Physics Letters B 706 (2012) 276–294

Contents lists available at SciVerse ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

Measurement of the $W \to \tau \nu_\tau$ cross section in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS experiment ☆

ATLAS Collaboration *

ARTICLE INFO

Article history:
Received 20 August 2011
Received in revised form 21 November 2011
Accepted 27 November 2011
Available online 1 December 2011
Editor: H. Weerts

Keywords:
W boson
Standard Model
τ Lepton

ABSTRACT

The cross section for the production of W bosons with subsequent decay $W \to \tau \nu_\tau$ is measured with the ATLAS detector at the LHC. The analysis is based on a data sample that was recorded in 2010 at a proton–proton center-of-mass energy of $\sqrt{s} = 7$ TeV and corresponds to an integrated luminosity of 34 pb^{-1}. The cross section is measured in a region of high detector acceptance and then extrapolated to the full phase space. The product of the total W production cross section and the $W \to \tau \nu_\tau$ branching ratio is measured to be $\sigma^{\text{tot}}_{W \to \tau \nu_\tau} = 11.1 \pm 0.3\ (\text{stat}) \pm 1.7\ (\text{syst}) \pm 0.4\ (\text{lumi})$ nb.

© 2011 CERN. Published by Elsevier B.V. Open access under CC BY-NC-ND license.

1. Introduction

The study of processes with τ leptons in the final state is an important part of the ATLAS physics program, for example in view of searches for the Higgs boson or supersymmetry [1–3]. Decays of Standard Model particles to τ leptons, in particular $Z \to \tau\tau$ and $W \to \tau \nu_\tau$, are important background processes in such searches. Studies of the $W \to \tau \nu_\tau$ decay complement the measurement of W production in the muon and electron decay modes [4,5]. In addition, $W \to \tau \nu_\tau$ decays can be used to validate the reconstruction and identification techniques for τ leptons and the measurement of the missing transverse energy ($E_{\text{T}}^{\text{miss}}$), which are both fundamental signatures in a wide spectrum of measurements at the LHC.

At next-to-next-to-leading order (NNLO), the $W \to \tau \nu_\tau$ signal is predicted to be produced at $\sqrt{s} = 7$ TeV with a cross section times branching ratio of $\sigma \times \text{BR} = 10.46 \pm 0.52$ nb [6–8]. Since purely leptonic τ decays cannot be easily distinguished from electrons and muons from $W \to e\nu_e$ or $W \to \mu\nu_\mu$ decays, the analysis presented in this Letter uses only hadronically decaying τ leptons (τ_{h}). Events from $W \to \tau \nu_\tau$ production contain predominantly low-p_{T} W bosons decaying into τ leptons with typical visible transverse momenta between 10 and 40 GeV. In addition, the distribution of the missing transverse energy, associated with the neutrinos from the W and τ_{h} decays, has a maximum around 20 GeV and a significant tail up to about 80 GeV.

Previous measurements at hadron colliders of W boson production with the subsequent decay $W \to \tau \nu_\tau$ based on $p\bar{p}$ collisions were reported by the UA1 Collaboration [9] at center-of-mass energies of $\sqrt{s} = 546$ GeV and $\sqrt{s} = 630$ GeV and by the CDF and D0 Collaborations [10,11] at a center-of-mass energy of $\sqrt{s} = 1.8$ TeV.

In this Letter, we describe the measurement of this process with $\sqrt{s} = 7$ TeV pp collision data, which were recorded with the ATLAS experiment at the LHC.

2. The ATLAS detector

The ATLAS detector is described in Ref. [12]. The cylindrical coordinate system is defined with polar angles θ relative to the beamline and azimuthal angles ϕ in the plane transverse to the beam. Pseudorapidities η are defined as $\eta = -\ln\tan\frac{\theta}{2}$. Transverse momenta, p_{T}, are defined as the component of momentum perpedicular to the beamline. Distances are measured in the η–ϕ plane as $\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$.

Measurements of charged-particle trajectories and momenta are performed with silicon detectors in the pseudorapidity range $|\eta| < 2.5$, and also by a straw-tube tracking chamber in the range $|\eta| < 2.0$. Together, these systems form the inner tracking detector, which is contained in a 2 T magnetic field produced by a superconducting solenoid. These tracking detectors are surrounded by a finely segmented calorimeter system which provides three-dimensional reconstruction of particle showers up to $|\eta| < 4.9$. The electromagnetic calorimeter uses liquid argon as the active material and comprises separate barrel ($|\eta| < 1.5$), end-cap ($1.4 < |\eta| < 3.2$) and forward ($3.2 < |\eta| < 4.9$) components. The hadron

☆ © CERN for the benefit of the ATLAS Collaboration.

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

0370-2693/© 2011 CERN. Published by Elsevier B.V. Open access under CC BY-NC-ND license.
doi:10.1016/j.physletb.2011.11.057

calorimeter is based on scintillating tiles in the central region ($|\eta| < 1.7$). It is extended up to $|\eta| = 4.9$ by end-caps and forward calorimeters which use liquid argon. The muon spectrometer measures the deflection of muon tracks in the field of three large superconducting toroidal magnets. It is instrumented with trigger and high-precision tracking chambers.

The trigger system consists of three levels. The first level is implemented as a hardware trigger, while the decision on the following levels is based on software event processing similar to the offline reconstruction.

3. Data samples

The data used in this measurement were recorded in proton–proton collisions at a center-of-mass energy of $\sqrt{s} = 7$ TeV during the 2010 LHC run. The integrated luminosity of the data sample, considering only data-taking periods where all relevant detector subsystems were fully operational, is 34 pb^{-1} [13,14]. The data were collected using triggers combining the two main signatures of $W \to \tau_{\mathrm{h}}\nu_\tau$ decays, namely the presence of a hadronically decaying τ lepton and missing transverse energy.

Processes producing W or Z bosons that subsequently decay into electrons or muons constitute important backgrounds to this measurement if the lepton from the decay or an accompanying jet is misidentified as a hadronically decaying τ lepton. Here, the missing transverse energy signature arises from a W decay neutrino or the misreconstruction of jets or of other objects in the event. Also, $W \to \tau\nu_\tau$ decays with the τ decaying leptonically are considered as a background. Incompletely reconstructed $Z \to \tau\tau$ and $t\bar{t}$ decays can also enter the signal sample. The number of background events from these electroweak processes is referred to as N_{EW} in the following.

The production of W and Z bosons in association with jets is simulated with the PYTHIA [15] generator with the modified LO parton distribution function (PDF) MRSTLO* [16] and normalized to the NNLO cross section; $t\bar{t}$ processes are generated with MC@NLO [17], where parton showers and hadronization are simulated with HERWIG [18] and the underlying event with JIMMY [19]. The TAUOLA [20] and PHOTOS [21] programs are used to model the decay of τ leptons and the QED radiation of photons, respectively.

All simulated samples include multiple proton–proton interactions (pile-up) produced with PYTHIA using the ATLAS MC10 tune [22]. Those samples are passed through a full detector simulation based on GEANT4 [23,24]. The simulated events are reweighted so that the distribution of the number of reconstructed primary vertices per bunch crossing matches the data.

Due to their large production cross sections, QCD processes provide a significant background if quark/gluon jets (QCD jets) are misidentified as hadronic τ decays and a significant amount of $E_{\mathrm{T}}^{\mathrm{miss}}$ is measured, mainly due to incomplete reconstruction. The number of QCD background events N_{QCD} is estimated directly from data.

4. Object reconstruction

Electron candidates, which together with muons are relevant for the electroweak background, are reconstructed from a cluster in the electromagnetic calorimeter matched to a track in the inner tracking detector. The cluster must have a shower profile consistent with an electromagnetic shower [25]. Muon candidates are reconstructed by combining tracks in the muon spectrometer with tracks in the inner tracking detector [26].

Jets are reconstructed with the anti-k_t algorithm [27] with a radius parameter $R = 0.4$. The jet energies are calibrated [28] using a p_{T}- and η-dependent calibration scheme, corrected for losses in dead material and outside the jet cone [29]. All jets considered in this analysis are required to have a transverse momentum above 20 GeV and a pseudorapidity in the range $|\eta| < 4.5$.

Reconstructed jets within $|\eta| < 2.5$ provide the starting point (seed) for the reconstruction of hadronic τ decays. The direction of a τ_{h} candidate is taken directly from the corresponding seed jet. The energy is calibrated by applying a dedicated correction extracted from Monte Carlo to the sum of energies of the cells that form the clusters of the seed jet [30]. Therefore, the energy of the τ_{h} refers to the visible decay products. The transverse momentum is calculated as $p_{\mathrm{T}} = E\sin\theta$, i.e. τ_{h} candidates are treated as massless. Good-quality tracks are associated with a τ_{h} candidate if they are found within $\Delta R < 0.2$ around the seed jet axis. At least one track must be associated to the candidate.

The τ_{h} identification [30] is based on eight observables: The invariant mass of the τ decay products is calculated separately using the associated tracks and the associated clusters. The fact that the τ decay products are typically more collimated than QCD jets is quantified by calculating the transverse momentum-weighted radius from tracks and the energy-weighted radius from electromagnetic energy information. The fraction of transverse energy within $\Delta R < 0.1$ of the τ_{h} seed direction is used as well. Further discrimination is provided by the fraction of the transverse τ_{h} momentum carried by the highest-p_{T} track and the fraction of transverse energy deposited in the electromagnetic calorimeter, for which higher values are expected in case of hadronic τ decays compared to QCD jets. For τ_{h} candidates with more than one associated track, the τ lifetime is also exploited by measuring the decay length significance of the associated secondary vertex in the transverse plane. The single most discriminating of these quantities is the energy-weighted radius

$$R_{\mathrm{EM}} = \frac{\sum_i^{\Delta R_i < 0.4} E_{\mathrm{T},i}^{\mathrm{EM}} \Delta R_i}{\sum_i^{\Delta R_i < 0.4} E_{\mathrm{T},i}^{\mathrm{EM}}}, \tag{1}$$

where i iterates over cells in the first three layers of the electromagnetic calorimeter associated with the τ_{h} candidate, ΔR_i is defined relative to the τ_{h} seed axis, and $E_{\mathrm{T},i}^{\mathrm{EM}}$ is the cell transverse energy.

These eight variables are combined in a boosted decision tree discriminator (BDT) [31], which provides an output value between 0 (background-like) and 1 (signal-like) with a continuous gradient of signal and background efficiency. This discriminator was optimized using a combination of $W \to \tau_{\mathrm{h}}\nu_\tau$ and $Z \to \tau\tau$ Monte Carlo samples for the signal. The background was modeled from dijet events selected from data. For τ_{h} transverse momenta ($p_{\mathrm{T}}^{\tau_{\mathrm{h}}}$) above 20 GeV, the efficiency of the τ_{h} identification at the tighter working point of the BDT identification considered for this measurement is about 30% with a jet rejection factor of 100 for τ_{h} candidates with one track, while for candidates with three tracks it is about 35% with a rejection factor of 300 [30]. Additional requirements on the calorimeter and tracking properties of τ_{h} candidates are used to discriminate against electrons and muons.

The missing transverse energy in the event, $E_{\mathrm{T}}^{\mathrm{miss}}$, is reconstructed as $\sqrt{(E_{\mathrm{x}}^{\mathrm{miss}})^2 + (E_{\mathrm{y}}^{\mathrm{miss}})^2}$, where $(E_{\mathrm{x}}^{\mathrm{miss}}, E_{\mathrm{y}}^{\mathrm{miss}})$ is the vector sum of all calorimeter energy clusters in the region $|\eta| < 4.5$, corrected for identified muons [32]. With good approximation, the resolution of $E_{\mathrm{T}}^{\mathrm{miss}}$ components is proportional to $a \times \sqrt{\sum E_{\mathrm{T}}}$, where the scaling factor a depends on both the detector and reconstruction performance and $\sum E_{\mathrm{T}}$ is calculated from all calorimeter energy clusters. The factor a is about $0.5\sqrt{\mathrm{GeV}}$ for minimum bias events [33].

In order to reject events with large reconstructed $E_{\mathrm{T}}^{\mathrm{miss}}$ due to fluctuations in the energy measurement, we define the significance of $E_{\mathrm{T}}^{\mathrm{miss}}$ as

$$S_{E_{\mathrm{T}}^{\mathrm{miss}}} = \frac{E_{\mathrm{T}}^{\mathrm{miss}}[\mathrm{GeV}]}{0.5\sqrt{\mathrm{GeV}}\sqrt{(\sum E_{\mathrm{T}}[\mathrm{GeV}])}}. \quad (2)$$

$S_{E_{\mathrm{T}}^{\mathrm{miss}}}$ is found to provide better discrimination between the signal and the background from QCD jets than a simple $E_{\mathrm{T}}^{\mathrm{miss}}$ requirement.

5. Event selection

Events are selected using triggers based on the presence of a τ_{h} jet and $E_{\mathrm{T}}^{\mathrm{miss}}$. In the earlier part of the 2010 data taking, corresponding to an integrated luminosity of 11 pb^{-1}, a loosely identified τ_{h} candidate with $p_{\mathrm{T}}^{\tau_{\mathrm{h}}} > 12$ GeV (as reconstructed at the trigger level) in combination with $E_{\mathrm{T}}^{\mathrm{miss}} > 20$ GeV was required. In the second part of the period (24 pb^{-1}), a tighter τ_{h} identification and higher thresholds of 16 GeV and 22 GeV had to be used for $p_{\mathrm{T}}^{\tau_{\mathrm{h}}}$ and $E_{\mathrm{T}}^{\mathrm{miss}}$, respectively, due to the increasing luminosity. The signal efficiencies of these two triggers with respect to the offline selection are estimated from the simulation to be $(81.3 \pm 0.8)\%$ and $(62.7 \pm 0.7)\%$, respectively.

Events satisfying the trigger selection are required to have at least one reconstructed vertex that is formed by three or more tracks with $p_{\mathrm{T}} > 150$ MeV. Further selection requirements based on calorimeter information are applied to reject non-collision events and events containing jets that were incompletely reconstructed or significantly affected by electronic noise in the calorimeters.

The calorimeter has a lower resolution for jets in the barrel-endcap transition regions. In order to ensure a uniform $E_{\mathrm{T}}^{\mathrm{miss}}$ resolution, events are rejected if a jet or a τ_{h} candidate with $1.3 < |\eta| < 1.7$ is found. In events where the $E_{\mathrm{T}}^{\mathrm{miss}}$ is found to be collinear to one of the jets, the reconstructed $E_{\mathrm{T}}^{\mathrm{miss}}$ is likely to originate from an incomplete reconstruction of this jet. Therefore, a minimum separation $|\Delta\phi(\mathrm{jet}, E_{\mathrm{T}}^{\mathrm{miss}})| > 0.5$ rad is required.

In order to suppress backgrounds from other leptonic W and Z decays, events containing identified electrons or muons with $p_{\mathrm{T}} > 15$ GeV are rejected. The highest-p_{T} identified τ_{h} candidate in the event is considered for further analysis and required to be in the pseudorapidity range $|\eta| < 2.5$ and to have $20 < p_{\mathrm{T}}^{\tau_{\mathrm{h}}} < 60$ GeV. A minimum $E_{\mathrm{T}}^{\mathrm{miss}}$ of 30 GeV is required and events are rejected if $S_{E_{\mathrm{T}}^{\mathrm{miss}}} < 6$.

6. Background estimation

The number of expected events from signal and electroweak background processes is obtained from simulation. This is justified by the good agreement between data and simulation observed in the ATLAS W cross section measurements [4,5] through decays into electrons or muons. It is further validated using a high-purity data sample of $W \to \mu\nu_{\mu}$ events, in which the muon is removed and replaced by a simulated τ_{h} lepton. Thus, only the τ decay and the corresponding detector response are taken from simulation while the underlying W kinematics and all the other properties of the event are obtained from the $W \to \mu\nu_{\mu}$ events selected in data. Fig. 1 compares the distribution of $S_{E_{\mathrm{T}}^{\mathrm{miss}}}$ for the τ_{h}-embedded data sample with simulated $W \to \tau_{\mathrm{h}}\nu_{\tau}$ events. A good agreement is observed within the statistical uncertainties, which adds further confidence in the electroweak background event model provided by the simulated event samples used in this analysis.

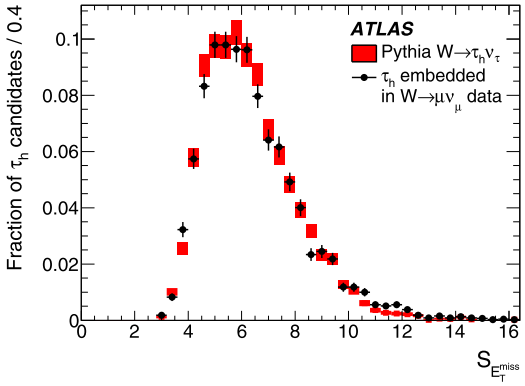

Fig. 1. Distribution of $S_{E_{\mathrm{T}}^{\mathrm{miss}}}$ for the τ_{h}-embedded $W \to \mu\nu_{\mu}$ data sample (points) and simulated $W \to \tau_{\mathrm{h}}\nu_{\tau}$ events (histogram), including statistical uncertainties.

The background contribution from QCD jet production, for which the cross section is large and the selection efficiency is low, cannot be reliably modeled using simulated events alone and is thus estimated from data. In addition to the signal-dominated data set defined by the selection described in Section 5, three background control regions are defined by inverting the requirements on the $S_{E_{\mathrm{T}}^{\mathrm{miss}}}$ and/or the τ_{h} identification (ID), resulting in the following four samples:

- Region A: $S_{E_{\mathrm{T}}^{\mathrm{miss}}} > 6.0$ and τ_{h} candidates satisfying the signal τ_{h} ID requirements described in Section 4;
- Region B: $S_{E_{\mathrm{T}}^{\mathrm{miss}}} < 4.5$ and τ_{h} candidates satisfying the signal-region τ_{h} ID requirements;
- Region C: $S_{E_{\mathrm{T}}^{\mathrm{miss}}} > 6.0$ and τ_{h} candidates satisfying a looser τ_{h}-ID but failing the signal-region τ_{h} ID requirements;
- Region D: $S_{E_{\mathrm{T}}^{\mathrm{miss}}} < 4.5$ and τ_{h} candidates satisfying a looser τ_{h}-ID but failing the signal-region τ_{h} ID requirements.

