Physics Letters B 719 (2013) 42–61

Contents lists available at SciVerse ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

Search for supersymmetry in events with photons and low missing transverse energy in pp collisions at $\sqrt{s} = 7$ TeV ☆

CMS Collaboration ⋆

CERN, Switzerland

ARTICLE INFO

Article history:
Received 7 October 2012
Received in revised form 5 December 2012
Accepted 22 December 2012
Available online 28 December 2012
Editor: M. Doser

Keywords:
CMS
Physics

ABSTRACT

Many models of new physics, including versions of supersymmetry (SUSY), predict production of events with low missing transverse energy, electroweak gauge bosons, and many energetic final-state particles. The stealth SUSY model yields this signature while conserving R-parity by means of a new hidden sector in which SUSY is approximately conserved. The results of a general search for new physics, with no requirement on missing transverse energy, in events with two photons and four or more hadronic jets are reported. The study is based on a sample of proton–proton collisions at $\sqrt{s} = 7$ TeV corresponding to 4.96 fb^{-1} of integrated luminosity collected with the CMS detector in 2011. Based on good agreement between the data and the standard model expectation, the data are used to determine model-independent cross-section limits and a limit on the squark mass in the framework of stealth SUSY. With this first study of its kind, squark masses less than 1430 GeV are excluded at the 95% confidence level.

Models of supersymmetry (SUSY) [1,2] that conserve R-parity and include a neutral, weakly interacting lightest supersymmetric particle (LSP) garner much interest because they simultaneously solve the hierarchy problem, allow unification of the fundamental interactions, and provide a candidate for dark matter. Many searches for SUSY focus on the presence of large missing transverse energy (E_T^{miss}) carried away by the LSP. It has been pointed out [3–5] that this approach neglects well motivated SUSY models that predict low E_T^{miss} without special tuning of masses – models characterized by R-parity violation [6], gauge mediated SUSY breaking [7], compressed spectra [8,9], and hidden valleys [10]. As the parameter space available for high-E_T^{miss} SUSY is reduced by recent results from the CERN Large Hadron Collider (LHC), low-E_T^{miss} alternatives become more important to study.

Without the discriminating power of large E_T^{miss}, new techniques are required to reduce standard model (SM) backgrounds. In general, searches in final states with many energetic particles, including photons or leptons, are sensitive to a wide range of new physics models producing heavy particles with cascade decays to hadronic jets and electroweak gauge bosons. This range includes theories of extra dimensions [11], heavy-flavor compositeness [12], little Higgs [13,14], and even SUSY. In particular, such searches are sensitive to the R-parity conserving stealth SUSY model [5,15], which, as formulated in this study, produces events with low E_T^{miss}, two photons, and more than five jets.

The simplest stealth SUSY models assume low scale SUSY breaking and introduce a new hidden sector of particles at the weak scale in which only a small amount of SUSY breaking occurs through interactions with SM fields, resulting in a hidden sector that is approximately supersymmetric and nearly mass degenerate hidden sector superpartners. In this framework, the standard LSP takes on a new role as the lightest "visible sector" SUSY particle (LVSP) which decays without violating R-parity into a lighter hidden sector SUSY particle. In the subsequent decay of this particle to its SM partner and the true LSP, the near mass degeneracy leaves little phase space for the true LSP to carry momentum. In this way, stealth SUSY models naturally produce signatures of low E_T^{miss} without special tuning of masses.

In this Letter we describe a search for new phenomena (NP) in events with at least two photons and four or more jets produced in proton–proton collisions at $\sqrt{s} = 7$ TeV. The analysis is based on a data sample corresponding to 4.96 ± 0.11 fb^{-1} of integrated luminosity [16] collected in 2011 with the Compact Muon Solenoid (CMS) detector at the LHC. We perform a model-independent search for an excess of events with respect to the SM expectation, and we interpret this search in the framework of stealth SUSY. To minimize the impact of SM backgrounds on the sensitivity to NP, event excesses are determined as functions of final-state jet multiplicity and the scalar sum of the transverse momentum p_T of jets, photons, and E_T^{miss} (for $E_T^{miss} > 20$ GeV) in

⋆ *E-mail address:* cms-publication-committee-chair@cern.ch.

0370-2693/ © 2012 CERN. Published by Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.physletb.2012.12.055

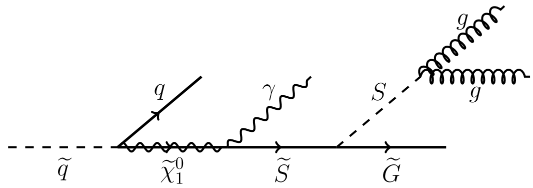

Fig. 1. Decay of a squark in stealth SUSY. See text for a complete description.

each event; this sum is referred to as S_T. We define E_T^{miss} as the magnitude of the negative of the vector sum of the p_T of all final state objects in the event; the definitions of other objects included in the sum are described below.

We consider a model that includes degenerate light squarks ($\tilde{q}$), a "bino-like" LVSP $\tilde{\chi}_1^0$, a gluino ($\tilde{g}$) with mass of 1500 GeV, and a hidden sector containing a singlet state S and its fermionic "singlino" superpartner $\tilde{S}$. The model is similar to squark–antisquark ($\tilde{q}\tilde{q}^*$) production with the decay $\tilde{q} \to q\tilde{\chi}_1^0$ described in Ref. [17] with two differences: the addition of the hidden sector and the participation of $\tilde{g}$ in the production mechanism. After initial production of two $\tilde{\chi}_1^0$ and jets, each $\tilde{\chi}_1^0$ decays into the hidden sector producing a photon and $\tilde{S}$, which subsequently decays to S and a gravitino, $\tilde{S} \to S\tilde{G}$. The S state is even under R-parity and decays to jets via $S \to gg$. The resulting $\tilde{G}$ LSP has small momentum because the hidden sector superpartners (S, $\tilde{S}$) are nearly mass degenerate, so the final state tends to have low E_T^{miss}. The decay of a squark in this model is shown in Fig. 1.

The model is characterized by the masses of the particles in the decay chain. We consider a range of squark masses $M_{\tilde{q}}$ from 400 to 2000 GeV in steps of 100 GeV. We make the following assumptions inspired by benchmark points described in Ref. [5]: $\tilde{S}$ and S masses of 100 GeV and 90 GeV, respectively; $\tilde{\chi}_1^0$ with mass equal to $\frac{1}{2}M_{\tilde{q}}$; and branching fractions of unity for the decays of $\tilde{\chi}_1^0$, $\tilde{S}$, and S described above. The production cross section for this process (and its uncertainty) is calculated as a function of $M_{\tilde{q}}$ at next-to-leading order (NLO) accuracy including the resummation of soft gluon emission at next-to-leading logarithmic (NLL) accuracy as described in Refs. [18–23].

A detailed description of the CMS detector can be found in Ref. [24]. The CMS coordinate system is right-handed with the origin at the center of the detector, the x-axis directed toward the center of the LHC ring, and the y-axis directed upward; ϕ is the azimuthal angle, θ is the polar angle, and $\eta = -\ln[\tan(\theta/2)]$ is the pseudorapidity. The central feature of the CMS apparatus is a superconducting solenoid of 6 m inner diameter that surrounds a silicon pixel and strip tracker, covering the region $|\eta| < 2.5$, as well as a lead-tungstate crystal electromagnetic calorimeter (ECAL) and a brass/scintillator hadron calorimeter (HCAL), both covering $|\eta| < 3$. Muons are detected by gas-ionization detectors embedded in the steel flux return yoke covering the range $|\eta| < 2.4$.

The triggers, event reconstruction methods, and selection criteria for photons and jets are identical to those used in the CMS search for SUSY in events with photons, jets, and E_T^{miss} [25]. Events are recorded with the CMS two-level trigger system requiring the presence of one photon with transverse energy (E_T) greater than 36 GeV and a second with $E_T > 22$ GeV. To suppress jets giving rise to photon candidates, these triggers require the latter to be isolated from other activity in the tracker, ECAL, and HCAL. As instantaneous luminosity increased throughout 2011, isolation requirements were gradually changed to keep the trigger rate approximately constant, but the isolation in the trigger is always less restrictive than offline requirements described below.

Photon candidates are reconstructed from clusters of energy in the ECAL barrel with $|\eta| < 1.44$. Candidate events are required to have a leading photon with $E_T > 40$ GeV and an additional photon with $E_T > 25$ GeV; at these thresholds the triggers are more than 99% efficient. We require the ECAL cluster shape to be consistent with that expected for photons, and the energy detected in HCAL in the direction of the photon shower to not exceed 5% of the ECAL energy. We ensure isolation from other activity in the event by requiring that the scalar E_T sum of tracks and calorimeter deposits within $\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} = 0.3$ of the photon candidate's direction be less than 6 GeV after correcting for contributions from the products of additional collisions in the event (pile-up) and the candidate itself. These criteria efficiently select both photons and electrons; candidates that cannot be matched to hit patterns in the pixel detector are considered photons.

Jets are reconstructed with the particle-flow algorithm [26], which simultaneously reconstructs all particles produced in a collision based on information from all detector subsystems and identifies each as a charged or neutral hadron, photon, muon, or electron. All of these particles are clustered into jets with the anti-k_T clustering algorithm [27] with radius parameter of 0.5. To remove jets arising from potential instrumental and non-collision backgrounds, we require the fraction of jet energy coming from charged and neutral electromagnetic deposits to be less than 0.99, the neutral hadron fraction to be less than 0.99, and the charged hadron fraction to be greater than zero. The jet energy and momentum are corrected for the nonlinear response of the calorimeter and the effects of pile-up. Jets are required to have $p_T > 20$ GeV, $|\eta| < 2.4$, and to be isolated from photon candidates by $\Delta R > 0.5$.

We determine the fraction of stealth SUSY events that pass these reconstruction procedures and selection criteria (the "acceptance") and the leading order plus leading logarithm (LO) cross section for stealth SUSY using the PYTHIA 6.424 event generator [28], the D6T underlying event tune [29], the CTEQ6L1 [30] parton distribution functions (PDFs), and a full simulation of the CMS detector based on GEANT4 [31]. The acceptance when including a requirement for five or more jets rises monotonically from 17% to 35% for $M_{\tilde{q}}$ from 400 to 1100 GeV and falls monotonically from 35% to 25% for $M_{\tilde{q}}$ from 1100 to 2000 GeV as additional hadronic activity makes it less likely that photons will be isolated. The acceptance when requiring exactly four jets is 12–13% (1–2%) of the ⩾5-jet acceptance for $M_{\tilde{q}} \leqslant 1500$ GeV ($M_{\tilde{q}} > 1500$ GeV). The LO acceptance for each of the dominant subprocesses ($pp \to \tilde{q}\tilde{q}$, $\tilde{q}\tilde{q}^*$, $\tilde{q}\tilde{g}$, and $\tilde{g}\tilde{g}$) is weighted with the appropriate NLO/LO K-factor; the corrected acceptance is within 5% of the LO acceptance at all $M_{\tilde{q}}$.

The SM events satisfying the selection criteria come mainly from direct production of two photons or a single photon and a jet, which is misidentified as a photon. In both cases, additional jets come from radiation via quantum chromodynamics. These events are divided into three samples: a signal-rich "search sample" comprising events with four or more jets and $S_T > 700$ GeV, a signal-depleted "jet multiplicity sideband" (JMSB) composed of events with two or three jets and $S_T > 600$ GeV, and a signal-depleted "S_T sideband" composed of events with four or more jets and 600 GeV $< S_T <$ 700 GeV. We examine the search sample for evidence of NP in the form of an excess of events over the SM expectation.

The SM expectation is estimated from the data based on the observation that the shape of the S_T spectrum of the SM background is independent of jet multiplicity. This multiplicity invariance arises because the S_T of an event is dominated by the initial hard parton-parton scattering process; additional radiation, which is largely collinear with incoming or outgoing partons, does not have a large effect on event S_T. For this reason, we are able to take the S_T shape from the JMSB and the normalization from the S_T sideband.

