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Interpretation of searches for supersymmetry with simplified models

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The results of searches for supersymmetry by the CMS experiment are interpreted in the framework of simplified models. The results are based on data corresponding to an integrated luminosity of 4.73 to 4.98 fb^{-1}. The data were collected at the LHC in proton–proton collisions at a center-of-mass energy of 7 TeV. This paper describes the method of interpretation and provides upper limits on the product of the production cross section and branching fraction as a function of new particle masses for a number of simplified models. These limits and the corresponding experimental acceptance calculations can be used to constrain other theoretical models and to compare different supersymmetry-inspired analyses.

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I. INTRODUCTION

The results of searches for supersymmetry (SUSY) [1] at particle colliders are often used to test the validity of a few, specific, theoretical models. These models predict a large number of experimental observables at hadron colliders as a function of a few theoretical parameters. Most of the SUSY analyses performed by the Compact Muon Solenoid (CMS) experiment present their results as an exclusion of a range of parameters for the constrained minimal supersymmetric standard model (CMSSM) [2–4]. However, the results of the SUSY analyses can be used to test a wide range of alternative models, since many SUSY and non-SUSY models predict a similar phenomenology. These similarities inspired the formulation of the simplified model framework for presenting experimental results [5–9]. Specific applications of these ideas have appeared in Refs. [10,11].

A simplified model is defined by a set of hypothetical particles and a sequence of their production and decay. For each simplified model, values for the product of the experimental acceptance and efficiency ($\mathcal{A} \times \epsilon$) are calculated to translate a number of signal events into a signal cross section. From this information, a 95% confidence level upper limit (UL) on the product of the cross section and branching fraction ($[\sigma \times \mathcal{B}]_{\mathrm{UL}}$) is derived as a function of particle masses. The simplified model framework can quantify the dependence of an experimental limit on the particle spectrum or a particular sequence of particle production and decay in a manner that is more general than the CMSSM. Furthermore, the values of $[\sigma \times \mathcal{B}]_{\mathrm{UL}}$ can be compared with theoretical predictions from a SUSY or non-SUSY model to determine whether the theory is compatible with data.

This paper collects and describes simplified model interpretations of a large number of SUSY-inspired analyses performed on data collected by the CMS Collaboration in 2011 [12–26]. The simplified model framework was also applied by CMS to a limited number of analyses in 2010 [27]. The ATLAS Collaboration has published similar interpretations [28–34].

The paper is organized as follows. Section II provides a brief description of the CMS analyses considered here; Sec. III describes simplified models; Sec. IV demonstrates the calculation of the product of the experimental acceptance and efficiency and the upper limits on cross sections; Sec. V contains comparisons of the results for different simplified models and analyses; Sec. VI contains a summary.

II. THE CMS DETECTOR AND ANALYSES

The CMS detector consists of a silicon tracker, an electromagnetic calorimeter, and a hadronic calorimeter, all located within the field volume of a central solenoid magnet, and a muon-detection system located outside the magnet [35]. Information from these components is combined to define objects such as electrons, muons, photons, jets, jets identified as b jets (b-tagged jets), and missing transverse energy ($\not\!\!E_{\mathrm{T}}$). The exact definition of these objects depends on the specific analysis, and can be found in the analysis references. The data were collected by the CMS experiment at the Large Hadron Collider in proton–proton collisions at a center-of-mass energy of 7 TeV. Unless stated otherwise, the data corresponds to an integrated luminosity of $4.98 \pm 0.11\ \mathrm{fb}^{-1}$ [36].

The descriptions of the analyses are categorized by the main features of the event selection. Detailed descriptions of these analyses can be found in Refs. [12–26]. The target of these analyses is a signal of the production of new, heavy particles that decay into standard model particles and stable, neutral particles that escape detection. The stable, neutral particles can produce a signature of large $\not\!\!E_{\mathrm{T}}$. The standard model also produces $\not\!\!E_{\mathrm{T}}$ in top quark, weak gauge

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light-flavor quark and a neutralino, a squark mass of approximately 800 GeV is excluded for a neutralino of mass 50 GeV, corresponding to an upper limit on the squark-antisquark production cross section of approximately 10 fb. The excluded mass for a single bottom-antibottom squark pair is 550 GeV. The comparable exclusion in mass for a single top-antitop squark pair is approximately 150 GeV lower. In the case of the electroweak production of a chargino-neutralino pair, the upper limit on the cross section is approximately 1 order of magnitude higher than the corresponding limit for gluino pair production at the same mass.

The predictions for experimental acceptance and exclusion limits on cross sections presented here for a range of simplified models and mass parameters can be used to constrain other theoretical models and compare different analyses.

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