UNIVERSITY OF AMSTERDAM

UvA-DARE (Digital Academic Repository)

Measurement of the charge asymmetry in highly boosted top-quark pair production in √s = 8 TeV pp collision data collected by the ATLAS experiment

ATLAS Collaboration

DOI
10.1016/j.physletb.2016.02.055

Publication date
2016

Document Version
Final published version

Published in
Physics Letters B

License
CC BY

Link to publication

Citation for published version (APA):
ATLAS Collaboration (2016). Measurement of the charge asymmetry in highly boosted top-quark pair production in √s = 8 TeV *pp* collision data collected by the ATLAS experiment. *Physics Letters B*, *756*, 52-71. https://doi.org/10.1016/j.physletb.2016.02.055

General rights
It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Disclaimer/Complaints regulations
If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: https://uba.uva.nl/en/contact, or a letter to: Library of the University of Amsterdam, Secretariat, P.O. Box 19185, 1000 GD Amsterdam, The Netherlands. You will be contacted as soon as possible.

UvA-DARE is a service provided by the library of the University of Amsterdam (https://dare.uva.nl)

Download date:07 Sept 2026

Physics Letters B 756 (2016) 52–71

Contents lists available at ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

Measurement of the charge asymmetry in highly boosted top-quark pair production in $\sqrt{s} = 8$ TeV pp collision data collected by the ATLAS experiment

ATLAS Collaboration *

ARTICLE INFO

Article history:
Received 21 December 2015
Received in revised form 10 February 2016
Accepted 24 February 2016
Available online 2 March 2016
Editor: W.-D. Schlatter

ABSTRACT

In the $pp \to t\bar{t}$ process the angular distributions of top and anti-top quarks are expected to present a subtle difference, which could be enhanced by processes not included in the Standard Model. This Letter presents a measurement of the charge asymmetry in events where the top-quark pair is produced with a large invariant mass. The analysis is performed on 20.3 fb^{-1} of pp collision data at $\sqrt{s} = 8$ TeV collected by the ATLAS experiment at the LHC, using reconstruction techniques specifically designed for the decay topology of highly boosted top quarks. The charge asymmetry in a fiducial region with large invariant mass of the top-quark pair ($m_{t\bar{t}} > 0.75$ TeV) and an absolute rapidity difference of the top and anti-top quark candidates within $-2 < |y_t| - |y_{\bar{t}}| < 2$ is measured to be $4.2 \pm 3.2\%$, in agreement with the Standard Model prediction at next-to-leading order. A differential measurement in three $t\bar{t}$ mass bins is also presented.

© 2016 CERN for the benefit of the ATLAS Collaboration. Published by Elsevier B.V. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/). Funded by SCOAP[3].

1. Introduction

The charge asymmetry [1,2] in top-quark pair production at hadron colliders constitutes one of the more interesting developments in the last decade of top-quark physics. In the Standard Model (SM), a forward–backward asymmetry (A_{FB}), of order α_s, is expected at a proton–antiproton ($p\bar{p}$) collider such as the Tevatron, with a much enhanced asymmetry in certain kinematical regions. Early measurements [3,4] found a larger A_{FB} than predicted by the SM. Later determinations confirmed this deviation and measurements in intervals of the invariant mass, $m_{t\bar{t}}$, of the system formed by the top-quark pair [5–9] found a stronger dependence on $m_{t\bar{t}}$ than anticipated. Recent calculations of electroweak effects [10] and the full next-to-next-to-leading-order (NNLO) corrections [11] to the asymmetry have brought the difference between the observed asymmetry at the Tevatron and the SM prediction down to the 1.5 σ level and reduced the tension with the differential measurements in $m_{t\bar{t}}$ [12,13].

At the Large Hadron Collider (LHC), the forward–backward asymmetry is not present due to the symmetric initial state, but a related charge asymmetry, A_{C}, is expected in the distribution of the difference of absolute rapidities of the top and anti-top quarks,

$$A_{\mathrm{C}} = \frac{N(\Delta|y| > 0) - N(\Delta|y| < 0)}{N(\Delta|y| > 0) + N(\Delta|y| < 0)}, \tag{1}$$

where $\Delta|y| = |y_t| - |y_{\bar{t}}|$ and y denotes the rapidity of the top and anti-top quarks.[1] For quark–antiquark ($q\bar{q}$) initial states, the difference in the average momentum carried by valence and sea quarks leads to a positive asymmetry. These quark-initiated processes are strongly diluted by the charge-symmetric gluon-initiated processes, yielding a SM expectation for the charge asymmetry of less than 1%. Many beyond-the-Standard-Model (BSM) scenarios predict an alteration to this asymmetry. Previous measurements at 7 TeV [14–17] and 8 TeV [18–20] by ATLAS and CMS are consistent with the SM prediction.

With a centre-of-mass energy of 8 TeV and a top-quark pair sample of millions of events, the LHC experiments can access the charge asymmetry in a kinematic regime not probed by previous experiments. The development of new techniques involving Lorentz-boosted objects and jet substructure [21–24] and their use in the analysis of LHC data [25,26] have enabled an efficient se-

[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 coinciding with the axis of the beam pipe. The x-axis points from the IP towards the centre of the LHC ring, and the y-axis points upward. Polar coordinates (r, ϕ) are used in the transverse plane, ϕ being the azimuthal angle around the z-axis. The rapidity y is given as $y = -\frac{1}{2}\ln[(E + p_z)/(E - p_z)]$, while the pseudorapidity is defined in terms of the polar angle θ as $\eta = -\ln[\tan(\theta/2)]$. The distance in (η, ϕ) coordinates, $\Delta R = \sqrt{(\Delta\phi)^2 + (\Delta\eta)^2}$, is used to define cone sizes and the distance between reconstructed objects. Transverse momentum and energy are defined as $p_{\mathrm{T}} = p\sin\theta$ and $E_{\mathrm{T}} = E\sin\theta$, respectively.

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

http://dx.doi.org/10.1016/j.physletb.2016.02.055
0370-2693/© 2016 CERN for the benefit of the ATLAS Collaboration. Published by Elsevier B.V. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/). Funded by SCOAP[3].

lection of highly boosted objects and an accurate reconstruction of their momentum.

This Letter presents a measurement of the rapidity-dependent charge asymmetry in top-quark pair production that is based on techniques specifically designed to deal with the collimated decay topology of boosted top quarks. Specifically, it is based on the techniques described in Refs. [27–30]. The analysis focuses on the lepton + jets (ℓ + jets) final state, where the hadronic top-quark decay is reconstructed as a single large-radius (large-R) jet and tagged as such using jet substructure variables. The leptonic top-quark decay is reconstructed from a single small-radius (small-R) jet, a single charged lepton (muon or electron), and missing transverse momentum, corresponding to the neutrino from the W boson decay. The event selection and reconstruction follow the prescriptions of Ref. [27], where a detailed description and discussion of their performance can be found.

Compared to previous analyses [18,20] based on the classical, *resolved* top-quark selection criteria and reconstruction schemes, this approach offers a more precise reconstruction of the $t\bar{t}$ invariant mass and top-quark direction for highly boosted top quarks. It is therefore possible to perform accurate measurements of the charge asymmetry in events with a $t\bar{t}$ invariant mass in the TeV range. This kinematic regime has a higher sensitivity for the SM asymmetry due to a higher fraction of quark-initiated processes, as well as for BSM models that introduce massive new states.

This Letter is structured as follows. The data sample analysed is presented in Section 2, along with a description of the Monte Carlo (MC) simulation samples in Section 3. A brief overview of the reconstructed object definitions and of the event selection and reconstruction is given in Sections 4 and 5. The observed yields and several kinematic distributions are compared to the SM expectations in Section 6. The unfolding technique used to correct the reconstructed $\Delta|y|$ spectrum to the parton level is discussed in Section 7. The estimates of the systematic uncertainties that affect the measurement are described and estimated in Section 8. The results are presented in Section 9, and their impact on several BSM theories is discussed in Section 10. Finally, the conclusions are presented in Section 11.

2. Data sample

The data for this analysis were collected by the ATLAS [31] experiment in the 8 TeV proton–proton (pp) collisions at the CERN LHC in 2012. Collision events are selected using isolated or non-isolated single-lepton triggers, where the isolated triggers have a threshold of 24 GeV on the transverse momentum (p_{T}) of muons or on the transverse energy of electrons. The non-isolated triggers have higher thresholds: 60 GeV for electrons and 36 GeV for muons. The contribution from events with leptons passing only the non-isolated triggers but having p_{T} below these higher thresholds is negligible. The collected data set is limited to periods with stable beam conditions when all sub-systems were operational. The sample corresponds to an integrated luminosity of 20.3 ± 0.6 fb^{-1}.

3. Monte Carlo simulation

Samples of MC simulated events are used to characterise the detector response and efficiency to reconstruct $t\bar{t}$ events, estimate systematic uncertainties, and predict the background contributions from various physics processes. The response of the detector and trigger is simulated [32] using a detailed model implemented in GEANT4 [33]. Simulated events are reconstructed with the same software as the data. Additional pp interactions, simultaneously present in the detector (pile-up), are generated using Pythia 8.1 [34] with the MSTW2008 leading order PDF set [35] and the AUET2 set of tune parameters (tune). The pile-up events are reweighted to the number of interactions per bunch crossing in data (on average 21 in 2012). For some samples used to evaluate systematic uncertainties, the detailed description of the calorimeter response is parameterised using the ATLFAST-II simulation [32]. For all samples the top-quark mass is set to $m_{\mathrm{top}} = 172.5$ GeV.

The nominal signal $t\bar{t}$ sample is produced using the Powheg-Box (version 1, r2330) generator [36], which is based on next-to-leading-order (NLO) QCD matrix elements. The CT10 [37] set of parton distribution functions (PDF) is used. The h_{damp} parameter, which controls the matrix element (ME) to parton shower (PS) matching in Powheg-Box and effectively regulates the high-p_{T} radiation, is set to the top-quark mass. The parton shower, hadronisation, and the underlying event are simulated with Pythia 6.427 [38] using the CTEQ6L1 PDF set and the Perugia 2011 [39] tune. Electroweak corrections are applied to this sample through a reweighting scheme; they are calculated with Hathor 2.1-alpha [40] implementing the theoretical calculations of Refs. [41–43]. Alternative samples are used to evaluate uncertainties in modelling the $t\bar{t}$ signal. These include samples produced with MC@NLO 4.01 [44] interfaced with Herwig 6.520 [45] and Jimmy 4.31 [46], as well as samples generated with Powheg-Box + Herwig/Jimmy and Powheg-Box + Pythia, both with $h_{\mathrm{damp}} =$ infinity. Samples are also produced with differing initial- and final-state radiation (ISR/FSR), using the AcerMC generator [47] interfaced with Pythia. All $t\bar{t}$ samples are normalised to cross-section at NNLO + next-to-next-to-leading logarithmic (NNLL) accuracy[2] [49–54]: $\sigma_{t\bar{t}} = 253^{+13}_{-15}$ pb.

Leptonic decays of vector bosons produced in association with several high-p_{T} jets, referred to as W + jets and Z + jets events, with up to five additional final-state partons in the leading-order (LO) matrix-elements, are produced with the Alpgen generator [55] interfaced with Pythia 6.426 for parton fragmentation using the MLM matching scheme [56]. Heavy-flavour quarks are included in the ME calculations to model the $Wb\bar{b}$, $Wc\bar{c}$, Wc, $Zb\bar{b}$ and $Zc\bar{c}$ processes. The W + jets samples are normalised to the inclusive W boson NNLO cross-section [57,58].

Single top-quark production is simulated using Powheg-Box interfaced with Pythia 6.425 using the CTEQ6L1 PDF set and the Perugia 2011 tune. The cross-sections multiplied by the sum of the branching ratios for the leptonic W decay employed for these processes are 28 pb (t-channel) [59], 22 pb (Wt production) [60], and 1.8 pb (s-channel) [61], obtained from NNLO + NNLL calculations.

Diboson production is modelled using Sherpa [62] with the CT10 PDF set, and the yields are normalised to the NLO cross-sections: 23 pb ($WW \to \ell\nu qq$), 0.7 pb ($ZZ \to \ell\ell qq$), 6.0 pb ($WZ \to \ell\nu qq$) and 4.6 pb ($ZW \to \ell\ell qq$).

4. Object definitions

Electron candidates are reconstructed using charged-particle tracks in the inner detector associated with energy deposits in the electromagnetic calorimeter. Muon candidates are identified by matching track segments in the muon spectrometer with tracks in the inner detector. Lepton candidates are required to be isolated using the "mini-isolation" criteria described in Ref. [63].

Jets are reconstructed using the anti-k_t algorithm [64] implemented in the FastJet package [65] with radius parameter $R = 0.4$ (small-R) or $R = 1.0$ (large-R), using as input calibrated topological clusters [66] of energy deposits in the calorimeters. The jet-trimming algorithm [67] is applied to the large-R jets to reduce

[2] The top++2.0 [48] calculation includes the NNLO QCD corrections and resums NNLL soft gluon terms. The quoted cross-section corresponds to a top-quark mass of 172.5 GeV.

the effect of soft and diffuse radiation, such as that from pile-up, multiple parton interactions and initial-state radiation. Large-R jets are trimmed by reclustering the constituents with the k_t algorithm [68,69] with a radius parameter $R_{\text{sub}} = 0.3$ and retaining sub-jets that have a momentum exceeding 5% of that of the large-R jet ($f_{\text{cut}} = 0.05$). For small-R jets, a pile-up correction based on the jet area, the number of primary vertices, the bunch spacing, and jet η is applied. Both jet collections are calibrated to the stable-particle level as a function of p_{T} and η (and mass for large-R jets) [25]. The stable-particle level refers to generator-level jets reconstructed from particles with a lifetime of at least 10 ps. Small-R jets are b-tagged using an algorithm that exploits the relatively large decay time of b-hadrons and their large mass [70,71].

The missing transverse momentum (with magnitude $E_{\text{T}}^{\text{miss}}$) is computed as the negative vector sum of the energy of all calorimeter cells, taking into account the calibration of reconstructed objects, and the presence of muons.

5. Event selection and reconstruction

Each event must have a reconstructed primary vertex with five or more associated tracks of $p_{\text{T}} > 400$ MeV. The events are required to contain exactly one reconstructed lepton candidate, which must then be geometrically matched to the trigger object. To reduce the multi-jet background, the magnitude of the missing transverse momentum and the W-boson transverse mass m_{T}^{W} must satisfy $E_{\text{T}}^{\text{miss}} > 20$ GeV and $E_{\text{T}}^{\text{miss}} + m_{\text{T}}^{W} > 60$ GeV, where

$$m_{\text{T}}^{W} = \sqrt{2p_{\text{T}}^{\text{lepton}} E_{\text{T}}^{\text{miss}}(1 - \cos\Delta\phi)} \tag{2}$$

and $\Delta\phi$ is the azimuthal angle between the lepton and the missing transverse momentum. At least one small-R jet ($R = 0.4$) must be found close to, but not coincident with, the lepton ($\Delta R(\ell, \text{jet}_{R=0.4}) < 1.5$).

The leptonic top-quark candidate is reconstructed by adding the highest-p_{T} jet among those satisfying the above criteria, the selected charged lepton and the reconstructed neutrino. The longitudinal component of the neutrino momentum is calculated by constraining the lepton-plus-missing-momentum system to have the W boson mass and solving the resulting quadratic equation. If two real solutions are found, the one that yields the smallest longitudinal momentum for the neutrino is used. If no real solution exists, the missing transverse momentum vector is varied by the minimal amount required to produce exactly one real solution.

The hadronically decaying top quark is reconstructed as a single trimmed jet with $R = 1.0$. The selected jet must have $p_{\text{T}} > 300$ GeV, must be well separated from both the charged lepton ($\Delta\phi(\ell, \text{jet}_{R=1.0}) > 2.3$) and the small-$R$ jet associated with the leptonic top-quark candidate ($\Delta R(\text{jet}_{R=1.0}, \text{jet}_{R=0.4}) > 1.5$). A substructure analysis of the large-R jet is used to tag the boosted top-quark candidate: the invariant mass of the jet $m_{\text{jet}}^{\text{trim}}$ after calibration to the particle level [26] must be larger than 100 GeV and the k_t splitting scale[3] $\sqrt{d_{12}^{\text{trim}}}$ must exceed 40 GeV.

Finally, at least one of the highest-p_{T} small-R jets associated with the decay of a top-quark candidates ($\Delta R(\ell, \text{jet}_{R=0.4}) < 1.5$ or $\Delta R(\text{jet}_{R=1.0}, \text{jet}_{R=0.4}) < 1.0$) must be b-tagged. Events with a reconstructed $t\bar{t}$ mass of less than 750 GeV are rejected, as the performance of the reconstruction of boosted top quarks is strongly degraded at low mass.

The selection and reconstruction schemes yield good efficiency and $t\bar{t}$ mass determination for high-mass pairs. Detailed MC studies presented in Ref. [27] show that the mass resolution is approximately 6% for a large range of $t\bar{t}$ mass, starting at $m_{t\bar{t}} \sim 1$ TeV. The measurement of the top and anti-top-quark rapidities are nearly unambiguous. The quality of the top quark rapidity reconstruction can be expressed in terms of the dilution factor $D = 2p - 1$, where p is the probability of a correct assignment of the $\Delta|y|$ sign. A dilution factor $D = 1$ indicates perfect charge assignment. The MC simulation predicts a value of approximately $D = 0.75$ for the selected sample. The remaining dilution is largely due to events with small values of the absolute rapidity difference; if events with $|\Delta|y|| < 0.5$ are excluded, the MC simulation predicts a dilution factor greater than 0.9.

Table 1
Observed and expected number of events in the signal region. The two columns correspond to the $e+$jets and $\mu+$jets selected data samples. The systematic uncertainties of the SM expectation include those from detector-related uncertainties, uncertainties in the normalisation, the luminosity uncertainty and the uncertainty in the cross-section predictions used to normalise the expected yields.