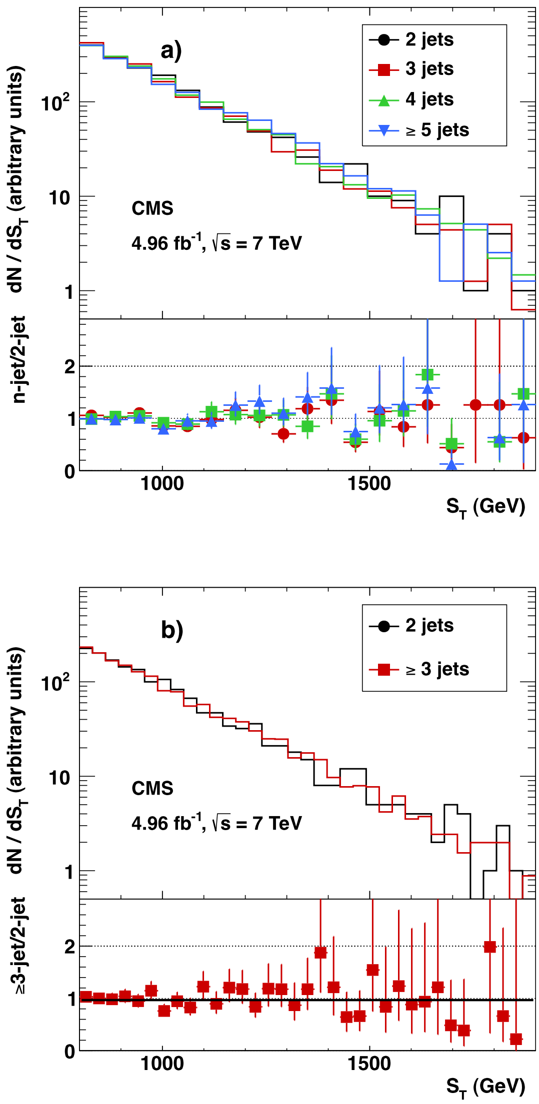

Fig. 2. S_T spectra from the photon + jets data control sample, area-normalized for $S_T > 800$ GeV. We show (a) the spectra for events with two, three, four, and five or more jets along with the n-jet/2-jet ratio where $n = 3, 4$, or $\geqslant 5$; and (b) the spectra for events with two and three or more jets along with the $\geqslant$3-jet/2-jet ratio.

This method of background estimation was first used in the CMS search for black holes [32,33], in which the jet-multiplicity invariance of the S_T shape in jet dominated events was demonstrated. We confirm that this invariance holds for events with photons in addition to jets using a data sample of events with one photon and two or more jets (photon + jets). The event selection criteria for this sample are the same as those described above except for changes required by differences in the trigger and event topology: we require that events include a single photon with $E_T > 80$ GeV and $H_T > 450$ GeV, where H_T is defined as the scalar sum of the p_T of jets with $p_T > 40$ GeV and $|\eta| < 3.0$.

In Fig. 2 we compare the S_T spectra for five subsamples of this photon + jets dataset characterized by jet multiplicity: the 2-jet, 3-jet, 4-jet, $\geqslant$5-jet, and $\geqslant$3-jet samples. We show these spectra (area-normalized for $S_T > 800$ GeV) along with the n-jet/2-jet ratio where $n = 3, 4, \geqslant 5$, and $\geqslant 3$. The shape of each ratio is consistent with a flat line within the statistical uncertainty. As an example, the fit of the $\geqslant$ 3-jet/2-jet ratio from Fig. 2b with the function $a + bx$ where $x \equiv S_T/7$ TeV yields $a = 1.0 \pm 0.2$ and $b = -0.3 \pm 1.1$ (statistical uncertainty). A slope of this size would affect the expected background rate by 6%, which is negligible compared to the systematic uncertainty from other sources (described below).

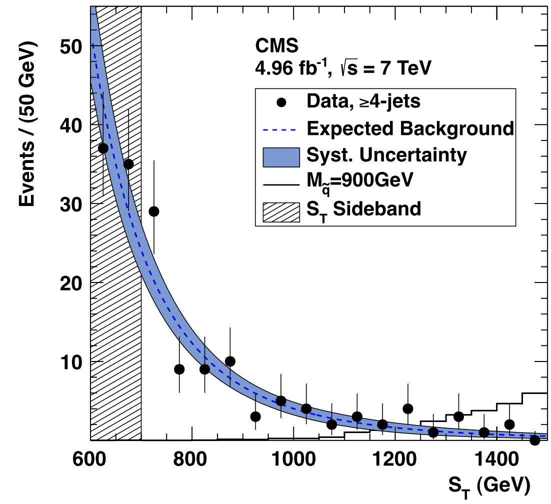

Fig. 3. Observed S_T spectrum, background expectation with systematic uncertainty, and predicted signal for a squark mass of 900 GeV in events with four or more jets.

As introduced above, we model the shape of the S_T distribution for the background by fitting the JMSB data with the function $1/x^{\alpha}$, where x is defined above and α is a free parameter. We find $\alpha = 5.02 \pm 0.32$ from the fit of the entire JMSB; in the 2-jet (3-jet) subsample of the JMSB we find a best fit value of $\alpha = 5.00 \pm 0.45$ (5.03 ± 0.45). This background shape is normalized for use in the search sample with data in the S_T sideband.

We compare this background prediction to the observed S_T spectrum in the search sample in Fig. 3 along with the systematic uncertainty on the prediction (described below). The data are in good agreement with the background expectation. The probability for the most significant excess (at 700 GeV $< S_T <$ 750 GeV) to have local significance as high or higher than that observed is 0.08.

Supported by the good agreement of the data with the background expectation, we use the data to compute $N^{\text{lim}}_{\text{exc}}(S_T^{\text{min}})$, the upper limit on the number of events exceeding the SM expectation as a function of lower S_T threshold. Limits are computed at the 95% confidence level (CL) with the modified frequentist CL$_s$ method [34,35] based on a profile likelihood ratio test statistic constructed from the Poisson probability for the observed number of events given the expectations for background and signal. For the model-independent cross-section limits, we separately compute $N^{\text{lim}}_{\text{exc}}(S_T^{\text{min}})$ for two categories of jet multiplicity, $\geqslant$4-jet and $\geqslant$5-jet. For stealth SUSY limits, we compute $N^{\text{lim}}_{\text{exc}}(S_T^{\text{min}})$ using exclusive 4-jet and $\geqslant$5-jet jet-multiplicity bins combined as described in Ref. [36]; the inclusion of the 4-jet bin improves the expected cross-section limit by 7.5% at $M_{\tilde{q}} = 1400$ GeV.

Using the measured integrated luminosity, we convert $N^{\text{lim}}_{\text{exc}}(S_T^{\text{min}})$ into a model-independent limit on the product of the acceptance and cross section of any new process that may be present in addition to the SM (the "effective NP cross section"). Using the integrated luminosity and the signal acceptance, we convert $N^{\text{lim}}_{\text{exc}}(S_T^{\text{min}})$ into a limit on the stealth SUSY cross section as a function of $M_{\tilde{q}}$. For each value of $M_{\tilde{q}}$, we use the value of S_T^{min} that maximizes the sensitivity to the stealth SUSY signal accounting for systematic uncertainty on the background expectation; these S_T^{min} values range from 800 to 2400 GeV for $M_{\tilde{q}}$ from 400 to 2000 GeV.

Systematic uncertainties on the expected numbers of background events, the signal acceptance, and the integrated luminosity

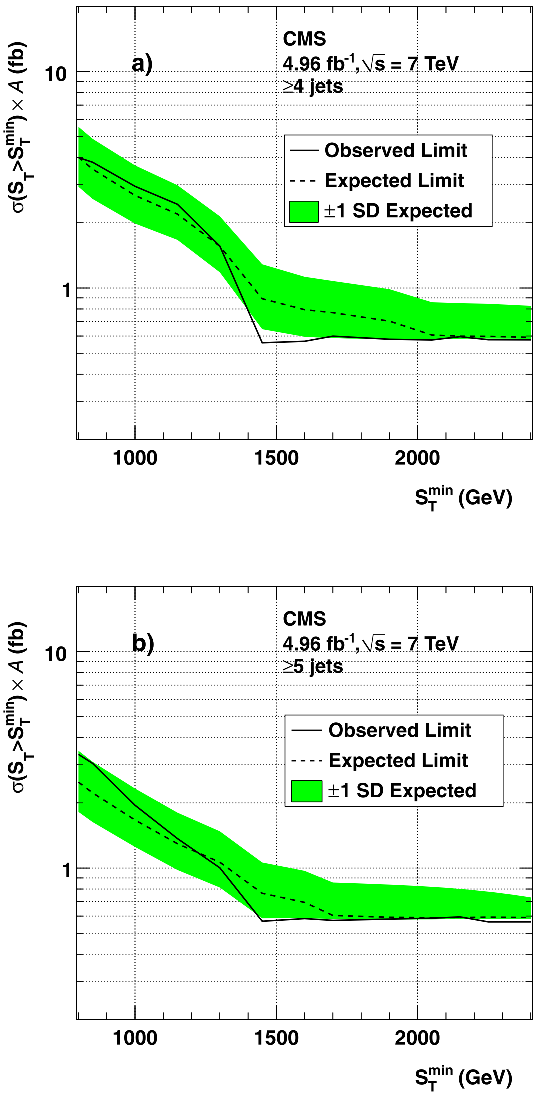

Fig. 4. Model-independent limit at the 95% CL on the product of the acceptance and cross section for events with (a) four or more jets and (b) five or more jets. We show the observed limits, median expected limits, and a band corresponding to ±1 SD on the median expected limits.

are treated as nuisance parameters with a Gamma function prior distribution for the uncertainty related to the normalization of the background prediction and log-normal prior distributions for the other uncertainties. The theoretical uncertainty on the predicted cross section does not enter the cross-section limit, but is used in determining the limit on $M_{\tilde{q}}$.

We estimate that the following sources of uncertainty affect our knowledge of the expected background at the stated level: statistical uncertainty from the background normalization method (15%), statistical uncertainty on the background shape (10–55%), and the choice of background function (5–100%) (ranges indicate dependence on $M_{\tilde{q}}$ and S_T^{min}). We use the change in background expectation obtained by varying the shape parameter by ±1 standard deviation (SD) as the statistical uncertainty on the background shape. We estimate the uncertainty related to the choice of background function by constructing background models from the alternate fit functions $e^{\alpha x}$ and $1/x^{\alpha_0+\alpha_1 \log(x)}$ instead of the nominal $1/x^{\alpha}$; we take the largest alternate-nominal difference in the background expectation as the uncertainty. The relative effect of these

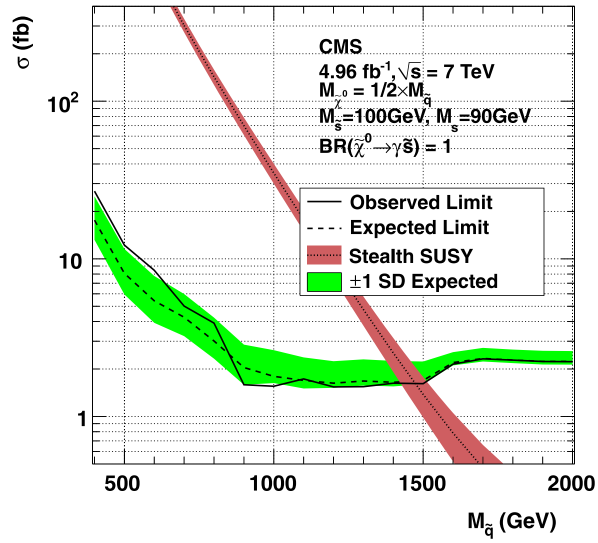

Fig. 5. Stealth SUSY cross-section limit at the 95% CL as a function of $M_{\tilde{q}}$. We show the observed limit, median expected limit, and a band corresponding to ±1 SD on the median expected limits. We also show the predicted NLO + NLL cross section from stealth SUSY with a band denoting ±1 SD from theoretical uncertainty.

background uncertainties is large at high S_T where very few background events are expected.

