Study of a Like-Sign Dilepton Search for Chargino-Neutralino Production at CDF

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We propose a like-sign dilepton search for chargino-neutralino production in $\mathrm{p\bar{p}}$ collisions at $\sqrt{s} = 1.8$ TeV, which complements the previously published trilepton search by the CDF detector using Fermilab Run I data. Monte Carlo predictions for the signal and background efficiencies indicate a significant increase in sensitivity to chargino-neutralino production compared to the traditional trilepton analysis alone.

I. INTRODUCTION

Previous searches for chargino-neutralino production at the Tevatron have focused primarily on signatures with three charged leptons (trileptons) plus missing transverse energy ($\not\!\!E_T$) [1]. In the Minimal Supersymmetric (SUSY) Standard Model, chargino-neutralino production occurs in proton-antiproton ($\mathrm{p\bar{p}}$) collisions via a virtual W (s channel) or a virtual squark (t channel). In a representative minimal Supergravity (SUGRA) model (parameters: $\mu < 0, \tan\beta = 2, \mathrm{A_0} = 0, \mathrm{m_0} = 200\ \mathrm{GeV}/c^2$, $m_{1/2} = 90-140\ \mathrm{GeV}/c^2$), we expect three-body chargino and neutralino decays through virtual bosons and sleptons in a chargino mass region of $80-130\ \mathrm{GeV}/c^2$. Conserving R-parity, these decays produce a distinct signature: trileptons plus $\not\!\!E_T$ from a neutrino and the lightest supersymmetric particle. We demonstrate that the sensitivity to this signature can be significantly increased by searching for events with two like-sign leptons. The Like-Sign Dilepton (LSD) search provides a strong rejection of Standard Model background through the like-sign requirement, and enhances the acceptance of the signal by requiring only two of the three leptons produced in the chargino-neutralino decay.

II. LIKE-SIGN DILEPTON ANALYSIS

Signal and most background processes were generated using ISAJET 7.20 and the CDF detector Monte Carlo simulation. For the signal estimation, we used representative SUGRA parameters of $\mu < 0, \tan\beta = 2, \mathrm{A_0} = 0, \mathrm{m_0} = 200\ \mathrm{GeV}/c^2$, and $m_{1/2} = 90-140\ \mathrm{GeV}/c^2$. The relevant mass relations are $\mathrm{M}_{\tilde{\chi}_1^\pm} \sim \mathrm{M}_{\tilde{\chi}_2^0} \sim 2\mathrm{M}_{\tilde{\chi}_1^0}$, with $\mathrm{M}_{\tilde{\chi}_1^\pm}$ between $80-130\ \mathrm{GeV}/c^2$. The sleptons and sneutrinos have masses between $200-220\ \mathrm{GeV}/c^2$, so we generate only three-body chargino and neutralino decays.

The LSD analysis begins with the selection of a pair of leptons ($ee, \mu\mu, e\mu$) with the same charge. We then impose kinematic requirements on the selected events in order to remove Standard Model and other non-SUSY backgrounds. Our primary requirements are minimum transverse momentum ($P_T > 11\ \mathrm{GeV}/c$) for both leptons, and isolation, in which we remove events where at least one lepton has excess transverse energy greater than 2 GeV in a cone of 0.4 radians around the lepton. Monte Carlo simulations indicate that isolation removes heavy flavor ($\mathrm{b\bar{b}, c\bar{c}}$) backgrounds most effectively. As the like-sign cut requires us to select both leptons from a b or c decay in such an event, and as semi-leptonic b and c decays produce leptons associated with jets, neither of the selected leptons will be isolated. Isolation also reduces $\mathrm{t\bar{t}}$ because at least one lepton from the like-sign pair will be selected from a b decay in such an event. The isolation cut, when applied to both like-sign leptons, reduces $\mathrm{b\bar{b}}$ and $\mathrm{c\bar{c}}$ to a negligible level.

We remove diboson events through a Z-mass rejection, in which the combined mass of a third opposite-sign, same-flavor lepton selected by the analysis and either of the LSDs is between $80-100\ \mathrm{GeV}/c^2$, reducing WZ and ZZ

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backgrounds. We impose no requirement on $\not\!\!E_T$. This leaves WZ production as the dominant source of Standard Model background, as shown in Table 1.

