EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH (CERN)

CERN-PH-EP-2012-259

Submitted to: PLB

Search for long-lived, heavy particles in final states with a muon and multi-track displaced vertex in proton-proton collisions at $\sqrt{s} = 7\ \mathrm{TeV}$ with the ATLAS detector

The ATLAS Collaboration

Abstract

Many extensions of the Standard Model posit the existence of heavy particles with long lifetimes. In this Letter, results are presented of a search for such particles, which decay at a significant distance from their production point, using a final state containing charged hadrons and an associated muon. This analysis uses a data sample of proton-proton collisions at $\sqrt{s} = 7\ \mathrm{TeV}$ corresponding to an integrated luminosity of 4.4 fb^{-1} collected in 2011 by the ATLAS detector operating at the Large Hadron Collider. Results are interpreted in the context of R-parity violating supersymmetric scenarios. No events in the signal region are observed and limits are set on the production cross section for supersymmetric particles, multiplied by the square of the branching ratio for a neutralino to decay to charged hadrons and a muon, as a function of the neutralino lifetime. To allow these limits to be used in a variety of models, they are presented for a range of squark and neutralino masses.

Search for long-lived, heavy particles in final states with a muon and multi-track displaced vertex in proton-proton collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector

The ATLAS Collaboration

Abstract

Many extensions of the Standard Model posit the existence of heavy particles with long lifetimes. In this Letter, results are presented of a search for such particles, which decay at a significant distance from their production point, using a final state containing charged hadrons and an associated muon. This analysis uses a data sample of proton-proton collisions at $\sqrt{s} = 7$ TeV corresponding to an integrated luminosity of 4.4 fb^{-1} collected in 2011 by the ATLAS detector operating at the Large Hadron Collider. Results are interpreted in the context of R-parity violating supersymmetric scenarios. No events in the signal region are observed and limits are set on the production cross section for supersymmetric particles, multiplied by the square of the branching ratio for a neutralino to decay to charged hadrons and a muon, as a function of the neutralino lifetime. To allow these limits to be used in a variety of models, they are presented for a range of squark and neutralino masses.

1. Introduction

Several extensions to the Standard Model predict the production of heavy particles with lifetimes that may be of order picoseconds up to about a nanosecond [1], at the Large Hadron Collider (LHC). One such scenario is gravity-mediated supersymmetry (SUGRA [2]) with R-parity violation (RPV) [3, 4]. If the results of R-parity conserving supersymmetry searches at the LHC (see, for example, Refs. [5, 6]) continue to disfavour light super-partners, then scenarios in which R-parity is violated may be required if supersymmetry is the solution to the hierarchy problem [7]. The present (largely indirect) constraints on RPV couplings [3, 4] would allow the decay of the lightest supersymmetric particle as it traverses a particle detector at the LHC. Signatures of heavy, long-lived particles also feature in models of gauge-mediated supersymmetry breaking [8], split-supersymmetry [9], hidden-valley [10], dark-sector gauge bosons [11] and stealth supersymmetry [12] though some of these models are disfavoured [13] by the recent results on the search for the Higgs boson [14, 15].

This Letter presents the results of a search for the decay of a heavy particle, producing a multi-track vertex that contains a muon with high transverse momentum (p_{T}) at a distance between millimeters and tens of centimeters from the pp interaction point. As in the earlier ATLAS work [16], the results are interpreted in the context of an R-parity violating supersymmetric scenario. In this model, the signature under consideration corresponds to the decay of the lightest supersymmetric particle, resulting in a muon and many high-p_{T} charged tracks originating from a single displaced vertex (DV). This can arise from a diagram such as that shown in Fig. 1, where the decay occurs due to the non-zero RPV coupling λ'_{2ij}.

Searches for related signatures have also been made at the Tevatron with $\sqrt{s} = 1.96$ TeV $p\bar{p}$ collisions. The DØ collaboration has searched for a long-lived neutral particle decaying into a final state containing two muons [17] or a $b\bar{b}$ pair [18]. Similar searches have also been made at LEP [19]. The result reported here improves on the previous ATLAS search for this signature [16] in several ways. The dataset is around 100 times larger, corresponding to an integrated luminosity of 4.4 fb^{-1} [20]. Furthermore, the signal efficiency is increased by improving the reconstruction efficiency for reconstructing tracks that do not originate from the primary vertex. The dependence on simulation to estimate background levels is also removed.

2. The ATLAS detector

The ATLAS detector [21] is a multipurpose apparatus at the LHC. The detector consists of several layers of subdetectors. From the interaction point (IP) outwards there is an inner detector (ID), measuring the tracks of charged particles, electromagnetic and hadronic calorimeters, and an outer muon spectrometer (MS).

The ID is immersed in a 2 T axial magnetic field, and

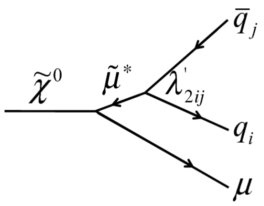

Figure 1: Diagram of the massive lightest neutralino $\tilde{\chi}^0$ decaying into a muon and two jets via a virtual smuon, with lepton-number and R-parity violating coupling λ'_{2ij}.

extends from a radius[1] of about 45 mm to 1100 mm and to $|z|$ of about 3100 mm. It provides tracking and vertex information for charged particles within the pseudorapidity region $|\eta| < 2.5$. At small radii, silicon pixel layers and stereo pairs of silicon microstrip detectors provide high resolution pattern recognition. The pixel system consists of three barrel layers, and three forward disks on either side of the interaction point (the beam pipe envelope is at a radius of about 30 mm). The barrel pixel layers, which are positioned at radii of 50.5 mm, 88.5 mm, and 122.5 mm are of particular relevance to this work. The silicon microstrip tracker (SCT) comprises four double layers in the barrel, and nine forward disks on either side. A further tracking system, a transition-radiation tracker (TRT), is positioned at larger radii. This device is made of straw-tube elements interleaved with transition-radiation material; it provides coverage within the region $|\eta| < 2.0$.

The calorimeter provides coverage over the pseudorapidity range $|\eta| < 4.9$. It consists of a lead/liquid-argon electromagnetic calorimeter, a hadronic calorimeter comprising a steel and scintillator-tile system in the barrel region and a liquid-argon system with copper and tungsten absorbers in the end-caps.

Muon identification and momentum measurement is provided by the MS. This device has a coverage in pseudorapidity of $|\eta| < 2.7$ and is a three-layer system of gas-filled precision-tracking chambers. The pseudorapidity region $|\eta| < 2.4$ is additionally covered by separate trigger chambers, used by the hardware trigger for the first level of triggering (level-1). The MS is immersed in a magnetic field which is produced by a set of toroid magnets, one for the barrel and one each for the two end-caps. Online event selection is performed with a three-level trigger system. It comprises a hardware-based level-1 trigger, which uses information from the MS trigger chambers and the calorimeters, followed by two software-based trigger levels.

3. Data and simulation

The data used in this analysis were collected between March and October, 2011. After the application of beam, detector, and data-quality requirements, the integrated luminosity considered corresponds to 4.4 fb^{-1}, with an uncertainty of $\pm 3.9\%$ [20].

Signal Monte Carlo (MC) events are generated with Pythia 6 [22], using the MRST LO** [23] set of parton distribution functions (PDFs). Processes are simulated in which a $\tilde{q}\tilde{q}$, $\bar{\tilde{q}}\bar{\tilde{q}}$, or $\tilde{q}\bar{\tilde{q}}$ pair is produced in the pp collision, with each squark (antisquark) decaying into a long-lived lightest neutralino and a quark (antiquark). Degeneracy of the first and second generations and for the left-handed and right-handed squarks is assumed. The masses of the gluino, sleptons and third-generation squarks are set at such a high value (5 TeV) that they are not directly produced in the supersymmetry scenario considered here.

The parameter settings for the samples of signal MC events are summarised in Table 1. The chosen values of squark and neutralino masses correspond to a wide range in the quantities to which the signal efficiency is most sensitive: neutralino speed and final-state multiplicities (see Section 5). The Higgsino-gaugino mixing determines the neutralino mass values. The signal MC samples are labelled in Table 1 according to the squark mass and neutralino mass, respectively: MH (medium-mass squark, heavy neutralino), ML (medium-mass squark, light neutralino), and HH (heavy squark and heavy neutralino). It is assumed that all RPV couplings other than λ'_{211} are zero. This leads to each neutralino decaying to $\mu^- u\bar{d}$ (or the charge-conjugate state). Decays of neutralinos to a neutrino and jets final state, which would also occur via a non-zero λ'_{211}, are not considered in this work. The values of the λ'_{211} coupling in the various samples are selected such that a significant fraction of neutralino decays occur in the detector volume considered in this analysis. The average neutralino proper flight distances ($c\tau_{\mathrm{MC}}$, where τ_{MC} is the generated neutralino lifetime) are provided in Table 1.

The PROSPINO [24] program is used to calculate the signal cross section (hereafter referred to as the supersymmetry production cross section) at next-to-leading order; cross section values are listed in Table 1. The CTEQ6.6 PDF set [25] is used. Owing to differences in the predicted cross sections for the $\tilde{q}\tilde{q}$ and $\tilde{q}\bar{\tilde{q}}$ processes from Pythia and PROSPINO, and the possible sensitivity of the neutralino-speed distribution to the assumed process, signal samples are generated for each process separately with Pythia and reweighted according to the relative cross sections of the two processes as estimated with PROSPINO. The reweighting procedure, however, has a minimal effect on the distributions of physical quantities

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

Sample	$m_{\tilde{q}}$ [GeV]	σ [fb]	$m_{\tilde{\chi}_1^0}$ [GeV]	$\langle\gamma\beta\rangle_{\tilde{\chi}_1^0}$	$c\tau_{\rm MC}$ [mm]	λ'_{211} $\times 10^{-5}$
MH	700	66.4	494	1.0	78	0.3
ML	700	66.4	108	3.1	101	1.5
HH	1500	0.2	494	1.9	82	1.5

Table 1: The parameter values for the three signal MC samples used in this work: the assumed squark mass, production cross section (calculated with PROSPINO), neutralino mass, average value of the Lorentz boost factor (from PYTHIA), average proper decay length, and value of λ'_{211} coupling used in the generation of the signal MC samples.

used in this work and typically leads to changes of much less than 1%.

Each generated event in the signal samples is processed with the GEANT4-based [26] ATLAS detector simulation [27] and treated in the same way as the collision data. The samples include a realistic modelling of the effects of multiple *pp* collision per bunch crossing (pile-up) observed in the data.

4. Vertex reconstruction and event selection

It is required that the trigger identifies a muon candidate with transverse momentum $p_{\rm T} > 40$ GeV and $|\eta| < 1.05$, i.e., in the barrel region of the MS. The latter selection is necessary since there is no ID track requirement in the trigger and there is a higher fake-muon rate in the (larger $|\eta|$) end-cap region.

Owing to the higher instantaneous luminosity of the LHC in 2011 compared to that in 2010, most events contain more than one primary vertex (PV). The PV with the highest sum of $p_{\rm T}^2$ of the tracks associated to it is required to have at least five tracks and a z position in the range $|z_{\rm PV}| < 200$ mm. In order to reduce cosmic-ray background, events are rejected if they contain two muons which appear back-to-back. A selection $\sqrt{(\pi - (\phi_1 - \phi_2))^2 - (\eta_1 + \eta_2)^2)} > 0.1$ is applied where ϕ_1, ϕ_2, η_1 and η_2 are the azimuthal angles and pseudorapidities of the two reconstructed muons.

A muon candidate is required to have been reconstructed in both the MS and the ID with transverse momentum $p_{\rm T} > 50$ GeV (which is well into the region where the trigger efficiency is approximately independent of the muon momentum) and $|\eta| < 1.07$. The impact parameter relative to the transverse position of the primary vertex (d_0) is required to satisfy $|d_0| > 1.5$ mm. To ensure that the muon candidate is associated with the muon that satisfied the trigger requirement, the selection $\sqrt{(\Delta\phi)^2 + (\Delta\eta)^2} < 0.15$ is imposed, where $\Delta\phi$ ($\Delta\eta$) is the difference between the azimuthal angle (pseudorapidity) of the reconstructed muon and that of the muon identified by the trigger. The ID track associated with the muon candidate is required to have at least six SCT hits, and at most one SCT hit that is expected but not found i.e. in an active detector element with no known read-out problems. Furthermore, the track must satisfy an $|\eta|$-dependent requirement on the number of TRT hits. No pixel-hit requirements are applied to the muon track. The combination of requirements described above is referred to as the muon-selection criteria.

In order to reconstruct a DV it is first necessary to select high quality tracks. This is done by requiring that candidate tracks have two or more associated SCT hits and a value of $|d_0|$ greater than 2 mm. Studies made with the MC simulation show that 98% of all tracks originating from the primary *pp* interaction are rejected by the selection on $|d_0|$. Standard ATLAS tracking [21] is based on three passes in which the initial track candidates are formed in different ways: initially found in the silicon detectors, initially found in the TRT detector, and only found in the TRT detector. The algorithms all assume that tracks originate from close to the PV, and hence have reduced reconstruction efficiency for signal tracks which originate at a DV. To counter this problem and recover some of these lost tracks, the silicon-seeded tracking algorithm is re-run with looser requirements on the radial and z impact parameters, and on the number of detector hits that can be shared among more than one seed track. To reduce the rate of false seed tracks, it is required that these additional tracks have $p_{\rm T} > 1$ GeV, which is greater than the standard-tracking requirement of $p_{\rm T} > 400$ MeV. This procedure is termed "re-tracking". Fig. 2 shows the efficiency for vertex reconstruction (described later) as a function of the radial position of the vertex $r_{\rm DV}$ when using standard tracking and re-tracking for sample MH. As can be seen, there is a substantial improvement due to re-tracking at values of $r_{\rm DV}$ greater than about 10 mm. The dips in the plot correspond to losses in efficiency for decays immediately before a pixel layer, where many tracks from the vertex have shared pixel hits and therefore fail the selection.

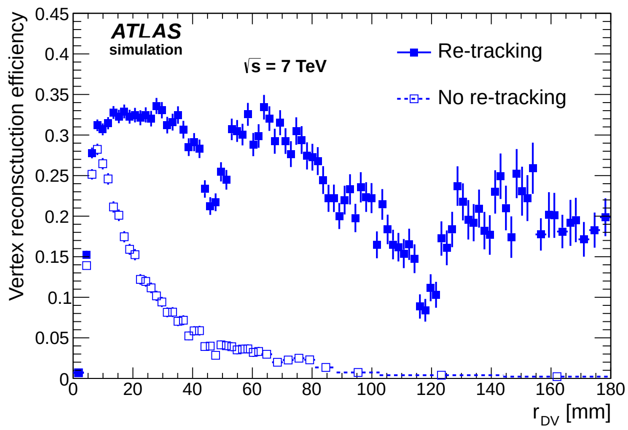

Figure 2: The vertex reconstruction efficiency as a function of $r_{\rm DV}$ for the MH sample, with and without re-tracking. All selection criteria, except for the material veto, have been applied.

Using an algorithm based on the incompatibility-graph approach [28], DVs are sought with the selected tracks. The method adopted is similar to that used in Ref. [29]. The algorithm starts by finding two-track seed vertices from all pairs of tracks; those that have a vertex-fit χ^2 of less than 5.0 per degree of freedom are retained. A seed vertex is rejected if at least one of its tracks has hits between the vertex and the PV. Multi-track vertices are formed from combinations of seed vertices in an iterative process. The following method is used to do this. If a track is assigned to two different vertices, the action taken depends on the distance D between the vertices. If $D < 3\sigma_D$, where σ_D is the estimated uncertainty on D, a single vertex is formed from the tracks of the two vertices. Otherwise, a track is associated with that vertex for which the track has the smaller χ^2 value. In the event of the χ^2 of a track relative to the resulting vertex exceeding 3.0 per degree of freedom, the track is removed from the vertex, and the vertex is refitted. This process continues until no track is associated with more than one vertex. Finally, vertices are combined and refitted if they are separated by less than 1 mm.

To ensure a good quality DV fit, the χ^2 per degree of freedom of the fit must be less than 5. Furthermore, the DV position is required to be in the fiducial region, defined as $|z_{\rm DV}| < 300$ mm and $r_{\rm DV} < 180$ mm, where $r_{\rm DV}$ and $z_{\rm DV}$ are the radial and longitudinal vertex positions with respect to the origin. To minimise background coming from the PVs, the transverse distance $\sqrt{(x_{\rm DV} - x_{\rm PV})^2 + (y_{\rm DV} - y_{\rm PV})^2}$ between any of the PVs and the DV must be at least 4 mm. Here x and y are the transverse coordinates of a given vertex, with the subscripts PV and DV denoting the type of vertex. The number of tracks $N_{\rm DV}^{\rm trk}$ associated with the DV is required to be at least five. This reduces background from random combinations of tracks and from material interactions. Background due to particle interactions with material is suppressed by requiring $m_{\rm DV} > 10$ GeV. Here, $m_{\rm DV}$ is the invariant mass of the set of tracks associated with the DV, using the charged-pion mass hypothesis for each track. Candidate vertices which pass (fail) the $m_{\rm DV} > 10$ GeV requirement are hereafter referred to as being high-$m_{\rm DV}$ (low-$m_{\rm DV}$) vertices.