The following sources of uncertainty affect our knowledge of the expected numbers of signal events at the stated level: jet energy scale (3%), statistical uncertainty on signal acceptance from finite simulated samples (2%), and the measurement of integrated luminosity (2.2%) [16]. The effects on the signal acceptance of variations in pile-up and PDFs are less than 1%. The theoretical uncertainty on the predicted cross section related to PDFs, renormalization and factorization scales, and α_S variations is estimated to be 9–57% for $M_{\tilde{q}}$ from 400 to 2000 GeV; the dominant source is the PDF uncertainty.

Fig. 4 provides the model-independent limit on the effective NP cross section as a function of S_T^{min} for events with four or more jets and five or more jets. We show the observed limits, median expected limits, and a band corresponding to ±1 SD on the median expected limits. In Fig. 5 we show the same curves for the stealth SUSY cross-section limit as a function of $M_{\tilde{q}}$. We also show the predicted NLO + NLL cross section with a band denoting ±1 SD from theoretical uncertainty. Based on the intersection of the cross-section limit and the −1 SD edge of the predicted cross-section band, we exclude squarks with $M_{\tilde{q}} < 1430$ GeV for the stealth SUSY model described above.

In summary, we perform a search for NP in events with two photons and four or more jets. The selection requirements are general and provide sensitivity to a broad range of NP phenomena. We observe no excess over the SM expectation in a data sample corresponding to 4.96 fb^{-1} of integrated luminosity collected in 2011. We determine model-independent limits on the effective NP cross section of 0.6 to 4 fb depending on S_T^{min}. We also compute the limit on the stealth SUSY cross section as a function of $M_{\tilde{q}}$. Comparing this limit to the predicted stealth SUSY cross section, we exclude the production of squarks with $M_{\tilde{q}} < 1430$ GeV. Existing SUSY searches based on photons and E_T^{miss} [25] are insensitive to most of the stealth SUSY region excluded by this analysis; this region is characterized by low E_T^{miss} predicting 1.5 ± 0.1 (21.3 ± 1.6) events with $E_T^{miss} > 100$ GeV for $M_{\tilde{q}}$ of 1400 (800) GeV. This is the first limit on the parameters of the stealth SUSY model.

Acknowledgements

We thank Joshua Ruderman for help in stealth SUSY event generation. We 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 BMWF and FWF (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); MEYS (Czech Republic); MoER, SF0690030s09 and ERDF (Estonia); Academy of Finland, MEC, 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); MSI (New Zealand); PAEC (Pakistan); MSHE and NSC (Poland); FCT (Portugal); JINR (Armenia, Belarus, Georgia, Ukraine, Uzbekistan); MON, RosAtom, RAS and RFBR (Russia); MSTD (Serbia); SEIDI and CPAN (Spain); Swiss Funding Agencies (Switzerland); NSC (Taipei); ThEP, IPST and NECTEC (Thailand); TUBITAK and TAEK (Turkey); NASU (Ukraine); STFC (United Kingdom); DOE and NSF (USA).

Open access

References

[1] P. Fayet, S. Ferrara, Phys. Rept. 32 (1977) 249, http://dx.doi.org/10.1016/0370-1573(77)90066-7.
[2] S.P. Martin, A supersymmetry primer, arXiv:hep-ph/9709356, 1997.
[3] D.S.M. Alves, E. Izaguirre, J.G. Wacker, JHEP 1110 (2011) 012, http://dx.doi.org/10.1007/JHEP10(2011)012, arXiv:1102.5338.
[4] M. Lisanti, P. Schuster, M. Strassler, N. Toro, Study of LHC searches for a lepton and many jets, arXiv:1107.5055, 2011.
[5] J. Fan, M. Reece, J.T. Ruderman, JHEP 1111 (2011) 012, http://dx.doi.org/10.1007/JHEP11(2011)012, arXiv:1105.5135.
[6] R. Barbier, C. Berat, M. Besancon, M. Chemtob, A. Deandrea, E. Dudas, P. Fayet, S. Lavignac, G. Moreau, E. Perez, Y. Sirois, Phys. Rept. 420 (2005) 1, http://dx.doi.org/10.1016/j.physrep.2005.08.006, arXiv:hep-ph/0406039.
[7] G.F. Giudice, R. Rattazzi, Phys. Rept. 322 (1999) 419, http://dx.doi.org/10.1016/S0370-1573(99)00042-3, arXiv:hep-ph/9801271.
[8] S.P. Martin, Phys. Rev. D 75 (2007) 115005, http://dx.doi.org/10.1103/PhysRevD.75.115005, arXiv:hep-ph/0703097.
[9] T.J. LeCompte, S.P. Martin, Phys. Rev. D 84 (2011) 015004, http://dx.doi.org/10.1103/PhysRevD.84.015004, arXiv:1105.4304.
[10] M.J. Strassler, Possible effects of a hidden valley on supersymmetric phenomenology, arXiv:hep-ph/0607160, 2006.
[11] T. Appelquist, H.-C. Cheng, B.A. Dobrescu, Phys. Rev. D 64 (2001) 035002, http://dx.doi.org/10.1103/PhysRevD.64.035002.
[12] T. Gregoire, E. Katz, JHEP 0812 (2008) 084, http://dx.doi.org/10.1088/1126-6708/2008/12/084, arXiv:0801.4799.
[13] N. Arkani-Hamed, A.G. Cohen, H. Georgi, Phys. Lett. B 513 (2001) 232, http://dx.doi.org/10.1016/S0370-2693(01)00741-9, arXiv:hep-ph/0105239.
[14] E. Katz, J. Lee, A.E. Nelson, D.G.E. Walker, JHEP 0510 (2005) 088, http://dx.doi.org/10.1088/1126-6708/2005/10/088, arXiv:hep-ph/0312287.
[15] J. Fan, M. Reece, J.T. Ruderman, JHEP 1207 (2012) 196, http://dx.doi.org/10.1007/JHEP07(2012)196, arXiv:1201.4875.
[16] CMS Collaboration, Absolute calibration of the luminosity measurement at CMS: Winter 2012 update, CMS Physics Analysis Summary CMS-PAS-SMP-12-008, 2012, http://cdsweb.cern.ch/record/1434360.
[17] D. Alves, et al., LHC New Physics Working Group, Simplified models for LHC new physics searches, arXiv:1105.2838, 2011.
[18] W. Beenakker, R. Höpker, M. Spira, P.M. Zerwas, Nucl. Phys. B 492 (1997) 51, http://dx.doi.org/10.1016/S0550-3213(97)00084-9, arXiv:hep-ph/9610490.
[19] A. Kulesza, L. Motyka, Phys. Rev. Lett. 102 (2009) 111802, http://dx.doi.org/10.1103/PhysRevLett.102.111802, arXiv:0807.2405.
[20] A. Kulesza, L. Motyka, Phys. Rev. D 80 (2009) 095004, http://dx.doi.org/10.1103/PhysRevD.80.095004, arXiv:0905.4749.
[21] W. Beenakker, S. Brensing, M. Krämer, A. Kulesza, E. Laenen, I. Niessen, JHEP 0912 (2009) 041, http://dx.doi.org/10.1088/1126-6708/2009/12/041, arXiv:0909.4418.
[22] W. Beenakker, S. Brensing, M. Krämer, A. Kulesza, E. Laenen, L. Motyka, I. Niessen, Int. J. Mod. Phys. A 26 (2011) 2637, http://dx.doi.org/10.1142/S0217751X11053560, arXiv:1105.1110.
[23] M. Krämer, A. Kulesza, R. van der Leeuw, M. Mangano, S. Padhi, T. Plehn, X. Portell, Supersymmetry production cross sections in pp collisions at $\sqrt{s} = 7$ TeV, arXiv:1206.2892, 2012.
[24] S. Chatrchyan, et al., CMS Collaboration, JINST 03 (2008) S08004, http://dx.doi.org/10.1088/1748-0221/3/08/S08004.
[25] CMS Collaboration, Search for new physics in events with photons, jets, and missing transverse energy in pp collisions at $\sqrt{s} = 7$ TeV, arXiv:1211.4784, 2012, JHEP, submitted for publication.
[26] CMS Collaboration, Particle-flow event reconstruction in CMS and performance for jets, taus, and E_T^{miss}, CMS Physics Analysis Summary CMS-PAS-PFT-09-001, 2009, http://cdsweb.cern.ch/record/1194487.
[27] M. Cacciari, G.P. Salam, G. Soyez, JHEP 0804 (2008) 063, http://dx.doi.org/10.1088/1126-6708/2008/04/063, arXiv:0802.1189.
[28] T. Sjöstrand, S. Mrenna, P. Skands, JHEP 0605 (2006) 026, http://dx.doi.org/10.1088/1126-6708/2006/05/026, arXiv:hep-ph/0603175.
[29] M.G. Albrow, et al., TeV4LHC QCD Working Group, Tevatron-for-LHC report of the QCD Working Group, 2006, arXiv:hep-ph/0610012.
[30] J. Pumplin, D.R. Stump, J. Huston, H.-L. Lai, P. Nadolsky, W.-K. Tung, JHEP 0207 (2002) 012, http://dx.doi.org/10.1088/1126-6708/2002/07/012, arXiv:hep-ph/0201195.
[31] S. Agostinelli, et al., Nucl. Instrum. Meth. A 506 (2003) 250, http://dx.doi.org/10.1016/S0168-9002(03)01368-8.
[32] V. Khachatryan, et al., CMS Collaboration, Phys. Lett. B 697 (2011) 434, http://dx.doi.org/10.1016/j.physletb.2011.02.032, arXiv:1012.3375.
[33] S. Chatrychan, et al., CMS Collaboration, JHEP 1204 (2012) 061, http://dx.doi.org/10.1007/JHEP04(2012)061, arXiv:1202.6396.
[34] A.L. Read, J. Phys. G 28 (2002) 2693, http://dx.doi.org/10.1088/0954-3899/28/10/313.
[35] T. Junk, Nucl. Instrum. Meth. A 434 (1999) 435, http://dx.doi.org/10.1016/S0168-9002(99)00498-2, arXiv:hep-ex/9902006.
[36] S. Chatrchyan, et al., CMS Collaboration, Phys. Lett. B 710 (2012) 26, http://dx.doi.org/10.1016/j.physletb.2012.02.064, arXiv:1202.1488.

