

EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH (CERN)



Submitted to: Phys. Lett. B.

CERN-PH-EP-2015-164  
22nd October 2015

## Measurement of the branching ratio $\Gamma(\Lambda_b^0 \rightarrow \psi(2S)\Lambda^0)/\Gamma(\Lambda_b^0 \rightarrow J/\psi\Lambda^0)$ with the ATLAS detector

The ATLAS Collaboration

### Abstract

An observation of the  $\Lambda_b^0 \rightarrow \psi(2S)\Lambda^0$  decay and a comparison of its branching fraction with that of the  $\Lambda_b^0 \rightarrow J/\psi\Lambda^0$  decay has been made with the ATLAS detector in proton–proton collisions at  $\sqrt{s} = 8$  TeV at the LHC using an integrated luminosity of  $20.6 \text{ fb}^{-1}$ . The  $J/\psi$  and  $\psi(2S)$  mesons are reconstructed in their decays to a muon pair, while the  $\Lambda^0 \rightarrow p\pi^-$  decay is exploited for the  $\Lambda^0$  baryon reconstruction. The  $\Lambda_b^0$  baryons are reconstructed with transverse momentum  $p_T > 10 \text{ GeV}$  and pseudorapidity  $|\eta| < 2.1$ . The measured branching ratio of the  $\Lambda_b^0 \rightarrow \psi(2S)\Lambda^0$  and  $\Lambda_b^0 \rightarrow J/\psi\Lambda^0$  decays is  $\Gamma(\Lambda_b^0 \rightarrow \psi(2S)\Lambda^0)/\Gamma(\Lambda_b^0 \rightarrow J/\psi\Lambda^0) = 0.501 \pm 0.033(\text{stat}) \pm 0.019(\text{syst})$ , lower than the expectation from the covariant quark model.

# Contents

<b>1</b>	<b>Introduction</b>	<b>2</b>
<b>2</b>	<b>The ATLAS detector, data and Monte Carlo simulation samples</b>	<b>2</b>
<b>3</b>	<b>Event and <math>\Lambda_b^0</math> candidate selection</b>	<b>4</b>
3.1	Charmonium candidate selection	4
3.2	$\Lambda^0$ and $\bar{\Lambda}^0$ candidate selection	4
3.3	$\Lambda_b^0$ reconstruction	4
<b>4</b>	<b>Measurement of the <math>\Lambda_b^0</math> branching ratio <math>\Gamma(\Lambda_b^0 \rightarrow \psi(2S)\Lambda^0)/\Gamma(\Lambda_b^0 \rightarrow J/\psi\Lambda^0)</math></b>	<b>8</b>
<b>5</b>	<b>Summary</b>	<b>10</b>

## 1 Introduction

The  $\Lambda_b^0$  baryon properties have been extensively studied at the Large Hadron Collider (LHC) [1–7]. The decay channel  $\Lambda_b^0 \rightarrow J/\psi(\mu^+\mu^-)\Lambda^0(p\pi^-)$ <sup>1</sup> has been primarily used by the LHC experiments in these studies, although a number of other  $\Lambda_b^0$  decay channels have been exploited by the LHCb experiment. In particular, a measurement of the differential branching fraction and angular analysis of the rare decay  $\Lambda_b^0 \rightarrow \mu^+\mu^-\Lambda^0$  was performed by LHCb [8, 9] following observation of this decay by the CDF experiment [10] at the Tevatron collider. However, no results for the decay mode  $\Lambda_b^0 \rightarrow \psi(2S)\Lambda^0$  have yet been reported, although a measurement of the decay properties would be useful for verification of theoretical predictions [11].

The  $\Lambda_b^0 \rightarrow \psi(2S)\Lambda^0$  branching fraction should be of the same order as that of the decay  $\Lambda_b^0 \rightarrow J/\psi\Lambda^0$  as suggested by the branching fraction values of the  $B^0$ ,  $B^+$  and  $B_s^0$  meson decays to  $\psi(2S)/J/\psi$  and either a pseudoscalar ( $K^0$ ,  $K^+$ ,  $\eta$ ) or vector ( $K^{*0}$ ,  $K^{*+}$ ,  $\phi$ ) meson. The branching ratios of such  $B$  meson decays to  $\psi(2S)X$  and  $J/\psi X$  are within the 0.5–0.8 range [12], and are generally reproduced by factorisation calculations [13]. The only available theoretical calculation of the branching ratio of the  $\Lambda_b^0 \rightarrow \psi(2S)\Lambda^0$  and  $\Lambda_b^0 \rightarrow J/\psi\Lambda^0$  decays, performed in the framework of the covariant quark model [14], predicts 0.8 with an uncertainty of approximately 0.1 [11].

An observation of the  $\Lambda_b^0 \rightarrow \psi(2S)\Lambda^0$  decay and a measurement of the branching ratio of the  $\Lambda_b^0 \rightarrow \psi(2S)\Lambda^0$  and  $\Lambda_b^0 \rightarrow J/\psi\Lambda^0$  decays is reported in this Letter. The  $J/\psi$  and  $\psi(2S)$  mesons are reconstructed in their decays to a muon pair, while the  $\Lambda^0 \rightarrow p\pi^-$  decay is exploited for the  $\Lambda^0$  baryon reconstruction. The  $\Lambda_b^0$  baryons are reconstructed with transverse momentum  $p_T > 10$  GeV and pseudorapidity  $|\eta| < 2.1$ .

## 2 The ATLAS detector, data and Monte Carlo simulation samples

A detailed description of the ATLAS detector can be found elsewhere [15]. A brief outline of the components most relevant to this analysis is given below.

---

<sup>1</sup> Hereafter, charge conjugation is implied, unless explicitly stated otherwise.

The ATLAS inner detector (ID) has full coverage<sup>2</sup> in  $\phi$ , covers the pseudorapidity range  $|\eta| < 2.5$  and operates inside an axial magnetic field of 2 T. It consists of a silicon pixel detector (Pixel), a silicon microstrip detector (semiconductor tracker, SCT) and a transition radiation tracker (TRT). The inner-detector barrel (end-cap) parts consist of 3 ( $2 \times 3$ ) Pixel layers, 4 ( $2 \times 9$ ) double-layers of single-sided SCT strips and 73 ( $2 \times 160$ ) layers of TRT straws. The ATLAS muon spectrometer (MS) covers the pseudorapidity range  $|\eta| < 2.7$ . It consists of precision tracking chambers, fast trigger detectors and a large toroidal magnet system generating an average field of 0.5 T in the barrel region ( $|\eta| < 1.05$ ) and 1 T in the end-cap regions ( $1.05 < |\eta| < 2.7$ ).

The ATLAS detector has a three-level trigger system [16]: the hardware-based Level-1 system and the two-stage High Level Trigger (HLT). For this measurement, dimuon triggers are used. At Level-1, the dimuon triggers search for patterns of MS hits corresponding to dimuons passing various  $p_T$  thresholds. Since the rate from the low- $p_T$  dimuon triggers was too high, prescale factors were applied to reduce their output rates. The data sample used in this analysis was collected using three dimuon triggers with  $p_T$  thresholds of 4 GeV for both muons, 4 GeV and 6 GeV for the two muons, and 6 GeV for both muons. At the HLT, the dimuon triggers used require muons with opposite charges and dimuon mass in the range  $2.5 < m(\mu^+\mu^-) < 4.3$  GeV.

This analysis uses  $20.6 \text{ fb}^{-1}$  of proton–proton collision data with a centre-of-mass energy of 8 TeV recorded by the ATLAS detector at the LHC in 2012. The uncertainty on the integrated luminosity is  $\pm 2.8\%$ . It is derived following the same methodology as that detailed in [17]. The event sample is processed using the standard offline ATLAS detector calibration and event reconstruction code. There are typically a few primary vertex candidates in each event due to multiple collisions per bunch crossing. Only events with at least four reconstructed tracks with  $p_T > 0.4$  GeV and at least one reconstructed primary vertex candidate are kept for further analysis.

To model inelastic  $pp$  events containing  $\Lambda_b^0 \rightarrow J/\psi(\mu^+\mu^-)\Lambda^0$ ,  $\Lambda_b^0 \rightarrow \psi(\mu^+\mu^-)\Lambda^0$ ,  $B^0 \rightarrow J/\psi(\mu^+\mu^-)K_S^0$  or  $B^0 \rightarrow \psi(\mu^+\mu^-)K_S^0$  decays,<sup>3</sup> four large samples of Monte Carlo (MC) simulated events are prepared using the PYTHIA 8.1 [18] MC generator. The  $B^0$  MC samples are needed to control reflections from  $B^0$  decays to the  $\Lambda_b^0$  signal distributions. The generation is based on leading-order matrix elements for all  $2 \rightarrow 2$  QCD processes. Initial- and final-state parton showering is used to simulate higher-order processes. Generated events with both muons from  $J/\psi$  or  $\psi(2S)$  decays having transverse momenta above 3.5 GeV and pseudorapidities within  $\pm 2.5$ , and, for  $\Lambda_b^0$  MC samples, with the  $\Lambda^0$  transverse momentum above 1 GeV are passed through a full simulation of the detector using the ATLAS simulation framework [19] based on GEANT4 [20, 21] and processed with the same reconstruction program as used for the data. An emulation of the three triggers used for the data collection is applied to the MC samples. The angular decay distributions of the  $\Lambda_b^0 \rightarrow J/\psi(\mu^+\mu^-)\Lambda^0(p\pi^-)$  decay are modelled using the helicity amplitudes measured by ATLAS [2]. For the  $\Lambda_b^0 \rightarrow \psi(\mu^+\mu^-)\Lambda^0(p\pi^-)$  decay, the helicity amplitudes are set to the predicted values [11].

<sup>2</sup> The ATLAS coordinate system is a Cartesian right-handed system, with the coordinate origin at the nominal interaction point. The anti-clockwise beam direction defines the positive  $z$ -axis, with the  $x$ -axis pointing to the centre of the LHC ring. Polar ( $\theta$ ) and azimuthal ( $\phi$ ) angles are measured with respect to this reference system. The pseudorapidity is defined as  $\eta = -\ln \tan(\theta/2)$ .

<sup>3</sup> In this Letter,  $\psi(2S)$  is referred to as  $\psi$  when its decay channel is indicated.

### 3 Event and $\Lambda_b^0$ candidate selection

#### 3.1 Charmonium candidate selection

Events are required to contain at least two muons identified by the MS with tracks reconstructed in the ID. The reconstructed muons are required to match the muon candidates identified by the trigger. The muon track parameters are taken from the ID measurement alone, since the MS does not significantly improve the precision in the momentum range relevant for the charmonium measurements presented here. To ensure accurate measurements, each muon track must contain at least six SCT hits and at least one Pixel hit. Muon candidates satisfying these criteria are required to have opposite charges and a successful fit to a common vertex with  $\chi^2/N_{\text{dof}} < 10$ , where  $\chi^2$  is the fit quality with the number of degrees of freedom  $N_{\text{dof}} = 1$ . Events with  $m(\mu^+\mu^-)$  values within  $\pm 200$  MeV intervals around the  $J/\psi$  and  $\psi(2S)$  world average masses [12] are used to search for  $\Lambda^0 \rightarrow p\pi^-$  candidates.

#### 3.2 $\Lambda^0$ and $\bar{\Lambda}^0$ candidate selection

In all events with  $J/\psi$  or  $\psi(2S)$  candidates, pairs of tracks from particles with opposite charge are combined to form  $\Lambda^0$  candidates. Each track is required to have at least one Pixel or SCT hit. Only pairs successfully fitted to a common vertex with  $\chi^2/N_{\text{dof}} < 5$  are kept. The track with larger momentum is assigned the proton mass hypothesis since the proton always has a larger momentum than the pion for  $\Lambda^0$  baryons with momenta larger than 0.3 GeV. To suppress combinatorial background the following requirements are used:

- $p_T(p) > 1.7$  GeV.
- $|z_0(p)| < 25$  mm, where  $z_0(p)$  is the proton longitudinal impact parameter with respect to the dimuon vertex. MC studies show the requirement produces no loss of signal.
- $L_{xy}^{\text{BL}}(\Lambda^0) > 7$  mm, where  $L_{xy}^{\text{BL}}(\Lambda^0)$  is the transverse decay length<sup>4</sup> of the  $\Lambda^0$  candidate measured from the beam line.

Events with  $m(p\pi^-)$  values within an interval of  $\pm 20$  MeV around the  $\Lambda^0$  world average mass [12] are kept for further analysis.

#### 3.3 $\Lambda_b^0$ reconstruction

Tracks of the selected charmonium and  $\Lambda^0$  candidates are simultaneously refitted with the dimuon and dihadron masses constrained to the world average masses of  $J/\psi$  ( $m_{J/\psi}$ ) or  $\psi(2S)$  ( $m_{\psi(2S)}$ ) and  $\Lambda^0$  ( $m_{\Lambda^0}$ ) [12], respectively. The combined momentum of the refitted  $\Lambda^0$  track pair is required to point to the dimuon vertex. To control  $B^0$  reflections to the  $\Lambda_b^0$  signal distributions, a  $B^0$  decay topology fit is also attempted for each track quadruplet successfully fitted to the  $\Lambda_b^0$  topology, i.e. the pion mass is assigned to both hadron tracks and the dihadron mass is constrained to the world average mass of  $K_S^0$  [12]. To suppress combinatorial and  $B^0$  backgrounds the following requirements are used:

---

<sup>4</sup> The transverse decay length of a particle is the transverse distance between the primary or production vertex and the particle decay vertex projected along the transverse momentum of the particle.

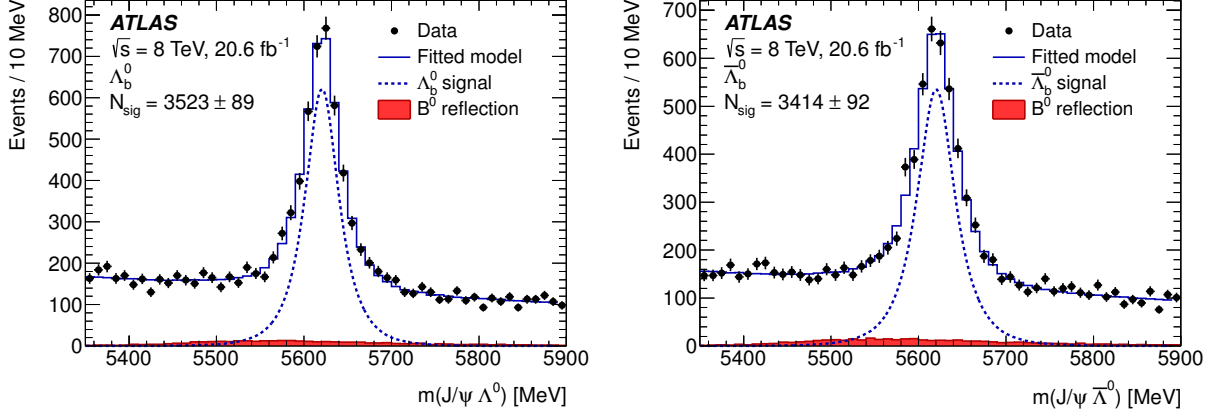


Figure 1: The invariant mass distributions  $m(J/\psi \Lambda^0)$  (left plot) and  $m(J/\psi \bar{\Lambda}^0)$  (right plot) for selected  $\Lambda_b^0$  and  $\bar{\Lambda}_b^0$  candidates, respectively. The solid histograms represent the fit results (see text). The  $\Lambda_b^0$  signals (dashed lines) and the  $B^0$  reflections are also shown.

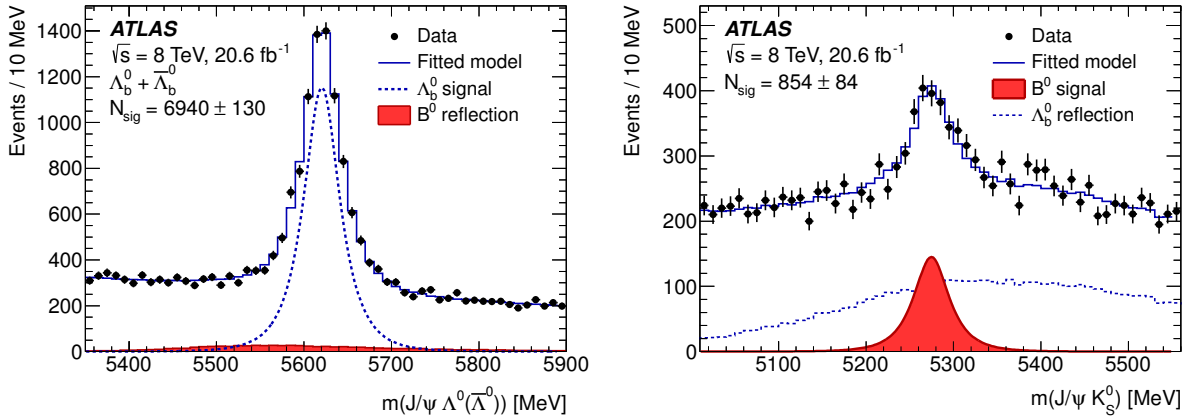


Figure 2: The invariant mass distributions for the combined sample of the selected  $\Lambda_b^0$  and  $\bar{\Lambda}_b^0$  candidates obtained after their fits to the  $\Lambda_b^0 \rightarrow J/\psi \Lambda^0$  (left plot) and  $B^0 \rightarrow J/\psi K_S^0$  (right plot) topologies. The solid histograms represent fit results (see text). The  $\Lambda_b^0$  and  $B^0$  signals and their mutual reflections are also shown.

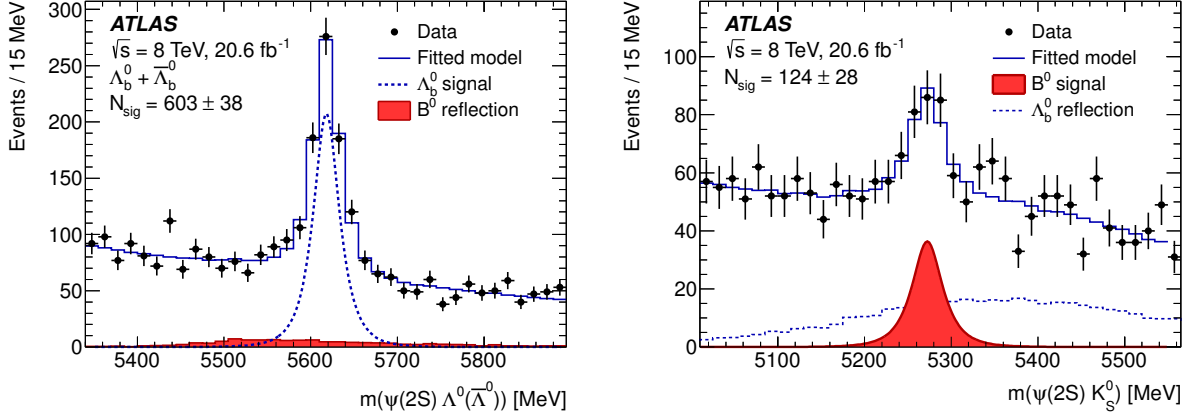


Figure 3: The invariant mass distributions for the combined sample of the selected  $\Lambda_b^0$  and  $\bar{\Lambda}_b^0$  candidates obtained after their fits to the  $\Lambda_b^0 \rightarrow \psi(2S)\Lambda^0$  (left plot) and  $B^0 \rightarrow \psi(2S)K_S^0$  (right plot) topologies. The solid histograms represent fit results (see text). The  $\Lambda_b^0$  and  $B^0$  signals and their mutual reflections are also shown.

- $\chi^2(\Lambda_b^0)/N_{\text{dof}} < 3$ , where  $\chi^2$  is the quality of the fit to the  $\Lambda_b^0$  topology with  $N_{\text{dof}} = 6$ .
- $L_{xy}(\Lambda^0) > 10$  mm, where  $L_{xy}(\Lambda^0)$  is the transverse decay length of the refitted  $\Lambda^0$  vertex measured from the  $\Lambda_b^0$  (dimuon) vertex.
- $p_T(\Lambda^0) > 2.5$  GeV.
- $p_T(\pi^-) > 0.45$  GeV.
- $\tau(\Lambda_b^0) > 0.35$  ps, where  $\tau(\Lambda_b^0) = L_{xy}(\Lambda_b^0) \cdot m_{\Lambda_b^0}/p_T(\Lambda_b^0)$  is the  $\Lambda_b^0$  proper decay time,  $L_{xy}(\Lambda_b^0)$  is the transverse decay length of the  $\Lambda_b^0$  vertex measured from the primary vertex and  $m_{\Lambda_b^0}$  is the  $\Lambda_b^0$  world average mass [12]. The primary vertex candidate with at least three tracks and the smallest value of the three-dimensional impact parameter of the  $\Lambda_b^0$  candidate is selected as the actual primary vertex.
- $\mathcal{P}(\Lambda_b^0) > \mathcal{P}(B^0)$ , where  $\mathcal{P}(\Lambda_b^0)$  and  $\mathcal{P}(B^0)$  are the  $\chi^2$  probabilities of the quadruplet fits with  $\Lambda_b^0$  and  $B^0$  topologies, respectively.

The muon transverse momenta and pseudorapidities are required to be in the ranges with high values of the trigger and reconstruction acceptances:

$$p_T(\mu^\pm) > 4 \text{ GeV}, |\eta(\mu^\pm)| < 2.3.$$

The kinematic range of the  $\Lambda_b^0$  measurement is fixed to

$$p_T(\Lambda_b^0) > 10 \text{ GeV}, |\eta(\Lambda_b^0)| < 2.1.$$

The invariant mass distribution  $m(J/\psi\Lambda^0)$ , calculated using track parameters from the  $\Lambda_b^0$  topology fits, is shown in Figure 1 separately for the selected  $\Lambda_b^0$  and  $\bar{\Lambda}_b^0$  candidates. Clear signals with similar size are seen in the two distributions around the world average mass of the  $\Lambda_b^0$  baryon. Figures 2 and 3 show the  $m(J/\psi\Lambda^0)$  and  $m(\psi(2S)\Lambda^0)$  distributions for the combined sample of the  $\Lambda_b^0$  and  $\bar{\Lambda}_b^0$  candidates. The invariant mass distributions  $m(J/\psi K_S^0)$  and  $m(\psi(2S)K_S^0)$  from the  $B^0$  topology fits are also shown.

Clear signals are seen in the  $m(J/\psi\Lambda^0)$  and  $m(\psi(2S)\Lambda^0)$  distributions<sup>5</sup> around the world average mass of the  $\Lambda_b^0$  baryon. There are also signals in the  $m(J/\psi K_S^0)$  and  $m(\psi(2S)K_S^0)$  distributions near the world average mass of the  $B^0$  meson [12]. The  $B^0$  signals are smaller than the  $\Lambda_b^0$  signals due to the selection requirements.

