



# Search for $W \rightarrow tb \rightarrow qqbb$ decays in pp collisions at $\sqrt{s} =$ 8 TeV with the ATLAS detector

The Harvard community has made this  
article openly available. [Please share](#) how  
this access benefits you. Your story matters

Citation	ATLAS Collaboration. 2015. "Search for $W \rightarrow tb \rightarrow qqbb$ decays in pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector." The European Physical Journal C 75 (4) (April). doi:10.1140/epjc/s10052-015-3372-2.
Published Version	doi:10.1140/epjc/s10052-015-3372-2
Citable link	<a href="http://nrs.harvard.edu/urn-3:HUL.InstRepos:33470142">http://nrs.harvard.edu/urn-3:HUL.InstRepos:33470142</a>
Terms of Use	This article was downloaded from Harvard University's DASH repository, and is made available under the terms and conditions applicable to Other Posted Material, as set forth at <a href="http://nrs.harvard.edu/urn-3:HUL.InstRepos:dash.current.terms-of-use#LAA">http://nrs.harvard.edu/urn-3:HUL.InstRepos:dash.current.terms-of-use#LAA</a>

# Search for $W' \rightarrow tb \rightarrow qqbb$ decays in $pp$ collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector

ATLAS Collaboration\*

CERN, 1211 Geneva 23, Switzerland

Received: 6 August 2014 / Accepted: 26 March 2015

© CERN for the benefit of the ATLAS collaboration 2015. This article is published with open access at Springerlink.com

**Abstract** A search for a massive  $W'$  gauge boson decaying to a top quark and a bottom quark is performed with the ATLAS detector in  $pp$  collisions at the LHC. The dataset was taken at a centre-of-mass energy of  $\sqrt{s} = 8$  TeV and corresponds to  $20.3 \text{ fb}^{-1}$  of integrated luminosity. This analysis is done in the hadronic decay mode of the top quark, where novel jet substructure techniques are used to identify jets from high-momentum top quarks. This allows for a search for high-mass  $W'$  bosons in the range 1.5–3.0 TeV.  $b$ -tagging is used to identify jets originating from  $b$ -quarks. The data are consistent with Standard Model background-only expectations, and upper limits at 95 % confidence level are set on the  $W' \rightarrow tb$  cross section times branching ratio ranging from 0.16 pb to 0.33 pb for left-handed  $W'$  bosons, and ranging from 0.10 pb to 0.21 pb for  $W'$  bosons with purely right-handed couplings. Upper limits at 95 % confidence level are set on the  $W'$ -boson coupling to  $tb$  as a function of the  $W'$  mass using an effective field theory approach, which is independent of details of particular models predicting a  $W'$  boson.

## 1 Introduction

Several theories beyond the Standard Model (SM) [1–3] involve enhanced symmetries that introduce new charged vector currents carried by new heavy gauge bosons, usually called  $W'$  bosons. For instance, Grand Unified Theories [4–7] extend fundamental symmetries of the SM, in which a massive right-handed counterpart to the SM  $W$  boson may occur.  $W'$  bosons can appear in phenomenological models involving extra space-time dimensions such as Kaluza-Klein excitations of the SM  $W$  boson [8] or in technicolor models [9]. Also Little Higgs theories [10] predict several new particles, including a  $W'$  boson. In order to interpret a direct experimental search independently of the details of particular models predicting a  $W'$  boson, it is advantageous to rely on

an effective model describing the couplings of the  $W'$  boson to fermions [11].

The search for a  $W'$  boson decaying to a top quark and a  $b$ -quark ( $W' \rightarrow tb$ )<sup>1</sup> explores models potentially inaccessible to  $W' \rightarrow \ell\nu$  searches. Also, in the right-handed sector, it is assumed that there is no light right-handed neutrino to which a  $W'$  boson could decay, and, hence, only hadronic decays are allowed [11, 12]. In some theories beyond the SM, new physics couples more strongly to the third generation than to the first and second [9]. Searches for  $W'$  bosons decaying to  $tb$  have been performed at the Tevatron [13–15] and at the LHC [16, 17], in leptonic top-quark decay channels excluding a  $W'$  boson with purely right-handed couplings (referred to as  $W'_R$ ) with mass less than 2.13 TeV at 95 % Confidence Level (CL).

This document describes the first search for the  $W' \rightarrow tb$  process in the fully hadronic final state of the top-quark decay. For high  $W'$  masses, the final state signature consists of one high-momentum  $b$ -quark and another  $b$ -quark close to the two light-quarks from the  $W$ -boson decay. The distinct signature of high-momentum top quarks is exploited to isolate the signal from the copious hadronic multijet background making use of novel jet substructure techniques to identify boosted hadronically decaying top quarks. This allows for particularly good sensitivity at high  $W'$  masses. 95 % CL exclusion limits are presented on the  $W'$ -boson coupling as a function of the  $W'$  mass in an effective model.

## 2 The ATLAS detector

Charged particles in the pseudorapidity<sup>2</sup> range  $|\eta| < 2.5$  are reconstructed with the inner detector (ID), which consists of several layers of semiconductor detectors (pixel and

<sup>1</sup> Decays of  $W'^+$  to a top quark and an anti- $b$  quark and of  $W'^-$  to an anti-top quark and a  $b$ -quark are equally taken into account. For simplicity, both decays are referred to as  $W' \rightarrow tb$  in this document.

<sup>2</sup> The ATLAS experiment uses a right-handed coordinate system with its origin at the nominal interaction point (IP) in the centre of the

\* e-mail: [atlas.publications@cern.ch](mailto:atlas.publications@cern.ch)

strip) and a straw-tube transition-radiation tracker, the latter extending to  $|\eta| < 2.0$ . The inner tracking system is immersed in a 2 T magnetic field provided by a superconducting solenoid. The solenoid is surrounded by sampling calorimeters, which span the pseudorapidity range up to  $|\eta| = 4.9$ . High-granularity liquid-argon (LAr) electromagnetic calorimeters are present up to  $|\eta| = 3.2$ . Hadronic calorimeters with scintillating tiles as active material cover  $|\eta| < 1.74$  while LAr technology is used for hadronic calorimetry from  $|\eta| = 1.5$  to  $|\eta| = 4.9$ . Outside the calorimeter system, air-core toroids provide a magnetic field for the muon spectrometer (MS). Three stations of precision drift tubes and cathode strip chambers provide a measurement of the muon track in the region of  $|\eta| < 2.7$ . Resistive-plate and thin-gap chambers provide muon triggering capability up to  $|\eta| < 2.4$ .

### 3 Data and Monte-Carlo simulation samples

#### 3.1 Data samples

The data used for this analysis was collected in  $pp$  collisions in 2012 at a centre-of-mass energy of  $\sqrt{s} = 8$  TeV. All candidate events must satisfy data-quality requirements that include being recorded during the LHC stable-beam periods and proper functioning of the detector and trigger subsystems. After the trigger and data-quality requirements, the amount of data used by this analysis corresponds to an integrated luminosity of  $20.3 \text{ fb}^{-1}$  with an average number of interactions per bunch-crossing of 20.7.

#### 3.2 Signal modelling

The right- and left-handed  $W'$  boson (denoted as  $W'_R$  and  $W'_L$ , respectively) models are implemented in MADGRAPH 5 [18] using FeynRules [19,20], which is used to generate events at leading-order (LO) in  $\alpha_s$  through Drell-Yan like production. MADGRAPH also simulates the decay of the top quark taking spin correlations into account. PYTHIA 8.165 [21] is used for parton showering and hadronisation. CTEQ6L1 [22] parton distribution functions (PDFs) are used for the event generation.

The  $W'_R$  and  $W'_L$  cross sections times branching ratios to the  $tb$  final state are obtained from next-to-leading order

Footnote 2 continued

detector, and the  $z$ -axis along the beam line. The  $x$ -axis points from the IP to the centre of the LHC ring, and the  $y$ -axis points upwards. Cylindrical coordinates  $(r, \phi)$  are used in the transverse plane,  $\phi$  being the azimuthal angle around the beam line. Observables labelled “transverse” are projected into the  $x - y$  plane. The pseudorapidity is defined in terms of the polar angle  $\theta$  as  $\eta = -\ln \tan \theta/2$ . The transverse momentum is defined as  $p_T = p \sin \theta = p/\cosh \eta$ , and the transverse energy  $E_T$  has an analogous definition.

**Table 1** NLO cross sections times branching ratio to  $tb$  for different  $W'$  masses for the left-handed and for the right-handed model [11,23]

Mass (TeV)	$\sigma \times \text{BR}(W'_L \rightarrow tb)$	$\sigma \times \text{BR}(W'_R \rightarrow tb)$
1.5	0.40 pb	0.52 pb
2.0	0.067 pb	0.086 pb
2.5	0.014 pb	0.017 pb
3.0	0.0035 pb	0.0039 pb

(NLO) QCD calculations [11,23] and are shown for different  $W'$  masses in Table 1. The mass of a possible right-handed neutrino is assumed to be larger than the mass of the  $W'_R$  boson, allowing only hadronic decays of the  $W'_R$ . In the case of a  $W'_L$  boson, leptonic decays are allowed. Dedicated Monte-Carlo (MC) simulation samples with interference effects between  $W'_L$  and SM  $W$  included have been used to estimate the change in the number of expected signal events. In the high mass signal region the change in event yield is less than 1% after kinematic requirements. Interference effects with the SM  $s$ -channel single-top quark process are ignored. All simulated samples are normalised to these NLO calculations using NLO/LO  $k$ -factors ranging from 1.15 to 1.35 depending on the mass and the chirality of the  $W'$  boson. The models assume that the  $W'$ -boson coupling strength to quarks is the same as for the SM  $W$  boson:  $g'_R = g_{\text{SM}}$  and  $g'_L = 0$  ( $g'_R = 0$  and  $g'_L = g_{\text{SM}}$ ) for  $W'_R$  ( $W'_L$ ) bosons, where  $g_{\text{SM}}$  is the SM  $SU(2)$  coupling.

#### 3.3 Background samples

The background estimate in this analysis is derived from a fit to data. However, an initial background estimate is introduced in Sect. 5.2, which uses a data-driven technique based on sideband regions for the multijet process and MC simulation samples for top-quark pair production ( $t\bar{t}$ ). For this purpose,  $t\bar{t}$  production is simulated using the POWHEG-BOX generator [24,25] coupled to PYTHIA 6.426 [26,27] for parton showering and hadronisation. This sample uses the CTEQ6L1 PDF set. The  $t\bar{t}$  samples are normalised to the next-to-next-to-leading order (NNLO) calculations in  $\alpha_s$  including resummation of next-to-next-to-leading logarithmic soft gluon terms with TOP++2.0 [28–33]:  $\sigma_{t\bar{t}} = 253^{+14}_{-16}$  pb. PDF and  $\alpha_s$  uncertainties are calculated using the PDF4LHC prescription [34] with the MSTW2008 68% CL NNLO [35,36], CT10 NNLO [37,38] and NNPDF2.3 [39] PDF sets, added in quadrature to the scale uncertainty. An uncertainty on the top-quark mass of 1 GeV is also considered.

For the optimisation of the  $W'$  top-tagger (Sect. 4.1), MC samples are generated with PYTHIA 8.160 using the AU2 tune [40] and the CT10 [37] PDF set.

After event generation, all signal and background MC samples are passed through a full simulation of the ATLAS detector [41] based on GEANT4 [42] and then reconstructed using the same algorithms as for collision data. All MC processes are simulated with pile-up interactions included and re-weighted to match the conditions of the data sample.

#### 4 Physics objects and boosted top identification

This analysis relies on the reconstruction and identification of jets. Jets are built from energy depositions in the calorimeters with the anti- $k_T$  algorithm [43] using locally-calibrated topological clusters as inputs. Jets are further calibrated using energy and  $\eta$ -dependent correction factors derived from simulation and with residual corrections from *in-situ* measurements [44]. Events with jets built from noisy calorimeter cells or non-collision backgrounds are removed [45]. In this analysis two radius parameters are used for jet reconstruction: a small- $R$  radius of 0.4 and a large- $R$  radius of 1.0. Small- $R$  jets are required to have  $p_T > 25$  GeV and  $|\eta| < 2.5$ . To minimise the impact of energy depositions from pile-up interactions the large- $R$  jets are trimmed [46]. The trimming algorithm reconstructs jets using the  $k_T$  jet algorithm with  $R = 0.3$  built out of the constituents of the original large- $R$  jet. Constituent jets contributing less than 5% of the large- $R$  jet  $p_T$  are removed. The remaining energy depositions are used to calculate the jet kinematics and substructure properties. Large- $R$  jets are required to have  $p_T > 350$  GeV and  $|\eta| < 2.0$ .

In order to identify small- $R$  jets which originate from  $b$ -quarks, this analysis uses a neural-network based  $b$ -tagging algorithm [47]. Different observables based on the long lifetime of  $B$  hadrons are used as inputs and are able to discriminate between  $b$ -jets,  $c$ -jets and light-quark jets.

Events with reconstructed high-quality electrons [48] or muons [49] are vetoed in order to ensure orthogonality to analyses using the leptonic decay of the top quark [17]. Electrons and muons with transverse momenta above 30 GeV are considered for this veto.

##### 4.1 The $W'$ top-tagger

This analysis searches for  $W'$  bosons in the high mass ( $m_{W'} > 1.5$  TeV) region, where the top quark and bottom quark have high transverse momentum. The average distance between the decay products of the top quark falls with increasing top-quark  $p_T$ , and their hadronic showers begin to overlap. This high- $p_T$  topology, where the decay products of a massive particle can be captured in one single large- $R$  jet, is referred to as “boosted” [50–53].

The discrimination of large- $R$  jets originating from hadronic top-quark decays from large- $R$  jets originating

from other sources using calorimeter information is termed top-tagging. The  $W'$  top-tagging algorithm is a cut-based algorithm using different large- $R$  jet substructure properties developed to efficiently select large- $R$  jets from  $W'$  signal events over the dominant background from multijet production featuring light-quark,  $b$ -quark and gluon-initiated jets. The procedure uses three substructure variables: the one-to-two  $k_T$ -splitting scale  $\sqrt{d_{12}}$  [54] and two ratios of  $N$ -subjettiness ( $\tau_N$ ) variables [55,56]  $\tau_{32} = \tau_3/\tau_2$  and  $\tau_{21} = \tau_2/\tau_1$ .

The splitting scale  $\sqrt{d_{12}}$  distinguishes jets containing top-quark decays, which are relatively  $p_T$ -symmetric in the top-quark rest frame, from  $p_T$ -asymmetric light jets. It is calculated by reclustering the constituents of the large- $R$  jet using the  $k_T$  algorithm, where the reclustering procedure is stopped at the last merging step. Since the  $k_T$  algorithm clusters the hardest objects last, the last clustering step corresponds to the merging of the two hardest subjets, and  $\sqrt{d_{12}}$  is defined as the corresponding scale:

$$\sqrt{d_{12}} = \min(p_{T,1}, p_{T,2}) \times \sqrt{(\Delta\eta_{12})^2 + (\Delta\phi_{12})^2},$$

where  $p_{T,1}$  and  $p_{T,2}$  are the transverse momenta of the two remaining subjets, and  $\Delta\eta_{12}$  and  $\Delta\phi_{12}$  are the distances in  $\eta$  and  $\phi$  between these two subjets. For jets from hadronic top-quark decays the  $\sqrt{d_{12}}$  distribution is expected to peak at approximately half the top-quark mass. For jets initiated by light quarks,  $b$ -quarks and gluons, the  $\sqrt{d_{12}}$  distribution is expected to peak near zero.

$N$ -subjettiness is a measure of the compatibility of a large- $R$  jet with a given number of subjets. The  $\tau_N$  are calculated by reclustering the large- $R$  jet constituents with the  $k_T$  algorithm requiring exactly  $N$  subjets to be found. The  $\tau_N$  are then defined by:

$$\tau_N = \frac{1}{d_0} \sum_k p_{Tk} \times \min(\delta R_{1k}, \dots, \delta R_{Nk}),$$

with  $d_0 = \sum_k p_{Tk} \times R$ , where the sum runs over all constituents of the jet,  $p_{Tk}$  is the  $p_T$  of the  $k$ th constituent,  $R$  is the radius parameter of the original jet, and the variable  $\delta R_{ik}$  is the distance in  $\eta$ - $\phi$  space from the  $i$ th subject to the  $k$ th constituent. Ratios of the  $\tau_N$  ( $\tau_{ij} = \tau_i/\tau_j$ ) are then defined to discriminate if a jet is more  $i$ - or  $j$ -subjett-like. The  $\tau_{ij}$  distributions peak closer to 0 for  $i$ -subjett-like jets and closer to 1 for  $j$ -subjett-like jets.

The optimisation procedure for the  $W'$  top-tagger aims for an optimal compromise between the efficiency for jets originating from hadronically decaying top quarks and the rejection of jets originating from QCD-multijet production. First, an optimal requirement on  $\sqrt{d_{12}}$  is applied and then, selection criteria on the  $N$ -subjettiness variables are determined. The MC samples used are the 2 TeV  $W'_L \rightarrow tb$  signal sample and a high- $p_T$  QCD-multijet sample with a similar range in

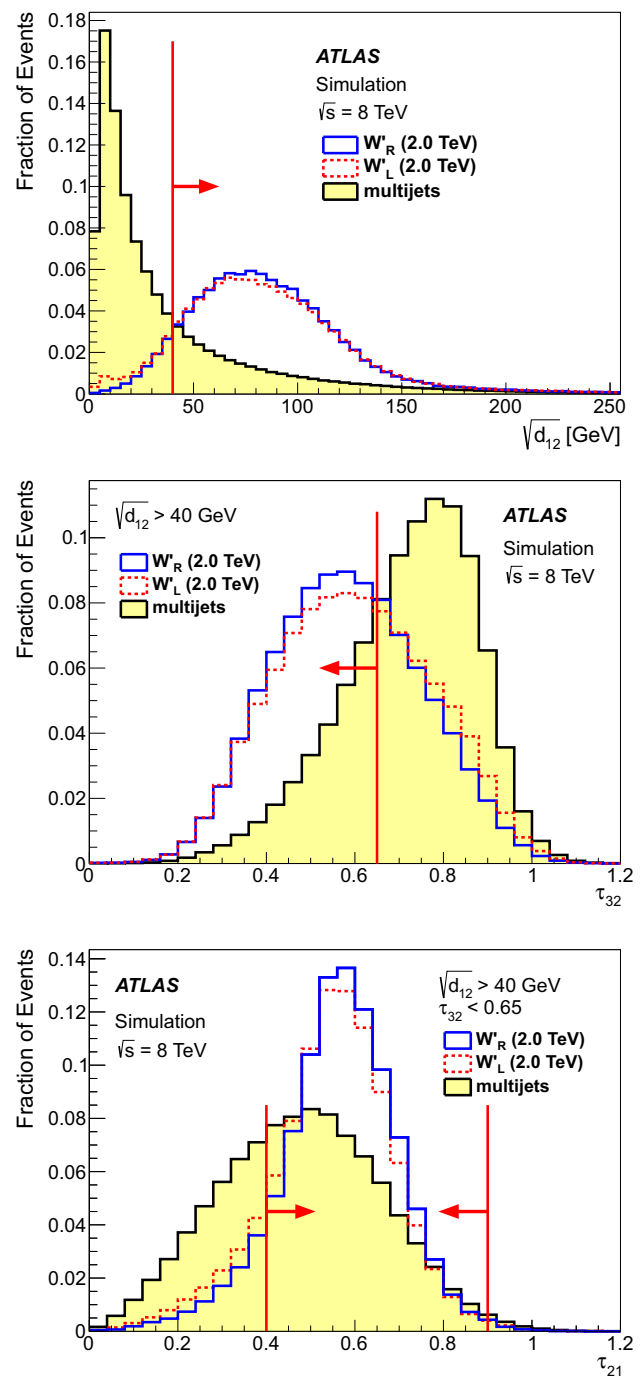
transverse momentum. It has been checked that changing the order in which  $\sqrt{d_{12}}$ ,  $\tau_{32}$  and  $\tau_{21}$  are optimised yields very similar results.

Figure 1 shows distributions of  $\sqrt{d_{12}}$  (top),  $\tau_{32}$  with the  $\sqrt{d_{12}}$  requirement applied (centre), and  $\tau_{21}$  with both  $\sqrt{d_{12}}$  and  $\tau_{32}$  requirements applied (bottom) for jets originating from hadronically decaying top quarks in 2 TeV  $W'_L$  and  $W'_R$  MC simulations. These are compared to the distributions for jets originating from light-quark,  $b$ -quark and gluon jets from QCD-multijet MC simulations. The optimised top-tagging requirements are  $\sqrt{d_{12}} > 40$  GeV,  $\tau_{32} < 0.65$  and  $0.4 < \tau_{21} < 0.9$ . While  $\tau_N$  is an infrared- and collinear-safe observable [55], infrared-safety of  $\tau_{32}$  is ensured by the requirements on  $\tau_{21}$ . The selection efficiency for jets originating from hadronic top-quark decays is estimated in MC simulations to be larger than 50% for jet  $p_T$  above 500 GeV, while the probability to falsely tag a light-quark,  $b$ -quark or gluon jet is below 10% [51]. For jet  $p_T$  below 800 GeV, where the sample size is sufficient, the top-tagging efficiency is cross-checked in data using single lepton  $t\bar{t}$  events, and the top-tagging efficiency is found to be consistent between data and MC.

### 5 Analysis

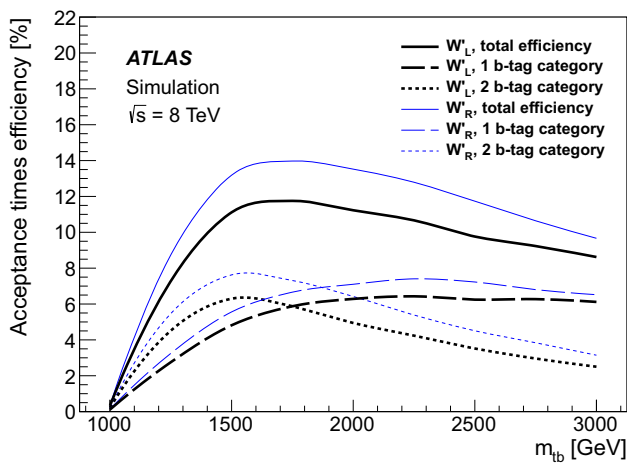
#### 5.1 Event selection

Candidate events are triggered by requiring the scalar sum of the  $E_T$  of the energy deposits in the calorimeters at trigger level to be at least 700 GeV. In order to perform the offline analysis in the fully efficient regime of this trigger, the scalar sum of the transverse momenta of reconstructed small- $R$  jets with  $p_T > 25$  GeV and  $|\eta| < 2.5$  is required to be at least 850 GeV. Candidate events must have at least one primary vertex with at least five tracks associated to it and have exactly one large- $R$   $W'$  top-tagged jet (top candidate) and one small- $R$   $b$ -tagged jet ( $b$ -candidate) each with  $p_T > 350$  GeV and an angular separation  $\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2}$  larger than 2.0 between the flight direction of the top candidate and the  $b$ -candidate. The invariant mass of the dijet system must be at least 1.1 TeV in order to avoid turn-on effects from the kinematic selection. The events are divided into two categories: the one  $b$ -tag category and the two  $b$ -tag category. For the two  $b$ -tag category, an additional  $b$ -tagged small- $R$  jet with  $p_T > 25$  GeV has to be present close to the top candidate by requiring  $\Delta R$  between the small- $R$   $b$ -jet and the top candidate to be less than the large- $R$  jet radius parameter 1.0. Figure 2 shows the acceptance times selection efficiency as a function of  $tb$  invariant mass at truth level in the one and two  $b$ -tag categories and the total signal efficiency corresponding to their sum. The difference in the efficiencies observed in the  $W'_L$  and  $W'_R$  models originates from the different top-tagging



**Fig. 1** Distributions in simulated samples of the substructure observables used for the  $W'$  top-tagger for trimmed large- $R$  jets originating from QCD-multijet production and originating from hadronic decays of top quarks from 2 TeV  $W'_L$  and  $W'_R$  boson decays. The *top* figure shows the  $\sqrt{d_{12}}$  distributions and the *middle* (*bottom*) figures show the  $\tau_{32}$  ( $\tau_{21}$ ) distribution after requiring  $\sqrt{d_{12}} > 40$  GeV ( $\sqrt{d_{12}} > 40$  GeV and  $\tau_{32} < 0.65$ ). All distributions are normalised to unity. The *arrows* indicate the cut values used in the  $W'$  top-tagger

efficiencies, which is due to the preferred flight directions of the top-quark decay products in the top-quark rest frame for the two chiralities.



**Fig. 2** Selection acceptance times efficiency as a function of  $tb$  invariant mass at truth level for *left-* and *right-handed*  $W'$  MC. The total efficiency curves correspond to the sum of the efficiencies of the one  $b$ -tag and two  $b$ -tag categories

### 5.2 Initial background estimate

An initial background estimate is performed to choose the fit function which is used to estimate the background from data. It is also used to derive the associated systematic uncertainties on the background modelling.

Multijet events are the dominant background comprising 99% (88%) of the events in the one (two)  $b$ -tag category. The estimate of the contribution of multijet events is based on a data-driven method which categorises events based on top- and  $b$ -tagging. Requiring the high- $p_T$  small- $R$  jet to fail the  $b$ -tagging requirement or the large- $R$  jet to fail the top-tagging requirement provides three orthogonal control regions in each  $b$ -tag category that are dominated by multijet events. These control regions are then used to make an estimate of the multijet contribution in the signal region, as defined by the event selection.

The other significant background is top-quark pairs, contributing 11% in the two  $b$ -tag category as estimated using MC simulations. Other backgrounds, such as single-top,  $W$ -boson+jets, and  $Z$ -boson+jets production are found to have a very small contribution.

Table 2 reports the number of data and expected background events in the signal region for the one  $b$ -tag and two  $b$ -tag categories.

