IL NUOVO CIMENTO Vol. 32 C, N. 3-4 Maggio-Agosto 2009
DOI 10.1393/ncc/i2009-10481-9

Colloquia: IFAE 2009

Looking for SUSY at the Tevatron

A. Canepa
TRIUMF - Vancouver, BC, Canada

(ricevuto il 19 Settembre 2009; pubblicato online il 24 Novembre 2009)

Summary. — The latest results of searches for Supersymmetry in up to 4 fb^{-1} of proton-antiproton collisions produced at the Tevatron and analyzed by the CDF and D0 Collaborations are reported.

PACS 12.60.Jv – Supersymmetric models.
PACS 13.35.Hb – Decays of heavy neutrinos.
PACS 14.80.Ly – Supersymmetric partners of known particles.

1. – Introduction

Supersymmetry (SUSY) [1] is one of the most promising theories for physics beyond the Standard Model (SM) [2] as it provides a solution to the hierarchy problem and leads to unification of the gauge interactions; if a newly introduced parity, called R-parity and defined as $P_R = (-1)^{3(B-L)+2s}$, is conserved, SUSY also provides an excellent candidate for Dark Matter. In Supersymmetry, each SM particle acquires partners with same quantum numbers but spin differing by $\frac{1}{2}$. Several SUSY breaking scenarios are proposed to explain the non-observation of sparticles with the same mass as their SM partners. Among others, mSUGRA is a favored one. Its phenomenology depends on the sparticle masses and on the ratio of the expectation values of the two Higgs doublets of the theory, $\tan\beta$. For large values of $\tan\beta$ couplings to the third generation are enhanced.

2. – Squark and gluino

Light squarks and gluinos are produced in pair if P_R is conserved and subsequentely decay as $\tilde{g} \to q\tilde{q}$ and $\tilde{q} \to q\tilde{\chi}_1^0$. The signature of the process is characterized by large transverse missing energy due to the stable neutralino escaping detection. Depending on the mass hierarchy, the final state will contain at least 2 jets if $m_{\tilde{q}} < m_{\tilde{g}}$, at least 3 jets if $m_{\tilde{q}} \sim m_{\tilde{g}}$ and at least 4 four jets for $m_{\tilde{q}} > m_{\tilde{g}}$. The results of the CDF [3] and D0 [4] searches, optimized in the three scenarios and carried out in $\sim 2\,\text{fb}^{-1}$ of Run II data, are consistent with the SM expectations. Limits on the mass of the squark and gluino are set in the mSUGRA scenario with the assumption of mass degeneracy of the squarks (fig. 1).

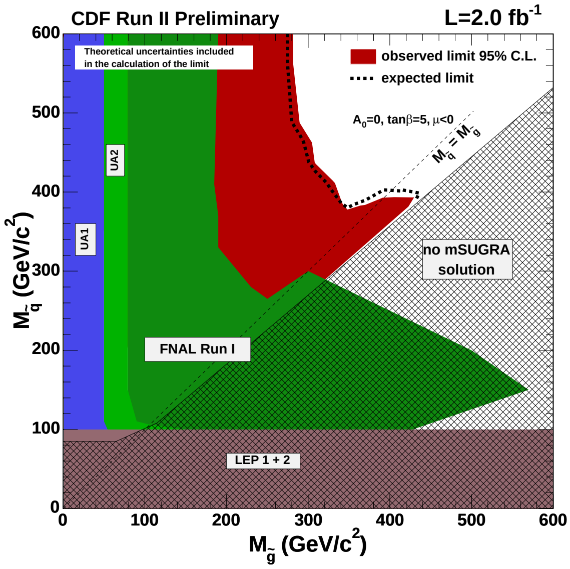

Fig. 1. – Exclusion plane for squark and gluino masses at 95% CL.

Production of sbottom and stop is not included in the current analyses. D0 extended the search to final states with $\tilde{\tau}$s to probe squark pair production with $\tilde{q} \to q\tilde{\chi}_1^{\pm} \to q\tilde{\tau}_1\nu$ in $\sim 1\,\text{fb}^{-1}$ [5].

