Search for Chargino-Neutralino Production at the Collider Detector at Fermilab

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Abstract. The chargino-neutralino production is one of the most promising SUSY processes that could be observed at the Tevatron. Cross sections of the order of 0.1 pb have not been excluded yet under the mSUGRA scenario, whereas the trilepton signature of the process is not contaminated by significant standard model backgrounds. We report on the status of CDF search for chargino-neutralino production at the Tevatron by presenting the results of five multilepton subanalyses as well as the result of their combination which leads to our current lower limit on the chargino mass of 127 GeV/c^2 and upper limit on the production cross section times branching ratio to leptons of 0.25 pb at 95% confidence level.

Keywords: SUSY, mSUGRA, chargino, neutralino, trileptons, dileptons, Tevatron, CDF.
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1. INTRODUCTION

Supersymmetry (SUSY) predicts fermionic partners for the standard model (SM) gauge bosons and the Higgs, the gauginos and higgsinos, which mix to give the observable charginos and neutralinos. In minimal supersymmetric extensions of the Standard Model (MSSM) with R-parity conservation, the charginos and neutralinos are produced always in association, whereas the lightest supersymmetric particle (LSP) is stable. In the mSUGRA scenario, the LSP is the lightest neutralino. In this paper we consider the associated production of the chargino and the next-to-lightest neutralino at the proton-antiproton Tevatron collider. Depending on the slepton masses, their decay will proceed either through sleptons, which will always decay to leptons, or through off-shell gauge bosons which will decay to leptons only a fraction of the time. In the former case missing E_T ($\not\!\!E_T$) will result from the undetected LSPs, whereas in the latter case from both the LSPs and neutrinos from the W decays. In both cases, the experimental signature is three leptons and $\not\!\!E_T$ or two same-charge leptons and $\not\!\!E_T$, the trilepton signature demonstrating the lowest SM backgrounds.

2. MSUGRA PARAMETERS

Our mSUGRA benchmark assumes $M_0 = 100$ GeV/c^2, $M_{1/2} = 180$ GeV/c^2, $A_0 = 0$, $\tan\beta = 5$ and $\mu > 0$, and corresponds to chargino, next-to-lightest neutralino, and LSP neutralino masses of ~ 113, ~ 118, and ~ 66 GeV/c^2, respectively. The production cross section times branching ratio to leptons ($\sigma\times$BR) is 0.642×0.22 pb. For the establisment of our chargino mass and production cross section limits we use an mSUGRA-inspired

TABLE 1. The CDF chargino-neutralino analyses characterized based on final lepton flavor, triggers, and kinematics.

Analysis	Trigger	Lepton p_T cuts (GeV/c)
μ + e/μ + e/μ	High-p_T single muon	20, 10, 5
e + e + e/μ	High-E_T single electron	20, 8, 5
μ +μ + e/μ	Low-p_T dimuon	5, 5, 5
e + e + track	Low-E_T dielectron	15, 5, 4
Same-charge ee/$\mu\mu$/eμ	Low-$E_T(p_T)$ single electron(muon)	20, 10

MSSM model for a higher BR to electrons and muons: we assume degenerate slepton masses, which reduces the decays through taus, use $M_0 = 60$ GeV/c^2, $A_0 = 0$, $\tan\beta = 3$ and $\mu > 0$, where the lower value of M_0 enhances the decays through sleptons, and vary the $M_{1/2}$ gaugino mass from 160 to 230 GeV/c^2.

3. CDF CHARGINO-NEUTRALINO SEARCHES

The Tevatron is currently the highest-energy hadron collider in the world colliding protons with antiprotons at center-of-mass energy of $\sqrt{s} = 1.96$ TeV. CDF [1] is a multiple-purpose detector of particles coming from the Tevatron collisions. The CDF analyses we present use integrated luminosities between 300 and 750 pb^{-1}. Five analyses were developed, characterized by the kind, number, and momenta of the final objects. High-$E_T(p_T)$ single electron(muon) and low-$E_T(p_T)$ double electron(muon) triggers were utilized, requiring a single lepton with transverse energy or momentum higher than 18 GeV(GeV/c), or two leptons with transverse energy or momentum greater than 4 GeV(GeV/c) respectively. The standard CDF lepton identification cuts are applied to electron and muon candidates offline, and the jets are corrected and counted if their energy exceeds 20 GeV. Table 1 describes the five analyses we present in this paper. All of our analyses are statistically unbiased; kinematic control regions are investigated to establish the correct understanding of the SM backgrounds in both number of events and shapes, whereas the signal-region results are only studied at the very end.