The typical position resolution of the DV in the signal MC samples is tens of microns for $r_{\rm DV}$ and about 200 μm for $z_{\rm DV}$ near the interaction point. For vertices beyond the outermost pixel layer, which is located at a radius of 122.5 mm, the typical resolution is several hundred microns for both coordinates.

Low-$m_{\rm DV}$ vertices from particle–material interactions are abundant in regions in which the detector material is dense. High-$m_{\rm DV}$ background may arise from the random spatial coincidence of a material-interaction vertex with a high-$p_{\rm T}$ track, especially when this track and the particle that initiated the material-interaction vertex originate from different primary interactions, resulting in a large angle between their momentum vectors.

To reduce this source of background, vertices that are reconstructed in regions of high-density material are removed. The high-density material was mapped using low-$m_{\rm DV}$ material-interaction candidate vertices in data and true material-interaction vertices in minimum-bias MC events. The $z_{\rm DV}$ and $r_{\rm DV}$ positions of these vertices are used to make a two-dimensional material-density distribution with a bin size of 4 mm in $z_{\rm DV}$ and 1 mm in $r_{\rm DV}$. It has been demonstrated [29] that the detector simulation describes the positions of pixel layers and associated material reasonably well, while the simulated position of the beampipe is shifted with respect to the actual position. The use of data events to construct the material map therefore ensures that the beampipe material is correctly mapped, while the use of the simulation provides a high granularity of the map at the outer pixel layers, where material-interaction vertices in the data are comparatively rare. Material-map bins with vertex density greater than an $r_{\rm DV}$- and $z_{\rm DV}$-dependent density criterion are characterised as high-density-material regions. These make up 34% of the volume at $|z_{\rm DV}| < 300$ mm, $r_{\rm DV} < 180$ mm.

To ensure that the muon candidate is associated with the reconstructed DV, the distance of closest approach of the muon with respect to the DV is required to be less than 0.5 mm. The aforementioned selections are collectively referred to as the vertex-selection criteria.

5. Signal efficiency

The signal efficiency depends strongly on the efficiencies for track reconstruction and track selection, which are affected by several factors: (1) The number of tracks originating from the DV and their total invariant mass increase with the neutralino mass. (2) More tracks fail the $|d_0| > 2$ mm requirement for small $r_{\rm DV}$ or if a neutralino with large $p_{\rm T}$ has a small decay length, thereby leaving its daughters pointing back closer to the PV. (3) The efficiency for reconstructing tracks decreases with increasing values of $|d_0|$. Because the MH and HH samples have the same neutralino mass, but different boosts, a cross–check of the efficiency estimation procedure can be made. The HH sample is reweighted vertex-by-vertex such that the $\beta\gamma$ versus η distributions match the MH sample. It was checked that they have the same efficiency as a function of decay position.

The total efficiency for each of the signal MC samples is shown in Fig. 3 as a function of $c\tau$. This is an overall event efficiency, derived from the determination of (the single) vertex efficiency, and is based on having two displaced vertices per event in the signal MC. This efficiency as a function of $c\tau$ is calculated from the samples generated with a single-$c\tau$ value (see Table 1) using a two-dimensional map in $(|z_{\rm DV}|, r_{\rm DV})$ (Fig. 4) and distributions of decay positions for different values of $c\tau$. Events are reweighted according to their probability of being found at different positions in the map, where the probability depends on $c\tau$. Figure 3 includes systematic corrections and uncertainties that are discussed in Section 7.

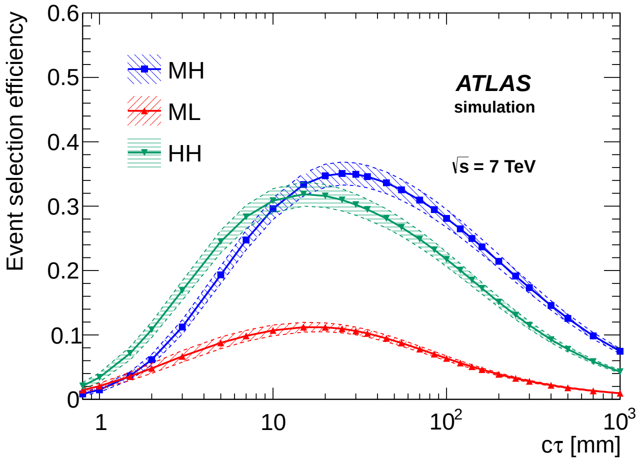

Figure 3: The event selection efficiency as a function of $c\tau$ for the three signal samples. The total uncertainties on the efficiency are shown as bands; the estimation of the uncertainties is discussed in Section 7.

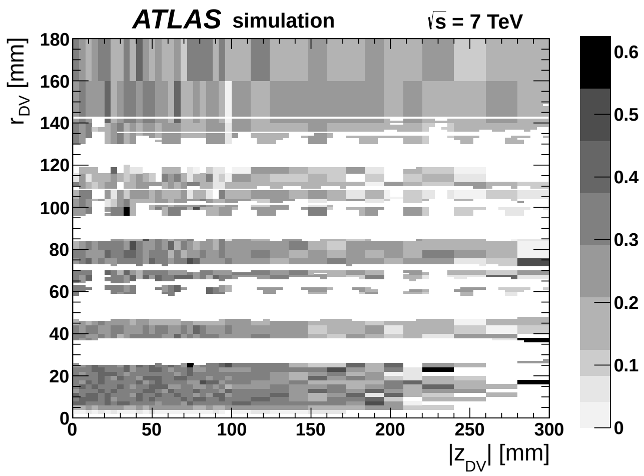

Figure 4: The efficiency as a function of $r_{\rm DV}$ and $z_{\rm DV}$ for vertices in the signal MC sample MH. The blank areas represent regions of dense material which are not considered when looking for DVs. Bin-to-bin fluctuations due to limited MC sample size are compensated for by recalculating this map many times, varying each bin content within its statistical uncertainty.

6. Background estimation

Spurious high-$m_{\rm DV}$, high-multiplicity vertices in non-material regions could come from one of two sources: (1) Purely random combinations of tracks (real or fake). This type of background is expected to form the largest contribution at small radii where the track density is highest. (2) Vertices from real hadronic interactions with gas molecules. Although most of these events will have masses below the 10 GeV requirement, the high-mass tail of the distribution indicates a potential background, in particular if the vertex is crossed by a random track (real or fake) at large crossing angle.

The first source of background mentioned above gives rise to displaced vertices inside the beampipe (where there are few real hadronic interactions due to the good vacuum, but where random combinations are expected to dominate). The expected background yield is evaluated using two independent control samples. One control sample uses jet-triggered events (rather than muon-triggered events), and the other uses vertices with 4 GeV $< m_{\rm DV} <$ 10 GeV, which is below the standard vertex selection requirement. This procedure gives an estimate of $0.00^{+0.06}_{-0}$ vertices for this source of background.

To estimate the second source of background i.e. vertices arising from real hadronic interactions, including those crossed by tracks from different PVs, two $m_{\rm DV}$-distributions are constructed. One distribution is formed from vertices which do not include a so-called large-angle track, i.e. the average angle between a constituent track and the rest of the tracks in the vertex must be less than one radian. The four-momentum of a randomly-selected track in the event is added to the vertex to build the second distribution. Both of these distributions are taken from a large control sample of jet-triggered events. The relative normalisations of these distributions are determined using an estimate of the "crossing probability". This is obtained by fitting a function representing a K_S mass peak to the invariant mass distribution of all two-track combinations within three-track vertices, and comparing the integral of this function (which is a measure of how many real K_S were crossed by a random track to form a three-track vertex), to the number of two-track K_S mesons observed.

With the shape of the $m_{\rm DV}$-distribution determined in this manner, the absolute normalisation for the muon-triggered sample can be found. It is extracted from a maximum likelihood fit, which takes as input the numbers of vertices in each material layer (i.e., the beam pipe and three pixel detector layers[2]), and the numbers of low-track-multiplicity vertices in the regions in which there is no material, which are termed "air gaps". It has been empirically observed that in each material layer or air gap, the relation between the numbers of n-track, $(n+1)$-track, $(n+2)$-track vertices etc., is well modelled by an exponential function. Furthermore, the ratio of the number of n-track vertices in a material layer to the number in the air gap immediately outside it, is consistent between several different control samples. These relations can therefore be used in the fit to predict the number of vertices with at least five tracks in the air gaps. This procedure was tested on various control samples. For instance, in events that fail the muon trigger requirement, the fit predicted 105.4 ± 5.7 events, whereas 110 events were observed. The

[2]A detailed study of the material distribution within the ID is provided in Ref. [29].

m_{DV} distribution, scaled by the prediction, is then integrated to obtain an estimate of the number of vertices with $m_{\mathrm{DV}} > 10$ GeV, and a final scale factor is applied, based on the fraction of events in our muon-triggered sample that pass the offine muon requirements. The scale factors are data-derived and arise due to the imperfect simulation of the muon triggers; they change the predicted number of vertices by up to around 4%. Finally, the background from hadronic interactions in the air gaps is estimated to be $3.7^{+4.4}_{-3.7} \times 10^{-3}$ vertices.

The total background estimate is therefore taken to be $4^{+60}_{-4} \times 10^{-3}$ vertices.

7. Systematic corrections and uncertainties

Several categories of uncertainties and corrections are considered. The values of the uncertainties depend on the neutralino lifetime and the signal sample under investigation. However, they can be ordered in approximately decreasing size. Uncertainties on the muon reconstruction efficiency are largest, followed by tracking and trigger efficiency uncertainties. The imperfect simulation of pile-up and the limited number of events in the signal samples lead to uncertainties of a similar size while the integrated luminosity makes the smallest contribution to the total uncertainty.

To estimate the uncertainty on the efficiency as a function of $c\tau$ (Fig. 3) from finite MC sample size, the efficiency in each bin of the two-dimensional efficiency map (Fig. 4) was varied randomly within its statistical uncertainty and the total efficiency was repeatedly re-measured. The spread in those results is taken as the contribution to the systematic uncertainty on the efficiency at each $c\tau$ value.

To compensate for the different z-distributions of the primary vertices in data and MC simulation, a weight is applied to each simulated event such that the reweighted z_{PV} distribution matches that in data. This weight is applied to both the numerator and denominator in the efficiency calculation.

Similarly, a weight is applied to each simulated event such that the distribution of $\langle\mu\rangle$, the average number of interactions per bunch-crossing, matches that in data. An uncertainty associated with this procedure is estimated by scaling the $\langle\mu\rangle$ values used as input to this correction calculation by a factor 0.9 (motivated by taking the difference between scaling the MC simulation by $\langle\mu\rangle$ calculated from luminosity measurements and by using the number of reconstructed PVs in data and MC simulation). The difference in the efficiency is evaluated as a function of $c\tau$, and is applied as a symmetric systematic uncertainty.

A trigger efficiency correction and its associated systematic uncertainty are derived from a study of $Z \to \mu^+\mu^-$ events in which at least one of the muons was selected with a single-muon trigger. The trigger efficiency for selecting a signal event is about 90%. The ratio of the trigger efficiencies in data and simulation is applied as a correction factor. Furthermore, the statistical uncertainty on this ratio is added in quadrature to the differences in trigger efficiency between the $Z \to \mu^+\mu^-$ sample and the signal samples to estimate a systematic uncertainty.

The systematic uncertainty on the track reconstruction efficiency is estimated by comparing the track-finding performance in data and MC simulation. The uncertainty is estimated from a study where the number of K_S vertices in data and simulation are compared over a range of radii and η-values. Based on the outcome of this study, some fraction of tracks in the signal MC are randomly removed from the input to the vertexing algorithm, and the same procedure is used to obtain efficiency-vs-$c\tau$ is performed. The difference between this and the nominal efficiency at each $c\tau$ point is taken as the systematic uncertainty.

Since the distribution of the true values of d_0 for cosmic-ray muons is flat over the limited d_0 range considered here, as predicted by cosmic-ray simulation, the shapes of the measured (and simulated) d_0-spectra of such muons are used to determine the accuracy to which the simulation reproduces the muon-finding efficiency as a function of d_0. The ratio of the number of observed cosmic-ray muons (recorded during 2011) and the simulated muon-finding efficiency is studied as a function of d_0. The degree to which the distribution is not flat is used to estimate the d_0-dependent muon-finding efficiency, which is used for the results in Figs. 3 and 4. The uncertainties on the efficiency (largely due to the limited statistical precision of the cosmic-ray background sample) are propagated to uncertainties of between $\pm 3.5\%$ (MH) and $\pm 8\%$ (ML) on the signal reconstruction efficiency, depending on the signal sample.

8. Results

Figure 5 shows the distribution of m_{DV} vs. $N_{\mathrm{DV}}^{\mathrm{trk}}$ for vertices in the selected data events, including vertices that are rejected by the selection on m_{DV} and $N_{\mathrm{DV}}^{\mathrm{trk}}$. The signal distribution for the MH sample is also indicated. The signal region, corresponding to a minimum number of five tracks in a vertex and a minimum vertex mass of 10 GeV, is also shown. No events are observed in the signal region.

Given the lack of candidate events in data, upper limits are evaluated on the supersymmetry production cross section (σ) times the square of the branching ratio (BR^2) for produced squarks to decay via long-lived neutralinos to muons and quarks. The limits are presented for different assumed values of squark and neutralino mass and $c\tau$, where τ is the neutralino lifetime. Based on the efficiency, background estimate, and luminosity of 4.4 fb^{-1}(with the uncertainties on each of these treated as nuisance parameters), the CL_s method [30] is used to set limits on the plane of $\sigma \cdot \mathrm{BR}^2$ versus $c\tau$. The resulting limits are shown in Fig. 6, with the PROSPINO-calculated cross sections for squark masses of 700 GeV and 1500 GeV. The PROSPINO predictions are shown as a

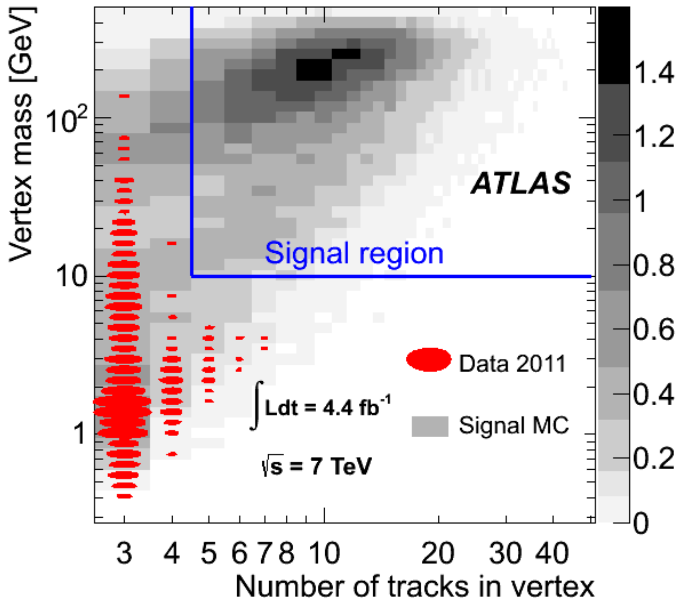

Figure 5: Vertex mass (m_{DV}) vs. vertex track multiplicity ($N_{\mathrm{DV}}^{\mathrm{trk}}$) for DVs in events with no muon requirements other than the trigger, and all other selection criteria except the m_{DV} and $N_{\mathrm{DV}}^{\mathrm{trk}}$ requirements. Shaded bins show the distribution for the signal MC MH sample (see Table 1), and data are shown as filled ellipses, with the area of the ellipse proportional to the number of vertices in the corresponding bin.

