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Standard Model Higgs Boson Searches at CDF

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Abstract

We present recent results from searches for a standard model Higgs boson by the CDF experiment at the Tevatron $p\bar{p}$ collider with the full Run II data set. An excess of events above the expected background is observed and is the strongest in the associated production search channels where the Higgs is produced together with a W or Z boson, and then decays to a bottom-antibottom quark pair, with a global significance of 2.5σ. Both limits and best fit values of the Higgs production cross section are presented. For a Higgs mass of 125 GeV/c^2, the best agreement with data in the $(\sigma_{WH} + \sigma_{ZH}) \times Br(H \to b\bar{b}) = 291\pm^{118}_{113}$ fb.

Keywords: Higgs boson, Tevatron, standard model

1. Introduction

In the standard model (SM) of particle physics, electroweak symmetry breaking generates a fundamental scalar boson known as the Higgs boson. However, the standard model does not predict its mass. Only after decades of searching with increasingly more powerful tools has experimental access to the Higgs boson become possible thanks to the large data sets collected by the Tevatron at $\sqrt{s} = 2$ TeV and the Large Hadron Collider (LHC) at $\sqrt{s} = 7$ and 8 TeV.

The higher energy of the LHC collisions results in a higher statistical power for the same integrated luminosity for most of the Higgs search channels. However, the Tevatron Run-II data set has a comparable sensitivity to the recent LHC results for the associated production channel $q\bar{q} \to VH \to llb\bar{b}$, where the Higgs decays to a bottom-antibottom quark pair and the vector boson to a lepton pair [1][2], due to the larger ratio of signal to background production cross sections at the Tevatron for this channel.

2. CDF detector

The CDF detector [3] is a general purpose detector with cylindrical geometry. The layout of the inner tracking detectors is shown in figure 1. The momentum of charged particles is measured with silicon detectors and an open-cell drift chamber (COT) inside the 1.4T field of a superconducting solenoid magnet. The silicon vertex detector (SVX) identifies the displaced vertices characteristic of long-lived bottom and charm hadron decays both for online trigger event selection and offline analyses. Calorimeters and muon systems located outside the solenoid measure the energy of jets and electromagnetic particles and identify leptons.

3. Higgs Boson Search Strategies

The standard model Higgs boson production cross sections at the Tevatron are shown in figure 2 as a function of the mass of the Higgs and the decay branching ratios are shown in figure 3 [4]. For a mass below 130 GeV/c^2, the Higgs boson decays predominantly into a bottom-antibottom quark pair and the process $q\bar{q} \to VH \to llb\bar{b}$, where $V = W$ or Z, has the largest sensitivity because of the large multi-jet QCD background to the process $gg \to H \to b\bar{b}$. We look for a $b\bar{b}$ mass resonance in events containing a W/Z boson, where the W/Z decays leptonically into two or more jets. To suppress large backgrounds from W/Z+jets

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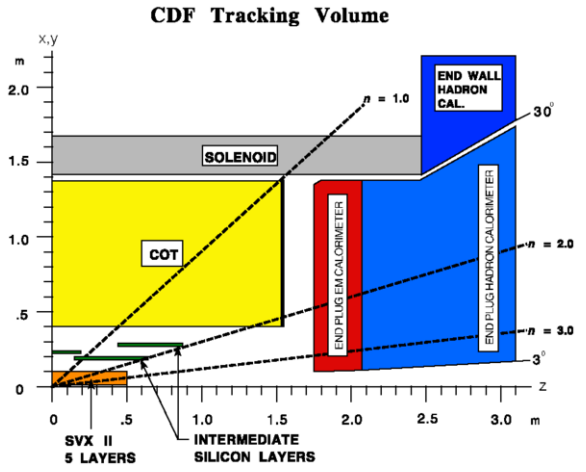

Figure 1: A schematic layout of the CDF tracking system.