The  $m(J/\psi\Lambda^0)$  and  $m(J/\psi K_S^0)$  distributions are simultaneously fitted to sums of signal and two-component background distributions. The signals are described by modified Gaussian functions [22]. The modified Gaussian function is defined as

$$\text{Gauss}^{\text{mod}} \propto \exp[-0.5 \cdot x^{1+1/(1+0.5 \cdot x)}],$$

where  $x = |(m - m_0)/\sigma|$ . This functional form, introduced to take into account the non-Gaussian tails of resonant signals, describes both data and MC signals well. The signal position,  $m_0$ , and width,  $\sigma$ , as well as the number of the signal events are free parameters of the fit. The non-resonant backgrounds in the distributions are described by independent exponential functions. The mutual  $B^0$  and  $\Lambda_b^0$  reflections are described by MC templates normalised to the numbers of  $B^0$  and  $\Lambda_b^0$  hadrons obtained in the fit. The reflection normalisations are corrected for small losses (2–6%) of  $\Lambda_b^0$  and  $B^0$  hadrons that passed the  $\Lambda_b^0$  reconstruction but failed the  $B^0$  reconstruction. The corrections are obtained using MC simulation. A similar fit is performed for the  $m(\psi(2S)\Lambda^0)$  and  $m(\psi(2S)K_S^0)$  distributions. In the analysis of the combined  $\Lambda_b^0$  and  $\bar{\Lambda}_b^0$  samples, the ratio of the MC  $\Lambda_b^0$  and  $\bar{\Lambda}_b^0$  events is set to the data ratio obtained in the separate  $\Lambda_b^0 \rightarrow J/\psi\Lambda^0$  and  $\bar{\Lambda}_b^0 \rightarrow J/\psi\bar{\Lambda}^0$  fits (Figure 1). The  $\Lambda_b^0$  and  $\bar{\Lambda}_b^0$  fitted yields are  $3523 \pm 89$  and  $3414 \pm 92$ , respectively, providing the ratio  $1.03 \pm 0.04(\text{stat})$ .

The results of the fits for the combined  $\Lambda_b^0$  and  $\bar{\Lambda}_b^0$  samples are summarised in Table 1. The  $\Lambda_b^0$  mass values obtained from the fits of the  $m(J/\psi\Lambda^0)$  and  $m(\psi(2S)\Lambda^0)$  distributions agree with each other and with the world average  $\Lambda_b^0$  mass value [12]. The signal widths are different, reflecting the difference in charmonium masses in the two decay channels, in agreement with the MC expectations. The quality,  $\chi^2/N_{\text{dof}}$ , of the  $\Lambda_b^0 \rightarrow J/\psi\Lambda^0$  and  $\Lambda_b^0 \rightarrow \psi(2S)\Lambda^0$  signal fits are 1.0 and 1.1, respectively.

	$\Lambda_b^0 \rightarrow J/\psi\Lambda^0$	$B^0 \rightarrow J/\psi K_S^0$	$\Lambda_b^0 \rightarrow \psi(2S)\Lambda^0$	$B^0 \rightarrow \psi(2S)K_S^0$
$N_{\text{sig}}$	$6940 \pm 130$	$854 \pm 84$	$603 \pm 38$	$124 \pm 28$
$m_{\text{sig}}$ [MeV]	$5620.4 \pm 0.4$	$5274.7 \pm 2.3$	$5618.2 \pm 1.2$	$5272.4 \pm 4.9$
$\sigma_{\text{sig}}$ [MeV]	$19.7 \pm 0.5$	$19.2 \pm 2.2$	$14.3 \pm 1.1$	$16.7 \pm 4.1$

Table 1: The numbers of signal events,  $N_{\text{sig}}$ , signal masses,  $m_{\text{sig}}$ , and signal widths,  $\sigma_{\text{sig}}$ , obtained by the fits (see text). Only statistical uncertainties are shown.

To verify that the observed  $\Lambda_b^0$  signals correspond to the  $\Lambda_b^0 \rightarrow J/\psi\Lambda^0$  and  $\Lambda_b^0 \rightarrow \psi(2S)\Lambda^0$  decays the signal reconstruction is repeated with only one mass constraint for either the dimuon or the dihadron track pair in the cascade fit and the  $\Lambda_b^0$  mass is calculated using the mass-difference method. In the case that the dihadron mass is fixed to the  $\Lambda^0$  mass, the  $\Lambda_b^0$  mass is calculated as  $m(\mu^+\mu^-\Lambda^0) - m(\mu^+\mu^-) + m_{J/\psi}$  ( $m(\mu^+\mu^-\Lambda^0) - m(\mu^+\mu^-) + m_{\psi(2S)}$ ) for  $m(\mu^+\mu^-) < 3.4$  GeV ( $m(\mu^+\mu^-) > 3.4$  GeV). When the dimuon mass is fixed to the  $J/\psi$  ( $\psi(2S)$ ) mass, the  $\Lambda_b^0$  mass is calculated as  $m(J/\psi p\pi^-) - m(p\pi^-) + m_{\Lambda^0}$  ( $m(\psi(2S)p\pi^-) - m(p\pi^-) + m_{\Lambda^0}$ ). In both cases clean  $\Lambda_b^0$  signals are reconstructed with numbers of signal events compatible

<sup>5</sup> Studies with MC simulated events show that the fraction of reconstructed  $\Lambda_b^0 \rightarrow J/\psi\Lambda^0$  decays which can contribute to the reconstructed  $\Lambda_b^0 \rightarrow \psi(2S)\Lambda^0$  signal is  $\sim 10^{-5}$ .



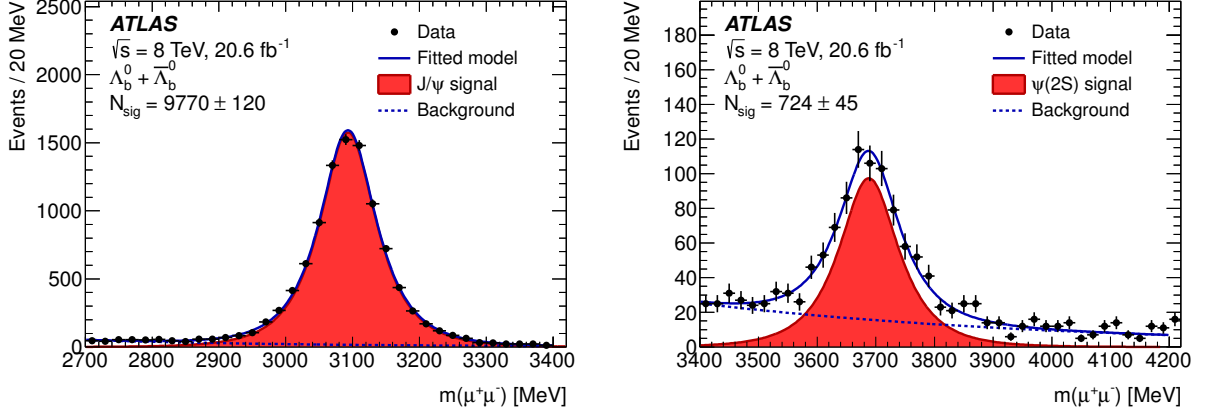


Figure 4: The  $m(\mu^+\mu^-)$  distributions for  $\Lambda_b^0 \rightarrow J/\psi\Lambda^0$  candidates (left plot) and  $\Lambda_b^0 \rightarrow \psi(2S)\Lambda^0$  candidates (right plot) after full selection, without a mass constraint on the charmonium mass in the cascade fit. The spectra are fitted with a sum of an exponential function and a modified Gaussian function.

with those in Table 1. Figure 4 shows the  $m(\mu^+\mu^-)$  distributions for the  $\Lambda_b^0 \rightarrow J/\psi\Lambda^0$  and  $\Lambda_b^0 \rightarrow \psi(2S)\Lambda^0$  candidates reconstructed with the mass constraint for the dihadron pair and selected within  $\pm 3\sigma_{\text{sig}}$  around the world average  $\Lambda_b^0$  mass. Clear signals from  $J/\psi$  and  $\psi(2S)$  are seen. The  $m(\mu^+\mu^-)$  distributions are fitted to a sum of an exponential function describing the background and a modified Gaussian function describing the signal. The signal yields are found to be  $N_{J/\psi} = 9770 \pm 120$  and  $N_{\psi(2S)} = 724 \pm 45$ . Figure 5 shows the  $m(p\pi^-)$  distributions for the  $\Lambda_b^0$  candidates reconstructed with the mass constraint for the dimuon pair and selected within  $\pm 3\sigma_{\text{sig}}$  around the world average  $\Lambda_b^0$  mass. Clear signals from  $\Lambda^0$  are seen. The  $m(p\pi^-)$  distributions are fitted to a sum of a threshold function describing the background and a modified Gaussian function describing the signal. The threshold function has the form

$$A \cdot (m - m_p - m_{\pi^-})^B \cdot \exp[C \cdot (m - m_p - m_{\pi^-}) + D \cdot (m - m_p - m_{\pi^-})^2],$$

where  $m_p$  and  $m_{\pi^-}$  are the proton and pion masses, respectively, and  $A$ ,  $B$ ,  $C$  and  $D$  are free parameters. The  $\Lambda^0$  signal yields are found to be  $7710 \pm 120$  and  $702 \pm 38$  for the  $\Lambda_b^0 \rightarrow J/\psi\Lambda^0$  and  $\Lambda_b^0 \rightarrow \psi(2S)\Lambda^0$  candidates, respectively. The numbers of signal charmonium and  $\Lambda^0$  events are larger than the numbers of the corresponding  $\Lambda_b^0$  signal events because the backgrounds are partly due to genuine charmonium and  $\Lambda^0$  states.

#### 4 Measurement of the $\Lambda_b^0$ branching ratio

$$\Gamma(\Lambda_b^0 \rightarrow \psi(2S)\Lambda^0)/\Gamma(\Lambda_b^0 \rightarrow J/\psi\Lambda^0)$$

The numbers of  $\Lambda_b^0$  signal events in the two decay modes, reported in Table 1, are corrected for detector effects and selection efficiencies as  $N_{\text{cor}} = N_{\text{sig}}/\mathcal{A}$ , where  $N_{\text{cor}}$  is the corrected number and  $\mathcal{A}$  is the MC acceptance. The MC events with the  $\psi(2S)/J/\psi$  muons having transverse momenta above 3.5 GeV and pseudorapidities within  $\pm 2.5$ , and  $\Lambda^0$  transverse momentum above 1 GeV, passed through the detector simulation and event reconstruction, are used to correct the numbers of signal events in the fiducial range, defined as follows:



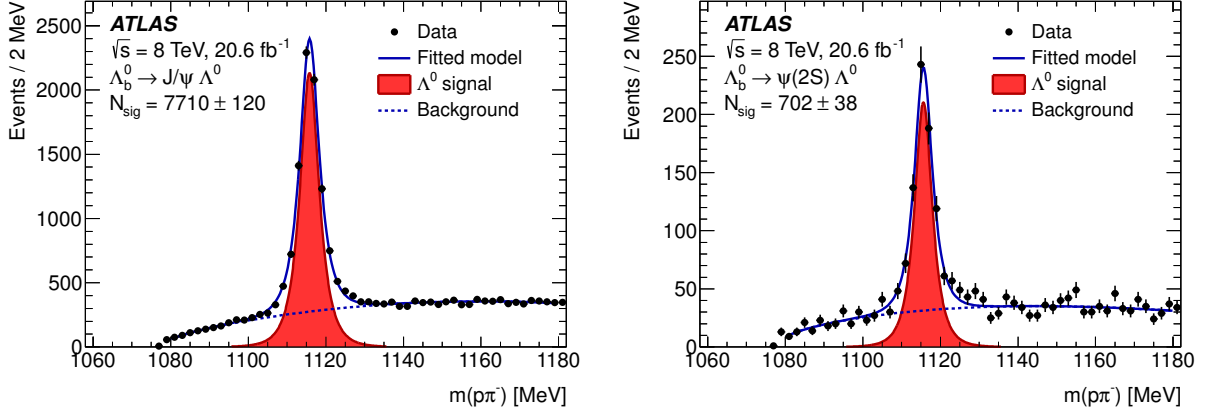


Figure 5: The  $m(p\pi^-)$  distributions for  $\Lambda_b^0 \rightarrow J/\psi \Lambda^0$  candidates (left plot) and  $\Lambda_b^0 \rightarrow \psi(2S) \Lambda^0$  candidates (right plot) after full selection, without a mass constraint on the  $\Lambda^0$  mass in the cascade fit. The spectra are fitted with a sum of a threshold function and a modified Gaussian function.

$$\begin{aligned}
 p_T(\Lambda_b^0) &> 10 \text{ GeV}, |\eta(\Lambda_b^0)| < 2.1, \\
 p_T(\mu^\pm) &> 4 \text{ GeV}, |\eta(\mu^\pm)| < 2.3, \\
 p_T(\Lambda^0) &> 2.5 \text{ GeV}.
 \end{aligned}$$

The acceptances are calculated as the ratio of the number of reconstructed  $\Lambda_b^0$  signal events passing all selection requirements in the above fiducial range to the number of  $\Lambda_b^0$  baryons in the same decay mode and fiducial range at the MC generator level. These acceptances are  $4.16 \pm 0.02(\text{stat})\%$  and  $4.30 \pm 0.03(\text{stat})\%$  for the  $\Lambda_b^0 \rightarrow J/\psi \Lambda^0$  and  $\Lambda_b^0 \rightarrow \psi(2S) \Lambda^0$  decays, respectively. In the fiducial range, the ratio of the corrected numbers of  $\Lambda_b^0$  signal events in the two decay modes is  $0.0841 \pm 0.0055(\text{stat})$ .

Then the numbers are corrected, using generator-level MC samples with no requirements on the  $\mu^\pm$  and  $\Lambda^0$  selection, from the above fiducial range to the kinematic range of the  $\Lambda_b^0$  measurement

$$p_T(\Lambda_b^0) > 10 \text{ GeV}, |\eta(\Lambda_b^0)| < 2.1.$$

The acceptances of the latter corrections are  $7.57 \pm 0.06(\text{stat})\%$  and  $9.61 \pm 0.07(\text{stat})\%$  for the  $\Lambda_b^0 \rightarrow J/\psi \Lambda^0$  and  $\Lambda_b^0 \rightarrow \psi(2S) \Lambda^0$  decays, respectively. Finally, the branching ratio of the two  $\Lambda_b^0$  decays is calculated as

$$\frac{\Gamma(\Lambda_b^0 \rightarrow \psi(2S) \Lambda^0)}{\Gamma(\Lambda_b^0 \rightarrow J/\psi \Lambda^0)} = \frac{N_{\text{cor}}(\Lambda_b^0 \rightarrow \psi(\mu^+\mu^-) \Lambda^0)}{N_{\text{cor}}(\Lambda_b^0 \rightarrow J/\psi(\mu^+\mu^-) \Lambda^0)} \cdot \frac{\mathcal{B}(J/\psi \rightarrow \ell^+\ell^-)}{\mathcal{B}(\psi(2S) \rightarrow \ell^+\ell^-)},$$

where  $\mathcal{B}$  is the branching fraction of the corresponding charmonium decay to a lepton pair. In the case of  $J/\psi$ , the branching fraction  $\mathcal{B}(J/\psi \rightarrow \mu^+\mu^-) = 0.05961 \pm 0.00033$  [12] is used. For  $\mathcal{B}(\psi(2S) \rightarrow \ell^+\ell^-)$ , the branching fraction  $\mathcal{B}(\psi(2S) \rightarrow e^+e^-) = 0.00789 \pm 0.00017$  is used, assuming lepton universality, because it is measured with better precision than in the muon channel,  $\mathcal{B}(\psi(2S) \rightarrow \mu^+\mu^-) = 0.0079 \pm 0.0009$  [12].

Five groups of systematic uncertainty sources are considered. The effect of each group on the measured ratio, obtained by adding in quadrature the effects of independent sources, is shown in parentheses:

- Dependence on the  $\Lambda_b^0$  production model ( $\pm 0.1\%$ ). The uncertainty is obtained by
  - varying the MC  $p_T(\Lambda_b^0)$  and  $|\eta(\Lambda_b^0)|$  distributions while preserving agreement with the data distributions,
  - varying the MC ratio of  $\Lambda_b^0$  and  $\bar{\Lambda}_b^0$  baryons in the range allowed by the separate data fits (Section 3),
  - varying the lifetimes of the  $\Lambda^0$  and  $\Lambda_b^0$  baryons in the ranges of their uncertainties [12].
- Dependence on the  $\Lambda_b^0$  polarisation model ( $\pm 1.1\%$ ). The uncertainty is obtained by varying the MC  $\Lambda_b^0 \rightarrow J/\psi(\mu^+\mu^-)\Lambda^0(p\pi^-)$  helicity amplitudes in the range of their uncertainties [2], and by changing the MC  $\Lambda_b^0 \rightarrow \psi(\mu^+\mu^-)\Lambda^0(p\pi^-)$  helicity amplitudes to those measured by ATLAS for the  $\Lambda_b^0 \rightarrow J/\psi(\mu^+\mu^-)\Lambda^0(p\pi^-)$  decay [2].
- The uncertainty of the signal extraction procedures ( $\pm 2.8\%$ ). The uncertainty is determined by changing the background parameterisations to second order polynomials and by reducing the ranges used for the signal fits by 20 MeV from either left or right side, independently for the two  $\Lambda_b^0$  signals. In addition, the corrections of the reflection normalisations, obtained from MC simulation, are varied by half of their values. This uncertainty is affected by statistical fluctuations.
- The uncertainty originating from the MC statistical uncertainty ( $\pm 1.3\%$ ).
- The uncertainty of the charmonium branching fractions  $\mathcal{B}(J/\psi \rightarrow \mu^+\mu^-)$  and  $\mathcal{B}(\psi(2S) \rightarrow e^+e^-)$  ( $\pm 2.2\%$ ).

The measured branching ratio of the two  $\Lambda_b^0$  decays is

$$\frac{\Gamma(\Lambda_b^0 \rightarrow \psi(2S)\Lambda^0)}{\Gamma(\Lambda_b^0 \rightarrow J/\psi\Lambda^0)} = 0.501 \pm 0.033(\text{stat}) \pm 0.016(\text{syst}) \pm 0.011(\mathcal{B}),$$

where the contributions from the first four groups of systematic uncertainty are added in quadrature. The uncertainty due to the uncertainties of the charmonium branching fractions  $\mathcal{B}$  is quoted separately. The luminosity uncertainty, uncertainties of the muon and hadron track reconstruction and the vertexing uncertainties cancel out in the ratio. The bias in the measured ratio due to contributions from the rare decay  $\Lambda_b^0 \rightarrow \mu^+\mu^-\Lambda^0$  is estimated using the LHCb measurement [9] of the rare decay's differential branching fraction to be below 0.5% and thus neglected. Consistent ratio values are found when calculated in bins of  $p_T(\Lambda_b^0)$  or separately for  $\Lambda_b^0$  and  $\bar{\Lambda}_b^0$  baryons.

The measured ratio lies in the range 0.5–0.8 found for the branching ratios of analogous  $B$  meson decays [12]. The only available calculation for the branching ratio of the two  $\Lambda_b^0$  decays ( $0.8 \pm 0.1$  [11]) exceeds the measured value.

## 5 Summary

The  $\Lambda_b^0 \rightarrow \psi(2S)\Lambda^0$  decay has been observed with the ATLAS detector in  $pp$  collisions at  $\sqrt{s} = 8$  TeV at the LHC using an integrated luminosity of  $20.6 \text{ fb}^{-1}$ . The branching ratio of the  $\Lambda_b^0 \rightarrow \psi(2S)\Lambda^0$  and  $\Lambda_b^0 \rightarrow J/\psi\Lambda^0$  decays has been measured to be  $\Gamma(\Lambda_b^0 \rightarrow \psi(2S)\Lambda^0)/\Gamma(\Lambda_b^0 \rightarrow J/\psi\Lambda^0) = 0.501 \pm 0.033(\text{stat}) \pm 0.016(\text{syst}) \pm 0.011(\mathcal{B})$ . The ratio falls into the range 0.5–0.8, as found for the branching

ratios of analogous  $B$  meson decays [12]. The only available theoretical expectation for the branching ratio of the two  $\Lambda_b^0$  decays ( $0.8 \pm 0.1$  [11]) exceeds the measured value.

## Acknowledgements

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

We acknowledge the support of ANPCyT, Argentina; YerPhI, Armenia; ARC, Australia; BMWFW and FWF, Austria; ANAS, Azerbaijan; SSTC, Belarus; CNPq and FAPESP, Brazil; NSERC, NRC and CFI, Canada; CERN; CONICYT, Chile; CAS, MOST and NSFC, China; COLCIENCIAS, Colombia; MSMT CR, MPO CR and VSC CR, Czech Republic; DNRF, DNSRC and Lundbeck Foundation, Denmark; EPLANET, ERC and NSRF, European Union; IN2P3-CNRS, CEA-DSM/IRFU, France; GNSF, Georgia; BMBF, DFG, HGF, MPG and AvH Foundation, Germany; GSRT and NSRF, Greece; RGC, Hong Kong SAR, China; ISF, MINERVA, GIF, I-CORE and Benoziyo Center, Israel; INFN, Italy; MEXT and JSPS, Japan; CNRST, Morocco; FOM and NWO, Netherlands; BRF and RCN, Norway; MNiSW and NCN, Poland; GRICES and FCT, Portugal; MNE/IFA, Romania; MES of Russia and NRC KI, Russian Federation; JINR; MSTB, Serbia; MSSR, Slovakia; ARRS and MIZŠ, Slovenia; DST/NRF, South Africa; MINECO, 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] ATLAS Collaboration, [Phys. Rev. D 87 \(2013\) 032002](#), [arXiv:1207.2284 \[hep-ex\]](#).
- [2] ATLAS Collaboration, [Phys. Rev. D 89 \(2014\) 092009](#), [arXiv:1404.1071 \[hep-ex\]](#).
- [3] CMS Collaboration, [Phys. Lett. B 714 \(2012\) 136](#), [arXiv:1205.0594 \[hep-ex\]](#).
- [4] CMS Collaboration, [JHEP 07 \(2013\) 163](#), [arXiv:1304.7495 \[hep-ex\]](#).
- [5] LHCb Collaboration, R. Aaij et al., [Phys. Rev. Lett. 110 \(2013\) 182001](#), [arXiv:1302.1072 \[hep-ex\]](#).
- [6] LHCb Collaboration, R. Aaij et al., [Phys. Rev. Lett. 111 \(2013\) 102003](#), [arXiv:1307.2476 \[hep-ex\]](#).
- [7] LHCb Collaboration, R. Aaij et al., [Phys. Lett. B 724 \(2013\) 27](#), [arXiv:1302.5578 \[hep-ex\]](#).
- [8] LHCb Collaboration, R. Aaij et al., [Phys. Lett. B 725 \(2013\) 25](#), [arXiv:1306.2577 \[hep-ex\]](#).
- [9] LHCb Collaboration, R. Aaij et al., [JHEP 06 \(2015\) 115](#), [arXiv:1503.07138 \[hep-ex\]](#).
- [10] CDF Collaboration, T. Aaltonen et al., [Phys. Rev. Lett. 107 \(2011\) 201802](#), [arXiv:1107.3753 \[hep-ex\]](#).

