CDF Note xxxx

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

The CDF Collaboration
April 23, 2005

Abstract

We present in this note the analyses to search for Chargino-Neutralino production in mSUGRA Model in a di-electron + track channel at CDF Run2. The search assumes R-parity conservation. A key feature of this analysis is that its p_T reach is as low as 4 GeV which results in higher acceptance. We expect 0.36 ± 0.27 background events in 224 pb^{-1} of data and we observe 2 events.

preliminary results

1 Introduction

Supersymmetry (SUSY) [1] theory incorporates an additional symmetry between fermions and bosons beyond what are already in the Standard Model (SM). It offers a solution to the fine-tuning problem and a possible mechanism for 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 at the GUT scale: 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 ($\tan\beta$), and the sign of μ, where μ is the Higgsino mass parameter.

One of the most striking signature of mSUGRA is the production and decay of $\widetilde{\chi}_2^0\widetilde{\chi}_1^\pm \rightarrow$ three leptons plus $\not\!\!E_T$. It offers a reasonable signal $\sigma \times BR$ and there is very small contributions from Standard Model backgrounds. In this analysis, we search for events with two electrons and an isolated track, where the track can come from leptons or tau hadronic decays in the signal. We also require $\not\!\!E_T$ in the event to remove the dominant SM backgrounds.

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

2 Data and Initial Event Selection

This analysis uses an integrated luminosity of 224 pb^{-1} of data collected by the CDF [7] detector between March 2002 and February 2004. The data were collected with a di-electron trigger which has an identical 4 GeV threshould for both electrons. The trigger efficiency for each electron is $95.6 \pm 4.1\%$.

For each event two isolated electrons which pass restrictive idenfication requirement are selected with $E_T > 10$ and 5 GeV, respectively. The electron identification efficiency is about 80% in most of the region ($E_T^e > 5$ GeV) of interest. We also require an isolated track with $p_T > 4$ GeV. The track isolation is evalulated based on the nearby track activity.

The analysis is conducted “blind” from the signal region initially and we look into the signal region only when background dominant control regions are understood.

3 Backgrounds

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

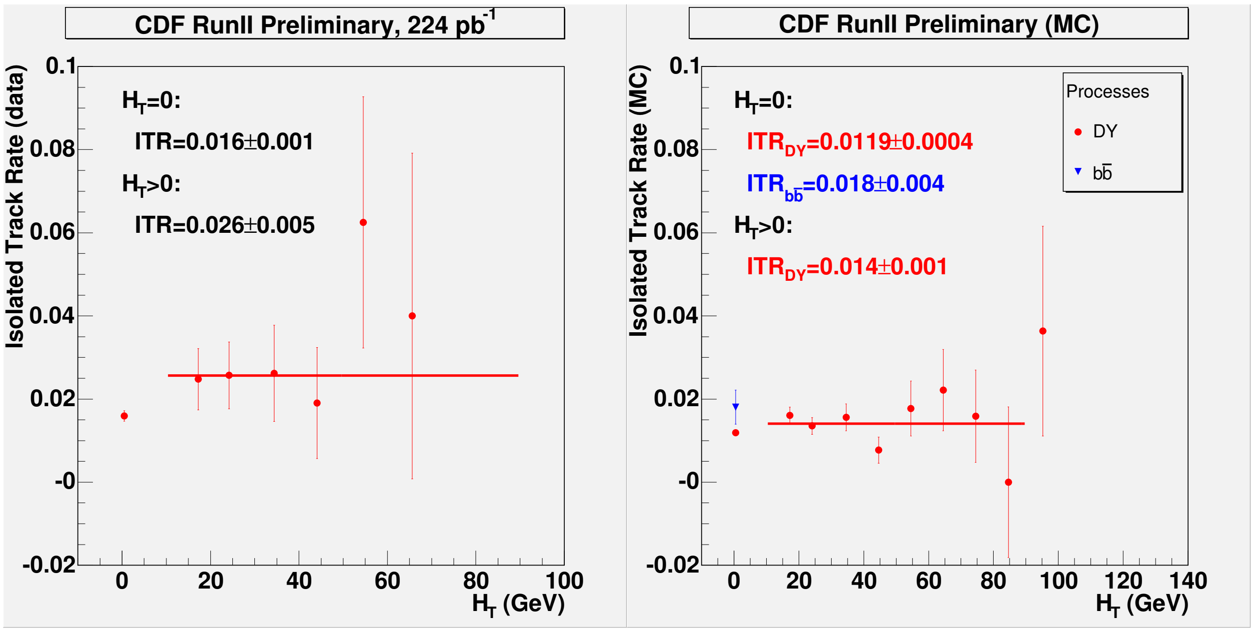

Figure 1: Left: the ITR measured in the Z data; right: the ITR in Drell-Yan and $b\bar{b}$ MC.