Main backgrounds to the chargino-neutralino leptonic signal are SM processes that result to final state charged leptons and $\not\!\!E_T$ from either undetected or misreconstructed physical objects. The main common background for all analyses is the Drell-Yan (DY) process, which results to two real charged leptons, with the presence of a third lepton coming from lepton-misrecostruction (fake) or conversions, and $\not\!\!E_T$ coming from the misreconstruction of the event. The diboson production (WW, WZ, and ZZ) is another significant background, with an abundance of leptons, and $\not\!\!E_T$ coming from the neutrino(s) or misreconstruction. The heavy-flavor (HF) production is a significant background for the dimuon+lepton analysis that considers leptons at very low transverse momenta, whereas the $W + \gamma$ production is a significant background for the same-charge dilepton analysis. Most background control regions investigated are sub-domains of the $\not\!\!E_T$ vs. dilepton mass region, with lower $\not\!\!E_T$ and mass regions used for the understanding of the photon DY and possible HF production, whereas the Z-mass region is used for our DY Monte Carlo validation.

TABLE 2. Fraction of expected SUSY signal, determined for our benchmark SUSY scenario, and sources of SM background for all channels.

Analysis	SUSY	$WW/WZ/ZZ$	DY+γ	Fakes	Other
μ + e/μ + e/μ	65%	16%	9%	9%	1% ($t\bar{t}$)
e + e + e/μ	74%	10%	10%	5%	1% ($t\bar{t}$)
μ +μ + e/μ	58%	10%	6%	16%	10% (HF)
e + e + track	63%	17%	12%	included	8% ($t\bar{t}$)
Same-charge ee/$\mu\mu$/eμ	32%	9%	12%	13%	34% ($W+\gamma$)

The signal-region requirement for all analyses is the energy isolation and good space separation of the final objects, electrons, muons and tracks. High $\not{E}_T$ above 15 or 20 GeV is required and $\not{E}_T$ is corrected for the muons and jets. The dilepton mass of at least the leading leptons is required to be away from the Z-mass region (76-106 GeV/c^2). The dilepton mass must be above 15 or 25 GeV/c^2, for the reduction of the QCD background, photon DY and removal of resonances. Low multiplicity of jets is required, for the reduction of the top background and W/Z+jets. $\Delta\phi$ cuts between the muons for the reduction of residual cosmics, and between any leptons for the reduction of the DY background are applied.

Common challenges for all analyses are the fake estimation and the conversions modeling. The fakes are estimated by the application of a fake rate, extracted from several jet-rich data samples, on all the tracks and jets of each event. The conversions are studied in detail in conversions-rich data samples and a scale factor (SF) of the inefficiency of the conversions removal is applied on the DY+γ MC. The HF background is estimated using data: a HF-rich data sample is constructed by reversing the impact parameter requirement for at least one of the two muons, and its dimuon mass fitted to the data for proper weighting. The result of our data-based background estimation is very satisfactory in both absolute yields and kinematic distributions. Table 2 summarizes the sources of the backgrounds for our analyses and the fraction of expected signal for our SUSY benchmark.

Systematic uncertainties come from MC statistics (15-20%), the jet energy scale (15-20%), the fake rate and HF estimation (5-15%), conversions removal (10%), lepton identification and trigger SF (2-6%), theoretical cross sections (1-7%), initial and final state radiation (5%), and PDF and Q^2 (2-6%).

4. RESULTS AND CONCLUSIONS

After satisfactory agreement between data and expectation in our control regions, we look at the data in our signal regions. Table 3 shows the expected SM and SUSY events in the signal region for all analyses, as well as the observed data. We see one high-p_T $\mu\mu\mu$ event, when we expect 1.4 ± 0.2 from the SM for that channel, one ee+track, when we expect 0.5 ± 0.1, and 9 same-charge dileptons, when we expect 7 ± 1. These results are consistent with the SM prediction, and we thus proceed setting a limit on the chargino mass and production cross section. Using a frequentists approach [2], and properly combining our results taking overlaps into account, we obtain the exclusion plot

TABLE 3. Expected SUSY signal, estimated SM background, and observed events for all channels.

