Physics Letters B 705 (2011) 452–470

Contents lists available at SciVerse ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

Search for the Standard Model Higgs boson in the two photon decay channel with the ATLAS detector at the LHC ☆

The ATLAS Collaboration *

ARTICLE INFO

Article history:
Received 30 August 2011
Received in revised form 20 October 2011
Accepted 20 October 2011
Available online 21 October 2011
Editor: H. Weerts

ABSTRACT

A search for the Standard Model Higgs boson in the two photon decay channel is reported, using 1.08 fb^{-1} of proton–proton collision data at a centre-of-mass energy of 7 TeV recorded by the ATLAS detector. No significant excess is observed in the investigated mass range of 110–150 GeV. Upper limits on the cross-section times branching ratio of between 2.0 and 5.8 times the Standard Model prediction are derived for this mass range.

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

1. Introduction

The search for the Standard Model Higgs boson [1–3] is one of the key goals of the Large Hadron Collider (LHC) at CERN. The allowed Higgs boson mass (m_H) is constrained at the 95% confidence level by a lower limit of 114.4 GeV from the LEP experiments [4] and an excluded region between 156 and 177 GeV from the Tevatron experiments [5,6]. First results have been reported by the ATLAS experiment in a variety of channels [7] and the CMS experiment [8] using the data recorded in 2010, which correspond to an integrated luminosity about thirty times smaller than the 2011 dataset used in this analysis.

In the low mass range, from the LEP limit to $m_H \approx 140$ GeV, one of the most promising search channels at the LHC is the rare decay of the Higgs boson into a pair of photons. Despite the low branching ratio ($\approx 0.2\%$), this channel provides good experimental sensitivity in the mass region below 150 GeV. The results presented in this Letter are based on proton–proton collision data taken at $\sqrt{s} = 7$ TeV by the ATLAS experiment between April and June 2011.

The data analysis proceeds by selecting photon pairs with tight identification and isolation cuts to minimize backgrounds other than direct diphoton production. A narrow peak in the reconstructed invariant mass distribution is searched for over a large, smooth background whose normalisation and shape are left free in a maximum likelihood fit. To increase the sensitivity, the sample is divided into five categories based on the presence of photon conversions and on the photon impact point on the calorimeter, with different invariant mass resolutions and signal-to-background ratios for the different categories.

The results of the fit are compared to the prediction from the Standard Model using the Higgs boson production cross-section and branching ratio from Ref. [9]. Limits on the production cross-section relative to the Standard Model value are then derived as a function of the hypothesised Higgs boson mass. Although with the current dataset the analysis is not yet sensitive to the predicted rate for a Standard Model Higgs boson, the limits on the yield in this decay channel improve on those obtained in the same channel by the Tevatron experiments [10–12], and are sensitive to possible enhancements in the Higgs boson production and decay rate compared with the Standard Model expectations.

2. Experimental setup and data set

The ATLAS detector is described in detail in Ref. [13]. The main subdetectors relevant to this analysis are the calorimeter, in particular its electromagnetic section, and the inner tracking detector.

The electromagnetic calorimeter is a lead–liquid argon sampling calorimeter with accordion geometry. It is divided into a barrel section covering the pseudorapidity[1] region $|\eta| < 1.45$ and two end-cap sections covering the pseudorapidity region $1.375 < |\eta| < 3.2$. It has three longitudinal layers. The first one, with a thickness between 3 and 5 radiation lengths, has a high granularity in η (between 0.003 and 0.006 depending on η, with the exception of the regions $1.4 < |\eta| < 1.5$ and $|\eta| > 2.4$), sufficient to provide discrimination between single photon showers and two photons from a π^0 decay. The second layer has a thickness of around 17 radiation lengths and a granularity of 0.025×0.025 in $\eta \times \phi$.

☆ © CERN for the benefit of the ATLAS Collaboration.

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

[1] ATLAS uses a right-handed coordinate system with its origin at the nominal interaction point (IP) in the centre of the detector and the z-axis along the beam pipe. The x-axis points from the IP to the centre of the LHC ring, and the y axis points upward. Cylindrical coordinates (r, 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 $\eta = -\ln\tan(\theta/2)$.

0370-2693 © 2011 CERN. Published by Elsevier B.V. Open access under CC BY-NC-ND license.
doi:10.1016/j.physletb.2011.10.051

A third layer, with a thickness varying between 4 and 15 radiation lengths, is used to correct for leakage beyond the calorimeter for high energy showers. In front of the calorimeter, a thin presampler layer, covering $|\eta| < 1.8$, is used to correct for fluctuations in upstream energy losses. The sampling term a of the energy resolution, $\sigma(E)/E \approx a/\sqrt{E\ (\mathrm{GeV})}$, varies between 9% and 14% as a function of $|\eta|$ for unconverted photons [14]. It reaches up to 20% for converted photons near $|\eta|$ of 1.3 where the upstream material effect is the largest. The sampling term is the largest contribution to the resolution up to about 100 GeV, where the constant term starts to dominate. After 0.17 fb^{-1} of data were accumulated, some calorimeter cells could not be read out. The affected region size is $\Delta\eta \times \Delta\phi \approx 1.5 \times 0.2$ in the barrel electromagnetic calorimeter, resulting in an acceptance loss for diphoton candidates of about 3%. A hadronic sampling calorimeter is located behind the electromagnetic calorimeter. It is made of steel and scintillating tiles in the barrel section, and of copper and liquid argon in the end-cap.

The inner detector consists of three subsystems: at small radial distance R from the beam axis ($5 < R < 15$ cm), pixel silicon detectors are arranged in three cylindrical layers in the barrel and in three disks in each end-cap; at intermediate radii ($30 < R < 56$ cm), double layers of single-sided silicon microstrip detectors are used, organised in four cylindrical layers in the barrel and nine disks in each end-cap; at larger radii ($56 < R < 107$ cm), a straw tracker with transition radiation capabilities is used. These three systems are immersed in a 2 T axial magnetic field. The silicon pixel and strip subsystems cover the range $|\eta| < 2.5$, while the transition radiation tracker acceptance is limited to the range $|\eta| < 2.0$. The inner detector allows reconstruction of secondary vertices, in particular of photon conversions occurring in the inner detector material up to a radius of ≈ 80 cm.

The total amount of material in front of the first active layer of the electromagnetic calorimeter (including that in the presampler) varies between 2.5 and 6 radiation lengths as a function of pseudorapidity, excluding the transition region ($1.37 < |\eta| < 1.52$) between the barrel and the end-caps.

Data used in this analysis were selected using a di-photon trigger with a 20 GeV transverse energy threshold on each photon. At the first trigger level, which uses reduced granularity, two clusters with transverse energies above 14 GeV are required in the electromagnetic calorimeter. At the higher trigger levels, loose photon identification cuts are applied using the full calorimeter granularity. This trigger has an efficiency greater than 99% for the signal after the final event selection.

In these data, the instantaneous luminosity varies between $\approx 10^{32}$ cm^{-2} s^{-1} and $\approx 10^{33}$ cm^{-2} s^{-1} with a bunch spacing of 50 ns. The average number of collisions per bunch crossing is around 6. Collisions in the same bunch crossing as the signal (in-time pileup) or in other bunch crossings within the detector sensitive time (out-of-time pileup) influence the event reconstruction. The inner detector is only sensitive to in-time pileup while the electromagnetic calorimeter is sensitive to pileup within a ≈ 450 ns time window.

The application of beam, detector, and data-quality requirements to the recorded data results in a data sample corresponding to a total integrated luminosity of (1.08 ± 0.04) fb^{-1} [15].

3. Simulated samples

The Higgs boson signal from the dominant gluon fusion production process (corresponding to 86% of the production cross-section for a Higgs boson with a mass of 120 GeV) is generated with POWHEG [16]. MC@NLO [17] is used as a cross-check. POWHEG [18] is also used to generate the signal events from the sub-leading vector boson fusion process (7% of the cross-section at 120 GeV). For the other production modes, namely associated production with a W or Z boson or a $t\bar{t}$ pair, PYTHIA [19] is used.

The predicted signal is normalised using NNLO cross-sections for the gluon fusion process [20–24], the vector boson fusion process [25], the associated production with a W or Z boson [26] and NLO cross-section for the associated production with a $t\bar{t}$ pair [27]. The NLO electroweak corrections are applied to the gluon fusion [28,29], vector boson fusion [30,31], and the associated production with a W or Z boson [32] processes. The uncertainty on the theoretical cross-section is estimated [9] to be $^{+20}_{-15}$%, mostly due to the renormalisation and factorisation scale variations and the uncertainties in the parton distribution functions [33–36]. The Higgs boson decay branching fractions are taken from Refs. [9,37]. The uncertainty on the branching ratio to two photons is negligible compared with the cross-section uncertainty.

Signal events are generated in steps of 5 GeV for Higgs boson masses in the range of 110–150 GeV. PYTHIA and ALPGEN [38] have been chosen to generate the background samples, which are, however, only used for cross-checks and not to extract the final results.

All Monte Carlo (MC) samples are processed through a complete simulation of the ATLAS detector [39] using the GEANT4 programme [40]. Pileup effects are simulated by overlaying each MC event with a variable number of MC inelastic pp collisions, taking into account both in-time and out-of-time pileup and the LHC bunch train structure. MC events are weighted to have the same distribution of average number of interactions per bunch crossing as in the data.

4. Photon reconstruction, event selection and backgrounds

4.1. Photon reconstruction

Photon reconstruction is seeded by energy clusters in the electromagnetic calorimeter with transverse energies exceeding 2.5 GeV in projective towers of size 0.075×0.125 in $\eta \times \phi$ made from the presampler and the three electromagnetic calorimeter layers. These energy clusters are then matched to tracks that are reconstructed in the inner detector and extrapolated to the calorimeter. Clusters without matching tracks are classified as unconverted photon candidates. Clusters matched to either pairs of tracks which are consistent with the hypothesis of a photon conversion or single tracks without hits in the pixel layer nearest to the beam pipe are considered as converted photon candidates. The photon reconstruction efficiency is $\approx 98\%$.

The energy measurement is made in the electromagnetic calorimeter using a cluster size which depends on the photon classification. In the barrel, a size of 0.075×0.125 in $\eta \times \phi$ is used for unconverted photons and 0.075×0.175 for converted photon candidates, to account for the larger spread of the shower in ϕ for converted photons due to the magnetic field. In the end-cap, a cluster size of 0.125×0.125 is used for all candidates. A dedicated energy calibration [14] is applied to account for upstream energy losses, lateral leakage and longitudinal leakage, separately for converted and unconverted photon candidates.

The final energy calibration is determined from $Z \to ee$ decays, resulting in η-dependent correction factors of the order of $\pm 1\%$. After this calibration procedure, the constant term in the energy resolution is estimated to be $1.1^{+0.5}_{-0.6}$% in the barrel region and $1.8^{+0.5}_{-0.6}$% in the end-cap region [41]. The energy resolution in the simulation is adjusted to match these values.

Photon identification is based on the lateral and longitudinal energy profiles of the shower in the calorimeter [42]. The photon candidate is required to deposit only a small fraction of its en-

ergy in the hadronic calorimeter. The transverse shower shape in the second layer of the electromagnetic calorimeter needs to be consistent with that expected for a single electromagnetic shower. Finally, the high granularity first layer is used to discriminate single photons from overlapping photon pairs from neutral meson decays produced in jet fragmentation, which are the main background source. Based on these criteria, a set of tight identification cuts, different for converted and unconverted candidates, is applied.

To take into account small differences in shower shapes between data and simulation, the shape variables are shifted in the simulation before the identification cuts are applied. The photon identification efficiency ranges typically from 75% to 90% for transverse energies between 25 and 100 GeV.

To increase the background rejection, an isolation cut is applied. The isolation variable [42] is computed by summing the transverse energy in calorimeter cells in a cone of radius 0.4 in the $\eta \times \phi$ space around the photon candidate. Cells in the electromagnetic calorimeter within 0.125×0.175 from the shower barycentre are excluded from the sum. The small photon energy leakage outside the excluded cells is evaluated as a function of the transverse energy in simulated samples and is subtracted from the isolation variable. To reduce the effect from the underlying event and pileup, the isolation is further corrected using a method suggested in Ref. [43]: for each of the two different pseudorapidity regions $|\eta| < 1.5$ and $1.5 < |\eta| < 3.0$, low energy jets are used to compute an "ambient" energy density, which is then multiplied by the area of the isolation cone and subtracted from the isolation energy.

In the following, photon candidates having isolation transverse energies lower than 5 GeV are considered as isolated. The isolation cut efficiency is checked in data using a control sample of $Z \to ee$ events. The per-event efficiency of requiring both electrons to be isolated is found to be 3% lower in the data than in the simulated samples. In the MC, the isolation cut efficiency is found to be the same for $Z \to ee$ and $H \to \gamma\gamma$ events ($\approx 93\%$). The number of events predicted by the simulation after the isolation cut is therefore reduced by 3%.

4.2. Event selection

Two photon candidates are required to pass tight identification criteria, to be isolated, and to be within the region $|\eta| < 2.37$, excluding $1.37 < |\eta| < 1.52$, where the first calorimeter layer has high granularity. The highest and second highest photon transverse energies are required be above 40 and 25 GeV respectively. Both photons must be clear of problematic regions in the calorimeter. As the goal is to investigate Higgs boson mass hypotheses between 110 and 150 GeV, the invariant mass of the photon pair is required to be within 100–160 GeV. After these cuts 5063 events remain in the selected data sample.

The acceptance of the kinematic cuts, as estimated with generated photons in the MC signal samples, is 60% for the dominant gluon fusion process for a mass of 120 GeV. The overall event selection efficiency, taking into account both kinematic cut acceptance and reconstruction and identification efficiencies, is 39%. The event selection efficiency is slightly larger in the vector boson fusion process. It is somewhat smaller in the associated production mode. It increases with the Higgs boson mass from 34% at 110 GeV to 43% at 150 GeV.

To enhance the sensitivity of the analysis, the data sample is split in five categories, with different invariant mass resolutions and different signal-to-background ratios:

- Unconverted central (8% of the candidates): Both photons are unconverted and in the central part of the barrel calorimeter ($|\eta| < 0.75$). This is the category with the best invariant mass resolution and the best signal-to-background ratio;
- Unconverted rest (28% of the candidates): Both photons are unconverted and at least one photon does not lie in the central part of the barrel calorimeter;
- Converted central (7% of the candidates): At least one photon is converted and both photons are in the central part of the barrel calorimeter;
- Converted transition (16% of the candidates): At least one photon is converted and at least one photon is near the transition between barrel and end-cap calorimeter ($1.3 < |\eta| < 1.75$). Given the larger amount of material in this region, the energy resolution, in particular for converted photons, can be significantly degraded;
- Converted rest (41% of the candidates): All other events with at least one converted photon.

Table 1
Cross-section times branching ratio and expected numbers of signal events after all cuts (total and per category), for various Higgs boson masses and for an integrated luminosity of 1.08 fb^{-1}.

m_H [GeV]	110	120	130	140	150
$\sigma \times$ BR [fb]	45	43	37	27	16
Signal yield	17.0	17.6	15.8	12.1	7.7
Unconverted central	2.6	2.6	2.3	1.7	1.1
Unconverted rest	4.6	4.7	4.2	3.4	2.1
Converted central	2.0	2.0	1.7	1.3	0.8
Converted transition	2.3	2.2	2.1	1.5	1.0
Converted rest	5.6	6.0	5.6	4.2	2.7

Table 1 shows the cross-section times branching ratio to two photons, the expected total and per category signal yields for 1.08 fb^{-1} for different Standard Model Higgs boson mass hypotheses. Using these categories improves the signal sensitivity of the analysis by around 15% for a 120 GeV Higgs boson mass compared with a fully inclusive analysis.

4.3. Invariant mass reconstruction

In addition to the energies, the angle between the photons is needed for the computation of the diphoton invariant mass. This angle is determined from the interaction vertex position and the photon impact points in the calorimeter. The resolution of the angle measurement is dominated by the reconstruction of the primary vertex z position. The RMS vertex spread in the z direction is ≈ 5.5 cm, and a more accurate event-by-event estimate is performed to reduce the impact on the invariant mass resolution. Given the non-negligible level of pileup in the 2011 data, the determination of the vertex position is based only on the photon candidates, without relying on other charged tracks in the event. For converted photons with tracks having a precise measurement in the z direction, the vertex position is estimated from the intercept of the line joining the reconstructed conversion position and the calorimeter impact point with the beam line. For all other photons, the vertex position is estimated from the shower position measurements in the first and second layers of the electromagnetic calorimeter, which can be used to calculate the photon direction. Finally, the vertex positions from both photons are combined taking also into account the average beam spot position in z. When both photons are unconverted, the typical vertex position resolution is ≈ 1.6 cm in z. The resolution is better in events with converted photons. The resulting impact of the angle measurement on the invariant mass resolution is negligible compared to the contribution from the photon energy resolution.

