Squarks and gluino searches at the Tevatron

P. Gris

Squarks and gluinos searches at the TeVatron

Philippe Gris[1]
on behalf on the CDF and D0 collaborations

1- Laboratoire de Physique Corpusculaire - IN2P3/CNRS
24 avenue des Landais - 63177 Aubière cedex - France

A search for squarks and gluinos performed by the CDF and DØ collaborations is presented. The sample taken during the RunII of the Fermilab TeVatron collider at $\sqrt{s} = 1.96$ TeV is used.

Supersymmetry (SUSY) is one of the most promising ways to solve crucial problems of the Standard Model (SM). This spacetime symmetry links bosons to fermions by introducing supersymmetric partners (sparticles) to all SM particles: squarks and gluinos are SUSY partners of quarks and gluons. The mass difference between the squark mass eigenstates depend on the mass of the corresponding quark. Hence squarks are (to a good approximation) mass degenerate for the two first generations whereas a (potentially) large mixing may appear for the third family, leading to a light stop. The former case corresponds to squarks and gluinos searches whereas dedicated searches for stop are performed for the latter.

1 Squarks and gluinos searches

At the TeVatron, the production cross section of squarks and gluinos is of the order of few pb. Searches have been performed in the mSUGRA model with the lightest neutralino $\tilde{\chi}_1^0$ as the lightest supersymmetric particle (LSP). Three regimes may be distinguished leading to three different analyses (Tab. 1). All squark species were considered except the stop (CDF and DØ) and the sbottom (CDF). The triggers retained were dijet+$\not\!\!E_T$ and multijet+$\not\!\!E_T$.

Regime	main production	decay	signature
$m_{\tilde{q}} << m_{\tilde{g}}$	$\tilde{q}\tilde{q}$	$\tilde{q} \to q\tilde{\chi}_1^0$	2 jets+$\not\!\!E_T$ "dijet" analysis
$m_{\tilde{q}} \sim m_{\tilde{g}}$	$\tilde{q}\tilde{g}$	$\tilde{q} \to q\tilde{\chi}_1^0$ $\tilde{g} \to q\bar{q}\tilde{\chi}_1^0$	at least 3 jets+$\not\!\!E_T$ "3 jets" analysis
$m_{\tilde{g}} << m_{\tilde{q}}$	$\tilde{g}\tilde{g}$	$\tilde{g} \to q\bar{q}\tilde{\chi}_1^0$	n(≥ 4) jets+$\not\!\!E_T$ "gluino" analysis

Table 1: Final states considered in the squark and gluino searches by CDF and DØ.

The main background was composed of two parts: SM processes (W/Z +jets, dibosons, $t\bar{t}$), estimated from Monte-Carlo simulations, and the instrumental background (mismeasured jets), evaluated from data. Selections on $\not\!\!E_T$, jets requirements and lepton vetos were made at the first stages of the analyses, followed by specific cuts for each final state. The ultimate selection was performed on $\not\!\!E_T$ and H_T (defined as the p_T sum of the jets). The cut values were rather different for CDF and DØ. A good agreement was observed between data and MC expectation (Table 2) in a sample of 2 fb^{-1}. The main systematics uncertainties considered were: the Jet Energy scale (JES)(6-15% DØ, 15-30% CDF), the background normalization (15% DØ, 2-10% CDF), the luminosity (6%) and the ISR/FSR (6% DØ, 3-8% CDF). These uncertainties were combined to the statistical ones to draw limits in the plane ($m_{\tilde{q}}$,$m_{\tilde{g}}$) (Fig. 1). For $tan\beta$= 3, $A_0 = 0$, and $\mu < 0$, squark masses lower than 392 GeV/c^2 and gluino mass lower than 327 GeV/c^2 have been excluded at 95% C.L. by DØ [2]. These values decrease to 379 GeV/c^2 and 308 GeV/c^2 for squarks and gluino respectively if theoretical uncertainties related to the Parton Distribution Function (PDF's) choice and to the renormalisation and factorisation scales are included. CDF has obtained similar results: for $tan\beta$= 5, $A_0 = 0$, and $\mu < 0$, squark masses lower than 378 GeV/c^2 and gluino mass lower than 280 GeV/c^2 have been excluded at 95% C.L. These limits include the theoretical uncertainties. CDF and DØ results are the best constraints to date on the squarks and gluino masses.