### 5.3 Statistical analysis

An unbinned likelihood fit to the  $m_{tb}$  distributions combining the one  $b$ -tag category and the two  $b$ -category is performed, where the range considered is 1.1–4 TeV. The lower bound of  $m_{tb}$  is due to turn-on effects of the  $m_{tb}$  distribution originating in the kinematic selection. This allows  $W'$  signals

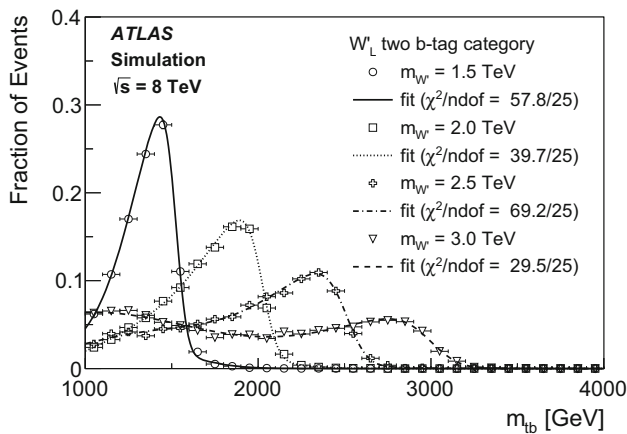
**Table 2** Event yields in the signal region for SM processes using the initial background estimate compared to the yield observed in data. The uncertainties quoted for multijet and for  $t\bar{t}$  production contain statistical as well as systematic uncertainties (Sect. 6). The contributions from other background sources (single-top,  $W$ -boson+jets and  $Z$ -boson+jets production) have only been estimated approximately, but were found to be smaller than 0.4% of the expectation for multijet production. An uncertainty of 100% is quoted here in order to reflect the approximations made

Process	One $b$ -tag	Two $b$ -tag
Multijet	$16100 \pm 800$	$2600 \pm 300$
Hadronic $t\bar{t}$	$130 \pm 30$	$210 \pm 60$
Leptonic $t\bar{t}$	$60 \pm 20$	$90 \pm 30$
Other	$60 \pm 60$	$8 \pm 8$
Total SM prediction	$16400 \pm 800$	$2900 \pm 300$
Data	16601	2925

of  $m_{W'} \geq 1.5$  TeV to be tested, because for lower values of  $m_{W'}$ , the peak of the signal shape is only partially contained in the  $m_{tb}$  range considered. The upper bound of  $m_{tb}$  is motivated by the low expected number of events in the two  $b$ -tag category at such high values. Hence,  $W'$  signals of  $m_{W'} \leq 3.0$  TeV can be tested, in order to constrain the background function parameters also for high  $m_{tb}$  values. A profile likelihood-based test statistic is used for the evaluation of  $p$ -values for observations as well as a  $CL_s$  test statistic for setting 95% CL exclusion limits, where asymptotic formulas [57] are used. The expected and observed limits are corrected for small differences observed using toy experiments.

The reconstructed  $m_{tb}$  spectrum for the  $W'$  signal is parametrised using the sum of a skew-normal [58] and a Gaussian function. The skew-normal accounts for the asymmetric shape of the resonant  $W'$  signal and is the product of a Gaussian and a Gaussian error function. Non-resonant off-shell  $W'$  production is accounted for with the additional Gaussian distribution. This allows the signal shape to be fully parametrised. In order to search for a  $W'$  signal over the full mass range, the signal shape parameters, as well as the signal acceptance and the expected cross sections are interpolated between the generated mass points. Figure 3 shows the parametric fits to the  $W'$  signal distributions in the two  $b$ -tag category for  $W'_L$  masses between 1.5 and 3 TeV overlaid to the corresponding MC distributions.

Additional contributions from  $W' \rightarrow tb \rightarrow \ell\nu bb$  are between 3.5 and 10%. The leptonic contribution is taken into account by fitting the reconstructed  $m_{tb}$  distribution with a double-Gaussian function and interpolating between generated masses analogously to the treatment of the  $W' \rightarrow tb \rightarrow qqbb$  signal. Large- $R$  jets can falsely be top-tagged in events with leptonic top-quark decays due to several effects including hard gluon radiation, calorimeter activity from



**Fig. 3** Parametric fits to the  $W' \rightarrow tb \rightarrow qqbb$  signal distributions in the two  $b$ -tag category for  $W'_L$  masses between 1.5 and 3 TeV overlaid to the corresponding MC distributions. While unbinned fits are performed, the events from MC simulation are shown as a histogram for presentational purposes

non-identified electrons and hadronically decaying tau leptons.

The sum of all backgrounds is fitted with an analytic function. For each of the two categories, a function is chosen among several tested functions following a procedure based on the  $m_{tb}$  distribution obtained from the initial background estimate (Sect. 5.2). For each function under study the corresponding fake signal bias is quantified by fitting the  $m_{tb}$  distribution from the initial background estimate with a background-plus-signal model. The maximal extracted fake signal observed over the full range of  $W'$  masses is chosen as systematic uncertainty on the background modelling (Sect. 6). The function with the least number of free parameters is chosen out of all tested functions giving similarly small bias. This procedure yields an exponential function with a polynomial of order  $n$  as its argument:  $\exp(\sum_{k=1}^n c_k m_{tb}^k)$ , with  $n = 4$  ( $n = 2$ ) in the one (two)  $b$ -tag category. Figure 4 shows background-only fits to the initial background estimate in the one and two  $b$ -tag categories using the chosen functions. The ratio of the distribution and the fit is also shown, where the uncertainties are the control-region and MC statistical uncertainties and the grey shaded band shows the statistical uncertainty in each bin as expected for  $20.3 \text{ fb}^{-1}$ . Deviations from 1 in the ratio plot are much smaller than the expected statistical uncertainty and the chosen background functions are hence shown to be flexible enough to describe the background distribution in the signal region.

## 6 Systematic uncertainties

Systematic uncertainties may change the acceptance and shape of the potential  $W'$  signal, and are included as nui-

sance parameters in the likelihood function. Table 3 shows the impact of the systematic uncertainties on the event yield of a 2 TeV  $W'$  boson in the one and two  $b$ -tag categories. The largest sources of uncertainty come from the uncertainties associated with  $b$ -tagging, top-tagging and background modelling.

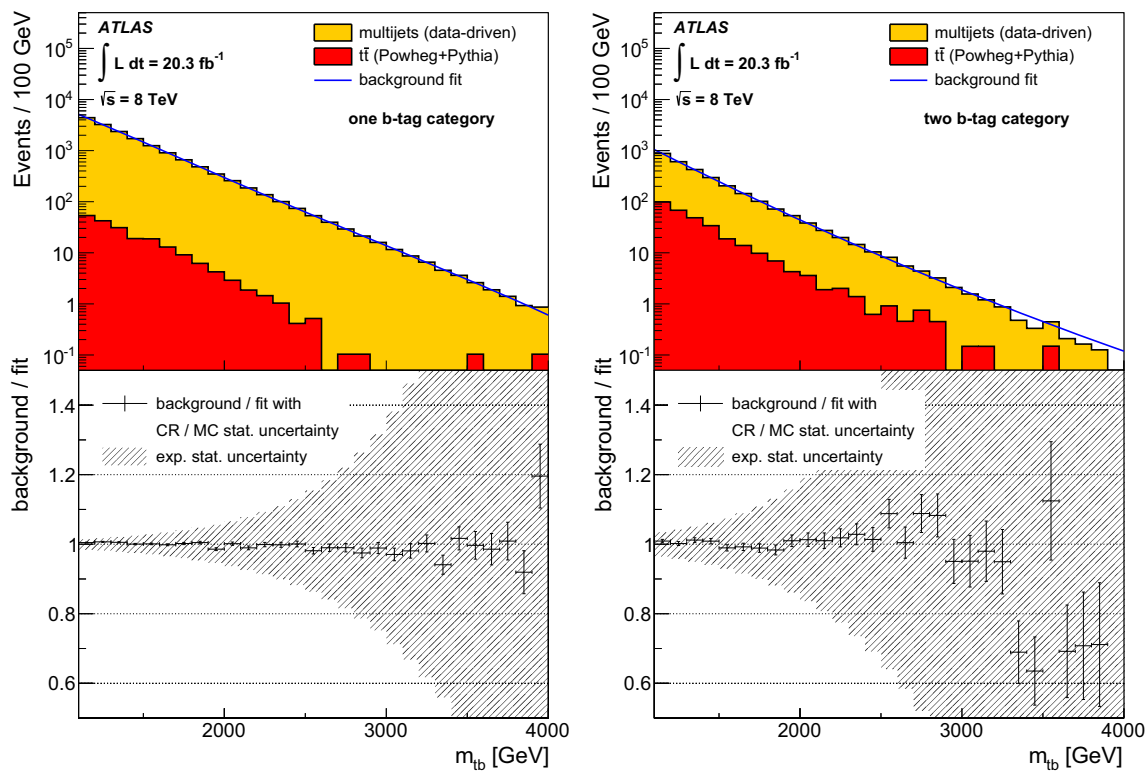
Uncertainties on the  $b$ -tagging efficiency and mistag rates are estimated from data using  $t\bar{t}$  di-lepton decays [47,59]. The  $b$ -tagging (mistagging) uncertainties are increased for high  $p_T$  and reach up to 34% (60%) per jet. Uncertainties on the  $W'$  top-tagger performance are evaluated based on the data-MC agreement as shown in Refs. [52,53]. They are derived comparing the ratio of each variable from jets built from calorimeter clusters and the corresponding jet built from tracks in the ID. The observed differences between data and MC are taken as variations on the substructure variables and are translated into an uncertainty on the efficiency of the  $W'$  top-tagger. Within the kinematic reach, it has been shown with  $t\bar{t}$  events in the single-lepton channel that these uncertainties cover any possible disagreement between the efficiency observed in data and MC simulations. The jet energy scale (JES) uncertainty [44] depends on the  $p_T$  and  $\eta$  of the reconstructed jet and includes the uncertainty on the  $b$ -jet energy scale. The JES of the two jet types are assumed to be correlated. The impact of the jet energy resolution uncertainty is evaluated by smearing the jet energy in the simulation to increase the nominal resolution. The uncertainty on the integrated luminosity is 2.8% as derived from beam-separated scans [60]. Theoretical uncertainties are included by evaluating the change in the expected number of signal events. The deviations from varying the CTEQ6L1 PDF eigenvectors are summed in quadrature with the uncertainty from  $\alpha_s$ , the renormalisation scale, and the change in acceptance at LO and NLO. In addition, the uncertainty on the beam energy [61] is included.

Uncertainties due to background mismodelling are quantified as discussed in Sect. 5.3. This uncertainty amounts to 28 (24) events in the two  $b$ -tag category and 44 (45) events in the one  $b$ -tag category for the  $W'_L$  ( $W'_R$ ) model.

## 7 Results

Figure 5 shows the observed  $m_{tb}$  spectra in the two categories. The highest mass event in the two (one)  $b$ -tag category is at 3.25 TeV (4.68 TeV). A background-only fit to the spectra is also shown and good agreement is observed between the fit and the data.

Figure 6 shows the observed  $p$ -values for background plus left-handed or right-handed  $W'$  model as a function of the  $W'$  mass allowing the background parameters to float. The  $p$ -value from both categories combined is shown taking into account all systematic uncertainties. The maximum



**Fig. 4** Fit to the  $m_{tb}$  distribution from the initial background estimate in the one  $b$ -tag category (left) and in the two  $b$ -tag category (right). The ratio background/fit is also shown, where the uncertainties are the

control-region and MC statistical uncertainties and the grey shaded band shows the statistical uncertainty in each bin as expected for  $20.3 \text{ fb}^{-1}$

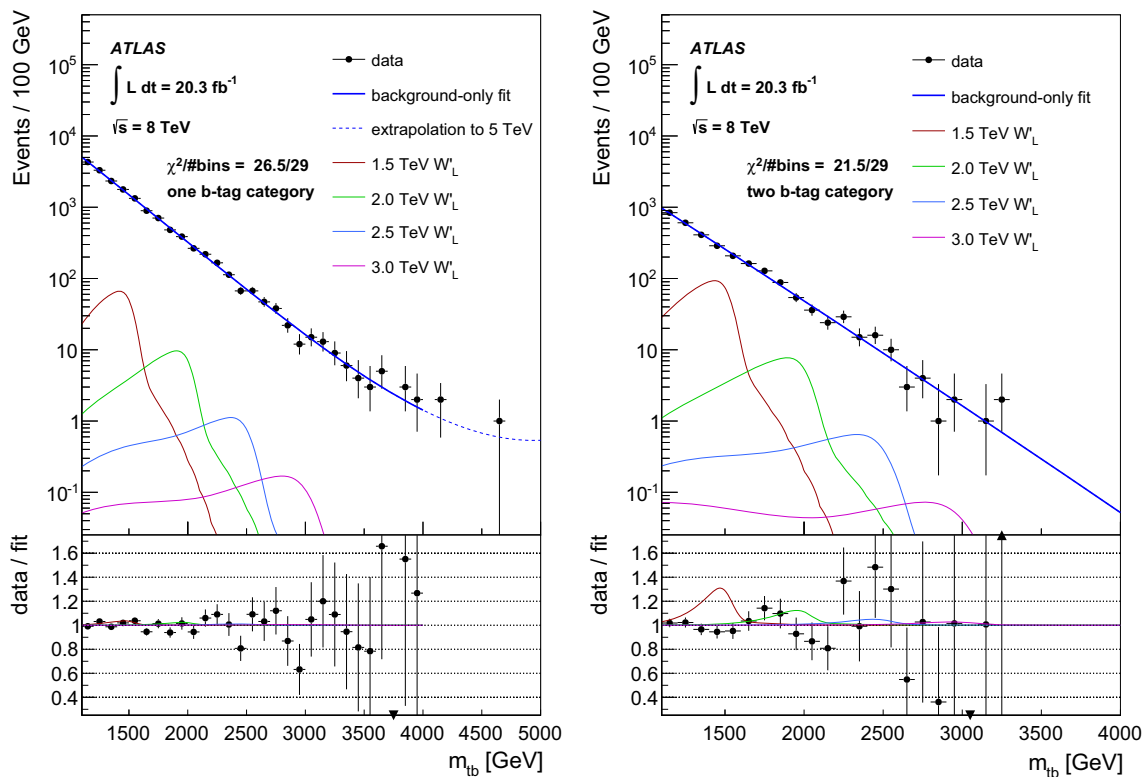
**Table 3** Systematic uncertainties on the event yields of a 2 TeV  $W'$  boson in both categories in percent and on the background modelling in numbers of expected  $W'$  boson events

Systematic uncertainties (%)	$W'_L$		$W'_R$	
	One $b$ -tag	Two $b$ -tag	One $b$ -tag	Two $b$ -tag
$b$ -Tagging	+13, -20	+45, -37	+15, -21	+40, -34
$W'$ Top-tagging	$\pm 13$	$\pm 10$	$\pm 11$	$\pm 9$
Jet energy scale	$\pm 1.3$	$\pm 1.9$	$\pm 0.8$	$\pm 1.9$
Jet energy resolution	$< 0.1$	$\pm 0.2$	$\pm 0.1$	$\pm 0.5$
Theoretical	$\pm 10$		+8, -10	
Luminosity	$\pm 2.8$			
Background modelling	$\pm 44$ events	$\pm 28$ events	$\pm 45$ events	$\pm 24$ events

local significance is  $1.4\sigma$ . Hence, no significant excess over the background-only hypothesis is observed and 95% CL limits are derived on the cross section times branching ratio to  $tb$  as shown in Fig. 7. The observed limits agree with the expected limits roughly within  $1\sigma$  over the whole range for both  $W'$  models and range from 0.16 pb to 0.33 pb for left-handed  $W'$  bosons and from 0.10 pb to 0.21 pb for  $W'$  bosons with purely right-handed couplings. The relative mass independence of the expected sensitivity and observed limits is a unique feature of this search arising from the flat signal efficiency when combining the one and two  $b$ -tag categories.

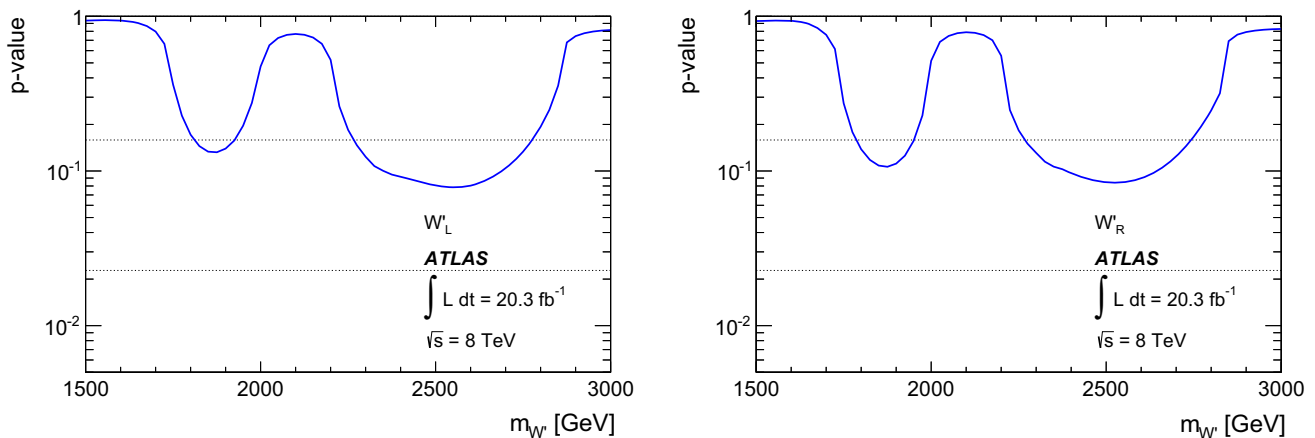
For  $g' = g_{SM}$ , the limits on the cross section times branching ratio translate to observed (expected) limits on the mass to be above 1.68 TeV (1.63 TeV) and 1.76 TeV (1.85 TeV) in the left- and right-handed models, respectively. The observed cross-section limits are also interpreted as limits on other values of the couplings  $g'_{L/R}$ . For  $g'_{L/R}/g_{SM} < 2$ , the reconstructed  $m_{tb}$  distributions are dominated by the experimental width. The results obtained for  $g'_{L/R} = g_{SM}$  can hence be interpreted as limits in the  $g'_L$ - $W'_L$  mass ( $g'_R$ - $W'_R$  mass) plane, making use of the approximately quadratic dependence of the  $W'$  production cross section on  $g'$ . The observed and expected limits on the ratio of couplings  $g'_L/g_{SM}$  ( $g'_R/g_{SM}$ )





**Fig. 5**  $m_{tb}$  distributions in data in the one  $b$ -tag (left) and the two  $b$ -tag category (right). Background-only fits are shown, and the bottom plots show the ratio of the data and the fit. The left plot shows an extrapolation of the background fit into the region 4–5 TeV. The ratio plot,

however does not show the three data points in this range, because they are beyond the range considered for this analysis. Potential  $W'_L$  signal shapes in the hadronic top-quark decay channel with  $g' = g_{SM}$  are also overlaid for resonance masses of 1.5, 2.0, 2.5 and 3.0 TeV



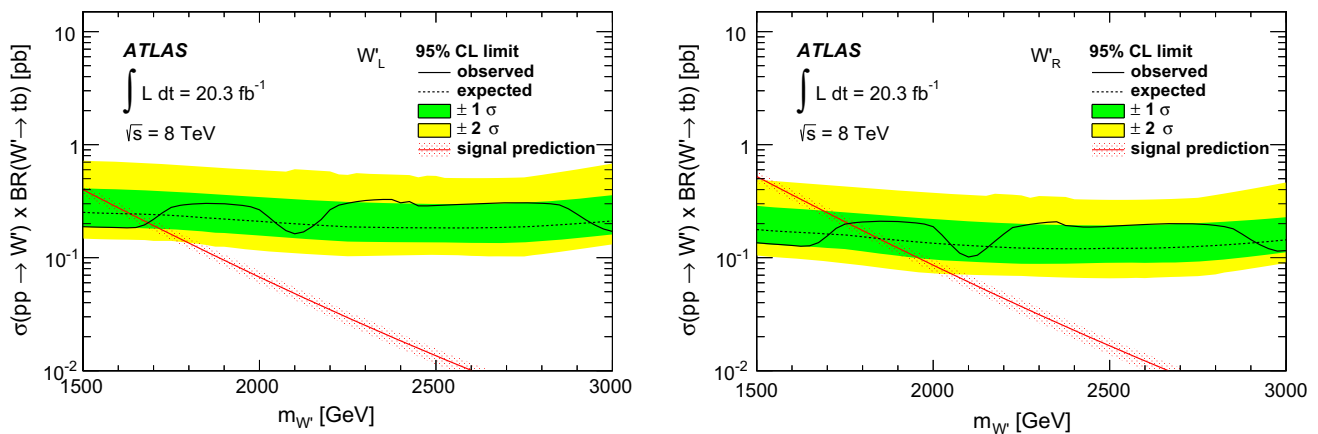
**Fig. 6** Observed  $p$ -values for a left-handed (left) and right-handed (right)  $W'$  model as a function of the  $W'$  mass

of the  $W'_L$  ( $W'_R$ ) model as a function of  $W'$  mass are shown in Fig. 8 and amount to  $g' < 0.70$  ( $g' < 0.55$ ) for a 1.5 TeV  $W'_L$  ( $W'_R$ ) and to  $g' < 2$  for a 2.18 (2.29) TeV  $W'_L$  ( $W'_R$ ) boson.

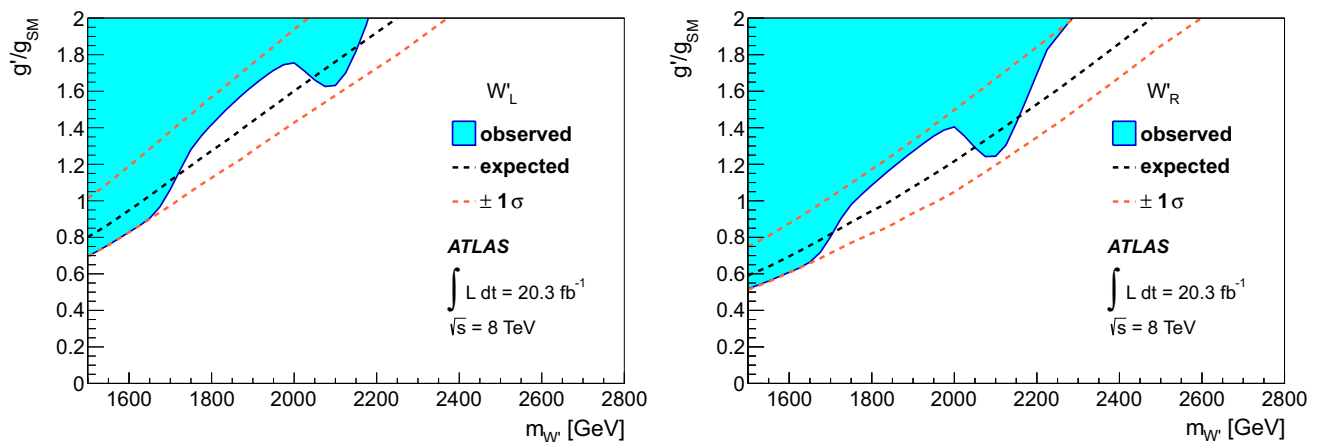
### 8 Summary and conclusion

A search for  $W' \rightarrow tb \rightarrow qqbb$  was presented using  $20.3 \text{ fb}^{-1}$  of 8 TeV proton-proton collisions data taken with

the ATLAS detector. The analysis makes use of jet substructure tagging optimised to select large- $R$  jets coming from hadronically decaying top quarks and  $b$ -tagging of small- $R$  jets. The observed  $m_{tb}$  spectrum from data is consistent with the background-only prediction and exclusion limits at 95% CL are set on the  $W'$  boson production cross section times branching ratio to  $tb$ . The use of novel jet substructure techniques allows cross-section limits to be set at high  $W'$  masses, which are similar to the limits at lower masses and



**Fig. 7** Limits at 95 % CL on the cross section times branching ratio to  $tb$  for the left-handed (left) and for the right-handed (right)  $W'$  model. The expected cross section for  $W'$  production with  $g' = g_{SM}$  is also shown



**Fig. 8** Observed and expected 95 % CL limits on the ratio of coupling  $g'_L/g_{SM}$  ( $g'_R/g_{SM}$ ) of the  $W'_L$  ( $W'_R$ ) model as a function of the  $W'$  mass

range from 0.16 pb to 0.33 pb for left-handed  $W'$  bosons, and from 0.10 pb to 0.21 pb for  $W'$  bosons with purely right-handed couplings. In addition, limits are set at 95 % CL on the  $W'$ -boson effective couplings as a function of the  $W'$  mass.

**Acknowledgments** We thank CERN for the very successful operation of the LHC, as well as the support staff from our institutions without whom ATLAS could not be operated efficiently. We acknowledge the support of ANPCyT, Argentina; YerPhI, Armenia; ARC, Australia; BMWFW and FWF, Austria; ANAS, Azerbaijan; SSTC, Belarus; CNPq and FAPESP, Brazil; NSERC, NRC and CFI, Canada; CERN; CONICYT, Chile; CAS, MOST and NSFC, China; COLCIENCIAS, Colombia; MSMT CR, MPO CR and VSC CR, Czech Republic; DNRF, DNSRC and Lundbeck Foundation, Denmark; EPLANET, ERC and NSRF, European Union; IN2P3-CNRS, CEA-DSM/IRFU, France; GNSF, Georgia; BMBF, DFG, HGF, MPG and AvH Foundation, Germany; GSRT and NSRF, Greece; RGC, Hong Kong SAR, China; ISF, MINERVA, GIF, I-CORE and Benoziyo Center, Israel; INFN, Italy; MEXT and JSPS, Japan; CNRST, Morocco; FOM and NWO, Netherlands; BRF and RCN, Norway; MNiSW and NCN, Poland; GRICES and FCT, Portugal; MNE/IFA, Romania; MES of Russia and ROSATOM, Russian Federation; JINR; MSTD, Serbia; MSSR, Slovakia; ARRS and MIZŠ, Slovenia; DST/NRF, South Africa; MINECO, Spain; SRC and Wallenberg Foundation, Sweden; SER, SNSF and Can-

tons of Bern and Geneva, Switzerland; NSC, Taiwan; TAEK, Turkey; STFC, the Royal Society and Leverhulme Trust, United Kingdom; DOE and NSF, United States of America. 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 distributed under the terms of the Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. Funded by SCOAP<sup>3</sup>.