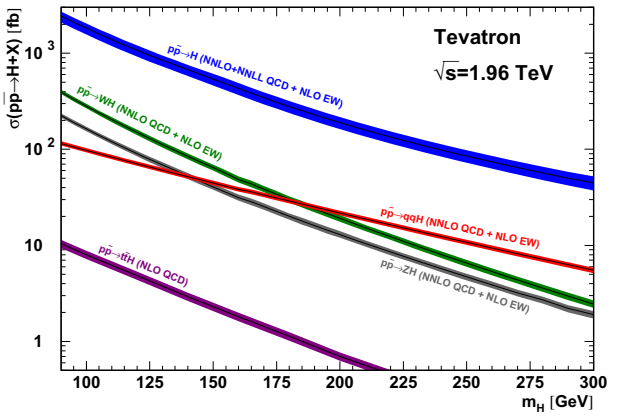

Figure 2: Cross sections for standard model Higgs boson production in $p\bar{p}$ collisions at 1.96 TeV [4].

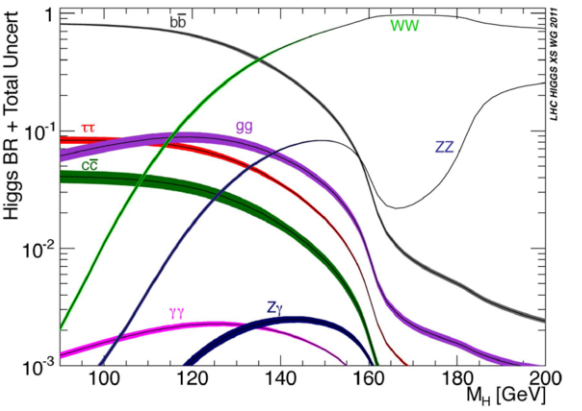

Figure 3: Branching ratios for the principal decays of standard model Higgs boson [4].

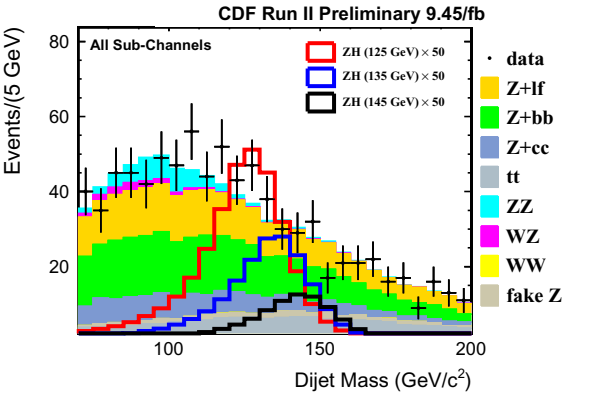

Figure 4: The dijet invariant mass distribution of simulated Higgs events with two charged leptons from a Z decay and two jets in the final state, for three different values of the Higgs mass. The simulated backgrounds are shown as different shades and the data with circles.

events, at least one jet must be b-tagged. Events are separated into final state categories based on the number of detected leptons, the number of jets and the quality of the b-tag(s) [5][6][7].

The dijet mass resolution for signal events at CDF is expected to be 10-15% of their mean reconstructed mass [8] and the presence of a signal would appear as a broad enhancement in the invariant mass distribution of jets. Figure 4 shows the dijet invariant mass distribution of simulated Higgs events with two charged leptons from a Z decay in the final state, for three different values of the Higgs mass. The dijet mass provides the greatest discrimination between signal and background. However, to enhance sensitivity the dijet mass is combined with other kinematic information in multivariate analysis (MVA) to optimize the separation of the Higgs signal from the backgrounds.

Above 130 GeV/c^2, the WW decay modes dominates and $gg \rightarrow H \rightarrow WW$ is the most sensitive process. For high mass signatures, we look for inclusive Higgs events, with the Higgs decaying into a WW pair. Events are separated into categories according to the number of jets and the number of leptons to take advantage of event kinematics that results from the different dominant signal and background processes associated with each final state. Each final state uses a customized MVA to separate the Higgs boson signal from the backgrounds.

The best overall sensitivity is obtained by combining all production and decay channels together. There are 71 mutually exclusive final states in the current CDF combined result, a complete list can be found in reference [9]. As a cross-check to establish the reliability of