In some region of the SUSY parameter space, squarks may decay to the lightest chargino $\tilde{\chi}_1^{\pm}$ or the second neutralino $\tilde{\chi}_2^0$, leading to final states with leptons. For high $tan\beta$ values, the stau $\tilde{\tau}_1$ may be the lightest slepton, and squark production dominates. Final states wit τ's are then favoured. A search for squarks (stop excepted) with τ's in the final state has been performed by DØ, in a 0.96 pb^{-1} data sample. Acoplanar dijets and multijets triggers were used by two analyses which were then ored after optimisation. Events were selected on the basis of their $\not\!\!E_T$ values, and two jets were to be present. Suitable angular cuts were applied to remove part of the instrumental background. At least one hadronic τ (in one of the mode: $\pi^{\pm}\nu_\tau$, $\pi^{\pm}\pi^0\nu_\tau$, $\pi^{\pm}\pi^{\pm}\pi^{\pm}(\pi^0)\nu_\tau$) was requested. The final optimisation was performed with two variables: sum of the transverse energy of the leading τ and the jets, and on the $\not\!\!E_T$. A good agreement between data and SM expectations has been interpreted as a limit in the plane (m_0, $m_{1/2}$) [3].

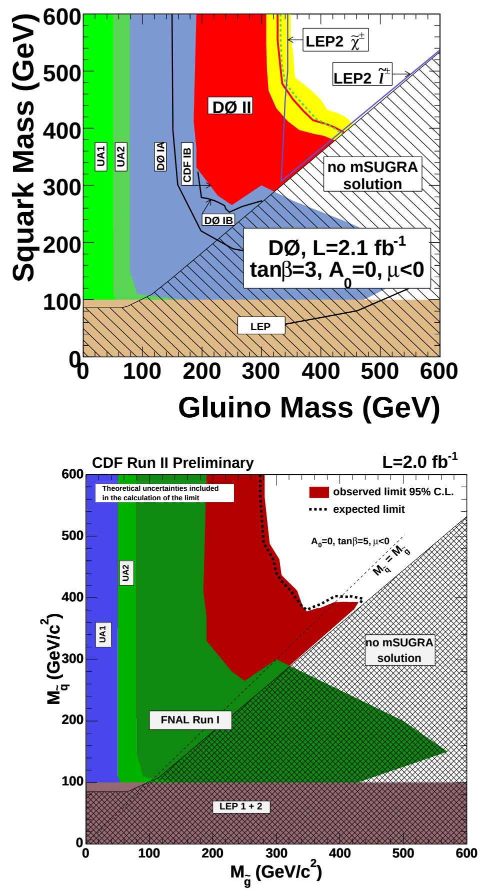


Figure 1: Limits on squark and gluino masses for DØ (top) and CDF (bottom).

For high $tan\beta$ values, the sbottom $\tilde{b}_1$ may be light. The $\tilde{g}\tilde{g}$ pair production cross section is quite high ($\sigma_{\tilde{g}\tilde{g}} \simeq 10\ \sigma_{\tilde{b}_1\tilde{b}_1}$) if $\tilde{b}_1$ and $\tilde{g}$ are mass degenerate. In this configuration, the final state resulting from the gluino pair production $\tilde{g}\tilde{g} \rightarrow \tilde{b}_1\tilde{b}_1\bar{\tilde{b}}_1\bar{\tilde{b}}_1 \rightarrow b\bar{b}b\bar{b}\ \tilde{\chi}_1^0\tilde{\chi}_1^0\tilde{\chi}_1^0\tilde{\chi}_1^0$ is comprised of 4 bjets+$\not\!\!E_T$($\tilde{\chi}_1^0$ LSP). CDF has searched this signature in a data sample of 156 pb^{-1}. After selecting the events with a jets+$\not\!\!E_T$ trigger, standard cuts have been applied to remove the background(W/Z+jets, $t\bar{t}$, multijets): $\not\!\!E_T > 80$ GeV, $\Delta\phi(\not\!\!E_T, jets) > 2\pi/9$.

