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SUSY Searches at the Tevatron

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Recent results of a variety of searches for Supersymmetry in the data collected by the CDF and D0 experiments at the Tevatron are presented. As no signal was found, limits on the signatures and models are derived.

Introduction

Supersymmetry searches are done at the Tevatron for a variety of models. The searches are developed starting with the high-pt objects reconstructed by the CDF and D0 detectors; for example leptons, photons, jets (including b-quark jets), and missing E_T. Theoretical input from models of Supersymmetry guides the development of analyses to look for signatures which follow from the Minimal Supersymmetric extension of the Standard Model (MSSM) or Gauge Mediated Supersymmetry Breaking (GMSB) models. R-Parity can be conserved or violated, leading to very different signatures. In addition, the high center-of-mass energy of the Tevatron allows production of heavier-than-threshold sparticles; the cascade decays of these sparticles to other supersymmetric and Standard Model particles leads to a variety of signatures. Here, only a few of the more recent analyses with the Run 1 dataset ($\sim 100\text{pb}^{-1}$ at $\sqrt{s}$=1.8 TeV) will be presented, along with a look ahead to what can be expected at Run 2.

Search for a Superlight Gravitino

In some GMSB models, the gravitino is the Lightest Supersymmetric Particle (LSP), and the other sparticles are much heavier, and inaccessible at the Tevatron. The production cross section of gravitino pairs is proportional to $1/M_{\tilde{G}}$, giving significant cross sections for gravitino masses less than 10^{-4}eV/c^2. In addition, the gravitino mass is proportional to F, the SUSY-breaking scale. The signature of this process is large missing E_T and high-E_T jets, and has been searched for in the CDF data [1]. After removing detector- and machine-related background, the missing E_T spectrum along with the expected Standard Model backgrounds are shown in Figure 1. The optimal region to search for new physics is where Missing $E_T > 200$GeV/c^2. No excess is found, and limits are set on the production cross section ($\sigma_{\tilde{G}\tilde{G}}$ for Missing$E_T > 200$GeV/c^2 < 93fb), the gravitino mass ($M_{\tilde{G}} > 1.2 \times 10^{-5}$eV/c^2), and the SUSY-breaking scale($\sqrt{F} > 221$ GeV).

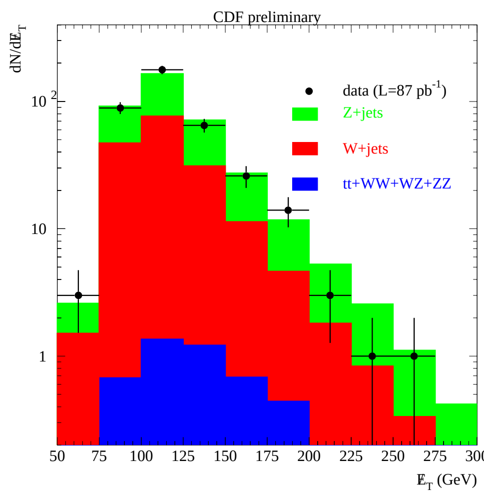

Figure 1: Spectrum of Missing E_T after all selection cuts except for Missing $E_T > 200$GeV/c^2 in the CDF search for superlight gravitinos [1]. The points indicate the data, and the solid colors show the Standard Model background prediction.

Stop Searches

Stop squarks can be lighter than the other squarks, and could be accessible at the Tevatron. Depending on the masses of other sparticles such as charginos, neutralinos, and sneutrinos, different signatures could arise from the decay of stops. An impressive list of possible decays of stop squarks has been examined, including $t \to \tilde{t}$, $\tilde{t} \to t$, $\tilde{t} \to c\tilde{\chi}_1^0$, $\tilde{t} \to b\tilde{\chi}^{\pm}$, and $\tilde{t} \to b\ell\tilde{\nu}$.

A new search for stops decaying to either $b\tilde{\chi}^{\pm}$ (where $\tilde{\chi}^{\pm} \to \ell\nu\tilde{\chi}_1^0$) or $b\ell\tilde{\nu}$, giving the same signature, has been performed by the CDF collaboration [2]. The latter mode can dominate if sneutrinos are light. This analysis looks for the pair production of stops, but only imposes the requirement that one of the stops decay as indicated. This allows the analysis to have a greater acceptance. No signal was found, and the exclusion is shown in Figure 2. Stop masses between 100 and 120 GeV/c^2 can be excluded for low sneutrino masses. With the larger dataset which will be available from the Tevatron's Run 2, greater sensitivity is possible. This result complements the other searches for stop squarks performed with the CDF and D0 Run 1 datasets.

Other searches for stop which have been performed at CDF and D0, and are discussed in more detail elsewhere, so will be only briefly summarized here. Searches for top decays to stop squarks have set limits on stops by looking at the kinematic differences between Standard Model top and Supersymmetric top decays([3]). Searches for charm jets along with missing E_T attempt to identify the stop decay $\tilde{t} \to c\tilde{\chi}_1^0$ [4,5]

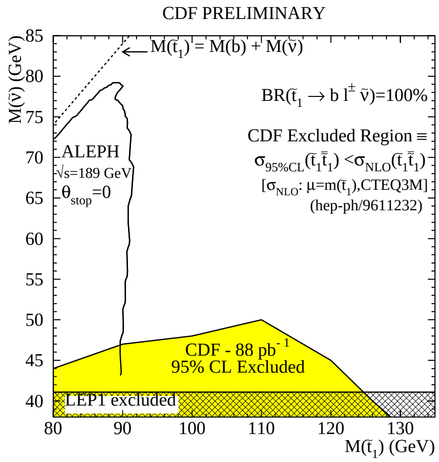

Figure 2: Exclusion from the search for $\tilde{\mathrm{t}} \to \mathrm{b}\ell\tilde{\nu}$, from CDF [2].

