Higgs Results from the Tevatron

Massimo Casarsa (on behalf of the CDF and DØ Collaborations)
INFN – Sezione di Trieste
Padriciano, 99
I-34149 Trieste, ITALY

1 Introduction

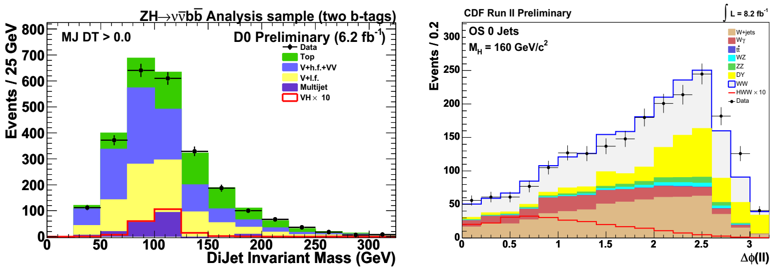
The Higgs mechanism has been introduced in the Standard Model (SM) to account for the electroweak symmetry breaking and the generation of particle masses. It predicts, as a by-product, the existence of a scalar boson, which is still awaiting an experimental confirmation. Although the Higgs boson mass cannot be predicted by theory, indications on its value are provided by the direct searches conducted at LEP, which excluded the mass region $m_H < 114.4$ at 95% C.L. [1], by indirect constraints from the W boson and the top quark masses and by precision global electroweak fits, which seem to prefer a relatively light Higgs [2]: the preferred value for m_H is at $89\,^{+35}_{-26}$ GeV/c^2 and m_H is lower than 158 GeV/c^2 at 95% C.L.

The CDF and DØ Collaborations are pursuing a direct search for a SM Higgs boson over the mass range 100-200 GeV/c^2. This contribution will present an overview of the most recent results as of June 2011.

The Tevatron is a $p\overline{p}$ collider operating at the Fermi National Accelerator Laboratory. Proton and antiproton beams collide at a center of mass energy of 1.96 TeV in two interaction points, where the CDF and DØ detectors are located. To date, the Tevatron has delivered 12 fb^{-1} of data per experiment, approximately 10 fb^{-1} of which are recorded on tape and available for analysis. CDF and DØ are multipurpose central detectors which present similar features: silicon microvertex trackers, a central tracker in a superconducting solenoidal magnetic field, electromagnetic and hadronic calorimeters surrounding the tracking system, and muon detectors in the outermost part. Detailed descriptions of the two detectors can be found in [3] and [4].

2 Higgs Searches at the Tevatron

At a $p\overline{p}$ center of mass energy of 1.96 TeV the Higgs boson is predominantly produced via a gluon-gluon fusion process through a quark loop, where the main contribution is given by the massive top quark [5]. The cross section of this process decreases from $\sim$1.5 to $\sim$0.2 pb as the Higgs boson mass varies between 100 and 200 GeV/c^2. The



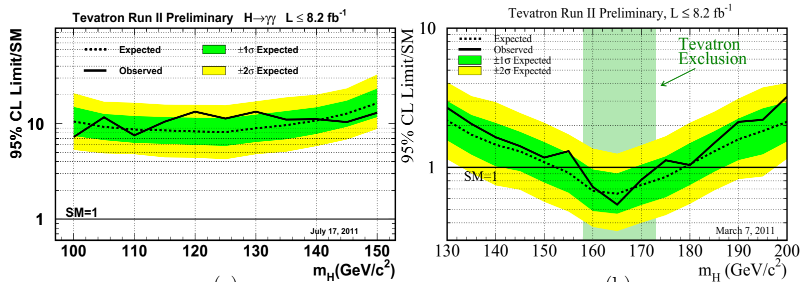
(a) (b)

Figure 1: Distributions of the invariant mass of the b-tagged jets in the DØ $ZH \to \nu\overline{\nu}b\overline{b}$ search (a) and of the $\Delta\phi$ between the leptons from the W decays in the CDF $H \to WW$ analysis (b) with the expected backgrounds and signal superimposed.

rates of the electroweak Higgs production mechanisms in association with a W or Z boson or via virtual vector boson fusion are about an order of magnitude lower.

