. Slawinska [108], K. Sliwa [166], R. Slovak [130], V. Smakhtin [176], B.H. Smart [5], L. Smestad [15], J. Smiesko [147a], S.Yu. Smirnov [99], Y. Smirnov [99], L.N. Smirnova [100,an], O. Smirnova [83], M.N.K. Smith [37], R.W. Smith [37], M. Smizanska [74], K. Smolek [129], A.A. Snesarev [97], I.M. Snyder [117], S. Snyder [27], R. Sobie [173,m], F. Socher [46], A. Soffer [156], D.A. Soh [154], G. Sokhrannyi [77], C.A. Solans Sanchez [32], M. Solar [129], E.Yu. Soldatov [99], U. Soldevila [171], A.A. Solodkov [131], A. Soloshenko [67], O.V. Solovyanov [131], V. Solovyev [124], P. Sommer [50], H. Son [166], H.Y. Song [59,ao], A. Sood [16], A. Sopczak [129], V. Sopko [129], V. Sorin [13], D. Sosa [60b], C.L. Sotiropoulou [125a,125b], R. Soualah [168a,168c], A.M. Soukharev [110,c], D. South [44], B.C. Sowden [79], S. Spagnolo [75a,75b], M. Spalla [125a,125b], M. Spangenberg [174], F. Spanò [79], D. Sperlich [17], F. Spettel [102], R. Spighi [22a], G. Spigo [32], L.A. Spiller [90], M. Spousta [130], R.D. St. Denis [55,*], A. Stabile [93a], R. Stamen [60a], S. Stamm [17], E. Stanecka [41], R.W. Stanek [6], C. Stanescu [135a], M. Stanescu-Bellu [44], M.M. Stanitzki [44], S. Stapnes [120], E.A. Starchenko [131], G.H. Stark [33], J. Stark [57], P. Staroba [128], P. Starovoitov [60a], S. Stärz [32], R. Staszewski [41], P. Steinberg [27], B. Stelzer [145], H.J. Stelzer [32], O. Stelzer-Chilton [164a], H. Stenzel [54], G.A. Stewart [55], J.A. Stillings [23], M.C. Stockton [89], M. Stoebe [89], G. Stoicea [28b], P. Stolte [56], S. Stonjek [102], A.R. Stradling [8], A. Straessner [46], M.E. Stramaglia [18], J. Strandberg [150], S. Strandberg [149a,149b], A. Strandlie [120], M. Strauss [114], P. Strizenec [147b], R. Ströhmer [178], D.M. Strom [117], R. Stroynowski [42], A. Strubig [107], S.A. Stucci [27], B. Stugu [15], N.A. Styles [44], D. Su [146], J. Su [126], S. Suchek [60a], Y. Sugaya [119], M. Suk [129], V.V. Sulin [97], S. Sultansoy [4c], T. Sumida [70], S. Sun [58], X. Sun [35a], J.E. Sundermann [50], K. Suruliz [152], G. Susinno [39a,39b], M.R. Sutton [152], S. Suzuki [68], M. Svatos [128], M. Swiatlowski [33], I. Sykora [147a], T. Sykora [130], D. Ta [50], C. Taccini [135a,135b], K. Tackmann [44], J. Taenzer [162], A. Taffard [167], R. Tafirout [164a], N. Taiblum [156], H. Takai [27], R. Takashima [71], T. Takeshita [143], Y. Takubo [68], M. Talby [87], A.A. Talyshev [110,c], K.G. Tan [90], J. Tanaka [158], M. Tanaka [160], R. Tanaka [118], S. Tanaka [68], R. Tanioka [69], B.B. Tannenwald [112], S. Tapia Araya [34b], S. Tapprogge [85], S. Tarem [155], G.F. Tartarelli [93a], P. Tas [130], M. Tasevsky [128], T. Tashiro [70], E. Tassi [39a,39b], A. Tavares Delgado [127a,127b], Y. Tayalati [136e], A.C. Taylor [106], G.N. Taylor [90], P.T.E. Taylor [90], W. Taylor [164b], F.A. Teischinger [32],

P. Teixeira-Dias [79], K.K. Temming [50], D. Temple [145], H. Ten Kate [32], P.K. Teng [154], J.J. Teoh [119], F. Tepel [179], S. Terada [68], K. Terashi [158], J. Terron [84], S. Terzo [13], M. Testa [49], R.J. Teuscher [162,m], T. Theveneaux-Pelzer [87], J.P. Thomas [19], J. Thomas-Wilsker [79], E.N. Thompson [37], P.D. Thompson [19], A.S. Thompson [55], L.A. Thomsen [180], E. Thomson [123], M. Thomson [30], M.J. Tibbetts [16], R.E. Ticse Torres [87], V.O. Tikhomirov [97,ap], Yu.A. Tikhonov [110,c], S. Timoshenko [99], P. Tipton [180], S. Tisserant [87], K. Todome [160], T. Todorov [5,*], S. Todorova-Nova [130], J. Tojo [72], S. Tokár [147a], K. Tokushuku [68], E. Tolley [58], L. Tomlinson [86], M. Tomoto [104], L. Tompkins [146,aq], K. Toms [106], B. Tong [58], P. Tornambe [50], E. Torrence [117], H. Torres [145], E. Torró Pastor [139], J. Toth [87,ar], F. Touchard [87], D.R. Tovey [142], T. Trefzger [178], A. Tricoli [27], I.M. Trigger [164a], S. Trincaz-Duvoid [82], M.F. Tripiana [13], W. Trischuk [162], B. Trocmé [57], A. Trofymov [44], C. Troncon [93a], M. Trottier-McDonald [16], M. Trovatelli [173], L. Truong [168a,168c], M. Trzebinski [41], A. Trzupek [41], J.C-L. Tseng [121], P.V. Tsiareshka [94], G. Tsipolitis [10], N. Tsirintanis [9], S. Tsiskaridze [13], V. Tsiskaridze [50], E.G. Tskhadadze [53a], K.M. Tsui [62a], I.I. Tsukerman [98], V. Tsulaia [16], S. Tsuno [68], D. Tsybychev [151], Y. Tu [62b], A. Tudorache [28b], V. Tudorache [28b], A.N. Tuna [58], S.A. Tupputi [22a,22b], S. Turchikhin [67], D. Turecek [129], D. Turgeman [176], R. Turra [93a,93b], P.M. Tuts [37], M. Tyndel [132], G. Ucchielli [22a,22b], I. Ueda [158], M. Ughetto [149a,149b], F. Ukegawa [165], G. Unal [32], A. Undrus [27], G. Unel [167], F.C. Ungaro [90], Y. Unno [68], C. Unverdorben [101], J. Urban [147b], P. Urquijo [90], P. Urrejola [85], G. Usai [8], L. Vacavant [87], V. Vacek [129], B. Vachon [89], C. Valderanis [101], E. Valdes Santurio [149a,149b], N. Valencic [108], S. Valentinetti [22a,22b], A. Valero [171], L. Valery [13], S. Valkar [130], J.A. Valls Ferrer [171], W. Van Den Wollenberg [108], P.C. Van Der Deijl [108], H. van der Graaf [108], N. van Eldik [155], P. van Gemmeren [6], J. Van Nieuwkoop [145], I. van Vulpen [108], M.C. van Woerden [32], M. Vanadia [133a,133b], W. Vandelli [32], R. Vanguri [123], A. Vaniachine [161], P. Vankov [108], G. Vardanyan [181], R. Vari [133a], E.W. Varnes [7], T. Varol [42], D. Varouchas [82], A. Vartapetian [8], K.E. Varvell [153], J.G. Vasquez [180], G.A. Vasquez [34b], F. Vazeille [36], T. Vazquez Schroeder [89], J. Veatch [56], V. Veeraraghavan [7], L.M. Veloce [162], F. Veloso [127a,127c], S. Veneziano [133a], A. Ventura [75a,75b], M. Venturi [173], N. Venturi [162], A. Venturini [25], V. Vercesi [122a], M. Verducci [133a,133b], W. Verkerke [108], J.C. Vermeulen [108], A. Vest [46,as], M.C. Vetterli [145,d], O. Viazlo [83], I. Vichou [170,*], T. Vickey [142], O.E. Vickey Boeriu [142], G.H.A. Viehhauser [121], S. Viel [16], L. Vigani [121], M. Villa [22a,22b], M. Villaplana Perez [93a,93b], E. Vilucchi [49], M.G. Vincter [31], V.B. Vinogradov [67], C. Vittori [22a,22b], I. Vivarelli [152], S. Vlachos [10], M. Vlasak [129], M. Vogel [179], P. Vokac [129], G. Volpi [125a,125b], M. Volpi [90], H. von der Schmitt [102], E. von Toerne [23], V. Vorobel [130], K. Vorobev [99], M. Vos [171], R. Voss [32], J.H. Vossebeld [76], N. Vranjes [14], M. Vranjes Milosavljevic [14], V. Vrba [128], M. Vreeswijk [108], R. Vuillermet [32], I. Vukotic [33], Z. Vykydal [129], P. Wagner [23], W. Wagner [179], H. Wahlberg [73], S. Wahrmund [46], J. Wakabayashi [104], J. Walder [74], R. Walker [101], W. Walkowiak [144], V. Wallangen [149a,149b], C. Wang [35b], C. Wang [140,87], F. Wang [177], H. Wang [16], H. Wang [42], J. Wang [44], J. Wang [153], K. Wang [89], R. Wang [6], S.M. Wang [154], T. Wang [23], T. Wang [37], W. Wang [59], X. Wang [180], C. Wanotayaroj [117], A. Warburton [89], C.P. Ward [30], D.R. Wardrope [80], A. Washbrook [48], P.M. Watkins [19], A.T. Watson [19], M.F. Watson [19], G. Watts [139], S. Watts [86], B.M. Waugh [80], S. Webb [85], M.S. Weber [18], S.W. Weber [178], S.A. Weber [31], J.S. Webster [6], A.R. Weidberg [121], B. Weinert [63], J. Weingarten [56], C. Weiser [50], H. Weits [108], P.S. Wells [32], T. Wenaus [27], T. Wengler [32], S. Wenig [32], N. Wermes [23], M. Werner [50], M.D. Werner [66], P. Werner [32], M. Wessels [60a], J. Wetter [166], K. Whalen [117], N.L. Whallon [139], A.M. Wharton [74], A. White [8], M.J. White [1], R. White [34b], D. Whiteson [167], F.J. Wickens [132], W. Wiedenmann [177], M. Wielers [132], C. Wiglesworth [38], L.A.M. Wiik-Fuchs [23], A. Wildauer [102], F. Wilk [86], H.G. Wilkens [32], H.H. Williams [123], S. Williams [108], C. Willis [92], S. Willocq [88], J.A. Wilson [19], I. Wingerter-Seez [5], F. Winklmeier [117], O.J. Winston [152], B.T. Winter [23], M. Wittgen [146], J. Wittkowski [101], T.M.H. Wolf [108], M.W. Wolter [41], H. Wolters [127a,127c], S.D. Worm [132], B.K. Wosiek [41], J. Wotschack [32], M.J. Woudstra [86], K.W. Wozniak [41], M. Wu [57], M. Wu [33], S.L. Wu [177], X. Wu [51], Y. Wu [91], T.R. Wyatt [86], B.M. Wynne [48], S. Xella [38], D. Xu [35a], L. Xu [27], B. Yabsley [153], S. Yacoob [148a], D. Yamaguchi [160], Y. Yamaguchi [119], A. Yamamoto [68], S. Yamamoto [158], T. Yamanaka [158], K. Yamauchi [104], Y. Yamazaki [69], Z. Yan [24], H. Yang [141], H. Yang [177], Y. Yang [154], Z. Yang [15], W-M. Yao [16], Y.C. Yap [82], Y. Yasu [68], E. Yatsenko [5], K.H. Yau Wong [23], J. Ye [42], S. Ye [27], I. Yeletskikh [67], A.L. Yen [58], E. Yildirim [85], K. Yorita [175], R. Yoshida [6], K. Yoshihara [123], C. Young [146], C.J.S. Young [32], S. Youssef [24], D.R. Yu [16], J. Yu [8], J.M. Yu [91], J. Yu [66], L. Yuan [69], S.P.Y. Yuen [23], I. Yusuff [30,at], B. Zabinski [41], R. Zaidan [65], A.M. Zaitsev [131,ae], N. Zakharchuk [44], J. Zalieckas [15], A. Zaman [151], S. Zambito [58], L. Zanello [133a,133b], D. Zanzi [90], C. Zeitnitz [179], M. Zeman [129], A. Zemla [40a], J.C. Zeng [170], Q. Zeng [146], K. Zengel [25], O. Zenin [131],

T. Ženiš [147a], D. Zerwas [118], D. Zhang [91], F. Zhang [177], G. Zhang [59,ao], H. Zhang [35b], J. Zhang [6], L. Zhang [50], R. Zhang [23], R. Zhang [59,au], X. Zhang [140], Z. Zhang [118], X. Zhao [42], Y. Zhao [140], Z. Zhao [59], A. Zhemchugov [67], J. Zhong [121], B. Zhou [91], C. Zhou [177], L. Zhou [37], L. Zhou [42], M. Zhou [151], N. Zhou [35c], C.G. Zhu [140], H. Zhu [35a], J. Zhu [91], Y. Zhu [59], X. Zhuang [35a], K. Zhukov [97], A. Zibell [178], D. Zieminska [63], N.I. Zimine [67], C. Zimmermann [85], S. Zimmermann [50], Z. Zinonos [56], M. Zinser [85], M. Ziolkowski [144], L. Živković [14], G. Zobernig [177], A. Zoccoli [22a,22b], M. zur Nedden [17], L. Zwalinski [32]

[1] *Department of Physics, University of Adelaide, Adelaide, Australia*
[2] *Physics Department, SUNY Albany, Albany, NY, United States*
[3] *Department of Physics, University of Alberta, Edmonton, AB, Canada*
[4] [(a)] *Department of Physics, Ankara University, Ankara;* [(b)] *Istanbul Aydin University, Istanbul;* [(c)] *Division of Physics, TOBB University of Economics and Technology, Ankara, Turkey*
[5] *LAPP, CNRS/IN2P3 and Université Savoie Mont Blanc, Annecy-le-Vieux, France*
[6] *High Energy Physics Division, Argonne National Laboratory, Argonne, IL, United States*
[7] *Department of Physics, University of Arizona, Tucson, AZ, United States*
[8] *Department of Physics, The University of Texas at Arlington, Arlington, TX, United States*
[9] *Physics Department, University of Athens, Athens, Greece*
[10] *Physics Department, National Technical University of Athens, Zografou, Greece*
[11] *Department of Physics, The University of Texas at Austin, Austin, TX, United States*
[12] *Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan*
[13] *Institut de Física d'Altes Energies (IFAE), The Barcelona Institute of Science and Technology, Barcelona, Spain*
[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*
[17] *Department of Physics, Humboldt University, 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)] *Department of Physics, Bogazici University, Istanbul;* [(b)] *Department of Physics Engineering, Gaziantep University, Gaziantep;* [(d)] *Istanbul Bilgi University, Faculty of Engineering and Natural Sciences, Istanbul;* [(e)] *Bahcesehir University, Faculty of Engineering and Natural Sciences, Istanbul, Turkey*
[21] *Centro de Investigaciones, Universidad Antonio Narino, Bogota, Colombia*
[22] [(a)] *INFN Sezione di Bologna;* [(b)] *Dipartimento di Fisica e Astronomia, Università di Bologna, Bologna, Italy*
[23] *Physikalisches Institut, University of Bonn, Bonn, Germany*
