



MIT Open Access Articles

Search for Supersymmetry at the LHC in Events with Jets and Missing Transverse Energy

The MIT Faculty has made this article openly available. ***Please share*** how this access benefits you. Your story matters.

Citation	Chatrchyan, S. et al. "Search for Supersymmetry at the LHC in Events with Jets and Missing Transverse Energy." Physical Review Letters 107, 221804 (2011) 1-16.
As Published	http://dx.doi.org/10.1103/PhysRevLett.107.221804
Publisher	American Physical Society
Version	Final published version
Accessed	Fri Sep 21 17:51:53 EDT 2018
Citable Link	http://hdl.handle.net/1721.1/69837
Terms of Use	Article is made available in accordance with the publisher's policy and may be subject to US copyright law. Please refer to the publisher's site for terms of use.
Detailed Terms	



Search for Supersymmetry at the LHC in Events with Jets and Missing Transverse Energy

S. Chatrchyan *et al.**

(CMS Collaboration)

(Received 12 September 2011; published 21 November 2011)

A search for events with jets and missing transverse energy is performed in a data sample of pp collisions collected at $\sqrt{s} = 7$ TeV by the CMS experiment at the LHC. The analyzed data sample corresponds to an integrated luminosity of 1.14 fb^{-1} . In this search, a kinematic variable α_T is used as the main discriminator between events with genuine and misreconstructed missing transverse energy. No excess of events over the standard model expectation is found. Exclusion limits in the parameter space of the constrained minimal supersymmetric extension of the standard model are set. In this model, squark masses below 1.1 TeV are excluded at 95% C.L. Gluino masses below 1.1 TeV are also ruled out at 95% C.L. for values of the universal scalar mass parameter below 500 GeV.

DOI: 10.1103/PhysRevLett.107.221804

PACS numbers: 14.80.Ly, 12.60.Jv, 13.85.Rm

The standard model (SM) of particle physics is generally considered to be valid only at low energy scales and is expected to be superseded by a more complete theory at higher scales. Supersymmetric (SUSY) extensions to the SM [1–8] introduce a large number of new particles with the same quantum numbers as their SM partners, but differing by half a unit of spin. If R -parity conservation [9] is assumed, supersymmetric particles, such as squarks and gluinos, are produced in pairs and decay to the lightest, stable supersymmetric particle (LSP). If the LSP is neutral and weakly interacting, a typical signature is a final state of multijets accompanied by significant missing transverse energy, \cancel{E}_T . Experiments at the Tevatron [10–13], $S\bar{p}\bar{p}S$ [14,15], HERA [16,17], and LEP [18] colliders have performed extensive searches for signs of SUSY. In 2010, the Large Hadron Collider (LHC) at CERN delivered an integrated luminosity of almost 50 pb^{-1} at a center-of-mass energy $\sqrt{s} = 7$ TeV, leading to several new searches from both the ATLAS Collaboration [19–22] and CMS Collaboration [23–27].

This Letter presents a search for SUSY based on a data sample corresponding to an integrated luminosity of $1.14 \pm 0.05 \text{ fb}^{-1}$. The search strategy follows Ref. [23] and is designed to be sensitive to \cancel{E}_T signatures in events with two or more energetic jets. The search is not optimized for any particular model of SUSY and is applicable to other new physics scenarios with a \cancel{E}_T signature. In this Letter, nevertheless, the results are interpreted in the constrained minimal supersymmetric extension of the standard model (CMSSM) [28–30]. The CMSSM is described by the following five parameters: the universal scalar and

gaugino mass parameters, m_0 and $m_{1/2}$; the universal trilinear soft SUSY-breaking parameter, A_0 ; the ratio of the vacuum expectation values of the two Higgs doublets, $\tan\beta$; and the sign of the Higgs mixing parameter, μ . We consider only parameter sets for which the LSP is the lightest neutralino. The following example parameter set, referred to as LM6, is used to illustrate possible CMSSM yields: $m_0 = 85 \text{ GeV}$, $m_{1/2} = 400 \text{ GeV}$, $A_0 = 0$, $\tan\beta = 10$, and $\mu > 0$.

A detailed description of the CMS apparatus can be found in Ref. [31]. Its central feature is a superconducting solenoid providing an axial magnetic field of 3.8 T. The bore of the solenoid is instrumented with several particle detection systems. Charged particle trajectories are measured by a silicon pixel and strip tracker system, with full azimuth (ϕ) coverage and a pseudorapidity (η) acceptance from -2.5 to $+2.5$. Here, $\eta \equiv -\ln[\tan(\theta/2)]$ and θ is the polar angle with respect to the counterclockwise beam direction. A lead tungstate crystal electromagnetic calorimeter (ECAL) and a brass or scintillator hadron calorimeter surround the tracking volume and provide coverage in η from -3 to $+3$. The forward hadron calorimeter extends symmetrically the coverage by a further two units in η . Muons are identified in gas ionization detectors embedded in the steel return yoke of the magnet. The CMS detector is nearly hermetic, which allows for momentum-balance measurements in the plane transverse to the beam axis.

The offline event reconstruction and selection criteria described below are explained in more detail in Ref. [23]. Jets are reconstructed from the energy deposits in the calorimeter towers, clustered by the anti- k_T algorithm [32] with a size parameter of 0.5. The raw jet energies measured by the calorimeter systems are corrected to establish a uniform relative response in η and a calibrated absolute response in transverse momentum p_T with an associated uncertainty between 2% and 4%, depending on the jet η and p_T [33]. Jets considered in the analysis

*Full author list given at the end of the article.

Published by the American Physical Society under the terms of the Creative Commons Attribution 3.0 License. Further distribution of this work must maintain attribution to the author(s) and the published article's title, journal citation, and DOI.

are required to have transverse energy $E_T > 50$ GeV. Events are vetoed if any additional jet satisfies $E_T > 50$ GeV and $|\eta| > 3$, or rare, spurious signals are identified in the calorimeters [34,35]. The highest- E_T jet is required to be within the central tracker acceptance and the two highest- E_T jets must each have $E_T > 100$ GeV. To suppress SM processes with genuine \cancel{E}_T from neutrinos, events containing an isolated electron [36] or muon [37] with $p_T > 10$ GeV are vetoed. To select a pure multijet topology, events are vetoed in which an isolated photon [38] with $p_T > 25$ GeV is found.

The following two variables characterize the visible energy and missing momentum in the transverse plane: the scalar sum of the transverse energy E_T of jets, defined as $H_T = \sum_{i=1}^{N_{\text{jet}}} E_{T,i}$, and the magnitude of the vector sum of the transverse momenta \vec{p}_T of jets, defined as $H_T = |\sum_{i=1}^{N_{\text{jet}}} \vec{p}_{T,i}|$, where N_{jet} is the number of jets with $E_T > 50$ GeV. Significant hadronic activity in the event is ensured by requiring $H_T > 275$ GeV. Following these selections, the background from multijet production, a manifestation of quantum chromodynamics (QCD), is still several orders of magnitude larger than the typical signal expected from SUSY. While the bulk of these multijet events do not exhibit significant \cancel{E}_T , large values can be observed due to stochastic fluctuations in the measurement of jet energies or mismeasurements caused by nonuniformities in the calibration of the calorimeters or detector inefficiencies.

The α_T kinematic variable, first introduced in Refs. [39–41], is used in the selection to efficiently reject events either without significant \cancel{E}_T or with transverse energy mismeasurements, while retaining a large sensitivity to new physics with genuine \cancel{E}_T signatures. For events with two jets, the variable is defined as $\alpha_T = E_T^{j_2} / M_T = E_T^{j_2} / \sqrt{H_T^2 - H_T^{j_1^2}}$, where $E_T^{j_2}$ is the transverse energy of the less-energetic jet, and M_T is the transverse mass of the dijet system. For a perfectly measured dijet event with $E_T^{j_1} = E_T^{j_2}$ and jets back to back in ϕ , and in the limit of large jet momenta compared to their masses, the value of α_T is 0.5. In the case of an imbalance in the measured transverse energies of back-to-back jets, α_T is smaller than 0.5. Values significantly greater than 0.5 are observed when the two jets are not back to back and balancing genuine \cancel{E}_T . For events with three or more jets, a dijet system is formed by combining the jets in the event into two *pseudojets*. The total E_T of each of the two pseudojets is calculated as the scalar sum of the measured E_T of contributing jets. The combination chosen is the one that minimizes the E_T difference between the two pseudojets. This simple clustering criterion provides the best separation between QCD multijet events and events with genuine \cancel{E}_T . Events with multiple jets with $E_T < 50$ GeV or with severe jet energy undermeasurements due to detector inefficiencies can lead to values of α_T slightly above 0.5. Such events are

effectively rejected by requiring $\alpha_T > 0.55$ and by applying dedicated vetoes, described further in Ref. [23]. These final selections complete the definition of the hadronic signal sample. A disjoint hadronic control sample consisting predominantly of QCD multijet events is defined by requiring $\alpha_T < 0.55$.

As can be seen in Fig. 1, the only expected remaining backgrounds with $\alpha_T > 0.55$ stem from SM processes with genuine \cancel{E}_T in the final state. In the dijet case, the largest backgrounds with genuine \cancel{E}_T are the associated production of W or Z bosons with jets, followed by either the weak decays $Z \rightarrow \nu\bar{\nu}$ or $W \rightarrow \tau\nu$, where the τ decays hadronically and is identified as a jet, or by leptonic decays that are not rejected by the dedicated electron or muon vetoes. At higher jet multiplicities, top quark production, followed by semileptonic weak top quark decay, becomes important.

Events in the hadronic signal sample are recorded with a trigger condition that identifies candidate events with energetic jets and significant \cancel{E}_T . Events are selected if they have $H_T > 250$ GeV and \cancel{E}_T above a threshold that evolves with instantaneous luminosity, from 60 to 90 GeV. In the region $275 < H_T < 325$ GeV, the efficiency with which events satisfying the full reconstruction and selection criteria are triggered is $0.99^{+0.01}_{-0.02}$. For events with $H_T > 325$ GeV, the efficiency is $1.00^{+0.00}_{-0.03}$. A set of pre-scaled H_T trigger conditions are used to record events for the hadronic control sample.

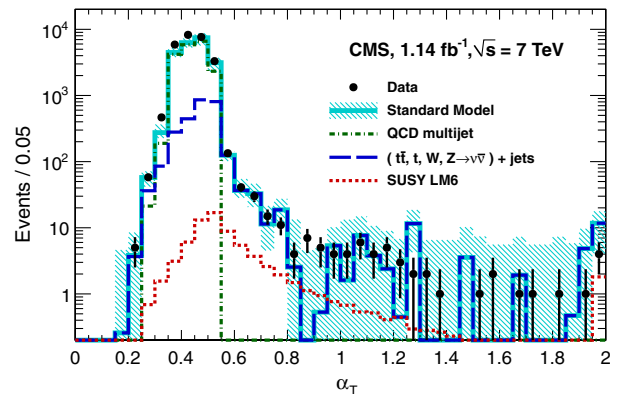


FIG. 1 (color online). The distribution of α_T , described in the text, for events in data with two or more jets (black dots with error bars representing the statistical uncertainties), after all event selection criteria except α_T are applied and $H_T > 375$ GeV. For illustrative purposes only, expected yields from simulation are also shown for QCD multijet events (dot-dashed line), associated production of top quarks, W , or Z with jets (long-dashed line), the sum of all aforementioned SM processes (solid line) and the SUSY LM6 model (dotted line). The uncertainties for the SM expectation, due to the limited accuracy of the available simulation data sets and jet energy calibrations, are represented by the hatched area. The highest bin contains the overflows.

The analysis makes use of two additional data samples to estimate the backgrounds with genuine \cancel{E}_T . First, a $\mu + \text{jets}$ sample is recorded with the hadronic trigger condition described above. The event selection, following closely the prescription described in Ref. [42], requires a single, isolated muon with $p_T > 10$ GeV in the final state and the transverse mass of the muon and H_T system to be larger than 30 GeV to ensure a sample rich in W bosons. The muon is required to be separated from the closest jet in the event by $\Delta\eta$ and $\Delta\phi$ such that the distance $\Delta R \equiv \sqrt{\Delta\eta^2 + \Delta\phi^2} > 0.5$. Second, a $\gamma + \text{jets}$ sample is selected using a dedicated photon trigger condition requiring a localized, large energy deposit in the ECAL with $p_T > 90$ GeV and that satisfies loose photon identification and isolation criteria [38]. The offline selection requires a single photon to be reconstructed with $p_T > 100$ GeV, $|\eta| < 1.45$, satisfying tight isolation criteria, and with a minimum distance to any jet of $\Delta R > 1.0$. For these selection criteria, the photon trigger condition is found to be fully efficient.

The hadronic signal region is divided into eight bins of H_T : two bins of width 50 GeV in the range $275 < H_T < 375$ GeV, five bins of width 100 GeV in the range $375 < H_T < 875$ GeV, and a final open bin, $H_T > 875$ GeV. As in Ref. [23], jet E_T thresholds are scaled down from their nominal values in the lowest two H_T bins to maintain jet multiplicities and thus comparable event kinematics, topologies, and background composition throughout the entire H_T range. The background estimation methods described below are combined in the statistical interpretation of the observed data yields to provide a single prediction of the SM background in each H_T bin of the hadronic signal region. With respect to Ref. [23], these refinements provide greater sensitivity across a broader SUSY parameter space and, in the context of CMSSM, up to higher-mass states.

The $\mu + \text{jets}$ data sample provides an estimate of the contributions from top quark and W production (leading to $W + \text{jets}$ final states) still remaining in each H_T bin of the hadronic signal region after all selection criteria are applied. Factors obtained from simulation [23] are then used to translate the yields in the $\mu + \text{jets}$ sample to estimates in each H_T bin of the hadronic signal region. These factors are found to be only weakly dependent on H_T , ranging from 1.14 at low H_T to 0.90 at high H_T . Conservative uncertainties on all the parameters entering these translation factors are assigned. The total systematic uncertainty is estimated to be 30%, dominated by the uncertainty on the efficiency for vetoing leptons. The remaining irreducible background of $Z \rightarrow \nu\bar{\nu} + \text{jets}$ events in the hadronic signal sample is estimated from $\gamma + \text{jets}$ events. These two processes have similar kinematic properties when the photon is ignored [43,44], while the latter has a larger production cross section. Translation factors that account for the ratio of cross sections for $\gamma + \text{jets}$ and $Z \rightarrow \nu\bar{\nu} + \text{jets}$, and their relative acceptances, are obtained from simulation [23] and

are used to estimate the number of $Z \rightarrow \nu\bar{\nu} + \text{jets}$ events in each H_T bin of the hadronic signal region. As is the case of the $\mu + \text{jets}$ sample, these translation factors are only weakly dependent on H_T , ranging from 0.35 at low H_T to 0.45 at high H_T . The main systematic uncertainties on these factors are associated with the ratio of cross sections between $\gamma + \text{jets}$ and $Z \rightarrow \nu\bar{\nu} + \text{jets}$ in the simulation (30%), the efficiency for photon identification (20%), and the purity of the photon selection (20%), which add up in quadrature to 40%. These uncertainty estimates are verified by predicting the number of $\mu + \text{two-jet}$ events in each H_T bin using the $\gamma + \text{two-jet}$ sample. The requirement of exactly two jets suppresses the top quark contribution in the muon sample, thus leaving a relatively pure $W + \text{jets}$ sample that is kinematically similar to the $Z \rightarrow \nu\bar{\nu} + \text{jets}$ sample. The predicted and observed event yields are consistent within the assigned systematic uncertainties.

Furthermore, the H_T dependence of the ratio R_{α_T} is exploited to constrain the SM background estimate for each H_T bin. This ratio is defined as the number of events with α_T above and below a threshold value of 0.55 for a given bin in H_T . The denominator of the ratio is always dominated by events from QCD multijet production and is measured in data with samples selected by the set of prescaled H_T trigger conditions. The chosen α_T threshold ensures that, for a given bin in H_T , the numerator of the ratio is dominated by events from SM processes with genuine \cancel{E}_T from neutrinos, with no significant contribution from QCD multijet production. As observed in Ref. [23], this property leads to R_{α_T} being independent of H_T . The remaining backgrounds are those with genuine \cancel{E}_T from associated production of top quarks, W , or Z with jets. By relaxing the α_T threshold to values lower than 0.55, the numerator is instead dominated by mismeasured QCD multijet events, and an exponential dependence of R_{α_T} on H_T is observed [23]. The behaviors of α_T and $R_{\alpha_T}(H_T)$ are observed in data and simulation to be robust against the effects of multiple pp collisions per beam crossing (pileup). In the statistical interpretation of the analysis, $R_{\alpha_T}(H_T)$ is modeled as a superposition of a H_T -independent contribution from SM processes with genuine \cancel{E}_T , and an exponentially falling contribution to accommodate any potential QCD contamination. The latter is considered even though no evidence of a significant QCD contamination is found in the hadronic signal region.

