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CDF Public Note

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We present a search for Supersymmetry in final states with two electrons and a third lepton. This signature is the golden mode to look for associated production of chargino and neutralino in Supersymmetry. This search uses 346 pb^{-1} of data collected with the CDF experiment at the $p\bar{p}$ Tevatron collider at $\sqrt{s}$=1.96 TeV. No event is observed, which is consistent with a standard model background of 0.17±0.05.

Preliminary Results for Winter 2005 Conferences

I. INTRODUCTION

Supersymmetry(SUSY) is one of the most appealing theories for physics beyond the standard model(SM), as it solves the hierarchy problem and could provide a good candidate for the cold dark matter(CDM) in the universe. SUSY predicts the existence of a super-partner for each SM particle, sharing the same quantum numbers but differing by half a unit of spin. Despite numerous attempts, SUSY particles("sparticles") have not yet been observed; this means that SUSY must be broken and sparticles must be heavier than their SM counterparts. A new quantum number is introduced, R-Parity(R_P), which is $+1$ for SM and -1 for SUSY particles. The conservation of R_P implies that the lightest supersymmetric particle(LSP) is stable and escapes the experimental apparatus undetected, causing a striking experimental signature of large missing transverse energy($\not\!\!E_T$). Most SUSY theories predict the sparticle spectrum to become accessible at the TeV scale; in these scenarios the Tevatron might be able to discover SUSY before the advent of the LHC [1]. The associated production of the lightest chargino $\tilde{\chi}_1^{\pm}$ and the second to lightest neutralino $\tilde{\chi}_2^0$ (the mass-eigenstates of the super-partners of the W,Z and photon), although carrying small values of cross sections times branching ratios between 0.1 and 0.4 pb, is expected to be the dominant SUSY production mechanism if sparticles are accessible at these energies [5]. We present searches for charginos($\tilde{\chi}^{\pm}$) and neutralinos($\tilde{\chi}^0$) decaying through W/Z bosons or sleptons (see Figure 1) into signatures including missing energy and three isolated leptons ($ee + \ell, \ell = e, \mu$) at the CDF experiment [6]. As there are very few SM processes which carry this signature, the trileptons + $\not\!\!E_T$ is considered one of the most promising discovery channels for Supersymmetry at the Fermilab. The current best limit on the chargino mass comes from LEP2 $m_{\tilde{\chi}_1^{\pm}} > 103.5$ GeV/c^2 [2] and is independent on the SUSY model. DØ [3] has also recently presented results in this channel.

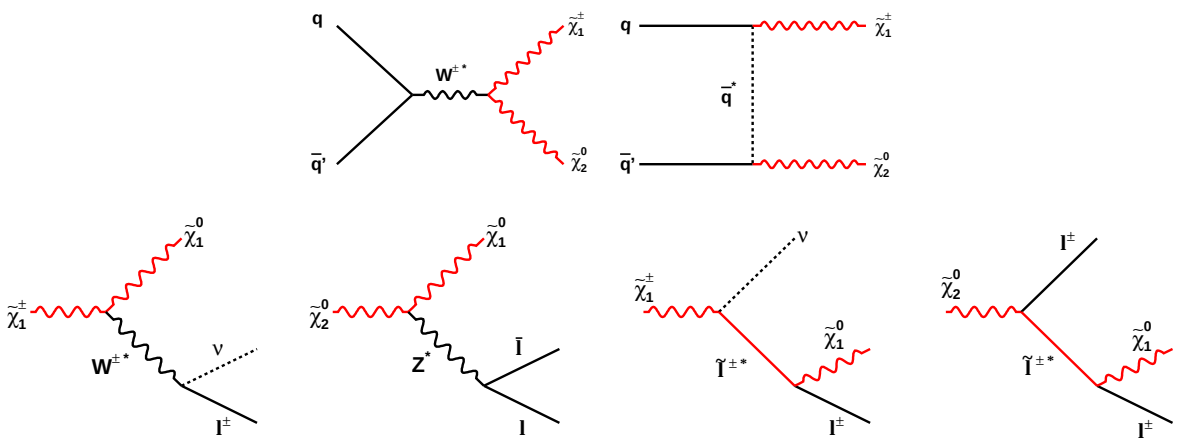

FIG. 1: *Feynman diagrams for chargino and neutralino production at hadron colliders (top) and their possible decays (bottom) giving a final state with three leptons and missing energy.*

II. DATA SAMPLE & EVENT SELECTION

This analysis is based on the integrated luminosity of 346 pb^{-1} collected with the CDFII detector between March 2002 and January 2004. The data are collected with an inclusive lepton trigger that requires an electron with E_T^e >18 GeV. From this inclusive lepton dataset we select events offline with two reconstructed isolated electrons with E_T^e greater than 20 and 8 GeV, with invariant mass greater than 15 GeV/c^2 and away from the Z peak (76-106 GeV/c^2). Additional cuts include $\Delta\Phi$ between the two electrons (less than 160°), missing E_T >15 GeV and fewer than two jets with E_T^{jet} >20 GeV. The third lepton (which can be an electron or a muon) is required to have E_T^{ℓ} >5 GeV and, if an electron, satisfy the same requirements on the invariant mass with each of the first two leptons.