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 $|M_{ll} - M_Z| < 10$ GeV and with a cut of $\not\!\!E_T < 10$ GeV, we calculate the ratio of the number of events with at least one isolated tracks and 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 parameterize this ratio as a function of the event H_T, which is the scalar sum of jet E_T's, where the jets are required to have $E_T > 15$ GeV themselves. Figure 1 shows the ITR in both data and Monte-Carlo (MC). Two constants 0.016 ± 0.001 and 0.026 ± 0.005 are used for di-lepton events with $H_T < 15$ GeV and $H_T > 15$ GeV, respectively. The constant parametrization with $H_T > 15$ GeV is supported by MC. It is expected that $b\bar{b}/c\bar{c}$ events may have higher ITR than that in Drell-Yan events. We therefore scale the measured ITR in data Z events by a factor which equals to the ratio of MC ITR between $b\bar{b}$ and Drell-Yan (only between the points at $H_T < 15$ GeV due to MC statistics) and apply it for the estimation of $b\bar{b}/c\bar{c}$ backgrounds.

Two control regions are designed to test the correctness of the measured ITR. In addition to the initial selection as described in Section 2, we require $\not\!\!E_T < 10$ GeV for control region I and $\not\!\!E_T > 10$ GeV and $76 < M_{ee} < 106$ GeV for control region II. We test that the measure ITR in low-$\not\!\!E_T$ Z events can be universally applied to Drell-Yan events with lower mass or high $\not\!\!E_T$. Figure 2 shows the H_T distributions in control regions I and II. In control region I, we expect 51.5 ± 6.6[1]

[1] The uncertainties quoted in the number of expected events in this section are derived from contributions from MC statistics and systematic uncertainties due to ITR measurement, electron ID and trigger efficiencies.

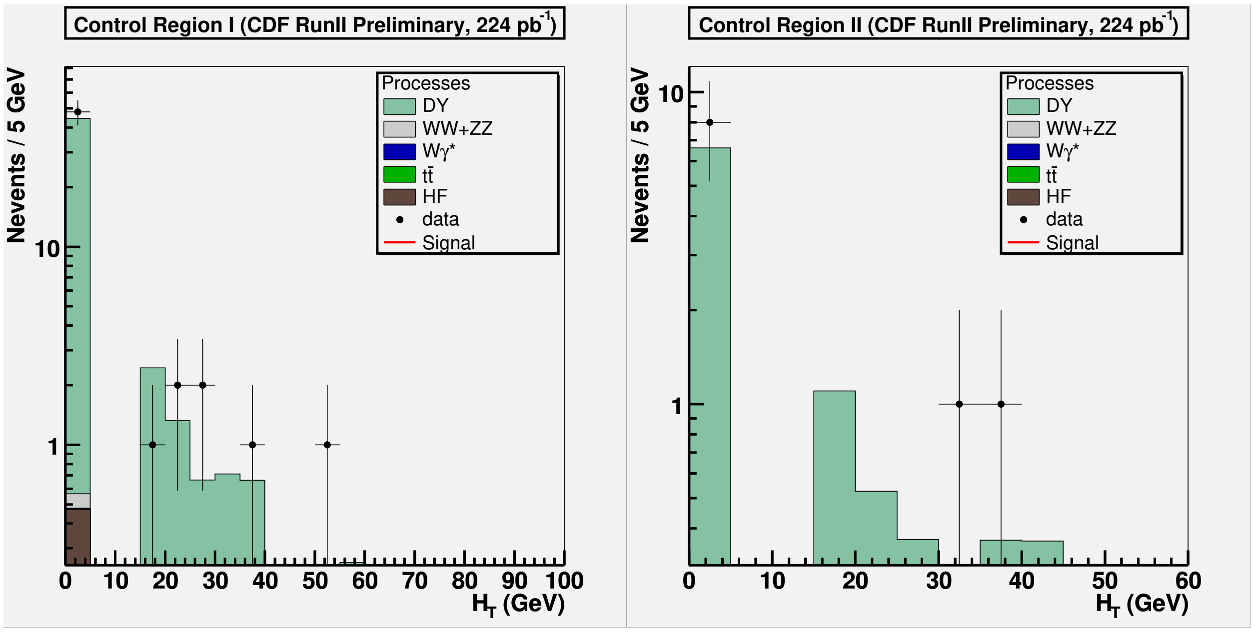

Figure 2: H_T distributions in control region I (left) and II (right).