To obtain an accurate and consistent prediction of the SM background, a simultaneous binned likelihood fit using information from all three data samples is performed. The fit maximizes the likelihood $L_{\text{total}} = L_{\text{hadronic}} \times L_{\mu+\text{jets}} \times L_{\gamma+\text{jets}}$, where L_{hadronic} characterizes $R_{\alpha_T}(H_T)$ in the hadronic sample with a single exponential function, Ae^{-kH_T} , to accommodate any QCD contamination and a constant, H_T -independent contribution, B , to describe SM processes with genuine \cancel{E}_T . The likelihoods $L_{\mu+\text{jets}}$ and $L_{\gamma+\text{jets}}$ describe the H_T -dependent yields in the $\mu + \text{jets}$ and

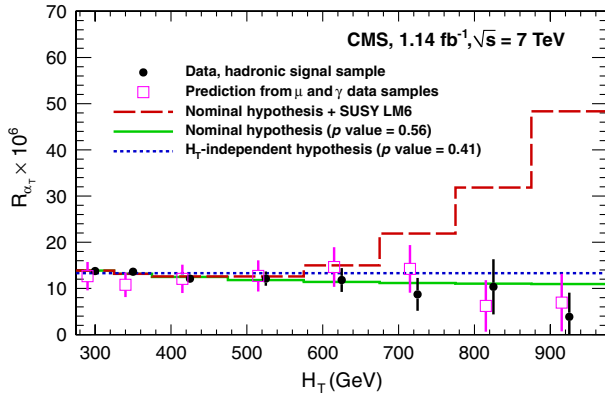


FIG. 2 (color online). The ratio R_{α_T} as a function of H_T , as measured in the hadronic data samples (black dots with error bars representing the statistical uncertainties). The ratios using the direct predictions from the μ + jets and γ + jets data samples are shown as open squares (offset for clarity, with error bars representing the statistical and systematic uncertainties). Also shown is the result of the simultaneous fit to the three data samples (solid line); the analogous result when assuming a H_T -independent hypothesis (dotted line); and, for illustrative purposes only, the expectation from the SUSY LM6 model when superimposed on the nominal fit result (long-dashed line).

γ + jets samples. For each H_T bin, these yields are related to the numerator of $R_{\alpha_T}(H_T)$, measured in the hadronic signal sample, via the translation factors from the simulation.

With a fit probability (p value) of 0.56, the hypothesis for the R_{α_T} dependence on H_T reproduces the data well, as shown in Fig. 2. The only parameter with a significant nonzero value as determined by the fit is the constant term $B = (1.1 \pm 0.2) \times 10^{-5}$. The other two fit parameters, $A = (1.4 \pm 1.9) \times 10^{-5}$ and $k = (5.2 \pm 5.6) \times 10^{-3} \text{ GeV}^{-1}$, are compatible with zero, indicating that no significant QCD contamination has been observed in the signal region. Furthermore, as a cross check, the fit is repeated with the assumption that R_{α_T} is independent of H_T , which in turn implies that the numerator of the ratio is fully dominated by SM backgrounds with genuine \cancel{E}_T . The result of this fit, shown in Fig. 2, has a p value of 0.41 and is in good agreement with the nominal fit.

To validate the background estimation of the simultaneous fit, the μ + jets and γ + jets samples are used to

predict directly the SM backgrounds with genuine \cancel{E}_T in the different H_T bins, independently of the fit. The prediction for each H_T bin is taken as the numerator of the ratio R_{α_T} , and the observed behavior in H_T is shown in Fig. 2. This cross-check confirms, within the statistical and systematic uncertainties, the H_T independence of R_{α_T} when the numerator is dominated by SM events with genuine \cancel{E}_T .

The fit results for all three data samples are listed in Table I, along with the observed yields in the data. Good agreement between the measured H_T distribution and the fit is observed for all three data samples, indicating that the observed yields are compatible with the SM background expectation provided by the fit. The uncertainties listed with the SM predictions are obtained from an ensemble of pseudoexperiments. Figure 3 compares the result of the simultaneous fit to the observed yields in the hadronic signal sample.

Given the lack of an excess of events above the expected SM backgrounds, limits are set in the parameter space of the CMSSM. At each point of the parameter space, the SUSY particle spectrum is calculated with SOFTSUSY [45], and the signal events are generated at leading order with PYTHIA 6.4 [46]. Inclusive, process-dependent, next-to-leading-order (NLO) cross sections, obtained with the program PROSPINO [47], are used to calculate the observed and expected exclusion contours. The simulated signal events are reweighted so that the distribution of number of pileup events per beam crossing from the simulation matches that observed in data. Uncertainties on the SM background prediction, the luminosity measurement (4.5%) [48], the total acceptance times efficiency of the selection for the considered signal model (4.5%) [23,49], and NLO cross section and parton distribution functions (10%) are included in the limit. Although signal contributions to the total yield in each of the three considered data samples are allowed, the only relevant signal contribution originates from the hadronic data sample in the case of the CMSSM.

Figure 4 shows the observed and expected exclusion limits at 95% confidence level (C.L.) in the $(m_0, m_{1/2})$ plane for $\tan\beta = 10$ and $A_0 = 0 \text{ GeV}$, calculated with the CL_s method [50]. For this choice of parameters in the CMSSM, squark masses below 1.1 TeV are excluded and gluino masses below the same value are ruled out for

TABLE I. Comparison of the measured yields in the different H_T bins for the hadronic, μ + jets and γ + jets samples with the SM expectations and combined statistical and systematic uncertainties given by the simultaneous fit.

H_T bin (GeV)	275–325	325–375	375–475	475–575	575–675	675–775	775–875	>875
SM hadronic	787^{+32}_{-22}	310^{+8}_{-12}	202^{+9}_{-9}	$60.4^{+4.2}_{-3.0}$	$20.3^{+1.8}_{-1.1}$	$7.7^{+0.8}_{-0.5}$	$3.2^{+0.4}_{-0.2}$	$2.8^{+0.4}_{-0.2}$
Data hadronic	782	321	196	62	21	6	3	1
SM μ + jets	367^{+15}_{-15}	182^{+8}_{-9}	113^{+8}_{-7}	$36.5^{+3.8}_{-3.3}$	$13.4^{+2.2}_{-1.8}$	$4.0^{+1.4}_{-1.2}$	$0.8^{+0.9}_{-0.1}$	$0.7^{+0.9}_{-0.1}$
Data μ + jets	389	156	113	39	17	5	0	0
SM γ + jets	834^{+28}_{-30}	325^{+17}_{-17}	210^{+12}_{-12}	$64.7^{+6.9}_{-7.0}$	$21.1^{+3.9}_{-4.3}$	$10.5^{+2.5}_{-2.6}$	$6.1^{+0.9}_{-1.7}$	$5.5^{+0.9}_{-1.6}$
Data γ + jets	849	307	210	67	24	12	4	4

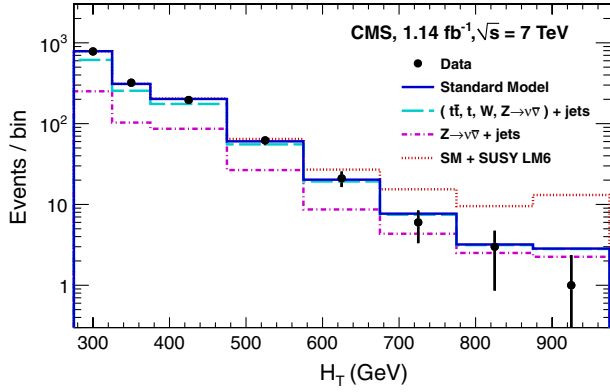


FIG. 3 (color online). The observed event yields versus H_T in the hadronic signal sample (black dots with error bars representing the statistical uncertainties). Also shown are the expectations given by the simultaneous fit for the $Z \rightarrow \nu\bar{\nu} + \text{jets}$ process (dot-dashed line); the associated production of top, W , or Z with jets (long-dashed line); the sum of QCD and all aforementioned processes (solid line); and, for illustrative purposes only, the SUSY LM6 model superimposed on the SM expectation (dotted line).

$m_0 < 500$ GeV. The exclusion limit changes at most by 20 GeV in the $(m_0, m_{1/2})$ plane for different parameter values (e.g., $\tan\beta = 40$ and $A_0 = -500$ GeV), indicating that the limit is only weakly dependent on these parameters.

In summary, the first search for supersymmetry from CMS based on an integrated luminosity in excess of 1 fb^{-1} has been reported. Final states with two or more jets and significant \cancel{E}_T , as expected from high-mass squark and gluino production and decays, have been analyzed. The search has been performed in eight bins of the scalar sum of the transverse energy of jets, H_T , considering events with H_T in excess of 275 GeV. The sum of standard model backgrounds per H_T bin has been estimated from

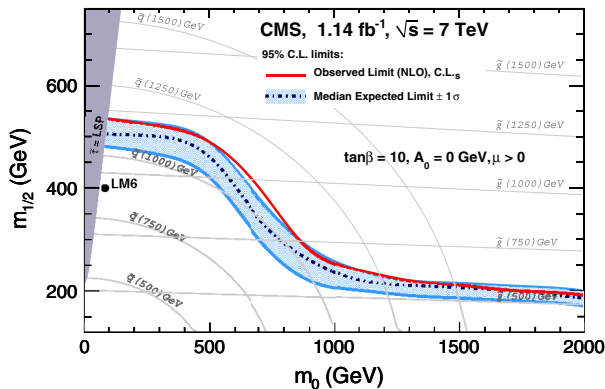


FIG. 4 (color online). Observed and expected 95% C.L. exclusion contours in the CMSSM $(m_0, m_{1/2})$ plane ($\tan\beta = 10$, $A_0 = 0$, $\mu > 0$) using NLO signal cross sections with the C.L._s method. The expected limit is shown with its 68% C.L. range. The SUSY benchmark model LM6 is also shown.

a simultaneous binned likelihood fit to hadronic, $\mu + \text{jets}$, and $\gamma + \text{jets}$ samples. The observed yields in the eight H_T bins have been found to be in agreement with the expected contributions from standard model processes. Limits on the CMSSM parameters have been derived and squark masses below 1.1 TeV are excluded at 95% C.L. in this model. Gluino masses in the same range are ruled out at 95% C.L. for $m_0 < 500$ GeV. This limit represents a tight constraint on the parameter space of SUSY models like the CMSSM.

We wish to congratulate our colleagues in the CERN accelerator departments for the excellent performance of the LHC machine. We thank the technical and administrative staff at CERN and other CMS institutes, and acknowledge support from: FMSR (Austria); FNRS and FWO (Belgium); CNPq, CAPES, FAPERJ, and FAPESP (Brazil); MES (Bulgaria); CERN; CAS, MoST, and NSFC (China); COLCIENCIAS (Colombia); MSES (Croatia); RPF (Cyprus); Academy of Sciences and NICPB (Estonia); Academy of Finland, ME, and HIP (Finland); CEA and CNRS/IN2P3 (France); BMBF, DFG, and HGF (Germany); GSRT (Greece); OTKA and NKTH (Hungary); DAE and DST (India); IPM (Iran); SFI (Ireland); INFN (Italy); NRF and WCU (Korea); LAS (Lithuania); CINVESTAV, CONACYT, SEP, and UASLP-FAI (Mexico); PAEC (Pakistan); SCSR (Poland); FCT (Portugal); JINR (Armenia, Belarus, Georgia, Ukraine, Uzbekistan); MST and MAE (Russia); MSTD (Serbia); MICINN and CPAN (Spain); Swiss Funding Agencies (Switzerland); NSC (Taipei); TUBITAK and TAEK (Turkey); STFC (U.K.); DOE and NSF (U.S.).

- [1] Y. A. Gol'fand and E. P. Likhtman, JETP Lett. **13**, 323 (1971), http://www.jetpletters.ac.ru/ps/1584/article_24309.shtml.
- [2] J. Wess and B. Zumino, Nucl. Phys. **B70**, 39 (1974).
- [3] H. P. Nilles, Phys. Rep. **110**, 1 (1984).
- [4] H. Haber and G. Kane, Phys. Rep. **117**, 75 (1985).
- [5] R. Barbieri, S. Ferrara, and C. A. Savoy, Phys. Lett. B **119**, 343 (1982).
- [6] S. Dawson, E. Eichten, and C. Quigg, Phys. Rev. D **31**, 1581 (1985).
- [7] E. Witten, Nucl. Phys. **B188**, 513 (1981).
- [8] S. Dimopoulos and H. Georgi, Nucl. Phys. **B193**, 150 (1981).
- [9] G. R. Farrar and P. Fayet, Phys. Lett. B **76**, 575 (1978).
- [10] T. Aaltonen *et al.* (CDF Collaboration), Phys. Rev. Lett. **101**, 251801 (2008).
- [11] T. Aaltonen *et al.* (CDF Collaboration), Phys. Rev. Lett. **102**, 121801 (2009).
- [12] V. M. Abazov *et al.* (D0 Collaboration), Phys. Lett. B **660**, 449 (2008).
- [13] V. M. Abazov *et al.* (D0 Collaboration), Phys. Lett. B **680**, 34 (2009).
- [14] C. Albajar *et al.* (UA1 Collaboration), Phys. Lett. B **198**, 261 (1987).

- [15] R. Ansari *et al.* (UA2 Collaboration), *Phys. Lett. B* **195**, 613 (1987).
- [16] S. Chekanov *et al.* (ZEUS Collaboration), *Eur. Phys. J. C* **50**, 269 (2007).
- [17] S. Aid *et al.* (H1 Collaboration), *Phys. Lett. B* **380**, 461 (1996).
- [18] LEPSUSYWG (ALEPH, DELPHI, L3, and OPAL Collaborations), Joint SUSY working group, Report No. LEPSUSYWG/02-06-2 2002.
- [19] G. Aad *et al.* (ATLAS Collaboration), *Phys. Rev. Lett.* **106**, 131802 (2011).
- [20] G. Aad *et al.* (ATLAS Collaboration), *Phys. Lett. B* **701**, 186 (2011).
- [21] G. Aad *et al.* (ATLAS Collaboration), *Phys. Lett. B* **701**, 398 (2011).
- [22] G. Aad *et al.* (ATLAS Collaboration), *Eur. Phys. J. C* **71**, 1 (2011).
- [23] V. Khachatryan *et al.* (CMS Collaboration), *Phys. Lett. B* **698**, 196 (2011).
- [24] CMS Collaboration, *J. High Energy Phys.* **08** (2011) 155.
- [25] CMS Collaboration, [arXiv:1107.1279](https://arxiv.org/abs/1107.1279).
- [26] S. Chatrchyan *et al.* (CMS Collaboration), *Phys. Rev. Lett.* **106**, 211802 (2011).
- [27] V. Khachatryan *et al.* (CMS Collaboration), *J. High Energy Phys.* **07** (2011) 113.
- [28] A. H. Chamseddine, R. Arnowitt, and P. Nath, *Phys. Rev. Lett.* **49**, 970 (1982).
- [29] R. Arnowitt and P. Nath, *Phys. Rev. Lett.* **69**, 725 (1992).
- [30] G. L. Kane *et al.*, *Phys. Rev. D* **49**, 6173 (1994).
- [31] S. Chatrchyan *et al.* (CMS Collaboration), *JINST* **03**, S08004 (2008).
- [32] M. Cacciari, G. P. Salam, and G. Soyez, *J. High Energy Phys.* **04** (2008) 063.
- [33] CMS Collaboration, [arXiv:1107.4277](https://arxiv.org/abs/1107.4277) [JINST (to be published)].
- [34] S. Chatrchyan *et al.* (CMS), *JINST* **5**, T03014 (2010).
- [35] CMS Collaboration, CMS Report No. CMS-NOTE-2010-012, 2010.
- [36] CMS Collaboration, CMS Physics Analysis Summary Report No. EGM-10-004, 2010.
- [37] CMS Collaboration, CMS Physics Analysis Summary Report No. MUO-10-002, 2010.
- [38] CMS Collaboration, CMS Physics Analysis Summary Report No. EGM-10-006, 2010.
- [39] L. Randall and D. Tucker-Smith, *Phys. Rev. Lett.* **101**, 221803 (2008).
- [40] CMS Collaboration, CMS Physics Analysis Summary Report No. SUS-08-005, 2008.
- [41] CMS Collaboration, CMS Physics Analysis Summary Report No. SUS-09-001, 2009.
- [42] V. Khachatryan *et al.* (CMS), *Phys. Lett. B* **695**, 424 (2011).
- [43] CMS Collaboration, CMS Physics Analysis Summary Report No. SUS-08-002, 2008.
- [44] Z. Bern *et al.*, [arXiv:1106.1423](https://arxiv.org/abs/1106.1423) [*Phys. Rev. D* (to be published)].
- [45] B. C. Allanach, *Comput. Phys. Commun.* **143**, 305 (2002).
- [46] T. Sjöstrand, S. Mrenna, and P. Z. Skands, *J. High Energy Phys.* **05** (2006), 026.
- [47] W. Beenakker *et al.*, *Nucl. Phys.* **B492**, 51 (1997).
- [48] CMS Collaboration, CMS Physics Analysis Summary Report No. EWK-10-004, 2010.
- [49] CMS Collaboration, CMS Physics Analysis Summary Report No. JME-10-010, 2010.
- [50] K. Nakamura (Particle Data Group), *J. Phys. G* **37**, 075021 (2010).

