

## SEARCHES FOR NEW PHENOMENA WITH LEPTON FINAL STATES AT THE TEVATRON

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Numerous searches for new phenomena have been carried out using data from proton-antiproton collisions at Fermilab's Tevatron. Final states with leptons give signatures which are relatively unique and generally have small backgrounds. We present many of the latest results from the CDF and D0 collaborations from 0.4-1.2 fb<sup>-1</sup> of data. Topics include supersymmetry, extra gauge bosons, Randall-Sundrum gravitons, excited electrons and neutral, long-lived particles.

New phenomena searches with leptons favor analyses with relatively small or well-understood backgrounds. At the Tevatron, the CDF and D0 collaborations have strong programs of searches with leptonic final states in a wide range of topics. Some of the most recent results are discussed here. All limits presented are at the 95% CL.

### 1 Charginos and Neutralinos in Trileptons

Supersymmetry has been a popular extension to the standard model for several decades and numerous searches for evidence of any of the superpartners have been carried out. At hadron colliders, a unique signature for supersymmetry comes in the trilepton ("three lepton") final states. If the masses lie in the correct region, proton-antiproton collisions can produce charginos and neutralinos in association:

$$p\bar{p} \rightarrow \tilde{\chi}_1^\pm \tilde{\chi}_2^0 \tag{1}$$

with decay modes

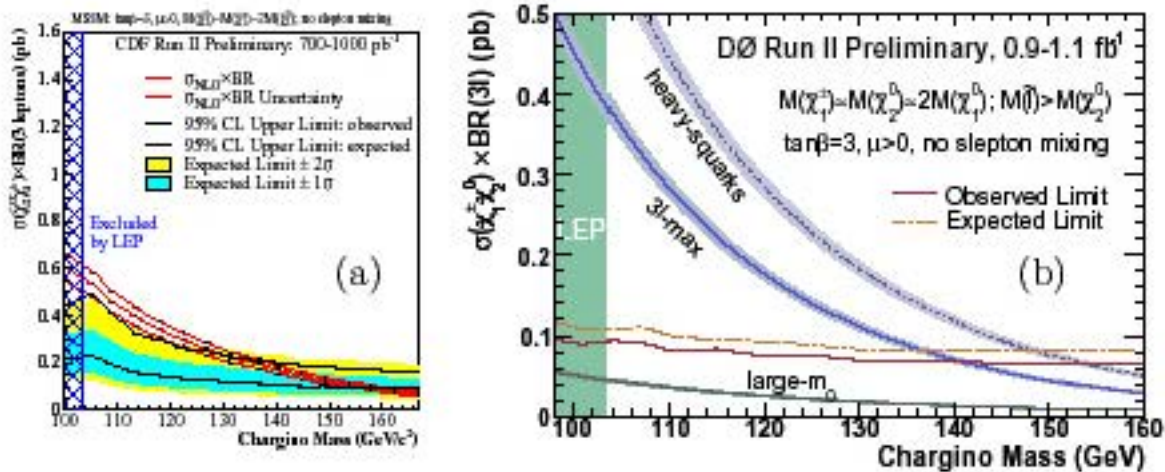


Figure 1: Limits on SUSY production of charginos and neutralinos. (a) CDF limit using a model of MSSM without slepton mixing and  $m_0 = 60$  GeV; (b) D0 limit using three mSUGRA inspired models.

$$\tilde{\chi}_1^\pm \rightarrow \ell^\pm \nu \tilde{\chi}_1^0 \quad \tilde{\chi}_2^0 \rightarrow \ell^\pm \ell^\mp \tilde{\chi}_1^0 \quad (2)$$

In the standard model, trilepton final states are only produced by rare processes (such as di-bosons) which means these searches will naturally have small backgrounds. The challenge lies in the inefficiency to uniquely identify all three leptons. The solution is to use three search techniques: (1) observe all three leptons; (2) observe two leptons and a third isolated track; (3) observe two same-signed leptons. By combining all three search methods and combinations of electrons, muons and isolated tracks, the experiments improve the sensitivity to discovery.

CDF has performed searches in 14 different channels<sup>1</sup> ranging in luminosity 0.7-1.1 fb<sup>-1</sup>. While a slight excess of data vs. background is observed, there is no strong evidence of supersymmetry. Therefore limits on the production cross-section times branching ratio can be set. CDF interprets this within three different mSUGRA inspired models with  $m_0 = 60$  GeV: (A) mSUGRA; (B) MSSM without slepton mixing; (C) MSSM with lepton branching ratio set to same as W/Z. For model (B) a limit on the  $\tilde{\chi}_1^\pm$  mass greater than 130 GeV is set (Fig. 1(a)).