3. – Stops and sbottoms

Pair productions of gluinos with $\tilde{g} \to b\tilde{b}$ are predicted in scenarios with large values of $\tan\beta$ and lead to final states with 4 b-jets and large missing transverse energy. The CDF search [6] is optmized depending on the mass difference between the gluino and the sbottom for neutralino mass of $60\,\text{GeV}/c^2$ and light squark mass of $500\,\text{GeV}/c^2$. Dedicated Neural Networks are exploited to enhance the sensitivity. No excess with respect to the SM expectation is observed in $2.5\,\text{fb}^{-1}$ and limits on the gluino and sbottom mass are set with the assumption of $BR(\tilde{g} \to b\tilde{b}) = 100\%$ and $BR(\tilde{b} \to b\tilde{\chi}_1^0) = 100\%$ (fig. 2). CDF and D0 searched for the pair production of scalar top quarks via their decay channel $\tilde{t_1} \to b\tilde{\chi}_1^{\pm}$, in the di-lepton ($2.7\,\text{fb}^{-1}$ [8]) and lepton-jet ($0.9\,\text{fb}^{-1}$ [7]) final state, respectively. A kinematic fitter is used to reconstruct the objects to a SM $t\bar{t}$ hypothesis. The signal is extracted from the background using a likelihood ratio fit on the combination of the reconstructed stop mass template by CDF and exploiting a multivariate likelihood discriminant by D0. The observations agree with the predictions and limits on the stop mass as a function of the neutralino mass are set depending on the assumed branching ratio of the chargino (fig. 3).

4. – Charginos and neutralinos

Charginos and neutralinos are pair produced and subsequentally can decay as $\tilde{\chi}_1^{\pm} \to \ell\nu\tilde{\chi}_1^0$ and $\tilde{\chi}_2^0 \to \ell\ell\tilde{\chi}_1^0$. The final state will therefore be characterized by large missing transverse energy and three leptons. A cut-based analysis is sensitive to this low back-

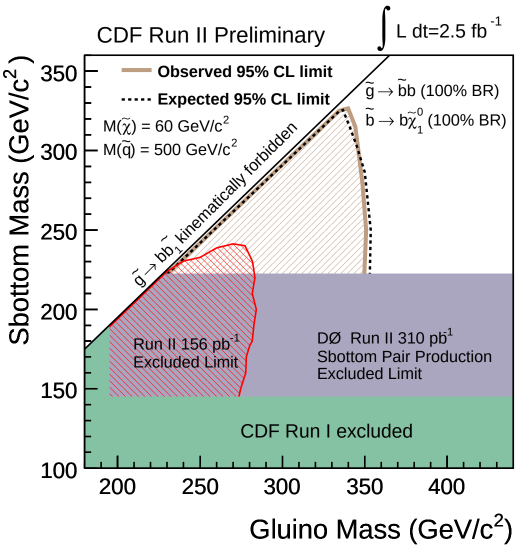

Fig. 2. – Exclusion plane for sbottom and gluino masses at 95% CL.

ground signature and carried out by the CDF [9] and D0 [10] Collaborations on $2.0\,\text{fb}^{-1}$ and $2.3\,\text{fb}^{-1}$ of data, respectively. Agreement is found between the expectations and the observations and limits are set in the plane $m_{\frac{1}{2}}$ (unified gaugino mass at the GUT scale) and m_0 (unified sfermion mass at the GUT scale) for $\tan\beta = 3$ (fig. 4). D0 excludes values of $\tan\beta$ below 10 for a chargino mass of $130\,\text{GeV}/c^2$ (fig. 5).

5. – Higgs sector

The minimal supersymmetric SM (MSSM) has an enlarged Higgs sector including two charged $H^\pm$; one CP-odd neutral A; and two CP-even neutrals H; h_0. For large $\tan\beta$

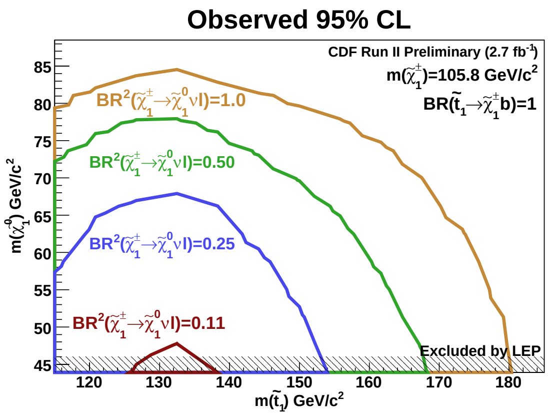

Fig. 3. – Exclusion plane for neutralino and stop masses at 95% CL. We assume electrons, muons and taus all equally contribute to the dilepton final state.