CMS Collaboration

S. Chatrchyan, V. Khachatryan, A.M. Sirunyan, A. Tumasyan

Yerevan Physics Institute, Yerevan, Armenia

W. Adam, E. Aguilo, T. Bergauer, M. Dragicevic, J. Erö, C. Fabjan [1], M. Friedl, R. Frühwirth [1], V.M. Ghete, J. Hammer, N. Hörmann, J. Hrubec, M. Jeitler [1], W. Kiesenhofer, V. Knünz, M. Krammer [1], I. Krätschmer, D. Liko, I. Mikulec, M. Pernicka [†], B. Rahbaran, C. Rohringer, H. Rohringer, R. Schöfbeck, J. Strauss, A. Taurok, W. Waltenberger, G. Walzel, E. Widl, C.-E. Wulz [1]

Institut für Hochenergiephysik der OeAW, Wien, Austria

V. Mossolov, N. Shumeiko, J. Suarez Gonzalez

National Centre for Particle and High Energy Physics, Minsk, Belarus

M. Bansal, S. Bansal, T. Cornelis, E.A. De Wolf, X. Janssen, S. Luyckx, L. Mucibello, S. Ochesanu, B. Roland, R. Rougny, M. Selvaggi, Z. Staykova, H. Van Haevermaet, P. Van Mechelen, N. Van Remortel, A. Van Spilbeeck

Universiteit Antwerpen, Antwerpen, Belgium

F. Blekman, S. Blyweert, J. D'Hondt, R. Gonzalez Suarez, A. Kalogeropoulos, M. Maes, A. Olbrechts, W. Van Doninck, P. Van Mulders, G.P. Van Onsem, I. Villella

Vrije Universiteit Brussel, Brussel, Belgium

B. Clerbaux, G. De Lentdecker, V. Dero, A.P.R. Gay, T. Hreus, A. Léonard, P.E. Marage, A. Mohammadi, T. Reis, L. Thomas, G. Vander Marcken, C. Vander Velde, P. Vanlaer, J. Wang

Université Libre de Bruxelles, Bruxelles, Belgium

V. Adler, K. Beernaert, A. Cimmino, S. Costantini, G. Garcia, M. Grunewald, B. Klein, J. Lellouch, A. Marinov, J. Mccartin, A.A. Ocampo Rios, D. Ryckbosch, N. Strobbe, F. Thyssen, M. Tytgat, P. Verwilligen, S. Walsh, E. Yazgan, N. Zaganidis

Ghent University, Ghent, Belgium

S. Basegmez, G. Bruno, R. Castello, L. Ceard, C. Delaere, T. du Pree, D. Favart, L. Forthomme, A. Giammanco [2], J. Hollar, V. Lemaitre, J. Liao, O. Militaru, C. Nuttens, D. Pagano, A. Pin, K. Piotrzkowski, N. Schul, J.M. Vizan Garcia

Université Catholique de Louvain, Louvain-la-Neuve, Belgium

N. Beliy, T. Caebergs, E. Daubie, G.H. Hammad

Université de Mons, Mons, Belgium

G.A. Alves, M. Correa Martins Junior, D. De Jesus Damiao, T. Martins, M.E. Pol, M.H.G. Souza

Centro Brasileiro de Pesquisas Fisicas, Rio de Janeiro, Brazil

W.L. Aldá Júnior, W. Carvalho, A. Custódio, E.M. Da Costa, C. De Oliveira Martins, S. Fonseca De Souza, D. Matos Figueiredo, L. Mundim, H. Nogima, V. Oguri, W.L. Prado Da Silva, A. Santoro, L. Soares Jorge, A. Sznajder

Universidade do Estado do Rio de Janeiro, Rio de Janeiro, Brazil

T.S. Anjos [3], C.A. Bernardes [3], F.A. Dias [4], T.R. Fernandez Perez Tomei, E.M. Gregores [3], C. Lagana, F. Marinho, P.G. Mercadante [3], S.F. Novaes, Sandra S. Padula

Instituto de Fisica Teorica, Universidade Estadual Paulista, Sao Paulo, Brazil

V. Genchev [5], P. Iaydjiev [5], S. Piperov, M. Rodozov, S. Stoykova, G. Sultanov, V. Tcholakov, R. Trayanov, M. Vutova

Institute for Nuclear Research and Nuclear Energy, Sofia, Bulgaria

A. Dimitrov, R. Hadjiiska, V. Kozhuharov, L. Litov, B. Pavlov, P. Petkov

University of Sofia, Sofia, Bulgaria

J.G. Bian, G.M. Chen, H.S. Chen, C.H. Jiang, D. Liang, S. Liang, X. Meng, J. Tao, J. Wang, X. Wang, Z. Wang, H. Xiao, M. Xu, J. Zang, Z. Zhang

Institute of High Energy Physics, Beijing, China

C. Asawatangtrakuldee, Y. Ban, Y. Guo, W. Li, S. Liu, Y. Mao, S.J. Qian, H. Teng, D. Wang, L. Zhang, W. Zou

State Key Laboratory of Nuclear Physics and Technology, Peking University, Beijing, China

C. Avila, J.P. Gomez, B. Gomez Moreno, A.F. Osorio Oliveros, J.C. Sanabria

Universidad de Los Andes, Bogota, Colombia

N. Godinovic, D. Lelas, R. Plestina [6], D. Polic, I. Puljak [5]

Technical University of Split, Split, Croatia

Z. Antunovic, M. Kovac

University of Split, Split, Croatia

V. Brigljevic, S. Duric, K. Kadija, J. Luetic, S. Morovic

Institute Rudjer Boskovic, Zagreb, Croatia

A. Attikis, M. Galanti, G. Mavromanolakis, J. Mousa, C. Nicolaou, F. Ptochos, P.A. Razis

University of Cyprus, Nicosia, Cyprus

M. Finger, M. Finger Jr.

Charles University, Prague, Czech Republic

Y. Assran [7], S. Elgammal [8], A. Ellithi Kamel [9], S. Khalil [8], M.A. Mahmoud [10], A. Radi [11,12]

Academy of Scientific Research and Technology of the Arab Republic of Egypt, Egyptian Network of High Energy Physics, Cairo, Egypt

M. Kadastik, M. Müntel, M. Raidal, L. Rebane, A. Tiko

National Institute of Chemical Physics and Biophysics, Tallinn, Estonia

P. Eerola, G. Fedi, M. Voutilainen

Department of Physics, University of Helsinki, Helsinki, Finland

J. Härkönen, A. Heikkinen, V. Karimäki, R. Kinnunen, M.J. Kortelainen, T. Lampén, K. Lassila-Perini, S. Lehti, T. Lindén, P. Luukka, T. Mäenpää, T. Peltola, E. Tuominen, J. Tuominiemi, E. Tuovinen, D. Ungaro, L. Wendland

Helsinki Institute of Physics, Helsinki, Finland

K. Banzuzi, A. Karjalainen, A. Korpela, T. Tuuva

Lappeenranta University of Technology, Lappeenranta, Finland

M. Besancon, S. Choudhury, M. Dejardin, D. Denegri, B. Fabbro, J.L. Faure, F. Ferri, S. Ganjour, A. Givernaud, P. Gras, G. Hamel de Monchenault, P. Jarry, E. Locci, J. Malcles, L. Millischer, A. Nayak, J. Rander, A. Rosowsky, I. Shreyber, M. Titov

DSM/IRFU, CEA/Saclay, Gif-sur-Yvette, France

S. Baffioni, F. Beaudette, L. Benhabib, L. Bianchini, M. Bluj [13], C. Broutin, P. Busson, C. Charlot, N. Daci, T. Dahms, M. Dalchenko, L. Dobrzynski, R. Granier de Cassagnac, M. Haguenauer, P. Miné, C. Mironov, I.N. Naranjo, M. Nguyen, C. Ochando, P. Paganini, D. Sabes, R. Salerno, Y. Sirois, C. Veelken, A. Zabi

Laboratoire Leprince-Ringuet, Ecole Polytechnique, IN2P3-CNRS, Palaiseau, France

J.-L. Agram [14], J. Andrea, D. Bloch, D. Bodin, J.-M. Brom, M. Cardaci, E.C. Chabert, C. Collard, E. Conte [14], F. Drouhin [14], C. Ferro, J.-C. Fontaine [14], D. Gelé, U. Goerlach, P. Juillot, A.-C. Le Bihan, P. Van Hove

Institut Pluridisciplinaire Hubert Curien, Université de Strasbourg, Université de Haute Alsace Mulhouse, CNRS/IN2P3, Strasbourg, France

F. Fassi, D. Mercier

Centre de Calcul de l'Institut National de Physique Nucleaire et de Physique des Particules, CNRS/IN2P3, Villeurbanne, France

S. Beauceron, N. Beaupere, O. Bondu, G. Boudoul, J. Chasserat, R. Chierici [5], D. Contardo, P. Depasse, H. El Mamouni, J. Fay, S. Gascon, M. Gouzevitch, B. Ille, T. Kurca, M. Lethuillier, L. Mirabito, S. Perries, L. Sgandurra, V. Sordini, Y. Tschudi, P. Verdier, S. Viret

Université de Lyon, Université Claude Bernard Lyon 1, CNRS-IN2P3, Institut de Physique Nucléaire de Lyon, Villeurbanne, France

Z. Tsamalaidze [15]

Institute of High Energy Physics and Informatization, Tbilisi State University, Tbilisi, Georgia

G. Anagnostou, C. Autermann, S. Beranek, M. Edelhoff, L. Feld, N. Heracleous, O. Hindrichs, R. Jussen, K. Klein, J. Merz, A. Ostapchuk, A. Perieanu, F. Raupach, J. Sammet, S. Schael, D. Sprenger, H. Weber, B. Wittmer, V. Zhukov [16]

RWTH Aachen University, I. Physikalisches Institut, Aachen, Germany

M. Ata, J. Caudron, E. Dietz-Laursonn, D. Duchardt, M. Erdmann, R. Fischer, A. Güth, T. Hebbeker, C. Heidemann, K. Hoepfner, D. Klingebiel, P. Kreuzer, M. Merschmeyer, A. Meyer, M. Olschewski, P. Papacz, H. Pieta, H. Reithler, S.A. Schmitz, L. Sonnenschein, J. Steggemann, D. Teyssier, M. Weber

RWTH Aachen University, III Physikalisches Institut A, Aachen, Germany

M. Bontenackels, V. Cherepanov, Y. Erdogan, G. Flügge, H. Geenen, M. Geisler, W. Haj Ahmad, F. Hoehle, B. Kargoll, T. Kress, Y. Kuessel, J. Lingemann [5], A. Nowack, L. Perchalla, O. Pooth, P. Sauerland, A. Stahl

RWTH Aachen University, III. Physikalisches Institut B, Aachen, Germany

M. Aldaya Martin, J. Behr, W. Behrenhoff, U. Behrens, M. Bergholz [17], A. Bethani, K. Borras, A. Burgmeier, A. Cakir, L. Calligaris, A. Campbell, E. Castro, F. Costanza, D. Dammann, C. Diez Pardos, G. Eckerlin, D. Eckstein, G. Flucke, A. Geiser, I. Glushkov, P. Gunnellini, S. Habib, J. Hauk, G. Hellwig, H. Jung, M. Kasemann, P. Katsas, C. Kleinwort, H. Kluge, A. Knutsson, M. Krämer, D. Krücker, E. Kuznetsova, W. Lange, W. Lohmann [17], B. Lutz, R. Mankel, I. Marfin, M. Marienfeld, I.-A. Melzer-Pellmann, A.B. Meyer, J. Mnich, A. Mussgiller, S. Naumann-Emme, O. Novgorodova, J. Olzem, H. Perrey, A. Petrukhin, D. Pitzl, A. Raspereza, P.M. Ribeiro Cipriano, C. Riedl, E. Ron, M. Rosin, J. Salfeld-Nebgen, R. Schmidt [17], T. Schoerner-Sadenius, N. Sen, A. Spiridonov, M. Stein, R. Walsh, C. Wissing

Deutsches Elektronen-Synchrotron, Hamburg, Germany

V. Blobel, J. Draeger, H. Enderle, J. Erfle, U. Gebbert, M. Görner, T. Hermanns, R.S. Höing, K. Kaschube, G. Kaussen, H. Kirschenmann, R. Klanner, J. Lange, B. Mura, F. Nowak, T. Peiffer, N. Pietsch, D. Rathjens, C. Sander, H. Schettler, P. Schleper, E. Schlieckau, A. Schmidt, M. Schröder, T. Schum, M. Seidel, V. Sola, H. Stadie, G. Steinbrück, J. Thomsen, L. Vanelderen

