

CERN-PH-EP-2012-258

Submitted to: Physics Letters B

arXiv:1210.5468v1 [hep-ex] 19 Oct 2012

## Search for pair production of heavy top-like quarks decaying to a high- $p_T$ $W$ boson and a $b$ quark in the lepton plus jets final state at $\sqrt{s} = 7$ TeV with the ATLAS detector

The ATLAS Collaboration

### Abstract

A search is presented for production of a heavy up-type quark ( $t'$ ) together with its antiparticle, assuming a significant branching ratio for subsequent decay into a  $W$  boson and a  $b$  quark. The search is based on  $4.7 \text{ fb}^{-1}$  of  $pp$  collisions at  $\sqrt{s} = 7$  TeV recorded in 2011 with the ATLAS detector at the CERN Large Hadron Collider. Data are analyzed in the lepton+jets final state, characterized by a high-transverse-momentum isolated electron or muon, large missing transverse momentum and at least three jets. The analysis strategy relies on the substantial boost of the  $W$  bosons in the  $t'\bar{t}'$  signal when  $m_{t'} \gtrsim 400$  GeV. No significant excess of events above the Standard Model expectation is observed and the result of the search is interpreted in the context of fourth-generation and vector-like quark models. Under the assumption of a branching ratio  $BR(t' \rightarrow Wb) = 1$ , a fourth-generation  $t'$  quark with mass lower than 656 GeV is excluded at 95% confidence level. In addition, in light of the recent discovery of a new boson of mass  $\sim 126$  GeV at the LHC, upper limits are derived in the two-dimensional plane of  $BR(t' \rightarrow Wb)$  versus  $BR(t' \rightarrow Ht)$ , where  $H$  is the Standard Model Higgs boson, for vector-like quarks of various masses.

# Search for pair production of heavy top-like quarks decaying to a high- $p_T$ $W$ boson and a $b$ quark in the lepton plus jets final state at $\sqrt{s} = 7$ TeV with the ATLAS detector

ATLAS Collaboration

---

## Abstract

A search is presented for production of a heavy up-type quark ( $t'$ ) together with its antiparticle, assuming a significant branching ratio for subsequent decay into a  $W$  boson and a  $b$  quark. The search is based on  $4.7 \text{ fb}^{-1}$  of  $pp$  collisions at  $\sqrt{s} = 7$  TeV recorded in 2011 with the ATLAS detector at the CERN Large Hadron Collider. Data are analyzed in the lepton+jets final state, characterized by a high-transverse-momentum isolated electron or muon, large missing transverse momentum and at least three jets. The analysis strategy relies on the substantial boost of the  $W$  bosons in the  $t'\bar{t}'$  signal when  $m_{t'} \gtrsim 400$  GeV. No significant excess of events above the Standard Model expectation is observed and the result of the search is interpreted in the context of fourth-generation and vector-like quark models. Under the assumption of a branching ratio  $BR(t' \rightarrow Wb) = 1$ , a fourth-generation  $t'$  quark with mass lower than 656 GeV is excluded at 95% confidence level. In addition, in light of the recent discovery of a new boson of mass  $\sim 126$  GeV at the LHC, upper limits are derived in the two-dimensional plane of  $BR(t' \rightarrow Wb)$  versus  $BR(t' \rightarrow Ht)$ , where  $H$  is the Standard Model Higgs boson, for vector-like quarks of various masses.

---

## 1. Introduction

Since the discovery of the top quark [1, 2], which completed the third generation of fundamental fermions in the quark sector of the Standard Model (SM) of particle physics, searches for heavier quarks have been of particular interest in high-energy physics research. These quarks are often present in new physics models aimed at solving some of the limitations of the SM.

One possibility is the addition of a fourth generation of heavy chiral fermions [3, 4], which can provide new sources of CP violation that could explain the matter-antimatter asymmetry in the universe. The new weak-isospin doublet contains heavy up-type ( $t'$ ) and down-type ( $b'$ ) quarks that mix with the lighter quarks via an extended CKM matrix. In order to be consistent with precision electroweak data, a relatively small mass splitting between the new quarks is required [5]. Assuming that  $m_{t'} - m_{b'} < m_W$ , where  $m_W$  is the  $W$  boson mass, the  $t'$  quark decays predominantly to a  $W$  boson and a down-type quark  $q$  ( $q = d, s, b$ ). Based on the mixing pattern of the known quarks, it is natural to expect that this quark would be dominantly

a  $b$  quark, which has motivated the assumption of  $BR(t' \rightarrow Wb) = 1$  in most experimental searches.

Another possibility is the addition of weak-isospin singlets, doublets or triplets of vector-like quarks [6], defined as quarks for which both chiralities have the same transformation properties under the electroweak group  $SU(2) \times U(1)$ . Vector-like quarks appear in many extensions of the SM such as little Higgs or extra-dimensional models. In these models, a top-partner quark, for simplicity referred to here as  $t'$ , often plays a key role in canceling the quadratic divergences in the Higgs boson mass induced by radiative corrections involving the top quark. Vector-like quarks can mix preferentially with third-generation quarks, as the mixing is proportional to the mass of the SM quark [7], and they present a richer phenomenology than chiral quarks in fourth-generation models. In particular, a vector-like  $t'$  quark has *a priori* three possible decay modes,  $t' \rightarrow Wb$ ,  $t' \rightarrow Zt$ , and  $t' \rightarrow Ht$ , with branching ratios that vary as a function of  $m_{t'}$  and depend on the weak-isospin quantum number of the  $t'$  quark. While all three decay modes can be sizable for a weak-isospin singlet, decays to only  $Zt$

and  $Ht$  are most natural for a doublet. In the case of a triplet, the  $t'$  quark can decay either as a singlet or a doublet depending on its hypercharge.

The large centre-of-mass energy ( $\sqrt{s}$ ) and integrated luminosity in proton-proton ( $pp$ ) collisions produced at the CERN Large Hadron Collider (LHC) offer a unique opportunity to probe these models. At the LHC, these new heavy quarks would be produced predominantly in pairs via the strong interaction for masses below  $O(1 \text{ TeV})$  [6], with sizable cross sections and clean experimental signatures. For higher masses, single production mediated by the electroweak interaction can potentially dominate, depending on the strength of the interaction between the  $t'$  quark and the weak gauge bosons.

Recent results of SM Higgs boson searches at the LHC have significantly impacted the prospects and focus of heavy-quark searches. In particular, the observation of a new boson by the ATLAS [8] and CMS [9] Collaborations with a mass of  $\sim 126 \text{ GeV}$  and couplings close to those expected for the SM Higgs boson disfavors [5, 10] fourth-generation models. These models predict a large increase in the production rate for  $gg \rightarrow H$ , which is in tension with searches in the  $H \rightarrow WW^{(*)}$  and  $H \rightarrow ZZ^{(*)}$  decay channels [11, 12]. These results severely constrain perturbative fourth-generation models, although they may not completely exclude them yet. For example, it has been pointed out that a fourth family of fermions can substantially modify the Higgs boson partial decay widths [13] and various scenarios may still remain viable [5, 14]. At the same time, the observation of this new boson raises the level of interest for vector-like quark searches, as  $t' \rightarrow Ht$  and  $b' \rightarrow Hb$  decays now have completely specified final states which offer an exciting opportunity for discovery of new heavy quarks.

In this Letter a search is presented for  $t'\bar{t}'$  production using  $pp$  collision data at  $\sqrt{s} = 7 \text{ TeV}$  collected with the ATLAS detector. The search is optimized for  $t'$  quark decays with large branching ratio to  $Wb$ . The lepton+jets final state signature, where one of the  $W$  bosons decays leptonically and the other hadronically, is considered. The most recent search by the ATLAS Collaboration in this final state [15] was based on  $1.04 \text{ fb}^{-1}$  of  $pp$  collisions at  $\sqrt{s} = 7 \text{ TeV}$  and, under the assumption of  $BR(t' \rightarrow Wb) = 1$ , excluded the existence of a  $t'$  quark with a mass below  $404 \text{ GeV}$  at 95% confidence level (CL). A more stringent lower 95% CL limit of  $m_{t'} > 570 \text{ GeV}$  [16] was ob-

tained by the CMS Collaboration using  $5.0 \text{ fb}^{-1}$  of data at  $\sqrt{s} = 7 \text{ TeV}$ . Searches have also been performed exploiting the dilepton signature resulting from the leptonic decay of both  $W$  bosons. A search by the ATLAS Collaboration in the dilepton final state using  $1.04 \text{ fb}^{-1}$  of data at  $\sqrt{s} = 7 \text{ TeV}$  obtained a lower 95% CL limit of  $m_{t'} > 350 \text{ GeV}$  [17]. This search did not attempt to identify the flavor of the jets, making a more relaxed assumption of  $BR(t' \rightarrow Wq) = 1$ , where  $q$  could be any down-type SM quark. A 95% CL limit of  $m_{t'} > 557 \text{ GeV}$  [18], assuming  $BR(t' \rightarrow Wb) = 1$ , was obtained by the CMS Collaboration using  $5.0 \text{ fb}^{-1}$  of data at  $\sqrt{s} = 7 \text{ TeV}$ .

In comparison with the previous result by the ATLAS Collaboration in the lepton+jets final state [15], the search presented in this Letter uses almost a factor of five more data and has revisited the overall strategy, as advocated in Refs. [19–21], to take advantage of the kinematic differences that exist between top quark and  $t'$  quark decays when  $m_{t'} \gtrsim 400 \text{ GeV}$ . In particular, the hadronically-decaying  $W$  boson can be reconstructed as a single isolated jet when it is sufficiently boosted, leading to a significantly improved sensitivity in comparison to previous searches. In addition, the result of this search is interpreted more generically in the context of vector-like quark models where  $BR(t' \rightarrow Wb)$  can be substantially smaller than unity. In this case the additional signals, other than  $t'\bar{t}' \rightarrow WbWb$ , contribute to the signal acceptance and are accounted for in the analysis.

## 2. ATLAS detector

The ATLAS detector [22] consists of an inner tracking system surrounded by a superconducting solenoid, electromagnetic and hadronic calorimeters, and a muon spectrometer. The inner tracking system is immersed in a 2 T axial magnetic field and consists of a silicon pixel detector, a silicon microstrip detector, and a transition radiation tracker, providing charged particle identification in the region  $|\eta| < 2.5$ <sup>1</sup>. The electromagnetic (EM)

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

sampling calorimeter uses lead and liquid-argon. The hadron calorimetry is based on two different detector technologies with either scintillator tiles or liquid argon as the active medium. The barrel hadronic calorimeter consists of scintillating tiles with steel plates as the absorber material. The end-cap and forward hadronic calorimeters both use liquid argon, and copper or tungsten as the absorber, respectively. The calorimeters provide coverage up to  $|\eta| = 4.9$ . The muon spectrometer consists of superconducting air-core toroids, a system of trigger chambers covering the range  $|\eta| < 2.4$ , and high-precision tracking chambers allowing muon momentum measurements in the range  $|\eta| < 2.7$ .

### 3. Data sample and event preselection

The data used in this analysis correspond to the full dataset recorded in 2011, and were acquired using single-electron and single-muon triggers. The corresponding integrated luminosity is  $4.7 \text{ fb}^{-1}$ .

The event preselection criteria closely follow those used in recent ATLAS top quark studies [23] and require exactly one isolated electron or muon with large transverse momentum ( $p_T$ ), at least three jets among which at least one is identified as originating from a  $b$  quark, and large missing transverse momentum ( $E_T^{\text{miss}}$ ).

Electron candidates are required to have transverse momentum  $p_T > 25 \text{ GeV}$  and  $|\eta| < 2.47$ , excluding the transition region ( $1.37 < |\eta| < 1.52$ ) between the barrel and endcap EM calorimeters. Muon candidates are required to satisfy  $p_T > 20 \text{ GeV}$  and  $|\eta| < 2.5$ . For leptons satisfying these  $p_T$  requirements the efficiencies of the relevant single-lepton triggers have reached their plateau values. To reduce background from non-prompt leptons produced in semileptonic  $b$ - or  $c$ -hadron decays, or in  $\pi^\pm/K^\pm$  decays, the selected leptons are required to be isolated, *i.e.* to have little calorimetric energy or track transverse momentum around them [24]. In this analysis  $\tau$  leptons are not explicitly reconstructed. Because of the high  $p_T$  threshold requirements, only a small fraction of  $\tau$  leptons decaying leptonically are reconstructed as electrons or muons, while the majority of  $\tau$  leptons decaying hadronically are reconstructed as jets.

Jets are reconstructed with the anti- $k_t$  algorithm [25] with radius parameter  $R = 0.4$ , from topological clusters [26] of energy deposits in the calorimeters, calibrated at the EM scale. These jets are then calibrated to the particle (truth) level [27]

using  $p_T$ - and  $\eta$ -dependent correction factors derived from a combination of data and simulation. Jets are required to have  $p_T > 25 \text{ GeV}$  and  $|\eta| < 2.5$ . To avoid selecting jets from other  $pp$  interactions in the same bunch crossing, at least 75% of the sum of the  $p_T$  of tracks associated with a jet is required to come from tracks compatible with originating from the identified hard-scatter primary vertex. This primary vertex is chosen among the reconstructed candidates as the one with the highest  $\sum p_T^2$  of associated tracks and is required to have at least three tracks with  $p_T > 0.4 \text{ GeV}$ .

To identify jets as originating from the hadronization of a  $b$  quark ( $b$  tagging), a continuous discriminant is produced by an algorithm [28] using multivariate techniques to combine information from the impact parameter of displaced tracks, as well as topological properties of secondary and tertiary decay vertices reconstructed within the jet. In the preselection, at least one jet is required to have a discriminant value larger than the point corresponding to an average efficiency in simulated  $t\bar{t}$  events of  $\sim 70\%$  for  $b$ -quark jets, of  $\sim 20\%$  for  $c$ -quark jets and of  $\sim 0.7\%$  for jets originating from light quarks ( $u, d, s$ ) or gluons.

The  $E_T^{\text{miss}}$  is constructed [29] from the vector sum of all calorimeter energy deposits<sup>2</sup> contained in topological clusters, calibrated at the energy scale of the associated high- $p_T$  object (*e.g.* jet or electron), and including contributions from selected muons. Background from multi-jet production is suppressed by the requirement  $E_T^{\text{miss}} > 35(20) \text{ GeV}$  in the electron (muon) channel, and  $E_T^{\text{miss}} + m_T > 60 \text{ GeV}$ , where  $m_T$  is the transverse mass<sup>3</sup> of the lepton and  $E_T^{\text{miss}}$ .

### 4. Background and signal modeling

After event preselection the main background is  $t\bar{t}$  production, with lesser contributions from the production of a  $W$  boson in association with jets

<sup>2</sup>Each calorimeter cluster/cell is considered a massless object and is assigned the four-momentum  $(E_{\text{cell}}, \vec{p}_{\text{cell}})$ , where  $E_{\text{cell}}$  is the measured energy and  $\vec{p}_{\text{cell}}$  is a vector of magnitude  $E_{\text{cell}}$  directed from  $(x, y, z) = (0, 0, 0)$  to the center of the cell.

<sup>3</sup>The transverse mass is defined by the formula  $m_T = \sqrt{2p_T^\ell E_T^{\text{miss}}(1 - \cos \Delta\phi)}$ , where  $p_T^\ell$  is the  $p_T$  of the lepton and  $\Delta\phi$  is the azimuthal angle separation between the lepton and  $E_T^{\text{miss}}$  directions.

( $W$ +jets) and multi-jet events. Small contributions arise from single top-quark,  $Z$ +jets and diboson production. Multi-jet events contribute to the selected sample mostly via the misidentification of a jet or a photon as an electron, or via the presence of a non-prompt lepton, *e.g.* from a semileptonic  $b$ - or  $c$ -hadron decay. The corresponding yield is estimated via a data-driven method [30], which compares the number of events obtained with either standard or relaxed criteria for the selection of leptons. For the  $W$ +jets background, the shape of the distributions of kinematic variables is estimated from simulation but the normalization is estimated from data using the predicted asymmetry between  $W^+$ +jets and  $W^-$ +jets production in  $pp$  collisions [31]. All other backgrounds, including the dominant  $t\bar{t}$  background, and the signal, are estimated from simulation and normalized to their theoretical cross sections.

Simulated samples of  $t\bar{t}$  and single top-quark backgrounds (in the s-channel and for the associated production with a  $W$  boson) are generated with MC@NLO v4.01 [32–34] using the CT10 set of parton distribution functions (PDFs) [35]. In the case of t-channel single-top quark production, the ACERMC v3.8 leading-order (LO) generator [36] with the MRST LO\*\* PDF set [37] is used. These samples are generated assuming a top quark mass of 172.5 GeV and are normalized to approximate next-to-next-to-LO (NNLO) theoretical cross sections [38–40] using the MSTW2008 NNLO PDF set [41]. Samples of  $W/Z$ +jets events are generated with up to five additional partons using the ALPGEN v2.13 [42] LO generator and the CTEQ6L1 PDF set [43]. The parton-shower and fragmentation steps are performed by HERWIG v6.520 [44] in the case of MC@NLO and ALPGEN, and by PYTHIA 6.421 [45] in the case of ACERMC. To avoid double-counting of partonic configurations in  $W/Z$ +jets events generated by both the matrix-element calculation and the parton shower, a matching scheme [46] is employed. The  $W$ +jets samples are generated separately for  $W$ +light jets,  $Wb\bar{b}$ +jets,  $Wc\bar{c}$ +jets, and  $Wc$ +jets, and their relative contributions are normalized using the fraction of  $b$ -tagged jets in  $W$ +1-jet and  $W$ +2-jets data control samples [47]. The  $Z$ +jets background is normalized to the inclusive NNLO theoretical cross section [48]. The diboson backgrounds are modeled using HERWIG with the MRST LO\*\* PDF set, and are normalized to their NLO theoretical cross sections [49]. In all cases where HERWIG is

used, the underlying event is simulated with JIMMY v4.31 [50].

For fourth-generation  $t'$  quark signals, samples are generated with PYTHIA using the CTEQ6.6 PDF set [43] for a range of masses,  $m_{t'}$ , from 400 GeV to 750 GeV in steps of 50 GeV. For vector-like  $t'$  signals, samples corresponding to a singlet  $t'$  quark decaying to  $Wb$ ,  $Zt$  and  $Ht$  are generated with the PROTOS v2.2 LO generator [6, 51] using the CTEQ6L1 PDF set, and interfaced to PYTHIA for the parton shower and fragmentation. The  $m_{t'}$  values considered range from 400 GeV to 600 GeV in steps of 50 GeV, and the Higgs boson mass is assumed to be 125 GeV. All Higgs boson decay modes are considered, with branching ratios as predicted by HDECAY [52]. For both types of signal, the samples are normalized to the approximate NNLO theoretical cross sections [38] using the MSTW2008 NNLO PDF set.

All simulated samples include multiple  $pp$  interactions and simulated events are weighted such that the distribution of the average number of interactions per bunch crossing agrees with data. The simulated samples are processed through a simulation [53] of the detector geometry and response using GEANT4 [54], and the same reconstruction software as the data. Simulated events are corrected so that the physics object identification efficiencies, energy scales and energy resolutions match those determined in data control samples, enriched in the physics objects of interest.

## 5. Final selection

After preselection, further background suppression is achieved by applying requirements aimed at exploiting the distinct kinematic features of the signal. The large  $t'$  quark mass results in energetic  $W$  bosons and  $b$  quarks in the final state with large angular separation between them, while the decay products from the boosted  $W$  bosons have small angular separation. The combination of these properties is very effective in suppressing the dominant  $t\bar{t}$  background since  $t\bar{t}$  events with boosted  $W$  boson configurations are rare, and are typically characterized by a small angular separation between the  $W$  boson and  $b$  quark from the top quark decay.

To take advantage of these properties, it is necessary to identify the hadronically-decaying  $W$  boson ( $W_{\text{had}}$ ) as well as the  $b$  jets in the event. The candidate  $b$  jets are defined as the two jets with the highest  $b$ -tag discriminant (although only one of them

	<i>loose</i> selection	<i>tight</i> selection
$t\bar{t}$	$94 \pm 26$	$4.2 \pm 2.9$
$W$ +jets	$5.4 \pm 4.2$	$2.0 \pm 1.4$
$Z$ +jets	$0.5 \pm 0.4$	$0.2 \pm 0.2$
Single top	$7.2 \pm 1.7$	$1.1 \pm 0.5$
Dibosons	$0.1 \pm 0.1$	$0.04 \pm 0.04$
Multi-jet	$5.9 \pm 8.4$	$3.8 \pm 3.2$
Total background	$113 \pm 30$	$11.3 \pm 4.8$
Data	122	11
$t'\bar{t}'(500 \text{ GeV})$		
$Wb : Zt : Ht = 1.0 : 0.0 : 0.0$	$47.4 \pm 6.3$	$28.2 \pm 3.6$
$Wb : Zt : Ht = 0.5 : 0.0 : 0.5$	$25.4 \pm 3.6$	$11.2 \pm 1.5$

Table 1: Number of observed events, integrated over the whole mass spectrum, compared to the SM expectation for the combined  $e$ +jets and  $\mu$ +jets channels after the *loose* and *tight* selections. The expected signal yields assuming  $m_{t'} = 500 \text{ GeV}$  for different values of  $BR(t' \rightarrow Wb)$ ,  $BR(t' \rightarrow Zt)$  and  $BR(t' \rightarrow Ht)$  are also shown. The case of  $BR(t' \rightarrow Wb) = 1$  corresponds to a fourth-generation  $t'$  quark. The quoted uncertainties include both statistical and systematic contributions.

is explicitly required to be  $b$  tagged in the event selection). Two types of  $W_{\text{had}}$  candidates are defined,  $W_{\text{had}}^{\text{type I}}$  and  $W_{\text{had}}^{\text{type II}}$ , depending on the angular separation between their decay products.  $W_{\text{had}}^{\text{type I}}$  is defined as a single jet with  $p_{\text{T}} > 250 \text{ GeV}$  and mass in the range of 60–110 GeV. The mass distribution for  $W_{\text{had}}^{\text{type I}}$  candidates, prior to the jet mass requirement itself, is shown in Fig. 1(a).  $W_{\text{had}}^{\text{type II}}$  is defined as a dijet system with  $p_{\text{T}} > 150 \text{ GeV}$ , angular separation <sup>4</sup>  $\Delta R(j, j) < 0.8$  and mass within the range of 60–110 GeV. If multiple pairs satisfy the above requirements, the one with mass closest to the nominal  $W$  boson mass is chosen. The mass distribution for  $W_{\text{had}}^{\text{type II}}$  candidates, prior to the dijet mass requirement, is shown in Fig. 1(b). In the construction of both types of  $W_{\text{had}}$  candidates, all selected jets except for the two candidate  $b$  jets are considered. Small discrepancies observed between the data and the background prediction, e.g. at low  $W_{\text{had}}^{\text{type II}}$  candidate invariant mass, are not significant and covered by the systematic uncertainties.

The leptonically-decaying  $W$  boson is reconstructed using the lepton and  $E_{\text{T}}^{\text{miss}}$ , identified as the neutrino  $p_{\text{T}}$ . Requiring that the invariant mass of the lepton–neutrino system equals the nominal

<sup>4</sup>The angular separation is defined as  $\Delta R = \sqrt{(\Delta\phi)^2 + (\Delta\eta)^2}$  where  $\phi$  is the azimuthal angle and  $\eta$  the pseudorapidity.

$W$  boson mass allows reconstruction of the neutrino longitudinal momentum up to a two-fold ambiguity. In case no real solution exists, the neutrino pseudorapidity is set equal to that of the lepton, since in the kinematic regime of interest for this analysis the decay products of the  $W$  boson tend to be collinear.