Here, the looser τ_{h}-ID region is defined by selecting τ_{h} candidates with a lower value of the BDT output.

After ensuring that the shape of the $S_{E_{\mathrm{T}}^{\mathrm{miss}}}$ distribution for the QCD background is independent of the τ_{h}-ID requirement and assuming that the signal and electroweak background contributions in the three control regions are negligible, an estimate for the number of QCD background events in the signal region A is provided by

$$N_{\mathrm{QCD}}^{\mathrm{A}} = N^{\mathrm{B}} N^{\mathrm{C}} / N^{\mathrm{D}}, \quad (3)$$

where N^{i} represents the number of observed events in region i.

In order to take into account the residual signal and EW background contamination in the control regions $i = \mathrm{B}, \mathrm{C}, \mathrm{D}$, the number of selected events, N^{i}, needs to be replaced in Eq. (3) by $N^{i} - c_i(N^{\mathrm{A}} - N_{\mathrm{QCD}}^{\mathrm{A}})$, where

$$c_i = \frac{N_{\mathrm{sig}}^{i} + N_{\mathrm{EW}}^{i}}{N_{\mathrm{sig}}^{\mathrm{A}} + N_{\mathrm{EW}}^{\mathrm{A}}} \quad (4)$$

is the ratio of simulated signal and EW background events in the control region i and the signal region. Therefore Eq. (3) becomes

$$N_{\mathrm{QCD}}^{\mathrm{A}} = \frac{[N^{\mathrm{B}} - c_{\mathrm{B}}(N^{\mathrm{A}} - N_{\mathrm{QCD}}^{\mathrm{A}})][N^{\mathrm{C}} - c_{\mathrm{C}}(N^{\mathrm{A}} - N_{\mathrm{QCD}}^{\mathrm{A}})]}{N^{\mathrm{D}} - c_{\mathrm{D}}(N^{\mathrm{A}} - N_{\mathrm{QCD}}^{\mathrm{A}})}. \quad (5)$$

The statistical error on $N_{\mathrm{QCD}}^{\mathrm{A}}$ includes both the uncertainty on the calculation of the c_i coefficients, due to the Monte Carlo statis-

Table 1
Estimated sample compositions and c_i factors (as defined in Eq. (4)) in the signal region A and control regions B, C, and D defined in the text.

	A	B	C	D
N^i (Data)	2335	4796	1577	27 636
N^i_{sig} ($W \to \tau_{\text{h}}\nu_\tau$)	1811 ± 25	683 ± 16	269 ± 8	93 ± 5
N^i_{EW}	284 ± 7	118 ± 4	388 ± 9	90 ± 4
c_i		0.38 ± 0.01	0.31 ± 0.01	0.087 ± 0.003
N^i_{QCD}	127 ± 8	3953 ± 75	885 ± 45	$27\,444 \pm 166$

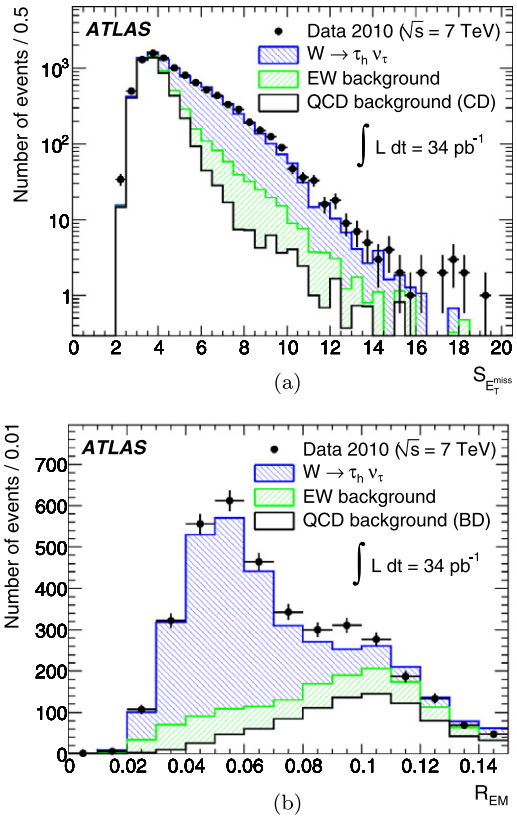

Fig. 2. (a) $S_{E_{\text{T}}^{\text{miss}}}$ distribution in the combined region AB, extended over the full $S_{E_{\text{T}}^{\text{miss}}}$ range. The QCD background shape has been extracted from regions CD. Monte Carlo signal and EW background in regions AB are also shown; (b) the τ_{h} identification variable R_{EM} in the combined region AC. The QCD background shape has been extracted from regions BD. Monte Carlo signal and EW background in regions AC are also shown.

tics, and the statistical uncertainty of the data in the four regions. The resulting estimates of the sample compositions are summarized in Table 1.

The quality of the description of the selected data by the background models can be judged from Figs. 2 and 3, where data and the background estimates (EW and QCD) are shown. Fig. 2(a) shows the distribution of $S_{E_{\text{T}}^{\text{miss}}}$ in regions A and B, extended over the full $S_{E_{\text{T}}^{\text{miss}}}$ range, for all events passing the selection criteria except for the $S_{E_{\text{T}}^{\text{miss}}}$ requirement. In Fig. 2(b) the distribution of R_{EM} is shown. In this case events passing the selection criteria but considering τ_{h} candidates identified by the loose and the tight selections in regions A and C are shown. The agreement between data and Monte Carlo expectation confirms the results obtained by the data-driven background estimation. In Fig. 3 the distribution of $E_{\text{T}}^{\text{miss}}$, the $p_{\text{T}}^{\tau_{\text{h}}}$ spectrum, the number of tracks associated to the τ_{h} candidate, the distribution of $\Delta\phi(\tau_{\text{h}}, E_{\text{T}}^{\text{miss}})$ and the transverse mass, $m_{\text{T}} = \sqrt{2 \cdot p_{\text{T}}^{\tau_{\text{h}}} \cdot E_{\text{T}}^{\text{miss}} \cdot (1 - \cos\Delta\phi(\tau_{\text{h}}, E_{\text{T}}^{\text{miss}}))}$, in the selected signal region A are shown, illustrating the characteristic properties of $W \to \tau_{\text{h}}\nu_\tau$ decays. In all the distributions reasonable agreement is observed between the data and Monte Carlo prediction.

7. Cross section measurement

The fiducial cross section is measured in a phase space region given by the geometrical acceptance of the detector and by the kinematic selection of the analysis (as described in Section 5). This region is defined based on the decay products from a simulated hadronic τ decay and corresponds to the criteria presented in Table 2.

Here, the visible τ momentum $p_{\text{T}}^{\tau,\text{vis}}$ and pseudorapidity $\eta^{\tau,\text{vis}}$ are calculated from the sum of the four-vectors of the decay products from the simulated hadronic τ decay, except for the neutrinos. This momentum also includes photons radiated both from the τ lepton and from the decay products themselves, considering only photons within $\Delta R < 0.4$ with respect to the τ_{h}. The minimum $E_{\text{T}}^{\text{miss}}$ requirement translates into a cut on the transverse component of the sum of the simulated neutrino four-vectors $(\sum p^{\nu})_{\text{T}}$.

The fiducial cross section, including the branching ratio $\text{BR}(W \to \tau_{\text{h}}\nu_\tau)$, is computed as

$$\sigma^{\text{fid}}_{W\to\tau_{\text{h}}\nu_\tau} = \frac{N_{\text{obs}} - N_{\text{bkg}}}{C_W \mathcal{L}}, \tag{6}$$

where N_{obs} is the number of observed events in data, N_{bkg} is the number of estimated (QCD and EW) background events (signal region A in Table 1), and $\mathcal{L}$ is the integrated luminosity. C_W is the correction factor that takes into account the efficiency of trigger, τ_{h} reconstruction and identification and the efficiency of all selection cuts within the acceptance:

$$C_W = \frac{N_{\text{reco, all cuts}}}{N_{\text{gen, kin/geom}}}, \tag{7}$$

where $N_{\text{reco, all cuts}}$ is the number of fully simulated signal events passing the reconstruction, trigger and the selection cuts of the analysis and $N_{\text{gen, kin/geom}}$ is the number of simulated signal events within the fiducial region defined above.

With the kinematic and geometrical signal acceptance

$$A_W = \frac{N_{\text{gen, kin/geom}}}{N_{\text{gen, all}}}, \tag{8}$$

where $N_{\text{gen, all}}$ is the total number of simulated signal events while $N_{\text{gen, kin/geom}}$ is the denominator of C_W, the total cross section

$$\sigma^{\text{tot}}_{W\to\tau_{\text{h}}\nu_\tau} = \sigma^{\text{fid}}_{W\to\tau_{\text{h}}\nu_\tau}/A_W = \frac{N_{\text{obs}} - N_{\text{bkg}}}{A_W C_W \mathcal{L}} \tag{9}$$

can be obtained. A_W and C_W are determined using a PYTHIA Monte Carlo signal sample described in Section 3. The fiducial acceptance is found to be $A_W = 0.0975 \pm 0.0004$ (MC stat) and the correction factor $C_W = 0.0799 \pm 0.0011$ (MC stat).

The measured fiducial cross section of the $W \to \tau_{\text{h}}\nu_\tau$ decay is $\sigma^{\text{fid}}_{W\to\tau_{\text{h}}\nu_\tau} = 0.70 \pm 0.02$ (stat) nb and the total cross section is found to be $\sigma^{\text{tot}}_{W\to\tau_{\text{h}}\nu_\tau} = 7.2 \pm 0.2$ (stat) nb.

Several alternative analyses are performed to confirm these results. For example, the BDT τ_{h} ID is replaced by a simpler identification based on cuts on three of the ID variables only [30]. Also, in order to study the influence of pile-up on the result, the signal selection is restricted to events with only one reconstructed primary vertex. In both cases consistent results are found.

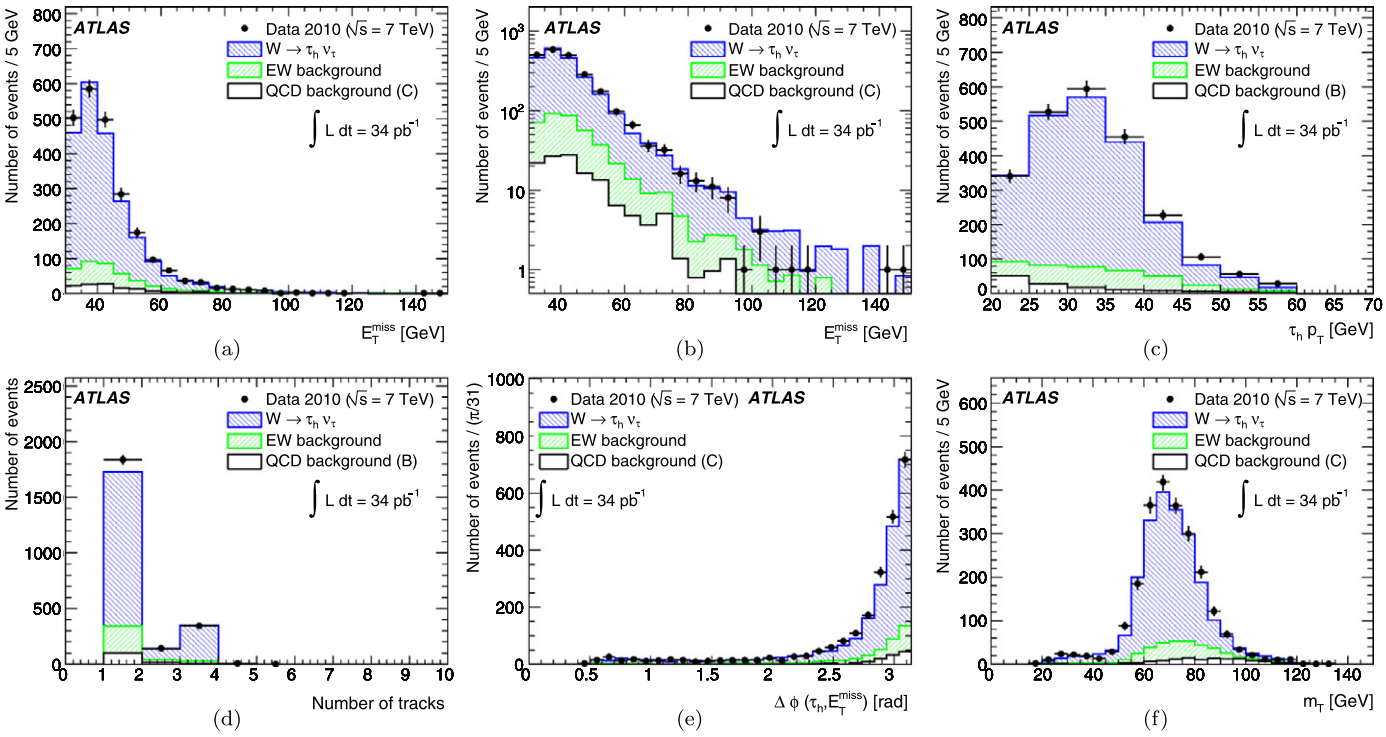

Fig. 3. (a) Distribution of missing transverse energy in signal region A on a linear scale. The QCD background shape has been extracted from control region C. (b) Same distribution on a logarithmic scale. (c) Transverse momentum and (d) number of tracks of τ_h candidates in signal region A. The QCD background shape has been extracted from control region B. (e) Distribution of $\Delta\phi(\tau_h, E_T^{miss})$ and (f) transverse mass m_T in signal region A. The QCD background shape has been extracted from control region C. The expectation from Monte Carlo signal and EW background in region A are also shown.

Table 2
Definition of the acceptance region.

$20\ \text{GeV} < p_T^{\tau,vis} < 60\ \text{GeV}$
$\lvert\eta^{\tau,vis}\rvert < 2.5$, excluding $1.3 < \lvert\eta^{\tau,vis}\rvert < 1.7$
$(\sum p^{\nu})_T > 30\ \text{GeV}$
$\lvert\Delta\phi(p^{\tau,vis}, \sum p^{\nu})\rvert > 0.5$

8. Systematic uncertainties

Table 3 summarizes the systematic uncertainties. The main sources are discussed in the following.

8.1. Monte Carlo predictions

The trigger efficiency is determined in Monte Carlo for the combined E_T^{miss} and τ_h triggers used in the two data periods. The differences between the measured trigger responses of the two trigger components in data and Monte Carlo are used to determine the systematic uncertainty. A pure and unbiased sample enriched with $W \to \tau_h \nu_\tau$ events is obtained in data by applying an independent $\tau_h(E_T^{miss})$ trigger and selected cuts of the event selection like the BDT τ_h ID. The corresponding $E_T^{miss}(\tau_h)$ trigger part is applied to this sample and the response of this trigger is compared to the response in Monte Carlo. The observed differences are integrated over the offline $p_T^{\tau_h}$ and E_T^{miss} range used for the cross section measurement. The total systematic uncertainty after the combination of the different trigger parts is 6.1%.

The signal and background acceptance depends on the energy scale of the clusters used in the computation of E_T^{miss} and $S_{E_T^{miss}}$ and the energy scale of the calibrated τ_h candidates. Based on the current knowledge of the calibration the uncertainty due to cluster energy within the detector region $|\eta| < 3.2$ is at most 10% for p_T of 500 MeV and within 3% at high p_T [34]. In the forward region $|\eta| > 3.2$ it is estimated to be 10%. The effect on E_T^{miss} and $S_{E_T^{miss}}$ has been evaluated by scaling all clusters in the event according to these uncertainties and recalculating E_T^{miss} and $\sum E_T$. At the same time, the τ_h energy scale has been varied according to its uncertainty [30]. This uncertainty depends on the number of tracks associated to the τ_h candidate, its p_T and the η region in which it was reconstructed, and ranges from 2.5% to 10%. In addition, the sensitivity of the signal and background efficiency to the E_T^{miss} resolution has been investigated [33]. Consequently, the yield of signal and EW background varies within 6.7% and 8.7%, respectively.

The identification and reconstruction efficiency of τ_h candidates was studied with Monte Carlo $W \to \tau_h \nu_\tau$ and $Z \to \tau\tau$ samples and was found to vary with different simulation conditions such as different underlying event models, detector geometry, hadronic shower modeling and noise thresholds for calorimeter cells in the cluster reconstruction. In Ref. [30], these uncertainties are evaluated as a function of $p_T^{\tau_h}$, separately for candidates with one or multiple tracks and low or high multiplicity of primary vertices in the event. The corresponding changes in the signal and EW background efficiencies are found to be 9.6% and 4.1%, respectively.

The probability of a jet or electron to be misidentified as a τ_h candidate has been evaluated in data and compared with the expectation from Monte Carlo. The rate of jets that are misidentified as τ_h candidates was calculated using a selection of $W \to \ell\nu_\ell$ + jets events (with $\ell = e, \mu$) and measuring the fraction of reconstructed candidates that are found by the τ_h identification. The difference of this misidentification rate in Monte Carlo compared to that in data is 30% and this was applied as a systematic uncertainty to the fraction of events mimicked by a jet. The overall uncertainty on the EW background is 7.2%. The misidentification probability of

Table 3
Summary table for systematic uncertainties. For the systematic uncertainty on the fiducial cross section measurement, correlations between the systematics affecting C_W and N_{EW} have been taken into account.