University of Hamburg, Hamburg, Germany

C. Barth, J. Berger, C. Böser, T. Chwalek, W. De Boer, A. Descroix, A. Dierlamm, M. Feindt, M. Guthoff [5], C. Hackstein, F. Hartmann, T. Hauth [5], M. Heinrich, H. Held, K.H. Hoffmann, U. Husemann, I. Katkov [16], J.R. Komaragiri, P. Lobelle Pardo, D. Martschei, S. Mueller, Th. Müller, M. Niegel, A. Nürnberg, O. Oberst, A. Oehler, J. Ott, G. Quast, K. Rabbertz, F. Ratnikov, N. Ratnikova, S. Röcker, F.-P. Schilling, G. Schott, H.J. Simonis, F.M. Stober, D. Troendle, R. Ulrich, J. Wagner-Kuhr, S. Wayand, T. Weiler, M. Zeise

Institut für Experimentelle Kernphysik, Karlsruhe, Germany

G. Daskalakis, T. Geralis, S. Kesisoglou, A. Kyriakis, D. Loukas, I. Manolakos, A. Markou, C. Markou, C. Mavrommatis, E. Ntomari

Institute of Nuclear Physics "Demokritos", Aghia Paraskevi, Greece

L. Gouskos, T.J. Mertzimekis, A. Panagiotou, N. Saoulidou

University of Athens, Athens, Greece

I. Evangelou, C. Foudas, P. Kokkas, N. Manthos, I. Papadopoulos, V. Patras

University of Ioánnina, Ioánnina, Greece

G. Bencze, C. Hajdu, P. Hidas, D. Horvath [18], F. Sikler, V. Veszpremi, G. Vesztergombi [19]

KFKI Research Institute for Particle and Nuclear Physics, Budapest, Hungary

N. Beni, S. Czellar, J. Molnar, J. Palinkas, Z. Szillasi

Institute of Nuclear Research ATOMKI, Debrecen, Hungary

J. Karancsi, P. Raics, Z.L. Trocsanyi, B. Ujvari

University of Debrecen, Debrecen, Hungary

S.B. Beri, V. Bhatnagar, N. Dhingra, R. Gupta, M. Kaur, M.Z. Mehta, N. Nishu, L.K. Saini, A. Sharma, J.B. Singh

Panjab University, Chandigarh, India

Ashok Kumar, Arun Kumar, S. Ahuja, A. Bhardwaj, B.C. Choudhary, S. Malhotra, M. Naimuddin, K. Ranjan, V. Sharma, R.K. Shivpuri

University of Delhi, Delhi, India

S. Banerjee, S. Bhattacharya, S. Dutta, B. Gomber, Sa. Jain, Sh. Jain, R. Khurana, S. Sarkar, M. Sharan

Saha Institute of Nuclear Physics, Kolkata, India

A. Abdulsalam, R.K. Choudhury, D. Dutta, S. Kailas, V. Kumar, P. Mehta, A.K. Mohanty [5], L.M. Pant, P. Shukla

Bhabha Atomic Research Centre, Mumbai, India

T. Aziz, S. Ganguly, M. Guchait [20], M. Maity [21], G. Majumder, K. Mazumdar, G.B. Mohanty, B. Parida, K. Sudhakar, N. Wickramage

Tata Institute of Fundamental Research – EHEP, Mumbai, India

S. Banerjee, S. Dugad

Tata Institute of Fundamental Research – HECR, Mumbai, India

H. Arfaei [22], H. Bakhshiansohi, S.M. Etesami [23], A. Fahim [22], M. Hashemi, H. Hesari, A. Jafari, M. Khakzad, M. Mohammadi Najafabadi, S. Paktinat Mehdiabadi, B. Safarzadeh [24], M. Zeinali

Institute for Research in Fundamental Sciences (IPM), Tehran, Iran

M. Abbrescia [a,b], L. Barbone [a,b], C. Calabria [a,b,5], S.S. Chhibra [a,b], A. Colaleo [a], D. Creanza [a,c], N. De Filippis [a,c,5], M. De Palma [a,b], L. Fiore [a], G. Iaselli [a,c], L. Lusito [a,b], G. Maggi [a,c], M. Maggi [a], B. Marangelli [a,b], S. My [a,c], S. Nuzzo [a,b], N. Pacifico [a,b], A. Pompili [a,b], G. Pugliese [a,c], G. Selvaggi [a,b], L. Silvestris [a], G. Singh [a,b], R. Venditti [a,b], G. Zito [a]

[a] *INFN Sezione di Bari, Bari, Italy*
[b] *Università di Bari, Bari, Italy*
[c] *Politecnico di Bari, Bari, Italy*

G. Abbiendi [a], A.C. Benvenuti [a], D. Bonacorsi [a,b], S. Braibant-Giacomelli [a,b], L. Brigliadori [a,b], P. Capiluppi [a,b], A. Castro [a,b], F.R. Cavallo [a], M. Cuffiani [a,b], G.M. Dallavalle [a], F. Fabbri [a], A. Fanfani [a,b],

D. Fasanella [a,b,5], P. Giacomelli [a], C. Grandi [a], L. Guiducci [a,b], S. Marcellini [a], G. Masetti [a], M. Meneghelli [a,b,5], A. Montanari [a], F.L. Navarria [a,b], F. Odorici [a], A. Perrotta [a], F. Primavera [a,b], A.M. Rossi [a,b], T. Rovelli [a,b], G.P. Siroli [a,b], R. Travaglini [a,b]

[a] INFN Sezione di Bologna, Bologna, Italy
[b] Università di Bologna, Bologna, Italy

S. Albergo [a,b], G. Cappello [a,b], M. Chiorboli [a,b], S. Costa [a,b], R. Potenza [a,b], A. Tricomi [a,b], C. Tuve [a,b]

[a] INFN Sezione di Catania, Catania, Italy
[b] Università di Catania, Catania, Italy

G. Barbagli [a], V. Ciulli [a,b], C. Civinini [a], R. D'Alessandro [a,b], E. Focardi [a,b], S. Frosali [a,b], E. Gallo [a], S. Gonzi [a,b], M. Meschini [a], S. Paoletti [a], G. Sguazzoni [a], A. Tropiano [a,b]

[a] INFN Sezione di Firenze, Firenze, Italy
[b] Università di Firenze, Firenze, Italy

L. Benussi, S. Bianco, S. Colafranceschi [25], F. Fabbri, D. Piccolo

INFN Laboratori Nazionali di Frascati, Frascati, Italy

P. Fabbricatore [a], R. Musenich [a], S. Tosi [a,b]

[a] INFN Sezione di Genova, Genova, Italy
[b] Università di Genova, Genova, Italy

A. Benaglia [a,b], F. De Guio [a,b], L. Di Matteo [a,b,5], S. Fiorendi [a,b], S. Gennai [a,5], A. Ghezzi [a,b], S. Malvezzi [a], R.A. Manzoni [a,b], A. Martelli [a,b], A. Massironi [a,b,5], D. Menasce [a], L. Moroni [a], M. Paganoni [a,b], D. Pedrini [a], S. Ragazzi [a,b], N. Redaelli [a], S. Sala [a], T. Tabarelli de Fatis [a,b]

[a] INFN Sezione di Milano-Bicocca, Milano, Italy
[b] Università di Milano-Bicocca, Milano, Italy

S. Buontempo [a], C.A. Carrillo Montoya [a], N. Cavallo [a,26], A. De Cosa [a,b,5], O. Dogangun [a,b], F. Fabozzi [a,26], A.O.M. Iorio [a,b], L. Lista [a], S. Meola [a,27], M. Merola [a,b], P. Paolucci [a,5]

[a] INFN Sezione di Napoli, Napoli, Italy
[b] Università di Napoli "Federico II", Napoli, Italy

P. Azzi [a], N. Bacchetta [a,5], D. Bisello [a,b], A. Branca [a,b,5], R. Carlin [a,b], P. Checchia [a], T. Dorigo [a], U. Dosselli [a], F. Gasparini [a,b], A. Gozzelino [a], K. Kanishchev [a,c], S. Lacaprara [a], I. Lazzizzera [a,c], M. Margoni [a,b], A.T. Meneguzzo [a,b], J. Pazzini [a,b], N. Pozzobon [a,b], P. Ronchese [a,b], F. Simonetto [a,b], E. Torassa [a], M. Tosi [a,b], S. Vanini [a,b], P. Zotto [a,b], A. Zucchetta [a,b], G. Zumerle [a,b]

[a] INFN Sezione di Padova, Padova, Italy
[b] Università di Padova, Padova, Italy
[c] Università di Trento (Trento), Padova, Italy

M. Gabusi [a,b], S.P. Ratti [a,b], C. Riccardi [a,b], P. Torre [a,b], P. Vitulo [a,b]

[a] INFN Sezione di Pavia, Pavia, Italy
[b] Università di Pavia, Pavia, Italy

M. Biasini [a,b], G.M. Bilei [a], L. Fanò [a,b], P. Lariccia [a,b], G. Mantovani [a,b], M. Menichelli [a], A. Nappi [a,b,†], F. Romeo [a,b], A. Saha [a], A. Santocchia [a,b], A. Spiezia [a,b], S. Taroni [a,b]

[a] INFN Sezione di Perugia, Perugia, Italy
[b] Università di Perugia, Perugia, Italy

P. Azzurri [a,c], G. Bagliesi [a], J. Bernardini [a], T. Boccali [a], G. Broccolo [a,c], R. Castaldi [a], R.T. D'Agnolo [a,c,5], R. Dell'Orso [a], F. Fiori [a,b,5], L. Foà [a,c], A. Giassi [a], A. Kraan [a], F. Ligabue [a,c], T. Lomtadze [a], L. Martini [a,28], A. Messineo [a,b], F. Palla [a], A. Rizzi [a,b], A.T. Serban [a,29], P. Spagnolo [a], P. Squillacioti [a,5], R. Tenchini [a],

G. Tonelli [a,b], A. Venturi [a], P.G. Verdini [a]

[a] INFN Sezione di Pisa, Pisa, Italy
[b] Università di Pisa, Pisa, Italy
[c] Scuola Normale Superiore di Pisa, Pisa, Italy

L. Barone [a,b], F. Cavallari [a], D. Del Re [a,b], M. Diemoz [a], C. Fanelli [a,b], M. Grassi [a,b,5], E. Longo [a,b], P. Meridiani [a,5], F. Micheli [a,b], S. Nourbakhsh [a,b], G. Organtini [a,b], R. Paramatti [a], S. Rahatlou [a,b], M. Sigamani [a], L. Soffi [a,b]

[a] INFN Sezione di Roma, Roma, Italy
[b] Università di Roma, Roma, Italy

N. Amapane [a,b], R. Arcidiacono [a,c], S. Argiro [a,b], M. Arneodo [a,c], C. Biino [a], N. Cartiglia [a], M. Costa [a,b], N. Demaria [a], C. Mariotti [a,5], S. Maselli [a], E. Migliore [a,b], V. Monaco [a,b], M. Musich [a,5], M.M. Obertino [a,c], N. Pastrone [a], M. Pelliccioni [a], A. Potenza [a,b], A. Romero [a,b], M. Ruspa [a,c], R. Sacchi [a,b], A. Solano [a,b], A. Staiano [a], A. Vilela Pereira [a]

[a] INFN Sezione di Torino, Torino, Italy
[b] Università di Torino, Torino, Italy
[c] Università del Piemonte Orientale (Novara), Torino, Italy

S. Belforte [a], V. Candelise [a,b], M. Casarsa [a], F. Cossutti [a], G. Della Ricca [a,b], B. Gobbo [a], M. Marone [a,b,5], D. Montanino [a,b,5], A. Penzo [a], A. Schizzi [a,b]

[a] INFN Sezione di Trieste, Trieste, Italy
[b] Università di Trieste, Trieste, Italy

S.G. Heo, T.Y. Kim, S.K. Nam

Kangwon National University, Chunchon, Republic of Korea

S. Chang, D.H. Kim, G.N. Kim, D.J. Kong, H. Park, S.R. Ro, D.C. Son, T. Son

Kyungpook National University, Daegu, Republic of Korea

J.Y. Kim, Zero J. Kim, S. Song

Chonnam National University, Institute for Universe and Elementary Particles, Kwangju, Republic of Korea

