SUSY and non-SM Higgs Searches at the Tevatron

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We report on recent results on searches for non-standard model Higgs bosons and for supersymmetric partners of the standard-model particles. The Higgs searches are performed in the channels $\phi b(\bar{b}) \rightarrow b\bar{b}b(\bar{b})$ and $\phi \rightarrow \tau\tau$. Di- and trilepton final sates are studied in the context of gaugino searches. Squark and gluino searches are performed in final states containing at least two jets and a large missing transverse energy. Long-lived neutralinos are searched for by studying the timing of photons in the CDF electromagnetic calorimeter.

1 Non-standard model Higgs

The minimal supersymmetric extension of the standard model (MSSM) contains two Higgs doublets leading to 5 observable Higgs-bosons (h^0, H^0, A^0, $H^{\pm}$). For large values of the ratio of the vacuum expectation values of the two Higgs doublets $\tan\beta = v_u/v_d$ the production cross sections for neutral Higgs bosons are significantly increased. In addition the A-boson is nearly mass-degenerate with either the h-boson or the H-boson. Searches therefore take the contributions from all three neutral Higgs-bosons which will be denoted generically as ϕ in to consideration. The main decays in the relevant parameter range are $\phi \rightarrow \tau\tau$ (10%) and $\phi \rightarrow b\bar{b}$ (90%). For the latter decay only the associated production with one or two additional b quarks is considered in order to reduce backgrounds sufficiently. D0 studied in a 900 pb^{-1} the invariant dijet mass for events with 3 tagged b jets. The background shape was estimated from events with two tagged b jets and normalized outside the signal region. Depending on the $\tilde{t}$ *mix parameter* values of $\tan\beta < 50 - 60$ could be excluded for a 120 GeV Higgs boson. The decay $\phi \rightarrow \tau\tau$ was studied in the channels $e\mu$, $e\tau$, and $\mu\tau$ by CDF and the channel $\mu\tau$ by D0 (e and μ denote the leptonic τ-decays while τ denotes the hadronic decay). The visible mass was reconstructed as $m_{vis} = P_{\tau_1}^{vis} + P_{\tau_2}^{vis} + P_t^{miss}$ (see Fig. 1).

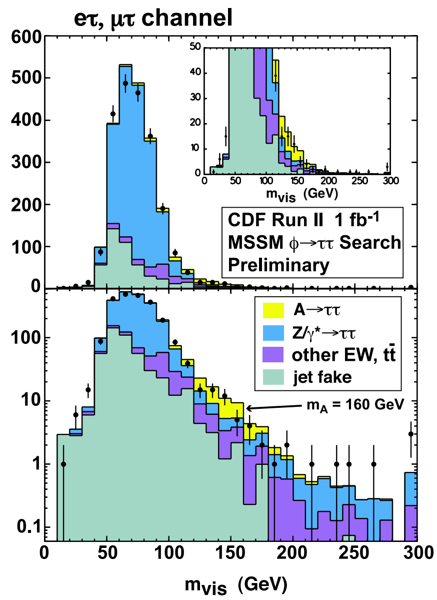

Figure 1: Visible mass for the CDF $\phi \rightarrow \tau\tau$ search

D0 did not see any excess while CDF observed a less than two sigma excess in the region expected from an 160 GeV Higgs in the $e\tau$ and $\mu\tau$ channels. The exclusion region as function of $\tan\beta$ and the Higgs mass have only a minimal dependence on the

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model parameters ($\tilde{t}$ mixing and $sign\ \mu$). They are shown for the m_h^{max} scenario in which the $\tilde{t}$ mixing is chosen to maximize the Higgs mass and for $\mu > 0$ in Fig. 2.