[24] *Department of Physics, Boston University, Boston, MA, United States*
[25] *Department of Physics, Brandeis University, Waltham, MA, United States*
[26] [(a)] *Universidade Federal do Rio De Janeiro COPPE/EE/IF, Rio de Janeiro;* [(b)] *Electrical Circuits Department, Federal University of Juiz de Fora (UFJF), Juiz de Fora;* [(c)] *Federal University of Sao Joao del Rei (UFSJ), Sao Joao del Rei;* [(d)] *Instituto de Fisica, Universidade de Sao Paulo, Sao Paulo, Brazil*
[27] *Physics Department, Brookhaven National Laboratory, Upton, NY, United States*
[28] [(a)] *Transilvania University of Brasov, Brasov, Romania;* [(b)] *National Institute of Physics and Nuclear Engineering, Bucharest;* [(c)] *National Institute for Research and Development of Isotopic and Molecular Technologies, Physics Department, Cluj Napoca;* [(d)] *University Politehnica Bucharest, Bucharest;* [(e)] *West University in Timisoara, Timisoara, Romania*
[29] *Departamento de Física, Universidad de Buenos Aires, Buenos Aires, Argentina*
[30] *Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom*
[31] *Department of Physics, Carleton University, Ottawa, ON, Canada*
[32] *CERN, Geneva, Switzerland*
[33] *Enrico Fermi Institute, University of Chicago, Chicago, IL, United States*
[34] [(a)] *Departamento de Física, Pontificia Universidad Católica de Chile, Santiago;* [(b)] *Departamento de Física, Universidad Técnica Federico Santa María, Valparaíso, Chile*
[35] [(a)] *Institute of High Energy Physics, Chinese Academy of Sciences, Beijing;* [(b)] *Department of Physics, Nanjing University, Jiangsu;* [(c)] *Physics Department, Tsinghua University, Beijing 100084, China*
[36] *Laboratoire de Physique Corpusculaire, Clermont Université and Université Blaise Pascal and CNRS/IN2P3, Clermont-Ferrand, France*
[37] *Nevis Laboratory, Columbia University, Irvington, NY, United States*
[38] *Niels Bohr Institute, University of Copenhagen, Kobenhavn, Denmark*
[39] [(a)] *INFN Gruppo Collegato di Cosenza, Laboratori Nazionali di Frascati;* [(b)] *Dipartimento di Fisica, Università della Calabria, Rende, Italy*
[40] [(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*
[41] *Institute of Nuclear Physics Polish Academy of Sciences, Krakow, Poland*
[42] *Physics Department, Southern Methodist University, Dallas, TX, United States*
[43] *Physics Department, University of Texas at Dallas, Richardson, TX, United States*
[44] *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*
[48] *SUPA - School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom*
[49] *INFN Laboratori Nazionali di Frascati, Frascati, Italy*
[50] *Fakultät für Mathematik und Physik, Albert-Ludwigs-Universität, Freiburg, Germany*
[51] *Section de Physique, Université de Genève, Geneva, Switzerland*
[52] [(a)] *INFN Sezione di Genova;* [(b)] *Dipartimento di Fisica, Università di Genova, Genova, Italy*
[53] [(a)] *E. Andronikashvili Institute of Physics, Iv. Javakhishvili Tbilisi State University, Tbilisi;* [(b)] *High Energy Physics Institute, Tbilisi State University, Tbilisi, Georgia*
[54] *II Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen, Germany*
[55] *SUPA - School of Physics and Astronomy, University of Glasgow, Glasgow, United Kingdom*
[56] *II Physikalisches Institut, Georg-August-Universität, Göttingen, Germany*
[57] *Laboratoire de Physique Subatomique et de Cosmologie, Université Grenoble-Alpes, CNRS/IN2P3, Grenoble, France*
[58] *Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge, MA, United States*
[59] *Department of Modern Physics, University of Science and Technology of China, Anhui, China*
[60] [(a)] *Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Heidelberg;* [(b)] *Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg;* [(c)] *ZITI Institut für technische Informatik, Ruprecht-Karls-Universität Heidelberg, Mannheim, Germany*