D0 has performed four searches<sup>2</sup> with luminosity 1.0-1.1 fb<sup>-1</sup> with no excess of data observed. Three mSUGRA-inspired models (with no slepton mixing) are explored: (1) large  $m_0$  where W/Z decays dominate; (2) 3 $\ell$ -max with slepton mass slightly larger than the  $\tilde{\chi}_2^0$  mass; (3) heavy squarks where scalar mass unification is relaxed (Fig. 1(b)). For the 3 $\ell$ -max model, a limit of  $M(\tilde{\chi}_1^\pm) > 141$  GeV is found.

## 2 W'

Some extensions of the standard model predict the existence of additional, heavy, gauge bosons. D0 has performed a search for a  $W'$  decaying to an electron and neutrino<sup>3</sup> using a dataset of 0.9 fb<sup>-1</sup>. Data selection requires a high energy electron ( $E_T > 30$  GeV), large missing transverse energy (MET > 30 GeV) and large transverse mass ( $M_T > 150$  GeV). Figure 2(a) shows the transverse mass distribution (without  $M_T$  cut) for data, background and signal. D0 observes 630 events with an expected background of  $623 \pm 18^{+83}_{-78}$  events. Therefore, a limit on a  $W'$  mass > 965 GeV is set assuming standard model couplings (Fig. 2(b)).



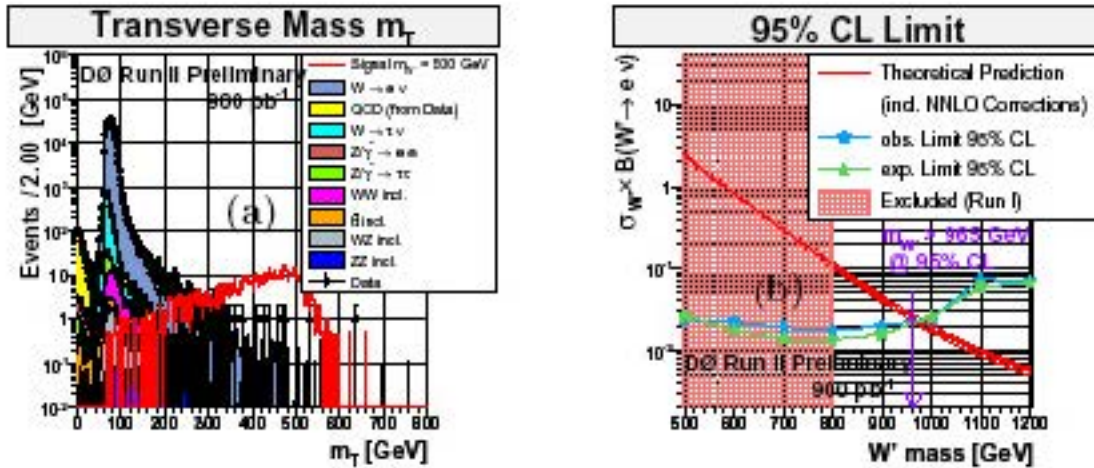


Figure 2: (a) Distribution of transverse mass without  $M_T$  mass cut. Data is shown as points with error bars, background is the solid histogram, while a sample signal with  $M_{W'} = 500$  GeV is represented by the open histogram. (b) D0 limit on the  $W' \rightarrow e\nu$  cross-section times branching ratio as a function of the  $W'$  mass.

### 3 $Z'$

CDF has performed a model independent search for narrow resonances decaying to an electron and a positron<sup>4</sup> using  $1.3 \text{ fb}^{-1}$  of data. They scan the mass region 150-900 GeV in 4 GeV mass bins looking for an excess of data over predicted background (Fig 3(a)). The small excesses seen are consistent with statistical fluctuations. This is interpreted to exclude a standard model type  $Z'$  with mass below 923 GeV. Additional models are shown in Fig. 3(b).

### 4 Randall-Sundrum Gravitons

Both CDF and D0 have combined searches in di-electron final states with similar searches in di-photon to explore models of extra dimensions involving Randall-Sundrum gravitons<sup>4,5</sup>. Models of extra dimensions attempt to address the hierarchy problem between the strength of the weak force and gravity. At hadron colliders, RS gravitons may be observed in the invariant mass or angular distributions of electron and/or photon pairs. Both experiments observe data in agreement with background predictions and exclude large regions in the graviton mass vs.  $k/\bar{M}_{pl}$  parameter space (Fig. 4). At  $k/\bar{M}_{pl}=0.1$  CDF(D0) exclude gravitons with masses below 889(865) GeV.