**References**

1. S. Glashow, Nucl. Phys. **22**, 579–588 (1961)
2. S. Weinberg, Phys. Rev. Lett. **19**, 1264–1266 (1967)
3. A. Salam, Conf. Proc. C680519 367–377 (1968)

4. J.C. Pati, A. Salam, Phys. Rev. D **10**, 275–289 (1974)
5. H. Georgi, S. Glashow, Phys. Rev. Lett. **32**, 438–441 (1974)
6. H. Georgi, AIP Conf. Proc. **23**, 575–582 (1975)
7. H. Fritzsch, P. Minkowski Annals Phys. **93**, 193–266 (1975)
8. G. Burdman, B.A. Dobrescu, E. Pontón, Phys. Rev. D **74**, 075008 (2006). [arXiv:hep-ph/0601186](#)
9. E. Malkawi, T.M. Tait, C.-P. Yuan, Phys. Lett. B **385**, 304–310 (1996). [arXiv:hep-ph/9603349](#)
10. M. Perelstein, Prog. Part. Nucl. Phys. **58**, 247–291 (2007). [arXiv:hep-ph/0512128](#)
11. Z. Sullivan, Phys. Rev. D **66**, 075011 (2002). [arXiv:hep-ph/0207290](#)
12. D. Duffy, Z. Sullivan, Phys. Rev. D **90**, 015031 (2014). [arXiv:1307.1820](#)
13. D0 Collaboration, V. Abazov et al., Phys. Rev. Lett. **100**, 211803 (2008). [arXiv:0803.3256](#)
14. CDF Collaboration, T. Aaltonen et al., Phys. Rev. Lett. **103**, 041801 (2009). [arXiv:0902.3276](#)
15. CDF Collaboration, T. Aaltonen et al., Phys. Rev. Lett. (submitted). [arXiv:1504.01536](#)
16. CMS Collaboration, JHEP **1405**, 108 (2014). [arXiv:1402.2176](#)
17. ATLAS Collaboration, Phys. Lett. B **743**, 235–255 (2015). [arXiv:1410.4103](#)
18. J. Alwall et al., JHEP **1106**, 128 (2011). [arXiv:1106.0522](#)
19. A. Alloul et al., Comput. Phys. Commun. **185**, 2250–2300 (2014). [arXiv:1310.1921](#)
20. C. Degrande et al., Comput. Phys. Commun. **183**, 1201–1214 (2012). [arXiv:1108.2040](#)
21. T. Sjöstrand, S. Mrenna, P.Z. Skands, Comput. Phys. Commun. **178**, 852–867 (2008). [arXiv:0710.3820](#)
22. J. Pumplin et al., JHEP **0207**, 012 (2002). [arXiv:hep-ph/0201195](#)
23. D. Duffy, Z. Sullivan, Phys. Rev. D **86**, 075018 (2012). [arXiv:1208.4858](#)
24. S. Alioli et al., JHEP **1006**, 043 (2010). [arXiv:1002.2581](#)
25. S. Frixione, G. Ridolfi, P. Nason, JHEP **0709**, 126 (2007). [arXiv:0707.3088](#)
26. T. Sjöstrand, S. Mrenna, P.Z. Skands, JHEP **0605**, 026 (2006). [arXiv:hep-ph/0603175](#)
27. P.Z. Skands, Phys. Rev. D **82**, 074018 (2010). [arXiv:1005.3457](#)
28. M. Cacciari et al., Phys. Lett. B **710**, 612–622 (2012). [arXiv:1111.5869](#)
29. P. Bärnreuther, M. Czakon, Phys. Rev. Lett. **109**, 132001 (2012). [arXiv:1204.5201](#)
30. M. Czakon, A. Mitov JHEP **1212**, 054 (2012). [arXiv:1207.0236](#)
31. M. Czakon, A. Mitov JHEP **1301**, 080 (2013). [arXiv:1210.6832](#)
32. M. Czakon, P. Fiedler, A. Mitov, Phys. Rev. Lett. **110**, 252004 (2013). [arXiv:1303.6254](#)
33. M. Czakon, A. Mitov, Comput. Phys. Commun. **185**, 2930–2938 (2014). [arXiv:1112.5675](#)
34. M. Botje et al. [arXiv:1101.0538](#)
35. A. Martin et al., Eur. Phys. J. C **63**, 189–285 (2009). [arXiv:0901.0002](#)
36. A. Martin et al., Eur. Phys. J. C **64**, 653–680 (2009). [arXiv:0905.3531](#)
37. H.-L. Lai et al., Phys. Rev. D **82**, 074024 (2010). [arXiv:1007.2241](#)
38. J. Gao et al., Phys. Rev. D **89**, 033009 (2014). [arXiv:1302.6246](#)
39. R.D. Ball et al., Nucl. Phys. B **867**, 244–289 (2013). [arXiv:1207.1303](#)
40. ATLAS Collaboration, ATL-PHYS-PUB-2012-003. <http://cdsweb.cern.ch/record/1474107>
41. ATLAS Collaboration, Eur. Phys. J. C **70**, 823–874 (2010). [arXiv:1005.4568](#)
42. GEANT4 Collaboration, S. Agostinelli et al., Nucl. Instrum. Meth. A **506**, 250–303 (2003)
43. G.P. Salam, G. Soyez JHEP **0705**, 086 (2007). [arXiv:0704.0292](#)
44. ATLAS Collaboration, ATLAS-CONF-2013-004. <http://cdsweb.cern.ch/record/1509552>
45. ATLAS Collaboration, ATLAS-CONF-2010-038. <https://cdsweb.cern.ch/record/1277678>
46. D. Krohn, J. Thaler, L.-T. Wang, JHEP **1002**, 084 (2010). [arXiv:0912.1342](#)
47. ATLAS Collaboration, ATLAS-CONF-2014-046. <http://cdsweb.cern.ch/record/1741020>
48. ATLAS Collaboration, Eur. Phys. J. C **74**, 2941 (2014). [arXiv:1404.2240](#)
49. ATLAS Collaboration, Eur. Phys. J. C **74**, 3034 (2014). [arXiv:1404.4562](#)
50. K. Rehermann, B. Tweedie JHEP **1103**, 059 (2011). [arXiv:1007.2221](#)
51. ATLAS Collaboration ATLAS-CONF-2013-084. <https://cdsweb.cern.ch/record/1571040>
52. ATLAS Collaboration ATLAS-CONF-2012-065. <http://cdsweb.cern.ch/record/1459530>
53. ATLAS Collaboration ATLAS-CONF-2011-066. <http://cdsweb.cern.ch/record/1459531>
54. J. Butterworth, B. Cox, J.R. Forshaw Phys. Rev. D **65**, 096014 (2002). [arXiv:hep-ph/0201098](#)
55. J. Thaler, K. Van Tilburg, JHEP **1103**, 015 (2011). [arXiv:1011.2268](#)
56. J. Thaler, K. Van Tilburg JHEP **1202**, 93 (2012). [arXiv:1108.2701](#)
57. G. Cowan et al., Eur. Phys. J. C **71**, 1554 (2011). [arXiv:1007.1727](#)
58. A. O’Hagan, T. Leonard, Biometrika **63**(1), 201–203 (1976)
59. ATLAS Collaboration ATLAS-CONF-2014-004. <http://cdsweb.cern.ch/record/1664335>
60. ATLAS Collaboration, Eur. Phys. J. C **73**, 2518 (2013). [arXiv:1302.4393](#)
61. J. Wenninger CERN-ATS-2013-040. <http://cdsweb.cern.ch/record/1546734>

## ATLAS Collaboration

G. Aad<sup>84</sup>, B. Abbott<sup>112</sup>, J. Abdallah<sup>152</sup>, S. Abdel Khalek<sup>116</sup>, O. Abdinov<sup>11</sup>, R. Aben<sup>106</sup>, B. Abi<sup>113</sup>, M. Abolins<sup>89</sup>, O. S. AbouZeid<sup>159</sup>, H. Abramowicz<sup>154</sup>, H. Abreu<sup>153</sup>, R. Abreu<sup>30</sup>, Y. Abulaiti<sup>147a,147b</sup>, B. S. Acharya<sup>165a,165b,a</sup>, L. Adamczyk<sup>38a</sup>, D. L. Adams<sup>25</sup>, J. Adelman<sup>177</sup>, S. Adomeit<sup>99</sup>, T. Adye<sup>130</sup>, T. Agatonovic-Jovin<sup>13a</sup>, J. A. Aguilar-Saavedra<sup>125a,125f</sup>, M. Agustoni<sup>17</sup>, S. P. Ahlen<sup>22</sup>, F. Ahmadov<sup>64,b</sup>, G. Aielli<sup>134a,134b</sup>, H. Akerstedt<sup>147a,147b</sup>, T. P. A. Åkesson<sup>80</sup>, G. Akimoto<sup>156</sup>, A. V. Akimov<sup>95</sup>, G. L. Alberghi<sup>20a,20b</sup>, J. Albert<sup>170</sup>, S. Albrand<sup>55</sup>, M. J. Alconada Verzini<sup>70</sup>, M. Aleksa<sup>30</sup>, I. N. Aleksandrov<sup>64</sup>, C. Alexa<sup>26a</sup>, G. Alexander<sup>154</sup>, G. Alexandre<sup>49</sup>, T. Alexopoulos<sup>10</sup>, M. Alhroob<sup>165a,165c</sup>, G. Alimonti<sup>90a</sup>, L. Alio<sup>84</sup>, J. Alison<sup>31</sup>, B. M. M. Allbrooke<sup>18</sup>, L. J. Allison<sup>71</sup>, P. P. Allport<sup>73</sup>, J. Almond<sup>83</sup>, A. Aloisio<sup>103a,103b</sup>, A. Alonso<sup>36</sup>, F. Alonso<sup>70</sup>, C. Alpigiani<sup>75</sup>, A. Altheimer<sup>35</sup>, B. Alvarez Gonzalez<sup>89</sup>, M. G. Alviggi<sup>103a,103b</sup>, K. Amako<sup>65</sup>, Y. Amaral Coutinho<sup>24a</sup>, C. Amelung<sup>23</sup>, D. Amidei<sup>88</sup>, S. P. Amor Dos Santos<sup>125a,125c</sup>, A. Amorim<sup>125a,125b</sup>, S. Amoroso<sup>48</sup>, N. Amram<sup>154</sup>, G. Amundsen<sup>23</sup>, C. Anastopoulos<sup>140</sup>, L. S. Ancu<sup>49</sup>, N. Andari<sup>30</sup>, T. Andeen<sup>35</sup>, C. F. Anders<sup>58b</sup>, G. Anders<sup>30</sup>, K. J. Anderson<sup>31</sup>, A. Andreazza<sup>90a,90b</sup>, V. Andrei<sup>58a</sup>, X. S. Anduaga<sup>70</sup>, S. Angelidakis<sup>9</sup>, I. Angelozzi<sup>106</sup>, P. Anger<sup>44</sup>, A. Angerami<sup>35</sup>, F. Anghinolfi<sup>30</sup>, A. V. Anisenkov<sup>108</sup>, N. Anjos<sup>125a</sup>, A. Annovi<sup>47</sup>, A. Antonaki<sup>9</sup>, M. Antonelli<sup>47</sup>, A. Antonov<sup>97</sup>, J. Antos<sup>145b</sup>, F. Anulli<sup>133a</sup>, M. Aoki<sup>65</sup>, L. Aperio Bella<sup>18</sup>, R. Apolle<sup>119,c</sup>, G. Arabidze<sup>89</sup>, I. Aracena<sup>144</sup>, Y. Arai<sup>65</sup>, J. P. Araque<sup>125a</sup>, A. T. H. Arce<sup>45</sup>, J-F. Arguin<sup>94</sup>, S. Argyropoulos<sup>42</sup>, M. Arik<sup>19a</sup>, A. J. Armbruster<sup>30</sup>, O. Arnaez<sup>30</sup>, V. Arnal<sup>81</sup>, H. Arnold<sup>48</sup>, M. Arratia<sup>28</sup>, O. Arslan<sup>21</sup>, A. Artamonov<sup>96</sup>, G. Artoni<sup>23</sup>, S. Asai<sup>156</sup>, N. Asbah<sup>42</sup>, A. Ashkenazi<sup>154</sup>, B. Åsman<sup>147a,147b</sup>, L. Asquith<sup>6</sup>, K. Assamagan<sup>25</sup>, R. Astalos<sup>145a</sup>, M. Atkinson<sup>166</sup>, N. B. Atlay<sup>142</sup>, B. Auerbach<sup>6</sup>, K. Augsten<sup>127</sup>, M. Aourousseau<sup>146b</sup>, G. Avolio<sup>30</sup>, G. Azuelos<sup>94,d</sup>, Y. Azuma<sup>156</sup>, M. A. Baak<sup>30</sup>, A. Baas<sup>58a</sup>, C. Bacci<sup>135a,135b</sup>, H. Bachacou<sup>137</sup>, K. Bachas<sup>155</sup>, M. Backes<sup>30</sup>, M. Backhaus<sup>30</sup>, J. Backus Mayes<sup>144</sup>, E. Badescu<sup>26a</sup>, P. Bagicchi<sup>133a,133b</sup>, P. Bagnaia<sup>133a,133b</sup>, Y. Bai<sup>33a</sup>, T. Bain<sup>35</sup>, J. T. Baines<sup>130</sup>, O. K. Baker<sup>177</sup>, P. Balek<sup>128</sup>, F. Balli<sup>137</sup>, E. Banas<sup>39</sup>, Sw. Banerjee<sup>174</sup>, A. A. E. Bannoura<sup>176</sup>, V. Bansal<sup>170</sup>, H. S. Bansil<sup>18</sup>, L. Barak<sup>173</sup>, S. P. Baranov<sup>95</sup>, E. L. Barberio<sup>87</sup>, D. Barberis<sup>50a,50b</sup>, M. Barbero<sup>84</sup>, T. Barillari<sup>100</sup>, M. Barisonzi<sup>176</sup>, T. Barklow<sup>144</sup>, N. Barlow<sup>28</sup>, B. M. Barnett<sup>130</sup>, R. M. Barnett<sup>15</sup>, Z. Barnovska<sup>5</sup>, A. Baroncelli<sup>135a</sup>, G. Barone<sup>49</sup>, A. J. Barr<sup>119</sup>, F. Barreiro<sup>81</sup>, J. Barreiro Guimarães da Costa<sup>57</sup>, R. Bartoldus<sup>144</sup>, A. E. Barton<sup>71</sup>, P. Bartos<sup>145a</sup>, V. Bartsch<sup>150</sup>, A. Bassalat<sup>116</sup>, A. Basye<sup>166</sup>, R. L. Bates<sup>53</sup>, J. R. Batley<sup>28</sup>, M. Battaglia<sup>138</sup>, M. Battistin<sup>30</sup>, F. Bauer<sup>137</sup>, H. S. Bawa<sup>144,e</sup>, M. D. Beattie<sup>71</sup>, T. Beau<sup>79</sup>, P. H. Beauchemin<sup>162</sup>, R. Beccherle<sup>123a,123b</sup>, P. Bechtel<sup>21</sup>, H. P. Beck<sup>17</sup>, K. Becker<sup>176</sup>, S. Becker<sup>99</sup>, M. Beckingham<sup>171</sup>, C. Becot<sup>116</sup>, A. J. Beddall<sup>19c</sup>, A. Beddall<sup>19c</sup>, S. Bedikian<sup>177</sup>, V. A. Bednyakov<sup>64</sup>, C. P. Bee<sup>149</sup>, L. J. Beemster<sup>106</sup>, T. A. Beermann<sup>176</sup>, M. Begel<sup>25</sup>, K. Behr<sup>119</sup>, C. Belanger-Champagne<sup>86</sup>, P. J. Bell<sup>49</sup>, W. H. Bell<sup>49</sup>, G. Bella<sup>154</sup>, L. Bellagamba<sup>20a</sup>, A. Bellerive<sup>29</sup>, M. Bellomo<sup>85</sup>, K. Belotskiy<sup>97</sup>, O. Beltramello<sup>30</sup>, O. Benary<sup>154</sup>, D. Benchechroun<sup>136a</sup>, K. Bendtz<sup>147a,147b</sup>, N. Benekos<sup>166</sup>, Y. Benhammou<sup>154</sup>, E. Benhar Nocchioli<sup>49</sup>, J. A. Benitez Garcia<sup>160b</sup>, D. P. Benjamin<sup>45</sup>, J. R. Bensinger<sup>23</sup>, K. Benslama<sup>131</sup>, S. Bentvelsen<sup>106</sup>, D. Berge<sup>106</sup>, E. Bergeaas Kuutmann<sup>16</sup>, N. Berger<sup>5</sup>, F. Berghaus<sup>170</sup>, J. Beringer<sup>15</sup>, C. Bernard<sup>22</sup>, P. Bernat<sup>77</sup>, C. Bernius<sup>78</sup>, F. U. Bernlochner<sup>170</sup>, T. Berry<sup>76</sup>, P. Berta<sup>128</sup>, C. Bertella<sup>84</sup>, G. Bertoli<sup>147a,147b</sup>, F. Bertolucci<sup>123a,123b</sup>, C. Bertsche<sup>112</sup>, D. Bertsche<sup>112</sup>, M. I. Besana<sup>90a</sup>, G. J. Besjes<sup>105</sup>, O. Bessidskaia Bylund<sup>147a,147b</sup>, M. Bessner<sup>42</sup>, N. Besson<sup>137</sup>, C. Betancourt<sup>48</sup>, S. Bethke<sup>100</sup>, W. Bhimji<sup>46</sup>, R. M. Bianchi<sup>124</sup>, L. Bianchini<sup>23</sup>, M. Bianco<sup>30</sup>, O. Biebel<sup>99</sup>, S. P. Bieniek<sup>77</sup>, K. Bierwagen<sup>54</sup>, J. Biesiada<sup>15</sup>, M. Biglietti<sup>135a</sup>, J. Bilbao De Mendizabal<sup>49</sup>, H. Bilokon<sup>47</sup>, M. Bindi<sup>54</sup>, S. Binet<sup>116</sup>, A. Bingul<sup>19c</sup>, C. Bini<sup>133a,133b</sup>, C. W. Black<sup>151</sup>, J. E. Black<sup>144</sup>, K. M. Black<sup>22</sup>, D. Blackburn<sup>139</sup>, R. E. Blair<sup>6</sup>, J.-B. Blanchard<sup>137</sup>, T. Blazek<sup>145a</sup>, I. Bloch<sup>42</sup>, C. Blocker<sup>23</sup>, W. Blum<sup>82,\*</sup>, U. Blumenschein<sup>54</sup>, G. J. Bobbink<sup>106</sup>, V. S. Bobrovnikov<sup>108</sup>, S. S. Bocchetta<sup>80</sup>, A. Bocci<sup>45</sup>, C. Bock<sup>99</sup>, C. R. Boddy<sup>119</sup>, M. Boehler<sup>48</sup>, T. T. Boek<sup>176</sup>, J. A. Bogaerts<sup>30</sup>, A. G. Bogdanchikov<sup>108</sup>, A. Bogouch<sup>91,\*</sup>, C. Boehm<sup>147a</sup>, J. Boehm<sup>126</sup>, V. Boisvert<sup>76</sup>, T. Bold<sup>38a</sup>, V. Boldea<sup>26a</sup>, A. S. Boldyrev<sup>98</sup>, M. Bomben<sup>79</sup>, M. Bona<sup>75</sup>, M. Boonekamp<sup>137</sup>, A. Borisov<sup>129</sup>, G. Borissov<sup>71</sup>, M. Borri<sup>83</sup>, S. Borroni<sup>42</sup>, J. Bortfeldt<sup>99</sup>, V. Bortolotto<sup>135a,135b</sup>, K. Bos<sup>106</sup>, D. Boscherini<sup>20a</sup>, M. Bosman<sup>12</sup>, H. Boterenbrood<sup>106</sup>, J. Boudreau<sup>124</sup>, J. Bouffard<sup>2</sup>, E. V. Bouhova-Thacker<sup>71</sup>, D. Boumediene<sup>34</sup>, C. Bourdarios<sup>116</sup>, N. Bousson<sup>113</sup>, S. Boutouil<sup>136d</sup>, A. Boveia<sup>31</sup>, J. Boyd<sup>30</sup>, I. R. Boyko<sup>64</sup>, J. Bracinik<sup>18</sup>, A. Brandt<sup>8</sup>, G. Brandt<sup>15</sup>, O. Brandt<sup>58a</sup>, U. Bratzler<sup>157</sup>, B. Brau<sup>85</sup>, J. E. Brau<sup>115</sup>, H. M. Braun<sup>176,\*</sup>, S. F. Brazzale<sup>165a,165c</sup>, B. Brelief<sup>159</sup>, K. Brendlinger<sup>121</sup>, A. J. Brennan<sup>87</sup>, R. Brenner<sup>167</sup>, S. Bressler<sup>173</sup>, K. Bristow<sup>146c</sup>, T. M. Bristow<sup>46</sup>, D. Britton<sup>53</sup>, F. M. Brochu<sup>28</sup>, I. Brock<sup>21</sup>, R. Brock<sup>89</sup>, C. Bromberg<sup>89</sup>, J. Bronner<sup>100</sup>, G. Brooijmans<sup>35</sup>, T. Brooks<sup>76</sup>, W. K. Brooks<sup>32b</sup>, J. Brosamer<sup>15</sup>, E. Brost<sup>115</sup>, J. Brown<sup>55</sup>, P. A. Bruckman de Renstrom<sup>39</sup>, D. Bruncko<sup>145b</sup>, R. Bruneliere<sup>48</sup>, S. Brunet<sup>60</sup>, A. Bruni<sup>20a</sup>, G. Bruni<sup>20a</sup>, M. Bruschi<sup>20a</sup>, L. Bryngemark<sup>80</sup>, T. Buanes<sup>14</sup>, Q. Buat<sup>143</sup>, F. Bucci<sup>49</sup>, P. Buchholz<sup>142</sup>, R. M. Buckingham<sup>119</sup>, A. G. Buckley<sup>53</sup>, S. I. Buda<sup>26a</sup>, I. A. Budagov<sup>64</sup>, F. Buehrer<sup>48</sup>, L. Bugge<sup>118</sup>, M. K. Bugge<sup>118</sup>, O. Bulekov<sup>97</sup>, A. C. Bundock<sup>73</sup>, H. Burckhart<sup>30</sup>, S. Burdin<sup>73</sup>, B. Burghgrave<sup>107</sup>, S. Burke<sup>130</sup>, I. Burmeister<sup>43</sup>, E. Busato<sup>34</sup>, D. Büscher<sup>48</sup>, V. Büscher<sup>82</sup>, P. Bussey<sup>53</sup>, C. P. Buszello<sup>167</sup>, B. Butler<sup>57</sup>, J. M. Butler<sup>22</sup>, A. I. Butti<sup>3</sup>, C. M. Buttar<sup>53</sup>, J. M. Butterworth<sup>77</sup>, P. Butti<sup>106</sup>, W. Buttinger<sup>28</sup>, A. Buzatu<sup>53</sup>, M. Byszewski<sup>10</sup>