An important source of non-SUSY background estimated from data is events with one true lepton, such as W $\rightarrow \ell\nu$ + jets, and a "fake" lepton, *i.e.* an isolated track misidentified as a lepton. This fake lepton, in combination with the true lepton from the W decay, can be selected as a signal event in this analysis. In order to estimate this background, we first look at Z $\rightarrow$ e^+e^- + jets, which we assume provides a model for W + jets events. Removing the true leptons, we then measure the rate of underlying isolated tracks in the event. Next we search minimum bias data, in which we assume there are no true leptons, to find the probability of an isolated track to be misidentified as a lepton. The probability of misidentifying an isolated track as a lepton is 1.5% per track. We multiply this probability by the isolated track rate from the Z $\rightarrow$ e^+e^- events, by the number of W + jets events expected [2], and by a factor of 0.5 for the like-sign requirement. This "fake" rate drops rapidly with an increasing minimum P_T requirement. Optimization of the number of expected background events as a function of the P_T requirement yields 0.3 events expected from W + jets in 100 pb^{-1} of data.

III. RESULTS

Applying the analysis requirements and normalizing the luminosity to 100 pb^{-1}, the expected background is a total of 0.56 events, as shown in Table 1. Drell-Yan and W + jets are the most significant non-SUSY backgrounds; WZ production is the largest Standard Model background. There is little background overlap of the trilepton and LSD analyses in the selected events based on Monte Carlo studies. Therefore, the backgrounds are treated as independent. For the trilepton analysis, the expected background for the Run I luminosity of 107 pb^{-1} is 1.2 events [1]. The total expected background for the combined LSD and trilepton analyses is 1.8 events.

TABLE I. Background estimates for the number of events expected in 100 pb^{-1} of data based on Monte Carlo (except for the W + jets data estimation). The errors are one-sigma statistical errors.

Process	Luminosity(pb^{-1})	N_{events} expected
WZ	16,684	0.11 ± 0.02
ZZ	13,992	0.01 ± 0.01
WW	6,870	$0^{+0.02}_{-0}$
$t\bar{t}$	5,558	$0^{+0.02}_{-0}$
Drell-Yan(γ^*/Z)	1,728	$0.11^{+0.10}_{-0.06}$
$b\bar{b}$, $c\bar{c}$	3,122	$0.03^{+0.04}_{-0.02}$
W + jets	(from data)	0.30
Total		0.56

Figure 1 shows the efficiency versus chargino mass for the trilepton analysis, the LSD analysis, and the combined analyses, taking into account the signal overlap between the trilepton and LSD analyses. These efficiencies are calculated for all three analyses as number of selected events divided by total number of chargino-neutralino events where both sparticles decay leptonically, where a lepton can be e, μ, or τ. All τ decays are included in this calculation, even though the analyses are only sensitive to the leptonic decays.

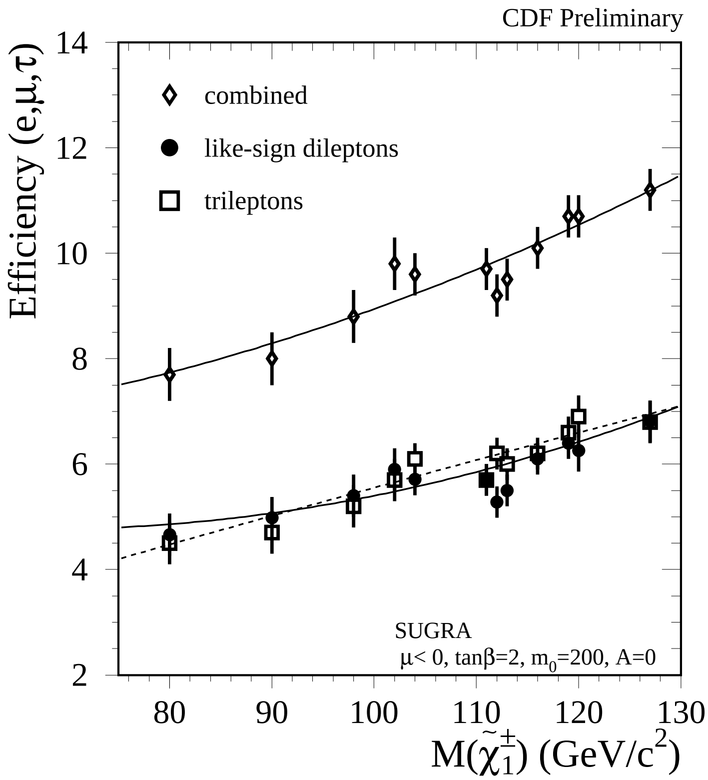

FIG. 1. The efficiency (as the percentage of events selected) for the trilepton, LSD, and combined analyses as a function of chargino mass. SUGRA parameters of $\mu < 0, \tan\beta = 2, \mathrm{A}_0 = 0, \mathrm{m}_0 = 200$ GeV$/c^2$, and $m_{1/2} = 90 - 140$ GeV$/c^2$ were used to measure the efficiency.

