

Search for Chargino-Neutralino Production at CDF and DØ

Sourabh Dube (for the CDF and DØ collaborations)

*Department of Astronomy and Physics, Rutgers University,
136 Frelinghuysen Road, Piscataway, New Jersey, USA 08854*

Abstract. Searches for associated production of chargino-neutralino in lepton final states at the Tevatron are summarized in this paper. The results from CDF and DØ are consistent with the standard model and no signs of chargino-neutralino production are found. Limits are set on the production cross section by both experiments, and charginos with mass less than $\sim 145 \text{ GeV}/c^2$ are excluded in favorable scenarios.

Keywords: supersymmetry, chargino-neutralino, trileptons, mSUGRA

PACS: 14.80.Ly 12.60.Jv 13.85.Rm

INTRODUCTION

The standard model (SM) has been successful at describing physics phenomena up to electroweak scales. However, the SM leaves a few unanswered questions. It presents no explanation for the origins of the mass hierarchies of particles. It does not include a description of gravity. It also suffers from the hierarchy problem, and gives no hints about the nature of dark matter or dark energy which constitute 96% of our universe.

Of the several proposed models of new physics beyond the standard model supersymmetry (SUSY) is a leading candidate. SUSY is a new proposed symmetry between fermions and bosons. It posits the existence of boson superpartners to all SM fermions and vice versa. This solves the hierarchy problem and with certain conditions suggests an attractive dark matter candidate particle.

In R-parity¹ conserving models of supersymmetry, the associated production of chargino $\tilde{\chi}_1^\pm$ and neutralino $\tilde{\chi}_2^0$ gives rise to a distinctive signature. The $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$ each decay to leptons along with invisible particles giving a final state with three leptons and a momentum imbalance (missing E_T or $\cancel{E}_T$) in the detector. The decays proceed as follows :

$$\tilde{\chi}_1^\pm \rightarrow l^\pm \nu \tilde{\chi}_1^0, \text{ and } \tilde{\chi}_2^0 \rightarrow l^\pm l^\mp \tilde{\chi}_1^0$$

where $\tilde{\chi}_1^0$ is the stable lightest supersymmetric particle (LSP) which escapes the detector and is the dark matter candidate. The decay is through a virtual W or Z .

The $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$ can also decay through intermediate slepton states,

$$\tilde{\chi}_1^\pm \rightarrow \tilde{l}^\pm \nu, \text{ and } \tilde{\chi}_2^0 \rightarrow \tilde{l}^\pm l^\mp$$

where the slepton decays as $\tilde{l}^\pm \rightarrow l^\pm \tilde{\chi}_1^0$. The final state in each case is $3l + \cancel{E}_T$.

TABLE 1. CDF results of a search for $\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \rightarrow 3l + \cancel{E}_T$. The signal quoted is for mSUGRA model with parameters $m_0 = 60 \text{ GeV}/c^2$, $m_{1/2} = 190 \text{ GeV}/c^2$, $\tan\beta = 3$, $A_0 = 0$, $\mu > 0$. l_t =tight lepton, l_l =loose lepton, T =isolated track.

Channel	Exp. Signal	Bkgd.	Data
$l_t l_t l_t$	2.3 ± 0.3	0.5 ± 0.1	1
$l_t l_t l_l$	1.6 ± 0.2	0.3 ± 0.04	0
$l_t l_l l_l$	0.7 ± 0.1	0.1 ± 0.03	0
$l_t l_l T$	4.4 ± 0.6	3.2 ± 0.7	4
$l_l l_l T$	2.4 ± 0.3	2.3 ± 0.6	2

CDF ANALYSIS

CDF conducted a analysis which looked in five final states defined by purity of leptons used for the final states. Tight leptons have stricter selections and lower backgrounds, looser leptons are less pure, and tracks are simply charged particles. The analysis was performed with 2 fb^{-1} of data.

Several standard model processes can mimic the trilepton signature with three leptons or two leptons and one isolated track. The leading background for the trilepton channels is from the leptonic decay of WZ , and ZZ production. The leading background for channels with a track is from Drell-Yan dilepton production accompanied by a bremsstrahlung photon conversion, a fake lepton or an isolated track from the underlying event. Other sources of background are WW , $t\bar{t}$, and for channels with a track W +jets production. Background estimates are calculated using both data and Monte Carlo simulations.

Backgrounds with an on-shell Z boson are removed by

¹ A multiplicative quantum number defined as $R_p = (-1)^{2s+3B+L}$.