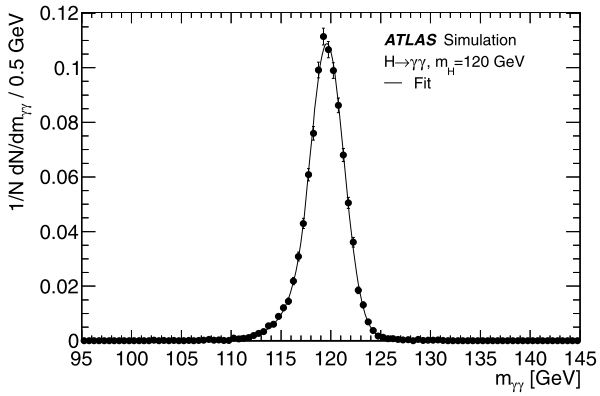

Fig. 1. Distribution of the reconstructed diphoton invariant mass of a simulated 120 GeV mass Higgs boson signal, for all categories together. The line shows the fit of the mass resolution using the function described in the text. The core component of the mass resolution is 1.7 GeV.

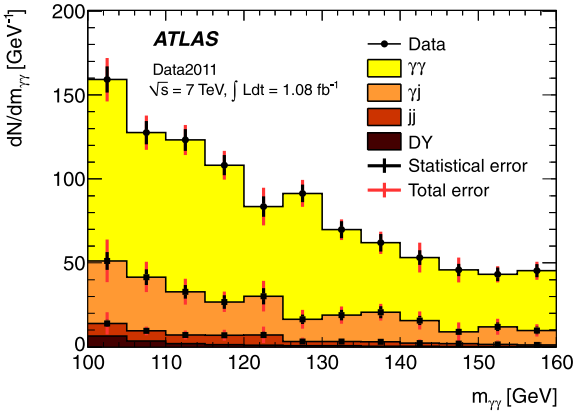

Fig. 2. Diphoton, photon-jet, dijet and Drell–Yan contributions to the diphoton candidate invariant mass distribution, as obtained from a data-driven method. The various components are stacked on top of each other. The error bars correspond to the uncertainties on each component separately.

Fig. 1 shows the invariant mass distribution for simulated Higgs boson events with mass 120 GeV. The mass resolution for the signal is modelled by the sum of a Crystal Ball function [44] (for the bulk of the events which have a narrow Gaussian spectrum in the peak region and tails toward lower reconstructed mass) and a Gaussian distribution with a wide sigma (to model the far outliers in the distribution). The Crystal Ball function is defined as:

$$N \cdot \begin{cases} e^{-t^2/2} & \text{if } t > -\alpha_{CB}, \\ \left(\frac{n_{CB}}{\alpha_{CB}}\right)^{n_{CB}} \cdot e^{-\alpha_{CB}^2/2} \cdot \left(\frac{n_{CB}}{\alpha_{CB}} - \alpha_{CB} - t\right)^{-n_{CB}} & \text{otherwise} \end{cases}$$

where $t = (m_{\gamma\gamma} - \mu_{CB})/\sigma_{CB}$, N is a normalisation parameter, μ_{CB} is the peak of the narrow Gaussian distribution, σ_{CB} represents the Gaussian resolution for the core component, and n_{CB} and α_{CB} parametrise the non-Gaussian tail.

The core component of the mass resolution, σ_{CB}, ranges from 1.4 GeV in the "Unconverted central" category to 2.1 GeV in the "Converted transition" category. The non-Gaussian contributions to the mass resolution arise mostly from converted photons with at least one electron losing a significant fraction of its energy through bremsstrahlung in the inner detector material.

4.4. Sample composition

The main background components are the diphoton production, the photon-jet production with one fake photon from jets fragmenting into a high energy π^0, the dijet production with two fake photons, and Drell–Yan events where both electrons are misidentified as photons. A measurement of the diphoton production cross-section with 2010 ATLAS data can be found in Ref. [45], where the techniques used to estimate the purity of the sample are described in more detail. Although the final result does not rely on it, a quantitative understanding of the sample composition is an important cross-check of the diphoton selection procedure.

A method based on the use of control regions for two discriminating variables is applied to measure the contributions of fake photon background directly from the data. This method exploits relaxed isolation and photon identification cuts to estimate the fake components, by relying on the fact that the rejections from these two cuts are almost independent. It is a generalisation of the method used in Ref. [42]. The Drell–Yan background is estimated by measuring the probability for an electron to be reconstructed as a photon candidate with Z events and applying this probability to the observed yield of Drell–Yan events at high mass.

The number of diphoton events in the 100–160 GeV mass range is found to be $3650 \pm 100 \pm 290$, where the first uncertainty is statistical and the second is systematic. The systematic uncertainty arises from the definition of the relaxed identification control region, the possible correlations between isolation and identification variables, and the fraction of real photons leaking into the background control regions. The extracted yields of photon-jet and dijet are $1110 \pm 60 \pm 270$ and $220 \pm 20 \pm 130$ events respectively. The Drell–Yan background, which is most prominent in the categories with at least one converted photon, is estimated to be $86 \pm 1 \pm 14$ events in the mass range of 100–160 GeV.

Fig. 2 shows the extracted components of the diphoton, photon-jet, dijet and Drell–Yan processes. The purity of the sample (fraction of diphoton events) is about 72%. The measurement of the purity has also been made separately in each category, and ranges from 69% to 83%.

Other methods have been used to cross-check the purity estimate, in particular using template fits of the photon isolation distribution, where both signal and background templates are derived from data. The results are in agreement with the results quoted here.

5. Systematic uncertainties

Experimental systematic uncertainties affecting the extraction of the signal from the diphoton invariant mass distribution related to the modelling of the signal can be classified in two types: uncertainties affecting the predicted yield and uncertainties affecting the modelling of the mass resolution.

The uncertainties on the event yield are the following:

- The uncertainty from the photon reconstruction and identification efficiency amounts to ±11% per event. It is estimated from data and MC differences in shower shape variables, the impact of additional material in front of the calorimeter and the impact of pileup on the photon shower shape variables.
- The uncertainty on the isolation cut efficiency is taken as the difference between data and MC found in $Z \to ee$ decays and amounts to ±3% per event.
- The uncertainty on the photon trigger efficiency is ±1%. It comes from the uncertainty in the measurement of the trigger efficiency for diphoton candidates using control triggers and from possible differences between the trigger efficiency for photons from Higgs boson decays and all diphoton candidates.
- The uncertainty on the kinematic cut acceptance from the modelling of the Higgs boson transverse momentum distribu-

tion is investigated with HQT [46] and RESBOS [47,48], which account for all-orders soft-gluon resummation up to NNLL accuracy. The resulting uncertainty is found to be at the level of ±1%.
- The luminosity uncertainty is 3.7% [15].

The total uncertainty on the expected signal event yield is ±12%.

The uncertainties on the invariant mass resolution are the following:

- The uncertainty on the cluster energy resolution comes from the uncertainty on the sampling term, estimated to be 10%, and from the uncertainty on the constant term, which is estimated using $Z \to ee$ decays. Both uncertainties are taken into account with their proper correlation from the Z control sample constraint. The uncertainty on the cluster energy resolution amounts to a ±12% relative uncertainty on the diphoton invariant mass resolution.
- The uncertainty on the photon energy calibration arising from the extrapolation of the electron energy scale calibration is estimated from MC studies. The difference between the photon and the electron response in the calorimeter comes from the material in front of the active part of the calorimeter. The uncertainty is estimated using simulations with a different amount of material in front of the calorimeter and is found to be ±6% on the mass resolution.
- The contribution of pileup fluctuations to the cluster energy measurement is checked using random clusters in randomly triggered bunch crossings, with a frequency corresponding to expectations from the instantaneous luminosity. The relative uncertainty on the mass resolution is found to be less than 3%.
- The uncertainty on the resolution of the photon angle measurement is studied with $Z \to ee$ decays. The calorimeter-based direction measurement is compared with the much more precise track-based direction measurement. In the barrel calorimeter, the resolution measured in data agrees well with the one predicted by the simulation. In the end-cap region, the resolution measured in data is ≈ 20% worse than in the simulation. The impact of this difference is a 1% relative uncertainty on the diphoton mass resolution.

The total relative uncertainty on the diphoton invariant mass resolution is thus ±14%. This systematic uncertainty is applied to both the Crystal Ball and the wide Gaussian resolution parameters.

These systematic uncertainties are taken as fully correlated between the different categories. The impact of uncorrelated systematic uncertainties in the different categories and migration between categories has been investigated and found to be negligible.

The background is modelled by an exponentially falling invariant mass distribution. Systematic uncertainties arise from possible deviations of the background distribution from this assumed shape. This has been estimated by checking how accurately the chosen model fits different predicted diphoton mass distributions [49,50] and comparing different functional forms for the background model. The resulting uncertainty is between ±5 events at 110 GeV and ±3 events at 150 GeV for a Higgs boson mass signal region about 4 GeV wide.

6. Results

The data are compared to background and signal-plus-background hypotheses using a profile likelihood test statistic as described in Refs. [7,51]. The exponentially falling invariant mass distribution used for the background model is determined by two

Table 2
Fractions of background (f_b), predicted signal (f_s) and core Gaussian mass resolution (σ) in each category for a Higgs boson mass hypothesis of 120 GeV. The fractions are normalised to the total yield summed over categories.

Category	f_b	f_s	σ (GeV)
Unconverted central	7%	15%	1.4
Unconverted rest	29%	27%	1.6
Converted central	8%	11%	1.5
Converted transition	16%	13%	2.1
Converted rest	40%	34%	1.8

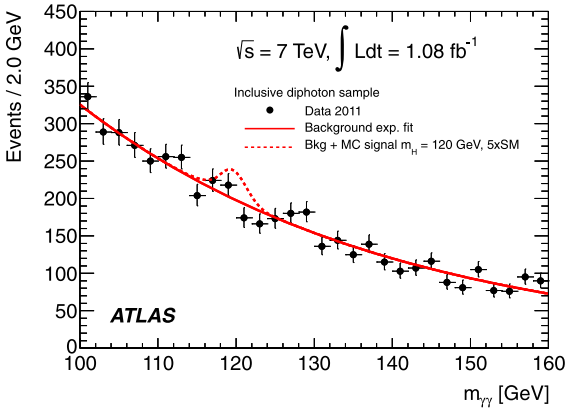

Fig. 3. Distribution of the reconstructed diphoton mass. All five diphoton categories have been combined. The exponential fit to the full sample of the background-only hypothesis, as well as the expected signal for a Higgs boson mass of 120 GeV with five times the Standard Model predicted yield, are also shown for illustration.

nuisance parameters per category (the normalisation and the exponential negative slope), which are left free in the unbinned fit. The signal is modelled with the mass resolution functions described above, one per category, fixing the fraction of events in each category to the MC predictions. Table 2 summarises the measured fractions of background events in each category, the predicted fractions of signal events and the predicted core Gaussian signal mass resolutions for a Higgs boson mass hypothesis of 120 GeV.

The fitted parameters for the signal are thus the overall signal strength relative to the Standard Model prediction and the nuisance parameters on the predicted event yield and mass resolution which have Gaussian constraints in the fit. The uncertainty on the predicted event yield includes both the experimental systematic uncertainties described in Section 5 and the uncertainty on the predicted cross-section described in Section 3. The systematic uncertainty on the background shape is included as another nuisance parameter with a Gaussian constraint in the fit. From this fit, the best estimate of the signal yield is extracted, as well as the likelihood ratio (profile likelihood) between any assumed signal yield (leaving the nuisance parameters free to maximise the likelihood) and the best estimate. The fit is performed in 1 GeV steps for the Higgs boson mass hypothesis, which is significantly smaller than the invariant mass resolution. The signal parameters for these fine mass steps are interpolated from the fully simulated samples.

Fig. 3 shows the reconstructed diphoton mass spectrum. No excess is visible. This is quantified by the p-value of the background-only hypothesis, which gives the fraction of background-only experiments that would have a profile likelihood ratio of the zero signal hypothesis relative to the best-fitted signal strength at least as low as the one found in the data. Negative signals are not allowed in the fit, so p-values above 0.5 are truncated. This p-value is shown in Fig. 4(a) as a function of the hypothesised Higgs boson mass. The minimal p-value, corresponding to the largest back-

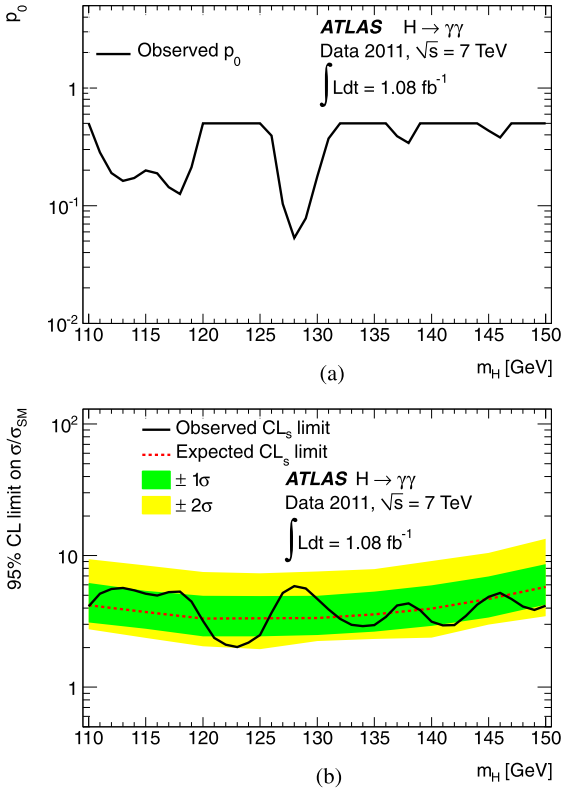

Fig. 4. (a) p-value (p_0) of the background-only hypothesis as a function of the investigated Higgs boson mass; (b) 95% confidence level upper limits on a Standard Model Higgs boson production cross-section, relative to the Standard Model cross-section, as a function of Higgs boson mass hypothesis. The solid line shows the observed limit. The dashed line shows the median expected limit for background-only pseudo-experiments, with the bands indicating the expected fluctuations around this limit at the 1σ and 2σ levels.

ground upward fluctuation, is ≈5% and is found for a hypothesised mass of ≈128 GeV. The probability for such an excess to appear anywhere in the investigated mass range is around 40%.

Exclusion limits on the inclusive production cross-section of a Standard Model Higgs boson relative to the Standard Model cross-section are derived. For this purpose, a modified frequentist approach CL_s [52], corresponding to the ratio of p-values for the signal-plus-background and the background-only hypothesis for a given assumed signal strength is used. A given signal strength is excluded at 95% confidence level if its CL_s is smaller than 0.05. The confidence levels are computed using a large number of signal-plus-background pseudo-experiments, with different signal yields, and background-only pseudo-experiments. The results, including systematic uncertainties, are shown in Fig. 4(b). The impact of the experimental systematic uncertainties is about 5% on the expected limit for the mass hypothesis of 120 GeV.

The expected median limit in the case of no signal varies from 3.3 to 5.8 as a function of the Higgs boson mass. The variations of the observed limit, between 2.0 and 5.8, are consistent with expected statistical fluctuations around the median limit.

7. Conclusions

A search for the Standard Model Higgs boson in the $H \to \gamma\gamma$ decay mode has been performed using an integrated luminosity of 1.08 fb^{-1} recorded by the ATLAS experiment in 2011. A high purity diphoton sample is selected. No excess is found in the diphoton invariant mass distribution in the mass range of 110-150 GeV. The observed limit on the cross-section of a Standard Model-like Higgs boson decaying into a pair of photons ranges between 2.0 and 5.8 times the Standard Model cross-section. These variations are compatible with statistical fluctuations around the expected limit for this data set. These limits are the most stringent to date in this channel.

Acknowledgements

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

We acknowledge the support of ANPCyT, Argentina; YerPhI, Armenia; ARC, Australia; BMWF, Austria; ANAS, Azerbaijan; SSTC, Belarus; CNPq and FAPESP, Brazil; NSERC, NRC and CFI, Canada; CERN; CONICYT, Chile; CAS, MOST and NSFC, China; COLCIENCIAS, Colombia; MSMT CR, MPO CR and VSC CR, Czech Republic; DNRF, DNSRC and Lundbeck Foundation, Denmark; ARTEMIS, European Union; IN2P3-CNRS, CEA-DSM/IRFU, France; GNAS, Georgia; BMBF, DFG, HGF, MPG and AvH Foundation, Germany; GSRT, Greece; ISF, MINERVA, GIF, DIP and Benoziyo Center, Israel; INFN, Italy; MEXT and JSPS, Japan; CNRST, Morocco; FOM and NWO, Netherlands; RCN, Norway; MNiSW, Poland; GRICES and FCT, Portugal; MERYS (MECTS), Romania; MES of Russia and ROSATOM, Russian Federation; JINR; MSTD, Serbia; MSSR, Slovakia; ARRS and MVZT, Slovenia; DST/NRF, South Africa; MICINN, Spain; SRC and Wallenberg Foundation, Sweden; SER, SNSF and Cantons of Bern and Geneva, Switzerland; NSC, Taiwan; TAEK, Turkey; STFC, the Royal Society and Leverhulme Trust, United Kingdom; DOE and NSF, United States.