(50.9 ± 6.6 from Drell-Yan[2]) events and we observe 55 events in data. In control region II, we expect 10.3 ± 1.4 (10.0 ± 1.4 from Drell-Yan) event and we observe 10 events in data. From the comparison we conclude that the measured ITR can be applied to all regions for the backgrounds.

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 either taken from the next-to-leading order calculation ($WZ/W\gamma$ [9], $ZZ/Z\gamma$ [10], WW [10], $t\bar{t}$ [11]) or from direct measurement in data (Drell-Yan, $b\bar{b}/c\bar{c}$). 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 signal sample we use as a bench mark is generated with the following parameters: $m_0 = 100$ GeV, $m_{1/2} = 180$ GeV, $tan(\beta) = 5$, $A_0 = 0$, and $\mu > 0$. The corresponding mass of interest

[2] a correction factor of 1.34 ± 0.02 measured from Drell-Yan data is multiplied to the PYTHIA [8] Drell-Yan cross section to obtain this number.

are: $m_{\widetilde{\chi}_1^\pm} = 113$ GeV and $m_{\widetilde{\chi}_1^0} = 66$ GeV. The cross section: 0.642 pb is calculated with a next-to-leading order program: PROSPINO [12].

Since the three leptons in the signal events cannot be of the same sign, we require $|\sum$ lepton charge$| = 1$. We also require that the two pairs masses formed by the opposite-sign leptons be above 15 GeV to remove υ events. To further reduce backgrounds, we apply the following advanced cuts:

- $\Delta\phi_{ele12} < 2.9$. Leptons in SUSY event are not as back-to-back as the Drell-Yan events (which is the dominant background).
- $H_T < 80$ GeV. Jets from $\widetilde{\chi}_1^\pm\widetilde{\chi}_2^0 \rightarrow 3l$ process mostly come from initial state radiation (ISR) which contributes little to H_T compared with $t\bar{t}$ events.
- $\not{E}_T > 15$ GeV. Signal events tend to have higher $\not{E}_T$ than Drell-Yan background due to the undetected neutrals.
- M_OS_1 < 76 GeV or M_OS_1 > 106 GeV to reject the Z events.
- M_OS_2 < 60 GeV. 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 66 GeV. This means that for a $\widetilde{\chi}_2^0$ decay to LSP and two electrons, the dielectron mass is limited to about 66 GeV. This is not the case for $W\gamma*$ and ZZ events.
- $\min(M_T) > 10$ GeV. This is the smallest transverse mass formed by the 3 leptons and the $\not{E}_T$. The signal lepton and $\not{E}_T$ are more separated than the Drell-Yan background.

5 Results

Using the cuts described in Section 4, the expected number of signal and background events are shown in Table 1 shows the expected number of signal. The uncertainties are derived from contributions due to MC statistics and all systematics, including uncertainties in ITR, electron ID and trigger efficiencies, jet energy scale correction, process cross section, parton distribution functions (PDF), ISR, final state radiation (FSR), and simulation of extra minimum-bias interactions. We observe 2 data events. Figure 3 shows the $\not{E}_T$ distribution for the signal, background, and the observed data after all advanced cuts but the $\not{E}_T$ cut.

6 Conclusion

We conducted a search for SUSY (mSUGRA) production of $\widetilde{\chi}_1^\pm$-$\widetilde{\chi}_2^0$pair production decaying into 3 leptons in the final state of two electrons and a track. We expect 0.36 ± 0.27 SM background events and 0.480 ± 0.66 signal events (if it exists). We observe 2 events. The existence of SUSY is therefore not conclusive with the statistices we have.

CDF teams are carrying out three other parallel "trilepton" searches. One search is in ee+lepton, where the leading electron must satisfy $E_T > 20$ GeV. The other two use $\mu\mu$+lepton

Sample	Nevents
Signal	0.480 ± 0.066
Drell-Yan	0.25 ± 0.17
$WW + ZZ/Z\gamma$	0.062 ± 0.023
$WZ/W\gamma$	0.032 ± 0.005
$t\bar{t}$	0.010 ± 0.007
HF	0 ± 0.21
Total Bkgd	0.36 ± 0.27
Data	2

Table 1: Expected number of signal and background events and observed number of events in 224 pb^{-1} of data after all cuts. The uncertainty includes statistical and all systematic uncertainties.