### 5 Excited Electrons

Some models predict that quarks and leptons are composite particles composed of smaller pieces. These models allow for excited quark/lepton states. D0 has carried out a search for excited electrons ( $e^*$ ) from the process  $p\bar{p} \rightarrow ee^* \rightarrow ee\gamma$ . After selecting events with  $p_T(e_1, e_2, \gamma) > 25, 15, 15$  GeV, 259 events are observed with an expected background of  $232 \pm 3 \pm 29$  events. From this, limits are set on the mass of the excited electron and the compositeness scale (Fig. 5). For  $\Lambda = 1$ , the limit is  $m_{e^*} > 756$  GeV. If decays via contact interaction are neglected, D0 finds a limit of  $m_{e^*} > 946$  GeV for  $\Lambda = m_{e^*}$ .

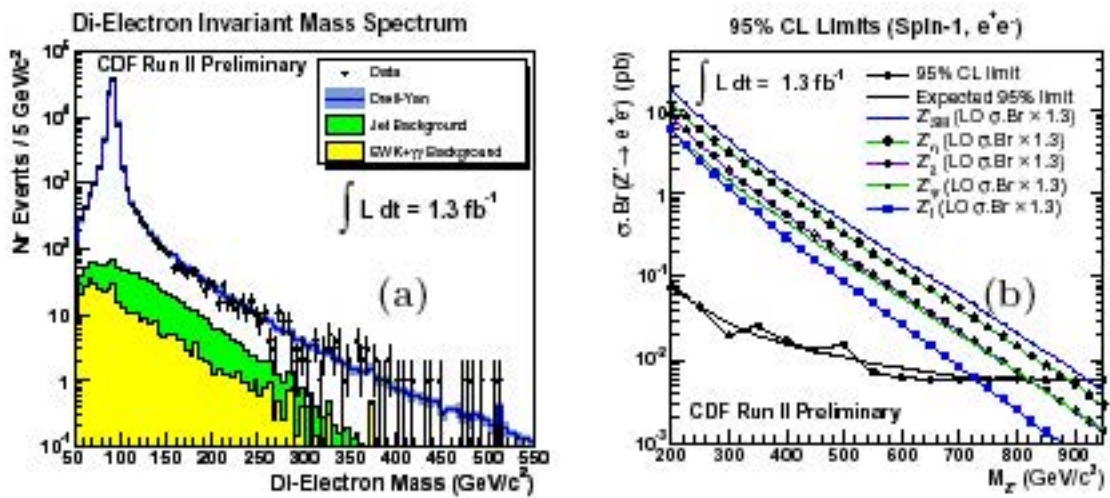


Figure 3: (a) Distribution of di-electron invariant mass with data shown as points with errors and background as the histograms. (b) CDF limit on the cross-section times branching ratio for a spin 1 object along with various models of Z' production.

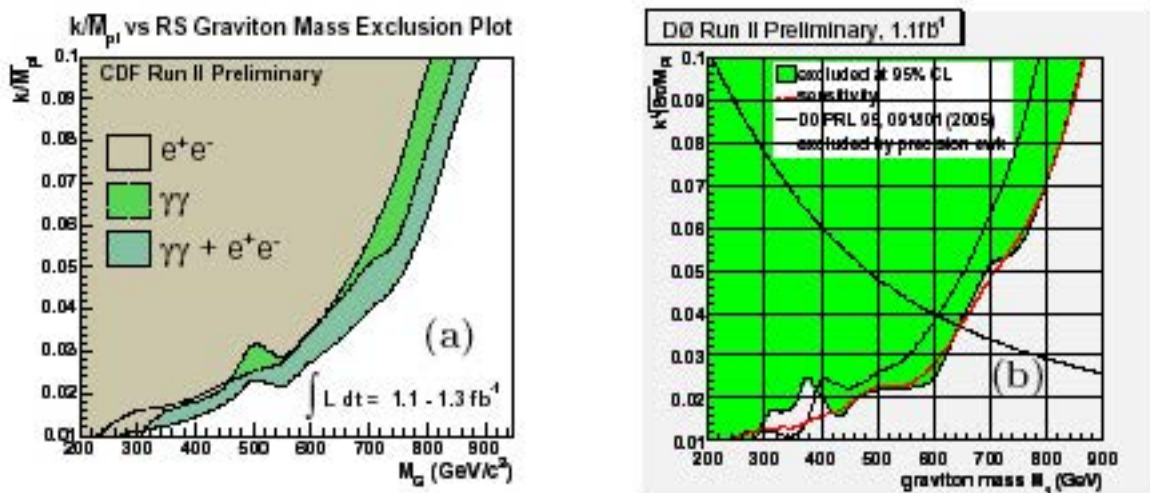


Figure 4: Limits on extra dimensions using the Randall-Sundrum model from (a) CDF and (b) D0. Limits are set on the parameters  $k/\bar{M}_{pl}$  and the graviton mass.