Searches for Supersymmetry with R-Parity Violation

Charginos and neutralinos can be produced at the Tevatron either directly, or indirectly as the product of cascade decays of squarks and gluinos. Signatures can be very distinctive, for example exhibiting several leptons or two leptons with the same charge. If R-Parity is conserved, missing transverse energy will also be part of the signature, due to the escape of the lightest neutralinos from the detector. If R-Parity is violated, a variety of signatures can appear. For example, single production of sparticles is allowed, or the lightest neutralino can decay. The signature of supersymmetry is determined by parameters $\lambda_{ijk}, \lambda^{'}_{ijk}, \lambda^{''}_{ijk}$ which appear in the supersymmetric Lagrangian. (The indices ijk indicate generations of leptons and quarks.) Typical searches at the Tevatron assume the dominance of the λ_{ijk} term which leads to leptonic decays of the lightest neutralino, giving multi-lepton events.

The D0 Collaboration recently finished an analysis which uses the R-Parity Conserving analysis for trileptons from chargino-neutralino production [6] and applies the selection to the case of R-Parity violating supersymmetry [7]. The analysis assumes λ_{122} or $\lambda_{121} > 10^{-4}$ and scans the SUSY parameter space for positive and negative values of μ, and high and low values of tanβ. For example, for the SUSY parameters $\mathrm{A}_0 = 0$, tanβ = 5, and $\mu < 0$, values of $m_{1/2} < 180$ are excluded for $\lambda_{121} > 10^{-4}$, as shown in Figure 3.

Additional searches for Supersymmetry with R-Parity violation producing multi-lepton signatures have been done at the Tevatron. The D0 Collaboration assumed the dominance of the λ'_{1jk} coupling, where j = 1,2 and k = 1,2,3, which gives a signature of events with dilectrons plus jets. For $\mathrm{A}_0 = 0$, $\mu < 0$, and tan$\beta = 2$, lower limits are set on the masses of squarks at 243 GeV/c^2 and gluinos at 227 GeV/c^2 [8]. The CDF Collaboration assumed the dominance of λ_{121}, which gives a signature of four leptons. In this scenario, for tan$\beta = 2$ and $\mu < 0$, lower limits of 350 GeV/c^2 on squarks and nearly 400 GeV/c^2 on gluinos are set [9].

Discovery Potential for Run 2

The Tevatron and the CDF and D0 detectors are currently undergoing a major upgrade, and will start taking data at $\sqrt{s} = 2$ TeV in the spring of 2001. The initial dataset will consist of at least 2 fb^{-1}, twenty times the amount of data collected in Run 1. The CDF and D0 Collaborations have studied the potential for the discovery of Supersymmetry with the Run 2 data, both with analyses that have been done with Run 1 data, where the discovery potential is

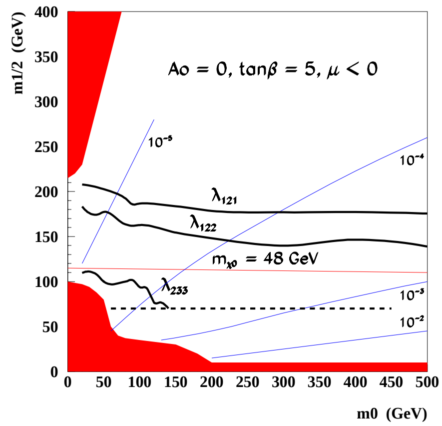

Figure 3: Exclusion limits obtained from the D0 trilepton search for R-Parity violating signatures [7].

significantly increased due to the larger dataset anticipated, and with new searches that require new detection techniques made possible by the upgraded detectors.

For example, the D0 detector can be effectively exploited for the detection of long-lived charged and stable particles [10]. Particles which decay within 0.1 to 10 cm of the interaction region can be detected through the secondary vertices observed using the silicon vertex detector. Charged particles which decay within 10 to 100 cm of the interaction region leave kinked tracks in the tracking chamber, and anomalous ionization energy (dE/dx) in the silicon detector. Particles decaying outside of the tracking chamber (100 to 200 cm of the interaction region) are detected by jet-like energy in the calorimeter and anomalous dE/dx. Particles which decay more than 200 cm from the interaction region give a signature of Missing E_T, as well as anomalous dE/dx if the particle is charged.

The most potentially difficult part of this search is triggering on the stable particles. The D0 analysis can trigger on stable charged particles using dE/dx, retaining a high efficiency for heavy slow-moving particles but low efficiency for minimum-ionizing particles.

Summary

The CDF and D0 Collaborations have performed extensive searches for evidence of Supersymmetry in the Run 1 dataset. No evidence has been found so far, and we are looking forward to the challenges and opportunites of Run 2.

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