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Search for squarks and gluinos using data from the DØ detector at the Tevatron

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Abstract. A search for squarks and gluinos is performed in the topology of multijet events accompanied by large missing transverse energy in 2.1fb^{-1} of $p\bar{p}$ collision data collected using the DØ detector at the Fermilab Tevatron Collider at a center of mass energy of 1.96 TeV. About half of this dataset is specifically analysed for events involving at least one tau lepton decaying hadronically in addition. No deviation from the Standard Model expectation is observed and the analyses are combined to set limits on the squark and gluino masses and on parameters of minimal supergravity.

Keywords: Supersymmetry, mSUGRA, squarks, gluinos, taus, Fermilab, Tevatron, DØ
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INTRODUCTION

Squarks and gluinos interact strongly. If sufficiently light, they can be abundantly produced at hadron colliders. Their search at the Tevatron is thus particularly interesting and it is a major topic of the DØ physics program. The analyses covered here are the inclusive search for squarks and gluinos in the jets and missing transverse energy ($\not\!\!E_T$) topology using 2.1fb^{-1}of $p\bar{p}$ collision data collected by the DØ experiment at the Fermilab Tevatron Collider at a center of mass energy of 1.96 TeV [1] and the recently published analysis searching for squark pair production in events with jets, $\not\!\!E_T$ and at least one tau lepton decaying hadronically (τ_{had}) [2] using half the dataset of the former analyses. These searches are interpreted in the minimal supergravity model (mSUGRA) with R-parity conserved, leading to the typical high $\not\!\!E_T$ signature due to the lightest supersymmetric particle (LSP), the lightest neutralino $\tilde{\chi}_1^0$, escaping the detection. The DØ searches for third generation squarks were covered separately in this conference [3, 4]. In the following, modified frequentist limits are used. They are given at the 95% C.L.

INCLUSIVE SEARCHES FOR SQUARKS AND GLUINOS

Squarks generally decay into $q+\tilde{\chi}_1^0$ while gluinos lead to $q+q+\tilde{\chi}_1^0$. DØ developed three analyses, requiring at least two, three and four jets, respectively, and large $\not\!\!E_T$, and referred to as the "dijet", "3-jets" and "gluino" analyses. They cover the main production mechanisms over the mSUGRA parameter space ($\tilde{q}\bar{\tilde{q}}$ dominates at low m_0 while $\tilde{g}\tilde{g}$ dominates at high m_0, and $\tilde{q}\tilde{g}$ dominates at intermediate m_0).

Events must contain high p_T jets (35 GeV or 20 GeV for the fourth jet), and large $\not\!\!E_T$ ($>$ 40 GeV). The two highest p_T jets are required to be acoplanar and central. Electron and muon veto are applied to reject $W \to \ell\nu$ (possibly coming from top decays). The

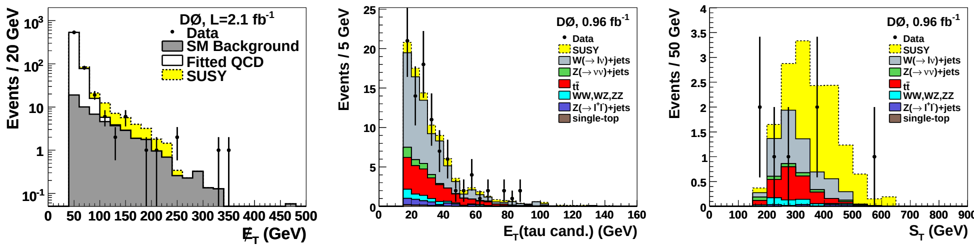

FIGURE 1. Left: in the "gluino" analysis, $\not{E}_T$ distribution after applying all analysis cuts but $\not{E}_T$. The signal refers to (m_0,$m_{1/2}$)=(500,110) GeV in the mSUGRA model with $\tan\beta$=3, A_0=0 and $\mu < 0$. Middle: in the "tau-dijet" analysis, distribution of the tau candidate p_T prior to the optimised $\not{E}_T$ and S_T cuts. The signal refers to (m_0,$m_{1/2}$)=(100,150) GeV in the mSUGRA model with $\tan\beta$=15, A_0=-2m_0 and $\mu < 0$. Right: in the "tau" analysis, distribution of S_T with all analysis requirements applied but S_T. The signal refers to (m_0,$m_{1/2}$)=(100,150) GeV in the mSUGRA model with $\tan\beta$=15, A_0=-2m_0 and $\mu < 0$.