- [11] T. Gutsche et al., [Phys. Rev. D 88 \(2013\) 114018](#), [arXiv:1309.7879 \[hep-ph\]](#). The uncertainty of the branching fraction ratio  $\Gamma(\Lambda_b^0 \rightarrow \psi(2S)\Lambda^0)/\Gamma(\Lambda_b^0 \rightarrow J/\psi\Lambda^0)$  has been provided privately by the authors.
- [12] K. A. Olive et al. (Particle Data Group), [Chin. Phys. C 38 \(2014\) 090001](#).
- [13] A. N. Kamal and A. B. Santra, [Phys. Rev. D 51 \(1995\) 1415](#), [arXiv:hep-ph/9409364](#).
- [14] M. A. Ivanov, M. P. Locher and V. E. Lyubovitskij, [Few Body Syst. 21 \(1996\) 131](#), [arXiv:hep-ph/9602372](#).
- [15] ATLAS Collaboration, [JINST 3 \(2008\) S08003](#).
- [16] ATLAS Collaboration, [Eur. Phys. J. C 72 \(2012\) 1849](#), [arXiv:1110.1530 \[hep-ex\]](#).
- [17] ATLAS Collaboration, [Eur. Phys. J. C 73 \(2013\) 2518](#), [arXiv:1302.4393 \[hep-ex\]](#).
- [18] T. Sjöstrand, S. Mrenna, P. Skands, [Comput. Phys. Commun. 178 \(2008\) 852](#), [arXiv:0710.3820 \[hep-ph\]](#).
- [19] ATLAS Collaboration, [Eur. Phys. J. C 70 \(2010\) 823](#), [arXiv:1005.4568 \[hep-ex\]](#).
- [20] S. Agostinelli et al., [Nucl. Instr. Meth. A 506 \(2003\) 250](#).
- [21] J. Allison et al., [IEEE Trans. Nucl. Sci. 53 \(2006\) 270](#).
- [22] ZEUS Collaboration, S. Chekanov et al., [Eur. Phys. J. C 44 \(2005\) 13](#), [arXiv:hep-ex/0505008](#).

## The ATLAS Collaboration

G. Aad<sup>85</sup>, B. Abbott<sup>113</sup>, J. Abdallah<sup>151</sup>, O. Abdinov<sup>11</sup>, R. Aben<sup>107</sup>, M. Abolins<sup>90</sup>, O.S. AbouZeid<sup>158</sup>, H. Abramowicz<sup>153</sup>, H. Abreu<sup>152</sup>, R. Abreu<sup>116</sup>, Y. Abulaiti<sup>146a,146b</sup>, B.S. Acharya<sup>164a,164b,a</sup>, L. Adamczyk<sup>38a</sup>, D.L. Adams<sup>25</sup>, J. Adelman<sup>108</sup>, S. Adomeit<sup>100</sup>, T. Adye<sup>131</sup>, A.A. Affolder<sup>74</sup>, T. Agatonovic-Jovin<sup>13</sup>, J. Agricola<sup>54</sup>, J.A. Aguilar-Saavedra<sup>126a,126f</sup>, S.P. Ahlen<sup>22</sup>, F. Ahmadov<sup>65,b</sup>, G. Aielli<sup>133a,133b</sup>, H. Akerstedt<sup>146a,146b</sup>, T.P.A. Åkesson<sup>81</sup>, A.V. Akimov<sup>96</sup>, G.L. Alberghi<sup>20a,20b</sup>, J. Albert<sup>169</sup>, S. Albrand<sup>55</sup>, M.J. Alconada Verzini<sup>71</sup>, M. Aleksa<sup>30</sup>, I.N. Aleksandrov<sup>65</sup>, C. Alexa<sup>26a</sup>, G. Alexander<sup>153</sup>, T. Alexopoulos<sup>10</sup>, M. Alhroob<sup>113</sup>, G. Alimonti<sup>91a</sup>, L. Alio<sup>85</sup>, J. Alison<sup>31</sup>, S.P. Alkire<sup>35</sup>, B.M.M. Allbrooke<sup>149</sup>, P.P. Allport<sup>74</sup>, A. Aloisio<sup>104a,104b</sup>, A. Alonso<sup>36</sup>, F. Alonso<sup>71</sup>, C. Alpigiani<sup>76</sup>, A. Altheimer<sup>35</sup>, B. Alvarez Gonzalez<sup>30</sup>, D. Álvarez Piqueras<sup>167</sup>, M.G. Alviggi<sup>104a,104b</sup>, B.T. Amadio<sup>15</sup>, K. Amako<sup>66</sup>, Y. Amaral Coutinho<sup>24a</sup>, C. Amelung<sup>23</sup>, D. Amidei<sup>89</sup>, S.P. Amor Dos Santos<sup>126a,126c</sup>, A. Amorim<sup>126a,126b</sup>, S. Amoroso<sup>48</sup>, N. Amram<sup>153</sup>, G. Amundsen<sup>23</sup>, C. Anastopoulos<sup>139</sup>, L.S. Ancu<sup>49</sup>, N. Andari<sup>108</sup>, T. Andeen<sup>35</sup>, C.F. Anders<sup>58b</sup>, G. Anders<sup>30</sup>, J.K. Anders<sup>74</sup>, K.J. Anderson<sup>31</sup>, A. Andreazza<sup>91a,91b</sup>, V. Andrei<sup>58a</sup>, S. Angelidakis<sup>9</sup>, I. Angelozzi<sup>107</sup>, P. Anger<sup>44</sup>, A. Angerami<sup>35</sup>, F. Anghinolfi<sup>30</sup>, A.V. Anisenkov<sup>109,c</sup>, N. Anjos<sup>12</sup>, A. Annovi<sup>124a,124b</sup>, M. Antonelli<sup>47</sup>, A. Antonov<sup>98</sup>, J. Antos<sup>144b</sup>, F. Anulli<sup>132a</sup>, M. Aoki<sup>66</sup>, L. Aperio Bella<sup>18</sup>, G. Arabidze<sup>90</sup>, Y. Arai<sup>66</sup>, J.P. Araque<sup>126a</sup>, A.T.H. Arce<sup>45</sup>, F.A. Arduh<sup>71</sup>, J-F. Arguin<sup>95</sup>, S. Argyropoulos<sup>42</sup>, M. Arik<sup>19a</sup>, A.J. Armbruster<sup>30</sup>, O. Arnaez<sup>30</sup>, V. Arnal<sup>82</sup>, H. Arnold<sup>48</sup>, M. Arratia<sup>28</sup>, O. Arslan<sup>21</sup>, A. Artamonov<sup>97</sup>, G. Artoni<sup>23</sup>, S. Asai<sup>155</sup>, N. Asbah<sup>42</sup>, A. Ashkenazi<sup>153</sup>, B. Åsman<sup>146a,146b</sup>, L. Asquith<sup>149</sup>, K. Assamagan<sup>25</sup>, R. Astalos<sup>144a</sup>, M. Atkinson<sup>165</sup>, N.B. Atlay<sup>141</sup>, K. Augsten<sup>128</sup>, M. Aurousseau<sup>145b</sup>, G. Avolio<sup>30</sup>, B. Axen<sup>15</sup>, M.K. Ayoub<sup>117</sup>, G. Azuelos<sup>95,d</sup>, M.A. Baak<sup>30</sup>, A.E. Baas<sup>58a</sup>, M.J. Baca<sup>18</sup>, C. Bacci<sup>134a,134b</sup>, H. Bachacou<sup>136</sup>, K. Bachas<sup>154</sup>, M. Backes<sup>30</sup>, M. Backhaus<sup>30</sup>, P. Bagiacchi<sup>132a,132b</sup>, P. Bagnaia<sup>132a,132b</sup>, Y. Bai<sup>33a</sup>, T. Bain<sup>35</sup>, J.T. Baines<sup>131</sup>, O.K. Baker<sup>176</sup>, E.M. Baldin<sup>109,c</sup>, P. Balek<sup>129</sup>, T. Balestri<sup>148</sup>, F. Balli<sup>84</sup>, E. Banas<sup>39</sup>, Sw. Banerjee<sup>173</sup>, A.A.E. Bannoura<sup>175</sup>, H.S. Bansil<sup>18</sup>, L. Barak<sup>30</sup>, E.L. Barberio<sup>88</sup>, D. Barberis<sup>50a,50b</sup>, M. Barbero<sup>85</sup>, T. Barillari<sup>101</sup>, M. Barisonzi<sup>164a,164b</sup>, T. Barklow<sup>143</sup>, N. Barlow<sup>28</sup>, S.L. Barnes<sup>84</sup>, B.M. Barnett<sup>131</sup>, R.M. Barnett<sup>15</sup>, Z. Barnovska<sup>5</sup>, A. Baroncelli<sup>134a</sup>, G. Barone<sup>23</sup>, A.J. Barr<sup>120</sup>, F. Barreiro<sup>82</sup>, J. Barreiro Guimarães da Costa<sup>57</sup>, R. Bartoldus<sup>143</sup>, A.E. Barton<sup>72</sup>, P. Bartos<sup>144a</sup>, A. Basalaev<sup>123</sup>, A. Bassalat<sup>117</sup>, A. Basye<sup>165</sup>, R.L. Bates<sup>53</sup>, S.J. Batista<sup>158</sup>, J.R. Batley<sup>28</sup>, M. Battaglia<sup>137</sup>, M. Bause<sup>132a,132b</sup>, F. Bauer<sup>136</sup>, H.S. Bawa<sup>143,e</sup>, J.B. Beacham<sup>111</sup>, M.D. Beattie<sup>72</sup>, T. Beau<sup>80</sup>, P.H. Beauchemin<sup>161</sup>, R. Beccherle<sup>124a,124b</sup>, P. Bechtel<sup>21</sup>, H.P. Beck<sup>17,f</sup>, K. Becker<sup>120</sup>, M. Becker<sup>83</sup>, S. Becker<sup>100</sup>, M. Beckingham<sup>170</sup>, C. Becot<sup>117</sup>, A.J. Beddall<sup>19b</sup>, A. Beddall<sup>19b</sup>, V.A. Bednyakov<sup>65</sup>, C.P. Bee<sup>148</sup>, L.J. Beemster<sup>107</sup>, T.A. Beermann<sup>175</sup>, M. Begel<sup>25</sup>, J.K. Behr<sup>120</sup>, C. Belanger-Champagne<sup>87</sup>, W.H. Bell<sup>49</sup>, G. Bella<sup>153</sup>, L. Bellagamba<sup>20a</sup>, A. Bellerive<sup>29</sup>, M. Bellomo<sup>86</sup>, K. Belotskiy<sup>98</sup>, O. Beltramello<sup>30</sup>, O. Benary<sup>153</sup>, D. Bencheikroun<sup>135a</sup>, M. Bender<sup>100</sup>, K. Bendtz<sup>146a,146b</sup>, N. Benekos<sup>10</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>, J.R. Bensinger<sup>23</sup>, S. Bentvelsen<sup>107</sup>, L. Beresford<sup>120</sup>, M. Beretta<sup>47</sup>, D. Berge<sup>107</sup>, E. Bergeas Kuutmann<sup>166</sup>, N. Berger<sup>5</sup>, F. Berghaus<sup>169</sup>, J. Beringer<sup>15</sup>, C. Bernard<sup>22</sup>, N.R. Bernard<sup>86</sup>, C. Bernius<sup>110</sup>, F.U. Bernlochner<sup>21</sup>, T. Berry<sup>77</sup>, P. Berta<sup>129</sup>, C. Bertella<sup>83</sup>, G. Bertoli<sup>146a,146b</sup>, F. Bertolucci<sup>124a,124b</sup>, C. Bertsche<sup>113</sup>, D. Bertsche<sup>113</sup>, M.I. Besana<sup>91a</sup>, G.J. Besjes<sup>36</sup>, O. Bessidskaia Bylund<sup>146a,146b</sup>, M. Bessner<sup>42</sup>, N. Besson<sup>136</sup>, C. Betancourt<sup>48</sup>, S. Bethke<sup>101</sup>, A.J. Bevan<sup>76</sup>, W. Bhimji<sup>15</sup>, R.M. Bianchi<sup>125</sup>, L. Bianchini<sup>23</sup>, M. Bianco<sup>30</sup>, O. Biebel<sup>100</sup>, D. Biedermann<sup>16</sup>, S.P. Bieniek<sup>78</sup>, M. Biglietti<sup>134a</sup>, J. Bilbao De Mendizabal<sup>49</sup>, H. Bilokon<sup>47</sup>, M. Bindi<sup>54</sup>, S. Binet<sup>117</sup>, A. Bingul<sup>19b</sup>, C. Bini<sup>132a,132b</sup>, S. Biondi<sup>20a,20b</sup>, C.W. Black<sup>150</sup>, J.E. Black<sup>143</sup>, K.M. Black<sup>22</sup>, D. Blackburn<sup>138</sup>, R.E. Blair<sup>6</sup>, J.-B. Blanchard<sup>136</sup>, J.E. Blanco<sup>77</sup>, T. Blazek<sup>144a</sup>, I. Bloch<sup>42</sup>, C. Blocker<sup>23</sup>, W. Blum<sup>83,\*</sup>, U. Blumenschein<sup>54</sup>, G.J. Bobbink<sup>107</sup>, V.S. Bobrovnikov<sup>109,c</sup>, S.S. Bocchetta<sup>81</sup>, A. Bocci<sup>45</sup>,

C. Bock<sup>100</sup>, M. Boehler<sup>48</sup>, J.A. Bogaerts<sup>30</sup>, D. Bogavac<sup>13</sup>, A.G. Bogdanchikov<sup>109</sup>, C. Bohm<sup>146a</sup>, V. Boisvert<sup>77</sup>, T. Bold<sup>38a</sup>, V. Boldea<sup>26a</sup>, A.S. Boldyrev<sup>99</sup>, M. Bomben<sup>80</sup>, M. Bona<sup>76</sup>, M. Boonekamp<sup>136</sup>, A. Borisov<sup>130</sup>, G. Borissov<sup>72</sup>, S. Borroni<sup>42</sup>, J. Bortfeldt<sup>100</sup>, V. Bortolotto<sup>60a,60b,60c</sup>, K. Bos<sup>107</sup>, D. Boscherini<sup>20a</sup>, M. Bosman<sup>12</sup>, J. Boudreau<sup>125</sup>, J. Bouffard<sup>2</sup>, E.V. Bouhova-Thacker<sup>72</sup>, D. Boumediene<sup>34</sup>, C. Bourdarios<sup>117</sup>, N. Bousson<sup>114</sup>, A. Boveia<sup>30</sup>, J. Boyd<sup>30</sup>, I.R. Boyko<sup>65</sup>, I. Bozic<sup>13</sup>, J. Bracinik<sup>18</sup>, A. Brandt<sup>8</sup>, G. Brandt<sup>54</sup>, O. Brandt<sup>58a</sup>, U. Bratzler<sup>156</sup>, B. Brau<sup>86</sup>, J.E. Brau<sup>116</sup>, H.M. Braun<sup>175,\*</sup>, S.F. Brazzale<sup>164a,164c</sup>, W.D. Breaden Madden<sup>53</sup>, K. Brendlinger<sup>122</sup>, A.J. Brennan<sup>88</sup>, L. Brenner<sup>107</sup>, R. Brenner<sup>166</sup>, S. Bressler<sup>172</sup>, K. Bristow<sup>145c</sup>, T.M. Bristow<sup>46</sup>, D. Britton<sup>53</sup>, D. Britzger<sup>42</sup>, F.M. Brochu<sup>28</sup>, I. Brock<sup>21</sup>, R. Brock<sup>90</sup>, J. Bronner<sup>101</sup>, G. Brooijmans<sup>35</sup>, T. Brooks<sup>77</sup>, W.K. Brooks<sup>32b</sup>, J. Brosamer<sup>15</sup>, E. Brost<sup>116</sup>, J. Brown<sup>55</sup>, P.A. Bruckman de Renstrom<sup>39</sup>, D. Bruncko<sup>144b</sup>, R. Bruneliere<sup>48</sup>, A. Bruni<sup>20a</sup>, G. Bruni<sup>20a</sup>, M. Bruschi<sup>20a</sup>, N. Bruscinio<sup>21</sup>, L. Bryngemark<sup>81</sup>, T. Buanes<sup>14</sup>, Q. Buat<sup>142</sup>, P. Buchholz<sup>141</sup>, A.G. Buckley<sup>53</sup>, S.I. Buda<sup>26a</sup>, I.A. Budagov<sup>65</sup>, F. Buehrer<sup>48</sup>, L. Bugge<sup>119</sup>, M.K. Bugge<sup>119</sup>, O. Bulekov<sup>98</sup>, D. Bullock<sup>8</sup>, H. Burckhart<sup>30</sup>, S. Burdin<sup>74</sup>, C.D. Burgard<sup>48</sup>, B. Burghgrave<sup>108</sup>, S. Burke<sup>131</sup>, I. Burmeister<sup>43</sup>, E. Busato<sup>34</sup>, D. Büscher<sup>48</sup>, V. Büscher<sup>83</sup>, P. Bussey<sup>53</sup>, J.M. Butler<sup>22</sup>, A.I. Butt<sup>3</sup>, C.M. Buttar<sup>53</sup>, J.M. Butterworth<sup>78</sup>, P. Butti<sup>107</sup>, W. Buttinger<sup>25</sup>, A. Buzatu<sup>53</sup>, A.R. Buzykaev<sup>109,c</sup>, S. Cabrera Urbán<sup>167</sup>, D. Caforio<sup>128</sup>, V.M. Cairo<sup>37a,37b</sup>, O. Cakir<sup>4a</sup>, N. Calace<sup>49</sup>, P. Calafiura<sup>15</sup>, A. Calandri<sup>136</sup>, G. Calderini<sup>80</sup>, P. Calfayan<sup>100</sup>, L.P. Caloba<sup>24a</sup>, D. Calvet<sup>34</sup>, S. Calvet<sup>34</sup>, R. Camacho Toro<sup>31</sup>, S. Camarda<sup>42</sup>, P. Camarri<sup>133a,133b</sup>, D. Cameron<sup>119</sup>, R. Caminal Armadans<sup>165</sup>, S. Campana<sup>30</sup>, M. Campanelli<sup>78</sup>, A. Campoverde<sup>148</sup>, V. Canale<sup>104a,104b</sup>, A. Canepa<sup>159a</sup>, M. Cano Bret<sup>33e</sup>, J. Cantero<sup>82</sup>, R. Cantrill<sup>126a</sup>, T. Cao<sup>40</sup>, M.D.M. Capeans Garrido<sup>30</sup>, I. Caprini<sup>26a</sup>, M. Caprini<sup>26a</sup>, M. Capua<sup>37a,37b</sup>, R. Caputo<sup>83</sup>, R. Cardarelli<sup>133a</sup>, F. Cardillo<sup>48</sup>, T. Carli<sup>30</sup>, G. Carlino<sup>104a</sup>, L. Carminati<sup>91a,91b</sup>, S. Caron<sup>106</sup>, E. Carquin<sup>32a</sup>, G.D. Carrillo-Montoya<sup>30</sup>, J.R. Carter<sup>28</sup>, J. Carvalho<sup>126a,126c</sup>, D. Casadei<sup>78</sup>, M.P. Casado<sup>12</sup>, M. Casolino<sup>12</sup>, E. Castaneda-Miranda<sup>145b</sup>, A. Castelli<sup>107</sup>, V. Castillo Gimenez<sup>167</sup>, N.F. Castro<sup>126a,g</sup>, P. Catastini<sup>57</sup>, A. Catinaccio<sup>30</sup>, J.R. Catmore<sup>119</sup>, A. Cattai<sup>30</sup>, J. Caudron<sup>83</sup>, V. Cavaliere<sup>165</sup>, D. Cavalli<sup>91a</sup>, M. Cavalli-Sforza<sup>12</sup>, V. Cavasinni<sup>124a,124b</sup>, F. Ceradini<sup>134a,134b</sup>, B.C. Cerio<sup>45</sup>, K. Cerny<sup>129</sup>, A.S. Cerqueira<sup>24b</sup>, A. Cerri<sup>149</sup>, L. Cerrito<sup>76</sup>, F. Cerutti<sup>15</sup>, M. Cerv<sup>30</sup>, A. Cervelli<sup>17</sup>, S.A. Cetin<sup>19c</sup>, A. Chafaq<sup>135a</sup>, D. Chakraborty<sup>108</sup>, I. Chalupkova<sup>129</sup>, P. Chang<sup>165</sup>, J.D. Chapman<sup>28</sup>, D.G. Charlton<sup>18</sup>, C.C. Chau<sup>158</sup>, C.A. Chavez Barajas<sup>149</sup>, S. Cheatham<sup>152</sup>, A. Chegwiddden<sup>90</sup>, S. Chekanov<sup>6</sup>, S.V. Chekulaev<sup>159a</sup>, G.A. Chelkov<sup>65,h</sup>, M.A. Chelstowska<sup>89</sup>, C. Chen<sup>64</sup>, H. Chen<sup>25</sup>, K. Chen<sup>148</sup>, L. Chen<sup>33d,i</sup>, S. Chen<sup>33c</sup>, X. Chen<sup>33f</sup>, Y. Chen<sup>67</sup>, H.C. Cheng<sup>89</sup>, Y. Cheng<sup>31</sup>, A. Cheplakov<sup>65</sup>, E. Cheremushkina<sup>130</sup>, R. Cherkaoui El Moursli<sup>135e</sup>, V. Chernyatin<sup>25,\*</sup>, E. Cheu<sup>7</sup>, L. Chevalier<sup>136</sup>, V. Chiarella<sup>47</sup>, G. Chiarelli<sup>124a,124b</sup>, G. Chiodini<sup>73a</sup>, A.S. Chisholm<sup>18</sup>, R.T. Chislett<sup>78</sup>, A. Chitan<sup>26a</sup>, M.V. Chizhov<sup>65</sup>, K. Choi<sup>61</sup>, S. Chouridou<sup>9</sup>, B.K.B. Chow<sup>100</sup>, V. Christodoulou<sup>78</sup>, D. Chromek-Burckhart<sup>30</sup>, J. Chudoba<sup>127</sup>, A.J. Chuinard<sup>87</sup>, J.J. Chwastowski<sup>39</sup>, L. Chytka<sup>115</sup>, G. Ciapetti<sup>132a,132b</sup>, A.K. Ciftci<sup>4a</sup>, D. Cinca<sup>53</sup>, V. Cindro<sup>75</sup>, I.A. Cioara<sup>21</sup>, A. Cicio<sup>15</sup>, F. Ciotto<sup>104a,104b</sup>, Z.H. Citron<sup>172</sup>, M. Ciubancan<sup>26a</sup>, A. Clark<sup>49</sup>, B.L. Clark<sup>57</sup>, P.J. Clark<sup>46</sup>, R.N. Clarke<sup>15</sup>, W. Cleland<sup>125</sup>, C. Clement<sup>146a,146b</sup>, Y. Coadou<sup>85</sup>, M. Cobal<sup>164a,164c</sup>, A. Coccaro<sup>49</sup>, J. Cochran<sup>64</sup>, L. Coffey<sup>23</sup>, J.G. Cogan<sup>143</sup>, L. Colasurdo<sup>106</sup>, B. Cole<sup>35</sup>, S. Cole<sup>108</sup>, A.P. Colijn<sup>107</sup>, J. Collot<sup>55</sup>, T. Colombo<sup>58c</sup>, G. Compostella<sup>101</sup>, P. Conde Muiño<sup>126a,126b</sup>, E. Coniavitis<sup>48</sup>, S.H. Connell<sup>145b</sup>, I.A. Connelly<sup>77</sup>, V. Consorti<sup>48</sup>, S. Constantinescu<sup>26a</sup>, C. Conta<sup>121a,121b</sup>, G. Conti<sup>30</sup>, F. Conventi<sup>104a,j</sup>, M. Cooke<sup>15</sup>, B.D. Cooper<sup>78</sup>, A.M. Cooper-Sarkar<sup>120</sup>, T. Cornelissen<sup>175</sup>, M. Corradi<sup>20a</sup>, F. Corriveau<sup>87,k</sup>, A. Corso-Radu<sup>163</sup>, A. Cortes-Gonzalez<sup>12</sup>, G. Cortiana<sup>101</sup>, G. Costa<sup>91a</sup>, M.J. Costa<sup>167</sup>, D. Costanzo<sup>139</sup>, D. Côte<sup>8</sup>, G. Cottin<sup>28</sup>, G. Cowan<sup>77</sup>, B.E. Cox<sup>84</sup>, K. Cranmer<sup>110</sup>, G. Cree<sup>29</sup>, S. Crépe-Renaudin<sup>55</sup>, F. Crescioli<sup>80</sup>, W.A. Cribbs<sup>146a,146b</sup>, M. Crispin Ortuzar<sup>120</sup>, M. Cristinziani<sup>21</sup>, V. Croft<sup>106</sup>, G. Crosetti<sup>37a,37b</sup>, T. Cuhadar Donszelmann<sup>139</sup>, J. Cummings<sup>176</sup>, M. Curatolo<sup>47</sup>, C. Cuthbert<sup>150</sup>, H. Czirr<sup>141</sup>, P. Czodrowski<sup>3</sup>, S. D'Auria<sup>53</sup>, M. D'Onofrio<sup>74</sup>, M.J. Da Cunha Sargedas De Sousa<sup>126a,126b</sup>, C. Da Via<sup>84</sup>, W. Dabrowski<sup>38a</sup>, A. Dafinca<sup>120</sup>, T. Dai<sup>89</sup>,