	$e+$jets	$\mu+$jets
$t\bar{t}$	4100 ± 600	3600 ± 500
$W+$jets	263 ± 32	264 ± 32
Single top	140 ± 20	138 ± 19
Multi-jet	44 ± 8	4 ± 1
$Z+$jets	40 ± 27	16 ± 11
Dibosons	20 ± 7	18 ± 7
$t\bar{t}V$	37 ± 19	33 ± 17
Prediction	4600 ± 600	4100 ± 500
Data	4141	3600

6. Comparison of data to the SM template

A template for the expected yield of most SM processes is based on Monte Carlo simulation, where the production rate is normalised using the prediction of the inclusive cross-section specified in Section 3. Exceptions are the $W+$jets background and the multi-jet background. The $W+$jets background normalisation and heavy-flavour fractions are corrected with scale factors derived from data, as in Ref. [27], using the observed asymmetry in the yields of positively and negatively charged leptons. The multi-jet background estimate is fully data-driven, using the matrix method. This method uses the selection efficiencies of leptons from prompt and non-prompt sources to predict the number of events with non-prompt leptons in the signal region. These methods and their results are documented in detail in Ref. [27].

The event yields are compared to the SM expectation in Table 1. The distributions of two key observables, the invariant mass of the $t\bar{t}$ system and the difference of the absolute rapidities of the candidate top and anti-top quarks are shown in Fig. 1, for the combination of the $e+$jets and $\mu+$jets channels. The observed event yield is approximately 10% less than the MC prediction, the result of the softer top-quark p_{T} spectrum in data, which is also reported in Refs. [73–75].

Since A_{C} is measured as a ratio, it is not sensitive to the absolute cross-section. The impact of the differences in the expected and observed shapes of the distributions in Fig. 1 on the measurement is estimated by reweighting the simulated $\Delta|y|$ and top quark p_{T} distributions to match the data and found to be negligible.

[3] The k_t splitting scale [72] is obtained by reclustering the large-R jet components with the k_t algorithm with a radius parameter $R = 0.3$. The first splitting scale $\sqrt{d_{12}^{\text{trim}}}$ corresponds to the scale at which the last two sub-jets are merged into one: $\sqrt{d_{12}^{\text{trim}}} = \min(p_{\text{T},1}, p_{\text{T},2}) \times \Delta R_{1,2}$, where 1 and 2 denote the two sub-jets merged in the last step of the k_t algorithm.

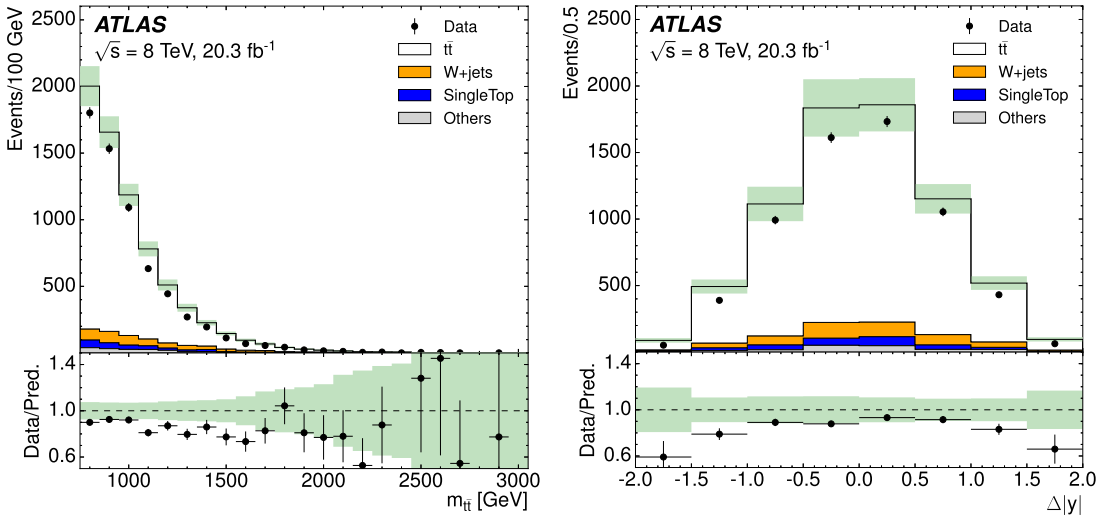

Fig. 1. Detector-level distributions of (a) the invariant mass of the $t\bar{t}$ system and (b) the difference of the absolute rapidities $\Delta|y|$ of top and anti-top-quark candidates, for the combination of the $e+$jets and $\mu+$jets channels. The observed distributions are compared to the SM expectation based on a mixture of data-driven techniques and Monte Carlo simulation. The ratio of data to the SM expectation is shown in the lower plots. Error bars on the data points indicate the statistical uncertainty. The hashed area shows the uncertainty of the SM prediction. This includes the statistical uncertainty, the theory uncertainties in the cross-sections, the effect of detector systematic uncertainties on the expected yield, the luminosity uncertainty, the uncertainty in the normalisations, and the signal modelling uncertainty.

7. Unfolding

An unfolding procedure transforms the observed charge asymmetry into a parton-level result in the phase space covered by the measurement:

$$m_{t\bar{t}} > 750\ \text{GeV},\ -2 < \Delta|y| < 2. \tag{3}$$

The corrected result can thus be compared directly to fixed-order calculations that implement these constraints.

The unfolding procedure is identical to the one used in a previous ATLAS charge asymmetry measurement [20]. The $e+$jets and $\mu+$jets channels are combined to form a single set of events. The data are corrected for migrations due to detector resolution using a matrix unfolding method based on the open source PyFBU implementation of the fully Bayesian unfolding (FBU) [76] algorithm. A bias in the charge asymmetry introduced by the selection criteria is corrected using a bin-by-bin acceptance correction.

The asymmetry in the full region of Eq. (3) is obtained by correcting the content of four $\Delta|y|$ bins with the following boundaries: $[-2, -0.7, 0, 0.7, 2]$. For simulated events with a reconstructed $\Delta|y|$ that falls within $-2 < \Delta|y| < 2$, but a true $\Delta|y|$ outside this boundary (0.1% of events), the true value is included in the outermost $\Delta|y|$ bin. A differential result in three $m_{t\bar{t}}$ intervals ($0.75\ \text{TeV} < m_{t\bar{t}} < 0.9\ \text{TeV}$, $0.9\ \text{TeV} < m_{t\bar{t}} < 1.3\ \text{TeV}$, and $1.3\ \text{TeV} < m_{t\bar{t}}$) is obtained using a $(1+12)\times 12$ matrix that corrects for mass and $\Delta|y|$ migrations. The extra *underflow* bin keeps track of migrations of selected events from outside of the fiducial volume, $m_{t\bar{t}} < 0.75$ TeV. The $\Delta|y|$ binning in each mass bin is optimised to yield minimal bias when non-SM asymmetries are injected.

Uncertainties due to limitations in the understanding of object reconstruction and in the calibration of the experiment described in Section 8 are included as nuisance parameters in the unfolding procedure, as well as the normalisation of the backgrounds. In this study, the data sample is too small for FBU to significantly constrain any of the nuisance parameters, and therefore the size of the detector-related and normalisation uncertainties are not reduced by the unfolding process.

8. Systematic uncertainties

Systematic uncertainties are estimated as in Ref. [27] and propagated to the A_C measurement following the procedure of Ref. [20]. The non-negligible uncertainties in the unfolded charge asymmetry measurement are presented in Table 2.

The most important uncertainties among the detector-related and background normalisation uncertainties are the scale and resolution of the jet energy (17 nuisance parameters for large-R jets and 21 for small-R jets) and the b-tagging performance (10 nuisance parameters) [66,77,78]. The impact of uncertainties in the reconstruction of electrons and muons and the missing transverse momentum is negligible. Detector-related uncertainties and background normalisation uncertainties have a small impact on the analysis.

The uncertainty due to imperfections in the MC generator modelling is estimated using a number of alternative generators. The most important effects are the choice of NLO ME and parton shower/hadronisation model. Each alternative sample is unfolded using the nominal procedure. The ME modelling uncertainty is taken as the difference between the results for Powheg-Box + Herwig/Jimmy and MC@NLO + Herwig/Jimmy. The PS/hadronisation modelling uncertainty is evaluated as the difference between Powheg-Box + Pythia and Powheg-Box + Herwig/Jimmy. The results are corrected for the small differences in the prediction of the true A_C among the generators. The ISR/FSR uncertainty is estimated as half the difference between two AcerMC samples with radiation settings varied within the range allowed by data. The uncertainty associated with the choice of PDF is evaluated using the MC@NLO + Herwig/Jimmy sample, by comparing the differences when reweighting the sample to CT10, MSTW 2008 [35], and NNPDF2.1 [79] PDF sets. The three contributions are assumed to be uncorrelated and are added in quadrature, forming the dominant systematic uncertainty in the measurement.

The unfolding uncertainty includes two components. The first component, the uncertainty due to the limited number of events in the Monte Carlo samples used to correct the data, is estimated by propagating the statistical uncertainty of the elements of the

Table 2
The effect on the corrected charge asymmetry, in each $m_{t\bar{t}}$ interval, of systematic uncertainties on the signal and background modelling and the description of the detector response. The uncertainties are given in absolute percentages.

$m_{t\bar{t}}$ interval	>0.75 TeV	0.75–0.9 TeV	0.9–1.3 TeV	>1.3 TeV
Breakdown of detector-related systematic uncertainties				
Jet energy and resolution – $R = 0.4$ jets	0.1%	0.4%	0.3%	0.4%
Jet energy and resolution – $R = 1.0$ jets	0.3%	1.6%	0.6%	1.0%
b-tag/mis-tag efficiency	0.2%	0.2%	0.2%	0.7%
Lepton reconstruction/identification/scale	0.1%	0.2%	0.1%	0.1%
Missing transverse momentum ($E_{\mathrm{T}}^{\mathrm{miss}}$)	0.1%	<0.1%	<0.1%	0.1%
Background normalization	0.1%	0.2%	0.3%	0.4%
Combined detector-related uncertainties and others				
Statistical + detector-related systematic	2.0%	6.0%	4.1%	11.6%
Signal modelling – matrix element	1.5%	2.4%	0.6%	5.3%
Signal modelling – parton shower	2.0%	3.2%	1.2%	6.2%
Signal modelling – ISR/FSR	0.1%	0.3%	0.1%	3.0%
Signal modelling – PDF	0.4%	0.4%	0.3%	3.3%
Unfolding & MC statistics	0.5%	1.2%	0.8%	2.1%
Total	3.2%	7.3%	4.4%	15.0%

response matrix with pseudo-experiments. To evaluate the second component due to the non-linearity of the unfolding, different charge asymmetry values are injected by reweighting the $t\bar{t}$ Monte Carlo sample according to several functional forms. The uncertainty is taken as the bias estimated for the observed charge asymmetry values. A number of stress tests are performed, where the MC samples are reweighted to mimic the observed differences in the $m_{t\bar{t}}$ and $\Delta|y|$ distributions. The impact on the results of the unfolding procedure is found to be small compared to the unfolding uncertainty and is not taken into account as a separate uncertainty. In addition, the measurement is performed in a more restricted $|\Delta|y||$ region, excluding events with $|\Delta|y|| < 0.5$, where the dilution factor D is smaller. The result is found to be consistent with the nominal measurement, and no uncertainty is assigned.

9. Results

The results for the charge asymmetry in the four $m_{t\bar{t}}$ intervals are presented in Fig. 2 and Table 3. The measurement for $m_{t\bar{t}} > 0.75$ TeV and $|\Delta|y|| < 2$ yields $A_{\mathrm{C}} = (4.2 \pm 3.2)\%$, where the uncertainty is dominated by the modelling uncertainty, followed by the statistical uncertainty of the data. The result is within one standard deviation of the SM expectation. A differential measurement is also presented, in three $m_{t\bar{t}}$ bins: 0.75–0.9 TeV, 0.9–1.3 TeV and $m_{t\bar{t}} > 1.3$ TeV ($|\Delta|y|| < 2$ for all measurements). The largest difference with respect to the SM prediction is observed in the bin with $m_{t\bar{t}} = 0.9$–1.3 TeV, where it reaches 1.6σ.

10. Impact on BSM scenarios

Extensions of the SM with heavy particles can predict a significantly enhanced high-mass charge asymmetry at the LHC. In Fig. 3, BSM predictions of the charge asymmetry in 8 TeV pp collisions with $m_{t\bar{t}} > 0.75$ TeV and $m_{t\bar{t}} > 1.3$ TeV are compared with A_{FB} integrated over $m_{t\bar{t}}$ in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV. The measurements presented in this Letter are indicated as horizontal bands. The measurements of A_{FB} integrated over $m_{t\bar{t}}$ in top-quark pair production at 1.96 TeV in $p\bar{p}$ collisions by CDF [7] and D0 [8] are shown as vertical bands.

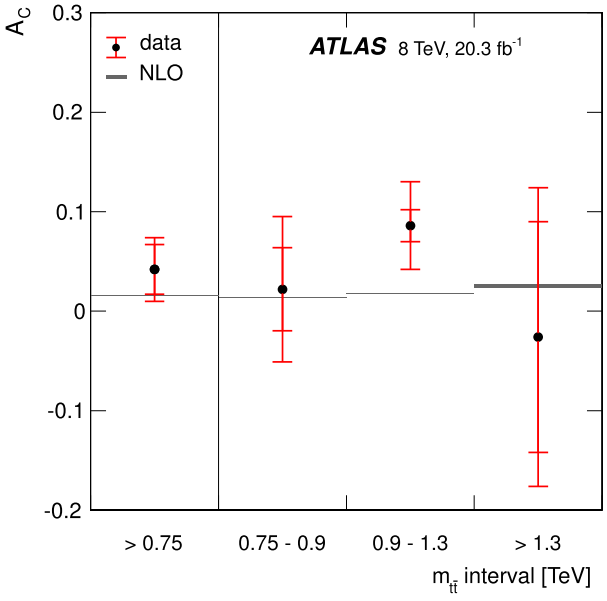

Fig. 2. A summary of the charge asymmetry measurements. The error bars on the data indicate the modelling and unfolding systematic uncertainties, shown as the inner bar, and the total uncertainty, which includes the statistical uncertainty and the experimental systematic uncertainties. The SM prediction of the NLO calculation in Ref. [13] for the charge asymmetry of top-quark pairs with $|\Delta|y|| < 2$ is indicated as a shaded horizontal bar in each $m_{t\bar{t}}$ bin, where the width of the bar indicates the uncertainty.

The clouds of points in Fig. 3 correspond to a number of models in Refs. [80,81]: a heavy W' boson exchanged in the t-channel, a heavy axi-gluon G_μ exchanged in the s-channel, and doublet (ϕ), triplet (ω^4) or sextet (Ω^4) scalars. Each point corresponds to a choice of the new particle's mass, in the range between 100 GeV and 10 TeV, and of the couplings to SM particles, where all values

Table 3
The measured charge asymmetry after the unfolding to parton level in four intervals of the invariant mass of the $t\bar{t}$ system. The result is compared to the SM prediction using the NLO calculation in Ref. [13]. The phase space is limited to $|(\Delta|y|)| < 2$. The uncertainties correspond to the sum in quadrature of statistical and systematic uncertainties (for the data) or to the theory uncertainty (for the SM prediction).

$m_{t\bar{t}}$ interval	>0.75 TeV	0.75–0.9 TeV	0.9–1.3 TeV	>1.3 TeV
Measurement	$(4.2 \pm 3.2)\%$	$(2.2 \pm 7.3)\%$	$(8.6 \pm 4.4)\%$	$(-2.9 \pm 15.0)\%$
SM prediction	$(1.60 \pm 0.04)\%$	$(1.42 \pm 0.04)\%$	$(1.75 \pm 0.05)\%$	$(2.55 \pm 0.18)\%$

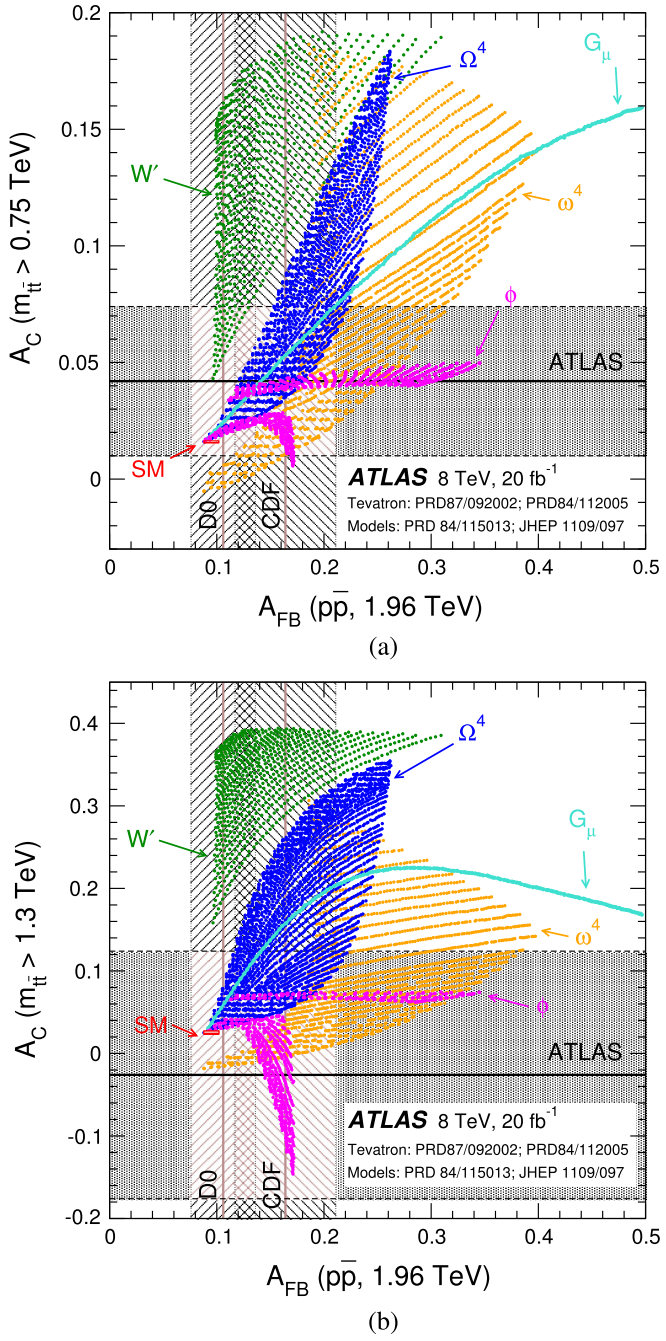

Fig. 3. Predictions from a number of extensions of the SM from Refs. [80,81], for the forward–backward asymmetry integrated over $m_{t\bar{t}}$ at the Tevatron (on the x-axis in both plots) and two high-mass charge asymmetry measurements at the LHC. The y-axis in both figures represents the measurement for (a) $m_{t\bar{t}} > 0.75$ TeV and for (b) $m_{t\bar{t}} > 1.3$ TeV. The SM predictions of both the forward–backward asymmetry at the Tevatron and the charge asymmetry at the LHC are also shown [11,82].

allowed give a total cross-section for top-quark pair production at the Tevatron compatible with observations and a high-mass $t\bar{t}$ production cross-section ($m_{t\bar{t}} > 1$ TeV) at the LHC that is at most three times the SM prediction. The contribution from new physics to the Tevatron A_{FB} is moreover required to be positive. The predictions of the Tevatron forward–backward asymmetry and the LHC high-mass charge asymmetry are calculated using PROTOS [83], which includes the tree-level SM amplitude plus the one(s) from the new particle(s), taking into account the interference between the two contributions. This measurement extends the reach of previous ATLAS and CMS measurements to beyond 1 TeV (adding a bin with $m_{t\bar{t}} = 0.9$–1.3 TeV). The BSM sensitivity of this measurement is also complementary to that of the most recently published ATLAS measurement [20] and can be seen to disfavour the t-channel W' boson model in the highest $m_{t\bar{t}}$ bin.

