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Searches for Associated Production of Chargino-Neutralino Pair in a Di-electron + Track Channel

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Abstract

We search for Chargino-Neutralino production in a di-electron + track channel using 1.01 fb^{-1} of data collected by the CDF II detector. The electrons and tracks are identified to as low as 4 GeV/c in P_T to improve the acceptance. We observe 3 events and we expect 0.97 ± 0.28 event from standard model backgrounds.

Preliminary results

1 Introduction

Supersymmetry (SUSY) [1] theory incorporates an additional symmetry between fermions and bosons beyond the Standard Model (SM). It offers a solution to the fine-tuning problem and a possible mechanism for electroweak symmetry breaking (EWSB). Different SUSY breaking mechanisms give different SUSY signatures. In this analysis, we focus our study on the extensively-studied mSUGRA model [3], in which gravity communicates the origins of SUSY breaking from a high mass scale ($\approx 10^{16}$ GeV) to the electroweak scale, and that grand unification at the grand unification theory (GUT) [4] scale is assumed. With R-parity conservation, mSUGRA can be completely characterized by 4 parameters and a sign: a common scalar mass (m_0), a common gaugino mass ($m_{1/2}$), a common trilinear coupling value (A_0), the ratio of the vacuum expectation values of the two Higgs doublets (tanβ), and the sign of μ, where μ is the Higgsino mass parameter.

One of the most striking signatures of mSUGRA is the production and decay of $\widetilde{\chi}_1^{\pm}\widetilde{\chi}_2^0 \longrightarrow$ three leptons plus imbalance in the energy in the detector (missing transverse energy or $\not\!\!E_T$). This imbalance is due to the escape of undetectable particles such as neutrinos and $\widetilde{\chi}_1^0$ from the detector. This signature offers a reasonable $\sigma \times BR$ and there is very small contribution from SM backgrounds.

The current world limit on the mass of $\widetilde{\chi}_1^{\pm}(M_{\chi_1^{\pm}})$ is 103.5 GeV [5]. The most recent DZero tri-lepton search [6] increased that limit to 117 GeV in the parameter space where the leptonic branching fractions of $\widetilde{\chi}_2^0$ and $\widetilde{\chi}_1^{\pm}$ are enhanced. The mass limits for the LSP ($M_{\chi_1^0}$ in mSUGRA) are 59.0 GeV for $\mu > 0$ and 58.6 GeV for $\mu < 0$ [5].

In this analysis, we search for events with two electrons and an isolated track, where the track can come from leptons (electron,muon) or tau hadronic decays. We also require $\not\!\!E_T$ in the event to reduce dominant SM backgrounds.

2 Data and Initial Event Selection

This analysis is carried out in a statistically unbiased way using an integrated luminosity of 1.01 fb^{-1} of data collected by the CDF detector [7] between March 2002 and September 2005. The data were collected with a di-electron trigger which has an identical 4 GeV threshold for both electrons. The trigger efficiency for each electron is $96.3 \pm 0.2\%$.

For each event two isolated electrons which pass restrictive identification requirements are selected with E_T> 15 and 5 GeV respectively. The electron identification efficiency is about 80% in most of the region ($E_T^{ele} > 5$ GeV) of interest. We also require an isolated track with $p_T > 4$ GeV. The track isolation is evaluated based on nearby track activity.

We next define controlled regions which are dominated by SM background and test our predictions. After a complete validation of these controlled regions, we look at the signal-dominated (or signal) region in data. Figure 1 shows an example of such validation in the dielectron sample. The data is in good agreement with the background prediction. We note that a previous analysis was based on a subset (607 pb^{-1}) of present dataset (1.01 fb^{-1}).

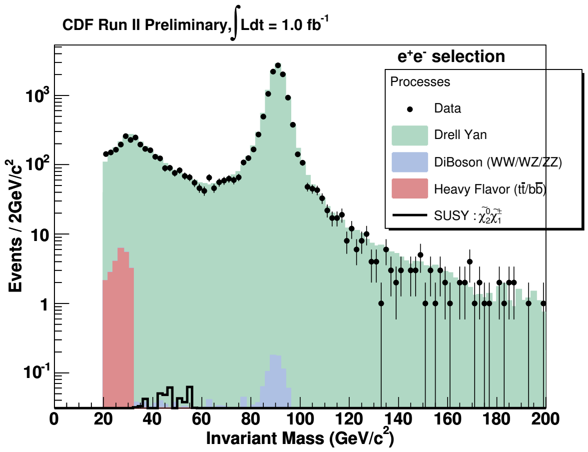

Figure 1: Invariant Mass of the two highest E_T electrons for events where the $\not\!\!E_T < 10$ GeV.

3 Backgrounds in Di-electron + Track selection

The dominant SM backgrounds are from Drell-Yan+track, WW+track, $ZZ/Z\gamma$, $WZ/W\gamma$, and $t\bar{t}$ production. All but the first two background sources may produce genuine tri-lepton final states.