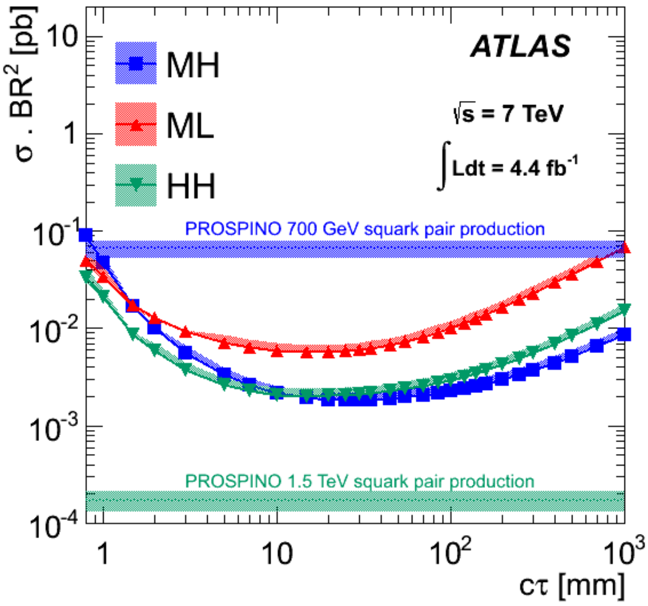

Figure 6: Upper limits at 95% confidence level on $\sigma \cdot \mathrm{BR}^2$ vs. the neutralino lifetime for different combinations of squark and neutralino masses, based on the observation of zero events satisfying all criteria in a 4.4 fb^{-1} data sample. The shaded areas around these curves represent the $\pm 1\sigma$ uncertainty bands on the expected limits. The horizontal lines show the cross sections calculated from PROSPINO for squark masses of 700 GeV and 1500 GeV. The shaded regions around these lines represent the uncertainties on the cross sections obtained from the procedure described in the text.

band which represents the variation in predicted cross section when using two different sets of PDFs (CTEQ6.6 and MSTW2008NLO [31]) and varying the factorisation and renormalisation scales each up and down by a factor of two. Since essentially no background is expected and no events are observed, the expected and observed limits are indistinguishable. Based on the observation of no signal events in a data sample of 4.4 fb^{-1}, a 95% confidence-level upper limit of 0.68 fb is set on $\sigma \cdot \mathrm{BR}^2$ multiplied by the detector acceptance and the reconstruction efficiency for any signal vertex.

9. Summary and conclusions

An improved search is presented for new, heavy particles that decay at radial distances between 4 mm and 180 mm from the *pp* interaction point, in association with a high-transverse-momentum muon. This search is based on data collected by the ATLAS detector at the LHC at a center-of-mass energy of 7 TeV. Fewer than 0.06 background events are expected in the data sample of 4.4 fb^{-1}, and no events are observed. Limits are derived on the product of di-squark production cross section and decay chain branching fraction squared, in a SUGRA scenario where the lightest neutralino produced in the primary-squark decay undergoes an R-parity violating decay into a muon and two quarks. The limits are reported as a function of the neutralino lifetime and for a range of neutralino masses and velocities, which are the factors with greatest impact on the reconstruction efficiency. Limits for a variety of other models can thus be approximated from these results, based on the neutralino mass and velocity distribution in a given model.

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

We acknowledge the support of ANPCyT, Argentina; YerPhI, Armenia; ARC, Australia; BMWF and FWF, Austria; ANAS, Azerbaijan; SSTC, Belarus; CNPq and FAPESP, Brazil; NSERC, NRC 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 and ERC, European Union; IN2P3-CNRS, CEA-DSM/IRFU, France; GNSF, Georgia; BMBF, DFG, HGF, MPG and AvH Foundation, Germany; GSRT, Greece; ISF, MINERVA, GIF, DIP and Benoziyo Center, Israel; INFN, Italy; MEXT and JSPS, Japan; CNRST, Morocco; FOM and NWO, Netherlands; BRF and RCN, Norway; MNiSW, Poland; GRICES and FCT, Portugal; MERYS (MECTS), Romania; MES of Russia and ROSATOM, Russian Federation; JINR;

MSTD, Serbia; MSSR, Slovakia; ARRS and MVZT, Slovenia; DST/NRF, South Africa; MICINN, Spain; SRC and Wallenberg Foundation, Sweden; SER, SNSF and Cantons of Bern and Geneva, Switzerland; NSC, Taiwan; TAEK, Turkey; STFC, the Royal Society and Leverhulme Trust, United Kingdom; DOE and NSF, United States of America.

The crucial computing support from all WLCG partners is acknowledged gratefully, in particular from CERN and the ATLAS Tier-1 facilities at TRIUMF (Canada), NDGF (Denmark, Norway, Sweden), CC-IN2P3 (France), KIT/GridKA (Germany), INFN-CNAF (Italy), NL-T1 (Netherlands), PIC (Spain), ASGC (Taiwan), RAL (UK) and BNL (USA) and in the Tier-2 facilities worldwide.

References

[1] M. Fairbairn, A. C. Kraan, D. A. Milstead, T. Sjöstrand, P. Z. Skands and T. Sloan, "Stable massive particles at colliders", Phys. Rept. 438, 1 (2007) [hep-ph/0611040].

[2] A. H. Chamseddine, R. L. Arnowitt and P. Nath, "Locally Supersymmetric Grand Unification", Phys. Rev. Lett. 49 (1982) 970; R. Barbieri, S. Ferrara and C. A. Savoy, "Gauge Models with Spontaneously Broken Local Supersymmetry", Phys. Lett. B 119 (1982) 343; L. E. Ibanez, "Locally Supersymmetric SU(5) Grand Unification", Phys. Lett. B 118 (1982) 73; L. J. Hall, J. D. Lykken and S. Weinberg, "Supergravity as the Messenger of Supersymmetry Breaking", Phys. Rev. D 27 (1983) 2359; N. Ohta, "Grand Unified Theories Based On Local Supersymmetry", Prog. Theor. Phys. **70** (1983) 542.

[3] R. Barbier *et al.*, "R-parity violating supersymmetry", Phys. Rept. 420 (2005) 1 [hep-ph/0406039].

[4] B. C. Allanach, M. A. Bernhardt, H. K. Dreiner, C. H. Kom and P. Richardson, "Mass Spectrum in R-Parity Violating mSUGRA and Benchmark Points", Phys. Rev. D 75 (2007) 035002 [hep-ph/0609263].

[5] ATLAS Collaboration, "Search for top and bottom squarks from gluino pair production in final states with missing transverse energy and at least three b-jets with the ATLAS detector", [hep-ex/1207.4686]; ATLAS Collaboration, "Hunt for new phenomena using large jet multiplicities and missing transverse momentum with ATLAS in 4.7 fb^{-1} of $\sqrt{s} = 7$ TeV proton-proton collisions", JHEP 1207 (2012) 167 [hep-ex/1206.1760].

[6] CMS Collaboration, "Search for new physics in events with opposite-sign leptons, jets, and missing transverse energy in pp collisions at sqrt(s) = 7 TeV," [hep-ex/1206.3949]; CMS Collaboration, "Search for new physics in the multijet and missing transverse momentum final state in proton-proton collisions at $\sqrt{s} = 7$ TeV," [hep-ex/1207.1898].

[7] P. W. Graham, D. E. Kaplan, S. Rajendran and P. Saraswat, "Displaced Supersymmetry," JHEP 1207 (2012) 149 [hep-ph/1204.6038].

[8] S. Dimopoulos, M. Dine, S. Raby and S. D. Thomas, "Experimental signatures of low-energy gauge mediated supersymmetry breaking", Phys. Rev. Lett. 76 (1996) 3494 [hep-ph/9601367].

[9] J. L. Hewett, B. Lillie, M. Masip and T. G. Rizzo, "Signatures of long-lived gluinos in split supersymmetry", JHEP 0409 (2004) 070 [hep-ph/0408248].

[10] M. J. Strassler and K. M. Zurek, "Echoes of a hidden valley at hadron colliders", Phys. Lett. B 651 (2007) 374 [hep-ph/0604261].

[11] P. Schuster, N. Toro and I. Yavin, "Terrestrial and Solar Limits on Long-Lived Particles in a Dark Sector", Phys. Rev. D 81 (2010) 016002 [hep-ph/0910.1602].

[12] J. Fan, M. Reece, J. T. Ruderman, "Stealth Supersymmetry", JHEP 1111 (2011) 012 [hep-ph/1105.5135].

[13] A. Arbey, M. Battaglia, A. Djouadi, F. Mahmoudi and J. Quevillon, Phys. Lett. B 708 (2012) 162 [hep-ph/1112.3028].

[14] ATLAS Collaboration, "Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC," Accepted by Phys.Lett.B [hep-ex/1207.7214].

[15] CMS Collaboration, "Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC," Accepted by: Phys.Lett.B [hep-ex/1207.7235].

[16] ATLAS Collaboration, "Search for displaced vertices arising from decays of new heavy particles in 7 TeV pp collisions at ATLAS", Phys. Lett. B 707 (2012) 478 [hep-ex/1109.2242].

[17] D0 Collaboration, V. M. Abazov *et al.*, "Search for neutral, long-lived particles decaying into two muons in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$-TeV", Phys. Rev. Lett. 97 (2006) 161802 [hep-ex/0607028].

[18] D0 Collaboration, V. M. Abazov *et al.*, "Search for Resonant Pair Production of long-lived particles decaying to b anti-b in p anti-p collisions at s**(1/2) = 1.96-TeV", Phys. Rev. Lett. 103 (2009) 071801 [hep-ex/0906.1787].

[19] ALEPH Collaboration, A. Heister *et al.*, "Search for gauge mediated SUSY breaking topologies in e^+e^- collisions at center-of-mass energies up to 209-GeV," Eur. Phys. J. C 25 (2002) 339 [hep-ex/0203024].

[20] ATLAS Collaboration, "Luminosity Determination in pp Collisions at sqrt(s) = 7 TeV using the ATLAS Detector in 2011", ATLAS-CONF-2011-116 (2011), URL:http://cdsweb.cern.ch/record/1376384.

[21] ATLAS Collaboration, "The ATLAS Experiment at the CERN Large Hadron Collider", JINST 3 (2008) S08003.

[22] T. Sjöstrand, S. Mrenna and P. Z. Skands, "PYTHIA 6.4 Physics and Manual," JHEP 0605 (2006) 026 [hep-ph/0603175].

[23] A. Sherstnev and R. S. Thorne, "Parton distributions for LO generators", Eur. Phys. J C55 (2008) 553 [hep-ph/0711.2473]

[24] W. Beenakker, R. Hopker and M. Spira, "PROSPINO: A Program for the production of supersymmetric particles in next-to-leading order QCD", hep-ph/9611232.

[25] P. M. Nadolsky, H. -L. Lai, Q. -H. Cao, J. Huston, J. Pumplin, D. Stump, W. -K. Tung and C. -P. Yuan, "Implications of CTEQ global analysis for collider observables", Phys. Rev. D 78 (2008) 013004 [hep-ph/0802.0007].

[26] S. Agostinelli *et al.* [GEANT4 Collaboration], "GEANT4: A Simulation toolkit", Nucl. Instrum. Meth. A 506 (2003) 250.

[27] ATLAS Collaboration, "The ATLAS Simulation Infrastructure", Eur. Phys. J. C 70 (2010) 823 [physics.ins-det/1005.4568].

[28] S. R. Das, "On a new approach for finding all the modified cut-sets in an incompatibility graph", IEEE Transactions on Computers v22(2) (1973) 187.

[29] ATLAS Collaboration, "A study of the material in the ATLAS inner detector using secondary hadronic interactions", JINST 7 (2012) P01013 [hep-ex/1110.6191].

[30] A. L. Read, "Presentation of search results: The CL(s) technique", J. Phys. G 28 (2002) 2693.

[31] A. D. Martin, W. J. Stirling, R. S. Thorne and G. Watt, "Parton distributions for the LHC", Eur. Phys. J. C 63 (2009) 189 [hep-ph/0901.0002].

The ATLAS Collaboration

G. Aad[48], T. Abajyan[21], B. Abbott[111], J. Abdallah[12], S. Abdel Khalek[115], A.A. Abdelalim[49], O. Abdinov[11], R. Aben[105], B. Abi[112], M. Abolins[88], O.S. AbouZeid[158], H. Abramowicz[153], H. Abreu[136], B.S. Acharya[164a,164b], L. Adamczyk[38], D.L. Adams[25], T.N. Addy[56], J. Adelman[176], S. Adomeit[98], P. Adragna[75], T. Adye[129], S. Aefsky[23], J.A. Aguilar-Saavedra[124b,a], M. Agustoni[17], M. Aharrouche[81], S.P. Ahlen[22], F. Ahles[48], A. Ahmad[148], M. Ahsan[41], G. Aielli[133a,133b], T. Akdogan[19a], T.P.A. Åkesson[79], G. Akimoto[155], A.V. Akimov[94], M.S. Alam[2], M.A. Alam[76], J. Albert[169], S. Albrand[55], M. Aleksa[30], I.N. Aleksandrov[64], F. Alessandria[89a], C. Alexa[26a], G. Alexander[153], G. Alexandre[49], T. Alexopoulos[10], M. Alhroob[164a,164c], M. Aliev[16], G. Alimonti[89a], J. Alison[120], B.M.M. Allbrooke[18], P.P. Allport[73], S.E. Allwood-Spiers[53], J. Almond[82], A. Aloisio[102a,102b], R. Alon[172], A. Alonso[79], F. Alonso[70], A. Altheimer[35], B. Alvarez Gonzalez[88], M.G. Alviggi[102a,102b], K. Amako[65], C. Amelung[23], V.V. Ammosov[128,*], S.P. Amor Dos Santos[124a], A. Amorim[124a,b], N. Amram[153], C. Anastopoulos[30], L.S. Ancu[17], N. Andari[115], T. Andeen[35], C.F. Anders[58b], G. Anders[58a], K.J. Anderson[31], A. Andreazza[89a,89b], V. Andrei[58a], M-L. Andrieux[55], X.S. Anduaga[70], S. Angelidakis[9], P. Anger[44], A. Angerami[35], F. Anghinolfi[30], A. Anisenkov[107], N. Anjos[124a], A. Annovi[47], A. Antonaki[9], M. Antonelli[47], A. Antonov[96], J. Antos[144b], F. Anulli[132a], M. Aoki[101], S. Aoun[83], L. Aperio Bella[5], R. Apolle[118,c], G. Arabidze[88], I. Aracena[143], Y. Arai[65], A.T.H. Arce[45], S. Arfaoui[148], J-F. Arguin[93], E. Arik[19a,*], M. Arik[19a], A.J. Armbruster[87], O. Arnaez[81], V. Arnal[80], C. Arnault[115], A. Artamonov[95], G. Artoni[132a,132b], D. Arutinov[21], S. Asai[155], S. Ask[28], B. Åsman[146a,146b], L. Asquith[6], K. Assamagan[25], A. Astbury[169], M. Atkinson[165], B. Aubert[5], E. Auge[115], K. Augsten[127], M. Aurousseau[145a], G. Avolio[30], R. Avramidou[10], D. Axen[168], G. Azuelos[93,d], Y. Azuma[155], M.A. Baak[30], G. Baccaglioni[89a], C. Bacci[134a,134b], A.M. Bach[15], H. Bachacou[136], K. Bachas[30], M. Backes[49], M. Backhaus[21], J. Backus Mayes[143], E. Badescu[26a], P. Bagnaia[132a,132b], S. Bahinipati[3], Y. Bai[33a], D.C. Bailey[158], T. Bain[158], J.T. Baines[129], O.K. Baker[176], M.D. Baker[25], S. Baker[77], P. Balek[126], E. Banas[39], P. Banerjee[93], Sw. Banerjee[173], D. Banfi[30], A. Bangert[150], V. Bansal[169], H.S. Bansil[18], L. Barak[172], S.P. Baranov[94], A. Barbaro Galtieri[15], T. Barber[48], E.L. Barberio[86], D. Barberis[50a,50b], M. Barbero[21], D.Y. Bardin[64], T. Barillari[99], M. Barisonzi[175], T. Barklow[143], N. Barlow[28], B.M. Barnett[129], R.M. Barnett[15], A. Baroncelli[134a], G. Barone[49], A.J. Barr[118], F. Barreiro[80], J. Barreiro Guimarães da Costa[57], P. Barrillon[115], R. Bartoldus[143], A.E. Barton[71], V. Bartsch[149], A. Basye[165], R.L. Bates[53], L. Batkova[144a], J.R. Batley[28], A. Battaglia[17], M. Battistin[30], F. Bauer[136], H.S. Bawa[143,e], S. Beale[98], T. Beau[78], P.H. Beauchemin[161], R. Beccherle[50a], P. Bechtle[21], H.P. Beck[17], A.K. Becker[175], S. Becker[98], M. Beckingham[138], K.H. Becks[175], A.J. Beddall[19c], A. Beddall[19c], S. Bedikian[176], V.A. Bednyakov[64], C.P. Bee[83], L.J. Beemster[105], M. Begel[25], S. Behar Harpaz[152], P.K. Behera[62], M. Beimforde[99], C. Belanger-Champagne[85], P.J. Bell[49], W.H. Bell[49], G. Bella[153], L. Bellagamba[20a], M. Bellomo[30], A. Belloni[57], O. Beloborodova[107,f], K. Belotskiy[96], O. Beltramello[30], O. Benary[153], D. Benchekroun[135a], K. Bendtz[146a,146b], N. Benekos[165], Y. Benhammou[153], E. Benhar Noccioli[49], J.A. Benitez Garcia[159b], D.P. Benjamin[45], M. Benoit[115], J.R. Bensinger[23], K. Benslama[130], S. Bentvelsen[105], D. Berge[30], E. Bergeaas Kuutmann[42], N. Berger[5], F. Berghaus[169], E. Berglund[105], J. Beringer[15], P. Bernat[77], R. Bernhard[48], C. Bernius[25], T. Berry[76], C. Bertella[83], A. Bertin[20a,20b], F. Bertolucci[122a,122b], M.I. Besana[89a,89b], G.J. Besjes[104], N. Besson[136], S. Bethke[99], W. Bhimji[46], R.M. Bianchi[30], L. Bianchini[23], M. Bianco[72a,72b], O. Biebel[98], S.P. Bieniek[77], K. Bierwagen[54], J. Biesiada[15], M. Biglietti[134a], H. Bilokon[47], M. Bindi[20a,20b], S. Binet[115], A. Bingul[19c], C. Bini[132a,132b], C. Biscarat[178], B. Bittner[99], K.M. Black[22], R.E. Blair[6], J.-B. Blanchard[136], G. Blanchot[30], T. Blazek[144a], I. Bloch[42], C. Blocker[23], J. Blocki[39], A. Blondel[49], W. Blum[81], U. Blumenschein[54], G.J. Bobbink[105], V.B. Bobrovnikov[107], S.S. Bocchetta[79], A. Bocci[45], C.R. Boddy[118], M. Boehler[48], J. Boek[175], N. Boelaert[36], J.A. Bogaerts[30], A. Bogdanchikov[107], A. Bogouch[90,*], C. Bohm[146a], J. Bohm[125], V. Boisvert[76], T. Bold[38], V. Boldea[26a], N.M. Bolnet[136], M. Bomben[78], M. Bona[75], M. Boonekamp[136], S. Bordoni[78], C. Borer[17], A. Borisov[128], G. Borissov[71], I. Borjanovic[13a], M. Borri[82], S. Borroni[87], J. Bortfeldt[98], V. Bortolotto[134a,134b], K. Bos[105], D. Boscherini[20a], M. Bosman[12], H. Boterenbrood[105], J. Bouchami[93], J. Boudreau[123], E.V. Bouhova-Thacker[71], D. Boumediene[34], C. Bourdarios[115], N. Bousson[83], A. Boveia[31], J. Boyd[30], I.R. Boyko[64], I. Bozovic-Jelisavcic[13b], J. Bracinik[18], P. Branchini[134a], A. Brandt[8], G. Brandt[118], O. Brandt[54], U. Bratzler[156], B. Brau[84], J.E. Brau[114], H.M. Braun[175,*], S.F. Brazzale[164a,164c], B. Brelier[158], J. Bremer[30], K. Brendlinger[120], R. Brenner[166], S. Bressler[172], D. Britton[53], F.M. Brochu[28], I. Brock[21], R. Brock[88], F. Broggi[89a], C. Bromberg[88], J. Bronner[99], G. Brooijmans[35], T. Brooks[76], W.K. Brooks[32b], G. Brown[82], H. Brown[8], P.A. Bruckman de Renstrom[39], D. Bruncko[144b], R. Bruneliere[48], S. Brunet[60], A. Bruni[20a], G. Bruni[20a], M. Bruschi[20a], T. Buanes[14], Q. Buat[55], F. Bucci[49], J. Buchanan[118], P. Buchholz[141], R.M. Buckingham[118], A.G. Buckley[46], S.I. Buda[26a], I.A. Budagov[64], B. Budick[108], V. Büscher[81], L. Bugge[117], O. Bulekov[96], A.C. Bundock[73], M. Bunse[43], T. Buran[117], H. Burckhart[30], S. Burdin[73], T. Burgess[14], S. Burke[129], E. Busato[34], P. Bussey[53], C.P. Buszello[166], B. Butler[143], J.M. Butler[22], C.M. Buttar[53], J.M. Butterworth[77], W. Buttinger[28], S. Cabrera Urbán[167], D. Caforio[20a,20b], O. Cakir[4a], P. Calafiura[15], G. Calderini[78], P. Calfayan[98], R. Calkins[106], L.P. Caloba[24a], R. Caloi[132a,132b], D. Calvet[34], S. Calvet[34], R. Camacho Toro[34], P. Camarri[133a,133b], D. Cameron[117], L.M. Caminada[15], R. Caminal Armadans[12], S. Campana[30],