11. Conclusions

The charge asymmetry in the rapidity distribution of top-quark pairs produced at large $t\bar{t}$ invariant mass has been measured in a sample of $\sqrt{s} = 8$ TeV pp collisions corresponding to an integrated luminosity of 20.3 fb^{-1}, collected with the ATLAS experiment at the LHC in 2012. The selection criteria and the reconstruction algorithm designed for ℓ + jets events with the decay topology of highly boosted top quarks are found to give good control over the sign of the absolute rapidity difference of top and anti-top quarks, with a dilution factor that reaches 0.75, significantly higher than more traditional methods.

The observed asymmetry is corrected to the fiducial space $m_{t\bar{t}} > 0.75$ TeV and $-2 < \Delta|y| < 2$. The result, $A_{\mathrm{C}} = (4.2 \pm 3.2)\%$, is less than one standard deviation from the SM prediction of $1.60 \pm 0.04\%$. The charge asymmetry is also determined in three $t\bar{t}$ mass intervals. The most significant deviation from the SM prediction, 1.6σ, is observed in the mass bin that ranges from 0.9 TeV to 1.3 TeV: $A_{\mathrm{C}} = (8.6 \pm 4.4)\%$. The other two mass bins yield values compatible with the SM prediction within 1σ. These measurements provide a constraint on extensions of the SM, some of which predict a very sizeable charge asymmetry at large $t\bar{t}$ mass.

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, DNSRC and Lundbeck Foundation, 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 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, Region 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; the Royal Society and Leverhulme Trust, United Kingdom.

The crucial computing support from all WLCG partners is acknowledged gratefully, in particular from CERN and 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) and in the Tier-2 facilities worldwide.

References

[1] J.H. Kühn, G. Rodrigo, Charge asymmetry of heavy quarks at hadron colliders, Phys. Rev. D 59 (1999) 054017, arXiv:hep-ph/9807420.

[2] J.H. Kühn, G. Rodrigo, Charge asymmetry in hadroproduction of heavy quarks, Phys. Rev. Lett. 81 (1998) 49–52, arXiv:hep-ph/9802268.

[3] V.M. Abazov, et al., D0 Collaboration, First measurement of the forward–backward charge asymmetry in top quark pair production, Phys. Rev. Lett. 100 (2008) 142002, arXiv:0712.0851 [hep-ex].

[4] T. Aaltonen, et al., CDF Collaboration, Forward–backward asymmetry in top quark production in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV, Phys. Rev. Lett. 101 (2008) 202001, arXiv:0806.2472 [hep-ex].

[5] V.M. Abazov, et al., D0 Collaboration, Simultaneous measurement of forward–backward asymmetry and top polarization in dilepton final states from $t\bar{t}$ production at the Tevatron, Phys. Rev. D 92 (5) (2015) 052007, arXiv:1507.05666 [hep-ex].

[6] V.M. Abazov, et al., D0 Collaboration, Measurement of the forward–backward asymmetry in top quark–antiquark production in $p\bar{p}$ collisions using the lepton + jets channel, Phys. Rev. D 90 (2014) 072011, arXiv:1405.0421 [hep-ex].

[7] T. Aaltonen, et al., CDF Collaboration, Measurement of the top quark forward–backward production asymmetry and its dependence on event kinematic properties, Phys. Rev. D 87 (2013) 092002, arXiv:1211.1003 [hep-ex].

[8] V.M. Abazov, et al., D0 Collaboration, Forward–backward asymmetry in top quark–antiquark production, Phys. Rev. D 84 (2011) 112005, arXiv:1107.4995 [hep-ex].

[9] T. Aaltonen, et al., CDF Collaboration, Evidence for a mass dependent forward–backward asymmetry in top quark pair production, Phys. Rev. D 83 (2011) 112003, arXiv:1101.0034 [hep-ex].

[10] W. Hollik, D. Pagani, The electroweak contribution to the top quark forward–backward asymmetry at the Tevatron, Phys. Rev. D 84 (2011) 093003, arXiv:1107.2606 [hep-ph].

[11] M. Czakon, P. Fiedler, A. Mitov, Resolving the Tevatron top quark forward–backward asymmetry puzzle: fully differential next-to-next-to-leading-order calculation, Phys. Rev. Lett. 115 (5) (2015) 052001, arXiv:1411.3007 [hep-ph].

[12] J.A. Aguilar-Saavedra, et al., Asymmetries in top quark pair production at hadron colliders, Rev. Mod. Phys. 87 (2015) 421–455, arXiv:1406.1798 [hep-ph].

[13] J.H. Kuhn, G. Rodrigo, Charge asymmetries of top quarks at hadron colliders revisited, J. High Energy Phys. 01 (2012) 063, arXiv:1109.6830 [hep-ph].

[14] CMS Collaboration, Measurements of the $t\bar{t}$ charge asymmetry using the dilepton decay channel in pp collisions at $\sqrt{s} = 7$ TeV, J. High Energy Phys. 04 (2014) 191, arXiv:1402.3803 [hep-ex].

[15] ATLAS Collaboration, Measurement of the top quark pair production charge asymmetry in proton–proton collisions at $\sqrt{s} = 7$ TeV using the ATLAS detector, J. High Energy Phys. 02 (2014) 107, arXiv:1311.6724 [hep-ex].

[16] CMS Collaboration, Inclusive and differential measurements of the $t\bar{t}$ charge asymmetry in proton–proton collisions at 7 TeV, Phys. Lett. B 717 (2012) 129–150, arXiv:1207.0065 [hep-ex].

[17] ATLAS Collaboration, Measurement of the charge asymmetry in top quark pair production in pp collisions at $\sqrt{s} = 7$ TeV using the ATLAS detector, Eur. Phys. J. C 72 (2012) 2039, arXiv:1203.4211 [hep-ex].

[18] CMS Collaboration, Inclusive and differential measurements of the $t\bar{t}$ charge asymmetry in pp collisions at $\sqrt{s} = 8$ TeV, arXiv:1507.03119 [hep-ex], 2015.

[19] V. Khachatryan, et al., Measurement of the charge asymmetry in top quark pair production in pp collisions at $\sqrt{s} = 8$ TeV using a template method, arXiv:1508.03862 [hep-ex], 2015.

[20] ATLAS Collaboration, Measurement of the charge asymmetry in top-quark pair production in the lepton-plus-jets final state in pp collision data at $\sqrt{s} = 8$ TeV with the ATLAS detector, arXiv:1509.02358 [hep-ex], 2015.

[21] D. Adams, et al., Towards an understanding of the correlations in jet substructure, Eur. Phys. J. C 75 (9) (2015) 409, arXiv:1504.00679 [hep-ph].

[22] A. Altheimer, et al., Boosted objects and jet substructure at the LHC, Report of BOOST2012, held at IFIC Valencia, 23rd–27th of July 2012, Eur. Phys. J. C 74 (2014) 2792, arXiv:1311.2708 [hep-ex].

[23] A. Altheimer, et al., Jet substructure at the Tevatron and LHC: new results, new tools, new benchmarks, J. Phys. G 39 (2012) 063001, arXiv:1201.0008 [hep-ph].

[24] A. Abdesselam, et al., Boosted objects: a probe of beyond the Standard Model physics, Eur. Phys. J. C 71 (2011) 1661, arXiv:1012.5412 [hep-ph].

[25] 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 [hep-ex].

[26] ATLAS Collaboration, Jet mass and substructure of inclusive jets in $\sqrt{s} = 7$ TeV pp collisions with the ATLAS experiment, J. High Energy Phys. 05 (2012) 128, arXiv:1203.4606 [hep-ex].

[27] ATLAS Collaboration, A search for $t\bar{t}$ resonances using lepton-plus-jets events in proton–proton collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector, J. High Energy Phys. 08 (2015) 148, arXiv:1505.07018 [hep-ex].

[28] ATLAS Collaboration, Search for $t\bar{t}$ resonances in the lepton plus jets final state with ATLAS using 4.7 fb^{-1} of pp collisions at $\sqrt{s} = 7$ TeV, Phys. Rev. D 88 (1) (2013) 012004, arXiv:1305.2756 [hep-ex].

[29] ATLAS Collaboration, A search for $t\bar{t}$ resonances in lepton + jets events with highly boosted top quarks collected in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector, J. High Energy Phys. 09 (2012) 041, arXiv:1207.2409 [hep-ex].

[30] ATLAS Collaboration, Prospects for top anti-top resonance searches using early ATLAS data, ATLAS-PHYS-PUB-2010-008, https://cds.cern.ch/record/1278454, 2010.

[31] ATLAS Collaboration, The ATLAS experiment at the CERN large hadron collider, J. Instrum. 3 (2008) S08003.

[32] ATLAS Collaboration, The ATLAS simulation infrastructure, Eur. Phys. J. C 70 (2010) 823, arXiv:1005.4568 [physics.ins-det].

[33] S. Agostinelli, et al., GEANT4: a simulation toolkit, Nucl. Instrum. Methods, Sect. A 506 (2003) 250–303.

[34] T. Sjostrand, S. Mrenna, P.Z. Skands, A brief introduction to PYTHIA 8.1, Comput. Phys. Commun. 178 (2008) 852–867, arXiv:0710.3820 [hep-ph].

[35] A. Martin, et al., Parton distributions for the LHC, Eur. Phys. J. C 63 (2009) 109–285, arXiv:0901.0002 [hep-ph].

[36] S. Frixione, P. Nason, C. Oleari, Matching NLO QCD computations with parton shower simulations: the POWHEG method, J. High Energy Phys. 11 (2007) 070, arXiv:0709.2092 [hep-ph].

[37] H.-L. Lai, et al., New parton distributions for collider physics, Phys. Rev. D 82 (2010) 074024, arXiv:1007.2241 [hep-ph].

[38] T. Sjostrand, S. Mrenna, P. Skands, PYTHIA generator version 6.418, J. High Energy Phys. 05 (2006) 026.

[39] P. Skands, Tuning Monte Carlo generators: the Perugia tunes, Phys. Rev. D 82 (2010) 074018.

[40] M. Aliev, et al., HATHOR: HAdronic Top and Heavy Quarks crOss section calculatoR, Comput. Phys. Commun. 182 (2011) 1034–1046, arXiv:1007.1327 [hep-ph].

[41] J.H. Kuhn, A. Scharf, P. Uwer, Electroweak corrections to top-quark pair production in quark–antiquark annihilation, Eur. Phys. J. C 45 (2006) 139–150, arXiv:hep-ph/0508092.

[42] J.H. Kuhn, A. Scharf, P. Uwer, Electroweak effects in top-quark pair production at hadron colliders, Eur. Phys. J. C 51 (2007) 37–53, arXiv:hep-ph/0610335.

[43] J.H. Kuhn, A. Scharf, P. Uwer, Weak interactions in top-quark pair production at hadron colliders: an update, Phys. Rev. D 91 (1) (2015) 014020, arXiv:1305.5773 [hep-ph].

[44] S. Frixione, P. Nason, B.R. Webber, Matching NLO QCD and parton showers in heavy flavor production, J. High Energy Phys. 08 (2003) 007, arXiv:hep-ph/0305252.

[45] G. Corcella, et al., HERWIG 6.5: an event generator for Hadron Emission Reactions With Interfering Gluons (including supersymmetric processes), J. High Energy Phys. 01 (2001) 010, arXiv:hep-ph/0011363.

[46] J.M. Butterworth, J.R. Forshaw, M.H. Seymour, Multiparton interactions in photoproduction at HERA, Z. Phys. C 72 (1996) 637–646, arXiv:hep-ph/9601371.

[47] B.P. Kersevan, E. Richter-Was, The Monte Carlo event generator AcerMC versions 2.0 to 3.8 with interfaces to PYTHIA 6.4, HERWIG 6.5 and ARIADNE 4.1, Comput. Phys. Commun. 184 (2013) 919, arXiv:hep-ph/0405247.

[48] M. Czakon, A. Mitov, Top++: a program for the calculation of the top-pair cross-section at hadron colliders, Comput. Phys. Commun. 185 (2014) 2930, arXiv:1112.5675 [hep-ph].

[49] M. Cacciari, et al., Top-pair production at hadron colliders with next-to-next-to-leading logarithmic soft-gluon resummation, Phys. Lett. B 710 (2012) 612–622, arXiv:1111.5869 [hep-ph].

[50] M. Beneke, et al., Hadronic top-quark pair production with NNLL threshold resummation, Nucl. Phys. B 855 (2012) 695–741, arXiv:1109.1536 [hep-ph].

[51] P. Baernreuther, M. Czakon, A. Mitov, Percent level precision physics at the Tevatron: first genuine NNLO QCD corrections to $q\bar{q} \to t\bar{t} + X$, Phys. Rev. Lett. 109 (2012) 132001, arXiv:1204.5201 [hep-ph].

[52] M. Czakon, A. Mitov, NNLO corrections to top-pair production at hadron colliders: the all-fermionic scattering channels, J. High Energy Phys. 12 (2012) 054, arXiv:1207.0236 [hep-ph].

[53] M. Czakon, A. Mitov, NNLO corrections to top pair production at hadron colliders: the quark–gluon reaction, J. High Energy Phys. 01 (2013) 080, arXiv:1210.6832 [hep-ph].

[54] M. Czakon, P. Fiedler, A. Mitov, Total top-quark pair-production cross section at hadron colliders through $O(\alpha_s^4)$, Phys. Rev. Lett. 110 (2013) 252004, arXiv:1303.6254 [hep-ph].

[55] M.L. Mangano, et al., ALPGEN, a generator for hard multiparton processes in hadronic collisions, J. High Energy Phys. 07 (2003) 001, arXiv:hep-ph/0206293.

[56] M.L. Mangano, M. Moretti, R. Pittau, Multijet matrix elements and shower evolution in hadronic collisions: $Wb\bar{b} + n$ jets as a case study, Nucl. Phys. B 632 (2002) 343–362, arXiv:hep-ph/0108069.

