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Searches for MSSM Higgs at the Tevatron

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Summary. — This proceeding reports the latest results of the experimental searches for Minimal Supersymmetric Standard Model (MSSM) Higgs bosons at the Tevatron $p\bar{p}$ collider of Fermilab. Analyses have been performed on samples corresponding to an integrated luminosity of up to $2.2\,\mathrm{fb}^{-1}$, collected by the CDF and D0 detectors. No significant excess of events above the Standard Model (SM) background is observed, so the measurements are used to set exclusion limits on production cross-sections and theory parameters.

PACS 12.60.Jv – Supersymmetric models.
PACS 14.80.Cp – Non-standard-model Higgs bosons.
PACS 13.85.Rm – Limits on production of particles.

1. – Introduction

The discovery of the Higgs boson(s) could be the strong key element confirming the validity of the SM or its supersymmetric extensions. The CDF and D0 Collaborations are carrying out several searches for Higgs production in $p\bar{p}$ collisions at the Tevatron, at a center-of-mass energy of 1.96 TeV.

We will summarize here the latest results of the searches performed within the contest of the MSSM, which is the simplest realistic SUSY theory.

2. – Higgs bosons in the MSSM

The MSSM requires the existence of two isodoublets of Higgs fields which lead to five observable physical states: two charged ($H^{\pm}$) and three neutral scalar bosons (A, H, h). At tree level, Higgs phenomenology in the MSSM is described by two free parameters, the mass of A (m_A) and $\tan\beta = v_2/v_1$, where v_2 and v_1 are the vacuum expectation values of the neutral Higgs fields that couple to up-type and down-type fermions, respectively.

The Yukawa couplings of neutral Higgs bosons to down-type fermions are enhanced by a factor of $\tan\beta$ relative to SM: this can increase both the production and the decay to b-quarks and τ-leptons. Moreover, for certain MSSM parameters values, the pseudoscalar A and one of the other neutral Higgs bosons, commonly denoted by Φ, become

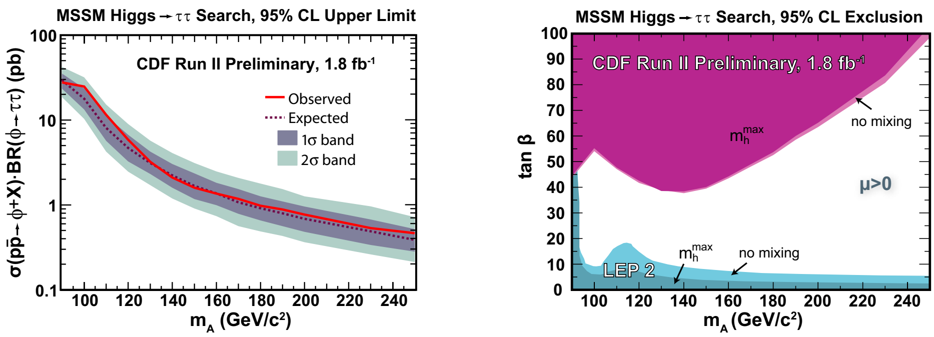

Fig. 1. – Left: CDF cross-section upper limit for the process $\Phi \to \tau^+\tau^-$, as a function of M_A. Right: corresponding exclusion region at 95% CL in the plane m_A-$\tan\beta$, for the maximum Higgs mass and the no-mixing scenarios, with the Higgs mixing parameter $\mu \geq 0$.

nearly degenerate in mass, and can be looked for simultaneously, providing a further enhancement of the searched signal.

Charged Higgs bosons, if lighter than top quark, could appear in the process $t \to bH^+$ and compete with the SM top decay $t \to bW^+$; if their mass would be heavier than top, they could instead be directly produced by quark-antiquark annihilation and then decay into the $t\bar{b}$ final state.

When considering radiative corrections, additional parameters of the MSSM are required to accurately describe Higgs phenomenology. As a consequence, results of the analyses presented in this paper are interpreted by considering benchmark scenarios in the parameter space.

3. – Neutral Higgs bosons

The dominant production mechanisms of neutral MSSM Higgs bosons at Tevatron are gluon and $b\bar{b}$ fusion. In the high $\tan\beta$ region the dominant decay is into $b\bar{b}$ (branching ratio (BR) $\sim$ 90%) or $\tau^+\tau^-$ (BR $\sim$ 10%). As for the SM case, the inclusive search of $\Phi \to b\bar{b}$, while offering a higher cross-section, is impractical because of the overwhelming di-jet and multi-jet QCD background; as a consequence the inclusive production has only been explored in the decay mode to taus. The associated production, with an extra b-jet in the final state, is more accessible and has been investigated in both the decay channels.

