Trilepton Searches for Chargino-Neutralino Production at the Tevatron

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The Tevatron Collider experiments, CDF and D0, have collected substantial data sets with which to probe for physics beyond the Standard Model. Two recent searches for trilepton events arising from supersymmetric $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production are presented. [1]

1 Introduction

In the search for new phenomena, one well-motivated extension to the Standard Model (SM) is supersymmetry (SUSY), which relates particles with different spin.[2] This theory introduces a new boson for each SM fermion and vice versa, and these SUSY particles (sparticles) contribute to the Higgs mass squared with opposite sign relative to the contributions of SM particles, and thus protect the weak mass scale, M_W, from divergences. SUSY is a broken symmetry since the sparticles obviously do not have the same mass as their SM partners, but the breaking must be 'soft' to allow the divergence canceling to remain effective. If R_p parity is conserved[a], the lightest SUSY particle (LSP) is absolutely stable and provides a viable candidate for cosmological dark matter.

One of the promising modes for SUSY detection at hadron colliders is that of chargino-neutralino associated production with decay into a trilepton signature. Charginos decay into a single lepton through a slepton ($\tilde{\chi}_1^{\pm} \to \tilde{l}^{(*)}\ \nu_l \to \tilde{\chi}_1^0\ l\ \nu_l$) and neutralinos similarly decay to two detectable leptons ($\tilde{\chi}_2^0 \to \tilde{l}^{\pm(*)}\ l^{\mp} \to \tilde{\chi}_1^0\ l^{\pm}\ l^{\mp}$).[b] The detector signature is then three SM leptons with associated missing energy from the undetected neutrinos and lightest neutralinos, $\tilde{\chi}_1^0$ (LSP), in the event. Due to its electroweak production, this is one of the few 'jet-free' SUSY signatures.

We present recent results in the search for supersymmetry at the Tevatron, assuming associated production of charginos and neutralinos with decays to trileptons.

2 CDF Search for Chargino-Neutralino production

CDF performs a trileptons search using 2/fb of data and 5 exclusive channels. Three of the channels correspond to 'trilepton' signals with different requirements on the first, second, and third lepton (electrons and/or muons, with stringent or relaxed cuts). The p_T or E_T requirements vary between 20 GeV and 5 GeV depending on the lepton and channel. To increase acceptance for the analysis, two additional channels are included. These 'dilepton plus track' modes add acceptance for hadronic tau decays by allowing the third lepton to be identified as an isolated track.

[a] $R_p = (-1)^{3B+L+2S}$, where B is baryon number, L is lepton number, and S is spin.
[b] The decays can also proceed via W and Z bosons.

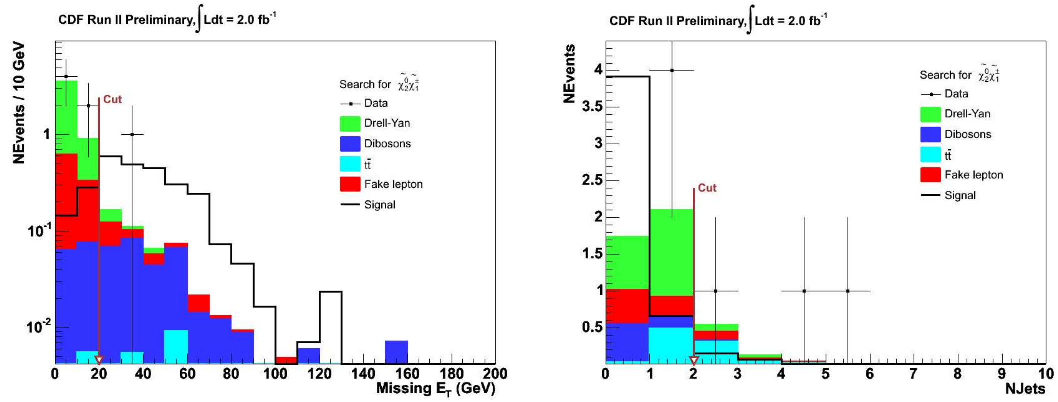

Figure 1: CDF trilepton distributions for SM backgrounds, SUSY signal, and data.