[61] *Faculty of Applied Information Science, Hiroshima Institute of Technology, Hiroshima, Japan*
[62] [(a)] *Department of Physics, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong;* [(b)] *Department of Physics, The University of Hong Kong, Hong Kong;* [(c)] *Department of Physics, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, China*

[63] Department of Physics, Indiana University, Bloomington, IN, United States
[64] Institut für Astro- und Teilchenphysik, Leopold-Franzens-Universität, Innsbruck, Austria
[65] University of Iowa, Iowa City, IA, United States
[66] Department of Physics and Astronomy, Iowa State University, Ames, IA, United States
[67] Joint Institute for Nuclear Research, JINR Dubna, Dubna, Russia
[68] KEK, High Energy Accelerator Research Organization, Tsukuba, Japan
[69] Graduate School of Science, Kobe University, Kobe, Japan
[70] Faculty of Science, Kyoto University, Kyoto, Japan
[71] Kyoto University of Education, Kyoto, Japan
[72] Department of Physics, Kyushu University, Fukuoka, Japan
[73] Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata, Argentina
[74] Physics Department, Lancaster University, Lancaster, United Kingdom
[75] [(a)] INFN Sezione di Lecce; [(b)] Dipartimento di Matematica e Fisica, Università del Salento, Lecce, Italy
[76] Oliver Lodge Laboratory, University of Liverpool, Liverpool, United Kingdom
[77] Department of Physics, Jožef Stefan Institute and University of Ljubljana, Ljubljana, Slovenia
[78] School of Physics and Astronomy, Queen Mary University of London, London, United Kingdom
[79] Department of Physics, Royal Holloway University of London, Surrey, United Kingdom
[80] Department of Physics and Astronomy, University College London, London, United Kingdom
[81] Louisiana Tech University, Ruston, LA, United States
[82] Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France
[83] Fysiska institutionen, Lunds universitet, Lund, Sweden
[84] Departamento de Fisica Teorica C-15, Universidad Autonoma de Madrid, Madrid, Spain
[85] Institut für Physik, Universität Mainz, Mainz, Germany
[86] School of Physics and Astronomy, University of Manchester, Manchester, United Kingdom
[87] CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France
[88] Department of Physics, University of Massachusetts, Amherst, MA, United States
[89] Department of Physics, McGill University, Montreal, QC, Canada
[90] School of Physics, University of Melbourne, Victoria, Australia
[91] Department of Physics, The University of Michigan, Ann Arbor, MI, United States
[92] Department of Physics and Astronomy, Michigan State University, East Lansing, MI, United States
[93] [(a)] INFN Sezione di Milano; [(b)] Dipartimento di Fisica, Università di Milano, Milano, Italy
[94] B.I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk, Belarus
[95] National Scientific and Educational Centre for Particle and High Energy Physics, Minsk, Belarus
[96] Group of Particle Physics, University of Montreal, Montreal, QC, Canada
[97] P.N. Lebedev Physical Institute of the Russian Academy of Sciences, Moscow, Russia
[98] Institute for Theoretical and Experimental Physics (ITEP), Moscow, Russia
[99] National Research Nuclear University MEPhI, Moscow, Russia
[100] D.V. Skobeltsyn Institute of Nuclear Physics, M.V. Lomonosov Moscow State University, Moscow, Russia
[101] Fakultät für Physik, Ludwig-Maximilians-Universität München, München, Germany
[102] Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), München, Germany
[103] Nagasaki Institute of Applied Science, Nagasaki, Japan
[104] Graduate School of Science and Kobayashi-Maskawa Institute, Nagoya University, Nagoya, Japan
[105] [(a)] INFN Sezione di Napoli; [(b)] Dipartimento di Fisica, Università di Napoli, Napoli, Italy
[106] Department of Physics and Astronomy, University of New Mexico, Albuquerque, NM, United States
