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LIMITS ON CHARGED HIGGS USING $t\bar{t}$ CROSS SECTION MEASUREMENTS

RICARDO EUSEBI
(On behalf of the CDF Collaboration)
Physics and Astronomy Department, University of Rochester
Rochester, New York 14627, United States of America

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We present the results of a search for charged Higgs in the decay products of $t\bar{t}$ at the CDF II detector at the Tevatron. The search is based on the cross section measurements of $t\bar{t}$ production in three exclusive decay channels: dilepton, lepton + jets and lepton + hadronic tau. Assuming the charged Higgs decays only via $H^+ \rightarrow c\bar{s}$, $H^+ \rightarrow \tau\bar{\nu}$, and $H^+ \rightarrow t^*b \rightarrow Wb\bar{b}$, limits in the MSSM ($m_{Higgs}$,tan($\beta$)) plane are obtained at tree level. A model-independent analysis is introduced in which the results are independent of Higgs branching ratios. This analysis results in BR(t→Hb)<0.7 at 95%CL for 80 GeV < m_{Higgs} < 150 GeV.

Keywords: Charged Higgs; MSSM; top quark.

1. Introduction

At the Tevatron the main source of top quarks is the production of $t\bar{t}$ pairs. The Standard Model (SM) predicts the decay of the top quark to be almost exclusively to Wb and the $t\bar{t}$ production cross section has been measured under that assumption in many different channels.

Many extensions of the SM predict the existence of two Higgs doublets (2HDM). In these electroweak symmetry breaking produces five Higgs bosons, three of which are neutral (h^0, A^0, H^0) and two of which are charged ($H^{\pm}$). In the context of a Type II 2HDM if $M_{H^{\pm}} \leq M_t - M_b$ the top is allowed to decay to H^+b in addition to the SM decay W^+b, while the dominant Higgs decay modes are $H^+ \rightarrow c\bar{s}$, $H^+ \rightarrow \tau^+\nu$, and the three-body decay $H^+ \rightarrow t^*\bar{b} \rightarrow W^+b\bar{b}$ [a]. In this study we assume that the charged Higgs, if present, will decay through one of these three decay modes.

The Higgs sector of the minimal supersymmetric extension of the SM (MSSM) has a Type II 2HDM structure, however the tree level predictions are significantly altered as a result of its rich extra-particle structure. In this study we consider tree

[a] Charged conjugation is implied throughout this paper

level relations, in order to compare our results to similar studies performed under this assumption. At tree level the mass of the charged Higgs (m_H) and the ratio of vacuum expectation values of the two doublets ($\tan(\beta)$) completely determine the branching ratios of the top and Higgs particles.

2. Methodology

In this study we take advantage of three cross section analyses: "Dilepton", in which two well-identified leptons are required, "Lepton+Jets", in which a lepton and at least a single b-tagged jet is required, and "Lepton+Hadronic Tau" in which a lepton and a hadronically decaying tau are required.

These three cross section analyses compute the $\mathrm{t\bar{t}}$ production cross section ($\sigma_{\mathrm{t\bar{t}}}^{prod}$) based on the number of candidates pasing their selection cuts, the estimated number of SM-background events, and the luminosity times the efficiency of detection of $\mathrm{t\bar{t}}$ decay products assuming the SM decay $\mathrm{t}\rightarrow$ Wb. We will invert the idea and assume $\sigma_{\mathrm{t\bar{t}}}^{prod}$ to be the theoretical SM prediction, calculate the total detection efficiency (which now includes the $\mathrm{t}\rightarrow$ Hb decay) and the number of expected events and compare with the observed number of events in data.

The total detection efficiency is obtained by the proper combination of Monte Carlo efficiencies for each final state and the top and Higgs branching fractions, which in turn can be derived from a particular point in (m_H,$\tan(\beta)$).

3. Likelihood and MSSM results

The comparison between the number of observed and expected events is performed by means of a likelihood using Bayesian statistics. For a given mass of the Higgs we evaluate the likelihood as a function of $\tan(\beta)$ using a flat prior in $log_{10}(\tan(\beta))$. The posterior likelihood is integrated to find the 95% confidence limits. Figure 1 shows the results.

4. Likelihood and Model Independent results

SUSY radiative corrections can significantly modify the tree level predictions for branching fractions. It is of interest then to obtain results that are independent of these predictions.