	$\frac{\delta C_W}{C_W}$	$\frac{\delta N_{\mathrm{EW}}}{N_{\mathrm{EW}}}$	$\frac{\delta N_{\mathrm{QCD}}}{N_{\mathrm{QCD}}}$	$\frac{\delta\sigma^{\mathrm{fid}}_{W\to\tau_{\mathrm{h}}\nu_\tau}}{\sigma^{\mathrm{fid}}_{W\to\tau_{\mathrm{h}}\nu_\tau}}$
Trigger efficiency	6.1%	6.1%	–	7.0%
Energy scale	6.7%	8.7%	–	8.0%
τ_{h} ID efficiency	9.6%	4.1%	–	10.3%
Jet τ_{h} misidentification	–	7.2%	–	1.1%
Electron τ_{h} misidentification	–	4.5%	–	0.7%
Pile-up reweighting	1.4%	1.2%	–	1.6%
Electron reconstruction/identification	–	1.2%	–	0.2%
Muon reconstruction	–	0.3%	–	0.04%
Underlying event modeling	1.3%	1.1%	–	1.5%
Cross section	–	4.5%	–	0.7%
QCD estimation: Stability/correlation	–	–	2.7%	0.2%
QCD estimation: Sig./EW contamination	–	–	2.1%	0.1%
Monte Carlo statistics	1.4%	2.4%	6.0%	1.5%
Total systematic uncertainty	13.4%	15.2%	6.9%	15.1%

electrons as τ_{h} candidates has been determined with a "tag-and-probe" method using $Z \to ee$ events where the τ_{h} identification and τ_{h} electron veto is applied to one of the electrons. The difference between the misidentification probability in data and Monte Carlo as a function of η has been applied as a systematic uncertainty to τ_{h} candidates mimicked by an electron. It amounts to 4.5% for the total EW background.

Other sources of systematic uncertainty have been evaluated and were found to have only small effects on the resulting cross section measurement, for example the procedure to include pile-up effects, the uncertainty on the lepton selection efficiency entering via the veto of electrons and muons and the influence of the underlying event modeling on $E_{\mathrm{T}}^{\mathrm{miss}}$ quantities. The uncertainties on the cross sections used for the EW background are taken from ATLAS measurements, when available, or theoretical NNLO calculations, and lie between 3 and 9.7% [8,35,6,7]. The uncertainty on the integrated luminosity is 3.4% [13,14].

8.2. QCD background estimation

Two different sources of systematic uncertainty arising from the method of estimating the QCD background events from data have been studied. The stability of the method and the small correlation of the two variables (τ_{h} ID and $S_{E_{\mathrm{T}}^{\mathrm{miss}}}$) used to define the control regions have been tested by varying the $S_{E_{\mathrm{T}}^{\mathrm{miss}}}$ threshold. The systematic uncertainty due to the correction for signal and EW background contamination in the control regions was obtained by varying the fraction of these events in the regions within the combined systematic and statistical uncertainties on the Monte Carlo predictions discussed above. The total uncertainty on the QCD background estimation is 3.4%.

8.3. Acceptance

The theoretical uncertainty on the geometric and kinematic acceptance factor A_W is dominated by the limited knowledge of the proton PDFs and the modeling of W boson production at the LHC.

The uncertainty resulting from the choice of the PDF set is evaluated by comparing the acceptance obtained with different PDF sets (the default MRST LO*, CTEQ6.6 and HERAPDF 1.0 [36]) and within one PDF set by re-weighting the default sample to the different error eigenvectors available for the CTEQ6.6 NLO PDF [37]. The uncertainty is 1.6 % and 1.0%, respectively, which combines to 1.9%.

The uncertainty on the modeling of W production was evaluated by comparing the default sample acceptance to that obtained from an MC@NLO sample where the parton shower is modeled by HERWIG. The difference in acceptance is found to be smaller than 0.5%.

Table 4
Resulting numbers for the cross section calculation. The errors include statistical and systematic uncertainties here.

N_{obs}	2335
N_{QCD}	127 ± 9
N_{EW}	284 ± 43
A_W	0.0975 ± 0.0019
C_W	0.0799 ± 0.0107

9. Results

The results of the analysis relevant to the cross section measurement are summarized in Table 4. Within the acceptance region defined in Table 2 they translate into a fiducial cross section $\sigma^{\mathrm{fid}}_{W\to\tau_{\mathrm{h}}\nu_\tau}$ of

$$0.70 \pm 0.02\ (\mathrm{stat}) \pm 0.11\ (\mathrm{syst}) \pm 0.02\ (\mathrm{lumi})\ \mathrm{nb}$$

and a total cross section $\sigma^{\mathrm{tot}}_{W\to\tau_{\mathrm{h}}\nu_\tau}$ of

$$7.2 \pm 0.2\ (\mathrm{stat}) \pm 1.1\ (\mathrm{syst}) \pm 0.2\ (\mathrm{lumi})\ \mathrm{nb}.$$

After correcting the cross section for the hadronic τ decay branching ratio $\mathrm{BR}(\tau \to h\nu_\tau) = 0.6479 \pm 0.0007$ [38] this yields the following inclusive cross section $\sigma^{\mathrm{tot}}_{W\to\tau\nu_\tau}$:

$$11.1 \pm 0.3\ (\mathrm{stat}) \pm 1.7\ (\mathrm{syst}) \pm 0.4\ (\mathrm{lumi})\ \mathrm{nb}.$$

The measured cross section is in good agreement with the theoretical NNLO cross section 10.46 ± 0.52 nb [6–8] and the ATLAS measurements of the $W \to e\nu_e$ and $W \to \mu\nu_\mu$ cross sections [4,5]. The comparison of the cross section measurements for the different lepton final states and the theoretical expectation is shown in Fig. 4. This is the first $W \to \tau\nu_\tau$ cross section measurement performed at the LHC.

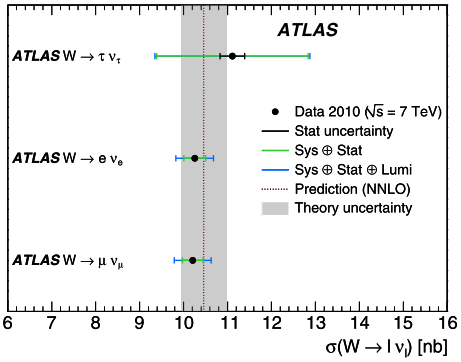

Fig. 4. Cross sections for the different $W \to \ell\nu_\ell$ channels measured in ATLAS with 2010 data (points). Systematic, luminosity and statistical uncertainties are added in quadrature. The theoretical NNLO expectation is also shown (dashed line), together with its uncertainty (filled area).

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; BMWF, 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; ARTEMIS, European Union; IN2P3–CNRS, CEA-DSM/IRFU, France; GNAS, Georgia; BMBF, DFG, HGF, MPG and AvH Foundation, Germany; GSRT, Greece; ISF, MINERVA, GIF, DIP and Benoziyo Center, Israel; INFN, Italy; MEXT and JSPS, Japan; CNRST, Morocco; FOM and NWO, Netherlands; RCN, Norway; MNiSW, Poland; GRICES and FCT, Portugal; MERYS (MECTS), Romania; MES of Russia and ROSATOM, Russian Federation; JINR; MSTD, Serbia; MSSR, Slovakia; ARRS and MVZT, Slovenia; DST/NRF, South Africa; MICINN, Spain; SRC and Wallenberg Foundation, Sweden; SER, SNSF and Cantons of Bern and Geneva, Switzerland; NSC, Taiwan; TAEK, Turkey; STFC, the Royal Society and Leverhulme Trust, United Kingdom; DOE and NSF, United States.

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.

Open access

This article is published Open Access at sciencedirect.com. It is distributed under the terms of the Creative Commons Attribution License 3.0, which permits unrestricted use, distribution, and reproduction in any medium, provided the original authors and source are credited.

References

[1] ATLAS Collaboration, CERN-OPEN-2008-020, 2008.
[2] ATLAS Collaboration, arXiv:1107.5003 [hep-ex].
[3] ATLAS Collaboration, ATLAS Note ATL-PHYS-PUB-2010-006, 2010.
[4] ATLAS Collaboration, ATLAS Conference Note ATLAS-CONF-2011-041, 2011.
[5] ATLAS Collaboration, arXiv:1109.5141 [hep-ex].
[6] C. Anastasiou, L. Dixon, K. Melnikov, F. Petriello, Phys. Rev. D 69 (2004) 094008.
[7] A.D. Martin, W.J. Stirling, R.S. Thorne, G. Watt, Eur. Phys. J. C 63 (2009) 189.
[8] ATLAS Collaboration, JHEP 1012 (2010) 060.
[9] UA1 Collaboration, C. Albajar, et al., Phys. Lett. B 185 (1–2) (1987) 233.
[10] CDF Collaboration, F. Abe, et al., Phys. Rev. Lett. 68 (23) (1992) 3398.
[11] D0 Collaboration, B. Abbott, et al., Phys. Rev. Lett. 84 (2000) 5710.
[12] ATLAS Collaboration, JINST 3 (2008) S08003.
[13] ATLAS Collaboration, Eur. Phys. J. C Part. Fields 71 (2011) 1.
[14] ATLAS Collaboration, ATLAS Conference Note ATLAS-CONF-2011-011, 2011.
[15] T. Sjöstrand, S. Mrenna, P. Skands, JHEP 0605 (2006) 026.
[16] A. Sherstnev, R.S. Thorne, Eur. Phys. J. C Part. Fields 55 (2008) 553.
[17] S. Frixione, B.R. Webber, JHEP 0206 (2002) 029.
[18] G. Corcella, et al., JHEP 0101 (2001) 010.
[19] J.M. Butterworth, J.R. Forshaw, M.H. Seymour, Z. Phys. C 72 (1996) 637.
[20] S. Jadach, J.H. Kuhn, Z. Was, Comput. Phys. Comm. 64 (1990) 275.
[21] E. Barberio, B.v. Eijk, Z. Was, Comput. Phys. Comm. 66 (1991) 115.
[22] ATLAS Collaboration, ATLAS Note ATL-PHYS-PUB-2010-014, 2010.
[23] GEANT4 Collaboration, S. Agostinelli, et al., Nucl. Instrum. Meth. A 506 (2003) 250.
[24] ATLAS Collaboration, Eur. Phys. J. C 70 (2010) 823.
[25] ATLAS Collaboration, arXiv:1110.3174 [hep-ex].
[26] ATLAS Collaboration, ATLAS Conference Note ATLAS-CONF-2011-063, 2011.
[27] M. Cacciari, G.P. Salam, G. Soyez, JHEP 0804 (2008) 063.
[28] ATLAS Collaboration, Eur. Phys. J. C 71 (2011) 1512.
[29] T. Barillari et al., ATLAS Note ATL-LARG-PUB-2009-001, 2009.
[30] ATLAS Collaboration, ATLAS Conference Note ATLAS-CONF-2011-077, 2011.
[31] Y. Freund, R. Shapire, in: Proceedings 13th International Conference on Machine Learning, 1996.
[32] ATLAS Collaboration, JHEP 1009 (2010) 056.
[33] ATLAS Collaboration, ATLAS Conference Note ATLAS-CONF-2010-057, 2010.
[34] ATLAS Collaboration, ATLAS Conference Note ATLAS-CONF-2011-080, 2011.
[35] ATLAS Collaboration, ATLAS Conference Note ATLAS-CONF-2011-040, 2011.
[36] H1 Collaboration, ZEUS Collaboration, JHEP 1001 (2010) 109.
[37] P.M. Nadolsky, et al., Phys. Rev. D 78 (2008) 013004.
[38] Particle Data Group, K. Nakamura, et al., J. Phys. G 37 (2010).

ATLAS Collaboration

G. Aad [48], B. Abbott [111], J. Abdallah [11], A.A. Abdelalim [49], A. Abdesselam [118], O. Abdinov [10], B. Abi [112], M. Abolins [88], H. Abramowicz [153], H. Abreu [115], E. Acerbi [89a,89b], B.S. Acharya [164a,164b], D.L. Adams [24], T.N. Addy [56], J. Adelman [175], M. Aderholz [99], S. Adomeit [98], P. Adragna [75], T. Adye [129], S. Aefsky [22], J.A. Aguilar-Saavedra [124b,a], M. Aharrouche [81], S.P. Ahlen [21], F. Ahles [48], A. Ahmad [148], M. Ahsan [40], G. Aielli [133a,133b], T. Akdogan [18a], T.P.A. Åkesson [79], G. Akimoto [155], A.V. Akimov [94], A. Akiyama [67], M.S. Alam [1], M.A. Alam [76], J. Albert [169], S. Albrand [55], M. Aleksa [29], I.N. Aleksandrov [65], F. Alessandria [89a], C. Alexa [25a], G. Alexander [153], G. Alexandre [49], T. Alexopoulos [9], M. Alhroob [20], M. Aliev [15], G. Alimonti [89a], J. Alison [120], M. Aliyev [10], P.P. Allport [73], S.E. Allwood-Spiers [53], J. Almond [82], A. Aloisio [102a,102b], R. Alon [171], A. Alonso [79], M.G. Alviggi [102a,102b], K. Amako [66], P. Amaral [29], C. Amelung [22], V.V. Ammosov [128], A. Amorim [124a,b], G. Amorós [167], N. Amram [153], C. Anastopoulos [29], L.S. Ancu [16], N. Andari [115], T. Andeen [34], C.F. Anders [20], G. Anders [58a], K.J. Anderson [30], A. Andreazza [89a,89b], V. Andrei [58a], M.-L. Andrieux [55], X.S. Anduaga [70], A. Angerami [34], F. Anghinolfi [29], N. Anjos [124a], A. Annovi [47], A. Antonaki [8], M. Antonelli [47], A. Antonov [96], J. Antos [144b], F. Anulli [132a], S. Aoun [83],