O. Dale<sup>14</sup>, F. Dallaire<sup>95</sup>, C. Dallapiccola<sup>86</sup>, M. Dam<sup>36</sup>, J.R. Dandoy<sup>31</sup>, N.P. Dang<sup>48</sup>, A.C. Daniells<sup>18</sup>, M. Danninger<sup>168</sup>, M. Dano Hoffmann<sup>136</sup>, V. Dao<sup>48</sup>, G. Darbo<sup>50a</sup>, S. Darmora<sup>8</sup>, J. Dassoulas<sup>3</sup>, A. Dattagupta<sup>61</sup>, W. Davey<sup>21</sup>, C. David<sup>169</sup>, T. Davidek<sup>129</sup>, E. Davies<sup>120,l</sup>, M. Davies<sup>153</sup>, P. Davison<sup>78</sup>, Y. Davygora<sup>58a</sup>, E. Dawe<sup>88</sup>, I. Dawson<sup>139</sup>, R.K. Daya-Ishmukhametova<sup>86</sup>, K. De<sup>8</sup>, R. de Asmundis<sup>104a</sup>, A. De Benedetti<sup>113</sup>, S. De Castro<sup>20a,20b</sup>, S. De Cecco<sup>80</sup>, N. De Groot<sup>106</sup>, P. de Jong<sup>107</sup>, H. De la Torre<sup>82</sup>, F. De Lorenzi<sup>64</sup>, D. De Pedis<sup>132a</sup>, A. De Salvo<sup>132a</sup>, U. De Sanctis<sup>149</sup>, A. De Santo<sup>149</sup>, J.B. De Vivie De Regie<sup>117</sup>, W.J. Dearnaley<sup>72</sup>, R. Debbe<sup>25</sup>, C. Debenedetti<sup>137</sup>, D.V. Dedovich<sup>65</sup>, I. Deigaard<sup>107</sup>, J. Del Peso<sup>82</sup>, T. Del Prete<sup>124a,124b</sup>, D. Delgove<sup>117</sup>, F. Deliot<sup>136</sup>, C.M. Delitzsch<sup>49</sup>, M. Deliyergiyev<sup>75</sup>, A. Dell'Acqua<sup>30</sup>, L. Dell'Asta<sup>22</sup>, M. Dell'Orso<sup>124a,124b</sup>, M. Della Pietra<sup>104a,j</sup>, D. della Volpe<sup>49</sup>, M. Delmastro<sup>5</sup>, P.A. Delsart<sup>55</sup>, C. Deluca<sup>107</sup>, D.A. DeMarco<sup>158</sup>, S. Demers<sup>176</sup>, M. Demichev<sup>65</sup>, A. Demilly<sup>80</sup>, S.P. Denisov<sup>130</sup>, D. Derendarz<sup>39</sup>, J.E. Derkaoui<sup>135d</sup>, F. Derue<sup>80</sup>, P. Dervan<sup>74</sup>, K. Desch<sup>21</sup>, C. Deterre<sup>42</sup>, P.O. Deviveiros<sup>30</sup>, A. Dewhurst<sup>131</sup>, S. Dhaliwal<sup>23</sup>, A. Di Ciaccio<sup>133a,133b</sup>, L. Di Ciaccio<sup>5</sup>, A. Di Domenico<sup>132a,132b</sup>, C. Di Donato<sup>104a,104b</sup>, A. Di Girolamo<sup>30</sup>, B. Di Girolamo<sup>30</sup>, A. Di Mattia<sup>152</sup>, B. Di Micco<sup>134a,134b</sup>, R. Di Nardo<sup>47</sup>, A. Di Simone<sup>48</sup>, R. Di Sipio<sup>158</sup>, D. Di Valentino<sup>29</sup>, C. Diaconu<sup>85</sup>, M. Diamond<sup>158</sup>, F.A. Dias<sup>46</sup>, M.A. Diaz<sup>32a</sup>, E.B. Diehl<sup>89</sup>, J. Dietrich<sup>16</sup>, S. Diglio<sup>85</sup>, A. Dimitrievska<sup>13</sup>, J. Dingfelder<sup>21</sup>, P. Dita<sup>26a</sup>, S. Dita<sup>26a</sup>, F. Dittus<sup>30</sup>, F. Djama<sup>85</sup>, T. Djobava<sup>51b</sup>, J.I. Djuvsland<sup>58a</sup>, M.A.B. do Vale<sup>24c</sup>, D. Dobos<sup>30</sup>, M. Dobre<sup>26a</sup>, C. Doglioni<sup>81</sup>, T. Dohmae<sup>155</sup>, J. Dolejsi<sup>129</sup>, Z. Dolezal<sup>129</sup>, B.A. Dolgoshein<sup>98,\*</sup>, M. Donadelli<sup>24d</sup>, S. Donati<sup>124a,124b</sup>, P. Dondero<sup>121a,121b</sup>, J. Donini<sup>34</sup>, J. Dopke<sup>131</sup>, A. Doria<sup>104a</sup>, M.T. Dova<sup>71</sup>, A.T. Doyle<sup>53</sup>, E. Drechsler<sup>54</sup>, M. Dris<sup>10</sup>, E. Dubreuil<sup>34</sup>, E. Duchovni<sup>172</sup>, G. Duckeck<sup>100</sup>, O.A. Ducu<sup>26a,85</sup>, D. Duda<sup>107</sup>, A. Dudarev<sup>30</sup>, L. Duflot<sup>117</sup>, L. Duguid<sup>77</sup>, M. Dührssen<sup>30</sup>, M. Dunford<sup>58a</sup>, H. Duran Yildiz<sup>4a</sup>, M. Düren<sup>52</sup>, A. Durglishvili<sup>51b</sup>, D. Duschinger<sup>44</sup>, M. Dyndal<sup>38a</sup>, C. Eckardt<sup>42</sup>, K.M. Ecker<sup>101</sup>, R.C. Edgar<sup>89</sup>, W. Edson<sup>2</sup>, N.C. Edwards<sup>46</sup>, W. Ehrenfeld<sup>21</sup>, T. Eifert<sup>30</sup>, G. Eigen<sup>14</sup>, K. Einsweiler<sup>15</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>175</sup>, A.A. Elliot<sup>169</sup>, N. Ellis<sup>30</sup>, J. Elmsheuser<sup>100</sup>, M. Elsing<sup>30</sup>, D. Emelianov<sup>131</sup>, Y. Enari<sup>155</sup>, O.C. Endner<sup>83</sup>, M. Endo<sup>118</sup>, J. Erdmann<sup>43</sup>, A. Ereditato<sup>17</sup>, G. Ernis<sup>175</sup>, J. Ernst<sup>2</sup>, M. Ernst<sup>25</sup>, S. Errede<sup>165</sup>, E. Ertel<sup>83</sup>, M. Escalier<sup>117</sup>, H. Esch<sup>43</sup>, C. Escobar<sup>125</sup>, B. Esposito<sup>47</sup>, A.I. Etienvre<sup>136</sup>, E. Etzion<sup>153</sup>, H. Evans<sup>61</sup>, A. Ezhilov<sup>123</sup>, L. Fabbri<sup>20a,20b</sup>, G. Facini<sup>31</sup>, R.M. Fakhruddinov<sup>130</sup>, S. Falciano<sup>132a</sup>, R.J. Falla<sup>78</sup>, J. Faltova<sup>129</sup>, Y. Fang<sup>33a</sup>, M. Fanti<sup>91a,91b</sup>, A. Farbin<sup>8</sup>, A. Farilla<sup>134a</sup>, T. Farooque<sup>12</sup>, S. Farrell<sup>15</sup>, S.M. Farrington<sup>170</sup>, P. Farthouat<sup>30</sup>, F. Fassi<sup>135e</sup>, P. Fassnacht<sup>30</sup>, D. Fassouliotis<sup>9</sup>, M. Fauci Giannelli<sup>77</sup>, A. Favareto<sup>50a,50b</sup>, L. Fayard<sup>117</sup>, P. Federic<sup>144a</sup>, O.L. Fedin<sup>123,m</sup>, W. Fedorko<sup>168</sup>, S. Feigl<sup>30</sup>, L. Feligioni<sup>85</sup>, C. Feng<sup>33d</sup>, E.J. Feng<sup>6</sup>, H. Feng<sup>89</sup>, A.B. Fenyuk<sup>130</sup>, L. Feremenga<sup>8</sup>, P. Fernandez Martinez<sup>167</sup>, S. Fernandez Perez<sup>30</sup>, J. Ferrando<sup>53</sup>, A. Ferrari<sup>166</sup>, P. Ferrari<sup>107</sup>, R. Ferrari<sup>121a</sup>, D.E. Ferreira de Lima<sup>53</sup>, A. Ferrer<sup>167</sup>, D. Ferrere<sup>49</sup>, C. Ferretti<sup>89</sup>, A. Ferretto Parodi<sup>50a,50b</sup>, M. Fiassarini<sup>31</sup>, F. Fiedler<sup>83</sup>, A. Filipčič<sup>75</sup>, M. Filipuzzi<sup>42</sup>, F. Filthaut<sup>106</sup>, M. Fincke-Keeler<sup>169</sup>, K.D. Finelli<sup>150</sup>, M.C.N. Fiolhais<sup>126a,126c</sup>, L. Fiorini<sup>167</sup>, A. Firan<sup>40</sup>, A. Fischer<sup>2</sup>, C. Fischer<sup>12</sup>, J. Fischer<sup>175</sup>, W.C. Fisher<sup>90</sup>, E.A. Fitzgerald<sup>23</sup>, N. Flaschel<sup>42</sup>, I. Fleck<sup>141</sup>, P. Fleischmann<sup>89</sup>, S. Fleischmann<sup>175</sup>, G.T. Fletcher<sup>139</sup>, G. Fletcher<sup>76</sup>, R.R.M. Fletcher<sup>122</sup>, T. Flick<sup>175</sup>, A. Floderus<sup>81</sup>, L.R. Flores Castillo<sup>60a</sup>, M.J. Flowerdew<sup>101</sup>, A. Formica<sup>136</sup>, A. Forti<sup>84</sup>, D. Fournier<sup>117</sup>, H. Fox<sup>72</sup>, S. Fracchia<sup>12</sup>, P. Francavilla<sup>80</sup>, M. Franchini<sup>20a,20b</sup>, D. Francis<sup>30</sup>, L. Franconi<sup>119</sup>, M. Franklin<sup>57</sup>, M. Frate<sup>163</sup>, M. Fraternali<sup>121a,121b</sup>, D. Freeborn<sup>78</sup>, S.T. French<sup>28</sup>, F. Friedrich<sup>44</sup>, D. Froidevaux<sup>30</sup>, J.A. Frost<sup>120</sup>, C. Fukunaga<sup>156</sup>, E. Fullana Torregrosa<sup>83</sup>, B.G. Fulsom<sup>143</sup>, T. Fusayasu<sup>102</sup>, J. Fuster<sup>167</sup>, C. Gabaldon<sup>55</sup>, O. Gabizon<sup>175</sup>, A. Gabrielli<sup>20a,20b</sup>, A. Gabrielli<sup>132a,132b</sup>, G.P. Gach<sup>38a</sup>, S. Gadatsch<sup>30</sup>, S. Gadomski<sup>49</sup>, G. Gagliardi<sup>50a,50b</sup>, P. Gagnon<sup>61</sup>, C. Galea<sup>106</sup>, B. Galhardo<sup>126a,126c</sup>, E.J. Gallas<sup>120</sup>, B.J. Gallop<sup>131</sup>, P. Gallus<sup>128</sup>, G. Galster<sup>36</sup>, K.K. Gan<sup>111</sup>, J. Gao<sup>33b,85</sup>, Y. Gao<sup>46</sup>, Y.S. Gao<sup>143,e</sup>, F.M. Garay Walls<sup>46</sup>, F. Garbersson<sup>176</sup>, C. García<sup>167</sup>, J.E. García Navarro<sup>167</sup>, M. Garcia-Sciveres<sup>15</sup>, R.W. Gardner<sup>31</sup>, N. Garelli<sup>143</sup>, V. Garonne<sup>119</sup>, C. Gatti<sup>47</sup>, A. Gaudiello<sup>50a,50b</sup>, G. Gaudio<sup>121a</sup>, B. Gaur<sup>141</sup>, L. Gauthier<sup>95</sup>, P. Gauzzi<sup>132a,132b</sup>, I.L. Gavrilenko<sup>96</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>131</sup>, Ch. Geich-Gimbel<sup>21</sup>, M.P. Geisler<sup>58a</sup>, C. Gemme<sup>50a</sup>, M.H. Genest<sup>55</sup>, S. Gentile<sup>132a,132b</sup>, M. George<sup>54</sup>, S. George<sup>77</sup>, D. Gerbaudo<sup>163</sup>, A. Gershon<sup>153</sup>, S. Ghasemi<sup>141</sup>, H. Ghazlane<sup>135b</sup>, B. Giacobbe<sup>20a</sup>, S. Giagu<sup>132a,132b</sup>, V. Giangiobbe<sup>12</sup>, P. Giannetti<sup>124a,124b</sup>, B. Gibbard<sup>25</sup>, S.M. Gibson<sup>77</sup>, M. Gilchriese<sup>15</sup>, T.P.S. Gillam<sup>28</sup>, D. Gillberg<sup>30</sup>, G. Gilles<sup>34</sup>, D.M. Gingrich<sup>3,d</sup>, N. Giokaris<sup>9</sup>, M.P. Giordani<sup>164a,164c</sup>, F.M. Giorgi<sup>20a</sup>, F.M. Giorgi<sup>16</sup>, P.F. Giraud<sup>136</sup>, P. Giromini<sup>47</sup>, D. Giugni<sup>91a</sup>, C. Giuliani<sup>48</sup>, M. Giulini<sup>58b</sup>, B.K. Gjølsten<sup>119</sup>, S. Gkaitatzis<sup>154</sup>, I. Gkialas<sup>154</sup>, E.L. Gkoukousis<sup>117</sup>, L.K. Gladilin<sup>99</sup>, C. Glasman<sup>82</sup>, J. Glatzer<sup>30</sup>, P.C.F. Glaysher<sup>46</sup>, A. Glazov<sup>42</sup>, M. Goblirsch-Kolb<sup>101</sup>, J.R. Goddard<sup>76</sup>, J. Godlewski<sup>39</sup>, S. Goldfarb<sup>89</sup>, T. Golling<sup>49</sup>, D. Golubkov<sup>130</sup>, A. Gomes<sup>126a,126b,126d</sup>, R. Gonçalo<sup>126a</sup>, J. Goncalves Pinto Firmino Da Costa<sup>136</sup>, L. Gonella<sup>21</sup>, S. González de la Hoz<sup>167</sup>, G. Gonzalez Parra<sup>12</sup>, S. Gonzalez-Sevilla<sup>49</sup>, L. Goossens<sup>30</sup>, P.A. Gorbounov<sup>97</sup>, H.A. Gordon<sup>25</sup>, I. Gorelov<sup>105</sup>, B. Gorini<sup>30</sup>, E. Gorini<sup>73a,73b</sup>, A. Gorišek<sup>75</sup>, E. Gornicki<sup>39</sup>, A.T. Goshaw<sup>45</sup>, C. Gössling<sup>43</sup>, M.I. Gostkin<sup>65</sup>, D. Goujdami<sup>135c</sup>, A.G. Goussiou<sup>138</sup>, N. Govender<sup>145b</sup>, E. Gozani<sup>152</sup>, H.M.X. Grabas<sup>137</sup>, L. Graber<sup>54</sup>, I. Grabowska-Bold<sup>38a</sup>, P.O.J. Gradin<sup>166</sup>, P. Grafström<sup>20a,20b</sup>, K-J. Grahn<sup>42</sup>, J. Gramling<sup>49</sup>, E. Gramstad<sup>119</sup>, S. Grancagnolo<sup>16</sup>, V. Gratchev<sup>123</sup>, H.M. Gray<sup>30</sup>, E. Graziani<sup>134a</sup>, Z.D. Greenwood<sup>79,n</sup>, K. Gregersen<sup>78</sup>, I.M. Gregor<sup>42</sup>, P. Grenier<sup>143</sup>, J. Griffiths<sup>8</sup>, A.A. Grillo<sup>137</sup>, K. Grimm<sup>72</sup>, S. Grinstein<sup>12,o</sup>, Ph. Gris<sup>34</sup>, J.-F. Grivaz<sup>117</sup>, J.P. Grohs<sup>44</sup>, A. Grohsjean<sup>42</sup>, E. Gross<sup>172</sup>, J. Grosse-Knetter<sup>54</sup>, G.C. Grossi<sup>79</sup>, Z.J. Grout<sup>149</sup>, L. Guan<sup>89</sup>, J. Guenther<sup>128</sup>, F. Guescini<sup>49</sup>, D. Guest<sup>176</sup>, O. Gueta<sup>153</sup>, E. Guido<sup>50a,50b</sup>, T. Guillemin<sup>117</sup>, S. Guindon<sup>2</sup>, U. Gul<sup>53</sup>, C. Gumpert<sup>44</sup>, J. Guo<sup>33e</sup>, Y. Guo<sup>33b</sup>, S. Gupta<sup>120</sup>, G. Gustavino<sup>132a,132b</sup>, P. Gutierrez<sup>113</sup>, N.G. Gutierrez Ortiz<sup>78</sup>, C. Gutschow<sup>44</sup>, C. Guyot<sup>136</sup>, C. Gwenlan<sup>120</sup>, C.B. Gwilliam<sup>74</sup>, A. Haas<sup>110</sup>, C. Haber<sup>15</sup>, H.K. Hadavand<sup>8</sup>, N. Haddad<sup>135e</sup>, P. Haefner<sup>21</sup>, S. Hageböck<sup>21</sup>, Z. Hajduk<sup>39</sup>, H. Hakobyan<sup>177</sup>, M. Haleem<sup>42</sup>, J. Haley<sup>114</sup>, D. Hall<sup>120</sup>, G. Halladjian<sup>90</sup>, G.D. Hallewell<sup>85</sup>, K. Hamacher<sup>175</sup>, P. Hamal<sup>115</sup>, K. Hamano<sup>169</sup>, A. Hamilton<sup>145a</sup>, G.N. Hamity<sup>139</sup>, P.G. Hamnett<sup>42</sup>, L. Han<sup>33b</sup>, K. Hanagaki<sup>66,p</sup>, K. Hanawa<sup>155</sup>, M. Hance<sup>15</sup>, P. Hanke<sup>58a</sup>, R. Hanna<sup>136</sup>, J.B. Hansen<sup>36</sup>, J.D. Hansen<sup>36</sup>, M.C. Hansen<sup>21</sup>, P.H. Hansen<sup>36</sup>, K. Hara<sup>160</sup>, A.S. Hard<sup>173</sup>, T. Harenberg<sup>175</sup>, F. Hariri<sup>117</sup>, S. Harkusha<sup>92</sup>, R.D. Harrington<sup>46</sup>, P.F. Harrison<sup>170</sup>, F. Hartjes<sup>107</sup>, M. Hasegawa<sup>67</sup>, Y. Hasegawa<sup>140</sup>, A. Hasib<sup>113</sup>, S. Hassani<sup>136</sup>, S. Haug<sup>17</sup>, R. Hauser<sup>90</sup>, L. Hauswald<sup>44</sup>, M. Havranek<sup>127</sup>, C.M. Hawkes<sup>18</sup>, R.J. Hawkings<sup>30</sup>, A.D. Hawkins<sup>81</sup>, T. Hayashi<sup>160</sup>, D. Hayden<sup>90</sup>, C.P. Hays<sup>120</sup>, J.M. Hays<sup>76</sup>, H.S. Hayward<sup>74</sup>, S.J. Haywood<sup>131</sup>, S.J. Head<sup>18</sup>, T. Heck<sup>83</sup>, V. Hedberg<sup>81</sup>, L. Heelan<sup>8</sup>, S. Heim<sup>122</sup>, T. Heim<sup>175</sup>, B. Heinemann<sup>15</sup>, L. Heinrich<sup>110</sup>, J. Hejbal<sup>127</sup>, L. Helary<sup>22</sup>, S. Hellman<sup>146a,146b</sup>, D. Hellmich<sup>21</sup>, C. Helsens<sup>12</sup>, J. Henderson<sup>120</sup>, R.C.W. Henderson<sup>72</sup>, Y. Heng<sup>173</sup>, C. Hengler<sup>42</sup>, A. Henrichs<sup>176</sup>, A.M. Henriques Correia<sup>30</sup>, S. Henrot-Versille<sup>117</sup>, G.H. Herbert<sup>16</sup>, Y. Hernández Jiménez<sup>167</sup>, R. Herrberg-Schubert<sup>16</sup>, G. Herten<sup>48</sup>, R. Hertenberger<sup>100</sup>, L. Hervas<sup>30</sup>, G.G. Hesketh<sup>78</sup>, N.P. Hessey<sup>107</sup>, J.W. Hetherly<sup>40</sup>, R. Hickling<sup>76</sup>, E. Higón-Rodríguez<sup>167</sup>, E. Hill<sup>169</sup>, J.C. Hill<sup>28</sup>, K.H. Hiller<sup>42</sup>, S.J. Hillier<sup>18</sup>, I. Hinchliffe<sup>15</sup>, E. Hines<sup>122</sup>, R.R. Hinman<sup>15</sup>, M. Hirose<sup>157</sup>, D. Hirschbuehl<sup>175</sup>, J. Hobbs<sup>148</sup>, N. Hod<sup>107</sup>, M.C. Hodgkinson<sup>139</sup>, P. Hodgson<sup>139</sup>, A. Hoecker<sup>30</sup>, M.R. Hoefkamp<sup>105</sup>, F. Hoenig<sup>100</sup>, M. Hohlfeld<sup>83</sup>, D. Hohn<sup>21</sup>, T.R. Holmes<sup>15</sup>, M. Homann<sup>43</sup>, T.M. Hong<sup>125</sup>, L. Hooft van Huysduynen<sup>110</sup>, W.H. Hopkins<sup>116</sup>, Y. Hori<sup>103</sup>, A.J. Horton<sup>142</sup>, J.-Y. Hostachy<sup>55</sup>, S. Hou<sup>151</sup>, A. Hoummada<sup>135a</sup>, J. Howard<sup>120</sup>, J. Howarth<sup>42</sup>, M. Hrabovsky<sup>115</sup>, I. Hristova<sup>16</sup>, J. Hrivnac<sup>117</sup>, T. Hryn'ova<sup>5</sup>, A. Hrynevich<sup>93</sup>, C. Hsu<sup>145c</sup>, P.J. Hsu<sup>151,q</sup>, S.-C. Hsu<sup>138</sup>, D. Hu<sup>35</sup>, Q. Hu<sup>33b</sup>, X. Hu<sup>89</sup>, Y. Huang<sup>42</sup>, Z. Hubacek<sup>128</sup>, F. Hubaut<sup>85</sup>, F. Huegging<sup>21</sup>, T.B. Huffman<sup>120</sup>, E.W. Hughes<sup>35</sup>, G. Hughes<sup>72</sup>, M. Huhtinen<sup>30</sup>, T.A. Hülsing<sup>83</sup>, N. Huseynov<sup>65,b</sup>, J. Huston<sup>90</sup>, J. Huth<sup>57</sup>, G. Iacobucci<sup>49</sup>, G. Iakovidis<sup>25</sup>, I. Ibragimov<sup>141</sup>, L. Iconomidou-Fayard<sup>117</sup>, E. Ideal<sup>176</sup>, Z. Idrissi<sup>135e</sup>, P. Iengo<sup>30</sup>, O. Igonkina<sup>107</sup>, T. Iizawa<sup>171</sup>, Y. Ikegami<sup>66</sup>, K. Ikematsu<sup>141</sup>, M. Ikeno<sup>66</sup>, Y. Ilchenko<sup>31,r</sup>, D. Iliadis<sup>154</sup>, N. Ilic<sup>143</sup>, T. Ince<sup>101</sup>, G. Introzzi<sup>121a,121b</sup>, P. Ioannou<sup>9</sup>, M. Iodice<sup>134a</sup>, K. Iordanidou<sup>35</sup>, V. Ippolito<sup>57</sup>, A. Irles Quiles<sup>167</sup>, C. Isaksson<sup>166</sup>, M. Ishino<sup>68</sup>, M. Ishitsuka<sup>157</sup>, R. Ishmukhametov<sup>111</sup>, C. Issever<sup>120</sup>, S. Istin<sup>19a</sup>, J.M. Iturbe Ponce<sup>84</sup>, R. Iuppa<sup>133a,133b</sup>, J. Ivarsson<sup>81</sup>, W. Iwanski<sup>39</sup>, H. Iwasaki<sup>66</sup>, J.M. Izen<sup>41</sup>, V. Izzo<sup>104a</sup>, S. Jabbar<sup>3</sup>, B. Jackson<sup>122</sup>,