S. Cabrera Urbán<sup>168</sup>, D. Caforio<sup>20a,20b</sup>, O. Cakir<sup>4a</sup>, P. Calafiura<sup>15</sup>, A. Calandri<sup>137</sup>, G. Calderini<sup>79</sup>, P. Calfayan<sup>99</sup>, R. Calkins<sup>107</sup>, L. P. Caloba<sup>24a</sup>, D. Calvet<sup>34</sup>, S. Calvet<sup>34</sup>, R. Camacho Toro<sup>49</sup>, S. Camarda<sup>42</sup>, D. Cameron<sup>118</sup>, L. M. Caminada<sup>15</sup>, R. Caminal Armadans<sup>12</sup>, S. Campana<sup>30</sup>, M. Campanelli<sup>77</sup>, A. Campoverde<sup>149</sup>, V. Canale<sup>103a,103b</sup>, A. Canepa<sup>160a</sup>, M. Cano Bret<sup>75</sup>, J. Cantero<sup>81</sup>, R. Cantrill<sup>125a</sup>, T. Cao<sup>40</sup>, M. D. M. Capeans Garrido<sup>30</sup>, I. Caprini<sup>26a</sup>, M. Caprini<sup>26a</sup>, M. Capua<sup>37a,37b</sup>, R. Caputo<sup>82</sup>, R. Cardarelli<sup>134a</sup>, T. Carli<sup>30</sup>, G. Carlino<sup>103a</sup>, L. Carminati<sup>90a,90b</sup>, S. Caron<sup>105</sup>, E. Carquin<sup>32a</sup>, G. D. Carrillo-Montoya<sup>146c</sup>, J. R. Carter<sup>28</sup>, J. Carvalho<sup>125a,125c</sup>, D. Casadei<sup>77</sup>, M. P. Casado<sup>12</sup>, M. Casolino<sup>12</sup>, E. Castaneda-Miranda<sup>146b</sup>, A. Castelli<sup>106</sup>, V. Castillo Gimenez<sup>168</sup>, N. F. Castro<sup>125a</sup>, P. Catastini<sup>57</sup>, A. Catinaccio<sup>30</sup>, J. R. Catmore<sup>118</sup>, A. Cattai<sup>30</sup>, G. Cattani<sup>134a,134b</sup>, S. Caughron<sup>89</sup>, V. Cavaliere<sup>166</sup>, D. Cavalli<sup>90a</sup>, M. Cavalli-Sforza<sup>12</sup>, V. Cavasinni<sup>123a,123b</sup>, F. Ceradini<sup>135a,135b</sup>, B. Cerio<sup>45</sup>, K. Cerny<sup>128</sup>, A. S. Cerqueira<sup>24b</sup>, A. Cerri<sup>150</sup>, L. Cerrito<sup>75</sup>, F. Cerutti<sup>15</sup>, M. Cerv<sup>30</sup>, A. Cervelli<sup>17</sup>, S. A. Cetin<sup>19b</sup>, A. Chafaq<sup>136a</sup>, D. Chakraborty<sup>107</sup>, I. Chalupkova<sup>128</sup>, P. Chang<sup>166</sup>, B. Chapleau<sup>86</sup>, J. D. Chapman<sup>28</sup>, D. Charfeddine<sup>116</sup>, D. G. Charlton<sup>18</sup>, C. C. Chau<sup>159</sup>, C. A. Chavez Barajas<sup>150</sup>, S. Cheatham<sup>86</sup>, A. Chegwiddden<sup>89</sup>, S. Chekanov<sup>6</sup>, S. V. Chekulaev<sup>160a</sup>, G. A. Chelkov<sup>64,f</sup>, M. A. Chelstowska<sup>88</sup>, C. Chen<sup>63</sup>, H. Chen<sup>25</sup>, K. Chen<sup>149</sup>, L. Chen<sup>33d,g</sup>, S. Chen<sup>33c</sup>, X. Chen<sup>146c</sup>, Y. Chen<sup>66</sup>, Y. Chen<sup>35</sup>, H. C. Cheng<sup>88</sup>, Y. Cheng<sup>31</sup>, A. Cheplakov<sup>64</sup>, R. Cherkaoui El Moursli<sup>136e</sup>, V. Chernyatin<sup>25,\*</sup>, E. Cheu<sup>7</sup>, L. Chevalier<sup>137</sup>, V. Chiarella<sup>47</sup>, G. Chiefari<sup>103a,103b</sup>, J. T. Childers<sup>6</sup>, A. Chilingarov<sup>71</sup>, G. Chiodini<sup>72a</sup>, A. S. Chisholm<sup>18</sup>, R. T. Chislett<sup>77</sup>, A. Chitan<sup>26a</sup>, M. V. Chizhov<sup>64</sup>, S. Chouridou<sup>9</sup>, B. K. B. Chow<sup>99</sup>, D. Chromek-Burckhart<sup>30</sup>, M. L. Chu<sup>152</sup>, J. Chudoba<sup>126</sup>, J. J. Chwastowski<sup>39</sup>, L. Chytka<sup>114</sup>, G. Ciapetti<sup>133a,133b</sup>, A. K. Ciftci<sup>4a</sup>, R. Ciftci<sup>4a</sup>, D. Cinca<sup>53</sup>, V. Cindro<sup>74</sup>, A. Ciocio<sup>15</sup>, P. Cirkovic<sup>13b</sup>, Z. H. Citron<sup>173</sup>, M. Citterio<sup>90a</sup>, M. Ciubancan<sup>26a</sup>, A. Clark<sup>49</sup>, P. J. Clark<sup>46</sup>, R. N. Clarke<sup>15</sup>, W. Cleland<sup>124</sup>, J. C. Clemens<sup>84</sup>, C. Clement<sup>147a,147b</sup>, Y. Coadou<sup>84</sup>, M. Cobal<sup>165a,165c</sup>, A. Coccaro<sup>139</sup>, J. Cochran<sup>63</sup>, L. Coffey<sup>23</sup>, J. G. Cogan<sup>144</sup>, J. Coggeshall<sup>166</sup>, B. Cole<sup>35</sup>, S. Cole<sup>107</sup>, A. P. Colijn<sup>106</sup>, J. Collot<sup>55</sup>, T. Colombo<sup>58c</sup>, G. Colon<sup>85</sup>, G. Compostella<sup>100</sup>, P. Conde Muiño<sup>125a,125b</sup>, E. Coniavitis<sup>48</sup>, M. C. Conidi<sup>12</sup>, S. H. Connell<sup>146b</sup>, I. A. Connelly<sup>76</sup>, S. M. Consonni<sup>90a,90b</sup>, V. Consorti<sup>48</sup>, S. Constantinescu<sup>26a</sup>, C. Conta<sup>120a,120b</sup>, G. Conti<sup>57</sup>, F. Conventi<sup>103a,h</sup>, M. Cooke<sup>15</sup>, B. D. Cooper<sup>77</sup>, A. M. Cooper-Sarkar<sup>119</sup>, N. J. Cooper-Smith<sup>76</sup>, K. Copic<sup>15</sup>, T. Cornelissen<sup>176</sup>, M. Corradi<sup>20a</sup>, F. Corriveau<sup>86,i</sup>, A. Corso-Radu<sup>164</sup>, A. Cortes-Gonzalez<sup>12</sup>, G. Cortiana<sup>100</sup>, G. Costa<sup>90a</sup>, M. J. Costa<sup>168</sup>, D. Costanzo<sup>140</sup>, D. Côté<sup>8</sup>, G. Cottin<sup>28</sup>, G. Cowan<sup>76</sup>, B. E. Cox<sup>83</sup>, K. Cranmer<sup>109</sup>, G. Cree<sup>29</sup>, S. Crépe-Renaudin<sup>55</sup>, F. Crescioli<sup>79</sup>, W. A. Cribbs<sup>147a,147b</sup>, M. Crispin Ortuzar<sup>119</sup>, M. Cristinziani<sup>21</sup>, V. Croft<sup>105</sup>, G. Crosetti<sup>37a,37b</sup>, C.-M. Cuciuc<sup>26a</sup>, T. Cuhadar Donszelmann<sup>140</sup>, J. Cummings<sup>177</sup>, M. Curatolo<sup>47</sup>, C. Cuthbert<sup>151</sup>, H. Czirr<sup>142</sup>, P. Czodrowski<sup>3</sup>, Z. Czcycula<sup>177</sup>, S. D'Auria<sup>53</sup>, M. D'Onofrio<sup>73</sup>, M. J. Da Cunha Sargedas De Sousa<sup>125a,125b</sup>, C. Da Via<sup>83</sup>, W. Dabrowski<sup>38a</sup>, A. Dafinca<sup>119</sup>, T. Dai<sup>88</sup>, O. Dale<sup>14</sup>, F. Dallaire<sup>94</sup>, C. Dallapiccola<sup>85</sup>, M. Dam<sup>36</sup>, A. C. Daniells<sup>18</sup>, M. Dano Hoffmann<sup>137</sup>, V. Dao<sup>48</sup>, G. Darbo<sup>50a</sup>, S. Darmora<sup>8</sup>, J. A. Dassoulas<sup>42</sup>, A. Dattagupta<sup>60</sup>, W. Davey<sup>21</sup>, C. David<sup>170</sup>, T. Davidek<sup>128</sup>, E. Davies<sup>119,c</sup>, M. Davies<sup>154</sup>, O. Davignon<sup>79</sup>, A. R. Davison<sup>77</sup>, P. Davison<sup>77</sup>, Y. Davygora<sup>58a</sup>, E. Dawe<sup>143</sup>, I. Dawson<sup>140</sup>, R. K. Daya-Ishmukhametova<sup>85</sup>, K. De<sup>8</sup>, R. de Asmundis<sup>103a</sup>, S. De Castro<sup>20a,20b</sup>, S. De Cecco<sup>79</sup>, N. De Groot<sup>105</sup>, P. de Jong<sup>106</sup>, H. De la Torre<sup>81</sup>, F. De Lorenzi<sup>63</sup>, L. De Nooij<sup>106</sup>, D. De Pedis<sup>133a</sup>, A. De Salvo<sup>133a</sup>, U. De Sanctis<sup>165a,165b</sup>, A. De Santo<sup>150</sup>, J. B. De Vivie De Regie<sup>116</sup>, W. J. Dearnaley<sup>71</sup>, R. Debbé<sup>25</sup>, C. Debenedetti<sup>138</sup>, B. Dechenaux<sup>55</sup>, D. V. Dedovich<sup>64</sup>, I. Deigaard<sup>106</sup>, J. Del Peso<sup>81</sup>, T. Del Prete<sup>123a,123b</sup>, F. Deliot<sup>137</sup>, C. M. Delitzsch<sup>49</sup>, M. Deliyergiyev<sup>74</sup>, A. Dell'Acqua<sup>30</sup>, L. Dell'Asta<sup>22</sup>, M. Dell'Orso<sup>123a,123b</sup>, M. Della Pietra<sup>103a,h</sup>, D. della Volpe<sup>49</sup>, M. Delmastro<sup>5</sup>, P. A. Delsart<sup>55</sup>, C. Deluca<sup>106</sup>, S. Demers<sup>177</sup>, M. Demichev<sup>64</sup>, A. Demilly<sup>79</sup>, S. P. Denisov<sup>129</sup>, D. Derendarz<sup>39</sup>, J. E. Derkaoui<sup>136d</sup>, F. Derue<sup>79</sup>, P. Dervan<sup>73</sup>, K. Desch<sup>21</sup>, C. Deterre<sup>42</sup>, P. O. Deviveiros<sup>106</sup>, A. Dewhurst<sup>130</sup>, S. Dhaliwal<sup>106</sup>, A. Di Ciaccio<sup>134a,134b</sup>, L. Di Ciaccio<sup>5</sup>, A. Di Domenico<sup>133a,133b</sup>, C. Di Donato<sup>103a,103b</sup>, A. Di Girolamo<sup>30</sup>, B. Di Girolamo<sup>30</sup>, A. Di Mattia<sup>153</sup>, B. Di Micco<sup>135a,135b</sup>, R. Di Nardo<sup>47</sup>, A. Di Simone<sup>48</sup>, R. Di Sipio<sup>20a,20b</sup>, D. Di Valentino<sup>29</sup>, F. A. Dias<sup>46</sup>, M. A. Diaz<sup>32a</sup>, E. B. Diehl<sup>88</sup>, J. Dietrich<sup>42</sup>, T. A. Dietzsch<sup>58a</sup>, S. Diglio<sup>84</sup>, A. Dimitrievska<sup>13a</sup>, J. Dingfelder<sup>21</sup>, C. Dionisi<sup>133a,133b</sup>, P. Dita<sup>26a</sup>, S. Dita<sup>26a</sup>, F. Dittus<sup>30</sup>, F. Djama<sup>84</sup>, T. Djobava<sup>51b</sup>, M. A. B. do Vale<sup>24c</sup>, A. Do Valle Wemans<sup>125a,125g</sup>, T. K. O. Doan<sup>5</sup>, D. Dobos<sup>30</sup>, C. Doglioni<sup>49</sup>, T. Doherty<sup>53</sup>, T. Dohmae<sup>156</sup>, J. Dolejsi<sup>128</sup>, Z. Dolezal<sup>128</sup>, B. A. Dolgoshein<sup>97,\*</sup>, M. Donadelli<sup>24d</sup>, S. Donati<sup>123a,123b</sup>, P. Dondero<sup>120a,120b</sup>, J. Donini<sup>34</sup>, J. Dopke<sup>130</sup>, A. Doria<sup>103a</sup>, M. T. Dova<sup>70</sup>, A. T. Doyle<sup>53</sup>, M. Dris<sup>10</sup>, J. Dubbert<sup>88</sup>, S. Dube<sup>15</sup>, E. Dubreuil<sup>34</sup>, E. Duchovni<sup>173</sup>, G. Duckeck<sup>99</sup>, O. A. Ducu<sup>26a</sup>, D. Duda<sup>176</sup>, A. Dudarev<sup>30</sup>, F. Dudziak<sup>63</sup>, L. Duflot<sup>116</sup>, L. Duguid<sup>76</sup>, M. Dührssen<sup>30</sup>, M. Dunford<sup>58a</sup>, H. Duran Yildiz<sup>4a</sup>, M. Düren<sup>52</sup>, A. Durglishvili<sup>51b</sup>, M. Dwuznik<sup>38a</sup>, M. Dyndal<sup>38a</sup>, J. Ebke<sup>99</sup>, W. Edson<sup>2</sup>, N. C. Edwards<sup>46</sup>, W. Ehrenfeld<sup>21</sup>, T. Eifert<sup>144</sup>, G. Eigen<sup>14</sup>, K. Einsweiler<sup>15</sup>, T. Ekelof<sup>167</sup>, M. El Kacimi<sup>136c</sup>, M. Ellert<sup>167</sup>, S. Elles<sup>5</sup>, F. Ellinghaus<sup>82</sup>, N. Ellis<sup>30</sup>, J. Elmsheuser<sup>99</sup>, M. Elsing<sup>30</sup>, D. Emelianov<sup>130</sup>, Y. Enari<sup>156</sup>, O. C. Endner<sup>82</sup>, M. Endo<sup>117</sup>, R. Engelmann<sup>149</sup>, J. Erdmann<sup>177</sup>, A. Ereditato<sup>17</sup>, D. Eriksson<sup>147a</sup>, G. Ernis<sup>176</sup>, J. Ernst<sup>2</sup>, M. Ernst<sup>25</sup>, J. Ernwein<sup>137</sup>, D. Errede<sup>166</sup>, S. Errede<sup>166</sup>, E. Ertel<sup>82</sup>, M. Escalier<sup>116</sup>, H. Esch<sup>43</sup>, C. Escobar<sup>124</sup>, B. Esposito<sup>47</sup>, A. I. Etienne<sup>137</sup>, E. Etzion<sup>154</sup>, H. Evans<sup>60</sup>, A. Ezhilov<sup>122</sup>, L. Fabbri<sup>20a,20b</sup>, G. Facini<sup>31</sup>, R. M. Fakhruddinov<sup>129</sup>, S. Falciano<sup>133a</sup>, R. J. Falla<sup>77</sup>, J. Faltova<sup>128</sup>, Y. Fang<sup>33a</sup>, M. Fanti<sup>90a,90b</sup>, A. Farbin<sup>8</sup>, A. Farilla<sup>135a</sup>, T. Farooque<sup>12</sup>, S. Farrell<sup>15</sup>, S. M. Farrington<sup>171</sup>, P. Farthouat<sup>30</sup>, F. Fassi<sup>136e</sup>,

P. Fassnacht<sup>30</sup>, D. Fassouliotis<sup>9</sup>, A. Favareto<sup>50a,50b</sup>, L. Fayard<sup>116</sup>, P. Federic<sup>145a</sup>, O. L. Fedin<sup>122,j</sup>, W. Fedorko<sup>169</sup>, M. Fehling-Kaschek<sup>48</sup>, S. Feigl<sup>30</sup>, L. Feligioni<sup>84</sup>, C. Feng<sup>33d</sup>, E. J. Feng<sup>6</sup>, H. Feng<sup>88</sup>, A. B. Fenyuk<sup>129</sup>, S. Fernandez Perez<sup>30</sup>, S. Ferrag<sup>53</sup>, J. Ferrando<sup>53</sup>, A. Ferrari<sup>167</sup>, P. Ferrari<sup>106</sup>, R. Ferrari<sup>120a</sup>, D. E. Ferreira de Lima<sup>53</sup>, A. Ferrer<sup>168</sup>, D. Ferrere<sup>49</sup>, C. Ferretti<sup>88</sup>, A. Ferretto Parodi<sup>50a,50b</sup>, M. Fiascaris<sup>31</sup>, F. Fiedler<sup>82</sup>, A. Filipčić<sup>74</sup>, M. Filipuzzi<sup>42</sup>, F. Filthaut<sup>105</sup>, M. Fincke-Keeler<sup>170</sup>, K. D. Finelli<sup>151</sup>, M. C. N. Fiolhais<sup>125a,125c</sup>, L. Fiorini<sup>168</sup>, A. Firan<sup>40</sup>, A. Fischer<sup>2</sup>, J. Fischer<sup>176</sup>, W. C. Fisher<sup>89</sup>, E. A. Fitzgerald<sup>23</sup>, M. Flechl<sup>48</sup>, I. Fleck<sup>142</sup>, P. Fleischmann<sup>88</sup>, S. Fleischmann<sup>176</sup>, G. T. Fletcher<sup>140</sup>, G. Fletcher<sup>75</sup>, T. Flick<sup>176</sup>, A. Floderus<sup>80</sup>, L. R. Flores Castillo<sup>174,k</sup>, A. C. Florez Bustos<sup>160b</sup>, M. J. Flowerdew<sup>100</sup>, A. Formica<sup>137</sup>, A. Forti<sup>83</sup>, D. Fortin<sup>160a</sup>, D. Fournier<sup>116</sup>, H. Fox<sup>71</sup>, S. Fracchia<sup>12</sup>, P. Francavilla<sup>79</sup>, M. Franchini<sup>20a,20b</sup>, S. Franchino<sup>30</sup>, D. Francis<sup>30</sup>, L. Franconi<sup>118</sup>, M. Franklin<sup>57</sup>, S. Franz<sup>61</sup>, M. Fraternali<sup>120a,120b</sup>, S. T. French<sup>28</sup>, C. Friedrich<sup>42</sup>, F. Friedrich<sup>44</sup>, D. Froidevaux<sup>30</sup>, J. A. Frost<sup>28</sup>, C. Fukunaga<sup>157</sup>, E. Fullana Torregrosa<sup>82</sup>, B. G. Fulsom<sup>144</sup>, J. Fuster<sup>168</sup>, C. Gabaldon<sup>55</sup>, O. Gabizon<sup>173</sup>, A. Gabrielli<sup>20a,20b</sup>, A. Gabrielli<sup>133a,133b</sup>, S. Gadatsch<sup>106</sup>, S. Gadomski<sup>49</sup>, G. Gagliardi<sup>50a,50b</sup>, P. Gagnon<sup>60</sup>, C. Galea<sup>105</sup>, B. Galhardo<sup>125a,125c</sup>, E. J. Gallas<sup>119</sup>, V. Gallo<sup>17</sup>, B. J. Gallop<sup>130</sup>, P. Gallus<sup>127</sup>, G. Galster<sup>36</sup>, K. K. Gan<sup>110</sup>, J. Gao<sup>33b,g</sup>, Y. S. Gao<sup>144,e</sup>, F. M. Garay Walls<sup>46</sup>, F. Garbersson<sup>177</sup>, C. García<sup>168</sup>, J. E. García Navarro<sup>168</sup>, M. Garcia-Sciveres<sup>15</sup>, R. W. Gardner<sup>31</sup>, N. Garelli<sup>144</sup>, V. Garonne<sup>30</sup>, C. Gatti<sup>47</sup>, G. Gaudio<sup>120a</sup>, B. Gaur<sup>142</sup>, L. Gauthier<sup>94</sup>, P. Gauzzi<sup>133a,133b</sup>, I. L. Gavrilenko<sup>95</sup>, C. Gay<sup>169</sup>, G. Gaycken<sup>21</sup>, E. N. Gazis<sup>10</sup>, P. Ge<sup>33d</sup>, Z. Gece<sup>169</sup>, C. N. P. Gee<sup>130</sup>, D. A. A. Geerts<sup>106</sup>, Ch. Geich-Gimbel<sup>21</sup>, K. Gellerstedt<sup>147a,147b</sup>, C. Gemme<sup>50a</sup>, A. Gemmell<sup>53</sup>, M. H. Genest<sup>55</sup>, S. Gentile<sup>133a,133b</sup>, M. George<sup>54</sup>, S. George<sup>76</sup>, D. Gerbaudo<sup>164</sup>, A. Gershon<sup>154</sup>, H. Ghazlane<sup>136b</sup>, N. Ghodbane<sup>34</sup>, B. Giacobbe<sup>20a</sup>, S. Giagu<sup>133a,133b</sup>, V. Giangiobbe<sup>12</sup>, P. Giannetti<sup>123a,123b</sup>, F. Gianotti<sup>30</sup>, B. Gibbard<sup>25</sup>, S. M. Gibson<sup>76</sup>, M. Gilchriese<sup>15</sup>, T. P. S. Gillam<sup>28</sup>, D. Gillberg<sup>30</sup>, G. Gilles<sup>34</sup>, D. M. Gingrich<sup>3,d</sup>, N. Giokaris<sup>9</sup>, M. P. Giordani<sup>165a,165c</sup>, R. Giordano<sup>103a,103b</sup>, F. M. Giorgi<sup>20a</sup>, F. M. Giorgi<sup>16</sup>, P. F. Giraud<sup>137</sup>, D. Giugni<sup>90a</sup>, C. Giuliani<sup>48</sup>, M. Giuliani<sup>58b</sup>, B. K. Gjelsten<sup>118</sup>, S. Gkaitatzis<sup>155</sup>, I. Gkialas<sup>155,1</sup>, L. K. Gladilin<sup>98</sup>, C. Glasman<sup>81</sup>, J. Glatzer<sup>30</sup>, P. C. F. Glaysher<sup>46</sup>, A. Glazov<sup>42</sup>, G. L. Glonti<sup>64</sup>, M. Goblirsch-Kolb<sup>100</sup>, J. R. Goddard<sup>75</sup>, J. Godfrey<sup>143</sup>, J. Godlewski<sup>30</sup>, C. Goeringer<sup>82</sup>, S. Goldfarb<sup>88</sup>, T. Golling<sup>177</sup>, D. Golubkov<sup>129</sup>, A. Gomes<sup>125a,125b,125d</sup>, L. S. Gomez Fajardo<sup>42</sup>, R. Gonçalo<sup>125a</sup>, J. Goncalves Pinto Firmino Da Costa<sup>137</sup>, L. Gonella<sup>21</sup>, S. González de la Hoz<sup>168</sup>, G. Gonzalez Parra<sup>12</sup>, S. Gonzalez-Sevilla<sup>49</sup>, L. Goossens<sup>30</sup>, P. A. Gorbounov<sup>96</sup>, H. A. Gordon<sup>25</sup>, I. Gorelov<sup>104</sup>, B. Gorini<sup>30</sup>, E. Gorini<sup>72a,72b</sup>, A. Gorišek<sup>74</sup>, E. Gornicki<sup>39</sup>, A. T. Goshaw<sup>6</sup>, C. Gössling<sup>43</sup>, M. I. Gostkin<sup>64</sup>, M. Gouighri<sup>136a</sup>, D. Goujdami<sup>136c</sup>, M. P. Goulette<sup>49</sup>, A. G. Goussiou<sup>139</sup>, C. Goy<sup>5</sup>, S. Gozpinar<sup>23</sup>, H. M. X. Grabas<sup>137</sup>, L. Graber<sup>54</sup>, I. Grabowska-Bold<sup>38a</sup>, P. Grafström<sup>20a,20b</sup>, K.-J. Grahn<sup>42</sup>, J. Gramling<sup>49</sup>, E. Gramstad<sup>118</sup>, S. Grancagnolo<sup>16</sup>, V. Grassi<sup>149</sup>, V. Gratchev<sup>122</sup>, H. M. Gray<sup>30</sup>, E. Graziani<sup>135a</sup>, O. G. Grebenyuk<sup>122</sup>, Z. D. Greenwood<sup>78,m</sup>, K. Gregersen<sup>77</sup>, I. M. Gregor<sup>42</sup>, P. Grenier<sup>144</sup>, J. Griffiths<sup>8</sup>, A. A. Grillo<sup>138</sup>, K. Grimm<sup>71</sup>, S. Grinstein<sup>12,n</sup>, Ph. Gris<sup>34</sup>, Y. V. Grishkevich<sup>98</sup>, J.-F. Grivaz<sup>116</sup>, J. P. Grohs<sup>44</sup>, A. Grohsjean<sup>42</sup>, E. Gross<sup>173</sup>, J. Grosse-Knetter<sup>54</sup>, G. C. Grossi<sup>134a,134b</sup>, J. Groth-Jensen<sup>173</sup>, Z. J. Grout<sup>150</sup>, L. Guan<sup>33b</sup>, F. Guescini<sup>49</sup>, D. Guest<sup>177</sup>, O. Gueta<sup>154</sup>, C. Guicheney<sup>34</sup>, E. Guido<sup>50a,50b</sup>, T. Guillemin<sup>116</sup>, S. Guindon<sup>2</sup>, U. Gul<sup>53</sup>, C. Gumpert<sup>44</sup>, J. Gunther<sup>127</sup>, J. Guo<sup>35</sup>, S. Gupta<sup>119</sup>, P. Gutierrez<sup>112</sup>, N. G. Gutierrez Ortiz<sup>53</sup>, C. Gutsche<sup>77</sup>, N. Guttman<sup>154</sup>, C. Guyot<sup>137</sup>, C. Gwenlan<sup>119</sup>, C. B. Gwilliam<sup>73</sup>, A. Haas<sup>109</sup>, C. Haber<sup>15</sup>, H. K. Hadavand<sup>8</sup>, N. Haddad<sup>136e</sup>, P. Haefner<sup>21</sup>, S. Hageböck<sup>21</sup>, Z. Hajduk<sup>39</sup>, H. Hakobyan<sup>178</sup>, M. Haleem<sup>42</sup>, D. Hall<sup>119</sup>, G. Halladjian<sup>89</sup>, K. Hamacher<sup>176</sup>, P. Hamal<sup>114</sup>, K. Hamano<sup>170</sup>, M. Hamer<sup>54</sup>, A. Hamilton<sup>146a</sup>, S. Hamilton<sup>162</sup>, G. N. Hamity<sup>146c</sup>, P. G. Hamnett<sup>42</sup>, L. Han<sup>33b</sup>, K. Hanagaki<sup>117</sup>, K. Hanawa<sup>156</sup>, M. Hance<sup>15</sup>, P. Hanke<sup>58a</sup>, R. Hanna<sup>137</sup>, J. B. Hansen<sup>36</sup>, J. D. Hansen<sup>36</sup>, P. H. Hansen<sup>36</sup>, K. Hara<sup>161</sup>, A. S. Hard<sup>174</sup>, T. Harenberg<sup>176</sup>, F. Hariri<sup>116</sup>, S. Harkusha<sup>91</sup>, D. Harper<sup>88</sup>, R. D. Harrington<sup>46</sup>, O. M. Harris<sup>139</sup>, P. F. Harrison<sup>171</sup>, F. Hartjes<sup>106</sup>, M. Hasegawa<sup>66</sup>, S. Hasegawa<sup>102</sup>, Y. Hasegawa<sup>141</sup>, A. Hasib<sup>112</sup>, S. Hassani<sup>137</sup>, S. Haug<sup>17</sup>, M. Hauschild<sup>30</sup>, R. Hauser<sup>89</sup>, M. Havranek<sup>126</sup>, C. M. Hawkes<sup>18</sup>, R. J. Hawkins<sup>30</sup>, A. D. Hawkins<sup>80</sup>, T. Hayashi<sup>161</sup>, D. Hayden<sup>89</sup>, C. P. Hays<sup>119</sup>, H. S. Hayward<sup>73</sup>, S. J. Haywood<sup>130</sup>, S. J. Head<sup>18</sup>, T. Heck<sup>82</sup>, V. Hedberg<sup>80</sup>, L. Heelan<sup>8</sup>, S. Heim<sup>121</sup>, T. Heim<sup>176</sup>, B. Heinemann<sup>15</sup>, L. Heinrich<sup>109</sup>, J. Hejbal<sup>126</sup>, L. Helary<sup>22</sup>, C. Heller<sup>99</sup>, M. Heller<sup>30</sup>, S. Hellman<sup>147a,147b</sup>, D. Hellmich<sup>21</sup>, C. Helsens<sup>30</sup>, J. Henderson<sup>119</sup>, R. C. W. Henderson<sup>71</sup>, Y. Heng<sup>174</sup>, C. Hengler<sup>42</sup>, A. Henrichs<sup>177</sup>, A. M. Henriques Correia<sup>30</sup>, S. Henrot-Versille<sup>116</sup>, C. Hensel<sup>54</sup>, G. H. Herbert<sup>16</sup>, Y. Hernández Jiménez<sup>168</sup>, R. Herrberg-Schubert<sup>16</sup>, G. Herten<sup>48</sup>, R. Hertenberger<sup>99</sup>, L. Hervas<sup>30</sup>, G. G. Hesketh<sup>77</sup>, N. P. Hessey<sup>106</sup>, R. Hickling<sup>75</sup>, E. Higón-Rodríguez<sup>168</sup>, E. Hill<sup>170</sup>, J. C. Hill<sup>28</sup>, K. H. Hiller<sup>42</sup>, S. Hillert<sup>21</sup>, S. J. Hillier<sup>18</sup>, I. Hinchliffe<sup>15</sup>, E. Hines<sup>121</sup>, M. Hirose<sup>158</sup>, D. Hirschebuehl<sup>176</sup>, J. Hobbs<sup>149</sup>, N. Hod<sup>106</sup>, M. C. Hodgkinson<sup>140</sup>, P. Hodgson<sup>140</sup>, A. Hoecker<sup>30</sup>, M. R. Hoferkamp<sup>104</sup>, F. Hoenig<sup>99</sup>, J. Hoffman<sup>40</sup>, D. Hoffmann<sup>84</sup>, J. I. Hofmann<sup>58a</sup>, M. Hohlfield<sup>82</sup>, T. R. Holmes<sup>15</sup>, T. M. Hong<sup>121</sup>, L. Hooft van Huysduynen<sup>109</sup>, Y. Horii<sup>102</sup>, J.-Y. Hostachy<sup>55</sup>, S. Hou<sup>152</sup>, A. Houmada<sup>136a</sup>, J. Howard<sup>119</sup>, J. Howarth<sup>42</sup>, M. Hrabovsky<sup>114</sup>, I. Hristova<sup>16</sup>, J. Hrivnac<sup>116</sup>, T. Hryn'ova<sup>5</sup>, C. Hsu<sup>146c</sup>, P. J. Hsu<sup>82</sup>, S.-C. Hsu<sup>139</sup>, D. Hu<sup>35</sup>, X. Hu<sup>25</sup>, Y. Huang<sup>42</sup>, Z. Hubacek<sup>30</sup>, F. Hubaut<sup>84</sup>, F. Huegging<sup>21</sup>, T. B. Huffman<sup>119</sup>, E. W. Hughes<sup>35</sup>, G. Hughes<sup>71</sup>, M. Huhtinen<sup>30</sup>, T. A. Hülsing<sup>82</sup>, M. Hurwitz<sup>15</sup>, N. Huseynov<sup>64,b</sup>, J. Huston<sup>89</sup>, J. Huth<sup>57</sup>, G. Iacobucci<sup>49</sup>, G. Iakovidis<sup>10</sup>, I. Ibragimov<sup>142</sup>, L. Iconomidou-Fayard<sup>116</sup>, E. Ideal<sup>177</sup>, P. Iengo<sup>103a</sup>, O. Igonkina<sup>106</sup>, T. Iizawa<sup>172</sup>, Y. Ikegami<sup>65</sup>,

