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D0 SUSY/BSM Searches

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Abstract

We report on D0 searches for supersymmetry (SUSY) at the TEVATRON Run II. Analyses with data samples in the following range of integrated luminosities $1 < \int \mathcal{L}dt < 2.1 fb^{-1}$ are summarized. These searches look for different production processes and decay channels in gravity and gauge mediated SUSY breaking models. No excess of observed events is found with respect to the Standard Model (SM) predictions, therefore a series of exclusion limits at the 95% confidence level (C.L.) are drawn.

1 Introduction

Even though many alternatives exist and continue to develop [1][2][3], SUSY [4][5][6] is still the most promising extension of the SM. The main problem in this theoretical framework is the nature and the details of the mechanism of the SUSY breaking. However it was realized in the early 1980's [11] that the SUSY breaking which occurs at a high energy scale (hidden sector) can be decoupled from the TeV scale (visible sector) in several schemes. The only manifestation of the SUSY breaking in the visible sector being the mass degeneracy lift between SM particles and their SUSY partners (sparticles). Therefore the main distinctions between the SUSY models is the nature of the interactions which transmit the SUSY breaking between the hidden and the visible sectors.

The most motivated, and therefore the most studied, models are called "gravity mediated SUSY breaking" (SUGRA) [8][9][10] and "gauge mediated SUSY breaking" (GMSB) [12][13]. These models suppose the SUSY breaking transmission is due to gravitational interactions and gauge interactions respectively.

In practice, we'll distinguish two cases for the experimental searches reported below.

There are cases (see sub-sections 2.1.1,2.1.5,2.1.6,3.1) where the sparticles production mechanisms involve several sub-processes of comparable cross sections. Another (or a further) complication may be that the produced sparticles decay through complicated cascades. Those cascade decays depend on the corresponding model parameters both through the hypothesized SUSY mass spectrum and through the relevant couplings. In order to handle these multi-parametric situations we use the minimal models: mSUGRA and mGMSB. This reduces the number of parameters to manage as well as automatically takes care of the correlations between the possible sub-processes cross sections and between the sparticles masses and couplings. For these cases, the obvious drawback is that the results are model-dependent.

In contrast (see sub-sections 2.1.2,2.1.3,2.2) when the sparticles are produced through single processes and undergo direct decays, we'll suppose those decays saturate the branching ratios ($BR = 100\%$). The results are then directly presented as functions of the sparticles masses, irrespective of the parameters of the corresponding SUSY model. Consequently, the interpretation in any other SUSY models (that verifies the initial hypotheses) only requires the rescaling of the BR.

The analyses presented hereafter were performed on data from $p\bar{p}$ collisions at a center-of-mass energy of $\sqrt{s} = 1.96$ TeV at the TEVATRON Run II [15]. These data samples, with integrated luminosities ranging from 1 to 2.1 fb^{-1}, were collected by the D0 experiment [7].

In section 2 we'll present the SUGRA searches and in section 3 the GMSB ones.

2 Searches in Gravity Mediated SUSY Breaking Models

In this section we'll first present searches (2.1.1 to 2.1.6) for R-parity (R_P) [1] conserving SUSY. Their common topological feature is the presence of missing transverse energy ($\not\!\!E_T$). The seventh analysis presented in section 2.2 assumes R_P violation and hence has no $\not\!\!E_T$ in its search topology.

2.1 R-parity Conserving Searches

2.1.1 Search for chargino+neutralino in trilepton plus $\not\!\!E_T$ events

The following process: $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \to 3\ell^{\pm} + \not\!\!E_T$ is searched for in a dataset of $0.59 fb^{-1}$ in the e^+e^-+track topology.
The event selection requires 2 electrons both with a matching track and a loose identification of the third lepton as just an additional isolated track. After the final selection, no data events are observed (N_{obs} =0) for an expected SM background of $N_{exp} = 1.0 \pm 0.3$ events. This analysis is combined with previous trilepton searches leading to a lower limit of $m(\tilde{\chi}_1^{\pm}) > 145$ GeV in the so-called "3l-max" scenario [2] [16].

2.1.2 Search for stop pairs in dilepton plus $\not\!\!E_T$ events

Stop pairs production where each stop decays leptonically: $\tilde{t} \to b + \tilde{\nu} + \ell^{\pm}$ is considered. The search is made in the $e^{\pm} + \mu^{\mp} + 2b + \not\!\!E_T$ topology. The dataset amounts to 1 fb^{-1}. The event selection requires hard and isolated electron and muon accompanied by b-jets and $\not\!\!E_T$. After the final selection cuts 6 events are observed for 7±1 expected. Therefore an improved exclusion limit is placed in the $(m_{\tilde{t}}, m_{\tilde{\nu}})$ plane (see Fig. 1 right hand part).

2.1.3 Search for stop pairs in acoplanar c-dijet events

A search for stop pairs production where each stop decays in the $\tilde{t} \to c + \tilde{\chi}_1^0$ mode is performed in a 1 fb^{-1} dataset. The selection is based on the presence of 2 hard c-tagged jets. Since these jets have to be acoplanar, a large $\not\!\!E_T$ is required. Since no excess in this topology is observed, an improved exclusion limit is drawn in the $(m_{\tilde{t}}, m_{\tilde{\chi}_1^0})$ plane (see Fig. 1 left hand part).

2.1.4 Search for stops contributions in top pair production

A test of a possible contamination from stop leptonic decays within $t\bar{t} \to \ell^{\pm} + jets$ samples of 0.9 fb^{-1} is made. A multivariate function is built to

[1] $R_P = (-1)^{L+2S+3B}$ where L, S and B are the lepton, spin and baryon quantum numbers

[2] This Minimal SUGRA inspired scenario supposes an enhanced trilepton BR. This is ensured by charged sleptons being slightly heavier than the $\tilde{\chi}_1^{\pm}$ and the $\tilde{\chi}_2^0$.