[107] Institute for Mathematics, Astrophysics and Particle Physics, Radboud University Nijmegen/Nikhef, Nijmegen, Netherlands
[108] Nikhef National Institute for Subatomic Physics and University of Amsterdam, Amsterdam, Netherlands
[109] Department of Physics, Northern Illinois University, DeKalb, IL, United States
[110] Budker Institute of Nuclear Physics, SB RAS, Novosibirsk, Russia
[111] Department of Physics, New York University, New York, NY, United States
[112] Ohio State University, Columbus, OH, United States
[113] Faculty of Science, Okayama University, Okayama, Japan
[114] Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman, OK, United States
[115] Department of Physics, Oklahoma State University, Stillwater, OK, United States
[116] Palacký University, RCPTM, Olomouc, Czech Republic
[117] Center for High Energy Physics, University of Oregon, Eugene, OR, United States
[118] LAL, Univ. Paris-Sud, CNRS/IN2P3, Université Paris-Saclay, Orsay, France
[119] Graduate School of Science, Osaka University, Osaka, Japan
[120] Department of Physics, University of Oslo, Oslo, Norway
[121] Department of Physics, Oxford University, Oxford, United Kingdom
[122] [(a)] INFN Sezione di Pavia; [(b)] Dipartimento di Fisica, Università di Pavia, Pavia, Italy
[123] Department of Physics, University of Pennsylvania, Philadelphia, PA, United States
[124] National Research Centre "Kurchatov Institute" B.P. Konstantinov Petersburg Nuclear Physics Institute, St. Petersburg, Russia
[125] [(a)] INFN Sezione di Pisa; [(b)] Dipartimento di Fisica E. Fermi, Università di Pisa, Pisa, Italy
[126] Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh, PA, United States
[127] [(a)] Laboratório de Instrumentação e Física Experimental de Partículas - LIP, Lisboa; [(b)] Faculdade de Ciências, Universidade de Lisboa, Lisboa; [(c)] Department of Physics, University of Coimbra, Coimbra; [(d)] Centro de Física Nuclear da Universidade de Lisboa, Lisboa; [(e)] Departamento de Fisica, Universidade do Minho, Braga; [(f)] Departamento de Fisica Teorica y del Cosmos and CAFPE, Universidad de Granada, Granada (Spain); [(g)] Dep Fisica and CEFITEC of Faculdade de Ciencias e Tecnologia, Universidade Nova de Lisboa, Caparica, Portugal
[128] Institute of Physics, Academy of Sciences of the Czech Republic, Praha, Czech Republic
[129] Czech Technical University in Prague, Praha, Czech Republic
[130] Faculty of Mathematics and Physics, Charles University in Prague, Praha, Czech Republic
[131] State Research Center Institute for High Energy Physics (Protvino), NRC KI, Russia
[132] Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom
[133] [(a)] INFN Sezione di Roma; [(b)] Dipartimento di Fisica, Sapienza Università di Roma, Roma, Italy
[134] [(a)] INFN Sezione di Roma Tor Vergata; [(b)] Dipartimento di Fisica, Università di Roma Tor Vergata, Roma, Italy
[135] [(a)] INFN Sezione di Roma Tre; [(b)] Dipartimento di Matematica e Fisica, Università Roma Tre, Roma, Italy
[136] [(a)] Faculté des Sciences Ain Chock, Réseau Universitaire de Physique des Hautes Energies - Université Hassan II, Casablanca; [(b)] Centre National de l'Energie des Sciences Techniques Nucleaires, Rabat; [(c)] Faculté des Sciences Semlalia, Université Cadi Ayyad, LPHEA-Marrakech; [(d)] Faculté des Sciences, Université Mohamed Premier and LPTPM, Oujda; [(e)] Faculté des sciences, Université Mohammed V, Rabat, Morocco
[137] DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat à l'Energie Atomique et aux Energies Alternatives), Gif-sur-Yvette, France

[138] Santa Cruz Institute for Particle Physics, University of California Santa Cruz, Santa Cruz, CA, United States
[139] Department of Physics, University of Washington, Seattle, WA, United States
[140] School of Physics, Shandong University, Shandong, China