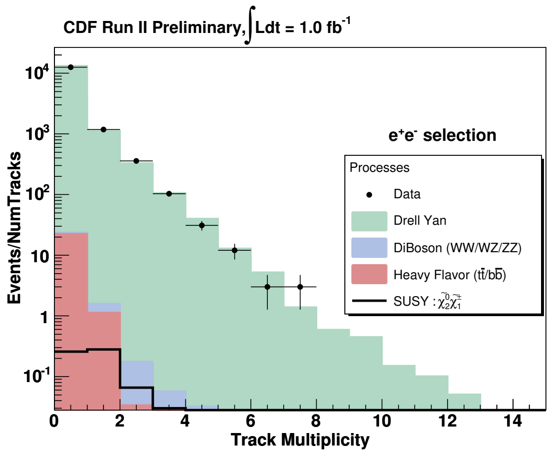

Figure 2: Track multiplicity for dielectron events where the $\not\!\!E_T < 10$ GeV.

3.1 Isolated Track Rate

We measure the background due to non-leptonic track using $Z \to ee, \mu\mu$ events. In the mass window of $|M_{ll} - 91| < 15$ GeV and with a requirement of $\not\!\!E_T < 10$ GeV, we calculate the ratio of number of events with at least one isolated track to total number of Z events. The ratio is the isolated track rate (ITR), which represents the fraction of di-lepton events which have at least one isolated track. We parametrize this ratio as a function of event track multiplicity. Figure 2 shows the distribution of event track multiplicity for all backgrounds and data. The background histograms are stacked. The track multiplicity is defined as number of good (passing certain requirements, except isolation) tracks, excluding the two tracks which form the invariant mass.

Two control regions are designed to test the measured ITR. We require $\not\!\!E_T < 10$ GeV for control region I and $\not\!\!E_T > 15$ GeV and $76 < M_{ee} < 106$ GeV for control region II. We test that the measured ITR in low-$\not\!\!E_T$ Z events can be universally applied to Drell-Yan events with lower mass or higher $\not\!\!E_T$. The results for these control regions are summarized in Table 1. From the comparison we conclude that the measured ITR can be applied to all regions for the backgrounds.

Selection	Expected	Observed
$\not\!\!E_T < 10$	189 ± 18	136
$\not\!\!E_T > 15$ GeV,$76 < M_{ee} < 106$ GeV	16.8 ± 1.9	16

Table 1: Expected and observed number of events in two control regions designed to test measured ITR. The uncertainties quoted here are derived from contributions from MC statistics, and systematic uncertainties due to ITR measurement, electron identification and trigger efficiencies.

3.2 Calculation of Backgrounds

Large MC background samples are generated for this analysis. The $WZ/W\gamma$ background sample is generated using MadGraph [9]. All other samples are generated using PYTHIA. For each background, the cross-section is taken either from the next-to-leading order calculation ($WZ/W\gamma$ [9], $ZZ/Z\gamma$ [10], WW [10], Drell-Yan [8]) or from measurements made at CDF RunII ($t\bar{t}$ [13]). We apply the ITR to the samples when only two electrons satisfying our initial selection requirement (see Section 2) are found. MC events can also have an isolated track satisfying our initial selection requirement. In that case, the event is kept to go through further event kinematic cuts (see Section 4).

4 Advanced Cuts

The benchmark mSUGRA point is at: m_0 = 60 GeV, $m_{1/2}$ = 190 GeV, tan(β)=5, A_0 =0, and μ >0. The corresponding masses of interest are: $M_{\chi_1^\pm}$ = 119.6 GeV, $M_{\chi_2^0}$ = 122 GeV, and $M_{\chi_1^0}$ = 67 GeV. and the corresponding $\tilde{\chi}_1^\pm \tilde{\chi}_2^0$ production cross section is 0.327 pb [14]

Since the three leptons in the signal event cannot be of the same sign, we require $|\Sigma Q_i| = 1$ where Q_i is the charge of the i^{th} lepton. We also require that the two massed formed by the opposite-sign lepton pairs be above 20 GeV to remove J/Ψ, and Υ events. To further reduce backgounds, we apply the following selections:

- $\Delta\phi_{e_1e_2} < 2.8$ radians. Leptons in the SUSY event are not as in back-to-back as the Drell-Yan events.

- $\Sigma E_T^{jets} < 80$ GeV. ΣE_T^{jets} is defined as the sum of E_T of all jets (with $E_T > 20$ GeV) in the event. Jets from $\widetilde{\chi}_1^{\pm}\widetilde{\chi}_2^0 \longrightarrow 3l$ process are mostly from initial state radiation (ISR) which contributes little to ΣE_T as compared to $t\bar{t}$ events.

- $M_{os}^1 < 76$ or $M_{os}^1 > 106$ GeV to reject Z events. This is the larger of the two opposite sign pair masses.

- $M_{os}^2 < 60$ GeV. This is the smaller of the two opposite sign pair masses. For mSUGRA model, the mass of $\widetilde{\chi}_1^{\pm}$ and $\widetilde{\chi}_2^0$ is about twice as large as the LSP. For the signal point under study, the LSP mass is 67 GeV. This means that for a $\widetilde{\chi}_2^0$ to decay to LSP and two electrons, the dielectron mass is limited to about 55 GeV. This is not the case for W/γ^*, and ZZ events.