[57] R. Hamberg, W. van Neerven, T. Matsuura, A complete calculation of the order $\alpha - s^2$ correction to the Drell–Yan K factor, Nucl. Phys. B 359 (1991) 343–405.
[58] R. Gavin, et al., W Physics at the LHC with FEWZ 2.1, Comput. Phys. Commun. 184 (2013) 208–214, arXiv:1201.5896 [hep-ph].
[59] N. Kidonakis, Next-to-next-to-leading-order collinear and soft gluon corrections for t-channel single top quark production, Phys. Rev. D 83 (2011) 091503, arXiv:1103.2792 [hep-ph].
[60] N. Kidonakis, Two-loop soft anomalous dimensions for single top quark associated production with a W- or H-, Phys. Rev. D 82 (2010) 054018, arXiv:1005.4451 [hep-ph].
[61] N. Kidonakis, NNLL resummation for s-channel single top quark production, Phys. Rev. D 81 (2010) 054028, arXiv:1001.5034 [hep-ph].
[62] T. Gleisberg, et al., Event generation with SHERPA 1.1, J. High Energy Phys. 02 (2009) 007, arXiv:0811.4622 [hep-ph].
[63] K. Rehermann, B. Tweedie, Efficient identification of boosted semileptonic top quarks at the LHC, J. High Energy Phys. 03 (2011) 059, arXiv:1007.2221 [hep-ph].
[64] M. Cacciari, G.P. Salam, G. Soyez, The anti-$k(t)$ jet clustering algorithm, J. High Energy Phys. 04 (2008) 063, arXiv:0802.1189 [hep-ph].
[65] M. Cacciari, G.P. Salam, G. Soyez, FastJet user manual, Eur. Phys. J. C 72 (2012) 1896, arXiv:1111.6097 [hep-ph].
[66] ATLAS Collaboration, Jet energy measurement with the ATLAS detector in proton–proton collisions at $\sqrt{s} = 7$ TeV, Eur. Phys. J. C 73 (3) (2013) 2304, arXiv:1112.6426 [hep-ex].
[67] D. Krohn, J. Thaler, L.-T. Wang, Jet trimming, J. High Energy Phys. 02 (2010) 084, arXiv:0912.1342 [hep-ph].
[68] S. Catani, et al., Longitudinally invariant K_t clustering algorithms for hadron hadron collisions, Nucl. Phys. B 406 (1993) 187–224.
[69] S.D. Ellis, D.E. Soper, Successive combination jet algorithm for hadron collisions, Phys. Rev. D 48 (1993) 3160–3166, arXiv:hep-ph/9305266.
[70] ATLAS Collaboration, Calibration of b-tagging using dileptonic top pair events in a combinatorial likelihood approach with the ATLAS experiment, ATLAS-CONF-2014-004, https://cds.cern.ch/record/1664335, 2014.
[71] ATLAS Collaboration, Calibration of the performance of b-tagging for c and light-flavour jets in the 2012 ATLAS data, ATLAS-CONF-2014-046, https://cds.cern.ch/record/1741020, 2014.
[72] J. Butterworth, B. Cox, J.R. Forshaw, WW scattering at the CERN LHC, Phys. Rev. D 65 (2002) 096014, arXiv:hep-ph/0201098.
[73] ATLAS Collaboration, Measurement of the differential cross-section of highly boosted top quarks as a function of their transverse momentum in $\sqrt{s} = 8$ TeV proton–proton collisions using the ATLAS detector, arXiv:1510.03818 [hep-ex], 2015.
[74] ATLAS Collaboration, Measurement of the normalized differential cross sections for $t\bar{t}$ production in pp collisions at $\sqrt{s} = 7$ TeV using the ATLAS detector, Phys. Rev. D 90 (2014), arXiv:1407.0371 [hep-ex].
[75] CMS Collaboration, Measurement of the differential cross section for top quark pair production in pp collisions at $\sqrt{s} = 8$ TeV, Eur. Phys. J. C 75 (11) (2015) 542, arXiv:1505.04480 [hep-ex].
[76] G. Choudalakis, Fully Bayesian unfolding, arXiv:1201.4612 [physics.data-an], 2012.
[77] ATLAS Collaboration, Jet energy measurement and its systematic uncertainty in proton–proton collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector, Eur. Phys. J. C 75 (2015) 17, arXiv:1406.0076 [hep-ex].
[78] ATLAS Collaboration, Single hadron response measurement and calorimeter jet energy scale uncertainty with the ATLAS detector at the LHC, Eur. Phys. J. C 73 (2013) 2305, arXiv:1203.1302 [hep-ex].
[79] R. Ball, et al., Impact of heavy quark masses on parton distributions and LHC phenomenology, Nucl. Phys. B 849 (2011) 296–363, arXiv:1101.1300 [hep-ph].
[80] J. Aguilar-Saavedra, M. Perez-Victoria, Asymmetries in $t\bar{t}$ production: LHC versus Tevatron, Phys. Rev. D 84 (2011) 115013, arXiv:1105.4606 [hep-ph].
[81] J. Aguilar-Saavedra, M. Perez-Victoria, Simple models for the top asymmetry: constraints and predictions, J. High Energy Phys. 09 (2011) 097, arXiv:1107.0841 [hep-ph].
[82] W. Bernreuther, Z.-G. Si, Top quark and leptonic charge asymmetries for the Tevatron and LHC, Phys. Rev. D 86 (2012) 034026, arXiv:1205.6580 [hep-ph].
[83] J. Aguilar-Saavedra, Single top quark production at LHC with anomalous Wtb couplings, Nucl. Phys. B 804 (2008) 160–192, arXiv:0803.3810 [hep-ph].

ATLAS Collaboration

G. Aad [87], B. Abbott [114], J. Abdallah [152], O. Abdinov [11], B. Abeloos [118], R. Aben [108], M. Abolins [92], O.S. AbouZeid [138], H. Abramowicz [154], H. Abreu [153], R. Abreu [117], Y. Abulaiti [147a,147b], B.S. Acharya [163a,163b,a], L. Adamczyk [39a], D.L. Adams [26], J. Adelman [109], S. Adomeit [101], T. Adye [132], A.A. Affolder [76], T. Agatonovic-Jovin [13], J. Agricola [55], J.A. Aguilar-Saavedra [127a,127f], S.P. Ahlen [23], F. Ahmadov [67,b], G. Aielli [134a,134b], H. Akerstedt [147a,147b], T.P.A. Åkesson [83], A.V. Akimov [97], G.L. Alberghi [21a,21b], J. Albert [168], S. Albrand [56], M.J. Alconada Verzini [73], M. Aleksa [31], I.N. Aleksandrov [67], C. Alexa [27b], G. Alexander [154], T. Alexopoulos [10], M. Alhroob [114], G. Alimonti [93a], J. Alison [32], S.P. Alkire [36], B.M.M. Allbrooke [150], B.W. Allen [117], P.P. Allport [18], A. Aloisio [105a,105b], A. Alonso [37], F. Alonso [73], C. Alpigiani [139], B. Alvarez Gonzalez [31], D. Álvarez Piqueras [166], M.G. Alviggi [105a,105b], B.T. Amadio [15], K. Amako [68], Y. Amaral Coutinho [25a], C. Amelung [24], D. Amidei [91], S.P. Amor Dos Santos [127a,127c], A. Amorim [127a,127b], S. Amoroso [31], N. Amram [154], G. Amundsen [24], C. Anastopoulos [140], L.S. Ancu [50], N. Andari [109], T. Andeen [32], C.F. Anders [59b], G. Anders [31], J.K. Anders [76], K.J. Anderson [32], A. Andreazza [93a,93b], V. Andrei [59a], S. Angelidakis [9], I. Angelozzi [108], P. Anger [45], A. Angerami [36], F. Anghinolfi [31], A.V. Anisenkov [110,c], N. Anjos [12], A. Annovi [125a,125b], M. Antonelli [48], A. Antonov [99], J. Antos [145b], F. Anulli [133a], M. Aoki [68], L. Aperio Bella [18], G. Arabidze [92], Y. Arai [68], J.P. Araque [127a], A.T.H. Arce [46], F.A. Arduh [73], J-F. Arguin [96], S. Argyropoulos [64], M. Arik [19a], A.J. Armbruster [31], L.J. Armitage [78], O. Arnaez [31], H. Arnold [49], M. Arratia [29], O. Arslan [22], A. Artamonov [98], G. Artoni [121], S. Artz [85], S. Asai [156], N. Asbah [43], A. Ashkenazi [154], B. Åsman [147a,147b], L. Asquith [150], K. Assamagan [26], R. Astalos [145a], M. Atkinson [165], N.B. Atlay [142], K. Augsten [129], G. Avolio [31], B. Axen [15], M.K. Ayoub [118], G. Azuelos [96,d], M.A. Baak [31], A.E. Baas [59a], M.J. Baca [18], H. Bachacou [137], K. Bachas [75a,75b], M. Backes [31], M. Backhaus [31], P. Bagiacchi [133a,133b], P. Bagnaia [133a,133b], Y. Bai [34a], J.T. Baines [132], O.K. Baker [175], E.M. Baldin [110,c], P. Balek [130], T. Balestri [149], F. Balli [137], W.K. Balunas [123], E. Banas [40], Sw. Banerjee [172,e], A.A.E. Bannoura [174], L. Barak [31], E.L. Barberio [90], D. Barberis [51a,51b], M. Barbero [87], T. Barillari [102], M. Barisonzi [163a,163b], T. Barklow [144], N. Barlow [29], S.L. Barnes [86], B.M. Barnett [132], R.M. Barnett [15], Z. Barnovska [5], A. Baroncelli [135a], G. Barone [24], A.J. Barr [121], L. Barranco Navarro [166], F. Barreiro [84], J. Barreiro Guimarães da Costa [34a], R. Bartoldus [144], A.E. Barton [74], P. Bartos [145a], A. Basalaev [124], A. Bassalat [118], A. Basye [165], R.L. Bates [54], S.J. Batista [159], J.R. Batley [29], M. Battaglia [138], M. Bauce [133a,133b],

F. Bauer [137], H.S. Bawa [144,f], J.B. Beacham [112], M.D. Beattie [74], T. Beau [82], P.H. Beauchemin [162], R. Beccherle [125a,125b], P. Bechtle [22], H.P. Beck [17,g], K. Becker [121], M. Becker [85], M. Beckingham [169], C. Becot [111], A.J. Beddall [19e], A. Beddall [19b], V.A. Bednyakov [67], M. Bedognetti [108], C.P. Bee [149], L.J. Beemster [108], T.A. Beermann [31], M. Begel [26], J.K. Behr [121], C. Belanger-Champagne [89], A.S. Bell [80], W.H. Bell [50], G. Bella [154], L. Bellagamba [21a], A. Bellerive [30], M. Bellomo [88], K. Belotskiy [99], O. Beltramello [31], N.L. Belyaev [99], O. Benary [154], D. Benchekroun [136a], M. Bender [101], K. Bendtz [147a,147b], N. Benekos [10], Y. Benhammou [154], E. Benhar Noccioli [175], J. Benitez [64], J.A. Benitez Garcia [160b], D.P. Benjamin [46], J.R. Bensinger [24], S. Bentvelsen [108], L. Beresford [121], M. Beretta [48], D. Berge [108], E. Bergeaas Kuutmann [164], N. Berger [5], F. Berghaus [168], J. Beringer [15], S. Berlendis [56], C. Bernard [23], N.R. Bernard [88], C. Bernius [111], F.U. Bernlochner [22], T. Berry [79], P. Berta [130], C. Bertella [85], G. Bertoli [147a,147b], F. Bertolucci [125a,125b], I.A. Bertram [74], C. Bertsche [114], D. Bertsche [114], G.J. Besjes [37], O. Bessidskaia Bylund [147a,147b], M. Bessner [43], N. Besson [137], C. Betancourt [49], S. Bethke [102], A.J. Bevan [78], W. Bhimji [15], R.M. Bianchi [126], L. Bianchini [24], M. Bianco [31], O. Biebel [101], D. Biedermann [16], R. Bielski [86], N.V. Biesuz [125a,125b], M. Biglietti [135a], J. Bilbao De Mendizabal [50], H. Bilokon [48], M. Bindi [55], S. Binet [118], A. Bingul [19b], C. Bini [133a,133b], S. Biondi [21a,21b], D.M. Bjergaard [46], C.W. Black [151], J.E. Black [144], K.M. Black [23], D. Blackburn [139], R.E. Blair [6], J.-B. Blanchard [137], J.E. Blanco [79], T. Blazek [145a], I. Bloch [43], C. Blocker [24], W. Blum [85,*], U. Blumenschein [55], S. Blunier [33a], G.J. Bobbink [108], V.S. Bobrovnikov [110,c], S.S. Bocchetta [83], A. Bocci [46], C. Bock [101], M. Boehler [49], D. Boerner [174], J.A. Bogaerts [31], D. Bogavac [13], A.G. Bogdanchikov [110], C. Bohm [147a], V. Boisvert [79], T. Bold [39a], V. Boldea [27b], A.S. Boldyrev [163a,163c], M. Bomben [82], M. Bona [78], M. Boonekamp [137], A. Borisov [131], G. Borissov [74], J. Bortfeldt [101], D. Bortoletto [121], V. Bortolotto [61a,61b,61c], K. Bos [108], D. Boscherini [21a], M. Bosman [12], J.D. Bossio Sola [28], J. Boudreau [126], J. Bouffard [2], E.V. Bouhova-Thacker [74], D. Boumediene [35], C. Bourdarios [118], N. Bousson [115], S.K. Boutle [54], A. Boveia [31], J. Boyd [31], I.R. Boyko [67], J. Bracinik [18], A. Brandt [8], G. Brandt [55], O. Brandt [59a], U. Bratzler [157], B. Brau [88], J.E. Brau [117], H.M. Braun [174,*], W.D. Breaden Madden [54], K. Brendlinger [123], A.J. Brennan [90], L. Brenner [108], R. Brenner [164], S. Bressler [171], T.M. Bristow [47], D. Britton [54], D. Britzger [43], F.M. Brochu [29], I. Brock [22], R. Brock [92], G. Brooijmans [36], T. Brooks [79], W.K. Brooks [33b], J. Brosamer [15], E. Brost [117], J.H Broughton [18], P.A. Bruckman de Renstrom [40], D. Bruncko [145b], R. Bruneliere [49], A. Bruni [21a], G. Bruni [21a], BH Brunt [29], M. Bruschi [21a], N. Bruscino [22], P. Bryant [32], L. Bryngemark [83], T. Buanes [14], Q. Buat [143], P. Buchholz [142], A.G. Buckley [54], I.A. Budagov [67], F. Buehrer [49], M.K. Bugge [120], O. Bulekov [99], D. Bullock [8], H. Burckhart [31], S. Burdin [76], C.D. Burgard [49], B. Burghgrave [109], K. Burka [40], S. Burke [132], I. Burmeister [44], E. Busato [35], D. Büscher [49], V. Büscher [85], P. Bussey [54], J.M. Butler [23], A.I. Butt [3], C.M. Buttar [54], J.M. Butterworth [80], P. Butti [108], W. Buttinger [26], A. Buzatu [54], A.R. Buzykaev [110,c], S. Cabrera Urbán [166], D. Caforio [129], V.M. Cairo [38a,38b], O. Cakir [4a], N. Calace [50], P. Calafiura [15], A. Calandri [87], G. Calderini [82], P. Calfayan [101], L.P. Caloba [25a], D. Calvet [35], S. Calvet [35], T.P. Calvet [87], R. Camacho Toro [32], S. Camarda [43], P. Camarri [134a,134b], D. Cameron [120], R. Caminal Armadans [165], C. Camincher [56], S. Campana [31], M. Campanelli [80], A. Campoverde [149], V. Canale [105a,105b], A. Canepa [160a], M. Cano Bret [34e], J. Cantero [84], R. Cantrill [127a], T. Cao [41], M.D.M. Capeans Garrido [31], I. Caprini [27b], M. Caprini [27b], M. Capua [38a,38b], R. Caputo [85], R.M. Carbone [36], R. Cardarelli [134a], F. Cardillo [49], T. Carli [31], G. Carlino [105a], L. Carminati [93a,93b], S. Caron [107], E. Carquin [33a], G.D. Carrillo-Montoya [31], J.R. Carter [29], J. Carvalho [127a,127c], D. Casadei [80], M.P. Casado [12,h], M. Casolino [12], D.W. Casper [66], E. Castaneda-Miranda [146a], A. Castelli [108], V. Castillo Gimenez [166], N.F. Castro [127a,i], A. Catinaccio [31], J.R. Catmore [120], A. Cattai [31], J. Caudron [85], V. Cavaliere [165], D. Cavalli [93a], M. Cavalli-Sforza [12], V. Cavasinni [125a,125b], F. Ceradini [135a,135b], L. Cerda Alberich [166], B.C. Cerio [46], A.S. Cerqueira [25b], A. Cerri [150], L. Cerrito [78], F. Cerutti [15], M. Cerv [31], A. Cervelli [17], S.A. Cetin [19d], A. Chafaq [136a], D. Chakraborty [109], I. Chalupkova [130], S.K. Chan [58], Y.L. Chan [61a], P. Chang [165], J.D. Chapman [29], D.G. Charlton [18], A. Chatterjee [50], C.C. Chau [159], C.A. Chavez Barajas [150], S. Che [112], S. Cheatham [74], A. Chegwidden [92], S. Chekanov [6], S.V. Chekulaev [160a], G.A. Chelkov [67,j], M.A. Chelstowska [91], C. Chen [65], H. Chen [26], K. Chen [149], S. Chen [34c], S. Chen [156], X. Chen [34f], Y. Chen [69], H.C. Cheng [91], Y. Cheng [32], A. Cheplakov [67], E. Cheremushkina [131], R. Cherkaoui El Moursli [136e], V. Chernyatin [26,*], E. Cheu [7], L. Chevalier [137], V. Chiarella [48], G. Chiarelli [125a,125b], G. Chiodini [75a], A.S. Chisholm [18], A. Chitan [27b], M.V. Chizhov [67], K. Choi [62], A.R. Chomont [35], S. Chouridou [9], B.K.B. Chow [101], V. Christodoulou [80], D. Chromek-Burckhart [31], J. Chudoba [128], A.J. Chuinard [89],

