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Non-inclusive searches for squarks and gluinos at the Tevatron

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Abstract. Recent results from the CDF and DØ Collaborations on searches for squarks and gluinos at the Run II of the Fermilab Tevatron collider are presented. This review covers searches for final states involving specific mass hierarchies. The analysed datasets correspond to an integrated luminosity of 300-1000 pb^{-1} collected from proton anti-proton collisions at a center-of-mass energy of 1.96 TeV. No significant deviations from the Standard Model expectations are observed and limits on parameters of supersymmetry are set in generic MSSM and in specific mSUGRA scenarios.

1. Introduction

Supersymmetric models predict the emergence of new particles with a mass possibly within the reach of the Run II of the Fermilab Tevatron, which collides protons and anti-protons at a center-of-mass energy of 1.96 TeV. Regarding squarks and gluinos, direct searches performed by the CDF and DØ Collaborations can be separated into two types. On one hand, inclusive final states with jets and missing transverse energy ($\not\!\!E_T$) are focused on. This area is covered in [1]. On the other hand, dedicated searches aimed at specific mass hierarchies (generally due to the large mixing in the third generation of sfermions) are performed. They are described in the present review. In the following, R-parity conservation is assumed and emphasis is given on most recent results. Limits are given at the 95% confidence level.

2. Scalar top quark

At the Tevatron, two-body decays of the lightest scalar top (*e.g.*, $\tilde{t}_1 \to t\tilde{\chi}_1^0$ and $\tilde{t}_1 \to b\tilde{\chi}_1^+$) are kinematically difficult to reach and other decays are explored.

If the lightest sneutrino is the NLSP and the mass hierarchy is $m(\tilde{\chi}_1^+) > m(\tilde{t}_1) > m(\tilde{\nu}) > m(\tilde{\chi}_1^0)$, the stop three-body decay $\tilde{t}_1 \to b\ell\tilde{\nu}$ via a virtual $\tilde{\chi}_1^+$ dominates. DØ recently finalised analyses in the $\mu\mu$ and $e\mu$ final states with an integrated luminosity of approximately $\mathcal{L} = 400$ pb^{-1} [2]. In both channels, the two leptons are identified and the minimum lepton transverse momentum (p_T) requirements are low. In the $\mu\mu$ channel, background is efficiently rejected by selecting events with at least one b-tagged jet, where the tag is based on the displacement of the jet vertex relative to the event vertex. In the $e\mu$ channel, event jet activity is used as a discriminating variable to set the limits on the signal cross-section. In both final states, no evidence for $\tilde{t}_1$ pair production is observed. Channels are combined and an exclusion limit in the $\tilde{t}_1 - \tilde{\nu}$ plane is set (Fig. 1) assuming the branching fraction (BF) of the stop to $b\ell\nu\tilde{\chi}^0_1$ is 100%, and an equal BF to all lepton flavours.

If the lightest stop is the NLSP, its flavor-changing decay $\tilde{t}_1 \to c\tilde{\nu}^0_1$ dominates, leading to two c-jets and large $\not\!\!E_T$ final states. Past published results from CDF [3] ($\mathcal{L} = 295$ pb^{-1}) and DØ [4] ($\mathcal{L} = 360$ pb^{-1}) are improved by recent preliminary limits from DØ [5] set with an increased dataset of $\mathcal{L} = 995$ pb^{-1}. The event selection is similar to past analyses. It requires exactly two jets and large $\not\!\!E_T$. Vector boson production is rejected by applying a veto on isolated leptons and isolated tracks. Constraints in angular correlation between jets and $\not\!\!E_T$ remove events with mismeasured jets. Since c-quarks are produced, a loose heavy flavour tag is required on one of the jets (the light flavor jet efficiency is around 6%). The signal topology depends on the stop and $\tilde{\chi}^0_1$ masses and thus signal extraction is optimised per stop mass range using the scalar sum of the jet p_T, the $\not\!\!E_T$, and the azimuthal distributions of the jets and the $\not\!\!E_T$. Remaining background events are dominated by $W \to \ell\nu$ and $Z \to \nu\nu$ produced with additional light and heavy flavour quarks. Results are interpreted in the generic MSSM assuming BF($\tilde{t}_1 \to c\tilde{\chi}^0_1$)=100% (Fig. 2).

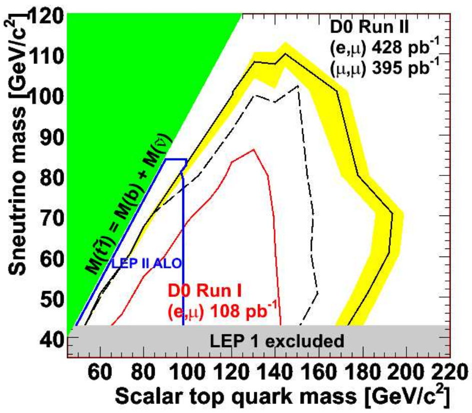

Figure 1. Exclusion limit in the $\tilde{t}_1$-$\tilde{\nu}$ mass plane from the DØ search for stop pairs decaying to two b-quarks, two leptons and $\not\!\!E_T$. The yellow band represents the lower and upper bounds of the signal cross-section variation.