M. Jackson<sup>74</sup>, P. Jackson<sup>1</sup>, M.R. Jaekel<sup>30</sup>, V. Jain<sup>2</sup>, K. Jakobs<sup>48</sup>, S. Jakobsen<sup>30</sup>, T. Jakoubek<sup>127</sup>,  
J. Jakubek<sup>128</sup>, D.O. Jamin<sup>114</sup>, D.K. Jana<sup>79</sup>, E. Jansen<sup>78</sup>, R. Jansky<sup>62</sup>, J. Janssen<sup>21</sup>, M. Janus<sup>54</sup>,  
G. Jarlskog<sup>81</sup>, N. Javadov<sup>65,b</sup>, T. Javůrek<sup>48</sup>, L. Jeanty<sup>15</sup>, J. Jejelava<sup>51a,s</sup>, G.-Y. Jeng<sup>150</sup>, D. Jennens<sup>88</sup>,  
P. Jenni<sup>48,t</sup>, J. Jentzsch<sup>43</sup>, C. Jeske<sup>170</sup>, S. Jézéquel<sup>5</sup>, H. Ji<sup>173</sup>, J. Jia<sup>148</sup>, Y. Jiang<sup>33b</sup>, S. Jiggins<sup>78</sup>,  
J. Jimenez Pena<sup>167</sup>, S. Jin<sup>33a</sup>, A. Jinaru<sup>26a</sup>, O. Jinnouchi<sup>157</sup>, M.D. Joergensen<sup>36</sup>, P. Johansson<sup>139</sup>,  
K.A. Johns<sup>7</sup>, K. Jon-And<sup>146a,146b</sup>, G. Jones<sup>170</sup>, R.W.L. Jones<sup>72</sup>, T.J. Jones<sup>74</sup>, J. Jongmanns<sup>58a</sup>,  
P.M. Jorge<sup>126a,126b</sup>, K.D. Joshi<sup>84</sup>, J. Jovicevic<sup>159a</sup>, X. Ju<sup>173</sup>, C.A. Jung<sup>43</sup>, P. Jussel<sup>62</sup>, A. Juste Rozas<sup>12,o</sup>,  
M. Kaci<sup>167</sup>, A. Kaczmarzka<sup>39</sup>, M. Kado<sup>117</sup>, H. Kagan<sup>111</sup>, M. Kagan<sup>143</sup>, S.J. Kahn<sup>85</sup>, E. Kajomovitz<sup>45</sup>,  
C.W. Kalderon<sup>120</sup>, S. Kama<sup>40</sup>, A. Kamenshchikov<sup>130</sup>, N. Kanaya<sup>155</sup>, S. Kaneti<sup>28</sup>, V.A. Kantserov<sup>98</sup>,  
J. Kanzaki<sup>66</sup>, B. Kaplan<sup>110</sup>, L.S. Kaplan<sup>173</sup>, A. Kapliy<sup>31</sup>, D. Kar<sup>145c</sup>, K. Karakostas<sup>10</sup>, A. Karamaoun<sup>3</sup>,  
N. Karastathis<sup>10,107</sup>, M.J. Kareem<sup>54</sup>, E. Karentzos<sup>10</sup>, M. Karnevskiy<sup>83</sup>, S.N. Karpov<sup>65</sup>, Z.M. Karpova<sup>65</sup>,  
K. Karthik<sup>110</sup>, V. Kartvelishvili<sup>72</sup>, A.N. Karyukhin<sup>130</sup>, L. Kashif<sup>173</sup>, R.D. Kass<sup>111</sup>, A. Kastanas<sup>14</sup>,  
Y. Kataoka<sup>155</sup>, C. Kato<sup>155</sup>, A. Katre<sup>49</sup>, J. Katzy<sup>42</sup>, K. Kawagoe<sup>70</sup>, T. Kawamoto<sup>155</sup>, G. Kawamura<sup>54</sup>,  
S. Kazama<sup>155</sup>, V.F. Kazanin<sup>109,c</sup>, R. Keeler<sup>169</sup>, R. Kehoe<sup>40</sup>, J.S. Keller<sup>42</sup>, J.J. Kempster<sup>77</sup>,  
H. Keoshkerian<sup>84</sup>, O. Kepka<sup>127</sup>, B.P. Kerševan<sup>75</sup>, S. Kersten<sup>175</sup>, R.A. Keyes<sup>87</sup>, F. Khalil-zada<sup>11</sup>,  
H. Khandanyan<sup>146a,146b</sup>, A. Khanov<sup>114</sup>, A.G. Kharlamov<sup>109,c</sup>, T.J. Khoo<sup>28</sup>, V. Khovanskij<sup>97</sup>,  
E. Khramov<sup>65</sup>, J. Khubua<sup>51b,u</sup>, S. Kido<sup>67</sup>, H.Y. Kim<sup>8</sup>, S.H. Kim<sup>160</sup>, Y.K. Kim<sup>31</sup>, N. Kimura<sup>154</sup>,  
O.M. Kind<sup>16</sup>, B.T. King<sup>74</sup>, M. King<sup>167</sup>, S.B. King<sup>168</sup>, J. Kirk<sup>131</sup>, A.E. Kiryunin<sup>101</sup>, T. Kishimoto<sup>67</sup>,  
D. Kisielewska<sup>38a</sup>, F. Kiss<sup>48</sup>, K. Kiuchi<sup>160</sup>, O. Kivernyk<sup>136</sup>, E. Kladiva<sup>144b</sup>, M.H. Klein<sup>35</sup>, M. Klein<sup>74</sup>,  
U. Klein<sup>74</sup>, K. Kleinknecht<sup>83</sup>, P. Klimek<sup>146a,146b</sup>, A. Klimentov<sup>25</sup>, R. Klingenberg<sup>43</sup>, J.A. Klinger<sup>139</sup>,  
T. Klioutchnikova<sup>30</sup>, E.-E. Kluge<sup>58a</sup>, P. Kluit<sup>107</sup>, S. Kluth<sup>101</sup>, J. Knapik<sup>39</sup>, E. Kneringer<sup>62</sup>,  
E.B.F.G. Knoop<sup>85</sup>, A. Knue<sup>53</sup>, A. Kobayashi<sup>155</sup>, D. Kobayashi<sup>157</sup>, T. Kobayashi<sup>155</sup>, M. Kobel<sup>44</sup>,  
M. Kocian<sup>143</sup>, P. Kodys<sup>129</sup>, T. Koffas<sup>29</sup>, E. Koffeman<sup>107</sup>, L.A. Kogan<sup>120</sup>, S. Kohlmann<sup>175</sup>, Z. Kohout<sup>128</sup>,  
T. Kohriki<sup>66</sup>, T. Koi<sup>143</sup>, H. Kolanoski<sup>16</sup>, I. Koletsou<sup>5</sup>, A.A. Komar<sup>96,\*</sup>, Y. Komori<sup>155</sup>, T. Kondo<sup>66</sup>,  
N. Kondrashova<sup>42</sup>, K. Köneke<sup>48</sup>, A.C. König<sup>106</sup>, T. Kono<sup>66</sup>, R. Konoplich<sup>110,v</sup>, N. Konstantinidis<sup>78</sup>,  
R. Kopeliansky<sup>152</sup>, S. Koperny<sup>38a</sup>, L. Köpke<sup>83</sup>, A.K. Kopp<sup>48</sup>, K. Korcyl<sup>39</sup>, K. Kordas<sup>154</sup>, A. Korn<sup>78</sup>,  
A.A. Korol<sup>109,c</sup>, I. Korolkov<sup>12</sup>, E.V. Korolkova<sup>139</sup>, O. Kortner<sup>101</sup>, S. Kortner<sup>101</sup>, T. Kosek<sup>129</sup>,  
V.V. Kostyukhin<sup>21</sup>, V.M. Kotov<sup>65</sup>, A. Kotwal<sup>45</sup>, A. Kourkoulis-Charalampidi<sup>154</sup>, C. Kourkoulis<sup>9</sup>,  
V. Kouskoura<sup>25</sup>, A. Koutsman<sup>159a</sup>, R. Kowalewski<sup>169</sup>, T.Z. Kowalski<sup>38a</sup>, W. Kozanecki<sup>136</sup>,  
A.S. Kozhin<sup>130</sup>, V.A. Kramarenko<sup>99</sup>, G. Kramberger<sup>75</sup>, D. Krasnopevtsev<sup>98</sup>, M.W. Krasny<sup>80</sup>,  
A. Krasznahorkay<sup>30</sup>, J.K. Kraus<sup>21</sup>, A. Kravchenko<sup>25</sup>, S. Kreiss<sup>110</sup>, M. Kretz<sup>58c</sup>, J. Kretzschmar<sup>74</sup>,  
K. Kreutzfeldt<sup>52</sup>, P. Krieger<sup>158</sup>, K. Krizka<sup>31</sup>, K. Kroeninger<sup>43</sup>, H. Kroha<sup>101</sup>, J. Kroll<sup>122</sup>, J. Kroseberg<sup>21</sup>,  
J. Krstic<sup>13</sup>, U. Kruchonak<sup>65</sup>, H. Krüger<sup>21</sup>, N. Krumnack<sup>64</sup>, A. Kruse<sup>173</sup>, M.C. Kruse<sup>45</sup>, M. Kruskal<sup>22</sup>,  
T. Kubota<sup>88</sup>, H. Kucuk<sup>78</sup>, S. Kudah<sup>4b</sup>, S. Kuehn<sup>48</sup>, A. Kugel<sup>58c</sup>, F. Kuger<sup>174</sup>, A. Kuhl<sup>137</sup>, T. Kuhl<sup>42</sup>,  
V. Kukhtin<sup>65</sup>, R. Kukla<sup>136</sup>, Y. Kulchitsky<sup>92</sup>, S. Kuleshov<sup>32b</sup>, M. Kuna<sup>132a,132b</sup>, T. Kunigo<sup>68</sup>, A. Kupco<sup>127</sup>,  
H. Kurashige<sup>67</sup>, Y.A. Kurochkin<sup>92</sup>, V. Kus<sup>127</sup>, E.S. Kuwertz<sup>169</sup>, M. Kuze<sup>157</sup>, J. Kvita<sup>115</sup>, T. Kwan<sup>169</sup>,  
D. Kyriazopoulos<sup>139</sup>, A. La Rosa<sup>137</sup>, J.L. La Rosa Navarro<sup>24d</sup>, L. La Rotonda<sup>37a,37b</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>80</sup>, V.R. Lacuesta<sup>167</sup>, E. Ladygin<sup>65</sup>, R. Lafaye<sup>5</sup>,  
B. Laforge<sup>80</sup>, T. Lagouri<sup>176</sup>, S. Lai<sup>54</sup>, L. Lambourne<sup>78</sup>, S. Lammers<sup>61</sup>, C.L. Lampen<sup>7</sup>, W. Lampl<sup>7</sup>,  
E. Lançon<sup>136</sup>, U. Landgraf<sup>48</sup>, M.P.J. Landon<sup>76</sup>, V.S. Lang<sup>58a</sup>, J.C. Lange<sup>12</sup>, A.J. Lankford<sup>163</sup>, F. Lanni<sup>25</sup>,  
K. Lantzscht<sup>21</sup>, A. Lanza<sup>121a</sup>, S. Laplace<sup>80</sup>, C. Lapoire<sup>30</sup>, J.F. Laporte<sup>136</sup>, T. Lari<sup>91a</sup>,  
F. Lasagni Manghi<sup>20a,20b</sup>, M. Lassnig<sup>30</sup>, P. Laurelli<sup>47</sup>, W. Lavrijsen<sup>15</sup>, A.T. Law<sup>137</sup>, P. Laycock<sup>74</sup>,  
T. Lazovich<sup>57</sup>, O. Le Dortz<sup>80</sup>, E. Le Guirriec<sup>85</sup>, E. Le Menedeu<sup>12</sup>, M. LeBlanc<sup>169</sup>, T. LeCompte<sup>6</sup>,  
F. Ledroit-Guillon<sup>55</sup>, C.A. Lee<sup>145b</sup>, S.C. Lee<sup>151</sup>, L. Lee<sup>1</sup>, G. Lefebvre<sup>80</sup>, M. Lefebvre<sup>169</sup>, F. Legger<sup>100</sup>,  
C. Leggett<sup>15</sup>, A. Lehan<sup>74</sup>, G. Lehmann Miotto<sup>30</sup>, X. Lei<sup>7</sup>, W.A. Leight<sup>29</sup>, A. Leisos<sup>154,w</sup>, A.G. Leister<sup>176</sup>,  
M.A.L. Leite<sup>24d</sup>, R. Leitner<sup>129</sup>, D. Lellouch<sup>172</sup>, B. Lemmer<sup>54</sup>, K.J.C. Leney<sup>78</sup>, T. Lenz<sup>21</sup>, B. Lenzi<sup>30</sup>,  
R. Leone<sup>7</sup>, S. Leone<sup>124a,124b</sup>, C. Leonidopoulos<sup>46</sup>, S. Leontsinis<sup>10</sup>, C. Leroy<sup>95</sup>, C.G. Lester<sup>28</sup>,