K. Ikematsu<sup>142</sup>, M. Ikeno<sup>65</sup>, Y. Ilchenko<sup>31,o</sup>, D. Iliadis<sup>155</sup>, N. Ilic<sup>159</sup>, Y. Inamaru<sup>66</sup>, T. Ince<sup>100</sup>, P. Ioannou<sup>9</sup>, M. Iodice<sup>135a</sup>, K. Iordanidou<sup>9</sup>, V. Ippolito<sup>57</sup>, A. Irlles Quiles<sup>168</sup>, C. Isaksson<sup>167</sup>, M. Ishino<sup>67</sup>, M. Ishitsuka<sup>158</sup>, R. Ishmukhametov<sup>110</sup>, C. Issever<sup>119</sup>, S. Istin<sup>19a</sup>, J. M. Iturbe Ponce<sup>83</sup>, R. Iuppa<sup>134a,134b</sup>, J. Ivarsson<sup>80</sup>, W. Iwanski<sup>39</sup>, H. Iwasaki<sup>65</sup>, J. M. Izen<sup>41</sup>, V. Izzo<sup>103a</sup>, B. Jackson<sup>121</sup>, M. Jackson<sup>73</sup>, P. Jackson<sup>1</sup>, M. R. Jaekel<sup>30</sup>, V. Jain<sup>2</sup>, K. Jakobs<sup>48</sup>, S. Jakobsen<sup>30</sup>, T. Jakoubek<sup>126</sup>, J. Jakubek<sup>127</sup>, D. O. Jamin<sup>152</sup>, D. K. Jana<sup>78</sup>, E. Jansen<sup>77</sup>, H. Jansen<sup>30</sup>, J. Janssen<sup>21</sup>, M. Janus<sup>171</sup>, G. Jarlskog<sup>80</sup>, N. Javadov<sup>64,b</sup>, T. Javůrek<sup>48</sup>, L. Jeanty<sup>15</sup>, J. Jejelava<sup>51a,p</sup>, G.-Y. Jeng<sup>151</sup>, D. Jennens<sup>87</sup>, P. Jenni<sup>48,q</sup>, J. Jentsch<sup>43</sup>, C. Jeske<sup>171</sup>, S. Jézéquel<sup>5</sup>, H. Ji<sup>174</sup>, J. Jia<sup>149</sup>, Y. Jiang<sup>33b</sup>, M. Jimenez Belenguer<sup>42</sup>, S. Jin<sup>33a</sup>, A. Jinaru<sup>26a</sup>, O. Jinnouchi<sup>158</sup>, M. D. Joergensen<sup>36</sup>, K. E. Johansson<sup>147a,147b</sup>, P. Johansson<sup>140</sup>, K. A. Johns<sup>7</sup>, K. Jon-And<sup>147a,147b</sup>, G. Jones<sup>171</sup>, R. W. L. Jones<sup>71</sup>, T. J. Jones<sup>73</sup>, J. Jongmanns<sup>58a</sup>, P. M. Jorge<sup>125a,125b</sup>, K. D. Joshi<sup>83</sup>, J. Jovicevic<sup>148</sup>, X. Ju<sup>174</sup>, C. A. Jung<sup>43</sup>, R. M. Jungst<sup>30</sup>, P. Jussel<sup>61</sup>, A. Juste Rozas<sup>12,n</sup>, M. Kaci<sup>168</sup>, A. Kaczmarek<sup>39</sup>, M. Kado<sup>116</sup>, H. Kagan<sup>110</sup>, M. Kagan<sup>144</sup>, E. Kajomovitz<sup>45</sup>, C. W. Kalderon<sup>119</sup>, S. Kama<sup>40</sup>, A. Kamenshchikov<sup>129</sup>, N. Kanaya<sup>156</sup>, M. Kaneda<sup>30</sup>, S. Kaneti<sup>28</sup>, V. A. Kantserov<sup>97</sup>, J. Kanzaki<sup>65</sup>, B. Kaplan<sup>109</sup>, A. Kapliy<sup>31</sup>, D. Kar<sup>53</sup>, K. Karakostas<sup>10</sup>, N. Karastathis<sup>10</sup>, M. Karnevskiy<sup>82</sup>, S. N. Karpov<sup>64</sup>, Z. M. Karpova<sup>64</sup>, K. Karthik<sup>109</sup>, V. Kartvelishvili<sup>71</sup>, A. N. Karyukhin<sup>129</sup>, L. Kashif<sup>174</sup>, G. Kasieczka<sup>58b</sup>, R. D. Kass<sup>110</sup>, A. Kastanas<sup>14</sup>, Y. Kataoka<sup>156</sup>, A. Katre<sup>49</sup>, J. Katzy<sup>42</sup>, V. Kaushik<sup>7</sup>, K. Kawagoe<sup>69</sup>, T. Kawamoto<sup>156</sup>, G. Kawamura<sup>54</sup>, S. Kazama<sup>156</sup>, V. F. Kazanin<sup>108</sup>, M. Y. Kazarinov<sup>64</sup>, R. Keeler<sup>170</sup>, R. Kehoe<sup>40</sup>, M. Keil<sup>54</sup>, J. S. Keller<sup>42</sup>, J. J. Kempster<sup>76</sup>, H. Keoshkerian<sup>5</sup>, O. Kepka<sup>126</sup>, B. P. Kerševan<sup>74</sup>, S. Kersten<sup>176</sup>, K. Kessoku<sup>156</sup>, J. Keung<sup>159</sup>, F. Khalil-zada<sup>11</sup>, H. Khandanyan<sup>147a,147b</sup>, A. Khanov<sup>113</sup>, A. Khodinov<sup>97</sup>, A. Khomich<sup>58a</sup>, T. J. Khoo<sup>28</sup>, G. Khoraiuli<sup>21</sup>, A. Khoroshilov<sup>176</sup>, V. Khovanskiy<sup>96</sup>, E. Khramov<sup>64</sup>, J. Khubua<sup>51b</sup>, H. Y. Kim<sup>8</sup>, H. Kim<sup>147a,147b</sup>, S. H. Kim<sup>161</sup>, N. Kimura<sup>172</sup>, O. Kind<sup>16</sup>, B. T. King<sup>73</sup>, M. King<sup>168</sup>, R. S. B. King<sup>119</sup>, S. B. King<sup>169</sup>, J. Kirk<sup>130</sup>, A. E. Kiryunin<sup>100</sup>, T. Kishimoto<sup>66</sup>, D. Kisielewska<sup>38a</sup>, F. Kiss<sup>48</sup>, T. Kittelmann<sup>124</sup>, K. Kiuchi<sup>161</sup>, E. Kladiva<sup>145b</sup>, M. Klein<sup>73</sup>, U. Klein<sup>73</sup>, K. Kleinknecht<sup>82</sup>, P. Klimek<sup>147a,147b</sup>, A. Klimentov<sup>25</sup>, R. Klingenberg<sup>43</sup>, J. A. Klinger<sup>83</sup>, T. Klioutchnikova<sup>30</sup>, P. F. Klok<sup>105</sup>, E.-E. Kluge<sup>58a</sup>, P. Kluit<sup>106</sup>, S. Kluth<sup>100</sup>, E. Kneringer<sup>61</sup>, E. B. F. G. Knoops<sup>84</sup>, A. Knue<sup>53</sup>, D. Kobayashi<sup>158</sup>, T. Kobayashi<sup>156</sup>, M. Kobel<sup>44</sup>, M. Kocian<sup>144</sup>, P. Kodys<sup>128</sup>, P. Koesvesarki<sup>21</sup>, T. Koffas<sup>29</sup>, E. Koffeman<sup>106</sup>, L. A. Kogan<sup>119</sup>, S. Kohlmann<sup>176</sup>, Z. Kohout<sup>127</sup>, T. Kohriki<sup>65</sup>, T. Koi<sup>144</sup>, H. Kolanoski<sup>16</sup>, I. Koletsou<sup>5</sup>, J. Koll<sup>89</sup>, A. A. Komar<sup>95,\*</sup>, Y. Komori<sup>156</sup>, T. Kondo<sup>65</sup>, N. Kondrashova<sup>42</sup>, K. Köneke<sup>48</sup>, A. C. König<sup>105</sup>, S. König<sup>82</sup>, T. Kono<sup>65,r</sup>, R. Konoplich<sup>109,s</sup>, N. Konstantinidis<sup>77</sup>, R. Kopeliainsky<sup>153</sup>, S. Koperny<sup>38a</sup>, L. Köpke<sup>82</sup>, A. K. Kopp<sup>48</sup>, K. Korcyl<sup>39</sup>, K. Kordas<sup>155</sup>, A. Korn<sup>77</sup>, A. A. Korol<sup>108,t</sup>, I. Korolkov<sup>12</sup>, E. V. Korolkova<sup>140</sup>, V. A. Korotkov<sup>129</sup>, O. Kortner<sup>100</sup>, S. Kortner<sup>100</sup>, V. V. Kostyukhin<sup>21</sup>, V. M. Kotov<sup>64</sup>, A. Kotwal<sup>45</sup>, C. Kourkoumelis<sup>9</sup>, V. Kouskoura<sup>155</sup>, A. Koutsman<sup>160a</sup>, R. Kowalewski<sup>170</sup>, T. Z. Kowalski<sup>38a</sup>, W. Kozanecki<sup>137</sup>, A. S. Kozhin<sup>129</sup>, V. Kral<sup>127</sup>, V. A. Kramarenko<sup>98</sup>, G. Kramberger<sup>74</sup>, D. Krasnopevtsev<sup>97</sup>, M. W. Krasny<sup>79</sup>, A. Krasznahorkay<sup>30</sup>, J. K. Kraus<sup>21</sup>, A. Kravchenko<sup>25</sup>, S. Kreiss<sup>109</sup>, M. Kretz<sup>58c</sup>, J. Kretschmar<sup>73</sup>, K. Kreutzfeldt<sup>52</sup>, P. Krieger<sup>159</sup>, K. Kroeninger<sup>54</sup>, H. Kroha<sup>100</sup>, J. Kroll<sup>121</sup>, J. Kroseberg<sup>21</sup>, J. Krstic<sup>13a</sup>, U. Kruchonak<sup>64</sup>, H. Krüger<sup>21</sup>, T. Kruker<sup>17</sup>, N. Krumnack<sup>63</sup>, Z. V. Krumshteyn<sup>64</sup>, A. Kruse<sup>174</sup>, M. C. Kruse<sup>45</sup>, M. Kruskal<sup>22</sup>, T. Kubota<sup>87</sup>, S. Kudah<sup>4a</sup>, S. Kuehn<sup>48</sup>, A. Kugel<sup>58c</sup>, A. Kuhl<sup>138</sup>, T. Kuhl<sup>42</sup>, V. Kukhtin<sup>64</sup>, Y. Kulchitsky<sup>91</sup>, S. Kuleshov<sup>32b</sup>, M. Kuna<sup>133a,133b</sup>, J. Kunkle<sup>121</sup>, A. Kupco<sup>126</sup>, H. Kurashige<sup>66</sup>, Y. A. Kurochkin<sup>91</sup>, R. Kurumida<sup>66</sup>, V. Kus<sup>126</sup>, E. S. Kuwertz<sup>148</sup>, M. Kuze<sup>158</sup>, J. Kvita<sup>114</sup>, A. La Rosa<sup>49</sup>, L. La Rotonda<sup>37a,37b</sup>, C. Lacasta<sup>168</sup>, F. Lacava<sup>133a,133b</sup>, J. Lacey<sup>29</sup>, H. Lacker<sup>16</sup>, D. Lacour<sup>79</sup>, V. R. Lacuesta<sup>168</sup>, E. Ladygin<sup>64</sup>, R. Lafaye<sup>5</sup>, B. Laforge<sup>79</sup>, T. Lagouri<sup>177</sup>, S. Lai<sup>48</sup>, H. Laier<sup>58a</sup>, L. Lambourne<sup>77</sup>, S. Lammers<sup>60</sup>, C. L. Lampen<sup>7</sup>, W. Lampl<sup>7</sup>, E. Lançon<sup>137</sup>, U. Landgraf<sup>48</sup>, M. P. J. Landon<sup>75</sup>, V. S. Lang<sup>58a</sup>, A. J. Lankford<sup>164</sup>, F. Lanni<sup>25</sup>, K. Lantzsch<sup>30</sup>, S. Laplace<sup>79</sup>, C. Lapoire<sup>21</sup>, J. F. Laporte<sup>137</sup>, T. Lari<sup>90a</sup>, M. Lassnig<sup>30</sup>, P. Laurelli<sup>47</sup>, W. Lavrijsen<sup>15</sup>, A. T. Law<sup>138</sup>, P. Laycock<sup>73</sup>, O. Le Dortz<sup>79</sup>, E. Le Guirriec<sup>84</sup>, E. Le Menedeu<sup>12</sup>, T. LeCompte<sup>6</sup>, F. Ledroit-Guillon<sup>55</sup>, C. A. Lee<sup>152</sup>, H. Lee<sup>106</sup>, J. S. H. Lee<sup>117</sup>, S. C. Lee<sup>152</sup>, L. Lee<sup>1</sup>, G. Lefebvre<sup>79</sup>, M. Lefebvre<sup>170</sup>, F. Legger<sup>99</sup>, C. Leggett<sup>15</sup>, A. Lehan<sup>73</sup>, M. Lehmann<sup>21</sup>, G. Lehmann Miotto<sup>30</sup>, X. Lei<sup>7</sup>, W. A. Leight<sup>29</sup>, A. Leisos<sup>155</sup>, A. G. Leister<sup>177</sup>, M. A. L. Leite<sup>24d</sup>, R. Leitner<sup>128</sup>, D. Lellouch<sup>173</sup>, B. Lemmer<sup>54</sup>, K. J. C. Leney<sup>77</sup>, T. Lenz<sup>21</sup>, G. Lenzen<sup>176</sup>, B. Lenzi<sup>30</sup>, R. Leone<sup>7</sup>, S. Leone<sup>123a,123b</sup>, K. Leonhardt<sup>44</sup>, C. Leonidopoulos<sup>46</sup>, S. Leontsinis<sup>10</sup>, C. Leroy<sup>94</sup>, C. G. Lester<sup>28</sup>, C. M. Lester<sup>121</sup>, M. Levchenko<sup>122</sup>, J. Levêque<sup>5</sup>, D. Levin<sup>88</sup>, L. J. Levinson<sup>173</sup>, M. Levy<sup>18</sup>, A. Lewis<sup>119</sup>, G. H. Lewis<sup>109</sup>, A. M. Leyko<sup>21</sup>, M. Leyton<sup>41</sup>, B. Li<sup>33b,u</sup>, B. Li<sup>84</sup>, H. Li<sup>149</sup>, H. L. Li<sup>31</sup>, L. Li<sup>45</sup>, L. Li<sup>33e</sup>, S. Li<sup>45</sup>, Y. Li<sup>33c,v</sup>, Z. Liang<sup>138</sup>, H. Liao<sup>34</sup>, B. Liberti<sup>134a</sup>, P. Lichard<sup>30</sup>, K. Lie<sup>166</sup>, J. Liebal<sup>21</sup>, W. Liebig<sup>14</sup>, C. Limbach<sup>21</sup>, A. Limosani<sup>87</sup>, S. C. Lin<sup>152,w</sup>, T. H. Lin<sup>82</sup>, F. Linde<sup>106</sup>, B. E. Lindquist<sup>149</sup>, J. T. Linnemann<sup>89</sup>, E. Lipeles<sup>121</sup>, A. Lipniacka<sup>14</sup>, M. Lisovsky<sup>42</sup>, T. M. Liss<sup>166</sup>, D. Lissauer<sup>25</sup>, A. Lister<sup>169</sup>, A. M. Litke<sup>138</sup>, B. Liu<sup>152</sup>, D. Liu<sup>55</sup>, J. B. Liu<sup>33b</sup>, K. Liu<sup>33b,x</sup>, L. Liu<sup>88</sup>, M. Liu<sup>45</sup>, M. Liu<sup>33b</sup>, Y. Liu<sup>33b</sup>, M. Livan<sup>120a,120b</sup>, S. S. A. Livermore<sup>119</sup>, A. Lleres<sup>55</sup>, J. Llorente Merino<sup>81</sup>, S. L. Lloyd<sup>75</sup>, F. Lo Sterzo<sup>152</sup>, E. Lobodzinska<sup>42</sup>, P. Loch<sup>7</sup>, W. S. Lockman<sup>138</sup>, T. Loddenkoetter<sup>21</sup>, F. K. Loebinger<sup>83</sup>, A. E. Loevschall-Jensen<sup>36</sup>, A. Loginov<sup>177</sup>, T. Lohse<sup>16</sup>, K. Lohwasser<sup>42</sup>, M. Lokajicek<sup>126</sup>, V. P. Lombardo<sup>5</sup>, B. A. Long<sup>22</sup>, J. D. Long<sup>88</sup>, R. E. Long<sup>71</sup>, L. Lopes<sup>125a</sup>, D. Lopez Mateos<sup>57</sup>, B. Lopez Paredes<sup>140</sup>, I. Lopez Paz<sup>12</sup>, J. Lorenz<sup>99</sup>, N. Lorenzo Martinez<sup>60</sup>, M. Losada<sup>163</sup>, P. Loscutoff<sup>15</sup>, X. Lou<sup>41</sup>, A. Lounis<sup>116</sup>, J. Love<sup>6</sup>