L. Aperio Bella [4], R. Apolle [118,c], G. Arabidze [88], I. Aracena [143], Y. Arai [66], A.T.H. Arce [44], J.P. Archambault [28], S. Arfaoui [29,d], J.-F. Arguin [14], E. Arik [18a,*], M. Arik [18a], A.J. Armbruster [87], O. Arnaez [81], C. Arnault [115], A. Artamonov [95], G. Artoni [132a,132b], D. Arutinov [20], S. Asai [155], R. Asfandiyarov [172], S. Ask [27], B. Åsman [146a,146b], L. Asquith [5], K. Assamagan [24], A. Astbury [169], A. Astvatsatourov [52], G. Atoian [175], B. Aubert [4], E. Auge [115], K. Augsten [127], M. Aurousseau [145a], N. Austin [73], G. Avolio [163], R. Avramidou [9], D. Axen [168], C. Ay [54], G. Azuelos [93,e], Y. Azuma [155], M.A. Baak [29], G. Baccaglioni [89a], C. Bacci [134a,134b], A.M. Bach [14], H. Bachacou [136], K. Bachas [29], G. Bachy [29], M. Backes [49], M. Backhaus [20], E. Badescu [25a], P. Bagnaia [132a,132b], S. Bahinipati [2], Y. Bai [32a], D.C. Bailey [158], T. Bain [158], J.T. Baines [129], O.K. Baker [175], M.D. Baker [24], S. Baker [77], E. Banas [38], P. Banerjee [93], Sw. Banerjee [172], D. Banfi [29], A. Bangert [137], V. Bansal [169], H.S. Bansil [17], L. Barak [171], S.P. Baranov [94], A. Barashkou [65], A. Barbaro Galtieri [14], T. Barber [27], E.L. Barberio [86], D. Barberis [50a,50b], M. Barbero [20], D.Y. Bardin [65], T. Barillari [99], M. Barisonzi [174], T. Barklow [143], N. Barlow [27], B.M. Barnett [129], R.M. Barnett [14], A. Baroncelli [134a], G. Barone [49], A.J. Barr [118], F. Barreiro [80], J. Barreiro Guimarães da Costa [57], P. Barrillon [115], R. Bartoldus [143], A.E. Barton [71], D. Bartsch [20], V. Bartsch [149], R.L. Bates [53], L. Batkova [144a], J.R. Batley [27], A. Battaglia [16], M. Battistin [29], G. Battistoni [89a], F. Bauer [136], H.S. Bawa [143,f], B. Beare [158], T. Beau [78], P.H. Beauchemin [118], R. Beccherle [50a], P. Bechtle [41], H.P. Beck [16], M. Beckingham [48], K.H. Becks [174], A.J. Beddall [18c], A. Beddall [18c], S. Bedikian [175], V.A. Bednyakov [65], C.P. Bee [83], M. Begel [24], S. Behar Harpaz [152], P.K. Behera [63], M. Beimforde [99], C. Belanger-Champagne [85], P.J. Bell [49], W.H. Bell [49], G. Bella [153], L. Bellagamba [19a], F. Bellina [29], M. Bellomo [29], A. Belloni [57], O. Beloborodova [107], K. Belotskiy [96], O. Beltramello [29], S. Ben Ami [152], O. Benary [153], D. Benchekroun [135a], C. Benchouk [83], M. Bendel [81], N. Benekos [165], Y. Benhammou [153], D.P. Benjamin [44], M. Benoit [115], J.R. Bensinger [22], K. Benslama [130], S. Bentvelsen [105], D. Berge [29], E. Bergeaas Kuutmann [41], N. Berger [4], F. Berghaus [169], E. Berglund [49], J. Beringer [14], K. Bernardet [83], P. Bernat [77], R. Bernhard [48], C. Bernius [24], T. Berry [76], A. Bertin [19a,19b], F. Bertinelli [29], F. Bertolucci [122a,122b], M.I. Besana [89a,89b], N. Besson [136], S. Bethke [99], W. Bhimji [45], R.M. Bianchi [29], M. Bianco [72a,72b], O. Biebel [98], S.P. Bieniek [77], K. Bierwagen [54], J. Biesiada [14], M. Biglietti [134a,134b], H. Bilokon [47], M. Bindi [19a,19b], S. Binet [115], A. Bingul [18c], C. Bini [132a,132b], C. Biscarat [177], U. Bitenc [48], K.M. Black [21], R.E. Blair [5], J.-B. Blanchard [115], G. Blanchot [29], T. Blazek [144a], C. Blocker [22], J. Blocki [38], A. Blondel [49], W. Blum [81], U. Blumenschein [54], G.J. Bobbink [105], V.B. Bobrovnikov [107], S.S. Bocchetta [79], A. Bocci [44], C.R. Boddy [118], M. Boehler [41], J. Boek [174], N. Boelaert [35], S. Böser [77], J.A. Bogaerts [29], A. Bogdanchikov [107], A. Bogouch [90,*], C. Bohm [146a], V. Boisvert [76], T. Bold [163,g], V. Boldea [25a], N.M. Bolnet [136], M. Bona [75], V.G. Bondarenko [96], M. Bondioli [163], M. Boonekamp [136], G. Boorman [76], C.N. Booth [139], S. Bordoni [78], C. Borer [16], A. Borisov [128], G. Borissov [71], I. Borjanovic [12a], S. Borroni [132a,132b], K. Bos [105], D. Boscherini [19a], M. Bosman [11], H. Boterenbrood [105], D. Botterill [129], J. Bouchami [93], J. Boudreau [123], E.V. Bouhova-Thacker [71], C. Bourdarios [115], N. Bousson [83], A. Boveia [30], J. Boyd [29], I.R. Boyko [65], N.I. Bozhko [128], I. Bozovic-Jelisavcic [12b], J. Bracinik [17], A. Braem [29], P. Branchini [134a], G.W. Brandenburg [57], A. Brandt [7], G. Brandt [15], O. Brandt [54], U. Bratzler [156], B. Brau [84], J.E. Brau [114], H.M. Braun [174], B. Brelier [158], J. Bremer [29], R. Brenner [166], S. Bressler [152], D. Breton [115], D. Britton [53], F.M. Brochu [27], I. Brock [20], R. Brock [88], T.J. Brodbeck [71], E. Brodet [153], F. Broggi [89a], C. Bromberg [88], G. Brooijmans [34], W.K. Brooks [31b], G. Brown [82], H. Brown [7], P.A. Bruckman de Renstrom [38], D. Bruncko [144b], R. Bruneliere [48], S. Brunet [61], A. Bruni [19a], G. Bruni [19a], M. Bruschi [19a], T. Buanes [13], F. Bucci [49], J. Buchanan [118], N.J. Buchanan [2], P. Buchholz [141], R.M. Buckingham [118], A.G. Buckley [45], S.I. Buda [25a], I.A. Budagov [65], B. Budick [108], V. Büscher [81], L. Bugge [117], D. Buira-Clark [118], O. Bulekov [96], M. Bunse [42], T. Buran [117], H. Burckhart [29], S. Burdin [73], T. Burgess [13], S. Burke [129], E. Busato [33], P. Bussey [53], C.P. Buszello [166], F. Butin [29], B. Butler [143], J.M. Butler [21], C.M. Buttar [53], J.M. Butterworth [77], W. Buttinger [27], T. Byatt [77], S. Cabrera Urbán [167], D. Caforio [19a,19b], O. Cakir [3a], P. Calafiura [14], G. Calderini [78], P. Calfayan [98], R. Calkins [106], L.P. Caloba [23a], R. Caloi [132a,132b], D. Calvet [33], S. Calvet [33], R. Camacho Toro [33], P. Camarri [133a,133b], M. Cambiaghi [119a,119b], D. Cameron [117], S. Campana [29], M. Campanelli [77], V. Canale [102a,102b], F. Canelli [30,h], A. Canepa [159a], J. Cantero [80], L. Capasso [102a,102b], M.D.M. Capeans Garrido [29], I. Caprini [25a], M. Caprini [25a], D. Capriotti [99], M. Capua [36a,36b], R. Caputo [148], C. Caramarcu [25a], R. Cardarelli [133a], T. Carli [29], G. Carlino [102a], L. Carminati [89a,89b], B. Caron [159a], S. Caron [48], G.D. Carrillo Montoya [172], A.A. Carter [75], J.R. Carter [27], J. Carvalho [124a,i], D. Casadei [108], M.P. Casado [11], M. Cascella [122a,122b], C. Caso [50a,50b,*], A.M. Castaneda Hernandez [172],

E. Castaneda-Miranda [172], V. Castillo Gimenez [167], N.F. Castro [124a], G. Cataldi [72a], F. Cataneo [29], A. Catinaccio [29], J.R. Catmore [71], A. Cattai [29], G. Cattani [133a,133b], S. Caughron [88], D. Cauz [164a,164c], P. Cavalleri [78], D. Cavalli [89a], M. Cavalli-Sforza [11], V. Cavasinni [122a,122b], F. Ceradini [134a,134b], A.S. Cerqueira [23a], A. Cerri [29], L. Cerrito [75], F. Cerutti [47], S.A. Cetin [18b], F. Cevenini [102a,102b], A. Chafaq [135a], D. Chakraborty [106], K. Chan [2], B. Chapleau [85], J.D. Chapman [27], J.W. Chapman [87], E. Chareyre [78], D.G. Charlton [17], V. Chavda [82], C.A. Chavez Barajas [29], S. Cheatham [85], S. Chekanov [5], S.V. Chekulaev [159a], G.A. Chelkov [65], M.A. Chelstowska [104], C. Chen [64], H. Chen [24], S. Chen [32c], T. Chen [32c], X. Chen [172], S. Cheng [32a], A. Cheplakov [65], V.F. Chepurnov [65], R. Cherkaoui El Moursli [135e], V. Chernyatin [24], E. Cheu [6], S.L. Cheung [158], L. Chevalier [136], G. Chiefari [102a,102b], L. Chikovani [51], J.T. Childers [58a], A. Chilingarov [71], G. Chiodini [72a], M.V. Chizhov [65], G. Choudalakis [30], S. Chouridou [137], I.A. Christidi [77], A. Christov [48], D. Chromek-Burckhart [29], M.L. Chu [151], J. Chudoba [125], G. Ciapetti [132a,132b], K. Ciba [37], A.K. Ciftci [3a], R. Ciftci [3a], D. Cinca [33], V. Cindro [74], M.D. Ciobotaru [163], C. Ciocca [19a,19b], A. Ciocio [14], M. Cirilli [87], M. Ciubancan [25a], A. Clark [49], P.J. Clark [45], W. Cleland [123], J.C. Clemens [83], B. Clement [55], C. Clement [146a,146b], R.W. Clifft [129], Y. Coadou [83], M. Cobal [164a,164c], A. Coccaro [50a,50b], J. Cochran [64], P. Coe [118], J.G. Cogan [143], J. Coggeshall [165], E. Cogneras [177], C.D. Cojocaru [28], J. Colas [4], A.P. Colijn [105], C. Collard [115], N.J. Collins [17], C. Collins-Tooth [53], J. Collot [55], G. Colon [84], P. Conde Muiño [124a], E. Coniavitis [118], M.C. Conidi [11], M. Consonni [104], V. Consorti [48], S. Constantinescu [25a], C. Conta [119a,119b], F. Conventi [102a,j], J. Cook [29], M. Cooke [14], B.D. Cooper [77], A.M. Cooper-Sarkar [118], N.J. Cooper-Smith [76], K. Copic [34], T. Cornelissen [50a,50b], M. Corradi [19a], F. Corriveau [85,k], A. Cortes-Gonzalez [165], G. Cortiana [99], G. Costa [89a], M.J. Costa [167], D. Costanzo [139], T. Costin [30], D. Côté [29], L. Courneyea [169], G. Cowan [76], C. Cowden [27], B.E. Cox [82], K. Cranmer [108], F. Crescioli [122a,122b], M. Cristinziani [20], G. Crosetti [36a,36b], R. Crupi [72a,72b], S. Crépé-Renaudin [55], C.-M. Cuciuc [25a], C. Cuenca Almenar [175], T. Cuhadar Donszelmann [139], M. Curatolo [47], C.J. Curtis [17], P. Cwetanski [61], H. Czirr [141], Z. Czyczula [117], S. D'Auria [53], M. D'Onofrio [73], A. D'Orazio [132a,132b], P.V.M. Da Silva [23a], C. Da Via [82], W. Dabrowski [37], T. Dai [87], C. Dallapiccola [84], M. Dam [35], M. Dameri [50a,50b], D.S. Damiani [137], H.O. Danielsson [29], D. Dannheim [99], V. Dao [49], G. Darbo [50a], G.L. Darlea [25b], C. Daum [105], J.P. Dauvergne [29], W. Davey [86], T. Davidek [126], N. Davidson [86], R. Davidson [71], E. Davies [118,c], M. Davies [93], A.R. Davison [77], Y. Davygora [58a], E. Dawe [142], I. Dawson [139], J.W. Dawson [5,*], R.K. Daya [39], K. De [7], R. de Asmundis [102a], S. De Castro [19a,19b], P.E. De Castro Faria Salgado [24], S. De Cecco [78], J. de Graat [98], N. De Groot [104], P. de Jong [105], C. De La Taille [115], H. De la Torre [80], B. De Lotto [164a,164c], L. De Mora [71], L. De Nooij [105], D. De Pedis [132a], A. De Salvo [132a], U. De Sanctis [164a,164c], A. De Santo [149], J.B. De Vivie De Regie [115], S. Dean [77], R. Debbe [24], D.V. Dedovich [65], J. Degenhardt [120], M. Dehchar [118], C. Del Papa [164a,164c], J. Del Peso [80], T. Del Prete [122a,122b], M. Deliyergiyev [74], A. Dell'Acqua [29], L. Dell'Asta [89a,89b], M. Della Pietra [102a,j], D. della Volpe [102a,102b], M. Delmastro [29], P. Delpierre [83], N. Delruelle [29], P.A. Delsart [55], C. Deluca [148], S. Demers [175], M. Demichev [65], B. Demirkoz [11,l], J. Deng [163], S.P. Denisov [128], D. Derendarz [38], J.E. Derkaoui [135d], F. Derue [78], P. Dervan [73], K. Desch [20], E. Devetak [148], P.O. Deviveiros [158], A. Dewhurst [129], B. DeWilde [148], S. Dhaliwal [158], R. Dhullipudi [24,m], A. Di Ciaccio [133a,133b], L. Di Ciaccio [4], A. Di Girolamo [29], B. Di Girolamo [29], S. Di Luise [134a,134b], A. Di Mattia [88], B. Di Micco [29], R. Di Nardo [133a,133b], A. Di Simone [133a,133b], R. Di Sipio [19a,19b], M.A. Diaz [31a], F. Diblen [18c], E.B. Diehl [87], J. Dietrich [41], T.A. Dietzsch [58a], S. Diglio [115], K. Dindar Yagci [39], J. Dingfelder [20], C. Dionisi [132a,132b], P. Dita [25a], S. Dita [25a], F. Dittus [29], F. Djama [83], T. Djobava [51], M.A.B. do Vale [23a], A. Do Valle Wemans [124a], T.K.O. Doan [4], M. Dobbs [85], R. Dobinson [29,*], D. Dobos [42], E. Dobson [29], M. Dobson [163], J. Dodd [34], C. Doglioni [118], T. Doherty [53], Y. Doi [66,*], J. Dolejsi [126], I. Dolenc [74], Z. Dolezal [126], B.A. Dolgoshein [96,*], T. Dohmae [155], M. Donadelli [23d], M. Donega [120], J. Donini [55], J. Dopke [29], A. Doria [102a], A. Dos Anjos [172], M. Dosil [11], A. Dotti [122a,122b], M.T. Dova [70], J.D. Dowell [17], A.D. Doxiadis [105], A.T. Doyle [53], Z. Drasal [126], J. Drees [174], N. Dressnandt [120], H. Drevermann [29], C. Driouichi [35], M. Dris [9], J. Dubbert [99], T. Dubbs [137], S. Dube [14], E. Duchovni [171], G. Duckeck [98], A. Dudarev [29], F. Dudziak [64], M. Dührssen [29], I.P. Duerdoth [82], L. Duflot [115], M.-A. Dufour [85], M. Dunford [29], H. Duran Yildiz [3b], R. Duxfield [139], M. Dwuznik [37], F. Dydak [29], M. Düren [52], W.L. Ebenstein [44], J. Ebke [98], S. Eckert [48], S. Eckweiler [81], K. Edmonds [81], C.A. Edwards [76], N.C. Edwards [53], W. Ehrenfeld [41], T. Ehrich [99], T. Eifert [29], G. Eigen [13], K. Einsweiler [14], E. Eisenhandler [75], T. Ekelof [166], M. El Kacimi [135c], M. Ellert [166], S. Elles [4], F. Ellinghaus [81], K. Ellis [75], N. Ellis [29], J. Elmsheuser [98], M. Elsing [29], D. Emeliyanov [129], R. Engelmann [148], A. Engl [98], B. Epp [62],

A. Eppig [87], J. Erdmann [54], A. Ereditato [16], D. Eriksson [146a], J. Ernst [1], M. Ernst [24], J. Ernwein [136], D. Errede [165], S. Errede [165], E. Ertel [81], M. Escalier [115], C. Escobar [167], X. Espinal Curull [11], B. Esposito [47], F. Etienne [83], A.I. Etienvre [136], E. Etzion [153], D. Evangelakou [54], H. Evans [61], L. Fabbri [19a,19b], C. Fabre [29], R.M. Fakhrutdinov [128], S. Falciano [132a], Y. Fang [172], M. Fanti [89a,89b], A. Farbin [7], A. Farilla [134a], J. Farley [148], T. Farooque [158], S.M. Farrington [118], P. Farthouat [29], P. Fassnacht [29], D. Fassouliotis [8], B. Fatholahzadeh [158], A. Favareto [89a,89b], L. Fayard [115], S. Fazio [36a,36b], R. Febbraro [33], P. Federic [144a], O.L. Fedin [121], W. Fedorko [88], M. Fehling-Kaschek [48], L. Feligioni [83], D. Fellmann [5], C.U. Felzmann [86], C. Feng [32d], E.J. Feng [30], A.B. Fenyuk [128], J. Ferencei [144b], J. Ferland [93], W. Fernando [109], S. Ferrag [53], J. Ferrando [53], V. Ferrara [41], A. Ferrari [166], P. Ferrari [105], R. Ferrari [119a], A. Ferrer [167], M.L. Ferrer [47], D. Ferrere [49], C. Ferretti [87], A. Ferretto Parodi [50a,50b], M. Fiascaris [30], F. Fiedler [81], A. Filipčič [74], A. Filippas [9], F. Filthaut [104], M. Fincke-Keeler [169], M.C.N. Fiolhais [124a,i], L. Fiorini [167], A. Firan [39], G. Fischer [41], P. Fischer [20], M.J. Fisher [109], S.M. Fisher [129], M. Flechl [48], I. Fleck [141], J. Fleckner [81], P. Fleischmann [173], S. Fleischmann [174], T. Flick [174], L.R. Flores Castillo [172], M.J. Flowerdew [99], M. Fokitis [9], T. Fonseca Martin [16], D.A. Forbush [138], A. Formica [136], A. Forti [82], D. Fortin [159a], J.M. Foster [82], D. Fournier [115], A. Foussat [29], A.J. Fowler [44], K. Fowler [137], H. Fox [71], P. Francavilla [122a,122b], S. Franchino [119a,119b], D. Francis [29], T. Frank [171], M. Franklin [57], S. Franz [29], M. Fraternali [119a,119b], S. Fratina [120], S.T. French [27], F. Friedrich [43], R. Froeschl [29], D. Froidevaux [29], J.A. Frost [27], C. Fukunaga [156], E. Fullana Torregrosa [29], J. Fuster [167], C. Gabaldon [29], O. Gabizon [171], T. Gadfort [24], S. Gadomski [49], G. Gagliardi [50a,50b], P. Gagnon [61], C. Galea [98], E.J. Gallas [118], M.V. Gallas [29], V. Gallo [16], B.J. Gallop [129], P. Gallus [125], E. Galyaev [40], K.K. Gan [109], Y.S. Gao [143,f], V.A. Gapienko [128], A. Gaponenko [14], F. Garberson [175], M. Garcia-Sciveres [14], C. García [167], J.E. García Navarro [49], R.W. Gardner [30], N. Garelli [29], H. Garitaonandia [105], V. Garonne [29], J. Garvey [17], C. Gatti [47], G. Gaudio [119a], O. Gaumer [49], B. Gaur [141], L. Gauthier [136], I.L. Gavrilenko [94], C. Gay [168], G. Gaycken [20], J.-C. Gayde [29], E.N. Gazis [9], P. Ge [32d], C.N.P. Gee [129], D.A.A. Geerts [105], Ch. Geich-Gimbel [20], K. Gellerstedt [146a,146b], C. Gemme [50a], A. Gemmell [53], M.H. Genest [98], S. Gentile [132a,132b], M. George [54], S. George [76], P. Gerlach [174], A. Gershon [153], C. Geweniger [58a], H. Ghazlane [135b], P. Ghez [4], N. Ghodbane [33], B. Giacobbe [19a], S. Giagu [132a,132b], V. Giakoumopoulou [8], V. Giangiobbe [122a,122b], F. Gianotti [29], B. Gibbard [24], A. Gibson [158], S.M. Gibson [29], L.M. Gilbert [118], M. Gilchriese [14], V. Gilewsky [91], D. Gillberg [28], A.R. Gillman [129], D.M. Gingrich [2,e], J. Ginzburg [153], N. Giokaris [8], R. Giordano [102a,102b], F.M. Giorgi [15], P. Giovannini [99], P.F. Giraud [136], D. Giugni [89a], M. Giunta [93], P. Giusti [19a], B.K. Gjelsten [117], L.K. Gladilin [97], C. Glasman [80], J. Glatzer [48], A. Glazov [41], K.W. Glitza [174], G.L. Glonti [65], J. Godfrey [142], J. Godlewski [29], M. Goebel [41], T. Göpfert [43], C. Goeringer [81], C. Gössling [42], T. Göttfert [99], S. Goldfarb [87], T. Golling [175], S.N. Golovnia [128], A. Gomes [124a,b], L.S. Gomez Fajardo [41], R. Gonçalo [76], J. Goncalves Pinto Firmino Da Costa [41], L. Gonella [20], A. Gonidec [29], S. Gonzalez [172], S. González de la Hoz [167], M.L. Gonzalez Silva [26], S. Gonzalez-Sevilla [49], J.J. Goodson [148], L. Goossens [29], P.A. Gorbounov [95], H.A. Gordon [24], I. Gorelov [103], G. Gorfine [174], B. Gorini [29], E. Gorini [72a,72b], A. Gorišek [74], E. Gornicki [38], S.A. Gorokhov [128], V.N. Goryachev [128], B. Gosdzik [41], M. Gosselink [105], M.I. Gostkin [65], I. Gough Eschrich [163], M. Gouighri [135a], D. Goujdami [135c], M.P. Goulette [49], A.G. Goussiou [138], C. Goy [4], I. Grabowska-Bold [163,g], V. Grabski [176], P. Grafström [29], C. Grah [174], K.-J. Grahn [41], F. Grancagnolo [72a], S. Grancagnolo [15], V. Grassi [148], V. Gratchev [121], N. Grau [34], H.M. Gray [29], J.A. Gray [148], E. Graziani [134a], O.G. Grebenyuk [121], D. Greenfield [129], T. Greenshaw [73], Z.D. Greenwood [24,m], K. Gregersen [35], I.M. Gregor [41], P. Grenier [143], J. Griffiths [138], N. Grigalashvili [65], A.A. Grillo [137], S. Grinstein [11], Y.V. Grishkevich [97], J.-F. Grivaz [115], J. Grognuz [29], M. Groh [99], E. Gross [171], J. Grosse-Knetter [54], J. Groth-Jensen [171], K. Grybel [141], V.J. Guarino [5], D. Guest [175], C. Guicheney [33], A. Guida [72a,72b], T. Guillemin [4], S. Guindon [54], H. Guler [85,n], J. Gunther [125], B. Guo [158], J. Guo [34], A. Gupta [30], Y. Gusakov [65], V.N. Gushchin [128], A. Gutierrez [93], P. Gutierrez [111], N. Guttman [153], O. Gutzwiller [172], C. Guyot [136], C. Gwenlan [118], C.B. Gwilliam [73], A. Haas [143], S. Haas [29], C. Haber [14], R. Hackenburg [24], H.K. Hadavand [39], D.R. Hadley [17], P. Haefner [99], F. Hahn [29], S. Haider [29], Z. Hajduk [38], H. Hakobyan [176], J. Haller [54], K. Hamacher [174], P. Hamal [113], A. Hamilton [49], S. Hamilton [161], H. Han [32a], L. Han [32b], K. Hanagaki [116], M. Hance [120], C. Handel [81], P. Hanke [58a], J.R. Hansen [35], J.B. Hansen [35], J.D. Hansen [35], P.H. Hansen [35], P. Hansson [143], K. Hara [160], G.A. Hare [137], T. Harenberg [174], S. Harkusha [90], D. Harper [87], R.D. Harrington [21], O.M. Harris [138], K. Harrison [17], J. Hartert [48], F. Hartjes [105], T. Haruyama [66], A. Harvey [56], S. Hasegawa [101], Y. Hasegawa [140], S. Hassani [136], M. Hatch [29], D. Hauff [99], S. Haug [16],