J.J. Chwastowski [40], L. Chytka [116], G. Ciapetti [133a,133b], A.K. Ciftci [4a], D. Cinca [54], V. Cindro [77], I.A. Cioara [22], A. Ciocio [15], F. Cirotto [105a,105b], Z.H. Citron [171], M. Ciubancan [27b], A. Clark [50], B.L. Clark [58], P.J. Clark [47], R.N. Clarke [15], C. Clement [147a,147b], Y. Coadou [87], M. Cobal [163a,163c], A. Coccaro [50], J. Cochran [65], L. Coffey [24], L. Colasurdo [107], B. Cole [36], S. Cole [109], A.P. Colijn [108], J. Collot [56], T. Colombo [31], G. Compostella [102], P. Conde Muiño [127a,127b], E. Coniavitis [49], S.H. Connell [146b], I.A. Connelly [79], V. Consorti [49], S. Constantinescu [27b], C. Conta [122a,122b], G. Conti [31], F. Conventi [105a,k], M. Cooke [15], B.D. Cooper [80], A.M. Cooper-Sarkar [121], T. Cornelissen [174], M. Corradi [133a,133b], F. Corriveau [89,l], A. Corso-Radu [66], A. Cortes-Gonzalez [12], G. Cortiana [102], G. Costa [93a], M.J. Costa [166], D. Costanzo [140], G. Cottin [29], G. Cowan [79], B.E. Cox [86], K. Cranmer [111], S.J. Crawley [54], G. Cree [30], S. Crépé-Renaudin [56], F. Crescioli [82], W.A. Cribbs [147a,147b], M. Crispin Ortuzar [121], M. Cristinziani [22], V. Croft [107], G. Crosetti [38a,38b], T. Cuhadar Donszelmann [140], J. Cummings [175], M. Curatolo [48], J. Cúth [85], C. Cuthbert [151], H. Czirr [142], P. Czodrowski [3], S. D'Auria [54], M. D'Onofrio [76], M.J. Da Cunha Sargedas De Sousa [127a,127b], C. Da Via [86], W. Dabrowski [39a], T. Dai [91], O. Dale [14], F. Dallaire [96], C. Dallapiccola [88], M. Dam [37], J.R. Dandoy [32], N.P. Dang [49], A.C. Daniells [18], N.S. Dann [86], M. Danninger [167], M. Dano Hoffmann [137], V. Dao [49], G. Darbo [51a], S. Darmora [8], J. Dassoulas [3], A. Dattagupta [62], W. Davey [22], C. David [168], T. Davidek [130], M. Davies [154], P. Davison [80], Y. Davygora [59a], E. Dawe [90], I. Dawson [140], R.K. Daya-Ishmukhametova [88], K. De [8], R. de Asmundis [105a], A. De Benedetti [114], S. De Castro [21a,21b], S. De Cecco [82], N. De Groot [107], P. de Jong [108], H. De la Torre [84], F. De Lorenzi [65], D. De Pedis [133a], A. De Salvo [133a], U. De Sanctis [150], A. De Santo [150], J.B. De Vivie De Regie [118], W.J. Dearnaley [74], R. Debbe [26], C. Debenedetti [138], D.V. Dedovich [67], I. Deigaard [108], J. Del Peso [84], T. Del Prete [125a,125b], D. Delgove [118], F. Deliot [137], C.M. Delitzsch [50], M. Deliyergiyev [77], A. Dell'Acqua [31], L. Dell'Asta [23], M. Dell'Orso [125a,125b], M. Della Pietra [105a,k], D. della Volpe [50], M. Delmastro [5], P.A. Delsart [56], C. Deluca [108], D.A. DeMarco [159], S. Demers [175], M. Demichev [67], A. Demilly [82], S.P. Denisov [131], D. Denysiuk [137], D. Derendarz [40], J.E. Derkaoui [136d], F. Derue [82], P. Dervan [76], K. Desch [22], C. Deterre [43], K. Dette [44], P.O. Deviveiros [31], A. Dewhurst [132], S. Dhaliwal [24], A. Di Ciaccio [134a,134b], L. Di Ciaccio [5], W.K. Di Clemente [123], A. Di Domenico [133a,133b], C. Di Donato [133a,133b], A. Di Girolamo [31], B. Di Girolamo [31], A. Di Mattia [153], B. Di Micco [135a,135b], R. Di Nardo [48], A. Di Simone [49], R. Di Sipio [159], D. Di Valentino [30], C. Diaconu [87], M. Diamond [159], F.A. Dias [47], M.A. Diaz [33a], E.B. Diehl [91], J. Dietrich [16], S. Diglio [87], A. Dimitrievska [13], J. Dingfelder [22], P. Dita [27b], S. Dita [27b], F. Dittus [31], F. Djama [87], T. Djobava [52b], J.I. Djuvsland [59a], M.A.B. do Vale [25c], D. Dobos [31], M. Dobre [27b], C. Doglioni [83], T. Dohmae [156], J. Dolejsi [130], Z. Dolezal [130], B.A. Dolgoshein [99,*], M. Donadelli [25d], S. Donati [125a,125b], P. Dondero [122a,122b], J. Donini [35], J. Dopke [132], A. Doria [105a], M.T. Dova [73], A.T. Doyle [54], E. Drechsler [55], M. Dris [10], Y. Du [34d], J. Duarte-Campderros [154], E. Duchovni [171], G. Duckeck [101], O.A. Ducu [27b], D. Duda [108], A. Dudarev [31], L. Duflot [118], L. Duguid [79], M. Dührssen [31], M. Dunford [59a], H. Duran Yildiz [4a], M. Düren [53], A. Durglishvili [52b], D. Duschinger [45], B. Dutta [43], M. Dyndal [39a], C. Eckardt [43], K.M. Ecker [102], R.C. Edgar [91], W. Edson [2], N.C. Edwards [47], T. Eifert [31], G. Eigen [14], K. Einsweiler [15], T. Ekelof [164], M. El Kacimi [136c], V. Ellajosyula [87], M. Ellert [164], S. Elles [5], F. Ellinghaus [174], A.A. Elliot [168], N. Ellis [31], J. Elmsheuser [101], M. Elsing [31], D. Emeliyanov [132], Y. Enari [156], O.C. Endner [85], M. Endo [119], J.S. Ennis [169], J. Erdmann [44], A. Ereditato [17], G. Ernis [174], J. Ernst [2], M. Ernst [26], S. Errede [165], E. Ertel [85], M. Escalier [118], H. Esch [44], C. Escobar [126], B. Esposito [48], A.I. Etienvre [137], E. Etzion [154], H. Evans [62], A. Ezhilov [124], F. Fabbri [21a,21b], L. Fabbri [21a,21b], G. Facini [32], R.M. Fakhrutdinov [131], S. Falciano [133a], R.J. Falla [80], J. Faltova [130], Y. Fang [34a], M. Fanti [93a,93b], A. Farbin [8], A. Farilla [135a], C. Farina [126], T. Farooque [12], S. Farrell [15], S.M. Farrington [169], P. Farthouat [31], F. Fassi [136e], P. Fassnacht [31], D. Fassouliotis [9], M. Faucci Giannelli [79], A. Favareto [51a,51b], L. Fayard [118], O.L. Fedin [124,m], W. Fedorko [167], S. Feigl [120], L. Feligioni [87], C. Feng [34d], E.J. Feng [31], H. Feng [91], A.B. Fenyuk [131], L. Feremenga [8], P. Fernandez Martinez [166], S. Fernandez Perez [12], J. Ferrando [54], A. Ferrari [164], P. Ferrari [108], R. Ferrari [122a], D.E. Ferreira de Lima [54], A. Ferrer [166], D. Ferrere [50], C. Ferretti [91], A. Ferretto Parodi [51a,51b], F. Fiedler [85], A. Filipčič [77], M. Filipuzzi [43], F. Filthaut [107], M. Fincke-Keeler [168], K.D. Finelli [151], M.C.N. Fiolhais [127a,127c], L. Fiorini [166], A. Firan [41], A. Fischer [2], C. Fischer [12], J. Fischer [174], W.C. Fisher [92], N. Flaschel [43], I. Fleck [142], P. Fleischmann [91], G.T. Fletcher [140], G. Fletcher [78], R.R.M. Fletcher [123], T. Flick [174], A. Floderus [83], L.R. Flores Castillo [61a], M.J. Flowerdew [102], G.T. Forcolin [86], A. Formica [137], A. Forti [86], A.G. Foster [18], D. Fournier [118], H. Fox [74], S. Fracchia [12], P. Francavilla [82], M. Franchini [21a,21b], D. Francis [31], L. Franconi [120], M. Franklin [58],

M. Frate [66], M. Fraternali [122a,122b], D. Freeborn [80], S.M. Fressard-Batraneanu [31], F. Friedrich [45], D. Froidevaux [31], J.A. Frost [121], C. Fukunaga [157], E. Fullana Torregrosa [85], T. Fusayasu [103], J. Fuster [166], C. Gabaldon [56], O. Gabizon [174], A. Gabrielli [21a,21b], A. Gabrielli [15], G.P. Gach [39a], S. Gadatsch [31], S. Gadomski [50], G. Gagliardi [51a,51b], L.G. Gagnon [96], P. Gagnon [62], C. Galea [107], B. Galhardo [127a,127c], E.J. Gallas [121], B.J. Gallop [132], P. Gallus [129], G. Galster [37], K.K. Gan [112], J. Gao [34b,87], Y. Gao [47], Y.S. Gao [144,f], F.M. Garay Walls [47], C. García [166], J.E. García Navarro [166], M. Garcia-Sciveres [15], R.W. Gardner [32], N. Garelli [144], V. Garonne [120], A. Gascon Bravo [43], C. Gatti [48], A. Gaudiello [51a,51b], G. Gaudio [122a], B. Gaur [142], L. Gauthier [96], I.L. Gavrilenko [97], C. Gay [167], G. Gaycken [22], E.N. Gazis [10], Z. Gecse [167], C.N.P. Gee [132], Ch. Geich-Gimbel [22], M.P. Geisler [59a], C. Gemme [51a], M.H. Genest [56], C. Geng [34b,n], S. Gentile [133a,133b], S. George [79], D. Gerbaudo [66], A. Gershon [154], S. Ghasemi [142], H. Ghazlane [136b], B. Giacobbe [21a], S. Giagu [133a,133b], P. Giannetti [125a,125b], B. Gibbard [26], S.M. Gibson [79], M. Gignac [167], M. Gilchriese [15], T.P.S. Gillam [29], D. Gillberg [30], G. Gilles [174], D.M. Gingrich [3,d], N. Giokaris [9], M.P. Giordani [163a,163c], F.M. Giorgi [21a], F.M. Giorgi [16], P.F. Giraud [137], P. Giromini [58], D. Giugni [93a], C. Giuliani [102], M. Giulini [59b], B.K. Gjelsten [120], S. Gkaitatzis [155], I. Gkialas [155], E.L. Gkougkousis [118], L.K. Gladilin [100], C. Glasman [84], J. Glatzer [31], P.C.F. Glaysher [47], A. Glazov [43], M. Goblirsch-Kolb [102], J. Godlewski [40], S. Goldfarb [91], T. Golling [50], D. Golubkov [131], A. Gomes [127a,127b,127d], R. Gonçalo [127a], J. Goncalves Pinto Firmino Da Costa [137], L. Gonella [18], A. Gongadze [67], S. González de la Hoz [166], G. Gonzalez Parra [12], S. Gonzalez-Sevilla [50], L. Goossens [31], P.A. Gorbounov [98], H.A. Gordon [26], I. Gorelov [106], B. Gorini [31], E. Gorini [75a,75b], A. Gorišek [77], E. Gornicki [40], A.T. Goshaw [46], C. Gössling [44], M.I. Gostkin [67], C.R. Goudet [118], D. Goujdami [136c], A.G. Goussiou [139], N. Govender [146b], E. Gozani [153], L. Graber [55], I. Grabowska-Bold [39a], P.O.J. Gradin [164], P. Grafström [21a,21b], J. Gramling [50], E. Gramstad [120], S. Grancagnolo [16], V. Gratchev [124], H.M. Gray [31], E. Graziani [135a], Z.D. Greenwood [81,o], C. Grefe [22], K. Gregersen [80], I.M. Gregor [43], P. Grenier [144], K. Grevtsov [5], J. Griffiths [8], A.A. Grillo [138], K. Grimm [74], S. Grinstein [12,p], Ph. Gris [35], J.-F. Grivaz [118], S. Groh [85], J.P. Grohs [45], E. Gross [171], J. Grosse-Knetter [55], G.C. Grossi [81], Z.J. Grout [150], L. Guan [91], W. Guan [172], J. Guenther [129], F. Guescini [50], D. Guest [66], O. Gueta [154], E. Guido [51a,51b], T. Guillemin [5], S. Guindon [2], U. Gul [54], C. Gumpert [31], J. Guo [34e], Y. Guo [34b,n], S. Gupta [121], G. Gustavino [133a,133b], P. Gutierrez [114], N.G. Gutierrez Ortiz [80], C. Gutschow [45], C. Guyot [137], C. Gwenlan [121], C.B. Gwilliam [76], A. Haas [111], C. Haber [15], H.K. Hadavand [8], N. Haddad [136e], A. Hadef [87], P. Haefner [22], S. Hageböck [22], Z. Hajduk [40], H. Hakobyan [176,*], M. Haleem [43], J. Haley [115], D. Hall [121], G. Halladjian [92], G.D. Hallewell [87], K. Hamacher [174], P. Hamal [116], K. Hamano [168], A. Hamilton [146a], G.N. Hamity [140], P.G. Hamnett [43], L. Han [34b], K. Hanagaki [68,q], K. Hanawa [156], M. Hance [138], B. Haney [123], P. Hanke [59a], R. Hanna [137], J.B. Hansen [37], J.D. Hansen [37], M.C. Hansen [22], P.H. Hansen [37], K. Hara [161], A.S. Hard [172], T. Harenberg [174], F. Hariri [118], S. Harkusha [94], R.D. Harrington [47], P.F. Harrison [169], F. Hartjes [108], M. Hasegawa [69], Y. Hasegawa [141], A. Hasib [114], S. Hassani [137], S. Haug [17], R. Hauser [92], L. Hauswald [45], M. Havranek [128], C.M. Hawkes [18], R.J. Hawkings [31], A.D. Hawkins [83], D. Hayden [92], C.P. Hays [121], J.M. Hays [78], H.S. Hayward [76], S.J. Haywood [132], S.J. Head [18], T. Heck [85], V. Hedberg [83], L. Heelan [8], S. Heim [123], T. Heim [15], B. Heinemann [15], J.J. Heinrich [101], L. Heinrich [111], C. Heinz [53], J. Hejbal [128], L. Helary [23], S. Hellman [147a,147b], C. Helsens [31], J. Henderson [121], R.C.W. Henderson [74], Y. Heng [172], S. Henkelmann [167], A.M. Henriques Correia [31], S. Henrot-Versille [118], G.H. Herbert [16], Y. Hernández Jiménez [166], G. Herten [49], R. Hertenberger [101], L. Hervas [31], G.G. Hesketh [80], N.P. Hessey [108], J.W. Hetherly [41], R. Hickling [78], E. Higón-Rodriguez [166], E. Hill [168], J.C. Hill [29], K.H. Hiller [43], S.J. Hillier [18], I. Hinchliffe [15], E. Hines [123], R.R. Hinman [15], M. Hirose [158], D. Hirschbuehl [174], J. Hobbs [149], N. Hod [108], M.C. Hodgkinson [140], P. Hodgson [140], A. Hoecker [31], M.R. Hoeferkamp [106], F. Hoenig [101], M. Hohlfeld [85], D. Hohn [22], T.R. Holmes [15], M. Homann [44], T.M. Hong [126], B.H. Hooberman [165], W.H. Hopkins [117], Y. Horii [104], A.J. Horton [143], J-Y. Hostachy [56], S. Hou [152], A. Hoummada [136a], J. Howard [121], J. Howarth [43], M. Hrabovsky [116], I. Hristova [16], J. Hrivnac [118], T. Hryn'ova [5], A. Hrynevich [95], C. Hsu [146c], P.J. Hsu [152,r], S.-C. Hsu [139], D. Hu [36], Q. Hu [34b], Y. Huang [43], Z. Hubacek [129], F. Hubaut [87], F. Huegging [22], T.B. Huffman [121], E.W. Hughes [36], G. Hughes [74], M. Huhtinen [31], T.A. Hülsing [85], N. Huseynov [67,b], J. Huston [92], J. Huth [58], G. Iacobucci [50], G. Iakovidis [26], I. Ibragimov [142], L. Iconomidou-Fayard [118], E. Ideal [175], Z. Idrissi [136e], P. Iengo [31], O. Igonkina [108], T. Iizawa [170], Y. Ikegami [68], M. Ikeno [68], Y. Ilchenko [32,s], D. Iliadis [155], N. Ilic [144], T. Ince [102], G. Introzzi [122a,122b], P. Ioannou [9,*], M. Iodice [135a], K. Iordanidou [36], V. Ippolito [58], A. Irles Quiles [166], C. Isaksson [164], M. Ishino [70], M. Ishitsuka [158],