[141] Department of Physics and Astronomy, Shanghai Key Laboratory for Particle Physics and Cosmology, Shanghai Jiao Tong University, Shanghai, China [av]
[142] Department of Physics and Astronomy, University of Sheffield, Sheffield, United Kingdom
[143] Department of Physics, Shinshu University, Nagano, Japan
[144] Fachbereich Physik, Universität Siegen, Siegen, Germany
[145] Department of Physics, Simon Fraser University, Burnaby, BC, Canada
[146] SLAC National Accelerator Laboratory, Stanford, CA, United States
[147] (a) Faculty of Mathematics, Physics & Informatics, Comenius University, Bratislava; (b) Department of Subnuclear Physics, Institute of Experimental Physics of the Slovak Academy of Sciences, Kosice, Slovak Republic
[148] (a) Department of Physics, University of Cape Town, Cape Town; (b) Department of Physics, University of Johannesburg, Johannesburg; (c) School of Physics, University of the Witwatersrand, Johannesburg, South Africa
[149] (a) Department of Physics, Stockholm University; (b) The Oskar Klein Centre, Stockholm, Sweden
[150] Physics Department, Royal Institute of Technology, Stockholm, Sweden
[151] Departments of Physics & Astronomy and Chemistry, Stony Brook University, Stony Brook, NY, United States
[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] Department of Physics, Technion: Israel Institute of Technology, Haifa, Israel
[156] Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel
[157] Department of Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece
[158] International Center for Elementary Particle Physics and Department of Physics, The University of Tokyo, Tokyo, Japan
[159] Graduate School of Science and Technology, Tokyo Metropolitan University, 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) INFN-TIFPA; (b) University of Trento, Trento, Italy
[164] (a) TRIUMF, Vancouver, BC; (b) Department of Physics and Astronomy, York University, Toronto, ON, Canada
[165] Faculty of Pure and Applied Sciences, and Center for Integrated Research in Fundamental Science and Engineering, University of Tsukuba, Tsukuba, Japan
[166] Department of Physics and Astronomy, Tufts University, Medford, MA, United States
[167] Department of Physics and Astronomy, University of California Irvine, Irvine, CA, United States
[168] (a) INFN Gruppo Collegato di Udine, Sezione di Trieste, Udine; (b) ICTP, Trieste; (c) Dipartimento di Chimica, Fisica e Ambiente, Università di Udine, Udine, Italy
[169] Department of Physics and Astronomy, University of Uppsala, Uppsala, Sweden
[170] Department of Physics, University of Illinois, Urbana, IL, United States
[171] Instituto de Fisica Corpuscular (IFIC) and Departamento de Fisica Atomica, Molecular y Nuclear and Departamento de Ingeniería Electrónica and Instituto de Microelectrónica de Barcelona (IMB-CNM), University of Valencia and CSIC, Valencia, Spain
[172] Department of Physics, University of British Columbia, Vancouver, BC, Canada
[173] Department of Physics and Astronomy, University of Victoria, Victoria, BC, Canada
[174] Department of Physics, University of Warwick, Coventry, United Kingdom
[175] Waseda University, Tokyo, Japan
[176] Department of Particle Physics, The Weizmann Institute of Science, Rehovot, Israel
[177] Department of Physics, University of Wisconsin, Madison, WI, United States
[178] Fakultät für Physik und Astronomie, Julius-Maximilians-Universität, Würzburg, Germany
[179] Fakultät für Mathematik und Naturwissenschaften, Fachgruppe Physik, Bergische Universität Wuppertal, Wuppertal, Germany
[180] Department of Physics, Yale University, New Haven, CT, United States
[181] Yerevan Physics Institute, Yerevan, Armenia
[182] Centre de Calcul de l'Institut National de Physique Nucléaire et de Physique des Particules (IN2P3), Villeurbanne, France

[a] Also at Department of Physics, King's College London, London, United Kingdom.
