Physics Letters B 716 (2012) 260–284

Contents lists available at SciVerse ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

Search for physics beyond the standard model in events with a Z boson, jets, and missing transverse energy in pp collisions at $\sqrt{s} = 7$ TeV ☆

CMS Collaboration *

CERN, Switzerland

ARTICLE INFO

Article history:
Received 17 April 2012
Received in revised form 10 August 2012
Accepted 13 August 2012
Available online 16 August 2012
Editor: M. Doser

Keywords:
CMS
Physics
Supersymmetry
SUSY

ABSTRACT

A search is presented for physics beyond the standard model (BSM) in events with a Z boson, jets, and missing transverse energy (E_T^{miss}). This signature is motivated by BSM physics scenarios, including supersymmetry. The study is performed using a sample of proton–proton collision data collected at $\sqrt{s} = 7$ TeV with the CMS experiment at the LHC, corresponding to an integrated luminosity of 4.98 fb^{-1}. The contributions from the dominant standard model backgrounds are estimated from data using two complementary strategies, the jet-Z balance technique and a method based on modeling E_T^{miss} with data control samples. In the absence of evidence for BSM physics, we set limits on the non-standard-model contributions to event yields in the signal regions and interpret the results in the context of simplified model spectra. Additional information is provided to facilitate tests of other BSM physics models.

1. Introduction

This Letter describes a search for physics beyond the standard model (BSM) in proton–proton collisions at a center-of-mass energy of 7 TeV. Results are reported from a data sample collected with the Compact Muon Solenoid (CMS) detector at the Large Hadron Collider (LHC) at CERN corresponding to an integrated luminosity of 4.98 fb^{-1}. This search is part of a broad program of inclusive, signature-based searches for BSM physics at CMS, characterized by the number and type of objects in the final state. Since it is not known a priori how the BSM physics will be manifest, we perform searches in events containing jets and missing transverse energy (E_T^{miss}) [1–3], single isolated leptons [4], pairs of opposite-sign [5] and same-sign [6] isolated leptons, photons [7,8], etc. Here we search for evidence of BSM physics in final states containing a Z boson that decays to a pair of oppositely-charged isolated electrons or muons. Searches for BSM physics in events containing oppositely-charged leptons have also been performed by the ATLAS Collaboration [9–11].

This strategy offers two advantages with respect to other searches. First, the requirement of a leptonically-decaying Z boson significantly suppresses large standard model (SM) backgrounds including QCD multijet production, events containing Z bosons decaying to a pair of invisible neutrinos, and events containing leptonically-decaying W bosons, and hence provides a clean environment in which to search for BSM physics. Second, final states with Z bosons are predicted in many models of BSM physics, such as supersymmetry (SUSY) [12–16]. For example, the production of a Z boson in the decay $\tilde{\chi}_2^0 \to \tilde{\chi}_1^0$ Z, where $\tilde{\chi}_1^0$ ($\tilde{\chi}_2^0$) is the lightest (second lightest) neutralino, is a direct consequence of the gauge structure of SUSY, and can become a favored channel in regions of the SUSY parameter space where the neutralinos have a large Higgsino or neutral Wino component [17–19]. Our search is also motivated by the existence of cosmological cold dark matter [20], which could consist of weakly-interacting massive particles [21] such as the lightest SUSY neutralino in R-parity conserving SUSY models [22]. If produced in pp collisions, these particles would escape detection and yield events with large E_T^{miss}. Finally, we search for BSM physics in events containing hadronic jets. This is motivated by the fact that new, heavy, strongly-interacting particles predicted by many BSM scenarios may be produced with a large cross section and hence be observable in early LHC data, and such particles tend to decay to hadronic jets. These considerations lead us to our target signature consisting of a leptonically-decaying Z boson produced in association with jets and E_T^{miss}.

After selecting events with jets and a $Z \to \ell^+\ell^-$ ($\ell = e, \mu$) candidate, the dominant background consists of SM Z production accompanied by jets from initial-state radiation (Z + jets). The E_T^{miss} in Z + jets events arises primarily when jet energies are mismeasured. The Z + jets cross section is several orders of magnitude larger than our signal, and the artificial E_T^{miss} is not necessarily well reproduced in simulation. Therefore, the critical

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

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http://dx.doi.org/10.1016/j.physletb.2012.08.026

Table 6
Parameters of the JZB (top) and E_T^{miss} (bottom) response function. The parameter σ is the resolution, x_{thresh} is the JZB or E_T^{miss} value at the center of the efficiency curve, and $\varepsilon_{plateau}$ is the efficiency on the plateau.

Region	σ [GeV]	x_{thresh} [GeV]	$\varepsilon_{plateau}$
JZB > 50 GeV	30	55	0.99
JZB > 100 GeV	30	108	0.99
JZB > 150 GeV	32	156	0.99
JZB > 200 GeV	39	209	0.99
JZB > 250 GeV	45	261	0.98
$E_T^{miss} > 100$ GeV	29	103	1.00
$E_T^{miss} > 200$ GeV	38	214	0.99
$E_T^{miss} > 300$ GeV	40	321	0.98

have tested this efficiency model with the LM4 and LM8 benchmark models, and find that the efficiency from our model is consistent with the expectation from the full reconstruction to within about 15%.