Two final selections, *loose* and *tight*, are defined. The *loose* selection considers events with either  $\geq 3$  jets, at least one of which is a  $W_{\text{had}}^{\text{type I}}$  candidate, or  $\geq 4$  jets, two of which combine to make at least one  $W_{\text{had}}^{\text{type II}}$  candidate, and no  $W_{\text{had}}^{\text{type I}}$  candidate. The events must satisfy  $H_{\text{T}} > 750 \text{ GeV}$ , where  $H_{\text{T}}$  is the scalar sum of the lepton  $p_{\text{T}}$ ,  $E_{\text{T}}^{\text{miss}}$  and the  $p_{\text{T}}$  of the four (or three if there are only three) highest- $p_{\text{T}}$  jets. The  $H_{\text{T}}$  distribution peaks at  $\sim 2m_{t'}$  for signal events, which makes the  $H_{\text{T}} > 750 \text{ GeV}$  requirement particularly efficient for signal with  $m_{t'} \gtrsim 400 \text{ GeV}$ , while rejecting a large fraction of the background. In addition, the highest- $p_{\text{T}}$   $b$ -jet candidate ( $b_1$ ) and the next-to-highest- $p_{\text{T}}$   $b$ -jet candidate ( $b_2$ ) are required to have  $p_{\text{T}} > 160 \text{ GeV}$  and  $p_{\text{T}} > 60 \text{ GeV}$ , respectively. Finally, the angular separation between the lepton and the reconstructed neutrino is required to satisfy  $\Delta R(\ell, \nu) < 1.4$ . The *tight* selection adds the following isolation requirements to the *loose* selection:  $\min(\Delta R(W_{\text{had}}, b_{1,2})) > 1.4$  and  $\min(\Delta R(\ell, b_{1,2})) > 1.4$ , which are particularly

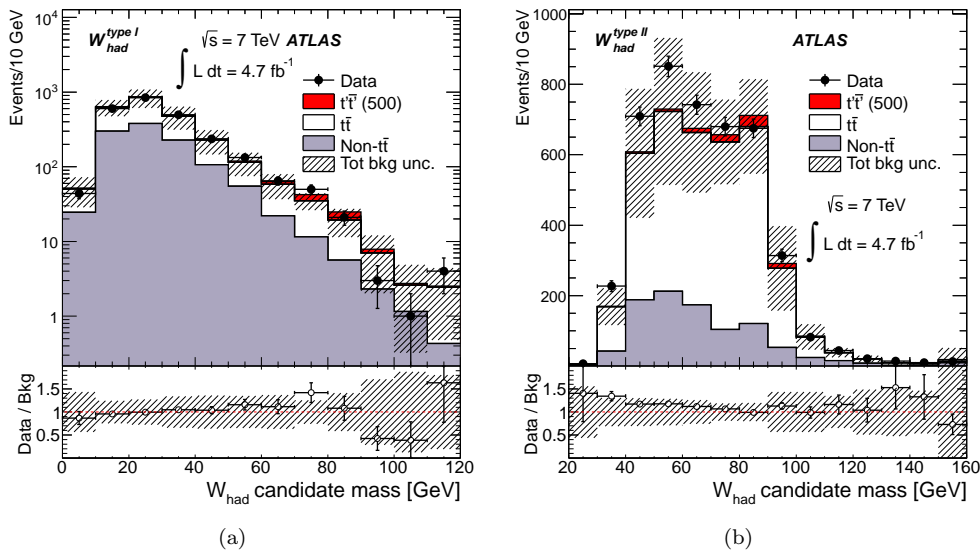


Figure 1: Distribution of the reconstructed mass for (a)  $W_{\text{had}}^{\text{type I}}$  and (b)  $W_{\text{had}}^{\text{type II}}$  candidates for the combined  $e+\text{jets}$  and  $\mu+\text{jets}$  channels after preselection. Figure (a) corresponds to events with  $\geq 3$  jets and  $\geq 1$   $W_{\text{had}}^{\text{type I}}$  candidates, while (b) corresponds to events with  $\geq 4$  jets and  $\geq 1$   $W_{\text{had}}^{\text{type II}}$  candidates (see text for details). The data (solid black points) are compared to the SM prediction (stacked histograms). The total uncertainty on the background estimation (see Section 7 for details) is shown as a black hashed band. The expected contribution from a fourth-generation  $t'$  quark with mass  $m_{t'} = 500$  GeV is also shown (red shaded histogram), stacked on top of the SM background. The last bin of each figure contains overflow events. The lower panel shows the ratio of data to SM prediction.

effective at suppressing  $t\bar{t}$  background. Table 1 presents a summary of the background estimates for the *loose* and *tight* selections, as well as a comparison of the total predicted and observed yields. The quoted uncertainties include both statistical and systematic contributions. The latter are discussed in Section 7. The predicted and observed yields are in agreement within these uncertainties.

## 6. Heavy-quark mass reconstruction

The main discriminant variable used in this search is the reconstructed heavy-quark mass ( $m_{\text{reco}}$ ), built from the  $W_{\text{had}}$  candidate and one of the two  $b$ -jet candidates. The reconstruction of the leptonically-decaying  $W$  boson usually yields two solutions, and there are two possible ways to pair the  $b$ -jet candidates with the  $W$  boson candidates to form the heavy quarks. Among the four possible combinations, the one yielding the smallest absolute difference between the two reconstructed heavy quark masses is chosen. The resulting  $m_{\text{reco}}$  distributions in Fig. 2 show that the SM background has been effectively suppressed, and that, as is most visible for the *loose* selection, good discrimination

between signal and background is achieved. The small contributions from  $W+\text{jets}$ ,  $Z+\text{jets}$ , diboson, single-top and multi-jet events are combined into a single background source referred to as non- $t\bar{t}$ . It was verified *a priori* that the *tight* selection has the best sensitivity, and it is therefore chosen to derive the final result for the search. The *loose* selection, displaying a significant  $t\bar{t}$  background at low  $m_{\text{reco}}$  which is in good agreement with the expectation, provides further confidence in the background modeling prior to the application of  $b$ -jet isolation requirements in the *tight* selection.

## 7. Systematic uncertainties

Systematic uncertainties affecting the normalization and shape of the  $m_{\text{reco}}$  distribution are estimated taking into account correlations.

Uncertainties affecting only the normalization include the integrated luminosity (3.9%), lepton identification and trigger efficiencies (2%), jet identification efficiency (2%), and cross sections for the various background processes. The uncertainties on the theoretical cross sections for  $t\bar{t}$ , single-top and diboson production are (+9.9/−10.7)% [38],

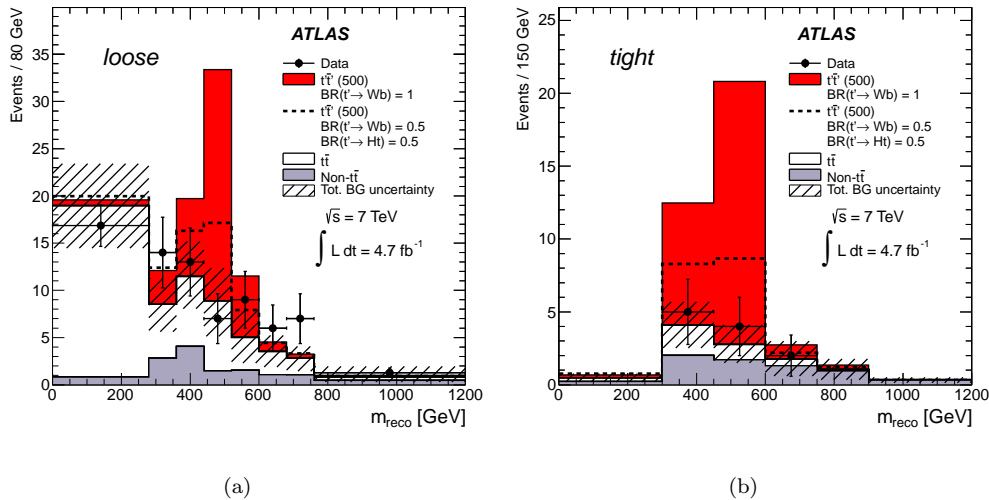


Figure 2: Distribution of  $m_{\text{reco}}$  for the combined  $e$ +jets and  $\mu$ +jets channels after the (a) *loose* and (b) *tight* selection. The data (solid black points) are compared to the SM prediction. The total uncertainty on the background estimation (see Section 7 for details) is shown as a black hashed band. Also shown, stacked on top of the SM background, are the expected contributions from a signal with mass  $m_{t'} = 500$  GeV for the case of  $BR(t' \rightarrow Wb) = 1$  (red shaded histogram), corresponding to a fourth-generation  $t'$  quark, as well as the case of  $BR(t' \rightarrow Wb) = BR(t' \rightarrow Ht) = 0.5$  (dashed black histogram). The overflow has been added to the last bin.

(+4.7/−3.7)% [39, 40], and  $\pm 5\%$  [49] respectively. A total uncertainty on the  $W$ +jets normalization of 58% is assumed, including contributions from uncertainties on the  $W$ +4-jets cross section (48%) [55], the heavy-flavor content measured in  $W$ +1,2-jets data samples (23%) [47], as well as its extrapolation to higher jet multiplicities (19%). The latter is estimated from the simulation where the  $W$ +heavy-flavor fractions are studied as a function of variations in the ALPGEN generator parameters. Similarly, the  $Z$ +jets normalization is assigned an uncertainty of 48% due to the dominant  $Z$ +4-jets contribution after final selection, which is evaluated at LO by ALPGEN. The multi-jet normalization is assigned an uncertainty of 80% including contributions from the limited size of the data sample (64%) as well as the uncertainty on the jet misidentification rate (50%) in the data-driven prediction.

The rest of the systematic uncertainties modify both the normalization and shape of the  $m_{\text{reco}}$  distribution. To indicate their magnitudes, their impact on the normalization for the *tight* selection is discussed in the following. Among the largest uncertainties affecting the  $t\bar{t}$  background are those related to modeling, such as (1) the choice of NLO event generator (evaluated by comparing MC@NLO and POWHEG [56]), (2) the modeling

of initial- and final-state QCD radiation (evaluated by varying the relevant parameters in PYTHIA in a range given by current experimental data [57]), and (3) the choice of parton-shower and fragmentation models (based on the comparison of HERWIG and PYTHIA). These result in  $t\bar{t}$  normalization uncertainties of 55%, 1% and 26%, respectively. The uncertainty on the jet energy scale [27] affects the normalization of the  $t't'$  signal,  $t\bar{t}$  background and non- $t\bar{t}$  backgrounds by  $\pm 6\%$ , (+22/−25)%, and (+19/−10)%, respectively. The uncertainties due to the jet energy resolution are 2%, 3% and 3%, respectively. Uncertainties associated with the jet mass scale and resolution, affecting the selection of  $W_{\text{had}}^{\text{type I}}$  candidates, are smaller in magnitude but are also taken into account. Uncertainties on the modeling of the  $b$ -tagging algorithms affect the identification of  $b$ ,  $c$  and light jets [28, 58, 59], and collectively result in uncertainties for the  $t't'$  signal, as well as the  $t\bar{t}$  and non- $t\bar{t}$  backgrounds, of (5–6)%. Other systematic uncertainties such as those on jet reconstruction efficiency or the effect of multiple  $pp$  interactions on the modeling of  $E_{\text{T}}^{\text{miss}}$  have been verified to be negligible.

In summary, taking into account all systematic uncertainties discussed above, the total uncertainty on the normalization affecting the *tight* selection for a  $t't'$  signal with  $m_{t'} = 500$  GeV,  $t\bar{t}$  and non- $t\bar{t}$



backgrounds is 11%, 67% and 50%, respectively.

## 8. Statistical analysis

In the absence of any significant data excess, the  $m_{\text{reco}}$  spectrum shown in Fig. 2(b) is used to derive 95% CL upper limits on the  $t'\bar{t}'$  production cross section using the  $CL_s$  method [60, 61]. This method employs a log-likelihood ratio  $LLR = -2\log(L_{s+b}/L_b)$  as test-statistic, where  $L_{s+b}$  ( $L_b$ ) is a binned likelihood function (product of Poisson probabilities) to observe the data under the signal-plus-background (background-only) hypothesis. Pseudo-experiments are generated for both hypotheses, taking into account per-bin statistical fluctuations of the total predictions according to Poisson statistics, as well as Gaussian fluctuations describing the effect of systematic uncertainties. The fraction of pseudo-experiments for the signal-plus-background (background-only) hypothesis with  $LLR$  larger than a given threshold defines  $CL_{s+b}$  ( $CL_b$ ). Such threshold is set to the observed (median)  $LLR$  for the observed (expected) limit. Signal cross sections for which  $CL_s = CL_{s+b}/CL_b < 0.05$  are deemed to be excluded at 95% CL. Dividing by  $CL_b$  avoids the possibility of mistakenly excluding a small signal due to a downward fluctuation of the background.

## 9. Results

The resulting observed and expected upper limits on the  $t'\bar{t}'$  production cross section are shown in Fig. 3 as a function of  $m_{t'}$ , and compared to the theoretical prediction, assuming  $BR(t' \rightarrow Wb) = 1$ . The total uncertainty on the theoretical cross section [38] includes the contributions from scale variations and PDF uncertainties. An observed (expected) 95% CL limit  $m_{t'} > 656$  (638) GeV is obtained for the central value of the theoretical cross section. This represents the most stringent limit to date on the mass of a fourth-generation  $t'$  quark decaying exclusively into a  $W$  boson and a  $b$  quark. This limit is also applicable to a down-type vector-like quark with electric charge of  $-4/3$  and decaying into a  $W$  boson and a  $b$  quark [6].

The same analysis is used to derive exclusion limits on vector-like  $t'$  quark production, for different values of  $m_{t'}$  and as a function of the two branching ratios  $BR(t' \rightarrow Wb)$  and  $BR(t' \rightarrow Ht)$ . The branching ratio  $BR(t' \rightarrow Zt)$  is fixed by  $BR(t' \rightarrow$

$Zt) = 1 - BR(t' \rightarrow Wb) - BR(t' \rightarrow Ht)$ . To probe this two-dimensional branching-ratio plane, the signal samples with the original branching ratios as generated by PROTOS are weighted. The resulting 95% CL exclusion limits are shown in Fig. 4 for different values of  $m_{t'}$ . For instance, a  $t'$  quark with a mass of 550 GeV and  $BR(t' \rightarrow Wb) > 0.63$  is excluded at  $\geq 95\%$  CL, regardless of the value of its branching ratios to  $Ht$  and  $Zt$ . All the decay modes contribute to the final sensitivity when setting limits. For example, assuming  $m_{t'} = 550$  GeV, the efficiency of the *tight* selection with at least four jets is 2.67%, 0.64%, 0.81%, 0.27%, 0.24% and 0.25%, for decays to  $WbWb$ ,  $WbHt$ ,  $WbZt$ ,  $ZtHt$ ,  $ZtZt$  and  $HtHt$ , respectively. The default predictions from PROTOS for the weak-isospin singlet and doublet cases are also shown. A weak-isospin singlet  $t'$  quark with  $400 \leq m_{t'} \leq 500$  GeV is excluded at  $\geq 95\%$  CL. It should be noted that since this analysis is optimized for  $m_{t'} \gtrsim 400$  GeV (recall the  $H_T > 750$  GeV requirement), it is not sensitive for vector-like quark scenarios where  $m_{t'} < 400$  GeV. The doublet scenarios are shown in Fig. 4 to illustrate the fact that this analysis has no sensitivity in these cases.

## 10. Conclusion

The strategy followed in this search, directly exploiting the distinct boosted signature expected in the decay of a heavy  $t'$  quark, has resulted in the most stringent limits to date on a fourth-generation  $t'$  quark. This approach shows great promise for improved sensitivity in future LHC searches at higher centre-of-mass energy and integrated luminosity. This search is also interpreted more generically in the context of vector-like quark models, resulting in the first quasi-model-independent exclusions in the two-dimensional plane of  $BR(t' \rightarrow Wb)$  versus  $BR(t' \rightarrow Ht)$ , for different values of the  $t'$  quark mass.

## Acknowledgements

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

We acknowledge the support of ANPCyT, Argentina; YerPhI, Armenia; ARC, Australia; BMWF and FWF, Austria; ANAS, Azerbaijan; SSTC, Belarus; CNPq and FAPESP, Brazil; NSERC, NRC

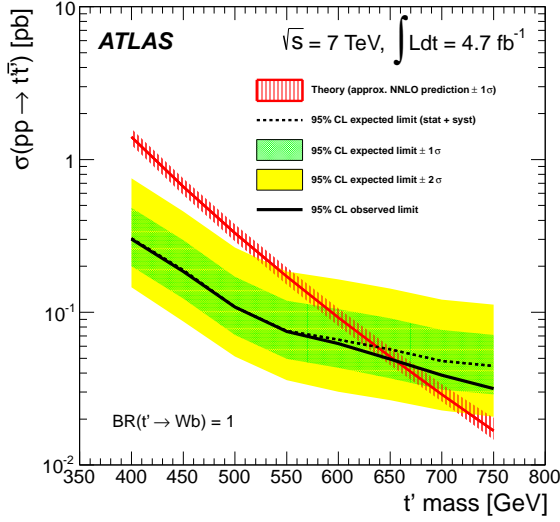


Figure 3: Observed (solid line) and expected (dashed line) 95% CL upper limits on the  $t't'$  cross section as a function of the  $t'$  quark mass. The surrounding shaded bands correspond to the  $\pm 1$  and  $\pm 2$  standard deviations around the expected limit. The thin red line and band show the theoretical prediction and its  $\pm 1$  standard deviation uncertainty.

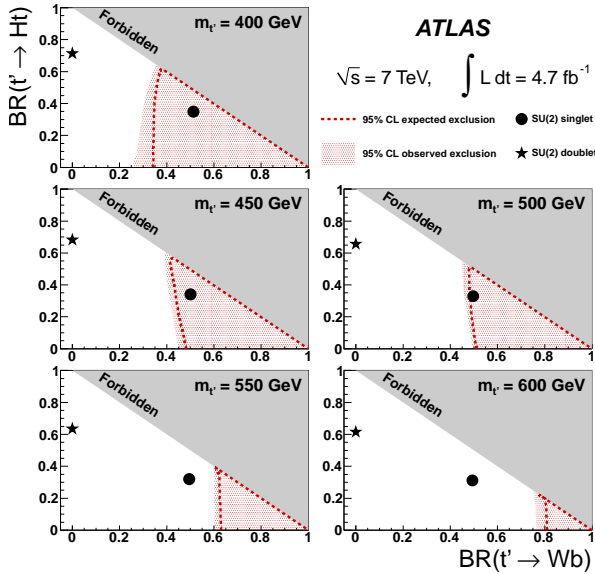


Figure 4: Observed (red filled area) and expected (red dashed line) 95% CL exclusion in the plane of  $BR(t' \rightarrow Ht)$  versus  $BR(t' \rightarrow Wb)$  for different values of the vector-like  $t'$  quark mass. The grey (dark shaded) area corresponds to the unphysical region where the sum of branching ratios exceeds unity. The default branching ratio values from the PROTONS event generator for the weak-isospin singlet and doublet cases are shown as plain circle and star symbols, respectively.

and CFI, Canada; CERN; CONICYT, Chile; CAS, MOST and NSFC, China; COLCIENCIAS, Colombia; MSMT CR, MPO CR and VSC CR, Czech Republic; D NRF, DNSRC and Lundbeck Foundation, Denmark; EPLANET and ERC, European Union; IN2P3-CNRS, CEA-DSM/IRFU, France; GNSF, Georgia; BMBF, DFG, HGF, MPG and AvH Foundation, Germany; GSRT, Greece; ISF, MINERVA, GIF, DIP and Benozziyo Center, Israel; INFN, Italy; MEXT and JSPS, Japan; CNRST, Morocco; FOM and NWO, Netherlands; BRF and RCN, Norway; MNiSW, Poland; GRICES and FCT, Portugal; MERYS (MECTS), Romania; MES of Russia and ROSATOM, Russian Federation; JINR; MSTD, Serbia; MSSR, Slovakia; ARRS and MVZT, Slovenia; DST/NRF, South Africa; MICINN, Spain; SRC and Wallenberg Foundation, Sweden; SER, SNSF and Cantons of Bern and Geneva, Switzerland; NSC, Taiwan; TAEK, Turkey; STFC, the Royal Society and Leverhulme Trust, United Kingdom; DOE and NSF, United States 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.

## References

- [1] F. Abe, et al. (CDF Collaboration), Observation of top quark production in  $p\bar{p}$  collisions, Phys. Rev. Lett. 74 (1995) 2626.
- [2] S. Abachi, et al. (D0 Collaboration), Observation of the top quark, Phys. Rev. Lett. 74 (1995) 2632.
- [3] B. Holdom, et al., Four statements about the fourth generation, PMC Physics A 3 (2009) 4.
- [4] S. A. Çetin, et al., Status of the Fourth Generation (2011). arXiv:1112.2907 [hep-ex].
- [5] M. Buchkremer, J.-M. Gérard, F. Maltoni, Closing in on a perturbative fourth generation (2012). arXiv:1204.5403 [hep-ex].
- [6] J. A. Aguilar-Saavedra, Identifying top partners at LHC, JHEP 11 (2009) 030.
- [7] F. del Aguila, M. J. Bowick, The Possibility of New Fermions with  $\Delta I = 0$  Mass, Nucl. Phys. B 224 (1983) 107.
- [8] ATLAS Collaboration, Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC, Phys. Lett. B 716 (2012) 1.
- [9] CMS Collaboration, Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC, Phys. Lett. B 716 (2012) 30.

- [10] A. Djouadi, A. Lenz, Sealing the fate of a fourth generation of fermions (2012). arXiv:1204.1252v2 [hep-ex].
- [11] ATLAS Collaboration, Update of the Combination of Higgs Boson Searches in 1.0 to 2.3 fb<sup>-1</sup> of *pp* Collisions Data Taken at  $\sqrt{s} = 7$  TeV with the ATLAS Experiment at the LHC (2011). ATLAS-CONF-2011-135.
- [12] CMS Collaboration, Combined results of searches for a Higgs boson in the context of the standard model and beyond-standard models (2012). CMS PAS HIG-12-008.
- [13] A. Denner, et al., Higgs production and decay with a fourth Standard-Model-like fermion generation (2012). arXiv:1111.6395 [hep-ex].
- [14] A. Rozanov, M. Vysotsky, Tevatron constraints on the Higgs boson mass in the fourth-generation fermion models revisited, Phys. Lett. B 700 (2011) 313.
- [15] ATLAS Collaboration, Search for pair production of a heavy up-type quark decaying to a *W* boson and a *b* quark in the lepton+jets channel with the ATLAS detector, Phys. Rev. Lett. 108 (2012) 261802.
- [16] CMS Collaboration, Search for pair produced fourth-generation up-type quarks in *pp* collisions at  $\sqrt{s} = 7$  TeV with a lepton in the final state (2012). arXiv:1209.0471 [hep-ex].
- [17] ATLAS Collaboration, Search for pair-produced heavy quarks decaying to *Wq* in the two-lepton channel at  $\sqrt{s} = 7$  TeV with the ATLAS detector, Phys. Rev. D 86 (2012) 012007.
- [18] CMS Collaboration, Search for heavy, top-like quark pair production in the dilepton final state in *pp* collisions at  $\sqrt{s} = 7$  TeV, Phys. Lett. B 716 (2012) 103.
- [19] B. Holdom, *t'* at the LHC: the physics of discovery, JHEP 03 (2007) 063.
- [20] B. Holdom, The heavy quark search at the LHC, JHEP 08 (2007) 069.
- [21] B. Holdom, Approaching a strong fourth family, Phys. Lett. B 686 (2010) 146.
- [22] ATLAS Collaboration, The ATLAS Experiment at the CERN Large Hadron Collider, JINST 3 (2008) S08003.
- [23] ATLAS Collaboration, Measurement of the top quark pair production cross-section with ATLAS in the single lepton channel, Phys. Lett. B 711 (2012) 244.
- [24] ATLAS Collaboration, Electron performance measurements with the ATLAS detector using the 2010 LHC proton-proton collision data, Eur. Phys. J. C 72 (2012) 1909.
- [25] M. Cacciari, G. P. Salam, G. Soyez, The anti-*k<sub>t</sub>* jet clustering algorithm, JHEP 04 (2008) 063.
- [26] W. Lampl, et al., Calorimeter clustering algorithms: Description and performance (2012). ATL-LARG-PUB-2008-002.
- [27] ATLAS Collaboration, Jet energy measurement with the ATLAS detector in proton-proton collisions at  $\sqrt{s} = 7$  TeV (2011). arXiv:1112.6426 [hep-ex].
- [28] ATLAS Collaboration, Measurement of the *b*-tagging efficiency in a sample of jets containing muons with 5 fb<sup>-1</sup> of data from the ATLAS detector (2012). ATLAS-CONF-2012-043.
- [29] ATLAS Collaboration, Performance of Missing Transverse Momentum Reconstruction in Proton-Proton Collisions at 7 TeV with ATLAS, Eur. Phys. J. C 72 (2012) 1844.
- [30] ATLAS Collaboration, Measurement of the top quark-pair production cross section with ATLAS in *pp* collisions at  $\sqrt{s} = 7$  TeV, Eur. Phys. J. C 71 (2011) 1577.
- [31] ATLAS Collaboration, Measurement of the charge asymmetry in top quark pair production in *pp* collisions at  $\sqrt{s} = 7$  TeV using the ATLAS detector, Eur. Phys. J. C 72 (2012) 2039.
- [32] S. Frixione, B. R. Webber, Matching NLO QCD computations and parton shower simulations, JHEP 06 (2002) 029.
- [33] S. Frixione, E. Laenen, P. Motylinski, B. R. Webber, Single-top production in MC@NLO, JHEP 03 (2006) 092.
- [34] S. Frixione, E. Laenen, P. Motylinski, C. White, B. R. Webber, Single-top hadroproduction in association with a *W* boson, JHEP 07 (2008) 029.
- [35] H.-L. Lai, et al., New parton distributions for collider physics, Phys. Rev. D 82 (2010) 074024.
- [36] B. P. Kersevan, E. Richter-Was, The Monte Carlo Event Generator AcerMC 2.0 with Interfaces to PYTHIA 6.2 and HERWIG 6.5 (2004). arXiv:0405247 [hep-ex].
- [37] A. Sherstnev, R. Thorne, Parton distributions for LO generators, Eur. Phys. J. C 55 (2008) 553.
- [38] M. Aliev, et al., HATHOR: a Hadronic Top and Heavy quarks cross section calculator, Comput. Phys. Commun. 182 (2011) 1034.
- [39] N. Kidonakis, Next-to-next-to-leading-order collinear and soft gluon corrections for *t*-channel single top quark production, Phys. Rev. D 83 (2011) 091503.
- [40] N. Kidonakis, Next-to-next-to-leading logarithm resummation for *s*-channel single top quark production, Phys. Rev. D 81 (2010) 054028.
- [41] A. D. Martin, et al., Parton distributions for the LHC, Eur. Phys. J. C 63 (2009) 189.
- [42] M. L. Mangano, et al., ALPGEN, a generator for hard multiparton processes in hadronic collisions, JHEP 07 (2003) 001.
- [43] P. M. Nadolsky, et al., Implications of CTEQ global analysis for collider observables, Phys. Rev. D 78 (2008) 013004.
- [44] G. Corcella, et al., HERWIG 6: an event generator for hadron emission reactions with interfering gluons (including supersymmetric processes), JHEP 01 (2001) 010.
- [45] T. Sjostrand, et al., High-energy-physics event generation with Pythia-6.1, Comput. Phys. Commun. 135 (2001) 238.
- [46] M. L. Mangano, et al., Multijet matrix elements and shower evolution in hadronic collisions: *Wb $\bar{b}$  + n* jets as a case study, Nucl. Phys. B 632 (2002) 343.
- [47] ATLAS Collaboration, Measurement of the *t*-channel single top-quark production cross section in *pp* collisions at  $\sqrt{s} = 7$  TeV with the ATLAS detector (2012). arXiv:1205.3130 [hep-ex].
- [48] K. Melnikov, F. Petriello, Electroweak gauge boson production at hadron colliders through  $\mathcal{O}(\alpha_s^2)$ , Phys. Rev. D 74 (2006) 114017.
- [49] J. Campbell, R. Ellis, An update on vector boson pair production at hadron colliders, Phys. Rev. D 60 (1999) 113006.
- [50] J. Butterworth, J. Forshaw, M. Seymour, Multiparton interactions in photoproduction at HERA, Z. Phys. C 72 (1996) 637.
- [51] J. A. Aguilar-Saavedra, PROTOS, a Program for Top Simulations (2009). <http://jaguilar.web.cern.ch/jaguilar/protos/>.
- [52] A. Djouadi, J. Kalinowski, M. Spira, Hdecay: a pro-

