SEARCHES IN LEPTON FINAL STATES

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Abstract

Searches for new physics in lepton final states at the Tevatron are summarized in this paper. I describe the searches for supersymmetric particles such as chargino/neutralino and tau-sneutrino. I also describe searches for excited gauge bosons (W', Z') and excited electrons.

1 Introduction

The standard model(SM) of physics gives a successful description of natural phenomena. It is applicable over a wide range of energy scales. However, the standard model has a few unanswered questions. It does not include gravity, or describe the origins of masses of the fundamental particles. It suffers from the hierarchy problem, and gives no hints about the nature of dark matter or dark energy which constitute 96% or our universe.

There are several proposed models of new physics beyond the standard model. Supersymmetry(SUSY) is a new proposed symmetry between fermions and bosons. It posits the existence of boson superpartners to all SM fermions and vice versa. It solves the hierarchy problem and in certain models suggests an attractive dark matter candidate particle. Other models such as left-right-symmetric models (broken $SU(2)_L \times SU(2)_R$) or Grand Unification Theories which unify the electroweak and strong forces predict additional gauge bosons. The Randall-Sundrum model of warped extra dimensions predicts the existence of a massive spin-2 particle.

The search for new physics in lepton final states has many advantages over other channels. Lepton final states are relatively clean and free from backgrounds. Since identifying leptons is well understood at the CDF and DØ detectors, the backgrounds in lepton final states from SM processes are straightforward to estimate. Many new models predict leptonic final states and thus these analyses are sensitive to a wide variety of models beyond the standard model.

Results shown here use from 1 to 2.5 fb^{-1} of data from the Tevatron for each CDF and DØ

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Table 1: CDF results of a search for $\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \to lll + \not\!\!E_T$. The signal quoted is for mSUGRA model with parameters $m_0 = 60$ GeV/c^2, $m_{1/2} = 190$ GeV/c^2, tan(β)=3, $A_0 = 0$, $\mu > 0$.

Channel	Expected Signal	Background	Observed
3 tight leptons	2.3±0.3	0.5±0.1	1
2 tight + 1 loose	1.6±0.2	0.3±0.04	0
1 tight + 2 loose	0.7±0.1	0.1±0.03	0
2 tight + track	4.4±0.6	3.2±0.7	4
1 tight + 1 loose + 1 track	2.4±0.3	2.3±0.6	2

Table 2: DØ results of a search for $\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \to lll + \not\!\!E_T$. The signal quoted is for mSUGRA-inspired model with parameters $m_0 = 88 - 121$ GeV/c^2, $m_{1/2} = 182 - 221$ GeV/c^2, tan(β)=3, $A_0 = 0$, $\mu > 0$. The RunIIb analysis is a new analysis.

Channel	Expected Signal	Background	Observed
ee + Track (RunIIb)	0.5-2.1	1.0±0.3	0
ee + Track (RunIIa)	1.7-4.7	0.8±0.7	0
$\mu\mu$ + Track (RunIIa)	0.5-2.5	$0.3\pm^{1.3}_{0.3}$	2
$e\mu$ + Track (RunIIa)	2.0-2.6	0.9±0.4	0
$\mu^\pm\mu^\pm$ (RunIIa)	0.6-3.8	1.1±0.4	1

2 Supersymmetry searches

2.1 Chargino-Neutralino

In R-parity [a] conserving models of supersymmetry, the associated production of chargino and neutralino gives rise to a distinctive signature. The chargino ($\tilde{\chi}_1^\pm$) and neutralino($\tilde{\chi}_2^0$) each decay to leptons along with invisible particles ($\tilde{\chi}_1^\pm \to l^\pm \nu \tilde{\chi}_1^0$, $\tilde{\chi}_2^0 \to l^\pm l^\mp \tilde{\chi}_1^0$), giving a final state with three leptons and a momentum imbalance (missing E_T or $\not\!\!E_T$) in the detector.

CDF conducted a analysis which looked in five final states defined by purity of leptons used for the final states. Tight leptons have stricter selections and lower backgrounds, looser leptons are less pure, and tracks are simply charged particles. The results are summarized in Table 1. In this table lepton refers to electrons or muons. The final cross-section × branching ratio limits are shown in Figure 1. This analysis was performed with 2 fb^{-1}of data. It improves the CDF published limits [1]. Charginos with mass below 145 GeV/c^2 are excluded. These are first direct limits on mSUGRA chargino mass from the Tevatron.