Figure 2 shows the average expected limit normalized to 100 pb^{-1} for the trilepton, LSD, and combined analyses. These limits were calculated from the efficiencies in Figure 1 and from the expected number of background events based on Monte Carlo.

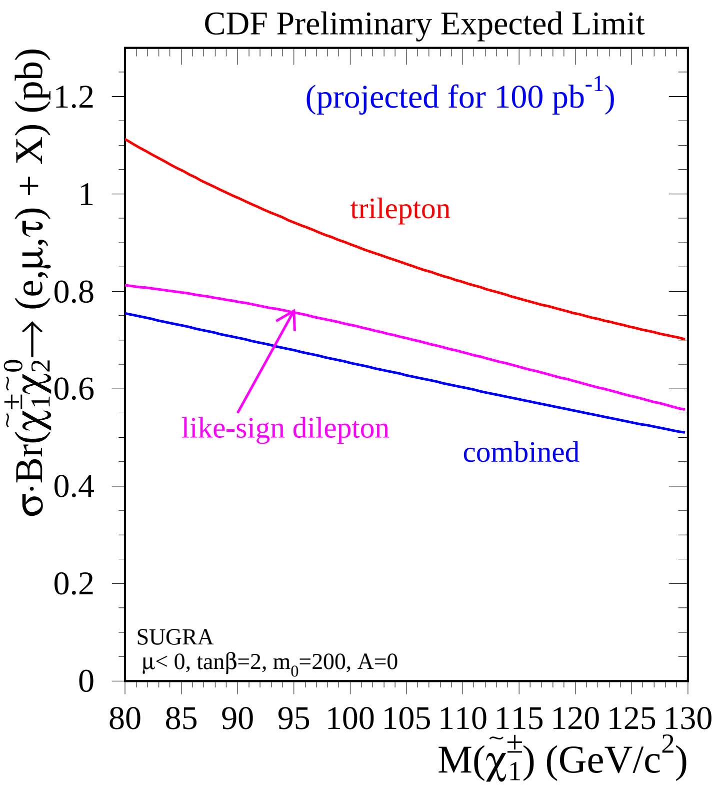

FIG. 2. Average expected limit on $\sigma \cdot \mathcal{B}$ as a function of $M_{\tilde{\chi}_1^\pm}$ for the LSD analysis, trilepton analysis, and the combination of both analyses. The parametrized efficiencies shown in Figure 1 are used along with the expected background from Monte Carlo in this calculation.

IV. CONCLUSION

This study indicates that a fully realized Like-Sign Dilepton analysis will increase the sensitivity of searches for chargino-neutralino production with the CDF detector using existing data of $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV. It has been shown that the sensitivity of the previously published trilepton analysis can be improved by combining it with this new LSD signature search. Significantly, the LSD search has fewer requirements than the trilepton analysis, *e.g.* the trilepton analysis requires $\not{E}_T > 15$ GeV$/c^2$ whereas the LSD analysis has no $\not{E}_T$ requirement, making the Like-Sign Dilepton channel sensitive to a greater number of signatures.

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[1] F. Abe, *et al.*, "Search for Chargino-Neutralino Associated Production at the Fermilab Tevatron Collider," Phys. Rev. Lett. **80**, 5275 (1998); F. Abe, *et al.*, "Search for Chargino-Neutralino Production in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV," Phys. Rev. Lett. **76**, 438 (1996).

[2] F. Abe, *et al.*, "Measurement of the ratio $\sigma B(p\bar{p} \rightarrow W \rightarrow e\nu)/\sigma B(p\bar{p} \rightarrow Z^0 \rightarrow ee)$ in $p\bar{p}$ collisions at $\sqrt{s} = 1800$ GeV," Phys. Rev. **D 52**, 2624 (1995).