The analyses of the CDF and DØ experiments, which have been constantly improved and refined over the past ten years, exploit a set of common techniques and present similar features. The backgrounds from SM processes are in general estimated from Monte Carlo samples, normalized to the highest order cross section calculations available, whereas multijet backgrounds and backgrounds from misidentified leptons or jets are usually estimated from data. Appropriate control regions are defined to check and validate the background normalizations and modeling. The signal-background discrimination is enhanced by ∼15-20% by means of advanced multivariate techniques like artificial neural networks and boosted decision trees, which combine information from kinematical, event global and particle identification observables. Furthermore, to improve the sensitivity to a particular Higgs production mechanism and better characterize the corresponding backgrounds and increase the signal-background discriminating power, separate searches are targeted to distinct final state signatures. Finally, combining is the main theme of Higgs searches at the Tevatron: in order to maximize the sensitivity each experiment combines the results from different analyses and the results of both experiments are combined together.

The search strategies are driven by the dominant decay modes of the Higgs boson. For masses below 135 GeV/c^2 the Higgs decays predominantly into a pair of $b\overline{b}$ quarks. An inclusive search in this mass range would be spoiled by the overwhelming multijet background, therefore the channels with an associated W or Z boson are in general more convenient. The most promising discovery channels, in terms of signal yield and background level, are represented by $WH \to \ell\nu_\ell b\overline{b}$ and $ZH \to \nu_\ell\overline{\nu}_\ell b\overline{b}$ or $WH \to$



(a) (b)

Figure 2: Combined CDF and DØ upper limits on the Standard Model Higgs boson production for the decay channels into two photons (a) and two W bosons (b), where the shaded vertical band represents the excluded mass range.

$(\ell)\nu_\ell b\bar{b}$ with the lepton escaping detection.

DØ has recently updated the latter search with a dataset of 6.2 fb^{-1} [6]. Fig. 1(a) shows the invariant mass distribution of two jets identified as produced by b quarks for the data and the expected backgrounds. The measured 95% C.L. upper limits on the production cross section times the branching ratio of the Higgs boson range from 2.5 to 22.0 times the SM cross section for masses between 100 and 150 GeV/c^2. The expected 95% C.L. limits are between 3.2 and 30.6.

Another promising analysis by CDF in the low mass range searches for a Higgs boson associated to one or more jets and decaying to two tau leptons using 6 fb^{-1} of data [7]. Most of the signal events with this signature are produced via the gluon-gluon fusion and the virtual vector boson fusion processes. The CDF sensitivity to this channel is highest at a test mass of 120 GeV/c^2, for which value an upper limit of 15.3 times the Standard Model cross section is expected at 95% C.L. The corresponding observed 95% C.L. upper limit is 14.6.

Although the Higgs decay to two photons suffers from a very low branching ratio in the SM, ∼0.2% for m_H = 120 GeV/c^2, it provides a very clean signature due to an excellent experimental resolution, of a few GeV/c^2, on the reconstructed diphoton mass. Both CDF and DØ search for this channel using datasets of 7 fb^{-1} and 8.2 fb^{-1}, respectively [8]. Fig. 2(a) reports the combined upper limits on the SM Higgs boson production cross section [9]. The limits are expressed as a multiple of the SM prediction for each test mass. The green and yellow bands indicate the 68% and 95% probability regions where the limits can fluctuate in the absence of a signal.

For masses higher than 135 GeV/c^2 the decay to WW is dominant. In this case the final states with electrons and muons provide clean experimental signatures with relatively low backgrounds. The SM Higgs acceptance is further improved by including hadronically decaying taus. The search is divided into exclusive sub-channels which are analysed separately and then combined: events with two opposite-sign leptons are mostly sensitive to the gluon-gluon fusion production, while events with two same-sign leptons or three leptons receive mainly contributions from the associated production. Multivariate methods are utilized to enhance the discrimination between signal and background. As an example, Fig. 1(b) shows one of the observables used in the artificial neural network of the CDF analysis with two opposite sign leptons. The Tevatron combined result is graphically represented in Fig. 2(b): the Higgs boson masses in the range between 158 and 173 GeV/c^2 are excluded at 95% C.L.

3 Conclusion

An overview of the most recent searches for a Standard Model Higgs boson at the Tevatron has been presented. Both CDF and DØ are sensitive to the Standard Model production cross section in a mass region around 165 GeV/c^2. At the end of the Tevatron Run II in September 2011 each experiment will have a dataset of 10 fb^{-1} available for analysis. The final Tevatron combination is expected to have a sensitivity better than 2.4 σ up to a mass of 180 GeV/c^2.

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