CMS Conference Report

CMS detector sensitivity to the Standard Model Higgs boson in $H \rightarrow ZZ^{(*)} \rightarrow 4\text{leptons}$ decay channel

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Abstract

The search for the Higgs boson is one of the most important tasks of the CMS experiment at pp LHC collider. The most recent results on the Standard Model Higgs boson discovery potential are presented, obtained using the most recent full simulation and reconstruction software as well as with detailed treatment of systematic uncertainties. Results show that the whole Standard Model Higgs boson mass range will be covered with about $\sim 10fb^{-1}$.

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Figure 1: The signal significance as a function of the Higgs boson mass for 30 fb^{-1} of the integrated luminosity is shown for the different Higgs boson production and decay channels for analyses with CMS.

One of the most important tasks for the CMS [1] experiment (one of 4 large experiments on future pp LHC [2] collider) is to search for the Higgs boson, the last missing piece of the Standard Model (SM) that is still not confirmed experimentally.

1 Introduction

The main production channels for the SM Higgs boson are: gluon fusion via top loop, vector boson (W/Z) fusion, W/Z associated production, $t\bar{t}$ fusion. In the Higgs boson search analyses, NLO corrections for signal and background processes were used when available.

For Higgs masses above $135 \text{ GeV}/c^2$ the main decay modes are those into WW and ZZ pairs. These are very important discovery channels, in particular $H \rightarrow ZZ^{(*)} \rightarrow 4\mu$ is called the “golden mode” for its very clean (4 muons) final state, which provides a low/medium integrated luminosity level for discovery of the Higgs boson for all possible Higgs boson masses in consideration ($\sim 115 - 600 \text{ GeV}/c^2$).

Details of reported $H \rightarrow ZZ^{(*)} \rightarrow 4\text{leptons}$ analysis [3] as well as many other Higgs boson searches can be found in Ref. [4]. Below we will consider an example of $H \rightarrow ZZ^{(*)} \rightarrow 4\mu$ analysis and give CMS Higgs boson discovery reach summary.

2 $H \rightarrow ZZ^{(*)} \rightarrow 4\mu$ analysis

In the $H \rightarrow ZZ^{(*)} \rightarrow 4\mu$ analysis counting and Log-Likelihood ratio techniques were used as well as genetic algorithm techniques [5] to optimize the outcome of the analysis, which led to $M_{4\mu}$ -dynamic cuts and about 1σ improvement in terms of signal to background significance all over the $M_{4\mu}$ spectrum. Effort was made to make analysis as close as possible to “as one would do it with real data”: lepton reconstruction and isolation techniques from data were developed and tested.

A detailed study of systematic uncertainties was performed in this analysis. Some of the main systematic uncertainties come from the major background cross section and NLO k-factors as well as possible contribution from unaccounted backgrounds (including processes, which become important when fake leptons, for example, are taken into account). Also estimations were made to rescale the local excess of significance due to the fact that we look for a narrow resonance in a broad range of M_H .

3 Discovery reach summary

Figure 1 [4] shows the signal significance as a function of the Higgs boson mass for 30 fb^{-1} of integrated luminosity for the different Higgs boson production and decay channels with CMS.

Figure 2 [4] shows the integrated luminosity needed for the 5σ discovery of the inclusive Higgs boson production $pp \rightarrow H + X$ with the Higgs boson decay modes $H \rightarrow \gamma\gamma$, $H \rightarrow ZZ \rightarrow 4\ell$, and $H \rightarrow WW \rightarrow 2\ell 2\nu$ – the three

Figure 2: The integrated luminosity needed for the 5σ discovery of the inclusive Higgs boson production $pp \rightarrow H + X$ is shown for the Higgs boson decay modes $H \rightarrow \gamma\gamma$, $H \rightarrow ZZ \rightarrow 4\ell$, and $H \rightarrow WW \rightarrow 2\ell 2\nu$.

front runners among all possible decay channels. $H \rightarrow \gamma\gamma$ dominates the discovery reach up to $m_H \sim 130 \text{ GeV}/c^2$, similarly $H \rightarrow WW \rightarrow 2\ell 2\nu$ dominates for $\sim 150 - 180 \text{ GeV}$ and $H \rightarrow ZZ \rightarrow 4\ell$ – in the rest of the possible Higgs boson masses.

4 Summary

It was shown that discoveries may be expected already at integrated luminosity, about 1 fb^{-1} . The SM Higgs boson, if it exists, is expected to be discovered by the time we reach $L \approx 10 \text{ fb}^{-1}$.

References

- [1] CMS Collaboration, <http://cms.cern.ch/>
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