Before examining the data, control regions are defined. These are tested both at the dilepton and trilepton (or dilepton plus track) levels. Distributions and event counts are in good agreement for regions of leading dilepton invariant mass in the Z peak region for high missing E_T, $\not\!\!E_T > 15$ GeV, and for all dilepton masses for $\not\!\!E_T < 10$ GeV. Signal sensitivity is expected in the complementary kinematic regions: high $\not\!\!E_T$ either below or above the Z mass peak.

Event level requirements further enhance the sensitivity by reducing SM backgrounds. Two opposite-sign (OS) pairs are required among the three leptons, and the maximum OS invariant mass must exceed 20 GeV, while the minimum OS invariant mass must exceed 13 GeV. The OS pairs must not include back-to-back leptons or invariant masses in the Z peak window. The event $\not\!\!E_T$ is required to be greater than 20 GeV. This reduces Z plus jets and ZZ background. Events with more than one jet are removed, and $E_T(j) < 80$ GeV is required to reject the t-tbar background.

Resulting distributions at the trilepton level are shown in Fig. 1. The SUSY signal corresponds to the mSUGRA parameter choice: $m_0 = 60$ GeV; $m_{1/2} = 190$ GeV; $\tan\beta = 3$; $A_0 = 0$; and $\mu > 0$. After the event level selection, one event remains in the trilepton channels whereas 0.9 events are expected from SM sources and 4.5 events are expected in the signal. For the dilepton plus track channels, 6 events are observed, with a SM background expectation of 5.5 events and 6.9 events expected in the signal.

Given the good agreement between the data and the SM expectations, cross section times branching ratio upper limits are derived. The result is shown as a function of chargino mass in Fig. 2. The maximum sensitivity is reached for heavy charginos with an upper limit of 200 fb. Comparing with theoretical cross section expectations, a chargino lower mass limit of 140 GeV is obtained.

3 D0 Search for Chargino-Neutralino production

Probing the electron-electron-lepton signature, D0 uses 590/pb of integrated luminosity to search for $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ production. Here, the 'lepton' is identified as an isolated track. Results

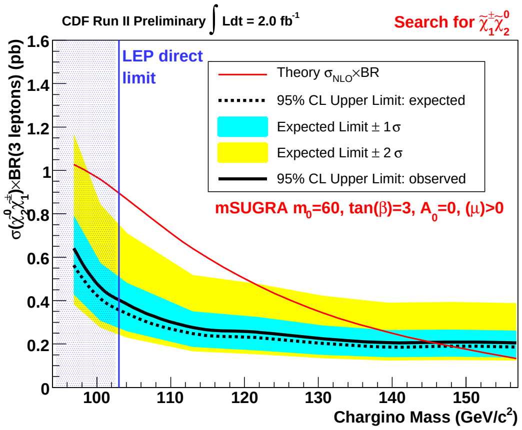

Figure 2: CDF cross section times branching ratio upper limit as a function of chargino mass.

from this analysis are then combined with 4 other channels from previous searches: electron-electron-lepton, like-sign (LS) muons, muon-muon-lepton, and electron-muon-lepton. Each includes 1/fb of integrated luminosity; the results are summarized in Table 1.

channel	signal	background	obs.
$ee + trk$	1.7-4.7	0.8 ± 0.7	0
$\mu\mu + trk$	0.5-2.5	$0.3\pm^{1.3}_{0.3}$	2
$e\mu + trk$	2.0 - 2.6	0.9 ± 0.4	0
LS $\mu\mu$	0.6-3.8	1.1 ± 0.4	1

Table 1: D0 previous searches for trileptons.

The data reduction for the present search is performed in three main stages. First, a dilepton sample is selected. Electrons satisfying $p_T(e_1) > 12$ GeV, $p_T(e_2) > 8$ GeV, with high electron likelihoods, based on tracking and calorimeter information, are kept. The $\not\!\!E_T$ for the dilepton selection is shown for SM backgrounds, signal, and data in Fig. 3. The SUSY signal corresponds to the mSUGRA parameter choice: $m_0 = 98$ GeV; $m_{1/2} = 192$ GeV; $\tan\beta = 3$; $A_0 = 0$; and $\mu > 0$. This sample is purified by removing dielectron invariant masses in the Z peak window and above, as well as back-to-back electron pairs. Top quark backgrounds are reduced by requiring the scalar sum of transverse energies and $\not\!\!E_T$ be small: $H_T < 80$ GeV.