S. Chatrchyan,¹ V. Khachatryan,¹ A. M. Sirunyan,¹ A. Tumasyan,¹ W. Adam,² T. Bergauer,² M. Dragicevic,² J. Erö,² C. Fabjan,² M. Friedl,² R. Frühwirth,² V. M. Ghete,² J. Hammer,^{2,b} S. Hänsel,² M. Hoch,² N. Hörmann,² J. Hrubec,² M. Jeitler,² W. Kiesenhofer,² M. Krammer,² D. Liko,² I. Mikulec,² M. Pernicka,² B. Rahbaran,² H. Rohringer,² R. Schöfbeck,² J. Strauss,² A. Taurok,² F. Teischinger,² C. Trauner,² P. Wagner,² W. Waltenberger,² G. Walzel,² E. Widl,² C.-E. Wulz,² V. Mossolov,³ N. Shumeiko,³ J. Suarez Gonzalez,³ S. Bansal,⁴ L. Benucci,⁴ E. A. De Wolf,⁴ X. Janssen,⁴ S. Luyckx,⁴ T. Maes,⁴ L. Mucibello,⁴ S. Ochesanu,⁴ B. Roland,⁴ R. Rougny,⁴ M. Selvaggi,⁴ H. Van Haevermaet,⁴ P. Van Mechelen,⁴ N. Van Remortel,⁴ F. Blekman,⁵ S. Blyweert,⁵ J. D'Hondt,⁵ R. Gonzalez Suarez,⁵ A. Kalogeropoulos,⁵ M. Maes,⁵ A. Olbrechts,⁵ W. Van Doninck,⁵ P. Van Mulders,⁵ G. P. Van Onsem,⁵ I. Vilella,⁵ O. Charaf,⁶ B. Clerbaux,⁶ G. De Lentdecker,⁶ V. Dero,⁶ A. P. R. Gay,⁶ G. H. Hammad,⁶ T. Hreus,⁶ P. E. Marage,⁶ A. Raval,⁶ L. Thomas,⁶ G. Vander Marcken,⁶ C. Vander Velde,⁶ P. Vanlaer,⁶ V. Adler,⁷ A. Cimmino,⁷ S. Costantini,⁷ M. Grunewald,⁷ B. Klein,⁷ J. Lellouch,⁷ A. Marinov,⁷ J. Mccartin,⁷ D. Ryckbosch,⁷ F. Thyssen,⁷ M. Tytgat,⁷ L. Vanelderen,⁷ P. Verwilligen,⁷ S. Walsh,⁷ N. Zaganidis,⁷ S. Basegmez,⁸ G. Bruno,⁸ J. Caudron,⁸ L. Ceard,⁸ E. Cortina Gil,⁸ J. De Favereau De Jeneret,⁸ C. Delaere,⁸ D. Favart,⁸ A. Giammanco,⁸ G. Grégoire,⁸ J. Hollar,⁸ V. Lemaitre,⁸ J. Liao,⁸ O. Militaru,⁸ C. Nuttens,⁸ S. Ovin,⁸ D. Pagano,⁸ A. Pin,⁸ K. Piotrkowski,⁸ N. Schul,⁸ N. Bely,⁹ T. Caebergs,⁹ E. Daubie,⁹ G. A. Alves,¹⁰ L. Brito,¹⁰ D. De Jesus Damiao,¹⁰ M. E. Pol,¹⁰ M. H. G. Souza,¹⁰ W. L. Aldá Júnior,¹¹ W. Carvalho,¹¹ E. M. Da Costa,¹¹ C. De Oliveira Martins,¹¹ S. Fonseca De Souza,¹¹ D. Matos Figueiredo,¹¹ L. Mundim,¹¹ H. Nogima,¹¹ V. Oguri,¹¹ W. L. Prado Da Silva,¹¹ A. Santoro,¹¹ S. M. Silva Do Amaral,¹¹ A. Sznajder,¹¹ T. S. Anjos,^{12,c} C. A. Bernardes,^{12,c} F. A. Dias,^{12,d} T. R. Fernandez Perez Tomei,¹² E. M. Gregores,^{12,c} C. Lagana,¹² F. Marinho,¹² P. G. Mercadante,^{12,c} S. F. Novaes,¹² Sandra S. Padula,¹² N. Darmenov,^{13,b} V. Genchev,^{13,b} P. Iaydjiev,^{13,b} S. Piperov,¹³ M. Rodozov,¹³ S. Stoykova,¹³ G. Sultanov,¹³ V. Tcholakov,¹³ R. Trayanov,¹³ M. Vutova,¹³ A. Dimitrov,¹⁴ R. Hadjiiska,¹⁴ A. Karadzhinova,¹⁴

V. Kozhuharov,¹⁴ L. Litov,¹⁴ M. Mateev,¹⁴ B. Pavlov,¹⁴ P. Petkov,¹⁴ J. G. Bian,¹⁵ G. M. Chen,¹⁵ H. S. Chen,¹⁵ C. H. Jiang,¹⁵ D. Liang,¹⁵ S. Liang,¹⁵ X. Meng,¹⁵ J. Tao,¹⁵ J. Wang,¹⁵ J. Wang,¹⁵ X. Wang,¹⁵ Z. Wang,¹⁵ H. Xiao,¹⁵ M. Xu,¹⁵ J. Zang,¹⁵ Z. Zhang,¹⁵ Y. Ban,¹⁶ S. Guo,¹⁶ Y. Guo,¹⁶ W. Li,¹⁶ Y. Mao,¹⁶ S. J. Qian,¹⁶ H. Teng,¹⁶ B. Zhu,¹⁶ W. Zou,¹⁶ A. Cabrera,¹⁷ B. Gomez Moreno,¹⁷ A. A. Ocampo Rios,¹⁷ A. F. Osorio Oliveros,¹⁷ J. C. Sanabria,¹⁷ N. Godinovic,¹⁸ D. Lelas,¹⁸ K. Lelas,¹⁸ R. Plestina,^{18,e} D. Polic,¹⁸ I. Puljak,¹⁸ Z. Antunovic,¹⁹ M. Dzelalija,¹⁹ M. Kovac,¹⁹ V. Brigljevic,²⁰ S. Duric,²⁰ K. Kadija,²⁰ J. Luetic,²⁰ S. Morovic,²⁰ A. Attikis,²¹ M. Galanti,²¹ J. Mousa,²¹ C. Nicolaou,²¹ F. Ptochos,²¹ P. A. Razis,²¹ M. Finger,²² M. Finger, Jr.,²² Y. Assran,^{23,f} A. Ellithi Kamel,^{23,g} S. Khalil,^{23,h} M. A. Mahmoud,^{23,i} A. Radi,^{23,j} A. Hektor,²⁴ M. Kadastik,²⁴ M. Müntel,²⁴ M. Raidal,²⁴ L. Rebane,²⁴ A. Tiko,²⁴ V. Azzolini,²⁵ P. Eerola,²⁵ G. Fedi,²⁵ M. Voutilainen,²⁵ S. Czellar,²⁶ J. Härkönen,²⁶ A. Heikkinen,²⁶ V. Karimäki,²⁶ R. Kinnunen,²⁶ M. J. Kortelainen,²⁶ T. Lampén,²⁶ K. Lassila-Perini,²⁶ S. Lehti,²⁶ T. Lindén,²⁶ P. Luukka,²⁶ T. Mäenpää,²⁶ E. Tuominen,²⁶ J. Tuominiemi,²⁶ E. Tuovinen,²⁶ D. Ungaro,²⁶ L. Wendland,²⁶ K. Banzuzi,²⁷ A. Karjalainen,²⁷ A. Korpela,²⁷ T. Tuuva,²⁷ D. Sillou,²⁸ M. Besancon,²⁹ S. Choudhury,²⁹ M. Dejardin,²⁹ D. Denegri,²⁹ B. Fabbro,²⁹ J. L. Faure,²⁹ F. Ferri,²⁹ S. Ganjour,²⁹ A. Givernaud,²⁹ P. Gras,²⁹ G. Hamel de Monchenault,²⁹ P. Jarry,²⁹ E. Locci,²⁹ J. Malcles,²⁹ M. Marionneau,²⁹ L. Millischer,²⁹ J. Rander,²⁹ A. Rosowsky,²⁹ I. Shreyber,²⁹ M. Titov,²⁹ S. Baffioni,³⁰ F. Beaudette,³⁰ L. Benhabib,³⁰ L. Bianchini,³⁰ M. Bluj,^{30,k} C. Broutin,³⁰ P. Busson,³⁰ C. Charlot,³⁰ T. Dahms,³⁰ L. Dobrzynski,³⁰ S. Elgammal,³⁰ R. Granier de Cassagnac,³⁰ M. Haguenaer,³⁰ P. Miné,³⁰ C. Mironov,³⁰ C. Ochando,³⁰ P. Paganini,³⁰ D. Sabes,³⁰ R. Salerno,³⁰ Y. Sirois,³⁰ C. Thiebaux,³⁰ C. Veelken,³⁰ A. Zabi,³⁰ J.-L. Agram,^{31,l} J. Andrea,³¹ D. Bloch,³¹ D. Bodin,³¹ J.-M. Brom,³¹ M. Cardaci,³¹ E. C. Chabert,³¹ C. Collard,³¹ E. Conte,^{31,l} F. Drouhin,^{31,l} C. Ferro,³¹ J.-C. Fontaine,^{31,l} D. Gelé,³¹ U. Goerlach,³¹ S. Greder,³¹ P. Juillot,³¹ M. Karim,^{31,l} A.-C. Le Bihan,³¹ Y. Mikami,³¹ P. Van Hove,³¹ F. Fassi,³² D. Mercier,³² C. Baty,³³ S. Beauceron,³³ N. Beaupere,³³ M. Bedjidian,³³ O. Bondu,³³ G. Boudoul,³³ D. Boumediene,³³ H. Brun,³³ J. Chasserat,³³ R. Chierici,³³ D. Contardo,³³ P. Depasse,³³ H. El Mamouni,³³ J. Fay,³³ S. Gascon,³³ B. Ille,³³ T. Kurca,³³ T. Le Grand,³³ M. Lethuillier,³³ L. Mirabito,³³ S. Perries,³³ V. Sordini,³³ S. Tosi,³³ Y. Tschudi,³³ P. Verdier,³³ S. Viret,³³ D. Lomidze,³⁴ G. Anagnostou,³⁵ S. Beranek,³⁵ M. Edelhoff,³⁵ L. Feld,³⁵ N. Heracleous,³⁵ O. Hindrichs,³⁵ R. Jussen,³⁵ K. Klein,³⁵ J. Merz,³⁵ N. Mohr,³⁵ A. Ostapchuk,³⁵ A. Perieanu,³⁵ F. Raupach,³⁵ J. Sammet,³⁵ S. Schael,³⁵ D. Sprenger,³⁵ H. Weber,³⁵ M. Weber,³⁵ B. Wittmer,³⁵ V. Zhukov,^{35,m} M. Ata,³⁶ E. Dietz-Laursonn,³⁶ M. Erdmann,³⁶ T. Hebbeker,³⁶ C. Heidemann,³⁶ A. Hinzmann,³⁶ K. Hoepfner,³⁶ T. Klimovich,³⁶ D. Klingebiel,³⁶ P. Kreuzer,³⁶ D. Lanske,^{36,a} J. Lingemann,³⁶ C. Magass,³⁶ M. Merschmeyer,³⁶ A. Meyer,³⁶ P. Papacz,³⁶ H. Pieta,³⁶ H. Reithler,³⁶ S. A. Schmitz,³⁶ L. Sonnenschein,³⁶ J. Steggemann,³⁶ D. Teyssier,³⁶ M. Bontenackels,³⁷ V. Cherepanov,³⁷ M. Davids,³⁷ G. Flüge,³⁷ H. Geenen,³⁷ M. Giffels,³⁷ W. Haj Ahmad,³⁷ F. Hoehle,³⁷ B. Kargoll,³⁷ T. Kress,³⁷ Y. Kuessel,³⁷ A. Linn,³⁷ A. Nowack,³⁷ L. Perchalla,³⁷ O. Pooth,³⁷ J. Rennefeld,³⁷ P. Sauerland,³⁷ A. Stahl,³⁷ D. Tornier,³⁷ M. H. Zoeller,³⁷ M. Aldaya Martin,³⁸ W. Behrenhoff,³⁸ U. Behrens,³⁸ M. Bergholz,^{38,n} A. Bethani,³⁸ K. Borras,³⁸ A. Cakir,³⁸ A. Campbell,³⁸ E. Castro,³⁸ D. Dammann,³⁸ G. Eckerlin,³⁸ D. Eckstein,³⁸ A. Flossdorf,³⁸ G. Flucke,³⁸ A. Geiser,³⁸ J. Hauk,³⁸ H. Jung,^{38,b} M. Kasemann,³⁸ P. Katsas,³⁸ C. Kleinwort,³⁸ H. Kluge,³⁸ A. Knutsson,³⁸ M. Krämer,³⁸ D. Krücker,³⁸ E. Kuznetsova,³⁸ W. Lange,³⁸ W. Lohmann,^{38,n} B. Lutz,³⁸ R. Mankel,³⁸ M. Marienfeld,³⁸ I.-A. Melzer-Pellmann,³⁸ A. B. Meyer,³⁸ J. Mnich,³⁸ A. Mussgiller,³⁸ J. Olzem,³⁸ A. Petrukhin,³⁸ D. Pitzl,³⁸ A. Raspereza,³⁸ M. Rosin,³⁸ R. Schmidt,^{38,n} T. Schoerner-Sadenius,³⁸ N. Sen,³⁸ A. Spiridonov,³⁸ M. Stein,³⁸ J. Tomaszewska,³⁸ R. Walsh,³⁸ C. Wissing,³⁸ C. Autermann,³⁹ V. Blobel,³⁹ S. Bobrovskiy,³⁹ J. Draeger,³⁹ H. Enderle,³⁹ U. Gebbert,³⁹ M. Görner,³⁹ T. Hermanns,³⁹ K. Kaschube,³⁹ G. Kaussen,³⁹ H. Kirschenmann,³⁹ R. Klanner,³⁹ J. Lange,³⁹ B. Mura,³⁹ S. Naumann-Emme,³⁹ F. Nowak,³⁹ N. Pietsch,³⁹ C. Sander,³⁹ H. Schettler,³⁹ P. Schleper,³⁹ E. Schlieckau,³⁹ M. Schröder,³⁹ T. Schum,³⁹ H. Stadie,³⁹ G. Steinbrück,³⁹ J. Thomsen,³⁹ C. Barth,⁴⁰ J. Bauer,⁴⁰ J. Berger,⁴⁰ V. Buege,⁴⁰ T. Chwalek,⁴⁰ W. De Boer,⁴⁰ A. Dierlamm,⁴⁰ G. Dirkes,⁴⁰ M. Feindt,⁴⁰ J. Gruschke,⁴⁰ C. Hackstein,⁴⁰ F. Hartmann,⁴⁰ M. Heinrich,⁴⁰ H. Held,⁴⁰ K. H. Hoffmann,⁴⁰ S. Honc,⁴⁰ I. Katkov,^{40,m} J. R. Komaragiri,⁴⁰ T. Kuhr,⁴⁰ D. Martschei,⁴⁰ S. Mueller,⁴⁰ Th. Müller,⁴⁰ M. Niegel,⁴⁰ O. Oberst,⁴⁰ A. Oehler,⁴⁰ J. Ott,⁴⁰ T. Peiffer,⁴⁰ G. Quast,⁴⁰ K. Rabbertz,⁴⁰ F. Ratnikov,⁴⁰ N. Ratnikova,⁴⁰ M. Renz,⁴⁰ S. Röcker,⁴⁰ C. Saout,⁴⁰ A. Scheurer,⁴⁰ P. Schieferdecker,⁴⁰ F.-P. Schilling,⁴⁰ M. Schmanau,⁴⁰ G. Schott,⁴⁰ H. J. Simonis,⁴⁰ F. M. Stober,⁴⁰ D. Troendle,⁴⁰ J. Wagner-Kuhr,⁴⁰ T. Weiler,⁴⁰ M. Zeise,⁴⁰ E. B. Ziebarth,⁴⁰ G. Daskalakis,⁴¹ T. Geralis,⁴¹ S. Kesisoglou,⁴¹ A. Kyriakis,⁴¹ D. Loukas,⁴¹ I. Manolagos,⁴¹ A. Markou,⁴¹ C. Markou,⁴¹ C. Mavrommatis,⁴¹ E. Ntomari,⁴¹ E. Petrakou,⁴¹ L. Gouskos,⁴² T. J. Mertzimekis,⁴² A. Panagiotou,⁴² N. Saoulidou,⁴² E. Stiliaris,⁴² I. Evangelou,⁴³ C. Foudas,^{43,b} P. Kokkas,⁴³ N. Manthos,⁴³ I. Papadopoulos,⁴³ V. Patras,⁴³ F. A. Triantis,⁴³ A. Aranyi,⁴⁴ G. Bencze,⁴⁴ L. Boldizsar,⁴⁴ C. Hajdu,^{44,b}