- gram for higgs boson decays in the standard model and its supersymmetric extension, *Comput. Phys. Commun.* 108 (1998) 56.
- [53] ATLAS Collaboration, The ATLAS Simulation Infrastructure, *Eur. Phys. J. C* 70 (2010) 823.
  - [54] S. Agostinelli, et al., Geant4: a simulation toolkit, *Nucl. Instr. Meth. A* 506 (2003) 250.
  - [55] J. Alwall, et al., Comparative study of various algorithms for the merging of parton showers and matrix elements in hadronic collisions, *Eur. Phys. J. C* 53 (2008) 473.
  - [56] P. Nason, A new method for combining NLO QCD with shower Monte Carlo algorithms, *JHEP* 11 (2004) 040.
  - [57] ATLAS Collaboration, Measurement of  $t\bar{t}$  production with a veto on additional central jet activity in  $pp$  collisions at  $\sqrt{s} = 7$  TeV using the ATLAS detector, *Eur. Phys. J. C* 72 (2012) 2043.
  - [58] ATLAS Collaboration,  $b$ -jet tagging calibration on  $c$ -jets containing  $D^{*+}$  mesons (2012). ATLAS-CONF-2012-039.
  - [59] ATLAS Collaboration, Measurement of the mistag rate of  $b$ -tagging algorithms with  $5 \text{ fb}^{-1}$  of data collected by the ATLAS detector (2012). ATLAS-CONF-2012-040.
  - [60] T. Junk, Confidence level computation for combining searches with small statistics, *Nucl. Instr. Meth. A* 434 (1999) 435.
  - [61] A. L. Read, Presentation of search results: the  $CL_s$  technique, *J. Phys. G* 28 (2002) 2693.

## The ATLAS Collaboration

G. Aad<sup>48</sup>, T. Abajyan<sup>21</sup>, B. Abbott<sup>111</sup>, J. Abdallah<sup>12</sup>, S. Abdel Khalek<sup>115</sup>, A.A. Abdelalim<sup>49</sup>, O. Abidinov<sup>11</sup>, R. Aben<sup>105</sup>, B. Abi<sup>112</sup>, M. Abolins<sup>88</sup>, O.S. AbouZeid<sup>158</sup>, H. Abramowicz<sup>153</sup>, H. Abreu<sup>136</sup>, B.S. Acharya<sup>164a,164b</sup>, L. Adamczyk<sup>38</sup>, D.L. Adams<sup>25</sup>, T.N. Addy<sup>56</sup>, J. Adelman<sup>176</sup>, S. Adomeit<sup>98</sup>, P. Adragna<sup>75</sup>, T. Adye<sup>129</sup>, S. Aefsky<sup>23</sup>, J.A. Aguilar-Saavedra<sup>124b,a</sup>, M. Agustoni<sup>17</sup>, M. Aharrouche<sup>81</sup>, S.P. Ahlen<sup>22</sup>, F. Ahles<sup>48</sup>, A. Ahmad<sup>148</sup>, M. Ahsan<sup>41</sup>, G. Aielli<sup>133a,133b</sup>, T.P.A. Åkesson<sup>79</sup>, G. Akimoto<sup>155</sup>, A.V. Akimov<sup>94</sup>, M.S. Alam<sup>2</sup>, M.A. Alam<sup>76</sup>, J. Albert<sup>169</sup>, S. Albrand<sup>55</sup>, M. Aleksa<sup>30</sup>, I.N. Aleksandrov<sup>64</sup>, F. Alessandria<sup>89a</sup>, C. Alexa<sup>26a</sup>, G. Alexander<sup>153</sup>, G. Alexandre<sup>49</sup>, T. Alexopoulos<sup>10</sup>, M. Alhroob<sup>164a,164c</sup>, M. Aliev<sup>16</sup>, G. Alimonti<sup>89a</sup>, J. Alison<sup>120</sup>, B.M.M. Allbrooke<sup>18</sup>, P.P. Allport<sup>73</sup>, S.E. Allwood-Spiers<sup>53</sup>, J. Almond<sup>82</sup>, A. Aloisio<sup>102a,102b</sup>, R. Alon<sup>172</sup>, A. Alonso<sup>79</sup>, F. Alonso<sup>70</sup>, A. Altheimer<sup>35</sup>, B. Alvarez Gonzalez<sup>88</sup>, M.G. Alviggi<sup>102a,102b</sup>, K. Amako<sup>65</sup>, C. Amelung<sup>23</sup>, V.V. Ammosov<sup>128,\*</sup>, S.P. Amor Dos Santos<sup>124a</sup>, A. Amorim<sup>124a,b</sup>, N. Amram<sup>153</sup>, C. Anastopoulos<sup>30</sup>, L.S. Ancu<sup>17</sup>, N. Andari<sup>115</sup>, T. Andeen<sup>35</sup>, C.F. Anders<sup>58b</sup>, G. Anders<sup>58a</sup>, K.J. Anderson<sup>31</sup>, A. Andreazza<sup>89a,89b</sup>, V. Andrei<sup>58a</sup>, M-L. Andrieux<sup>55</sup>, X.S. Anduaga<sup>70</sup>, S. Angelidakis<sup>9</sup>, P. Anger<sup>44</sup>, A. Angerami<sup>35</sup>, F. Anghinolfi<sup>30</sup>, A. Anisenkov<sup>107</sup>, N. Anjos<sup>124a</sup>, A. Annovi<sup>47</sup>, A. Antonaki<sup>9</sup>, M. Antonelli<sup>47</sup>, A. Antonov<sup>96</sup>, J. Antos<sup>144b</sup>, F. Anulli<sup>132a</sup>, M. Aoki<sup>101</sup>, S. Aoun<sup>83</sup>, L. Aperio Bella<sup>5</sup>, R. Apolle<sup>118,c</sup>, G. Arabidze<sup>88</sup>, I. Aracena<sup>143</sup>, Y. Arai<sup>65</sup>, A.T.H. Arce<sup>45</sup>, S. Arfaoui<sup>148</sup>, J-F. Arguin<sup>93</sup>, S. Argyropoulos<sup>42</sup>, E. Arik<sup>19a,\*</sup>, M. Arik<sup>19a</sup>, A.J. Armbruster<sup>87</sup>, O. Arnaez<sup>81</sup>, V. Arnal<sup>80</sup>, C. Arnault<sup>115</sup>, A. Artamonov<sup>95</sup>, G. Artoni<sup>132a,132b</sup>, D. Arutinov<sup>21</sup>, S. Asai<sup>155</sup>, S. Ask<sup>28</sup>, B. Åsman<sup>146a,146b</sup>, L. Asquith<sup>6</sup>, K. Assamagan<sup>25</sup>, A. Astbury<sup>169</sup>, M. Atkinson<sup>165</sup>, B. Aubert<sup>5</sup>, E. Auge<sup>115</sup>, K. Augsten<sup>127</sup>, M. Aourousseau<sup>145a</sup>, G. Avolio<sup>30</sup>, R. Avramidou<sup>10</sup>, D. Axen<sup>168</sup>, G. Azeleos<sup>93,d</sup>, Y. Azuma<sup>155</sup>, M.A. Baak<sup>30</sup>, G. Baccaglioni<sup>89a</sup>, C. Bacci<sup>134a,134b</sup>, A.M. Bach<sup>15</sup>, H. Bachacou<sup>136</sup>, K. Bachas<sup>30</sup>, M. Backes<sup>49</sup>, M. Backhaus<sup>21</sup>, J. Backus Mayes<sup>143</sup>, E. Badescu<sup>26a</sup>, P. Bagnaia<sup>132a,132b</sup>, S. Bahinipati<sup>3</sup>, Y. Bai<sup>33a</sup>, D.C. Bailey<sup>158</sup>, T. Bain<sup>158</sup>, J.T. Baines<sup>129</sup>, O.K. Baker<sup>176</sup>, M.D. Baker<sup>25</sup>, S. Baker<sup>77</sup>, P. Balek<sup>126</sup>, E. Banas<sup>39</sup>, P. Banerjee<sup>93</sup>, Sw. Banerjee<sup>173</sup>, D. Banfi<sup>30</sup>, A. Bangert<sup>150</sup>, V. Bansal<sup>169</sup>, H.S. Bansil<sup>18</sup>, L. Barak<sup>172</sup>, S.P. Baranov<sup>94</sup>, A. Barbaro Galtieri<sup>15</sup>, T. Barber<sup>48</sup>, E.L. Barberio<sup>86</sup>, D. Barberis<sup>50a,50b</sup>, M. Barbero<sup>21</sup>, D.Y. Bardin<sup>64</sup>, T. Barillari<sup>99</sup>, M. Barisonzi<sup>175</sup>, T. Barklow<sup>143</sup>, N. Barlow<sup>28</sup>, B.M. Barnett<sup>129</sup>, R.M. Barnett<sup>15</sup>, A. Baroncelli<sup>134a</sup>, G. Barone<sup>49</sup>, A.J. Barr<sup>118</sup>, F. Barreiro<sup>80</sup>, J. Barreiro Guimarães da Costa<sup>57</sup>, P. Barrillon<sup>115</sup>, R. Bartoldus<sup>143</sup>, A.E. Barton<sup>71</sup>, V. Bartsch<sup>149</sup>, A. Basye<sup>165</sup>, R.L. Bates<sup>53</sup>, L. Batkova<sup>144a</sup>, J.R. Batley<sup>28</sup>, A. Battaglia<sup>17</sup>, M. Battistin<sup>30</sup>, F. Bauer<sup>136</sup>, H.S. Bawa<sup>143,e</sup>, S. Beale<sup>98</sup>, T. Beau<sup>78</sup>, P.H. Beauchemin<sup>161</sup>, R. Beccherle<sup>50a</sup>, P. Bechtel<sup>21</sup>, H.P. Beck<sup>17</sup>, A.K. Becker<sup>175</sup>, S. Becker<sup>98</sup>, M. Beckingham<sup>138</sup>, K.H. Becks<sup>175</sup>, A.J. Beddall<sup>19c</sup>, A. Beddall<sup>19c</sup>, S. Bedikian<sup>176</sup>, V.A. Bednyakov<sup>64</sup>, C.P. Bee<sup>83</sup>, L.J. Beemster<sup>105</sup>, M. Begel<sup>25</sup>, S. Behar Harpaz<sup>152</sup>, P.K. Behera<sup>62</sup>, M. Beimforde<sup>99</sup>, C. Belanger-Champagne<sup>85</sup>, P.J. Bell<sup>49</sup>, W.H. Bell<sup>49</sup>, G. Bella<sup>153</sup>, L. Bellagamba<sup>20a</sup>, M. Bellomo<sup>30</sup>, A. Belloni<sup>57</sup>, O. Beloborodova<sup>107,f</sup>, K. Belotskiy<sup>96</sup>, O. Beltramello<sup>30</sup>, O. Benary<sup>153</sup>, D. Bencheekroun<sup>135a</sup>, K. Bendtz<sup>146a,146b</sup>, N. Benekos<sup>165</sup>, Y. Benhammou<sup>153</sup>, E. Benhar Noccioli<sup>49</sup>, J.A. Benitez Garcia<sup>159b</sup>, D.P. Benjamin<sup>45</sup>, M. Benoit<sup>115</sup>, J.R. Bensinger<sup>23</sup>, K. Benslama<sup>130</sup>, S. Bentvelsen<sup>105</sup>, D. Berge<sup>30</sup>, E. Bergeaas Kuutmann<sup>42</sup>, N. Berger<sup>5</sup>, F. Berghaus<sup>169</sup>, E. Berglund<sup>105</sup>, J. Beringer<sup>15</sup>, P. Bernat<sup>77</sup>, R. Bernhard<sup>48</sup>, C. Bernius<sup>25</sup>, T. Berry<sup>76</sup>, C. Bertella<sup>83</sup>, A. Bertin<sup>20a,20b</sup>, F. Bertolucci<sup>122a,122b</sup>, M.I. Besana<sup>89a,89b</sup>, G.J. Besjes<sup>104</sup>, N. Besson<sup>136</sup>, S. Bethke<sup>99</sup>, W. Bhimji<sup>46</sup>, R.M. Bianchi<sup>30</sup>, L. Bianchini<sup>23</sup>, M. Bianco<sup>72a,72b</sup>, O. Biebel<sup>98</sup>, S.P. Bieniek<sup>77</sup>, K. Bierwagen<sup>54</sup>, J. Biesiada<sup>15</sup>, M. Biglietti<sup>134a</sup>, H. Bilokon<sup>47</sup>, M. Bindi<sup>20a,20b</sup>, S. Binet<sup>115</sup>, A. Bingul<sup>19c</sup>, C. Bini<sup>132a,132b</sup>, C. Biscarat<sup>178</sup>, B. Bittner<sup>99</sup>, C.W. Black<sup>150</sup>, K.M. Black<sup>22</sup>, R.E. Blair<sup>6</sup>, J.-B. Blanchard<sup>136</sup>, G. Blanchot<sup>30</sup>, T. Blazek<sup>144a</sup>, I. Bloch<sup>42</sup>, C. Blocker<sup>23</sup>, J. Blocki<sup>39</sup>, A. Blondel<sup>49</sup>, W. Blum<sup>81</sup>, U. Blumenschein<sup>54</sup>, G.J. Bobbink<sup>105</sup>, V.B. Bobrovnikov<sup>107</sup>, S.S. Bocchetta<sup>79</sup>, A. Bocci<sup>45</sup>, C.R. Boddy<sup>118</sup>, M. Boehler<sup>48</sup>, J. Boek<sup>175</sup>, N. Boelaert<sup>36</sup>, J.A. Bogaerts<sup>30</sup>, A. Bogdanchikov<sup>107</sup>, A. Bogouch<sup>90,\*</sup>, C. Bohm<sup>146a</sup>, J. Bohm<sup>125</sup>, V. Boisvert<sup>76</sup>, T. Bold<sup>38</sup>, V. Boldea<sup>26a</sup>, N.M. Bolnet<sup>136</sup>, M. Bomben<sup>78</sup>, M. Bona<sup>75</sup>, M. Boonekamp<sup>136</sup>, S. Bordini<sup>78</sup>, C. Borer<sup>17</sup>, A. Borisov<sup>128</sup>, G. Borissov<sup>71</sup>, I. Borjanovic<sup>13a</sup>, M. Borri<sup>82</sup>, S. Borroni<sup>87</sup>, J. Bortfeldt<sup>98</sup>, V. Bortolotto<sup>134a,134b</sup>, K. Bos<sup>105</sup>, D. Boscherini<sup>20a</sup>, M. Bosman<sup>12</sup>, H. Boterenbrood<sup>105</sup>, J. Bouchami<sup>93</sup>, J. Boudreau<sup>123</sup>, E.V. Bouhova-Thacker<sup>71</sup>, D. Boumediene<sup>34</sup>, C. Bourdarios<sup>115</sup>, N. Bousson<sup>83</sup>, A. Boveia<sup>31</sup>, J. Boyd<sup>30</sup>, I.R. Boyko<sup>64</sup>, I. Bozovic-Jelisavcic<sup>13b</sup>, J. Bracinik<sup>18</sup>, P. Branchini<sup>134a</sup>, A. Brandt<sup>8</sup>, G. Brandt<sup>118</sup>,

O. Brandt<sup>54</sup>, U. Bratzler<sup>156</sup>, B. Brau<sup>84</sup>, J.E. Brau<sup>114</sup>, H.M. Braun<sup>175,\*</sup>, S.F. Brazzale<sup>164a,164c</sup>,  
 B. Brelrier<sup>158</sup>, J. Bremer<sup>30</sup>, K. Brendlinger<sup>120</sup>, R. Brenner<sup>166</sup>, S. Bressler<sup>172</sup>, D. Britton<sup>53</sup>, F.M. Brochu<sup>28</sup>,  
 I. Brock<sup>21</sup>, R. Brock<sup>88</sup>, F. Broggi<sup>89a</sup>, C. Bromberg<sup>88</sup>, J. Bronner<sup>99</sup>, G. Brooijmans<sup>35</sup>, T. Brooks<sup>76</sup>,  
 W.K. Brooks<sup>32b</sup>, G. Brown<sup>82</sup>, H. Brown<sup>8</sup>, P.A. Bruckman de Renstrom<sup>39</sup>, D. Bruncko<sup>144b</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>, T. Buanes<sup>14</sup>, Q. Buat<sup>55</sup>, F. Bucci<sup>49</sup>, J. Buchanan<sup>118</sup>,  
 P. Buchholz<sup>141</sup>, R.M. Buckingham<sup>118</sup>, A.G. Buckley<sup>46</sup>, S.I. Buda<sup>26a</sup>, I.A. Budagov<sup>64</sup>, B. Budick<sup>108</sup>,  
 V. Büscher<sup>81</sup>, L. Bugge<sup>117</sup>, O. Bulekov<sup>96</sup>, A.C. Bundock<sup>73</sup>, M. Bunse<sup>43</sup>, T. Buran<sup>117</sup>, H. Burckhart<sup>30</sup>,  
 S. Burdin<sup>73</sup>, T. Burgess<sup>14</sup>, S. Burke<sup>129</sup>, E. Busato<sup>34</sup>, P. Bussey<sup>53</sup>, C.P. Buszello<sup>166</sup>, B. Butler<sup>143</sup>,  
 J.M. Butler<sup>22</sup>, C.M. Buttar<sup>53</sup>, J.M. Butterworth<sup>77</sup>, W. Buttinger<sup>28</sup>, S. Cabrera Urbán<sup>167</sup>,  
 D. Caforio<sup>20a,20b</sup>, O. Cakir<sup>4a</sup>, P. Calafiura<sup>15</sup>, G. Calderini<sup>78</sup>, P. Calfayan<sup>98</sup>, R. Calkins<sup>106</sup>, L.P. Caloba<sup>24a</sup>,  
 R. Caloi<sup>132a,132b</sup>, D. Calvet<sup>34</sup>, S. Calvet<sup>34</sup>, R. Camacho Toro<sup>34</sup>, P. Camarri<sup>133a,133b</sup>, D. Cameron<sup>117</sup>,  
 L.M. Caminada<sup>15</sup>, R. Caminal Armadans<sup>12</sup>, S. Campana<sup>30</sup>, M. Campanelli<sup>77</sup>, V. Canale<sup>102a,102b</sup>,  
 F. Canelli<sup>31</sup>, A. Canepa<sup>159a</sup>, J. Cantero<sup>80</sup>, R. Cantrill<sup>76</sup>, L. Capasso<sup>102a,102b</sup>, M.D.M. Capeans Garrido<sup>30</sup>,  
 I. Caprini<sup>26a</sup>, M. Caprini<sup>26a</sup>, D. Capriotti<sup>99</sup>, M. Capua<sup>37a,37b</sup>, R. Caputo<sup>81</sup>, R. Cardarelli<sup>133a</sup>, T. Carli<sup>30</sup>,  
 G. Carlino<sup>102a</sup>, L. Carminati<sup>89a,89b</sup>, B. Caron<sup>85</sup>, S. Caron<sup>104</sup>, E. Carquin<sup>32b</sup>, G.D. Carrillo-Montoya<sup>145b</sup>,  
 A.A. Carter<sup>75</sup>, J.R. Carter<sup>28</sup>, J. Carvalho<sup>124a,g</sup>, D. Casadei<sup>108</sup>, M.P. Casado<sup>12</sup>, M. Cascella<sup>122a,122b</sup>,  
 C. Caso<sup>50a,50b,\*</sup>, A.M. Castaneda Hernandez<sup>173,h</sup>, E. Castaneda-Miranda<sup>173</sup>, V. Castillo Gimenez<sup>167</sup>,  
 N.F. Castro<sup>124a</sup>, G. Cataldi<sup>72a</sup>, P. Catastini<sup>57</sup>, A. Catinaccio<sup>30</sup>, J.R. Catmore<sup>30</sup>, A. Cattai<sup>30</sup>,  
 G. Cattani<sup>133a,133b</sup>, S. Caughron<sup>88</sup>, V. Cavaliere<sup>165</sup>, P. Cavalleri<sup>78</sup>, D. Cavalli<sup>89a</sup>, M. Cavalli-Sforza<sup>12</sup>,  
 V. Cavasinni<sup>122a,122b</sup>, F. Ceradini<sup>134a,134b</sup>, A.S. Cerqueira<sup>24b</sup>, A. Cerri<sup>30</sup>, L. Cerrito<sup>75</sup>, F. Cerutti<sup>47</sup>,  
 S.A. Cetin<sup>19b</sup>, A. Chafaq<sup>135a</sup>, D. Chakraborty<sup>106</sup>, I. Chalupkova<sup>126</sup>, K. Chan<sup>3</sup>, P. Chang<sup>165</sup>,  
 B. Chapleau<sup>85</sup>, J.D. Chapman<sup>28</sup>, J.W. Chapman<sup>87</sup>, E. Chareyre<sup>78</sup>, D.G. Charlton<sup>18</sup>, V. Chavda<sup>82</sup>,  
 C.A. Chavez Barajas<sup>30</sup>, S. Cheatham<sup>85</sup>, S. Chekanov<sup>6</sup>, S.V. Chekulaev<sup>159a</sup>, G.A. Chelkov<sup>64</sup>,  
 M.A. Chelstowska<sup>104</sup>, C. Chen<sup>63</sup>, H. Chen<sup>25</sup>, S. Chen<sup>33c</sup>, X. Chen<sup>173</sup>, Y. Chen<sup>35</sup>, Y. Cheng<sup>31</sup>,  
 A. Cheplakov<sup>64</sup>, R. Cherkaoui El Moursli<sup>135e</sup>, V. Chernyatin<sup>25</sup>, E. Cheu<sup>7</sup>, S.L. Cheung<sup>158</sup>, L. Chevalier<sup>136</sup>,  
 G. Chiefari<sup>102a,102b</sup>, L. Chikovani<sup>51a,\*</sup>, J.T. Childers<sup>30</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>, G. Choudalakis<sup>31</sup>, S. Chouridou<sup>137</sup>, I.A. Christidi<sup>77</sup>,  
 A. Christov<sup>48</sup>, D. Chromek-Burckhart<sup>30</sup>, M.L. Chu<sup>151</sup>, J. Chudoba<sup>125</sup>, G. Ciapetti<sup>132a,132b</sup>, A.K. Ciftci<sup>4a</sup>,  
 R. Ciftci<sup>4a</sup>, D. Cinca<sup>34</sup>, V. Cindro<sup>74</sup>, C. Ciocca<sup>20a,20b</sup>, A. Ciocio<sup>15</sup>, M. Cirilli<sup>87</sup>, P. Cirkovic<sup>13b</sup>,  
 Z.H. Citron<sup>172</sup>, M. Citterio<sup>89a</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>123</sup>,  
 J.C. Clemens<sup>83</sup>, B. Clement<sup>55</sup>, C. Clement<sup>146a,146b</sup>, Y. Coadou<sup>83</sup>, M. Cobal<sup>164a,164c</sup>, A. Cocco<sup>138</sup>,  
 J. Cochran<sup>63</sup>, L. Coffey<sup>23</sup>, J.G. Cogan<sup>143</sup>, J. Coggeshall<sup>165</sup>, E. Cogneras<sup>178</sup>, J. Colas<sup>5</sup>, S. Cole<sup>106</sup>,  
 A.P. Colijn<sup>105</sup>, N.J. Collins<sup>18</sup>, C. Collins-Tooth<sup>53</sup>, J. Collot<sup>55</sup>, T. Colombo<sup>119a,119b</sup>, G. Colon<sup>84</sup>,  
 G. Compostella<sup>99</sup>, P. Conde Muiño<sup>124a</sup>, E. Coniavitis<sup>166</sup>, M.C. Conidi<sup>12</sup>, S.M. Consonni<sup>89a,89b</sup>,  
 V. Consorti<sup>48</sup>, S. Constantinescu<sup>26a</sup>, C. Conta<sup>119a,119b</sup>, G. Conti<sup>57</sup>, F. Conventi<sup>102a,i</sup>, M. Cooke<sup>15</sup>,  
 B.D. Cooper<sup>77</sup>, A.M. Cooper-Sarkar<sup>118</sup>, K. Copic<sup>15</sup>, T. Cornelissen<sup>175</sup>, M. Corradi<sup>20a</sup>, F. Corriveau<sup>85,j</sup>,  
 A. Cortes-Gonzalez<sup>165</sup>, G. Cortiana<sup>99</sup>, G. Costa<sup>89a</sup>, M.J. Costa<sup>167</sup>, D. Costanzo<sup>139</sup>, D. Côté<sup>30</sup>,  
 L. Courneyea<sup>169</sup>, G. Cowan<sup>76</sup>, C. Cowden<sup>28</sup>, B.E. Cox<sup>82</sup>, K. Cranmer<sup>108</sup>, F. Crescioli<sup>122a,122b</sup>,  
 M. Cristinziani<sup>21</sup>, G. Crosetti<sup>37a,37b</sup>, S. Crépé-Renaudin<sup>55</sup>, C.-M. Cuciuc<sup>26a</sup>, C. Cuenca Almenar<sup>176</sup>,  
 T. Cuhadar Donszelmann<sup>139</sup>, J. Cummings<sup>176</sup>, M. Curatolo<sup>47</sup>, C.J. Curtis<sup>18</sup>, C. Cuthbert<sup>150</sup>,  
 P. Cwetanski<sup>60</sup>, H. Czirr<sup>141</sup>, P. Czodrowski<sup>44</sup>, Z. Czyczula<sup>176</sup>, S. D'Auria<sup>53</sup>, M. D'Onofrio<sup>73</sup>,  
 A. D'Orazio<sup>132a,132b</sup>, M.J. Da Cunha Sargedas De Sousa<sup>124a</sup>, C. Da Via<sup>82</sup>, W. Dabrowski<sup>38</sup>, A. Dafinca<sup>118</sup>,  
 T. Dai<sup>87</sup>, C. Dallapiccola<sup>84</sup>, M. Dam<sup>36</sup>, M. Dameri<sup>50a,50b</sup>, D.S. Damiani<sup>137</sup>, H.O. Danielsson<sup>30</sup>, V. Dao<sup>49</sup>,  
 G. Darbo<sup>50a</sup>, G.L. Darlea<sup>26b</sup>, J.A. Dassoulas<sup>42</sup>, W. Davey<sup>21</sup>, T. Davidek<sup>126</sup>, N. Davidson<sup>86</sup>, R. Davidson<sup>71</sup>,  
 E. Davies<sup>118,c</sup>, M. Davies<sup>93</sup>, O. Davignon<sup>78</sup>, A.R. Davison<sup>77</sup>, Y. Davygora<sup>58a</sup>, E. Dawe<sup>142</sup>, I. Dawson<sup>139</sup>,  
 R.K. Daya-Ishmukhametova<sup>23</sup>, K. De<sup>8</sup>, R. de Asmundis<sup>102a</sup>, S. De Castro<sup>20a,20b</sup>, S. De Cecco<sup>78</sup>,  
 J. de Graat<sup>98</sup>, N. De Groot<sup>104</sup>, P. de Jong<sup>105</sup>, C. De La Taille<sup>115</sup>, H. De la Torre<sup>80</sup>, F. De Lorenzi<sup>63</sup>,  
 L. de Mora<sup>71</sup>, L. De Nooij<sup>105</sup>, D. De Pedis<sup>132a</sup>, A. De Salvo<sup>132a</sup>, U. De Sanctis<sup>164a,164c</sup>, A. De Santo<sup>149</sup>,  
 J.B. De Vivie De Regie<sup>115</sup>, G. De Zorzi<sup>132a,132b</sup>, W.J. Dearnaley<sup>71</sup>, R. Debbe<sup>25</sup>, C. Debenedetti<sup>46</sup>,  
 B. Dechenaux<sup>55</sup>, D.V. Dedovich<sup>64</sup>, J. Degenhardt<sup>120</sup>, J. Del Peso<sup>80</sup>, T. Del Prete<sup>122a,122b</sup>,  
 T. Delemontex<sup>55</sup>, M. Deliyergiyev<sup>74</sup>, A. Dell'Acqua<sup>30</sup>, L. Dell'Asta<sup>22</sup>, M. Della Pietra<sup>102a,i</sup>,  
 D. della Volpe<sup>102a,102b</sup>, M. Delmastro<sup>5</sup>, P.A. Delsart<sup>55</sup>, C. Deluca<sup>105</sup>, S. Demers<sup>176</sup>, M. Demichev<sup>64</sup>,