9. Summary

We have performed a search for BSM physics in final states with a leptonically-decaying Z boson, jets, and missing transverse energy. Two complementary strategies are used to suppress the dominant Z + jets background and to estimate the remaining background from data control samples: the jet-Z balance method and the E_T^{miss} template method. Backgrounds from $t\bar{t}$ processes are estimated using opposite-flavor lepton pairs and dilepton invariant mass sidebands. We find no evidence for anomalous yields beyond standard model (SM) expectations and place upper limits on the non-SM contributions to the yields in the signal regions. The results are interpreted in the context of simplified model spectra. We also provide information on the detector response and efficiencies to allow tests of BSM models with Z bosons that are not considered in the present study.

Acknowledgements

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); 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 (Republic of 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); MICINN and CPAN (Spain); Swiss Funding Agencies (Switzerland); NSC (Taipei); TUBITAK and TAEK (Turkey); STFC (United Kingdom); DOE and NSF (USA). Individuals have received support from the Marie-Curie programme and the European Research Council (European Union); the Leventis Foundation; the A.P. Sloan Foundation; the Alexander von Humboldt Foundation; the Belgian Federal Science Policy Office; the Fonds pour la Formation à la Recherche dans l'Industrie et dans l'Agriculture (FRIA-Belgium); the Agentschap voor Innovatie door Wetenschap en Technologie (IWT-Belgium); the Council of Science and Industrial Research, India; and the HOMING PLUS programme of Foundation for Polish Science, cofinanced from European Union, Regional Development Fund.

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Appendix A. Supplementary material

Supplementary material related to this article can be found online at http://dx.doi.org/10.1016/j.physletb.2012.08.026.

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J. Cuevas, J. Fernandez Menendez, S. Folgueras, I. Gonzalez Caballero, L. Lloret Iglesias, J. Piedra Gomez [32], J.M. Vizan Garcia

Universidad de Oviedo, Oviedo, Spain

J.A. Brochero Cifuentes, I.J. Cabrillo, A. Calderon, S.H. Chuang, J. Duarte Campderros, M. Felcini [33], M. Fernandez, G. Gomez, J. Gonzalez Sanchez, C. Jorda, P. Lobelle Pardo, 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, M. Sobron Sanudo, I. Vila, R. Vilar Cortabitarte

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

D. Abbaneo, E. Auffray, G. Auzinger, P. Baillon, A.H. Ball, D. Barney, C. Bernet [5], G. Bianchi, P. Bloch, A. Bocci, A. Bonato, H. Breuker, K. Bunkowski, T. Camporesi, G. Cerminara, T. Christiansen, J.A. Coarasa Perez, D. D'Enterria, 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. 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, P. Lenzi, C. Lourenço, T. Mäki, M. Malberti, L. Malgeri, M. Mannelli, L. Masetti, F. Meijers, S. Mersi, E. Meschi, R. Moser, M.U. Mozer, M. Mulders, E. Nesvold, M. Nguyen, T. Orimoto, L. Orsini, E. Palencia Cortezon, E. Perez, A. Petrilli, A. Pfeiffer, M. Pierini, M. Pimiä, D. Piparo, G. Polese, L. Quertenmont, A. Racz, W. Reece, J. Rodrigues Antunes, G. Rolandi [34], T. Rommerskirchen, C. Rovelli [35], M. Rovere, H. Sakulin, F. Santanastasio, C. Schäfer, C. Schwick, I. Segoni, S. Sekmen, A. Sharma, P. Siegrist, P. Silva, M. Simon, P. Sphicas [36,*], D. Spiga, M. Spiropulu [4], M. Stoye, A. Tsirou, G.I. Veres [17], J.R. Vlimant, H.K. Wöhri, S.D. Worm [37], 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 [38]

Paul Scherrer Institut, Villigen, Switzerland

L. Bäni, P. Bortignon, M.A. Buchmann, B. Casal, N. Chanon, Z. Chen, A. Deisher, G. Dissertori, M. Dittmar, M. Dünser, J. Eugster, K. Freudenreich, C. Grab, P. Lecomte, W. Lustermann, A.C. Marini, P. Martinez Ruiz del Arbol, N. Mohr, F. Moortgat, C. Nägeli [39], P. Nef, F. Nessi-Tedaldi, L. Pape, F. Pauss, M. Peruzzi, F.J. Ronga, M. Rossini, L. Sala, A.K. Sanchez, M.-C. Sawley, A. Starodumov [40], 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

E. Aguilo, C. Amsler, 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, A. Go, C.M. Kuo, S.W. Li, W. Lin, Z.K. Liu, Y.J. Lu, D. Mekterovic, 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, M. Wang

National Taiwan University (NTU), Taipei, Taiwan

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