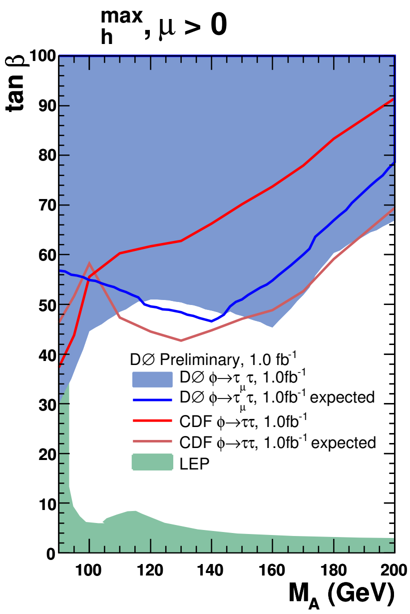

Figure 2: Exclusion region of the $\phi \to \tau\tau$ search

2 Search for Supersymmetric Particles

In the search for supersymmetry the lightest supersymmetric particle (LSP) plays an important role. Heavier supersymmetric particles will decay via decay chains into it. In the minimal supersymmetric model (replacing fields by superfields without introducing additional couplings) the LSP is stable because no decay in only non supersymmetric particle is allowed since replacing only one particle with its supersymmetric partner in Feynman diagrams included in the standard-model would violate angular momentum conservation by $\frac{1}{2}\hbar$. Cosmological constrains require the LSP to be neutral leading to signatures with large missing transverse energy due to the unobserved (only weakly interacting) LSP. In scenarios with a gravitino as LSP and a neutralino as next to lighted supersymmetric particle one would expect isolated photons and missing energy in the final state. If the LSP only weakly couples to other SUSY particles one would expect long lived particles.

Since the SUSY particles are pair produced and have cascade decays one can expect signals with multiple jets and/or leptons. Up to now no SUSY particles have been observed. Therefore they have to be heavy which might result in decay products with high transverse momentum, as long as the mass difference between the heavier SUSY particle and the LSP is not too small and the momentum is not shared by too many particles in the decay chain.

2.1 Trilepton Final States

Figure 3 shows one of the diagrams Feynman diagram of a chargino neutralino pair decaying into a final state of three leptons and missing transverse energy. The signal is in principal very clean however requiring both the chargino and the neutralino to decay leptonically leads to small branching ratios. In addition in the relevant parameter space the mass difference of the neutralino and the chargino to the LSP is only of about 50 GeV leading to low transverse momenta of the lowest p_t lepton. Fig. 4 shows a scenario ($m_0 = 72$ GeV,$m_{1/2} = 175$ GeV, $tan\beta = 3$, $A_0 = 0$ GeV and $\mu > 0$ with a slepton mass of $m_{\tilde{l}_R} = 104.4$ Gev slightly below the neutralino mass $m_{\tilde{\chi}_0^2} = 112.4$ GeV leading to a very low p_t lepton.

The selection efficiency has been significantly increased by only requiring 2 identified leptons. In order to reduce the background sufficiently two approaches have been followed. Either both leptons were required to have same signed electric charges or an additional isolated track without explicit lepton identification was required. In order to cover the

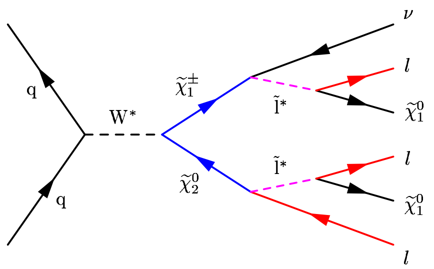

Figure 3: Feynman diagram of a trilepton final state

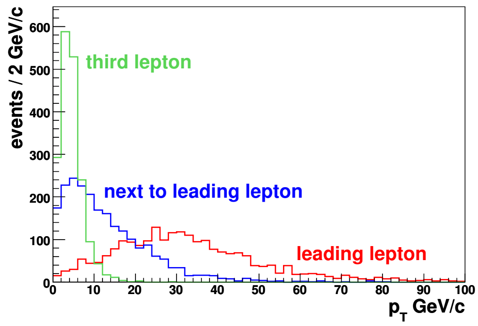

Figure 4: Transverse momentum of the three leptons at generator level

different combinations of final state leptons and different lepton trigger requirements CDF performed a total of 14 different analysis while D0 performed 6 analysis.

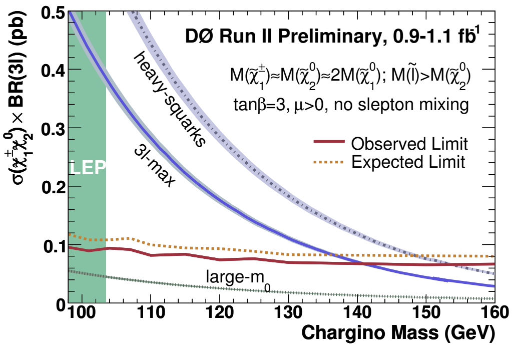

Figure 5: Limits and model predictions for $\sigma \times Br(3l)$

Limits on the cross section times branching ratio $\sigma \times Br(3l)$ have been compared with different mSUGRA inspired scenarios (see Fig.5). For a chargino mass of 140 GeV the observed 95 % CL limit of D0 on $\sigma \times Br(3l)$ is 0.07 pb^{-1} while the expected limit is 0.08 pb^{-1}. For CDF, using different model assumptions, the observed and expected limits are 0.2 pb^{-1} and 0.1 pb^{-1} respectively. In the *large-*m_0 scenario with large $\tilde{l}$ and $\tilde{q}$ the branching ratio into leptons is too small to exclude any chargino masses. On the other hand in the *3l-max* scenario with $M(\tilde{l}) \simeq M(\tilde{\chi}_1^\pm)$ the D0 experiment can exclude chargino masses below 140 GeV.