multijet event background is rejected by requiring minimal opening angles between the jets and the $\not{E}_T$. The analyses are optimised by applying additional minimal requirements on H_T (the scalar sum of the jet p_T) and $\not{E}_T$. They are chosen to minimise the expected upper limit on the cross section in the absence of signal. The mSUGRA framework with $\tan\beta$=3, A_0=0 and $\mu < 0$ is considered. The optimised cuts are (H_T,$\not{E}_T$)=(325,225), (375,175) and (400,100) GeV for the "dijet", "3-jets" and "gluino" analyses respectively, leading to 11, 9 and 20 selected data events, in good agreement with the standard model (SM) expectations. The jet energy scale (JES) is the major systematic uncertainty (it reaches 15% on the SM background expectation). The multijet event contribution is estimated from data. It is the largest in the "gluino" analysis, with 1.4 ± 0.8 events. It is conservatively neglected in the limit setting. Figure 1 illustrates the $\not{E}_T$ distribution with the multijet event contribution in the "gluino" analysis.

The three analyses are further combined with seven independent channels and exclusion regions are derived, see Fig. 2. The theoretical uncertainty on the signal cross section, coming from the parton distribution function (PDF) (15-60%) and the renormalisation and factorisation scale (15-20%) are translated into an error band on the excluded region, defining conservative, nominal and maximal limits. Under the nominal hypothesis, the observed (expected) limit on the squark mass are 392 (391) GeV and they are 327 (332) GeV on the gluino mass. Interpreted in the mSUGRA parameter space, the preliminary limits from LEP2 chargino and slepton searches are well improved.

SQUARK PRODUCTION SEARCH INTO TAU FINAL STATES

If the slepton mass matrix exhibits a large mixing, the lightest stau ($\tilde{\tau}_1$) could be the lightest of all sleptons and it could be the NLSP. In this case, the lightest chargino ($\tilde{\chi}_1^{\pm}$) and the second lightest neutralino ($\tilde{\chi}_2^0$) decay exclusively to $\tilde{\tau}_1$ followed by $\tilde{\tau}_1 \to \tau\tilde{\chi}_1^0$. In this region (referred to as the "tau corridor"), $p\bar{p} \to \tilde{q}_R\tilde{q}_L$ dominates and $\tilde{q}_R$ decay to $q+\tilde{\chi}_1^0$ while $\tilde{q}_L$ decay to $q+\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0$, leading to final states with jets, one or two taus and undetected particles. Build on the inclusive search for squarks and gluinos strategy, DØ developed specific analyses for events with at least two jets, at least one τ_{had} and $\not{E}_T$.

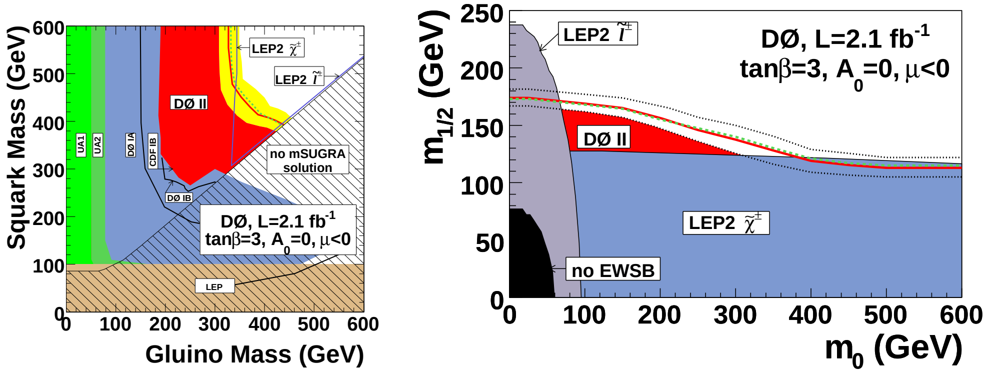

FIGURE 2. Excluded regions set by direct searches in the mSUGRA framework with $\tan\beta$=3, A_0=0 and $\mu < 0$, in the gluino and squark mass plane on the left, and in the m_0-$m_{1/2}$ plane on the right. The dark area corresponds to the region excluded by the combination of the "dijet", "3-jets" and "gluino" analyses in the most conservative hypothesis. The adjoining bands correspond to the theoretical error on the signal cross section. The middle plain and dashed lines represent, respectively, the observed and expected limits in the nominal hypothesis.