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

Open access

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

References

[1] F. Englert, R. Brout, Phys. Rev. Lett. 13 (1963) 321.
[2] P.W. Higgs, Phys. Lett. 12 (1964) 132.
[3] G. Guralnik, C. Hagen, T. Kibble, Phys. Rev. Lett. 13 (1964) 585.
[4] The LEP Working Group for Higgs boson searches, R. Barate, et al., Phys. Lett. B 565 (2003) 61.
[5] The TEVNPH Working Group for the CDF and D0 Collaboration, Combined CDF and D0 upper limits on Standard Model Higgs boson production with up to 6.7 fb^{-1} of data, arXiv:1007.4587.
[6] The TEVNPH Working Group for the CDF and D0 Collaboration, Combined CDF and D0 upper limits on Standard Model Higgs boson production with up to 8.6 fb^{-1} of data, arXiv:1107.5518.
[7] ATLAS Collaboration, Eur. Phys. J. C 71 (2011) 1728.
[8] CMS Collaboration, Phys. Lett. B 699 (2011) 25.
[9] LHC Higgs cross-section working group, arXiv:1101.0593.
[10] D0 Collaboration, arXiv:1107.4587.
[11] CDF Collaboration, Search for a Standard Model Higgs Boson Decaying Into Photons at CDF Using 7.0 fb^{-1} of Data, CDF note CDF/PUB/EXOTIC/PUBLIC/10485.
[12] The TEVNPH Working Group for the CDF and D0 Collaboration, Combined CDF and D0 searches for the Standard Model Higgs boson decaying to two photons with up to 8.2 fb^{-1}, arXiv:1107.4960.
[13] ATLAS Collaboration, JINST 3 (2008) S08003.

[14] ATLAS Collaboration, Expected performance of the ATLAS experiment, detector, trigger and physics: Calibration and performance of the electromagnetic calorimeter CERN-OPEN-2008-020 (2008) 44.
[15] ATLAS Collaboration, Luminosity determination in pp collisions at $\sqrt{s} = 7$ TeV using the ATLAS detector in 2011, ATLAS-CONF-2011-116.
[16] S. Alioli, P. Nason, C. Oleari, E. Re, JHEP (2009) 002.
[17] S. Frixione, B.R. Webber, JHEP 0206 (2002) 029.
[18] P. Nason, C. Oleari, JHEP 1002 (2010) 037.
[19] T. Sjostrand, S. Mrenna, P.Z. Skands, JHEP 0605 (2006) 026.
[20] R.V. Harlander, W.B. Kilgore, Phys. Rev. Lett. 88 (2002) 201801.
[21] C. Anastasiou, K. Melnikov, Nucl. Phys. B 646 (2002) 220.
[22] V. Ravindran, J. Smith, W.L. van Neerven, Nucl. Phys. B 665 (2003) 325.
[23] C. Anastasiou, R. Boughezal, F. Petriello, JHEP 0904 (2009) 003.
[24] D. de Florian, M. Grazzini, Phys. Lett. B 674 (2009) 291.
[25] P. Bolzoni, F. Maltoni, S.-O. Moch, M. Zaro, Phys. Rev. Lett. 105 (2010) 011801.
[26] O. Brein, A. Djouadi, R. Harlander, Phys. Lett. B 579 (2004) 149.
[27] S. Dawson, L.H. Orr, L. Reina, D. Wackeroth, Phys. Rev. D 67 (2003) 071503.
[28] U. Aglietti, R. Bonciani, G. Degrassi, A. Vicini, Phys. Lett. B 595 (2004) 432.
[29] S. Actis, G. Passarino, C. Sturm, S. Uccirati, Phys. Lett. B 670 (2008) 12.
[30] M. Ciccolini, A. Denner, S. Dittmaier, Phys. Rev. Lett. 99 (2007) 161803.
[31] M. Ciccolini, A. Denner, S. Dittmaier, Phys. Rev. D 77 (2008) 013002.
[32] M.L. Ciccolini, S. Dittmaier, M. Krämer, Phys. Rev. D 68 (2003) 073003.
[33] M. Botje, J. Butterworth, A. Cooper-Sarkar, A. de Roeck, J. Feltesse, et al., The PDF4LHC working group interim recommendations, arXiv:1101.0538.
[34] H.-L. Lai, M. Guzzi, J. Huston, Z. Li, P.M. Nadolsky, et al., Phys. Rev. D 82 (2010) 074024.
[35] A.D. Martin, W.J. Stirling, R.S. Thorne, G. Watt, Eur. Phys. J. C 63 (2009) 189.
[36] R.D. Ball, V. Bertone, F. Cerutti, L. Del Debbio, S. Forte, et al., Nucl. Phys. B 849 (2011) 296.
[37] A. Djouadi, J. Kalinowski, M. Spira, Comput. Phys. Commun. 108 (1998) 56.
[38] M.L. Mangano, M. Moretti, F. Piccinini, R. Pittau, A.D. Polosa, JHEP 0307 (2003) 001.
[39] ATLAS Collaboration, Eur. Phys. J. C 70 (2010) 823.
[40] GEANT4 Collaboration, S. Agostinelli, et al., Nucl. Instrum. Meth. A 506 (2003) 250.
[41] ATLAS Collaboration, Electron performance measurements with the ATLAS detector using the 2010 LHC proton–proton collision data, Eur. Phys. J. C, submitted for publication.
[42] ATLAS Collaboration, Phys. Rev. D 83 (2011) 052005.
[43] M. Cacciari, G.P. Salam, G. Soyez, JHEP 0804 (2008) 005.
[44] J.E. Gaiser, Charmonium spectroscopy from radiative decays of the J/Ψ and Ψ', PhD Thesis, SLAC-R-255 (1982).
[45] ATLAS Collaboration, Measurement of the isolated di-photon cross-section in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector, Phys. Rev. D, in press.
[46] G. Bozzi, S. Catani, D. de Florian, M. Grazzini, Nucl. Phys. B 737 (2006) 73.
[47] C. Balazs, C.-P. Yuan, Phys. Lett. B 478 (2000) 192.
[48] Q.-H. Cao, C.-R. Chen, C. Schmidt, C.-P. Yuan, arXiv:0909.2305.
[49] T. Binoth, J. Guillet, E. Pilon, M. Werlen, Eur. Phys. J. C 16 (2000) 311.
[50] C. Balazs, E.L. Berger, P.M. Nadolsky, C.P. Yuan, Phys. Rev. D 76 (2007) 013009.
[51] G. Gowan, K. Cranmer, E. Gross, O. Vitells, Eur. Phys. J. C 71 (2011) 1.
[52] A.L. Read, J. Phys. G 28 (2002) 2693.

The ATLAS Collaboration

G. Aad [48], B. Abbott [111], J. Abdallah [11], A.A. Abdelalim [49], A. Abdesselam [118], O. Abdinov [10], B. Abi [112], M. Abolins [88], H. Abramowicz [153], H. Abreu [115], E. Acerbi [89a,89b], B.S. Acharya [164a,164b], D.L. Adams [24], T.N. Addy [56], J. Adelman [175], M. Aderholz [99], S. Adomeit [98], P. Adragna [75], T. Adye [129], S. Aefsky [22], J.A. Aguilar-Saavedra [124b,a], M. Aharrouche [81], S.P. Ahlen [21], F. Ahles [48], A. Ahmad [148], M. Ahsan [40], G. Aielli [133a,133b], T. Akdogan [18a], T.P.A. Åkesson [79], G. Akimoto [155], A.V. Akimov [94], A. Akiyama [67], M.S. Alam [1], M.A. Alam [76], J. Albert [169], S. Albrand [55], M. Aleksa [29], I.N. Aleksandrov [65], F. Alessandria [89a], C. Alexa [25a], G. Alexander [153], G. Alexandre [49], T. Alexopoulos [9], M. Alhroob [20], M. Aliev [15], G. Alimonti [89a], J. Alison [120], M. Aliyev [10], P.P. Allport [73], S.E. Allwood-Spiers [53], J. Almond [82], A. Aloisio [102a,102b], R. Alon [171], A. Alonso [79], M.G. Alviggi [102a,102b], K. Amako [66], P. Amaral [29], C. Amelung [22], V.V. Ammosov [128], A. Amorim [124a,b], G. Amorós [167], N. Amram [153], C. Anastopoulos [29], L.S. Ancu [16], N. Andari [115], T. Andeen [34], C.F. Anders [20], G. Anders [58a], K.J. Anderson [30], A. Andreazza [89a,89b], V. Andrei [58a], M.-L. Andrieux [55], X.S. Anduaga [70], A. Angerami [34], F. Anghinolfi [29], N. Anjos [124a], A. Annovi [47], A. Antonaki [8], M. Antonelli [47], A. Antonov [96], J. Antos [144b], F. Anulli [132a], S. Aoun [83], L. Aperio Bella [4], R. Apolle [118,c], G. Arabidze [88], I. Aracena [143], Y. Arai [66], A.T.H. Arce [44], J.P. Archambault [28], S. Arfaoui [29,d], J.-F. Arguin [14], E. Arik [18a,*], M. Arik [18a], A.J. Armbruster [87], O. Arnaez [81], C. Arnault [115], A. Artamonov [95], G. Artoni [132a,132b], D. Arutinov [20], S. Asai [155], R. Asfandiyarov [172], S. Ask [27], B. Åsman [146a,146b], L. Asquith [5], K. Assamagan [24], A. Astbury [169], A. Astvatsatourov [52], G. Atoian [175], B. Aubert [4], E. Auge [115], K. Augsten [127], M. Aurousseau [145a], N. Austin [73], G. Avolio [163], R. Avramidou [9], D. Axen [168], C. Ay [54], G. Azuelos [93,e], Y. Azuma [155], M.A. Baak [29], G. Baccaglioni [89a], C. Bacci [134a,134b], A.M. Bach [14], H. Bachacou [136], K. Bachas [29], G. Bachy [29], M. Backes [49], M. Backhaus [20], E. Badescu [25a], P. Bagnaia [132a,132b], S. Bahinipati [2], Y. Bai [32a], D.C. Bailey [158], T. Bain [158], J.T. Baines [129], O.K. Baker [175], M.D. Baker [24], S. Baker [77], E. Banas [38], P. Banerjee [93], Sw. Banerjee [172], D. Banfi [29], A. Bangert [137], V. Bansal [169], H.S. Bansil [17], L. Barak [171], S.P. Baranov [94], A. Barashkou [65], A. Barbaro Galtieri [14], T. Barber [27], E.L. Barberio [86], D. Barberis [50a,50b], M. Barbero [20], D.Y. Bardin [65], T. Barillari [99], M. Barisonzi [174], T. Barklow [143], N. Barlow [27], B.M. Barnett [129], R.M. Barnett [14], A. Baroncelli [134a], G. Barone [49], A.J. Barr [118], F. Barreiro [80], J. Barreiro Guimarães da Costa [57], P. Barrillon [115], R. Bartoldus [143], A.E. Barton [71], D. Bartsch [20], V. Bartsch [149], R.L. Bates [53], L. Batkova [144a], J.R. Batley [27], A. Battaglia [16], M. Battistin [29], G. Battistoni [89a], F. Bauer [136], H.S. Bawa [143,f], B. Beare [158], T. Beau [78], P.H. Beauchemin [118], R. Beccherle [50a], P. Bechtle [41], H.P. Beck [16], M. Beckingham [48], K.H. Becks [174], A.J. Beddall [18c], A. Beddall [18c], S. Bedikian [175], V.A. Bednyakov [65], C.P. Bee [83], M. Begel [24], S. Behar Harpaz [152], P.K. Behera [63], M. Beimforde [99], C. Belanger-Champagne [85], P.J. Bell [49], W.H. Bell [49], G. Bella [153],

L. Bellagamba [19a], F. Bellina [29], M. Bellomo [29], A. Belloni [57], O. Beloborodova [107], K. Belotskiy [96], O. Beltramello [29], S. Ben Ami [152], O. Benary [153], D. Benchekroun [135a], C. Benchouk [83], M. Bendel [81], N. Benekos [165], Y. Benhammou [153], D.P. Benjamin [44], M. Benoit [115], J.R. Bensinger [22], K. Benslama [130], S. Bentvelsen [105], D. Berge [29], E. Bergeaas Kuutmann [41], N. Berger [4], F. Berghaus [169], E. Berglund [49], J. Beringer [14], K. Bernardet [83], P. Bernat [77], R. Bernhard [48], C. Bernius [24], T. Berry [76], A. Bertin [19a,19b], F. Bertinelli [29], F. Bertolucci [122a,122b], M.I. Besana [89a,89b], N. Besson [136], S. Bethke [99], W. Bhimji [45], R.M. Bianchi [29], M. Bianco [72a,72b], O. Biebel [98], S.P. Bieniek [77], K. Bierwagen [54], J. Biesiada [14], M. Biglietti [134a,134b], H. Bilokon [47], M. Bindi [19a,19b], S. Binet [115], A. Bingul [18c], C. Bini [132a,132b], C. Biscarat [177], U. Bitenc [48], K.M. Black [21], R.E. Blair [5], J.-B. Blanchard [115], G. Blanchot [29], T. Blazek [144a], C. Blocker [22], J. Blocki [38], A. Blondel [49], W. Blum [81], U. Blumenschein [54], G.J. Bobbink [105], V.B. Bobrovnikov [107], S.S. Bocchetta [79], A. Bocci [44], C.R. Boddy [118], M. Boehler [41], J. Boek [174], N. Boelaert [35], S. Böser [77], J.A. Bogaerts [29], A. Bogdanchikov [107], A. Bogouch [90,*], C. Bohm [146a], V. Boisvert [76], T. Bold [163,g], V. Boldea [25a], N.M. Bolnet [136], M. Bona [75], V.G. Bondarenko [96], M. Bondioli [163], M. Boonekamp [136], G. Boorman [76], C.N. Booth [139], S. Bordoni [78], C. Borer [16], A. Borisov [128], G. Borissov [71], I. Borjanovic [12a], S. Borroni [132a,132b], K. Bos [105], D. Boscherini [19a], M. Bosman [11], H. Boterenbrood [105], D. Botterill [129], J. Bouchami [93], J. Boudreau [123], E.V. Bouhova-Thacker [71], C. Bourdarios [115], N. Bousson [83], A. Boveia [30], J. Boyd [29], I.R. Boyko [65], N.I. Bozhko [128], I. Bozovic-Jelisavcic [12b], J. Bracinik [17], A. Braem [29], P. Branchini [134a], G.W. Brandenburg [57], A. Brandt [7], G. Brandt [15], O. Brandt [54], U. Bratzler [156], B. Brau [84], J.E. Brau [114], H.M. Braun [174], B. Brelier [158], J. Bremer [29], R. Brenner [166], S. Bressler [152], D. Breton [115], D. Britton [53], F.M. Brochu [27], I. Brock [20], R. Brock [88], T.J. Brodbeck [71], E. Brodet [153], F. Broggi [89a], C. Bromberg [88], G. Brooijmans [34], W.K. Brooks [31b], G. Brown [82], H. Brown [7], P.A. Bruckman de Renstrom [38], D. Bruncko [144b], R. Bruneliere [48], S. Brunet [61], A. Bruni [19a], G. Bruni [19a], M. Bruschi [19a], T. Buanes [13], F. Bucci [49], J. Buchanan [118], N.J. Buchanan [2], P. Buchholz [141], R.M. Buckingham [118], A.G. Buckley [45], S.I. Buda [25a], I.A. Budagov [65], B. Budick [108], V. Büscher [81], L. Bugge [117], D. Buira-Clark [118], O. Bulekov [96], M. Bunse [42], T. Buran [117], H. Burckhart [29], S. Burdin [73], T. Burgess [13], S. Burke [129], E. Busato [33], P. Bussey [53], C.P. Buszello [166], F. Butin [29], B. Butler [143], J.M. Butler [21], C.M. Buttar [53], J.M. Butterworth [77], W. Buttinger [27], T. Byatt [77], S. Cabrera Urbán [167], D. Caforio [19a,19b], O. Cakir [3a], P. Calafiura [14], G. Calderini [78], P. Calfayan [98], R. Calkins [106], L.P. Caloba [23a], R. Caloi [132a,132b], D. Calvet [33], S. Calvet [33], R. Camacho Toro [33], P. Camarri [133a,133b], M. Cambiaghi [119a,119b], D. Cameron [117], S. Campana [29], M. Campanelli [77], V. Canale [102a,102b], F. Canelli [30,h], A. Canepa [159a], J. Cantero [80], L. Capasso [102a,102b], M.D.M. Capeans Garrido [29], I. Caprini [25a], M. Caprini [25a], D. Capriotti [99], M. Capua [36a,36b], R. Caputo [148], R. Cardarelli [133a], T. Carli [29], G. Carlino [102a], L. Carminati [89a,89b], B. Caron [159a], S. Caron [48], G.D. Carrillo Montoya [172], A.A. Carter [75], J.R. Carter [27], J. Carvalho [124a,i], D. Casadei [108], M.P. Casado [11], M. Cascella [122a,122b], C. Caso [50a,50b,*], A.M. Castaneda Hernandez [172], E. Castaneda-Miranda [172], V. Castillo Gimenez [167], N.F. Castro [124a], G. Cataldi [72a], F. Cataneo [29], A. Catinaccio [29], J.R. Catmore [71], A. Cattai [29], G. Cattani [133a,133b], S. Caughron [88], D. Cauz [164a,164c], P. Cavalleri [78], D. Cavalli [89a], M. Cavalli-Sforza [11], V. Cavasinni [122a,122b], F. Ceradini [134a,134b], A.S. Cerqueira [23a], A. Cerri [29], L. Cerrito [75], F. Cerutti [47], S.A. Cetin [18b], F. Cevenini [102a,102b], A. Chafaq [135a], D. Chakraborty [106], K. Chan [2], B. Chapleau [85], J.D. Chapman [27], J.W. Chapman [87], E. Chareyre [78], D.G. Charlton [17], V. Chavda [82], C.A. Chavez Barajas [29], S. Cheatham [85], S. Chekanov [5], S.V. Chekulaev [159a], G.A. Chelkov [65], M.A. Chelstowska [104], C. Chen [64], H. Chen [24], S. Chen [32c], T. Chen [32c], X. Chen [172], S. Cheng [32a], A. Cheplakov [65], V.F. Chepurnov [65], R. Cherkaoui El Moursli [135e], V. Chernyatin [24], E. Cheu [6], S.L. Cheung [158], L. Chevalier [136], G. Chiefari [102a,102b], L. Chikovani [51], J.T. Childers [58a], A. Chilingarov [71], G. Chiodini [72a], M.V. Chizhov [65], G. Choudalakis [30], S. Chouridou [137], I.A. Christidi [77], A. Christov [48], D. Chromek-Burckhart [29], M.L. Chu [151], J. Chudoba [125], G. Ciapetti [132a,132b], K. Ciba [37], A.K. Ciftci [3a], R. Ciftci [3a], D. Cinca [33], V. Cindro [74], M.D. Ciobotaru [163], C. Ciocca [19a,19b], A. Ciocio [14], M. Cirilli [87], M. Ciubancan [25a], A. Clark [49], P.J. Clark [45], W. Cleland [123], J.C. Clemens [83], B. Clement [55], C. Clement [146a,146b], R.W. Clifft [129], Y. Coadou [83], M. Cobal [164a,164c], A. Coccaro [50a,50b], J. Cochran [64], P. Coe [118], J.G. Cogan [143], J. Coggeshall [165], E. Cogneras [177], C.D. Cojocaru [28], J. Colas [4], A.P. Colijn [105], C. Collard [115], N.J. Collins [17], C. Collins-Tooth [53], J. Collot [55], G. Colon [84], P. Conde Muiño [124a], E. Coniavitis [118], M.C. Conidi [11], M. Consonni [104], V. Consorti [48], S. Constantinescu [25a], C. Conta [119a,119b], F. Conventi [102a,j], J. Cook [29], M. Cooke [14], B.D. Cooper [77], A.M. Cooper-Sarkar [118], N.J. Cooper-Smith [76],