M. Levchenko<sup>123</sup>, J. Levêque<sup>5</sup>, D. Levin<sup>89</sup>, L.J. Levinson<sup>172</sup>, M. Levy<sup>18</sup>, A. Lewis<sup>120</sup>, A.M. Leyko<sup>21</sup>,  
M. Leyton<sup>41</sup>, B. Li<sup>33b,x</sup>, H. Li<sup>148</sup>, H.L. Li<sup>31</sup>, L. Li<sup>45</sup>, L. Li<sup>33e</sup>, S. Li<sup>45</sup>, X. Li<sup>84</sup>, Y. Li<sup>33c,y</sup>, Z. Liang<sup>137</sup>,  
H. Liao<sup>34</sup>, B. Liberti<sup>133a</sup>, A. Liblong<sup>158</sup>, P. Lichard<sup>30</sup>, K. Lie<sup>165</sup>, J. Liebal<sup>21</sup>, W. Liebig<sup>14</sup>, C. Limbach<sup>21</sup>,  
A. Limosani<sup>150</sup>, S.C. Lin<sup>151,z</sup>, T.H. Lin<sup>83</sup>, F. Linde<sup>107</sup>, B.E. Lindquist<sup>148</sup>, J.T. Linnemann<sup>90</sup>,  
E. Lipeles<sup>122</sup>, A. Lipniacka<sup>14</sup>, M. Lisovyi<sup>58b</sup>, T.M. Liss<sup>165</sup>, D. Lissauer<sup>25</sup>, A. Lister<sup>168</sup>, A.M. Litke<sup>137</sup>,  
B. Liu<sup>151,aa</sup>, D. Liu<sup>151</sup>, H. Liu<sup>89</sup>, J. Liu<sup>85</sup>, J.B. Liu<sup>33b</sup>, K. Liu<sup>85</sup>, L. Liu<sup>165</sup>, M. Liu<sup>45</sup>, M. Liu<sup>33b</sup>,  
Y. Liu<sup>33b</sup>, M. Livan<sup>121a,121b</sup>, A. Lleres<sup>55</sup>, J. Llorente Merino<sup>82</sup>, S.L. Lloyd<sup>76</sup>, F. Lo Sterzo<sup>151</sup>,  
E. Lobodzinska<sup>42</sup>, P. Loch<sup>7</sup>, W.S. Lockman<sup>137</sup>, F.K. Loebinger<sup>84</sup>, A.E. Loevschall-Jensen<sup>36</sup>,  
A. Loginov<sup>176</sup>, T. Lohse<sup>16</sup>, K. Lohwasser<sup>42</sup>, M. Lokajicek<sup>127</sup>, B.A. Long<sup>22</sup>, J.D. Long<sup>89</sup>, R.E. Long<sup>72</sup>,  
K.A. Looper<sup>111</sup>, L. Lopes<sup>126a</sup>, D. Lopez Mateos<sup>57</sup>, B. Lopez Paredes<sup>139</sup>, I. Lopez Paz<sup>12</sup>, J. Lorenz<sup>100</sup>,  
N. Lorenzo Martinez<sup>61</sup>, M. Losada<sup>162</sup>, P. Loscutoff<sup>15</sup>, P.J. Lösel<sup>100</sup>, X. Lou<sup>33a</sup>, A. Lounis<sup>117</sup>, J. Love<sup>6</sup>,  
P.A. Love<sup>72</sup>, N. Lu<sup>89</sup>, H.J. Lubatti<sup>138</sup>, C. Luci<sup>132a,132b</sup>, A. Lucotte<sup>55</sup>, F. Luehring<sup>61</sup>, W. Lukas<sup>62</sup>,  
L. Luminari<sup>132a</sup>, O. Lundberg<sup>146a,146b</sup>, B. Lund-Jensen<sup>147</sup>, D. Lynn<sup>25</sup>, R. Lysak<sup>127</sup>, E. Lytken<sup>81</sup>,  
V. Lyubushkin<sup>65</sup>, H. Ma<sup>25</sup>, L.L. Ma<sup>33d</sup>, G. Maccarrone<sup>47</sup>, A. Macchiolo<sup>101</sup>, C.M. Macdonald<sup>139</sup>,  
B. Maček<sup>75</sup>, J. Machado Miguens<sup>122,126b</sup>, D. Macina<sup>30</sup>, D. Madaffari<sup>85</sup>, R. Madar<sup>34</sup>, H.J. Maddocks<sup>72</sup>,  
W.F. Mader<sup>44</sup>, A. Madsen<sup>166</sup>, J. Maeda<sup>67</sup>, S. Maeland<sup>14</sup>, T. Maeno<sup>25</sup>, A. Maevskiy<sup>99</sup>, E. Magradze<sup>54</sup>,  
K. Mahboubi<sup>48</sup>, J. Mahlstedt<sup>107</sup>, C. Maiani<sup>136</sup>, C. Maidantchik<sup>24a</sup>, A.A. Maier<sup>101</sup>, T. Maier<sup>100</sup>,  
A. Maio<sup>126a,126b,126d</sup>, S. Majewski<sup>116</sup>, Y. Makida<sup>66</sup>, N. Makovec<sup>117</sup>, B. Malaescu<sup>80</sup>, Pa. Malecki<sup>39</sup>,  
V.P. Maleev<sup>123</sup>, F. Malek<sup>55</sup>, U. Mallik<sup>63</sup>, D. Malon<sup>6</sup>, C. Malone<sup>143</sup>, S. Maltezos<sup>10</sup>, V.M. Malyshev<sup>109</sup>,  
S. Malyukov<sup>30</sup>, J. Mamuzic<sup>42</sup>, G. Mancini<sup>47</sup>, B. Mandelli<sup>30</sup>, L. Mandelli<sup>91a</sup>, I. Mandić<sup>75</sup>,  
R. Mandrysch<sup>63</sup>, J. Maneira<sup>126a,126b</sup>, A. Manfredini<sup>101</sup>, L. Manhaes de Andrade Filho<sup>24b</sup>,  
J. Manjarres Ramos<sup>159b</sup>, A. Mann<sup>100</sup>, A. Manousakis-Katsikakis<sup>9</sup>, B. Mansoulie<sup>136</sup>, R. Mantifel<sup>87</sup>,  
M. Mantoani<sup>54</sup>, L. Mapelli<sup>30</sup>, L. March<sup>145c</sup>, G. Marchiori<sup>80</sup>, M. Marcisovsky<sup>127</sup>, C.P. Marino<sup>169</sup>,  
M. Marjanovic<sup>13</sup>, D.E. Marley<sup>89</sup>, F. Marroquim<sup>24a</sup>, S.P. Marsden<sup>84</sup>, Z. Marshall<sup>15</sup>, L.F. Marti<sup>17</sup>,  
S. Marti-Garcia<sup>167</sup>, B. Martin<sup>90</sup>, T.A. Martin<sup>170</sup>, V.J. Martin<sup>46</sup>, B. Martin dit Latour<sup>14</sup>, M. Martinez<sup>12,o</sup>,  
S. Martin-Haugh<sup>131</sup>, V.S. Martoiu<sup>26a</sup>, A.C. Martyniuk<sup>78</sup>, M. Marx<sup>138</sup>, F. Marzano<sup>132a</sup>, A. Marzin<sup>30</sup>,  
L. Masetti<sup>83</sup>, T. Mashimo<sup>155</sup>, R. Mashinistov<sup>96</sup>, J. Masik<sup>84</sup>, A.L. Maslennikov<sup>109,c</sup>, I. Massa<sup>20a,20b</sup>,  
L. Massa<sup>20a,20b</sup>, N. Massol<sup>5</sup>, P. Mastrandrea<sup>148</sup>, A. Mastroberardino<sup>37a,37b</sup>, T. Masubuchi<sup>155</sup>,  
P. Mättig<sup>175</sup>, J. Mattmann<sup>83</sup>, J. Maurer<sup>26a</sup>, S.J. Maxfield<sup>74</sup>, D.A. Maximov<sup>109,c</sup>, R. Mazini<sup>151</sup>,  
S.M. Mazza<sup>91a,91b</sup>, L. Mazzaferro<sup>133a,133b</sup>, G. Mc Goldrick<sup>158</sup>, S.P. Mc Kee<sup>89</sup>, A. McCarn<sup>89</sup>,  
R.L. McCarthy<sup>148</sup>, T.G. McCarthy<sup>29</sup>, N.A. McCubbin<sup>131</sup>, K.W. McFarlane<sup>56,\*</sup>, J.A. Mcfayden<sup>78</sup>,  
G. Mchedlidze<sup>54</sup>, S.J. McMahon<sup>131</sup>, R.A. McPherson<sup>169,k</sup>, M. Medinnis<sup>42</sup>, S. Meehan<sup>145a</sup>,  
S. Mehlhase<sup>100</sup>, A. Mehta<sup>74</sup>, K. Meier<sup>58a</sup>, C. Meineck<sup>100</sup>, B. Meirose<sup>41</sup>, B.R. Mellado Garcia<sup>145c</sup>,  
F. Meloni<sup>17</sup>, A. Mengarelli<sup>20a,20b</sup>, S. Menke<sup>101</sup>, E. Meoni<sup>161</sup>, K.M. Mercurio<sup>57</sup>, S. Mergelmeyer<sup>21</sup>,  
P. Mermod<sup>49</sup>, L. Merola<sup>104a,104b</sup>, C. Meroni<sup>91a</sup>, F.S. Merritt<sup>31</sup>, A. Messina<sup>132a,132b</sup>, J. Metcalfe<sup>25</sup>,  
A.S. Mete<sup>163</sup>, C. Meyer<sup>83</sup>, C. Meyer<sup>122</sup>, J-P. Meyer<sup>136</sup>, J. Meyer<sup>107</sup>, H. Meyer Zu Theenhausen<sup>58a</sup>,  
R.P. Middleton<sup>131</sup>, S. Miglioranzì<sup>164a,164c</sup>, L. Mijović<sup>21</sup>, G. Mikenberg<sup>172</sup>, M. Mikestikova<sup>127</sup>,  
M. Mikuž<sup>75</sup>, M. Milesi<sup>88</sup>, A. Milic<sup>30</sup>, D.W. Miller<sup>31</sup>, C. Mills<sup>46</sup>, A. Milov<sup>172</sup>, D.A. Milstead<sup>146a,146b</sup>,  
A.A. Minaenko<sup>130</sup>, Y. Minami<sup>155</sup>, I.A. Minashvili<sup>65</sup>, A.I. Mincer<sup>110</sup>, B. Mindur<sup>38a</sup>, M. Mineev<sup>65</sup>,  
Y. Ming<sup>173</sup>, L.M. Mir<sup>12</sup>, T. Mitani<sup>171</sup>, J. Mitrevski<sup>100</sup>, V.A. Mitsou<sup>167</sup>, A. Miucci<sup>49</sup>, P.S. Miyagawa<sup>139</sup>,  
J.U. Mjörnmark<sup>81</sup>, T. Moa<sup>146a,146b</sup>, K. Mochizuki<sup>85</sup>, S. Mohapatra<sup>35</sup>, W. Mohr<sup>48</sup>, S. Molander<sup>146a,146b</sup>,  
R. Moles-Valls<sup>21</sup>, K. Mönig<sup>42</sup>, C. Monini<sup>55</sup>, J. Monk<sup>36</sup>, E. Monnier<sup>85</sup>, J. Montejo Berlingen<sup>12</sup>,  
F. Monticelli<sup>71</sup>, S. Monzani<sup>132a,132b</sup>, R.W. Moore<sup>3</sup>, N. Morange<sup>117</sup>, D. Moreno<sup>162</sup>, M. Moreno Llácer<sup>54</sup>,  
P. Morettini<sup>50a</sup>, D. Mori<sup>142</sup>, M. Morii<sup>57</sup>, M. Morinaga<sup>155</sup>, V. Morisbak<sup>119</sup>, S. Moritz<sup>83</sup>, A.K. Morley<sup>150</sup>,  
G. Mornacchi<sup>30</sup>, J.D. Morris<sup>76</sup>, S.S. Mortensen<sup>36</sup>, A. Morton<sup>53</sup>, L. Morvaj<sup>103</sup>, M. Mosidze<sup>51b</sup>,  
J. Moss<sup>111</sup>, K. Motohashi<sup>157</sup>, R. Mount<sup>143</sup>, E. Mountricha<sup>25</sup>, S.V. Mouraviev<sup>96,\*</sup>, E.J.W. Moyse<sup>86</sup>,  
S. Muanza<sup>85</sup>, R.D. Mudd<sup>18</sup>, F. Mueller<sup>101</sup>, J. Mueller<sup>125</sup>, R.S.P. Mueller<sup>100</sup>, T. Mueller<sup>28</sup>,

D. Muenstermann<sup>49</sup>, P. Mullen<sup>53</sup>, G.A. Mullier<sup>17</sup>, J.A. Murillo Quijada<sup>18</sup>, W.J. Murray<sup>170,131</sup>, H. Musheghyan<sup>54</sup>, E. Musto<sup>152</sup>, A.G. Myagkov<sup>130,ab</sup>, M. Myska<sup>128</sup>, B.P. Nachman<sup>143</sup>, O. Nackenhorst<sup>54</sup>, J. Nadal<sup>54</sup>, K. Nagai<sup>120</sup>, R. Nagai<sup>157</sup>, Y. Nagai<sup>85</sup>, K. Nagano<sup>66</sup>, A. Nagarkar<sup>111</sup>, Y. Nagasaka<sup>59</sup>, K. Nagata<sup>160</sup>, M. Nagel<sup>101</sup>, E. Nagy<sup>85</sup>, A.M. Nairz<sup>30</sup>, Y. Nakahama<sup>30</sup>, K. Nakamura<sup>66</sup>, T. Nakamura<sup>155</sup>, I. Nakano<sup>112</sup>, H. Namasivayam<sup>41</sup>, R.F. Naranjo Garcia<sup>42</sup>, R. Narayan<sup>31</sup>, D.I. Narrias Villar<sup>58a</sup>, T. Naumann<sup>42</sup>, G. Navarro<sup>162</sup>, R. Nayyar<sup>7</sup>, H.A. Neal<sup>89</sup>, P.Yu. Nechaeva<sup>96</sup>, T.J. Neep<sup>84</sup>, P.D. Nef<sup>143</sup>, A. Negri<sup>121a,121b</sup>, M. Negrini<sup>20a</sup>, S. Nektarijevic<sup>106</sup>, C. Nellist<sup>117</sup>, A. Nelson<sup>163</sup>, S. Nemecek<sup>127</sup>, P. Nemethy<sup>110</sup>, A.A. Nepomuceno<sup>24a</sup>, M. Nessi<sup>30,ac</sup>, M.S. Neubauer<sup>165</sup>, M. Neumann<sup>175</sup>, R.M. Neves<sup>110</sup>, P. Nevski<sup>25</sup>, P.R. Newman<sup>18</sup>, D.H. Nguyen<sup>6</sup>, R.B. Nickerson<sup>120</sup>, R. Nicolaidou<sup>136</sup>, B. Nicquevert<sup>30</sup>, J. Nielsen<sup>137</sup>, N. Nikiforou<sup>35</sup>, A. Nikiforov<sup>16</sup>, V. Nikolaenko<sup>130,ab</sup>, I. Nikolic-Audit<sup>80</sup>, K. Nikolopoulos<sup>18</sup>, J.K. Nilsen<sup>119</sup>, P. Nilsson<sup>25</sup>, Y. Ninomiya<sup>155</sup>, A. Nisati<sup>132a</sup>, R. Nisius<sup>101</sup>, T. Nobe<sup>155</sup>, M. Nomachi<sup>118</sup>, I. Nomidis<sup>29</sup>, T. Nooney<sup>76</sup>, S. Norberg<sup>113</sup>, M. Nordberg<sup>30</sup>, O. Novgorodova<sup>44</sup>, S. Nowak<sup>101</sup>, M. Nozaki<sup>66</sup>, L. Nozka<sup>115</sup>, K. Ntekas<sup>10</sup>, G. Nunes Hanninger<sup>88</sup>, T. Nunnemann<sup>100</sup>, E. Nurse<sup>78</sup>, F. Nuti<sup>88</sup>, B.J. O'Brien<sup>46</sup>, F. O'grady<sup>7</sup>, D.C. O'Neil<sup>142</sup>, V. O'Shea<sup>53</sup>, F.G. Oakham<sup>29,d</sup>, H. Oberlack<sup>101</sup>, T. Obermann<sup>21</sup>, J. Ocariz<sup>80</sup>, A. Ochi<sup>67</sup>, I. Ochoa<sup>78</sup>, J.P. Ochoa-Ricoux<sup>32a</sup>, S. Oda<sup>70</sup>, S. Odaka<sup>66</sup>, H. Ogren<sup>61</sup>, A. Oh<sup>84</sup>, S.H. Oh<sup>45</sup>, C.C. Ohm<sup>15</sup>, H. Ohman<sup>166</sup>, H. Oide<sup>30</sup>, W. Okamura<sup>118</sup>, H. Okawa<sup>160</sup>, Y. Okumura<sup>31</sup>, T. Okuyama<sup>66</sup>, A. Olariu<sup>26a</sup>, S.A. Olivares Pino<sup>46</sup>, D. Oliveira Damazio<sup>25</sup>, E. Oliver Garcia<sup>167</sup>, A. Olszewski<sup>39</sup>, J. Olszowska<sup>39</sup>, A. Onofre<sup>126a,126e</sup>, P.U.E. Onyisi<sup>31,r</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>154</sup>, C. Oropeza Barrera<sup>53</sup>, R.S. Orr<sup>158</sup>, B. Osculati<sup>50a,50b</sup>, R. Ospanov<sup>84</sup>, G. Otero y Garzon<sup>27</sup>, H. Otono<sup>70</sup>, M. Ouchrif<sup>135d</sup>, F. Ould-Saada<sup>119</sup>, A. Ouraou<sup>136</sup>, K.P. Oussoren<sup>107</sup>, Q. Ouyang<sup>33a</sup>, A. Ovcharova<sup>15</sup>, M. Owen<sup>53</sup>, R.E. Owen<sup>18</sup>, V.E. Ozcan<sup>19a</sup>, N. Ozturk<sup>8</sup>, K. Pachal<sup>142</sup>, A. Pacheco Pages<sup>12</sup>, C. Padilla Aranda<sup>12</sup>, M. Pagáčová<sup>48</sup>, S. Pagan Griso<sup>15</sup>, E. Paganis<sup>139</sup>, F. Paige<sup>25</sup>, P. Pais<sup>86</sup>, K. Pajchel<sup>119</sup>, G. Palacino<sup>159b</sup>, S. Palestini<sup>30</sup>, M. Palka<sup>38b</sup>, D. Pallin<sup>34</sup>, A. Palma<sup>126a,126b</sup>, Y.B. Pan<sup>173</sup>, E. Panagiotopoulou<sup>10</sup>, C.E. Pandini<sup>80</sup>, J.G. Panduro Vazquez<sup>77</sup>, P. Pani<sup>146a,146b</sup>, S. Panitkin<sup>25</sup>, D. Pantea<sup>26a</sup>, L. Paolozzi<sup>49</sup>, Th.D. Papadopoulou<sup>10</sup>, K. Papageorgiou<sup>154</sup>, A. Paramonov<sup>6</sup>, D. Paredes Hernandez<sup>154</sup>, M.A. Parker<sup>28</sup>, K.A. Parker<sup>139</sup>, F. Parodi<sup>50a,50b</sup>, J.A. Parsons<sup>35</sup>, U. Parzefall<sup>48</sup>, E. Pasqualucci<sup>132a</sup>, S. Passaggio<sup>50a</sup>, F. Pastore<sup>134a,134b,\*</sup>, Fr. Pastore<sup>77</sup>, G. Pásztor<sup>29</sup>, S. Patariaia<sup>175</sup>, N.D. Patel<sup>150</sup>, J.R. Pater<sup>84</sup>, T. Pauly<sup>30</sup>, J. Pearce<sup>169</sup>, B. Pearson<sup>113</sup>, L.E. Pedersen<sup>36</sup>, M. Pedersen<sup>119</sup>, S. Pedraza Lopez<sup>167</sup>, R. Pedro<sup>126a,126b</sup>, S.V. Peleganchuk<sup>109,c</sup>, D. Pelikan<sup>166</sup>, O. Penc<sup>127</sup>, C. Peng<sup>33a</sup>, H. Peng<sup>33b</sup>, B. Penning<sup>31</sup>, J. Penwell<sup>61</sup>, D.V. Perepelitsa<sup>25</sup>, E. Perez Codina<sup>159a</sup>, M.T. Pérez García-Están<sup>167</sup>, L. Perini<sup>91a,91b</sup>, H. Pernegger<sup>30</sup>, S. Perrella<sup>104a,104b</sup>, R. Peschke<sup>42</sup>, V.D. Peshekhonov<sup>65</sup>, K. Peters<sup>30</sup>, R.F.Y. Peters<sup>84</sup>, B.A. Petersen<sup>30</sup>, T.C. Petersen<sup>36</sup>, E. Petit<sup>42</sup>, A. Petridis<sup>1</sup>, C. Petridou<sup>154</sup>, P. Petroff<sup>117</sup>, E. Petrolu<sup>132a</sup>, F. Petrucci<sup>134a,134b</sup>, N.E. Pettersson<sup>157</sup>, R. Pezoa<sup>32b</sup>, P.W. Phillips<sup>131</sup>, G. Piacquadio<sup>143</sup>, E. Pianori<sup>170</sup>, A. Picazio<sup>49</sup>, E. Piccaro<sup>76</sup>, M. Piccinini<sup>20a,20b</sup>, M.A. Pickering<sup>120</sup>, R. Piegaia<sup>27</sup>, D.T. Pignotti<sup>111</sup>, J.E. Pilcher<sup>31</sup>, A.D. Pilkington<sup>84</sup>, J. Pina<sup>126a,126b,126d</sup>, M. Pinamonti<sup>164a,164c,ad</sup>, J.L. Pinfold<sup>3</sup>, A. Pingel<sup>36</sup>, S. Pires<sup>80</sup>, H. Pirumov<sup>42</sup>, M. Pitt<sup>172</sup>, C. Pizio<sup>91a,91b</sup>, L. Plazak<sup>144a</sup>, M.-A. Pleier<sup>25</sup>, V. Pleskot<sup>129</sup>, E. Plotnikova<sup>65</sup>, P. Plucinski<sup>146a,146b</sup>, D. Pluth<sup>64</sup>, R. Poettgen<sup>146a,146b</sup>, L. Poggioli<sup>117</sup>, D. Pohl<sup>21</sup>, G. Polesello<sup>121a</sup>, A. Poley<sup>42</sup>, A. Policicchio<sup>37a,37b</sup>, R. Polifka<sup>158</sup>, A. Polini<sup>20a</sup>, C.S. Pollard<sup>53</sup>, V. Polychronakos<sup>25</sup>, K. Pommès<sup>30</sup>, L. Pontecorvo<sup>132a</sup>, B.G. Pope<sup>90</sup>, G.A. Popeneciu<sup>26b</sup>, D.S. Popovic<sup>13</sup>, A. Poppleton<sup>30</sup>, S. Pospisil<sup>128</sup>, K. Potamianos<sup>15</sup>, I.N. Potrap<sup>65</sup>, C.J. Potter<sup>149</sup>, C.T. Potter<sup>116</sup>, G. Poulard<sup>30</sup>, J. Poveda<sup>30</sup>, V. Pozdnyakov<sup>65</sup>, P. Pralavorio<sup>85</sup>, A. Pranko<sup>15</sup>, S. Prasad<sup>30</sup>, S. Prell<sup>64</sup>, D. Price<sup>84</sup>, L.E. Price<sup>6</sup>, M. Primavera<sup>73a</sup>, S. Prince<sup>87</sup>, M. Proissl<sup>46</sup>, K. Prokofiev<sup>60c</sup>, F. Prokoshin<sup>32b</sup>, E. Protopapadaki<sup>136</sup>, S. Protopopescu<sup>25</sup>, J. Proudfoot<sup>6</sup>, M. Przybycien<sup>38a</sup>, E. Ptacek<sup>116</sup>, D. Puddu<sup>134a,134b</sup>, E. Pueschel<sup>86</sup>, D. Poldon<sup>148</sup>, M. Purohit<sup>25,ae</sup>, P. Puzo<sup>117</sup>, J. Qian<sup>89</sup>, G. Qin<sup>53</sup>, Y. Qin<sup>84</sup>, A. Quadt<sup>54</sup>, D.R. Quarrie<sup>15</sup>, W.B. Quayle<sup>164a,164b</sup>, M. Queitsch-Maitland<sup>84</sup>, D. Quilty<sup>53</sup>, S. Raddum<sup>119</sup>, V. Radeka<sup>25</sup>, V. Radescu<sup>42</sup>, S.K. Radhakrishnan<sup>148</sup>, P. Radloff<sup>116</sup>, P. Rados<sup>88</sup>, F. Ragusa<sup>91a,91b</sup>, G. Rahal<sup>178</sup>, S. Rajagopalan<sup>25</sup>,