P. A. Love<sup>71</sup>, A. J. Lowe<sup>144,e</sup>, F. Lu<sup>33a</sup>, N. Lu<sup>88</sup>, H. J. Lubatti<sup>139</sup>, C. Luci<sup>133a,133b</sup>, A. Lucotte<sup>55</sup>, F. Luehring<sup>60</sup>, W. Lukas<sup>61</sup>, L. Luminari<sup>133a</sup>, O. Lundberg<sup>147a,147b</sup>, B. Lund-Jensen<sup>148</sup>, M. Lungwitz<sup>82</sup>, D. Lynn<sup>25</sup>, R. Lysak<sup>126</sup>, E. Lytken<sup>80</sup>, H. Ma<sup>25</sup>, L. L. Ma<sup>33d</sup>, G. Maccarrone<sup>47</sup>, A. Macchiolo<sup>100</sup>, J. Machado Miguens<sup>125a,125b</sup>, D. Macina<sup>30</sup>, D. Madaffari<sup>84</sup>, R. Madar<sup>48</sup>, H. J. Maddocks<sup>71</sup>, W. F. Mader<sup>44</sup>, A. Madsen<sup>167</sup>, M. Maeno<sup>8</sup>, T. Maeno<sup>25</sup>, E. Magradze<sup>54</sup>, K. Mahboubi<sup>48</sup>, J. Mahlstedt<sup>106</sup>, S. Mahmoud<sup>73</sup>, C. Maiani<sup>137</sup>, C. Maidantchik<sup>24a</sup>, A. A. Maier<sup>100</sup>, A. Maio<sup>125a,125b,125d</sup>, S. Majewski<sup>115</sup>, Y. Makida<sup>65</sup>, N. Makovec<sup>116</sup>, P. Mal<sup>137,y</sup>, B. Malaescu<sup>79</sup>, Pa. Malecki<sup>39</sup>, V. P. Maleev<sup>122</sup>, F. Malek<sup>55</sup>, U. Mallik<sup>62</sup>, D. Malon<sup>6</sup>, C. Malone<sup>144</sup>, S. Maltezos<sup>10</sup>, V. M. Malyshev<sup>108</sup>, S. Malyukov<sup>30</sup>, J. Mamuzic<sup>13b</sup>, B. Mandelli<sup>30</sup>, L. Mandelli<sup>90a</sup>, I. Mandić<sup>74</sup>, R. Mandrysch<sup>62</sup>, J. Maneira<sup>125a,125b</sup>, A. Manfredini<sup>100</sup>, L. Manhaes de Andrade Filho<sup>24b</sup>, J. A. Manjarres Ramos<sup>160b</sup>, A. Mann<sup>99</sup>, P. M. Manning<sup>138</sup>, A. Manousakis-Katsikakis<sup>9</sup>, B. Mansoulie<sup>137</sup>, R. Mantifel<sup>86</sup>, L. Mapelli<sup>30</sup>, L. March<sup>168</sup>, J. F. Marchand<sup>29</sup>, G. Marchiori<sup>79</sup>, M. Marcisovsky<sup>126</sup>, C. P. Marino<sup>170</sup>, M. Marjanovic<sup>13a</sup>, C. N. Marques<sup>125a</sup>, F. Marroquim<sup>24a</sup>, S. P. Marsden<sup>83</sup>, Z. Marshall<sup>15</sup>, L. F. Marti<sup>17</sup>, S. Marti-Garcia<sup>168</sup>, B. Martin<sup>30</sup>, B. Martin<sup>89</sup>, T. A. Martin<sup>171</sup>, V. J. Martin<sup>46</sup>, B. Martin dit Latour<sup>14</sup>, H. Martinez<sup>137</sup>, M. Martinez<sup>12,n</sup>, S. Martin-Haugh<sup>130</sup>, A. C. Martyniuk<sup>77</sup>, M. Marx<sup>139</sup>, F. Marzano<sup>133a</sup>, A. Marzin<sup>30</sup>, L. Masetti<sup>82</sup>, T. Mashimo<sup>156</sup>, R. Mashinistov<sup>95</sup>, J. Masik<sup>83</sup>, A. L. Maslennikov<sup>108</sup>, I. Massa<sup>20a,20b</sup>, L. Massa<sup>20a,20b</sup>, N. Massol<sup>5</sup>, P. Mastrandrea<sup>149</sup>, A. Mastroberardino<sup>37a,37b</sup>, T. Masubuchi<sup>156</sup>, P. Mättig<sup>176</sup>, J. Mattmann<sup>82</sup>, J. Maurer<sup>26a</sup>, S. J. Maxfield<sup>73</sup>, D. A. Maximov<sup>108,t</sup>, R. Mazini<sup>152</sup>, L. Mazzaferro<sup>134a,134b</sup>, G. Mc Goldrick<sup>159</sup>, S. P. Mc Kee<sup>88</sup>, A. McCann<sup>88</sup>, R. L. McCarthy<sup>149</sup>, T. G. McCarthy<sup>29</sup>, N. A. McCubbin<sup>130</sup>, K. W. McFarlane<sup>56,\*</sup>, J. A. McFayden<sup>77</sup>, G. Mchedlidze<sup>54</sup>, S. J. McMahon<sup>130</sup>, R. A. McPherson<sup>170,i</sup>, A. Meade<sup>85</sup>, J. Mechnich<sup>106</sup>, M. Medinnis<sup>42</sup>, S. Meehan<sup>31</sup>, S. Mehlhase<sup>99</sup>, A. Mehta<sup>73</sup>, K. Meier<sup>58a</sup>, C. Meineck<sup>99</sup>, B. Meirose<sup>80</sup>, C. Melachrinos<sup>31</sup>, B. R. Mellado Garcia<sup>146c</sup>, F. Meloni<sup>17</sup>, A. Mengarelli<sup>20a,20b</sup>, S. Menke<sup>100</sup>, E. Meoni<sup>162</sup>, K. M. Mercurio<sup>57</sup>, S. Mergelmeyer<sup>21</sup>, N. Meric<sup>137</sup>, P. Mermod<sup>49</sup>, L. Merola<sup>103a,103b</sup>, C. Meroni<sup>90a</sup>, F. S. Merritt<sup>31</sup>, H. Merritt<sup>110</sup>, A. Messina<sup>30,z</sup>, J. Metcalfe<sup>25</sup>, A. S. Mete<sup>164</sup>, C. Meyer<sup>82</sup>, C. Meyer<sup>121</sup>, J-P. Meyer<sup>137</sup>, J. Meyer<sup>30</sup>, R. P. Middleton<sup>130</sup>, S. Migas<sup>73</sup>, L. Mijovic<sup>21</sup>, G. Mikenberg<sup>173</sup>, M. Mikesikova<sup>126</sup>, M. Mikuž<sup>74</sup>, A. Milic<sup>30</sup>, D. W. Miller<sup>31</sup>, C. Mills<sup>46</sup>, A. Milov<sup>173</sup>, D. A. Milstead<sup>147a,147b</sup>, D. Milstein<sup>173</sup>, A. A. Minaenko<sup>129</sup>, I. A. Minashvili<sup>64</sup>, A. I. Mincer<sup>109</sup>, B. Mindur<sup>38a</sup>, M. Mineev<sup>64</sup>, Y. Ming<sup>174</sup>, L. M. Mir<sup>12</sup>, G. Mirabelli<sup>133a</sup>, T. Mitani<sup>172</sup>, J. Mitrevski<sup>99</sup>, V. A. Mitsou<sup>168</sup>, S. Mitsui<sup>65</sup>, A. Miucci<sup>49</sup>, P. S. Miyagawa<sup>140</sup>, J. U. Mjörnmark<sup>80</sup>, T. Moa<sup>147a,147b</sup>, K. Mochizuki<sup>84</sup>, S. Mohapatra<sup>35</sup>, W. Mohr<sup>48</sup>, S. Molander<sup>147a,147b</sup>, R. Moles-Valls<sup>168</sup>, K. Mönig<sup>42</sup>, C. Monini<sup>55</sup>, J. Monk<sup>36</sup>, E. Monnier<sup>84</sup>, J. Montejo Berlingen<sup>12</sup>, F. Monticelli<sup>70</sup>, S. Monzani<sup>133a,133b</sup>, R. W. Moore<sup>3</sup>, N. Morange<sup>62</sup>, D. Moreno<sup>82</sup>, M. Moreno Llácer<sup>54</sup>, P. Morettini<sup>50a</sup>, M. Morgenstern<sup>44</sup>, M. Morii<sup>57</sup>, S. Moritz<sup>82</sup>, A. K. Morley<sup>148</sup>, G. Mornacchi<sup>30</sup>, J. D. Morris<sup>75</sup>, L. Morvaj<sup>102</sup>, H. G. Moser<sup>100</sup>, M. Mosidze<sup>51b</sup>, J. Moss<sup>110</sup>, K. Motohashi<sup>158</sup>, R. Mount<sup>144</sup>, E. Mountricha<sup>25</sup>, S. V. Mouraviev<sup>95,\*</sup>, E. J. W. Moyse<sup>85</sup>, S. Muanza<sup>84</sup>, R. D. Mudd<sup>18</sup>, F. Mueller<sup>58a</sup>, J. Mueller<sup>124</sup>, K. Mueller<sup>21</sup>, T. Mueller<sup>28</sup>, T. Mueller<sup>82</sup>, D. Muenstermann<sup>49</sup>, Y. Munwes<sup>154</sup>, J. A. Murillo Quijada<sup>18</sup>, W. J. Murray<sup>171,130</sup>, H. Musheghyan<sup>54</sup>, E. Musto<sup>153</sup>, A. G. Myagkov<sup>129,aa</sup>, M. Myska<sup>127</sup>, O. Nackenhorst<sup>54</sup>, J. Nadal<sup>54</sup>, K. Nagai<sup>61</sup>, R. Nagai<sup>158</sup>, Y. Nagai<sup>84</sup>, K. Nagano<sup>65</sup>, A. Nagarkar<sup>110</sup>, Y. Nagasaka<sup>59</sup>, M. Nagel<sup>100</sup>, A. M. Nairz<sup>30</sup>, Y. Nakahama<sup>30</sup>, K. Nakamura<sup>65</sup>, T. Nakamura<sup>156</sup>, I. Nakano<sup>111</sup>, H. Namasivayam<sup>41</sup>, G. Nanava<sup>21</sup>, R. Narayan<sup>58b</sup>, T. Nattermann<sup>21</sup>, T. Naumann<sup>42</sup>, G. Navarro<sup>163</sup>, R. Nayyar<sup>7</sup>, H. A. Neal<sup>88</sup>, P. Yu. Nechaeva<sup>95</sup>, T. J. Neep<sup>83</sup>, P. D. Nef<sup>144</sup>, A. Negri<sup>120a,120b</sup>, G. Negri<sup>30</sup>, M. Negrini<sup>20a</sup>, S. Nektarijevic<sup>49</sup>, A. Nelson<sup>164</sup>, T. K. Nelson<sup>144</sup>, S. Nemecek<sup>126</sup>, P. Nemethy<sup>109</sup>, A. A. Nepomuceno<sup>24a</sup>, M. Nessi<sup>30,ab</sup>, M. S. Neubauer<sup>166</sup>, M. Neumann<sup>176</sup>, R. M. Neves<sup>109</sup>, P. Nevski<sup>25</sup>, P. R. Newman<sup>18</sup>, D. H. Nguyen<sup>6</sup>, R. B. Nickerson<sup>119</sup>, R. Nicolaidou<sup>137</sup>, B. Nicquevert<sup>30</sup>, J. Nielsen<sup>138</sup>, N. Nikiforou<sup>35</sup>, A. Nikiforov<sup>16</sup>, V. Nikolaenko<sup>129,aa</sup>, I. Nikolic-Audit<sup>79</sup>, K. Nikolics<sup>49</sup>, K. Nikolopoulos<sup>18</sup>, P. Nilsson<sup>8</sup>, Y. Ninomiya<sup>156</sup>, A. Nisati<sup>133a</sup>, R. Nisius<sup>100</sup>, T. Nobe<sup>158</sup>, L. Nodulman<sup>6</sup>, M. Nomachi<sup>117</sup>, I. Nomidis<sup>29</sup>, S. Norberg<sup>112</sup>, M. Nordberg<sup>30</sup>, O. Novgorodova<sup>44</sup>, S. Nowak<sup>100</sup>, M. Nozaki<sup>65</sup>, L. Nozka<sup>114</sup>, K. Ntekas<sup>10</sup>, G. Nunes Hanninger<sup>87</sup>, T. Nunnemann<sup>99</sup>, E. Nurse<sup>77</sup>, F. Nuti<sup>87</sup>, B. J. O'Brien<sup>46</sup>, F. O'grady<sup>7</sup>, D. C. O'Neil<sup>143</sup>, V. O'Shea<sup>53</sup>, F. G. Oakham<sup>29,d</sup>, H. Oberlack<sup>100</sup>, T. Obermann<sup>21</sup>, J. Ocariz<sup>79</sup>, A. Ochi<sup>66</sup>, M. I. Ochoa<sup>77</sup>, S. Oda<sup>69</sup>, S. Odaka<sup>65</sup>, H. Ogren<sup>60</sup>, A. Oh<sup>83</sup>, S. H. Oh<sup>45</sup>, C. C. Ohm<sup>15</sup>, H. Ohman<sup>167</sup>, W. Okamura<sup>117</sup>, H. Okawa<sup>25</sup>, Y. Okumura<sup>31</sup>, T. Okuyama<sup>156</sup>, A. Olariu<sup>26a</sup>, A. G. Olchevski<sup>64</sup>, S. A. Olivares Pino<sup>46</sup>, D. Oliveira Damazio<sup>25</sup>, E. Oliver Garcia<sup>168</sup>, A. Olszewski<sup>39</sup>, J. Olszowska<sup>39</sup>, A. Onofre<sup>125a,125c</sup>, P. U. E. Onyisi<sup>31,o</sup>, C. J. Oram<sup>160a</sup>, M. J. Oreglia<sup>31</sup>, Y. Oren<sup>154</sup>, D. Orestano<sup>135a,135b</sup>, N. Orlando<sup>72a,72b</sup>, C. Oropeza Barrera<sup>53</sup>, R. S. Orr<sup>159</sup>, B. Osculati<sup>50a,50b</sup>, R. Ospanov<sup>121</sup>, G. Otero y Garzon<sup>27</sup>, H. Otono<sup>69</sup>, M. Ouchrif<sup>136d</sup>, E. A. Ouellette<sup>170</sup>, F. Ould-Saada<sup>118</sup>, A. Ouraou<sup>137</sup>, K. P. Oussoren<sup>106</sup>, Q. Ouyang<sup>33a</sup>, A. Ovcharova<sup>15</sup>, M. Owen<sup>83</sup>, V. E. Ozcan<sup>19a</sup>, N. Ozturk<sup>8</sup>, K. Pachal<sup>119</sup>, A. Pacheco Pages<sup>12</sup>, C. Padilla Aranda<sup>12</sup>, M. Pagáčová<sup>48</sup>, S. Pagan Griso<sup>15</sup>, E. Paganis<sup>140</sup>, C. Pahl<sup>100</sup>, F. Paige<sup>25</sup>, P. Pais<sup>85</sup>, K. Pajchel<sup>118</sup>, G. Palacino<sup>160b</sup>, S. Palestini<sup>30</sup>, M. Palka<sup>38b</sup>, D. Pallin<sup>34</sup>, A. Palma<sup>125a,125b</sup>, J. D. Palmer<sup>18</sup>, Y. B. Pan<sup>174</sup>, E. Panagiotopoulou<sup>10</sup>, J. G. Panduro Vazquez<sup>76</sup>, P. Pani<sup>106</sup>, N. Panikashvili<sup>88</sup>, S. Panitkin<sup>25</sup>, D. Pantea<sup>26a</sup>, L. Paolozzi<sup>134a,134b</sup>, Th. D. Papadopoulou<sup>10</sup>, K. Papageorgiou<sup>155,l</sup>, A. Paramonov<sup>6</sup>, D. Paredes Hernandez<sup>34</sup>, M. A. Parker<sup>28</sup>, F. Parodi<sup>50a,50b</sup>, J. A. Parsons<sup>35</sup>, U. Parzefall<sup>48</sup>, E. Pasqualucci<sup>133a</sup>, S. Passaggio<sup>50a</sup>, A. Passeri<sup>135a</sup>, F. Pastore<sup>135a,135b,\*</sup>, Fr. Pastore<sup>76</sup>, G. Pásztor<sup>29</sup>, S. Pataraja<sup>176</sup>,



N. D. Patel<sup>151</sup>, J. R. Pater<sup>83</sup>, S. Patricelli<sup>103a,103b</sup>, T. Pauly<sup>30</sup>, J. Pearce<sup>170</sup>, L. E. Pedersen<sup>36</sup>, M. Pedersen<sup>118</sup>, S. Pedraza Lopez<sup>168</sup>, R. Pedro<sup>125a,125b</sup>, S. V. Peleganchuk<sup>108</sup>, D. Pelikan<sup>167</sup>, H. Peng<sup>33b</sup>, B. Penning<sup>31</sup>, J. Penwell<sup>60</sup>, D. V. Perepelitsa<sup>25</sup>, E. Perez Codina<sup>160a</sup>, M. T. Pérez García-Estañ<sup>168</sup>, V. Perez Reale<sup>35</sup>, L. Perini<sup>90a,90b</sup>, H. Pernegger<sup>30</sup>, R. Perrino<sup>72a</sup>, R. Peschke<sup>42</sup>, V. D. Peshekhonov<sup>64</sup>, K. Peters<sup>30</sup>, R. F. Y. Peters<sup>83</sup>, B. A. Petersen<sup>30</sup>, T. C. Petersen<sup>36</sup>, E. Petit<sup>42</sup>, A. Petridis<sup>147a,147b</sup>, C. Petridou<sup>155</sup>, E. Petrolu<sup>133a</sup>, F. Petrucci<sup>135a,135b</sup>, N. E. Pettersson<sup>158</sup>, R. Pezoa<sup>32b</sup>, P. W. Phillips<sup>130</sup>, G. Piacquadio<sup>144</sup>, E. Pianori<sup>171</sup>, A. Picazio<sup>49</sup>, E. Piccaro<sup>75</sup>, M. Piccinini<sup>20a,20b</sup>, R. Piegai<sup>27</sup>, D. T. Pignotti<sup>110</sup>, J. E. Pilcher<sup>31</sup>, A. D. Pilkington<sup>77</sup>, J. Pina<sup>125a,125b,125d</sup>, M. Pinamonti<sup>165a,165c</sup>, A. Pinder<sup>119</sup>, J. L. Pinfold<sup>3</sup>, A. Pingel<sup>36</sup>, B. Pinto<sup>125a</sup>, S. Pires<sup>79</sup>, M. Pitt<sup>173</sup>, C. Pizio<sup>90a,90b</sup>, L. Plazak<sup>145a</sup>, M.-A. Pleier<sup>25</sup>, V. Pleskot<sup>128</sup>, E. Plotnikova<sup>64</sup>, P. Plucinski<sup>147a,147b</sup>, S. Poddar<sup>58a</sup>, F. Podlyski<sup>34</sup>, R. Poettgen<sup>82</sup>, L. Poggioli<sup>116</sup>, D. Pohl<sup>21</sup>, M. Pohl<sup>49</sup>, G. Polesello<sup>120a</sup>, A. Policicchio<sup>37a,37b</sup>, R. Polifka<sup>159</sup>, A. Polini<sup>20a</sup>, C. S. Pollard<sup>45</sup>, V. Polychronakos<sup>25</sup>, K. Pommès<sup>30</sup>, L. Pontecorvo<sup>133a</sup>, B. G. Pope<sup>89</sup>, G. A. Popeneciu<sup>26b</sup>, D. S. Popovic<sup>13a</sup>, A. Poppleton<sup>30</sup>, X. Portell Bueso<sup>12</sup>, S. Pospisil<sup>127</sup>, K. Potamianos<sup>15</sup>, I. N. Potrap<sup>64</sup>, C. J. Potter<sup>150</sup>, C. T. Potter<sup>115</sup>, G. Poulard<sup>30</sup>, J. Poveda<sup>60</sup>, V. Pozdnyakov<sup>64</sup>, P. Pralavorio<sup>84</sup>, A. Pranko<sup>15</sup>, S. Prasad<sup>30</sup>, R. Pravahan<sup>8</sup>, S. Prell<sup>63</sup>, D. Price<sup>83</sup>, J. Price<sup>73</sup>, L. E. Price<sup>6</sup>, D. Prieur<sup>124</sup>, M. Primavera<sup>72a</sup>, M. Proissl<sup>46</sup>, K. Prokofiev<sup>47</sup>, F. Prokoshin<sup>32b</sup>, E. Protopapadaki<sup>137</sup>, S. Protopopescu<sup>25</sup>, J. Proudfoot<sup>6</sup>, M. Przybycien<sup>38a</sup>, H. Przysieszniak<sup>5</sup>, E. Ptacek<sup>115</sup>, D. Puddu<sup>135a,135b</sup>, E. Pueschel<sup>85</sup>, D. Poldon<sup>149</sup>, M. Purohit<sup>25,ad</sup>, P. Puzo<sup>116</sup>, J. Qian<sup>88</sup>, G. Qin<sup>53</sup>, Y. Qin<sup>83</sup>, A. Quadt<sup>54</sup>, D. R. Quarrie<sup>15</sup>, W. B. Quayle<sup>165a,165b</sup>, M. Queitsch-Maitland<sup>83</sup>, D. Quilty<sup>53</sup>, A. Qureshi<sup>160b</sup>, V. Radeka<sup>25</sup>, V. Radescu<sup>42</sup>, S. K. Radhakrishnan<sup>149</sup>, P. Radloff<sup>115</sup>, P. Rados<sup>87</sup>, F. Ragusa<sup>90a,90b</sup>, G. Rahal<sup>179</sup>, S. Rajagopalan<sup>25</sup>, M. Rammensee<sup>30</sup>, A. S. Randle-Conde<sup>40</sup>, C. Rangel-Smith<sup>167</sup>, K. Rao<sup>164</sup>, F. Rauscher<sup>99</sup>, T. C. Rave<sup>48</sup>, T. Ravenscroft<sup>53</sup>, M. Raymond<sup>30</sup>, A. L. Read<sup>118</sup>, N. P. Readioff<sup>73</sup>, D. M. Rebuffi<sup>120a,120b</sup>, A. Redelbach<sup>175</sup>, G. Redlinger<sup>25</sup>, R. Reece<sup>138</sup>, K. Reeves<sup>41</sup>, L. Rehnisch<sup>16</sup>, H. Reisin<sup>27</sup>, M. Relich<sup>164</sup>, C. Rembser<sup>30</sup>, H. Ren<sup>33a</sup>, Z. L. Ren<sup>152</sup>, A. Renaud<sup>116</sup>, M. Rescigno<sup>133a</sup>, S. Resconi<sup>90a</sup>, O. L. Rezanova<sup>108,t</sup>, P. Reznicek<sup>128</sup>, R. Rezvani<sup>94</sup>, R. Richter<sup>100</sup>, M. Ridel<sup>79</sup>, P. Rieck<sup>16</sup>, J. Rieger<sup>54</sup>, M. Rijssenbeek<sup>149</sup>, A. Rimoldi<sup>120a,120b</sup>, L. Rinaldi<sup>20a</sup>, E. Ritsch<sup>61</sup>, I. Riu<sup>12</sup>, F. Rizatdinova<sup>113</sup>, E. Rizvi<sup>75</sup>, S. H. Robertson<sup>86,i</sup>, A. Robichaud-Veronneau<sup>86</sup>, D. Robinson<sup>28</sup>, J. E. M. Robinson<sup>83</sup>, A. Robson<sup>53</sup>, C. Roda<sup>123a,123b</sup>, L. Rodrigues<sup>30</sup>, S. Roe<sup>30</sup>, O. Røhne<sup>118</sup>, S. Rolli<sup>162</sup>, A. Romaniouk<sup>97</sup>, M. Romano<sup>20a,20b</sup>, E. Romero Adam<sup>168</sup>, N. Rompotis<sup>139</sup>, M. Ronzani<sup>48</sup>, L. Roos<sup>79</sup>, E. Ros<sup>168</sup>, S. Rosati<sup>133a</sup>, K. Rosbach<sup>49</sup>, M. Rose<sup>76</sup>, P. Rose<sup>138</sup>, P. L. Rosendahl<sup>14</sup>, O. Rosenthal<sup>142</sup>, V. Rossetti<sup>147a,147b</sup>, E. Rossi<sup>103a,103b</sup>, L. P. Rossi<sup>50a</sup>, R. Rosten<sup>139</sup>, M. Rotaru<sup>26a</sup>, I. Roth<sup>173</sup>, J. Rothberg<sup>139</sup>, D. Rousseau<sup>116</sup>, C. R. Royon<sup>137</sup>, A. Rozanov<sup>84</sup>, Y. Rozen<sup>153</sup>, X. Ruan<sup>146c</sup>, F. Rubbo<sup>12</sup>, I. Rubinskiy<sup>42</sup>, V. I. Rud<sup>98</sup>, C. Rudolph<sup>44</sup>, M. S. Rudolph<sup>159</sup>, F. Rühr<sup>48</sup>, A. Ruiz-Martinez<sup>30</sup>, Z. Rurikova<sup>48</sup>, N. A. Rusakovich<sup>64</sup>, A. Ruschke<sup>99</sup>, J. P. Rutherford<sup>7</sup>, N. Ruthmann<sup>48</sup>, Y. F. Ryabov<sup>122</sup>, M. Rybar<sup>128</sup>, G. Rybkin<sup>116</sup>, N. C. Ryder<sup>119</sup>, A. F. Saavedra<sup>151</sup>, S. Sacerdoti<sup>27</sup>, A. Saddique<sup>3</sup>, I. Sadeh<sup>154</sup>, H.F.-W. Sadrozinski<sup>138</sup>, R. Sadykov<sup>64</sup>, F. Safai Tehrani<sup>133a</sup>, H. Sakamoto<sup>156</sup>, Y. Sakurai<sup>172</sup>, G. Salamanna<sup>135a,135b</sup>, A. Salamon<sup>134a</sup>, M. Saleem<sup>112</sup>, D. Salek<sup>106</sup>, P. H. Sales De Bruin<sup>139</sup>, D. Salihagic<sup>100</sup>, A. Salnikov<sup>144</sup>, J. Salt<sup>168</sup>, D. Salvatore<sup>37a,37b</sup>, F. Salvatore<sup>150</sup>, A. Salvucci<sup>105</sup>, A. Salzburger<sup>30</sup>, D. Sampsonidis<sup>155</sup>, A. Sanchez<sup>103a,103b</sup>, J. Sánchez<sup>168</sup>, V. Sanchez Martinez<sup>168</sup>, H. Sandaker<sup>14</sup>, R. L. Sandbach<sup>75</sup>, H. G. Sander<sup>82</sup>, M. P. Sanders<sup>99</sup>, M. Sandhoff<sup>176</sup>, T. Sandoval<sup>28</sup>, C. Sandoval<sup>163</sup>, R. Sandstroem<sup>100</sup>, D. P. C. Sankey<sup>130</sup>, A. Sansoni<sup>47</sup>, C. Santoni<sup>34</sup>, R. Santonico<sup>134a,134b</sup>, H. Santos<sup>125a</sup>, I. Santoyo Castillo<sup>150</sup>, K. Sapp<sup>124</sup>, A. Saponov<sup>64</sup>, J. G. Saraiva<sup>125a,125d</sup>, B. Sarrazin<sup>21</sup>, G. Sartisohn<sup>176</sup>, O. Sasaki<sup>65</sup>, Y. Sasaki<sup>156</sup>, G. Sauvage<sup>5,\*</sup>, E. Sauvan<sup>5</sup>, P. Savard<sup>159,d</sup>, D. O. Savu<sup>30</sup>, C. Sawyer<sup>119</sup>, L. Sawyer<sup>78,m</sup>, D. H. Saxon<sup>53</sup>, J. Saxon<sup>121</sup>, C. Sbarra<sup>20a</sup>, A. Sbrizzi<sup>3</sup>, T. Scanlon<sup>77</sup>, D. A. Scannicchio<sup>164</sup>, M. Scarcella<sup>151</sup>, V. Scarfone<sup>37a,37b</sup>, J. Schaarschmidt<sup>173</sup>, P. Schacht<sup>100</sup>, D. Schaefer<sup>30</sup>, R. Schaefer<sup>42</sup>, S. Schaepe<sup>21</sup>, S. Schaezel<sup>58b</sup>, U. Schäfer<sup>82</sup>, A. C. Schaffer<sup>116</sup>, D. Schaile<sup>99</sup>, R. D. Schamberger<sup>149</sup>, V. Scharf<sup>58a</sup>, V. A. Schegelsky<sup>122</sup>, D. Scheirich<sup>128</sup>, M. Schernau<sup>164</sup>, M. I. Scherzer<sup>35</sup>, C. Schiavi<sup>50a,50b</sup>, J. Schieck<sup>99</sup>, C. Schillo<sup>48</sup>, M. Schioppa<sup>37a,37b</sup>, S. Schlenker<sup>30</sup>, E. Schmidt<sup>48</sup>, K. Schmieden<sup>30</sup>, C. Schmitt<sup>82</sup>, S. Schmitt<sup>58b</sup>, B. Schneider<sup>17</sup>, Y. J. Schnellbach<sup>73</sup>, U. Schnoor<sup>44</sup>, L. Schoeffel<sup>137</sup>, A. Schoening<sup>58b</sup>, B. D. Schoenrock<sup>89</sup>, A. L. S. Schorlemmer<sup>54</sup>, M. Schott<sup>82</sup>, D. Schouten<sup>160a</sup>, J. Schovancova<sup>25</sup>, S. Schramm<sup>159</sup>, M. Schreyer<sup>175</sup>, C. Schroeder<sup>82</sup>, N. Schuh<sup>82</sup>, M. J. Schultens<sup>21</sup>, H.-C. Schultz-Coulon<sup>58a</sup>, H. Schulz<sup>16</sup>, M. Schumacher<sup>48</sup>, B. A. Schumm<sup>138</sup>, Ph. Schune<sup>137</sup>, C. Schwanenberger<sup>83</sup>, A. Schwartzman<sup>144</sup>, Ph. Schwegler<sup>100</sup>, Ph. Schwemling<sup>137</sup>, R. Schwienhorst<sup>89</sup>, J. Schwinding<sup>137</sup>, T. Schwindt<sup>21</sup>, M. Schwoerer<sup>5</sup>, F. G. Sciacca<sup>17</sup>, E. Scifo<sup>116</sup>, G. Sciolla<sup>23</sup>, W. G. Scott<sup>130</sup>, F. Scuri<sup>123a,123b</sup>, F. Scutti<sup>21</sup>, J. Searcy<sup>88</sup>, G. Sedov<sup>42</sup>, E. Sedykh<sup>122</sup>, S. C. Seidel<sup>104</sup>, A. Seiden<sup>138</sup>, F. Seifert<sup>127</sup>, J. M. Seixas<sup>24a</sup>, G. Sekhniaidze<sup>103a</sup>, S. J. Sekula<sup>40</sup>, K. E. Selbach<sup>46</sup>, D. M. Seliverstov<sup>122,\*</sup>, G. Sellers<sup>73</sup>, N. Semprini-Cesari<sup>20a,20b</sup>, C. Serfon<sup>30</sup>, L. Serin<sup>116</sup>, L. Serkin<sup>54</sup>, T. Serre<sup>84</sup>, R. Seuster<sup>160a</sup>, H. Severini<sup>112</sup>, T. Sfiligoi<sup>74</sup>, F. Sforza<sup>100</sup>, A. Sfyrla<sup>30</sup>, E. Shabalina<sup>54</sup>, M. Shamim<sup>115</sup>, L. Y. Shan<sup>33a</sup>, R. Shang<sup>166</sup>, J. T. Shank<sup>22</sup>, M. Shapiro<sup>15</sup>, P. B. Shatalov<sup>96</sup>, K. Shaw<sup>165a,165b</sup>, C. Y. Shehu<sup>150</sup>, P. Sherwood<sup>77</sup>, L. Shi<sup>152,ae</sup>, S. Shimizu<sup>66</sup>, C. O. Shimmin<sup>164</sup>, M. Shimojima<sup>101</sup>, M. Shiyakova<sup>64</sup>, A. Shmeleva<sup>95</sup>, M. J. Shochet<sup>31</sup>, D. Short<sup>119</sup>, S. Shrestha<sup>63</sup>, E. Shulga<sup>97</sup>, M. A. Shupe<sup>7</sup>, S. Shushkevich<sup>42</sup>, P. Sicho<sup>126</sup>, O. Sidiropoulou<sup>155</sup>, D. Sidorov<sup>113</sup>, A. Sidoti<sup>133a</sup>, F. Siegert<sup>44</sup>, Dj. Sijacki<sup>13a</sup>, J. Silva<sup>125a,125d</sup>, Y. Silver<sup>154</sup>, D. Silverstein<sup>144</sup>, S. B. Silverstein<sup>147a</sup>,