M. Hauschild [29], R. Hauser [88], M. Havranek [20], B.M. Hawes [118], C.M. Hawkes [17], R.J. Hawkings [29], D. Hawkins [163], T. Hayakawa [67], D. Hayden [76], H.S. Hayward [73], S.J. Haywood [129], E. Hazen [21], M. He [32d], S.J. Head [17], V. Hedberg [79], L. Heelan [7], S. Heim [88], B. Heinemann [14], S. Heisterkamp [35], L. Helary [4], M. Heller [115], S. Hellman [146a,146b], D. Hellmich [20], C. Helsens [11], R.C.W. Henderson [71], M. Henke [58a], A. Henrichs [54], A.M. Henriques Correia [29], S. Henrot-Versille [115], F. Henry-Couannier [83], C. Hensel [54], T. Henß [174], C.M. Hernandez [7], Y. Hernández Jiménez [167], R. Herrberg [15], A.D. Hershenhorn [152], G. Herten [48], R. Hertenberger [98], L. Hervas [29], N.P. Hessey [105], A. Hidvegi [146a], E. Higón-Rodriguez [167], D. Hill [5,*], J.C. Hill [27], N. Hill [5], K.H. Hiller [41], S. Hillert [20], S.J. Hillier [17], I. Hinchliffe [14], E. Hines [120], M. Hirose [116], F. Hirsch [42], D. Hirschbuehl [174], J. Hobbs [148], N. Hod [153], M.C. Hodgkinson [139], P. Hodgson [139], A. Hoecker [29], M.R. Hoeferkamp [103], J. Hoffman [39], D. Hoffmann [83], M. Hohlfeld [81], M. Holder [141], S.O. Holmgren [146a], T. Holy [127], J.L. Holzbauer [88], Y. Homma [67], T.M. Hong [120], L. Hooft van Huysduynen [108], T. Horazdovsky [127], C. Horn [143], S. Horner [48], K. Horton [118], J.-Y. Hostachy [55], S. Hou [151], M.A. Houlden [73], A. Hoummada [135a], J. Howarth [82], D.F. Howell [118], I. Hristova [15], J. Hrivnac [115], I. Hruska [125], T. Hryn'ova [4], P.J. Hsu [175], S.-C. Hsu [14], G.S. Huang [111], Z. Hubacek [127], F. Hubaut [83], F. Huegging [20], T.B. Huffman [118], E.W. Hughes [34], G. Hughes [71], R.E. Hughes-Jones [82], M. Huhtinen [29], P. Hurst [57], M. Hurwitz [14], U. Husemann [41], N. Huseynov [65,o], J. Huston [88], J. Huth [57], G. Iacobucci [49], G. Iakovidis [9], M. Ibbotson [82], I. Ibragimov [141], R. Ichimiya [67], L. Iconomidou-Fayard [115], J. Idarraga [115], M. Idzik [37], P. Iengo [102a,102b], O. Igonkina [105], Y. Ikegami [66], M. Ikeno [66], Y. Ilchenko [39], D. Iliadis [154], D. Imbault [78], M. Imhaeuser [174], M. Imori [155], T. Ince [20], J. Inigo-Golfin [29], P. Ioannou [8], M. Iodice [134a], G. Ionescu [4], A. Irles Quiles [167], K. Ishii [66], A. Ishikawa [67], M. Ishino [68], R. Ishmukhametov [39], C. Issever [118], S. Istin [18a], A.V. Ivashin [128], W. Iwanski [38], H. Iwasaki [66], J.M. Izen [40], V. Izzo [102a], B. Jackson [120], J.N. Jackson [73], P. Jackson [143], M.R. Jaekel [29], V. Jain [61], K. Jakobs [48], S. Jakobsen [35], J. Jakubek [127], D.K. Jana [111], E. Jankowski [158], E. Jansen [77], A. Jantsch [99], M. Janus [20], G. Jarlskog [79], L. Jeanty [57], K. Jelen [37], I. Jen-La Plante [30], P. Jenni [29], A. Jeremie [4], P. Jež [35], S. Jézéquel [4], M.K. Jha [19a], H. Ji [172], W. Ji [81], J. Jia [148], Y. Jiang [32b], M. Jimenez Belenguer [41], G. Jin [32b], S. Jin [32a], O. Jinnouchi [157], M.D. Joergensen [35], D. Joffe [39], L.G. Johansen [13], M. Johansen [146a,146b], K.E. Johansson [146a], P. Johansson [139], S. Johnert [41], K.A. Johns [6], K. Jon-And [146a,146b], G. Jones [82], R.W.L. Jones [71], T.W. Jones [77], T.J. Jones [73], O. Jonsson [29], C. Joram [29], P.M. Jorge [124a,b], J. Joseph [14], T. Jovin [12b], X. Ju [130], V. Juranek [125], P. Jussel [62], A. Juste Rozas [11], V.V. Kabachenko [128], S. Kabana [16], M. Kaci [167], A. Kaczmarska [38], P. Kadlecik [35], M. Kado [115], H. Kagan [109], M. Kagan [57], S. Kaiser [99], E. Kajomovitz [152], S. Kalinin [174], L.V. Kalinovskaya [65], S. Kama [39], N. Kanaya [155], M. Kaneda [29], T. Kanno [157], V.A. Kantserov [96], J. Kanzaki [66], B. Kaplan [175], A. Kapliy [30], J. Kaplon [29], D. Kar [43], M. Karagoz [118], M. Karnevskiy [41], K. Karr [5], V. Kartvelishvili [71], A.N. Karyukhin [128], L. Kashif [172], A. Kasmi [39], R.D. Kass [109], A. Kastanas [13], M. Kataoka [4], Y. Kataoka [155], E. Katsoufis [9], J. Katzy [41], V. Kaushik [6], K. Kawagoe [67], T. Kawamoto [155], G. Kawamura [81], M.S. Kayl [105], V.A. Kazanin [107], M.Y. Kazarinov [65], J.R. Keates [82], R. Keeler [169], R. Kehoe [39], M. Keil [54], G.D. Kekelidze [65], M. Kelly [82], J. Kennedy [98], C.J. Kenney [143], M. Kenyon [53], O. Kepka [125], N. Kerschen [29], B.P. Kerševan [74], S. Kersten [174], K. Kessoku [155], C. Ketterer [48], J. Keung [158], M. Khakzad [28], F. Khalil-zada [10], H. Khandanyan [165], A. Khanov [112], D. Kharchenko [65], A. Khodinov [96], A.G. Kholodenko [128], A. Khomich [58a], T.J. Khoo [27], G. Khoriauli [20], A. Khoroshilov [174], N. Khovanskiy [65], V. Khovanskiy [95], E. Khramov [65], J. Khubua [51], H. Kim [7], M.S. Kim [2], P.C. Kim [143], S.H. Kim [160], N. Kimura [170], O. Kind [15], B.T. King [73], M. King [67], R.S.B. King [118], J. Kirk [129], L.E. Kirsch [22], A.E. Kiryunin [99], T. Kishimoto [67], D. Kisielewska [37], T. Kittelmann [123], A.M. Kiver [128], E. Kladiva [144b], J. Klaiber-Lodewigs [42], M. Klein [73], U. Klein [73], K. Kleinknecht [81], M. Klemetti [85], A. Klier [171], A. Klimentov [24], R. Klingenberg [42], E.B. Klinkby [35], T. Klioutchnikova [29], P.F. Klok [104], S. Klous [105], E.-E. Kluge [58a], T. Kluge [73], P. Kluit [105], S. Kluth [99], N.S. Knecht [158], E. Kneringer [62], J. Knobloch [29], E.B.F.G. Knoops [83], A. Knue [54], B.R. Ko [44], T. Kobayashi [155], M. Kobel [43], M. Kocian [143], A. Kocnar [113], P. Kodys [126], K. Köneke [29], A.C. König [104], S. Koenig [81], L. Köpke [81], F. Koetsveld [104], P. Koevesarki [20], T. Koffas [28], E. Koffeman [105], F. Kohn [54], Z. Kohout [127], T. Kohriki [66], T. Koi [143], T. Kokott [20], G.M. Kolachev [107], H. Kolanoski [15], V. Kolesnikov [65], I. Koletsou [89a], J. Koll [88], D. Kollar [29], M. Kollefrath [48], S.D. Kolya [82], A.A. Komar [94], Y. Komori [155], T. Kondo [66], T. Kono [41,p], A.I. Kononov [48], R. Konoplich [108,q], N. Konstantinidis [77], A. Kootz [174], S. Koperny [37], S.V. Kopikov [128], K. Korcyl [38], K. Kordas [154], V. Koreshev [128], A. Korn [14], A. Korol [107], I. Korolkov [11], E.V. Korolkova [139], V.A. Korotkov [128], O. Kortner [99], S. Kortner [99], V.V. Kostyukhin [20], M.J. Kotamäki [29], S. Kotov [99],

V.M. Kotov [65], A. Kotwal [44], C. Kourkoumelis [8], V. Kouskoura [154], A. Koutsman [105], R. Kowalewski [169], T.Z. Kowalski [37], W. Kozanecki [136], A.S. Kozhin [128], V. Kral [127], V.A. Kramarenko [97], G. Kramberger [74], M.W. Krasny [78], A. Krasznahorkay [108], J. Kraus [88], J.K. Kraus [20], A. Kreisel [153], F. Krejci [127], J. Kretzschmar [73], N. Krieger [54], P. Krieger [158], K. Kroeninger [54], H. Kroha [99], J. Kroll [120], J. Kroseberg [20], J. Krstic [12a], U. Kruchonak [65], H. Krüger [20], T. Kruker [16], Z.V. Krumshteyn [65], A. Kruth [20], T. Kubota [86], S. Kuehn [48], A. Kugel [58c], T. Kuhl [41], D. Kuhn [62], V. Kukhtin [65], Y. Kulchitsky [90], S. Kuleshov [31b], C. Kummer [98], M. Kuna [78], N. Kundu [118], J. Kunkle [120], A. Kupco [125], H. Kurashige [67], M. Kurata [160], Y.A. Kurochkin [90], V. Kus [125], W. Kuykendall [138], M. Kuze [157], P. Kuzhir [91], J. Kvita [29], R. Kwee [15], A. La Rosa [172], L. La Rotonda [36a,36b], L. Labarga [80], J. Labbe [4], S. Lablak [135a], C. Lacasta [167], F. Lacava [132a,132b], H. Lacker [15], D. Lacour [78], V.R. Lacuesta [167], E. Ladygin [65], R. Lafaye [4], B. Laforge [78], T. Lagouri [80], S. Lai [48], E. Laisne [55], M. Lamanna [29], C.L. Lampen [6], W. Lampl [6], E. Lancon [136], U. Landgraf [48], M.P.J. Landon [75], H. Landsman [152], J.L. Lane [82], C. Lange [41], A.J. Lankford [163], F. Lanni [24], K. Lantzsch [29], S. Laplace [78], C. Lapoire [20], J.F. Laporte [136], T. Lari [89a], A.V. Larionov [128], A. Larner [118], C. Lasseur [29], M. Lassnig [29], P. Laurelli [47], A. Lavorato [118], W. Lavrijsen [14], P. Laycock [73], A.B. Lazarev [65], O. Le Dortz [78], E. Le Guirriec [83], C. Le Maner [158], E. Le Menedeu [136], C. Lebel [93], T. LeCompte [5], F. Ledroit-Guillon [55], H. Lee [105], J.S.H. Lee [150], S.C. Lee [151], L. Lee [175], M. Lefebvre [169], M. Legendre [136], A. Leger [49], B.C. LeGeyt [120], F. Legger [98], C. Leggett [14], M. Lehmacher [20], G. Lehmann Miotto [29], X. Lei [6], M.A.L. Leite [23d], R. Leitner [126], D. Lellouch [171], M. Leltchouk [34], B. Lemmer [54], V. Lendermann [58a], K.J.C. Leney [145b], T. Lenz [105], G. Lenzen [174], B. Lenzi [29], K. Leonhardt [43], S. Leontsinis [9], C. Leroy [93], J.-R. Lessard [169], J. Lesser [146a], C.G. Lester [27], A. Leung Fook Cheong [172], J. Levêque [4], D. Levin [87], L.J. Levinson [171], M.S. Levitski [128], M. Lewandowska [21], A. Lewis [118], G.H. Lewis [108], A.M. Leyko [20], M. Leyton [15], B. Li [83], H. Li [172], S. Li [32b,d], X. Li [87], Z. Liang [39], Z. Liang [118,r], H. Liao [33], B. Liberti [133a], P. Lichard [29], M. Lichtnecker [98], K. Lie [165], J. Liebal [20], W. Liebig [13], R. Lifshitz [152], J.N. Lilley [17], C. Limbach [20], A. Limosani [86], M. Limper [63], S.C. Lin [151,s], F. Linde [105], J.T. Linnemann [88], E. Lipeles [120], L. Lipinsky [125], A. Lipniacka [13], T.M. Liss [165], D. Lissauer [24], A. Lister [49], A.M. Litke [137], C. Liu [28], D. Liu [151,t], H. Liu [87], J.B. Liu [87], M. Liu [32b], S. Liu [2], Y. Liu [32b], M. Livan [119a,119b], S.S.A. Livermore [118], A. Lleres [55], J. Llorente Merino [80], S.L. Lloyd [75], E. Lobodzinska [41], P. Loch [6], W.S. Lockman [137], T. Loddenkoetter [20], F.K. Loebinger [82], A. Loginov [175], C.W. Loh [168], T. Lohse [15], K. Lohwasser [48], M. Lokajicek [125], J. Loken [118], V.P. Lombardo [4], R.E. Long [71], L. Lopes [124a,b], D. Lopez Mateos [57], M. Losada [162], P. Loscutoff [14], F. Lo Sterzo [132a,132b], M.J. Losty [159a], X. Lou [40], A. Lounis [115], K.F. Loureiro [162], J. Love [21], P.A. Love [71], A.J. Lowe [143,f], F. Lu [32a], H.J. Lubatti [138], C. Luci [132a,132b], A. Lucotte [55], A. Ludwig [43], D. Ludwig [41], I. Ludwig [48], J. Ludwig [48], F. Luehring [61], G. Luijckx [105], D. Lumb [48], L. Luminari [132a], E. Lund [117], B. Lund-Jensen [147], B. Lundberg [79], J. Lundberg [146a,146b], J. Lundquist [35], M. Lungwitz [81], A. Lupi [122a,122b], G. Lutz [99], D. Lynn [24], J. Lys [14], E. Lytken [79], H. Ma [24], L.L. Ma [172], J.A. Macana Goia [93], G. Maccarrone [47], A. Macchiolo [99], B. Maček [74], J. Machado Miguens [124a], R. Mackeprang [35], R.J. Madaras [14], W.F. Mader [43], R. Maenner [58c], T. Maeno [24], P. Mättig [174], S. Mättig [41], L. Magnoni [29], E. Magradze [54], Y. Mahalalel [153], K. Mahboubi [48], G. Mahout [17], C. Maiani [132a,132b], C. Maidantchik [23a], A. Maio [124a,b], S. Majewski [24], Y. Makida [66], N. Makovec [115], P. Mal [6], Pa. Malecki [38], P. Malecki [38], V.P. Maleev [121], F. Malek [55], U. Mallik [63], D. Malon [5], C. Malone [143], S. Maltezos [9], V. Malyshev [107], S. Malyukov [29], R. Mameghani [98], J. Mamuzic [12b], A. Manabe [66], L. Mandelli [89a], I. Mandić [74], R. Mandrysch [15], J. Maneira [124a], P.S. Mangeard [88], I.D. Manjavidze [65], A. Mann [54], P.M. Manning [137], A. Manousakis-Katsikakis [8], B. Mansoulie [136], A. Manz [99], A. Mapelli [29], L. Mapelli [29], L. March [80], J.F. Marchand [29], F. Marchese [133a,133b], G. Marchiori [78], M. Marcisovsky [125], A. Marin [21,*], C.P. Marino [61], F. Marroquim [23a], R. Marshall [82], Z. Marshall [29], F.K. Martens [158], S. Marti-Garcia [167], A.J. Martin [175], B. Martin [29], B. Martin [88], F.F. Martin [120], J.P. Martin [93], Ph. Martin [55], T.A. Martin [17], B. Martin dit Latour [49], S. Martin–Haugh [149], M. Martinez [11], V. Martinez Outschoorn [57], A.C. Martyniuk [82], M. Marx [82], F. Marzano [132a], A. Marzin [111], L. Masetti [81], T. Mashimo [155], R. Mashinistov [94], J. Masik [82], A.L. Maslennikov [107], I. Massa [19a,19b], G. Massaro [105], N. Massol [4], P. Mastrandrea [132a,132b], A. Mastroberardino [36a,36b], T. Masubuchi [155], M. Mathes [20], P. Matricon [115], H. Matsumoto [155], H. Matsunaga [155], T. Matsushita [67], C. Mattravers [118,c], J.M. Maugain [29], S.J. Maxfield [73], D.A. Maximov [107], E.N. May [5], A. Mayne [139], R. Mazini [151], M. Mazur [20], M. Mazzanti [89a], E. Mazzoni [122a,122b], S.P. Mc Kee [87], A. McCarn [165], R.L. McCarthy [148], T.G. McCarthy [28], N.A. McCubbin [129], K.W. McFarlane [56],