P. Hidas,⁴⁴ D. Horvath,^{44,o} A. Kapusi,⁴⁴ K. Krajczar,^{44,p} F. Sikler,^{44,b} G. I. Veres,^{44,p} G. Vesztergombi,^{44,p} N. Beni,⁴⁵ J. Molnar,⁴⁵ J. Palinkas,⁴⁵ Z. Szillasi,⁴⁵ V. Veszpremi,⁴⁵ J. Karancsi,⁴⁶ P. Raics,⁴⁶ Z. L. Trocsanyi,⁴⁶ B. Ujvari,⁴⁶ S. B. Beri,⁴⁷ V. Bhatnagar,⁴⁷ N. Dhingra,⁴⁷ R. Gupta,⁴⁷ M. Jindal,⁴⁷ M. Kaur,⁴⁷ J. M. Kohli,⁴⁷ M. Z. Mehta,⁴⁷ N. Nishu,⁴⁷ L. K. Saini,⁴⁷ A. Sharma,⁴⁷ A. P. Singh,⁴⁷ J. Singh,⁴⁷ S. P. Singh,⁴⁷ S. Ahuja,⁴⁸ B. C. Choudhary,⁴⁸ P. Gupta,⁴⁸ A. Kumar,⁴⁸ A. Kumar,⁴⁸ S. Malhotra,⁴⁸ M. Naimuddin,⁴⁸ K. Ranjan,⁴⁸ R. K. Shivpuri,⁴⁸ S. Banerjee,⁴⁹ S. Bhattacharya,⁴⁹ S. Dutta,⁴⁹ B. Gomber,⁴⁹ S. Jain,⁴⁹ S. Jain,⁴⁹ R. Khurana,⁴⁹ S. Sarkar,⁴⁹ R. K. Choudhury,⁵⁰ D. Dutta,⁵⁰ S. Kailas,⁵⁰ V. Kumar,⁵⁰ P. Mehta,⁵⁰ A. K. Mohanty,^{50,b} L. M. Pant,⁵⁰ P. Shukla,⁵⁰ T. Aziz,⁵¹ M. Guchait,^{51,q} A. Gurtu,⁵¹ M. Maity,^{51,r} D. Majumder,⁵¹ G. Majumder,⁵¹ T. Mathew,⁵¹ K. Mazumdar,⁵¹ G. B. Mohanty,⁵¹ B. Parida,⁵¹ A. Saha,⁵¹ K. Sudhakar,⁵¹ N. Wickramage,⁵¹ S. Banerjee,⁵² S. Dugad,⁵² N. K. Mondal,⁵² H. Arfaei,⁵³ H. Bakhshiansohi,^{53,s} S. M. Etesami,^{53,t} A. Fahim,^{53,s} M. Hashemi,⁵³ H. Hesari,⁵³ A. Jafari,^{53,s} M. Khakzad,⁵³ A. Mohammadi,^{53,u} M. Mohammadi Najafabadi,⁵³ S. Paktinat Mehdiabadi,⁵³ B. Safarzadeh,⁵³ M. Zeinali,^{53,t} M. Abbrescia,^{54a,54b} L. Barbone,^{54a,54b} C. Calabria,^{54a,54b} A. Colaleo,^{54a} D. Creanza,^{54a,54c} N. De Filippis,^{54a,54c,b} M. De Palma,^{54a,54b} L. Fiore,^{54a} G. Iaselli,^{54a,54c} L. Lusito,^{54a,54b} G. Maggi,^{54a,54c} M. Maggi,^{54a} N. Manna,^{54a,54b} B. Marangelli,^{54a,54b} S. My,^{54a,54c} S. Nuzzo,^{54a,54b} N. Pacifico,^{54a,54b} G. A. Pierro,^{54a} A. Pompili,^{54a,54b} G. Pugliese,^{54a,54c} F. Romano,^{54a,54c} G. Roselli,^{54a,54b} G. Selvaggi,^{54a,54b} L. Silvestris,^{54a} R. Trentadue,^{54a} S. Tuppiti,^{54a,54b} G. Zito,^{54a} G. Abbiendi,^{55a} A. C. Benvenuti,^{55a} D. Bonacorsi,^{55a} S. Braibant-Giacomelli,^{55a,55b} L. Brigliadori,^{55a} P. Capiluppi,^{55a,55b} A. Castro,^{55a,55b} F. R. Cavallo,^{55a} M. Cuffiani,^{55a,55b} G. M. Dallavalle,^{55a} F. Fabbri,^{55a} A. Fanfani,^{55a,55b} D. Fasanella,^{55a,b} P. Giacomelli,^{55a} M. Giunta,^{55a} C. Grandi,^{55a} S. Marcellini,^{55a} G. Masetti,^{55b} M. Meneghelli,^{55a,55b} A. Montanari,^{55a} F. L. Navarria,^{55a,55b} F. Odorici,^{55a} A. Perrotta,^{55a} F. Primavera,^{55a} A. M. Rossi,^{55a,55b} T. Rovelli,^{55a,55b} G. Sirotti,^{55a,55b} R. Travaglini,^{55a,55b} S. Albergo,^{56a,56b} G. Cappello,^{56a,56b} M. Chiorboli,^{56a,56b} S. Costa,^{56a,56b} R. Potenza,^{56a,56b} A. Tricomi,^{56a,56b} C. Tuve,^{56a,56b} G. Barbagli,^{57a} V. Ciulli,^{57a,57b} C. Civinini,^{57a} R. D'Alessandro,^{57a,57b} E. Focardi,^{57a,57b} S. Frosali,^{57a,57b} E. Gallo,^{57a} S. Gonzi,^{57a,57b} M. Meschini,^{57a} S. Paoletti,^{57a} G. Sguazzoni,^{57a} A. Tropiano,^{57a,b} L. Benussi,⁵⁸ S. Bianco,⁵⁸ S. Colafranceschi,^{58,v} F. Fabbri,⁵⁸ D. Piccolo,⁵⁸ P. Fabbricatore,⁵⁹ R. Musenich,⁵⁹ A. Benaglia,^{60a,60b,b} F. De Guio,^{60a,60b} L. Di Matteo,^{60a,60b} S. Gennai,^{60a,b} A. Ghezzi,^{60a,60b} S. Malvezzi,^{60a} A. Martelli,^{60a,60b} A. Massironi,^{60a,60b,b} D. Menasce,^{60a} L. Moroni,^{60a} M. Paganoni,^{60a,60b} D. Pedrini,^{60a} S. Ragazzi,^{60a,60b} N. Redaelli,^{60a} S. Sala,^{60a} T. Tabarelli de Fatis,^{60a,60b} S. Buontempo,^{61a} C. A. Carrillo Montoya,^{61a,b} N. Cavallo,^{61a,w} A. De Cosa,^{61a,61b} F. Fabozzi,^{61a,w} A. O. M. Iorio,^{61a,b} L. Lista,^{61a} M. Merola,^{61a,61b} P. Paolucci,^{61a} P. Azzi,^{62a} N. Bacchetta,^{62a,b} P. Bellan,^{62a,62b} D. Bisello,^{62a,62b} A. Branca,^{62a} R. Carlin,^{62a,62b} P. Checchia,^{62a} T. Dorigo,^{62a} U. Dosselli,^{62a} F. Fanzago,^{62a} F. Gasparini,^{62a,62b} U. Gasparini,^{62a,62b} A. Gozzelino,^{62a} S. Lacaprara,^{62a,x} I. Lazzizzera,^{62a,62c} M. Margoni,^{62a,62b} M. Mazzucato,^{62a} A. T. Meneguzzo,^{62a,62b} M. Nespolo,^{62a,b} L. Perrozzini,^{62a} N. Pozzobon,^{62a,62b} P. Ronchese,^{62a,62b} F. Simonetto,^{62a,62b} E. Torassa,^{62a} M. Tosi,^{62a,62b,b} S. Vanini,^{62a,62b} P. Zotto,^{62a,62b} G. Zumerle,^{62a,62b} P. Baesso,^{63a,63b} U. Berzano,^{63a} S. P. Ratti,^{63a,63b} C. Riccardi,^{63a,63b} P. Torre,^{63a,63b} P. Vitulo,^{63a,63b} C. Viviani,^{63a,63b} M. Biasini,^{64a,64b} G. M. Bilei,^{64a} B. Caponeri,^{64a,64b} L. Fanò,^{64a,64b} P. Lariccia,^{64a,64b} A. Lucaroni,^{64a,64b,b} G. Mantovani,^{64a,64b} M. Menichelli,^{64a} A. Nappi,^{64a,64b} F. Romeo,^{64a,64b} A. Santocchia,^{64a,64b} S. Taroni,^{64a,64b,b} M. Valdata,^{64a,64b} P. Azzurri,^{65a,65c} G. Bagliesi,^{65a} J. Bernardini,^{65a,65b} T. Boccali,^{65a} G. Broccolo,^{65a,65c} R. Castaldi,^{65a} R. T. D'Agnolo,^{65a,65c} R. Dell'Orso,^{65a} F. Fiori,^{65a,65b} L. Foà,^{65a,65c} A. Giassi,^{65a} A. Kraan,^{65a} F. Ligabue,^{65a,65c} T. Lomtadze,^{65a} L. Martini,^{65a,y} A. Messineo,^{65a,65b} F. Palla,^{65a} F. Palmonari,^{65a} G. Segneri,^{65a} A. T. Serban,^{65a} P. Spagnolo,^{65a} R. Tenchini,^{65a} G. Tonelli,^{65a,65b,b} A. Venturi,^{65a,b} P. G. Verdini,^{65a} L. Barone,^{66a,66b} F. Cavallari,^{66a} D. Del Re,^{66a,66b,b} E. Di Marco,^{66a,66b} M. Diemoz,^{66a} D. Franci,^{66a,66b} M. Grassi,^{66a,b} E. Longo,^{66a,66b} P. Meridiani,^{66a} S. Nourbakhsh,^{66a} G. Organtini,^{66a,66b} F. Pandolfi,^{66a,66b} R. Paramatti,^{66a} S. Rahatlou,^{66a,66b} M. Sigamani,^{66a} N. Amapane,^{67a,67b} R. Arcidiacono,^{67a,67c} S. Argiro,^{67a,67b} M. Arneodo,^{67a,67c} C. Biino,^{67a} C. Botta,^{67a,67b} N. Cartiglia,^{67a} R. Castello,^{67a,67b} M. Costa,^{67a,67b} N. Demaria,^{67a} A. Graziano,^{67a,67b} C. Mariotti,^{67a} S. Maselli,^{67a} E. Migliore,^{67a,67b} V. Monaco,^{67a,67b} M. Musich,^{67a} M. M. Obertino,^{67a,67c} N. Pastrone,^{67a} M. Pelliccioni,^{67a,67b} A. Potenza,^{67a,67b} A. Romero,^{67a,67b} M. Ruspa,^{67a,67c} R. Sacchi,^{67a,67b} V. Sola,^{67a,67b} A. Solano,^{67a,67b} A. Staiano,^{67a} A. Vilela Pereira,^{67a} S. Belforte,^{68a} F. Cossutti,^{68a} G. Della Ricca,^{68a,68b} B. Gobbo,^{68a} M. Marone,^{68a,68b} D. Montanino,^{68a,68b} A. Penzo,^{68a} S. G. Heo,⁶⁹ S. K. Nam,⁶⁹ S. Chang,⁷⁰ J. Chung,⁷⁰ D. H. Kim,⁷⁰ G. N. Kim,⁷⁰ J. E. Kim,⁷⁰ D. J. Kong,⁷⁰ H. Park,⁷⁰ S. R. Ro,⁷⁰ D. C. Son,⁷⁰ T. Son,⁷⁰ J. Y. Kim,⁷¹ Zero J. Kim,⁷¹ S. Song,⁷¹ H. Y. Jo,⁷² S. Choi,⁷³ D. Gyun,⁷³ B. Hong,⁷³ M. Jo,⁷³ H. Kim,⁷³ J. H. Kim,⁷³ T. J. Kim,⁷³ K. S. Lee,⁷³ D. H. Moon,⁷³ S. K. Park,⁷³ E. Seo,⁷³ K. S. Sim,⁷³ M. Choi,⁷⁴ S. Kang,⁷⁴ H. Kim,⁷⁴ C. Park,⁷⁴ I. C. Park,⁷⁴ S. Park,⁷⁴