M. Rammensee<sup>30</sup>, C. Rangel-Smith<sup>166</sup>, F. Rauscher<sup>100</sup>, S. Rave<sup>83</sup>, T. Ravenscroft<sup>53</sup>, M. Raymond<sup>30</sup>, A.L. Read<sup>119</sup>, N.P. Readioff<sup>74</sup>, D.M. Rebuzzi<sup>121a,121b</sup>, A. Redelbach<sup>174</sup>, G. Redlinger<sup>25</sup>, R. Reece<sup>137</sup>, K. Reeves<sup>41</sup>, L. Rehnisch<sup>16</sup>, J. Reichert<sup>122</sup>, H. Reisin<sup>27</sup>, M. Relich<sup>163</sup>, C. Rembser<sup>30</sup>, H. Ren<sup>33a</sup>, A. Renaud<sup>117</sup>, M. Rescigno<sup>132a</sup>, S. Resconi<sup>91a</sup>, O.L. Rezanova<sup>109,c</sup>, P. Reznicek<sup>129</sup>, R. Rezvani<sup>95</sup>, R. Richter<sup>101</sup>, S. Richter<sup>78</sup>, E. Richter-Was<sup>38b</sup>, O. Ricken<sup>21</sup>, M. Ridel<sup>80</sup>, P. Rieck<sup>16</sup>, C.J. Riegel<sup>175</sup>, J. Rieger<sup>54</sup>, M. Rijssenbeek<sup>148</sup>, A. Rimoldi<sup>121a,121b</sup>, L. Rinaldi<sup>20a</sup>, B. Ristić<sup>49</sup>, E. Ritsch<sup>30</sup>, I. Riu<sup>12</sup>, F. Rizatdinova<sup>114</sup>, E. Rizvi<sup>76</sup>, S.H. Robertson<sup>87,k</sup>, A. Robichaud-Veronneau<sup>87</sup>, D. Robinson<sup>28</sup>, J.E.M. Robinson<sup>42</sup>, A. Robson<sup>53</sup>, C. Roda<sup>124a,124b</sup>, S. Roe<sup>30</sup>, O. Røhne<sup>119</sup>, S. Rolli<sup>161</sup>, A. Romanouk<sup>98</sup>, M. Romano<sup>20a,20b</sup>, S.M. Romano Saez<sup>34</sup>, E. Romero Adam<sup>167</sup>, N. Rompotis<sup>138</sup>, M. Ronzani<sup>48</sup>, L. Roos<sup>80</sup>, E. Ros<sup>167</sup>, S. Rosati<sup>132a</sup>, K. Rosbach<sup>48</sup>, P. Rose<sup>137</sup>, P.L. Rosendahl<sup>14</sup>, O. Rosenthal<sup>141</sup>, V. Rossetti<sup>146a,146b</sup>, E. Rossi<sup>104a,104b</sup>, L.P. Rossi<sup>50a</sup>, J.H.N. Rosten<sup>28</sup>, R. Rosten<sup>138</sup>, M. Rotaru<sup>26a</sup>, I. Roth<sup>172</sup>, J. Rothberg<sup>138</sup>, D. Rousseau<sup>117</sup>, C.R. Royon<sup>136</sup>, A. Rozanov<sup>85</sup>, Y. Rozen<sup>152</sup>, X. Ruan<sup>145c</sup>, F. Rubbo<sup>143</sup>, I. Rubinskiy<sup>42</sup>, V.I. Rud<sup>99</sup>, C. Rudolph<sup>44</sup>, M.S. Rudolph<sup>158</sup>, F. Rühr<sup>48</sup>, A. Ruiz-Martinez<sup>30</sup>, Z. Rurikova<sup>48</sup>, N.A. Rusakovich<sup>65</sup>, A. Ruschke<sup>100</sup>, H.L. Russell<sup>138</sup>, J.P. Rutherford<sup>7</sup>, N. Ruthmann<sup>48</sup>, Y.F. Ryabov<sup>123</sup>, M. Rybar<sup>165</sup>, G. Rybkin<sup>117</sup>, N.C. Ryder<sup>120</sup>, A.F. Saavedra<sup>150</sup>, G. Sabato<sup>107</sup>, S. Sacerdoti<sup>27</sup>, A. Saddique<sup>3</sup>, H.F.W. Sadrozinski<sup>137</sup>, R. Sadykov<sup>65</sup>, F. Safai Tehrani<sup>132a</sup>, M. Sahinsoy<sup>58a</sup>, M. Saimpert<sup>136</sup>, T. Saito<sup>155</sup>, H. Sakamoto<sup>155</sup>, Y. Sakurai<sup>171</sup>, G. Salamanna<sup>134a,134b</sup>, A. Salamon<sup>133a</sup>, J.E. Salazar Loyola<sup>32b</sup>, M. Saleem<sup>113</sup>, D. Salek<sup>107</sup>, P.H. Sales De Bruin<sup>138</sup>, D. Saliagic<sup>101</sup>, A. Salnikov<sup>143</sup>, J. Salt<sup>167</sup>, D. Salvatore<sup>37a,37b</sup>, F. Salvatore<sup>149</sup>, A. Salvucci<sup>60a</sup>, A. Salzburger<sup>30</sup>, D. Sammel<sup>48</sup>, D. Sampsonidis<sup>154</sup>, A. Sanchez<sup>104a,104b</sup>, J. Sánchez<sup>167</sup>, V. Sanchez Martinez<sup>167</sup>, H. Sandaker<sup>119</sup>, R.L. Sandbach<sup>76</sup>, H.G. Sander<sup>83</sup>, M.P. Sanders<sup>100</sup>, M. Sandhoff<sup>175</sup>, C. Sandoval<sup>162</sup>, R. Sandstroem<sup>101</sup>, D.P.C. Sankey<sup>131</sup>, M. Sannino<sup>50a,50b</sup>, A. Sansoni<sup>47</sup>, C. Santoni<sup>34</sup>, R. Santonico<sup>133a,133b</sup>, H. Santos<sup>126a</sup>, I. Santoyo Castillo<sup>149</sup>, K. Sapp<sup>125</sup>, A. Saponov<sup>65</sup>, J.G. Saraiva<sup>126a,126d</sup>, B. Sarrazin<sup>21</sup>, O. Sasaki<sup>66</sup>, Y. Sasaki<sup>155</sup>, K. Sato<sup>160</sup>, G. Sauvage<sup>5,\*</sup>, E. Sauvan<sup>5</sup>, G. Savage<sup>77</sup>, P. Savard<sup>158,d</sup>, C. Sawyer<sup>131</sup>, L. Sawyer<sup>79,n</sup>, J. Saxon<sup>31</sup>, C. Sbarra<sup>20a</sup>, A. Sbrizzi<sup>20a,20b</sup>, T. Scanlon<sup>78</sup>, D.A. Scannicchio<sup>163</sup>, M. Scarcella<sup>150</sup>, V. Scarfone<sup>37a,37b</sup>, J. Schaarschmidt<sup>172</sup>, P. Schacht<sup>101</sup>, D. Schaefer<sup>30</sup>, R. Schaefer<sup>42</sup>, J. Schaeffer<sup>83</sup>, S. Schaepe<sup>21</sup>, S. Schaetzel<sup>58b</sup>, U. Schäfer<sup>83</sup>, A.C. Schaffer<sup>117</sup>, D. Schaile<sup>100</sup>, R.D. Schamberger<sup>148</sup>, V. Scharf<sup>58a</sup>, V.A. Schegelsky<sup>123</sup>, D. Scheirich<sup>129</sup>, M. Schernau<sup>163</sup>, C. Schiavi<sup>50a,50b</sup>, C. Schillo<sup>48</sup>, M. Schioppa<sup>37a,37b</sup>, S. Schlenker<sup>30</sup>, K. Schmieden<sup>30</sup>, C. Schmitt<sup>83</sup>, S. Schmitt<sup>58b</sup>, S. Schmitt<sup>42</sup>, B. Schneider<sup>159a</sup>, Y.J. Schnellbach<sup>74</sup>, U. Schnoor<sup>44</sup>, L. Schoeffel<sup>136</sup>, A. Schoening<sup>58b</sup>, B.D. Schoenrock<sup>90</sup>, E. Schopf<sup>21</sup>, A.L.S. Schorlemmer<sup>54</sup>, M. Schott<sup>83</sup>, D. Schouten<sup>159a</sup>, J. Schovancova<sup>8</sup>, S. Schramm<sup>49</sup>, M. Schreyer<sup>174</sup>, C. Schroeder<sup>83</sup>, N. Schuh<sup>83</sup>, M.J. Schultens<sup>21</sup>, H.-C. Schultz-Coulon<sup>58a</sup>, H. Schulz<sup>16</sup>, M. Schumacher<sup>48</sup>, B.A. Schumm<sup>137</sup>, Ph. Schune<sup>136</sup>, C. Schwanenberger<sup>84</sup>, A. Schwartzman<sup>143</sup>, T.A. Schwarz<sup>89</sup>, Ph. Schwegler<sup>101</sup>, H. Schweiger<sup>84</sup>, Ph. Schwemling<sup>136</sup>, R. Schwienhorst<sup>90</sup>, J. Schwindling<sup>136</sup>, T. Schwindt<sup>21</sup>, F.G. Sciacca<sup>17</sup>, E. Scifo<sup>117</sup>, G. Sciolla<sup>23</sup>, F. Scuri<sup>124a,124b</sup>, F. Scutti<sup>21</sup>, J. Searcy<sup>89</sup>, G. Sedov<sup>42</sup>, E. Sedykh<sup>123</sup>, P. Seema<sup>21</sup>, S.C. Seidel<sup>105</sup>, A. Seiden<sup>137</sup>, F. Seifert<sup>128</sup>, J.M. Seixas<sup>24a</sup>, G. Sekhniaidze<sup>104a</sup>, K. Sekhon<sup>89</sup>, S.J. Sekula<sup>40</sup>, D.M. Seliverstov<sup>123,\*</sup>, N. Semprini-Cesari<sup>20a,20b</sup>, C. Serfon<sup>30</sup>, L. Serin<sup>117</sup>, L. Serkin<sup>164a,164b</sup>, T. Serre<sup>85</sup>, M. Sessa<sup>134a,134b</sup>, R. Seuster<sup>159a</sup>, H. Severini<sup>113</sup>, T. Sfiligoj<sup>75</sup>, F. Sforza<sup>30</sup>, A. Sfyrila<sup>30</sup>, E. Shabalina<sup>54</sup>, M. Shamim<sup>116</sup>, L.Y. Shan<sup>33a</sup>, R. Shang<sup>165</sup>, J.T. Shank<sup>22</sup>, M. Shapiro<sup>15</sup>, P.B. Shatalov<sup>97</sup>, K. Shaw<sup>164a,164b</sup>, S.M. Shaw<sup>84</sup>, A. Shcherbakova<sup>146a,146b</sup>, C.Y. Shehu<sup>149</sup>, P. Sherwood<sup>78</sup>, L. Shi<sup>151,af</sup>, S. Shimizu<sup>67</sup>, C.O. Shimmin<sup>163</sup>, M. Shimojima<sup>102</sup>, M. Shiyakova<sup>65</sup>, A. Shmeleva<sup>96</sup>, D. Shoaleh Saadi<sup>95</sup>, M.J. Shochet<sup>31</sup>, S. Shojai<sup>91a,91b</sup>, S. Shrestha<sup>111</sup>, E. Shulga<sup>98</sup>, M.A. Shupe<sup>7</sup>, S. Shushkevich<sup>42</sup>, P. Sicho<sup>127</sup>, P.E. Sidebo<sup>147</sup>, O. Sidiropoulou<sup>174</sup>, D. Sidorov<sup>114</sup>, A. Sidoti<sup>20a,20b</sup>, F. Siegert<sup>44</sup>, Dj. Sijacki<sup>13</sup>, J. Silva<sup>126a,126d</sup>, Y. Silver<sup>153</sup>, S.B. Silverstein<sup>146a</sup>, V. Simak<sup>128</sup>, O. Simard<sup>5</sup>, Lj. Simic<sup>13</sup>, S. Simion<sup>117</sup>, E. Simioni<sup>83</sup>, B. Simmons<sup>78</sup>, D. Simon<sup>34</sup>, P. Sinervo<sup>158</sup>, N.B. Sinev<sup>116</sup>, M. Sioli<sup>20a,20b</sup>, G. Siragusa<sup>174</sup>, A.N. Sisakyan<sup>65,\*</sup>, S.Yu. Sivoklov<sup>99</sup>, J. Sjölin<sup>146a,146b</sup>, T.B. Sjursen<sup>14</sup>,

M.B. Skinner<sup>72</sup>, H.P. Skottowe<sup>57</sup>, P. Skubic<sup>113</sup>, M. Slater<sup>18</sup>, T. Slavicek<sup>128</sup>, M. Slawinska<sup>107</sup>,  
K. Sliwa<sup>161</sup>, V. Smakhtin<sup>172</sup>, B.H. Smart<sup>46</sup>, L. Smestad<sup>14</sup>, S.Yu. Smirnov<sup>98</sup>, Y. Smirnov<sup>98</sup>,  
L.N. Smirnova<sup>99,ag</sup>, O. Smirnova<sup>81</sup>, M.N.K. Smith<sup>35</sup>, R.W. Smith<sup>35</sup>, M. Smizanska<sup>72</sup>, K. Smolek<sup>128</sup>,  
A.A. Snesarev<sup>96</sup>, G. Snidero<sup>76</sup>, S. Snyder<sup>25</sup>, R. Sobie<sup>169,k</sup>, F. Socher<sup>44</sup>, A. Soffer<sup>153</sup>, D.A. Soh<sup>151,af</sup>,  
G. Sokhrannyi<sup>75</sup>, C.A. Solans<sup>30</sup>, M. Solar<sup>128</sup>, J. Solc<sup>128</sup>, E.Yu. Soldatov<sup>98</sup>, U. Soldevila<sup>167</sup>,  
A.A. Solodkov<sup>130</sup>, A. Soloshenko<sup>65</sup>, O.V. Solovyanov<sup>130</sup>, V. Solovyev<sup>123</sup>, P. Sommer<sup>48</sup>, H.Y. Song<sup>33b</sup>,  
N. Soni<sup>1</sup>, A. Sood<sup>15</sup>, A. Sopczak<sup>128</sup>, B. Sopko<sup>128</sup>, V. Sopko<sup>128</sup>, V. Sorin<sup>12</sup>, D. Sosa<sup>58b</sup>, M. Sosebee<sup>8</sup>,  
C.L. Sotiropoulou<sup>124a,124b</sup>, R. Soualah<sup>164a,164c</sup>, A.M. Soukharev<sup>109,c</sup>, D. South<sup>42</sup>, B.C. Sowden<sup>77</sup>,  
S. Spagnolo<sup>73a,73b</sup>, M. Spalla<sup>124a,124b</sup>, M. Spangenberg<sup>170</sup>, F. Spanò<sup>77</sup>, W.R. Spearman<sup>57</sup>, D. Sperlich<sup>16</sup>,  
F. Spettel<sup>101</sup>, R. Spighi<sup>20a</sup>, G. Spigo<sup>30</sup>, L.A. Spiller<sup>88</sup>, M. Spousta<sup>129</sup>, T. Spreitzer<sup>158</sup>, R.D. St. Denis<sup>53,\*</sup>,  
S. Staerz<sup>44</sup>, J. Stahlman<sup>122</sup>, R. Stamen<sup>58a</sup>, S. Stamm<sup>16</sup>, E. Stanecka<sup>39</sup>, C. Stanescu<sup>134a</sup>,  
M. Stanescu-Bellu<sup>42</sup>, M.M. Stanitzki<sup>42</sup>, S. Stapnes<sup>119</sup>, E.A. Starchenko<sup>130</sup>, J. Stark<sup>55</sup>, P. Staroba<sup>127</sup>,  
P. Starovoitov<sup>58a</sup>, R. Staszewski<sup>39</sup>, P. Stavina<sup>144a,\*</sup>, P. Steinberg<sup>25</sup>, B. Stelzer<sup>142</sup>, H.J. Stelzer<sup>30</sup>,  
O. Stelzer-Chilton<sup>159a</sup>, H. Stenzel<sup>52</sup>, G.A. Stewart<sup>53</sup>, J.A. Stillings<sup>21</sup>, M.C. Stockton<sup>87</sup>, M. Stoebe<sup>87</sup>,  
G. Stoica<sup>26a</sup>, P. Stolte<sup>54</sup>, S. Stonjek<sup>101</sup>, A.R. Stradling<sup>8</sup>, A. Straessner<sup>44</sup>, M.E. Stramaglia<sup>17</sup>,  
J. Strandberg<sup>147</sup>, S. Strandberg<sup>146a,146b</sup>, A. Strandlie<sup>119</sup>, E. Strauss<sup>143</sup>, M. Strauss<sup>113</sup>, P. Strizenec<sup>144b</sup>,  
R. Ströhmer<sup>174</sup>, D.M. Strom<sup>116</sup>, R. Stroynowski<sup>40</sup>, A. Strubig<sup>106</sup>, S.A. Stucci<sup>17</sup>, B. Stugu<sup>14</sup>,  
N.A. Styles<sup>42</sup>, D. Su<sup>143</sup>, J. Su<sup>125</sup>, R. Subramaniam<sup>79</sup>, A. Succurro<sup>12</sup>, Y. Sugaya<sup>118</sup>, C. Suhr<sup>108</sup>,  
M. Suk<sup>128</sup>, V.V. Sulin<sup>96</sup>, S. Sultansoy<sup>4c</sup>, T. Sumida<sup>68</sup>, S. Sun<sup>57</sup>, X. Sun<sup>33a</sup>, J.E. Sundermann<sup>48</sup>,  
K. Suruliz<sup>149</sup>, G. Susinno<sup>37a,37b</sup>, M.R. Sutton<sup>149</sup>, S. Suzuki<sup>66</sup>, M. Svatos<sup>127</sup>, M. Swiatlowski<sup>143</sup>,  
I. Sykora<sup>144a</sup>, T. Sykora<sup>129</sup>, D. Ta<sup>90</sup>, C. Taccini<sup>134a,134b</sup>, K. Tackmann<sup>42</sup>, J. Taenzer<sup>158</sup>, A. Taffard<sup>163</sup>,  
R. Tafirout<sup>159a</sup>, N. Taiblum<sup>153</sup>, H. Takai<sup>25</sup>, R. Takashima<sup>69</sup>, H. Takeda<sup>67</sup>, T. Takeshita<sup>140</sup>, Y. Takubo<sup>66</sup>,  
M. Talby<sup>85</sup>, A.A. Talyshev<sup>109,c</sup>, J.Y.C. Tam<sup>174</sup>, K.G. Tan<sup>88</sup>, J. Tanaka<sup>155</sup>, R. Tanaka<sup>117</sup>, S. Tanaka<sup>66</sup>,  
B.B. Tannenwald<sup>111</sup>, N. Tannoury<sup>21</sup>, S. Tapprogge<sup>83</sup>, S. Tarem<sup>152</sup>, F. Tarrade<sup>29</sup>, G.F. Tartarelli<sup>91a</sup>,  
P. Tas<sup>129</sup>, M. Tasevsky<sup>127</sup>, T. Tashiro<sup>68</sup>, E. Tassi<sup>37a,37b</sup>, A. Tavares Delgado<sup>126a,126b</sup>, Y. Tayalati<sup>135d</sup>,  
F.E. Taylor<sup>94</sup>, G.N. Taylor<sup>88</sup>, W. Taylor<sup>159b</sup>, F.A. Teischinger<sup>30</sup>, M. Teixeira Dias Castanheira<sup>76</sup>,  
P. Teixeira-Dias<sup>77</sup>, K.K. Temming<sup>48</sup>, D. Temple<sup>142</sup>, H. Ten Kate<sup>30</sup>, P.K. Teng<sup>151</sup>, J.J. Teoh<sup>118</sup>,  
F. Tepel<sup>175</sup>, S. Terada<sup>66</sup>, K. Terashi<sup>155</sup>, J. Terron<sup>82</sup>, S. Terzo<sup>101</sup>, M. Testa<sup>47</sup>, R.J. Teuscher<sup>158,k</sup>,  
T. Theveneaux-Pelzer<sup>34</sup>, J.P. Thomas<sup>18</sup>, J. Thomas-Wilsker<sup>77</sup>, E.N. Thompson<sup>35</sup>, P.D. Thompson<sup>18</sup>,  
R.J. Thompson<sup>84</sup>, A.S. Thompson<sup>53</sup>, L.A. Thomsen<sup>176</sup>, E. Thomson<sup>122</sup>, M. Thomson<sup>28</sup>, R.P. Thun<sup>89,\*</sup>,  
M.J. Tibbetts<sup>15</sup>, R.E. Ticse Torres<sup>85</sup>, V.O. Tikhomirov<sup>96,ah</sup>, Yu.A. Tikhonov<sup>109,c</sup>, S. Timoshenko<sup>98</sup>,  
E. Tiouchichine<sup>85</sup>, P. Tipton<sup>176</sup>, S. Tisserant<sup>85</sup>, K. Todome<sup>157</sup>, T. Todorov<sup>5</sup>, S. Todorova-Nova<sup>129</sup>,  
J. Tojo<sup>70</sup>, S. Tokár<sup>144a</sup>, K. Tokushuku<sup>66</sup>, K. Tollefson<sup>90</sup>, E. Tolley<sup>57</sup>, L. Tomlinson<sup>84</sup>, M. Tomoto<sup>103</sup>,  
L. Tompkins<sup>143,ai</sup>, K. Toms<sup>105</sup>, E. Torrence<sup>116</sup>, H. Torres<sup>142</sup>, E. Torró Pastor<sup>138</sup>, J. Toth<sup>85,aj</sup>,  
F. Touchard<sup>85</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. Trincas-Duvoid<sup>80</sup>, M.F. Tripiana<sup>12</sup>, W. Trischuk<sup>158</sup>, B. Trocme<sup>55</sup>, C. Troncon<sup>91a</sup>,  
M. Trottier-McDonald<sup>15</sup>, M. Trovatelli<sup>169</sup>, P. True<sup>90</sup>, L. Truong<sup>164a,164c</sup>, M. Trzebinski<sup>39</sup>, A. Trzupek<sup>39</sup>,  
C. Tsarouchas<sup>30</sup>, J.C.-L. Tseng<sup>120</sup>, P.V. Tsireshka<sup>92</sup>, D. Tsionou<sup>154</sup>, G. Tsipolitis<sup>10</sup>, N. Tsirintanis<sup>9</sup>,  
S. Tsiskaridze<sup>12</sup>, V. Tsiskaridze<sup>48</sup>, E.G. Tskhadadze<sup>51a</sup>, I.I. Tsukerman<sup>97</sup>, V. Tsulaia<sup>15</sup>, S. Tsuno<sup>66</sup>,  
D. Tsybychev<sup>148</sup>, A. Tudorache<sup>26a</sup>, V. Tudorache<sup>26a</sup>, A.N. Tuna<sup>122</sup>, S.A. Tupputi<sup>20a,20b</sup>,  
S. Turchikhin<sup>99,ag</sup>, D. Turecek<sup>128</sup>, R. Turra<sup>91a,91b</sup>, A.J. Turvey<sup>40</sup>, P.M. Tuts<sup>35</sup>, A. Tykhonov<sup>49</sup>,  
M. Tylmad<sup>146a,146b</sup>, M. Tyndel<sup>131</sup>, I. Ueda<sup>155</sup>, R. Ueno<sup>29</sup>, M. Ughetto<sup>146a,146b</sup>, M. Uglan<sup>14</sup>,  
F. Ukegawa<sup>160</sup>, G. Unal<sup>30</sup>, A. Undrus<sup>25</sup>, G. Unel<sup>163</sup>, F.C. Ungaro<sup>48</sup>, Y. Unno<sup>66</sup>, C. Unverdorben<sup>100</sup>,  
J. Urban<sup>144b</sup>, P. Urquijo<sup>88</sup>, P. Urrejola<sup>83</sup>, G. Usai<sup>8</sup>, A. Usanova<sup>62</sup>, L. Vacavant<sup>85</sup>, V. Vacek<sup>128</sup>,  
B. Vachon<sup>87</sup>, C. Valderanis<sup>83</sup>, N. Valencic<sup>107</sup>, S. Valentini<sup>20a,20b</sup>, A. Valero<sup>167</sup>, L. Valery<sup>12</sup>,  
S. Valkar<sup>129</sup>, E. Valladolid Gallego<sup>167</sup>, S. Vallecorsa<sup>49</sup>, J.A. Valls Ferrer<sup>167</sup>, W. Van Den Wollenberg<sup>107</sup>,  
P.C. Van Der Deijl<sup>107</sup>, R. van der Geer<sup>107</sup>, H. van der Graaf<sup>107</sup>, N. van Eldik<sup>152</sup>, P. van Gemmeren<sup>6</sup>,