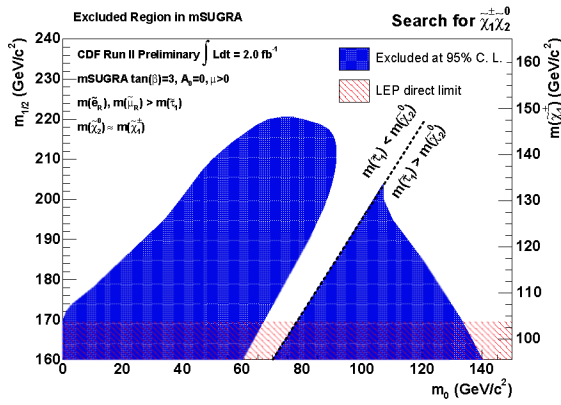


FIGURE 1. Figure shows the excluded region in mSUGRA parameter space from the CDF $\tilde{\chi}_1^\pm \tilde{\chi}_2^0$ search. The exclusion is presented in the m_0 - $m_{1/2}$ plane with other mSUGRA parameters fixed at $\tan\beta = 3$, $A_0 = 0$, and $\mu > 0$.

rejecting events if either opposite charge lepton-lepton² pair falls within 15 GeV/c^2 of the Z mass, i.e. 91 GeV/c^2 . The higher (lower) invariant mass of opposite charge lepton pairs is required to be above 20 (13) GeV/c^2 to remove Drell-Yan, and the J/Ψ , Υ resonances. The $\cancel{E}_T$ is required to be above 20 GeV, and the azimuthal angle between oppositely charged lepton-lepton (lepton-track) pairs is required to be < 2.9 (< 2.8) radians. The $t\bar{t}$ background is suppressed by rejecting events with more than one jet with $E_T > 15$ GeV.

The results are summarized in Table 1. In this table lepton refers to electrons or muons. No excesses over standard model predictions are observed.

The observations are used to constrain the mSUGRA model. An exclusion region is presented in Fig. 1 in the m_0 - $m_{1/2}$ plane. The other mSUGRA parameters are fixed as indicated in the Figure. The exclusion region is divided into a region dominated by the decay-through- W, Z of $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$ on the right and a region where the $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$ decay through an intermediate slepton. A line indicating equal mass of the $\tilde{\chi}_1^\pm$ and the $\tilde{\tau}_1$ is also indicated. To the immediate left of the line, the $\tilde{\chi}_2^0$ decay through a slepton leads to a lepton with momentum below analysis thresholds. The analysis acceptance drops as a result, and there is a gap in the exclusion region.

A cross-section $\times$ branching ratio limit is shown in Figure 2 by further fixing m_0 at 60 GeV/c^2 . This analysis improves the CDF published limits [1]. Charginos with mass below 145 GeV/c^2 are excluded. These are first direct limits on mSUGRA chargino mass from the Tevatron. Further details of this analysis can be found in Ref. [2].

² or lepton-track

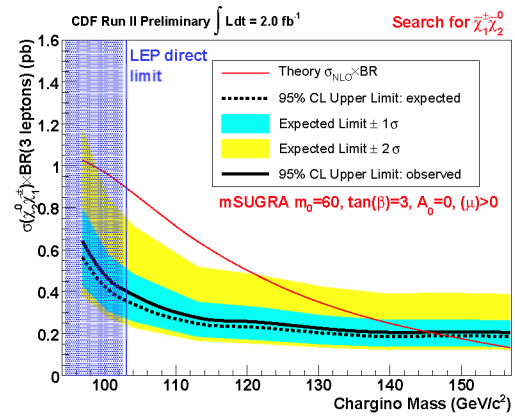


FIGURE 2. Figure shows the cross section $\times$ branching ratio limits from the CDF $\tilde{\chi}_1^\pm \tilde{\chi}_2^0$ search for the mSUGRA model. $\tilde{\chi}_1^\pm$ with mass below 145 GeV/c^2 is excluded.

TABLE 2. DØ results of a search for $\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \rightarrow lll + \cancel{E}_T$. The signal quoted is for mSUGRA-inspired model with parameters $m_0 = 88 - 121$ GeV/c^2 , $m_{1/2} = 182 - 221$ GeV/c^2 , $\tan(\beta)=3$, $A_0 = 0$, $\mu > 0$. The RunIIb analysis is a new analysis. T = isolated track.

