Search for supersymmetry in trilepton final states with the D0 detector.

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FERMILAB-CONF-06-393-E

Search for Supersymmetry in Trilepton Final States with the DØ Detector

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Abstract. The data taken by the DØ experiment at the proton–antiproton collider Tevatron has been used to search for signatures with two or more leptons and missing transverse energy as they are expected for the decay of pair produced Charginos and Neutralinos. No excess above the Standard Model prediction has been observed and the results have been used to set mass limits for these particles.

Keywords: Supersymmetry, Tevatron, DØ
PACS: 13.85.Rm, 14.80.Ly

INTRODUCTION

The proton–antiproton collider Tevatron provides at present the highest center of mass energy worldwide with $\sqrt{s} = 1.96$ TeV. The DØ experiment [1], one of the two detectors located at the Tevatron ring, has collected data corresponding to an integrated luminosity of $\approx$1.2 fb^{-1} in the so called RunII A, which ended in February this year. One of the main physics goals of the DØ experiment is the search for supersymmetric (SUSY) particles. Among these SUSY particles, the Charginos $\tilde{\chi}^{\pm}$ and Neutralinos $\tilde{\chi}^{0}$, the superpartners of the gauge bosons, are of particular interest, because they are predicted to be relatively light, which allows for pair production, and the decay mode into three charged leptons and missing transverse energy provides a clean signature with small Standard Model background expectation.

SEARCH FOR CHARGINOS AND NEUTRALINOS

Supersymmetric model and decay properties

The results presented here are interpreted using minimal supergravity (mSUGRA) models. mSUGRA models are characterized by five parameters m_0, $m_{1/2}$, A_0, $\tan\beta$, and sign(μ). Only models with R–parity conversation are considered, where R is given by $(-1)^{3(B-L)+2s}$, leading to a stable lightest supersymmetric particle (LSP), here the lightest Neutralino $\tilde{\chi}_1^0$. In addition, the mSUGRA parameters are chosen such that the Chargino and Neutralino masses mainly follow the relation $m_{\tilde{\chi}_1^{\pm}} \approx m_{\tilde{\chi}_2^0} \approx 2m_{\tilde{\chi}_1^0}$. No slepton mixing is considered and the masses of $\tilde{e}_R$, $\tilde{\mu}_R$, and $\tilde{\tau}_R$ are degenerated.

At the Tevatron, the dominant production process for Charginos and Neutralinos is via an off–shell W boson (s–channel). The t–channel production via squarks interferes destructively with the s–channel and may be suppressed depending on the squark mass.

The decay of Charginos and Neutralinos depends on the mass relation of gauginos and sleptons. The parameters are chosen such that slepton masses are comparable or larger than the gaugino masses. The gauginos decay via off-shell gauge bosons and sleptons, while cascade decays are suppressed. For sleptons that are mass degenerated with the Neutralino $\tilde{\chi}_2^0$ the leptonic branching ratio is maximally enhanced (3ℓ–max scenario).

Selection strategy

The trilepton final state is the golden mode for the search of Charginos and Neutralinos at the Tevatron. The signature is characterized by three charged leptons and missing transverse energy, $\not{E}_T$, caused by the escaping lightest Neutralinos and the neutrino. Nevertheless the search is very challenging because the leptons have low transverse momenta and the cross sections times branching fraction are only in the order of 0.5 fb.

To get a high signal reconstruction efficiency, only two leptons (either e or μ) are required to be reconstructed. For the third lepton, only an additional high quality isolated track is required to maximize the reconstruction efficiency and to be sensitive to electrons, muons, and taus. For some points in the five dimensional SUSY parameter space the third lepton has very low p_T, thus the dilepton+track analysis becomes inefficient and a different approach is necessary. Requiring two like–sign leptons of the same flavor is sufficient to suppress large fractions of the Standard Model backgrounds and the demand for a third object is not necessary.