B. Demirkoz<sup>12,k</sup>, S.P. Denisov<sup>128</sup>, D. Derendarz<sup>39</sup>, J.E. Derkaoui<sup>135d</sup>, F. Derue<sup>78</sup>, P. Dervan<sup>73</sup>, K. Desch<sup>21</sup>,  
 E. Devetak<sup>148</sup>, P.O. Deviveiros<sup>105</sup>, A. Dewhurst<sup>129</sup>, B. DeWilde<sup>148</sup>, S. Dhaliwal<sup>158</sup>, R. Dhullipudi<sup>25,l</sup>,  
 A. Di Ciaccio<sup>133a,133b</sup>, L. Di Ciaccio<sup>5</sup>, C. Di Donato<sup>102a,102b</sup>, A. Di Girolamo<sup>30</sup>, B. Di Girolamo<sup>30</sup>,  
 S. Di Luise<sup>134a,134b</sup>, A. Di Mattia<sup>173</sup>, B. Di Micco<sup>30</sup>, R. Di Nardo<sup>47</sup>, A. Di Simone<sup>133a,133b</sup>,  
 R. Di Sipio<sup>20a,20b</sup>, M.A. Diaz<sup>32a</sup>, E.B. Diehl<sup>87</sup>, J. Dietrich<sup>42</sup>, T.A. Dietzsch<sup>58a</sup>, S. Diglio<sup>86</sup>,  
 K. Dindar Yagci<sup>40</sup>, J. Dingfelder<sup>21</sup>, F. Dinut<sup>26a</sup>, C. Dionisi<sup>132a,132b</sup>, P. Dita<sup>26a</sup>, S. Dita<sup>26a</sup>, F. Dittus<sup>30</sup>,  
 F. Djama<sup>83</sup>, T. Djobava<sup>51b</sup>, M.A.B. do Vale<sup>24c</sup>, A. Do Valle Wemans<sup>124a,m</sup>, T.K.O. Doan<sup>5</sup>, M. Dobbs<sup>85</sup>,  
 D. Dobos<sup>30</sup>, E. Dobson<sup>30,n</sup>, J. Dodd<sup>35</sup>, C. Doglioni<sup>49</sup>, T. Doherty<sup>53</sup>, Y. Doi<sup>65,\*</sup>, J. Dolejsi<sup>126</sup>, I. Dolenc<sup>74</sup>,  
 Z. Dolezal<sup>126</sup>, B.A. Dolgoshein<sup>96,\*</sup>, T. Dohmae<sup>155</sup>, M. Donadelli<sup>24d</sup>, J. Donini<sup>34</sup>, J. Dopke<sup>30</sup>, A. Doria<sup>102a</sup>,  
 A. Dos Anjos<sup>173</sup>, A. Dotti<sup>122a,122b</sup>, M.T. Dova<sup>70</sup>, A.D. Doxiadis<sup>105</sup>, A.T. Doyle<sup>53</sup>, N. Dressnandt<sup>120</sup>,  
 M. Dris<sup>10</sup>, J. Dubbert<sup>99</sup>, S. Dube<sup>15</sup>, E. Duchovni<sup>172</sup>, G. Duckeck<sup>98</sup>, D. Duda<sup>175</sup>, A. Dudarev<sup>30</sup>,  
 F. Dudziak<sup>63</sup>, M. Dührssen<sup>30</sup>, I.P. Duerdoth<sup>82</sup>, L. Duflo<sup>115</sup>, M-A. Dufour<sup>85</sup>, L. Duguid<sup>76</sup>, M. Dunford<sup>58a</sup>,  
 H. Duran Yildiz<sup>4a</sup>, R. Duxfield<sup>139</sup>, M. Dwuznik<sup>38</sup>, M. Düren<sup>52</sup>, W.L. Ebenstein<sup>45</sup>, J. Ebke<sup>98</sup>,  
 S. Eckweiler<sup>81</sup>, K. Edmonds<sup>81</sup>, W. Edson<sup>2</sup>, C.A. Edwards<sup>76</sup>, N.C. Edwards<sup>53</sup>, W. Ehrenfeld<sup>42</sup>, T. Eifert<sup>143</sup>,  
 G. Eigen<sup>14</sup>, K. Einsweiler<sup>15</sup>, E. Eisenhandler<sup>75</sup>, T. Ekelof<sup>166</sup>, M. El Kacimi<sup>135c</sup>, M. Ellert<sup>166</sup>, S. Elles<sup>5</sup>,  
 F. Ellinghaus<sup>81</sup>, K. Ellis<sup>75</sup>, N. Ellis<sup>30</sup>, J. Elmsheuser<sup>98</sup>, M. Elsing<sup>30</sup>, D. Emelianov<sup>129</sup>, R. Engelmann<sup>148</sup>,  
 A. Engl<sup>98</sup>, B. Epp<sup>61</sup>, J. Erdmann<sup>54</sup>, A. Ereditato<sup>17</sup>, D. Eriksson<sup>146a</sup>, J. Ernst<sup>2</sup>, M. Ernst<sup>25</sup>, J. Ernwein<sup>136</sup>,  
 D. Errede<sup>165</sup>, S. Errede<sup>165</sup>, E. Ertel<sup>81</sup>, M. Escalier<sup>115</sup>, H. Esch<sup>43</sup>, C. Escobar<sup>123</sup>, X. Espinal Curull<sup>12</sup>,  
 B. Esposito<sup>47</sup>, F. Etienne<sup>83</sup>, A.I. Etienne<sup>136</sup>, E. Etzion<sup>153</sup>, D. Evangelakou<sup>54</sup>, H. Evans<sup>60</sup>, L. Fabbri<sup>20a,20b</sup>,  
 C. Fabre<sup>30</sup>, R.M. Fakhruddinov<sup>128</sup>, S. Falciano<sup>132a</sup>, Y. Fang<sup>173</sup>, M. Fanti<sup>89a,89b</sup>, A. Farbin<sup>8</sup>, A. Farilla<sup>134a</sup>,  
 J. Farley<sup>148</sup>, T. Farooque<sup>158</sup>, S. Farrell<sup>163</sup>, S.M. Farrington<sup>170</sup>, P. Farthouat<sup>30</sup>, F. Fassi<sup>167</sup>, P. Fassnacht<sup>30</sup>,  
 D. Fassouliotis<sup>9</sup>, B. Fatholahzadeh<sup>158</sup>, A. Favareto<sup>89a,89b</sup>, L. Fayard<sup>115</sup>, S. Fazio<sup>37a,37b</sup>, R. Febbraro<sup>34</sup>,  
 P. Federic<sup>144a</sup>, O.L. Fedin<sup>121</sup>, W. Fedorko<sup>88</sup>, M. Fehling-Kaschek<sup>48</sup>, L. Felgioni<sup>83</sup>, C. Feng<sup>33d</sup>, E.J. Feng<sup>6</sup>,  
 A.B. Fenyuk<sup>128</sup>, J. Ferencei<sup>144b</sup>, W. Fernando<sup>6</sup>, S. Ferrag<sup>53</sup>, J. Ferrando<sup>53</sup>, V. Ferrara<sup>42</sup>, A. Ferrari<sup>166</sup>,  
 P. Ferrari<sup>105</sup>, R. Ferrari<sup>119a</sup>, D.E. Ferreira de Lima<sup>53</sup>, A. Ferrer<sup>167</sup>, D. Ferrere<sup>49</sup>, C. Ferretti<sup>87</sup>,  
 A. Ferretto Parodi<sup>50a,50b</sup>, M. Fiascaris<sup>31</sup>, F. Fiedler<sup>81</sup>, A. Filipčić<sup>74</sup>, F. Filthaut<sup>104</sup>, M. Fincke-Keeler<sup>169</sup>,  
 M.C.N. Fiolhais<sup>124a,g</sup>, L. Fiorini<sup>167</sup>, A. Firan<sup>40</sup>, G. Fischer<sup>42</sup>, M.J. Fisher<sup>109</sup>, M. Flechl<sup>48</sup>, I. Fleck<sup>141</sup>,  
 J. Fleckner<sup>81</sup>, P. Fleischmann<sup>174</sup>, S. Fleischmann<sup>175</sup>, T. Flick<sup>175</sup>, A. Floderus<sup>79</sup>, L.R. Flores Castillo<sup>173</sup>,  
 M.J. Flowerdew<sup>99</sup>, T. Fonseca Martin<sup>17</sup>, A. Formica<sup>136</sup>, A. Forti<sup>82</sup>, D. Fortin<sup>159a</sup>, D. Fournier<sup>115</sup>,  
 A.J. Fowler<sup>45</sup>, H. Fox<sup>71</sup>, P. Francavilla<sup>12</sup>, M. Franchini<sup>20a,20b</sup>, S. Franchino<sup>119a,119b</sup>, D. Francis<sup>30</sup>,  
 T. Frank<sup>172</sup>, M. Franklin<sup>57</sup>, S. Franz<sup>30</sup>, M. Fraternali<sup>119a,119b</sup>, S. Fratina<sup>120</sup>, S.T. French<sup>28</sup>, C. Friedrich<sup>42</sup>,  
 F. Friedrich<sup>44</sup>, R. Froeschl<sup>30</sup>, D. Froidevaux<sup>30</sup>, J.A. Frost<sup>28</sup>, C. Fukunaga<sup>156</sup>, E. Fullana Torregrosa<sup>30</sup>,  
 B.G. Fulson<sup>143</sup>, J. Fuster<sup>167</sup>, C. Gabaldon<sup>30</sup>, O. Gabizon<sup>172</sup>, T. Gadfort<sup>25</sup>, S. Gadomski<sup>49</sup>,  
 G. Gagliardi<sup>50a,50b</sup>, P. Gagnon<sup>60</sup>, C. Galea<sup>98</sup>, B. Galhardo<sup>124a</sup>, E.J. Gallas<sup>118</sup>, V. Gallo<sup>17</sup>, B.J. Gallop<sup>129</sup>,  
 P. Gallus<sup>125</sup>, K.K. Gan<sup>109</sup>, Y.S. Gao<sup>143,e</sup>, A. Gaponenko<sup>15</sup>, F. Garbersson<sup>176</sup>, M. Garcia-Sciveres<sup>15</sup>,  
 C. García<sup>167</sup>, J.E. García Navarro<sup>167</sup>, R.W. Gardner<sup>31</sup>, N. Garelli<sup>30</sup>, H. Garitaonandia<sup>105</sup>, V. Garonne<sup>30</sup>,  
 C. Gatti<sup>47</sup>, G. Gaudio<sup>119a</sup>, B. Gaur<sup>141</sup>, L. Gauthier<sup>136</sup>, P. Gauzzi<sup>132a,132b</sup>, I.L. Gavrilenko<sup>94</sup>, C. Gay<sup>168</sup>,  
 G. Gaycken<sup>21</sup>, E.N. Gazis<sup>10</sup>, P. Ge<sup>33d</sup>, Z. Gecse<sup>168</sup>, C.N.P. Gee<sup>129</sup>, D.A.A. Geerts<sup>105</sup>, Ch. Geich-Gimbel<sup>21</sup>,  
 K. Gellerstedt<sup>146a,146b</sup>, C. Gemme<sup>50a</sup>, A. Gemmell<sup>53</sup>, M.H. Genest<sup>55</sup>, S. Gentile<sup>132a,132b</sup>, M. George<sup>54</sup>,  
 S. George<sup>76</sup>, P. Gerlach<sup>175</sup>, A. Gershon<sup>153</sup>, C. Geweniger<sup>58a</sup>, H. Ghazlane<sup>135b</sup>, N. Ghodbane<sup>34</sup>,  
 B. Giacobbe<sup>20a</sup>, S. Giagu<sup>132a,132b</sup>, V. Giakoumopoulou<sup>9</sup>, V. Giangiobbe<sup>12</sup>, F. Gianotti<sup>30</sup>, B. Gibbard<sup>25</sup>,  
 A. Gibson<sup>158</sup>, S.M. Gibson<sup>30</sup>, M. Gilchriese<sup>15</sup>, D. Gillberg<sup>29</sup>, A.R. Gillman<sup>129</sup>, D.M. Gingrich<sup>3,d</sup>,  
 J. Ginzburg<sup>153</sup>, N. Giokaris<sup>9</sup>, M.P. Giordani<sup>164c</sup>, R. Giordano<sup>102a,102b</sup>, F.M. Giorgi<sup>16</sup>, P. Giovannini<sup>99</sup>,  
 P.F. Giraud<sup>136</sup>, D. Giugni<sup>89a</sup>, M. Giunta<sup>93</sup>, B.K. Gjølsten<sup>117</sup>, L.K. Gladilin<sup>97</sup>, C. Glasman<sup>80</sup>, J. Glatzer<sup>21</sup>,  
 A. Glazov<sup>42</sup>, K.W. Glitza<sup>175</sup>, G.L. Glonti<sup>64</sup>, J.R. Goddard<sup>75</sup>, J. Godfrey<sup>142</sup>, J. Godlewski<sup>30</sup>, M. Goebel<sup>42</sup>,  
 T. Göpfert<sup>44</sup>, C. Goeringer<sup>81</sup>, C. Gössling<sup>43</sup>, S. Goldfarb<sup>87</sup>, T. Golling<sup>176</sup>, A. Gomes<sup>124a,b</sup>,  
 L.S. Gomez Fajardo<sup>42</sup>, R. Gonçalo<sup>76</sup>, J. Goncalves Pinto Firmino Da Costa<sup>42</sup>, L. Gonella<sup>21</sup>, S. González de  
 la Hoz<sup>167</sup>, G. Gonzalez Parra<sup>12</sup>, M.L. Gonzalez Silva<sup>27</sup>, S. Gonzalez-Sevilla<sup>49</sup>, J.J. Goodson<sup>148</sup>,  
 L. Goossens<sup>30</sup>, P.A. Gorbounov<sup>95</sup>, H.A. Gordon<sup>25</sup>, I. Gorelov<sup>103</sup>, G. Gorfine<sup>175</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>, M. Gosselink<sup>105</sup>, M.I. Gostkin<sup>64</sup>,  
 I. Gough Eschrich<sup>163</sup>, M. Gouighri<sup>135a</sup>, D. Goujdami<sup>135c</sup>, M.P. Goulette<sup>49</sup>, A.G. Goussiou<sup>138</sup>, C. Goy<sup>5</sup>,  
 S. Gozpinar<sup>23</sup>, I. Grabowska-Bold<sup>38</sup>, P. Grafström<sup>20a,20b</sup>, K.-J. Grahm<sup>42</sup>, E. Gramstad<sup>117</sup>,