M. Campanelli[77], V. Canale[102a,102b], F. Canelli[31], A. Canepa[159a], J. Cantero[80], R. Cantrill[76], L. Capasso[102a,102b], M.D.M. Capeans Garrido[30], I. Caprini[26a], M. Caprini[26a], D. Capriotti[99], M. Capua[37a,37b], R. Caputo[81], R. Cardarelli[133a], T. Carli[30], G. Carlino[102a], L. Carminati[89a,89b], B. Caron[85], S. Caron[104], E. Carquin[32b], G.D. Carrillo-Montoya[173], A.A. Carter[75], J.R. Carter[28], J. Carvalho[124a,g], D. Casadei[108], M.P. Casado[12], M. Cascella[122a,122b], C. Caso[50a,50b,*], A.M. Castaneda Hernandez[173,h], E. Castaneda-Miranda[173], V. Castillo Gimenez[167], N.F. Castro[124a], G. Cataldi[72a], P. Catastini[57], A. Catinaccio[30], J.R. Catmore[30], A. Cattai[30], G. Cattani[133a,133b], S. Caughron[88], V. Cavaliere[165], P. Cavalleri[78], D. Cavalli[89a], M. Cavalli-Sforza[12], V. Cavasinni[122a,122b], F. Ceradini[134a,134b], A.S. Cerqueira[24b], A. Cerri[30], L. Cerrito[75], F. Cerutti[47], S.A. Cetin[19b], A. Chafaq[135a], D. Chakraborty[106], I. Chalupkova[126], K. Chan[3], P. Chang[165], B. Chapleau[85], J.D. Chapman[28], J.W. Chapman[87], E. Chareyre[78], D.G. Charlton[18], V. Chavda[82], C.A. Chavez Barajas[30], S. Cheatham[85], S. Chekanov[6], S.V. Chekulaev[159a], G.A. Chelkov[64], M.A. Chelstowska[104], C. Chen[63], H. Chen[25], S. Chen[33c], X. Chen[173], Y. Chen[35], Y. Cheng[31], A. Cheplakov[64], R. Cherkaoui El Moursli[135e], V. Chernyatin[25], E. Cheu[7], S.L. Cheung[158], L. Chevalier[136], G. Chiefari[102a,102b], L. Chikovani[51a,*], J.T. Childers[30], A. Chilingarov[71], G. Chiodini[72a], A.S. Chisholm[18], R.T. Chislett[77], A. Chitan[26a], M.V. Chizhov[64], G. Choudalakis[31], S. Chouridou[137], I.A. Christidi[77], A. Christov[48], D. Chromek-Burckhart[30], M.L. Chu[151], J. Chudoba[125], G. Ciapetti[132a,132b], A.K. Ciftci[4a], R. Ciftci[4a], D. Cinca[34], V. Cindro[74], C. Ciocca[20a,20b], A. Ciocio[15], M. Cirilli[87], P. Cirkovic[13b], Z.H. Citron[172], M. Citterio[89a], M. Ciubancan[26a], A. Clark[49], P.J. Clark[46], R.N. Clarke[15], W. Cleland[123], J.C. Clemens[83], B. Clement[55], C. Clement[146a,146b], Y. Coadou[83], M. Cobal[164a,164c], A. Coccaro[138], J. Cochran[63], L. Coffey[23], J.G. Cogan[143], J. Coggeshall[165], E. Cogneras[178], J. Colas[5], S. Cole[106], A.P. Colijn[105], N.J. Collins[18], C. Collins-Tooth[53], J. Collot[55], T. Colombo[119a,119b], G. Colon[84], G. Compostella[99], P. Conde Muiño[124a], E. Coniavitis[166], M.C. Conidi[12], S.M. Consonni[89a,89b], V. Consorti[48], S. Constantinescu[26a], C. Conta[119a,119b], G. Conti[57], F. Conventi[102a,i], M. Cooke[15], B.D. Cooper[77], A.M. Cooper-Sarkar[118], K. Copic[15], T. Cornelissen[175], M. Corradi[20a], F. Corriveau[85,j], A. Cortes-Gonzalez[165], G. Cortiana[99], G. Costa[89a], M.J. Costa[167], D. Costanzo[139], D. Côté[30], L. Courneyea[169], G. Cowan[76], C. Cowden[28], B.E. Cox[82], K. Cranmer[108], F. Crescioli[122a,122b], M. Cristinziani[21], G. Crosetti[37a,37b], S. Crépé-Renaudin[55], C.-M. Cuciuc[26a], C. Cuenca Almenar[176], T. Cuhadar Donszelmann[139], J. Cummings[176], M. Curatolo[47], C.J. Curtis[18], C. Cuthbert[150], P. Cwetanski[60], H. Czirr[141], P. Czodrowski[44], Z. Czyczula[176], S. D'Auria[53], M. D'Onofrio[73], A. D'Orazio[132a,132b], M.J. Da Cunha Sargedas De Sousa[124a], C. Da Via[82], W. Dabrowski[38], A. Dafinca[118], T. Dai[87], C. Dallapiccola[84], M. Dam[36], M. Dameri[50a,50b], D.S. Damiani[137], H.O. Danielsson[30], V. Dao[49], G. Darbo[50a], G.L. Darlea[26b], J.A. Dassoulas[42], W. Davey[21], T. Davidek[126], N. Davidson[86], R. Davidson[71], E. Davies[118,c], M. Davies[93], O. Davignon[78], A.R. Davison[77], Y. Davygora[58a], E. Dawe[142], I. Dawson[139], R.K. Daya-Ishmukhametova[23], K. De[8], R. de Asmundis[102a], S. De Castro[20a,20b], S. De Cecco[78], J. de Graat[98], N. De Groot[104], P. de Jong[105], C. De La Taille[115], H. De la Torre[80], F. De Lorenzi[63], L. de Mora[71], L. De Nooij[105], D. De Pedis[132a], A. De Salvo[132a], U. De Sanctis[164a,164c], A. De Santo[149], J.B. De Vivie De Regie[115], G. De Zorzi[132a,132b], W.J. Dearnaley[71], R. Debbe[25], C. Debenedetti[46], B. Dechenaux[55], D.V. Dedovich[64], J. Degenhardt[120], J. Del Peso[80], T. Del Prete[122a,122b], T. Delemontex[55], M. Deliyergiyev[74], A. Dell'Acqua[30], L. Dell'Asta[22], M. Della Pietra[102a,i], D. della Volpe[102a,102b], M. Delmastro[5], P.A. Delsart[55], C. Deluca[105], S. Demers[176], M. Demichev[64], B. Demirkoz[12,k], J. Deng[163], S.P. Denisov[128], D. Derendarz[39], J.E. Derkaoui[135d], F. Derue[78], P. Dervan[73], K. Desch[21], E. Devetak[148], P.O. Deviveiros[105], A. Dewhurst[129], B. DeWilde[148], S. Dhaliwal[158], R. Dhullipudi[25,l], A. Di Ciaccio[133a,133b], L. Di Ciaccio[5], C. Di Donato[102a,102b], A. Di Girolamo[30], B. Di Girolamo[30], S. Di Luise[134a,134b], A. Di Mattia[173], B. Di Micco[30], R. Di Nardo[47], A. Di Simone[133a,133b], R. Di Sipio[20a,20b], M.A. Diaz[32a], E.B. Diehl[87], J. Dietrich[42], T.A. Dietzsch[58a], S. Diglio[86], K. Dindar Yagci[40], J. Dingfelder[21], F. Dinut[26a], C. Dionisi[132a,132b], P. Dita[26a], S. Dita[26a], F. Dittus[30], F. Djama[83], T. Djobava[51b], M.A.B. do Vale[24c], A. Do Valle Wemans[124a,m], T.K.O. Doan[5], M. Dobbs[85], D. Dobos[30], E. Dobson[30,n], J. Dodd[35], C. Doglioni[49], T. Doherty[53], Y. Doi[65,*], J. Dolejsi[126], I. Dolenc[74], Z. Dolezal[126], B.A. Dolgoshein[96,*], T. Dohmae[155], M. Donadelli[24d], J. Donini[34], J. Dopke[30], A. Doria[102a], A. Dos Anjos[173], A. Dotti[122a,122b], M.T. Dova[70], A.D. Doxiadis[105], A.T. Doyle[53], N. Dressnandt[120], M. Dris[10], J. Dubbert[99], S. Dube[15], E. Duchovni[172], G. Duckeck[98], D. Duda[175], A. Dudarev[30], F. Dudziak[63], M. Dührssen[30], I.P. Duerdoth[82], L. Duflot[115], M-A. Dufour[85], L. Duguid[76], M. Dunford[58a], H. Duran Yildiz[4a], R. Duxfield[139], M. Dwuznik[38], F. Dydak[30], M. Düren[52], W.L. Ebenstein[45], J. Ebke[98], S. Eckweiler[81], K. Edmonds[81], W. Edson[2], C.A. Edwards[76], N.C. Edwards[53], W. Ehrenfeld[42], T. Eifert[143], G. Eigen[14], K. Einsweiler[15], E. Eisenhandler[75], T. Ekelof[166], M. El Kacimi[135c], M. Ellert[166], S. Elles[5], F. Ellinghaus[81], K. Ellis[75], N. Ellis[30], J. Elmsheuser[98], M. Elsing[30], D. Emeliyanov[129], R. Engelmann[148], A. Engl[98], B. Epp[61], J. Erdmann[54], A. Ereditato[17], D. Eriksson[146a], J. Ernst[2], M. Ernst[25], J. Ernwein[136], D. Errede[165], S. Errede[165], E. Ertel[81], M. Escalier[115], H. Esch[43], C. Escobar[123], X. Espinal Curull[12], B. Esposito[47], F. Etienne[83], A.I. Etienvre[136], E. Etzion[153], D. Evangelakou[54], H. Evans[60], L. Fabbri[20a,20b], C. Fabre[30], R.M. Fakhrutdinov[128], S. Falciano[132a], Y. Fang[173], M. Fanti[89a,89b], A. Farbin[8], A. Farilla[134a], J. Farley[148], T. Farooque[158], S. Farrell[163], S.M. Farrington[170], P. Farthouat[30], F. Fassi[167], P. Fassnacht[30], D. Fassouliotis[9], B. Fatholahzadeh[158], A. Favareto[89a,89b], L. Fayard[115], S. Fazio[37a,37b], R. Febbraro[34],