DØ has added to their published result [2] an analysis which looks in the final state with two electrons and a track. The results are summarized in Table 2 and the limit is shown for an 'mSUGRA-inspired' scenario in Figure 2. The analyses performed by DØ used between 0.9 and 1.7 fb^{-1}. Charginos with mass below 145 GeV/c^2 are ruled out in this scenario.

2.2 Tau-sneutrino

Imposing R_P conservation is not necessary for supersymmetry. An analysis probing R_P violating SUSY is the DØ search for the superpartner to the tau-neutrino, the tau-sneutrino ($\tilde{\nu}_\tau$). The supersymmetric Lagrangian can then be modified to include terms such as

$$W_{RPV} = \frac{1}{2}\epsilon_{ab}\lambda_{ijk}L_i^a L_j^b E_k + \epsilon_{ab}\lambda'_{ijk}L_i^a Q_j^b D_k \qquad (1)$$

[a] A multiplicative quantum number defined as $R_P = (-1)^{2S+3B+L}$.

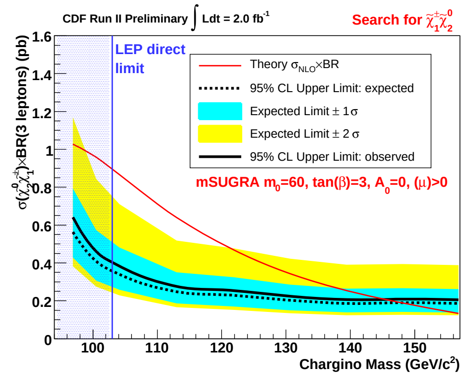

Figure 1: Figure shows the cross section × branching ratio limits from the CDF $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ search for the mSUGRA model. $\tilde{\chi}_1^{\pm}$ with mass below 145 GeV/c^2 is excluded.

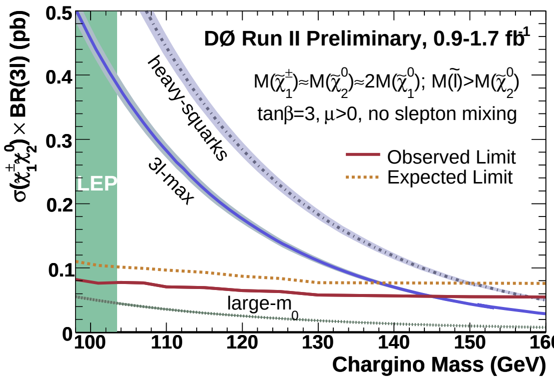

Figure 2: Figure shows the cross section × branching ratio limits from the DØ $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ search for an 'mSUGRA-inspired model'. $\tilde{\chi}_1^{\pm}$ with mass below 145 GeV/c^2 are excluded.

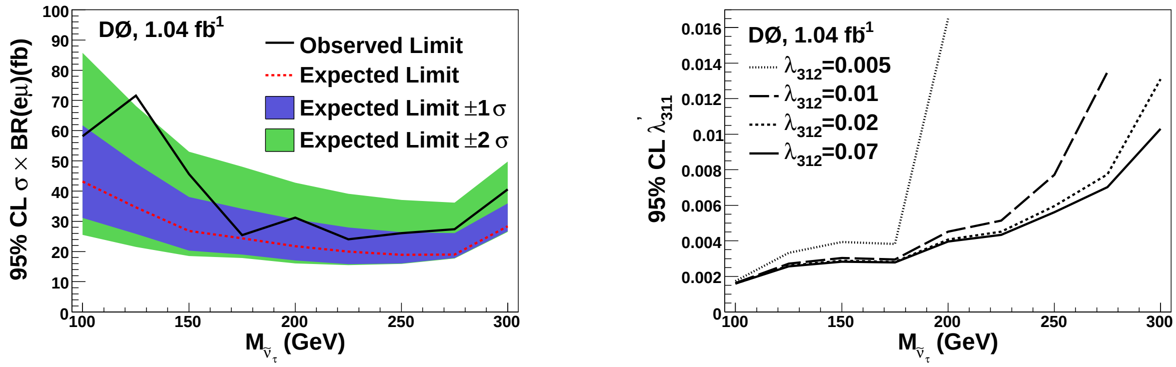

Figure 3: Figure shows the limits on the R_P violating couplings on the left side and cross section × branching ratio limits on the right from the DØ $\tilde{\nu}_\tau$ search as a function of the $\tilde{\nu}_\tau$ mass.

where the LLE and LQD terms represent lapton flavor violating interactions. The analysis is a direct search for resonant production of sneutrinos decaying into an electron and a muon performed under the hypothesis that the third-generation sneutrino ($\tilde{\nu}_\tau$) is the lightest supersymmetric particle and dominant, namely by assuming that all couplings but λ'_{311} and $\lambda_{312} = \lambda_{321}$ are zero. This analyses used 1 fb^{-1}of data to set limits on the R_P violating couplings as a function of $\tilde{\nu}_\tau$ mass. Figure 3 shows the limits.