J. Van Nieuwkoop<sup>142</sup>, I. van Vulpen<sup>107</sup>, M.C. van Woerden<sup>30</sup>, M. Vanadia<sup>132a,132b</sup>, W. Vandelli<sup>30</sup>, R. Vanguri<sup>122</sup>, A. Vaniachine<sup>6</sup>, F. Vannucci<sup>80</sup>, G. Vardanyan<sup>177</sup>, R. Vari<sup>132a</sup>, E.W. Varnes<sup>7</sup>, T. Varol<sup>40</sup>, D. Varouchas<sup>80</sup>, A. Vartapetian<sup>8</sup>, K.E. Varvell<sup>150</sup>, F. Vazeille<sup>34</sup>, T. Vazquez Schroeder<sup>87</sup>, J. Veatch<sup>7</sup>, L.M. Veloce<sup>158</sup>, F. Veloso<sup>126a,126c</sup>, T. Velz<sup>21</sup>, S. Veneziano<sup>132a</sup>, A. Ventura<sup>73a,73b</sup>, D. Ventura<sup>86</sup>, M. Venturi<sup>169</sup>, N. Venturi<sup>158</sup>, A. Venturini<sup>23</sup>, V. Vercesi<sup>121a</sup>, M. Verducci<sup>132a,132b</sup>, W. Verkerke<sup>107</sup>, J.C. Vermeulen<sup>107</sup>, A. Vest<sup>44</sup>, M.C. Vetterli<sup>142,d</sup>, O. Viazlo<sup>81</sup>, I. Vichou<sup>165</sup>, T. Vickey<sup>139</sup>, O.E. Vickey Boeriu<sup>139</sup>, G.H.A. Viehhauser<sup>120</sup>, S. Viel<sup>15</sup>, R. Vigne<sup>62</sup>, M. Villa<sup>20a,20b</sup>, M. Villaplana Perez<sup>91a,91b</sup>, E. Vilucchi<sup>47</sup>, M.G. Vinciter<sup>29</sup>, V.B. Vinogradov<sup>65</sup>, I. Vivarelli<sup>149</sup>, F. Vives Vaque<sup>3</sup>, S. Vlachos<sup>10</sup>, D. Vladoiu<sup>100</sup>, M. Vlasak<sup>128</sup>, M. Vogel<sup>32a</sup>, P. Vokac<sup>128</sup>, G. Volpi<sup>124a,124b</sup>, M. Volpi<sup>88</sup>, H. von der Schmitt<sup>101</sup>, H. von Radziewski<sup>48</sup>, E. von Toerne<sup>21</sup>, V. Vorobel<sup>129</sup>, K. Vorobev<sup>98</sup>, M. Vos<sup>167</sup>, R. Voss<sup>30</sup>, J.H. Vosseveld<sup>74</sup>, N. Vranjes<sup>13</sup>, M. Vranjes Milosavljevic<sup>13</sup>, V. Vrba<sup>127</sup>, M. Vreeswijk<sup>107</sup>, R. Vuillermet<sup>30</sup>, I. Vukotic<sup>31</sup>, Z. Vykydal<sup>128</sup>, P. Wagner<sup>21</sup>, W. Wagner<sup>175</sup>, H. Wahlberg<sup>71</sup>, S. Wahrmund<sup>44</sup>, J. Wakabayashi<sup>103</sup>, J. Walder<sup>72</sup>, R. Walker<sup>100</sup>, W. Walkowiak<sup>141</sup>, C. Wang<sup>151</sup>, F. Wang<sup>173</sup>, H. Wang<sup>15</sup>, H. Wang<sup>40</sup>, J. Wang<sup>42</sup>, J. Wang<sup>33a</sup>, K. Wang<sup>87</sup>, R. Wang<sup>6</sup>, S.M. Wang<sup>151</sup>, T. Wang<sup>21</sup>, T. Wang<sup>35</sup>, X. Wang<sup>176</sup>, C. Wanotayaroj<sup>116</sup>, A. Warburton<sup>87</sup>, C.P. Ward<sup>28</sup>, D.R. Wardrope<sup>78</sup>, A. Washbrook<sup>46</sup>, C. Wasicki<sup>42</sup>, P.M. Watkins<sup>18</sup>, A.T. Watson<sup>18</sup>, I.J. Watson<sup>150</sup>, M.F. Watson<sup>18</sup>, G. Watts<sup>138</sup>, S. Watts<sup>84</sup>, B.M. Waugh<sup>78</sup>, S. Webb<sup>84</sup>, M.S. Weber<sup>17</sup>, S.W. Weber<sup>174</sup>, J.S. Webster<sup>31</sup>, A.R. Weidberg<sup>120</sup>, B. Weinert<sup>61</sup>, J. Weingarten<sup>54</sup>, C. Weiser<sup>48</sup>, H. Weits<sup>107</sup>, P.S. Wells<sup>30</sup>, T. Wenaus<sup>25</sup>, T. Wengler<sup>30</sup>, S. Wenig<sup>30</sup>, N. Wermes<sup>21</sup>, M. Werner<sup>48</sup>, P. Werner<sup>30</sup>, M. Wessels<sup>58a</sup>, J. Wetter<sup>161</sup>, K. Whalen<sup>116</sup>, A.M. Wharton<sup>72</sup>, A. White<sup>8</sup>, M.J. White<sup>1</sup>, R. White<sup>32b</sup>, S. White<sup>124a,124b</sup>, D. Whiteson<sup>163</sup>, F.J. Wickens<sup>131</sup>, W. Wiedenmann<sup>173</sup>, M. Wielers<sup>131</sup>, P. Wienemann<sup>21</sup>, C. Wigglesworth<sup>36</sup>, L.A.M. Wiik-Fuchs<sup>21</sup>, A. Wildauer<sup>101</sup>, H.G. Wilkens<sup>30</sup>, H.H. Williams<sup>122</sup>, S. Williams<sup>107</sup>, C. Willis<sup>90</sup>, S. Willocq<sup>86</sup>, A. Wilson<sup>89</sup>, J.A. Wilson<sup>18</sup>, I. Wingerter-Seez<sup>5</sup>, F. Winklmeier<sup>116</sup>, B.T. Winter<sup>21</sup>, M. Wittgen<sup>143</sup>, J. Wittkowski<sup>100</sup>, S.J. Wollstadt<sup>83</sup>, M.W. Wolter<sup>39</sup>, H. Wolters<sup>126a,126c</sup>, B.K. Wosiek<sup>39</sup>, J. Wotschack<sup>30</sup>, M.J. Woudstra<sup>84</sup>, K.W. Wozniak<sup>39</sup>, M. Wu<sup>55</sup>, M. Wu<sup>31</sup>, S.L. Wu<sup>173</sup>, X. Wu<sup>49</sup>, Y. Wu<sup>89</sup>, T.R. Wyatt<sup>84</sup>, B.M. Wynne<sup>46</sup>, S. Xella<sup>36</sup>, D. Xu<sup>33a</sup>, L. Xu<sup>25</sup>, B. Yabsley<sup>150</sup>, S. Yacoub<sup>145a</sup>, R. Yakabe<sup>67</sup>, M. Yamada<sup>66</sup>, D. Yamaguchi<sup>157</sup>, Y. Yamaguchi<sup>118</sup>, A. Yamamoto<sup>66</sup>, S. Yamamoto<sup>155</sup>, T. Yamanaka<sup>155</sup>, K. Yamauchi<sup>103</sup>, Y. Yamazaki<sup>67</sup>, Z. Yan<sup>22</sup>, H. Yang<sup>33e</sup>, H. Yang<sup>173</sup>, Y. Yang<sup>151</sup>, W.-M. Yao<sup>15</sup>, Y. Yasu<sup>66</sup>, E. Yatsenko<sup>5</sup>, K.H. Yau Wong<sup>21</sup>, J. Ye<sup>40</sup>, S. Ye<sup>25</sup>, I. Yeletskikh<sup>65</sup>, A.L. Yen<sup>57</sup>, E. Yildirim<sup>42</sup>, K. Yorita<sup>171</sup>, R. Yoshida<sup>6</sup>, K. Yoshihara<sup>122</sup>, C. Young<sup>143</sup>, C.J.S. Young<sup>30</sup>, S. Youssef<sup>22</sup>, D.R. Yu<sup>15</sup>, J. Yu<sup>8</sup>, J.M. Yu<sup>89</sup>, J. Yu<sup>114</sup>, L. Yuan<sup>67</sup>, S.P.Y. Yuen<sup>21</sup>, A. Yurkewicz<sup>108</sup>, I. Yusuff<sup>28,ak</sup>, B. Zabinski<sup>39</sup>, R. Zaidan<sup>63</sup>, A.M. Zaitsev<sup>130,ab</sup>, J. Zalieckas<sup>14</sup>, A. Zaman<sup>148</sup>, S. Zambito<sup>57</sup>, L. Zanello<sup>132a,132b</sup>, D. Zanzi<sup>88</sup>, C. Zeitnitz<sup>175</sup>, M. Zeman<sup>128</sup>, A. Zemla<sup>38a</sup>, Q. Zeng<sup>143</sup>, K. Zengel<sup>23</sup>, O. Zenin<sup>130</sup>, T. Ženiš<sup>144a</sup>, D. Zerwas<sup>117</sup>, D. Zhang<sup>89</sup>, F. Zhang<sup>173</sup>, H. Zhang<sup>33c</sup>, J. Zhang<sup>6</sup>, L. Zhang<sup>48</sup>, R. Zhang<sup>33b</sup>, X. Zhang<sup>33d</sup>, Z. Zhang<sup>117</sup>, X. Zhao<sup>40</sup>, Y. Zhao<sup>33d,117</sup>, Z. Zhao<sup>33b</sup>, A. Zhemchugov<sup>65</sup>, J. Zhong<sup>120</sup>, B. Zhou<sup>89</sup>, C. Zhou<sup>45</sup>, L. Zhou<sup>35</sup>, L. Zhou<sup>40</sup>, M. Zhou<sup>148</sup>, N. Zhou<sup>33f</sup>, C.G. Zhu<sup>33d</sup>, H. Zhu<sup>33a</sup>, J. Zhu<sup>89</sup>, Y. Zhu<sup>33b</sup>, X. Zhuang<sup>33a</sup>, K. Zhukov<sup>96</sup>, A. Zibell<sup>174</sup>, D. Zieminska<sup>61</sup>, N.I. Zimine<sup>65</sup>, C. Zimmermann<sup>83</sup>, S. Zimmermann<sup>48</sup>, Z. Zinonos<sup>54</sup>, M. Zinser<sup>83</sup>, M. Ziolkowski<sup>141</sup>, L. Živković<sup>13</sup>, G. Zobernig<sup>173</sup>, A. Zoccoli<sup>20a,20b</sup>, M. zur Nedden<sup>16</sup>, G. Zurzolo<sup>104a,104b</sup>, L. Zwalinski<sup>30</sup>.

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

<sup>2</sup> Physics Department, SUNY Albany, Albany NY, 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) Istanbul Aydin University, Istanbul; (c)

Division of Physics, TOBB University of Economics and Technology, Ankara, Turkey

<sup>5</sup> LAPP, CNRS/IN2P3 and Université Savoie Mont Blanc, 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, Barcelona, Spain
- <sup>13</sup> Institute of Physics, 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> Department of Physics Engineering, Gaziantep University, Gaziantep; <sup>(c)</sup> Department of Physics, Dogus University, Istanbul, Turkey
- <sup>20</sup> <sup>(a)</sup> INFN Sezione di Bologna; <sup>(b)</sup> Dipartimento di Fisica e Astronomia, Università di Bologna, Bologna, Italy
- <sup>21</sup> Physikalisches Institut, University of Bonn, Bonn, Germany
- <sup>22</sup> Department of Physics, Boston University, Boston MA, 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> Electrical Circuits Department, 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 Física, 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> National Institute for Research and Development of Isotopic and Molecular Technologies, Physics Department, Cluj Napoca; <sup>(c)</sup> University Politehnica Bucharest, Bucharest; <sup>(d)</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; <sup>(e)</sup> Department of Physics and Astronomy, Shanghai Key Laboratory for Particle Physics and Cosmology, Shanghai Jiao Tong University, Shanghai; <sup>(f)</sup> Physics Department, Tsinghua University, Beijing 100084, 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, Laboratori Nazionali di Frascati; <sup>(b)</sup> Dipartimento di Fisica,

Università della Calabria, Rende, Italy

<sup>38</sup> <sup>(a)</sup> AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Krakow; <sup>(b)</sup> Marian Smoluchowski Institute of Physics, Jagiellonian University, Krakow, Poland

<sup>39</sup> 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, Technische Universität Dresden, Dresden, Germany

<sup>45</sup> Department of Physics, Duke University, Durham NC, United States of America

<sup>46</sup> SUPA - School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom

<sup>47</sup> INFN Laboratori Nazionali di Frascati, Frascati, Italy

<sup>48</sup> Fakultät für Mathematik und Physik, Albert-Ludwigs-Universität, Freiburg, Germany

<sup>49</sup> Section de Physique, Université de Genève, Geneva, Switzerland

<sup>50</sup> <sup>(a)</sup> INFN Sezione di Genova; <sup>(b)</sup> Dipartimento di Fisica, Università di Genova, Genova, Italy

<sup>51</sup> <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

<sup>52</sup> II Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen, Germany

<sup>53</sup> SUPA - School of Physics and Astronomy, University of Glasgow, Glasgow, United Kingdom

<sup>54</sup> II Physikalisches Institut, Georg-August-Universität, Göttingen, Germany

<sup>55</sup> Laboratoire de Physique Subatomique et de Cosmologie, Université Grenoble-Alpes, CNRS/IN2P3, Grenoble, France

<sup>56</sup> Department of Physics, Hampton University, Hampton VA, United States of America

<sup>57</sup> Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge MA, United States of America

<sup>58</sup> <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

<sup>59</sup> Faculty of Applied Information Science, Hiroshima Institute of Technology, Hiroshima, Japan

<sup>60</sup> <sup>(a)</sup> Department of Physics, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong; <sup>(b)</sup> Department of Physics, The University of Hong Kong, Hong Kong; <sup>(c)</sup> Department of Physics, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, China

<sup>61</sup> Department of Physics, Indiana University, Bloomington IN, United States of America

<sup>62</sup> Institut für Astro- und Teilchenphysik, Leopold-Franzens-Universität, Innsbruck, Austria

<sup>63</sup> University of Iowa, Iowa City IA, United States of America

<sup>64</sup> Department of Physics and Astronomy, Iowa State University, Ames IA, United States of America

<sup>65</sup> Joint Institute for Nuclear Research, JINR Dubna, Dubna, Russia

<sup>66</sup> KEK, High Energy Accelerator Research Organization, Tsukuba, Japan

<sup>67</sup> Graduate School of Science, Kobe University, Kobe, Japan

<sup>68</sup> Faculty of Science, Kyoto University, Kyoto, Japan

<sup>69</sup> Kyoto University of Education, Kyoto, Japan

<sup>70</sup> Department of Physics, Kyushu University, Fukuoka, Japan

<sup>71</sup> Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata, Argentina

<sup>72</sup> Physics Department, Lancaster University, Lancaster, United Kingdom

<sup>73</sup> <sup>(a)</sup> INFN Sezione di Lecce; <sup>(b)</sup> Dipartimento di Matematica e Fisica, Università del Salento, Lecce, Italy

<sup>74</sup> Oliver Lodge Laboratory, University of Liverpool, Liverpool, United Kingdom

- <sup>75</sup> Department of Physics, Jožef Stefan Institute and University of Ljubljana, Ljubljana, Slovenia
- <sup>76</sup> School of Physics and Astronomy, Queen Mary University of London, London, United Kingdom
- <sup>77</sup> Department of Physics, Royal Holloway University of London, Surrey, United Kingdom
- <sup>78</sup> Department of Physics and Astronomy, University College London, London, United Kingdom
- <sup>79</sup> Louisiana Tech University, Ruston LA, United States of America
- <sup>80</sup> Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France
- <sup>81</sup> Fysiska institutionen, Lunds universitet, Lund, Sweden
- <sup>82</sup> Departamento de Física Teórica C-15, Universidad Autónoma de Madrid, Madrid, Spain
- <sup>83</sup> Institut für Physik, Universität Mainz, Mainz, Germany
- <sup>84</sup> School of Physics and Astronomy, University of Manchester, Manchester, United Kingdom
- <sup>85</sup> CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France
- <sup>86</sup> Department of Physics, University of Massachusetts, Amherst MA, United States of America
- <sup>87</sup> Department of Physics, McGill University, Montreal QC, Canada
- <sup>88</sup> School of Physics, University of Melbourne, Victoria, Australia
- <sup>89</sup> Department of Physics, The University of Michigan, Ann Arbor MI, United States of America
- <sup>90</sup> Department of Physics and Astronomy, Michigan State University, East Lansing MI, United States of America
- <sup>91</sup> <sup>(a)</sup> INFN Sezione di Milano; <sup>(b)</sup> Dipartimento di Fisica, Università di Milano, Milano, Italy
- <sup>92</sup> B.I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk, Republic of Belarus
- <sup>93</sup> National Scientific and Educational Centre for Particle and High Energy Physics, Minsk, Republic of Belarus
- <sup>94</sup> Department of Physics, Massachusetts Institute of Technology, Cambridge MA, United States of America
- <sup>95</sup> Group of Particle Physics, University of Montreal, Montreal QC, Canada
- <sup>96</sup> P.N. Lebedev Institute of Physics, Academy of Sciences, Moscow, Russia
- <sup>97</sup> Institute for Theoretical and Experimental Physics (ITEP), Moscow, Russia
- <sup>98</sup> National Research Nuclear University MEPhI, Moscow, Russia
- <sup>99</sup> D.V. Skobeltsyn Institute of Nuclear Physics, M.V. Lomonosov Moscow State University, Moscow, Russia
- <sup>100</sup> Fakultät für Physik, Ludwig-Maximilians-Universität München, München, Germany
- <sup>101</sup> Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), München, Germany
- <sup>102</sup> Nagasaki Institute of Applied Science, Nagasaki, Japan
- <sup>103</sup> Graduate School of Science and Kobayashi-Maskawa Institute, Nagoya University, Nagoya, Japan
- <sup>104</sup> <sup>(a)</sup> INFN Sezione di Napoli; <sup>(b)</sup> Dipartimento di Fisica, Università di Napoli, Napoli, Italy
- <sup>105</sup> Department of Physics and Astronomy, University of New Mexico, Albuquerque NM, United States of America
- <sup>106</sup> Institute for Mathematics, Astrophysics and Particle Physics, Radboud University Nijmegen/Nikhef, Nijmegen, Netherlands
- <sup>107</sup> Nikhef National Institute for Subatomic Physics and University of Amsterdam, Amsterdam, Netherlands
- <sup>108</sup> Department of Physics, Northern Illinois University, DeKalb IL, United States of America
- <sup>109</sup> Budker Institute of Nuclear Physics, SB RAS, Novosibirsk, Russia
- <sup>110</sup> Department of Physics, New York University, New York NY, United States of America
- <sup>111</sup> Ohio State University, Columbus OH, United States of America
- <sup>112</sup> Faculty of Science, Okayama University, Okayama, Japan

- <sup>113</sup> Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman OK, United States of America
- <sup>114</sup> Department of Physics, Oklahoma State University, Stillwater OK, United States of America
- <sup>115</sup> Palacký University, RCPTM, Olomouc, Czech Republic
- <sup>116</sup> Center for High Energy Physics, University of Oregon, Eugene OR, United States of America
- <sup>117</sup> LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France
- <sup>118</sup> Graduate School of Science, Osaka University, Osaka, Japan
- <sup>119</sup> Department of Physics, University of Oslo, Oslo, Norway
- <sup>120</sup> Department of Physics, Oxford University, Oxford, United Kingdom
- <sup>121</sup> <sup>(a)</sup> INFN Sezione di Pavia; <sup>(b)</sup> Dipartimento di Fisica, Università di Pavia, Pavia, Italy
- <sup>122</sup> Department of Physics, University of Pennsylvania, Philadelphia PA, United States of America
- <sup>123</sup> National Research Centre "Kurchatov Institute" B.P.Konstantinov Petersburg Nuclear Physics Institute, St. Petersburg, Russia
- <sup>124</sup> <sup>(a)</sup> INFN Sezione di Pisa; <sup>(b)</sup> Dipartimento di Fisica E. Fermi, Università di Pisa, Pisa, Italy
- <sup>125</sup> Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh PA, United States of America
- <sup>126</sup> <sup>(a)</sup> Laboratório de Instrumentação e Física Experimental de Partículas - LIP, Lisboa; <sup>(b)</sup> Faculdade de Ciências, Universidade de Lisboa, Lisboa; <sup>(c)</sup> Department of Physics, University of Coimbra, Coimbra; <sup>(d)</sup> Centro de Física Nuclear da Universidade de Lisboa, Lisboa; <sup>(e)</sup> Departamento de Física, Universidade do Minho, Braga; <sup>(f)</sup> Departamento de Física Teórica y del Cosmos and CAFPE, Universidad de Granada, Granada (Spain); <sup>(g)</sup> Dep Física and CEFITEC of Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Caparica, Portugal
- <sup>127</sup> Institute of Physics, Academy of Sciences of the Czech Republic, Praha, Czech Republic
- <sup>128</sup> Czech Technical University in Prague, Praha, Czech Republic
- <sup>129</sup> Faculty of Mathematics and Physics, Charles University in Prague, Praha, Czech Republic
- <sup>130</sup> State Research Center Institute for High Energy Physics, Protvino, Russia
- <sup>131</sup> Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom
- <sup>132</sup> <sup>(a)</sup> INFN Sezione di Roma; <sup>(b)</sup> Dipartimento di Fisica, Sapienza Università di Roma, 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 Matematica e 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 à l'Energie Atomique et aux Energies Alternatives), 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> (a) Faculty of Mathematics, Physics & Informatics, Comenius University, Bratislava; (b) Department of Subnuclear Physics, Institute of Experimental Physics of the Slovak Academy of Sciences, Kosice, Slovak Republic
- <sup>145</sup> (a) Department of Physics, University of Cape Town, Cape Town; (b) Department of Physics, University of Johannesburg, Johannesburg; (c) School of Physics, University of the Witwatersrand, Johannesburg, South Africa
- <sup>146</sup> (a) Department of Physics, Stockholm University; (b) 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> (a) TRIUMF, Vancouver BC; (b) 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> (a) INFN Gruppo Collegato di Udine, Sezione di Trieste, Udine; (b) ICTP, Trieste; (c) Dipartimento di Chimica, Fisica e Ambiente, Università di Udine, Udine, Italy
- <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 Department of Physics, King's College London, London, United Kingdom

<sup>b</sup> Also at Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan

<sup>c</sup> Also at Novosibirsk State University, Novosibirsk, Russia

<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 Department of Physics, University of Fribourg, Fribourg, Switzerland

<sup>g</sup> Also at Departamento de Fisica e Astronomia, Faculdade de Ciencias, Universidade do Porto, Portugal

<sup>h</sup> Also at Tomsk State University, Tomsk, Russia

<sup>i</sup> Also at CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France

<sup>j</sup> Also at Università di Napoli Parthenope, Napoli, Italy

<sup>k</sup> Also at Institute of Particle Physics (IPP), Canada

<sup>l</sup> Also at Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom

<sup>m</sup> Also at Department of Physics, St. Petersburg State Polytechnical University, St. Petersburg, Russia

<sup>n</sup> Also at Louisiana Tech University, Ruston LA, United States of America

<sup>o</sup> Also at Institutio Catalana de Recerca i Estudis Avancats, ICREA, Barcelona, Spain

<sup>p</sup> Also at Graduate School of Science, Osaka University, Osaka, Japan

<sup>q</sup> Also at Department of Physics, National Tsing Hua University, Taiwan

<sup>r</sup> Also at Department of Physics, The University of Texas at Austin, Austin TX, United States of America

<sup>s</sup> Also at Institute of Theoretical Physics, Ilia State University, Tbilisi, Georgia

<sup>t</sup> Also at CERN, Geneva, Switzerland

<sup>u</sup> Also at Georgian Technical University (GTU), Tbilisi, Georgia

<sup>v</sup> Also at Manhattan College, New York NY, United States of America

<sup>w</sup> Also at Hellenic Open University, Patras, Greece

<sup>x</sup> Also at Institute of Physics, Academia Sinica, Taipei, Taiwan

<sup>y</sup> Also at LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France

<sup>z</sup> Also at Academia Sinica Grid Computing, Institute of Physics, Academia Sinica, Taipei, Taiwan

<sup>aa</sup> Also at School of Physics, Shandong University, Shandong, China

<sup>ab</sup> Also at Moscow Institute of Physics and Technology State University, Dolgoprudny, Russia

<sup>ac</sup> Also at Section de Physique, Université de Genève, Geneva, Switzerland

<sup>ad</sup> Also at International School for Advanced Studies (SISSA), Trieste, Italy

<sup>ae</sup> Also at Department of Physics and Astronomy, University of South Carolina, Columbia SC, United States of America

<sup>af</sup> Also at School of Physics and Engineering, Sun Yat-sen University, Guangzhou, China

<sup>ag</sup> Also at Faculty of Physics, M.V.Lomonosov Moscow State University, Moscow, Russia

<sup>ah</sup> Also at National Research Nuclear University MEPhI, Moscow, Russia

<sup>ai</sup> Also at Department of Physics, Stanford University, Stanford CA, United States of America

<sup>aj</sup> Also at Institute for Particle and Nuclear Physics, Wigner Research Centre for Physics, Budapest, Hungary

<sup>ak</sup> Also at University of Malaya, Department of Physics, Kuala Lumpur, Malaysia

\* Deceased