F. Grancagnolo<sup>72a</sup>, S. Grancagnolo<sup>16</sup>, V. Grassi<sup>148</sup>, V. Gratchev<sup>121</sup>, N. Grau<sup>35</sup>, H.M. Gray<sup>30</sup>,  
 J.A. Gray<sup>148</sup>, E. Graziani<sup>134a</sup>, O.G. Grebenyuk<sup>121</sup>, T. Greenshaw<sup>73</sup>, Z.D. Greenwood<sup>25,l</sup>, K. Gregersen<sup>36</sup>,  
 I.M. Gregor<sup>42</sup>, P. Grenier<sup>143</sup>, J. Griffiths<sup>8</sup>, N. Grigalashvili<sup>64</sup>, A.A. Grillo<sup>137</sup>, S. Grinstein<sup>12</sup>, Ph. Gris<sup>34</sup>,  
 Y.V. Grishkevich<sup>97</sup>, J.-F. Grivaz<sup>115</sup>, E. Gross<sup>172</sup>, J. Grosse-Knetter<sup>54</sup>, J. Groth-Jensen<sup>172</sup>, K. Grybel<sup>141</sup>,  
 D. Guest<sup>176</sup>, C. Guicheney<sup>34</sup>, E. Guido<sup>50a,50b</sup>, S. Guindon<sup>54</sup>, U. Gul<sup>53</sup>, J. Gunther<sup>125</sup>, B. Guo<sup>158</sup>, J. Guo<sup>35</sup>,  
 P. Gutierrez<sup>111</sup>, N. Guttman<sup>153</sup>, O. Gutzwiller<sup>173</sup>, C. Guyot<sup>136</sup>, C. Gwenlan<sup>118</sup>, C.B. Gwilliam<sup>73</sup>,  
 A. Haas<sup>108</sup>, S. Haas<sup>30</sup>, C. Haber<sup>15</sup>, H.K. Hadavand<sup>8</sup>, D.R. Hadley<sup>18</sup>, P. Haefner<sup>21</sup>, F. Hahn<sup>30</sup>,  
 Z. Hajduk<sup>39</sup>, H. Hakobyan<sup>177</sup>, D. Hall<sup>118</sup>, K. Hamacher<sup>175</sup>, P. Hamal<sup>113</sup>, K. Hamano<sup>86</sup>, M. Hamer<sup>54</sup>,  
 A. Hamilton<sup>145b,o</sup>, S. Hamilton<sup>161</sup>, L. Han<sup>33b</sup>, K. Hanagaki<sup>116</sup>, K. Hanawa<sup>160</sup>, M. Hance<sup>15</sup>, C. Handel<sup>81</sup>,  
 P. Hanke<sup>58a</sup>, J.R. Hansen<sup>36</sup>, J.B. Hansen<sup>36</sup>, J.D. Hansen<sup>36</sup>, P.H. Hansen<sup>36</sup>, P. Hansson<sup>143</sup>, K. Hara<sup>160</sup>,  
 T. Harenberg<sup>175</sup>, S. Harkusha<sup>90</sup>, D. Harper<sup>87</sup>, R.D. Harrington<sup>46</sup>, O.M. Harris<sup>138</sup>, J. Hartert<sup>48</sup>,  
 F. Hartjes<sup>105</sup>, T. Haruyama<sup>65</sup>, A. Harvey<sup>56</sup>, S. Hasegawa<sup>101</sup>, Y. Hasegawa<sup>140</sup>, S. Hassani<sup>136</sup>, S. Haug<sup>17</sup>,  
 M. Hauschild<sup>30</sup>, R. Hauser<sup>88</sup>, M. Havranek<sup>21</sup>, C.M. Hawkes<sup>18</sup>, R.J. Hawkings<sup>30</sup>, A.D. Hawkins<sup>79</sup>,  
 T. Hayakawa<sup>66</sup>, T. Hayashi<sup>160</sup>, D. Hayden<sup>76</sup>, C.P. Hays<sup>118</sup>, H.S. Hayward<sup>73</sup>, S.J. Haywood<sup>129</sup>, S.J. Head<sup>18</sup>,  
 V. Hedberg<sup>79</sup>, L. Heelan<sup>8</sup>, S. Heim<sup>120</sup>, B. Heinemann<sup>15</sup>, S. Heisterkamp<sup>36</sup>, L. Helary<sup>22</sup>, C. Heller<sup>98</sup>,  
 M. Heller<sup>30</sup>, S. Hellman<sup>146a,146b</sup>, D. Hellmich<sup>21</sup>, C. Hensens<sup>12</sup>, R.C.W. Henderson<sup>71</sup>, M. Henke<sup>58a</sup>,  
 A. Henrichs<sup>176</sup>, A.M. Henriques Correia<sup>30</sup>, S. Henrot-Versille<sup>115</sup>, C. Hensel<sup>54</sup>, T. Henß<sup>175</sup>,  
 C.M. Hernandez<sup>8</sup>, Y. Hernández Jiménez<sup>167</sup>, R. Herrberg<sup>16</sup>, G. Hertel<sup>48</sup>, R. Hertenberger<sup>98</sup>, L. Hervás<sup>30</sup>,  
 G.G. Hesketh<sup>77</sup>, N.P. Hessey<sup>105</sup>, E. Higón-Rodríguez<sup>167</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>120</sup>, M. Hirose<sup>116</sup>, F. Hirsch<sup>43</sup>, D. Hirschbuehl<sup>175</sup>, J. Hobbs<sup>148</sup>,  
 N. Hod<sup>153</sup>, M.C. Hodgkinson<sup>139</sup>, P. Hodgson<sup>139</sup>, A. Hoecker<sup>30</sup>, M.R. Hoefkamp<sup>103</sup>, J. Hoffman<sup>40</sup>,  
 D. Hoffmann<sup>83</sup>, M. Höhlfeld<sup>81</sup>, M. Holder<sup>141</sup>, S.O. Holmgren<sup>146a</sup>, T. Holy<sup>127</sup>, J.L. Holzbauer<sup>88</sup>,  
 T.M. Hong<sup>120</sup>, L. Hooft van Huysduynen<sup>108</sup>, S. Horner<sup>48</sup>, J.-Y. Hostachy<sup>55</sup>, S. Hou<sup>151</sup>, A. Houmada<sup>135a</sup>,  
 J. Howard<sup>118</sup>, J. Howarth<sup>82</sup>, I. Hristova<sup>16</sup>, J. Hrivnac<sup>115</sup>, T. Hryn'ova<sup>5</sup>, P.J. Hsu<sup>81</sup>, S.-C. Hsu<sup>15</sup>, D. Hu<sup>35</sup>,  
 Z. Hubacek<sup>127</sup>, F. Hubaut<sup>83</sup>, F. Huegging<sup>21</sup>, A. Huettmann<sup>42</sup>, T.B. Huffman<sup>118</sup>, E.W. Hughes<sup>35</sup>,  
 G. Hughes<sup>71</sup>, M. Huhtinen<sup>30</sup>, M. Hurwitz<sup>15</sup>, N. Huseynov<sup>64,p</sup>, J. Huston<sup>88</sup>, J. Huth<sup>57</sup>, G. Iacobucci<sup>49</sup>,  
 G. Iakovidis<sup>10</sup>, M. Ibbotson<sup>82</sup>, I. Ibragimov<sup>141</sup>, L. Iconomidou-Fayard<sup>115</sup>, J. Idarraga<sup>115</sup>, P. Iengo<sup>102a</sup>,  
 O. Igonkina<sup>105</sup>, Y. Ikegami<sup>65</sup>, M. Ikeno<sup>65</sup>, D. Iliadis<sup>154</sup>, N. Ilic<sup>158</sup>, T. Ince<sup>99</sup>, P. Ioannou<sup>9</sup>, M. Iodice<sup>134a</sup>,  
 K. Iordanidou<sup>9</sup>, V. Ippolito<sup>132a,132b</sup>, A. Irlés Quiles<sup>167</sup>, C. Isaksson<sup>166</sup>, M. Ishino<sup>67</sup>, M. Ishitsuka<sup>157</sup>,  
 R. Ishmukhametov<sup>109</sup>, C. Issever<sup>118</sup>, S. Istin<sup>19a</sup>, A.V. Ivashin<sup>128</sup>, W. Iwanski<sup>39</sup>, H. Iwasaki<sup>65</sup>, J.M. Izen<sup>41</sup>,  
 V. Izzo<sup>102a</sup>, B. Jackson<sup>120</sup>, J.N. Jackson<sup>73</sup>, P. Jackson<sup>1</sup>, M.R. Jaekel<sup>30</sup>, V. Jain<sup>60</sup>, K. Jakobs<sup>48</sup>,  
 S. Jakobsen<sup>36</sup>, T. Jakoubek<sup>125</sup>, J. Jakubek<sup>127</sup>, D.O. Jamin<sup>151</sup>, D.K. Jana<sup>111</sup>, E. Jansen<sup>77</sup>, H. Jansen<sup>30</sup>,  
 J. Janssen<sup>21</sup>, A. Jantsch<sup>99</sup>, M. Janus<sup>48</sup>, R.C. Jared<sup>173</sup>, G. Jarlskog<sup>79</sup>, L. Jeanty<sup>57</sup>, I. Jen-La Plante<sup>31</sup>,  
 D. Jennens<sup>86</sup>, P. Jenni<sup>30</sup>, A.E. Loevschall-Jensen<sup>36</sup>, P. Jez<sup>36</sup>, S. Jézéquel<sup>5</sup>, M.K. Jha<sup>20a</sup>, H. Ji<sup>173</sup>, W. Ji<sup>81</sup>,  
 J. Jia<sup>148</sup>, Y. Jiang<sup>33b</sup>, M. Jimenez Belenguer<sup>42</sup>, S. Jin<sup>33a</sup>, O. Jinnouchi<sup>157</sup>, M.D. Joergensen<sup>36</sup>, D. Joffe<sup>40</sup>,  
 M. Johansen<sup>146a,146b</sup>, K.E. Johansson<sup>146a</sup>, P. Johansson<sup>139</sup>, S. Johnert<sup>42</sup>, K.A. Johns<sup>7</sup>,  
 K. Jon-And<sup>146a,146b</sup>, G. Jones<sup>170</sup>, R.W.L. Jones<sup>71</sup>, T.J. Jones<sup>73</sup>, C. Joram<sup>30</sup>, P.M. Jorge<sup>124a</sup>, K.D. Joshi<sup>82</sup>,  
 J. Jovicevic<sup>147</sup>, T. Jovin<sup>13b</sup>, X. Ju<sup>173</sup>, C.A. Jung<sup>43</sup>, R.M. Jungst<sup>30</sup>, V. Juránek<sup>125</sup>, P. Jussel<sup>61</sup>,  
 A. Juste Rozas<sup>12</sup>, S. Kabana<sup>17</sup>, M. Kaci<sup>167</sup>, A. Kaczmarska<sup>39</sup>, P. Kadlecik<sup>36</sup>, M. Kado<sup>115</sup>, H. Kagan<sup>109</sup>,  
 M. Kagan<sup>57</sup>, E. Kajomovitz<sup>152</sup>, S. Kalinin<sup>175</sup>, L.V. Kalinovskaya<sup>64</sup>, S. Kama<sup>40</sup>, N. Kanaya<sup>155</sup>,  
 M. Kaneda<sup>30</sup>, S. Kaneti<sup>28</sup>, T. Kanno<sup>157</sup>, V.A. Kantserov<sup>96</sup>, J. Kanzaki<sup>65</sup>, B. Kaplan<sup>108</sup>, A. Kapliy<sup>31</sup>,  
 J. Kaplon<sup>30</sup>, D. Kar<sup>53</sup>, M. Karagounis<sup>21</sup>, K. Karakostas<sup>10</sup>, M. Karnevskiy<sup>42</sup>, V. Kartvelishvili<sup>71</sup>,  
 A.N. Karyukhin<sup>128</sup>, L. Kashif<sup>173</sup>, G. Kasieczka<sup>58b</sup>, R.D. Kass<sup>109</sup>, A. Kastanas<sup>14</sup>, M. Kataoka<sup>5</sup>,  
 Y. Kataoka<sup>155</sup>, E. Katsoufis<sup>10</sup>, J. Katzy<sup>42</sup>, V. Kaushik<sup>7</sup>, K. Kawagoe<sup>69</sup>, T. Kawamoto<sup>155</sup>, G. Kawamura<sup>81</sup>,  
 M.S. Kayl<sup>105</sup>, S. Kazama<sup>155</sup>, V.A. Kazanin<sup>107</sup>, M.Y. Kazarinov<sup>64</sup>, R. Keeler<sup>169</sup>, P.T. Keener<sup>120</sup>,  
 R. Kehoe<sup>40</sup>, M. Keil<sup>54</sup>, G.D. Kekelidze<sup>64</sup>, J.S. Keller<sup>138</sup>, M. Kenyon<sup>53</sup>, O. Kepka<sup>125</sup>, N. Kerschen<sup>30</sup>,  
 B.P. Kerševan<sup>74</sup>, S. Kersten<sup>175</sup>, K. Kessoku<sup>155</sup>, J. Keung<sup>158</sup>, F. Khalil-zada<sup>11</sup>, H. Khandanyan<sup>146a,146b</sup>,  
 A. Khanov<sup>112</sup>, D. Kharchenko<sup>64</sup>, A. Khodinov<sup>96</sup>, A. Khomich<sup>58a</sup>, T.J. Khoo<sup>28</sup>, G. Khoriauli<sup>21</sup>,  
 A. Khoroshilov<sup>175</sup>, V. Khovanskiy<sup>95</sup>, E. Khramov<sup>64</sup>, J. Khubua<sup>51b</sup>, H. Kim<sup>146a,146b</sup>, S.H. Kim<sup>160</sup>,  
 N. Kimura<sup>171</sup>, O. Kind<sup>16</sup>, B.T. King<sup>73</sup>, M. King<sup>66</sup>, R.S.B. King<sup>118</sup>, J. Kirk<sup>129</sup>, A.E. Kiryunin<sup>99</sup>,  
 T. Kishimoto<sup>66</sup>, D. Kisielewska<sup>38</sup>, T. Kitamura<sup>66</sup>, T. Kittelmann<sup>123</sup>, K. Kiuchi<sup>160</sup>, E. Kladiva<sup>144b</sup>,  
 M. Klein<sup>73</sup>, U. Klein<sup>73</sup>, K. Kleinknecht<sup>81</sup>, M. Klemetti<sup>85</sup>, A. Klier<sup>172</sup>, P. Klimek<sup>146a,146b</sup>, A. Klimentov<sup>25</sup>,



R. Klingenberg<sup>43</sup>, J.A. Klinger<sup>82</sup>, E.B. Klinkby<sup>36</sup>, T. Klioutchnikova<sup>30</sup>, P.F. Klok<sup>104</sup>, S. Klous<sup>105</sup>,  
 E.-E. Kluge<sup>58a</sup>, T. Kluge<sup>73</sup>, P. Kluit<sup>105</sup>, S. Kluth<sup>99</sup>, E. Kneringer<sup>61</sup>, E.B.F.G. Knoop<sup>83</sup>, A. Knue<sup>54</sup>,  
 B.R. Ko<sup>45</sup>, T. Kobayashi<sup>155</sup>, M. Kobel<sup>44</sup>, M. Kocian<sup>143</sup>, P. Kodys<sup>126</sup>, K. Köneke<sup>30</sup>, A.C. König<sup>104</sup>,  
 S. Koenig<sup>81</sup>, L. Köpke<sup>81</sup>, F. Koetsveld<sup>104</sup>, P. Koevesarki<sup>21</sup>, T. Koffas<sup>29</sup>, E. Koffeman<sup>105</sup>, L.A. Kogan<sup>118</sup>,  
 S. Kohlmann<sup>175</sup>, F. Kohn<sup>54</sup>, Z. Kohout<sup>127</sup>, T. Kohriki<sup>65</sup>, T. Koi<sup>143</sup>, G.M. Kolachev<sup>107,\*</sup>, H. Kolanoski<sup>16</sup>,  
 V. Kolesnikov<sup>64</sup>, I. Koletsou<sup>89a</sup>, J. Koll<sup>88</sup>, A.A. Komar<sup>94</sup>, Y. Komori<sup>155</sup>, T. Kondo<sup>65</sup>, T. Kono<sup>42,q</sup>,  
 A.I. Kononov<sup>48</sup>, R. Konoplich<sup>108,r</sup>, N. Konstantinidis<sup>77</sup>, R. Kopeliansky<sup>152</sup>, S. Koperny<sup>38</sup>, K. Korcyl<sup>39</sup>,  
 K. Kordas<sup>154</sup>, A. Korn<sup>118</sup>, A. Korol<sup>107</sup>, I. Korolkov<sup>12</sup>, E.V. Korolkova<sup>139</sup>, V.A. Korotkov<sup>128</sup>, O. Kortner<sup>99</sup>,  
 S. Kortner<sup>99</sup>, V.V. Kostyukhin<sup>21</sup>, S. Kotov<sup>99</sup>, V.M. Kotov<sup>64</sup>, A. Kotwal<sup>45</sup>, C. Kourkoumelis<sup>9</sup>,  
 V. Kouskoura<sup>154</sup>, A. Koutsman<sup>159a</sup>, R. Kowalewski<sup>169</sup>, T.Z. Kowalski<sup>38</sup>, W. Kozanecki<sup>136</sup>, A.S. Kozhin<sup>128</sup>,  
 V. Kral<sup>127</sup>, V.A. Kramarenko<sup>97</sup>, G. Kramberger<sup>74</sup>, M.W. Krasny<sup>78</sup>, A. Krasznahorkay<sup>108</sup>, J.K. Kraus<sup>21</sup>,  
 S. Kreiss<sup>108</sup>, F. Krejci<sup>127</sup>, J. Kretzschmar<sup>73</sup>, N. Krieger<sup>54</sup>, P. Krieger<sup>158</sup>, K. Kroening<sup>54</sup>, H. Kroha<sup>99</sup>,  
 J. Kroll<sup>120</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>, M.K. Kruse<sup>45</sup>, T. Kubota<sup>86</sup>, S. Kuday<sup>4a</sup>, S. Kuehn<sup>48</sup>, A. Kugel<sup>58c</sup>, T. Kuhl<sup>42</sup>,  
 D. Kuhn<sup>61</sup>, V. Kukhtin<sup>64</sup>, Y. Kulchitsky<sup>90</sup>, S. Kuleshov<sup>32b</sup>, C. Kummer<sup>98</sup>, M. Kuna<sup>78</sup>, J. Kunkle<sup>120</sup>,  
 A. Kupco<sup>125</sup>, H. Kurashige<sup>66</sup>, M. Kurata<sup>160</sup>, Y.A. Kurochkin<sup>90</sup>, V. Kus<sup>125</sup>, E.S. Kuwertz<sup>147</sup>, M. Kuze<sup>157</sup>,  
 J. Kvita<sup>142</sup>, R. Kwee<sup>16</sup>, A. La Rosa<sup>49</sup>, L. La Rotonda<sup>37a,37b</sup>, L. Labarga<sup>80</sup>, J. Labbe<sup>5</sup>, S. Lablak<sup>135a</sup>,  
 C. Lacasta<sup>167</sup>, F. Lacava<sup>132a,132b</sup>, J. Lacey<sup>29</sup>, H. Lacker<sup>16</sup>, D. Lacour<sup>78</sup>, V.R. Lacuesta<sup>167</sup>, E. Ladygin<sup>64</sup>,  
 R. Lafaye<sup>5</sup>, B. Laforge<sup>78</sup>, T. Lagouri<sup>176</sup>, S. Lai<sup>48</sup>, E. Laisne<sup>55</sup>, L. Lambourne<sup>77</sup>, C.L. Lampen<sup>7</sup>,  
 W. Lampl<sup>7</sup>, E. Lancon<sup>136</sup>, U. Landgraf<sup>48</sup>, M.P.J. Landon<sup>75</sup>, V.S. Lang<sup>58a</sup>, C. Lange<sup>42</sup>, A.J. Lankford<sup>163</sup>,  
 F. Lanni<sup>25</sup>, K. Lantzschi<sup>175</sup>, S. Laplace<sup>78</sup>, C. Lapoire<sup>21</sup>, J.F. Laporte<sup>136</sup>, T. Lari<sup>89a</sup>, A. Larner<sup>118</sup>,  
 M. Lassnig<sup>30</sup>, P. Laurelli<sup>47</sup>, V. Lavorini<sup>37a,37b</sup>, W. Lavrijsen<sup>15</sup>, P. Laycock<sup>73</sup>, O. Le Dortz<sup>78</sup>,  
 E. Le Guirriec<sup>83</sup>, E. Le Menedeu<sup>12</sup>, T. LeCompte<sup>6</sup>, F. Ledroit-Guillon<sup>55</sup>, H. Lee<sup>105</sup>, J.S.H. Lee<sup>116</sup>,  
 S.C. Lee<sup>151</sup>, L. Lee<sup>176</sup>, M. Lefebvre<sup>169</sup>, M. Legendre<sup>136</sup>, F. Legger<sup>98</sup>, C. Leggett<sup>15</sup>, M. Lehmacher<sup>21</sup>,  
 G. Lehmann Miotto<sup>30</sup>, M.A.L. Leite<sup>24d</sup>, R. Leitner<sup>126</sup>, D. Lellouch<sup>172</sup>, B. Lemmer<sup>54</sup>, V. Lendermann<sup>58a</sup>,  
 K.J.C. Leney<sup>145b</sup>, T. Lenz<sup>105</sup>, G. Lenzen<sup>175</sup>, B. Lenzi<sup>30</sup>, K. Leonhardt<sup>44</sup>, S. Leontsinis<sup>10</sup>, F. Lepold<sup>58a</sup>,  
 C. Leroy<sup>93</sup>, J.-R. Lessard<sup>169</sup>, C.G. Lester<sup>28</sup>, C.M. Lester<sup>120</sup>, J. Levêque<sup>5</sup>, D. Levin<sup>87</sup>, L.J. Levinson<sup>172</sup>,  
 A. Lewis<sup>118</sup>, G.H. Lewis<sup>108</sup>, A.M. Leyko<sup>21</sup>, M. Leyton<sup>16</sup>, B. Li<sup>33b</sup>, B. Li<sup>83</sup>, H. Li<sup>148</sup>, H.L. Li<sup>31</sup>, S. Li<sup>33b,s</sup>,  
 X. Li<sup>87</sup>, Z. Liang<sup>118,t</sup>, H. Liao<sup>34</sup>, B. Liberti<sup>133a</sup>, P. Lichard<sup>30</sup>, M. Lichtnecker<sup>98</sup>, K. Lie<sup>165</sup>, W. Liebig<sup>14</sup>,  
 C. Limbach<sup>21</sup>, A. Limosani<sup>86</sup>, M. Limper<sup>62</sup>, S.C. Lin<sup>151,u</sup>, F. Linde<sup>105</sup>, J.T. Linnemann<sup>88</sup>, E. Lipeles<sup>120</sup>,  
 A. Lipniacka<sup>14</sup>, T.M. Liss<sup>165</sup>, D. Lissauer<sup>25</sup>, A. Lister<sup>49</sup>, A.M. Litke<sup>137</sup>, C. Liu<sup>29</sup>, D. Liu<sup>151</sup>, H. Liu<sup>87</sup>,  
 J.B. Liu<sup>87</sup>, L. Liu<sup>87</sup>, M. Liu<sup>33b</sup>, Y. Liu<sup>33b</sup>, M. Livan<sup>119a,119b</sup>, S.S.A. Livermore<sup>118</sup>, A. Lleres<sup>55</sup>,  
 J. Llorente Merino<sup>80</sup>, S.L. Lloyd<sup>75</sup>, E. Lobodzinska<sup>42</sup>, P. Loch<sup>7</sup>, W.S. Lockman<sup>137</sup>, T. Loddenkoetter<sup>21</sup>,  
 F.K. Loebinger<sup>82</sup>, A. Loginov<sup>176</sup>, C.W. Loh<sup>168</sup>, T. Lohse<sup>16</sup>, K. Lohwasser<sup>48</sup>, M. Lokajicek<sup>125</sup>,  
 V.P. Lombardo<sup>5</sup>, R.E. Long<sup>71</sup>, L. Lopes<sup>124a</sup>, D. Lopez Mateos<sup>57</sup>, J. Lorenz<sup>98</sup>, N. Lorenzo Martinez<sup>115</sup>,  
 M. Losada<sup>162</sup>, P. Loscutoff<sup>15</sup>, F. Lo Sterzo<sup>132a,132b</sup>, M.J. Losty<sup>159a,\*</sup>, X. Lou<sup>41</sup>, A. Lounis<sup>115</sup>,  
 K.F. Loureiro<sup>162</sup>, J. Love<sup>6</sup>, P.A. Love<sup>71</sup>, A.J. Lowe<sup>143,e</sup>, F. Lu<sup>33a</sup>, H.J. Lubatti<sup>138</sup>, C. Luci<sup>132a,132b</sup>,  
 A. Lucotte<sup>55</sup>, A. Ludwig<sup>44</sup>, D. Ludwig<sup>42</sup>, I. Ludwig<sup>48</sup>, J. Ludwig<sup>48</sup>, F. Luehring<sup>60</sup>, G. Luijckx<sup>105</sup>,  
 W. Lukas<sup>61</sup>, L. Luminari<sup>132a</sup>, E. Lund<sup>117</sup>, B. Lund-Jensen<sup>147</sup>, B. Lundberg<sup>79</sup>, J. Lundberg<sup>146a,146b</sup>,  
 O. Lundberg<sup>146a,146b</sup>, J. Lundquist<sup>36</sup>, M. Lungwitz<sup>81</sup>, D. Lynn<sup>25</sup>, E. Lytken<sup>79</sup>, H. Ma<sup>25</sup>, L.L. Ma<sup>173</sup>,  
 G. Maccarrone<sup>47</sup>, A. Macchiolo<sup>99</sup>, B. Maček<sup>74</sup>, J. Machado Miguens<sup>124a</sup>, D. Macina<sup>30</sup>, R. Mackeprang<sup>36</sup>,  
 R.J. Madaras<sup>15</sup>, H.J. Maddocks<sup>71</sup>, W.F. Mader<sup>44</sup>, R. Maenner<sup>58c</sup>, T. Maeno<sup>25</sup>, P. Mättig<sup>175</sup>, S. Mättig<sup>42</sup>,  
 L. Magnoni<sup>163</sup>, E. Magradze<sup>54</sup>, K. Mahboubi<sup>48</sup>, J. Mahlstedt<sup>105</sup>, S. Mahmoud<sup>73</sup>, G. Mahout<sup>18</sup>,  
 C. Maiani<sup>136</sup>, C. Maidantchik<sup>24a</sup>, A. Maio<sup>124a,b</sup>, S. Majewski<sup>25</sup>, Y. Makida<sup>65</sup>, N. Makovec<sup>115</sup>, P. Mal<sup>136</sup>,  
 B. Malaescu<sup>30</sup>, Pa. Malecki<sup>39</sup>, P. Malecki<sup>39</sup>, V.P. Maleev<sup>121</sup>, F. Malek<sup>55</sup>, U. Mallik<sup>62</sup>, D. Malon<sup>6</sup>,  
 C. Malone<sup>143</sup>, S. Maltezos<sup>10</sup>, V. Malyshev<sup>107</sup>, S. Malyukov<sup>30</sup>, R. Mameghani<sup>98</sup>, J. Mamuzic<sup>13b</sup>,  
 A. Manabe<sup>65</sup>, L. Mandelli<sup>89a</sup>, I. Mandić<sup>74</sup>, R. Mandrysch<sup>16</sup>, J. Maneira<sup>124a</sup>, A. Manfredini<sup>99</sup>,  
 L. Manhaes de Andrade Filho<sup>24b</sup>, J.A. Manjarres Ramos<sup>136</sup>, A. Mann<sup>54</sup>, P.M. Manning<sup>137</sup>,  
 A. Manousakis-Katsikakis<sup>9</sup>, B. Mansoulie<sup>136</sup>, A. Mapelli<sup>30</sup>, L. Mapelli<sup>30</sup>, L. March<sup>167</sup>, J.F. Marchand<sup>29</sup>,  
 F. Marchese<sup>133a,133b</sup>, G. Marchiori<sup>78</sup>, M. Marcisovsky<sup>125</sup>, C.P. Marino<sup>169</sup>, F. Marroquim<sup>24a</sup>, Z. Marshall<sup>30</sup>,  
 L.F. Marti<sup>17</sup>, S. Marti-Garcia<sup>167</sup>, B. Martin<sup>30</sup>, B. Martin<sup>88</sup>, J.P. Martin<sup>93</sup>, T.A. Martin<sup>18</sup>, V.J. Martin<sup>46</sup>,  
 B. Martin dit Latour<sup>49</sup>, S. Martin-Haugh<sup>149</sup>, M. Martinez<sup>12</sup>, V. Martinez Outschoorn<sup>57</sup>,