3 Non-SUSY searches

3.1 Excited electrons

A possible way to explain the observed mass hierarchy of the three generations in the SM is compositeness. According to this approach, a quark or a lepton is a bound state of three fermions or of a fermion and a boson. DØ performs a search for an excited electron with 1 fb^{-1}of data. Single production of an excited electron (e^*) is considered in association with an electron via a four-fermion contact interactions, with the subsequent electroweak decay of the e^* into an electron and a photon. The $ee\gamma$ final state is fully reconstructable and nearly background-free. The selection is optimized for the mass of the e^* using two variables $\Delta R_{e\gamma}$ (separation between electron and photon) and $M_{e\gamma}$ (invariant mass of electron and photon). The limits on the cross section are shown in Figure 4. For the scale for contact interactions to be $\Lambda = 1$ TeV, excited electron masses below 756 GeV are excluded at the 95% C.L.

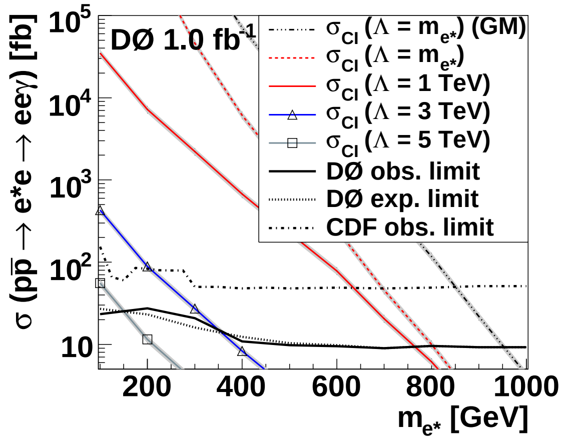

Figure 4: Figure shows the limits on the cross section $\times$ branching ratio of production of excited electron from a search performed at DØ . Experimental limits are compared to the contact interaction model prediction for different choices of Λ.

CDF Run II Preliminary

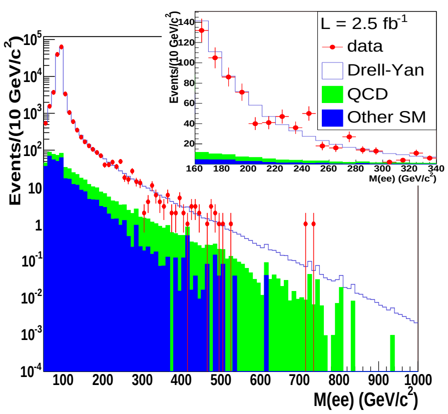

Figure 5: Figure shows the invariant mass distribution in the e^+e^- final state for the CDF Z' search. The most significant excess over standard model predictions is 3.8σ and occurs at 240 GeV/c^2 (shown in inset).

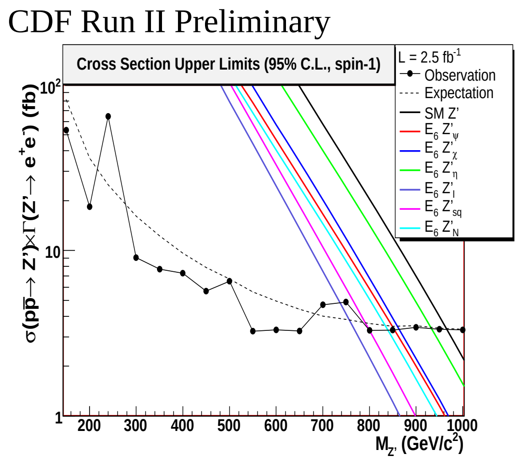

Figure 6: Figure shows the cross section limits on the Z' production from a CDF search. The different Z's are also shown. Standard model-like Z' with mass below 966 GeV/c^2 is excluded.