G. Ryu,⁷⁴ Y. Cho,⁷⁵ Y. Choi,⁷⁵ Y. K. Choi,⁷⁵ J. Goh,⁷⁵ M. S. Kim,⁷⁵ B. Lee,⁷⁵ J. Lee,⁷⁵ S. Lee,⁷⁵ H. Seo,⁷⁵ I. Yu,⁷⁵ M. J. Bilinskas,⁷⁶ I. Grigelionis,⁷⁶ M. Janulis,⁷⁶ D. Martisiute,⁷⁶ P. Petrov,⁷⁶ M. Polujanskas,⁷⁶ T. Sabonis,⁷⁶ H. Castilla-Valdez,⁷⁷ E. De La Cruz-Burelo,⁷⁷ I. Heredia-de La Cruz,⁷⁷ R. Lopez-Fernandez,⁷⁷ R. Magaña Villalba,⁷⁷ J. Martínez-Ortega,⁷⁷ A. Sánchez-Hernández,⁷⁷ L. M. Villasenor-Cendejas,⁷⁷ S. Carrillo Moreno,⁷⁸ F. Vazquez Valencia,⁷⁸ H. A. Salazar Ibarguen,⁷⁹ E. Casimiro Linares,⁸⁰ A. Morelos Pineda,⁸⁰ M. A. Reyes-Santos,⁸⁰ D. Krofcheck,⁸¹ J. Tam,⁸¹ P. H. Butler,⁸² R. Doesburg,⁸² H. Silverwood,⁸² M. Ahmad,⁸³ I. Ahmed,⁸³ M. H. Ansari,⁸³ M. I. Asghar,⁸³ H. R. Hoorani,⁸³ S. Khalid,⁸³ W. A. Khan,⁸³ T. Khurshid,⁸³ S. Qazi,⁸³ M. A. Shah,⁸³ M. Shoaib,⁸³ G. Brona,⁸⁴ M. Cwiok,⁸⁴ W. Dominik,⁸⁴ K. Doroba,⁸⁴ A. Kalinowski,⁸⁴ M. Konecki,⁸⁴ J. Krolikowski,⁸⁴ T. Frueboes,⁸⁵ R. Gokieli,⁸⁵ M. Górski,⁸⁵ M. Kazana,⁸⁵ K. Nawrocki,⁸⁵ K. Romanowska-Rybinska,⁸⁵ M. Szeleper,⁸⁵ G. Wrochna,⁸⁵ P. Zalewski,⁸⁵ N. Almeida,⁸⁶ P. Bargassa,⁸⁶ A. David,⁸⁶ P. Faccioli,⁸⁶ P. G. Ferreira Parracho,⁸⁶ M. Gallinaro,^{86,b} P. Musella,⁸⁶ A. Nayak,⁸⁶ J. Pela,^{86,b} P. Q. Ribeiro,⁸⁶ J. Seixas,⁸⁶ J. Varela,⁸⁶ S. Afanasiev,⁸⁷ I. Belotelov,⁸⁷ P. Bunin,⁸⁷ M. Gavrilenko,⁸⁷ I. Golutvin,⁸⁷ A. Kamenev,⁸⁷ V. Karjavin,⁸⁷ G. Kozlov,⁸⁷ A. Lanev,⁸⁷ P. Moisenz,⁸⁷ V. Palichik,⁸⁷ V. Perelygin,⁸⁷ S. Shmatov,⁸⁷ V. Smirnov,⁸⁷ A. Volodko,⁸⁷ A. Zarubin,⁸⁷ V. Golovtsov,⁸⁸ Y. Ivanov,⁸⁸ V. Kim,⁸⁸ P. Levchenko,⁸⁸ V. Murzin,⁸⁸ V. Oreshkin,⁸⁸ I. Smirnov,⁸⁸ V. Sulimov,⁸⁸ L. Uvarov,⁸⁸ S. Vavilov,⁸⁸ A. Vorobyev,⁸⁸ An. Vorobyev,⁸⁸ Yu. Andreev,⁸⁹ A. Dermenev,⁸⁹ S. Gninenko,⁸⁹ N. Golubev,⁸⁹ M. Kirsanov,⁸⁹ N. Krasnikov,⁸⁹ V. Matveev,⁸⁹ A. Pashenkov,⁸⁹ A. Toropin,⁸⁹ S. Troitsky,⁸⁹ V. Epshteyn,⁹⁰ M. Erofeeva,⁹⁰ V. Gavrilo, ⁹⁰ V. Kaftanov,^{90,a} M. Kossov,^{90,b} A. Krokhotin,⁹⁰ N. Lychkovskaya,⁹⁰ V. Popov,⁹⁰ G. Safronov,⁹⁰ S. Semenov,⁹⁰ V. Stolin,⁹⁰ E. Vlasov,⁹⁰ A. Zhokin,⁹⁰ A. Belyaev,⁹¹ E. Boos,⁹¹ M. Dubinin,^{91,d} L. Dudko,⁹¹ A. Ershov,⁹¹ A. Gribushin,⁹¹ O. Kodolova,⁹¹ I. Lokhtin,⁹¹ A. Markina,⁹¹ S. Obraztsov,⁹¹ M. Perfilov,⁹¹ S. Petrushanko,⁹¹ L. Sarycheva,⁹¹ V. Savrin,⁹¹ A. Snigirev,⁹¹ V. Andreev,⁹² M. Azarkin,⁹² I. Dremin,⁹² M. Kirakosyan,⁹² A. Leonidov,⁹² G. Mesyats,⁹² S. V. Rusakov,⁹² A. Vinogradov,⁹² I. Azhgirey,⁹³ I. Bayshev,⁹³ S. Bitiukov,⁹³ V. Grishin,^{93,b} V. Kachanov,⁹³ D. Konstantinov,⁹³ A. Korablev,⁹³ V. Krychkin,⁹³ V. Petrov,⁹³ R. Rytin,⁹³ A. Sobol,⁹³ L. Tourtchanovitch,⁹³ S. Troshin,⁹³ N. Tyurin,⁹³ A. Uzunian,⁹³ A. Volkov,⁹³ P. Adzic,^{94,z} M. Djordjevic,⁹⁴ D. Krpic,^{94,z} J. Milosevic,⁹⁴ M. Aguilar-Benitez,⁹⁵ J. Alcaraz Maestre,⁹⁵ P. Arce,⁹⁵ C. Battilana,⁹⁵ E. Calvo,⁹⁵ M. Cerrada,⁹⁵ M. Chamizo Llatas,⁹⁵ N. Colino,⁹⁵ B. De La Cruz,⁹⁵ A. Delgado Peris,⁹⁵ C. Diez Pardos,⁹⁵ D. Domínguez Vázquez,⁹⁵ C. Fernandez Bedoya,⁹⁵ J. P. Fernández Ramos,⁹⁵ A. Ferrando,⁹⁵ J. Flix,⁹⁵ M. C. Fouz,⁹⁵ P. Garcia-Abia,⁹⁵ O. Gonzalez Lopez,⁹⁵ S. Goy Lopez,⁹⁵ J. M. Hernandez,⁹⁵ M. I. Josa,⁹⁵ G. Merino,⁹⁵ J. Puerta Pelayo,⁹⁵ I. Redondo,⁹⁵ L. Romero,⁹⁵ J. Santaolalla,⁹⁵ M. S. Soares,⁹⁵ C. Willmott,⁹⁵ C. Albajar,⁹⁶ G. Codispoti,⁹⁶ J. F. de Trocóniz,⁹⁶ J. Cuevas,⁹⁷ J. Fernandez Menendez,⁹⁷ S. Folgueras,⁹⁷ I. Gonzalez Caballero,⁹⁷ L. Lloret Iglesias,⁹⁷ J. M. Vizan Garcia,⁹⁷ J. A. Brochero Cifuentes,⁹⁸ I. J. Cabrillo,⁹⁸ A. Calderon,⁹⁸ S. H. Chuang,⁹⁸ J. Duarte Campderros,⁹⁸ M. Felcini,^{98,aa} M. Fernandez,⁹⁸ G. Gomez,⁹⁸ J. Gonzalez Sanchez,⁹⁸ C. Jorda,⁹⁸ P. Lobelle Pardo,⁹⁸ A. Lopez Virto,⁹⁸ J. Marco,⁹⁸ R. Marco,⁹⁸ C. Martinez Rivero,⁹⁸ F. Matorras,⁹⁸ F. J. Munoz Sanchez,⁹⁸ J. Piedra Gomez,^{98,bb} T. Rodrigo,⁹⁸ A. Y. Rodríguez-Marrero,⁹⁸ A. Ruiz-Jimeno,⁹⁸ L. Scodellaro,⁹⁸ M. Sobron Sanudo,⁹⁸ I. Vila,⁹⁸ R. Vilar Cortabitarte,⁹⁸ D. Abbaneo,⁹⁹ E. Auffray,⁹⁹ G. Auzinger,⁹⁹ P. Baillon,⁹⁹ A. H. Ball,⁹⁹ D. Barney,⁹⁹ A. J. Bell,^{99,cc} D. Benedetti,⁹⁹ C. Bernet,^{99,e} W. Bialas,⁹⁹ P. Bloch,⁹⁹ A. Bocci,⁹⁹ S. Bolognesi,⁹⁹ M. Bona,⁹⁹ H. Breuker,⁹⁹ K. Bunkowski,⁹⁹ T. Camporesi,⁹⁹ G. Cerminara,⁹⁹ T. Christiansen,⁹⁹ J. A. Coarasa Perez,⁹⁹ B. Curé,⁹⁹ D. D'Enterria,⁹⁹ A. De Roeck,⁹⁹ S. Di Guida,⁹⁹ N. Dupont-Sagorin,⁹⁹ A. Elliott-Peisert,⁹⁹ B. Frisch,⁹⁹ W. Funk,⁹⁹ A. Gaddi,⁹⁹ G. Georgiou,⁹⁹ H. Gerwig,⁹⁹ D. Gigi,⁹⁹ K. Gill,⁹⁹ D. Giordano,⁹⁹ F. Glege,⁹⁹ R. Gomez-Reino Garrido,⁹⁹ M. Gouzevitch,⁹⁹ P. Govoni,⁹⁹ S. Gowdy,⁹⁹ R. Guida,⁹⁹ L. Guiducci,⁹⁹ M. Hansen,⁹⁹ C. Hartl,⁹⁹ J. Harvey,⁹⁹ J. Hegeman,⁹⁹ B. Hegner,⁹⁹ H. F. Hoffmann,⁹⁹ V. Innocente,⁹⁹ P. Janot,⁹⁹ K. Kaadze,⁹⁹ E. Karavakis,⁹⁹ P. Lecoq,⁹⁹ P. Lenzi,⁹⁹ C. Lourenço,⁹⁹ T. Mäki,⁹⁹ M. Malberti,⁹⁹ L. Malgeri,⁹⁹ M. Mannelli,⁹⁹ L. Masetti,⁹⁹ A. Maurisset,⁹⁹ G. Mavromanolakis,⁹⁹ F. Meijers,⁹⁹ S. Mersi,⁹⁹ E. Meschi,⁹⁹ R. Moser,⁹⁹ M. U. Mozer,⁹⁹ M. Mulders,⁹⁹ E. Nesvold,⁹⁹ M. Nguyen,⁹⁹ T. Orimoto,⁹⁹ L. Orsini,⁹⁹ E. Palencia Cortezon,⁹⁹ E. Perez,⁹⁹ A. Petrilli,⁹⁹ A. Pfeiffer,⁹⁹ M. Pierini,⁹⁹ M. Pimiä,⁹⁹ D. Piparo,⁹⁹ G. Polese,⁹⁹ L. Quertenmont,⁹⁹ A. Racz,⁹⁹ W. Reece,⁹⁹ J. Rodrigues Antunes,⁹⁹ G. Rolandi,^{99,dd} T. Rommelskirchen,⁹⁹ C. Rovelli,^{99,ee} M. Rovere,⁹⁹ H. Sakulin,⁹⁹ C. Schäfer,⁹⁹ C. Schwick,⁹⁹ I. Segoni,⁹⁹ A. Sharma,⁹⁹ P. Siegrist,⁹⁹ P. Silva,⁹⁹ M. Simon,⁹⁹ P. Sphicas,^{99,ff} D. Spiga,⁹⁹ M. Spiropulu,^{99,d} M. Stoye,⁹⁹ A. Tsirou,⁹⁹ P. Vichoudis,⁹⁹ H. K. Wöhri,⁹⁹ S. D. Worm,^{99,zz} W. D. Zeuner,⁹⁹ W. Bertl,¹⁰⁰ K. Deiters,¹⁰⁰ W. Erdmann,¹⁰⁰ K. Gabathuler,¹⁰⁰ R. Horisberger,¹⁰⁰ Q. Ingram,¹⁰⁰ H. C. Kaestli,¹⁰⁰ S. König,¹⁰⁰ D. Kotlinski,¹⁰⁰ U. Langenegger,¹⁰⁰ F. Meier,¹⁰⁰ D. Renker,¹⁰⁰ T. Rohe,¹⁰⁰ J. Sibille,^{100,gg} L. Bäni,¹⁰¹ P. Bortignon,¹⁰¹ L. Caminada,^{101,hh} B. Casal,¹⁰¹ N. Chanon,¹⁰¹ Z. Chen,¹⁰¹ S. Cittolin,¹⁰¹ G. Dissertori,¹⁰¹ M. Dittmar,¹⁰¹