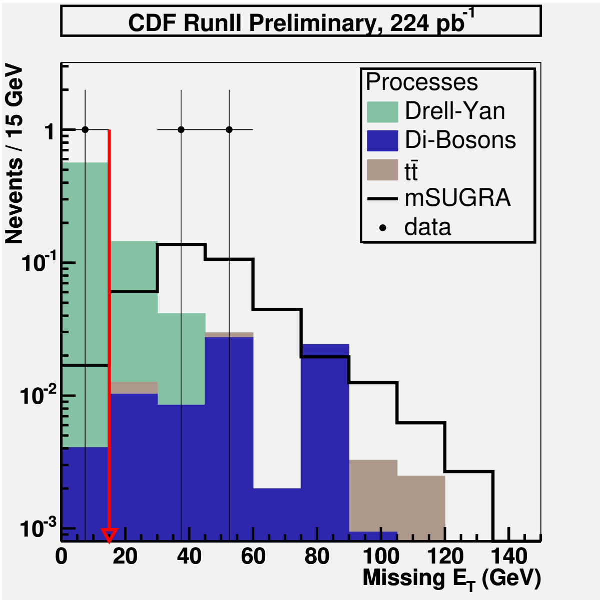

Figure 3: $\not\!\!E_T$ distributions for signal, data, and the observed data events.

channels but differ on whether the leading muon has $p_T > 20$ GeV or not. We exect the combined result to yield much more information than single analysis alone.

7 Acknowledgement

We thank the Fermilab staff and the technical staffs of the participating institutions for their vital contributions. This work was supported by the U.S. Department of Energy and National Science Foundation; the Italian Istituto Nazionale di Fisica Nucleare; the Ministry of Education, Culture, Sports, Science and Technology of Japan; the Natural Sciences and Engineering Research Council of Canada; the National Science Council of the Republic of China; the Swiss National Science Foundation; the A.P. Sloan Foundation; the Bundesministerium fuer Bildung und Forschung, Germany; the Korean Science and Engineering Foundation and the Korean Research Foundation; the Particle Physics and Astronomy Research Council and the Royal Society, UK; the Russian Foundation for Basic Research; the Comision Interministerial de Ciencia y Tecnologia, Spain; in part by the European Community's Human Potential Programme under contract HPRN-CT-2002-00292; and the Academy of Finland.

References

[1] For a review, see e.g., H. Haber and G. Kane, Phys. Rept. **117**, 75 (1985). 1

[2] V. Barger, C. E. M. Wagner, *et al.*, "Report of the SUGRA Working Group for Run II of the Tevatron", hep-ph/0003154.

[3] H. Baer, C. Chen, F. Paige, and X. Tata, Phys. Rev. D **54** (1996) 5866; *op. cit.* **53** (1996) 6241; *op.cit.* **D52** (1995) 1565; **52** (1995) 2746; M. Machacek and M. Vaughn, Nucl. Phys. B **222** (1983) 83; C. Ford, D. Jones, P. Stephenson, and M. Einhorn, Nucl. Phys. B **395** (1993) 17. 1

[4] J. Ellis, S. Kelley, and D. Nanopoulos, Phys. Lett. B **260** (1991)131; P. Langacker and M. Luo, Phys. Rev. D **44** (1991) 817; U. Amaldi, W. deBoer, and H. Furstenau, Phys. Lett. B **260**(1991) 447; M. Carena, S. Pokorski, and C. Wagner, Nucl. Phys. B **406** (1993) 59; P. Langacker and N. Polonsky, Phys. Rev. D **47** (1993) 4028. 1

[5] http://lepsusy.web.cern.ch/lepsusy/ 1

[6] V. M. Abazov, *et al.*, "Search for Supersymmetry via Associated Production of Charginos and Neutralinos in Final States with Three Leptons", FERMILAB-PUB-05/075-E, hep-ex/0504032. 1

[7] The CDF II Detector Technical Design Report, Fermilab-Pub-96/390-E, 1996. 1

[8] T. Sjöstrand, P. Edén, C. Friberg, L. Lönnblad, G. Miu, S. Mrenna and E. Norrbin, Computer Physics Commun. **135** (2001) 238 3

[9] F. Maltoni and T. Stelzer, hep-ph/0208156; T. Stelzer and W. F . Long, Phys. Commun. **81** (1994) 357-371. 3

[10] J. M. Campbell and R. K. Ellis; next-to-leading-order calculation using MCFM version 3.4.5. Phys. Rev. D **60** (1999) 113006. 3

[11] M. Cacciari, S. Frixione, G. Fidolfi, M. Mangano and P. Nason, JHEP **404**(2004) 68. 3

[12] W. Beenakker, *et al.*, "The Production of Chargions/Neutralinos and Sleptons at Hadron Colliders", Phys. Rev. Lett. **83** (1999) 3780-3783. 4