R. Ishmukhametov [112], C. Issever [121], S. Istin [19a], F. Ito [161], J.M. Iturbe Ponce [86], R. Iuppa [134a,134b], J. Ivarsson [83], W. Iwanski [40], H. Iwasaki [68], J.M. Izen [42], V. Izzo [105a], S. Jabbar [3], B. Jackson [123], M. Jackson [76], P. Jackson [1], V. Jain [2], K.B. Jakobi [85], K. Jakobs [49], S. Jakobsen [31], T. Jakoubek [128], D.O. Jamin [115], D.K. Jana [81], E. Jansen [80], R. Jansky [63], J. Janssen [22], M. Janus [55], G. Jarlskog [83], N. Javadov [67,b], T. Javůrek [49], F. Jeanneau [137], L. Jeanty [15], J. Jejelava [52a,t], G.-Y. Jeng [151], D. Jennens [90], P. Jenni [49,u], J. Jentzsch [44], C. Jeske [169], S. Jézéquel [5], H. Ji [172], J. Jia [149], H. Jiang [65], Y. Jiang [34b], S. Jiggins [80], J. Jimenez Pena [166], S. Jin [34a], A. Jinaru [27b], O. Jinnouchi [158], P. Johansson [140], K.A. Johns [7], W.J. Johnson [139], K. Jon-And [147a,147b], G. Jones [169], R.W.L. Jones [74], S. Jones [7], T.J. Jones [76], J. Jongmanns [59a], P.M. Jorge [127a,127b], J. Jovicevic [160a], X. Ju [172], A. Juste Rozas [12,p], M.K. Köhler [171], A. Kaczmarska [40], M. Kado [118], H. Kagan [112], M. Kagan [144], S.J. Kahn [87], E. Kajomovitz [46], C.W. Kalderon [121], A. Kaluza [85], S. Kama [41], A. Kamenshchikov [131], N. Kanaya [156], S. Kaneti [29], V.A. Kantserov [99], J. Kanzaki [68], B. Kaplan [111], L.S. Kaplan [172], A. Kapliy [32], D. Kar [146c], K. Karakostas [10], A. Karamaoun [3], N. Karastathis [10,108], M.J. Kareem [55], 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 [161], L. Kashif [172], R.D. Kass [112], A. Kastanas [14], Y. Kataoka [156], C. Kato [156], A. Katre [50], J. Katzy [43], K. Kawade [104], K. Kawagoe [72], T. Kawamoto [156], G. Kawamura [55], S. Kazama [156], V.F. Kazanin [110,c], R. Keeler [168], R. Kehoe [41], J.S. Keller [43], J.J. Kempster [79], H. Keoshkerian [86], O. Kepka [128], B.P. Kerševan [77], S. Kersten [174], R.A. Keyes [89], F. Khalil-zada [11], H. Khandanyan [147a,147b], A. Khanov [115], A.G. Kharlamov [110,c], T.J. Khoo [29], V. Khovanskiy [98], E. Khramov [67], J. Khubua [52b,v], S. Kido [69], H.Y. Kim [8], S.H. Kim [161], Y.K. Kim [32], N. Kimura [155], O.M. Kind [16], B.T. King [76], M. King [166], S.B. King [167], J. Kirk [132], A.E. Kiryunin [102], T. Kishimoto [69], D. Kisielewska [39a], F. Kiss [49], K. Kiuchi [161], O. Kivernyk [137], E. Kladiva [145b], M.H. Klein [36], M. Klein [76], U. Klein [76], K. Kleinknecht [85], P. Klimek [147a,147b], A. Klimentov [26], R. Klingenberg [44], J.A. Klinger [140], T. Klioutchnikova [31], E.-E. Kluge [59a], P. Kluit [108], S. Kluth [102], J. Knapik [40], E. Kneringer [63], E.B.F.G. Knoops [87], A. Knue [54], A. Kobayashi [156], D. Kobayashi [158], T. Kobayashi [156], M. Kobel [45], M. Kocian [144], P. Kodys [130], T. Koffas [30], E. Koffeman [108], L.A. Kogan [121], T. Kohriki [68], T. Koi [144], H. Kolanoski [16], M. Kolb [59b], I. Koletsou [5], A.A. Komar [97,*], Y. Komori [156], T. Kondo [68], N. Kondrashova [43], K. Köneke [49], A.C. König [107], T. Kono [68,w], R. Konoplich [111,x], N. Konstantinidis [80], R. Kopeliansky [62], S. Koperny [39a], L. Köpke [85], A.K. Kopp [49], K. Korcyl [40], K. Kordas [155], A. Korn [80], A.A. Korol [110,c], I. Korolkov [12], E.V. Korolkova [140], O. Kortner [102], S. Kortner [102], T. Kosek [130], V.V. Kostyukhin [22], V.M. Kotov [67], A. Kotwal [46], A. Kourkoumeli-Charalampidi [155], C. Kourkoumelis [9], V. Kouskoura [26], A. Koutsman [160a], A.B. Kowalewska [40], R. Kowalewski [168], T.Z. Kowalski [39a], W. Kozanecki [137], A.S. Kozhin [131], V.A. Kramarenko [100], G. Kramberger [77], D. Krasnopevtsev [99], M.W. Krasny [82], A. Krasznahorkay [31], J.K. Kraus [22], A. Kravchenko [26], M. Kretz [59c], J. Kretzschmar [76], K. Kreutzfeldt [53], P. Krieger [159], K. Krizka [32], K. Kroeninger [44], H. Kroha [102], J. Kroll [123], J. Kroseberg [22], J. Krstic [13], U. Kruchonak [67], H. Krüger [22], N. Krumnack [65], A. Kruse [172], M.C. Kruse [46], M. Kruskal [23], T. Kubota [90], H. Kucuk [80], S. Kuday [4b], J.T. Kuechler [174], S. Kuehn [49], A. Kugel [59c], F. Kuger [173], A. Kuhl [138], T. Kuhl [43], V. Kukhtin [67], R. Kukla [137], Y. Kulchitsky [94], S. Kuleshov [33b], M. Kuna [133a,133b], T. Kunigo [70], A. Kupco [128], H. Kurashige [69], Y.A. Kurochkin [94], V. Kus [128], E.S. Kuwertz [168], M. Kuze [158], J. Kvita [116], T. Kwan [168], D. Kyriazopoulos [140], A. La Rosa [102], J.L. La Rosa Navarro [25d], L. La Rotonda [38a,38b], C. Lacasta [166], F. Lacava [133a,133b], J. Lacey [30], H. Lacker [16], D. Lacour [82], V.R. Lacuesta [166], E. Ladygin [67], R. Lafaye [5], B. Laforge [82], T. Lagouri [175], S. Lai [55], S. Lammers [62], W. Lampl [7], E. Lançon [137], U. Landgraf [49], M.P.J. Landon [78], V.S. Lang [59a], J.C. Lange [12], A.J. Lankford [66], F. Lanni [26], K. Lantzsch [22], A. Lanza [122a], S. Laplace [82], C. Lapoire [31], J.F. Laporte [137], T. Lari [93a], F. Lasagni Manghi [21a,21b], M. Lassnig [31], P. Laurelli [48], W. Lavrijsen [15], A.T. Law [138], P. Laycock [76], T. Lazovich [58], M. Lazzaroni [93a,93b], O. Le Dortz [82], E. Le Guirriec [87], E. Le Menedeu [12], E.P. Le Quilleuc [137], M. LeBlanc [168], T. LeCompte [6], F. Ledroit-Guillon [56], C.A. Lee [26], S.C. Lee [152], L. Lee [1], G. Lefebvre [82], M. Lefebvre [168], F. Legger [101], C. Leggett [15], A. Lehan [76], G. Lehmann Miotto [31], X. Lei [7], W.A. Leight [30], A. Leisos [155,y], A.G. Leister [175], M.A.L. Leite [25d], R. Leitner [130], D. Lellouch [171], B. Lemmer [55], K.J.C. Leney [80], T. Lenz [22], B. Lenzi [31], R. Leone [7], S. Leone [125a,125b], C. Leonidopoulos [47], S. Leontsinis [10], C. Leroy [96], A.A.J. Lesage [137], C.G. Lester [29], M. Levchenko [124], J. Levêque [5], D. Levin [91], L.J. Levinson [171], M. Levy [18], A.M. Leyko [22], M. Leyton [42], B. Li [34b,z], H. Li [149], H.L. Li [32], L. Li [46], L. Li [34e], Q. Li [34a], S. Li [46], X. Li [86], Y. Li [142], Z. Liang [138], H. Liao [35], B. Liberti [134a], A. Liblong [159], P. Lichard [31], K. Lie [165], J. Liebal [22], W. Liebig [14], C. Limbach [22],

A. Limosani [151], S.C. Lin [152,aa], T.H. Lin [85], B.E. Lindquist [149], E. Lipeles [123], A. Lipniacka [14], M. Lisovyi [59b], T.M. Liss [165], D. Lissauer [26], A. Lister [167], A.M. Litke [138], B. Liu [152,ab], D. Liu [152], H. Liu [91], H. Liu [26], J. Liu [87], J.B. Liu [34b], K. Liu [87], L. Liu [165], M. Liu [46], M. Liu [34b], Y.L. Liu [34b], Y. Liu [34b], M. Livan [122a,122b], A. Lleres [56], J. Llorente Merino [84], S.L. Lloyd [78], F. Lo Sterzo [152], E. Lobodzinska [43], P. Loch [7], W.S. Lockman [138], F.K. Loebinger [86], A.E. Loevschall-Jensen [37], K.M. Loew [24], A. Loginov [175], T. Lohse [16], K. Lohwasser [43], M. Lokajicek [128], B.A. Long [23], J.D. Long [165], R.E. Long [74], L. Longo [75a,75b], K.A. Looper [112], L. Lopes [127a], D. Lopez Mateos [58], B. Lopez Paredes [140], I. Lopez Paz [12], A. Lopez Solis [82], J. Lorenz [101], N. Lorenzo Martinez [62], M. Losada [20], P.J. Lösel [101], X. Lou [34a], A. Lounis [118], J. Love [6], P.A. Love [74], H. Lu [61a], N. Lu [91], H.J. Lubatti [139], C. Luci [133a,133b], A. Lucotte [56], C. Luedtke [49], F. Luehring [62], W. Lukas [63], L. Luminari [133a], O. Lundberg [147a,147b], B. Lund-Jensen [148], D. Lynn [26], R. Lysak [128], E. Lytken [83], H. Ma [26], L.L. Ma [34d], G. Maccarrone [48], A. Macchiolo [102], C.M. Macdonald [140], B. Maček [77], J. Machado Miguens [123,127b], D. Madaffari [87], R. Madar [35], H.J. Maddocks [164], W.F. Mader [45], A. Madsen [43], J. Maeda [69], S. Maeland [14], T. Maeno [26], A. Maevskiy [100], E. Magradze [55], J. Mahlstedt [108], C. Maiani [118], C. Maidantchik [25a], 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 [40], V.P. Maleev [124], F. Malek [56], U. Mallik [64], D. Malon [6], C. Malone [144], S. Maltezos [10], V.M. Malyshev [110], S. Malyukov [31], J. Mamuzic [43], G. Mancini [48], B. Mandelli [31], L. Mandelli [93a], I. Mandić [77], J. Maneira [127a,127b], L. Manhaes de Andrade Filho [25b], J. Manjarres Ramos [160b], A. Mann [101], B. Mansoulie [137], R. Mantifel [89], M. Mantoani [55], S. Manzoni [93a,93b], L. Mapelli [31], G. Marceca [28], L. March [50], G. Marchiori [82], M. Marcisovsky [128], M. Marjanovic [13], D.E. Marley [91], F. Marroquim [25a], S.P. Marsden [86], Z. Marshall [15], L.F. Marti [17], S. Marti-Garcia [166], B. Martin [92], T.A. Martin [169], V.J. Martin [47], B. Martin dit Latour [14], M. Martinez [12,p], S. Martin-Haugh [132], V.S. Martoiu [27b], A.C. Martyniuk [80], M. Marx [139], F. Marzano [133a], A. Marzin [31], L. Masetti [85], T. Mashimo [156], R. Mashinistov [97], J. Masik [86], A.L. Maslennikov [110,c], I. Massa [21a,21b], L. Massa [21a,21b], P. Mastrandrea [5], A. Mastroberardino [38a,38b], T. Masubuchi [156], P. Mättig [174], J. Mattmann [85], J. Maurer [27b], S.J. Maxfield [76], D.A. Maximov [110,c], R. Mazini [152], S.M. Mazza [93a,93b], N.C. Mc Fadden [106], G. Mc Goldrick [159], S.P. Mc Kee [91], A. McCarn [91], R.L. McCarthy [149], T.G. McCarthy [30], L.I. McClymont [80], K.W. McFarlane [57,*], J.A. Mcfayden [80], G. Mchedlidze [55], S.J. McMahon [132], R.A. McPherson [168,l], M. Medinnis [43], S. Meehan [139], S. Mehlhase [101], A. Mehta [76], K. Meier [59a], C. Meineck [101], B. Meirose [42], B.R. Mellado Garcia [146c], F. Meloni [17], A. Mengarelli [21a,21b], S. Menke [102], E. Meoni [162], K.M. Mercurio [58], S. Mergelmeyer [16], P. Mermod [50], L. Merola [105a,105b], C. Meroni [93a], F.S. Merritt [32], A. Messina [133a,133b], J. Metcalfe [6], A.S. Mete [66], C. Meyer [85], C. Meyer [123], J-P. Meyer [137], J. Meyer [108], H. Meyer Zu Theenhausen [59a], R.P. Middleton [132], S. Miglioranzi [163a,163c], L. Mijović [22], G. Mikenberg [171], M. Mikestikova [128], M. Mikuž [77], M. Milesi [90], A. Milic [31], D.W. Miller [32], C. Mills [47], A. Milov [171], D.A. Milstead [147a,147b], A.A. Minaenko [131], Y. Minami [156], I.A. Minashvili [67], A.I. Mincer [111], B. Mindur [39a], M. Mineev [67], Y. Ming [172], L.M. Mir [12], K.P. Mistry [123], T. Mitani [170], J. Mitrevski [101], V.A. Mitsou [166], A. Miucci [50], P.S. Miyagawa [140], J.U. Mjörnmark [83], T. Moa [147a,147b], K. Mochizuki [87], S. Mohapatra [36], W. Mohr [49], S. Molander [147a,147b], R. Moles-Valls [22], R. Monden [70], M.C. Mondragon [92], K. Mönig [43], J. Monk [37], E. Monnier [87], A. Montalbano [149], J. Montejo Berlingen [31], F. Monticelli [73], S. Monzani [93a,93b], R.W. Moore [3], N. Morange [118], D. Moreno [20], M. Moreno Llácer [55], P. Morettini [51a], D. Mori [143], T. Mori [156], M. Morii [58], M. Morinaga [156], V. Morisbak [120], S. Moritz [85], A.K. Morley [151], G. Mornacchi [31], J.D. Morris [78], S.S. Mortensen [37], L. Morvaj [149], M. Mosidze [52b], J. Moss [144], K. Motohashi [158], R. Mount [144], E. Mountricha [26], S.V. Mouraviev [97,*], E.J.W. Moyse [88], S. Muanza [87], R.D. Mudd [18], F. Mueller [102], J. Mueller [126], R.S.P. Mueller [101], T. Mueller [29], D. Muenstermann [74], P. Mullen [54], G.A. Mullier [17], F.J. Munoz Sanchez [86], J.A. Murillo Quijada [18], W.J. Murray [169,132], H. Musheghyan [55], A.G. Myagkov [131,ac], M. Myska [129], B.P. Nachman [144], O. Nackenhorst [50], J. Nadal [55], K. Nagai [121], R. Nagai [68,w], Y. Nagai [87], K. Nagano [68], Y. Nagasaka [60], K. Nagata [161], M. Nagel [102], E. Nagy [87], A.M. Nairz [31], Y. Nakahama [31], K. Nakamura [68], T. Nakamura [156], I. Nakano [113], H. Namasivayam [42], R.F. Naranjo Garcia [43], R. Narayan [32], D.I. Narrias Villar [59a], I. Naryshkin [124], T. Naumann [43], G. Navarro [20], R. Nayyar [7], H.A. Neal [91], P.Yu. Nechaeva [97], T.J. Neep [86], P.D. Nef [144], A. Negri [122a,122b], M. Negrini [21a], S. Nektarijevic [107], C. Nellist [118], A. Nelson [66], S. Nemecek [128], P. Nemethy [111], A.A. Nepomuceno [25a], M. Nessi [31,ad], M.S. Neubauer [165], M. Neumann [174], R.M. Neves [111], P. Nevski [26], P.R. Newman [18], D.H. Nguyen [6], R.B. Nickerson [121], R. Nicolaidou [137], B. Nicquevert [31], J. Nielsen [138], A. Nikiforov [16], V. Nikolaenko [131,ac],