V. Simak<sup>127</sup>, O. Simard<sup>5</sup>, Lj. Simic<sup>13a</sup>, S. Simion<sup>116</sup>, E. Simioni<sup>82</sup>, B. Simmons<sup>77</sup>, R. Simoniello<sup>90a,90b</sup>, M. Simonyan<sup>36</sup>, P. Sinervo<sup>159</sup>, N. B. Sinev<sup>115</sup>, V. Sipica<sup>142</sup>, G. Siragusa<sup>175</sup>, A. Sircar<sup>78</sup>, A. N. Sisakyan<sup>64,\*</sup>, S. Yu. Sivoklov<sup>98</sup>, J. Sjölin<sup>147a,147b</sup>, T. B. Sjrursen<sup>14</sup>, H. P. Skottowe<sup>57</sup>, K. Yu. Skovpen<sup>108</sup>, P. Skubic<sup>112</sup>, M. Slater<sup>18</sup>, T. Slavicek<sup>127</sup>, K. Sliwa<sup>162</sup>, V. Smakhtin<sup>173</sup>, B. H. Smart<sup>46</sup>, L. Smestad<sup>14</sup>, S. Yu. Smirnov<sup>97</sup>, Y. Smirnov<sup>97</sup>, L. N. Smirnova<sup>98.af</sup>, O. Smirnova<sup>80</sup>, K. M. Smith<sup>53</sup>, M. Smizanska<sup>71</sup>, K. Smolek<sup>127</sup>, A. A. Snesarev<sup>95</sup>, G. Snidero<sup>75</sup>, S. Snyder<sup>25</sup>, R. Sobie<sup>170.i</sup>, F. Socher<sup>44</sup>, A. Soffer<sup>154</sup>, D. A. Soh<sup>152.ae</sup>, C. A. Solans<sup>30</sup>, M. Solar<sup>127</sup>, J. Solc<sup>127</sup>, E. Yu. Soldatov<sup>97</sup>, U. Soldevila<sup>168</sup>, A. A. Solodkov<sup>129</sup>, A. Soloshenko<sup>64</sup>, O. V. Solovyanov<sup>129</sup>, V. Solovyev<sup>122</sup>, P. Sommer<sup>48</sup>, H. Y. Song<sup>33b</sup>, N. Soni<sup>1</sup>, A. Sood<sup>15</sup>, A. Sopczak<sup>127</sup>, B. Sopko<sup>127</sup>, V. Sopko<sup>127</sup>, V. Sorin<sup>12</sup>, M. Sosebee<sup>8</sup>, R. Soualah<sup>165a,165c</sup>, P. Soueid<sup>94</sup>, A. M. Soukharev<sup>108</sup>, D. South<sup>42</sup>, S. Spagnolo<sup>72a,72b</sup>, F. Spanò<sup>76</sup>, W. R. Spearman<sup>57</sup>, F. Spettel<sup>100</sup>, R. Spighi<sup>20a</sup>, G. Spigo<sup>30</sup>, L. A. Spiller<sup>87</sup>, M. Spousta<sup>128</sup>, T. Spreitzer<sup>159</sup>, B. Spurlock<sup>8</sup>, R. D. St. Denis<sup>53,\*</sup>, S. Staerz<sup>44</sup>, J. Stahlman<sup>121</sup>, R. Stamen<sup>58a</sup>, S. Stamm<sup>16</sup>, E. Stanecka<sup>39</sup>, R. W. Stanek<sup>6</sup>, C. Stanescu<sup>135a</sup>, M. Stanescu-Bellu<sup>42</sup>, M. M. Stanitzki<sup>42</sup>, S. Stapnes<sup>118</sup>, E. A. Starchenko<sup>129</sup>, J. Stark<sup>55</sup>, P. Staroba<sup>126</sup>, P. Starovoitov<sup>42</sup>, R. Staszewski<sup>39</sup>, P. Stavina<sup>145a,\*</sup>, P. Steinberg<sup>25</sup>, B. Stelzer<sup>143</sup>, H. J. Stelzer<sup>30</sup>, O. Stelzer-Chilton<sup>160a</sup>, H. Stenzel<sup>52</sup>, S. Stern<sup>100</sup>, G. A. Stewart<sup>53</sup>, J. A. Stillings<sup>21</sup>, M. C. Stockton<sup>86</sup>, M. Stoebe<sup>86</sup>, G. Stoicea<sup>26a</sup>, P. Stolte<sup>54</sup>, S. Stonjek<sup>100</sup>, A. R. Stradling<sup>8</sup>, A. Straessner<sup>44</sup>, M. E. Stramaglia<sup>17</sup>, J. Strandberg<sup>148</sup>, S. Strandberg<sup>147a,147b</sup>, A. Strandlie<sup>118</sup>, E. Strauss<sup>144</sup>, M. Strauss<sup>112</sup>, P. Strizenc<sup>145b</sup>, R. Ströhmer<sup>175</sup>, D. M. Strom<sup>115</sup>, R. Stroynowski<sup>40</sup>, A. Struebig<sup>105</sup>, S. A. Stucci<sup>17</sup>, B. Stugu<sup>14</sup>, N. A. Styles<sup>42</sup>, D. Su<sup>144</sup>, J. Su<sup>124</sup>, R. Subramaniam<sup>78</sup>, A. Succurro<sup>12</sup>, Y. Sugaya<sup>117</sup>, C. Suhr<sup>107</sup>, M. Suk<sup>127</sup>, V. V. Sulin<sup>95</sup>, S. Sultansoy<sup>4c</sup>, T. Sumida<sup>67</sup>, S. Sun<sup>57</sup>, X. Sun<sup>33a</sup>, J. E. Sundermann<sup>48</sup>, K. Suruliz<sup>140</sup>, G. Susinno<sup>37a,37b</sup>, M. R. Sutton<sup>150</sup>, Y. Suzuki<sup>65</sup>, M. Svatos<sup>126</sup>, S. Swedish<sup>169</sup>, M. Swiatlowski<sup>144</sup>, I. Sykora<sup>145a</sup>, T. Sykora<sup>128</sup>, D. Ta<sup>89</sup>, C. Taccini<sup>135a,135b</sup>, K. Tackmann<sup>42</sup>, J. Taenzer<sup>159</sup>, A. Taffard<sup>164</sup>, R. Tafirout<sup>160a</sup>, N. Taiblum<sup>154</sup>, H. Takai<sup>25</sup>, R. Takashima<sup>68</sup>, H. Takeda<sup>66</sup>, T. Takeshita<sup>141</sup>, Y. Takubo<sup>65</sup>, M. Talby<sup>84</sup>, A. A. Talyshv<sup>108.t</sup>, J. Y. C. Tam<sup>175</sup>, K. G. Tan<sup>87</sup>, J. Tanaka<sup>156</sup>, R. Tanaka<sup>116</sup>, S. Tanaka<sup>132</sup>, S. Tanaka<sup>65</sup>, A. J. Tanasijczuk<sup>143</sup>, B. B. Tannenwald<sup>110</sup>, N. Tannoury<sup>21</sup>, S. Tapprogge<sup>82</sup>, S. Tarem<sup>153</sup>, F. Tarrade<sup>29</sup>, G. F. Tartarelli<sup>90a</sup>, P. Tas<sup>128</sup>, M. Tasevsky<sup>126</sup>, T. Tashiro<sup>67</sup>, E. Tassi<sup>37a,37b</sup>, A. Tavares Delgado<sup>125a,125b</sup>, Y. Tayalati<sup>136d</sup>, F. E. Taylor<sup>93</sup>, G. N. Taylor<sup>87</sup>, W. Taylor<sup>160b</sup>, F. A. Teischinger<sup>30</sup>, M. Teixeira Dias Castanheira<sup>75</sup>, P. Teixeira-Dias<sup>76</sup>, K. K. Temming<sup>48</sup>, H. Ten Kate<sup>30</sup>, P. K. Teng<sup>152</sup>, J. J. Teoh<sup>117</sup>, S. Terada<sup>65</sup>, K. Terashi<sup>156</sup>, J. Terron<sup>81</sup>, S. Terzo<sup>100</sup>, M. Testa<sup>47</sup>, R. J. Teuscher<sup>159.i</sup>, J. Therhaag<sup>21</sup>, T. Thevenaux-Pelzer<sup>34</sup>, J. P. Thomas<sup>18</sup>, J. Thomas-Wilsker<sup>76</sup>, E. N. Thompson<sup>35</sup>, P. D. Thompson<sup>18</sup>, P. D. Thompson<sup>159</sup>, R. J. Thompson<sup>83</sup>, A. S. Thompson<sup>53</sup>, L. A. Thomsen<sup>36</sup>, E. Thomson<sup>121</sup>, M. Thomson<sup>28</sup>, W. M. Thong<sup>87</sup>, R. P. Thun<sup>88,\*</sup>, F. Tian<sup>35</sup>, M. J. Tibbetts<sup>15</sup>, V. O. Tikhomirov<sup>95.ag</sup>, Yu. A. Tikhonov<sup>108.t</sup>, S. Timoshenko<sup>97</sup>, E. Tiouchichine<sup>84</sup>, P. Tipton<sup>177</sup>, S. Tisserant<sup>84</sup>, T. Todorov<sup>5</sup>, S. Todorova-Nova<sup>128</sup>, B. Toggerson<sup>7</sup>, J. Tojo<sup>69</sup>, S. Tokár<sup>145a</sup>, K. Tokushuku<sup>65</sup>, K. Tollefson<sup>89</sup>, L. Tomlinson<sup>83</sup>, M. Tomoto<sup>102</sup>, L. Tompkins<sup>31</sup>, K. Toms<sup>104</sup>, N. D. Topilin<sup>64</sup>, E. Torrence<sup>115</sup>, H. Torres<sup>143</sup>, E. Torró Pastor<sup>168</sup>, J. Toth<sup>84.ah</sup>, F. Touchard<sup>84</sup>, D. R. Tovey<sup>140</sup>, H. L. Tran<sup>116</sup>, T. Trefzger<sup>175</sup>, L. Tremblet<sup>30</sup>, A. Tricoli<sup>30</sup>, I. M. Trigger<sup>160a</sup>, S. Trincaz-Duvoid<sup>79</sup>, M. F. Tripiana<sup>12</sup>, W. Trischuk<sup>159</sup>, B. Trocme<sup>55</sup>, C. Troncon<sup>90a</sup>, M. Trotter-McDonald<sup>143</sup>, M. Trovatelli<sup>135a,135b</sup>, P. True<sup>89</sup>, M. Trzebinski<sup>39</sup>, A. Trzupek<sup>39</sup>, C. Tsarouchas<sup>30</sup>, J.C.-L. Tseng<sup>119</sup>, P. V. Tsiareshka<sup>91</sup>, D. Tsionou<sup>137</sup>, G. Tsipolitis<sup>10</sup>, N. Tsirintanis<sup>9</sup>, S. Tsiskaridze<sup>12</sup>, V. Tsiskaridze<sup>48</sup>, E. G. Tskhadadze<sup>51a</sup>, I. I. Tsukerman<sup>96</sup>, V. Tsulaia<sup>15</sup>, S. Tsuno<sup>65</sup>, D. Tsybychev<sup>149</sup>, A. Tudorache<sup>26a</sup>, V. Tudorache<sup>26a</sup>, A. N. Tuna<sup>121</sup>, S. A. Tuppuri<sup>20a,20b</sup>, S. Turchikhin<sup>98.af</sup>, D. Turecek<sup>127</sup>, I. Turk Cakir<sup>4d</sup>, R. Turra<sup>90a,90b</sup>, P. M. Tuts<sup>35</sup>, A. Tykhonov<sup>49</sup>, M. Tylmad<sup>147a,147b</sup>, M. Tyndel<sup>130</sup>, K. Uchida<sup>21</sup>, I. Ueda<sup>156</sup>, R. Ueno<sup>29</sup>, M. Ughetto<sup>84</sup>, M. Uglan<sup>14</sup>, M. Uhlenbrock<sup>21</sup>, F. Ukegawa<sup>161</sup>, G. Unal<sup>30</sup>, A. Undrus<sup>25</sup>, G. Unel<sup>164</sup>, F. C. Ungaro<sup>48</sup>, Y. Unno<sup>65</sup>, C. Unverdorben<sup>99</sup>, D. Urbaniec<sup>35</sup>, P. Urquijo<sup>87</sup>, G. Usai<sup>8</sup>, A. Usanova<sup>61</sup>, L. Vacavant<sup>84</sup>, V. Vacek<sup>127</sup>, B. Vachon<sup>86</sup>, N. Valencic<sup>106</sup>, S. Valentinetti<sup>20a,20b</sup>, A. Valero<sup>168</sup>, L. Valery<sup>34</sup>, S. Valkar<sup>128</sup>, E. Valladolid Gallego<sup>168</sup>, S. Vallecorsa<sup>49</sup>, J. A. Valls Ferrer<sup>168</sup>, W. Van Den Wollenberg<sup>106</sup>, P. C. Van Der Deijl<sup>106</sup>, R. van der Geer<sup>106</sup>, H. van der Graaf<sup>106</sup>, R. Van Der Leeuw<sup>106</sup>, D. van der Ster<sup>30</sup>, N. van Eldik<sup>30</sup>, P. van Gemmeren<sup>6</sup>, J. Van Nieuwkoop<sup>143</sup>, I. van Vulpen<sup>106</sup>, M. C. van Woerden<sup>30</sup>, M. Vanadia<sup>133a,133b</sup>, W. Vandelli<sup>30</sup>, R. Vanguri<sup>121</sup>, A. Vaniachine<sup>6</sup>, P. Vankov<sup>42</sup>, F. Vannucci<sup>79</sup>, G. Vardanyan<sup>178</sup>, R. Vari<sup>133a</sup>, E. W. Varnes<sup>7</sup>, T. Varol<sup>85</sup>, D. Varouchas<sup>79</sup>, A. Vartapetian<sup>8</sup>, K. E. Varvell<sup>151</sup>, F. Vazeille<sup>34</sup>, T. Vazquez Schroeder<sup>54</sup>, J. Veatch<sup>7</sup>, F. Veloso<sup>125a,125c</sup>, S. Veneziano<sup>133a</sup>, A. Ventura<sup>72a,72b</sup>, D. Ventura<sup>85</sup>, M. Venturi<sup>170</sup>, N. Venturi<sup>159</sup>, A. Venturini<sup>23</sup>, V. Vercesi<sup>120a</sup>, M. Verducci<sup>133a,133b</sup>, W. Verkerke<sup>106</sup>, J. C. Vermeulen<sup>106</sup>, A. Vest<sup>44</sup>, M. C. Vetterli<sup>143.d</sup>, O. Viazlo<sup>80</sup>, I. Vichou<sup>166</sup>, T. Vickey<sup>146c.ai</sup>, O. E. Vickey Boeriu<sup>146c</sup>, G. H. A. Viehhauser<sup>119</sup>, S. Viel<sup>169</sup>, R. Vigne<sup>30</sup>, M. Villa<sup>20a,20b</sup>, M. Villaplana Perez<sup>90a,90b</sup>, E. Vilucchi<sup>47</sup>, M. G. Vincter<sup>29</sup>, V. B. Vinogradov<sup>64</sup>, J. Virzi<sup>15</sup>, I. Vivarelli<sup>150</sup>, F. Vives Vaque<sup>3</sup>, S. Vlachos<sup>10</sup>, D. Vladoiu<sup>99</sup>, M. Vlasak<sup>127</sup>, A. Vogel<sup>21</sup>, M. Vogel<sup>32a</sup>, P. Vokac<sup>127</sup>, G. Volpi<sup>123a,123b</sup>, M. Volpi<sup>87</sup>, H. von der Schmitt<sup>100</sup>, H. von Radziewski<sup>48</sup>, E. von Toerne<sup>21</sup>, V. Vorobel<sup>128</sup>, K. Vorobev<sup>97</sup>, M. Vos<sup>168</sup>, R. Voss<sup>30</sup>, J. H. Vossebeld<sup>73</sup>, N. Vranjes<sup>137</sup>, M. Vranjes Milosavljevic<sup>13a</sup>, V. Vrba<sup>126</sup>, M. Vreeswijk<sup>106</sup>, T. Vu Anh<sup>48</sup>, R. Vuillermet<sup>30</sup>, I. Vukotic<sup>31</sup>, Z. Vykydal<sup>127</sup>, P. Wagner<sup>21</sup>, W. Wagner<sup>176</sup>, H. Wahlberg<sup>70</sup>, S. Wahrmund<sup>44</sup>, J. Wakabayashi<sup>102</sup>, J. Walder<sup>71</sup>, R. Walker<sup>99</sup>, W. Walkowiak<sup>142</sup>, R. Wall<sup>177</sup>, P. Waller<sup>73</sup>, B. Walsh<sup>177</sup>, C. Wang<sup>152.aj</sup>

C. Wang<sup>45</sup>, F. Wang<sup>174</sup>, H. Wang<sup>15</sup>, H. Wang<sup>40</sup>, J. Wang<sup>42</sup>, J. Wang<sup>33a</sup>, K. Wang<sup>86</sup>, R. Wang<sup>104</sup>, S. M. Wang<sup>152</sup>, T. Wang<sup>21</sup>, X. Wang<sup>177</sup>, C. Wanotayaroj<sup>115</sup>, A. Warburton<sup>86</sup>, C. P. Ward<sup>28</sup>, D. R. Wardrope<sup>77</sup>, M. Warsinsky<sup>48</sup>, A. Washbrook<sup>46</sup>, C. Wasicki<sup>42</sup>, P. M. Watkins<sup>18</sup>, A. T. Watson<sup>18</sup>, I. J. Watson<sup>151</sup>, M. F. Watson<sup>18</sup>, G. Watts<sup>139</sup>, S. Watts<sup>83</sup>, B. M. Waugh<sup>77</sup>, S. Webb<sup>83</sup>, M. S. Weber<sup>17</sup>, S. W. Weber<sup>175</sup>, J. S. Webster<sup>31</sup>, A. R. Weidberg<sup>119</sup>, P. Weigell<sup>100</sup>, B. Weinert<sup>60</sup>, J. Weingarten<sup>54</sup>, C. Weiser<sup>48</sup>, H. Weits<sup>106</sup>, P. S. Wells<sup>30</sup>, T. Wenaus<sup>25</sup>, D. Wendland<sup>16</sup>, Z. Weng<sup>152,ae</sup>, T. Wengler<sup>30</sup>, S. Wenig<sup>30</sup>, N. Wermes<sup>21</sup>, M. Werner<sup>48</sup>, P. Werner<sup>30</sup>, M. Wessels<sup>58a</sup>, J. Wetter<sup>162</sup>, K. Whalen<sup>29</sup>, A. White<sup>8</sup>, M. J. White<sup>1</sup>, R. White<sup>32b</sup>, S. White<sup>123a,123b</sup>, D. Whiteson<sup>164</sup>, D. Wicke<sup>176</sup>, F. J. Wickens<sup>130</sup>, W. Wiedenmann<sup>174</sup>, M. Wielers<sup>130</sup>, P. Wienemann<sup>21</sup>, C. Wiglesworth<sup>36</sup>, L. A. M. Wiik-Fuchs<sup>21</sup>, P. A. Wijeratne<sup>77</sup>, A. Wildauer<sup>100</sup>, M. A. Wildt<sup>42,ak</sup>, H. G. Wilkens<sup>30</sup>, J. Z. Will<sup>99</sup>, H. H. Williams<sup>121</sup>, S. Williams<sup>28</sup>, C. Willis<sup>89</sup>, S. Willocq<sup>85</sup>, A. Wilson<sup>88</sup>, J. A. Wilson<sup>18</sup>, I. Wingerter-Seez<sup>5</sup>, F. Winklmeier<sup>115</sup>, B. T. Winter<sup>21</sup>, M. Wittgen<sup>144</sup>, T. Wittig<sup>43</sup>, J. Wittkowski<sup>99</sup>, S. J. Wollstadt<sup>82</sup>, M. W. Wolter<sup>39</sup>, H. Wolters<sup>125a,125c</sup>, B. K. Wosiek<sup>39</sup>, J. Wotschack<sup>30</sup>, M. J. Woudstra<sup>83</sup>, K. W. Wozniak<sup>39</sup>, M. Wright<sup>53</sup>, M. Wu<sup>55</sup>, S. L. Wu<sup>174</sup>, X. Wu<sup>49</sup>, Y. Wu<sup>88</sup>, E. Wulf<sup>35</sup>, T. R. Wyatt<sup>83</sup>, B. M. Wynne<sup>46</sup>, S. Xella<sup>36</sup>, M. Xiao<sup>137</sup>, D. Xu<sup>33a</sup>, L. Xu<sup>33b,al</sup>, B. Yabsley<sup>151</sup>, S. Yacoub<sup>146b,am</sup>, R. Yakabe<sup>66</sup>, M. Yamada<sup>65</sup>, H. Yamaguchi<sup>156</sup>, Y. Yamaguchi<sup>117</sup>, A. Yamamoto<sup>65</sup>, K. Yamamoto<sup>63</sup>, S. Yamamoto<sup>156</sup>, T. Yamamura<sup>156</sup>, T. Yamanaka<sup>156</sup>, K. Yamauchi<sup>102</sup>, Y. Yamazaki<sup>66</sup>, Z. Yan<sup>22</sup>, H. Yang<sup>33e</sup>, H. Yang<sup>174</sup>, U. K. Yang<sup>83</sup>, Y. Yang<sup>110</sup>, S. Yanush<sup>92</sup>, L. Yao<sup>33a</sup>, W-M. Yao<sup>15</sup>, Y. Yasu<sup>65</sup>, E. Yatsenko<sup>42</sup>, K. H. Yau Wong<sup>21</sup>, J. Ye<sup>40</sup>, S. Ye<sup>25</sup>, I. Yeletsikh<sup>64</sup>, A. L. Yen<sup>57</sup>, E. Yildirim<sup>42</sup>, M. Yilmaz<sup>4b</sup>, R. Yoosoofmiya<sup>124</sup>, K. Yorita<sup>172</sup>, R. Yoshida<sup>6</sup>, K. Yoshihara<sup>156</sup>, C. Young<sup>144</sup>, C. J. S. Young<sup>30</sup>, S. Youssef<sup>22</sup>, D. R. Yu<sup>15</sup>, J. Yu<sup>8</sup>, J. M. Yu<sup>88</sup>, J. Yu<sup>113</sup>, L. Yuan<sup>66</sup>, A. Yurkewicz<sup>107</sup>, I. Yusuff<sup>28,an</sup>, B. Zabinski<sup>39</sup>, R. Zaidan<sup>62</sup>, A. M. Zaitsev<sup>129,aa</sup>, A. Zaman<sup>149</sup>, S. Zambito<sup>23</sup>, L. Zanello<sup>133a,133b</sup>, D. Zanzi<sup>100</sup>, C. Zeitnitz<sup>176</sup>, M. Zeman<sup>127</sup>, A. Zemla<sup>38a</sup>, K. Zengel<sup>23</sup>, O. Zenin<sup>129</sup>, T. Ženiš<sup>145a</sup>, D. Zerwas<sup>116</sup>, G. Zevi della Porta<sup>57</sup>, D. Zhang<sup>88</sup>, F. Zhang<sup>174</sup>, H. Zhang<sup>89</sup>, J. Zhang<sup>6</sup>, L. Zhang<sup>152</sup>, X. Zhang<sup>33d</sup>, Z. Zhang<sup>116</sup>, Z. Zhao<sup>33b</sup>, A. Zhemchugov<sup>64</sup>, J. Zhong<sup>119</sup>, B. Zhou<sup>88</sup>, L. Zhou<sup>35</sup>, N. Zhou<sup>164</sup>, C. G. Zhu<sup>33d</sup>, H. Zhu<sup>33a</sup>, J. Zhu<sup>88</sup>, Y. Zhu<sup>33b</sup>, X. Zhuang<sup>33a</sup>, K. Zhukov<sup>95</sup>, A. Zibell<sup>175</sup>, D. Zieminska<sup>60</sup>, N. I. Zimine<sup>64</sup>, C. Zimmermann<sup>82</sup>, R. Zimmermann<sup>21</sup>, S. Zimmermann<sup>21</sup>, S. Zimmermann<sup>48</sup>, Z. Zinonos<sup>54</sup>, M. Ziolkowski<sup>142</sup>, G. Zobernig<sup>174</sup>, A. Zoccoli<sup>20a,20b</sup>, M. zur Nedden<sup>16</sup>, G. Zurzolo<sup>103a,103b</sup>, V. Zutshi<sup>107</sup>, L. Zwalinski<sup>30</sup>

