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Search for the standard model Higgs boson in the $H \to ZZ \to \ell^+\ell^- q^+ q^-$ channel with the CMS experiment at LHC

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Summary. — A search for the standard model (SM) Higgs boson decaying into two Z bosons with a subsequent decay into two leptons and two quark jets, $H \to ZZ \to \ell^+\ell^- q^+ q^-$, is presented. The data sample, corresponding to an integrated luminosity of $4.6\,fb^{-1}$, is collected from proton proton collisions at the centre-of-mass energy of 7 TeV, with the CMS detector at the LHC at CERN, in proton-proton collisions at the centre-of-mass energy of 7 TeV. Discrimination of signal from background events is based on a kinematic selection and exploiting the different angular distribution of signal and background. No evidence for the Higgs boson is found, and upper limits on the Higgs boson production cross section are set between 130 and 600 GeV mass.

PACS 14.80.Bn – Standard-model Higgs bosons.
PACS 14.70.Hp – Z bosons.
PACS 14.65.Fy – Bottom quarks.

1. – Introduction

The SM of particle physics predicts the existence of the Higgs boson, a scalar boson responsible for the mechanism of the electroweak symmetry breaking, whose discovery is one of the main goals of the LHC scientific program. The results for a search for the Higgs boson decaying into two Z bosons with 2 leptons and 2 jets in the final state in a sample of proton proton collisions at the centre-of-mass energy of 7 TeV by the CMS experiment [1] at LHC are presented. The data sample corresponds to an integrated luminosity of $4.6\,fb^{-1}$.

2. – The analysis strategy

The branching ratio of the $H \to ZZ \to \ell^+\ell^- q^+ q^-$ channel is about 20 times higher than the $H \to ZZ \to 4\ell$ channel. The main sources of background are Z+jets, $t\bar{t}$ and

diboson events. The search is optimized separately for $H \to ZZ^*$ and $H \to ZZ$ analyses, the former deployed in the reconstructed mass range $125 < m_{ZZ} < 170\,\text{GeV}$, the latter in the range $183 < m_{ZZ} < 800\,\text{GeV}$. The statistical analysis is performed on Higgs boson candidates reconstructed from two oppositely charged leptons, $\ell^+\ell^-$, either electrons or muons, and two quarks identified as jets in the CMS detector. Muons and electrons are reconstructed in pseudorapidity region $|\eta| < 2.4$ and $|\eta| < 2.5$, respectively. Both are required to be isolated from hadronic activity in the detector. In the high mass (low mass) analysis, leading and subleading leptons must have transverse momentum, p_T, greater than 20 GeV and 10 GeV (40 GeV and 20 GeV), respectively. Jets are reconstructed with the particle-flow algorithm, based on the combination of information from all subdetectors. Only jets within the tracker acceptance ($|\eta| < 2.5$) and p_T greater than 30 GeV are selected. Dijet and dilepton pairs must have invariant masses $75\,\text{GeV} < m_{jj} < 105\,\text{GeV}$ and $70\,\text{GeV} < m_{\ell\ell} < 110\,\text{GeV}$ ($m_{\ell\ell} < 80\,\text{GeV}$ in the low mass analysis). Selected Higgs candidates are classified into three categories according to the numbers of jets identified as b-quark jets in the final state (0, 1, 2 b-jet). At high mass the angular distribution of Higgs decay products is a powerful discriminant. The kinematics of the $gg \to H \to ZZ^* \to \ell^+\ell^-q^+q^-$ process is fully described by five angles as defined in [2]. A requirement on the likelihood discriminant based on the probability ratio of the signal and background hypotheses [3] is applied. In the 0 b-jet category the contamination from Z+jets events is reduced with a requirement on a quark-gluon discriminant, exploiting differences between jets of the two types. In the 2 b-jet category, contamination from $t\bar{t}$ events is reduced by rejecting events with large missing transverse energy.

The statistical analysis is performed on the reconstructed m_{ZZ} distribution. The background shape and normalization are determined from data by studying the sidebands of the m_{jj} spectrum: $60\,\text{GeV} < m_{jj} < 75\,\text{GeV}$ and $105\,\text{GeV} < m_{jj} < 130\,\text{GeV}$. The background shape in the sideband is rescaled to signal region using coefficients derived from simulation and parameterized with an empirical function. The signal shape is determined from simulation.

3. – Results

A limit on the ratio of the production cross section for the Higgs boson compared to the SM expectation has been obtained according to the LHC Higgs Combination Group prescription [4] using the CLs modified frequentist method. The observed limits are within the expectation for the background-only hypothesis, no evidence for the Higgs boson is found and exclusion limits at 95% confidence level (CL) are set on the mass range analyzed. The most stringent limit found in the low mass range is ~ 2.5 larger than the SM cross section at 157 GeV. In the high mass range the search approaches the SM Higgs boson exclusion in the range 354–358 GeV. The presence of the Higgs boson for the SM extended to a fourth fermion generation has been excluded at 95% CL in the mass ranges 145–161 GeV and 200–600 GeV.

REFERENCES

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