I. Nikolic-Audit [82], K. Nikolopoulos [18], J.K. Nilsen [120], P. Nilsson [26], Y. Ninomiya [156], A. Nisati [133a], R. Nisius [102], T. Nobe [156], L. Nodulman [6], M. Nomachi [119], I. Nomidis [30], T. Nooney [78], S. Norberg [114], M. Nordberg [31], O. Novgorodova [45], S. Nowak [102], M. Nozaki [68], L. Nozka [116], K. Ntekas [10], E. Nurse [80], F. Nuti [90], F. O'grady [7], D.C. O'Neil [143], A.A. O'Rourke [43], V. O'Shea [54], F.G. Oakham [30,d], H. Oberlack [102], T. Obermann [22], J. Ocariz [82], A. Ochi [69], I. Ochoa [36], J.P. Ochoa-Ricoux [33a], S. Oda [72], S. Odaka [68], H. Ogren [62], A. Oh [86], S.H. Oh [46], C.C. Ohm [15], H. Ohman [164], H. Oide [31], H. Okawa [161], Y. Okumura [32], T. Okuyama [68], A. Olariu [27b], L.F. Oleiro Seabra [127a], S.A. Olivares Pino [47], D. Oliveira Damazio [26], A. Olszewski [40], J. Olszowska [40], A. Onofre [127a,127e], K. Onogi [104], P.U.E. Onyisi [32,s], C.J. Oram [160a], M.J. Oreglia [32], Y. Oren [154], D. Orestano [135a,135b], N. Orlando [61b], R.S. Orr [159], B. Osculati [51a,51b], R. Ospanov [86], G. Otero y Garzon [28], H. Otono [72], M. Ouchrif [136d], F. Ould-Saada [120], A. Ouraou [137], K.P. Oussoren [108], Q. Ouyang [34a], A. Ovcharova [15], M. Owen [54], R.E. Owen [18], V.E. Ozcan [19a], N. Ozturk [8], K. Pachal [143], A. Pacheco Pages [12], C. Padilla Aranda [12], M. Pagáčová [49], S. Pagan Griso [15], F. Paige [26], P. Pais [88], K. Pajchel [120], G. Palacino [160b], S. Palestini [31], M. Palka [39b], D. Pallin [35], A. Palma [127a,127b], E. St. Panagiotopoulou [10], C.E. Pandini [82], J.G. Panduro Vazquez [79], P. Pani [147a,147b], S. Panitkin [26], D. Pantea [27b], L. Paolozzi [50], Th.D. Papadopoulou [10], K. Papageorgiou [155], A. Paramonov [6], D. Paredes Hernandez [175], M.A. Parker [29], K.A. Parker [140], F. Parodi [51a,51b], J.A. Parsons [36], U. Parzefall [49], V. Pascuzzi [159], E. Pasqualucci [133a], S. Passaggio [51a], F. Pastore [135a,135b,*], Fr. Pastore [79], G. Pásztor [30], S. Pataraia [174], N.D. Patel [151], J.R. Pater [86], T. Pauly [31], J. Pearce [168], B. Pearson [114], L.E. Pedersen [37], M. Pedersen [120], S. Pedraza Lopez [166], R. Pedro [127a,127b], S.V. Peleganchuk [110,c], D. Pelikan [164], O. Penc [128], C. Peng [34a], H. Peng [34b], J. Penwell [62], B.S. Peralva [25b], D.V. Perepelitsa [26], E. Perez Codina [160a], L. Perini [93a,93b], H. Pernegger [31], S. Perrella [105a,105b], R. Peschke [43], V.D. Peshekhonov [67], K. Peters [31], R.F.Y. Peters [86], B.A. Petersen [31], T.C. Petersen [37], E. Petit [56], A. Petridis [1], C. Petridou [155], P. Petroff [118], E. Petrolo [133a], M. Petrov [121], F. Petrucci [135a,135b], N.E. Pettersson [158], A. Peyaud [137], R. Pezoa [33b], P.W. Phillips [132], G. Piacquadio [144], E. Pianori [169], A. Picazio [88], E. Piccaro [78], M. Piccinini [21a,21b], M.A. Pickering [121], R. Piegaia [28], J.E. Pilcher [32], A.D. Pilkington [86], A.W.J. Pin [86], J. Pina [127a,127b,127d], M. Pinamonti [163a,163c,ae], J.L. Pinfold [3], A. Pingel [37], S. Pires [82], H. Pirumov [43], M. Pitt [171], L. Plazak [145a], M.-A. Pleier [26], V. Pleskot [85], E. Plotnikova [67], P. Plucinski [147a,147b], D. Pluth [65], R. Poettgen [147a,147b], L. Poggioli [118], D. Pohl [22], G. Polesello [122a], A. Poley [43], A. Policicchio [38a,38b], R. Polifka [159], A. Polini [21a], C.S. Pollard [54], V. Polychronakos [26], K. Pommès [31], L. Pontecorvo [133a], B.G. Pope [92], G.A. Popeneciu [27c], D.S. Popovic [13], A. Poppleton [31], S. Pospisil [129], K. Potamianos [15], I.N. Potrap [67], C.J. Potter [29], C.T. Potter [117], G. Poulard [31], J. Poveda [31], V. Pozdnyakov [67], M.E. Pozo Astigarraga [31], P. Pralavorio [87], A. Pranko [15], S. Prell [65], D. Price [86], L.E. Price [6], M. Primavera [75a], S. Prince [89], M. Proissl [47], K. Prokofiev [61c], F. Prokoshin [33b], S. Protopopescu [26], J. Proudfoot [6], M. Przybycien [39a], D. Puddu [135a,135b], D. Puldon [149], M. Purohit [26,af], P. Puzo [118], J. Qian [91], G. Qin [54], Y. Qin [86], A. Quadt [55], D.R. Quarrie [15], W.B. Quayle [163a,163b], M. Queitsch-Maitland [86], D. Quilty [54], S. Raddum [120], V. Radeka [26], V. Radescu [43], S.K. Radhakrishnan [149], P. Radloff [117], P. Rados [90], F. Ragusa [93a,93b], G. Rahal [177], S. Rajagopalan [26], M. Rammensee [31], C. Rangel-Smith [164], M.G. Ratti [93a,93b], F. Rauscher [101], S. Rave [85], T. Ravenscroft [54], M. Raymond [31], A.L. Read [120], N.P. Readioff [76], D.M. Rebuzzi [122a,122b], A. Redelbach [173], G. Redlinger [26], R. Reece [138], K. Reeves [42], L. Rehnisch [16], J. Reichert [123], H. Reisin [28], C. Rembser [31], H. Ren [34a], 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 [39b], O. Ricken [22], M. Ridel [82], P. Rieck [16], C.J. Riegel [174], J. Rieger [55], O. Rifki [114], M. Rijssenbeek [149], A. Rimoldi [122a,122b], L. Rinaldi [21a], B. Ristić [50], E. Ritsch [31], I. Riu [12], F. Rizatdinova [115], E. Rizvi [78], S.H. Robertson [89,l], A. Robichaud-Veronneau [89], D. Robinson [29], J.E.M. Robinson [43], A. Robson [54], C. Roda [125a,125b], Y. Rodina [87], A. Rodriguez Perez [12], D. Rodriguez Rodriguez [166], S. Roe [31], C.S. Rogan [58], O. Røhne [120], A. Romaniouk [99], M. Romano [21a,21b], S.M. Romano Saez [35], E. Romero Adam [166], N. Rompotis [139], M. Ronzani [49], L. Roos [82], E. Ros [166], S. Rosati [133a], K. Rosbach [49], P. Rose [138], O. Rosenthal [142], V. Rossetti [147a,147b], E. Rossi [105a,105b], L.P. Rossi [51a], J.H.N. Rosten [29], R. Rosten [139], M. Rotaru [27b], I. Roth [171], J. Rothberg [139], D. Rousseau [118], C.R. Royon [137], A. Rozanov [87], Y. Rozen [153], X. Ruan [146c], F. Rubbo [144], I. Rubinskiy [43], V.I. Rud [100], M.S. Rudolph [159], F. Rühr [49], A. Ruiz-Martinez [31], Z. Rurikova [49], N.A. Rusakovich [67], A. Ruschke [101], H.L. Russell [139], J.P. Rutherfoord [7], N. Ruthmann [31], Y.F. Ryabov [124], M. Rybar [165], G. Rybkin [118], S. Ryu [6], A. Ryzhov [131], A.F. Saavedra [151], G. Sabato [108], S. Sacerdoti [28], H.F-W. Sadrozinski [138], R. Sadykov [67], F. Safai Tehrani [133a], P. Saha [109],

M. Sahinsoy [59a], M. Saimpert [137], T. Saito [156], H. Sakamoto [156], Y. Sakurai [170], G. Salamanna [135a,135b], A. Salamon [134a,134b], J.E. Salazar Loyola [33b], D. Salek [108], P.H. Sales De Bruin [139], D. Salihagic [102], A. Salnikov [144], J. Salt [166], D. Salvatore [38a,38b], F. Salvatore [150], A. Salvucci [61a], A. Salzburger [31], D. Sammel [49], D. Sampsonidis [155], A. Sanchez [105a,105b], J. Sánchez [166], V. Sanchez Martinez [166], H. Sandaker [120], R.L. Sandbach [78], H.G. Sander [85], M.P. Sanders [101], M. Sandhoff [174], C. Sandoval [20], R. Sandstroem [102], D.P.C. Sankey [132], M. Sannino [51a,51b], A. Sansoni [48], C. Santoni [35], R. Santonico [134a,134b], H. Santos [127a], I. Santoyo Castillo [150], K. Sapp [126], A. Sapronov [67], J.G. Saraiva [127a,127d], B. Sarrazin [22], O. Sasaki [68], Y. Sasaki [156], K. Sato [161], G. Sauvage [5,*], E. Sauvan [5], G. Savage [79], P. Savard [159,d], C. Sawyer [132], L. Sawyer [81,o], J. Saxon [32], C. Sbarra [21a], A. Sbrizzi [21a,21b], T. Scanlon [80], D.A. Scannicchio [66], M. Scarcella [151], V. Scarfone [38a,38b], J. Schaarschmidt [171], P. Schacht [102], D. Schaefer [31], R. Schaefer [43], J. Schaeffer [85], S. Schaepe [22], S. Schaetzel [59b], U. Schäfer [85], A.C. Schaffer [118], D. Schaile [101], R.D. Schamberger [149], V. Scharf [59a], V.A. Schegelsky [124], D. Scheirich [130], M. Schernau [66], C. Schiavi [51a,51b], C. Schillo [49], M. Schioppa [38a,38b], S. Schlenker [31], K. Schmieden [31], C. Schmitt [85], S. Schmitt [43], S. Schmitz [85], B. Schneider [160a], Y.J. Schnellbach [76], U. Schnoor [49], L. Schoeffel [137], A. Schoening [59b], B.D. Schoenrock [92], E. Schopf [22], A.L.S. Schorlemmer [44], M. Schott [85], D. Schouten [160a], J. Schovancova [8], S. Schramm [50], M. Schreyer [173], N. Schuh [85], M.J. Schultens [22], H.-C. Schultz-Coulon [59a], H. Schulz [16], M. Schumacher [49], B.A. Schumm [138], Ph. Schune [137], C. Schwanenberger [86], A. Schwartzman [144], T.A. Schwarz [91], Ph. Schwegler [102], H. Schweiger [86], Ph. Schwemling [137], R. Schwienhorst [92], J. Schwindling [137], T. Schwindt [22], G. Sciolla [24], F. Scuri [125a,125b], F. Scutti [90], J. Searcy [91], P. Seema [22], S.C. Seidel [106], A. Seiden [138], F. Seifert [129], J.M. Seixas [25a], G. Sekhniaidze [105a], K. Sekhon [91], S.J. Sekula [41], D.M. Seliverstov [124,*], N. Semprini-Cesari [21a,21b], C. Serfon [31], L. Serin [118], L. Serkin [163a,163b], M. Sessa [135a,135b], R. Seuster [160a], H. Severini [114], T. Sfiligoj [77], F. Sforza [31], A. Sfyrla [50], E. Shabalina [55], N.W. Shaikh [147a,147b], L.Y. Shan [34a], R. Shang [165], J.T. Shank [23], M. Shapiro [15], P.B. Shatalov [98], K. Shaw [163a,163b], S.M. Shaw [86], A. Shcherbakova [147a,147b], C.Y. Shehu [150], P. Sherwood [80], L. Shi [152,ag], S. Shimizu [69], C.O. Shimmin [66], M. Shimojima [103], M. Shiyakova [67,ah], A. Shmeleva [97], D. Shoaleh Saadi [96], M.J. Shochet [32], S. Shojaii [93a,93b], S. Shrestha [112], E. Shulga [99], M.A. Shupe [7], P. Sicho [128], P.E. Sidebo [148], O. Sidiropoulou [173], D. Sidorov [115], A. Sidoti [21a,21b], F. Siegert [45], Dj. Sijacki [13], J. Silva [127a,127d], S.B. Silverstein [147a], V. Simak [129], O. Simard [5], Lj. Simic [13], S. Simion [118], E. Simioni [85], B. Simmons [80], D. Simon [35], M. Simon [85], P. Sinervo [159], N.B. Sinev [117], M. Sioli [21a,21b], G. Siragusa [173], S.Yu. Sivoklokov [100], J. Sjölin [147a,147b], T.B. Sjursen [14], M.B. Skinner [74], H.P. Skottowe [58], P. Skubic [114], M. Slater [18], T. Slavicek [129], M. Slawinska [108], K. Sliwa [162], V. Smakhtin [171], B.H. Smart [5], L. Smestad [14], S.Yu. Smirnov [99], Y. Smirnov [99], L.N. Smirnova [100,ai], O. Smirnova [83], M.N.K. Smith [36], R.W. Smith [36], M. Smizanska [74], K. Smolek [129], A.A. Snesarev [97], G. Snidero [78], S. Snyder [26], R. Sobie [168,l], F. Socher [45], A. Soffer [154], D.A. Soh [152,ag], G. Sokhrannyi [77], C.A. Solans Sanchez [31], M. Solar [129], E.Yu. Soldatov [99], U. Soldevila [166], A.A. Solodkov [131], A. Soloshenko [67], O.V. Solovyanov [131], V. Solovyev [124], P. Sommer [49], H.Y. Song [34b,z], N. Soni [1], A. Sood [15], A. Sopczak [129], V. Sopko [129], V. Sorin [12], D. Sosa [59b], C.L. Sotiropoulou [125a,125b], R. Soualah [163a,163c], A.M. Soukharev [110,c], D. South [43], B.C. Sowden [79], S. Spagnolo [75a,75b], M. Spalla [125a,125b], M. Spangenberg [169], F. Spanò [79], D. Sperlich [16], F. Spettel [102], R. Spighi [21a], G. Spigo [31], L.A. Spiller [90], M. Spousta [130], R.D. St. Denis [54,*], A. Stabile [93a], S. Staerz [31], J. Stahlman [123], R. Stamen [59a], S. Stamm [16], E. Stanecka [40], R.W. Stanek [6], C. Stanescu [135a], M. Stanescu-Bellu [43], M.M. Stanitzki [43], S. Stapnes [120], E.A. Starchenko [131], G.H. Stark [32], J. Stark [56], P. Staroba [128], P. Starovoitov [59a], R. Staszewski [40], P. Steinberg [26], B. Stelzer [143], H.J. Stelzer [31], O. Stelzer-Chilton [160a], H. Stenzel [53], G.A. Stewart [54], J.A. Stillings [22], M.C. Stockton [89], M. Stoebe [89], G. Stoicea [27b], P. Stolte [55], S. Stonjek [102], A.R. Stradling [8], A. Straessner [45], M.E. Stramaglia [17], J. Strandberg [148], S. Strandberg [147a,147b], A. Strandlie [120], M. Strauss [114], P. Strizenec [145b], R. Ströhmer [173], D.M. Strom [117], R. Stroynowski [41], A. Strubig [107], S.A. Stucci [17], B. Stugu [14], N.A. Styles [43], D. Su [144], J. Su [126], R. Subramaniam [81], S. Suchek [59a], Y. Sugaya [119], M. Suk [129], V.V. Sulin [97], S. Sultansoy [4c], T. Sumida [70], S. Sun [58], X. Sun [34a], J.E. Sundermann [49], K. Suruliz [150], G. Susinno [38a,38b], M.R. Sutton [150], S. Suzuki [68], M. Svatos [128], M. Swiatlowski [32], I. Sykora [145a], T. Sykora [130], D. Ta [49], C. Taccini [135a,135b], K. Tackmann [43], J. Taenzer [159], A. Taffard [66], R. Tafirout [160a], N. Taiblum [154], H. Takai [26], R. Takashima [71], H. Takeda [69], T. Takeshita [141], Y. Takubo [68], M. Talby [87], A.A. Talyshev [110,c], J.Y.C. Tam [173], K.G. Tan [90], J. Tanaka [156], R. Tanaka [118], S. Tanaka [68], B.B. Tannenwald [112], S. Tapia Araya [33b], S. Tapprogge [85],

