PROCEEDINGS OF SCIENCE

Vector Boson Fusion leading to Higgs production and subsequent decay in bottom quarks

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A search for the standard model Higgs boson in the vector boson fusion production channel with decay to bottom quarks is reported. A data sample comprising 19.0 fb^{-1} of proton-proton collisions at $\sqrt{s} = 8$ TeV collected during the 2012 running period has been analyzed and 95% Confidence Level upper limits are derived for five mass points from 115 to 135 GeV. At a Higgs boson mass of 125 GeV the observed limit is 3.6 while the expected limit is 3.0 times the standard model prediction. For a 125 GeV Higgs boson signal the fitted signal strength is $\mu = \sigma/\sigma_{SM} = 0.7 \pm 1.4$.

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1. Introduction

At the LHC, the expected production cross sections predict the two dominant SM Higgs boson production mechanisms to be gluon-fusion (GF) and vector boson fusion (VBF). Furthermore, the expected dominant decay mode at low mass (< 135 GeV) is to a b-quark pair ($b\bar{b}$). The search for a SM Higgs boson in the VBF production mode, followed by a $b\bar{b}$ decay, is complicated by the presence of a very large QCD background. It can, however, provide more information about the nature of the boson observed previously at the LHC at a mass near 125 GeV, adding to previous studies of the Higgs to $b\bar{b}$ decay which focused on the VH and ttH production modes.

2. Search Strategy

For this VBF $H \to b\bar{b}$ search, the signal is characterized by a four-jet final state. Two jets are expected to originate from the VBF process: two light quarks scattered roughly in forward and backward direction with respect to the beam line. Two additional jets are then expected from the Higgs boson decay to a b-quark pair, situated more central than the two VBF tagging jets. It is also true for the signal that, because no QCD colour is exchanged in the VBF production process, no colourflow is expected between the b-jets and the VBF tagging jets.

The largest background to the search is the QCD production of multijets. Next to that, hadronic decays of Z or W bosons in association with additional QCD jets, hadronic or semi-leptonic decays of top-pairs, and hadronic decays of single-top productions are taken into account. Lastly, when establishing the expected signal yields, also the Higgs boson production arising from GF processes with two or more associated QCD jets, needs to be considered.

A dedicated trigger has been set up, selecting four-jet events with progressive p_T thresholds optimized to the expected p_T distributions for the signal. The trigger also requires one or two significantly b-tagged jets, as well as large invariant mass and large separation in pseudorapidity for the least b-tagged jet pair. In the offline analysis kinematic cuts are required similar to, but slightly harder than those contained in the trigger. On top of this, maximum separation between signal and background is pursued by characterizing events according to the response of an artificial neural network (ANN). Since the search strategy relies on a background fit of the $b\bar{b}$ invariant mass spectrum ($m_{b\bar{b}}$), it is critical that the correlation between the multivariate discriminant and $m_{b\bar{b}}$ is minimal. Hence, no kinematic information of the two b-tagged jets is used in the training of the ANN. Finally, to utilize all information efficiently, the search is conducted simultaneously in four bins of the ANN reponse (categories).

In the offline analysis, three extra steps aiding the event reconstruction are included: (i) quark/gluon discrimination to identify the origin of the least b-tagged jet pair, (ii) a study of the additional hadronic activity between the VBF tagging jets, and (iii) an additional jet energy correction based on a jet transverse momentum regression, to improve the $b\bar{b}$ mass resolution.

3. Fit to the data

For the background fit of the $m_{b\bar{b}}$ spectrum, a template comprising three parts is used. Included are: (i) a fifth-degree Bernstein polynomial representing the non-peaking QCD background, (ii) a Z/W template taken from simulation, and (iii) a top template combining the $t\bar{t}$ and single-top contributions, also taken from simulation. When considering the signal hypothesis, as opposed to the null hypothesis, a fourth part is added to the template: a signal template. The fits are performed for each of the four ANN event categories, in the 70 GeV $< m_{b\bar{b}} <$ 250 GeV mass range. Fig. 1 shows the result for the event category with the highest ANN reponse.

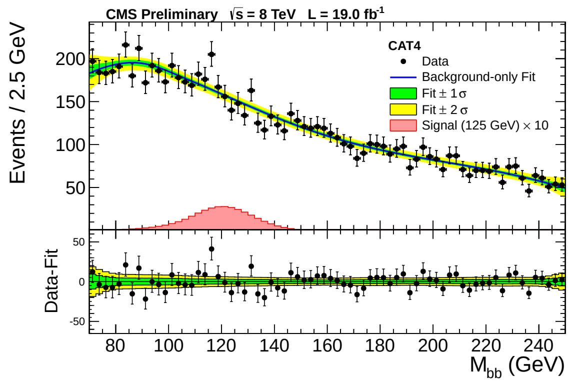

Figure 1: Fit of the background model to the data $m_{b\bar{b}}$ distribution for preselected events, for ANN category four (ANN>0.96). In red also the amplified distribution of the searched SM signal.

4. Results

The limits as shown in Fig. 2, are computed with the Asymptotic CLs method, in function of the Higgs boson mass (M_H), taking into account systematic uncertainties. The 95% CL expected (observed) limit ranges from ~ 2 (2) at $M_H = 115$ GeV to ~ 4 (5) at $M_H = 135$ GeV. The fitted signal strength for a 125 GeV Higgs boson signal is $\mu = \sigma/\sigma_{SM} = 0.7 \pm 1.4$.

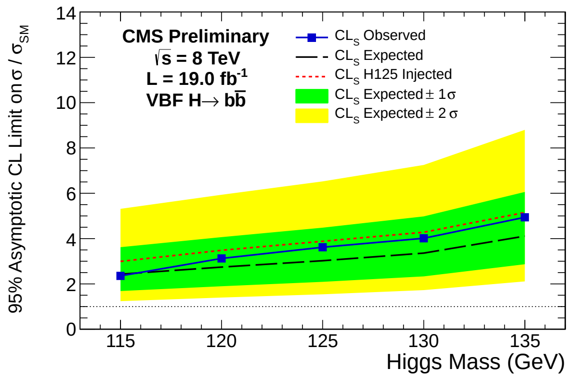

Figure 2: 95% Asymptotic CL limits on σ/σ_{SM}, as a function of the Higgs boson mass, including all four higher ANN event categories.

References

[1] CMS Collaboration, *"Search for the standard model Higgs boson produced in vector boson fusion, and decaying to bottom quarks"*, CMS Physics Analysis Summary CMS-PAS-HIG-13-011, CERN, (2013).

[2] CMS Collaboration, *"The CMS experiment at the CERN LHC"*, JINST 3 (2008) S08004.