J.A. Mcfayden [139], H. McGlone [53], G. Mchedlidze [51], R.A. McLaren [29], T. Mclaughlan [17], S.J. McMahon [129], R.A. McPherson [169,k], A. Meade [84], J. Mechnich [105], M. Mechtel [174], M. Medinnis [41], R. Meera-Lebbai [111], T. Meguro [116], R. Mehdiyev [93], S. Mehlhase [35], A. Mehta [73], K. Meier [58a], J. Meinhardt [48], B. Meirose [79], C. Melachrinos [30], B.R. Mellado Garcia [172], L. Mendoza Navas [162], Z. Meng [151,t], A. Mengarelli [19a,19b], S. Menke [99], C. Menot [29], E. Meoni [11], K.M. Mercurio [57], P. Mermod [118], L. Merola [102a,102b], C. Meroni [89a], F.S. Merritt [30], A. Messina [29], J. Metcalfe [103], A.S. Mete [64], S. Meuser [20], C. Meyer [81], J.-P. Meyer [136], J. Meyer [173], J. Meyer [54], T.C. Meyer [29], W.T. Meyer [64], J. Miao [32d], S. Michal [29], L. Micu [25a], R.P. Middleton [129], P. Miele [29], S. Migas [73], L. Mijović [41], G. Mikenberg [171], M. Mikestikova [125], M. Mikuž [74], D.W. Miller [143], R.J. Miller [88], W.J. Mills [168], C. Mills [57], A. Milov [171], D.A. Milstead [146a,146b], D. Milstein [171], A.A. Minaenko [128], M. Miñano [167], I.A. Minashvili [65], A.I. Mincer [108], B. Mindur [37], M. Mineev [65], Y. Ming [130], L.M. Mir [11], G. Mirabelli [132a], L. Miralles Verge [11], A. Misiejuk [76], J. Mitrevski [137], G.Y. Mitrofanov [128], V.A. Mitsou [167], S. Mitsui [66], P.S. Miyagawa [139], K. Miyazaki [67], J.U. Mjörnmark [79], T. Moa [146a,146b], P. Mockett [138], S. Moed [57], V. Moeller [27], K. Mönig [41], N. Möser [20], S. Mohapatra [148], W. Mohr [48], S. Mohrdieck-Möck [99], A.M. Moisseev [128,*], R. Moles-Valls [167], J. Molina-Perez [29], J. Monk [77], E. Monnier [83], S. Montesano [89a,89b], F. Monticelli [70], S. Monzani [19a,19b], R.W. Moore [2], G.F. Moorhead [86], C. Mora Herrera [49], A. Moraes [53], N. Morange [136], J. Morel [54], G. Morello [36a,36b], D. Moreno [81], M. Moreno Llácer [167], P. Morettini [50a], M. Morii [57], J. Morin [75], Y. Morita [66], A.K. Morley [29], G. Mornacchi [29], S.V. Morozov [96], J.D. Morris [75], L. Morvaj [101], H.G. Moser [99], M. Mosidze [51], J. Moss [109], R. Mount [143], E. Mountricha [136], S.V. Mouraviev [94], E.J.W. Moyse [84], M. Mudrinic [12b], F. Mueller [58a], J. Mueller [123], K. Mueller [20], T.A. Müller [98], D. Muenstermann [29], A. Muir [168], Y. Munwes [153], W.J. Murray [129], I. Mussche [105], E. Musto [102a,102b], A.G. Myagkov [128], M. Myska [125], J. Nadal [11], K. Nagai [160], K. Nagano [66], Y. Nagasaka [60], A.M. Nairz [29], Y. Nakahama [29], K. Nakamura [155], I. Nakano [110], G. Nanava [20], A. Napier [161], M. Nash [77,c], N.R. Nation [21], T. Nattermann [20], T. Naumann [41], G. Navarro [162], H.A. Neal [87], E. Nebot [80], P.Yu. Nechaeva [94], A. Negri [119a,119b], G. Negri [29], S. Nektarijevic [49], S. Nelson [143], T.K. Nelson [143], S. Nemecek [125], P. Nemethy [108], A.A. Nepomuceno [23a], M. Nessi [29,u], S.Y. Nesterov [121], M.S. Neubauer [165], A. Neusiedl [81], R.M. Neves [108], P. Nevski [24], P.R. Newman [17], V. Nguyen Thi Hong [136], R.B. Nickerson [118], R. Nicolaidou [136], L. Nicolas [139], B. Nicquevert [29], F. Niedercorn [115], J. Nielsen [137], T. Niinikoski [29], N. Nikiforou [34], A. Nikiforov [15], V. Nikolaenko [128], K. Nikolaev [65], I. Nikolic-Audit [78], K. Nikolics [49], K. Nikolopoulos [24], H. Nilsen [48], P. Nilsson [7], Y. Ninomiya [155], A. Nisati [132a], T. Nishiyama [67], R. Nisius [99], L. Nodulman [5], M. Nomachi [116], I. Nomidis [154], M. Nordberg [29], B. Nordkvist [146a,146b], P.R. Norton [129], J. Novakova [126], M. Nozaki [66], M. Nožička [41], L. Nozka [113], I.M. Nugent [159a], A.-E. Nuncio-Quiroz [20], G. Nunes Hanninger [86], T. Nunnemann [98], E. Nurse [77], T. Nyman [29], B.J. O'Brien [45], S.W. O'Neale [17,*], D.C. O'Neil [142], V. O'Shea [53], F.G. Oakham [28,e], H. Oberlack [99], J. Ocariz [78], A. Ochi [67], S. Oda [155], S. Odaka [66], J. Odier [83], H. Ogren [61], A. Oh [82], S.H. Oh [44], C.C. Ohm [146a,146b], T. Ohshima [101], H. Ohshita [140], T.K. Ohska [66], T. Ohsugi [59], S. Okada [67], H. Okawa [163], Y. Okumura [101], T. Okuyama [155], M. Olcese [50a], A.G. Olchevski [65], M. Oliveira [124a,i], D. Oliveira Damazio [24], E. Oliver Garcia [167], D. Olivito [120], A. Olszewski [38], J. Olszowska [38], C. Omachi [67], A. Onofre [124a,v], P.U.E. Onyisi [30], C.J. Oram [159a], M.J. Oreglia [30], Y. Oren [153], D. Orestano [134a,134b], I. Orlov [107], C. Oropeza Barrera [53], R.S. Orr [158], B. Osculati [50a,50b], R. Ospanov [120], C. Osuna [11], G. Otero y Garzon [26], J.P. Ottersbach [105], M. Ouchrif [135d], F. Ould-Saada [117], A. Ouraou [136], Q. Ouyang [32a], M. Owen [82], S. Owen [139], V.E. Ozcan [18a], N. Ozturk [7], A. Pacheco Pages [11], C. Padilla Aranda [11], S. Pagan Griso [14], E. Paganis [139], F. Paige [24], K. Pajchel [117], G. Palacino [159b], C.P. Paleari [6], S. Palestini [29], D. Pallin [33], A. Palma [124a,b], J.D. Palmer [17], Y.B. Pan [172], E. Panagiotopoulou [9], B. Panes [31a], N. Panikashvili [87], S. Panitkin [24], D. Pantea [25a], M. Panuskova [125], V. Paolone [123], A. Papadelis [146a], Th.D. Papadopoulou [9], A. Paramonov [5], W. Park [24,w], M.A. Parker [27], F. Parodi [50a,50b], J.A. Parsons [34], U. Parzefall [48], E. Pasqualucci [132a], A. Passeri [134a], F. Pastore [134a,134b], Fr. Pastore [76], G. Pásztor [49,x], S. Pataraia [172], N. Patel [150], J.R. Pater [82], S. Patricelli [102a,102b], T. Pauly [29], M. Pecsy [144a], M.I. Pedraza Morales [172], S.V. Peleganchuk [107], H. Peng [32b], R. Pengo [29], A. Penson [34], J. Penwell [61], M. Perantoni [23a], K. Perez [34,y], T. Perez Cavalcanti [41], E. Perez Codina [11], M.T. Pérez García-Estañ [167], V. Perez Reale [34], L. Perini [89a,89b], H. Pernegger [29], R. Perrino [72a], P. Perrodo [4], S. Persembe [3a], V.D. Peshekhonov [65], B.A. Petersen [29], J. Petersen [29], T.C. Petersen [35], E. Petit [83], A. Petridis [154], C. Petridou [154], E. Petrolo [132a], F. Petrucci [134a,134b], D. Petschull [41], M. Petteni [142], R. Pezoa [31b], A. Phan [86], A.W. Phillips [27], P.W. Phillips [129], G. Piacquadio [29],

E. Piccaro [75], M. Piccinini [19a,19b], A. Pickford [53], S.M. Piec [41], R. Piegaia [26], J.E. Pilcher [30], A.D. Pilkington [82], J. Pina [124a,b], M. Pinamonti [164a,164c], A. Pinder [118], J.L. Pinfold [2], J. Ping [32c], B. Pinto [124a,b], O. Pirotte [29], C. Pizio [89a,89b], R. Placakyte [41], M. Plamondon [169], W.G. Plano [82], M.-A. Pleier [24], A.V. Pleskach [128], A. Poblaguev [24], S. Poddar [58a], F. Podlyski [33], L. Poggioli [115], T. Poghosyan [20], M. Pohl [49], F. Polci [55], G. Polesello [119a], A. Policicchio [138], A. Polini [19a], J. Poll [75], V. Polychronakos [24], D.M. Pomarede [136], D. Pomeroy [22], K. Pommès [29], L. Pontecorvo [132a], B.G. Pope [88], G.A. Popeneciu [25a], D.S. Popovic [12a], A. Poppleton [29], X. Portell Bueso [29], R. Porter [163], C. Posch [21], G.E. Pospelov [99], S. Pospisil [127], I.N. Potrap [99], C.J. Potter [149], C.T. Potter [114], G. Poulard [29], J. Poveda [172], R. Prabhu [77], P. Pralavorio [83], S. Prasad [57], R. Pravahan [7], S. Prell [64], K. Pretzl [16], L. Pribyl [29], D. Price [61], L.E. Price [5], M.J. Price [29], P.M. Prichard [73], D. Prieur [123], M. Primavera [72a], K. Prokofiev [108], F. Prokoshin [31b], S. Protopopescu [24], J. Proudfoot [5], X. Prudent [43], H. Przysiezniak [4], S. Psoroulas [20], E. Ptacek [114], E. Pueschel [84], J. Purdham [87], M. Purohit [24,w], P. Puzo [115], Y. Pylypchenko [117], J. Qian [87], Z. Qian [83], Z. Qin [41], A. Quadt [54], D.R. Quarrie [14], W.B. Quayle [172], F. Quinonez [31a], M. Raas [104], V. Radescu [58b], B. Radics [20], T. Rador [18a], F. Ragusa [89a,89b], G. Rahal [177], A.M. Rahimi [109], D. Rahm [24], S. Rajagopalan [24], M. Rammensee [48], M. Rammes [141], M. Ramstedt [146a,146b], A.S. Randle-Conde [39], K. Randrianarivony [28], P.N. Ratoff [71], F. Rauscher [98], E. Rauter [99], M. Raymond [29], A.L. Read [117], D.M. Rebuzzi [119a,119b], A. Redelbach [173], G. Redlinger [24], R. Reece [120], K. Reeves [40], A. Reichold [105], E. Reinherz-Aronis [153], A. Reinsch [114], I. Reisinger [42], D. Reljic [12a], C. Rembser [29], Z.L. Ren [151], A. Renaud [115], P. Renkel [39], M. Rescigno [132a], S. Resconi [89a], B. Resende [136], P. Reznicek [98], R. Rezvani [158], A. Richards [77], R. Richter [99], E. Richter-Was [4,z], M. Ridel [78], S. Rieke [81], M. Rijpstra [105], M. Rijssenbeek [148], A. Rimoldi [119a,119b], L. Rinaldi [19a], R.R. Rios [39], I. Riu [11], G. Rivoltella [89a,89b], F. Rizatdinova [112], E. Rizvi [75], S.H. Robertson [85,k], A. Robichaud-Veronneau [49], D. Robinson [27], J.E.M. Robinson [77], M. Robinson [114], A. Robson [53], J.G. Rocha de Lima [106], C. Roda [122a,122b], D. Roda Dos Santos [29], S. Rodier [80], D. Rodriguez [162], A. Roe [54], S. Roe [29], O. Røhne [117], V. Rojo [1], S. Rolli [161], A. Romaniouk [96], V.M. Romanov [65], G. Romeo [26], L. Roos [78], E. Ros [167], S. Rosati [132a,132b], K. Rosbach [49], A. Rose [149], M. Rose [76], G.A. Rosenbaum [158], E.I. Rosenberg [64], P.L. Rosendahl [13], O. Rosenthal [141], L. Rosselet [49], V. Rossetti [11], E. Rossi [132a,132b], L.P. Rossi [50a], L. Rossi [89a,89b], M. Rotaru [25a], I. Roth [171], J. Rothberg [138], D. Rousseau [115], C.R. Royon [136], A. Rozanov [83], Y. Rozen [152], X. Ruan [115], I. Rubinskiy [41], B. Ruckert [98], N. Ruckstuhl [105], V.I. Rud [97], C. Rudolph [43], G. Rudolph [62], F. Rühr [6], F. Ruggieri [134a,134b], A. Ruiz-Martinez [64], E. Rulikowska-Zarebska [37], V. Rumiantsev [91,*], L. Rumyantsev [65], K. Runge [48], O. Runolfsson [20], Z. Rurikova [48], N.A. Rusakovich [65], D.R. Rust [61], J.P. Rutherfoord [6], C. Ruwiedel [14], P. Ruzicka [125], Y.F. Ryabov [121], V. Ryadovikov [128], P. Ryan [88], M. Rybar [126], G. Rybkin [115], N.C. Ryder [118], S. Rzaeva [10], A.F. Saavedra [150], I. Sadeh [153], H.F.-W. Sadrozinski [137], R. Sadykov [65], F. Safai Tehrani [132a,132b], H. Sakamoto [155], G. Salamanna [75], A. Salamon [133a], M. Saleem [111], D. Salihagic [99], A. Salnikov [143], J. Salt [167], B.M. Salvachua Ferrando [5], D. Salvatore [36a,36b], F. Salvatore [149], A. Salvucci [104], A. Salzburger [29], D. Sampsonidis [154], B.H. Samset [117], A. Sanchez [102a,102b], H. Sandaker [13], H.G. Sander [81], M.P. Sanders [98], M. Sandhoff [174], T. Sandoval [27], C. Sandoval [162], R. Sandstroem [99], S. Sandvoss [174], D.P.C. Sankey [129], A. Sansoni [47], C. Santamarina Rios [85], C. Santoni [33], R. Santonico [133a,133b], H. Santos [124a], J.G. Saraiva [124a,b], T. Sarangi [172], E. Sarkisyan-Grinbaum [7], F. Sarri [122a,122b], G. Sartisohn [174], O. Sasaki [66], T. Sasaki [66], N. Sasao [68], I. Satsounkevitch [90], G. Sauvage [4], E. Sauvan [4], J.B. Sauvan [115], P. Savard [158,e], V. Savinov [123], D.O. Savu [29], P. Savva [9], L. Sawyer [24,m], D.H. Saxon [53], L.P. Says [33], C. Sbarra [19a,19b], A. Sbrizzi [19a,19b], O. Scallon [93], D.A. Scannicchio [163], J. Schaarschmidt [115], P. Schacht [99], U. Schäfer [81], S. Schaepe [20], S. Schaetzel [58b], A.C. Schaffer [115], D. Schaile [98], R.D. Schamberger [148], A.G. Schamov [107], V. Scharf [58a], V.A. Schegelsky [121], D. Scheirich [87], M. Schernau [163], M.I. Scherzer [14], C. Schiavi [50a,50b], J. Schieck [98], M. Schioppa [36a,36b], S. Schlenker [29], J.L. Schlereth [5], E. Schmidt [48], K. Schmieden [20], C. Schmitt [81], S. Schmitt [58b], M. Schmitz [20], A. Schöning [58b], M. Schott [29], D. Schouten [142], J. Schovancova [125], M. Schram [85], C. Schroeder [81], N. Schroer [58c], S. Schuh [29], G. Schuler [29], J. Schultes [174], H.-C. Schultz-Coulon [58a], H. Schulz [15], J.W. Schumacher [20], M. Schumacher [48], B.A. Schumm [137], Ph. Schune [136], C. Schwanenberger [82], A. Schwartzman [143], Ph. Schwemling [78], R. Schwienhorst [88], R. Schwierz [43], J. Schwindling [136], T. Schwindt [20], W.G. Scott [129], J. Searcy [114], E. Sedykh [121], E. Segura [11], S.C. Seidel [103], A. Seiden [137], F. Seifert [43], J.M. Seixas [23a], G. Sekhniaidze [102a], D.M. Seliverstov [121], B. Sellden [146a], G. Sellers [73], M. Seman [144b], N. Semprini-Cesari [19a,19b], C. Serfon [98], L. Serin [115], R. Seuster [99], H. Severini [111], M.E. Sevior [86], A. Sfyrla [29], E. Shabalina [54], M. Shamim [114], L.Y. Shan [32a],