S. Tarem [153], G.F. Tartarelli [93a], P. Tas [130], M. Tasevsky [128], T. Tashiro [70], E. Tassi [38a,38b], A. Tavares Delgado [127a,127b], Y. Tayalati [136d], A.C. Taylor [106], G.N. Taylor [90], P.T.E. Taylor [90], W. Taylor [160b], F.A. Teischinger [31], P. Teixeira-Dias [79], K.K. Temming [49], D. Temple [143], H. Ten Kate [31], P.K. Teng [152], J.J. Teoh [119], F. Tepel [174], S. Terada [68], K. Terashi [156], J. Terron [84], S. Terzo [102], M. Testa [48], R.J. Teuscher [159,l], T. Theveneaux-Pelzer [87], J.P. Thomas [18], J. Thomas-Wilsker [79], E.N. Thompson [36], P.D. Thompson [18], R.J. Thompson [86], A.S. Thompson [54], L.A. Thomsen [175], E. Thomson [123], M. Thomson [29], M.J. Tibbetts [15], R.E. Ticse Torres [87], V.O. Tikhomirov [97,aj], Yu.A. Tikhonov [110,c], S. Timoshenko [99], P. Tipton [175], S. Tisserant [87], K. Todome [158], T. Todorov [5,*], S. Todorova-Nova [130], J. Tojo [72], S. Tokár [145a], K. Tokushuku [68], E. Tolley [58], L. Tomlinson [86], M. Tomoto [104], L. Tompkins [144,ak], K. Toms [106], B. Tong [58], E. Torrence [117], H. Torres [143], E. Torró Pastor [139], J. Toth [87,al], F. Touchard [87], D.R. Tovey [140], T. Trefzger [173], L. Tremblet [31], A. Tricoli [31], I.M. Trigger [160a], S. Trincaz-Duvoid [82], M.F. Tripiana [12], W. Trischuk [159], B. Trocmé [56], A. Trofymov [43], C. Troncon [93a], M. Trottier-McDonald [15], M. Trovatelli [168], L. Truong [163a,163b], M. Trzebinski [40], A. Trzupek [40], J.C-L. Tseng [121], P.V. Tsiareshka [94], G. Tsipolitis [10], N. Tsirintanis [9], S. Tsiskaridze [12], V. Tsiskaridze [49], E.G. Tskhadadze [52a], K.M. Tsui [61a], I.I. Tsukerman [98], V. Tsulaia [15], S. Tsuno [68], D. Tsybychev [149], A. Tudorache [27b], V. Tudorache [27b], A.N. Tuna [58], S.A. Tupputi [21a,21b], S. Turchikhin [100,ai], D. Turecek [129], D. Turgeman [171], R. Turra [93a,93b], A.J. Turvey [41], P.M. Tuts [36], M. Tylmad [147a,147b], M. Tyndel [132], G. Ucchielli [21a,21b], I. Ueda [156], R. Ueno [30], M. Ughetto [147a,147b], F. Ukegawa [161], G. Unal [31], A. Undrus [26], G. Unel [66], F.C. Ungaro [90], Y. Unno [68], C. Unverdorben [101], J. Urban [145b], P. Urquijo [90], P. Urrejola [85], G. Usai [8], A. Usanova [63], L. Vacavant [87], V. Vacek [129], B. Vachon [89], C. Valderanis [85], E. Valdes Santurio [147a,147b], N. Valencic [108], S. Valentinetti [21a,21b], A. Valero [166], L. Valery [12], S. Valkar [130], S. Vallecorsa [50], J.A. Valls Ferrer [166], W. Van Den Wollenberg [108], P.C. Van Der Deijl [108], R. van der Geer [108], H. van der Graaf [108], N. van Eldik [153], P. van Gemmeren [6], J. Van Nieuwkoop [143], I. van Vulpen [108], M.C. van Woerden [31], M. Vanadia [133a,133b], W. Vandelli [31], R. Vanguri [123], A. Vaniachine [6], P. Vankov [108], G. Vardanyan [176], R. Vari [133a], E.W. Varnes [7], T. Varol [41], D. Varouchas [82], A. Vartapetian [8], K.E. Varvell [151], F. Vazeille [35], T. Vazquez Schroeder [89], J. Veatch [7], L.M. Veloce [159], F. Veloso [127a,127c], S. Veneziano [133a], A. Ventura [75a,75b], M. Venturi [168], N. Venturi [159], A. Venturini [24], V. Vercesi [122a], M. Verducci [133a,133b], W. Verkerke [108], J.C. Vermeulen [108], A. Vest [45,am], M.C. Vetterli [143,d], O. Viazlo [83], I. Vichou [165], T. Vickey [140], O.E. Vickey Boeriu [140], G.H.A. Viehhauser [121], S. Viel [15], R. Vigne [63], M. Villa [21a,21b], M. Villaplana Perez [93a,93b], E. Vilucchi [48], M.G. Vincter [30], V.B. Vinogradov [67], I. Vivarelli [150], S. Vlachos [10], M. Vlasak [129], M. Vogel [174], P. Vokac [129], G. Volpi [125a,125b], M. Volpi [90], H. von der Schmitt [102], E. von Toerne [22], V. Vorobel [130], K. Vorobev [99], M. Vos [166], R. Voss [31], J.H. Vossebeld [76], N. Vranjes [13], M. Vranjes Milosavljevic [13], V. Vrba [128], M. Vreeswijk [108], R. Vuillermet [31], I. Vukotic [32], Z. Vykydal [129], P. Wagner [22], W. Wagner [174], H. Wahlberg [73], S. Wahrmund [45], J. Wakabayashi [104], J. Walder [74], R. Walker [101], W. Walkowiak [142], V. Wallangen [147a,147b], C. Wang [152], C. Wang [34d,87], F. Wang [172], H. Wang [15], H. Wang [41], J. Wang [43], J. Wang [151], K. Wang [89], R. Wang [6], S.M. Wang [152], T. Wang [22], T. Wang [36], X. Wang [175], C. Wanotayaroj [117], A. Warburton [89], C.P. Ward [29], D.R. Wardrope [80], A. Washbrook [47], P.M. Watkins [18], A.T. Watson [18], I.J. Watson [151], M.F. Watson [18], G. Watts [139], S. Watts [86], B.M. Waugh [80], S. Webb [85], M.S. Weber [17], S.W. Weber [173], J.S. Webster [6], A.R. Weidberg [121], B. Weinert [62], J. Weingarten [55], C. Weiser [49], H. Weits [108], P.S. Wells [31], T. Wenaus [26], T. Wengler [31], S. Wenig [31], N. Wermes [22], M. Werner [49], P. Werner [31], M. Wessels [59a], J. Wetter [162], K. Whalen [117], A.M. Wharton [74], A. White [8], M.J. White [1], R. White [33b], S. White [125a,125b], D. Whiteson [66], F.J. Wickens [132], W. Wiedenmann [172], M. Wielers [132], P. Wienemann [22], C. Wiglesworth [37], L.A.M. Wiik-Fuchs [22], A. Wildauer [102], H.G. Wilkens [31], H.H. Williams [123], S. Williams [108], C. Willis [92], S. Willocq [88], J.A. Wilson [18], I. Wingerter-Seez [5], F. Winklmeier [117], O.J. Winston [150], B.T. Winter [22], M. Wittgen [144], J. Wittkowski [101], S.J. Wollstadt [85], M.W. Wolter [40], H. Wolters [127a,127c], B.K. Wosiek [40], J. Wotschack [31], M.J. Woudstra [86], K.W. Wozniak [40], M. Wu [56], M. Wu [32], S.L. Wu [172], X. Wu [50], Y. Wu [91], T.R. Wyatt [86], B.M. Wynne [47], S. Xella [37], D. Xu [34a], L. Xu [26], B. Yabsley [151], S. Yacoob [146a], R. Yakabe [69], D. Yamaguchi [158], Y. Yamaguchi [119], A. Yamamoto [68], S. Yamamoto [156], T. Yamanaka [156], K. Yamauchi [104], Y. Yamazaki [69], Z. Yan [23], H. Yang [34e], H. Yang [172], Y. Yang [152], Z. Yang [14], W-M. Yao [15], Y.C. Yap [82], Y. Yasu [68], E. Yatsenko [5], K.H. Yau Wong [22], J. Ye [41], S. Ye [26], I. Yeletskikh [67], A.L. Yen [58], E. Yildirim [43], K. Yorita [170], R. Yoshida [6], K. Yoshihara [123], C. Young [144], C.J.S. Young [31], S. Youssef [23], D.R. Yu [15], J. Yu [8], J.M. Yu [91], J. Yu [65], L. Yuan [69], S.P.Y. Yuen [22], I. Yusuff [29,an], B. Zabinski [40], R. Zaidan [34d], A.M. Zaitsev [131,ac],

N. Zakharchuk [43], J. Zalieckas [14], A. Zaman [149], S. Zambito [58], L. Zanello [133a,133b], D. Zanzi [90], C. Zeitnitz [174], M. Zeman [129], A. Zemla [39a], J.C. Zeng [165], Q. Zeng [144], K. Zengel [24], O. Zenin [131], T. Ženiš [145a], D. Zerwas [118], D. Zhang [91], F. Zhang [172], G. Zhang [34b,z], H. Zhang [34c], J. Zhang [6], L. Zhang [49], R. Zhang [22], R. Zhang [34b,ao], X. Zhang [34d], Z. Zhang [118], X. Zhao [41], Y. Zhao [34d,118], Z. Zhao [34b], A. Zhemchugov [67], J. Zhong [121], B. Zhou [91], C. Zhou [46], L. Zhou [36], L. Zhou [41], M. Zhou [149], N. Zhou [34f], C.G. Zhu [34d], H. Zhu [34a], J. Zhu [91], Y. Zhu [34b], X. Zhuang [34a], K. Zhukov [97], A. Zibell [173], D. Zieminska [62], N.I. Zimine [67], C. Zimmermann [85], S. Zimmermann [49], Z. Zinonos [55], M. Zinser [85], M. Ziolkowski [142], L. Živković [13], G. Zobernig [172], A. Zoccoli [21a,21b], M. zur Nedden [16], G. Zurzolo [105a,105b], L. Zwalinski [31]

[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] *Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan*
[12] *Institut de Física d'Altes Energies (IFAE), The Barcelona Institute of Science and Technology, Barcelona, Spain*
[13] *Institute of Physics, University of Belgrade, Belgrade, Serbia*
[14] *Department for Physics and Technology, University of Bergen, Bergen, Norway*
[15] *Physics Division, Lawrence Berkeley National Laboratory and University of California, Berkeley, CA, United States*
[16] *Department of Physics, Humboldt University, Berlin, Germany*
[17] *Albert Einstein Center for Fundamental Physics and Laboratory for High Energy Physics, University of Bern, Bern, Switzerland*
[18] *School of Physics and Astronomy, University of Birmingham, Birmingham, United Kingdom*
[19] [(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, Turkey;* [(e)] *Bahcesehir University, Faculty of Engineering and Natural Sciences, Istanbul, Turkey*
[20] *Centro de Investigaciones, Universidad Antonio Narino, Bogota, Colombia*
[21] [(a)] *INFN Sezione di Bologna;* [(b)] *Dipartimento di Fisica e Astronomia, Università di Bologna, Bologna, Italy*
[22] *Physikalisches Institut, University of Bonn, Bonn, Germany*
[23] *Department of Physics, Boston University, Boston, MA, United States*
[24] *Department of Physics, Brandeis University, Waltham, MA, United States*
[25] [(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*
[26] *Physics Department, Brookhaven National Laboratory, Upton, NY, United States*
[27] [(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*
[28] *Departamento de Física, Universidad de Buenos Aires, Buenos Aires, Argentina*
[29] *Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom*
[30] *Department of Physics, Carleton University, Ottawa, ON, Canada*
[31] *CERN, Geneva, Switzerland*
[32] *Enrico Fermi Institute, University of Chicago, Chicago, IL, United States*
[33] [(a)] *Departamento de Física, Pontificia Universidad Católica de Chile, Santiago;* [(b)] *Departamento de Física, Universidad Técnica Federico Santa María, Valparaíso, Chile*
[34] [(a)] *Institute of High Energy Physics, Chinese Academy of Sciences, Beijing;* [(b)] *Department of Modern Physics, University of Science and Technology of China, Anhui;* [(c)] *Department of Physics, Nanjing University, Jiangsu;* [(d)] *School of Physics, Shandong University, Shandong;* [(e)] *Department of Physics and Astronomy, Shanghai Key Laboratory for Particle Physics and Cosmology, Shanghai Jiao Tong University, Shanghai [ap];* [(f)] *Physics Department, Tsinghua University, Beijing 100084, China*
[35] *Laboratoire de Physique Corpusculaire, Clermont Université and Université Blaise Pascal and CNRS/IN2P3, Clermont-Ferrand, France*
[36] *Nevis Laboratory, Columbia University, Irvington, NY, United States*
[37] *Niels Bohr Institute, University of Copenhagen, Kobenhavn, Denmark*
[38] [(a)] *INFN Gruppo Collegato di Cosenza, Laboratori Nazionali di Frascati;* [(b)] *Dipartimento di Fisica, Università della Calabria, Rende, Italy*
[39] [(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*
[40] *Institute of Nuclear Physics Polish Academy of Sciences, Krakow, Poland*
[41] *Physics Department, Southern Methodist University, Dallas, TX, United States*
[42] *Physics Department, University of Texas at Dallas, Richardson, TX, United States*
[43] *DESY, Hamburg and Zeuthen, Germany*
[44] *Institut für Experimentelle Physik IV, Technische Universität Dortmund, Dortmund, Germany*
[45] *Institut für Kern- und Teilchenphysik, Technische Universität Dresden, Dresden, Germany*
[46] *Department of Physics, Duke University, Durham, NC, United States*
[47] *SUPA – School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom*
[48] *INFN Laboratori Nazionali di Frascati, Frascati, Italy*
[49] *Fakultät für Mathematik und Physik, Albert-Ludwigs-Universität, Freiburg, Germany*
[50] *Section de Physique, Université de Genève, Geneva, Switzerland*
[51] [(a)] *INFN Sezione di Genova;* [(b)] *Dipartimento di Fisica, Università di Genova, Genova, Italy*
[52] [(a)] *E. Andronikashvili Institute of Physics, Iv. Javakhishvili Tbilisi State University, Tbilisi;* [(b)] *High Energy Physics Institute, Tbilisi State University, Tbilisi, Georgia*
[53] *II Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen, Germany*
[54] *SUPA – School of Physics and Astronomy, University of Glasgow, Glasgow, United Kingdom*
[55] *II Physikalisches Institut, Georg-August-Universität, Göttingen, Germany*
[56] *Laboratoire de Physique Subatomique et de Cosmologie, Université Grenoble-Alpes, CNRS/IN2P3, Grenoble, France*
[57] *Department of Physics, Hampton University, Hampton, VA, United States*
[58] *Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge, MA, United States*
[59] [(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*

[60] Faculty of Applied Information Science, Hiroshima Institute of Technology, Hiroshima, Japan
[61] [(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
[62] Department of Physics, Indiana University, Bloomington, IN, United States
[63] Institut für Astro- und Teilchenphysik, Leopold-Franzens-Universität, Innsbruck, Austria
[64] University of Iowa, Iowa City, IA, United States
[65] Department of Physics and Astronomy, Iowa State University, Ames, IA, United States
[66] Department of Physics and Astronomy, University of California Irvine, Irvine, CA, 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] Department of Physics and Astronomy, University of Sheffield, Sheffield, United Kingdom
[141] Department of Physics, Shinshu University, Nagano, Japan
[142] Fachbereich Physik, Universität Siegen, Siegen, Germany
[143] Department of Physics, Simon Fraser University, Burnaby, BC, Canada
[144] SLAC National Accelerator Laboratory, Stanford, CA, United States
[145] [(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
[146] [(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
[147] [(a)] Department of Physics, Stockholm University; [(b)] The Oskar Klein Centre, Stockholm, Sweden
[148] Physics Department, Royal Institute of Technology, Stockholm, Sweden
[149] Departments of Physics & Astronomy and Chemistry, Stony Brook University, Stony Brook, NY, United States
[150] Department of Physics and Astronomy, University of Sussex, Brighton, United Kingdom
[151] School of Physics, University of Sydney, Sydney, Australia
[152] Institute of Physics, Academia Sinica, Taipei, Taiwan
[153] Department of Physics, Technion: Israel Institute of Technology, Haifa, Israel
[154] Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel
[155] Department of Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece
[156] International Center for Elementary Particle Physics and Department of Physics, The University of Tokyo, Tokyo, Japan
[157] Graduate School of Science and Technology, Tokyo Metropolitan University, Tokyo, Japan
[158] Department of Physics, Tokyo Institute of Technology, Tokyo, Japan
[159] Department of Physics, University of Toronto, Toronto, ON, Canada
[160] [(a)] TRIUMF, Vancouver, BC; [(b)] Department of Physics and Astronomy, York University, Toronto, ON, Canada
[161] Faculty of Pure and Applied Sciences, and Center for Integrated Research in Fundamental Science and Engineering, University of Tsukuba, Tsukuba, Japan
[162] Department of Physics and Astronomy, Tufts University, Medford, MA, United States
[163] [(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
[164] Department of Physics and Astronomy, University of Uppsala, Uppsala, Sweden
[165] Department of Physics, University of Illinois, Urbana, IL, United States
[166] Instituto de Física Corpuscular (IFIC) and Departamento de Física Atómica, Molecular y Nuclear and Departamento de Ingeniería Electrónica and Instituto de Microelectrónica de Barcelona (IMB-CNM), University of Valencia and CSIC, Valencia, Spain
[167] Department of Physics, University of British Columbia, Vancouver, BC, Canada
[168] Department of Physics and Astronomy, University of Victoria, Victoria, BC, Canada
[169] Department of Physics, University of Warwick, Coventry, United Kingdom
[170] Waseda University, Tokyo, Japan
[171] Department of Particle Physics, The Weizmann Institute of Science, Rehovot, Israel
[172] Department of Physics, University of Wisconsin, Madison, WI, United States
[173] Fakultät für Physik und Astronomie, Julius-Maximilians-Universität, Würzburg, Germany
[174] Fakultät für Mathematik und Naturwissenschaften, Fachgruppe Physik, Bergische Universität Wuppertal, Wuppertal, Germany
[175] Department of Physics, Yale University, New Haven, CT, United States
[176] Yerevan Physics Institute, Yerevan, Armenia
[177] 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 of America.
[f] Also at Department of Physics, California State University, Fresno, CA, United States.
[g] Also at Department of Physics, University of Fribourg, Fribourg, Switzerland.
[h] Also at Departament de Fisica de la Universitat Autonoma de Barcelona, Barcelona, Spain.
[i] Also at Departamento de Fisica e Astronomia, Faculdade de Ciencias, Universidade do Porto, Portugal.
[j] Also at Tomsk State University, Tomsk, Russia.
[k] Also at Universita di Napoli Parthenope, Napoli, Italy.
[l] Also at Institute of Particle Physics (IPP), Canada.
[m] Also at Department of Physics, St. Petersburg State Polytechnical University, St. Petersburg, Russia.
[n] Also at Department of Physics, The University of Michigan, Ann Arbor, MI, United States.
[o] Also at Louisiana Tech University, Ruston, LA, United States.
[p] Also at Institucio Catalana de Recerca i Estudis Avancats, ICREA, Barcelona, Spain.
[q] Also at Graduate School of Science, Osaka University, Osaka, Japan.
[r] Also at Department of Physics, National Tsing Hua University, Taiwan.
[s] Also at Department of Physics, The University of Texas at Austin, Austin, TX, United States.
[t] Also at Institute of Theoretical Physics, Ilia State University, Tbilisi, Georgia.
[u] Also at CERN, Geneva, Switzerland.
[v] Also at Georgian Technical University (GTU), Tbilisi, Georgia.
[w] Also at Ochadai Academic Production, Ochanomizu University, Tokyo, Japan.
[x] Also at Manhattan College, New York, NY, United States.
[y] Also at Hellenic Open University, Patras, Greece.
[z] Also at Institute of Physics, Academia Sinica, Taipei, Taiwan.
[aa] Also at Academia Sinica Grid Computing, Institute of Physics, Academia Sinica, Taipei, Taiwan.
[ab] Also at School of Physics, Shandong University, Shandong, China.
[ac] Also at Moscow Institute of Physics and Technology State University, Dolgoprudny, Russia.

[ad] Also at Section de Physique, Université de Genève, Geneva, Switzerland.
[ae] Also at International School for Advanced Studies (SISSA), Trieste, Italy.
[af] Also at Department of Physics and Astronomy, University of South Carolina, Columbia, SC, United States.
[ag] Also at School of Physics and Engineering, Sun Yat-sen University, Guangzhou, China.
[ah] Also at Institute for Nuclear Research and Nuclear Energy (INRNE) of the Bulgarian Academy of Sciences, Sofia, Bulgaria.
[ai] Also at Faculty of Physics, M.V. Lomonosov Moscow State University, Moscow, Russia.
[aj] Also at National Research Nuclear University MEPhI, Moscow, Russia.
[ak] Also at Department of Physics, Stanford University, Stanford, CA, United States.
[al] Also at Institute for Particle and Nuclear Physics, Wigner Research Centre for Physics, Budapest, Hungary.
[am] Also at Flensburg University of Applied Sciences, Flensburg, Germany.
[an] Also at University of Malaya, Department of Physics, Kuala Lumpur, Malaysia.
[ao] Also at CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France.
[ap] Also affiliated with PKU-CHEP.
[*] Deceased.