At this point, an additional track with $p_T > 4$ GeV, and isolated from other tracking or calorimeter activity, is required. This selection significantly reduces backgrounds while keeping acceptance for hadronically decaying taus. Event level cuts are applied to further reduce contributions from SM backgrounds. As the SUSY signal is expected to result in appreciable $\not\!\!E_T$, events are required to have $\not\!\!E_T > 22$ GeV. Additional cuts are imposed to reduce remaining W and Z production by examining the transverse mass of the first electron and $\not\!\!E_T$ and the invariant mass of each of the first two electrons with the isolated track. Remaining $Z \to ee$ and QCD multijet events are suppressed by requiring that $\not\!\!E_T \times p_T^{trk} > 220$ GeV^2, as shown in Fig. 3.

The data are then analyzed for the SUSY trilepton signal. Zero events are observed

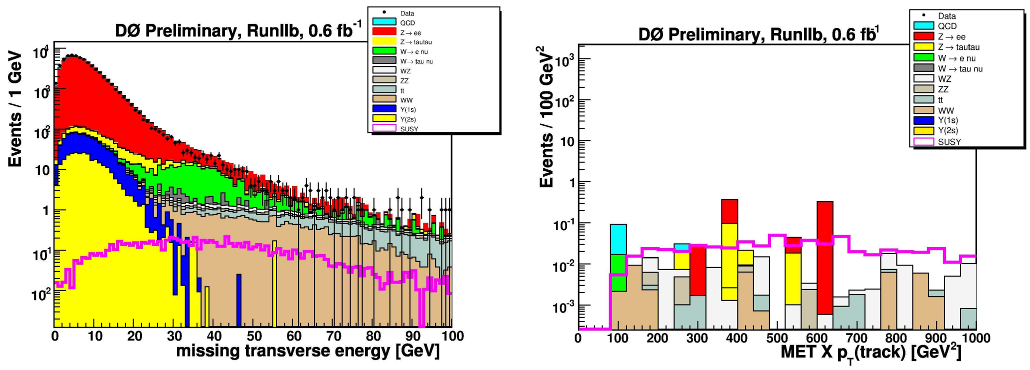

Figure 3: D0 (L) Dilepton selection $\not{E}_T$ for SM backgrounds, SUSY signal, and data. (R) $\not{E}_T \times p_T^{trk}$ after $\not{E}_T$ requirements.

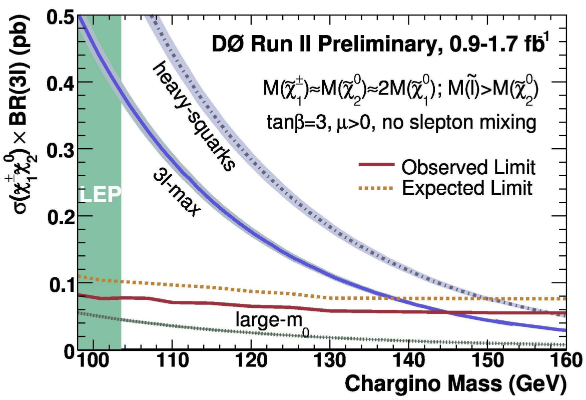

Figure 4: D0 combined analysis cross section times branching ratio upper limit as a function of chargino mass.

to pass the full selection, while 1.0 events are expected from SM sources and 1.4 events are expected for the nominal SUSY point. Thus, limits are derived by combining with the 4 previous searches described above, and the combined results are shown in Fig. 4 for an mSUGRA inspired model with no slepton mixing. For slepton masses similar to the $\tilde{\chi}_2^0$ mass, the decay rate to leptons is maximal. This is '3l-max'. The $\tilde{\chi}_1^\pm \tilde{\chi}_2^0$ production cross section includes a squark-exchange diagram, which for heavy squarks, maximizes the production. The upper limit is 80/fb; for 3l-max, this corresponds to a chargino mass limit of 145 GeV.

References

[1] Slides:
`http://indico.cern.ch/contributionDisplay.py?contribId=74&sessionId=15&confId=24657`

[2] For a phenomenological introduction to SUSY, see S.P. Martin, A Supersymmetry Primer, arXiv:hep-ph/9709356v4, (2006).