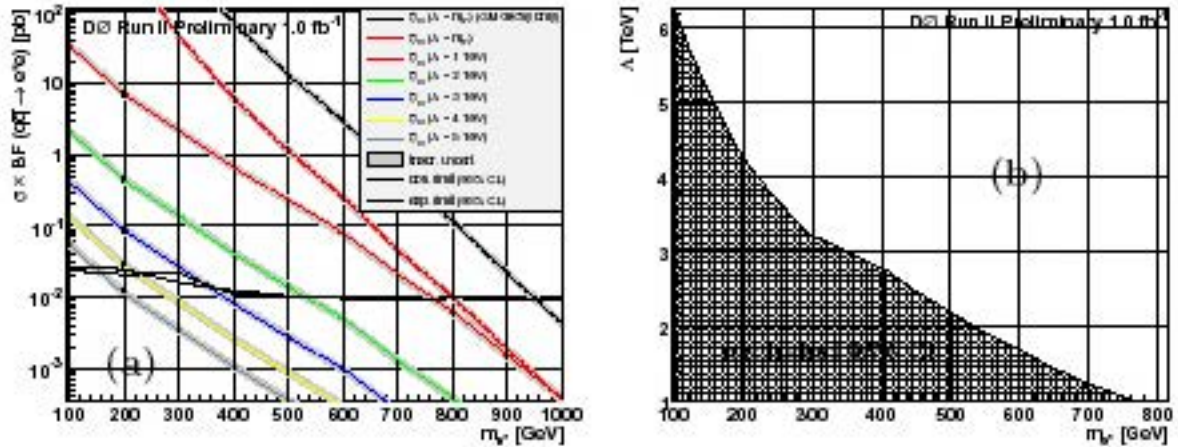


Figure 5: Limits on excited electrons from D0. (a) shows the limit on the cross-section times branching ratio as a function of the mass of the excited electron. (b) shows the limit on the compositeness scale vs. the mass of the excited electron.

## 6 Neutral, Long-lived Particles

D0 has performed a search for neutral, long-lived particles decaying to two muons after traveling at least 5 cm from the production point. A sample of pair production of neutralinos with R-parity violating decays and long lifetime is used to model the signal. Background is estimated from data to be  $0.75 \pm 1.1 \pm 1.1$  events. No events are observed with a decay length in the transverse plane of 5-20 cm. Limits are set on the production cross-section times branching ratio as well as a comparison with a previous result from NuTeV<sup>7</sup> using the sample model (Fig. 6). This comparison limits the possible interpretations of NuTeV's result.

## 7 Summary

The CDF and D0 collaborations have performed numerous searches for new phenomena using leptonic final states. Recent results place limits on associated chargino and neutralino production, extra gauge bosons, Randall-Sundrum gravitons, excited electrons and neutral, long-lived particles. Most of these are the world's best limits.

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## References

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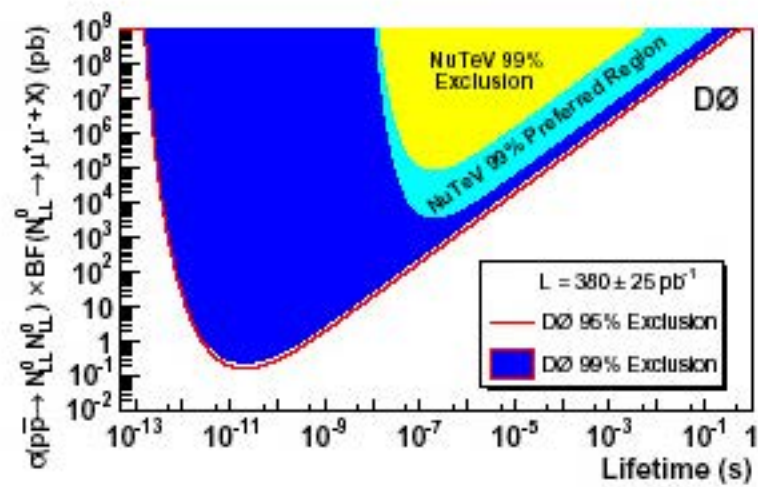


Figure 6: Limits on the cross-section times branching ratio for neutral, long-lived particles decaying to two muons as a function of the lifetime. The area above the (red) line is excluded at the 95% CL. The dark blue shaded region is a 99% CL from DØ. The yellow region shows the limit from NuTeV converted to  $p\bar{p}$  collisions at  $\sqrt{s} = 1.96$  TeV. The light blue region shows the area favored by a signal interpretation of NuTeV's result.

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