The jets and $\not{E}_T$ selections of the "dijet" and "3-jets" analyses prior to the optimisations are applied, with $\not{E}_T > 75$ GeV but no lepton veto. In addition, a high p_T (> 15 GeV) τ_{had} is selected. The tau candidate is separated in space from the two leading p_T jets. Neural net techniques are used to efficiently reject ordinary jets from quarks and gluons, as well as electrons, mimicking τ_{had}. Muons faking tau candidates are rejected using E/p. Events selected by either of these two streams, called "tau-dijet" and "tau-multijet", are kept. This selection is referred to as the "tau" analysis. The analysis is optimised by applying additional cuts on $\not{E}_T$ and S_T, the scalar sum of the two leading jet p_T and the tau candidate p_T, which characterises the signal. The optimised cuts are (S_T,$\not{E}_T$)=(325,175) GeV. Three data events are selected, in agreement with the SM expectation. The multijet event contribution, estimated from data, is negligible. Systematic errors are lead by the JES uncertainties. Fig. 1 illustrates the tau candidate p_T and S_T.

The "tau" analysis results are interpreted in term of exclusion in mSUGRA with $\tan\beta$=15, A_0=-2m_0 and $\mu < 0$, a model favoring final state with taus. Limits are extracted only in the "tau corridor", see Fig. 3. The sensitivity of this analysis exceeds the preliminary LEP2 limits from chargino and slepton searches. It is kinematically limited by squark masses, and the region where the stau is a few GeV lighter than the $\tilde{\chi}_1^+$ (or the $\tilde{\chi}_2^0$), along the high m_0 border of the "tau corridor", is covered. It completes the direct search for chargino-neutralino production which is not sensitive to this mass configuration. The inclusive analyses do not reject hadronically decaying taus. To gain in sensitivity on the present signature, the "dijet", "3-jets" and "tau" analyses are combined with 10 independent channels. Results are interpreted within the same model, as shown in Fig. 3. In the nominal signal cross section hypothesis, squark masses are excluded up to 410 GeV. Although the "tau" analysis is performed on about half the size of the "dijet" and "3-jets" dataset, the relative gain in the production cross section is 11% if the "tau" analysis is included in the combination, see Fig. 3. This gain reaches 33% if datasets of equal integrated luminosity are analysed by each analysis.

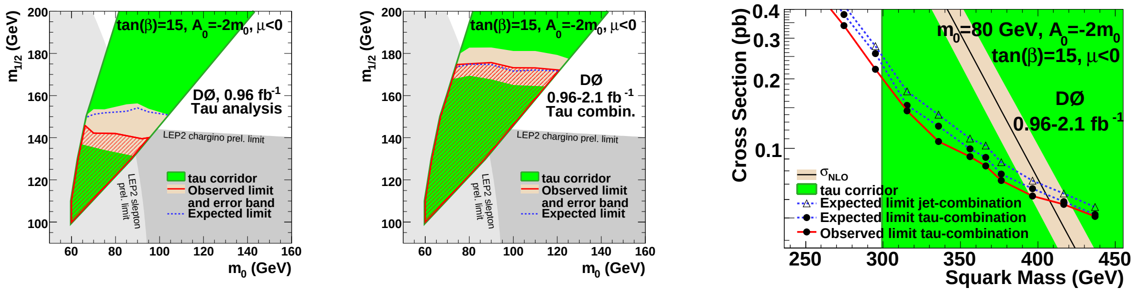

FIGURE 3. In mSUGRA with $\tan\beta$=15, A_0=-2m_0 and $\mu < 0$, left: in the m_0-$m_{1/2}$ plane, expected and observed limits (with one standard deviation error band) set by the "tau" analysis derived in the "tau corridor" only; middle: same as the left drawing for the combination of the "tau", "dijet" and "3-jets" analyses; right: observed and expected upper limit on squark and gluino production cross sections with the combination of the "tau", "dijet" and "3-jets" analyses (labeled "tau-combination") for m_0=80 GeV. The expected cross section upper limit from the "dijet" and "3-jets" analysis combination alone is also displayed (labeled "jet-combination").

SUMMARY

The inclusive searches for squarks and gluinos pursued by the DØ collaboration set stringent limits on the squark and gluino masses. However, SUSY could be hiding in very special corner of the phase space. In the most promising examples, taus play a important role and DØ explores this scenario with a dedicated analysis. The highest sensitivity is obtained by combining the dedicated analysis and the inclusive ones, and no significant deviation form the SM has been observed in final states including taus. Nevertheless, the "tau" analysis is crucial to get insight of any new phenomena that could be soon discovered at the Tevatron or at the LHC.

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