J.T. Shank [21], Q.T. Shao [86], M. Shapiro [14], P.B. Shatalov [95], L. Shaver [6], K. Shaw [164a,164c], D. Sherman [175], P. Sherwood [77], A. Shibata [108], H. Shichi [101], S. Shimizu [29], M. Shimojima [100], T. Shin [56], A. Shmeleva [94], M.J. Shochet [30], D. Short [118], M.A. Shupe [6], P. Sicho [125], A. Sidoti [132a,132b], A. Siebel [174], F. Siegert [48], J. Siegrist [14], Dj. Sijacki [12a], O. Silbert [171], J. Silva [124a,b], Y. Silver [153], D. Silverstein [143], S.B. Silverstein [146a], V. Simak [127], O. Simard [136], Lj. Simic [12a], S. Simion [115], B. Simmons [77], M. Simonyan [35], P. Sinervo [158], N.B. Sinev [114], V. Sipica [141], G. Siragusa [173], A. Sircar [24], A.N. Sisakyan [65], S.Yu. Sivoklokov [97], J. Sjölin [146a,146b], T.B. Sjursen [13], L.A. Skinnari [14], K. Skovpen [107], P. Skubic [111], N. Skvorodnev [22], M. Slater [17], T. Slavicek [127], K. Sliwa [161], T.J. Sloan [71], J. Sloper [29], V. Smakhtin [171], S.Yu. Smirnov [96], L.N. Smirnova [97], O. Smirnova [79], B.C. Smith [57], D. Smith [143], K.M. Smith [53], M. Smizanska [71], K. Smolek [127], A.A. Snesarev [94], S.W. Snow [82], J. Snow [111], J. Snuverink [105], S. Snyder [24], M. Soares [124a], R. Sobie [169,k], J. Sodomka [127], A. Soffer [153], C.A. Solans [167], M. Solar [127], J. Solc [127], E. Soldatov [96], U. Soldevila [167], E. Solfaroli Camillocci [132a,132b], A.A. Solodkov [128], O.V. Solovyanov [128], J. Sondericker [24], N. Soni [2], V. Sopko [127], B. Sopko [127], M. Sorbi [89a,89b], M. Sosebee [7], A. Soukharev [107], S. Spagnolo [72a,72b], F. Spanò [76], R. Spighi [19a], G. Spigo [29], F. Spila [132a,132b], E. Spiriti [134a], R. Spiwoks [29], M. Spousta [126], T. Spreitzer [158], B. Spurlock [7], R.D. St. Denis [53], T. Stahl [141], J. Stahlman [120], R. Stamen [58a], E. Stanecka [29], R.W. Stanek [5], C. Stanescu [134a], S. Stapnes [117], E.A. Starchenko [128], J. Stark [55], P. Staroba [125], P. Starovoitov [91], A. Staude [98], P. Stavina [144a], G. Stavropoulos [14], G. Steele [53], P. Steinbach [43], P. Steinberg [24], I. Stekl [127], B. Stelzer [142], H.J. Stelzer [88], O. Stelzer-Chilton [159a], H. Stenzel [52], K. Stevenson [75], G.A. Stewart [29], J.A. Stillings [20], T. Stockmanns [20], M.C. Stockton [29], K. Stoerig [48], G. Stoicea [25a], S. Stonjek [99], P. Strachota [126], A.R. Stradling [7], A. Straessner [43], J. Strandberg [147], S. Strandberg [146a,146b], A. Strandlie [117], M. Strang [109], E. Strauss [143], M. Strauss [111], P. Strizenec [144b], R. Ströhmer [173], D.M. Strom [114], J.A. Strong [76,*], R. Stroynowski [39], J. Strube [129], B. Stugu [13], I. Stumer [24,*], J. Stupak [148], P. Sturm [174], D.A. Soh [151,r], D. Su [143], H.S. Subramania [2], A. Succurro [11], Y. Sugaya [116], T. Sugimoto [101], C. Suhr [106], K. Suita [67], M. Suk [126], V.V. Sulin [94], S. Sultansoy [3d], T. Sumida [29], X. Sun [55], J.E. Sundermann [48], K. Suruliz [139], S. Sushkov [11], G. Susinno [36a,36b], M.R. Sutton [149], Y. Suzuki [66], Y. Suzuki [67], M. Svatos [125], Yu.M. Sviridov [128], S. Swedish [168], I. Sykora [144a], T. Sykora [126], B. Szeless [29], J. Sánchez [167], D. Ta [105], K. Tackmann [41], A. Taffard [163], R. Tafirout [159a], N. Taiblum [153], Y. Takahashi [101], H. Takai [24], R. Takashima [69], H. Takeda [67], T. Takeshita [140], M. Talby [83], A. Talyshev [107], M.C. Tamsett [24], J. Tanaka [155], R. Tanaka [115], S. Tanaka [131], S. Tanaka [66], Y. Tanaka [100], K. Tani [67], N. Tannoury [83], G.P. Tappern [29], S. Tapprogge [81], D. Tardif [158], S. Tarem [152], F. Tarrade [28], G.F. Tartarelli [89a], P. Tas [126], M. Tasevsky [125], E. Tassi [36a,36b], M. Tatarkhanov [14], Y. Tayalati [135d], C. Taylor [77], F.E. Taylor [92], G.N. Taylor [86], W. Taylor [159b], M. Teinturier [115], M. Teixeira Dias Castanheira [75], P. Teixeira-Dias [76], K.K. Temming [48], H. Ten Kate [29], P.K. Teng [151], S. Terada [66], K. Terashi [155], J. Terron [80], M. Terwort [41,p], M. Testa [47], R.J. Teuscher [158,k], J. Thadome [174], J. Therhaag [20], T. Theveneaux-Pelzer [78], M. Thioye [175], S. Thoma [48], J.P. Thomas [17], E.N. Thompson [84], P.D. Thompson [17], P.D. Thompson [158], A.S. Thompson [53], E. Thomson [120], M. Thomson [27], R.P. Thun [87], F. Tian [34], T. Tic [125], V.O. Tikhomirov [94], Y.A. Tikhonov [107], C.J.W.P. Timmermans [104], P. Tipton [175], F.J. Tique Aires Viegas [29], S. Tisserant [83], J. Tobias [48], B. Toczek [37], T. Todorov [4], S. Todorova-Nova [161], B. Toggerson [163], J. Tojo [66], S. Tokár [144a], K. Tokunaga [67], K. Tokushuku [66], K. Tollefson [88], M. Tomoto [101], L. Tompkins [14], K. Toms [103], G. Tong [32a], A. Tonoyan [13], C. Topfel [16], N.D. Topilin [65], I. Torchiani [29], E. Torrence [114], H. Torres [78], E. Torró Pastor [167], J. Toth [83,x], F. Touchard [83], D.R. Tovey [139], D. Traynor [75], T. Trefzger [173], L. Tremblet [29], A. Tricoli [29], I.M. Trigger [159a], S. Trincaz-Duvoid [78], T.N. Trinh [78], M.F. Tripiana [70], W. Trischuk [158], A. Trivedi [24,w], B. Trocmé [55], C. Troncon [89a], M. Trottier-McDonald [142], A. Trzupek [38], C. Tsarouchas [29], J.C.-L. Tseng [118], M. Tsiakiris [105], P.V. Tsiareshka [90], D. Tsionou [4], G. Tsipolitis [9], V. Tsiskaridze [48], E.G. Tskhadadze [51], I.I. Tsukerman [95], V. Tsulaia [14], J.-W. Tsung [20], S. Tsuno [66], D. Tsybychev [148], A. Tua [139], J.M. Tuggle [30], M. Turala [38], D. Turecek [127], I. Turk Cakir [3e], E. Turlay [105], R. Turra [89a,89b], P.M. Tuts [34], A. Tykhonov [74], M. Tylmad [146a,146b], M. Tyndel [129], H. Tyrvainen [29], G. Tzanakos [8], K. Uchida [20], I. Ueda [155], R. Ueno [28], M. Ugland [13], M. Uhlenbrock [20], M. Uhrmacher [54], F. Ukegawa [160], G. Unal [29], D.G. Underwood [5], A. Undrus [24], G. Unel [163], Y. Unno [66], D. Urbaniec [34], E. Urkovsky [153], P. Urrejola [31a], G. Usai [7], M. Uslenghi [119a,119b], L. Vacavant [83], V. Vacek [127], B. Vachon [85], S. Vahsen [14], J. Valenta [125], P. Valente [132a], S. Valentinetti [19a,19b], S. Valkar [126], E. Valladolid Gallego [167], S. Vallecorsa [152], J.A. Valls Ferrer [167], H. van der Graaf [105], E. van der Kraaij [105], R. Van Der Leeuw [105], E. van der Poel [105], D. van der Ster [29],

B. Van Eijk [105], N. van Eldik [84], P. van Gemmeren [5], Z. van Kesteren [105], I. van Vulpen [105], W. Vandelli [29], G. Vandoni [29], A. Vaniachine [5], P. Vankov [41], F. Vannucci [78], F. Varela Rodriguez [29], R. Vari [132a], D. Varouchas [14], A. Vartapetian [7], K.E. Varvell [150], V.I. Vassilakopoulos [56], F. Vazeille [33], G. Vegni [89a,89b], J.J. Veillet [115], C. Vellidis [8], F. Veloso [124a], R. Veness [29], S. Veneziano [132a], A. Ventura [72a,72b], D. Ventura [138], M. Venturi [48], N. Venturi [16], V. Vercesi [119a], M. Verducci [138], W. Verkerke [105], J.C. Vermeulen [105], A. Vest [43], M.C. Vetterli [142,e], I. Vichou [165], T. Vickey [145b,aa], O.E. Vickey Boeriu [145b], G.H.A. Viehhauser [118], S. Viel [168], M. Villa [19a,19b], M. Villaplana Perez [167], E. Vilucchi [47], M.G. Vincter [28], E. Vinek [29], V.B. Vinogradov [65], M. Virchaux [136,*], J. Virzi [14], O. Vitells [171], M. Viti [41], I. Vivarelli [48], F. Vives Vaque [2], S. Vlachos [9], M. Vlasak [127], N. Vlasov [20], A. Vogel [20], P. Vokac [127], G. Volpi [47], M. Volpi [86], G. Volpini [89a], H. von der Schmitt [99], J. von Loeben [99], H. von Radziewski [48], E. von Toerne [20], V. Vorobel [126], A.P. Vorobiev [128], V. Vorwerk [11], M. Vos [167], R. Voss [29], T.T. Voss [174], J.H. Vossebeld [73], N. Vranjes [12a], M. Vranjes Milosavljevic [105], V. Vrba [125], M. Vreeswijk [105], T. Vu Anh [81], R. Vuillermet [29], I. Vukotic [115], W. Wagner [174], P. Wagner [120], H. Wahlen [174], J. Wakabayashi [101], J. Walbersloh [42], S. Walch [87], J. Walder [71], R. Walker [98], W. Walkowiak [141], R. Wall [175], P. Waller [73], C. Wang [44], H. Wang [172], H. Wang [32b,ab], J. Wang [151], J. Wang [32d], J.C. Wang [138], R. Wang [103], S.M. Wang [151], A. Warburton [85], C.P. Ward [27], M. Warsinsky [48], P.M. Watkins [17], A.T. Watson [17], M.F. Watson [17], G. Watts [138], S. Watts [82], A.T. Waugh [150], B.M. Waugh [77], J. Weber [42], M. Weber [129], M.S. Weber [16], P. Weber [54], A.R. Weidberg [118], P. Weigell [99], J. Weingarten [54], C. Weiser [48], H. Wellenstein [22], P.S. Wells [29], M. Wen [47], T. Wenaus [24], S. Wendler [123], Z. Weng [151,r], T. Wengler [29], S. Wenig [29], N. Wermes [20], M. Werner [48], P. Werner [29], M. Werth [163], M. Wessels [58a], C. Weydert [55], K. Whalen [28], S.J. Wheeler-Ellis [163], S.P. Whitaker [21], A. White [7], M.J. White [86], S.R. Whitehead [118], D. Whiteson [163], D. Whittington [61], F. Wicek [115], D. Wicke [174], F.J. Wickens [129], W. Wiedenmann [172], M. Wielers [129], P. Wienemann [20], C. Wiglesworth [75], L.A.M. Wiik [48], P.A. Wijeratne [77], A. Wildauer [167], M.A. Wildt [41,p], I. Wilhelm [126], H.G. Wilkens [29], J.Z. Will [98], E. Williams [34], H.H. Williams [120], W. Willis [34], S. Willocq [84], J.A. Wilson [17], M.G. Wilson [143], A. Wilson [87], I. Wingerter-Seez [4], S. Winkelmann [48], F. Winklmeier [29], M. Wittgen [143], M.W. Wolter [38], H. Wolters [124a,i], W.C. Wong [40], G. Wooden [118], B.K. Wosiek [38], J. Wotschack [29], M.J. Woudstra [84], K. Wraight [53], C. Wright [53], B. Wrona [73], S.L. Wu [172], X. Wu [49], Y. Wu [32b,ac], E. Wulf [34], R. Wunstorf [42], B.M. Wynne [45], L. Xaplanteris [9], S. Xella [35], S. Xie [48], Y. Xie [32a], C. Xu [32b,ad], D. Xu [139], G. Xu [32a], B. Yabsley [150], S. Yacoob [145b], M. Yamada [66], H. Yamaguchi [155], A. Yamamoto [66], K. Yamamoto [64], S. Yamamoto [155], T. Yamamura [155], T. Yamanaka [155], J. Yamaoka [44], T. Yamazaki [155], Y. Yamazaki [67], Z. Yan [21], H. Yang [87], U.K. Yang [82], Y. Yang [61], Y. Yang [32a], Z. Yang [146a,146b], S. Yanush [91], Y. Yao [14], Y. Yasu [66], G.V. Ybeles Smit [130], J. Ye [39], S. Ye [24], M. Yilmaz [3c], R. Yoosoofmiya [123], K. Yorita [170], R. Yoshida [5], C. Young [143], S. Youssef [21], D. Yu [24], J. Yu [7], J. Yu [32c,ad], L. Yuan [32a,ae], A. Yurkewicz [148], V.G. Zaets [128], R. Zaidan [63], A.M. Zaitsev [128], Z. Zajacova [29], Yo.K. Zalite [121], L. Zanello [132a,132b], P. Zarzhitsky [39], A. Zaytsev [107], C. Zeitnitz [174], M. Zeller [175], M. Zeman [125], A. Zemla [38], C. Zendler [20], O. Zenin [128], T. Ženiš [144a], Z. Zenonos [122a,122b], S. Zenz [14], D. Zerwas [115], G. Zevi della Porta [57], Z. Zhan [32d], D. Zhang [32b,ab], H. Zhang [88], J. Zhang [5], X. Zhang [32d], Z. Zhang [115], L. Zhao [108], T. Zhao [138], Z. Zhao [32b], A. Zhemchugov [65], S. Zheng [32a], J. Zhong [151,af], B. Zhou [87], N. Zhou [163], Y. Zhou [151], C.G. Zhu [32d], H. Zhu [41], J. Zhu [87], Y. Zhu [172], X. Zhuang [98], V. Zhuravlov [99], D. Zieminska [61], R. Zimmermann [20], S. Zimmermann [20], S. Zimmermann [48], M. Ziolkowski [141], R. Zitoun [4], L. Živković [34], V.V. Zmouchko [128,*], G. Zobernig [172], A. Zoccoli [19a,19b], Y. Zolnierowski [4], A. Zsenei [29], M. zur Nedden [15], V. Zutshi [106], L. Zwalinski [29]