S. Choi, D. Gyun, B. Hong, M. Jo, H. Kim, T.J. Kim, K.S. Lee, D.H. Moon, S.K. Park

Korea University, Seoul, Republic of Korea

M. Choi, J.H. Kim, C. Park, I.C. Park, S. Park, G. Ryu

University of Seoul, Seoul, Republic of Korea

Y. Cho, Y. Choi, Y.K. Choi, J. Goh, M.S. Kim, E. Kwon, B. Lee, J. Lee, S. Lee, H. Seo, I. Yu

Sungkyunkwan University, Suwon, Republic of Korea

M.J. Bilinskas, I. Grigelionis, M. Janulis, A. Juodagalvis

Vilnius University, Vilnius, Lithuania

H. Castilla-Valdez, E. De La Cruz-Burelo, I. Heredia-de La Cruz, R. Lopez-Fernandez, R. Magaña Villalba, J. Martínez-Ortega, A. Sánchez-Hernández, L.M. Villasenor-Cendejas

Centro de Investigacion y de Estudios Avanzados del IPN, Mexico City, Mexico

S. Carrillo Moreno, F. Vazquez Valencia

Universidad Iberoamericana, Mexico City, Mexico

H.A. Salazar Ibarguen

Benemerita Universidad Autonoma de Puebla, Puebla, Mexico

E. Casimiro Linares, A. Morelos Pineda, M.A. Reyes-Santos

Universidad Autónoma de San Luis Potosí, San Luis Potosí, Mexico

D. Krofcheck

University of Auckland, Auckland, New Zealand

A.J. Bell, P.H. Butler, R. Doesburg, S. Reucroft, H. Silverwood

University of Canterbury, Christchurch, New Zealand

M. Ahmad, M.H. Ansari, M.I. Asghar, H.R. Hoorani, S. Khalid, W.A. Khan, T. Khurshid, S. Qazi, M.A. Shah, M. Shoaib

National Centre for Physics, Quaid-I-Azam University, Islamabad, Pakistan

H. Bialkowska, B. Boimska, T. Frueboes, R. Gokieli, M. Górski, M. Kazana, K. Nawrocki, K. Romanowska-Rybinska, M. Szleper, G. Wrochna, P. Zalewski

National Centre for Nuclear Research, Swierk, Poland

G. Brona, K. Bunkowski, M. Cwiok, W. Dominik, K. Doroba, A. Kalinowski, M. Konecki, J. Krolikowski

Institute of Experimental Physics, Faculty of Physics, University of Warsaw, Warsaw, Poland

N. Almeida, P. Bargassa, A. David, P. Faccioli, P.G. Ferreira Parracho, M. Gallinaro, J. Seixas, J. Varela, P. Vischia

Laboratório de Instrumentação e Física Experimental de Partículas, Lisboa, Portugal

I. Belotelov, P. Bunin, M. Gavrilenko, I. Golutvin, I. Gorbunov, A. Kamenev, V. Karjavin, G. Kozlov, A. Lanev, A. Malakhov, P. Moisenz, V. Palichik, V. Perelygin, S. Shmatov, V. Smirnov, A. Volodko, A. Zarubin

Joint Institute for Nuclear Research, Dubna, Russia

S. Evstyukhin, V. Golovtsov, Y. Ivanov, V. Kim, P. Levchenko, V. Murzin, V. Oreshkin, I. Smirnov, V. Sulimov, L. Uvarov, S. Vavilov, A. Vorobyev, An. Vorobyev

Petersburg Nuclear Physics Institute, Gatchina (St. Petersburg), Russia

Yu. Andreev, A. Dermenev, S. Gninenko, N. Golubev, M. Kirsanov, N. Krasnikov, V. Matveev, A. Pashenkov, D. Tlisov, A. Toropin

Institute for Nuclear Research, Moscow, Russia

V. Epshteyn, M. Erofeeva, V. Gavrilov, M. Kossov, N. Lychkovskaya, V. Popov, G. Safronov, S. Semenov, V. Stolin, E. Vlasov, A. Zhokin

Institute for Theoretical and Experimental Physics, Moscow, Russia

A. Belyaev, E. Boos, M. Dubinin [4], L. Dudko, A. Ershov, A. Gribushin, V. Klyukhin, O. Kodolova, I. Lokhtin, A. Markina, S. Obraztsov, M. Perfilov, S. Petrushanko, A. Popov, L. Sarycheva [†], V. Savrin, A. Snigirev

Moscow State University, Moscow, Russia

V. Andreev, M. Azarkin, I. Dremin, M. Kirakosyan, A. Leonidov, G. Mesyats, S.V. Rusakov, A. Vinogradov

P.N. Lebedev Physical Institute, Moscow, Russia

I. Azhgirey, I. Bayshev, S. Bitioukov, V. Grishin [5], V. Kachanov, D. Konstantinov, V. Krychkine, V. Petrov, R. Ryutin, A. Sobol, L. Tourtchanovitch, S. Troshin, N. Tyurin, A. Uzunian, A. Volkov

State Research Center of Russian Federation, Institute for High Energy Physics, Protvino, Russia

P. Adzic [30], M. Djordjevic, M. Ekmedzic, D. Krpic [30], J. Milosevic

University of Belgrade, Faculty of Physics and Vinca Institute of Nuclear Sciences, Belgrade, Serbia

M. Aguilar-Benitez, J. Alcaraz Maestre, P. Arce, C. Battilana, E. Calvo, M. Cerrada, M. Chamizo Llatas, N. Colino, B. De La Cruz, A. Delgado Peris, D. Domínguez Vázquez, C. Fernandez Bedoya, J.P. Fernández Ramos, A. Ferrando, J. Flix, M.C. Fouz, P. Garcia-Abia, O. Gonzalez Lopez, S. Goy Lopez, J.M. Hernandez, M.I. Josa, G. Merino, J. Puerta Pelayo, A. Quintario Olmeda, I. Redondo, L. Romero, J. Santaolalla, M.S. Soares, C. Willmott

Centro de Investigaciones Energéticas Medioambientales y Tecnológicas (CIEMAT), Madrid, Spain

C. Albajar, G. Codispoti, J.F. de Trocóniz

Universidad Autónoma de Madrid, Madrid, Spain

H. Brun, J. Cuevas, J. Fernandez Menendez, S. Folgueras, I. Gonzalez Caballero, L. Lloret Iglesias, J. Piedra Gomez

Universidad de Oviedo, Oviedo, Spain

J.A. Brochero Cifuentes, I.J. Cabrillo, A. Calderon, S.H. Chuang, J. Duarte Campderros, M. Felcini [31], M. Fernandez, G. Gomez, J. Gonzalez Sanchez, A. Graziano, C. Jorda, A. Lopez Virto, J. Marco, R. Marco, C. Martinez Rivero, F. Matorras, F.J. Munoz Sanchez, T. Rodrigo, A.Y. Rodríguez-Marrero, A. Ruiz-Jimeno, L. Scodellaro, I. Vila, R. Vilar Cortabitarte

Instituto de Física de Cantabria (IFCA), CSIC – Universidad de Cantabria, Santander, Spain

D. Abbaneo, E. Auffray, G. Auzinger, M. Bachtis, P. Baillon, A.H. Ball, D. Barney, J.F. Benitez, C. Bernet [6], G. Bianchi, P. Bloch, A. Bocci, A. Bonato, C. Botta, H. Breuker, T. Camporesi, G. Cerminara, T. Christiansen, J.A. Coarasa Perez, D. D'Enterria, A. Dabrowski, A. De Roeck, S. Di Guida, M. Dobson, N. Dupont-Sagorin, A. Elliott-Peisert, B. Frisch, W. Funk, G. Georgiou, M. Giffels, D. Gigi, K. Gill, D. Giordano, M. Girone, M. Giunta, F. Glege, R. Gomez-Reino Garrido, P. Govoni, S. Gowdy, R. Guida, M. Hansen, P. Harris, C. Hartl, J. Harvey, B. Hegner, A. Hinzmann, V. Innocente, P. Janot, K. Kaadze, E. Karavakis, K. Kousouris, P. Lecoq, Y.-J. Lee, P. Lenzi, C. Lourenço, N. Magini, T. Mäki, M. Malberti, L. Malgeri, M. Mannelli, L. Masetti, F. Meijers, S. Mersi, E. Meschi, R. Moser, M.U. Mozer, M. Mulders, P. Musella, E. Nesvold, T. Orimoto, L. Orsini, E. Palencia Cortezon, E. Perez, L. Perrozzi, A. Petrilli, A. Pfeiffer, M. Pierini, M. Pimiä, D. Piparo, G. Polese, L. Quertenmont, A. Racz, W. Reece, J. Rodrigues Antunes, G. Rolandi [32], C. Rovelli [33], M. Rovere, H. Sakulin, F. Santanastasio, C. Schäfer, C. Schwick, I. Segoni, S. Sekmen, A. Sharma, P. Siegrist, P. Silva, M. Simon, P. Sphicas [34,*], D. Spiga, A. Tsirou, G.I. Veres [19], J.R. Vlimant, H.K. Wöhri, S.D. Worm [35], W.D. Zeuner

CERN, European Organization for Nuclear Research, Geneva, Switzerland

W. Bertl, K. Deiters, W. Erdmann, K. Gabathuler, R. Horisberger, Q. Ingram, H.C. Kaestli, S. König, D. Kotlinski, U. Langenegger, F. Meier, D. Renker, T. Rohe, J. Sibille [36]

Paul Scherrer Institut, Villigen, Switzerland

L. Bäni, P. Bortignon, M.A. Buchmann, B. Casal, N. Chanon, A. Deisher, G. Dissertori, M. Dittmar, M. Donegà, M. Dünser, J. Eugster, K. Freudenreich, C. Grab, D. Hits, P. Lecomte, W. Lustermann, A.C. Marini, P. Martinez Ruiz del Arbol, N. Mohr, F. Moortgat, C. Nägeli [37], P. Nef, F. Nessi-Tedaldi, F. Pandolfi, L. Pape, F. Pauss, M. Peruzzi, F.J. Ronga, M. Rossini, L. Sala, A.K. Sanchez, A. Starodumov [38], B. Stieger, M. Takahashi, L. Tauscher [†], A. Thea, K. Theofilatos, D. Treille, C. Urscheler, R. Wallny, H.A. Weber, L. Wehrli

Institute for Particle Physics, ETH Zurich, Zurich, Switzerland

C. Amsler [39], V. Chiochia, S. De Visscher, C. Favaro, M. Ivova Rikova, B. Millan Mejias, P. Otiougova, P. Robmann, H. Snoek, S. Tupputi, M. Verzetti

Universität Zürich, Zurich, Switzerland

Y.H. Chang, K.H. Chen, C.M. Kuo, S.W. Li, W. Lin, Z.K. Liu, Y.J. Lu, D. Mekterovic, A.P. Singh, R. Volpe, S.S. Yu

National Central University, Chung-Li, Taiwan

P. Bartalini, P. Chang, Y.H. Chang, Y.W. Chang, Y. Chao, K.F. Chen, C. Dietz, U. Grundler, W.-S. Hou, Y. Hsiung, K.Y. Kao, Y.J. Lei, R.-S. Lu, D. Majumder, E. Petrakou, X. Shi, J.G. Shiu, Y.M. Tzeng, X. Wan, M. Wang

National Taiwan University (NTU), Taipei, Taiwan

B. Asavapibhop, N. Srimanobhas

Chulalongkorn University, Bangkok, Thailand

A. Adiguzel, M.N. Bakirci [40], S. Cerci [41], C. Dozen, I. Dumanoglu, E. Eskut, S. Girgis, G. Gokbulut, E. Gurpinar, I. Hos, E.E. Kangal, T. Karaman, G. Karapinar [42], A. Kayis Topaksu, G. Onengut, K. Ozdemir, S. Ozturk [43], A. Polatoz, K. Sogut [44], D. Sunar Cerci [41], B. Tali [41], H. Topakli [40], L.N. Vergili, M. Vergili