A.C. Martyniuk<sup>169</sup>, M. Marx<sup>82</sup>, F. Marzano<sup>132a</sup>, A. Marzin<sup>111</sup>, L. Masetti<sup>81</sup>, T. Mashimo<sup>155</sup>,  
 R. Mashinistov<sup>94</sup>, J. Masik<sup>82</sup>, A.L. Maslennikov<sup>107</sup>, I. Massa<sup>20a,20b</sup>, G. Massaro<sup>105</sup>, N. Massol<sup>5</sup>,  
 P. Mastrandrea<sup>148</sup>, A. Mastroberardino<sup>37a,37b</sup>, T. Masubuchi<sup>155</sup>, P. Matricon<sup>115</sup>, H. Matsunaga<sup>155</sup>,  
 T. Matsushita<sup>66</sup>, C. Mattravers<sup>118,c</sup>, J. Maurer<sup>83</sup>, S.J. Maxfield<sup>73</sup>, D.A. Maximov<sup>107,f</sup>, A. Mayne<sup>139</sup>,  
 R. Mazini<sup>151</sup>, M. Mazur<sup>21</sup>, L. Mazzaferro<sup>133a,133b</sup>, M. Mazzanti<sup>89a</sup>, J. Mc Donald<sup>85</sup>, S.P. Mc Kee<sup>87</sup>,  
 A. McCarn<sup>165</sup>, R.L. McCarthy<sup>148</sup>, T.G. McCarthy<sup>29</sup>, N.A. McCubbin<sup>129</sup>, K.W. McFarlane<sup>56,\*</sup>,  
 J.A. Mcfayden<sup>139</sup>, G. Mchedlidze<sup>51b</sup>, T. McLaughlan<sup>18</sup>, S.J. McMahon<sup>129</sup>, R.A. McPherson<sup>169,j</sup>,  
 A. Meade<sup>84</sup>, J. Mechnich<sup>105</sup>, M. Mechtel<sup>175</sup>, M. Medinnis<sup>42</sup>, S. Meehan<sup>31</sup>, R. Meera-Lebbai<sup>111</sup>,  
 T. Meguro<sup>116</sup>, S. Mehlhase<sup>36</sup>, A. Mehta<sup>73</sup>, K. Meier<sup>58a</sup>, B. Meirose<sup>79</sup>, C. Melachrinou<sup>31</sup>,  
 B.R. Mellado Garcia<sup>173</sup>, F. Meloni<sup>89a,89b</sup>, L. Mendoza Navas<sup>162</sup>, Z. Meng<sup>151,v</sup>, A. Mengarelli<sup>20a,20b</sup>,  
 S. Menke<sup>99</sup>, E. Meoni<sup>161</sup>, K.M. Mercurio<sup>57</sup>, P. Mermod<sup>49</sup>, L. Merola<sup>102a,102b</sup>, C. Meroni<sup>89a</sup>, F.S. Merritt<sup>31</sup>,  
 H. Merritt<sup>109</sup>, A. Messina<sup>30,w</sup>, J. Metcalfe<sup>25</sup>, A.S. Mete<sup>163</sup>, C. Meyer<sup>81</sup>, C. Meyer<sup>31</sup>, J-P. Meyer<sup>136</sup>,  
 J. Meyer<sup>174</sup>, J. Meyer<sup>54</sup>, S. Michal<sup>30</sup>, L. Micu<sup>26a</sup>, R.P. Middleton<sup>129</sup>, S. Migas<sup>73</sup>, L. Mijović<sup>136</sup>,  
 G. Mikenberg<sup>172</sup>, M. Mikesikova<sup>125</sup>, M. Mikuz<sup>74</sup>, D.W. Miller<sup>31</sup>, R.J. Miller<sup>88</sup>, W.J. Mills<sup>168</sup>, C. Mills<sup>57</sup>,  
 A. Milov<sup>172</sup>, D.A. Milstead<sup>146a,146b</sup>, D. Milstein<sup>172</sup>, A.A. Minaenko<sup>128</sup>, M. Miñano Moya<sup>167</sup>,  
 I.A. Minashvili<sup>64</sup>, A.I. Mincer<sup>108</sup>, B. Mindur<sup>38</sup>, M. Mineev<sup>64</sup>, Y. Ming<sup>173</sup>, L.M. Mir<sup>12</sup>, G. Mirabelli<sup>132a</sup>,  
 J. Mitrevski<sup>137</sup>, V.A. Mitsou<sup>167</sup>, S. Mitsui<sup>65</sup>, P.S. Miyagawa<sup>139</sup>, J.U. Mjörnmark<sup>79</sup>, T. Moa<sup>146a,146b</sup>,  
 V. Moeller<sup>28</sup>, K. Mönig<sup>42</sup>, N. Möser<sup>21</sup>, S. Mohapatra<sup>148</sup>, W. Mohr<sup>48</sup>, R. Moles-Valls<sup>167</sup>, A. Molfetas<sup>30</sup>,  
 J. Monk<sup>77</sup>, E. Monnier<sup>83</sup>, J. Montejo Berlingen<sup>12</sup>, F. Monticelli<sup>70</sup>, S. Monzani<sup>20a,20b</sup>, R.W. Moore<sup>3</sup>,  
 G.F. Moorhead<sup>86</sup>, C. Mora Herrera<sup>49</sup>, A. Moraes<sup>53</sup>, N. Morange<sup>136</sup>, J. Morel<sup>54</sup>, G. Morello<sup>37a,37b</sup>,  
 D. Moreno<sup>81</sup>, M. Moreno Llacer<sup>167</sup>, P. Morettini<sup>50a</sup>, M. Morgenstern<sup>44</sup>, M. Morii<sup>57</sup>, A.K. Morley<sup>30</sup>,  
 G. Mornacchi<sup>30</sup>, J.D. Morris<sup>75</sup>, L. Morvaj<sup>101</sup>, H.G. Moser<sup>99</sup>, M. Mosidze<sup>51b</sup>, J. Moss<sup>109</sup>, R. Mount<sup>143</sup>,  
 E. Mountricha<sup>10,x</sup>, S.V. Mouraviev<sup>94,\*</sup>, E.J.W. Moyse<sup>84</sup>, F. Mueller<sup>58a</sup>, J. Mueller<sup>123</sup>, K. Mueller<sup>21</sup>,  
 T.A. Müller<sup>98</sup>, T. Mueller<sup>81</sup>, D. Muenstermann<sup>30</sup>, Y. Munwes<sup>153</sup>, W.J. Murray<sup>129</sup>, I. Mussche<sup>105</sup>,  
 E. Musto<sup>152</sup>, A.G. Myagkov<sup>128</sup>, M. Myska<sup>125</sup>, O. Nackenhorst<sup>54</sup>, J. Nadal<sup>12</sup>, K. Nagai<sup>160</sup>, R. Nagai<sup>157</sup>,  
 K. Nagano<sup>65</sup>, A. Nagarkar<sup>109</sup>, Y. Nagasaka<sup>59</sup>, M. Nagel<sup>99</sup>, A.M. Nairz<sup>30</sup>, Y. Nakahama<sup>30</sup>, K. Nakamura<sup>155</sup>,  
 T. Nakamura<sup>155</sup>, I. Nakano<sup>110</sup>, G. Nanava<sup>21</sup>, A. Napier<sup>161</sup>, R. Narayan<sup>58b</sup>, M. Nash<sup>77,c</sup>, T. Nattermann<sup>21</sup>,  
 T. Naumann<sup>42</sup>, G. Navarro<sup>162</sup>, H.A. Neal<sup>87</sup>, P.Yu. Nechaeva<sup>94</sup>, T.J. Neep<sup>82</sup>, A. Negri<sup>119a,119b</sup>, G. Negri<sup>30</sup>,  
 M. Negrini<sup>20a</sup>, S. Nektarijevic<sup>49</sup>, A. Nelson<sup>163</sup>, T.K. Nelson<sup>143</sup>, S. Nemecek<sup>125</sup>, P. Nemethy<sup>108</sup>,  
 A.A. Nepomuceno<sup>24a</sup>, M. Nessi<sup>30,y</sup>, M.S. Neubauer<sup>165</sup>, M. Neumann<sup>175</sup>, A. Neusiedl<sup>81</sup>, R.M. Neves<sup>108</sup>,  
 P. Nevski<sup>25</sup>, F.M. Newcomer<sup>120</sup>, P.R. Newman<sup>18</sup>, V. Nguyen Thi Hong<sup>136</sup>, R.B. Nickerson<sup>118</sup>,  
 R. Nicolaidou<sup>136</sup>, B. Nicquevert<sup>30</sup>, F. Niedercorn<sup>115</sup>, J. Nielsen<sup>137</sup>, N. Nikiforou<sup>35</sup>, A. Nikiforov<sup>16</sup>,  
 V. Nikolaenko<sup>128</sup>, I. Nikolic-Audit<sup>78</sup>, K. Nikolics<sup>49</sup>, K. Nikolopoulos<sup>18</sup>, H. Nilsen<sup>48</sup>, P. Nilsson<sup>8</sup>,  
 Y. Ninomiya<sup>155</sup>, A. Nisati<sup>132a</sup>, R. Nisius<sup>99</sup>, T. Nobe<sup>157</sup>, L. Nodulman<sup>6</sup>, M. Nomachi<sup>116</sup>, I. Nomidis<sup>154</sup>,  
 S. Norberg<sup>111</sup>, M. Nordberg<sup>30</sup>, P.R. Norton<sup>129</sup>, J. Novakova<sup>126</sup>, M. Nozaki<sup>65</sup>, L. Nozka<sup>113</sup>, I.M. Nugent<sup>159a</sup>,  
 A.-E. Nuncio-Quiroz<sup>21</sup>, G. Nunes Hanninger<sup>86</sup>, T. Nunnemann<sup>98</sup>, E. Nurse<sup>77</sup>, B.J. O'Brien<sup>46</sup>,  
 D.C. O'Neil<sup>142</sup>, V. O'Shea<sup>53</sup>, L.B. Oakes<sup>98</sup>, F.G. Oakham<sup>29,d</sup>, H. Oberlack<sup>99</sup>, J. Ocariz<sup>78</sup>, A. Ochi<sup>66</sup>,  
 S. Oda<sup>69</sup>, S. Odaka<sup>65</sup>, J. Odier<sup>83</sup>, H. Ogren<sup>60</sup>, A. Oh<sup>82</sup>, S.H. Oh<sup>45</sup>, C.C. Ohm<sup>30</sup>, T. Ohshima<sup>101</sup>,  
 W. Okamura<sup>116</sup>, H. Okawa<sup>25</sup>, Y. Okumura<sup>31</sup>, T. Okuyama<sup>155</sup>, A. Olariu<sup>26a</sup>, A.G. Olchevski<sup>64</sup>,  
 S.A. Olivares Pino<sup>32a</sup>, M. Oliveira<sup>124a,g</sup>, D. Oliveira Damazio<sup>25</sup>, E. Oliver Garcia<sup>167</sup>, D. Olivito<sup>120</sup>,  
 A. Olszewski<sup>39</sup>, J. Olszowska<sup>39</sup>, A. Onofre<sup>124a,z</sup>, P.U.E. Onyisi<sup>31</sup>, C.J. Oram<sup>159a</sup>, M.J. Oreglia<sup>31</sup>,  
 Y. Oren<sup>153</sup>, D. Orestano<sup>134a,134b</sup>, N. Orlando<sup>72a,72b</sup>, I. Orlov<sup>107</sup>, C. Oropeza Barrera<sup>53</sup>, R.S. Orr<sup>158</sup>,  
 B. Osculati<sup>50a,50b</sup>, R. Ospanov<sup>120</sup>, C. Osuna<sup>12</sup>, G. Otero y Garzon<sup>27</sup>, J.P. Ottersbach<sup>105</sup>, M. Ouchrif<sup>135d</sup>,  
 E.A. Ouellette<sup>169</sup>, F. Ould-Saada<sup>117</sup>, A. Ouraou<sup>136</sup>, Q. Ouyang<sup>33a</sup>, A. Ovcharova<sup>15</sup>, M. Owen<sup>82</sup>,  
 S. Owen<sup>139</sup>, V.E. Ozcan<sup>19a</sup>, N. Ozturk<sup>8</sup>, A. Pacheco Pages<sup>12</sup>, C. Padilla Aranda<sup>12</sup>, S. Pagan Griso<sup>15</sup>,  
 E. Paganis<sup>139</sup>, C. Pahl<sup>99</sup>, F. Paige<sup>25</sup>, P. Pais<sup>84</sup>, K. Pajchel<sup>117</sup>, G. Palacino<sup>159b</sup>, C.P. Paleari<sup>7</sup>,  
 S. Palestini<sup>30</sup>, D. Pallin<sup>34</sup>, A. Palma<sup>124a</sup>, J.D. Palmer<sup>18</sup>, Y.B. Pan<sup>173</sup>, E. Panagiotopoulou<sup>10</sup>,  
 J.G. Panduro Vazquez<sup>76</sup>, P. Pani<sup>105</sup>, N. Panikashvili<sup>87</sup>, S. Panitkin<sup>25</sup>, D. Pantea<sup>26a</sup>, A. Papadelis<sup>146a</sup>,  
 Th.D. Papadopoulou<sup>10</sup>, A. Paramonov<sup>6</sup>, D. Paredes Hernandez<sup>34</sup>, W. Park<sup>25,aa</sup>, M.A. Parker<sup>28</sup>,  
 F. Parodi<sup>50a,50b</sup>, J.A. Parsons<sup>35</sup>, U. Parzefall<sup>48</sup>, S. Pashapour<sup>54</sup>, E. Pasqualucci<sup>132a</sup>, S. Passaggio<sup>50a</sup>,  
 A. Passeri<sup>134a</sup>, F. Pastore<sup>134a,134b,\*</sup>, Fr. Pastore<sup>76</sup>, G. Pásztor<sup>49,ab</sup>, S. Patariaia<sup>175</sup>, N. Patel<sup>150</sup>,  
 J.R. Pater<sup>82</sup>, S. Patricelli<sup>102a,102b</sup>, T. Pauly<sup>30</sup>, M. Pecsý<sup>144a</sup>, S. Pedraza Lopez<sup>167</sup>,

M.I. Pedraza Morales<sup>173</sup>, S.V. Peleganchuk<sup>107</sup>, D. Pelikan<sup>166</sup>, H. Peng<sup>33b</sup>, B. Penning<sup>31</sup>, A. Penson<sup>35</sup>,  
J. Penwell<sup>60</sup>, M. Perantoni<sup>24a</sup>, K. Perez<sup>35,ac</sup>, T. Perez Cavalcanti<sup>42</sup>, E. Perez Codina<sup>159a</sup>, M.T. Pérez  
García-Estañ<sup>167</sup>, V. Perez Reale<sup>35</sup>, L. Perini<sup>89a,89b</sup>, H. Pernegger<sup>30</sup>, R. Perrino<sup>72a</sup>, P. Perrodo<sup>5</sup>,  
V.D. Peshekhonov<sup>64</sup>, K. Peters<sup>30</sup>, B.A. Petersen<sup>30</sup>, J. Petersen<sup>30</sup>, T.C. Petersen<sup>36</sup>, E. Petit<sup>5</sup>,  
A. Petridis<sup>154</sup>, C. Petridou<sup>154</sup>, E. Petrolo<sup>132a</sup>, F. Petrucci<sup>134a,134b</sup>, D. Petschull<sup>42</sup>, M. Petteni<sup>142</sup>,  
R. Pezoa<sup>32b</sup>, A. Phan<sup>86</sup>, P.W. Phillips<sup>129</sup>, G. Piacquadio<sup>30</sup>, A. Picazio<sup>49</sup>, E. Piccaro<sup>75</sup>, M. Piccinini<sup>20a,20b</sup>,  
S.M. Piec<sup>42</sup>, R. Piegaia<sup>27</sup>, D.T. Pignotti<sup>109</sup>, J.E. Pilcher<sup>31</sup>, A.D. Pilkington<sup>82</sup>, J. Pina<sup>124a,b</sup>,  
M. Pinamonti<sup>164a,164c</sup>, A. Pinder<sup>118</sup>, J.L. Pinfeld<sup>3</sup>, B. Pinto<sup>124a</sup>, C. Pizio<sup>89a,89b</sup>, M. Plamondon<sup>169</sup>,  
M.-A. Pleier<sup>25</sup>, E. Plotnikova<sup>64</sup>, A. Poblaguev<sup>25</sup>, S. Poddar<sup>58a</sup>, F. Podlyski<sup>34</sup>, L. Poggioli<sup>115</sup>, D. Pohl<sup>21</sup>,  
M. Pohl<sup>49</sup>, G. Polesello<sup>119a</sup>, A. Policicchio<sup>37a,37b</sup>, A. Polini<sup>20a</sup>, J. Poll<sup>75</sup>, V. Polychronakos<sup>25</sup>,  
D. Pomeroy<sup>23</sup>, K. Pommès<sup>30</sup>, L. Pontecorvo<sup>132a</sup>, B.G. Pope<sup>88</sup>, G.A. Popeneciu<sup>26a</sup>, D.S. Popovic<sup>13a</sup>,  
A. Poppleton<sup>30</sup>, X. Portell Bueso<sup>30</sup>, G.E. Pospelov<sup>99</sup>, S. Pospisil<sup>127</sup>, I.N. Potrap<sup>99</sup>, C.J. Potter<sup>149</sup>,  
C.T. Potter<sup>114</sup>, G. Poulard<sup>30</sup>, J. Poveda<sup>60</sup>, V. Pozdnyakov<sup>64</sup>, R. Prabhu<sup>77</sup>, P. Pralavorio<sup>83</sup>, A. Pranko<sup>15</sup>,  
S. Prasad<sup>30</sup>, R. Pravahan<sup>25</sup>, S. Prell<sup>63</sup>, K. Pretzl<sup>17</sup>, D. Price<sup>60</sup>, J. Price<sup>73</sup>, L.E. Price<sup>6</sup>, D. Prieur<sup>123</sup>,  
M. Primavera<sup>72a</sup>, K. Prokofiev<sup>108</sup>, F. Prokoshin<sup>32b</sup>, S. Protopopescu<sup>25</sup>, J. Proudfoot<sup>6</sup>, X. Prudent<sup>44</sup>,  
M. Przybycien<sup>38</sup>, H. Przysieszniak<sup>5</sup>, S. Psoroulas<sup>21</sup>, E. Ptacek<sup>114</sup>, E. Pueschel<sup>84</sup>, J. Purdham<sup>87</sup>,  
M. Purohit<sup>25,aa</sup>, P. Puzo<sup>115</sup>, Y. Pylypchenko<sup>62</sup>, J. Qian<sup>87</sup>, A. Quadt<sup>54</sup>, D.R. Quarrie<sup>15</sup>, W.B. Quayle<sup>173</sup>,  
F. Quinonez<sup>32a</sup>, M. Raas<sup>104</sup>, V. Radeka<sup>25</sup>, V. Radescu<sup>42</sup>, P. Radloff<sup>114</sup>, F. Ragusa<sup>89a,89b</sup>, G. Rahal<sup>178</sup>,  
A.M. Rahimi<sup>109</sup>, D. Rahm<sup>25</sup>, S. Rajagopalan<sup>25</sup>, M. Rammensee<sup>48</sup>, M. Rammes<sup>141</sup>, A.S. Randle-Conde<sup>40</sup>,  
K. Randrianarivony<sup>29</sup>, F. Rauscher<sup>98</sup>, T.C. Rave<sup>48</sup>, M. Raymond<sup>30</sup>, A.L. Read<sup>117</sup>, D.M. Rebuffi<sup>119a,119b</sup>,  
A. Redelbach<sup>174</sup>, G. Redlinger<sup>25</sup>, R. Reece<sup>120</sup>, K. Reeves<sup>41</sup>, A. Reinsch<sup>114</sup>, I. Reisinger<sup>43</sup>, C. Rembser<sup>30</sup>,  
Z.L. Ren<sup>151</sup>, A. Renaud<sup>115</sup>, M. Rescigno<sup>132a</sup>, S. Resconi<sup>89a</sup>, B. Resende<sup>136</sup>, P. Reznicek<sup>98</sup>, R. Rezvani<sup>158</sup>,  
R. Richter<sup>99</sup>, E. Richter-Was<sup>5,ad</sup>, M. Ridel<sup>78</sup>, M. Rijpstra<sup>105</sup>, M. Rijssenbeek<sup>148</sup>, A. Rimoldi<sup>119a,119b</sup>,  
L. Rinaldi<sup>20a</sup>, R.R. Rios<sup>40</sup>, I. Riu<sup>12</sup>, G. Rivoltella<sup>89a,89b</sup>, F. Rizatdinova<sup>112</sup>, E. Rizvi<sup>75</sup>, S.H. Robertson<sup>85,j</sup>,  
A. Robichaud-Veronneau<sup>118</sup>, D. Robinson<sup>28</sup>, J.E.M. Robinson<sup>82</sup>, A. Robson<sup>53</sup>, J.G. Rocha de Lima<sup>106</sup>,  
C. Roda<sup>122a,122b</sup>, D. Roda Dos Santos<sup>30</sup>, A. Roe<sup>54</sup>, S. Roe<sup>30</sup>, O. Röhne<sup>117</sup>, S. Rolli<sup>161</sup>, A. Romanouk<sup>96</sup>,  
M. Romano<sup>20a,20b</sup>, G. Romeo<sup>27</sup>, E. Romero Adam<sup>167</sup>, N. Rompotis<sup>138</sup>, L. Roos<sup>78</sup>, E. Ros<sup>167</sup>, S. Rosati<sup>132a</sup>,  
K. Rosbach<sup>49</sup>, A. Rose<sup>149</sup>, M. Rose<sup>76</sup>, G.A. Rosenbaum<sup>158</sup>, E.I. Rosenberg<sup>63</sup>, P.L. Rosendahl<sup>14</sup>,  
O. Rosenthal<sup>141</sup>, L. Rossetlet<sup>49</sup>, V. Rossetti<sup>12</sup>, E. Rossi<sup>132a,132b</sup>, L.P. Rossi<sup>50a</sup>, M. Rotaru<sup>26a</sup>, I. Roth<sup>172</sup>,  
J. Rothberg<sup>138</sup>, D. Rousseau<sup>115</sup>, C.R. Royon<sup>136</sup>, A. Rozanov<sup>83</sup>, Y. Rozen<sup>152</sup>, X. Ruan<sup>33a,ae</sup>, F. Rubbo<sup>12</sup>,  
I. Rubinskiy<sup>42</sup>, N. Ruckstuhl<sup>105</sup>, V.I. Rud<sup>97</sup>, C. Rudolph<sup>44</sup>, G. Rudolph<sup>61</sup>, F. Rühr<sup>7</sup>, A. Ruiz-Martinez<sup>63</sup>,  
L. Rumyantsev<sup>64</sup>, Z. Rurikova<sup>48</sup>, N.A. Rusakovich<sup>64</sup>, A. Ruschke<sup>98</sup>, J.P. Rutherford<sup>7</sup>, P. Ruzicka<sup>125</sup>,  
Y.F. Ryabov<sup>121</sup>, M. Rybar<sup>126</sup>, G. Rybkin<sup>115</sup>, N.C. Ryder<sup>118</sup>, A.F. Saavedra<sup>150</sup>, I. Sadeh<sup>153</sup>,  
H.F.W. Sadrozinski<sup>137</sup>, R. Sadykov<sup>64</sup>, F. Safai Tehrani<sup>132a</sup>, H. Sakamoto<sup>155</sup>, G. Salamanna<sup>75</sup>,  
A. Salamon<sup>133a</sup>, M. Saleem<sup>111</sup>, D. Salek<sup>30</sup>, D. Salihagic<sup>99</sup>, A. Salmikov<sup>143</sup>, J. Salt<sup>167</sup>,  
B.M. Salvachua Ferrando<sup>6</sup>, D. Salvatore<sup>37a,37b</sup>, F. Salvatore<sup>149</sup>, A. Salvucci<sup>104</sup>, A. Salzburger<sup>30</sup>,  
D. Sampsonidis<sup>154</sup>, B.H. Samset<sup>117</sup>, A. Sanchez<sup>102a,102b</sup>, V. Sanchez Martinez<sup>167</sup>, H. Sandaker<sup>14</sup>,  
H.G. Sander<sup>81</sup>, M.P. Sanders<sup>98</sup>, M. Sandhoff<sup>175</sup>, T. Sandoval<sup>28</sup>, C. Sandoval<sup>162</sup>, R. Sandstroem<sup>99</sup>,  
D.P.C. Sankey<sup>129</sup>, A. Sansoni<sup>47</sup>, C. Santamarina Rios<sup>85</sup>, C. Santoni<sup>34</sup>, R. Santonico<sup>133a,133b</sup>, H. Santos<sup>124a</sup>,  
I. Santoyo Castillo<sup>149</sup>, J.G. Saraiva<sup>124a</sup>, T. Sarangi<sup>173</sup>, E. Sarkisyan-Grinbaum<sup>8</sup>, F. Sarri<sup>122a,122b</sup>,  
G. Sartisohn<sup>175</sup>, O. Sasaki<sup>65</sup>, Y. Sasaki<sup>155</sup>, N. Sasao<sup>67</sup>, I. Satsounkevitch<sup>90</sup>, G. Sauvage<sup>5,\*</sup>, E. Sauvan<sup>5</sup>,  
J.B. Sauvan<sup>115</sup>, P. Savard<sup>158,d</sup>, V. Savinov<sup>123</sup>, D.O. Savu<sup>30</sup>, L. Sawyer<sup>25,l</sup>, D.H. Saxon<sup>53</sup>, J. Saxon<sup>120</sup>,  
C. Sbarra<sup>20a</sup>, A. Sbrizzi<sup>20a,20b</sup>, D.A. Scannicchio<sup>163</sup>, M. Scarcella<sup>150</sup>, J. Schaarschmidt<sup>115</sup>, P. Schacht<sup>99</sup>,  
D. Schaefer<sup>120</sup>, U. Schäfer<sup>81</sup>, A. Schaelicke<sup>46</sup>, S. Schaepe<sup>21</sup>, S. Schaezel<sup>58b</sup>, A.C. Schaffer<sup>115</sup>, D. Schaile<sup>98</sup>,  
R.D. Schamberger<sup>148</sup>, A.G. Schamov<sup>107</sup>, V. Scharf<sup>58a</sup>, V.A. Schegelsky<sup>121</sup>, D. Scheirich<sup>87</sup>, M. Schernau<sup>163</sup>,  
M.I. Scherzer<sup>35</sup>, C. Schiavi<sup>50a,50b</sup>, J. Schieck<sup>98</sup>, M. Schioppa<sup>37a,37b</sup>, S. Schlenker<sup>30</sup>, E. Schmidt<sup>48</sup>,  
K. Schmieden<sup>21</sup>, C. Schmitt<sup>81</sup>, S. Schmitt<sup>58b</sup>, B. Schneider<sup>17</sup>, U. Schnoor<sup>44</sup>, L. Schoeffel<sup>136</sup>,  
A. Schoening<sup>58b</sup>, A.L.S. Schorlemmer<sup>54</sup>, M. Schott<sup>30</sup>, D. Schouten<sup>159a</sup>, J. Schovancova<sup>125</sup>, M. Schram<sup>85</sup>,  
C. Schroeder<sup>81</sup>, N. Schroer<sup>58c</sup>, M.J. Schultens<sup>21</sup>, J. Schultes<sup>175</sup>, H.-C. Schultz-Coulon<sup>58a</sup>, H. Schulz<sup>16</sup>,  
M. Schumacher<sup>48</sup>, B.A. Schumm<sup>137</sup>, Ph. Schune<sup>136</sup>, C. Schwanenberger<sup>82</sup>, A. Schwartzman<sup>143</sup>,  
Ph. Schwegler<sup>99</sup>, Ph. Schwemling<sup>78</sup>, R. Schwienhorst<sup>88</sup>, R. Schwierz<sup>44</sup>, J. Schwindling<sup>136</sup>, T. Schwindt<sup>21</sup>,  
M. Schwoerer<sup>5</sup>, F.G. Sciacca<sup>17</sup>, G. Sciolla<sup>23</sup>, W.G. Scott<sup>129</sup>, J. Searcy<sup>114</sup>, G. Sedov<sup>42</sup>, E. Sedykh<sup>121</sup>,