K. Copic [34], T. Cornelissen [50a,50b], M. Corradi [19a], F. Corriveau [85,k], A. Cortes-Gonzalez [165], G. Cortiana [99], G. Costa [89a], M.J. Costa [167], D. Costanzo [139], T. Costin [30], D. Côté [29], L. Courneyea [169], G. Cowan [76], C. Cowden [27], B.E. Cox [82], K. Cranmer [108], F. Crescioli [122a,122b], M. Cristinziani [20], G. Crosetti [36a,36b], R. Crupi [72a,72b], S. Crépé-Renaudin [55], C.-M. Cuciuc [25a], C. Cuenca Almenar [175], T. Cuhadar Donszelmann [139], M. Curatolo [47], C.J. Curtis [17], P. Cwetanski [61], H. Czirr [141], Z. Czyczula [117], S. D'Auria [53], M. D'Onofrio [73], A. D'Orazio [132a,132b], P.V.M. Da Silva [23a], C. Da Via [82], W. Dabrowski [37], T. Dai [87], C. Dallapiccola [84], M. Dam [35], M. Dameri [50a,50b], D.S. Damiani [137], H.O. Danielsson [29], D. Dannheim [99], V. Dao [49], G. Darbo [50a], G.L. Darlea [25b], C. Daum [105], J.P. Dauvergne [29], W. Davey [86], T. Davidek [126], N. Davidson [86], R. Davidson [71], E. Davies [118,c], M. Davies [93], A.R. Davison [77], Y. Davygora [58a], E. Dawe [142], I. Dawson [139], J.W. Dawson [5,*], R.K. Daya [39], K. De [7], R. de Asmundis [102a], S. De Castro [19a,19b], P.E. De Castro Faria Salgado [24], S. De Cecco [78], J. de Graat [98], N. De Groot [104], P. de Jong [105], C. De La Taille [115], H. De la Torre [80], B. De Lotto [164a,164c], L. De Mora [71], L. De Nooij [105], D. De Pedis [132a], A. De Salvo [132a], U. De Sanctis [164a,164c], A. De Santo [149], J.B. De Vivie De Regie [115], S. Dean [77], R. Debbe [24], D.V. Dedovich [65], J. Degenhardt [120], M. Dehchar [118], C. Del Papa [164a,164c], J. Del Peso [80], T. Del Prete [122a,122b], M. Deliyergiyev [74], A. Dell'Acqua [29], L. Dell'Asta [89a,89b], M. Della Pietra [102a,j], D. della Volpe [102a,102b], M. Delmastro [29], P. Delpierre [83], N. Delruelle [29], P.A. Delsart [55], C. Deluca [148], S. Demers [175], M. Demichev [65], B. Demirkoz [11,l], J. Deng [163], S.P. Denisov [128], D. Derendarz [38], J.E. Derkaoui [135d], F. Derue [78], P. Dervan [73], K. Desch [20], E. Devetak [148], P.O. Deviveiros [158], A. Dewhurst [129], B. DeWilde [148], S. Dhaliwal [158], R. Dhullipudi [24,m], A. Di Ciaccio [133a,133b], L. Di Ciaccio [4], A. Di Girolamo [29], B. Di Girolamo [29], S. Di Luise [134a,134b], A. Di Mattia [88], B. Di Micco [29], R. Di Nardo [133a,133b], A. Di Simone [133a,133b], R. Di Sipio [19a,19b], M.A. Diaz [31a], F. Diblen [18c], E.B. Diehl [87], J. Dietrich [41], T.A. Dietzsch [58a], S. Diglio [115], K. Dindar Yagci [39], J. Dingfelder [20], C. Dionisi [132a,132b], P. Dita [25a], S. Dita [25a], F. Dittus [29], F. Djama [83], T. Djobava [51], M.A.B. do Vale [23a], A. Do Valle Wemans [124a], T.K.O. Doan [4], M. Dobbs [85], R. Dobinson [29,*], D. Dobos [42], E. Dobson [29], M. Dobson [163], J. Dodd [34], C. Doglioni [118], T. Doherty [53], Y. Doi [66,*], J. Dolejsi [126], I. Dolenc [74], Z. Dolezal [126], B.A. Dolgoshein [96,*], T. Dohmae [155], M. Donadelli [23d], M. Donega [120], J. Donini [55], J. Dopke [29], A. Doria [102a], A. Dos Anjos [172], M. Dosil [11], A. Dotti [122a,122b], M.T. Dova [70], J.D. Dowell [17], A.D. Doxiadis [105], A.T. Doyle [53], Z. Drasal [126], J. Drees [174], N. Dressnandt [120], H. Drevermann [29], C. Driouichi [35], M. Dris [9], J. Dubbert [99], T. Dubbs [137], S. Dube [14], E. Duchovni [171], G. Duckeck [98], A. Dudarev [29], F. Dudziak [64], M. Dührssen [29], I.P. Duerdoth [82], L. Duflot [115], M.-A. Dufour [85], M. Dunford [29], H. Duran Yildiz [3b], R. Duxfield [139], M. Dwuznik [37], F. Dydak [29], M. Düren [52], W.L. Ebenstein [44], J. Ebke [98], S. Eckert [48], S. Eckweiler [81], K. Edmonds [81], C.A. Edwards [76], N.C. Edwards [53], W. Ehrenfeld [41], T. Ehrich [99], T. Eifert [29], G. Eigen [13], K. Einsweiler [14], E. Eisenhandler [75], T. Ekelof [166], M. El Kacimi [135c], M. Ellert [166], S. Elles [4], F. Ellinghaus [81], K. Ellis [75], N. Ellis [29], J. Elmsheuser [98], M. Elsing [29], D. Emeliyanov [129], R. Engelmann [148], A. Engl [98], B. Epp [62], A. Eppig [87], J. Erdmann [54], A. Ereditato [16], D. Eriksson [146a], J. Ernst [1], M. Ernst [24], J. Ernwein [136], D. Errede [165], S. Errede [165], E. Ertel [81], M. Escalier [115], C. Escobar [167], X. Espinal Curull [11], B. Esposito [47], F. Etienne [83], A.I. Etienvre [136], E. Etzion [153], D. Evangelakou [54], H. Evans [61], L. Fabbri [19a,19b], C. Fabre [29], R.M. Fakhrutdinov [128], S. Falciano [132a], Y. Fang [172], M. Fanti [89a,89b], A. Farbin [7], A. Farilla [134a], J. Farley [148], T. Farooque [158], S.M. Farrington [118], P. Farthouat [29], P. Fassnacht [29], D. Fassouliotis [8], B. Fatholahzadeh [158], A. Favareto [89a,89b], L. Fayard [115], S. Fazio [36a,36b], R. Febbraro [33], P. Federic [144a], O.L. Fedin [121], W. Fedorko [88], M. Fehling-Kaschek [48], L. Feligioni [83], D. Fellmann [5], C.U. Felzmann [86], C. Feng [32d], E.J. Feng [30], A.B. Fenyuk [128], J. Ferencei [144b], J. Ferland [93], W. Fernando [109], S. Ferrag [53], J. Ferrando [53], V. Ferrara [41], A. Ferrari [166], P. Ferrari [105], R. Ferrari [119a], A. Ferrer [167], M.L. Ferrer [47], D. Ferrere [49], C. Ferretti [87], A. Ferretto Parodi [50a,50b], M. Fiascaris [30], F. Fiedler [81], A. Filipčič [74], A. Filippas [9], F. Filthaut [104], M. Fincke-Keeler [169], M.C.N. Fiolhais [124a,i], L. Fiorini [167], A. Firan [39], G. Fischer [41], P. Fischer [20], M.J. Fisher [109], S.M. Fisher [129], M. Flechl [48], I. Fleck [141], J. Fleckner [81], P. Fleischmann [173], S. Fleischmann [174], T. Flick [174], L.R. Flores Castillo [172], M.J. Flowerdew [99], M. Fokitis [9], T. Fonseca Martin [16], D.A. Forbush [138], A. Formica [136], A. Forti [82], D. Fortin [159a], J.M. Foster [82], D. Fournier [115], A. Foussat [29], A.J. Fowler [44], K. Fowler [137], H. Fox [71], P. Francavilla [122a,122b], S. Franchino [119a,119b], D. Francis [29], T. Frank [171], M. Franklin [57], S. Franz [29], M. Fraternali [119a,119b], S. Fratina [120], S.T. French [27], F. Friedrich [43], R. Froeschl [29], D. Froidevaux [29], J.A. Frost [27], C. Fukunaga [156], E. Fullana Torregrosa [29], J. Fuster [167], C. Gabaldon [29], O. Gabizon [171], T. Gadfort [24], S. Gadomski [49], G. Gagliardi [50a,50b], P. Gagnon [61], C. Galea [98],

E.J. Gallas [118], M.V. Gallas [29], V. Gallo [16], B.J. Gallop [129], P. Gallus [125], E. Galyaev [40], K.K. Gan [109], Y.S. Gao [143,f], V.A. Gapienko [128], A. Gaponenko [14], F. Garberson [175], M. Garcia-Sciveres [14], C. García [167], J.E. García Navarro [49], R.W. Gardner [30], N. Garelli [29], H. Garitaonandia [105], V. Garonne [29], J. Garvey [17], C. Gatti [47], G. Gaudio [119a], O. Gaumer [49], B. Gaur [141], L. Gauthier [136], I.L. Gavrilenko [94], C. Gay [168], G. Gaycken [20], J.-C. Gayde [29], E.N. Gazis [9], P. Ge [32d], C.N.P. Gee [129], D.A.A. Geerts [105], Ch. Geich-Gimbel [20], K. Gellerstedt [146a,146b], C. Gemme [50a], A. Gemmell [53], M.H. Genest [98], S. Gentile [132a,132b], M. George [54], S. George [76], P. Gerlach [174], A. Gershon [153], C. Geweniger [58a], H. Ghazlane [135b], P. Ghez [4], N. Ghodbane [33], B. Giacobbe [19a], S. Giagu [132a,132b], V. Giakoumopoulou [8], V. Giangiobbe [122a,122b], F. Gianotti [29], B. Gibbard [24], A. Gibson [158], S.M. Gibson [29], L.M. Gilbert [118], M. Gilchriese [14], V. Gilewsky [91], D. Gillberg [28], A.R. Gillman [129], D.M. Gingrich [2,e], J. Ginzburg [153], N. Giokaris [8], M.P. Giordani [164c], R. Giordano [102a,102b], F.M. Giorgi [15], P. Giovannini [99], P.F. Giraud [136], D. Giugni [89a], M. Giunta [93], P. Giusti [19a], B.K. Gjelsten [117], L.K. Gladilin [97], C. Glasman [80], J. Glatzer [48], A. Glazov [41], K.W. Glitza [174], G.L. Glonti [65], J. Godfrey [142], J. Godlewski [29], M. Goebel [41], T. Göpfert [43], C. Goeringer [81], C. Gössling [42], T. Göttfert [99], S. Goldfarb [87], T. Golling [175], S.N. Golovnia [128], A. Gomes [124a,b], L.S. Gomez Fajardo [41], R. Gonçalo [76], J. Goncalves Pinto Firmino Da Costa [41], L. Gonella [20], A. Gonidec [29], S. Gonzalez [172], S. González de la Hoz [167], M.L. Gonzalez Silva [26], S. Gonzalez-Sevilla [49], J.J. Goodson [148], L. Goossens [29], P.A. Gorbounov [95], H.A. Gordon [24], I. Gorelov [103], G. Gorfine [174], B. Gorini [29], E. Gorini [72a,72b], A. Gorišek [74], E. Gornicki [38], S.A. Gorokhov [128], V.N. Goryachev [128], B. Gosdzik [41], M. Gosselink [105], M.I. Gostkin [65], I. Gough Eschrich [163], M. Gouighri [135a], D. Goujdami [135c], M.P. Goulette [49], A.G. Goussiou [138], C. Goy [4], I. Grabowska-Bold [163,g], V. Grabski [176], P. Grafström [29], C. Grah [174], K.-J. Grahn [41], F. Grancagnolo [72a], S. Grancagnolo [15], V. Grassi [148], V. Gratchev [121], N. Grau [34], H.M. Gray [29], J.A. Gray [148], E. Graziani [134a], O.G. Grebenyuk [121], D. Greenfield [129], T. Greenshaw [73], Z.D. Greenwood [24,m], K. Gregersen [35], I.M. Gregor [41], P. Grenier [143], J. Griffiths [138], N. Grigalashvili [65], A.A. Grillo [137], S. Grinstein [11], Y.V. Grishkevich [97], J.-F. Grivaz [115], J. Grognuz [29], M. Groh [99], E. Gross [171], J. Grosse-Knetter [54], J. Groth-Jensen [171], K. Grybel [141], V.J. Guarino [5], D. Guest [175], C. Guicheney [33], A. Guida [72a,72b], T. Guillemin [4], S. Guindon [54], H. Guler [85,n], J. Gunther [125], B. Guo [158], J. Guo [34], A. Gupta [30], Y. Gusakov [65], V.N. Gushchin [128], A. Gutierrez [93], P. Gutierrez [111], N. Guttman [153], O. Gutzwiller [172], C. Guyot [136], C. Gwenlan [118], C.B. Gwilliam [73], A. Haas [143], S. Haas [29], C. Haber [14], R. Hackenburg [24], H.K. Hadavand [39], D.R. Hadley [17], P. Haefner [99], F. Hahn [29], S. Haider [29], Z. Hajduk [38], H. Hakobyan [176], J. Haller [54], K. Hamacher [174], P. Hamal [113], A. Hamilton [49], S. Hamilton [161], H. Han [32a], L. Han [32b], K. Hanagaki [116], M. Hance [120], C. Handel [81], P. Hanke [58a], J.R. Hansen [35], J.B. Hansen [35], J.D. Hansen [35], P.H. Hansen [35], P. Hansson [143], K. Hara [160], G.A. Hare [137], T. Harenberg [174], S. Harkusha [90], D. Harper [87], R.D. Harrington [21], O.M. Harris [138], K. Harrison [17], J. Hartert [48], F. Hartjes [105], T. Haruyama [66], A. Harvey [56], S. Hasegawa [101], Y. Hasegawa [140], S. Hassani [136], M. Hatch [29], D. Hauff [99], S. Haug [16], M. Hauschild [29], R. Hauser [88], M. Havranek [20], B.M. Hawes [118], C.M. Hawkes [17], R.J. Hawkings [29], D. Hawkins [163], T. Hayakawa [67], D. Hayden [76], H.S. Hayward [73], S.J. Haywood [129], E. Hazen [21], M. He [32d], S.J. Head [17], V. Hedberg [79], L. Heelan [7], S. Heim [88], B. Heinemann [14], S. Heisterkamp [35], L. Helary [4], M. Heller [115], S. Hellman [146a,146b], D. Hellmich [20], C. Helsens [11], R.C.W. Henderson [71], M. Henke [58a], A. Henrichs [54], A.M. Henriques Correia [29], S. Henrot-Versille [115], F. Henry-Couannier [83], C. Hensel [54], T. Henß [174], C.M. Hernandez [7], Y. Hernández Jiménez [167], R. Herrberg [15], A.D. Hershenhorn [152], G. Herten [48], R. Hertenberger [98], L. Hervas [29], N.P. Hessey [105], A. Hidvegi [146a], E. Higón-Rodriguez [167], D. Hill [5,*], J.C. Hill [27], N. Hill [5], K.H. Hiller [41], S. Hillert [20], S.J. Hillier [17], I. Hinchliffe [14], E. Hines [120], M. Hirose [116], F. Hirsch [42], D. Hirschbuehl [174], J. Hobbs [148], N. Hod [153], M.C. Hodgkinson [139], P. Hodgson [139], A. Hoecker [29], M.R. Hoeferkamp [103], J. Hoffman [39], D. Hoffmann [83], M. Hohlfeld [81], M. Holder [141], S.O. Holmgren [146a], T. Holy [127], J.L. Holzbauer [88], Y. Homma [67], T.M. Hong [120], L. Hooft van Huysduynen [108], T. Horazdovsky [127], C. Horn [143], S. Horner [48], K. Horton [118], J.-Y. Hostachy [55], S. Hou [151], M.A. Houlden [73], A. Hoummada [135a], J. Howarth [82], D.F. Howell [118], I. Hristova [15], J. Hrivnac [115], I. Hruska [125], T. Hryn'ova [4], P.J. Hsu [175], S.-C. Hsu [14], G.S. Huang [111], Z. Hubacek [127], F. Hubaut [83], F. Huegging [20], T.B. Huffman [118], E.W. Hughes [34], G. Hughes [71], R.E. Hughes-Jones [82], M. Huhtinen [29], P. Hurst [57], M. Hurwitz [14], U. Husemann [41], N. Huseynov [65,o], J. Huston [88], J. Huth [57], G. Iacobucci [49], G. Iakovidis [9], M. Ibbotson [82], I. Ibragimov [141], R. Ichimiya [67], L. Iconomidou-Fayard [115], J. Idarraga [115], M. Idzik [37], P. Iengo [102a,102b], O. Igonkina [105], Y. Ikegami [66], M. Ikeno [66], Y. Ilchenko [39], D. Iliadis [154],