3˙1. $\Phi \to \tau^+\tau^-$. – The key ingredient of this search is the optimization of tau identification efficiency and the reduction of jets faking taus. A handle to increase the purity of the final state is the request of at least one tau decaying to an electron or a muon.

D0 and CDF have analyzed 1.8 and 2.2 fb^{-1} of integrated luminosity, respectively, and have seen no evidence for Higgs signal. Both searches place upper limits to the production cross-section, which can be interpreted as exclusion regions in the two-dimensional plane m_A-$\tan\beta$. Figure 1 shows the results for the analysis performed by CDF.

3˙2. $b\Phi \to b\tau^+\tau^-$. – The D0 experiment has performed a search where the Higgs, decaying to taus, is produced in association with a b-quark, which provides an additional tool for background rejection. The final state includes a muon candidate, coming from the leptonic decay of a tau, while the other one is reconstructed by its hadronic decay

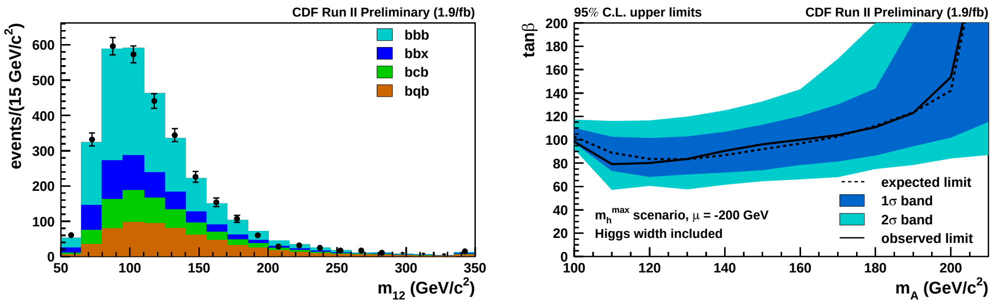

Fig. 2. – Left: the CDF mass distribution of two leading jets in events with three b-tagged jets, for the $b\Phi \to bbb$ search. Right: 95% CL exclusion region in the m_A-$\tan\beta$ space.

products. The analysis is based on $1.2\,\text{fb}^{-1}$ of data, with a similar sensitivity to the inclusive production searches.

3˙3. $b\Phi \to bbb$. – CDF ($1.9\,\text{fb}^{-1}$) and D0 ($2.6\,\text{fb}^{-1}$) looked for a Higgs decaying into $b\bar{b}$, produced in association with an additional b quark. The key ingredient of this kind of search is understanding the flavour of quarks which originate jets in the final state.

Sensitivity of the analyses are comparable to those based on the tau pair channel. Figure 2 shows the CDF invariant mass distribution of the two most energetic b-tagged jets, for data fitted with all the QCD background templates. Also the corresponding exclusion region in the $\tan\beta$-M_A plane for the maximum Higgs mass scenario, with $\mu = -200\,\text{GeV}$, is displayed.

4. – Charged Higgs bosons

4˙1. $H^+ \to c\bar{s}$ $(\tau^+\nu)$. – The process $t \to bH^+$ becomes the most accessible production mechanism at the Tevatron in the hypothesis of a charged Higgs lighter than top quark. An analysis approach, explored by CDF ($192\,\text{pb}^{-1}$) and D0 ($0.9\,\text{fb}^{-1}$), consists in computing the effects that such process could have on the expected number of events in the different final states of a top quark pair sample.