Events with at least three jets were selected and at least two b-identified. 4 events remained in data whereas 2.6±0.7 were expected. A limit in the plane $(m_{\tilde{g}}, m_{\tilde{b}_1})$ has thus been estimated (Fig. 2). Systematic uncertainties (JES, luminosity, b-tagging efficiency and rate, cross sections) were taken into account. A gluino mass lower than 280 GeV/c^2 has been excluded for a sbottom mass of 230 GeV/c^2 [4].

2 Stop searches

	dijet		3 jets		gluino	
DØ	$H_T>$ 330 $\not\!\!E_T>$225		$H_T>$375 $\not\!\!E_T>$175		$H_T>$ 400 $\not\!\!E_T>$100	
	11	11.1±1.2	9	10.7±0.9	20	17.7±1.1
CDF	$H_T>$ 330 $\not\!\!E_T>$180		$H_T>$330 $\not\!\!E_T>$120		$H_T>$ 280 $\not\!\!E_T>$90	
	18	16±5	38	37±12	45	47±17

Table 2: Final selections for the squarks and gluino searches.

At the TeVatron, scalar tops are pair produced through gluon-gluon fusion or $q\bar{q}$ annihilation. For a stop mass of 100 (160) GeV/c^2, 9000 (1000) events are expected at $\sqrt{s}$ = 1.96 TeV.

The number of possible stop decays may be numerous, depending on the model under consideration. Two channels were considered at the TeVatron: $\tilde{t}_1 \rightarrow c\tilde{\chi}_1^0$ and $\tilde{t}_1 \rightarrow bl\tilde{\nu}_l$.

The $\tilde{t}_1 \rightarrow c\tilde{\chi}_1^0$ decay leads to a final state with two acoplanar jets and $\not\!\!E_T$ coming mainly from undetected $\tilde{\chi}_1^0$-LSP. DØ and CDF studied this signature in data sample of a luminosity of 995 pb^{-1} and 295 pb^{-1} respectively. The jets+$\not\!\!E_T$ trigger was used. The search strategy involved three steps which include the application of the selection criteria on kinematical variables, heavy flavor (HF) tagging and optimization of the final selection depending on the $\tilde{t}_1$ and $\tilde{\chi}_1^0$ masses. Fifteen selection criteria are applied to remove the multijet and the W+jets backgrounds. At the final stage of the analysis, additional criteria on three kinematic variables: $\not\!\!E_T$, S=$\Delta\phi_{min} + \Delta\phi_{max}$ ($\Delta\phi_{min}$($\Delta\phi_{max}$) is the smallest(largest) azimuthal separation between a jet and $\not\!\!E_T$), and H_T (scalar sum of the p_T of all jets), are optimized by maximizing the expected lower limit on the neutralino mass for a given $m_{\tilde{t}_1}$. Systematic uncertainties, evaluated for each $\tilde{t}_1$ and $\tilde{\chi}_1^0$ mass combination, included jet energy scale (1.7-2%), jet energy resolution (1%), trigger (6%), scale factor(5%), HF tagging (3-4%) and the normalization of the background (10%). A good agreement has been observed between data and SM expectation. A limit has been drawn in the plane ($m_{\tilde{t}_1}$,$m_{\tilde{\chi}_1^0}$) assuming that $\tilde{t}_1$ decays into a charm quark and a neutralino with a 100% branching ratio. The largest stop mass excluded is 155 GeV/c^2, for a neutralino mass of 70 GeV/c^2 (Fig. 3)[5].

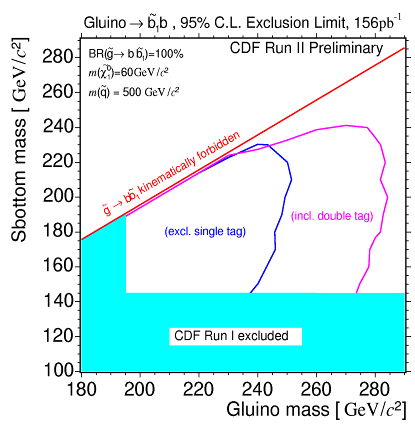


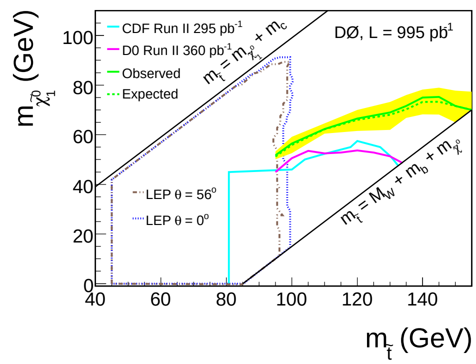
Figure 2: CDF limit in the gluino decaying to sbottom search.