Cukurova University, Adana, Turkey

I.V. Akin, T. Aliev, B. Bilin, S. Bilmis, M. Deniz, H. Gamsizkan, A.M. Guler, K. Ocalan, A. Ozpineci, M. Serin, R. Sever, U.E. Surat, M. Yalvac, E. Yildirim, M. Zeyrek

Middle East Technical University, Physics Department, Ankara, Turkey

E. Gülmez, B. Isildak [45], M. Kaya [46], O. Kaya [46], S. Ozkorucuklu [47], N. Sonmez [48]

Bogazici University, Istanbul, Turkey

K. Cankocak

Istanbul Technical University, Istanbul, Turkey

L. Levchuk

National Scientific Center, Kharkov Institute of Physics and Technology, Kharkov, Ukraine

F. Bostock, J.J. Brooke, E. Clement, D. Cussans, H. Flacher, R. Frazier, J. Goldstein, M. Grimes, G.P. Heath, H.F. Heath, L. Kreczko, S. Metson, D.M. Newbold [35], K. Nirunpong, A. Poll, S. Senkin, V.J. Smith, T. Williams

University of Bristol, Bristol, United Kingdom

L. Basso [49], K.W. Bell, A. Belyaev [49], C. Brew, R.M. Brown, D.J.A. Cockerill, J.A. Coughlan, K. Harder, S. Harper, J. Jackson, B.W. Kennedy, E. Olaiya, D. Petyt, B.C. Radburn-Smith, C.H. Shepherd-Themistocleous, I.R. Tomalin, W.J. Womersley

Rutherford Appleton Laboratory, Didcot, United Kingdom

R. Bainbridge, G. Ball, R. Beuselinck, O. Buchmuller, D. Colling, N. Cripps, M. Cutajar, P. Dauncey, G. Davies, M. Della Negra, W. Ferguson, J. Fulcher, D. Futyan, A. Gilbert, A. Guneratne Bryer, G. Hall, Z. Hatherell, J. Hays, G. Iles, M. Jarvis, G. Karapostoli, L. Lyons, A.-M. Magnan, J. Marrouche, B. Mathias, R. Nandi, J. Nash, A. Nikitenko [38], A. Papageorgiou, J. Pela, M. Pesaresi, K. Petridis, M. Pioppi [50], D.M. Raymond, S. Rogerson, A. Rose, M.J. Ryan, C. Seez, P. Sharp[†], A. Sparrow, M. Stoye, A. Tapper, M. Vazquez Acosta, T. Virdee, S. Wakefield, N. Wardle, T. Whyntie

Imperial College, London, United Kingdom

M. Chadwick, J.E. Cole, P.R. Hobson, A. Khan, P. Kyberd, D. Leggat, D. Leslie, W. Martin, I.D. Reid, P. Symonds, L. Teodorescu, M. Turner

Brunel University, Uxbridge, United Kingdom

K. Hatakeyama, H. Liu, T. Scarborough

Baylor University, Waco, USA

O. Charaf, C. Henderson, P. Rumerio

The University of Alabama, Tuscaloosa, USA

A. Avetisyan, T. Bose, C. Fantasia, A. Heister, J. St. John, P. Lawson, D. Lazic, J. Rohlf, D. Sperka, L. Sulak

Boston University, Boston, USA

J. Alimena, S. Bhattacharya, D. Cutts, Z. Demiragli, A. Ferapontov, A. Garabedian, U. Heintz, S. Jabeen, G. Kukartsev, E. Laird, G. Landsberg, M. Luk, M. Narain, D. Nguyen, M. Segala, T. Sinthuprasith, T. Speer, K.V. Tsang

Brown University, Providence, USA

R. Breedon, G. Breto, M. Calderon De La Barca Sanchez, S. Chauhan, M. Chertok, J. Conway, R. Conway, P.T. Cox, J. Dolen, R. Erbacher, M. Gardner, R. Houtz, W. Ko, A. Kopecky, R. Lander, O. Mall, T. Miceli, D. Pellett, F. Ricci-tam, B. Rutherford, M. Searle, J. Smith, M. Squires, M. Tripathi, R. Vasquez Sierra, R. Yohay

University of California, Davis, Davis, USA

V. Andreev, D. Cline, R. Cousins, J. Duris, S. Erhan, P. Everaerts, C. Farrell, J. Hauser, M. Ignatenko, C. Jarvis, C. Plager, G. Rakness, P. Schlein[†], P. Traczyk, V. Valuev, M. Weber

University of California, Los Angeles, Los Angeles, USA

J. Babb, R. Clare, M.E. Dinardo, J. Ellison, J.W. Gary, F. Giordano, G. Hanson, G.Y. Jeng[51], H. Liu, O.R. Long, A. Luthra, H. Nguyen, S. Paramesvaran, J. Sturdy, S. Sumowidagdo, R. Wilken, S. Wimpenny

University of California, Riverside, Riverside, USA

W. Andrews, J.G. Branson, G.B. Cerati, S. Cittolin, D. Evans, F. Golf, A. Holzner, R. Kelley, M. Lebourgeois, J. Letts, I. Macneill, B. Mangano, S. Padhi, C. Palmer, G. Petrucciani, M. Pieri, M. Sani, V. Sharma, S. Simon, E. Sudano, M. Tadel, Y. Tu, A. Vartak, S. Wasserbaech[52], F. Würthwein, A. Yagil, J. Yoo

University of California, San Diego, La Jolla, USA

D. Barge, R. Bellan, C. Campagnari, M. D'Alfonso, T. Danielson, K. Flowers, P. Geffert, J. Incandela, C. Justus, P. Kalavase, S.A. Koay, D. Kovalskyi, V. Krutelyov, S. Lowette, N. Mccoll, V. Pavlunin, F. Rebassoo, J. Ribnik, J. Richman, R. Rossin, D. Stuart, W. To, C. West

University of California, Santa Barbara, Santa Barbara, USA

A. Apresyan, A. Bornheim, Y. Chen, E. Di Marco, J. Duarte, M. Gataullin, Y. Ma, A. Mott, H.B. Newman, C. Rogan, M. Spiropulu, V. Timciuc, J. Veverka, R. Wilkinson, S. Xie, Y. Yang, R.Y. Zhu

California Institute of Technology, Pasadena, USA

B. Akgun, V. Azzolini, A. Calamba, R. Carroll, T. Ferguson, Y. Iiyama, D.W. Jang, Y.F. Liu, M. Paulini, H. Vogel, I. Vorobiev

Carnegie Mellon University, Pittsburgh, USA

J.P. Cumalat, B.R. Drell, W.T. Ford, A. Gaz, E. Luiggi Lopez, J.G. Smith, K. Stenson, K.A. Ulmer, S.R. Wagner

University of Colorado at Boulder, Boulder, USA

J. Alexander, A. Chatterjee, N. Eggert, L.K. Gibbons, B. Heltsley, A. Khukhunaishvili, B. Kreis, N. Mirman, G. Nicolas Kaufman, J.R. Patterson, A. Ryd, E. Salvati, W. Sun, W.D. Teo, J. Thom, J. Thompson, J. Tucker, J. Vaughan, Y. Weng, L. Winstrom, P. Wittich

Cornell University, Ithaca, USA

D. Winn

Fairfield University, Fairfield, USA

S. Abdullin, M. Albrow, J. Anderson, L.A.T. Bauerdick, A. Beretvas, J. Berryhill, P.C. Bhat, I. Bloch, K. Burkett, J.N. Butler, V. Chetluru, H.W.K. Cheung, F. Chlebana, V.D. Elvira, I. Fisk, J. Freeman, Y. Gao, D. Green, O. Gutsche, J. Hanlon, R.M. Harris, J. Hirschauer, B. Hooberman, S. Jindariani, M. Johnson, U. Joshi, B. Kilminster, B. Klima, S. Kunori, S. Kwan, C. Leonidopoulos, J. Linacre, D. Lincoln, R. Lipton, J. Lykken, K. Maeshima, J.M. Marraffino, S. Maruyama, D. Mason, P. McBride, K. Mishra, S. Mrenna, Y. Musienko [53], C. Newman-Holmes, V. O'Dell, O. Prokofyev, E. Sexton-Kennedy, S. Sharma, W.J. Spalding, L. Spiegel, L. Taylor, S. Tkaczyk, N.V. Tran, L. Uplegger, E.W. Vaandering, R. Vidal, J. Whitmore, W. Wu, F. Yang, F. Yumiceva, J.C. Yun

Fermi National Accelerator Laboratory, Batavia, USA

D. Acosta, P. Avery, D. Bourilkov, M. Chen, T. Cheng, S. Das, M. De Gruttola, G.P. Di Giovanni, D. Dobur, A. Drozdetskiy, R.D. Field, M. Fisher, Y. Fu, I.K. Furic, J. Gartner, J. Hugon, B. Kim, J. Konigsberg, A. Korytov, A. Kropivnitskaya, T. Kypreos, J.F. Low, K. Matchev, P. Milenovic [54], G. Mitselmakher, L. Muniz, M. Park, R. Remington, A. Rinkevicius, P. Sellers, N. Skhirtladze, M. Snowball, J. Yelton, M. Zakaria

University of Florida, Gainesville, USA

V. Gaultney, S. Hewamanage, L.M. Lebolo, S. Linn, P. Markowitz, G. Martinez, J.L. Rodriguez

Florida International University, Miami, USA

T. Adams, A. Askew, J. Bochenek, J. Chen, B. Diamond, S.V. Gleyzer, J. Haas, S. Hagopian, V. Hagopian, M. Jenkins, K.F. Johnson, H. Prosper, V. Veeraraghavan, M. Weinberg

Florida State University, Tallahassee, USA

M.M. Baarmand, B. Dorney, M. Hohlmann, H. Kalakhety, I. Vodopiyanov

Florida Institute of Technology, Melbourne, USA

M.R. Adams, I.M. Anghel, L. Apanasevich, Y. Bai, V.E. Bazterra, R.R. Betts, I. Bucinskaite, J. Callner, R. Cavanaugh, O. Evdokimov, L. Gauthier, C.E. Gerber, D.J. Hofman, S. Khalatyan, F. Lacroix, M. Malek, C. O'Brien, C. Silkworth, D. Strom, P. Turner, N. Varelas

University of Illinois at Chicago (UIC), Chicago, USA

U. Akgun, E.A. Albayrak, B. Bilki [55], W. Clarida, F. Duru, J.-P. Merlo, H. Mermerkaya [56], A. Mestvirishvili, A. Moeller, J. Nachtman, C.R. Newsom, E. Norbeck, Y. Onel, F. Ozok [57], S. Sen, P. Tan, E. Tiras, J. Wetzel, T. Yetkin, K. Yi

The University of Iowa, Iowa City, USA

B.A. Barnett, B. Blumenfeld, S. Bolognesi, D. Fehling, G. Giurgiu, A.V. Gritsan, Z.J. Guo, G. Hu, P. Maksimovic, S. Rappoccio, M. Swartz, A. Whitbeck

Johns Hopkins University, Baltimore, USA

P. Baringer, A. Bean, G. Benelli, R.P. Kenny Iii, M. Murray, D. Noonan, S. Sanders, R. Stringer, G. Tinti, J.S. Wood, V. Zhukova

The University of Kansas, Lawrence, USA

A.F. Barfuss, T. Bolton, I. Chakaberia, A. Ivanov, S. Khalil, M. Makouski, Y. Maravin, S. Shrestha, I. Svintradze

Kansas State University, Manhattan, USA

J. Gronberg, D. Lange, D. Wright

Lawrence Livermore National Laboratory, Livermore, USA

A. Baden, M. Boutemeur, B. Calvert, S.C. Eno, J.A. Gomez, N.J. Hadley, R.G. Kellogg, M. Kirn, T. Kolberg, Y. Lu, M. Marionneau, A.C. Mignerey, K. Pedro, A. Skuja, J. Temple, M.B. Tonjes, S.C. Tonwar, E. Twedt