D. Imbault [78], M. Imhaeuser [174], M. Imori [155], T. Ince [20], J. Inigo-Golfin [29], P. Ioannou [8], M. Iodice [134a], G. Ionescu [4], A. Irles Quiles [167], K. Ishii [66], A. Ishikawa [67], M. Ishino [68], R. Ishmukhametov [39], C. Issever [118], S. Istin [18a], A.V. Ivashin [128], W. Iwanski [38], H. Iwasaki [66], J.M. Izen [40], V. Izzo [102a], B. Jackson [120], J.N. Jackson [73], P. Jackson [143], M.R. Jaekel [29], V. Jain [61], K. Jakobs [48], S. Jakobsen [35], J. Jakubek [127], D.K. Jana [111], E. Jankowski [158], E. Jansen [77], A. Jantsch [99], M. Janus [20], G. Jarlskog [79], L. Jeanty [57], K. Jelen [37], I. Jen-La Plante [30], P. Jenni [29], A. Jeremie [4], P. Jež [35], S. Jézéquel [4], M.K. Jha [19a], H. Ji [172], W. Ji [81], J. Jia [148], Y. Jiang [32b], M. Jimenez Belenguer [41], G. Jin [32b], S. Jin [32a], O. Jinnouchi [157], M.D. Joergensen [35], D. Joffe [39], L.G. Johansen [13], M. Johansen [146a,146b], K.E. Johansson [146a], P. Johansson [139], S. Johnert [41], K.A. Johns [6], K. Jon-And [146a,146b], G. Jones [82], R.W.L. Jones [71], T.W. Jones [77], T.J. Jones [73], O. Jonsson [29], C. Joram [29], P.M. Jorge [124a,b], J. Joseph [14], T. Jovin [12b], X. Ju [130], V. Juranek [125], P. Jussel [62], A. Juste Rozas [11], V.V. Kabachenko [128], S. Kabana [16], M. Kaci [167], A. Kaczmarska [38], P. Kadlecik [35], M. Kado [115], H. Kagan [109], M. Kagan [57], S. Kaiser [99], E. Kajomovitz [152], S. Kalinin [174], L.V. Kalinovskaya [65], S. Kama [39], N. Kanaya [155], M. Kaneda [29], T. Kanno [157], V.A. Kantserov [96], J. Kanzaki [66], B. Kaplan [175], A. Kapliy [30], J. Kaplon [29], D. Kar [43], M. Karagoz [118], M. Karnevskiy [41], K. Karr [5], V. Kartvelishvili [71], A.N. Karyukhin [128], L. Kashif [172], A. Kasmi [39], R.D. Kass [109], A. Kastanas [13], M. Kataoka [4], Y. Kataoka [155], E. Katsoufis [9], J. Katzy [41], V. Kaushik [6], K. Kawagoe [67], T. Kawamoto [155], G. Kawamura [81], M.S. Kayl [105], V.A. Kazanin [107], M.Y. Kazarinov [65], J.R. Keates [82], R. Keeler [169], R. Kehoe [39], M. Keil [54], G.D. Kekelidze [65], M. Kelly [82], J. Kennedy [98], C.J. Kenney [143], M. Kenyon [53], O. Kepka [125], N. Kerschen [29], B.P. Kerševan [74], S. Kersten [174], K. Kessoku [155], C. Ketterer [48], J. Keung [158], M. Khakzad [28], F. Khalil-zada [10], H. Khandanyan [165], A. Khanov [112], D. Kharchenko [65], A. Khodinov [96], A.G. Kholodenko [128], A. Khomich [58a], T.J. Khoo [27], G. Khoriauli [20], A. Khoroshilov [174], N. Khovanskiy [65], V. Khovanskiy [95], E. Khramov [65], J. Khubua [51], H. Kim [7], M.S. Kim [2], P.C. Kim [143], S.H. Kim [160], N. Kimura [170], O. Kind [15], B.T. King [73], M. King [67], R.S.B. King [118], J. Kirk [129], L.E. Kirsch [22], A.E. Kiryunin [99], T. Kishimoto [67], D. Kisielewska [37], T. Kittelmann [123], A.M. Kiver [128], E. Kladiva [144b], J. Klaiber-Lodewigs [42], M. Klein [73], U. Klein [73], K. Kleinknecht [81], M. Klemetti [85], A. Klier [171], A. Klimentov [24], R. Klingenberg [42], E.B. Klinkby [35], T. Klioutchnikova [29], P.F. Klok [104], S. Klous [105], E.-E. Kluge [58a], T. Kluge [73], P. Kluit [105], S. Kluth [99], N.S. Knecht [158], E. Kneringer [62], J. Knobloch [29], E.B.F.G. Knoops [83], A. Knue [54], B.R. Ko [44], T. Kobayashi [155], M. Kobel [43], M. Kocian [143], A. Kocnar [113], P. Kodys [126], K. Köneke [29], A.C. König [104], S. Koenig [81], L. Köpke [81], F. Koetsveld [104], P. Koevesarki [20], T. Koffas [28], E. Koffeman [105], F. Kohn [54], Z. Kohout [127], T. Kohriki [66], T. Koi [143], T. Kokott [20], G.M. Kolachev [107], H. Kolanoski [15], V. Kolesnikov [65], I. Koletsou [89a], J. Koll [88], D. Kollar [29], M. Kollefrath [48], S.D. Kolya [82], A.A. Komar [94], Y. Komori [155], T. Kondo [66], T. Kono [41,p], A.I. Kononov [48], R. Konoplich [108,q], N. Konstantinidis [77], A. Kootz [174], S. Koperny [37], S.V. Kopikov [128], K. Korcyl [38], K. Kordas [154], V. Koreshev [128], A. Korn [118], A. Korol [107], I. Korolkov [11], E.V. Korolkova [139], V.A. Korotkov [128], O. Kortner [99], S. Kortner [99], V.V. Kostyukhin [20], M.J. Kotamäki [29], S. Kotov [99], V.M. Kotov [65], A. Kotwal [44], C. Kourkoumelis [8], V. Kouskoura [154], A. Koutsman [105], R. Kowalewski [169], T.Z. Kowalski [37], W. Kozanecki [136], A.S. Kozhin [128], V. Kral [127], V.A. Kramarenko [97], G. Kramberger [74], M.W. Krasny [78], A. Krasznahorkay [108], J. Kraus [88], A. Kreisel [153], F. Krejci [127], J. Kretzschmar [73], N. Krieger [54], P. Krieger [158], K. Kroeninger [54], H. Kroha [99], J. Kroll [120], J. Kroseberg [20], J. Krstic [12a], U. Kruchonak [65], H. Krüger [20], T. Kruker [16], Z.V. Krumshteyn [65], A. Kruth [20], T. Kubota [86], S. Kuehn [48], A. Kugel [58c], T. Kuhl [41], D. Kuhn [62], V. Kukhtin [65], Y. Kulchitsky [90], S. Kuleshov [31b], C. Kummer [98], M. Kuna [78], N. Kundu [118], J. Kunkle [120], A. Kupco [125], H. Kurashige [67], M. Kurata [160], Y.A. Kurochkin [90], V. Kus [125], W. Kuykendall [138], M. Kuze [157], P. Kuzhir [91], J. Kvita [29], R. Kwee [15], A. La Rosa [172], L. La Rotonda [36a,36b], L. Labarga [80], J. Labbe [4], S. Lablak [135a], C. Lacasta [167], F. Lacava [132a,132b], H. Lacker [15], D. Lacour [78], V.R. Lacuesta [167], E. Ladygin [65], R. Lafaye [4], B. Laforge [78], T. Lagouri [80], S. Lai [48], E. Laisne [55], M. Lamanna [29], C.L. Lampen [6], W. Lampl [6], E. Lancon [136], U. Landgraf [48], M.P.J. Landon [75], H. Landsman [152], J.L. Lane [82], C. Lange [41], A.J. Lankford [163], F. Lanni [24], K. Lantzsch [29], S. Laplace [78], C. Lapoire [20], J.F. Laporte [136], T. Lari [89a], A.V. Larionov [128], A. Larner [118], C. Lasseur [29], M. Lassnig [29], P. Laurelli [47], A. Lavorato [118], W. Lavrijsen [14], P. Laycock [73], A.B. Lazarev [65], O. Le Dortz [78], E. Le Guirriec [83], C. Le Maner [158], E. Le Menedeu [136], C. Lebel [93], T. LeCompte [5], F. Ledroit-Guillon [55], H. Lee [105], J.S.H. Lee [150], S.C. Lee [151], L. Lee [175], M. Lefebvre [169], M. Legendre [136], A. Leger [49], B.C. LeGeyt [120], F. Legger [98], C. Leggett [14], M. Lehmacher [20], G. Lehmann Miotto [29], X. Lei [6], M.A.L. Leite [23d], R. Leitner [126], D. Lellouch [171], M. Leltchouk [34], B. Lemmer [54], V. Lendermann [58a], K.J.C. Leney [145b], T. Lenz [105],

G. Lenzen [174], B. Lenzi [29], K. Leonhardt [43], S. Leontsinis [9], C. Leroy [93], J.-R. Lessard [169], J. Lesser [146a], C.G. Lester [27], A. Leung Fook Cheong [172], J. Levêque [4], D. Levin [87], L.J. Levinson [171], M.S. Levitski [128], M. Lewandowska [21], A. Lewis [118], G.H. Lewis [108], A.M. Leyko [20], M. Leyton [15], B. Li [83], H. Li [172], S. Li [32b,d], X. Li [87], Z. Liang [39], Z. Liang [118,r], H. Liao [33], B. Liberti [133a], P. Lichard [29], M. Lichtnecker [98], K. Lie [165], W. Liebig [13], R. Lifshitz [152], J.N. Lilley [17], C. Limbach [20], A. Limosani [86], M. Limper [63], S.C. Lin [151,s], F. Linde [105], J.T. Linnemann [88], E. Lipeles [120], L. Lipinsky [125], A. Lipniacka [13], T.M. Liss [165], D. Lissauer [24], A. Lister [49], A.M. Litke [137], C. Liu [28], D. Liu [151,t], H. Liu [87], J.B. Liu [87], M. Liu [32b], S. Liu [2], Y. Liu [32b], M. Livan [119a,119b], S.S.A. Livermore [118], A. Lleres [55], J. Llorente Merino [80], S.L. Lloyd [75], E. Lobodzinska [41], P. Loch [6], W.S. Lockman [137], T. Loddenkoetter [20], F.K. Loebinger [82], A. Loginov [175], C.W. Loh [168], T. Lohse [15], K. Lohwasser [48], M. Lokajicek [125], J. Loken [118], V.P. Lombardo [4], R.E. Long [71], L. Lopes [124a,b], D. Lopez Mateos [57], M. Losada [162], P. Loscutoff [14], F. Lo Sterzo [132a,132b], M.J. Losty [159a], X. Lou [40], A. Lounis [115], K.F. Loureiro [162], J. Love [21], P.A. Love [71], A.J. Lowe [143,f], F. Lu [32a], H.J. Lubatti [138], C. Luci [132a,132b], A. Lucotte [55], A. Ludwig [43], D. Ludwig [41], I. Ludwig [48], J. Ludwig [48], F. Luehring [61], G. Luijckx [105], D. Lumb [48], L. Luminari [132a], E. Lund [117], B. Lund-Jensen [147], B. Lundberg [79], J. Lundberg [146a,146b], J. Lundquist [35], M. Lungwitz [81], A. Lupi [122a,122b], G. Lutz [99], D. Lynn [24], J. Lys [14], E. Lytken [79], H. Ma [24], L.L. Ma [172], J.A. Macana Goia [93], G. Maccarrone [47], A. Macchiolo [99], B. Maček [74], J. Machado Miguens [124a], R. Mackeprang [35], R.J. Madaras [14], W.F. Mader [43], R. Maenner [58c], T. Maeno [24], P. Mättig [174], S. Mättig [41], L. Magnoni [29], E. Magradze [54], Y. Mahalalel [153], K. Mahboubi [48], G. Mahout [17], C. Maiani [132a,132b], C. Maidantchik [23a], A. Maio [124a,b], S. Majewski [24], Y. Makida [66], N. Makovec [115], P. Mal [6], Pa. Malecki [38], P. Malecki [38], V.P. Maleev [121], F. Malek [55], U. Mallik [63], D. Malon [5], C. Malone [143], S. Maltezos [9], V. Malyshev [107], S. Malyukov [29], R. Mameghani [98], J. Mamuzic [12b], A. Manabe [66], L. Mandelli [89a], I. Mandić [74], R. Mandrysch [15], J. Maneira [124a], P.S. Mangeard [88], I.D. Manjavidze [65], A. Mann [54], P.M. Manning [137], A. Manousakis-Katsikakis [8], B. Mansoulie [136], A. Manz [99], A. Mapelli [29], L. Mapelli [29], L. March [80], J.F. Marchand [29], F. Marchese [133a,133b], G. Marchiori [78], M. Marcisovsky [125], A. Marin [21,*], C.P. Marino [61], F. Marroquim [23a], R. Marshall [82], Z. Marshall [29], F.K. Martens [158], S. Marti-Garcia [167], A.J. Martin [175], B. Martin [29], B. Martin [88], F.F. Martin [120], J.P. Martin [93], Ph. Martin [55], T.A. Martin [17], V.J. Martin [45], B. Martin dit Latour [49], S. Martin-Haugh [149], M. Martinez [11], V. Martinez Outschoorn [57], A.C. Martyniuk [82], M. Marx [82], F. Marzano [132a], A. Marzin [111], L. Masetti [81], T. Mashimo [155], R. Mashinistov [94], J. Masik [82], A.L. Maslennikov [107], I. Massa [19a,19b], G. Massaro [105], N. Massol [4], P. Mastrandrea [132a,132b], A. Mastroberardino [36a,36b], T. Masubuchi [155], M. Mathes [20], P. Matricon [115], H. Matsumoto [155], H. Matsunaga [155], T. Matsushita [67], C. Mattravers [118,c], J.M. Maugain [29], S.J. Maxfield [73], D.A. Maximov [107], E.N. May [5], A. Mayne [139], R. Mazini [151], M. Mazur [20], M. Mazzanti [89a], E. Mazzoni [122a,122b], S.P. Mc Kee [87], A. McCarn [165], R.L. McCarthy [148], T.G. McCarthy [28], N.A. McCubbin [129], K.W. McFarlane [56], J.A. Mcfayden [139], H. McGlone [53], G. Mchedlidze [51], R.A. McLaren [29], T. Mclaughlan [17], S.J. McMahon [129], R.A. McPherson [169,k], A. Meade [84], J. Mechnich [105], M. Mechtel [174], M. Medinnis [41], R. Meera-Lebbai [111], T. Meguro [116], R. Mehdiyev [93], S. Mehlhase [35], A. Mehta [73], K. Meier [58a], J. Meinhardt [48], B. Meirose [79], C. Melachrinos [30], B.R. Mellado Garcia [172], L. Mendoza Navas [162], Z. Meng [151,t], A. Mengarelli [19a,19b], S. Menke [99], C. Menot [29], E. Meoni [11], K.M. Mercurio [57], P. Mermod [118], L. Merola [102a,102b], C. Meroni [89a], F.S. Merritt [30], A. Messina [29], J. Metcalfe [103], A.S. Mete [64], S. Meuser [20], C. Meyer [81], J.-P. Meyer [136], J. Meyer [173], J. Meyer [54], T.C. Meyer [29], W.T. Meyer [64], J. Miao [32d], S. Michal [29], L. Micu [25a], R.P. Middleton [129], P. Miele [29], S. Migas [73], L. Mijović [41], G. Mikenberg [171], M. Mikestikova [125], M. Mikuž [74], D.W. Miller [143], R.J. Miller [88], W.J. Mills [168], C. Mills [57], A. Milov [171], D.A. Milstead [146a,146b], D. Milstein [171], A.A. Minaenko [128], M. Miñano [167], I.A. Minashvili [65], A.I. Mincer [108], B. Mindur [37], M. Mineev [65], Y. Ming [130], L.M. Mir [11], G. Mirabelli [132a], L. Miralles Verge [11], A. Misiejuk [76], J. Mitrevski [137], G.Y. Mitrofanov [128], V.A. Mitsou [167], S. Mitsui [66], P.S. Miyagawa [139], K. Miyazaki [67], J.U. Mjörnmark [79], T. Moa [146a,146b], P. Mockett [138], S. Moed [57], V. Moeller [27], K. Mönig [41], N. Möser [20], S. Mohapatra [148], W. Mohr [48], S. Mohrdieck-Möck [99], A.M. Moisseev [128,*], R. Moles-Valls [167], J. Molina-Perez [29], J. Monk [77], E. Monnier [83], S. Montesano [89a,89b], F. Monticelli [70], S. Monzani [19a,19b], R.W. Moore [2], G.F. Moorhead [86], C. Mora Herrera [49], A. Moraes [53], N. Morange [136], J. Morel [54], G. Morello [36a,36b], D. Moreno [81], M. Moreno Llácer [167], P. Morettini [50a], M. Morii [57], J. Morin [75], Y. Morita [66], A.K. Morley [29], G. Mornacchi [29], S.V. Morozov [96], J.D. Morris [75], L. Morvaj [101], H.G. Moser [99], M. Mosidze [51], J. Moss [109], R. Mount [143], E. Mountricha [136], S.V. Mouraviev [94], E.J.W. Moyse [84], M. Mudrinic [12b], F. Mueller [58a],