[1] *University at Albany, Albany, NY, United States*
[2] *Department of Physics, University of Alberta, Edmonton, AB, Canada*
[3] [(a)] *Department of Physics, Ankara University, Ankara;* [(b)] *Department of Physics, Dumlupinar University, Kutahya;* [(c)] *Department of Physics, Gazi University, Ankara;* [(d)] *Division of Physics, TOBB University of Economics and Technology, Ankara;* [(e)] *Turkish Atomic Energy Authority, Ankara, Turkey*
[4] *LAPP, CNRS/IN2P3 and Université de Savoie, Annecy-le-Vieux, France*
[5] *High Energy Physics Division, Argonne National Laboratory, Argonne, IL, United States*
[6] *Department of Physics, University of Arizona, Tucson, AZ, United States*
[7] *Department of Physics, The University of Texas at Arlington, Arlington, TX, United States*
[8] *Physics Department, University of Athens, Athens, Greece*
[9] *Physics Department, National Technical University of Athens, Zografou, Greece*
[10] *Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan*
[11] *Institut de Física d'Altes Energies and Departament de Física de la Universitat Autònoma de Barcelona and ICREA, Barcelona, Spain*
[12] [(a)] *Institute of Physics, University of Belgrade, Belgrade;* [(b)] *Vinca Institute of Nuclear Sciences, Belgrade, Serbia*
[13] *Department for Physics and Technology, University of Bergen, Bergen, Norway*
[14] *Physics Division, Lawrence Berkeley National Laboratory and University of California, Berkeley, CA, United States*
[15] *Department of Physics, Humboldt University, Berlin, Germany*

[16] Albert Einstein Center for Fundamental Physics and Laboratory for High Energy Physics, University of Bern, Bern, Switzerland
[17] School of Physics and Astronomy, University of Birmingham, Birmingham, United Kingdom
[18] [(a)] Department of Physics, Bogazici University, Istanbul; [(b)] Division of Physics, Dogus University, Istanbul; [(c)] Department of Physics Engineering, Gaziantep University, Gaziantep; [(d)] Department of Physics, Istanbul Technical University, Istanbul, Turkey
[19] [(a)] INFN Sezione di Bologna; [(b)] Dipartimento di Fisica, Università di Bologna, Bologna, Italy
[20] Physikalisches Institut, University of Bonn, Bonn, Germany
[21] Department of Physics, Boston University, Boston, MA, United States
[22] Department of Physics, Brandeis University, Waltham, MA, United States
[23] [(a)] Universidade Federal do Rio De Janeiro COPPE/EE/IF, Rio de Janeiro; [(b)] 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
[24] Physics Department, Brookhaven National Laboratory, Upton, NY, United States
[25] [(a)] National Institute of Physics and Nuclear Engineering, Bucharest; [(b)] University Politehnica Bucharest, Bucharest; [(c)] West University in Timisoara, Timisoara, Romania
[26] Departamento de Física, Universidad de Buenos Aires, Buenos Aires, Argentina
[27] Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom
[28] Department of Physics, Carleton University, Ottawa, ON, Canada
[29] CERN, Geneva, Switzerland
[30] Enrico Fermi Institute, University of Chicago, Chicago, IL, United States
[31] [(a)] Departamento de Fisica, Pontificia Universidad Católica de Chile, Santiago; [(b)] Departamento de Física, Universidad Técnica Federico Santa María, Valparaíso, Chile
[32] [(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)] High Energy Physics Group, Shandong University, Shandong, China
[33] Laboratoire de Physique Corpusculaire, Clermont Université and Université Blaise Pascal and CNRS/IN2P3, Aubiere Cedex, France
[34] Nevis Laboratory, Columbia University, Irvington, NY, United States
[35] Niels Bohr Institute, University of Copenhagen, Kobenhavn, Denmark
[36] [(a)] INFN Gruppo Collegato di Cosenza; [(b)] Dipartimento di Fisica, Università della Calabria, Arcavata di Rende, Italy
[37] Faculty of Physics and Applied Computer Science, AGH – University of Science and Technology, Krakow, Poland
[38] The Henryk Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences, Krakow, Poland
[39] Physics Department, Southern Methodist University, Dallas, TX, United States
[40] Physics Department, University of Texas at Dallas, Richardson, TX, United States
[41] DESY, Hamburg and Zeuthen, Germany
[42] Institut für Experimentelle Physik IV, Technische Universität Dortmund, Dortmund, Germany
[43] Institut für Kern- und Teilchenphysik, Technical University Dresden, Dresden, Germany
[44] Department of Physics, Duke University, Durham, NC, United States
[45] SUPA – School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom
[46] Fachhochschule Wiener Neustadt, Johannes Gutenbergstrasse 3, 2700 Wiener Neustadt, Austria
[47] INFN Laboratori Nazionali di Frascati, Frascati, Italy
[48] Fakultät für Mathematik und Physik, Albert-Ludwigs-Universität, Freiburg i.Br., Germany
[49] Section de Physique, Université de Genève, Geneva, Switzerland
[50] [(a)] INFN Sezione di Genova; [(b)] Dipartimento di Fisica, Università di Genova, Genova, Italy
[51] Institute of Physics and HEP Institute, Georgian Academy of Sciences and Tbilisi State University, Tbilisi, Georgia
[52] II Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen, Germany
[53] SUPA – School of Physics and Astronomy, University of Glasgow, Glasgow, United Kingdom
[54] II Physikalisches Institut, Georg-August-Universität, Göttingen, Germany
[55] Laboratoire de Physique Subatomique et de Cosmologie, Université Joseph Fourier and CNRS/IN2P3 and Institut National Polytechnique de Grenoble, Grenoble, France
[56] Department of Physics, Hampton University, Hampton, VA, United States
[57] Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge, MA, United States
[58] [(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
[59] Faculty of Science, Hiroshima University, Hiroshima, Japan
[60] Faculty of Applied Information Science, Hiroshima Institute of Technology, Hiroshima, Japan
[61] Department of Physics, Indiana University, Bloomington, IN, United States
[62] Institut für Astro- und Teilchenphysik, Leopold-Franzens-Universität, Innsbruck, Austria
[63] University of Iowa, Iowa City, IA, United States
[64] Department of Physics and Astronomy, Iowa State University, Ames, IA, United States
[65] Joint Institute for Nuclear Research, JINR Dubna, Dubna, Russia
[66] KEK, High Energy Accelerator Research Organization, Tsukuba, Japan
[67] Graduate School of Science, Kobe University, Kobe, Japan
[68] Faculty of Science, Kyoto University, Kyoto, Japan
[69] Kyoto University of Education, Kyoto, Japan
[70] Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata, Argentina
[71] Physics Department, Lancaster University, Lancaster, United Kingdom
[72] [(a)] INFN Sezione di Lecce; [(b)] Dipartimento di Fisica, Università del Salento, Lecce, Italy
[73] Oliver Lodge Laboratory, University of Liverpool, Liverpool, United Kingdom
[74] Department of Physics, Jožef Stefan Institute and University of Ljubljana, Ljubljana, Slovenia
[75] Department of Physics, Queen Mary University of London, London, United Kingdom
[76] Department of Physics, Royal Holloway University of London, Surrey, United Kingdom
[77] Department of Physics and Astronomy, University College London, London, United Kingdom
[78] Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France
[79] Fysiska Institutionen, Lunds Universitet, Lund, Sweden
[80] Departamento de Fisica Teorica, C-15, Universidad Autonoma de Madrid, Madrid, Spain
[81] Institut für Physik, Universität Mainz, Mainz, Germany
[82] School of Physics and Astronomy, University of Manchester, Manchester, United Kingdom
[83] CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France
[84] Department of Physics, University of Massachusetts, Amherst, MA, United States
[85] Department of Physics, McGill University, Montreal, QC, Canada
[86] School of Physics, University of Melbourne, Victoria, Australia
[87] Department of Physics, The University of Michigan, Ann Arbor, MI, United States
[88] Department of Physics and Astronomy, Michigan State University, East Lansing, MI, United States
[89] [(a)] INFN Sezione di Milano; [(b)] Dipartimento di Fisica, Università di Milano, Milano, Italy
[90] B.I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk, Belarus

[91] National Scientific and Educational Centre for Particle and High Energy Physics, Minsk, Belarus
[92] Department of Physics, Massachusetts Institute of Technology, Cambridge, MA, United States
[93] Group of Particle Physics, University of Montreal, Montreal, QC, Canada
[94] P.N. Lebedev Institute of Physics, Academy of Sciences, Moscow, Russia
[95] Institute for Theoretical and Experimental Physics (ITEP), Moscow, Russia
[96] Moscow Engineering and Physics Institute (MEPhI), Moscow, Russia
[97] Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia
[98] Fakultät für Physik, Ludwig-Maximilians-Universität München, München, Germany
[99] Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), München, Germany
[100] Nagasaki Institute of Applied Science, Nagasaki, Japan
[101] Graduate School of Science, Nagoya University, Nagoya, Japan
[102] [(a)] INFN Sezione di Napoli; [(b)] Dipartimento di Scienze Fisiche, Università di Napoli, Napoli, Italy
[103] Department of Physics and Astronomy, University of New Mexico, Albuquerque, NM, United States
[104] Institute for Mathematics, Astrophysics and Particle Physics, Radboud University Nijmegen/Nikhef, Nijmegen, Netherlands
[105] Nikhef National Institute for Subatomic Physics and University of Amsterdam, Amsterdam, Netherlands
[106] Department of Physics, Northern Illinois University, DeKalb, IL, United States
[107] Budker Institute of Nuclear Physics (BINP), Novosibirsk, Russia
[108] Department of Physics, New York University, New York, NY, United States
[109] Ohio State University, Columbus, OH, United States
[110] Faculty of Science, Okayama University, Okayama, Japan
[111] Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman, OK, United States
[112] Department of Physics, Oklahoma State University, Stillwater, OK, United States
[113] Palacký University, RCPTM, Olomouc, Czech Republic
[114] Center for High Energy Physics, University of Oregon, Eugene, OR, United States
[115] LAL, Univ. Paris-Sud and CNRS/IN2P3, Orsay, France
[116] Graduate School of Science, Osaka University, Osaka, Japan
[117] Department of Physics, University of Oslo, Oslo, Norway
[118] Department of Physics, Oxford University, Oxford, United Kingdom
[119] [(a)] INFN Sezione di Pavia; [(b)] Dipartimento di Fisica Nucleare e Teorica, Università di Pavia, Pavia, Italy
[120] Department of Physics, University of Pennsylvania, Philadelphia, PA, United States
[121] Petersburg Nuclear Physics Institute, Gatchina, Russia
[122] [(a)] INFN Sezione di Pisa; [(b)] Dipartimento di Fisica E. Fermi, Università di Pisa, Pisa, Italy
[123] Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh, PA, United States
[124] [(a)] Laboratorio de Instrumentacao e Fisica Experimental de Particulas – LIP, Lisboa, Portugal; [(b)] Departamento de Fisica Teorica y del Cosmos and CAFPE, Universidad de Granada, Granada, Spain
[125] Institute of Physics, Academy of Sciences of the Czech Republic, Praha, Czech Republic
[126] Faculty of Mathematics and Physics, Charles University in Prague, Praha, Czech Republic
[127] Czech Technical University in Prague, Praha, Czech Republic
[128] State Research Center Institute for High Energy Physics, Protvino, Russia
[129] Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom
[130] Physics Department, University of Regina, Regina, SK, Canada
[131] Ritsumeikan University, Kusatsu, Shiga, Japan
[132] [(a)] INFN Sezione di Roma I; [(b)] Dipartimento di Fisica, Università La Sapienza, Roma, Italy
[133] [(a)] INFN Sezione di Roma Tor Vergata; [(b)] Dipartimento di Fisica, Università di Roma Tor Vergata, Roma, Italy
[134] [(a)] INFN Sezione di Roma Tre; [(b)] Dipartimento di Fisica, Università Roma Tre, Roma, Italy
[135] [(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)] Université Cadi Ayyad, Faculté des Sciences Semlalia, Département de Physique, B.P. 2390, Marrakech 40000; [(d)] Faculté des Sciences, Université Mohamed Premier and LPTPM, Oujda; [(e)] Faculté des Sciences, Université Mohammed V, Rabat, Morocco
[136] DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat a l'Energie Atomique), Gif-sur-Yvette, France
[137] Santa Cruz Institute for Particle Physics, University of California Santa Cruz, Santa Cruz, CA, United States
[138] Department of Physics, University of Washington, Seattle, WA, United States
[139] Department of Physics and Astronomy, University of Sheffield, Sheffield, United Kingdom
[140] Department of Physics, Shinshu University, Nagano, Japan
[141] Fachbereich Physik, Universität Siegen, Siegen, Germany
[142] Department of Physics, Simon Fraser University, Burnaby, BC, Canada
[143] SLAC National Accelerator Laboratory, Stanford, CA, United States
[144] [(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
[145] [(a)] Department of Physics, University of Johannesburg, Johannesburg; [(b)] School of Physics, University of the Witwatersrand, Johannesburg, South Africa
[146] [(a)] Department of Physics, Stockholm University; [(b)] The Oskar Klein Centre, Stockholm, Sweden
[147] Physics Department, Royal Institute of Technology, Stockholm, Sweden
[148] Department of Physics and Astronomy, Stony Brook University, Stony Brook, NY, United States
[149] Department of Physics and Astronomy, University of Sussex, Brighton, United Kingdom
[150] School of Physics, University of Sydney, Sydney, Australia
[151] Institute of Physics, Academia Sinica, Taipei, Taiwan
[152] Department of Physics, Technion – Israel Inst. of Technology, Haifa, Israel
[153] Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel
[154] Department of Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece
[155] International Center for Elementary Particle Physics and Department of Physics, The University of Tokyo, Tokyo, Japan
[156] Graduate School of Science and Technology, Tokyo Metropolitan University, Tokyo, Japan
[157] Department of Physics, Tokyo Institute of Technology, Tokyo, Japan
[158] Department of Physics, University of Toronto, Toronto, ON, Canada
[159] [(a)] TRIUMF, Vancouver, BC; [(b)] Department of Physics and Astronomy, York University, Toronto, ON, Canada
[160] Institute of Pure and Applied Sciences, University of Tsukuba, Ibaraki, Japan
[161] Science and Technology Center, Tufts University, Medford, MA, United States
[162] Centro de Investigaciones, Universidad Antonio Narino, Bogota, Colombia
[163] Department of Physics and Astronomy, University of California Irvine, Irvine CA, United States
[164] [(a)] INFN Gruppo Collegato di Udine; [(b)] ICTP, Trieste; [(c)] Dipartimento di Fisica, Università di Udine, Udine, Italy
[165] Department of Physics, University of Illinois, Urbana, IL, United States

[166] *Department of Physics and Astronomy, University of Uppsala, Uppsala, Sweden*
[167] *Instituto de Física Corpuscular (IFIC) and Departamento de Física Atómica, Molecular y Nuclear and Departamento de Ingenierá Electrónica and Instituto de Microelectrónica de Barcelona (IMB-CNM), University of Valencia and CSIC, Valencia, Spain*
[168] *Department of Physics, University of British Columbia, Vancouver, BC, Canada*
[169] *Department of Physics and Astronomy, University of Victoria, Victoria, BC, Canada*
[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] *Fachbereich C Physik, Bergische Universität Wuppertal, Wuppertal, Germany*
[175] *Department of Physics, Yale University, New Haven, CT, United States*
[176] *Yerevan Physics Institute, Yerevan, Armenia*
[177] *Domaine scientifique de la Doua, Centre de Calcul CNRS/IN2P3, Villeurbanne Cedex, France*

[a] Also at Laboratorio de Instrumentacao e Fisica Experimental de Particulas – LIP, Lisboa, Portugal.
[b] Also at Faculdade de Ciencias and CFNUL, Universidade de Lisboa, Lisboa, Portugal.
[c] Also at Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom.
[d] Also at CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France.
[e] Also at TRIUMF, Vancouver, BC, Canada.
[f] Also at Department of Physics, California State University, Fresno, CA, United States.
[g] Also at Faculty of Physics and Applied Computer Science, AGH – University of Science and Technology, Krakow, Poland.
[h] Also at Fermilab, Batavia, IL, United States.
[i] Also at Department of Physics, University of Coimbra, Coimbra, Portugal.
[j] Also at Università di Napoli Parthenope, Napoli, Italy.
[k] Also at Institute of Particle Physics (IPP), Canada.
[l] Also at Department of Physics, Middle East Technical University, Ankara, Turkey.
[m] Also at Louisiana Tech University, Ruston, LA, United States.
[n] Also at Group of Particle Physics, University of Montreal, Montreal, QC, Canada.
[o] Also at Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan.
[p] Also at Institut für Experimentalphysik, Universität Hamburg, Hamburg, Germany.
[q] Also at Manhattan College, New York, NY, United States.
[r] Also at School of Physics and Engineering, Sun Yat-sen University, Guanzhou, China.
[s] Also at Academia Sinica Grid Computing, Institute of Physics, Academia Sinica, Taipei, Taiwan.
[t] Also at High Energy Physics Group, Shandong University, Shandong, China.
[u] Also at Section de Physique, Université de Genève, Geneva, Switzerland.
[v] Also at Departamento de Fisica, Universidade de Minho, Braga, Portugal.
[w] Also at Department of Physics and Astronomy, University of South Carolina, Columbia, SC, United States.
[x] Also at KFKI Research Institute for Particle and Nuclear Physics, Budapest, Hungary.
[y] Also at California Institute of Technology, Pasadena, CA, United States.
[z] Also at Institute of Physics, Jagiellonian University, Krakow, Poland.
[aa] Also at Department of Physics, Oxford University, Oxford, United Kingdom.
[ab] Also at Institute of Physics, Academia Sinica, Taipei, Taiwan.
[ac] Also at Department of Physics, The University of Michigan, Ann Arbor, MI, United States.
[ad] Also at DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat a l'Energie Atomique), Gif-sur-Yvette, France.
[ae] Also at Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France.
[af] Also at Department of Physics, Nanjing University, Jiangsu, China.
[*] Deceased.