J. Eugster,¹⁰¹ K. Freudenreich,¹⁰¹ C. Grab,¹⁰¹ W. Hintz,¹⁰¹ P. Lecomte,¹⁰¹ W. Lustermann,¹⁰¹ C. Marchica,^{101,hh}
P. Martinez Ruiz del Arbol,¹⁰¹ P. Milenovic,^{101,ii} F. Moortgat,¹⁰¹ C. Nägeli,^{101,hh} P. Nef,¹⁰¹ F. Nessi-Tedaldi,¹⁰¹
L. Pape,¹⁰¹ F. Pauss,¹⁰¹ T. Punz,¹⁰¹ A. Rizzi,¹⁰¹ F. J. Ronga,¹⁰¹ M. Rossini,¹⁰¹ L. Sala,¹⁰¹ A. K. Sanchez,¹⁰¹
M.-C. Sawley,¹⁰¹ A. Starodumov,^{101,ji} B. Stieger,¹⁰¹ M. Takahashi,¹⁰¹ L. Tauscher,^{101,a} A. Thea,¹⁰¹ K. Theofilatos,¹⁰¹
D. Treille,¹⁰¹ C. Urscheler,¹⁰¹ R. Wallny,¹⁰¹ M. Weber,¹⁰¹ L. Wehrli,¹⁰¹ J. Weng,¹⁰¹ E. Aguilo,¹⁰² C. Amsler,¹⁰²
V. Chiochia,¹⁰² S. De Visscher,¹⁰² C. Favaro,¹⁰² M. Ivova Rikova,¹⁰² A. Jaeger,¹⁰² B. Millan Mejias,¹⁰²
P. Otiougova,¹⁰² P. Robmann,¹⁰² A. Schmidt,¹⁰² H. Snoek,¹⁰² Y. H. Chang,¹⁰³ K. H. Chen,¹⁰³ C. M. Kuo,¹⁰³
S. W. Li,¹⁰³ W. Lin,¹⁰³ Z. K. Liu,¹⁰³ Y. J. Lu,¹⁰³ D. Mekterovic,¹⁰³ R. Volpe,¹⁰³ S. S. Yu,¹⁰³ P. Bartalini,¹⁰⁴
P. Chang,¹⁰⁴ Y. H. Chang,¹⁰⁴ Y. W. Chang,¹⁰⁴ Y. Chao,¹⁰⁴ K. F. Chen,¹⁰⁴ C. Dietz,¹⁰⁴ U. Grundler,¹⁰⁴ W.-S. Hou,¹⁰⁴
Y. Hsiung,¹⁰⁴ K. Y. Kao,¹⁰⁴ Y. J. Lei,¹⁰⁴ R.-S. Lu,¹⁰⁴ J. G. Shiu,¹⁰⁴ Y. M. Tzeng,¹⁰⁴ X. Wan,¹⁰⁴ M. Wang,¹⁰⁴
A. Adiguzel,¹⁰⁵ M. N. Bakirci,^{105,kk} S. Cerci,^{105,ll} C. Dozen,¹⁰⁵ I. Dumanoglu,¹⁰⁵ E. Eskut,¹⁰⁵ S. Girgis,¹⁰⁵
G. Gokbulut,¹⁰⁵ I. Hos,¹⁰⁵ E. E. Kangal,¹⁰⁵ A. Kayis Topaksu,¹⁰⁵ G. Onengut,¹⁰⁵ K. Ozdemir,¹⁰⁵ S. Ozturk,^{105,mm}
A. Polatoz,¹⁰⁵ K. Sogut,^{105,nn} D. Sunar Cerci,^{105,ll} B. Tali,^{105,ll} H. Topakli,^{105,kk} D. Uzun,¹⁰⁵ L. N. Vergili,¹⁰⁵
M. Vergili,¹⁰⁵ I. V. Akin,¹⁰⁶ T. Aliev,¹⁰⁶ B. Bilin,¹⁰⁶ S. Bilmis,¹⁰⁶ M. Deniz,¹⁰⁶ H. Gamsizkan,¹⁰⁶ A. M. Guler,¹⁰⁶
K. Ocalan,¹⁰⁶ A. Ozpineci,¹⁰⁶ M. Serin,¹⁰⁶ R. Sever,¹⁰⁶ U. E. Surat,¹⁰⁶ M. Yalvac,¹⁰⁶ E. Yildirim,¹⁰⁶ M. Zeyrek,¹⁰⁶
M. Deliomeroglu,¹⁰⁷ D. Demir,^{107,oo} E. Gülmez,¹⁰⁷ B. Isildak,¹⁰⁷ M. Kaya,^{107,pp} O. Kaya,^{107,pp} M. Özbek,¹⁰⁷
S. Ozkorucuklu,^{107,qq} N. Sonmez,^{107,rr} L. Levchuk,¹⁰⁸ F. Bostock,¹⁰⁹ J. J. Brooke,¹⁰⁹ T. L. Cheng,¹⁰⁹ E. Clement,¹⁰⁹
D. Cussans,¹⁰⁹ R. Frazier,¹⁰⁹ J. Goldstein,¹⁰⁹ M. Grimes,¹⁰⁹ G. P. Heath,¹⁰⁹ H. F. Heath,¹⁰⁹ L. Kreczko,¹⁰⁹
S. Metson,¹⁰⁹ D. M. Newbold,^{109,ss} K. Nirunpong,¹⁰⁹ A. Poll,¹⁰⁹ S. Senkin,¹⁰⁹ V. J. Smith,¹⁰⁹ L. Basso,^{110,tt}
K. W. Bell,¹¹⁰ A. Belyaev,^{110,tt} C. Brew,¹¹⁰ R. M. Brown,¹¹⁰ B. Camanzi,¹¹⁰ D. J. A. Cockerill,¹¹⁰ J. A. Coughlan,¹¹⁰
K. Harder,¹¹⁰ S. Harper,¹¹⁰ J. Jackson,¹¹⁰ B. W. Kennedy,¹¹⁰ E. Olaiya,¹¹⁰ D. Petyt,¹¹⁰ B. C. Radburn-Smith,¹¹⁰
C. H. Shepherd-Themistocleous,¹¹⁰ I. R. Tomalin,¹¹⁰ W. J. Womersley,¹¹⁰ R. Bainbridge,¹¹¹ G. Ball,¹¹¹ J. Ballin,¹¹¹
R. Beuselinck,¹¹¹ O. Buchmuller,¹¹¹ D. Colling,¹¹¹ N. Cripps,¹¹¹ M. Cutajar,¹¹¹ G. Davies,¹¹¹ M. Della Negra,¹¹¹
W. Ferguson,¹¹¹ J. Fulcher,¹¹¹ D. Futyan,¹¹¹ A. Gilbert,¹¹¹ A. Guneratne Bryer,¹¹¹ G. Hall,¹¹¹ Z. Hatherell,¹¹¹
J. Hays,¹¹¹ G. Iles,¹¹¹ M. Jarvis,¹¹¹ G. Karapostoli,¹¹¹ L. Lyons,¹¹¹ A.-M. Magnan,¹¹¹ J. Marrouche,¹¹¹
B. Mathias,¹¹¹ R. Nandi,¹¹¹ J. Nash,¹¹¹ A. Nikitenko,^{111,ji} A. Papageorgiou,¹¹¹ M. Pesaresi,¹¹¹ K. Petridis,¹¹¹
M. Pioppi,^{111,uu} D. M. Raymond,¹¹¹ S. Rogerson,¹¹¹ N. Rompotis,¹¹¹ A. Rose,¹¹¹ M. J. Ryan,¹¹¹ C. Seez,¹¹¹
P. Sharp,¹¹¹ A. Sparrow,¹¹¹ A. Tapper,¹¹¹ S. Tourneur,¹¹¹ M. Vazquez Acosta,¹¹¹ T. Virdee,¹¹¹ S. Wakefield,¹¹¹
N. Wardle,¹¹¹ D. Wardrope,¹¹¹ T. Whyntie,¹¹¹ M. Barrett,¹¹² M. Chadwick,¹¹² J. E. Cole,¹¹² P. R. Hobson,¹¹²
A. Khan,¹¹² P. Kyberd,¹¹² D. Leslie,¹¹² W. Martin,¹¹² I. D. Reid,¹¹² L. Teodorescu,¹¹² K. Hatakeyama,¹¹³ H. Liu,¹¹³
C. Henderson,¹¹⁴ T. Bose,¹¹⁵ E. Carrera Jarrin,¹¹⁵ C. Fantasia,¹¹⁵ A. Heister,¹¹⁵ J. St. John,¹¹⁵ P. Lawson,¹¹⁵
D. Ladic,¹¹⁵ J. Rohlf,¹¹⁵ D. Sperka,¹¹⁵ L. Sulak,¹¹⁵ A. Avetisyan,¹¹⁶ S. Bhattacharya,¹¹⁶ J. P. Chou,¹¹⁶ D. Cutts,¹¹⁶
A. Ferapontov,¹¹⁶ U. Heintz,¹¹⁶ S. Jabeen,¹¹⁶ G. Kukartsev,¹¹⁶ G. Landsberg,¹¹⁶ M. Luk,¹¹⁶ M. Narain,¹¹⁶
D. Nguyen,¹¹⁶ M. Segala,¹¹⁶ T. Sinthuprasith,¹¹⁶ T. Speer,¹¹⁶ K. V. Tsang,¹¹⁶ R. Breedon,¹¹⁷ G. Breto,¹¹⁷
M. Calderon De La Barca Sanchez,¹¹⁷ S. Chauhan,¹¹⁷ M. Chertok,¹¹⁷ J. Conway,¹¹⁷ R. Conway,¹¹⁷ P. T. Cox,¹¹⁷
J. Dolen,¹¹⁷ R. Erbacher,¹¹⁷ R. Houtz,¹¹⁷ W. Ko,¹¹⁷ A. Kopecky,¹¹⁷ R. Lander,¹¹⁷ H. Liu,¹¹⁷ O. Mall,¹¹⁷
S. Maruyama,¹¹⁷ T. Miceli,¹¹⁷ M. Nikolic,¹¹⁷ D. Pellett,¹¹⁷ J. Robles,¹¹⁷ B. Rutherford,¹¹⁷ S. Salur,¹¹⁷ M. Searle,¹¹⁷
J. Smith,¹¹⁷ M. Squires,¹¹⁷ M. Tripathi,¹¹⁷ R. Vasquez Sierra,¹¹⁷ V. Andreev,¹¹⁸ K. Arisaka,¹¹⁸ D. Cline,¹¹⁸
R. Cousins,¹¹⁸ A. Deisher,¹¹⁸ J. Duris,¹¹⁸ S. Erhan,¹¹⁸ C. Farrell,¹¹⁸ J. Hauser,¹¹⁸ M. Ignatenko,¹¹⁸ C. Jarvis,¹¹⁸
C. Plager,¹¹⁸ G. Rakness,¹¹⁸ P. Schlein,^{118,a} J. Tucker,¹¹⁸ V. Valuev,¹¹⁸ J. Babb,¹¹⁹ R. Clare,¹¹⁹ J. Ellison,¹¹⁹
J. W. Gary,¹¹⁹ F. Giordano,¹¹⁹ G. Hanson,¹¹⁹ G. Y. Jeng,¹¹⁹ S. C. Kao,¹¹⁹ H. Liu,¹¹⁹ O. R. Long,¹¹⁹ A. Luthra,¹¹⁹
H. Nguyen,¹¹⁹ S. Paramesvaran,¹¹⁹ J. Sturdy,¹¹⁹ S. Sumowidagdo,¹¹⁹ R. Wilken,¹¹⁹ S. Wimpenny,¹¹⁹ W. Andrews,¹²⁰
J. G. Branson,¹²⁰ G. B. Cerati,¹²⁰ D. Evans,¹²⁰ F. Golf,¹²⁰ A. Holzner,¹²⁰ R. Kelley,¹²⁰ M. Lebourgeois,¹²⁰ J. Letts,¹²⁰
B. Mangano,¹²⁰ S. Padhi,¹²⁰ C. Palmer,¹²⁰ G. Petrucciani,¹²⁰ H. Pi,¹²⁰ M. Pieri,¹²⁰ R. Ranieri,¹²⁰ M. Sani,¹²⁰
V. Sharma,¹²⁰ S. Simon,¹²⁰ E. Sudano,¹²⁰ M. Tadel,¹²⁰ Y. Tu,¹²⁰ A. Vartak,¹²⁰ S. Wasserbaech,^{120,vv} F. Würthwein,¹²⁰
A. Yagil,¹²⁰ J. Yoo,¹²⁰ D. Barge,¹²¹ R. Bellan,¹²¹ C. Campagnari,¹²¹ M. D'Alfonso,¹²¹ T. Danielson,¹²¹
K. Flowers,¹²¹ P. Geffert,¹²¹ J. Incandela,¹²¹ C. Justus,¹²¹ P. Kalavase,¹²¹ S. A. Koay,¹²¹ D. Kovalskyi,^{121,b}
V. Krutelyov,¹²¹ S. Lowette,¹²¹ N. Mccoll,¹²¹ S. D. Mullin,¹²¹ V. Pavlunin,¹²¹ F. Rebassoo,¹²¹ J. Ribnik,¹²¹
J. Richman,¹²¹ R. Rossin,¹²¹ D. Stuart,¹²¹ W. To,¹²¹ J. R. Vlimant,¹²¹ C. West,¹²¹ A. Apresyan,¹²² A. Bornheim,¹²²
J. Bunn,¹²² Y. Chen,¹²² J. Duarte,¹²² M. Gataullin,¹²² Y. Ma,¹²² A. Mott,¹²² H. B. Newman,¹²² C. Rogan,¹²²
K. Shin,¹²² V. Timciuc,¹²² P. Traczyk,¹²² J. Veverka,¹²² R. Wilkinson,¹²² Y. Yang,¹²² R. Y. Zhu,¹²² B. Akgun,¹²³

R. Carroll,¹²³ T. Ferguson,¹²³ Y. Iiyama,¹²³ D. W. Jang,¹²³ S. Y. Jun,¹²³ Y. F. Liu,¹²³ M. Paulini,¹²³ J. Russ,¹²³ H. Vogel,¹²³ I. Vorobiev,¹²³ J. P. Cumalat,¹²⁴ M. E. Dinardo,¹²⁴ B. R. Drell,¹²⁴ C. J. Edelmaier,¹²⁴ W. T. Ford,¹²⁴ A. Gaz,¹²⁴ B. Heyburn,¹²⁴ E. Luiggi Lopez,¹²⁴ U. Nauenberg,¹²⁴ J. G. Smith,¹²⁴ K. Stenson,¹²⁴ K. A. Ulmer,¹²⁴ S. R. Wagner,¹²⁴ S. L. Zang,¹²⁴ L. Agostino,¹²⁵ J. Alexander,¹²⁵ A. Chatterjee,¹²⁵ N. Eggert,¹²⁵ L. K. Gibbons,¹²⁵ B. Heltsley,¹²⁵ W. Hopkins,¹²⁵ A. Khukhunaishvili,¹²⁵ B. Kreis,¹²⁵ G. Nicolas Kaufman,¹²⁵ J. R. Patterson,¹²⁵ D. Puigh,¹²⁵ A. Ryd,¹²⁵ E. Salvati,¹²⁵ X. Shi,¹²⁵ W. Sun,¹²⁵ W. D. Teo,¹²⁵ J. Thom,¹²⁵ J. Thompson,¹²⁵ J. Vaughan,¹²⁵ Y. Weng,¹²⁵ L. Winstrom,¹²⁵ P. Wittich,¹²⁵ A. Biselli,¹²⁶ G. Cirino,¹²⁶ D. Winn,¹²⁶ S. Abdullin,¹²⁷ M. Albrow,¹²⁷ J. Anderson,¹²⁷ G. Apollinari,¹²⁷ M. Atac,¹²⁷ J. A. Bakken,¹²⁷ L. A. T. Bauerdick,¹²⁷ A. Beretvas,¹²⁷ J. Berryhill,¹²⁷ P. C. Bhat,¹²⁷ I. Bloch,¹²⁷ K. Burkett,¹²⁷ J. N. Butler,¹²⁷ V. Chetluru,¹²⁷ H. W. K. Cheung,¹²⁷ F. Chlebana,¹²⁷ S. Cihangir,¹²⁷ W. Cooper,¹²⁷ D. P. Eartly,¹²⁷ V. D. Elvira,¹²⁷ S. Esen,¹²⁷ I. Fisk,¹²⁷ J. Freeman,¹²⁷ Y. Gao,¹²⁷ E. Gottschalk,¹²⁷ D. Green,¹²⁷ K. Gunthoti,¹²⁷ O. Gutsche,¹²⁷ J. Hanlon,¹²⁷ R. M. Harris,¹²⁷ J. Hirschauer,¹²⁷ B. Hooberman,¹²⁷ H. Jensen,¹²⁷ S. Jindariani,¹²⁷ M. Johnson,¹²⁷ U. Joshi,¹²⁷ R. Khatiwada,¹²⁷ B. Klima,¹²⁷ K. Kousouris,¹²⁷ S. Kunori,¹²⁷ S. Kwan,¹²⁷ C. Leonidopoulos,¹²⁷ P. Limon,¹²⁷ D. Lincoln,¹²⁷ R. Lipton,¹²⁷ J. Lykken,¹²⁷ K. Maeshima,¹²⁷ J. M. Marraffino,¹²⁷ D. Mason,¹²⁷ P. McBride,¹²⁷ T. Miao,¹²⁷ K. Mishra,¹²⁷ S. Mrenna,¹²⁷ Y. Musienko,^{127,ww} C. Newman-Holmes,¹²⁷ V. O'Dell,¹²⁷ J. Pivarski,¹²⁷ R. Pordes,¹²⁷ O. Prokofyev,¹²⁷ T. Schwarz,¹²⁷ E. Sexton-Kennedy,¹²⁷ S. Sharma,¹²⁷ W. J. Spalding,¹²⁷ L. Spiegel,¹²⁷ P. Tan,¹²⁷ L. Taylor,¹²⁷ S. Tkaczyk,¹²⁷ L. Uplegger,¹²⁷ E. W. Vaandering,¹²⁷ R. Vidal,¹²⁷ J. Whitmore,¹²⁷ W. Wu,¹²⁷ F. Yang,¹²⁷ F. Yumiceva,¹²⁷ J. C. Yun,¹²⁷ D. Acosta,¹²⁸ P. Avery,¹²⁸ D. Bourilkov,¹²⁸ M. Chen,¹²⁸ S. Das,¹²⁸ M. De Gruttola,¹²⁸ G. P. Di Giovanni,¹²⁸ D. Dobur,¹²⁸ A. Drozdetskiy,¹²⁸ R. D. Field,¹²⁸ M. Fisher,¹²⁸ Y. Fu,¹²⁸ I. K. Furic,¹²⁸ J. Gartner,¹²⁸ S. Goldberg,¹²⁸ J. Hugon,¹²⁸ B. Kim,¹²⁸ J. Konigsberg,¹²⁸ A. Korytov,¹²⁸ A. Kropivnitskaya,¹²⁸ T. Kypreos,¹²⁸ J. F. Low,¹²⁸ K. Matchev,¹²⁸ G. Mitselmakher,¹²⁸ L. Muniz,¹²⁸ P. Myeonghun,¹²⁸ R. Remington,¹²⁸ A. Rinkevicius,¹²⁸ M. Schmitt,¹²⁸ B. Scurlock,¹²⁸ P. Sellers,¹²⁸ N. Skhirtladze,¹²⁸ M. Snowball,¹²⁸ D. Wang,¹²⁸ J. Yelton,¹²⁸ M. Zakaria,¹²⁸ V. Gaultney,¹²⁹ L. M. Lebolo,¹²⁹ S. Linn,¹²⁹ P. Markowitz,¹²⁹ G. Martinez,¹²⁹ J. L. Rodriguez,¹²⁹ T. Adams,¹³⁰ A. Askew,¹³⁰ J. Bochenek,¹³⁰ J. Chen,¹³⁰ B. Diamond,¹³⁰ S. V. Gleyzer,¹³⁰ J. Haas,¹³⁰ S. Hagopian,¹³⁰ V. Hagopian,¹³⁰ M. Jenkins,¹³⁰ K. F. Johnson,¹³⁰ H. Prosper,¹³⁰ S. Sekmen,¹³⁰ V. Veeraraghavan,¹³⁰ M. M. Baarmand,¹³¹ B. Dorney,¹³¹ M. Hohmann,¹³¹ H. Kalakhety,¹³¹ I. Vodopyanov,¹³¹ M. R. Adams,¹³² I. M. Anghel,¹³² L. Apanasevich,¹³² Y. Bai,¹³² V. E. Bazterra,¹³² R. R. Betts,¹³² J. Callner,¹³² R. Cavanaugh,¹³² C. Dragoiu,¹³² L. Gauthier,¹³² C. E. Gerber,¹³² D. J. Hofman,¹³² S. Khalatyan,¹³² G. J. Kunde,^{132,xx} F. Lacroix,¹³² M. Malek,¹³² C. O'Brien,¹³² C. Silkworth,¹³² C. Silvestre,¹³² A. Smoron,¹³² D. Strom,¹³² N. Varelas,¹³² U. Akgun,¹³³ E. A. Albayrak,¹³³ B. Bilki,¹³³ W. Clarida,¹³³ F. Duru,¹³³ C. K. Lae,¹³³ E. McCliment,¹³³ J.-P. Merlo,¹³³ H. Mermerkaya,^{133,yy} A. Mestvirishvili,¹³³ A. Moeller,¹³³ J. Nachtman,¹³³ C. R. Newsom,¹³³ E. Norbeck,¹³³ J. Olson,¹³³ Y. Onel,¹³³ F. Ozok,¹³³ S. Sen,¹³³ J. Wetzel,¹³³ T. Yetkin,¹³³ K. Yi,¹³³ B. A. Barnett,¹³⁴ B. Blumenfeld,¹³⁴ A. Bonato,¹³⁴ C. Eskew,¹³⁴ D. Fehling,¹³⁴ G. Giurgiu,¹³⁴ A. V. Gritsan,¹³⁴ Z. J. Guo,¹³⁴ G. Hu,¹³⁴ P. Maksimovic,¹³⁴ S. Rappoccio,¹³⁴ M. Swartz,¹³⁴ N. V. Tran,¹³⁴ A. Whitbeck,¹³⁴ P. Baringer,¹³⁵ A. Bean,¹³⁵ G. Benelli,¹³⁵ O. Grachov,¹³⁵ R. P. Kenny Iii,¹³⁵ M. Murray,¹³⁵ D. Noonan,¹³⁵ S. Sanders,¹³⁵ R. Stringer,¹³⁵ J. S. Wood,¹³⁵ V. Zhukova,¹³⁵ A. F. Barfuss,¹³⁶ T. Bolton,¹³⁶ I. Chakaberia,¹³⁶ A. Ivanov,¹³⁶ S. Khalil,¹³⁶ M. Makouski,¹³⁶ Y. Maravin,¹³⁶ S. Shrestha,¹³⁶ I. Svintradze,¹³⁶ J. Gronberg,¹³⁷ D. Lange,¹³⁷ D. Wright,¹³⁷ A. Baden,¹³⁸ M. Boutemeur,¹³⁸ S. C. Eno,¹³⁸ D. Ferencek,¹³⁸ J. A. Gomez,¹³⁸ N. J. Hadley,¹³⁸ R. G. Kellogg,¹³⁸ M. Kirn,¹³⁸ Y. Lu,¹³⁸ A. C. Mignerey,¹³⁸ K. Rossato,¹³⁸ P. Rumerio,¹³⁸ F. Santanastasio,¹³⁸ A. Skuja,¹³⁸ J. Temple,¹³⁸ M. B. Tonjes,¹³⁸ S. C. Tonwar,¹³⁸ E. Twedt,¹³⁸ B. Alver,¹³⁹ G. Bauer,¹³⁹ J. Bendavid,¹³⁹ W. Busza,¹³⁹ E. Butz,¹³⁹ I. A. Cali,¹³⁹ M. Chan,¹³⁹ V. Dutta,¹³⁹ P. Everaerts,¹³⁹ G. Gomez Ceballos,¹³⁹ M. Goncharov,¹³⁹ K. A. Hahn,¹³⁹ P. Harris,¹³⁹ Y. Kim,¹³⁹ M. Klute,¹³⁹ Y.-J. Lee,¹³⁹ W. Li,¹³⁹ C. Loizides,¹³⁹ P. D. Luckey,¹³⁹ T. Ma,¹³⁹ S. Nahn,¹³⁹ C. Paus,¹³⁹ D. Ralph,¹³⁹ C. Roland,¹³⁹ G. Roland,¹³⁹ M. Rudolph,¹³⁹ G. S. F. Stephans,¹³⁹ F. Stöckli,¹³⁹ K. Sumorok,¹³⁹ K. Sung,¹³⁹ D. Velicanu,¹³⁹ E. A. Wenger,¹³⁹ R. Wolf,¹³⁹ B. Wyslouch,¹³⁹ S. Xie,¹³⁹ M. Yang,¹³⁹ Y. Yilmaz,¹³⁹ A. S. Yoon,¹³⁹ M. Zanetti,¹³⁹ S. I. Cooper,¹⁴⁰ P. Cushman,¹⁴⁰ B. Dahmes,¹⁴⁰ A. De Benedetti,¹⁴⁰ G. Franzoni,¹⁴⁰ A. Gude,¹⁴⁰ J. Haupt,¹⁴⁰ K. Klapoetke,¹⁴⁰ Y. Kubota,¹⁴⁰ J. Mans,¹⁴⁰ N. Pastika,¹⁴⁰ V. Rekovic,¹⁴⁰ R. Rusack,¹⁴⁰ M. Sasseville,¹⁴⁰ A. Singovsky,¹⁴⁰ N. Tambe,¹⁴⁰ J. Turkewitz,¹⁴⁰ L. M. Cremaldi,¹⁴¹ R. Godang,¹⁴¹ R. Kroeger,¹⁴¹ L. Perera,¹⁴¹ R. Rahmat,¹⁴¹ D. A. Sanders,¹⁴¹ D. Summers,¹⁴¹ K. Bloom,¹⁴² S. Bose,¹⁴² J. Butt,¹⁴² D. R. Claes,¹⁴² A. Dominguez,¹⁴² M. Eads,¹⁴² P. Jindal,¹⁴² J. Keller,¹⁴² T. Kelly,¹⁴² I. Kravchenko,¹⁴² J. Lazo-Flores,¹⁴² H. Malbouisson,¹⁴² S. Malik,¹⁴² G. R. Snow,¹⁴² U. Baur,¹⁴³ A. Godshalk,¹⁴³ I. Iashvili,¹⁴³ S. Jain,¹⁴³ A. Kharchilava,¹⁴³ A. Kumar,¹⁴³ K. Smith,¹⁴³ Z. Wan,¹⁴³ G. Alverson,¹⁴⁴ E. Barberis,¹⁴⁴