J. Mueller [123], K. Mueller [20], T.A. Müller [98], D. Muenstermann [29], A. Muir [168], Y. Munwes [153], W.J. Murray [129], I. Mussche [105], E. Musto [102a,102b], A.G. Myagkov [128], M. Myska [125], J. Nadal [11], K. Nagai [160], K. Nagano [66], Y. Nagasaka [60], A.M. Nairz [29], Y. Nakahama [29], K. Nakamura [155], I. Nakano [110], G. Nanava [20], A. Napier [161], M. Nash [77,c], N.R. Nation [21], T. Nattermann [20], T. Naumann [41], G. Navarro [162], H.A. Neal [87], E. Nebot [80], P.Yu. Nechaeva [94], A. Negri [119a,119b], G. Negri [29], S. Nektarijevic [49], A. Nelson [64], S. Nelson [143], T.K. Nelson [143], S. Nemecek [125], P. Nemethy [108], A.A. Nepomuceno [23a], M. Nessi [29,u], S.Y. Nesterov [121], M.S. Neubauer [165], A. Neusiedl [81], R.M. Neves [108], P. Nevski [24], P.R. Newman [17], V. Nguyen Thi Hong [136], R.B. Nickerson [118], R. Nicolaidou [136], L. Nicolas [139], B. Nicquevert [29], F. Niedercorn [115], J. Nielsen [137], T. Niinikoski [29], N. Nikiforou [34], A. Nikiforov [15], V. Nikolaenko [128], K. Nikolaev [65], I. Nikolic-Audit [78], K. Nikolics [49], K. Nikolopoulos [24], H. Nilsen [48], P. Nilsson [7], Y. Ninomiya [155], A. Nisati [132a], T. Nishiyama [67], R. Nisius [99], L. Nodulman [5], M. Nomachi [116], I. Nomidis [154], M. Nordberg [29], B. Nordkvist [146a,146b], P.R. Norton [129], J. Novakova [126], M. Nozaki [66], M. Nožička [41], L. Nozka [113], I.M. Nugent [159a], A.-E. Nuncio-Quiroz [20], G. Nunes Hanninger [86], T. Nunnemann [98], E. Nurse [77], T. Nyman [29], B.J. O'Brien [45], S.W. O'Neale [17,*], D.C. O'Neil [142], V. O'Shea [53], F.G. Oakham [28,e], H. Oberlack [99], J. Ocariz [78], A. Ochi [67], S. Oda [155], S. Odaka [66], J. Odier [83], H. Ogren [61], A. Oh [82], S.H. Oh [44], C.C. Ohm [146a,146b], T. Ohshima [101], H. Ohshita [140], T.K. Ohska [66], T. Ohsugi [59], S. Okada [67], H. Okawa [163], Y. Okumura [101], T. Okuyama [155], M. Olcese [50a], A.G. Olchevski [65], M. Oliveira [124a,i], D. Oliveira Damazio [24], E. Oliver Garcia [167], D. Olivito [120], A. Olszewski [38], J. Olszowska [38], C. Omachi [67], A. Onofre [124a,v], P.U.E. Onyisi [30], C.J. Oram [159a], M.J. Oreglia [30], Y. Oren [153], D. Orestano [134a,134b], I. Orlov [107], C. Oropeza Barrera [53], R.S. Orr [158], B. Osculati [50a,50b], R. Ospanov [120], C. Osuna [11], G. Otero y Garzon [26], J.P. Ottersbach [105], M. Ouchrif [135d], F. Ould-Saada [117], A. Ouraou [136], Q. Ouyang [32a], M. Owen [82], S. Owen [139], V.E. Ozcan [18a], N. Ozturk [7], A. Pacheco Pages [11], C. Padilla Aranda [11], S. Pagan Griso [14], E. Paganis [139], F. Paige [24], K. Pajchel [117], G. Palacino [159b], C.P. Paleari [6], S. Palestini [29], D. Pallin [33], A. Palma [124a,b], J.D. Palmer [17], Y.B. Pan [172], E. Panagiotopoulou [9], B. Panes [31a], N. Panikashvili [87], S. Panitkin [24], D. Pantea [25a], M. Panuskova [125], V. Paolone [123], A. Papadelis [146a], Th.D. Papadopoulou [9], A. Paramonov [5], W. Park [24,w], M.A. Parker [27], F. Parodi [50a,50b], J.A. Parsons [34], U. Parzefall [48], E. Pasqualucci [132a], A. Passeri [134a], F. Pastore [134a,134b], Fr. Pastore [76], G. Pásztor [49,x], S. Pataraia [172], N. Patel [150], J.R. Pater [82], S. Patricelli [102a,102b], T. Pauly [29], M. Pecsy [144a], M.I. Pedraza Morales [172], S.V. Peleganchuk [107], H. Peng [32b], R. Pengo [29], A. Penson [34], J. Penwell [61], M. Perantoni [23a], K. Perez [34,y], T. Perez Cavalcanti [41], E. Perez Codina [11], M.T. Pérez García-Estañ [167], V. Perez Reale [34], L. Perini [89a,89b], H. Pernegger [29], R. Perrino [72a], P. Perrodo [4], S. Persembe [3a], V.D. Peshekhonov [65], B.A. Petersen [29], J. Petersen [29], T.C. Petersen [35], E. Petit [83], A. Petridis [154], C. Petridou [154], E. Petrolo [132a], F. Petrucci [134a,134b], D. Petschull [41], M. Petteni [142], R. Pezoa [31b], A. Phan [86], A.W. Phillips [27], P.W. Phillips [129], G. Piacquadio [29], E. Piccaro [75], M. Piccinini [19a,19b], A. Pickford [53], S.M. Piec [41], R. Piegaia [26], J.E. Pilcher [30], A.D. Pilkington [82], J. Pina [124a,b], M. Pinamonti [164a,164c], A. Pinder [118], J.L. Pinfold [2], J. Ping [32c], B. Pinto [124a,b], O. Pirotte [29], C. Pizio [89a,89b], R. Placakyte [41], M. Plamondon [169], W.G. Plano [82], M.-A. Pleier [24], A.V. Pleskach [128], A. Poblaguev [24], S. Poddar [58a], F. Podlyski [33], L. Poggioli [115], T. Poghosyan [20], M. Pohl [49], F. Polci [55], G. Polesello [119a], A. Policicchio [138], A. Polini [19a], J. Poll [75], V. Polychronakos [24], D.M. Pomarede [136], D. Pomeroy [22], K. Pommès [29], L. Pontecorvo [132a], B.G. Pope [88], G.A. Popeneciu [25a], D.S. Popovic [12a], A. Poppleton [29], X. Portell Bueso [29], R. Porter [163], C. Posch [21], G.E. Pospelov [99], S. Pospisil [127], I.N. Potrap [99], C.J. Potter [149], C.T. Potter [114], G. Poulard [29], J. Poveda [172], R. Prabhu [77], P. Pralavorio [83], S. Prasad [57], R. Pravahan [7], S. Prell [64], K. Pretzl [16], L. Pribyl [29], D. Price [61], L.E. Price [5], M.J. Price [29], P.M. Prichard [73], D. Prieur [123], M. Primavera [72a], K. Prokofiev [108], F. Prokoshin [31b], S. Protopopescu [24], J. Proudfoot [5], X. Prudent [43], H. Przysiezniak [4], S. Psoroulas [20], E. Ptacek [114], E. Pueschel [84], J. Purdham [87], M. Purohit [24,w], P. Puzo [115], Y. Pylypchenko [117], J. Qian [87], Z. Qian [83], Z. Qin [41], A. Quadt [54], D.R. Quarrie [14], W.B. Quayle [172], F. Quinonez [31a], M. Raas [104], V. Radescu [58b], B. Radics [20], T. Rador [18a], F. Ragusa [89a,89b], G. Rahal [177], A.M. Rahimi [109], D. Rahm [24], S. Rajagopalan [24], M. Rammensee [48], M. Rammes [141], M. Ramstedt [146a,146b], A.S. Randle-Conde [39], K. Randrianarivony [28], P.N. Ratoff [71], F. Rauscher [98], E. Rauter [99], M. Raymond [29], A.L. Read [117], D.M. Rebuzzi [119a,119b], A. Redelbach [173], G. Redlinger [24], R. Reece [120], K. Reeves [40], A. Reichold [105], E. Reinherz-Aronis [153], A. Reinsch [114], I. Reisinger [42], D. Reljic [12a], C. Rembser [29], Z.L. Ren [151], A. Renaud [115], P. Renkel [39], M. Rescigno [132a], S. Resconi [89a], B. Resende [136], P. Reznicek [98], R. Rezvani [158], A. Richards [77], R. Richter [99], E. Richter-Was [4,z], M. Ridel [78],

S. Rieke [81], M. Rijpstra [105], M. Rijssenbeek [148], A. Rimoldi [119a,119b], L. Rinaldi [19a], R.R. Rios [39], I. Riu [11], G. Rivoltella [89a,89b], F. Rizatdinova [112], E. Rizvi [75], S.H. Robertson [85,k], A. Robichaud-Veronneau [49], D. Robinson [27], J.E.M. Robinson [77], M. Robinson [114], A. Robson [53], J.G. Rocha de Lima [106], C. Roda [122a,122b], D. Roda Dos Santos [29], S. Rodier [80], D. Rodriguez [162], A. Roe [54], S. Roe [29], O. Røhne [117], V. Rojo [1], S. Rolli [161], A. Romaniouk [96], V.M. Romanov [65], G. Romeo [26], L. Roos [78], E. Ros [167], S. Rosati [132a,132b], K. Rosbach [49], A. Rose [149], M. Rose [76], G.A. Rosenbaum [158], E.I. Rosenberg [64], P.L. Rosendahl [13], O. Rosenthal [141], L. Rosselet [49], V. Rossetti [11], E. Rossi [132a,132b], L.P. Rossi [50a], L. Rossi [89a,89b], M. Rotaru [25a], I. Roth [171], J. Rothberg [138], D. Rousseau [115], C.R. Royon [136], A. Rozanov [83], Y. Rozen [152], X. Ruan [115], I. Rubinskiy [41], B. Ruckert [98], N. Ruckstuhl [105], V.I. Rud [97], C. Rudolph [43], G. Rudolph [62], F. Rühr [6], F. Ruggieri [134a,134b], A. Ruiz-Martinez [64], E. Rulikowska-Zarebska [37], V. Rumiantsev [91,*], L. Rumyantsev [65], K. Runge [48], O. Runolfsson [20], Z. Rurikova [48], N.A. Rusakovich [65], D.R. Rust [61], J.P. Rutherfoord [6], C. Ruwiedel [14], P. Ruzicka [125], Y.F. Ryabov [121], V. Ryadovikov [128], P. Ryan [88], M. Rybar [126], G. Rybkin [115], N.C. Ryder [118], S. Rzaeva [10], A.F. Saavedra [150], I. Sadeh [153], H.F.-W. Sadrozinski [137], R. Sadykov [65], F. Safai Tehrani [132a,132b], H. Sakamoto [155], G. Salamanna [75], A. Salamon [133a], M. Saleem [111], D. Salihagic [99], A. Salnikov [143], J. Salt [167], B.M. Salvachua Ferrando [5], D. Salvatore [36a,36b], F. Salvatore [149], A. Salvucci [104], A. Salzburger [29], D. Sampsonidis [154], B.H. Samset [117], A. Sanchez [102a,102b], H. Sandaker [13], H.G. Sander [81], M.P. Sanders [98], M. Sandhoff [174], T. Sandoval [27], C. Sandoval [162], R. Sandstroem [99], S. Sandvoss [174], D.P.C. Sankey [129], A. Sansoni [47], C. Santamarina Rios [85], C. Santoni [33], R. Santonico [133a,133b], H. Santos [124a], J.G. Saraiva [124a,b], T. Sarangi [172], E. Sarkisyan-Grinbaum [7], F. Sarri [122a,122b], G. Sartisohn [174], O. Sasaki [66], T. Sasaki [66], N. Sasao [68], I. Satsounkevitch [90], G. Sauvage [4], E. Sauvan [4], J.B. Sauvan [115], P. Savard [158,e], V. Savinov [123], D.O. Savu [29], P. Savva [9], L. Sawyer [24,m], D.H. Saxon [53], L.P. Says [33], C. Sbarra [19a,19b], A. Sbrizzi [19a,19b], O. Scallon [93], D.A. Scannicchio [163], J. Schaarschmidt [115], P. Schacht [99], U. Schäfer [81], S. Schaepe [20], S. Schaetzel [58b], A.C. Schaffer [115], D. Schaile [98], R.D. Schamberger [148], A.G. Schamov [107], V. Scharf [58a], V.A. Schegelsky [121], D. Scheirich [87], M. Schernau [163], M.I. Scherzer [14], C. Schiavi [50a,50b], J. Schieck [98], M. Schioppa [36a,36b], S. Schlenker [29], J.L. Schlereth [5], E. Schmidt [48], K. Schmieden [20], C. Schmitt [81], S. Schmitt [58b], M. Schmitz [20], A. Schöning [58b], M. Schott [29], D. Schouten [142], J. Schovancova [125], M. Schram [85], C. Schroeder [81], N. Schroer [58c], S. Schuh [29], G. Schuler [29], J. Schultes [174], H.-C. Schultz-Coulon [58a], H. Schulz [15], J.W. Schumacher [20], M. Schumacher [48], B.A. Schumm [137], Ph. Schune [136], C. Schwanenberger [82], A. Schwartzman [143], Ph. Schwemling [78], R. Schwienhorst [88], R. Schwierz [43], J. Schwindling [136], T. Schwindt [20], W.G. Scott [129], J. Searcy [114], E. Sedykh [121], E. Segura [11], S.C. Seidel [103], A. Seiden [137], F. Seifert [43], J.M. Seixas [23a], G. Sekhniaidze [102a], D.M. Seliverstov [121], B. Sellden [146a], G. Sellers [73], M. Seman [144b], N. Semprini-Cesari [19a,19b], C. Serfon [98], L. Serin [115], R. Seuster [99], H. Severini [111], M.E. Sevior [86], A. Sfyrla [29], E. Shabalina [54], M. Shamim [114], L.Y. Shan [32a], J.T. Shank [21], Q.T. Shao [86], M. Shapiro [14], P.B. Shatalov [95], L. Shaver [6], K. Shaw [164a,164c], D. Sherman [175], P. Sherwood [77], A. Shibata [108], H. Shichi [101], S. Shimizu [29], M. Shimojima [100], T. Shin [56], A. Shmeleva [94], M.J. Shochet [30], D. Short [118], M.A. Shupe [6], P. Sicho [125], A. Sidoti [132a,132b], A. Siebel [174], F. Siegert [48], J. Siegrist [14], Dj. Sijacki [12a], O. Silbert [171], J. Silva [124a,b], Y. Silver [153], D. Silverstein [143], S.B. Silverstein [146a], V. Simak [127], O. Simard [136], Lj. Simic [12a], S. Simion [115], B. Simmons [77], M. Simonyan [35], P. Sinervo [158], N.B. Sinev [114], V. Sipica [141], G. Siragusa [173], A. Sircar [24], A.N. Sisakyan [65], S.Yu. Sivoklokov [97], J. Sjölin [146a,146b], T.B. Sjursen [13], L.A. Skinnari [14], K. Skovpen [107], P. Skubic [111], N. Skvorodnev [22], M. Slater [17], T. Slavicek [127], K. Sliwa [161], T.J. Sloan [71], J. Sloper [29], V. Smakhtin [171], S.Yu. Smirnov [96], L.N. Smirnova [97], O. Smirnova [79], B.C. Smith [57], D. Smith [143], K.M. Smith [53], M. Smizanska [71], K. Smolek [127], A.A. Snesarev [94], S.W. Snow [82], J. Snow [111], J. Snuverink [105], S. Snyder [24], M. Soares [124a], R. Sobie [169,k], J. Sodomka [127], A. Soffer [153], C.A. Solans [167], M. Solar [127], J. Solc [127], E. Soldatov [96], U. Soldevila [167], E. Solfaroli Camillocci [132a,132b], A.A. Solodkov [128], O.V. Solovyanov [128], J. Sondericker [24], N. Soni [2], V. Sopko [127], B. Sopko [127], M. Sorbi [89a,89b], M. Sosebee [7], A. Soukharev [107], S. Spagnolo [72a,72b], F. Spanò [76], R. Spighi [19a], G. Spigo [29], F. Spila [132a,132b], E. Spiriti [134a], R. Spiwoks [29], M. Spousta [126], T. Spreitzer [158], B. Spurlock [7], R.D. St. Denis [53], T. Stahl [141], J. Stahlman [120], R. Stamen [58a], E. Stanecka [29], R.W. Stanek [5], C. Stanescu [134a], S. Stapnes [117], E.A. Starchenko [128], J. Stark [55], P. Staroba [125], P. Starovoitov [91], A. Staude [98], P. Stavina [144a], G. Stavropoulos [14], G. Steele [53], P. Steinbach [43], P. Steinberg [24], I. Stekl [127], B. Stelzer [142], H.J. Stelzer [88], O. Stelzer-Chilton [159a], H. Stenzel [52], K. Stevenson [75], G.A. Stewart [29], J.A. Stillings [20], T. Stockmanns [20], M.C. Stockton [29], K. Stoerig [48],