[b] Also at Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan.
[c] Also at Novosibirsk State University, Novosibirsk, Russia.
[d] Also at TRIUMF, Vancouver BC, Canada.
[e] Also at Department of Physics & Astronomy, University of Louisville, Louisville, KY, United States.
[f] Also at Physics Department, An-Najah National University, Nablus, Palestine.
[g] Also at Department of Physics, California State University, Fresno, CA, United States.
[h] Also at Department of Physics, University of Fribourg, Fribourg, Switzerland.
[i] Also at Departament de Fisica de la Universitat Autonoma de Barcelona, Barcelona, Spain.
[j] Also at Departamento de Fisica e Astronomia, Faculdade de Ciencias, Universidade do Porto, Portugal.
[k] Also at Tomsk State University, Tomsk, Russia.
[l] Also at Universita di Napoli Parthenope, Napoli, Italy.
[m] Also at Institute of Particle Physics (IPP), Canada.
[n] Also at National Institute of Physics and Nuclear Engineering, Bucharest, Romania.
[o] Also at Department of Physics, St. Petersburg State Polytechnical University, St. Petersburg, Russia.
[p] Also at Department of Physics, The University of Michigan, Ann Arbor, MI, United States.
[q] Also at Centre for High Performance Computing, CSIR Campus, Rosebank, Cape Town, South Africa.
[r] Also at Louisiana Tech University, Ruston, LA, United States.
[s] Also at Institucio Catalana de Recerca i Estudis Avancats, ICREA, Barcelona, Spain.
[t] Also at Graduate School of Science, Osaka University, Osaka, Japan.
[u] Also at Department of Physics, National Tsing Hua University, Taiwan.
[v] Also at Institute for Mathematics, Astrophysics and Particle Physics, Radboud University Nijmegen/Nikhef, Nijmegen, Netherlands.
[w] Also at Department of Physics, The University of Texas at Austin, Austin, TX, United States.
[x] Also at CERN, Geneva, Switzerland.
[y] Also at Georgian Technical University (GTU), Tbilisi, Georgia.
[z] Also at Ochadai Academic Production, Ochanomizu University, Tokyo, Japan.
[aa] Also at Manhattan College, New York, NY, United States.
[ab] Also at Academia Sinica Grid Computing, Institute of Physics, Academia Sinica, Taipei, Taiwan.

[ac] Also at School of Physics, Shandong University, Shandong, China.
[ad] Also at Department of Physics, California State University, Sacramento, CA, United States.
[ae] Also at Moscow Institute of Physics and Technology State University, Dolgoprudny, Russia.
[af] Also at Section de Physique, Université de Genève, Geneva, Switzerland.
[ag] Also at Eotvos Lorand University, Budapest, Hungary.
[ah] Also at Departments of Physics & Astronomy and Chemistry, Stony Brook University, Stony Brook, NY, United States.
[ai] Also at International School for Advanced Studies (SISSA), Trieste, Italy.
[aj] Also at Department of Physics and Astronomy, University of South Carolina, Columbia, SC, United States.
[ak] Also at Institut de Física d'Altes Energies (IFAE), The Barcelona Institute of Science and Technology, Barcelona, Spain.
[al] Also at School of Physics and Engineering, Sun Yat-sen University, Guangzhou, China.
[am] Also at Institute for Nuclear Research and Nuclear Energy (INRNE) of the Bulgarian Academy of Sciences, Sofia, Bulgaria.
[an] Also at Faculty of Physics, M.V. Lomonosov Moscow State University, Moscow, Russia.
[ao] Also at Institute of Physics, Academia Sinica, Taipei, Taiwan.
[ap] Also at National Research Nuclear University MEPhI, Moscow, Russia.
[aq] Also at Department of Physics, Stanford University, Stanford, CA, United States.
[ar] Also at Institute for Particle and Nuclear Physics, Wigner Research Centre for Physics, Budapest, Hungary.
[as] Also at Flensburg University of Applied Sciences, Flensburg, Germany.
[at] Also at University of Malaya, Department of Physics, Kuala Lumpur, Malaysia.
[au] Also at CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France.
[av] Also affiliated with PKU-CHEP.
[*] Deceased.