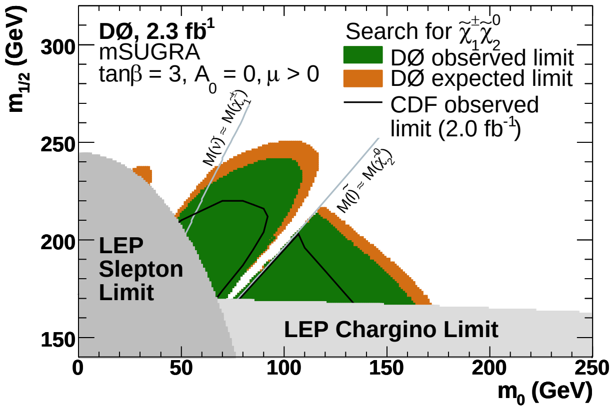

Fig. 4. – Exclusion plane for the $m_{\frac{1}{2}}$ and m_0 masses at 95% CL.

the lightest Higgs (h_0) is degenerate with the CP-even H (CP-odd A) for low (high) mass values. Due to enhanced coupling to the third generation, h_0 is produced with large cross-section and can be searched for in the di-τ final state. Both CDF [11] and D0 [12] carried out the analysis in up to $\sim 2\,\text{fb}^{-1}$ of data in the final state with an electron and a muon, and with one electron/muon and a hadronically decaying τ. The observations are in agreement with the expectation and limits are calculated with a morphing technique and set in the plane $\tan\beta$ and m_A for different mixing scenarios (fig. 6).

The lightest Higgs (h_0) could also be produced in association with b-quarks and could decay into a pair of b-quarks. CDF [13] searched for an enhancement in the mass of the two leading jets in events with at least 3 b-tagged jets. In the MSSM scenario with maximal mixing in the third generation, values of $\tan\beta$ between 80 and 120 are excluded over a h_0 mass range 90–190 GeV/c^2.

Because the branching ratio of $H^{\pm}$ into quarks and leptons depends on $\tan\beta$, the existence of a charged Higgs $H^{\pm}$ can be detected as a deviation in the rate of $p\bar{p} \to t\bar{t} \to W^+bH^-b$ with respect to the SM expectations of $p\bar{p} \to t\bar{t} \to W^+bW^-b$. CDF [14]

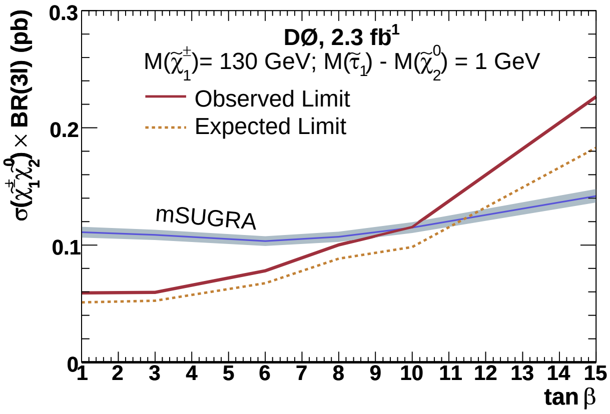

Fig. 5. – Exclusion range for $\tan\beta$ at 95% CL.

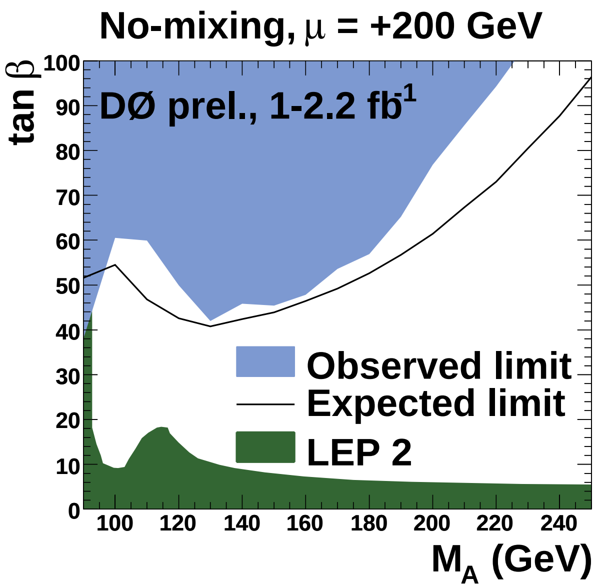

Fig. 6. – Exclusion plane for m_A and $\tan\beta$ at 95% CL.