G. Stoicea [25a], S. Stonjek [99], P. Strachota [126], A.R. Stradling [7], A. Straessner [43], J. Strandberg [147], S. Strandberg [146a,146b], A. Strandlie [117], M. Strang [109], E. Strauss [143], M. Strauss [111], P. Strizenec [144b], R. Ströhmer [173], D.M. Strom [114], J.A. Strong [76,*], R. Stroynowski [39], J. Strube [129], B. Stugu [13], I. Stumer [24,*], J. Stupak [148], P. Sturm [174], D.A. Soh [151,r], D. Su [143], H.S. Subramania [2], A. Succurro [11], Y. Sugaya [116], T. Sugimoto [101], C. Suhr [106], K. Suita [67], M. Suk [126], V.V. Sulin [94], S. Sultansoy [3d], T. Sumida [29], X. Sun [55], J.E. Sundermann [48], K. Suruliz [139], S. Sushkov [11], G. Susinno [36a,36b], M.R. Sutton [149], Y. Suzuki [66], Y. Suzuki [67], M. Svatos [125], Yu.M. Sviridov [128], S. Swedish [168], I. Sykora [144a], T. Sykora [126], B. Szeless [29], J. Sánchez [167], D. Ta [105], K. Tackmann [41], A. Taffard [163], R. Tafirout [159a], N. Taiblum [153], Y. Takahashi [101], H. Takai [24], R. Takashima [69], H. Takeda [67], T. Takeshita [140], M. Talby [83], A. Talyshev [107], M.C. Tamsett [24], J. Tanaka [155], R. Tanaka [115], S. Tanaka [131], S. Tanaka [66], Y. Tanaka [100], K. Tani [67], N. Tannoury [83], G.P. Tappern [29], S. Tapprogge [81], D. Tardif [158], S. Tarem [152], F. Tarrade [28], G.F. Tartarelli [89a], P. Tas [126], M. Tasevsky [125], E. Tassi [36a,36b], M. Tatarkhanov [14], Y. Tayalati [135d], C. Taylor [77], F.E. Taylor [92], G.N. Taylor [86], W. Taylor [159b], M. Teinturier [115], M. Teixeira Dias Castanheira [75], P. Teixeira-Dias [76], K.K. Temming [48], H. Ten Kate [29], P.K. Teng [151], S. Terada [66], K. Terashi [155], J. Terron [80], M. Terwort [41,p], M. Testa [47], R.J. Teuscher [158,k], J. Thadome [174], J. Therhaag [20], T. Theveneaux-Pelzer [78], M. Thioye [175], S. Thoma [48], J.P. Thomas [17], E.N. Thompson [84], P.D. Thompson [17], P.D. Thompson [158], A.S. Thompson [53], E. Thomson [120], M. Thomson [27], R.P. Thun [87], F. Tian [34], T. Tic [125], V.O. Tikhomirov [94], Y.A. Tikhonov [107], C.J.W.P. Timmermans [104], P. Tipton [175], F.J. Tique Aires Viegas [29], S. Tisserant [83], J. Tobias [48], B. Toczek [37], T. Todorov [4], S. Todorova-Nova [161], B. Toggerson [163], J. Tojo [66], S. Tokár [144a], K. Tokunaga [67], K. Tokushuku [66], K. Tollefson [88], M. Tomoto [101], L. Tompkins [14], K. Toms [103], G. Tong [32a], A. Tonoyan [13], C. Topfel [16], N.D. Topilin [65], I. Torchiani [29], E. Torrence [114], H. Torres [78], E. Torró Pastor [167], J. Toth [83,x], F. Touchard [83], D.R. Tovey [139], D. Traynor [75], T. Trefzger [173], L. Tremblet [29], A. Tricoli [29], I.M. Trigger [159a], S. Trincaz-Duvoid [78], T.N. Trinh [78], M.F. Tripiana [70], W. Trischuk [158], A. Trivedi [24,w], B. Trocmé [55], C. Troncon [89a], M. Trottier-McDonald [142], A. Trzupek [38], C. Tsarouchas [29], J.C.-L. Tseng [118], M. Tsiakiris [105], P.V. Tsiareshka [90], D. Tsionou [4], G. Tsipolitis [9], V. Tsiskaridze [48], E.G. Tskhadadze [51], I.I. Tsukerman [95], V. Tsulaia [14], J.-W. Tsung [20], S. Tsuno [66], D. Tsybychev [148], A. Tua [139], J.M. Tuggle [30], M. Turala [38], D. Turecek [127], I. Turk Cakir [3e], E. Turlay [105], R. Turra [89a,89b], P.M. Tuts [34], A. Tykhonov [74], M. Tylmad [146a,146b], M. Tyndel [129], H. Tyrvainen [29], G. Tzanakos [8], K. Uchida [20], I. Ueda [155], R. Ueno [28], M. Ugland [13], M. Uhlenbrock [20], M. Uhrmacher [54], F. Ukegawa [160], G. Unal [29], D.G. Underwood [5], A. Undrus [24], G. Unel [163], Y. Unno [66], D. Urbaniec [34], E. Urkovsky [153], P. Urrejola [31a], G. Usai [7], M. Uslenghi [119a,119b], L. Vacavant [83], V. Vacek [127], B. Vachon [85], S. Vahsen [14], J. Valenta [125], P. Valente [132a], S. Valentinetti [19a,19b], S. Valkar [126], E. Valladolid Gallego [167], S. Vallecorsa [152], J.A. Valls Ferrer [167], H. van der Graaf [105], E. van der Kraaij [105], R. Van Der Leeuw [105], E. van der Poel [105], D. van der Ster [29], B. Van Eijk [105], N. van Eldik [84], P. van Gemmeren [5], Z. van Kesteren [105], I. van Vulpen [105], W. Vandelli [29], G. Vandoni [29], A. Vaniachine [5], P. Vankov [41], F. Vannucci [78], F. Varela Rodriguez [29], R. Vari [132a], D. Varouchas [14], A. Vartapetian [7], K.E. Varvell [150], V.I. Vassilakopoulos [56], F. Vazeille [33], G. Vegni [89a,89b], J.J. Veillet [115], C. Vellidis [8], F. Veloso [124a], R. Veness [29], S. Veneziano [132a], A. Ventura [72a,72b], D. Ventura [138], M. Venturi [48], N. Venturi [16], V. Vercesi [119a], M. Verducci [138], W. Verkerke [105], J.C. Vermeulen [105], A. Vest [43], M.C. Vetterli [142,e], I. Vichou [165], T. Vickey [145b,aa], O.E. Vickey Boeriu [145b], G.H.A. Viehhauser [118], S. Viel [168], M. Villa [19a,19b], M. Villaplana Perez [167], E. Vilucchi [47], M.G. Vincter [28], E. Vinek [29], V.B. Vinogradov [65], M. Virchaux [136,*], J. Virzi [14], O. Vitells [171], M. Viti [41], I. Vivarelli [48], F. Vives Vaque [2], S. Vlachos [9], M. Vlasak [127], N. Vlasov [20], A. Vogel [20], P. Vokac [127], G. Volpi [47], M. Volpi [86], G. Volpini [89a], H. von der Schmitt [99], J. von Loeben [99], H. von Radziewski [48], E. von Toerne [20], V. Vorobel [126], A.P. Vorobiev [128], V. Vorwerk [11], M. Vos [167], R. Voss [29], T.T. Voss [174], J.H. Vossebeld [73], N. Vranjes [12a], M. Vranjes Milosavljevic [105], V. Vrba [125], M. Vreeswijk [105], T. Vu Anh [81], R. Vuillermet [29], I. Vukotic [115], W. Wagner [174], P. Wagner [120], H. Wahlen [174], J. Wakabayashi [101], J. Walbersloh [42], S. Walch [87], J. Walder [71], R. Walker [98], W. Walkowiak [141], R. Wall [175], P. Waller [73], C. Wang [44], H. Wang [172], H. Wang [32b,ab], J. Wang [151], J. Wang [32d], J.C. Wang [138], R. Wang [103], S.M. Wang [151], A. Warburton [85], C.P. Ward [27], M. Warsinsky [48], P.M. Watkins [17], A.T. Watson [17], M.F. Watson [17], G. Watts [138], S. Watts [82], A.T. Waugh [150], B.M. Waugh [77], J. Weber [42], M. Weber [129], M.S. Weber [16], P. Weber [54], A.R. Weidberg [118], P. Weigell [99], J. Weingarten [54], C. Weiser [48], H. Wellenstein [22], P.S. Wells [29], M. Wen [47], T. Wenaus [24], S. Wendler [123], Z. Weng [151,r], T. Wengler [29], S. Wenig [29], N. Wermes [20], M. Werner [48], P. Werner [29],

M. Werth [163], M. Wessels [58a], C. Weydert [55], K. Whalen [28], S.J. Wheeler-Ellis [163], S.P. Whitaker [21], A. White [7], M.J. White [86], S.R. Whitehead [118], D. Whiteson [163], D. Whittington [61], F. Wicek [115], D. Wicke [174], F.J. Wickens [129], W. Wiedenmann [172], M. Wielers [129], P. Wienemann [20], C. Wiglesworth [75], L.A.M. Wiik [48], P.A. Wijeratne [77], A. Wildauer [167], M.A. Wildt [41,p], I. Wilhelm [126], H.G. Wilkens [29], J.Z. Will [98], E. Williams [34], H.H. Williams [120], W. Willis [34], S. Willocq [84], J.A. Wilson [17], M.G. Wilson [143], A. Wilson [87], I. Wingerter-Seez [4], S. Winkelmann [48], F. Winklmeier [29], M. Wittgen [143], M.W. Wolter [38], H. Wolters [124a,i], W.C. Wong [40], G. Wooden [118], B.K. Wosiek [38], J. Wotschack [29], M.J. Woudstra [84], K. Wraight [53], C. Wright [53], B. Wrona [73], S.L. Wu [172], X. Wu [49], Y. Wu [32b,ac], E. Wulf [34], R. Wunstorf [42], B.M. Wynne [45], L. Xaplanteris [9], S. Xella [35], S. Xie [48], Y. Xie [32a], C. Xu [32b,ad], D. Xu [139], G. Xu [32a], B. Yabsley [150], S. Yacoob [145b], M. Yamada [66], H. Yamaguchi [155], A. Yamamoto [66], K. Yamamoto [64], S. Yamamoto [155], T. Yamamura [155], T. Yamanaka [155], J. Yamaoka [44], T. Yamazaki [155], Y. Yamazaki [67], Z. Yan [21], H. Yang [87], U.K. Yang [82], Y. Yang [61], Y. Yang [32a], Z. Yang [146a,146b], S. Yanush [91], Y. Yao [14], Y. Yasu [66], G.V. Ybeles Smit [130], J. Ye [39], S. Ye [24], M. Yilmaz [3c], R. Yoosoofmiya [123], K. Yorita [170], R. Yoshida [5], C. Young [143], S. Youssef [21], D. Yu [24], J. Yu [7], J. Yu [32c,ad], L. Yuan [32a,ae], A. Yurkewicz [148], V.G. Zaets [128], R. Zaidan [63], A.M. Zaitsev [128], Z. Zajacova [29], Yo.K. Zalite [121], L. Zanello [132a,132b], P. Zarzhitsky [39], A. Zaytsev [107], C. Zeitnitz [174], M. Zeller [175], M. Zeman [125], A. Zemla [38], C. Zendler [20], O. Zenin [128], T. Ženiš [144a], Z. Zenonos [122a,122b], S. Zenz [14], D. Zerwas [115], G. Zevi della Porta [57], Z. Zhan [32d], D. Zhang [32b,ab], H. Zhang [88], J. Zhang [5], X. Zhang [32d], Z. Zhang [115], L. Zhao [108], T. Zhao [138], Z. Zhao [32b], A. Zhemchugov [65], S. Zheng [32a], J. Zhong [151,af], B. Zhou [87], N. Zhou [163], Y. Zhou [151], C.G. Zhu [32d], H. Zhu [41], J. Zhu [87], Y. Zhu [172], X. Zhuang [98], V. Zhuravlov [99], D. Zieminska [61], R. Zimmermann [20], S. Zimmermann [20], S. Zimmermann [48], M. Ziolkowski [141], R. Zitoun [4], L. Živković [34], V.V. Zmouchko [128,*], G. Zobernig [172], A. Zoccoli [19a,19b], Y. Zolnierowski [4], A. Zsenei [29], M. zur Nedden [15], V. Zutshi [106], L. Zwalinski [29]