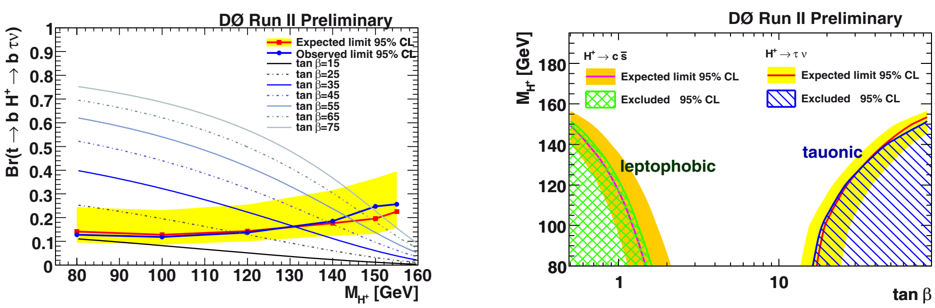

Fig. 3. – Left: D0 cross-section upper limit for the $t \to bH^+ \to b\tau^+\nu$ process, as a function of $M_{H^\pm}$. Right D0 exclusion regions at 95% CL in the plane $\tan\beta$-$M_{H^\pm}$ for the decay in the leptophobic ($H^+ \to c\bar{s}$) and tauonic ($H^+ \to \tau^+\nu$) scenarios.

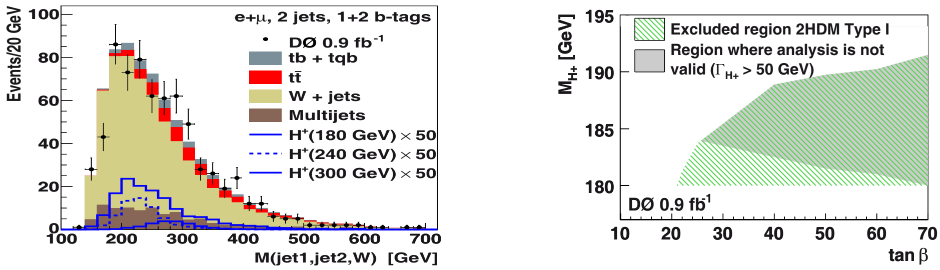

Fig. 4. – Left: D0 distribution of the discriminating variable M(jet1, jet2, W) for the data and the expected signal and backgrounds. Right: exclusion region in the $\tan\beta$-$M_{H^\pm}$ space.

The absence of deficits and excesses, with respect to SM predictions, is used to set a limit on the BR of top decay to charged Higgs for a large $H^\pm$ mass range. This limit is interpreted by excluding wide regions in the M_{H^+}-$\tan\beta$ plane, at 95% CL. Figure 3 shows the results of D0's analysis in two scenarios for the Higgs decay, corresponding to particular low and high $\tan\beta$ values.

CDF ($2.2\,\text{fb}^{-1}$) has also looked for charged Higgs in $t\bar{t}$ pair events, by considering only the "lepton plus jets" channel where the W, coming from one of the two tops, decays leptonically, and the bottom quarks in the final state are required to be tagged. This search, sensitive to low $\tan\beta$ values, is performed by fitting the (not tagged) dijet mass distribution with Monte Carlo templates of $H^\pm \to c\bar{s}$ and $W^\pm \to q\bar{q}'$. Also in this case an upper limit on the BR of the top decay to Higgs has been set.

4·2. $H^+ \to t\bar{b}$. – In addition to the $M_{H^+} \le m_t$ region, D0 looked for a charged Higgs boson ($0.9\,\text{fb}^{-1}$) in the complementary mass range $180 \le M_{H^+} \le 300\,\text{GeV}/c^2$. The search is based on the $H^+ \to t\bar{b} \to l^+\nu b\bar{b}$ signal, where the invariant mass of the two jets plus the reconstructed W (one identified electron or muon and large missing transverse energy) is the variable used to discriminate signal from background. No excess over SM background has been observed and then an upper limit to $H^\pm$ production has been set, along with an excluded region in the M_{H^+}-$\tan\beta$ plane. See fig. 4 for details.

5. – Conclusions

We presented the status of MSSM charged and neutral Higgs bosons searches at the Tevatron. Both CDF and D0 have explored a wide range of possible Higgs masses, for the most relevant production and decay channels. No evidence for signal has been found yet, but large areas of MSSM parameters space have been excluded. More details on the analyses described in this proceeding are available on the CDF [1] and D0 [2] web pages.

There is still space for improvements before the LHC start: sensitivity will enhance soon thanks to the increased statistics (more than $5\,\text{fb}^{-1}$ of data are to tape, while blessed results cover up to $2.2\,\text{fb}^{-1}$) and the steady improvement of analyses techniques.

REFERENCES

[1] http://www-cdf.fnal.gov/physics/new/hdg/hdg.html.
[2] http://www-d0.fnal.gov/Run2Physics/WWW/results/higgs.htm.