3.2 New gauge bosons

Search for Z'

The E6 model, which unifies the forces in the SM into a E6 gauge group, predicts the presence of additional neutral spin-1 bosons. These new bosons are referred to as Z's and they can mix with some arbitrary angle. Changing the value of the mixing angle used to benchmark the model gives the following six states : Z'_η, Z'_χ, Z'_ψ, Z'_I and Z'. The search based on 2.5 fb^{-1}and is carried out as a search for a narrow resonance in the dielectron (e^+e^-) final state with a mass range from 150 GeV/c^2 to 1050 GeV/c^2. The invariant mass distribution is shown in Figure 5 with the most significant excess (3.8σ) at 240 GeV/c^2 (inset).

Search for W'

Left-right-symmetric models, along with E6 models, also introduce additional gauge bosons. In the most general case, a new gauge group is comprised of a new mixing angle ζ, new couplings

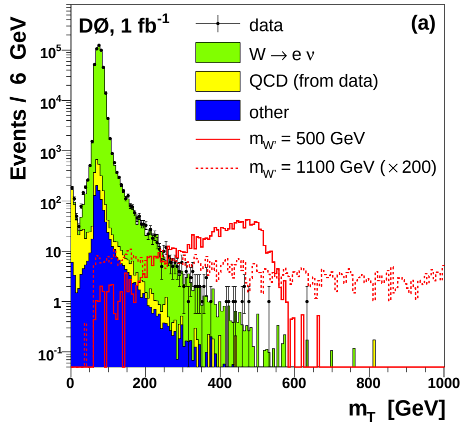

Figure 7: Figure shows the transverse mass (m_T) distribution in the $e\nu$ final state for the DØ W' search. The signal from a 500 GeV/c^2, and 1.1 TeV/c^2 W' boson is also shown..

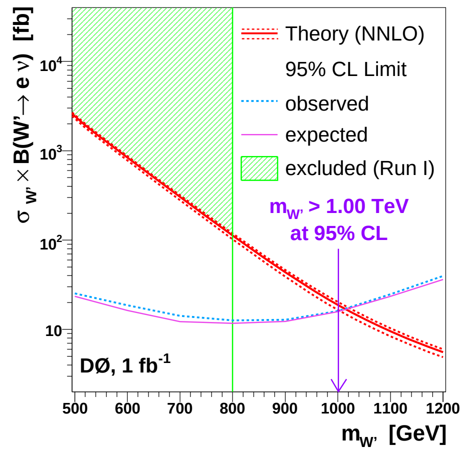

Figure 8: Figure shows the cross section limits on the W' production from a search at DØ . W' with standard model like couplings is ruled out below 1 TeV.

to fermions and a new CKM matrik U'. This analysis [3], based on 1 fb^{-1}, assumes no mixing, couplings equal to the SM couplings and the same CKM matrix as the SM. The width of the W' is assumed to scale with its mass, $m_{W'}$. The final state is an electron and a neutrino ($W' \rightarrow e\nu$). The transverse mass (m_T) of the electron and neutrino is constructed, and the tail of the m_T distribution is searched for possible excesses. Figure 7 shows the m_T distribution with signal shown for two possible masses of the W'. Figure 8 shows the cross section $\times$ branching ratio limits on W' production. A W' boson with mass below 1 TeV is ruled out at 95% C.L.

4 Conclusions

CDF and DØ have searched for new physics in lepton final states with more than 2 fb^{-1}. The leptonic final states provide a rich set for searches for physics beyond the standard model. No signs of new physics have been found yet, but new constraints have been set on new-physics models. With the improving Tevatron performance and optimal working of the two experiments, next year will push the boundaries of physics even further.

References

1. Search for Chargino-Neutralino Production in $p\overline{p}$ Collisions at $\sqrt{s} = 1.96$ TeV, T. Aaltonen *et al*, *Phys. Rev. Lett.* **99**, 191806 (2007)
2. Search for Supersymmetry via Associated Production of Charginos and Neutralinos in Final States with Three Leptons, V. Abazov *et al*, *Phys. Rev. Lett.* **95**, 151805 (2005)
3. Search for W' Bosons Decaying to an Electron and a Neutrino with the D0 Detector , V. Abazov *et al*, *Phys. Rev. Lett.* **100**, 031804 (2008)
4. CDF collaboration , http://www-cdf.fnal.gov/physics/exotic/exotic.html
5. DØ collaboration, http://www-d0.fnal.gov/Run2Physics/WWW/results/np.htm