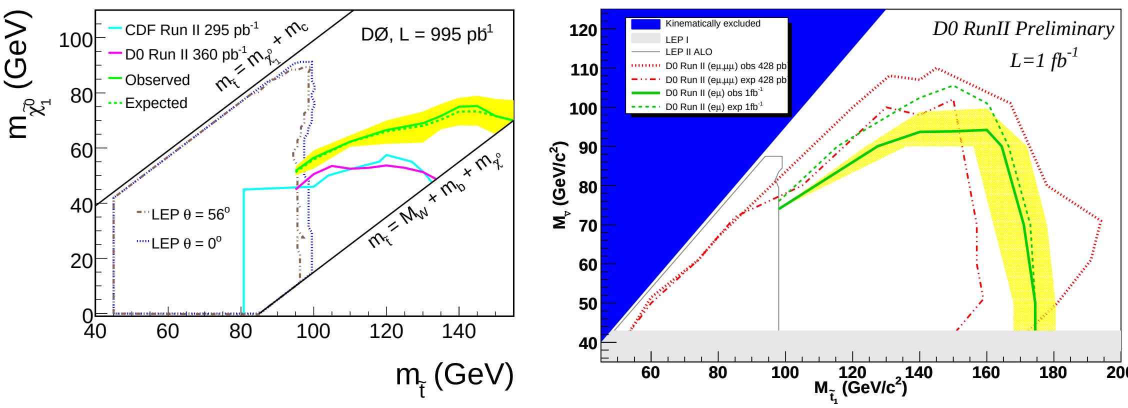

Figure 1: Exclusion limits for the stop pair production in the acoplanar c-dijet events (left) and in the dilepton $+\not\!\!E_T$ events (right).

discriminate a stop signal essentially from the SM $t\bar{t}$ background. Though this analysis constitutes an original example of a top precision measurement recycled into a SUSY search, due to the limited integrated luminosity, the sensitivity is still unsufficient to exclude any stop contributions.

2.1.5 Search for squark-gluino pairs in jets+$\not\!\!E_T$ events

A search for $\tilde{q}\tilde{\bar{q}} + \tilde{q}\tilde{g} + \tilde{g}\tilde{g} \to jets + \not\!\!E_T$ is made in 2.1 fb^{-1} of data. The selection asks for hard multijet events with large $\not\!\!E_T$ and no isolated leptons. Since no excess of such events is seen above the expected SM background the following mass lower limits: $m(\tilde{q}) > 392$ GeV and $m(\tilde{g}) > 327$ GeV are set in the mSUGRA model.

2.1.6 Search for squark-gluino pairs in jets+$\tau_{(s)} + \not\!\!E_T$

The same search as in 2.1.5 is performed in a 1 fb^{-1} dataset. But here, for the first time at a hadron collider, at least 1 hadronic tau decay is explicitely requested in the already complex search topology. No such signal is found and the consequently derived limit extends the exclusion from the LEP experiments into the mSUGRA parameter space region where the $\tilde{\tau}^{\pm}$ are light with respect to the $\tilde{\chi}_1^{\pm}$ and the $\tilde{\chi}_2^0$.

2.2 R-parity Violating Searches

2.2.1 Search for a Resonant Sneutrino Production

A search for the R-parity violating process: $\tilde{\nu} \to e^{\pm}\mu^{\mp}$ is conducted in a 1 fb^{-1} dataset. The observed events are in agreement with the SM expectations, hence a limit on the R-parity violating coupling $\lambda'_{311} > 0.0016$ is established for the following hypotheses: $\lambda_{312} = 0.01$ and $m(\tilde{\nu}_\tau) = 100$ GeV.

3 Searches in Gauge Mediated SUSY Breaking Models

3.1 Search for Prompt Diphotons

A search for $\tilde{\chi}\tilde{\chi} \to 2\gamma + \not{E}_T$ events is made using a 1.1 fb^{-1} dataset. No excess of such events above the SM predictions is observed enabling to exclude $m(\tilde{\chi}_1^0) < 125$ GeV and $m(\tilde{\chi}_1^{\pm}) < 229$ GeV in the mGMSB model.

3.2 Search for Long-Lived Chargino-Neutralino pairs

A search for long-lived neutralinos in the GMSB model is made by looking for $\tilde{\chi}\tilde{\chi} \to e^{\pm} + e^{\mp} + \not{E}_T$ events in a 1.1 fb^{-1} dataset. The analysis selects events containing 2 hard and isolated EM clusters, reconstructs their primary vertex using a photon pointing technique as well as its vertex radius. Since the vertex radii in the data with $\not{E}_T > 30$ GeV and $m_{e^+e^-} > 20$ GeV are in agreement with those predicted by the SM, an upper limit can be placed on the production cross section of neutralinos with a proper decay length of 100 mm: $\sigma \times \mathrm{BR} < 1.9$ pb.

4 Conclusions and Prospects

We have presented recent results from SUSY searches of the D0 experiment at the TEVATRON Run II in data samples with integrated luminosities ranging from 1 to 2.1 fb^{-1}. No signs of SUSY has been found and a series of 95% C.L. exclusion limits have been drawn. These limits superseed the corresponding ones previously published by the D0 collaboration.
Improvements in the D0 SUSY searches are already underway. On a quantitaive point of view, they will come from increasing the analyzed dataset. We'll also combine different D0 SUSY searches and combine D0 and CDF searches to increase the sensitivity.
On a qualitative point of view, improvments may come from reduced systematic uncertainties and from multivariate events selection. However, the performances of the identification algorithms at high instantaneous luminosity will have to be maintained.
Further details on the above analyses can be found at [14].

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