Channel	Exp. Signal	Bkgd.	Data
eeT (RunIIb)	0.5-2.1	1.0 ± 0.3	0
eeT (RunIIa)	1.7-4.7	0.8 ± 0.7	0
$\mu\mu T$ (RunIIa)	0.5-2.5	$0.3 \pm_{0.3}^{1.3}$	2
$e\mu T$ (RunIIa)	2.0-2.6	0.9 ± 0.4	0
$\mu^\pm \mu^\pm$ (RunIIa)	0.6-3.8	1.1 ± 0.4	1

DØ ANALYSIS

DØ has added to their published result[3] an analysis which looks in the final state with two electrons and a track. The new eeT analysis is performed with integrated luminosity of 0.6 fb^{-1} and will be described here.

The backgrounds from standard model processes are similar to those for the CDF analysis. The backgrounds are reduced by imposing similar selections. The $\cancel{E}_T$ is required to be above 22 GeV to reduce Drell-Yan background. Events are rejected if the two electrons have an azimuthal separation greater than 2.9 radians. The invariant mass of the dielectron pair is required to be greater than 18 GeV/c^2 , and less than 60 GeV/c^2 . Events are required to have $\cancel{E}_T \times p_T > 200$ (GeV)². The sum of E_T 's of all jets in each event is required to be less than 80 GeV.

The results from previously published analyses and the new eeT analysis (labelled as RunIIb in the table) are summarized in Table 2 and the combined limit from all searches is shown for an ‘mSUGRA-inspired’ scenario in Figure 3. The mass conditions imposed on the superparti-

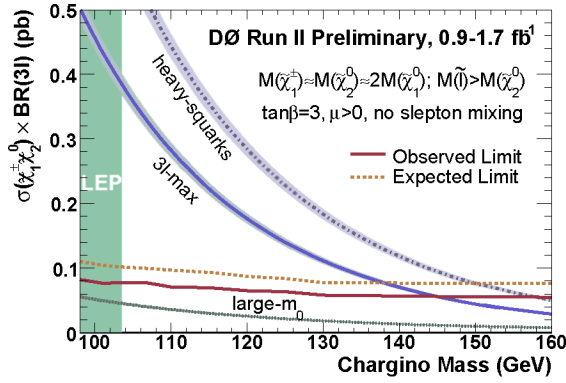


FIGURE 3. Figure shows the cross section $\times$ branching ratio limits from the DØ $\tilde{\chi}_1^\pm \tilde{\chi}_2^0$ search for an ‘mSUGRA-inspired model’. $\tilde{\chi}_1^\pm$ with mass below 145 GeV/ c^2 are excluded.

cles are indicated in the Figure. The analyses performed by DØ used between 0.9 and 1.7 fb⁻¹. Charginos with mass below 145 GeV/ c^2 are ruled out in this scenario.

CONCLUSIONS

CDF and DØ have performed searches for $\tilde{\chi}_1^\pm \tilde{\chi}_2^0$ production in the trilepton final state. CDF performs a unified search using 2 fb⁻¹ of data and presents an exclusion region in the m_0 - $m_{1/2}$ plane of mSUGRA. For a specific choice of mSUGRA parameters, $\tilde{\chi}_1^\pm$ ’s with mass less than 145 GeV/ c^2 are excluded. DØ adds a eeT final state to its published result which uses 0.6 fb⁻¹ of integrated luminosity. The eeT search is combined with previous searches and $\tilde{\chi}_1^\pm$ ’s with mass less than 145 GeV/ c^2 are excluded for a specific scenario in MSSM. Further information about CDF and DØ results can be found in Refs. [4] and [5]. With the improving Tevatron performance and optimal working of the two experiments, next year will push the boundaries of $\tilde{\chi}_1^\pm \tilde{\chi}_2^0$ searches even further.

REFERENCES

1. T. Aaltonen *et al.* (CDF Collaboration), Phys. Rev. Lett. **99**, 191806 (2007), and references therein.
2. S. Dube, “Search for super symmetry at the Tevatron using the trilepton signature,” FERMILAB-THESIS-2008-45.
3. V. Abazov *et al.* (DØ Collaboration), Phys. Rev. Lett. **95**, 151805 (2005).
4. CDF collaboration, <http://www-cdf.fnal.gov/physics/exotic/exotic.html>
5. DØ collaboration, <http://www-d0.fnal.gov/Run2Physics/WWW/results/np.htm>