[1] *University at Albany, Albany, NY, United States*
[2] *Department of Physics, University of Alberta, Edmonton, AB, Canada*
[3] [(a)] *Department of Physics, Ankara University, Ankara;* [(b)] *Department of Physics, Dumlupinar University, Kutahya;* [(c)] *Department of Physics, Gazi University, Ankara;* [(d)] *Division of Physics, TOBB University of Economics and Technology, Ankara;* [(e)] *Turkish Atomic Energy Authority, Ankara, Turkey*
[4] *LAPP, CNRS/IN2P3 and Université de Savoie, Annecy-le-Vieux, France*
[5] *High Energy Physics Division, Argonne National Laboratory, Argonne, IL, United States*
[6] *Department of Physics, University of Arizona, Tucson, AZ, United States*
[7] *Department of Physics, The University of Texas at Arlington, Arlington, TX, United States*
[8] *Physics Department, University of Athens, Athens, Greece*
[9] *Physics Department, National Technical University of Athens, Zografou, Greece*
[10] *Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan*
[11] *Institut de Física d'Altes Energies and Departament de Física de la Universitat Autònoma de Barcelona and ICREA, Barcelona, Spain*
[12] [(a)] *Institute of Physics, University of Belgrade, Belgrade;* [(b)] *Vinca Institute of Nuclear Sciences, Belgrade, Serbia*
[13] *Department for Physics and Technology, University of Bergen, Bergen, Norway*
[14] *Physics Division, Lawrence Berkeley National Laboratory and University of California, Berkeley, CA, United States*
[15] *Department of Physics, Humboldt University, Berlin, Germany*
[16] *Albert Einstein Center for Fundamental Physics and Laboratory for High Energy Physics, University of Bern, Bern, Switzerland*
[17] *School of Physics and Astronomy, University of Birmingham, Birmingham, United Kingdom*
[18] [(a)] *Department of Physics, Bogazici University, Istanbul;* [(b)] *Division of Physics, Dogus University, Istanbul;* [(c)] *Department of Physics Engineering, Gaziantep University, Gaziantep;* [(d)] *Department of Physics, Istanbul Technical University, Istanbul, Turkey*
[19] [(a)] *INFN Sezione di Bologna;* [(b)] *Dipartimento di Fisica, Università di Bologna, Bologna, Italy*
[20] *Physikalisches Institut, University of Bonn, Bonn, Germany*
[21] *Department of Physics, Boston University, Boston, MA, United States*
[22] *Department of Physics, Brandeis University, Waltham, MA, United States*
[23] [(a)] *Universidade Federal do Rio De Janeiro COPPE/EE/IF, Rio de Janeiro;* [(b)] *Federal University of Juiz de Fora (UFJF), Juiz de Fora;* [(c)] *Federal University of Sao Joao del Rei (UFSJ), Sao Joao del Rei;* [(d)] *Instituto de Fisica, Universidade de Sao Paulo, Sao Paulo, Brazil*
[24] *Physics Department, Brookhaven National Laboratory, Upton, NY, United States*
[25] [(a)] *National Institute of Physics and Nuclear Engineering, Bucharest;* [(b)] *University Politehnica Bucharest, Bucharest;* [(c)] *West University in Timisoara, Timisoara, Romania*
[26] *Departamento de Física, Universidad de Buenos Aires, Buenos Aires, Argentina*
[27] *Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom*
[28] *Department of Physics, Carleton University, Ottawa, ON, Canada*
[29] *CERN, Geneva, Switzerland*
[30] *Enrico Fermi Institute, University of Chicago, Chicago, IL, United States*
[31] [(a)] *Departamento de Fisica, Pontificia Universidad Católica de Chile, Santiago;* [(b)] *Departamento de Física, Universidad Técnica Federico Santa María, Valparaíso, Chile*
[32] [(a)] *Institute of High Energy Physics, Chinese Academy of Sciences, Beijing;* [(b)] *Department of Modern Physics, University of Science and Technology of China, Anhui;* [(c)] *Department of Physics, Nanjing University, Jiangsu;* [(d)] *High Energy Physics Group, Shandong University, Shandong, China*
[33] *Laboratoire de Physique Corpusculaire, Clermont Université and Université Blaise Pascal and CNRS/IN2P3, Aubiere Cedex, France*
[34] *Nevis Laboratory, Columbia University, Irvington, NY, United States*
[35] *Niels Bohr Institute, University of Copenhagen, Kobenhavn, Denmark*
[36] [(a)] *INFN Gruppo Collegato di Cosenza;* [(b)] *Dipartimento di Fisica, Università della Calabria, Arcavata di Rende, Italy*
[37] *Faculty of Physics and Applied Computer Science, AGH – University of Science and Technology, Krakow, Poland*
[38] *The Henryk Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences, Krakow, Poland*
[39] *Physics Department, Southern Methodist University, Dallas, TX, United States*
[40] *Physics Department, University of Texas at Dallas, Richardson, TX, United States*
[41] *DESY, Hamburg and Zeuthen, Germany*

[42] Institut für Experimentelle Physik IV, Technische Universität Dortmund, Dortmund, Germany
[43] Institut für Kern- und Teilchenphysik, Technical University Dresden, Dresden, Germany
[44] Department of Physics, Duke University, Durham, NC, United States
[45] SUPA – School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom
[46] Fachhochschule Wiener Neustadt, Johannes Gutenbergstrasse 3, 2700 Wiener Neustadt, Austria
[47] INFN Laboratori Nazionali di Frascati, Frascati, Italy
[48] Fakultät für Mathematik und Physik, Albert-Ludwigs-Universität, Freiburg i.Br., Germany
[49] Section de Physique, Université de Genève, Geneva, Switzerland
[50] [(a)] INFN Sezione di Genova; [(b)] Dipartimento di Fisica, Università di Genova, Genova, Italy
[51] Institute of Physics and HEP Institute, Georgian Academy of Sciences and Tbilisi State University, Tbilisi, Georgia
[52] II Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen, Germany
[53] SUPA – School of Physics and Astronomy, University of Glasgow, Glasgow, United Kingdom
[54] II Physikalisches Institut, Georg-August-Universität, Göttingen, Germany
[55] Laboratoire de Physique Subatomique et de Cosmologie, Université Joseph Fourier and CNRS/IN2P3 and Institut National Polytechnique de Grenoble, Grenoble, France
[56] Department of Physics, Hampton University, Hampton, VA, United States
[57] Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge, MA, United States
[58] [(a)] Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Heidelberg; [(b)] Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg; [(c)] ZITI Institut für technische Informatik, Ruprecht-Karls-Universität Heidelberg, Mannheim, Germany
[59] Faculty of Science, Hiroshima University, Hiroshima, Japan
[60] Faculty of Applied Information Science, Hiroshima Institute of Technology, Hiroshima, Japan
[61] Department of Physics, Indiana University, Bloomington, IN, United States
[62] Institut für Astro- und Teilchenphysik, Leopold-Franzens-Universität, Innsbruck, Austria
[63] University of Iowa, Iowa City, IA, United States
[64] Department of Physics and Astronomy, Iowa State University, Ames, IA, United States
[65] Joint Institute for Nuclear Research, JINR Dubna, Dubna, Russia
[66] KEK, High Energy Accelerator Research Organization, Tsukuba, Japan
[67] Graduate School of Science, Kobe University, Kobe, Japan
[68] Faculty of Science, Kyoto University, Kyoto, Japan
[69] Kyoto University of Education, Kyoto, Japan
[70] Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata, Argentina
[71] Physics Department, Lancaster University, Lancaster, United Kingdom
[72] [(a)] INFN Sezione di Lecce; [(b)] Dipartimento di Fisica, Università del Salento, Lecce, Italy
[73] Oliver Lodge Laboratory, University of Liverpool, Liverpool, United Kingdom
[74] Department of Physics, Jožef Stefan Institute and University of Ljubljana, Ljubljana, Slovenia
[75] Department of Physics, Queen Mary University of London, London, United Kingdom
[76] Department of Physics, Royal Holloway University of London, Surrey, United Kingdom
[77] Department of Physics and Astronomy, University College London, London, United Kingdom
[78] Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France
[79] Fysiska institutionen, Lunds universitet, Lund, Sweden
[80] Departamento de Fisica Teorica C-15, Universidad Autonoma de Madrid, Madrid, Spain
[81] Institut für Physik, Universität Mainz, Mainz, Germany
[82] School of Physics and Astronomy, University of Manchester, Manchester, United Kingdom
[83] CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France
[84] Department of Physics, University of Massachusetts, Amherst, MA, United States
[85] Department of Physics, McGill University, Montreal, QC, Canada
[86] School of Physics, University of Melbourne, Victoria, Australia
[87] Department of Physics, The University of Michigan, Ann Arbor, MI, United States
[88] Department of Physics and Astronomy, Michigan State University, East Lansing, MI, United States
[89] [(a)] INFN Sezione di Milano; [(b)] Dipartimento di Fisica, Università di Milano, Milano, Italy
[90] B.I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk, Belarus
[91] National Scientific and Educational Centre for Particle and High Energy Physics, Minsk, Belarus
[92] Department of Physics, Massachusetts Institute of Technology, Cambridge, MA, United States
[93] Group of Particle Physics, University of Montreal, Montreal, QC, Canada
[94] P.N. Lebedev Institute of Physics, Academy of Sciences, Moscow, Russia
[95] Institute for Theoretical and Experimental Physics (ITEP), Moscow, Russia
[96] Moscow Engineering and Physics Institute (MEPhI), Moscow, Russia
[97] Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia
[98] Fakultät für Physik, Ludwig-Maximilians-Universität München, München, Germany
[99] Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), München, Germany
[100] Nagasaki Institute of Applied Science, Nagasaki, Japan
[101] Graduate School of Science, Nagoya University, Nagoya, Japan
[102] [(a)] INFN Sezione di Napoli; [(b)] Dipartimento di Scienze Fisiche, Università di Napoli, Napoli, Italy
[103] Department of Physics and Astronomy, University of New Mexico, Albuquerque, NM, United States
[104] Institute for Mathematics, Astrophysics and Particle Physics, Radboud University Nijmegen/Nikhef, Nijmegen, Netherlands
[105] Nikhef National Institute for Subatomic Physics and University of Amsterdam, Amsterdam, Netherlands
[106] Department of Physics, Northern Illinois University, DeKalb, IL, United States
[107] Budker Institute of Nuclear Physics (BINP), Novosibirsk, Russia
[108] Department of Physics, New York University, New York, NY, United States
[109] Ohio State University, Columbus, OH, United States
[110] Faculty of Science, Okayama University, Okayama, Japan
[111] Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman, OK, United States
[112] Department of Physics, Oklahoma State University, Stillwater, OK, United States
[113] Palacký University, RCPTM, Olomouc, Czech Republic
[114] Center for High Energy Physics, University of Oregon, Eugene, OR, United States
[115] LAL, Univ. Paris-Sud and CNRS/IN2P3, Orsay, France
[116] Graduate School of Science, Osaka University, Osaka, Japan
[117] Department of Physics, University of Oslo, Oslo, Norway
[118] Department of Physics, Oxford University, Oxford, United Kingdom
[119] [(a)] INFN Sezione di Pavia; [(b)] Dipartimento di Fisica Nucleare e Teorica, Università di Pavia, Pavia, Italy

[120] Department of Physics, University of Pennsylvania, Philadelphia, PA, United States
[121] Petersburg Nuclear Physics Institute, Gatchina, Russia
[122] [(a)] INFN Sezione di Pisa; [(b)] Dipartimento di Fisica E. Fermi, Università di Pisa, Pisa, Italy
[123] Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh, PA, United States
[124] [(a)] Laboratorio de Instrumentacao e Fisica Experimental de Particulas – LIP, Lisboa, Portugal; [(b)] Departamento de Fisica Teorica y del Cosmos and CAFPE, Universidad de Granada, Granada, Spain
[125] Institute of Physics, Academy of Sciences of the Czech Republic, Praha, Czech Republic
[126] Faculty of Mathematics and Physics, Charles University in Prague, Praha, Czech Republic
[127] Czech Technical University in Prague, Praha, Czech Republic
[128] State Research Center Institute for High Energy Physics, Protvino, Russia
[129] Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom
[130] Physics Department, University of Regina, Regina, SK, Canada
[131] Ritsumeikan University, Kusatsu, Shiga, Japan
[132] [(a)] INFN Sezione di Roma I; [(b)] Dipartimento di Fisica, Università La Sapienza, Roma, Italy
[133] [(a)] INFN Sezione di Roma Tor Vergata; [(b)] Dipartimento di Fisica, Università di Roma Tor Vergata, Roma, Italy
[134] [(a)] INFN Sezione di Roma Tre; [(b)] Dipartimento di Fisica, Università Roma Tre, Roma, Italy
[135] [(a)] Faculté des Sciences Ain Chock, Réseau Universitaire de Physique des Hautes Energies – Université Hassan II, Casablanca; [(b)] Centre National de l'Energie des Sciences Techniques Nucleaires, Rabat; [(c)] Université Cadi Ayyad, Faculté des sciences Semlalia Département de Physique, B.P. 2390 Marrakech 40000; [(d)] Faculté des Sciences, Université Mohamed Premier and LPTPM, Oujda; [(e)] Faculté des Sciences, Université Mohammed V, Rabat, Morocco
[136] DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat a l'Energie Atomique), Gif-sur-Yvette, France
[137] Santa Cruz Institute for Particle Physics, University of California Santa Cruz, Santa Cruz, CA, United States
[138] Department of Physics, University of Washington, Seattle, WA, United States
[139] Department of Physics and Astronomy, University of Sheffield, Sheffield, United Kingdom
[140] Department of Physics, Shinshu University, Nagano, Japan
[141] Fachbereich Physik, Universität Siegen, Siegen, Germany
[142] Department of Physics, Simon Fraser University, Burnaby, BC, Canada
[143] SLAC National Accelerator Laboratory, Stanford, CA, United States
[144] [(a)] Faculty of Mathematics, Physics & Informatics, Comenius University, Bratislava; [(b)] Department of Subnuclear Physics, Institute of Experimental Physics of the Slovak Academy of Sciences, Kosice, Slovak Republic
[145] [(a)] Department of Physics, University of Johannesburg, Johannesburg; [(b)] School of Physics, University of the Witwatersrand, Johannesburg, South Africa
[146] [(a)] Department of Physics, Stockholm University; [(b)] The Oskar Klein Centre, Stockholm, Sweden
[147] Physics Department, Royal Institute of Technology, Stockholm, Sweden
[148] Department of Physics and Astronomy, Stony Brook University, Stony Brook, NY, United States
[149] Department of Physics and Astronomy, University of Sussex, Brighton, United Kingdom
[150] School of Physics, University of Sydney, Sydney, Australia
[151] Institute of Physics, Academia Sinica, Taipei, Taiwan
[152] Department of Physics, Technion: Israel Inst. of Technology, Haifa, Israel
[153] Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel
[154] Department of Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece
[155] International Center for Elementary Particle Physics and Department of Physics, The University of Tokyo, Tokyo, Japan
[156] Graduate School of Science and Technology, Tokyo Metropolitan University, Tokyo, Japan
[157] Department of Physics, Tokyo Institute of Technology, Tokyo, Japan
[158] Department of Physics, University of Toronto, Toronto, ON, Canada
[159] [(a)] TRIUMF, Vancouver, BC; [(b)] Department of Physics and Astronomy, York University, Toronto, ON, Canada
[160] Institute of Pure and Applied Sciences, University of Tsukuba, Ibaraki, Japan
[161] Science and Technology Center, Tufts University, Medford, MA, United States
[162] Centro de Investigaciones, Universidad Antonio Narino, Bogota, Colombia
[163] Department of Physics and Astronomy, University of California Irvine, Irvine, CA, United States
[164] [(a)] INFN Gruppo Collegato di Udine; [(b)] ICTP, Trieste; [(c)] Dipartimento di Fisica, Università di Udine, Udine, Italy
[165] Department of Physics, University of Illinois, Urbana, IL, United States
[166] Department of Physics and Astronomy, University of Uppsala, Uppsala, Sweden
[167] Instituto de Física Corpuscular (IFIC) and Departamento de Física Atómica, Molecular y Nuclear and Departamento de Ingenierá Electrónica and Instituto de Microelectrónica de Barcelona (IMB-CNM), University of Valencia and CSIC, Valencia, Spain
[168] Department of Physics, University of British Columbia, Vancouver, BC, Canada
[169] Department of Physics and Astronomy, University of Victoria, Victoria, BC, Canada
[170] Waseda University, Tokyo, Japan
[171] Department of Particle Physics, The Weizmann Institute of Science, Rehovot, Israel
[172] Department of Physics, University of Wisconsin, Madison, WI, United States
[173] Fakultät für Physik und Astronomie, Julius-Maximilians-Universität, Würzburg, Germany
[174] Fachbereich C Physik, Bergische Universität Wuppertal, Wuppertal, Germany
[175] Department of Physics, Yale University, New Haven, CT, United States
[176] Yerevan Physics Institute, Yerevan, Armenia
[177] Domaine scientifique de la Doua, Centre de Calcul CNRS/IN2P3, Villeurbanne Cedex, France

[a] Also at Laboratorio de Instrumentacao e Fisica Experimental de Particulas – LIP, Lisboa, Portugal.
[b] Also at Faculdade de Ciencias and CFNUL, Universidade de Lisboa, Lisboa, Portugal.
[c] Also at Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom.
[d] Also at CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France.
[e] Also at TRIUMF, Vancouver, BC, Canada.
[f] Also at Department of Physics, California State University, Fresno, CA, United States.
[g] Also at Faculty of Physics and Applied Computer Science, AGH – University of Science and Technology, Krakow, Poland.
[h] Also at Fermilab, Batavia, IL, United States.
[i] Also at Department of Physics, University of Coimbra, Coimbra, Portugal.
[j] Also at Università di Napoli Parthenope, Napoli, Italy.
[k] Also at Institute of Particle Physics (IPP), Canada.
[l] Also at Department of Physics, Middle East Technical University, Ankara, Turkey.
[m] Also at Louisiana Tech University, Ruston, LA, United States.

[n] Also at Group of Particle Physics, University of Montreal, Montreal, QC, Canada.
[o] Also at Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan.
[p] Also at Institut für Experimentalphysik, Universität Hamburg, Hamburg, Germany.
[q] Also at Manhattan College, New York, NY, United States.
[r] Also at School of Physics and Engineering, Sun Yat-sen University, Guanzhou, China.
[s] Also at Academia Sinica Grid Computing, Institute of Physics, Academia Sinica, Taipei, Taiwan.
[t] Also at High Energy Physics Group, Shandong University, Shandong, China.
[u] Also at Section de Physique, Université de Genève, Geneva, Switzerland.
[v] Also at Departamento de Fisica, Universidade de Minho, Braga, Portugal.
[w] Also at Department of Physics and Astronomy, University of South Carolina, Columbia, SC, United States.
[x] Also at KFKI Research Institute for Particle and Nuclear Physics, Budapest, Hungary.
[y] Also at California Institute of Technology, Pasadena, CA, United States.
[z] Also at Institute of Physics, Jagiellonian University, Krakow, Poland.
[aa] Also at Department of Physics, Oxford University, Oxford, United Kingdom.
[ab] Also at Institute of Physics, Academia Sinica, Taipei, Taiwan.
[ac] Also at Department of Physics, The University of Michigan, Ann Arbor, MI, United States.
[ad] Also at DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat a l'Energie Atomique), Gif-sur-Yvette, France.
[ae] Also at Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France.
[af] Also at Department of Physics, Nanjing University, Jiangsu, China.
[*] Deceased.