D. Baumgartel,¹⁴⁴ O. Boeriu,¹⁴⁴ M. Chasco,¹⁴⁴ S. Reucroft,¹⁴⁴ J. Swain,¹⁴⁴ D. Trocino,¹⁴⁴ D. Wood,¹⁴⁴ J. Zhang,¹⁴⁴
A. Anastassov,¹⁴⁵ A. Kubik,¹⁴⁵ N. Mucia,¹⁴⁵ N. Odell,¹⁴⁵ R. A. Ofierzynski,¹⁴⁵ B. Pollack,¹⁴⁵ A. Pozdnyakov,¹⁴⁵
M. Schmitt,¹⁴⁵ S. Stoynev,¹⁴⁵ M. Velasco,¹⁴⁵ S. Won,¹⁴⁵ L. Antonelli,¹⁴⁶ D. Berry,¹⁴⁶ A. Brinkerhoff,¹⁴⁶
M. Hildreth,¹⁴⁶ C. Jessop,¹⁴⁶ D. J. Karmgard,¹⁴⁶ J. Kolb,¹⁴⁶ T. Kolberg,¹⁴⁶ K. Lannon,¹⁴⁶ W. Luo,¹⁴⁶ S. Lynch,¹⁴⁶
N. Marinelli,¹⁴⁶ D. M. Morse,¹⁴⁶ T. Pearson,¹⁴⁶ R. Ruchti,¹⁴⁶ J. Slaunwhite,¹⁴⁶ N. Valls,¹⁴⁶ M. Wayne,¹⁴⁶
J. Ziegler,¹⁴⁶ B. Bylsma,¹⁴⁷ L. S. Durkin,¹⁴⁷ C. Hill,¹⁴⁷ P. Killewald,¹⁴⁷ K. Kotov,¹⁴⁷ T. Y. Ling,¹⁴⁷ M. Rodenburg,¹⁴⁷
C. Vuosalo,¹⁴⁷ G. Williams,¹⁴⁷ N. Adam,¹⁴⁸ E. Berry,¹⁴⁸ P. Elmer,¹⁴⁸ D. Gerbaudo,¹⁴⁸ V. Halyo,¹⁴⁸ P. Hebda,¹⁴⁸
A. Hunt,¹⁴⁸ E. Laird,¹⁴⁸ D. Lopes Pegna,¹⁴⁸ D. Marlow,¹⁴⁸ T. Medvedeva,¹⁴⁸ M. Mooney,¹⁴⁸ J. Olsen,¹⁴⁸ P. Piroué,¹⁴⁸
X. Quan,¹⁴⁸ B. Safdi,¹⁴⁸ H. Saka,¹⁴⁸ D. Stickland,¹⁴⁸ C. Tully,¹⁴⁸ J. S. Werner,¹⁴⁸ A. Zuranski,¹⁴⁸ J. G. Acosta,¹⁴⁹
X. T. Huang,¹⁴⁹ A. Lopez,¹⁴⁹ H. Mendez,¹⁴⁹ S. Oliveros,¹⁴⁹ J. E. Ramirez Vargas,¹⁴⁹ A. Zatserklyaniy,¹⁴⁹
E. Alagoz,¹⁵⁰ V. E. Barnes,¹⁵⁰ G. Bolla,¹⁵⁰ L. Borrello,¹⁵⁰ D. Bortoletto,¹⁵⁰ M. De Mattia,¹⁵⁰ A. Everett,¹⁵⁰
L. Gutay,¹⁵⁰ Z. Hu,¹⁵⁰ M. Jones,¹⁵⁰ O. Koybasi,¹⁵⁰ M. Kress,¹⁵⁰ A. T. Laasanen,¹⁵⁰ N. Leonardo,¹⁵⁰ V. Maroussov,¹⁵⁰
P. Merkel,¹⁵⁰ D. H. Miller,¹⁵⁰ N. Neumeister,¹⁵⁰ I. Shipsey,¹⁵⁰ D. Silvers,¹⁵⁰ A. Svyatkovskiy,¹⁵⁰
M. Vidal Marono,¹⁵⁰ H. D. Yoo,¹⁵⁰ J. Zablocki,¹⁵⁰ Y. Zheng,¹⁵⁰ S. Guragain,¹⁵¹ N. Parashar,¹⁵¹ A. Adair,¹⁵²
C. Boulaouache,¹⁵² K. M. Ecklund,¹⁵² F. J. M. Geurts,¹⁵² B. P. Padley,¹⁵² R. Redjimi,¹⁵² J. Roberts,¹⁵² J. Zabel,¹⁵²
B. Betchart,¹⁵³ A. Bodek,¹⁵³ Y. S. Chung,¹⁵³ R. Covarelli,¹⁵³ P. de Barbaro,¹⁵³ R. Demina,¹⁵³ Y. Eshaq,¹⁵³
H. Flacher,¹⁵³ A. Garcia-Bellido,¹⁵³ P. Goldenzweig,¹⁵³ Y. Gotra,¹⁵³ J. Han,¹⁵³ A. Harel,¹⁵³ D. C. Miner,¹⁵³
G. Petrillo,¹⁵³ W. Sakumoto,¹⁵³ D. Vishnevskiy,¹⁵³ M. Zielinski,¹⁵³ A. Bhatti,¹⁵⁴ R. Ciesielski,¹⁵⁴ L. Demortier,¹⁵⁴
K. Goulianos,¹⁵⁴ G. Lungu,¹⁵⁴ S. Malik,¹⁵⁴ C. Mesropian,¹⁵⁴ S. Arora,¹⁵⁵ O. Atramentov,¹⁵⁵ A. Barker,¹⁵⁵
C. Contreras-Campana,¹⁵⁵ E. Contreras-Campana,¹⁵⁵ D. Duggan,¹⁵⁵ Y. Gershtein,¹⁵⁵ R. Gray,¹⁵⁵ E. Halkiadakis,¹⁵⁵
D. Hidas,¹⁵⁵ D. Hits,¹⁵⁵ A. Lath,¹⁵⁵ S. Panwalkar,¹⁵⁵ M. Park,¹⁵⁵ R. Patel,¹⁵⁵ A. Richards,¹⁵⁵ K. Rose,¹⁵⁵
S. Schnetzer,¹⁵⁵ S. Somalwar,¹⁵⁵ R. Stone,¹⁵⁵ S. Thomas,¹⁵⁵ G. Cerizza,¹⁵⁶ M. Hollingsworth,¹⁵⁶ S. Spanier,¹⁵⁶
Z. C. Yang,¹⁵⁶ A. York,¹⁵⁶ R. Eusebi,¹⁵⁷ W. Flanagan,¹⁵⁷ J. Gilmore,¹⁵⁷ A. Gurrola,¹⁵⁷ T. Kamon,¹⁵⁷
V. Khotilovich,¹⁵⁷ R. Montalvo,¹⁵⁷ I. Osipenkov,¹⁵⁷ Y. Pakhotin,¹⁵⁷ A. Perloff,¹⁵⁷ J. Roe,¹⁵⁷ A. Safonov,¹⁵⁷
S. Sengupta,¹⁵⁷ I. Suarez,¹⁵⁷ A. Tatarinov,¹⁵⁷ D. Toback,¹⁵⁷ N. Akchurin,¹⁵⁸ C. Bardak,¹⁵⁸ J. Damgov,¹⁵⁸
P. R. Duderø,¹⁵⁸ C. Jeong,¹⁵⁸ K. Kovitanggoon,¹⁵⁸ S. W. Lee,¹⁵⁸ T. Libeiro,¹⁵⁸ P. Mane,¹⁵⁸ Y. Roh,¹⁵⁸ A. Sill,¹⁵⁸
I. Volobouev,¹⁵⁸ R. Wigmans,¹⁵⁸ E. Yazgan,¹⁵⁸ E. Appelt,¹⁵⁹ E. Brownson,¹⁵⁹ D. Engh,¹⁵⁹ C. Florez,¹⁵⁹
W. Gabella,¹⁵⁹ M. Issah,¹⁵⁹ W. Johns,¹⁵⁹ C. Johnston,¹⁵⁹ P. Kurt,¹⁵⁹ C. Maguire,¹⁵⁹ A. Melo,¹⁵⁹ P. Sheldon,¹⁵⁹
B. Snook,¹⁵⁹ S. Tuo,¹⁵⁹ J. Velkovska,¹⁵⁹ M. W. Arenton,¹⁶⁰ M. Balazs,¹⁶⁰ S. Boutle,¹⁶⁰ B. Cox,¹⁶⁰ B. Francis,¹⁶⁰
S. Goadhouse,¹⁶⁰ J. Goodell,¹⁶⁰ R. Hirosky,¹⁶⁰ A. Ledovskoy,¹⁶⁰ C. Lin,¹⁶⁰ C. Neu,¹⁶⁰ J. Wood,¹⁶⁰ R. Yohay,¹⁶⁰
S. Gollapinni,¹⁶¹ R. Harr,¹⁶¹ P. E. Karchin,¹⁶¹ C. Kottachchi Kankanamge Don,¹⁶¹ P. Lamichhane,¹⁶¹ M. Mattson,¹⁶¹
C. Milstène,¹⁶¹ A. Sakharov,¹⁶¹ M. Anderson,¹⁶² M. Bachtis,¹⁶² D. Belknap,¹⁶² J. N. Bellinger,¹⁶² D. Carlsmith,¹⁶²
M. Cepeda,¹⁶² S. Dasu,¹⁶² J. Efron,¹⁶² E. Friis,¹⁶² L. Gray,¹⁶² K. S. Grogg,¹⁶² M. Grothe,¹⁶² R. Hall-Wilton,¹⁶²
M. Herndon,¹⁶² A. Hervé,¹⁶² P. Klabbers,¹⁶² J. Klukas,¹⁶² A. Lanaro,¹⁶² C. Lazaridis,¹⁶² J. Leonard,¹⁶²
R. Loveless,¹⁶² A. Mohapatra,¹⁶² I. Ojalvo,¹⁶² W. Parker,¹⁶² I. Ross,¹⁶² A. Savin,¹⁶² W. H. Smith,¹⁶²
J. Swanson,¹⁶² and M. Weinberg¹⁶²

(CMS Collaboration)

¹*Yerevan Physics Institute, Yerevan, Armenia*²*Institut für Hochenergiephysik der OeAW, Wien, Austria*³*National Centre for Particle and High Energy Physics, Minsk, Belarus*⁴*Universiteit Antwerpen, Antwerpen, Belgium*⁵*Vrije Universiteit Brussel, Brussel, Belgium*⁶*Université Libre de Bruxelles, Bruxelles, Belgium*⁷*Ghent University, Ghent, Belgium*⁸*Université Catholique de Louvain, Louvain-la-Neuve, Belgium*⁹*Université de Mons, Mons, Belgium*¹⁰*Centro Brasileiro de Pesquisas Físicas, Rio de Janeiro, Brazil*¹¹*Universidade do Estado do Rio de Janeiro, Rio de Janeiro, Brazil*¹²*Instituto de Física Teórica, Universidade Estadual Paulista, Sao Paulo, Brazil*¹³*Institute for Nuclear Research and Nuclear Energy, Sofia, Bulgaria*¹⁴*University of Sofia, Sofia, Bulgaria*