III. ANALYSIS STRATEGY

We scanned the Supersymmetry parameter space to look for the region of M_0 and $M_{1/2}$ in which the reach of the Tevatron for $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production cross section and branching ratio to three leptons would be enhanced. We chose as

benchmark the point close to the maximum of $\sigma \times BR$ for which the masses of the chargino and neutralino were not excluded by LEPII, with M_0 =100 , $M_{1/2}$=180 , A_0 =0 , $\tan\beta$ = 5 , μ >0 (point(I)). In this point the mass of the $\tilde{\chi}_1^{\pm}(\tilde{\chi}_1^0)$ is approximately 113(66) GeV/c^2, and the squark masses are about 400 GeV/c^2. The NLO [4] cross section for $p\bar{p} \to \tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ is 0.642 pb. We generated a sample of approximately 30,000 events using the PYTHIA event generator [7].

IV. BACKGROUNDS

We divided the backgrounds in three categories:

A. Processes which can give three genuine leptons in the final state; these are dominated by WZ/γ^*, ZZ and $t\bar{t}$ production. This background contribution is estimated from Monte Carlo.

B. Processes which produce two leptons in the final state and the third lepton can be a fake or result from a photon conversion. These are mainly Drell-Yan and WW. For these events, we distinguish if the fake is coming from general QCD processes, or from a photon which is emitted by one of the initial leptons and then converts. We estimate the latter using Monte Carlo since the material and thus the conversion probability is well understood. In the other case we use the estimate of the fake rate calculated in the data using samples dominated by hadron jets. The fake rate is calculated per "fakeable object", which is a jet for the electron and a track with calorimeter isolation < 4 GeV for the muon.

C. Processes with one real lepton and two fakes. This contribution is estimated on the dielectron data in the signal region, per each additional track or jet in the sample separated from the selected leptons. We assign a systematic uncertainty of 50% to this technique.

The backgrounds are summarized in Table I. The number of expected events from the signal point(I) is also shown. The background prediction has been compared to the data in a number of regions, defined by orthogonal cuts with

Sample	Number of Events (346 pb^{-1})
2-lepton+fake	0.031 ± 0.015
2-lepton+conv.	$0.067 \pm 0.026 \pm 0.024$
Di Bosons	$0.065 \pm 0.006 \pm 0.009$
$t\bar{t}$	$0.007 \pm 0.004 \pm 0.002$
Sum	$0.171 \pm 0.027 \pm 0.044$
Signal (I)	$0.491 \pm 0.030 \pm 0.040$

TABLE I: *Background and signal expectation after final selection in the signal region. The "mass" cut is* $15 < M(ee) < 76$ *or* $M(ee) > 106$ GeV/c^2. *The first uncertainty is statistical, the second systematic as discussed in Section V.*

respect to the signal region ("control regions") where we expect the signal contamination to be small. We find good agreement between data and Monte Carlo predictions in all the control regions.

V. SYSTEMATIC UNCERTAINTIES

The main systematic uncertainties are divided in uncertainties on the signal determination, the background and the ones which are common to both. The main uncertainties on the background are the jet energy scale(22%), which affects the jet removal and the missing energy, the uncertainty on the theoretical cross sections (6.5%) and the uncertainty associated with the fake rate estimate(4.5%). The dominant uncertainty on the signal comes from the uncertainty on the theoretical cross sections (7%) and on the initial and final state radiation(4.2%). The uncertainties on the luminosity measurement(6%) and the lepton ID scale factors(3%) are correlated between signal and background. A summary of all the systematic uncertainties and their effect on the signal and background predictions is given in Table II.

VI. RESULTS

With the final selection we expect 0.17 ± 0.05 standard model background events in 346 pb^{-1}. The main sources of background are $W + Z/\gamma^*$ production, fake leptons and conversion electrons. We observe 0 events with three leptons,

Source	Uncertainty	Effect on Signal	Effect on Background
Monte Carlo Statistics	MC	12.2%	15%
PDF's	CTEQ suggested procedure [8]	2.0%	2.0%
Electron ID	varying by their uncertainty	3.3%	2.7%
e Energy Scale	2%	2.5%	2.9%
e Energy Resolution	1%	<0.01%	<0.01%
Conversion Removal Efficiency	1%	-	0.7%
Muon ID	varying by their uncertainty	0.7%	0.2%
Muon isolation	6%	0.7%	0.1%
Jet Energy Scale and $\not\!\!E_T$	varying by their uncertainty	1.0%	22%
ISR/FSR	(on-off)/2	4.2%	4.1%
Fake Rate	50%	-	4.5%
Luminosity	6%	6%	6%
Theoretical Cross Section	varying Q^2	7.0%	6.5%

TABLE II: *Sources of systematic uncertainties, the assumed uncertainty and the effect on the signal and background expectation. All uncertainties are given relative to the central value.*

with 0.49 ± 0.05 events expected from the SUSY benchmark point we quote. We plan to improve the current result by increasing the acceptance with the inclusion of electrons in the plug and combinining with the $e\mu + \ell$ and $\mu\mu + \ell$ channels. A more extensive scan of the SUSY parameter space is currently undergoing.

VII. CONCLUSIONS AND OUTLOOK

We have completed a first pass of the analysis and demonstrated good understanding of the data and standard model backgrounds. In the future we will extend the analysis by including electrons in the forward region and analysing events of the category $e\mu$+lepton and $\mu\mu$+lepton.

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