Following the above strategies, four different analyses are presented here. Three of these analyses require two leptons plus a third track, where ee [2], $e\mu$, and $\mu\mu$ [3] final states are considered for the two leptons. The fourth analysis is based on a like–sign $\mu\mu$ selection [4].

The main background components for the dilepton+track analyses are vector boson pair production (WW, WZ, and ZZ) and Z/γ^* and W production, where either the missing transverse energy or one of the leptons is misidentified. The background for the like–sign di–muon analysis is dominated by multijet events from QCD production.

$ee+\ell$ selection

Already at preselection stage (two electrons with $p_T > 12$ GeV and $p_T > 8$ GeV), the Standard Model background is well under control. Fig. 1 (left) shows the $\not{E}_T$ distribution for these events. To reject the large contribution from $Z/\gamma^* \rightarrow ee$ events, the invariant mass is required to be in the the mass range between 18 and 60 GeV and events are vetoed with a cut on the opening angle in the transverse plane of $\Delta\phi_{ee} < 2.9$. Events with large jet activity are rejected to suppress remaining events from $t\bar{t}$–production.

Several cuts related to the missing transverse energy are applied. The missing transverse energy itself is required to be $\not{E}_T > 22$ GeV. The transverse mass, calculated from $\not{E}_T$ and the p_T of the leptons using $m_T = \sqrt{p_T \cdot \not{E}_T \cdot (1 - \Delta\phi(e, \not{E}_T))}$, must be larger than 20 GeV and the significance of $\not{E}_T$, a measure of the contribution of jets to $\not{E}_T$, is required to be in excess of 8.

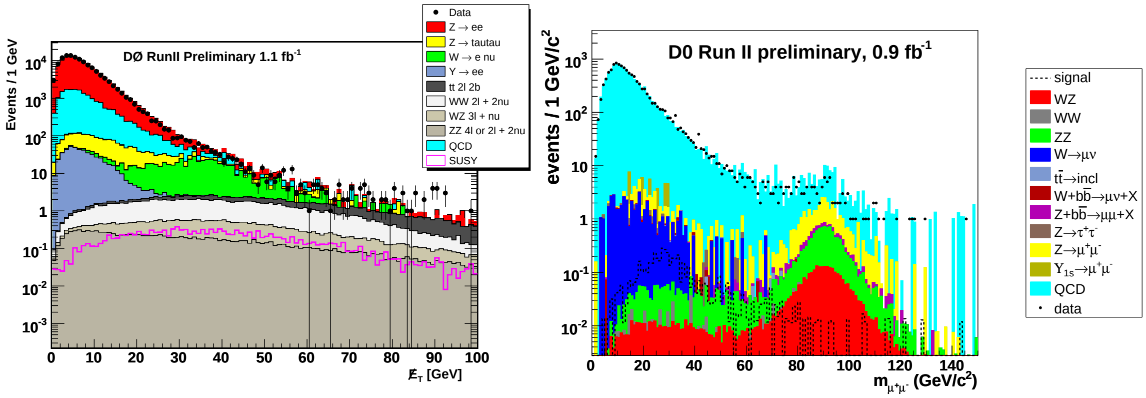

FIGURE 1. $\not\!\!E_T$ in the $ee+\ell$ channel (left) and invariant mass in the ls $\mu\mu$ channel (right).

Finally an isolated track with transverse momentum of at least 4 GeV is required and the product of track p_T and $\not\!\!E_T$ must fulfill the relation $p_T \times \not\!\!E_T > 220$ GeV^2. The number of events expected from Standard Model processes and observed in data as well as typical signal expectations are summarized in Table 1.

Like–sign $\mu\mu$ selection

The preselection in the like–sign di–muon channel [4] requires two muons of the same charge with transverse momenta $p_T > 5$ GeV which are not back–to–back ($\Delta\phi_{\mu\mu} < 2.9$). Three–muon events with opposite sign pairs of invariant mass above 65 GeV are discarded and the p_T requirements are tightened to 13 and 8 GeV. The invariant mass for these opposite sign pairs is shown in Fig. 1 (right).