2.2 Search for Squarks and Gluinos

Scalar quarks and gluinos can be pair produced via the strong interaction. The decays $\tilde{q} \to q\tilde{\chi}_0^1$ and $\tilde{g} \to gq\tilde{\chi}_0^1$ lead to final states with large missing transverse energy and 2, 3, or 4 jets from the decays of $\tilde{q}\tilde{q}$, $\tilde{q}\tilde{g}$, or $\tilde{g}\tilde{g}$ respectively. The background can be reduced by cuts on the missing transverse energy, the sum of the transverse energies of the jets (e.g. $E_t^{mis} > 150$ GeV and $H_T = \Sigma E_T < 400$ GeV for the 3 jet analysis as shown in Fig.6), and the requirement that the missing energy does not point in the directions of the leading jets. Limits can be either given as functions of the squark and gluino mass or as function of the mSUGRA parameters as shown in Fig.7. For mSUGRA scenarios with $\tan\beta = 0$, $A_0 = 0$ and $\mu < 0$ squark masses below 375 GeV and gluon masses below 289 GeV can be excluded with 95 % CL.

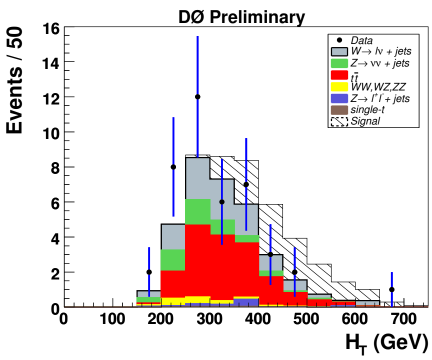

Figure 6: Sum of the transverse energies of the jets ($H_T = \Sigma_{jet} E_T$) for the 3 jet gluino and squark search.

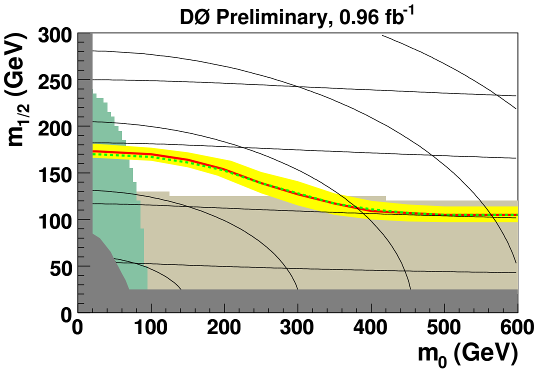

Figure 7: Limits on mSUGRA parameters. Values below the red line are excluded by the D0 squark and gluino search. The green and brown regions are excluded by LEP searches for sleptons and charginos respectively.

2.3 Long-lived Neutralinos

For neutralinos with lifetimes of order 5 ns the arrival time of the photons in the CDF calorimeter can be used to search for $\tilde{\chi}_1^0 \to \gamma \tilde{G}$. For a gauge mediated SUSY braking model (GMSB) with $M_{mess} = 2\Lambda$, $\tan\beta = 15$ $N_{mess} = 1$, $\mu > 0$, $m_{\tilde{\chi}_1^0} = 100$ GeV and $\tau_{\tilde{\chi}_1^0} = 5$ ns cross sections below 0.128 pb have been excluded by the CDF experiment with 95 % CL.

3 Conclusions

Due to the increased Higgs production cross section at large $\tan\beta$ searches for SUSY Higgs in $b\bar{b}$ and $\tau\tau$ final states have a large potential if SUSY at large $\tan\beta$ is realized.

SUSY searches in the trilepton final states for squarks and gluino decays and for long lived neutralinos have been discussed. In addition to these CDF and D0 performed many other searches like searches for GMSB signals with isolated photons and missing transverse energy, long lived charged particles, stopped gluinos, stop and sbottom quarks, R-parity violation SUSY signatures, and rare B decays. Current analysis are based on an integrated luminosity of about $1 fb^{-1}$. One can therefore expect either significant improvements of the limits or evidence for physics beyond the standard-model with increased statistics.

References

[1] Slides:
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