S.C. Seidel<sup>103</sup>, A. Seiden<sup>137</sup>, F. Seifert<sup>44</sup>, J.M. Seixas<sup>24a</sup>, G. Sekhniadze<sup>102a</sup>, S.J. Sekula<sup>40</sup>, K.E. Selbach<sup>46</sup>,  
 D.M. Seliverstov<sup>121</sup>, B. Sellden<sup>146a</sup>, G. Sellers<sup>73</sup>, M. Seman<sup>144b</sup>, N. Semprini-Cesari<sup>20a,20b</sup>, C. Serfon<sup>98</sup>,  
 L. Serin<sup>115</sup>, L. Serkin<sup>54</sup>, R. Seuster<sup>159a</sup>, H. Severini<sup>111</sup>, A. Sfyrla<sup>30</sup>, E. Shabalina<sup>54</sup>, M. Shamim<sup>114</sup>,  
 L.Y. Shan<sup>33a</sup>, J.T. Shank<sup>22</sup>, Q.T. Shao<sup>86</sup>, M. Shapiro<sup>15</sup>, P.B. Shatalov<sup>95</sup>, K. Shaw<sup>164a,164c</sup>, D. Sherman<sup>176</sup>,  
 P. Sherwood<sup>77</sup>, S. Shimizu<sup>101</sup>, M. Shimojima<sup>100</sup>, T. Shin<sup>56</sup>, M. Shiyakova<sup>64</sup>, A. Shmeleva<sup>94</sup>,  
 M.J. Shochet<sup>31</sup>, D. Short<sup>118</sup>, S. Shrestha<sup>63</sup>, E. Shulga<sup>96</sup>, M.A. Shupe<sup>7</sup>, P. Sicho<sup>125</sup>, A. Sidoti<sup>132a</sup>,  
 F. Siegert<sup>48</sup>, Dj. Sijacki<sup>13a</sup>, O. Silbert<sup>172</sup>, J. Silva<sup>124a</sup>, Y. Silver<sup>153</sup>, D. Silverstein<sup>143</sup>, S.B. Silverstein<sup>146a</sup>,  
 V. Simak<sup>127</sup>, O. Simard<sup>136</sup>, Lj. Simic<sup>13a</sup>, S. Simion<sup>115</sup>, E. Simioni<sup>81</sup>, B. Simmons<sup>77</sup>, R. Simoniello<sup>89a,89b</sup>,  
 M. Simonyan<sup>36</sup>, P. Sinervo<sup>158</sup>, N.B. Sinev<sup>114</sup>, V. Sipica<sup>141</sup>, G. Siragusa<sup>174</sup>, A. Sircar<sup>25</sup>, A.N. Sisakyan<sup>64,\*</sup>,  
 S.Yu. Sivoklokov<sup>97</sup>, J. Sjölin<sup>146a,146b</sup>, T.B. Sjursen<sup>14</sup>, L.A. Skinnari<sup>15</sup>, H.P. Skottowe<sup>57</sup>, K. Skovpen<sup>107</sup>,  
 P. Skubic<sup>111</sup>, M. Slater<sup>18</sup>, T. Slavicek<sup>127</sup>, K. Sliwa<sup>161</sup>, V. Smakhtin<sup>172</sup>, B.H. Smart<sup>46</sup>, L. Smestad<sup>117</sup>,  
 S.Yu. Smirnov<sup>96</sup>, Y. Smirnov<sup>96</sup>, L.N. Smirnova<sup>97</sup>, O. Smirnova<sup>79</sup>, B.C. Smith<sup>57</sup>, D. Smith<sup>143</sup>,  
 K.M. Smith<sup>53</sup>, M. Smizanska<sup>71</sup>, K. Smolek<sup>127</sup>, A.A. Snesarev<sup>94</sup>, S.W. Snow<sup>82</sup>, J. Snow<sup>111</sup>, S. Snyder<sup>25</sup>,  
 R. Sobie<sup>169,j</sup>, J. Sodomka<sup>127</sup>, A. Soffer<sup>153</sup>, C.A. Solans<sup>167</sup>, M. Solar<sup>127</sup>, J. Solc<sup>127</sup>, E.Yu. Soldatov<sup>96</sup>,  
 U. Soldevila<sup>167</sup>, E. Solfaroli Camillocci<sup>132a,132b</sup>, A.A. Solodkov<sup>128</sup>, O.V. Solovyanov<sup>128</sup>, V. Solovyev<sup>121</sup>,  
 N. Soni<sup>1</sup>, V. Sopko<sup>127</sup>, B. Sopko<sup>127</sup>, M. Sosebee<sup>8</sup>, R. Soualah<sup>164a,164c</sup>, A. Soukharev<sup>107</sup>, S. Spagnolo<sup>72a,72b</sup>,  
 F. Spanò<sup>76</sup>, R. Spighi<sup>20a</sup>, G. Spigo<sup>30</sup>, R. Spiwox<sup>30</sup>, M. Spousta<sup>126,af</sup>, T. Spreitzer<sup>158</sup>, B. Spurlock<sup>8</sup>,  
 R.D. St. Denis<sup>53</sup>, J. Stahlman<sup>120</sup>, R. Stamen<sup>58a</sup>, E. Stanecka<sup>39</sup>, R.W. Stanek<sup>6</sup>, C. Stanescu<sup>134a</sup>,  
 M. Stanescu-Bellu<sup>42</sup>, M.M. Stanitzki<sup>42</sup>, S. Stapnes<sup>117</sup>, E.A. Starchenko<sup>128</sup>, J. Stark<sup>55</sup>, P. Staroba<sup>125</sup>,  
 P. Starovoitov<sup>42</sup>, R. Staszewski<sup>39</sup>, A. Staude<sup>98</sup>, P. Stavina<sup>144a,\*</sup>, G. Steele<sup>53</sup>, P. Steinbach<sup>44</sup>,  
 P. Steinberg<sup>25</sup>, I. Stekl<sup>127</sup>, B. Stelzer<sup>142</sup>, H.J. Stelzer<sup>88</sup>, O. Stelzer-Chilton<sup>159a</sup>, H. Stenzel<sup>52</sup>, S. Stern<sup>99</sup>,  
 G.A. Stewart<sup>30</sup>, J.A. Stillings<sup>21</sup>, M.C. Stockton<sup>85</sup>, K. Stoerig<sup>48</sup>, G. Stoicea<sup>26a</sup>, S. Stonjek<sup>99</sup>,  
 P. Strachota<sup>126</sup>, A.R. Stradling<sup>8</sup>, A. Straessner<sup>44</sup>, J. Strandberg<sup>147</sup>, S. Strandberg<sup>146a,146b</sup>, A. Strandlie<sup>117</sup>,  
 M. Strang<sup>109</sup>, E. Strauss<sup>143</sup>, M. Strauss<sup>111</sup>, P. Striznec<sup>144b</sup>, R. Ströhmer<sup>174</sup>, D.M. Strom<sup>114</sup>,  
 J.A. Strong<sup>76,\*</sup>, R. Stroynowski<sup>40</sup>, B. Stugu<sup>14</sup>, I. Stumer<sup>25,\*</sup>, J. Stupak<sup>148</sup>, P. Sturm<sup>175</sup>, N.A. Styles<sup>42</sup>,  
 D.A. Soh<sup>151,t</sup>, D. Su<sup>143</sup>, H.S. Subramania<sup>3</sup>, R. Subramaniam<sup>25</sup>, A. Succurro<sup>12</sup>, Y. Sugaya<sup>116</sup>, C. Suhr<sup>106</sup>,  
 M. Suk<sup>126</sup>, V.V. Sulin<sup>94</sup>, S. Sultansoy<sup>4d</sup>, T. Sumida<sup>67</sup>, X. Sun<sup>55</sup>, J.E. Sundermann<sup>48</sup>, K. Suruliz<sup>139</sup>,  
 G. Susinno<sup>37a,37b</sup>, M.R. Sutton<sup>149</sup>, Y. Suzuki<sup>65</sup>, Y. Suzuki<sup>66</sup>, M. Svatos<sup>125</sup>, S. Swedish<sup>168</sup>, I. Sykora<sup>144a</sup>,  
 T. Sykora<sup>126</sup>, J. Sánchez<sup>167</sup>, D. Ta<sup>105</sup>, K. Tackmann<sup>42</sup>, A. Taffard<sup>163</sup>, R. Tafirout<sup>159a</sup>, N. Taiblum<sup>153</sup>,  
 Y. Takahashi<sup>101</sup>, H. Takai<sup>25</sup>, R. Takashima<sup>68</sup>, H. Takeda<sup>66</sup>, T. Takeshita<sup>140</sup>, Y. Takubo<sup>65</sup>, M. Talby<sup>83</sup>,  
 A. Talyshev<sup>107,f</sup>, M.C. Tamsett<sup>25</sup>, K.G. Tan<sup>86</sup>, J. Tanaka<sup>155</sup>, R. Tanaka<sup>115</sup>, S. Tanaka<sup>131</sup>, S. Tanaka<sup>65</sup>,  
 A.J. Tanasijczuk<sup>142</sup>, K. Tani<sup>66</sup>, N. Tannoury<sup>83</sup>, S. Tapprogge<sup>81</sup>, D. Tardif<sup>158</sup>, S. Tarem<sup>152</sup>, F. Tarrade<sup>29</sup>,  
 G.F. Tartarelli<sup>89a</sup>, P. Tas<sup>126</sup>, M. Tasevsky<sup>125</sup>, E. Tassi<sup>37a,37b</sup>, Y. Tayalati<sup>135d</sup>, C. Taylor<sup>77</sup>, F.E. Taylor<sup>92</sup>,  
 G.N. Taylor<sup>86</sup>, W. Taylor<sup>159b</sup>, M. Teinturier<sup>115</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>151</sup>, S. Terada<sup>65</sup>, K. Terashi<sup>155</sup>, J. Terron<sup>80</sup>,  
 M. Testa<sup>47</sup>, R.J. Teuscher<sup>158,j</sup>, J. Therhaag<sup>21</sup>, T. Theveneaux-Pelzer<sup>78</sup>, S. Thoma<sup>48</sup>, J.P. Thomas<sup>18</sup>,  
 E.N. Thompson<sup>35</sup>, P.D. Thompson<sup>18</sup>, P.D. Thompson<sup>158</sup>, A.S. Thompson<sup>53</sup>, L.A. Thomsen<sup>36</sup>,  
 E. Thomson<sup>120</sup>, M. Thomson<sup>28</sup>, W.M. Thong<sup>86</sup>, R.P. Thun<sup>87</sup>, F. Tian<sup>35</sup>, M.J. Tibbetts<sup>15</sup>, T. Tic<sup>125</sup>,  
 V.O. Tikhomirov<sup>94</sup>, Y.A. Tikhonov<sup>107,f</sup>, S. Timoshenko<sup>96</sup>, E. Tiouchichine<sup>83</sup>, P. Tipton<sup>176</sup>, S. Tisserant<sup>83</sup>,  
 T. Todorov<sup>5</sup>, S. Todorova-Nova<sup>161</sup>, B. Toggerson<sup>163</sup>, J. Tojo<sup>69</sup>, S. Tokár<sup>144a</sup>, K. Tokushuku<sup>65</sup>,  
 K. Tollefson<sup>88</sup>, M. Tomoto<sup>101</sup>, L. Tompkins<sup>31</sup>, K. Toms<sup>103</sup>, A. Tonoyan<sup>14</sup>, C. Topfel<sup>17</sup>, N.D. Topilin<sup>64</sup>,  
 E. Torrence<sup>114</sup>, H. Torres<sup>78</sup>, E. Torró Pastor<sup>167</sup>, J. Toth<sup>83,ab</sup>, F. Touchard<sup>83</sup>, D.R. Tovey<sup>139</sup>,  
 T. Trefzger<sup>174</sup>, L. Tremblet<sup>30</sup>, A. Tricoli<sup>30</sup>, I.M. Trigger<sup>159a</sup>, S. Trincaz-Duvoid<sup>78</sup>, M.F. Tripiana<sup>70</sup>,  
 N. Triplett<sup>25</sup>, W. Trischuk<sup>158</sup>, B. Trocmé<sup>55</sup>, C. Troncon<sup>89a</sup>, M. Trottier-McDonald<sup>142</sup>, P. True<sup>88</sup>,  
 M. Trzebinski<sup>39</sup>, A. Trzupek<sup>39</sup>, C. Tsarouchas<sup>30</sup>, J.C-L. Tseng<sup>118</sup>, M. Tsiakiris<sup>105</sup>, P.V. Tsiarehka<sup>90</sup>,  
 D. Tsionou<sup>5,ag</sup>, G. Tsipolitis<sup>10</sup>, S. Tsiskaridze<sup>12</sup>, V. Tsiskaridze<sup>48</sup>, E.G. Tskhadadze<sup>51a</sup>, I.I. Tsukerman<sup>95</sup>,  
 V. Tsulaia<sup>15</sup>, J.-W. Tsung<sup>21</sup>, S. Tsuno<sup>65</sup>, D. Tsybychev<sup>148</sup>, A. Tua<sup>139</sup>, A. Tudorache<sup>26a</sup>, V. Tudorache<sup>26a</sup>,  
 J.M. Tuggle<sup>31</sup>, M. Turala<sup>39</sup>, D. Turecek<sup>127</sup>, I. Turk Cakir<sup>4e</sup>, E. Turlay<sup>105</sup>, R. Turra<sup>89a,89b</sup>, P.M. Tuts<sup>35</sup>,  
 A. Tykhonov<sup>74</sup>, M. Tylmad<sup>146a,146b</sup>, M. Tyndel<sup>129</sup>, G. Tzanakos<sup>9</sup>, K. Uchida<sup>21</sup>, I. Ueda<sup>155</sup>, R. Ueno<sup>29</sup>,  
 M. Ugland<sup>14</sup>, M. Uhlenbrock<sup>21</sup>, M. Uhrmacher<sup>54</sup>, F. Ukegawa<sup>160</sup>, G. Unal<sup>30</sup>, A. Undrus<sup>25</sup>, G. Unel<sup>163</sup>,  
 Y. Unno<sup>65</sup>, D. Urbaniec<sup>35</sup>, P. Urquijo<sup>21</sup>, G. Usai<sup>8</sup>, M. Uslenghi<sup>119a,119b</sup>, L. Vacavant<sup>83</sup>, V. Vacek<sup>127</sup>,  
 B. Vachon<sup>85</sup>, S. Vahsen<sup>15</sup>, J. Valenta<sup>125</sup>, S. Valentineti<sup>20a,20b</sup>, A. Valero<sup>167</sup>, S. Valkar<sup>126</sup>,

E. Valladolid Gallego<sup>167</sup>, S. Vallecorsa<sup>152</sup>, J.A. Valls Ferrer<sup>167</sup>, R. Van Berg<sup>120</sup>, P.C. Van Der Deijl<sup>105</sup>, R. van der Geer<sup>105</sup>, H. van der Graaf<sup>105</sup>, R. Van Der Leeuw<sup>105</sup>, E. van der Poel<sup>105</sup>, D. van der Ster<sup>30</sup>, N. van Eldik<sup>30</sup>, P. van Gemmeren<sup>6</sup>, I. van Vulpen<sup>105</sup>, M. Vanadia<sup>99</sup>, W. Vandelli<sup>30</sup>, A. Vaniachine<sup>6</sup>, P. Vankov<sup>42</sup>, F. Vannucci<sup>78</sup>, R. Vari<sup>132a</sup>, E.W. Varnes<sup>7</sup>, T. Varol<sup>84</sup>, D. Varouchas<sup>15</sup>, A. Vartapetian<sup>8</sup>, K.E. Varvell<sup>150</sup>, V.I. Vassilakopoulos<sup>56</sup>, F. Vazeille<sup>34</sup>, T. Vazquez Schroeder<sup>54</sup>, G. Vegni<sup>89a,89b</sup>, J.J. Veillet<sup>115</sup>, F. Veloso<sup>124a</sup>, R. Veness<sup>30</sup>, S. Veneziano<sup>132a</sup>, A. Ventura<sup>72a,72b</sup>, D. Ventura<sup>84</sup>, M. Venturi<sup>48</sup>, N. Venturi<sup>158</sup>, V. Vercesi<sup>119a</sup>, M. Verducci<sup>138</sup>, W. Verkerke<sup>105</sup>, J.C. Vermeulen<sup>105</sup>, A. Vest<sup>44</sup>, M.C. Vetterli<sup>142,d</sup>, I. Vichou<sup>165</sup>, T. Vickey<sup>145b,ah</sup>, O.E. Vickey Boeriu<sup>145b</sup>, G.H.A. Viehhauser<sup>118</sup>, S. Viel<sup>168</sup>, M. Villa<sup>20a,20b</sup>, M. Villaplana Perez<sup>167</sup>, E. Vilucchi<sup>47</sup>, M.G. Vincter<sup>29</sup>, E. Vinek<sup>30</sup>, V.B. Vinogradov<sup>64</sup>, M. Virchaux<sup>136,\*</sup>, J. Virzi<sup>15</sup>, O. Vitells<sup>172</sup>, M. Viti<sup>42</sup>, I. Vivarelli<sup>48</sup>, F. Vives Vaque<sup>3</sup>, S. Vlachos<sup>10</sup>, D. Vladoiu<sup>98</sup>, M. Vlasak<sup>127</sup>, A. Vogel<sup>21</sup>, P. Vokac<sup>127</sup>, G. Volpi<sup>47</sup>, M. Volpi<sup>86</sup>, G. Volpini<sup>89a</sup>, H. von der Schmitt<sup>99</sup>, H. von Radziewski<sup>48</sup>, E. von Toerne<sup>21</sup>, V. Vorobel<sup>126</sup>, V. Vorwerk<sup>12</sup>, M. Vos<sup>167</sup>, R. Voss<sup>30</sup>, T.T. Voss<sup>175</sup>, J.H. Vossebeld<sup>73</sup>, N. Vranjes<sup>136</sup>, M. Vranjes Milosavljevic<sup>105</sup>, V. Vrba<sup>125</sup>, M. Vreeswijk<sup>105</sup>, T. Vu Anh<sup>48</sup>, R. Vuillermet<sup>30</sup>, I. Vukotic<sup>31</sup>, W. Wagner<sup>175</sup>, P. Wagner<sup>120</sup>, H. Wahlen<sup>175</sup>, S. Wahrmund<sup>44</sup>, J. Wakabayashi<sup>101</sup>, S. Walch<sup>87</sup>, J. Walder<sup>71</sup>, R. Walker<sup>98</sup>, W. Walkowiak<sup>141</sup>, R. Wall<sup>176</sup>, P. Waller<sup>73</sup>, B. Walsh<sup>176</sup>, C. Wang<sup>45</sup>, H. Wang<sup>173</sup>, H. Wang<sup>40</sup>, J. Wang<sup>151</sup>, J. Wang<sup>55</sup>, R. Wang<sup>103</sup>, S.M. Wang<sup>151</sup>, T. Wang<sup>21</sup>, A. Warburton<sup>85</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>, I. Watanabe<sup>66</sup>, P.M. Watkins<sup>18</sup>, A.T. Watson<sup>18</sup>, I.J. Watson<sup>150</sup>, M.F. Watson<sup>18</sup>, G. Watts<sup>138</sup>, S. Watts<sup>82</sup>, A.T. Waugh<sup>150</sup>, B.M. Waugh<sup>77</sup>, M.S. Weber<sup>17</sup>, J.S. Webster<sup>31</sup>, A.R. Weidberg<sup>118</sup>, P. Weigell<sup>99</sup>, J. Weingarten<sup>54</sup>, C. Weiser<sup>48</sup>, P.S. Wells<sup>30</sup>, T. Wenaus<sup>25</sup>, D. Wendland<sup>16</sup>, Z. Weng<sup>151,t</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. Werth<sup>163</sup>, M. Wessels<sup>58a</sup>, J. Wetter<sup>161</sup>, C. Weydert<sup>55</sup>, K. Whalen<sup>29</sup>, A. White<sup>8</sup>, M.J. White<sup>86</sup>, S. White<sup>122a,122b</sup>, S.R. Whitehead<sup>118</sup>, D. Whiteson<sup>163</sup>, D. Whittington<sup>60</sup>, F. Wicek<sup>115</sup>, D. Wicke<sup>175</sup>, F.J. Wickens<sup>129</sup>, W. Wiedenmann<sup>173</sup>, M. Wielers<sup>129</sup>, P. Wienemann<sup>21</sup>, C. Wiglesworth<sup>75</sup>, L.A.M. Wiik-Fuchs<sup>21</sup>, P.A. Wijeratne<sup>77</sup>, A. Wildauer<sup>99</sup>, M.A. Wildt<sup>42,q</sup>, I. Wilhelm<sup>126</sup>, H.G. Wilkens<sup>30</sup>, J.Z. Will<sup>98</sup>, E. Williams<sup>35</sup>, H.H. Williams<sup>120</sup>, W. Willis<sup>35</sup>, S. Willocq<sup>84</sup>, J.A. Wilson<sup>18</sup>, M.G. Wilson<sup>143</sup>, A. Wilson<sup>87</sup>, I. Wingerter-Seez<sup>5</sup>, S. Winkelmann<sup>48</sup>, F. Winklmeier<sup>30</sup>, M. Wittgen<sup>143</sup>, S.J. Wollstadt<sup>81</sup>, M.W. Wolter<sup>39</sup>, H. Wolters<sup>124a,g</sup>, W.C. Wong<sup>41</sup>, G. Wooden<sup>87</sup>, B.K. Wosiek<sup>39</sup>, J. Wotschack<sup>30</sup>, M.J. Woudstra<sup>82</sup>, K.W. Wozniak<sup>39</sup>, K. Wraight<sup>53</sup>, M. Wright<sup>53</sup>, B. Wrona<sup>73</sup>, S.L. Wu<sup>173</sup>, X. Wu<sup>49</sup>, Y. Wu<sup>33b,ai</sup>, E. Wulf<sup>35</sup>, B.M. Wynne<sup>46</sup>, S. Xella<sup>36</sup>, M. Xiao<sup>136</sup>, S. Xie<sup>48</sup>, C. Xu<sup>33b,x</sup>, D. Xu<sup>139</sup>, L. Xu<sup>33b</sup>, B. Yabsley<sup>150</sup>, S. Yacoub<sup>145a,aj</sup>, M. Yamada<sup>65</sup>, H. Yamaguchi<sup>155</sup>, A. Yamamoto<sup>65</sup>, K. Yamamoto<sup>63</sup>, S. Yamamoto<sup>155</sup>, T. Yamamura<sup>155</sup>, T. Yamanaka<sup>155</sup>, T. Yamazaki<sup>155</sup>, Y. Yamazaki<sup>66</sup>, Z. Yan<sup>22</sup>, H. Yang<sup>87</sup>, U.K. Yang<sup>82</sup>, Y. Yang<sup>109</sup>, Z. Yang<sup>146a,146b</sup>, S. Yanush<sup>91</sup>, L. Yao<sup>33a</sup>, Y. Yao<sup>15</sup>, Y. Yasu<sup>65</sup>, G.V. Ybeles Smit<sup>130</sup>, J. Ye<sup>40</sup>, S. Ye<sup>25</sup>, M. Yilmaz<sup>4c</sup>, R. Yoosofmiya<sup>123</sup>, K. Yorita<sup>171</sup>, R. Yoshida<sup>6</sup>, K. Yoshihara<sup>155</sup>, C. Young<sup>143</sup>, C.J. Young<sup>118</sup>, S. Youssef<sup>22</sup>, D. Yu<sup>25</sup>, J. Yu<sup>8</sup>, J. Yu<sup>112</sup>, L. Yuan<sup>66</sup>, A. Yurkewicz<sup>106</sup>, M. Byszewski<sup>30</sup>, B. Zabinski<sup>39</sup>, R. Zaidan<sup>62</sup>, A.M. Zaitsev<sup>128</sup>, Z. Zajacova<sup>30</sup>, L. Zanello<sup>132a,132b</sup>, D. Zanzi<sup>99</sup>, A. Zaytsev<sup>25</sup>, C. Zeitnitz<sup>175</sup>, M. Zeman<sup>125</sup>, A. Zemla<sup>39</sup>, C. Zendler<sup>21</sup>, O. Zenin<sup>128</sup>, T. Ženis<sup>144a</sup>, Z. Zinonos<sup>122a,122b</sup>, D. Zerwas<sup>115</sup>, G. Zevi della Porta<sup>57</sup>, D. Zhang<sup>33b,ak</sup>, H. Zhang<sup>88</sup>, J. Zhang<sup>6</sup>, X. Zhang<sup>33d</sup>, Z. Zhang<sup>115</sup>, L. Zhao<sup>108</sup>, Z. Zhao<sup>33b</sup>, A. Zhemchugov<sup>64</sup>, J. Zhong<sup>118</sup>, B. Zhou<sup>87</sup>, N. Zhou<sup>163</sup>, Y. Zhou<sup>151</sup>, C.G. Zhu<sup>33d</sup>, H. Zhu<sup>42</sup>, J. Zhu<sup>87</sup>, Y. Zhu<sup>33b</sup>, X. Zhuang<sup>98</sup>, V. Zhuravlov<sup>99</sup>, A. Zibell<sup>98</sup>, D. Zieminska<sup>60</sup>, N.I. Zimin<sup>64</sup>, R. Zimmermann<sup>21</sup>, S. Zimmermann<sup>21</sup>, S. Zimmermann<sup>48</sup>, M. Ziolkowski<sup>141</sup>, R. Zitoun<sup>5</sup>, L. Živković<sup>35</sup>, V.V. Zmouchko<sup>128,\*</sup>, G. Zobernig<sup>173</sup>, A. Zoccoli<sup>20a,20b</sup>, M. zur Nedden<sup>16</sup>, V. Zutshi<sup>106</sup>, L. Zwalinski<sup>30</sup>.