Using the three independent branching ratios BR($\mathrm{t}\rightarrow$Hb), BR($\mathrm{H}\rightarrow\mathrm{c\bar{s}}$), and BR($\mathrm{H}\rightarrow\mathrm{Wb\bar{b}}$) [b] as the parameters in the likelihood expression we can obtain limits in one, say BR($\mathrm{t}\rightarrow$Hb), while explicity expressing our ignorance in the other two. In the Bayesian formulation we can do so by integrating over the other unknown BR's, effectively regarding them as nuisance parameters. The results are shown in Figure 2.

[b] BR($\mathrm{H}\rightarrow\tau\bar{\nu}$) $\equiv$ 1 - BR($\mathrm{H}\rightarrow\mathrm{c\bar{s}}$) - BR($\mathrm{H}\rightarrow\mathrm{Wb\bar{b}}$)

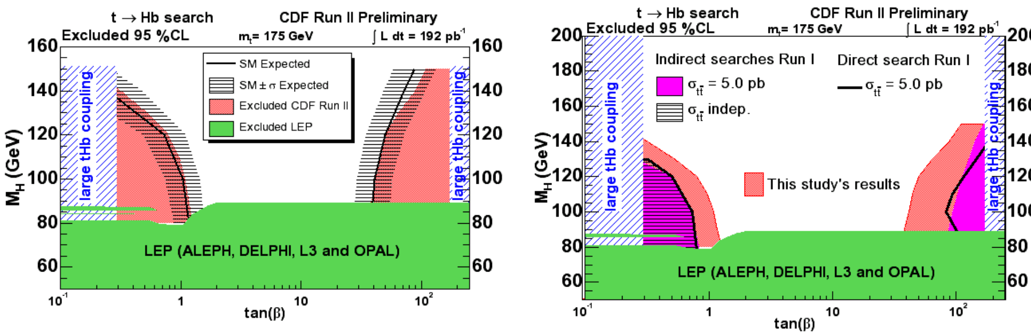

Fig. 1. Results at tree level MSSM. The green bottom solid regions are the latest LEP exclusion limits. The blue striped at high and low tan(β)are regions in which the perturbative expansions are not trusted. The red region is the observed exclusion region which is compared to the expected exclusion (left plot) and previous exclusions (right).

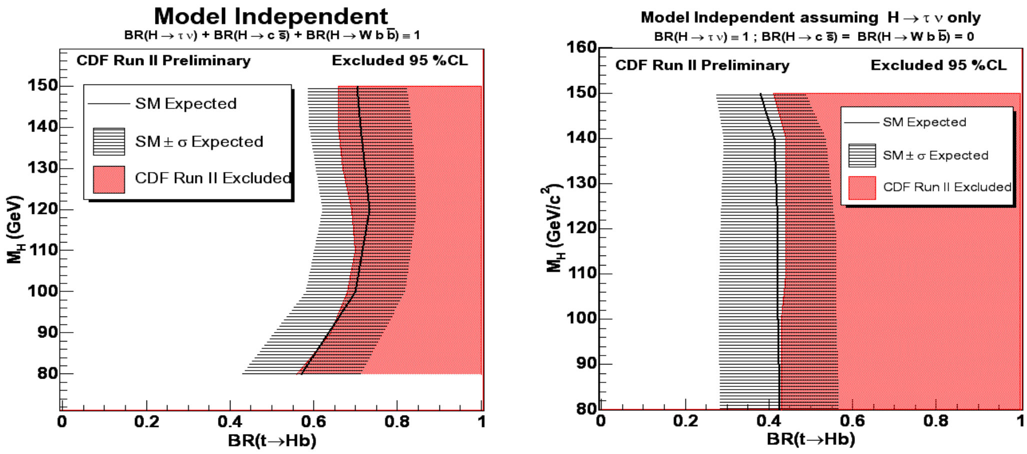

Fig. 2. Model-independent results. Upper 95 % confidence limit of BR(t→ Hb) as a function m_H. The horizontal band represent the SM expected limits. Left : Assumes that H decays to either $c\bar{s}$ $\tau\bar{\nu}$ and $Wb\bar{b}$ in any proportion. Right : Assuming that H decays to $\tau\bar{\nu}$ all the time.

5. Conclusions

We have used the results of the $t\bar{t}$ cross section measurements in the “Dilepton”, “Lepton+Jets” and “Lepon + Had. Tau” channels to search for top decays to charged Higgs. We have set limits at tree level in the (m_H,tan(β)) plane which improve upon previous results obtained under the same assumptions.

We have also introduced a model-independent analysis where results are independent of loop corrections to the branching fractions. From the model independent analysis we conclude that BR(t→Hb)<0.70 @ 95% CL.