P. Federic[144a], O.L. Fedin[121], W. Fedorko[88], M. Fehling-Kaschek[48], L. Feligioni[83], D. Fellmann[6], C. Feng[33d], E.J. Feng[6], A.B. Fenyuk[128], J. Ferencei[144b], W. Fernando[6], S. Ferrag[53], J. Ferrando[53], V. Ferrara[42], A. Ferrari[166], P. Ferrari[105], R. Ferrari[119a], D.E. Ferreira de Lima[53], A. Ferrer[167], D. Ferrere[49], C. Ferretti[87], A. Ferretto Parodi[50a,50b], M. Fiascaris[31], F. Fiedler[81], A. Filipčič[74], F. Filthaut[104], M. Fincke-Keeler[169], M.C.N. Fiolhais[124a,g], L. Fiorini[167], A. Firan[40], G. Fischer[42], M.J. Fisher[109], M. Flechl[48], I. Fleck[141], J. Fleckner[81], P. Fleischmann[174], S. Fleischmann[175], T. Flick[175], A. Floderus[79], L.R. Flores Castillo[173], M.J. Flowerdew[99], T. Fonseca Martin[17], A. Formica[136], A. Forti[82], D. Fortin[159a], D. Fournier[115], A.J. Fowler[45], H. Fox[71], P. Francavilla[12], M. Franchini[20a,20b], S. Franchino[119a,119b], D. Francis[30], T. Frank[172], M. Franklin[57], S. Franz[30], M. Fraternali[119a,119b], S. Fratina[120], S.T. French[28], C. Friedrich[42], F. Friedrich[44], R. Froeschl[30], D. Froidevaux[30], J.A. Frost[28], C. Fukunaga[156], E. Fullana Torregrosa[30], B.G. Fulsom[143], J. Fuster[167], C. Gabaldon[30], O. Gabizon[172], T. Gadfort[25], S. Gadomski[49], G. Gagliardi[50a,50b], P. Gagnon[60], C. Galea[98], B. Galhardo[124a], E.J. Gallas[118], V. Gallo[17], B.J. Gallop[129], P. Gallus[125], K.K. Gan[109], Y.S. Gao[143,e], A. Gaponenko[15], F. Garberson[176], M. Garcia-Sciveres[15], C. García[167], J.E. García Navarro[167], R.W. Gardner[31], N. Garelli[30], H. Garitaonandia[105], V. Garonne[30], C. Gatti[47], G. Gaudio[119a], B. Gaur[141], L. Gauthier[136], P. Gauzzi[132a,132b], I.L. Gavrilenko[94], C. Gay[168], G. Gaycken[21], E.N. Gazis[10], P. Ge[33d], Z. Gecse[168], C.N.P. Gee[129], D.A.A. Geerts[105], Ch. Geich-Gimbel[21], K. Gellerstedt[146a,146b], C. Gemme[50a], A. Gemmell[53], M.H. Genest[55], S. Gentile[132a,132b], M. George[54], S. George[76], P. Gerlach[175], A. Gershon[153], C. Geweniger[58a], H. Ghazlane[135b], N. Ghodbane[34], B. Giacobbe[20a], S. Giagu[132a,132b], V. Giakoumopoulou[9], V. Giangiobbe[12], F. Gianotti[30], B. Gibbard[25], A. Gibson[158], S.M. Gibson[30], M. Gilchriese[15], D. Gillberg[29], A.R. Gillman[129], D.M. Gingrich[3,d], J. Ginzburg[153], N. Giokaris[9], M.P. Giordani[164c], R. Giordano[102a,102b], F.M. Giorgi[16], P. Giovannini[99], P.F. Giraud[136], D. Giugni[89a], M. Giunta[93], P. Giusti[20a], B.K. Gjelsten[117], L.K. Gladilin[97], C. Glasman[80], J. Glatzer[21], A. Glazov[42], K.W. Glitza[175], G.L. Glonti[64], J.R. Goddard[75], J. Godfrey[142], J. Godlewski[30], M. Goebel[42], T. Göpfert[44], C. Goeringer[81], C. Gössling[43], S. Goldfarb[87], T. Golling[176], A. Gomes[124a,b], L.S. Gomez Fajardo[42], R. Gonçalo[76], J. Goncalves Pinto Firmino Da Costa[42], L. Gonella[21], S. González de la Hoz[167], G. Gonzalez Parra[12], M.L. Gonzalez Silva[27], S. Gonzalez-Sevilla[49], J.J. Goodson[148], L. Goossens[30], P.A. Gorbounov[95], H.A. Gordon[25], I. Gorelov[103], G. Gorfine[175], B. Gorini[30], E. Gorini[72a,72b], A. Gorišek[74], E. Gornicki[39], B. Gosdzik[42], A.T. Goshaw[6], M. Gosselink[105], M.I. Gostkin[64], I. Gough Eschrich[163], M. Gouighri[135a], D. Goujdami[135c], M.P. Goulette[49], A.G. Goussiou[138], C. Goy[5], S. Gozpinar[23], I. Grabowska-Bold[38], P. Grafström[20a,20b], K-J. Grahn[42], E. Gramstad[117], F. Grancagnolo[72a], S. Grancagnolo[16], V. Grassi[148], V. Gratchev[121], N. Grau[35], H.M. Gray[30], J.A. Gray[148], E. Graziani[134a], O.G. Grebenyuk[121], T. Greenshaw[73], Z.D. Greenwood[25,l], K. Gregersen[36], I.M. Gregor[42], P. Grenier[143], J. Griffiths[8], N. Grigalashvili[64], A.A. Grillo[137], S. Grinstein[12], Ph. Gris[34], Y.V. Grishkevich[97], J.-F. Grivaz[115], E. Gross[172], J. Grosse-Knetter[54], J. Groth-Jensen[172], K. Grybel[141], D. Guest[176], C. Guicheney[34], S. Guindon[54], U. Gul[53], J. Gunther[125], B. Guo[158], J. Guo[35], P. Gutierrez[111], N. Guttman[153], O. Gutzwiller[173], C. Guyot[136], C. Gwenlan[118], C.B. Gwilliam[73], A. Haas[108], S. Haas[30], C. Haber[15], H.K. Hadavand[8], D.R. Hadley[18], P. Haefner[21], F. Hahn[30], S. Haider[30], Z. Hajduk[39], H. Hakobyan[177], D. Hall[118], K. Hamacher[175], P. Hamal[113], K. Hamano[86], M. Hamer[54], A. Hamilton[145b,o], S. Hamilton[161], L. Han[33b], K. Hanagaki[116], K. Hanawa[160], M. Hance[15], C. Handel[81], P. Hanke[58a], J.R. Hansen[36], J.B. Hansen[36], J.D. Hansen[36], P.H. Hansen[36], P. Hansson[143], K. Hara[160], G.A. Hare[137], T. Harenberg[175], S. Harkusha[90], D. Harper[87], R.D. Harrington[46], O.M. Harris[138], J. Hartert[48], F. Hartjes[105], T. Haruyama[65], A. Harvey[56], S. Hasegawa[101], Y. Hasegawa[140], S. Hassani[136], S. Haug[17], M. Hauschild[30], R. Hauser[88], M. Havranek[21], C.M. Hawkes[18], R.J. Hawkings[30], A.D. Hawkins[79], T. Hayakawa[66], T. Hayashi[160], D. Hayden[76], C.P. Hays[118], H.S. Hayward[73], S.J. Haywood[129], S.J. Head[18], V. Hedberg[79], L. Heelan[8], S. Heim[120], B. Heinemann[15], S. Heisterkamp[36], L. Helary[22], C. Heller[98], M. Heller[30], S. Hellman[146a,146b], D. Hellmich[21], C. Helsens[12], R.C.W. Henderson[71], M. Henke[58a], A. Henrichs[176], A.M. Henriques Correia[30], S. Henrot-Versille[115], C. Hensel[54], T. Henß[175], C.M. Hernandez[8], Y. Hernández Jiménez[167], R. Herrberg[16], G. Herten[48], R. Hertenberger[98], L. Hervas[30], G.G. Hesketh[77], N.P. Hessey[105], E. Higón-Rodriguez[167], J.C. Hill[28], K.H. Hiller[42], S. Hillert[21], S.J. Hillier[18], I. Hinchliffe[15], E. Hines[120], M. Hirose[116], F. Hirsch[43], D. Hirschbuehl[175], J. Hobbs[148], N. Hod[153], M.C. Hodgkinson[139], P. Hodgson[139], A. Hoecker[30], M.R. Hoeferkamp[103], J. Hoffman[40], D. Hoffmann[83], M. Hohlfeld[81], M. Holder[141], S.O. Holmgren[146a], T. Holy[127], J.L. Holzbauer[88], T.M. Hong[120], L. Hooft van Huysduynen[108], S. Horner[48], J-Y. Hostachy[55], S. Hou[151], A. Hoummada[135a], J. Howard[118], J. Howarth[82], I. Hristova[16], J. Hrivnac[115], T. Hryn'ova[5], P.J. Hsu[81], S.-C. Hsu[15], D. Hu[35], Z. Hubacek[127], F. Hubaut[83], F. Huegging[21], A. Huettmann[42], T.B. Huffman[118], E.W. Hughes[35], G. Hughes[71], M. Huhtinen[30], M. Hurwitz[15], N. Huseynov[64,p], J. Huston[88], J. Huth[57], G. Iacobucci[49], G. Iakovidis[10], M. Ibbotson[82], I. Ibragimov[141], L. Iconomidou-Fayard[115], J. Idarraga[115], P. Iengo[102a], O. Igonkina[105], Y. Ikegami[65], M. Ikeno[65], D. Iliadis[154], N. Ilic[158], T. Ince[99], J. Inigo-Golfin[30], P. Ioannou[9], M. Iodice[134a], K. Iordanidou[9], V. Ippolito[132a,132b], A. Irles Quiles[167], C. Isaksson[166], M. Ishino[67], M. Ishitsuka[157], R. Ishmukhametov[109], C. Issever[118], S. Istin[19a], A.V. Ivashin[128], W. Iwanski[39], H. Iwasaki[65], J.M. Izen[41], V. Izzo[102a], B. Jackson[120], J.N. Jackson[73], P. Jackson[1], M.R. Jaekel[30], V. Jain[60], K. Jakobs[48], S. Jakobsen[36], T. Jakoubek[125], J. Jakubek[127], D.O. Jamin[151], D.K. Jana[111], E. Jansen[77], H. Jansen[30], A. Jantsch[99], M. Janus[48], R.C. Jared[173], G. Jarlskog[79], L. Jeanty[57], I. Jen-La Plante[31],

D. Jennens[86], P. Jenni[30], A.E. Loevschall-Jensen[36], P. Jež[36], S. Jézéquel[5], M.K. Jha[20a], H. Ji[173], W. Ji[81], J. Jia[148], Y. Jiang[33b], M. Jimenez Belenguer[42], S. Jin[33a], O. Jinnouchi[157], M.D. Joergensen[36], D. Joffe[40], M. Johansen[146a,146b], K.E. Johansson[146a], P. Johansson[139], S. Johnert[42], K.A. Johns[7], K. Jon-And[146a,146b], G. Jones[170], R.W.L. Jones[71], T.J. Jones[73], C. Joram[30], P.M. Jorge[124a], K.D. Joshi[82], J. Jovicevic[147], T. Jovin[13b], X. Ju[173], C.A. Jung[43], R.M. Jungst[30], V. Juranek[125], P. Jussel[61], A. Juste Rozas[12], S. Kabana[17], M. Kaci[167], A. Kaczmarska[39], P. Kadlecik[36], M. Kado[115], H. Kagan[109], M. Kagan[57], E. Kajomovitz[152], S. Kalinin[175], L.V. Kalinovskaya[64], S. Kama[40], N. Kanaya[155], M. Kaneda[30], S. Kaneti[28], T. Kanno[157], V.A. Kantserov[96], J. Kanzaki[65], B. Kaplan[108], A. Kapliy[31], J. Kaplon[30], D. Kar[53], M. Karagounis[21], K. Karakostas[10], M. Karnevskiy[42], V. Kartvelishvili[71], A.N. Karyukhin[128], L. Kashif[173], G. Kasieczka[58b], R.D. Kass[109], A. Kastanas[14], M. Kataoka[5], Y. Kataoka[155], E. Katsoufis[10], J. Katzy[42], V. Kaushik[7], K. Kawagoe[69], T. Kawamoto[155], G. Kawamura[81], M.S. Kayl[105], S. Kazama[155], V.A. Kazanin[107], M.Y. Kazarinov[64], R. Keeler[169], P.T. Keener[120], R. Kehoe[40], M. Keil[54], G.D. Kekelidze[64], J.S. Keller[138], M. Kenyon[53], O. Kepka[125], N. Kerschen[30], B.P. Kerševan[74], S. Kersten[175], K. Kessoku[155], J. Keung[158], F. Khalil-zada[11], H. Khandanyan[146a,146b], A. Khanov[112], D. Kharchenko[64], A. Khodinov[96], A. Khomich[58a], T.J. Khoo[28], G. Khoriauli[21], A. Khoroshilov[175], V. Khovanskiy[95], E. Khramov[64], J. Khubua[51b], H. Kim[146a,146b], S.H. Kim[160], N. Kimura[171], O. Kind[16], B.T. King[73], M. King[66], R.S.B. King[118], J. Kirk[129], A.E. Kiryunin[99], T. Kishimoto[66], D. Kisielewska[38], T. Kitamura[66], T. Kittelmann[123], K. Kiuchi[160], E. Kladiva[144b], M. Klein[73], U. Klein[73], K. Kleinknecht[81], M. Klemetti[85], A. Klier[172], P. Klimek[146a,146b], A. Klimentov[25], R. Klingenberg[43], J.A. Klinger[82], E.B. Klinkby[36], T. Klioutchnikova[30], P.F. Klok[104], S. Klous[105], E.-E. Kluge[58a], T. Kluge[73], P. Kluit[105], S. Kluth[99], E. Kneringer[61], E.B.F.G. Knoops[83], A. Knue[54], B.R. Ko[45], T. Kobayashi[155], M. Kobel[44], M. Kocian[143], P. Kodys[126], K. Köneke[30], A.C. König[104], S. Koenig[81], L. Köpke[81], F. Koetsveld[104], P. Koevesarki[21], T. Koffas[29], E. Koffeman[105], L.A. Kogan[118], S. Kohlmann[175], F. Kohn[54], Z. Kohout[127], T. Kohriki[65], T. Koi[143], G.M. Kolachev[107,*], H. Kolanoski[16], V. Kolesnikov[64], I. Koletsou[89a], J. Koll[88], A.A. Komar[94], Y. Komori[155], T. Kondo[65], T. Kono[42,q], A.I. Kononov[48], R. Konoplich[108,r], N. Konstantinidis[77], R. Kopeliansky[152], S. Koperny[38], K. Korcyl[39], K. Kordas[154], A. Korn[118], A. Korol[107], I. Korolkov[12], E.V. Korolkova[139], V.A. Korotkov[128], O. Kortner[99], S. Kortner[99], V.V. Kostyukhin[21], S. Kotov[99], V.M. Kotov[64], A. Kotwal[45], C. Kourkoumelis[9], V. Kouskoura[154], A. Koutsman[159a], R. Kowalewski[169], T.Z. Kowalski[38], W. Kozanecki[136], A.S. Kozhin[128], V. Kral[127], V.A. Kramarenko[97], G. Kramberger[74], M.W. Krasny[78], A. Krasznahorkay[108], J.K. Kraus[21], S. Kreiss[108], F. Krejci[127], J. Kretzschmar[73], N. Krieger[54], P. Krieger[158], K. Kroeninger[54], H. Kroha[99], J. Kroll[120], J. Kroseberg[21], J. Krstic[13a], U. Kruchonak[64], H. Krüger[21], T. Kruker[17], N. Krumnack[63], Z.V. Krumshteyn[64], M.K. Kruse[45], T. Kubota[86], S. Kuday[4a], S. Kuehn[48], A. Kugel[58c], T. Kuhl[42], D. Kuhn[61], V. Kukhtin[64], Y. Kulchitsky[90], S. Kuleshov[32b], C. Kummer[98], M. Kuna[78], J. Kunkle[120], A. Kupco[125], H. Kurashige[66], M. Kurata[160], Y.A. Kurochkin[90], V. Kus[125], E.S. Kuwertz[147], M. Kuze[157], J. Kvita[142], R. Kwee[16], A. La Rosa[49], L. La Rotonda[37a,37b], L. Labarga[80], J. Labbe[5], S. Lablak[135a], C. Lacasta[167], F. Lacava[132a,132b], J. Lacey[29], H. Lacker[16], D. Lacour[78], V.R. Lacuesta[167], E. Ladygin[64], R. Lafaye[5], B. Laforge[78], T. Lagouri[176], S. Lai[48], E. Laisne[55], M. Lamanna[30], L. Lambourne[77], C.L. Lampen[7], W. Lampl[7], E. Lancon[136], U. Landgraf[48], M.P.J. Landon[75], V.S. Lang[58a], C. Lange[42], A.J. Lankford[163], F. Lanni[25], K. Lantzsch[175], S. Laplace[78], C. Lapoire[21], J.F. Laporte[136], T. Lari[89a], A. Larner[118], M. Lassnig[30], P. Laurelli[47], V. Lavorini[37a,37b], W. Lavrijsen[15], P. Laycock[73], O. Le Dortz[78], E. Le Guirriec[83], E. Le Menedeu[12], T. LeCompte[6], F. Ledroit-Guillon[55], H. Lee[105], J.S.H. Lee[116], S.C. Lee[151], L. Lee[176], M. Lefebvre[169], M. Legendre[136], F. Legger[98], C. Leggett[15], M. Lehmacher[21], G. Lehmann Miotto[30], M.A.L. Leite[24d], R. Leitner[126], D. Lellouch[172], B. Lemmer[54], V. Lendermann[58a], K.J.C. Leney[145b], T. Lenz[105], G. Lenzen[175], B. Lenzi[30], K. Leonhardt[44], S. Leontsinis[10], F. Lepold[58a], C. Leroy[93], J-R. Lessard[169], C.G. Lester[28], C.M. Lester[120], J. Levêque[5], D. Levin[87], L.J. Levinson[172], A. Lewis[118], G.H. Lewis[108], A.M. Leyko[21], M. Leyton[16], B. Li[83], H. Li[148], H.L. Li[31], S. Li[33b,s], X. Li[87], Z. Liang[118,t], H. Liao[34], B. Liberti[133a], P. Lichard[30], M. Lichtnecker[98], K. Lie[165], W. Liebig[14], C. Limbach[21], A. Limosani[86], M. Limper[62], S.C. Lin[151,u], F. Linde[105], J.T. Linnemann[88], E. Lipeles[120], A. Lipniacka[14], T.M. Liss[165], D. Lissauer[25], A. Lister[49], A.M. Litke[137], C. Liu[29], D. Liu[151], H. Liu[87], J.B. Liu[87], L. Liu[87], M. Liu[33b], Y. Liu[33b], M. Livan[119a,119b], S.S.A. Livermore[118], A. Lleres[55], J. Llorente Merino[80], S.L. Lloyd[75], E. Lobodzinska[42], P. Loch[7], W.S. Lockman[137], T. Loddenkoetter[21], F.K. Loebinger[82], A. Loginov[176], C.W. Loh[168], T. Lohse[16], K. Lohwasser[48], M. Lokajicek[125], V.P. Lombardo[5], R.E. Long[71], L. Lopes[124a], D. Lopez Mateos[57], J. Lorenz[98], N. Lorenzo Martinez[115], M. Losada[162], P. Loscutoff[15], F. Lo Sterzo[132a,132b], M.J. Losty[159a,*], X. Lou[41], A. Lounis[115], K.F. Loureiro[162], J. Love[6], P.A. Love[71], A.J. Lowe[143,e], F. Lu[33a], H.J. Lubatti[138], C. Luci[132a,132b], A. Lucotte[55], A. Ludwig[44], D. Ludwig[42], I. Ludwig[48], J. Ludwig[48], F. Luehring[60], G. Luijckx[105], W. Lukas[61], L. Luminari[132a], E. Lund[117], B. Lund-Jensen[147], B. Lundberg[79], J. Lundberg[146a,146b], O. Lundberg[146a,146b], J. Lundquist[36], M. Lungwitz[81], D. Lynn[25], E. Lytken[79], H. Ma[25], L.L. Ma[173], G. Maccarrone[47], A. Macchiolo[99], B. Maček[74], J. Machado Miguens[124a], R. Mackeprang[36], R.J. Madaras[15], H.J. Maddocks[71], W.F. Mader[44], R. Maenner[58c], T. Maeno[25], P. Mättig[175], S. Mättig[81], L. Magnoni[163], E. Magradze[54], K. Mahboubi[48], J. Mahlstedt[105], S. Mahmoud[73], G. Mahout[18], C. Maiani[136], C. Maidantchik[24a], A. Maio[124a,b], S. Majewski[25], Y. Makida[65], N. Makovec[115], P. Mal[136], B. Malaescu[30], Pa. Malecki[39], P. Malecki[39], V.P. Maleev[121], F. Malek[55], U. Mallik[62], D. Malon[6], C. Malone[143], S. Maltezos[10], V. Malyshev[107], S. Malyukov[30],