In the $\tilde{t}_1 \rightarrow bl\tilde{\nu}_l$ case, $\tilde{\nu}_l$ is considered to be the LSP. The most promising final state is

$\tilde{t}_1\bar{\tilde{t}}_1 \to b\bar{b}e^{\pm}\mu^{\pm}\tilde{\nu}_e\tilde{\nu}_\mu$: the cross section times the branching ratio is twice the one of the same flavor case, and the SM background is also lower. The signal characteristics (lepton or b-jet p_T 's, $\not{E}_T$ spectrum) depend both on the stop mass and on the difference between the stop mass and the sneutrino mass $\Delta m = m_{\tilde{t}_1} - m_{\tilde{\nu}}$: the p_T 's decrease with Δm . For a given Δm , $\not{E}_T$ values increase with the stop mass. For a stop mass, $\not{E}_T$ values increase with Δm . A search for $\tilde{t}_1\bar{\tilde{t}}_1 \to b\bar{b}e^{\pm}\mu^{\pm}\tilde{\nu}_e\tilde{\nu}_\mu$ has been performed by DØ in a 1 fb^{-1}data sample. A leptonic trigger (electron+muon) has been used. The SM background was composed of $Z/\gamma^* \to \tau^+\tau^-$, multijets, WW and $t\bar{t}$. Events were selected with the following criteria: one electron and one muon with p_T bigger than 15 GeV/c, $\not{E}_T$ bigger than 30 GeV. Additional cuts were applied to remove Drell-Yan and instrumental background events. After the last selection, 61 events survived in data whereas 64±4 were expected (mostly WW and $t\bar{t}$ events). Limits were drawn in the plane ($m_{\tilde{t}_1}$,$m_{\tilde{\nu}}$) assuming that the stop decays to $bl\tilde{\nu}_l$ with a 100% branching ratio. A stop mass of 175 GeV/c^2 has been excluded if $m_{\tilde{\nu}}$= 45 GeV/c^2(Fig. 3).

3 Conclusion

The most constraining direct limits on squark and gluino masses to date have been obtained at the TeVatron: squark masses lower than 392 GeV/c^2 and gluino mass lower than 327 GeV/c^2 have been excluded at 95% C.L. for $tan\beta$= 3, $A_0 = 0$, and $\mu < 0$. Stop pair production has been searched in the $c\tilde{\chi}_1^0$ and $bl\tilde{\nu}_l$ channels. No excess with respect to the Standard Model expectations has been observed and mass regions have been excluded. CDF and DØ have performed an impressive set of SUSY research and further information may be found on the public web pages of the two experiments [6].



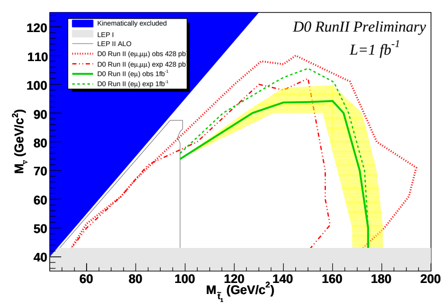


Figure 3: Stop limits for the $c\tilde{\chi}_1^0$ case (top) and the $bl\tilde{\nu}_l$ analysis (bottom).

Acknowledgement

Special thanks to my colleagues from CDF and DØ for providing the results. I also thank the organizers of the conference for their hospitality.

References

[1] Slides: http://indico.cern.ch/getFile.py/access?contribId=73&sessionId=15&resId=0&materialId=slides&confId=24657

[2] V.M. Abazov *et al.*, Phys. Lett. B **660** 449 (2008).

[3] http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/NP/N58/

[4] A. Ambulencia *et al.*, Phys. Rev. Lett. **96** 171802 (2006).

[5] V.M. Abazov *et al.*, FERMILAB-PUB-08-063E, submitted to Phys. Lett. B.

[6] http://www-d0.fnal.gov/Run2Physics/WWW/results/np.htm
http://www-cdf.fnal.gov/physics/exotic/exotic.html