<sup>1</sup> Department of Physics, University of Adelaide, Adelaide, Australia

<sup>2</sup> Physics Department, SUNY Albany, Albany, NY, USA

<sup>3</sup> Department of Physics, University of Alberta, Edmonton, AB, Canada

<sup>4</sup> (a) Department of Physics, Ankara University, Ankara, Turkey; (b) Department of Physics, Gazi University, Ankara, Turkey; (c) Division of Physics, TOBB University of Economics and Technology, Ankara, Turkey; (d) Turkish Atomic Energy Authority, Ankara, Turkey

<sup>5</sup> LAPP, CNRS/IN2P3 and Université de Savoie, Annecy-le-Vieux, France

<sup>6</sup> High Energy Physics Division, Argonne National Laboratory, Argonne, IL, USA

<sup>7</sup> Department of Physics, University of Arizona, Tucson, AZ, USA

<sup>8</sup> Department of Physics, The University of Texas at Arlington, Arlington, TX, USA

<sup>9</sup> Physics Department, University of Athens, Athens, Greece

<sup>10</sup> Physics Department, National Technical University of Athens, Zografou, Greece

<sup>11</sup> Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan

<sup>12</sup> Institut de Física d'Altes Energies and Departament de Física de la Universitat Autònoma de Barcelona, Barcelona, Spain

<sup>13</sup> (a) Institute of Physics, University of Belgrade, Belgrade, Serbia; (b) Vinca Institute of Nuclear Sciences, University of Belgrade, Belgrade, Serbia

<sup>14</sup> Department for Physics and Technology, University of Bergen, Bergen, Norway

<sup>15</sup> Physics Division, Lawrence Berkeley National Laboratory and University of California, Berkeley, CA, USA

<sup>16</sup> Department of Physics, Humboldt University, Berlin, Germany

<sup>17</sup> Albert Einstein Center for Fundamental Physics and Laboratory for High Energy Physics, University of Bern, Bern, Switzerland

<sup>18</sup> School of Physics and Astronomy, University of Birmingham, Birmingham, UK

<sup>19</sup> (a) Department of Physics, Bogazici University, Istanbul, Turkey; (b) Department of Physics, Dogus University, Istanbul, Turkey; (c) Department of Physics Engineering, Gaziantep University, Gaziantep, Turkey

- <sup>20</sup> (a) INFN Sezione di Bologna, Bologna, Italy; (b) Dipartimento di Fisica e Astronomia, Università di Bologna, Bologna, Italy
- <sup>21</sup> Physikalisches Institut, University of Bonn, Bonn, Germany
- <sup>22</sup> Department of Physics, Boston University, Boston, MA, USA
- <sup>23</sup> Department of Physics, Brandeis University, Waltham, MA, USA
- <sup>24</sup> (a) Universidade Federal do Rio De Janeiro COPPE/EE/IF, Rio de Janeiro, Brazil; (b) Federal University of Juiz de Fora (UFJF), Juiz de Fora, Brazil; (c) Federal University of Sao Joao del Rei (UFSJ), Sao Joao del Rei, Brazil; (d) Instituto de Fisica, Universidade de Sao Paulo, São Paulo, Brazil
- <sup>25</sup> Physics Department, Brookhaven National Laboratory, Upton, NY, USA
- <sup>26</sup> (a) National Institute of Physics and Nuclear Engineering, Bucharest, Romania; (b) Physics Department, National Institute for Research and Development of Isotopic and Molecular Technologies, Cluj Napoca, Romania; (c) University Politehnica Bucharest, Bucharest, Romania; (d) West University in Timisoara, Timisoara, Romania
- <sup>27</sup> Departamento de Física, Universidad de Buenos Aires, Buenos Aires, Argentina
- <sup>28</sup> Cavendish Laboratory, University of Cambridge, Cambridge, UK
- <sup>29</sup> Department of Physics, Carleton University, Ottawa, ON, Canada
- <sup>30</sup> CERN, Geneva, Switzerland
- <sup>31</sup> Enrico Fermi Institute, University of Chicago, Chicago, IL, USA
- <sup>32</sup> (a) Departamento de Física, Pontificia Universidad Católica de Chile, Santiago, Chile; (b) Departamento de Física, Universidad Técnica Federico Santa María, Valparaiso, Chile
- <sup>33</sup> (a) Institute of High Energy Physics, Chinese Academy of Sciences, Beijing, China; (b) Department of Modern Physics, University of Science and Technology of China, Anhui, China; (c) Department of Physics, Nanjing University, Jiangsu, China; (d) School of Physics, Shandong University, Shandong, China; (e) Physics Department, Shanghai Jiao Tong University, Shanghai, China
- <sup>34</sup> Laboratoire de Physique Corpusculaire, Clermont Université and Université Blaise Pascal and CNRS/IN2P3, Clermont-Ferrand, France
- <sup>35</sup> Nevis Laboratory, Columbia University, Irvington, NY, USA
- <sup>36</sup> Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark
- <sup>37</sup> (a) INFN Gruppo Collegato di Cosenza, Laboratori Nazionali di Frascati, Italy; (b) Dipartimento di Fisica, Università della Calabria, Rende, Italy
- <sup>38</sup> (a) Faculty of Physics and Applied Computer Science, AGH University of Science and Technology, Kraków, Poland; (b) Marian Smoluchowski Institute of Physics, Jagiellonian University, Kraków, Poland
- <sup>39</sup> The Henryk Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences, Kraków, Poland
- <sup>40</sup> Physics Department, Southern Methodist University, Dallas, TX, USA
- <sup>41</sup> Physics Department, University of Texas at Dallas, Richardson, TX, USA
- <sup>42</sup> DESY, Hamburg and Zeuthen, Germany
- <sup>43</sup> Institut für Experimentelle Physik IV, Technische Universität Dortmund, Dortmund, Germany
- <sup>44</sup> Institut für Kern- und Teilchenphysik, Technische Universität Dresden, Dresden, Germany
- <sup>45</sup> Department of Physics, Duke University, Durham, NC, USA
- <sup>46</sup> SUPA-School of Physics and Astronomy, University of Edinburgh, Edinburgh, UK
- <sup>47</sup> INFN Laboratori Nazionali di Frascati, Frascati, Italy
- <sup>48</sup> Fakultät für Mathematik und Physik, Albert-Ludwigs-Universität, Freiburg, Germany
- <sup>49</sup> Section de Physique, Université de Genève, Geneva, Switzerland
- <sup>50</sup> (a) INFN Sezione di Genova, Genoa, Italy; (b) Dipartimento di Fisica, Università di Genova, Genoa, Italy
- <sup>51</sup> (a) E. Andronikashvili Institute of Physics, Iv. Javakhishvili Tbilisi State University, Tbilisi, Georgia; (b) High Energy Physics Institute, Tbilisi State University, Tbilisi, Georgia
- <sup>52</sup> II Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen, Germany
- <sup>53</sup> SUPA-School of Physics and Astronomy, University of Glasgow, Glasgow, UK
- <sup>54</sup> II Physikalisches Institut, Georg-August-Universität, Göttingen, Germany
- <sup>55</sup> Laboratoire de Physique Subatomique et de Cosmologie, Université Grenoble-Alpes, CNRS/IN2P3, Grenoble, France
- <sup>56</sup> Department of Physics, Hampton University, Hampton, VA, USA
- <sup>57</sup> Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge, MA, USA

- <sup>58</sup> (a) Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany; (b) Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany; (c) ZITI Institut für technische Informatik, Ruprecht-Karls-Universität Heidelberg, Mannheim, Germany
- <sup>59</sup> Faculty of Applied Information Science, Hiroshima Institute of Technology, Hiroshima, Japan
- <sup>60</sup> Department of Physics, Indiana University, Bloomington, IN, USA
- <sup>61</sup> Institut für Astro- und Teilchenphysik, Leopold-Franzens-Universität, Innsbruck, Austria
- <sup>62</sup> University of Iowa, Iowa City, IA, USA
- <sup>63</sup> Department of Physics and Astronomy, Iowa State University, Ames, IA, USA
- <sup>64</sup> Joint Institute for Nuclear Research, JINR Dubna, Dubna, Russia
- <sup>65</sup> KEK, High Energy Accelerator Research Organization, Tsukuba, Japan
- <sup>66</sup> Graduate School of Science, Kobe University, Kobe, Japan
- <sup>67</sup> Faculty of Science, Kyoto University, Kyoto, Japan
- <sup>68</sup> Kyoto University of Education, Kyoto, Japan
- <sup>69</sup> Department of Physics, Kyushu University, Fukuoka, Japan
- <sup>70</sup> Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata, Argentina
- <sup>71</sup> Physics Department, Lancaster University, Lancaster, UK
- <sup>72</sup> (a) INFN Sezione di Lecce, Lecce, Italy; (b) Dipartimento di Matematica e Fisica, Università del Salento, Lecce, Italy
- <sup>73</sup> Oliver Lodge Laboratory, University of Liverpool, Liverpool, UK
- <sup>74</sup> Department of Physics, Jožef Stefan Institute and University of Ljubljana, Ljubljana, Slovenia
- <sup>75</sup> School of Physics and Astronomy, Queen Mary University of London, London, UK
- <sup>76</sup> Department of Physics, Royal Holloway University of London, Surrey, UK
- <sup>77</sup> Department of Physics and Astronomy, University College London, London, UK
- <sup>78</sup> Louisiana Tech University, Ruston, LA, USA
- <sup>79</sup> Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France
- <sup>80</sup> Fysiska institutionen, Lunds universitet, Lund, Sweden
- <sup>81</sup> Departamento de Física Teórica C-15, Universidad Autónoma de Madrid, Madrid, Spain
- <sup>82</sup> Institut für Physik, Universität Mainz, Mainz, Germany
- <sup>83</sup> School of Physics and Astronomy, University of Manchester, Manchester, UK
- <sup>84</sup> CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France
- <sup>85</sup> Department of Physics, University of Massachusetts, Amherst, MA, USA
- <sup>86</sup> Department of Physics, McGill University, Montreal, QC, Canada
- <sup>87</sup> School of Physics, University of Melbourne, Melbourne, VIC, Australia
- <sup>88</sup> Department of Physics, The University of Michigan, Ann Arbor, MI, USA
- <sup>89</sup> Department of Physics and Astronomy, Michigan State University, East Lansing, MI, USA
- <sup>90</sup> (a) INFN Sezione di Milano, Milan, Italy; (b) Dipartimento di Fisica, Università di Milano, Milan, Italy
- <sup>91</sup> B.I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk, Republic of Belarus
- <sup>92</sup> National Scientific and Educational Centre for Particle and High Energy Physics, Minsk, Republic of Belarus
- <sup>93</sup> Department of Physics, Massachusetts Institute of Technology, Cambridge, MA, USA
- <sup>94</sup> Group of Particle Physics, University of Montreal, Montreal, QC, Canada
- <sup>95</sup> P.N. Lebedev Institute of Physics, Academy of Sciences, Moscow, Russia
- <sup>96</sup> Institute for Theoretical and Experimental Physics (ITEP), Moscow, Russia
- <sup>97</sup> Moscow Engineering and Physics Institute (MEPhI), Moscow, Russia
- <sup>98</sup> D.V. Skobeltsyn Institute of Nuclear Physics, M.V. Lomonosov Moscow State University, Moscow, Russia
- <sup>99</sup> Fakultät für Physik, Ludwig-Maximilians-Universität München, Munich, Germany
- <sup>100</sup> Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), Munich, Germany
- <sup>101</sup> Nagasaki Institute of Applied Science, Nagasaki, Japan
- <sup>102</sup> Graduate School of Science and Kobayashi-Maskawa Institute, Nagoya University, Nagoya, Japan
- <sup>103</sup> (a) INFN Sezione di Napoli, Naples, Italy; (b) Dipartimento di Fisica, Università di Napoli, Naples, Italy
- <sup>104</sup> Department of Physics and Astronomy, University of New Mexico, Albuquerque, NM, USA
- <sup>105</sup> Institute for Mathematics, Astrophysics and Particle Physics, Radboud University Nijmegen/Nikhef, Nijmegen, The Netherlands
- <sup>106</sup> Nikhef National Institute for Subatomic Physics and University of Amsterdam, Amsterdam, The Netherlands

- <sup>107</sup> Department of Physics, Northern Illinois University, DeKalb, IL, USA  
<sup>108</sup> Budker Institute of Nuclear Physics, SB RAS, Novosibirsk, Russia  
<sup>109</sup> Department of Physics, New York University, New York, NY, USA  
<sup>110</sup> Ohio State University, Columbus, OH, USA  
<sup>111</sup> Faculty of Science, Okayama University, Okayama, Japan  
<sup>112</sup> Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman, OK, USA  
<sup>113</sup> Department of Physics, Oklahoma State University, Stillwater, OK, USA  
<sup>114</sup> Palacký University, RCPTM, Olomouc, Czech Republic  
<sup>115</sup> Center for High Energy Physics, University of Oregon, Eugene, OR, USA  
<sup>116</sup> LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France  
<sup>117</sup> Graduate School of Science, Osaka University, Osaka, Japan  
<sup>118</sup> Department of Physics, University of Oslo, Oslo, Norway  
<sup>119</sup> Department of Physics, Oxford University, Oxford, UK  
<sup>120</sup> (a) INFN Sezione di Pavia, Pavia, Italy; (b) Dipartimento di Fisica, Università di Pavia, Pavia, Italy  
<sup>121</sup> Department of Physics, University of Pennsylvania, Philadelphia, PA, USA  
<sup>122</sup> Petersburg Nuclear Physics Institute, Gatchina, Russia  
<sup>123</sup> (a) INFN Sezione di Pisa, Pisa, Italy; (b) Dipartimento di Fisica E. Fermi, Università di Pisa, Pisa, Italy  
<sup>124</sup> Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh, PA, USA  
<sup>125</sup> (a) Laboratório de Instrumentação e Física Experimental de Partículas-LIP, Lisbon, Portugal; (b) Faculdade de Ciências, Universidade de Lisboa, Lisbon, Portugal; (c) Department of Physics, University of Coimbra, Coimbra, Portugal; (d) Centro de Física Nuclear da Universidade de Lisboa, Lisbon, Portugal; (e) Departamento de Física, Universidade do Minho, Braga, Portugal; (f) Departamento de Física Teórica y del Cosmos and CAFPE, Universidad de Granada, Granada, Spain; (g) Dep Física and CEFITEC of Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Caparica, Portugal  
<sup>126</sup> Institute of Physics, Academy of Sciences of the Czech Republic, Prague, Czech Republic  
<sup>127</sup> Czech Technical University in Prague, Prague, Czech Republic  
<sup>128</sup> Faculty of Mathematics and Physics, Charles University in Prague, Prague, Czech Republic  
<sup>129</sup> State Research Center Institute for High Energy Physics, Protvino, Russia  
<sup>130</sup> Particle Physics Department, Rutherford Appleton Laboratory, Didcot, UK  
<sup>131</sup> Physics Department, University of Regina, Regina, SK, Canada  
<sup>132</sup> Ritsumeikan University, Kusatsu, Shiga, Japan  
<sup>133</sup> (a) INFN Sezione di Roma, Rome, Italy; (b) Dipartimento di Fisica, Sapienza Università di Roma, Rome, Italy  
<sup>134</sup> (a) INFN Sezione di Roma Tor Vergata, Rome, Italy; (b) Dipartimento di Fisica, Università di Roma Tor Vergata, Rome, Italy  
<sup>135</sup> (a) INFN Sezione di Roma Tre, Rome, Italy; (b) Dipartimento di Matematica e Fisica, Università Roma Tre, Rome, Italy  
<sup>136</sup> (a) Faculté des Sciences Ain Chock, Réseau Universitaire de Physique des Hautes Energies-Université Hassan II, Casablanca, Morocco; (b) Centre National de l'Energie des Sciences Techniques Nucleaires, Rabat, Morocco; (c) Faculté des Sciences Semlalia, Université Cadi Ayyad, LPHEA-Marrakech, Marrakech, Morocco; (d) Faculté des Sciences, Université Mohamed Premier and LPTPM, Oujda, Morocco; (e) Faculté des Sciences, Université Mohammed V-Agdal, Rabat, Morocco  
<sup>137</sup> DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat à l'Energie Atomique et aux Energies Alternatives), Gif-sur-Yvette, France  
<sup>138</sup> Santa Cruz Institute for Particle Physics, University of California Santa Cruz, Santa Cruz, CA, USA  
<sup>139</sup> Department of Physics, University of Washington, Seattle, WA, USA  
<sup>140</sup> Department of Physics and Astronomy, University of Sheffield, Sheffield, UK  
<sup>141</sup> Department of Physics, Shinshu University, Nagano, Japan  
<sup>142</sup> Fachbereich Physik, Universität Siegen, Siegen, Germany  
<sup>143</sup> Department of Physics, Simon Fraser University, Burnaby, BC, Canada  
<sup>144</sup> SLAC National Accelerator Laboratory, Stanford, CA, USA  
<sup>145</sup> (a) Faculty of Mathematics, Physics and Informatics, Comenius University, Bratislava, Slovak Republic; (b) Department of Subnuclear Physics, Institute of Experimental Physics of the Slovak Academy of Sciences, Kosice, Slovak Republic

- 146 (a) Department of Physics, University of Cape Town, Cape Town, South Africa; (b) Department of Physics, University of Johannesburg, Johannesburg, South Africa; (c) School of Physics, University of the Witwatersrand, Johannesburg, South Africa
- 147 (a) Department of Physics, Stockholm University, Stockholm, Sweden; (b) The Oskar Klein Centre, Stockholm, Sweden
- 148 Physics Department, Royal Institute of Technology, Stockholm, Sweden
- 149 Departments of Physics and Astronomy and Chemistry, Stony Brook University, Stony Brook, NY, USA
- 150 Department of Physics and Astronomy, University of Sussex, Brighton, UK
- 151 School of Physics, University of Sydney, Sydney, Australia
- 152 Institute of Physics, Academia Sinica, Taipei, Taiwan
- 153 Department of Physics, Technion: Israel Institute of Technology, Haifa, Israel
- 154 Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel
- 155 Department of Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece
- 156 International Center for Elementary Particle Physics and Department of Physics, The University of Tokyo, Tokyo, Japan
- 157 Graduate School of Science and Technology, Tokyo Metropolitan University, Tokyo, Japan
- 158 Department of Physics, Tokyo Institute of Technology, Tokyo, Japan
- 159 Department of Physics, University of Toronto, Toronto, ON, Canada
- 160 (a) TRIUMF, Vancouver, BC, Canada; (b) Department of Physics and Astronomy, York University, Toronto, ON, Canada
- 161 Faculty of Pure and Applied Sciences, University of Tsukuba, Tsukuba, Japan
- 162 Department of Physics and Astronomy, Tufts University, Medford, MA, USA
- 163 Centro de Investigaciones, Universidad Antonio Narino, Bogota, Colombia
- 164 Department of Physics and Astronomy, University of California Irvine, Irvine, CA, USA
- 165 (a) INFN Gruppo Collegato di Udine, Sezione di Trieste, Udine, Italy; (b) ICTP, Trieste, Italy; (c) Dipartimento di Chimica, Fisica e Ambiente, Università di Udine, Udine, Italy
- 166 Department of Physics, University of Illinois, Urbana, IL, USA
- 167 Department of Physics and Astronomy, University of Uppsala, Uppsala, Sweden
- 168 Instituto de Física Corpuscular (IFIC) and Departamento de Física Atómica, Molecular y Nuclear and Departamento de Ingeniería Electrónica and Instituto de Microelectrónica de Barcelona (IMB-CNM), University of Valencia and CSIC, Valencia, Spain
- 169 Department of Physics, University of British Columbia, Vancouver, BC, Canada
- 170 Department of Physics and Astronomy, University of Victoria, Victoria, BC, Canada
- 171 Department of Physics, University of Warwick, Coventry, UK
- 172 Waseda University, Tokyo, Japan
- 173 Department of Particle Physics, The Weizmann Institute of Science, Rehovot, Israel
- 174 Department of Physics, University of Wisconsin, Madison, WI, USA
- 175 Fakultät für Physik und Astronomie, Julius-Maximilians-Universität, Würzburg, Germany
- 176 Fachbereich C Physik, Bergische Universität Wuppertal, Wuppertal, Germany
- 177 Department of Physics, Yale University, New Haven, CT, USA
- 178 Yerevan Physics Institute, Yerevan, Armenia
- 179 Centre de Calcul de l'Institut National de Physique Nucléaire et de Physique des Particules (IN2P3), Villeurbanne, France
- <sup>a</sup> Also at Department of Physics, King's College London, London, UK
- <sup>b</sup> Also at Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan
- <sup>c</sup> Also at Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom
- <sup>d</sup> Also at TRIUMF, Vancouver, BC, Canada
- <sup>e</sup> Also at Department of Physics, California State University, Fresno, CA, USA
- <sup>f</sup> Also at Tomsk State University, Tomsk, Russia
- <sup>g</sup> Also at CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France
- <sup>h</sup> Also at Università di Napoli Parthenope, Naples, Italy
- <sup>i</sup> Also at Institute of Particle Physics (IPP), Victoria, Canada
- <sup>j</sup> Also at Department of Physics, St. Petersburg State Polytechnical University, St. Petersburg, Russia
- <sup>k</sup> Also at Chinese University of Hong Kong, Hong Kong, China

- <sup>l</sup> Also at Department of Financial and Management Engineering, University of the Aegean, Chios, Greece
- <sup>m</sup> Also at Louisiana Tech University, Ruston, LA, USA
- <sup>n</sup> Also at Institutio Catalana de Recerca i Estudis Avancats, ICREA, Barcelona, Spain
- <sup>o</sup> Also at Department of Physics, The University of Texas at Austin, Austin, TX, USA
- <sup>p</sup> Also at Institute of Theoretical Physics, Ilia State University, Tbilisi, Georgia
- <sup>q</sup> Also at CERN, Geneva, Switzerland
- <sup>r</sup> Also at O Chadai Academic Production, Ochanomizu University, Tokyo, Japan
- <sup>s</sup> Also at Manhattan College, New York, NY, USA
- <sup>t</sup> Also at Novosibirsk State University, Novosibirsk, Russia
- <sup>u</sup> Also at Institute of Physics, Academia Sinica, Taipei, Taiwan
- <sup>v</sup> Also at LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France
- <sup>w</sup> Also at Academia Sinica Grid Computing, Institute of Physics, Academia Sinica, Taipei, Taiwan
- <sup>x</sup> Also at Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France
- <sup>y</sup> Also at School of Physical Sciences, National Institute of Science Education and Research, Bhubaneswar, India
- <sup>z</sup> Also at Dipartimento di Fisica, Sapienza Università di Roma, Rome, Italy
- <sup>aa</sup> Also at Moscow Institute of Physics and Technology State University, Dolgoprudny, Russia
- <sup>ab</sup> Also at Section de Physique, Université de Genève, Geneva, Switzerland
- <sup>ac</sup> Also at International School for Advanced Studies (SISSA), Trieste, Italy
- <sup>ad</sup> Also at Department of Physics and Astronomy, University of South Carolina, Columbia, SC, USA
- <sup>ae</sup> Also at School of Physics and Engineering, Sun Yat-sen University, Guangzhou, China
- <sup>af</sup> Also at Faculty of Physics, M.V. Lomonosov Moscow State University, Moscow, Russia
- <sup>ag</sup> Also at Moscow Engineering and Physics Institute (MEPhI), Moscow, Russia
- <sup>ah</sup> Also at Institute for Particle and Nuclear Physics, Wigner Research Centre for Physics, Budapest, Hungary
- <sup>ai</sup> Also at Department of Physics, Oxford University, Oxford, UK
- <sup>aj</sup> Also at Department of Physics, Nanjing University, Jiangsu, China
- <sup>ak</sup> Also at Institut für Experimentalphysik, Universität Hamburg, Hamburg, Germany
- <sup>al</sup> Also at Department of Physics, The University of Michigan, Ann Arbor, MI, USA
- <sup>am</sup> Also at Discipline of Physics, University of KwaZulu-Natal, Durban, South Africa
- <sup>an</sup> Also at University of Malaya, Department of Physics, Kuala Lumpur, Malaysia
- \* Deceased