R. Mameghani[98], J. Mamuzic[13b], A. Manabe[65], L. Mandelli[89a], I. Mandić[74], R. Mandrysch[16], J. Maneira[124a], A. Manfredini[99], P.S. Mangeard[88], L. Manhaes de Andrade Filho[24b], J.A. Manjarres Ramos[136], A. Mann[54], P.M. Manning[137], A. Manousakis-Katsikakis[9], B. Mansoulie[136], A. Mapelli[30], L. Mapelli[30], L. March[167], J.F. Marchand[29], F. Marchese[133a,133b], G. Marchiori[78], M. Marcisovsky[125], C.P. Marino[169], F. Marroquim[24a], Z. Marshall[30], F.K. Martens[158], L.F. Marti[17], S. Marti-Garcia[167], B. Martin[30], B. Martin[88], J.P. Martin[93], T.A. Martin[18], V.J. Martin[46], B. Martin dit Latour[49], S. Martin-Haugh[149], M. Martinez[12], V. Martinez Outschoorn[57], A.C. Martyniuk[169], M. Marx[82], F. Marzano[132a], A. Marzin[111], L. Masetti[81], T. Mashimo[155], R. Mashinistov[94], J. Masik[82], A.L. Maslennikov[107], I. Massa[20a,20b], G. Massaro[105], N. Massol[5], P. Mastrandrea[148], A. Mastroberardino[37a,37b], T. Masubuchi[155], P. Matricon[115], H. Matsunaga[155], T. Matsushita[66], C. Mattravers[118,c], J. Maurer[83], S.J. Maxfield[73], D.A. Maximov[107,f], A. Mayne[139], R. Mazini[151], M. Mazur[21], L. Mazzaferro[133a,133b], M. Mazzanti[89a], J. Mc Donald[85], S.P. Mc Kee[87], A. McCarn[165], R.L. McCarthy[148], T.G. McCarthy[29], N.A. McCubbin[129], K.W. McFarlane[56,*], J.A. Mcfayden[139], G. Mchedlidze[51b], T. Mclaughlan[18], S.J. McMahon[129], R.A. McPherson[169,j], A. Meade[84], J. Mechnich[105], M. Mechtel[175], M. Medinnis[42], R. Meera-Lebbai[111], T. Meguro[116], S. Mehlhase[36], A. Mehta[73], K. Meier[58a], B. Meirose[79], C. Melachrinos[31], B.R. Mellado Garcia[173], F. Meloni[89a,89b], L. Mendoza Navas[162], Z. Meng[151,v], A. Mengarelli[20a,20b], S. Menke[99], E. Meoni[161], K.M. Mercurio[57], P. Mermod[49], L. Merola[102a,102b], C. Meroni[89a], F.S. Merritt[31], H. Merritt[109], A. Messina[30,w], J. Metcalfe[25], A.S. Mete[163], C. Meyer[81], C. Meyer[31], J-P. Meyer[136], J. Meyer[174], J. Meyer[54], T.C. Meyer[30], S. Michal[30], L. Micu[26a], R.P. Middleton[129], S. Migas[73], L. Mijović[136], G. Mikenberg[172], M. Mikestikova[125], M. Mikuž[74], D.W. Miller[31], R.J. Miller[88], W.J. Mills[168], C. Mills[57], A. Milov[172], D.A. Milstead[146a,146b], D. Milstein[172], A.A. Minaenko[128], M. Miñano Moya[167], I.A. Minashvili[64], A.I. Mincer[108], B. Mindur[38], M. Mineev[64], Y. Ming[173], L.M. Mir[12], G. Mirabelli[132a], J. Mitrevski[137], V.A. Mitsou[167], S. Mitsui[65], P.S. Miyagawa[139], J.U. Mjörnmark[79], T. Moa[146a,146b], V. Moeller[28], K. Mönig[42], N. Möser[21], S. Mohapatra[148], W. Mohr[48], R. Moles-Valls[167], A. Molfetas[30], J. Monk[77], E. Monnier[83], J. Montejo Berlingen[12], F. Monticelli[70], S. Monzani[20a,20b], R.W. Moore[3], G.F. Moorhead[86], C. Mora Herrera[49], A. Moraes[53], N. Morange[136], J. Morel[54], G. Morello[37a,37b], D. Moreno[81], M. Moreno Llácer[167], P. Morettini[50a], M. Morgenstern[44], M. Morii[57], A.K. Morley[30], G. Mornacchi[30], J.D. Morris[75], L. Morvaj[101], H.G. Moser[99], M. Mosidze[51b], J. Moss[109], R. Mount[143], E. Mountricha[10,x], S.V. Mouraviev[94,*], E.J.W. Moyse[84], F. Mueller[58a], J. Mueller[123], K. Mueller[21], T.A. Müller[98], T. Mueller[81], D. Muenstermann[30], Y. Munwes[153], W.J. Murray[129], I. Mussche[105], E. Musto[102a,102b], A.G. Myagkov[128], M. Myska[125], O. Nackenhorst[54], J. Nadal[12], K. Nagai[160], R. Nagai[157], K. Nagano[65], A. Nagarkar[109], Y. Nagasaka[59], M. Nagel[99], A.M. Nairz[30], Y. Nakahama[30], K. Nakamura[155], T. Nakamura[155], I. Nakano[110], G. Nanava[21], A. Napier[161], R. Narayan[58b], M. Nash[77,c], T. Nattermann[21], T. Naumann[42], G. Navarro[162], H.A. Neal[87], P.Yu. Nechaeva[94], T.J. Neep[82], A. Negri[119a,119b], G. Negri[30], M. Negrini[20a], S. Nektarijevic[49], A. Nelson[163], T.K. Nelson[143], S. Nemecek[125], P. Nemethy[108], A.A. Nepomuceno[24a], M. Nessi[30,y], M.S. Neubauer[165], M. Neumann[175], A. Neusiedl[81], R.M. Neves[108], P. Nevski[25], F.M. Newcomer[120], P.R. Newman[18], V. Nguyen Thi Hong[136], R.B. Nickerson[118], R. Nicolaidou[136], B. Nicquevert[30], F. Niedercorn[115], J. Nielsen[137], N. Nikiforou[35], A. Nikiforov[16], V. Nikolaenko[128], I. Nikolic-Audit[78], K. Nikolics[49], K. Nikolopoulos[18], H. Nilsen[48], P. Nilsson[8], Y. Ninomiya[155], A. Nisati[132a], R. Nisius[99], T. Nobe[157], L. Nodulman[6], M. Nomachi[116], I. Nomidis[154], S. Norberg[111], M. Nordberg[30], P.R. Norton[129], J. Novakova[126], M. Nozaki[65], L. Nozka[113], I.M. Nugent[159a], A.-E. Nuncio-Quiroz[21], G. Nunes Hanninger[86], T. Nunnemann[98], E. Nurse[77], B.J. O'Brien[46], D.C. O'Neil[142], V. O'Shea[53], L.B. Oakes[98], F.G. Oakham[29,d], H. Oberlack[99], J. Ocariz[78], A. Ochi[66], S. Oda[69], S. Odaka[65], J. Odier[83], H. Ogren[60], A. Oh[82], S.H. Oh[45], C.C. Ohm[30], T. Ohshima[101], W. Okamura[116], H. Okawa[25], Y. Okumura[31], T. Okuyama[155], A. Olariu[26a], A.G. Olchevski[64], S.A. Olivares Pino[32a], M. Oliveira[124a,g], D. Oliveira Damazio[25], E. Oliver Garcia[167], D. Olivito[120], A. Olszewski[39], J. Olszowska[39], A. Onofre[124a,z], P.U.E. Onyisi[31], C.J. Oram[159a], M.J. Oreglia[31], Y. Oren[153], D. Orestano[134a,134b], N. Orlando[72a,72b], I. Orlov[107], C. Oropeza Barrera[53], R.S. Orr[158], B. Osculati[50a,50b], R. Ospanov[120], C. Osuna[12], G. Otero y Garzon[27], J.P. Ottersbach[105], M. Ouchrif[135d], E.A. Ouellette[169], F. Ould-Saada[117], A. Ouraou[136], Q. Ouyang[33a], A. Ovcharova[15], M. Owen[82], S. Owen[139], V.E. Ozcan[19a], N. Ozturk[8], A. Pacheco Pages[12], C. Padilla Aranda[12], S. Pagan Griso[15], E. Paganis[139], C. Pahl[99], F. Paige[25], P. Pais[84], K. Pajchel[117], G. Palacino[159b], C.P. Paleari[7], S. Palestini[30], D. Pallin[34], A. Palma[124a], J.D. Palmer[18], Y.B. Pan[173], E. Panagiotopoulou[10], J.G. Panduro Vazquez[76], P. Pani[105], N. Panikashvili[87], S. Panitkin[25], D. Pantea[26a], A. Papadelis[146a], Th.D. Papadopoulou[10], A. Paramonov[6], D. Paredes Hernandez[34], W. Park[25,aa], M.A. Parker[28], F. Parodi[50a,50b], J.A. Parsons[35], U. Parzefall[48], S. Pashapour[54], E. Pasqualucci[132a], S. Passaggio[50a], A. Passeri[134a], F. Pastore[134a,134b,*], Fr. Pastore[76], G. Pásztor[49,ab], S. Pataraia[175], N. Patel[150], J.R. Pater[82], S. Patricelli[102a,102b], T. Pauly[30], M. Pecsy[144a], S. Pedraza Lopez[167], M.I. Pedraza Morales[173], S.V. Peleganchuk[107], D. Pelikan[166], H. Peng[33b], B. Penning[31], A. Penson[35], J. Penwell[60], M. Perantoni[24a], K. Perez[35,ac], T. Perez Cavalcanti[42], E. Perez Codina[159a], M.T. Pérez García-Estañ[167], V. Perez Reale[35], L. Perini[89a,89b], H. Pernegger[30], R. Perrino[72a], P. Perrodo[5], V.D. Peshekhonov[64], K. Peters[30], B.A. Petersen[30], J. Petersen[30], T.C. Petersen[36], E. Petit[5], A. Petridis[154], C. Petridou[154], E. Petrolo[132a], F. Petrucci[134a,134b], D. Petschull[42], M. Petteni[142], R. Pezoa[32b], A. Phan[86], P.W. Phillips[129], G. Piacquadio[30],