Analysis	Luminosity (pb^{-1})	SM Background	SUSY signal	Observed events
μ + e/μ + e/μ	745	1.4 ± 0.2	2.6 ± 0.2	1
e + e + e/μ	345	0.17 ± 0.05	0.49 ± 0.05	0
μ +μ + e/μ	310	0.13 ± 0.04	0.17 ± 0.03	0
e + e + track	610	0.5 ± 0.1	0.82 ± 0.06	1
Same-charge ee/$\mu\mu$/eμ	705	7 ± 1	3.2 ± 0.3	9

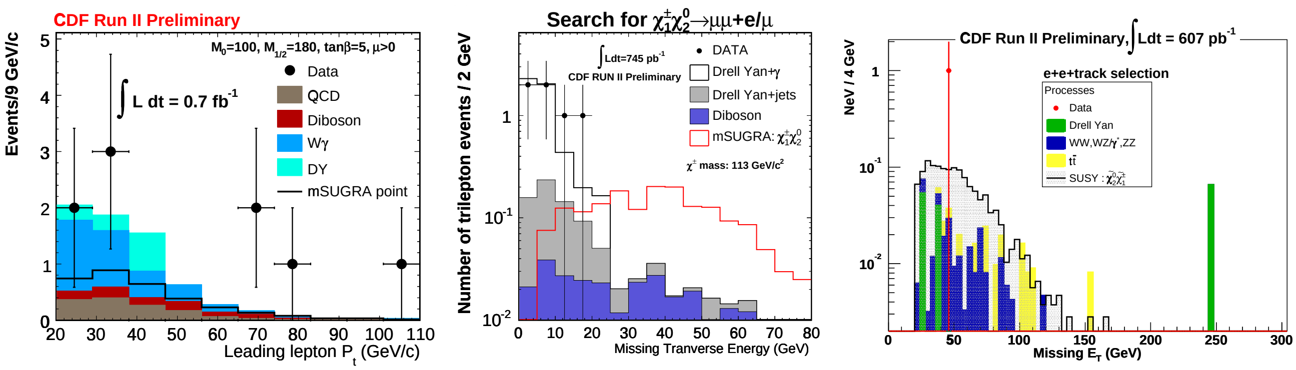

FIGURE 1. The observed events for same-charge ee/$\mu\mu$/eμ, μ + e/μ + e/μ and e + e + track analyses (signal expectation for our benchmark SUSY scenario).

of $\sigma \times$BR as a function of chargino mass, presented in Figure 2. The chargino mass limit is $M(\tilde{\chi}_0^{\pm}) > 127$ GeV/c^2 and the cross section limit is $\sigma \times$BR< 0.25 pb^{-1} at 95% confidence level (CL) in the MSSM model described in Section 2. These limits are consistent with those set by other experiments using similar models [3]. Our analyses will be extended to include more channels and use luminosity reaching and exeeding 1 fb^{-1} in the immediate future.

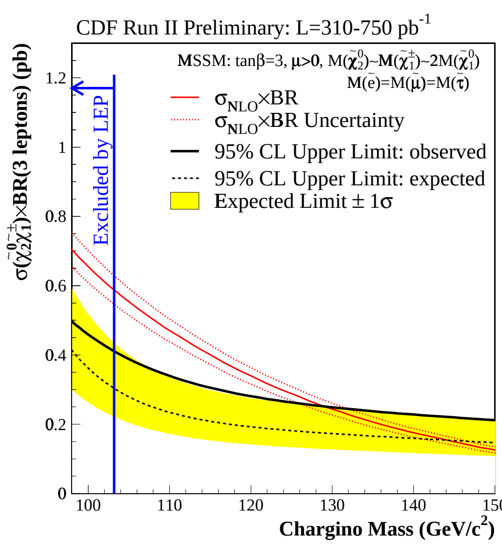

FIGURE 2. The exclusion plot after combining all analyses.

REFERENCES

1. D. Acosta *et al.* (CDF Collaboration), Phys. Rev. D **71**, 032001 (2005).
2. T. Junk, Nucl. Instrum. Methods A **434**, 435 (1999).
3. V. M. Abazov *et al.* (DØ Collaboration), Phys. Rev. Lett. **95**, 151805 (2005).