searched $2.2\,\text{fb}^{-1}$ of data for an excess of events in the invariant mass distribution of the two non-b-jets originating in the top decay and excluded $H^{\pm}$ masses between 120 and $140\,\text{GeV}/c^2$ at 95% CL for $\tan\beta \leq 1$. The $BR(H^{\pm} \to c\bar{s})$ is assumed to be 100%. D0 [15] looked for deviations in the relative branching ratios in di-lepton and lepton-jet final states in $1.0\,\text{fb}^{-1}$ of data. For leptophobic models, D0 excludes $BR(t \to H^{+}b) > 0.2$ for the charged Higgs masses between 80 and $155\,\text{GeV}/c^2$. In the tauonic model, the excluded branching fractions range from 0.12 at low Higgs boson mass up to 0.2 at high mass.

6. – Rare decays

The flavor changing neutral current $B_s \to \mu^+\mu^-$ is suppressed in the SM to $\sim 10^{-9}$. In SUSY scenarios with large $\tan\beta$ an enhancement to $\sim 10^{-7}$ is expected. CDF looked for the rare decay and placed an upper limit on the BR of 5.8×10^{-8} at 95% CL using $2\,\text{fb}^{-1}$ of data [16].

7. – P_R violation

Third-generation neutrinos can be produced as $d\bar{d} \to \tilde{\nu_\tau}$ and can decay into leptons of different flavors via P_R violation interactions. D0 searched $4.1\,\text{fb}^{-1}$ of data for a bump in the high-mass region of the electron-muon invariant mass. No excess is observed and 95% CL limits on the $\sigma \times BR$ and RPV couplings for different sneutrino masses [17]. CDF extended the search to include final states with τs to probe $\tilde{\nu_\tau} \to e(\mu)\tau$ in $1\,\text{fb}^{-1}$ [18].

REFERENCES

[1] Ambrosanio S., Kane G. L., Kribs G. D., Martin S. P. and Mrenna S., *Phys. Rev. D*, **55** (1997) 1372; Allanach B. C., Lola S. and Sridhar K., *Phys. Rev. Lett.*, **89** (2002) 011801.

[2] Glashow S. L., *Nucl. Phys.*, **22** (1961) 588; Weinberg S., *Phys. Rev. Lett.*, **19** (1967) 1264; Salam A., *Proc. 8th Nobel Symposium, Stockholm, 1979*, *Rev. Mod. Phys.*, **52** (1980) 525.

[3] Aaltonen T. *et al.* (CDF Collaboration), *Phys. Rev. Lett.*, **102** (2009) 121801.

[4] Abazov V. *et al.* (D0 Collaboration), *Phys. Rev. Lett.*, **660** (2008) 449.

[5] Abazov V. *et al.* (D0 Collaboration), hep-ex/0905.4086 (2009).

[6] Aaltonen T. *et al.* (CDF Collaboration), *Phys. Rev. Lett.*, **102** (2009) 221801.

[7] Abazov V. *et al.* (D0 Collaboration), *Phys. Rev. Lett. B*, **674** (2009) 4.

[8] CDF Collaboration, Conference Note 9604 (2008).

[9] Aaltonen T. *et al.* (CDF Collaboration), *Phys. Rev. Lett.*, **101** (2008) 251801.

[10] Abazov V. *et al.* (D0 Collaboration), hep-ex/0901.0646 (2009).

[11] Aaltonen T. *et al.* (CDF Collaboration), hep-ex/0906.1014 (2009).

[12] D0 Collaboration, Conference Note H59 (2009).

[13] CDF Collaboration, Conference Note 9284 (2008).

[14] CDF Collaboration, Conference Note 9322 (2008).

[15] D0 Collaboration, Conference Note H5715 (2009).

[16] Aaltonen T. *et al.* (CDF Collaboration), *Phys. Rev. Lett.*, **100** (2008) 101802.

[17] D0 Collaboration, Conference Note N64 (2009).

[18] CDF Collaboration, Conference Note 9430 (2009).