A. Picazio[49], E. Piccaro[75], M. Piccinini[20a,20b], S.M. Piec[42], R. Piegaia[27], D.T. Pignotti[109], J.E. Pilcher[31], A.D. Pilkington[82], J. Pina[124a,b], M. Pinamonti[164a,164c], A. Pinder[118], J.L. Pinfold[3], B. Pinto[124a], C. Pizio[89a,89b], M. Plamondon[169], M.-A. Pleier[25], E. Plotnikova[64], A. Poblaguev[25], S. Poddar[58a], F. Podlyski[34], L. Poggioli[115], D. Pohl[21], M. Pohl[49], G. Polesello[119a], A. Policicchio[37a,37b], A. Polini[20a], J. Poll[75], V. Polychronakos[25], D. Pomeroy[23], K. Pommès[30], L. Pontecorvo[132a], B.G. Pope[88], G.A. Popeneciu[26a], D.S. Popovic[13a], A. Poppleton[30], X. Portell Bueso[30], G.E. Pospelov[99], S. Pospisil[127], I.N. Potrap[99], C.J. Potter[149], C.T. Potter[114], G. Poulard[30], J. Poveda[60], V. Pozdnyakov[64], R. Prabhu[77], P. Pralavorio[83], A. Pranko[15], S. Prasad[30], R. Pravahan[25], S. Prell[63], K. Pretzl[17], D. Price[60], J. Price[73], L.E. Price[6], D. Prieur[123], M. Primavera[72a], K. Prokofiev[108], F. Prokoshin[32b], S. Protopopescu[25], J. Proudfoot[6], X. Prudent[44], M. Przybycien[38], H. Przysiezniak[5], S. Psoroulas[21], E. Ptacek[114], E. Pueschel[84], J. Purdham[87], M. Purohit[25,aa], P. Puzo[115], Y. Pylypchenko[62], J. Qian[87], A. Quadt[54], D.R. Quarrie[15], W.B. Quayle[173], F. Quinonez[32a], M. Raas[104], V. Radeka[25], V. Radescu[42], P. Radloff[114], T. Rador[19a], F. Ragusa[89a,89b], G. Rahal[178], A.M. Rahimi[109], D. Rahm[25], S. Rajagopalan[25], M. Rammensee[48], M. Rammes[141], A.S. Randle-Conde[40], K. Randrianarivony[29], F. Rauscher[98], T.C. Rave[48], M. Raymond[30], A.L. Read[117], D.M. Rebuzzi[119a,119b], A. Redelbach[174], G. Redlinger[25], R. Reece[120], K. Reeves[41], E. Reinherz-Aronis[153], A. Reinsch[114], I. Reisinger[43], C. Rembser[30], Z.L. Ren[151], A. Renaud[115], M. Rescigno[132a], S. Resconi[89a], B. Resende[136], P. Reznicek[98], R. Rezvani[158], R. Richter[99], E. Richter-Was[5,ad], M. Ridel[78], M. Rijpstra[105], M. Rijssenbeek[148], A. Rimoldi[119a,119b], L. Rinaldi[20a], R.R. Rios[40], I. Riu[12], G. Rivoltella[89a,89b], F. Rizatdinova[112], E. Rizvi[75], S.H. Robertson[85,j], A. Robichaud-Veronneau[118], D. Robinson[28], J.E.M. Robinson[82], A. Robson[53], J.G. Rocha de Lima[106], C. Roda[122a,122b], D. Roda Dos Santos[30], A. Roe[54], S. Roe[30], O. Røhne[117], S. Rolli[161], A. Romaniouk[96], M. Romano[20a,20b], G. Romeo[27], E. Romero Adam[167], N. Rompotis[138], L. Roos[78], E. Ros[167], S. Rosati[132a], K. Rosbach[49], A. Rose[149], M. Rose[76], G.A. Rosenbaum[158], E.I. Rosenberg[63], P.L. Rosendahl[14], O. Rosenthal[141], L. Rosselet[49], V. Rossetti[12], E. Rossi[132a,132b], L.P. Rossi[50a], M. Rotaru[26a], I. Roth[172], J. Rothberg[138], D. Rousseau[115], C.R. Royon[136], A. Rozanov[83], Y. Rozen[152], X. Ruan[33a,ae], F. Rubbo[12], I. Rubinskiy[42], N. Ruckstuhl[105], V.I. Rud[97], C. Rudolph[44], G. Rudolph[61], F. Rühr[7], A. Ruiz-Martinez[63], L. Rumyantsev[64], Z. Rurikova[48], N.A. Rusakovich[64], A. Ruschke[98], J.P. Rutherfoord[7], P. Ruzicka[125], Y.F. Ryabov[121], M. Rybar[126], G. Rybkin[115], N.C. Ryder[118], A.F. Saavedra[150], I. Sadeh[153], H.F-W. Sadrozinski[137], R. Sadykov[64], F. Safai Tehrani[132a], H. Sakamoto[155], G. Salamanna[75], A. Salamon[133a], M. Saleem[111], D. Salek[30], D. Salihagic[99], A. Salnikov[143], J. Salt[167], B.M. Salvachua Ferrando[6], D. Salvatore[37a,37b], F. Salvatore[149], A. Salvucci[104], A. Salzburger[30], D. Sampsonidis[154], B.H. Samset[117], A. Sanchez[102a,102b], V. Sanchez Martinez[167], H. Sandaker[14], H.G. Sander[81], M.P. Sanders[98], M. Sandhoff[175], T. Sandoval[28], C. Sandoval[162], R. Sandstroem[99], D.P.C. Sankey[129], A. Sansoni[47], C. Santamarina Rios[85], C. Santoni[34], R. Santonico[133a,133b], H. Santos[124a], J.G. Saraiva[124a], T. Sarangi[173], E. Sarkisyan-Grinbaum[8], F. Sarri[122a,122b], G. Sartisohn[175], O. Sasaki[65], Y. Sasaki[155], N. Sasao[67], I. Satsounkevitch[90], G. Sauvage[5,*], E. Sauvan[5], J.B. Sauvan[115], P. Savard[158,d], V. Savinov[123], D.O. Savu[30], L. Sawyer[25,l], D.H. Saxon[53], J. Saxon[120], C. Sbarra[20a], A. Sbrizzi[20a,20b], D.A. Scannicchio[163], M. Scarcella[150], J. Schaarschmidt[115], P. Schacht[99], D. Schaefer[120], U. Schäfer[81], A. Schaelicke[46], S. Schaepe[21], S. Schaetzel[58b], A.C. Schaffer[115], D. Schaile[98], R.D. Schamberger[148], A.G. Schamov[107], V. Scharf[58a], V.A. Schegelsky[121], D. Scheirich[87], M. Schernau[163], M.I. Scherzer[35], C. Schiavi[50a,50b], J. Schieck[98], M. Schioppa[37a,37b], S. Schlenker[30], E. Schmidt[48], K. Schmieden[21], C. Schmitt[81], S. Schmitt[58b], M. Schmitz[21], B. Schneider[17], U. Schnoor[44], L. Schoeffel[136], A. Schoening[58b], A.L.S. Schorlemmer[54], M. Schott[30], D. Schouten[159a], J. Schovancova[125], M. Schram[85], C. Schroeder[81], N. Schroer[58c], M.J. Schultens[21], J. Schultes[175], H.-C. Schultz-Coulon[58a], H. Schulz[16], M. Schumacher[48], B.A. Schumm[137], Ph. Schune[136], C. Schwanenberger[82], A. Schwartzman[143], Ph. Schwegler[99], Ph. Schwemling[78], R. Schwienhorst[88], R. Schwierz[44], J. Schwindling[136], T. Schwindt[21], M. Schwoerer[5], G. Sciolla[23], W.G. Scott[129], J. Searcy[114], G. Sedov[42], E. Sedykh[121], S.C. Seidel[103], A. Seiden[137], F. Seifert[44], J.M. Seixas[24a], G. Sekhniaidze[102a], S.J. Sekula[40], K.E. Selbach[46], D.M. Seliverstov[121], B. Sellden[146a], G. Sellers[73], M. Seman[144b], N. Semprini-Cesari[20a,20b], C. Serfon[98], L. Serin[115], L. Serkin[54], R. Seuster[159a], H. Severini[111], A. Sfyrla[30], E. Shabalina[54], M. Shamim[114], L.Y. Shan[33a], J.T. Shank[22], Q.T. Shao[86], M. Shapiro[15], P.B. Shatalov[95], K. Shaw[164a,164c], D. Sherman[176], P. Sherwood[77], S. Shimizu[101], M. Shimojima[100], T. Shin[56], M. Shiyakova[64], A. Shmeleva[94], M.J. Shochet[31], D. Short[118], S. Shrestha[63], E. Shulga[96], M.A. Shupe[7], P. Sicho[125], A. Sidoti[132a], F. Siegert[48], Dj. Sijacki[13a], O. Silbert[172], J. Silva[124a], Y. Silver[153], D. Silverstein[143], S.B. Silverstein[146a], V. Simak[127], O. Simard[136], Lj. Simic[13a], S. Simion[115], E. Simioni[81], B. Simmons[77], R. Simoniello[89a,89b], M. Simonyan[36], P. Sinervo[158], N.B. Sinev[114], V. Sipica[141], G. Siragusa[174], A. Sircar[25], A.N. Sisakyan[64,*], S.Yu. Sivoklokov[97], J. Sjölin[146a,146b], T.B. Sjursen[14], L.A. Skinnari[15], H.P. Skottowe[57], K. Skovpen[107], P. Skubic[111], M. Slater[18], T. Slavicek[127], K. Sliwa[161], V. Smakhtin[172], B.H. Smart[46], L. Smestad[117], S.Yu. Smirnov[96], Y. Smirnov[96], L.N. Smirnova[97], O. Smirnova[79], B.C. Smith[57], D. Smith[143], K.M. Smith[53], M. Smizanska[71], K. Smolek[127], A.A. Snesarev[94], S.W. Snow[82], J. Snow[111], S. Snyder[25], R. Sobie[169,j], J. Sodomka[127], A. Soffer[153], C.A. Solans[167], M. Solar[127], J. Solc[127], E.Yu. Soldatov[96], U. Soldevila[167], E. Solfaroli Camillocci[132a,132b], A.A. Solodkov[128], O.V. Solovyanov[128], V. Solovyev[121], N. Soni[1], V. Sopko[127], B. Sopko[127], M. Sosebee[8], R. Soualah[164a,164c], A. Soukharev[107], S. Spagnolo[72a,72b], F. Spanò[76], R. Spighi[20a], G. Spigo[30], R. Spiwoks[30],

M. Spousta[126,af], T. Spreitzer[158], B. Spurlock[8], R.D. St. Denis[53], J. Stahlman[120], R. Stamen[58a], E. Stanecka[39], R.W. Stanek[6], C. Stanescu[134a], M. Stanescu-Bellu[42], M.M. Stanitzki[42], S. Stapnes[117], E.A. Starchenko[128], J. Stark[55], P. Staroba[125], P. Starovoitov[42], R. Staszewski[39], A. Staude[98], P. Stavina[144a,*], G. Steele[53], P. Steinbach[44], P. Steinberg[25], I. Stekl[127], B. Stelzer[142], H.J. Stelzer[88], O. Stelzer-Chilton[159a], H. Stenzel[52], S. Stern[99], G.A. Stewart[30], J.A. Stillings[21], M.C. Stockton[85], K. Stoerig[48], G. Stoicea[26a], S. Stonjek[99], P. Strachota[126], A.R. Stradling[8], A. Straessner[44], J. Strandberg[147], S. Strandberg[146a,146b], A. Strandlie[117], M. Strang[109], E. Strauss[143], M. Strauss[111], P. Strizenec[144b], R. Ströhmer[174], D.M. Strom[114], J.A. Strong[76,*], R. Stroynowski[40], B. Stugu[14], I. Stumer[25,*], J. Stupak[148], P. Sturm[175], N.A. Styles[42], D.A. Soh[151,t], D. Su[143], HS. Subramania[3], R. Subramaniam[25], A. Succurro[12], Y. Sugaya[116], C. Suhr[106], M. Suk[126], V.V. Sulin[94], S. Sultansoy[4d], T. Sumida[67], X. Sun[55], J.E. Sundermann[48], K. Suruliz[139], G. Susinno[37a,37b], M.R. Sutton[149], Y. Suzuki[65], Y. Suzuki[66], M. Svatos[125], S. Swedish[168], I. Sykora[144a], T. Sykora[126], J. Sánchez[167], D. Ta[105], K. Tackmann[42], A. Taffard[163], R. Tafirout[159a], N. Taiblum[153], Y. Takahashi[101], H. Takai[25], R. Takashima[68], H. Takeda[66], T. Takeshita[140], Y. Takubo[65], M. Talby[83], A. Talyshev[107,f], M.C. Tamsett[25], K.G. Tan[86], J. Tanaka[155], R. Tanaka[115], S. Tanaka[131], S. Tanaka[65], A.J. Tanasijczuk[142], K. Tani[66], N. Tannoury[83], S. Tapprogge[81], D. Tardif[158], S. Tarem[152], F. Tarrade[29], G.F. Tartarelli[89a], P. Tas[126], M. Tasevsky[125], E. Tassi[37a,37b], M. Tatarkhanov[15], Y. Tayalati[135d], C. Taylor[77], F.E. Taylor[92], G.N. Taylor[86], W. Taylor[159b], M. Teinturier[115], F.A. Teischinger[30], M. Teixeira Dias Castanheira[75], P. Teixeira-Dias[76], K.K. Temming[48], H. Ten Kate[30], P.K. Teng[151], S. Terada[65], K. Terashi[155], J. Terron[80], M. Testa[47], R.J. Teuscher[158,j], J. Therhaag[21], T. Theveneaux-Pelzer[78], S. Thoma[48], J.P. Thomas[18], E.N. Thompson[35], P.D. Thompson[18], P.D. Thompson[158], A.S. Thompson[53], L.A. Thomsen[36], E. Thomson[120], M. Thomson[28], W.M. Thong[86], R.P. Thun[87], F. Tian[35], M.J. Tibbetts[15], T. Tic[125], V.O. Tikhomirov[94], Y.A. Tikhonov[107,f], S. Timoshenko[96], E. Tiouchichine[83], P. Tipton[176], S. Tisserant[83], T. Todorov[5], S. Todorova-Nova[161], B. Toggerson[163], J. Tojo[69], S. Tokár[144a], K. Tokushuku[65], K. Tollefson[88], M. Tomoto[101], L. Tompkins[31], K. Toms[103], A. Tonoyan[14], C. Topfel[17], N.D. Topilin[64], I. Torchiani[30], E. Torrence[114], H. Torres[78], E. Torró Pastor[167], J. Toth[83,ab], F. Touchard[83], D.R. Tovey[139], T. Trefzger[174], L. Tremblet[30], A. Tricoli[30], I.M. Trigger[159a], S. Trincaz-Duvoid[78], M.F. Tripiana[70], N. Triplett[25], W. Trischuk[158], B. Trocmé[55], C. Troncon[89a], M. Trottier-McDonald[142], P. True[88], M. Trzebinski[39], A. Trzupek[39], C. Tsarouchas[30], J.C-L. Tseng[118], M. Tsiakiris[105], P.V. Tsiareshka[90], D. Tsionou[5,ag], G. Tsipolitis[10], S. Tsiskaridze[12], V. Tsiskaridze[48], E.G. Tskhadadze[51a], I.I. Tsukerman[95], V. Tsulaia[15], J.-W. Tsung[21], S. Tsuno[65], D. Tsybychev[148], A. Tua[139], A. Tudorache[26a], V. Tudorache[26a], J.M. Tuggle[31], M. Turala[39], D. Turecek[127], I. Turk Cakir[4e], E. Turlay[105], R. Turra[89a,89b], P.M. Tuts[35], A. Tykhonov[74], M. Tylmad[146a,146b], M. Tyndel[129], G. Tzanakos[9], K. Uchida[21], I. Ueda[155], R. Ueno[29], M. Ugland[14], M. Uhlenbrock[21], M. Uhrmacher[54], F. Ukegawa[160], G. Unal[30], A. Undrus[25], G. Unel[163], Y. Unno[65], D. Urbaniec[35], P. Urquijo[21], G. Usai[8], M. Uslenghi[119a,119b], L. Vacavant[83], V. Vacek[127], B. Vachon[85], S. Vahsen[15], J. Valenta[125], S. Valentinetti[20a,20b], A. Valero[167], S. Valkar[126], E. Valladolid Gallego[167], S. Vallecorsa[152], J.A. Valls Ferrer[167], R. Van Berg[120], P.C. Van Der Deijl[105], R. van der Geer[105], H. van der Graaf[105], R. Van Der Leeuw[105], E. van der Poel[105], D. van der Ster[30], N. van Eldik[30], P. van Gemmeren[6], I. van Vulpen[105], M. Vanadia[99], W. Vandelli[30], A. Vaniachine[6], P. Vankov[42], F. Vannucci[78], R. Vari[132a], E.W. Varnes[7], T. Varol[84], D. Varouchas[15], A. Vartapetian[8], K.E. Varvell[150], V.I. Vassilakopoulos[56], F. Vazeille[34], T. Vazquez Schroeder[54], G. Vegni[89a,89b], J.J. Veillet[115], F. Veloso[124a], R. Veness[30], S. Veneziano[132a], A. Ventura[72a,72b], D. Ventura[84], M. Venturi[48], N. Venturi[158], V. Vercesi[119a], M. Verducci[138], W. Verkerke[105], J.C. Vermeulen[105], A. Vest[44], M.C. Vetterli[142,d], I. Vichou[165], T. Vickey[145b,ah], O.E. Vickey Boeriu[145b], G.H.A. Viehhauser[118], S. Viel[168], M. Villa[20a,20b], M. Villaplana Perez[167], E. Vilucchi[47], M.G. Vincter[29], E. Vinek[30], V.B. Vinogradov[64], M. Virchaux[136,*], J. Virzi[15], O. Vitells[172], M. Viti[42], I. Vivarelli[48], F. Vives Vaque[3], S. Vlachos[10], D. Vladoiu[98], M. Vlasak[127], A. Vogel[21], P. Vokac[127], G. Volpi[47], M. Volpi[86], G. Volpini[89a], H. von der Schmitt[99], H. von Radziewski[48], E. von Toerne[21], V. Vorobel[126], V. Vorwerk[12], M. Vos[167], R. Voss[30], T.T. Voss[175], J.H. Vossebeld[73], N. Vranjes[136], M. Vranjes Milosavljevic[105], V. Vrba[125], M. Vreeswijk[105], T. Vu Anh[48], R. Vuillermet[30], I. Vukotic[31], W. Wagner[175], P. Wagner[120], H. Wahlen[175], S. Wahrmund[44], J. Wakabayashi[101], S. Walch[87], J. Walder[71], R. Walker[98], W. Walkowiak[141], R. Wall[176], P. Waller[73], B. Walsh[176], C. Wang[45], H. Wang[173], H. Wang[33b,ai], J. Wang[151], J. Wang[55], R. Wang[103], S.M. Wang[151], T. Wang[21], A. Warburton[85], C.P. Ward[28], D.R. Wardrope[77], M. Warsinsky[48], A. Washbrook[46], C. Wasicki[42], I. Watanabe[66], P.M. Watkins[18], A.T. Watson[18], I.J. Watson[150], M.F. Watson[18], G. Watts[138], S. Watts[82], A.T. Waugh[150], B.M. Waugh[77], M.S. Weber[17], P. Weber[54], J.S. Webster[31], A.R. Weidberg[118], P. Weigell[99], J. Weingarten[54], C. Weiser[48], P.S. Wells[30], T. Wenaus[25], D. Wendland[16], Z. Weng[151,t], T. Wengler[30], S. Wenig[30], N. Wermes[21], M. Werner[48], P. Werner[30], M. Werth[163], M. Wessels[58a], J. Wetter[161], C. Weydert[55], K. Whalen[29], A. White[8], M.J. White[86], S. White[122a,122b], S.R. Whitehead[118], D. Whiteson[163], D. Whittington[60], F. Wicek[115], D. Wicke[175], F.J. Wickens[129], W. Wiedenmann[173], M. Wielers[129], P. Wienemann[21], C. Wiglesworth[75], L.A.M. Wiik-Fuchs[21], P.A. Wijeratne[77], A. Wildauer[99], M.A. Wildt[42,q], I. Wilhelm[126], H.G. Wilkens[30], J.Z. Will[98], E. Williams[35], H.H. Williams[120], W. Willis[35], S. Willocq[84], J.A. Wilson[18], M.G. Wilson[143], A. Wilson[87], I. Wingerter-Seez[5], S. Winkelmann[48], F. Winklmeier[30], M. Wittgen[143], S.J. Wollstadt[81], M.W. Wolter[39], H. Wolters[124a,g], W.C. Wong[41], G. Wooden[87], B.K. Wosiek[39], J. Wotschack[30], M.J. Woudstra[82], K.W. Wozniak[39], K. Wraight[53], M. Wright[53], B. Wrona[73], S.L. Wu[173], X. Wu[49], Y. Wu[33b,aj], E. Wulf[35], B.M. Wynne[46], S. Xella[36], M. Xiao[136], S. Xie[48], C. Xu[33b,x], D. Xu[139], B. Yabsley[150], S. Yacoob[145a,ak], M. Yamada[65], H. Yamaguchi[155], A. Yamamoto[65], K. Yamamoto[63], S. Yamamoto[155], T. Yamamura[155], T. Yamanaka[155], T. Yamazaki[155], Y. Yamazaki[66], Z. Yan[22], H. Yang[87], U.K. Yang[82], Y. Yang[109], Z. Yang[146a,146b], S. Yanush[91], L. Yao[33a], Y. Yao[15], Y. Yasu[65], G.V. Ybeles Smit[130], J. Ye[40], S. Ye[25], M. Yilmaz[4c], R. Yoosoofmiya[123], K. Yorita[171], R. Yoshida[6], K. Yoshihara[155], C. Young[143], C.J. Young[118], S. Youssef[22], D. Yu[25], J. Yu[8], J. Yu[112], L. Yuan[66], A. Yurkewicz[106], M. Byszewski[30], B. Zabinski[39], R. Zaidan[62], A.M. Zaitsev[128], Z. Zajacova[30], L. Zanello[132a,132b], D. Zanzi[99], A. Zaytsev[25], C. Zeitnitz[175], M. Zeman[125], A. Zemla[39], C. Zendler[21], O. Zenin[128], T. Ženiš[144a], Z. Zinonos[122a,122b], S. Zenz[15], D. Zerwas[115], G. Zevi della Porta[57], D. Zhang[33b,ai], H. Zhang[88], J. Zhang[6], X. Zhang[33d], Z. Zhang[115], L. Zhao[108], Z. Zhao[33b], A. Zhemchugov[64], J. Zhong[118], B. Zhou[87], N. Zhou[163], Y. Zhou[151], C.G. Zhu[33d], H. Zhu[42], J. Zhu[87], Y. Zhu[33b], X. Zhuang[98], V. Zhuravlov[99], A. Zibell[98], D. Zieminska[60], N.I. Zimin[64], R. Zimmermann[21], S. Zimmermann[21], S. Zimmermann[48], M. Ziolkowski[141], R. Zitoun[5], L. Živković[35], V.V. Zmouchko[128,*], G. Zobernig[173], A. Zoccoli[20a,20b], M. zur Nedden[16], V. Zutshi[106], L. Zwalinski[30].