<sup>1</sup> School of Chemistry and Physics, University of Adelaide, Adelaide, Australia

<sup>2</sup> Physics Department, SUNY Albany, Albany NY, United States of America

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

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

<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, United States of America

<sup>7</sup> Department of Physics, University of Arizona, Tucson AZ, United States of America

- <sup>8</sup> Department of Physics, The University of Texas at Arlington, Arlington TX, United States of America
- <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 and ICREA, Barcelona, Spain
- <sup>13</sup> <sup>(a)</sup>Institute of Physics, University of Belgrade, Belgrade; <sup>(b)</sup>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, United States of America
- <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, United Kingdom
- <sup>19</sup> <sup>(a)</sup>Department of Physics, Bogazici University, Istanbul; <sup>(b)</sup>Division of Physics, Dogus University, Istanbul; <sup>(c)</sup>Department of Physics Engineering, Gaziantep University, Gaziantep; <sup>(d)</sup>Department of Physics, Istanbul Technical University, Istanbul, Turkey
- <sup>20</sup> <sup>(a)</sup>INFN Sezione di Bologna; <sup>(b)</sup>Dipartimento di Fisica, 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, United States of America
- <sup>23</sup> Department of Physics, Brandeis University, Waltham MA, United States of America
- <sup>24</sup> <sup>(a)</sup>Universidade Federal do Rio De Janeiro COPPE/EE/IF, Rio de Janeiro; <sup>(b)</sup>Federal University of Juiz de Fora (UFJF), Juiz de Fora; <sup>(c)</sup>Federal University of Sao Joao del Rei (UFSJ), Sao Joao del Rei; <sup>(d)</sup>Instituto de Fisica, Universidade de Sao Paulo, Sao Paulo, Brazil
- <sup>25</sup> Physics Department, Brookhaven National Laboratory, Upton NY, United States of America
- <sup>26</sup> <sup>(a)</sup>National Institute of Physics and Nuclear Engineering, Bucharest; <sup>(b)</sup>University Politehnica Bucharest, Bucharest; <sup>(c)</sup>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, United Kingdom
- <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, United States of America
- <sup>32</sup> <sup>(a)</sup>Departamento de Física, Pontificia Universidad Católica de Chile, Santiago; <sup>(b)</sup>Departamento de Física, Universidad Técnica Federico Santa María, Valparaíso, Chile
- <sup>33</sup> <sup>(a)</sup>Institute of High Energy Physics, Chinese Academy of Sciences, Beijing; <sup>(b)</sup>Department of Modern Physics, University of Science and Technology of China, Anhui; <sup>(c)</sup>Department of Physics, Nanjing University, Jiangsu; <sup>(d)</sup>School of Physics, Shandong University, Shandong, 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, United States of America
- <sup>36</sup> Niels Bohr Institute, University of Copenhagen, Kobenhavn, Denmark
- <sup>37</sup> <sup>(a)</sup>INFN Gruppo Collegato di Cosenza; <sup>(b)</sup>Dipartimento di Fisica, Università della Calabria, Arcavata di Rende, Italy
- <sup>38</sup> AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Krakow, Poland
- <sup>39</sup> The Henryk Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences, Krakow, Poland
- <sup>40</sup> Physics Department, Southern Methodist University, Dallas TX, United States of America
- <sup>41</sup> Physics Department, University of Texas at Dallas, Richardson TX, United States of America
- <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, Technical University Dresden, Dresden, Germany

45 Department of Physics, Duke University, Durham NC, United States of America  
 46 SUPA - School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom  
 47 INFN Laboratori Nazionali di Frascati, Frascati, Italy  
 48 Fakultät für Mathematik und Physik, Albert-Ludwigs-Universität, Freiburg, Germany  
 49 Section de Physique, Université de Genève, Geneva, Switzerland  
 50 <sup>(a)</sup>INFN Sezione di Genova; <sup>(b)</sup>Dipartimento di Fisica, Università di Genova, Genova, Italy  
 51 <sup>(a)</sup>E. Andronikashvili Institute of Physics, Iv. Javakhishvili Tbilisi State University, Tbilisi; <sup>(b)</sup>High Energy Physics Institute, Tbilisi State University, Tbilisi, Georgia  
 52 II Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen, Germany  
 53 SUPA - School of Physics and Astronomy, University of Glasgow, Glasgow, United Kingdom  
 54 II Physikalisches Institut, Georg-August-Universität, Göttingen, Germany  
 55 Laboratoire de Physique Subatomique et de Cosmologie, Université Joseph Fourier and CNRS/IN2P3 and Institut National Polytechnique de Grenoble, Grenoble, France  
 56 Department of Physics, Hampton University, Hampton VA, United States of America  
 57 Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge MA, United States of America  
 58 <sup>(a)</sup>Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Heidelberg; <sup>(b)</sup>Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg; <sup>(c)</sup>ZITI Institut für technische Informatik, Ruprecht-Karls-Universität Heidelberg, Mannheim, Germany  
 59 Faculty of Applied Information Science, Hiroshima Institute of Technology, Hiroshima, Japan  
 60 Department of Physics, Indiana University, Bloomington IN, United States of America  
 61 Institut für Astro-und Teilchenphysik, Leopold-Franzens-Universität, Innsbruck, Austria  
 62 University of Iowa, Iowa City IA, United States of America  
 63 Department of Physics and Astronomy, Iowa State University, Ames IA, United States of America  
 64 Joint Institute for Nuclear Research, JINR Dubna, Dubna, Russia  
 65 KEK, High Energy Accelerator Research Organization, Tsukuba, Japan  
 66 Graduate School of Science, Kobe University, Kobe, Japan  
 67 Faculty of Science, Kyoto University, Kyoto, Japan  
 68 Kyoto University of Education, Kyoto, Japan  
 69 Department of Physics, Kyushu University, Fukuoka, Japan  
 70 Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata, Argentina  
 71 Physics Department, Lancaster University, Lancaster, United Kingdom  
 72 <sup>(a)</sup>INFN Sezione di Lecce; <sup>(b)</sup>Dipartimento di Matematica e Fisica, Università del Salento, Lecce, Italy  
 73 Oliver Lodge Laboratory, University of Liverpool, Liverpool, United Kingdom  
 74 Department of Physics, Jožef Stefan Institute and University of Ljubljana, Ljubljana, Slovenia  
 75 School of Physics and Astronomy, Queen Mary University of London, London, United Kingdom  
 76 Department of Physics, Royal Holloway University of London, Surrey, United Kingdom  
 77 Department of Physics and Astronomy, University College London, London, United Kingdom  
 78 Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France  
 79 Fysiska institutionen, Lunds universitet, Lund, Sweden  
 80 Departamento de Física Teórica C-15, Universidad Autónoma de Madrid, Madrid, Spain  
 81 Institut für Physik, Universität Mainz, Mainz, Germany  
 82 School of Physics and Astronomy, University of Manchester, Manchester, United Kingdom  
 83 CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France  
 84 Department of Physics, University of Massachusetts, Amherst MA, United States of America  
 85 Department of Physics, McGill University, Montreal QC, Canada  
 86 School of Physics, University of Melbourne, Victoria, Australia  
 87 Department of Physics, The University of Michigan, Ann Arbor MI, United States of America  
 88 Department of Physics and Astronomy, Michigan State University, East Lansing MI, United States of America  
 89 <sup>(a)</sup>INFN Sezione di Milano; <sup>(b)</sup>Dipartimento di Fisica, Università di Milano, Milano, Italy

- <sup>90</sup> B.I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk, Republic of Belarus
- <sup>91</sup> National Scientific and Educational Centre for Particle and High Energy Physics, Minsk, Republic of Belarus
- <sup>92</sup> Department of Physics, Massachusetts Institute of Technology, Cambridge MA, United States of America
- <sup>93</sup> Group of Particle Physics, University of Montreal, Montreal QC, Canada
- <sup>94</sup> P.N. Lebedev Institute of Physics, Academy of Sciences, Moscow, Russia
- <sup>95</sup> Institute for Theoretical and Experimental Physics (ITEP), Moscow, Russia
- <sup>96</sup> Moscow Engineering and Physics Institute (MEPhI), Moscow, Russia
- <sup>97</sup> Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia
- <sup>98</sup> Fakultät für Physik, Ludwig-Maximilians-Universität München, München, Germany
- <sup>99</sup> Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), München, Germany
- <sup>100</sup> Nagasaki Institute of Applied Science, Nagasaki, Japan
- <sup>101</sup> Graduate School of Science and Kobayashi-Maskawa Institute, Nagoya University, Nagoya, Japan
- <sup>102</sup> <sup>(a)</sup>INFN Sezione di Napoli; <sup>(b)</sup>Dipartimento di Scienze Fisiche, Università di Napoli, Napoli, Italy
- <sup>103</sup> Department of Physics and Astronomy, University of New Mexico, Albuquerque NM, United States of America
- <sup>104</sup> Institute for Mathematics, Astrophysics and Particle Physics, Radboud University Nijmegen/Nikhef, Nijmegen, Netherlands
- <sup>105</sup> Nikhef National Institute for Subatomic Physics and University of Amsterdam, Amsterdam, Netherlands
- <sup>106</sup> Department of Physics, Northern Illinois University, DeKalb IL, United States of America
- <sup>107</sup> Budker Institute of Nuclear Physics, SB RAS, Novosibirsk, Russia
- <sup>108</sup> Department of Physics, New York University, New York NY, United States of America
- <sup>109</sup> Ohio State University, Columbus OH, United States of America
- <sup>110</sup> Faculty of Science, Okayama University, Okayama, Japan
- <sup>111</sup> Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman OK, United States of America
- <sup>112</sup> Department of Physics, Oklahoma State University, Stillwater OK, United States of America
- <sup>113</sup> Palacký University, RCPTM, Olomouc, Czech Republic
- <sup>114</sup> Center for High Energy Physics, University of Oregon, Eugene OR, United States of America
- <sup>115</sup> LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France
- <sup>116</sup> Graduate School of Science, Osaka University, Osaka, Japan
- <sup>117</sup> Department of Physics, University of Oslo, Oslo, Norway
- <sup>118</sup> Department of Physics, Oxford University, Oxford, United Kingdom
- <sup>119</sup> <sup>(a)</sup>INFN Sezione di Pavia; <sup>(b)</sup>Dipartimento di Fisica, Università di Pavia, Pavia, Italy
- <sup>120</sup> Department of Physics, University of Pennsylvania, Philadelphia PA, United States of America
- <sup>121</sup> Petersburg Nuclear Physics Institute, Gatchina, Russia
- <sup>122</sup> <sup>(a)</sup>INFN Sezione di Pisa; <sup>(b)</sup>Dipartimento di Fisica E. Fermi, Università di Pisa, Pisa, Italy
- <sup>123</sup> Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh PA, United States of America
- <sup>124</sup> <sup>(a)</sup>Laboratorio de Instrumentacao e Fisica Experimental de Particulas - LIP, Lisboa, Portugal;  
<sup>(b)</sup>Departamento de Fisica Teorica y del Cosmos and CAFPE, Universidad de Granada, Granada, Spain
- <sup>125</sup> Institute of Physics, Academy of Sciences of the Czech Republic, Praha, Czech Republic
- <sup>126</sup> Faculty of Mathematics and Physics, Charles University in Prague, Praha, Czech Republic
- <sup>127</sup> Czech Technical University in Prague, Praha, Czech Republic
- <sup>128</sup> State Research Center Institute for High Energy Physics, Protvino, Russia
- <sup>129</sup> Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom
- <sup>130</sup> Physics Department, University of Regina, Regina SK, Canada
- <sup>131</sup> Ritsumeikan University, Kusatsu, Shiga, Japan
- <sup>132</sup> <sup>(a)</sup>INFN Sezione di Roma I; <sup>(b)</sup>Dipartimento di Fisica, Università La Sapienza, Roma, Italy
- <sup>133</sup> <sup>(a)</sup>INFN Sezione di Roma Tor Vergata; <sup>(b)</sup>Dipartimento di Fisica, Università di Roma Tor Vergata,



Roma, Italy

<sup>134</sup> <sup>(a)</sup>INFN Sezione di Roma Tre; <sup>(b)</sup>Dipartimento di Fisica, Università Roma Tre, Roma, Italy

<sup>135</sup> <sup>(a)</sup>Faculté des Sciences Ain Chock, Réseau Universitaire de Physique des Hautes Energies - Université Hassan II, Casablanca; <sup>(b)</sup>Centre National de l'Energie des Sciences Techniques Nucleaires, Rabat;

<sup>(c)</sup>Faculté des Sciences Semlalia, Université Cadi Ayyad, LPHEA-Marrakech; <sup>(d)</sup>Faculté des Sciences, Université Mohamed Premier and LPTPM, Oujda; <sup>(e)</sup>Faculté des sciences, Université Mohammed V-Agdal, Rabat, Morocco

<sup>136</sup> DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat a l'Energie Atomique), Gif-sur-Yvette, France

<sup>137</sup> Santa Cruz Institute for Particle Physics, University of California Santa Cruz, Santa Cruz CA, United States of America

<sup>138</sup> Department of Physics, University of Washington, Seattle WA, United States of America

<sup>139</sup> Department of Physics and Astronomy, University of Sheffield, Sheffield, United Kingdom

<sup>140</sup> Department of Physics, Shinshu University, Nagano, Japan

<sup>141</sup> Fachbereich Physik, Universität Siegen, Siegen, Germany

<sup>142</sup> Department of Physics, Simon Fraser University, Burnaby BC, Canada

<sup>143</sup> SLAC National Accelerator Laboratory, Stanford CA, United States of America

<sup>144</sup> <sup>(a)</sup>Faculty of Mathematics, Physics & Informatics, Comenius University, Bratislava; <sup>(b)</sup>Department of Subnuclear Physics, Institute of Experimental Physics of the Slovak Academy of Sciences, Kosice, Slovak Republic

<sup>145</sup> <sup>(a)</sup>Department of Physics, University of Johannesburg, Johannesburg; <sup>(b)</sup>School of Physics, University of the Witwatersrand, Johannesburg, South Africa

<sup>146</sup> <sup>(a)</sup>Department of Physics, Stockholm University; <sup>(b)</sup>The Oskar Klein Centre, Stockholm, Sweden

<sup>147</sup> Physics Department, Royal Institute of Technology, Stockholm, Sweden

<sup>148</sup> Departments of Physics & Astronomy and Chemistry, Stony Brook University, Stony Brook NY, United States of America

<sup>149</sup> Department of Physics and Astronomy, University of Sussex, Brighton, United Kingdom

<sup>150</sup> School of Physics, University of Sydney, Sydney, Australia

<sup>151</sup> Institute of Physics, Academia Sinica, Taipei, Taiwan

<sup>152</sup> Department of Physics, Technion: Israel Institute of Technology, Haifa, Israel

<sup>153</sup> Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel

<sup>154</sup> Department of Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece

<sup>155</sup> International Center for Elementary Particle Physics and Department of Physics, The University of Tokyo, Tokyo, Japan

<sup>156</sup> Graduate School of Science and Technology, Tokyo Metropolitan University, Tokyo, Japan

<sup>157</sup> Department of Physics, Tokyo Institute of Technology, Tokyo, Japan

<sup>158</sup> Department of Physics, University of Toronto, Toronto ON, Canada

<sup>159</sup> <sup>(a)</sup>TRIUMF, Vancouver BC; <sup>(b)</sup>Department of Physics and Astronomy, York University, Toronto ON, Canada

<sup>160</sup> Faculty of Pure and Applied Sciences, University of Tsukuba, Tsukuba, Japan

<sup>161</sup> Department of Physics and Astronomy, Tufts University, Medford MA, United States of America

<sup>162</sup> Centro de Investigaciones, Universidad Antonio Narino, Bogota, Colombia

<sup>163</sup> Department of Physics and Astronomy, University of California Irvine, Irvine CA, United States of America

<sup>164</sup> <sup>(a)</sup>INFN Gruppo Collegato di Udine; <sup>(b)</sup>ICTP, Trieste; <sup>(c)</sup>Dipartimento di Chimica, Fisica e Ambiente, Università di Udine, Udine, Italy

<sup>165</sup> Department of Physics, University of Illinois, Urbana IL, United States of America

<sup>166</sup> Department of Physics and Astronomy, University of Uppsala, Uppsala, Sweden

<sup>167</sup> 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

<sup>168</sup> Department of Physics, University of British Columbia, Vancouver BC, Canada

- <sup>169</sup> Department of Physics and Astronomy, University of Victoria, Victoria BC, Canada
- <sup>170</sup> Department of Physics, University of Warwick, Coventry, United Kingdom
- <sup>171</sup> Waseda University, Tokyo, Japan
- <sup>172</sup> Department of Particle Physics, The Weizmann Institute of Science, Rehovot, Israel
- <sup>173</sup> Department of Physics, University of Wisconsin, Madison WI, United States of America
- <sup>174</sup> Fakultät für Physik und Astronomie, Julius-Maximilians-Universität, Würzburg, Germany
- <sup>175</sup> Fachbereich C Physik, Bergische Universität Wuppertal, Wuppertal, Germany
- <sup>176</sup> Department of Physics, Yale University, New Haven CT, United States of America
- <sup>177</sup> Yerevan Physics Institute, Yerevan, Armenia
- <sup>178</sup> Centre de Calcul de l'Institut National de Physique Nucléaire et de Physique des Particules (IN2P3), Villeurbanne, France
- <sup>a</sup> Also at Laboratório de Instrumentação e Física Experimental de Partículas - LIP, Lisboa, Portugal
- <sup>b</sup> Also at Faculdade de Ciências and CFNUL, Universidade de Lisboa, Lisboa, Portugal
- <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, United States of America
- <sup>f</sup> Also at Novosibirsk State University, Novosibirsk, Russia
- <sup>g</sup> Also at Department of Physics, University of Coimbra, Coimbra, Portugal
- <sup>h</sup> Also at Department of Physics, UASLP, San Luis Potosi, Mexico
- <sup>i</sup> Also at Università di Napoli Parthenope, Napoli, Italy
- <sup>j</sup> Also at Institute of Particle Physics (IPP), Canada
- <sup>k</sup> Also at Department of Physics, Middle East Technical University, Ankara, Turkey
- <sup>l</sup> Also at Louisiana Tech University, Ruston LA, United States of America
- <sup>m</sup> Also at Dep Física and CEFITEC of Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Caparica, Portugal
- <sup>n</sup> Also at Department of Physics and Astronomy, University College London, London, United Kingdom
- <sup>o</sup> Also at Department of Physics, University of Cape Town, Cape Town, South Africa
- <sup>p</sup> Also at Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan
- <sup>q</sup> Also at Institut für Experimentalphysik, Universität Hamburg, Hamburg, Germany
- <sup>r</sup> Also at Manhattan College, New York NY, United States of America
- <sup>s</sup> Also at CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France
- <sup>t</sup> Also at School of Physics and Engineering, Sun Yat-sen University, Guanzhou, China
- <sup>u</sup> Also at Academia Sinica Grid Computing, Institute of Physics, Academia Sinica, Taipei, Taiwan
- <sup>v</sup> Also at School of Physics, Shandong University, Shandong, China
- <sup>w</sup> Also at Dipartimento di Fisica, Università La Sapienza, Roma, Italy
- <sup>x</sup> Also at DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat à l'Energie Atomique), Gif-sur-Yvette, France
- <sup>y</sup> Also at Section de Physique, Université de Genève, Geneva, Switzerland
- <sup>z</sup> Also at Departamento de Física, Universidade de Minho, Braga, Portugal
- <sup>aa</sup> Also at Department of Physics and Astronomy, University of South Carolina, Columbia SC, United States of America
- <sup>ab</sup> Also at Institute for Particle and Nuclear Physics, Wigner Research Centre for Physics, Budapest, Hungary
- <sup>ac</sup> Also at California Institute of Technology, Pasadena CA, United States of America
- <sup>ad</sup> Also at Institute of Physics, Jagiellonian University, Krakow, Poland
- <sup>ae</sup> Also at LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France
- <sup>af</sup> Also at Nevis Laboratory, Columbia University, Irvington NY, United States of America
- <sup>ag</sup> Also at Department of Physics and Astronomy, University of Sheffield, Sheffield, United Kingdom
- <sup>ah</sup> Also at Department of Physics, Oxford University, Oxford, United Kingdom
- <sup>ai</sup> Also at Department of Physics, The University of Michigan, Ann Arbor MI, United States of America
- <sup>aj</sup> Also at Discipline of Physics, University of KwaZulu-Natal, Durban, South Africa
- <sup>ak</sup> Also at Institute of Physics, Academia Sinica, Taipei, Taiwan

\* Deceased