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Contributed report: Probing non-universal gaugino masses – Prospects at the Tevatron

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Experiments at Fermilab Tevatron Run I [1] have obtained important bounds on the chargino–neutralino sector of the minimal supersymmetric extension of the standard model using the clean trilepton signal. However, the analyses used the universal gaugino mass hypothesis at the GUT scale (M_G) motivated by the minimal supergravity model (mSUGRA). On the other hand it is well-known that even within the supergravity framework, non-universal gaugino masses may naturally arise if non-minimal gauge kinetic functions [2] are allowed. Specific values of gaugino masses at M_G are somewhat model dependent. The main purpose of this work is to use the data from Tevatron Run I experiments to explore the possibility of constraining the chargino–neutralino sector of the MSSM without assuming gaugino mass universality. Rather than restricting ourselves to specific models, we shall focus our attention on the following generic hierarchies among the soft breaking parameters M_2 (the $SU(2)$ gaugino mass parameter), M_1 (the $U(1)$ gaugino mass parameter) and the Higgsino mass parameter (μ) at the weak scale. Each pattern leads to a qualitatively different signal. We believe that this classification would lead to a systematic analysis of Run II data without assuming gaugino mass unification.

(A) If $M_1 < M_2 \ll \mu$, the clean trilepton signal triggered by the decays $\widetilde{\chi}_1^{\pm} \to l^{\pm}\nu\widetilde{\chi}_1^0$ and $\widetilde{\chi}_2^0 \to l^+l^-\widetilde{\chi}_1^0$ ($l = e$ or μ) is the dominant one. Here $\widetilde{\chi}_1^{\pm}, \widetilde{\chi}_1^0$ and $\widetilde{\chi}_2^0$ are the lighter chargino (wino-like), the lightest neutralino (bino-like), assumed to be the lightest supersymmetric particle (LSP), and the second lightest neutralino (wino-like) respectively. For $M_2 \approx 2 \times M_1$, one regains the spectrum in the popular mSUGRA model with radiative electroweak symmetry breaking, which usually guarantees relatively large μ. If $M_2 \approx \mu$ both $\widetilde{\chi}_1^{\pm}$ and $\widetilde{\chi}_2^0$ have strong higgsino components, but the trilepton signal may still be sizeable.

(B) If $M_1 < \mu \lesssim M_2$, $\widetilde{\chi}_1^0$ is bino-like, $\widetilde{\chi}_2^0$ has a strong higgsino component and $\widetilde{\chi}_1^{\pm}$ is wino-like. In this scenario the loop-induced decay $\widetilde{\chi}_2^0 \to \gamma\widetilde{\chi}_1^0$ occurs with a large branching ratio (BR), spoiling the trilepton signal. The signature of $\widetilde{\chi}_1^{\pm} - \widetilde{\chi}_2^0$ production is a γ accompanied by standard model particles and large missing transverse energy.

(C) If $M_2 < M_1 \ll \mu$, $\widetilde{\chi}_1^{\pm}$ and $\widetilde{\chi}_1^0$ are wino-like and approximately degenerate. Here spectrum is similar to the one predicted by the AMSB model. Since the chargino decays almost invisibly, special search strategies are called for [3].

(D) If $\mu \ll M_1, M_2$, $\widetilde{\chi}_1^{\pm}, \widetilde{\chi}_1^0$ and $\widetilde{\chi}_2^0$ are approximately degenerate and higgsino-like. As in (C) special strategies for invisible/nearly invisible particles should be employed.

In this working group report we shall focus on scenario (A). The trilepton signal has the added advantage that it is independent of the gluino mass $m(\widetilde{g})$ and hence independent of additional assumptions about the $SU(3)$ gaugino sector.

The important parameters for the production of a $\widetilde{\chi}_1^{\pm}$–$\widetilde{\chi}_2^0$ pair at the Tevatron are M_2, μ, $\tan\beta$ and the masses of the L type squarks belonging to the first generation $m_{\tilde{q}_{\mathrm{L}}}$, where $q = u, d$. The squark masses in question can safely be assumed to be degenerate, as is guaranteed by the $SU(2)_{\mathrm{L}}$ symmetry, barring small calculable corrections due to $SU(2)$ breaking D-terms. The parameter M_1 hardly affects the production cross-section in scenario (A) as will be shown below.

It may be noted that the bulk of the LEP constraints on the electroweak gaugino sector arise due to negative results from chargino search. The chargino pair production cross-section at LEP is strongly suppressed for small sneutrino masses. The most conservative limits are, therefore, obtained for relatively light sleptons and sneutrinos.

Although the production cross-section at Tevatron is independent of slepton/sneutrino masses, the leptonic BR's of $\widetilde{\chi}_1^{\pm}$ and $\widetilde{\chi}_2^0$ depend on these masses. Since the BR's in question are relatively small for heavy slepton/sneutrinos, the conservative limits correspond to such choices. Hence the information from Tevatron and LEP play complementary roles.

Using the event generator PYTHIA [4] and the kinematical cuts used in the CDF paper [1], we have simulated the trilepton signal for Run I without assuming gaugino mass unification. For the purpose of illustration we present a subset of our results in table 1. The details will be presented elsewhere [5].

For the calculations in table 1 we have set $\mu = -400$ GeV, $\tan\beta = -6.0$ and $m_{\tilde{q}} = m_{\tilde{\ell}} = 1.5$ TeV. $m_{\widetilde{\chi}_1^{\pm}}$ is approximately fixed at a specific value using the parameter M_2 while the LSP mass is varied using the parameter M_1. The production cross-section is denoted by σ_p while BR is the branching ratio of the produced pair to decay into the clean trilepton channel.

Table 1.

$m_{\tilde{x}_1^+}$ (GeV)	$m_{\tilde{x}_1^0}$ (GeV)	σ_p (pb)	BR	Efficiency
77.23	50.85	5.41	0.0127	0.035
76.25	38.0	5.77	0.0128	0.076
77.02	31.0	5.54	0.0129	0.081

We have restricted ourselves to a relatively low value of tan β since large values of this parameter lead to light τ-sleptons and the final state is dominated by τ leptons instead of e or μ. It follows from table 1 that for a given chargino mass the production cross-section and the trilepton BR remain constant to a very good approximation for different choices of M_1 (or the $\widetilde{\chi}_1^0$ mass). The efficiency of the kinematical cuts on the other hand increases with lowering of M_1. Thus a lower limit on the mass of $\widetilde{\chi}_1^0$ as a function of $m_{\tilde{\chi}_1^\pm}$ is expected from the non-observation of any signal at Run I.

This limit may have important bearings on the viability of the LSP as the dark matter candidate. The current lower limit on $m_{\tilde{\chi}_1^0}$ from LEP [6] crucially hinges on the gaugino mass unification hypothesis since it essentially originates from the chargino mass limit. Thus it is worthwhile to re-examine the limit without assuming gaugino mass unification. The indirect limit on $m_{\tilde{\chi}_1^0}$ without gaugino mass unification is as low as 6 GeV [7]. It will also be interesting to see how far this limit can be strengthened by data from direct searches at Run I and Run II.

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