[1] School of Chemistry and Physics, University of Adelaide, Adelaide, Australia
[2] Physics Department, SUNY Albany, Albany NY, United States of America
[3] Department of Physics, University of Alberta, Edmonton AB, Canada
[4] [(a)]Department of Physics, Ankara University, Ankara; [(b)]Department of Physics, Dumlupinar University, Kutahya; [(c)]Department of Physics, Gazi University, Ankara; [(d)]Division of Physics, TOBB University of Economics and Technology, Ankara; [(e)]Turkish Atomic Energy Authority, Ankara, Turkey
[5] LAPP, CNRS/IN2P3 and Université de Savoie, Annecy-le-Vieux, France
[6] High Energy Physics Division, Argonne National Laboratory, Argonne IL, United States of America
[7] Department of Physics, University of Arizona, Tucson AZ, United States of America
[8] Department of Physics, The University of Texas at Arlington, Arlington TX, United States of America
[9] Physics Department, University of Athens, Athens, Greece
[10] Physics Department, National Technical University of Athens, Zografou, Greece
[11] Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan
[12] Institut de Física d'Altes Energies and Departament de Física de la Universitat Autònoma de Barcelona and ICREA, Barcelona, Spain
[13] [(a)]Institute of Physics, University of Belgrade, Belgrade; [(b)]Vinca Institute of Nuclear Sciences, University of Belgrade, Belgrade, Serbia
[14] Department for Physics and Technology, University of Bergen, Bergen, Norway
[15] Physics Division, Lawrence Berkeley National Laboratory and University of California, Berkeley CA, United States of America
[16] Department of Physics, Humboldt University, Berlin, Germany
[17] Albert Einstein Center for Fundamental Physics and Laboratory for High Energy Physics, University of Bern, Bern, Switzerland
[18] School of Physics and Astronomy, University of Birmingham, Birmingham, United Kingdom
[19] [(a)]Department of Physics, Bogazici University, Istanbul; [(b)]Division of Physics, Dogus University, Istanbul; [(c)]Department of Physics Engineering, Gaziantep University, Gaziantep; [(d)]Department of Physics, Istanbul Technical University, Istanbul, Turkey
[20] [(a)]INFN Sezione di Bologna; [(b)]Dipartimento di Fisica, Università di Bologna, Bologna, Italy
[21] Physikalisches Institut, University of Bonn, Bonn, Germany
[22] Department of Physics, Boston University, Boston MA, United States of America
[23] Department of Physics, Brandeis University, Waltham MA, United States of America
[24] [(a)]Universidade Federal do Rio De Janeiro COPPE/EE/IF, Rio de Janeiro; [(b)]Federal University of Juiz de Fora (UFJF), Juiz de Fora; [(c)]Federal University of Sao Joao del Rei (UFSJ), Sao Joao del Rei; [(d)]Instituto de Fisica, Universidade de Sao Paulo, Sao Paulo, Brazil
[25] Physics Department, Brookhaven National Laboratory, Upton NY, United States of America
[26] [(a)]National Institute of Physics and Nuclear Engineering, Bucharest; [(b)]University Politehnica Bucharest, Bucharest; [(c)]West University in Timisoara, Timisoara, Romania
[27] Departamento de Física, Universidad de Buenos Aires, Buenos Aires, Argentina
[28] Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom
[29] Department of Physics, Carleton University, Ottawa ON, Canada
[30] CERN, Geneva, Switzerland
[31] Enrico Fermi Institute, University of Chicago, Chicago IL, United States of America
[32] [(a)]Departamento de Física, Pontificia Universidad Católica de Chile, Santiago; [(b)]Departamento de Física,

Universidad Técnica Federico Santa María, Valparaíso, Chile
[33] [(a)]Institute of High Energy Physics, Chinese Academy of Sciences, Beijing; [(b)]Department of Modern Physics, University of Science and Technology of China, Anhui; [(c)]Department of Physics, Nanjing University, Jiangsu; [(d)]School of Physics, Shandong University, Shandong, China
[34] Laboratoire de Physique Corpusculaire, Clermont Université and Université Blaise Pascal and CNRS/IN2P3, Clermont-Ferrand, France
[35] Nevis Laboratory, Columbia University, Irvington NY, United States of America
[36] Niels Bohr Institute, University of Copenhagen, Kobenhavn, Denmark
[37] [(a)]INFN Gruppo Collegato di Cosenza; [(b)]Dipartimento di Fisica, Università della Calabria, Arcavata di Rende, Italy
[38] AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Krakow, Poland
[39] The Henryk Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences, Krakow, Poland
[40] Physics Department, Southern Methodist University, Dallas TX, United States of America
[41] Physics Department, University of Texas at Dallas, Richardson TX, United States of America
[42] DESY, Hamburg and Zeuthen, Germany
[43] Institut für Experimentelle Physik IV, Technische Universität Dortmund, Dortmund, Germany
[44] Institut für Kern-und Teilchenphysik, Technical University Dresden, Dresden, Germany
[45] Department of Physics, Duke University, Durham NC, United States of America
[46] SUPA - School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom
[47] INFN Laboratori Nazionali di Frascati, Frascati, Italy
[48] Fakultät für Mathematik und Physik, Albert-Ludwigs-Universität, Freiburg, Germany
[49] Section de Physique, Université de Genève, Geneva, Switzerland
[50] [(a)]INFN Sezione di Genova; [(b)]Dipartimento di Fisica, Università di Genova, Genova, Italy
[51] [(a)]E. Andronikashvili Institute of Physics, Iv. Javakhishvili Tbilisi State University, Tbilisi; [(b)]High Energy Physics Institute, Tbilisi State University, Tbilisi, Georgia
[52] II Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen, Germany
[53] SUPA - School of Physics and Astronomy, University of Glasgow, Glasgow, United Kingdom
[54] II Physikalisches Institut, Georg-August-Universität, Göttingen, Germany
[55] Laboratoire de Physique Subatomique et de Cosmologie, Université Joseph Fourier and CNRS/IN2P3 and Institut National Polytechnique de Grenoble, Grenoble, France
[56] Department of Physics, Hampton University, Hampton VA, United States of America
[57] Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge MA, United States of America
[58] [(a)]Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Heidelberg; [(b)]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg; [(c)]ZITI Institut für technische Informatik, Ruprecht-Karls-Universität Heidelberg, Mannheim, Germany
[59] Faculty of Applied Information Science, Hiroshima Institute of Technology, Hiroshima, Japan
[60] Department of Physics, Indiana University, Bloomington IN, United States of America
[61] Institut für Astro-und Teilchenphysik, Leopold-Franzens-Universität, Innsbruck, Austria
[62] University of Iowa, Iowa City IA, United States of America
[63] Department of Physics and Astronomy, Iowa State University, Ames IA, United States of America
[64] Joint Institute for Nuclear Research, JINR Dubna, Dubna, Russia
[65] KEK, High Energy Accelerator Research Organization, Tsukuba, Japan
[66] Graduate School of Science, Kobe University, Kobe, Japan
[67] Faculty of Science, Kyoto University, Kyoto, Japan
[68] Kyoto University of Education, Kyoto, Japan
[69] Department of Physics, Kyushu University, Fukuoka, Japan
[70] Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata, Argentina
[71] Physics Department, Lancaster University, Lancaster, United Kingdom
[72] [(a)]INFN Sezione di Lecce; [(b)]Dipartimento di Matematica e Fisica, Università del Salento, Lecce, Italy
[73] Oliver Lodge Laboratory, University of Liverpool, Liverpool, United Kingdom
[74] Department of Physics, Jožef Stefan Institute and University of Ljubljana, Ljubljana, Slovenia
[75] School of Physics and Astronomy, Queen Mary University of London, London, United Kingdom
[76] Department of Physics, Royal Holloway University of London, Surrey, United Kingdom
[77] Department of Physics and Astronomy, University College London, London, United Kingdom
[78] Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France
[79] Fysiska institutionen, Lunds universitet, Lund, Sweden
[80] Departamento de Fisica Teorica C-15, Universidad Autonoma de Madrid, Madrid, Spain

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

[135] [(a)]Faculté des Sciences Ain Chock, Réseau Universitaire de Physique des Hautes Energies - Université Hassan II, Casablanca; [(b)]Centre National de l'Energie des Sciences Techniques Nucleaires, Rabat; [(c)]Faculté des Sciences Semlalia, Université Cadi Ayyad, LPHEA-Marrakech; [(d)]Faculté des Sciences, Université Mohamed Premier and LPTPM, Oujda; [(e)]Faculté des sciences, Université Mohammed V-Agdal, Rabat, Morocco
[136] DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat a l'Energie Atomique), Gif-sur-Yvette, France
[137] Santa Cruz Institute for Particle Physics, University of California Santa Cruz, Santa Cruz CA, United States of America
[138] Department of Physics, University of Washington, Seattle WA, United States of America
[139] Department of Physics and Astronomy, University of Sheffield, Sheffield, United Kingdom
[140] Department of Physics, Shinshu University, Nagano, Japan
[141] Fachbereich Physik, Universität Siegen, Siegen, Germany
[142] Department of Physics, Simon Fraser University, Burnaby BC, Canada
[143] SLAC National Accelerator Laboratory, Stanford CA, United States of America
[144] [(a)]Faculty of Mathematics, Physics & Informatics, Comenius University, Bratislava; [(b)]Department of Subnuclear Physics, Institute of Experimental Physics of the Slovak Academy of Sciences, Kosice, Slovak Republic
[145] [(a)]Department of Physics, University of Johannesburg, Johannesburg; [(b)]School of Physics, University of the Witwatersrand, Johannesburg, South Africa
[146] [(a)]Department of Physics, Stockholm University; [(b)]The Oskar Klein Centre, Stockholm, Sweden
[147] Physics Department, Royal Institute of Technology, Stockholm, Sweden
[148] Departments of Physics & Astronomy and Chemistry, Stony Brook University, Stony Brook NY, United States of America
[149] Department of Physics and Astronomy, University of Sussex, Brighton, United Kingdom
[150] School of Physics, University of Sydney, Sydney, Australia
[151] Institute of Physics, Academia Sinica, Taipei, Taiwan
[152] Department of Physics, Technion: Israel Institute of Technology, Haifa, Israel
[153] Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel
[154] Department of Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece
[155] International Center for Elementary Particle Physics and Department of Physics, The University of Tokyo, Tokyo, Japan
[156] Graduate School of Science and Technology, Tokyo Metropolitan University, Tokyo, Japan
[157] Department of Physics, Tokyo Institute of Technology, Tokyo, Japan
[158] Department of Physics, University of Toronto, Toronto ON, Canada
[159] [(a)]TRIUMF, Vancouver BC; [(b)]Department of Physics and Astronomy, York University, Toronto ON, Canada
[160] Faculty of Pure and Applied Sciences, University of Tsukuba, Tsukuba, Japan
[161] Department of Physics and Astronomy, Tufts University, Medford MA, United States of America
[162] Centro de Investigaciones, Universidad Antonio Narino, Bogota, Colombia
[163] Department of Physics and Astronomy, University of California Irvine, Irvine CA, United States of America
[164] [(a)]INFN Gruppo Collegato di Udine; [(b)]ICTP, Trieste; [(c)]Dipartimento di Chimica, Fisica e Ambiente, Università di Udine, Udine, Italy
[165] Department of Physics, University of Illinois, Urbana IL, United States of America
[166] Department of Physics and Astronomy, University of Uppsala, Uppsala, Sweden
[167] Instituto de Física Corpuscular (IFIC) and Departamento de Física Atómica, Molecular y Nuclear and Departamento de Ingeniería Electrónica and Instituto de Microelectrónica de Barcelona (IMB-CNM), University of Valencia and CSIC, Valencia, Spain
[168] Department of Physics, University of British Columbia, Vancouver BC, Canada
[169] Department of Physics and Astronomy, University of Victoria, Victoria BC, Canada
[170] Department of Physics, University of Warwick, Coventry, United Kingdom
[171] Waseda University, Tokyo, Japan
[172] Department of Particle Physics, The Weizmann Institute of Science, Rehovot, Israel
[173] Department of Physics, University of Wisconsin, Madison WI, United States of America
[174] Fakultät für Physik und Astronomie, Julius-Maximilians-Universität, Würzburg, Germany
[175] Fachbereich C Physik, Bergische Universität Wuppertal, Wuppertal, Germany
[176] Department of Physics, Yale University, New Haven CT, United States of America
[177] Yerevan Physics Institute, Yerevan, Armenia
[178] Centre de Calcul de l'Institut National de Physique Nucléaire et de Physique des Particules (IN2P3), Villeurbanne, France

[a] Also at Laboratorio de Instrumentacao e Fisica Experimental de Particulas - LIP, Lisboa, Portugal
[b] Also at Faculdade de Ciencias and CFNUL, Universidade de Lisboa, Lisboa, Portugal
[c] Also at Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom
[d] Also at TRIUMF, Vancouver BC, Canada
[e] Also at Department of Physics, California State University, Fresno CA, United States of America
[f] Also at Novosibirsk State University, Novosibirsk, Russia
[g] Also at Department of Physics, University of Coimbra, Coimbra, Portugal
[h] Also at Department of Physics, UASLP, San Luis Potosi, Mexico
[i] Also at Università di Napoli Parthenope, Napoli, Italy
[j] Also at Institute of Particle Physics (IPP), Canada
[k] Also at Department of Physics, Middle East Technical University, Ankara, Turkey
[l] Also at Louisiana Tech University, Ruston LA, United States of America
[m] Also at Dep Fisica and CEFITEC of Faculdade de Ciencias e Tecnologia, Universidade Nova de Lisboa, Caparica, Portugal
[n] Also at Department of Physics and Astronomy, University College London, London, United Kingdom
[o] Also at Department of Physics, University of Cape Town, Cape Town, South Africa
[p] Also at Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan
[q] Also at Institut für Experimentalphysik, Universität Hamburg, Hamburg, Germany
[r] Also at Manhattan College, New York NY, United States of America
[s] Also at CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France
[t] Also at School of Physics and Engineering, Sun Yat-sen University, Guanzhou, China
[u] Also at Academia Sinica Grid Computing, Institute of Physics, Academia Sinica, Taipei, Taiwan
[v] Also at School of Physics, Shandong University, Shandong, China
[w] Also at Dipartimento di Fisica, Università La Sapienza, Roma, Italy
[x] Also at DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat a l'Energie Atomique), Gif-sur-Yvette, France
[y] Also at Section de Physique, Université de Genève, Geneva, Switzerland
[z] Also at Departamento de Fisica, Universidade de Minho, Braga, Portugal
[aa] Also at Department of Physics and Astronomy, University of South Carolina, Columbia SC, United States of America
[ab] Also at Institute for Particle and Nuclear Physics, Wigner Research Centre for Physics, Budapest, Hungary
[ac] Also at California Institute of Technology, Pasadena CA, United States of America
[ad] Also at Institute of Physics, Jagiellonian University, Krakow, Poland
[ae] Also at LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France
[af] Also at Nevis Laboratory, Columbia University, Irvington NY, United States of America
[ag] Also at Department of Physics and Astronomy, University of Sheffield, Sheffield, United Kingdom
[ah] Also at Department of Physics, Oxford University, Oxford, United Kingdom
[ai] Also at Institute of Physics, Academia Sinica, Taipei, Taiwan
[aj] Also at Department of Physics, The University of Michigan, Ann Arbor MI, United States of America
[ak] Also at Discipline of Physics, University of KwaZulu-Natal, Durban, South Africa
[*] Deceased