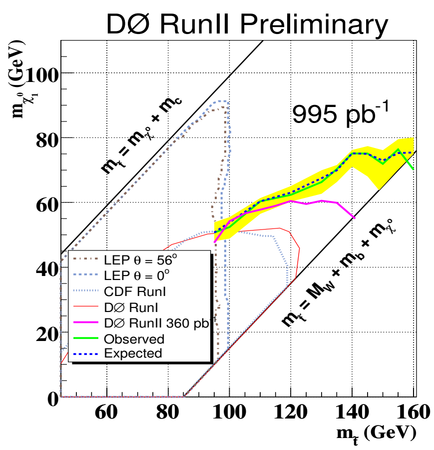

Figure 2. Exclusion domain in $\tilde{t}_1$-$\tilde{\chi}^0_1$ mass plane from the DØ search for stop pairs decaying to two c-quarks and $\not\!\!E_T$. The yellow band represents the theoretical uncertainties on the signal production cross-section. CDF has also published Run II limits, which are not shown in this plot.

3. Scalar bottom quark

The supersymmetric partner of the bottom quark could be the NLSP (*e.g.*, for high tanβ). In this case the sbottom decays to $b\tilde{\chi}^0_1$, leading to a final state with two acoplanar b-jets and $\not\!\!E_T$. Both CDF [3] and DØ [6] explored this final state with $\mathcal{L} \approx 300$ pb^{-1} each. The selection is similar to the search for stop pairs decaying to two c-quarks and $\not\!\!E_T$ discussed above, though the heavy flavour tagging requirement is tightened. Data and Standard Model expectations are consistent and limits in the $\tilde{b}_1$-$\tilde{\chi}^0_1$ mass plane are derived, assuming a generic MSSM with BF($\tilde{b}_1 \to b\tilde{\chi}^0_1$)=100%. As a result, a scalar bottom quark lighter than ≈ 220 GeV/c^2 is excluded for a neutralino mass up to ≈ 80 GeV/c^2. This improves by about 70 GeV/c^2 the previous limit on the sbottom mass set by CDF at the Run I.

CDF also searches for scalar bottom quarks produced in gluino decays with a b-quark. Events with large $\not\!\!E_T$ and two or more b-tagged jets are analysed in a dataset of $\mathcal{L} = 156$ pb^{-1} [7].

4. Light flavor squark

If the stau is the lightest of all sleptons (as in the case of high tanβ) and it is lighter than $\tilde{\chi}_1^+$ and $\tilde{\chi}_2^0$, then squarks decaying via a chargino or a neutralino lead to final states with two jets, large $\not\!\!E_T$ and one or two taus. This signature, not exploited before at the Tevatron for sypersymmetric particle searches, is explored by DØ with $\mathcal{L} = 960$ pb^{-1} [8]. Jets and $\not\!\!E_T$ selection is similar to the DØ inclusive search for squark and gluinos [9] using dijet and multijet final states, but no lepton veto is applied. In addition, one tau is identified in its hadronic decay mode. $\not\!\!E_T$ and the scalar sum of the two highest p_T jets and the tau are used to further disentangle signal from background events, which are dominated by $W \to \tau\nu$ decays, either directly produced or coming from top decays (Fig. 3). No evidence for new physics is found and preliminary lower limits on the squark mass up to 366 GeV/c^2 are derived in the framework of mSUGRA with parameters enhancing final states with taus ($A_0 = -2m_0$, tanβ = 15, $\mu < 0$), see Fig. 4. Limits are restricted to the region saturated with taus and no theoretical uncertainties on signal cross-section are included.

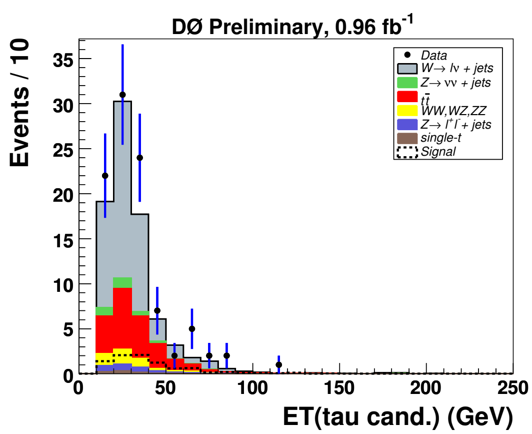

Figure 3. Transverse energy of tau candidates selected in the DØ search for squark pairs decaying to jets, taus and $\not\!\!E_T$.

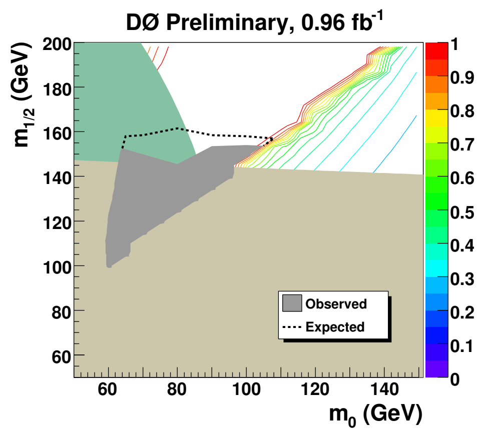

Figure 4. Exclusion domain in the m_0-$m_{1/2}$ plane set by the DØ search for squark pairs decaying to jets, taus and $\not\!\!E_T$.

5. Conclusion

Supersymmetric models predict a large variety of new particle mass hierarchies and couplings. CDF and DØ try not to leave any stone unturned. No evidence for new physics has been found yet, but the quest is not over and the powerful techniques developed to probe difficult final states at hadron colliders (like b-quark or tau identification) give promise for the future.

References

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