As in the $ee+\ell$ analysis a set of cuts related to $\not\!\!E_T$ are applied. The missing transverse energy must be in excess of 10 GeV while the transverse mass is required to be in the range of 15 to 65 GeV. The significance of $\not\!\!E_T$ must be greater than 12 and the product of $\not\!\!E_T$ and trailing muon p_T is required to be greater than 160 GeV^2. A summary of the signal and background expectation as well as events observed in data is shown in Table 1.

$e\mu+\ell$ and $\mu\mu+\ell$ selection

A detailed description of these two analyses can be found in Ref. [3]. A brief summary of events expected and observed as well as signal expectation is presented in Table 1.

RESULTS

The number of events observed in the data are in good agreement with the Standard Model expectation. Thus no evidence for the production of Charginos and Neutralinos

TABLE 1. Number of events expected and observed in data and signal predictions.

Final state	$\mathscr{L}_{int}$ (fb)	Background	Data	Signal
$ee+\ell$	1.1	0.82±0.66	0	1.88±0.01 – 5.26±0.02
ls $\mu\mu$	0.9	1.1±0.4	1	0.61±0.01 – 3.76±0.15
$e\mu+\ell$	0.3	0.31±0.15	0	0.70±0.03 – 2.45±0.09
$\mu\mu+\ell$	0.3	1.75±0.57	1	0.47±0.02 – 1.94±0.08

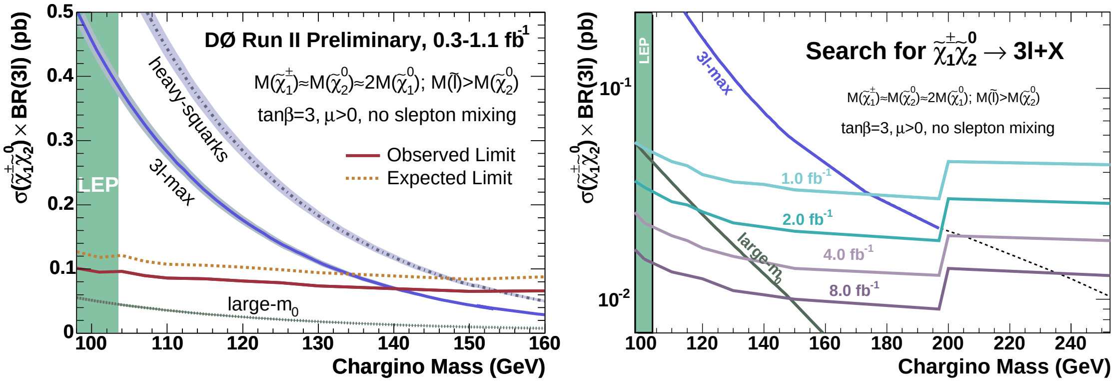

FIGURE 2. Upper limit on the *sigma* $\times Br(3\ell)$ (left) and future predictions (right) as function of $m_{\tilde{\chi}_1^\pm}$.

has been found. Instead upper limits on the production cross section times branching ratio have been set using a modified frequentist approach. To avoid double counting while combining the four analyses, signal events found by more than one analyses are assigned to the selection with the best signal–to–background ratio and removed from the others. The expected and observed upper limits on $\sigma \times Br(3\ell)$ are shown in Fig. 2 (left) as a function of the $\tilde{\chi}_1^\pm$ mass and are in the range of 0.8–1 pb. Assuming a specific scenario, the cross section limits can be translated into a mass limit. Assuming the 3ℓ–max scenario Charginos with masses below 146 GeV can be excluded.

CONCLUSION AND OUTLOOK

A search for Charginos and Neutralinos has been performed. No evidence for SUSY has been found. Mass limits that improve significantly on the Run I and LEP limits have been set. The Tevatron reach for the Chargino and Neutralino search with larger datasets is shown in Fig. 2 (right).

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