- ¹⁵*Institute of High Energy Physics, Beijing, China*
- ¹⁶*State Key Laboratory of Nuclear Physics and Technology, Peking University, Beijing, China*
- ¹⁷*Universidad de Los Andes, Bogota, Colombia*
- ¹⁸*Technical University of Split, Split, Croatia*
- ¹⁹*University of Split, Split, Croatia*
- ²⁰*Institute Rudjer Boskovic, Zagreb, Croatia*
- ²¹*University of Cyprus, Nicosia, Cyprus*
- ²²*Charles University, Prague, Czech Republic*
- ²³*Academy of Scientific Research and Technology of the Arab Republic of Egypt, Egyptian Network of High Energy Physics, Cairo, Egypt*
- ²⁴*National Institute of Chemical Physics and Biophysics, Tallinn, Estonia*
- ²⁵*Department of Physics, University of Helsinki, Helsinki, Finland*
- ²⁶*Helsinki Institute of Physics, Helsinki, Finland*
- ²⁷*Lappeenranta University of Technology, Lappeenranta, Finland*
- ²⁸*Laboratoire d'Annecy-le-Vieux de Physique des Particules, IN2P3-CNRS, Annecy-le-Vieux, France*
- ²⁹*DSM/IRFU, CEA/Saclay, Gif-sur-Yvette, France*
- ³⁰*Laboratoire Leprince-Ringuet, Ecole Polytechnique, IN2P3-CNRS, Palaiseau, France*
- ³¹*Institut Pluridisciplinaire Hubert Curien, Université de Strasbourg, Université de Haute Alsace Mulhouse, CNRS/IN2P3, Strasbourg, France*
- ³²*Centre de Calcul de l'Institut National de Physique Nucléaire et de Physique des Particules (IN2P3), Villeurbanne, France*
- ³³*Université de Lyon, Université Claude Bernard Lyon 1, CNRS-IN2P3, Institut de Physique Nucléaire de Lyon, Villeurbanne, France*
- ³⁴*Institute of High Energy Physics and Informatization, Tbilisi State University, Tbilisi, Georgia*
- ³⁵*RWTH Aachen University, I. Physikalisches Institut, Aachen, Germany*
- ³⁶*RWTH Aachen University, III. Physikalisches Institut A, Aachen, Germany*
- ³⁷*RWTH Aachen University, III. Physikalisches Institut B, Aachen, Germany*
- ³⁸*Deutsches Elektronen-Synchrotron, Hamburg, Germany*
- ³⁹*University of Hamburg, Hamburg, Germany*
- ⁴⁰*Institut für Experimentelle Kernphysik, Karlsruhe, Germany*
- ⁴¹*Institute of Nuclear Physics "Demokritos," Aghia Paraskevi, Greece*
- ⁴²*University of Athens, Athens, Greece*
- ⁴³*University of Ioánnina, Ioánnina, Greece*
- ⁴⁴*KFKI Research Institute for Particle and Nuclear Physics, Budapest, Hungary*
- ⁴⁵*Institute of Nuclear Research ATOMKI, Debrecen, Hungary*
- ⁴⁶*University of Debrecen, Debrecen, Hungary*
- ⁴⁷*Panjab University, Chandigarh, India*
- ⁴⁸*University of Delhi, Delhi, India*
- ⁴⁹*Saha Institute of Nuclear Physics, Kolkata, India*
- ⁵⁰*Bhabha Atomic Research Centre, Mumbai, India*
- ⁵¹*Tata Institute of Fundamental Research-EHEP, Mumbai, India*
- ⁵²*Tata Institute of Fundamental Research-HECR, Mumbai, India*
- ⁵³*Institute for Research and Fundamental Sciences (IPM), Tehran, Iran*
- ^{54a}*INFN Sezione di Bari, Bari, Italy*
- ^{54b}*Università di Bari, Bari, Italy*
- ^{54c}*Politecnico di Bari, Bari, Italy*
- ^{55a}*INFN Sezione di Bologna, Bologna, Italy*
- ^{55b}*Università di Bologna, Bologna, Italy*
- ^{56a}*INFN Sezione di Catania, Catania, Italy*
- ^{56b}*Università di Catania, Catania, Italy*
- ^{57a}*INFN Sezione di Firenze, Firenze, Italy*
- ^{57b}*Università di Firenze, Firenze, Italy*
- ⁵⁸*INFN Laboratori Nazionali di Frascati, Frascati, Italy*
- ⁵⁹*INFN Sezione di Genova, Genova, Italy*
- ^{60a}*INFN Sezione di Milano-Bicocca, Milano, Italy*
- ^{60b}*Università di Milano-Bicocca, Milano, Italy*
- ^{61a}*INFN Sezione di Napoli, Napoli, Italy*
- ^{61b}*Università di Napoli "Federico II," Napoli, Italy*
- ^{62a}*INFN Sezione di Padova, Padova, Italy*
- ^{62b}*Università di Padova, Padova, Italy*
- ^{62c}*Università di Trento (Trento), Padova, Italy*
- ^{63a}*INFN Sezione di Pavia, Pavia, Italy*
- ^{63b}*Università di Pavia, Pavia, Italy*

- ^{64a}INFN Sezione di Perugia, Perugia, Italy
^{64b}Università di Perugia, Perugia, Italy
^{65a}INFN Sezione di Pisa, Pisa, Italy
^{65b}Università di Pisa, Pisa, Italy
^{65c}Scuola Normale Superiore di Pisa, Pisa, Italy
^{66a}INFN Sezione di Roma, Roma, Italy
^{66b}Università di Roma “La Sapienza,” Roma, Italy
^{67a}INFN Sezione di Torino, Torino, Italy
^{67b}Università di Torino, Torino, Italy
^{67c}Università del Piemonte Orientale (Novara), Torino, Italy
^{68a}INFN Sezione di Trieste, Trieste, Italy
^{68b}Università di Trieste, Trieste, Italy
⁶⁹Kangwon National University, Chunchon, Korea
⁷⁰Kyungpook National University, Daegu, Korea
⁷¹Chonnam National University, Institute for Universe and Elementary Particles, Kwangju, Korea
⁷²Konkuk University, Seoul, Korea
⁷³Korea University, Seoul, Korea
⁷⁴University of Seoul, Seoul, Korea
⁷⁵Sungkyunkwan University, Suwon, Korea
⁷⁶Vilnius University, Vilnius, Lithuania
⁷⁷Centro de Investigación y de Estudios Avanzados del IPN, Mexico City, Mexico
⁷⁸Universidad Iberoamericana, Mexico City, Mexico
⁷⁹Benemerita Universidad Autónoma de Puebla, Puebla, Mexico
⁸⁰Universidad Autónoma de San Luis Potosí, San Luis Potosí, Mexico
⁸¹University of Auckland, Auckland, New Zealand
⁸²University of Canterbury, Christchurch, New Zealand
⁸³National Centre for Physics, Quaid-I-Azam University, Islamabad, Pakistan
⁸⁴Institute of Experimental Physics, Faculty of Physics, University of Warsaw, Warsaw, Poland
⁸⁵Soltan Institute for Nuclear Studies, Warsaw, Poland
⁸⁶Laboratório de Instrumentação e Física Experimental de Partículas, Lisboa, Portugal
⁸⁷Joint Institute for Nuclear Research, Dubna, Russia
⁸⁸Petersburg Nuclear Physics Institute, Gatchina (St. Petersburg), Russia
⁸⁹Institute for Nuclear Research, Moscow, Russia
⁹⁰Institute for Theoretical and Experimental Physics, Moscow, Russia
⁹¹Moscow State University, Moscow, Russia
⁹²P.N. Lebedev Physical Institute, Moscow, Russia
⁹³State Research Center of Russian Federation, Institute for High Energy Physics, Protvino, Russia
⁹⁴University of Belgrade, Faculty of Physics and Vinca Institute of Nuclear Sciences, Belgrade, Serbia
⁹⁵Centro de Investigaciones Energéticas Medioambientales y Tecnológicas (CIEMAT), Madrid, Spain
⁹⁶Universidad Autónoma de Madrid, Madrid, Spain
⁹⁷Universidad de Oviedo, Oviedo, Spain
⁹⁸Instituto de Física de Cantabria (IFCA), CSIC-Universidad de Cantabria, Santander, Spain
⁹⁹CERN, European Organization for Nuclear Research, Geneva, Switzerland
¹⁰⁰Paul Scherrer Institut, Villigen, Switzerland
¹⁰¹Institute for Particle Physics, ETH Zurich, Zurich, Switzerland
¹⁰²Universität Zürich, Zurich, Switzerland
¹⁰³National Central University, Chung-Li, Taiwan
¹⁰⁴National Taiwan University (NTU), Taipei, Taiwan
¹⁰⁵Cukurova University, Adana, Turkey
¹⁰⁶Middle East Technical University, Physics Department, Ankara, Turkey
¹⁰⁷Bogazici University, Istanbul, Turkey
¹⁰⁸National Scientific Center, Kharkov Institute of Physics and Technology, Kharkov, Ukraine
¹⁰⁹University of Bristol, Bristol, United Kingdom
¹¹⁰Rutherford Appleton Laboratory, Didcot, United Kingdom
¹¹¹Imperial College, London, United Kingdom
¹¹²Brunel University, Uxbridge, United Kingdom
¹¹³Baylor University, Waco, Texas 76706, USA
¹¹⁴The University of Alabama, Tuscaloosa, Alabama 35487, USA
¹¹⁵Boston University, Boston, Massachusetts 02215, USA
¹¹⁶Brown University, Providence, Rhode Island 02912, USA
¹¹⁷University of California, Davis, Davis, California 95616, USA

- ¹¹⁸University of California, Los Angeles, Los Angeles, California 90095, USA
¹¹⁹University of California, Riverside, Riverside, California 92521, USA
¹²⁰University of California, San Diego, La Jolla, California 92093, USA
¹²¹University of California, Santa Barbara, Santa Barbara, California 93106, USA
¹²²California Institute of Technology, Pasadena, California 91125, USA
¹²³Carnegie Mellon University, Pittsburgh, Pennsylvania 15213, USA
¹²⁴University of Colorado at Boulder, Boulder, Colorado 80309, USA
¹²⁵Cornell University, Ithaca, New York 14853, USA
¹²⁶Fairfield University, Fairfield, Connecticut 06824, USA
¹²⁷Fermi National Accelerator Laboratory, Batavia, Illinois 60510, USA
¹²⁸University of Florida, Gainesville, Florida 32611, USA
¹²⁹Florida International University, Miami, Florida 33199, USA
¹³⁰Florida State University, Tallahassee, Florida 32306, USA
¹³¹Florida Institute of Technology, Melbourne, Florida 32901, USA
¹³²University of Illinois at Chicago (UIC), Chicago, Illinois 60607, USA
¹³³The University of Iowa, Iowa City, Iowa 52242, USA
¹³⁴Johns Hopkins University, Baltimore, Maryland 21218, USA
¹³⁵The University of Kansas, Lawrence, Kansas 66045, USA
¹³⁶Kansas State University, Manhattan, Kansas 66506, USA
¹³⁷Lawrence Livermore National Laboratory, Livermore, California 94720, USA
¹³⁸University of Maryland, College Park, Maryland 20742, USA
¹³⁹Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA
¹⁴⁰University of Minnesota, Minneapolis, Minnesota 55455, USA
¹⁴¹University of Mississippi, University, Mississippi 38677, USA
¹⁴²University of Nebraska-Lincoln, Lincoln, Nebraska 68588, USA
¹⁴³State University of New York at Buffalo, Buffalo, New York 14260, USA
¹⁴⁴Northeastern University, Boston, Massachusetts 02115, USA
¹⁴⁵Northwestern University, Evanston, Illinois 60208, USA
¹⁴⁶University of Notre Dame, Notre Dame, Indiana 46556, USA
¹⁴⁷The Ohio State University, Columbus, Ohio 43210, USA
¹⁴⁸Princeton University, Princeton, New Jersey 08544, USA
¹⁴⁹University of Puerto Rico, Mayaguez, Puerto Rico 00680
¹⁵⁰Purdue University, West Lafayette, Indiana 47907, USA
¹⁵¹Purdue University Calumet, Hammond, Indiana 46323, USA
¹⁵²Rice University, Houston, Texas 77251, USA
¹⁵³University of Rochester, Rochester, New York 14627, USA
¹⁵⁴The Rockefeller University, New York, New York 10021, USA
¹⁵⁵Rutgers, the State University of New Jersey, Piscataway, New Jersey 08854, USA
¹⁵⁶University of Tennessee, Knoxville, Tennessee 37996, USA
¹⁵⁷Texas A&M University, College Station, Texas 77843, USA
¹⁵⁸Texas Tech University, Lubbock, Texas 79409, USA
¹⁵⁹Vanderbilt University, Nashville, Tennessee 37235, USA
¹⁶⁰University of Virginia, Charlottesville, Virginia 22901, USA
¹⁶¹Wayne State University, Detroit, Michigan 48202, USA
¹⁶²University of Wisconsin, Madison, Wisconsin 53706, USA

^aDeceased.

^bAlso at CERN, European Organization for Nuclear Research, Geneva, Switzerland.

^cAlso at Universidade Federal do ABC, Santo Andre, Brazil.

^dAlso at California Institute of Technology, Pasadena, CA, USA.

^eAlso at Laboratoire Leprince-Ringuet, Ecole Polytechnique, IN2P3-CNRS, Palaiseau, France.

^fAlso at Suez Canal University, Suez, Egypt.

^gAlso at Cairo University, Cairo, Egypt.

^hAlso at British University, Cairo, Egypt.

ⁱAlso at Fayoum University, El-Fayoum, Egypt.

^jAlso at Ain Shams University, Cairo, Egypt.

^kAlso at Soltan Institute for Nuclear Studies, Warsaw, Poland.

^lAlso at Université de Haute-Alsace, Mulhouse, France.

^mAlso at Moscow State University, Moscow, Russia.

- ⁿAlso at Brandenburg University of Technology, Cottbus, Germany.
- ^oAlso at Institute of Nuclear Research ATOMKI, Debrecen, Hungary.
- ^pAlso at Eötvös Loránd University, Budapest, Hungary.
- ^qAlso at Tata Institute of Fundamental Research-HECR, Mumbai, India.
- ^rAlso at University of Visva-Bharati, Santiniketan, India.
- ^sAlso at Sharif University of Technology, Tehran, Iran.
- ^tAlso at Isfahan University of Technology, Isfahan, Iran.
- ^uAlso at Shiraz University, Shiraz, Iran.
- ^vAlso at Facoltà Ingegneria Università di Roma, Roma, Italy.
- ^wAlso at Università della Basilicata, Potenza, Italy.
- ^xAlso at Laboratori Nazionali di Legnaro dell' INFN, Legnaro, Italy.
- ^yAlso at Università degli studi di Siena, Siena, Italy.
- ^zAlso at Faculty of Physics of University of Belgrade, Belgrade, Serbia.
- ^{aa}Also at University of California, Los Angeles, Los Angeles, CA, USA.
- ^{bb}Also at University of Florida, Gainesville, FL, USA.
- ^{cc}Also at Université de Genève, Geneva, Switzerland.
- ^{dd}Also at Scuola Normale e Sezione dell' INFN, Pisa, Italy.
- ^{ee}Also at INFN Sezione di Roma, Università di Roma "La Sapienza", Roma, Italy.
- ^{ff}Also at University of Athens, Athens, Greece.
- ^{gg}Also at The University of Kansas, Lawrence, KS, USA.
- ^{hh}Also at Paul Scherrer Institut, Villigen, Switzerland.
- ⁱⁱAlso at University of Belgrade, Faculty of Physics and Vinca Institute of Nuclear Sciences, Belgrade, Serbia.
- ^{jj}Also at Institute for Theoretical and Experimental Physics, Moscow, Russia.
- ^{kk}Also at Gaziosmanpasa University, Tokat, Turkey.
- ^{ll}Also at Adiyaman University, Adiyaman, Turkey.
- ^{mm}Also at The University of Iowa, Iowa City, IA, USA.
- ⁿⁿAlso at Mersin University, Mersin, Turkey.
- ^{oo}Also at Izmir Institute of Technology, Izmir, Turkey.
- ^{pp}Also at Kafkas University, Kars, Turkey.
- ^{qq}Also at Suleyman Demirel University, Isparta, Turkey.
- ^{rr}Also at Ege University, Izmir, Turkey.
- ^{ss}Also at Rutherford Appleton Laboratory, Didcot, United Kingdom.
- ^{tt}Also at School of Physics and Astronomy, University of Southampton, Southampton, United Kingdom.
- ^{uu}Also at INFN Sezione di Perugia, Università di Perugia, Perugia, Italy.
- ^{vv}Also at Utah Valley University, Orem, UT, USA.
- ^{ww}Also at Institute for Nuclear Research, Moscow, Russia.
- ^{xx}Also at Los Alamos National Laboratory, Los Alamos, NM, USA.
- ^{yy}Also at Erzincan University, Erzincan, Turkey.
- ^{zz}Present address: Rutherford Appleton Laboratory, Didcot, United Kingdom.