- $\not\!\!E_T > 20$ GeV. Signal events tend to have higher $\not\!\!E_T$ than Drell-Yan background due to the undetected neutrals.

- Minimum transverse mass $(M_T^{min}) > 10$ GeV. This is the smallest transverse mass formed by the 3 leptons and the $\not\!\!E_T$. The signal point and $\not\!\!E_T$ are more separated than the Drell-Yan background.

We show the $\not\!\!E_T$ distribution after all selection requirements except $\not\!\!E_T$ in Figure 3 . Similarly the M_T^{min} distribution is shown in Figure 4. We see that the $\not\!\!E_T$ and M_T^{min} selections effectively reduce the Drell-Yan background.

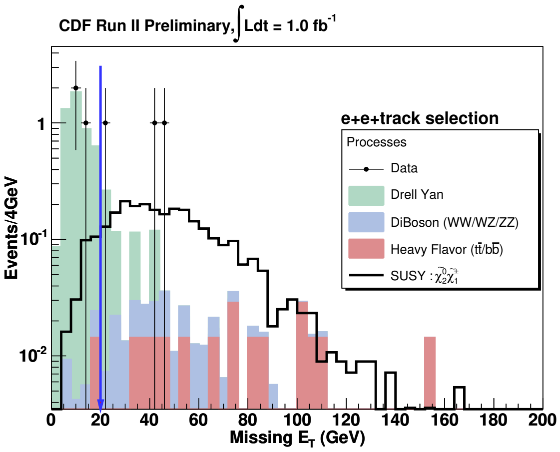

Figure 3: $\not\!\!E_T$ distribution for all background and signal dielectron+track events where all selection requirements except $\not\!\!E_T$ have been applied. We reject events with $\not\!\!E_T < 20$ GeV

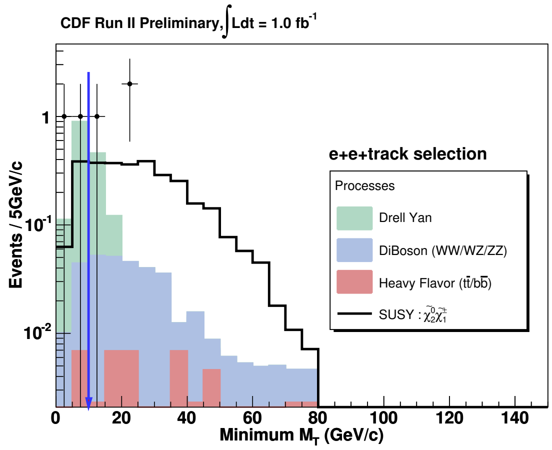

Figure 4: M_T^{min} distribution for all background and signal dielectron+track events where all selection requirements except M_T^{min} have been applied (see text for definition of M_T^{min}). We reject events with M_T^{min} < 10 GeV

5 Results

Using the selections described in Section 4, the expected number of signal and background events are shown in Table 2. The uncertainties are derived from contributions due to MC statistics and all systematics: uncertainties in ITR, electron identification and trigger efficiencies, jet energy scale correction, process cross section, parton distribution function (PDF), initial state radiation (ISR), final state radiation (FSR).

Signal	$2.1 \pm 0.05(stat) \pm 0.13(syst)$
DY	$0.54 \pm 0.22(stat) \pm 0.13(syst)$
$WW + ZZ$	$0.13 \pm 0.01(stat) \pm 0.02(syst)$
$W/Z\gamma*$	$0.081 \pm 0.0005(stat) \pm 0.018(syst)$
$t\bar{t}$	$0.22 \pm 0.05(stat) \pm 0.1(syst)$
Total Bkgd	$0.97 \pm 0.22(stat) \pm 0.18(syst)$
Data	3

Table 2: Expected number of signal and background events and observed number of events in data in the optimized signal region for the complete datset. The error includes statistical and all systematic uncertainties. (Signal corresponds to $m_0 = 60$, $m_{1/2} = 190$, $A_0 = 0$, tan(β)=3, $\mu > 0$)

6 Conclusion

We have searched for $\widetilde{\chi}_1^{\pm}\widetilde{\chi}_2^0$ pair production in the final state of two electrons and a track using 1.01 fb^{-1} of $p\overline{p}$ data. The expected SM background is 0.97 ± 0.28 events and contribution from signal is 2.1 ± 0.14 events (if it exists with parameters $m_0 = 60$, $m_{1/2} = 190$, $A_0 = 0$, $\tan(\beta)$=3, $\mu > 0$). We observe 3 events. This is consistent with the SM prediction and we see no evidence of chargino-neutralino production.

7 Acknowledgments

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[14] We use Isajet v7.69 input to Pythia to generate signal Monte-Carlo samples. Isajet is expected to better estimate the mass spectrum of supersymmetric particles than Pythia, however cascade decays of particles are better estimated in Pythia. 4