University of Maryland, College Park, USA

A. Apyan, G. Bauer, J. Bendavid, W. Busza, E. Butz, I.A. Cali, M. Chan, V. Dutta, G. Gomez Ceballos, M. Goncharov, K.A. Hahn, Y. Kim, M. Klute, K. Krajczar [58], P.D. Luckey, T. Ma, S. Nahn, C. Paus, D. Ralph, C. Roland, G. Roland, M. Rudolph, G.S.F. Stephans, F. Stöckli, K. Sumorok, K. Sung, D. Velicanu, E.A. Wenger, R. Wolf, B. Wyslouch, M. Yang, Y. Yilmaz, A.S. Yoon, M. Zanetti

Massachusetts Institute of Technology, Cambridge, USA

S.I. Cooper, B. Dahmes, A. De Benedetti, G. Franzoni, A. Gude, S.C. Kao, K. Klapoetke, Y. Kubota, J. Mans, N. Pastika, R. Rusack, M. Sasseville, A. Singovsky, N. Tambe, J. Turkewitz

University of Minnesota, Minneapolis, USA

L.M. Cremaldi, R. Kroeger, L. Perera, R. Rahmat, D.A. Sanders

University of Mississippi, Oxford, USA

E. Avdeeva, K. Bloom, S. Bose, J. Butt, D.R. Claes, A. Dominguez, M. Eads, J. Keller, I. Kravchenko, J. Lazo-Flores, H. Malbouisson, S. Malik, G.R. Snow

University of Nebraska-Lincoln, Lincoln, USA

A. Godshalk, I. Iashvili, S. Jain, A. Kharchilava, A. Kumar

State University of New York at Buffalo, Buffalo, USA

G. Alverson, E. Barberis, D. Baumgartel, M. Chasco, J. Haley, D. Nash, D. Trocino, D. Wood, J. Zhang

Northeastern University, Boston, USA

A. Anastassov, A. Kubik, N. Mucia, N. Odell, R.A. Ofierzynski, B. Pollack, A. Pozdnyakov, M. Schmitt, S. Stoynev, M. Velasco, S. Won

Northwestern University, Evanston, USA

L. Antonelli, D. Berry, A. Brinkerhoff, K.M. Chan, M. Hildreth, C. Jessop, D.J. Karmgard, J. Kolb, K. Lannon, W. Luo, S. Lynch, N. Marinelli, D.M. Morse, T. Pearson, M. Planer, R. Ruchti, J. Slaunwhite, N. Valls, M. Wayne, M. Wolf

University of Notre Dame, Notre Dame, USA

B. Bylsma, L.S. Durkin, C. Hill, R. Hughes, K. Kotov, T.Y. Ling, D. Puigh, M. Rodenburg, C. Vuosalo, G. Williams, B.L. Winer

The Ohio State University, Columbus, USA

N. Adam, E. Berry, P. Elmer, D. Gerbaudo, V. Halyo, P. Hebda, J. Hegeman, A. Hunt, P. Jindal, D. Lopes Pegna, P. Lujan, D. Marlow, T. Medvedeva, M. Mooney, J. Olsen, P. Piroué, X. Quan, A. Raval, B. Safdi, H. Saka, D. Stickland, C. Tully, J.S. Werner, A. Zuranski

Princeton University, Princeton, USA

E. Brownson, A. Lopez, H. Mendez, J.E. Ramirez Vargas

University of Puerto Rico, Mayaguez, USA

E. Alagoz, V.E. Barnes, D. Benedetti, G. Bolla, D. Bortoletto, M. De Mattia, A. Everett, Z. Hu, M. Jones, O. Koybasi, M. Kress, A.T. Laasanen, N. Leonardo, V. Maroussov, P. Merkel, D.H. Miller, N. Neumeister, I. Shipsey, D. Silvers, A. Svyatkovskiy, M. Vidal Marono, H.D. Yoo, J. Zablocki, Y. Zheng

Purdue University, West Lafayette, USA

S. Guragain, N. Parashar

Purdue University Calumet, Hammond, USA

A. Adair, C. Boulahouache, K.M. Ecklund, F.J.M. Geurts, W. Li, B.P. Padley, R. Redjimi, J. Roberts, J. Zabel

Rice University, Houston, USA

B. Betchart, A. Bodek, Y.S. Chung, R. Covarelli, P. de Barbaro, R. Demina, Y. Eshaq, T. Ferbel, A. Garcia-Bellido, P. Goldenzweig, J. Han, A. Harel, D.C. Miner, D. Vishnevskiy, M. Zielinski

University of Rochester, Rochester, USA

A. Bhatti, R. Ciesielski, L. Demortier, K. Goulianos, G. Lungu, S. Malik, C. Mesropian

The Rockefeller University, New York, USA

S. Arora, A. Barker, J.P. Chou, C. Contreras-Campana, E. Contreras-Campana, D. Duggan, D. Ferencek, Y. Gershtein, R. Gray, E. Halkiadakis, D. Hidas, A. Lath, S. Panwalkar, M. Park, R. Patel, V. Rekovic, J. Robles, K. Rose, S. Salur, S. Schnetzer, C. Seitz, S. Somalwar, R. Stone, S. Thomas

Rutgers, the State University of New Jersey, Piscataway, USA

G. Cerizza, M. Hollingsworth, S. Spanier, Z.C. Yang, A. York

University of Tennessee, Knoxville, USA

R. Eusebi, W. Flanagan, J. Gilmore, T. Kamon [59], V. Khotilovich, R. Montalvo, I. Osipenkov, Y. Pakhotin, A. Perloff, J. Roe, A. Safonov, T. Sakuma, S. Sengupta, I. Suarez, A. Tatarinov, D. Toback

Texas A&M University, College Station, USA

N. Akchurin, J. Damgov, C. Dragoiu, P.R. Dudero, C. Jeong, K. Kovitanggoon, S.W. Lee, T. Libeiro, Y. Roh, I. Volobouev

Texas Tech University, Lubbock, USA

E. Appelt, A.G. Delannoy, C. Florez, S. Greene, A. Gurrola, W. Johns, P. Kurt, C. Maguire, A. Melo, M. Sharma, P. Sheldon, B. Snook, S. Tuo, J. Velkovska

Vanderbilt University, Nashville, USA

M.W. Arenton, M. Balazs, S. Boutle, B. Cox, B. Francis, J. Goodell, R. Hirosky, A. Ledovskoy, C. Lin, C. Neu, J. Wood

University of Virginia, Charlottesville, USA

S. Gollapinni, R. Harr, P.E. Karchin, C. Kottachchi Kankanamge Don, P. Lamichhane, A. Sakharov

Wayne State University, Detroit, USA

M. Anderson, D. Belknap, L. Borrello, D. Carlsmith, M. Cepeda, S. Dasu, E. Friis, L. Gray, K.S. Grogg, M. Grothe, R. Hall-Wilton, M. Herndon, A. Hervé, P. Klabbers, J. Klukas, A. Lanaro, C. Lazaridis, J. Leonard, R. Loveless, A. Mohapatra, I. Ojalvo, F. Palmonari, G.A. Pierro, I. Ross, A. Savin, W.H. Smith, J. Swanson

University of Wisconsin, Madison, USA

[*] Corresponding author.
E-mail address: cms-publication-committee-chair@cern.ch (P. Sphicas).
[†] Deceased.
[1] Also at Vienna University of Technology, Vienna, Austria.
[2] Also at National Institute of Chemical Physics and Biophysics, Tallinn, Estonia.
[3] Also at Universidade Federal do ABC, Santo Andre, Brazil.
[4] Also at California Institute of Technology, Pasadena, USA.
[5] Also at CERN, European Organization for Nuclear Research, Geneva, Switzerland.
[6] Also at Laboratoire Leprince-Ringuet, Ecole Polytechnique, IN2P3-CNRS, Palaiseau, France.
[7] Also at Suez Canal University, Suez, Egypt.
[8] Also at Zewail City of Science and Technology, Zewail, Egypt.
[9] Also at Cairo University, Cairo, Egypt.
[10] Also at Fayoum University, El-Fayoum, Egypt.
[11] Also at British University, Cairo, Egypt.
[12] Now at Ain Shams University, Cairo, Egypt.
[13] Also at National Centre for Nuclear Research, Swierk, Poland.
[14] Also at Université de Haute-Alsace, Mulhouse, France.
[15] Now at Joint Institute for Nuclear Research, Dubna, Russia.
[16] Also at Moscow State University, Moscow, Russia.
[17] Also at Brandenburg University of Technology, Cottbus, Germany.
[18] Also at Institute of Nuclear Research ATOMKI, Debrecen, Hungary.
[19] Also at Eötvös Loránd University, Budapest, Hungary.
[20] Also at Tata Institute of Fundamental Research – HECR, Mumbai, India.
[21] Also at University of Visva-Bharati, Santiniketan, India.
[22] Also at Sharif University of Technology, Tehran, Iran.
[23] Also at Isfahan University of Technology, Isfahan, Iran.
[24] Also at Plasma Physics Research Center, Science and Research Branch, Islamic Azad University, Tehran, Iran.
[25] Also at Facoltà Ingegneria Università di Roma, Roma, Italy.
[26] Also at Università della Basilicata, Potenza, Italy.
[27] Also at Università degli Studi Guglielmo Marconi, Roma, Italy.
[28] Also at Università degli Studi di Siena, Siena, Italy.
[29] Also at University of Bucharest, Faculty of Physics, Bucuresti-Magurele, Romania.
[30] Also at Faculty of Physics of University of Belgrade, Belgrade, Serbia.
[31] Also at University of California, Los Angeles, Los Angeles, USA.
[32] Also at Scuola Normale e Sezione dell'INFN, Pisa, Italy.
[33] Also at INFN Sezione di Roma; Università di Roma, Roma, Italy.
[34] Also at University of Athens, Athens, Greece.
[35] Also at Rutherford Appleton Laboratory, Didcot, United Kingdom.
[36] Also at The University of Kansas, Lawrence, USA.
[37] Also at Paul Scherrer Institut, Villigen, Switzerland.
[38] Also at Institute for Theoretical and Experimental Physics, Moscow, Russia.
[39] Also at Albert Einstein Center for Fundamental Physics, BERN, Switzerland.
[40] Also at Gaziosmanpasa University, Tokat, Turkey.
[41] Also at Adiyaman University, Adiyaman, Turkey.
[42] Also at Izmir Institute of Technology, Izmir, Turkey.
[43] Also at The University of Iowa, Iowa City, USA.
[44] Also at Mersin University, Mersin, Turkey.
[45] Also at Ozyegin University, Istanbul, Turkey.
[46] Also at Kafkas University, Kars, Turkey.
[47] Also at Suleyman Demirel University, Isparta, Turkey.
[48] Also at Ege University, Izmir, Turkey.
[49] Also at School of Physics and Astronomy, University of Southampton, Southampton, United Kingdom.
[50] Also at INFN Sezione di Perugia; Università di Perugia, Perugia, Italy.

[51] Also at University of Sydney, Sydney, Australia.
[52] Also at Utah Valley University, Orem, USA.
[53] Also at Institute for Nuclear Research, Moscow, Russia.
[54] Also at University of Belgrade, Faculty of Physics and Vinca Institute of Nuclear Sciences, Belgrade, Serbia.
[55] Also at Argonne National Laboratory, Argonne, USA.
[56] Also at Erzincan University, Erzincan, Turkey.
[57] Also at Mimar Sinan University, Istanbul, Istanbul, Turkey.
[58] Also at KFKI Research Institute for Particle and Nuclear Physics, Budapest, Hungary.
[59] Also at Kyungpook National University, Daegu, Republic of Korea.